ELEKTOR ELECTRONICS USA

THE INTERNATIONAL JOURNAL FOR RECREATIONAL ELECTRONICS
OCTOBER 1992
$3.00 US
CANADA $4.00

8051 SINGLE-BOARD COMPUTER

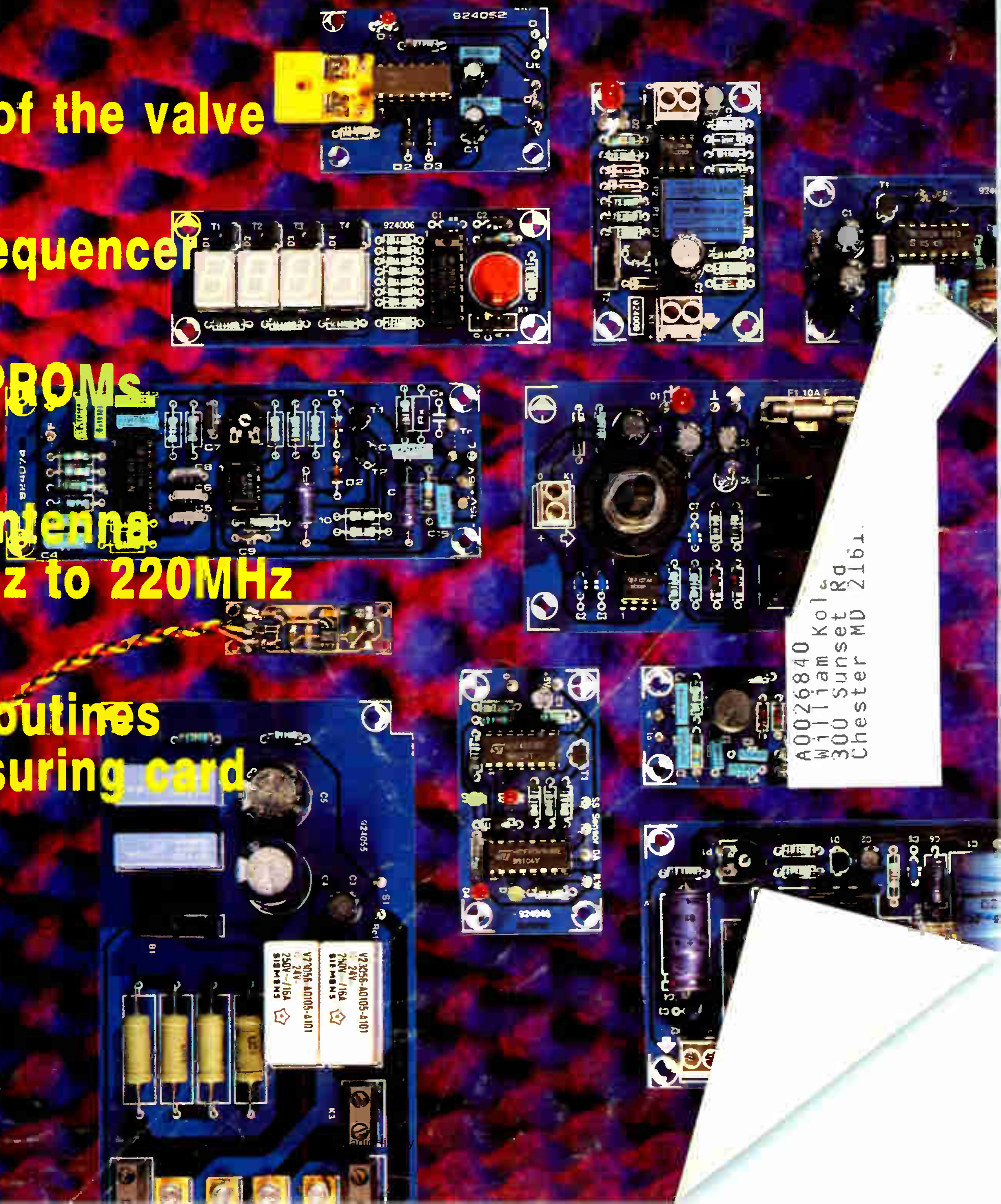
History of the valve

Mains sequencer

Flash EPROMs

Active antenna for 10kHz to 220MHz

Pascal routines for measuring card



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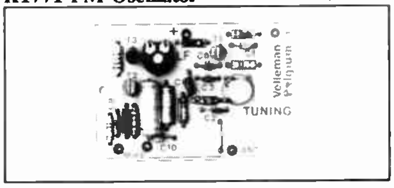
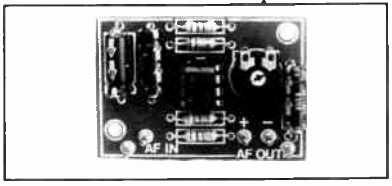
K1771 FM Oscillator — $16.95



Mini FM transmitter with good frequency stability (100-108MHZ). Built-in pre-amp (5mV Sensitivity). Interfaces to all microphones. Requires 9-12 VDC.

K1803 Universal Mono Pre-Amplifier — $7.95

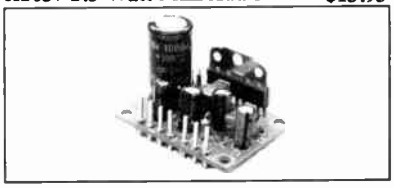


Ideally suited as a microphone amplifier, signal matching of tuner or tape outputs.• Supply voltage: 10-30 VDC (stabilized)• Gain: typ. 40 dB• Adjustable output level• Frequency range: 20 Hz to 20 KHZ (+/- 3 db)• Maximum input voltage: 40 mV.

K2622 AM-FM Antenna Amplifier $15.95

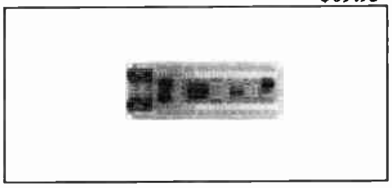
Do away with noisy signals! The K2622 gives you 22 dB gain where it's needed. DC supply direct or via the coax cable (50-75 Ohm impedance), metal box included.

K2637 2.5 Watt Mini Audio — $13.95



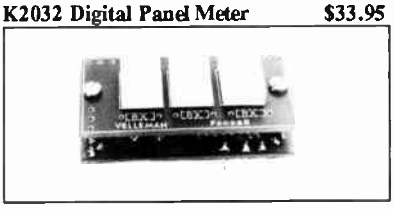
This small kit comes with a pre and power amplifier. No adjustments required. Short circuit protected. Power supply: 4,5 to 15 VDC• Input sensitivity: power-Amp: 150 mV (12V)• Pre-Amp: 20 mV (12V)• Max output 2.5W (4 Ohm, 12V)• Size: 42 x 32 x 27 mm.

K2666 Precision Stereo Vu-Meter — $69.95



Extremely precise VU-meter• 2 x 30 LED's "flying dot" readout• dB-linear scale from +6 to -6 dB (0.75dB per LED)• Steadily increasing scale partitions under -6dB• Peak measurements• No adjustments• Maximum error 0.5dB.

K2032 Digital Panel Meter — $33.95

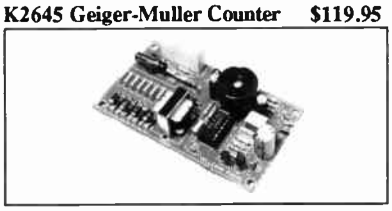


A compact kit that can be incorporated into many housings or into existing equipment• Power supply: 5VDC, 250 mA (regulated)• Read out: -999 mV to +99 mV, 1 mV resolution• Overload indication (positive and negative)• Linearity 0.1%• Input impedance: 100 Mohm.

K2653 Digital Voice Record/Playback — $61.95

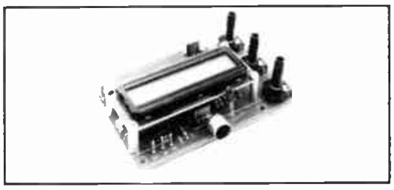
Record your voice message on a IC and play it back! Short messages (10-12 seconds) can be repeated to welcome your guests in your home or store. Use your imagination. Tech data: Loudspeaker output: 2W at 4 Ohm• 9VDC regulated.

K2645 Geiger-Muller Counter — $119.95



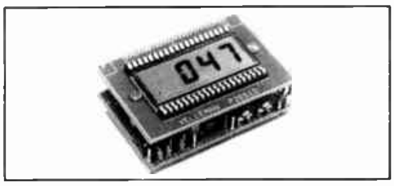
Reliable acoustic indication of radiation level. Excellent sensitivity to Gamma rays and high energy Beta rays. Battery operated (9V). Battery life exceeds 2 months in continual use and in normal natural radiation surroundings. Very compact: 99 x 54 x 25 mm. Light weight; assembled pcb weighs only 55 gr.

K2659 Moris decoder w/LC-display — $109.95



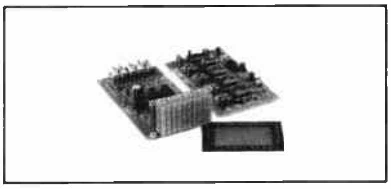
Decode Morse messages on your shortwave receiver. This decoder keeps up with the quickest signallers or automatic stations, and "notes" message on LCD.Alphanumeric LCD• 1 line of 16 characters• decodes Morse at almost any speed.

K2651 Digital Volt Meter — $39.95



This kit provides an easy-to-read display. Because of the simple power supply requirement and compact size of the kit, it can easily be incorporated into a variety of applications. Technical specs: Selectable - to + 200 mV or - to + 2V• Power supply: 8 to 15 VDC of 9V battery.

K4300 Audio Spectrum Analyzer $99.95



Provides visual composition of an audio signal. Kit consists of two boards and attractive front panel with 10 frequency bands. Technical specs: 10 bands: 32, 64, 125, 500, 1K, 2K, 4K, 8K and 16 KHZ• Range: 20 dB (10 LED's, 2dB per LED)• Line input: adjustable from 100 mV to 2 V rms, impedance 100K• Power supply 2 x 9v transformer: 12-15VDC• Current consumption 0.75ADC max, 70mA in stand-by.

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ELEKTOR ELECTRONICS USA

October 1992
Volume 2
Number 11

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- AF current amplifier
- Difference thermometer
- Compact spiral antenna
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- Sound sampler for Amiga
- Wheatstone bridge
- Model analysis

Front cover
The collage symbolizes the variety of projects we publish throughout the year and the technology used in them. In the past 12 issues, we have published no fewer than 74 large projects (a number of them multi-part) and over 100 smaller projects. These were backed up by descriptive articles on new components, new techniques and new applications. Also in that period we started the 8051/8032 assembler course which has proved popular beyond expectations.

ELEKTOR ELECTRONICS USA (US ISSN 1051-5690) is published monthly except August at $28 per year; $50 for two years by Audio Amateur Publications, Inc., 305 Union St., Peterborough NH 03458 USA. Second class postage paid at Peterborough NH and an additional mailing office.

POSTMASTER: Send address changes to **Elektor Electronics USA**, Caller Box 876, Peterborough NH 03458-0876.

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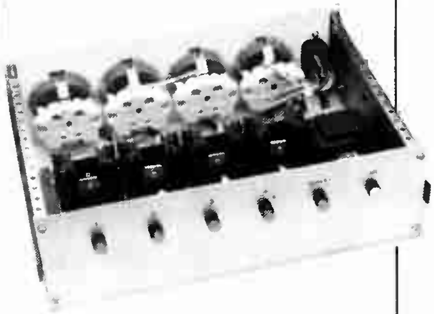

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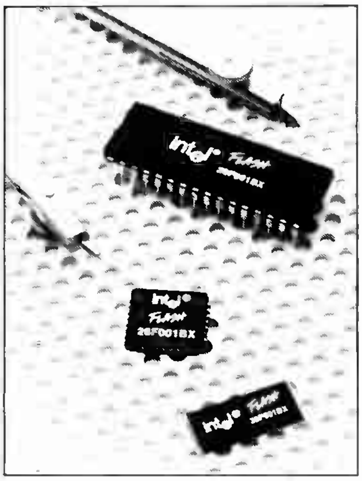

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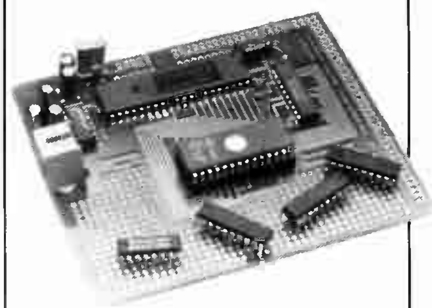

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A Bri

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Answering

These *Elektor Electronics USA* back issues are still available.

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AUDIO ANTHOLOGY: WHEN AUDIO WAS YOUNG VOLUME FIVE — BKAA3/5 — **$16.95**

C.G. McProud, editor

The major theme of this collection of forty-eight articles from *Audio* magazine, published in 1958-59, is the shift from monophonic to stereo reproduction. Twenty-eight years after Blumlein patented the basic stereo idea, its practical implementation finally took place.

Chapters include: The Stereo-Plus System; Compatible Stereo Multiplex Adaptor; A Panphonic Stereo Control Amplifier; A Stereophonic Tape Recorder Control; A Compact Two-Channel Amplifier for Stereo Systems; Multichannel Audio Mixer-Preamplifier; Stereo Without Bankruptcy; For Stereo, the Bi-Ortho Circuit; Stereo Recording Techniques; The Stereo Phasing Problem; The FM Multiplex Converter; A Stereo Compatibility Translator; A Variable Stereo Suppression Control; Stereophonic Recording and Playback Amplifier; Simple Single-Cabinet Corner Stereo Speaker; FM Commercial Eliminator for Fringe Areas; Variable Electronic Crossover and Biamplifier; FM Band Reception in Fringe Areas; Integrated Audio Monitor for Home and Studio Use; Hi-Fi for Lo-Do; Realistic Audio Engineering Philosophy; Sound Reproducing Systems: Monaural, Binaural, Monophonic, Stereophonic; A Heterodyne FM Multiplex Adaptor; A Transistorized Remote-Broadcast Amplifier; Transistor Music System Using Direct Coupling; Universal Stereo Control Center; A Continuously Variable Stereo-Dimension Control; Simple Electronic Switch for Magnetic Sound System; Three-Channel Remote Amplifier; A Transistorized Hi-Fi Preamp; The New "Isodyne" Phase Splitter; Understanding dB, dBm, and VU; Simple Transistor Tester; 60-Watt Amplifier with a Silicon Rectifier Power Supply; A Complete Tone Compensator; An Improved Loudness Control; Spiral Steel Shielding for Audio Circuits; Damping Factor Chart; Puzzled About Amplifiers?; Realistic Bass Without Boom; Output Power Measurements; RC Filter Design for High-Impedance Crossover Networks; Loading the Piezoelectric Cartridge; High-Power Audio Amplifiers; A Paging Preamplifier; Radio Interference in Audio Equipment; The Decibel--Fact or Fable?; and New High Fidelity Loudspeaker Enclosure. 1992, 8½ × 11, softbound. IN PRODUCTION; PLEASE CHECK AVAILABILITY.

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Aspen Pittman

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RÖRFÖRSTÄRKARE — BKEF1 — **$39.95**

Jean Hiraga

This hard-to-find book, edited by the renowned audiophile, is a true treasure trove of tube amplifier information. It is written completely in Danish, but fortunately (for English-language readers) the text occupies only about 20% of the book. The remainder contains literally scores of photos, schematics, drawings, spec sheets, and charts, all thoroughly delightful to peruse. Dynaco, Marantz, and MacIntosh are but a few of the familiar faces to be found in this volume. France, 1986, 150pp., 8¼ × 10⅝, softbound.

ELECTRONIC PROJECTS FOR MUSICIANS — BKAM1 — **$24.95**

Craig Anderton

This comprehensive guide, now revised and expanded, shows you how to build your own preamp, compressor/limiter, ring modulator, phase shifter, and talk box, as well as twenty-two other inexpensive electronic accessories. Written in clear language, with simple step-by-step directions and hundreds of helpful diagrams and illustrations. Also includes a 33⅓-rpm soundsheet for demonstrating electronic effects, as well as a glossary. 1975, 1980, 220pp., 9 × 11⅞, softbound.

ELECTRONIC TECHNIQUES: SHOP PRACTICES AND CONSTRUCTION — BKPH3 — **$54.95**

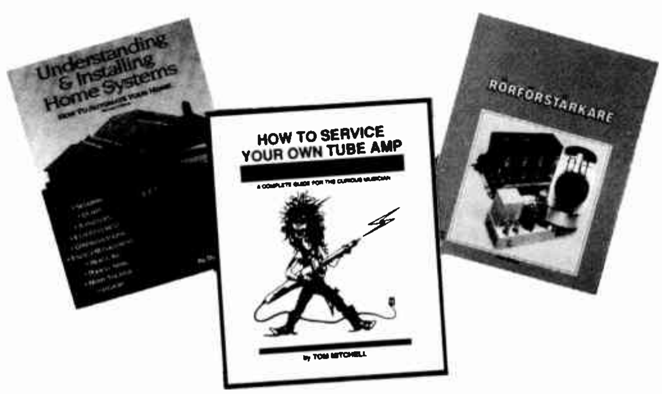
Robert S. Villanucci, et al.

Joined by fellow Wentworth Institute of Technology compatriots Alexander W. Avtgis and William F. Megow, Villanucci has written an excellent hands-on approach to training technicians in all aspects of electronic design and fabrication techniques, demonstrating current solid state devices and using a stereo amplifier system as a motivating example throughout. New chapters in this fourth edition cover surface mount technology and computer-aided design (CAD) of printed circuit boards. An extremely thorough presentation, covering all possible aspects of electronics construction and assembly, presented in textbook style. Appendices, Bibliography, Index. 1991, 591pp., 8½ × 11¼, hardbound.

INTRODUCTORY OPERATIONAL AMPLIFIERS AND LINEAR ICs: THEORY AND EXPERIMENTATION — BKPH4 — **$49.95**

Robert F. Coughlin, Robert S. Villanucci

This practical text/workbook presents state-of-the-art op amp and more complex linear integrated circuit techniques, complete with illustrative examples. Also included throughout are labs and manufacturers' data sheets. Certainly one of the best teaching tools available for this subject matter. 1990, 460pp., 8¼ × 11, softbound.



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David R. Gaddis

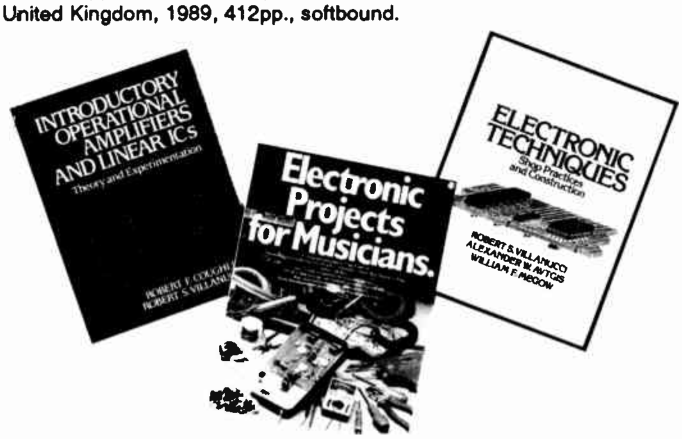
Now in a second edition, this handbook is designed to provide information that will help the reader to understand and install various home systems, as well as make his own decisions about home automation. In addition to giving standard how-to advice, the author also includes recommendations on materials and suppliers. Chapters include Basic Information, Installing Electrical Wiring, Home Security Systems, Lighting & Appliance Controls, Audio/Video Systems, Telephone & Communication Systems, Environmental Control Systems, and Automation System Controllers. Bearing in mind that this book emphasizes system theory and design rather than step-by-step construction, it is one of the most complete books of its type available anywhere. 1991, 140pp., 8½ × 11, softbound.

BROADCAST SOUND TECHNOLOGY — BKB9 — **$44.95**
Michael Talbot-Smith

This comprehensive and easy-to-read account of modern audio technology covers the main items in the broadcast chain: studio acoustics, microphones, loudspeakers, mixing consoles, recording and replay (analog and digital), and the principles of stereo. Chapters include Basic Sound, The Behavior of Sound Waves, Aspects of Hearing, Harming and Charming the Ear, Room Acoustics, Reverberation, Microphones, Phantom Power, Loudspeakers, Basic Stereo, Monitoring the Audio Signal, Processing the Audio Signal, Sockets and Symbols, Sound Desks (Mixing Consoles), Digital Audio, Further Digits, Analog Tape Recording and Reproduction, Digital Recording and Reproduction, Noise Reduction, Public Address, More Uses of Digits, and Further Reading. 1990, 212pp.

MEASURED TONES: THE INTERPLAY OF PHYSICS AND MUSIC — BKAH1 — **$34.95**
Ian Johnston

From the School of Physics at the University of Sydney, the author takes a nonmathematical look at the physics involved in music, to show that by linking these two subjects, enjoyment of music can be increased–as well as the understanding of physics. Using a completely fresh approach, the physical concepts are developed together with the musical applications and historical development of music. The physical principles underlying music are explained using analogies and examples, rather than mathematical reasoning. Anyone with an interest in music will find that an appreciation of the physics will add to his enjoyment of music. United Kingdom, 1989, 412pp., softbound.



HOW TO SERVICE YOUR OWN TUBE AMP: A COMPLETE GUIDE FOR THE CURIOUS MUSICIAN
Tom Mitchell

This program includes a fact-filled, illustrated, easy-to-read guidebook and a 75-minute VHS color videotape. Written in an informal, nontechnical, and entertaining style, the book takes readers on a step-by-step "crash course" in electronics while teaching troubleshooting, servicing, and problem prevention. The videotape helps to drive home key points from the text, demonstrating procedures and illustrating the use of hand tools and test equipment. Contents include an introduction to basic electronics; recognizing electronic components; in-depth coverage of tubes and transformers; detailed coverage of speakers and enclosures; amplifier circuit basics; demystifying biasing; tool and test equipment selection and use; using schematic diagrams; troubleshooting with voltage charts; how not to use an amplifier; voltage charts for most common amplifiers; ten troubleshooting flowcharts; tables and illustrations for international AC; many amplifier modifications; maintenance checklist for troublefree operation; and much useful reference information. Vinyl carrying case for book plus videotape is extremely handsome and durable. 1991, 250pp., 8½ × 11, spiralbound.

Purchasing options available:

VDMC — HOW TO SERVICE YOUR OWN TUBE AMP — **$44.95**
NTSC/VHS Video Only (does not include storage binder)

BKMC1 — HOW TO SERVICE YOUR OWN TUBE AMP — **$29.95**
Book Only (does not include storage binder)

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NTSC/VHS Video plus Book plus Vinyl Storage Binder, at a savings of $4.95!

LDCAD SOFTWARE
Madisound Speaker Components

Produced as an innovative supplement to the *The Loudspeaker Design Cookbook*, LDCAD is a special collection of programs and resource lists on a single 360K, DS/DD floppy disk designed to introduce speaker enthusiasts to the kind of work possible on IBM-type personal computers. The disk includes four design programs, beginning with BOX PLOT, a shareware program (please refer to PC-ECAP in our Software ads for shareware details) which works under Microsoft Windows 3.0 and does a graphics output for designing closed and vented boxes. EASY CROSSOVER DESIGN by Terry Cejka is also included, as well as two audio worksheets based on Lotus 1-2-3 which can also be run with Quattro Pro or Excel. LDCAD also contains a general box design program with graphics, and information on Madisound's audio bulletin board and its contents. It also has a large listing of United States bulletin boards where other audio design programs and info can be found. The disk is archived, or condensed, so that in actuality it contains almost 720K of information. The files unarchive automatically on a separate floppy or hard disk (be sure to read the "README.1ST" file for instructions). Prospective purchasers may wish to note that Old Colony's BKAA2, *The Loudspeaker Design Cookbook* (please see our Books ads), contains a coupon worth $5 off the price of LDCAD.

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VDVT302 PART 2: **$34.95**
Learn the octal and hexadecimal numbering system, as well as about the RS, D, JK, Edge-Triggered, and Master-Slave flipflops, and basic counter circuits and how they work. 55:00.

VDVT303 PART 3: **$34.95**
Begin with ones complement and twos complement, and then proceed into registers, multiplexers, demultiplexers, decoder drivers, and common display devices such as the seven-segment, LCD, and dot matrix. 56:00.

VDVT304 PART 4: **$34.95**
A must for the serious technician, this video presents how the computer communicates with real world through the use of digital-to-analog and analog-to-digital converter circuits. 57:00.

VDVT305 PART 5: **$34.95**
Examine the technologies in today's modern memory devices, including ROM, PROM, EPROM, EEPROM, SRAM, DRAM, and MBM (Magnetic Bubble Memory). 56:00.

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ELECTRONICS SCENE

LOOK MOM, NO WIRES

Audio-Technica's ATR45W, a professional-quality wireless microphone system for video camcorders consists of a transmitter, a receiver and an ATR35 omnidirectional condenser lavalier microphone.

The ATR45W's receiver employs a more durable rubber-coated flexible antenna rather than the standard telescoping metal tube style. The antenna can be rotated through a wide angle for better reception and convenience.

Both the receiver and the transmitter operate on 9V batteries and include a camera shoe mount, velcro strips for use when a shoe mount is unavailable, belt clips, earphone for monitoring recording and an ATR35 omnidirectional condenser microphone with tie clip land windscreen. ATR45W system is $239.95.

Contact Audio-Technica US, 1221 Commerce Dr., Stow, OH 44224-9971, (216) 688-2600, FAX (216) 688-3752.

Reader Service #232

DISH SET-UP

Baylin Publications announces the second, revised edition of *Install, Aim, and Repair Your Satellite TV System*, written for the layman. This new version contains 4 pages of illustrations, tables, and information on installing systems which receive new digital satellite broadcasts. A brief overview, step-by-step installation and trouble shooting guides, are included.

The book is $10 plus $3 for S/H. For information or a free catalog, contact Baylin Publications, 1905 Mariposa, Boulder, CO 80302.

Reader Service #236

IN CIRCUIT EMULATOR

The Engineers Collaborative announces the TECICE-HC05 In Circuit Emulator, which comes standard with a target system emulation probe and debugging software, and sports many real-time features such as hardware breakpoints with 16-bit pass counter. The Emulator also has a unique automatic clock speed switching feature that allows emulation at very low speeds.

The system includes the emulator, which comes in protective housing, a power supply, one emulation pod, a TASM-05 cross assembler, user's manual, tutorial, and a terminal emulation program.

The complete system sells for $1,110 (upgrade extra), through The Engineers Collaborative, Rt 3, Box 8C, Barton, VT 05822, (800) 336-8321.

Reader Service #290

LOOKING FOR MORSE

Designated as ID-8, **Communications Specialists**' Morse Station Identifier for commercial, public safety, and amateur radio applications, offers field programmability via a 12 button keypad that is included with each unit. Programmable features include: eight changeable messages (200 characters total) CW speed: 1-99 wpm, ID interval timing: 1-99 minutes, ; ID hold-off timing: 0-99 seconds; CW tone frequency; 100Hz-3kHz; "front porch" delay interval: 0-9.9 seconds; CW or MCW operation; courtesy tone: on/off; activate/inhibit ID: high/low.

The circuit utilizes a CMOS microprocessor for low voltage, low current operation, and is crystal controlled for high accuracy. All programming is stored in a non-volatile EEPROM, which may be reprogrammed with the included keypad.

The ID-8 sells for $89.95. Contact Communications Specialists, 426 West Taft Ave., Orange, CA 92665-4296, (800) 854-0547, (714) 998-3021, FAX (714) 974-3420.

Reader Service #235

Published by Audio Amateur Publishing Group
Editor/Publisher: Edward T. Dell, Jr.
Editorial Offices:
305 Union St., P.O. Box 876
Peterborough, NH 03458-0876 USA
Telephone: 603-924-9464 *(National)*
or +1 (603) 924-9464 *(International)*
FAX: (603) 924-9467 *(National)*
or +1 (603) 924-9467 *(International)*
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Elektor Electronics USA
Post Office Box 876,
Peterborough, New Hampshire 03458
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International Advertising:
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Telephone: +31 46 38 94 44
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European Offices:
Elektuur BV
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Managing Director: M.M.J. Landman

Overseas Editions:
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B.P. 59; 59850 NIEPPE
Editors: D.R.S. Meyer
G.C.P. Raedersdorf

GERMANY
Elektor Verlag GmbH
Susterfeld Strasse 25
5100 AACHEN
Editor: E.J.A. Krempelsauer

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Elektor EPE
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16673 Voula—Athena
Editor: E. Xanthoulis

HUNGARY
Elektor Elektronikai folyoirat
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Batthyany U. 13.
Editor: Lakatos Andras

INDIA
Elektor Electronics PVT Ltd
Chhotani Building
52C, Proctor Road, Grant Road (E)
BOMBAY 400 007
Editor: Surendra Iyer

ISRAEL
Elektorcal
P O Box 41096
TEL AVIV 61410
Publisher: M. Avraham

NETHERLANDS
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SWEDEN
Electronic Press AB
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14105 HUDDINGE
Editor: Bill Cedrum

UNITED KINGDOM
Elektor Electronics (Publishing)
P.O. Box 1414
Dorchester DT2 8YH
England
Editor/Publisher: Len Seymour

Printed in the United States of America.

ISSN: 1051-5690

ELECTRONICS SCENE

VIBRATION SCOOPER

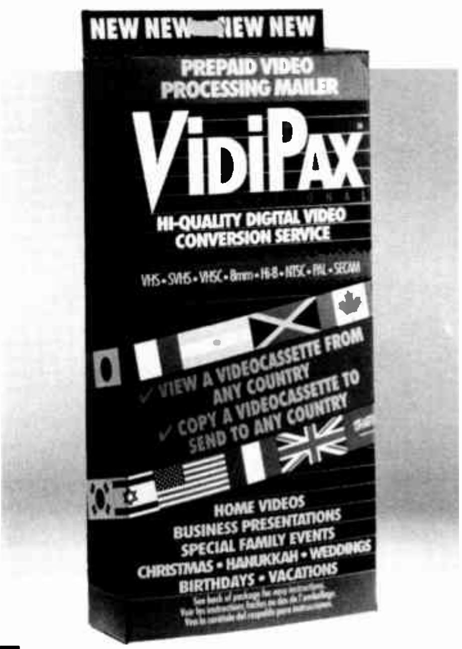
Scantek, announces MODENT software for testing mechanical components and structures which are subject to vibration and dynamic loads. Applications include vehicle components testing, PC board vibration characteristics, turbine blade development, and predicting switch-gear performance under earthquake conditions.

The MODENT modal-analysis function uses measured frequency response functions to describe the vibration properties of a structure. MODENT compares and validates finite element modeling results and modifies the models based on experimental findings.

You use MODENT on any industry standard 286, 386, or 486 PC, with high-resolution color graphics and co-processor capabilities and in conjunction with many signal analyzers including *Diagnostic Instruments*, H-P, B&K, Ono-Sokki, Schlumberger, and SD.

For information, contact Richard Peppin, Scantek, Inc., 916 Gist Ave., Silver Spring, MD 20910, (301) 495-7739, FAX (301) 495-7739.

Reader Service #275



GLOBAL VIDEO MAILER

VidiPax International offers a video cassette mailer service which digitally converts video tape to or from any country's standard, and returns both your tape and the converted one to you for $39.95.

The world's incompatible television standards need not prevent you from sharing videos for family, training, education, or other communication needs. Simply request an order form, (printed in English, Spanish, and French), and mail it in.

For the VidiPax dealer nearest you, call (914) 557-3600.

HAM SOURCE

Hart Publishing announced the fourth edition of the Amateur Radio Mail Order Catalog and Resource Directory which contains 220 pages and more than 1,200 entires of mail-order products and services for hams.

The catalog is alphabetized in categories from antennas to weather instruments. Listings include the name, address, phone, and FAX number of the vendor, plus a description of products or services. There are new, non-radio related listings in the catalog, such as environmental organization BBSs, and other informative sources under "Catalogs and References." The catalog also has the complete *Ham-Soft Shareware Catalog* included and includes directories of free catalogs, radio clubs, VECs, Amateur Radio-specific BBSs, and foreign radio magazines.

More information is available from Hart Publishing, 767 South Xenon Court, Suite 117, Lakewood, CO 80228, 303 987-9442.

Reader Service #254

OF GLOBAL CONCERN

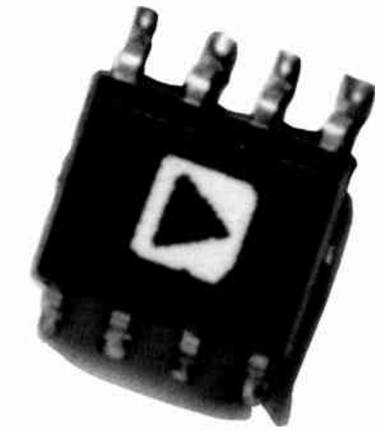
Global Specialties announced a portable design prototyping station, the PB-503-C. It is a complete electronics workstation housed in a rugged carrying case, for anyone who wishes to take their lab with them.

The design station is suited for analog, digital and microprocessor projects. It is complete with a large breadboard area which holds circuits up to 24 ICs. A full range of instrumentation, including a function generator, triple voltage power supply, 8-channel logic probe, and two digital pulsers are included. The triple voltage power supply features a fixed +5V 1A supply, and two variable 5–15V ½A supplies. The function generator is continuously variable in frequency, from 0.1Hz to 100kHz, with selectable waveform outputs of sine/square/triangle and TTL clock output.

The rugged carrying case folds into the size of a large briefcase, making the lab portable. Storage facilities are provided in the carrying case for manuals, an optional multimeter, and the optional WK-1 wire jumping kit. The PB-503-C retails for $349.95. The Proto-Meter 4000 and WK-1 are $139.95 and $13.95 respectively.

Contact Global Specialties, 70 Fulton Terrace, New Haven, CT 06512, (203) 624-3103, FAX (203) 468-0060.

Reader Service #294



GET MY DRIFT?

Analog Devices' AD621 is a low-drift instrumentation amplifier with 5ppm/°C maximum gain drift and 0.6μV/°C voltage offset drift, key parameters with weigh scales and bridge interfaces. The AD621 features a maximum nonlinearity of 10ppm of full scale, an initial offset voltage of 50μV and a gain error of 0.05%. Packaged in an eight-pin SOIC or DIP, the AD621 has pin-strappable gains of 10 and 100 and a low 1.3mA maximum supply current.

The AD621 operates from power supplies ranging between ±2.3 to ±18V. You can use it with data acquisitions systems and as a high-performance preamplifier: input voltage noise is a low 9nV/√Hz at 1kHz, 0.28μV p-p in the 0.1Hz to 10Hz band, while input current noise is 0.1%, sufficient for multiplexing. The AD621's bandwidth is 800 at a gain of 10, and 200kHz at a gain of 100.

Further information is available through Analog Devices, 181 Ballardvale St., Wilmington, MA 01887, (617) 937-1428, FAX (617) 821-4273.

Reader Service #231

A LITTLE MATH

Because engineers and scientists often spend days, even weeks "tweaking" their equations in an effort to make their model reflect an accurate representation of the observed data, **MicroMath** released DIFFEQ with Fitting version 2.0 for MS-DOS systems. Priced at $399, the program offers a solution environment that encourages experimentations and verification. It does least squares parameter estimation with differential equations. The program features several operators, including those supporting range functions, plot types including time and phase plots phase-portraits with varying initial conditions, and the capability to solve models using any of eight accepted numerical methods.

Current users may upgrade for $29; suggested retail is $399. Contact MicroMath Scientific Software, PO Box 21550, Salt Lake City, UT 84121, (801) 943-0290, FAX (801) 943-0299.

Reader Service #260

ELECTRONICS SCENE

VIDEO EDITING SYSTEM

Interactive MicroSystems, Inc. offers the MediaPhile Video editing system, which now supports Sony VISCA and controls Sony CTL-L/LANCS from the serial port of Commodore-Amiga computers.

MediaPhile is ideal for 8mm editing and interformat edits from 8mm to SVHS. Edit controllers give infrared and serial control over most prosumer video decks and camcorders. Other source devices include laser and compact disc players, audio cassette decks and DAT decks. The software supports insert and assembly edits with special effects and multimedia presentation.

Complete systems, including Commodore-Amiga computer and video deck, range from $2,500–10,000. Contact Interactive MicroSystems, Inc., 9 Red Roof Lane, Salem, NH 03079, (603) 898-3545, FAX (603) 898-3606.

Reader Service #248

TEAM FOR TUNES

Snell Acoustics and **Audio Alchemy** have formed a alliance in order to create a new company called MusicSoft. The new company plans to develop an open-architecture digital signal processing audio computer and a music operating system called MOS.

According to the participants, these products will make it possible to control and manipulate sound in new ways with conventional audio signal processors. Plans for the new system include the ability to digitally nullify unwanted loudspeaker characteristics and eliminate the unwanted acoustic characteristics of the listening room.

The audio computers will be sold under the Snell Digtal brand name and manufactured in the US by Audio Alchemy.

Snell Digital is located at 143 Essex St., Haverhill, MA 01832, (508) 373-6114, FAX (508) 373-6172.

Reader Service #287

SPECTRUM ANALYZER

Stanford Research Systems' SR760 ($4,350) is a full-featured FFT with 90dB dynamic range, frequency spans from 191MHz to 100kHz, and a fast 100kHz real-time bandwidth. Analysis functions such as THD, PSD, octave, band and sideband analysis are menu driven and supported with on-screen help. Averaging (vector, peak hold and RMS) can be performed on up to 64K scans. Data traces, Limit and Data tables, and instrument setup files can be stored on the 3.5-inch DOS format disk drive, or accessed through the standard RS-232 and GPIB interfaces. Applications include vibrations, acoustics, noise analysis and electronic design.

Additional data is available from Stanford Research Systems, 1290 D. Reamwood Ave., Sunnyvale, CA 94089, (408) 744-9040.

Reader Service #288

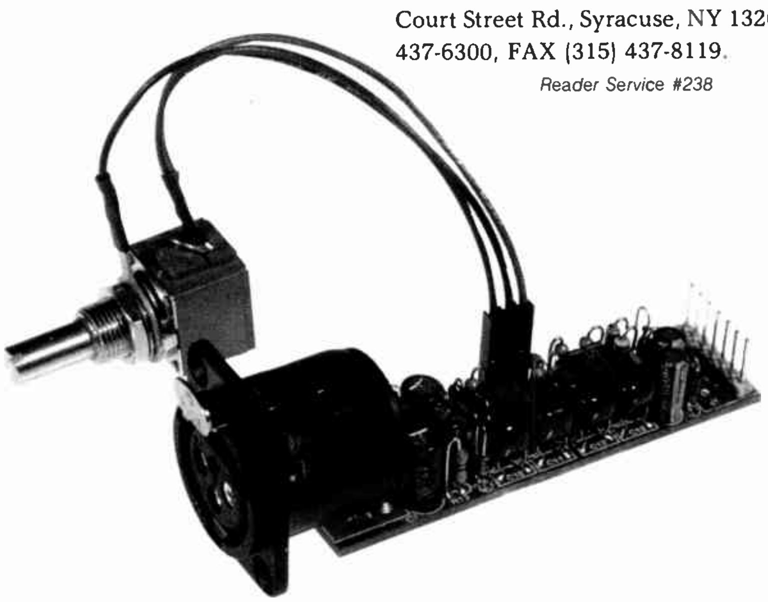
MICROPHONE PREAMP

New from **Benchmark Media Systems**: the MP-3, a high-quality microphone-preamp on a jack. The MP-3 has a balanced input, variable gain from 26–65dB, a balanced output, and can feed phantom power (external source required) to the microphone.

Performance is a 1dB noise figure, 2kHz THD at A = 40dB of 0.005%, and a bandwidth of greater than 200kHz. The balanced output allows it to drive lines up to 300′ in length. The MP-3 requires bipolar power, such as Benchmark's $35 PS-1 wall mount supply, and is ideal for applications such as classroom monitoring, sound reinforcement, E.N.G., etc.

Suggested retail for the MP-3 is $95. Contact Benchmark Media Systems, Inc., 5925 Court Street Rd., Syracuse, NY 13206, (315) 437-6300, FAX (315) 437-8119.

Reader Service #238



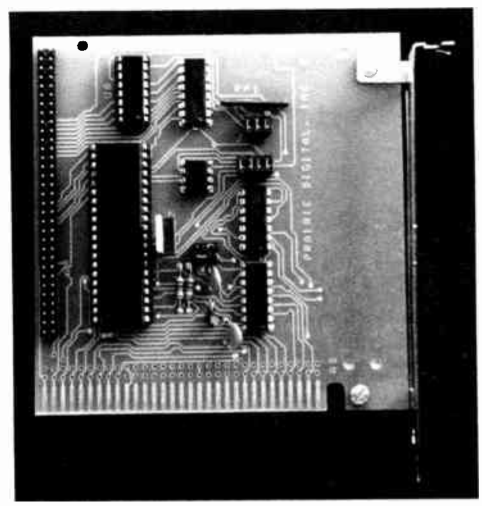
DATA ACQUISITION AND CONTROL

Prairie Digital, Inc. introduces the Model 30, a general purpose data-acquisition and control system for XTs, ATs, 386s, 486s, and PS/2 Model 30s.

The PCB plugs into the expansion bus and occupies a half slot, and includes 24 lines of programmable digital input/output, an 8-channel 8-bit A/D converter, and 12-bit CMOS counter (a 7-channel 50V 0.5A driver is also available). Communication to the PC is via 4 I/O memory locations and is easily interfaced to all popular languages. Sample BASIC, QuickBASIC, and Assembler programs are included on 5.25″ floppy.

The Model 30 costs $79 and is available for immediate shipment from Prairie Digital, Inc., 846 Seventeenth St., Industrial Park, Prairie du Sac, WI 53578, (608) 643-8599, FAX (608) 643-6754.

Reader Service #271



MIDI INSIDE & OUT

MIDI—the Musical Instrument Digital Interface—is the data communications system that enables music equipment, computers, and software from many different manufacturers to exchange information. Since its introduction in 1983, the impact of MIDI on the design and operation of synthesizers has been dramatic. **A-R Editions'** *MIDI: A Comprehensive Introduction* ($39.95), provides a practical guide for readers seeking a thorough discussion of the basic principles of MIDI. Rather than covering a limited number of particular brands of MIDI equipment, the text focuses on MIDI hardware and software as a system. It describes categories of MIDI instruments, accessories, and personal computer software, what to look for in each, and how to get it all to work together.

Book orders may be directed to A-R Editions, 801 Deming Way, Madison, WI 53717, (800) 736-0070, FAX (608) 831-8200.

Reader Service #227

WIDEBAND ACTIVE ANTENNA FOR 10 kHz - 220 MHz

This design goes to show that low noise and substantial amplification can go hand in hand in a single amplifier with excellent wideband characteristics. Ideal for use with car radios and communication receivers, or as an active probe for a high-frequency sampling oscilloscope, the design presented here is simple to build from a handful of components.

Design by J. Barendrecht

MOST wideband antenna amplifiers are simply impedance converters that provide some gain. The impedance of a whip or telescopic rod antenna is relatively high because these antennas are short with respect to the wavelength of the received signal. Obviously, this high impedance needs to be transformed down to 50 Ω or 75 Ω to match the receiver input, and that is why most wideband antenna amplifiers 'begin' with an old faithful: the J-FET based source follower.

Now while a J-FET is a nearly ideal impedance converter, its use in a wideband active antenna has two major disadvantages. First, it has a relatively large input capacitance (typically 10 pF), which easily creates a filter in combination with the high antenna impedance. Second, one of the rules of good antenna amplifier design is that the first active stage should provide at least some amplification to ensure the lowest overall noise figure of the design. Unfortunately, this requirement can not be met by the source follower, because it forms an attenuator, and so degrades the overall noise figure considerably.

A different approach

Thus, at the input of a wideband antenna amplifier we require a device that (1) has a low input capacitance; (2) is capable of very high frequency operation at low noise; (3) has a very high input impedance; (4) can cope with high signal levels without running into high intermodulation figures; and (5) provides some gain. That may seem a lot to ask from a single active device, but fortunately a good compromise can be struck by using a dual-gate MOSFET at the amplifier input.

The amplifier discussed here is one of the 'overall feedback' type, of which every one of the three stages provides amplification. Actually, it is a two-stage amplifier with an emitter follower at the output.

As opposed to the J-FET source follower, the MOSFET used here functions as an amplifier, and has an input capacitance of only 2 pF. As shown in the circuit diagram, Fig. 1, a BF981 is used.

The second stage is coupled direct to the MOSFET drain, and is built around the BF979 pnp UHF transistor. A medium-power wideband cable TV driver transistor Type 2N5109 (from Motorola) is used in the emitter follower stage.

Feedback is created by taking the emitter signal of T3 back to the source of T1, via network R7-C4. Without feedback, the gain of the amplifier lies between 15 dB and 20 dB (measured at an output impedance of 50 Ω). With the feedback parts fitted, the gain starts to rise a little at about 100 MHz. The increase amounts to about 2 dB towards the end of the mobile communications section of the VHF band, at about 160 MHz. This effect is caused by the increased phase shift at lower frequencies, which result in a less effective feedback.

The amplifier is powered by a 12-V regulated supply via the downlead coax cable. This so-called phantom supply is shown separately in the circuit diagram. If you are lucky, your receiver has a 12-V power supply, in which case it is conveniently used to power the antenna amplifier. It should be noted that the components in the phantom supply, i.e., the two connectors (K3 and K4), the choke (L2) and the decoupling capacitor (C7) are not fitted on the PCB.

The inductance of chokes L1 and L2 depends on the frequency that is of interest to you. The highest inductance value, 4.7 mH, is used for VLF reception; the lowest value, 470 μH, for VHF/UHF reception. Finding the best value may require some experimenting. In all cases, the d.c. resistance of the chokes must be smaller than 10 Ω.

The output of the amplifier is connected to the phantom supply via BNC connectors and a length of 50-75 Ω coax cable. Inexpensive TV coax cable will be adequate for this application.

The current consumption of the antenna amplifier is not more than 60 mA.

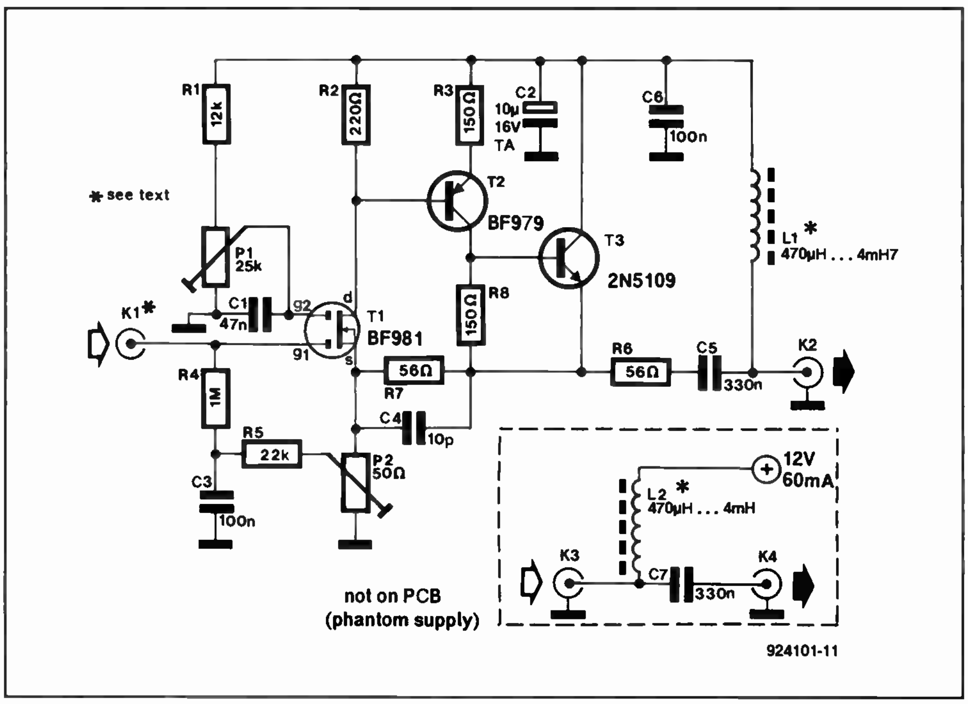


Fig. 1. Circuit diagram of the antenna booster and its phantom power supply.

Construction and adjustment

The amplifier is constructed on the small single-sided printed circuit board shown in Fig. 2. Note that the **dashed parts indicated on the component overlay are fitted at the track side of the board.** The whip or telescopic rod antenna is connected to the amplifier input via a banana socket. The antenna should not be longer than strictly

COMPONENTS LIST

Resistors:

1	12kΩ	R1
1	220Ω	R2
2	150Ω	R3;R8
1	1MΩ	R4
1	22kΩ	R5
2	56Ω	R6;R7
1	25kΩ preset H	P1
1	50Ω preset H	P2

Capacitors:

1	47nF	C1
1	10µF 16V tantalum	C2
2	100nF	C3;C6
1	10pF ceramic	C4
1	330nF	C5

Semiconductors:

1	BF981	T1
1	BF979	T2
1	2N5109	T3

Inductor

1	choke 470µH to 4mH7 (see text)	L1

Miscellaneous:

1	Banana socket, insulated, for chassis mounting, receptacle dia. 2.6 mm	K1
1	BNC socket	K2
1	Printed circuit board	924101

Phantom supply (not on PCB)

2	BNC socket	K3;K4
1	330nF	C7
1	choke 470µH to 4mH7 (see text)	L2

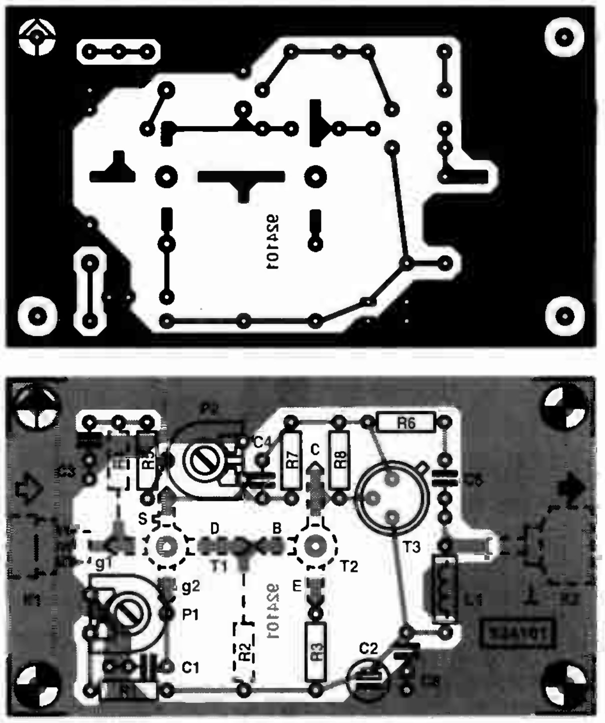
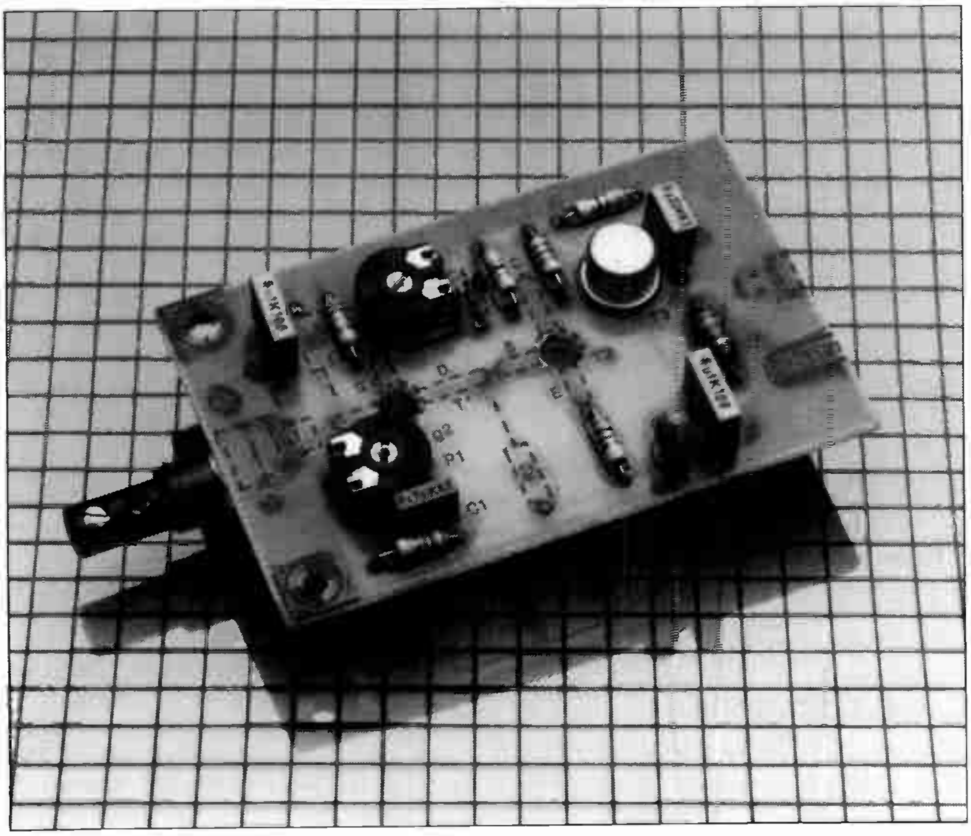


Fig. 2. PCB artwork for the project. Note that a number of components are fitted at the track side of the board.



necessary — 30 to 50 cm is long enough in most cases. The prototype used a bicycle spoke cut to about 40 cm and secured to a banana plug. When your reception area is 'infested' with hum (e.g., from nearby mains wiring), the antenna should be coupled to the amplifier input via a 10-pF capacitor.

To ensure proper screening, the completed printed circuit board is fitted in a metal box.

The d.c. setting of the amplifier is dependent on a number of factors, and may require some experimenting for best results. In general, P1 and P2 should be adjusted for a voltage of 6-8 V at the emitter of T3. When the amplifier is used for daytime short-wave or medium-wave reception, the best possible S/N ratio is required. Hence, preset P1 must be adjusted for a gate2-to-source voltage ($U_{g2\text{-}s}$) of between 3 V and 6 V. The lowest voltage that gives adequate reception of a weak station should be used.

For night-time reception, a different setting is required to cope with the much higher signal levels. In that case, we require the smallest possible IM (inter-modulation) distortion, which can only be achieved by passing more current through the MOSFET, so that $U_{g2\text{-}s}$ will be nearer 6 V than with daytime reception. Adjust P1 for minimum IM distortion when very strong signals are received. IM distortion will not occur easily, and a good way to pick up extremely strong signals is to tune to the 21-MHz band (14 m) in the late evening hours, or couple the amplifier input to a large antenna via a very small capacitance (a piece of wire wound around the 'outdoor antenna' cable and connected to K1 will be adequate). Remember, the amplifier input forms a very high impedance, which does **not** allow coax cable to be connected.

Finally, the prototype of the amplifier worked right up to 220 MHz, at which frequency a gain of 5 dB was achieved. ■

MAINS SEQUENCER

Design by T. Giesberts

When a group of mains-operated electrical or electronic appliances is switched on simultaneously, it may very well happen that the mains fuse(s) blow or the circuit-breakers cut out. This is caused by the peak currents that flow at switch-on, which can be many times larger than the nominal current. A circuit is described that obviates such an unwelcome happening.

WHEN an electrical or electronic apparatus is switched on, a peak current much larger than the nominal one flows, particularly in the case of motors and transformers. If a group of such equipment is switched on at the same time, it is quite likely that the relevant fuse in the consumer unit or distribution board gives up the ghost. Modern circuit breakers react even more quickly to peak currents than fuses. The load already connected to the consumer unit or distribution board must, of course, also be taken into account. The circuit proposed here obviates that risk by switching on the units in a group in a predetermined order at intervals of one second.

The circuit does more than just spreading the switch-on times. It also has a facility that enables determining the switch-on instant with respect to the zero (voltage) crossing of the mains supply. The zero (voltage) crossing is just about the most unfavourable instant for switching inductive loads if it comes to preventing high peak currents. Assuming a pure inductance, voltage and current are 90° out of phase, so that the zero crossing occurs at the instant when the current is maximum. If the appliance is switched on at the zero (voltage) crossing, the current will be extra large because it has a tendency to make up for the lag. If it is switched on at maximum voltage, however, the current will almost immediately assume its nominal value—see Fig. 1. In the upper half of the figure, the appliance is switched on at the zero (voltage) crossing. The current is then initially 'lifted' well above the base line, after which it drops back slowly until equilibrium is reached. In this theoretical case, the current at switch-on has about twice the nominal value. In the bottom half, equilibrium is reached immediately, because the appliance is switched on at maximum voltage. In practice, of course, the correct switch-on moment will lie somewhere between the zero crossing and maximum voltage. Two examples will illustrate the point.

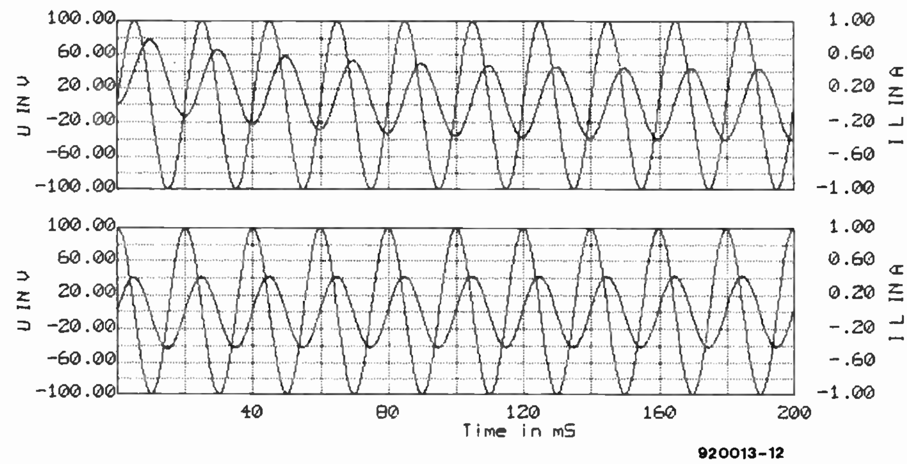


Fig. 1. When a sinusoidal voltage across an inductance is switched on, the phase angle at which this happens determines the level of the peak current through the inductance.

1. A problem occurs when iron-cored transformers and inductors are switched on. The core will have to become magnetized before it functions properly. That means that at switch-on the impedance is determined mainly by the primary winding. This may vary from a few ohms to several hundreds of ohms, depending on the nominal rating of the transformer. For instance, the impedance of a 300 VA toroidal transformer is 2–3 Ω, which could result in a peak current at switch-on of about 100 A. Although that current is limited to some extent by the mains supply, in practice, peak currents of 60 A can nevertheless arise.
2. Another problem occurs when inductors are switched off and then on again. Owing to residual magnetism, the core may have a weak magnetic field before switch-on. When switch-on occurs 90° after a zero (voltage) crossing, a large current will result. It is, therefore, better to ensure that no magnetic field exists just prior to switch-on.

In the proposed circuit, the instant of switch-on can be preset to enable the user to choose the best (or rather, the least bad) moment for the particular appliance(s).

Circuit description

Although the design can handle four outputs drawing a current of 5 A each, in the UK it is best to limit this to 3–4 A each, because the maximum rating of the fuse in the usual ring mains plug is 15 A. That means loads of 800–1000 W per output.

The ±5 V for the circuit is provided by a small power section that uses regulators Type 7805 and 7905. The transformer specified in the parts list is short-circuit-proof, so that a fuse is not needed.

There is no on/off switch, because that would have to be rated at 20 A, which is not a standard part. Instead, D_5 indicates whether the unit is plugged into the mains or not. This diode and its bias resistor, R_{39}, form a minimum load for the positive voltage regulator, while R_{40} provides the same function for the negative voltage regulator. This arrangement means that the regulators always deliver at least a small current, so that regulation is ensured. If no, or only a tiny, current flows, the output voltage tends to rise to the level of the input voltage.

The zero (voltage crossing) is determined by IC_2, a sort of comparator with a small hysteresis. Its output is a square-wave voltage that is in phase with the mains voltage. The hysteresis can be set with P_1 to a value where the trailing edge of the square-wave voltage

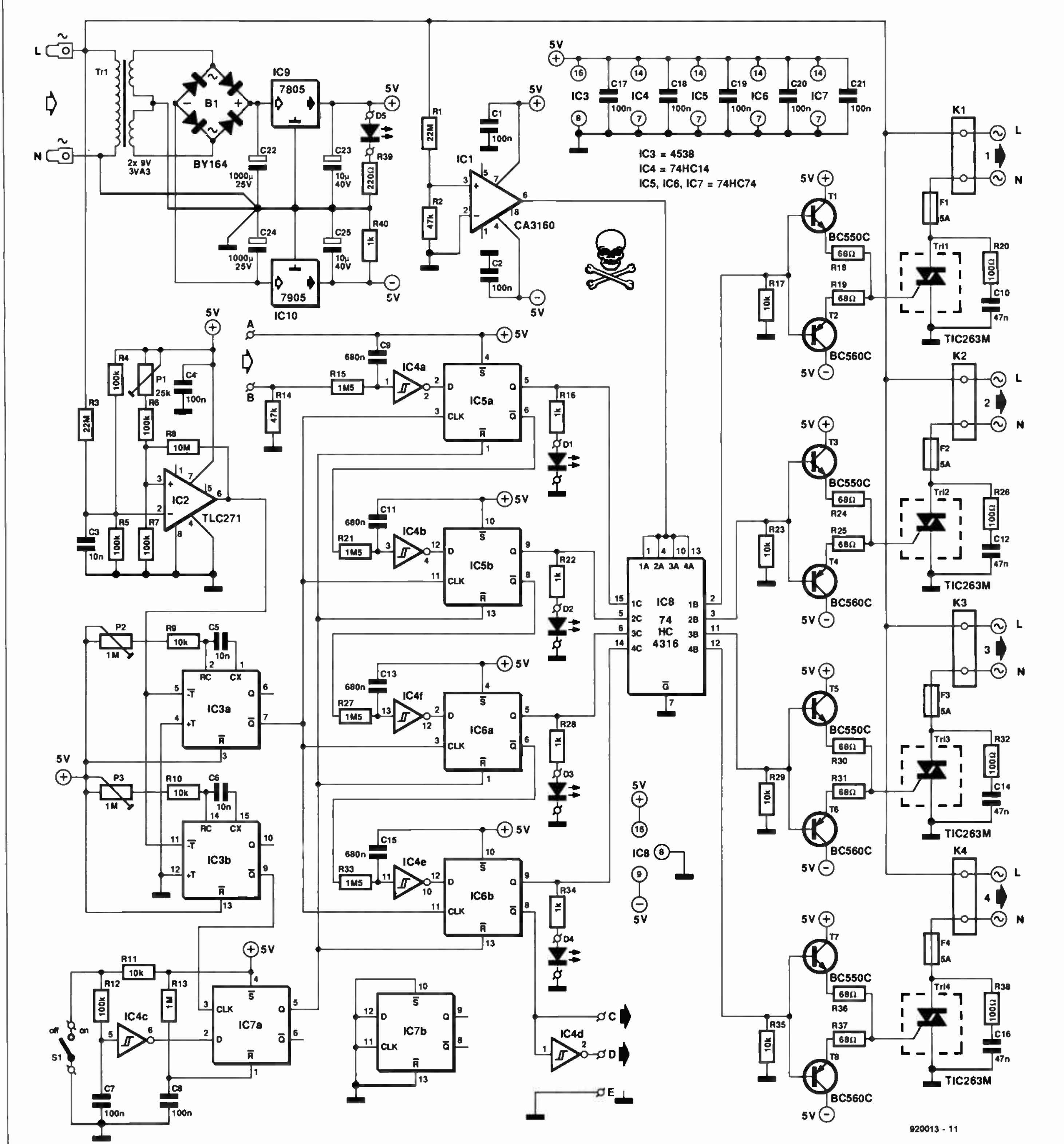


Fig. 2. Circuit diagram of the mains sequencer.

PARTS LIST

Resistors:
R1, R3 = 22 MΩ
R2, R14 = 47 kΩ
R4–R7, R12 = 100 kΩ
R8 = 10 MΩ
R9–R11, R17, R23, R29, R35 = 10 kΩ
R13 = 1 MΩ
R15, R21, R27, R33 = 1.5 MΩ
R16, R22, R28, R34, R40 = 1 kΩ
R18, R19, R24, R25, R30, R31, R36, R37 = 68 Ω
R20, R26, R32, R38 = 100 Ω
R39 = 220 Ω

Capacitors:
C1, C2, C4, C7, C8, C17–C21 = 100 nF
C3, C5, C6 = 10 nF
C9, C11, C13, C15 = 680 nF
C10, C12, C14, C16 = 47 nF, 630 V
C22, C24 = 1000 μF, 25 V, radial
C23, C25 = 10 μF, 40 V, radial

Semiconductors:
D1–D4 = LED, high efficiency*
D5 = LED*
B1 = BY164
T1, T3, T5, T7 = BC550C
T2, T4, T6, T8 = BC560C
IC1 = CA3160
IC2 = TLC271
IC3 = 4538
IC4 = 74HC14
IC5–IC7 = 74HC74
IC8 = 74HC4316
IC9 = 7805
IC10 = 7905
Tri1–Tri4 = TIC263M

* Use only with approved insulated holder.

Miscellaneous:
K1–K4 = 2-way terminal block, 7.5 mm pitch
S1 = single-pole mains switch
Tr1 = mains transformer; 2×9 V, 3.3 VA secondary (e.g. Monacor VTR3209)
F1–F4 = fuse, 5 A
4 fuse holders for PCVB mounting
2 heavy-duty mains terminals for screwing on to PCB
4 heat sinks for Tri1–Tri4, 5 K/W (e.g. Fischer SK129, available from Dau, Barnham, Sussex, Telephone 0243 553 031)
4 Mains outlet chassis socket
1 mains inlet chassis plug
5 insulated LED holders
4 LED lenses, red
1 LED lens, green
1 enclosure (e.g., LC860 from Telet)
1 PCB Type 920013 (see page 70)

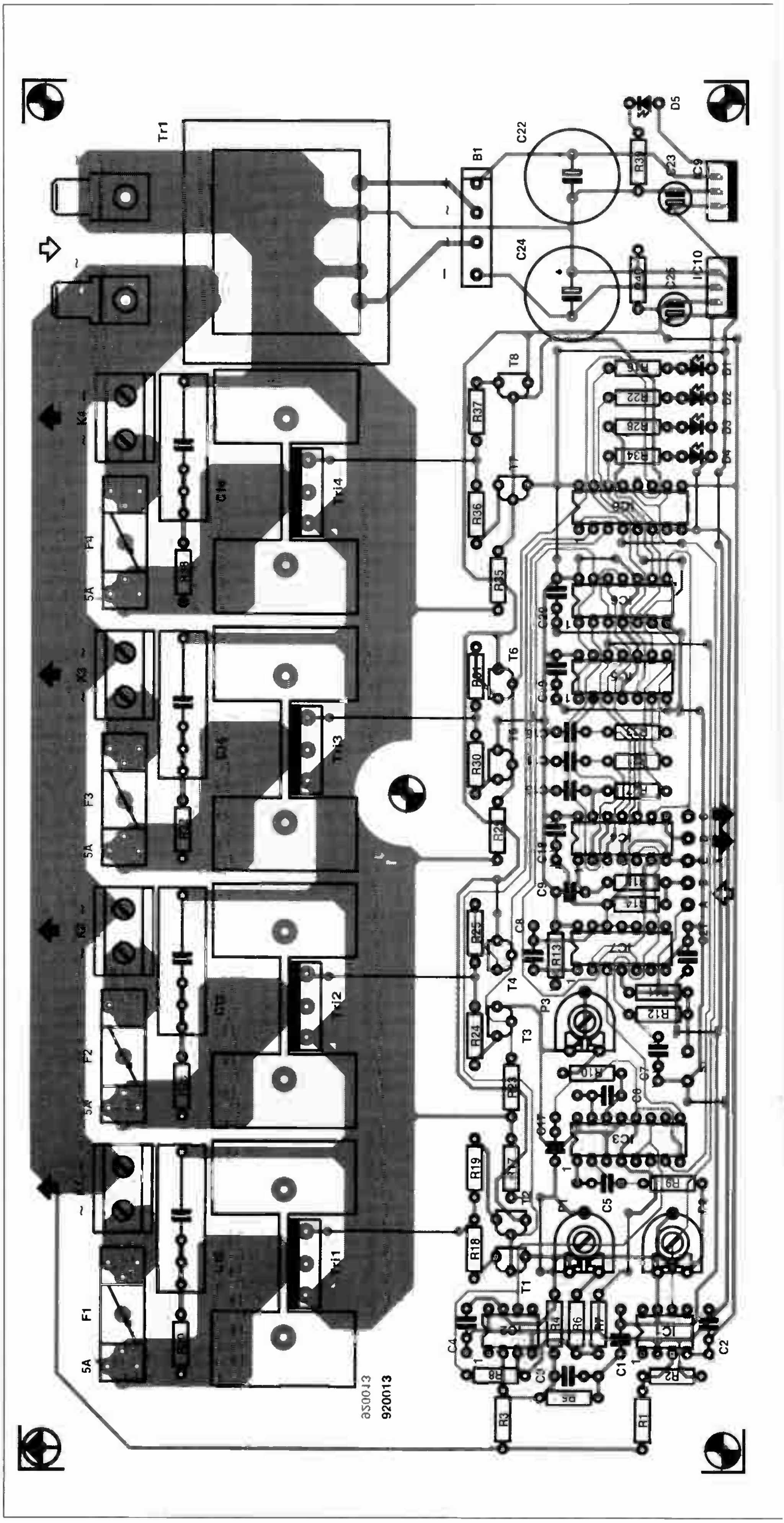
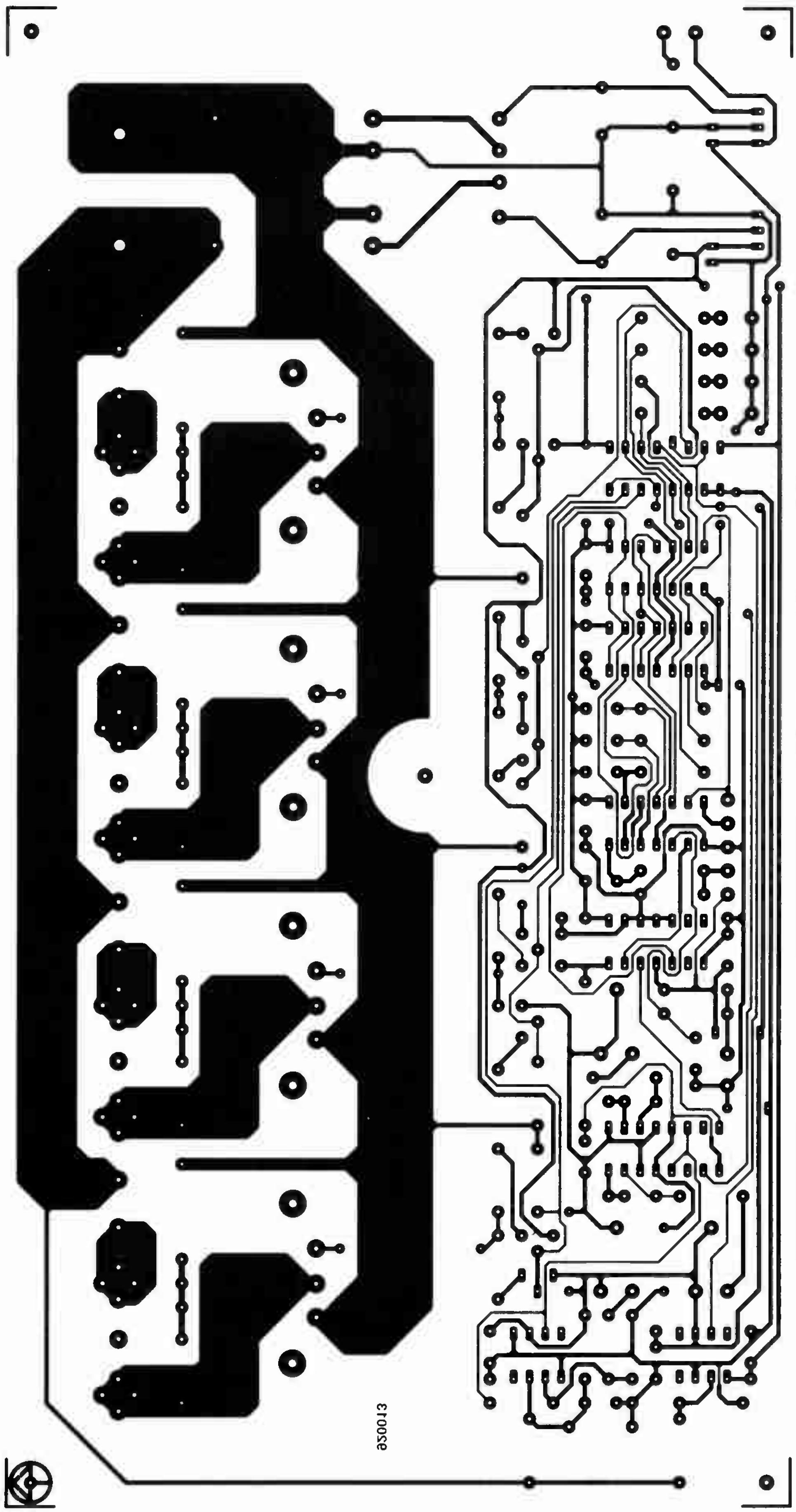


Fig. 3. Printed circuit board for the mains sequencer.



coincides exactly with the zero crossing at the start of a positive half cycle of the mains voltage.

The hysteresis, in conjunction with filter R_3–C_3, ensures that IC_2 is virtually not affected by noise on the mains.

The trailing edge of the output signal of IC_2 triggers two monostables, IC_{3a} and IC_{3b}, which, respectively, determine the switch-on and switch-off moment relative to the zero (voltage) crossing. The mono times may be set between 0.1 ms and 10 ms, which, in practical terms, means between a minute part of a period and a half period.

The sequential switching of the loads is effected by bistables IC_{5a}, IC_{5b}, IC_{6a}, and IC_{6b}. In the following, it is assumed that S_1 is closed and IC_{7a} reset. The bistables are chain-linked via an *RC* network and a Schmitt trigger/inverter that ensures a 1 second delay between their being switched. Bistable IC_{5a} is the first in the chain. When it is switched on, the D-input of IC_{5b} goes high; when this bistable is clocked, its Q output goes high and the associated output is switched on. At the same time, the D input of IC_{6a} goes high. The clock is provided by IC_{3a}, which, as we have seen, is triggered at a zero (voltage) crossing after every period. The four bistables are not clocked, however, until the mono time of IC_{3a} has elapsed. In other words, setting the pulse width also determines the delay between the zero crossing and the switch-on instant.

Switching off the outputs may be effected in two ways. The first is via IC_{3b}, IC_{7a} and S_1. This action is similar to that at switch-on: IC_{3b} clocks IC_{7a} in step with the mains voltage, so that the switch-off instant can also be set relative to the zero crossing. When S_1 is opened, the D input of IC_{7a} goes low via IC_{4c}, which causes the bistable to be reset. This results in the resetting of bistables IC_{5a}, IC_{5b}, IC_{6a} and IC_{6b}, so that all outputs are switched off. A power-up reset is arranged by IC_{7a} in conjunction with filter R_{13}–C_8.

The second way of switching off the outputs is by closing a switch between A and B, in which case the switching off is sequential.

The signals at the Q outputs of IC_{5a}, IC_{5b}, IC_{6a} and IC_{6b} indicate whether an output is on or off. This can be made visible by connecting an LED to each of these pins.

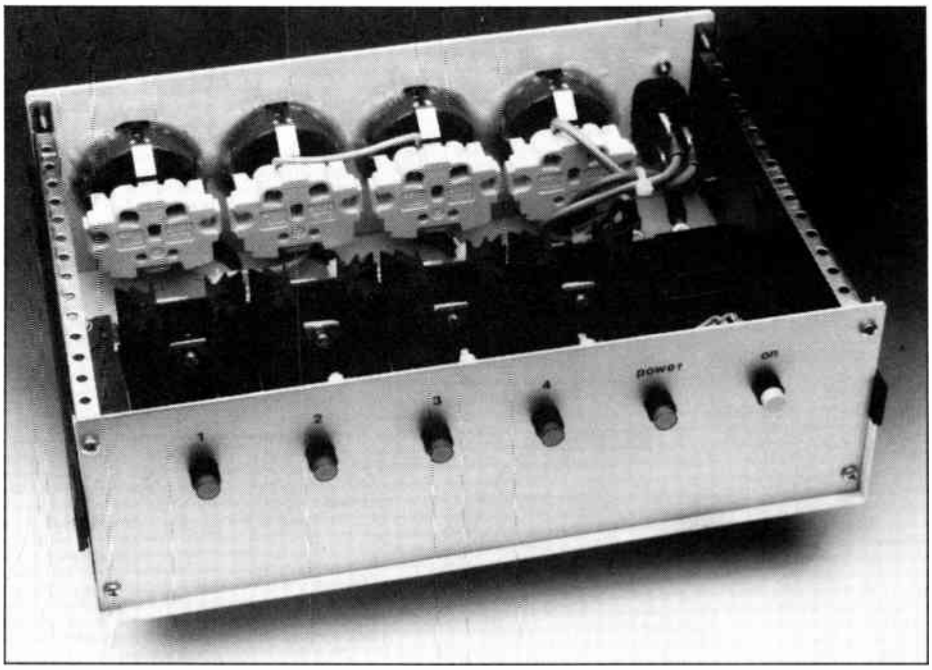
Unfortunately, these signals cannot be used directly to drive the gates of the triacs. This is because, if the mains has a polarity relative to ground different from that of the gate voltage, part of the gate current will not flow directly to ground, but via the load and the mains. That means that a small direct current will flow through the load, to which mains transformers react adversely.

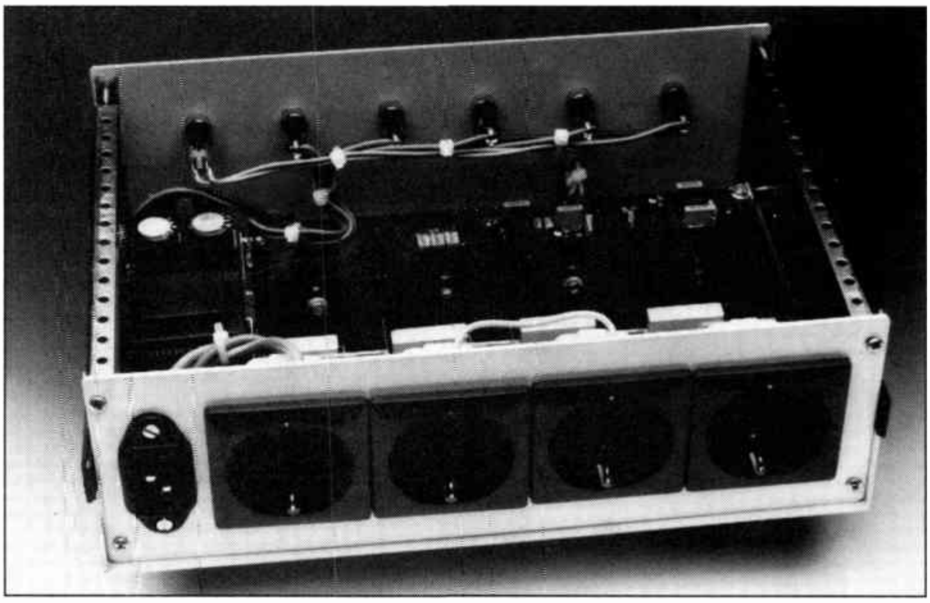
The design of the sequencer ensures that the gate current always flows directly to ground. The output signal of IC_1 indicates the polarity of the mains relative to ground. This signal is fed to four 'output stages', T_1–T_8, via four analogue CMOS switches contained in IC_3 and controlled by IC_{5a}, IC_{5b}, IC_{6a} and IC_{6b}. Depending on the output signal of IC_1, each of the output stages drives the associated gate with a current of ±50 mA. A switched-on triac is, therefore, driven constantly via its gate, so that it remains on. This design has the advantage over pulse-driving the gate that not only ohmic, but also reactive, loads can be switched without any problems.

Construction

It must be borne in mind at all times that the entire circuit is electrically connected to the mains supply. As long as the circuit has not been built into a suitable enclosure, no mains should be supplied to it or, if it is for test purposes, extreme care should be taken not to touch the circuit with your bare hands or non-insulated tools.

Furthermore, under no circumstances must the ground of the sequencer be connected to earth (mains or otherwise).





Populating the ready-made printed-circuit board should present no problems. Although the triacs may be mounted uninsulated on to the heat sinks, it is better to use an insulating washer to keep the heat sinks free of mains voltage (but not safe!). Note also that the LEDs should be fitted in holders as specified in the parts list, because a 'bare' LED does not meet safety requirements.

Do not use screws thicker than 4 mm (4 BA) to prevent them getting too close to voltage-carrying parts of the board.

Fix the board with *five* screws: the fifth is essential at the centre of the board in view of the length of the board and the weight of the heat sinks.

Fit the board on to 10 mm ($^{13}/_{32}$ in) long insulated (man-made fibre) spacers (metal ones might come too close to voltage-carrying parts, which would make protruding screws unsafe).

Keep conducting parts of the enclosure (also any metal parts of a man-made fibre one) that can be touched from the outside well away (at least 3 mm—$^{1}/_{8}$ in— preferably 10 mm—$^{13}/_{32}$ in) from voltage-carrying parts of the board.

When you link two boards, make absolutely sure that the mains connections are not interchanged, since the neutral line is connected to ground.

When choosing an enclosure, make sure that the ventilation holes are not larger than 5 mm ($^{3}/_{16}$ in), but preferably 3 mm ($^{1}/_{8}$ in).

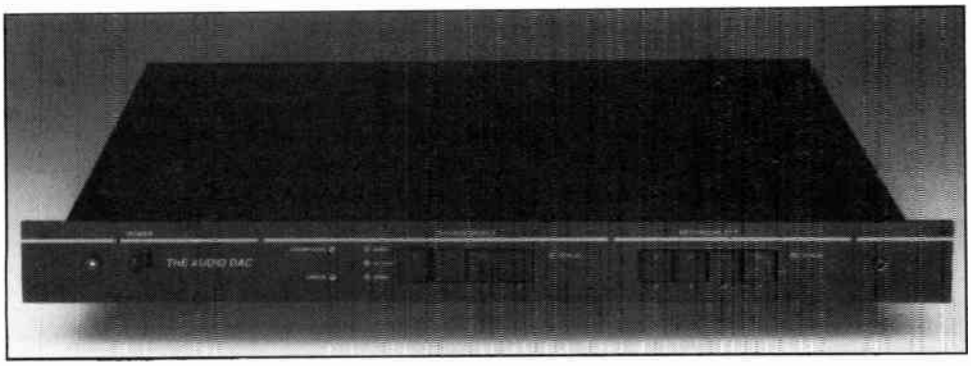
Any metal parts of the enclosure that can be touched should be connected to mains earth.

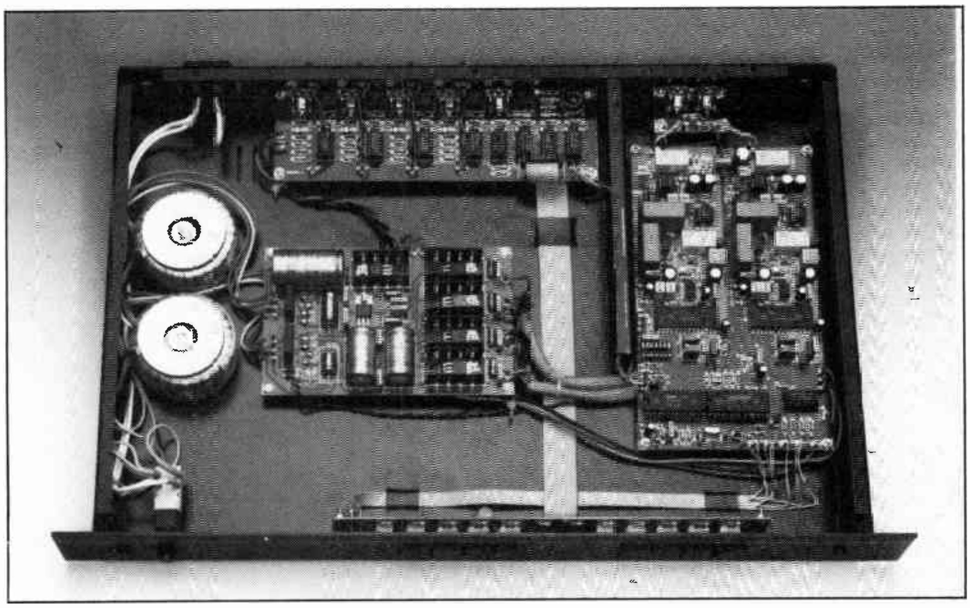
The insulation of switch S_1 must conform to the relevant safety regulations for mains-operating switches. ■

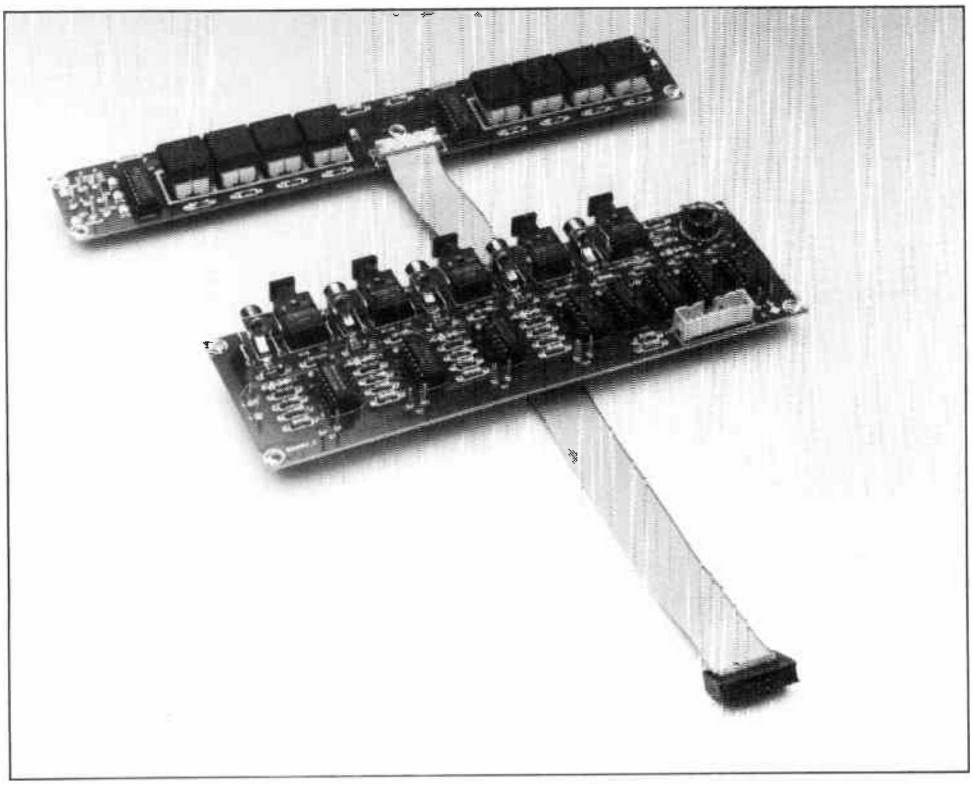
A.F. DIGITAL-TO-ANALOGUE CONVERTER

PART 3 (FINAL)

Design by T. Giesberts







STRICTLY speaking, the converter described so far does not need switching logic, since it can simply be connected direct to a CD player. However, developments in digital audio equipment make it a wise decision to fit the converter with the input/output selector circuit described in this final part of the article. This circuit enables the selection of one of four different digital input signals. Moreover, a tape out facility makes it possible to connect one of the four inputs to a digital recorder, while one of the other three can be listened to at the same time. All inputs and outputs can be linked to either coaxial or optical lines. The inputs are selected with key switches. Four more of these switches facilitate the looping of one of the inputs to the tape record output. The selected source and record inputs, as well as the various settings of the converter, are indicated on the front panel—see Fig. 18.

Circuit description

The circuit will be described with reference to channel 1: the design of the other three channels is identical—see Fig. 16.

The coaxial input is terminated into a 75 Ω resistor, R_1. The bi-phase signal is fed via C_1 and R_2 to inverter IC_{1a}, which operates as an amplifier. Capacitor C_{31} suppresses any tendency of the gate to oscillate. Feedback resistor R_3 enables an amplification of ×6 to be obtained, so that the output of the inverter is about 3 V_{pp}. Note that the design of the circuit is identical to that of the input circuit in Fig. 5 (in Part 1).

The level of the output of IC_{1a}, which is applied to IC_{1b}, is exactly half-way between that of the supply voltage and earth. This enables IC_{1b} to produce rectangular signals with minimal displacement of the transitions (edges) of the signal. This is important for an optimum reconstruction of the original digital signal.

The signal is then applied to three-state buffer IC_{3b}, which processes it if switch S_1 is open. If S_1 is closed, IC_{3b} is off and buffer IC_{3a}, which is fed with the signal from the optical input circuit, IC_9, is on.

The three-state buffers are followed by two more buffers, IC_{5d} and IC_{6d}, which are operated by the key-switch logic. In that way it is determined which of the input signals drives the converter (IC_{5d}) or the tape output (IC_{6d}).

The optical input consists of a receive diode and a components contained in a small plastic module called a Toslink (named after its manufacturer, Toshiba). Externally, the circuit, whose output is TTL compatible, only needs a power line decoupler, here consist-

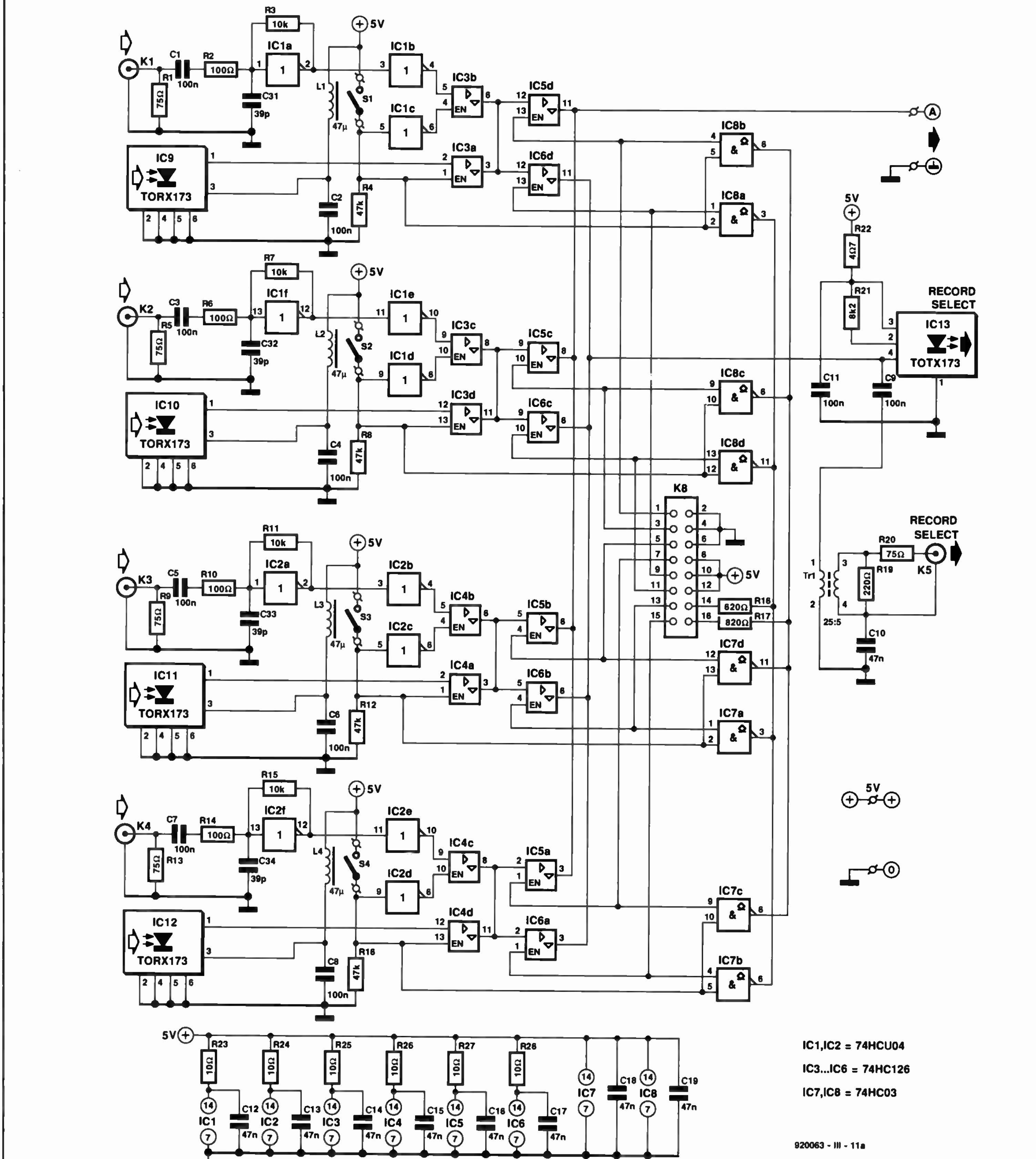
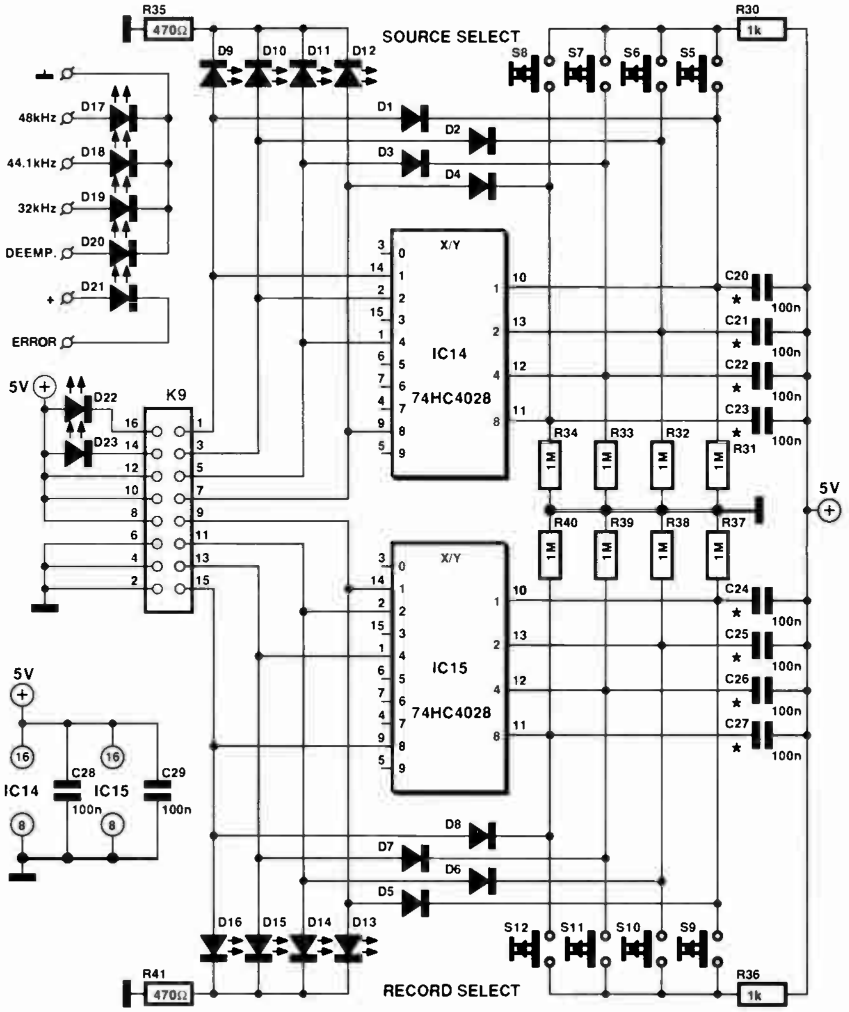


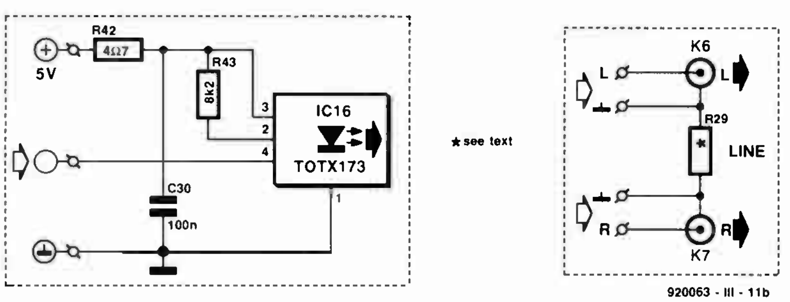
Fig. 16. Circuit diagram of the input/output selector.

Toslinks

The TORX173 and TOTX173 devices are available from

Highland Electronics Ltd
Albert Drive
Burgess Hill RH15 9TN
England
Telephone (0444) 236 000





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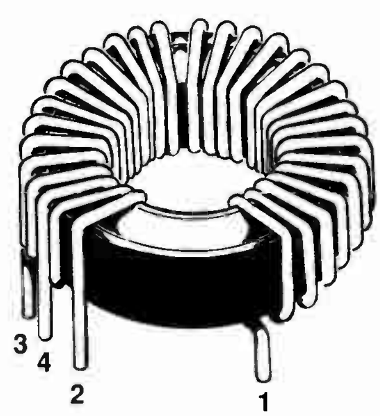


920063 • III • 12

ing of L_1 and C_2.

The tape output, too, is coaxial or optical, the latter again with the aid of a Toslink. Here, this circuit externally needs two resistors, R_{21} and R_{22}, and a capacitor, C_{11}. The coaxial output needs to be isolated (to ensure that no earth loop can arise via the ground line of the digital connection) and this is achieved by a small transformer, Tr_1. In the CD player a special Philips transformer was used, but here a wind-it-yourself type is used—how it is made is described later. Note already, however, that its bandwidth is far greater (at least in our prototype) than that of any ready-made type that was tried.

The switching signals are provided by two identical circuits, IC_{14}, which determines which signal is applied to the converter, and IC_{15}, which ensures that one of the input signals is applied to the tape output. Only the circuit based on IC_{14} will be described.

Four key-switches, S_5–S_8, are connected to the inputs of the circuit, a BCD-to-decimal decoder. When a key-switch is operated, the associated input becomes logic high. The decoder translates this into the relevant decimal level to render the appropriate output high (input A is associated with output Q_1, pin 14; input B with output Q_2, pin 2 and so on).

The outputs are fed back to the inputs via diodes D_1–D_4 to ensure that an output remains high when the relevant key-switch is released.

The outputs are connected to LEDs that indicate which output is active.

Of the four capacitors C_{20}–C_{23}, only that in the output associated with the input selected on power-up is used.

In the same way, only one of capacitors C_{24}–C_{27} in the tape select circuit is needed.

Gates IC_7 and IC_8 serve to show the user (on the front panel) which type of input (optical or coaxial) is in use with the selected source and record signal. To this end, each gate is connected with the control input of one of the three-state buffers and with one of the selector switches, S_1–S_8. When a given source or record input is selected, D_{22} or D_{23} indicates whether a coaxial (LED out) or optical connection (LED on) is in use with that input.

Five more LEDs at the front panel indicate which of the three sampling frequencies is being used, whether the deemphasis correction is on, and when there is an error in the digital transmission chain.

Audio output connectors K_6 and K_7 are shown separately on the diagram, because they are housed on a discrete small PCB. Resistor R_{29} is for use only if earth loops occur between the left-hand and right-hand channels. Its value (anywhere between a short circuit and a few ohms) must be determined empirically. If, as should be expected, there are no earth loops, R_{29} is simply omitted.

Also shown by itself is the optical output based on IC_{16}, which too is housed on a separate small PCB. This board is really intended for installation in the CD player (the output board of the player already has provision—in the shape of three solder pins—for receiving it).

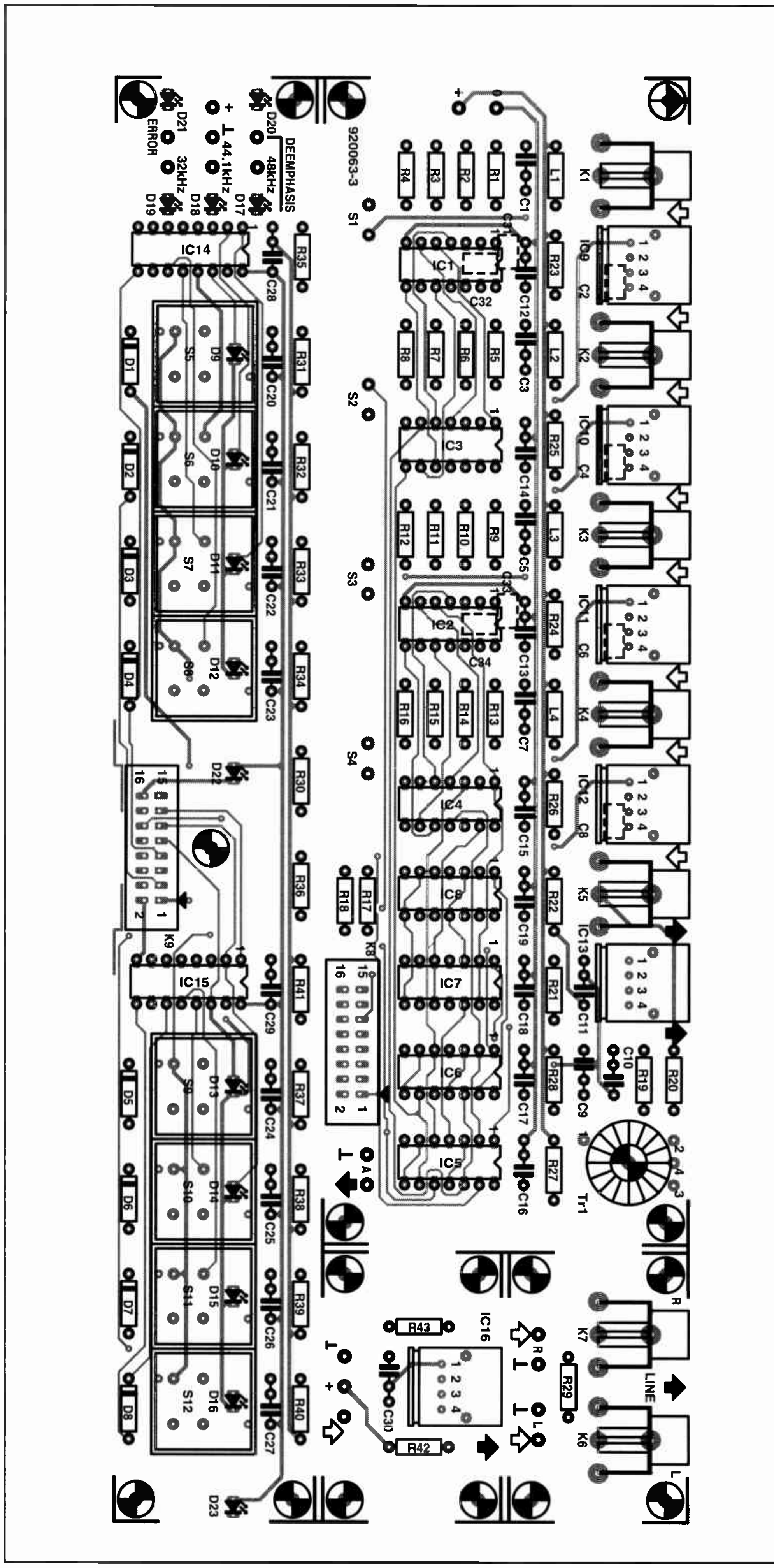
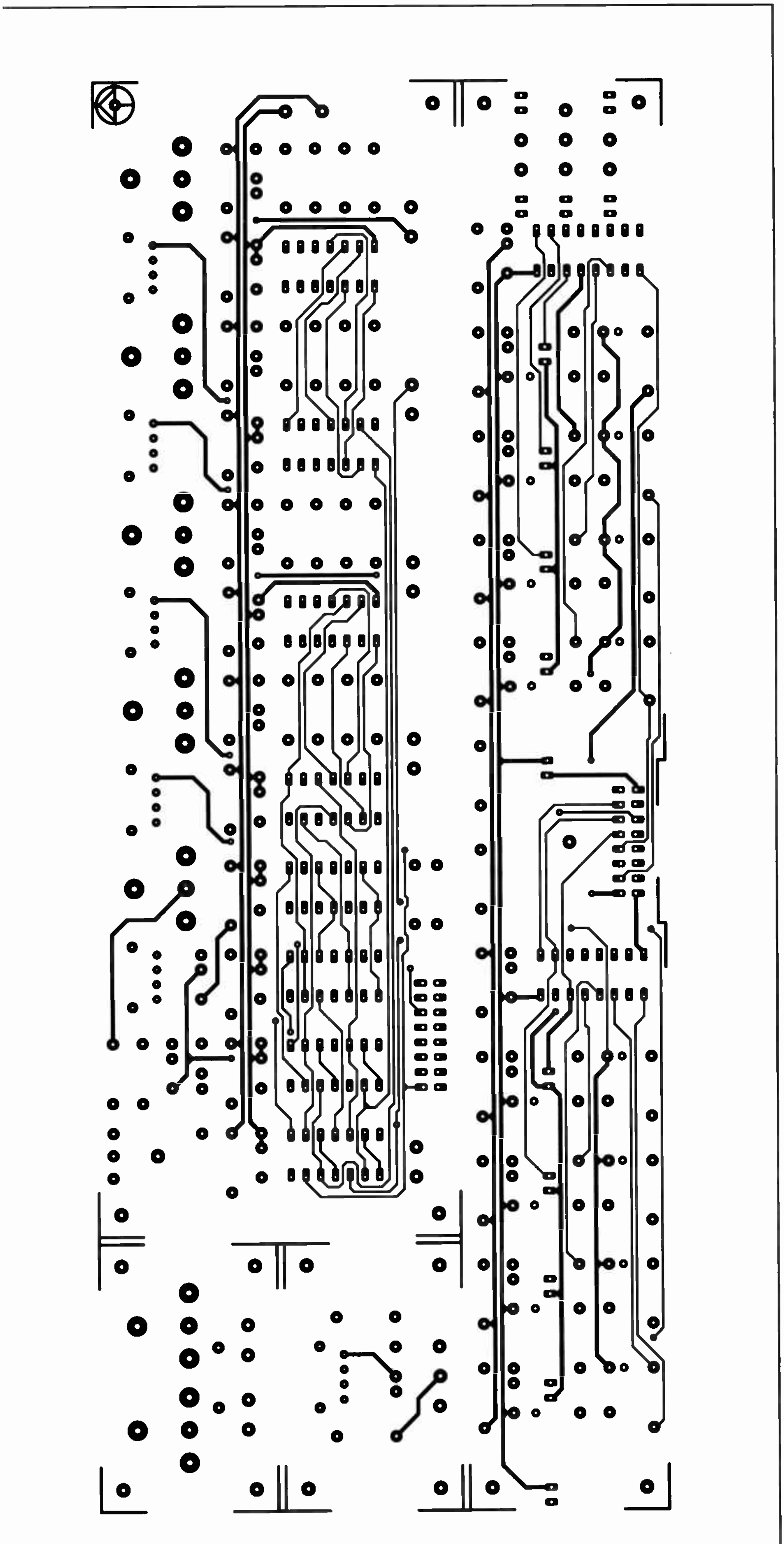


Fig. 17. Printed-circuit board for the input/output selector (continued on pages 25



Construction

The printed-circuit board in Fig. 17 should be snapped into four along the relevant seams. The resulting parts are: the busboard with the digital inputs and outputs, the switching board, the analogue output board, and the board for the optical output of the CD player. The analogue board is not needed if insulated audio sockets are used at the rear panel of the converter, and a number of users will not want the optical output for the CD player.

Before buying any LEDs, note that some of them alreay appeared on the mother board (see Fig. 15 in Part 2).

The core for Tr_1 (see inset at bottom right of Fig. 16) must be as indicated in the parts list or the transformer will not perform satisfactorily. Close-wind 25 turns of 1 mm^2 enamelled copper wire on to the core. Then wind five turns of the same type of copper wire over a width of about 5 mm ($^3/_{16}$ in) over one end of the primary 25 turns. The numbers at the terminals correspond with numbers on the PCB.

Capacitors C_2, C_4, C_6, and C_8, are SMD (surface mount design) types that must be soldered at the track side of the board beneath the Toslinks.

The key-switches should preferably be types with integral LEDs, but this is, of course, not essential.

The switching board and the busboard are linked by a short length of 16-core flatcable; normally a length of 30 cm (12 in) will suffice, but this does, of course, depend on the way the boards are fitted in the enclosure. This cable is fitted to the switching board via a flatcable connector with solder tags, while its other end is terminated into a connector that mates with the 16-way header on the busboard.

How everything should be installed into the 19-inch enclosure and what connections are necessary are shown in Fig. 18. Mount the switching board directly behind the front panel. Note the central fixing hole, which is provided to prevent the board bending unduly when the keys are pressed. Run the flatcable under the board to the rear of the enclosure.

Fit the busboard to the rear panel of the enclosure to ensure that all plugs and sockets are easily accessible. The rear panel may be given individual holes for the various connectors or a common rectangular slot. Mount a small slide switch above each audio connector/Toslink combination in such a way that, when open, it points in the direction of the audio connector. It is, of course, not mandatory to fit the Toslinks.

Mount the two transformers at the left of the enclosure and the power supply board roughly at the centre immediately adjacent to the transformers—see photo on page 21.

Fit the busboard at the extreme right of the enclosure in such a way that the analogue output board can just be mounted behind it. It is advisable to screen the left-hand side of the busboard with a small piece of tin

and 26).

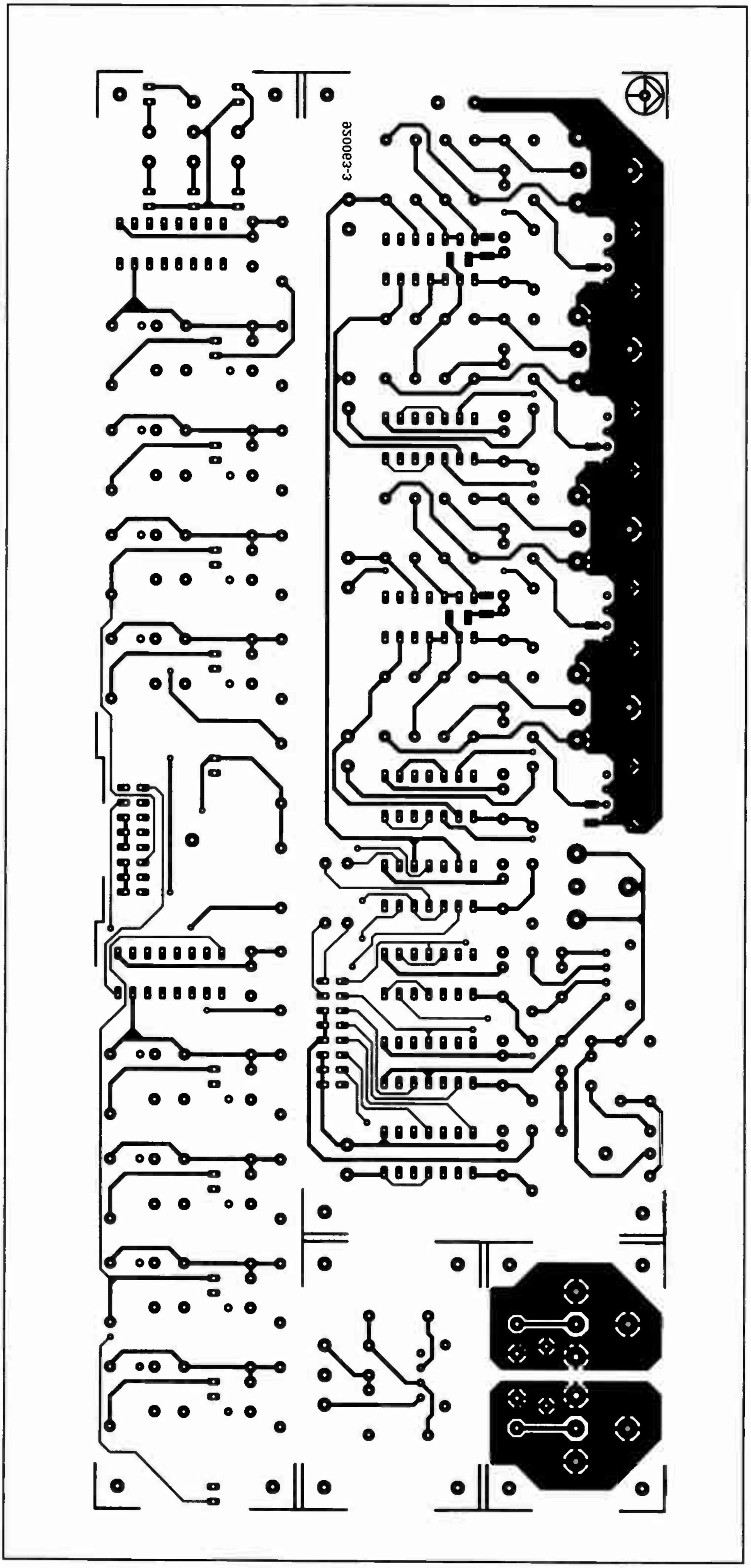


plate running from the rear panel to the power supply connections, that is, only along the analogue section of the board.

First connect the power lines to the boards and then the signal cables. For the mains inlet use a fused type. When all connections are made as shown in Fig. 18, you should have a correctly working converter. ■

PARTS LIST

Resistors:
R1, R5, R9, R13, R20 = 75 Ω
R2, R6, R10. R14 = 100 Ω
R3, R7, R11, R15 = 10 kΩ
R4, R8, R12, R16 = 47 kΩ
R17, R18 = 820 Ω
R19 = 220 Ω
R21 = 8.2 kΩ
R22 = 4.7 Ω
R23–R28 = 10 Ω
R29 = see text
R30, R36 = 1 kΩ
R31–R34, R37–R40 = 1 MΩ
R35, R41 = 470 Ω

Capacitors:
C1, C3, C5, C7, C9, C11 = 100 nF, ceramic
C2, C4, C6, C8 = 100 nF, SMD
C10, C12–C19 = 47 nF, ceramic
C20–C29 = 100 nF (see text)
C31–C34 = 39 pF, SMD

Inductors:
L1–L4 = 47 µH

Semiconductors:
D1–D8 = 1N4148
D9–D16 = LED (in S5–S12?)
D17, D21–D23 = LED, 3 mm, red*
D18, D20 = LED, 3 mm. yellow*
D19 = LED, 3 mm, green*
IC1, IC2 = 74HCU04
IC3–IC6 = 74HC126
IC7, IC8 = 74HC03
IC9–IC12 = TORX173
IC13 = TOTX173
IC14, IC15 = 74HCV4028

Miscellaneous:
K1–K7 = audio socket bus for PCB
K8 = 16-way header
K9 = 16-way flatcable connector for PCB mounting
S1–S4 = mini slide switch, 1 make
S5–S12 = key switch, 1 make
Tr1 = see text (core = LAB G2-3FT12)
PCB Type 920063-3
Front panel foil Type 920063-F

Optional (for optical output):
R42 = 4.7 Ω
R43 = 8.2 kΩ
C30 = 100 nF, ceramic
IC16 = TOTX173

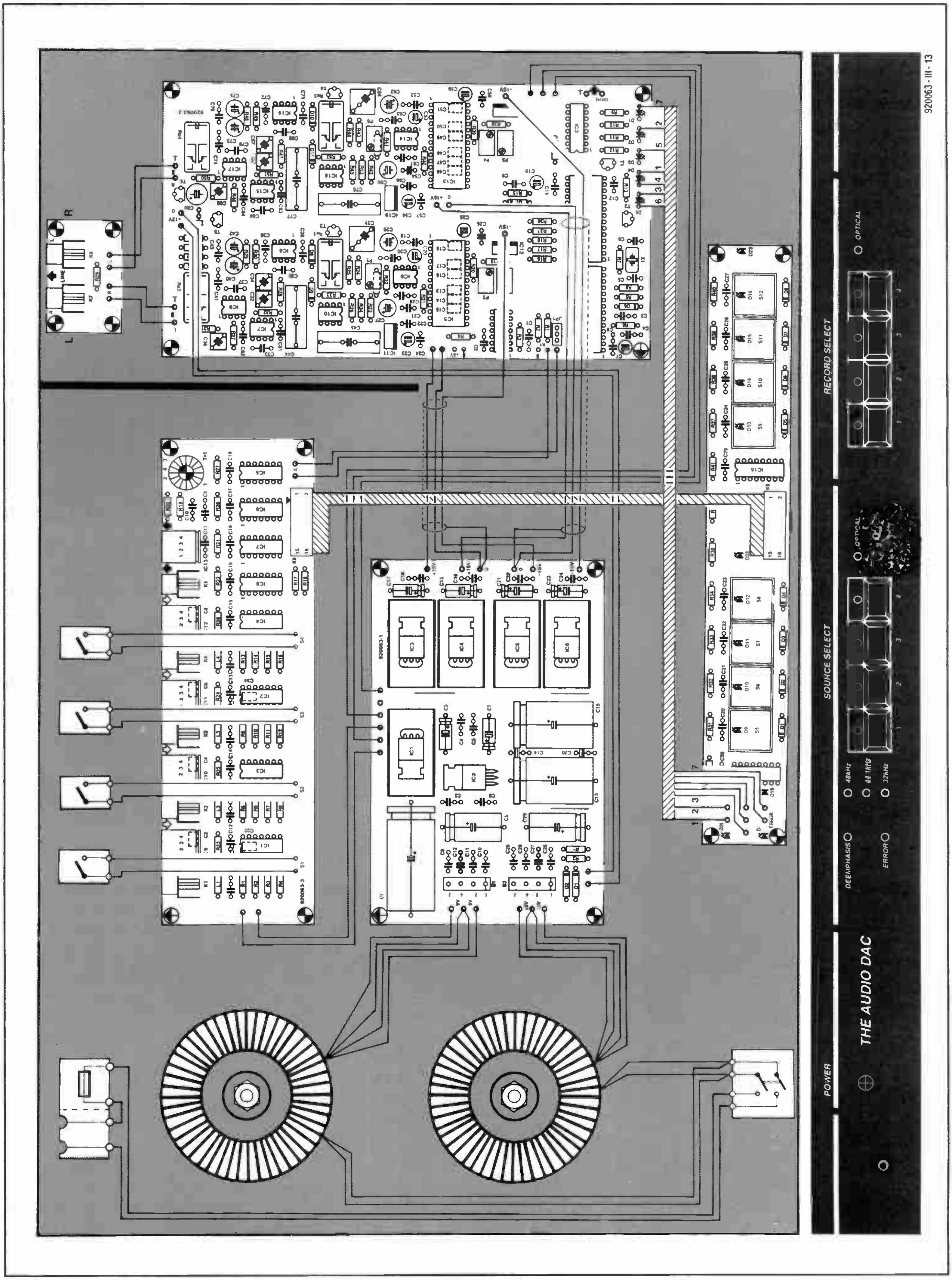
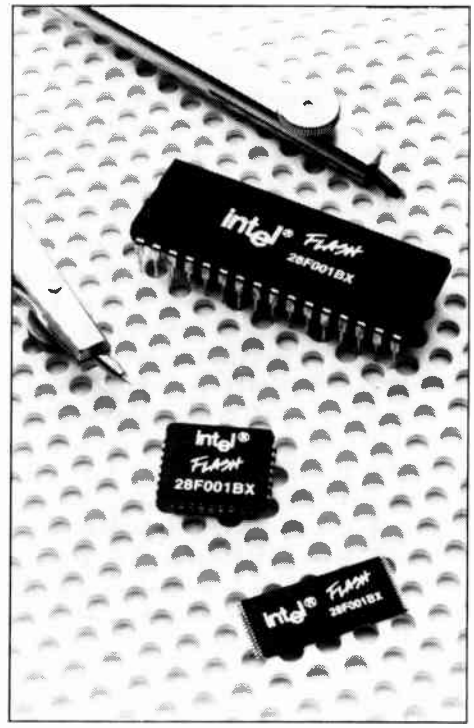


Fig. 18. Wiring and interconnecting diagram of the entire converter, and the suggested front panel (scaled down to half size).

FLASH EPROMS

by T. Scherer

For years nothing much happened in the field of nonvolatile read/write memory components until the EEPROM (Electrically Erasable and Programmable Read Only Memory), followed within a short time by the Flash EPROM, came along. The EEPROM has (not yet) lived up to its early promise, but the Flash EPROM has made a more auspicious start. Already, within two years of its commercial introduction, these devices are readily available and have been used in some commercial equipment. Chip manufacturers say (and, no doubt, hope) that the Flash EPROM has a promising future.



IF you have followed the fortunes of the world's giant semiconductor manufacturers over the past few years, you will know that, because competition in the chip markets is fierce and price wars are rife, the manufacture of memory chips is profitable only if gigantic quantities are produced. The manufacturer who is the first to develop a new technique and who will, therefore, be the first to bring a new generation of chips on the market has a decided advantage.

Currently, this intense rivalry is particularly noticeable in the market for dynamic RAMs (or DRAMs). These devices occupy the largest sector of the market. Since their structure is fairly simple, new techniques can be readily applied to them.

Processors also have a large share of the market, but they have been handled differently for a long time. Manufacturers of these devices created so-called industry standards that have given them a virtual monopoly for most of the 1980s. However, this cosy setup has recently started to show signs of movement. Intel processors are now being cloned or produced under licence (Harris, AMD, Sun). The most exciting development in the past18 months was undoubtedly the Apple-IBM cooperative setup that will ensure a much larger future market share for IBM processors.

What has all this to do with Flash EPROMs you may ask. As we have seen, all semiconductor manufacturers are under pressure. The market for DRAMs is nearing saturation, that for processors is hard to penetrate and it offers only small niches for all other types of chip. Now, as everyone knows, all computers contain at least one ROM or EPROM. However, since the market for computers expands (at present) only slowly, no fortunes can be made (any more) with these memory chips. Furthermore, the techniques for producing current ROMs or EPROMs are not really suitable for further development. However, Flash EPROMs with their different properties have given manufacturers (and users) new opportunities.

A comparison

The fact that Flash EPROMs are electrically erasable alone does not make these devices attractive. After all, EEPROMs are also electrically erasable. The important advantages of Flash EPROMs over the current erasable memory chips, summarized in Table 1, are as follows.

Table 1. Comparison of the various properties of erasable memory cells.

	EPROM	Flash EPROM	EEPROM
relative size of cell	1	1.2–1.3	about 3
programming	by external means	internal	internal
technique	hot electron injection	hot electron injection	tunnel effect
voltage	12.5 V	12 V	5 V
resolution	byte	byte	byte
time taken	<100 µs	<10 µs	5 ms
erasing	by external means	internal	internal
technique	ultraviolet light	tunnel effect	tunnel effect
voltage	12.5 V	12 V	5 V
resolution	whole chip	whole chip or block	byte
time taken	15 min	1 s	5 ms

There is first of all the relative size of the memory cel (transistor) for one bit; this is an important factor, since the density of the chip, that is, bits per unit area, determines the quantity price of the memory. If the area occupied by one cell in a standard EPROM is taken as unity, that in a Flash EPROM is 1.2–1.3, and in an EEPROM about 3. Assuming equal production quantities, that would make the Flash EPROM 20–30% dearer than the standard EPROM. The EEPROM, particularly since its production quantities are much smaller, is much more expensive than these two. At the time of writing (spring 1992), the price of a 1 Mbit Flash EPROM, in quantities of 1000, is £10–£12 each, while that of Intel's 8 Mbit Flash EPROMs (which they call FlashFile™ memories—Type 28F008SA) in quantities of 10 000 varies from £18 for the 120 ns version to £24 for the 85 ns version. Those prices are expected to come down rapidly over the next 12–18 months as more players enter the field.

Another aspect of chip density is that with current 1 µm technology only a certain number of transistors can be deposited on to a given area. At present, most DRAMs, EPROMs and Flash EPROMs are manufactured with a density of 1 Mbit per chip (although Intel introduced an 8 Mbit type in early 1992), and most static RAMs and EEPROMs with a density of 256 Kbit per chip.

Other important factors are the technology and manner of, and time taken for, programming of the memories. Between the three types, there is no difference in resolution: all three types can be programmed byte by byte, although the standard EPROM has the disadvantage that this must be done by an external apparatus. The other two types can be programmed in the equipment in which they are used, since the most important parts of the programming logic have been integrated in them. To make updating of an EPROM at a later date possible, the chip must be fitted in a socket, which increases manufacturing costs of the equipment in which it is used, ignoring for a moment the extra cost of updating to the user.

There is another aspect connected with programming: EPROMs and Flash EPROMs need an auxiliary voltage of 12 V, otherwise the hot electron injection technology does not work. An EEPROM can operate with the 5 V normally available in the computer: it raises this internally to 18 V. Since the load presented by a Flash EPROM on the 12 V supply is negligible (it draws no more than 30 mA), and most computers have a regulated +12 V line available, there is not likely to be a difficulty. If nevertheless there is no 12 V line available, a tiny voltage converter in a DIL package must be added at a cost of some £2.

It is also interesting to look at the time taken by the programming. A 1 Mbit EPROM needs not less than 15 s, whereas a Flash EPROM is programmed in about 1.5 s. An EEPROM may take minutes!

The technology and manner of erasing is also quite different. An EPROM must be removed from the apparatus in which it is used and be radiated for about 15 minutes with ultraviolet light in a special unit. Flash EPROMs and EEPROMs are electrically erasable and can, therefore, remain in the equipment in which they are used.

As far as the user is concerned, erasing an EEPROM is a normal read operation. Each byte can be erased and re-programmed separately. Since, as already mentioned, this can be a lengthy process, many (large) EEPROMs can be programmed in the so-called page mode at 16 or 32 times the normal speed.

A Flash EPROM is erased in a manner similar to that of an EEPROM, but it is not possible to do this byte by byte, that is, the entire memory or a block or blocks of bytes is erased. Erasure time for a 1 Mbit model is 1–4 s; moreover, before erasure can take place, all bits must be set to '0'.

It is clear that the Flash EPROM looks the most advantageous of the three memories. Its drawback of being erased completely, or in blocks, as compared with the byte-by-byte erasure of an EEPROM is more than made up by the speed with which it is erased (and re-programmed)—whence its name.

Construction and operation

The construction of a Flash EPROM differs not all that much from that of an EPROM. A bit is stored in the floating gate of a discrete MOS transistor—see Fig. 1. The figure also illustrates the manner in which programming and erasing take place. In the *p*-substrate are two n^+ zones that function as the drain and source of a MOSFET. Between the usual gate, that is, the select gate, and the channel there is another gate, the floating gate. The two gates are totally isolated from each other and from the substrate by a layer of silicon oxide. When the memory is erased, the floating gate is uncharged with respect to the source. When the drain is connected as normal to the Vpp line and the transistor is enabled via the select gate, the channel conducts and a logic 1 is available at the source. Programming such a cell requires a negative charge in or at the floating gate, which is not simple to arrange, since that gate is totally isolated.

That difficulty is overcome with the hot electron injection technique. Briefly, this process works as follows. If the cell is arranged as in Fig. 1a, the voltage at the drain and the gate is +12 V, and the source is at earth potential, a channel is formed through which a relatively high current flows. When that happens, a number of so-called hot electrons ensue and these capture other electrons from the substrate material; because of the high electron density, some of these electrons reach the oxide layer between substrate and floating gate. Because of the high potential of the select gate, several electrons actually pass through the substrate and reach the floating gate. The electron cluster so caused at the floating gate remains (according to the manufacturers for at least ten years) even when the +12 V programming voltage is removed. Thus, the floating gate is negative with respect to the source and the memory cell is inhibited.

In an EPROM there would be only one permissible way back: via ultraviolet light. For that reason, EPROMs have a window in the housing of the chip. Ultraviolet light has enough energy to remove the electrons from the floating gate.

A different process, based on the tunnel effect, is used in EEPROMs. Because of this effect, electrons are able to tunnel through a narrow potential barrier that would constitute a forbidden region if the electrons were treated as classical particles. However, quantum mechanics indicates that there is a definite probability of electrons tunnelling through the barrier. This technique, although slower than the injection process, has the advantage of permitting electrical erasing.

The Fowler- Nordheim variant of the tunnelling technique is used for erasing Flash EPROMs. Briefly, it operates as follows. If the memory cell is arranged as in Fig. 1b,

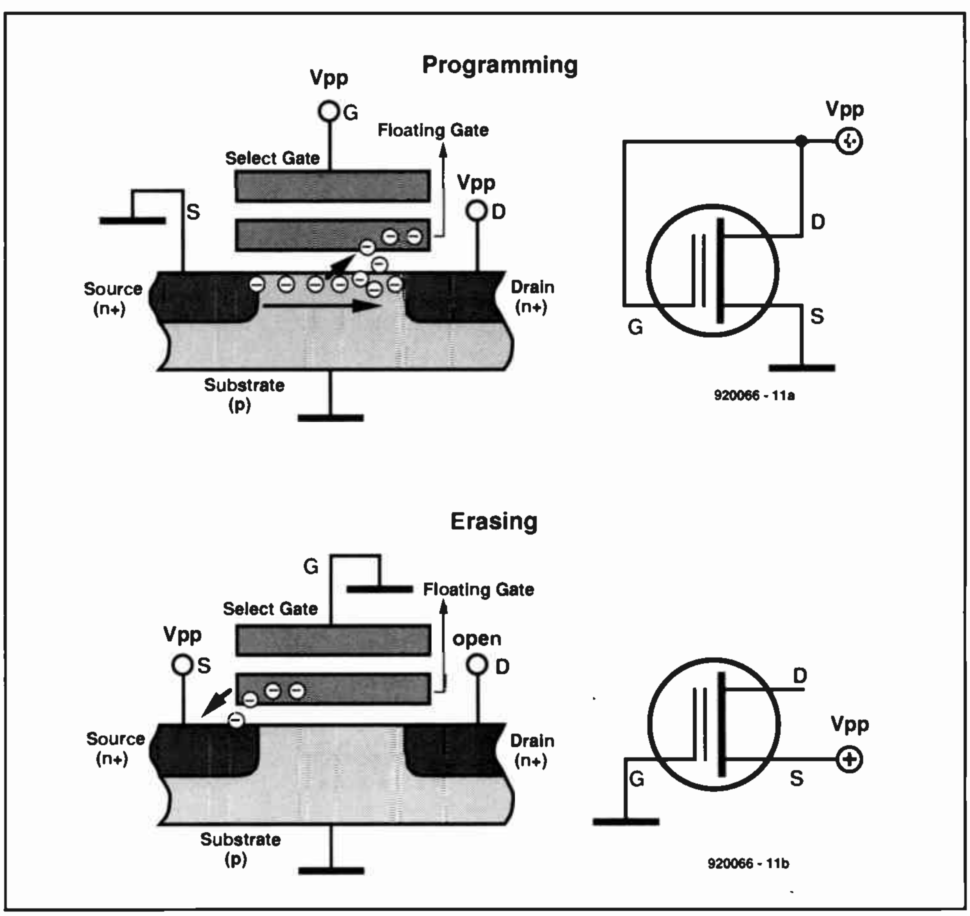


Fig. 1. Schematic representation of the construction and operation of a Flash EPROM.

the source is at +12 V, the drain is at earth potential, and the select gate is open, electrons will tunnel from the floating gate to the source. The floating gate will attain the same potential as the source so that the transistor is on, that is, erased.

The erasing process in a Flash EPROM is even slower than that in an EEPROM, because it happens at a lower internal potential. It is, however, kinder on the oxide layer and altogether more reliable. A Flash EPROM can therefore be cycled considerably more times (up to 100 000) than an EEPROM (a few thousand). The real difference between an EPROM and a Flash EPROM lies in the much thinner oxide layer between substrate and floating gate in the latter. Moreover, the architecture of the floating gate of a Flash EPROM is optimized for the tunnelling process, resulting in shorter write/erase times.

Types and properties

To prevent spurious voltage levels or voltage peaks, occurring when the apparatus in which a Flash EPROM is used is switched on or off, from modifying the stored information, the chip is provided with logic that enables the erasing or programming mode only if well-defined combinations of levels exist in a fixed sequence at the control pins of the chip. The algorithms needed for the erasing or programming are available from the manufacturers of the memory.

From a reliability consideration, it is important to know how a Flash EPROM behaves after a great many erase/write cycles. Manufacturers normally guarantee no fewer than 10 000, but Flash EPROMs usually still function properly after 100 000 cycles. It is interesting to note that with increasing cycling not one or more bytes become useless (which may, of course, happen once in a while), but that the erase/write times increase. Figure 2 shows the relevant correlations for a 2 Mbit (512 Kbyte capacity) Type 28F020 Flash EPROM from Intel.

Flash EPROMs are normally housed in 32-pin DIL cases (see Fig. 3) which makes it possible to substitute them for pin compatible EPROMs or static RAMs. There are other housings available, for instance, the 32-lead TSOP, which has the advantage of being very shallow (thickness 1.25 mm). The TSOP version is also available with a different pinout: standard E type, modified F type. As shown in Fig. 4, mixing these two types can simplify the layout of a printed circuit board greatly.

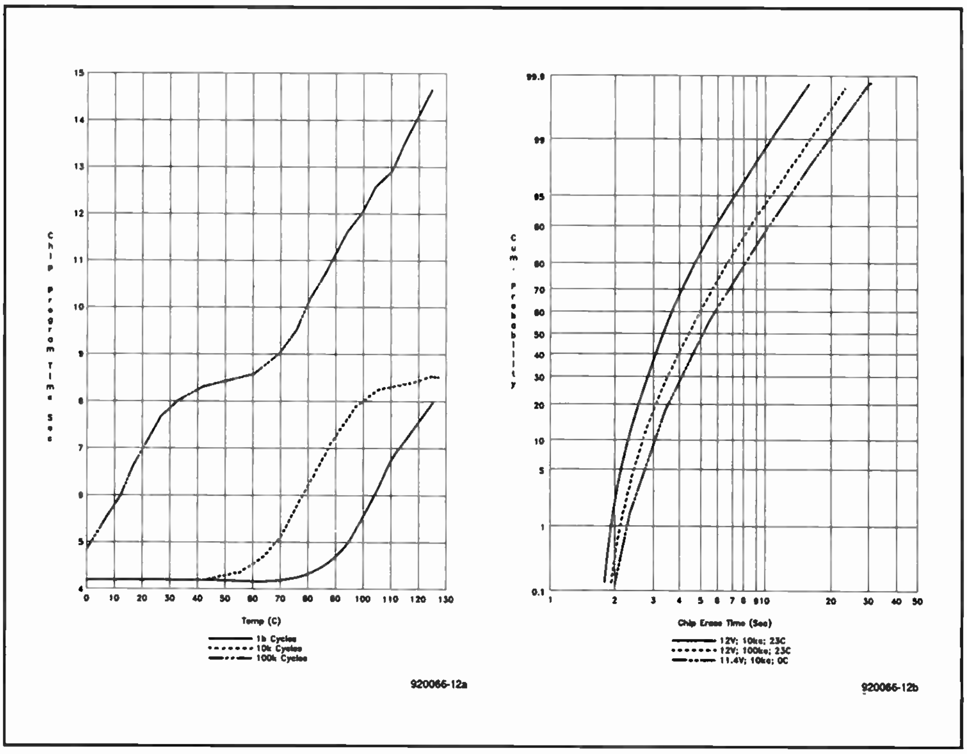


Fig. 2. Time taken by programming and erasing of Flash EPROMs as a function of the number of times the devices have been cycled.

At the time of writing (spring 1992), standard Flash EPROMs are available with capacities ranging from 256 Kbit to 8 Mbit. Like EPROMs they are organized in bytes (8-bit data). Indications are that within 18–24 months there will be 16 Mbit versions (2 Mbyte).

There are also special types available, for example, the Blocked Flash EPROM that contains a number of individually erasable blocks, such as Intel's 1 Mbit Type 28F001BX in which block 1 has a capacity of 8 Kbyte; blocks 2 and 3 one of 4 Kbyte; and block 4 one of 112 Kbyte. This type is particularly aimed at IBM compatible PCs, where block 1 would function as boot loader, blocks 2 and 3 as data store and block 4 as BIOS.

Finally, there are Flash EPROMs that function as SIMMs (Single Inline Memory Modules) or are used in memory cards with memories from 1 Mbyte up to 20 Mbyte.

Applications

When a Type 28F001BX is used in a PC, the BIOS of that computer can be updated at any time without the need for opening it. All the manufacturer has to do is to send his customers a diskette with the relevant program. Since this is a good sales point, many

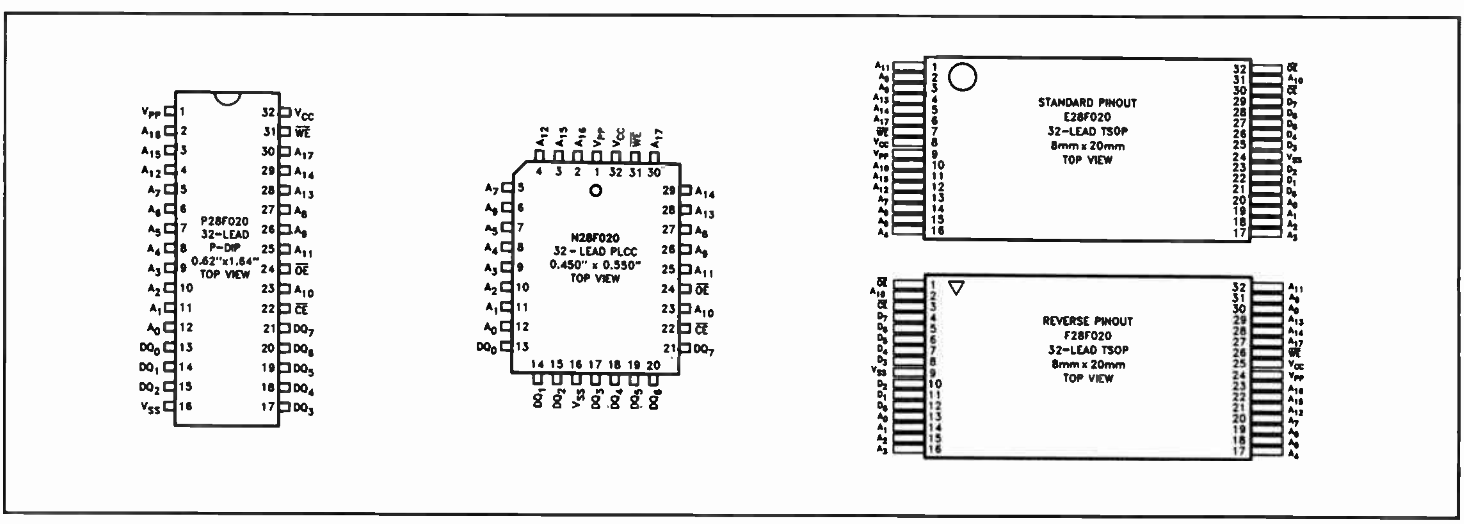


Fig. 3. Housings and pinouts of a 2 Mbit Flash EPROM (Intel's Type 28F020).

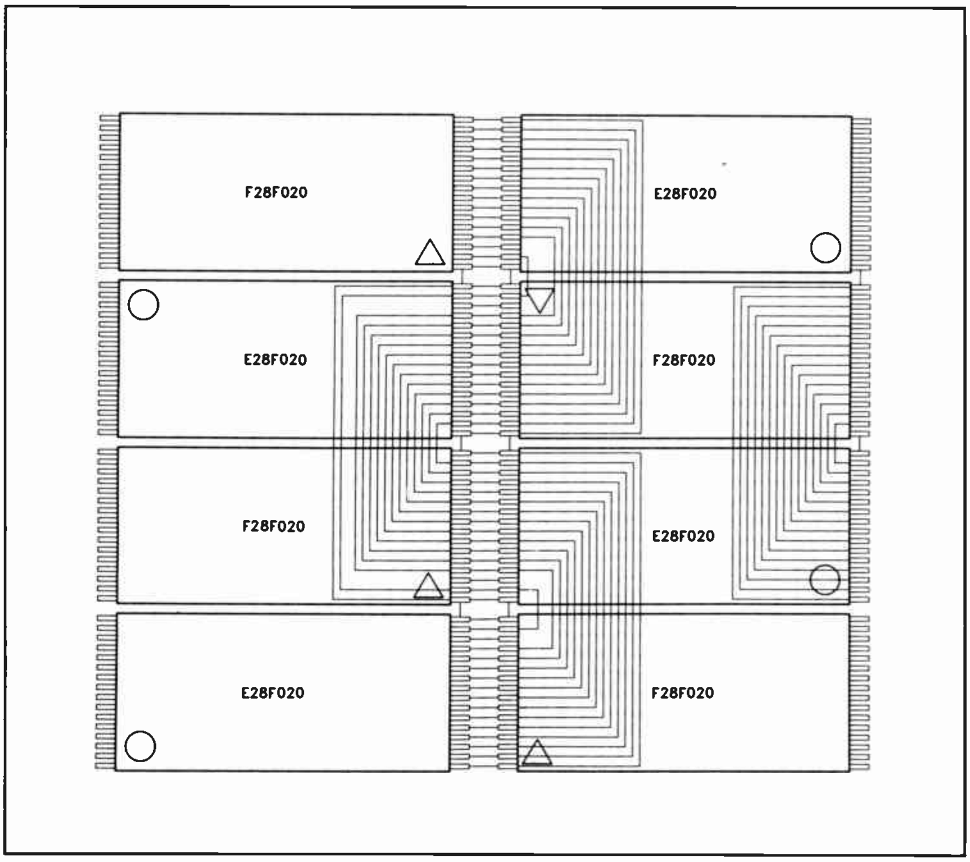


Fig. 4. The use of Flash EPROMs with mutually different pinouts simplifies the design of a printed circuit board greatly.

PCs have already been equippped with this Flash EPROM.

In Notebook computers, it is possible to incorporate the entire operating system in Flash EPROMs. The Notebook can then be updated as and when required. Manufacturers of operating systems such as Digital Research and Microsoft already offer their DOS in EPROM versions, and are now working on commercial operating systems using Flash EPROMs.

Flash EPROMs are also of great interest for industrial control equipment; they would enable such equipment to be reprogrammed without this having to be opened, which would reduce servicing costs.

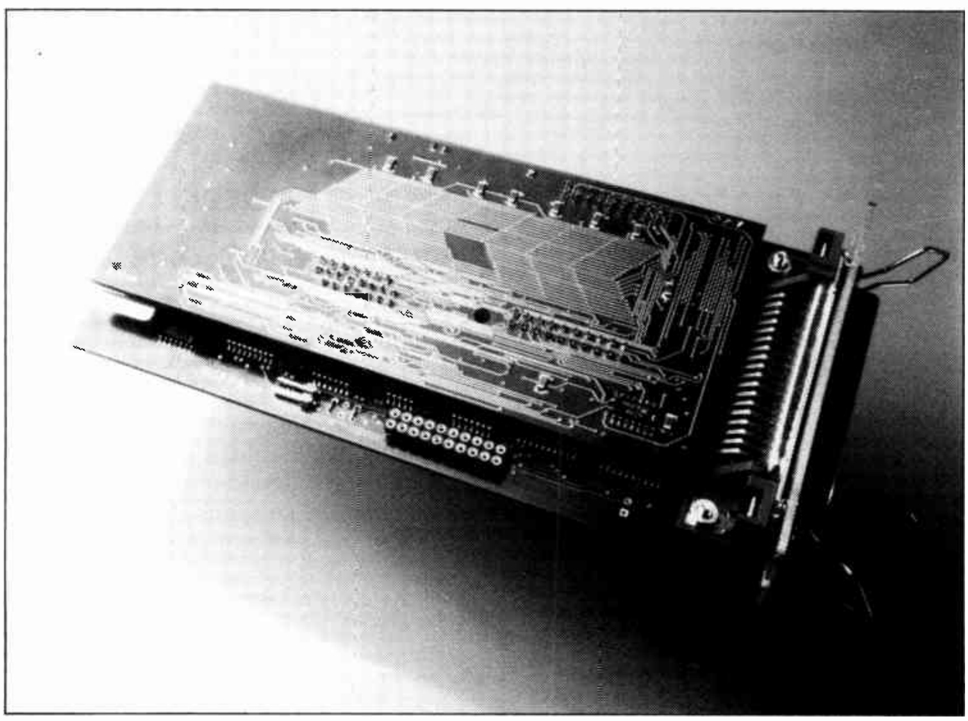


Fig. 5. The Mustang accelerator card from Pyramid Computer, intended primarily as a retrofit for HP Laserjet printers, uses Intel's Type 28F020 Flash EPROM.

Even more fascinating is the use of Flash EPROMs in apparatus whose operation depends on integrated software, such as modems and printers whose control software is normally contained in ROMs or EPROMs. With today's rapidly moving technology, such equipment is hopelessly out of date after about three years from purchase. This is particularly true of laser printers. Updated versions of page description languages, such as Adobe's PostScript or Hewlett Packard's PCL, appear at fairly short intervals. Many users would love to have a laser printer that can be updated easily. To meet that wish, the German firm Pyramid Computer has brought out an accelator card (see Fig. 5) for laser printers that contains a fast RISC (Reduced Instruction Set Coding) processor and a 2 Mbyte Flash EPROM. The latter device stores an easily updatable PostScript clone and the necessary fonts.

Manufacturers are also working on the replacement of the hard disk drive in laptop and notebook computers by a Flash EPROM, which would mean a reduction in current consumption (by a factor of 3–5) as well as in weight and size. Furthermore, the computer's reliability would increase tenfold.

The 16 Mbit chip, which is not far off, will enable the production of memory cards in the form of a 3.5 in diskette (or even smaller) with a capacity of 50 Mbyte. As yet, there are some drawbacks. First of all, the write speed of a current Flash EPROM is only about double that of an HD diskette, that is, roughtly ten times slower than a modern hard disk. Another one is the incompatibility with systems like MS-DOS™. However, Microsoft has already produced a DOS using Intel's FlashFile™ memory architecture.

Today's graphics oriented operating systems such as Microsoft Windows™, IBM's OS/2 and Apple's Finder may slowly but inexorably be replaced by solid-state architecture.

For the present, although technically Flash EPROMs can already replace diskettes, their price has to come down substantially before they can do so commercially. After all, 1 Mbyte on diskette today costs pence rather than pounds or just over a dollar. ■

References

Memory Products Data Book, AMD

Memory Products Data Book (210 830 010), Intel

Blocked Flash Memory Type 28F001BX, Data Sheet, Intel

Thin Small Outline Package Data Book (296514-001), Intel

Mustang Accelerator Card for Laser Printers, Data Sheet, Pyramid

PASCAL ROUTINES FOR MULTIFUNCTION MEASUREMENT CARD

This article presents a collection of Turbo Pascal routines that should assist constructors of the Multifunction Measurement Card for PCs in writing their own application software.

Design by J. Ruiters

PART of the success of the Multifunction Measurement Card publication (Ref. 1) must be due to the application software developed for it, for instance, that for the multi-channel voltmeter/frequency meter, and the computer-controlled weather station modules. This application software is remarkable because they allow you to set up, say, an advanced data acquisition system built around a PC, without much knowledge of IBM PC hardware and programming languages such as C and Pascal.

None the less, 'low-level' programming remains of interest to many enthusiastic users of the measurement card, witness the large number of requests we received for hints on programming, for example, the ADC (analogue-to-digital converter) contained on the card. These requests are honoured by the present article, which presents software that shows how the various I/O protocols, A-D functions and frequency measurement algorithms may be put to use. In fact, we have thrown together, in a kind of library, a large number of elementary routines for the control of the measurement card. Both 'die-hard' programmers and beginners should find this library, written in Turbo Pascal 5.5, of great use in the development of their own application programs.

A typical feature of today's electronics is that hardware and software are efficiently combined to achieve target specifications. Depending on certain requirements (cost, speed, flexibility and available firmware), a system designer must consciously decide to implement a function either in hardware or in software. Such considerations have also existed in the early design stages of the measurement card. The large computing power of the IBM PC was the factor that made us decide to choose hardware (MSI and LSI building blocks) only for those applications that are impossible, or very difficult, to realize with the aid of software. This decision does have consequences: on the one hand, it means inexpensive hardware and a high degree of flexibility; on the other, a fairly complex piece of programming. Fortunately, the last point is not a problem any more thanks to the availability of the software we present here. This software is available on a diskette with order code ESS 1751.

The unit PMEASURE.PAS, or the compiled version of it, PMEASURE.TPU, con-

```
$300        BASE_IO_ADDRESS: Possible values are $300 (JP1=A) and $310 (JP1=B).
10000000    RefFreq        : Frequency meter (crystal-) reference in Hz.
10          MaximumGateTime: Typical 410 seconds (10 Mhz referency frequency).
2.5         RefVolt        : ADC full-scale voltage
2           IRQ            : Hardware interrupt (Possible values: 2 .. 7)
```

920067-11

Fig. 1. Parameters in the configuration file ADCF.CFG may be edited with any ASCII-compatible wordprocessor.

tains, among others, functions for PPI initialization, multiplexer control, A-D conversion, digital I/O and pulse time and frequency measurement. These and all other procedures and functions that are declared in the unit may be called directly from the associated source file using the command 'uses PMEASURE'.

Before discussing the programming routines, we take the opportunity to refresh your memory: the 'specs' box of the measurement card is repeated on this page. Also, we suggest to once more go through the whole article on the measurement card.

Pascal unit

The effect of a unit function is nearly always apparent from the name: e.g., SelectFreqChannel(Channel:ZeroToSeven) connects channel number 'Channel' of multiplexer IC22 to the frequency meter. Where necessary, the declared constants, variables, procedures and functions are described by a few words of 'comment'. This comment obviates the need of a detailed description to be rendered here: for more information, refer to the source code.

The peripheral interfaces (PPIs), IC13 and IC14, are read from and written to via the procedures ReadPPI and WritePPI respectively. Although these are really very basic routines, they form the nucleus of the card control system. ReadPPI and WritePPI are, therefore, frequently called by other procedures and functions. Among the 'users' are: InvertInput, CounterValue, GetCurrentAnalogChannel, SelectRatioIO and StartEventCounter.

During the initialization phase, PMEASURE automatically loads the hardware configuration file ADCF.CFG, and the presence of the measurement card at the set base address is checked. If the card is found, the PPIs are automatically initialized at the end of the test (see the InitPPI routine in PMEASURE.PAS). This is an important event, because it takes place **before** the control program proper (i.e., your software) is started. The Boolean variable 'HardwareFound' thus allows software to decide to go on (card found) or not (card not found).

```
function ADC(var Overflow:boolean):word;
(***************************************)

{-ADC samples the analogue input and returns the previous 12 bit
  conversion result through ADC.
  The high order byte must be read first because reading the low
  order byte starts the next conversion cycle.}

var
  X:word;

begin (* ADC *)
  if not HardwareFound
    then
      begin
        ADC:=2048;
        Overflow:=false;
       end
    else
      begin
        X:=portw[BIO_Address+1];
        X:=swap(X);
        if (X=$FFF) OR (X=$000)
        then Overflow:=true
        else Overflow:=false;
        ADC:=X;
      end;
end;  (* ADC *)
```

920067-12

Fig. 2. This ADC function is one of the many routines contained in PMEASURE.PAS.

MULTIFUNCTION MEASUREMENT CARD FOR PCs

MAIN SPECIFICATIONS

DC Voltmeter
Range: 0.1 V to 300 V
Inputs: eight
A-D converter: 12 bits, 3 µs, 0 to 5 V

Frequency meter
Range: 0.0025 Hz to 10 MHz
Inputs: eight (TTL)
Max. error: 0.0001%
Accuracy: 6 digits

Pulse time meter
Range: 0 to 400 s
Resolution: 0.1 µs
Adjustable measurement level

Event counter
Range: 32 bits
Max. frequency: 10 MHz
Adjustable trigger edge

Time related measurements

PMEASURE makes the best possible use of the available hardware facilities. Hence, the pulse time and frequency measurements are fully interrupt-driven. The IRQ input used in the PC needs to be set in hardware as well as in software. On the measurement card, one of the jumpers JP2 to JP7 is fitted in the X-row. Make sure to use a free IRQ line (usually IRQ2), and check that jumper JP8 is in position E. As to the software setting, the IRQ line must be identified in line 5 of the configuration file (see Fig. 1).

Depending on the type of measurement, a measurement cycle starts with a call to StartPulseTimeConversion or StartFrequencyConversion. The associated interrupt routine, HardwareIntHandler, starts automatically the moment hardware flag EOC-F is actuated. This happens at the end of each (sub-) conversion. By virtue of the interrupt procedure, the entire measurement remains fully transparent to the main program. Yet, the measurement results are simple to call up by subsequently reading the records called PulseTime and Frequency.

A second interrupt routine plays an important role when frequency measurement is used. A routine called TimeIntHandler monitors the time taken by the second phase of the measurement (fm'), and verifies this time against the maximum conversion time calculated during the test measurement. When the time limit is exceeded, this is taken to mean that the fre-

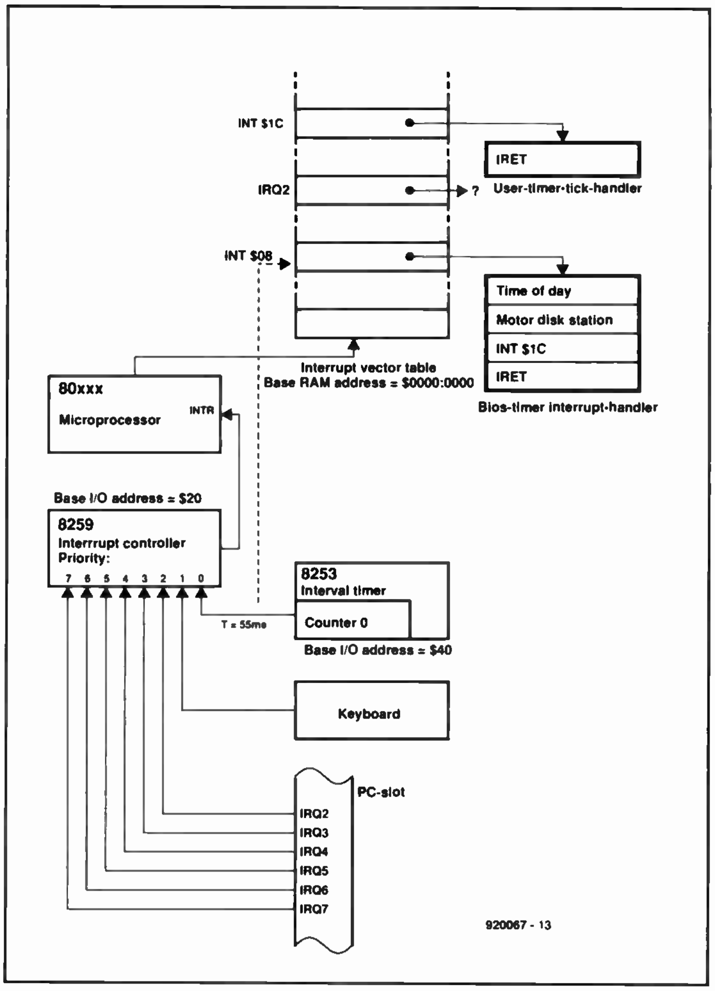


Fig. 3. Schematic representation of the standard PC interrupt network.

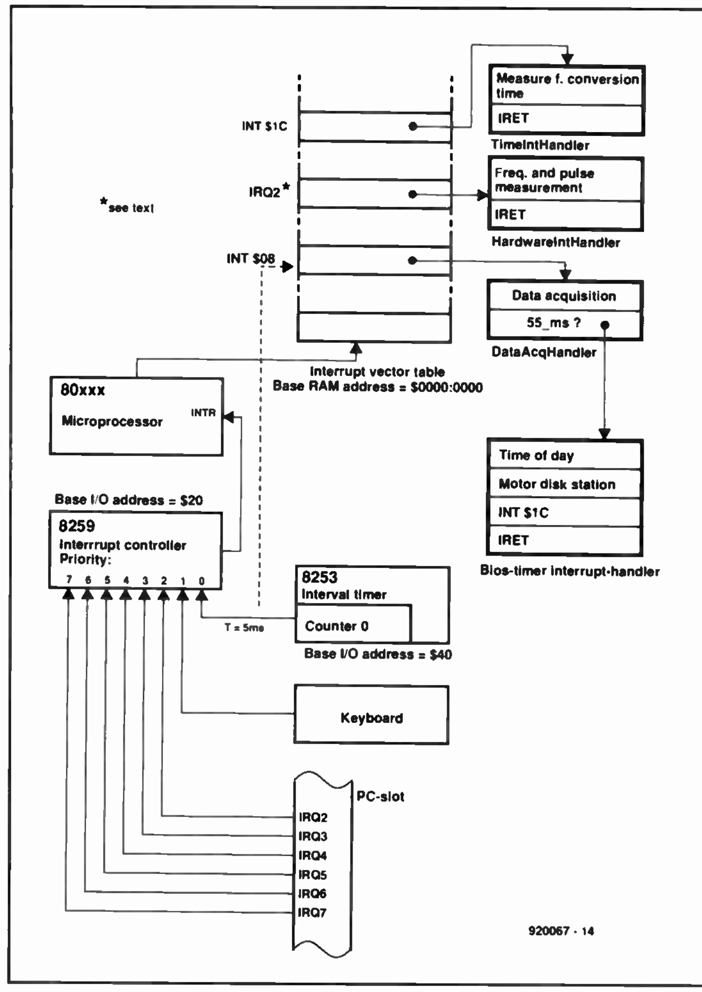


Fig. 4. As Fig. 3, but with the PMEASURE routines installed. Note the way the BIOS interrupt handler is given new parameters.

quency of the input signal has gone down so far that the test measurement and the set scale factor are no longer representative. To prevent frequency measurements taking up too much time, TimeIntHandler breaks off the current conversion, and starts a new test measurement. The procedure itself makes use of the PC-user-timer-tick-interrupt ($1C), and is therefore actuated every 55 ms.

DC measurements

The function 'ADC' (Fig. 2) allows a 12-bit binary representation of an analogue input voltage to be acquired. The important thing about ADC is that the A-to-D conversion operations are not started until at the end of the function. This means that the value of ADC is related to the previous conversion, and, inevitably, that the first conversion result is meaningless.

Functions SelectAnalogChannel and SelectRatioIO are intended for the control of the input multiplexer (IC10), and the setting of the stepped attenuator (IC12), respectively.

Since the analogue circuitry on the measurement card is designed for direct voltages, it would seem logical to base each measurement result on an average obtained from a number of samples. This so-called stochastic measurement enables noise pulses to be suppressed efficiently.

The ADC function is called from a periodic interrupt routine to make sure that the d.c. measurements can run in the background, just as the frequency and pulse time measurements. The TimeIntHandler is not suitable to control the timing: being started 'only' 18.2 times a second, it is too slow, and would cause a stochastic calculation using, say, 100 samples, to take far too long. A different data acquisition routine was, therefore, devised, to make sure that the selected input can be sampled at 200 Hz. This sounds simpler than it is, because the only periodic interrupt that is still available in the IBM PC is the user-timer-tick, which runs at a rate of 55 ms. Drastic measures are required to make sure that a much shorter interrupt period is available. This is achieved by replacing the BIOS timer interrupt handler (interrupt $08) by the data acquisition procedure 'DataAcqHandler'. After having reprogrammed the system clock prescaler, the handler is called at the desired rate, i.e., every 5 ms. The new scale factor (divisor) is supplied by ReProgTimer, while UnDoReProgTimer restores the default factor later.

To make sure that the real-time clock and the diskette station motors continue to function normally, the original BIOS timer interrupt handler (and, with it, interrupt $1C) is started with the original frequency, and from the DataAcqHandler. For clarity's sake, the usual interrupt network is drawn in Fig. 3, while Fig. 4 shows the configuration with the new interrupt routines installed.

Get cracking

Apart from the Pascal library, diskette ESS 1751 also contains an example program, PMDEMO.PAS. This program serves to demonstrate how the interrupt procedures are installed and removed, and show you how to get access to the measurement results. Incidentally, a nice feature of PMDEMO is that it makes use of the AutoScan mode. In this mode, the interrupt routines ensure that all channels defined in FChanScan and VChanScan are measured one by one.

As a matter of course, PMEASURE may be extended or adapted to meet your requirements. This will cause few problems as long as you keep to the rules of proper programming. Take care, however, with the special rules that apply to stack use and DOS interrupts, since these have many pitfalls in store for the 'unwary'. Once bitten, twice shy! ■

Reference

1. "Multifunction Measurement Card for PCs," *Elektor Electronics USA*, January and February 1991.

8051/8032 ASSEMBLER COURSE

PART 7: SERIAL INTERFACE PROGRAMMING

By Dr. M. Ohsmann

Perhaps unwittingly, you have been using the serial communication features of the 8051 or 8032, and the supporting routines contained in the system monitor, EMON51, ever since the 80C32 single-board computer (our 'course hardware') wrote its first 'welcome' message on your terminal. In this course instalment we will explore the not-so-simple operation of the serial interface with an aim to grasp the way it is programmed.

8051 serial interface

The serial interface contained in the 8051 family of microcontrollers is the most complex 'on-chip peripheral'. Hence, this instalment is probably the most difficult of all in the course, and should be studied thoroughly. This effort is also required, unfortunately, on part of those of you who intend to implement only very basic serial communication on a 8051-based controller system, and even if a range of examples of software building blocks is available in the system monitor, EMON51.

The serial interface can operate in a number of modes, some of which are of little interest here because they serve to implement 8051 network systems. We will concentrate on the simplest mode of operation: sending and receiving 8-bit data (asynchronously) with one start bit, one stop bit, and no parity. This mode allows the 80C32 SBC to communicate with a PC, as well as to exchange MIDI data (MIDI = musical instrument digital interface).

The special function register (SFR) identified as SCON (Serial CONtrol) at address 098H serves to control the on-chip serial interface, and determine its mode of operation. The function of the bits contained in the SCON register are shown in Fig. 44. The mode we require can be set by programming SM0=0 and SM1=1. As shown in Fig. 44, this is mode 1, in which bit SM2 may be used to signal transmission errors. The function of the remaining bits in SCON will be reverted to below.

(MSB) ... (LSB)

SM0	SM1	SM2	REN	TB8	RB8	TI	RI

Where SM0, SM1 specify the serial port mode, as follows:

SM0	SM1	Mode	Description	Baud Rate
0	0	0	shift register	$f_{osc.}/12$
0	1	1	8-bit UART	variable
1	0	2	9-bit UART	$f_{osc.}/64$ or $f_{osc.}/32$
1	1	3	9-bit UART	variable

- SM2 enables the multiprocessor communication feature in Modes 2 and 3. In Mode 2 or 3, if SM2 is set to 1 then RI will not be activated if the received 9th data bit (RB8) is 0. In Mode 1, if SM2 = 1 then RI will not be activated if a valid stop bit was not received. In Mode 0, SM2 should be 0.
- REN enables serial reception. Set by software to enable reception. Clear by software to disable reception.
- TB8 is the 9th data bit that will be transmitted in Modes 2 and 3. Set or clear by software as desired.
- RB8 in Modes 2 and 3, is the 9th data bit that was received. In Mode 1, if SM2 = 0, RB8 is the stop bit that was received. In Mode 0, RB8 is not used.
- TI is transmit interrupt flag. Set by hardware at the end of the 8th bit time in Mode 0, or at the beginning of the stop bit in the other modes, in any serial transmission. Must be cleared by software.
- RI is receive interrupt flag. Set by hardware at the end of the 8th bit time in Mode 0, or halfway through the stop bit time in the other modes, in any serial reception (except see SM2). Must be cleared by software.

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Fig. 44. Overview of SFR SCON bit functions.

The transmit and receive buffers

Inside the 8051, serial data is transmitted and received with the aid of a shift register. Bits are transmitted by first loading them, in parallel, into the shift register, and then shifting them out, one by one, at the programmed bit rate (baudrate). In receive mode, the bits are gathered, one by one, into the shift register, and are read out in parallel when all are in. In the 8051, the SFR called SBUF (at address 099H) is used as a receive and data buffer. It has the 'quasi-double' functions of a 'receive' buffer, and a 'data' buffer, the relevant function being selected by read or write operations on SBUF, respectively.

The transmit and receive functions are supported by their own shift registers, so that it is actually possible to transmit and receive simultaneously (full-duplex operation).

Configurations and functions

Figure 45 shows the internal structure of the serial interface contained in the 8051 family of microcontrollers. The baudrate generator is shown in the upper left-hand corner of the diagram. The overflow pulses produced by Timer 1 or Timer 2 (8052 only) may be used to clock the shift registers. The switch marked 'SMOD2' controls a divide-by-two scaler. The switches RCLK and TCLK (8032 and 8052 only!) select the receive clock and transmit clock respectively. The clock signals so obtained are divided by 16 before they are fed to the TX-CONTROL and RX-CONTROL sections.

The transmit control clocks and loads the transmit shift register, whose output is connected to the TXD terminal (pin 11) of the 8051 (upper part of the drawing). From the internal databus of the 8051, the databits are fed in parallel into the SBUF register. The 'zero-detector' finds out if all bits have been transmitted. If so, this is signalled to the transmit control section, which in return is capable of generating a serial port interrupt, TI. When this happens, the TI bit (SCON.1) is set.

The lower part of Fig. 45 shows the receive control section. Serial databits received on pin 10 (RXD) of the 8051 are gathered in the receiver shift register. The data simultaneously arrive in the 1-to-0 transition detector, which serves to recognize the start bit in the serial datastream, and to synchronize the receiver clock with the incoming bits. Data reception starts on a high-to-low level transition (falling pulse edge) at the RXD input, i.e., a start bit at pin 10 of the 8051. The incoming bits are clocked into the shift register. The last bit that is read is the stop bit (the receiver shift register has a width of 9 bits). Next, SBUF is loaded with the eight received bits, and the 'receiver full' bit is set (SCON.0=RI). This sequence does **not** take place, however, in the following two cases:

1). When RI is already set, which means that previously received data was not fetched.

2). When SM2=1, and the stop bit did not have the value '1'. Thus, by programming SM2=1, you can prevent bytes with a framing error (wrong stop bit) getting through.

The level of the RI bit thus allows us to check if a received byte is held ready in

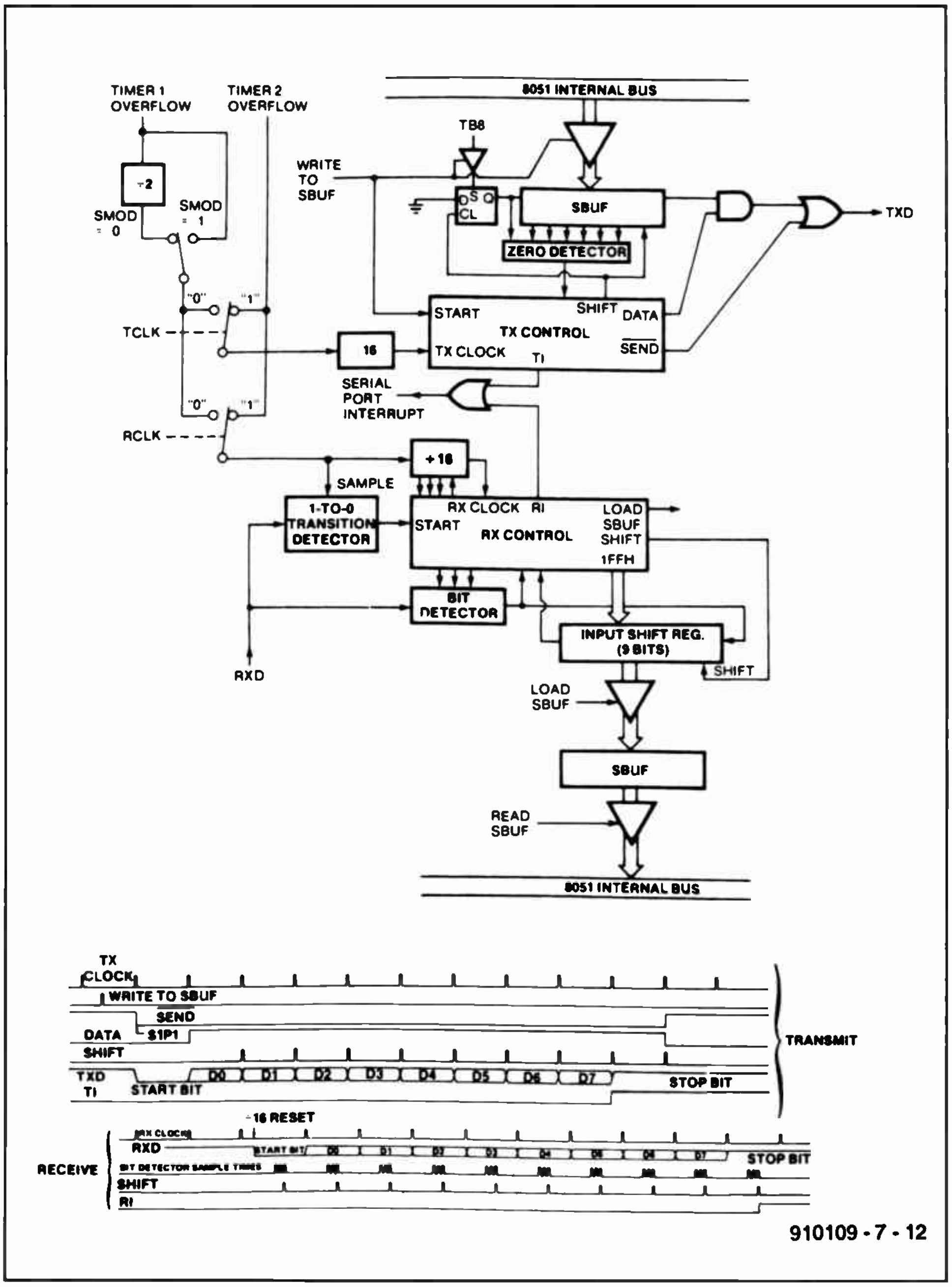

Fig. 45. 8051 serial interface architecture.

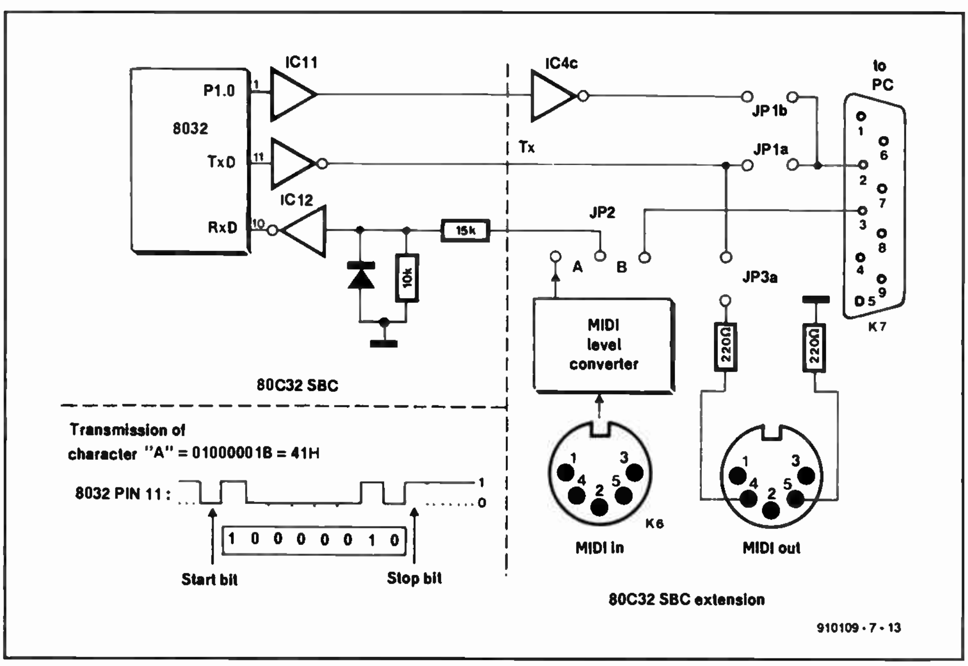

Fig. 46. V24 interface (80C32 single-board computer and extension board).

JOIN THE COURSE!

What you need to follow this course:

- a 8032/8052AH-BASIC single board computer as described in Elektor Electronics May 1991. The preferred CPU is a 8051 or 80C32. Alternatively, any other MCS52-based microcontroller system (but read part 1 of the course);
- a course diskette (IBM: order code ESS 1661; Atari: order code ESS 1681) containing programming examples, hex file conversion utilities, and an assembler;
- a monitor EPROM (order code ESS 6091);
- an IBM PC or compatible operating under MS-DOS, or an Atari ST with a monochrome display.

Appeared so far:
Part 1: Introduction (February 1992)
Part 2: First 8051 instructions (March 1992)
Part 3: Hardware extensions for 80C32 SBC (April 1992)
Part 4: Flags, bit addressing, PSW, conditional jumps, logic operators (June 1992)
Part 5: Arithmetic instructions (July 1992)
Part 6: Analogue signal processing and stack management (September 1992)

SBUF. If so, the byte can be fetched (read) for further processing.

The two interrupt events, TI (transmitter interrupt) and RI (receiver interrupt) actually generate only one interrupt, of which the cause (data transmitted, or data received) must be established by the interrupt software. The serial interface only generates interrupts when bit IE.4 in the interrupt enable register is set (see Part 6 of this course).

Details of the TXD and RXD wiring and external circuitry on the 80C32 SBC and the extension board (Part 3) are shown in Fig. 46. The diagram shows how the various jumpers enable the 8051 serial interface to be connected to a PC (via the 9-way sub-D connector) or a MIDI compatible instrument.

EMON51 communication

Studying a worked out example is probably the best way to familiarize oneself with the programming of the serial interface. Let us look at the listing in Fig. 47. This program is a series of subroutines contained in EMON51 relevant to communication via the serial interface, 'stitched together' to show how you can make use of them for your own programming work. Each of the points to be observed in programming the serial interface will be discussed below, with reference to certain parts of the listing. Note that this program is not contained on your course disk.

Baudrate generator

We wish to use mode 1 of the serial interface. In this mode, the baudrate is determined either by Timer1 or Timer2. Remember, Timer2 is not available if you use a 8031 or 8051 (i.e., TCLK=0 and RCLCK=0 in Fig. 45). In the interest of software compatibility we will, therefore, set the baudrate with the aid of Timer1. The 'counter overflow' pulses produced by this timer are fed to the transmit and receive controls. To ensure a continuous supply of pulses, the timer is operated in mode 2, i.e., as an 8-bit clock generator with automatic reload. In this way, the timer is capable of producing an overflow every *n* microseconds on the basis of the 1-MHz internal clock (quartz oscillator frequency 12 MHz), where *n* is a whole number between 2 and 256. Additionally, we can switch on the divide-by-two scaler by setting the SMOD bit (SFR PCON bit 7). The final baudrate clock is arrived at by dividing the clock signal by 16. If SMOD=1, we get:

Baudrate = (overflow rate Timer1)/16

alternatively, if SMOD=0,

Baudrate = (overflow rate Timer1)/32

In the system monitor software, EMON51, the following is done to obtain a baudrate of about 4,800. First, Timer1 is set to auto-preload mode with internal clock (here: 1 MHz). See line 22 in Fig. 47. The preload value is 243 (lines 4, 24 and 25), which causes Timer1 to divide by (256–243) = 13. SMOD is set to '1' in line 21 to disable the ÷2 scaler. Thus, the baudrate becomes

1 MHz/13/16 = 4,807.6923 bits/s

That is not exactly 4,800 baud, but sufficiently accurate for our application.

After being preloaded and set to the desired mode, Timer1 is switched on by setting TCON bit 6 (line 26). The baudrate generator is now running.

As an aside, Timer2 contained in the 8052 and 8032 may, of course, also be used as the baudrate generator. This can be achieved by setting bits TCLK and RCLK in the Timer2 control register, T2CON. Since T2CON contains the value 00H after a reset, the 8052 always starts with Timer1 as the baudrate generator (which ensures that programs written for the 8051 run on a 8052 too!).

The standardized baudrates (1200, 2400, 4800, etc.) can be achieved exactly by using a crystal clock of 11.0592 MHz rather than 12 MHz. However, a processor cycle then takes 0.9044225 μs rather than 1 μs exactly. Obviously, the deviation from 1 μs may be annoying in calculating loop times, since all the internal timing of the 8051 is derived from the quartz crystal clock oscillator. This dilemma, by the way, has resulted in the integration of on-chip baudrate generators in follow-up controllers such as the 80535 and 80537, whose serial interfaces are capable of operating at 4,800 baud and 9,600 baud exactly, while a 12 MHz quartz crystal is used. More about these interesting processors in future issues of *Elektor Electronics*.

```
***** LISTING of EASM51 (V24XAMPL) ******
INE LOC  OBJ          T          SOURCE
  1 0000                  ; taken from EMON51.A51
  2 0000                  ;------------------------------------------------------
  3 0000                  ;
  4 0000                  V24SPD  EQU 256-13       ; V24 speed: 1MHz/16/13 = 4807.69 baud
  5 0000                  ;------------------------------------------------------
  6 0000                  ;                        ; SFR definitions:
  7 0000                  PSW     EQU 0D0H
  8 0000                  ACC     EQU 0E0H
  9 0000                  ;
 10 0000                  PCON    EQU 087H
 11 0000                  TCON    EQU 088H
 12 0000                  TMOD    EQU 089H
 13 0000                  TL1     EQU 08BH
 14 0000                  TH1     EQU 08DH
 15 0000                  SCON    EQU 098H
 16 0000                  SBUF    EQU 099H
 17 0000                  ;-------------------------------------------------------------
 18 0000                  CNT1    EQU 050H        ; in RAM: counter for CR/LF time
 19 0000                  ;-------------------------------------------------------------
 20 0000                          ORG 0
 21 0000 75 87 80 [2] V24SET  MOV PCON,#80H    ; SMOD = 1
 22 0003 75 89 22 [2]         MOV TMOD,#22H    ; both counters as timer
 23 0006                                       ; RCLK=0, RCLK=0 with 8051, and in TCON also
 24 0006 75 8D F3 [2]         MOV TH1,#V24SPD ; preload value TIMER1 (baudrate generator)
 25 0009 75 8B F3 [2]         MOV TL1,#V24SPD
 26 000C D2 8E    [1]         SETB TCON.6      ; start counter 1
 27 000E 75 98 52 [2]         MOV SCON,#052H   ; MODE 1, REN=1, TI=1, RI=0
 28 0011                  ; etc.
 29 0011                  ;-------------------------------------------------------------
 30 0011 30 99 FD [2] SND    JNB   SCON.1,SND ; wait until last char. finally gone
 31 0014 C2 99    [1]        CLR   SCON.1     ; TI=0
 32 0016 F5 99    [1]        MOV   SBUF,A     ; start transmit
 33 0018 B4 0A 0D [2]        CJNE  A,#10,OK2  ; LF sent?
 34 001B 75 50 64 [2] WAITCR MOV   CNT1,#100  ; if so wait for slow scrolling terminals
 35 001E 74 FF    [1] LOP1   MOV   A,#255
 36 0020 D5 E0 FD [2] LOP2   DJNZ  ACC,LOP2
 37 0023 D5 50 F8 [2]        DJNZ  CNT1,LOP1
 38 0026 74 0A    [1]        MOV   A,#10
 39 0028 22       [2] OK2    RET              ; all ok
 40 0029                  ;-------------------------------------------------------------
 41 0029                  GETCHR EQU $            ; get character from serial port
 42 0029 30 98 FD [2] GETC1  JNB   SCON.0,GETC1; wait until  one available
 43 002C C2 98    [1]        CLR   SCON.0     ; signal: char. fetched
 44 002E E5 99    [1]        MOV   A,SBUF     ; fetch from buffer
 45 0030 22       [2]        RET              ; ready
 46 0031                  ;-------------------------------------------------------------
 47 0031 20 98 03 [2] TSTC   JB    SCON.0,isther   ; test if character there return 1 else 0
 48 0034 74 00    [1]        MOV   A,#0            ; no
 49 0036 22       [2]        RET
 50 0037 74 01    [1] isther MOV   A,#1            ; yes
 51 0039 22       [2]        RET
 52 003A                  ;-------------------------------------------------------------
 53 003A                         END
********* SYMBOLTABLE (21 symbols) **********
   V24SPD :00F3      PSW :00D0      ACC :00E0     PCON :0087
     TCON :0088     TMOD :0089      TL1 :008B      TH1 :008D
     SCON :0098     SBUF :0099     CNT1 :0050   V24SET :0000
      SND :0011   WAITCR :001B     LOP1 :001E     LOP2 :0020
      OK2 :0028   GETCHR :0029    GETC1 :0029     TSTC :0031
   isther :0037
```

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Fig. 47. Serial interface subroutines contained in EMON51.

Transmitting

Transmitting a byte is very simple: write it to the SBUF register. The write operation causes the transmitter control to start the shift-out operation. The transmit register has a ninth bit position, which is loaded with a '1' at the start of the transmit operation. Next, the start bit (0=low) is transmitted (Fig. 46).

Next, the eight databits are shifted out, starting with bit 0. The SBUF transmit register is filled with zeroes. When the ninth bit (i.e., the stop bit with value '1') has been sent, the TI bit in the SCON register is made '1' (Fig. 44) to mark the end of the transmission. This allows an interrupt to be generated (by setting the relevant bit in the interrupt enable register). It is also possible to interrogate this bit by software (polling), to check for the end of the transmission.

EMON51 contains a subroutine called SND (lines 30 to 39 in Fig. 47) that enables a character held in the accumulator to be transmitted via the serial interface.

This routine waits as long as bit 1 in the SCON register is '0'. This is necessary because a '0' means that the serial interface is still busy transmitting a character. When the TI bit changes to '1', the transmission is finished, and the serial interface is ready to start sending the current character. This is achieved by resetting the TI bit (line 31), and writing the current character to SBUF (line 32). Although TI remains '0' as long as it takes to transmit the current character, the processor already continues with the next instruction.

To make sure that it can be used with slow scrolling terminals, EMON51 is capable of providing a delay after the LF (line feed = 0AH = 1010) character. This delay allows the terminal (or terminal emulation software) to scroll the screen contents. Obviously, no character may be transmitted before the scroll operation is finished. EMON51 therefore checks if an LF was sent (line 33). If so, the loop WAITCR is called to introduce a delay of about 100×255×3 µs = 76.5 ms. This delay is sufficiently long for most terminals.

That completes the description of the SND subroutine contained in the system monitor EMON51. To enable it to function correctly, the TI bit must be set at the start of the program. After a reset, however, this bit is at '0' (refer back to Fig. 8 in Part 2). Therefore, if you want to use it as a 'transmitter empty' indicator, it must be set to '1' at the start of the program.

Interface control word SCON in EMON51

The above explains the value loaded into the SCON register in line 27. The control word, 52H (01010010B), is built as follows. To start with, bits 5, 6 and 7 (010B) select Mode 1. Next, we also wish to receive data. This requires the receiver enable bit (bit 4) to be set. Bits 2 and 3 are not of interest for the moment, and are left at '0'. Bit 1 (TI) is set to mark the SBUF register as 'empty' for the rest of the programming. This is necessary to be able to execute a subsequent transmit instruction. Since no byte has been received so far, RI (bit 0) is set to '0'.

That completes the initialization of the serial port for duplex operation at 4,800 baud, 8 databits, 1 stop bit and 1 start bit.

```
****** LISTING of EASM51 (XAMPLE13) ******
LINE LOC  OBJ        T          SOURCE
   1 0000                ; ****** FILE XAMPLE13.A51 ************************************
   2 0000                ;
   3 0000                ACC      EQU    0E0H
   4 0000                PCON     EQU    087H
   5 0000                TCON     EQU    088H
   6 0000                TMOD     EQU    089H
   7 0000                TL1      EQU    08BH
   8 0000                TH1      EQU    08DH
   9 0000                SCON     EQU    098H
  10 0000                SBUF     EQU    099H
  11 0000                ;
  12 0000                CH       EQU    090H                ; MIDI channel 0
  13 0000                ;
  14 0000                         ORG    4100H
  15 4100 75 87 80 [2]            MOV    PCON,#10000000B ; SMOD=1
  16 4103 75 89 22 [2]            MOV    TMOD,#00100010B ; both auto preset timer
  17 4106 75 8D FE [2]            MOV    TH1,#256-2      ; preset value for TIMER0
  18 4109 75 8B FE [2]            MOV    TL1,#256-2
  19 410C D2 8E    [1]            SETB   TCON.6          ; start TIMER0
  20 410E 75 98 52 [2]            MOV    SCON,#01010010B ; MODE 1 , enable receiver
  21 4111 90 C0 00 [2] START1     MOV    DPTR,#0C000H
  22 4114 E0       [2]            MOVX   A,@DPTR         ; read key
  23 4115 20 E7 F9 [2]            JB     ACC.7,START1    ; start when key pressed
  24 4118 90 41 4F [2]            MOV    DPTR,#NOTES     ; pointer to NOTES
  25 411B 74 90    [1] NOTELP     MOV    A,#CH
  26 411D 31 3F    [2]            ACALL  SNDMIDI         ; send to MIDI ( MIDI channel )
  27 411F 31 2F    [2]            ACALL  GETNXT
  28 4121 31 3F    [2]            ACALL  SNDMIDI         ; ( MIDI NOTE )
  29 4123 31 2F    [2]            ACALL  GETNXT
  30 4125 31 3F    [2]            ACALL  SNDMIDI         ; ( MIDI VOLUME )
  31 4127 31 2F    [2]            ACALL  GETNXT          ; duration
  32 4129 60 E6    [2]            JZ     START1          ; =0 means end
  33 412B 31 33    [2]            ACALL  WAIT            ; otherwise wait this time
  34 412D 80 EC    [2]            SJMP   NOTELP          ; and on at next note
  35 412F                ;
  36 412F E4       [1] GETNXT     CLR    A               ; offset 0
  37 4130 93       [2]            MOVC   A,@A+DPTR       ; fetch byte
  38 4131 A3       [2]            INC    DPTR            ; increment datapointer
  39 4132 22       [2]            RET                    ; done
  40 4133                ;
  41 4133 7F 64    [1] WAIT       MOV    R7,#100         ; wait approx. ACC*100*200*2 microsec
  42 4135 7E C8    [1] WAIT1      MOV    R6,#200
  43 4137 DE FE    [2] WAIT2      DJNZ   R6,WAIT2
  44 4139 DF FA    [2]            DJNZ   R7,WAIT1
  45 413B D5 E0 F5 [2]            DJNZ   ACC,WAIT
  46 413E 22       [2]            RET
  47 413F                ;
  48 413F 30 99 FD [2] SNDMIDI    JNB    SCON.1,SNDMIDI  ; wait until transmitter empty
  49 4142 C2 99    [1]            CLR    SCON.1          ; clear bit
  50 4144 F5 99    [1]            MOV    SBUF,A          ; send
  51 4146 22       [2]            RET
  52 4147                ;
  53 4147 30 98 FD [2] GETMIDI    JNB    SCON.0,GETMIDI  ; wait until receiver full
  54 414A C2 98    [1]            CLR    SCON.0          ; clear bit
  55 414C E5 99    [1]            MOV    A,SBUF          ; fetch byte
  56 414E 22       [2]            RET
  57 414F                ;
  58 414F 30 64 06     NOTES      DB     48,100,6       ; Note 48 w. 100 on, wait 6 periods
  59 4152 30 00 01                DB     48,0  ,1       ; Note 48 off again, wait 1 period
  60 4155 34 64 06                DB     52,100,6       ; Note 52 on w. 100
  61 4158 34 00 01                DB     52,0  ,1       ; and off again
  62 415B 37 64 0A                DB     55,100,10      ; etc.
  63 415E 37 00 00                DB     55,0  ,0       ; length 0 means end
  64 4161                         END
********** SYMBOLTABLE (18 symbols) **********
      ACC  :00E0      PCON  :0087      TCON  :0088      TMOD  :0089
      TL1  :008B       TH1  :008D      SCON  :0098      SBUF  :0099
       CH  :0090    START1  :4111    NOTELP  :411B    GETNXT  :412F
     WAIT  :4133     WAIT1  :4135     WAIT2  :4137   SNDMIDI  :413F
  GETMIDI  :4147     NOTES  :414F
```

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Fig. 48. Assembly language listing of the MIDI sequencer program.

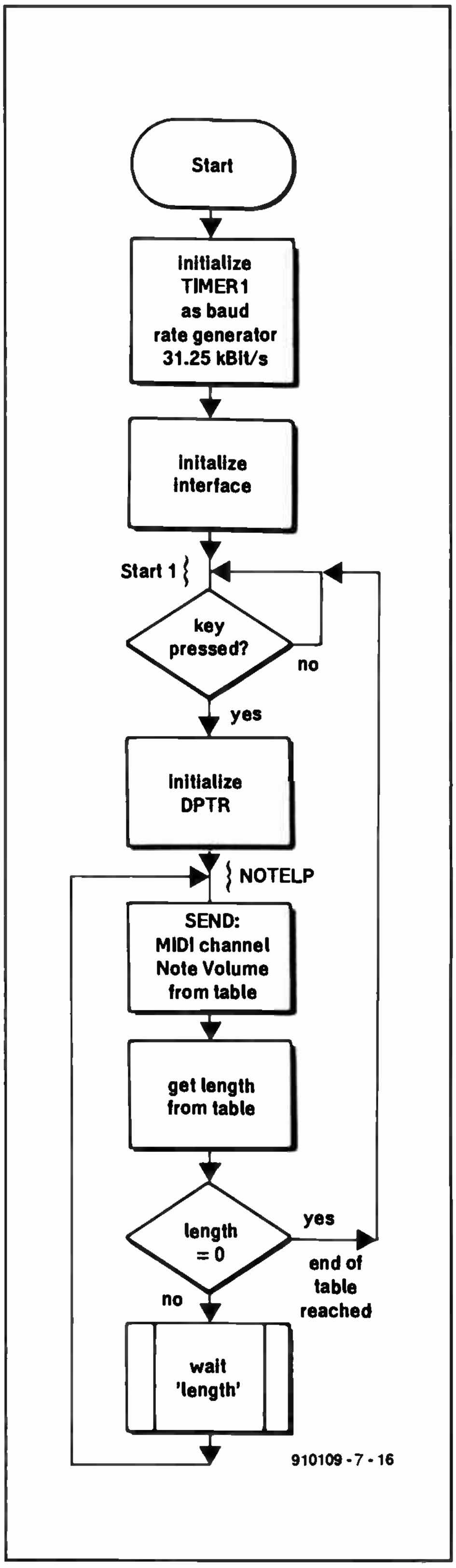


Fig. 49. Main MIDI transmit routine flowchart.

Receiving

Data reception is arranged by a subroutine called GETCHR (get character) contained in EMON51. Initially, this subroutine (line 42) waits until bit 0 in the SCON register is set. This position has the RI bit, and changes to '1' when a complete character has been received. Next, the program resets RI (in line 43). The received character is fetched from SBUF and copied into the accumulator. That is all there is to it.

In some cases, it is necessary to check if a character is ready to be fetched. For this purpose we have a subroutine called TSTC (lines 47 to 51), which returns a '1' to the accumulator when a character is ready. If not, it returns a '0'. The operation of TSTC will be clear at this point: it simply tests the RI bit.

MIDI transmit sequencer

To close off this instalment, let us look at how the serial interface can be used to send data to a MIDI compatible instrument. The aim is to develop a program that sends a series of note commands to the instrument when key S2 on the extension board is pressed. This allows a simple melody to be played, or a rhythm box to be realized.

To be able to program different melodies in a simple manner, the data to be transmitted should be contained in a table. In that way, the program could form the basis for a small sequencer.

A MIDI 'note' command consists of three bytes. The first byte tells the instrument that a note command follows, and indicates on which channel the note is to be played. Here, we wish to use channel 1 (internal number 0), for which the byte must have the value 090H. The next byte indicates the note proper, while the third byte indicates the volume at which it is to be played (note that this requires a note to be switched on and off!). Thus, every note requires the interface to send three bytes, of which first is always the same, hence, need not be stored in the table. Yet, we store a third byte to form a MIDI command. This byte determines the time that elapses before the next MIDI command is sent. The table therefore has three bytes (entries) for every MIDI command:

[Note, volume, duration]

The end of the table is marked by 'duration = 0'.

In the listing of the MIDI driver (Fig. 48), the table starts at the label NOTES. The individual table entries are addressed in the usual way with the aid of the DPTR. The operation of the main program is simple to analyse by studying the flowchart in Fig. 49.

Since the MIDI operates at a speed of 31.25 kBit/s, the baudrate clock is readily obtained by dividing the 8051 internal clock (1 MHz) by 32. Since the serial interface clock is always divided by 16 (internally in the 8051), Timer1 must be programmed to divide by 2, while SMOD must be set to '1'. This is done in lines 15 to 19 of our example program. Next, the control word copied into SCON (line 20) sets mode 1, receiver switched on, TI=1, i.e., transmitter empty. Apart from the baudrate setting, the mode selection procedure is identical to that used in EMON51.

SNDMIDI is the MIDI transmit routine proper. It transmits the character contained in the accumulator. First, it tests TI (SCON bit 1) to check if the previous character is still being transmitted. If so, it waits. If not, the 'transmitter empty' bit, SCON.1, is cleared, and the transmission of the current character (table entry) is triggered by a write operation to SBUF. Again, the transmit routine proper is largely identical to that in EMON51.

Next time

Next month's final instalment of this course will discuss the connection of a liquid crystal display (LCD) and a keyboard to the SBC extension board. ❑

NEW BOOKS

KU-BAND SATELLITE TV— THEORY, INSTALLATION AND REPAIR 4th Ed.
By Frank Baylin and Brent Gale
ISBN 0-917893-10-7
Price $30

This book covers 11GHz (Ku-band) satellite TV reception in virtually every detail. Remarkably, the authors are American, while the use of the Ku-band for satellite TV is not nearly as widespread in the USA as it is in Europe. Nonetheless, the coverage of the subject is outstanding, and the authors have succeeded in producing a manual with material that is understandable to anyone having a curiosity but not necessarily a technical background. Indeed, this reviewer agrees with them that there is no reason why laymen should not be able to participate in this exciting field in one way or another.

The particularly strong sections of the book are "component operation," "installation," and "troubleshooting and repair." Also, the collection of footprints of European, American, Australian and Japanese TV satellites in Appendix C is invaluable for a quick estimate of what can be received given your dish size and location. Solid material—well worth buying.

Baylin Publications
1905 Mariposa
Boulder, CO 80302

WORLD SATELLITE TV AND SCRAMBLING METHODS 2nd Ed.
By Frank Baylin, Richard Maddox and John McCormac
ISBN 0-917893-11-5
Price $40

This second edition of the "Technician's Handbook" is again aimed at everyone with an interest in satellite TV reception, and, in particular, decoder operation. Although the larger part of the book deals with principles of encoding and decoding satellite TV signals, a number of quite sizeable other chapters discuss the hardware layout of a TVRO station, from the dish antenna to the video connectors.

Interestingly, both North American and European technology is discussed in great detail. The European contributions are by John McCormac, who is known as a columnist in *Satellite Trader*.

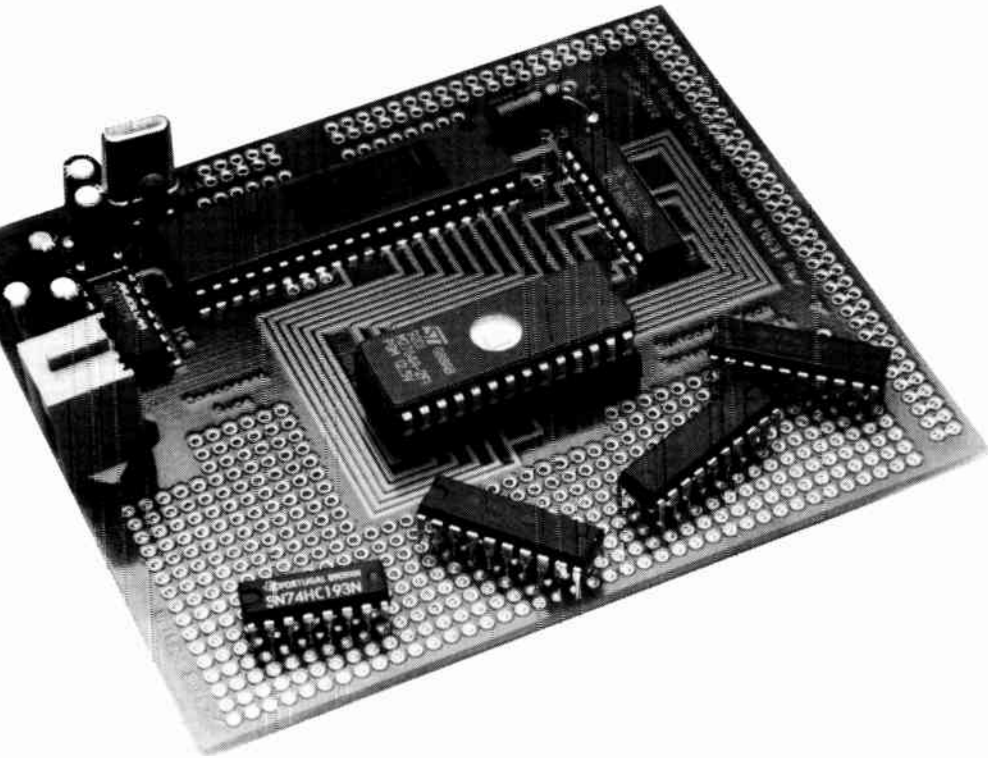
When comparing the second edition of the book with the first, it is salient to notice that the added sections (in which we find subjects like the SCART connector, SMARTcards, repair and service, and loopthrough decoder connections) are, firstly, nearly all European-oriented and, secondly, partly rewritten material already published in McCormac's book *European Scrambling Systems*, also known as "The Black Book."

The book has a wealth of illustrations, practical circuits, tables and overviews. It is also remarkable for its easy-going style. Unfortunately, some subjects are only covered superficially, although, admittedly, this can hardly be a serious criticism given the huge amount of information presented, and the large number of references to more detailed information.

Baylin Publications
1905 Mariposa
Boulder, CO 80302

8051 SINGLE BOARD COMPUTER

This article describes an inexpensive single board computer based on the popular 8051 microcontroller, plus a bit of assembly code to get things going.



By Steve Sokolowski

NORMALLY, a number of ICs having features in common can be classified as a 'family'. Devices such as the 87C541 and the 80C525 can be considered as part of the 8051 family of microcontrollers from Intel. Although internal ROM/RAM and the added presence of EPROM are different between individual chips, they have a number of common features. Figure 1 illustrates the main blocks of the 8051 computer family. Our development board is based on the easily obtainable HMOS 8051, of which the basic architecture, port functions, programming, and many other features are discussed in great detail in our *8051/8032 Assembler Course*, of which part 7 appears elsewhere in this issue.

Circuit description

The circuit diagram of the 8051 SBC, Fig. 2, shows that very few components are required to build a versatile development system around the Intel controller. In fact, the circuit is probably the absolute minimum that you will need to start programming the device.

The 8051 clock oscillator is run at 11.0592 MHz to enable the serial interface of the controller to transmit and receive at any of the standard baud rates between 300 and 9600 bits s^{-1}.

The address latch enable (ALE) signal is used to separate the data bus signals from the multiplexed data/address bus signals on the AD0-AD7 pins of the 8051. The latch used is a Type 74LS373 octal D-type flip flop with 3-state output buffers. When the output enable (OE) pin is low, the latched data appears at the outputs. When OE is high, the outputs are in the high-impedance 'off' state. The enabling pulses are supplied by the 8051's ALE output. These pulses effectively enable the 74LS373 to strip the low-order address bus from the eight AD lines by turning on the latches' eight 3-state buffer outputs at the correct instant, thus allowing only the addressing information to be fed to the memory.

The external access enable (EA) input of the 8051 (pin 31) is made permanently low here to enable the controller to fetch program code from the external program memory locations in the address range between 0000H and 0FFFH. Here, the program code is stored in an EPROM, IC3.

The serial interface is formed by the well-known MAX232 RS232 level converter, which is connected directly to the serial input and output pins of the 8051. The MAX232 has on-board positive and negative step-up voltage converters that obviate a symmetrical supply. The IC gen-

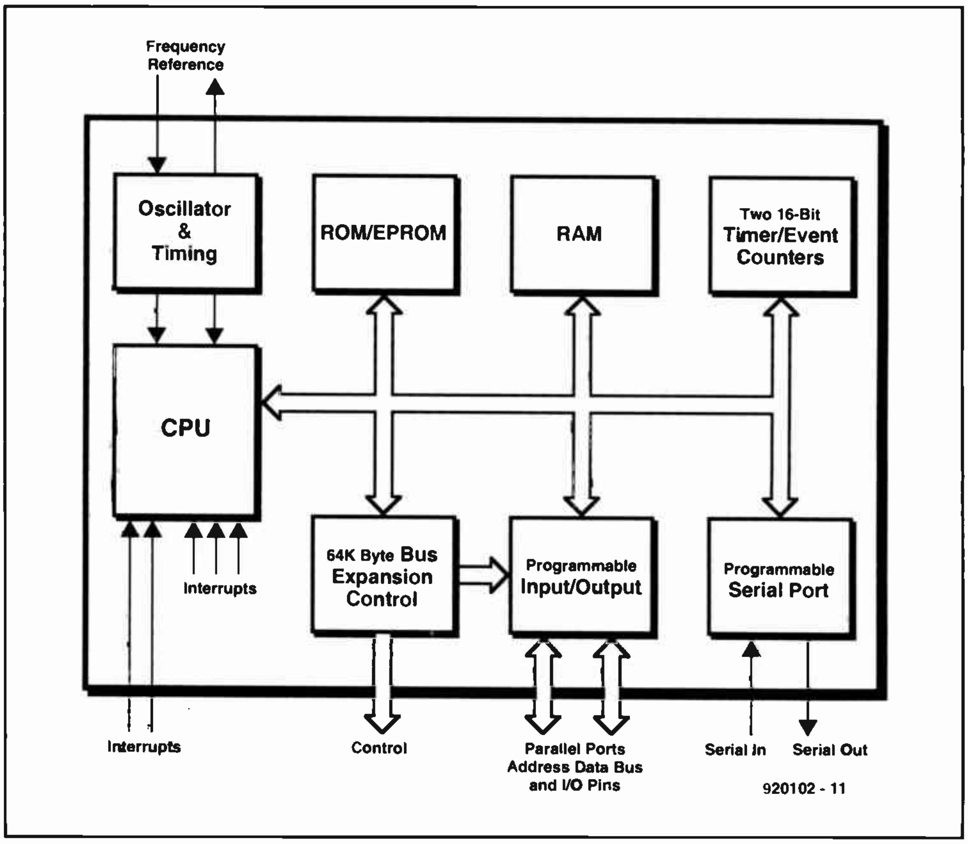


Fig. 1. 8051 family microcontroller architecture.

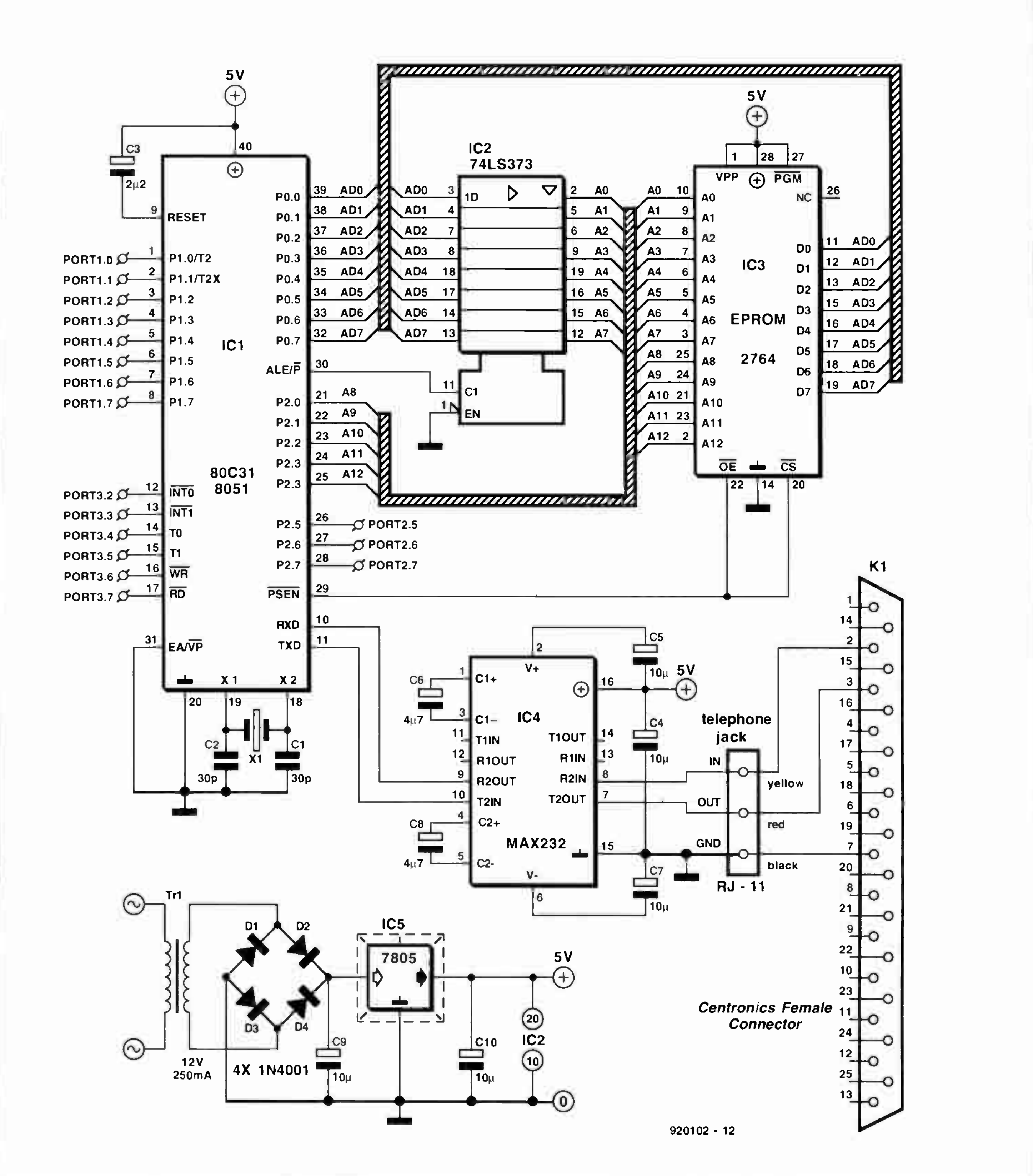


Fig. 2. Circuit diagram of the 8051 single-board computer, its power supply, and the serial interface connection to the PC.

erates internal supply voltages that result in a swing of 20 V (±10 V) on the RS232 output line.

A short length of inexpensive telephone cord is used to connect the 8051 board to the RS232 port on the PC. At the board side of the cable is a 4-way miniature latching telephone cord plug, while a standard D25 sub-D connector (female) is used at the computer side (for pinning details refer to the circuit diagram).

The power supply of the SBC is a classic one designed around the 7805. The mains transformer could be a small mains adaptor with a.c. output. Such and adaptor will in many cases be cheaper (and in all cases, safer to use!) than a discrete transformer. The current demand on the adaptor will be between 250 mA and 500 mA, depending on the circuit fitted in the extension area on the SBC board. In any case, the 7805 will run fairly hot, so it must be fitted with a heat-sink.

Building the SBC

If you are interested in building the present 8051 development system, you have two options: (1) produce the PCB yourself (using the artwork given in Fig. 3) and purchasing the components from your local stockist, or (2) purchase a complete kit from Suncoast Technologies.

The following few paragraphs are intended for those of you who wish to assemble the 8051 SBC on a home brewed printed circuit board, which will probably not be plated through, contrary to the one supplied by Suncoast Technologies. Since a fair number of PCB through connections is required, it is best to use Molex clip-type connectors for the IC sockets. These clips can be placed in the holes provided for the IC pins, and soldered at both sides of the board before they are removed from their metal carrier. The resulting pin strips then form an IC socket. To reduce cost, you may want to use Molex connector strips for the EPROM socket only, and solder the 8051, the 74LS373 and the MAX232 direct on to the board, making sure that all pins are soldered at both sides of the board.

Capacitors C4 and C8 are electrolytic types and require proper placement on the board. Mis-insertion of these polarity sensitive components can spell disaster for the part, so take care while fitting them.

The RJ-11 telephone jack was designed in such a way that it can be inserted on the board in only one way. Carefully line up the four 'pig-tail' terminals with their corresponding holes. When lined up, carefully press the jack on to the board until its mounting clips protrude on the opposite side of the board. Solder the four contacts at the solder side of the board. Finally, fit the crystal and the two ceramic capacitors.

Note that the SBC has a large prototyping area. To help eleminate the need for extra wiring of the voltage buses, the board also contains a common ground and positive supply bus etched in. It is this area where the required interfacing components for future projects can be mounted. The power supply may also be hand wired in this section.

Inspect the completed board for solder

COMPONENTS LIST

Capacitors:

2	33pF 16V disc ceramic	C1;C2
1	2µF2 16V radial	C3
3	10µF 16V radial	C4;C5;C7
2	4µF7 16V radial	C6;C8
1	470µF 35V radial	C9
1	100µF 16V radial	C10

Semiconductors:

4	1N4001	D1-D4
1	8051 or 8031	IC1
1	74LS373	IC2
1	2764 EPROM	IC3
1	MAX232	IC4
1	7805	IC5

Miscellaneous:

1	12V a.c. mains adaptor	Tr1
1	11.0592MHz quartz crystal	XTAL
1	25-pin female sub-D connector with hood	P1
1	4-conductor telephone line cord with clip (approx. 6 ft.)	
1	RJ-11 PCB mount telephone jack	
1	TO-220 heat-sink	
28	Molex connector pin or	
1	28-pin IC socket (see text)	
1	Printed circuit board (Suncoast Technologies)	

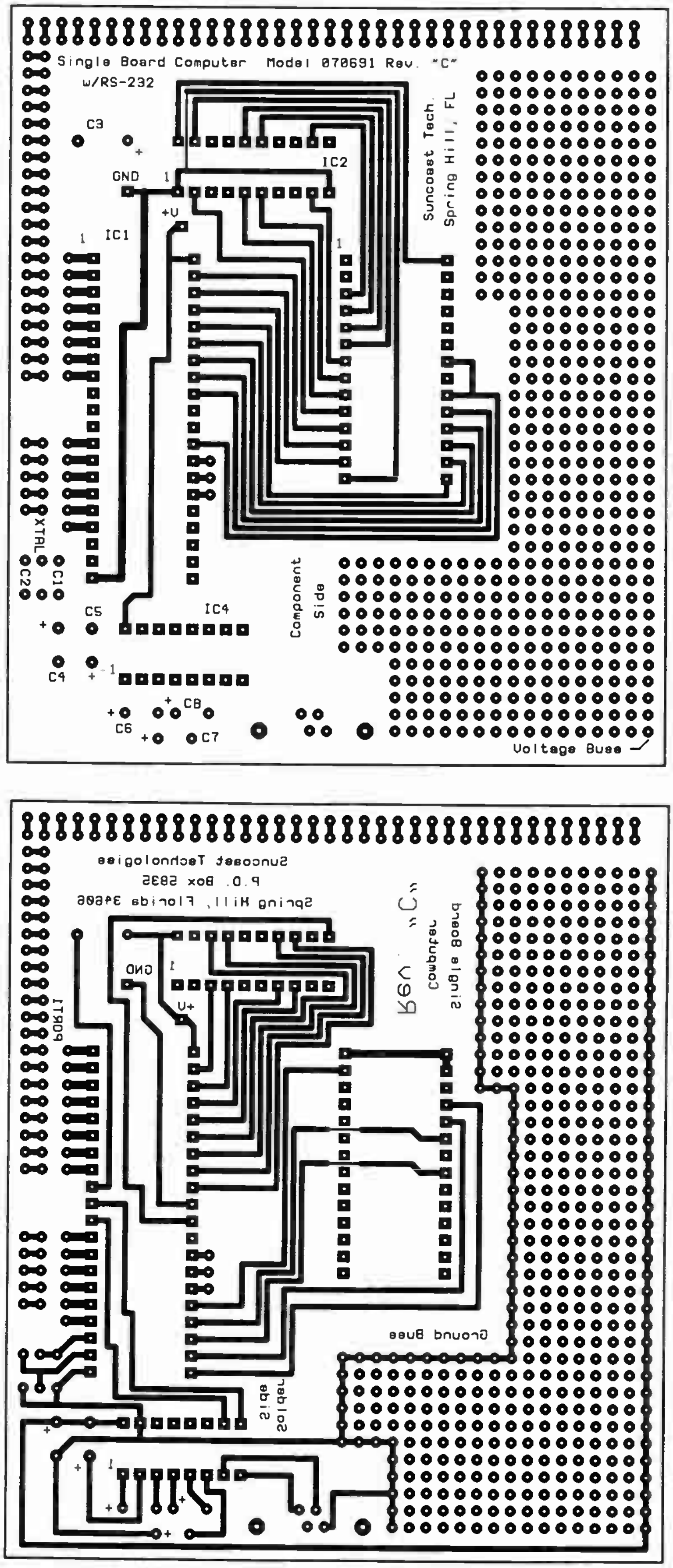


Fig. 3a. **Component side and solder side track layout of the PCB.**

splashes, dry joints and solder bridges. When all is to your satisfaction, the 5-volt power supply can be connected to the board.

Testing the SBC

Shown in Fig. 4 is a test program in assembly language. When programmed into a 2764 EPROM, TEST.ASM will determine if all address and data lines are wired correctly. It also checks the serial cable to the PC, and the wiring of the MAX232.

TEST.ASM uses the serial output feature (CHR_OUT) of the 8051 to print any character on the computer screen. It also allows keyboard input (CHR_IN) to be echoed to the screen. Both CHR_IN and CHR_OUT check out the operation of the MAX232 chip. If either feature does not work, double check the wiring of IC4 and that of the interface cable assembly (which also includes the RJ-11 telephone jack).

TEST.ASM was written to be assembled into machine code with the A51 assembler (version 1.4 or earlier), an inexpensive program that can be purchased from just about any shareware distributor. Once assembled, TEST.ASM is converted into a series of hexadecimal numbers (TEST.HEX). Although converted, TEST.HEX can not be loaded into an EPROM just like that. Further conversion is necessary, and for this HEXBIN.COM is proposed. HEXBIN.COM takes the hexadecimal format of TEST.HEX, and transforms it into a binary file (TEST.BIN), which is programmed into the 2764 EPROM.

```
;   8051 SBC Test Program
; by: Suncoast Technologies
;   Spring Hill, Florida
;
; Program set to 1200 Bauds
;
        .EQU     ESC,H'1B
        .ORG     H'0000
INIT:    MOV     A,#H'40
         MOV     SP,A
         CLR     A
         MOV     PSW,A
;
;  INITIALIZE SERIAL PORT
;
         MOV     SCON,#H'52
         MOV     TMOD,#H'20
         MOV     TH1,#H'E8
         SETB    TR1
;
;     PRINT GREETINGS
;
MENU:    LCALL   XSTRING
        .DB     "\n\r"
        .DB     "8051 Single Board "
        .DB     "Computer Test Program"
        .DB     "\r\n\n"
        .DB     ESC
LOOP_1:  LCALL   XSTRING
        .DB     "Hit a key - I will echo "
        .DB     "the character \n\n\r"
        .DB     ESC
LOOP_2:  LCALL   CHR_IN
         CJNE    A,#D'13,LOOP_2
        .DB     ESC

           LCALL    XSTRING
          .DB      "\n\r"
          .DB      ESC
           LJMP     LOOP_2
;
;     'PRINT'  PROGRAM
;
XSTRING:   POP      DPH
           POP      DPL
SRT_1:     CLR      A
           MOVC     A,@A+DPTR
STR_2:     JNB      TI,*
           CLR      TI
           MOV      SBUF,A
           INC      DPTR
           CLR      A
           MOVC     A,@A+DPTR
           CJNE     A,#ESC,STR_2
           MOV      A,#1
           JMP      @A+DPTR
;
;         SERIAL  I/O
;
CHR_IN:    JNB      RI,*
           CLR      RI
           MOV      A,SBUF
           ANL      A,#H'7F
           ACALL    CHR_OUT
           RET
;
CHR_OUT:   JNB      TI,*
           CLR      TI
           MOV      SBUF,A
           RET
          .END
```

920102-13

Fig. 4. An assembly language program to test your new 8051 single board computer.

Once programmed, carefully insert the EPROM into its IC3 location on the board. With your PC running your favourite communication program (QMODEM, PC TALK, Procomm, etc.) at 1200 baud, take the mains adaptor and plug it in. Within an instant the SBC will display the following:

8051 Single Board Computer Test Program
Hit a key — I will echo the character

Now, just for fun, type "Hello there" on the PC keyboard, then press the ENTER or RETURN key. The keyboard input will be echoed and printed on the next line. When the 25th line is reached, all text is scrolled up by one line.

If you wish to start programming to 8051 single board computer, I suggest you obtain the collection of 'start up' programs contained on a floppy disk supplied by Suncoast Technologies. This 5¼-inch MSDOS floppy disk (3½-inch not available) contains the following conversion tools that can be run on any IBM PC or compatible running under DOS 2.11 or higher:

- simple communication program
- program editor
- A51 program assembler
- D51 program disassembler
- hex-to-binary conversion program
- 8051 test program in .ASM and .BIN

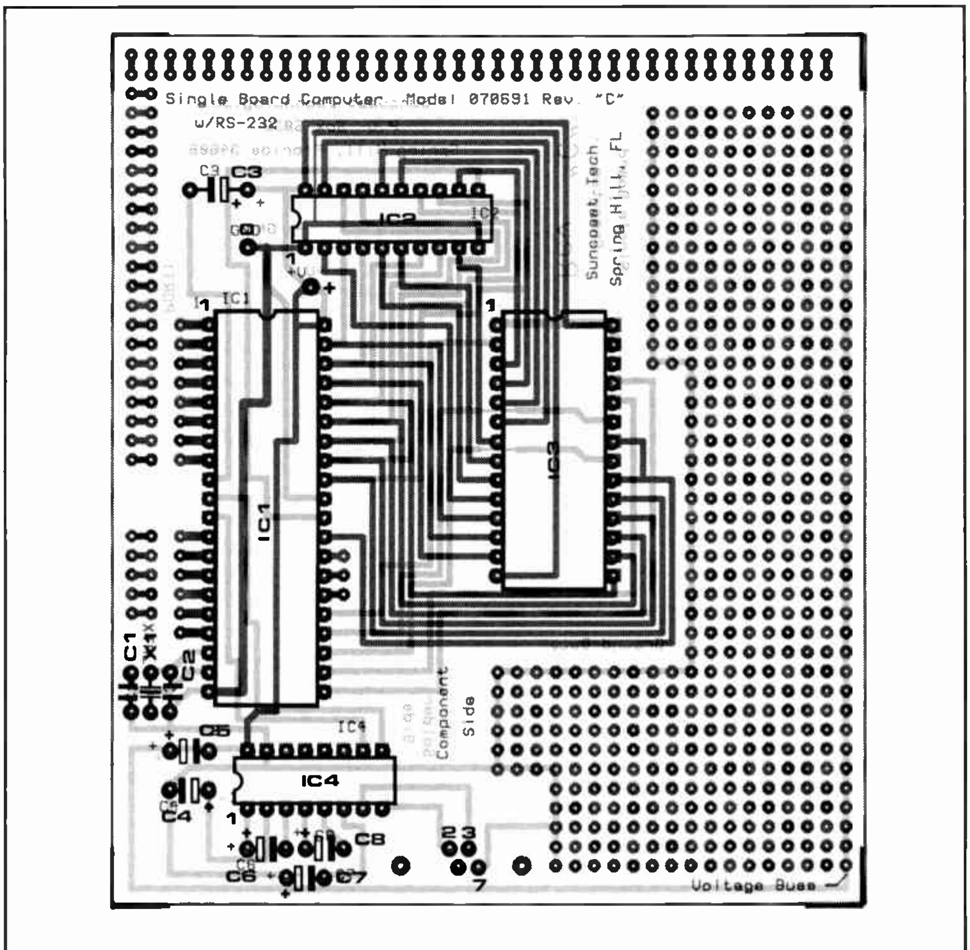


Fig. 3b. Component mounting plan.

Final thoughts

TEST.ASM is not a very elaborate program, and was not meant to be. It is included here so that you can quickly and easily determine that your 8051 SBC is functioning. As the programming of the 8051 chip becomes easier, you will no doubt start to come up with your own state-of-the-art programs. ■

Price and ordering information relevant to the 8051 single board computer and the associated software is available from **Suncoast Technologies, P.O. Box 5835, Spring Hill, Florida FL 34606, U.S.A.**

RDS DEMODULATOR WITH INTEGRATED FILTER

The RDS (Radio Data System) demodulator described in the May 1989 issue is based on the SAF7579T, and has an external 4-section 57-kHz bandpass filter ahead of it that is not easy to adjust. A follow-up type of the SAF7559T, the SAA6579T, has an on-chip pre-aligned RDS filter, which eliminates any adjustment.

Design by G. Kleine

BOTH the 'old' (Ref. 1) and the 'new' RDS demodulator are connected to a dedicated 80C32-based controller board (Ref. 2). The combination of the RDS demodulator and the controller board forms a stand-alone RDS decoder.

The SAF7579T requires an external bandpass filter to extract the RDS datastream from the baseband spectrum transmitted by the FM radio station the receiver is tuned to. Unfortunately, this filter is difficult to adjust because of the small bandwidth (approx. 5 kHz). Also, it adds to the total cost of the decoder, and takes up board space, which are important considerations in mass production (car radios!). Philips Components, the manufacturer of the SAF7579T, have, therefore, worked on an improved version of this RDS demodulator IC, and added an on-chip band filter that obviates the need for an external filter, and, importantly, filter adjustment. The follow-up type is designated SAA6579T, and is available in a 16-pin small outline SMA (surface mount assembly) package.

Operation

The internal organization of the SAA6579T is shown in Fig. 1. The multiplex signal supplied by the FM receiver is first taken through a second-order anti-aliasing filter. The main function of this filter is to prevent spurious products in the following filter, which is based on switched capacitors (SC filter). Without the anti-aliasing filter, the SC filter is prone to transform certain components in the input frequency spectrum into its pass-band (this effect is called 'aliasing').

The 57-kHz SC band-pass filter is an 8th order type with a bandwidth of about 3 kHz. It is followed by a reconstruction filter that serves to smooth and clean the output signal before it is fed to the SCOUT pin of the IC. Figure 2 shows the pass-band characteristic of the integrated SC filter (MUX-to-SCOUT).

The filter output signal is coupled capacitively to the input of a clocked comparator, which digitizes the biphase modulated 57-kHz signal. A so-called Costas loop recovers the suppressed 57-kHz carrier from the biphase-coded datastream. This recovered carrier provides a central clock signal that is locked on to the received RDS signal. It is used to clock the SC band-pass filter and the comparator, and also to recover the RDS data clock, RDCL.

The output signal of the Costas loop is taken to a biphase decoder, which turns the biphase-coded input signal into the original ones and zeros modulated at the transmitter side. Since these are still differentially coded, the biphase decoder is followed by a difference decoder that supplies the RDS data signal, RDDA.

A signal quality detector is implemented on the chip. It indicates whether the received RDS signal is valid (QUAL=H), or invalid (QUAL=L) because of interference or poor reception. The QUAL signal may be used by the RDS decoder to check that the bits on the RDDA line are error-free.

The central clock of the IC is provided by a quartz crystal oscillator (OSCI; OSCO). Depending on the level applied to the MODE input, the oscillator can work with either of two quartz frequencies: 4.332 MHz or 8.664 MHz.

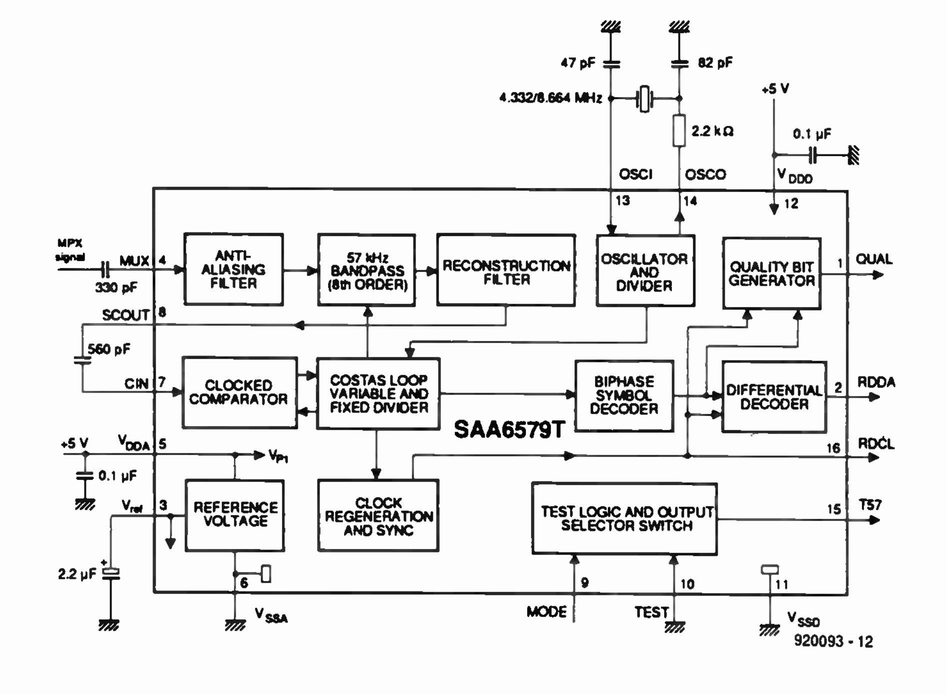


Fig. 1. Block diagram of the SAA6579T RDS demodulator (courtesy Philips Components).

A practical circuit

The circuit diagram of the 'new' RDS demodulator is shown in Fig. 3. This wonderfully simple circuit can be used as a

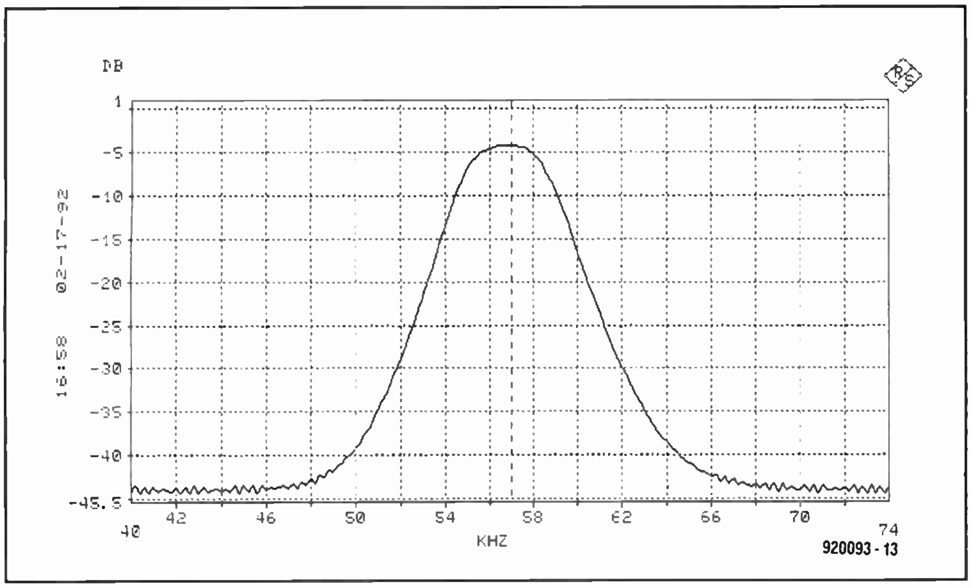


Fig. 2. Pass-band characteristic of the switched capacitor (SC) filter on board the SAA6579T. The dB levels are relative to the signal level at the MUX input.

COMPONENTS LIST

Resistors:

1	2kΩ2	R1

Capacitors:

1	330pF	C1
1	560pF	C2
3	100nF	C3;C7;C8
1	2µF2 16V	C4
1	47pF	C5
1	82pF	C6
1	100µF 16V	C9

Semiconductors:

1	SAA6579T	IC1
1	4050	IC2
1	78L05	IC3

Miscellaneous:

1	4.332MHz or 8.664MHz quartz crystal (see text)	X1
1	10-way PCB pin header	K1
1	Printed circuit board	880209

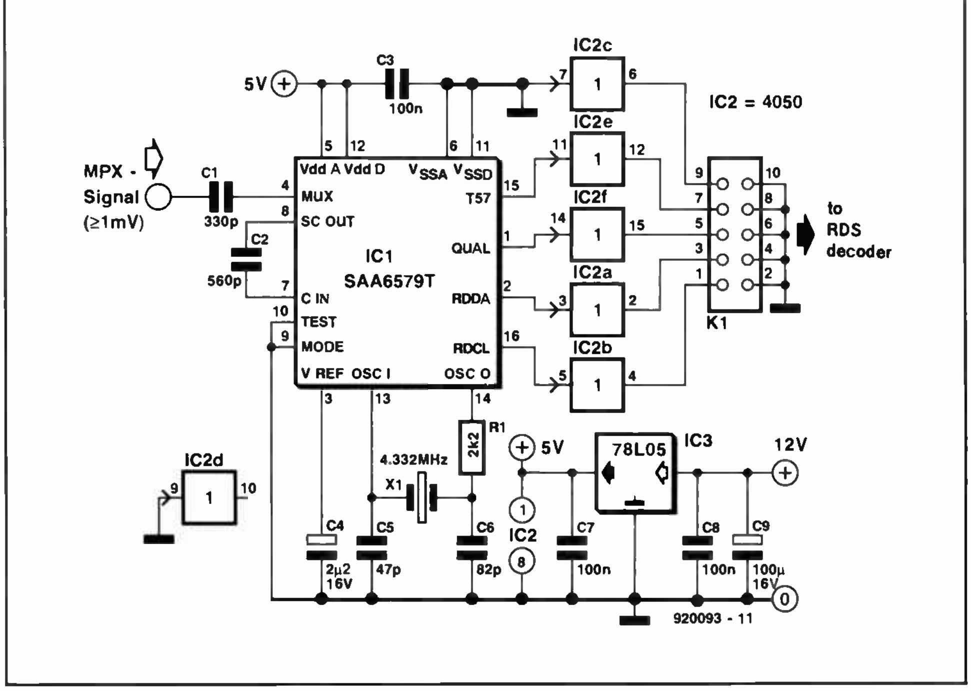


Fig. 3. Circuit diagram of the 'filterless' RDS demodulator. Hook up the FM tuner's MPX output to the input of this circuit, and an 80C32 RDS controller board to connector K1, and you have an experimental RDS decoder.

replacement for the earlier SAF7579T-based version, and is compatible with the associated RDS controller board. Comprising only a handful of components, the SAA6579T-based demodulator can handle input multiplex (MPX) signals in the range from 1 mV to a couple of volts. Capacitor C1 couples the MPX signal to the input filter contained in the SAA6579T. The relatively small value of C1 suppresses the lower-frequency components in the MPX signal because it forms a high-pass filter in combination with the input impedance of the IC.

As described above, a capacitor (here, C2) takes the SCOUT signal to the input of the digital section contained in the SAA6579T. Output signals T57, QUAL, RDDA and RDCL reach the outside world via a Type 4050 CMOS buffer and a 10-way PCB header, just as in the earlier design based on the SAF7579T. Only the ARI (Autofahrer Rundfunk Information; Motorists Broadcast Information) signal is omitted (ARI is a traffic information service broadcast along with RDS in Germany). Hence, the relevant pin header connection is taken to ground.

Apart from the components already mentioned there are two supply decoupling capacitors, C3 and C4, and two small capacitors, C5 and C6, that flank the quartz crystal. A resistor, R1, is connected in series with the OSCO output to minimize the quartz dissipation, and improve the oscillator stability. When an 8.664-MHz crystal is used, the mode pin (pin 9) is tied to +5 V instead of to ground.

A low-current 5-V regulator, IC3, is provided to allow the circuit to be powered from supplies with an output voltage between 7.5 V and about 30 V.

The circuit shown here can be constructed without problems on the printed circuit board originally designed for the SAA7579T-based demodulator. The filter components are, of course, not required in that case. The track layout and component mounting plan of this PCB (order code 880209) may be found in Ref. 1.

References:

1. "Radio Data System (RDS) demodulator". *Elektor Electronics* May 1989.
2. "Radio Data System (RDS) decoder". *Elektor Electronics* February 1991.

R·D·S RADIO DATA SYSTEM

A BRIEF HISTORY OF THE VALVE

Like the age of steam to railway enthusiasts, for anyone interested in radio and electronics there is the same nostalgia associated with the thermionic valve. Its discovery heralded the beginning of the age of electronics, and it enabled radio to make some major strides forwards.

By Ian Poole, G3YWX

SINCE then, the warm glow of their heaters, the gentle aroma that rises from them, and the hum from the sets which use them have generated a feeling of life in them. Unfortunately, the superior technical performance of transistors and ICs sounded the death knell for valves. Despite this, many valves are still in use around the world today.

How it began

Although the first valve was not made until the beginning of this century, the foundations for its discovery were laid many years before. People like Ampère, Faraday and Volta all played their part, but one of the first direct contributions was made in 1873 by professor Guthrie. Investigating effects associated with charged objects, he showed that a red hot iron sphere which was negatively charged and held in a vacuum, would become discharged. He also found that the same did not happen if the sphere was positively charged.

The next major step forwards was taken by Edison in 1883. At the time, electric light bulbs were in their infancy, and had a comparatively short life. One of the major problems was that the bulbs became blackened. Initially, it was thought that this was caused by atoms of carbon from the element hitting the glass. As it was known that the particles leaving the element were negatively charged, experiments were carried out to prevent them hitting the glass. One method which was tried involved placing a second element into the envelope. By placing a positive charge on this new element, it would be able to attract the particles away from the envelope, and prevent them hitting the bulb.

In doing this, Edison noticed that when the second element was made positive relative to the main element, a current flowed in the circuit. When the potentials were reversed, he noticed that this did not happen.

Edison was fascinated by the effect, but surprisingly he did not find a use for it, although it became known as the Edison effect. He demonstrated it to many other leading scientific personalities including Preece, a well known British electrical engineer, and Ambrose Fleming, the Professor of Electrical Engineering at University College London. Despite this, no developments were made for some time.

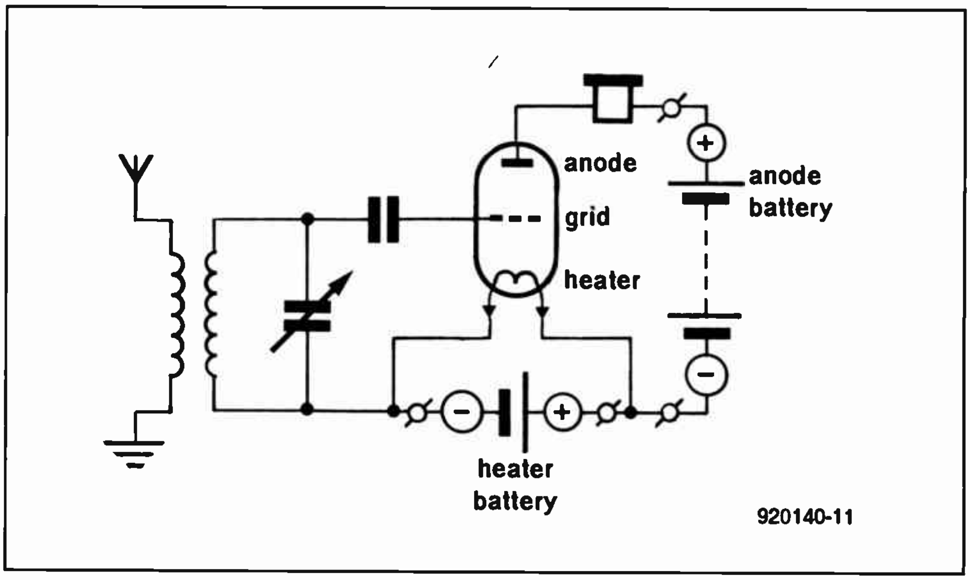


Fig. 1. A circuit using Fleming's oscillation valve.

More developments

Fleming was obviously fascinated by the effect, and experimented with it from time to time. In 1889, he had some bulbs made up for him by the Ediswan Company in the UK, and using these he reproduced the Edison effect. It was not until a few years later that he observed that if an alternating current of between 80 and 100 Hz was passed through the bulb, it became rectified. Finally, Fleming demonstrated this effect to the Physical Society in 1896.

One of the major problems that hampered any further developments was the lack of understanding of what was causing the Edison effect. Matters were made clearer when Sir Joseph Thomson discovered that atoms were made up from even smaller particles, which included negatively charged electrons.

A happy thought

Apart from being Professor of Electrical Engineering at University College

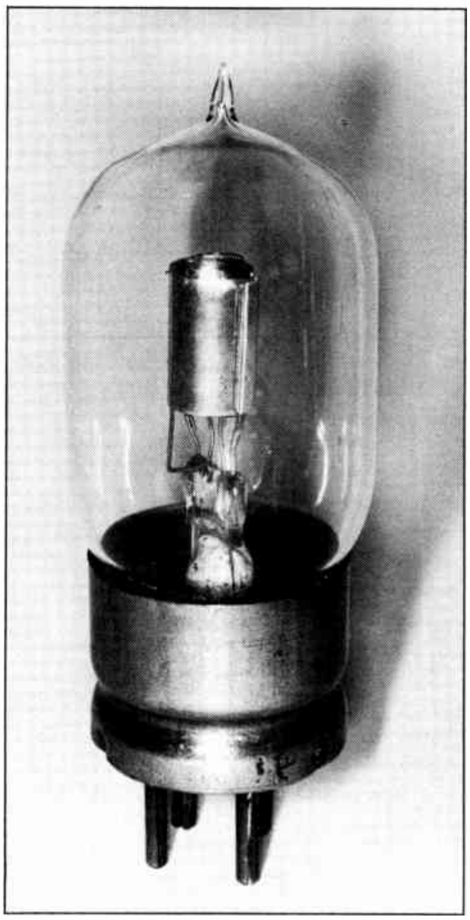


Fig. 2. An early triode.

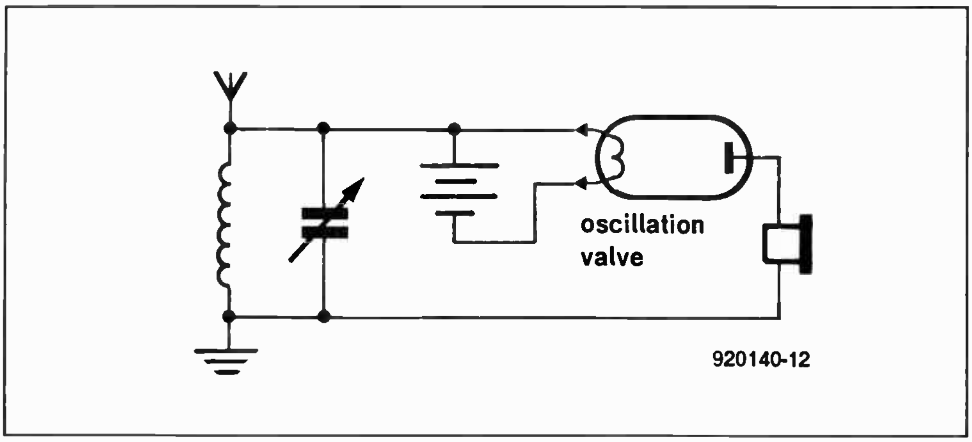


Fig. 3 De Forest's 'Audion' in circuit as a leaky grid detector.

London, Fleming was also a consultant to Marconi, who was pioneering wireless communications. In fact, it was Fleming who designed the transmitter to send the first message across the Atlantic. At this time, the main limitation in wireless communications was the lack of sensitivity of the apparatus which actually received the radio signals — both the coherers and the magnetic detectors were very inefficient.

It was with this problem in mind that Fleming was investigating methods of improving receiver sensitivity. In November 1904, he had what he called a 'sudden very happy thought'. He wondered if the Edison effect could be used to rectify what he called 'feeble to and fro motions of electricity from an aerial wire'. Fleming instructed his assistant to set up an experiment, and they were quickly able to prove that the idea indeed worked.

Fleming called the idea his 'oscillation valve' (Fig. 1) because it acted in a similar way to a valve in a pump which allows gas or water to move in only one direction. He quickly patented the idea, as it was clearly a major step forwards in wireless technology. Even though the diode was still in its infancy, it was still a major improvement over the coherers available at the time.

Other devices

Whilst Fleming's oscillation valve was a revolutionary idea, it did not become widely used. Valves were difficult and expensive to make, and their heaters consumed large amounts of power that had to be supplied by expensive batteries.

Then, in 1906, some cheaper devices were discovered. In fact, two different patents were filed, one by Ferdinand Braun for a crystal detector using hydrated crystals of manganese oxide, and the other by H. Dunwoody for a crystal detector using carborundum. These crystal devices were forerunners of the Cat's Whisker detectors which were used up until the mid 1920s. Although they had a number of limitations, they were much cheaper than valves, and this guaranteed their popularity.

Another electrode

Despite the success of crystal detectors, others still looked towards improving thermionic technology. One was a man named de Forest who had been working on various aspects of wireless, and saw himself as an American rival to Marconi. In his research, he made a number of copies of Fleming's valve, and obtained patents for some modifications and improvements to it. He experimented with a number of different configurations of electrodes, and from the records it can be seen that he took out patents for three-electrode devices in 1905 and 1906. However, it was not until 1907 that he took out a patent for a triode with a fine element between the cathode and the anode. It was this valve that he called his 'Audion' (a later version is shown in Fig. 2).

Slow road to success

Initially, valves were not widely used. They were expensive, and offered few advantages, partly because they were not used to their full potential. In fact, the triode was only used as a leaky grid detector (Fig. 3). The idea of using it to give amplification had not been considered.

It was not until 1911 that the valve was used as an amplifier or oscillator. After

Fig. 4. The famous 6L6 and 807 valves.

this discovery, people were quick to try to exploit it. De Forest built an amplifier using three Audions, and demonstrated it to the telephone company AT&T. Although the performance was poor, they saw its potential, and soon started to build repeaters using valves which they had improved.

It was not until 1915 when an American scientist named Langmuir discovered that gases were not required in the envelope. New, highly evacuated, valves (known as 'hard valves') were soon produced with much better performance. In addition to basic improvements, the full evacuation of the envelopes brought a number of other improvements. Filaments could now be coated to improve their electron emission. Previously, any coating would have been contaminated. Filament temperatures could also be reduced, and this improved reliability as well as reducing the heater current consumption.

The advantages of the new 'hard valves' soon became apparent, and large numbers were manufactured. One type manufactured in France by the military authorities under an engineer called Ferrie was called the TM, of which over 100,000 were produced. An English development of it, called the Type R triode, was equally successful. After the first World War, many of these valves came on to surplus market, and were snapped up by enthusiastic amateurs.

More electrodes

One of the major difficulties using the early triodes was to prevent them from oscillating, especially when they were used in high-frequency circuits of more than a few hundred kilohertz. The problem was caused chiefly by the inter-electrode capacitance between the anode and the grid. Many attempts were made to try to overcome this capacitance. In 1916, H.J. Round produced a low-capacitance valve known as the Type V24. In it, the anode lead was passed out of the glass envelope through a top cap on the valve, and not through the base. This idea has been used on many other radio frequency valves right up to recent times. Whilst this solution was reasonably successful, and Round managed to make his amplifier operate well for the day, it was by no means the answer to the problem.

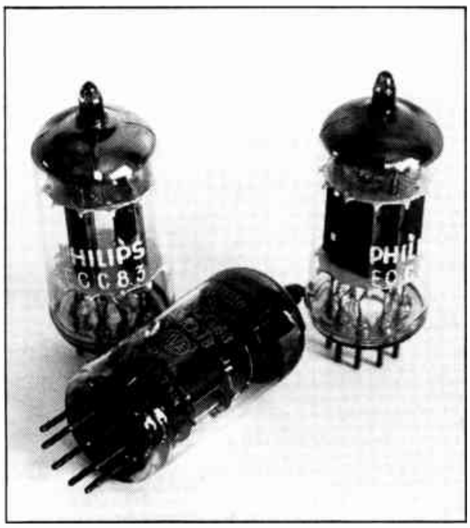


Fig. 5. Three modern all-glass dual triodes.

Many further attempts were made to reduce inter-electrode capacitance. However, it was not until 1926 that the complete solution was found with the introduction of the tetrode. This used a second grid called the screen grid. This was placed between the normal control grid and the anode. Its introduction reduced the anode to control grid capacitance to almost zero, and solved the problem of instability.

Later, the tetrode itself was improved in 1929 by the introduction of the pentode. This valve had yet another grid called the suppressor grid, which improved the discontinuity in the characteristic of the tetrode caused by electrons bouncing off the anode when they hit it.

Heaters

Apart from making improvements in the operation of valves by creating additional grids, further improvements were made in the heater arrangements. It was discovered that the cathode could be indirectly heated, and this meant that the heaters could be electrically isolated from the cathode. This, in turn, had the advantage that the heaters did not need to be powered by a battery (d.c.) supply. A major improvement indeed, because it meant that size of radios could be considerably reduced, as could be their running costs.

Increase in use

During the 1930s, valve use increased dramatically. Their use within domestic radios grew, and in addition to this they were used in a variety of applications within industry. By the late 1930s, many thousands of different types of valve were being manufactured, and there was a large number of different manufacturers appearing both in the USA and in Europe.

Many of the valves introduced in this period have long since disappeared from common use. However, a few were very successful, and remained in new designs for a long time. One such valve was the Type 6L6 used in many guitar amplifiers until quite recently. In many ways, it was quite revolutionary, being the first beam tetrode. It used a new technique to overcome the discontinuity in the characteristic of the tetrode caused by electrons bouncing off the anode. Rather than using a suppressor grid, it had a new arrangement connected to the screen grid. This valve became so popular that it was later modified for RF applications by giving it a top cap for the anode. This valve was called the 807, and was widely used in transmitters in the Second World War and afterwards. The 6L6 and 807 are shown in Fig. 4.

Prior to the war, all valves had used special metal or plastic bases attached to the glass envelopes to hold the pins. After the war, miniaturization and improvements in manufacturing techniques enabled the pins to be mounted into the glass envelope. By doing this, much smaller valves were made (Fig. 5), and costs were reduced.

The Fall

The heyday of the valve could not last forever. The invention of the transistor in 1948 took a long time to affect the supremacy of the valve. However, in the 1960s, when prices of transistors started to fall, it became obvious that valves were no longer the best option for many applications. Transistors and, later, ICs totally overtook the use of valves in domestic appliances. Radios, televisions and many other items which had previously used valves all turned to semiconductors.

Despite all this, thermionic technology still survives in a number of areas where semiconductors have not been able to compete. One of the most obvious is the cathode ray tube (CRT) in televisions and computer monitors. Although some semiconductor alternatives are slowly appearing, they have not yet supplanted the dominance of the CRT.

Another area where transistors have not been able to compete is in high-power transmitting applications. Today, valves offer the only real solution for transmitters producing a few tens of kilowatts or more. As a result of this, many developments have been made in this area recently.

Finale

Valves have been used now for nearly 100 years. Their contribution to electronics has been enormous. In fact, there is no doubt that electronics would not be nearly as advanced as it is today, had it not been for the invention of Fleming's oscillation valve, and all the subsequent developments. ■

LETTERS

4-Megabyte printer buffer

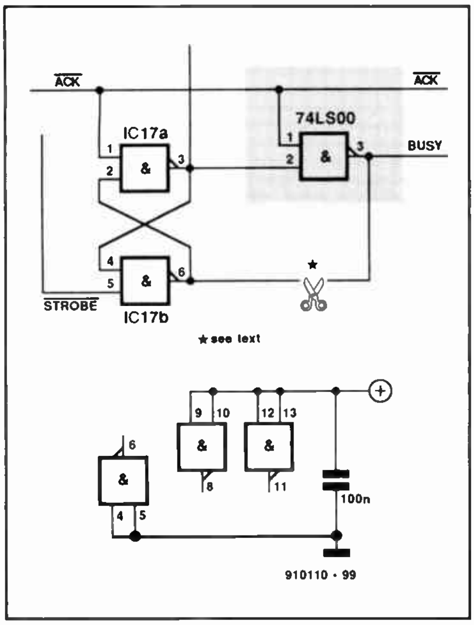
June 1992, page 34

Two points regarding this project.

(1) The input of the buffer is designed to be Centronics compatible. Problems may occur when this standard is not respected by the computer or the software. A number of "fast" PCs (in particular 386 and 486 based machines) appear to have printer interfaces derived from the Epson standard. These interfaces in general do not wait for the ACKNOWLEDGE signal, but instead process the BUSY signal.

Handshaking problems that may occur between these PCs and the printer buffer may be solved by combining the BUSY and ACKNOWLEDGE signals as shown in the diagram opposite. The result of the modification is that the printer buffer behaves like an Epson-compatible peripheral device.

(2) An updated version of the control software (in EPROM) is available that enables 1-Megabyte (1M x 8 and 1M x 9) SIP/SIM modules with three ICs to be used in the printer buffer.



Milli-ohm measurement adaptor

April 1992, page 58

To prevent its contacts burning out, switch S_1 must not be operated when an inductive component is connected to the adaptor.

Contrary to what is said under the heading "Extensions," the reference inputs of the DVM are connected to the pole of S_{1b} and ground, while the "normal" DVM inputs are connected to the resistor to be measured.

Inductance-capacitance meter

March 1992, page 30

Terminals "A" and "B" should be transposed in the circuit diagram of the meter circuit proper (*Figure 4* on page 32).

FM TUNER

Could you please supply details of where to obtain the TQF-2599 crystal filters used in "AM/FM Receiver" (*EEUSA* 4/91 p. 59).

P. Holton
Durhan, South Africa

Editor replies:

The TQF-2599 crystal filter for the FM tuner should by now have become available form several electronics retailers. Unfortunately, there is a delay in delivery from the manufacturers, Tyocom of Japan (yes, even Japanese manufacturers have their problems) and, consequently, the filters are not expected to be with the retailers until July. We are fortunate in being able to buy small quantities directly from the manufacturers, so that we have been able to complete our prototypes.

LETTERS

COMPONENT RATINGS

A number of readers have asked for ratings of circuit components to be specified in the parts lists. Ratings used to be specified in the "decoder" in the past, but for a number of reasons this was discontinued. In view of the requests, we will again publish them starting here.

In resistor and capacitor values, decimal points and large numbers of zeros are avoided wherever possible. The decimal point is usually replaced by one of the following abbreviations:

(pico-) = 10^{-12}
n (nano-) = 10^{-9}
μ (micro-) = 10^{-6}
m (milli-) = 10^{-3}
k (kilo-) = 10^{3}
M (mega-) = 10^{6}
G (giga-) = 10^{9}

Note that nano-farad (nF) is the international way of writing 1000pF or 0.001μF.

Resistors are ⅓W, 5% metal film types unless otherwise specified.

The d.c. working voltage of capacitors (other than electrolytic or tantalum types) is assumed to be ≥60V. As a rule of thumb, a safe value is about 12×d.c. supply voltage.

D.C. test voltages are measured with a 20kΩ/V instrument unless otherwise specified.

Mains (power line) voltages are not listed in the articles. It is assumed that our readers know what voltage is standard in their part of the world.

Readers in countries that use 60Hz supplies should note that our circuits are usually designed for 50Hz. This will not normally cause problems, although if the mains frequency is used for synchronization, some modification may be required.

The international letter symbol "U" is used for voltage instead of the ambiguous "V." The letter V is reserved for "volts".

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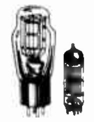

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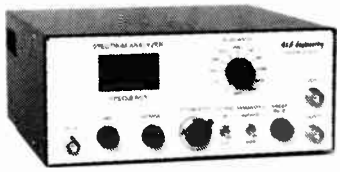

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If yes, approximate amount.
15 ❑ $20 or less 16 ❑ $21- $50 17 ❑ $51-$99 18 ❑ $100 +

E. Are there PCs in your office?
19 ❑ Yes 20 ❑ No

F. Do you make electronic equipment choices in your work place?
21 ❑ Yes 22 ❑ No

If yes, check estimated weekly value of components.
23 ❑ Less than $1K 24 ❑ $1K- $5K 25 ❑ $5K-$20K
26 ❑ $20K- $50K 27 ❑ $50K +

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28 ❑ 25 or less 29 ❑ 26- 99 30 ❑ 100-499
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2

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- Runs in background, totally transparent
- Share any device, any file, any time
- Needs only 14K of ram

Skeptical: We make believers!

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- Low cost - $75 per LAN, not per node!
- Hardware independent network
  ARCNET, Parallel, and Serial port support on first release
  Serial Speed: 6500(XT)-8500(AT) bytes per second
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  ARCNET Speed: 40000 plus bytes per second
- Use any PC/XT/AT/386 mix, even laptops and PS/2 machines
  Connect up to 254 computers, can mix connection methods (Serial, Parallel, Arcnet)
- DOS File and Record locking support
- Share any device, any file, any program
- Runs in the background, totally transparent
- Low memory overhead
  Typically only 28K is needed, but will vary with various setups
- Works with most software, including DBASE III, Microsoft
  WORD, LOTUS 123, Windows 3, AUTOCAD, Word Perfect, all compilers, GWBASIC, and, in fact, most anything!
- Works with DOS 2.0 to DOS 5.0 and DR-DOS
  DOS 3.1 or greater is preferred
- Open network, programmer API provided
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