

ELEKTOR

ELECTRONICS

USA

THE INTERNATIONAL JOURNAL
FOR RECREATIONAL ELECTRONICS

MARCH 1992

\$3.00 US
CANADA \$4.00

Inductance-Capacitance Meter

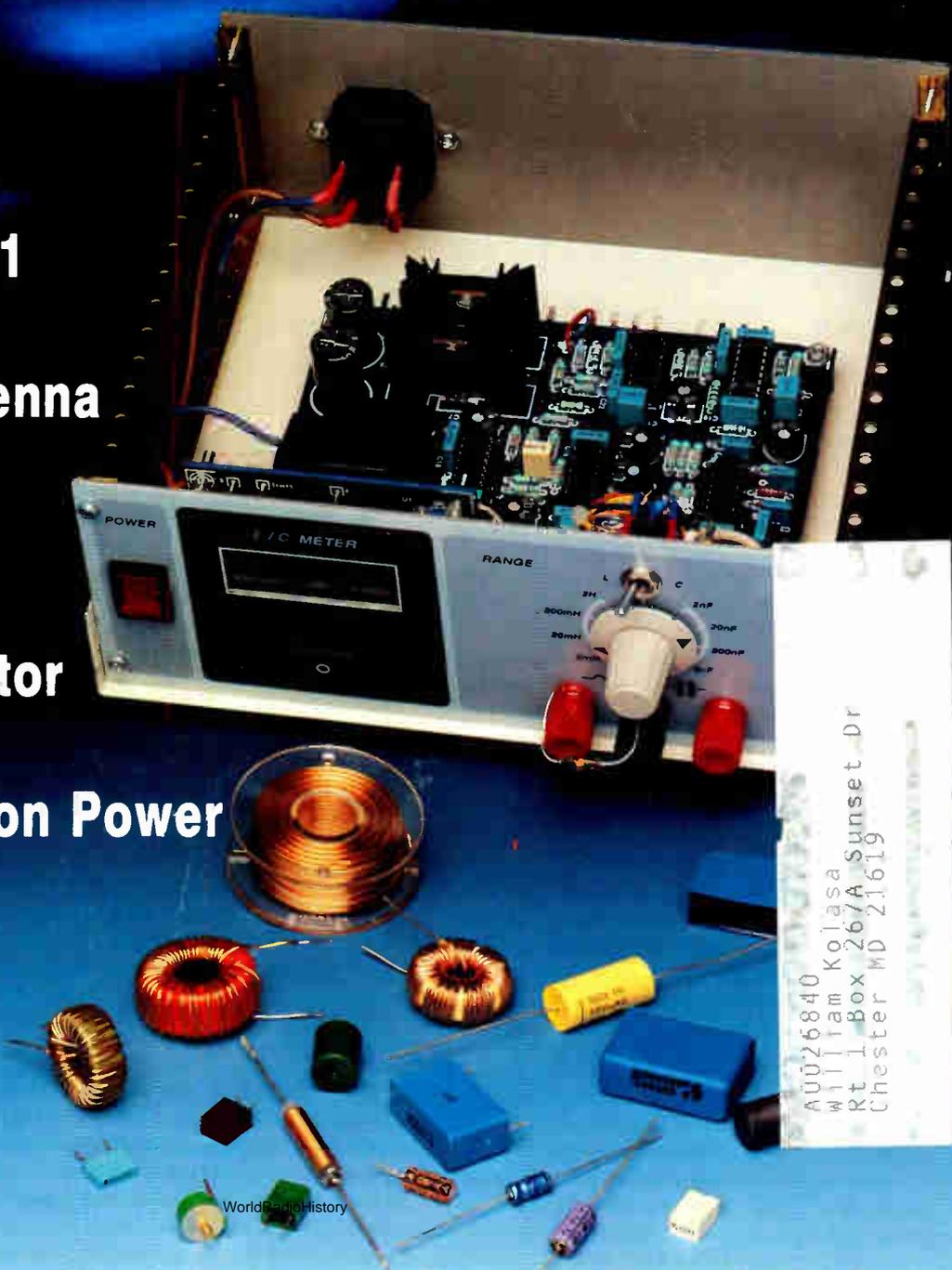
FM Tuner—Part 1

Flat-top 80 Antenna

8751 Emulator

AF Drive Indicator

Measurements on Power
Supplies



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| 1N4005 | 1 AMP 600 PRV | .12 |
| 1N4006 | 1 AMP 800 PRV | .15 |
| 1N4007 | 1 AMP 1000 PRV | .17 |
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| 1N5401 | 3 AMP 100 PRV | .20 |
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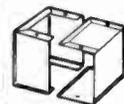
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POW-200
\$119.95



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| PART NO. | SIZE (IN.) | | | PRICE |
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| | L | W | H | |
| 1411B | 2.7 | 2.2 | 1.6 | 4.46 |
| 1411C | 3.2 | 2.2 | 1.1 | 4.78 |
| 1411D | 3.2 | 2.2 | 1.6 | 4.90 |
| 1411F | 4.0 | 2.2 | 2.7 | 5.66 |
| 1411G | 4.0 | 2.2 | 1.6 | 5.04 |
| 1411H | 4.0 | 2.2 | 2.2 | 5.47 |
| 1411K | 5.0 | 2.2 | 2.2 | 5.82 |
| 1411L | 5.0 | 4.0 | 3.0 | 7.53 |
| 1411M | 6.0 | 3.0 | 3.0 | 8.02 |
| 1411N | 5.0 | 3.0 | 2.1 | 6.30 |
| 1411P | 6.0 | 5.0 | 4.0 | 9.86 |
| 1411Q | 7.0 | 5.0 | 3.0 | 9.27 |
| 1411R | 8.0 | 6.0 | 3.5 | 12.28 |
| 1411S | 8.0 | 4.0 | 3.0 | 15.63 |
| 1411T | 10.0 | 2.2 | 1.6 | 8.68 |
| 1411U | 10.0 | 6.0 | 3.5 | 15.31 |
| 1411W | 12.0 | 3.0 | 2.2 | 11.15 |
| 1411X | 12.0 | 7.0 | 4.0 | 18.62 |
| 1411Z | 17.0 | 5.0 | 4.0 | 20.10 |

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| | | |
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|-------|--------|----|-------|--------|----|
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| LP-16 | 16 PIN | 12 | LP-28 | 28 PIN | 30 |
| LP-18 | 18 PIN | 17 | LP-40 | 40 PIN | 43 |
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| OFA13 | 1KΩ | OFA15 | 100KΩ |
| OFA23 | 2KΩ | OFA25 | 200KΩ |
| OFA53 | 5KΩ | OFA55 | 500KΩ |
| OFA14 | 10KΩ | OFA16 | 1MΩ |

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|---------|------|
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| 2N2222A | .35 |
| 2N3055 | .69 |
| 2N3553 | 2.75 |
| 2N3563 | .35 |
| 2N3771 | 1.95 |
| 2N3866 | 1.00 |
| 2N3904 | .10 |
| 2N3906 | .10 |
| 2N4401 | .15 |
| 2N4403 | .15 |
| MPF102 | .29 |

LINEAR IC'S

| | |
|-----------|------|
| MAX232CPE | 4.05 |
| LM311N | .45 |
| LM339N | .35 |
| LM386N | .99 |
| NE555 | .25 |
| NE564 | 1.75 |
| NE567 | .99 |
| NE602N | 2.25 |
| LM741N | .25 |
| CD22402E | 9.95 |
| CA3126E | 1.60 |
| MC1350P | 1.49 |

VOLTAGE REGULATORS

| | |
|--------|------|
| 7805 | .39 |
| 7812 | .39 |
| 7815 | .39 |
| 7824 | .39 |
| 7905 | .49 |
| 7912 | .49 |
| 78L05 | .39 |
| 78L12 | .39 |
| LM317T | .69 |
| LM338K | 4.43 |
| LM723 | .65 |

EPROMS

| | |
|----------------|-------|
| 2708 | 4.25 |
| 2716 | 3.30 |
| 2732 | 3.85 |
| 2764 | 3.55 |
| 27C64(150ns) | 3.85 |
| 27C28(150ns) | 3.85 |
| 27C256 | 4.55 |
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| 27C010(150ns) | 9.85 |
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Designed for modernistic equipment. Beautiful appearance, easy to read. D'Arsonval type movement, accuracy within 2%. Will mount in panels up to 3/8" thick, has zero adjustment screw. Size: 2 3/8" x 1 13/16" x 1 1/4" deep, including terminals and will mount into 1 1/2" hole



| PART NO. | METER READING | PRICE |
|----------|------------------|-------|
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| M60-121 | 0-15VDC | 16.00 |
| M60-122 | 0-30VDC | 16.00 |
| M60-125 | 0-150VDC | 16.00 |
| M60-127 | 50.0-50μA | 16.00 |
| M60-129 | 0-50μA | 16.00 |
| M60-130 | 0-100μA | 16.00 |
| M60-133 | VU METER | 16.00 |
| M60-149 | ILLUMINATION KIT | 2.85 |

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|----------|--------|-------|----------|--------|-------|
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| CD12-5 | 12PF | .12 | CD220-5 | 220PF | .14 |
| CD15-5 | 15PF | .12 | CD270-5 | 270PF | .14 |
| CD18-5 | 18PF | .12 | CD300-5 | 300PF | .15 |
| CD22-5 | 22PF | .12 | CD330-5 | 330PF | .15 |
| CD27-5 | 27PF | .12 | CD390-5 | 390PF | .15 |
| CD33-5 | 33PF | .12 | CD470-5 | 470PF | .15 |
| CD39-5 | 39PF | .12 | CD560-5 | 560PF | .15 |
| CD47-5 | 47PF | .12 | CD680-5 | 680PF | .15 |
| CD56-5 | 56PF | .12 | CD001-5 | 001μF | .15 |
| CD68-5 | 68PF | .12 | CD0047-5 | 0047μF | .15 |
| CD75-5 | 75PF | .12 | CD01-5 | 01μF | .15 |
| CD100-5 | 100PF | .12 | CD022-5 | 022μF | .15 |
| CD120-5 | 120PF | .14 | CD05-5 | 05μF | .20 |
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| PART NO. | CAP.μF | PRICE | PART NO. | CAP.μF | PRICE |
|-----------|--------|-------|------------|--------|-------|
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| CER1-50 | 1 | .17 | CER100-50 | 100 | .36 |
| CER2-50 | 2.2 | .17 | CER220-50 | 220 | .54 |
| CER3-50 | 3.3 | .17 | CER330-50 | 330 | .70 |
| CER4-50 | 4.7 | .17 | CER470-50 | 470 | .93 |
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| CER33-50 | 33 | .22 | | | |

KITS

Complete with PC Board and Instructions.
Educational, Fun to Build, and Practical.

SIGNAL INJECTOR/ TRACER

This handy tester is both a signal generator and receiver. As a generator use it to check out an amplifier, stage by stage. Also tests AM radio IF and RF stages. As a receiver you can pin point where a defective part exists. Will transmit and receive simultaneously.



In next month's issue (among others):

- Comb generator
- AD232 converter
- General array logic (GAL)
- Understanding waveform harmonics
- Super sign
- LCD for L/C meter
- 2 metre receiver
- Red-light diode lasers

Front cover

This month's instrument in our series of test and measuring instruments is an inductance/capacitance meter. Since it is essential that when the value of an inductor or capacitor is measured the ohmic losses do not affect the result, the meter has built-in automatic loss compensation.

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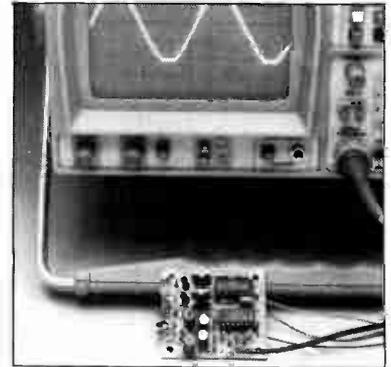
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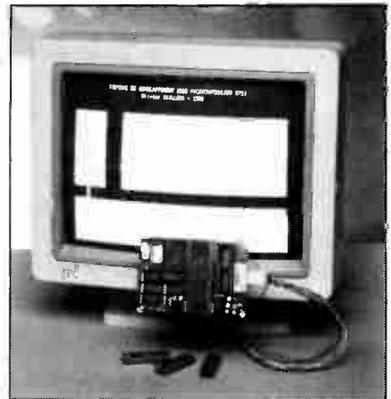
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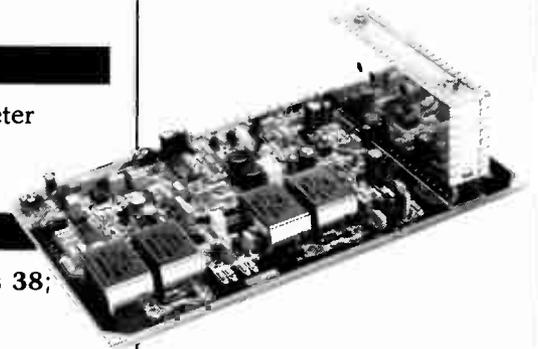
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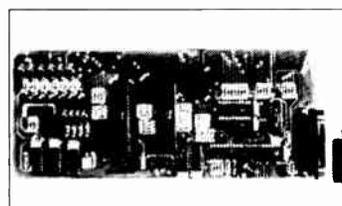


IBM PC SERVICE CARD

This card was developed for assistance in the field of service, development and test. The card is used as a bus-extension to reach the measurement points very easy. It is also possible to change cards without having a "hanging computer"

Ready Assembled Module

\$145

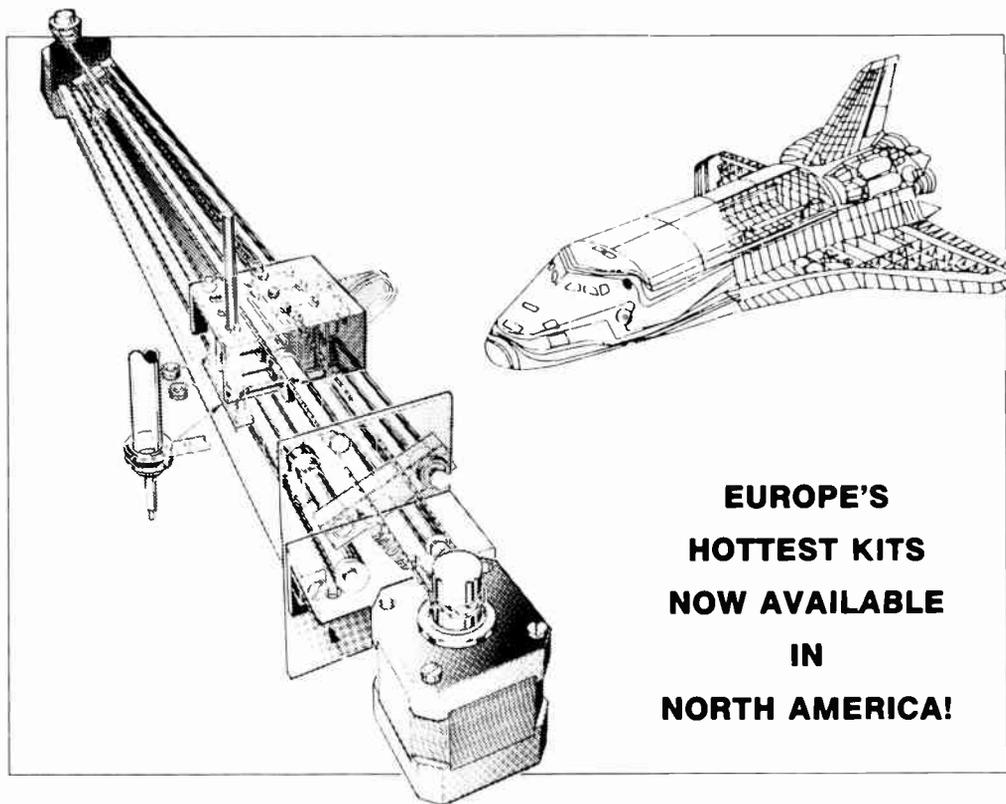


IC TESTER FOR IBM-PC-XT/AT

With the ELV IC tester logic function tests can be carried out on nearly all CMOS and TTL standard components, accommodated in DIL packages up to 20 pin. The tester is designed as an insertion card for IBM-PC-XT/AT and compatibles. A small ZIF test socket PCB is connected via a flat band cable. Over 500 standard components can be tested using the accompanying comprehensive test software. Complete Kit including Textool socket, connectors, sockets, Flat band cable, PCB, Software.

Ready Assembled Module

\$200



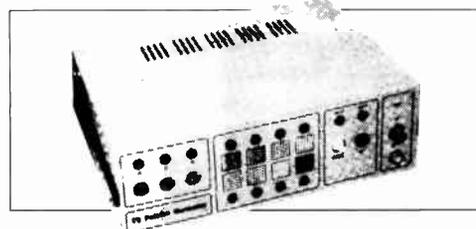
EUROPE'S HOTTEST KITS NOW AVAILABLE IN NORTH AMERICA!

PLOTTER MARK-II

completely reworked version: see Elektor Electronics March 1990.

- Max. width 50 cm.
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- Complete kit, including 2 stepper motors, 3 pen lift solenoids, HPGL software on disk (IBM), stepper motor control board

100.100 **\$275**



COLOUR TEST PATTERN GENERATOR

A PAL-compatible colour video source that supplies a number of test patterns for aligning television sets.

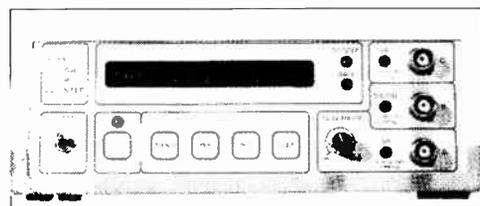
A test pattern generator is virtually indispensable for troubleshooting in television sets because it supplies a video signal that is known to be stable, and thus easily displayed and synchronized on an oscilloscope.

Inc. case and front 100.111 **\$175**



ELEKTOR P.C. i/o card

* 220.007 **\$175**



MICROPROCESSOR-CONTROLLED FREQUENCY METER

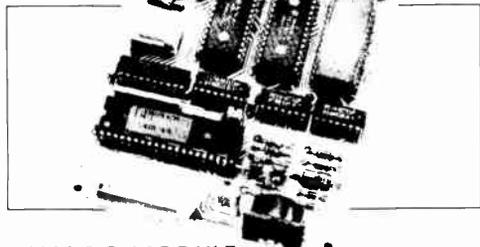
A professional grade multi-purpose frequency meter, designed by Elektor Electronics, that can be built by many at affordable cost. Described in Elektor Electronics December 1984, January & February 1985. U665B-based prescaler.

- Frequency meter: 0.01 Hz to 1.2 Ghz.
- Pulse duration meter: 0.1 to 100 s.
- Pulse counter: 0 to 10⁹ pulses
- Period meter: 10 ns to 100 ns
- Sensitivity: Input A: 10 mV_{rms} (Z_{in} = 2 MΩ); Input B: TTL or CMOS compatible (Z_{in} = 25 kΩ); Input C: prescaler input: 10 mV_{rms} (Z_{in} = 50 Ω).
- Auto-ranging and completely menu-driven.
- 6 or 7 digit accuracy.

Kit includes power supply, prescaler and enclosure.....100.112 **\$300**

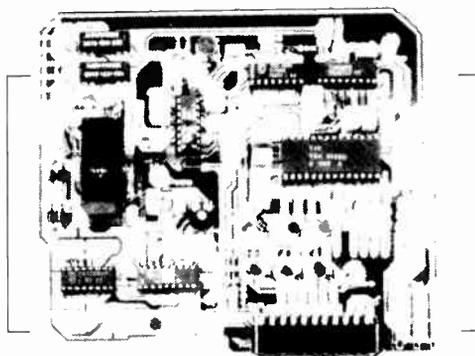
BASIC COMPUTER
With Intel 8052AH-BASIC

100.117
\$160



- ANALOG MODULE**
eps 880162 100.113 **\$80**
- DIGITAL MODULE**
eps 880163 100.114 **\$55**
- ADRESSDECODER**
eps 880159 100.115 **\$45**

S-VHS/CVBS-TO-RGB CONVERTER



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

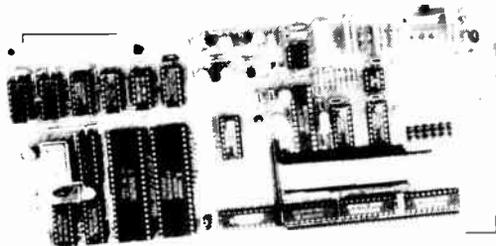
220.039 **\$150**



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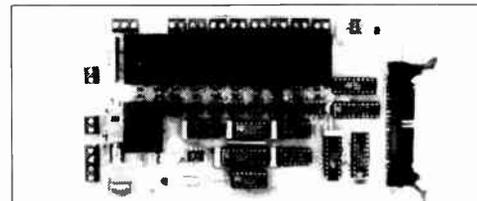
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- Please allow 6-8 weeks for delivery.
- **SHIPPING:** Airmail shipping to USA included in price. Others: Please inquire.
- **CUSTOMS:** USA residents may be required to pay 5-10% customs duty. Others may vary.



MULTIFUNCTION MEASUREMENT CARDS FOR PCs

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

220.040 **\$225**



MICROPROCESSOR-CONTROLLED TELEPHONE EXCHANGE

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

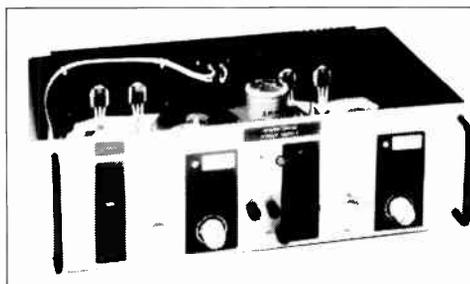
220.057 **\$190**

MAIN FEATURES

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

MAIN SPECIFICATIONS

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



400-WATT LABORATORY POWER SUPPLY

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

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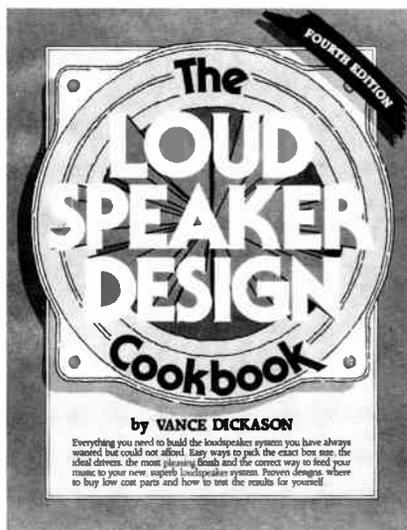
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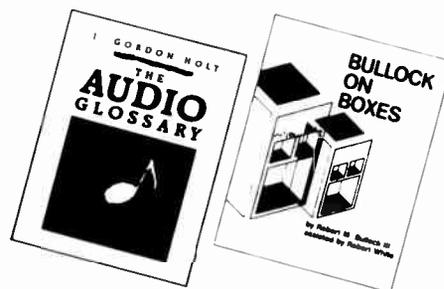
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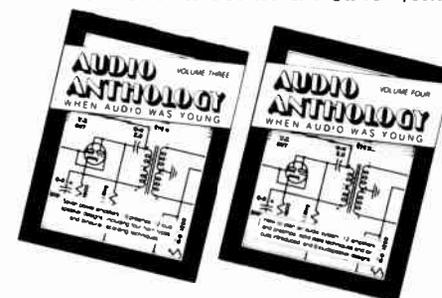


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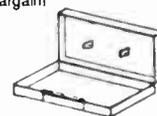
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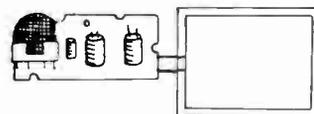
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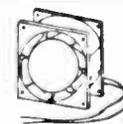
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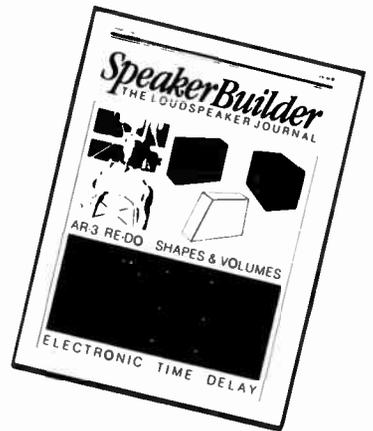
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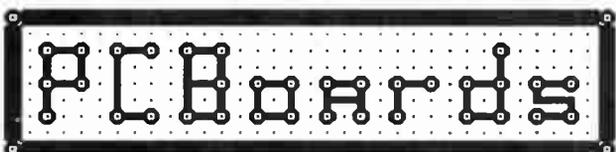
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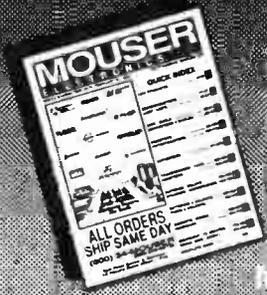
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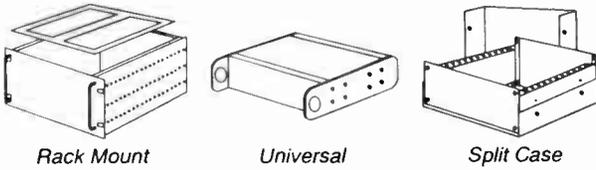
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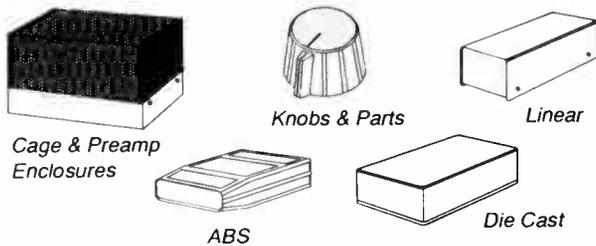


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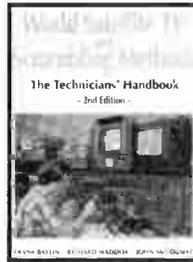
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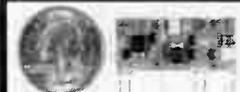
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GERM WARFARE—DIGITAL STYLE

With all the international worry about the use of deadly diseases as a way of dealing with military enemies—or obstreperous minorities—we computer users now have our community's own unique criminal element to deal with, somehow. These cowardly, gutless wonders who doubtless chuckle away to themselves in some kind of slimy psychological slum, haven't even the courage of a Saddam Hussein to flaunt their perverse tactics in public.

Computer viruses are yet another symptom of a society which must resort more and more to preventive maintenance to survive. All the new hazards of everything from nicotine laden smoke, industrial pollution, urban crime, a deteriorating ozone layer and plaque coated teeth seems to require all manner of defense systems. Our computers are now on the danger list as well.

Recently a neighboring engineering firm experienced severe virus infection of its minicomputer system after an employee took work home on his laptop, worked for the evening, and in the course of the period, inserted a friend's disk in his machine to examine some data. On returning to work the next day, he downloaded his updated work. The virus, however, did not begin its mischief until weeks later. Only with the most careful diagnostic effort did the company's computer people reconstruct what had happened, and how.

I thank Michael Chamness of *Speak Easy* software for the following helpful letter which I reproduce here in its entirety.

COMPUTER VIRUS MICHELANGELO

"We are writing at this time as a service to our customers and supporters because we recently discovered a software virus on our computer system. The virus we encountered is apparently widespread, and we would like you to be sure it has not contaminated your computer system from any source. Although it is unlikely we have passed this virus on to you, the virus threat is real and it is important that you take steps to keep your system virus-free."

"While our computer system and any software loaded into it is constantly monitored by anti-virus software, this particular strain known as Michelangelo went undetected until last week. This virus sits in the boot sector of your floppy or hard disk and does nothing until March 6th. Then it begins to write random characters to your disk.

It's sad to know there are people in the world who spend their time writing such destructive garbage."

"This virus enters your system when an infected diskette is in a disk drive on bootup regardless of whether it is bootable or not. It should not enter your system if you simply read from or write to the infected disk. However, once it is on your hard disk, it can copy itself onto a diskette accessed in any drive and therefore can be spread around quickly."

"We highly recommend anti-virus software be installed on your system. Until now we thought viruses were somebody else's problem and would never affect us. Although we keep our computer isolated to keep it immune, we were sadly surprised."

"The Michelangelo virus and hundreds of others can be detected with readily available software from Norton, Central Point Software and other companies. McAfee Associates provides virus detection and removal software which you can download and use FREE FOR 5 DAYS from their computer bulletin board system (BBS). Please do yourself a favor and scan your system with one of these programs to be sure it is virus-free! It is equally important of course, to back up all your work regularly."

"Since the Michelangelo virus resides on the boot sector of your hard disk, there is a way to easily get rid of it if you own Microsoft DOS, version 5.0. You can use FDISK with the undocumented option /MBR (for Master Boot Record) to refresh the master boot record thereby writing over the virus and eliminating it. This will work in most cases but it is still important to scan your disk to be sure NO viruses are present. This procedure will not remove the virus from your diskettes, if infected. Please practice SAFE computing." ■

Just as the prudent advice on backing up our data is drummed into all of us, and quite properly so, from all sorts of directions, we must now become equally and systematically vigilant about getting and using regularly, an anti-virus program. We have taken the advice recently advanced in the pages of *PC Magazine* and acquired the anti-virus program designed and marketed by PC-Tools™ called Central Point Anti-Virus. (Central Point Software, 15220 Greenbrier Parkway, #200, Beaverton OR 97006 (503) 690-8090.)—E.T.D.

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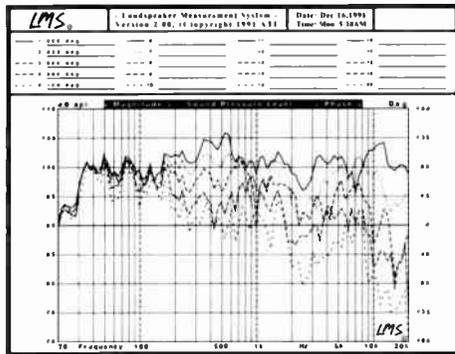
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ACCURATE MEASUREMENTS

Audio Teknology Inc. announces the Loudspeaker Measurement System (LMS) for LEAP users. Billed as a cost effective solution to electro-acoustic measurements, it solves the mic problem and can read out directly in absolute dB-SPL. Without requiring anything other than a single open expansion slot, you can now design crossovers with actual impedance and SPL, and even optimize these designs to your satisfaction. For \$995, you are up and running.

Contact Audio Teknology Inc., 7556 SW Bridgeport Rd., Portland, OR 97224, (503) 624-0405, FAX (503) 624-0194.



MULTIPLIER MODEL

Analog Devices offers its first analog multiplier on its updated SPICE Library Disk, which also adds 88 new models. These offer instrumentation, amplifiers, voltage references, and matched transistor pairs in addition to operational amplifier models. The analog multiplier model characterizes the AD734 wideband four-quadrant multiplier IC. It offers versatility in achieving analog functions such as modulation/demodulation, frequency doubling, and high-speed RMS-to-DC conversion circuits. The free SPICE Library is available on a 5 1/4" IBM PC-compatible floppy disk. To get your copy, call (800) 262-5643.



ELECTRONICS SCENE



WIDEBAND PORTABLES

Midland LMR (Land Mobile Radio) offers the Model 70-165 (VHF) and 70-265 (UHF) 48- and 99-channel two-way FM portable radios that feature a function keypad and LCD as standard. The built-in 40-channel/second scan lets you change the scan list at will without reprogramming. It provides controls for optional DTMF (telephone-type) signaling. RF power output of the portables is 5W switchable to 1W in VHF models, 4W switchable to 1W in UHF, and audio output is 0.5W. All models meet or exceed military specs for shock and vibration.

For further details, contact Midland LMR, Marketing Dept., 1690 N. Topping, Kansas City, MO 64120, (800)-MIDLAND, ext. 1690.

HEADPHONE AMP FROM HPX

Designed for professional and audiophile monitoring, the high performance headphone amplifier from HPX Somich Engineering uses a minimalist circuit topology and quality monolithic components. Technicians can use the HPX headphones for troubleshooting and fine-tuning audio systems.

Features include a Burr-Brown INA103 amp input with a floating 100kΩ input impedance, a premium gain stage, soundstage imaging network, Dale 1% low-noise metal film resistors, regulated DC power supply, and an integral ground plane for circuit stability.

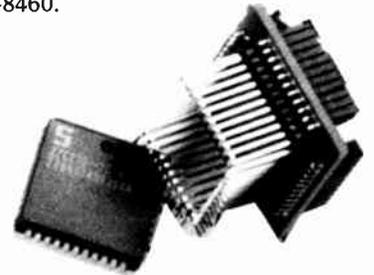
Contact Jim Somich, 1208 Stoney Run Trail, Broadview Heights, OH 44147, (800) 334-3925.

HIGH DENSITY ADAPTERS

Logical Systems Corporation offers PLCC adapters for high-density PC board. The 44FOOT-CS (\$100) emulates the footprint of a 44-pin PLCC device. It solders onto the solder pads and its L-shaped leads lie flat on the target system's PLCC solder pads to allow for easy hand soldering. Several adapter tops are available to complete the connection.

PLCC test socket to 44FOOT-CS adapters include the DA44-PAPF (\$170), which allows easy insertion and removal of a PLCC device. Numbered test pins allow for easy probing of device signals. Additional 44FOOT modules (\$80) let the top socket be used by several prototypes without desoldering.

OEM inquiries welcome. Contact Logical Systems Corp., PO Box 6184, Syracuse, NY 13217-6184, (315) 478-0722, FAX (315) 475-8460.



NEW EDITIONS FROM BAYLIN

Baylin Publications announces the release of new editions to three books. *Ku-Band Satellite TV—Theory, Installation, and Repair*, 4th edition, includes new information on small antennas, DBS systems, trends in satellite designs, and more. This edition also contains helpful appendixes, photographs, and illustrations. It costs \$30.

The 2nd edition of *World Satellite TV and Scrambling Methods: The Technician's Handbook*, by Frank Baylin, Richard Maddox, and John McCormac is available. Revised to include information on duobinary encoding, decoder connections, and broadcast formats, it also offers guidance on troubleshooting, testing, and servicing. All this information is enhanced by illustrations, photos, diagrams, tables, and wiring schematics. It costs \$40.

The Home Satellite TV Installation and Troubleshooting Manual is now in its 3rd edition. Written by Frank Baylin, with contributions by Brent Gale and Ron Long, it is updated to include small dish systems and upgrading existing systems, in addition to its original background theory, methods, and troubleshooting. It costs \$30.

A free catalog on all Baylin Publications is available on request. Include \$3 shipping and handling on each book. Write to Baylin Publications, 1905 Mariposa, Boulder, CO 80302.

LONG OVERDUE MULTI-AMP

World Audio Enterprises introduces the Multi-Amp 1.1 and 1.2, fully documented and designed to professional standards. These high-quality circuit boards contain all the necessary components to realize several op amp applications including differential amp buffer, inverting amp, DAC output, video amps, noninverting amp, and transconductance.

Features offer linear phase circuitry, RF filtering of input, on-board PS filtering, two mounting holes for 4-40 screws, and small size. They are made of a glass epoxy circuit board with copper foil for repairs, 1% metal film resistors, bipolar coupling capacitors bypassed with film types, hi-rel chip socket, and ground plane. They are pin-compatible with MCI tape recorder transformers.

Each one costs \$30; volume discounts are available. Contact World Audio Enterprises, 1550 N. Hayworth St., Suite 4, Los Angeles, CA 90046, (213) 876-9535.

SOLVE POWER PROBLEMS

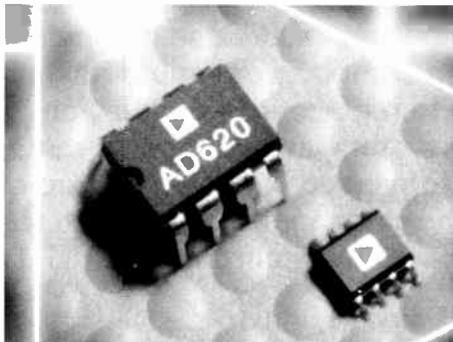
Eastern Time Designs offers Probe 100, a tool to identify and solve power spikes, surges, or sags. Common-mode noise, drop-outs, power failure, HF and wiring noise can be detected and reported in an easy-to-read LED display.

You can leave the Probe 100 plugged in overnight and it will record and store the disturbance events through LED lights that stay lit until you reset them.

A manual accompanies the Probe 100, which costs \$149.95. Contact Eastern Time Designs, 2626 Brown Ave., Manchester, NH 03103, (800) 872-4383.



ELECTRONICS SCENE



AD620 AMP OUTPERFORMS

Analog Devices' AD620 is the first monolithic instrumentation amplifier to outperform traditional discrete designs. It is offered in an 8-pin SOIC or DIP package, saving both space and power. It can be used wherever differential signals must be distinguished from common-mode signals.

The AD620 consumes less than one third the power of the discrete design. Total errors for the AD620 are under 15,000 ppm of full scale for low grades—40% less than the discrete design—and costs only \$3.85 (100s).

Well-suited as a preamp due to low input voltage noise of only $9nV/\sqrt{\text{Hz}}$ at 1kHz, $0.28\mu V$ p-p noise in the 0.1Hz-10Hz band, and $0.1pA/\sqrt{\text{Hz}}$ input current noise. It is specified over the ranges of -40° to $+85^\circ\text{C}$ industrial and -55°C to $+125^\circ\text{C}$ military temperatures.

Contact Analog Devices Inc., 804 Woburn St., Wilmington, MA 01887, (617) 937-2507 for application assistance.

LOW-COST ELECTRONICS PARTS

All Electronics Corporation has been selling surplus electronic parts to amateur and professional electronic enthusiasts for more than two decades. It is a source of low-cost parts often offered by leading suppliers. Much of its merchandise is acquired from one-time items, manufacturer over-runs, discontinued items, or new items that never got off the ground. Exclusive merchandise includes electroluminescent backlights and flash units. These items and hundreds more are featured in a 64-page catalog that is not only revised and published five times a year but is free of charge within the US. For a free catalog, and further information, contact All Electronics Corp., 15004 Oxnard St., Van Nuys, CA 91411, (818) 904-0524, (800) 826-5432, FAX (818) 781-2653.

SCIENTIFIC COMPUTING FOR MAC USERS

MicroMath announces a new line of scientific computing products for the Apple Macintosh. MM Calc offers not only standard math and financial functions but also handles complex numbers, Gaussian numbers, automatic unit calculations, and dimensional analysis. It can work in RPN, perform algebraic expressions, and perform hex calculations, logarithmic and trigonometric functions. This software also offers factoring, modulo, Bessel and gamma functions, and other number theory functions.

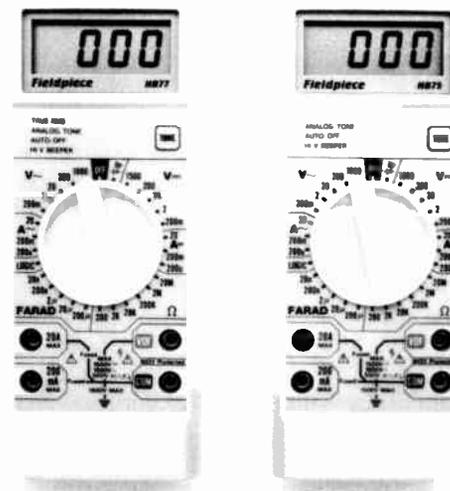
For computer scientists, numbers can be input and viewed in binary, octal, decimal, hexadecimal, and with their corresponding ASCII characters. MM Calc is one of the few calculators for the Mac that fully utilizes SANE with its IEEE compliance. Supporting both mouse and keyboard use, the special introductory price of this \$99 software is \$49.

For further details, contact MicroMath Scientific Software, PO Box 21550, Salt Lake City, UT 84121, (801) 943-0290, FAX (801) 943-0299.

DIGITAL MULTIMETER

Fieldpiece introduces HB75 and HB77, heavy-duty book-style digital multimeters that combine several functions. The HB77 can measure current accurately enough for applications involving power. It has true RMS capabilities with resolution down to $0.1\mu A$ and with a low voltage burden. Both models feature single rotary dials that provide ease of use. The meter displays all the capability on the front aimed directly at field service technicians. All voltage ranges withstand 1500V DC and 1000V AC. All other ranges will withstand 500V AC or DC. The price is \$139.

For details, contact Fieldpiece Instruments, 8322B Artesia Blvd., Buena Park, CA 90621, (714) 992-1239, FAX (714) 992-1239.



MIDI DATA TRANSFER

based on a design by M. Schreiber

More and more musicians make use of musical instruments that are controlled by a computer or keyboard via a MIDI cable. This article proposes to replace that cable by an optical-fibre type. That makes the system less vulnerable to noise signals and increases the top speed of the serial connection to about 60 kbit s⁻¹. The cable may also be used for transferring non-MIDI asynchronous serial data.

DIGITAL techniques have found their way even into the world of music where analogue information is of paramount importance. Inexorably, more and more popular music is being translated into a series of digital commands. MIDI (Musical Instrument Digital Interface) is the keyword for modern musicians. Not only organs, keyboards, and pianos, but also guitars and saxophones are available with the familiar 5-way DIN plug for the MIDI. The interface enables the instrument to receive information about the keys that must be operated, the voices to be used, and the force and speed of the key stroke. The MIDI standard stipulates that the digital information must be interchanged between instruments at a speed of 32.5 kbit s⁻¹.

A MIDI cable usually consists of two cores that together form a current loop. The MIDI protocol does not provide handshaking: all data are presented by the transmitter and processed by the receiver asynchronously. The data, which are transferred from transmitter to receiver more or less continuously, normally contain, apart from a status byte, one or more data bytes.

Because of the simple design of the serial connection, it is fairly simple to replace the current loop by an optical link. The block schematic of a typical system so modified is shown in Fig. 2. Electrical digital signals are transformed by the E-O (electrical-to-optical) converter into light pulses that can be transmitted over fairly long distances via an optical conductor. In that conductor, the signals lose their sharp corners, but, because of the digital nature of the information, that does not affect the information itself, unless the link is long. The O-E (optical-to-electrical) converter in the receiver transforms the light back to electrical signals at their original quality.

The application of the circuit need not be restricted to the transfer of MIDI signals: it may just as well be used with other links operating at up to 60 kbit s⁻¹. A few that jump to mind are its inclusion in a data acquisition system that transmits serial data and as a primitive connection to a printer. Thanks to the optical-fibre cable, data are not or hardly mutilated even under

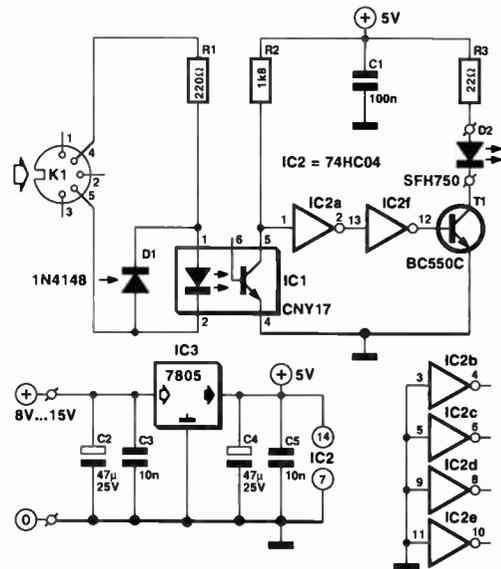
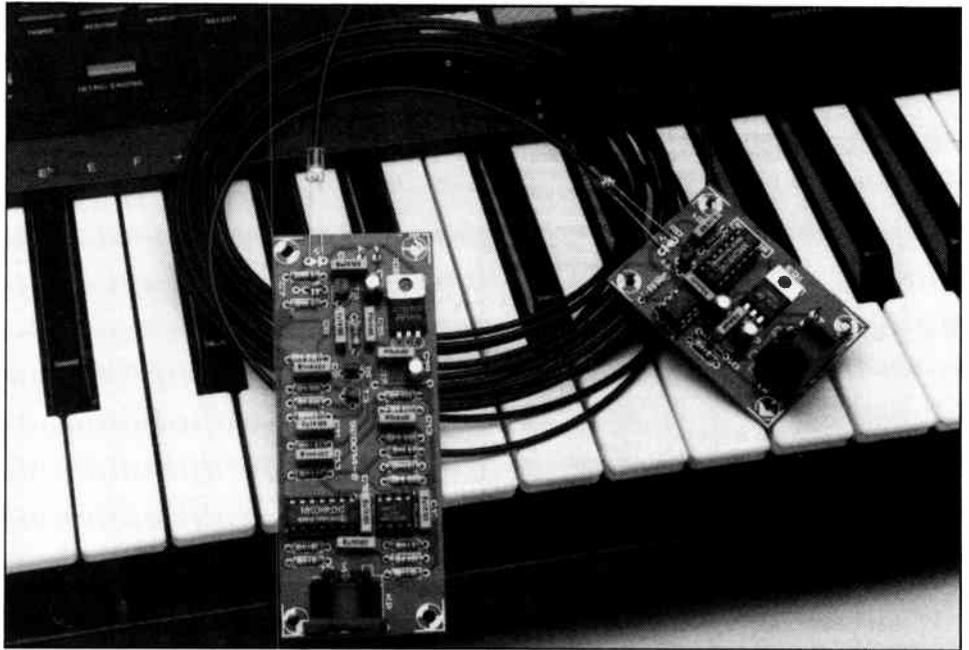


Fig. 1. Circuit diagram of the transmitter.

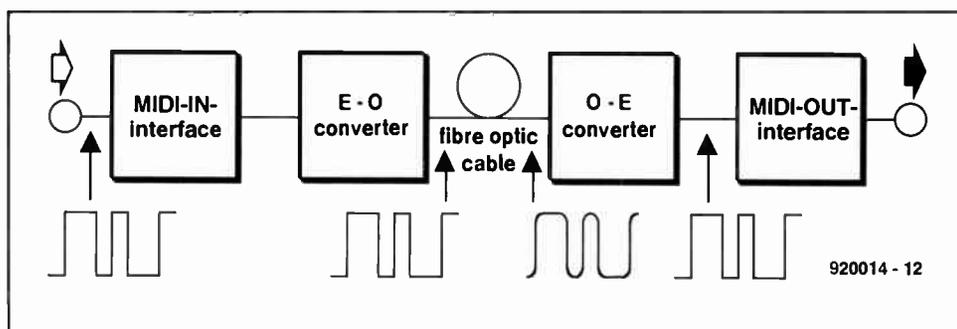


Fig. 2. Block schematic of typical system modified as described.

the most arduous operating conditions.

The electronics

The circuit of the transmitter is shown in Fig. 1 and that of the receiver in Fig. 3. The electrical information is applied to pins 2 and 4 of connector K_1 . The current flowing in the current loop ensures that the LED in optoisolator IC_1 lights. In case of a logic 0 (negative logic on the MIDI bus), the current is limited to about 5 mA by R_1 .

Because of the current pulses, the phototransistor in IC_1 conducts and changes the input level of inverter IC_{2a} in step with these pulses.

The signal is buffered and enhanced by IC_{2a} and IC_{2f} and then converted to an optical signal by transmit diode D_2 in the collector circuit of T_1 . The current through D_2 is limited by R_3 . This diode is of a type specially designed for straightforward connection to an optical-fibre cable. The 2.2 mm thick cable fits exactly into the hollow pro-

vided in the diode.

In the receiver, p-i-n diode D_3 has a similar hollow to receive the optical-fibre cable. The frequency range over which the diode remains usable is maximized by the negative bias obtained by connecting the cathode to the positive supply rail.

The sensitivity of the diode is determined by series resistor R_5 . The value of this resistor should not be too high, otherwise the resulting integrating action will adversely affect the properties of the receiver.

High-pass filter R_6 - C_7 suppresses noise and other spurious signals below 50 Hz. Its output is buffered and amplified by T_2 , and then amplified again ($\times 10$) by cascode circuit T_3 - T_4 . The advantage of a cascode circuit is that it virtually nullifies the Miller (base-collector) capacitance of the transistors, thereby yielding a wide frequency range. The Miller capacitance normally restricts the frequency range when the transistor operates as a voltage amplifier. Here, since the collector of amplifier T_4 is coupled to the

earthed base circuit of T_3 (very low input impedance), the Miller capacitance of T_4 is largely neutralized.

The design of the cascode circuit enables reliable reception of signals over optical-fibre cables up to 30 m (98 ft) long.

The output of T_3 - T_4 is applied to comparator IC_4 . This stage requires two reference voltages to convert this analogue output into digital signals. Resistor R_{14} serves to improve the common-mode rejection of the IC to ensure that the comparator switches reliably even when the level differences are small.

Since IC_4 has an open-collector output, a resistor, R_4 , is required from this output to the positive supply line. The value of this resistor determines the transition durations of the signal. With the value shown (1 k Ω), these durations are 400 ns: they should be short compared with the period of the signal.

The output signal of IC_4 is fed to the customary MIDI consisting of gates IC_{5e} and IC_{5f} ; resistors R_{20} and R_{21} determine the current flowing in the MIDI loop.

Construction & testing

The transmitter-receiver is best constructed on the printed-circuit board shown in Fig. 6. Before construction is started, however, this board should be cut into two.

Points to watch are the wire link on the transmitter board and the polarity of the electrolytic capacitors and diodes. If you are not a dyed-in-the-wool constructor, use sockets for the ICs to be on the safe side.

Connectors K_1 and K_2 are 5-way DIN types which are standard for interconnections in MIDI systems.

There are various types of transmit and receive diode that can be used—see Fig. 4. Those used in the prototype (and given in the Parts list) can be mounted directly on to the PCB. There are, however, other possibilities. For instance, Fig. 4 shows diodes integrated in a housing, to which the optical-fibre cable is fitted, that can be mounted directly on to the enclosure of the transmitter and the receiver. This type is connected to the PCB via two short lengths of wire. There are yet other types available: see the various mail order catalogues or ask your local retailer.

To test the transmitter and receiver, a function generator is required that can provide a square-wave voltage at a frequency of about 30 kHz and at a level of around 3 V_{pp}. Apply that signal and the generator earth to pins 4 and 2 of K_1 respectively and switch on the transmitter and receiver, whereupon the transmit LED should light. If an oscilloscope is available, check that the signal appears at the receiver output (assuming, of course, that the transmitter and receiver are interlinked by an optical-fibre cable). If these test instruments are not to hand, try the system in practice.

The absence of a power supply in the transmitter and receiver is deliberate: after all, most electrophonic instruments use 12 V supply lines so that 12 V will be available

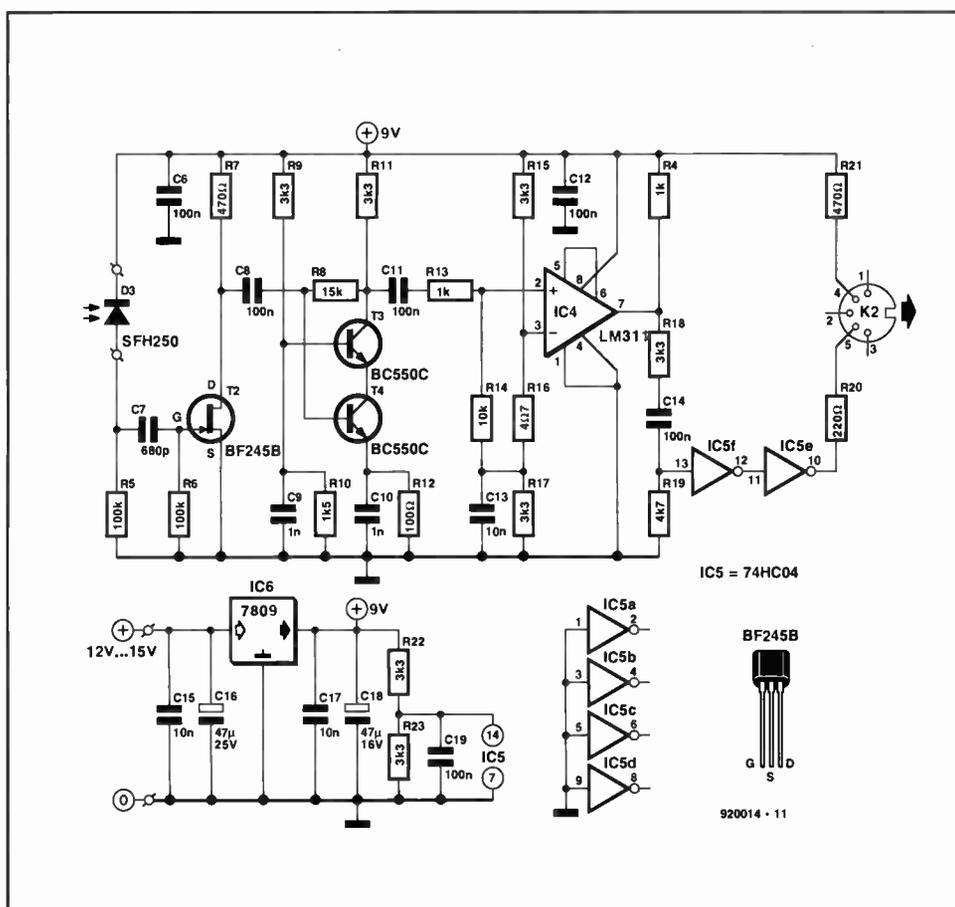


Fig. 3. Circuit diagram of the receiver.

somewhere. If that is not so, use a standard 12 V mains adaptor.

Finally

The design of the receiver provides compensation for signal losses of up to 30 dB. As available optical-fibre cables have an

attenuation of about 0.3 dB m^{-1} , a distance of up to 30 m between transmitter and receiver can be spanned. Since the system is broad-band, it can handle signals at a considerably higher transmission speed (up to 60 kbit s^{-1}) than encountered in MIDI systems.

If the amplification of the cascode stage

is increased by reducing the value of R_{12} , it becomes possible to work over even greater distances. Note, however, that dispersion may then degrade the pulse width: a phenomenon that is particularly noticeable in multi-mode cables. ■

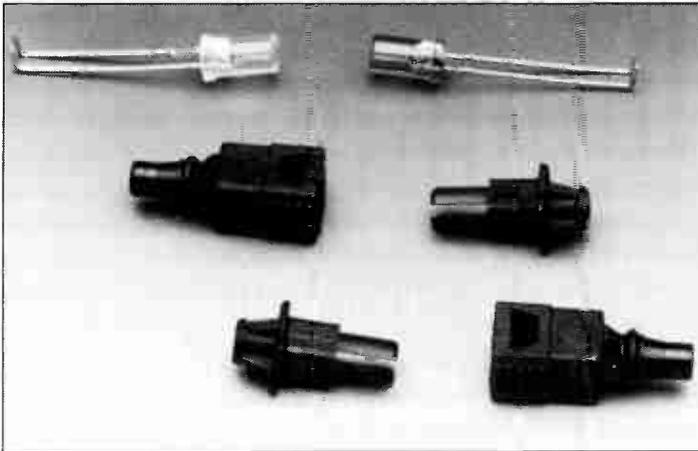


Fig. 4. Various transmit and receive diodes are available.

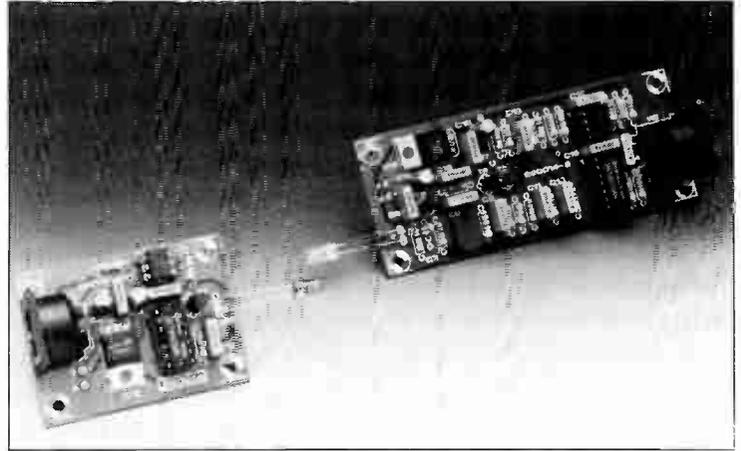


Fig. 5. The completed transmitter and receiver units.

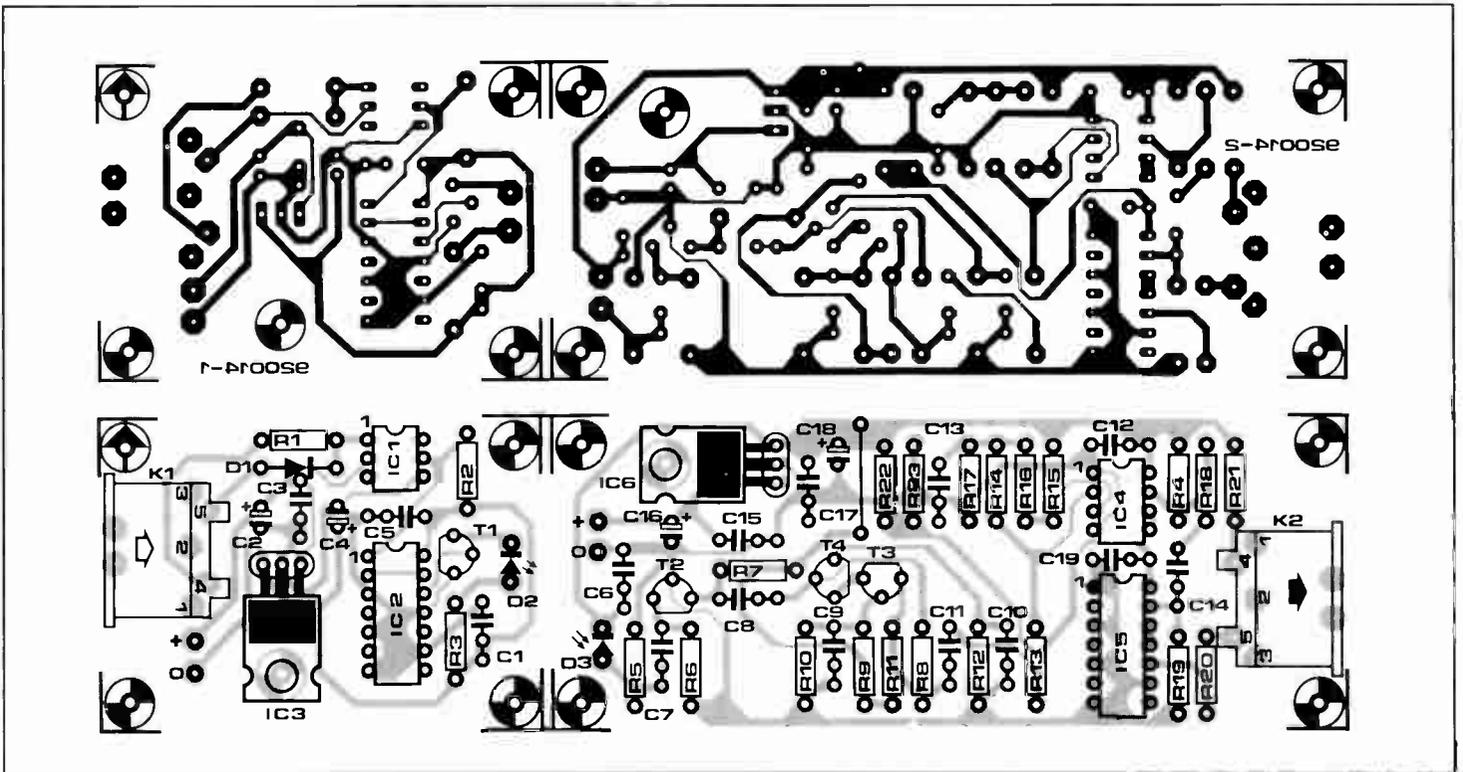


Fig. 6. The printed circuit board for the transmitter and receiver should be cut into two before construction is begun.

PARTS LIST

Resistors:

R1 = 220 Ω
 R2 = 1.8 k Ω
 R3 = 22 Ω
 R4, R13 = 1 k Ω
 R5, R6 = 100 k Ω
 R7, R21 = 470 Ω
 R8 = 15 k Ω
 R9, R11, R15, R17, R18, R22,
 R23 = 3.3 k Ω
 R10 = 1.5 k Ω
 R12 = 100 Ω
 R14 = 10 k Ω

R16 = 4.7 Ω
 R19 = 4.7 k Ω
 R20 = 220 Ω

Capacitors:

C1, C6, C8, C11, C12, C14,
 C19 = 100 nF
 C2, C4, C16, C18 = 47 μF , 16 V, radial
 C3, C5, C13, C15, C17 = 10 nF
 C7 = 680 pF
 C9, C10 = 1 nF

Semiconductors:

D1 = 1N4148
 D2 = SFH750

D3 = SFH250
 T1, T3, T4 = BC550C
 T2 = BF245B
 IC1 = CNY17
 IC2, IC5 = 74HC04
 IC3 = 7805
 IC4 = LM311P
 IC6 = 7809

Miscellaneous:

K1, K2 = 5-way DIN socket for PCB mounting
 PCB Type 920014

THE FLAT-TOP 80 ANTENNA

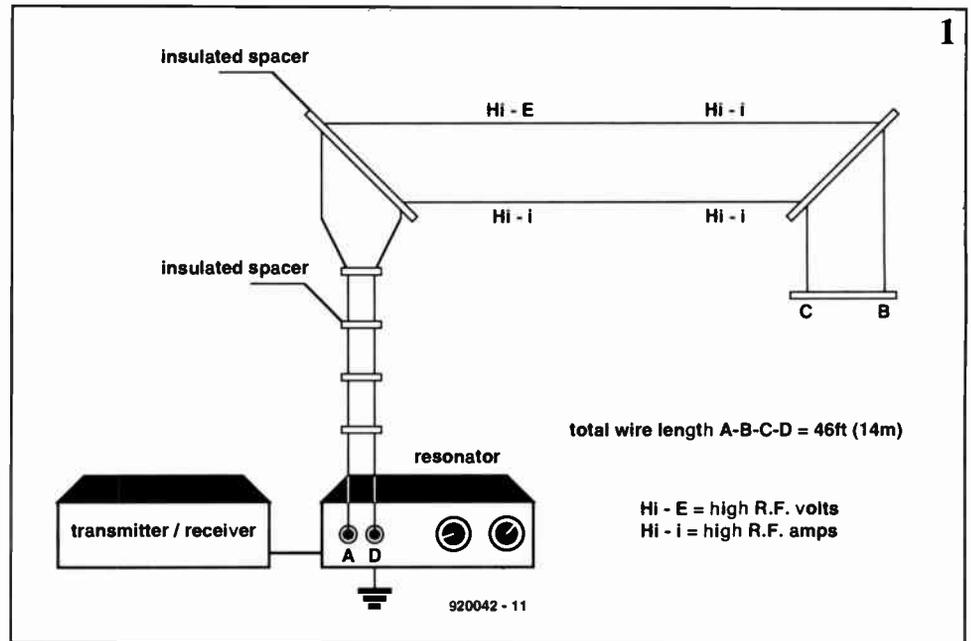
An experimental design with the apartment dweller in mind

by Richard Q. Marris, G2 BZQ

OLDER readers will remember the original flat-top antennas of the 1920s, 30s and 40s festooning battleships and other warships, ocean-going passenger and cargo vessels, and various military and civil trans-world wireless telegraphy beam stations. Alas, historically speaking, only a few remain.

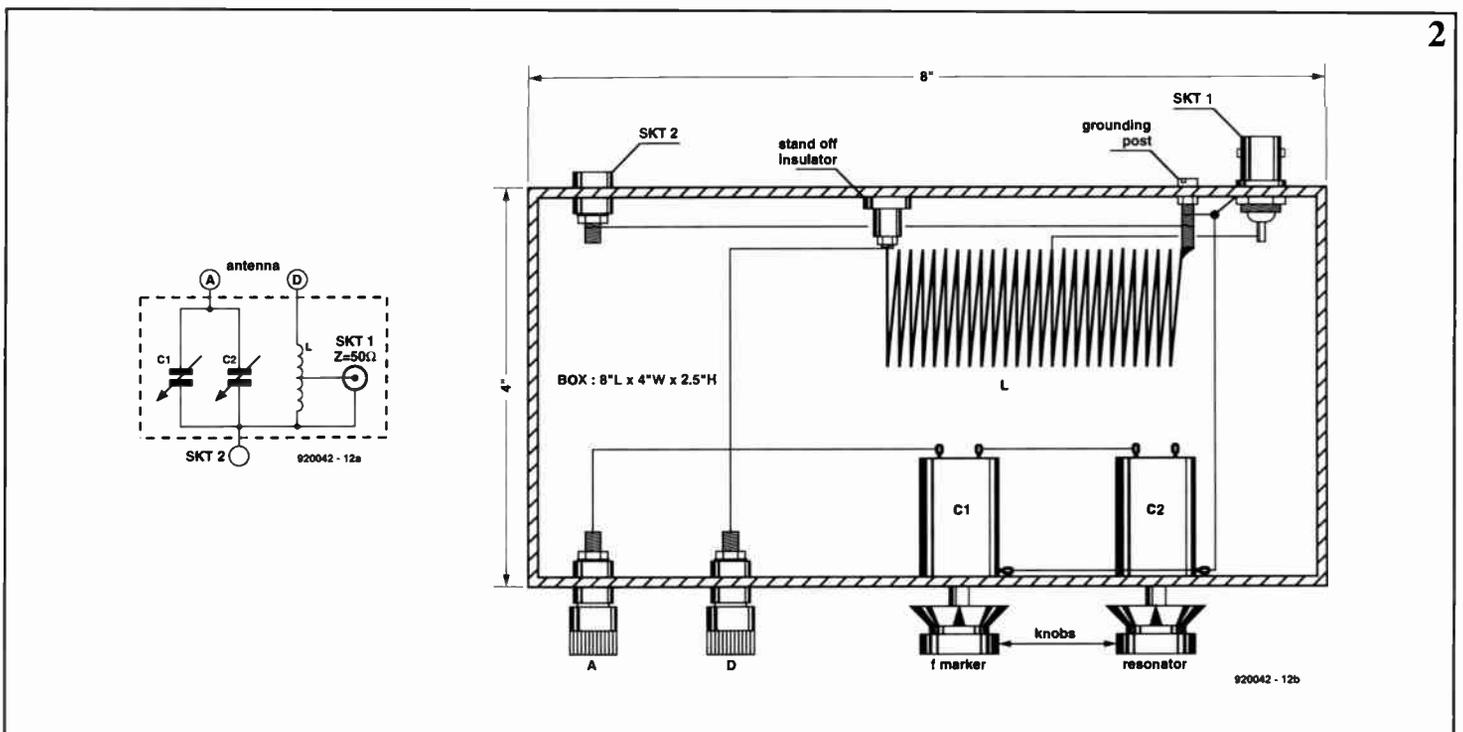
The original flat-tops, back in the early days of wireless, consisted of two or more parallel spaced horizontal wires with spreaders supported between two or more tall masts. They were usually, but not always, end-fed or T-fed by downloads descending from each wire and joined together and end-fed from the transmitter.

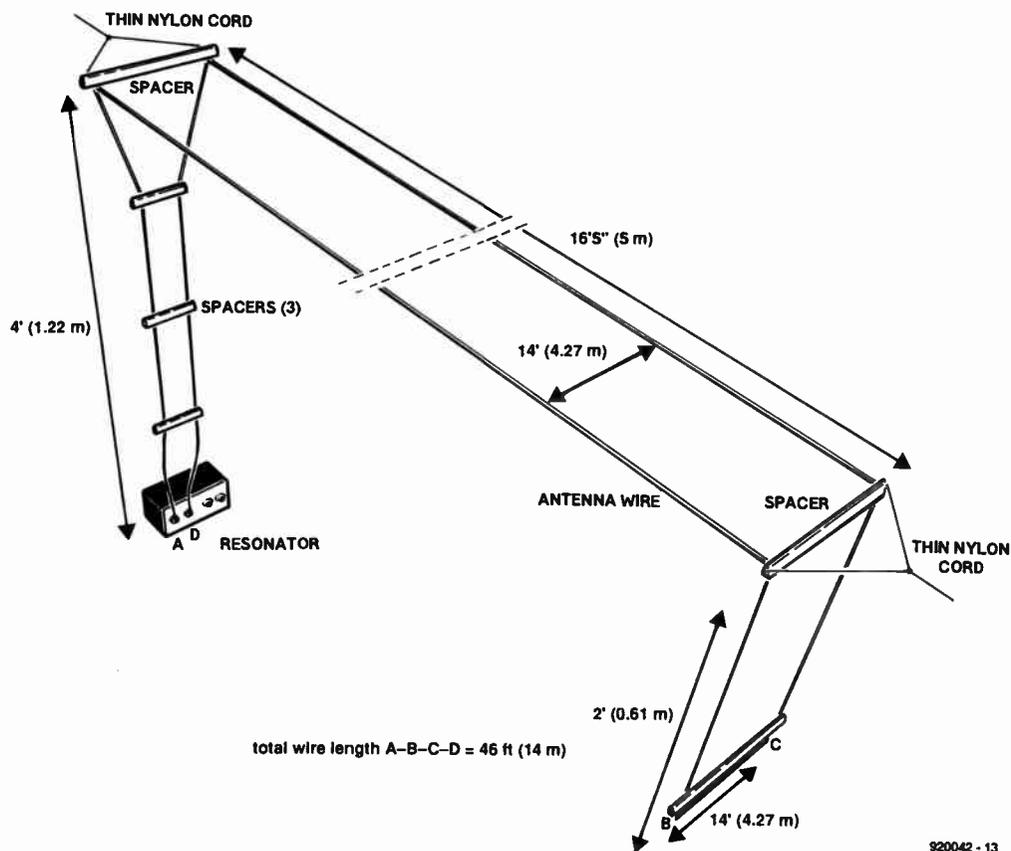
The Flat-top 80 described here has the appearance of an old-time flat-top, but is much smaller and electrically different in as much as it consists of two spaced horizontal wires folded back in series, with the resulting two ends connected to a resonator unit enabling it to be tuned to the operating frequency (here, the 80-meter or 3.5 MHz band)—see Fig. 1. It has been designed experimentally for the 3.5 MHz band for indoor use, in an apartment, where normal, full-size antennas are not a practical proposition. It can, of course, be adapted for use in other indoor situations or in a postage-stamp-sized outdoor back garden. The principle can also be used on other bands. Hopefully, it will encourage other experimenters to adapt the design to their particular needs and situations. After all, it is easy to use and produces quite acceptable results.



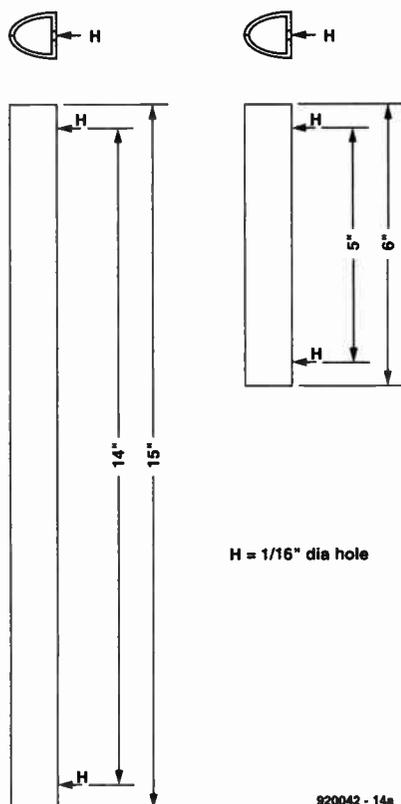
The simple configuration of the Flat-top 80 is shown in Fig. 1 and the novel resonator unit in Fig. 2. The two ends of the Flat-top arrive in parallel at the resonator input terminal posts. One down-lead is connected to loading coil L , which is tapped to form a correct 50 Ω impedance match to the RG58 coaxial feed-line connected to the transmitter/receiver. The other end is connected to two parallel variable capacitors, C_1 and C_2 , which tune the

antenna: C_1 is a frequency marker and C_2 is the fine resonator control. For low power transmission, these capacitors should be ceramic-framed, air-spaced variable types such as the Jackson C809 or similar. Arrangements are also made for a socket, SKT₂, to which an optional ground or earth connection can be made. Few apartments, or other in-house locations, have a satisfactory RF ground available, but a nearby metal water piper may

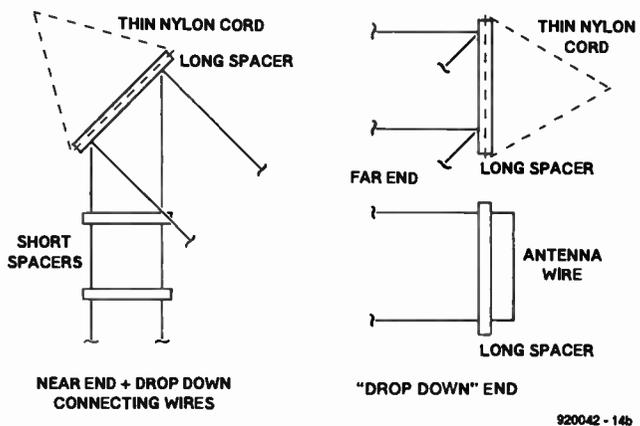




4a



4b



well suffice. DO NOT CONNECT THE AC MAINS TO SKT₂! Note that the Flat-top 80 will work equally well with or without a ground connection.

If the Flat-top 80 is erected indoors, in the interest of domestic household safety, only low RF transmitting power should be used. The writer uses 5–10 watts CW transmitter output and achieves quite satisfactory result.

Construction

The antenna.

Figure 3 shows the construction of the antenna, which consists of a total of 46 ft (14 m) white PVC covered 7/0.2 mm stranded wire. The insulated spacers, shown in Fig. 4, are made of white plastic sprung edging strip obtainable from most DIY stores. White was used throughout for spacers and wire since it is inconspicuous against a white ceiling. Thin white nylon cord supports the end of the Flat-top 80 diagonally across the room.

Three 15 in (38 cm) and three 6 in (15 cm) long spacers are cut as shown in Fig. 4; in each of these, two 1/16 in (1.5 mm) holes are drilled 1/2 in (12.5 mm) inside the ends as shown (H).

Commencing at one end, the wire is fed through the 1/16 in holes in the three short and the three long spacers (Fig. 3 and Fig. 4). The sprung plastic spacers securely grip the wire. The spacers are next adjusted by sliding them along the wire to form the lengths shown in Fig. 3. Thin nylon cord is fed through the two end spacers of the horizontal section (Fig. 4) and fastened to hooks in the diagonal corners of the room, leaving the 4 ft (1.22 m) drop down to the resonator and the 2 ft (61 cm) down at the far end. At this stage, the spacers can be moved slightly on the wires to balance up the assembly.

If there is not sufficient space for the 16 ft 5 in (5 m) flat-top horizontal section, it can be shortened as required, but the length of the far-end drop-down section should be increased pro-rata—more about this later.

The resonator

The prototype resonator—see Fig. 2—was built into an aluminium box 8 in (20 cm) long by 4 in (10 cm) wide by 2.5 in (6.5 cm) high. The box was a double U shape with the front, bottom and back made from one piece of aluminium. The inverted U cover slips over this.

The size of the box is not very important, as long as good clearance is provided for coil *L*, which consists of 19 one-inch (25 mm) dia. turns of 16 SWG (1.6 mm dia) tinned copper wire with the turns spaced about 3/32 in (2.5 mm). The impedance matching tap on the prototype was located 10.75 turns up from the bottom end.

The coil was supported by a 1 in ceramic stand-off insulator at one end and at the other by the common grounding post formed by a thin 1.25 in (30 mm) long brass screw. Coaxial socket SKT₁ and banana socket SKT₂ are fitted at either end of the back as shown.

Variable capacitors *C*₁ and *C*₂ are fitted directly to the front panel. Though the rotor plates are obviously connected to the front panel, a wire is also taken from them to the

common grounding post to reduce possible RF losses.

To bring the twin spaced down-leads of the antenna through the front panel, it is necessary to fit robust, well-insulated terminal posts or sockets. In the prototype, Archer 1.75 in (4.5 mm) nylon binding posts (Tandy/Radio Shack Type 274-662) were used. Internal unit wiring was in 16 SWG (1.6 mm dia) tinned copper wire with securely wrapped and soldered joints to keep potential RF losses to an absolute minimum.

Testing & operation

Assuming that the transmitter has a pi-network output, the resonator can be connected directly to the transmitter output socket ($Z=50\Omega$) via a few inches of RG58 coaxial cable. If the transmitter does not have a pi-network output, a good T-network transmatch should be inserted in the cable between resonator and transmitter.

The resonator will cover the entire 3.5–3.8 MHz (up to 4.0 MHz in some countries) band. This can be checked in the first instance with the receiver with *C*₂ set to minimum capacitance and *C*₁ set to 3.8 MHz (or, where appropriate, to 4.0 MHz). Rotation of *C*₂ then covers the whole band down to 3.5 MHz.

The impedance matching tap on coil *L* was earlier stated to be at 10.75 turns up from the common grounding post. As individual installations may vary slightly, the tap should be tried at one or two turns higher or lower to obtain minimum SWR (standing-wave ratio). On the prototype, no measurable harmonic radiation was detected, nor any TVI with the rod aerial of a portable TV close to the flat-top.

In operation, the usable bandwidth is about 60 kHz, which can be moved up or down the band with minimum adjustment of resonator control *C*, without touching frequency

marker *C*₁ which can be locked once set. It was found that it was worth while trying to reverse the twin down-leads at the terminal posts, since radiation from the flat-top is slightly higher from the high-*i* limb—see Fig. 1.

The Flat-top 80 is quite amenable to adaptation to fit the space available. Assuming it is installed indoors, it should be slung diagonally across the room with the transmitter-receiver in the corner. The dimensions shown in Fig. 3 are as used on the prototype. However, the length of the flat-top can be reduced to about 12 ft 5 in (3.8 m) if the far-end drop-down leads are increased to about 6 ft (1.8 m) or some similar arrangement. There is plenty of scope for experiment.

If the Flat-top 80 is to be used outdoors, the twin down leads should arrive at the window with the resonator located just inside. Outdoors, of course, a higher power is permissible, but it will be necessary to make the 15 in and 6 in (38 cm and 15 cm) spacers of more rigid insulating material, and, perhaps, insert a few more spacers along the flat-top. If higher power is used, a higher working voltage may be required for *C*₁ and *C*₂, and possibly a thicker gauge of PVC covered wire. Experiment is the life blood of amateur radio . . . ■

Useful reading

Antennas, 2nd Edition, by Dr. John D. Kraus (McGraw-Hill).

and if you're lucky enough to have or find a copy:

The Admiralty Handbook of Wireless Telegraphy 1938

Handbook of Technical Instruction for Wireless Telegraphists, 7th Edition, 1942, by H.M. Dowsett & L.E.Q. Walker.



AF DRIVE INDICATOR

Design by T. Giesberts

A universal drive indicator is described that can be used with virtually any AF output amplifier. It indicates precisely when the -3 dB cut-off point and the clipping level of the amplifier are exceeded.

THE idea for the indicator arose during the development of the Class-A power amplifier¹⁾. That amplifier delivers 25 W into 8 Ω in Class A or 50 W in Class B. The 3 dB difference between these two levels seemed an excellent starting point for the design of a drive indicator that, with the aid of two LEDs, would show the -3 dB point and the point at which clipping would set in. That gives an indication as to if and when there is power in reserve; moreover, the -3 dB LED will indicate when the transition from Class A to Class B takes place.

Nevertheless, the final design of the indicator is such that it can be used with any power amplifier operating from a symmetrical power supply of ± 30 –70 V. A -3 dB indicator is, of course, also very useful with Class-AB amplifiers, because the difference in sound pressure corresponding to a change

of 3 dB in output power cannot be heard (in many cases, it is just *loud*).

As long as the -3 dB LED lights and the 0 dB (clipping) LED does not, the output is free of overdrive distortion. When the clipping LED lights, however, the output contains a great number of harmonics. The present indicator is, therefore, recommended for use with any power amplifier not provided with a drive indicator.

Circuit description

Although the circuit in Fig. 1 appears rather larger than expected, a glance at Fig. 2 shows that all the components fit readily on a fairly small printed-circuit board.

The monitoring section of the circuit consists of two pairs of comparators contained in a single LM339. That IC is not very fast,

but fast enough for the present application. Its major advantage is that it draws only a tiny current, which is important in view of the fact that the indicator is intended for use with a large range of supply voltages.

One input of each comparator is connected to a potential divider, R₃–R₈, which provides the various reference voltages. Since the divider is connected directly to the supply voltage of the power amplifier via zener diodes D₁ and D₃, the switching levels of the comparators are adapted automatically to that supply voltage.

The two 2.7 V zener diodes at the ends of the divider serve to compensate the knee voltage that, with full drive to the output amplifier, remains across the power transistors and associated emitter resistors. This causes the clipping LED to light just before the actual clipping level is reached. In MOS-

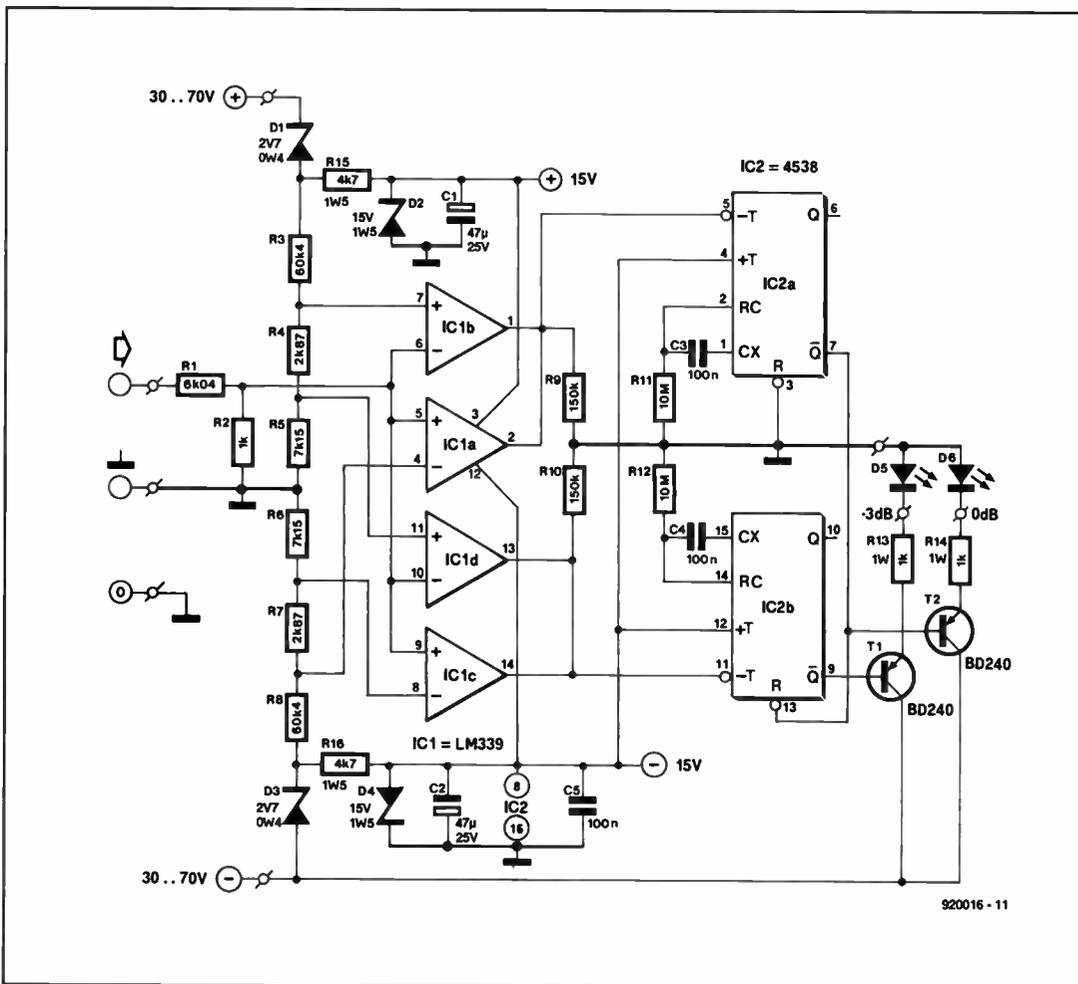


Fig. 1. Circuit diagram of the AF drive indicator.

PARTS LIST

Resistors:

- R1 = 6.04 kΩ, 1%
- R2 = 1 kΩ, 1%
- R3, R8 = 60.4 kΩ, 1%
- R4, R7 = 2.87 kΩ, 1%
- R5, R6 = 7.15 kΩ, 1%
- R9, R10 = 150 kΩ
- R11, R12 = 10 MΩ
- R13, R14 = 1 kΩ, 1 W
- R15, R16 = 4.7 kΩ, 1.5 W

Capacitors:

- C1, C2 = 47 μF, 25 V, radial
- C3, C4, C5 = 100 nF

Semiconductors:

- D1, D3 = zener, 2.7 V, 400 mW (see text)
- D2, D4 = zener, 15 V, 1.5 W
- D5 = LED, 3 mm, not red
- D6 = LED, 3 mm, red
- T1, T2 = BD240
- IC1 = LM339
- IC2 = 4538

Miscellaneous:

- PCB Type 920016

¹⁾ *Elektor Electronics* November-December 1991.

FET output amplifiers in a source-follower configuration, it is usually necessary to use 10–12 V zener diodes because of the much higher quiescent voltage across MOSFET devices. To be on the safe side, measure the maximum output voltage across the nominal load and choose correspondingly rated zener diodes.

The input signal to the indicator, that is, the output of the power amplifier, is applied across potential divider R_1 – R_2 . The resulting attenuation of the signal is necessary to prevent the inputs to the comparators exceeding 10 V. With values shown, the circuit is suitable for use with power amplifiers rated up to 300 W into 8 Ω .

The output of IC_{1d} toggles (changes state) when the half-power level (equivalent to 0.707 of the peak output voltage) is exceeded in the positive half period of the signal. The output of IC_{1c} toggles when the half-power level in the negative half period of the signal is exceeded.

When full power level is reached in the positive half-period, the output of IC_{1b} toggles. Similarly, when the full power level is reached in the negative half period, the output of IC_{1a} changes state.

In this way, an accurate indication is obtained of a power excess in the positive as well as in the negative half period of the signal.

The (open-collector) outputs of IC_{1d} and IC_{1c} , and those of IC_{1a} and IC_{1b} , are interconnected in parallel. Each linked pair is connected to a monostable, IC_{2a} and IC_{2b} respectively. These multivibrators ensure that

short pulses emanating from the comparators are stretched sufficiently to guarantee a reasonably long lighting time of the LEDs. Their mono period is set to 1 second (time constants R_{11} – C_3 and R_{12} – C_4).

The LEDs are connected to the \bar{Q} outputs of IC_{2a} and IC_{2b} via switching transistors T_1 and T_2 . Combinations T_1 – R_{13} and T_2 – R_{14} form current sources, because the \bar{Q} outputs of the monostables switch neatly between 0 V and –15 V, irrespective of the output amplifier power supply. Consequently, the current drawn by the diodes—about 15 mA per diode—need not be regulated.

To recap the switching operation: when the reference level of one of the comparators is exceeded, the output of that comparator goes low. The resulting (negative) transition triggers the $-T$ input of the relevant monostable, whose \bar{Q} output (high during quiescent operation) thereupon becomes 0 for 1 s (mono period). The transistor connected to that output is switched on and the associated LED lights.

The \bar{Q} output of IC_{2a} and the reset input of IC_{2b} are interlinked to ensure that when the 0 dB LED lights, IC_{2b} is reset and the –3 dB LED goes out. At any one time, therefore, only one of the LEDs can light.

The supply for the ICs is derived from the power amplifier supply via R_{15} and R_{16} and regulated by D_2 and D_4 . Because IC_1 draws only a small current, the diode current is a mere 2.5 mA. That is sufficient to ensure correct operation and low dissipa-

tion in R_{15} and R_{16} , even with high supply voltages in the power amplifier.

Construction

The printed-circuit board—see Fig. 2—is small enough to be fitted in almost any power amplifier. Note that the board must be cut into two if the indicator is to be used with mono amplifiers or stereo amplifiers with split power supplies. The indication remains correct, even when the supply voltage for one channel drops temporarily owing to a high drive level. The board can, of course, be left intact when used with a stereo amplifier.

Virtually all components are mounted upright. Start with placing the wire links between IC_1 and IC_2 . The ICs may be inserted in appropriate sockets, but that is not essential.

In view of their dissipation, mount R_{13} – R_{16} a little above the board.

The connections to the power amplifier consist of three wires to its power supply, for instance, +, 0 and –, which are usually within easy (soldering) reach, and a single-core screened wire between each loudspeaker terminal (after the relay) and each indicator input. Earth the screen of the latter cable only on the indicator board (beside the input terminal). DO NOT CONNECT THE 0 AND EARTH LINES WITH THE AMPLIFIER BECAUSE THAT CREATES A (POTENTIALLY DEGRADING) EARTH LOOP.

If at all possible, place the board directly behind the front panel of the amplifier so that the LEDs can be seen through two small holes (to be drilled). Otherwise, the two LEDs can be fitted behind the front panel and the PCB elsewhere: interconnection between them is by simple circuit wire, whose length is not critical. ■

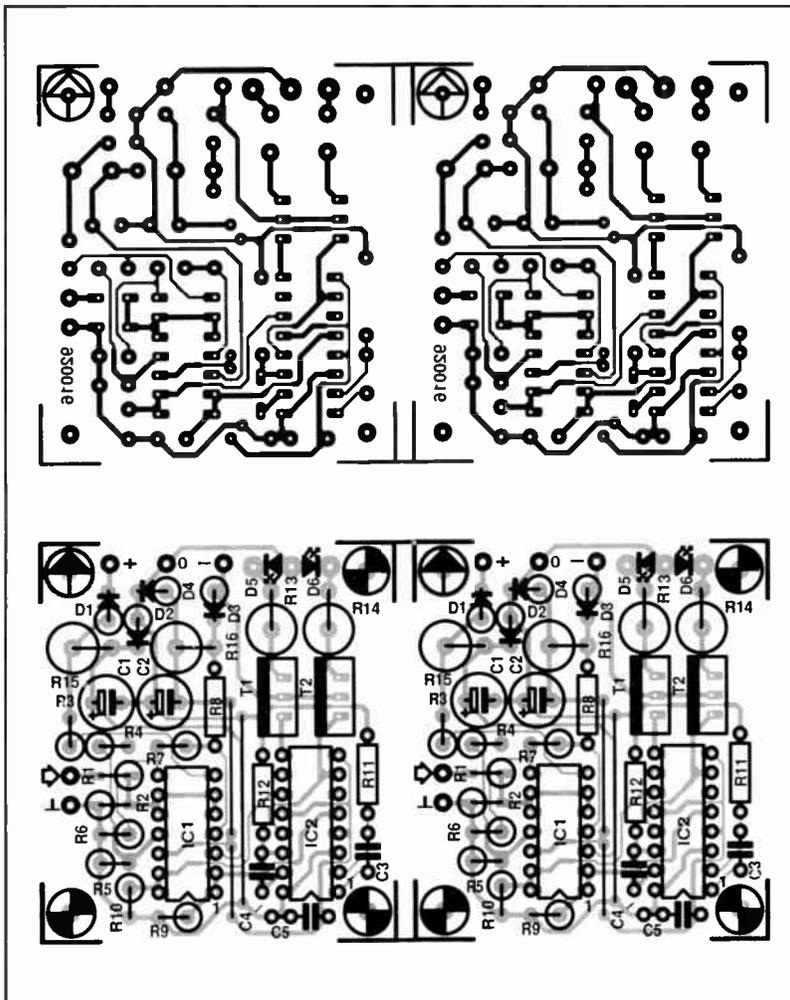


Fig. 2. Printed-circuit board for the AF drive indicator.

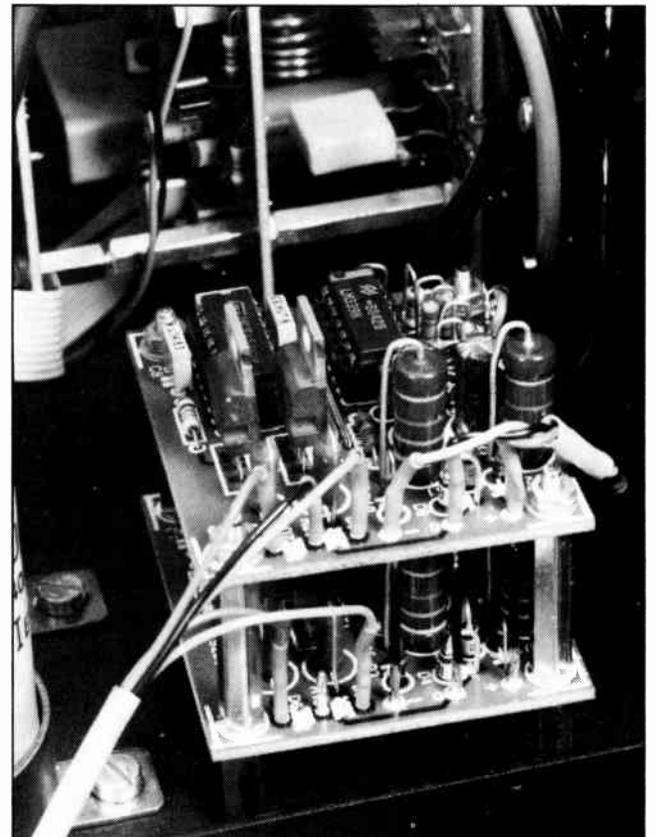


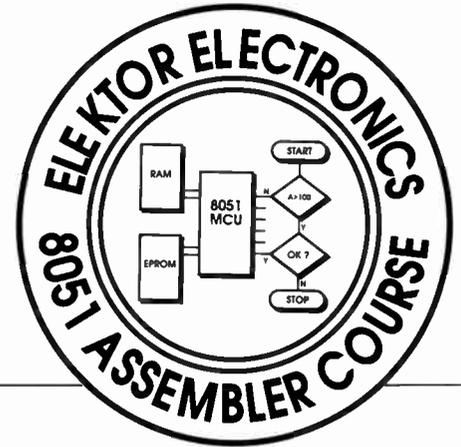
Fig. 3. One way of fitting the drive indicator in the power amplifier.

8051/8032 ASSEMBLER COURSE

PART 2: FIRST 8051 INSTRUCTIONS

by Dr. M. Ohsmann

Following last month's introduction to the course, we are now well armed and ready to discuss the first instructions of the 8051 family of microcontrollers. At the same time, addressing methods are tackled, all with the aid of the programming examples and other utilities contained on the course diskette.



ARITHMETIC OPERATIONS

| Mnemonic | Description | Byte | Cyc |
|---------------|---|------|-----|
| ADD A,Rn | Add register to Accumulator | 1 | 1 |
| ADD A,direct | Add direct byte to Accumulator | 2 | 1 |
| ADD A,@Ri | Add indirect RAM to Accumulator | 1 | 1 |
| ADD A,#data | Add immediate data to Accumulator | 2 | 1 |
| ADDC A,Rn | Add register to Accumulator with Carry | 1 | 1 |
| ADDC A,direct | Add direct byte to A with Carry flag | 2 | 1 |
| ADDC A,@Ri | Add indirect RAM to A with Carry flag | 1 | 1 |
| ADDC A,#data | Add immediate data to A with Carry flag | 2 | 1 |
| SUBB A,Rn | Subtract register from A with Borrow | 1 | 1 |
| SUBB A,direct | Subtract direct byte from A with Borrow | 2 | 1 |
| SUBB A,@Ri | Subtract indirect RAM from A w. Borrow | 1 | 1 |
| SUBB A,#data | Subtract immedi. data from A w. Borrow | 2 | 1 |
| INC A | Increment Accumulator | 1 | 1 |
| INC Rn | Increment register | 1 | 1 |
| INC direct | Increment direct byte | 2 | 1 |
| INC @Ri | Increment indirect RAM | 1 | 1 |
| DEC A | Decrement Accumulator | 1 | 1 |
| DEC Rn | Decrement register | 1 | 1 |
| DEC direct | Decrement direct byte | 2 | 1 |
| DEC @Ri | Decrement indirect RAM | 1 | 1 |
| INC DPTR | Increment Data Pointer | 1 | 2 |
| MUL AB | Multiply A & B | 1 | 4 |
| DIV AB | Divide A by B | 1 | 4 |
| DA A | Decimal Adjust Accumulator | 1 | 1 |

LOGICAL OPERATIONS

| Mnemonic | Destination | Byte | Cyc |
|------------------|---|------|-----|
| ANL A,Rn | AND register to Accumulator | 1 | 1 |
| ANL A,direct | AND direct byte to Accumulator | 2 | 1 |
| ANL A,@Ri | AND indirect RAM to Accumulator | 1 | 1 |
| ANL A,#data | AND immediate data to Accumulator | 2 | 1 |
| ANL direct,A | AND Accumulator to direct byte | 2 | 1 |
| ANL direct,#data | AND immediate data to direct byte | 3 | 2 |
| ORL A,Rn | OR register to Accumulator | 1 | 1 |
| ORL A,direct | OR direct byte to Accumulator | 2 | 1 |
| ORL A,@Ri | OR indirect RAM to Accumulator | 1 | 1 |
| ORL A,#data | OR immediate data to Accumulator | 2 | 1 |
| ORL direct,A | OR Accumulator to direct byte | 2 | 1 |
| ORL direct,#data | OR immediate data to direct byte | 3 | 2 |
| XRL A,Rn | Exclusive-OR register to Accumulator | 1 | 1 |
| XRL A,direct | Exclusive-OR direct byte to Accumulator | 2 | 1 |
| XRL A,@Ri | Exclusive-OR indirect RAM to A | 1 | 1 |
| XRL A,#data | Exclusive-OR immediate data to A | 2 | 1 |
| XRL direct,A | Exclusive-OR Accumulator to direct byte | 2 | 1 |
| XRL direct,#data | Exclusive-OR immediate data to direct | 3 | 2 |
| CLR A | Clear Accumulator | 1 | 1 |
| CPL A | Complement Accumulator | 1 | 1 |
| RL A | Rotate Accumulator Left | 1 | 1 |
| RLC A | Rotate A Left through the Carry flag | 1 | 1 |
| RR A | Rotate Accumulator Right | 1 | 1 |
| RRC A | Rotate A Right through Carry flag | 1 | 1 |
| SWAP A | Swap nibbles within the Accumulator | 1 | 1 |

DATA TRANSFER

| Mnemonic | Description | Byte | Cyc |
|-------------------|--|------|-----|
| MOV A,Rn | Move register to Accumulator | 1 | 1 |
| MOV A,direct | Move direct byte to Accumulator | 2 | 1 |
| MOV A,@Ri | Move indirect RAM to Accumulator | 1 | 1 |
| MOV A,#data | Move immediate data to Accumulator | 2 | 1 |
| MOV Rn,A | Move Accumulator to register | 1 | 1 |
| MOV Rn,direct | Move direct byte to register | 2 | 2 |
| MOV Rn,#data | Move immediate data to register | 2 | 1 |
| MOV direct,A | Move Accumulator to direct byte | 2 | 1 |
| MOV direct,Rn | Move register to direct byte | 2 | 2 |
| MOV direct,direct | Move direct byte to direct | 3 | 2 |
| MOV direct,@Ri | Move indirect RAM to direct byte | 2 | 2 |
| MOV direct,#data | Move immediate data to direct byte | 3 | 2 |
| MOV @Ri,A | Move Accumulator to indirect RAM | 1 | 1 |
| MOV @Ri,direct | Move direct byte to indirect RAM | 2 | 2 |
| MOV @Ri,#data | Move immediate data to indirect RAM | 2 | 1 |
| MOV DPTR,#data16 | Load Data Pointer with a 16-bit constant | 3 | 2 |

DATA TRANSFER (cont.)

| Mnemonic | Description | Byte | Cyc |
|----------------|--|------|-----|
| MOVC A,@A+DPTR | Move Code byte relative to DPTR to A | 1 | 2 |
| MOVC A,@A+PC | Move Code byte relative to PC to A | 1 | 2 |
| MOVX A,@Ri | Move External RAM (8-bit addr) to A | 1 | 2 |
| MOVX A,@DPTR | Move External RAM (16-bit addr) to A | 1 | 2 |
| MOVX @Ri,A | Move A to External RAM (8-bit addr) | 1 | 2 |
| MOVX @DPTR,A | Move A to External RAM (16-bit addr) | 1 | 2 |
| PUSH direct | Push direct byte onto stack | 2 | 2 |
| POP direct | Pop direct byte from stack | 2 | 2 |
| XCH A,Rn | Exchange register with Accumulator | 1 | 1 |
| XCH A,direct | Exchange direct byte with Accumulator | 2 | 1 |
| XCH A,@Ri | Exchange indirect RAM with A | 1 | 1 |
| XCHD A,@Ri | Exchange low-order Digit ind. RAM w. A | 1 | 1 |

BOOLEAN VARIABLE MANIPULATION

| Mnemonic | Description | Byte | Cyc |
|-----------|---------------------------------------|------|-----|
| CLR C | Clear Carry flag | 1 | 1 |
| CLR bit | Clear direct bit | 2 | 1 |
| SETB C | Set Carry flag | 1 | 1 |
| SETB bit | Set direct Bit | 2 | 1 |
| CPL C | Complement Carry flag | 1 | 1 |
| CPL bit | Complement direct bit | 2 | 1 |
| ANL C,bit | AND direct bit to Carry flag | 2 | 2 |
| ANL C,bit | AND complement of direct bit to Carry | 2 | 2 |
| ORL C,bit | OR direct bit to Carry flag | 2 | 2 |
| ORL C,bit | OR complement of direct bit to Carry | 2 | 2 |
| MOV C,bit | Move direct bit to Carry flag | 2 | 1 |
| MOV bit,C | Move Carry flag to direct bit | 2 | 2 |

PROGRAM AND MACHINE CONTROL

| Mnemonic | Description | Byte | Cyc |
|--------------------|--|------|-----|
| ACALL addr11 | Absolute Subroutine Call | 2 | 2 |
| LCALL addr16 | Long Subroutine Call | 3 | 2 |
| RET | Return from subroutine | 1 | 2 |
| RETI | Return from interrupt | 1 | 2 |
| AJMP addr11 | Absolute Jump | 2 | 2 |
| LJMP addr16 | Long Jump | 3 | 2 |
| SJMP rel | Short Jump (relative addr) | 2 | 2 |
| JMP @A+DPTR | Jump indirect relative to the DPTR | 1 | 2 |
| JZ rel | Jump if Accumulator is Zero | 2 | 2 |
| JNZ rel | Jump if Accumulator is Not Zero | 2 | 2 |
| JC rel | Jump if Carry flag is set | 2 | 2 |
| JNC rel | Jump if No Carry flag | 2 | 2 |
| JB bit,rel | Jump if direct Bit set | 3 | 2 |
| JNB bit,rel | Jump if direct Bit Not set | 3 | 2 |
| JBC bit,rel | Jump if direct Bit is set & Clear bit | 3 | 2 |
| CJNE A,direct,rel | Compare direct to A & Jump if Not Equal | 3 | 2 |
| CJNE A,#data,rel | Comp. immed. to A & Jump if Not Equal | 3 | 2 |
| CJNE Rn,#data,rel | Comp. immed. to reg. & Jump if Not Equal | 3 | 2 |
| CJNE @Ri,#data,rel | Comp. immed. to ind. & Jump if Not Equal | 3 | 2 |
| DJNZ Rn,rel | Decrement register & Jump if Not Zero | 2 | 2 |
| DJNZ direct,rel | Decrement direct & Jump if Not Zero | 3 | 2 |
| NOP | No operation | 1 | 1 |

Notes on data addressing modes:

| | |
|---------|--|
| Rn | Working register R0-R7 |
| direct | 128 internal RAM locations, any I/O port, control or status register |
| @Ri | Indirect internal RAM location addressed by register R0 or R1 |
| #data | 8-bit constant included in instruction |
| #data16 | 16-bit constant included as bytes 2 & 3 of instruction |
| bit | 128 software flags, any I/O pin, control or status bit |

Notes on program addressing modes:

| | |
|--------|--|
| addr16 | Destination address for LCALL & LJMP may be anywhere within the 64-Kilobyte program memory address space. |
| addr11 | Destination address for ACALL & AJMP will be within the same 2-Kilobyte page of program memory as the first byte of the following instruction. |
| rel | SJMP and all conditional jumps include an 8-bit offset byte. Range is +127 -128 bytes relative to first byte of the following instruction. |

All mnemonics copyrighted © Intel Corporation 1979

Fig. 5. MCS-52 microcontroller instruction set (courtesy Intel Corp.).

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***** LISTING of EASM51 (XAMPLE02) *****
LINE  LOC  OBJ      T      SOURCE
1  0000      ; ***** FILE XAMPLE02.A51 *****
2  0000      ;
3  0000      ACC    EQU   0E0H      ; SFR Accumulator address is 0E0H
4  0000      P1     EQU   090H      ; SFR PORT1 Address is 090H
5  0000      xR3   EQU   3        ; Address of register R3 in Bank 0
6  0000      VALU  EQU   100
7  0000      ;
8  0000      ;
9  4100  90 41 44 [2] START  MOV  DPTR,#txt1      ; Program to run from 4100H
10 4103 31 49 [2]      ACALL STXT
11 4105 74 00 [1]      MOV  A,#0           ; Initialise registers
12 4107 78 FF [1]      MOV  R0,#255        ; = 0FFH hexadecimal
13 4109 79 0A [1]      MOV  R1,#10         ; 10 decimal = 0AH hexadecimal
14 410B 7A 10 [1]      MOV  R2,#10H        ; 10H hexadecimal is 16 decimal
15 410D 7B 64 [1]      MOV  R3,#VALU       ; compare to EQU command above
16 410F 90 40 00 [2]     MOV  DPTR,#04000H   ; load 16-bit constant
17 4112 31 4F [2]      ACALL SNAP         ; do first snapshot
18 4114 74 14 [1]      MOV  A,#20         ; Addressing: immediate
19 4116 F9 [1]         MOV  R1,A           ; Addressing: register,A
20 4117 31 4F [2]      ACALL SNAP
21 4119 75 E0 12 [2]     MOV  ACC,#12H       ; Addressing: direct,immediate
22 411C F5 03 [1]      MOV  xR3,A          ; Addressing: direct,A
23 411E 31 4F [2]      ACALL SNAP
24 4120 78 02 [1]      MOV  R0,#2         ; Addressing: register,immediate
25 4122 C6 [1]         XCH  A,@R0          ; Addressing: A,indirect
26 4123 75 90 55 [2]     MOV  P1,#01010101B ; binary constant to port
27 4126 31 4F [2]      ACALL SNAP
28 4128 90 41 2B [2]     MOV  DPTR,#addr1   ; point at MOV A,#2 instruction
29 412B 74 02 [1]      addr1 MOV  A,#2        ; Address offset
30 412D 93 [2]         MOVX A,@A+DPTR     ; Addressing: A,code-byte relative
31 412E 31 4F [2]      ACALL SNAP
32 4130 E0 [2]         MOVX A,@DPTR       ; Addressing: A,external RAM
33 4131 A9 02 [2]      MOV  R1,2          ; quizzzz
34 4133 31 4F [2]      ACALL SNAP
35 4135 90 00 00 [2]     MOV  DPTR,#0       ; Addressing: DPTR,16-bit immediate
36 4138 74 F2 [1]      MOV  A,#0F2H       ; external data latch Addr 0 = 0F2H
37 413A F0 [2]         MOVX @DPTR,A       ;
38 413B 74 00 [1]      MOV  A,#0           ; Program memory offset
39 413D 93 [2]         MOVX A,@A+DPTR     ; Addressing: A,code-byte relative
40 413E 31 4F [2]      ACALL SNAP
41 4140 E0 [2]         MOVX A,@DPTR       ; Addressing: A,external RAM
42 4141 31 4F [2]      ACALL SNAP
43 4143 22 [2]         RET                ; return to MONITOR
44 4144 58 4D 50      txt1  DB 'XMP2',0
      32 00

45 4149      ;
46 4149      ; MONITOR INTERFACE
47 4149      ccSTXT EQU 2      ; MONITOR command to send text
48 4149      ccSNAP EQU 020H ; MONITOR command to do snapshot
49 4149      COMMAND EQU 030H ; MONITOR command memory location
50 4149      MON   EQU 0200H ; MONITOR start address
51 4149      ;
52 4149 75 30 02 [2] STXT  MOV  COMMAND,#ccSTXT ; MONITOR set command
53 414C 02 02 00 [2]      LJMPL MON        ; jump to MONITOR (RET from there)
54 414F 75 30 20 [2] SNAP  MOV  COMMAND,#ccSNAP ; MONITOR set command
55 4152 12 02 00 [2]      LCALL MON        ; call up monitor
56 4155 22 [2]         RET                ; return to caller
57 4156      END

***** SYMBOLTABLE (13 symbols) *****
ACC :00E0      P1 :0090      xR3 :0003      VALU :0064
START :4100   addr1 :412B     txt1 :4144   ccSTXT :0002
ccSNAP :0020  COMMAND :0030   MON :0200   STXT :4149
SNAP :414F

```

Fig. 6. LIST file of example program XAMPL02.A51.

All information pertinent to the monitor EPROM and the operation of the assembler may be found in the documentation (.DOC) files on the course diskette. The programs discussed and listed in the course instalments are also available to you on the same disk, which allows you to modify them as required. All you need to examine and edit these programs is a word processor capable of handling ASCII files. How this word processor can be linked to the MENU program is explained in a text file on the disk.

Further details on the serial link between the 80C32 board and the PC will be given in next month's instalment, which will concentrate mostly on hardware extensions for the 80C32 computer (keyboard input, liquid crystal display, MIDI interface).

8051 (MCS52) micro controller instruction set

Figure 5 shows the instruction set of the MCS52 family of microcontrollers, of which the 8051 and 80C32 are members of

particular interest to us. To begin with, we will discuss some of the simpler instructions in order to elucidate the operation of the example program listed in Fig. 6.

The structure of the list (.LST) file is pretty obvious: it consists of seven columns, each with a specific function. The list file shown is generated by assembling XAMPLE02.A51 on the course disk, with the aid of EASM51. The column marked **LINE** shows the line number of the source text, while **LOC** shows location of the object code on the program memory. The column **OBJ** shows the object code bytes, and **T** the execution time of the individual instructions in microseconds (based on a system clock frequency of 12 MHz). The **SOURCE** column repeats the information copied from the assembler (source) file (in this case, XAMPLE02.A51), and shows mnemonics, labels, addresses, equate statements and comment. As you can see, the list file is extremely useful because it relates opcode bytes to the line numbers by which they have been generated.

The format requirements for the source

JOIN THE COURSE!

Here is a breakdown of 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 a 80C32. Alternatively, any other MCS52-based microcontroller system (but read part 1 of the course);
- a course diskette (order code ESS 1661) containing programming examples, utilities, and an assembler;
- a monitor EPROM (order code ESS 6091).
- an IBM PC or compatible operating under MS-DOS.

Appeared so far:

Part I: Introduction (February 1992).

file (produced with the ASCII word processor) are found on the course disk. For now, you may simply use XAMPLE02.A51 and the associated documentation file, XAMPLE02.DOC, both of which are contained on the disk. Connect the PC and the 80C32 board via the serial link, and run the monitor on the SBC.

The various addressing methods of the MCS52 microcontrollers will be discussed in relation to the available MOV (move) instructions. To illustrate their practical use, a small program is discussed that lights a couple of LEDs, and produces tone sequences. A simple modification to this program allows you to realize a simple tea timer, which generates a tone after 2 minutes and 50 seconds.

Subroutines

What we call a computer program normally consists of a number of smaller subroutines. Once written, a subroutine can be called repeatedly later. In XAMPLE02 you find, for instance, a subroutine called STXT (send text), which sends text from the 80C32 board to the terminal via the V24 interface. In 8051 assembler, subroutines can be called in two ways:

```

ACALL addr11
LCALL addr16

```

Both instructions have the same result: they start a subroutine at the indicated address (addr11 or addr16). On finishing the

| XAMPL02 | | | | | | | | | | | | | |
|---------|----|-----|----|------|----|----|----|----|----|----|----|----|---------------|
| A | B | PSW | SP | DPTR | R0 | R1 | R2 | R3 | R4 | R5 | R6 | R7 | |
| 00 | 00 | 00 | 0D | 4000 | FF | 0A | 10 | 64 | 00 | 00 | 00 | 00 | after line 17 |
| 14 | 00 | 00 | 0D | 4000 | FF | 14 | 10 | 64 | 00 | 00 | 00 | 00 | after line 20 |
| 12 | 00 | 00 | 0D | 4000 | FF | 14 | 10 | 12 | 00 | 00 | 00 | 00 | after line 23 |
| 10 | 00 | 01 | 0D | 4000 | 02 | 14 | 12 | 12 | 00 | 00 | 00 | 00 | after line 27 |
| 93 | 00 | 00 | 0D | 412B | 02 | 14 | 12 | 12 | 00 | 00 | 00 | 00 | after line 31 |
| 74 | 00 | 00 | 0D | 412B | 02 | 12 | 12 | 12 | 00 | 00 | 00 | 00 | after line 34 |
| 02 | 00 | 01 | 0D | 0000 | 02 | 12 | 12 | 12 | 00 | 00 | 00 | 00 | after line 40 |
| F2 | 00 | 01 | 0D | 0000 | 02 | 12 | 12 | 12 | 00 | 00 | 00 | 00 | after line 42 |

Fig. 7. Output of XAMPL02, produced with the aid of the 'snapshot' (register freeze) utility in the system monitor.

subroutine, the processor continues with the instruction that follows the CALL.

ACALL (absolute call) is used when the subroutine address is in the same 2-KByte address area as the CALL. This means that the highest 5 bits of the 16-bit address must be equal. If, for example, ACALL is used at address 9A12H, the relevant subroutine may be anywhere in the range between 9800H and 9FFFH. ACALL requires two bytes.

LCALL (long call) enables a subroutine anywhere in the 64-KByte address area to be called. Obviously, in relatively large programs, subroutines may be pretty 'remote', and can not be called with ACALL. In that case, you must use LCALL, which requires three bytes. The assembler produces an error report if an ACALL is made to a too distant subroutine. An example of the use of the LCALL instruction may be found in line 55 in Fig. 6. Here, ACALL can not be used because the called subroutine (at 0200H) is too far away from the call location (at 4152H).

RET is used at the end of a subroutine to return to the call instruction. The RET instruction at line 43, for example, ends the example program, and returns us to the monitor.

Jump instructions

The first jump instructions to be discussed are:

```
SJMP rel
AJMP addr11
LJMP addr16
```

These instructions cause the processor to jump to the indicated address (rel, addr11

or addr16), and are unconditional. The A and L preceding JMP have the same meaning as those used for the two types of CALL instruction discussed above. In addition, there is SJMP (short jump), which allows jumps to addresses within the range +128 bytes and -128 bytes from the location of the SJUMP instruction. SJUMP is often used to skip a few bytes—an example is found in line 53 of the listing in Fig. 6.

Apart from unconditional jumps, there are also jump instructions that are not executed unless a certain condition is met. Conditional jumps are of the short jump type only, and will be discussed separately in due course.

Address indications

The target addresses of subroutines are entered into the source listing as **LABELS**, on which further information may be found in the file EASM51.DOC. In line 54 of the list file of XAMPLE02 (Fig. 6), a subroutine called **SNAP** (for snapshot) is assigned the value that equals the address of the next instruction, i.e., 414FH. In line 50, you find an equate (**EQU**) statement is used to assign the value 0200H to the routine labelled **MON** (monitor). Hence, the command

```
LCALL MON
```

calls up the monitor subroutine. Similarly, the command

```
ACALL SNAP
```

calls the snapshot routine at 414FH, which is basically a breakpoint analyser that sends the contents of the main processor registers (in hexadecimal notation) to the

terminal, via the serial interface. The use of this debugging aid is shown in Fig. 7.

Assembler listings are far easier to follow if meaningful labels are used. An example is the label **COMMAND** in lines 49, 52 and 54 of the list file. The actual addresses given to the labels are easily found in the **symbol table**, which is automatically added to the list file by the assembler. Many assemblers have a maximum label length of six characters, hence the frequent use of labels such as V24COM (for the serial interface routines) or SNDCHR for send character. The EASM51 assembler (on your disk) allows up to eight characters to be used for labels.

Addressing methods

The function of the program XAMPLE02 (Fig. 6) is to elucidate the operation and application of the various addressing modes of the microcontrollers in the 8051 family. After a few initial assembler commands and some comment, the program proper starts at line 9. First, the accumulator, A, and a few registers are loaded. Line 17 calls up SNAP, which sends the first register overview to the terminal. The output produced by XAMPLE02 is shown in Fig. 7. This overview allows the operation of the instructions between lines 11 and 42 to be analysed in detail with the aid of a number of snapshots. Line 45 and further serve to re-establish the control of the monitor program, and are not so important at this stage.

The **MOV** (move) command is used to load a byte from the program, data or internal memory to a processor register or a PORT. The byte moved is referred to as the **operand**. A number of addressing modes are used depending on the source and target location of the operand, and the function required. The general notation of the MOV instruction is

```
MOV target,source
```

The target is, for instance, the accumulator, A, a register (R0 to R7), or one of the different types of memory. Constants may be used as the source, although not all combinations are possible (see the instruction set in Fig. 5).

The different addressing methods will be discussed with reference to the example program in Fig. 6. The so-called bit-addressing modes will be held over till part 4 of the course, together with a discussion on the processor flags.

Register addressing

The accumulator or registers R0 to R7 may be used as the source as well as the target.

For example, in line 11, the accumulator is used as the target, while in line 13 the target is register R1.

When register addressing is applied, the register is always one in the currently selected bank (bank 0 is used during this course).

Immediate addressing

This addressing mode is used when a constant is used as the (source) operand. The assembler recognizes such constants by the # (hash) typed in front of them. The constant may be entered in four ways: decimal (as in line 12), hexadecimal (as in line 14; note the affixed H), binary (as in line 26; note the affixed B), or it may be a label (as in line 15). To enable the assembler to differentiate between labels and hexadecimal numbers that start with a letter, hexadecimal numbers must start with a 0 (nought). For example, E0H is a label, and 0E0H a hexadecimal constant with the value 224 (decimal).

This information should enable you to understand the instructions in lines 11 to 15, which load the registers with the indicated values. At this stage, it may be useful to check if you understand what happens by taking a close look at the program output shown in Fig. 7.

Direct addressing

Direct addressing allows access to the lower 128 bytes of the internal RAM and the special function registers (SFRs). The internal RAM is selected when the indicated address is smaller than 128. Else, one of the SFRs is addressed. The accumulator can also be addressed as an SFR at location 0E0H. In line 3, this constant is labelled ACC. Line 21 causes a constant to be loaded into the accumulator. Note that this instruction has a length of three bytes.

On the 80C32 processor board, port P1 is made externally accessible, and is located at SFR address 090H (line 4). The instruction in line 26 sends bit pattern 01010101B to this port.

The 16-bit wide data pointer, **DPTR**, makes it possible to address the full 64 Kbyte large data and program memory. The DPTR consists of two 8-bit SFRs: the low byte pointer, DPL, at 082H, and the high byte pointer, DPH at 083H. A special MOV instruction is available to load the DPTR with a 16-bit value, as illustrated in line 9, where the DPTR is set to point at the first byte of the text 'txt1'. Figure 8 lists the functions of all SFRs.

Indirect addressing

This addressing mode is indicated by **@R0** or **@R1**. The address of the byte in the internal RAM is contained in register R0 or

| Symbol | ADR | bit | binval | comment | name |
|---------|---|-----|------------|-----------|-------------------------|
| ACC | 0E0CH | * | 00000000B | | accumulator |
| B | 0F00H | * | 00000000B | | aux. accumulator |
| PSW | 0D0H | * | 00000000B | | program status word |
| SP | 081H | | 00000111B | | stack pointer |
| DPTR | | | | 16-bit | data pointer |
| DPL | 082H | | 00000000B | | low byte of DPTR |
| DPH | 083H | | 00000000B | | high byte of DPTR |
| P0 | 080H | * | 11111111B | | port 0 or addr./databus |
| P1 | 090H | * | 11111111B | | port 1 |
| P2 | 0A0H | * | 11111111B | | port 2 or addr. bus MSB |
| P3 | 0B0H | * | 11111111B | | port 3 |
| IP | 0B8H | * | xxx00000B | 8051 | interrupt priority reg. |
| | | | xx000000B | 8052 | |
| IE | 0A8H | * | 0xx00000B | 8051 | interrupt enable reg. |
| | | | 0x000000B | 8052 | |
| TMOD | 089H | | 00000000B | | timer mode register |
| TCON | 088H | * | 00000000B | | timer control |
| T2CON | 0C8H | * | 00000000B | 8052 only | timer-2 control |
| TH0 | 08CH | | 00000000B | | timer-0 high byte |
| TL0 | 08AH | | 00000000B | | timer-0 low byte |
| TH1 | 08DH | | 00000000B | | timer-1 high byte |
| TL1 | 08BH | | 00000000B | | timer-1 low byte |
| TH2 | 0CDH | | 00000000B | 8052 only | timer-2 high byte |
| TL2 | 0CCH | | 00000000B | 8052 only | timer-2 low byte |
| RCAP2H | 0CBH | | 00000000B | 8052 only | capture reg. high byte |
| RCAP2L | 0CAH | | 00000000B | 8052 only | capture reg. low byte |
| SCON | 098H | * | 00000000B | | serial control |
| SBUF | 099H | | xxxxxxxxxB | | serial buffer |
| PCON | 087H | | 0xxxxxxxB | HMS | processor control |
| | | | 0xxx0000B | CHMS | |
| ADR: | location of addressed SFR | | | | |
| bit: | * when SFR is bit-addressable | | | | |
| binval: | binary content after reset; x = not defined | | | | |

Fig. 8. Identifications and addresses of the special function registers (SFRs) in the 8051.

R1 as indicated. Registers R2 to R7 can not be used for indirect addressing. When, for instance, register R0 contains the value 43H, the instruction **@R0** addresses the byte at location 43H in the internal memory. The use of this addressing mode is illustrated in line 25, where R0 is seen to point at internal memory location 2 (as defined in line 24). This is the same location, however, where register R2 in bank 0 is addressed (see Fig. 4 in part 1 of this course). Hence, this instruction changes the value contained in register R2. The instruction **XCH** swaps target and source bytes.

Contrary to direct addressing, addresses greater than 127 do not give access to the SFRs. Instead, they select the upper 128 bytes of the internal RAM. In fact, these RAM locations can be accessed via indirect addressing only.

Program memory addressing

The processor can only read from the program memory, which is normally a ROM or an EPROM. For this the **MOVC** instruction is used, where the C stands for code memory. The target of **MOVC** is always the accumulator. The real (effective) address is formed by adding the content of the accumulator to either the data pointer, **DPTR**:

```
MOVC A, @A+DPTR
```

or the program counter, **PC**:

```
MOVC A, @A+PC
```

In line 39, the effective address is 0, since both the **DPTR** and **A** are loaded with 0.

Tables and fixed texts can be stored permanently in the program memory, and read when required with the aid of the **DPTR**. The routine **STXT** in the monitor, **EMON51**, makes use of the **DPTR** in this way to transmit texts to the terminal.

(External) data memory addressing

The **MOVX** (move eXternal) instruction gives access to the external data memory, which is usually a RAM. When the notation **@DPTR** is used, as in line 37 or 41, the contents of the data pointer are used as a 16-bit address. Similarly, the notations **@R0** and **@R1** cause the contents of these registers to be used as the least significant address byte, and the contents of port P2 (at SFR location 0A0H) as the most significant address byte. On the 80C32 SBC, the address range between 0C000H and 0FFFFH in the data memory is used for memory mapped I/O. If, therefore, you wish to select output devices at these addresses, you must use the **MOVX** instruction.

Monitor calls

The EPROM-resident monitor on the 80C32 board has a number of subroutines that may be used in your own programs.

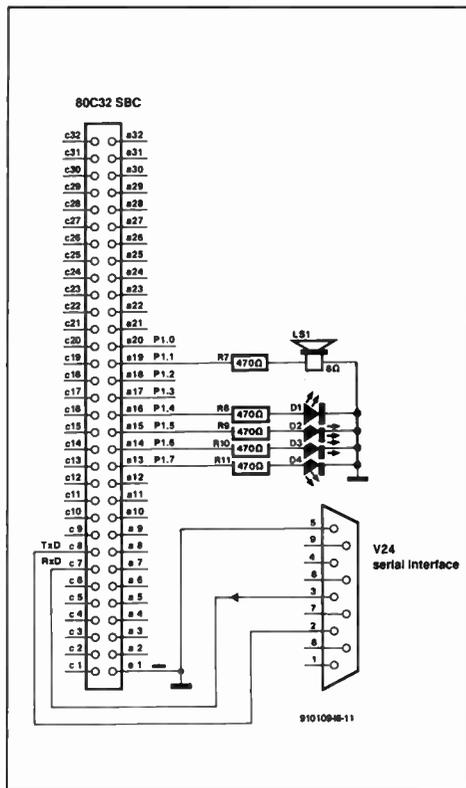


Fig. 9. Hardware extension for programming experiments with port 1.

Before these subroutines can be called, an appropriate command byte must be written into the internal RAM at address 030H (see lines 52 and 54 of XAMPLE02.LST). This byte forms an indication to the monitor as to which subroutine is to be used. The routines available in the monitor, along with the associated command bytes, are described in the file EMON51.DOC on your course diskette. These routines are useful, and can save you a lot of work. You are, therefore, well advised to examine them in detail, which is quite easily done because the source code of EMON51 can be loaded from the course disk.

A SNAP can be taken at any stage during a program. This requires command byte 20H before calling the monitor at address 0200H. A programming example:

```
MOV 030H,#020H
LCALL 0200H
```

This is, admittedly, not the easiest legible piece of assembler, as compared to, for instance, lines 52 and 54 in XAMPLE02.LST. Conclusion: the use of meaningful symbolic names (labels) makes programs easier to understand.

The course diskette contains all symbolic notations for the command bytes used. For instance, a monitor routine is available that sends a text string. The use of this routine, ccSTXT (command code send text; value 2) was shown already in part 1. The characters in the string to be transmitted must be available in the program

memory. To enable the transmission routine to know where the text ends, the code 0H is used as the end-of-text marker (line 44). The start address of the text must be contained in the DPTR. All this is taken care of in lines 9 and 10, and 52 and 53.

Simple port output operations

Up to now, we have been using the 80C32 board as a kind of black box, without making use of the microcontroller's ports for external control functions. The external circuitry around the 80C32 (or 8051) on the SBC does not allow us to use the ports indiscriminately: remember, ports P0 and P2 are used as address and data bus for the external RAM and EPROM. The eight lines of port P1 are taken to expansion connector pins a20 to a13 via a bidirectional driver IC, of which the direction is controlled by the signal level at pin a21. If this pin is not connected, port P1 can be used as an 8-bit output port. The circuit in Fig. 9 enables four LEDs to be switched on and off, and simple sounds to be sent to a small loudspeaker.

The eight bits that form a byte are numbered from the right to the left starting with 0 (the least significant bit, or LSB) to 7 (the most significant bit, or MSB). Thus, when we refer to P1.3, we mean the fourth bit of port P1. Knowing this, we can switch on LED D3 by programming:

```
MOV P1,#01000000B ;LED3 on, all
                    other bits 0
```

Line 26 of XAMPLE02 contains such an

output command. After a reset, when P1 contains 11111111B (all LEDs on), the LED pattern changes when line 26 is executed.

The principle of port output programming are taken a little further in example program XAMPLE05.A51, which you find on your course disk as well as listed in Fig. 10. This program causes the four LEDs to flash (object code from 4100H onwards), or a 500-Hz tone to sound (object code from 4200H onwards). The signals are generated simply by sending certain bit patterns to port P1, waiting a number of clock cycles, and then sending a new bit pattern. Use is made of TIME, a monitor subroutine that introduces a delay equal to the number of milliseconds loaded into the DPTR.

Assembler language programming is not learned by reading only. To increase your knowledge on the subject, work as much as you can with the examples provided, and make sure you understand what happens if you make changes to them. Set yourself assignments based on what you have acquired so far. For instance, modify XAMPLE05 such that the loudspeaker produces a tone after 2 minutes and 50 seconds exactly. There you have your tea timer, what about a programmable rectangular wave generator as the next project? □

Next time: hardware extensions for the 80C32 single board computer.

```
***** LISTING of EASM51 (XAMPLE05) *****
LINE LOC OBJ T SOURCE
1 0000 ; ***** FILE XAMPLE05.A51 *****
2 0000 ;
3 0000 P1 EQU 090H ; SFR PORT1 address = 090H
4 0000 ;
5 0000 ORG 4100H ; First program to run from 4100H
6 4100 75 90 10 [2] START MOV P1,#00010000B ; LED D1 on, the others off
7 4103 90 01 F4 [2] MOV DPTR,#500 ; 500 milliseconds
8 4106 51 12 [2] ACALL TIME ; Wait
9 4108 75 90 E0 [2] MOV P1,#11110000B ; LED D2,D3,D4 on, D1 off
10 410B 90 00 64 [2] MOV DPTR,#100 ; 100 milliseconds
11 410E 51 12 [2] ACALL TIME ; Wait
12 4110 80 EE [2] SJMP START ; Repeat
13 4112 ;
14 4112 ;
15 4200 75 90 02 [2] START2 ORG 4200H ; Second program to run from 4200H
16 4203 90 00 01 [2] MOV P1,#010B ; Loudspeaker +5 volt
17 4206 51 12 [2] MOV DPTR,#1 ; 1 millisecond
18 4208 75 90 00 [2] ACALL TIME ; Wait
19 420B 90 00 01 [2] MOV P1,#000B ; Loudspeaker 0 volt
20 420E 51 12 [2] MOV DPTR,#1 ; 1 millisecond
21 4210 80 EE [2] ACALL TIME ; Wait
22 4212 ; and again
23 4212 ;
24 4212 ; MONITOR INTERFACE
25 4212 ccLTIME EQU 021H ; MONITOR command, DPTR millisecs delay
26 4212 COMMAND EQU 030H ; MONITOR command memory location
27 4212 MON EQU 0200H ; MONITOR entry address
28 4212 75 30 21 [2] TIME MOV COMMAND,#ccLTIME
29 4215 02 02 00 [2] LJMP MON
30 4218 END
***** SYMBOLTABLE (7 symbols) *****
P1 :0090 START :4100 START2 :4200 ccLTIME :0021
COMMAND :0030 MON :0200 TIME :4212
```

Fig. 10. Two programs, one listing: a LED flasher (4100H) and a sound generator (4200H).

SCIENCE & TECHNOLOGY

A SYMMETRICAL ROUTE SWITCH FOR ELECTRONICS

by Michael Soper

THE logic relation 'exactly two of a, b, c , are true', or $((a, b, c))$, can perform all standard logic functions: for example, $a = \text{not } b$ is $((T, a, b))$ where T denotes true.

This enables the consideration of a new approach to circuitry also. We can move to see how relational approaches differ from standard ones. Suppose the function 'a implies b' is $T = c$ is required to have implementation. We may then use the symbol in

1

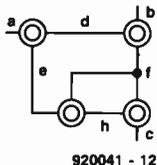


920041 - 11

Fig. 1 to denote $((a, b, c))$.

The network in Fig. 2 will perform this task. That is, $((a, d, e))$, $((b, d, f))$, $((e, f, h))$, $((f, h, c))$, since a implies b is true, is equivalent to $((-a) \vee b)$ is true, the auxiliary condition $c = 1$ or T, together with our NOT function above gives OR and NOT, from which all functional logic can be created. Each cell is almost equivalent to the XOR function, but, since XOR cannot create all logic alone, our relational system is simpler and more powerful, since it *can*.

2



920041 - 12

This logic system can be amended somewhat to provide a practical type of circuit element. The essence of the system consists of a symmetrical element with three wires and the rule that only two of the wires can carry current in either direction at any one time. That is, the circuit appears as a pi circuit in which exactly one of the three impedances has a low value at any one time. 'At any one time' is important. There will be some impedance to the low state, but this impedance can be relatively low. Thus, we have a dynamic new type of circuit element. The rule is that the middle voltage on the three wires is the high-impedance input. We may make the low impedance a partially linear function of high impedance voltage if required.

We may be keen on this approach for various reasons: one of them is symmetry, another is operational simplicity. The manufacture of devices that are both logic and analogue is straightforward. The devices

themselves would not be suitable for very high speeds until much development work is done, but this is not often a requirement.

The increased flexibility of use is a great advantage; for example, three-phase oscillators where the high impedance rotates about the device are possible. Many other standard approaches become simpler and with the devices any active circuit function, except the diode and very high speed, can be carried out. In theory, they can also be made to have no supply lines as operational amplifiers do, but the stability of this approach requires analysis. Thus, the distinct possibility exists of a new and useful three-wire device: the Symmetrical Route Switch—SRS.

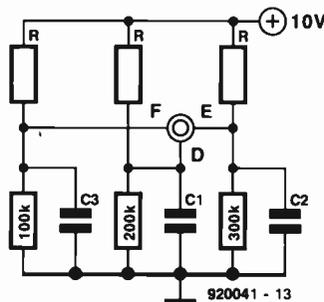
Liberation from directivity

The advantage of these devices is that they can be connected *any way* round at all. Thus, electronic methods can be non-directive in the sense that once a low-impedance link is established between two parts of the circuit, current can flow either way. This totally symmetrical property is new for an active element with three wires (the group of Symmetries is S_3).

The ability to rearrange elements in this way is a very considerable advantage. The devices can be used for linear or digital application and are, therefore, apart from speed, more powerful than transistors. The power of the system lies in the fact that only capacitors, resistors, diodes and SRSs are required for circuit implementation (the occasional use of inductance, although rare, is not ruled out).

One more factor is that the device can float at any potential and is, therefore, free from the restrictions that separate power lines to the device impose (this would be difficult to achieve at low voltages, but then SRSs with separate power lines would be used). Thus, the device defines its own relative levels and will not fail, as opamps do, when inputs are at disparate levels from the output.

3



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In other words, however complex the interior of the device, its behaviour is still intrinsically simple and the designer's friend.

One symmetrical route switch can serve as the active element in a circuit that oscillates while rotating the high impedance option about the centre of the device—see Fig. 3. In this circuit, on turn-on, D is high impedance so that C_1 is charged first until the voltage at D is greater than that at E, whereupon E becomes the high impedance and C_2 will be charged while the voltage across C_1 drops. If the values are chosen properly, C_3 is the next capacitor to be charged and the voltage on F increases. The cycle then begins again. In that way, a very simple one-device oscillator circuit has been designed.

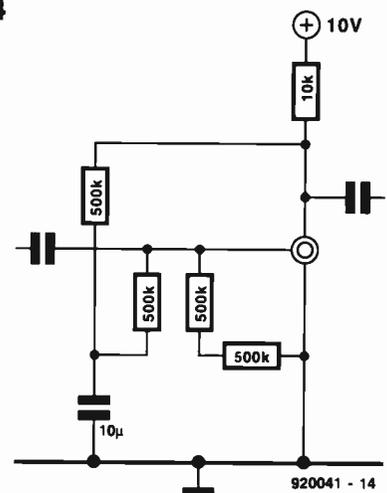
One device and perhaps six resistors and three capacitors is a component count that could be reduced if a slightly different operation is required, say, not such a symmetrical wave. Therefore, although one-transistor, coil-less oscillators can be designed, the circuit in Fig. 3 has a more predictable and usable response and can thus be used as required. That done, other circuits can be completed for similar purposes.

Now, the linear use.

Continuity

In order to use a symmetrical route switch for linear applications, we must bias the middle electrode so that it remains high impedance.

4



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The circuit would then appear as shown in Fig. 4. Note that the low impedance is directly proportional to the input voltage and steps must, therefore, be taken to prevent positive feedback. Apart from those requirements, the circuit is standard. The main point to

make here, though, is that this is not the best utilization of an asymmetrical route switch, since the sixfold symmetry is not used. But it must be said that linear amplification over the natural range of use of the device can be obtained. Multi-stage amplifiers with or without feedback can be built with the device. We thus already have dual types of operation: logical and linear.

Promotion

The reason that such a system should be promoted is clear: simplification. Although in extreme applications like very fast switching of low-noise amplifiers the SRS is probably best replaced, the neat and interesting possibilities the SRS creates suggest that it should ascend from the status of a theoretical curiosity to that of practical implementation.

One difficulty of the common transistor is that at the end of its standard range of operating conditions there is not always any discontinuous change into another mode, thus indicating a fault.

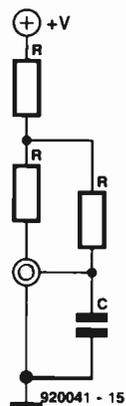
The system itself can be designed economically. Let U, V, W be the voltages at the three electrodes and I the current in the conducting branch. Then,

$$\begin{aligned} V + W - 2U &= V_1 + |I| \tanh(\alpha V_1) \\ U + W - 2V &= |I| \tanh(\alpha V_1) - V_1 \\ U + V - 2W &= V_1 - |I| \tanh(\alpha V_1) \end{aligned}$$

where $I = \alpha V_1 = \alpha(V-U)$ [for transistor]
 or $= \alpha \{(2V-U-W)/2\}$ [for SRS]
 $\alpha = \text{gain}$
 $\tanh(x) = (e^x - e^{-x}) / (e^x + e^{-x})$

These equations are included to give some idea of how a relational law can be defined. With this approach, the SRS can easily be modelled on a computer. The device is non-linear over a wide range with this law, but linear over a small range of signal inputs. Whether or not designers wish to appreciate the flexibility of the SRS depends on how skilful they are and, of course, on the cost of the device. In order to present a unified approach of relational logic and relational amplification in one object, it may be true and it must be admitted that many extreme active circuit functions cannot be performed by this device, but the very great advantage

5



of flexibility coupled with symmetry should not be ignored.

In fact, these devices can be scaled up whenever required and will prove useful at any scale. Design techniques are very different and in a sense relational, not functional. Also, the positive feedback feature makes for more rather than fewer useful circuits.

Another oscillator circuit—a relaxation type—is shown in Fig. 5. This type can have an ‘amplifier’ positively coupled back to a shunt capacitor over any number of stages, since all stages in the SRS’s ‘common-emitter-like’ configuration have positive feedback.

The chief strength of the SRS is for current routing, which will be reverted to later.

However, the ease with which either oscillators or amplifiers can be made is encouraging and leads one to speculate on how active electronics would have turned out if active devices had originally had ‘in-phase’ output and input.

Transformation

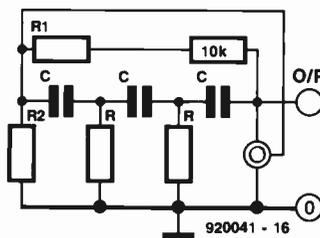
A transformation that mirrors the behaviour of the symmetrical route switch with one electrode at high impedance is the following: $v = v_{in}$ (between the common electrode and the high impedance electrode, where v is referred to either the mid-voltage of the output electrodes or the voltage on one of them) and $R = R_{o(ut)}$ is the (variable) resistance of the low-impedance (output) electrode and the common electrode.

$$R = R_o + (1 - \alpha v)u / (1 + u) + \alpha v$$

where v is again referred to either the mid-voltage of the output electrodes or the voltage on one of them, α is the gain and $u = (\alpha v)^{100}$.

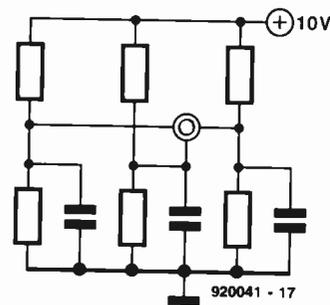
The use of a formula like this makes design work easy. The formula is chosen to have an almost perfect ramp before cut-off when the output electrode become high impedance: a change of state. An explicit formula can easily be written into a computer program, after which a simulation can be run and new circuits tried out. The juxtaposition and connection of many such circuits can be simulated. Relational rather than functional thinking can be difficult to get accustomed to, but in the phase shift oscillator of Fig. 6 the

6



ease of operation makes sense. Although this is a good example of the SRS used functionally, this really does not exploit the special properties of the circuit. In Fig. 7, however, our previous oscillator circuit produces a much better example of the use of a symmetrical route switch, since the switch is

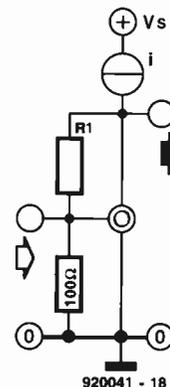
7



used symmetrically.

However, symmetrical use does involve a switching operation in the SRS and is thus not suitable for most linear circuits. An exception may be made for some class D or push-pull amplifiers. The distinction between linear and non-linear operation is also usually the distinction between stable use where small inputs produce small outputs and unstable use where a change of state in the device may occur. Class D amplifiers produce

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quasi-linear operation out of extremely non-linear components. The ramp function of our SRS combines both modes of operation—but may the effective slope of the amplification be changed? The best linear use of any symmetrical route switch is with a constant current tail of, say, current i , when

$$V_{out} = iR = iR_o + i\alpha V_{in}$$

under these conditions of linear use—see Fig. 8. Connecting a feedback impedance R_1 with feedback factor $1/n$, we find

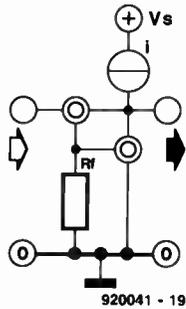
$$dv = V_{out}/n$$

so that

$$V_{out} = i \{ R_o + \alpha (V_{in} + V_{out}/n) \}$$

In other words, the output resistance and the effective transconductance are increased; the gain of the stage increases also and is usefully a function of i , the quiescent current. The factor $1/n$ depends linearly on R_1 so that we may replace R_1 by another suitable SRS to obtain a stage with negative gain. Thus, when more than one SRS is used—see Fig. 9—we have the capability of building an inverting stage: with constant current

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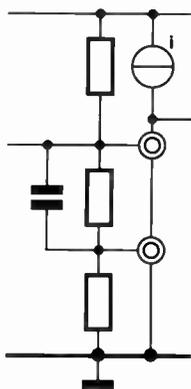
supplies, the linearity can be very good.

Buffer stages

The symmetrical route switch is naturally suitable as a buffer stage when it is used linearly—but, of course, this is not the best use, because the flexibility of the device is ignored. For good linearity, a constant-current stage can be used: the linearity of the SRSs is a direct function of the quality of the constant current supply. This fact and the symmetry of the high-impedance input connection means that stages can be paralleled for lower impedance or be put in series with no great problems as long as the input electrode sits at the correct point with respect to the output electrodes. Even this feature is simpler on the SRS, because, as long as the voltage on the input electrode lies between the voltage of the output electrodes, the behaviour will be linear at all times (given that the voltage is 'one side' of midway).

To reduce the output impedance of a transistor stage to low values, an emitter-follower is used: a circuit with negative feedback which similarly has non-linearity. The use of negative feedback is possible for the SRS when the input voltage is nearer the more negative 'through' electrode, because the gain is then negative and a simple impedance is enough. A diagram of the series connection is given in Fig. 10.

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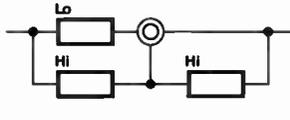


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For the reason just given, a 'switching' symmetrical route switch can make an ideal method for shunting out large currents. A suitable circuit is shown in Fig. 11. Assume the left-hand side of this to be temporarily positive: as the current increases, the voltage across the low resistance increases also until the knee voltage of diode D is reached.

Since the circuit is symmetrical under

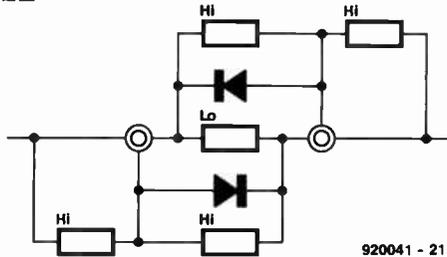
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some conditions, the same approach will work for alternating current also: a simple design for use with this case when the component values are correctly chosen is shown in Fig. 12.

12

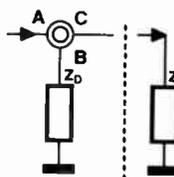


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Routes

The name symmetrical route switch suggests also that they can be used for signal routing: a task they are ideally suited for. Consider the simple arrangement in Fig. 13.

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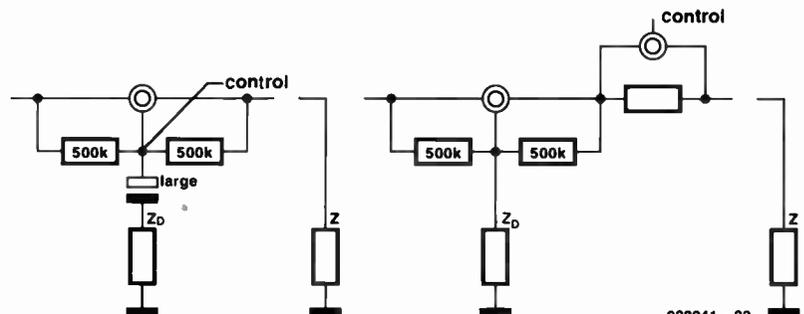


920041-26

While electrode B has a voltage between that of A and C, the signal will actuate load Z. But when the voltage on electrode B is above that on A and C, the signal is dissipated in matched load Z_d . The advantage is almost perfect matching. Practical circuits for AC and DC are given in Fig. 14.

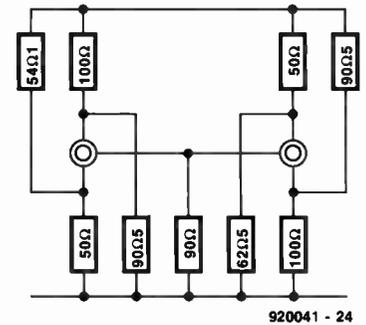
Designing a bistable from symmetrical route switches in conventional ways is possible but clumsy; a bistable based on an SRS on-impedance of 10 Ω is shown in Fig. 15. With 4.5 passive components per active device, this circuit is not very practical. The circuit in Fig. 16, however, is, mainly because it has greater natural stability.

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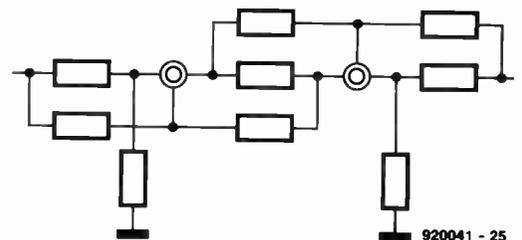
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The symmetrical route switch combines a non-linear function, as required for switching and for load and power supply protection, with at least two kinds of linear function: transistor-like and symmetrical input function referred to midpoint, when required. Thus, two distinct circuit operations are combined in one circuit. Look inside many hi-fi amplifiers and you will see that until recently small relays were used for protection on overload. The symmetrical route switch combines this function also, because, although it is a three-terminal device, the control connection (at very high impedance with respect to the others) controls the output impedance. Hence, one device can perform all logic, linear action and protective switching.

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The route ahead

Integration of circuits has led to a large pin-out count on many integrated circuits, followed by a partial reduction. Some useful ICs are three-terminal devices, usually unsymmetrical and polarized, although a few are symmetrical. The symmetrical route switch is the first three-terminal device capable of logic and linear action, which can be inserted *any way* into a circuit. The power it takes is absorbed from the current through the output impedance. ■

INDUCTANCE-CAPACITANCE METER

FRONT COVER PROJECT

based on a design by H. Kühne

When the value of a capacitor or inductor is measured, it is imperative that ohmic losses do not affect the result. The principle of measurement used in the meter presented here ensures that the influence of ohmic losses is reduced to nil.

BASICALLY, there are two problems in measuring inductance or capacitance: ohmic losses and frequency-dependence of the component. The effect of ohmic losses has been nullified in this design, while the frequency-dependence is, as usual, negated by choosing a measurement frequency that lies in the range in which the component is to operate. In the present design, the frequency lies in the audio range.

The principle of the design is shown in Fig. 1. The value of an inductance, L_x , is determined by passing a sinusoidal current of constant amplitude through the inductor and measuring the resulting voltage across it. The value of a capacitance, C_x , is determined by applying a constant-amplitude sinusoidal voltage across the capacitor and assessing the resulting current through it by measuring the voltage drop across R_C . In either case, that voltage (measured at A) is directly proportional to the inductance or capacitance plus the loss resistance. How that resistance is removed from the measurand (measured quantity) will be discussed later.

We will now consider how the current through the inductance, or the voltage across the capacitance, is held constant. The inverting input of the differential amplifier at the input of the circuit is fed with a sinusoidal measurement signal, U_E , and the non-inverting input with part of the voltage at G, U_A . Since the gain of the amplifier is unity, the voltage at B is $U_A - U_E$. The potential difference between A and B is $U_A - (U_A - U_E)$, which is U_E . Assuming that U_E is a constant-amplitude sinusoidal voltage, depending on the setting of switch S_2 , a constant voltage exists across R_L or C_x . This causes a constant current through R_L and thus through L_x . Since a constant current flows through the inductance, or a constant voltage exists across the capacitance, the loss resistances, R_L and R_C , have no effect on the measurement.

The signal at G consists of two components: a sinusoidal voltage that is *in phase* with U_E and a sinusoidal voltage that is 90° out of phase with U_E ($\cos U_E$). Added together, the components form a sinusoidal voltage that is x° out of phase with U_E . The components are separated by synchronous rectification of the signal. The rectifier is driven by a square wave (F) that is shifted 90° with respect to $\sin U_E$. That means that only the cosine component in the signal is rectified: the resulting mean value is directly proportional to the inductance or capacitance, whereas rectifi-



TECHNICAL DATA

| | |
|---|-------------------------------------|
| Measurement frequency | 1 kHz |
| Measurement ranges: | |
| inductance | 2, 20, 200 mH, 2 H |
| capacitance | 2, 20, 200 nF, 2 μ F |
| Accuracy (calibrated with 1% capacitor) | |
| with moving-coil meter | $\pm(1.5\%$ of reading + 2% of FSD) |
| with 3.5 digit digital voltmeter | $\pm(1.5\%$ of reading + 1 digit) |

cation of the sine component yields a mean value of zero.

The various signals encountered in this process are shown in Fig. 2. Figure 2a shows the situation when a perfect inductance or capacitance is being measured. Since ideal components are considered, both the measured signal, U_A , and the square-wave voltage, U_F , driving the rectifier are 90° out of phase with U_E . This means that the rectifier will switch exactly at the zero crossings of the measured signal, which results in a voltage whose mean value is directly proportional to the measured reactance.

If a resistance is substituted for the in-

ductance or capacitance—Fig. 2b—the measured signal will be in phase with U_E . The rectifier then switches exactly at the peaks of the signal, resulting in a mean voltage whose value is zero.

Although practical inductors and capacitors have parasitic or stray resistance, the effect of this is nullified in the synchronous rectification. When a practical inductor or capacitor is measured, the phase shift between the measuring signal, U_E , and the measured signal, U_A , will be somewhere between 0° and 90° . This means that the signal is neither wholly rectified nor reduced to zero: the resulting mean value will be representa-

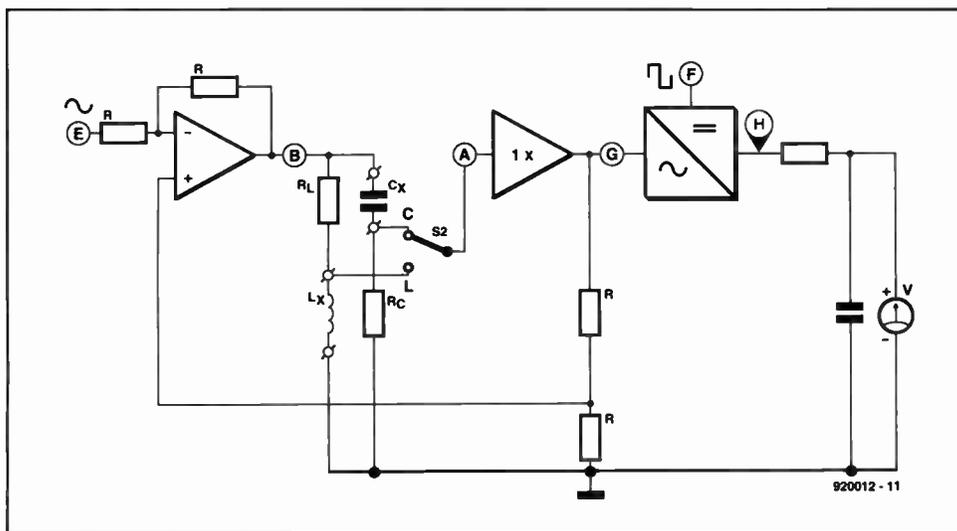


Fig. 1. Principle of the design of the meter.

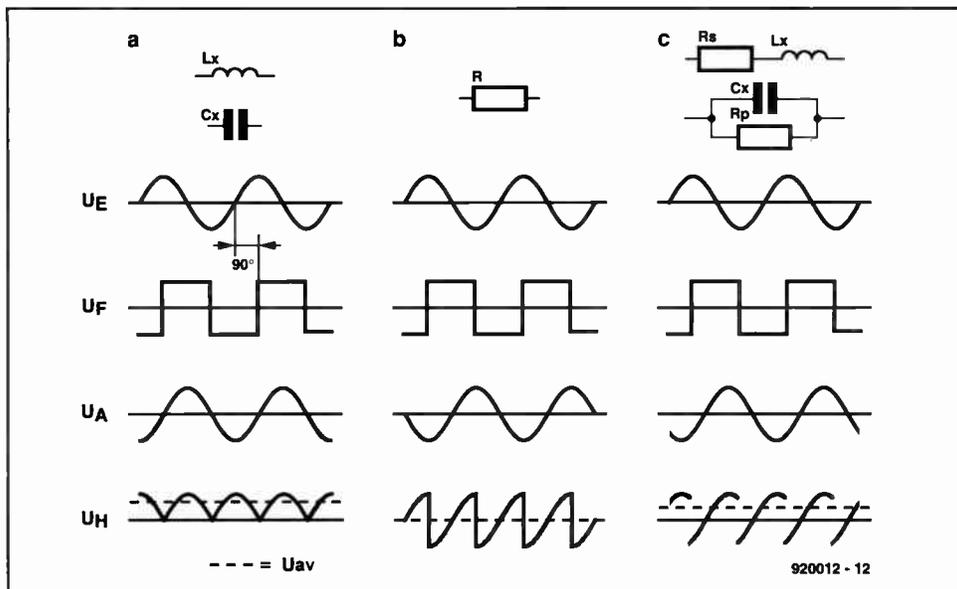


Fig. 2. Waveforms associated with the measurement process.

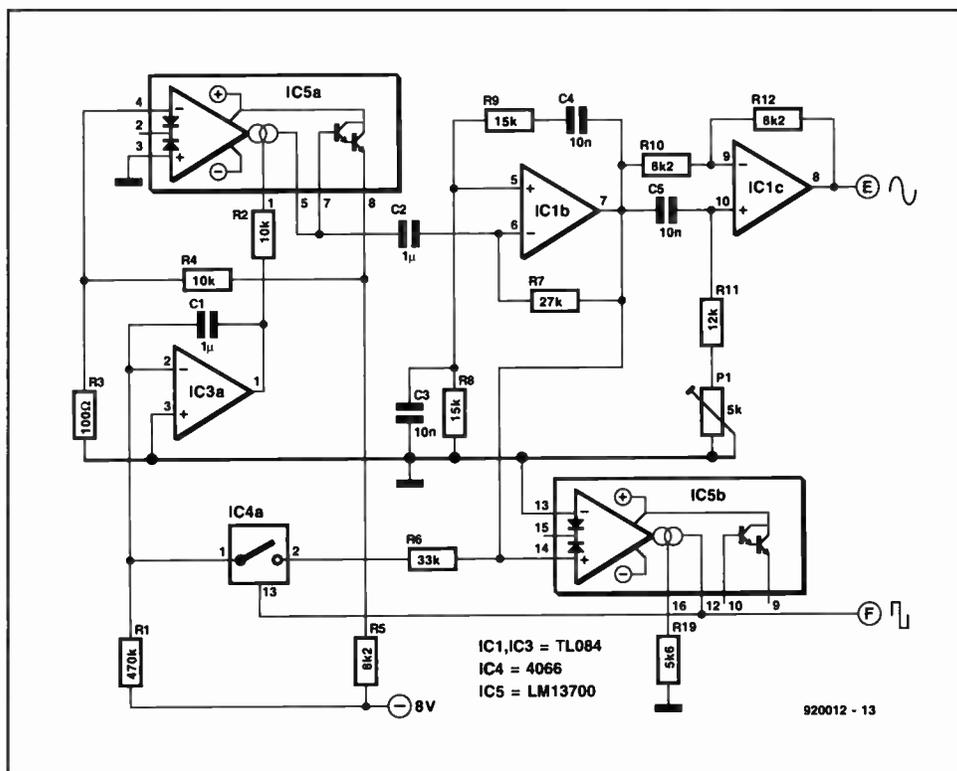


Fig. 3. The oscillator circuit.

tive of the real inductance or capacitance.

Returning to Fig. 1 for a moment, the rectifier is followed by an RC network which averages the rectified voltage before that is applied to a meter.

Oscillator

The measurement signal, U_E , and the square wave voltage, U_F , that drives the rectifier are generated by a Wien-bridge oscillator, IC_{1b}—see Fig. 3. The sinusoidal output of this stage is converted into a square-wave voltage by IC_{5b}, an operational transconductance amplifier (OTA) connected as comparator. Since the square-wave and sinusoidal signals are in phase, the latter is applied to phase shifter IC_{1c}. The required 90° phase difference between the two signals is set with P₁.

The remainder of the circuit in Fig. 3 serves to stabilize the level of the oscillator output. To that end, the output, pin 5, of IC_{5a} is used as a preset resistance in the feedback loop of IC_{1b}. That resistance is determined by the current entering via the control input, pin 1. This current, provided by integrator IC_{3a}, can be used to influence the gain of IC_{1b} and thus the amplitude of the sinusoidal signal. Its level is in turn determined by the amplitude of the positive halves of the sinusoidal signal. The negative halves are not passed by switch IC_{4a} since that is closed by IC_{5b} only during the positive halves of the signal.

Regulation is arranged so that the gain of IC_{1b} diminishes when the amplitude increases, and vice versa. Ultimately, the amplitude stabilizes around a value of 1.2 V.

Measuring circuit

Basically, of course, the measuring circuit in Fig. 4 is similar to Fig. 1 with the rectifier and meter omitted.

The differential input amplifier consists of IC_{1d}. Its output current is doubled in IC_{1a}, since the peak level should be about 15 mA, which a single TL084 cannot provide. The design ensures that the level of the voltage across R₁₇ is identical to that across R₁₆. Consequently, the currents through these resistors are also identical. Observe that one half of the current fed to the measuring circuit is provided by IC_{1d} and the other half by IC_{1a}.

Rangeswitch S₁ is provided with a section, S_{1c}, that enables the decimal points of a digital meter module, if used, to be controlled. In case of an LCD module, the pole of S_{1c} must be fed with the back-plane (BP) signal or, if an LED display is used, with a logic high or low, depending on the type of the display.

The various ranges are determined with the aid of 0.1% resistors. This has two advantages: calibration of only one range suffices and the tolerance of the resistors has a negligible effect on the total accuracy of the meter (if the tolerance were 1%, the meter accuracy would deteriorate by at least 1%). Note that the 1% resistors in parallel with R₄₃, R₄₇, and R₄₈, can be ignored since their tolerance is tiny compared with that of the parallel-connected low-value resistors.

Rectifier and power supply

The remainder of the circuit, that is, rectifier, meter, power supply and overflow indicator, is shown in Fig. 5.

The rectifier proper, IC_{2d}, is preceded by an amplifier, IC_{2c}, because the output of the metering circuit at full-scale deflection (FSD) is only 150 mV (assuming a perfect inductance or capacitance) and that is not enough to ensure a mean voltage of 2 V to the meter. The rectifier elements are not diodes, but two electronic switches, IC_{4b} and IC_{4d}, that are operated by the square-wave signal in step with the sinusoidal output of the oscillator. An inverter based on IC_{4c} controls IC_{4d}, so that IC_{4b} and IC_{4d} are alternately opened and closed. When IC_{4b} is closed, IC_{2d} amplifies $\times 1$; when IC_{4d} is closed, IC_{2d} amplifies $\times -1$. This ensures operation in step with the square-wave signal.

The output of the rectifier is smoothed by network R₂₇-C₇. Because this network can be loaded only lightly, the potential across C₇ is buffered by IC_{2a} before the signal is applied to the meter. The meter may be a digital or an analogue type. The digital type may be connected directly to buffer IC_{2a}. Series resistors and protection diodes for a moving coil meter are provided.

At first glance, an overflow indicator may seem superfluous, since the meter, M₁ or DM₁, shows immediately if the meter range is exceeded. That is true enough, but consider that if the meter range is grossly exceeded, IC_{2c} will clip and the resulting mean value of the rectified voltage may then fall under 2 V, that is, in the meter range. The meter reading then means nothing and this would not be evident without the overflow indicator.

The indicator is based on IC_{3b} (connected as comparator) and IC_{3c}. The output of the rectifier is compared by IC_{3b} with a voltage set with P₅ to a level of 4 V. If the rectified output exceeds the set level, buffer capacitor C₈ is charged via D₃. This results quickly to the output of IC_{3c} changing state and D₄ lighting.

Construction and calibration

There should be no particular difficulties in the construction of the instrument if the PCB shown in Fig. 6 is used. As usual, start with the lowest-lying components, that is, the wire links. When the highest protruding components, that is, electrolytic capacitors, IC₆ and IC₇ and the mains transformer, have been fitted, wire up those components that are not fitted on the board.

The low-tolerance resistors should be soldered direct to the range switch, S₁. It is, therefore, advisable to use a type of switch that has solder eyelets and not

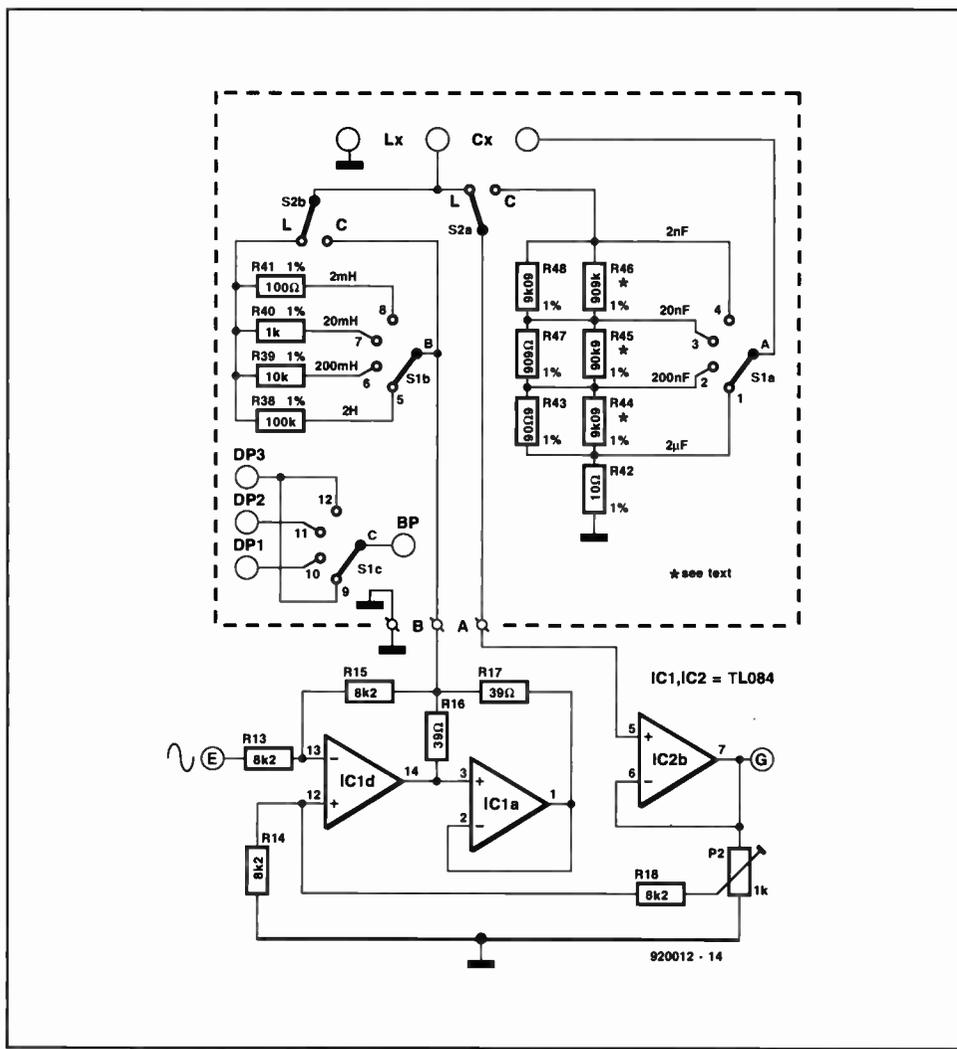


Fig. 4. The metering circuit proper.

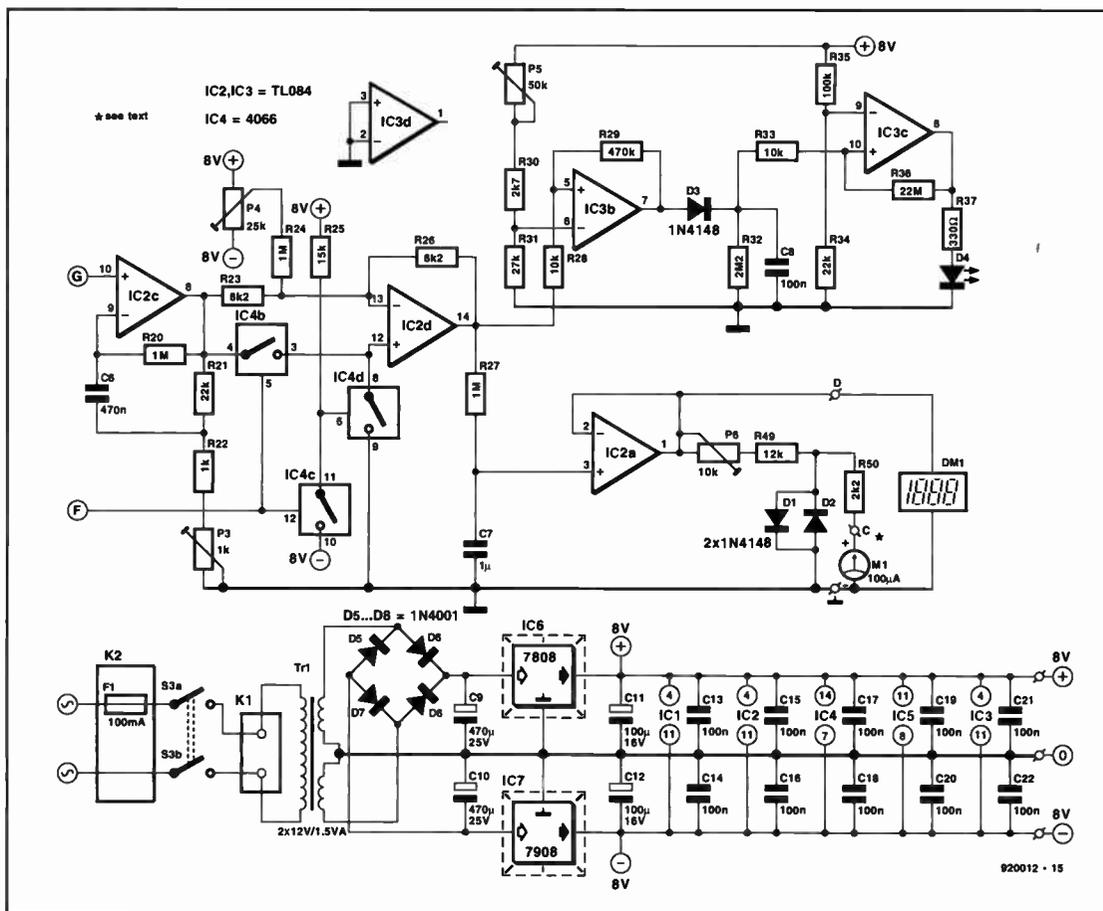


Fig. 5. Circuit of the rectifier, power supply, meter and overflow indicator.

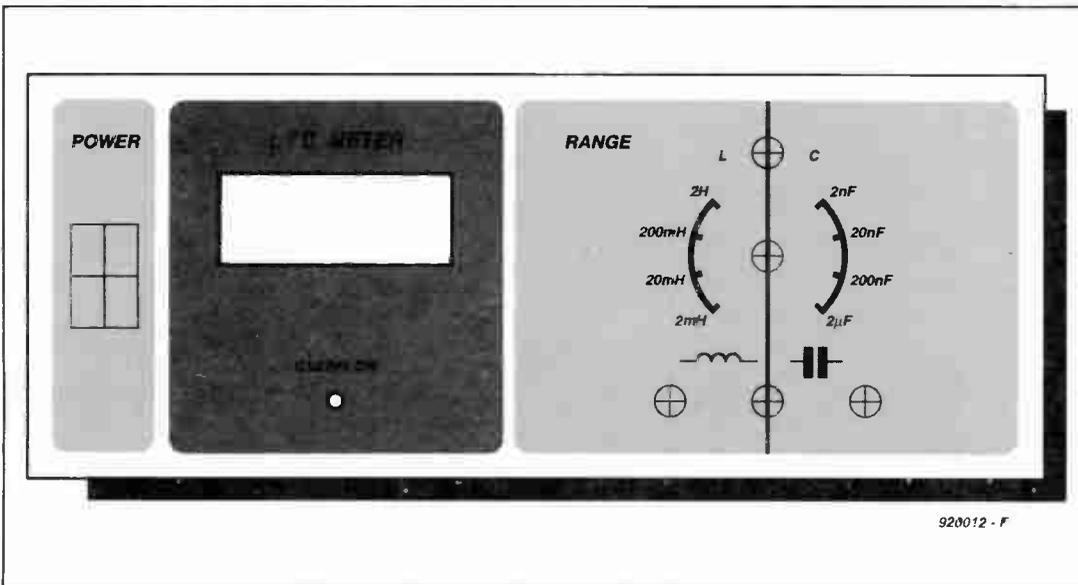


Fig. 6. Proposed front panel layout (foil Type 920012-F).

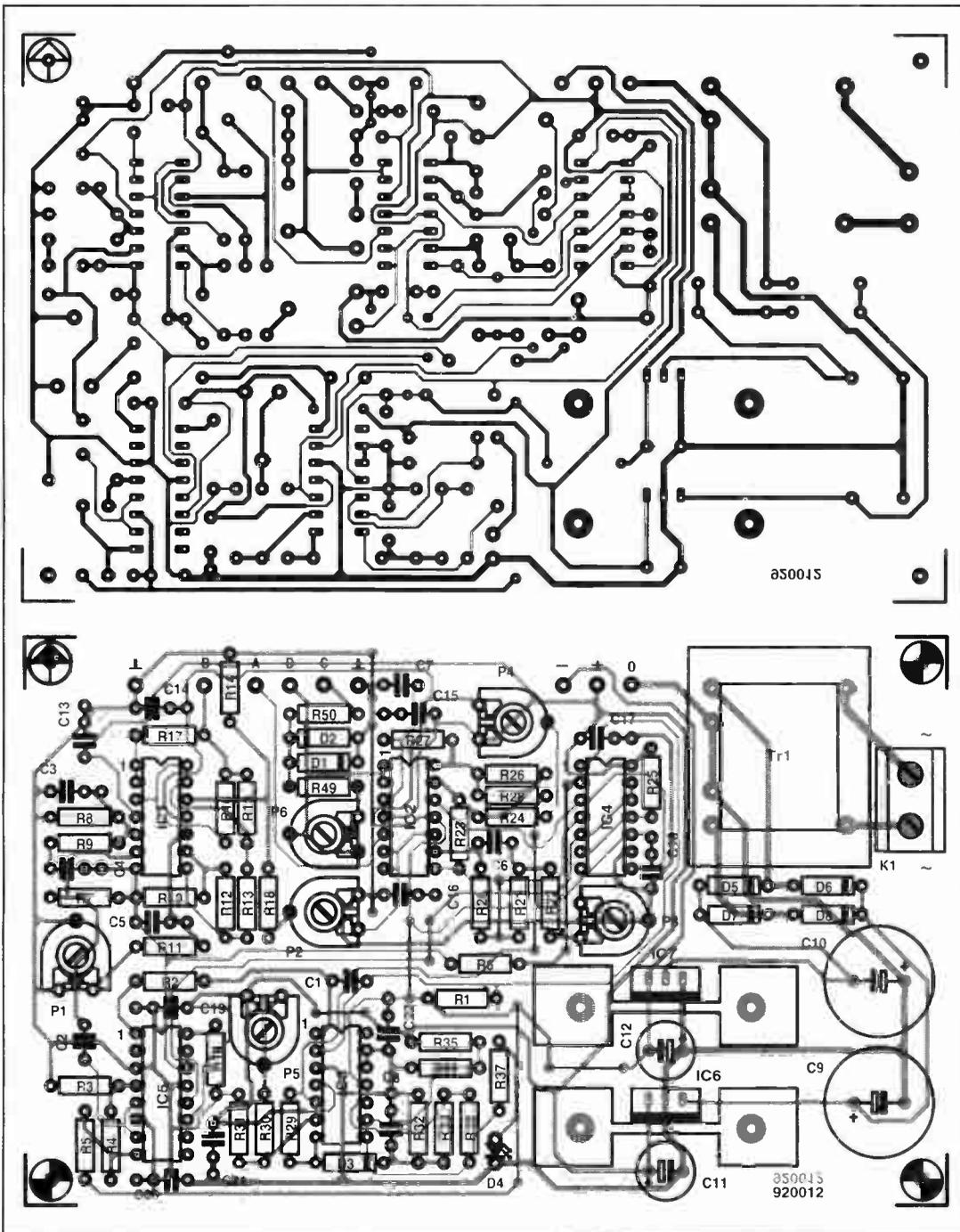


Fig. 7. Printed-circuit board for the inductance-capacitance meter – Type 920012.

PARTS LIST

Resistors:

- R1, R29 = 470 kΩ
- R2, R4, R28, R33 = 10 kΩ
- R3 = 100 Ω
- R5, R10, R12-R15, R18, R23, R26 = 8.2 kΩ
- R6 = 33 kΩ
- R7, R31 = 27 kΩ
- R8, R9 = 15 kΩ
- R11 = 12 kΩ
- R16, R17 = 30 Ω
- R19 = 5.6 kΩ
- R20, R24, R27 = 1 MΩ
- R21, R34 = 22 kΩ
- R22 = 1 kΩ
- R25 = 15 kΩ
- R30 = 2.7 kΩ
- R32 = 2.2 MΩ
- R35 = 100 kΩ
- R36 = 22 MΩ
- R37 = 330 Ω
- R38 = 100 kΩ, 0.1%
- R39 = 10 kΩ, 0.1%
- R40 = 1 kΩ, 0.1%
- R41 = 100 Ω, 0.1%
- R42 = 10 Ω, 0.1%
- R43 = 90.9 Ω, 0.1%
- R44 = 9.09 kΩ, 1%
- R45 = 90.9 kΩ, 1%
- R46 = 909 kΩ, 1%
- R47 = 909 Ω, 0.1%
- R48 = 9.09 kΩ, 0.1%
- R49 = 12 kΩ
- R50 = 2.2 kΩ
- P1 = 4.7 kΩ preset
- P2, P3 = 1 kΩ preset
- P4 = 25 kΩ preset
- P5 = 47 kΩ preset
- P6 = 10 kΩ preset

Capacitors:

- C1, C2, C7 = 1 μF
- C3-C5 = 10 nF
- C6 = 470 nF
- C8, C13-C20 = 100 nF
- C9, C10 = 470 μF, 25 V, radial
- C11, C12 = 100 μF, 16 V, radial
- (1×180 nF, 1%) for calibrating 2×100 nF, 1%) meters

Semiconductors:

- D1-D3 = 1N4148
- D4 = 5 mm LED, yellow
- D5-D8 = 1N4001
- IC1-IC3 = TL084
- IC4 = 4066
- IC5 = LM13700
- IC6 = 7808
- IC7 = 7908

Miscellaneous:

- K1 = 2-way terminal block for PCB mounting, 7.5 mm pitch
- K2 = mains panel plug with integral fuse holder and fuse, 100 mA delayed action
- K3-K5 = banana socket
- S1 = 3-pole, 4-position rotary switch with solder eyelets
- S2 = 2-pole change-over switch
- S3 = double-pole, double-throw switch with integral lamp
- Tr1 = mains transformer, 2×12 V, 1.5 VA
- M1 = 100 μA moving-coil meter
- DM1 = 3.5 digit digital voltmeter, 2 V
- Heat sinks for IC6 and IC7
- PCB 920012
- Front panel foil 920012-F

one for PCB mounting. It may be possible to bend these eyelets slightly outwards to give more space for the resistors.

If a digital meter module is used, do not forget to wire switch section S_{1c} , which controls the decimal points.

In spite of there being six preset potentiometers, the calibration of the instrument is fairly straightforward. Start with setting all the presets to the centre of their travel.

If a moving coil meter is used, connect a voltmeter between D and earth. With the instrument switched off, zero the moving-coil meter manually. When a digital meter is fitted, an external voltmeter is not required.

Set S_2 to position C (apacitor) and leave the input terminals open. Adjust P_4 till the voltmeter (or internal digital meter) reads 0. This arranges the offset compensation.

Connect two 100 nF in parallel to the input terminals and set the range switch to 200 nF. The value of these capacitors need not be accurate, since this test only serves to set the gain of IC_{2c} . This is done by adjusting P_3 until the voltage at D is 2 V. Because of R_{27} and C_7 ($\tau = 1$ s), this voltage rises only slowly; P_3 should, therefore, be adjusted slowly also. When P_3 has been adjusted as required, connect a resistor of 10 k Ω in parallel with the 100 nF capacitors. Then adjust P_1 to return the voltage at D to 2 V. This arranges the phase difference between sinusoidal and square-wave signals at 90°.

Next, remove the 10 k Ω resistor, but not the capacitors, from the input terminals. Ideally, P_2 should be set with its wiper at the output of IC_{2b} . This would, however, create a positive feedback loop with a gain of $\times 1$: not exactly conditions for oscillation, but very nearly so. It is, therefore, necessary to connect an oscilloscope to the output of IC_{2b} and adjust

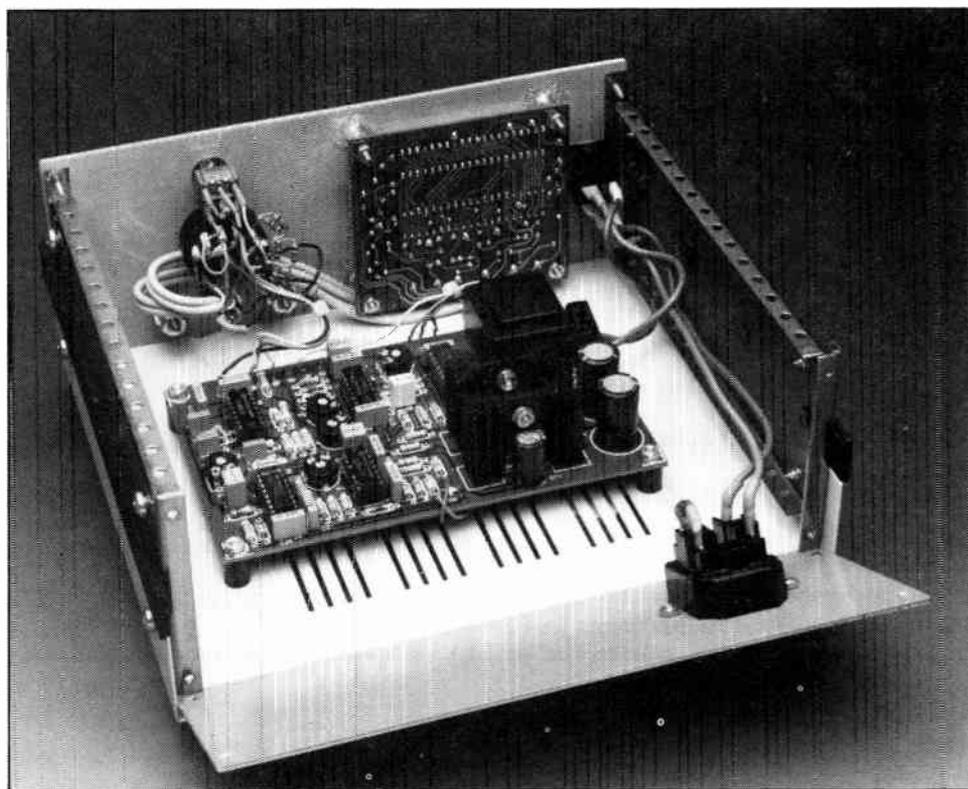


Fig. 8. Inside view of meter with top panel removed and rear panel hinged down.

P_2 so that oscillation just does not set in. If an oscilloscope is not available, set P_2 to about $\frac{3}{4}$ of its travel, that is, 750 Ω between wiper and earth.

If, apart from an oscilloscope, a function generator that provides a triangular output is available, P_2 can be adjusted even more accurately. To that end, R_{13} must be unsoldered from IC_{1c} and a 3-V, 1 kHz triangular signal applied across it. An oscilloscope connected to the output of IC_{2b} will then show a

square wave-form (because of the integrating action of the capacitors at the input). Adjust P_2 so that this wave-form is 'clean', that is, shows no overshoot.

Connect two 100 nF, 1%, capacitors (if a moving coil meter is used) or an 180 nF, 1%, capacitor (if a digital display is used) to the input terminals and adjust P_6 (moving-coil meter) or P_3 (digital display) until the correct value is read. ■

MEASUREMENTS ON POWER SUPPLIES

by our technical staff

How do you know whether your precious laboratory/workshop power supply unit is still working to specification? How do you measure the parameters of the PSU you have just built or purchased for fitting into an electronic apparatus and what do you specifically have to look out for? The answers to these and many other questions connected with the testing of power supplies are given in this practice-based article.

THE requirements of a laboratory/workshop power supply unit are exacting. Not only the output voltage and current, but also the dynamic and static internal resistance, noise, overshoot and thermal stability, to name but a few, are important. *Any electronic apparatus is only as good as its power supply is an adage that remains true.*

The extent to which a power supply can be tested depends primarily on the available

test equipment. Normally, the output voltage can be measured with a simple multimeter.

But even this measurement may be more complicated than appears at first sight. Imagine, for instance, that you have obtained a 6 V mains adapter to replace the batteries in a normally battery-operated apparatus, which is not only less expensive in the long run, but also more sensible from an ecological viewpoint. To your surprise, when you measure

the output voltage, it is 9–11 V. The first question that pops into your mind is: "Is it safe to connect to the equipment?" Practical considerations show that there is no harm in that whatsoever. The explanation for this statement is that such a simple mains adapter usually consists of a small transformer, rectifier and reservoir capacitor, nothing more. For all sorts of reason, small transformers generally have a fairly high internal resistance—

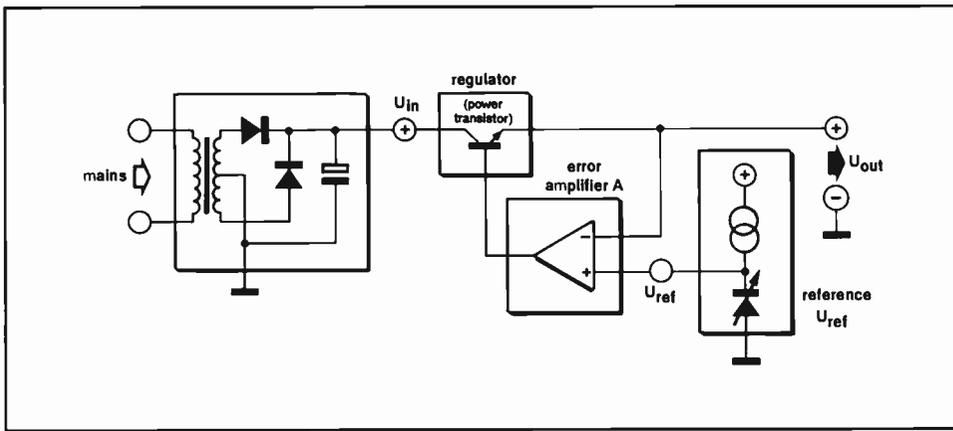


Fig. 1. Basic circuit of a regulated power supply. The quality of the supply is determined primarily by the regulator section.

of the order of a few ohms—and this makes the output voltage highly dependent on the output current. In other words, the e.m.f. is appreciably higher than the nominal (on-load) output voltage: if the load is small, the output voltage is high. That is why the load voltage is normally specified at a certain output current.

It is, therefore, essential to know how a parameter, even one as simple as the output voltage, is measured.

Parameters

In contrast to a simple mains adapter, a regulated power supply is designed to nullify the effect of different loads on the output voltage. In general, the more complex the design, the more the supply will approach the ideal. A perfect power supply has, irrespective of its application, some basic properties: it shall in all circumstances provide a constant output voltage, on which there is no ripple, noise or other spurious signals.

The following list shows which properties determine the quality of the supply.

Load voltage: the voltage that the supply will provide to a load over the nominal range of output currents.

Electro-motive force: the output voltage under no-load conditions; ideally, the e.m.f. and the load voltage should be

identical.

Nominal output current: the current that the supply can deliver to the load without becoming overloaded.

Internal resistance: ideally, this should be 0Ω , but all values in $m\Omega$ are good. It is sub-divided into:

Static internal resistance: this is discernible when the input voltage and the load remain constant with time.

Dynamic internal resistance: this is discernible only when the load changes with time.

Load regulation: this gives a measure of the fluctuations in the load voltage as the load current changes; it should ideally be infinitely large. The smaller the internal resistance, the better the load regulation.

Line regulation: this should ideally be infinitely large. It is a measure of the effect changes in the input voltage have on the nominal output voltage.

Ripple: this should ideally be fully suppressed. When rectification is full-wave its frequency is twice the mains frequency. The larger the regulating factor, the smaller the ripple at the output.

Noise: ideally, there should not be any. It originates primarily in the reference voltage source and in components in the regulator section.

Overshoot and undershoot: the regulating process causes small (mV range), short-

duration deviations from the load voltage. Ideally, these should not occur.

Long-term stability: affected primarily by ageing processes in the reference voltage source; ideally, the load voltage should not change with time.

Thermal stability: dependent mainly on the quality of the voltage reference source; the load voltage should ideally not vary with changes in ambient temperature.

Power dissipation: this should ideally be small; it is the product of the voltage drop across the regulator and the load current plus losses in the transformer and rectifier.

Overcurrent protection: this becomes active when the load current starts to exceed its nominal value. It is required not only to guard the load from excessive currents under fault conditions, but also to protect the power supply from damage.

Short-circuit protection: ideally, the supply should be able to withstand a short-circuit indefinitely; the protection is often combined with overcurrent protection.

Power supply operation

The basic circuit diagram of a regulated power supply is shown in Fig. 1. The input section consists of the mains transformer, rectifier and filter capacitor. The remainder, regulator, error amplifier and reference voltage source, is required for regulating the load voltage. The entire regulating circuit can be housed on an integrated chip, such as those in the 78xx series.

The quality of the power supply depends primarily on the excellence of the regulating section. Nevertheless, although the internal resistance of the supply, and thus its load regulation, is highly dependent on the gain of the error amplifier, the internal resistance of the transformer, rectifier and reservoir capacitor also play a role.

If the total (static) internal resistance of the input section is, say, 2Ω , and the amplification of the error amplifier is $\alpha = 1000$, the total (static) internal resistance of the supply is $2 m\Omega$. This ignores, of course, the resistance of the wiring, the PCB tracks, and so on. The amplification available for regulation consists of the open-loop gain and the closed-loop gain. The latter corresponds to the line regulation (\approx change in input voltage/resulting variation in output voltage).

Setting the amplification very high to reduce the internal resistance to an absolute minimum is not a practical proposition, because, since the error amplifier and power transistor require a finite time to react to changes, the build-up or decay transients increase in proportion to the amplification.

When top quality is required, close attention should be paid to the design of the mains transformer, particularly its (static) internal resistance. Above all, it should be designed so as to meet its requirements handsomely. C-type and toroidal cores, because of smaller stray losses, generally result in smaller internal resistances than the conventional laminated cores.

The capacitance of the reservoir capaci-

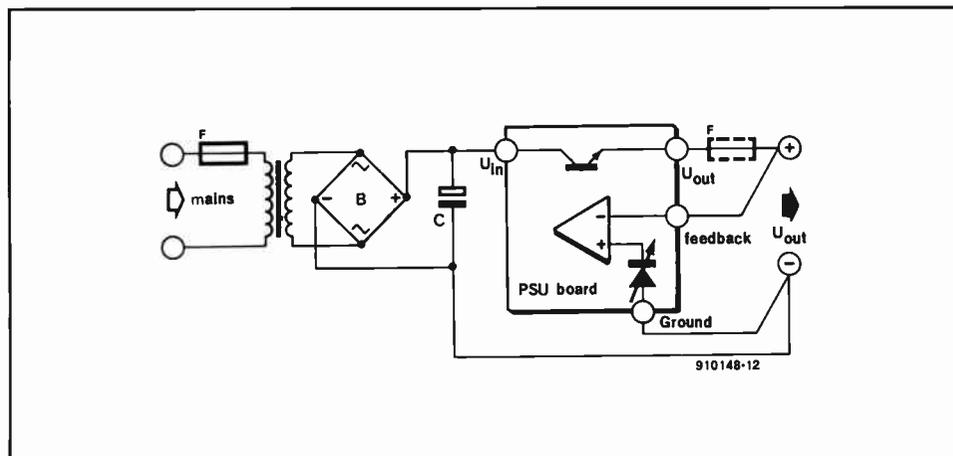


Fig. 2. Wiring diagram of a regulated power supply showing how the unit should be wired up. Note the location of the fuse(s).

tor affects not only the dynamic internal resistance, but also the ripple on the load voltage.

The thermal stability and noise are determined primarily by the reference voltage source. Three-terminal voltage regulators normally have this source on board, which therefore gets as hot as the power transistor—not an ideal situation.

Noise and other spurious signals can normally be reduced appreciably by shunting the voltage source with a small, foil-type decoupling capacitor.

Apart from the quality of the reference source itself, the power supplied to it is also important and should, therefore, be regulated.

It is, of course, essential that a power supply is wired correctly. If the general diagram in Fig. 2 is followed, and heavy-duty wire is used, the internal resistance and ripple will be a minimum.

Fuses should, in general, be located in the +ve input (UK: 'live') line to the mains transformer. Added security is obtained by a fuse between the power transistor and the feedback take-off for the error amplifier (as shown in dashed lines in Fig. 2). The voltage drop across the fuse is compensated by the regulating process. The fuse must be located on the PCB.

Measurement methods

The most important parameter of a power supply is its static internal resistance. Fortunately, this can be measured fairly easily with a multimeter and a suitable load.

Because of the greater accuracy of its read-out, a digital multimeter is preferred. Moreover, the measurement accuracy of a digital multimeter, even of economy types, is generally better (error <1% on d.c. ranges) than that of an analogue meter in the same price range.

During current measurements, the voltage drop across the meter is important: it should be small and even with large output currents not exceed 200 mV. Note that many 3 1/2 digit multimeters have no 200 mV range.

For a 12 V, 2 A power supply, a 6 Ω, 24 W load is needed. This can, for instance, be made from five 33 Ω, 5 W resistors in parallel. The total resistance is then 6.6 Ω, but that is more an advantage than disadvantage, because the load current will then be 1.8 A, a value that can be read very accurately on most digital multimeters. Note that the dissipated heat can easily burn the surface of a table or your fingers.

A better load is provided by a so-called resistor box containing, for instance, 20 or more 0.47 Ω, 5 W resistors that can be interconnected in various ways. Such a box (there are several varieties) can provide a variable load of 0.47–10 Ω rated at 3 A. It is invaluable if a number of power supplies are to be tested.

First, measure the open-circuit output (electro-motive force—e.m.f.), which is, say, 12.08 V. Next, connect the 6 Ω load and measure the current through it, which is, say, 1.836 A. Then, measure the voltage

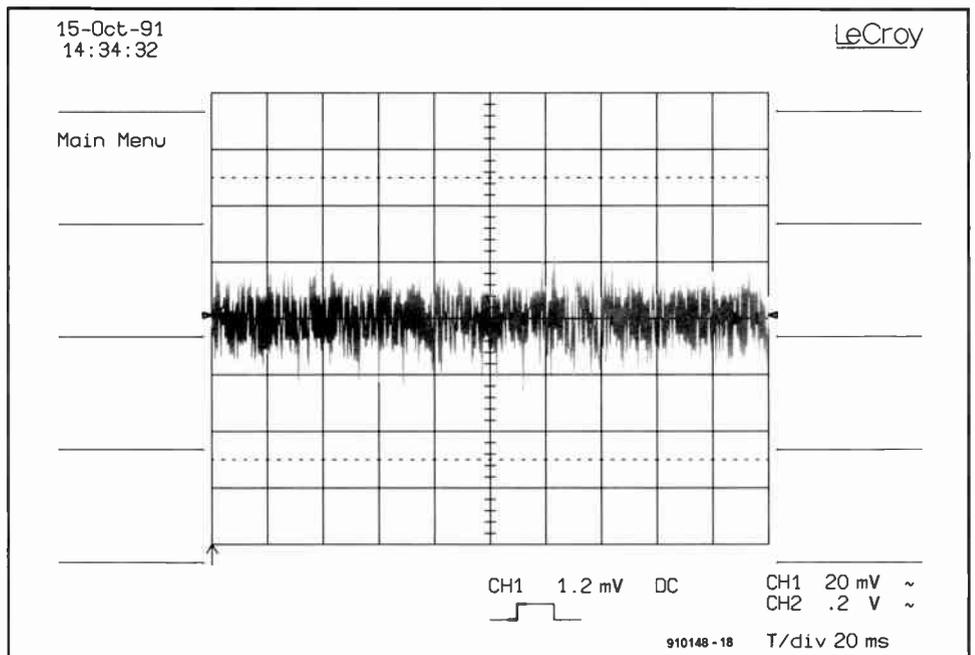


Fig. 3. Representation of noise output of a power supply as seen on an oscilloscope. Noise can be defined as random-frequency signals that extend over a considerable frequency spectrum.

across the load, which is, say, 11.98 V. The difference between the e.m.f. and the load voltage is thus 10 mV. Since the load current is 1.836 A, the internal resistance is $10 \times 10^{-3} / 1.836 \approx 5.5 \text{ m}\Omega$, a reasonably good value.

If the internal resistance of the multimeter is not taken into account during the current measurement (when the meter is in series with the load) a small error results. If, in the example discussed, the voltage drop across the meter was 186 mV ($R_i = 100 \text{ m}\Omega$), the calculated value of the internal resistance was 1.5% too large. This error can be ignored, because the tolerance of the load causes a larger error (do not forget the increase in resistance caused by heating).

To measure the dynamic internal resistance, and determine noise and ripple, an oscilloscope is indispensable. The scope, connected across the output terminals, is set to its lowest a.c. range, normally 5 mV per screen division, and the time base to 10 ms per division. Both noise, that is, random-frequency signals extending over a considerable frequency spectrum, and ripple, the unavoidable by-product of rectification, here with a period of 10 ms, are displayed—see Fig. 3 and Fig. 4 respectively. The ripple will increase slightly when a load is connected to the supply. As long as the peak-to-peak amplitudes do not exceed a few mV, all is well. If, however, on load, the ripple has a period of 10 ms and a peak-to-peak amplitude of sev-

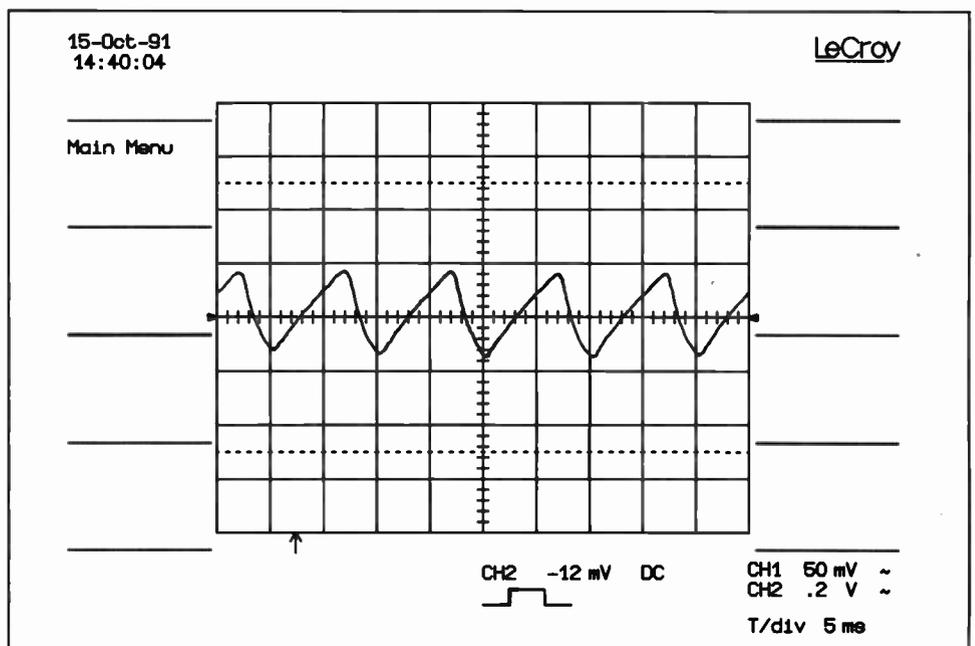


Fig. 4. Representation of a typical 100 mV ripple on the output of a power supply as seen on an oscilloscope.

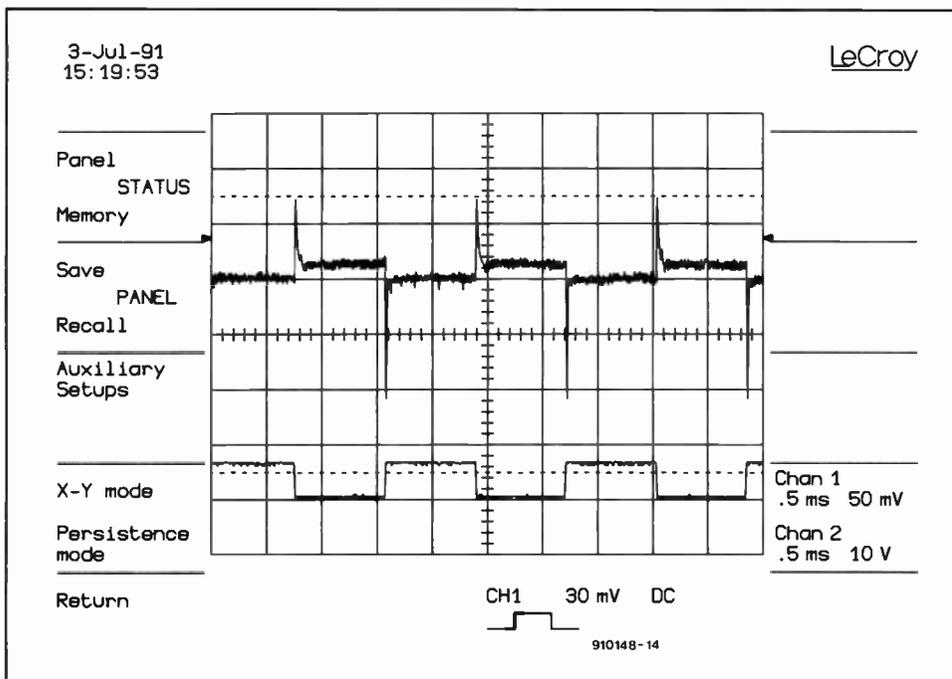


Fig. 5. Representation of the dynamic behaviour of the output voltage of a power supply (upper trace) loaded with the set-up of Fig. 6. The lower trace shows the drive (base signal) to T_1 .

eral hundred mV, the input voltage to the regulating section is too small. That means that either the current rating or the secondary voltage rating of the mains transformer is too low. The current rating should be some $1.5 \times$ the peak d.c. output current of the supply. The secondary voltage depends to some extent on the design of the regulator and on the capacitance of the reservoir capacitor. For instance, a rating of $12 \text{ V} \sim$ for a 12 V power supply is clearly too low and should have been 15 V . It is, however, also possible, provided the ripple on load is small, to increase the value of the reservoir capacitor from, say, $4700 \mu\text{F}$ to $10000 \mu\text{F}$.

To ascertain the behaviour of the power supply with rapidly changing load values,

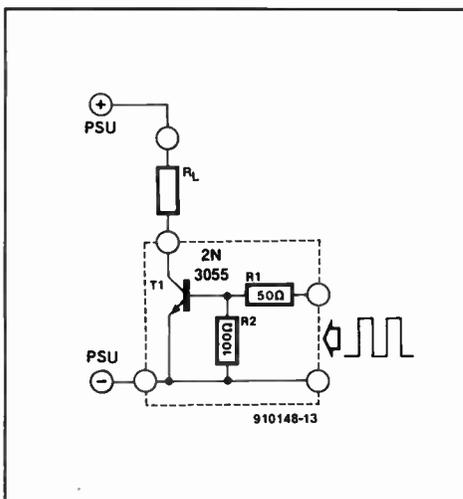


Fig. 6. Rapidly changing loads may be simulated by a power transistor and a rectangular-wave generator. Such a load enables the dynamic behaviour of a power supply to be determined.

its dynamic internal resistance must be determined and the load voltage observed on an oscilloscope. For this purpose, the rapidly changing load can be simulated by the set-up shown in Fig. 6. The function generator should be able to provide rectangular signals from a low-impedance ($<50 \Omega$) output at a level of not less than 5 V p-p. This ensures full drive for T_1 which then draws a current of about 2 A . If a larger current is required, T_1 must be replaced by an appropriate darlington power transistor.

If a function generator is not available, a rectangular-signal generator can be built with the aid of the well-known Type 555, which is ideal for this purpose.

The transistor should be fitted on a small heat sink, since, in spite of the switching operation, it dissipates $2\text{--}4 \text{ W}$ when the current is 2 A . If the power supply is rated above 45 V , it is advisable to use a sturdier type of transistor, for instance, the Type 2N3055.

The circuit in Fig. 6 is especially suitable for drive frequencies of up to about 2 kHz ; note that 1 kHz is the typical frequency at which the dynamic behaviour of a power supply is usually determined.

With the function generator, set to 1 kHz , connected to the power supply via the circuit in Fig. 6 and an oscilloscope (time base set to 0.5 ms per division; amplification set to 10 mV per division) connected across the load, the screen display should be roughly as shown in Fig. 5. The upper trace shows that the regulator cannot follow the rapid changes. When the load is switched on, the load voltage initially drops sharply; only when the power transistor has resumed full drive does the load voltage return to its nominal value. The process on switch-off is similar: the regulator allows the power transistor to remain on for just a little too long. The duration of

the voltage peaks in the upper trace gives an idea of how fast the regulator works.

The amplitude of the spikes can be reduced to some extent by a 100 nF capacitor across the output terminals or, preferably, directly across the load.

Apart from the overshoot and undershoot in Fig. 6, the trace also shows another, much smaller, variation with time when the load is constant. That tiny rectangular signal, superimposed on the load voltage, is caused by the dynamic internal resistance of the current source. Its magnitude is determined by reading the value of the rectangular signal on the oscilloscope screen (this is, say, 15 mV p-p) and divide this by the current through the load (measured with the multimeter in series with the load). To ensure that the current flows uninterrupted during the measurement, the input of the circuit in Fig. 6 (R_1) is connected to, say, 5 V d.c. If the load current is, say, 1.77 A , the dynamic internal resistance is $15 \times 10^{-3} / 1.77 = 8.5 \text{ m}\Omega$.

What quality is required?

Now it has been shown what parameters of a power supply can be measured, and how, the question remains "what quality should a power supply have for a given application?"

For a.f. output amplifiers, a regulated power is normally not needed, but in the a.f. pre-amplifier(s) the suppression of noise and ripple are of paramount importance.

For small digital circuits, the quality provided by a three-wire regulator is normally more than adequate. Care should be taken with 5 V power supplies for complex digital circuits that contain TTL ICs (computers, for instance). Here, the 5 V load voltage should be set accurately to 5.15 V , since at lower values, because of the potential drop across the PCB tracks, the supply to some TTL ICs may become too low for reliable operation.

Power supplies for use in a laboratory or workshop are, as might be expected, the most demanding as regards noise, ripple, static/dynamic internal resistance and dynamic behaviour. Moreover, they should have a variable voltage/current output. All these facilities cost money, of course, and this cost should be considered in relation to the applications for which the supply is, or may be, needed. ■

Useful literature:

Power Electronics Handbook by F.F. Mazda, Butterworths (1990), ISBN 0 408 03004 6.

Electronic Instruments and Measurement Techniques, by F.F. Mazda, Cambridge University Press (1987), ISBN 0 521 26873 7.

Design & Build Electronic Power Supplies, by Irving M. Gottlieb, Tab Books (McGraw-Hill) (1991), ISBN 0 8306 6540 4.

High-frequency Switching Power Supplies, by George C. Chryssis, McGraw-Hill (1989), ISBN 0 07 010951 6

CORRECTIONS & TIPS

Low-frequency counter

(January 1992, p. 44)

The parts list on p. 44 erroneously states that capacitors C_{11} and C_{12} are tantalum types. Since the polarity of the voltage across these capacitors may be inverted, the capacitors should be bipolar aluminium types.

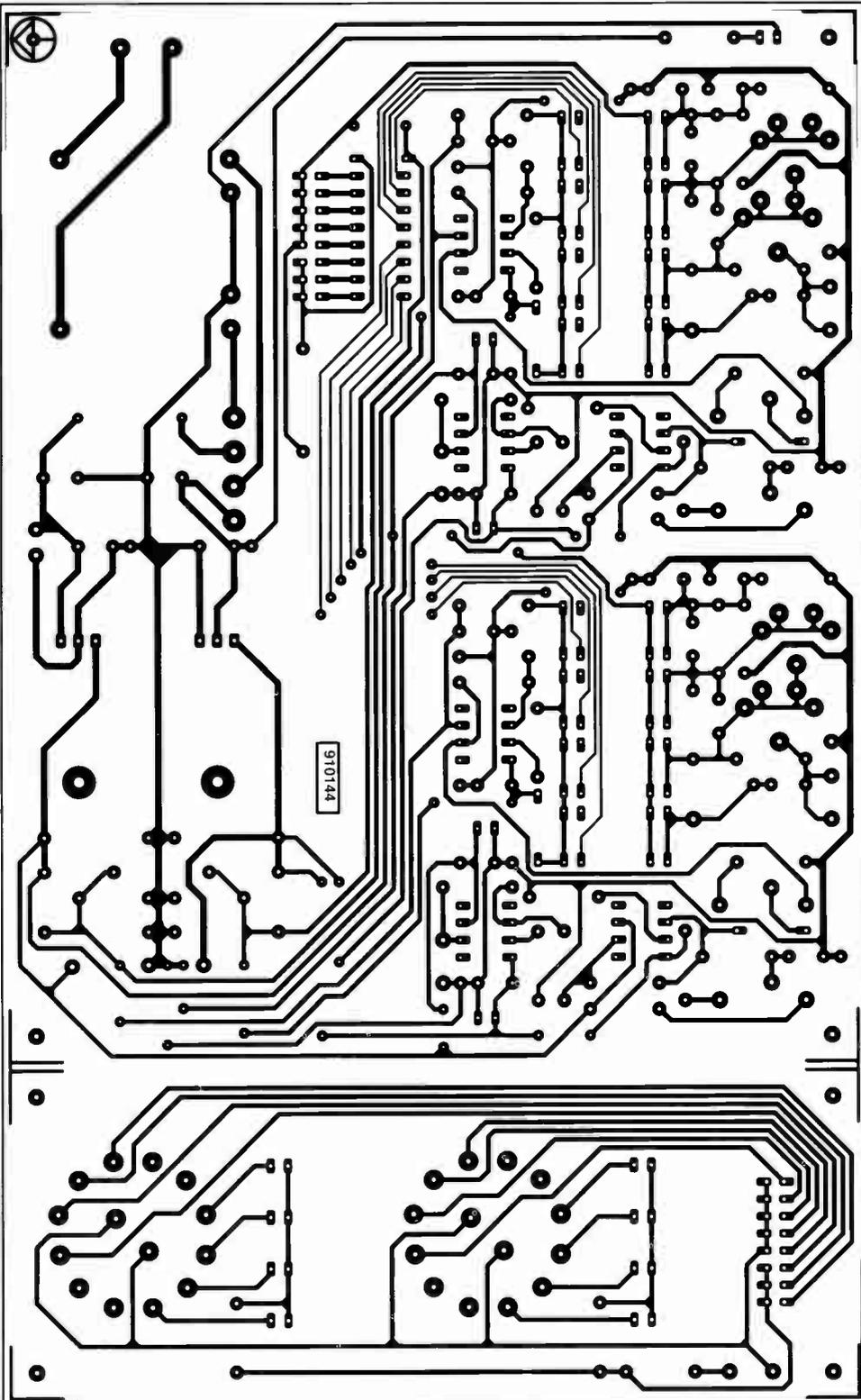
Under 'Construction' on p.45, it is stated in the penultimate paragraph that 'the connection between the input socket and C_{10} must be single screened cable'. In fact, the connection is so short that screened cable is not

necessary.

Measurement amplifier

(February 1992)

Owing to a misunderstanding, the track side of the printed circuit board (p.23) was not included with the article in our February 1992 issue. Our apologies for this oversight. The missing drawing is shown below.



Automatic cycle lights

(July/August 1991, p. 49)

Sir—In the construction of 'Automatic cycle lights', I have encountered three problems.

1. Triggering of IC_{1b} at input $-T$ (pin 11) and R (pin 13). A trailing edge at $-T$ triggers the IC if R is high. It is, however, possible that R is still low or is just changing state. A (not very elegant) solution to this is to connect the line from Q (pin 7) to R to junction R_2-D_1 (+ battery) via a $1\text{ k}\Omega$ resistor.
2. A short pulse caused by the switching on of the battery triggered input $+T$ of IC_{1b} (pin 4), which switched the battery off again. This was cured by connecting a 470 nF capacitor between $+T$ and earth.
3. Triggering at $+T$ of IC_{1b} was so sensitive that even a tiny movement of the bicycle causes the battery to be switched off. In other words, if you don't hold the bicycle absolutely still, its lights will flash on and off. The sensitivity can be made variable by replacing resistor R_4 by a $100\text{ k}\Omega$ preset.

Helge Bergmann, Hannover

Mini square-wave generator

(February 1992, p. 60)

Sir—On page 61 of 'Mini square-wave generator', you refer to the 7805 regulator as a "low-drop regulator, which ensures low power dissipation". I would disagree with that description: in my books that regulator is definitely not a low-drop type.

P. Thompson, Bristol

You are right: we apologize for that error.

Editor

Build a compact-disc player

(January 1992, p. 36)

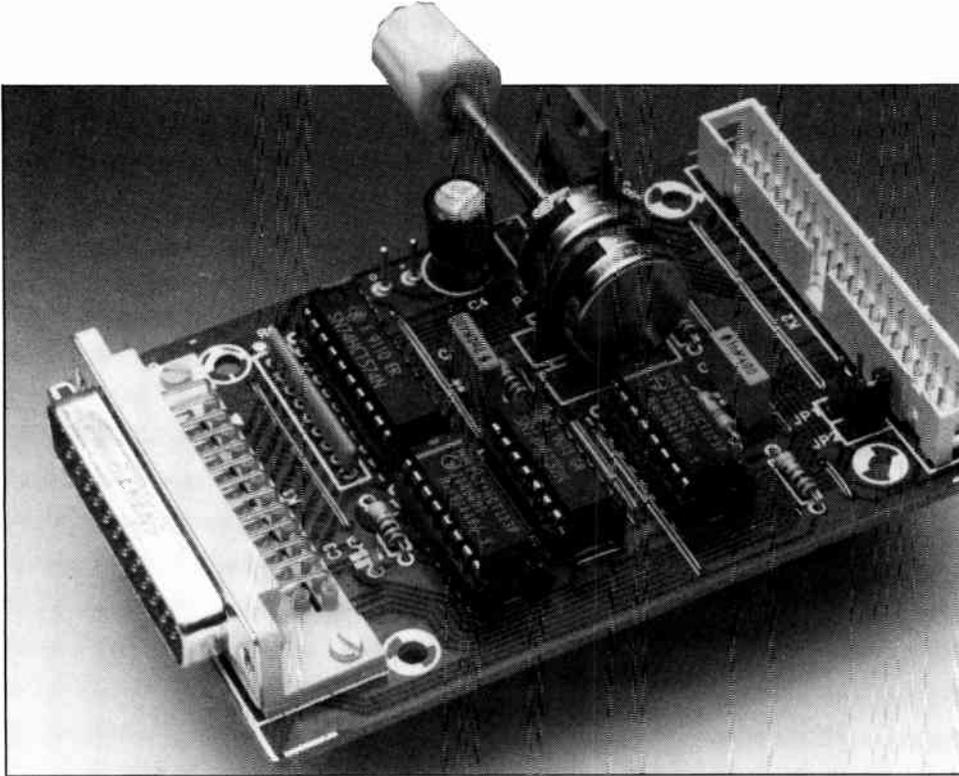
Sir—I think that your contributor, T. Giffard, in his article 'Build a compact-disc player' must be a lot more wealthy than I am if he considers £249 "an affordable price" (available from only one advertiser in your January issue!). Especially as Philips' own personal compact disc player complete and ready made costs only £149 (from Argos).

J. Easton, Watchet, Somerset

The price mentioned in the advertisement is HFL (Dutch guilders) 249 (equivalent to about \$145.00.

Editor

CENTRONICS LINE BOOSTER



Put your printer a little further away from the PC, connect it with a ready-made 5-metre long Centronics cable, and you may be in for a surprise. Missing characters and error beeps all around you. The problem is obvious: not enough drive power on the Centronics port!

Design by A. Rietjens

TODAY no PC is sold without one or more parallel printer ports. Interestingly, these ports are often referred to as 'Centronics compatible' when in fact they are simply TTL buffers, whose specifications certainly do not meet the Centronics standards as regards signal timing and drive capacity. Consequently, these 'stripped down' versions of the Centronics port can be used with relatively short printer cables only, and often result in erratic behaviour of an otherwise perfectly operating printer. The circuit described here overcomes this problem by boosting the signals on the parallel printer port, allowing long cables to be used between the PC and the printer.

On handshaking

It should be simple, really: only three lines arrange the handshaking necessary for unidirectional data transfer via eight parallel datalines. The Centronics standard further specifies the use of a couple of printer status lines, but these should not cause problems either. To reduce the cost of their products, most PC and printer manufacturers implement only one or two of the available printer

status lines: Paper End, Auto Feed, Printer Error, Printer Select and Printer Init.

When the PC starts a printer output job, the BUSY input on its parallel printer port is usually low, which indicates that the printer is waiting for data. Next, the PC puts the data on the eight datalines, D0-D7, and informs the printer that valid data is available by pulling the STROBE line low briefly. To indicate that it has received the databyte, the printer responds to the PC by making the BUSY line high on the negative edge of the STROBE pulse. Once the printer has processed the byte—which means that it has been either printed or stored in a buffer—it pulls BUSY low again, and in addition supplies a short pulse on the ACKNLG line to the PC.

As shown in Fig. 2, the time difference between the active ACKNLG and the BUSY signals is specific to the type of printer, and may differ by a few microseconds. With Centronics compatible printers, the ACKNLG pulse starts on the negative edge of the BUSY pulse, while with Epson compatible printers it is ended by that time.

Requirements

The Centronics standard specifies that each dataline and handshaking line must be indi-

vidually screened in the cable between the printer port and the printer. Not all 'Centronics' cables on the market meet this requirement, however, whence the problems that may occur when an inexpensive cable as short as, say, 3 m is used. The parasitic capacitances introduced by such a cable make a mess of the relatively short control signals, and the printer either produces error signals, or garbles the characters. This problem can be solved by a circuit that meets the following requirements:

- data must be held stable for a certain time;
- the length of the STROBE signal supplied by the PC must be adapted depending on the length of the printer cable;
- the BUSY signal must be available sufficiently long for the PC to process;
- the ACKNLG signal must be generated at a well-defined length after the BUSY line is deactivated;
- none of the other control lines should be affected.

Circuit description

The circuit shown in Fig. 1 is designed to meet all of the above requirements. The computer is connected to K1, the printer to K2. The functional description that follows is based on the assumption that the PC is running, and the printer is switched on and 'on line'.

The negative edge of the first strobe pulse supplied by the computer triggers monostable IC1a. The resultant pulse at the Q output of the monostable causes IC5 to latch the byte available on the datalines, D0-D7. The output of the latch is connected to the printer via the printer cable. The Q output of monostable IC1a, pin 4, supplies the STRBOUT pulse, which is a lengthened copy of the STRB (strobe) pulse supplied by the computer. The STRBOUT pulse is fed to the printer (via pin 3 of connector K2) as well as to the trigger input of a second monostable, IC1b, where it is again lengthened before it is combined with the BUSY signal from the printer in OR gate IC4c. The lengthened BUSY signal is fed to the respective port line on the PC. The upshot is that if the printer is still busy when the monotime of IC1b has lapsed, it can continue to keep the computer waiting. When the monotime of IC1b has lapsed, and the printer is ready again (i.e., the BUSYIN line has returned to low), the output of IC4c goes low also, and triggers the third monostable in the circuit, IC2a. By generating a short ACKNLG pulse for the computer, IC2a closes off the handshaking protocol for one databyte, and the system is then ready to process the next one when this is applied by the PC.

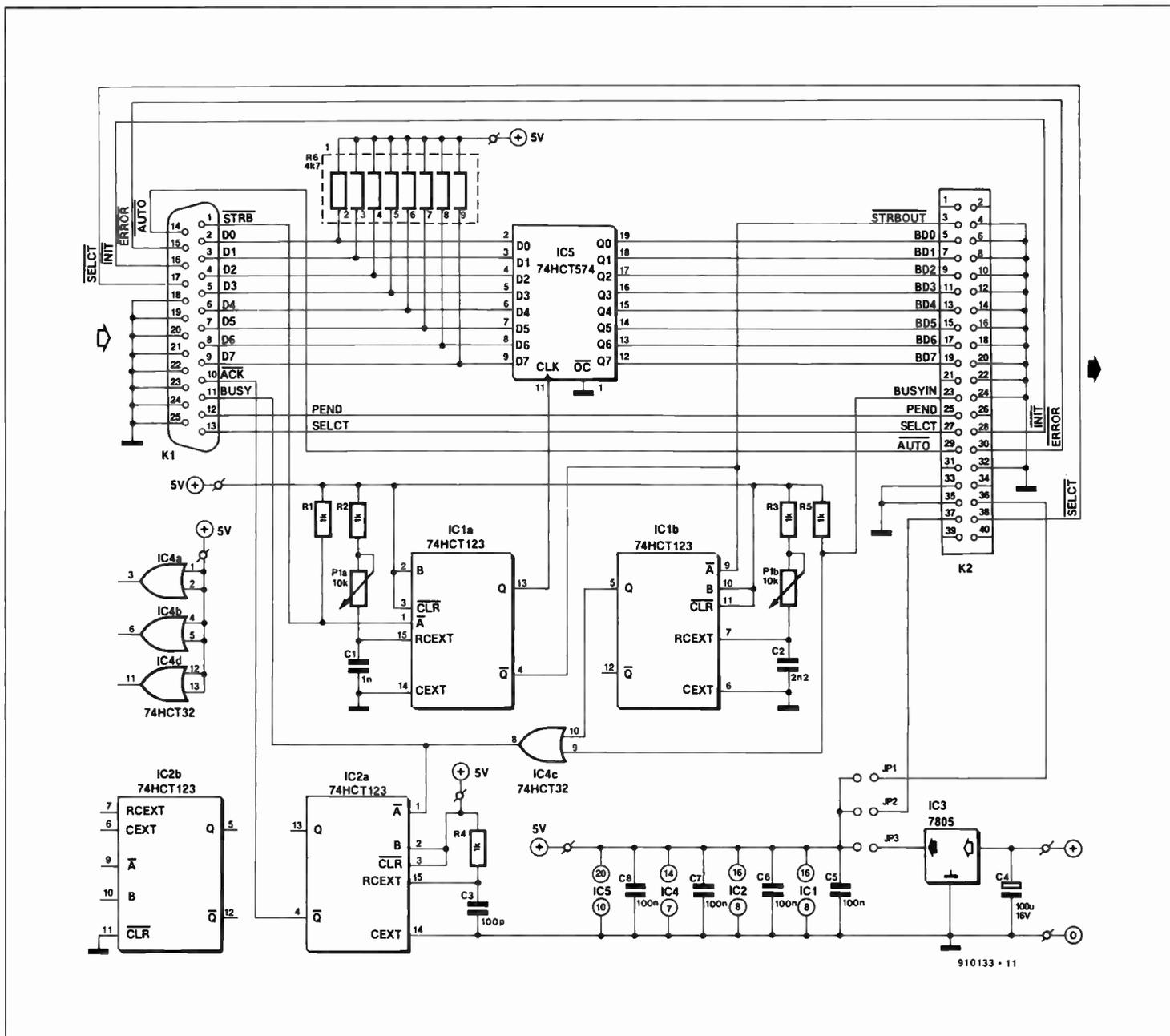


Fig. 1. Circuit diagram of the Centronics line booster.

All other control lines between the PC and the printer, such as AUTO and ERROR, are generally uncritical, and connected straight between the input connector, K1 (a 25-way sub-D type), and the output connector, K2 (a 40-way pin header or box header).

Construction

To keep the line booster as small as possible, the printed circuit board (Fig. 3) is pretty 'crowded'. Start the construction by fitting the ten wire links on the board. Next, fit the IC sockets and the passive components (ca-

pacitors, resistors and wire jumpers). Note that the power supply parts, IC3 and C4, are required only if the unit is powered by an external supply, i.e., not by the printer. Most printers supply +5 V at input connector pin 18 or 35. When this voltage is available, fit jumper JP1 or JP2 instead of JP3 on the

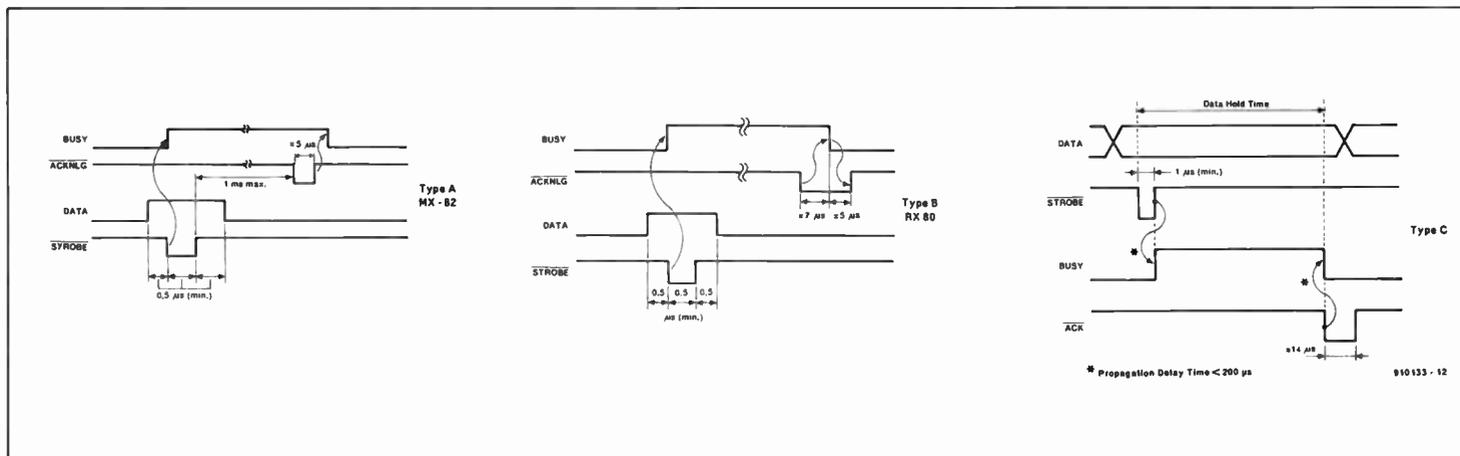


Fig. 2. Printers may differ in respect of the timing of the BUSY/ACKNOWLEDGE handshaking signals.

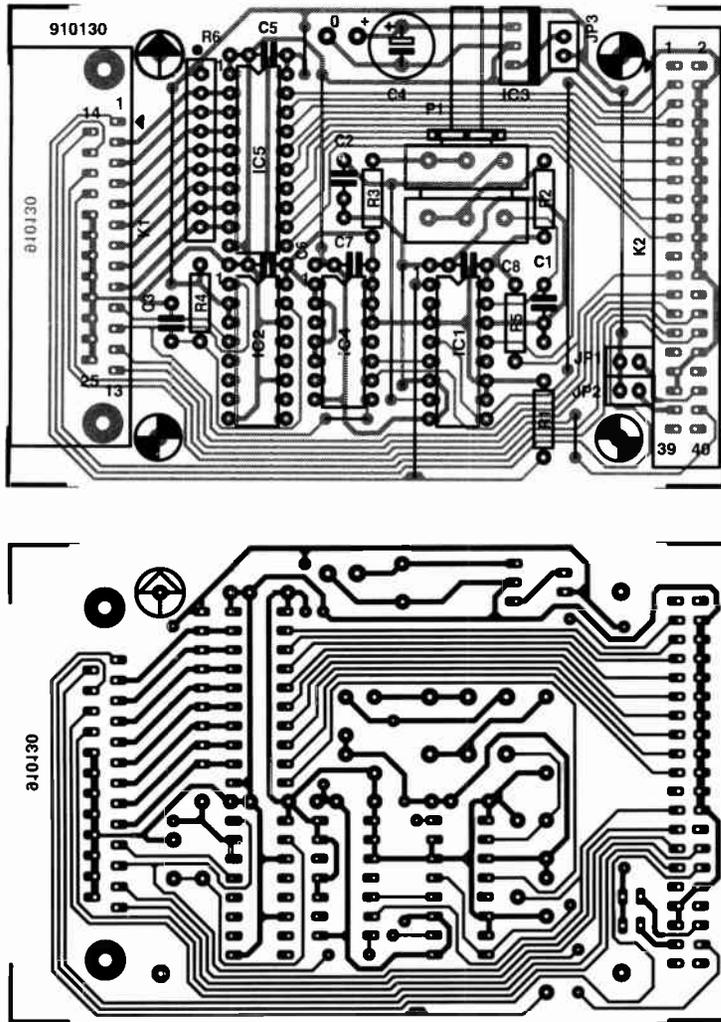


Fig. 3. Single-sided printed circuit board for the project.

board. The last parts to be fitted before inserting the ICs are the dual-gang (stereo) potentiometer, P1, and the connectors, K1 and K2.

The printer is connected via a short length of 40-way flatcable, one end of which

is fitted with an IDC socket (to mate with the pin header on the board), and the other with an IDC-type 36-way Centronics ('blue ribbon') connector. The PC is connected to the booster via an RS232 cable without swapped TxD/RxD wires (pins 2 and 3), while the

COMPONENTS LIST

Resistors:

| | | |
|---|--|-------|
| 5 | 1k Ω | R1-R5 |
| 1 | 8-way 4k Ω 7 SIL array | R6 |
| 1 | 10k Ω lin. stereo potentiometer | P1 |

Capacitors:

| | | |
|---|------------------------|-------|
| 1 | 1nF | C1 |
| 1 | 2nF2 | C2 |
| 1 | 100pF | C3 |
| 1 | 100 μ F 16V radial | C4 |
| 4 | 100nF | C5-C8 |

Semiconductors:

| | | |
|---|----------|---------|
| 2 | 74HCT123 | IC1;IC2 |
| 1 | 7805 | IC3 |
| 1 | 74HCT32 | IC4 |
| 1 | 74HCT574 | IC5 |

Miscellaneous:

| | | |
|---|------------------------------------|--------|
| 1 | 25-way sub-D plug for PCB mounting | K1 |
| 1 | 40-way box header | K2 |
| 1 | Printed circuit board | 910133 |

booster is connected to the printer via a Centronics extension cable. The booster should, of course, be located as close as possible to the PC.

The ACK/BUSY timing of the booster is simple to adjust. Initially, turn P1 fully clockwise (maximum resistance). Next, send a fairly long file to your printer, and while the printing is going on turn P1 anti-clockwise until you see the first errors appear. Turn P1 clockwise again until the errors disappear. This is the best setting of the delay, which should not be made larger than strictly necessary to prevent too low a data transfer speed. ■

Inmarsat to develop global paging via satellite

Business executives and professionals on the move will have access to a global satellite paging service using pocket-size receivers, as early as 1994.

Designed to operate via the Inmarsat satellite system, the pagers will enable mobile users on land to receive messages no matter where they are in the world. This will enable travelling executives, journalists and couriers to be contacted by their offices.

Although wide terrestrial paging services are available in many countries, including some that involve use of satellites for inter-system connections, the Inmarsat satellite paging service will be the first global, direct paging service via satellite, operating to a single worldwide

standard. It is designed to provide a higher degree of penetration into urban areas than would normally be achieved by purely line-of-sight mobile satellite services.

Inmarsat, a 64-nation cooperative, operates a system of geostationary satellites to provide global mobile telephone, telex, facsimile and data services to maritime, aeronautical and land mobile users all over the world.

The decision on paging follows a series of technical and commercial studies and experiments over the last couple of years. This new service is designed to complement existing and planned terrestrial paging systems by providing a very wide area of coverage at affordable prices through the Inmarsat global satellite network.

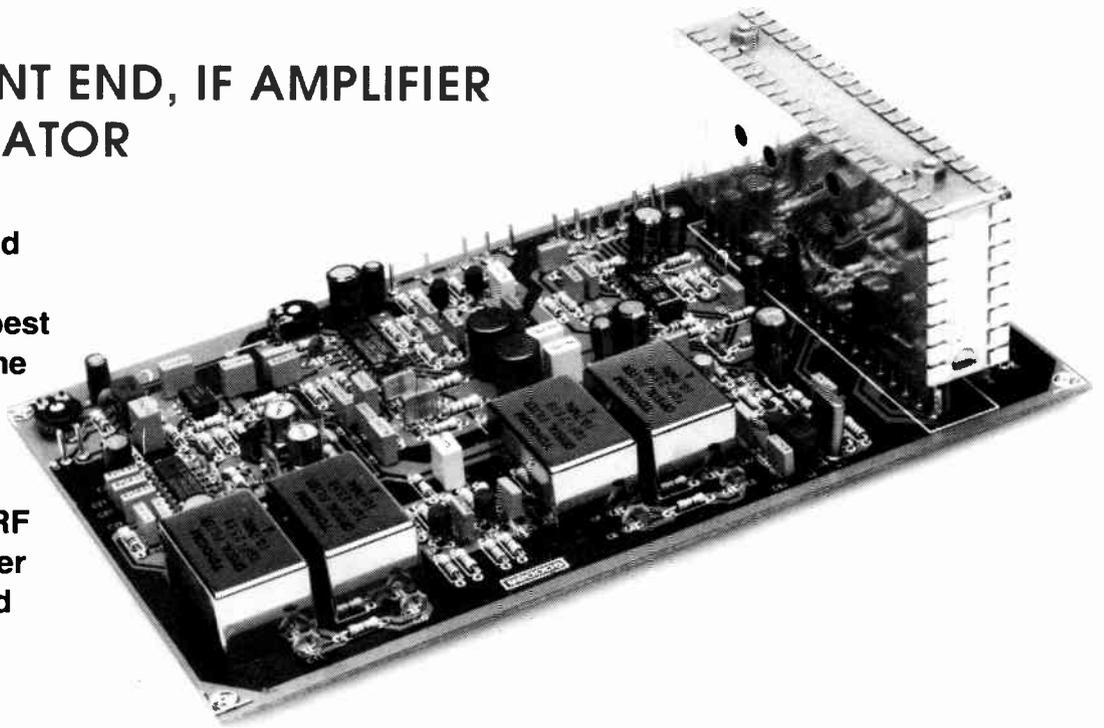
The system will provide for conventional tone paging, as well as alphanumeric messages and various forms of data, to be displayed on a small LCD screen. A variety of receiver models are expected to be available—from pocket-sized stand-alone units, to those integrated into briefcase-sized Inmarsat-C or -M satcom terminals, and receivers designed for installation on commercial vehicles. With satellite pagers integrated into their Inmarsat briefcase satcoms terminals, subscribers can be paged and advised to call their offices, even if their terminals are turned off.

International Maritime Satellite Organization (Inmarsat), 40 Melton Street, London NW1 2EQ. Telephone: (071) 728 1000. Fax: (071) 728 1044.

FM TUNER

PART 1: RF FRONT END, IF AMPLIFIER AND DEMODULATOR

An FM tuner is described whose specifications challenge those of the best receivers available on the market. A ready-made tuner module is used to prevent problems with building and adjusting RF circuitry, and the receiver is synthesizer controlled by a 80C32-based microprocessor circuit.



Design by H. Reelsen

SYNTHESIZER control of FM receivers acquire common these days, and even low-priced tuners offer a lot of technology in this respect. Whilst the performance and ease of control of such radios is quite reasonable, their design is almost invariably based on many compromises struck up to keep the price tag attractive. This not only applies to the design, but also to the materials used: plastic enclosures, a single, low-quality, PCB to hold all the components, simple front ends that suffer from cross-modulation, and IF (intermediate frequency) amplifiers based on ceramic filters.

Building your own FM tuner allows high quality components to be used throughout the design, while the total outlay remains within reason. Since synthesizer ICs used in professional communication receivers are now available on the component market, there should be no reason to design a synthesizer with, say, mediocre performance. The synthesizer used in the present FM tuner is controlled by a microcontroller from Intel's MCS51 family, with the program stored in an EPROM. This allows the tuner software to be modified, if necessary.

Overview

In contrast to much mass-produced equipment, home-made electronics can be designed to consist of separate modules (i.e., PCBs), each with its own function. Although this introduces wiring as a potential problem, modular construction is a must where digital and analogue technology meet. In the case of the tuner, it will be obvious that the digital signals produced in the synthesizer

must not be allowed to enter the sensitive RF and AF circuits, where they cause interference.

Figure 1 shows an overview of the building blocks that go into the making of the FM tuner. The RF front end is formed by a high-quality, ready-made and pre-aligned tuner Type FD12. The tuning voltage is furnished by a synthesizer with keypad control. The microcontroller used in the synthesizer allows up to 99 preset frequencies to be stored—more than the maximum number of stations that would 'fit' in the VHF FM broadcast band (87 MHz to 108 MHz). A large, bright, LED readout indicates the preset number as well as the station fre-

quency. The FD12 tuner module has a separate, buffered output for the VCO (voltage-controlled oscillator) signal, so that it does not need to be modified for the connection of the synthesizer.

The IF (intermediate frequency) amplifier is marked by excellent high-signal behaviour and selectivity. Four high-quality quartz filters are used in combination with two amplifier stages.

The limiter and demodulator functions are combined in a single IC, the TDA1576 from Philips Components. Interestingly, this IC is also found in many high-end FM receivers, of which some have been designated 'reference receiver' for comparative tests. A

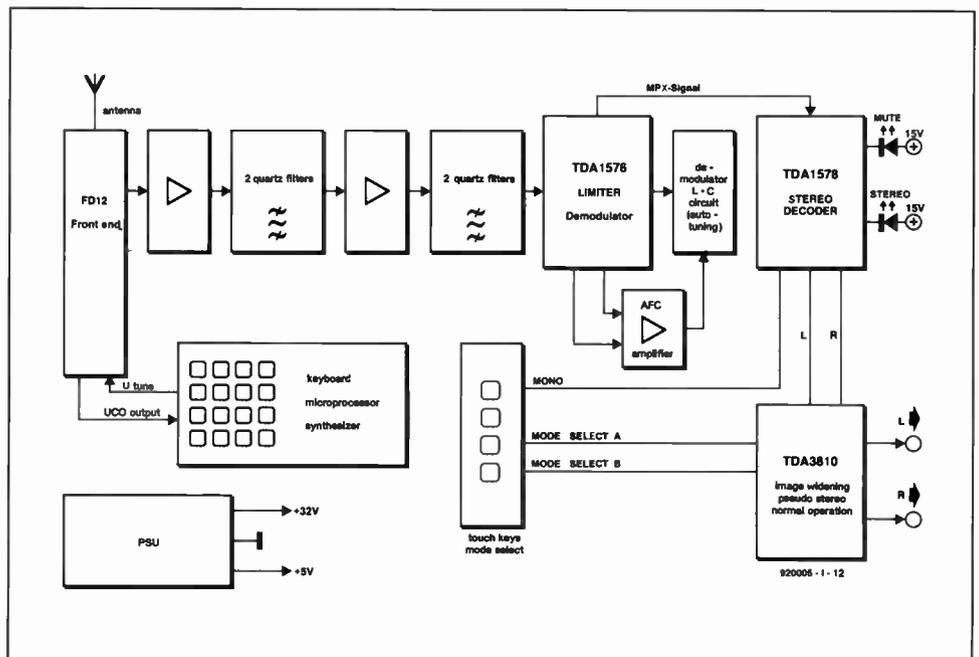


Fig. 1. Overview of the functional blocks that make up the FM tuner.

special feature of the present FM tuner is the automatic tuning of the resonant circuit used in the demodulator. This ensures very low distortion.

The stereo decoder is based on another Philips IC, the TDA1578. A phase correction filter is used to achieve the highest possible channel separation coupled with low distortion.

A TDA3810 is used in the AF output stage. As an option, this IC is capable of widening the stereo image and turning mono into pseudo-stereo. Normally, however, the IC will be used as a straight, high-quality, AF amplifier only that supplies a low-impedance output signal.

No adjustments?

Deciding to use high-quality components to build an FM tuner is one thing, building and adjusting RF circuitry quite another if you lack both experience and suitable test equipment. The FM tuner described here is designed such that adjustment is reduced to a minimum, and possible with simple equipment. First and foremost, a ready-made front end is used to eliminate all problems many of you would face when frequencies up to 150 MHz or so are involved.

The IF amplifier is a potentially bigger

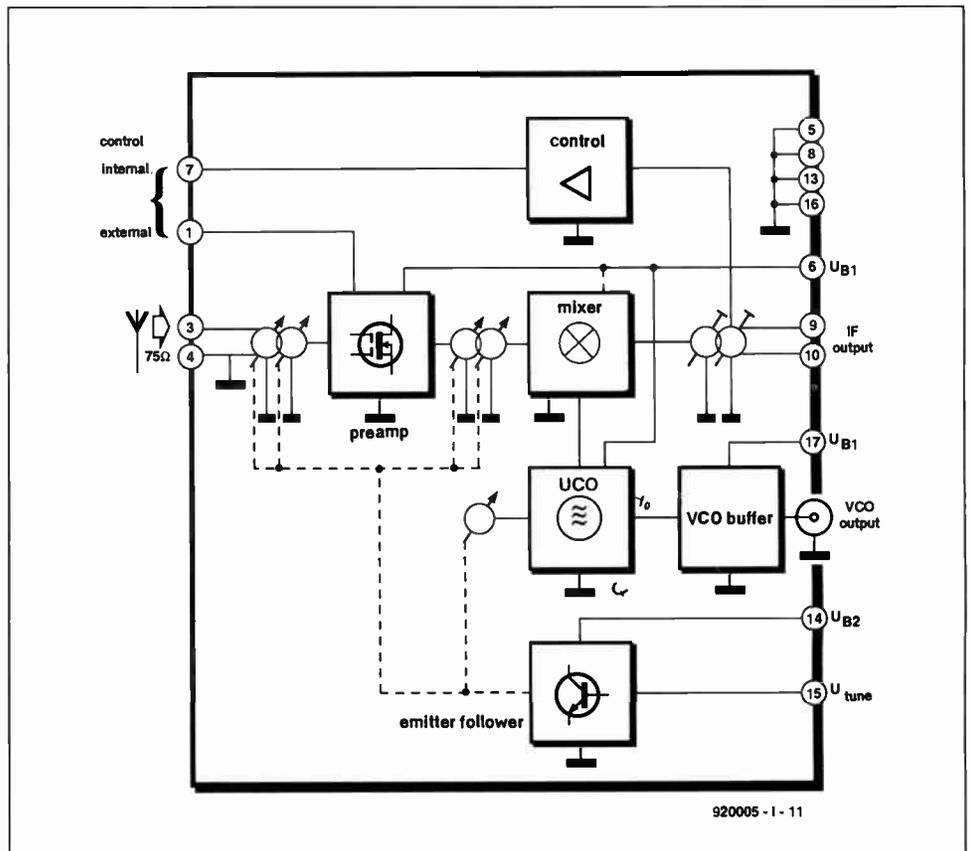


Fig. 2. Block diagram of the heart of the receiver, the FD12 FM tuner module.

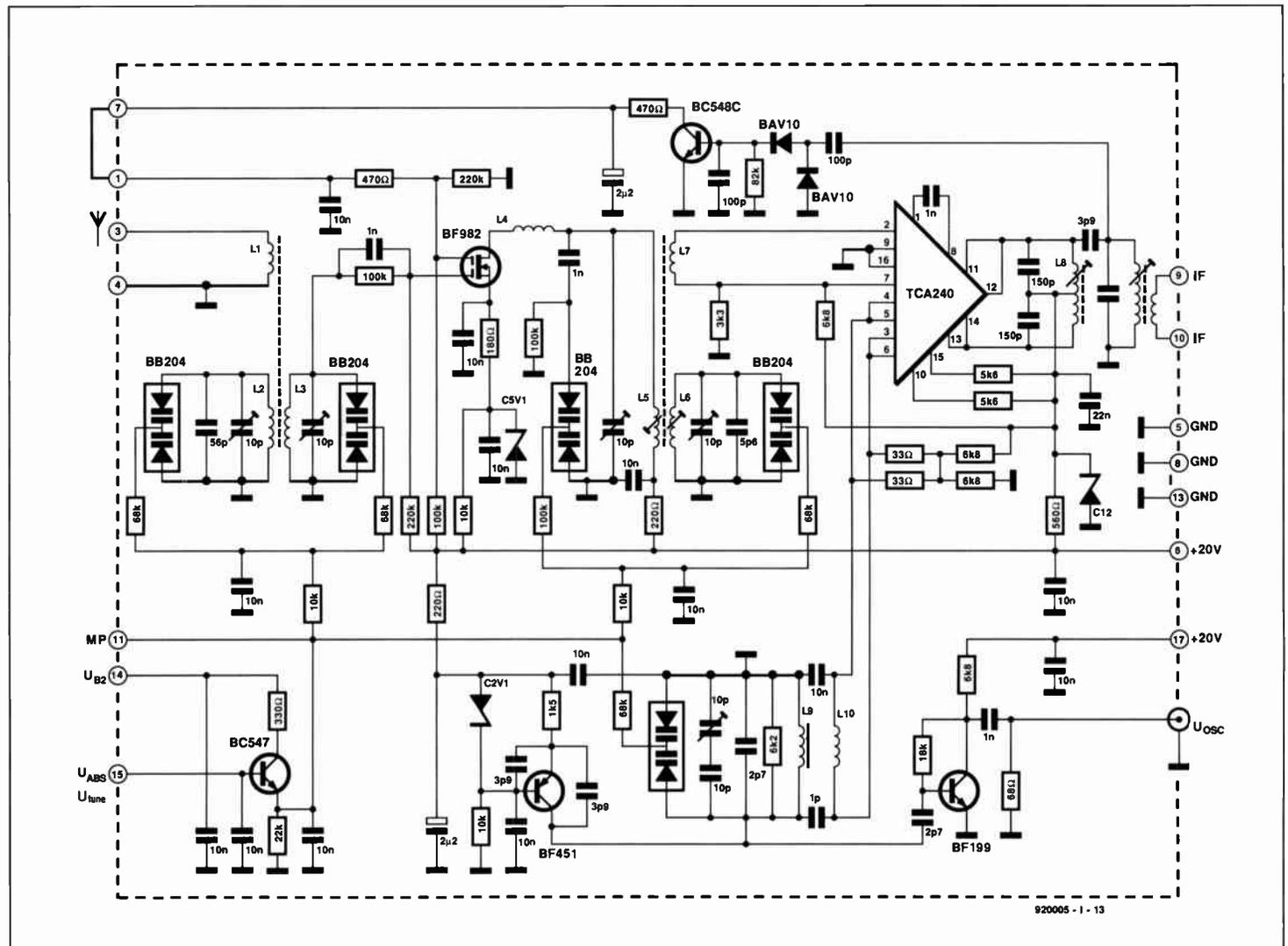
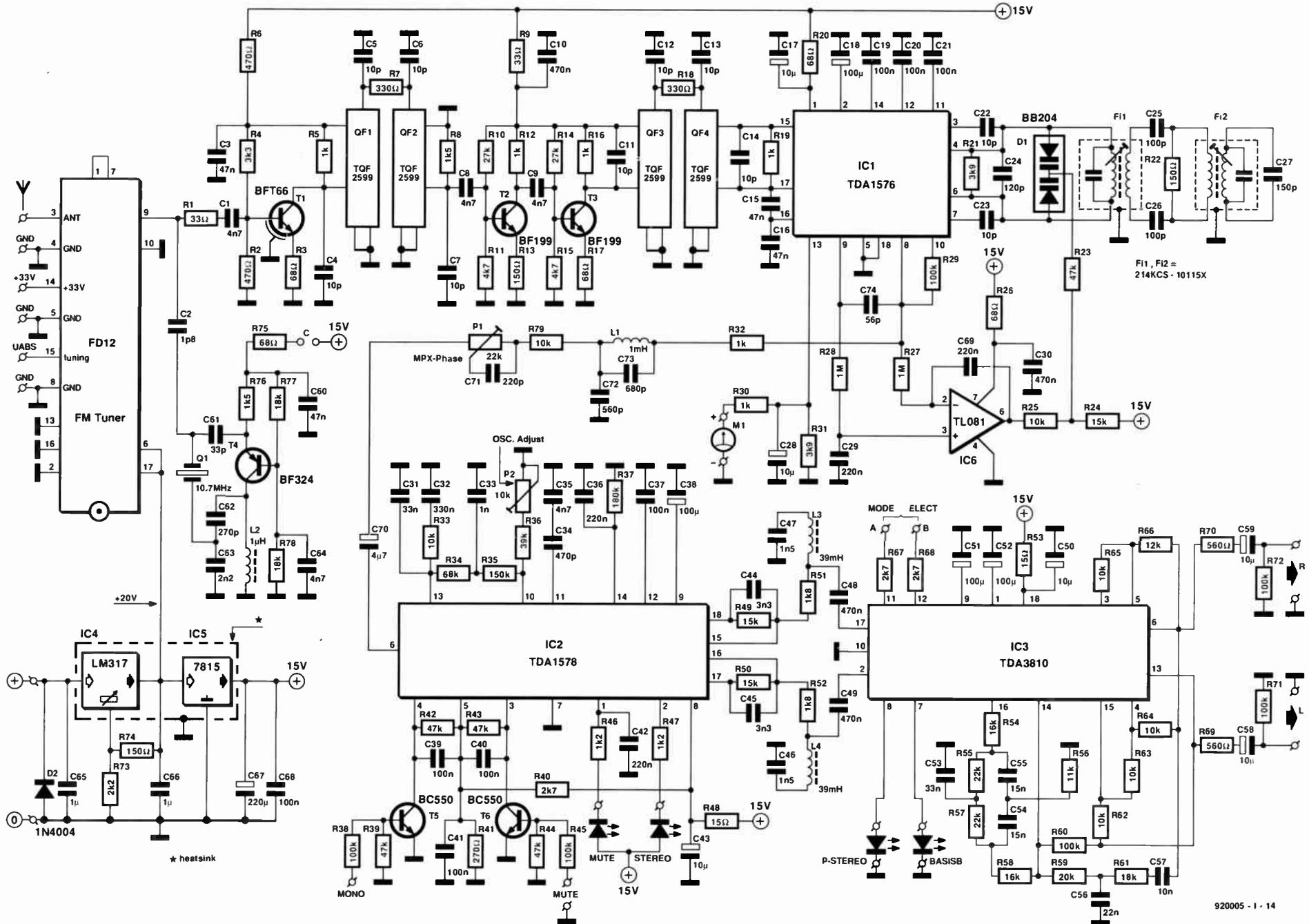


Fig. 3. Internal diagram of the FD12 tuner module.



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problem, as it is hard to design anything that does not need to be adjusted in some way. Even ceramic filters still require additional tuned circuits to optimize the image rejection and the pass-band characteristic. These adjustments normally call for a swept-frequency generator. Furthermore, ceramic filters are really unsuitable for use in high-quality receivers.

Although four-pole and six-pole *L-C* filters with low ripple and constant group delay times are a certain way to achieve good sound reproduction, their adjustment requires special RF laboratory equipment and a lot of knowhow. Although many designers are enthusiastic about the 6-pole filters produced by Toko, it should be noted that these devices are difficult to obtain in small quantities, and still require fine tuning. The only remaining alternative is, therefore, the quartz filter, which is generally applied in professional receivers. Quartz filters do not come cheap, but ensure very high selectivity and low pass-band ripple, without the need of adjustment (provided they are terminated correctly). As far as selectivity is concerned, the present tuner could make do with two quartz filters, provided an *L-C* filter is used for the image rejection. This, however, introduces an adjustment point, which was found undesirable.

Fortunately, the required image rejection,

selectivity and pass-band characteristics could be achieved by using two pairs of quartz filters with an amplifier in between. This means that the IF amplifier has no tuned circuits at all, and, thus, no adjustment points.

Since the distortion of the demodulator depends mainly on the linearity of the quadrature tuned circuit, adjustment is inevitable at this point (the use of a ceramic resonator in a high-end design like this is out of the question). Here, a two-section *L-C* filter is used to ensure the lowest possible distortion level. Adjustment of this filter is made easy by an on-board 10.7-MHz quartz crystal oscillator which is used as an RF signal generator. Also, there is the previously mentioned automatic tuning facility that takes care of the demodulator fine tuning. This circuit also ensures good long-term stability, and prevents drift caused by temperature changes. The control automatically corrects deviations and tolerances, so that the distortion level remains low even after long periods of use.

FD12 front end

This FM tuner module was originally designed by Valvo (Philips Components Germany) some ten years ago, and marketed for high-quality receiver concepts such as cable

head-end stations. Later, the production of the FD12 was taken over by a smaller company, Restek. The block diagram in Fig. 2 shows that the FD12 has a controlled RF prestage based on a dual-gate MOSFET and four tuned circuits with dual varicaps (variable capacitance diodes) Type BB204. The antenna input is 75- Ω unbalanced as customary on FM tuners. The extensive preamplifier and the double balanced mixer give the tuner very good specifications in regard of its noise figure and large signal behaviour. The noise figure is about 4 dB at a voltage gain of 40 dB, while the tuner can handle RF input levels up to 1 V_{rms} (in fact, the oscillator was found to be hardly detuned at an input voltage of 2 V_{rms}).

The tuning voltage for the five tuned circuits is buffered by an internal emitter follower. To make sure that the full tuning range can be covered (3.8 V to 27 V at pin 15 of the module), the supply voltage for the emitter follower must be about 30 V (pin 14). The normal supply voltage of the FD12 is 20 V (pins 6 and 17) at a current consumption of about 26 mA.

The IF signal is filtered at a bandwidth of 300 kHz by a tuned circuit at the output of the FD12. The IF signal is available at pin 9 of the module. The optimum termination impedance of the IF output is 330 Ω .

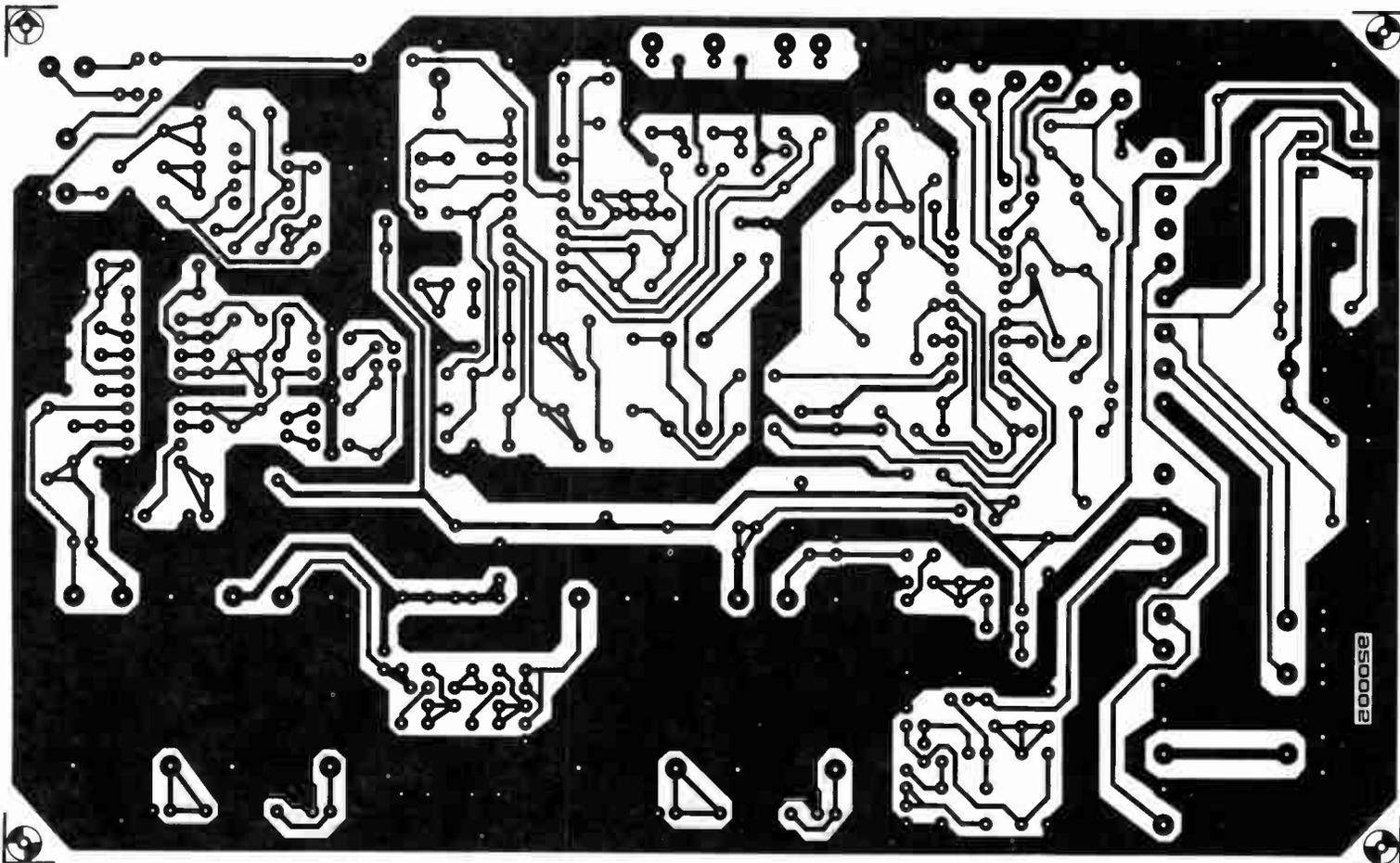


Fig. 5a. Track side copper layout of the PCB for the FM tuner.

Circuit description

The circuit diagram of the RF board is given in Fig. 4. The circuit shown comprises everything from the antenna input to the stereo outputs, and includes a simple regulated power supply with two output voltages.

IF amplifier

The IF output signal at pin 9 of the FD12 tuner module is fed to the first IF amplifier, T1, a bipolar transistor Type BFT66. The BFT66 is a low-noise type normally applied in low-noise antenna amplifiers because of its excellent linearity and large signal behaviour. The output of the previously mentioned 10.7-MHz test signal oscillator is coupled lightly (1.8 pF) to the IF output of the RF module. The test oscillator is enabled by fitting jumper 'C'. When the oscillator is not in use, the IF output signal is hardly loaded because of the light coupling via C2.

The output of the first IF amplifier is matched to the first quartz filter, QF1, a Type TQF2599 from Toyocom. Like the FD12 and the BFT66, this component was originally designed for use in cable head-end stations. QF1 is coupled to QF2 via a matching resistor, R7. Each filter block contains two quartz crystals.

Transistors T2 and T3 form an amplifier that serves to compensate the insertion loss

introduced by QF1 and QF2. The two stages are nearly identical, and their input and output impedance is defined accurately by the rather strong feedback created by emitter resistors R13 and R17. After passing through the second pair of quartz filters, QF3 and QF4, the IF signal reaches the

Demodulator

The FM demodulator is based on the TDA1576 limiter/quadrature detector from Philips Components. This IC also provides a field strength meter driver, which is essentially a linear to logarithmic converter. This subcircuit is capable of driving a moving coil meter, M1, directly.

In the design of an FM tuner it is important that signal limiting (clipping as a result of overloading) does not occur at any stage before the limiter proper. This means that both the front end and the IF amplifier must have excellent large signal behaviour. The limiter contained in the TDA1576 works well at small signal levels already, and, more importantly, entirely symmetrically. This is important to achieve good AM suppression (most interference picked up by the antenna or induced in the receiver will be of the AM type).

The phase shifting circuit to complement the quadrature demodulator is formed by two L-C filters, F1 and F2. Since the tuner is

synthesizer controlled, the AFC circuit contained in the TDA1576 can be used for a different purpose. When F1 is tuned exactly to 10.7 MHz (centre frequency), and when there is no modulation, the difference voltage between pin 8 and pin 9 of IC1 is 0 V. The level and the sign of the difference voltage is proportional to the deviation from the centre frequency. Normally, this is used to implement automatic frequency control (AFC) via the tuning voltage circuit. Here, however, a synthesizer affords the required frequency stability, so that an AFC is not required. This means that a voltage other than 0 V between pins 8 and 9 indicates that the tuned circuit of the quadrature demodulator is detuned. This drift may be caused by ageing, temperature changes, or simply by an incorrect centre frequency setting. In practice, it was found that demodulator detuning, however small, causes an increase in distortion from a very low level (0.05%) to 1 to 2%, which is unacceptable.

Opamp IC6 converts the AFC difference voltage into a tuning voltage for dual varicap D1 (a BB204). This keeps the quadrature inductor centred at 10.7 MHz. As with almost any frequency control system, there are limits to what can be corrected as far as the tuning is concerned. This means that the quadrature inductors, F1 and F2, have to be adjusted to enable the tuning system to

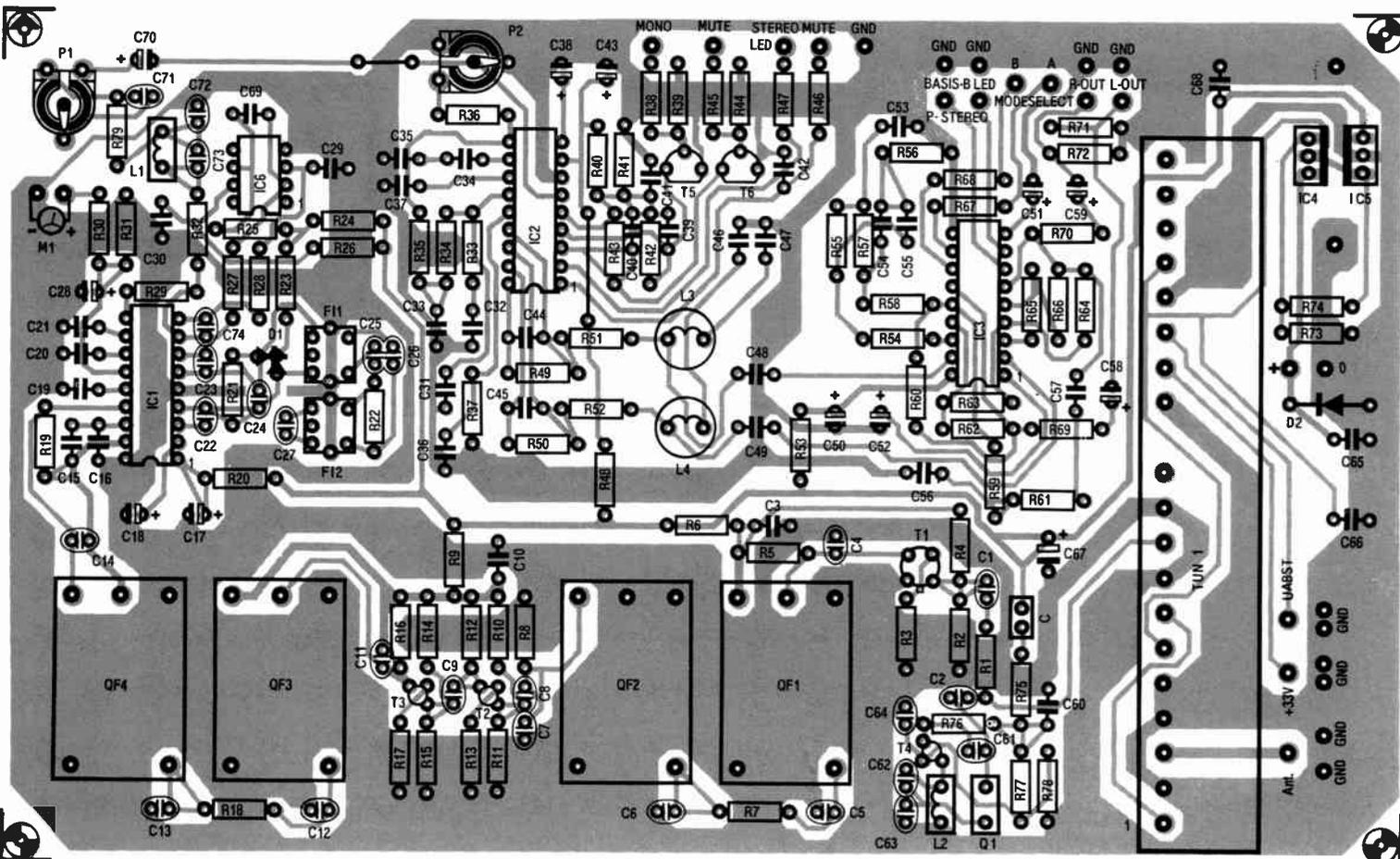


Fig. 5b. Component mounting plan.

COMPONENTS LIST

| Resistors: | | Capacitors: | | Semiconductors: | | | | |
|------------|---------|-----------------------------|--------------------|-----------------|-------------------------------------|------------------------|--|-------------------------|
| 2 | 33Ω | R1;R9 | 1 | 180kΩ | R37 | 1 | 4μF 25 V | C70 |
| 2 | 15Ω | R48;R53 | 2 | 1 MΩ | R27;R28 | 5 | 10μF 25 V radial | C28;C43;C50;C58; C59 |
| 5 | 58Ω | R3;R17;R20;R26; R75 | 1 | 10kΩ preset H | P2 | 1 | 10μF 63 V radial | C17 |
| 3 | 150Ω | R13;R22;R74 | 1 | 25kΩ preset H | P1 | 3 | 100μF 25 V radial | C38;C51;C52 |
| 1 | 270Ω | R41 | Capacitors: | | 1 | 100μF 30 V radial | C18 | |
| 2 | 330Ω | R7;R18 | 1 | 1pF8 | C2 | 1 | 220μF 25 V | C67 |
| 2 | 470Ω | R2;R6 | 10 | 10pF | C4-C7;C11-C14; C22;C23 | Semiconductors: | | |
| 2 | 560Ω | R69;R70 | 1 | 33pF | C61 | 1 | BB204B | D1 |
| 6 | 1kΩ | R5;R12;R16;R19; R30;R32 | 1 | 56pF | C74 | 1 | 1N4004 | D2 |
| 2 | 1kΩ2 | R46;R47 | 2 | 100pF | C25;C26 | 2 | BC550 | T5;T6 |
| 2 | 1kΩ5 | R8;R76 | 1 | 120pF | C24 | 2 | BF199 | T2;T3 |
| 2 | 1kΩ8 | R51;R52 | 1 | 150pF | C27 | 1 | BF324 | T4 |
| 1 | 2kΩ2 | R73 | 1 | 220pF | C71 | 1 | BFT66 | T1 |
| 3 | 2kΩ7 | R40;R67;R68 | 1 | 270pF | C62 | 1 | 7815 | IC5 |
| 1 | 3kΩ3 | R4 | 1 | 470pF | C34 | 1 | LM317 | IC4 |
| 2 | 3kΩ9 | R21;R31 | 1 | 560pF | C72 | 1 | TDA1576 | IC1 |
| 2 | 4kΩ7 | R11;R15 | 1 | 680pF | C73 | 1 | TDA1578A | IC2 |
| 7 | 10kΩ | R25;R33;R62-R65; R79 | 1 | 1nF | C33 | 1 | TDA3810 | IC3 |
| 1 | 11kΩ 1% | R56 | 2 | 1nF5 | C46;C47 | 1 | TL081 | IC6 |
| 1 | 12kΩ | R66 | 1 | 2nF2 | C63 | Inductors: | | |
| 3 | 15kΩ | R24;R49;R50 | 2 | 3nF3 | C44;C45 | 1 | 1mH | L1 |
| 2 | 16kΩ 1% | R54;R58 | 5 | 4nF7 | C1;C8;C9;C35; C64 | 2 | 39mH | L3;L4 |
| 3 | 18kΩ | R61;R77;R78 | 1 | 10nF | C57 | 1 | 1μH | L2 |
| 1 | 20kΩ 1% | R59 | 2 | 15nF | C54;C55 | Miscellaneous: | | |
| 2 | 22kΩ | R55;R57 | 1 | 22nF | C56 | 2 | 214KCS-10115X (Toko) | FI1;FI2 |
| 2 | 27kΩ | R10;R14 | 2 | 33nF | C31;C53 | 1 | 10.7MHz quartz crystal | Q1 |
| 1 | 39kΩ | R36 | 4 | 47nF | C3;C15;C16;C60 | 4 | 10.7MHz quartz crystal filter TQF2599 (Toyocom) | QF1-QF4 |
| 5 | 47kΩ | R23;R39;R42;R43; R44 | 8 | 100nF | C19;C20;C21;C37; C39;C40;C41;C68 | 1 | FM tuner FD12 | TUN1 |
| 1 | 68kΩ | R34 | 4 | 220nF | C29;C36;C42;C69 | 1 | Heat-sink SK104/40mm | |
| 6 | 100kΩ | R29;R38;R45;R60; R71;R72 | 1 | 330nF | C32 | 1 | Printed circuit board | 920005-1 |
| 1 | 150kΩ | R35 | 4 | 470nF | C10;C30;C48;C49 | | | |
| | | | 2 | 1μF solid | C65;C66 | | | |

work. For this, we make use of the on-board quartz-controlled 10.7-MHz test oscillator, which can be enabled (for the adjustment only) by fitting jumper 'C'.

The demodulated MPX (multiplex) signal is superimposed on the AFC difference voltage. It consists of the mono signal (sum of L+R) and everything else contained in the FM baseband spectrum:

the 19-kHz pilot carrier for the demodulation of the stereo difference signal (L_σ) and the control of the mono/stereo indicator;

the two sidebands of the stereo difference signal, which is modulated on a (suppressed) 38-kHz carrier;

any special service signals in the baseband, like RDS at 57 kHz (suppressed carrier).

An RDS decoder is readily connected to pin 8 of the TDA1576, since this supplies the full baseband spectrum.

Stereo decoder

The stereo decoder, IC2, is driven from pin 8 of the demodulator via a phase shift compensation network that consists of R32, L1, C72-C73, P1 and C71. The channel separation may be optimized by adjusting the preset, P1. A channel separation of 40 dB is achieved with P1 set to the centre of its travel.

Preset P2 serves to set the centre frequency of PLL (phase locked loop) for the recovery of the 38 kHz subcarrier. When more than 3 V is applied to the MONO input of the TDA1578, the decoder switches from stereo to mono. Similarly, it is possible to control the mute function of the IC via a switching voltage applied to the MUTE terminal of the board. The mute function affords noise-free on and off switching of the audio output signal. It may be controlled manually, by the synthesizer, or by a signal strength measurement circuit.

The state of the stereo and mute circuits on board the TDA1578 is indicated by two LEDs connected to the respective open-collector outputs of the IC.

The de-emphasis is implemented in the feedback networks of the output amplifier, R49-C44 and R50-C55. Series resonance tuned circuits L3-C47 and L4-C46 are fitted at outputs of the stereo decoder to provide additional suppression of the 19-kHz pilot signal.

AF output amplifier

The audio output driver Type TDA3810 has three modes of operation: (1) normal AF amplifier; (2) stereo image widening by adding a 50% inverted version of one channel to the other; (3) pseudo stereo by applying frequency-dependent phase shift to a mono sig-

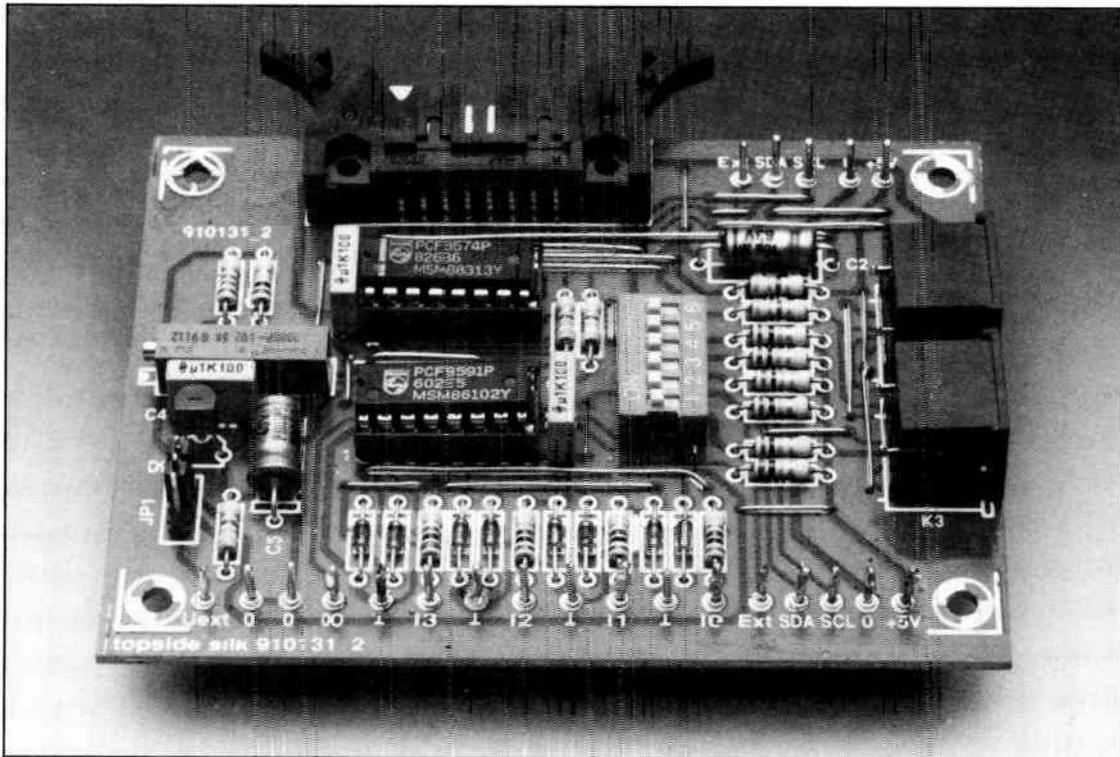
nal and splitting it into two. Mode selection is effected via inputs 'A' and 'B' on the tuner board.

The TDA3810 will normally be used as a straight amplifier with a noise level specification that is to CD player standards. The other two modes, image widening and pseudo stereo, are more fanciful, and not recommended for high-end use. The pseudo stereo mode, however, may be used occasionally to give an interesting 'touch' to pop music. Our advice is to try it out and see if you like the effect. If you don't, there is always the 'straight stereo' mode to return to.

The printed circuit board

Although the construction and adjustment of the tuner board are discussed in part 3 of this article, the track side copper layout and the component mounting plan are already given here (see Fig. 5). The board is single-sided, and easily completed as no 'difficult' RF construction is involved. The tuner is mounted vertically on solder pins. Note that the antenna cable is connected to two solder terminals on the board, i.e. not direct to the tuner. □

ADC/DAC AND I/O FOR I²C BUS



This article discusses a compact interface that allows PC users to communicate with I²C compatible ICs and circuits. The interface comprises an I/O port and a combined 8-bit analogue-to-digital and digital-to-analogue converter. Also, system software is described that brings life to the I²C PC insertion card described last month.

Design by J. Ruffell

AS promised last month, this article tackles the software necessary to control the I²C interface for PCs (Ref. 1). This device driver is basically an extension of the disk operating system (DOS) implemented on the PC, and contains all the routines necessary to write and read I²C codes to and from ICs connected to any I²C bus system. The device driver has been written to comply with the protocols drawn up by Philips for the I²C bus.

Device drivers are used at several levels in a PC. Examples of device drivers include 'software handles' for the screen, the printer, the RAM disk, and the keyboard, to mention but a few. There are basically two types of device driver: block drivers and character drivers. Block drivers are used for media such as disk drives, while character drivers are used for the screen, the keyboard and, in this case, the I²C bus. Any device driver is an extension of the DOS, and is invariably called via the DOS. According to the DOS specification, a device driver can contain up to 17 routines (i.e., not all of these need to be implemented). They are:

- 0* Driver initialisation
- 1 Media check
- 2 Build BIOS parameter block
- 3 I/O control read
- 4* Read
- 5 Non-destructive read
- 6 Input status
- 7 Erase input buffers
- 8* Write
- 9* Write and verify
- 10 Output status
- 11 Erase output buffers
- 12* I/O control write
- 13* Open device
- 14* Close device
- 15 Removable media
- 16* Output until busy

The routines marked with an asterisk are implemented in the present I²C device driver, which is written in machine language, and available on a diskette (along with the source file) supplied through our Readers Services. A full description of the operation of the device driver is beyond the scope of this article, and readers interested in the programming

MAIN SPECIFICATIONS

- Controlled via I²C bus
- 4 analogue inputs (256 steps)
- 1 analogue output (256 steps)
- 8 I/O lines (bidirectional)
- Up to 8 boards on one I²C bus
- Adjustable ADC/DAC reference voltage
- Complete with MSDOS compatible device driver
- Source code available in assembler, Pascal and C

aspects are advised to print the source file for close analysis. Further information on device drivers for PCs, and machine code programming, may be found in the many books and other publications that have been written on these subjects.

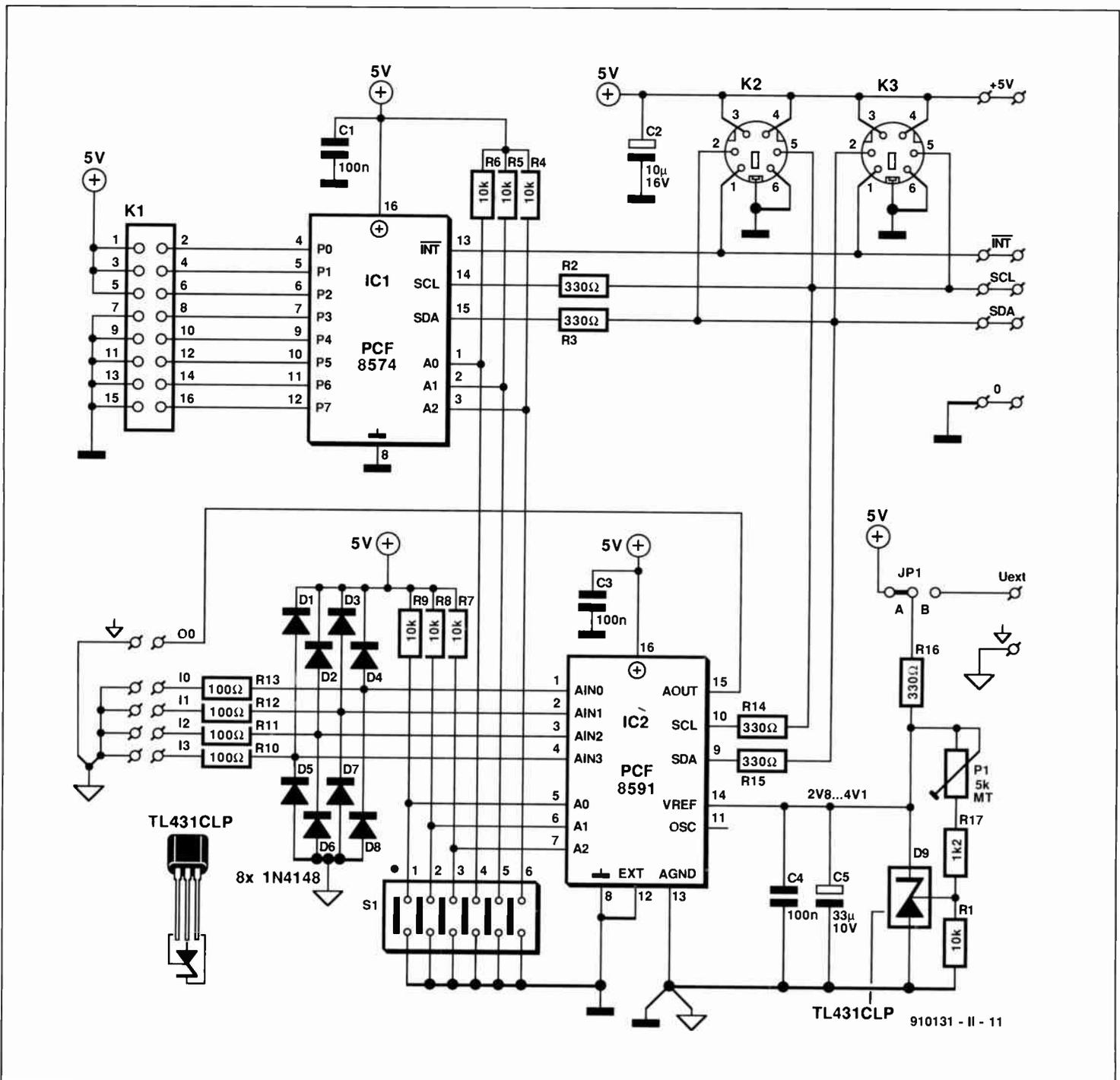


Fig. 1. Circuit diagram of the I²C extension card, which contains an I/O port and an 8-bit ADC/DAC.

Installation

The device driver disk contains the assembled file I2CDRIV.SYS, which may be placed in the root directory of the PC. Next, the CONFIG.SYS file has to be modified by adding the line

```
device = I2CDRIV.SYS
```

You may type two parameters after 'I2CDRIV.SYS': B:xxxx and/or C:y, where

xxx is the base address of the I²C insertion card. This address is set to a value between 300_H and 3FE_H with the aid of DIP switches.

y is a code that selects the clock frequency, SCL, used on the I²C bus. The available clock frequencies deviate slightly from the those

mentioned in the datasheets, because a clock of 7.16 MHz is used instead of the more usual 8 MHz. Parameter y can take the following values:

- 0: $f_{SCL} = 81 \text{ kHz}$
- 1: $f_{SCL} = 40 \text{ kHz}$
- 2: $f_{SCL} = 9.8 \text{ kHz}$
- 3: $f_{SCL} = 1.3 \text{ kHz}$

The default values for parameters B and C are 300_H and 9.8 kHz respectively.

When the PC is switched on or reset, it reads the new CONFIG.SYS file, and from then on recognizes all routines that support the I²C interface. That is when the real work can begin.

Useful for your own software experiments, the example programs on the diskette illustrate the use of the I²C driver routines in

assembler as well as in the higher programming languages C and Pascal.

Hardware

The circuit diagram of the ADC/DAC and I/O card for the I²C bus is shown in Fig. 1. The main components in the circuit are the PCF8574 I/O port and the PCF8591 ADC/DAC. These I²C compatible building blocks prove that interface circuits with I²C control can be kept very simple indeed. The 8-bit I/O port is simplicity itself. Its eight I/O lines may be linked to external digital devices via connector K1. Address lines A0, A1 and A2 are connected to the positive supply line via pull-up resistors. Three switches in DIP switch block S1 are used to set the programmable part of the I/O address of the IC. The DIP switch allows up to eight PCF8574s

to be used simultaneously via the I²C bus.

As with all I²C devices, the addresses are partly fixed in the ICs. The two ICs on the present card are addressed as follows:

PCF8574: 0100 A2 A1 A0 R/W

PCF8591: 1001 A2 A1 A0 R/W

In both cases, the first four bits cannot be changed by the user. The next three bits can be set on the DIP switches, and the last bit selects between reading and writing of data. Read operations are enabled when R/W is '1', write operations when R/W is '0'. As regards the device driver routines found on the diskette, it is assumed that all DIP switches are closed, which means that the I/O port and the ADC/DAC are located at the address pairs 40_H-41_H and 90_H-91_H respectively. If other address pairs are set on the switches, the software requires to be changed accordingly. Given that the example files have a copious amount of comment, this should not cause problems.

The quasi-bidirectional I/O port Type PCF8574, of which the block diagram is shown in Fig. 2, has only one read/write register. Depending on the application, this device allows its output lines to be used as input lines. The output lines have a current sink and source specification of 25 mA and 0.4 mA respectively. If a port line is to be used as an input, it is first made logic '1'. Next, the level of the 'output line' is read back to see if it is still at '1'. If not, it is apparently pulled low (i.e., held at '0') by an external device. Thus, the low level supplied by an external device to the port line overrides the previously programmed '1', and is so recognized by the software. The open-drain outputs allow this to be done with impunity.

The circuit around the PCF8591 ADC/DAC is far more complex than that around the I/O IC. The analogue inputs of the ADC/DAC are protected against over-voltages by resistor-diode combinations R10-R13 and D1-D8. Here, too, the three address inputs are connected to DIP switches that enable the variable part of the address to be set by the user. The external voltage reference is set up around precision zener diode D9, a TLC431CLP. Resistors R1, R16, R17 and P1 are used to set a reference voltage between 2.8 V and 4.1 V. The user may set the value in this range required for the desired A-D/D-A step size. One step corresponds to $U_{ref}/256$. Capacitors C4 and C5 serve to suppress noise on the reference voltage. Jumper JP1 allows the ADC/DAC to be fed with an external reference voltage, which may be useful in certain cases when there is a danger of accurate measurements being spoilt by noise on the 5-V supply. For most applications, however, an external reference will not be required.

Figure 3 shows the block diagram of the I²C compatible ADC/DAC. Because it has many more possibilities, the PCF8591 is more complex to control than the PCF8574. Apart from data bytes, the converter IC requires a control byte to determine a number of settings as shown in Fig. 4. The highest nibble in the control byte determines the con-

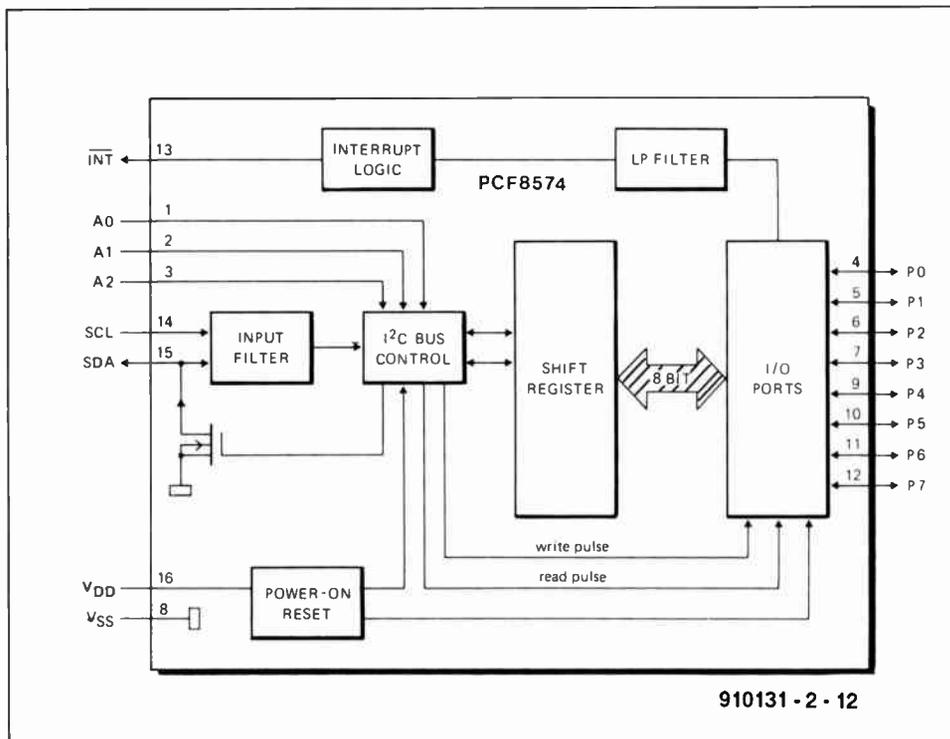


Fig. 2. Block diagram of the PCF8574 I²C compatible I/O port.

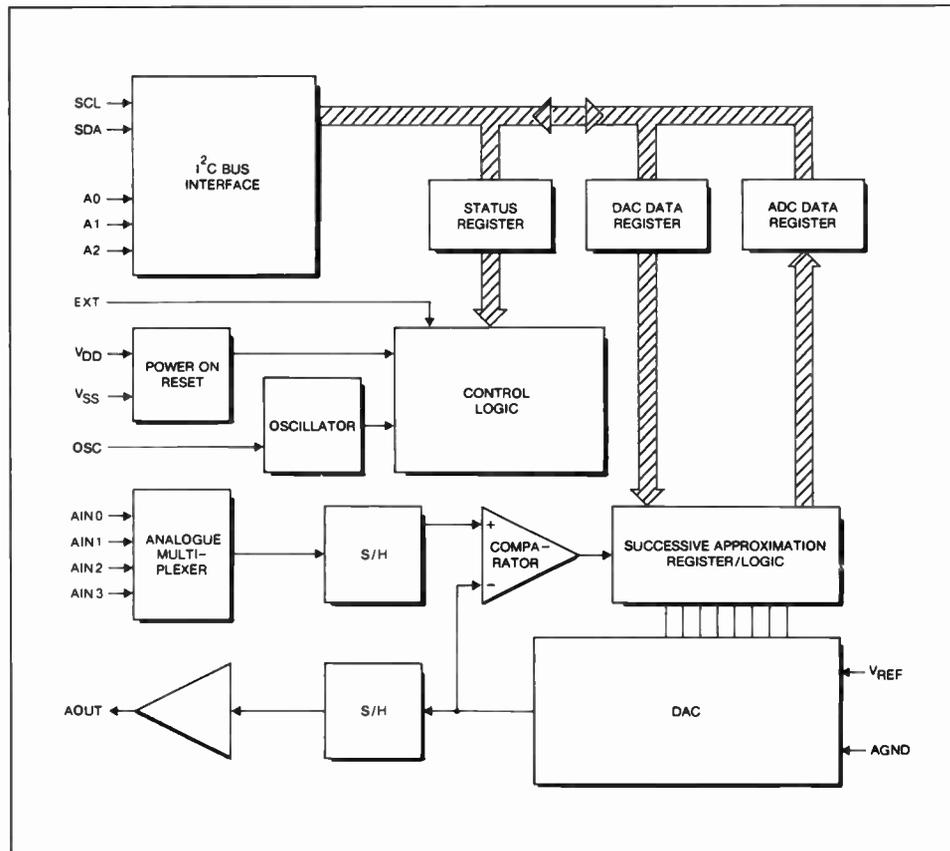


Fig. 3. The combined ADC/DAC Type PCF8591 is a fairly complex integrated circuit. An external voltage reference allows the conversion step size of the ADC and the DAC to be set as required.

figuration of the analogue inputs (either two differential inputs, or four ordinary inputs), and in addition switches the analogue output on and off. The low nibble selects one of four A-D inputs, and may be used to enable the auto-increment flag.

The third byte, sent to the IC after the address byte and the control byte, is stored in the DAC register. Next, the previously stored value is converted into an analogue

voltage that appears at output of the DAC. The output voltage increment equals $U_{ref}/256$. This means that a value of '00' results in 0 V at the output, and '255' in an output voltage of $255 \times U_{ref}/256$.

The reading back of ADC output values is performed in a slightly different manner. An A-D conversion cycle is started on the positive-going edge of the acknowledge pulse, which is returned to the master device

after the converter has been set to 'read' mode with the aid of a read command. The IC performs another A-to-D conversion cycle while it sends the data resulting from the previous conversion. At the start of the conversion, the voltage level at the selected input is sampled and subsequently converted into an 8-bit binary code. Input voltages supplied by a differential input are converted into an 8-bit two's complement code. The result is stored in the data register of the ADC, from which it can be transmitted. When the auto-increment flag is actuated, the next input is selected. In this manner, all inputs are selected in succession.

Construction

The ADC/DAC and I/O extension is easy to build on the printed circuit board of which the copper side layout and the component mounting plan are shown in Fig. 6. The 6-way miniature DIN-style connectors enable the extension card to be readily connected to the I²C interface in the PC. In principle, only one of the two mini-DIN sockets needs to be fitted on the board. The second socket is required only if further I²C boards are to be connected to form a chain. If a number of I²C extensions are fitted into a common enclosure, there is, of course, no objection against omitting the connectors, and using permanent wiring instead. The +5-V, ground, SCL, SDA and INT lines of the units are then connected from board to board.

The pinning of connector K1 is such that it can be linked direct to the 'Measurement amplifier' described last month (Ref. 2). All that is required to implement computer control on this amplifier is a short length of flat cable to link it to the ADC on the present board. By studying the source code of the test program 'ADIO', you will notice that the combination of the ADC and the measurement amplifier is readily turned into an autoranging measurement system.

The reference voltage is set to the required value by adjusting preset P1 and measuring the voltage across C5 with a digital multimeter. Since the program 'ADIO' on the diskette is based on a reference voltage of 4.0 V, it is advisable to set this value initially. Later, other values may be chosen, provided the relevant statements in the program are changed accordingly.

That completes the construction and adjustment of the I²C extension card, which is then ready to be tested. Testing is done in a 'hands-on' way with the aid of a well-documented test program, of which a Turbo Pascal and a C version is available on the diskette. Both versions of the test program cycle through a number of routines, including one that reads the levels at I/O port lines b4 to b7, and copies these to outputs b0 to b3. To run the test, force port lines b4 to b7 logic high with the aid of 10-k Ω pull-up resistors. Connect push-buttons that switch to ground to the same lines. Connect four LEDs between the b0 to b3 output lines and +5 V via 330- Ω series resistors. Run the test program, and check that one of the LEDs lights when the

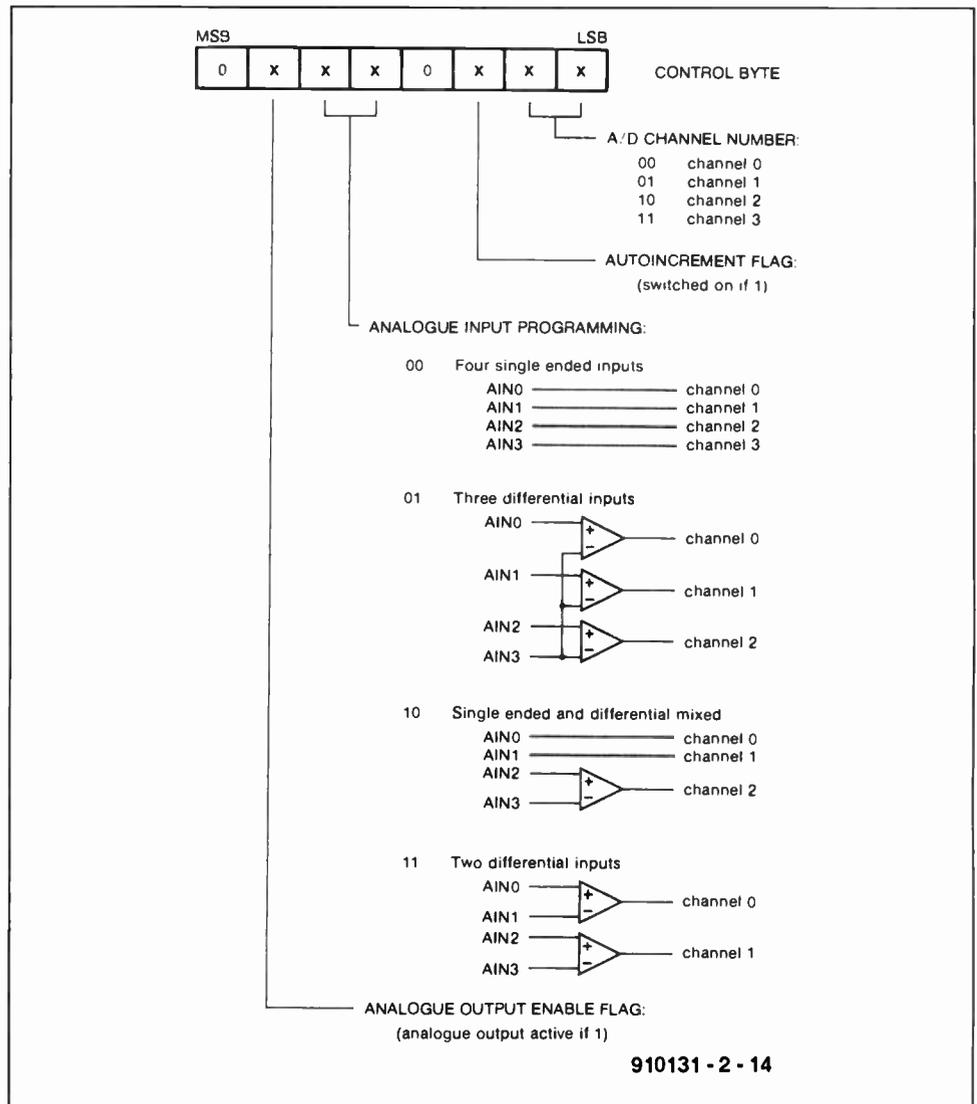


Fig. 4. Bit functions in the control byte sent to the PCF8591.

```
begin (* TestADDA *)
  Ctrl:=GetControlByte(1);          [-Load control byte with option# 1]
  Address(ADA_Addr);               [-Because the R/W bit (= LSB ADA_Addr)
                                   equals zero, the PCF8591 enters the
                                   write-mode. Therefore, the next trans-
                                   mitted byte is interpreted as a
                                   control byte.]
  write(bus, Ctrl);                [-Transmit control byte.]
  with AD do                        [-The next bytes sent to the PCF8591
                                   would be stored in the DAC register.
                                   But at this point, we switch to
                                   read-mode...]
    read(Bus, Dummy, Data[0], Data[1], Data[2], Data[3]); [-I2CDRIV.SYS now
                                                           generates a repeated start (same
                                                           address, but with R/W = 1) and reads
                                                           five AD-conversion bytes from the
                                                           PCF8591. This is done by using the
                                                           channel auto-increment function of
                                                           the chip. The first read byte (Dummy)
                                                           is the conversion result code of the
                                                           previous cycle! We are not interested
                                                           in that sample, so it is thrown away.]
    write(bus, Ctrl, AD.Data[Chan3]); [-I2CDRIV.SYS generates a repeated
                                       start condition; same address, but
                                       with R/W = 0. Thus, the PCF8591 is
                                       in write-mode again and expects a
                                       control byte and one or more data-
                                       bytes. All databytes are stored in
                                       the DAC-register, but the analogue
                                       output voltage is always calculated
                                       from the previous DAC-register
                                       contents.]
  for Channel:=Chan0 to Chan3 do
    ShowVoltage(Channel, AD.Data[Channel]);
    ShowVoltage(4, AD.Data[Chan3]);
  end; (* TestADDA *)
```

Fig. 5. Extract from the I²C device driver listing. This source code is written in Turbo Pascal.

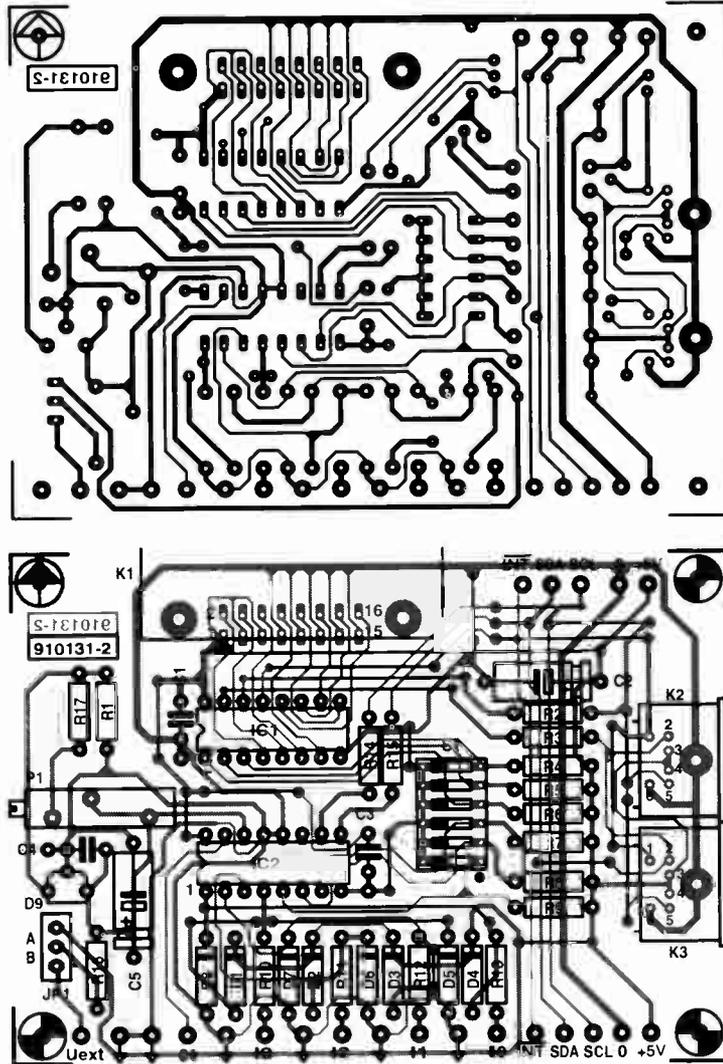
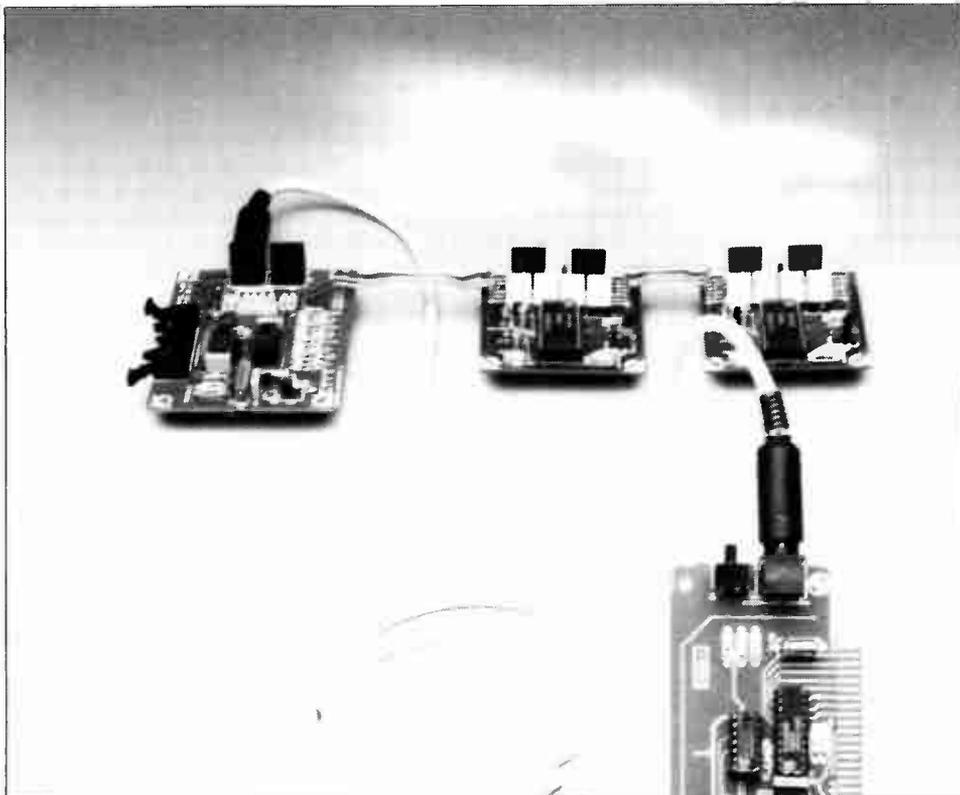


Fig. 6. Track side layout and component mounting plan of the PCB designed for the I²C extension card. Six-way mini-DIN connectors are used to connect I²C boards to the I²C interface fitted in the PC.



COMPONENTS LIST

Resistors:

| | | |
|---|----------------------|-----------------------|
| 7 | 10kΩ | R1;R4-R9 |
| 5 | 330Ω | R2;R3;R14; R15;R16 |
| 4 | 100Ω | R10;R13 |
| 1 | 1kΩ | R17 |
| 1 | 5kΩ multiturn preset | P1 |

Capacitors:

| | | |
|---|----------|----------|
| 3 | 100nF | C1;C3;C4 |
| 1 | 10μF 16V | C2 |
| 1 | 33μF 10V | C5 |

Semiconductors:

| | | |
|---|-----------|-------|
| 8 | 1N4148 | D1-D8 |
| 1 | TL431CLP* | D9 |
| 1 | PCF8574* | IC1 |
| 1 | PCF8591* | IC2 |

Miscellaneous:

| | | |
|--------------|--|----------|
| 1 | 16-way header, angled, with side latches | K1 |
| 2 | 6-way mini-DIN socket for PCB mounting | K2;K3 |
| 2 | 6-way mini-DIN plug | |
| 2m (approx.) | 6-wire cable | |
| 1 | 6-way DIP switch | S1 |
| 1 | Printed circuit board | 910131-2 |
| 1 | Control software on disk (MSDOS) | ESS1671 |

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

corresponding push-button is pressed.

The ADC/DAC is tested similarly. The program reads the voltage levels at the analogue inputs I0, I1, I2 and I3, and puts the level of I3 on output O0.

If the circuit passes the above tests, it is ready for use with your own applications. ■

Reference:

1. "I²C interface for PCs", *Elektor Electronics USA*, February 1992.
2. "Measurement amplifier", *Elektor Electronics USA*, February 1992.

Fig. 7. This demonstration set-up shows how different modules can work with a single interface. The display driver shown will be discussed in a future publication.

8751 EMULATOR

This article describes hardware and software that together form a powerful development system for the popular 8751 microcontroller from Intel.

Design by O. Bailleux

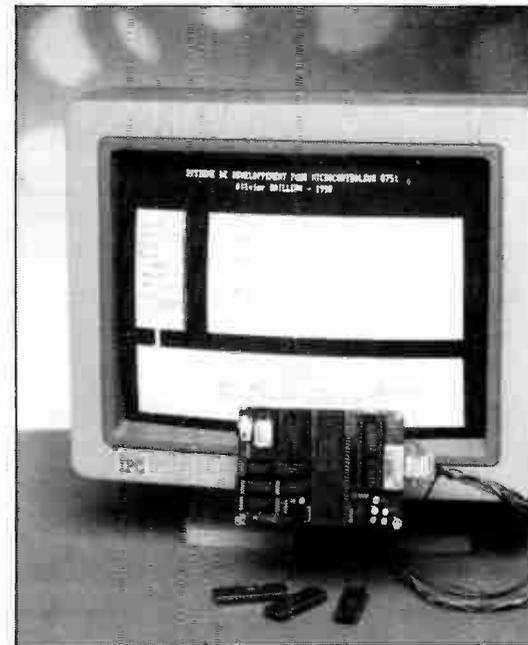
THE microcontroller emulator described here allows you to develop and debug 8751 application circuits with a minimum of effort. The emulator has two main connections: one to the serial port of a PC, and another to the IC socket reserved for the 8751 in the target system. The combination of the PC, the software that runs on it, and the emulator allows you to

- download, modify, and upload 8751 programs;
- erase and program a 8751;
- put breakpoints in programs;
- display register and memory contents;
- run programs in single step mode;
- modify the contents of certain registers.

Clearly, this makes the emulator a powerful and indispensable tool for all of you who, at a certain stage, are 'confronted' with a 8751 application.

General remarks

This article does not aim at discussing or even introducing all the hardware and software aspects of the 8751 microcontroller, since this field is covered adequately by the *Microcontroller Handbook* from Intel. As regards practical programming of the 8751, the '8051/8032 assembler course' published in this magazine will be very useful to follow (the 8032, 8051 and 8751 are all devices from Intel's MCS52 family of microcontrollers).



None the less, the file README on the diskette supplied in relation to the present emulator contains some basic information on the 8751.

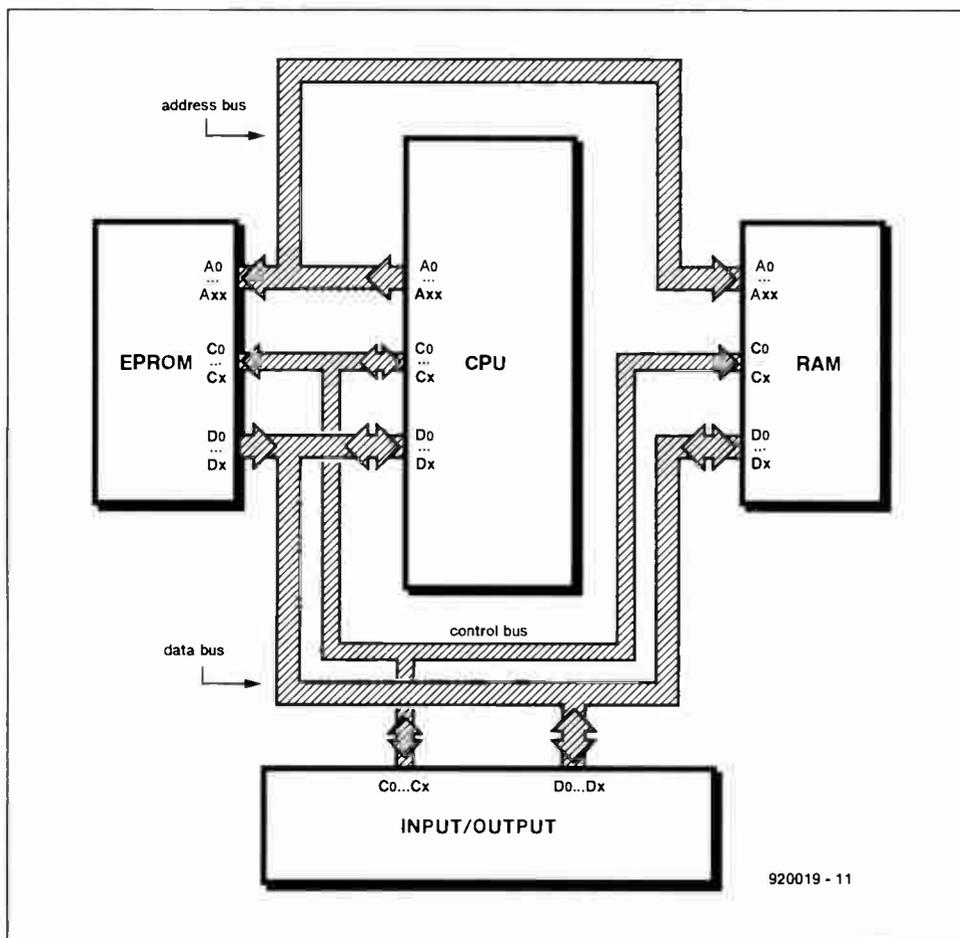


Fig. 1. Basic structure of a microcontroller system. ICs are available that combine all the functions shown here.

MAIN CHARACTERISTICS

- Real-time 8751 emulator
- Clock frequency: 8 MHz
- All I/O ports available
- All internal interrupt sources available
- Powered by target circuit
- 9,600 baud serial link to PC
- Breakpoint analysis and single-step mode
- Internal register and internal RAM contents displayed and available for editing
- Symbolic assembler for 8751
- Full-screen editor with error location facility
- Binary or Intel-hex output files
- Hard copy of formatted source program

Limitations:

- Monochip mode only (internal program memory, no external data memory)
- I/O bits P3.6 and P3.7 reserved for system
- Register 0 banks only
- System software uses 12 stack locations
- Masked interrupts during breakpoint processing

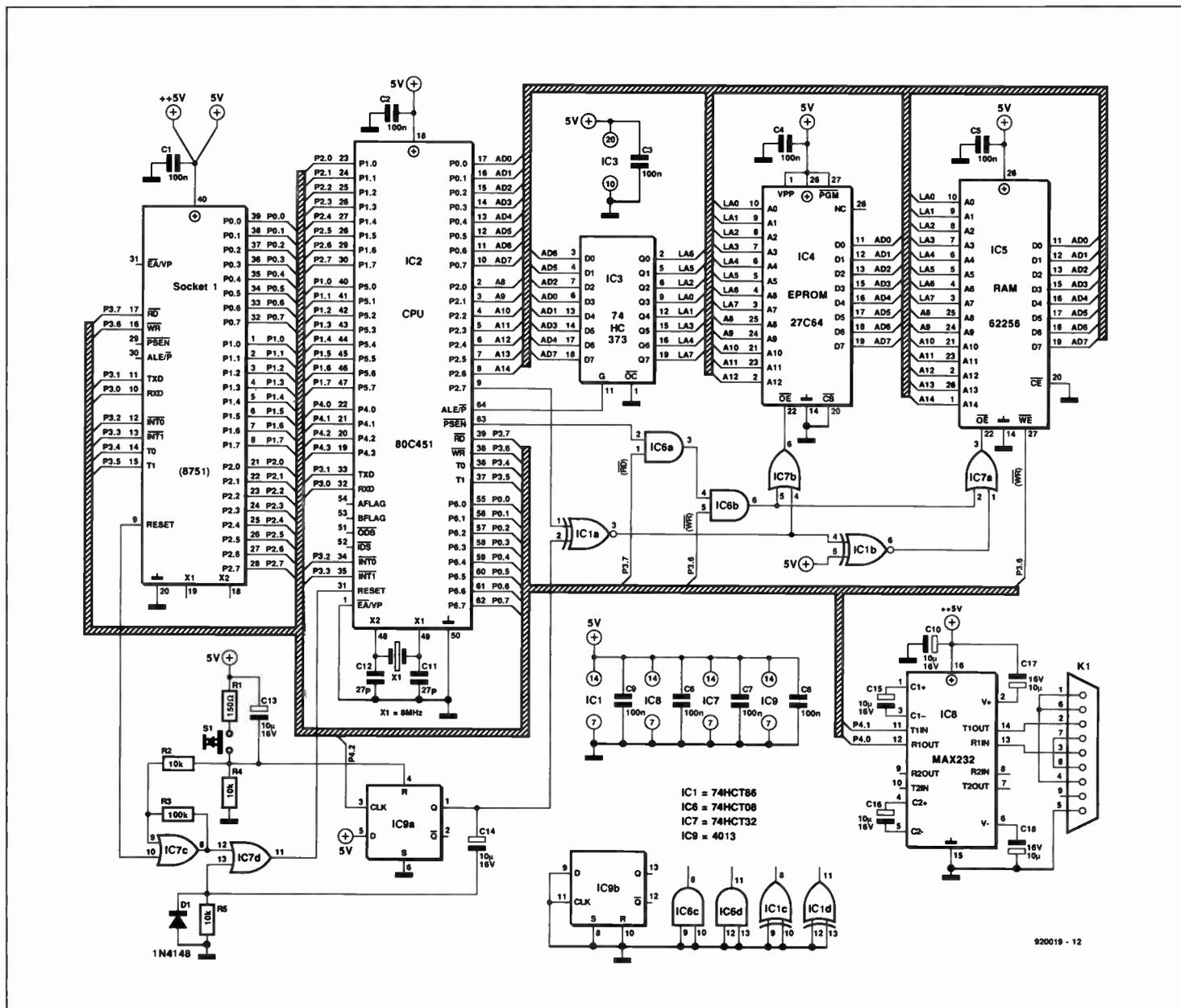


Fig. 2. Circuit diagram of the 8751 emulator. Note that some of the ports of the 80C451 are not used.

The 8751 is a microcontroller that integrates:

- an 8-bit microprocessor;
- a RAM of 128 bytes;
- 4 8-bit parallel I/O ports;
- 1 serial communication port;
- 2 programmable timers;
- 2 external interrupt lines.

The 8-bit (256-byte) addressable range of the 8751 is divided into two parts:

- user RAM between 00H and 7FH: this contains registers R0 to R7 (00H to 07H), and the system stack. A sub-range of 16 addresses is bit-addressable.
- control register range between 80H and FFH: this range can be accessed by direct addressing only, and contains the I/O ports, the timer control registers, and a number of other special functions.

Principle of operation

As illustrated by Fig. 1, a microprocessor system generally consists of microprocessor,

a program memory, a data memory, and input/output devices. The elements that form the system are interconnected by an address bus, a data bus and a control bus. Since the 8751 microcontroller works in 'mono-chip' mode, it has all of the above elements internally. Only the four 8-bit ports can be accessed by external devices. Emulating a 8751 thus calls for a device capable of:

- running object code from RAM instead of ROM—this is necessary to allow changes to the program to be made rapidly;
- providing four input/output ports as well as the basic hardware environment of the 8751;
- providing an instruction set that is compatible with that of the 8751.

The Type 80C451 meets all these requirements beautifully, and is used here to emulate a 8751. The pinning of this device is given in Fig. 3.

The emulator based on the 80C451 consists basically of:

- an EPROM with a start-up program;
- a 32-KByte RAM to hold the system routines and the user program being developed;
- a memory switching device with two states:

start state: the EPROM is located at address 000H, and the RAM at address 8000H

execute state: the RAM is at 0000H and the EPROM at 8000H;

- a TTL compatible (pseudo-RS232) serial interface for the connection the PC.

The initialization procedure consists of the following steps:

1. Initialization (reset), and start phase. EPROM-based program executed from address 0000H.

2. A routine in the start-up EPROM that sends the system program code from the PC to the emulator RAM. This is done via the serial link, and with the aid a simplified

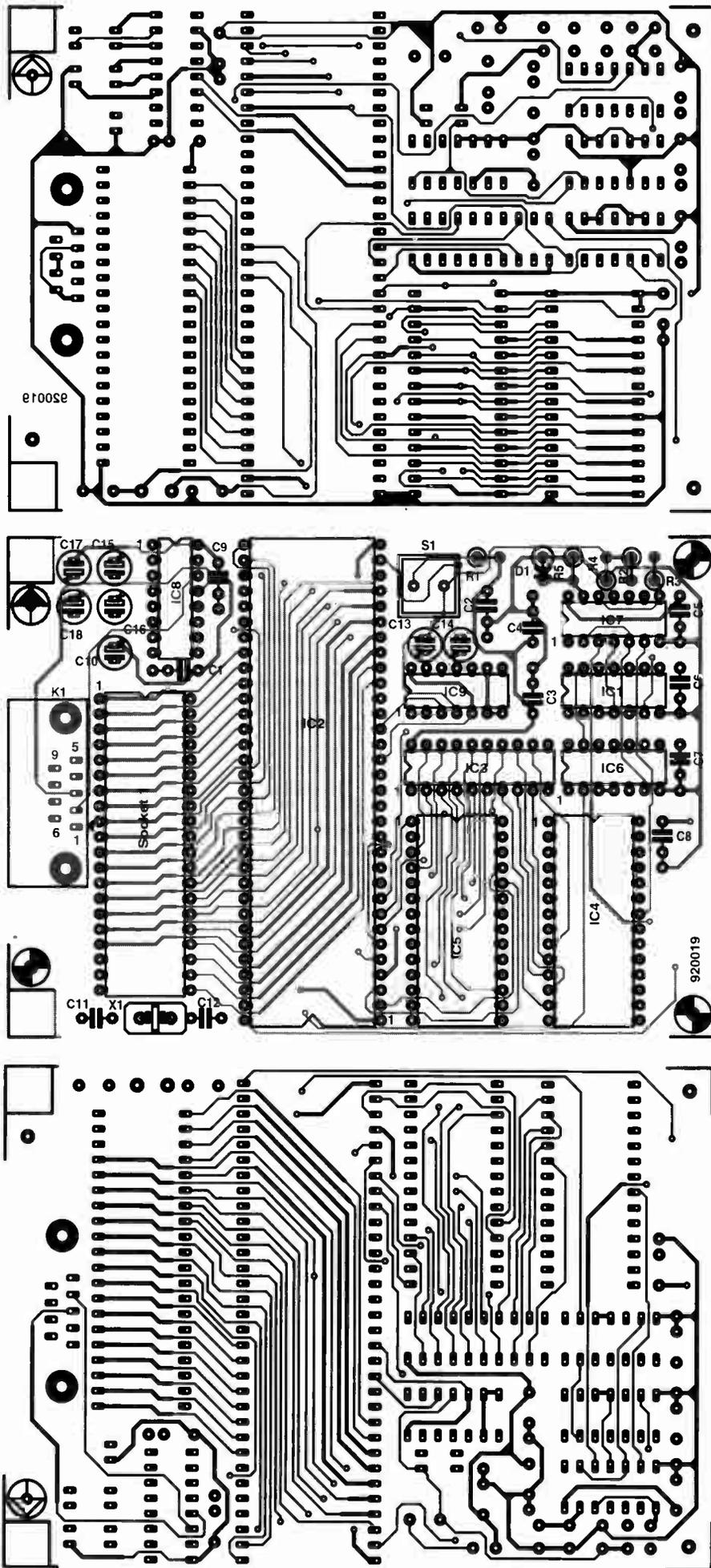


Fig. 5. Track layouts (component side and solder side) and component overlay of the double-sided, through-plated printed circuit board.

COMPONENTS LIST

Resistors:

| | | |
|---|-------|----------|
| 1 | 150Ω | R1 |
| 3 | 10kΩ | R2;R4;R5 |
| 1 | 100kΩ | R3 |

Capacitors:

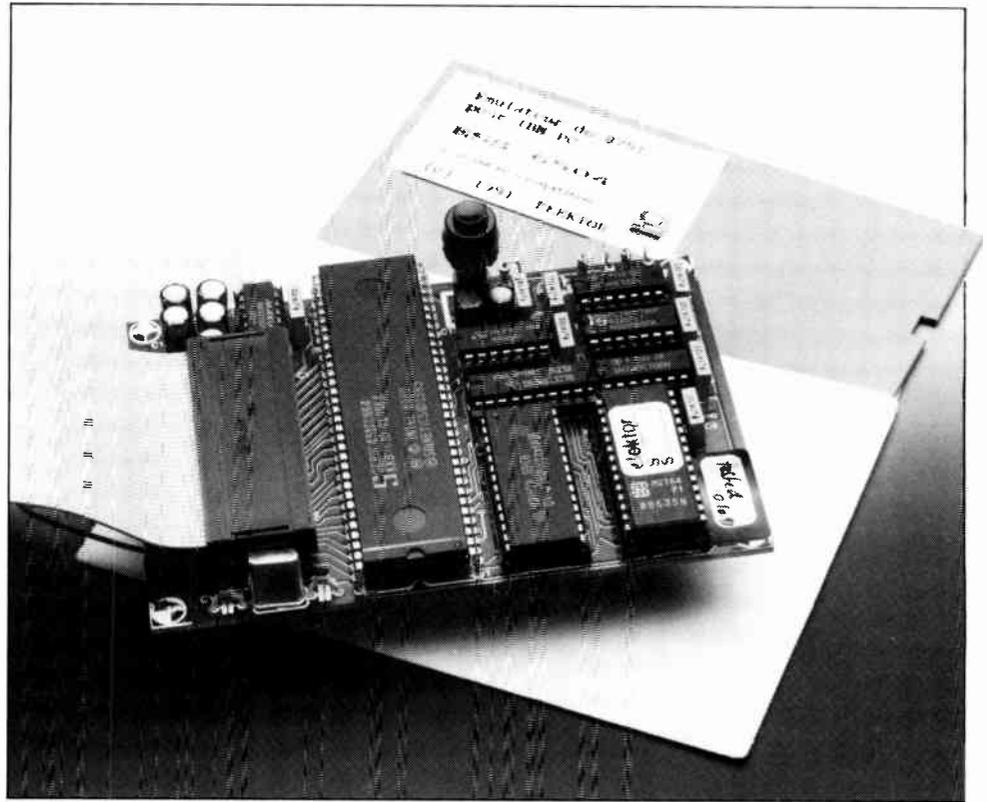
| | | |
|---|-----------------|-------------|
| 9 | 100nF | C1-C9 |
| 7 | 10μF 16V radial | C10;C13-C18 |
| 2 | 27pF | C11;C12 |

Semiconductors:

| | | |
|---|------------------------------|-----|
| 1 | 1N4148 | D1 |
| 1 | 74HCT86 | IC1 |
| 1 | SC80C451CCN64 (Signetics) | IC2 |
| 1 | 74HC373 | IC3 |
| 1 | 27C64 (ESS6051) | IC4 |
| 1 | 62256 | IC5 |
| 1 | 74HCT08 | IC6 |
| 1 | 74HCT32 | IC7 |
| 1 | MAX232 (Maxim) | IC8 |
| 1 | 4013 | IC9 |

Miscellaneous:

| | | |
|---|---|---------|
| 1 | 9-way female sub-D connector of PCB mounting | K1 |
| 1 | push-button n.o. | S1 |
| 1 | 8MHz quartz crystal | X1 |
| 1 | 64-pin strip to make IC socket | |
| 1 | 40-way IC socket with turned pins | H8 |
| 2 | 40-way IDC style DIP header | |
| 1 | length of 40-way flatcable | |
| 1 | enclosure; approx. dimensions: 92×146×28mm. | |
| 1 | printed circuit board | 920019 |
| 1 | control program on disk | ESS6051 |



Construction

The availability of a ready-made, through-plated printed circuit board (Fig. 5) makes the construction of the 8751 emulator relatively simple. A number of passive components are fitted upright. Due attention should be paid to the orientation of the ICs on the board, since they are not all mounted with the same direction. Naturally, the same goes for the orientation of the electrolytic capacitors and the diode.

The push-button, S1, may be fitted on to the enclosure, and is connected to the appropriate pins on the board.

The SC80C451 is best fitted into a socket made from two 32-pin strips. The RAM and the EPROM are also fitted in IC sockets.

SOCKET1 is best made from a good quality 40-pin IC socket. The connection to the 8751 socket in the target system is then readily made via a short length of flatcable fitted with a 40-way IDC-style DIP header at either end. Unfortunately, the pins of these DIP headers are pretty fragile, so take care not to break one, or the whole header is useless.

The completed printed circuit board is built into a suitable enclosure. A slot is cut in one of the sides to allow the 40-way flatcable to pass.

Practical use

Initially, the application (target) circuit and the PC are switched off. Note that the emulator is normally powered by the target circuit. Connect COM1: or COM2: of the PC to the emulator via an RS232 cable (the serial port selection is made in the file CONFIG.EMU as discussed below).

Do not connect the application circuit as yet. Connect a 5-V supply to the emulator.

The + goes to pin 40 (+), and the - to pins 9 and pin 20 of the DIL socket on the emulator board. Next, run the program DEV.EXE on the PC, and check that the error message "Emulator not connected -- PRESS ANY KEY TO CONTINUE" does not appear.

At this stage, it should be possible to emulate the example program (see the syntax requirements mentioned in READ.ME), without the need of inserting the DIP plug into the 8751 socket in the target system. If this works, remove the temporary 5-V supply connections, and plug the 40-way DIP header into the socket on the emulator board. Insert the DIP header at the other end of the cable into the 8751 socket on your target system board. Power up the application before switching on the PC.

Programs may be edited and assembled even when the emulator is not connected or powered. The configuration file, CONFIG.EMU, contains only two characters. The first is an M (for the monochrome Hercules video adapter) or a C (for the colour video adapters CGA, EGA and VGA). The second character selects the serial port, and is either a 1 for COM1:, or a 2 for COM2:.. If necessary, edit the configuration file using any ASCII compatible word processor. On the disk supplied through the Readers Services, the configuration is set to colour and COM1:.

The main program, DEV.EXE, is menu-driven, and uses the arrow keys to make selections. If you have the emulator powered up and connected to the target system at this stage, press switch S1 before running DEV.EXE.

Finally, READ.ME contains more information on the operation of the serial data link between the PC and the emulator. ■

ing 64 Kbytes of ROM, and an equal amount of RAM. The current consumption of the device is only about 24 mA at a supply voltage of 5 V and a clock frequency of 12 MHz, 3 mA in stand-by mode, and about 50 μA in the power-down ('sleep') mode.

The mask-programmable ROM version of the 80C451, the SC83C451, has 4 KBytes of ROM. Both the 80C451 and the SC83C451 have two 16-bit timers/counters. Their interrupt structure allows two priority levels to be implemented.

The presence of a serial I/O port in the 80C451 allows a UART (universal asynchronous receiver/transmitter) with true duplex operation to be realized quite easily. Alternatively, the serial I/O port may be used to extend the functions of the I/O lines, or to set up an inter-processor communication system.

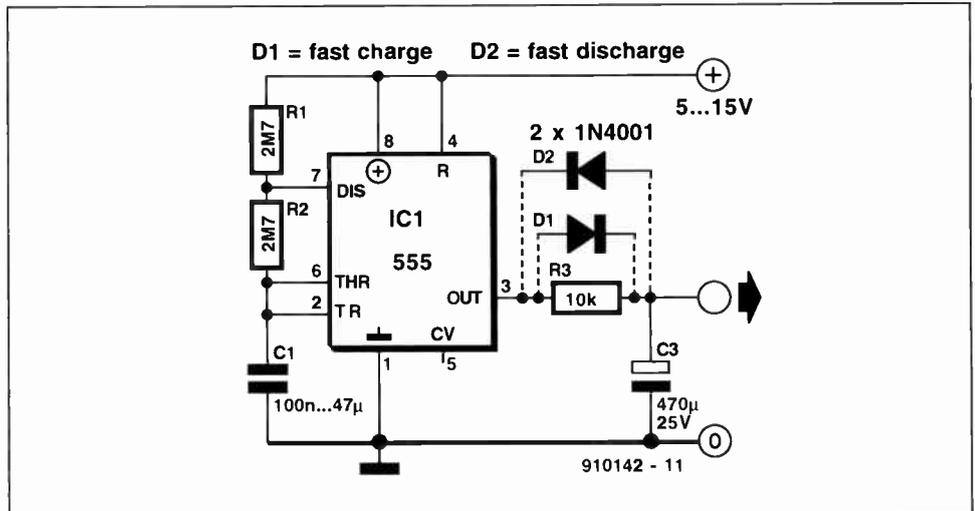
The stand-by and the power-down modes can be entered via software. In stand-by mode, the CPU proper is halted, while the RAM, the timers, the serial port and the interrupt system continue to function. In the power-down mode, the clock oscillator is disabled, which causes all functions to be switched off, but the RAM contents to be retained.

A 555-BASED RAMP GENERATOR

by R.G. Evans

WHILST developing a simple scanning receiver, a need occurred for a ramp generator to provide a varying voltage to apply to the varicap diodes fitted to the variable frequency oscillator (VCO). Referring to various literature suggested that a unijunction transistor (UJT) could be used to produce a reasonable 'sawtooth' waveform that would do the job. The circuit found provided a ramp upwards from about $\frac{1}{2}V_{cc}$ only, and in this case did not provide a sufficient range of voltage (and, therefore, scan) on the receiver. Since all the UJT circuit was doing was allowing a capacitor to charge/discharge (and was, therefore, not linear anyway), thoughts turned to other methods, hopefully cheaper and more flexible.

The ubiquitous 555 integrated circuit was chosen and put to work in a circuit based on an early application note (1976!). This circuit provided a linear charge/time graph, but allowed an output voltage swing between $\frac{1}{3}V_{cc}$ and $\frac{2}{3}V_{cc}$ only. Once again this proved insufficient for the required scan range. Thinking of ways to extend this led to the design shown in Fig. 1. The 555 is connected as an astable with a mark/space ratio of 2:1 (unfortunately 1:1 can not be achieved without additional external components) The frequency of operation can be selected by the



user, but in this instance is about 0.1 Hz.

The output on pin 3 is capable of sourcing or sinking 200 mA, and switches nearly to the supply rails under no-load conditions. This alternating high and low voltage is used to charge and discharge a relatively large electrolytic capacitor via a 10-k Ω resistor. The result is a conversion of the rectangular output wave of the 555 into a waveform described by an e^{-t} -function. By careful choice of the resistor and capacitor values, voltage

swings almost between the supply rails can be obtained.

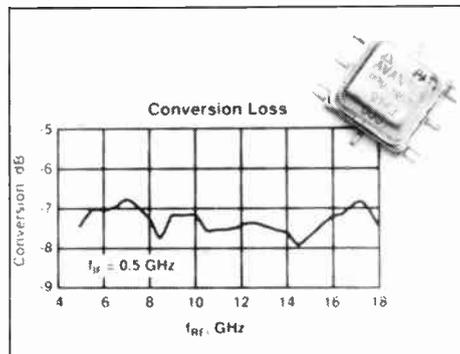
The 555-based circuit was found to provide the required voltage for the varicaps in the scanner. All this for less than the price of a suitable unijunction transistor, I hope many of you will find a use for this handy little circuit. It certainly solved my problems with the scanning receiver. ■

GHz surface-mount mixer

Avantek Inc. has introduced the industry's first high-performance, high-frequency broadband double-balanced mixer in a true low-profile surface-mount package. This means that a microwave system engineer can now effectively replace mixers in connectorized packages (typical dimensions of 0.6x0.8 inches) with a surface-mount component. This mixer is one of the last critical microwave components to become available in a surface-mount package, a major breakthrough in the miniaturization of microwave circuitry.

The PPM-1852L is a double-balanced mixer spanning the frequency range of 5 to 18 GHz on the RF and LO ports, with the DC-coupled IF port covering DC to 1 GHz. The LO power requirement is +10 dBm. Maximum conversion loss is 8 dB, conversion loss vs. frequency is flat to within ± 2 dB, and the VSWRs at the LO and RF ports are 3.5:1 and 2.5:1, worst case in the band. This mixer features typical unit-to-unit phase match within 5° , and amplitude match within 0.5 dB. The minimum and maximum

NEWS



specifications are guaranteed over the -55°C to $+85^\circ\text{C}$ temperature range.

Datasheets and additional information on this new device are available through **Avantek Inc., M/S M82, 481 Cottonwood Drive, Milpitas, CA 95035, USA. Telephone: (408) 943-3038. In Europe, call Avantek's UK offices at (0276) 685753.**

Computer-assisted electronic logic training programme

LOGIC is the English-language version of a software package from Fitec (France) aimed at perfecting and evaluating your skills in working with logic electronic circuits. The courseware, which consists of a training manual and software for the IBM PC, enables you to master the basic principles behind a wide variety of logic circuits, and check your progress as the various subjects are presented. Each section of the train-yourself course is based on three modules: (1) lesson on theory; (2) explanatory examples taken from everyday applications; (3) tests to check your knowledge. The program that runs on the PC supports the material presented in the training manual, and comes on three 3½-inch diskettes. Among the subjects tackled during the course are decimal and hexadecimal encoding, flip-flops, adders and subtractors, multiplexers and demultiplexers, counters and registers. **Fitec, 52-54 Avenue du 8 mai 1945, F-95200 Sarcelles, France. Telephone: +33 39 923290. Fax: +33 39 921764.**

THE LOUDSPEAKER DESIGN COOKBOOK, 4th ed.

By Vance Dickason

ISBN 0-96241-91-7-6

142 pages—illustrated

Price \$29.95 plus \$2 shipping (softcover)

Reviewed by David W. Davenport

Without a doubt, the book most reached for when I roll up my sleeves to get serious about designing a new speaker system is Vance Dickason's *Loudspeaker Design Cookbook*. I'm not alone in this; the cookbook has been around for over 14 years and is now available in its fourth edition. The extensive changes in this latest edition are pretty evenly split between material on new subjects and additions to existing subjects. A new chapter covers drivers, as well as sections on types of enclosures not mentioned in earlier editions. Another first is the extensive use of computer-aided design techniques to illustrate many characteristics of sealed and vented enclosures.

Study the Diagrams

It seems that every book on loudspeakers has a chapter titled "How Loudspeakers Work." The flavor here is a little different from the others however. It focuses on a view that will be of most interest to those of us wanting to build loudspeaker systems. For example, almost a full page is spent on discussing the significance of overhang and underhang in voice coils.

In addition to the in-depth treatment of the gap geometry, the section on motor system delves into the phenomenon of program current in the coil causing back EMF, and therefore modulation, of the magnetic field. This leads into a discussion on shorted turns and why they are used.

The section on the diaphragm covers such things as modes of resonance in a cone, and how directivity changes with frequency, as well as the effect of cone shape on the sound of the driver. It has more than you want to know about dust caps. Coverage of the suspension system is limited to the surround and the spider—what more is there?

The chapter on "Closed-Box Low Frequency Systems" provides all you need about designing Infinite Baffle and Air (Acoustic) Suspension loudspeaker systems. As you might expect, it begins with an in-depth discussion of enclosure response and driver Q , including the meaning of Q and a description of typical sounds of different Q s.

Here Dickason draws on his own vast experience using LEAP 4.0 (Loudspeaker Enclosure Analysis Program by Audio Teknology, Inc.), and introduces its use extensively in modeling enclosures. Although the examples shown are for a particular driver, ex-

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perienced designers may want to study the LEAP diagrams to acquire general insight.

Did You Know?

For example, I have never read a better portrayal of the trade-off between damping and power-handling ability. The chapter is not all theory—for implementing a design you are given the option of using formulas or the complete set of Q tables, which are included. The effects of parameter variances are covered. In addition to the basic ones, formulas are included to determine efficiency and output power limitation.

I was glad to see examples—they are often needed to clear up nagging questions. As an additional assist to designers, guidance is provided for selecting a driver. To top it off, the effects of thermal deviation are handled, as well as an extended section on enclosure filling. After this thorough treatment of the basics of a "simple" closed box enclosure, more advanced material is introduced.

The section on electronically assisted closed-box systems points out some of the pitfalls in an apparently attractive approach to a closed-box system design. You can read material on mass-loading modifications, as well as considerations of designing a loudspeaker containing compound woofer systems.

I accepted reviewing the fourth *LDC* because I was looking forward to new material on bandpass enclosures. And I was not disappointed—the treatment is exceptional. Instead of considering the bandpass enclosure to be a type of its own, it is addressed here as a closed-box system—with the addition of an acoustic filter in series with the front radiation of the driver. There's more to it than just a few tables and formulas—the

technique is discussed in detail. For example, did you know that, contrary to its name, the bandpass enclosure has substantial output outside of its range and therefore should be used with an appropriate adjunct electronic filter?

Illustrate the Differences

I hate to close a chapter on a sour note, but I was disappointed with the section on the aperiodic enclosure. To be fair, this type of enclosure has not benefitted from a rigorous analysis by Thiele or Small. Thus, treatment of the aperiodic enclosure was left wanting in comparison to the very thorough, analytical material on the closed-box enclosure.

The third chapter, "Vented Box Low-Frequency Systems," is a repeat of the second—the complete story. It starts with a short history, and discusses driver Q and enclosure response. Of course, because you can't control the Q in a vented design the way you can in a sealed box, the objectives are different.

The discussion on woofer selection initiated in the previous chapter is expanded upon to include determining what kind of enclosure would be best for your driver. The vented box design is associated with alignments; a term that is bandied about without really considering what it means. The introduction to the alignments in this chapter is as good as any I have seen. Dickason very effectively uses computer simulation to illustrate the differences between the various alignments as well as other factors, including vent length.

An Excellent Argument

This was a monumental effort resulting in pages and pages of graphs. But it was worth it—you can see how each parameter is affected by the different alignments. The expected sections on determining box size, losses, and vent dimension are complete and to the point. The pages of tables that are needed to design vented enclosures are all here along with welcome examples on using these charts.

I am pleased to see Dickason endorses a practice that is very important, and not at all emphasized by many texts on enclosure design. That is: to re-measure the driver parameters in a sample enclosure that is representative of the final design.

His in-depth discussion of vent geometry considers, among many other things, the ever-present temptation to go to a smaller vent to shorten it, and demonstrates the pitfalls of the vent being too small. This section also addresses coupling between the vent and driver as well as between multiple vents. As in the chapter on sealed boxes, dual woofers

and electronically assisted alignments are covered. Bandpass enclosures are revisited, this time with a vented rear enclosure.

"Passive Radiator Low-Frequency System" covers basic passive radiator design based on vented design, with the addition of material needed to determine parameters of the passive radiator substituting for the vent. It includes a convenient set of figures showing differences between a vented box design and passive radiator design.

A passive radiator bandpass enclosure section presents an excellent argument as to why the front enclosure of a bandpass design should be a passive radiator rather than a vented box. No, I'll not spill the beans here—you'll have to read it to see for yourself. And all in this chapter is not rosy: I thought the discussion on dual woofer formats for augmented passive radiators was confusing. It is probably moot because I suspect not many of us will build one of these beasts anyway.

Theory Using Examples

I was disappointed in the chapter on "Transmission Line Low-Frequency Systems." It covers the material needed to design a transmission line, but in comparison to the previous chapters, doesn't employ the same technical depth I've come to expect from *LDC*. I guess this demonstrates the still evolving nature of transmission line theory. The shape and damping chapter is just what it says—the Olson study in shapes and a lot on bracing and damping.

There's nothing new in the chapter on "Mid- and High-Frequency Drivers: Application and Enclosures." It discusses placement of drivers in order to avoid reflection-caused frequency aberration, and types of enclosures for midranges. There's a new chapter on computer-aided loudspeaker-design software that contains a short discussion on available CAD. It's a good compilation, but there's nothing new here. You have read about most of them in these pages already and know what is offered by Old Colony.

"Passive and Active Crossover Networks" starts with a short history and moves on to discuss basic crossover theory. The goal of any crossover is to provide a smooth transition between the two drivers. Although the proof is in the acoustic result, one cannot ignore the electrical characteristics of the filters. This chapter covers both. An excellent example of acoustic summation with response charts from MLSSA that illustrates the zero-delay plane, demonstrates how on-axis response with delay is not the same as sloped-baffle combined response.

The in-depth treatment of crossover-network power response shows amplitude, phase, and group delay for all popular filter

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types. It discusses the pros and cons, and then goes on to give the formulas for calculating the values for all of these filters. You may be surprised to learn that the first-order Butterworths are not the simple, universally acceptable solution that many have thought. It is as thorough a coverage of filters as I have seen—clearly written, complete, and concise. This chapter is not exclusively theory without any practical examples however. Rather, it lays down some rules and offers examples of how to meet them.

Good Alternatives

Dickason recommends something that I have believed in for years—begin your network design project by correcting the impedance of the drivers. Although series notch filters, impedance equalization, shelving, and response shaping are not part of a crossover filter, they are crucial in realizing an effective crossover.

Going from two- to three-way filters is entering a different domain of complexity. Dickason recommends an electronic filter for three-way systems, and discusses the complexity of them. I guess the only bone I pick with this chapter is that I would like to see much more on electronic crossovers.

Everything we have covered thus far assumes that you know quite a bit about the characteristics of your driver. Some of this data is available from manufacturers; although with manufacturing variances, you may want to check the values of your units. One whole chapter covers measuring just about anything that you can think of associated with loudspeakers. The list goes on and on, so I won't go through them all, but I would like to mention a few notable ones.

I like the discussion on measuring full-range frequency response as it includes three methods: anechoic, half space, and ground-plane. Use of the three methods is discussed, as well as some hints in interpreting results. Another topic that I've been interested in lately, and is well-covered, is the measurement of mechanical vibrations in the enclosure. Several techniques are described; some using inexpensive alternatives to professional accelerometers.

Pros and Cons

I suspect that there isn't a person reading this review who, one, doesn't already have a dog-eared third edition of *LDC* sitting on the workbench and who, two, is wondering what's so new in this one.

It's difficult to say what's different in this one as it's almost twice as large. I have mentioned the introductory chapter, "How Loudspeakers Work," and what amounts to a whole new chapter on the bandpass enclosure; but these are only part of the story.

The most significant improvement in this edition is the extensive use of computer-aided analysis to illustrate points of design. I literally spent hours going over the LEAP diagrams, not because I had to in order to prepare this review, but because I was fascinated by what I could see and learn.

Don't get me wrong—the book is not perfect. It cries for a section introducing test equipment and tools including Audio Precision, MLSSA, FFT analyzer, and LEAP 4.0. Saying that these things are beyond the scope of this book is begging the question. The results are there, showing the power of these tools. I simply would have liked to know more about them. Also, several graphic techniques are coming into vogue for displaying loudspeaker characteristics and I would have liked information on cumulative spectral decay plot, Wigner Distribution, and energy time curve.

This edition is no longer a compilation of advice and appropriate formulas, but has grown into a definitive reference to help amateur speaker builders understand their avocation. I say "amateur" but I expect that more than a few professionals will find this to be a handy reference as well.

For the most part, the material is available elsewhere, but unless you want to wade through volumes of journal articles and textbooks, the fourth edition of *LDC* fits the bill.

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Included in the book are, among others, the 68000 series; the 6502 family; the Z80, 8080, and 8085; Intel's 8086, 80186, 80188, 80286, and 80386; the NS32XXX series, and the INMOS transputers.

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Apart from the actual data, the book contains much other useful information, such as comparisons between and second sources for all important IC families; addresses of manufacturers and their representatives; and overviews of all peripheral chips (including many that could not be included in this book) that are available from various manufacturers.

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for '92

CONTENTS - TLK1

- 2 each: BNC to 1 each red & black Test Clips
- 1 each: red Banana Plug to red Banana Plug
- 1 each: black Banana Plug to black Banana Plug
- 1 each: red Test Clip to red Banana Plug
- 1 each: black Test Clip to black Banana Plug

- BNC to test clips use 50Ω RG58 cable
- All cables 36"

| Order # | Price | Description | Weight |
|---------|-------|---------------------|--------|
| TLK1 | 19.95 | Test Lead Kit | 8 oz. |
| TL108 | 6.49 | BNC to 2 Test Clips | 3 oz. |

CERAMIC TRIMMER CAPACITORS

Specifications

- Ins. Res.: >10mΩ @ 100Vdc
- Max. Volt.: 220Vdc
- Oper. Volt.: 100Vdc
- Rotat. Torque: 20 to 15 g/cm

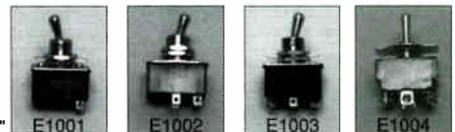
Color
Coded



| Order # | 1-9 | 10+ | Capacitance (pF) | | Q Factor @ 10MHz | Cap Color |
|-----------|-----|-----|------------------|------|------------------|-----------|
| | | | min. | max. | | |
| CVSSA0301 | .79 | .69 | 1.5 | 3.0 | >300 | Black |
| CVSSA0701 | .79 | .69 | 2.5 | 7.0 | >300 | Blue |
| CVSSA1001 | .79 | .69 | 2.7 | 10.0 | >300 | White |
| CVSSC2001 | .79 | .69 | 4.2 | 20.0 | >300 | Red |
| CVSSS3001 | .88 | .78 | 5.5 | 30.0 | >200 | Green |
| CVSSG5001 | .88 | .78 | 8.0 | 50.0 | >200 | Orange |

TOGGLE SWITCHES (125VAC)

AC Power Toggle Switches



*Mounting Hole: 1/2"

| Order # | 1-9 | 10+ | Action | Amps | Body | Terminals | Type |
|---------|------|------|-----------|------|---------------|------------|------|
| E1001 | .89 | .79 | On/Off | 3 | 1.02" x 0.55" | 2 (Solder) | SPST |
| E1002 | .99 | .89 | On/Off | 3 | 1.02" x 0.55" | 4 (Solder) | DPST |
| E1003 | 1.19 | 1.09 | On/On | 3 | 1.02" x 0.55" | 6 (Solder) | DPDT |
| E1004 | 1.49 | 1.39 | On/Off/On | 6 | 1.39" x 0.79" | 6 (Screw) | DPDT |

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