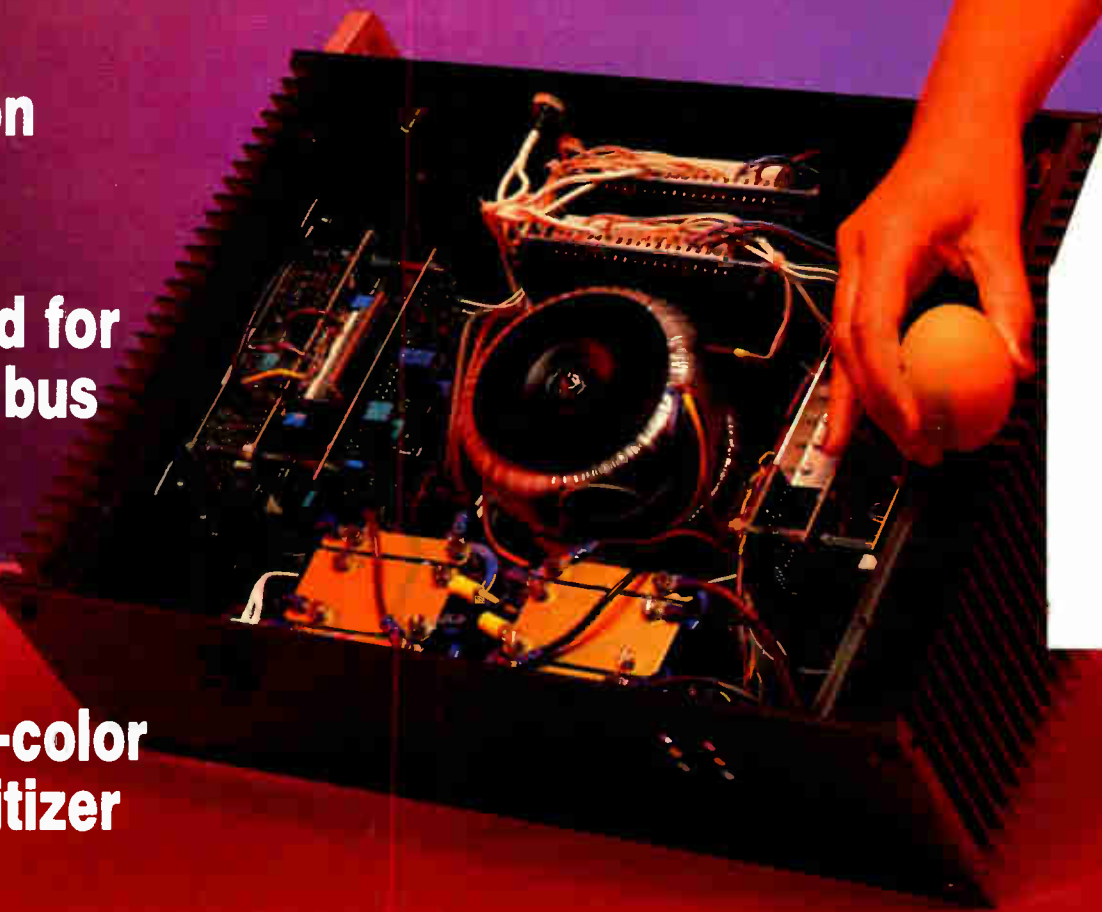# ELEKTOR ELECTRONICS USA

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CONTENTS

November 1991
Volume 2
Number 2

Front cover
For many years now, hi-fi equipment has almost exclusively used class AB operation. This method gives acceptable distortion and good efficiency, and the output amplifier remains relatively cool during normal operation. However, many designers and listeners prefer class A operation with its much lower distortion and consequent higher quality of sound reproduction.
To meet their demands, we have revamped the LFA 150 power amplifier we published about three years ago. In the new design, a good compromise has been achieved between class A quality and the high heat dissipation that characterizes this type of operation.

In next month's issue

More than 60 construction projects and informative/ educative articles including

- Connect 4
- FSK/RTTY decoder for PCs
- Function generator [3]
- Programmable filter ICs
- Class A amplifier [2]
- Temperature measurement techniques
- Economy power supply

24-bit full-colour video digitizer – p. 16

Dissipation limiter – p. 19

The cipher machine – p. 46

Relay card for universal I/O interface – p. 54

BASIC COMPUTER
With Intel 8052AH-BASIC

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$160

ANALOG MODULE
eps 880162   100.113   **$80**

DIGITAL MODULE
eps 880163   100.114   **$55**

ADRESSDECODER
eps 880159   100.115   **$45**

S-VHS/CVBS-TO-RGB CONVERTER
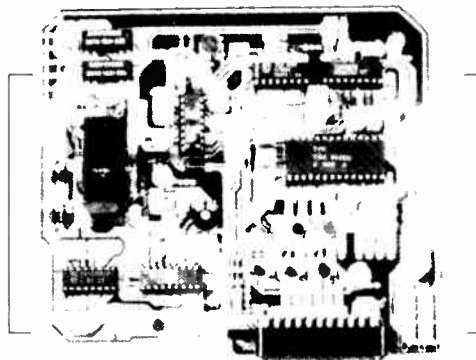
Following last month's introduction into the main characteristics of the Super-VHS system, we close off the article with details of a practical converter circuit that allows an S-VHS-VRC or camcorder to be connected to the RGB inputs of a colour TV or monitor. The circuit presented here forms a state-of-the-art approach to all-analogue picture standard conversion, and is based on the latest in IC technology available for this purpose.

220.039 **$150**
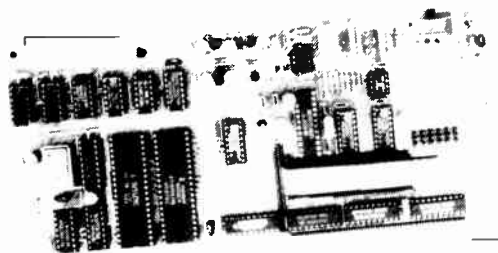
MULTIFUNCTION MEASUREMENT CARDS FOR PCs

The high-performance insertion card described in this article allows your IBM PC-XT, PC-AT or 100 % compatible to measure direct voltage at 12-bit accuracy, as well as frequency and a host of other parameters related to pulse-shaped signals. The accuracy and versatility afforded by the card are of a level associated with much more expensive, industrially rated products. The menu-driven control software developed for this exciting project allows you to keep tabs on up to eight voltages quasi-simultaneously, whi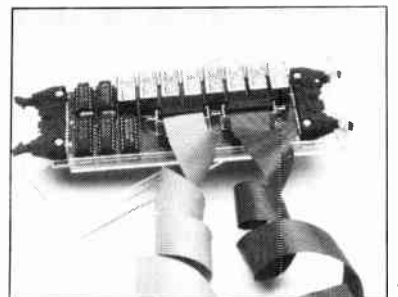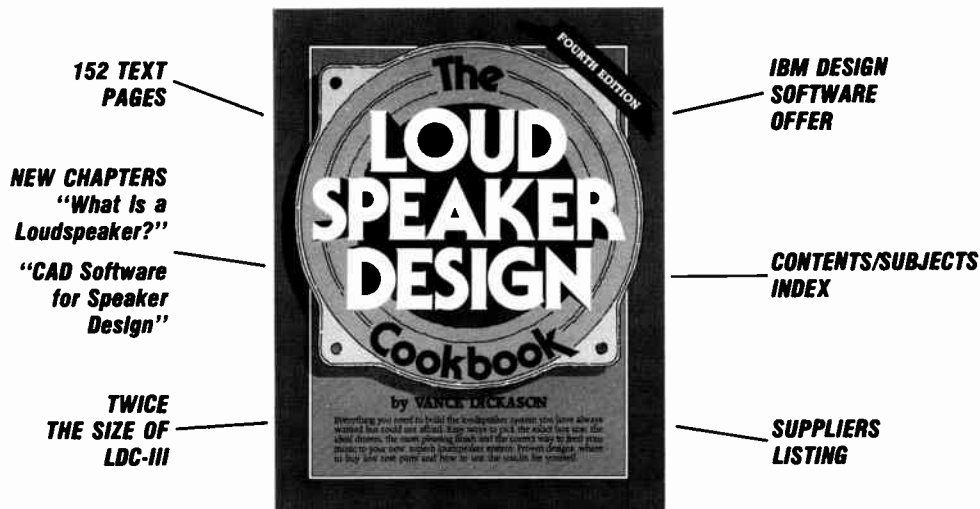le up to eight remaining inputs can be used for time-related measurements including frequency, duty factor and pulse duration, not forgetting the event counter. Connected to the sensors and timing devices of your choice, this card turns a PC into a powerful central controller in a complex measurement and control system.

220.040 **$225**

MICROPROCESSOR-CONTROLLED TELEPHONE EXCHANGE

The telephone exchange presented here allows up to eight pulse-dialling telephone sets to be connected, and has an option for connecting calls to or from an external (trunk) telephone line. The unit is controlled by the popular 8052-based BASIC computer we introduced a few years ago.

220.057 **$190**

MAIN FEATURES

- 8 Internal lines
- 1 external line
- memory for 10 numbers
- internal through connections
- versatile computer control
- automatic hold for external line
- simple to extend
- can be interfaced to a PC
- selective external call acceptance
- shortcut dial codes for external number
- works with pulse dialling telephone sets
- one optional relay for extra switching function

SPECIAL PARTS SERVICE

We are the no. 1 suppliers of hard-to-find components for Elektor Electronics projects. Always contact us first if you see an unfamiliar component. Items include analogue & digital ICs (HCT, SMD), precision resistors (1%, 0.1%), capacitors (MKT/styroflex), inductors (Neosid, Toko), transducers, enclosures (Telet, OKW) and quartz crystals.

FOR FURTHER INFORMATION, PLEASE SEND A BUSINESS-SIZE SASE TO OLD COLONY SOUND LAB (ADDRESS ABOVE), ATTN: MEEK IT.

400-WATT LABORATORY POWER SUPPLY

Here is an all-purpose d.c. power supply for symmetrical as well as asymmetrical use, and capable of supplying high output currents and voltages. An all-analogue design based on discrete parts only, this 400-watt PSU deserves a prominent place on your work bench.

ex. case 220.036 **$525**

MAIN SPECIFICATIONS

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  one adjustable power supply with current an voltage controls
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- **Mode: independent**
  - two identical, electrically separated, power supplies
  - Outputs   2 x 0 - 40 V at 2 x 0 - 5 A
- **Mode: Tracking**
  - two identical, series connected, power supplies
  - Outputs + 0 - 40 V at 0 - 5 A
     0 - 80 V at 0 - 5 A
  - Voltage and current of slave follow master
- **Mode: parallel**
  - two identical, parallel connected, power supplies
  - Outputs 0.6 - 39.4 V at 0 - 10 A
- **Maximum output voltage:**
  0 - 40 V (at full load)
  48 V (no load)
- **Maximum output current::**   5 A
- **Ripple:**   10 mV (no load)
  50 mV (at full load)
- **Voltage difference in tracking mode:**   50 mV

OLD COLONY SOFTWARE

SPEAKER DESIGNER
Stuart E. Bonney

SPEAKER DESIGNER is a loudspeaker system design aid and modeling tool for use with both closed and vented systems over the frequency range of 10–300Hz. The program computes and displays system frequency response, power handling capabilities, and relative sound pressure level (SPL) outputs for each of 26 discrete frequencies over this range. This package runs on any IBM PC/XT/AT, true compatible, or IBM PS/2 running MS/PC-DOS 2.0 or higher. Printer output compatible with any 80-column or wider printer. 1 x 5¼", 360K, DS/DD.

SOF-SPD1B5 **SPEAKER DESIGNER for IBM** **$19.50**

STEPPED VOLUME CONTROLS
Joseph O'Connell

These ready-to-run Macintosh programs come on a 3½" SS/DD disk initialized as a 400K disk for compatibility with all machines. Also included are the Pascal source codes, should you wish to customize them for your own use. The package contains two programs:

RESISTOR SELECTOR (Program A): This program simplifies the math necessary to build stepped volume controls.

RESISTOR CHECKER (Program B): This program would be superfluous if it were possible to obtain every resistor value that the above program called for. But because you will be limited to the nearest standard values, or with series and parallel combinations, this program quickly calculates the taper that will result with different actual values. It can also show the effects of different source and load impedances on the taper. Both programs (contained on the same disk) allow you to save their output to a text file. From *TAA* 4/88, 3/89; article reprints included.

SOF-SVC1M3 **STEPPED VOLUME CONTROLS**
for Macintosh **$25.00**

THE LISTENING ROOM
Sitting Duck Software

This interesting program predicts standing wave modes in small rooms and is designed for positioning speakers--and the listener--in such a way as to minimize standing wave effects and other room-generated influences. With proper speaker/listener positioning, serious frequency response dips and peaks due to room influences can be kept to a minimum. The program allows for a full range of speaker and listener movement in 3D space and continuously updates a standing wave Pressure Versus Frequency display. 256K RAM, DOS 2.11 or higher required. CGA, EGA, VGA, or Hercules graphics capability required. LaserJet or dot matrix printer recommended. 1 x 5¼"; supplied on the diskette is a second version of the program which recognizes a coprocessor. Softbound manual.

SOF-TLR1B5G **THE LISTENING ROOM WITH GRAPHICS**
for IBM **$34.95**

THIELE/SMALL DRIVER PARAMETERS
David Long

This package was written in order to make easier and faster the job of determining the Thiele/Small parameters of raw drivers. The final display screen will show, in addition to the usual parameters, the effects of amplifier and crossover losses on the driver (Q_E, Q_T, Q_{ES}, Q_{TS}, and SPL), driver impedance at f_S, the driver's moving mass (M_{MD}), the driver's suspension compliance (C_{MS}), and efficiency.

This disk also contains programs for Q_{LA}, Q_{TC}, and room resonance. 1 x 5¼", SS/DD. From *SB* 1/89; article reprint included.

SOF-TSD1C5 **THIELE/SMALL DRIVER PARAMETERS**
for Commodore 64 (disk) **$25.00**

TWO-WAY ACTIVE CROSSOVERS PLUS
Gary Galo

This program will perform the necessary calculations for the eight common two-way active crossover designs described by Dr. Robert M. Bullock III in *Speaker Builder* 3/85 (article reprint is included). The schematics are drawn in the text mode using the IBM line drawing characters. No graphics adapters are needed to display them, but your printer must be set up to emulate the IBM ProPrinter in the alternate character set mode. As an aid to selecting op amps suitable for use in audio circuits, also included is a program for calculating op amp V_{TH} (input dynamic range), based on an article in *TAA* 3/86 (article reprint included). This program is particularly valuable since the demands of CD players have made V_{TH} such an important consideration in designing analog circuitry. DS/DD.

Purchasing options available:

SOF-TWO1B3 **TWO-WAY ACTIVE CROSSOVERS PLUS**
3½" for IBM **$20.00**

SOF-TWO1B5 **TWO-WAY ACTIVE CROSSOVERS PLUS**
5¼" for IBM **$20.00**

VENTWRK VENTED BOX CONSTRUCTION (PLUS)
George L. Augspurger

A short segment of a much larger loudspeaker analog program, VENTWRK is provided by one of audio's most famous names as a companion to his article "New Guidelines for Vented-Box Construction," which appeared in *SB* 2/91 (article reprint included). The program encompasses simple design rules developed by the author which enable f_B (resonance frequency) to be predicted reasonably accurately for typical vented loudspeaker enclosures. The Apple IIe version is written in Applesoft BASIC and runs on any member of the Apple II family having an 80-column card. It contains the VENTWRK program *only*. The IBM PC version is written in Turbo Pascal. The source code and the compiled .EXE program are included on the high density diskette. In addition to VENTWRK, the IBM version also contains the following two programs:

SPCONV: This program performs very fast interactive conversion between Thiele/Small parameters and basic specifications such as B1 factor and cone assembly mass.

BXCKT: This calculates and displays the R-L-C analog circuit values for Locanthi's analog circuit. Closed box, vented system, and passive radiator system are provided.

Purchasing options available:

SOF-VNT1A5 **VENTWRK VENTED BOX CONSTRUCTION**
for Apple (not Mac) **$9.95**

SOF-VNT2B5 **VENTWRK VENTED BOX CONSTRUCTION PLUS**
for IBM **$19.95**

WOOFER-SATELLITE OFFSET
Sitting Duck Software

When, due to aesthetic considerations, woofer systems are placed at

distances from the listener which are different from that of the satellites, serious dips in frequency response may result. The magnitude, width, and frequency of the dips are a function of the distance differential and the crossover network in use. This program plots the frequency and phase response curve which results from user-determined offset differentials and network configurations. 256K RAM required. CGA, EGA, VGA, or Hercules graphics capability required. LaserJet or dot matrix printer recommended. 1 x 5¼".

SOF-WSO1B5G WOOFER-SATELLITE OFFSET WITH GRAPHICS for IBM **$34.95**

SPEAKER BUILDER AND THE AUDIO AMATEUR INDEXES, 1980–1990
Russell Schoof

These eleven-year indexes, available separately and as a set, chronicle in a very user-friendly fashion the contents of Speaker Builder and The Audio Amateur magazines. The indexes are not stand-alone software; they require database management software such as PCFile:dB or Alpha Four for implementation.

These are dBASE III+ files and can be used by any program that either directly accesses or imports that type of file. Since dBASE is the de facto industry standard, though, most database and spreadsheet programs will work--even some word processors will. Since the index contents are standard database files, the indexes themselves can be updated annually or otherwise modified by the user. Alternatively, registration of the index copy with the designer (card provided) will entitle the purchaser to a discounted price on professionally produced annual updates.

The Speaker Builder index comes on two 5¼" disks. The EDITORIAL CONTENTS disk contains more than 1000 entries for articles, columns, letters, and corrections. The DRIVERS disk contains more than 800 entries for raw drivers. It lists all raw drivers for which useful information is presented in articles, letters, and some advertisements. Further, it also gives data (when available) on the type, function, construction materials, voice coils, and use, as well as the other types of information published in SB. Occasionally, data has been supplemented by information from outside sources. The index for The Audio Amateur comes on one 5¼" disk and is presented in the same form and style as the Speaker Builder EDITORIAL CONTENTS.

Purchasing options available:

SOF-SBX2B5 SPEAKER BUILDER INDEX, 1980–1990, for IBM **$16.00**

SOF-AAX2B5 THE AUDIO AMATEUR INDEX, 1980–1990, for IBM **$16.00**

SOF-XXX2B5 SPEAKER BUILDER/THE AUDIO AMATEUR COMBINED INDEX SET, 1980–1990 **$30.00**

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24-Hour Lines
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FAX: (603) 924-9467

SHALL WE WORMS TURN?

If a healthy infrastructure for the electronics enthusiast who likes to build things is ever fully revived in the United States and Canada, it won't be by folks who are content to curse the darkness.

Our supply problems, because of the size of our two countries, and the resultant elephantiasis of the electronics distributors, are due largely to two factors, as I see it. The obesity of those who should be doing the supplying, and the unorganized lassitude on the part of those who are eager to do some genuinely satisfying work building electronics projects. And electronic construction means something more complex, as one reader put it recently, than another solar night light.

I commend to you the example of reader Jan Rowland of Houston, TX. Like most Texans he believes in doing something about problems when they crop up. He wrote a strong letter to Jameco Electronics protesting their 1991 $50 minimum order limit. His letter was eloquent and to the point, and perhaps it helped that he sent Jameco's people a copy of my editorial from the September '91 issue.

Jan got a reply. Jameco, according to John Rengstorff in the Customer Service department, will lower Jameco's minimum to $30 beginning with the release of the 1992 catalog. A fresh copy of this new, handsome, and remarkably complete publication landed on my desk yesterday. They can well be proud of it, its usefulness and the kind of service I know they have provided since their earliest days in the 1970s. (To receive a free copy FAX them at (415) 592-2503 or call (415) 592-8097.)

The lesson here is that the action of a single customer can make a difference. There are now 10,000 of us who read and enjoy this magazine. If I have my way, at 1992's end, there will be twice as many of us. Most of you who write to me are having very nice things to say about the magazine's content. I believe the quality of what appears in these pages is far above average.

But the problem we face is telling the vendors of our two countries that we are here, and we are looking for goods. If they do not stock what we need, we need to ask them why they don't. If we find a good vendor who supplies our needs, we will do ourselves, each other and this avocation a favor by asking the vendor why his goods are not being advertised in *Elektor*.

No hobby flourishes without good vendors. We are doing a massive job of acquainting the electronics community with *Elektor Electronics USA*. But only you can tell them that you are a customer, that you have needs, and that those needs are worth money to their enterprises.

I have had the pleasure over the last 22 years of founding four magazines. Three of them have built a whole range of new businesses which flourish by meeting the needs of those publications' readers. But it all came about because readers were vocal about their pleasures, their projects, their discoveries, and their hardware and tool needs. If you are an enthusiastic builder of electronics projects, you can enrich your enjoyment of it by becoming active.

If this sounds like huckstering to you, so be it. But I see no healthy hobby in North America which is without a vast array of specialized suppliers who are out to help the hobbyist find pleasure and satisfaction, and sell goods too, of course. Have a look at any magazine you wish to name that serves a hobby market and you'll find hundreds, sometimes thousands, of suppliers who provide an amazing variety of arcane and often highly imaginative products. Model railroads are a good example. Next time you are at a newsstand, have a look at *Model Railroader*. And there are hundreds more: *Telescope Maker*, *Guitar Player*, *Electronic Musician*, *Fly Tying*, *Truckin'*, *Low Rider*, *Street Rider*, and on and on.

We must begin thinking of ourselves as a market because that is what our wishes become in building the projects we wish to build. But the world will never know we are a market with needs unless we talk about it, act on it, write about how we feel, and what we want.

I said in the first North American issue of this publication that we are, collectively, a rich and incredibly talented resource group for each other. That, in the best sense, is what a publication does. It is a meeting place, an interchange point for the minds and ideas of all its readers. And the data is not all intellectual. Some of it involves excellent parts and supplies.

This issue marks the beginning of the second year of *Elektor*'s North American odyssey. I hope you join me in recognizing that we are helping to rebuild something that has sunk to a very low ebb in our two cultures. For our own pleasure, enhancement and for the sake of ours and other's humanness, building with our two hands is a worthwhile pursuit. Talk to us. Talk to our advertisers. Talk to those who should be spreading their wares here. Your voice is essential, and your contribution is unique.

We have been worms far too long. It is time to turn.—E.T.D.

ELECTRONICS SCENE

IC-2410A/H DUAL-BAND MOBILES

Icom has announced the IC-2410A and IC-2410H 144 and 440MHz dual-band transceivers. The IC-2410A puts out a maximum of 25W on UHF and VHF. Maximum output power for the IC-2410H is 45W on VHF and 35W on UHF. Both offer high, medium, and low power settings. In addition to receiving two bands simultaneously, the mobiles also receive two frequencies simultaneously on the same band.

You can set the main band on VHF or UHF, enter memory or VFO mode, directly enter frequencies and memory channels, and select high or low power. The IC-2410A/H has crossband repeat capability with repeater offsets on both bands. Each band has 15 memory channels, two scan edge channels, and one call channel. The HM-56 microphone has 14 DTMF memory channels.

For more information, contact Icom America, Inc., 2380 116th Ave. NE, PO Box C-90029, Bellevue, WA 98009-9029, (206) 454-8155, FAX (206) 454-1509, TELEX 152210.

SILVER EPOXY KIT FOR ELECTRONIC CONNECTIONS

Planned Projects has introduced the 2400 Circuit Works Conductive Epoxy Kit for quick, solderless connection and conductive bonding applications in electronic design, prototype, and repair. Other applications include solderless surface-mount connections, circuit board trace repair, die attach, static discharge drains, shield bonding, and grounding.

The Circuit Works conductor is a two-part silver epoxy featuring electrical conductivity with resistivity typically 0.001Ω/cm and 10-minute room-temperature curing. The material approaches maximum bond strength in 24 hours. Bonding performance can be accelerated by mild heat curing at less than 100°C.

The kit sells for $14.95. For more information, contact Planned Projects, 303 Potrero St., Suite 53, Santa Cruz, CA 95060, (408) 459-8088, FAX (408) 459-0426.

THE VI SERIES OF AUTOMATIC A/V SWITCHES

R.F. Engineering has announced the VI series of automatic A/V switches. The VI allows two video devices (a laser disc player and a VCR) to be connected to a single monitor. It detects which source is delivering a signal and routes the signal to the monitor.

The VI can detect either video or audio signals, so it can be used as an expansion input on an audio preamp. The device is designed so that if both signals are present, it will give priority to the device on the Video B connection. A sensitivity adjustment allows the VI to filter out noise that can cause erratic switching. A delay adjustment is used to prevent switching on missing signals, such as between tracks on a CD.

The VI is available with RCA connectors at $89.95 or S-VHS connectors at $119.95. For more information, contact R.F. Engineering, Inc., 9215 Lowell Blvd., Westminster, CO 80030, (303) 430-8281, FAX (303) 430-4023.

CONCERT SOUND REINFORCEMENT WORKSHOP

The third in a series of Concert Sound Reinforcement Workshops will be sponsored by Synergetic Audio Concepts on January 14–16, 1992 in Orange, CA. Don and Carolyn Davis will host the workshop. Workshop Chairman, Will Parry of MSI, announced that Audio Analysts, Clair Brothers, Electrotec, and Showco will again be represented at the workshop. David Scheirman of Concert Sound Consultants will be the facilities coordinator.

For more information, contact Synergetic Audio Concepts, Rte. 1, Box 267, Norman, IN 47264, (812) 995-8212, FAX (812) 995-2110.

CHIP MAKES VIDEOPHONES COMPACT AND PRACTICAL

Low cost compact video telephone systems are now possible with the integrated circuit chip from PMC Products. The chip allows PMC to provide still frame, high resolution, black/white video units (Phonvu) for less than $500. About the size of a paperback book, the unit lets you send still video images over ordinary phone lines to other locations in 12 seconds.

Possible applications include teleconferencing, videofax, video database retrieval, remote video surveillance, storing video images on audio tape, and sending video images by radio.

For more information, contact PMC Products, 4742A La Villa Marina, Marina del Rey, CA 90292, (800) 423-6377.

SURVEILLANCE TRANSMITTER KITS

Sheffield Electronics has available several transmitter kits and books. All transmitters tune from 65–305MHz FM. Line-of-sight transmitting distance measurements were made using Ace Communications' AR-2002 receiver. Alkaline battery operating times were calculated from Duracell's specification sheets (batteries not included).

For more information, contact Sheffield Electronics Co., 7223A Stony Island Ave., Chicago, IL 60649.

EPROM LABEL BLOCKS UV LIGHT

A UV opaque write-on label for programmable memory or PAL packages will be introduced at this year's WESCON show by DATAK Corp., Booth 1923. When used on EPROM packages, the label gives added assurance that the burned program will not accidentally be erased by stray light from fluorescent lamps or other UV sources.

The label can be written on with a typewriter, ball point pen, soft pencil, or any platen feed computer printer. It is permanent, but can be removed without leaving an adhesive residue.

Labels are available in sets of three sheets (cat no. EP-1), with 147 labels total, for $4. DATAK Corp., 55 Freeport Blvd., #23, Sparks, NV 89431, (702) 359-7474, FAX (702) 359-7494.

WorldRadioHistory
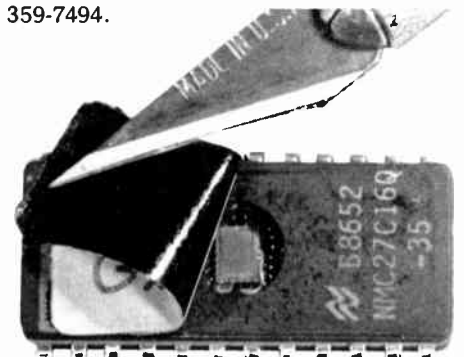
MONOLITHIC VCA WITH WIDE DYNAMIC RANGE/LOW DISTORTION

Analog Devices has announced the SSM-018 monolithic voltage-controlled amplifier designed for automated audio gain control. Professional audio applications include electronic volume control systems, mix consoles, dynamic range processors, compressors, limiters, and other noise reduction systems where remote, automatic, or computer control of gain and attenuation is desirable. It combines low distortion performance and wide dyamic range with the low cost of monolithic circuitry.

Maximum total harmonic distortion with gains of ±20dB (from 20Hz–20kHz) in Class A mode is 0.025%. Its patented design provides dynamic range to 118dB. An operational amplifier voltage controlled element (OVCE) architecture provides differential inputs and outputs that can operate in the voltage or current domain.

The 16-pin DIP version is $3 (in 100s), the SOIC is $3.25 (in 100s). For more information, contact Dan Parks, Analog Devices, Inc., Precision Monolithics Division, 1500 Space Park Dr., Santa Clara, CA 95052, (408) 562-7513.
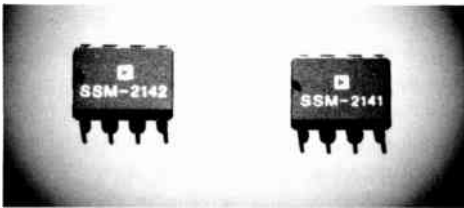
FULLY INTEGRATED BALANCED LINE DRIVER

Analog Devices' SSM-2142 is a highly integrated line driver system for audio, telecommunications, and industrial applications. This monolithic device replaces large, expensive transformer-based solutions and eliminates the need for expensive external trim circuitry.

The SSM-2142 is well-suited for a variety of applications that require superior noise immunity and common-mode rejection, including professional studio mix consoles, telecommunications, and industrial instrumentation. Total harmonic distortion plus noise from 20Hz–20kHz is 0.006%; output common-mode rejection is typically 45dB. When coupled with its companion, the SSM-2141 differential line receiver, the device offers a completely balanced low-cost, high-performance driver/receiver system for less than $5.

The SSM-2141 and SSM-2142 cost $1.95 and $2.95 in 100s, respectively. For more information, contact Analog Devices, One Technology Way, PO Box 9106, Norwood, MA 02062-9106, (617) 329-4700, FAX (617) 329-1241.

ELECTRONICS SCENE

FREQUENCY COUNTER WITH 1mV SENSITIVITY

Optoelectronics has announced the Model 2810, a frequency counter with full-range operation, 1mV sensitivity, and resolution to display 10Hz in 3GHz. It detects frequencies up to 200MHz and resolves them to 1Hz in one second. Frequencies up to 900MHz are resolved to 1Hz and displayed in four seconds; frequencies up to 3GHz are resolved to 10Hz and displayed in 1.6 seconds. Four gate times (0.01, 0.1, 1, and 10 seconds) are available from the front panel selector switch.

The Model 2810 sells for $259. The optional LCD backlight sells for $45, the extra NiCad battery pack for $24, and the ±2 PPM TCXO for $100. For more information, contact Optoelectronics, Inc., 5821 NE 14th Ave., Fort Lauderdale, FL 33334, (800) 327-5912 or (305) 771-2050, FAX (305) 771-2052.

ELECTRONIC SOURCE BOOK OF THE 1990s

The 1991 catalog from **EasyTech** features test equipment, connectors, enclosures, data books, soldering equipment, tools, designer boards, service aids, and many other items sought by electronics buffs. EasyTech also provides data sheets on most integrated circuits produced in the last ten years. They charge $1 to have the data sheet included with an order or $5 to have an individual data sheet printed and sent out on its own.

For a catalog, contact EasyTech at 2917 Bayview Dr., Fremont, CA 94538, (415) 770-2300, FAX (415) 770-2346.

INTERNATIONAL CONFERENCE ON INFORMATION ENGINEERING

An **International Conference on Information Engineering** will be held in Singapore December 2–5 at the Hyatt Regency. The conference will deal with the integration of computers and communication systems, emphasizing the networking aspects. Tutorial sessions will be offered on the first day. The conference will coincide with Singapore Information Technology Week and will precede the Singapore Informatics 91 Exhibition.

For more information, contact Secretariat, Associated Conventions & Exhibitors Pte. Ltd., 204 Bukit Timah Rd., #04-02 Boon Siew Building, Singapore 0922, Tel (65) 732-6839, FAX (65) 732-6309, TELEX RS 28615

DATABASE OF ELECTRONIC CIRCUIT ARTICLES

Circuit Search has announced Version 1.09 of their database of references to articles containing practical electronic circuit designs. This dBase III/III + compatible database references nearly 13,000 articles and papers from more than 300 technical and scientific journals and magazines. As an interdisciplinary reference source, it can locate circuits by key words from journals in fields as varied as electronics, astronomy, agriculture, physics, chemistry, nuclear science, education, biomedicine, and many more disciplines where electronics can be applied.

The database is installed on a hard disk on an IBM PC or compatible. It occupies about 7Mb and comes on a series of disks. Circuit Search also provides copies (FAX or mail) of articles that qualify under Copyright Clearance Center (CCC) provisions, as well as update and revision services on a semi-annual basis.

Circuit Search sells for $375 (US dollars), including one free semi-annual update/revision. Further updates cost $40 for one or $65 for two. A sample disk including 400 references, pricing, and additional information is available for $7. Contact Peter Sawatzky, Circuit Search, PO Box 268, Breslau, Ontario, Canada, N0B 1M0, (519) 241-1252, FAX (519) 742-4594.
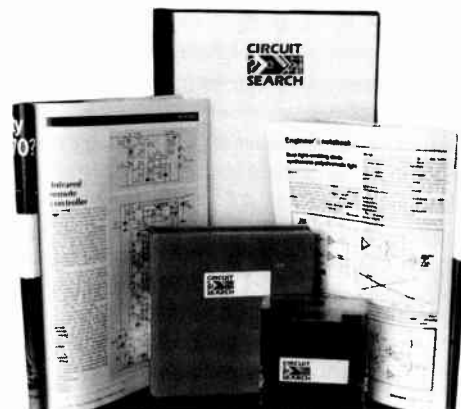
MEASUREMENT TECHNIQUES – PART 8

Measurements in digital circuits

by F.P. Zantis

MEASUREMENTS in digital circuits fall into two categories: (1) voltage, current and resistance; and (2) data. The first category presents no problems other than those already discussed in previous instalments of this article. The measurement of data and associated circuits will be described in this part in the series.
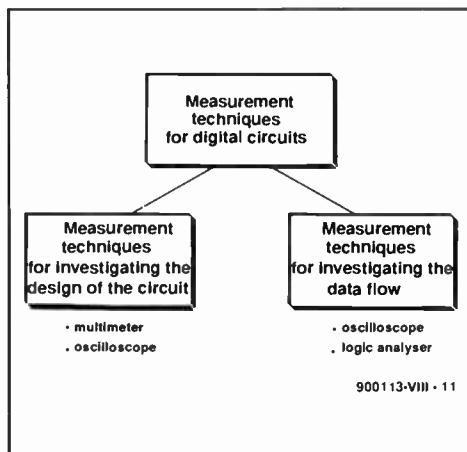
Fig. 1. Measurements in digital circuits fall into two categories.

Techniques for examining circuit design

Typical of digital circuit designs is the use of densely populated printed-circuit boards, whose tracks, owing to space limitation, are extremely thin. This makes faultfinding particularly difficult and it is, therefore, advisable to carry out a thorough inspection of the board before any work on it is begun. For this, an ohmmeter, multimeter, oscilloscope with component tester or a simple continuity tester is perfectly adequate.

Once the board has been populated, a multimeter is useful only for checking the various supply voltages. A component tester is also very useful: this quickly shows whether a component is all right or defect. Voltage levels and edges of digital signals can be checked with an oscilloscope.

Data pulses can cause problems with the triggering of an oscilloscope, however. Some oscilloscopes are, therefore, provided with special facilities, such as pre-trigger or hold-off. The pre-trigger function allows it to examine the trigger pulse just prior to its first mesial (see p. 41). In other words, the signal behaviour before triggering is displayed. The trigger pulse is then not shown at the left-hand of the screen, but in the centre, or

even at the right-hand.

The hold-off function allows the continuous lengthening of the delay between two time-base sweep voltages as shown in Fig. 2. Pulses or other spurious signals occurring during the hold-off time cannot influence the triggering, which is particularly useful in the case of aperiodic pulse bursts of constant amplitude. The oscilloscope can be triggered on different points of the waveform.

A digital storage oscilloscope is particularly useful for measuring an aperiodic signal. Note, however, that in moderately priced models short spurious pulses or glitches may not all be identified. The scanning rate and storage capacity limit the use of these oscilloscopes.

Examining the data flow

As is well-known, logic signals in digital engineering can only be 1 (high) or 0 (low). Errors caused by insufficient pulse voltage levels or resulting from too long a first transition duration of the pulse can be traced with standard test methods.

A typical problem encountered in measurements in digital circuits is that the examination of only one signal usually does not yield enough information about the functioning of the circuit. Generally, two or, in complex circuits, even more signals must be examined simultaneously.

For analysis of two signals, a dual-beam oscilloscope is required (not a dual-trace type, because that cannot capture two fast transient events). Examination of the data bus of an 8-bit microprocessor system requires an 8-channel oscilloscope. Even that is not sufficient if a control signal such as 'write' or 'read' must be triggered.

Some, rather expensive, oscilloscopes permit the simultaneous display of four signals—see Fig. 3. A dual-beam oscilloscope may be converted with a multi-channel adaptor to make relatively simple, qualitative test on a number of channels possible. The major disadvantage of such adaptors is their low chopping rate, which allows examination of relatively slow signals only.

In contrast to oscilloscopes, which measure voltage as a function of time, logic analysers are designed primarily for examining the data flow in complex digital circuits and microprocessor systems.

A logic analyser is suitable for testing hard-
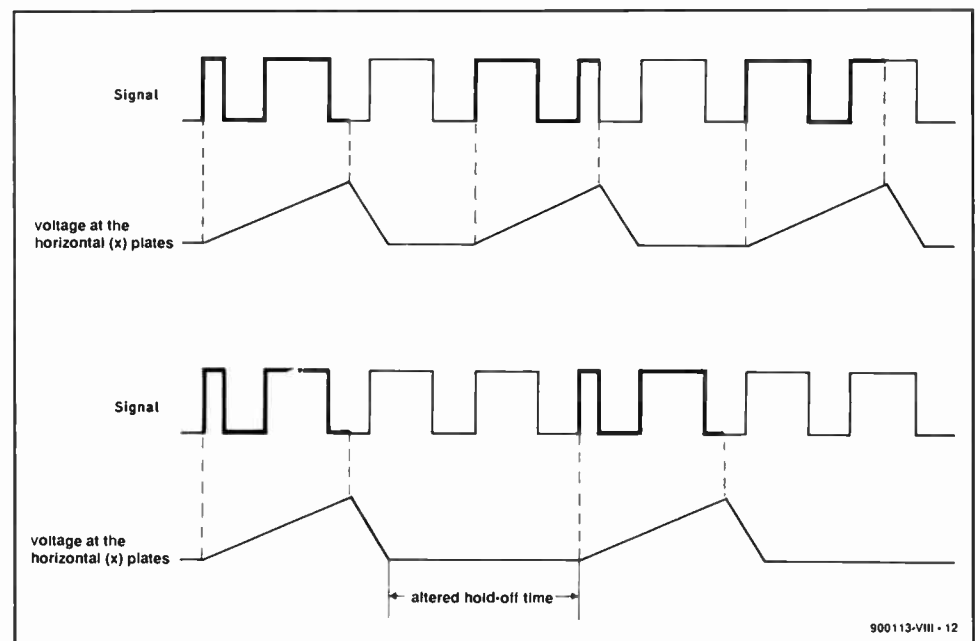
Fig. 2. Illustrating the hold-off function. At the top, this facility is not operating. The oscilloscope is then triggered when the electron beam is in its output position and a leading edge appears in the signal. The waveform in bold print is then shown on the screen; the picture runs across the screen. Analysis is not really possible. In the lower half, the hold-off time is altered in a manner that ensures that triggering always occurs at identical leading edges, so that the picture stands still. It is then possible to identify any glitches or other short, spurious pulses clearly.

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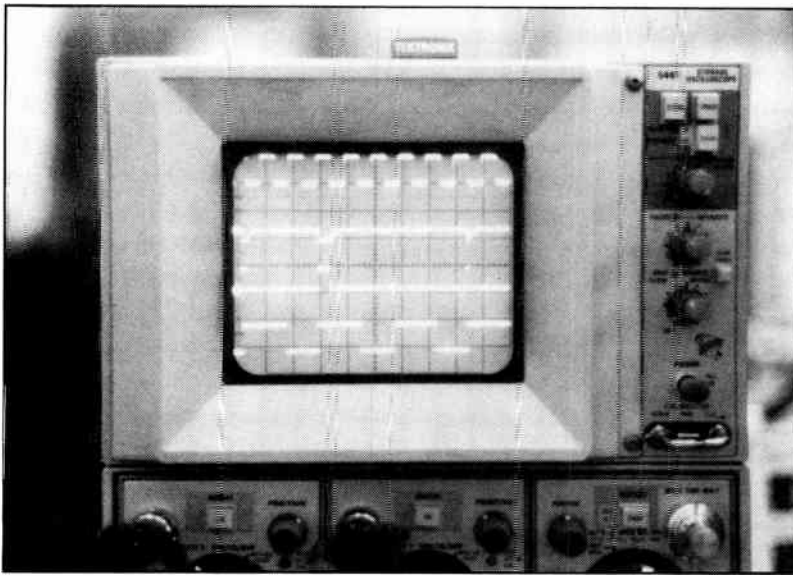
Fig. 3. Display of four logic signals on a 4-channel oscilloscope.
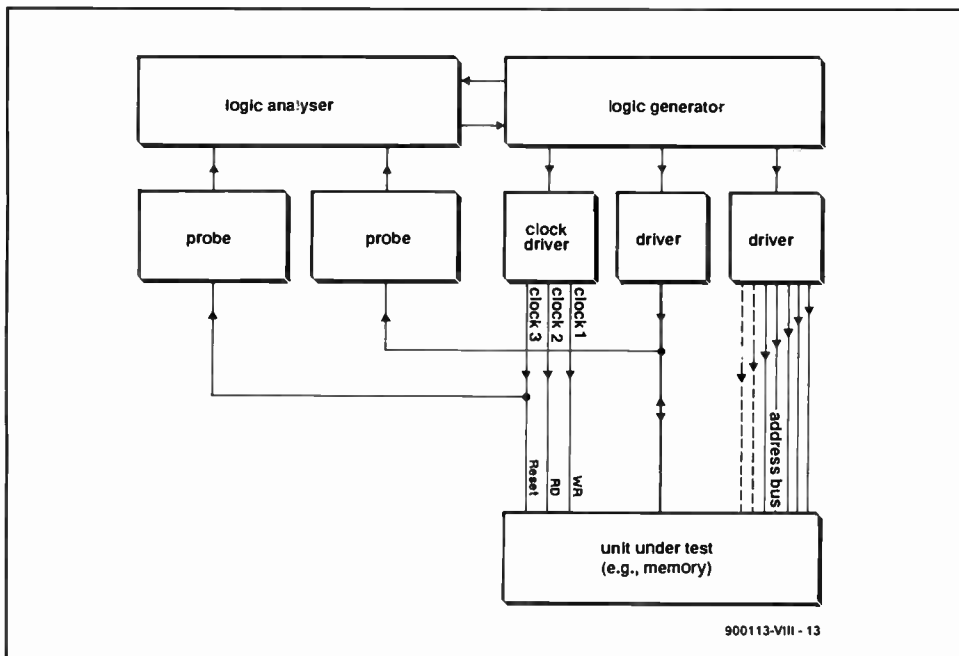
Fig. 4. Typical application of a combination of a logic analyser and a logic generator.
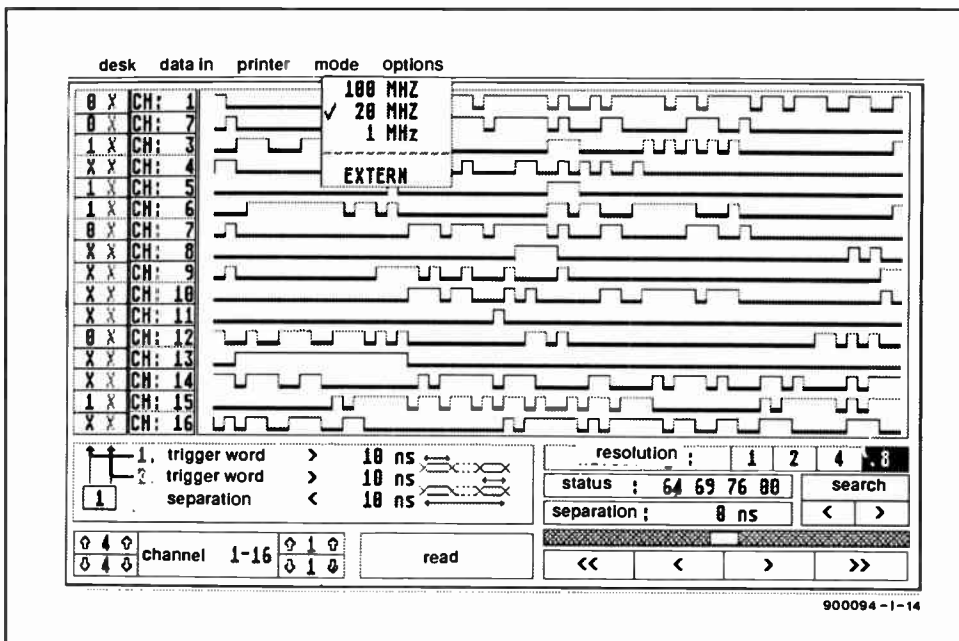
Fig. 5. Timing diagram displayed on a logic analyser.

ware as well as software; it measures data, that is, a pulse is considered as a bit with a value of 1 or 0, and not as a rectangular waveform with a certain amplitude. At the time of writing, logic analysers with up to 72 input channels are commercially available.

A combination of a logic analyser and a logic generator, which provides sample bits that can be fed to the circuit under test, is especially useful. It allows the analysis of circuit sections even when these are driven by external sources.

A typical application of such a combination is shown in Fig. 4, in which the unit on test is controlled via a data bus and an address bus. The logic generator provides the addresses, data input and clock, while the analyser records the test data.

The most important part of a logic analyser is the control computer, whose software serves to operate the analyser and to analyse and display the test results. In that process, it is necessary for the relevant information to be extracted from a vast mass of data. In the simplest case, it is only necessary for a given sample bit to be triggered. More complex systems permit triggering even when, for example, the operating conditions are normally set by one or a number of data buses.

Differences between various logic analysers, reflected in their price, are manifested particularly in the possibilities of data extraction and the way this is carried out.

The data display on the screen may take various forms. Apart from the usual timing diagram as shown in Fig. 5, which shows the behaviour of signals as a function of time, it is also possible for the status or the disassembler to be shown.

The status diagram shows the input channels in a circuit section that were determined previously by a configuration menu.

The disassembler diagram is particularly useful for an analysis of the interaction between hardware and software. The recorded data show the converted machine code of the computer system on test in mnemonic form. This process is called disassembly.

Every logic analyser is provided with special probes that facilitate proper connection of the many inputs to the unit under test. It is, of course, essential that fast pulse bursts be transmitted only via short lines that introduce no or negligible losses.

The probes contain drivers that amplify the signal prior to transmission to the appropriate analyser input. ∎

Reference:

'Logic analyser' (5 parts), *Elektor Electronics*, January, February, April, June, July 1991.

24-BIT FULL COLOUR VIDEO DIGITIZER

The circuit presented here enables the Archimedes video digitizer described a few months ago to handle full-colour images at an impressive resolution of 24 bits.

by J. Kortink

THE idea to process colour pictures with the aid of the video digitizer was born shortly after the publication of Ref. 1. Although computer-based colour image processing is far from simple (even a super-VGA card can only show 256 colours at a time), there is a growing demand for digitized colour photographs. This is mainly on account of the widespread use of professional DTP (desk-top publishing) packages capable of supporting 24-bit colour illustrations with the aid of colour separation techniques.

The hardware and software described here was developed with DTP applications (on the Acorn Archimedes) in mind. The performance of the digitizer is quite impressive: it needs only 10 seconds or so to 'read' and display a colour photograph — much faster than many commercial products currently offered.

Colour images

For black and white screen images, only one 'ink' colour is used: usually black. A video image may be reproduced with digital means by scanning the image at a sufficiently high resolution (both as regards the number of pixels and the number of grey levels). The video digitizer has a resolution of 640×512 pixels at 256 grey levels. The reproduction on paper of the image requires the discrete grey levels to be transformed back into ink spots. On a computer screen, intensity modulation is used, while on paper grey levels are reproduced by controlling the size of the ink spots. Hence, the resolution of the printer attached to the computer determines the number of grey levels that can be reproduced. Most 300-dpi (dots per inch) laser printers are capable of reproducing 16 simulated grey levels. Professional image setting machines typically achieve 200 levels when

set to a resolution of 2400 dpi. Photographic paper has no such limitations, offering a virtually infinite number of grey levels.

In practice, 64 intensity levels are sufficient to faithfully reproduce a photograph. The 256 grey levels offered by the video digitizer are, therefore, ample for most applications.

Colour images on a computer screen are invariably made by 'building' individual picture elements from three primary colours. In the case of the video digitizer, use is made of the three additive primary colours red, green and blue (RGB model). By contrast, magazine and book printers traditionally use the subtractive primary colours cyan, magenta and yellow, to which is added black (CMYk model).

During the digitizing operation, the saturation of the three primary colours red, green and blue of each picture element is measured. This means that the image is actually scanned three times: once for the red components, once for the blue components, and once for the green components, the saturation of which is stored as a digital value in the computer memory. A digitized colour image is then obtained by combining the three scanned images containing the primary colours. This technique is not unlike that used in the graphics and printing industry, where colour separations are used to produce three or four plates (screens) that each represent a primary colour. The fourth plate represents black, and is used for the brightness information only. During the offset printing process, the images on the plates are printed over one another to give an image with composite colours. Note, however, that the individual picture elements are not printed on top of each other, but side by side with an accurately controlled distance (off-set). In this system, the black plate is theoretically not required, since black can be re-

produced with the three primary colours also. In practice, however, black so printed has a brownish hue. Grey levels are, therefore, printed with black ink, which avoids undesirable sub-colours.

Returning to computers, the number of colours is usually determined by the type of video card used. Fortunately, we may avail ourselves of mixing techniques to take the number of colours that can be shown on the screen over the number of colours actually available. This is achieved by dithering, or pixel combination. Unfortunately, dithering has the inherent disadvantage of reducing the overall picture resolution.

Dithering techniques are based on error distribution protocols developed by, among others, R.W. Floyd and L. Steinberg. These protocols allow the difference between the desired colour and that produced on the basis of the actually available colours to be made as small as possible. Unfortunately, we have to leave the subject of dithering at this brief description, since a discussion of the related techniques is beyond the scope of this article. The software developed for the present colour extension of the video digitizer does, however, provide pixel dithering routines.

The hardware

As already mentioned, the black and white video digitizer described in Ref. 1 is taken as the starting point. To be able to process colour images, the video information has to supplied as RGB signals. Lacking an RGB output on your video equipment, existing composite video or S-VHS video signals have to be converted into RGB signals first. This may be done with a special converter — see Ref. 2. Cameras, video recorders, tuners and the like capable of producing RGB signals do not require an additional converter,
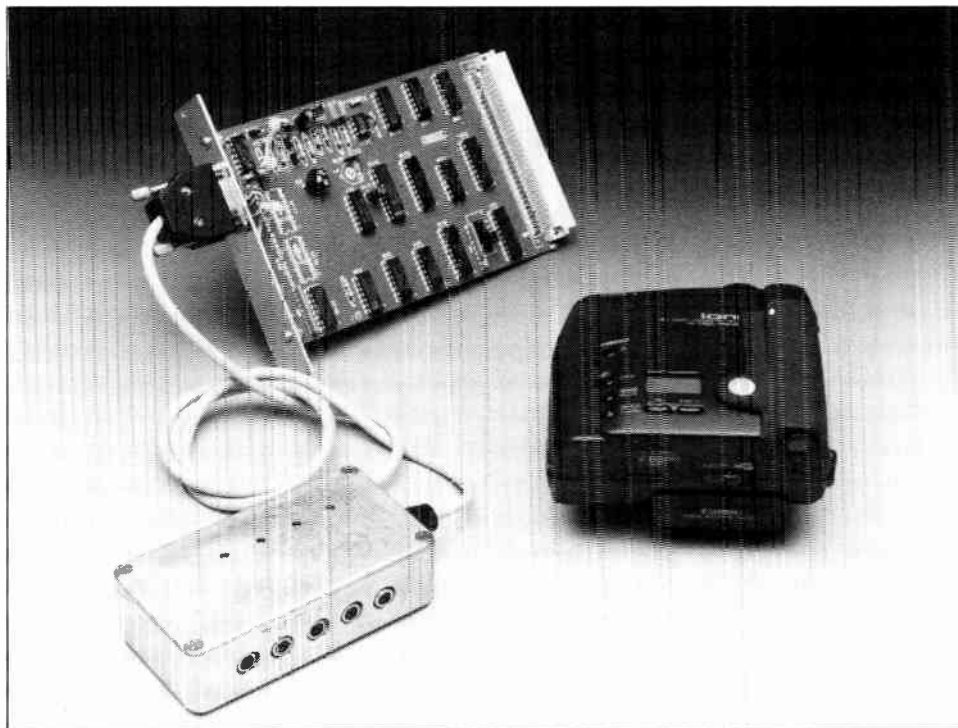
and can be connected direct to the input of the present circuit, which is basically an interface between the video source and the input of the video digitizer.

The circuit diagram of the RGB interface is given in Fig. 1. The circuit is really quite simple. Two control signals supplied by the digitizer select one of the four signal inputs via IC_{1a} and four relays. As indicated, three inputs are used for the primary colours, and a fourth for a composite video signal, allowing black and white images to be digitized in a simple manner. The fifth input serves to pass the synchronization signals to the video digitizer. This input is not switched because the sync signals must always be present. Four LEDs are used to indicate which of the four video inputs is connected to the digitizer.

The printed circuit board used to build the interface is shown in Fig. 2. The construction is straightforward, and should not present problems to those of you who have already successfully built the video digitizer.

A small modification

The circuit of the video digitizer requires a small modification to be made before it can be used for the colour applications we have in mind. First, a 9-pin sub-D connector is fitted on the aluminium support bracket of the podule. This connector takes the place of the existing cinch or BNC socket. For the original black and white application of the digitizer, the video input is fed to the A-D converter (IC_{10}) and the sync separator (IC_{11}) via a buffer stage. Since for colour applications the synchronization and colour signals have to be applied separately, capacitor C_{18} is removed from the board, and a wire is sol-

dered to pin 2 of IC_{11}. Next, a 100-nF capacitor (C_{18}) is soldered between the free end of the wire and pin 1 of the D9 connector. The video signal is connected to pin 2, the power supply to pin 3, and ground to pin 4.

Finally, we need two control signals. These are supplied by IC_{15}, a PCF8574 — one of the three optional I/O ICs on the podule. Fit this IC and the associated pull-up resistor array, R9, on the podule board. Output lines P0 and P1 (IB0 and IB1) are available on pins 1 and 2 of connector K2. These lines connected to the D9 connector, for instance, to pins 5 and 6.

The colour interface is connected to the video digitizer via a 6-way cable terminated with D9 connectors at both ends.

The above modification still allows black and white images to be digitized without the interface when a video connector is used with a 9-pin D plug, of which pin 1 is connected to pin 2, i.e., the video signal is connected to these two pins, while ground is connected to pin 4.

Software: !GreyEdit

The control program for the colour version of the video digitizer is called !GreyEdit, and comes on a diskette (Archimedes format) supplied through the Readers Services under order number ESS 1631. All other functions in the program !VidiDigi (see Ref. 1) are also included on this disk.

Fig. 1.   Circuit diagram of the colour interface for the video digitizer.
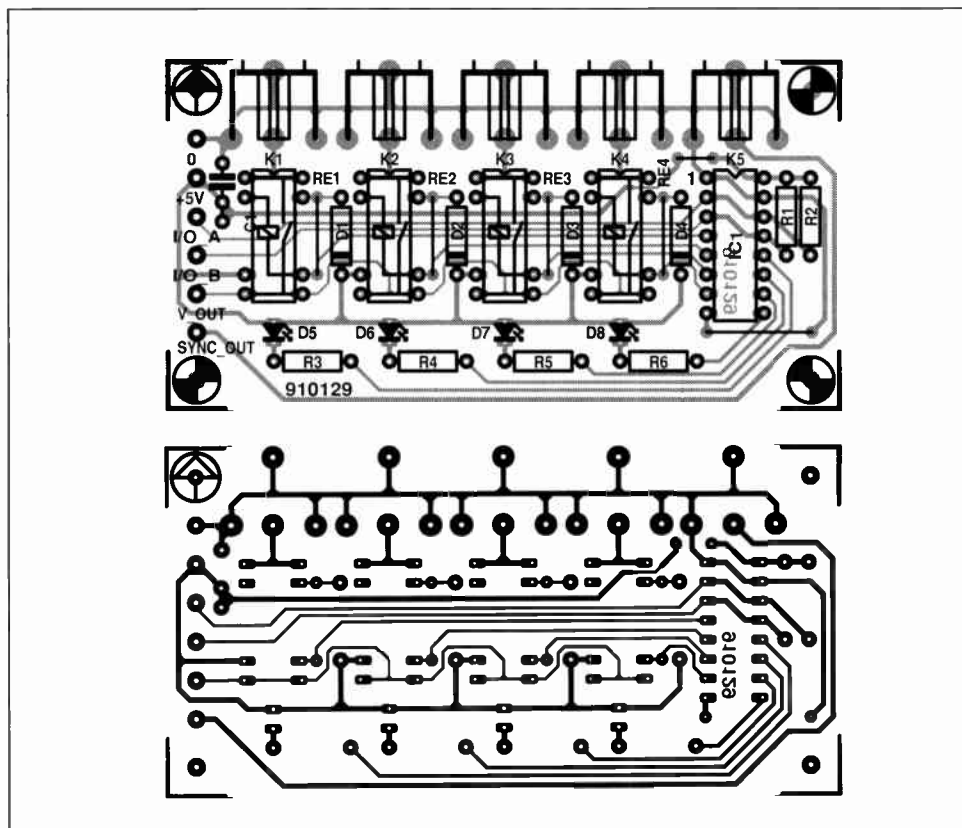
Fig. 2.   Printed circuit board for the colour interface.

COMPONENTS LIST

Resistors:

2	10kΩ	R1;R2
4	470Ω	R3-R6

Capacitors:

1	100nF	C1

Semiconductors:

1	74HCT139	IC1
4	1N4148	D1-D4
4	LED	D5-D8

Miscellaneous:

4	V23100-V4005-A000 (Siemens)	Re1-Re4
1	9-way sub-D plug, with hood	
1	9-way sub-D socket	
5	RCA (phono-) socket for PCB mounting	
1	enclosure, aluminium, size approx. 109×58×25 mm (e.g., Hammond 1590)	
1	control software on disk	ESS1631
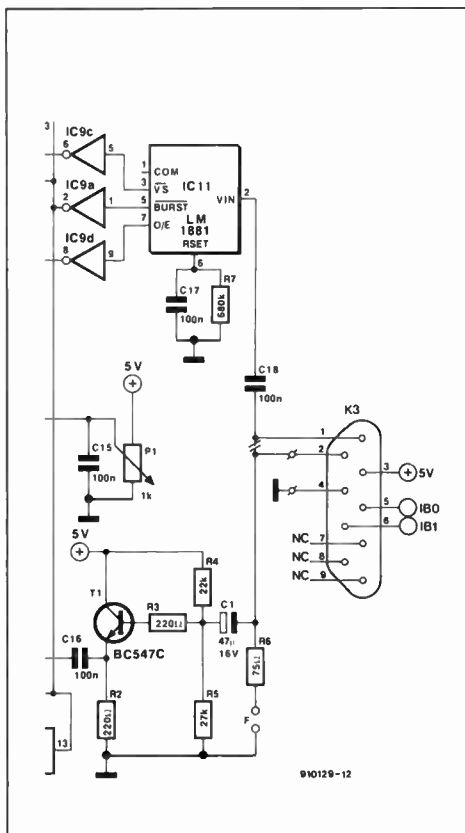
Fig. 3. The modifications to the original video digitizer are simple to make, while all functions are retained.

Fig. 4. Digitized photographs taken with a Canon ION. Use was made of the S-VHS output. Also, the picture was improved with the 'sharpen' function provided by the control software developed for the Acorn Archimedes.

The digitizer functions are available via the 'digitizer' sub-menu. The buttons on the screen allow you to select one of the three primary colour signals, or the black and white signal. The selection must be indicated by the LEDs on the interface board. The program also has a utility that allows a colour image to be digitized automatically. On selecting this function, you are prompted to inform the computer where the digitized images are to be stored. Simply drag the icon to a directory on the diskette or hard disk. The digitizing operation starts immediately after this has been done. The files containing the red, green and blue information are stored successively in the indicated directory. The digitizing process is complete after

three scans, and the R, G and B information is ready for combining into a new, larger, file. Drag the directory with the three primary colour files to the window marked !GreyEdit. Next, the program asks you where the photograph is to be stored (saved), and under what name. If everything works correctly, the colour photograph will be ready after a few seconds of number crunching activity. The photograph is written in the 'Clear' format and may be converted into a GIF, TIFF or PBM file with the aid of the !Creator utility. Mind you, the current versions of

the GIF protocol do not support 24-bit colours. It is, therefore, recommended to use the TIFF format to export files.

The picture may be edited with !Translator, which is supplied on the disk together with !GreyEdit and !Creator. Finally, note that the size of the image files requires a hard disk and a minimum memory of 2 MByte.

Black and white image enhancement

A couple of experiments with a Canon ION RC-260 camera showed that the quality of digitized black and white pictures can be improved considerably when a video source with an S-VHS (super-VHS) output is used. Where such a source is available, connect its luminance signal (pins 1 and 3) only to the digitizer. Results close to perfection may be obtained in this manner, particularly if the 'sharpen' function of !Greyedit is used. The two photographs in Fig. 4 were produced in this way. After digitizing, they were converted into Postscript, and printed on a Agfa Compugraphic Type 9800 photo typesetter.

■

References:
1. Black-and-white video digitizer (for Acorn Archimedes). *Elektor Electronics* July/August 1991.
2. S-VHS/CVBS-to-RGB converter. *Elektor Electronics* September and October 1990.
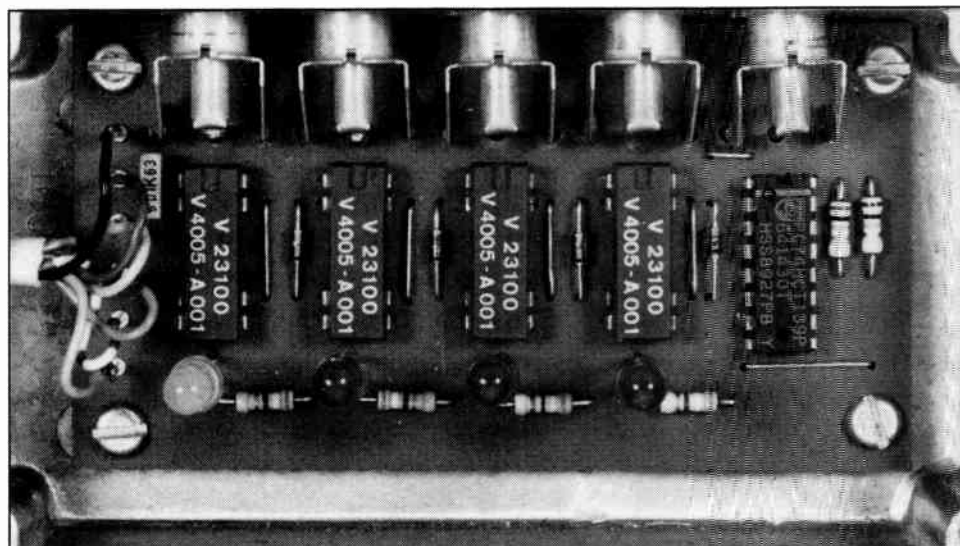
Fig. 5. Interface fitted in a compact enclosure. The unit is connected to the computer via a short flexible cable.

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DISSIPATION LIMITER

by C. Zschocke

Dissipation in electronically regulated power supplies, manifested by heat, is a problem that is normally tackled by providing external heat sinks. The limiter presented here offers a more intelligent solution. It can be used as an add-on unit with virtually any power supply.

THE secondary alternating voltage in power supplies stabilized with the aid of series regulators is normally calculated to ensure that with maximum output voltage and current the potential across the reservoir capacitor does not drop below the minimum voltage, U_r, required for satisfactory operation of the regulator. When the supply operates below maximum output voltage and current, the power that is then not required is converted into heat. Moreover, the design allows for maximum output voltage and current even when the mains voltage is at its lowest specified level.

The secondary voltage may well be specified too high, with the result that when the mains voltage is at its highest specified level and the power supply is open-circuited, the maximum permissible potential across the reservoir capacitor, and thus that at the input of the regulator, may easily be exceeded.

It is clear that in most power supplies, the specified voltage levels for the regulator and reservoir capacitor are needlessly high.

Possible solutions

The uneconomical design outlined above may be improved in several ways. It is, for instance, possible, with the aid of relays, to select secondary alternating voltages according to the load requirement. This is, however, possible only with a very special, and therefore expensive, mains transformer. Another possibility is to use phase gating control. This, however, requires fairly high switching currents and causes noise on the mains supply. Moreover, capacitors that can withstand high current pulses must be used and these are expensive.

A third method is used in the circuit presented here. In this, the charging of the reservoir capacitor is interrupted when a certain potential across the capacitor is reached. The circuit, which can be added to most existing
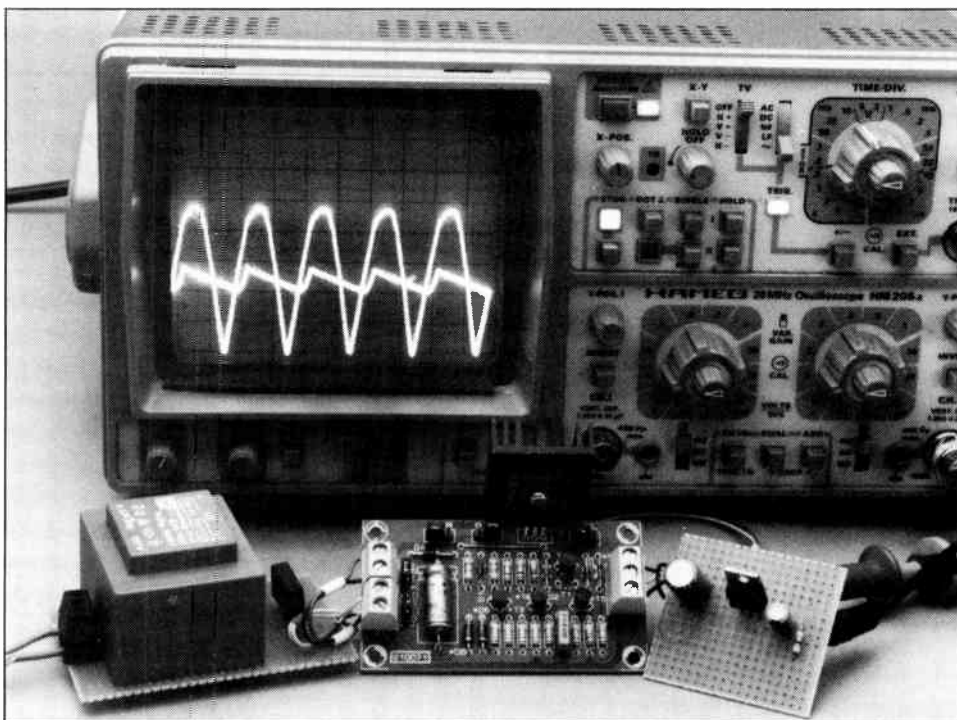
regulated mains power supplies,
- minimizes the power dissipation;
- offers an additional reduction in dissipation during a short-circuit or during current limiting;
- is inexpensive to build;
- uses only standard, readily available components;
- needs only little space;
- is suitable for high-current supplies;

- can be used with positive and negative series regulators.

Principle of operation

In Figure 1, an electronic switch, for instance, a SIPMOS transistor, is inserted between the rectifier and the reservoir capacitor. At the start of each half cycle, the switch is on ($U_r > 3$ V). A charging current flows into the capacitor
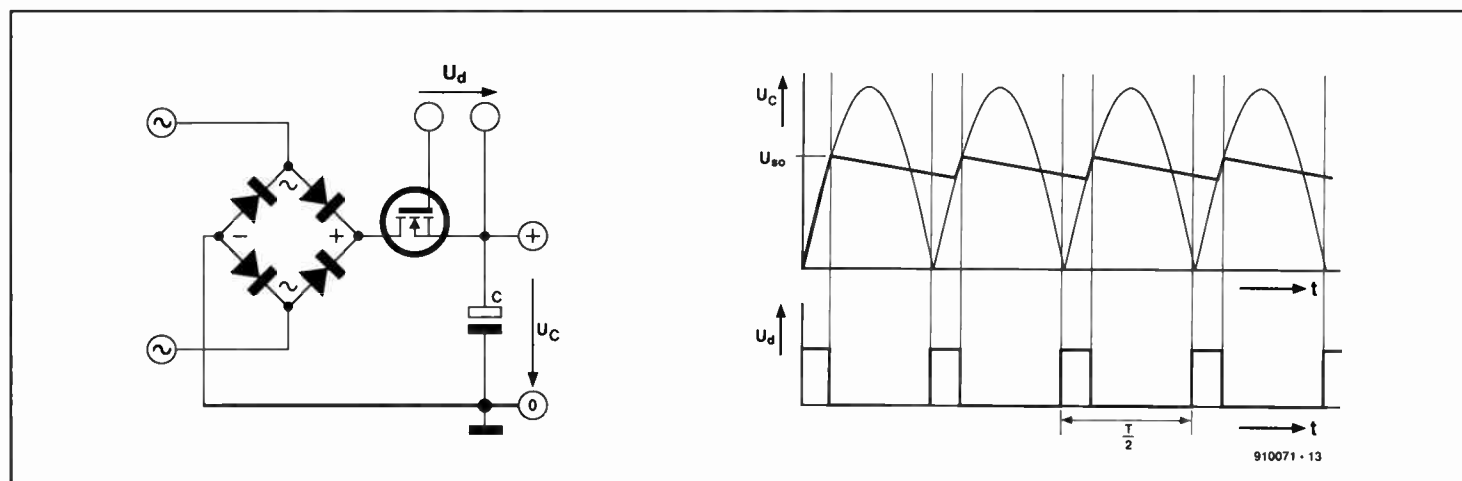
Fig. 1. Principle of operation of the dissipation limiter.

and the potential, U_c, across the capacitor follows the instantaneous level of the half-wave voltage. When U_c has reached the minimum level, U_{so}, required for the wanted output voltage, U_o, the charging current is switched off until the end of the half cycle. The level of U_{so} must be chosen to ensure that U_c does not drop below U_r until charging current begins to flow again at the start of the next half cycle. This voltage is the sum of the wanted output voltage, the drop across the regulator, U_d, and the voltage resulting from the discharging of the capacitor. The difference ΔU that is, the series switch-off voltage, $U_{so(m)}$, between U_r and U_{so} is easily determined, since it is directly proportional to the charging current; in fact, $\Delta U = It/C$, where I is the charging current, t is the time during which charging current flows, and C is the capacitance of the reservoir capacitor. Thus,

$$U_{so} = U_o + U_d + \Delta U$$

$$= U_o + U_d + It/C.$$

The time t is, in full-wave rectification, equal to a half cycle of the mains frequency, that is, $T/2$. Then,

$$U_{so} = U_o + U_d + IT/2C.$$

If now the maximum permissible output current, $I_{o(m)}$ is substituted for I, the highest potential drop across the regulator (at the start of each half cycle) is

$$U_{so(m)} = U_{so} - U_o = U_d + I_{o(m)}T/2C.$$

From this, the instantaneous dissipation, P_r, can be computed:

$$P_r = I_o U_{so(m)} = I_o[U_d + I_{o(m)}T/2C - I_o T/4C].$$

As an example: a power supply with a reservoir capacitor of 3 300 µF is required to provide an output voltage of 0–15 V at a maximum current of 1 A. Since the potential drop across the regulator is 3 V, the voltage across the capacitor, U_c, must be at least 18 V. Without limiting, the maximum power loss, $P_{r(m)}$, in the regulator is 18×1=18 W (which is, for instance, the case when maximum current flows at very low output voltage as in a short-circuit condition).

With limiting, the voltage across the capacitor, U_{so}, needs to be only

$$U_{so} = U_o + U_d + I_o t/C =$$
$$= 0 + 3 + 1 \times 10^{-2}/3300 \times 10^{-6} = 3.03 \text{ V}.$$

The maximum dissipation is reduced to

$$P_{r(m)} = I_o[U_d + I_{o(m)}T/2C - I_o T/4C].$$

Since $I_o = I_{o(m)}$,

$$P_{r(m)} = I_o(U_d + I_{o(m)}T/4C =$$

$$= 1(3 + 1 \times 2 \times 10^{-2}/4 \times 3300 \times 10^{-6} = 4.5 \text{ W},$$

which is an appreciable improvement.
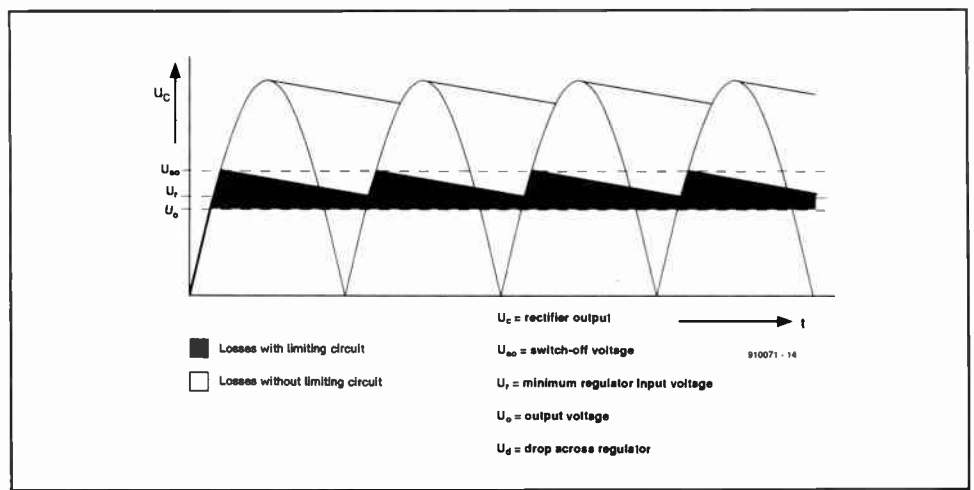
Fig. 2. Dissipation with and without limiter.
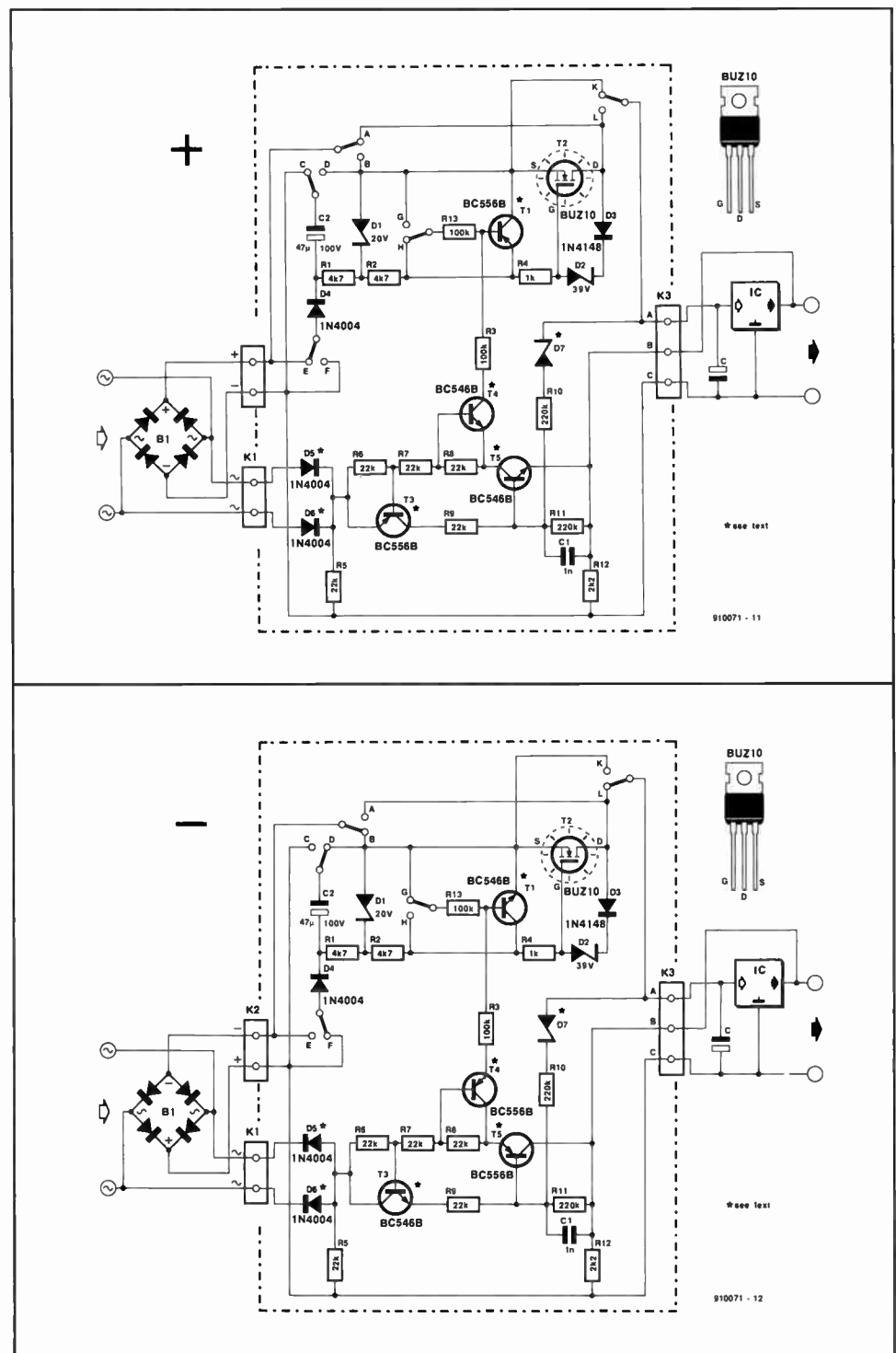
Fig. 3. Circuit diagram for both versions of the dissipation limiter.
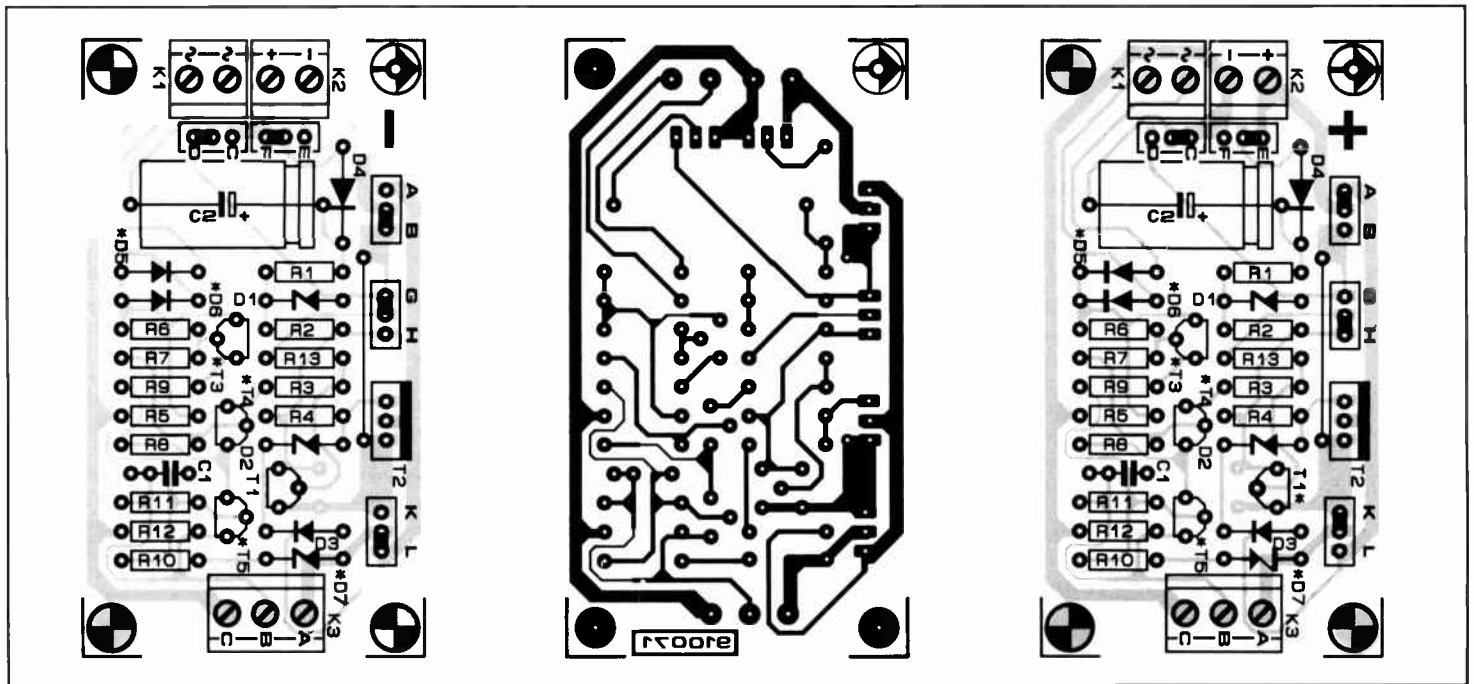
Fig. 4. Printed circuit boards are available for both versions of the dissipation limiter.

PARTS LIST

Resistors:
R1, R2 = 4.7 kΩ
R3 = 100 kΩ
R4 = 1 kΩ
R5–9 = 22 kΩ
R10, R11 = 220 kΩ
R12 = 2.2 kΩ
R13 = 100 kΩ

Capacitors:
C1 = 1 nF
C2 = 47 µF, 100 V

Semiconductors:
D1 = zener diode, 20 V, 400 mW
D2 = zener diode, 39 V, 400 mW
D3 = 1N4148
D4–6 = 1N4004
D7 = see text
T1, T3 = BC556B (pos); BC546B (neg)
T2 = BUZ10 or BUZ11 (see text)
T4, T5 = BC546B (pos); BC556B (neg)

Miscellaneous:
Heat sink for T2
PCB 910071

The practical circuit

The circuit in Fig. 3 may be split into the drive for the current switch, the switch itself (T_2) and a 'thyristor'. The thyristor is formed by transistors T_3 and T_5; its cathode is connected to the output terminal of the series regulator.

The thyristor is switched on via zener diode D_7 as soon as the voltage across the regulator exceeds the level fixed by the zener diode plus the b-e voltage of T_5. It switches itself off just before the next zero crossing. To make certain that it does, it is decoupled from the rectifier and the inverse diode of T_2 via D_4 and D_5, which are loaded by R_5.

When the thyristor is on, T_4 switches T_1 on and this in turn switches T_2 off.

Transistor T_4 also serves, in conjunction with R_3, to decouple the thyristor and the charging-current switch.

Diode D_4 and C_2 provide T_2 with the necessary switching voltage.

Zener diode D_1 protects the gate of T_2 against overvoltage.

The inductance of the mains transformer causes a high back e.m.f. when the charging current is switched off, and this may upset the correct operation of T_2. This is prevented by D_2 and D_3, which switch off T_2 as soon as the back e.m.f. exceeds the permissible reverse bias. A useful effect of the back e.m.f. is that it increases the potential across C_2, which guarantees satisfactory switching of T_2 even when the output voltage is a maximum.

Resistor R_{12} ensures correct switching of T_2 when the output is not loaded (open circuit). It must be rated at $U_{o(m)}^2/R_{12}$ Watt. It may be omitted if the power supply is permanently loaded.

Transistor T_2 must be fitted, *insulated*, on its own heat sink or on that of the regulator.

Depending on the component values, the limiter may be used with secondary alternating voltages of up to 50 V_{peak}. It is not possible to say what the maximum load current can be without knowing the value of the reservoir capacitor and the specification of the mains transformer. What can be said is that the maximum charging current pulses must not exceed the maximum permissible current through T_2, which is 19 A for the BUZ10 and 30 A for the BUZ11.

The limiter can be used without any problem in 5 A power supplies. The prototype operated satisfactorily with an output current of 10 A (reservoir capacitor was 10 000 µF). It is always possible in doubtful cases to connect two or three SIPMOS transistors (T_2) in parallel.

Here are some tips for calculating the values or ratings of a number of components.

- The zener voltage of D_7 must be U_{so}–0.7 V (U_{b-e} of T_5).
- The maximum reverse bias of T_2 must be greater than the peak value of the potential across the reservoir capacitor.
- The zener voltage of D_2 must be equal to the maximum reverse bias of T_2 minus 5 V.
- Capacitor C_2 must be rated at $U_{so(m)}$ plus 20 V (D_1).
- Transistor T_4 must be able to withstand voltages of $U_{so(m)}$ plus 20 V (D_1).
- Transistors T_3 and T_5 must have a reverse bias rating equal to the peak value of the secondary alternating voltage.
- Resistor R_{12} must be rated at $U_{o(m)}^2/R_{12}$ (watts).
- All connecting wires should be as short as possible and of appropriate thickness.
- The dimensions of the heat sink depend on the transformer, the reservoir capacitor and the maximum permissible short-circuit current.
- In most cases, it is possible to fit T_2 on the heat sink of the regulator.

Construction

The limiter described above is, of course, intended for positive voltages. One for negative voltages operates in a similar manner, but the polarity of some components must be reversed.

Whichever version is needed, it is best constructed on the appropriate printed-circuit board shown in Fig. 4. The differences between the two versions are indicated by an asterisk (*).

It is recommended to 'strengthen' the broad tracks by soldering thick, bare wire on them.

The completed unit is, as shown in Fig. 3, interposed between the rectifier and the reservoir capacitor. Short, heavy-duty wiring should be used.   ∎

DIGITAL FUNCTION GENERATOR – PART 2

by T. Giffard

THE ONLY connection between the PLL board and the discretely designed analogue parts of the generator is via plugs and sockets K_2, K_5, and K_8. Pin 1 of these connectors carries the 32 Hz–3.2 MHz clock, which is converted in the various sections to a 1 Hz–100 kHz sinusoidal, rectangular or triangular signal. The other pins carry information about the selected decadic range.

Sine-wave converter

The conversion of the rectangular output signal of the PLL loop into a sinusoidal waveform takes place in three stages—see Fig. 17. The first of these is a digital-to-analogue (D–A) converter with serial input, IC_{26}–IC_{28}; the second, a filter section that removes any unwanted harmonic frequencies; and the third, an output stage based on IC_{40}.

The D–A converter consists of two cascaded 8-bit shift registers, IC_{27} and IC_{28}, whose 16 outputs are fed via a single opamp, IC_{34}, to the filter section.

Before the first pulse arrives at the clock inputs of IC_{27}–IC_{28}, all 16 outputs of the registers are low, whereas inputs B are high. Input A of IC_{28} is low, but input A of IC_{27} is high, since the (low) level at pin 13 (QH) of IC_{28} is inverted by IC_{26d}. Therefore, when the first clock pulse is received, output QA

of IC_{27} goes high; on the second clock pulse, QB goes high (while QA remains high) and so on. When, on the eighth pulse, QH goes high, input A of IC_{28} becomes high, so that the outputs of this register also go high consecutively (QA→QH). After 16 clock pulses, all outputs of both registers are high, whereupon

input A of IC_{27} goes low, as explained earlier. The outputs then go low in succession until after a further 16 clock pulses the process repeats itself.

The high level at the outputs is 6 V and the low level is 0 V (earth). The values of the series resistors at the outputs have been cho-
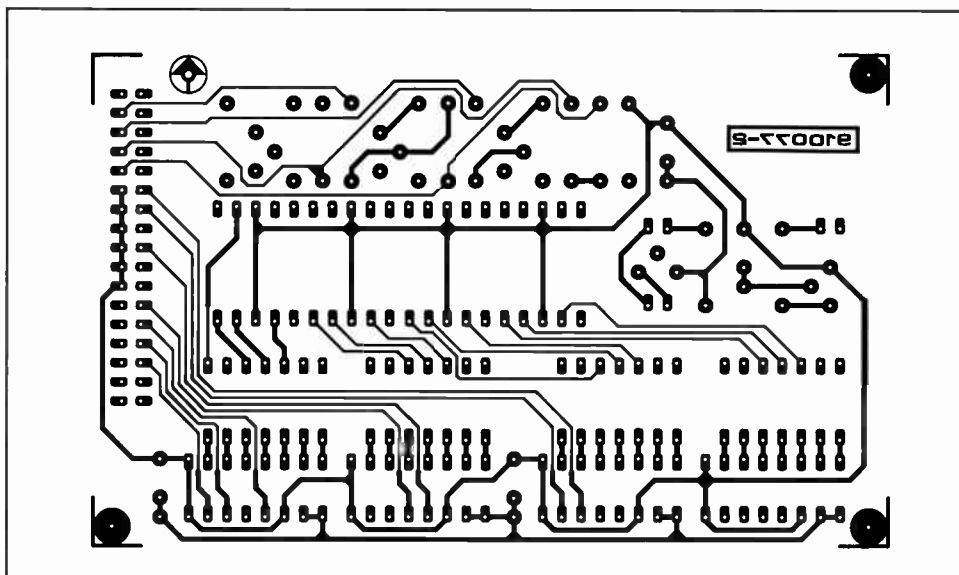
Fig. 13. Third overlay of the PCB for the analogue section of the function generator (belongs to Fig. 10)
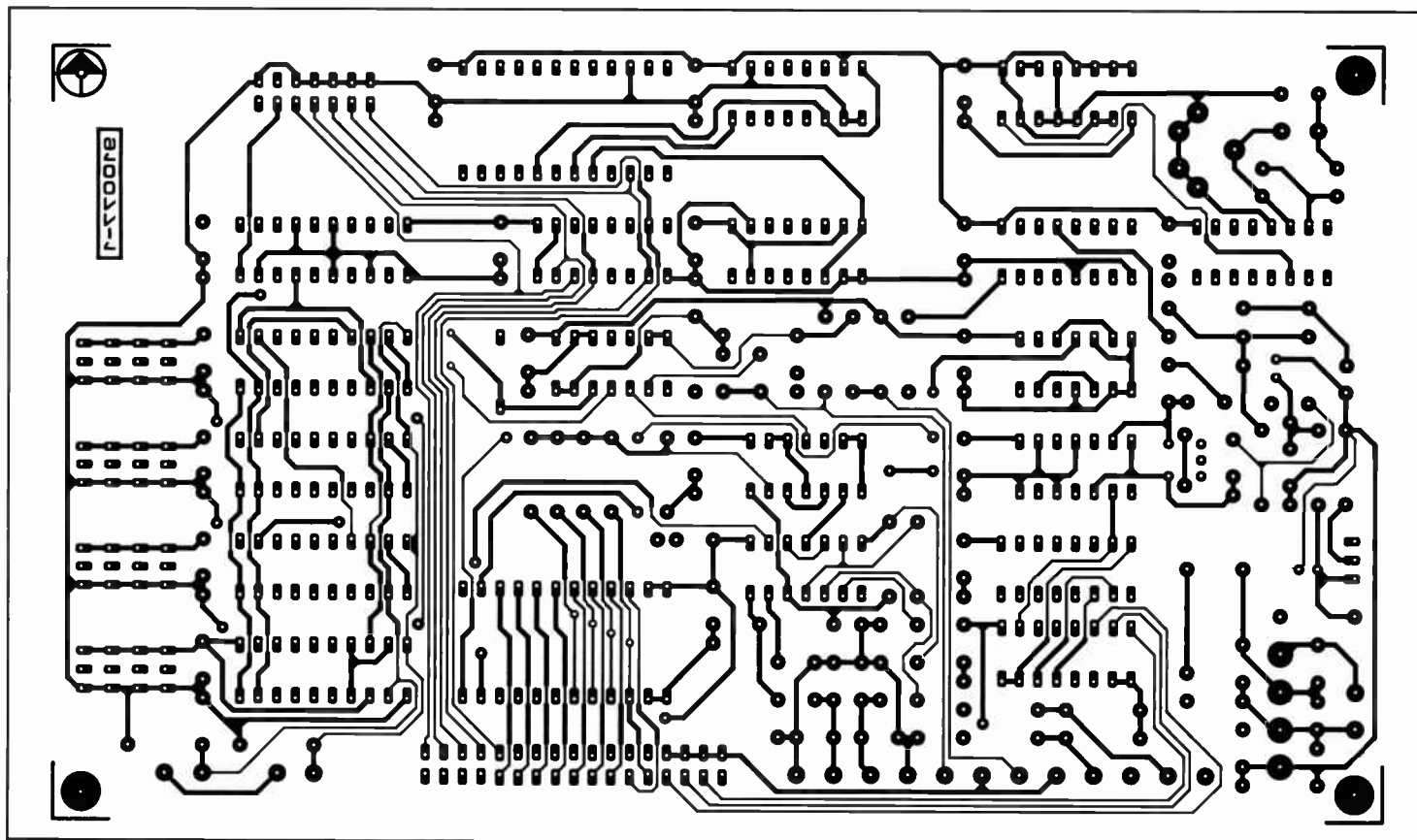
Fig. 14. Third overlay of the PCB for the digital section of the function generator (belongs to Fig. 7)

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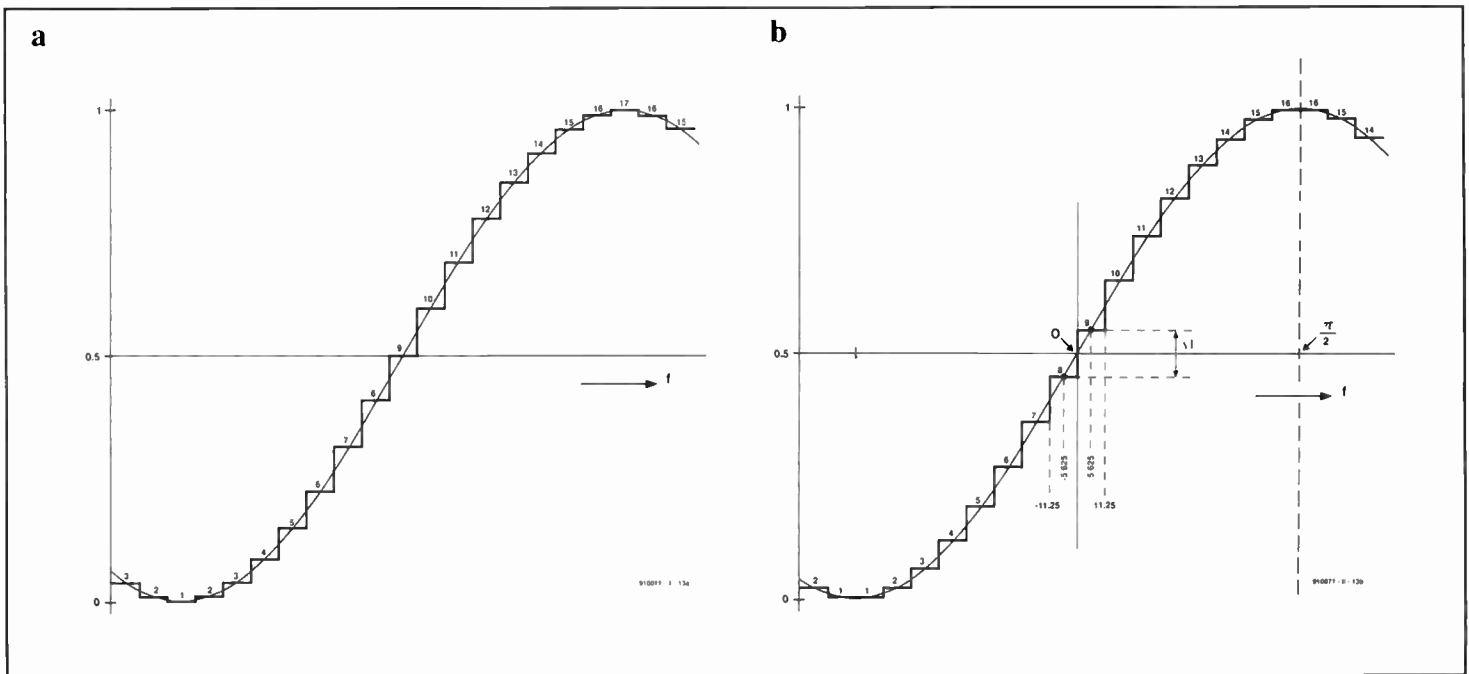
Fig. 15. Illustrating the two methods discussed to build up a sine wave from stepped voltages.
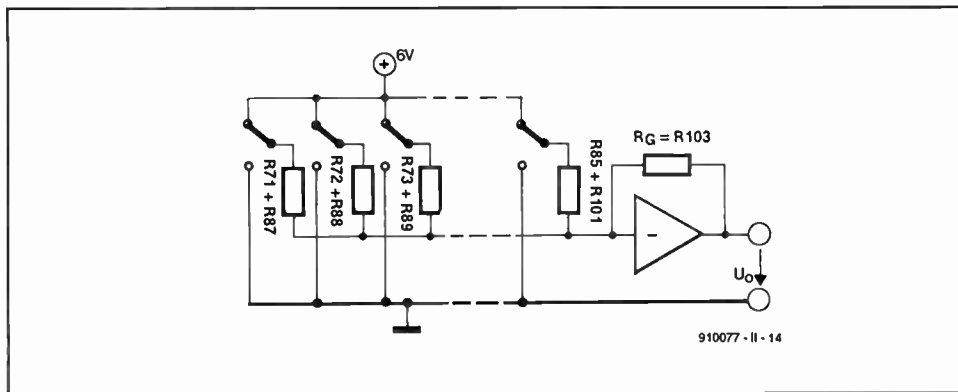
Fig. 16. Illustrating the fundamental operation of the digital-to-analogue converter.

Table 1

Data for computing the resistance networks in the digital-to-analogue converter

n	α_n	$\sin\alpha_n$	$\sin\alpha_n-\sin\alpha_{n-1}$	R_n
8	−5.625	−0.0980		
			0.1960	48 621.23
9	5.625	0.0980		
			0.1923	49 573.78
10	16.875	0.2903		
			0.1811	52 627.25
11	28.125	0.4714		
			0.1630	58 476.26
12	39.375	0.6344		
			0.1386	68 760.81
13	50.625	0.7730		
			0.1089	87 515.91
14	61.875	0.88119		
			0.0750	127 053.40
15	73.125	0.9569		
			0.0382	249 224.20
16	84.375	0.9952		
			0	
17	95.625	0.9952		

sen to ensure that the total current through the resistors is translated into a stepped output voltage as shown in Fig. 15. The computation of the resistance values is not simple, since more than one solution is possible.

The first method is also the most obvious: divide the sine wave into 32 equal parts, so that maximum and minimum values for the harmonic function are obtained. That means that 17 discrete values are required as shown in Fig. 15a. Fourier analysis shows that this method results in relatively high-level second and third harmonics.

An alternative method, used in the present design, is shown diagrammatically in Fig. 15b. It is based on the symmetry of a sine wave around the $\pi/2$ (90°) line. To the left and the right of this line, the corresponding steps are identical. Although the minimum and maximum values of the sine wave are not reached exactly, only a 16-step D–A converter is needed. Moreover, although the 31st and 33rd harmonic have roughly the same amplitude as those arising with the first method, the 2nd and 3rd harmonic are virtually absent.

The fundamental circuit for the second method is shown in Fig. 16. The maximum voltage is present when all resistors are connected to the 6 V source (high) and the minimum when all are at earth potential (low). In this method, resistors R_{86} and R_{102} in Fig. 17 are not used.

The computation of the resistance values is begun at a zero crossing (0°) of the sine wave. Then, one half of the resistors is at 6 V and the other half at 0 V. As an example, resistors R_{78} and R_{94} will be computed. First, the difference between the actual and the next higher value must be ascertained. After that it is only necessary to calculate the *additional* current that flows through the next higher resistance.

First, the period is divided into 32 equal intervals: 360°/32=11.25°. From Fig. 15b, it is evident that the level of the output voltage between 0° and 11.25° must be the same

as the instantaneous value at 5.625°. Next, the sine of the angles α_n=5.625° and α_{n-1}=–5.625° is computed and the difference $\sin\alpha_n$–$\sin\alpha_{n-1}$ established. That difference is in direct proportion to the value of the resistance, that is, R_{78}+R_{94}. In the above, n is the harmonic-number.

The resistance is calculated in the manner used for an inverting opamp:

$$R_n = R_G U_{ref} / (\sin\alpha_n - \sin\alpha_{n-1}).$$

In the denominator, the value 0.196 (as given in Table 1) is substituted and multiplied by 1.4 (to obtain the r.m.s. value). Thus,

$$R_{78}+R_{94}=2224\times6/0.196\times1.4=48\ 621.23\ \Omega.$$

This value is roughly equal to preferred (E96) resistors of 47.5 kΩ and 1.1 kΩ in series. The small difference of just over 20 Ω is useful since the output resistance of the shift registers is 20–30 Ω. The higher resistance value (0.1%!) must be just *below* the nearest preferred value in the series. Table 1 gives the resistance values from the zero crossing up to the peak of the sine wave.

Since the sine wave is not only symmetrical around the $\pi/2$ line, but also with respect to the x-axis, the steps (1–8) in the negative half of the sine wave are identical to the corresponding ones in the positive half. It is, therefore, only necessary to compute the values for a quarter wave ($\pi/2$)—see the values of the appropriate resistors in Fig. 17. Note that the arrangement ensures that the minimum and maximum values of the output voltage remain constant for the duration of two clock pulses.

Operational amplifier IC$_{34}$ not only converts the current into a corresponding voltage, but also ensures that the 'zero' line is 1.2–1.8 V (set with P$_1$) above earth potential, so that a clean, symmetrical sine wave with an r.m.s. value of about 1 V is obtained. The amplifier is a BiFET Type AD711, which is characterized by a slew rate of 16 V/μs, low off-set voltage, low drift, good bandwidth-gain product (3 MHz at unity gain) and above all by an excellent transient response of ±0.001% in 1 μs. Capacitors C$_{61}$ and C$_{62}$ remove any residual r.f. components from the signal and so ensure phase stability of the amplifier.

Locked filter

The filter consists of ten fourth-order low-pass sections, of which two are used for each decadic range. The discrete design offers real advantages as far as the harmonic spectrum is concerned over a simple switched filter with direct input of the clock pulses. The *RC* elements are switched on and off by analogue multiplexers Type 74HC4053, which have a very low transfer resistance. Each of the filter sections is buffered by a Type AD712 opamp.

The filter sections are fed with signals D1–D4 and the output of level comparator IC$_{17}$. It can be seen from Fig. 18 that the relevant section is active only when the corresponding decadic range D1–D4 is selected. The other sections are then short-circuited
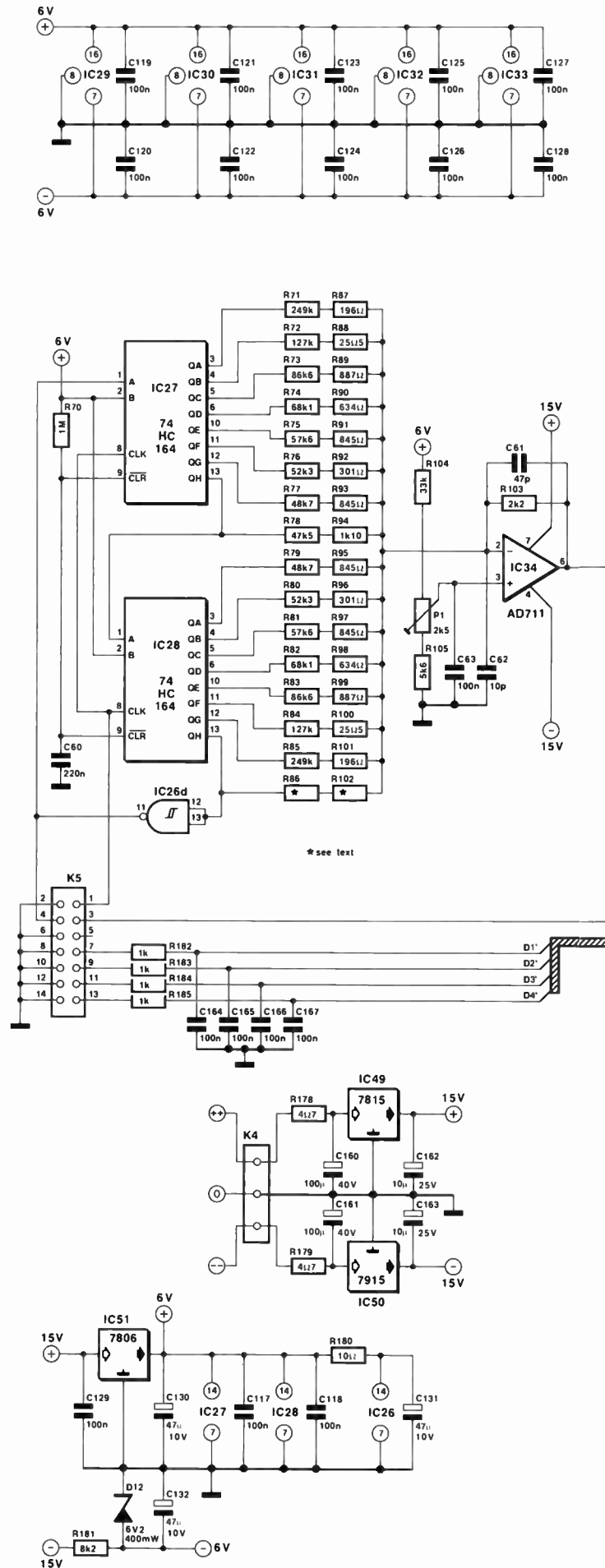
Fig. 17. Circuit diagram of the sine wave converter.
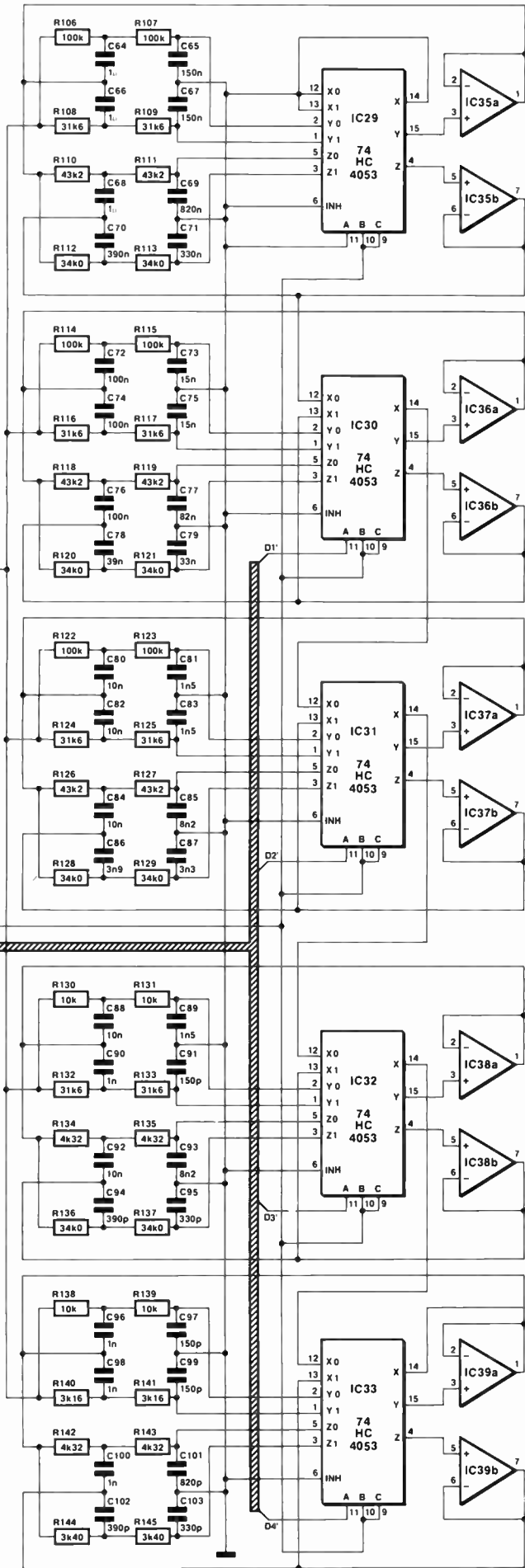
IC26 = 74HC132
IC35 ...IC39 = AD712
IC40 = NE5532

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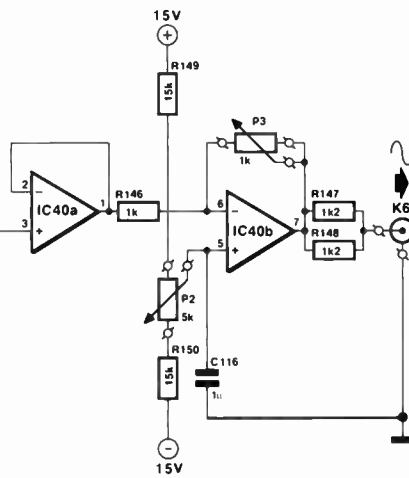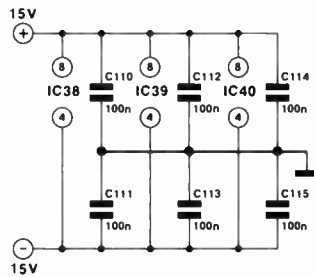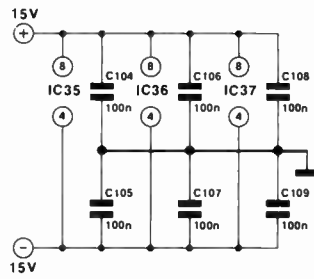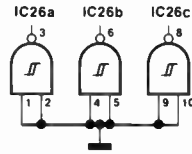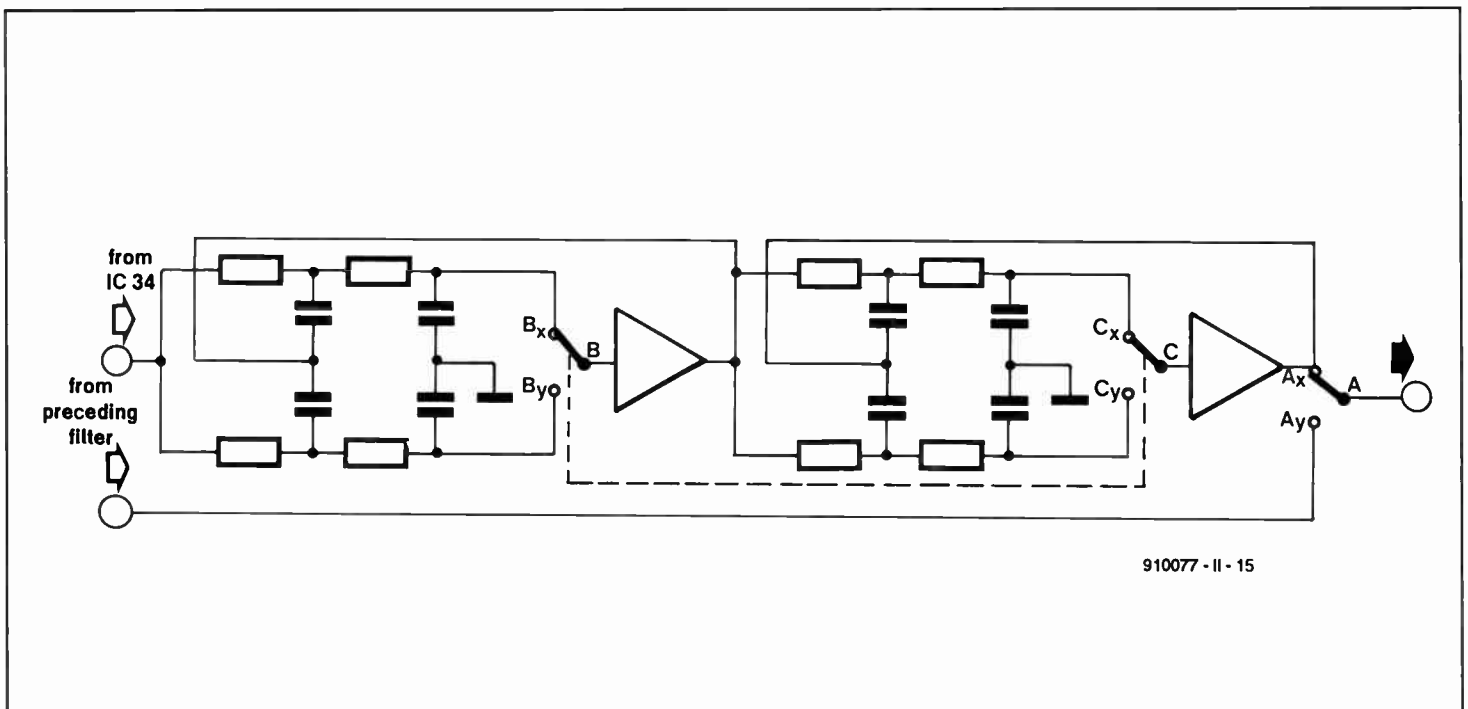
Fig. 18. Illustrating the fundamental operation of one of the five two-stage filter sections.

by switch A. The section for the lowest range is, however, always in circuit and, therefore, does not need signal D0. The other two switched inputs of the analogue circuit are strapped together.

When the ratio is lower than 3 200 (that is, when the frequency of the output signal is at the lower side of the decadic range), RC networks with different cut-off frequencies are switched in. In that way, the filter has an own frequency limit for the ranges $1-\sqrt{10}$ and $\sqrt{10}-10$ ($\sqrt{10}\approx3.2$).

The main function of the filter is attenuating the harmonics. Theoretically, only the 31st and 33rd harmonics are significant. The 31st is 30 dB below the fundamental and is attenuated by a further 70 dB by the filter, so that ultimately it is −100 dB with respect to the output sine wave.

Unfortunately, the cut-off frequencies of the filter have to be calculated for the lowest signal frequency of the decadic range. This means that at higher frequencies the fundamental frequency may be attenuated by about 0.7 dB, owing to an inherent property of the Butterworth design used. This attenuation may be accentuated by the tolerances of the components. The top of the filter characteristic, therefore, has a ripple (≥ 0.7 dB). This may be remedied by using higher cut-off frequencies, which increases the distortion, or using a different filter design, for example, Chebishev with 0.1 dB ripple, which requires high-tolerance (that is, more expensive) components. Table 2 gives component values for a Butterworth filter with higher cut-off frequencies, which give an attenuation of the 31st harmonic of only 50 dB instead of 70 dB, but which guarantee a ripple of ≤0.05 dB.

The output stage, IC_{40}, uses the well-known Type NE5532 dual opamp. One part, IC_{40a}, functions as a simple impedance converter to decouple the filter. The other part, IC_{40b}, operates as an inverting amplifier. The off-

set voltage can be set between −4.75 V and +4.75 V with P_2.

The amplitude of the sine wave output can be set to 0–1 V with P_3. If a higher output level is required, P_3 can be replaced by a 2.2 kΩ type. The value of R_{146} should not be reduced. Also, at higher amplification, it may be necessary to limit the off-set range by increasing the values of R_{149} and R_{150}.

Rectangular and triangular waveform converter

The rectangular / triangular converter, whose circuit diagram is given in Fig. 19, is controlled by the clock from the sine wave converter that enters the circuit via pin 4 of K_8. That connecter also feeds signals D0–D4 (con-

taining information on the selected decadic range) to the converter.

The clock signal is applied to the non-inverting input of opamp IC_{42b}, which transforms the asymmetrical 0–6 V to a symmetrical rectangular signal (±15 V).

Circuit IC_{42b} is one section of a dual operational amplifier Type OP260. This is a rather special device that operates with negative current feedback—see Fig. 20. The inverting 'input' of this section is, in reality, the low-resistance output of a buffer amplifier, whose input is connected to the non-inverting input of the opamp. If the voltage at this input rises, the current through R_1 increases. Since the current drives an impedance converter, the output voltage also rises (in proportion to the increase in current). Consequently,

Table 2			
Component values for higher cut-off frequencies			
R106 = 100 kΩ	R107 = 113 kΩ	C64 = 680 nF	C65 = 100 nF
R108 = 31.6 kΩ	R109 = 35.7 kΩ	C66 = 680 nF	C67 = 100 nF
R110 = 37.4 kΩ	R111 = 38.3 kΩ	C68 = 820 nF	C69 = 680 nF
R112 = 14.3 kΩ	R113 = 14.7 kΩ	C70 = 680 nF	C71 = 560 nF
R114 = 100 kΩ	R115 = 113 kΩ	C72 = 68 nF	C73 = 10 nF
R116 = 31.6 kΩ	R117 = 35.7 kΩ	C74 = 68 nF	C75 = 10 nF
R118 = 37.4 kΩ	R119 = 38.3 kΩ	C76 = 82 nF	C77 = 68 nF
R120 = 14.3 kΩ	R121 = 14.7 kΩ	C78 = 68 nF	C79 = 56 nF
R122 = 100 kΩ	R123 = 113 kΩ	C80 = 6.8 nF	C81 = 1 nF
R124 = 31.6 kΩ	R125 = 35.7 kΩ	C82 = 6.8 nF	C83 = 1 nF
R126 = 37.4 kΩ	R127 = 38.3 kΩ	C84 = 8.2 nF	C85 = 6.8 nF
R128 = 14.3 kΩ	R129 = 14.7 kΩ	C86 = 6.8 nF	C87 = 5.6 nF
R130 = 10.0 kΩ	R131 = 11.3 kΩ	C88 = 6.8 nF	C89 = 1 nF
R132 = 31.6 kΩ	R133 = 35.7 kΩ	C90 = 680 nF	C91 = 100 pF
R134 = 3.74 kΩ	R135 = 3.83 kΩ	C92 = 8.2 nF	C93 = 6.8 nF
R136 = 14.3 kΩ	R137 = 14.7 kΩ	C94 = 680 pF	C95 = 560 pF
R138 = 10.0 kΩ	R139 = 11.3 kΩ	C96 = 680 pF	C97 = 100 pF
R140 = 3.09 kΩ	R141 = 3.40 kΩ	C98 = 680 pF	C99 = 100 pF
R142 = 3.74 kΩ	R143 = 3.83 kΩ	C100 = 820 pF	C101 = 680 pF
R144 = 1.43 kΩ	R145 = 1.50 kΩ	C102 = 680 pF	C103 = 560 pF

the current through feedback resistor R_2 also increases and this will result in an equilibrium in the current through the buffer amplifier. The OP260 thus operates with a very small buffer current. The design has the important advantage over conventional opamps of a very fast slew rate: >1000 V / μs!

However, the operation is not entirely symmetrical as far as slope and amplitude are concerned. This is remedied by P_4–R_{152}, which make the signal symmetrical, and R_{167} in conjunction with D_{18}–D_{21} which equalizes the negative and positive halves of the signal. This

arrangement ensures that the high slew rate is retained at very low signal levels.

The rectangular signal is available at relay contact re_1.

The rectangular signal at the output of IC_{42b} is applied to operational transconductance amplifier (OTA) IC_{41a} via R_{154}. This amplifier has a slew rate of 125 V / μs; its operating point is set with P_6. Because of the current source at its output (which sets an OTA apart from a 'normal' opamp), the OTA functions as a variable resistance. This means that in conjunction with a capacitor, C_{146}–C_{149}, it is

readily made into an integrator. The four capacitors each belong to a different decadic range; they are selected by two analogue integrated switches, IC_{45} and IC_{46}. Capacitor C_{146} is connected between the OTA and buffer amplifier IC_{42a} when the D0 or D1 line is active; C_{147} when D2 is active; C_{148} when D3 is active; and C_{149} when D4 is active.

The use of a switch at either end of the capacitors is necessary, since the transfer resistance of the closed switch is not linear, but dependent on the supply voltage and the current through the switch. Switch IC_{45} is in

Fig. 19. Circuit diagram of the rectangular/triangular waveform converter.

series with the relevant capacitor and the current cource in the OTA. The current into the capacitor is independent of the transfer resistance of the switch. As far as the following opamp is concerned, only the *potential* across the capacitor is important. The transfer resistance of IC_{46} is in series with the very high input resistance of IC_{42a} and, therefore, has no relevance.

The signal at the output of IC_{42a} has a virtually perfect triangular waveform.

The two zener diodes, D_{16} and D_{17}, limit the output level of the OTA to 5.3 V (4.7 V zener voltage plus 0.6 V forward bias), so that the signal level at the switches cannot exceed the supply voltage to the ICs. The zener voltage can, if required, be chosen lower so as to reduce the regulating time of the OTA even further. An additional effect of the diodes is that, in combination with para-

sitic capacitances, they make necessary a reduction in the value of C_{149} from the calculated 100 pF to 47 pF.

A frequent problem with integrators is their inability to work with very small d.c. component. This is obviated by the d.c. feedback loop, R_{166}–C_{145}, between IC_{42a} and the OTA. This has the disadvantage, however, that there is no triangular signal available in the lowest decadic range of 1–10 Hz. (Our prototype delivered a triangular signal down to 3 Hz, but it was neither stable nor clean).

The level at the inverting input of IC_{41a}

may be increased by a d.c. component derived from R_{164}–P_5–R_{165} to minimize an off-set voltage (of the order of a few millivolts), which, owing to the input current's dependence on the control current, may arise, particularly at the inverting input.

Amplitude control is provided by dual opamp IC_{43}, which is connected as a simple inverter. Its input and output signals (in antiphase!) are combined by D_{13} and D_{14} and the rectified output is smoothed by C_{143}. This capacitor is charged via R_{158} and R_{159} to the peak value of the triangular signal. The higher

Fig. 20. Basic circuit of an opamp with current feedback.

Fig. 21. Block schematic of the triangular-wave shaper, integrator and amplitude regulation.

Fig. 22a. Printed-circuit board (component side) for the rectangular/triangular converter.

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the potential across C_{143}, the smaller the output voltage (=control voltage for the OTA). Since IC_{43b} tends to keep the voltage at its inverting input, and thus that across C_{143}, equal to that at its non-inverting input, the setting of P_9 will ultimately determine the peak value of the triangular signal.

A disadvantage of this design is that the regulating time, that is, the time span before the amplitude control operates correctly again after a frequency change, is relatively long, because the time constant of the rectifier circuit has to be sufficiently long even at the lowest frequency. Since the regulating time also depends, to some degree, on the setting of P_6, calibrating the two controls properly takes a little practice. This will be reverted to in the next instalment of the article.

The output of buffer IC_{42a}, like that of amplifier IC_{42b}, is applied to relay Re_1. Which of the two signals, rectangular or triangular, is fed to output stage IC_{40}, depends on the setting of switch S_8.

The use of a relay obviates any problems with feedback of the rectangular/triangular signal to the sine wave signal (since both may be connected via one cable to the change-over switch on the front panel). One cable can, therefore, be used to take the signal to and from preset P_8, which sets the peak value of
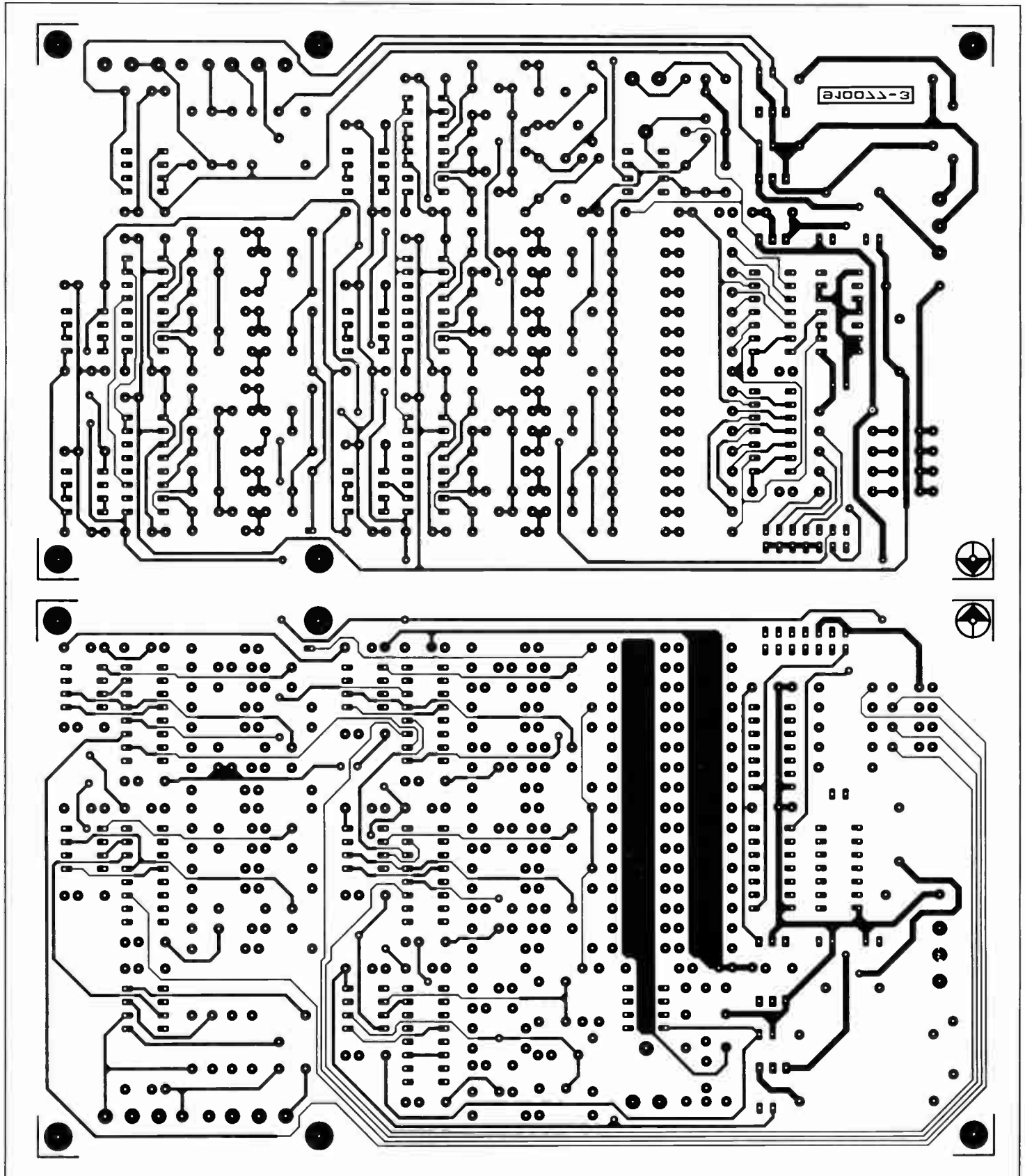
Fig. 22b. Printed-circuit board (track side and third overlay) for the rectangular/triangular converter.
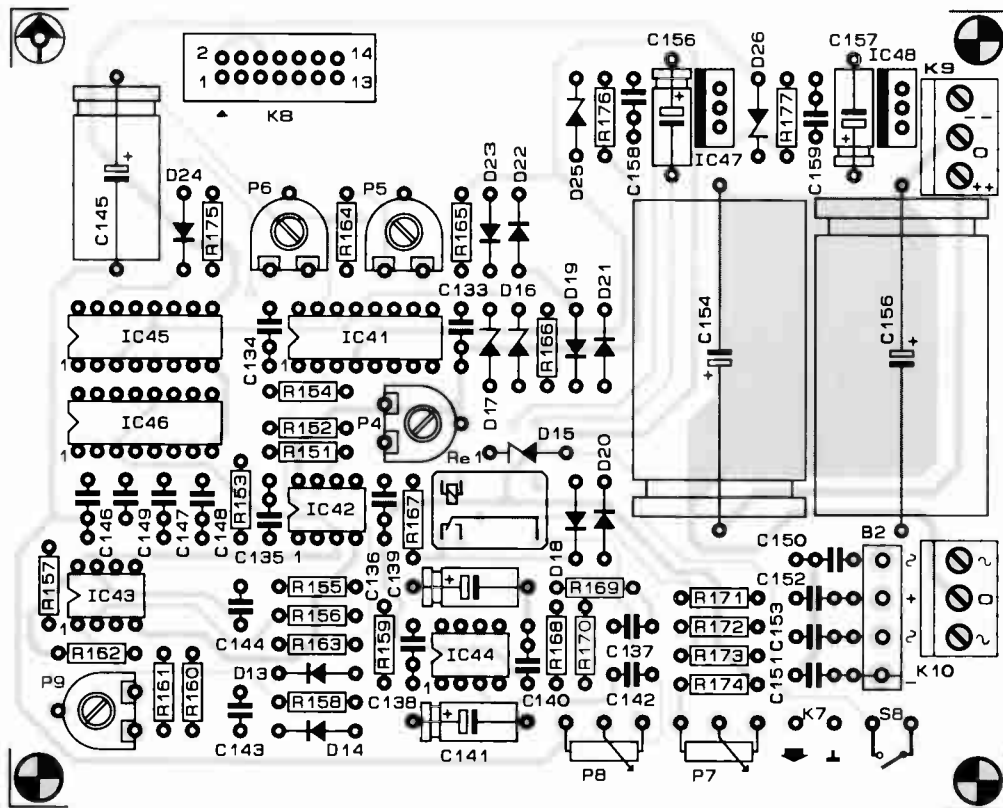
Fig. 23a. Printed-circuit board (component layout) for the sine wave converter.

PARTS LIST

Resistors:
R70, R160, R161 = 1 MΩ
R71, R85 = 249 kΩ, 0.1%
R72, R84 = 127 kΩ, 0.1%
R73, R83 = 86.6 kΩ, 0.1%
R74, R82 = 68.1 kΩ, 0.1%
R75, R81 = 57.6 kΩ, 0.1%
R76, R80 = 52.3 kΩ, 0.1%
R77, R79 = 48.7 kΩ, 0.1%
R78 = 47.5 kΩ, 0.1%
R86, R102 = see text
R87, R101 = 196 Ω, 1%
R88, R100 = 25.5 Ω, 1%
R89, R99 = 887 Ω, 1%
R90, R98 = 634 Ω, 1%
R91, R93, R95, R97 = 845 Ω, 1%
R92, R96 = 301 Ω, 1%
R94 = 1.1 kΩ, 1%
R103, R156, R157 = 2.2 kΩ
R104 = 33 kΩ
R105 = 5.6 kΩ
R106, R107, R114, R115, R122,
    R123 = 100 kΩ, 1%
R108, R109, R116, R117, R124, 125,
    R132, R133 = 31.6 kΩ, 1%
R110, R11, R118, R119, R126,
    R127 = 43.2 kΩ, 1%
R112, R113, R120, R121, R128, R129,
    R136, R137 = 34 kΩ, 1%
R130, R131, R138, R139 = 10 kΩ, 1%
R134, R135, R142, R143 = 4.32 kΩ, 1%
R140, R141 = 3.16 kΩ, 1%
R144, R145 = 3.4 kΩ, 1%
R146, R158, R159, R182–185 = 1 kΩ
R147, R148 = 1.2 kΩ
R149, R150 = 15 kΩ
R151, R155 = 2.49 kΩ, 1%
R152, R171, R172 = 100 Ω
R153 = 330 Ω
R154, R175 = 47 kΩ
R162 = 10 kΩ
R163, R166 = 100 kΩ
R164, R165 = 39 kΩ
R167 = 2.7 kΩ

R168 = 82 kΩ
R169 = 56 kΩ
R170, R176, R177, R181 = 8.2 kΩ
R173, R174 = 33 kΩ
R178, R179 = 4.7 Ω
R180 = 10 Ω
P1, P4, P9 = preset, 2.7 kΩ
P2, P7 = potentiometer, 5 kΩ, linear
P3 = potentiometer, 1 kΩ, log.
P5 = preset, 10 kΩ
P6 = preset, 250 kΩ
P8 = potentiometer, 1 kΩ, linear

Capacitors:
C60 = 220 nF
C61, C149 = 47 pF, polyester
C62 = 10 pF, polyester
C63, C72, C74, C76, C104–115,
    C119–129, C146 = 100 nF
C64, C66, C68, C116, C142, C144 = 1 µF
C65, C67 = 150 nF
C69 = 820 nF
C70 = 390 nF
C71 = 330 nF
C73, C75 = 15 nF
C77 = 82 nF
C78 = 39 nF
C79 = 33 nF
C80, C82, C84, C88, C92, C147 = 10 nF
C81, C83, C89 = 1.5 nF
C85, C93 = 8.2 nF
C86 = 3.9 nF
C87 = 3.3 nF
C90, C96, C98, C100, C148 = 1 nF
C91, C97, C99 = 150 pF, polyster
C94, C102 = 390 pF, polyester
C95, C103 = 330 pF, polyester
C101 = 820 pF, polyester
C117, C118, C133–136, C138, C140, C158,
    C159, C164–167 = 100 nF, ceramic
C130, C131 = 47 µF, 10 V, tantalum

C132 = 47 µF, 10 V, radial
C137 = see text
C139, C141, C156, C157 = 10 µF, 25 V
C143 = 1.5 µF
C145 = 220 µF, 16 V
C150–153 = 47 nF, ceramic
C154, C155 = 2200 µF, 40 V
C160, C161 = 100 µF, 40 V
C162, C163 = 10 µF, 25 V, radial

Semiconductors:
D12, D25, D26 = zener, 6.2 V, 400 mW
D13, D14, D22, D23 = BAT85
D15 = zener, 3.3 V, 400 mW
D16, D17 = zener, 4.7 V, 400 mW
D18–21, D24 = 1N4148
B2 = B80C1500
IC26 = 74HC132
IC27, IC28 = 74HC164
IC29–33 = 74HC4053
IC34 = AD711
IC35–39 = AD712
IC40 = NE5532
IC41 = CA3280
IC42 = OP260
IC43 = TL082 or TL072
IC44 = OP64
IC45, IC46 = 74HC4316
IC47, IC49 = 7815
IC48, IC50 = 7915
IC51 = 7806

Miscellaneous:
K4, K9, K10 = 3-way PCB connectors
K5, K8 = 14-way D-type plug
K6, K7 = BNC socket, insulated
Re1 = 12 V relay, 1 change-over contact
S8 = miniature on/off switch
Tr2 = mains transformer, 2×15 V, 12 VA
Heat sink for IC44 (e.g., Fischer ICK14/16B)
    [Dau UK Ltd, phone (0243) 553 031]
Enclosure, Telet LC970 (C-I Electronics, p.5)
PCB 910077-3
PCB 910077-4
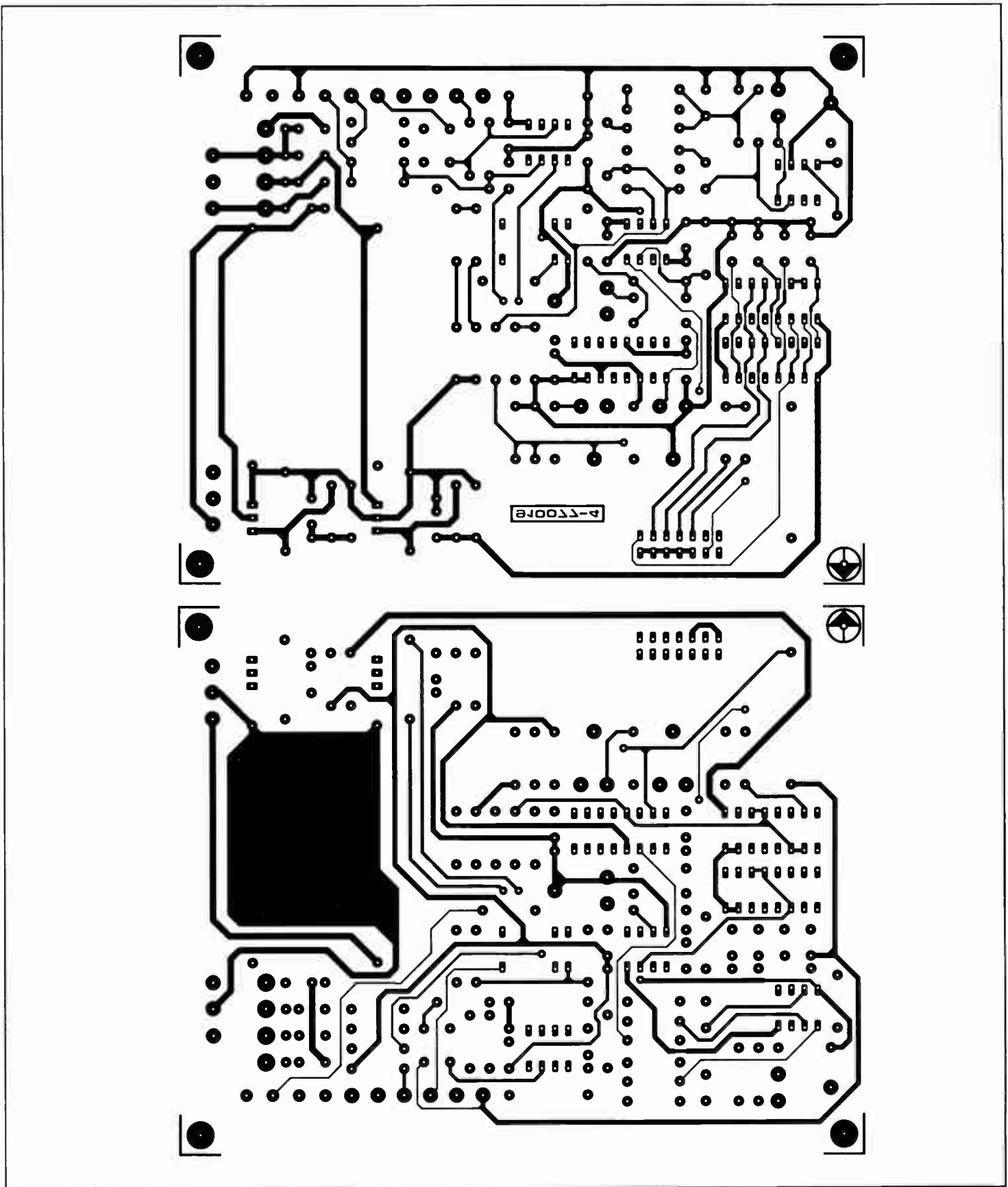
Fig. 23b. Printed-circuit board (track side and third overlay) for the sine wave converter.

the output.

The signal is amplified once more in IC_{44}. This opamp can provide a relatively high output current of ± 80 mA at a slew rate of 130 V/µs, so that no difficulties arise with loads down to about 150 Ω. Since R_{171} and R_{172} fix the output resistance at 50 Ω, the minimum load resistance may be as low as 100 Ω. Note that

the OP64 is *not* protected against short circuits and must be fitted on to a special heat sink (see parts list).

The OP64 tends to be overdriven by a rectangular signal. Network R_{169}–C_{137} in the feedback loop, therefore, reduces the amplification at high frequencies (that is, the 'corners' of the rectangular signal) slightly.

Capacitor C_{137} consists of two pieces of enamelled copper wire twisted together and cut to size as required.

The d.c. component of the output voltage, ± 12 V, is set with P_7.   ∎

The third and final instalment of this article will appear in our Special Large Christmas issue.

PRODUCT MODELLING

by R.G. Evans

EVER since I made my first circuit (a crystal radio) some twenty years ago, I have faced the problem of packaging the finished circuit. The methods I will describe can sensibly replace the aluminium or diecast boxes, the 'project boxes' sold by many of the mail order outlets, and at the same time provide very realistic cases tailor-made to your projects requirements, looking just like (or sometimes better) than the 'real thing'. It is perhaps worth mentioning that I teach Design & Technology in a secondary school (ages 11-18), and that my colleagues and I use this technique with our pupils aged 14 and above. The outstanding results obtained by these beginners should spur many of the readers of this magazine on to have a go themselves.

Basic tools and materials

I mentioned that I work in a school which has workshops and power tools, but these facilities are by no means necessary. Most electronics enthusiasts will have the tools required for making their own project box:

• A 'stanley' type knife with a scoring blade (or grind your own from a blunt ordinary knife). If this is not available, a suitable tool can be a made from an old hacksaw blade suitably shaped and given a simple handle.
• A try square of any shape or size.
• A sanding board — any material that is flat will do, e.g., a piece of kitchen worktop, blockboard etc. It must be **flat**. To this glue a whole sheet of 120 grit 'wet or dry' silicon carbide paper, and leave it weighted down to dry.
• A workbench (kitchen table??) and, if possible, some form of vice,. e.g., a Workmate or a wood or metal vice.
• A selection of files, or at least **one** (fairly coarse and fairly fine will do).
• A tenon-saw, although with care an ordinary hacksaw will suffice.

Useful, but by no means essential:

• A wood plane of any type, a small bandsaw and a sanding wheel (photo 1 shows a useful assemblage of the above).

Hopefully, the reader will have at least some of the above in his or her possession. The next thing to do is to acquire the essentials from which to make the boxes. Polystyrene is the type of plastic to get hold of (not the expanded ceiling tile stuff) Any colour will do, and two thicknesses are needed: 1.0 mm and 3.0 mm. Combinations of these thicknesses will cover most of our needs. The other main requirement is a suitable solvent with the name **dichloromethane**, also known as **methylene chloride**. This is available from laboratory chemical suppliers, some model shops (under the name of Plastic Weld), and from EMA
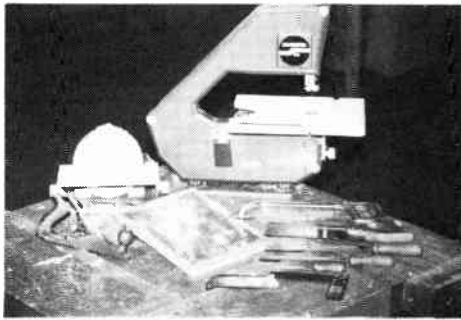
Fig. 1. Some of the basic tools you will need.
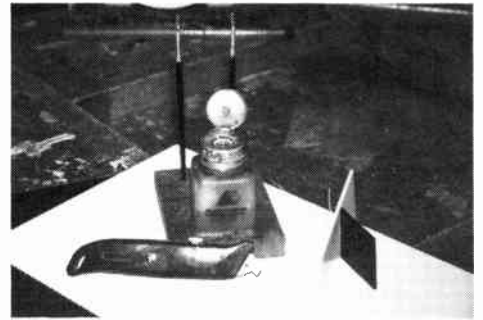
Fig. 2. The pump dispenser, a scoring knife and some plastic sheet.
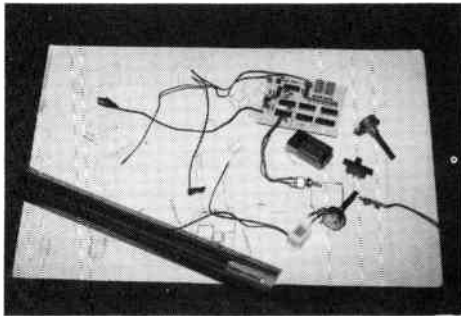
Fig. 3. Showing sensible planning of your work before you start.
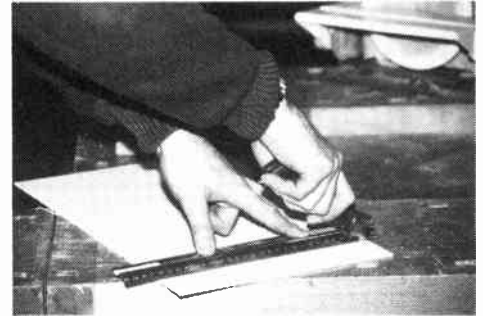
Fig. 4. Showing correct use of a safety ruler, scoring knife and the plastic sheet.
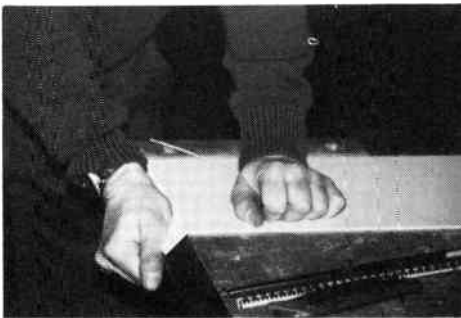
Fig. 5. Showing how to 'snap' the plastic cleanly over the edge of a bench.
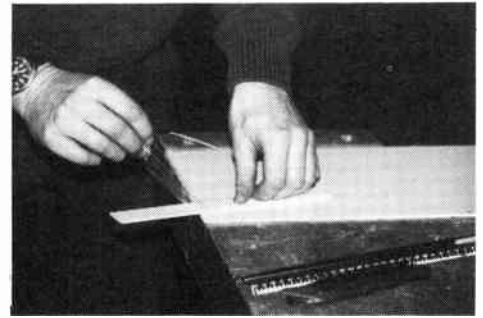
Fig. 6. Showing the removal of the protective plastic film before gluing.

Fig. 7. Edges may be squared up using a conventional wood plane.

Fig. 8. Edges may be squared up on a sanding board with equal ease.
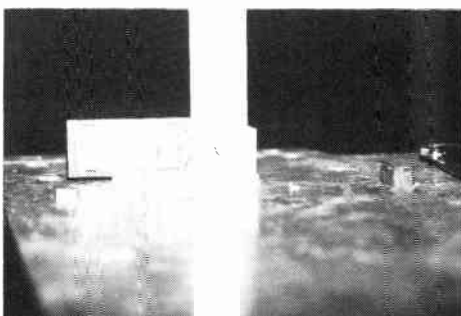
Fig. 9. Using a try-square to check the box shape.

Fig. 10. Adding solvent to each side (if possible) of the joint.

WorldRadioHistory
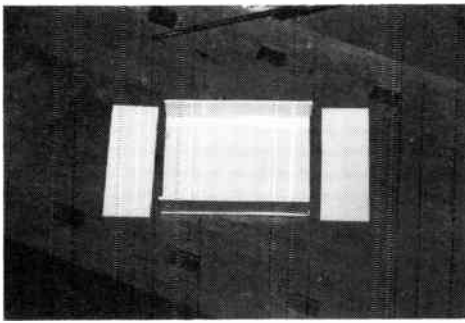
Fig. 11. Box with two sides, also showing slightly oversized end pieces.
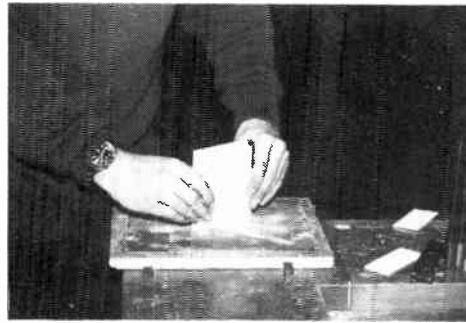
Fig. 12. Using a sanding board to square up the box ends.
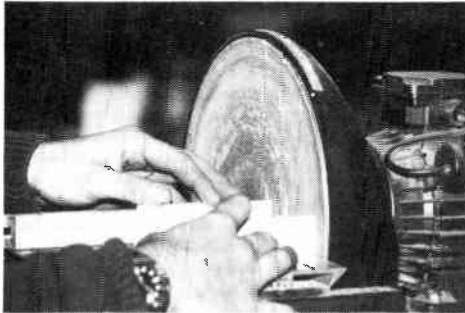
Fig. 13. A sanding wheel provides a quick alternative, but check its angle first!
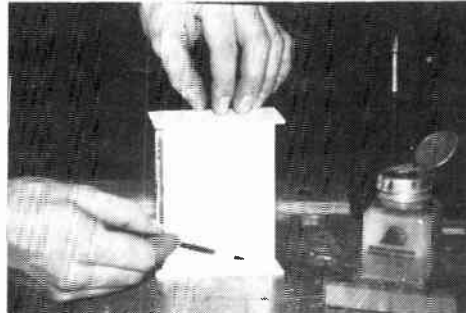
Fig. 14. Gluing the ends on to the box.
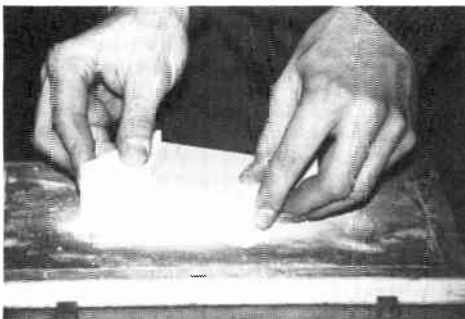
Fig. 15. Sanding the top of the box ready for the lid (shown upside down).
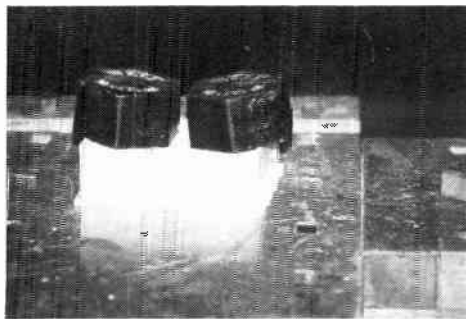
Fig. 16. After gluing the lid on, use some weights to keep it there for half an hour.
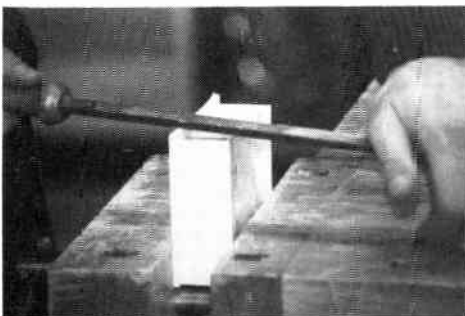
Fig. 17. Reducing the edges with a file — always work into the joint.
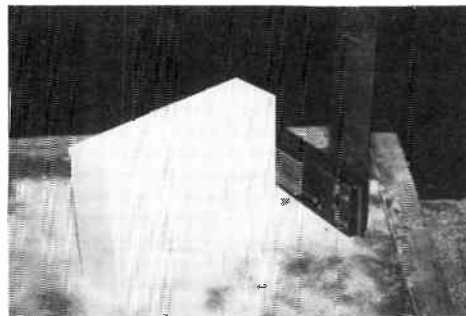
Fig. 18. A finished box, sanded smooth on all sides.
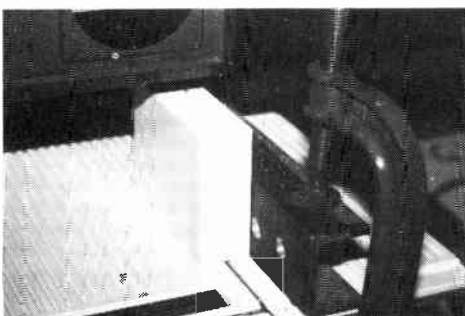
Fig. 19. Cutting the box on a band saw. Always use a fence!
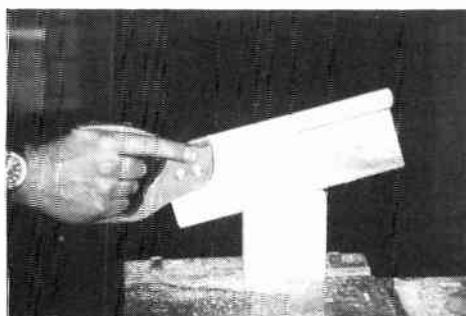
Fig. 20. With care, a tenon-saw can be used for the same task.

Model Supplies. The latter also supply a very neat pump dispenser which makes the use of the solvent much easier (see photo 2).

Planning

Having assembled the tools and materials, it is time to plan your box a little. I teach my students 'design based problem solving' which simply means that as much research and investigation should go into the generation of initial ideas as possible. There are several ways of packaging your circuit, and your first idea is unlikely to be the best. There are several things to consider, such as serviceability, replacement of battery, position and accessibility of the controls such as on/off switches, sensitivity adjustment and range switches. It is worth jotting down a few vital measurements at this stage (remember to leave plenty of room inside — I once had to squeeze a battery in a vice to get the lid on! Never again!), and to sketch a few ideas of the product (photo 3).

Box assembly

Once a few dimensions have been decided, construction can start. Mark out the base of the box (biro or pencil will suffice) on the 3-mm sheet of polystyrene. Cut it by using a ruler and a scoring knife (score to about $\frac{1}{2}$ the plastic's thickness — photo 4). Place the scored line over the edge of a bench or table, and apply sharp downward pressure to both sides. The plastic will snap cleanly along the scored line (photo 5).

The secret of making these boxes lies in making good butt joints, for which a square edge is essential, and a little time spent here will make your job easier later on. Note that some polystyrene sheets have a protective layer of polythene on one or both sides. For our application, this layer should be peeled off (photo 6). Next, cut a strip of the required height, and twice the length of the box. Leave a few millimetres extra for squaring up. At this stage, only one long side of each piece will need squaring. Use a wood plane if one is available, or sand on the sanding board, taking care to keep it at 90° to the board as you do so (photos 7 and 8). Keep sanding until a uniform square edge is obtained.

Next, place this edge on top of the base in the required position, and hold it up to a set square (photo 9). Using a small paint brush (maximum size 5 mm), dip the bristles into the solvent (photo 10), and then run the brush along the inside of the joint. If it is a long joint, replenish the brush as necessary. Once the solvent has been applied, capillary action will put it into the joint area, and there is little to be gained by continued application of the solvent. If both sides of the joint are accessible, the solvent may be applied to both sides. Hold the two pieces together while ensuring that the joint is at 90° to the base.

After some 15 to 30 seconds, the joint will be capable of supporting itself, and the other side can be glued in a similar manner. Although there are several proprietary polystyrene cements on the market, none have the ease of use and speed of bonding offered by dichloromethane. Unlike other cements, however, dichloromethane is purely a solvent, and as such it does not have any gap filling properties. It is therefore well worth making sure that your butt joints are good fits for

best results. Gaps can be filled at a later stage, but it is a lot quicker and easier to get it right first time.

Leave the two sides and base to dry while you prepare the ends and lid of the box. This is where some planning will have paid off. For ease and speed of construction, it is a lot easier to overlap joints, and sand down after construction, than to get it all to fit first. The two ends need to overlap both sides and base (photo 11), so cut out some suitable pieces. As they will be glued onto the **end** of the sides and base, there is no need to give them square edges. Cut a lid out on the same basis, that is, overlap on both sides and ends.

By now the base and sides will be workable, and now is the time to square up the ends. Those of you with a disc sander will find this easy, although the plastic does tend to melt more than sand. Those with sanding boards only will have to carefully sand the ends square, taking care to avoid 'rocking', and consequent rounding of the box ends. This process can be made easier if (a) you did not leave that much spare in the first place (careful marking out!), and (b) if you drag the box across the board towards you, rather than attempting to work both ways (photos 12 and 13).

Once each end is square, the end pieces can be glued on as per the sides (photo 14). Here, no set square will be needed, and pressure can be applied by hand until the solvent 'bites'. Give both ends a chance to dry as the next stage will put them under strain!

Gripping the box firmly upside down, sand it backwards and forwards (and circular) on your sanding board, until an even top surface is obtained (full width of 3 mm all the way round — photo 15). At this point, the lid can be glued on with liberal application of solvent, as the inside will not be accessible.

Leave the box weighted down (photo 16), and forget about it for 12 hours or so. Whilst the solvent is drying completely, it is worth mentioning why the box needs leaving. Although the solvent sticks the plastic very quickly, and allows work to proceed, it does nevertheless cause softening of the plastic in joint areas, and if fine finishing of the box is attempted, 'plucking out' of this softened material will result, and there will be a depression left to fill later. Be patient!

Once the box is dry, it can be externally tidied up. Large amounts of plastic hanging over edges can be removed by using a sanding wheel, if available, or simply filed away (photo 17). People used to working with harder materials will find this plastic quick to file and shape. With only small lips remaining (less than 1 mm), the whole box can be sanded on the sanding board until each and every surface has been 'sanded' (including the middle of plain sheets, photo 18). This may seem a long process, but better results are obtained this way.

Back to the planning stage, and how the box will be divided. Thought needs to be given to fitting the controls, switches, displays, etc. It is preferable, but not essential, that they are all mounted in one half of the box, but for mains powered projects it may be preferable to fit the transformer and circuitry in the base, and have flying leads to the front panel controls. Plan ahead now to avoid disasters later!

Most project boxes can be cut around their height anywhere between $\frac{1}{3}$ and $\frac{2}{3}$ the total
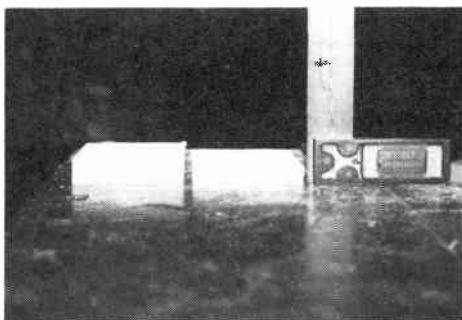
Fig. 21. You should now have two similar pieces of box. The heights can differ.

Fig. 22. Carefully sand the cut edges until they are free of saw marks.
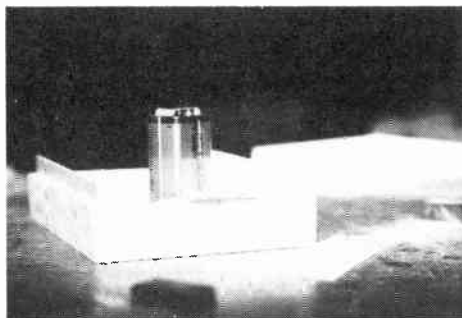
Fig. 23. The thin (1-mm) 'joining sheets' are shown resting in a box.
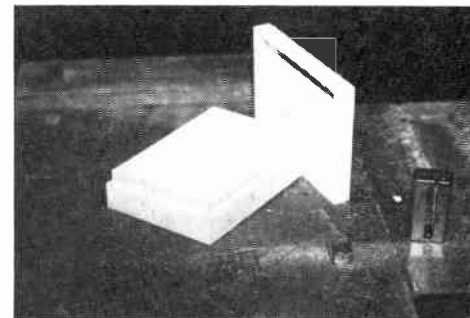
Fig. 24. All four thin strips fitted and glued.
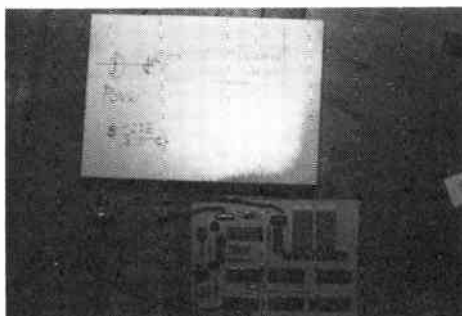
Fig. 25. Plan and mark out where your controls are going to be.
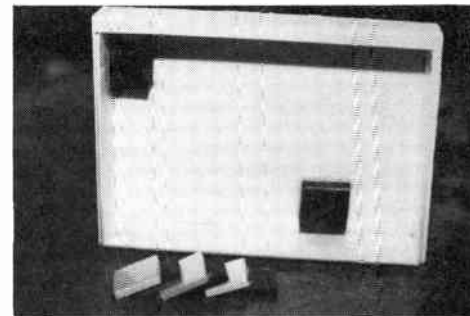
Fig. 26. Mounting pillars for PCBs are made by stacking up small squares.
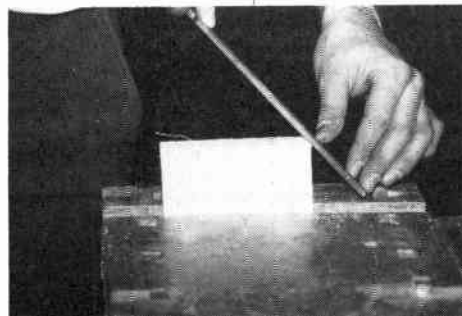
Fig. 27. Radius the box edges, starting with a file, then with wet and dry paper.
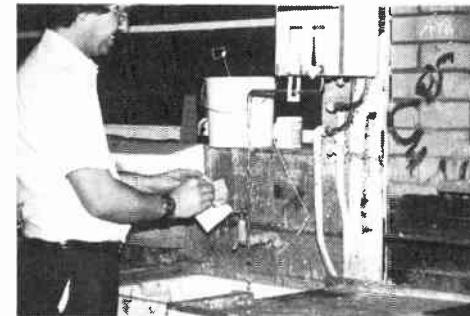
Fig. 28. Surface preparation is vital — use soap, water and wet or dry paper.
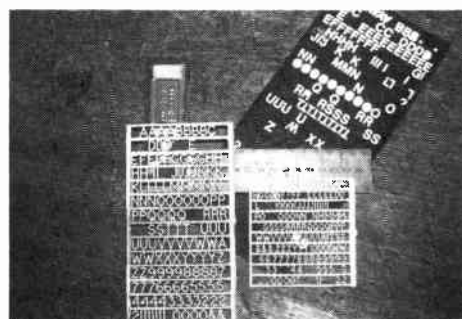
Fig. 29. There are two main types of lettering for surface detailing.
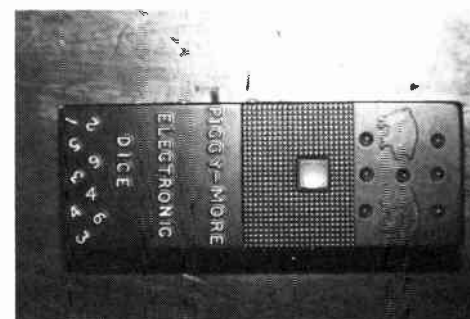
Fig. 30. A variety of effects can be achieved with relative ease.
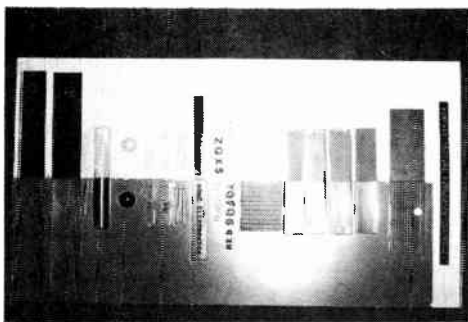
Fig. 31. All manner of 'things' will provide extra surface detail.
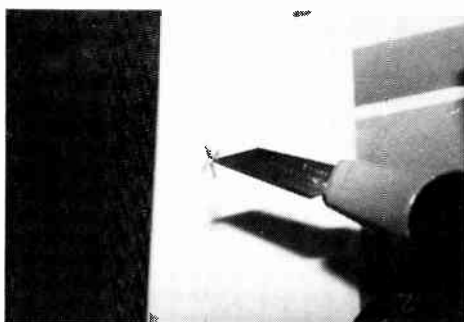
Fig. 32. Plasticard letters are easily picked up using the tip of a knife.
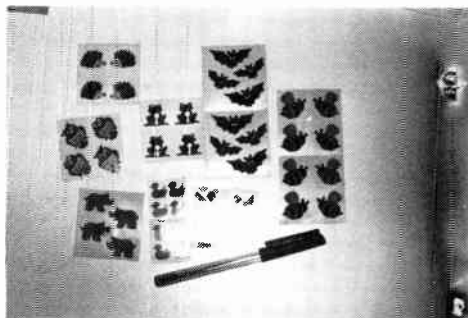
Fig. 33. A wide range of paper stickers are available.

Fig. 34. A range of suitable products to help finish your product.
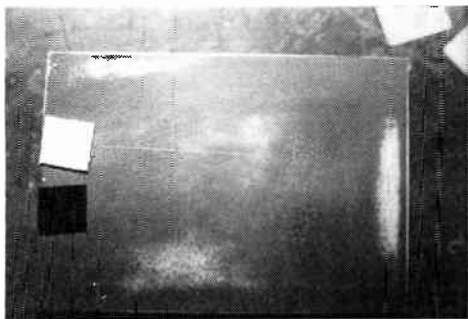
Fig. 35. Small patches showing through are not a problem — smooth finish is vital.
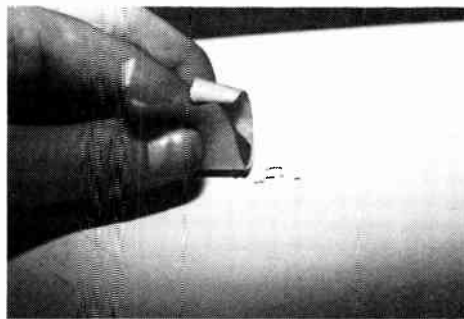
Fig. 36. Removing errant Letraset with a piece of masking tape.

height of the box. This is easily done with a small bandsaw, but take care and use a substantial fence to hold the box against (photo 19). Many boxes have been spoilt by the saw wandering off, so be careful! Those of you without a bandsaw will find that a tenon-saw (fairly fine toothed — see photo 20) will suffice, or failing that, a conventional hacksaw will work but may prove difficult to control directionally.

Assuming your box has now been cut into two (photo 21), the cut surfaces are sanded smooth on the sanding board once again, until any marks from the sawing have gone (photo 22). Take care to sand as evenly as possible, otherwise your box may develop a list. Using the 1-mm polystyrene sheet, cut a strip, or strips, of sufficient length and width to fit around the inside of the box, from the base up to nearly the full interior height. Using the solvent again, secure the two long sides first in the deeper part of the box, and then the two ends (photo 23). Squareness and close fits are not so important inside, and gaps for things like switches can be left in the thin strip. Leave all these to dry for 10 minutes or so. Then reassemble your box, and hopefully you should still have a reason-

ably square 'shape' (photo 24). If there are small discrepancies between the top and the bottom of the box, these can be sanded out on the sanding board before the next stage.

Fitting up

With the basic box finished, the fitting up can begin. Holes for switches, dials, controls, cables and the like should be added (photo 25). Inside the box, battery compartments can be fabricated quickly by using suitable pieces of plastic and solvent, as can PCB pillars made from small 'piles' of 3-mm plastic glued on top of each other (photo 26). The PCB and the pillars can then be drilled to suit suitable self-tappers which happily cut their own thread in the core diameter pilot holes. Please note that unlike acrylic (perspex), polystyrene does not take fine threads particularly well, so it is best to stick with self-tappers.

These pillars of material can also be used to good effect if you wish to 'sink' securing screws below the surface. In this way, results very similar to commercial injection moulding can be achieved. Simply build up a suitable thickness of

material in the area that you wish the screw to be sunk (probably around 12 mm). Drill a hole of sufficient depth and diameter to clear the screw head (allowing for paint and perhaps screwdriver size). Drill a clearance hole right through to allow the self-tapper to sit in the recess so created.

Next, build up a suitable pilar on the opposite side of the box, to the required height for the self-tapper to screw into. Take care to get the pillar height correct, or box distortion can occur. Whilst this provides a secure method of holding your box together, you will often find that the thin strips inside provide more than enough force to hold things together, especially non-critical items like small battery-powered test equipment, torches, etc. If all this sounds too much, countersunk self-tappers may be used.

Appearance!

With all the fitting and bracketry finished, the exterior of the box can now be finally prepared. Radiusing the edges and corners of the box will help its appearance, and, if it is hand-held, its 'touchability'. Use a fine file with caution, and aim for an even radius all over the box, just to take the sharp edges off (photo 27).

The next stage requires warm soapy water and several grades of wet-and-dry silicon carbide paper. Starting with 220 grit, rub the box all over, using plenty of water to avoid clogging the paper. This is the time to finally blend in the radiusing work that you may have done earlier. When you are sure that the whole of the box has been covered by this grade, move on to 320 grit and repeat the process. At this stage, you will probably be able to 'feel' the surface through your finger tips better than by visual inspection.

When you are sure the whole box has been covered by the 320 grit, move on to 400 grit and repeat the process. Finally, go over the whole box with 600 grit, feeling and looking for any scratches left over from coarser papers. If any are found, remove them gently with the appropriate grade, and then move on to 600 grit (photo 28).

With care you will have got this far, and have a very smooth box. If, however, there are some large holes, these can be filled with ordinary P38 car body filler or cellulose putty. It is much easier, however, to avoid them in the first place, which is not as difficult as it may sound. Give the box a final rinse inside and out in warm to hot water, pat it dry with a lint free cloth, and leave it somewhere warm and dry for a few hours.

Lettering

While the box is drying out (especially in the joint areas), some thought needs to be given to any surface detailing that you may wish to add. Simple things will help make your product look more convincing, and can make all the difference. Raised lettering can be added to give the impression of embossed or moulded-on letters. There are two main types, Plasticard polystyrene letters (usually sold to model railway enthusiasts) in several sizes, and Edding self-adhesive vinyl letters. Of the two, the latter are fairly low-profile, but are useful to give a 'makers name' to the product, as they will be painted over later, and so will form part of the product. The Plasticard letters are high-profile, and can be painted over also. The

tops of the letters can be carefully sanded clear of paint to create an additional effect should you so desire (photos 29 and 30), but their higher profile means that they are ideal for identifying important controls such as on/off switches, without being as obvious as, say, the devices' 'names' which can be added later in Letraset.

Other features that you can add include 'grips' made by gluing (with liberal amounts of solvent) strips or pieces of 180/220 wet or dry paper, and spraying over them later. This creates very effectively the 'moulded-on' appearance. Using coarser grades of paper spoils the effect. Embossed self-adhesive metal film is also available from EMA (details further on), and 'pinstripe' tape as sold in motor accessory shops can provide a useful way of breaking up large flat surfaces. This can either be sprayed over, or added later as a colour feature. It does not need much to make the product look real, so take care not to get carried away! (photo 31).

To get perfect edging on some of the items mentioned may necessitate going back to a **fine** file and the range of wet-and-dry papers, just to blend in an overhanging edge. This usually produces better results than just cutting a piece out and sticking it on.

The Plasticard polystyrene letters can be cut out and trimmed with a suitable craft knife. The tip of this knife is the best tool to pick the letters up and put them in place (photo 32). A dab of solvent on their rear immediately prior to placing each letter produces good results. Positioning the letters dry, and then applying solvent tends to leave a mark, so be careful. Getting all the letters in a neat line is also important, and a pre-drawn faint pencil line at 90° to an edge will help a lot here. The vinyl letters mentioned are self-adhesive and may be positioned similarly. If you are making a 'novelty' product for perhaps a child, it may be worth a visit to your local craft and stationary shop. These often have rolls and rolls of small paper stickers that can also be added to the surface of your product, and then sprayed over (photo 33). In this way, a variety of themes could be imparted on your model.

Painting

After the surface detailing is complete, the next stage is to paint the object. For this, aerosol paints as sold by car accessory shops are ideal (photo 34). The two halves of the box should be separated, and can then be given the first coat of grey cellulose primer. A reasonable covering should be given by starting the spray to, say, the left of the object, moving across it and clear to the right before returning. If you wish, you can stop spraying at either end, although some brands of aerosol tend to 'spit' a little when used in this fashion. Spraying this way helps prevent uneven paint buildup and runs! Leave the primer to dry overnight, and then **very carefully** rub down the surface with 800 grit wet-and-dry paper used with lots of soapy water. It is not necessary to re-expose the plastic underneath, just to achieve a silky smooth surface ready for the top coat (use your finger tips). If small areas of plastic re-appear, don't worry. So long as the preparation was good, the primer does not have a lot to do, and the small gaps in the coverage are not a problem (photo 35). When the box has been 'flatted' all

Fig. 37.   A selection of finished articles.

over, a final rinse in water is needed (inside and out), and then the box can be dried.

The top coat of paint is also aerosol cellulose car paint, and so there is an almost endless variety of colours. If you want black, choose Satin black, which shows fingerprints less than either gloss or matt. Metallic colours are also very effective, but choose carefully after looking at commercial products. Probably the best is Ford 'Graphite', Ford 'Pearl Grey', and one or two others, notably the blues.

A useful tip to improve the spray power of aerosols is to place them in hot water (max. 50°) for a few minutes. This raises the internal pressure, and helps them spray better for longer. Make sure that the whole aerosol is completely dry, as a single drop of water will play havoc with your smooth mirror-like surface!.

If you want an ordinary colour, try and stick with primary colours rather than sickly mixes. Some aerosols (especially the metallics) are what is known as '2-pack', which means that they need a coat of lacquer to give them the final gloss. If you intend to use any Letraset, then this will be needed anyway, and should not be feared.

After the paint has had time to dry, Letraset or similar dry transfer lettering can be added. Given that these dry transfer letters sometimes transfer themselves at the wrong time to the wrong place, the following may be useful. Take a piece of ordinary masking tape, and rub the sticky side against a cotton T-shirt or similar. This will help reduce its stickiness. Use this treated piece of masking tape to provide the baseline for your rub-down lettering. If any do come unstuck, they will probably be on the masking tape, which can be **carefully** removed after you have finished. Do take great care not to press it down too hard, or pull it off too briskly — you may find it brings the paint with it! If, despite this precaution, the odd letter does appear in the wrong place, or you make a mistake, do not despair, as individual letters can usually be removed by the careful application of a small piece of masking tape (untreated), wrapped around a finger tip, and 'dabbed' at the offending letter (photo 36). If this fails, it should be possible to remove it with the

aid of a scalpel or craft knife, and a scraping motion, although this method is likely to leave a mark.

If you have used a dark colour to spray your box, then white or red lettering can be used to great effect. Controls can be labelled, and some form of product name added. Very often code numbers at the bottom of the Letraset sheets provide convincing model numbers. It all adds to the realism of the finished article, and will make people look twice or even thrice in their attempt at determining the origin of the 'device' they see.

Finally, a coat of clear lacquer needs to be applied. Car accessory shops sell this as clear cellulose lacquer. Be careful how much you spray on in one coat. Sometimes the solvent attacks the Letraset, causing it to wrinkle up, and destroy all your hard work. Apply just enough to 'flow' into a gloss (allow it to stand a few seconds before adding more!), and spray it somewhere warm to help the solvent evaporate quickly.

Add extra coats as needed until you are happy with the appearance of the finished object (photo 37). All this paint will take quite a while to harden, depending on the number of layers present. I have known some objects (admittedly heavily laden with lacquer) to take up to a week to dry sufficiently to not take fingerprint impressions when handled. If you get the odd fingerprint, it can usually be polished out by using 'T-cut' colour restorer (also from your car accessory shop). That concludes the description of the process — it probably takes as long to read it as it does to make a box!   ∎

CLASS-A POWER AMPLIFIER – PART 1

by T. Giffard

The power amplifier presented is a revamped version of the LFA-150 we published in late 1988. It provides rather less power than its popular predecessor, but retains its class A quiescent-current setting up to –3 dB below its clipping limit. The aim of the design was to find a good compromise between class A quality and the dimensions of the necessary heat sinks.
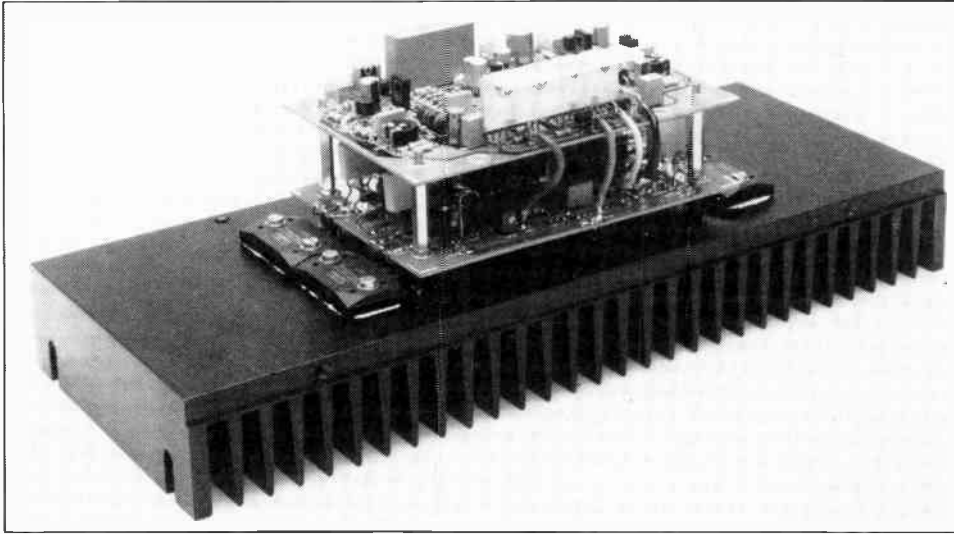
Fig. 1. Prototype of the class A amplifier.

TECHNICAL DATA

Power output (at 1 kHz)	48 W into 8 Ω
	83 W into 4 Ω
	122 W into 2 Ω
Music power (500 Hz burst, 5 periods on, 5 periods off)	50 W into 8 Ω
	90 W into 4 Ω
	150 W into 2 Ω
Power bandwidth (48 W into 8 Ω)	1 Hz–270 kHz (+0 dB, –3 dB)
Slew rate	>45 V/μs
Signal-to-noise ratio (1 W into 8 Ω)	>105 dB (A-weighted)
Harmonic distortion (25 W into 8 Ω)	<0.005% (1 kHz0
	<0.02% (20 Hz–20 kHz)
Intermodulation distortion (50 Hz: 7 kHz; 4:1)	<0.03% (25 W into 8 Ω)
	≤0.005% (1 W into 8 Ω)
Dynamic IM distortion (rectangular wave 3.15 kHz; sine wave 15 kHz)	<0.015% (25 W into 8 Ω)
Input sensitivity	1.1 V r.m.s.
Input impedance	25 kΩ
Quiescent current	1.25 A

ALTHOUGH most of our readers will know what is meant by class A, AB or B, it may be useful for others to recapitulate the properties of these classes of operation.

Most modern a.f. output amplifiers are designed as a push-pull configuration. In this, two power transistors (or valves) are connected in series between the positive and negative power supply lines, and the loudspeakers are connected to their junction. The transistors are driven by opposing signals, that is, when one conducts, the other is switched off.

The transfer characteristic (I_b/I_c curve) of a transistor is, unfortunately, not a straight line: particularly at its lower end, when the currents are low, it is very curved. In principle, the characteristics of two transistors in push-pull complement one another nicely, but the base-emitter transfer voltage puts a spanner in the works.

To prevent distortion, therefore, use is made of a bias that causes a small constant current to flow through the transistors. The result of this is that the curved part of the characteristic is not used. If virtually no current flows through the transistors, class B amplification is obtained, which is characterized by cross-over distortion. Nowadays, this method is used only in inexpensive, portable equipment where economy of battery usage is the prime requirement.

For many years now, class AB operation has been used in hi-fi equipment. In this, a small quiescent current flows through the output transistors, which makes them work in class A when the drive is small (say, 0.1 W) and in class B at higher drives. This method is characterized by acceptable low distortion and good efficiency (about 75%). Moreover, heat dissipation depends on the energy of the drive signal, so that the amplifier remains fairly cool during normal operation.

Many designers and listeners do not find AB operation good enough and prefer class A. In this, such a large quiescent current flows through the transistors, that even at maximum drive neither of the transistors switches off (as happens in class AB). The disadvantages of class A operation are its low efficiency (<50%) and large heat dissipation. Even during quiescent operation, a class A amplifier uses about twice its nominal power.

Naturally, commercial class A amplifiers are

available at many hi-fi retailers, but, although their superior quality cannot be denied, they are very expensive, have very large heat sinks or fans to get rid of the dissipated heat, and provide only a modest power output. These factors make it easy to understand why a 25–50 W class A amplifier is not exactly the most popular item in the hi-fi trade.

In the present design, we have tried to combine class A operation with an acceptable heat dissipation. Output power was specified at 50 W into 8 Ω. In true class A, that would mean a dissipation of rather more than 100 W per channel. To get rid of more than 200 W of heat in normal enclosures without the use of fans is virtually impossible. Fans are, however, anathema, because even the best ones can be heard, particularly during soft music passages.

The design is, therefore, near-class A, that is, the quiescent current is set to a level that ensures that the amplifier can deliver half its nominal power to the loudspeakers. The class A range is thus 25 W, which means that in actual use the amplifier operates in class A up to –3 dB below full drive. The dissipation then amounts to about 140 W and that can be got rid of with 'normal' heat sinks (based on an ambient temperature of not more than 35 °C and a maximum heat sink temperature of 75 °C).

It should be noted that a class A amplifier operates in its class only into its specified load impedance, normally 8 Ω. It is, of course, possible to provide more power into 4 Ω or 2 Ω, but that will not be in class A. This points to a serious disadvantage of class A amplifiers that is hardly ever highlighted: *into a lower than specified load, it operates in class AB*. Since the input impedance of virtually all modern loudspeakers varies between 4 Ω and 10 Ω, amplifier manufacturers have the near impossible task of designing an amplifier that remains in class A over this range of impedances. The power required to operate a class A output stage into a 4 Ω load is twice that for operating it into an 8 Ω load. A 25 W class A amplifier designed to operate into 8 Ω dissipates more than 100 W, but to enable it to operate in class A into 4 Ω, the quiescent current would have to be increased to a level where the dissipation would exceed 200 W.

The real requirement of a top-quality a.f. output amplifier is that it can deliver a reasonable power, say, not less than 10 W, into an impedance varying between 4 Ω and 10 Ω. That will meet the demands of all hi-fi listeners in 95% of the time. The present design provides 25 W into 8 Ω; 12.5 W into 4 Ω and rather more than 6 W into 2 Ω, all in class A. At the other 5% of the time, in class AB, it gives 48 W into 8 Ω, 83 W into 4 Ω and 122 W into 2 Ω.

The revamped circuit

The renovating of the LFA-150 started with a lowering of the supply voltage from ±56 V to ±29 V to ensure an appreciable lowering of the dissipation.

Next, a number of transistor were replaced, partly because some of them were no longer
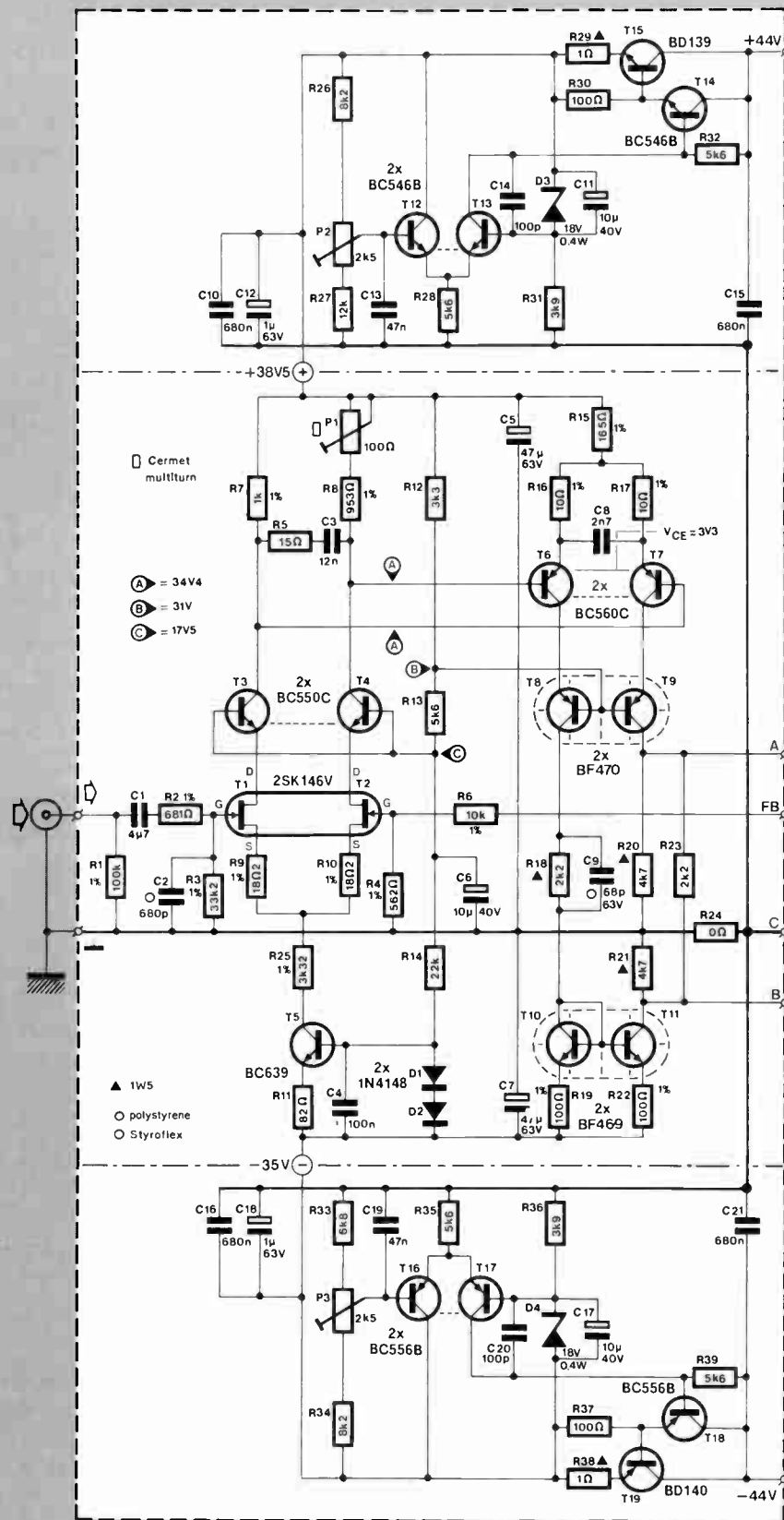
Fig. 2. Circuit diagram of the class A amplifier.

ERROR   LOW IMP

D29   D27

POWER ON

D40

LFA - A

Protection Circuit
880092 - 3

+30V

−30V

22V ~

22V ~

−70V

D35...D39 = 1N4002

R106   C58   D39

22µ

C52   C53
22n   22n

C56   C54   D35   D36
680n   1000µ
100V   63V

C57   C55   D37   D38
680n   1000µ
100V   63V

C50   C51
22n   22n

Tr 1   F1   F2   S1
50mA T   2AT

2x 9V
177mA

31V ~

31V ~

K2

22V ~   22V ~

K1

+30V
+30V

D13   Re1   R49   C26   R52   R54   R65   T27   C29
1N4148   56Ω   680n   0Ω22   138mV   0Ω22   82Ω   BC556B   100µ 40V

R66
150Ω

R51   T23
2SC2238   2Ω2

R48   T21   2x
47Ω   2SA1216   T24

R67
10k

R46   R53
680Ω   2Ω2   re1

T20   R62   R50   D9
470Ω   10Ω   1N   L1
2W5   4002

BD139   R63   LS 1
4Ω7

R47   FB
270Ω

P4   R45   C25   R55   R57   D10   R64   D11   D12   2x
1k   39Ω   100n   470Ω   10Ω   1N   4Ω7   1N4148
2W5   4002   T28   T29   2x
BC546B

R58   T25
2Ω2   C28   R68
120n   270Ω

2x
2SC2922   R71
47k

R60   T26   R69   T30
2Ω2   150Ω   BC546B
2SA968   R70   C30
680Ω   100µ 40V

3W inductance-free   R56   C27   R59   R61
56Ω   680n   0Ω22   138mV   0Ω22

C   1V9   A   B

Tr 2

C31
44000µ 40V

B1

C32
44000µ 40V

B1 = B100C
35000

(2 x 22 V, 5A11)

~30V
~30V

910124 - 11

available. Motorola's BF762 and BF759 have been replaced by the BF470 and BF469 respectively, while Sanken's Types 2SC2922 and 2SA1216 have been substituted for Toshiba's 2SC2565 and 2SA1095 output transistors.

Third, the amplification of some stages has been altered. The gain of the first differential amplifier is now 19 dB instead of 11 dB, while that of the second differential amplifier has been reduced by 6 dB. This results in the open-loop amplification rising from 2 300 to 3 000, which lowers the distortion to even lower levels than in the LFA–150.

Finally, the compensation and d.c. oper-

ating points have been changed at a number of places.

Because of all these alterations, the values of many components in the original LFA–150 have had to be changed. The amplifier is constructed on four PCBs: two for the output stages, one for the protection circuit, and one
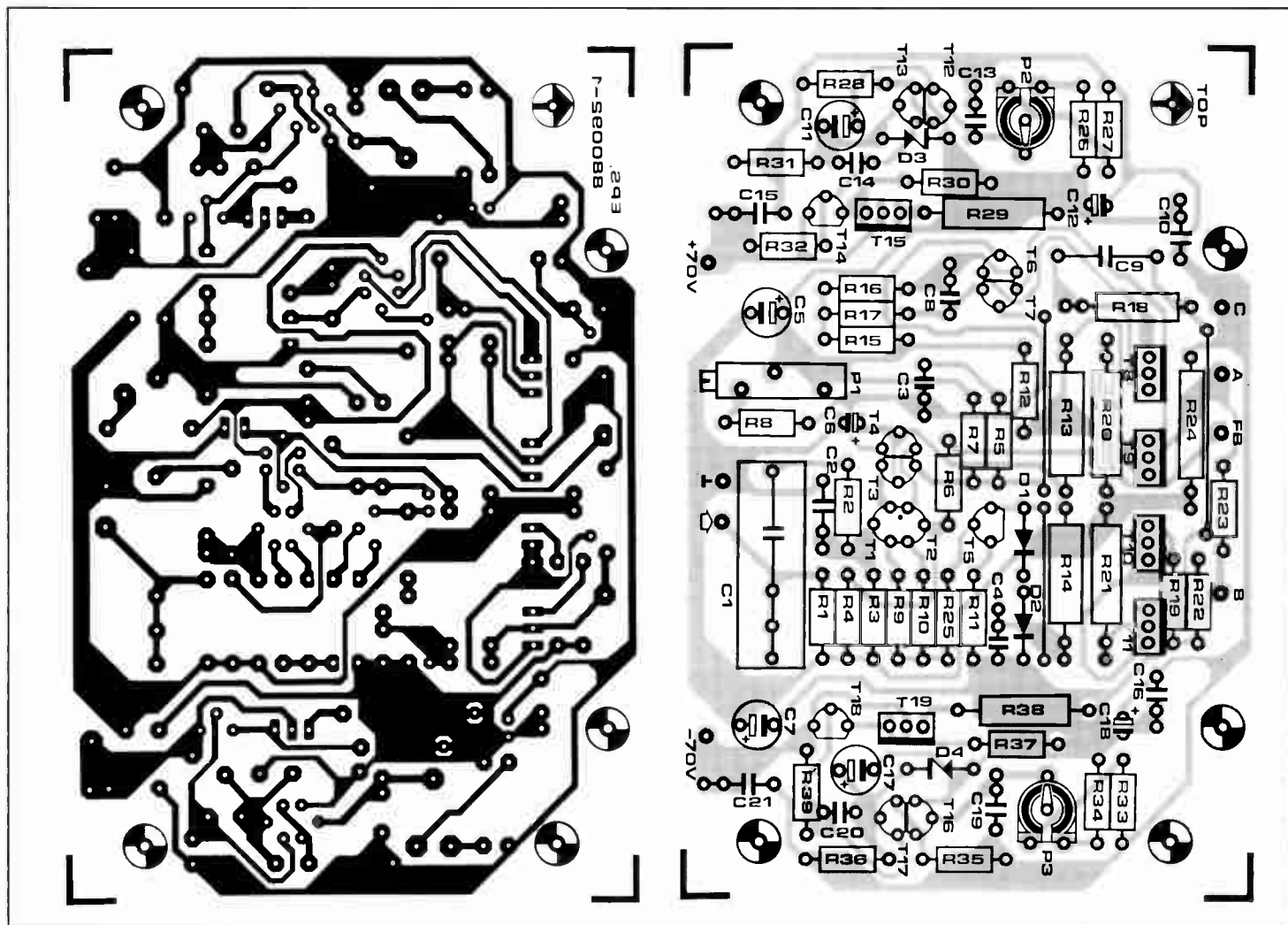
Fig. 3. Printed circuit board for the voltage amplifier.

PARTS LIST

Resistors:
R1 = 100 kΩ, 1%
R2 = 681 Ω, 1%
R3 = 33.2 kΩ, 1%
R4 = 562 Ω, 1%
R5 = 15 Ω
R6 = 10 kΩ, 1%
R7 = 1 kΩ, 1%
R8 = 953 Ω, 1%
R9, R10 = 18.2 Ω, 1%
R11, R65 = 82 Ω
R12 = 3.3 kΩ
R13 = 5.6 kΩ
R14 = 22 kΩ
R15 = 165 Ω, 1%
R16, R17 = 10 Ω, 1%
R18 = 2.2 kΩ, 1.5 W
R19, R22 = 100 Ω, 1%
R20, R21 = 4.7 kΩ, 1.5 W
R23 = 2,2 kΩ
R24 = wire bridge
R25 = 3.32 kΩ, 1%
R26, R34 = 8.2 kΩ
R27 = 12 kΩ
R28, R32, R35, R39 = 5.6 kΩ

R29, R38 = 1 Ω, 1.5 W
R30, R37 = 100 Ω
R31, R36 = 3.9 kΩ
R33 = 6.8 kΩ
R45 = 39 Ω
R46 = 680 Ω
R47 = 270 Ω
R48 = 47 Ω
R49, R56 = 56 Ω
R50, R57 = 10 Ω
R51, R53, R58, R60 = 2.2 Ω
R52, R54, R59, R61 = 0.22 Ω,
   3 W, inductance-free
R55, R62 = 470 Ω, 2.5 W
R63, R64 = 4.7 Ω, 1.5 W
R65 = 82 Ω
R66 = 150 Ω
R67 = 10 kΩ
R68 = 270 Ω
R69 = 150 Ω
R70 = 68 Ω
R71 = 47 kΩ
P1 = 100 Ω multiturn preset

P2, P3 = 2.5 kΩ preset
P4 = 1 kΩ, multiturn preset

Capacitors:
C1 = 4.7 μF, MKT
C2 = 680 pF, polyester
C3 = 12 nF
C4, C25 = 100 nF
C5, C7 = 47 μF, 63 V
C6, C11, C17 = 10 μF, 40 V
C8 = 2.7 nF
C9 = 68 pF, 63 V, polyester
C10, C15, C16, C21, C26,
   C27 = 680 pF
C12, C18 = 1 μF, 63 V
C13, C19 = 47 nF
C14, C20 = 100 pF
C28 = 120 nF
C29, C30 = 100 μF, 40 V

Semiconductors:
D1, D2, D11–13 = 1N4148
D3, D4 = zener, 18 V, 400 mW

D9, D10 = 1N4002
T1, T2 = 2SK146V
T3, T4 = BC550C
T5 = BC639
T6, T7 = BC560C (match!)
T8, T9 = BF470
T10, T11 = BF469 (match!)
T12–14 = BC546B
T15, T20 = BD139
T16–18 = BC556B
T19 = BD140
T21 = 2SC2238
T22 = 2SA968
T23, T24 = 2SA1216
T25, T26 = 2SC2922

Miscellaneous:
Re1 = 24 V for PCB mounting
   with 1 change-over contact
L1 = 6 turns, I/D 15 mm, of
1.5 mm enamelled copper wire
K1 = 10-way straight header
Heat sink, 0.4 K/W (see Part 2)
PCB 880092-1
PCB 880092-2

for the auxiliary power supply.

Only an outline description of the circuit in Fig. 2 will be given—for more details, see Ref. 1.

The input signal is applied to differential amplifier T_1-T_2 via C_1 (the only capacitor in the signal path) and low-pass filter R_2-C_2. The filter has a cut-off frequency of 340 kHz to prevent transient intermodulation distortion (TIM). The d.c. operating point of the two FETs is set by a constant-current source based on T_5.

Transistors T_3 and T_4 and the FETs form a cascode circuit that has an amplification of about 9.2 (=gain of about 19 dB). Preset P_1 serves to eliminate any inequalities (off-set) in the d.c. operating points.

Lag compensation is provided by R_5-C_3.

The amplified signal is fed to differential amplifier T_6-T_7 that together with T_8 and T_9 form a second cascode circuit to keep the bandwidth as large as possible. The amplifi-cation of this section is 308 (nearly 50 dB).

The output of T_8 is fed to the current am-plifier via current mirror T_{10}-T_{11}.

The power supply for the voltage ampli-fier is taken from discrete voltage regulators T_{12}-T_{15} (positive) and T_{16}-T_{19} (negative). The supply voltage for this section is higher than that for the current amplifier, so that the volt-age drop across the output transistors re-mains small, even at maximum drive levels.

The current amplifier consists of a quies-cent-current control based on T_{20}, and drivers T_{21} and T_{22}, followed by power transistors T_{23}, T_{24}, T_{25} and T_{26}, which are connected in a compound configuration. In contrast to the usual emitter-follower, this design provides some voltage amplification and combines very low distortion with a low output impedance. The output signal is fed to the loudspeakers via an inductor and a protection relay.

When the load current exceeds 15 A (peak), transistors T_{27} and T_{30} switch on and actu-ate the protection circuit via T_{28} and T_{29}. That circuit then de-energizes the relay.

The power supply uses two mains trans-formers in series, Tr_1 and Tr_2. Note that Fig. 2 shows the power supply for a mono ampli-fier; two (housed in one enclosure) need to be built for a stereo amplifier. The supply for the current amplifier is around ±30 V, and that for the voltage amplifier, ±44 V. The voltage amplifier, however, operates from +38.5 V and −35 V, because its voltage drop on the posi-tive line is about 3.5 V higher than that on the negative line. This supply arrangement ensures that the positive and negative drive levels are exactly equal.   ■

Reference.
"LFA-150: a fast power amplifier", *Elektor Electronics*, November 1988, pp. 20–26; December 1988, pp. 42–46.
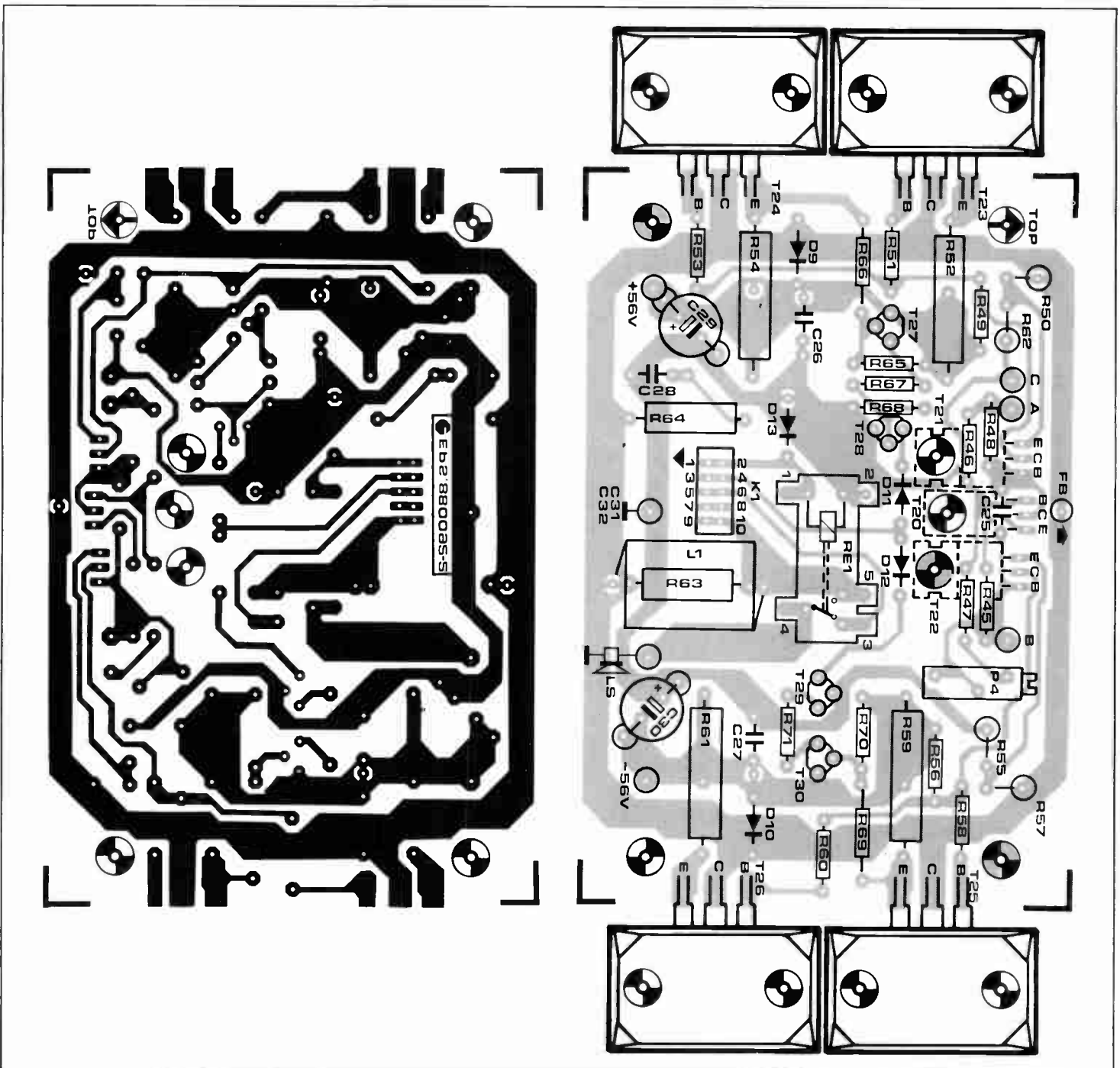
Fig. 4. Printed circuit board for the current amplifier.

FOUR-TERMINAL NETWORKS - PART 2

The design of attenuators

by Steve Knight, BSc

In this second and final part of our investigation into the design and uses of four-terminal attenuator systems, we shall first of all derive some simple relationships between the characteristic resistance of an attenuator T-section and the degree of attenuation provided by the section in terms of the resistive elements that make up the section.

THE calculations are not difficult, and those readers with an arithmetical bent might like to confirm some of the answers. We will relate our results with those of the π–section, consider insertion loss, and have a look at the practical design of attenuators.

Finding values

For the properly terminated symmetrical T-section shown in Fig. 8, we let the attenuation be expressed as $N=U_1/U_2$, in which numbered subscripts are used for conve-
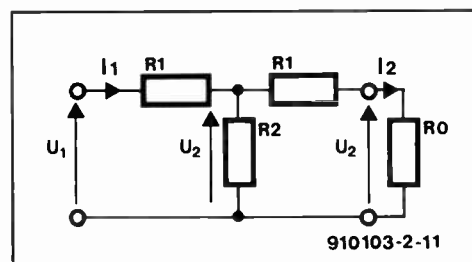
Fig. 8. Deriving the attenuation factor of a section.

nience. Since the input resistance is R_0, the input current, I_1, must be U_1/R_0 and the voltage, U, across the centre shunt arm will be

$$U=U_1-I_1R_1.$$

Hence,

$$U=U_1-U_1R_1/R_0=U_1[1-R_1/R_0].$$

But the output voltage, U_2, is clearly the proportion of U developed across R_0, given by

$$U_2=U[R_0/(R_1+R_0)],$$

whence

$$U_2=U_1[1-(R_1/R_0)][R_0/(R_1+R_0)].$$

From this, the ratio

$$U_1/U_2=N=(R_0+R_1)/(R_0-R_1).$$

This gives the attenuation factor in terms of R_0 and R_1. What we need now is a relationship involving R_1 and R_2 in terms of R_0 and N. Working from this last result, we find that

$$R_1=R_0[(N-1)/(N+1)].$$

Using the earlier result that

$$R_0=\sqrt{(R_1^2+2R_1R_2)},$$

we get

$$R_2=R_0[2N/(N^2-1)].$$

When R_0 and N are known, these simple expressions enable an attenuator to be designed that gives a desired signal reduction and the proper matching conditions for the circuit system concerned. Figure 9 illustrates the meaning of the two formulae.
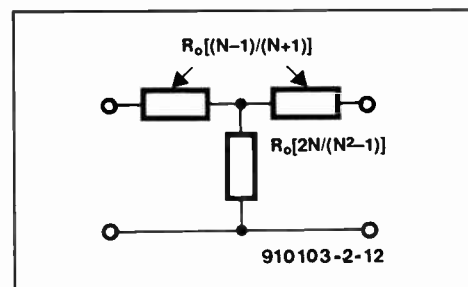
Fig. 9. Relationships to determine the elements in terms of R_0 and N.

Trying things out

A couple of examples will show how we can apply these results to solve some elementary design problems.

First, suppose we want a symmetrical T–section network to match into a 300 Ω line and have a voltage attenuation of 14 dB; what values of resistors do we want?

Well, the attenuation factor N=antilog 14/20 =antilog 0.7=5. In other words, the output will be one fifth of the input. We thus get

$$R_1=300[(5-1)/(5+1)]=300\times{}^4/_6=200\ \Omega;$$

and

$$R_2=300[(2\times5)/(25-1)]=300\times{}^{10}/_{24}=125\ \Omega.$$

Figure 10 shows the completed section.
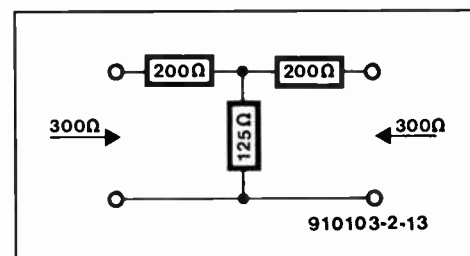
Fig. 10. Example of en elementary T-section design.

Suppose now that the output stage of a small transmitter has an internal resistance of 600 Ω and is intended to supply current to a 600 Ω load. We need to design a T-section which, when inserted into the line connecting generator and load, will reduce the load current to one third of its initial value.
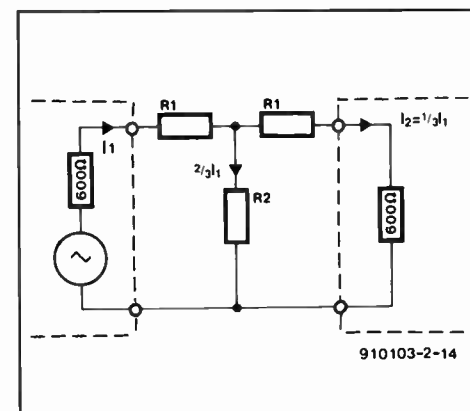
Fig. 11. A further design example relating to correct matching procedures.

This situation can be illustrated after the manner of Fig. 11. The section matches between equal impedances of 600 Ω and should, therefore, have R_0=600 Ω also. The attenuation factor, N, is 3, so that

WorldRadioHistory
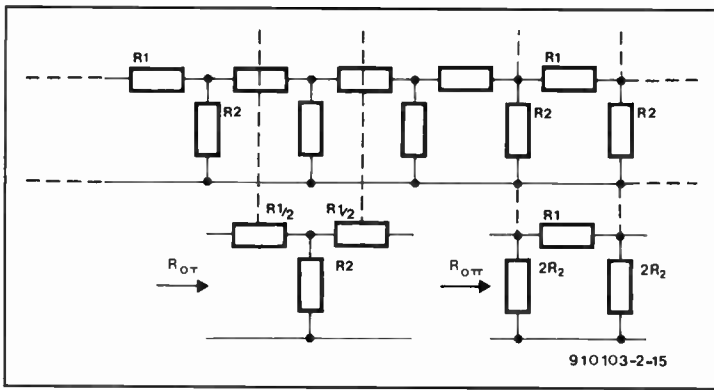
Fig. 12. These attenuator sections have the same total series and shunt resistances; then, $Z_{0T}Z_{0\pi}=R_1R_2$.

$R_a=R_0[(N^2-1)/2N]$ $R_b=R_0[(N+1)/(N-1)]$
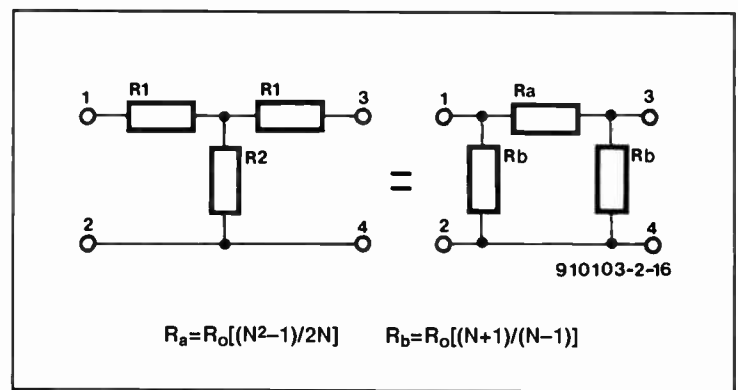
Fig. 13. Finding the element relationships between the T- and π–sections.

$R_1=600[(3-1)/(3+1)]=600\times2/4=300\ \Omega$

and

$R_2=600[(2\times3)/(9-1)]=600\times6/8=450\ \Omega.$

In a case like this, it is important to notice that current I_1 supplied by the generator is the *same* whether the section is in circuit or not. In both cases, the generator sees a resistive load of 600 Ω. With the section connected, the 'unwanted' current $(2/3 I_1)$ flows along the shunt arm, as an application of Ohm's law will immediately verify.

The π-section

It might appear that the π-section has been rather neglected, but there is a circuit relationship between the T-section and π-sections that makes an analysis of the π-section quite easy. Figure 12 shows a ladder network of series and shunt resistances; from an examination of this network, is it a chain of T-sections or π-sections? The answer is that it depends how you look at it. For, either a T-section can be taken from the network by considering the line division AA, or a π–section taken by considering the line division BB. The T-section cuts through the centre of each of the series elements R_1, while the π-section effectually splits the shunt element into two parallel parts, each of value $2R_2$. Hence, the ladder can be viewed as a string of T-sections or π-sections.

We might expect, therefore, that there would be little difference between the relationships derived for the two types of section, but for the matter of *equivalence* it isn't

just a job of halving the series arms and doubling up the shunts as this last analysis might have led us to believe.

We can make an exact comparison between the sections by looking at Fig. 13. Here, we use letter subscripts for the π-section resistors to avoid confusion.

For the two networks to be equivalent in their characteristics, the resistance seen between terminals 1 and 2 of both networks must be equal, as must the resistance between terminals 1 and 3 of both networks, with the output on open circuit. This means that R_1+R_2 on the T-section must equal $R_b(R_a+R_b)/(R_a+2R_b)$ on the π-section. Also,

$$2R_1=2R_aR_b/(R_a+2R_b)$$

or

$$R_1=R_aR_b/(R_a+2R_b).$$

Substituting back for R_1 in the first expression then gives us

$$R_2=R_b^2/(R_a+2R_b).$$

These relationships provide us with the elements of the T-network such that this will correspond to a given π-network.

It is also not too hard to demonstrate that for the basic π-section shown in Fig. 13

$$R_0=R_aR_b/\sqrt{(R_a^2+2R_aR_b)}=\sqrt{R_{oc}R_{sc}}$$

and that

$$R_a=R_0[(N^2-1)/2N]$$

and

$$R_b=R_0[(N+1)/(N-1)]$$

where the bracketed term is simply inverted from that of the T-section and R_a and R_b are themselves swapped over.

A useful relationship follows from the first of these: since $\sqrt{(R_1^2+2R_1R_2)}$ is the R_0 of a T-section (R_{0T}), we can deduce that for sections having the *same total series and shunt resistances* (see Fig. 12 again)

$$R_{0\pi}R_{0T}=R_1R_2=R_aR_b.$$

Don't confuse this with the equivalence relationships.

So, fundamentally there is no difference in the functions of these alternative forms of the sections and either may be used in a particular situation. The actual choice depends upon which form, given a particular value of characteristic resistance R_0, yields the more readily obtainable values of resistance for the elements.

In general design work, where stringent conditions are not of vital importance, the use of 5% resistors is quite acceptable; the resulting variation in attenuation will normally be no more than 0.5 dB and the mismatch in the characteristic resistance itself of the order of 5%. We will return to these points a little later on.

Insertion loss

The important thing in designing attenuators for general bench use is not to bother too much about getting exact answers to the calculations. It is no use working out a resistance to three or four decimal places and
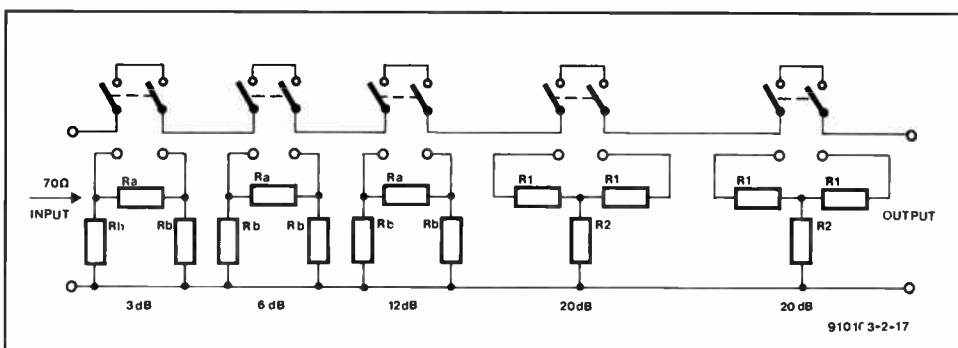
Fig. 14. Designing an attenuator knowing R_0 and the required attenuation.

$R_a=R_0[(N^2-1)/2N]$ $R_b=R_0[(N+1)/(N-1)]$
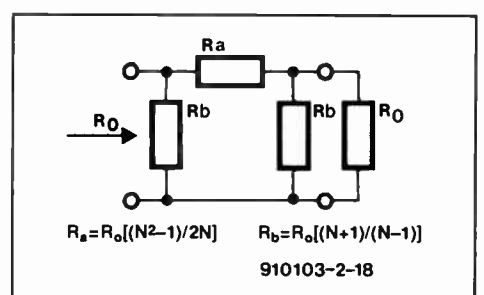
Fig. 15. The relationships should be compared with those for the T-section given earlier.

then discover that you've got to use a preferred value anyway. The attenuation factor can often be rounded off in the same way; 6 dB, for instance, is a voltage ratio of 1.9953... but we wouldn't put this into a formula: we use the nice round figure of 2. Of course, things don't always work out quite so conveniently, but anything beyond two decimal places is a waste of effort.

Let us now design a 5-section attenuator for a 70-Ω line giving switched positions of 3 dB, 6 dB, 12 dB and two 20 dB reductions. For interest, let the first three stages be derived from π-sections and the last two from T-sections. The job will look like Fig. 14, which also shows the appropriate switching.

Look first at the 3-dB section; the required attenuation is 3 dB for which attenuation factor N is found to be antilog $^3/_{20}$ or 1.41. Using the relationships shown for convenience in Fig. 15, and with $R_0=70$ Ω, we find that $R_a=24.8$ Ω and $R_b=410$ Ω. The last value is a bit of a problem, since it falls between 390 Ω and 430 Ω in the E24 range. One way out is to parallel 9.1 kΩ with a 430 Ω or get hold of a 412 Ω from the E96 precision range. Otherwise, use 24 Ω and 390 Ω in series; the mismatch is not very serious: R_0 then works out at 66 Ω.

Going through the same procedure for the 6 dB ($N=2$) and the 12 dB ($N=4$) π-sections, we find for the elements the respective values: $R_a=52\,\Omega$; $R_b=210\,\Omega$; $R_a=131\,\Omega$; $R_b=116$ Ω. Practical values here would be 51 Ω; 220 Ω; 130 Ω; and 120 Ω. Amuse yourself by calculating the above three ranges in terms of T-sections; do the resistance values fit any better?

For the two T-sections, we require an attenuation of 20 dB ($N=10$); hence, for $R_0=70\,\Omega$, we find

$$R_1=R_0[(N-1)/(N+1)]=70\times^9/_{11}=57\ \Omega$$

and

$$R_2=R_0[2N/(N^2-1)]=70\times^{20}/_{99}=14\ \Omega.$$

Practical values here would be 56 Ω and 13 Ω. The completed attenuator is shown in Fig. 16.

Now, try designing a series of five T-sections with switched ranges of 1 dB, 2 dB, 4 dB, 8 dB and 16 dB; this enables a maximum attenuation of 31 dB to be achieved in 1 dB steps. The R_0 should suit your own particular fancy. As a help, the respective N values are 1.12; 1.26; 1.58; 2.45 and 6.30.
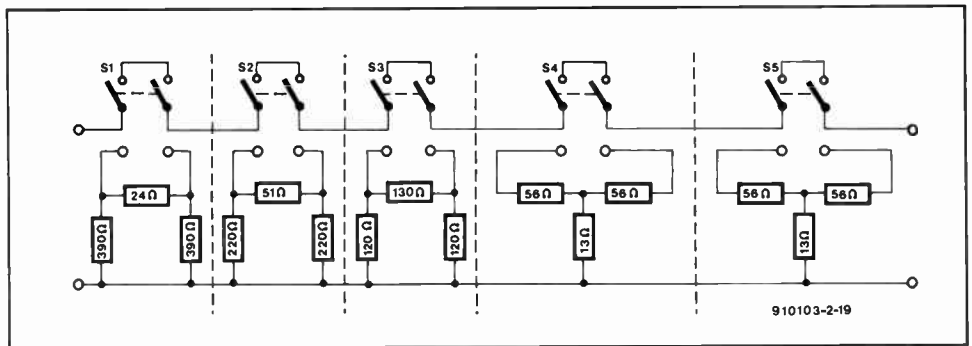
Fig. 16. The completed design.

Practical considerations

When we talk about purely resistive attenuators, we are, of course, in the realms of fantasy; it is not possible to make up an attenuator system having a number of sections in tandem without introducing some inductive and capacitive elements. The object of any design is to keep these to their absolute minimum, just as in filters, where inductance and capacitance are the necessary elements, we try to eliminate resistance.

It is necessary, then, to keep all interconnecting leads as short as possible and to avoid the proximity of these leads, as well as the resistances themselves, to any surrounding metal parts. Further, there must be no capacitive coupling between the sections or certain frequency components of the signal will sneak through without the desired attenuation, but with definite phase shifts. The resistances should not, for obvious reasons, be wirewound, though types with a noninductive construction might be used.

Simple aluminium boxes are available nowadays that can be used to house bench-type attenuators. Types measuring some 120–150 mm in length with perhaps 50 mm width and a depth of about the same are ideal. Figure 17 shows the general method of assembling such attenuators.

The box is divided up into the required number of compartments by cross screens that can be made of thin aluminium or tin-plate. If aluminium is used, the screen will have to be flanged and screwed to the side walls of the box, but with an all tinplate construction, soldering is the best approach.

Small holes are drilled centrally in each screen (before fitting!) to permit the series-arm resistors to feed through, and the shunt-arm resistors are returned either directly to each screen or to a convenient position on the box floor itself. A relatively heavy common wire running through the screens sometimes makes dependence on the box metal unnecessary.

Slide or miniature toggle switches are used for the attenuation selection, though it is possible, with certain forms of construction—see Fig. 18—to use rotary switches. It is often easier to use the base of the box to carry the terminals and switching, the actual lid being fitted last and becoming the working base. This avoids having long leads to connect the switches which would then be separated from the rest of the network in the body of the box.

Attenuators that are to be housed inside equipment, such as a signal generator for example, can be built into the general internal design method, but a divided-compartment assembly is still necessary if the best results are to be obtained. For less stringent work, the resistances can often be simply mounted directly to the tags on a rotary switch wafer or wafers as they could for the system shown in Fig. 18. Most simple 'dividers' are assembled this way.

The power ratings of the resistors used in attenuators must, of course, be such as to ensure that no appreciable temperature rise can occur in normal use. ∎
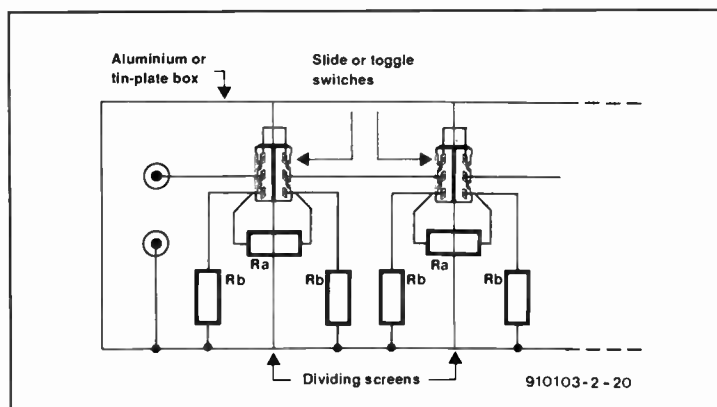
Fig. 17. Practical method of assembly.
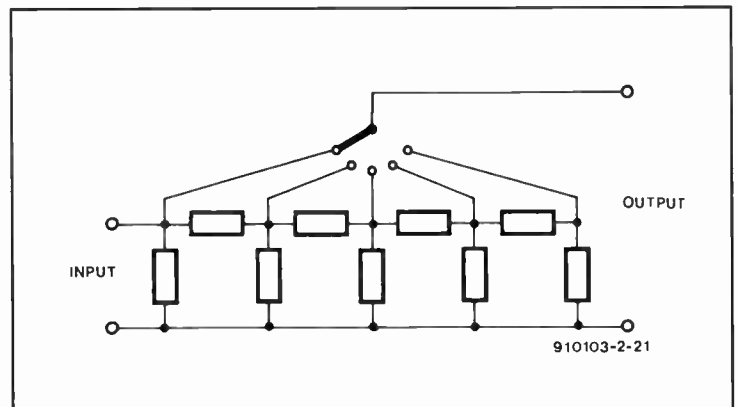
Fig. 18. An alternative switching system—more difficult to screen adequately.

A SIMPLE WATCHDOG CIRCUIT

by Akbar Afsoos

SINGLE-CHIP microcontrollers have been designed and optimized for specific applications such as industrial control and automotive applications. The Intel MCS-51 family of microcontrollers is a popular and typical example.

The presence of various types of electrical noise and interference in the above mentioned applications is by no means taken for granted, but generally accepted as hard to avoid. By virtue of some special features, such as powerful Boolean processing capabilities, single-chip microcontrollers are mostly used in industrial control applications which are known as electrically noisy environments.

In spite of a well-designed power supply, a shielded enclosure, and adequate decoupling provisions, noise may still enter a microcontroller system, upsetting the normal operation, or even causing a system crash. These situations are usually marked by the microprocessor going into its static state, or performing unpredictable operations. In such a case, normal operation can be restored only by a hardware reset (PC users know this as BRST — Big Red Switch Time).

A problem occurs when the microprocessor system operates unattended, which is usually the case in industrial applications. A total lockup of the system can then disrupt a production line, or cause expensive 'down time'. In such applications, hardware resetting must be performed automatically on detection of a software malfunction. The circuit described here (Fig. 1) provides a simple method to accomplish this.

Circuit description

The watchdog circuit consists of a power-up reset, a gated astable multivibrator, and a failure detector circuit. In fact, the total circuit simulates a retriggerable monostable
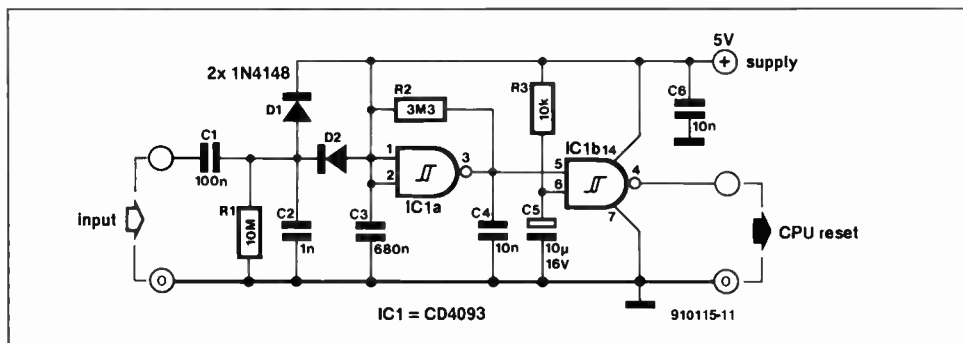
Fig. 1.   Circuit diagram of the watchdog. The input is connected to a CPU port line.

multivibrator, which detects a software upset whenever it is not triggered at a proper rate.

In the MCS-52 family of microcontrollers, PX.X can be any pin (bit) of the ports 1, 2 or 3. Ports 2 and 3 may not be used when performing their secondary functions. Components R3 and C5 form a power-up reset circuit that applies a reset pulse to the CPU via gate IC1b, whenever power is applied.

During normal operation, and in the main loop of the program, a periodic pulse must appear on port line PX.X. The frequency of this signal must be at least 10 Hz. The software determines which port line is used to keep the watchdog triggered. In 8051 assembler code, this is simple to implement by the instruction CPL PX.X, where X.X is the port line identification, e.g. 1.0 (bit 0 of port 1).

The software failure detector consists of C1, R1, D1 and D2. The pulse train applied to the PX.X input of the circuit continuously discharges C3 via D2 and C1. As a result, the gated bistable around gate IC1a is disabled, and its output goes high. Hence, during normal program execution, the two inputs of IC1b are high, so that the CPU reset line is held low.

As soon as a software upset occurs, the CPU very likely leaves the main loop of the program. This means that the pulses on PX.X fail, so that the port line takes on a static level. This enables the astable circuit which consists of IC1a, R2 and C3. After C3 has been fully charged by R2, the output of IC1a goes low. Consequently, a logic high reset pulse appears at the output of IC1b.

Because IC1a functions as an astable multivibrator, C3 is discharged again after about one second, so that the output of IC1a goes high. This causes the CPU reset line to revert to logic low, and the control program is executed starting at the reset address. The CPU has enough time (about one second) to restart the pulse train on PX.X, and resume its normal operation.

The reaction time of the watchdog may be shortened by using a smaller capacitor in position C3. Capacitors C2 and C4 reduce the effect of noise on the operation of the circuit. If a reset key is required, you can connect a pushbutton in parallel with capacitor C5.

This circuit may also be used with any of the devices in the Intel MCS-48 family of single-chip microcontrollers. This, however, requires an inverter gate to be inserted between the output of IC1b and the CPU reset line, because these controllers have active-low reset inputs. ∎
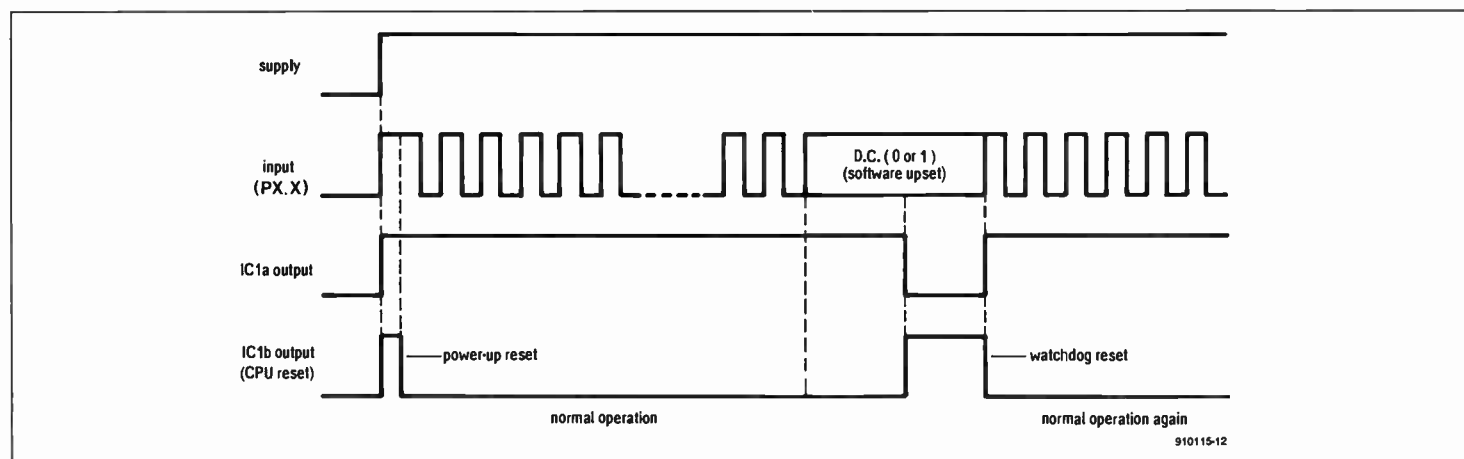
Fig. 2.   Ideal waveforms illustrating the operation of the watchdog circuit.

THE CIPHER MACHINE
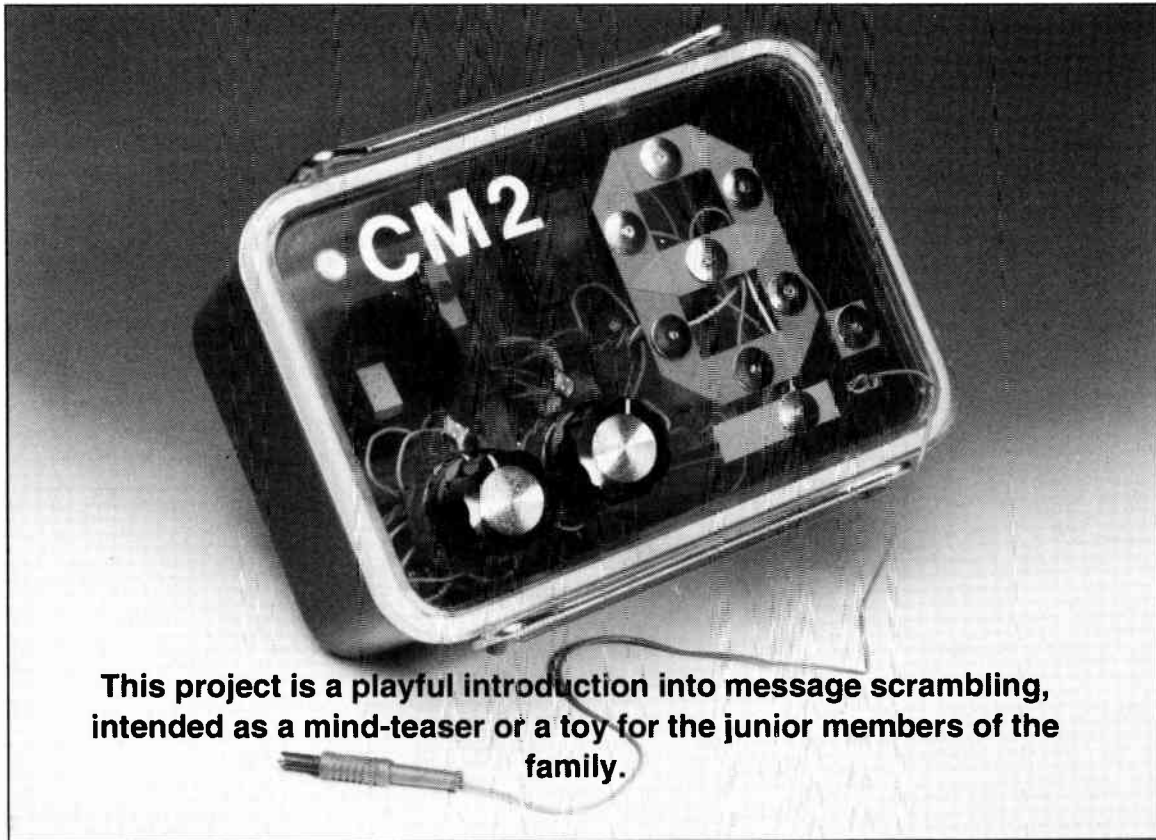
This project is a playful introduction into message scrambling, intended as a mind-teaser or a toy for the junior members of the family.

by Owen and Audrey Bishop

SINCE antiquity, the scrambling of the letters in a message has been a popular though elementary method of encryption. One of the earliest techniques was to write out the message in the rows of a square, or rectangular array of prearranged shape and size:

```
THISIS
ISNOTA
HIGHLY
SECURE
SYSTEM
```

The message is then written out by columns:

```
TIHSSHSIEYINGCSSOHUTITLRESAYEM
```

Needless to say, anyone who knows anything at all about ciphers will have no difficulty in breaking such a simple scrambled message. Another well-established method is to group the letters of the alphabet into pairs, and then exchange one member of a pair for the other when writing out the message. The pairs are usually determined by beginning with an agreed key-word, followed by the remaining letters in order:

```
MACHINEBDFGJK
LOPQRSTUVWXYZ
```

To encrypt the message, letters in the top row are exchanged for those in the bottom
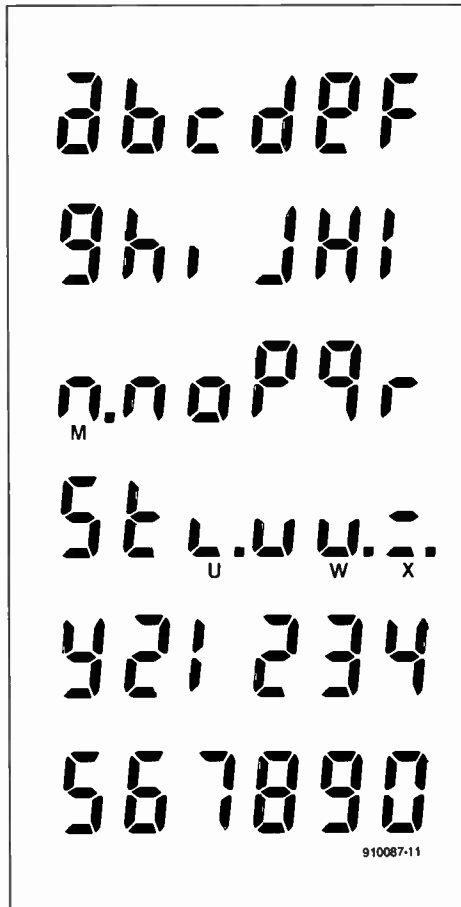
Fig.1. Representing letters and numerals on a 7-segment LED display.

row, and the other way about.

Message:
ALSO FAIRLY EASY TO BREAK
Cipher:
OMNA WORIMJ TONJ EA UITOZ

In this project we carry the idea of transposition into the letters themselves. We take the strokes used to write the letter, and scramble them by swapping them in pairs. The result is either a different letter or a weird and unrecognizable symbol. Most alphabetic and numeric characters can be written using the 7-segment matrix commonly employed in pocket calculators and digital clocks. Unfortunately, there are some problems in representing certain letters such as 'M', 'W' and 'X'. For these and a few others, a 16-segment 'starburst' matrix gives a better image, but such devices are expensive. This is intended to be a cheap, easy-to-wire, project for you to build for the youngsters. You may even want to build two, so that they can exchange messages.

So we have settled for a 7-segment display, even though there are difficulties with a few of the more 'awkward' letters. The scheme works better if we use a lower-case alphabet (Fig. 1). We make use of the eighth segment of the display, the decimal point, to distinguish 'm', 'u', 'w' and 'x'. This is used to represent a central vertical segment in the bottom half of the array.
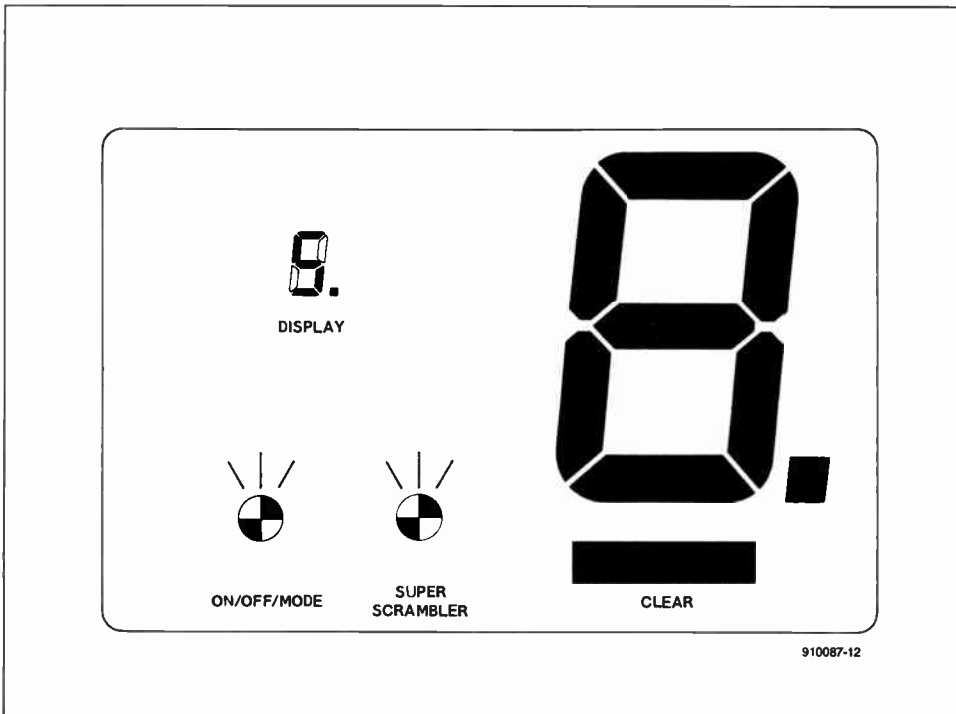
Fig. 2. Suggested layout of the panel of the Cipher machine.

Fig. 3. Simple scrambling.

Fig. 4. Scrambling with inversion.

Fig. 5. Use of the 'wild card' segment.

Practical use

The Cipher machine is used as follows. The letters or numerals of the message are entered one at a time by touching the appropriate segments of a 7-segment key-panel with a stylus (See Fig. 2.). The scrambled version of the character appears on a 7-segment LED display, and this is copied down onto paper. The receiver of the message has a Cipher Machine with identical wiring (or uses the same machine), and enters the symbols on to the key-plate. The machine unscrambles the segments, reproducing the original letter or numeral on the 7-segment display.

Choice of display

The original version of this project simply scrambled the segments, producing characters such as those in Fig. 3. The weakness of this technique lies in the fact that the scrambled character has the same number of segments as the regular character. This is a clue to the identity of the letter. For example, a 3-segment symbol obviously comes from a 3-segment letter, either 'c', 'n' or 'v'. It is usually easy to decide, for other reasons, which one of these it must be. Worse still, if the letter has only a few segments (for example, 'c' in Fig. 3), when the symbol tends to end up as a number of disconnected strokes. Such symbols are difficult to write convincingly. They also further advertise the fact that the system depends on interchanging segments.

To make unauthorized deciphering more difficult, the Cipher Machine logically inverts the scrambled segments when there are fewer than four. For example, the letter 'l' (or figure '1'), has only 2 segments, but is displayed as a 5-segment symbol (Fig. 4). This procedure has the advantage of increasing the average number of segments making up the symbols, giving them a more 'connected' appearance. There are a few exceptions to this inversion routine, for reasons which will be explained later.
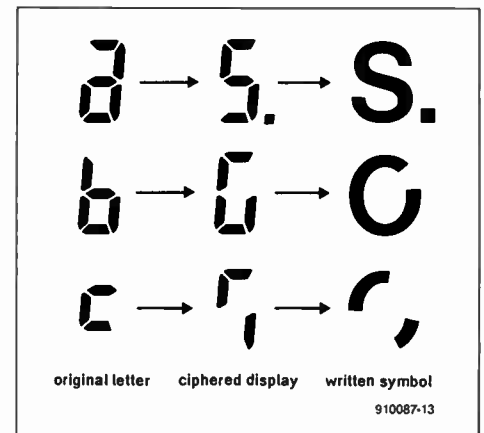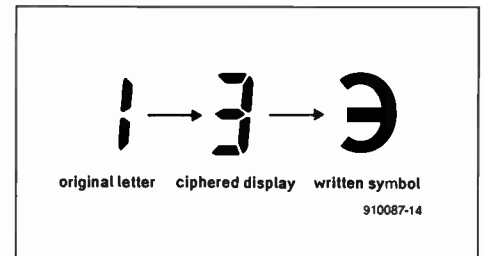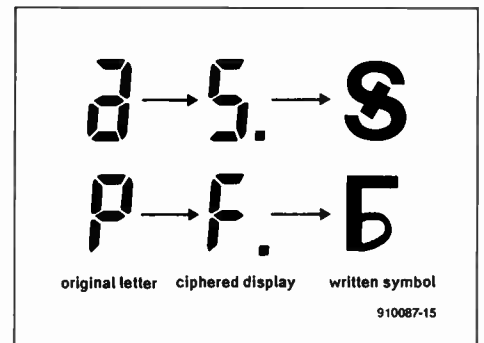
Scrambling twists

Another twist to confuse the snooper is the way we use the decimal point (segment h of the display), when this comes up as one of the scrambled segments. We think of this as a 'wild card' which can be added to the symbol anywhere that is not part of the 7-segment matrix, as in Fig. 5. You can add the 'wild card' in different places each time it occurs, producing a confusing set of variations that all represent the same letter.

Finally, there is the super-scrambler option. This consists of a 3-position switch that varies the scrambling of four pairs of segments. This switch is set to a given position before ciphering begins. The authorized recipient knows the setting, and uses this when deciphering. All sorts of routines can be used by prior agreement, such as to alter the switch at the start of each paragraph, or even for each word or letter, according to a regular system.

Circuit details

The eight segments of the key-panel are connected to the SET input of a set-reset bistable (flip-flop) (Fig. 6). The SET input is normally held logic high by a pull-up resistor, R1-R8.

Table 1. Ciphering rules

Case	Original character	Ciphered symbol	b lit?
A	1, 2 or 3 segments, not including h	All segments inverted	Yes
B	1, 2 or 3 segments, plus h	h inverted, rest not inverted	No
C	4 to 7 segments, not including h	None inverted	No

Table 2. Deciphering rules

Case	Ciphered symbol	Deciphered character	h lit?
A	4 to 7 segments, including b	All segments inverted	No
B	1, 2 or 3 segments, not including b	b inverted, rest not	Yes
C	4 to 7 segments, not including b	None inverted	No

When a segment is touched by grounded stylus, the low input to the corresponding bistable causes its Q output to go high. The RESET inputs of these bistables are all connected to a single CLEAR pad on the key-panel, and are held logic high by R9. Touching the CLEAR pad with the stylus resets all the bistables, and their outputs go low. Thus, the bistables store the segments that make up the character.

The output of each bistable goes to one input of an XOR (exclusive-OR) gate. When the inputs of the gates are low, the output of each gate has the same state as the corresponding bistable. If the other inputs are high, the output of each gate is the inverse of the bistable outputs. For example, if pad a is touched, the first bistable in IC1 is set, and its

output, pin 13, goes high. If pin 2 of IC3 is low, pin 3 of IC2 goes high, and the LED segment g is lit. If pin 2 is high, the segment is not lit. The pads and the LED segments are in exchanged pairs so that, for example, touching pad a lights (or turns off) segment g on the display. Conversely, touching pad g lights (or turns off) LED segment a.

The circuit diagram shows just one permutation for scrambling. The super scrambler switch, S1, gives a variable pairing between segments c to f. This part of the circuit is open to modification. Many different combinations of any four of segments a to g can be wired to the super scrambler switch, and those four segments not so wired can be paired in three different ways. Th only restriction is that h and its partner may not be

wired to the super scrambler switch. If you want to be able to use one machine for ciphering, and another for deciphering, both machines must be wired exactly alike.

The lower part of the circuit diagram shows the logic switch that decides when segments are to be inverted. The logic is summarized in Table 1.

In case 'A' we obtain a symbol with five to seven lit segments, plus b (assuming that h has been scrambled with b, as in the schematic). The letters included in case 'B' are the 'm', 'u', 'w' and 'x', all of which require the use of the h segment. Since we rely on the state of h (scrambled to b) when deciphering, we have no compromise by not inverting the segments of these few letters. Case 'C' includes all other letters with three or fewer
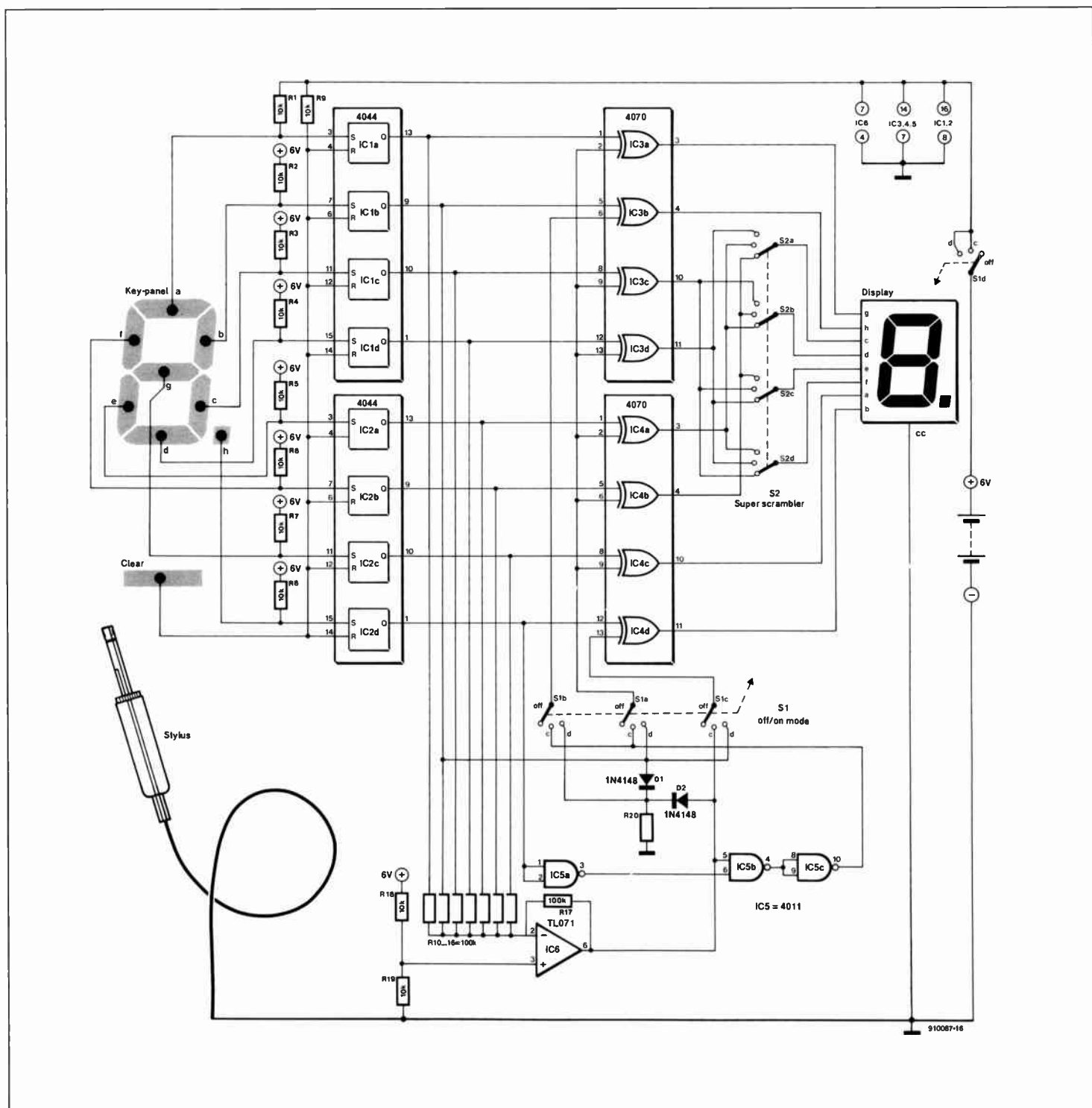
Fig. 6. Schematic diagram of the Cipher machine.

Elektor Electronics USA

PO Box 876, Dept. ELI
PETERBOROUGH, NH 03458-0876
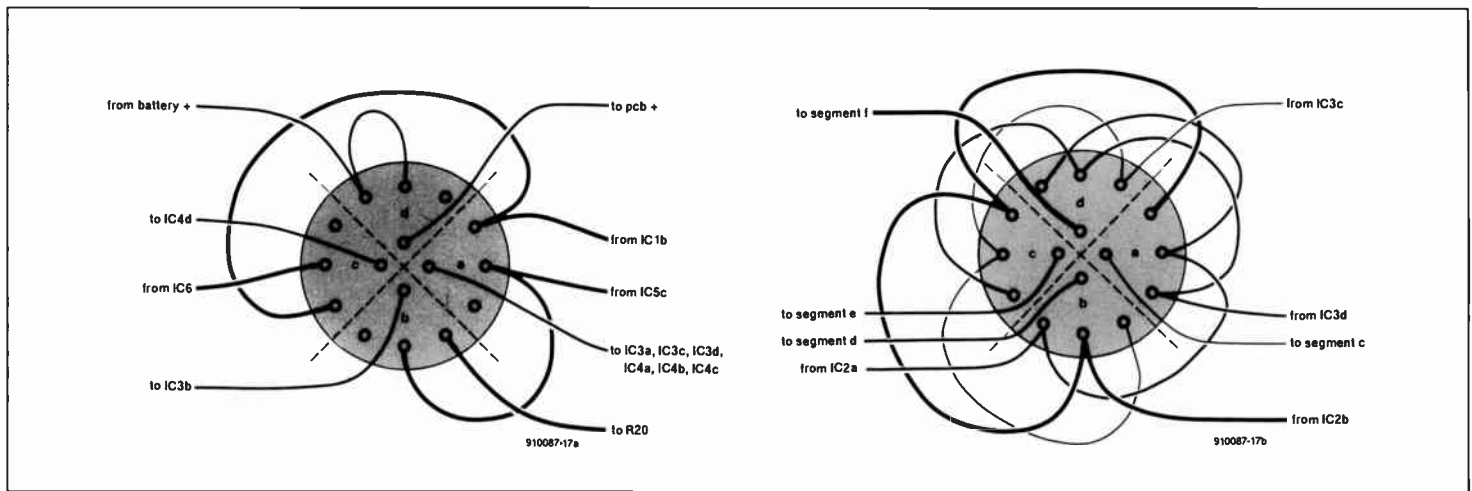
Fig.7. (a) Wiring of S1, as seen from the rear. (b) Wiring of S2, as seen from the rear.

segments. There are no characters that have four to seven segments and h.

From Table 1, we establish three rules for ciphering:

1. Invert a and c to g if there are one to three segments of a to g set, and h is not set (case 'A');
2. Invert b for the same conditions as in Rule 1 (Case 'A');
3. Invert h if there are one to three segments of a and c to g set (case 'B').

The number of segments set is 'counted' by an operational amplifier, IC6, wired as a summing amplifier. We could have used a digital equivalent, but no 7-input gate is available 'off-the-shelf'. This substitute is considerably less complex to wire up than a digital version made of discrete gates. The summing action is also accompanied by inversion. When three or fewer bistables have a high output, the output of the operational amplifier swings fully high. When four or more have a high output, the amplifier swings fully low.

When there are one to three segments lit, the output of IC6 is high; this is fed by way of S1c to IC4d, the XOR gate for segment h, which is thus inverted, causing segment b to remain off. This complies with Rule 3 above. The output of the h bistable is inverted by IC5a, so its output is high when h is not set. The output of IC6 is high when one to three segments are set. The two high inputs to the NAND gate, IC5b, make its output go low, and this is inverted by IC5c. Through switches S1a and S1b, this causes high levels at the inputs of the XOR gates, inverting segments a to g, and conforming to Rules 1 and 2.

The rules for deciphering are slightly different, which is why we need S1 to switch between ciphering (C) and deciphering (D) modes. The conditions for deciphering are given in Table 2. The logic for Rules 4 and 6 is effected by S1a and S1c connecting the output of the b bistable to the inputs of the XOR gates a and c to g. The outputs of IC6 and the b bistable need to be ORed together to perform deciphering Rule 5. Instead of installing an extra IC to provide an OR gate, we have used 'Mickey-Mouse' logic: the two diodes D1 and D2, and a 10-kΩ pull-down resistor, R20.

Construction

Since the Cipher Machine was intended as a not-too-serious toy for the junior members of the family, the prototype was built in a brightly-coloured novelty form (see the introductory photograph). The enclosure is a food storage box with a clear snap-on lid. This exposes the 'works' for all to see, so the battery holder, PCB, switches, ICs and other components are painted in red, blue and yellow. We also bought plastic knobs for S1 and S2.

There is no limit to the variety of the colour schemes you can employ but, if you prefer a rather different image, the project could be realized as a rugged all-black 'military-look' device. Alternatively, you could disguise it as a radio set, or even as a bound volume to hide away on the bookshelf.

The circuit should not be too difficult to build on a piece of Veroboard or stripboard. The battery holder is glued to the bottom of the enclosure, and special self-adhesive PCB mounting strip is used for the circuit board. The area around the display is shielded from direct light by a cylinder painted matt black inside, and a bright tint outside. The cap from a spray can makes a suitable shield.

The key-pads are laid out as an array of strips of coloured PVC insulating tape. A narrow hole is drilled at the centre of each strip, and through the lid below. A brass thumb-tack is pushed into each hole to form the contact for the stylus. Wire is wrapped around the pin of each tack, and soldered to it. The lid of our enclosure was made of high-impact polystyrene or similar plastic, so care was needed not to shatter it by over-enthusiastic drilling. The two switches are also mounted on the lid. Their decorative effect is enhanced by looping out the connecting wires in the shape of flower petals, as shown in Fig. 7. A hole is drilled in one side of the enclosure for the lead to the stylus.

There are no alignment problems: if correctly assembled, the Cipher Machine should work first time. The detailed description given above should help you iron out any discrepancies. ■

UPGRADE FOR MCS BASIC-52 V.1.1 (Part 2)

Following last month's dealings with the floating-point nucleus and the hex-to-BCD conversion routine in the MCS-52 BASIC interpreter, the authors now tackle some problems with multiplications.

by Z. Stojsavljevic and D. Mudric

Continued from the October 1991 issue.

INCONSISTENCIES in the multiplication of two numbers as performed by version 1.1 of Intel's MCS BASIC-52 interpreter can be demonstrated by running the following three small programs, all of which produce wrong results.

```
10    a=1.E–65
20    b=1.E–65
30    ?a*b          (result: 1.0E+126)

10    a=1.E–65
20    b=1.E–64
30    ?a*b          (result: 0)

10    a=1.E–64
20    b=1.E–64
30    ?a*b          (result: 1.0E–0)
```

In all three cases, the interpreter should have produced

ERROR: ARITH. UNDERFLOW - IN LINE 30

The above examples point to inconsistencies in limit cases when two numbers are multiplied. On investigating the operation of Intel's BASIC interpreter, a multiplication algorithm of the type shown in Fig. 1 was found. Apparently, the inconsistencies brought to our attention by the above example programs were caused by the exponent adjustment routine, which is listed in Fig. 2. Unfortunately, the errors found in this routine cannot be corrected in BASIC-52 machine code, because some expansion of the machine code is in order. This means that a number of lines should be added to the assembler source file for compensation.

A problem occurs when the result of the instruction SUBB A,#81H is 0FFH, which
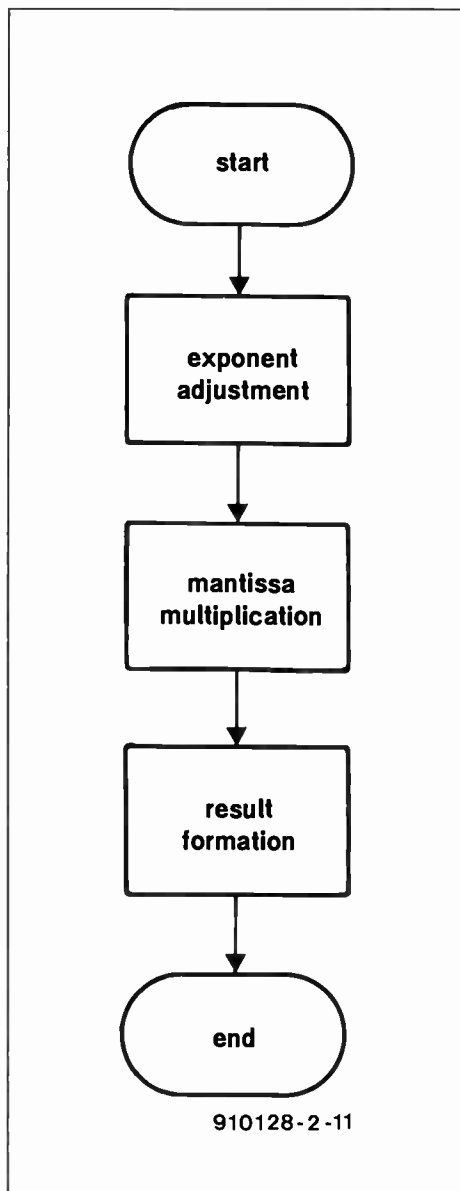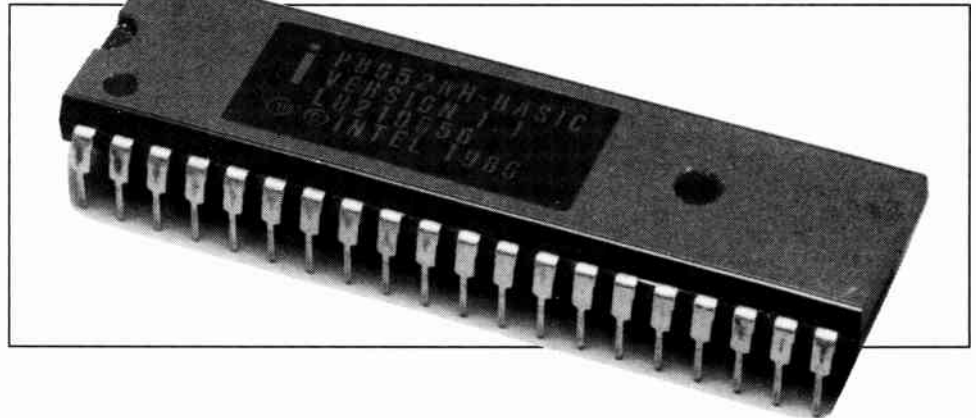
Fig. 1. Flowchart of the routine that handles multiplication of two numbers.

equals exponent E+127. If the program part for mantissa multiplication includes a result that begins with a 0 after the decimal point, the exponent is not incremented but remains

```
1A9AH  9175      ACALL   1C75H
1A9CH  BE0002    CJNE    R6,#00H,1AA1H
1A9FH  61B8      AJMP    1BB8H
1AA1H  8D2F      MOV     2FH,R5
1AA3H  EF        MOV     A,R7
1AA4H  60F9      JZ      1A9FH
1AA6H  2E        ADD     A,R6
1AA7H  20E705    JB      ACC.7,1AAFH
1AAAH  10D706    JBC     CY,1AB3H
1AADH  61B2      AJMP    1BB2H
1AAFH  5002      JNC     1AB3H
1AB1H  61A1      AJMP    1BA1H
1AB3H  9481      SUBB    A,#81H
1AB5H  FE        MOV     R6,A
1AB6H  718B      ACALL   1B8BH
1AB8H  7B04      MOV     R3,#04H
1ABAH  AC01      MOV     R4,01H
1ABCH  8C01      MOV     01H,R4
1ABEH  E3        MOVX    A,@R1
1ABFH  FA        MOV     R2,A
1B30H  7834      MOV     R0,#34H
1B32H  E6        MOV     A,@R0
1B33H  FE        MOV     R6,A
1B34H  6003      JZ      1B39H
1B36H  717F      ACALL   1B7FH
1B38H  18        DEC     R0
1B39H  08        INC     R0
1B3AH  7408      MOV     A,#08H
1B3CH  F9        MOV     R1,A
1B3DH  28        ADD     A,R0
1B3EH  F8        MOV     R0,A
1B3FH  B60500    CJNE    @R0,#05H,1B42H
1B42H  4013      JC      1B57H
1B44H  D3        SETB    C
1B45H  E4        CLR     A
1B46H  18        DEC     R0
1B47H  36        ADDC    A,@R0
1B48H  D4        DA      A
1B49H  D6        XCHD    A,@R0
1B4AH  30E409    JNB     ACC.4,1B56H
1B4DH  D9F5      DJNZ    R1,1B44H
1B4FH  18        DEC     R0
1B50H  7601      MOV     @R0,#01H
1B52H  717F      ACALL   1B7FH
1B54H  8006      SJMP    1B5CH
1B56H  19        DEC     R1
1B57H  E9        MOV     A,R1
1B58H  C3        CLR     C
1B59H  C8        XCH     A,R0
1B5AH  98        SUBB    A,R0
1B5BH  F8        MOV     R0,A
1B5CH  792B      MOV     R1,#2BH
1B5EH  E6        MOV     A,@R0
1B5FH  C4        SWAP    A
1B60H  08        INC     R0
1B61H  D6        XCHD    A,@R0
1B62H  4206      ORL     06H,A
1B64H  F7        MOV     @R1,A
1B65H  08        INC     R0
1B66H  09        INC     R1
1B67H  B92FF4    CJNE    R1,#2FH,1B5EH
1B6AH  EE        MOV     A,R6
1B6BH  7003      JNZ     1B70H
1B6DH  753000    MOV     30H,#00H
1B7FH  0530      INC     30H
1B81H  E530      MOV     A,30H
1B83H  70F9      JNZ     1B7EH
1B85H  D0E0      POP     ACC
1B87H  D0E0      POP     ACC
1B89H  61A1      AJMP    1BA1H
```

Fig. 2. Original program part for exponent adjustment.

WorldRadioHistory

To avoid inconsistencies, and eliminate errors in limit case multiplications, the program listed in Fig. 3 was developed. The lines marked by vertical bars in particular correct the limit case multiplication errors.

On the basis of the information contained in this and last month's instalment, the authors developed an improved, error-free floating-point (FP) arithmetic for the 8051, on the basis of the FP nucleus extracted from the 8052AH-BASIC. The new FP nucleus uses a modified way of accessing the arithmetic stack, and has faster, shorter code for a number of algorithms. It allows the length of the mantissa of a FP number to range from 2 to 16 digits, while the entire memory map of the FP arithmetic variables is located in the internal memory space of the 8051 microcontroller. ∎

```
                ORG     1A9AH

        . TOS     - Top Of arithmetic Stack
        . NXTOS - NeXt TOS (position behind)

        ; TOS_MUL1
        ; routine for multiplication of two FP numbers, one of which
        ; is located on TOS and the other on NXTOS (NXTOS*TOS)

TOS_MUL1:ACALL   PREP_MUL; clearing of FP working space and reg. prep.
        CJNE     R6,#0,NXTNM_0   ; is NXTOS equal 0?
TOSM_0:  AJMP     ZERO_MANTISSA    ; in case TOS or NXTOS are 0
NXTNM_0: MOV      SIGN,R5     ; result mark in SIGN
        MOV      A,R7     ; is TOS equal 0?
        JZ       TOSM_0
        ADD      A,R6    ; addition of exponent degree (exp. multipl.)
        JB       ACC.7,CMPM_EXP  ; exp. with different mark or overflow?
        JBC      CY,CORM_EXP    ; result is bigger than 0.1
        AJMP     UNDERFLOW       ; in this case exp. sum is < -127
CMPM_EXP:JNC     CORM_EXP; in this case result is smaller than 0.1
OVER_MD: AJMP     OVERFLOW  ; in this case exp. sum is > 127
CORM_EXP:CLR     MUL_LIMIT_CASE   ; flag of multiplication limit case
        SUBB     A,#82H   ; exp. multipl. results are within the limits
        INC      A       ; deduction  with  82H  because  of  reduced
        JNC      NMARK_L ;  conditions
        SETB     MUL_LIMIT_CASE  ; limit case
NMARK_L: MOV      R6,A    ; exp. adjustment to real value
        ACALL    BCD2_1  ; disassembl. of TOS mantissa in LEN_MANTISSA
        MOV      R3,#LEN_BYTE    ; acc. (one number in each byte)
        MOV      R4,AR1    ; R1 is pointer of NXTOS
MUL_NOOV:MOV      AR1,R4  ; @R1 contains few numbers and disassembled
        MOVX     A,@R1   ; mantissa is successively multiplied by each
        MOV      R2,A    ; of  them  in  argument  accumulator  (R2  is
                         ; auxilliary register)

-----------------------------------------

        ; TRANSFER
        ; routine  for  adjustment  of  multiplication  and  division
        ; results  of  FP  numbers  in  argument  stack  and  mantissa
        ; conversion  in  BCD  packed  format  in  argument  accumulator

TRANSFER:MOV     R0,#ASCII_DEC   ; pointer to MSB result number
        MOV      A,@R0   ; MSB result number is in acc.
        MOV      R6,A
        JZ       MSB_EQ_0; is MSB result number equal 0?
        ACALL    INC_EXP ; exp=exp+1 because from the start it was
        DEC      R0      ; taken that MSB result number is equal 0
MSB_EQ_0:INC     R0      ; pointer to MSB-1 number
        MOV      A,#LEN_MANTISSA ; positioning to LSB-1 number
        MOV      R1,A    ; R1 is counter
        ADD      A,R0
        MOV      R0,A    ; R0 contains the address of LSB-1 number
        CJNE     @R0,#05,ROUND1  ; test of remainder to rounding
ROUND1:  JC       NO_ROUND; in case remainder is smaller than 5 there
C_BCD:   SETB     C       ; is no rounding
        CLR      A       ; carry takes one because of rounding
        DEC      R0      ; transfer of carry into higher byte
        ADDC     A,@R0   ; addition of 1 to higher byte
        DA       A       ; adjustment to BCD format
        XCHD     A,@R0   ; result storing in higher byte
        JNB      ACC.4,NO_C_BCD  ; transfer in higher BCD nibble?
        DJNZ     R1,C_BCD; is @R0 the address of MSB number?
        DEC      R0      ; transfer memorizing in the place MSB+1
        MOV      @R0,#01
        ACALL    INC_EXP ; transfer is outside decimal point frame
        SJMP     BCD1_2
NO_C_BCD:DEC     R1
NO_ROUND:MOV     A,R1    ; address return in R0 to the first bigger BCD
        CLR      C       ; number which is not equal 0
        XCH      A,R0
        SUBB     A,R0
        MOV      R0,A
BCD1_2:  MOV      A,EXPONENT      ; test of exceeding in limit case
        JNB      MUL_LIMIT_CASE,N_LCASE
        JZ       UNDER_MD; message about underflow
        INC      A
        JZ       UNDER_MD; message about underflow
N_LCASE: MOV      R1,#ARGUMENT_ACC; repacking of BCD number in one byte
XFER_1:  MOV      A,@R0   ; in two BCD numbers in one byte
        SWAP     A       ; higher number in BCD packed  format is in
        INC      R0      ; upper nibble
        XCHD     A,@R0   ; BCD packed format is in ACC
        ORL      AR6,A   ; the indication if mantissa is 0 is in R6
        MOV      @R1,A   ; packing in argument accumulator mantissa
        INC      R0      ; two BCD packed numbers in one byte
        INC      R1
        CJNE     R1,#SIGN,XFER_1
        MOV      A,R6
        JNZ      RESULT_MAT_OP_TOS         ; is mantissa equal 0?
        MOV      EXPONENT,#0

-----------------------------------------

INC_EXP: INC     EXPONENT; exp. adjustment by 1 (consequence of
        MOV      A,EXPONENT      ; transfer after addition)
        JNZ      EXP_OK  ; test of exponent exceeding
        POP      ACC     ; removal from return address stack
        POP      ACC
        JBC      MUL_LIMIT_CASE,UNDER MD ; in limit case it is
        AJMP     OVERFLOW; underflow
UNDER_MD:AJMP     UNDERFLOW
                                910128-2-13
```

Fig. 3.   Source code of the improved multiplication routine. The vertical bars indicate lines that correct the limit case multiplication errors mentioned in this article.

AZ-87

CORK

INTERMEDIATE PROJECT

A series of projects for the not-so-experienced constructor. Although each article will describe in detail the operation, use, construction and, where relevant, the underlying theory of the project, constructors will, none the less, require an elementary knowledge of electronic engineering. Each project in the series will be based on inexpensive and commonly available parts.

TIMER FOR CENTRAL HEATING SYSTEMS

To achieve a comfortable room temperature quickly it is often required to switch on the central heating (CH) boiler for ten minutes or so, for instance, in the morning, or when you get home from work. Unfortunately, most CH systems can be switched on only by turning up one of the room thermostats. This works, but if you forget to turn it down again, the resultant hothouse is not only unhealthy but also a waste of energy.
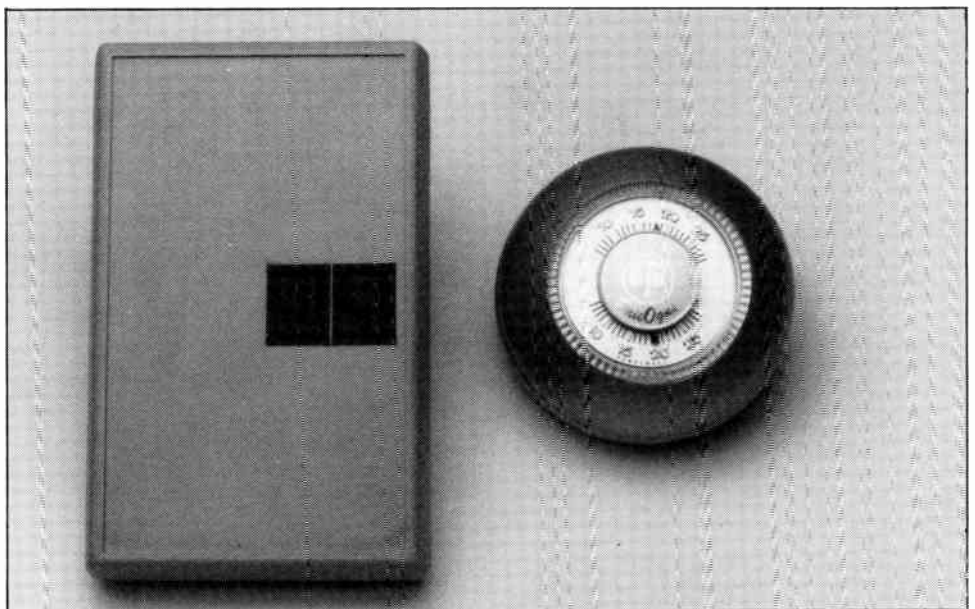
by J. Ruffell

THE circuit described here is a timer that can be connected to most types of CH room thermostats, including the well-known Honeywell types and look-alikes (see the above photograph). Its function is to actuate the CH boiler (and pump) for a certain period, overriding the thermostat output. Unlike you, it is not in the habit of forgetting to turn the boiler off again — all you have to do is press a button to start the timer. The circuit is simple to build, and conveniently fitted next to the room thermostat.

How it works

The timer is actually a monostable multivibrator with an adjustable on-time. The circuit diagram in Fig. 1 shows that a 4060 ripple counter IC is used as the timing device. The 4060 has an on-board oscillator,
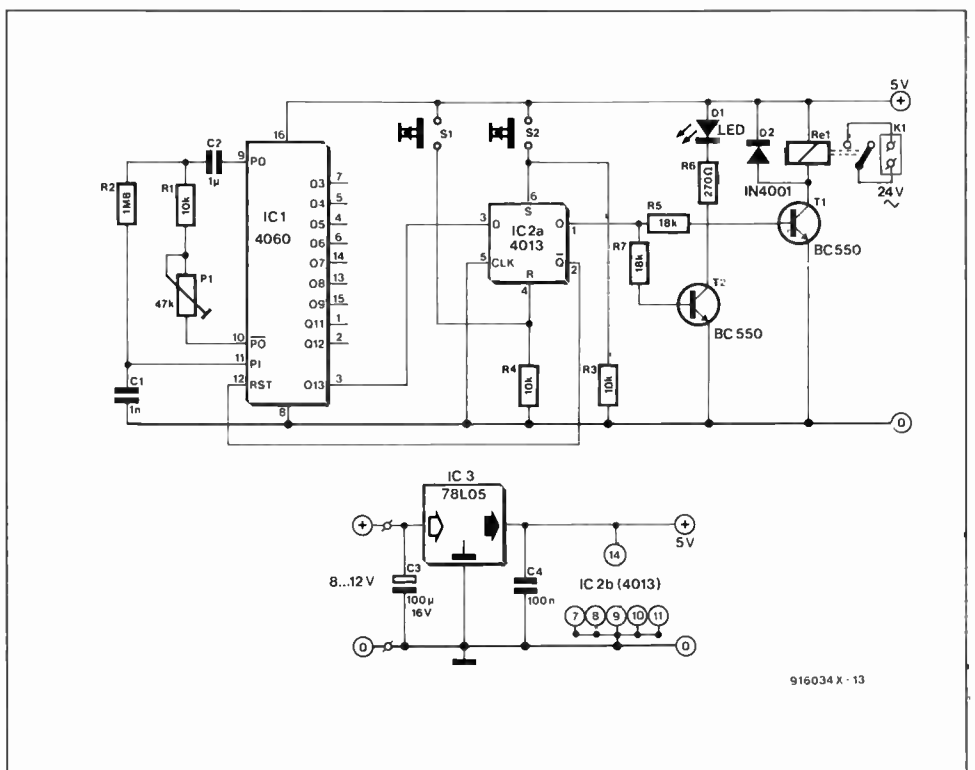
Fig. 1. Circuit diagram of the central heating timer.
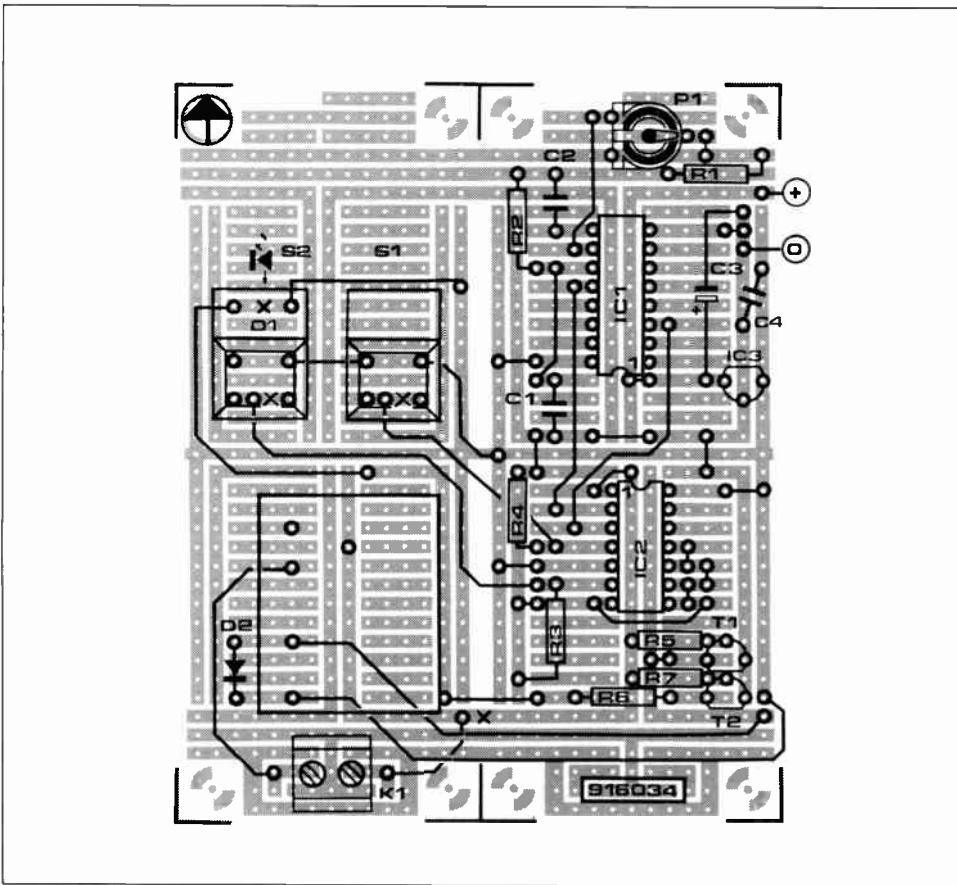
Fig. 2.   Component mounting plan on board UPBS-2.

COMPONENTS LIST

Resistors:

3	10kΩ	R1;R3;R4
1	1MΩ8	R2
2	18kΩ	R5;R7
1	270Ω	R6
1	50kΩ preset H	P1

Capacitors:

1	1nF	C1
1	1µF solid MKT	C2
1	100µF 16V axial	C3
1	100nF	C4

Semiconductors:

1	4060	IC1
1	4013	IC2
1	78L05	IC3
2	BC550	T1;T2
1	LED	D1
1	1N4148	D2

Miscellaneous:

1	V23127-A0001-A101 (Siemens) or similar 5-V PCB-mount relay	Re1
1	push-button with LED hole	S1
1	push-button	S2
1	2-way terminal block	K1
1	printed circuit board	UPBS-2

which is connected here to a resistor-capacitor network, R1-P1-R2-C1-C2. These components, connected to the PO (phase out), PO (phase out inverted) and PI (phase in) pins of the 4060 determine the oscillator frequency. Preset P1 gives the oscillator a frequency range of about 6 Hz to 27 Hz. The Q13 output of the 4060 goes high after 2^{13} (8,192) oscillator clock pulses, that is, after 5 to 20 minutes depending on the setting of P1.

The ripple counter in the 4060 operates only if the reset input of the IC is held logic low, which is the case when bistable IC2a is set. This happens when push-button S2 is pressed. When the Q13 output of the counter goes high, the logic level at the data (D) input of the bistable is clocked ('latched'). Since the D input is permanently connected to ground, a logic low is clocked, which has the same effect as resetting the bistable (note that resetting is also possible by pressing push-button S2).

The resetting of the bistable halts the counter. This happens either when the preset time has lapsed, or when the user presses S2 while the timer is still counting down. If the Q output of the bistable is high (i.e., when the counter is active), transistors T1 and T2 are switched on via R5 and R7 respectively. T1 in turn switches on a relay whose contacts are connected in parallel with the room thermostat contacts. The closed contact causes the CH boiler (and pump) to be switched on. At the same time, T2 turns on a LED that indicates the activity of the CH timer.

The timer has an internal 5-V supply based on a 100-mA 5-V regulator Type 78L05. The direct input voltage of between 8 V and 12 V may be supplied by a mains adaptor.

Construction and connection

The CH timer is built on a universal prototyping board size-2 (UPBS-2), which may be obtained through our Readers Services. A suggested component mounting plan is shown in Fig. 2. The two ICs are best fitted in sockets. Do not forget any of the wire links, and observe the polarity of the diodes and the electrolytic capacitors. Make sure connector K1 is soldered securely to the board to prevent it coming loose when the connecting wires cause strain. If you want a front panel control instead of the preset on the board, simply replace P1 by a 47-kΩ linear potentiometer. A simple timing scale may be provided around the pot by measuring the on-time of the relay at a few settings. Finally, the timer is connected to the CH system wiring as shown in Fig. 3
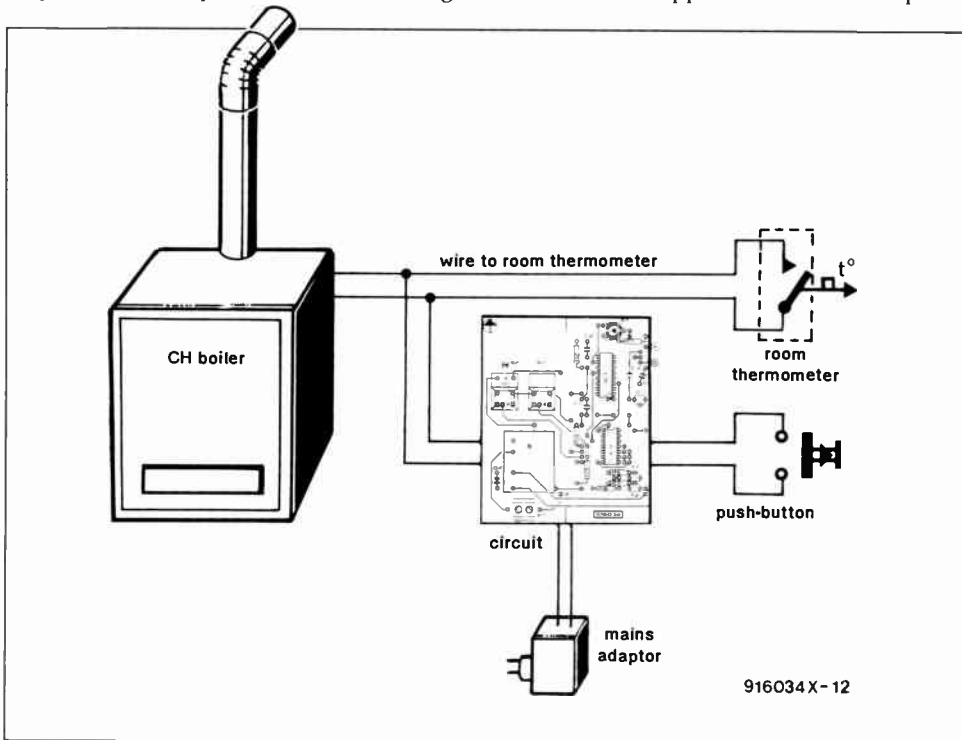
Fig. 3.   Connection of the unit to the CH wiring.

RELAY CARD FOR UNIVERSAL I/O INTERFACE
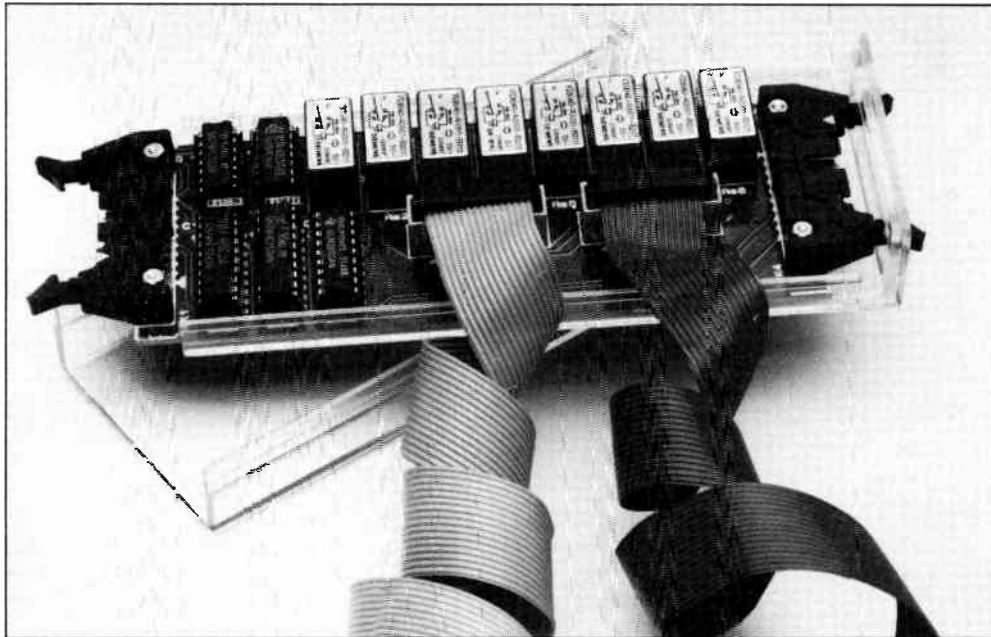
This relay card connects to the universal I/0 interface for IBM PCs described in the May 1991 issue. Simple to build and program, it offers a safe and easy way of controlling all sorts of equipment by means of a PC.

by A. Rigby

ALTHOUGH the relay card described here is designed specifically as an extension for the PC I/O interface (Ref. 1), its input control signals are readily found, or made, in non-IBM (PC) computers.

The circuit diagram of the relay card, Fig. 1, shows that it is linked to the I/O card via connector K1. It is also seen that the I/O card signals are buffered and fed to connector K4, which allows up to four extension circuits to be connected in series. Only two signals 'change' between K1 and K4: address lines A0 and A1 are interchanged on K4 (with respect to K1), and A0 is inverted. This allows all extension cards connected to the PC I/O interface to make use of a single, simple, address decoder. All cards connected in this way respond internally to address 00 (binary), but the successive interchanging of A0 and A1 causes their actual address to be determined by the order in which they are connected. Table 1 shows the address assignments.

More relays than ICs

The data flow between the PC I/O card and the relay extension is controlled by a bidirectional buffer, IC2. Although a unidirectional buffer would have been in order for the relay card (which functions as a write-only exten-

sion), bidirectional buffering is applied because two-way data flow may be required by other cards in the system.

The actual relay interface starts at register IC4, which is used to latch data when the relay card is addressed. The addressing is accomplished via the ENABLE and WR lines. When both are low, the output of IC1b is low also. To ensure that the data are stable at the input of the register, they are latched when the output of IC1b reverts to logic high. The logic pattern stored in IC4 is fed to driver IC5, which controls the relay coils. The relays are actuated by a logic high data bit written to IC4, so data inverting is not required.

The relay contacts are brought out to pins on connectors K2 and K3. Connector K2 carries the mother contacts and the normally open (NO) contacts of the relays, and K3 the mother contacts and the normally closed (NC) contacts.

Table 1. Address overview

Address	Relay card
base address + 0	1
base address + 1	2
base address + 2	3
base address + 3	4

Table 2. Relay specifications

Siemens V23040-A0001-B201
Contact specifications

Max. switching voltage:	150 V d.c.
	125 V a.c.
Max. switching current:	2 A
Max. continuous current:	2 A
Max. switching power:	35 W d.c.
	60 W a.c.
Max. switching frequency:	100 Hz
Mechanical lifetime:	10^8 s.o.
Mechanical lifetime with contacts loaded:	$10^3 - 10^8$ s.o.

s.o. = switching operations

Building and testing

The relay extension is built on a double-sided, through-plated printed circuit board, of which the track layouts and the component overlay are given in Fig. 2. The construction is mostly straightforward soldering work. The completed card is connected to the PC I/O interface via a 20-way flatcable with IDC connectors at both ends.
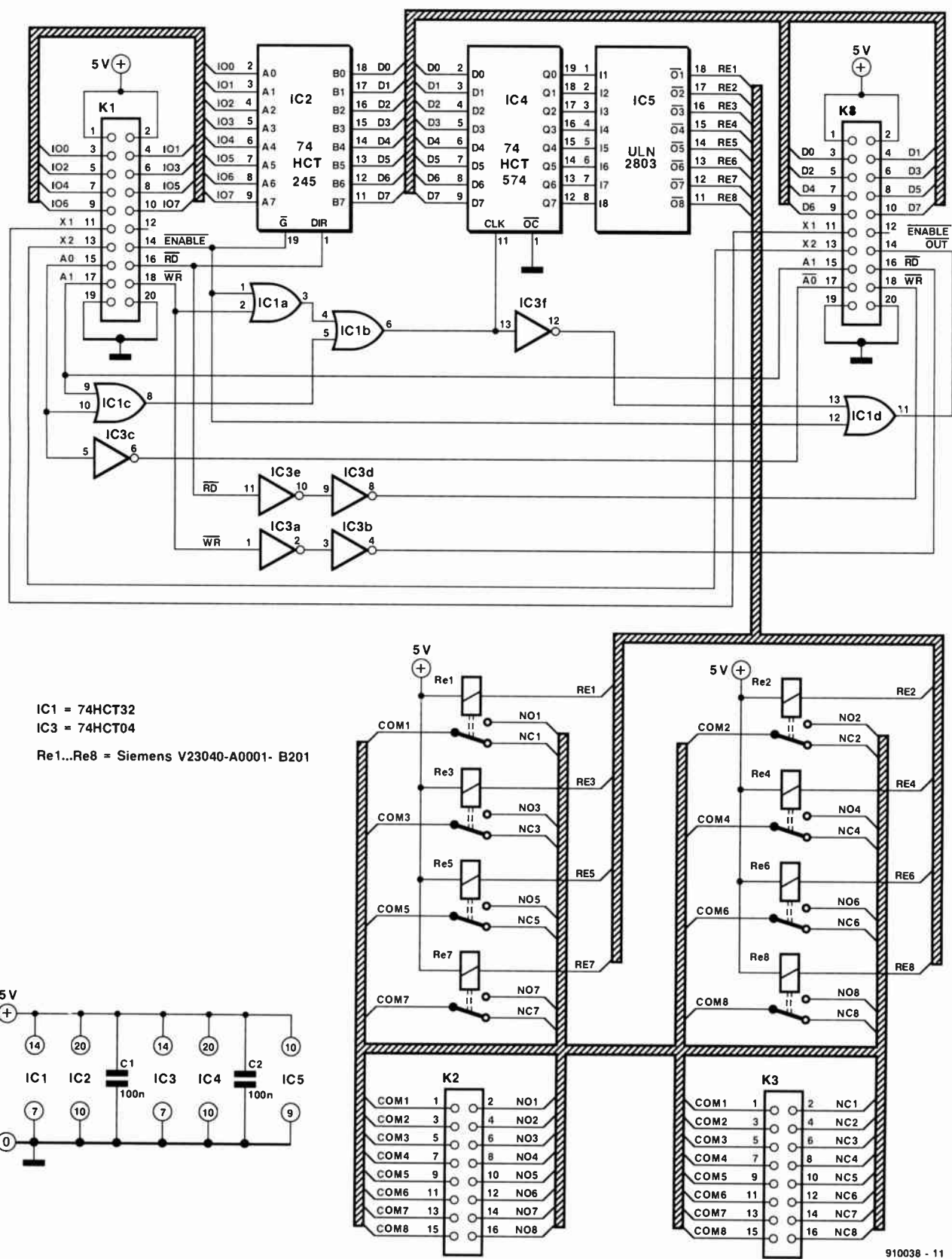
Fig. 1. Circuit diagram of the relay extension. Up to four of these circuits may be connected in series and controlled by a PC.

The current consumption of the relay card is determined by the number of actuated relays. When all relays are actuated, the current consumption is a little below 150 mA.

The switching functions of the relay card may be tested with the aid of the program listed in Fig. 3. When run, this program causes the relays to be actuated and deactuated in succession. The program may be used to test up to four relay cards connected in series.

Because of the track layout of the printed circuit board, the maximum voltage that may be switched by the relays is 42 V a.c. or 60 V d.c. This means that the relay card may not be used to switch mains loads directly.■

Reference:

1. Universal I/O card for IBM PCs. *Elektor Electronics* May 1991.
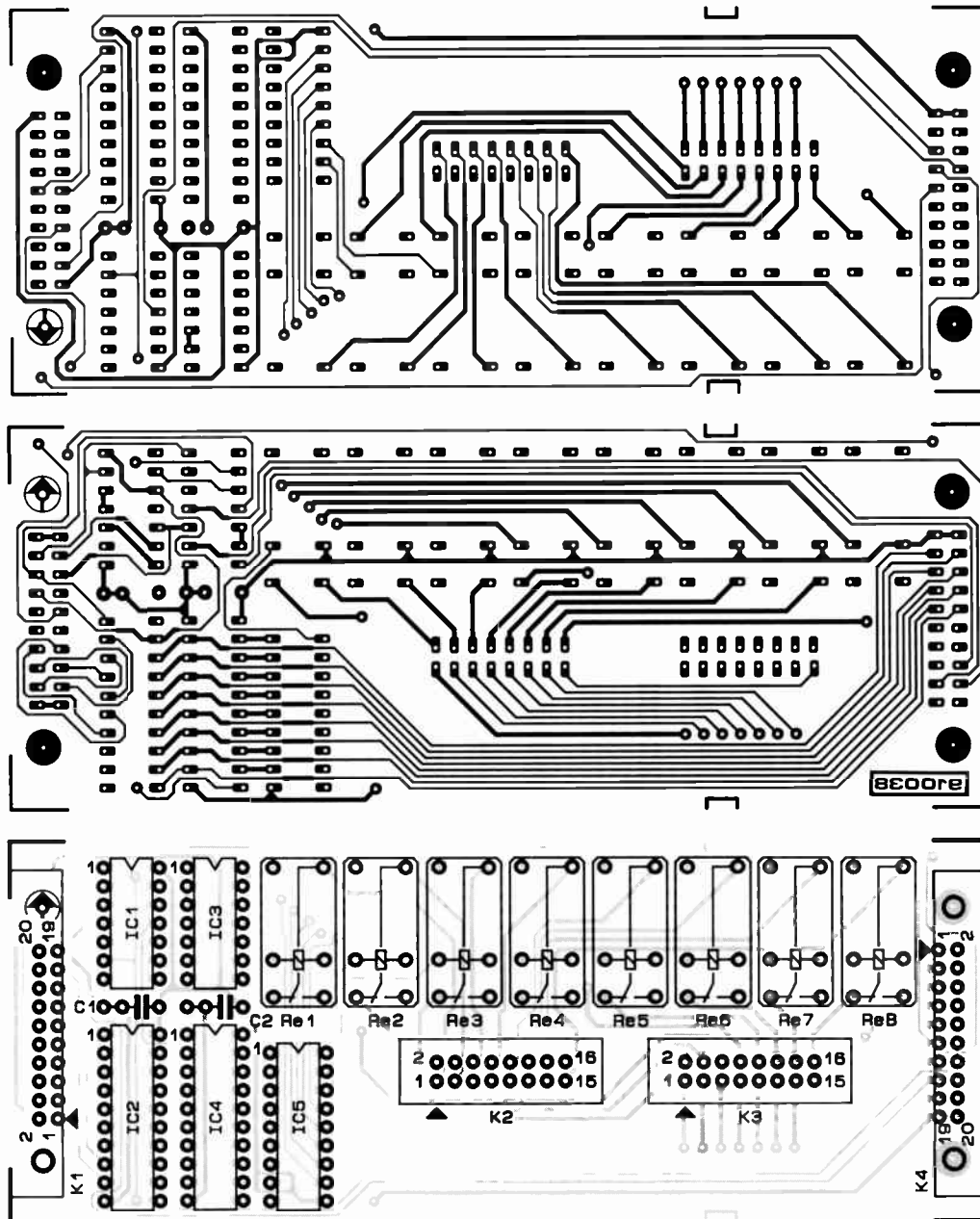
Fig. 2.   Printed-circuit board for the relay card. Note that this board is double-sided and through-plated.

```
10 CLS
20 ' .................................................... ibmio interface test
30 X=0 ' ................................................ address definition
40 ' .......... X=0: &H300-&H303 X=1: &H304-307 X=2: &H308-&H30B X=3: &H30C-30F
50 ' .......... X=4: &H310-&H313 X=5: &H314-317 X=6: &H318-&H31B X=7: &H31C-31F
60 X=&H300+X*&H4
70 ' ...............................................................addresses
80 A1=X+0: A2=X+1: A3=X+3: A4=X+2: ' ........................... I/O addresses
90 ' ...............................A1 - A4 = relay card 1  to  relay card 4
100 ' ............................................... test of I/O ports
110 CLS
120 PRINT "Testing I/O"
130 FOR I=0 TO 7
140 OUT A1,2^I ' ............................ close relay number i of card 1
150 OUT A2,2^I ' ............................ close relay number i of card 2
160 OUT A3,2^I ' ............................ close relay number i of card 3
170 OUT A4,2^I ' ............................ close relay number i of card 4
180 GOSUB 280 ' ........................................... wait
190 NEXT I
200 FOR I=0 TO 7
210 OUT A1,255-2^I ' ........................ open relay number i of card 1
220 OUT A2,255-2^I ' ........................ open relay number i of card 1
230 OUT A3,255-2^I ' ........................ open relay number i of card 1
240 OUT A4,255-2^I ' ........................ open relay number i of card 1
250 GOSUB 280 '  ........................................... wait
260 NEXT I
270 GOTO 130 ' ................................... return for next cycle
280 ' ............................... subroutine to execute a wait period
290 FOR J=0 TO 1000:NEXT
300 RETURN
```

Fig. 3.   Run this little BASIC program to test one to four relay cards.

COMPONENTS LIST

Capacitors:

2	100nF	C1;C2

Semiconductors:

1	74HCT32	IC1
1	74HCT245	IC2
1	74HCT04	IC3
1	74HCT574	IC4
1	ULN2803	IC5

Miscellaneous:

2	20-way pin header with side latches	K1;K4
2	16-way pin header	K2;K3
8	PCB mount relay V23040-A0001-B201 (Siemens)	Re1-Re8
1	enclosure (e.g., Heddic 222)	
1	Printed circuit board	910038

EXPERIMENTAL QUADRIFORM FERRITE TRANSMIT/RECEIVE ANTENNA

by Richard Q. Marris, G2BZQ

The quadriform is an experimental 3.5 MHz transmit/receive antenna of mini dimensions, consisting of four high-grade robust ferrite rods in a 9 in × 9 in (230×230 mm) loop configuration. Chambers 20th Century Dictionary defines quadriform as "fourfold; having four forms or aspects".

A = 9" (230 mm)

5 ft (1.5 m) RG58 cable

Skt1
Skt2
C1
Skt3

910146-12
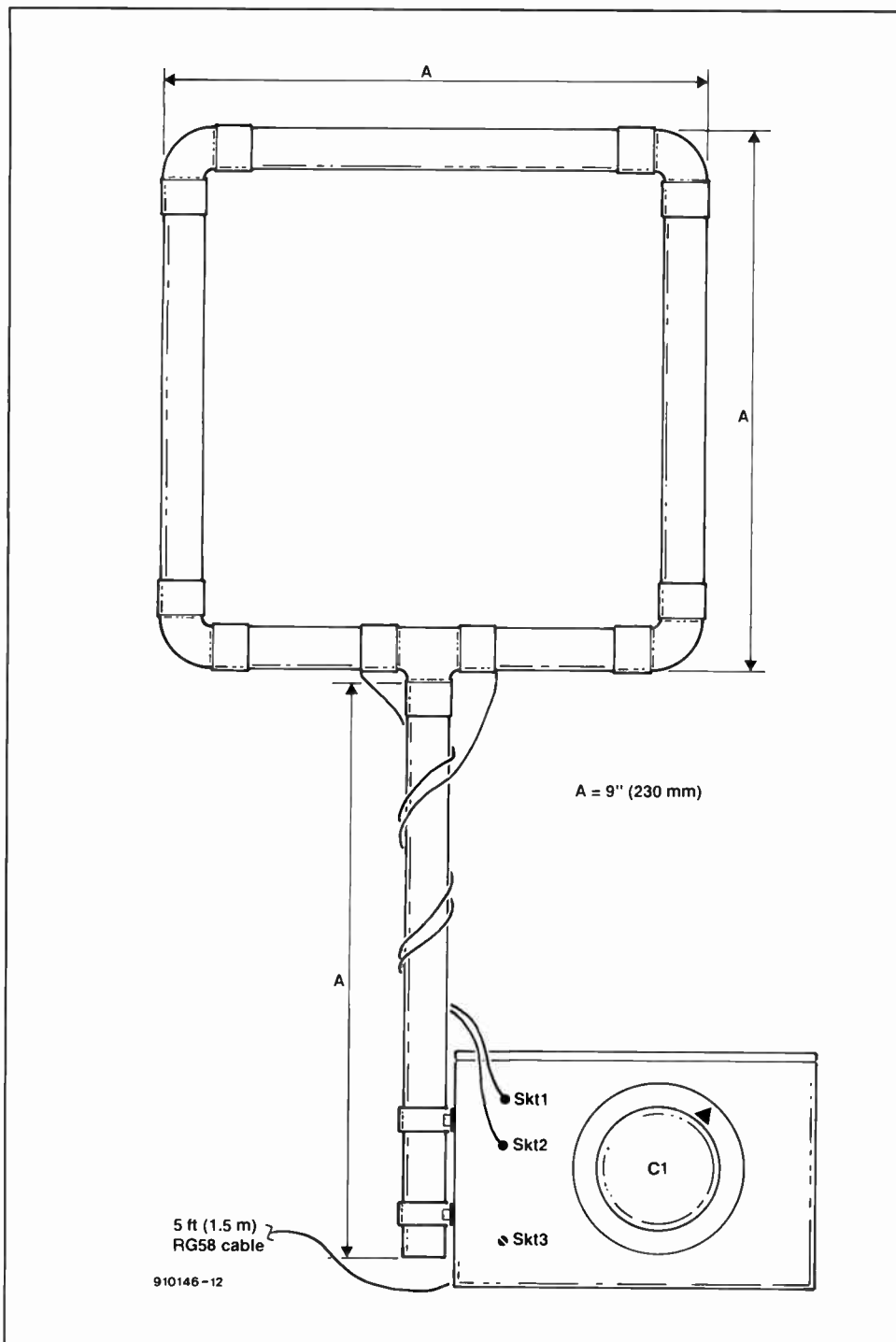
Fig. 1. Assembly of the quadriform ferrite transmit/receive antenna.

WHEN, a decade or so after the end of World War II, the transistor and ferrite rod antenna made their entry on the market, they quite revolutionized the domestic LW/MW radio scene with the arrival of small portable receivers with built-in aerials. One might have expected that ferrite antennas would also be used extensively for transmission, but this was not to be for various reasons. Obviously, however, experiments were taking place, especially in the American defence industry, but little or nothing has been published on the subject.

Nowadays, ferrite rod materials can be divided broadly into manganese-zinc mixtures and nickel-zinc mixtures. The former are used invariably for VLF and LF receiving applications between 1 kHz and 1 MHz, and there are several different mixtures. Nickel-zinc rods, again in several mixtures, have appeared with permeabilities between 40 and 850. In the latter types, apart from their use in domestic LW/MW radios, it has become possible over the years to obtain rods that can be used as HF band receiving antennas. An excellent booklet [1] is available from Amidon Associates (USA), which gives the full characteristics and sizes of many types of manganese-zinc and nickel-zinc rod. It may well enlighten the reader as regards ferrite rods for reception, but the contents are not geared to use of the rods for transmission.

Of particular interest are the Amidon Type 61 nickel-zinc rods, which are quoted as being suitable for use in receiving antennas for frequencies of 0.2–15 MHz. However, I have used these rods experimentally for reception in the VHF bands with acceptable results. I have also made several experimental single rod transmitting antennas from Type 61 ferrite material which gave widely varying results. A brief report on a small part of earlier experiments was published in Ref. 2. For convenience, all ferrite transmitting antennas used in my 'on the air' experiments have been designed for the 3.5 MHz (80 metres) amateur band.

Some of the problems that revealed themselves as the experiments progressed during the design of ferrite rod transmit antennas are listed here.

1. The difficulty of locating small supplies of suffciently large and robust rods suitable for high frequencies and, most importantly, for transmission.
2. How to couple the transmitter to the ferrite antenna: to feed RF power into the antenna? And then how to persuade the antenna to radiate that power over satisfactory distances to other stations?
3. Solving the serious problem of saturation of the core. As power into such an antenna is increased, a point is reached quickly where core saturation occurs. This saturation manifests itself by the heating up of the core, which appears to produce the following effects:

    (a) de-resonating the antenna from the selected frequency;

    (b) harmonics that cause intereference and TVI;

    (c) general instability, similar to (b).

It must be stressed that these findings are based entirely on the results of my own experiments.

Assuming that these problems can be solved, a tremendous advantage appears in that we have a tiny antenna—only a few inches long— compared with a traditional wire antenna: on 3.5 MHz, a wire dipole is about 140 ft (almost 43 metres) long!

It has been discovered that the main difficulty is that of core saturation, even when a suitable rod for h.f. transmission has been found. Experiments have shown, however, that this problem can be overcome to a large extent by leaving a large gap between the ferrite rod and the wire turns and distributing the turns over the entire length of the rod. From these findings, it was decided to try to produce a realistic unidirectional ferrite transmitting antenna with reasonable gain. The result is the Quadriform Ferrite Antenna.

Description

From Fig. 2, it is seen that the antenna consists of a 9×9 in. (230×230 mm) loop with small inductances, L_1–L_5, in each side. The wire sides are formed around a 7.5×0.5 in. dia. (190×12.5 mm) high-grade nickel-zinc (Type 61 material) rod enclosed in a plastic tube as shown in Fig. 3. It is fed at the bottom, between L_4 and L_5, with leads to plugs Pl_1 and Pl_2 that mate with appropriate sockets, Skt_1 and Skt_2.

The loop is resonated by a 100 pF ceramic, insulated, variable capacitor, C_1. The feed to and from the transmitter/receiver is a Type RG58 coaxial line via C_2 (a 150 pF ceramic, high-voltage disc type). Capacitors C_2 and C_3 form the actual coupling and impedance matching element to match the loop to a 50 Ω impedance. Socket Skt_3 is an optional earthing connection. The antenna is unidirectional.

The general layout is shown in Fig. 1. The loop is supported vertically by a 9 in (230 mm) long piece of plastic tube fastened with wall clips to the front vertical edge of the side of a 6×4×4 in (150×100×100 mm)aluminium box that houses the variable capacitor and some other components. The box is large and heavy
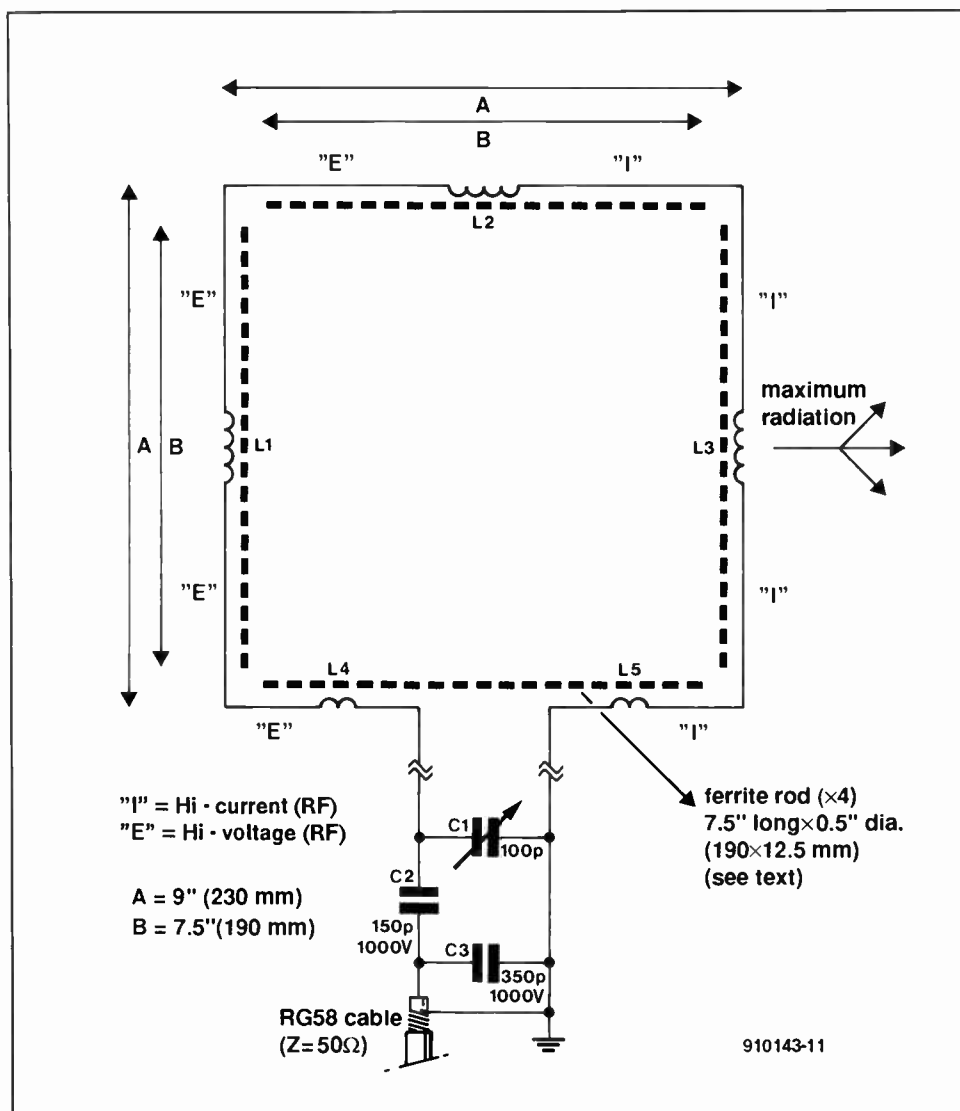
Fig. 2. Circuit diagram of the quadriform antenna.

enough to act as a base that stops the loop tilting. Sockets Skt_1–Skt_3, together with C_1, are mounted on the front panel; the RG58 cable exits through a grommet at the rear. The box is a two-piece interlocking double 'U'; the loop is clipped to the removable lid.

Care is needed in winding the inductors. First, cut three 7.5 in (190 mm) lengths of the $^{11}/_{16}$ in (17.5 mm) dia. tubing and two pieces of about 2.5 in (63 mm). The two shorter lengths, when fastened together with a standard T junction, form the bottom side that should also be 7.5 in long. The 9×9 in square is completed with four standard 90° plastic elbows. All plastic tubing and junctions are readily obtainable from most DIY stores (in the UK under the name POLY-YORC). A 7.5 in (190 mm) long,0.5 in (12.5 mm) dia., ferrite rod is inserted into each side before the corner elbows and T junction are fitted. It is necessary to wind a couple of turns of masking tape round the ends of each rod to ensure rigidity in the tube—see Fig. 3. The loop windings are made from PVC covered, single-strand, 1/0.6 mm wire, 1.2 mm o.d., rated at 1 kV, 1.8 A. They are wound as shown in Fig. 3. The wire linking inductors L_1 and L_5 is taped close along the outside of each of the tubes; over the 90° elbows it is held in place by a small 'V' filed in the outside radius of each elbow.

Black tubing, black PVC wire and black PVC tapes were used throughout.

The whole wire length, including the small coils, forms part of the ferrite-cored loop. Inductors L_1–L_5 are close wound, clockwise throughout.

Variable capacitor C_1 is mounted at dead centre of the front panel of the base box and it and the other few components are hard wired. A 9 in (230 mm) length of tube is inserted into the T junction of the finished loop; the bottom end of this is clipped to the front edge of the side of the lid of the box with two standard plastic wall clips—see Fig. 2.

CAUTION! It is essential that the specified ferrite rods are used—see parts list. They should be treated with great care. J ' they are dropped on to a hard surface, they may break, chip or suffer from core destabilization. They are expensive! At the time of writing, they cost $15.00 (about £8.50) each plus $8.00 for airmail shipping direct from Amidon. Delivery is by return mail and is usually within three weeks from airmailing the order to Amidon. Master Card and Visa are accepted.

Testing, operation and results

Initial testing of the antenna is carried out with a receiver tuned to 3600 kHz. Capacitor C_1 is

pad rod ends with masking tape

7.5" x 0.5" dia ferrite rod

90° plastic elbow
(each corner)

tape wire on outer edge

file small "V"
to hold wire
(each corner)

4 turns

4 turns

4 turns

2 turns

"T" piece

2 turns

910143-13

Fig. 3. Assembly details.

'on the air' with very satisfactory results. There was no detectable harmonic or TVI radiated. The use of an RF earth connection made no apparent difference.

> ### WARNING!
> IN THE INTERESTS OF DOMESTIC SAFETY, THE TRANSMITTER OUTPUT SHOULD NOT EXCEED 10 WATTS.

References
Iron-powder and Ferrite Coil Forms, published by Amidon Associates, P.O. Box 956, Torrance, California 90508, USA.

"Fe-ONE Experimental Transmitting Antenna" by Richard Q. Marris, *Practical Wireless*, January 1989.

PARTS LIST
- 4   nickel-zinc rods, 7.5 in. long by 0.5 in. dia. (190 x 12.5 mm), available from Amidon Associates Inc. P.O. Box 956, Torrance, Ca. 90508, USA; Tel. + 1 213 763 5770; Fax + 1 213 763 2250.
- 1   aluminum box 6 x 4 x 4 in. (153 x 102 x 102 mm) order code Box/J10 from Marco Trading.
- 1   variable capacitor, 100 pF, Jackson Bros Type 11 or equivalent style and quality plus knob to suit.
- 1   ceramic disc capacitor, 150 pF, ≥ 1 kV.
- 1   ceramic disc capacitor, 350 pF, ≥ 1 kV.
- 2   4 mm banana plugs
- 3   4 mm banana sockets
- 1 m   Poly-Yorc (or similar) black tubing, o.d. 0.7 in. (18 mm), i.d. 0.6 in. (13 mm); available from many DIY stores.
- 4   90° elbows to match the black tubing.
- 1   T junction to match the black tubing.
- 2   wall clips for fitting the black tubing.
- 5 ft   RG58 coaxial feed line; $Z = 50$ Ω, plus coaxial plug to suit transmitter/receiver. PVC covered, single strand 1/0.6 mm wire (black), 1.2 mm o.d., rated at 1 kV and 1.8 A. Order code CBL/EW1/black from Marco Trading.
  Black PVC tape and masking tape as required.

rotated for resonance, which is indicated by an increase in signal strength. The plates of the capacitor should then be enmeshed about 50%. The 3500–3800 (or 4000) kHz band is accommodated without any problem.

The polar diagram of a single horizontal ferrite rod antenna is a figure 8 off the two long sides. The polar diagram of the Quadriform is rather more complex and not easy to establish indoors, possibly owing to reflections off walls, and so on. However, it is, to all intents and purposes, unidirectional with one very large lobe off one end, which reduces interference appreciably. This lobe can be moved through 180° by reversing Pl_1 and Pl_2 in sockets Skt_1 and Skt_2, which is a simple way of achieving all-round operation. If necessary, further small adjustments can be made by a small rotation of the antenna. This radiation pattern holds good on transmit and receive.

Before the antenna can be tested for transmission, it is necessary to first set up the transmitter into a 50 Ω dummy load at the desired frequency. The antenna is then resonated with the receiver, at the same frequency, and subsequently substituted for the dummy load. It should be fully loaded by the transmitter on low power, after possible minor adjustments of C_1. The usual bandwidth on transmit, without readjusting C_1, is about 25 kHz.

The antenna is essentially a low-power device. In my experiments, it has been driven by over 20 watts RF without detectable core saturation. However, it is intended for use indoors near the transmitter/receiver, where a transmitter power of <10 watts has been used

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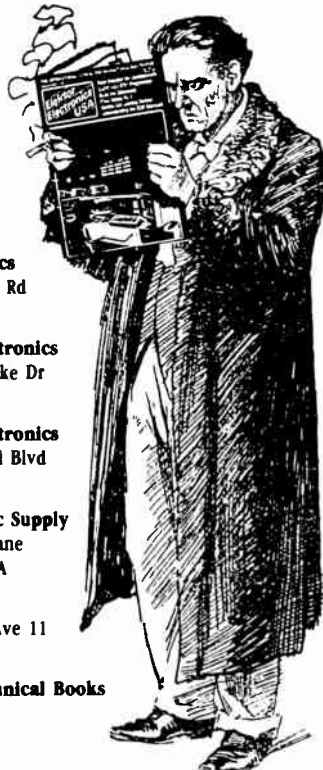
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The final part of the book deals with a number of computer chips, such as memory devices (including programming information for these) and I/O circuits. This section also includes data on a number of non-digital discrete and integrated devices, such as op amps, as well as on some microprocessor peripherals (e.g., the 6522 VIA, the 6580 ACIA, and the 8355A PPI).
ISBN 0-905705-27-0
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DATABOOK 3: PERIPHERAL CHIPS
This book lists the most important design data of peripheral chips whose type numbers and functions relate them unambiguously to a microprocessor in the same family. All listed devices form part of families based on widely used microprocessors or microcontrollers. Their most evident application will therefore be in conjunction with the associated microprocessor. This should, however, not be taken to mean that a peripheral cannot be used in another ap-

plication. Far from it, as witness the familiar type MC146818A real-time clock and the type MC6845 cathode-ray tube controller. It deserves a place on the bookshelf of anyone concerned with the design, maintenance and servicing of microprocessor-controlled electronic equipment.
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BKAA15   Price $17.95

MICROPROCESSOR DATA BOOK
This book has come about because of a need by *Elektor Electronics* engineers, technicians, and editorial staff of a ready reference work on the most important microprocessors. This implies that it does not only contain information on the latest devices, such as the transputer, but also on older, well-established types, such as the Z80 and the 6800.

A general description, hardware block schematic, software structure, DC characteristics, and instruction sets are given for over 70 microprocessors. To prevent the book from becoming unwieldy (and to keep costs down), timing diagrams and AC characteristics have, however, been omitted. The detailed information on all manufacturers mentioned will, however, enable any additional information to be obtained quite readily.

Included in the book are, among others, the 68000 series; the 6502 family; the Z80, 8080, and 8085; Intel's 8086, 80186, 80188, 80286, and 80386; the NS32XXX series, and the INMOS transputers.
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This final volume in *Elektor Electronics'* *Microprocessor Data Book* series deals with general peripheral chips that, at least as far as their type-coding is concerned, do not belong to a specific family of microprocessors. There are so many of these, however, that only a portion of them can be dealt with in one book. Those contained in this collection have been chosen carefully on the basis of their practical application and frequency of use. Complete data are given for coprocessors from the 80 series (AMD, Cyrix, ITT, Intel, Weitek); real-time clocks from MEM, OKI, Statek, National Semiconductor, and Dallas Semiconductor; transmitters and receivers of serial interfaces RS232, 422, 423, 485 from Motorola, Newport Components, Maxim, Texas Instruments, National Semiconductor, Dallas Semiconductor, and Linear Technology; UARTS, DUARTS, and QUARTS (i.e., programmable ICs intended for data transfer); and the CS8221 set of ICs from Chips & Technology that are used in a great number of PC mother boards (also included is the data sheet of associated software LIM 4.0 for the management of the Extended Memory System).

Apart from the actual data, the book contains much other useful information, such as comparisons between and second sources for all important IC families; addresses of manufacturers and their representatives; and overviews of all peripheral chips (including many that could not be included in this book) that are available from various manufacturers.
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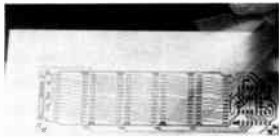**BKAAZ/1** BKAA11, 12, 13: all 3 for **$35** (Save $5.95!)
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