

Elektor Electronics USA

A Radar Detector

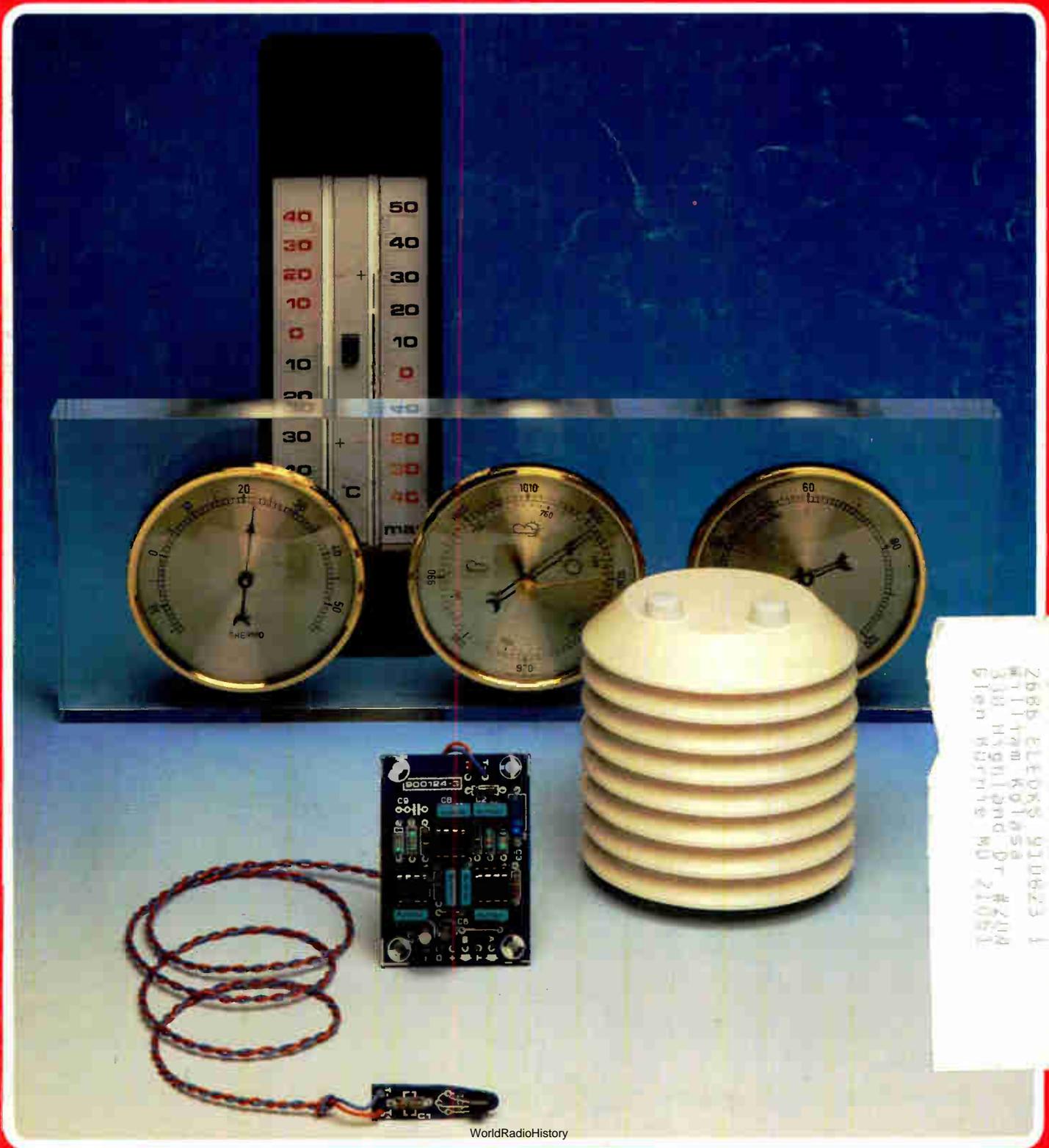
A Computer-Controlled Weather Station

An 8-Channel Audio/Video Switch

A PC-Controlled Semiconductor Tester

A 2-Meter Band Converter

PC-EGAP Software Review



2688 ELEKOR 910623 1
Wit Tam Kolasas
300 Highland Dr #214
Glen Burnie MD 21061

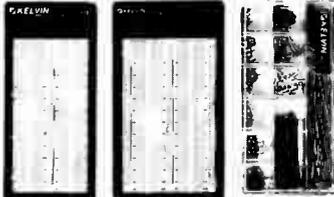
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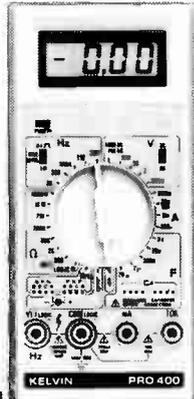
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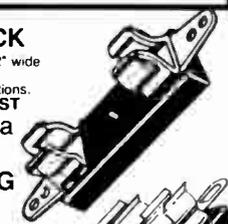
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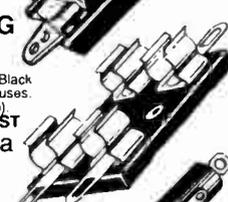
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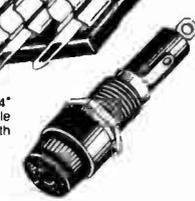
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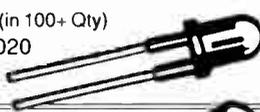
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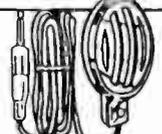
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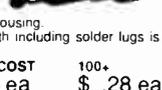
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CONTENTS

March 1991
Volume 1
Number 6

In our next issue:

- Microphone amplifier
- P-U converter
- MIDI programme changer
- Dimmer for halogen lights
- PC-controlled semiconductor tester – Part 2
- Video D-A and A-D
- 8-bit I/O interface for Atari ST
- Computer-controlled weather station – Part 2

Front cover

This month we start a short series of articles describing applications of the multifunction measurement card for PCs published in our January and February 1991 issues. The articles should appeal to many since they describe interfaces for turning an IBM PC or compatible into an independent weather station for the amateur meteorologist. The complete station will be able to measure temperature, relative humidity, air pressure, wind direction and wind speed.

EDITORIAL

11 One Small Step for Electronics

AUDIO & HI-FI

- 18 **PROJECT:** The Complete Preamplifier Pt. 2 by T. Giffard
- 48 **PROJECT:** Headphone Amplifier from an idea by U. Habschied

DESIGN IDEAS

28 8-Channel Audio/Video Switch (Philips Components) by J. Vinckier

ELECTROPHONICS

35 MIDI-to-CV Interface—Some Additional Notes

GENERAL INTEREST

- 14 **PROJECT:** Computer-Controlled Weather Station Pt. 1 by J. Ruffell
- 31 **PROJECT:** Electronic Exposure Timer by A. Ladwig
- 51 **PROJECT:** Central-Heating Controller Pt. 2 by K. Browne
- 61 **REVIEW:** PC-ECAP Circuit Simulator by Jan Didden

INTERMEDIATE PROJECT

37 2-Meter Band Converter by J. Bareford

RADIO, TELEVISION & COMMUNICATIONS

58 **PROJECT:** Radar Detector by M.R. Ebbell

TEST & MEASUREMENT

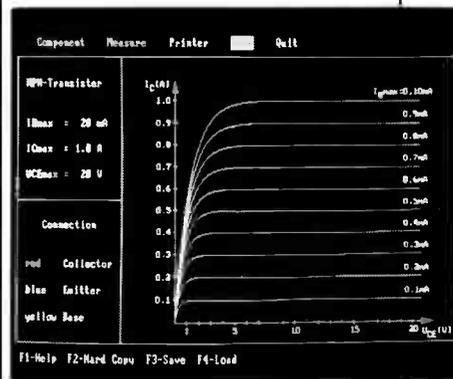
- 24 Measurement Techniques Pt. 5 by F.P. Zantis
- 42 **PROJECT:** PC-Controlled Semiconductor Tester Pt. 1 an ELV design

MISCELLANEOUS INFORMATION

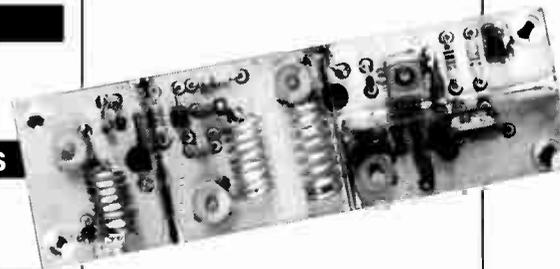
Electronics Scene 12, 13; Book Reviews 36; Advertisers' Index 64; Readers Services 65; Terms of Business 66.



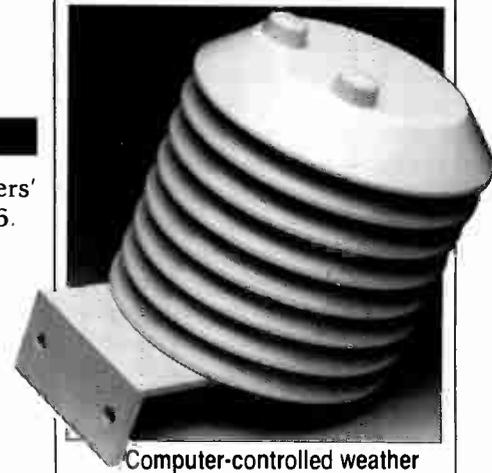
Headphone amplifier – p. 48



PC-controlled semiconductor tester – p. 42



2-metre band converter – p. 37



Computer-controlled weather station – p. 14

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BULLOCK ON BOXES

BY ROBERT M. BULLOCK III

with Robert White

Since 1980, readers of *Speaker Builder* magazine have delighted in the scope and clarity of Bob Bullock's explanations of vented-box loudspeaker systems. Now, for the first time, these articles have been collected into a single invaluable volume: *BULLOCK ON BOXES*.

This book is an easy-to-read guide to designing and building vented-box systems based on Thiele/Small models. And in addition to the background theory and descriptions of the models, *BULLOCK ON BOXES* carefully covers a host of related information drawn from numerous resources. Computer modeling, as demonstrated by the authors' BOXRESPONSE and BOXMODEL programs, is also explained in clear detail.

A professor of applied mathematics at Miami University (Ohio) since 1966 and long-time hands-on speaker buff, Dr. Bullock brings an unparalleled range of experience to the pages of *BULLOCK ON BOXES*. Fully indexed and referenced, with glossary, bibliography, and more than 100 illustrations, *BULLOCK ON BOXES* is a practical handbook and lasting reference indispensable to every serious speaker builder. Order yours today!

CHAPTERS:

- Thiele, Small, and Vented Loudspeaker Design
- Determining Design Parameters for Your Loudspeaker
- Fine Points of Vented Speaker Design
- Alternative Alignments (incl. Fourth Order)
- T/S Calculator Programs (TI-58/59, HP-67/97)
- BOXRESPONSE: An Apple Program for the Thiele/Small Models
- Realizing BOXRESPONSE's Potential
- BOXMODEL: An Aid to Woofer System Design
- Correspondence & Updates

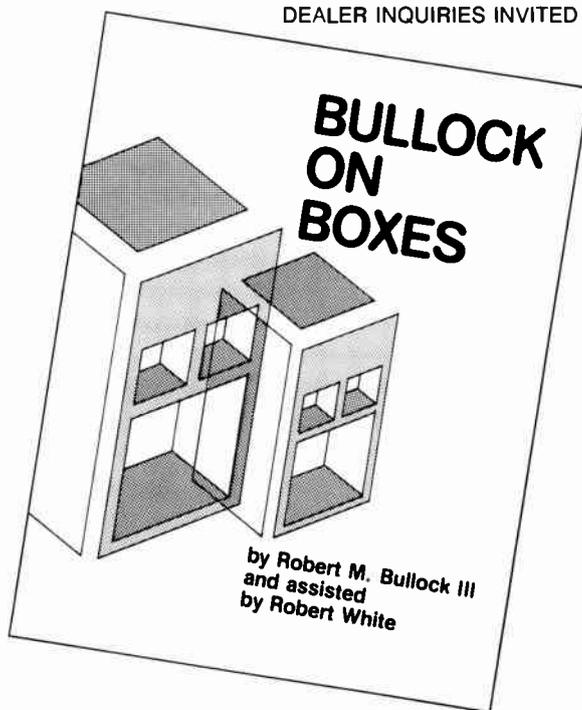
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[NOTE: In general, BOXRESPONSE automatically generates alignments for a given driver. BOXMODEL does not do this, but instead compares up to four given alignments simultaneously. Both programs display various performance aspects of passive-radiator or vented-box systems.]

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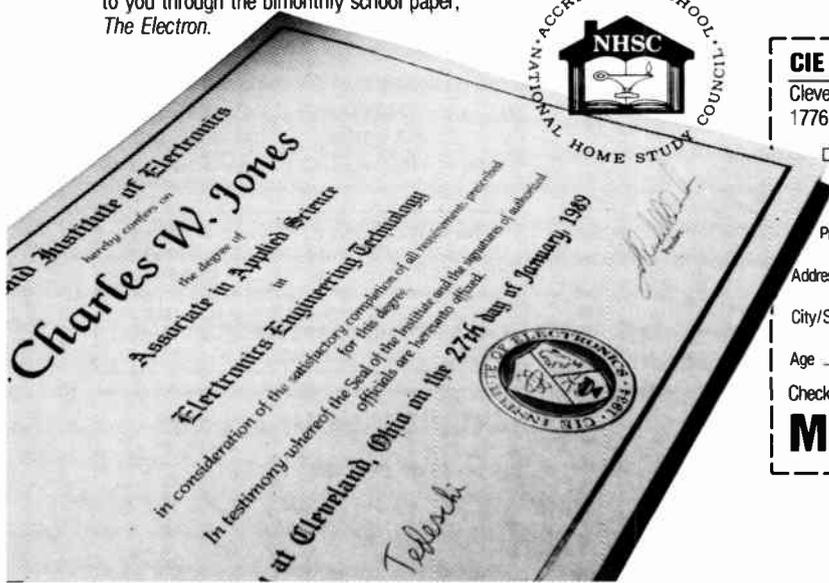
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Driver Evaluation and Crossover Design by **G. R. Koonce** (SB 5/88)

Disk 1 evaluates the suitability of drivers for closed, vented and passive radiator enclosures, and allows detailed designs of vented boxes.

Disk 2, in addition to driver evaluations, allows the design of first-, second-, and third-order crossovers. 5¼" IBM: 360K, DS/DD. Each **\$12.50**

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by **Fernando Garcia Viesca** (SB 4/88)

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IBM 5¼" 360K DS/DD **ACT-1B5**

Two-Way Active Crossover Design by **Gary Galo** (SB 5/88)

Performs the calculations for the eight two-way active crossover designs described by Bob Bullock using formulas exactly as given in the articles; plus a program to calculate V_{TH} . (Includes one year user support.) Each **\$20**

Specify:

IBM 5¼" 360K DS/DD **TWO-1B5**
IBM 3½" 720K DS/DD **TWO-1B3**

Stepped Volume Controls by **Joseph O'Connell** (TAA 4/88)

These ready-to-run Mac programs come on a 3½-inch 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. Program A. Precisely matches the resistor values to the measured or estimated source and load impedances, yielding great accuracy. Your volume control can have 3 to 99 positions. The program will ask you how many dB each step should be attenuated and has provisions for a standard audio taper or any other taper you devise. Program B. Calculates the taper that will result with your actual resistor values, because you are limited to standard values or with series and parallel combinations. 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 and include author support via mail. Each **\$25**

Apple Macintosh 3½" SS/DD **SVC-1M3**

BOXRESPONSE

Model-based performance data for either closed-box or vented-box loudspeakers with or without a first- or second-order electrical high pass filter as an active equalizer (SB 1/84). The program disk also contains seven additional programs as follows:

Air Core: This program was written as a quick way of evaluating the resistance effects of different gauge wire on a given value inductor. The basis for the program is an article in *Speaker Builder* (1/83, pp. 13-14) by Max Knittel. The program asks for the inductor value in millihenries (mH) and the gauge wire to be used. (NOTE: only gauges 16-38.)

Series Notch: Developed to study the effects of notch filters in the schematics of some manufacturers. Enter the components of the network in whole numbers (i.e., 10 for 10μF and 1.5 for 1.5mH) and indicate whether you want one or two octaves on either side of resonance. Output is frequency, phase angle and dB loss.

Stabilizer 1: Calculates the resistor-capacitor values needed to compensate for a known voice coil inductance and driver DC resistance.

Optimum Box: A quick program based on Thiele/Small to predict the proper vented box size, tuning and -3dB down point. It is based only on small signal parameters, therefore, it is only an estimate of the response at low power (i.e., limited excursion).

Response Function: Calculates the small signal response curve of a given box/driver combination after inputting the free-air resonance of the driver (f_s), the overall "Q" of the driver (Q_{TS}), the equivalent volume of air equal to the suspension (V_{AS}), the box tuning frequency (f_B), and the box volume (V_B). Output is the frequency and relative output at that frequency.

L-Pad Program by Glenn Phillips: Appeared in *Speaker Builder* (2/83, pp. 20-22). It is useful for padding down a tweeter or midrange while still retaining the same load as the driver itself.

Vent Computation by Glenn Phillips: Calculates the needed vent length for 1, 2 or 4 ports of the same diameter. Input box volume in cubic feet and required tuning frequency (f_B), output is vent length and vent area for each case.

Medium: 5¼" SS/DD Disk. Price, **\$25.**

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BOXRESPONSE

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IBM BOX-1B5

IBM Plus Graphics

BOXRESPONSE BOX-2B5G **\$50**

PASSIVE CROSSOVER

This disk is a result of Mr. Bullock's extensive research concerning first-, second-, third-, and fourth-order passive crossovers in *Speaker Builder* 1, 2 & 3/85; **\$25**

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Apple PAS-1A5
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CALSOD

Computer-Aided Loudspeaker System Optimization and Design by **Witold Waldman**

CALSOD is a new entry into the field of crossover network optimizing software available for the IBM PC desktop computer. It combines the transfer function of an LC network with the acoustic transfer function of the loudspeaker, by using some form of iterative analysis. CALSOD creates, through the process of trial-and-error curve fitting, a suitable transfer function model which it can then optimize. The program is the subject of CALSOD author Witold Waldman's research paper "Simulation and Optimization of Multiway Loudspeaker Systems Using a Personal Computer" which appeared in the *Audio Engineering Society Journal* for September 1988, pp. 651-663. CALSOD differs considerably from other software since it models the entire loudspeaker output of a multiway system, including the low-end response, and the summed responses of each system driver.

The program performs a lot of tricks. One of the more spectacular of these allows the designer to specify the location of the driver acoustic centers using an XYZ coordinate system. Thus, if the designer ex-

pects to mount a driver combination on a flat baffle, the summed response can be optimized to compensate for rearward displacement of a woofer's acoustic center with respect to a tweeter. CALSOD can model up to seven drivers at a time in a four-way system giving the summed response and acoustic phase response of the entire system.

The CALSOD program comes on a single 360K floppy, and requires one directory and two subdirectories in installation, plus access to the DOS GRAB-TABL file, which it uses for a couple of special symbols. The 133-page User Manual, provided on a second disk, is well written, adequately describes the various program functions, and contains an excellent tutorial example, which demonstrates the use of the program.

Specify:

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* Usable as credit toward later purchase of full CALSOD.

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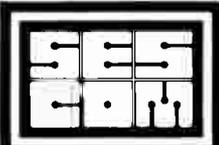
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| PD-13 | ROUND 1/4" | 6.00 |
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| PD-40 | ROUND 7/32" | 9.50 |
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| 2N3904 | NPN T092 | .12 | .10 | .08 |
| 2N3906 | PNP T092 | .12 | .10 | .08 |
| 2N2102 | PNP T039 | .80 | .67 | .54 |
| 2N4037 | PNP T039 | .90 | .75 | .60 |
| PN2219A | NPN T0237 | .40 | .34 | .28 |
| PN2905A | PNP T0237 | .40 | .34 | .28 |

DIODES:

| PART NO. | DESCRIPTION | 1-9 | 10-99 | 100 + |
|----------|-------------|-----|-------|-------|
| 1N34A | GE DIODE | .17 | .15 | .13 |
| 1N4001 | SI DIODE | .13 | .11 | .10 |
| 1N4148 | SI DIODE | .09 | .07 | .06 |

LINEAR INTEGRATED CIRCUITS:

| PART NO. | DESCRIPTION | 1-9 | 10-99 | 100 + |
|----------|-------------------------|------|-------|-------|
| LF351N | SINGLE OP-AMP | .60 | .54 | .48 |
| LF353N | DUAL OP-AMP | 1.05 | .95 | .84 |
| NE5534N | SINGLE OP-AMP | 1.28 | 1.15 | 1.02 |
| NE5534AN | LOW NOISE SINGLE OP-AMP | 1.80 | 1.62 | 1.44 |
| NE5532N | DUAL OP-AMP | 1.85 | 1.67 | 1.48 |

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| PART NO. | DESCRIPTION | 1-9 | 10-99 | 100 + |
|----------|-------------|-----|-------|-------|
| SOC-8 | 8 PIN TIN | .11 | .10 | .09 |
| SOC-14 | 14 PIN TIN | .12 | .11 | .10 |
| SOC-16 | 16 PIN TIN | .13 | .12 | .11 |
| SOC-18 | 18 PIN TIN | .15 | .14 | .13 |
| SOC-20 | 20 PIN TIN | .19 | .16 | .15 |

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| PART NO. | DESCRIPTION | 1-9 | 10-99 | 100 + |
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| XLR M CA | 3 PIN CABLE MALE | 2.75 | 2.48 | 2.20 |
| XLR F CH | 3 PIN CHASSIS FEMALE | 3.60 | 3.24 | 2.88 |
| XLR M CH | 3 PIN CHASSIS MALE | 2.60 | 2.40 | 2.08 |
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| 3.5 ST | 3.5mm STERIO JACK | .97 | .87 | .78 |
| RCA | RCA PHONO JACK CHASSIS | .65 | .59 | .52 |

CAPACITORS: Axial Lead Electrolytic

| PART NO. | DESCRIPTION | 1-9 | 10-99 | 100 + |
|------------|--------------|------|-------|-------|
| AC 1/50 | 1uf - 50V | .38 | .35 | .30 |
| AC 4/725 | 4.7uf - 25V | .39 | .35 | .30 |
| AC 10/25 | 10uf - 25V | .39 | .35 | .30 |
| AC 47/25 | 47uf - 25V | .46 | .42 | .37 |
| AC 100/25 | 100uf - 25V | .69 | .62 | .55 |
| AC 220/35 | 220uf - 35V | .97 | .87 | .78 |
| AC 470/35 | 470uf - 35V | 1.34 | 1.21 | 1.07 |
| AC 1000/35 | 1000uf - 35V | 2.22 | 2.00 | 1.78 |

CAPACITORS: Radial Lead Electrolytic

| PART NO. | DESCRIPTION | 1-9 | 10-99 | 100 + |
|------------|--------------|------|-------|-------|
| RC 1/50 | 1uf - 50V | .26 | .24 | .21 |
| RC 4.7/25 | 4.7uf - 25V | .28 | .26 | .23 |
| RC 10/25 | 10uf - 25V | .31 | .28 | .25 |
| RC 47/25 | 47uf - 25V | .39 | .35 | .28 |
| RC 100/25 | 100uf - 25V | .41 | .36 | .33 |
| RC 220/35 | 220uf - 35V | .61 | .55 | .49 |
| RC 470/35 | 470uf - 35V | .99 | .90 | .80 |
| RC 1000/35 | 1000uf - 35V | 1.27 | 1.15 | 1.02 |

ELEKTOR ELECTRONICS USA MARCH 1991

J. GORDON HOLT

If you had to invent a new language, where would you begin?

Back when high quality sound reproduction was a new idea and **J. Gordon Holt** was a staffer at *High Fidelity* magazine, manufacturers and journalists alike depended on the simple technical quality tests which everyone accepted as the yardsticks for performance. As the industry grew, equipment got better, competition fiercer, and technical reviewing became more crucial to sales managers. Before long, **J. Gordon** began to realize that reviewing was becoming more and more accommodating, and where the reviewers continued to rely on the standard tests, the measurement data began to look more and more alike.

Finally, in frustration, **Holt** left Great Barrington and headed for home in Pennsylvania where he founded *Stereophile* magazine in the spare room of his mother's house. He became convinced that although equipment tests and measurements were important, they no longer accounted for the differences he could hear. Two devices could easily measure the same and yet sound quite different.

Holt abhorred the tendency of the larger magazines to depend almost entirely on measurements, which he saw as a safe way to review without disturbing the manufacturer with any bad news. Not only that, he realized that not one of the US audio publications was publishing reviews that were critical of equipment. In fact, in some cases they were ignoring some flaws.

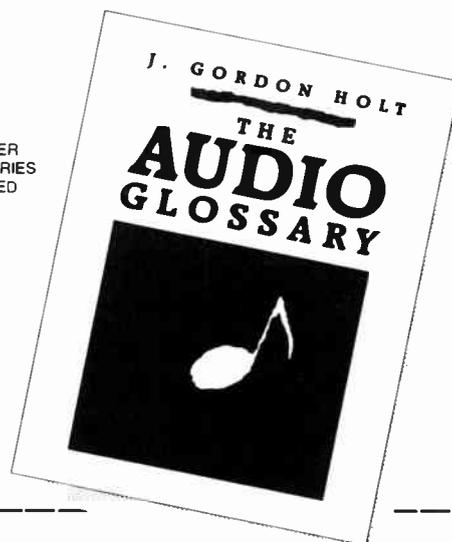
However, if the reviewer wishes to review how equipment sounds, he faces a severe problem. Our sense of hearing has the smallest vocabulary of any of our five senses. Thus, **Gordon** faced the difficulty of describing sound differences with all too few words with which to do it. He not only had to invent the techniques and disciplines of

what has become known as "subjective reviewing" but also the language with which to do it.

Today, the magazine he founded has become a major force in audio quality judgments around the world. And almost all the vocabulary definitions are his work.

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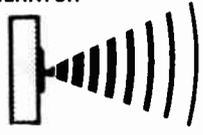
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- Featured in Spring '84 Special Projects by Radio Electronics

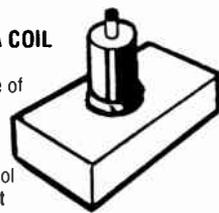


Highly spectacular device produces visible audible bolts of lightning appearing to flash into the air. Cause certain materials to burn from within and glow, lights bulbs without wires, produces induction fields, St. Elmo fire corona. Clearly demonstrates high frequency, high voltages yet terminal may be touched by user during operation with a metal object. 115VAC operation only.

BTC3 Plans\$10.00
 BTC3K Kit & Plans\$249.50
 BTC30 Assembled\$349.50

WORLDS SMALLEST TESLA COIL

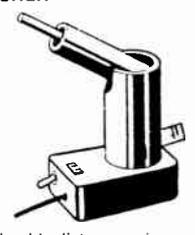
Produces 50 to 75,000 volts of lightning-like discharges capable of generating "plasma in a jar". St. Elmo's Fire, Corona or being just an excellent conversation piece. Unit contains power control and discharge terminal. Excellent lab or science project.



BTC1 Plans\$7.00
 BTC1K Kit & Plans\$49.50
 BTC10 Assembled & tested 115 VAC powered unit, requires caution\$69.50

ELECTRO MAGNETIC LAUNCHER

This device clearly demonstrates the magnetic and mechanical reaction produced by the "Lorentz" force. This is the basis of present research being done on rail and coil guns, weapons, or vehicle launching. Great research and controlled science fair project. Propels object to considerable distance using a discharge of 160 joules. Caution required, unit operates on 115VAC.



EML2K Kit & Plans\$69.50
 EML20 Assembled\$99.50

PLASMA FIRE SABER

Produces the spectacular effect that captured the fantasy of millions of movie fans. Visible plasma field is controlled by grip pressure & adjusts saber length. Active energy field produces weird & bizarre effects. Excellent for special effects. Available in photon blue/neon red/phasor green/starfire purple

PFS2 Plans\$8.00
 PFS2K Kit & Plans\$49.50
 PFS20 Assembled\$69.50



DECOR HI LITE NEON

26" display length. Available in choice of fire red, phasor green, photon blue. Operates from 12VDC or 115VAC. Produces a bizarre strobing effect when light is in motion.

DNE10 Assembled\$49.50

MUSICAL NEON DANCING PLASMA FIRE-RHAPSODY IN LITE

Highly visible plasma length varies with the volume of sounds and music.

- Supplement to home stereo
- Amusement for bars & entertainment areas
- Attention getting for point of sales
- Available in fire red, proton blue or phasor green

DPL1 Plans\$8.00
 DPL1K Kit & Plans\$59.50
 DPL10 Assembled\$79.50

- HARD TO FIND PARTS -

- VG20 - High Voltage 20KV Avalanche Diode\$3.50
- VG4 - High Voltage Sub Mini 4 KV Avalanche Diode\$1.50
- .001/15KV - High Voltage .001 AT 15KV Capacitor\$3.50
- TUD1 - Special Tunnel Diode & Plans for the Famous Martini Olive Voice Transmitter\$29.50
- 10K/25 - High Voltage 10KV 25MA 60HZ 115 AC Transformer\$69.50
- CD25B - High Voltage 50KV Mini Pulse Transformer\$16.50
- T08 - High Voltage 8" High Toroidal Terminal\$69.50
- Fans - Muffin Fans 115 VAC, 3 x 3"\$6.50
- XLD660 - 15 WATT Laser Diode with Plans\$19.50

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670NM Toshiba all new full spec
 VRD1 3 MW Laser Diode & Plans to Build a Complete System\$74.50



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VIDEO/AUDIO SURROUND SOUND PROCESSOR

SM-333 ▲▲▲▲

It has inputs for VCR Video Disc and Compact Disc and can also be used with FM tuners, tape decks and LP discs - in fact anything that can be connected to your pre-amplifier

It also has front panel control of dynamic noise reduction DNR, surround level, effect and time delay up to 50 milliseconds. Rear panel outputs for front and rear stereo speaker amplifiers. The unit may be purchased as a kit or fully assembled ready to plug in.

SPECIFICATIONS

Frequency response 20 Hz to 20KHz • Total harmonic distortion Front channel 0.05% Rear channel Less than 0.25% • Input signal voltage 0.1 to 3.5V • Output Front channel 0.1 to 3.5V • Rear channel 6V • Delay time 5 to 50 milliseconds • Input impedance 47 K • Power requirements 100 120 VAC 60 Hz • Dimensions 14 2 wide x 8 2 deep x 2 1 high



Complete Kit: \$65.00
Assembled & Tested: \$75.00

100W + 100W NEW CLASS A DC STEREO PRE AND MAIN AMPLIFIER TA-1500 ▲▲▲▲

The TA-1500 is a fully integrated stereo amplifier including a preamplifier. It has inputs for magnetic phono, tuner, aux, mic and tape in/out. Controls include volume, balance, mic gain, bass, treble and mid-band tone controls and input selector. It is also possible to connect an external separate pre-amplifier. Other features are fully complementary DC coupled circuitry with fast acting speaker protection relay. Power supply components are included on the printed circuit board and requires only the addition of an external transformer. The Mark V model 001 is a suitable transformer.



Complete Kit: \$73.70
Assembled & Tested: \$95.81

SPECIFICATIONS

Power output: 80 watts per channel into 8 ohms 100 watts per channel into 4 ohms • Total harmonic distortion: Less than 0.03% • Frequency response: Aux input 5 to 50 000 Hz • 0.2dB - 2 dB • Frequency response: Power amplifier section: DC to 200 KHz • Sensitivity: Phono 2.5 mV @ 47 K Aux 150 mV @ 47 K Mic 6 mV @ 10 K • Input Tape 150 mV @ 47 K Preamp 1V @ 600 ohms • Power transformer 26 V to 32 V AC x 2 @ 6 A [Mark V Model 001] • P.C. Board Dimensions: 10.5" x 6.13" x 2.25" • Heat sink 5.13" x 2.63" x 3" (Each) Use rack mount cabinet LG-1924 or LG-1925

60W + 60W Stereo Power Amplifier (with Mic. input) SM-302 ▲▲▲

SM-302 ▲▲▲

The SM-302 is a fully self-contained power amplifier. It is designed to be used with a wide variety of preamplifiers and the exciting Mark V surround sound processor. Assembly is greatly facilitated because all components mount directly on the printed circuit board and interconnect wires are held to a minimum. An added benefit is that hum noise and distortion are also minimized. The SM-302 provides three input jack pairs. One pair will accept a high impedance microphone. The two remaining pairs are for high level and low level input sources. These input jacks are selected by a panel mounted slide switch.

SPECIFICATIONS

Frequency response 20Hz to 20 KHz • Total harmonic distortion < 0.1% • Power output 60W per channel into 8 ohm load • 33W per channel into 4 ohm load • Input sensitivity Mic 10mV • Lo 380mV • Hi 640mV • Signal to noise ratio Better than 70 db • Power consumption 100W • Dimensions 360 mm x 75 mm x 200 mm



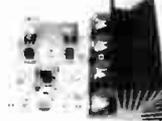
Complete Kit: \$67.00
Assembled & Tested: \$78.00

300 W HI-FI POWER AMPLIFIER (MONO) TA-3600 ▲▲▲

TA-3600 ▲▲▲

The TA-3600 is an extremely high power amplifier specifically designed to reproduce the high dynamic range available on compact discs.

It has low noise, high stability low distortion, extended frequency range and high efficiency in a compact package. Two of these units with appropriate power supply and pre-amplifier are required for stereo reproduction.



Complete Kit: \$85.00
Assembled & Tested: \$110.00

SPECIFICATIONS

Power output: 300 watts sine wave into 8 ohms 540 watts music power into 8 ohms • Frequency response: 10Hz to 20 KHz • Total harmonic distortion: Less than 0.05% • Intermodulation distortion: Less than 0.05% • Sensitivity: 1 V rms at 47K • Power requirements: 60 to 75 VDC at 8 amp • Dimensions: 8" x 7 1/2" x 2 1/2"

Universal Audio/Video KARAOKE Mixer Pre-Amp. SM-888 ★

SM-888 ★

The SM-888 is smartly styled and has a variety of functions such as echo mode, echo depth and a graphic equalizer to suit various environmental and individual tastes. The graphic equalizer is very effective to create a more lively effect. SM-888 features include two microphone jacks for mixing LO (laser disk) and VCR connection terminals, built-in phone pre-amp and tape recorder jacks, and all the facilities you need for live recording. An integral signal amplifier allows sources with varying signal levels to be controlled for best results. Additional connections are provided for CD (compact disc) and FM tuner inputs.

SPECIFICATIONS

Frequency Response 20Hz to 20KHz • T.H.D. < 0.01% from 20 Hz to 20 KHz • Input Sensitivity 3 mV rms • Input impedance 47 K • AV (audio) 300 mV at 47 K • AV (video) direct connection • FM Tuner 300 mV at 47 K • CD 300mV at 47 K • AUX 300 mV at 47 K • MIC 3 mV at 600 ohms Usable 300 ohms to 47 K • Line output 0 to 1.5 V with 300 mV input Equalization 100 Hz • 10 db 250 Hz • 10 db 1 KHz • 10 db 3 KHz • 10 db 10 KHz • 10 db • Echo delay time 62 to 220 ms • Power Requirements 110 220 VAC 50/60 Hz • Power consumption 28 W • Dimensions 17 W x 2 1/2 H x 7 7/8 D 432 mm x 64 mm x 200 mm



Assembled & Tested: \$225.00

80W + 80W PURE DC STEREO MAIN POWER AMPLIFIER TA-802 ▲▲

TA-802 ▲▲

Modern circuit design utilizes full complementary power output and differential cascode input stage. DC coupling provides superb transient response. A special output circuit guards against short circuits and overload operation.

SPECIFICATIONS

Power output: 80 watts per channel into 8 ohms Total harmonic distortion: Less than 0.05% at rated power Intermodulation distortion: Less than 0.05% at rated power Frequency response: DC to 200 KHz • 0 db • 3db @ 1 watt Power requirements: 30 VAC x 2 @ 6 amp. May use Mark V model 001 transformer P.C. Board 8 1/2" x 5" x 1-1/8" Heat sink 5 1/8" x 2 5/8" x 3" (Each)



Complete Kit: \$45.94
Assembled & Tested: \$59.72

120W MOSFET POWER AMPLIFIER (MONO) TA-477 ▲▲

TA-477 ▲▲

This amplifier is designed specifically for low TIM distortion. It uses parallel MOSFET output transistors. This is a very popular kit because of its superior sound reproducing ability and high power reserve. BUILD TWO KITS FOR A PROFESSIONAL STEREO AMP!

SPECIFICATIONS

T.H.D. Less than 0.007% • Power output 120 watts into 8 ohms • Frequency response 8 Hz to 20KHz • 0-0.4 dB • Sensitivity 1V • Power requirements 55 VDC @ 3 amps. May use Mark V Model 003 Transformer



Complete Kit: \$68.00
Assembled & Tested: \$85.00

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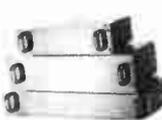
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* Free gift for any purchase before April.

| AMPLIFIERS | | KIT | ASSEMB. |
|----------------|--|---------|---------|
| MODEL | DESCRIPTION | | |
| TA-28MK2 | Digital Voice Memo ▲▲ | \$30.00 | |
| TA-50A/B | Multi-Purpose Melody Generator ▲ | 12.84 | \$17.20 |
| TA-50C | Multi-Purpose Melody Generator ▲ | 13.65 | 18.71 |
| TA-120MK2 | 35W Class 'A' Main Power Mono Amp ▲▲ | 31.50 | 42.80 |
| TA-300 | 30W Multi-Purpose Single Channel Amp ▲▲ | 20.00 | 29.00 |
| SM-302 | 60W + 60W Stereo Power Amplifier (with Mic. input) ▲▲▲ | 67.00 | 78.00 |
| TA-323A | 30W X 2 Stereo Pre-main Amp ▲▲ | 31.50 | 42.80 |
| TA-377A | Hi-Quality FET Stereo Pre-Amp ▲▲▲ | 59.95 | 75.00 |
| TA-400 | 40W Solid State Mono Amp ▲▲ | 28.00 | 34.93 |
| TA-477 | 120W Mostel Power Mono Amp ▲▲ | 68.00 | 85.00 |
| TA-800MK2 | 120W + 120W Low Tim Pre-Main Stereo Power Amp ▲▲ | 63.92 | |
| TA-802 | 80W + 80W DC Stereo Main Power Amp ▲▲ | 45.94 | 59.72 |
| TA-820A | 60W + 60W DCL DC Pre-Main Stereo Amp ▲▲ | 40.39 | 49.37 |
| TA-1000A | 100W Dynamic Class 'A' Main Power Mono Amp ▲▲ | 59.69 | 80.58 |
| TA-1500 | 100W X 2 Class 'A' DC Stereo Pre-Main Amp ▲▲ | 73.70 | 95.81 |
| TA-2200 | Fet Super Class 'A' OC Pre-Amp ▲▲ | 47.70 | 58.24 |
| TA-2400A | Electronic Echo & Reverberation Amp ★ | | 96.00 |
| TA-2500 | HD Pre-Amp w/10 band graphic equalizer ★ | | 68.80 |
| TA-2800 | HI-FET IC Pre-Amp w/3 way tone control ▲▲ | 48.90 | 63.57 |
| TA-3000 | Stereo Simulator (For Mono TV or Any Mono Source) ▲▲ | 27.00 | 38.50 |
| TA-3600 | 300W HD Hi-Fi Power Mono Amp ▲▲▲ | 85.00 | 110.00 |
| POWER SUPPLIES | | KIT | ASSEMB. |
| TR-100A | 0-15V 2A Regulated DC Power Supply (W/Case) ★ | \$69.50 | |
| TR-355A | 0-15V 5A Regulated DC Power Supply ▲ | \$15.65 | 21.76 |
| TR-355B | 0-30V 3A Regulated DC Power Supply ▲ | \$15.65 | 21.76 |
| TR-503 | 0-50V 3A Regulated DC Power Supply ▲▲ | 16.75 | 23.65 |
| INSTRUMENTS | | KIT | ASSEMB. |
| SM-43 | 3 1/2 Multi-Functional Led D P M (w/ABS plastic case) ▲▲ | \$34.50 | \$43.00 |
| SM-48 | 4 1/2 Hi-Precision D P M ▲▲▲ | 38.00 | 48.00 |
| SM-48A | 4 1/2 Hi-Precision D P M (w/ABS plastic case) ▲▲▲ | 41.20 | 52.00 |
| SM-49 | 3 1/2 Multi-Functional LCD D P M (w/Hold Function) ▲▲ | 36.00 | 44.50 |
| SM-100 | 150MC Digital Frequency Counter ▲▲▲ | 79.00 | 90.00 |
| FC-1000A | 1 GHz Frequency Counter ★ | | 179.00 |

| MISCELLANEOUS | | KIT | ASSEMB. | | |
|------------------------------------|---|--|--------------|----------|-------|
| MODEL | DESCRIPTION | | | | |
| TY-238 | 3 Channel Color Light Controller ★ | | \$65.00 | | |
| TY-25 | Stereo Loudspeaker Protector ▲ | \$14.85 | 20.85 | | |
| TY-35 | FM Wireless Microphone ▲ | 11.25 | | | |
| TY-36 | AC/DC Quartz Digital Clock ▲ | 19.00 | 26.20 | | |
| TY-38 | Sound / Touch Control Switch ▲ | 12.00 | | | |
| TY-41MK V | Infrared Remote Control Unit (w/Case) ▲▲ | 22.00 | 35.00 | | |
| TY-42 | Bar / Dot Level Meter ▲ | 24.15 | 33.81 | | |
| TY-43 | 3 1/2 Digital Panel Meter ▲ | 29.00 | 38.00 | | |
| TY-44 | 20 Steps Bar / Dot Audio Level Display ▲ | 38.45 | 46.14 | | |
| TY-47 | Superior Electronic Roulette ▲▲ | 19.46 | 27.24 | | |
| SM-222 | 7 Band Hi-Fi Graphic Equalizer ▲▲▲ | 26.80 | 38.80 | | |
| SM-328 | 4 Channel Professional Color Light Controller ★ | | 145.00 | | |
| SM-333 | Audio/Video Surround Sound Processor ▲▲▲▲ | 65.00 | 75.00 | | |
| SM-666 | Dynamic Noise Reduction ▲ | 26.00 | 34.00 | | |
| SM-888 | Universal Audio/Video KARAOKE Mixer, Pre-Amp ★ | | 225.00 | | |
| 10 000uF | 80 V Capacitor (Suggested for TA-3600, TA-477, TA-1000A & TA-802) | | 23.00 | | |
| METAL CABINETS WITH ALUMINUM PANEL | | MODEL | H" x W" x D" | MATCHING | PRICE |
| LG-1273 | 3' 12" 7" | TA-2800, TA-377A, TA-2200 | \$22.85 | | |
| LG-1684 | 4' 16" 8" | TA-323A, TA-377A, TA-2200 | 27.50 | | |
| LG-1924 | 4' 19" 11 1/2" | TA-802, TA-820A, TA-1500, TA-120MK 2, TA-800, TA-1000A | 32.80 | | |
| LG-1925 | 5' 19" 11 1/2" | TA-477, TA-800MK2, TA-1500, TA-1000A, TA-3600 | 35.80 | | |
| LG-1983 | 2 1/2' 19" 8" | TA-377A, TA-2800, TA-2200, TA-120MK 2 | 29.25 | | |
| POWER TRANSFORMERS | | MODEL | DESCRIPTION | MATCHING | PRICE |
| 001 | 28V x 2 6A to 30V x 2 6A | TA-800MK2, TA-802, TA-820A, TA-1000A, TA-1500 | \$27.00 | | |
| 002 | 36V x 2 3A | TR-503, TA-323A, TA-400, TA-300 | 22.00 | | |
| 003 | 40V x 2 6A | TA-477 | 28.00 | | |
| 004 | 24V x 2 6A | TA-120 MK 2 | 22.00 | | |
| 005 | 26V x 2 3A | TR-355B | 16.00 | | |
| 006 | 18V x 2 5A | TR-355A | 15.50 | | |
| 007 | 53V x 2 8A | TA-3600 | 43.00 | | |

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ONE SMALL STEP FOR ELECTRONICS

The Military-Industrial complex has had increasingly bad press ever since Dwight D. Eisenhower coined the term in the early 1950s. This General become President was certainly in a position to pronounce it a major danger to this republic. If anything, President Eisenhower underestimated what the group might accomplish in the way of shaping a nation's priorities and activities.

And the reputation of that coalition has not improved in the last decade, despite the loving attention and billions of budget dollars lavished on it during the Reagan years. Cost overruns, shoddy equipment, substandard goods that failed in field trials, and dubious ethical behavior have all contributed to a general cynicism about the munitions makers and the Pentagon.

Warfare has become an industrial enterprise. As we have developed manufacturing techniques, we have used such methods to enhance our capability for killing one another. The rising level of carnage, which began in earnest with the Civil War in the United States, escalated to a horrifying level in World War I on the European battlefields and to world-wide levels of mass destruction in World War II.

The rising tide of revulsion which has arisen in all thoughtful people everywhere regarding our nuclear capabilities has caused many to take the position that war itself is not a sane option. We all realize that if nuclear war on a global scale breaks out, we will have destroyed ourselves and the planet as well.

In such an environment, the claim of some military people that a "limited war" was possible has been met with cynical disbelief. The Korean and Vietnam "conflicts" bore the same old mass-destruction killing machine hallmarks of previous modern wars of this century.

Given such a grim and increasingly horrifying prospect regarding all wars and military operations of all descriptions, whether we are talking about Sharpeville, Tienamin Square, or Latvia, it may be naive to have anything positive to say about the Allied effort in the Persian Gulf to dislodge Iraqi forces from Kuwait.

However, after a week of war in that troubled area, I believe it is worth remarking on the effect of electronics communications and control systems on the execution of this war. The "old" technology of the SCUD missiles being used by the Iraqis for terrorist attacks on the civilians of Israel and Saudi Arabia represents crude techniques left over from World War II. The Patriot anti-missile devices used to counteract many of the SCUDS are obviously part of a new breed of weapon which feature much greater precision.

Almost all the equipment being used by the Allied forces is highly

electronic. A trade magazine reports on this growing electronic content of almost all weapons. The Tomahawk Cruise missile, for example, carries 1,270 individual parts to make up its guidance and control systems. An F-16 fighter has over 17,000 electronic parts.

The precision targeting of offensive efforts by the military and the effective defensive weaponry are the result of the Military-Industrial complex making more use of electronics. Efficiency is the primary goal of these changes. But one unlooked for result is a lowering of civilian casualties when industrial and military targets are destroyed.

There is some small hope that this "humane" bonus can be increased by technology in future. Some pilots in the Gulf area are already able, with computer simulation technology, to "practice" bombing runs ahead of the actual attack, to make the result more precise, thus avoiding unintended casualties because of "mistakes." This trend will doubtless continue. Missiles are already being designed with video cameras in their noses enabling a controller to "fly" them to their targets accurately from behind the front lines.

Gunships may eventually be flown by remote pilots on the ground, operating the machine's ability to drop bombs and fire missiles and cannon at targets visible through infra-red and conventional cameras.

Such capabilities, however, are a decidedly mixed blessing. In the hands of unscrupulous forces, the greater precision can add up to greater terror and greater loss of human life over the long term. The precise defensive capability of technology is probably the only humane bonus of any enduring value.

Nor can we say that this war will not become horrifyingly destructive when the land battles commence. Carpet bombing by B-52s, so reminiscent of the armageddon-like years in Vietnam, will undoubtedly come to Kuwaiti deserts and Iraqi frontier fortifications. The targets will no longer be airfields, power plants, and munitions factories, but human beings. War machinery still kills people and with increasing efficiency and larger and larger loss of human life.

Since the Hiroshima and Nagasaki bombs exploded over Japan in 1945, many people have hoped that technological advances might move our ability to kill each other to such a high level that we might eventually see war as futile. Perhaps the day will come that electronics will mean that a war is fought like a giant video game with each side maneuvering robotic weaponry until the side with the most advanced technology emerges victorious. Such an obvious waste of intelligence and treasure seems ludicrous at best when considered as a way to solve our differing aspirations and goals.—E.T.D.

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ECONOMICAL 8-CHANNEL WIDE-BAND UHF TWO-WAY MOBILE

Midland LMR has introduced a UHF two-way FM mobile radio, the model 70-1526. It is programmable for up to eight channels. The new PLL frequency-synthesized radio has adjustable RF output power of 15-25W and covers a frequency range of 406-430MHz or 450-470MHz, at full rated specifications, without retuning. Tone-coded and digitally coded squelch, programmable by channel at random in any combination, are built in. Audio output is 5W.

With a die-cast chassis and an optional bracket support added to the standard underdash mount, the 70-1526 meets MIL standard 810C/D for shock and vibration. The radio is 2" x 7" x 8 $\frac{1}{8}$ ". Options include priority scanning of 40 channels per second, a slide-rail mounting kit, a DTMF decoder, and a DTMF encoder microphone with ANI.

For more information, contact Midland LMR, Marketing Dept., 1690 N. Topping, Kansas City, MO 64120, (800) 643-5263, ext. 1690.

1MHZ TRIMDAC REPLACES EIGHT POTENTIOMETERS

Analog Devices' DAC-8840 and DAC-8841 TrimDACs™ are 8-bit octal-multiplying digital-to-analog converters (DACs) designed to replace mechanical potentiometers for automatic microprocessor adjustments of AC and DC voltage gain. Eight independent channels of digitally programmable signal-level attenuation provide 256 values of unipolar or bipolar gain (two- or four-quadrant multiplication) for DC-to-1MHz analog signal inputs. Each buffered channel can provide a minimum of 5mA of output drive current.

These converters accept 8-bit serial data inputs and differ primarily by their power supply requirements, multiplying capability, and signal input voltage range. Operating from $\pm 5V$ supplies and accepting bipolar $\pm 3V$ reference inputs, the DAC-8840 offers full four-quadrant multiplication. The DAC-8841 accepts unipolar 0-1.5V inputs and is designed for two-quadrant multiplication with non-inverting gain of two. Its requirement of a single 5V power supply makes it suitable for

ELECTRONICS SCENE

EASY-PC TOPS 5,000 WORLDWIDE

Shipments of Easy-PC, Number One Systems' award winning PCB and schematic CAD program, exceeded 5,000 copies in October. Design engineers from Australia to Zimbabwe are choosing Easy-PC because of its ease of use and Number One Systems' free technical support service.

The latest enhancement is the ability to print layouts and schematic drawings on LaserJet II printers and compatibles with adjustable scaling and resolution, selectable paper sizes, drill detail and solder resist, and an automatic method of correcting printer inaccuracies.

With its ability to create specialist drawing symbols, Easy-PC can be used with applications such as landscape gardening and kitchen design, as well as with electronic engineering. In addition to the library of more than 400 7400 series logic symbols, the new Easy-PC Library disk set contains more than 1,000 logic, microprocessor, and memory symbols and the most popular PC Adapter and Eurocard board outlines. All the schematic symbols are drawn in a consistent format, and all can be modified.

Easy-PC sells for \$195 and Easy-PC Library for \$75. For further information, contact Roger Wareham, Technical Director, Number One Systems Ltd., Harding Way, Somersham Rd., St. Ives, Huntingdon, Cambs, PE17 4WR, England, (+44 480) 61778.

INSTRUCTIONAL TECH SHOW DEBUTS IN '91

A conference and exposition program has been created for the rapidly expanding instructional technology field. InTech '91, will be held Sept. 5-7, 1991, at the Disneyland Convention Center in Anaheim, CA.

"The best way to meet America's educational and training needs in the 1990s, in corporations, higher educational institutions, and government agencies, will be through instructional technology," stated Carl Berndston, executive director of InTech. "With the emergence of powerful, cost-effective instruction methods, such as multimedia computing systems, distance learning networks, and computer simulation systems, technology-based instruction will become primary for future generations," he said.

InTech '91 will feature three days of workshops, conference sessions and product demonstrations. Instructional technology products, services, and systems will focus on computer-based training/computer assisted learning, interactive authoring, CD-ROM and videodisc, computer simulation, and distance learning incorporating videoconferencing and teletraining.

Attendees are expected to include instructional technologists, training directors, human resource executives, CEOs, educators, MIS directors, researchers, and consultants.

For information on the conference program, exhibiting, or registering for InTech '91, contact Exposition Management Inc., 1601 Trapelo Rd., Waltham, MA 02154, (800) 262-3378 or (617) 290-0400, FAX (617) 290-0409.



single-supply (portable) low-power equipment. The device achieves its performance with a low 95mW of dissipation.

Both converters are available in 0.3", 24-pin plastic and ceramic DIPs, and 24-lead SOICs. They operate over the industrial temperature range from -40 to $+85^{\circ}C$. Prices

begin at \$9.95 in 100s. A MIL-STD-883B version will be available in the second quarter of 1991.

For more information, contact Walt Heinzer, Analog Devices, Inc., 1500 Space Park Dr., Santa Clara, CA 95052-8020, (408) 562-7254.

UNIVERSAL LAPTOP PCXI EXPANSION CHASSIS

Rapid Systems has announced the PX1013, a universal expansion chassis for laptop computers that have at least one half-size expansion slot. It allows you to expand the PC I/O bus with 11 free slots. The expansion chassis is based on the PCXI mechanical format, which features cooling, modularity, an industrialized passive backplane, and metal shielding around each card that plugs into the expansion chassis. The chassis comes with an integrated PC bus expansion card set. One card is integrated into a PCXI module and the other is a half-size card that plugs into the laptop expansion slot. The PX1013 also includes a 200W power supply module.

The chassis sells for \$2,495. For more information, contact Rapid Systems, Inc., 433 N. 34th St., Seattle, WA 98103, (206) 547-8311, FAX (206) 548-0322.



BENCH DIGITAL MULTIMETER WITH BRIGHT LED DISPLAY

A 3½ Digit Bench DMM with 0.1% DC voltage accuracy, AC voltage response to 40kHz, and a 0.5" bright LED display is available from B&K Precision. The model 2831A measures current to 20A, voltage to 1.2kV DC or 1kV AC, and resistance to 20MΩ. It also includes a diode test function.

The 2831A features resolution to 0.1mV, 0.1A, and 0.1Ω for precise readings. A continuity-check feature sounds an audio tone for resistances under 10Ω. All functions are overload protected, with high-energy fusing on current ranges. A combination tilt handle/bail adds to its convenience. Designed for AC operation, the multimeter can be used worldwide (110/220/240V AC, 50/60Hz).

Each unit is supplied with test leads, spare fuses, and an instruction manual. Optional accessories include a test-probe assembly and demodulator, high-voltage, and temperature probes.

The model 2831A sells for \$295. For more information or the name of the nearest distributor, contact B&K Precision, 6470 W. Cortland St., Chicago, IL 60635, (312) 889-1448.

ELECTRONICS SCENE

MONOLITHIC DUAL 8-BIT A/D CONVERTER

The AD9058 from Analog Devices is an 8-bit analog-to-digital converter that can encode two input signals—independently or simultaneously—at rates up to 50 megasamples per second. This single monolithic IC is housed in a 0.5", 44-pin surface-mount package.

In addition to DC, the device has minimum AC performance specifications tested at 2.3 and 10.3MHz. Signal-to-noise ratio is 45 and 44dB and the effective number of bits is 7.2 and 7.1, respectively. At either frequency, second-harmonic distortion is 48dBc and third-harmonic distortion is 50dBc.

Switching specifications include a maximum 10pS aperture uncertainty (jitter). Aperture delay between channels is less than 0.5nS (0.2nS is typical).

Analog input specifications include 175MHz full-power analog bandwidth and 10pF input capacitance. The AD9058's flexible analog input range is optimized for 2V peak-to-peak



operation. Using the converter's +2V internal reference, unipolar (0-2V) operation is achieved; bipolar operation ($\pm 1V$) can be configured with external circuitry.

The AD9058 is available for commercial (0-70°C) and military (-55 to +125°C) temperature ranges and package options include hermetic 48-pin DIPs and 44-pin J-lead packages. Its power dissipation is 770mW. Prices begin at \$55 in 100s.

For more information, contact Allen Hill, Analog Devices, Inc., 7910 Triad Center Dr., Greensboro, NC 27409, (919) 668-9511.

ADVANCED PC GRAPHICS IC

Edsun Laboratories, Inc. and Analog Devices, Inc. presented details of an agreement for the development, manufacture, and marketing of the advanced PC graphics ICs. The new mixed-signal devices are pin-compatible replacements for the RAM-DAC circuits on VGA cards, and can upgrade graphics capabilities of low-end PCs to those of high-end workstations.

The alliance includes co-development roles. Edsun conceived and patented the Continuous Edge Graphics (CEG) architecture, logic, algorithms, and the software that drives the device. Analog Devices provided its analog and digital logic, digital signal processing (DSP), and manufacturing expertise. The combination of CEG and mixed-signal technology in the single chip eliminates jagged screen image areas, and provides the photo-realistic colors and shading associated with true color systems.

Analog Devices also obtained the rights to integrate CEG technology into RAM-DACs targeted for the workstation market. The agreement calls for Analog Devices to provide manufacturing and testing of the part, and allows for each company to deliver pin-compatible devices while serving as independent worldwide sources for the new ICs. For more information, contact Analog Devices, One Technology Way, PO Box 9106, Norwood, MA 02062, or call (617) 329-4700, FAX (617) 326-8703.

BILL TO PROTECT SPECTRUM INTRODUCED IN HOUSE

Rep. Jim Cooper (D-Tennessee), a member of the House Subcommittee on Telecommunications and Finance, introduced The Amateur Radio Spectrum Protection Act of 1991 (HR 73). This bill would prevent the Amateur Radio Service's loss of radio spectrum. It proposes that existing allocations of spectrum not be diminished and provides for equivalent replacement of spectrum for any reallocation after January 1, 1991.

AMATEUR RADIO VIDEO

ICOM released "More than Radios," an amateur radio video created and produced by Zman Productions. An exclusive premier showing for cast and crew, held on January 16, launched the video's national distribution to ham radio clubs and special events. The 28-minute tape, set in towns throughout Washington, is a story about real people with a simple statement about amateur radio woven into the plot. One project goal was to involve as many amateur radio operators in front of the camera as well as behind the scenes.

A copy of the video tape can be obtained by sending a letter on your club's stationery to Zman Productions, 8051 NE 143rd St., Bothell, WA 98011. A limited number are available.

COMPUTER-CONTROLLED WEATHER STATION

PART 1: INDOOR/OUTDOOR THERMOMETER

This is the first in a short series of articles on applications of the multifunction measurement card for PCs, described in the previous two issues of this magazine. The applications we have in mind should have a wide appeal, since they form the building blocks of a versatile weather station with advanced features for the amateur meteorologist.

J. Ruffell

ALTHOUGH we know that a state-of-the-art weather station is likely to score high on the list of popular electronic projects, it has taken us a while to come up with one mainly for want of a suitable central control unit. Fortunately, that has become available recently in the form of a PC insertion card offering a high resolution voltmeter and a frequency/pulse meter. This card, the multifunction measurement card for PCs, was described in two instalments in the previous two issues of this magazine (Ref. 1).

Provided that it is connected to the right types of interface and associated sensor, the measurement card forms the ideal starting point for a host of applications that require accurate processing and recording of analogue values. The PC used allows us to store measured values, such as temperature, in memory or on disk for analysis at a later stage. Few PC users will need to be informed that the results of such an analysis are perfect as input data for a graphics presentation package.

The interfaces we have in mind for the measurement card turn an IBM PC or compatible into an autonomous weather station, with sensors for temperature, relative humidity, air pressure, wind direction and wind speed. The first module, a dual indoor/outdoor thermometer, is described here.

Dedicated or in the background

The multifunction measurement card and the associated control programs allow the PC-controlled weather station to function in one of two ways. In the first mode, a measurement is performed when the PC is switched on just to do that. During the measurement, the PC collects the measured

values produced by all sensors, and converts the data such that they may be stored on disk. Thus, a complete meteorological reading may be performed without going out of doors — you may remain seated in front of your PC and comfortably look at the measured results presented graphically on the monitor.

In the second mode of operation, the PC collects the meteorological data with the aid of a background (memory-resident) program, which allows a foreground task, such as word processing, to be carried out without the operator noticing that the PC is performing a second task. The background program automatically scans all sensors, and reads the measured values. Provision is made for the user to determine (within limits) the sampling interval. All readings and the times they were taken are collected in a file and subsequently stored on a floppy disk or a hard disk for use by a statistics or graphics/statistics program later. The software routines supplied with the main control program for the weather station allow

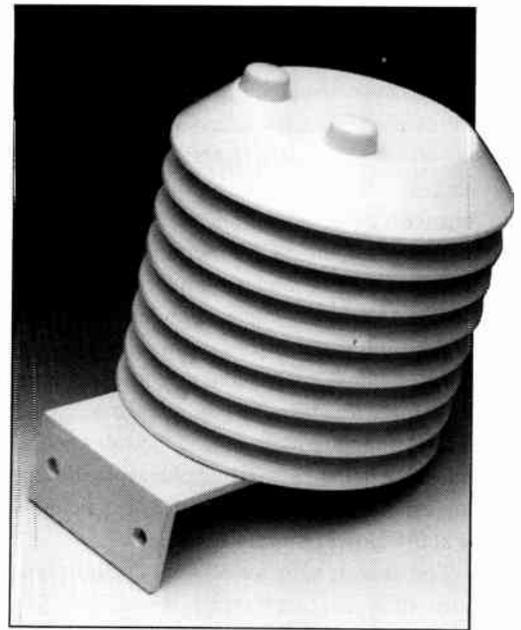
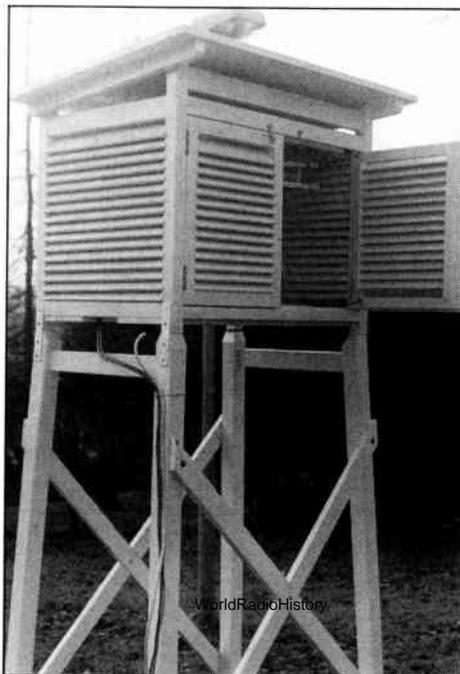


Fig. 1. This ready-made ABS enclosure contains the electronic thermometer that measures the outside temperature.

the trend of values measured over 24 hours to be presented in the form of a graph, while the current values are also shown graphically on the screen.

In this first article we describe the sensors used for measuring the temperature indoors and outside. For this purpose, most meteorologists use mercury thermometers with a mechanical minimum/maximum temperature indication. By contrast, the electronic version presented here uses a single sensor and software to record the minimum and maximum temperatures. If desired, these two parameters may be shown continuously on the PC screen.

Temperature measurement

Temperature measurement can be tricky if the position of the sensor is not taken into account. It is not difficult to have two identical thermometers indicate different temperatures by placing them in positions that are only marginally different. Meteorologists are aware of this and are forced, for obvious reasons, to comply with certain conventions as regards their daily measurements. For instance, temperature is measured at a height of 1.5 m above a grass lawn. To prevent direct sunlight causing additional heating, the thermometer cabin is painted white, and has a door facing north. To prevent precipitation affecting the temperature readings, the cabin usually has a sloping side facing south.

Inside a meteorology cabin you will typically find a number of mercury thermometers that indicate the maximum, minimum and current temperature. In most cases, a mechanical recorder is used to produce a temperature graph over a period of 24 hours.

Since a fully equipped cabin is probably unaffordable for most amateur meteorologists, a less expensive, but reliable, alternative is described here. The photograph in Fig. 1 above shows the white, plastic enclosure used for the prototype of the thermometer.

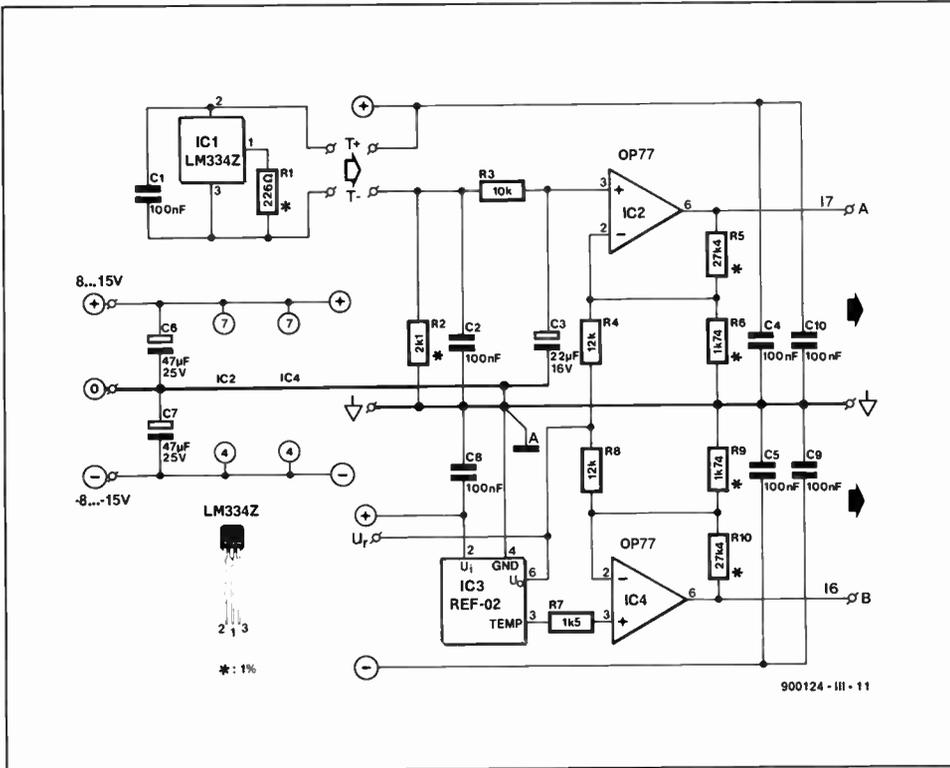


Fig. 2. Circuit diagram of the double electronic thermometer. The circuit is connected to the voltmeter input of the multifunction measurement card for PCs.

The construction of the enclosure prevents precipitation and direct sunlight reaching the temperature sensor, which is inserted through a hole at the underside, and fitted centrally in the enclosure. The ventilation

slots in the enclosure enable allow a free air-flow around the sensor. Since the enclosure shown can be bought ready-made, it fairly easy to make a number of identical thermometer boxes.

If are you not so fortunate as to have a garden with a lawn, we recommend that you fit the thermometer enclosure to the north-side wall or facade of your house. Since the north facing wall is heated less by sunlight than the south facing wall, this position is the best compromise.

The circuit

With the description of the electronics most of you will feel that you are returning to familiar ground. Figure 2 shows the circuit diagram of the interface for the two temperature sensors. Remember, this interface is connected to the multifunction measurement card for PCs.

The dual temperature sensor measures the inside (indoor) and the outside (outdoor) temperatures simultaneously. The inside temperature is measured with an REF-02, the outside temperature with an LM334Z.

The REF-02 (IC3) has two functions in the circuit. First, it provides a reference voltage of 5 V. This voltage, which is available on pin 6 of the stabilizer, is used for opamps IC2 and IC4. Pin 3 (TEMP), of the REF-02 supplies a temperature-dependent direct voltage. Since the REF-02 is fitted on a PCB that remains indoors, the TEMP output may be used for the indoor thermometer. The voltage at the TEMP output is 0.574 V at 0 °C, and rises at a rate of exactly 2.1 mV per Kelvin. Unfortunately, the TEMP voltage can not be applied direct to the ADC on the measurement card.

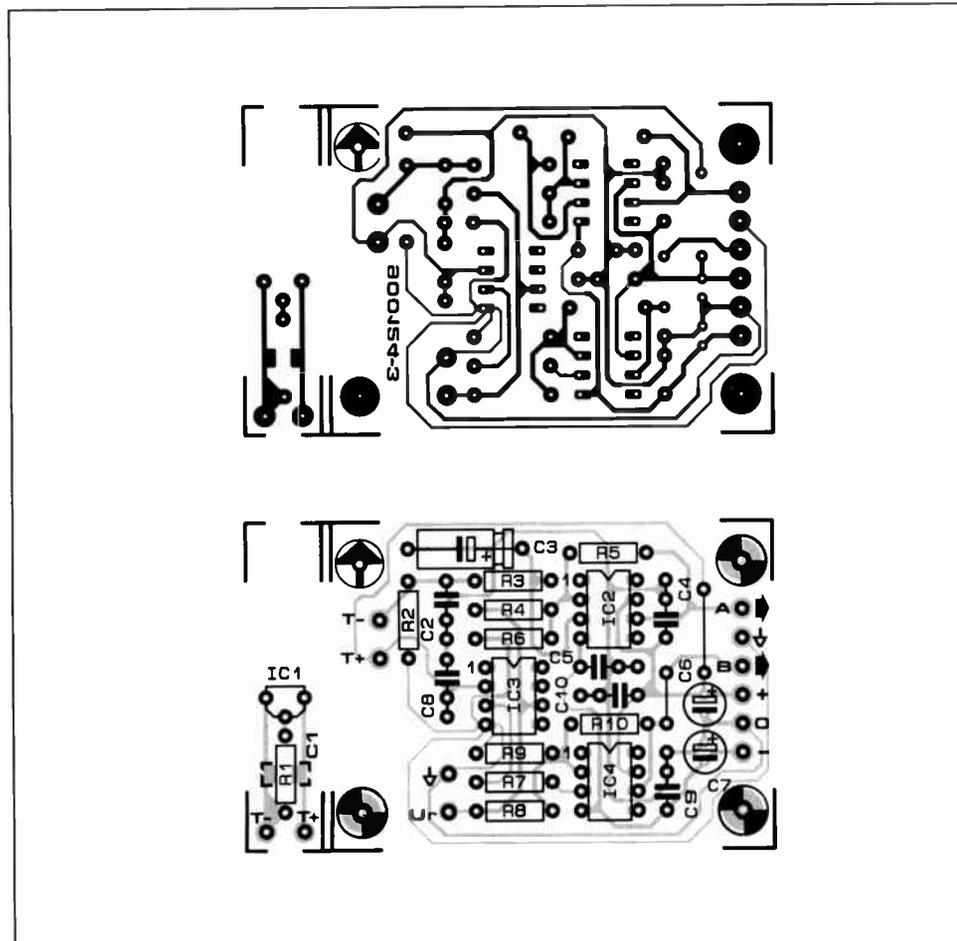


Fig. 3. Track layouts and component mounting plans of the two printed circuit boards needed for the indoor/outdoor thermometers.

COMPONENTS LIST

Resistors:

- 1 226Ω 1% R1
 - 1 2kΩ 1% R2
 - 1 10kΩ R3
 - 2 12kΩ R4;R8
 - 2 27kΩ 1% R5;R10
 - 2 1kΩ 74 1% R6;R9
 - 1 1kΩ 5 R7
- (1% resistors from E96 series)

Capacitors:

- 1 100nF SMA C1
- 6 100nF C2;C4;C5;C8; C9;C10
- 1 22μF 16V axial C3
- 2 47μF 25V radial C6;C7

Semiconductors:

- 1 LM334Z IC1
- 2 OP77 IC2;IC4
- 1 REF-02 IC3

Miscellaneous:

- 1 ABS enclosure; size approx. 100x50x25 mm (e.g. Bopla EG410)
- 1 printed circuit board 900124-3

Note: The sensor enclosure shown in the photograph in Fig. 1 was obtained from Mierij Meteo • Tuinstraat 1-3 • 3732 VJ De Bilt • Holland. Telephone: +31 30 200064

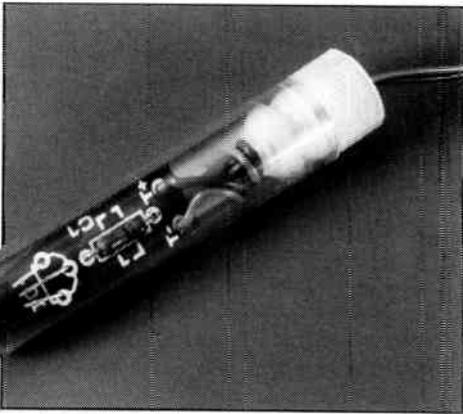


Fig. 4. The PCB with the LM334Z on it must be cut to size to fit into the plastic tube.

This problem is solved by a simple level converter in the form of an opamp, IC4. The converter is designed such that the output voltage of IC4 has a range of +2.5 V to -2.5 V for the desired temperature range, while the output voltage is 0.5 V at a temperature of 0 °C. The gradient of the output voltage is set to 40 mV/°C, so that an effective temperature range of -50 °C to +75 °C is achieved (although we know that the projects carried in this magazine are built and used around the globe, this seems a reasonably large temperature range...).

The electronic temperature measurement has a guaranteed resolution of 0.1 °C, which equals the resolution of mercury thermometers used by professional meteorologists.

The outside temperature is measured with the aid of an LM334Z, a temperature-dependent current source. As usual with this type of measurement 'in the field', the sensor is a current source rather than a voltage source. The current drive eliminates the effects of length, diameter and temperature of the cable between the sensor and the input amplifier. If voltage drive were applied, these parameters would cause a voltage drop that requires a complex type of compensation.

The sensor output current gradient is set to 1 μ A/K. Since the current flows through a 2.1 k Ω resistor, R2, a voltage gradient of 2.1 mV/K is created, which equals that of the indoor temperature sensor, IC3. Opamp IC2, like IC4, converts the temperature-dependent voltage into a value within the range between -2.5 V and +2.5 V, required for the ADC on the measurement card.

One thing that you will probably like about the interface circuit is the total absence of adjustment points or complex compensation circuits. This is by virtue of the control software, which provides routines that take care of the tracking and individual calibration of the two temperature sensors.

Construction

The two printed-circuit boards shown in Fig. 3 (one for the interface and one for the outdoor sensor) must be separated before they are populated. Start the construction with the wire links on the interface board. Next, fit all the components — a job that is

unlikely to present any difficulty.

The outdoor sensor PCB is cut and filed until it can be fitted into a small plastic tube of the type used for storing SMA components (see Fig. 4). The PCB area that has no components on it is first filed to a size to fit the tube. In view of the size of the plastic tube, the output wires are best soldered direct to the respective copper pads on the PCB.

After inserting the completed PCB into the tube, the wires are passed through small holes in the cap. Next, the cap is hermetically sealed with a few drops of epoxy resin or potting compound. The fitting of the tube at a suitable position in the centre of the thermometer enclosure is straightforward.

The PC connection

The outputs of the complete interface circuit are connected to analogue inputs I6 and I7 of the multifunction measurement card, while ground is connected to the analogue ground (on connector K3) of the measurement card. Note the following components at the analogue multiplexer input (refer to the circuit diagram of the measurement card):

- Resistor R6: 10 k Ω
- Resistor R7: not fitted
- Resistor R8: 10 k Ω
- Resistor R9: not fitted
- Capacitor C33: 100 nF
- Capacitor C34: 100 nF

These values ensure the correct measurement ranges.

The interface is powered by a simple symmetrical supply with an output voltage between ± 8 V and ± 15 V. Since the current consumption of the circuit is quite low (a few milliamperes only), a pair of fixed voltage regulators, such as the 7910 and 7810, may be used with the usual decoupling capacitors.

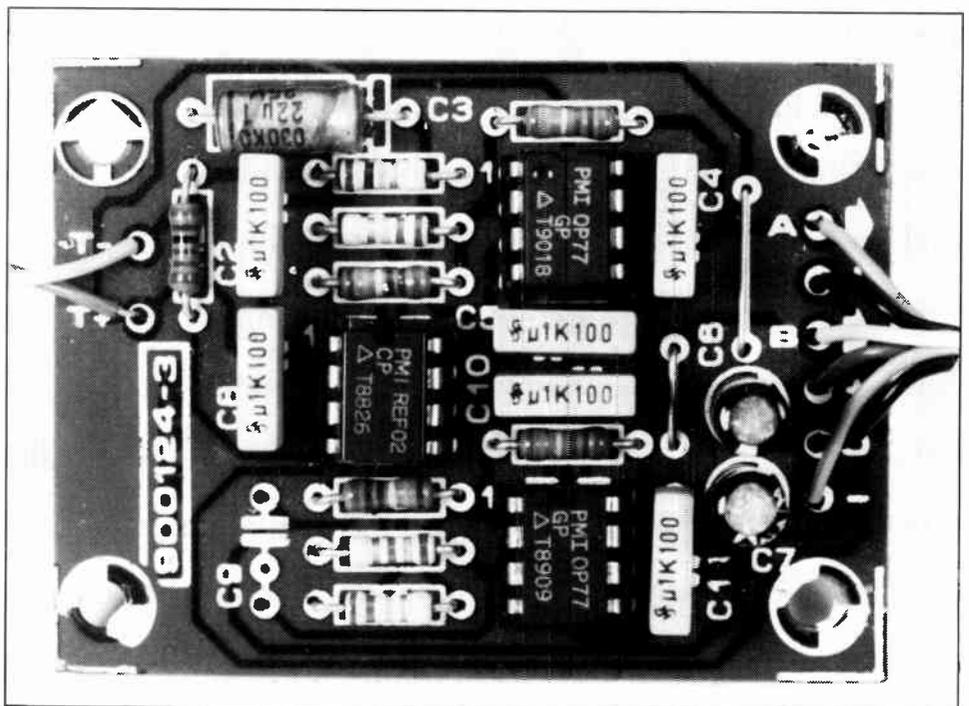


Fig. 5. Completed and ready for use: the indoor/outdoor thermometer is the first module in a computer-controlled weather station.

SOFTWARE SERVICE

The control software mentioned in this article is available on a 5¼-inch 360 KByte MSDOS formatted floppy disk which may be ordered through our Readers Service. The order code of the disk is ESS 1551.

Control software

As with the multifunction measurement card, the hardware is not complete without appropriate software. The control program written for the thermometer is supplied on a 5¼-inch floppy disk, and runs on any PC XT or AT fitted with a Hercules, EGA or VGA card (unfortunately, the program does not support CGA cards). The disk contains three programs: TADJUST.EXE for calibrating the sensors, TLOGGER.EXE for data logging as a background program, and TEMP.EXE, for the graphics presentation of the measured values.

The first thing to do is run TADJUST.EXE. This program requires two temperature measurements. The calibration of the outdoor thermometer is simple: immerse the sensor in melting ice, leave it there for a couple of minutes, and enter the value 0 °C in the relevant window on the screen. Next, place the sensor in free air. In the relevant window on the screen, enter the temperature read from a mercury thermometer fitted at the same position as the sensor.

Since the indoor temperature is measured with an IC fitted on the interface board, this sensor can not be calibrated with the aid of melting ice. Thus, a comparative calibration is required against a good quality mercury thermometer. As with the outdoor thermometer, two temperatures are re-

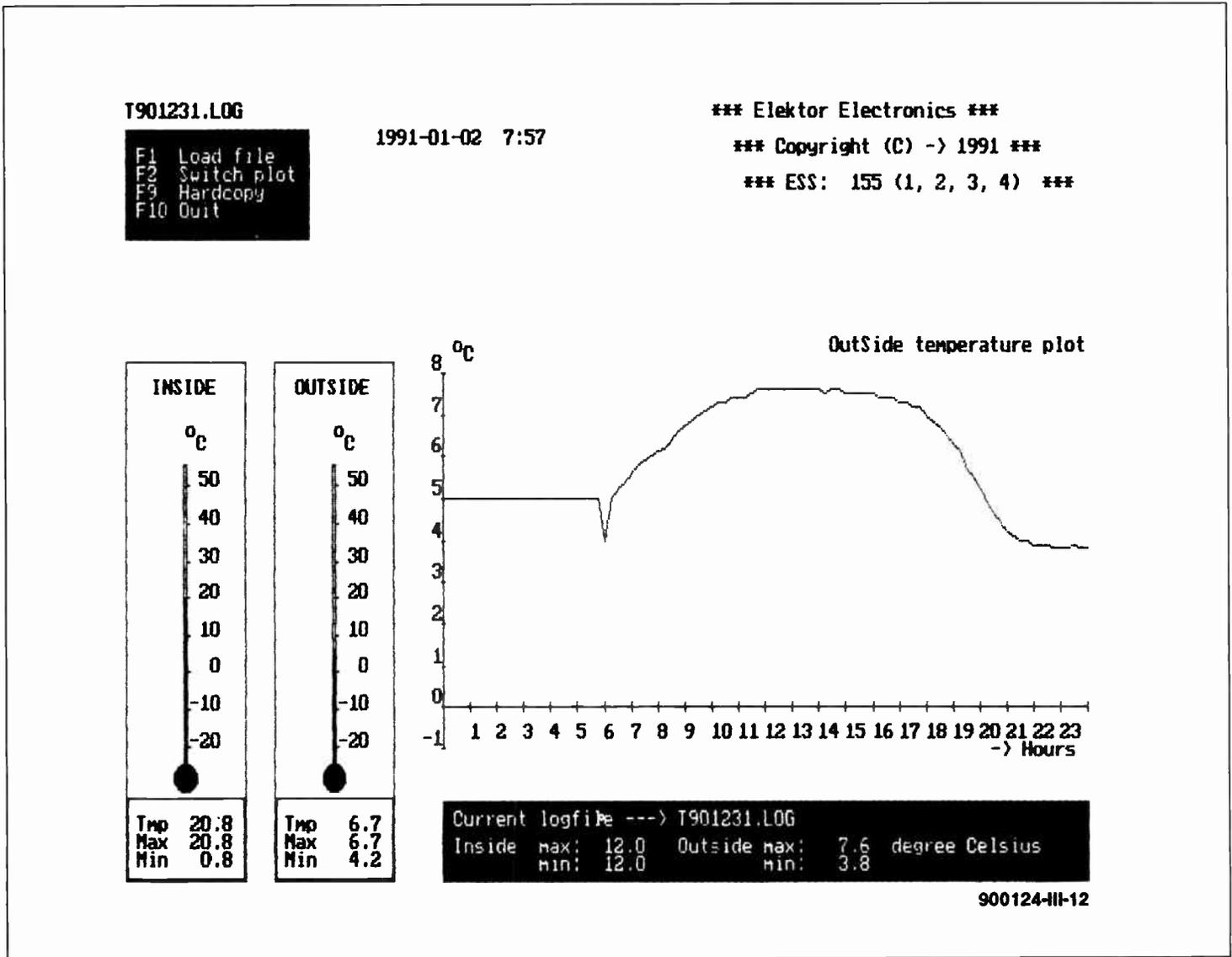


Fig. 6. Screenshot produced by the thermometer program, TEMP.EXE, which can run on any PC XT or AT fitted with a Hercules, EGA or VGA video card.

quired, which must be entered in the respective windows on the screen. The higher the temperature difference, the better. Since in most modern homes the daytime indoor temperature will typically be about 5 °C higher than the nighttime temperature, this difference may be used to calibrate the ther-



Fig. 7. Definitely a collector's item, this mechanical temperature recorder puts modern electronics in an interesting perspective.

mometer. A better, though slightly cumbersome, way of creating a larger temperature difference is to take the interface circuit out of doors for a short while.

This completes the calibration. The parameters used are automatically stored in a file called TADJUST.CFG.

Constructors who wish to use two remote sensors may build these on two separate PCBs. These sensors can share the 5-V reference voltage at terminal Ur, produced by a single REF-02.

The program TLOGGER.EXE is a background utility to collect measured data produced by the sensors. The program is made memory-resident by typing command

```
TLOGGER /I
```

(install), and removed from memory (uninstalled) by typing command

```
TLOGGER /U
```

The interval between the instants at which data is to be collected on hard disk or floppy disk is set in the configuration file, TLOGGER.CFG. The default is 60 minutes. The last update of the log file is always made at mid-

night. Since the program creates one log file every 24 hours, the file of the previous day is closed after midnight. From then, the measured results are available for further processing. After it is closed, every log file is automatically stored under a name that indicates the measurement period, i.e. Tyymmdd.LOG — until, of course, the disk is full. You may want to use your own programs to handle the collected data, and feed them into a statistics calculation or analysis program at this stage to produce a nice looking presentation. Initially, however, you may want to use TEMP.EXE on the distribution disk for this purpose. The program shows a graph with the temperatures measured from midnight onwards, as well as the current indoor and outdoor temperature. To ensure optimum resolution under all circumstances, the vertical axis of the temperature graph is autoranging. The horizontal axis shows the 24 hour marks. □

Reference:

1. "Multifunction measurement card for PCs". *Elektor Electronics* January and February 1991.

Next time: a relative humidity sensor.

THE COMPLETE PREAMPLIFIER (2)

by T. Giffard

Following the circuit description in our January 1991 issue, we will now focus our attention on the practical construction of the preamplifier. The busboard is shown in Fig. 5 and 6 and the motherboard in Fig. 7 and 8.

The busboard contains all the components shown in Fig. 2 and the SOURCE SELECT and RECORD SELECT switches. These switches are fitted with extension spindles to enable them to be controlled from the front panel.

The motherboard contains the components shown in Fig. 3 with the exception of the controls, which are fitted on the front panel. By virtue of its double-sided and through-plated design, this board will be fairly easy to populate.

Most of the work lies in preparing the enclosure and connecting the controls to the motherboard.

Choice of components

The quality of any preamplifier depends to a large degree on the opamps used and the type of capacitors in the signal paths.

In the present design, there is only one capacitor in the signal path: at the output. The board has space for two large parallel-connected types (C_{24} – C_{25} and C_{56} – C_{57}). These should preferably be MKP types, but at these values they are fairly expensive. Second choice is MKT types.

There are also some capacitors at the output of the dynamic pick-up section, but their values are fairly small so that MKP types here are not too dear.

Finally, the tone control circuit also contains a couple of capacitors which is virtually unavoidable. Since this circuit in any case degrades the quality to some degree, the quality of the capacitors used in it is hardly of any consequence.

There is a wide choice of suitable opamps. The quality of the preamplifier is, however, not necessarily in direct proportion to the price of the opamps chosen. It is rather a matter of choosing the opamps on their merits and to individual requirements. We shall look at each of them in turn.

IC_1 . In this position a low-noise type with small offset voltage is preferred. The Signetics 5532 is a good and economical choice. A slightly faster version is the 5535, while the SM2132 is even faster. National Semiconductor's LM833 is, as far as its specification is concerned, almost identical to the 5532. More expensive, but fast, is Analog Devices' AD712 (which has the added advantage of FET inputs). Then there is the OP270 (a double OP27) or the OP249, which has a high slew rate and FET inputs. In the Burr-Brown family there are the OPA2107 and OPA2604, both with FET



Fig. 4. General view of the preamplifier.

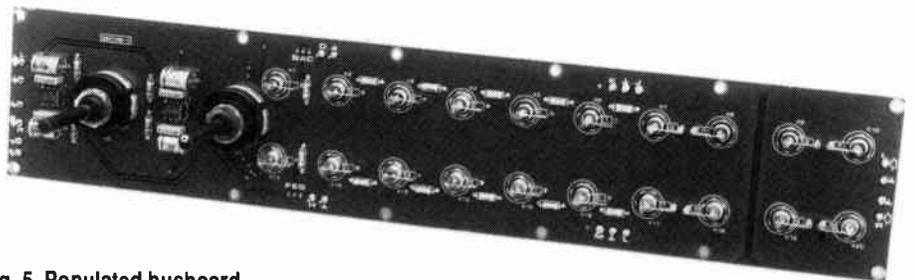


Fig. 5. Populated busboard.

TECHNICAL DATA

| | |
|------------------------------|--|
| Sensitivity | |
| dynamic PU | 2.4 mV r.m.s. |
| line inputs | 150 mV r.m.s. |
| Input impedance | 47 k Ω |
| Output voltage | |
| nominal | 1 V r.m.s. |
| maximum | 9.5 V r.m.s. |
| Output impedance | |
| | <100 Ω |
| Bandwidth | |
| dynamic PU | 20 Hz–20 kHz \pm 3 dB |
| line inputs | 5 Hz–1 MHz \pm 0.5 dB |
| | (load = 10 k Ω) |
| Signal/noise ratio | |
| dynamic PU | >80 dB (linear) |
| line inputs | >100 dB (linear) |
| | (inputs shorted) |
| Channel separation | |
| | >100 dB (1 kHz) |
| | >70 dB (20 kHz) |
| | ($Z_{source} = <600 \Omega$) |
| Cross-talk | |
| | >100 dB (1 kHz) |
| | >80 dB (20 kHz) |
| Harmonic distortion <0.003% | |
| | (line in, $U_o = 1$ V) (20 Hz–20 kHz) |
| Intermod. distortion <0.005% | |
| | (line in, $U_o = 1$ V) (250 Hz/4 kHz, 4:1) |

PARTS LIST

Resistors:

$R_1, R_3, R_5, R_7, R_9, R_{11}, R_{19}, R_{21}, R_{23}, R_{25}$
 R_{27}, R_{29} = see text (Part 1)
 $R_2, R_4, R_6, R_8, R_{10}, R_{12}, R_{20}, R_{22}, R_{24},$
 $R_{26}, R_{28}, R_{30} = 47$ k Ω
 $R_{13}, R_{14}, R_{31}, R_{32} = 100 \Omega$
 $R_{15}, R_{16}, R_{33}, R_{34} = 47 \Omega$
 $R_{17}, R_{18}, R_{35}, R_{36} = 1$ M Ω

Capacitors:

$C_1, C_3, C_5, C_7 = 47$ nF, ceramic
 $C_2, C_4, C_6, C_8 = 47$ μ F, 25 V

Semiconductors:

$IC_1 =$ NE5532
 $IC_2 =$ AD172 (NE5532 - see text)

Miscellaneous:

$S_1, S_2 =$ 2-pole, 6-position rotary switch for PCB mounting
 K_1 – $K_{20} =$ 3.5 mm audio chassis socket
 PCB Type 890169-1

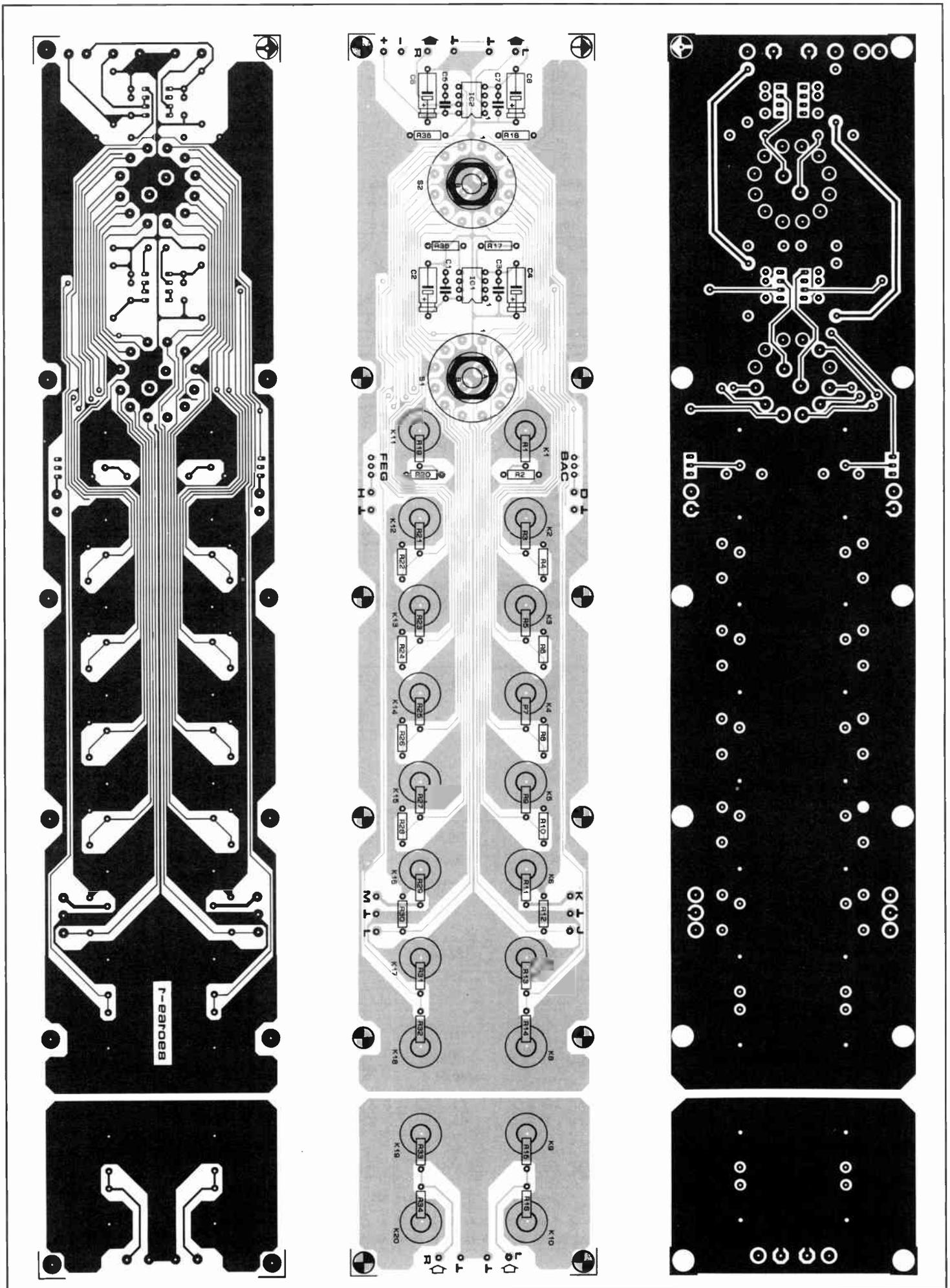


Fig. 6. Printed-circuit busboard. Note that these drawings are reproduced here at 71% of true size.

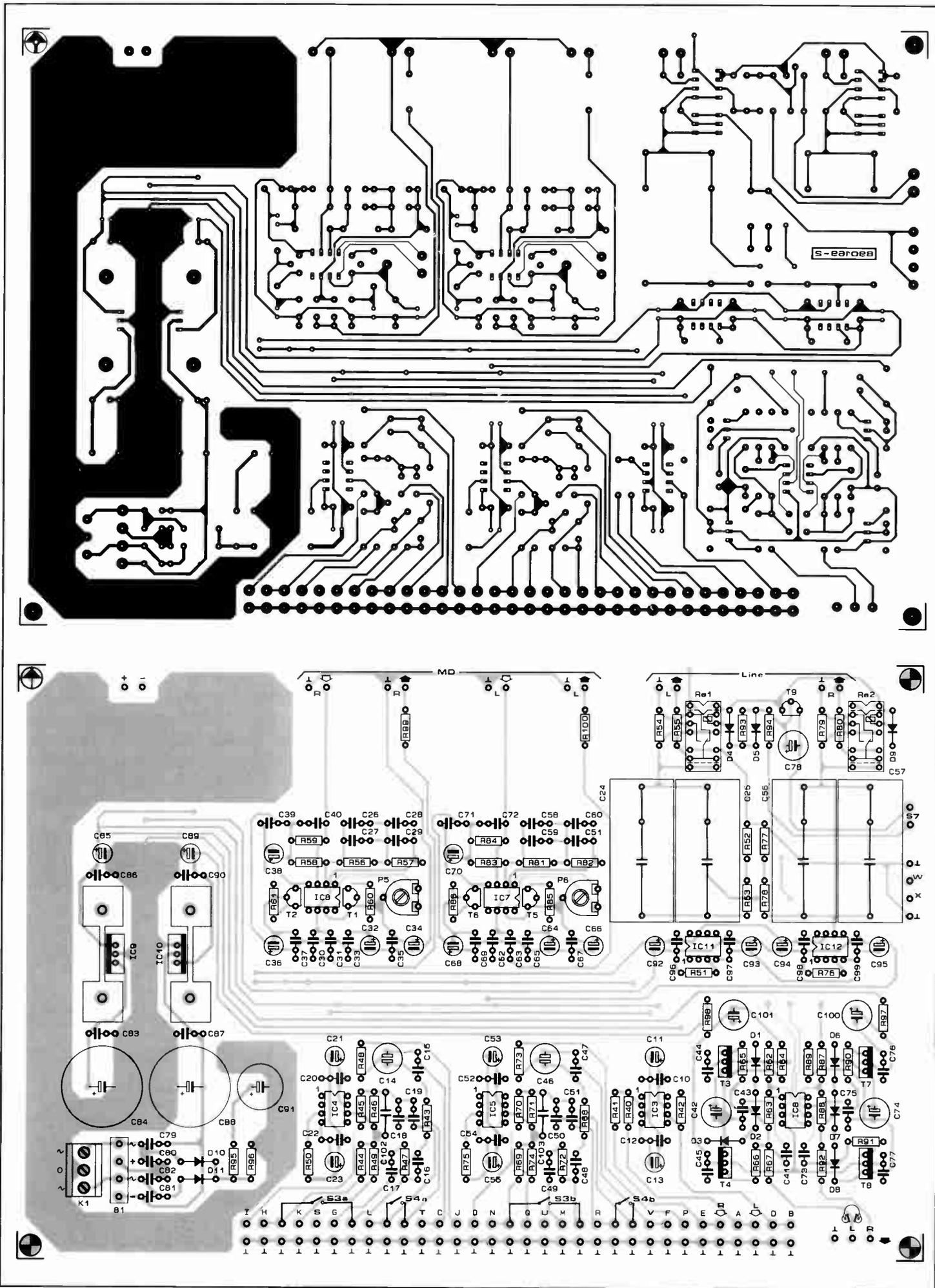


Fig. 7. Printed-circuit motherboard. Note that these drawings are reproduced here at 71% of true size.

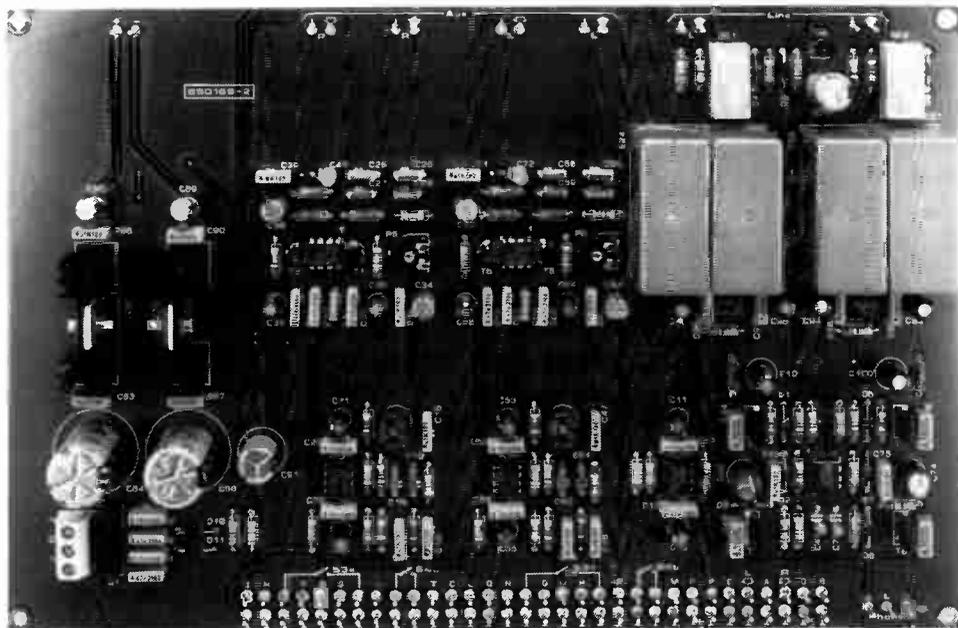


Fig. 8. Populated motherboard.

PARTS LIST

Resistors:

R₄₀, R₄₁, R₄₃, R₄₄, R₆₃, R₆₄, R₆₈, R₆₉, R₈₈, R₈₉ = 6k8

R₄₂ = 3k3

R₄₅, R₆₀, R₆₁, R₇₀, R₈₅, R₈₆ = 12 k

R₄₆, R₄₇, R₅₁, R₇₁, R₇₂, R₇₆ = 1 M

R₄₈, R₄₉, R₇₃, R₇₄ = 2k2

R₅₀, R₇₅ = 18 k

R₅₂, R₇₇ = 1 k, 1%

R₅₃, R₇₈ = 5k62, 1%

R₅₄, R₇₉ = 10 k

R₅₅, R₈₀ = 47 Ω

R₅₆, R₈₁ = 88k7, 1%

R₅₇, R₈₂ = 7k5, 1%

R₅₈, R₈₃ = 154 Ω, 1%

R₅₉, R₈₄ = 47k5, 1%

R₆₂, R₈₇ = 1 k

R₆₅, R₈₆, R₉₀, R₉₁ = 27 Ω

R₆₇, R₈₂, R₉₄, R₉₉, R₁₀₀ = 100 Ω

R₉₃ = 47 k

R₉₅ = 68 Ω, 1/2 W

R₉₆ = 2k7

R₉₇, R₉₈ = 4Ω7

P₁ = 10 k log. stereo potentiometer

P₂ = 10 k balance control

P₃ = 22 k (or 25 k) potentiometer

P₄ = 10 k linear potentiometer

P₅, P₆ = 10 k preset potentiometer

Capacitors:

C₁₀, C₁₂, C₂₀, C₂₂, C₃₃, C₃₇, C₅₂, C₅₄, C₆₅, C₆₉,

C₇₆, C₈₀, C₈₁, C₈₂, C₉₅ - C₉₈ = 47 nF ceramic

C₁₁, C₁₃, C₂₁, C₂₃, C₃₂, C₃₅, C₅₃, C₅₅, C₆₄, C₆₈,

C₈₂ - C₈₅ = 47 μF, 25 V, radial

C₁₄, C₁₆ = 10 μF, 40 V, bipolar, radial

C₁₈, C₁₉, C₁₇, C₃₅, C₃₉, C₄₃, C₄₇, C₄₈, C₄₉, C₆₇,

C₇₁, C₇₃, C₈₃, C₈₆, C₈₇, C₉₉ = 100 nF

C₁₅, C₃₀ = 1n8

C₁₆, C₃₁ = 1n2

C₂₄, C₂₅, C₂₆, C₅₇ = 10 μF, MKP or MKT

C₂₈, C₂₇, C₂₉, C₉₀ = 18 nF, 1%, MKT

C₂₉, C₉₀ = 5n6, 1%, MKT

C₂₉, C₆₁ = 379, 1%, MKT

C₃₀, C₈₂ = 47 nF, 1%, MKT

C₃₁, C₆₃ = 120 nF, 1%, MKT

C₃₄, C₃₈, C₅₆, C₇₀, C₈₅, C₈₉ = 10 μF, 25 V, radial

C₄₀, C₇₂ = 47 pF, polystyrene

C₄₁, C₇₃ = 100 pF, polystyrene

C₄₂, C₇₄ = 100 μF, 10 V, radial

C₄₄, C₄₅, C₇₆, C₇₇ = 150 nF

C₇₈, C₉₁ = 220 μF, 25 V, radial

C₈₄, C₈₈ = 2200 μF, 40 V, radial

C₁₀₀, C₁₀₁ = 100 μF, 25 V, radial

C₁₀₂, C₁₀₃ = 150 pF, polystyrene

Semiconductors:

D₁-D₄, D₆-D₉ = 1N4148

D₅, D₁₀, D₁₁ = 1N4001

B₁ = B80C1500

T₁, T₅ = BC550C

T₂, T₆ = BC560C

T₃, T₇ = BD139

T₄, T₈ = ED140

T₉ = BC517

IC₃, IC₄, IC₅ = OP27

IC₆, IC₇ = LT1028CN8

IC₈ = NE5532

IC₉ = 7415

IC₁₀ = 7915

IC₁₁, IC₁₂ = NE5534

Miscellaneous:

S₃, S₄ = DPST miniature toggle switch

S₅, S₆ = DPCO miniature toggle switch

S₇ = SPST miniature toggle switch

Re₁, Re₂ = 12 V relay, 1 CO contact

1 off 6.3mm stereo audio socket

2 off heat sink for IC₉ and IC₁₀

1 off 3-way PCB-type terminal block

1 off DPST mains press button switch

1 off fuse holder with 315 mA slow fuse

1 off strain relief sleeve

1 off mains transf. 2x15 V, 1 A

1 off PCB Type 890169-2

1 off front panel foil Type 890169-F

inputs. An inexpensive but good choice is the TL072, which has FET inputs but a rather-higher noise figure.

IC₂. The same considerations as for IC₁ apply, but in this position it is even more important to have a type with a low offset voltage, because all deviations between input and output are amplified. In view of the switching clicks and level changes that occur when a different input channel is selected, opamps with FET inputs are preferred. Both conditions are met by the AD712, OP249, OPA2107 and OPA2604. The least expensive choice is the TL072 (but remember its noise figure).

IC₃. In this, the mono count, position a low-noise opamp is essential: the OP27, 5534A and SSM2134 are suitable. The last two types are not unity-gain stable, however, which makes it necessary to fit a 22 pF capacitor between pins 5 and 8 at the underside of the motherboard. FET inputs are not necessary. Again, a TL072 may be used where economy is a must.

IC₄ and IC₅. The same considerations as for IC₃ apply: remember the 22 pF capacitors if a 5534A or SSM2134 is used.

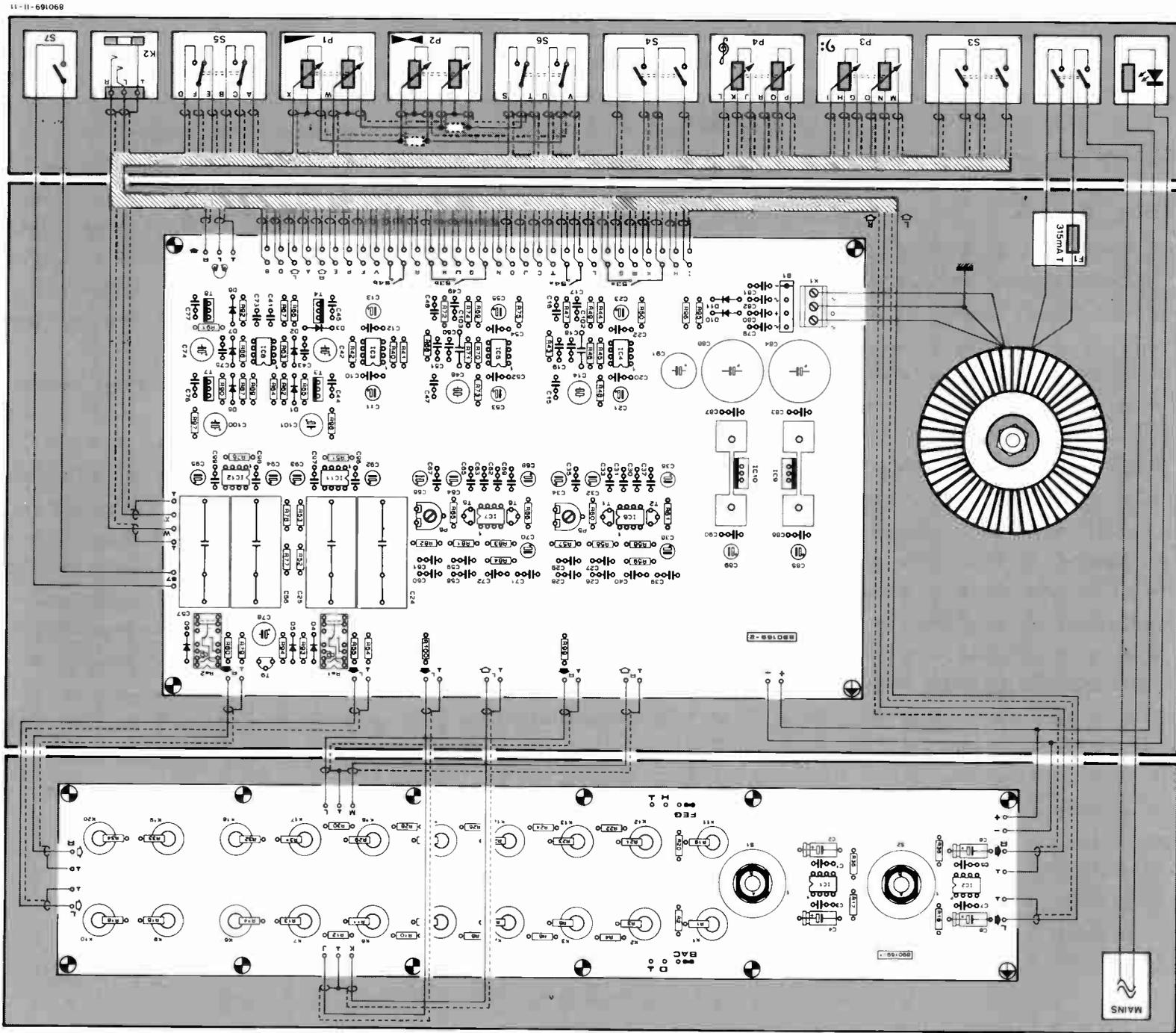
IC₆ and IC₇. Because very low noise in the dynamic pick-up circuit is imperative, a Linear Technology Type LT1028 would be ideally suitable in these positions, were it not for a tendency to become unstable (for reasons we have not been able to ascertain) and, therefore, the same manufacturers' Type LT1115 is preferred. This type has virtually the same specification as the 1028, but does not become unstable. A less expensive choice is the OP27, while the 5534A and SSM2134 would also be suitable. These last two types require, apart from the 22 pF capacitor mentioned earlier, a change of value to 100 kΩ for presets P₅ and P₆.

IC₈. In this, the headphone amplifier, position, very low noise is a prime requirement, and this is met by the Signetics Type 5532 or 5535, an SSM2132, an LM833 or an OP27. If the preamplifier will be required to deliver regularly fairly large output voltages, i.e. larger than the nominal 1 V r.m.s., a type with FET inputs should be used in this position. The inputs of the 5532, for instance, are provided with protection diodes that may cause small d.c. voltages at the line output if the amplifier is overdriven.

IC₁₁ and IC₁₂. The prime reason for using a 5534 in this position is its facility to provide sufficient current to low impedances (<600 Ω), but the SSM2134 is also suitable. Most opamps with FET inputs do not perform well with such low impedances. If the load on the preamplifier is never likely to be below 2 kΩ, an AD711 or TL071 may also be used.

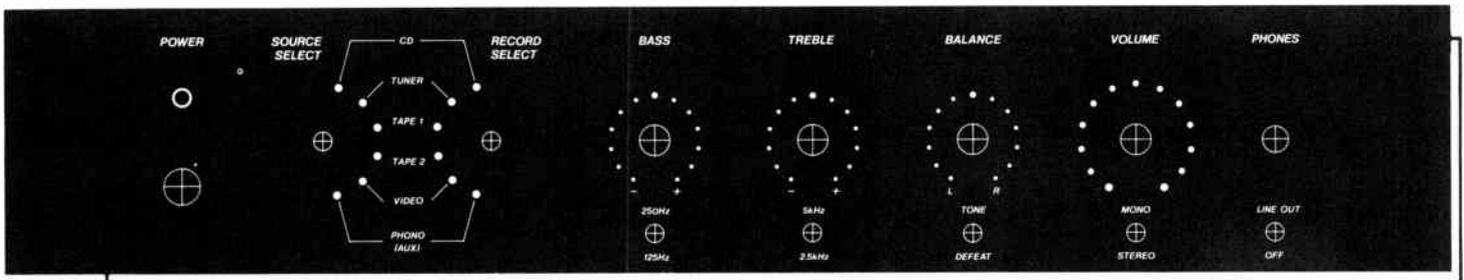
Construction

It is better not to use IC sockets: we believe that each extra point of contact, and this applies particularly to IC sockets, degrades the quality of any audio circuit. Our preference is to solder ICs on to the board, although we admit that sockets enable the quick and easy exchanging of ICs to compare their performance.



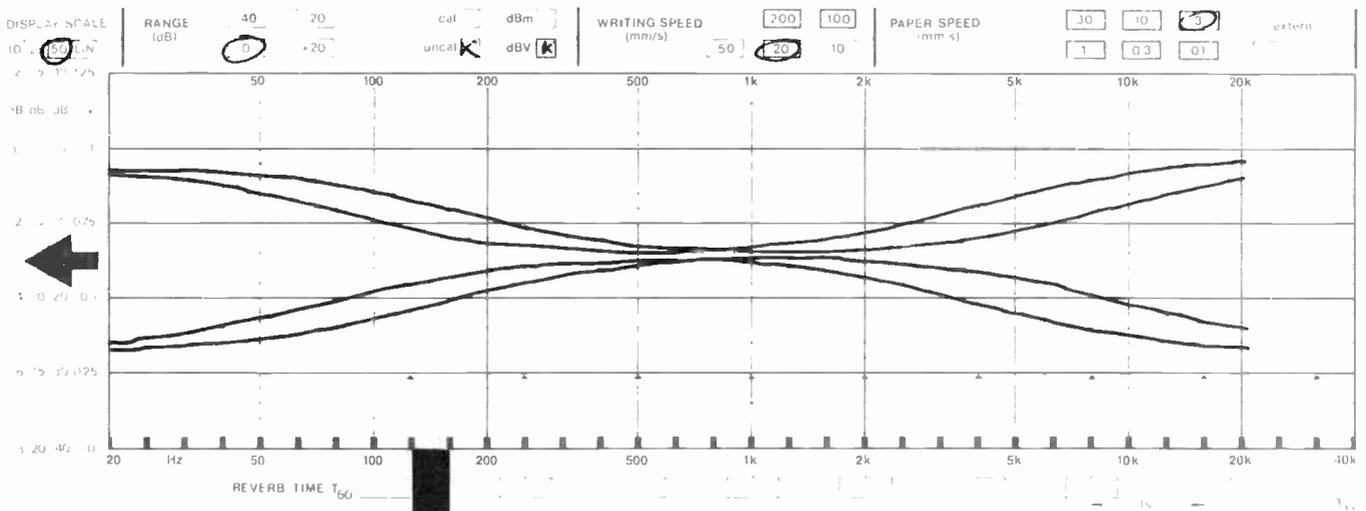
990169-11-11

Fig. 9. Wiring diagram.



890169F

Fig. 10. Front panel foil (available through our Readers' services).



890169

Fig. 11. Tone control characteristics.

Populating the boards should not give any difficulties. Fit solder pins at all input and output points: this will make the wiring later on that much easier. On the motherboard solder a wire bridge between J and K and between L and M if you do not intend to use the dynamic pick-up amplifier. Wire bridges are also required between A and B and between E and F.

Note that both voltage regulators need an individual heat sink.

Once the boards have been completed, they can be fitted in the enclosure when this has been prepared. As shown in the wiring diagram in Fig. 9, the motherboard fits into the left-hand side of the enclosure to enable the extension spindles of the rotary switches to just clear the heat sinks of the voltage regulators. At the right-hand side there is space for the mains transformers.

The layout of the front panel—see Fig. 10—determines the location of the busboard at the back of the enclosure. Depending on the dimensions of the enclosure, a mains input plug with integral fuse holder or a mains cable entry with strain relief may be used. In the last case, a fuse holder must be fitted within the enclosure, preferably near the transformer.

Photocopies of the front panel foil (shown in Fig. 10 at a scale of 3:4) and of the bus-

board (Fig. 6) may be used as templates for drilling the required holes in the front and rear panels respectively.

Once the enclosure is ready, the boards and the various controls can be fitted. If Bourns potentiometers are used, make sure that these have 6.3 mm spindles and not the usual 6 mm ones.

Finally, the inter-wiring can be carried out. Take good care to insulate all mains-voltage carrying parts. All signal wires should be screened, but their diameter should not exceed 5 mm to prevent difficulties in soldering them to the motherboard where they are very close together.

The wiring between bus- and motherboard should be carried out first, followed by that between the boards and the controls on the front panel and finally the power lines.

Although the screen of each and every signal line is connected to a separate solder pin, only those at the volume and balance controls are actually connected to the earth line: those of all other screened cables are left unconnected. The enclosure earth is connected to the mains earth and this is the only real earth connection of the preamplifier.

The output socket of the headphone amplifier must be well insulated from the enclosure to avoid earth loops ■



MEASUREMENT TECHNIQUES (5)

by F.P. Zantis

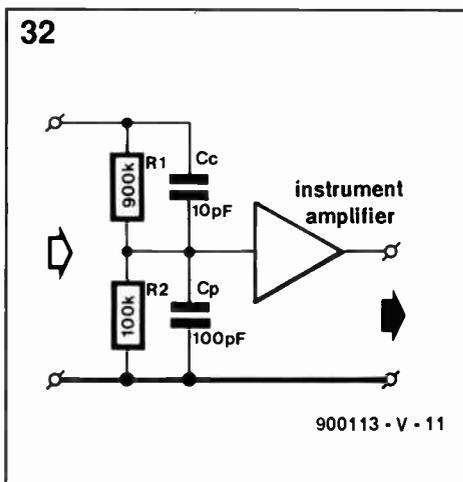
Audio-frequency technology is of particular interest to many electronics enthusiasts since it seems to surround us in our everyday life in the shape of television and broadcast receivers, audio amplifiers, equalizers, and so on. To keep such apparatus in tip-top condition, it is important to be able to test and check it with suitable equipment.

The first question that arises when audio-frequency (AF) equipment is to be checked or tested is what test gear is suitable. For example, a multimeter is only suitable if it is designed to work at frequencies between 30 Hz and 16,000 Hz. Such instruments are pretty expensive: a less expensive alternative is an audio-frequency millivoltmeter. Often, such an instrument is not readily available, but an oscilloscope is, and this is perfectly suitable for audio-frequency measurements. Even the simplest oscilloscope has an operating range extending from DC to about 10 MHz. It should be noted, however, that an oscilloscope measures peak values, while a multimeter or AF millivoltmeter measures root-mean-square (r.m.s.) values.

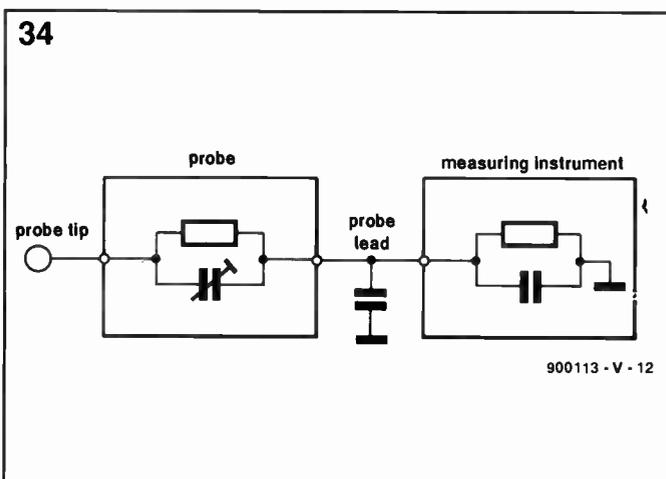
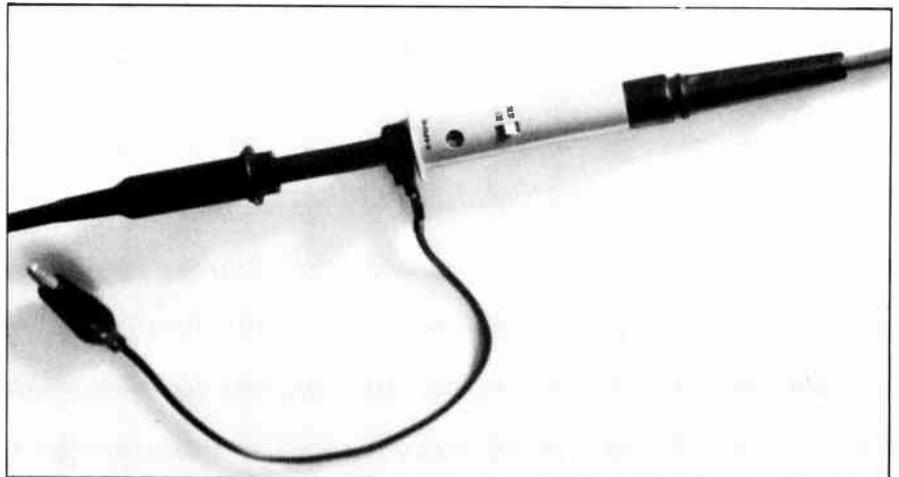
Apart from an oscilloscope or AF millivoltmeter, a function generator is required to provide sinusoidal and rectangular voltages in the audio frequency range.

The input resistance of most AF millivolts and oscilloscopes is of the order of 1 M Ω . The resistors of the input voltage dividers in all test equipment intended for AF measurements are shunted by small capacitors of 1–500 pF. The reason for these becomes clear from Fig. 32. Here, the lower resistor of the 1:10 divider is shunted by the parasitic capacitance, estimated at 100 pF, contained in the wiring and circuit. At a frequency of 16 kHz, this capacitance has a reactance of some 100 k Ω , which reduces the lower branch of the divider to 50 k Ω .

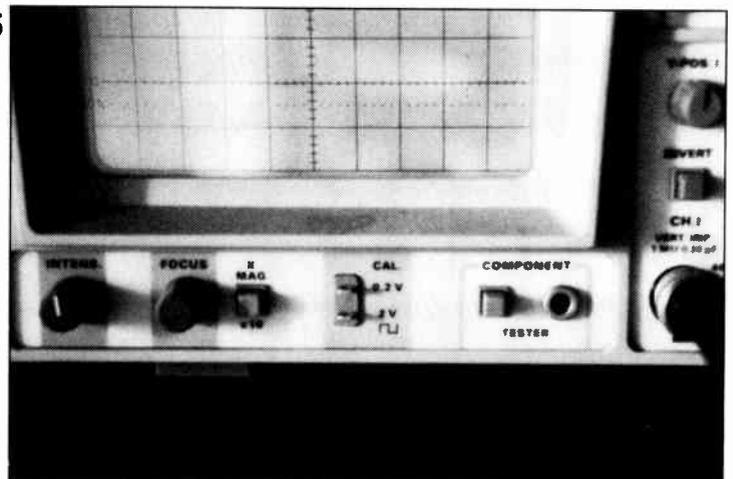
Clearly, this will cause a serious error in the measurement. To obviate this, a compensating capacitor is connected in parallel with the upper resistor of the divider. This solution has a disadvantage, however, in that the load presented by the measuring instrument to the measurand depends on the frequency, which is the reason for the limited frequency range of most instruments. The value of the input (i.e., compensating) capacitance is therefore always clearly stated on all instruments intended for operation at audio or high frequencies. The smaller it is, the better (and more expensive) is the instrument. But here again, when the cause of the error is known, its effect can be estimated fairly accurately. Also, it should be remembered that



33



35



WorldRadioHistory

error-free measurements are not possible.

The capacitance of the screened cable of a probe as shown in Fig. 33 also affects the measurement and it has therefore to be compensated in a similar manner. For this, a variable trimmer as shown in Fig. 34 is normally used. The probe is calibrated with the aid of a rectangular voltage. Such a signal consists of a large number of sinusoidal voltages superimposed on each other. If one or more of these sinusoidal voltages is attenuated, the rectangular signal becomes rounded. Most oscilloscopes have an integral 1 kHz rectangular-signal generator for this purpose as shown in Fig. 35 (CAL). The frequency of this signal is often not very precise, although its level is stabilized and stated in the technical specification, for instance, 0.2 V

peak-to-peak $\pm 1\%$. The compensating capacitor is adjusted until the waveform on the screen of the oscilloscope is truly rectangular as shown at the centre of Fig. 36.

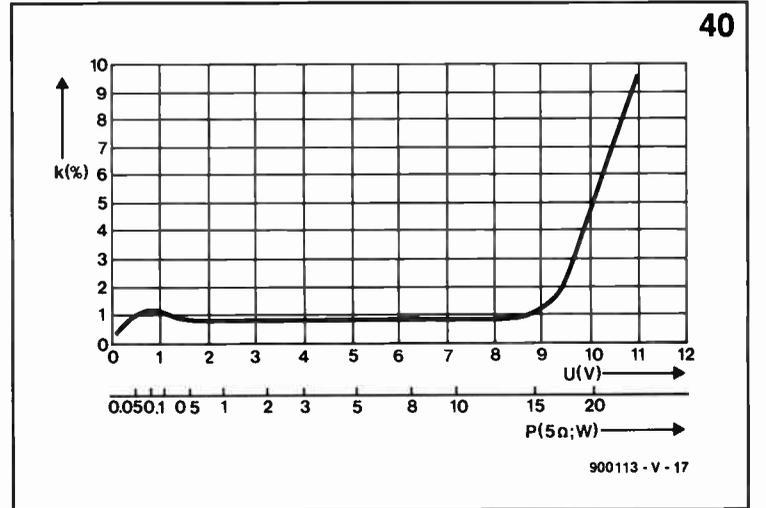
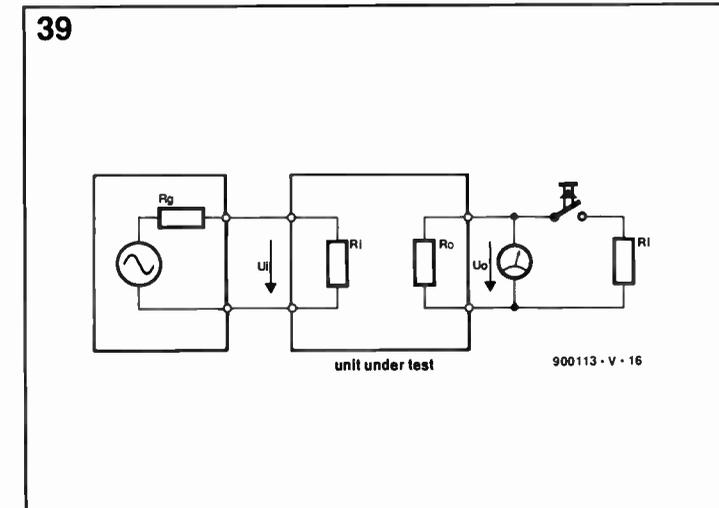
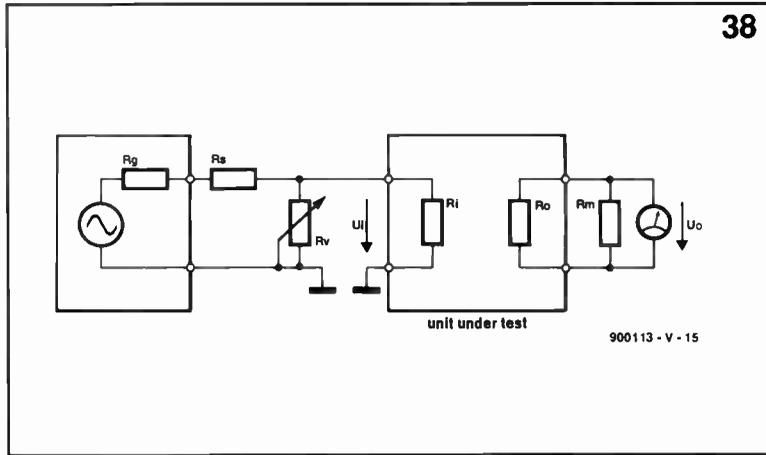
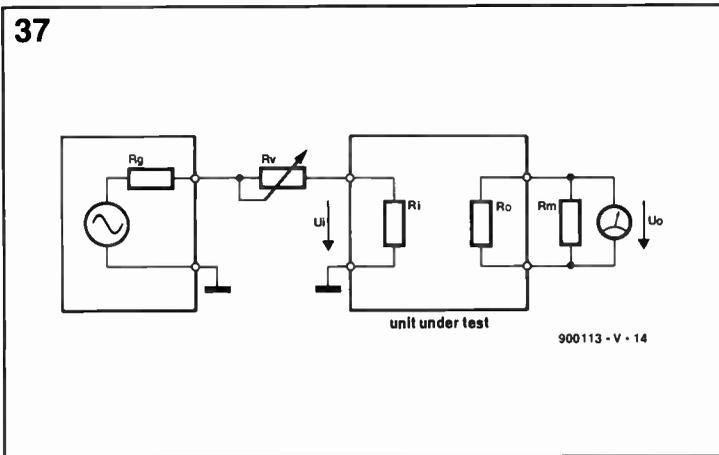
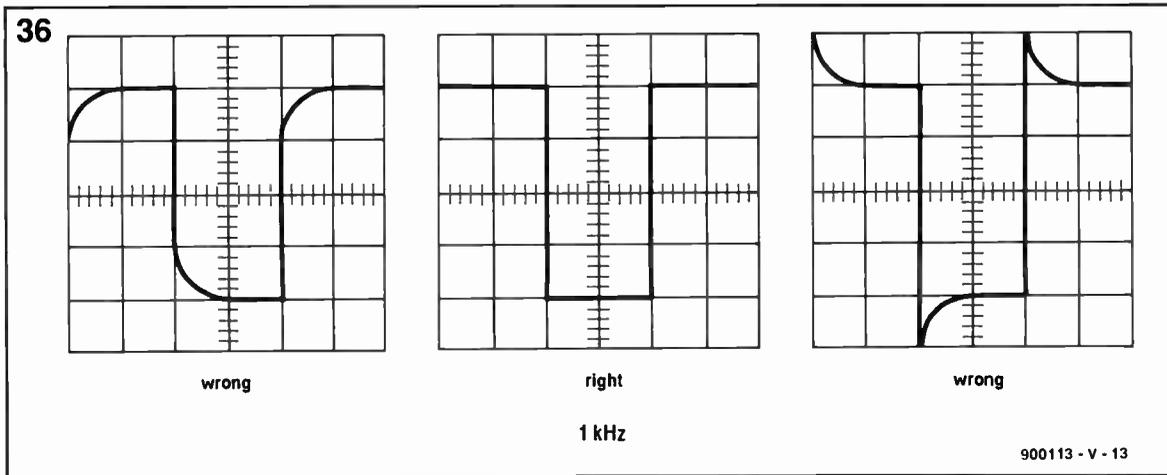
Measuring input and output resistance

The input resistance, R_i , of an audio circuit may be measured with a set-up as shown in Fig. 37 if it is appreciably larger than the internal resistance, R_g , of the signal generator. The output frequency of the generator is 1 kHz. A variable resistor, R_v , needs to be inserted between the generator and the amplifier input. To keep the error introduced by the load presented by the measuring instrument small, the output voltage rather

than the input voltage of the amplifier is measured. If $R_v = R_i$, the input voltage of the amplifier is halved, and so, of course, is its output signal. To be exact, R_g should be added to R_v . If the input resistance of the amplifier is very low, the test set-up shown in Fig. 38 should be used.

The output resistance of an amplifier may be ascertained with the set-up shown in Fig. 39. The unit under test, i.e., the amplifier, is driven, but not over-driven, by a tone generator. First, the open-circuit output voltage, U_1 , is measured and then the output voltage, U_2 , across R_L . From the values of these voltages the output resistance, R_o , may be calculated as follows

$$R_o = R_L \{ [U_1 - U_2] / U_2 \}$$



Some older amplifiers may have a tendency to become unstable under open-circuit conditions and then generate large spurious signals that not only invalidate the measurement, but may also damage the amplifier and the measuring instrument. It is therefore advisable to monitor the waveform at the output with an oscilloscope. This will also indicate if the amplifier is overdriven, which would also invalidate the test results.

the output power is specified at a distortion of 1%. If therefore the output power needs to be measured exactly, a distortion meter must be used as shown in Fig. 41. The amplifier, terminated into its nominal load R_L , is then driven till a distortion of 1% is indicated. The output power, P_o , is then

$$P_o = U_o / R_L$$

power ratio or twenty times the common logarithm of the voltage or current ratio. Thus, if two powers P_1 and P_2 differ by n decibels,

$$n = 10 \log_{10} [P_1 / P_2]$$

and, if two voltages or currents differ by n decibels,

$$n = 20 \log_{10} [U_1 / U_2]$$

or

$$n = 20 \log_{10} [I_1 / I_2]$$

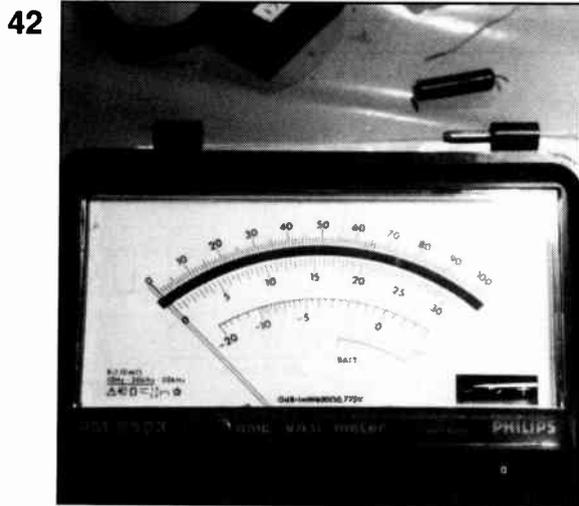
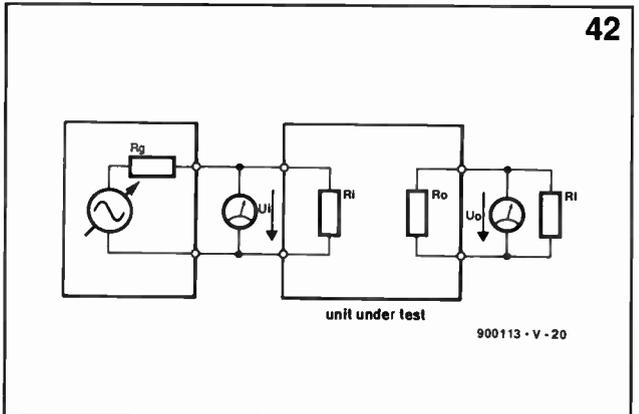
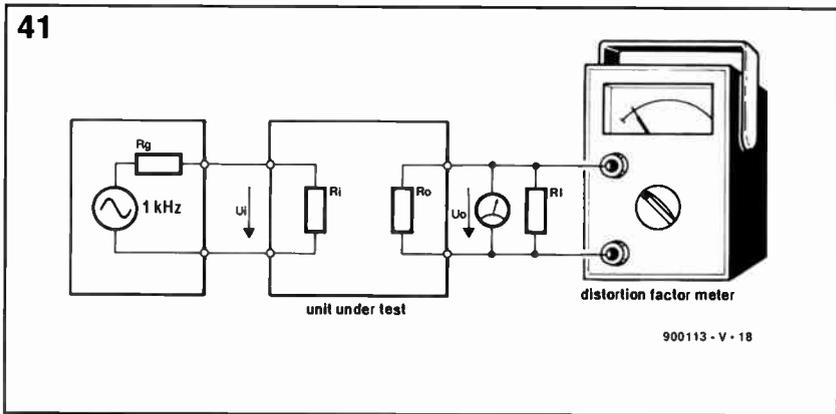
Low-frequency millivoltmeters and some good-quality multimeters have a decibel scale (see Fig. 43—lowest scale) that enables the ratio to be read directly. If, for instance, the gain of an amplifier is to be measured,

Measuring output power

The specification of the output power of an amplifier is of practical use only if it includes the distortion, which is an indication of the non-linearity of the amplifier. The distortion increases rapidly when the amplifier is over-driven as shown in Fig. 40. Normally,

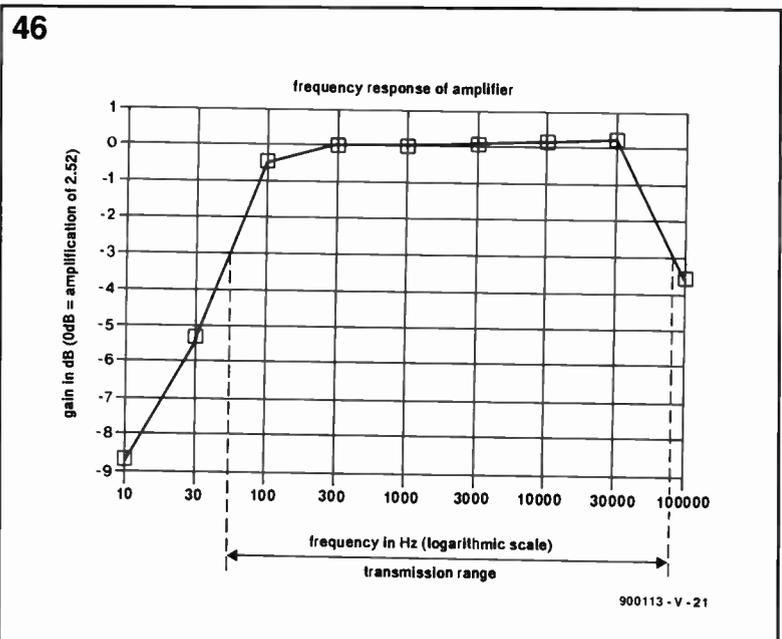
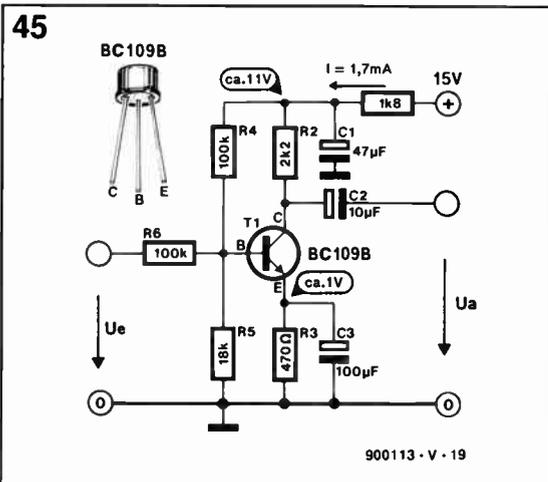
The decibel scale

The behaviour of audio components is often better observed on a logarithmic scale, which is calibrated in bel, B, or a tenth of this, the decibel, dB. These are dimensionless units expressing the ratio of two powers, currents, voltages, or sound intensities. The decibel is ten times the common logarithm of the



44

| f/Hz | A/dB |
|--------|----------|
| 10 | -8.67311 |
| 30 | -5.29 |
| 100 | -0.46962 |
| 300 | 0.0506 |
| 1000 | 0 |
| 3000 | 0.101 |
| 10000 | 0.200839 |
| 30000 | 0.2008 |
| 100000 | -3.52182 |



the amplifier is driven by a 1 kHz signal at a level at which it just is not over-driven. An AF millivoltmeter is connected across its input and the decibel scale read and noted. Then, the millivoltmeter is connected across its output and the decibel scale again read and noted. If the output is greater than the input, the difference between the two readings is the gain in dB; if the input is greater than the output, the difference is the attenuation in dB.

Measuring frequency response

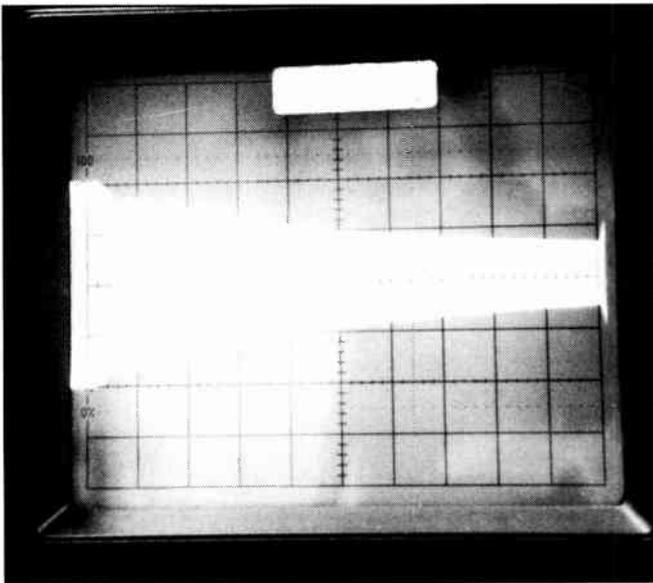
The circuit diagram of a small audio amplifier is shown in Fig. 45. Its frequency response may be determined in a manner similar to that used for measuring its gain: the test set-up is shown in Fig. 42. With a 1 kHz signal input, the level is set to give an output of 0 dB. The decibel readings are noted when the frequency is changed to, say, 10 Hz, 30 Hz, 100 Hz, 300 Hz, 3000 Hz, 10,000 Hz, and 30,000 Hz. The more frequencies are used, the more exact the test result will be. A voltmeter is used in parallel with the signal generator to make sure that the input level to the amplifier remains the same. From

the results, tabulated in Fig. 44, a frequency response curve as shown in Fig. 46 (relating to the amplifier in Fig. 45) may be drawn. The frequency range of the amplifier is that between the two -3 dB points.

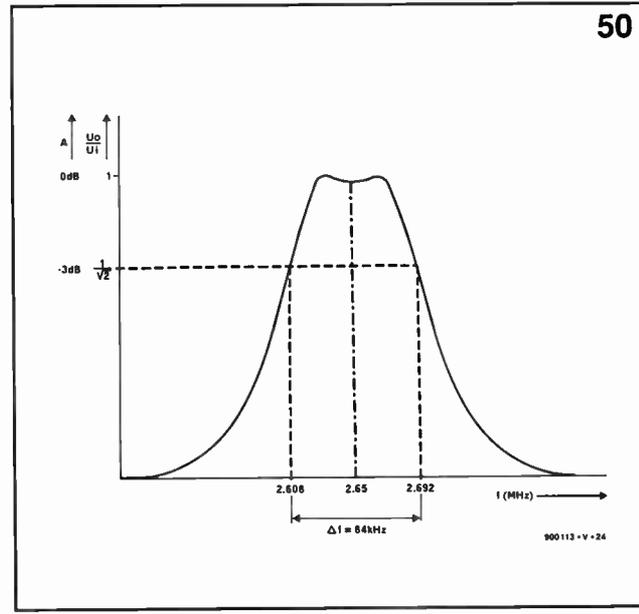
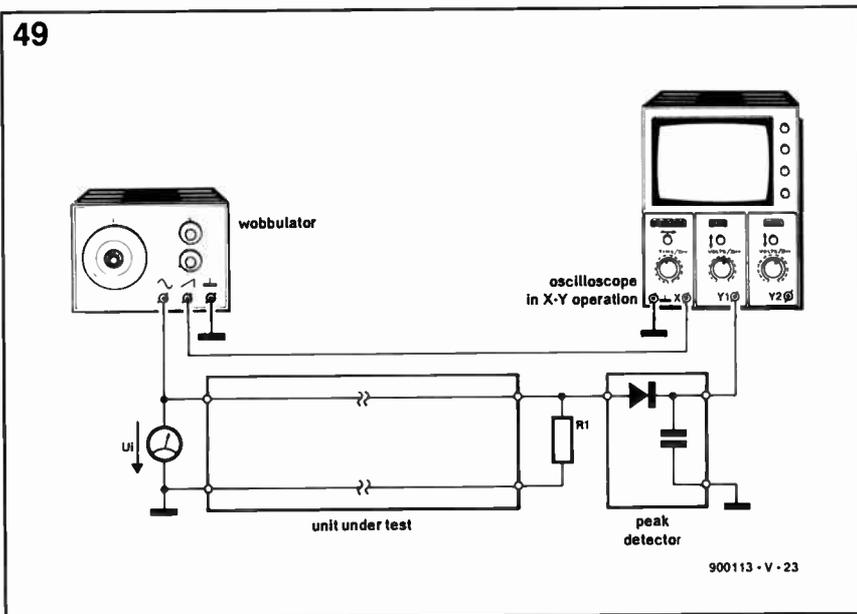
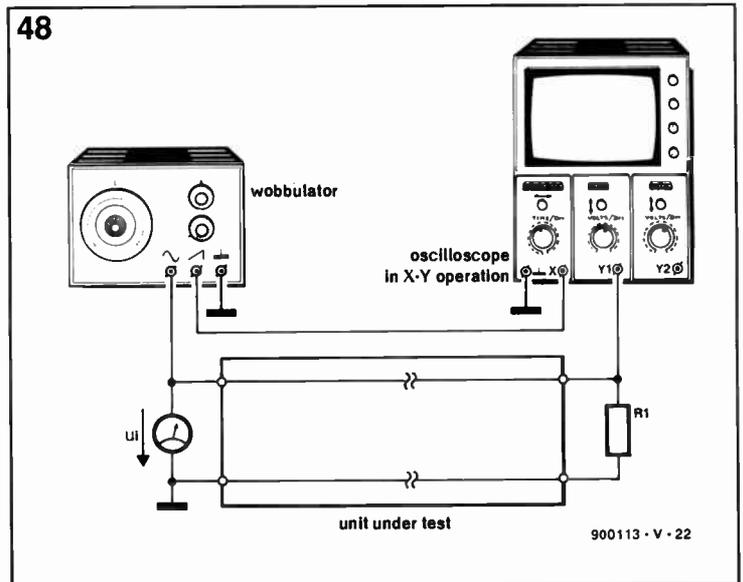
This method of determining the frequency response requires no special or expensive instruments, but it is very time-consuming. Far more convenient is the use of a wobulator, whose output is varied automatically over a predetermined range of frequencies. In the example discussed above, the frequencies would be varied between 10 Hz and 30,000 Hz. Moreover, its scanning rate may be synchronized with the horizontal deflection of the oscilloscope to give a stable trace on the screen. Some wobulators give an additional sawtooth output to facilitate the synchronization with the oscilloscope's horizontal time base. This sawtooth may also be used in X-Y operation to deflect the horizontal trace. Figure 47 shows the screen image during measurements on a cable in this manner. The test set-up for this is shown in Fig. 48: the frequency was varied from 10 Hz to 510 kHz; the horizontal scale was 50 kHz per division. The falling level of the signal at higher frequencies is quite evident.

The use of a wobulator gives an appreciable saving in test time and the oscilloscope always shows a complete signal period, provided the wobulator is adjusted properly. The peak-to-peak value of the signal is easily read from the screen.

The test becomes even more straightforward if the signal at the output of the unit under test is applied to the oscilloscope via a peak detector. The frequency response of the unit under test is then shown on the screen of the oscilloscope as a curve. Again, the screen shows the peak values of the signal, but these may be converted to r.m.s. values with the aid of a voltage divider. The test set-up is shown in Fig. 49, while Fig. 50 shows the result when a band-pass filter is measured in this.



47 48



DESIGN IDEAS

The contents of this article are based solely on information obtained from the author and do not imply practical experience by *Elektor Electronics*.

8-CHANNEL AUDIO/VIDEO SWITCH (PHILIPS COMPONENTS)

J. Vinckier

General description

The TDA8440 from Philips Components is a versatile video/audio switch, intended to be used in colour TV receivers equipped with an auxiliary video/audio (SCART) input.

The IC provides two 3-state switches for audio channels, and one 3-state switch for the video channel and a video amplifier with selectable gain (unity gain or 2 times).

The TDA8440 can be used in conjunction with a microcontroller from the MAB8400 family, and is then controlled via

a bidirectional I²C bus. Sufficient sub-addressing is provided for the I²C bus mode. The IC can also be controlled directly by d.c. switching signals. This option is worked out in the present application note.

Functional description

The block diagram of the TDA8440 is given in Fig. 1. The IC incorporates three 3-state switches with the following functions:

- one video switch with selectable gain (unity gain or 2 times) for switching between an internal video signal (from the TV's IC amplifier/demodulator) and an AUXILIARY input signal;
- two electronic audio switches for two sound channels (stereo or dual language), for switching between internal audio sources and signals from the AUXILIARY VIDEO/AUDIO connector.

Each switch on board the TDA8440 allows a selection to be made between two input signals and a high-impedance 'off' state. The 'off' state is necessary if more than one TDA8440 is used.

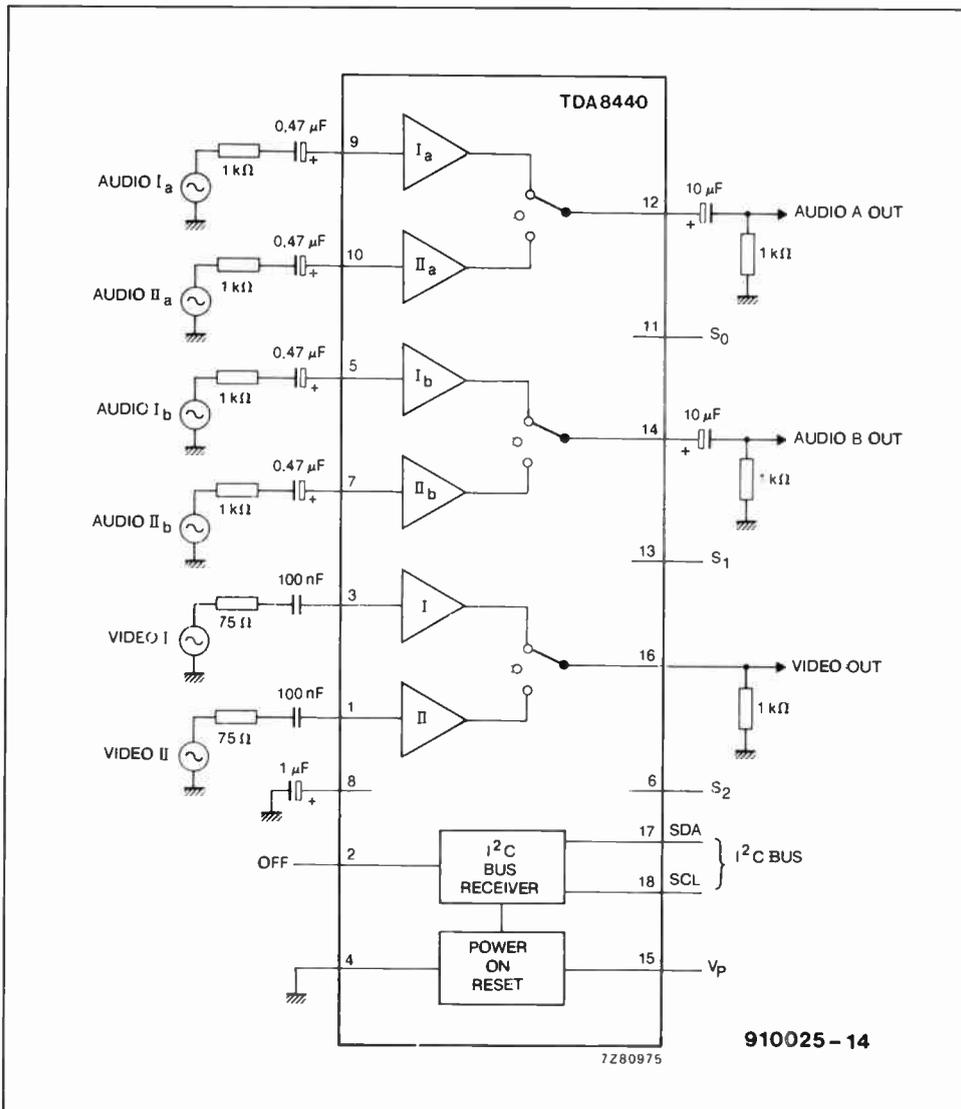


Fig. 1. Block diagram of the TDA8440 audio/video switch IC (illustration reproduced by courtesy of Philips Components).

TDA8440 MAIN SPECIFICATIONS

- Combined analogue and digital circuitry gives maximum flexibility in channel switching
- 3-state switches for all channels
- Selectable gain for the video channel
- Sub-addressing facility for I²C bus
- I²C bus or non-I²C bus mode (controlled by d.c. voltages)
- Slave receiver in the I²C bus mode
- External OFF command
- System expansion possible up to 7 devices (for 14 signal sources)
- Static short-circuit resistant outputs

The SDA and SCL pins can be connected to the I²C bus, or to d.c. switching voltages. Inputs S0 (pin 11), S1 (pin 13) and S2 (pin 6) are used for selection of sub-addressing or switching to the non-I²C bus mode.

The non-I²C bus mode is selected by making S0, S1 and S2 permanently logic high (+12 V). In this mode, the sources (internal and external), and the gain of the video amplifier can be selected via the SDA and SCL pins, by means of the switching voltage from the AUXILIARY VIDEO/AUDIO connector. The four available functions are controlled as follows:

- sources 1 are selected if SDA = 12 V (external source);
- sources 2 are selected if SDA = 0 V (TV mode);
- video amplifier gain is 2 times if SCL = 12 V (external source);
- video amplifier gain is unity if SCL = 0 V (TV mode).

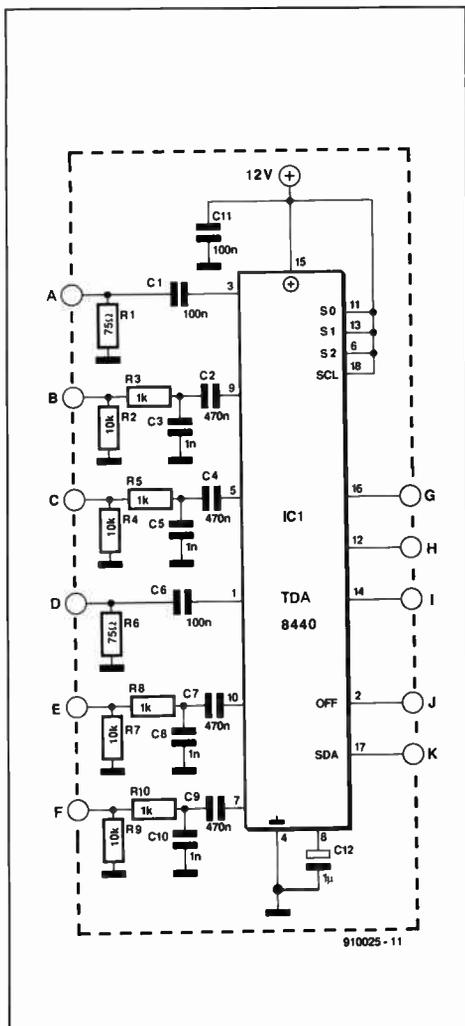


Fig. 2. Circuit diagram of the basic audio/video switching module .

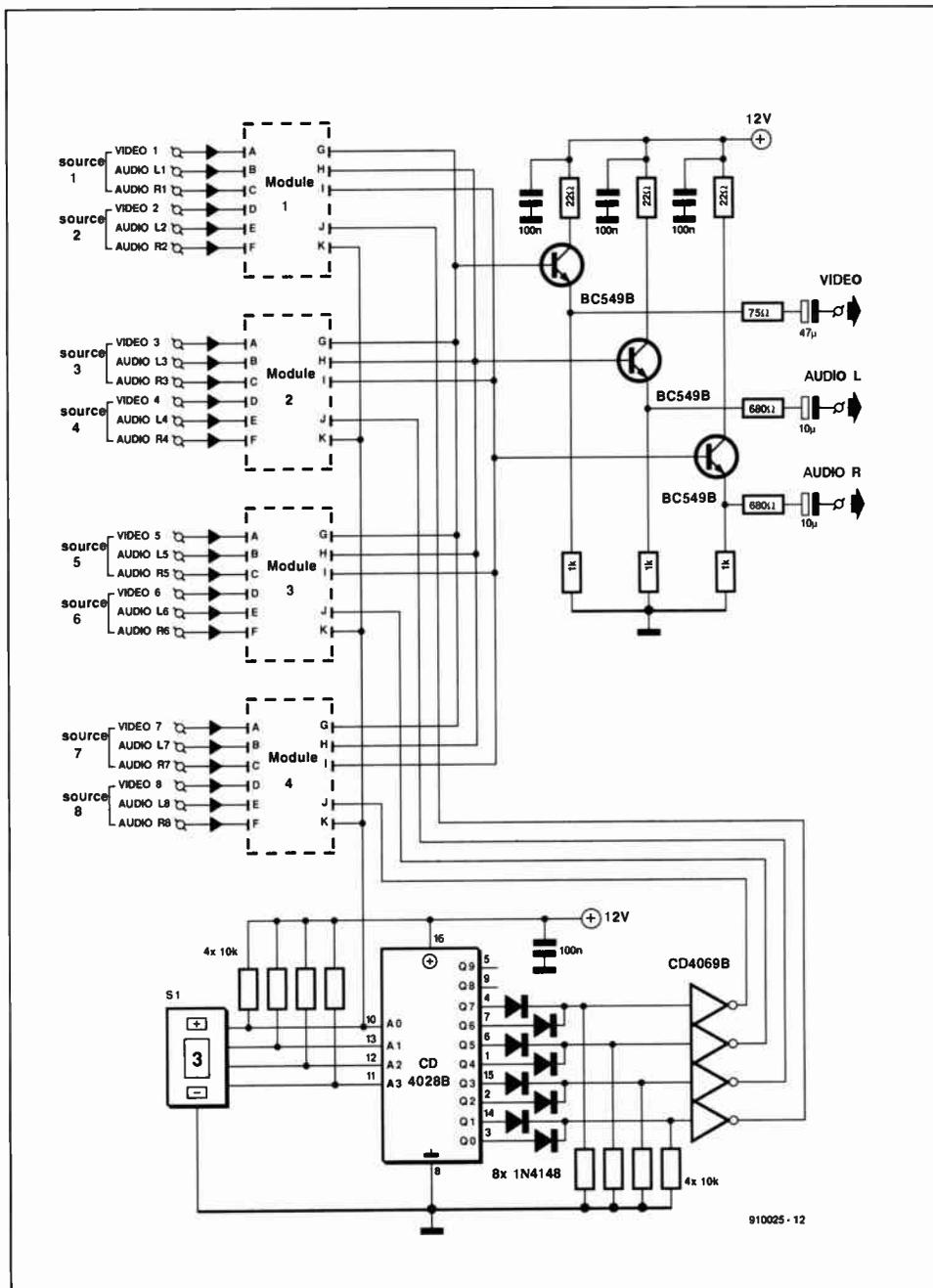


Fig. 3. Four modules as shown in Fig. 2 and a BCD thumbwheel switch interface together make a versatile eight-way electronic audio/video switch.

| switch position | BCD | | | | CD4028 decoder outputs | | | | | | | | SDA | OFF OFF OFF OFF | | | | Selection |
|-----------------|-----|---|---|---|------------------------|---|---|---|---|---|---|---|-----|-----------------|---|---|---|-----------|
| | 3 | 2 | 1 | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | | 1 | 2 | 3 | 4 | |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | - |
| 1 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 1 | 1 | source 1 |
| 2 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | source 2 |
| 3 | 0 | 0 | 1 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 1 | 1 | source 3 |
| 4 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 1 | source 4 |
| 5 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 1 | 1 | 0 | 1 | source 5 |
| 6 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 1 | 0 | 1 | source 6 |
| 7 | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 1 | 1 | 1 | 0 | source 7 |
| 8 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 1 | 1 | 0 | source 8 |

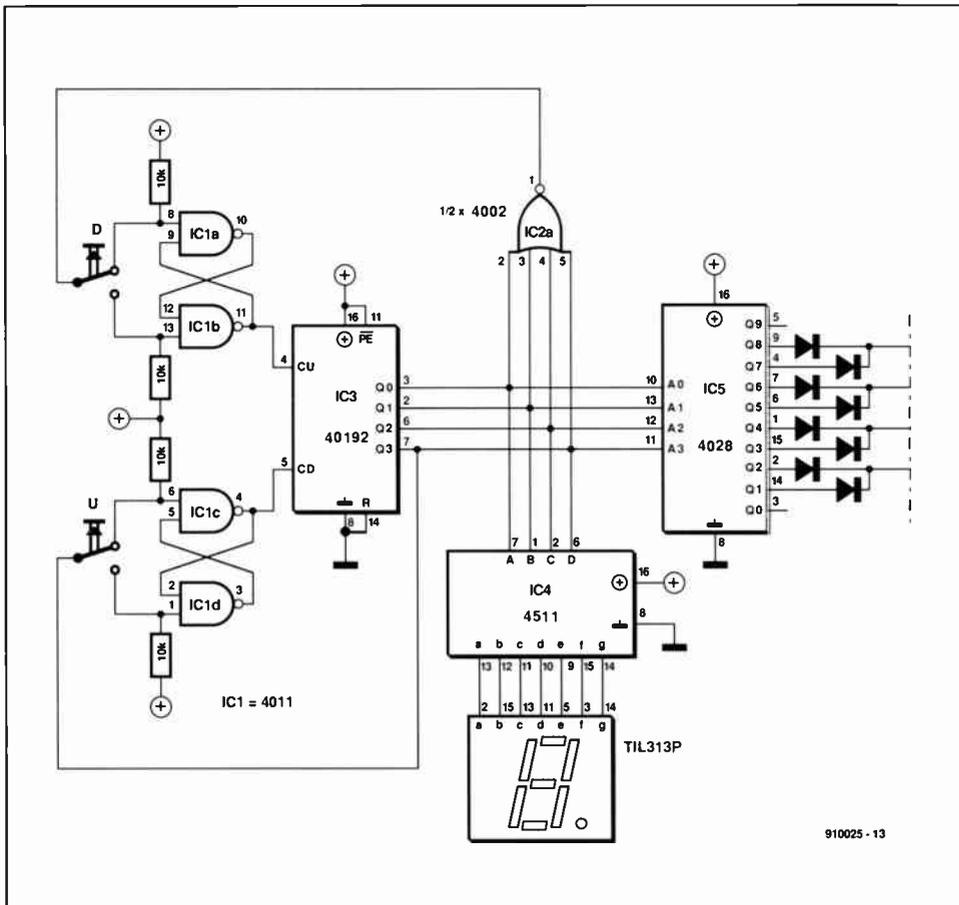


Fig. 4. A possible substitute for the BCD thumbwheel switch in the circuit of Fig. 3.

If more than one TDA8440 device is used in the non-I²C bus system, the OFF pin (pin 2) can be used to switch off the desired devices. This can be done via the 12-V switching voltage of the AUXILIARY VIDEO/AUDIO connector:

- all switches are in the high-Z (off) position if OFF = 12 V;
- all switches are in the position selected with SDA if OFF = 0 V.

Application circuits

The circuit shown in Fig. 2 is one of four identical switching modules based on the TDA8440. The two video inputs, A and D, are terminated with 75-Ω resistors, while the two stereo audio inputs (pairs B-C and E-F) are terminated with 10-kΩ resistors. The audio signals are filtered with R-C networks to suppress noise. The amplification of the video switch is set to 2 times here by the permanently high level at the SCL input. The voltage at the SDA input determines the source selection as discussed above.

The final 8-way audio/video switcher (Fig. 3) contains four modules of the type shown in Fig. 2. A thumbwheel switch with BCD-coded outputs is used to select one of eight AV channels. The LSB (least-significant bit) of the BCD switch is connected to the SDA inputs of the four modules.

The four 'module select' lines are created with a CD4028 BCD-to-decimal decoder. The eight decoded outputs of this IC are connected in pairs. Each of the four signals so obtained is inverted by a CD4069

gate to ensure the correct control of the OFF input of the relevant AV switching module. The channel selection of the 8-way switching unit is shown in the Table below Fig. 3. All channels are switched off by setting the thumbwheel switch to 0.

The audio and video outputs of the four modules are connected in parallel and buf-

fered with the aid of emitter follower stages that provide the appropriate source impedance (75 Ω for the video output and about 600 Ω for the audio outputs). The gain of the video channel is set to two times here to compensate the 6 dB voltage attenuation introduced by the series resistor at the video output and the input resistance of the load.

Connectors for the inputs and outputs are not specified here since they depend on the practical use of the switching unit. BNC sockets, phono sockets or SCART sockets may be used as required. Likewise, the switcher can be built to handle fewer or more than eight AV channels as proposed here. A simple AV switcher for two video and two audio channels, for instance, requires only one module controlled by a much simpler selection circuit than the BCD switch plus the 4028.

One application of the AV switching unit is the connection of a video recorder, a home computer and a CD player to the SCART input of the TV set, eliminating the need of changing lots of cables any time a different source is selected.

Finally, a 'discrete' replacement for the (expensive) BCD switch is given in Fig. 4. The channel selection is effected by pressing the U (up) and D (down) keys. The number of the selected channel appears on a 7-segment LED display.

Reference:

TDA8440 Development Data. Philips Components.

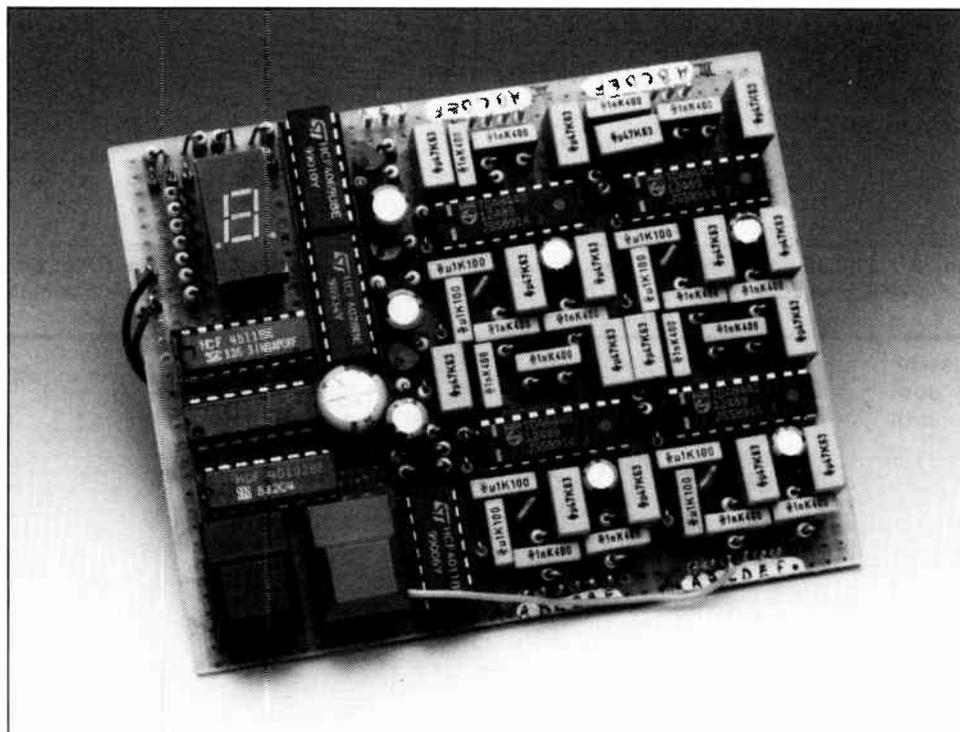


Fig. 5. Prototype of the eight-way audio/video switch built on a small piece of Vero stripboard. In this version, the unit has the up/down keys and the 7-segment LED display shown in Fig. 4 to set and visualize the selected AV channel.

ELECTRONIC EXPOSURE TIMER

by A. Ladwig

Many amateur photographers spend a disproportionate amount of their time in the dark-room. The exposure timer presented here can cut down that time because the exposure is controlled entirely electronically. That results not only in perfect prints every time, but also in a reduction in paper and chemicals used and that is good for the environment and for your wallet.

The traditional way to determine the exposure time for a photographic print is to use a test strip and expose the negative for a number of different periods. The strip is then developed and a judgment taken which exposure time is the most nearly perfect one and that time is taken to print the negative(s). Clearly, this technique wastes time, paper and chemicals. With the timer* described here, this technique becomes a thing of the past. It also ensures that the setting of the diaphragm in the enlarger does not affect the exposure meter.

The procedure with the timer is simplicity itself: the negative or slide is placed in the enlarger, the wanted size of the print is determined, the enlarger is focused, the photographic paper is placed on the easel and covered with a sheet of glass, and the start button on the timer is pressed. The electronics in the timer will ensure perfect exposure.

Principle of operation

Two methods are commonly in use to assess the correct exposure time for prints. The spot measurement is used for determining the exposure for a certain part of the photograph. This is of particular interest if the photo has sharp contrasts, such as somebody standing in the shade against a very bright background.

The second method is the integrated measurement in which the entire photograph is used to determine the correct exposure time. This is done by diffusing the light falling on to the paper with the aid of some frosted glass and measuring the light intensity.

The two methods may be combined by concentrating the integrated measurement on the light falling on the centre of the photograph, and this is the one used in the present timer. The light is measured at twelve different points spread across the paper. The diffuser is the paper on which the print will appear. This method of measurement is made possible by placing the light-sensitive cells of the exposure meter not above the paper as is usual, but underneath it. The only proviso of the method is, therefore, that the paper is translucent, which it normally is.

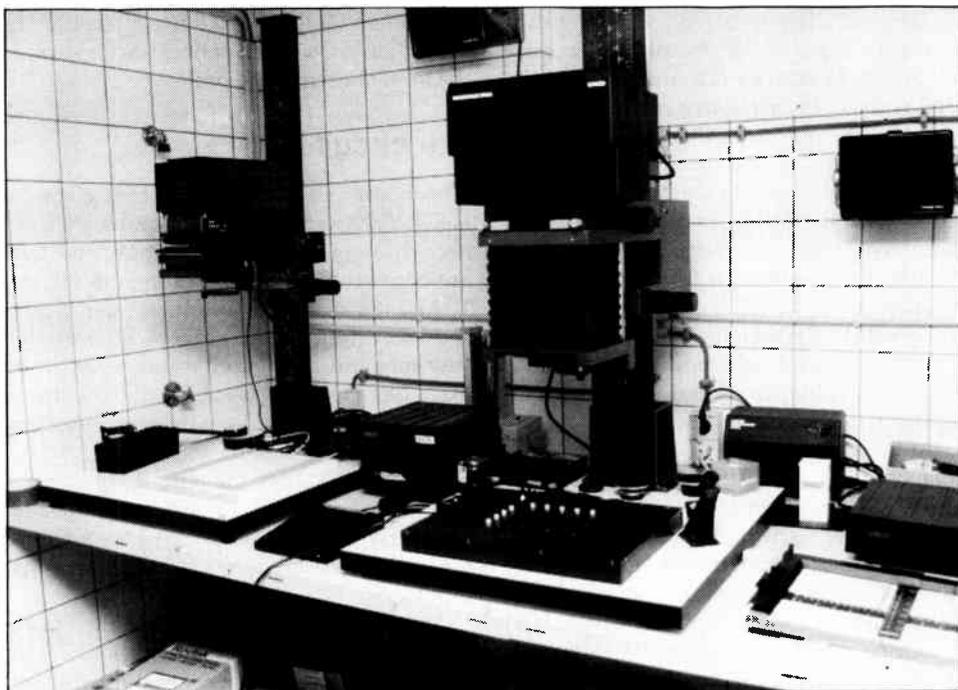


Fig. 1. The timer in use in a typical dark-room.

The design

The twelve light-sensitive cells are contained in a man-made fibre paper easel as shown in Fig. 2. Each of the cells consists of a photo-transistor Type BPW40. The easel consists of a sheet of transparent perspex (US: lucite) into which 12 holes are drilled. The cells must not protrude through the sheet (since the paper would then not lie flat and cause the photo to be distorted). The diameter of the holes should preferably be larger at the paper side than at the underside.

Since experience shows that most photos are printed in 130x180 mm (5x7 in.) format, the prototype easel has been made in that format, too, but you may, of course, decide on other dimensions.

Tests with the prototype to verify that the principle is sound resulted in output voltages at five of the cells (P₁-P₅) as shown in Table 1. The tests were made with the negative in the enlarger first not illuminated for 1 second and then exposed to maximum illumination for 32 seconds. The diaphragm of the enlarger was stopped down by two *f*-numbers. The voltages were measured with a digital volt-

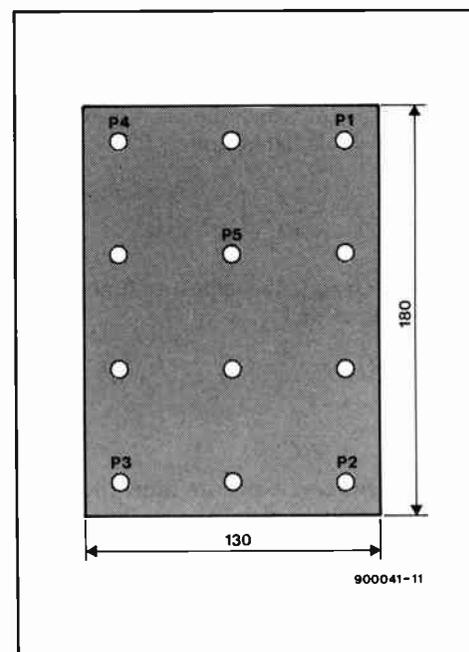


Fig. 2. Layout of the perspex (lucite) easel that houses the twelve photocells.

Patent applied for (provisional Patent No. G 90 08 446.2)

| | Exposure | |
|----------------|----------|--------|
| | Min. | Max. |
| P ₁ | 17 mV | 490 mV |
| P ₂ | 18 mV | 495 mV |
| P ₃ | 16 mV | 491 mV |
| P ₄ | 17 mV | 488 mV |
| P ₅ | 26 mV | 750 mV |

meter with $R_i = 10 \text{ M}\Omega$.

It is clear that the cell at the centre of the easel (P₅) receives more light than those at the edges. Furthermore, the tolerances of the phototransistors proved to be small enough to be of no consequence to the operation.

The block diagram in Fig. 3 shows how the output voltages of the phototransistors are processed. First, they are summed and the total voltage, U_t , is fed to a time-voltage integrator. The output of the integrator, U_{int} , is proportional to the luminous flux radiated on to the easel. The output is then compared with a reference voltage, U_r : when these two potentials are equal, the exposure is correct. Since the sensitivity of different printing paper varies, the integrator is provided with a control with which the integration constant can be altered. This enables the timer to be calibrated according to the photographic paper used.

At the moment $U_{int} = U_r$, the lamp of the enlarger is switched off and the photo is ready for chemical processing. Arrangements may be made to switch on the dark-room lighting at the same time; this is, however, not advisable when colour photographs are being processed as that should take place in the dark.

During exposure, the light in the dark-room must be switched off, since diffused light will adversely affect the exposure measurement and, consequently, the quality of the print. As stated earlier (see also Table 1), the photocells provide a maximum output of 490–750 mV at an exposure time of 1 s and a minimum potential of 16–19 mV at an exposure time of 32 s. The output voltage, U_{int} , of the integrator at which the print is exposed optimally is calculated from:

$$U_{int}(t) = -\frac{1}{RC} \int_{t_0}^{t_1} U_t dt$$

where $t_1 - t_0 = t_{exp}$, the exposure time. From this, it follows that

$$\begin{aligned} U_{int}(t) &= -\frac{1}{RC} (U_t t_1 - U_t t_0) \\ &= -\frac{1}{RC} U_t t_{exp} \end{aligned}$$

At the longest exposure time, the average output voltage of the photocells is 19 mV. The output of the integrator is then $32 \times 12 \times 19 \times 10^{-3} = 7.3 \text{ V}$.

At the shortest exposure time used in the design stages, the average output of the photocells is 620 mV. At 1 s, the shortest period possible on the timer, the output of the integrator is

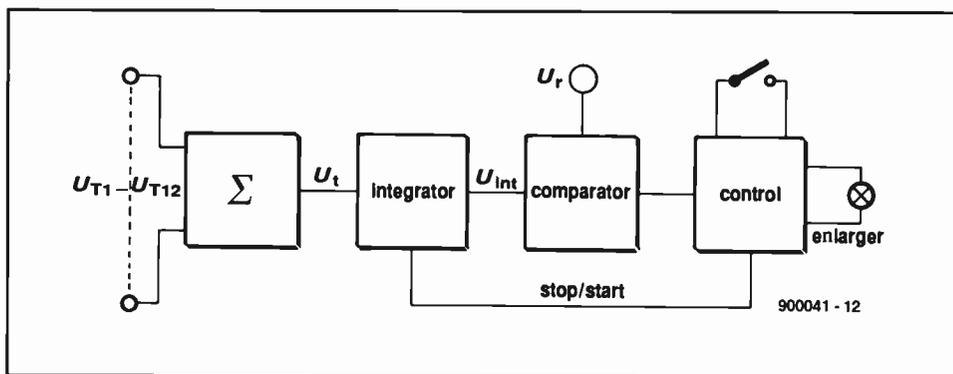


Fig. 3. Block diagram of the exposure timer.

$$12 \times 620 \times 10^{-3} = 7.44 \text{ V.}$$

From these results, it would appear that the reference voltage for the timer should be about 7.4 V. To make calibration possible, the level chosen in the prototype is 9 V.

The circuit

The circuit diagram of the timer is given in Fig. 4. The twelve phototransistors are connected as emitter followers whose emitters are connected to the summing circuit via $10 \text{ M}\Omega$ resistors. The phototransistors are shown in groups of four to coincide with the way they are to be fitted on three separate PCBs (see Fig. 5). This enables the constructor to experiment at an early stage with the mechanical layout of the exposure timer.

Opamp IC₁ sums the output voltages of phototransistors T₁–T₁₂ and inverts the result. This inversion is necessary because integrator IC₂, which follows IC₁, also inverts its input.

Integration constant RC is obtained from R₂₈, P₁, and C₆. Preset P₁ enables the constant to be varied so that calibration to allow for the various types of paper is possible. If the range of the preset is not sufficient for a certain type of paper, the value of C₆ may be altered accordingly. When the exposure time is too long, halving the value of C₆ results in one stop down; when it is too short, doubling the value of C₆ results in one stop up.

The integrator is followed by IC₃, which compares the output of the integrator with a reference voltage, U_r , derived from potential divider R₃₀–R₃₁. As soon as the integrator voltage becomes larger than the reference voltage, the level at the output of IC₃ goes high and bistable (flip-flop) IC_{4a} is reset. This causes output Q to go high, which results in transistor T₁₃ being switched on. The integrating capacitor, C₆, is then completely discharged and the timer is ready for use. At the same time, output Q of IC_{4a} goes low, which causes transistor T₁₄ to switch off, so that relay Re₁ is deenergized. The timer is then switched off and the light in the dark-room comes on again (if wanted).

Since the enlarger is required to be on permanently during focusing and some other operations, switch S₂ has been added to bypass the electronics.

Start switch S₁ passes a clock pulse to

PARTS LIST

Resistors:

R₁, R₃, R₅, R₇, R₉, R₁₁, R₁₃, R₁₅, R₁₇, R₁₉,
R₂₁, R₂₃ = 1 MΩ
R₂, R₄, R₆, R₈, R₁₀, R₁₂, R₁₄, R₁₆, R₁₈, R₂₀,
R₂₂, R₂₄, R₂₇ = 10 MΩ
R₂₅ = 470 kΩ
R₂₆ = 820 kΩ
R₂₈ = 6M8
R₂₉ = 22 kΩ
R₃₀, R₃₂, R₃₃ = 100 kΩ
R₃₁ = 330 kΩ
R₃₄ = 10 kΩ
P₁ = 2M5

Capacitors:

C₁–C₉, C₁₂ = 100 nF
C₁₀, C₁₁ = 100 μF, 25 V
C₁₄, C₁₅ = 100 μF, 25 V, radial

Semiconductors:

IC₁, IC₂ = LF356
IC₃ = LM741
IC₄ = 4013
IC₅ = 7812
IC₆ = 7912
T₁–T₁₂ = BPW40
T₁₃ = BS170
T₁₄ = BC547B
D₁, D₂ = 1N4148
D₃–D₆ = 1N4001

Miscellaneous:

K₁ = 5-way DIN plug, 180°
K₂ = 5-way DIN socket for PCB, 180°
S₁ = push-button switch, 1 make
S₂ = miniature switch, 1 make
Re₁ = relay, 12 V, for PCB mounting
Tr₁ = mains transformer, 2×9 V, 2.8 A
PCB Type 900041

bistable (flip-flop) IC_{4a}, which starts the entire measuring cycle. Since the D input of the bistable is connected permanently to the positive supply line, the Q output goes high

when S₁ is pressed. The integrator commences operation and the enlarger is switched on. When the supply is switched on, network R₃₃-C₉ ensures that the bistable receives a

clock pulse although the D input is then still low (because the time constant on that input is much longer). This ensures that after power-on the enlarger is switched off and the dark-

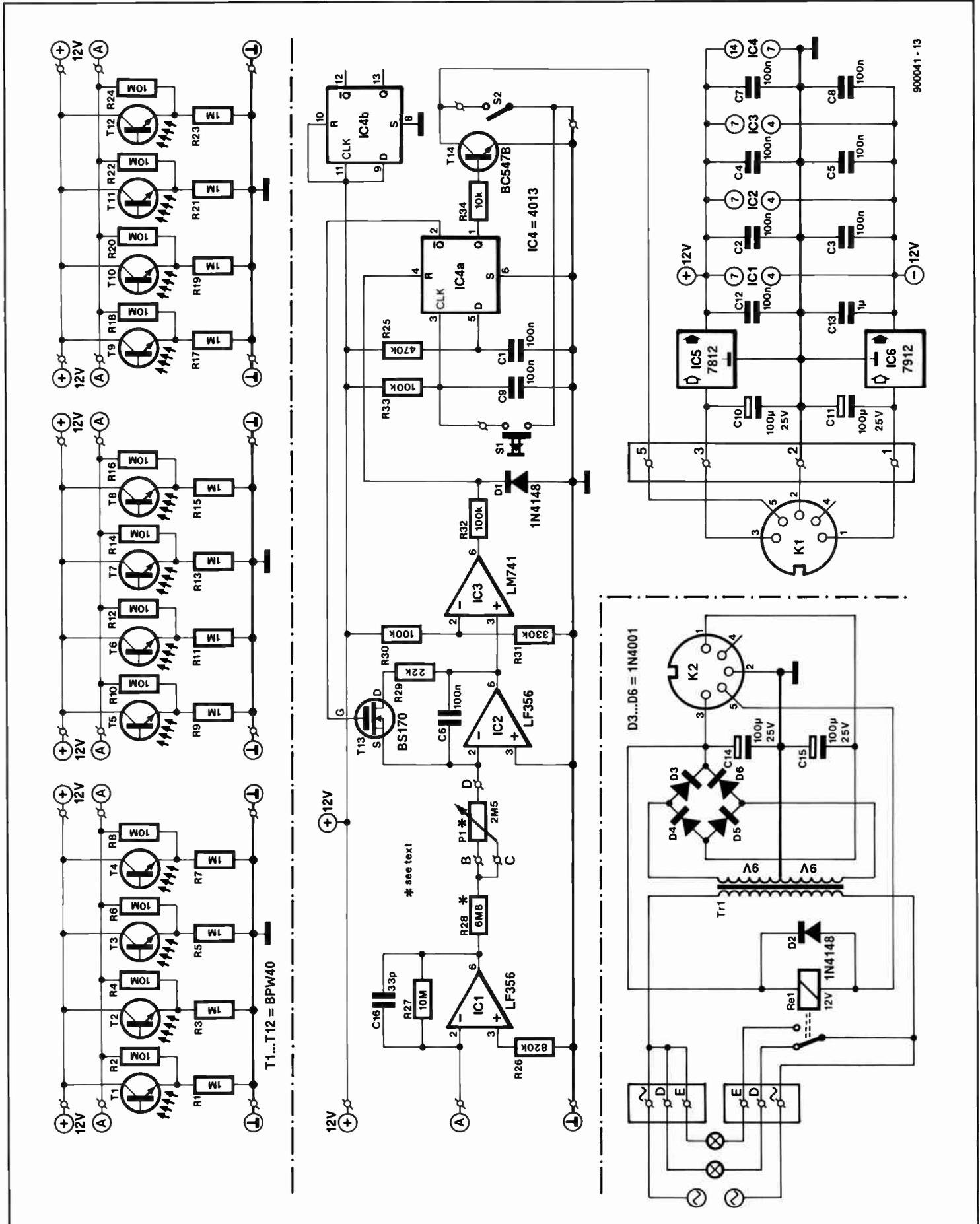


Fig. 4. Circuit diagram of the electronic exposure timer.

room lights are on.

From Fig. 4 it is seen that the circuit consists of two sections that are interconnected by a length of 4-way cable and two five-pin DIN plugs. This arrangement makes it possible for some of the components, such as the mains transformer, relay, mains entry to be fitted away from the working area, which then only needs to house the control box of the timer. An additional advantage is that mains-carrying parts are well away from the

chemicals to lessen the likelihood of any mishaps.

The power supply for the timer is fairly simple. The alternating voltage at the secondary winding of the mains transformer is rectified (full wave) by D₃-D₆ and smoothed by C₁₄ and C₁₅. A negative and a positive voltage are then supplied via a length of 4-way cable to the voltage regulators, IC₅ and IC₆, in the control box. These regulators provide supply voltages of +12 V and -12 V. The

mains supply for the dark-room lights and the enlarger may be taken from the 3-way terminal blocks.

Construction

The five printed-circuit boards for the entire timer are shown in Fig. 5. Since these are delivered as one, they need to be separated with a fret saw (US: jig saw) before being populated.

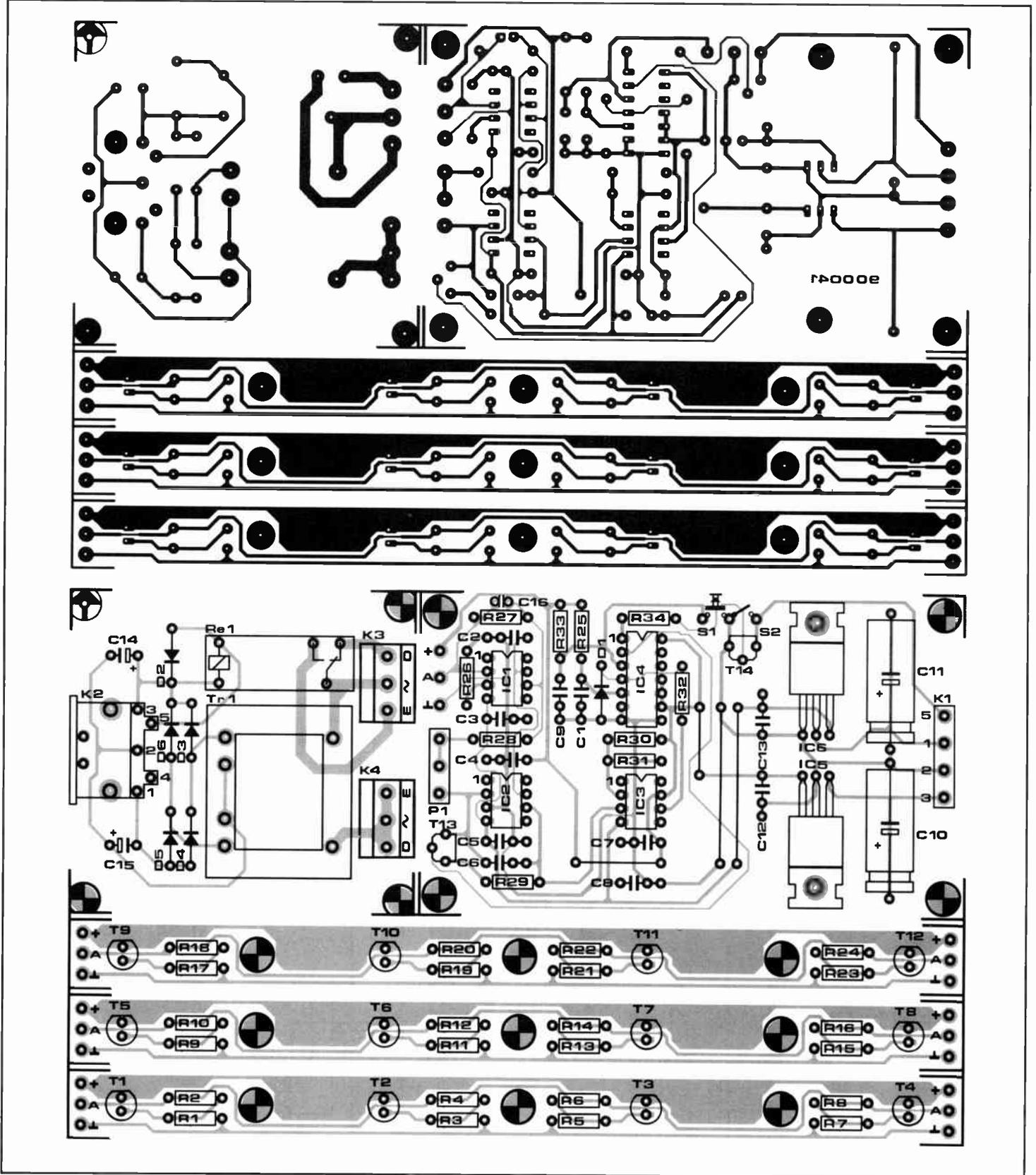


Fig. 5. The printed-circuit board for the electronic exposure timer consists of five parts.

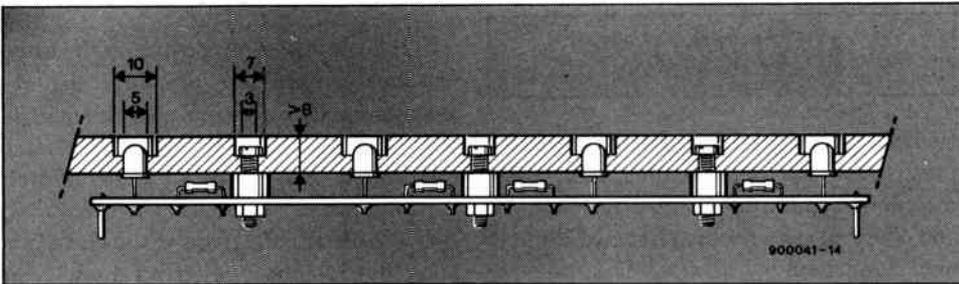


Fig. 6. Construction of the perspex (lucite) easel. It is important that the upper surface is smooth to ensure that the paper lies perfectly flat.

The three prints housing the phototransistors must be mounted on to the perspex (US: lucite) easel as shown in Fig. 6. The perspex sheet must be thick enough to take in the bodies of the phototransistors. After the three PCBs have been interconnected, they are linked to the motherboard by a length of

3-way cable.

It is advisable to start by placing the required wire bridges on the motherboard and then mount the other components. The regulators do not need a heat sink and may therefore be fitted directly on to the board. Potentiometer P_1 and switches S_1 and S_2 are

mounted on the front panel of the enclosure that contains the motherboard.

It also possible to fit the motherboard underneath the easel. Two different types of DIN connector must then be used for connecting the board to the power supply and to the switches and potentiometer which are then housed in a small, separate box.

If at all possible, fit the power supply board in a man-made fibre enclosure with moulded mains plug. If wanted, the dark-room light(s) can be switched from this unit via a separate cable. The enclosure should be fitted with a hole through which the DIN plug for the power lines can be passed.

Once the boards have been completed and fitted in the enclosures, P_1 must be adjusted with the aid of a number of test exposures. The setting so found needs to be altered only if photographic paper with a different sensitivity is used in the future. ■

MIDI-TO-CV INTERFACE

Some additional notes

Although the MIDI-to-CV interface was described fully in our February 1991 issue, it was thought that some additional notes might prove useful to a number of readers.

MIDI connections

The MIDI-IN socket, K_6 (next to the mains input plug) must be connected via a suitable MIDI cable to the MIDI output of your MIDI keyboard, synthesizer, or other equipment. The MIDI input signal appears unchanged at the MIDI OUT socket (MIDI through function). The name of that socket may seem somewhat confusing ('through' function at 'out'), but that is because the interface is principally intended to output the data in changed format (e.g., filtered). Other equipment may be connected to the MIDI OUT socket, but this must be controlled by the same data as the present interface.

Connection to CV/gate

The connection to a monophonic synthesizer is via the two 6.3 mm connectors marked "CV OUT" and "GATE OUT". The 1 V/octave tone control voltage is available at the CV socket. The 0 V reference point (i.e., the MIDI code for 0 V control voltage) is normally 36, which is equivalent to low C on a standard five-octave keyboard.

The 0–5 V gate voltage is available at the gate socket. Depending on the type of synthesizer, this is a positive gate signal, i.e., +5 V when a key is depressed and 0 V when the key is released, or a negative gate signal, i.e., 0 V when a key is depressed and +5 V when the key is released. Consult your

synthesizer handbook to ascertain which of these signals you need.

The gate LED lights when a correct gate signal is applied. This diode can also be used to check whether the interface is functioning correctly, even when this is not (yet) connected to a synthesizer.

Setting the MIDI channels

The MIDI channels are set with the aid of the 4-pole DIP switches, SW_1 – SW_4 , on the interface board. The settings and associated channels are shown in Fig. 3. The settings should be carried out before the equipment is switched on (if they are made while the equipment is switched on, the channel will not change).

Faultfinding check list

If the interface does not work (correctly) check the following.

- Is the power supply correct? The LED should light briefly on power on and then go out again. Are the power lines reversed?
- Are the connections to the MIDI transmitter and synthesizer in order? These include the earth connections!
- Has the correct MIDI channel be set on the interface? Does the gate LED light when the controlling MIDI equipment sends data on the set MIDI channel? Does the MIDI sender transmit on the correct channel? For security's sake, check the MIDI cable and whether the MIDI sender operates correctly.
- Do the sent tones lie in the correct range,

i.e., normally between 36 and 97 or five octaves from low C.

- Does the gate LED light correctly, but the connected equipment does not function? This is almost certainly a failure of the cable connecting the interface to the synthesizer.
- If the scale of the interface does not correspond exactly with that of the synthesizer, shown by the increasing detuning away from the reference point, a correction can be made with potentiometer P_1 .



THE NEW HEAT TRANSFER

By Eugene F. Adiutori

436 pages

Price \$29.95

This is the second edition of this fascinating work; the first edition was published in English in 1974 and in Russian in 1977. It is dedicated to "all who stand up for freedom"—particularly freedom of thought.

The main thrust of the book is a new heat transfer science that abandons the concept of the "heat transfer coefficient" and replaces it with the concept of "thermal behavior." The particular advantage of the new heat transfer is it greatly simplifies the solution of problems involving non-linear behavior.

The book also presents a new electrical science that abandons Ohm's law and the concept of "resistance" and replaces the latter with the concept of "electrical behavior." The particular advantage of the new electrical science is it deals with linear and non-linear devices in the same simple way, that is, it replaces Ohm's law science and non-Ohm's law science with one logical and simple science. The application of both new sciences is demonstrated in numerous practical problems solved in the text.

The New Heat Transfer is a fascinating book that should be read by all interested in science and particularly by those interested in new thoughts in science.

Ventuno Press

6792 Timberwood Dr.

West Chester, OH 45069

ELECTRONIC FILTER DESIGN HANDBOOK (Second Edition)**(LC, Active and Digital Filters)**

By Arthur B. Williams and Fred J. Taylor

ISBN 0-07-070434-1

672 pages—illustrated

Price \$62.95 (hardcover)

The second edition of the handbook on filter design has not only been revised to include new filter configurations and more tabulated material, but also has been expanded to include several new chapters on digital filters. It now includes design techniques for LC, active, and digital filters in one text. Some of these techniques will be hard, if not impossible, to find in other books.

After an introduction to modern network theory and a discussion of the tradeoffs between active and passive filter implementations, the mathematical properties of standard filter response types are covered. These include Butterworth, Chebyshev, Bessel, linear phase with equiripple error, transitional, synchronously tuned, and constant delay with Chebyshev stopband.

The design of passive and active low-pass filters is discussed with the use of normal-

NEW BOOKS

ized tables. Design techniques of specialized passive low-pass filters are illustrated; these include designing for unequal termination and compensating for the effects of component dissipation.

A separate chapter covers the design of networks whose properties are best described in the time domain. All pass delay and amplitude equalizers are discussed in detail.

Since the successful design of filters is dependent on the proper selection and manufacture of inductors, the design of magnetic components and the selection of these and coil winding techniques for optimum characteristics over the operating frequency range are discussed in depth.

Although the design of digital filters is introduced, this topic is not treated in the detail this reviewer would have liked. Fortunately, a 37-page appendix adds much design information missing from the relevant chapter, while a second appendix discusses digital filter design using the TMS320 family of digital signal processing products.

As before, the book is well indexed and should remain the reference handbook for filter design specialists. At the same time, it should continue to serve as a self-study handbook for engineers and technicians and as a supplementary textbook for technical college and university students in electrical/electronic engineering and communications.

McGraw-Hill Publishing

Princeton Rd.

Hightstown, NJ 08520

DIGITAL SATELLITE COMMUNICATIONS

By Dr. Tri T. Ha

ISBN 007-025-3897

574 pages

Price \$59.50 (hardcover)

Digital Satellite Communications, aimed at practicing engineers and advanced students in satellite systems, communications, and related areas, is, perhaps, the professional reference book on the subject. Although Dr. Ha says the book addresses fundamental principles of satellite communications in which the mathematics have been kept to a minimum, I found it a fairly complete treatment of the subject and the mathematics not too difficult.

The book starts with useful lists of acronyms (many of which cannot easily be found elsewhere) and symbols used. The geometry of artificial satellites in space is covered in great detail with plenty of clear drawings and mathematical treatment.

In spite of the word "digital" in the title—and most systems are, of course, digital—analog systems are also covered in detail. Examples are used throughout the book, while each chapter closes with a number of problems (for which no answers are provided). Appendices are not given at the end of the book, but rather at the end of the relevant chapter—unorthodox but useful.

Apart from the geometry of satellites, the book covers earth stations, satellite links, frequency-division multiple access, time-division multiple access, speech interpolation, satellite packet communications, digital modulation, carrier and symbol timing synchronization, and satellite spread spectrum communications.

I have no doubt *Digital Satellite Communications* will become, and remain, a cherished reference book of many for quite some time.

McGraw-Hill Publishing

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HANDBOOK OF NUMERICAL CALCULATIONS IN ENGINEERING

By Jan J. Tuma, Ph.D

ISBN 0-07-065446-8

406 pages

Price \$53 (hardcover)

Since nobody can possibly memorize (and recall) all the formulas connected with science and technology, we all rely on reference books. The new handbook by Jan Tuma is one of the most useful I have come across for a long time. In one volume it contains all the major numerical methods used in preparing micro, mini, and mainframe computer programs for engineering and sciences. The work was written to serve as a professional, user-oriented, desktop reference book for engineers, architects, and scientists.

Handbook of Numerical Calculations in Engineering is a companion to the author's well-known *Engineering Mathematics Handbook*. A detailed "browse" (more is not possible) failed to show any deficiencies within the intended framework.

Apart from 16 chapters on numerical calculations, algebraic and transcendental equations, special functions, Fourier approximations, and partial differential equations, to name some at random, the book contains useful appendices of numerical tables, a glossary of symbols, and detailed references and bibliography.

This is no doubt a work that will find its way not only to the desk of many a scientist and engineer, but also to the library of most universities and technical colleges.

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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.

2-METRE BAND CONVERTER

This month we tackle a high-frequency project by venturing out into the exciting world of VHF radio amateur communication. Build this converter if you have a general coverage SW receiver and would like to listen to licensed radio amateurs working in the popular 2-metre VHF band (144–146 MHz).

J. Bareford

MOST multimode SW receivers have a frequency range of about 150 kHz to 30 MHz, and are capable of receiving CW, SSB, AM and FM signals. The 10-metre radio amateur band between 28 MHz and about 29.6 MHz is located just above the CB band (27 MHz) towards the top of the receiver's frequency range (the actual frequency assignment of the 10-m band may differ de-

pending on the country you live in). The present 2-metre converter allows you to listen to radio amateurs working with SSB (single-sideband) and CW (morse) in the lower part of the 2-m band, as well as to 'local' FM (frequency modulation) traffic and repeater stations in the frequency range between 145.0 and 146.0 MHz. The 2-metre band is very popular among radio amateurs

because of the ready availability of transceivers, the small antenna size, and the low power required to cover considerable distances, even when going 'mobile'. All in all, if you are a beginning electronics enthusiast, listening to local radio amateurs might well prove useful to learn a lot about electronics, as most radio amateurs are keen and helpful experimenters. In and around large cities you can expect a lot of traffic in the 2-m band, with dominant repeater activity in the upper section of the band between 145.600 MHz and 145.875 MHz. At the low side of the band, just above 144 MHz, there is long-distance (DX) traffic in CW and SSB. Here, it pays to have a directional aerial to pick up signals from distances up to 300 km and more under favourable propagation conditions.

The basics

What we want to do is convert the frequency range from 144 MHz to 146 MHz down to 28 MHz to 30 MHz (see Fig. 1). Once this has been achieved, a general coverage receiver tuned to the 10-m band can be used to receive all signals of all types of modulation used (CW, SSB, FM and possibly AM).

The frequency conversion of the 2-MHz wide band is effected with the aid of a local oscillator operating at 116 MHz, as shown in the block diagram in Fig. 2. The arithmetic behind this conversion is simple: the output frequency of the converter equals the difference between the input frequency and the local oscillator frequency. Thus, for the low end of the band:



144 MHz – 116 MHz = 28 MHz

while for the high end of the band:

146 MHz – 116 MHz = 30 MHz

Note that in principle the required output frequency may also be obtained with a local oscillator operating at 172 MHz. A frequency of 116 MHz is used here, however, since this can be generated with a standard quartz crystal.

As shown in Fig. 2, the antenna signal is amplified before it is applied to a band-pass filter. Next, it is mixed ('heterodyned') with the 116 MHz local oscillator signal. The mixer consists of a transistor, T2. The output signal of the mixer is the intermediate frequency, 28 MHz – 30 MHz, obtained from subtractive mixing. A band-pass filter formed by L6 couples the output signal of the converter to the input of the general coverage receiver.

The band-pass filter ahead of the mixer is needed to suppress signals at the so-called image frequency. In the present converter, these signals occur between 86 MHz and 88 MHz, since these two frequencies result in intermediate frequencies of 30 MHz and 28 MHz respectively when mixed with 116 MHz. Since part of the image frequency band falls in the VHF broadcast band, a filter is a must to prevent signals in the 2-m band being blocked out by a local radio station!

Practical circuit

The circuit diagram in Fig. 3 shows a number of dashed lines, which indicate RF screening plates that serve to keep interference between the sub-sections of the circuit to a minimum. As shown, these screening plates are connected to ground.

The antenna signal is coupled to the converter via a low-impedance tap on inductor L1. Tuned circuit C1-L1 forms a bandfilter tuned to the 2-m band. At the same time, the L-C tuned circuit provides the necessary impedance conversion between the low impedance of the aerial cable (50–75 Ω) and the high impedance (several mega-ohms) of the gate-1 (G1) terminal of dual-gate MOSFET T1. This conversion is usually called impedance transforming or matching.

To reduce the risk of oscillation, the output signal of the amplifier based on T1 is connected capacitively to a low-impedance tap on inductor L3. The bandpass filter needed to suppress the image band is formed by L3, C5, L4 and C6. As you can see from the circuit diagram, the coupling between amplifier T1 and mixer T2 is inductive (no, we have not forgotten a coupling capacitor between L3 and L4). Both L3 and L4 are tuned to about 145 MHz by trimmer capacitors.

The mixer is formed by a second dual-gate MOSFET, T2. Conventionally, the RF signal is applied to gate 1, and the local oscillator signal is filtered out at the drain of T2 by transformer L6. The output winding of L6

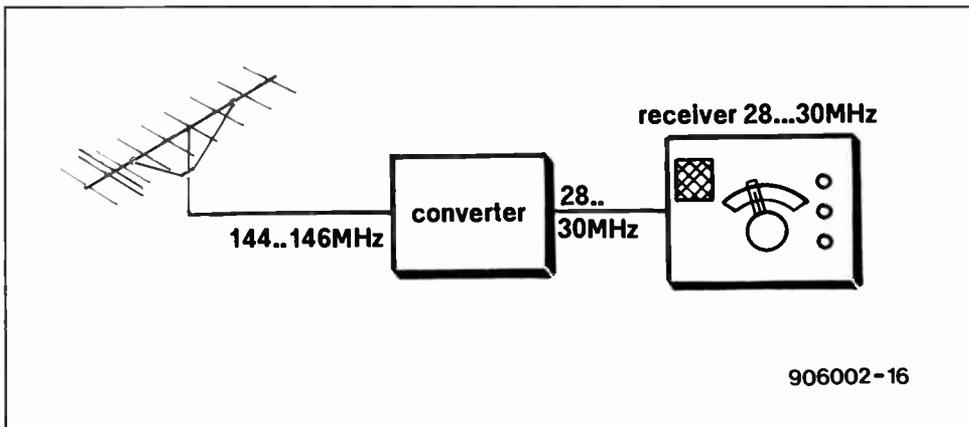


Fig. 1. The converter described here sits between a 2-metre antenna and the input of a multimode SW receiver tuned to the 10-m band

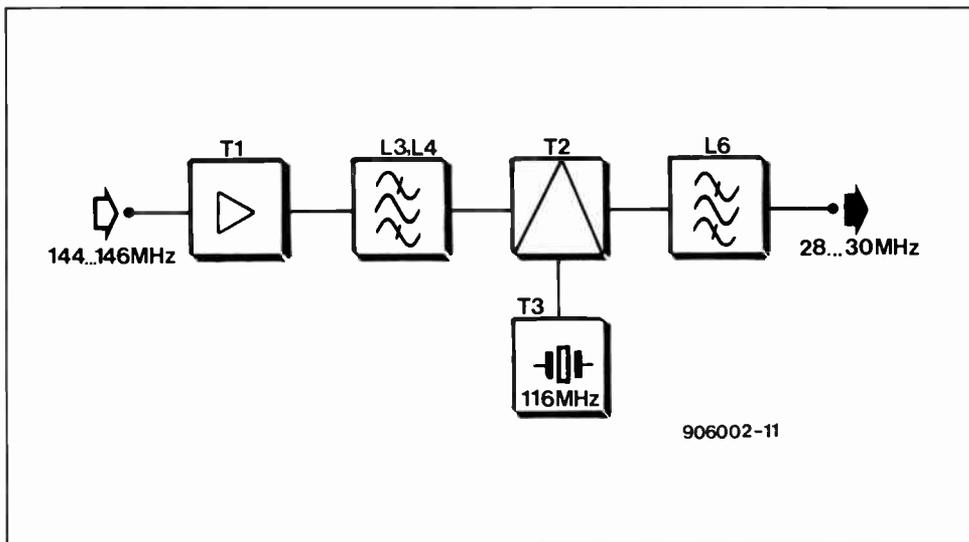


Fig. 2. Block diagram of the 2-metre converter.

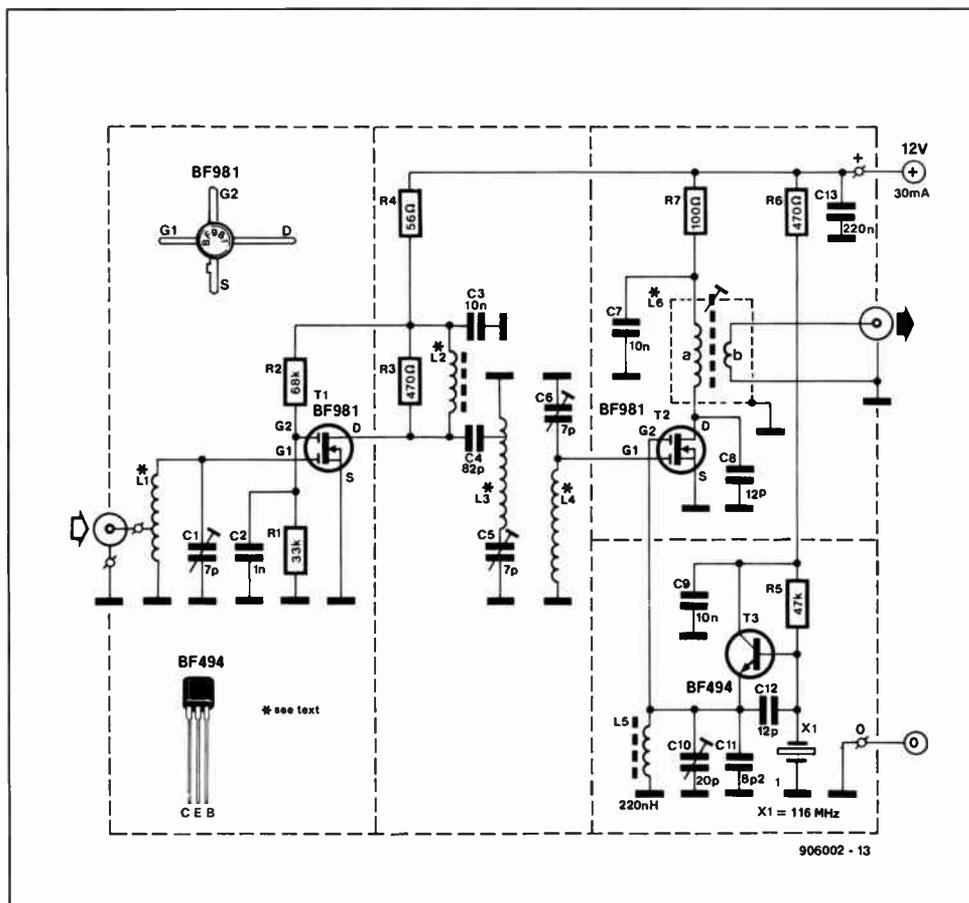


Fig. 3. Circuit diagram of the 2-metre converter. Note that only three transistors are used.

COMPONENTS LIST

Resistors:

- 1 33kΩ R1
- 1 68kΩ R2
- 2 470Ω R3;R6
- 1 56Ω R4
- 1 47kΩ R5
- 1 100Ω R7

Capacitors:

- 3 7pF trimmer C1;C5;C6
- 1 1nF coffin capacitor C2
- 3 10nF ceramic C3;C7;C9
- 1 82pF C4
- 1 12pF C8
- 1 20pF trimmer C10
- 1 8pF2 C11
- 1 12pF C12
- 1 220nF ceramic C13

Inductors:

- 1 0μH22 axial choke L5
- The other inductors are home made; see text. Required materials:
- 1-mm dia. silver-plated wire
 - 0.2-mm dia. enamelled copper wire
 - 1 7K S inductor assembly (Neosid)

Semiconductors:

- 2 BF981 T1;T2
- 1 BF494 T3

Miscellaneous:

- 1 quartz crystal 116MHz 5th overtone X1
- 1 tin-plated metal sheet
- 1 printed circuit board 900006-1

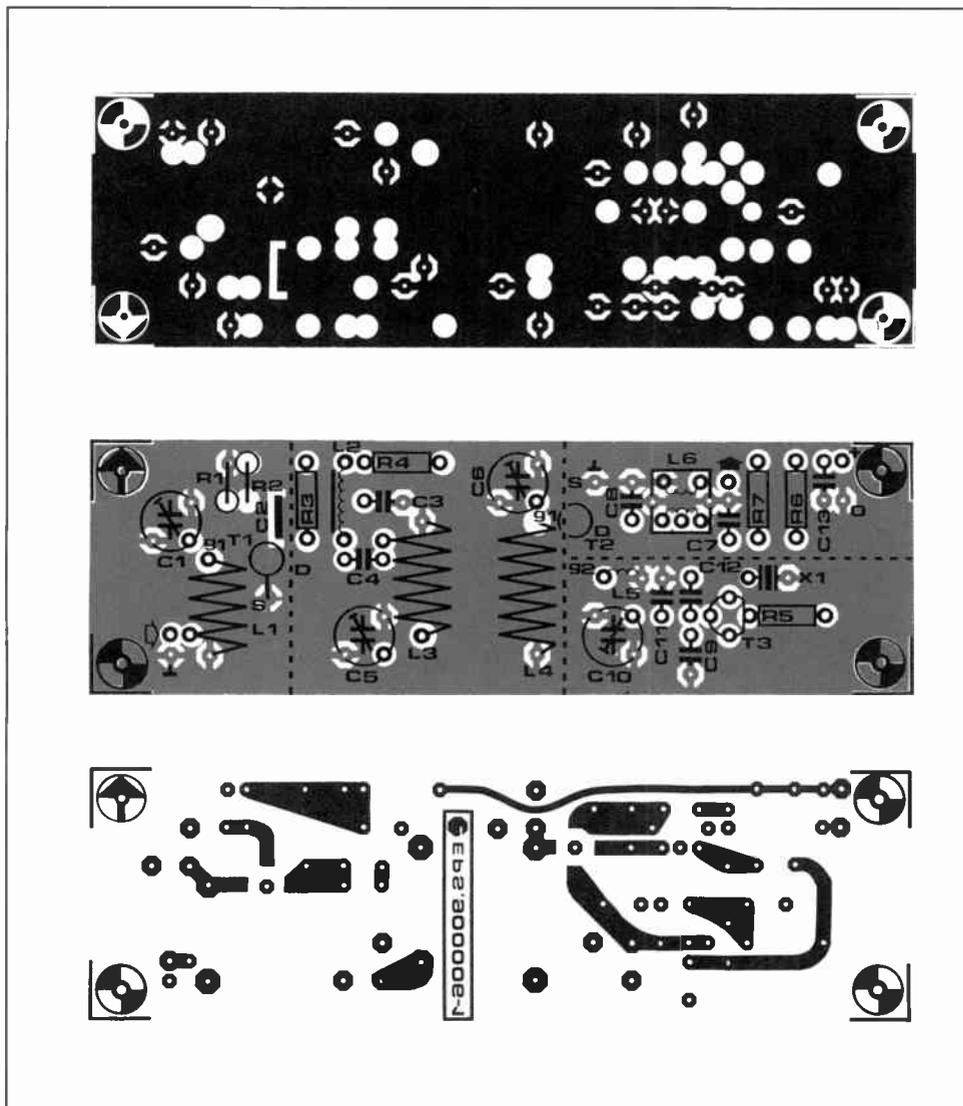


Fig. 4. Track layouts (mirror images) and component overlay of the double-sided printed circuit board for the converter.

has a relatively low impedance to enable the input of the SW receiver to be matched correctly. The output of the converter is connected to the input of the SW receiver via a

short length of 50-Ω coax cable fitted with suitable RF plugs.

The local oscillator based on T3 is quartz-controlled with a 116-MHz crystal, X1, oper-

ating at fifth overtone, i.e., the fundamental frequency of X1 is 23.2 MHz. Circuit L5-C10 is tuned to 116 MHz and serves to suppress any spurious output signals produced by the oscillator.

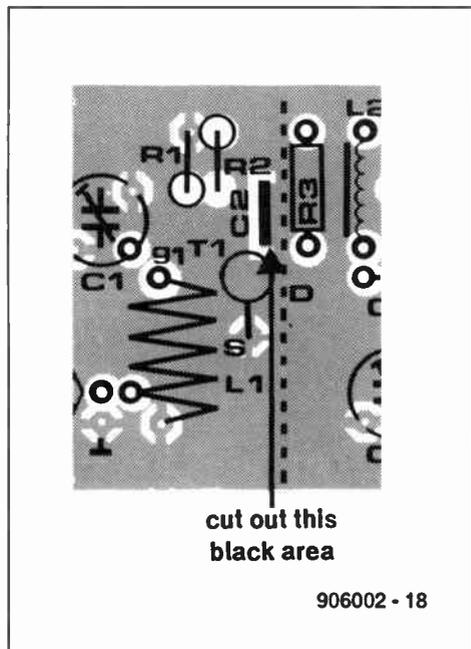


Fig. 5. Cut a small slot in the PCB to enable the coffin-type capacitor to be seated.

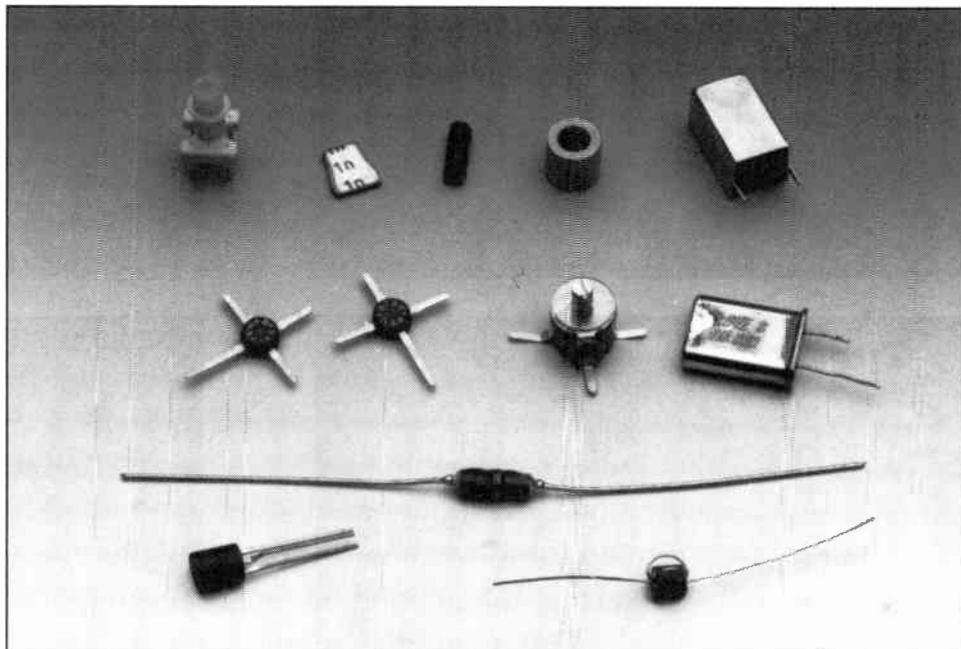


Fig. 6. The RF parts used in this project. The coffin-type leadless ceramic capacitor, C2, is the second device on the left in the top row.

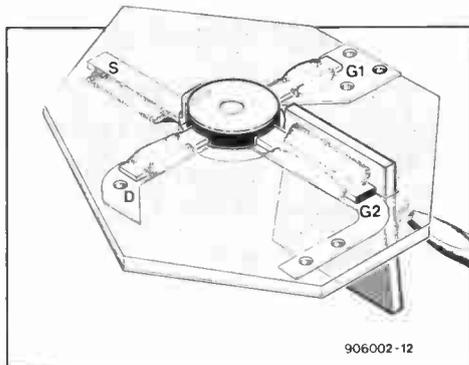


Fig. 7. Illustrating the mounting of dual-gate MOSFET T1 and capacitor C2.

Building the converter

The circuit is best built on the double-sided printed-circuit board shown in Fig. 4. This board is available ready-made and helps you to go round the pitfalls of RF circuit construction. Before you fit any component on the board, cut the slot for capacitor C2 as shown in Fig. 5. C2 is a so-called coffin-type leadless ceramic capacitor (quite a mouthful for a basically simple and small component). The slot is carefully cut and filed until the 'shoulders' of the capacitor rest on the component side of the PCB. One side of the capa-

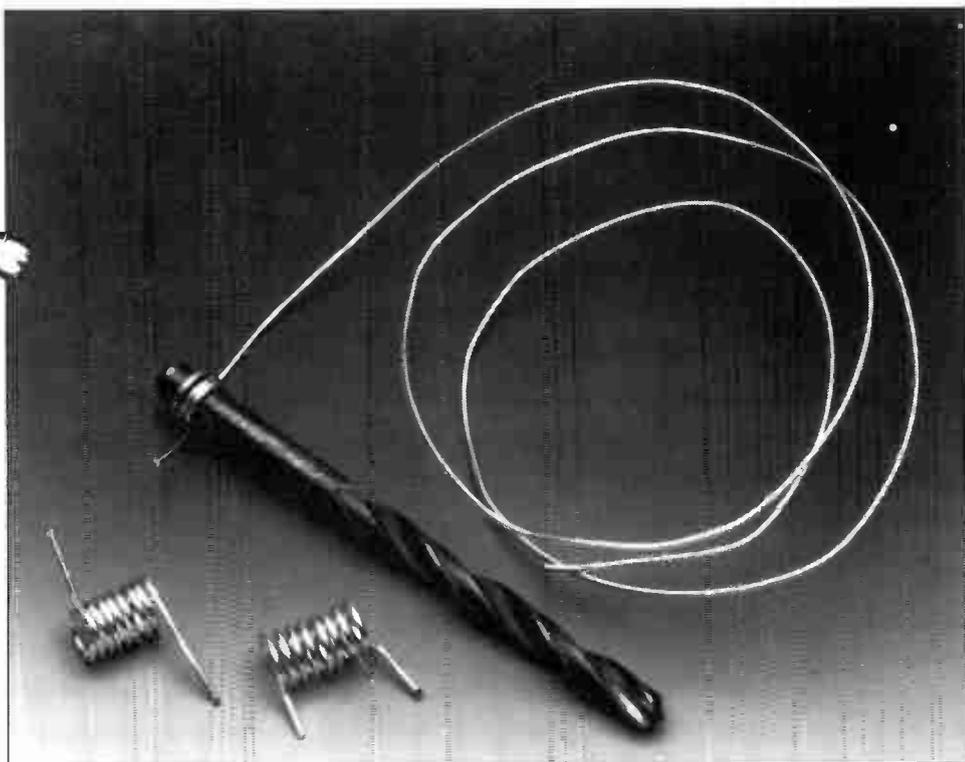


Fig. 8. A 6-mm dia. drill bit is used to wind to the three 145-MHz inductors in the converter.

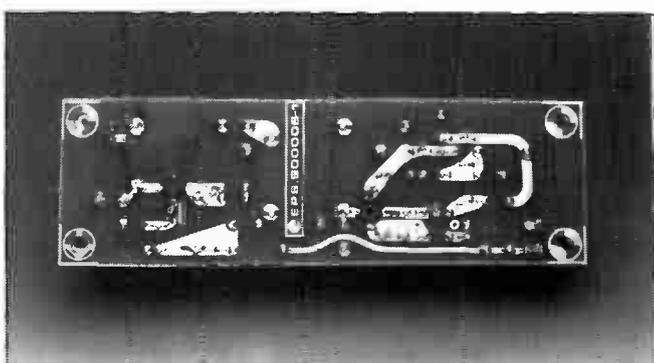
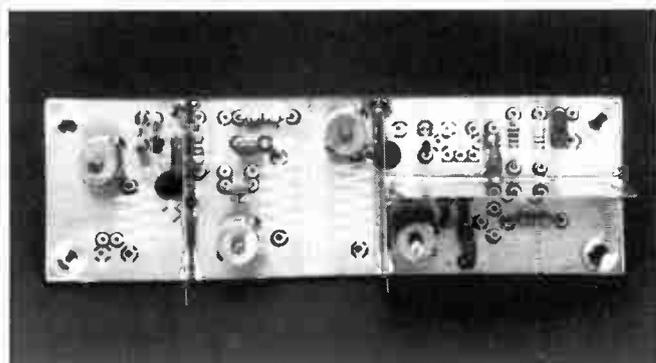
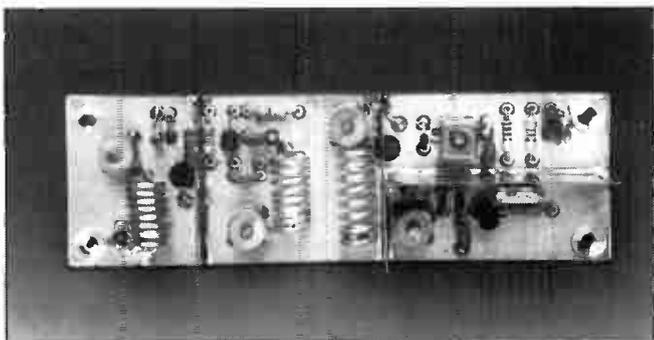
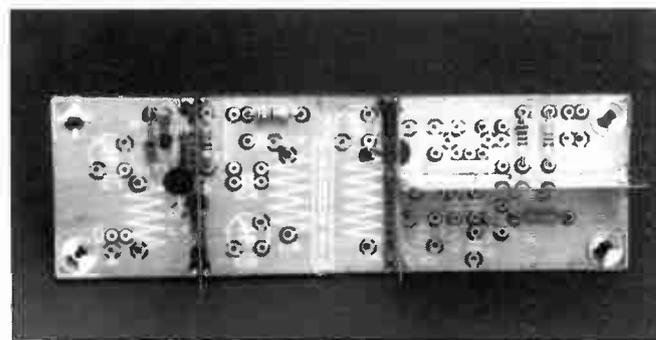
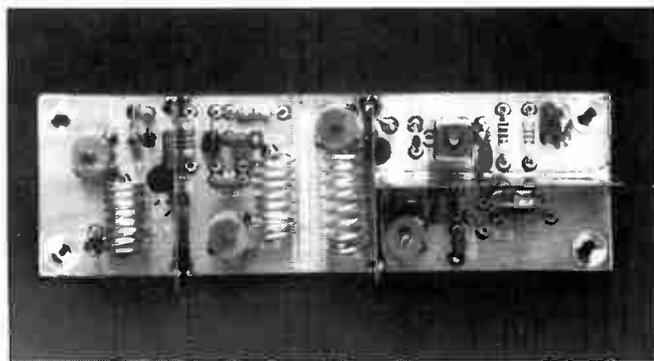
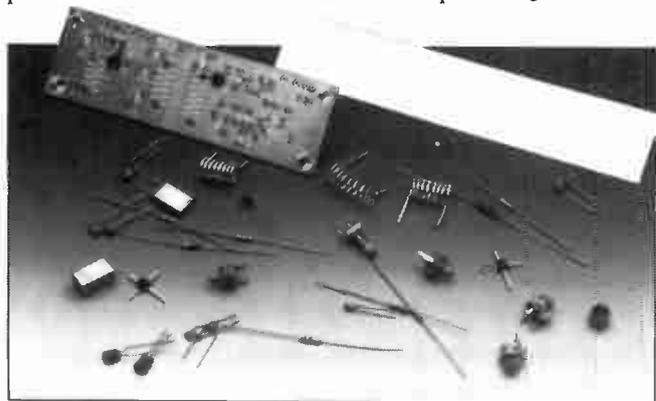


Fig. 9. These photographs illustrate the construction of the 2-m converter. Note the screening plates on the PCB.

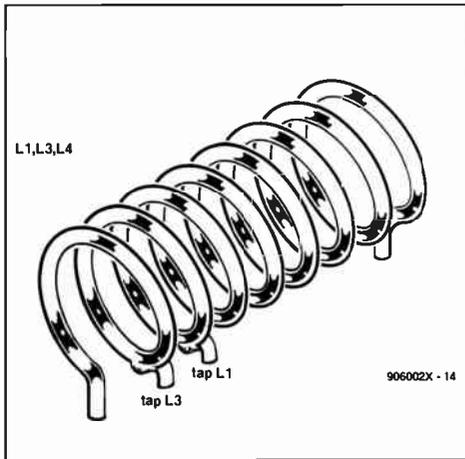


Fig. 10. Construction of the 145-MHz inductors in the circuit.

ductor is soldered to the same track as the G2 terminal of T1 (at the track side of the board; see Fig. 7), and the other side to ground formed by the copper surface at the component side of the board. Be careful not to break or overheat the coffin capacitor, as it is a relatively brittle component.

Next, cut the screening plates to size, noting their length from the dashed lines on the PCB overlay. The height of the screens is about 15 mm. Position the screens vertically on to the board, and solder them over the full length with a medium-power iron. Do not go for the easy way out by fixing the screens at a few positions only — to be effective, they must be soldered over the full length.

The next step in the construction is the fitting of the resistors. Note that two of these, R1 and R2, are mounted vertically, and that one terminal of R1 must be soldered at both sides of the PCB to effect a through-contact.

Proceed with the capacitors. With the exception of C4 and C12, all capacitors have one terminal soldered at both sides of the PCB. Miniature ceramic capacitors must be used where appropriate. In all cases, the capacitors must be fitted as close as possible to the PCB.

Except for L5, the inductors in this project are home-made. Start with L1, L3 and L4, which consist of eight turns of 1-mm dia. silver-plated wire. A drill bit is used to give these inductors an internal diameter of 6 mm (see Fig. 8). The taps on L1 and L3 are made as shown in Fig. 10.

Inductor L2 is the simplest to make, since it consists of four turns of 0.2 mm dia. enamelled copper wire through a ferrite bead. The construction is illustrated in Fig. 11.

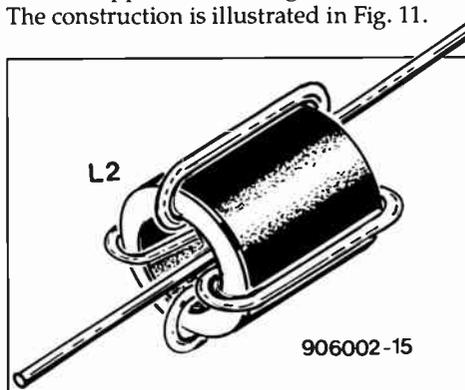


Fig. 11. Construction of choke L2.

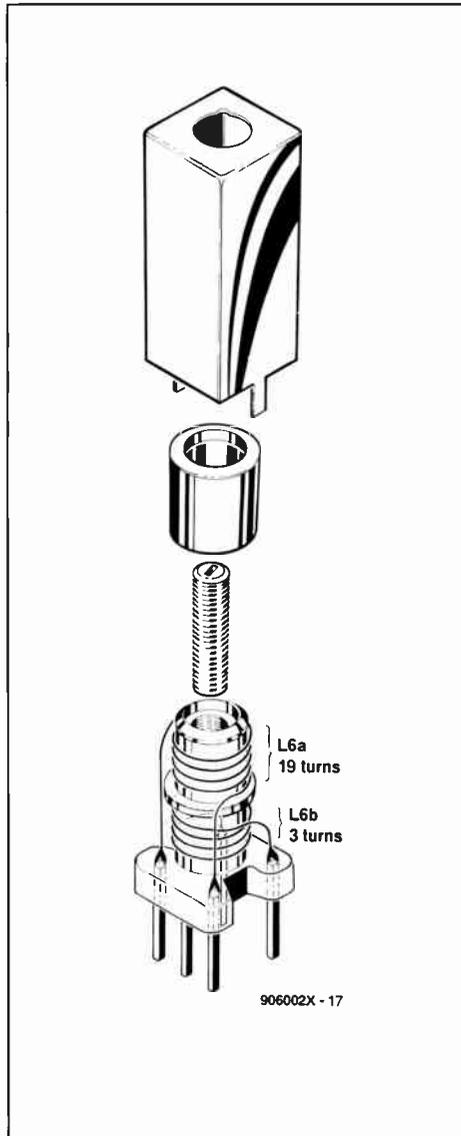


Fig. 12. Construction and assembly of the IF output transformer, L6.

The construction of the IF output transformer, L6, is slightly more complex as it requires an inductor assembly Type 7K1S from Neosid. Constructional details are however apparent from the drawing in Fig. 12. Although it is shown in the drawing, the small rim that divides the former into two equal lengths must be cut off carefully with the aid of a sharp hobby knife. Inspect the windings and check the continuity at the base pins of the inductor. Next, carefully fit the cup core and the screening can before you fit the inductor on to the PCB and subsequently solder the five base pins and the two pins at the sides of the screening can.

One terminal of the quartz crystal must be soldered to ground, while the device must be fitted as close as possible to the PCB surface. Unless you have a solder bit small enough to insert between the crystal body and the PCB, you will have to bend one terminal close to the crystal body, and solder it flat on to the ground plane of the PCB.

The last parts fitted on to the PCB are the semiconductors. Transistor T3 is fitted first in the normal manner. The MOSFETs, T1 and T2, require special attention. The PCB has 5-mm holes to accept these 4-pin transistors, whose terminals are soldered direct to the

copper tracks. The drawing in Fig. 7 illustrates the way in which T1 is fitted. Note that the source terminal is bent down before the transistor is inserted in the PCB hole. Next, the terminal is pushed flat on the ground plane at the component side of the board. Also note that the type number of T1 is legible from the component side of the board. The other FET, T2, is simpler to fit as all four terminals are soldered at the track side of the PCB. Note however that the device is turned such that its type number is legible from the track side of the PCB. The photographs in Fig. 9 further illustrate the construction of the converter.

Adjustment

To begin with, the tuned circuit in the local oscillator must be set to 116 MHz to force the crystal to operate at its fifth overtone. To perform this adjustment without the help of specialist test gear, place a simple portable FM radio near the converter board, and tune the radio to 94.6 MHz. In most cases, this will mean that the local oscillator in the FM radio operates at $94.6 + 10.7 = 105.3$ MHz. If necessary, check this with a second receiver. The image frequency of the FM radio is $105.3 + 10.7 = 116$ MHz. Provided its image rejection is bad enough, the radio will happily receive a sufficiently strong signal at 116 MHz. Solder a short length of thin, solid wire to the drain of T2, and wind this around the whip antenna of the FM radio. Switch the converter on, and adjust trimmer C10 until the FM receiver is silenced by the 116 MHz signal. Peak C10 for minimum noise (if necessary make the coupling at the antenna a little looser). Next, remove the wire from the drain of T2.

Connect a 50-cm long wire to the input of the converter, and the SW receiver to the output. Tune the receiver to 29.0 MHz, and check that its output noise in SSB mode increases when the converter is switched on. Next, peak L6, then C6, C5 and C1 for maximum noise. If you are lucky, the wire at the converter input will be sufficient to pick up local 2-m signals, and you may start to listen to radio amateurs by tuning the SW receiver between 28 MHz and 30 MHz. For serious DXing however you will soon find that a directional antenna is a must. ■

PC-CONTROLLED SEMICONDUCTOR TESTER PC-TT 90

PART 1: INTRODUCTION AND BASIC FEATURES

This versatile, PC-controlled, test instrument, designed and marketed as a kit by ELV, puts you in a position to view, on your PC monitor, the curves that describe the main electrical characteristics of transistors, LEDs, zener diodes, triacs and thyristors. These curves, like no other test on these devices, provide a definitive good/faulty indication and in addition can help you decide whether or not a discrete semiconductor is suitable for a particular application.

DISCRETE semiconductors, and in particular transistors, form an important component group in today's electronics scene. The PC-TT90 was developed by ELV to test discrete semiconductors with the aid of an IBM PC-XT/AT or compatible computer. The design of the tester follows the lines of the IC tester (Ref. 1), of which large numbers have been built.

Apart from bipolar n-p-n and p-n-p transistors, the tester is also simple to use with FETs, diodes, LEDs, zener diodes, triacs and thyristors. A complete test run takes less than a second to complete, and produces a plotted characteristic composed of up to ten individual curves.

The complete circuit of the PC-TT90 is built on a single card, which is inserted in a free slot in the PC. The three coloured wires that leave the card at the rear are connected to the device to be tested. The actual connection is made by three crocodile clips.

The easy-to-use control software for the tester allows comprehensive tests to be performed on all previously mentioned types of discrete semiconductor. The results of the tests are pretty conclusive. In the case of transistors, for instance, the so-called output characteristic is measured and presented on the screen as ten individually plotted curves. The test procedure is completely automatic. All you have to do is connect the transistor, select n-p-n or p-n-p, set the maximum collector current, and start the test. After a second or so, the output characteristic and the co-ordinate system appear on the screen. All further settings, such as the selection of the optimum measurement range, the required base currents, the scale factors in the co-ordinate system, etc., are performed automatically, ensuring that the device under test can not be damaged by overloading or in any other manner.

With transistors, for instance, the collector current, I_{CE} (on the Y axis) is plotted as a

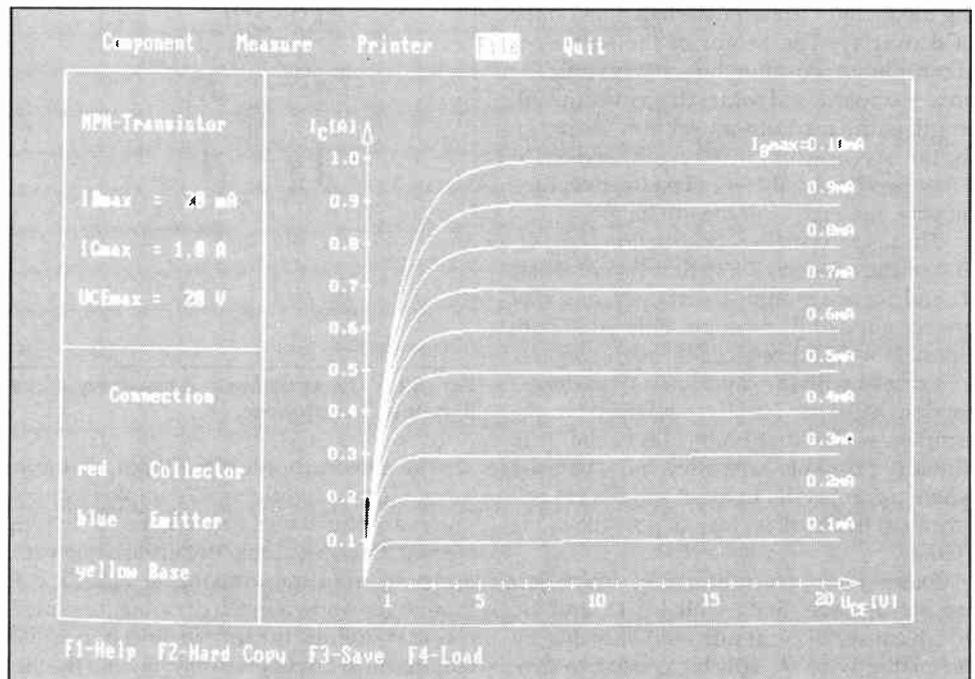


Fig. 1. Screen photograph of a transistor characteristic measured and plotted by the PC-TT90.

function of the collector-emitter voltage, U_{CE} (on the X axis), with 10 values of the base current, I_B , as parameters. The resultant screen is shown in Fig. 1.

Before discussing the operation of the PC-TT90, an understanding is required of the basic electrical properties and behaviour of the components we want to test. Hence the following sections cover some fundamentals of discrete semiconductors.

The group

Discrete semiconductors come in many shapes and sizes, and with a plethora of functions. Field-effect transistors (FETs), for instance, now form an important and widely

used sub-group of the larger class of transistors. Disregarding a possible sub-classification according to power, the group of FETs may be divided into no fewer than six basic types. Similarly with diodes: here, we only mention a few special types such as capacitance diodes, Schottky diodes, switching diodes, PIN diodes, tunnel diodes, field-effect diodes, four-layer diodes, and fast recovery diodes. Adding the photoelectric and wave devices we may mention the photodiode, the laser diode and the light-emitting diode. Also in common use these days, and testable with the PC-TT90, are the large classes of thyristors and triacs.

Unfortunately, it is beyond the scope of this article to discuss the basic characteristics

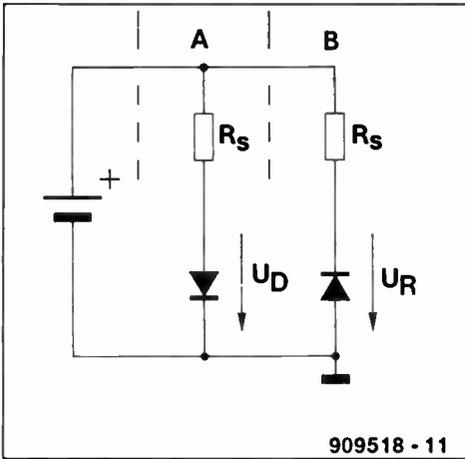


Fig. 2. Basic d.c. conditions of a diode.

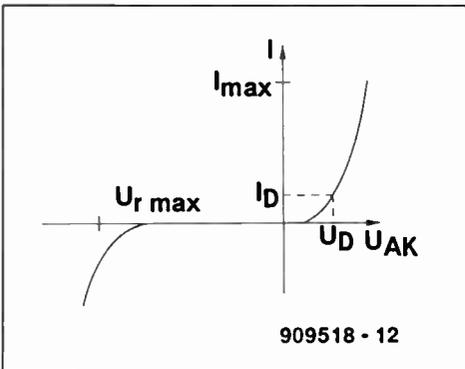


Fig. 3. Voltage-current characteristic of a typical small-signal diode.

of all currently available discrete semiconductors. Therefore, we will concentrate only on the most frequently used types.

Diodes

Diodes are devices that pass a current flowing in one direction without significant losses, and block current that flows in the reverse direction. As you are probably aware, this property allows a diode, in conjunction with a reservoir capacitor, to turn an alternating voltage into a direct voltage.

The diagram in Fig. 2 shows the two basic direct-voltage operating conditions of a diode. The left-hand drawing, Fig. 2a, shows the diode in its conductive state, i.e., passing a forward current. This current causes a forward voltage drop, U_D , across the device. Typically, at about one tenth of the maximum permissible forward current, U_D lies between 0.2 V and 0.4 V with germanium diodes, and 0.5 V to 0.8 V with silicon diodes.

The right-hand part of Fig. 2, marked 'b', shows the same diode, connected to a reverse voltage. In the permissible voltage range, the reverse, or leakage, current of small-signal diodes lies in the μA range with germanium types, and in the nA range with silicon types. When the permissible reverse voltage is exceeded, the resultant leakage current can rise to values of the order of the forward current. For most diodes, this leads to destruction of the device. The curve in Fig. 3 shows the relation between the voltage and the current of a typical small-signal diode.

The PC-TT90 uses only the emitter and

the collector lead to test diodes. The yellow (base) lead is not used in this case. The diode is connected in the conductive direction (red clip to the anode, and blue clip to the cathode). Next, the maximum current is set, and the measurement started. The computer plots the characteristic of the diode, taking into account the set maximum forward current.

Zener diodes

The so-called avalanche effect causes the reverse current to rise rapidly when the maximum reverse voltage is exceeded. This property of almost any semiconductor element is exploited in the zener diode, with the aid of a current limiting resistor. To avoid excessive local heating and subsequent destruction of the device, the reverse current is distributed equally on the semiconductor crystal. In general, a zener diode is operated in its safe electrical area as long as the power dissipation caused by the reverse current does not exceed the maximum permissible 'forward' power dissipation. The reverse voltage at which the current rises suddenly is called the zener voltage, U_Z .

Circuit section 'a' in Fig. 4 shows a zener diode connected in forward, i.e., conductive, direction. The electrical behaviour of a zener diode in this configuration is almost identical to that of a normal diode. The reverse connection, illustrated in the circuit 'b' in Fig. 4, is the more common for a zener diode. When the voltage applied via series resistor R_s is sufficiently high, the zener voltage can be measured across the diode. The typical U -vs- I characteristic of a zener diode is shown in Fig. 5. In the forward direction, zener diodes can be tested just as ordinary diodes, as described earlier.

The zener voltage, U_Z , may be determined by connecting the zener diode in the reverse direction, i.e., just as they are normally used. It should be noted, however, that the maximum reverse current may be much smaller than the maximum forward current.

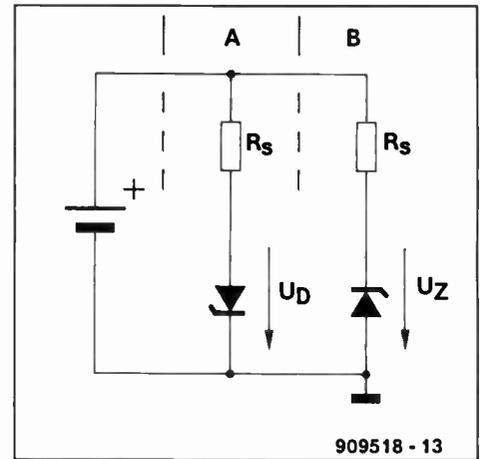


Fig. 4. Basic d.c. conditions of a zener diode.

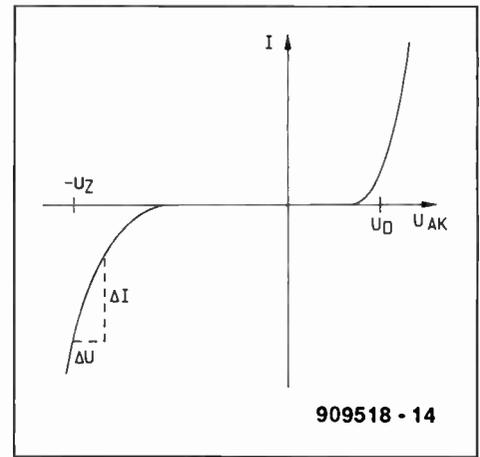


Fig. 5. Voltage-current characteristic of a zener diode.

Hence, this setting may have to be changed (on the computer) before connecting the zener diode. As a rule of thumb, the maximum permissible reverse current is roughly the maximum permissible power dissipation divided by the zener voltage. After starting the measurement cycle, the stabilization curve of the zener diode is plotted and displayed on the screen.

The PC-TT90 does not require a resistor

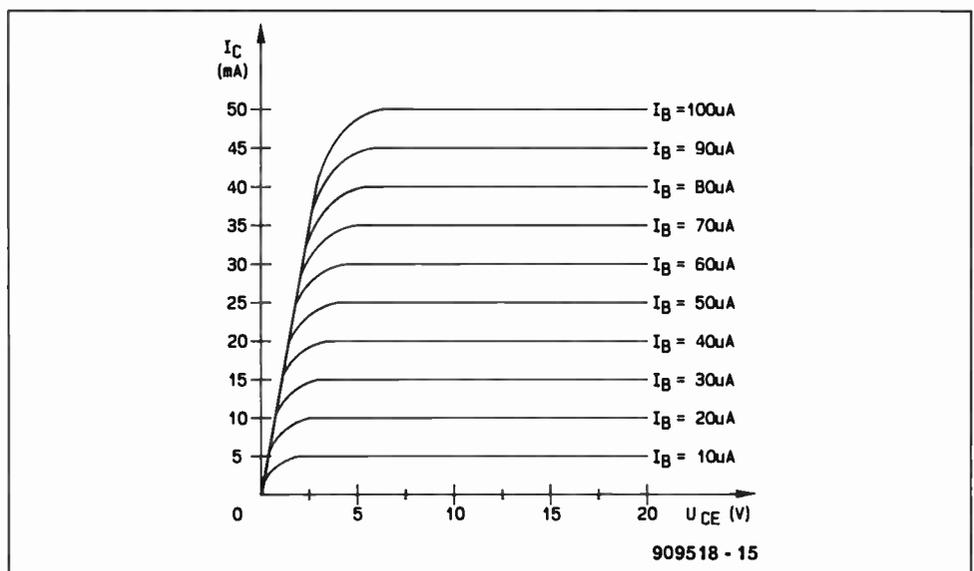


Fig. 6. Typical transistor characteristic. The graph shows the collector current, I_C , as a function the collector-emitter voltage, U_{CE} , with the base current, I_B , as a parameter.

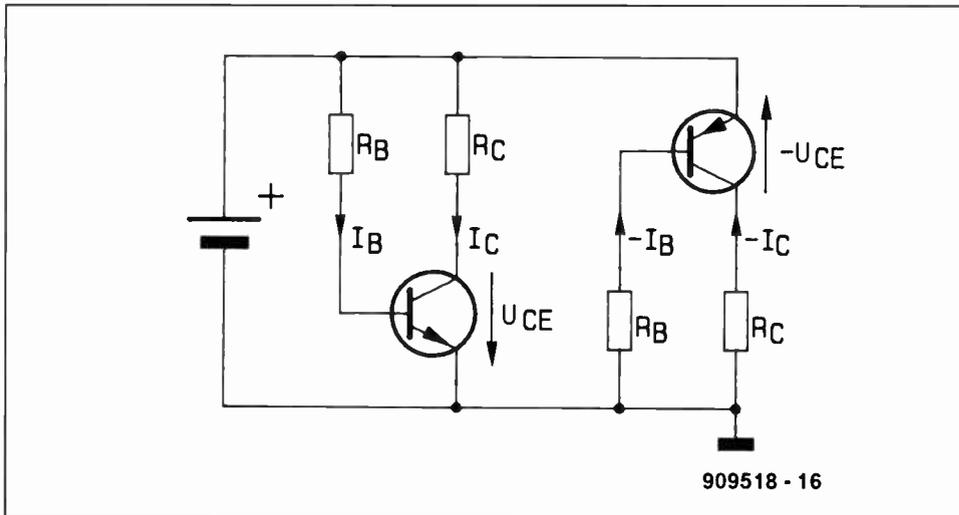


Fig. 7. Basic test circuits of n-p-n transistors (left) and p-n-p transistors (right).

to be connected in series with the zener diode. In fact, such a resistor would cause an unwanted off-set in the stabilization curve. Thus, the zener diode to be tested is connected direct between the red and the blue test lead.

Transistors

When we speak of a transistor, we usually have a bipolar type in mind. In most cases, special types such as the FET are referred to by their group name, i.e., not by the term transistor.

Transistors are semiconductors with three terminals. They are used mainly to switch and amplify electrical signals. Silicon transistors have now almost completely superseded germanium types that marked the beginning of the semiconductor era. Both silicon and germanium transistors are available in n-p-n and p-n-p versions.

The outstanding feature of the bipolar transistor is its ability to act as a current amplifier. A base current, I_B , is internally multiplied by the amplification factor, and gives rise to a collector current, I_C . The current gain, h_{FE} , is thus defined as the ratio of the collector current to the base current (see also Ref. 2).

As an example, Fig. 6 shows the output characteristic of a typical small-signal n-p-n transistor. The collector-emitter voltage, U_{CE} , is given on the horizontal axis in the range between 0 V and 20 V. The vertical axis indicates the collector current, I_C .

The ten curves describe the relation between these two voltages, with 10 base currents, I_B , as parameters. The first curve ($I_B = 10 \mu\text{A}$) shows that a collector current of 5 mA flows when U_{CE} increases from about 2.5 V to 20 V. It is seen that the collector current drops rapidly to virtually nought when U_{CE} is made smaller than about 1 V.

The magnitude of the collector current rises with the base current. In fact, the collector current appears to settle at a certain multiple of the base current. Hence, a constant base current causes a collector current that remains virtually constant within a fairly large range of U_{CE} (roughly between 5 V and 20 V). The collector current drops to small

values only with small voltages.

The basic circuits of the n-p-n and the p-n-p transistor are given in Fig. 7. The left-hand circuit shows an n-p-n transistor in common-emitter configuration. Series resistor R_B sends a constant current into the base. The resultant collector current, which flows through R_C , is the product of the base current and the current gain factor, h_{FE} , of the transistor. The collector and base current are added when they leave the transistor via the emitter terminal.

Typical current gain factors of small-signal transistors lie in the range between 100 and 1,000, and those of power transistors between 10 and 50. Hence, the base current is usually small with respect to the collector current, and may be neglected. So, for all practical purposes, the collector current equals the emitter current.

The curves in Fig. 6 are obtained by sending a constant current into the base of the transistor under test, and increasing the collector-emitter voltage from 0 V to the maximum value (here, 20 V) within a certain period (here, 100 ms). As the voltage is increased, the collector current is measured to enable the PC to compute the first curve. Next, the base current is set to the next high-

her value (here, $20 \mu\text{A}$), and the process is repeated to produce the second curve. After having computed all ten curves, the computer plots them in a graph as shown in Figs. 1 and 6. One advantage of the use of a computer here is that each curve needs to be measured only once. Hence, the process is completed fairly quickly, and thus prevents damage to the transistor, which inevitably heats up as a result of its own dissipation. In practice, even power transistors do not need a heat-sink when connected to the PC-TT90.

Field-effect transistors

A FET is a type of transistor that can be driven, virtually without power, via an electric field. In this respect, FETs behave very much like thermionic valves, and the similarity of these two component types is frequently noted in electronics textbooks.

The category of FETs falls into six basic types, whose circuit symbols are brought together in Fig. 8. The gate, G, is the input electrode that allows the current flow between the drain and the source to be controlled. The gate voltage, U_{GS} , exists between the gate and the source. The input resistance of a FET is typically very high, with values between $10^{10}\Omega$ and $10^{13}\Omega$ for junction FETs, and $10^{13}\Omega$ and $10^{15}\Omega$ for MOSFETs.

Analogous to the division into n-p-n and p-n-p classes of transistor, FETs come in n-channel and p-channel versions. Figure 9 shows the basic operation of an n-channel FET (left-hand circuit) and that of a p-channel FET (right-hand drawing). Both types of FET conduct at $U_{GS} = 0 \text{ V}$, and are therefore called depletion devices.

The circuit with the n-channel FET shown in Fig. 9 is taken as an example here to explain the basic operation. A typical example of an n-channel depletion FET is the well-known BF245. Similar to a bipolar transistor, the drain current (the 'FET' equivalent of the collector current) is virtually constant for values of the drain-source voltage, U_{DS} , between 5 V and the maximum value. Since the gate forms a very high resistance, it is volt-

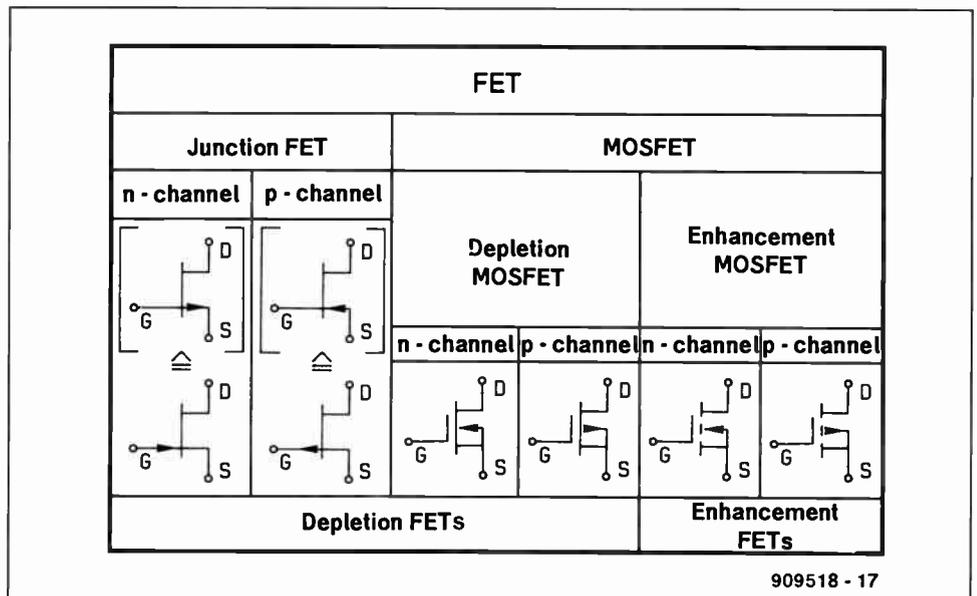


Fig. 8. Overview of field-effect transistors.

909518 - 17

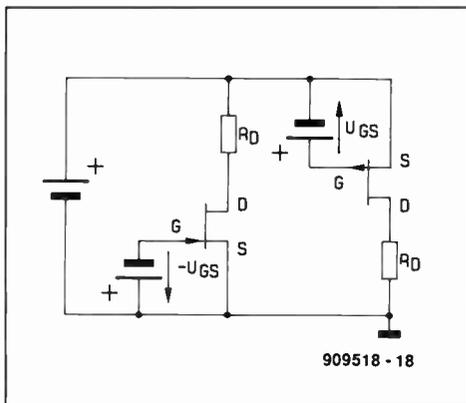


Fig. 9. Basic d.c. circuits of an n-channel FET (left) and a p-channel FET (right).

age-driven rather than current-driven like the base of a bipolar transistor. Hence, the voltage applied to the gate determines the drain current. A gate voltage of 0 V causes full conduction in a depletion FET. The drain current may be reduced by making the gate negative with respect to the source, as illustrated by the transfer characteristics in Fig. 10.

P-channel FETs are driven by a positive gate voltage. As shown in Fig. 9, the source is connected to the positive supply voltage, and the drain is, therefore, negative with respect to the source.

MOSFETs are also available as depletion types. In general, their extremely high input resistance is achieved by a thin isolation layer of SiO₂, which separates the gate from the drain-source channel. The electrical characteristics of depletion MOSFETs are largely similar to those of normal depletion FETs, discussed above. Depletion MOSFETs are typically used for high-frequency and digital circuits.

Enhancement-mode MOSFETs, or enhancement MOSFETs, require a voltage to be applied to the gate before conduction can occur, i.e., they are off when $U_{GS} = 0$ V. The n-channel enhancement MOSFET does not draw drain current until U_{GS} exceeds a certain threshold, when the drain is positive with respect to the source. This characteristic is reversed with p-channel types, i.e., the drain must be negative with respect to the source, while a negative gate-source voltage must be applied for the FET to conduct.

It should be noted that there are also FETs which seem to fall between the depletion and enhancement-mode classes. These devices are marked by a drain current of about half the maximum value when $U_{GS} = 0$ V, allowing the gate voltage to be made positive or negative with respect to the source.

Some MOSFETs have a fourth terminal, which is connected to the substrate. In most cases, the electrical function of this electrode is similar to that of the gate, although it must be noted that the substrate connection has only one isolation layer between it and the drain-source channel. The connection is usually indicated by the letter S (for substrate) or B (bulk).

The power MOSFET is a semiconductor from the class of enhancement-mode devices that will be discussed in detail below. Like

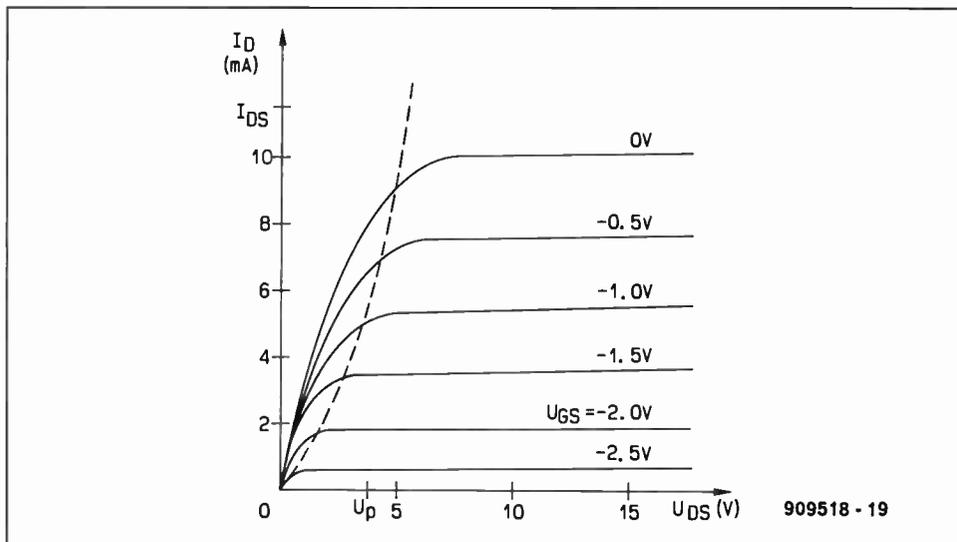


Fig. 10. Current-voltage transfer of a typical n-channel junction FET.

some types of bipolar transistor, power MOSFETs are capable of switching high voltages at high currents. Their drive characteristics, however, are fundamentally different and correspond to those of enhancement MOSFETs. N-channel power MOSFETs are driven by a positive gate voltage, when the drain is positive with respect to the source. Depending on the mode of operation, the gate voltage lies between 0 V and 20 V. The relevant transfer characteristics are shown in Fig. 11.

The number of n-channel FETs is greater than p-channel FETs, the reason being that electrons (in an n-channel) have a greater mobility than holes (in a p-channel). This gives n-channel FETs a higher gain than p-channel FETs. Also, in the case of power MOSFETs with an identical chip area and reverse voltage specification, the 'on' resistance of the drain-source channel in a p-channel type is roughly two times that of an n-channel type. Furthermore, the p-channel versions require a more complex production process, which shifts the price-performance ratio in favour of the n-channel types.

Returning to the transistor tester, the testing of any FET is started by selecting the relevant menu option, e.g., 'n-channel

depletion FET/depletion MOSFET', followed by the maximum drain-source current. The screen then indicates how the three wires of the tester are to be connected to the FET (red = drain; blue = source; yellow = gate). All further settings are provided automatically by the PC-TT90, which takes into account that FETs are driven with a control voltage, not a control current.

If you do not know which type of FET you are testing, select menu option 7, 'unknown FET'. After you have entered the maximum permissible drain-source current, the screen again indicates the connection of the test leads to the FET terminals. The yellow lead is connected to the gate. When the drain and the source are identified, the red wire goes to the drain, and the blue wire to the source. The connections of the drain and the source are reversed in the case of p-channel FETs. If you do not know the n- or p-channel classification, or the drain and source pinning, simply connect the drain and source in either way. The gate, however, must be connected correctly at all times.

When the test cycle is started, the PC-TT90 limits the drain current to the smallest value of 10 mA, and attempts to find a coherent transfer characteristic by varying the

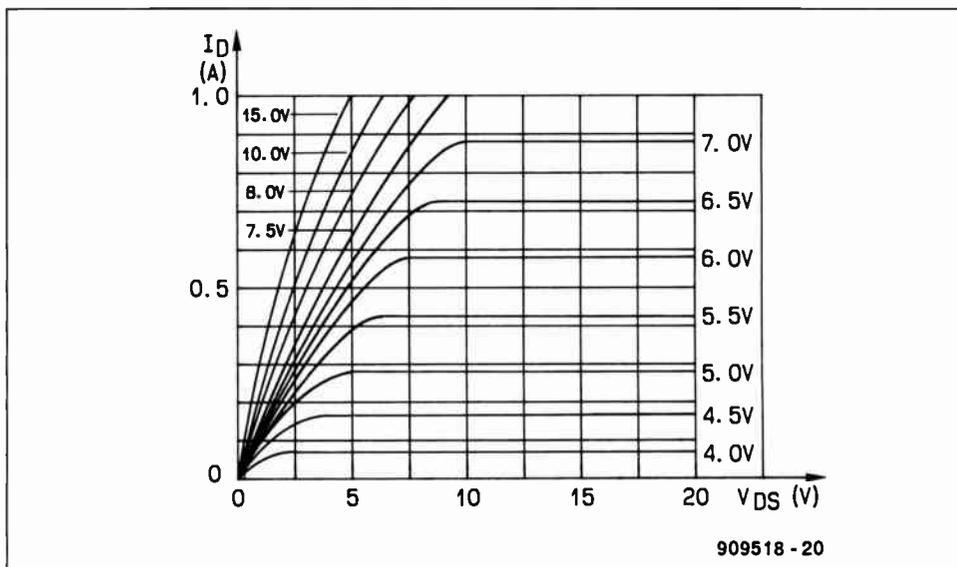
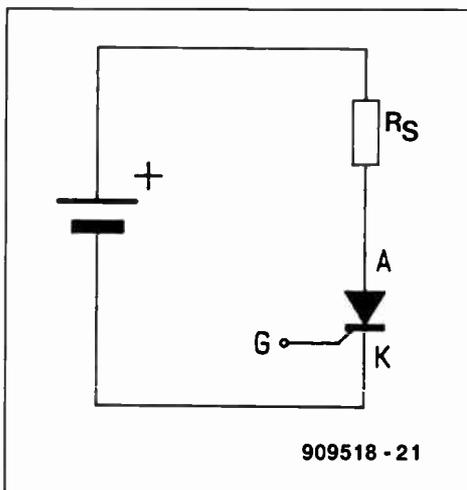
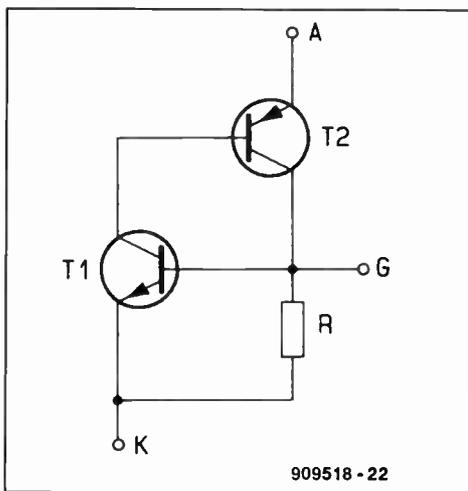


Fig. 11. Current-voltage transfer characteristic of a typical n-channel power MOSFET.



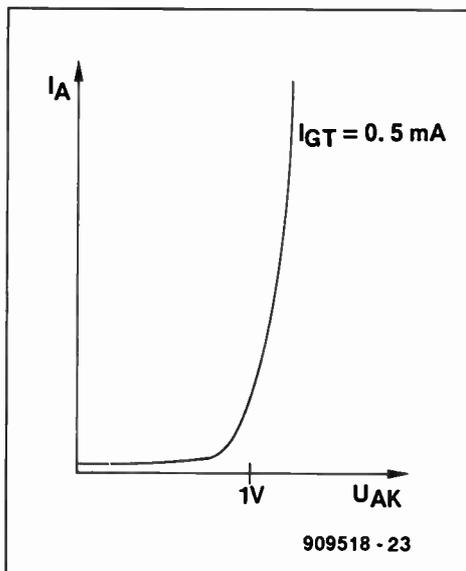
909518 - 21

Fig. 12. Basic connection of a thyristor.



909518 - 22

Fig. 13. Transistor-based equivalent of a thyristor.



909518 - 23

Fig. 14. Typical voltage-current characteristic of a thyristor.

control voltage between +5 V and -5 V. As soon as a clear indication is available about the operation of the device under test, the complete transfer characteristic is computed and subsequently displayed on the screen, along with the type classification of the FET. When this is not successful, the PC prompts you to swap the drain and source connection, and start a new test.

The trial-and-error test performed by the

PP-TT90 allows unknown FET types to be tested and classified. After the first test run, the complete transfer characteristic is measured, up to the maximum drain current specified by the user.

Thyristors

Figure 12 shows the circuit symbol of a thyristor. Thyristor is the original name of the solid-state equivalent of the thyatron valve, but is now more commonly called silicon-controlled rectifier (SCR). A version of the SCR for switching a.c. is the triac, which is discussed further on.

The anode-cathode (A-K) junction of a thyristor is normally blocked, so that series resistor R_S does not pass current (see Fig. 12). When a positive voltage, U_{GK} , of about 1 V is applied to the gate terminal (G), the gate-cathode junction becomes conductive, and passes a current. This gate current is usually denoted by the term triggering current, I_{GT} , and is not dependent on the anode voltage or the anode currents. When I_{GT} exceeds a certain value (the trigger threshold) the thyristor is triggered ('fired'), and the anode-cathode junction conducts. Current will keep flowing through this junction even when the gate current is removed. The current is interrupted, however, when it drops below a certain level, the holding current, I_H .

The equivalent circuit of a thyristor, based on transistors, is shown in Fig. 13. In principle, a reverse-biased thyristor blocks current just as a diode.

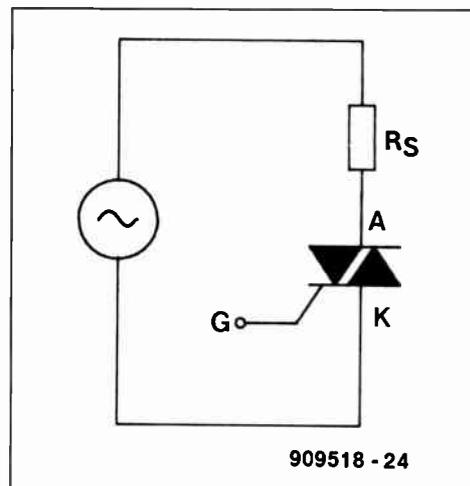
Apart from the maximum reverse voltage, which is usually fairly high and therefore not achievable with the PC-TT90, the main specifications of a thyristor are the I_A-U_{AK} characteristic (Fig. 14) and the triggering current, I_{GT} .

The red test terminal of the PC-TT90 is connected to the anode of the thyristor, the yellow lead to the gate, and the blue lead to the cathode. The instrument automatically and gradually raises U_{AK} to the maximum value before going back to nought and increasing the triggering current by one step. When the thyristor triggers, the relevant characteristic is computed, and the triggering current indicated on the screen. Since this current represents the minimum value of I_{GT} , the indication should be increased for practical purposes to ensure reliable triggering under all 'real' working conditions of the device. In most cases, it is best to use a value of 2 to 5 times the minimum, as long as the maximum permissible triggering current is not exceeded.

Triacs

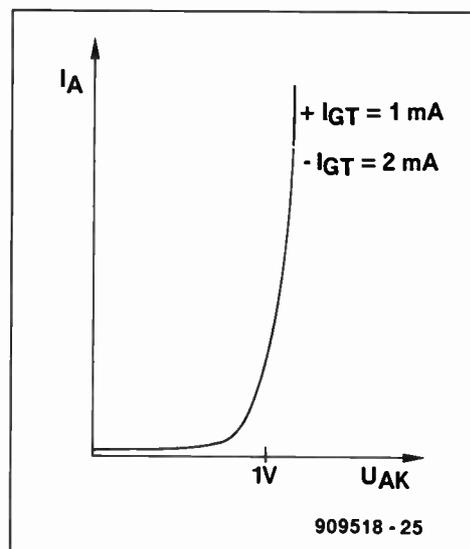
A triac consists basically of two thyristors connected in anti-parallel, sharing a common control input. The circuit symbol is shown in Fig. 15.

When a small voltage is applied between the anode (+) and the cathode (-), the triac, like the thyristor, can be triggered with a positive gate current. A further similarity is that the triggering voltage exists between the



909518 - 24

Fig. 15. Circuit symbol and basic connections of a triac.



909518 - 25

Fig. 16. Typical transfer characteristic of a triac.

gate and the cathode. Contrary to a thyristor, however, a triac can also be triggered with a negative gate voltage, both when the anode is positive with respect to the cathode, and vice versa. This characteristic allows a thyristor to be used as a switch for alternating current, controlled by triggering pulses that may occur in all four quadrants.

Most triacs require a relatively small triggering current when the anode and the gate voltage have the same polarity with respect to the cathode. More triggering current is generally needed when the gate voltage is positive, and the anode voltage negative. Thus, when direct-voltage triggering pulses are used with a triac in an alternating voltage circuit, the triggering voltage must be negative with respect to the cathode to enable the triac to be fired with a relatively small current.

The main characteristics of a triac are its transfer characteristic, i.e., the current-voltage response of the anode-cathode channel, and the gate current at which the device is triggered. Figure 16 shows a typical transfer characteristic.

The red test lead is connected to the anode, the yellow test lead to the gate, and the blue test lead to the cathode of the triac. The

PC-TT90 raises the supply voltage slowly while increasing the gate current in small steps. When the triac triggers, the I_A-U_{AK} characteristic is measured, and the required triggering current indicated. Next, the test procedure is repeated with reversed polarity of the triggering current. The I_A-U_{AK} characteristic is not measured, however, since it does not depend on the polarity of the triggering current. Once the triac is triggered, the required (reverse) triggering current is measured and indicated.

The characteristics of a triac may be tested as explained with reversed anode and cathode polarity also, simply by swapping the red and the blue test leads. In all cases, the monitor of the PC shows the main characteristics of the device under test. The main electrical properties measured allow you to classify the device, if it is an unknown type, or, if it is a known type, to check whether it is functional or not.

Working with the PC-TT90

As already mentioned, the PC-TT90 is simple to use because the component tests are performed virtually automatically, under the control of a computer program. Before we can use the PC-TT90, however, the instrument must be installed on the PC.

Hardware installation

The complete instrument is accommodated on a single printed-circuit board that is inserted in a free bus extension slot in your PC. The PC-TT90 may be used in PC-XT as well as PC-AT computers, and compatibles. It will be clear that an AT-type computer with a hard disk has certain advantages here.

The three test leads, each of a length of about 1 m, are fed out of the rear of the PC, and the small crocodile clips at the ends are located such that they are easily connected to the devices to be tested.

Software installation

The user software consists of a number of files, and is supplied on a 5¼-inch, 360-KByte diskette. The programs on this disk automatically identify the video adapter in the PC, and are suitable for Hercules, EGA, and VGA systems.

The control software for the PC-TT90 may be run under the control of a shell called ELV-DOSBATCH. This shell, or user-interface, offers menus and single-letter commands that take you off the DOS level, affording a less cumbersome way to work with the PC.

The software installation is straightforward. To begin with, insert the diskette supplied with the kit into drive A:. Make A: the current drive. If you do not have a hard disk, or do not want to use it for the PC-TT90, type

DOSBATCH

followed by a carriage return (CR). The shell is loaded, and the main menu appears on the screen after a few seconds. The transistor tester is loaded from this menu by typing '1'

and a CR. The program loads and is ready for use after a few seconds. The screen shows a menu bar that allows you to enter certain maximum values for the device to be tested. These values will be reverted to in the description of the test procedure.

The installation on a hard disk is equally simple. Type

INSTALL <CR>

from the A: prompt, and answer the questions regarding the language and the name of the subdirectory on the hard disk. If you are satisfied with the defaults offered by the installation program, a subdirectory called 'ELV' is created on the hard disk, and subsequently used to hold DOSBATCH and all other ELV programs. When the installation is complete, DOSBATCH appears on the screen. As described above, the transistor tester is run by typing '1' and a carriage return.

Practical use

The actual use of the program is straightforward, and is largely self-explanatory. Figure 17 shows the main menu. Items and options presented on the screen are selected in the usual way by pressing the arrow keys and the return key, or, if applicable, by typing the selection number. The maximum device current (for transistors, 10, 20, 50, 100, 200, 500 or 1000 mA) is selected in this way. The lower half of the screen indicates the function of the three test leads. For an n-p-n transistor, for instance, the leads are connected as follows:

blue: emitter
yellow: base
red: collector

In most cases, the red lead is positive with respect to the blue lead, while the yellow lead carries a control voltage, and can be at positive or negative potentials depending on the reference.

After connecting the device to be tested, start the actual test by pressing the space bar. The previously discussed transfer characteristics are computed and plotted in a co-ordinate system with automatically adapted scale factors. In the case of transistors, the appropriate base currents are also set automatically, depending on the maximum collector current. The maximum base current is set at 10% of the maximum collector current, while the maximum collector-emitter voltage is limited to 20 V. If smaller values are required for these parameters, call up a submenu by pressing the <CR> key instead of the space bar. Next, enter the values you require, and run the test by pressing the space bar.

In the case of transistors, the transfer characteristic consists of a maximum of 10 curves. Depending on the electrical behaviour of the transistor under test (TUT), fewer curves may appear. For instance, only six curves appear when the smallest meaningful collector current is caused by a base current of 1 mA, and the TUT draws its

A complete kit of parts for the PC-controlled semiconductor tester is available from the designers' exclusive worldwide distributors:

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maximum collector current at a base current of 6 mA.

In principle, the following maximum values of the base current are available, each with a subdivision factor of 10:

10, 20, 50, 100, 200, 500 μ A
1, 2, 5, 10, 20, 50, 100 mA.

this means that the smallest current range offers the values 1 μ A, 2 μ A, 3 μ A, and so on, up to and including 10 μ A. Similarly, the next higher range starts at 2 μ A, and ends at 20 μ A.

The plotted characteristic is static, i.e., it remains on the screen until the space bar is pressed again to run a new test on the same or another component. A minimum interval of 4 s must be allowed between subsequent tests, while care should be taken to avoid overheating of power semiconductors. If necessary, allow a longer pause, say, 10 s, between tests on these devices.

When another semiconductor type is to be tested, or when different parameters are required, press the ESC (escape) key to return to the main menu. Finally, on-line help is available and may be called up by pressing function key F1. To exit the transistor tester program, simply press ESC twice.

Storing measured characteristics

Hard copy of the computed characteristics may be obtained on a matrix printer set to 'Epson' mode. Press the F2 key to use this feature.

The curves and the associated co-ordinate system may also be written to a file. To use this option, press F3, enter the file name, followed by a <CR>. Files stored in this way may be retrieved later by pressing F4 and entering the file name.

I/O base address

The default I/O address setting of the PC-TT90 card is 300H. If you require a different address, load the program with the command

TRTEST [address] <CR>

where [address] is a hexadecimal number. This address must match that set in hardware on the card. More information on this setting is available in the 'README' documentation file. □

Continued next month

HEADPHONE AMPLIFIER

WITH DIGITAL VOLUME CONTROL

from an idea by U. Habschied

It is often socially not acceptable to turn up the volume of your amplifier, receiver or television set. In such cases a pair of headphones is the perfect medium for listening to your favourite record, tape or television programme. Also, headphones have a decided advantage over loudspeakers: their quality/price ratio is at least five times better

Normally, headphone amplifiers consist of a simple purpose-designed output stage. The one presented here is rather more sophisticated: it is not just a good-quality miniature stereo amplifier, but also offers a volume control that uses digital switches. Just two push-button switches enable the loudness to be set in 16 discrete steps. It also has two switch-selectable inputs. The design is based partly on that of the "All solid-state preamplifier" we published just over a year ago*. It is therefore particularly suitable for use with that unit, but may also be used in conjunction with other preamplifiers or integrated amplifiers without any problem. It may also be constructed in a stand-alone box with its own power supply.

The circuit

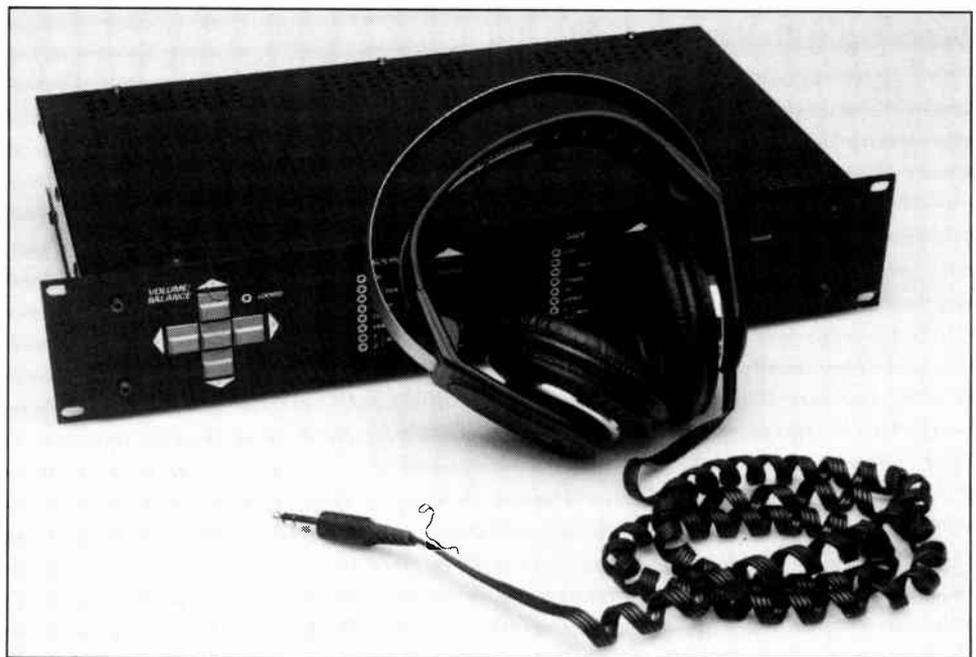
The circuit diagram shows the input selectors, step attenuators and amplifier stages for both stereo channels. The other components serve to control the input stages and the step attenuators.

At the top left are the four input sockets, K_1 – K_4 . A logic level provided by electronic switches IC_{1b} – IC_{1d} enables switching between the tape and line inputs: a sort of tape monitor switch as it were.

The switching signal is provided by push-button switches S_1 and S_2 via an R-S bistable (flip-flop), IC_{2a} – IC_{2b} . This stage retains the last selected position and at the same time prevents chaos if S_1 and S_2 were pressed simultaneously. Network R_1 – C_1 ensures that it is always set to position "line" when the supply is switched on.

The input signal is also applied to a potential divider connected across the inputs of a 16-channel multiplexer. The divider for the left-hand channel consists of resistors R_{14} – R_{29} , and that for the right-hand channel of R_{38} – R_{53} . The junctions of the successive resistors are connected to the 16 inputs of IC_5 (IC_6). The common output of the multiplexer is connected to the non-inverting input of opamp IC_7 (IC_8).

Since the FET switches on board the 4067



are in series with the fairly high input resistance of the opamp, they introduce virtually no distortion.

The logic combination at inputs A–D of the multiplexer determines which of its inputs is connected its output (pin 1).

The output stage consists of an opamp with two separate output transistors, T_3 and T_4 for the left-hand channel. These transistors are driven by the output of IC_7 via quiescent-current diodes D_1 – D_3 . The quiescent-current circuit also contains current sources T_1 – R_{32} and T_2 – R_{33} . These sources provide sufficient current for the output transistors even in high-drive conditions, so that the distortion is kept low right up to the maximum drive level.

The output stage is a class A type operating with a quiescent current of 50 mA. Negative feedback takes place via R_{30} and R_{31} . The stage uses no capacitors so that no loss of quality is caused by such components.

The output stage operates from a higher supply, ± 15 V, to ensure a good dynamic range even if fairly insensitive headphones are

used. This arrangement ensures that an output voltage of up to 8.5 V r.m.s. is available with a distortion of not greater than 0.01%. The bandwidth is 400 kHz.

Any offset compensation for the opamp has been omitted purposely. The offset voltage at the output varies by a couple of millivolts, which is caused by the relatively high bias current of the 5534 that flows through the feedback resistors. Compensation would, therefore, be largely ineffectual.

The output of the amplifier is protected by two parallel-connected resistors of 120 Ω to give an output resistance of 60 Ω . This value has been chosen to ensure that the power delivered to the headphones remains about the same, irrespective of whether a low- or high-impedance type is used. If it is felt that this arrangement does not provide optimum sound quality, the value of the resistors may be altered to personal taste. Bear in mind, however, that the values depend to a large extent on the impedance characteristic of the headphones.

The control stage for the multiplexers

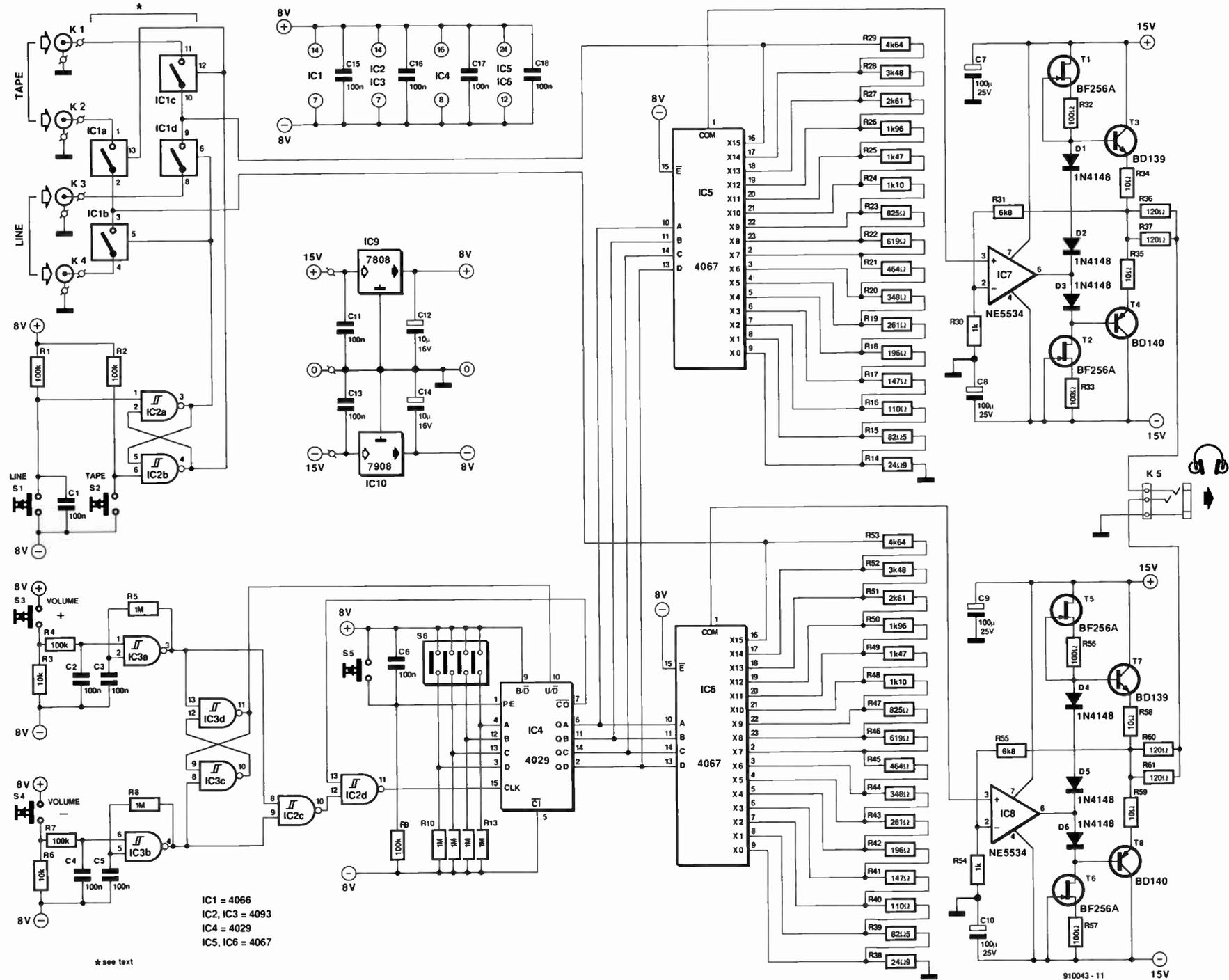


Fig. 1. Circuit diagram of the headphone amplifier.

consists of the circuit based on IC₃, IC₄, and (partly) IC₂. This section also contains two push-button switches, S₃ and S₄, to provide, respectively, an increase or a reduction in the volume. Each of the switches operates an oscillator, IC_{3a} and IC_{3b} respectively. When either of these switches is kept pressed, the volume is increased or reduced in pre-defined steps (see Table 1).

The oscillators are followed by an R-S bistable (flip-flop), IC_{3c} and IC_{3d}, that arranges for counter IC₄ to count up or down depending on which of the switches is pressed.

The signal generated by IC_{3a} or IC_{3b} is also applied via gates IC_{2c} and IC_{2d} to the clock input (pin 5) of IC₄. Circuit IC_{2d} ensures that when the highest or lowest volume is reached the counter is disabled.

The counter may also be preset to a given position with the aid of the DIP switches contained in S₆. Whenever the amplifier is switched on afterwards, the counter automatically assumes the preset position. The position is read via R₉ and C₆. Push-button switch S₅ enables the preset position to be selected during operation.

The power supply has been kept simple, since normally the present unit will be integrated into an existing amplifier, which almost certainly has a regulated ± 15 V supply available. All that is necessary to obtain a +8 V and -8 V supply for the circuit other than the output stages, therefore, is the addition of regulators IC₉ and IC₁₀.

Some practical points

No printed circuit has been designed for the amplifier, but its construction on a prototype board should not present undue difficulties.

The electronic input switches cause very slight distortion. If the switching between line and tape is not required, it is therefore advisable to omit IC₁ and its associated control circuitry to reduce the distortion. This may also be achieved by using Texas Instruments Type TLC4066 LinCMOS input switches instead of the standard 4066 types. Note that the TLC4066 ICs require 6 V instead of 8 V voltage regulators.

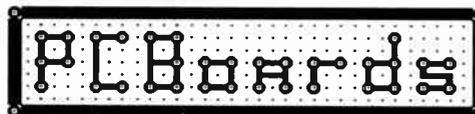
The values of the resistors in the voltage dividers as shown in the circuit diagram result in 2.5 dB steps in volume. This gives an overall volume range of 40 dB. If steps of different magnitude are required, the values of the resistors must be altered as shown in the examples in Table 1.

Although the BD139 and BD140 output transistors get pretty warm during normal operation, they do not need a heat sink. If, nevertheless, you are worried by their temperature, there is, of course, no harm in using a heat sink.

Circuit IC₇ may be a Type NE5534 or a Type OP37. Of these two, the OP37 is the slightly better, but it is also much dearer. ■

* *Elektor Electronics*, December 1989 and January 1990.

| Resistors | Step size | | | |
|-----------------------------------|-------------------|-----------------|-----------------|-----------------|
| | 2.5 dB | 3.0 dB | 4.0 dB | 5.0 dB |
| | value in Ω | | | |
| R ₂₉ , R ₅₃ | 4640 | 3650 | 4220 | 11000 |
| R ₂₈ , R ₅₂ | 3480 | 2610 | 2670 | 6190 |
| R ₂₇ , R ₅₁ | 2610 | 1820 | 1690 | 3480 |
| R ₂₆ , R ₅₀ | 1960 | 1270 | 1050 | 1960 |
| R ₂₅ , R ₄₉ | 1470 | 909 | 681 | 1100 |
| R ₂₄ , R ₄₈ | 1100 | 649 | 422 | 619 |
| R ₂₃ , R ₄₇ | 825 | 464 | 267 | 348 |
| R ₂₂ , R ₄₆ | 619 | 332 | 169 | 196 |
| R ₂₁ , R ₄₅ | 464 | 232 | 105 | 110 |
| R ₂₀ , R ₄₄ | 348 | 162 | 68.1 | 61.9 |
| R ₁₉ , R ₄₃ | 261 | 115 | 42.2 | 34.8 |
| R ₁₈ , R ₄₂ | 196 | 82.5 | 26.7 | 19.6 |
| R ₁₇ , R ₄₁ | 147 | 56.2 | 16.9 | 11.0 |
| R ₁₆ , R ₄₀ | 110 | 40.2 | 10.5 | 6.19 |
| R ₁₅ , R ₃₉ | 82.5 | 28.7 | 6.81 | 3.48 |
| R ₁₄ , R ₃₈ | 249 | 69.8 | 11.5 | 4.42 |
| R _{total} (abt) | 18.5 k Ω | 12.0 k Ω | 11.5 k Ω | 25.0 k Ω |



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CENTRAL HEATING CONTROLLER

PART 2: CONTROL SOFTWARE, CONSTRUCTION AND PROGRAMMING

K. Browne

continued from the February 1991 issue

Control software

Table 4 shows how the available RAM memory has been allocated in the control system. The first 64 bytes are allocated to system variables such as the current time, the date, etc., and the state of the system.

The largest slice of RAM memory is allocated to the user program store. This is where the instructions you input, e.g., 'heating ON Monday at 10.30' is stored. There is sufficient storage capacity for up to 255 program steps.

The final 64 bytes of the RAM memory are used for the Z80 stack.

The flowchart shown in Fig. 7 provides an overall view of how the program works. The first section deals with initializing the system from a cold start, i.e., the first time the CH controller is powered up. Since the system has a battery backup, the initialization would only take place again if the battery were removed and the system powered down. After initialization, the program enters the main program loop.

A separate section of the flowchart shows the timekeeping interrupt sequence. The CPU is diverted from the main program loop to the interrupt subroutine every 20 milliseconds by the 50 Hz synchronizing signal. As already noted in part 1 of this article, this signal is derived from the mains supply frequency. After completing the interrupt subroutine, the CPU returns to where it left off in the main program loop.

Each box in the flowchart represents at least one small subroutine in the timeswitch program. Note, however, that the flowchart is by no means complete, as there are over 80 separate subroutines in the heating controller program.

Unfortunately, it is beyond the scope of this article to give a full insight into the programming techniques of the Z80 microprocessor. Much has been written on this subject, however, and two useful references are given at the end of this article. Moreover, the Z80 has been with us for many years now, and has been used in many projects carried in this magazine.

To illustrate the basic steps in programming the present unit, three examples are given of subroutines used in the heating controller program. All subroutines below are written in assembler format.

Table 3

Codes written to the LCD instruction register

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | Clear display and home cursor |
| 0 | 0 | 0 | 0 | 0 | 0 | 1 | * | Home cursor and return shift |
| 0 | 0 | 0 | 0 | 0 | 1 | i | s | Entry mode set |
| 0 | 0 | 0 | 0 | 1 | m | c | b | Display on/off |
| 0 | 0 | 0 | 1 | 0 | d | * | * | Shift cursor position |
| 0 | 0 | 0 | 1 | 1 | d | * | * | Shift entire display |
| 0 | 0 | 1 | z | 1 | 0 | * | * | Function set (used once to initialize) |
| 0 | 1 | a | a | a | a | a | a | Set the user defined character RAM area |
| 1 | a | a | a | a | a | a | a | Set the display RAM address |

Notes

- * Bit has no effect
- a Address in character generator (range 00 to 3F hex)
Address in display RAM (range 00 to 4F hex)
- b Cursor character flashes (0 = no flash; 1 = flash)
- c Cursor (0 = off; 1 = on)
- d direction (0 = left; 1 = right)
- i Increase or decrease address (0 = decrease; 1 = increase)
- m Display mode (0 = off; 1 = on)
- s Shift display on entry (0 = no shift; 1 = shift)
- z Set number of data bits (0 = 4 bits; 1 = 8 bits)

Codes read from the LCD instruction register

| | | | | | | | | |
|---|---|---|---|---|---|---|---|----------------------------|
| f | a | a | a | a | a | a | a | Read busy flag and address |
|---|---|---|---|---|---|---|---|----------------------------|

Notes

- a current address in either character generator or display RAM, depending on previously set instruction
- f busy flag (1 = busy; 0 = ready)

| | | |
|-------------|------|--------------------------------|
| 3000 – 303F | 64 | System variables |
| 3040 – 363F | 1536 | User program store (256 items) |
| 3640 – 37BF | 384 | spare |
| 37C0 – 37FF | 64 | stack (32 items) |

Table 4. RAM memory allocation.
WorldRadioHistory

Example 1: zero RAM routine

This routine is used as part of the initialization of the system, to set all 2,048 bytes of RAM memory to zero.

LD HL, #3000 load the HL register pair with the first RAM address (see Table 1)

LD BC, #0800 load the BC register pair with 2048 (count value)

loop: LD A, #0 load A register with zero

LD (HL), A load the RAM address pointed to by HL with the contents of A (zero)

INC HL increase the HL register pair by one

DEC BC decrease the BC register pair

LD A,B load A register with contents of B

OR C 'OR' the contents of A register with C and leave result in A (i.e., check if both B and C are zero)

JR NZ, loop jump if the result of the check is not zero, to a point called 'loop' (i.e., test Zero Flag)

RET finish subroutine and return

Example 2: display a character

This routine is used extensively in the controller program to display a character pattern on the LC display. On entry to this routine, the A register contains a valid display code.

CALL busy call the 'busy' subroutine (see below)

LD (#9001),A load the LCD data register with contents of A register (see Table 2)

RET finish subroutine and return

Example 3: the busy subroutine

This routine checks that the LC display is ready to receive an instruction. The program will wait until the display module is ready.

busy: PUSH AF start here with saving AF registers on the stack

wait: LD A,(#9002) load 'A' with contents of LCD instruction register (see Tables 2 and 3b)

BIT 7,A test bit 7 of the A register (the busy bit)

JR NZ, wait jump back to 'wait' if bit 7 was not zero (i.e., wait until the LC display is ready for data)

POP AF restore the AF registers

RET finish subroutine and return to the character display routine

The mnemonic listing for the timeswitch program runs to over 15,000 characters in 1,400 lines of assembler text. The final object code produced by the assembler has just over 2,900 bytes of Z80 instructions and data. is given in Fig. 8. Details on ordering a copy of the hexdump listing of the control program are given at the end of this article.

WorldRadioHistory

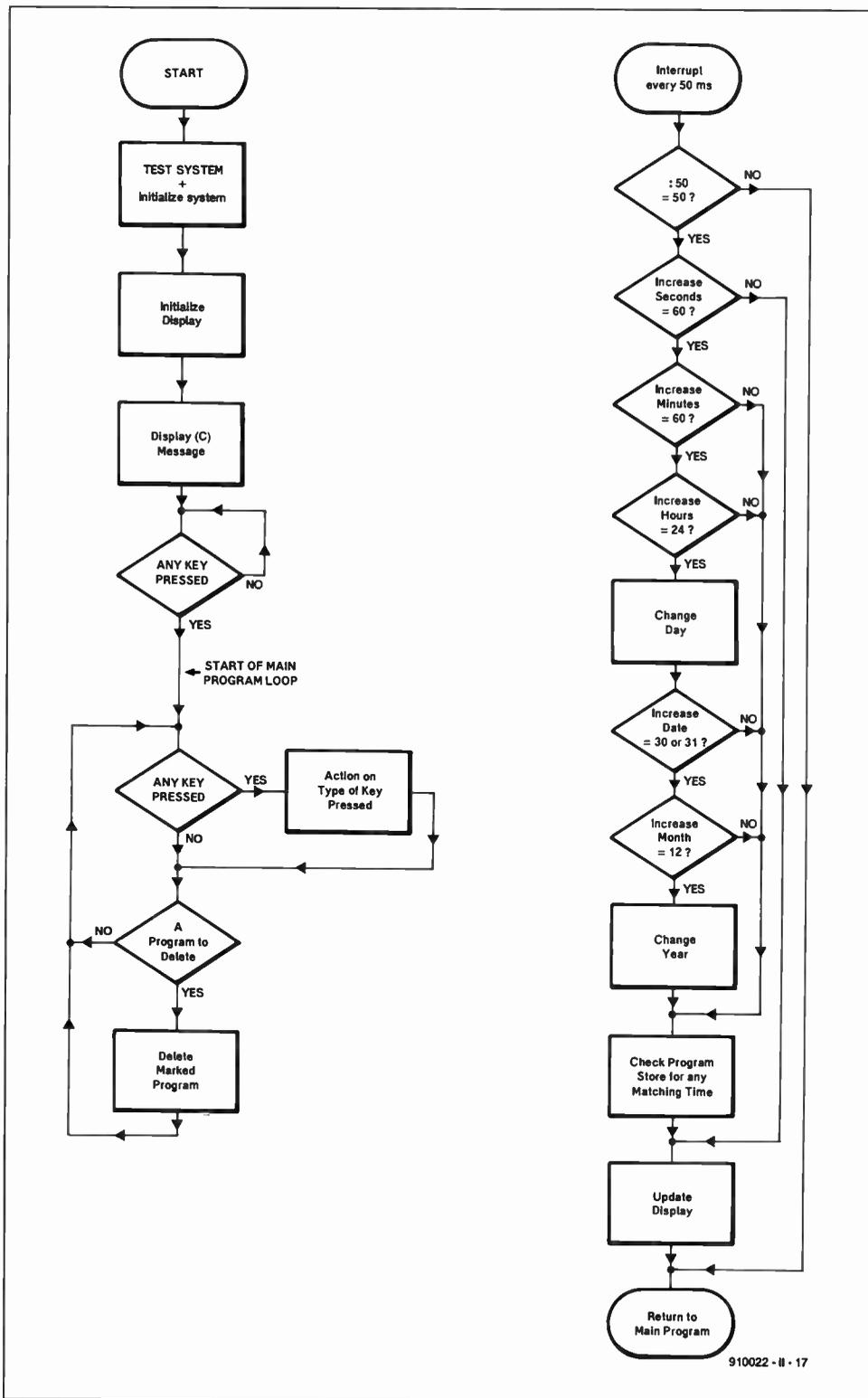


Fig. 7. Flowchart of the control program. The interrupt servicing routine is shown separately to the right.

Construction and adjustment**Main PCB assembly**

The assembly of the main PCB is fairly straightforward. First, fit the 14 wire links as shown on the component overlay. It is essential that these links are fitted first, and checked, because some of them go beneath ICs, and it would be difficult to make changes later. The components can then be fitted on to the PCB, starting with the smaller ones such as the resistors and diodes. IC sockets should be used for all the integrated circuits, but at this stage, do not fit the ICs into the sockets. Lengths of stranded wire should

COMPONENTS LIST

MAIN CONTROLLER PCB

Resistors:

| | | |
|---|-----------------------|--------------|
| 1 | 1k Ω | R1 |
| 2 | 27k Ω | R2;R5;R6;R11 |
| 1 | 27k Ω | R3 |
| 2 | 10k Ω | R4;R14 |
| 1 | 500k Ω | R6 |
| 1 | 22k Ω | R7 |
| 2 | 1k Ω | R9;R12 |
| 1 | 300 Ω | R10 |
| 1 | 270k Ω | R13 |
| 2 | 4k Ω | R15;R16 |
| 1 | 47k Ω preset H | P13 |

Semiconductors:

| | | |
|---|-----------|---------------|
| 6 | 1N4001 | D1-D4;D12;D13 |
| 7 | 1N914 | D5;D7-D11;D14 |
| 1 | BZY88C9V1 | D6 |
| 1 | TIL111 | IC1 |
| 1 | 78M05 | IC2 |
| 1 | 74HC14 | IC3 |
| 1 | Z84C00A | IC4 |
| 1 | 27C64 | IC5 |
| 1 | 516 | IC6 |
| 1 | 74HC373 | IC7 |
| 1 | 4011 | IC8 |
| 1 | 7555 | IC9 |
| 3 | BC108 | T1;T2;T3 |

Capacitors:

| | | |
|---|------------------------|----------|
| 1 | 10nF ceramic | C1 |
| 1 | 220 μ F 25V radial | C2 |
| 3 | 100nF ceramic | C3;C7;C8 |
| 1 | 1nF ceramic | C4 |
| 1 | 22 μ F 25V radial | C5 |
| 1 | 270pF ceramic | C6 |

Miscellaneous:

| | | |
|---|--------------------------------------|----|
| 1 | 2 MHz quartz crystal | X1 |
| 1 | 250mA 20-mm fuse | F1 |
| 2 | fuse clip | |
| 1 | 40-way IC socket | |
| 1 | 28-way IC socket | |
| 1 | 24-way IC socket | |
| 1 | 20-way IC socket | |
| 2 | 14-way IC socket | |
| 1 | 8-way IC socket | |
| 1 | case type AB13 (Maplin LF14Q) | |
| 1 | mains transformer 12V @ 250 mA | |
| 2 | miniature mains relay (Maplin YX97F) | |
| 1 | 12-way 2A connection strip | |
| 1 | battery (see text) | |

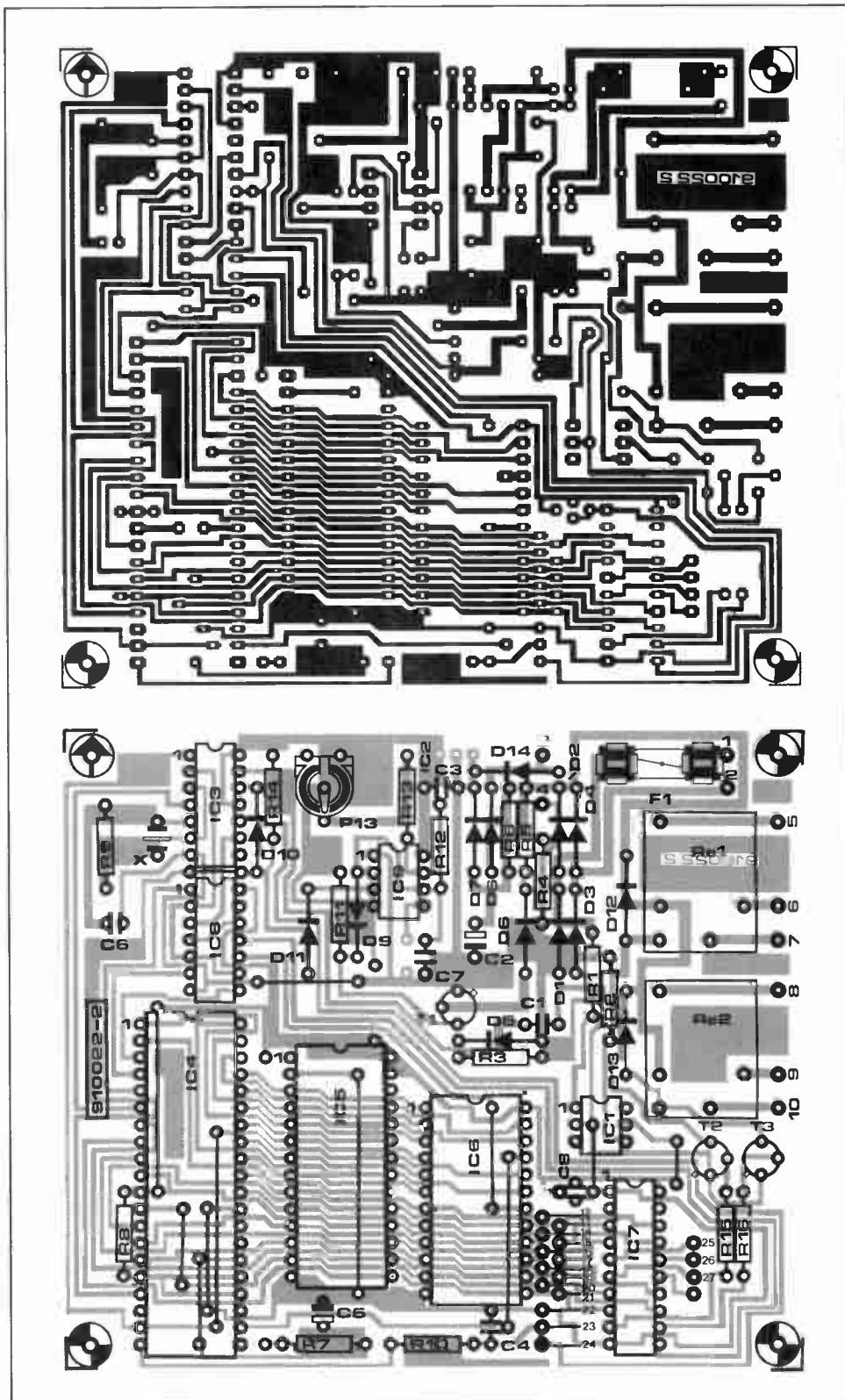


Fig. 8. Author's design of the main controller printed circuit board.

be soldered to the various connection points as shown.

At this stage it is advisable to do a number of preliminary checks. First, carefully check the PCB for short-circuits and dry joints, as any faults, particularly on the address and data lines of the CPU are difficult to trace, and could prove fatal to the CPU. Connect up the transformer, or an AC bench supply, to the circuit. Check the 5V and 12V supplies. Also check that a 5-V supply is present at all the IC sockets. Refer to the circuit diagrams to locate the supply terminals.

Disconnect the power, then insert IC1,

IC3, IC8 and IC9 into their respective sockets. Reconnect the power and check for the following pulses using either a logic probe or an oscilloscope.

- Pin 6 of IC4 socket: a 2-MHz clock pulse;
- Pin 17 of IC4 socket: 50 Hz very short duration pulses.

The next step is to disconnect the AC power supply and connect instead a 9-V DC supply to the points 3 and 4 on the main PCB (+Ve to point 3). Next, check the presence of 50 Hz very short duration pulses to pin 17 of the socket for IC4.

Display PCB assembly

Fit all the components, except the LEDs, to the display PCB as shown in Fig. 9. Start with the resistors, diodes and transistors. Next, fit the key switches, complete with the caps, ensuring the correct orientation. The pins of the switches should be pushed through the PCB only far enough to enable them to be soldered. You may find it easier to solder only two diagonally opposite pins at first. Once the switch alignment is satisfactory, the remaining pins may be soldered.

Mount the LCD display unit to the PCB

PROGRAMMING THE HEATING CONTROL UNIT

The control unit is programmed by way of the six control keys. Each key has a number of different functions, dependent on the menu shown on the display module. The basic key functions are as follows:

Arrow keys

These keys are used to step through the various options shown on the display module. When setting the time, the keys increase or decrease the displayed time, one count at a time. If a key is held pressed for more than two seconds, the displayed time is rapidly advanced or retarded until the key is released.

ENTER key

The 'enter' key is used to confirm a selection.

DELETE key

This key is used to cancel a selection.

HEATING/HOT WATER key

These keys are used to manually change the status of the heating and hot water outputs.

Initial power-up

When power is first connected to the control unit, it performs various self checks. If these checks are satisfactory, the display shows a continuously scrolling copyright message. It is only at this point in the program that entry can be made to the calibrate mode by pressing the HEATING key.

Assuming that calibration of the system has been completed successfully as described earlier in the text, there should be no further need to enter the calibrate mode.

If any key other than the HEATING key is pressed when the copyright message is showing, the display will show the current time. Initially, this time is set to 09:00 Monday 1st January 1990.

It is probably a good idea at this stage to fit the standby battery. This will preserve the time, and any programs you may enter, if the power is accidentally disconnected.

Setting the time and date

To set the system time and date, first press the TIME SET (down arrow) key to enter the time setting mode. The display will change to the hours and minute indication, with the hour shown between two arrow symbols. These arrows indicate the part of the display which is being edited at the moment, i.e., the hours. Press either of the arrow keys to change the hours display to the current time. Note that holding the arrow key pressed for more than two seconds will cause the display to advance rapidly.

When the correct hours indication is shown on the display, press the ENTER key. This will confirm the hours setting, and move the indicating arrows on the display to the minutes indication. Set the minutes to the correct time, again using the ARROW keys. Press the ENTER key.

Carry on setting the DAY, MONTH and YEAR in the same way, using the arrow keys to select the choice, and the ENTER key to confirm the choice. After the YEAR has been set, and the ENTER key pressed, the display will revert to the normal time display. Note that it is possible to set a non-existent date, i.e., 30th of February. The system will automatically correct this at midnight, however, making the next day the first of March.

Displaying the seconds

To change the display mode from the normal time and date display to hours, minutes and seconds, press the DISPLAY SECONDS (up arrow) key. To synchronize the seconds, press the ENTER key. The seconds count will be zeroed to the nearest minute. To return to the normal display mode, again press the DISPLAY SECONDS key.

Programming a switching operation

From the normal display time mode, press the PROGRAM SET (cancel) key to enter the program mode. The display will show 'Set a program'. Press the ENTER key to select this option. The display will then change to show either 'C heating' or 'Hot Water'. Use either of the arrow keys to select the option you wish to program. Again press the ENTER key to confirm your choice. Next, set the switch on time, and the switch off time, confirming your choice with the ENTER key. Then, again using the arrow keys, select the day(s) when switching is to take place. The choice is between any single day, every day, weekdays (i.e., Monday to Friday) or weekend (i.e., Saturday and Sunday). Again confirm your choice with the ENTER key. Finally, the display will show either 'once only' or 'repeat'. If you

require the switching to take place every week at the same time, select 'repeat'. Selecting 'once only' will cause the program to cancel itself automatically after execution. The final pressing of the ENTER key will return the display to the normal time display mode. A switching operation has now been programmed.

Displaying the switching programs

To display the switching programs, press the DISPLAY PROGRAM (ENTER) key to enter the display program mode. The display will then show part of the first program stored. Using the arrow keys, the display can be scrolled left or right to read the various parameters of the program. To select the next program, press the ENTER key. Once the last program has been displayed, the indication will revert to the normal time display.

Deleting a program

To delete a program, first display it as explained above. Press the CANCEL key. The display will then show 'ENT is Delete'. Press the ENTER key to delete the program, or press the CANCEL key again to revert to the program display mode.

Using manual overrides

A facility exists to manually switch the system on or off with the aid of the HEATING and HOT WATER keys. Each press of a key changes the status of the appropriate output in the sequence shown below. A LED indication is given of the current state of the outputs.

| | |
|-----------------------------|------------------------------------|
| Assuming the output is off: | LED not lit |
| Press an override key: | the output selected changes to on; |
| | LED flashes. |

In this state the output will be turned off automatically when the next programmed 'off' time is reached.

| | |
|----------------------------|--------------------------------|
| Assuming the output is on: | LED flashing |
| Press an override key: | the output selected changes to |
| | 'permanent on'; LED is on. |

In this state the output will ignore any programs, and remain permanently on.

| | |
|-----------------------------|-------------------------------------|
| Assuming that the output is | LED on |
| permanently on: | the output selected changes to off; |
| Press an override key: | LED not lit. |

In this state the output will respond to programmed controls as normal.

System inhibit

A further facility exists to suspend all switching operations for a period of time. This facility could be useful for instance, when on holiday or during the summer when the system is not required to operate. Although programs in the system are still retained, they are ignored until the inhibit is cancelled. A LED indicator is given when the system is inhibited.

To inhibit the system, press the PROGRAM SET (cancel) key. The display will show 'Set a Program'. Use either of the arrow keys to change the display to 'set inhibit'. Press the ENTER key. The inhibit LED will light and the display will revert to the normal time display.

To cancel the inhibit, press the PROGRAM SET (cancel) key. The display will show 'set a program'. Use either of the arrow keys to change the indication to 'inhibit Off'. Press the ENTER key. The inhibit is now cancelled. The display returns to the normal time display and all the programmed switching operations are re-enabled.

System errors

The only error possible is 'Memory Full' which will occur if you attempt to insert more than 255 programs in the system.

If this error occurs, the display will continue to show the error until the ENTER key is pressed. The display will then revert to the normal time indication mode.

Power failure

If a mains power failure occurs, the control unit is no longer able to control the heating system. However, by using the standby battery, the current time and all the stored programs are preserved in the memory. Once the power is restored, the control unit will restore the correct status to the control outputs, and control of the central heating system will resume.

COMPONENTS LIST

DISPLAY PCB

Resistors:

- 3 22kΩ R20;R21;R22
- 4 1kΩ R23-R26
- 1 10kΩ preset H P20

Semiconductors:

- 6 1N914 D20-D25
- 3 BC108 T20;T21;T22
- 2 yellow LED 5 mm D20;D21
- 1 red LED 5 mm D22
- 1 green LED 5 mm D23

Miscellaneous:

- 1 EA-D16015AR LCD module (Epson UK; STC part no. 029562P)
- 6 click-effect push-button S20-S25
- 4 black key cap (Maplin FF88V)
- 2 white key cap (Maplin FF49C)
- 4 LED clip 5 mm

with four small nuts and bolts, using 1/8-in spacers between the module and the PCB. Connect the LCD module to the PCB with the aid of short lengths of tinned copper wire. Note that the LCD module is a CMOS device, and precautions should be taken to prevent damage caused by static electricity. Before handling the LCD module, discharge yourself to an earth point, and use an earthed soldering iron bit. Once the display is wired to the PCB, treat the whole PCB with the same care.

Finally, wire the display PCB to the main PCB with stranded wire as shown in Fig. 11. Then check the wiring and soldering very carefully.

Testing and adjustment

At this stage in the assembly, further testing is advisable. In order to do this, the remaining ICs should be inserted into their respective sockets on the main PCB.

Connect up the power, and check the LCD module for the display message:

-(C) 1990 ...

If the display remains blank, or shows blank squares, adjust the contrast with P20 until the displayed message is clear. The usual setting for P20 is close to the minimum. Should, however, the display show random patterns, or remain totally blank, regardless of the contrast adjustment, switch off and check both PCBs for short circuits, dry joints, etc. The data and address lines are particularly suspect at this point.

Standby timing adjustment

If all is well so far, the standby timing circuit may be adjusted. The heating control system software helps you at this point by providing a calibration routine.

Connect a 9-V supply to points 3 and 4 on the main PCB (+Ve to point 3). Ensure that the copyright message is scrolling across the display. Next, press the HEATING switch, SW24. The the display will change to

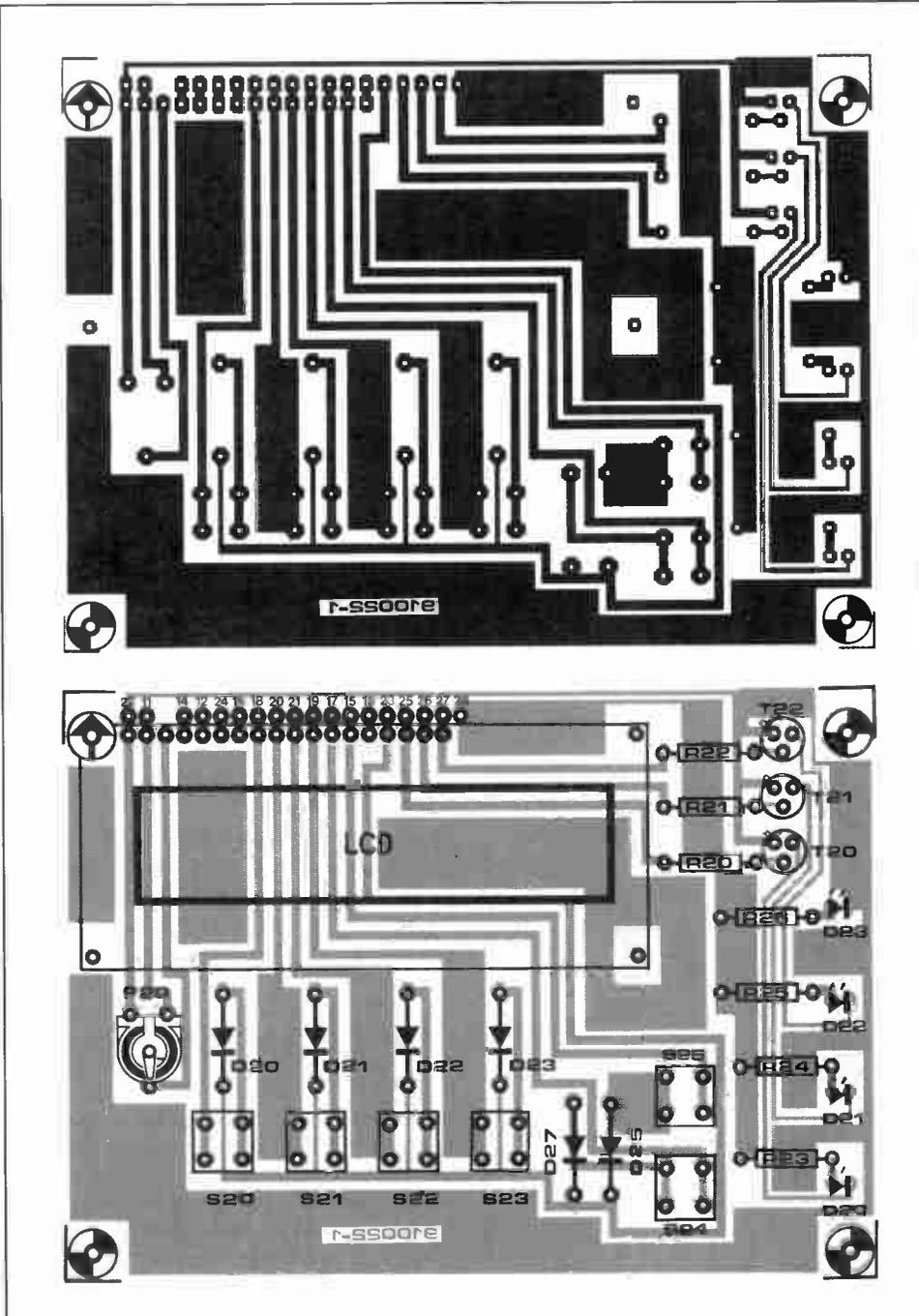


Fig. 9. Author's design of the display printed circuit board.

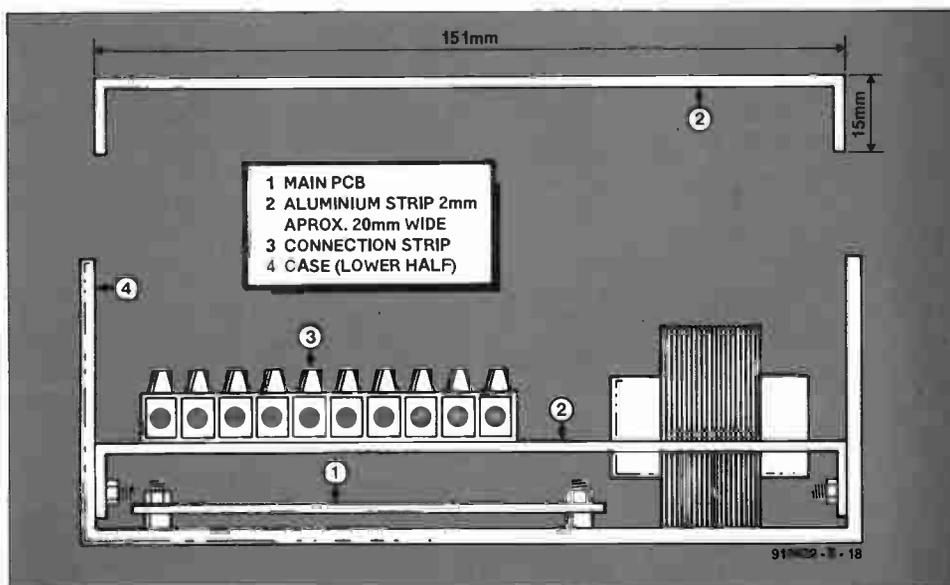


Fig. 10. Internal construction of the central heating controller.

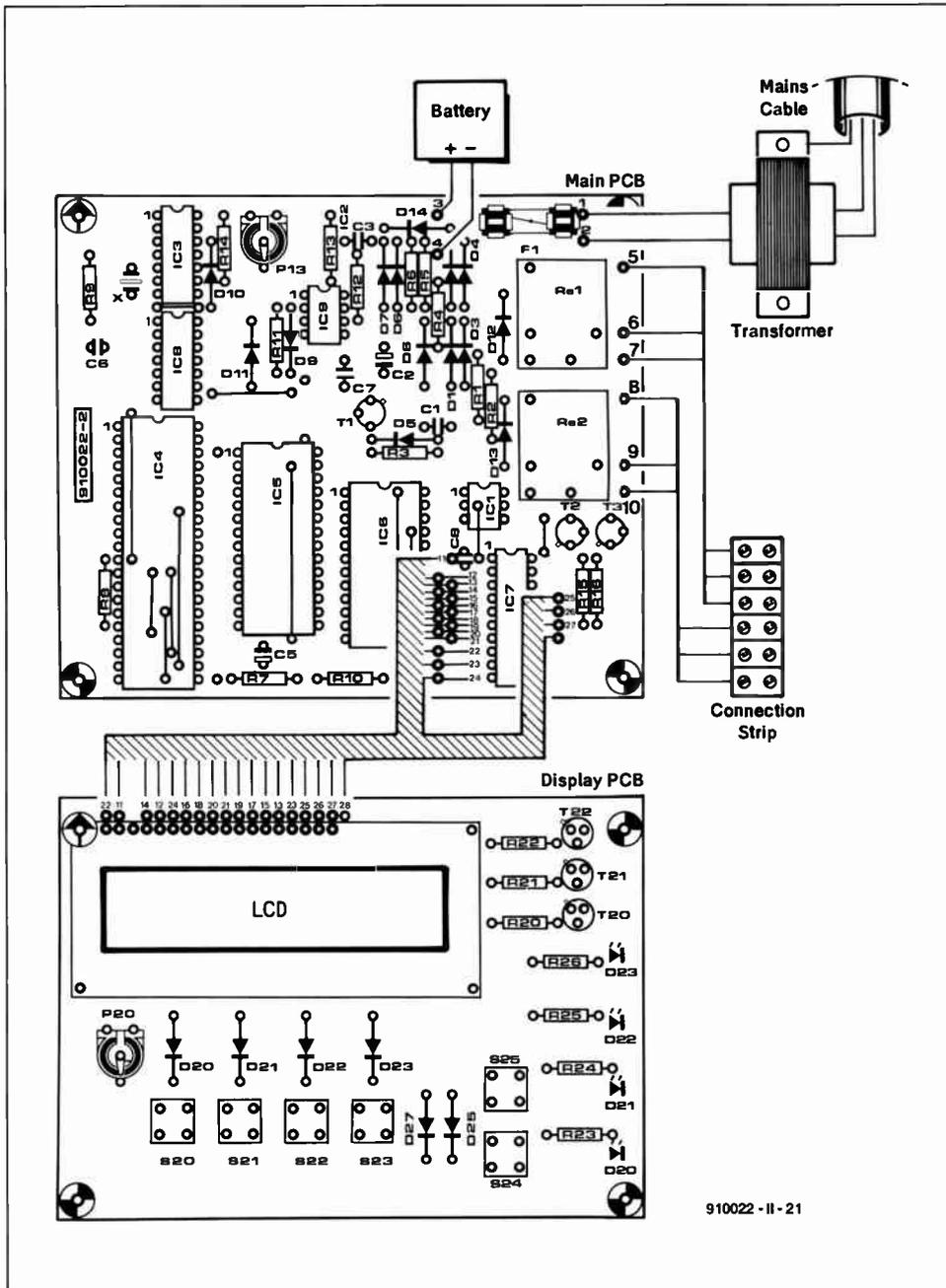


Fig. 11. Interconnection diagram for the two printed-circuit boards.

| Wire number | Use | Wire number | Use |
|-------------|-----------------------------|-------------|----------------------------|
| 1 | 12 V AC supply | 17 | Data D5 |
| 2 | 12 V AC supply | 18 | Data D1 |
| 3 | Battery + | 19 | Data D4 |
| 4 | Battery - | 20 | Data D2 |
| 5 | Relay1 Hot water control | 21 | Data D3 |
| 6 | | 22 | Ground |
| 7 | Relay 2 Heating control | 23 | KEY (key enable) |
| 8 | | 24 | \bar{E} (display enable) |
| 9 | | 25 | LED20 |
| 10 | +5V supply | 26 | LED21 |
| 11 | | 27 | LED27 |
| 12 | Address A1 | 28 | +12V supply |
| 13 | Data D7 | 29 | Mains (Live) |
| 14 | Address A0 | 30 | Mains (neutral) |
| 15 | Data D6 | 31 | Mains (earth) |
| 16 | Data D0 | 32 | |

Calibrate - 000

Adjust preset P13 until the digits show as near as possible a constant zero. The arrows next to the number indicate if an increase or decrease in resistance is required. Allow the circuit to settle for a few seconds between each adjustment.

Once you are satisfied with the adjustment of P13, disconnect the power. The calibration of the timing circuit is now complete.

Standby battery circuit

A suitable standby battery should be selected for the control unit. The type selected must be able to supply 50 mA whilst maintaining at least 7 V. The author used an 8.4 V PP3 style nickel-cadmium battery (Maplin HW31J), which gave a standby capacity of 2 hours.

In order to find the correct value of resistor R6 for the type of battery chosen, connect a 10 kΩ preset or potentiometer and an ammeter in place of R6 on the circuit board. Connect the power and adjust the preset until the recommended trickle charge current flows. Replace the preset with a standard resistor of approximately the set value.

Final assembly

The box suggested for the project is a low-cost aluminium type (size approx. 150 x 100 x 50 mm) from Maplin (order code LF14Q). The top of the box should be removed and cut as shown in Fig. 13. The base of the box should also be drilled to mount the main PCB and the transformer. Check the assembly of all parts of the box, then disassemble it before painting. The author used four or five coats of white cellulose spray paint of the type used to touch up cars. Allow the paint to dry for at least 24 hours before applying the 'Letraset' panel markings as shown. Ensure the letters are well rubbed down, then apply two coats of clear cellulose lacquer as used on 'metallic paint' cars. Allow these last two coats to dry for a further 24 hours.

Complete the inter-PCB wiring as shown in Fig. 11. Fit the transformer and the main PCB in the case, and secure them with small nuts and bolts as shown. It is recommended to use 1/4-inch spacers to support the PCB. The mains cable should enter the case through a small hole in the rear panel, and be fitted with a rubber grommet.

A length of 2-mm thick aluminium strip should be bent as shown in Fig. 10. Mount this just above the main circuit board to support a 12-way strip of connectors.

Next, fit the four LED clips to the top panel, and push the LEDs into place, ensuring that the leads align with the relevant PCB holes. Do not, however, fit the securing collars. Glue a thin piece of perspex sheet to the inside of the panel to form a protective window for the LC display.

Position the PCB behind the top panel, feeding the LED leads through the appropriate holes in the PCB at the same time. Secure the PCB with the aid of four small nuts and bolts with the appropriate spacers as required, so that the display module is pressed

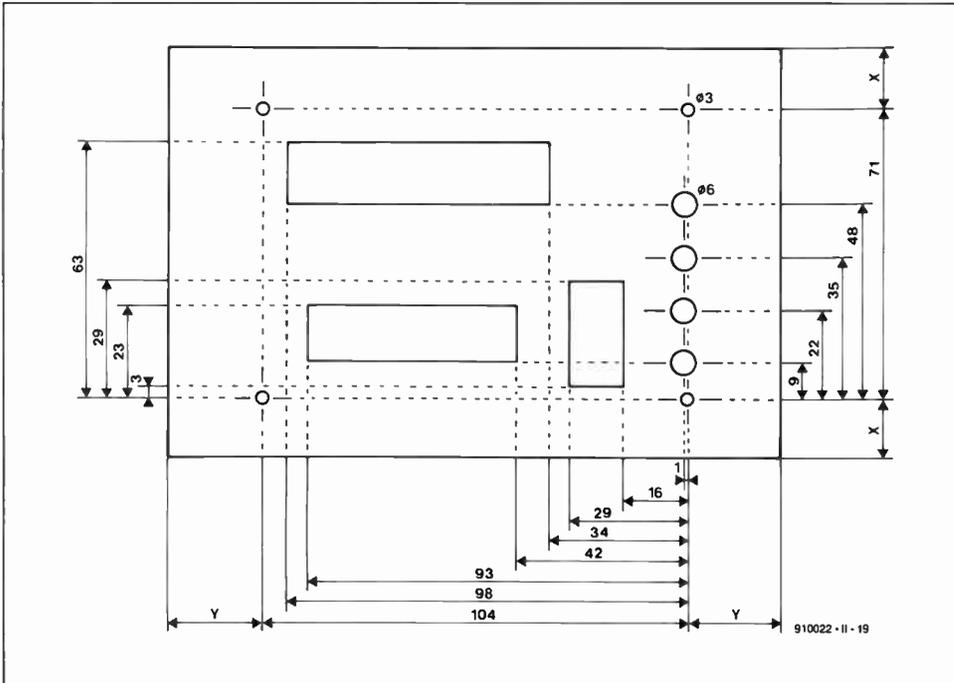


Fig. 12. Construction details of the front panel.

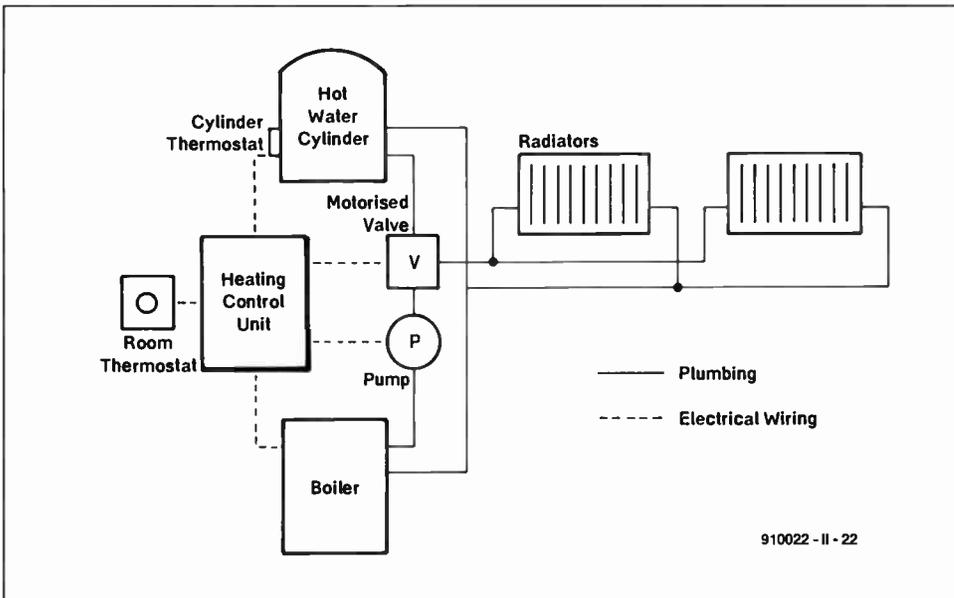


Fig. 13. Typical central heating system.

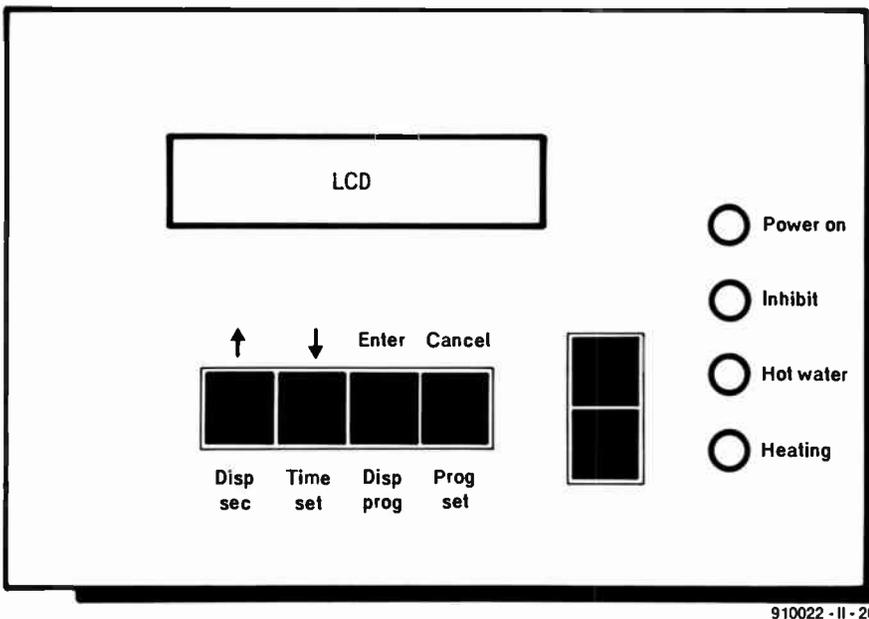


Fig. 14. Suggested front panel design (see also the introductory photograph in part 1).

against the perspex window. Finally, solder the four LEDs into position, to complete the assembly.

Typical central heating system

A typical central heating system is shown in Fig. 13. Individual control of the hot water and heating system is only possible if a suitable motorized valve is fitted in the system. Where such a valve is not fitted however, it is still possible to use the heating controller described here. The separate hot water control function is then ignored.

References:

The following reference material has been used in the preparation of this project:

1. Data sheets: Epson EA-D LCD modules (Epson UK Ltd., 081 902 8892); Z80 CPU (Maplin Electronics, 0702 552911).
2. Z80 programming: *Machine language programming made simple for your Sinclair* (Melbourne House Publishers).

Note:

Photocopies of the control program hexdump listing may be obtained free of charge from our service department (p. 65). Readers should send a self-addressed, stamped envelope. Canadian readers should send a self-addressed envelope and two International Reply Coupons (ICRs), which may be obtained from the post office. Write to Old Colony Sound Lab, PO Box 243, Peterborough, NH 03458-0243, Attn: Heating Hex.

RADAR DETECTOR

Radar signals are used in nautical navigation systems for vessel positioning and distance readings where visibility is restricted. Unfortunately, radar equipment is pretty expensive, so that many owners of small yachts have to make do without an 'electronic eye'. With the aid of the detector presented here these ship owners can, however, implement a basic warning and positioning system by making use of radar signals from other ships.

M.R. Ebbell

RADAR installations make it possible to survey large areas with the aid of electromagnetic waves. Not surprisingly, most radar equipment is produced for the avionics, military and nautical industries. Since a radar system includes a transmitter, its activity can always be detected. Most radars emit a pulsating RF signal at a frequency between 2 GHz and 12 GHz, and receive their own signals, which are reflected by objects within the covered area. The relative strength and the delay of the reflections are measured and used to determine the distance and the size of the object. This system allows the area around the radar installation to be mapped and surveyed.

For non-professional applications, such as pleasure craft, radar is often too expensive. Consequently, most pleasure craft can not sail when there is heavy rain or fog.

The radar detector presented here is a low-cost way of using the radar signals of professional craft to prevent collisions, and provide a basic way of ship positioning where visibility is restricted. A LED indicator starts to flash, and an audible warning is given, when a radar system is detected within the receive range of the detector. To the navigator, these signals are a sign that another ship is approaching. The detector is directional, that is, it can be aimed at the radar source for an approximate distance and position reading.

Frequency bands

Since the peak pulse power emitted by a radar transmitter is of the order of kilowatts, a relatively simple receiver can be used to detect the pulsating RF signals. Parts of the frequency bands listed in Table 1 have been reserved for radar systems. It should be noted that certain frequencies may be shared with other services, such as radio and TV microwave links, satellites, mobile services and radio amateurs. The primary or secondary services in a particular band are determined at a local (often national) level by the relevant telecommunication authorities. For example, although radio amateurs are

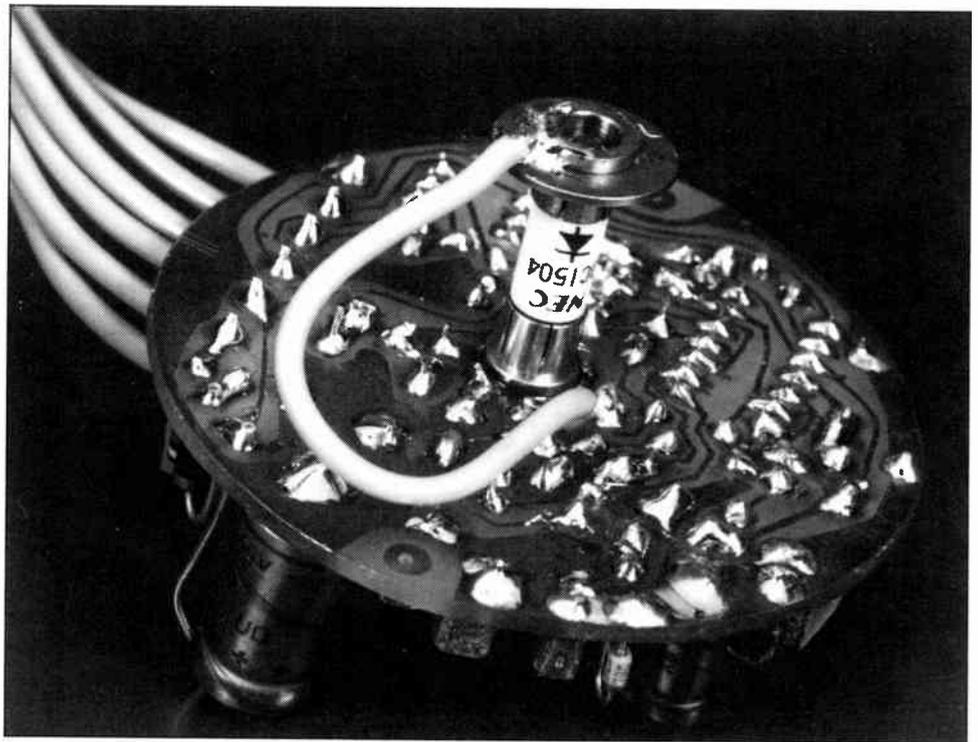


Fig. 1. Prototype of the radar detector, seen from the solder side of the PCB.

allowed to use certain sections of the 23 cm and 24 cm bands (L-band), they are forced to share them, on a secondary basis, with powerful radar transmitters used for automatic aircraft identification systems installed near military airports. Since the radio amateur service has a secondary status in these sections of the band, the interference caused by such radar stations has to be put up with.

Radar systems for nautical applications usually work in the X band or the S band. More precisely, in the X band the section from 8.5 GHz to 10.68 GHz is assigned to radar, while in the S band two sections are used: 2.3 GHz to 2.5 GHz, and 2.7 GHz to 3.7 GHz.

Although designed to detect X band signals, the present circuit will also work with S band radar systems, so that it is suitable for all conventional nautical radars.

The effective range of a nautical radar depends on the transmit power and the height of the antenna. Table 2 lists the most important characteristics of currently used radar systems. It should be noted that the transmit powers are peak pulse values, not continuous levels. The radar transmitter is pulsed to enable distances to be measured (when the transmitter is off, the receiver is on to detect the reflected signal). The transmitter pulse rate determines the maximum distance that can be measured. The longer the pulse spacing, the longer the signal will have to travel to cause a reflection that can be measured reliably. Because of the pulsating operation, the continuous power rating of most radars is only a fraction of the peak pulse power.

In practice, the range of a radar system depends on a number of factors, including the transmit power, the directivity of the antenna, the propagation characteristics of the

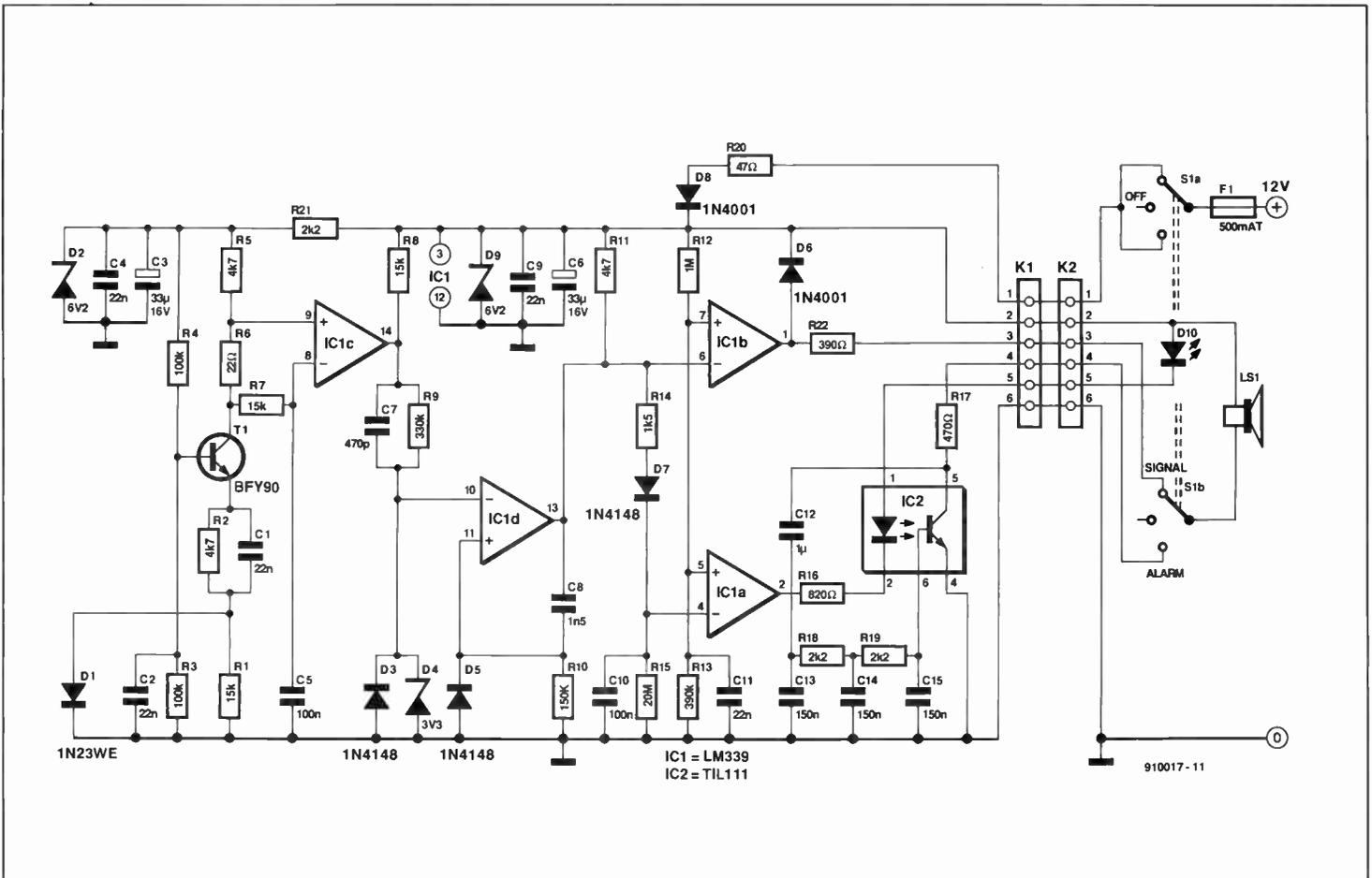


Fig. 2. Circuit diagram of the radar detector.

band used, and atmospheric conditions. The frequencies used for radar are so high that the propagation of the signals is largely similar to that of light. This means that a microwave radar can not, in principle, see objects over the horizon. In practice, however, diffraction, scattering and partial reflection in some atmospheric layers give a radar system a range that extends just over the horizon.

Circuit description

The circuit diagram of the radar detector is given in Fig. 2. Although the circuit is designed to receive very high frequencies, it is relatively simple. The only RF parts in the circuit are a detector diode Type 1N23 and a rudimentary type of antenna which is constructed with the aid of the diode fitting. To achieve maximum sensitivity, a small forward current is sent through the 1N23. This current is supplied by transistor T1. The diode current rises considerably when an RF pulse is received on the antenna. The resultant current pulse causes T1 to conduct harder and supply a voltage pulse at its collector. In this way, the pulsating SHF radar signal is converted into a pulse train that can be processed by low-frequency circuitry. The pulse rate and duration depend on the radar system received by the detector. In general, the pulse rate will lie between 400 Hz and 4 kHz.

The large changes in the collector current of T1 cause the voltage at the +input of opamp IC1c to drop considerably. The voltage at the inverting input remains stable

much longer because of capacitor C5. The output of the opamp goes low when a radar signal is received. Components R9 and D4 limit the output signal of IC1c to a value of 3.3 V.

A further opamp, IC1d, is used to convert the short pulses into a signal with a fixed pulse length of 1 ms. The output of this monostable multivibrator is applied to two sub-circuits. Opamp IC1b amplifies the pul-

| Band designation | Nominal frequency range | Specific radiolocation (radar) bands (ITU Assignments for Region 2) |
|------------------|-------------------------|---|
| VHF | 30 – 300 MHz | 138 – 144 MHz |
| UHF | 300 – 1000 MHz | 420 – 450 MHz |
| L | 1 – 2 GHz | 1,215 – 1,400 MHz |
| S | 2 – 4 GHz | 2,300 – 2,500 MHz |
| C | 4 – 8 GHz | 2,700 – 3,700 MHz |
| X | 8 – 12 GHz | 5,250 – 5,925 MHz |
| Ku | 12 – 18 GHz | 8.5 – 10.68 GHz |
| K | 18 – 27 GHz | 13.4 – 14.0 GHz |
| Ka | 27 – 40 GHz | 24.05 – 24.25 GHz |
| V | 40 – 75 GHz | 33.4 – 36.0 GHz |
| W | 75 – 110 GHz | 59 – 64 GHz |
| mm | 110 – 300 GHz | 76 – 81 GHz |
| | | 92 – 100 GHz |
| | | 126 – 142 GHz |
| | | 144 – 149 GHz |
| | | 231 – 235 GHz |
| | | 238 – 248 GHz |

Table 2

| Vessel type | Beamwidth (degrees) | Antenna height (metres) | Power (kW) | Range (naut miles) |
|--------------------------------|---------------------|-------------------------|------------|--------------------|
| river transport | 1.5° | 4 | 5 | 2.5 |
| yacht | 3° | 4 | 3 | 1.5 |
| trawler | 2° | 6 | 10 | 3 |
| coaster | 1.5° | 8 | 10 | 5 |
| container/bulk vessel (X-band) | 1° | 30 | 50 | 8 |
| container/bulk vessel (S-band) | 3° | 30 | 50 | 3 |

ses supplied by IC1d, and drives a small loudspeaker. The output signal of IC1d is also fed to a single-phase rectifier that consists of R14, R15, C10 and D7. Capacitor C10 is charged via R14 and D7 as long as the output of IC1d supplies positive pulses. The capacitor can only be discharged via R15. Since R15 has a much higher value than R14, C2 can not be discharged completely until the pulse train from IC1d has ceased. When C2 is kept charged, the inverting input of IC1a is at a higher voltage than the non-inverting input. Consequently, the LED in optocoupler IC2 lights, and causes an oscillator based on the transistor in IC2 to operate. The generated AF signal is fed to the loudspeaker via resistor R17. At the same time, LED D10 lights.

Switch S1 allows the loudspeaker to produce either the detected pulses or the continuous warning signal. The same switch is also used to switch the detector on and off.

The battery voltage is filtered with the aid of R20 and C11. Diode D9 limits the circuit supply voltage to about 13 V and prevents the circuit being damaged by overvoltage.

The supply voltage of the detection diode is reduced to about 8 V by D2 and R21, with capacitors C11 and C3 providing additional filtering, and C4 and C6 ensuring the required RF decoupling of the power supply.

Construction

As shown in the photograph of the prototype, the detection diode is mounted centrally at the track side of a round printed-circuit board. The crucial part in the circuit, the 1N23, is a point-contact diode with an extremely low stray inductance. The device, which is probably familiar to those of you who have 'microwave' experience, has a white ceramic body and gold-plated terminals. Since the device is easily damaged by overheating, it must never be soldered. Always secure the diode with the appropriate fixing sockets, which can be salvaged from surplus SHF military equipment such as the famous APX-6 transponder (a visit to an electronics surplus shop will probably secure the 1N23 and the associated fixing com-

ponents as spare items). It should be noted that there exist a number of equivalent or near-equivalent types of the 1N23, all of which can be expected to work in the circuit. One near equivalent, the DC1504 from NEC, is shown in the photograph of the prototype, Fig. 1.

The antenna of the radar detector consists of a 15-mm dia. plate soldered to the anode connector as shown in Fig. 2. A short piece of wire connects the antenna to C1-R2 on the printed-circuit board. Although a purpose-designed PCB is shown in Figs. 2 and 3, the circuit should also work without problems when constructed on a piece of veroboard or stripboard.

The completed circuit board and the attached detector diode must be fitted in a metal enclosure with a small hole drilled in the front cover. The hole is drilled at a position facing the antenna fixed to the detector diode. The hole gives the radar detector a directivity of about 25°.

Depending on the mode selected with S1, the loudspeaker produces either the rattle of the received radar, or an intermittent alarm sound with pauses of about 1.5 s. As already noted, the frequency of the received radar pulses depends on the system used. In practice, you can expect almost any frequency between 400 Hz and 4 kHz. The sound is probably produced as short bursts because radar antenna rotates. Usually, the antenna has a speed of 22 rotations per minute, which results in bursts with a repeat rate of 3 seconds. You can tell the presence of more than one ship equipped with radar when the detector produces bursts with a repeat rate shorter than 3 seconds. To determine the approximate position of a radar source, hold the detector in your hand and slowly turn it horizontally, sweeping the horizon. ■

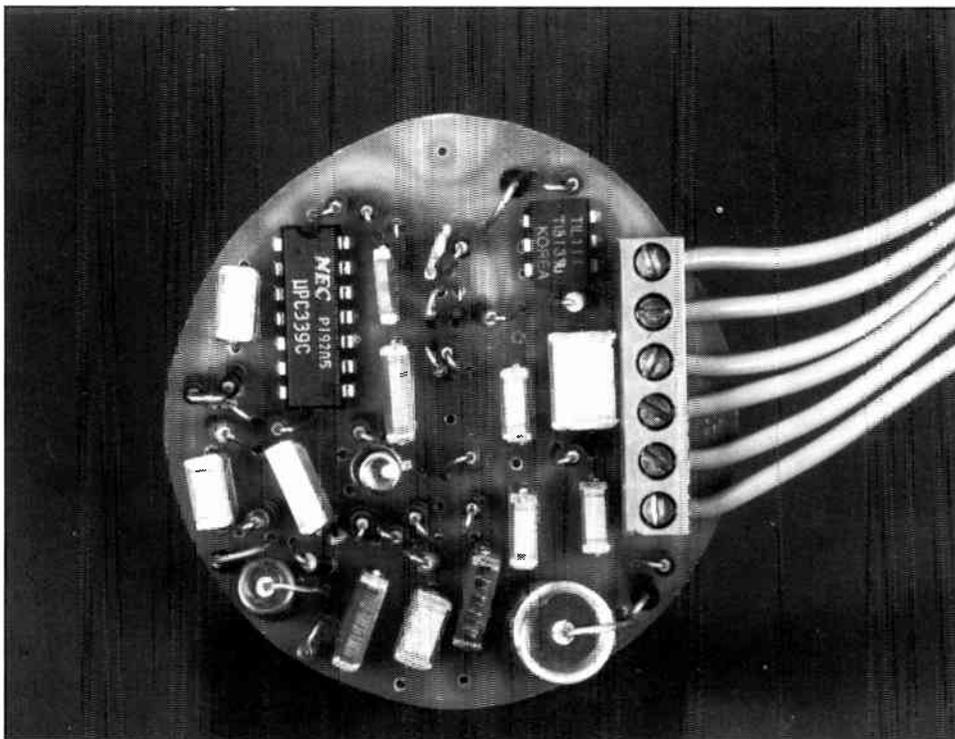


Fig. 3. Component side view of the radar detector PCB. A six-way terminal block is used to connect the supply, switch S1, the LED and the loudspeaker.

PC-ECAP: CIRCUIT SIMULATION

Reviewed by Jan Didden

TRADITIONALLY, circuit design has been not only a science but also an art. Amateurs and professionals alike start a circuit with a rough idea, calculate component values, and choose devices from data books. A prototype is built and tested. Seldom is it correct the first time. So, the designer recalculates, makes changes, re-tests, substitutes devices, and continues this process until he has a working product.

Sometimes experienced designers get very close the first time and know that, say, a calculated resistor value must be increased by 20% to be right. This is the "art" part. It gets more difficult if you must build 100 units of your design. For instance, you might be faced with spreads in transistor H_{FE} from 100 to 500. The one in your prototype might be a 500 H_{FE} unit. Will the circuit be within spec with a 100 H_{FE} unit?

Selecting transistors is expensive. You would have to build several prototypes, with worst-case combinations, and make sure all of them meet the specifications. But finding the worst-case combination for a particular spec. can be a major project in itself. These problems were particularly important for the design of early integrated circuits, when engineers faced large spreads in IC production processes.

Therefore, it is no surprise that as early as

the 1960s people began looking to computers to assist in the design process. The program that is the basis of almost all current circuit simulators was developed at the University of California at Berkely and was called SPICE (simulation program with integrated circuit emphasis). This was a powerful R&D tool. An engineer could describe a circuit to the computer (using, in those days, a stack of punched cards). The program would then print a list of output values for the circuit according to the specified input values.

With the advent of the PC, circuit simulators have evolved from a science tool for the happy few to another piece of engineering software, within reach of almost anyone.

The state of the art

Modern spice-based programs are unbelievably powerful. A widely used commercial version called PSpice is marketed by Microsim Corp. To simulate a circuit with PSpice, you draw a schematic diagram and number the interconnection nodes.

Next, you create a text file that contains each component's description and connection node numbers. For a simple resistor the value in ohms describes it, but you can also specify parasitic capacitance and inductance. For complicated components, like MOSFETs,

you can specify dozens of parameters, including physical properties of the transistor chip. (PSpice comes with a library of thousands of pre-defined components.)

You also tell the program which node is the input and the type of input signal (which can be the wildest waveforms you can imagine) and what kind of data you wish as output. PSpice takes this list, constructs a mathematical matrix of the circuit, and calculates the output.

A full-blown system can calculate frequency response (amplitude, phase, and group delay), DC transfer curve, transient response, distortion, waveform Fourier transforms, the voltage/current/power associated with a component, noise signal levels, and quiescent bias point. It can even calculate all this at different operating temperatures.

Options include Probe, to display waveforms and spectra graphically, a Monte Carlo statistical analysis that uses component tolerances you can specify to find those worst-case combinations. An option called Parts lets you build a component model from (limited) data-book information and measurements.

Also, the program requires a mathematical coprocessor in your PC. Not really within the amateur's reach. But there is an inexpensive limited capacity student version.¹

PSpice is so powerful it takes time and ex-

TABLE 1
CIRCUIT ELEMENTS SUPPORTED BY PC-ECAP

Resistors: RXXXX N1 N2 value

N1 and N2 are the two element nodes. Value is the resistance in ohms. Example: R1 1 2 100 Ω .

Capacitors: CXXXX N1 N2 value

N1 and N2 are the two element nodes. Value is the capacitance in farads. Example: COSC 2 3 22pF.

Inductors: LXXXX N1 N2 value

N1 and N2 are the two element nodes. Value is the inductor value in henries. Example: L3 7 0 10mH.

Transformers: TXXXX +Pri -Pri +Sec -Sec

N + Pri and - Pri are the nodes for the primary. + Sec and - Sec are the nodes for the secondary. N is the turns ratio between primary and secondary. The plus and minus signs denote the phasing of the windings. Example: T1 3 0 4 5 10 turns.

Bipolar Transistors (NPN and PNP): BXXXX NB NE NC Beta Rbe

NB, NE, and NC are the b, e, and c nodes. Beta is the transistor current gain. Rbe is the equivalent b-e resistance (in ohms) used in the Hybrid-Pi transistor model. Example: B1 9 0 11 100 1,250 Ω .

Field Effect Transistors (JFETs and MOSFETs): FXXXX NG NS ND gm

NG, NS, and ND are the gate, source, and drain nodes, respectively. Gm is the FET transconductance in milliamperes/volt. Example: F2 3 4 0 2,000 μ mhos.

Operational Amplifiers: OXXXX N+ N- NO gain rout

N+, N-, and NO are the non-inverting input, inverting input, and output nodes, respectively. The op amp output is referenced to ground (node 0). Gain is the open-loop gain of the op amp. Rout is the open-loop output resistance for the op amp. Example: O1 1 2 2 100k 75 (yes, this is a unity-gain buffer).

Transconductance Amplifiers: GXXXX N+ N- NO+ NO- gm

N+, and N- are the non-inverting input and inverting input. NO+ and NO- are the non-inverting output and the inverting output. Note that these outputs are floating. In other words, the actual output is not from either output to ground, but is developed between the outputs. Either output (but not both) may be tied to ground if a single-ended output is desired. Gm is the amplifier transconductance in milliamperes/volt. The transconductance amplifier may be used in its own right or to perform a voltage-to-current conversion, sometimes useful when simulating other devices. Example: GXXXX 1 2 3 0 100mhos.

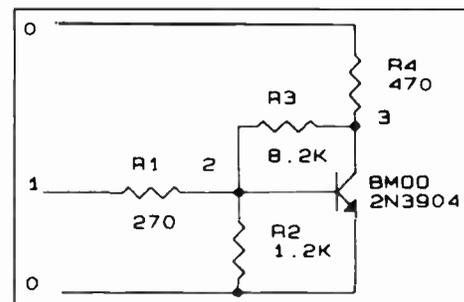


Fig. 1. Example 4 circuit diagram.

TABLE 2
EXAMPLE4 CIRCUIT DESCRIPTION FILE

; Example4.dat—Single stage transistor amplifier made with ; a 2N3904 transistor modeled using PC-ECAP's "Model Maker"

R1 1 2 270

R2 2 0 1.2k

R3 2 3 8.2k

R4 3 0 470

BMOD 2 0 3 100 250

CCB 3 2 4E-12

CPI 2 0 2.08207E-10

P 1 3 1K 100MEG LOG

From here to end
created by the Model
Maker

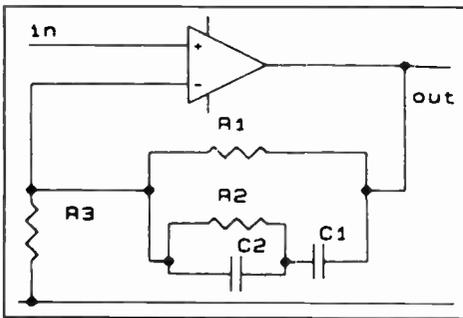


Fig. 2. Basic RIAA preamp (TAA 2/90, Fig. 6b, p. 20).

perience to use it adequately. But lately these types of programs have begun to appear in the shareware circuit, which makes them attractive to amateurs and professionals.

Share what?

For those unfamiliar with the term shareware: the shareware concept lets you legally copy a program and give it to others. You may not charge anything for it, except for copying and distributing (no more than \$5 or \$6). After you have examined the program and decided to use it, you are expected to register with the author and pay the license fee. You are considered using it if you would miss it if you did not have it.

Distribution takes place mostly through shareware dealers,² bulletin boards, and users. Shareware programs have low marketing costs, which is reflected in low-end prices. PC-ECAP costs \$69 to register. This also gives you a right to technical support and update notes. The updates cost a nominal fee. For \$10 more you get a printed manual instead of the manual on the disk.

Note that a lot of trust is involved. If nobody paid, no new or improved shareware would be produced.

PC-ECAP

PC-ECAP calculates the frequency response (amplitude and phase) for a given circuit. A user friendly program, it uses a point-and-shoot technique to select and edit the circuit to be simulated and the various presentation options. Its simple but adequate built-in editor generates a text file that describes the circuit to be simulated (more on these circuit files later). On-line help is also available.

The output data can be graphs (frequency versus amplitude or phase, but not both in the same graph), a tabular data list of output values, or a printout of each. The components PC-ECAP knows about are listed in Table 1. The program can handle circuits with up to 40 nodes and an unlimited number of components. It can best be explained by discussing a couple of typical uses.

Figure 1 shows the circuit's program as example4 and Table 2 describes the elements. Note the resistors with their connection nodes and values. The node numbers for ground and V_{cc} are the same. PC-ECAP

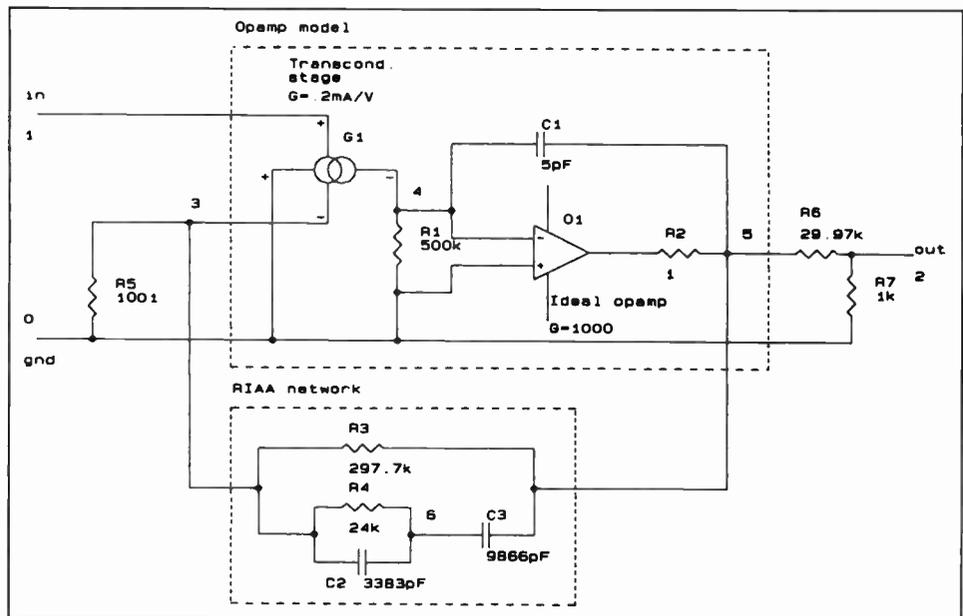


Fig. 3. Circuit model for Fig. 2.

knows only AC, and for AC a power supply is transparent (or should be).

Now for the transistor. PC-ECAP has a clever feature to model transistors. When you edit a circuit file, pressing F2 brings up the "model maker." You must specify the node numbers for b, e, and c, the collector current and current gain that goes with it, the gain-bandwidth product, and C_{cb} (the internal feedback capacitor from collector to base). Model maker then puts in the lines you see in Table 2. The last line instructs PC-ECAP to plot the output signal at node 3 and the input at 1, starting at 1kHz up to 100MHz on a log scale.

The proof of the pudding is the eating: I built this circuit and measured 27.6dB mid-band gain on the real thing, while PC-ECAP calculated 27.73dB. Close. I guessed on the C_{cb} (10pF) for the transistor I used, but I changed the model maker specification to

20pF to get the same -3dB point on the bench as calculated by PC-ECAP (around 500kHz). The calculated phase shift at the -3dB point was given as 135°, which is correct. But I wanted to test the program with a more complex circuit of known properties, which I found (where else) in *Audio Amateur*.

The RIAA connection

I turned to Reg Williamson's article in TAA 2/90 (p. 18) on the RIAA curve to get a benchmark. I built a circuit file for his Fig. 6b, which is shown in my Fig. 2. PC-ECAP includes a model for an ideal op amp, but the manual also gives a method to make a more realistic op amp model. This consists of a transconductance input stage followed by a high-gain amp, with a first-order rolloff.

The circuit model is shown in Fig. 3. Those who followed the discussions in TAA on op amps will recognize the basic setup. The input transconductance stage G1 converts the input differential voltage to an output current, which in turn is converted by the load resistor R1 to an input voltage for the voltage gain stage O1. Capacitor C1 rolls the gain stage off from approximately 80Hz for a 5pF value. This stage is specified as having a gain of 1,000 at DC. Total DC gain is thus:

$$0.2\text{mA/V} \times 500\text{k} \times 1,000 = 100,000 \text{ or } 100\text{dB}$$

with a frequency response rolling off as mentioned above: a cheap 741-type op amp. The resulting circuit file is shown in Table 3.

In his article, Reg Williamson provided a small Basic program to calculate the RIAA components and the required gain versus frequency. The circuit as specified has a 30.97x gain. For comparison purposes, I added an output attenuator to the model to get back to Reg's 0dB level at 1kHz.

Table 4 shows part of PC-ECAP's results for $c1 = 5\text{pF}$. Table 5 shows selected values for two values of $c1$ compared to Mr. William-

TABLE 3

```

:circuit file for Fig. 3.
:ref: Fig. 6b, TAA 2/90, p. 20

;RIAA network
r3 3 5 297.672k
r4 3 6 24k
c3 5 6 9886.25p
c2 3 6 3383.488p

;output attenuator
r8 2 5 29.97k
r7 2 0 1k

;gain setting resistor
r5 3 0 1000.861

;uA741 macro model
; +in -in +out -out gm
g1 1 3 0 4 .2M
;input transcond. stage
r1 4 0 500k
;I/V converter impedance
o1 +in -in out Gain Rout
o1 0 4 5 1000 1
;ideal op amp gain voltage stage
c1 4 5 5p
;internal rolloff capacitor (see text)
p 1 2 10 100k
;plot command

```

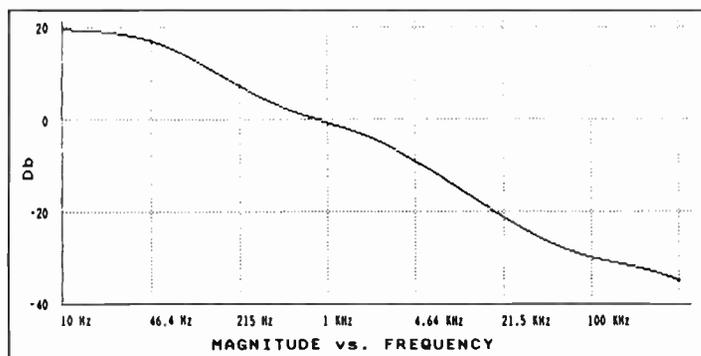


Fig. 4a. Simulation plot for Fig. 3 ($c_1 = 100\text{pF}$) showing magnitude versus frequency.

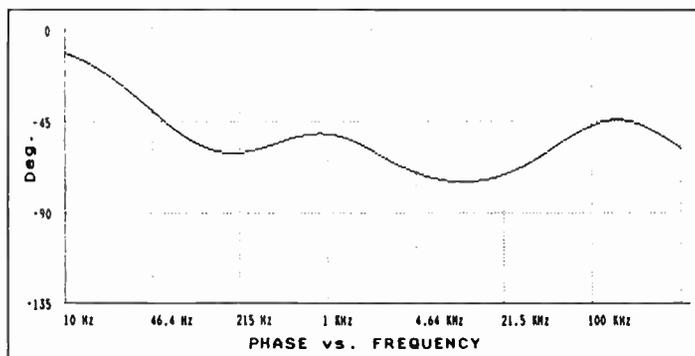


Fig. 4b. Simulation plot for Fig. 3 ($c_1 = 100\text{pF}$) showing phase versus frequency.

TABLE 4
PART OF SIMULATION RESULTS
FOR FIG. 3 ($c_1 = 5\text{pF}$)

| Frequency | Magnitude (dB) | Phase (deg.) |
|------------|----------------|--------------|
| 251.19 | 6.43 | -58.12 |
| 292.86 | 5.43 | -57.05 |
| 341.46 | 4.50 | -55.65 |
| 398.11 | 3.63 | -54.04 |
| 464.16 | 2.84 | -52.36 |
| 541.17 | 2.14 | -50.76 |
| 630.96 | 1.50 | -49.37 |
| 735.64 | .93 | -48.33 |
| 857.70 | .40 | -47.76 |
| 1,000.00 | -.10 | -47.72 |
| 1,165.91 | -.61 | -48.25 |
| 1,359.36 | -1.13 | -49.33 |
| 1,584.89 | -1.70 | -50.91 |
| 1,847.85 | -2.33 | -52.92 |
| 2,154.43 | -3.03 | -55.22 |
| 2,511.89 | -3.82 | -57.70 |
| 2,928.64 | -4.69 | -60.22 |
| 3,414.55 | -5.64 | -62.66 |
| 3,981.07 | -6.66 | -64.92 |
| 4,641.59 | -7.75 | -66.93 |
| 5,411.70 | -8.89 | -68.64 |
| 6,309.57 | -10.07 | -70.01 |
| 7,356.42 | -11.27 | -71.03 |
| 8,576.96 | -12.51 | -71.67 |
| 10,000.00 | -13.75 | -71.94 |
| 11,659.10 | -15.00 | -71.82 |
| 13,593.60 | -16.25 | -71.32 |
| 15,848.90 | -17.49 | -70.41 |
| 18,478.50 | -18.72 | -69.11 |
| 21,544.30 | -19.92 | -67.39 |
| 25,118.90 | -21.09 | -65.24 |
| 29,286.40 | -22.22 | -62.69 |
| 34,145.50 | -23.29 | -59.73 |
| 39,810.70 | -24.29 | -56.39 |
| 46,415.90 | -25.22 | -52.74 |
| 54,117.00 | -26.05 | -48.85 |
| 63,095.70 | -26.78 | -44.81 |
| 73,564.20 | -27.41 | -40.73 |
| 85,769.60 | -27.95 | -36.72 |
| 100,000.00 | -28.39 | -32.88 |
| 116,591.00 | -28.74 | -29.29 |

son's calculations. The model with the wider bandwidth ($c_1 = 5\text{pF}$) is very close to the theoretical values for audio frequencies. In the case of $c_1 = 100\text{pF}$, the deltas are higher and increase earlier. The open-loop gain of this model rolls off already from 4Hz. The high DC gain cannot be maintained at higher frequencies.

I am puzzled, though, by the high delta above 5.4kHz in the $c_1 = 5\text{pF}$ case. It is not clear whether this is a characteristic of the circuit or an inaccuracy in the model.

Yes, but . . .

As you can see, the program generates clear and useful graphs. Also, the data tables can be sent to a disk file and be processed by other graphing or presentation software. There are, however, a few remarks I must make.

It is not possible to save the graphs and overlay them on graphs from other simulation runs. This makes it much harder to compare results. The rather coarse scale marks do not help too much either. You cannot set this scaling yourself. What would help a lot here is a cursor that can be moved along the curve with readout of the x- and y-values. Note that these are things to make repeated use much easier and more efficient. The program itself works fine.

The map is not the world

It is clear that programs like PC-ECAP can be very useful. You can verify a design idea and zero in on a particular result without having a load of components in stock. But like all powerful tools, a circuit simulator does not

make you a seasoned expert. The paradox is that to get results that will correspond reasonably well to the real world, you must know what you are doing. It is like a bank loan: you can make creative use of it only if you do not actually need it.

In the above example on the RIAA preamp, if you find deviations from the benchmark, you are still back to your own knowledge and insight. Mostly you do not have benchmarks (that is why you use a simulator in the first place). Choosing the values for the op amp model carelessly gives unrealistic results. You should be able to recognize such a condition. Good planning is necessary.

Before I put together the complete RIAA circuit, I ran simulations on both the bare op amp and the combination transconductance amp/op amp. This gave me confidence that the model was reasonably accurate.

Another area where you can be misled is component values. For instance, you can multiply all resistors in the RIAA network by 1,000 and divide all capacitor values by 1,000 and get the same results. But it would behave very differently in a practical realization [read the discussion on "reasonable values" by Reg Williamson in his article].

With care and a healthy dose of distrust, a circuit simulator is an excellent design and learning tool. Despite its limitation, PC-ECAP is no exception. And for a price not much higher than a good soldering iron. ■

REFERENCES

1. *Spice, Guide to Circuit Simulation and Analysis Using PSpice*, Prentice-Hall, ISBN 0-13-834607-0 (book only). Order #834614 (book plus disk) includes a student version of PSpice, limited to five nodes and ten transistors. This is a valuable book for anyone interested in analog circuit simulation.

2. PC-ECAP: The Public (Software) Library, PO Box 35705, Houston, TX 77235-5705, (713)-524-6394. Probably the world's largest shareware distributor, with thousands of programs.

TABLE 5
SIMULATION RESULTS OF ECAP vs. WILLIAMSON'S CALCULATIONS
SHOWING GAIN IN DECIBELS

| Freq. (Hz) | Williamson | ECAP ($c_1 = 5\text{pF}$) | delta | ECAP ($c_1 = 100\text{pF}$) | delta |
|------------|------------|-----------------------------|-------|-------------------------------|-------|
| 10 | +19.75 | +19.48 | -0.27 | +19.47 | -0.28 |
| 22 | +19.19 | +18.92 | -0.27 | +18.87 | -0.32 |
| 100 | +13.09 | +12.84 | -0.27 | +12.56 | -0.53 |
| 1,000 | +00.00 | -00.10 | -0.10 | -00.69 | -0.69 |
| 10,000 | -13.73 | -13.75 | -0.02 | -15.20 | -1.47 |
| 22,000 | -20.26 | -19.92 | +0.34 | -21.42 | -1.16 |
| 54,000 | -28.23 | -26.05 | +1.82 | -27.63 | +0.60 |
| 100,000 | -33.56 | -28.39 | +5.17 | -30.17 | +3.39 |

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INDEX OF ADVERTISERS

| | |
|---|--------|
| All Electronics | 70 |
| Antique Electronic Supply | 69 |
| Audio Amateur Publications | |
| Audio Amateur | 67 |
| CIE | 5 |
| Information Unlimited | 9 |
| Kelvin Electronics | CV II |
| Madisound Speaker Components | 70 |
| Mark V Electronics | 10 |
| The Meadowlake Corporation | 70 |
| Morel Acoustics USA | CV III |
| Old Colony Sound Laboratory | |
| Audio Glossary/Holt | 8 |
| Books | 66 |
| Bullock on Boxes | 4 |
| Fundamentals of Musical Acoustics | 68 |
| "Save Your Invoice" Sale | 68 |
| Software | 6 |
| Optoelectronics | CV IV |
| PacComm Systems | 69 |
| PC Boards | 50 |
| The R.F. Connection | 70 |
| Sescom | 7 |

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| 41 | 42 | 43 | 44 | 45 | 46 | 47 | 48 | 49 | 50 |

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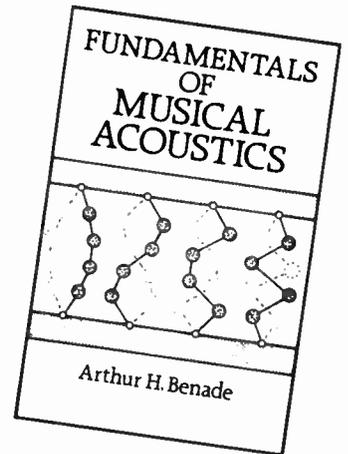
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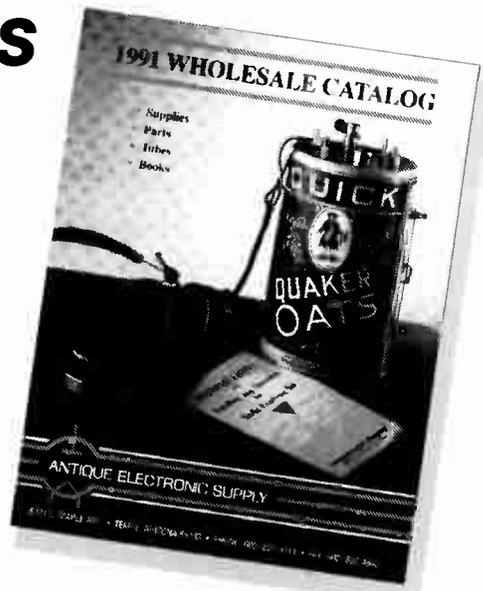
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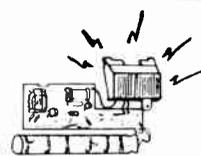
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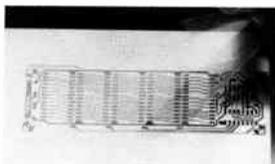
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Dept B, P.O. Box 497, Northport, NY 11768

more

high fidelity
range



ALUMINIUM
HEXATECH
VOICE COIL

85^{MM} DOUBLE MAGNET
SOFT DOME
MICRO-PAPER

The MDM 85 is a mid range 75mm soft dome unit of extremely high standard, both from a design and technical viewpoint.

It incorporates the renowned Morel double magnet and Hexatech voice coil techniques, and results in a unit of above average sensitivity with extremely low distortion and high power handling capability.

With an output level of 96dB distortion in the area of 400-800Hz is slightly over 1% falling to 0.015% from 1Khz.

There are two different types available, one with a rear enclosure and one without (MDM 85NE). The type with the rear enclosure can be fitted into a cabinet as an integral unit.

The MDM 85NE without the rear enclosure can only be fitted into a system having a separate housing to enclose the unit. A volume of 0.7 litre is recommended for this housing, which is essential to prevent interaction with the bass unit compressions and expansions. This housing must be filled full with damping material, such as fibreglass or rock wool.

The Thiele small parameters are given for both types under specifications. The contribution of this unit to a suitably designed system will be evident in the clarity and detail given in the 500-5000Hz region.

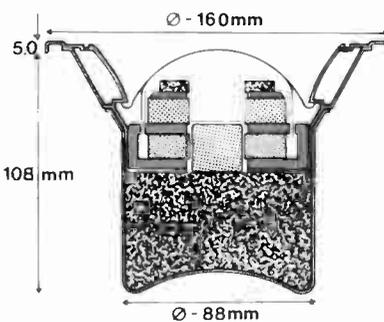
Specification

MDM 85 (with enclosure)

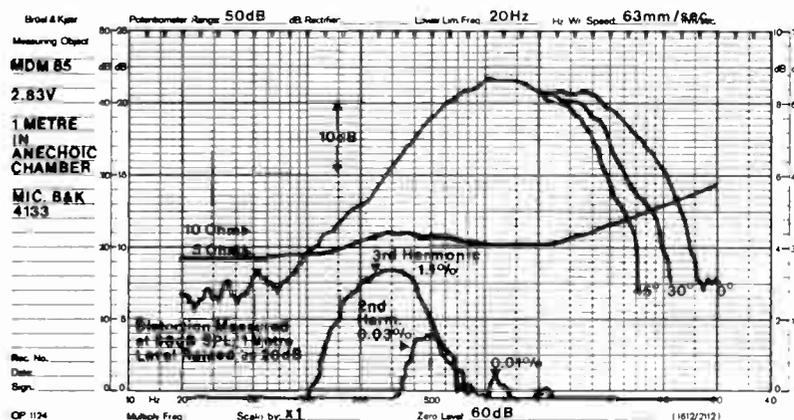
| | |
|--|---------------------------|
| Overall Dimensions | ∅ - 160mm x 113mm |
| Nominal Power Handling Din | 300W |
| Transient Power 10ms | 1500W |
| Voice Coil Diameter | 75mm (3") |
| | Hexatech Aluminium |
| Voice Coil Former | Aluminium |
| Frequency Response | 300-5000 Hz |
| Resonant Frequency | 250 Hz |
| Sensitivity | 92 dB (1W/1M) |
| Nominal Impedance | 8 ohms |
| Harmonic Distortion for 96 dB SPL | <1% |
| Intermodulation Distortion for 96 dB SPL | <0.25% |
| Voice Coil Inductance @ 1 KHz | 0.2mh |
| Air Gap Width | 1.05mm |
| Air Gap Height | 3.0mm |
| Voice Coil Height | 6.0mm |
| Flux Density | 1.0T |
| Force Factor (BXL) | 4.6 WB/M |
| Rdc | 5.2 ohms |
| Rmec | 37.90 |
| Qms | 0.29 |
| Qes | 2.66 |
| Q/T | 0.20 |
| Vas | 0.33 litre |
| Moving Mass including Air Load | 7.0 grams |
| Effective Dome Area | 63.50 cm ² |
| Dome Material | Chemically Treated Fabric |
| Nett Weight | 1.25 kg |

Variations to specification for MDM 85NE (without enclosure)

| | |
|--------------------|------------------|
| Overall Dimensions | ∅ - 160mm x 60mm |
| Frequency Response | 250-5000 Hz |
| Resonant Frequency | 170 Hz |
| Rmec | 39.33 |
| Qms | 0.19 |
| Qes | 1.81 |
| Q/T | 0.17 |
| Vas | 0.7 litre |
| Nett Weight | 1.05 kg |



Specifications given are as after 24 hours of running.



morel (u.k.) ltd.

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| 3000 | 10Hz 2.4GHz | | • | • | • | ± .2ppm add \$ 80. |
| 2600 | 1MHz 2.4GHz | • | | • | • | ± .2ppm add \$ 80. |
| 2210A | 10Hz 2.4GHz | • | | | | ± .5ppm add \$ 75. |
| 1300H/A | 1MHz 1.3GHz | • | | | | ± .5ppm add \$ 75. |

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