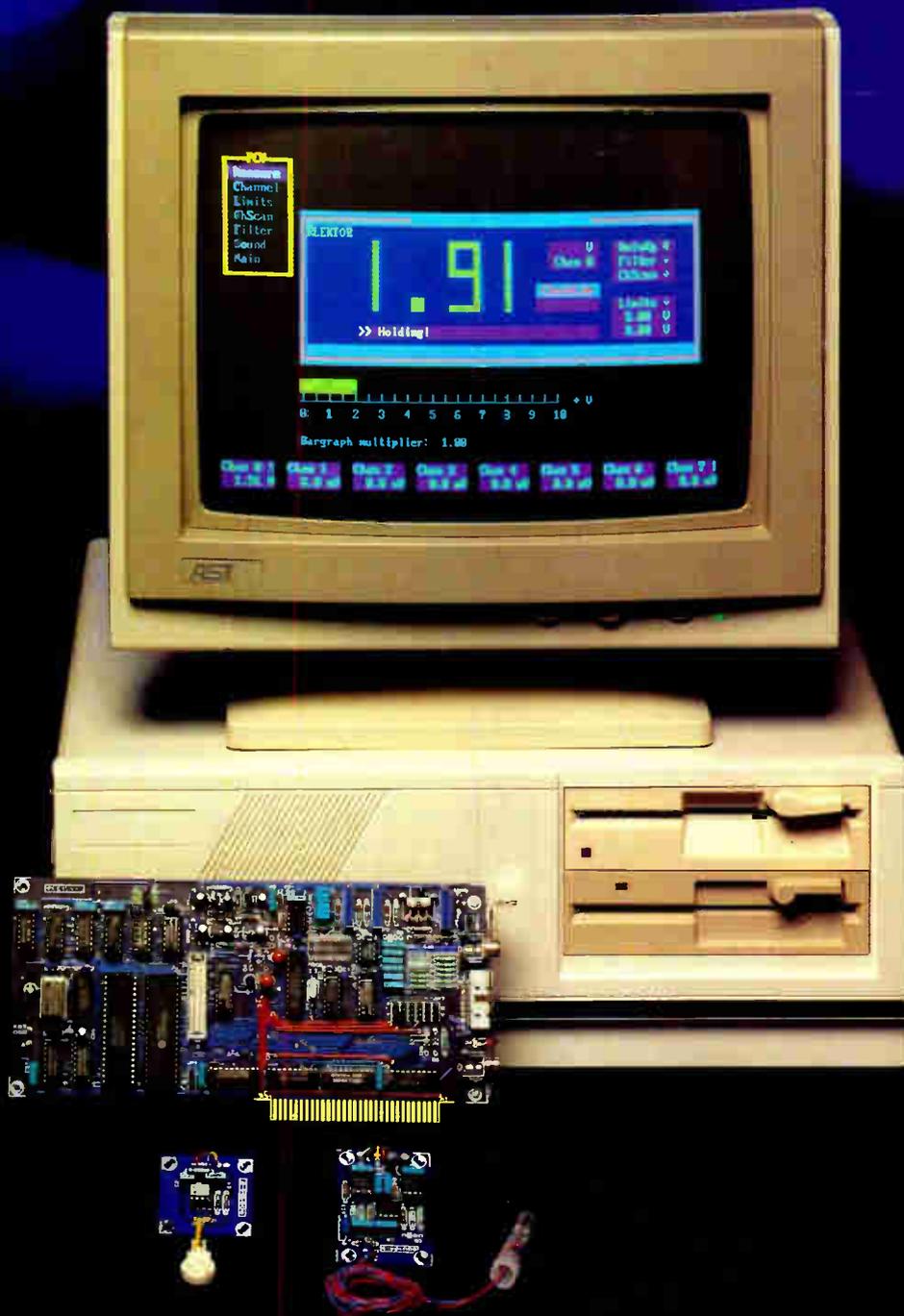


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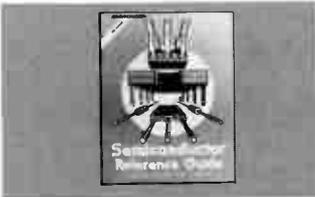
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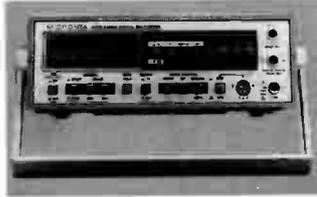
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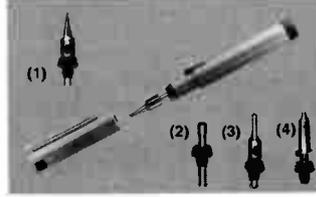
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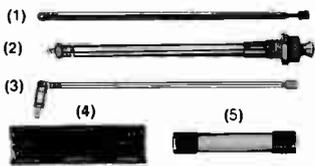


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K15	4.8	700	272-1162
K*2	6.0	650	272-1163
K18	7.2	700	272-1164



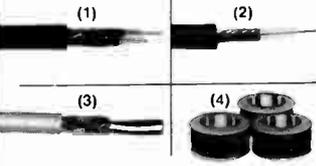
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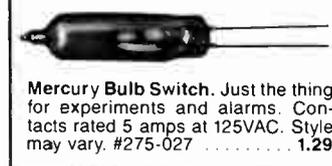
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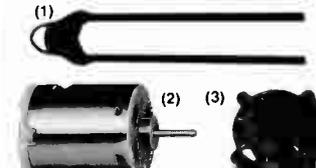
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In our next issue:

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- PC-controlled semiconductor tester
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- Multi-channel audio/video switch

Front cover

The picture shows the voltmeter function, PCV, of the Multifunction Measurement Card for PCs in action. The two basic measurement functions offered by the card, a voltmeter and a frequency /pulse meter, are frequently required in the electronic workshop or laboratory, but not commonly implemented on a PC. At least, not at the accuracy achieved by this card: the voltmeter and the frequency meter have the remarkable precision of 12 bits and 6 digits respectively, which is up to par with the specs of much more expensive (industrial) products. On the EGA monitor you can see the colourful PCV menu, which offers a host of features for multi-channel multiplexed measurements, auto-calibration and range settings. The large voltmeter indication will be familiar to readers who have already digested Part 1 of the relevant article (don't worry if you don't get the meaning of 1.91). In forthcoming issues, we intend to publish a number of practical applications of the system.

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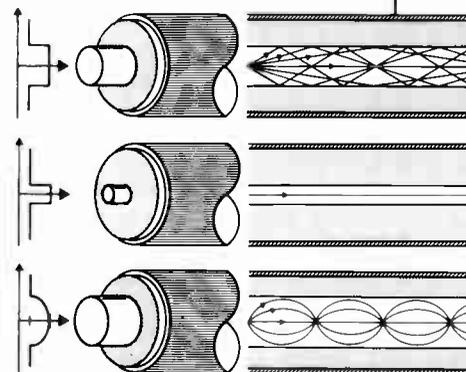
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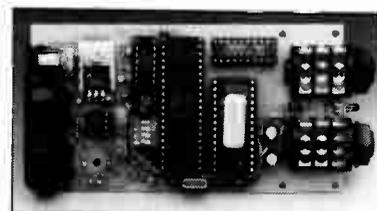
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Release 1.2 by Stuart E. Bonney

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"Souped-Up" LMP provides professional-quality graphics and a fast, friendly, user interface. Remains compatible with LMP data files and is available for IBM PC (CGA, EGA, VGA, or Hercules graphics) and Macintosh computers. The Macintosh version also provides square wave analysis with audible output.

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

These ready-to-run Mac programs come on a 3½-inch SS/DD disk initialized as a 400K disk for compatibility with all machines. Also included are the Pascal source codes, should you wish to customize them for your own use. Program A. Precisely matches the resistor values to the measured or estimated source and load impedances, yielding great accuracy. Your volume control can have 3 to 99 positions. The program will ask you how many dB each step should be attenuated and has provisions for a standard audio taper or any other taper you devise. Program B. Calculates the taper that will result with your actual resistor values, because you are limited to standard values or with series and parallel combinations. It can also show the effects of different source and load impedances on the taper. Both programs (contained on the same disk) allow you to save their output to a text file and include author support via mail. Each \$25

Apple Macintosh 3½" SS/DD SVC-1M3

BOXRESPONSE

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

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

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

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

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

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

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

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

Medium: 5¼" SS/DD Disk. Price, \$25.

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BOXRESPONSE

Apple BOX-1A5
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IBM BOX-1B5

IBM Plus Graphics

BOXRESPONSE BOX-2B5G \$50

PASSIVE CROSSOVER

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

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PASSIVE CROSSOVER CAD

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CALSOD

Computer-Aided Loudspeaker System Optimization and Design by Witold Waldman

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

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

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

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

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* Usable as credit toward later purchase of full CALSOD.

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

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

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

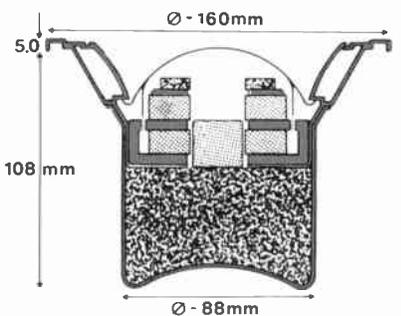
Specification

MDM 85 (with enclosure)

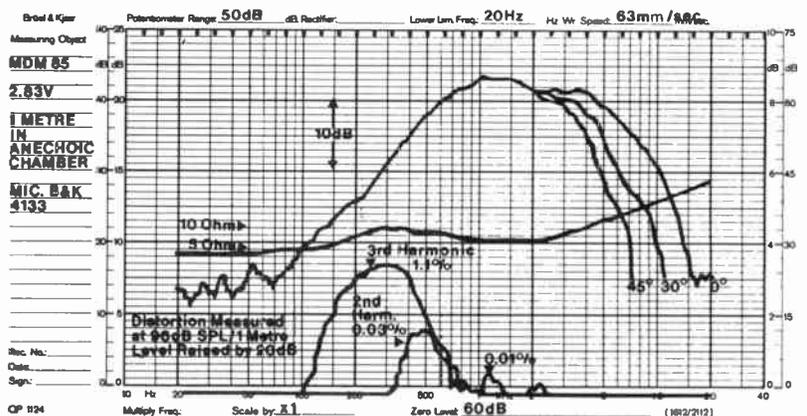
Overall Dimensions	Ø - 160mm x 113mm
Nominal Power Handling Din	300W
Transient Power 10ms	1500W
Voice Coil Diameter	75mm (3")
	Hexatech Aluminium
Voice Coil Former	Aluminium
Frequency Response	300-5000 Hz
Resonant Frequency	250 Hz
Sensitivity	92 dB (1W/1M)
Nominal Impedance	8 ohms
Harmonic Distortion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

Variations to specification for MDM 85NE (without enclosure)

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



Specifications given are as after 24 hours of running.



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BY ROBERT M. BULLOCK III

with Robert White

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

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

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

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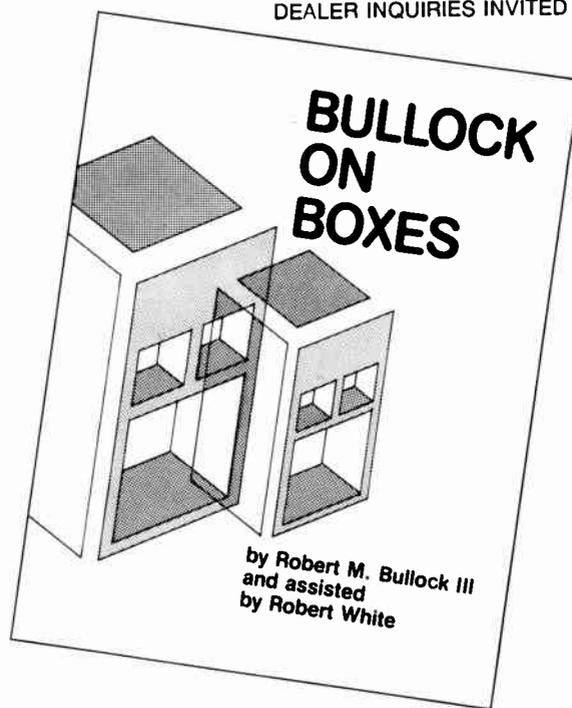
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BOXRESPONSE WITH GRAPHICS \$45

IBM only #BOX2B5G

BOXMODEL WITH GRAPHICS \$45

IBM only #MOD3B5G

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

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SPECIFICATIONS

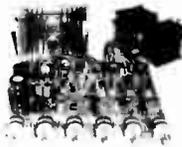
Frequency response 20 Hz to 20KHz • Total harmonic distortion: Front channel 0.05%, Rear channel Less than 0.25% • Input signal voltage 0.1 to 3.5V • Output Front channel 0.1 to 3.5V • Rear channel 6.6V • Delay time 5 to 50 milliseconds • Input impedance 47 k • Power requirements 100-120 VAC, 60 Hz • Dimensions 14 2" wide x 8 2" deep x 2 1" high



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Assembled & Tested: \$75.00

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

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



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

SPECIFICATIONS

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

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

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

SPECIFICATIONS

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



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

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

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

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



Complete Kit: \$85.00
Assembled & Tested: \$110.00
Transformer: \$43.00

SPECIFICATIONS

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

Rack Mount Metal Cabinets with aluminium panel are suitable for many projects and most of our kits.



We provide transformers for most of our Mark V amplifier kits.

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

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

SPECIFICATIONS

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



Assembled & Tested: \$225.00

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

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



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

SPECIFICATIONS

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

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

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



Complete Kit: \$68.00
Assembled & Tested: \$90.00

SPECIFICATIONS

THD Less Than 0.007% • Power output 120 watts into 8 ohms • Frequency response 8 Hz to 20KHz • 0.0-0.4 dB • Sensitivity 1V • Power requirements 55 VDC @ 3 amps May use Mark V Model 003 Transformer

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

* Free gift for any purchase before April.

MISCELLANEOUS		KIT	ASSEMB.
MODEL	DESCRIPTION		
IY-23B	3 Channel Color Light Controller ★		\$65.00
IY-25	Stereo Loudspeaker Protector ▲	\$14.85	20.85
IY-35	FM Wireless Microphone ▲	11.25	
IY-36	AC/DC Quartz Digital Clock ▲	19.00	26.20
IY-38	Sound Touch Control Switch ▲	12.00	
IY-41MK V	Infrared Remote Control Unit (w/Case) ▲▲	22.00	35.00
IY-42	Bar / Dot Level Meter ▲▲	24.15	33.81
IY-43	3 - Digital Panel Meter ▲	29.00	38.00
IY-45	20 Steps Bar / Dot Audio Level Display ▲▲	38.45	46.14
IY-47	Superior Electronic Roulette ▲▲	19.46	27.24
SM-222	7 Band Hi-Fi Graphic Equalizer ▲▲▲	26.80	38.80
SM-328	4 Channel Professional Color Light Controller ★		145.00
SM-333	Audio/Video Surround Sound Processor ▲▲▲	65.00	75.00
SM-666	Dynamic Noise Reduction ▲	26.00	34.00
SM-888	Universal Audio/Video KARAOKE Mixer Pre-Amp ★		225.00
10000uf	80 V Capacitor (Suggested for TA-3600 TA-477 TA-1000A & TA-802)		23.00
METAL CABINETS WITH ALUMINUM PANEL			
MODEL	H x W x D	MATCHING	PRICE
LG-1273	3 12 7	TA-2800 TA-377A TA-2200	\$22.85
LG-1684	4 16 8	TA-323A TA-377A TA-2200	27.50
LG-1924	4 19 11	TA-802 TA-820A TA-1500 TA120MK2 TA-800 TA-1000A	32.80
LG-1925	5 19 11	TA-477 TA-800MK2 TA-1500 TA-1000A TA-3600	35.80
LG-1983	2 1/2 19 8	TA-377A TA-2800 TA-2200 TA-120MK2	29.25
POWER TRANSFORMERS			
MODEL	DESCRIPTION	MATCHING	PRICE
001	28V x 2.6A to 30V x 2.6A	TA-800MK2 TA-802 TA-820A TA-1000A TA-1500	\$27.00
002	36V x 2.3A	TR-503 TA-323A TA-400 TA-300	22.00
003	40V x 2.6A	TA-477	28.00
004	24V x 2.6A	TA-120 MK 2	22.00
005	26V x 2.3A	TR-355B	16.00
006	18V x 2.5A	TR-355A	15.50
007	53V x 2.8A	TA-3600	43.00

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J. GORDON HOLT

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

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

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

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

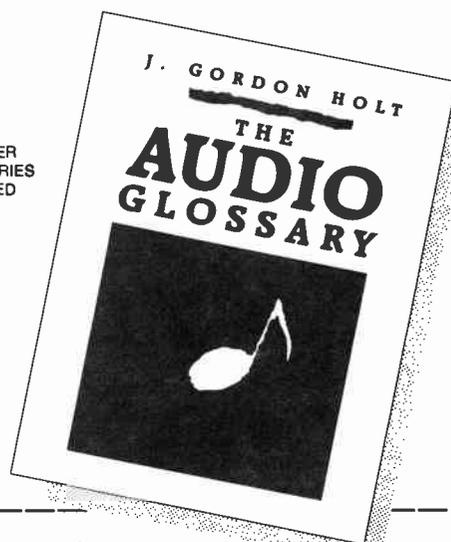
However, if the reviewer wishes to review how equipment sounds, he faces a severe problem. Our sense of hearing has the smallest vocabulary of any of our five senses. Thus, **Gordon** faced the difficulty of describing sound differences with all too few words with which to do it. He not only had to invent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

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

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

Seldom will you have the opportunity to purchase a reference work backed by so much primary research and experience. Few reviewers have spent more time and energy in an honest search for a defined, factual account of what matters in good sound reproduction techniques. In audio equipment reviewing, **J. Gordon Holt** is not only a pioneer but a master.

THE AUDIO GLOSSARY is the first publication of not only a vocabulary for sound description, but also a comprehensive overview of over 1,900 audio terms: technical and subjective. Your copy is waiting—at your favorite dealer—or order direct using the coupon below.



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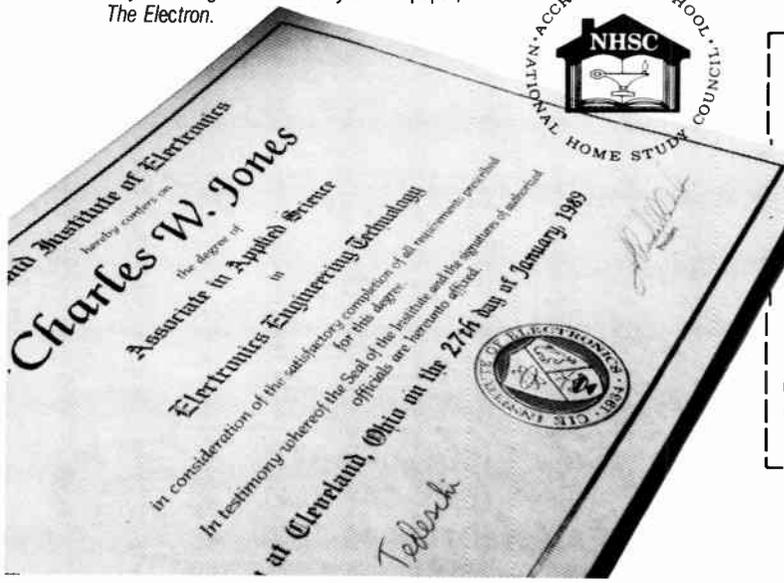
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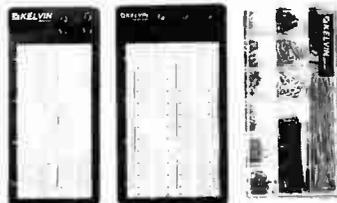


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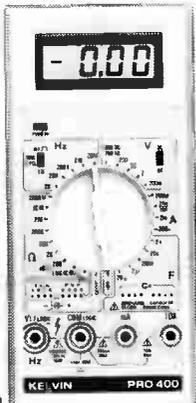
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\$ 69⁹⁵
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 Stock No. YOUR COST 6+
 810002 \$8.55 ea \$7.95 ea

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Soldering stand with base, sponge. For W60P, WP25P, WP40P, and irons with barrel diameters up to 15/32".
 Stock No. Description YOUR COST 6+
 810041 PH60 Stand \$13.78 ea \$13.09 ea
 810042 Replacement \$1.89 ea \$1.80 ea

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RESIN CORE SOLDERS 1 LB. ROLL

Stock No.	Inch	Dia.	GA.	Type	YOUR COST
580010	1/64"	.025	23	63/37	\$11.95 ea
580005	1/32"	.031	21	60/40	\$9.95 ea
580001	1/16"	.062	16	60/40	\$8.95 ea
580011	3/32"	.093	13	60/50	\$11.75 ea

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Model	YOUR COST	SALE	Model	YOUR COST
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- DC CURRENT
- RESISTANCE
- DIODE TEST
- BATTERY TEST
- LOW BATTERY Warning
- ACCURACY +/- 0.5%

KELVIN 150

Stock No. 990090 **\$ 29⁹⁵**

- AC/DC VOLTAGE
- DC CURRENT
- RESISTANCE
- DIODE & BATTERY TEST
- LOW BATTERY Warning
- ACCURACY +/- 0.5%
- CONTINUITY TEST
- TRANSISTOR CHECK

KELVIN 200

Stock No. 990091 **\$ 39⁹⁵**

- AC/DC VOLTAGE
- AC/DC CURRENT
- RESISTANCE
- DIODE TEST
- LOW BATTERY Warning
- ACCURACY +/- 0.5%
- CONTINUITY TEST/BUZZER
- TRANSISTOR CHECKER
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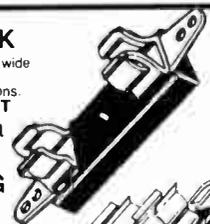
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 Stock No. 990093 \$4.95 ea

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A COMPLETE LINE OF FUSES
 FAST ACTING - SLO-BLO TYPE - PIGTAIL

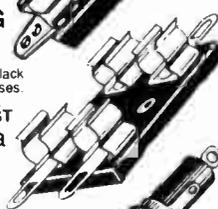
3AG FUSE BLOCK

Black laminated phenolic, 1/2" wide 1 7/8" long. For 1/4" x 1 1/4" long fuses. Solder lug connections.
 Stock No. YOUR COST
 380030 \$.45 ea



FUSE MOUNTING BLOCK

Dual fuse block 2 1/4" x 1" long. Black bakelite base. For 1/4" x 1 1/4" fuses. Mounting centers 5/8" (15.8mm).
 Stock No. YOUR COST
 380010 \$.62 ea



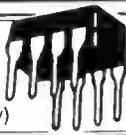
FUSE POST TYPE HKP

Bayonet type. 2 3/16" L for 1/4" x 1 1/4" fuses. 15 Ampere 250V. Panel hole size 1/2" (12.7mm). Complete with mounting nut.
 Stock No. YOUR COST
 380001 \$.90 ea



TIMER - LM555

Stock No. 600021
20 ¢ ea. (in 100+ Qty)



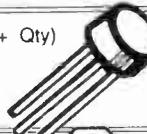
L.E.D. RED (in 100+ Qty)

Stock No. 260020
6 ¢ ea.



Transistors (in 100+ Qty)

2N2222 **18 ¢ ea.**
 PN2222 **.08 ¢ ea.**



Project BUZZER

6-9V DC, 80 dB
 Stock No. 680089
\$1.59 ea \$1.39/10+ ea.



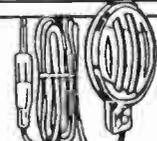
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Snap .15 ea. .10ea/100+
 Holder .20 ea. .10ea/100+



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Silent action red push button molded housing. Requires 1/4" panel hole. Overall length including solder lugs is 1". Rated 115 VAC, 1 AMP.
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 990002 Red \$.35 ea \$.28 ea



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WHEN ALL ELSE FAILS, LITIGATE

In a world where the achievement of peace seemed at last possible, and where, the communistic world has generally renounced an economic ideology which was the basis for forty years of "cold war," it is depressing to consider the spectacle of some of America's largest technical companies engulfed in a orgy of legal suits and countersuits. It would almost appear that since we cannot engage in dropping atomic bombs on enemies, US high tech companies, as an alternative, are attacking each other on grounds of patent infringement.

Lotus Development is suing Borland International, Microsoft and Apple Computer are suing each other over something many people suspect they both originally borrowed, without permission or royalties, from Xerox. Intel and Advanced Micro Devices, Motorola and Hitachi have been involved in suits.

I find it curious to reflect on the relative merits and shortcomings of the economic systems of state capitalism and private capitalism. The first lacks enough self interest (greed) to work and the latter is now severely threatened by an overabundance of the same commodity. We have been through a decade of loosening restraints on how private capitalistic enterprises function in this country. On balance we find ourselves with a corrupted and discredited banking system, a more and more heavily burdened class of very poor and a growing class of super rich.

I cannot refrain from noticing, since we are faced with a possible 23% increase in second class postal rates next February, that we are still attempting to operate the US Postal Service with a system of management thoroughly discredited by the USSR's abandonment of state capitalism. I hope someone finally notices it is impossible to run a business with a bureaucracy.

It is difficult to escape the conclusion that decisions about US business are made purely on considerations of profit, nothing else. The end result will be what we are already seeing, unbridled aggressiveness and greed. The people who use these companies' products will not benefit from legal hassles, and if we realize that a growing portion of what we pay for products must pay legal

and lawyer's fees, we ought not to be too happy about the situation. Lawyers are a lot like fire hydrants, necessary in emergencies, but fire prevention is a better answer.

It is important to differentiate here between those who sue in response to outright theft of ideas, and those who do so to retain exclusive right to patents which by law ought to be shared on some sort of royalty basis. If AT&T had refused to license others to make transistors where would we be today? If Lotus can keep exclusively for itself the "look" of the spreadsheet interface, then every spreadsheet user will be inconvenienced merely to push profits at Lotus ever higher.

Anyone who lifts his or her head for a few minutes to survey the world economic scene will realize that American businesses could hardly pick a less appropriate time for fighting with each other.

The situation now developing in our country has, classically, bred revolution. I doubt we will have mobs in the streets, although there are some cities where this has happened in our recent memory. It is not outside the realm of possibility it could happen again. But the more subtle and pervasive effect is a general sense among most people of sad cynicism about business generally, as well as deepening disenchantment with government and politicians generally. And the level of helpless anger seems to me more evident in more people every day. Aggressive rudeness seems more pervasive. Just note how many more people are running red traffic lights.

I believe a large part of the economic "slowdown," that euphemism we are using instead of talking about a recession, is due to lack of confidence by the consumer. Times are bad because people generally are discouraged, frightened or both. That miasma is causing what we fear.

America has the strength and power to do wonderful things. But we won't do them if the profit-oriented managers make all the decisions. We won't do them if every person's goal is self preservation.

—E.T.D.

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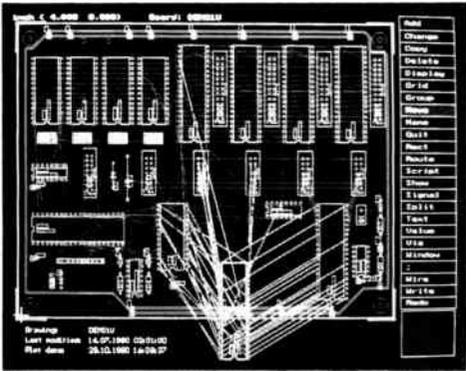
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PROFESSIONAL CIRCUIT BOARD DESIGN SYSTEM

American Small Business Computers (ASBC) announced its EAGLE printed circuit board design system at the fall COMDEX. EAGLE (easily applicable graphics layout editor) targets the PCB industry, enabling design of custom PCBs from the schematic stage to auto routing to the completed board design.

EAGLE incorporates three major component modules: Layout Editor, Auto Router, and Schematics Editor. All modules share the same database and operate within an integrated environment, so moving from one to another never requires leaving the system or booting a separate program. The Layout Editor module contains library symbols for designing the pre-production schematic layout and the PCB. These symbols include many 8- to 40-pin dual in-line packages (DIPs), connection symbols, a surface mount device (SMD) library, Zilog and PAL libraries, an Intel library, standard IBM PC expansion slot boards, capacitors, diodes, resistors, potentiometers, and more. You can edit the symbols and add others.

EAGLE comes standard with pop-up

WAVEFORM WORKSTATION

The R4050 from Rapid Systems is a workstation for creating, generating, and editing waveforms. By using the program's mouse, you can translate mental waveform images into signals without writing equations or typing in numbers. Editing real-world signals from digital scopes and visualizing or processing math functions are possible. The Integrated Arbitrary Waveform Generator features 12-bit resolution and 5MHz output frequency range. The system integrates the power, flexibility, and cost of an AT with an ARB and turnkey intuitive software.

The workstation includes the following applications: educational instruction, expert systems, CAE software, AM/FM modulation, power supply testing, rectified signals, noise, stairstep waveforms, glitches, servo outputs, telephone/communication waveforms, and transducer simulation. Additional features are continuous, sweep, and burst modes

ELECTRONICS SCENE

menus, on-screen prompts, and side-bar menus and the ability to modify practically everything. Operation can be by mouse, keyboard abbreviations, or a combination of both. You can write your own macros and assign them to function keys.

EAGLE has an Undo/Redo function. Other features include multiple grids on the same drawing; 225 layers; "graphical" Design Rule Checking (not just a list); adjustable size drillholes, vias, and pads; rubberbanding and ratsnests; cut and paste; scalable output with mirror and rotate; import and conversion of netlists into script files; use of expanded memory if available; continuous coordinate display; and 64" x 64" drawing area. EAGLE has WYSIWYG viewing of all steps in the design process, and the zoom capability is continuous and infinite.

The program requires IBM or compatible with 640K RAM and a hard drive and supports EGA and VGA graphics (color and monochrome), dot matrix and laser printers, HPGL plotters and mice, and the Gerber Photo-Plotter. All peripheral drivers are included with the Layout Editor module.

Eagle is available for \$399 without Auto Router and for \$699 with it. The Schematics Editor costs \$495. A demo copy costs \$50, with the price applied to future purchase. The program comes with free technical support. For more information, contact American Small Business Computers, Inc., 327 S. Mill St., Pryor, OK 74361, or (918) 825-4844, FAX (918) 825-6359, or contact your local dealer.



with external gate input; 16K waveform memory; programmable amplitude to 10V p-p; amplitude, phase, and DC offset control; built-in waveform and equation library; and integrated AT/EGA/40Meg computer.

The workstation sells for \$4,995. Contact Rapid Systems, Inc. at 433 N. 34th St., Seattle, WA 98103, (206) 547-8311, FAX (206) 548-0322.

ANSI CATALOG LISTS SAFETY AND HEALTH STANDARDS

The American National Standards Institute (ANSI) has released its 1990-91 Safety and Health Catalog at the National Safety Council Congress and Exposition held October 29-31 at the Las Vegas Convention Center. Listing more than 1,150 approved and revised standards to help safeguard consumers and individuals in the workplace, the catalog features standards in areas such as agriculture, construction, consumer and recreation, electrical devices and wiring, fire protection, health, highway and traffic, nuclear, occupation safety, and security. Free copies of the catalog can be obtained by calling ANSI's Publications Department at (212) 642-4916.

DesignCAD REVEALS PROPOSED UPDATE FEATURES

At the fall COMDEX, DesignCAD released features to be included in the DesignCAD Macintosh update, scheduled for release by the first quarter of 1991. Features include more image-rendering and image-manipulation options, increased speed and better placement of menus, larger array of commands, and continuing emphasis on transportability to and from other file formats and operating systems.

Increased image-rendering and manipulation options include Phong and Gouraud shading, transparent object rendering, and the ability to alter the perspective of drawings and to adjust the clipping distances of objects. You can adjust the amount of "gloss" in the reflection to improve specular reflection, and you can mark a specific region to be rendered.

DesignCAD Macintosh is Apple/UNIX compatible and has 2-D and 3-D CAD features, including 32-bit floating-point accuracy and complete dimension/annotation capabilities. The 3-D features include built-in shading (with smooth shading and specular reflection using the Ray Casting technique), unprecedented parametric surface construction and modification, and Unified Parametric Representation and real-time rotation. DesignCAD Macintosh transfers drawings to and from most common file formats, including DXF, IGES, PostScript, PICT, and coordinate files, plus DesignCAD MS-DOS files.

DesignCAD Macintosh is priced at \$699. It carries free technical support directly from the manufacturer. Current users will be able to update the program for \$50. For more information, contact your local dealer or DesignCAD, Inc., 327 S. Mill St., Pryor, OK 74361, (918) 825-4848, FAX (918) 825-6359.

ACOUSTICAL SOCIETY OF AMERICA MEETING

The 121st meeting of the Acoustical Society of America will be held Monday through Friday, April 29 to May 3, 1991 at the Omni Inner Harbor Hotel in Baltimore, Maryland. A full program of sessions will be held every morning and afternoon, Tuesday through Friday, and a tutorial lecture on Monday evening. Registration will begin Monday at 4 p.m.

For more information, contact Acoustical Society of America, 500 Sunnyside Blvd., Woodbury, NY 11797, (516) 349-7800.

MICROMATH ANNOUNCES EDUCATIONAL GRANT PROGRAM

MicroMath Scientific Software has announced a grant program for accredited schools, colleges, and universities in the US. When a school purchases four or more programs for its computer center, a "buy one, get one free" site licensing policy takes effect. This policy applies to all MicroMath software: GRAPH, for scientific plotting and data transformation; MINSQ, for curve fitting and model development; EQUIL, for solution chemistry equilibrium calculations; LAPLACE, for numerical inversion of Laplace transforms; and RSTRIP, for polyexponential curve stripping.

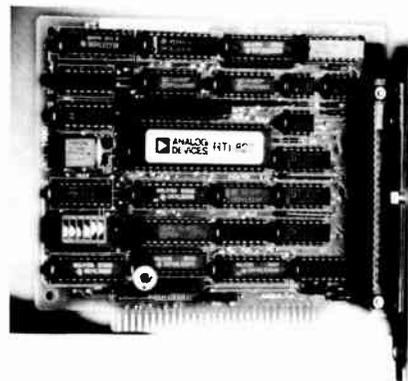
Interested schools are welcome to contact MicroMath Scientific Software at (800) 942-MATH for further information.

ELECTRONICS SCENE

COUNTER/TIMER I/O BOARD FOR PC/XT/AT INTERFACES

Analog Devices' RTI-827, a PC/XT/AT compatible counter/timer board, has five independent 16-bit counter/timers and seven digital input/output (I/O) channels. To allow for direct connection to signal sources in industrial environments, the RTI-827 uses input line receivers and high-current peripheral output drivers. The counter/timers can be programmed to operate independently or simultaneously in applications requiring frequency and period measurement and event counting—and generation of single, defined-count, and time proportional-width pulses. These operations can be synchronized or controlled by outside events through external gating and triggering.

The RTI-287's interface input options allow it to be connected to $\pm 24V$ AC or DC signals. It will measure frequency and count events at rates up to 5MHz (400kHz when software-programmable debounce is enabled). Counter/timer outputs can be configured for TTL or open collector. In the open-collector mode, they can sink up to 300mA, connect directly to +35V DC, and



easily drive relay coils, lamps, and other high-current control devices. Interrupts occur when an internal counter reaches a preset terminal count or when an external line goes to its active state.

The RTI-827 is supported by DOS software drivers for a variety of high-level languages: Microsoft C and Borland International Turbo C; Borland International Turbo Pascal; and IBM Interpreted BASIC, Microsoft Interpreted, Compiled, and QuickBASIC.

The RTI-827 half-size counter/timer board plugs into one PC/XT/AT slot and costs \$325. It is shipped with a 5¼" or 3½" utilities disk containing I/O exercise routines and configuration programs. For more information, contact Lori Berenson, Analog Devices, Inc., One Technology Way, Norwood, MA 02062, (617) 461-4125 for applications assistance.



SWEEP/FUNCTION GENERATOR OFFERS LAB CAPABILITIES

The B&K Precision Model 3022 Sweep/Function Generator with five-digit frequency counter has lab and service capabilities, including TTL and CMOS pulse signal outputs and sine, triangle, square wave, and ramp. All have variable duty cycle. Operating modes are sweep, AM, FM, and voltage controlled generator.

The 3022 covers from 0.02Hz to 2MHz in seven ranges. It has internal or external sweep capability, with continuously adjustable sweep width to a maximum ratio of

1,000:1. A sweep ramp output lets you synchronize an oscilloscope for frequency response measurements.

Separate outputs are available for TTL/CMOS and other waveforms. For engineering applications, a variable DC offset simulates a DC signal on the generator output. This is useful for matching the DC voltage at the signal input point and evaluating the effects of DC bias on AC circuits and other tests. Other features include variable duty cycle with ratios to at least 1:20 and adjustable sweep time from 0.5 to 30 seconds with selectable linear or logarithmic operation. The

TTL output provides a fast rise time pulse or square-wave preset to TTL levels. CMOS output pulses are variable from 5-15V.

The generator output can be amplitude or frequency modulated by an internal 400Hz sine wave or an external source. For AM, the external signal can extend to 1MHz, while FM operation accepts input of any audio range signal to 20kHz. Both modulation ratio and FM deviation are adjustable.

Sine-wave distortion is less than 1% from 0.02Hz to 100kHz with square-wave symmetry of better than 2% from 0.02Hz to 100kHz and triangle-wave linearity at 98% to 100kHz and 95% at 2MHz. Output level is adjustable from zero to -40dB; a 20dB step attenuator extends the range from zero to -60dB.

The built-in five-digit frequency counter displays the output frequency of the generator or reads an external signal from 5Hz to 10MHz. The external counter has four table gating times for resolution to 0.1Hz.

The Model 3022 has a suggested price of \$450 from local distributors. For more information, contact B&K Precision, Division of Maxtec International Corp., 6470 W. Cortland St., Chicago, IL 60635, (312) 889-1448.

MULTIFUNCTION MEASUREMENT CARD FOR PCs

PART 2: CONSTRUCTION, ADJUSTMENT, SOFTWARE AND PRACTICAL USE

Following last month's formal description of the operation of the measurement card, many of you will be keen on tackling the more practical side of things. In this second and final instalment we concentrate mostly on the construction, which is fairly easy, and on the powerful, menu-driven control software package that brings the card alive on your PC.

J. Ruffell

Reorienting

Having digested all the information on the design and operation of the measurement card presented in last month's instalment, we can now start to look at the construction of the unit. As shown in the photograph of our prototype, the printed-circuit board is fitted with a support bracket of the type used in PCs to secure insertion cards to a frame at the rear side of the computer. The PCB accommodates four connectors used for the various types of measurement. The upper two connectors, K1 and K3, are for the analogue measurements, while the lower one, K2, forms the protected digital input for frequency and pulse measurements. The other digital inputs are provided on connector K6, which is located next to the two PPIs (8255s) on the left-hand part of the PCB. Between connectors K2 and K3 we find LED D4, an indicator which lights during the gate time when measurements are carried out on digital signals.

The lower edge of the PCB has the familiar PC extension bus connector, which consists of gold-plated contact fingers. To the top, at the right, we find the three multiterminal presets, P1, P2 and P3, and switch S1. As will be detailed later, these components play an important role in the adjustment of the card. During the adjustment, the switch is used to generate two calibration signals. The two PCB solder pins to the right of P3 (marked 'adj.') form an adjust output, which is used during the alignment of the ADC only.

Building the card

The track layouts and the component mounting plan of the printed-circuit board are given in Fig. 3. As a matter of course, this PCB is double-sided and through-plated. Having noted that the PC bus extension con-

COMPONENTS LIST

Resistors:

1	10 Ω	R1 (see text)
2	13k Ω 1%	R2;R4
2	6k Ω 19 1%	R3;R5
*	see text	R6-R19
2	22k Ω	R20;R34
1	24k Ω 3 1%	R21
1	1k Ω 0 1%	R22
1	280 Ω 1%	R23
1	953 Ω 1%	R24
1	3k Ω 09 1%	R25
5	10k Ω 1%	R26;R39-R42
1	32k Ω 4 1%	R27
1	110k Ω 1%	R28
1	453k Ω 1%	R29
1	22M Ω	R30
1	523k Ω 1%	R31
1	487k Ω 1%	R32
1	10k Ω	R33
3	330 Ω	R35;R37;R38
1	100 Ω	R36
1	2M Ω	R43
1	820 Ω	R44
3	500 Ω multiterm preset	P1;P2;P3

Capacitors:

5	100nF ceramic	C1;C4;C7;C9;C10
2	47 μ F 25V tantalum	C2;C8
1	10 μ F 25V tantalum	C3
2	56pF	C5;C6
7	22nF ceramic	C13;C14; C19-C22;C40
2	470nF 63V MKT	C11;C12
8	47 μ F 16V radial	C15-C18; C23-C26
7	100nF	C27-C32;C42
7	optional; see text	C33-C39
1	470nF	C41
1	1nF	C43
3	100nF ceramic SMD	C44-C46
1	10 μ F 25V tantalum	C47

Semiconductors:

3	BAT85 (PC)	D1;D5;D6
2	1N4148	D2;D3

1	LED red 3 mm	D4
2	TL431CLP (TI)	D7;D8
1	BC557B	T1
1	74HCT245	IC1
1	74HCT240	IC2
1	74HCT244	IC3
1	AD7572AJN03 (AD)	IC4
1	74HCT08	IC5
3	74HCT74	IC6;IC19;IC20
1	PAL 16L8 (ESS561)	IC7
1	74HCT02	IC8
1	OP200 (PMI)	IC9
2	74HCT4051	IC10;IC12
1	TLC2652 (TI)	IC11
2	82C55 (I;UMC)	IC13;IC14
1	74HCT86	IC15
1	74LS292	IC16
1	79L08	IC17
1	74HCT153	IC18
1	LS7060 (LSI)	IC21
1	74HCT151	IC22
1	78L08	IC23

Miscellaneous:

1	10-MHz oscillator block	OSC1
2	PCB-mount phono socket	K1;K2
1	16-way box header with angled pins	K3
1	26-way box header	K6
1	SPDT slide switch	S1
1	4 MHz quartz crystal	X1
1	PC card support bracket BICC-Vero type G99.	
1	printed circuit board	900124

Manufacturer codes:

TI = Texas Instruments
 PMI = Precision Monolithics Inc.
 PC = Philips Components
 I = Intel
 UMC = United MicroElectronics Corp.
 LSI = LSI Computer Systems Inc.
 AD = Analogue Devices

nector is gold-plated for optimum contact with the slot connector in the PC, you will agree that is hard, if not impossible, to produce this PCB yourself and match the quality of the one supplied ready-made.

It is recommended to use thin solder tin, and a low-power solder bit with a very fine tip. Those of you confident of their soldering skills may want to do without IC sockets in the analogue section of the circuit (the analogue section essentially consists of the ADC, the two multiplexers and the three associated opamps). In practice, it is often found that soldered connections are better than (inexpensive) IC sockets, which tend to develop bad contacts. If you are hesitant about soldering the (fairly expensive) components in the analogue section, consider the use of IC sockets with turned pins.

Overall, the construction of the card is simple and straightforward if you follow the parts list and the component overlay printed in white on the PCB. One area that deserves special attention, though, is the decoupling of the ADC chip. To enable the ADC to achieve the specified accuracy, it requires decoupling capacitors that are fitted as close as possible to the IC. If the decoupling is inadequate, a number of the lower significant bits are not stable, making the measurements unreliable. From the PCB layout it is seen that the ADC chip is fitted with three surface-mount assembly (SMA) decoupling capacitors, C44, C45 and C46, which can be mounted very close to the IC because they have no leads. It should be noted that C44 is mounted only when the -A type ADC is used. A further decoupling capacitor, C47, is a tantalum bead type mounted at the solder side (i.e., the non-component side) of the board.

The special decoupling of the ADC, together with the filter function of the software, ensures that the measurement results are degraded only by the ± 1 -bit error of the LSB (least-significant bit). As discussed last month, this error occurs in all analogue-to-digital conversion processes, and can not be eliminated.

The final accuracy of the frequency measurement is basically achieved by the software, which has a filter function that builds the actual measurement value from up to a thousand measurement results obtained from very fast sampling. By evaluating all these measurement results, the software is capable of eliminating errors caused by, say, a small spike, or random interference.

Jumpers JP2 to JP8 need not be fitted as yet, because the software will also function without hardware interrupts implemented. As detailed last month, jumper JP1 sets the base address of the card. Install it as required, with reference to Table 1.

Jumper JP9 must be set to position C when the on-board 10-MHz oscillator is used. Position D is used when an external reference oscillator is connected. The function and use of jumper JP10 is discussed later in connection with the adjustment of the ADC.

Depending on the desired measurement

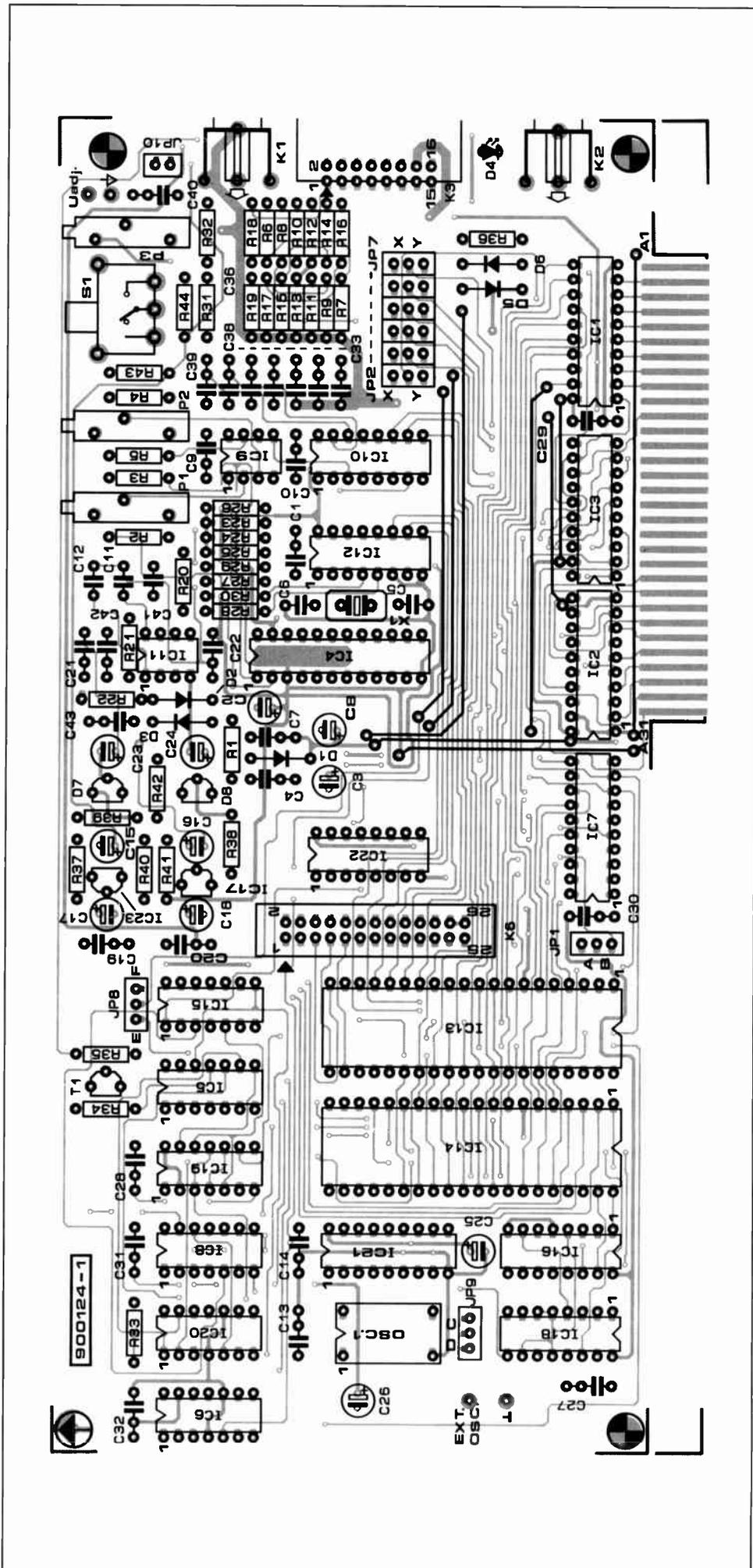


Fig. 3a. Component overlay of the double-sided, through-plated printed circuit board.

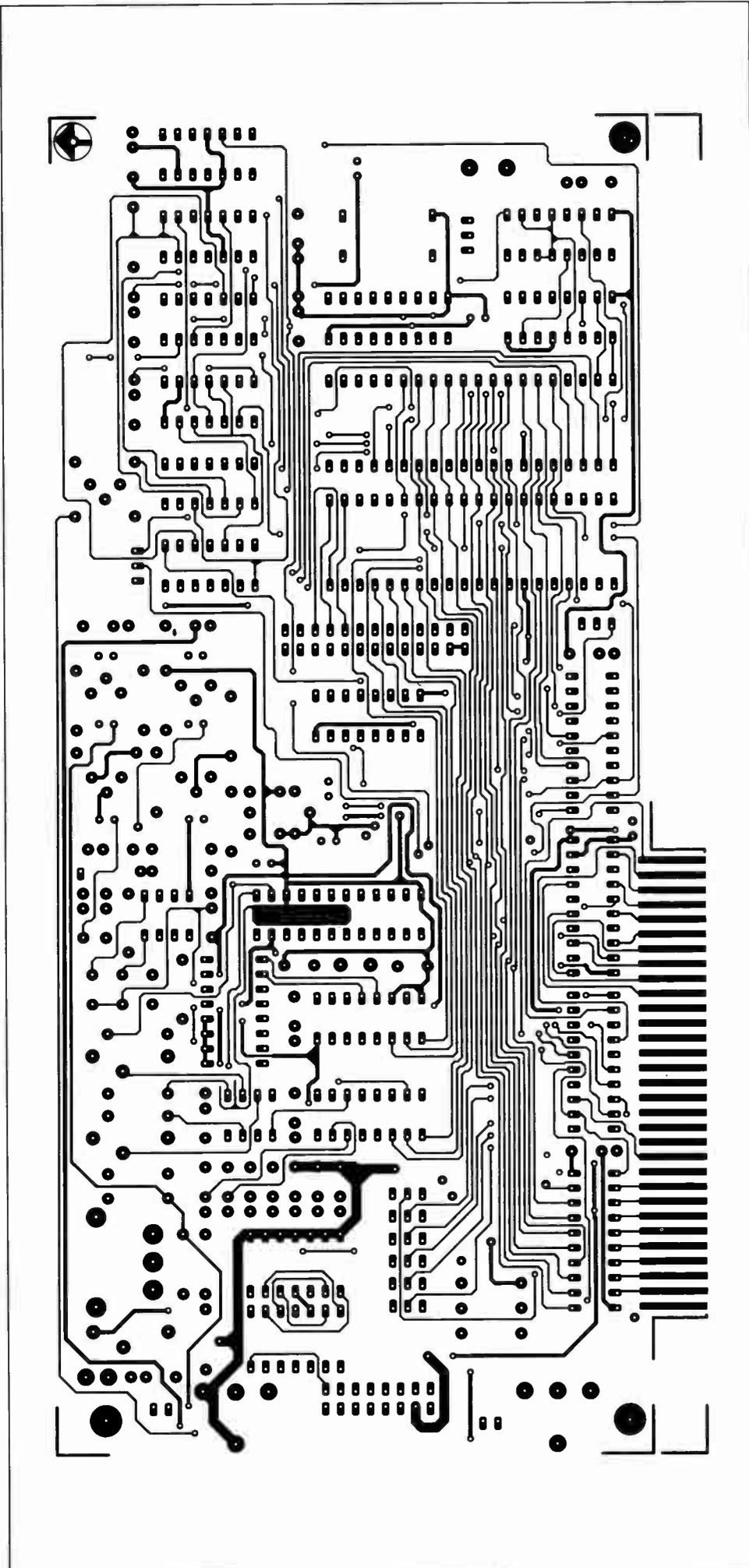


Fig. 3b. Track layout (mirror image) of the component side of the board.

SOFTWARE SERVICE

This project is supported by two items in the Elektor Software Service (ESS) range:

- a diskette, order number 1451, containing the control program (MS-DOS format, 5¼-inch, 360 k);
- a ready-programmed PAL type 16L8 (IC7), order number 561.

For prices and details on ordering these products please refer to the Readers Services page elsewhere in this issue.

range on multiplex channels I1 to I7, you must dimension resistors R6 to R19 yourself. To prevent measurement errors caused by large ground currents, these resistors preferably take high values. For the same reason, do not load the +8 V reference voltage on connector K3. As indicated in the circuit diagram, the junction of each potential divider may be decoupled for alternating voltages with the aid of a capacitor (C33 to C39).

Software

In all fairness, a piece of high-tech electronics like the PC measurement card is of little use when you have no software to control it properly. Fortunately, such software exists, and is available in a ready-to-go state on a diskette for all PC-XT/AT MS-DOS computers.

The control program developed for the measurement card has been written in Turbo Pascal, and uses a large number of coloured menus to show the various measurement results. The software is uncritical as regards the type of PC, and can be used with video adapters such as the Hercules, EGA and VGA (not with the CGA). The software for the prototype card was written and successfully tested on a PC-AT with a hard disk, 640 kB of memory, MS-DOS version 3.2, and an EGA video card. A hard disk is not strictly required for the software to be used, but it does offer the additional comfort of faster switching between parts of the program.

If you have a hard disk, create a subdirectory for the measurement card, and copy all the files from the distribution floppy disk into this subdirectory. If you do not have a hard disk, make a working copy of the distribution disk, and store the latter safely for use as a back-up. Make sure that the working copy is not write-protected.

The diskette supplied for the project has two .EXE files: PCV.EXE, which starts the voltmeter program, and PCF.EXE, which starts the program for time-related measurements. Also on the disk are a number of configuration files used by the two programs.

Before using PCV.EXE or PCF.EXE, make sure that the configuration contained in ADCF.CFG is correct. If you inspect this file, you will find that the defaults are:

- base address: \$0300
- reference frequency: 10 MHz,
on-board XTO
- maximum gate time: 410 s
- full-scale voltage: 2.5 V

In most cases, the default settings allow PCF and PCV to be used straight away, unless you require a change in the base address. If necessary, edit the ADCF.CFG configuration file with the aid of a (simple) word processor such as EDLIN, PCTools, Norton or Side-Kick.

PCV, the PC-controlled Voltmeter

After fitting the card in the PC, leave the cover open as yet to provide access to the three multirun presets. Run PCV, and check that the main menu appears (see Fig. 4). If the program reports that the card is not found, you have a problem. Not to worry, though: check for the correct base address in software (the configuration file) and in hardware (jumper JP1). If this is all right, a section of the hardware may not function properly, or the card causes an address conflict in the PC. Investigate and rectify the problem before proceeding.

Once you are looking at the main menu, you may confidently embark on the adjustment of the card. The adjustment procedure effectively matches the software to the hardware, ruling out the effect of component tolerances on the measurement results.

Adjust

Start by selecting the 'Adjust' option from the main menu. The information presented by this option, shown in Fig. 5, is clear and allows the ADC on the card to be calibrated quickly and efficiently. As already mentioned in part 1 of this article, channel I1 is used for the calibration of the ADC. Therefore, do not forget to disconnect R19, and fit R18 (or, if applicable, a wire link) on the PCB. The program then performs the adjust routine and provides all the instructions and help you need to achieve satisfactory results.

Learn

On completion of the 'Adjust' routine, return to the main menu. From there, select the 'Learn' option to calibrate the attenuators on the eight analogue inputs. The 'Learn' routine allows you to tell the program which attenuation is applicable at the inputs of the various analogue channels. The software automatically eliminates the tolerances in the ladder attenuators, and offers a number of options that allow you to select the analogue channel of which the transfer function (i.e., the attenuation) is to be 'learned'. As long as inputs I1 to I7 are not connected to additional attenuators, their maximum input voltage range is ± 2.5 V at a conversion input factor of 1. Nonetheless, these inputs need to be calibrated to enable the program to be initialised.

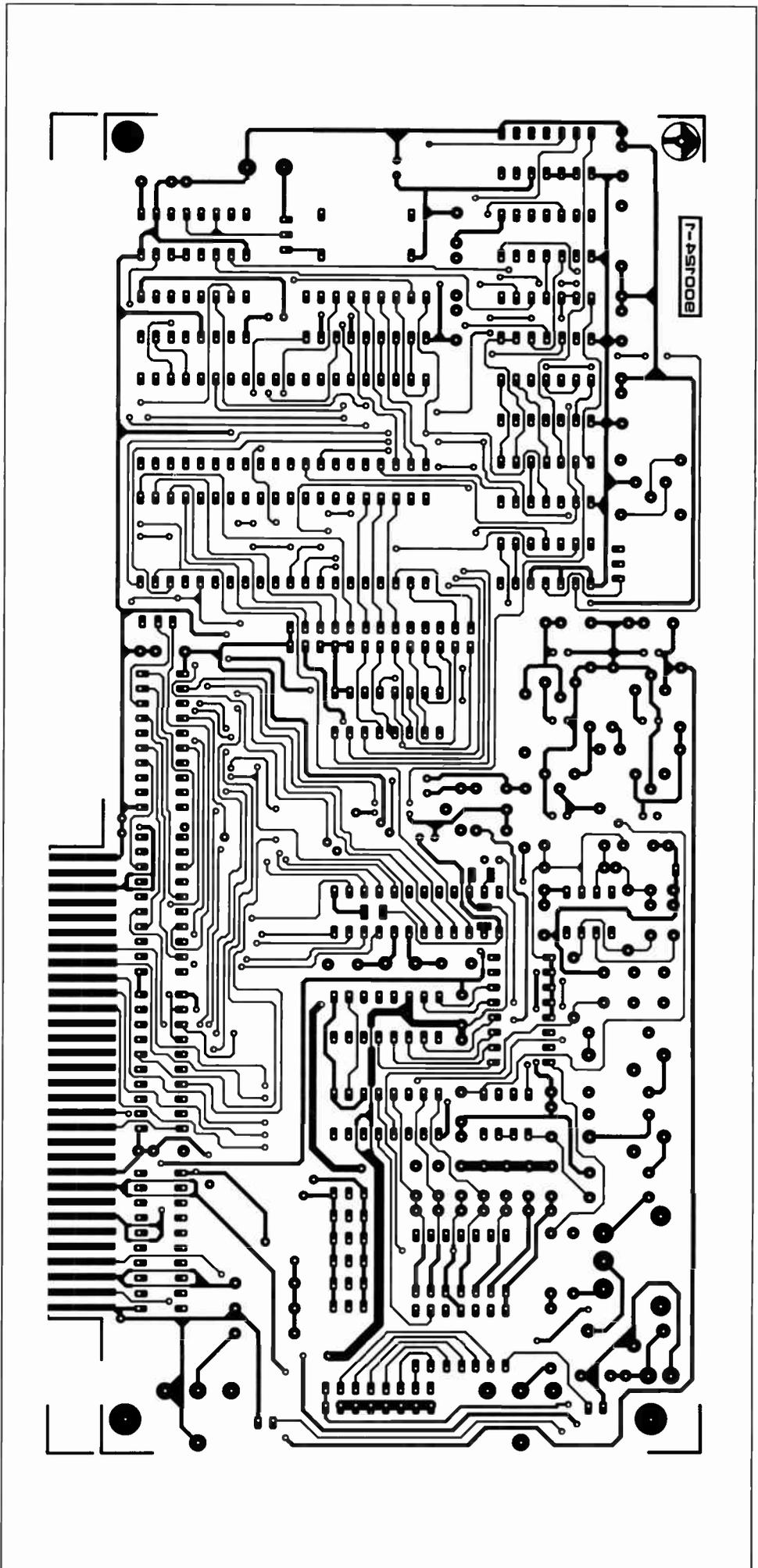
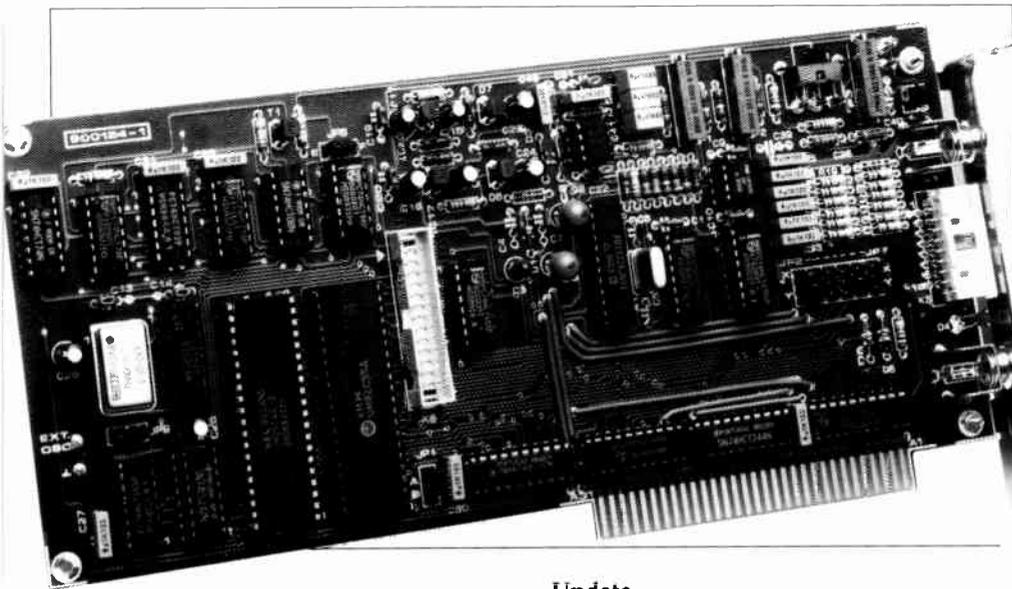


Fig. 3c. Track layout (mirror image) of the solder side of the board.



The calibration is equally important on channel 0, since the passive attenuator used here may give rise to measurement errors. That is why the program calculates the exact attenuation for each attenuator position. The switching between the attenuation factors is performed by multiplexer IC12. Attenuator position '0' corresponds to a measurement range in which voltages up to 0.1 V can be measured. The highest measurement range, 300 V, is selected by position '7'. All positions between '1' and '7' must be calibrated one by one in the 'Learn' routine.

Since the results of the calibration are stored in a file, the software is capable of accurately determining the values of the input voltages every time it is used. If the attenuation changes after a while owing to ageing effects, the correction factors may be updated simply by running the 'Learn' routine. A further advantage of the software-controlled calibration is that the actual attenuator can be kept relatively simple, and based on resistor values from the E96 series.

The 'Learn' option is relatively simple to use. Connect a test voltage of about half the maximum value to the relevant analogue input. Monitor this voltage with an accurate digital voltmeter (DVM). Select the 'Edit' option to open a small window in which the value of the input voltage is entered (see Fig. 6). This input voltage is read from the DVM. Next, the software computes the conversion factor and the maximum input voltage that may be applied to the input in this range before the ADC starts to produce overflows. Overflows must not occur until the input voltage exceeds the maximum level defined for the particular range. If the maximum measurement value is not reached in a particular range, the relevant resistor in the attenuator must be made a little smaller. If this is not done, the maximum level can never be measured, making it impossible for the autoranging function to work properly (remember, the software does not select the next higher range until the maximum level in the currently used range is exceeded).

Update

When all measurement ranges (and channels) have been calibrated, the conversion factors may be written to a file on disk. This is accomplished automatically on selection of the 'Update' function. The conversion fac-

tors are stored in a file called `RATIO.CFG` for use by the program when this is started.

After this calibration procedure, the card is ready for use. It is recommended to store the different `.CFG` files on a separate diskette for use as back-ups when, for some reason or other, the files on the hard disk or the working copy of the floppy disk, are lost or corrupted (which would force you to go through the calibration routine again).

PCV

To start the PC Voltmeter, simply select the option 'PCV' from the main menu. The result is shown in Fig. 7: the measured value is displayed in the form of large numbers on the screen. Below the voltage indication is a bargraph showing a corresponding value. The associated menu allows a number of preferences to be set. For example, the 'Sound' option enables a short beep to be produced when an overflow occurs. The optional filter function uses an algorithm to produce an average measurement value on the basis of a large number of measurements, thus reducing the risk of errors to a minimum.

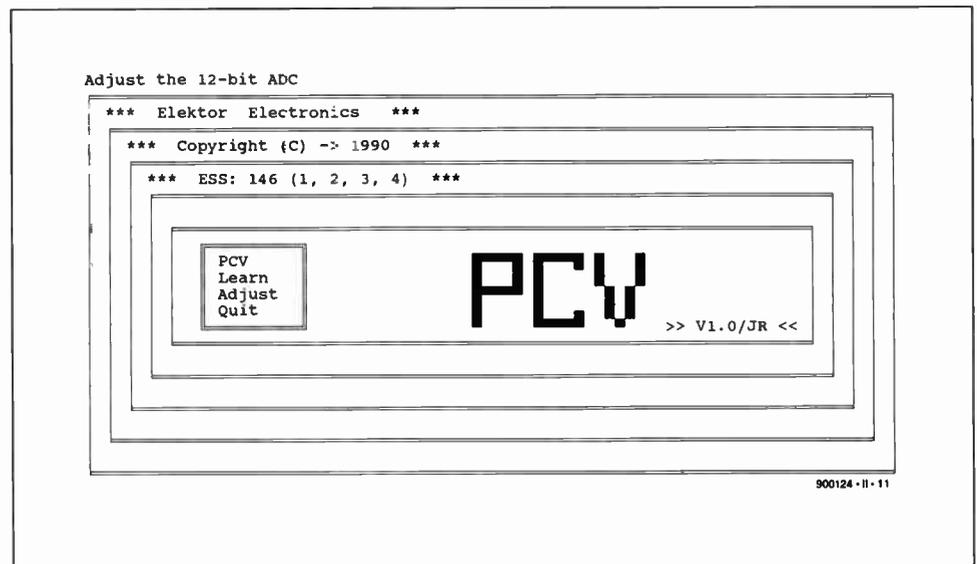


Fig. 4. Screenshot of the PCV main menu.

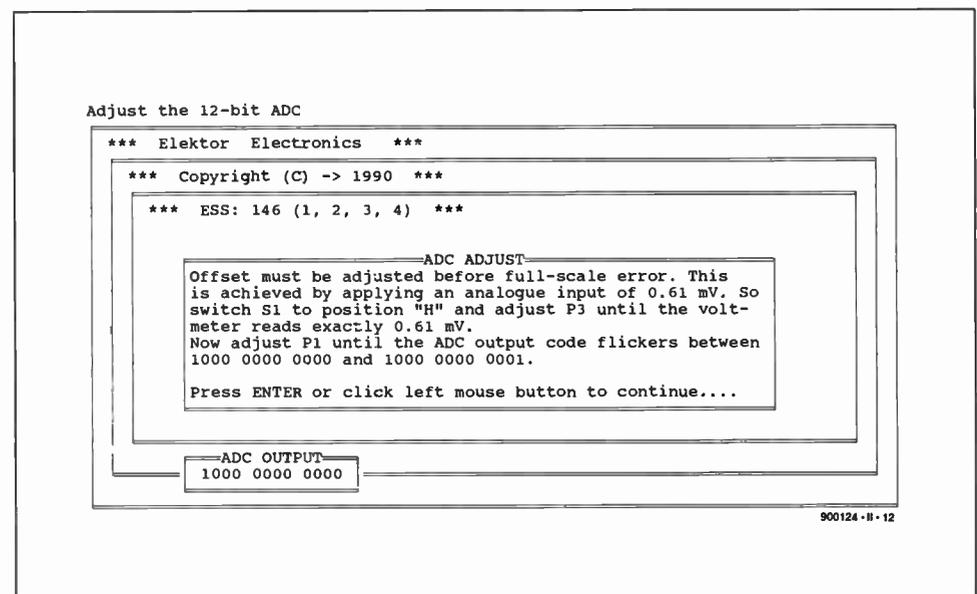


Fig. 5. On selecting the 'Adjust' option from the above menu, you enter a guided calibration procedure for the ADC.

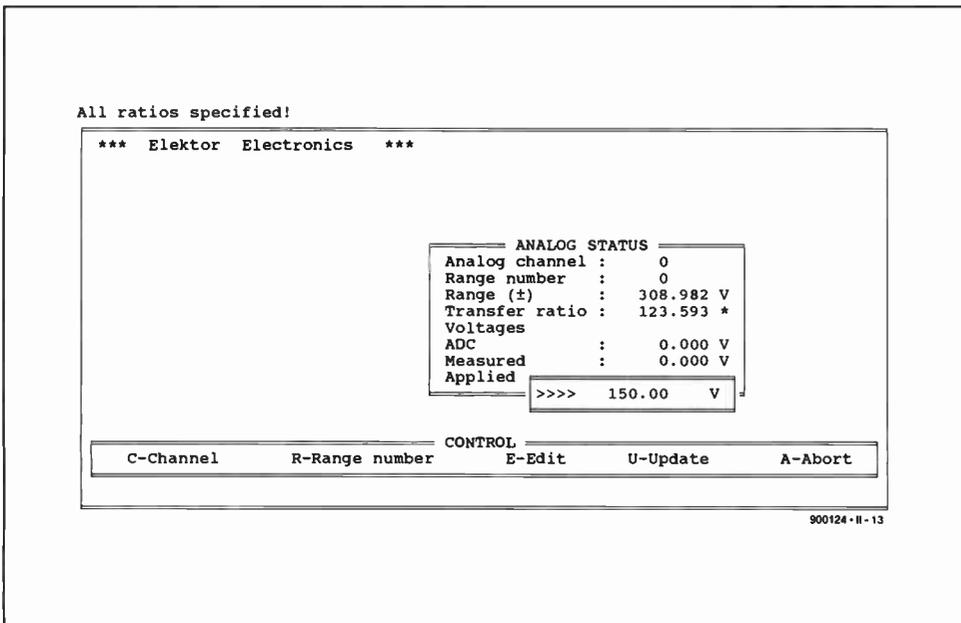


Fig. 6. The 'Learn' sub-menu of PCV is used to calibrate the ladder attenuator on the card.

The 'Channel' function enables you to select the channel of which the measurement results are shown in the large window.

Finally, a maximum input voltage level may be defined individually for each channel. A screen indication is provided when this value is exceeded. This indication takes the form of an exclamation mark (!) in the eight small windows at the bottom of the screen, a short beep, and a special 'Check-Lim' indicator in the large window.

Quit

When the 'Quit' option is selected, the most recent settings are stored in the file PCV.CFG. These settings are called up automatically by PCV when the program is started.

PCF, the PC-controlled Frequency/Pulse Meter

The PCF.EXE program is used for all time-related measurements on digital signals. As al-

ready mentioned in part 1 of this article, the available measurements are very accurate, covering the basic signal parameters frequency, period time, pulse/pause (on/off) ratio, and pulse time.

The program PCF.EXE does it all. Like PCV, it is user-friendly and features menus as well as windows for the measurement results. The menu allows you to select frequency measurement, event count, period time, duty cycle, or pulse time of the input signal. The screen shows the most recent results obtained from a measurement. These results are not updated until the relevant measurement is performed again. To keep you informed about what is being measured, the current type of measurement is underlined.

The event count and pulse time measurement each offer two submenus which allow the trigger edge and the on or off time to be selected respectively. The desired input channel is also selected via a submenu.

During the measurements, the measure-

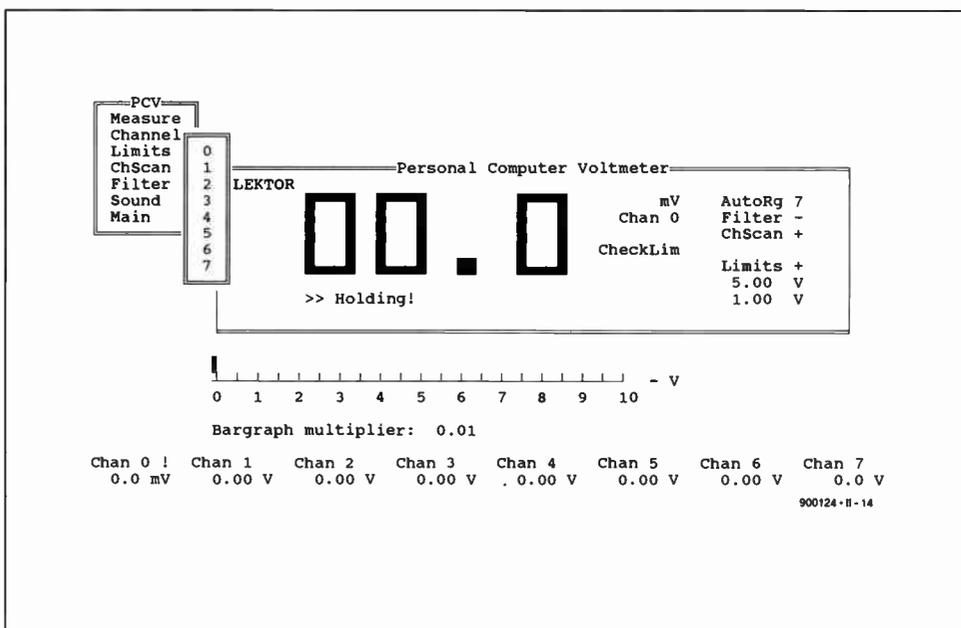


Fig. 7. The PCV in action. The display shows a large voltmeter indication as well as a bargraph read-out.

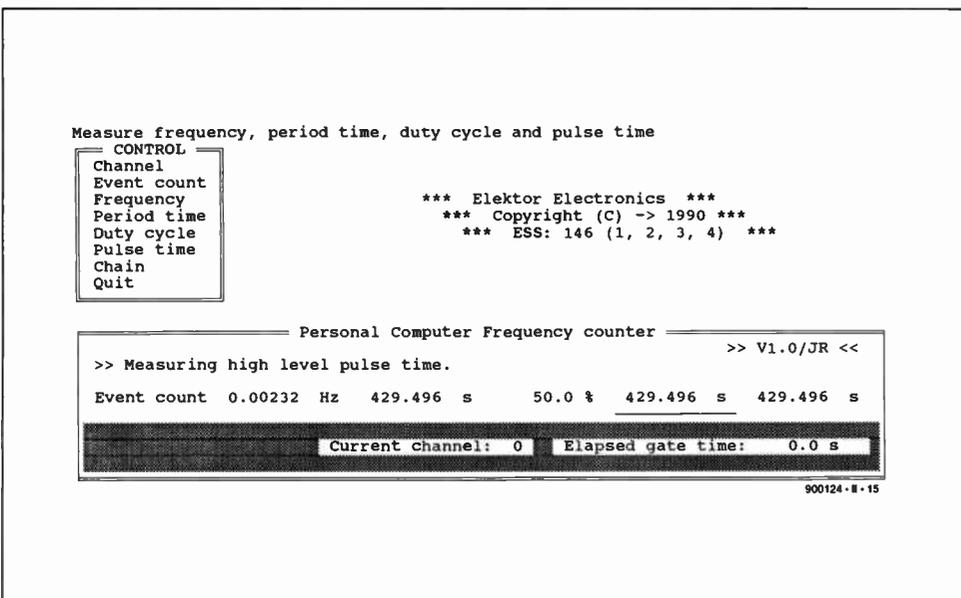


Fig. 8. The PCF function of the software is used for all time-related measurements.

ment window indicates the current channel and the lapsed gate time. The latter indication is particularly useful for measurements involving relatively long gate times. When an option is selected that requires additional information to be entered via a submenu (for instance, the 'Channel' option which takes the channel number in this way) the measurement window shows the indication 'Waiting for instructions!'. The relevant measurement does not start until you have entered the requested additional information.

The last menu option, 'Chain', provides an 'all-in-one' type of measurement, returning values on frequency, duty cycle, period time and pulse time (pulse 'on' as well as pulse 'off'). Since it has little meaning in the case of continuous signals, the event count function is excluded from the 'Chain' measurement, which, without doubt, is a good starting point for most measurements. ■

PHONES IN THE AIR

Telephones for use on board aircraft, employing satellite systems around the globe, must be the ultimate in mobile phone use. What was once considered to be feasible only in the realms of Gerry and Sylvia's puppetry is now common practice thanks to technological advances in the last few years.



Bill Higgins

A number of systems are currently being planned to provide telephone communication from aircraft for use via satellites to anywhere with telephone contact. One such system that is currently being launched is called 'Skyphone'.

What is Skyphone?

Skyphone is a telephone service provided by a consortium formed by British Telecom International, Norwegian Telecom and Singapore Telecom. It can be used in passenger airliners and private jets. Calls can be initiated in either direction, i.e., air to ground transmission or ground to air transmission. Inmarsat satellites are used to afford coverage around the world, from aircraft in flight.

Region	Longitude	Satellite name	Use
AOR	26° W	Marecs B2	Operational
AOR	18.5° W	Intelsat V (MCS)	Dual
AOR	15° W	Marisat F1	Spare
IOR	63° E	Intelsat V (MCS)	Operational
IOR	60° E	Intelsat V (MCS)	Dual
IOR	73° E	Marisat F2	Spare
POR	180° E	Intelsat V (MCS)	Operational
POR	177.5° E	Marecs A	Dual
POR	176.5° E	Marisat F3	Spare

Note: AOR to be widened to the West, when Marecs B2 will move from 26° W to 55.5° W.

Table 1. Positions and usage of satellites employed for airborne telephone services.

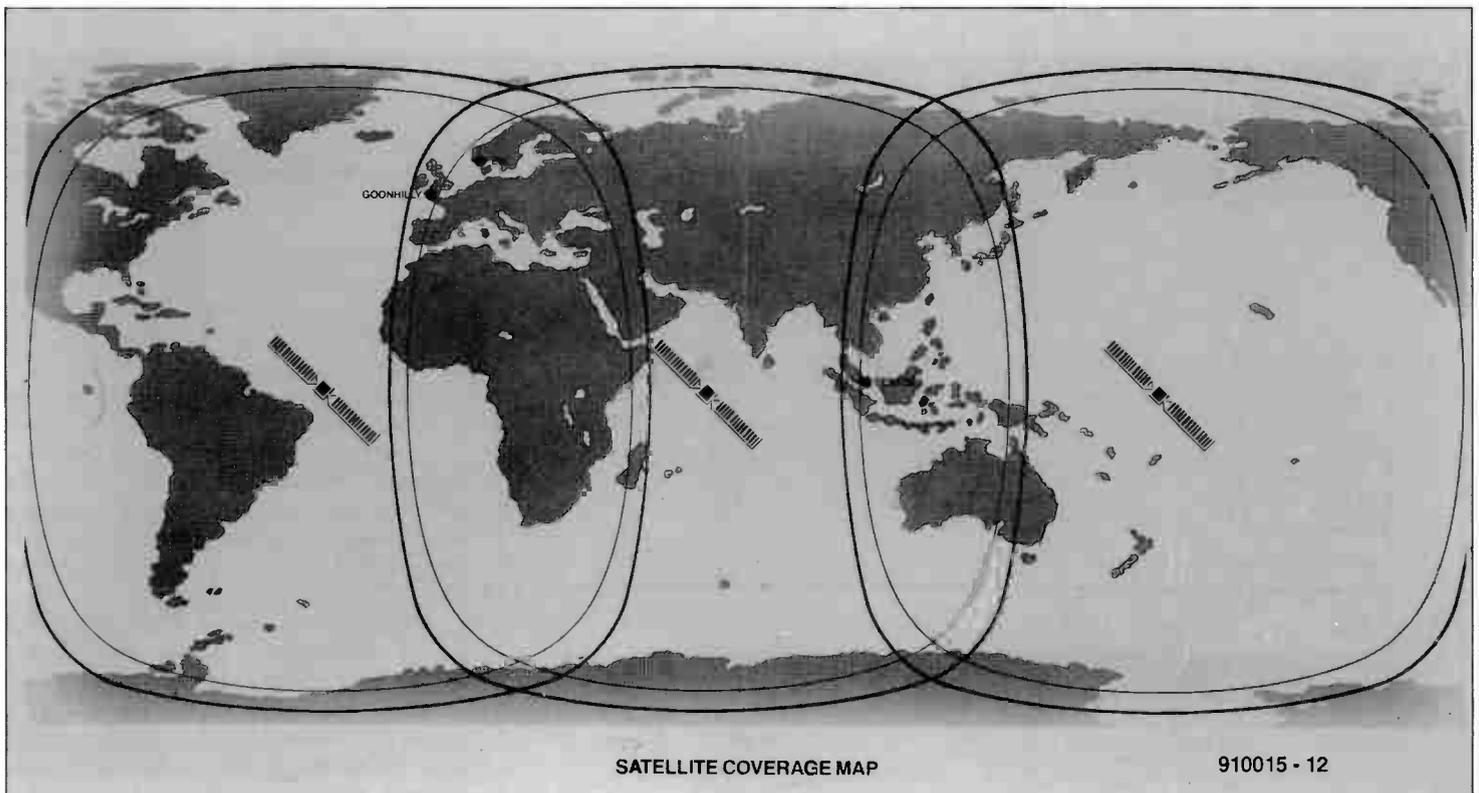


Fig. 1. Map showing Skyphone service coverage based on 0° and 5° angles of aircraft elevation at ground level. (source: British Telecom).

Region	Location	Operator
AOR	Goonhilly	British Telecom
POR	Sentosa	Singapore Telecom
IOR	Eik	Norwegian Telecom

Table 2. The three earth regions, Atlantic, Ocean, Pacific Ocean and Indian Ocean are served by different ground stations.

Technical considerations

Signals from the system on board aircraft are relayed via an Inmarsat satellite in geostationary orbit, to a Ground Station for connection by the appropriate land based telecommunications company.

Satellites

Inmarsat uses geostationary satellites in three geographical regions of the Atlantic, Pacific and Indian Oceans. For each region, a working pair, known as a dual, and one spare satellite are employed. Table 1 lists the nine satellites that are used.

Ground stations

Connection to the ground network is via Ground Stations within each satellite region, as shown in Table 2. The uplink/downlink division and frequency band used in the aeronautical satellite system are given in Table 3.

Within the Atlantic Ocean Region (AOR), calls are routed by British Telecom International via their Ground Station at Goonhilly. British Telecom's Skyphone ground network is shown schematically in Fig. 3. The station at Goonhilly houses equipment that separates telephone signals, including routing and billing signals, from the SHF link via the satellite. Links to London are normally in digital form to tie into the International Digital Switching Equipment (IDSE). Air traffic controls are linked directly to voice and data channel equipment at Goonhilly.

As might be expected, operator and customer services are linked to both Goonhilly and IDSE in London. A voice coding rate of 9.6 KBit/s is used for passenger and operational services.

Similar setups are provided by Norwegian Telecom using their Ground Station at Eik to serve the Indian Ocean Region (IOR), and by Singapore Telecom using Sentosa Ground Station to serve the Pacific Ocean Region (POR).

Equipment on board aircraft

Airborne equipment is manufactured by a number of companies, mainly within the UK and USA. Table 4 lists equipment along with manufacturer and locations.

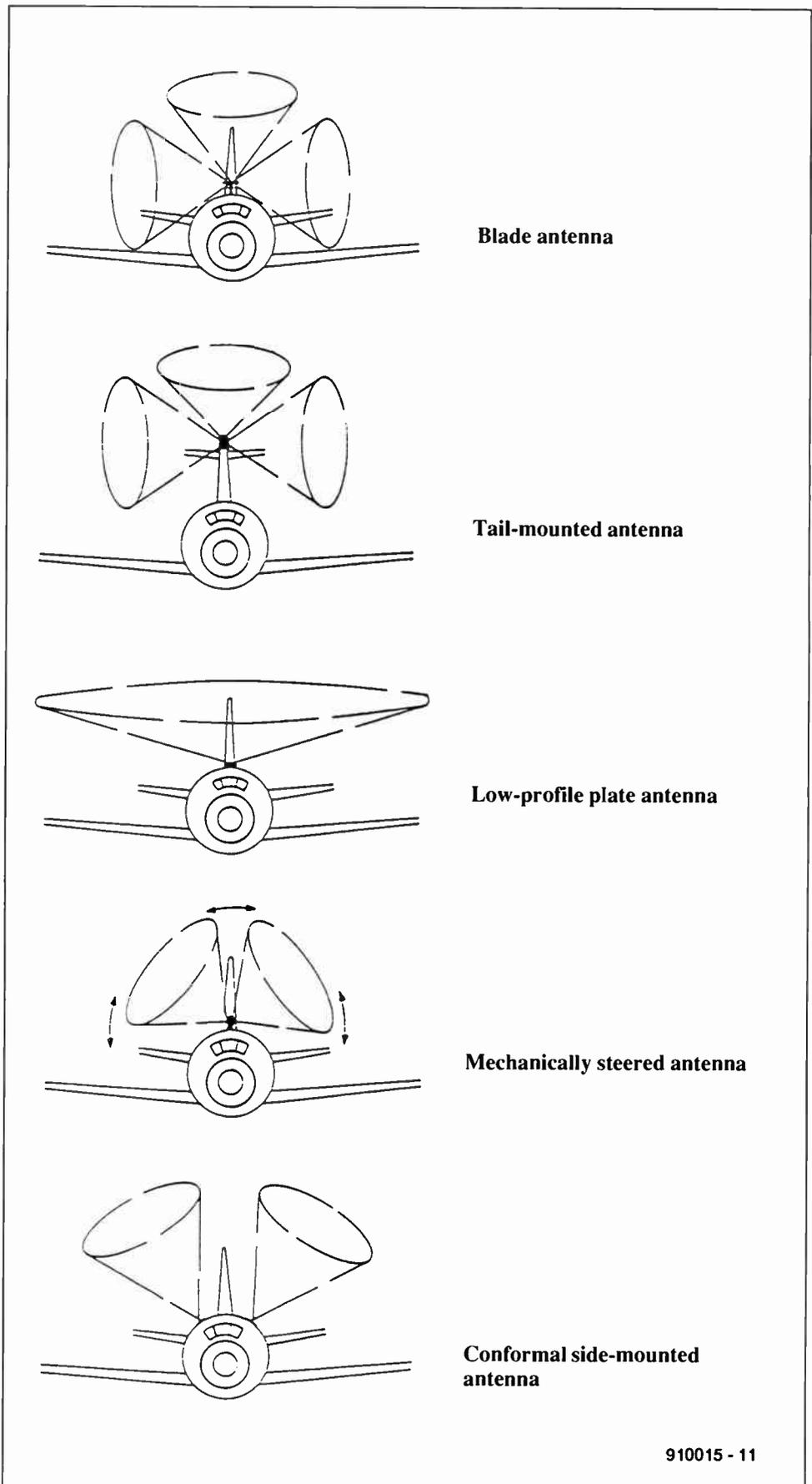


Fig. 2. Some currently available antenna options for aircraft. (source: Racal Avionics).

Antennas

Various designs of antenna are available to be connected to the outside of aircraft. Each design has its own characteristics including scan coverage patterns of five types of antenna (see Fig. 2).

Blade antenna

This type normally has high gain (12 dBi) with narrow beam width. It is used on a number of wide body aircraft such as the Boeing 747.

Tail-mounted antenna

Basically, this is a customized version of the

Use	Up/Down link	Frequency	Radio band
Ground Station	up	6 GHz	C
Ground Station	down	4 GHz	C
Aircraft Earth Station	up	1.6 GHz	L
Aircraft Earth Station	down	1.5 GHz	L

Table 3. Frequency and radio band assignment for the uplinks and downlinks.

Equipment	Manufacturer	Town/Country
Antennas:		
Lo & Hi Gain	Ball Aerospace	Boulder, Colorado, USA
CMA-2100	Canadian Marconi	Kanata, Ontario, Canada
Mech. Steered	E-Systems	Greenville, Texas, USA
Lo-profile radome & side-mounted	Teledyna Ryan	San Diego, California, USA
Avionics:		
E-Sat 300A	E-Systems	Greenville, Texas, USA
Satfone	Honeywell	Phoenix, Arizona, USA
Satfone	Racal	London, England
Satcom 900	Rockwell-Collins	Cedar Rapids, Iowa, USA
Cabin equipment, handsets & PABX		
-	GEC sensors	Basildon, Essex, England
-	Global Wulfsberg	Irvine, California, USA

Table 4. Overview of UK- and USA-based manufacturers engaged in the production of airborne telephone equipment.

blade antenna. It is sited on top of the aircraft vertical stabilizer. The tail-mounted antenna is currently used on Gulfstream-2, -3, and -4 series of aircraft. Plans for its use on the Falcon 900 are under way, and it could be used on Lockheed L-1011 Tristar and other three-engined aircraft.

Low-profile plate antenna

This type is top-mounted and consists of 32 identical elements of about 3½-inch long placed in a rectangular grid of 8 elements long by 4 elements wide, enclosed in an aerodynamically shaped radome.

Mechanically steered antenna

This is a high-gain single-helix antenna that is situated on a pedestal. Coverage is about 360° azimuth and +90° to -30° elevation by means of an avionic signalling control system. Pedestal and antenna are both enclosed in an aerodynamically designed radome.

Conformal side-mounted antenna

This antenna is mounted on two sides of the aircraft fuselage to conform to its contours.

Ring off

Things are happening at a fast pace in the development of services for passengers in aircraft. This article, although only an introduction to the operation of a complex system, may well be of use to readers, either as possible users of telephone equipment on board aircraft, or as people that may be involved in future designs and manufacture of systems and components.

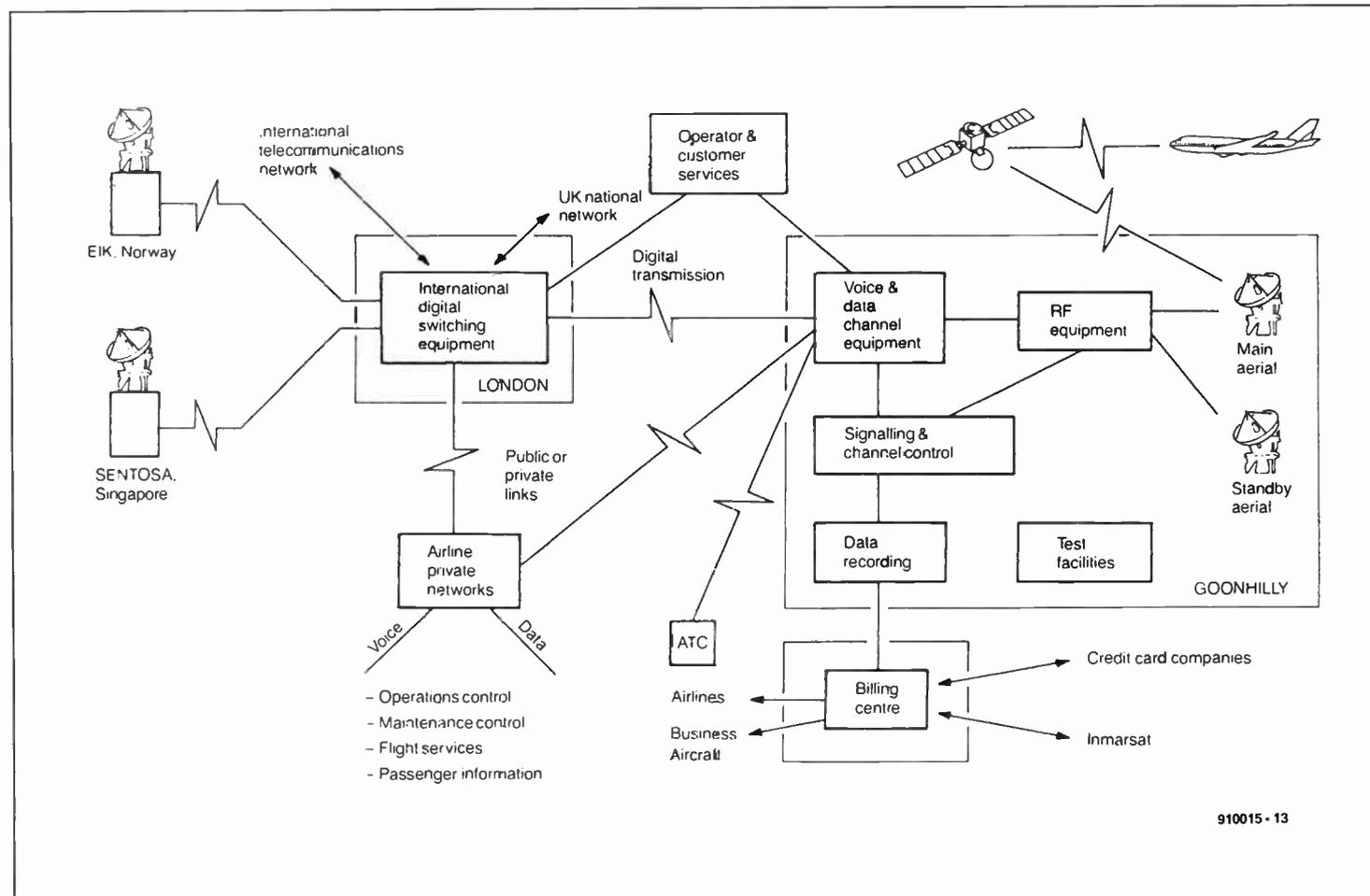


Fig. 3. Structure of the Skyphone ground network. (source: British Telecom).

MEASUREMENT TECHNIQUES (4)

by F.P. Zantis

This month's instalment deals with a very important measurement: that of resistance. This measurement is important not only in faultfinding, but also in design and development. It is, unfortunately, not possible to deal with the gamut of methods available: only the most common ones will be discussed

VIRTUALLY all multimeters have several ranges for measuring ohmic (also called true or d.c.) resistance. The battery provided in analogue types is there for one purpose only: the measurement of resistance. The two most common methods of measurement use either a constant-voltage source or a constant-current source.

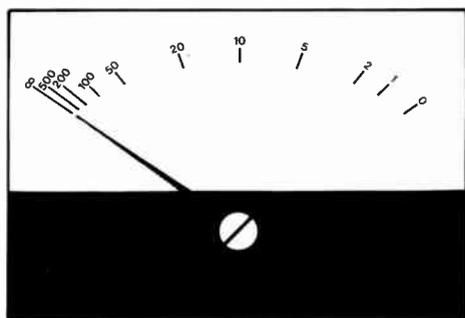


Fig. 24. An analogue meter becomes difficult to read at the left-hand side of the scale.

In the first, a constant voltage, U_c , is applied across the component under test: the resulting current, I_r , is used as the basis of the resistance measurement: $I_r = U_c/R_x$, where R_x is the resistance of the component under test. Since I_r is inversely proportional to R_x , a separate scale is required, which is calibrated in ohms (or multiples thereof) and runs

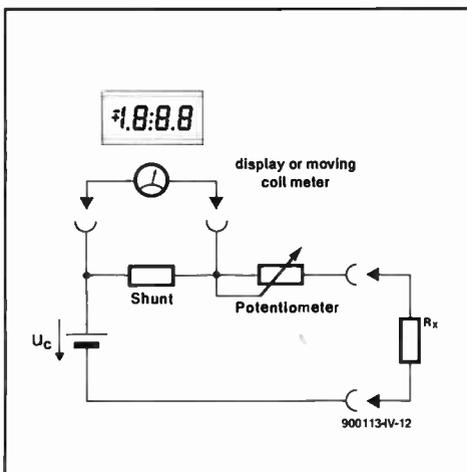


Fig. 25. Basic circuit for constant-voltage measurements.

from right to left, that is, "0" is at the right-hand side of the scale—see Fig. 24. It should be noted that accurate measurements are only possible over the right-hand half or three-quarter of the scale.

The basic circuit for this method of measurement is shown in Fig. 25. The "0" value (meter terminals short-circuited) is set with

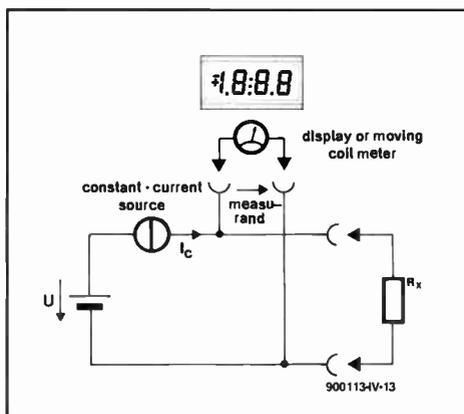


Fig. 26. Basic circuit for constant-current measurements.

the aid of the potentiometer. This obviates any circuit properties affecting subsequent measurements.

The fundamental circuit for constant-current measurements is shown in Fig. 26. In this method, a constant current, I_c , is passed through the component under test and the consequent voltage, U_r , across it is the basis of

the resistance measurement: $U_r = I_c R_x$. Note that in this method U_r is directly proportional to the resistance. A separate scale is, therefore, not required. Moreover, the scale division is more linear, so that the values of resistance may be read fairly accurately over the entire scale.

Small or large resistance values cannot be measured accurately with either of these methods. A Wheatstone bridge or a comparison method must be used for these.

Component testing with an ohmmeter

Most ohmmeters may be used for testing semiconductors, provided that the potential at the test terminals is sufficiently high. A diode has a very large resistance when the test leads are connected across it in one way and a much smaller one, depending on the type of diode, when the test leads are reversed. In the first case, the diode is reverse-biased and in the other, forward-biased. The forward-bias resistance of point-contact diodes is considerably higher than that of junction diodes. Measurements of this nature indicate only whether the diode is functional or defect: other than that, they do not show how the diode will behave in a circuit.

Testing of transistors must be done in six stages—see Fig. 27. The resistance between emitter and collector is high in both directions. That between base and collector or emit-

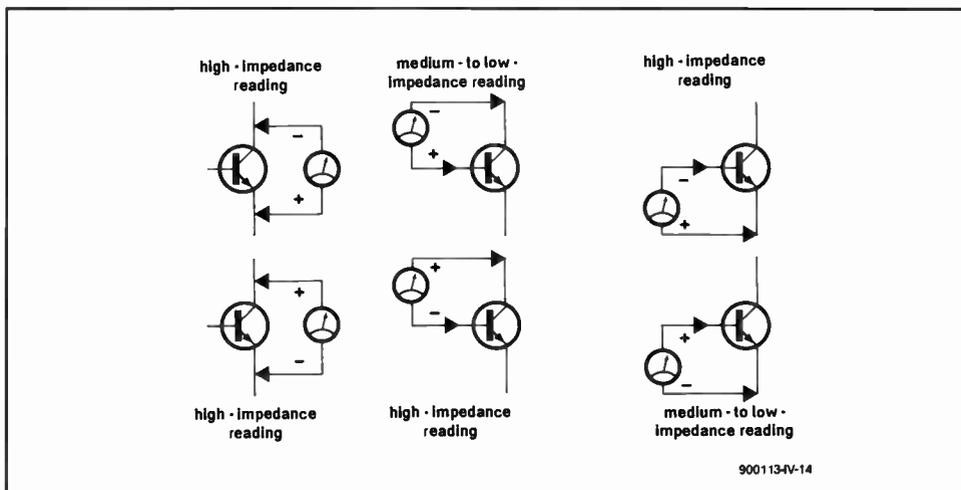


Fig. 27. Testing a transistor with an ohmmeter requires six measurements.

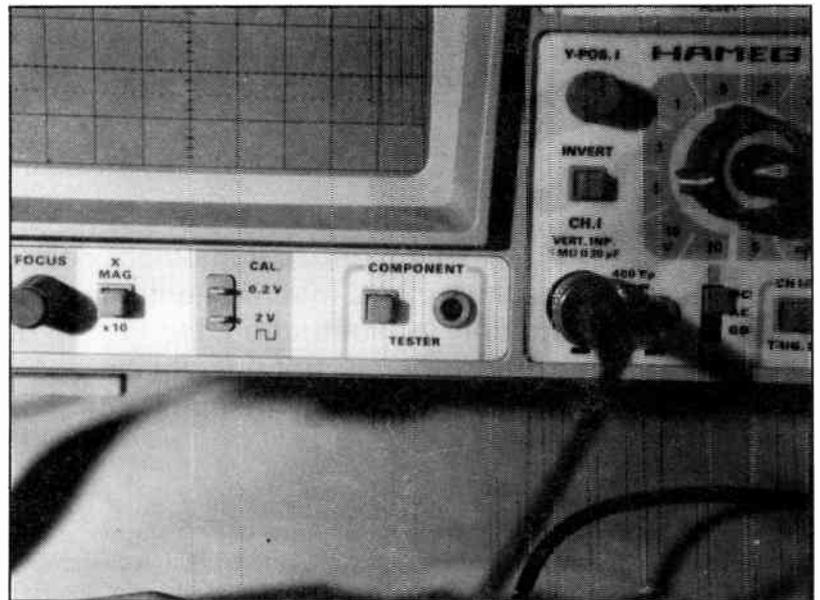
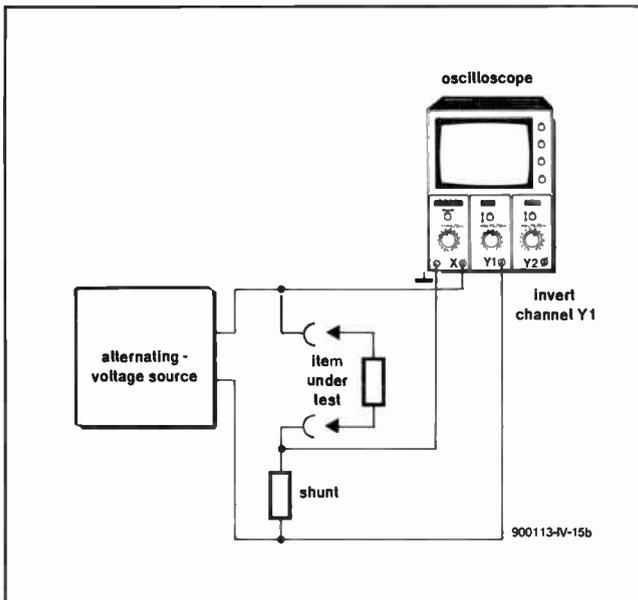


Fig. 28. Component tester: (left) test set-up and (right) incorporated in an oscilloscope.

ter is small in one direction and large in the other. The measured values depend on the applied voltage and current, as well as on the ambient temperature. It is thus not possible to measure absolute values, but short-circuits and open-circuits are, of course, indicated. When transistors are tested in-circuit in this manner, the effect of surrounding components must, of course, be taken into account. For more accurate measurements, the transistor should be removed from the circuit.

Component tester

On the basis of the foregoing, special component testers for use with, or incorporation in, oscilloscopes have been developed as shown in Fig. 28. The basic circuit of the tester is fairly simple: a low alternating voltage, drawn for instance from a mains transformer, is used as the supply for the series network of component under test and shunt resistor. The alternating voltage is used as the horizontal time-base, while the potential drop across the shunt resistor is used for the vertical deflection of the electron beam. When the component tester is in use, the internal time-base of the oscilloscope is, of course, switched off.

The voltage drop across the shunt resistor determines the current through the component under test. The screen of the oscilloscope shows the IU characteristic (U in horizontal direction), and thus the resistance curve of the component under test. No reference is provided, so that the trace only shows the relative resistance of the component under test.

Since the component tester is so simple, it is possible to use it with, or build it into, any oscilloscope whose time-base can be switched off and which has an additional X-input available.

Note that since the earth potential must be at the centre between component under test and shunt resistor, the current trace is inverted. In a number of oscilloscopes, the Y-channel can, however, be inverted, so that

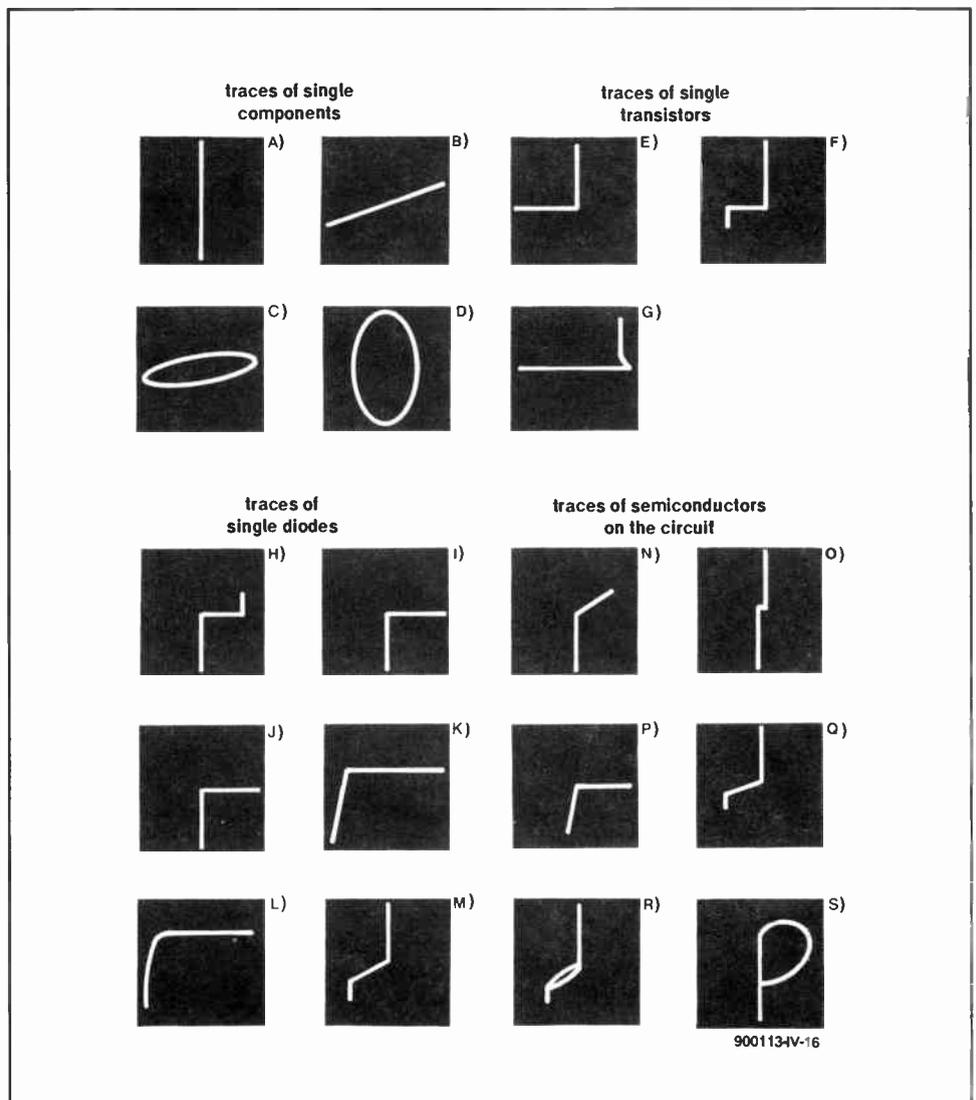


Fig. 29. Traces obtained from measurements with a component tester: A) test terminals short-circuited; B) true resistance; C) inductor; D) capacitor; E) base-collector junction of a transistor; F) base-emitter junction of a transistor; G) emitter-collector junction of a transistor; H) zener diode whose zener voltage is lower than the maximum test voltage; I) zener diode whose zener voltage is higher than the maximum test voltage; J) silicon diode; K) germanium diode; L) rectifier; M) thyristor whose gate is connected to its anode; N) parallel network of diode and resistor; O) two diodes connected in anti-parallel; P) series network of diode and resistor; Q) resistor in parallel with the base-emitter junction of a transistor; R) parallel network of resistor, capacitor and base-emitter junction of a transistor; S) diode and capacitor connected in parallel.

a correct trace is obtained.

There must be no voltage across the circuit or component under test, otherwise the measurement becomes meaningless.

Correctly interpreting the trace requires some practice, particularly when the measurement is carried out on a circuit.

If the component under test is a true resistance, there is no phase shift between the two deflection voltages and the trace is a straight line. The tilt of the line is a measure of the resistance: when this is 0, the trace is upright, when it is ∞ , the trace is horizontal.

Measurement of impedance

The component tester may also be used to determine impedance values. Capacitors and inductors cause a phase shift between the voltage across, and the current through, them, and thus between the deflection voltages. This gives rise to elliptical traces, the height and width of which are typical of the impedance of the component under test—see Fig. 29. Exact measurements are possible only if the relation between the horizontal and vertical deflection voltages is known. The vertical deflection is calibrated on all oscilloscopes. When the set value is divided by the value of the shunt resistance, the deflection on the screen is in A/div or mA/div. The X-deflection is often not calibrated, but the voltage at the relevant input may be measured fairly easily by switching off the time base and setting the trace exactly in the centre of the screen. Then deflect the trace to the nearest graticule division by applying a voltage to the X-input. The level of that voltage gives the value V/div. Once this has been determined, the values of voltage and current can be read directly from the traced characteristic.

Impedances may, of course, also be measured without the use of an oscilloscope and component tester. A sine-wave generator and an instrument that can process frequencies are then required. The component under test is connected to the generator, after which the voltage across it, and the current through it, may be measured. The impedance, Z , is determined from the relation $Z = U / I$. The true resistance must be deducted from the obtained value to arrive at the value of the reactance, X . In view of the phase shifts, however, this must be done geometrically, that is, $X^2 = Z^2 - R^2$. The values of reactance and impedance are valid only at the

frequency of the test signal.

The reactance, X_L , of an inductor is

$$X_L = \omega L = 2\pi fL,$$

whence,

$$L = X_L / 2\pi f.$$

The reactance and value of a capacitor are calculated in a similar manner

$$X_C = 1 / \omega C,$$

and

$$C = 1 / \omega X_C = 1 / 2\pi f X_C.$$

Measuring the supply voltage

One of the most frequent measurements is checking the supply voltage of an equipment. Moreover, preliminary tests in design and development aim at deciding whether a given voltage- or current-source is suitable for the project in hand. Most supplies can be checked with three or four measurements of: e.m.f.; short-circuit current; internal resistance, R_i ; and, in the case of a d.c. source, the hum voltage, U_h . Most voltage sources provide a direct voltage or an alternating voltage with a frequency of 50 Hz. Both of these may be measured with a multimeter without any problem.

To measure the e.m.f., it is imperative that the source is not loaded: if the output impedance of the source is not particularly high, the input resistance of the multimeter may be ignored.

Measuring the short-circuit current is in many cases not recommended. It is better to determine the internal resistance, which in most cases will enable the short-circuit current to be calculated.

Measuring the internal resistance of a home-made regulated supply can be very revealing: for one thing, it shows how good the supply really is. A pretty good and simple way of determining R_i is possible with the circuit shown in Fig. 30. The source is loaded with a variable resistor that is set to a position where exactly half the e.m.f. is dropped across it. The drop across R_i must then be the same, which means that the internal resistance must have the same value as that presented by the variable resistance. Note that this

method is not suitable when the value of R_i is relatively high, because the current may then become relatively large. The method is, however suitable for determining the input and output resistance of an electronic circuit.

The simplest way of determining the internal resistance of a voltage source is as follows and requires knowing two operating points. The first of these may be the e.m.f., U_0 . The second may be determined by loading the source with a resistance, R_1 , whose value must cause the output voltage to be appreciably lower than the e.m.f. The internal resistance is then calculated from:

$$R_i = (U_0 - U_1) / (U_1 / R_1) = R_1(U_0 - U_1) / U_1.$$

If, for example, the e.m.f. of an a.c. source is 25.2 V and the output voltage drops to 23.5 V when a load of 5.6 Ω is connected across the output, the value of the internal resistance is:

$$R_i = 5.6 (25.2 - 23.5) / 23.5 = 0.41 \Omega.$$

Note that the output current is then 4.2 A: this value must be lower than the maximum output current before current limiting sets in. As soon as current limiting takes place, the internal resistance rises rapidly, which invalidates the measurement.

Compensating method of measurement

The smaller the internal resistance of a voltage source, the better regulated the output voltage. Electronically stabilized power supply units have a very small internal resistance, provided the maximum output current is not exceeded. Such small resistances cannot be measured by the methods described so far, at least not with any degree of accuracy. They can be measured accurately by the so-called compensating method, which requires some care in calibration, however.

The test set-up is shown in Fig. 31. The unit under test is loaded by a variable resistance, R_1 , and the resulting current, I_1 , is measured. The voltmeter indicates the difference, U_d , between the potential across R_1 and the compensating voltage, U_{ref} , which is set by R_2 . This resistance is varied until $U_d = 0$. At the same time, lower and lower ranges of the voltmeter are selected to make the calibration as accurate as possible. Then, R_1 is

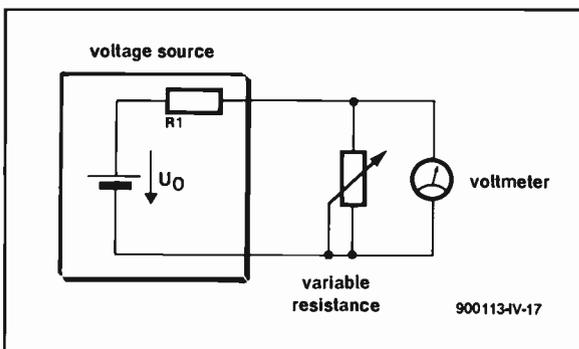


Fig. 30. A pretty good and simple way of measuring the internal resistance of a voltage source.

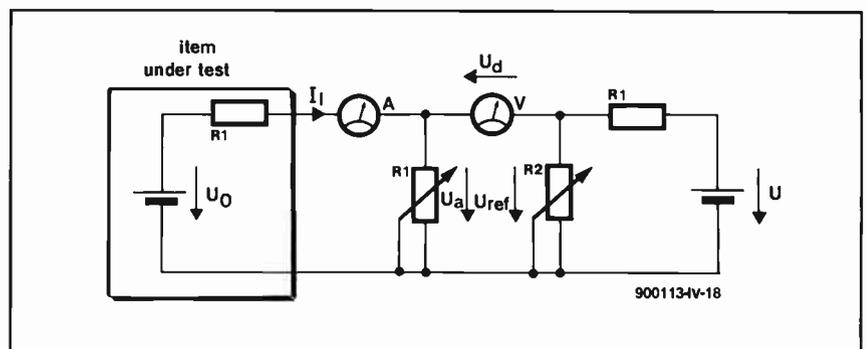


Fig. 31. Compensating method of measuring small internal resistances.

carefully varied in small steps. This will cause a change in I_1 as well as in U_o as indicated by the two meters. The internal resistance is calculated by dividing the change in output voltage by the change in current.

Measuring hum voltage

All d.c. supplies derived from an alternating voltage retain a certain amount of a.c., how-

ever small, superimposed on the direct voltage output. This a.c. component manifests itself as hum. The lower the hum level, the better the power supply, at least in this respect. The a.c. component can be measured by removing the d.c. with the aid of a capacitor. On oscilloscopes this is done by setting the input selector (AC/GND/DC) to AC. The a.c. component may then be displayed on the screen with very good resolu-

tion. Since the hum voltage is seldom sinusoidal, it is normally specified as peak-to-peak, and this is clearly seen on the screen.

Multimeters set to a.c. ranges also isolate the d.c. voltage from the input signal, so that only the a.c. component is measured. Since this component is normally not sinusoidal, the indicated value is only reliable if a true-r.m.s. multimeter is used.

(to be continued)

DECADIC VOLTAGE DIVIDERS

by Ing. G. Peltz

Designing decadic voltage dividers is not as simple as it may seem. One decade is not too difficult, but when a number of decade steps are to be selected by a rotary switch the design becomes rather more tricky. Or does it? In this article, an old divider circuit is rehashed that otherwise may easily be overlooked in these days of microprocessor-controlled digital potentiometers.

FIGURE 1 shows the basic circuit of a 3-decade voltage divider. Switches S_1 and S_2 are 2-pole, 10-position types, while S_3 is a single-pole, 11 position type. Both S_1 and S_2 select two resistors at a time from a divider chain. The value of the parallel combination of these two resistors and the following chain is equal to that of a single resistor. This requirement is fulfilled when, for example, chain 1 contains resistors of value R , chain 2 contains resistors of value $R/5$, and chain 3 contains resistors of value $R/25$. Note that S_1 and S_2 are always displaced two positions with respect to each other.

Since the value of the parallel combination of the two resistors between the poles of S_1 and the following chain is equal to that of a single resistor in the first chain, the voltage drop across each resistor is the same as the potential between the two poles of S_1 , that is, the input voltage, U_r , divided by 10. Similarly, the potential across each of the resistors in the second chain is $U_r/100$, and that across each of the resistors in the third chain is $U_r/1000$. This means that the output voltage (with respect to earth) may be selected in steps of a thousandth of U_r , depending, of course, on the tolerance of the resistors, which in this case must be 0.1%.

Figure 2 shows a practical application of the foregoing: two resistor chains and a potentiometer provide an accurate, variable voltage source. Potentiometer P_3 may be replaced by a third chain of 47 Ω resistors.

A temperature-compensated zener diode provides a very stable reference voltage, U_r , of 6.8 V from the supply voltage, U_b .

The values of the two resistor chains may

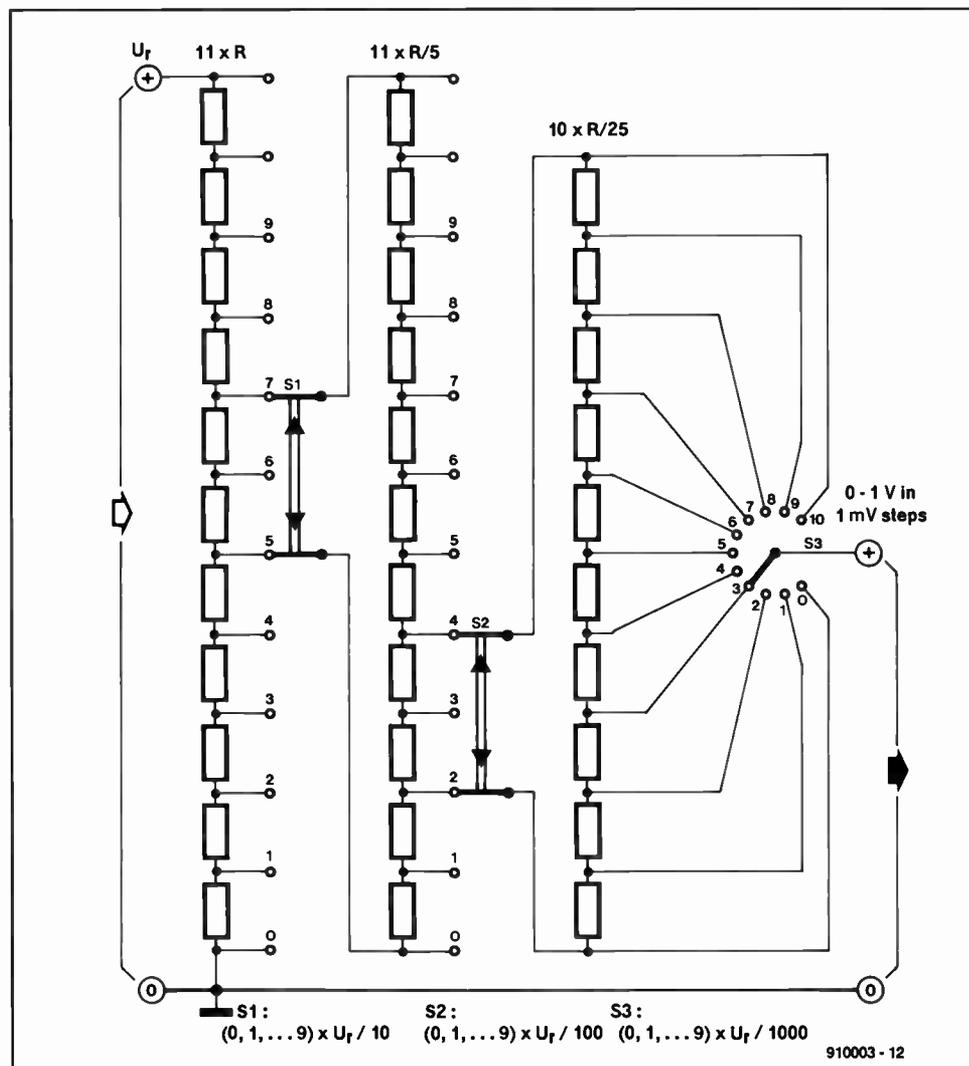


Fig. 1. Basic design of a decadic voltage divider.

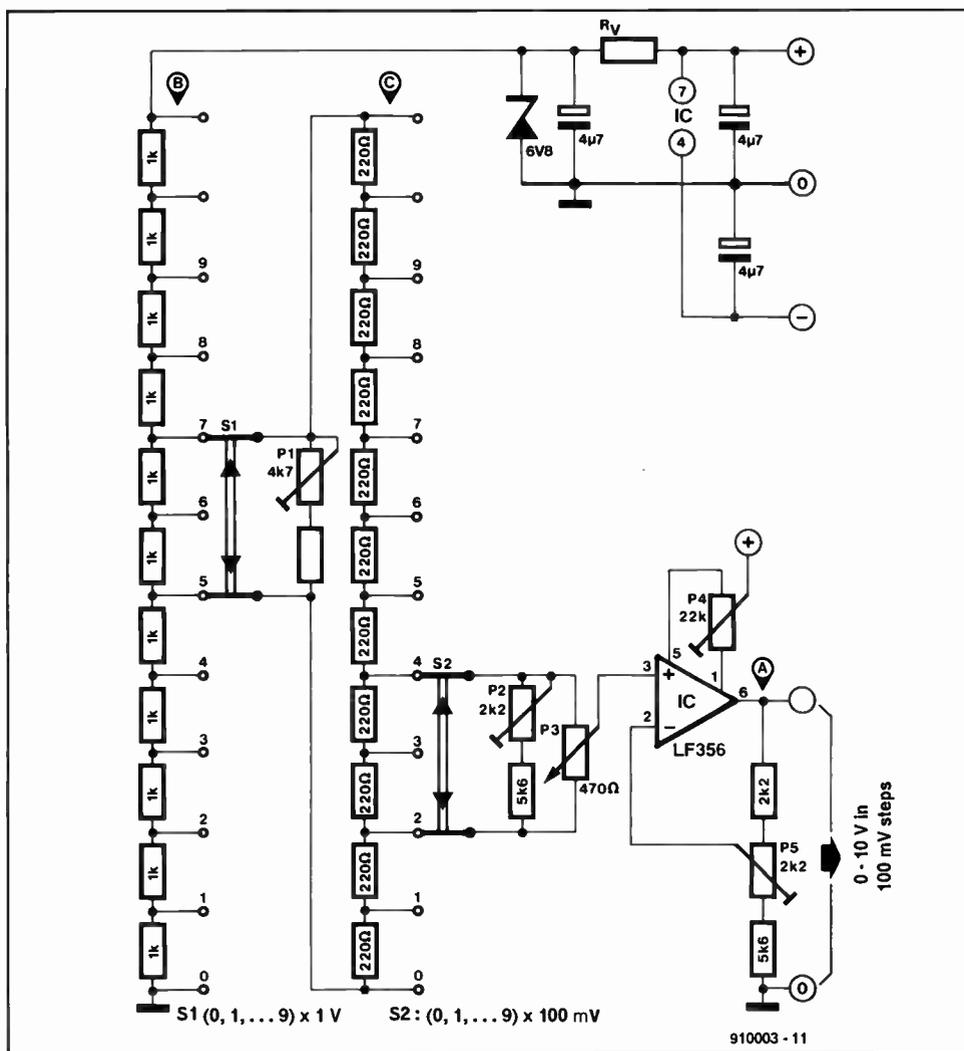


Fig. 2. Voltage source providing 0–10 V in 100 mV steps.

be adjusted by presets P_1 and P_2 respectively to give the second chain a total resistance of exactly 2 k Ω and “the third”, that is, P_3 , a value of 4 k Ω . If 2% resistors (of the same

batch) are used in the dividers, an overall accuracy of 0.5% is obtained. This accuracy will, of course, be even better if 1% or 0.5% resistors (from the same batch) are used.

The potential at the wiper of P_3 covers a range of only 0–6.8 V and must not be loaded too heavily to avoid unacceptable errors. For that reason, the potential is applied to an opamp with FET inputs, which gives an output voltage range of 0–10 V preset by P_5 .

The opamp is powered by an asymmetric voltage source: $+U_b = 12\text{--}18\text{ V}$; $-U_b = 5\text{--}10\text{ V}$

Series resistor R_v in the positive supply rail has a value between 1 k Ω and 2.2 k Ω , depending on the level of the supply voltage; it carries a current of about 5 mA.

Except for R_v , all resistors should be metal film types with a temperature coefficient, T_k , not greater than ± 50 p.p.m. and a tolerance of $\pm 1\%$ or better. Presets P_1 , P_2 , P_4 and P_5 are multturn cermet types, while P_3 is a good-quality wirewound type or a 47 Ω resistor chain as in Fig. 1. The switches should also be high-quality types.

Calibration

For calibration, a digital multimeter with a 4 $\frac{1}{2}$ digit display is required. Set all presets to the centre of their travel, and P_3 and the switches to their lowest position.

Turn P_4 until the output voltage is 0 V with respect to earth.

Check that the level at B is exactly the same as the zener voltage.

Turn P_1 until the potential at C is exactly one tenth of the voltage at B.

Set S_1 to position 1, i.e., between terminals 1 and 3, and turn P_5 until a voltage of exactly 1.000 V is obtained at the output.

Adjust P_3 for maximum output and then turn P_2 to give an output of 1.100 V.

Reset S_1 to position 0: the output should then be exactly 100 mV.

Since the controls affect one another slightly, the calibration needs to be repeated a couple of times. ■



NEW DIGITAL/ANALOGUE MULTIMETER FROM ITT

THE new Type MX570 from ITT Instruments is a combined analogue/digital multimeter that offers auto-ranging on both the traditional analogue pointer and the digital LCD read-out.

The instrument is aimed at traditional multimeter users who appreciate the accuracy and unambiguity of a digital read-out, but who find that alternative analogue solutions on simple bar-graph displays lack the same response and ‘feel’ of a true analogue pointer.

Both the analogue and digital displays of the MX570 share the same auto/manual ranging and auto-polarity electronics, and yet the pointer response is not restricted by the sampling rate of the analogue-to-digital converter.

ITT products are manufactured at a number of locations world-wide and are available in most countries.

NEW WAVEFORM GENERATOR FROM GOULD ELECTRONICS

GOULD has introduced the DWG-7000 digital waveform generator that covers the frequency range 10 μHz –10 MHz, and can produce both standard and arbitrary waveforms with a resolution of 100 ns per point. Internal memory is sufficient to store 8192 digital points. The vertical resolution is 12 bits.

Built-in standard functions include sine, square, triangle, d.c., positive ramp, negative ramp, positive pulse and negative pulse. All can be selected from the front panel or from a remote controller via IEEE-488 or RS 232 interfaces. A full complement of sweep functions is also available.

The DWG-7000 is suitable for all general purpose electronics applications.

Gould Electronics manufactures a wide range of electronic instruments, which are available in most countries of the world. ■

LOGIC ANALYSER PART 2

by K. Nischalke and H.J. Schulz

The busboard

The busboard does not look it, but it is the heart of the analyser—see Fig. 3. It can accept up to five other cards, each via a discrete connector. A sixth connector provides a link to the computer interface. The majority of the signals handled is common to all the boards, as is usual in the case of busboards. Only the five board-select signals, the 5-volt supply and the earth connections are individually provided for each card as is shown in Fig. 4 (Part 1).

The clock

The fact that the analyser is provided with a clock frequency of 100 MHz indicates that it is not intended for measuring direct voltages or currents. It does not mean, however, that a 100 MHz signal can be applied to the input without further consideration. What in an analyser is called clock frequency is in other applications often a sampling frequency (as, for instance, in CD systems). According to Shannon's Theorem, the sampled signal may be reconstructed correctly only if the highest frequency of the input signal is not greater than half the sampling frequency. That is not all, however, because rectangular waveforms are used in the analyser that contain, apart from the fundamental frequency, a whole series of harmonics. For reliable sampling a digital input signal, a maximum fundamental frequency of, say, 30 MHz must be assumed. The most important, and also the strongest, harmonic is the third and that is then nearly equal to the clock frequency. In real terms, that means that the frequency range of the signals that are required to be transported over the metering leads extends to at least 100 MHz. That cannot be done reliably and without distorting the signals over even small distances, however, by means of some twisted cable terminated into croc clips. The analyser therefore uses an active probe, which is discussed below.

The probe

From a purely electronics point of view, the probe (see Fig. 6) is very simple: a few resistors, two connectors and some buffers. Nevertheless, it forms an important link in the transport of the input signals to the analyser. It is, as it were, a "forward" input. The item under test may be connected to it with short leads, so that it only "sees" these leads and the probe input. This is fortuitous as the following example shows. Assume that a test lead has a capacitance of 10 pF (with many test leads, this is much higher). If the signal across the lead has a frequency of 30 MHz, the

lead represents a load of 530 Ω on the signal source. The very short leads used here ensure very low capacitance. The load presented by the long cable following the buffers in the probe is not reflected on to the signal source.

The buffers in the probe are of the familiar 245 type in the 74 series, but in ACT technology, that is, fast. The more usual types are not fast enough. Moreover, the ACT types have a high-impedance input, so that they present only a small load.

The outputs of the buffers provide a signal that is strong enough to bridge a 1 m cable. If a longer cable is required, more buffers must be added. The connectors of the probe are therefore designed to enable the probe and cable to serve as an extension lead. They carry, apart from the data lines, the 5-V supply and also a ± 12 -V supply to enable a probe to be constructed that can handle higher input voltages.

Populating the printed-circuit board—see

Fig. 7—is straightforward, but care must be taken to ensure that pin 1 of K₄ is located correctly. Before the board can be mounted in the case, the cover must be prepared. One of the long sides must be given a recess through which K₅ can be passed. The other long side must be given a slot through which the flat-cable can be passed. Note that this must be done before the second connector is fitted on to the cable. The photograph in Fig. 8 shows how these modifications should be carried out.

The board is fitted on to the inside bottom of the enclosure with two screws. The flat-cable can now be fitted to the connector, after which the top of the case can be put into place.

The connection between probe and item under test is made by a short length of flat-cable and a number of single-core leads terminated into a test clip. The flat-cable is terminated at both ends by a female connector fitted with a strain relief clamp. One of the

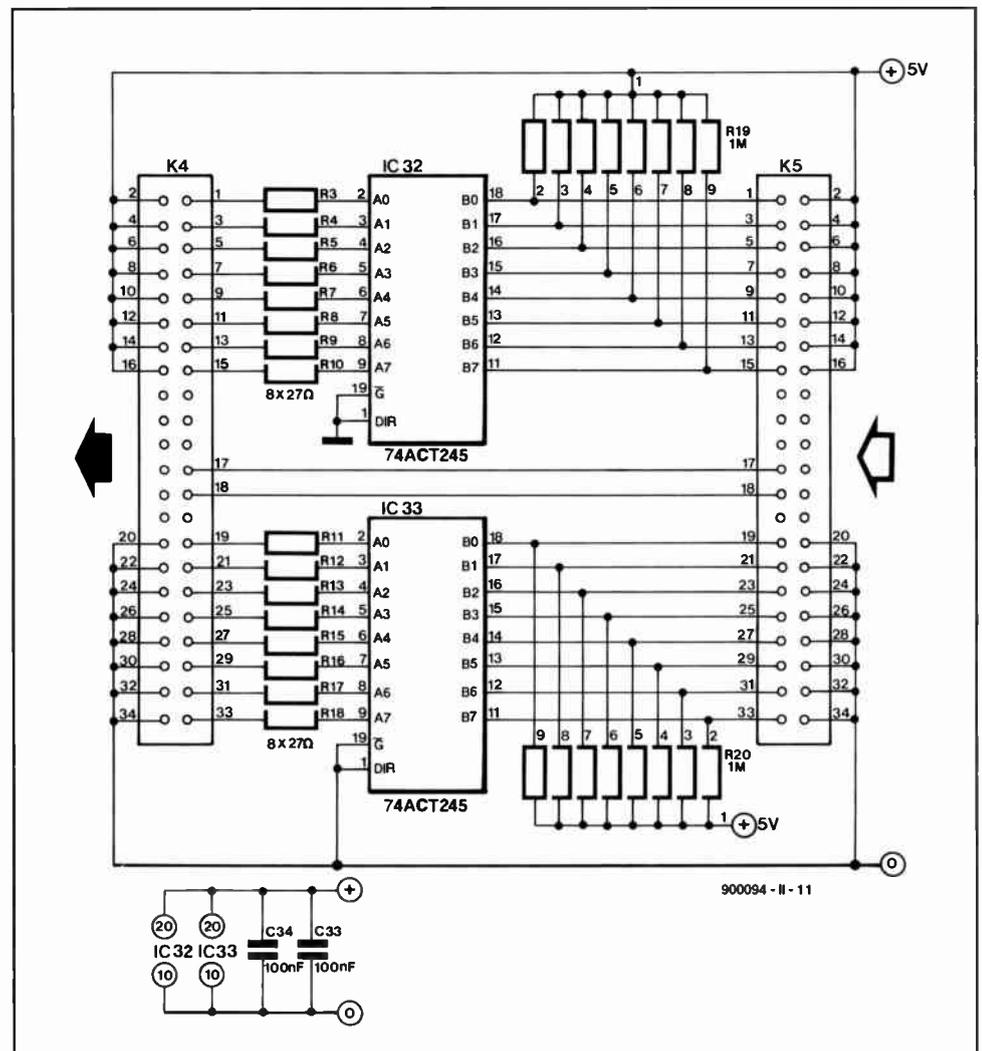


Fig. 6. Circuit diagram of the probe.

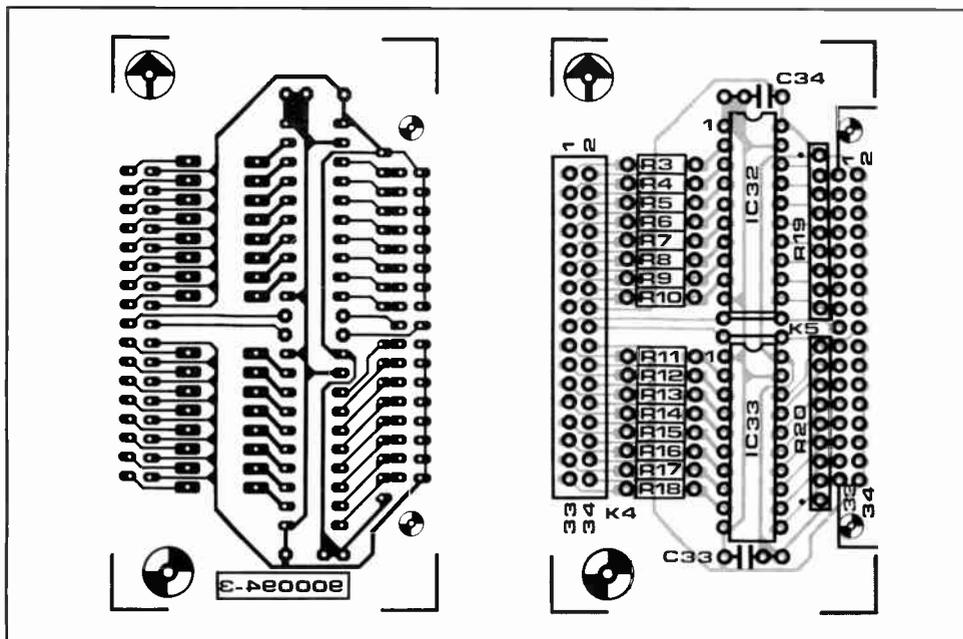


Fig. 7. Printed-circuit board for the probe.

PARTS LIST

Resistors:

R₃–R₁₈ = 27Ω
R₁₉–R₂₀ = array, 1MΩ

Capacitors:

C₃₃, C₃₄ = 100 nF

Semiconductors:

IC₃₂, IC₃₃ = 74ACT245

Miscellaneous:

K₄ = 34-way male box header
K₅ = 34-way right-angle print header with ejector
Four 34-way IDC sockets (three with strain relief clips)
1 metre 34-strand flatcable
16 red miniature test clips
1 black miniature test clip
Enclosure, 50×25 mm e.g.
OKW A9010087; Bopla 410;
Multibox 110
PCB Type 900094-3

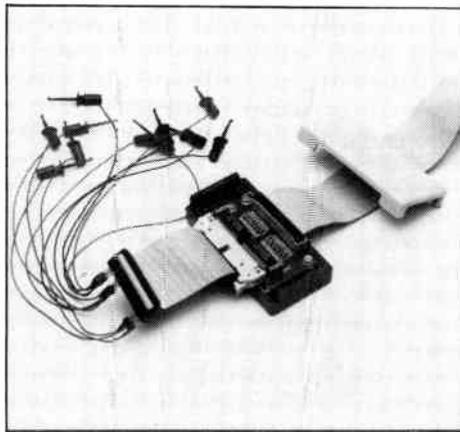
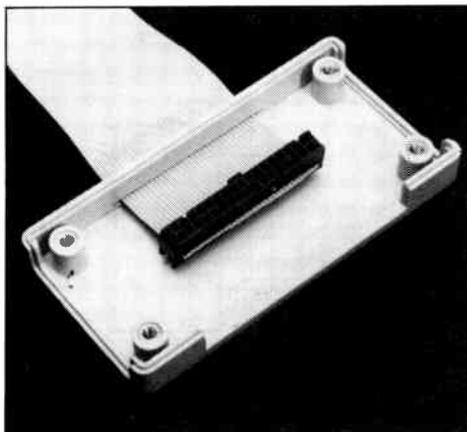


Fig. 8. (left) a slot and a recess have to be provided in the top of the enclosure; (right) general view of the probe and the required ancillaries.

sockets is connected to the probe, while the other is used as a multiple connector for the individual test leads. These test leads are terminated into wire-wrapping pins that fit nicely into the socket. These pins may be bought from your local retailer or cut off contacts strips that normally serve as IC socket – see Fig. 8. The test cable is then soldered into one of the two buses. The other end of the individual leads, which should not be longer than 20 cm, is fitted with a test clip. The other bus remains unused except for one plug per probe where an earth connection is soldered.

The RAM card

The RAM card is at the heart of the input signal processing: it writes and temporarily stores the data. The relevant circuit is straightforward as may be seen in Fig. 9. The input signals are passed to ICs 17, 18, 28 and 29.

Depending on the logic state of the 100/25 MHz signal at the S₁ input of the ICs, these devices function either as shift register or as latch. When the signal is high (25 MHz mode), the data present at parallel inputs AD are accepted into the registers of the ICs at every clock pulse. In this state, 16 input signals can therefore be processed.

When the 100/25 MHz signal is low (100 MHz mode), the four ICs function as shift registers that accept the logic state of input SR at every clock pulse. This means that only four inputs are left per RAM card, but these may be processed at a clock frequency of 100 MHz. Since the clock frequency can go up to 100 MHz, the clock signal is not carried via the bus board but via a short coaxial cable that connected the CLK input directly to the control board.

From the input shift register, the signal is split into two: one part goes to the word rec-

ognizer and the other to a latch formed by IC₁₀ and IC₂₁. The three-state outputs of this latch ensure that the RAM can be read without any problems.

Furthermore, the latch ensures that in the 100 MHz mode the data are stable long enough to be written into the RAM. True, in the 100 MHz mode the data are offered at a frequency of 25 MHz, but in spite of that they remain stable for only 10 ns, which is too short for IC₈ and IC₂₀, the RAM ICs. It is for that reason that they are first stored in the latch. The R/W signal from the control card clocks the latch and controls the RAM. The control board also provides the address lines that contain the address into which the data are written in the RAM. Every time this occurs, the address is increased by one.

When the measurement has been completed, the R/W control goes high. The outputs of latches IC₁₀ and IC₂₁ are then high-resistance and the RAM is in the read position. The computer can then read the contents of the RAM address by address via three-state buffers IC₉ and IC₁₉. Since only eight bits can be read at a time, the buffers must be addressed individually, and this is done via address decoder IC₃₀. The two register address lines and WR₁ determine into which register may be written and from which one may be read. The address decoder is also controlled by a card select signal to enable a distinction to be made between the RAM cards (up to four) and the controller card.

Apart from the RAM, the RAM board also contains the word recognizer that arranges the triggering of the logic analyser. Via the interface the computer writes into the four registers, IC₁₃, IC₁₆, IC₂₄ and IC₂₇, the data that determine whether a bit is to be high, low or don't care to trigger the analyser. An XOR-NAND combination is used for each

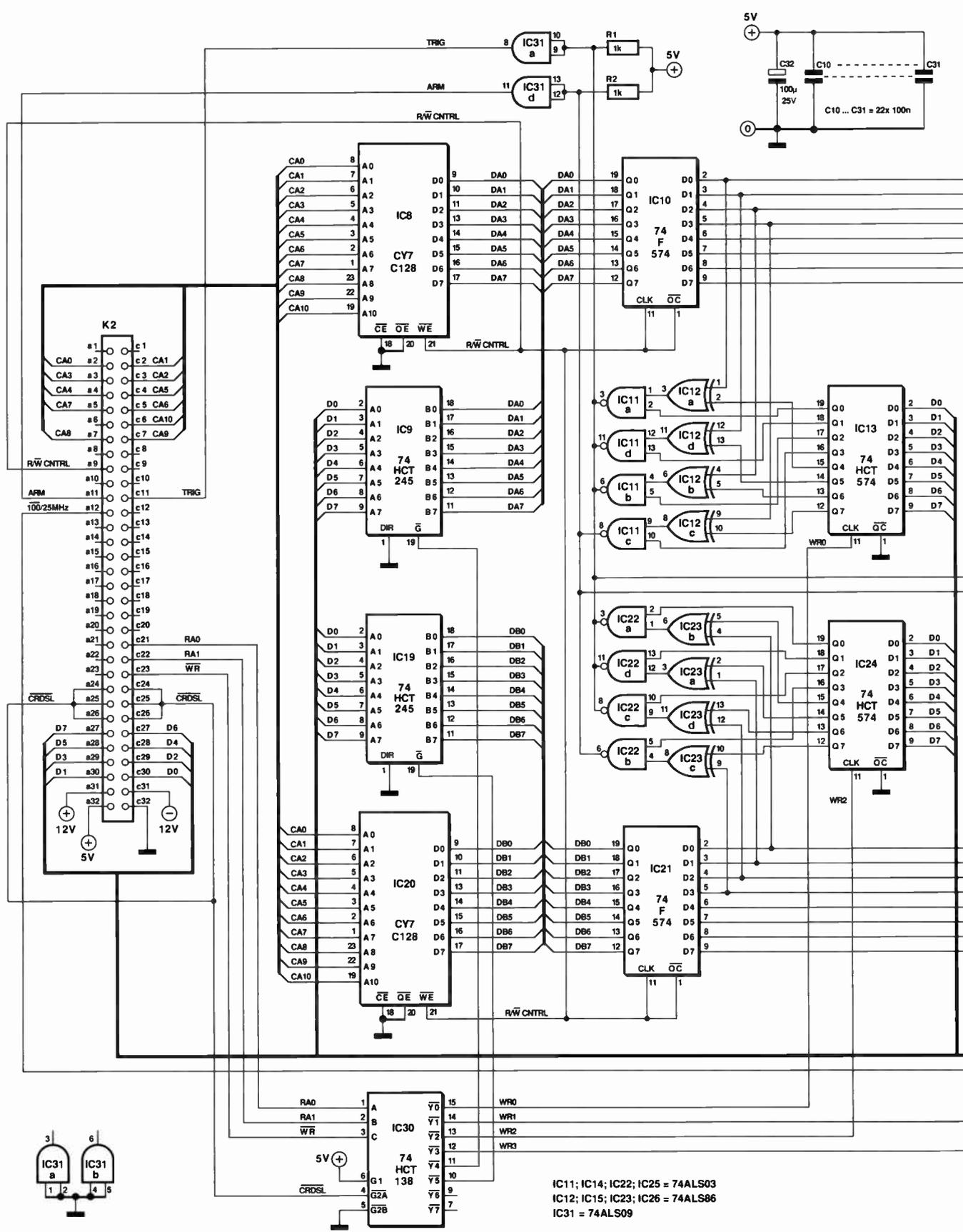
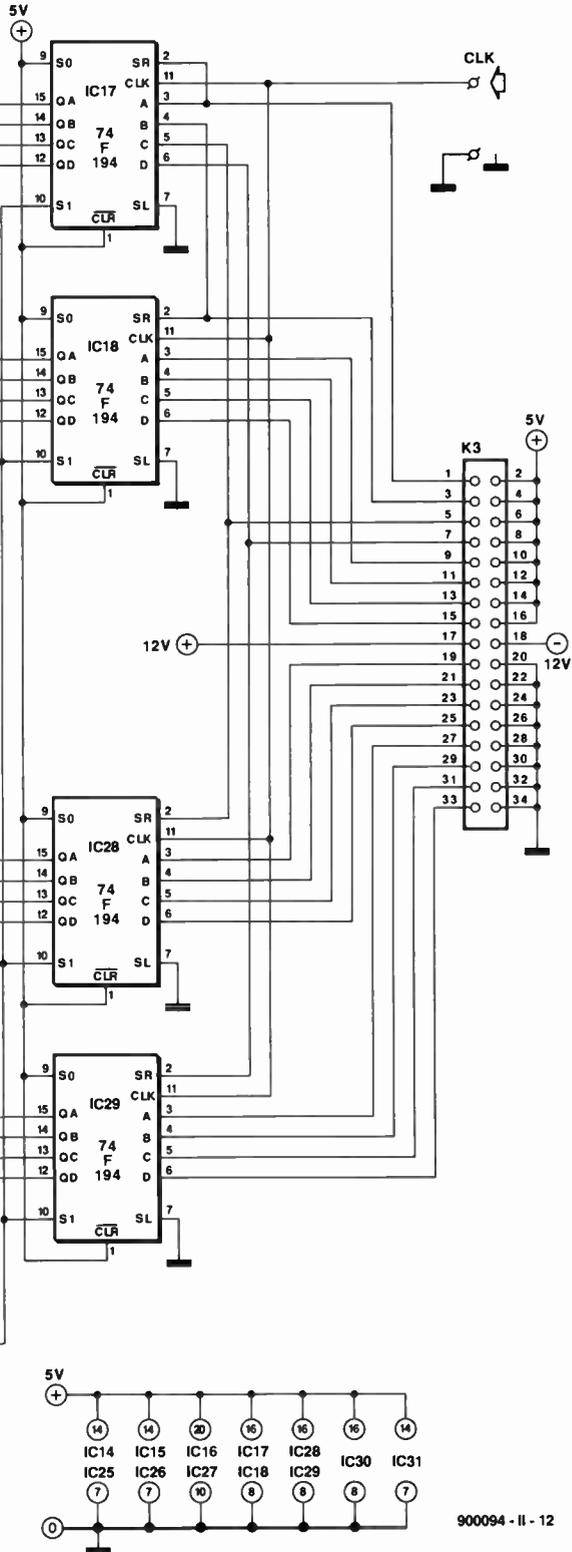
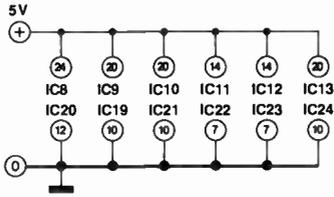


Fig. 9. Circuit diagram of the RAM card.

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bit to compare the input data with the set trigger pattern. The individual comparisons are combined into signals ARM and TRIG via the open-collector outputs of the NANDs, which have been linked to form a wired-OR gate. Signals ARM and TRIG are buffered by gates IC_{31c} and IC_{31d} and then applied to the bus. These gates also have an open-collector output, so that the trigger signals on the bus are again passed through a wired-OR gate, which ensures that the control board receives two complete trigger signals. The XOR-NAND combination and its truth table are shown separately in Fig. 10. The output of this combination must be high for the trigger condition for the relevant bit to be met. When the X input is made low, the output is always high. The bit is then a don't care one in the trigger pattern. When the X input is high, the 0/1 input is used to determine whether the data input must be low or high to meet the trigger condition. The XOR-NAND combinations are connected to the four registers in a manner that ensures that in each of the registers

four 0/1 inputs and four X inputs are juxtaposed.

The printed-circuit board shown in Fig. 11 is straightforward, although some constructors will wonder about the number of wire links. These were found necessary because of the density of the board in a number of places. It was considered that in these instances wire links are safer than copper tracks. Also, they provide a way of keeping the supply to groups of ICs separate, which makes thorough decoupling of the power lines that much simpler. Note that the resistance of the power lines may be made even lower by giving the relevant tracks an extra layer of tin.

Note also the layout of the board around IC₉ and IC₂₀. These ICs are normally supplied in widths of 0.3 in., but wider versions are also available. The board is suitable for both types. Whichever type is used, pin 1 must always be inserted into the appropriately marked hole.

(Part 3 will follow in our April 1991 issue)

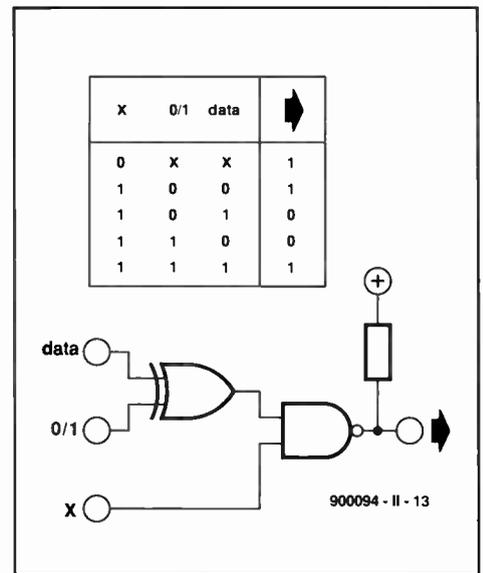


Fig. 10. The word recognizer consists of 16 of the circuits shown here.

Resistors:

R₁, R₂ = 1 kΩ

Capacitors:

C₁₀–C₃₁ = 100 nF

C₃₂ = 100 μF, 25 V

Semiconductors:

IC₈, IC₂₀ = CY7C128 (6116, 20 ns)

IC₉, IC₁₉ = 74HCT245

PARTS LIST

IC₁₀, IC₂₁ = 74F574

IC₁₁, IC₁₄, IC₂₂, IC₂₅ = 74ALS03

IC₁₂, IC₁₅, IC₂₃, IC₂₆ = 74ALS86

IC₁₃, IC₁₆, IC₂₄, IC₂₇ = 74HCT574

IC₁₇, IC₁₈, IC₂₈, IC₂₉ = 74F194

IC₃₀ = 74HCT138

IC₃₁ = 74ALS09

Miscellaneous:

K₂ = 64-way right-angle male AC connector to DIN 41612

K₃ = 34-way right-angle male header with ejector

PCB Type 900094-2

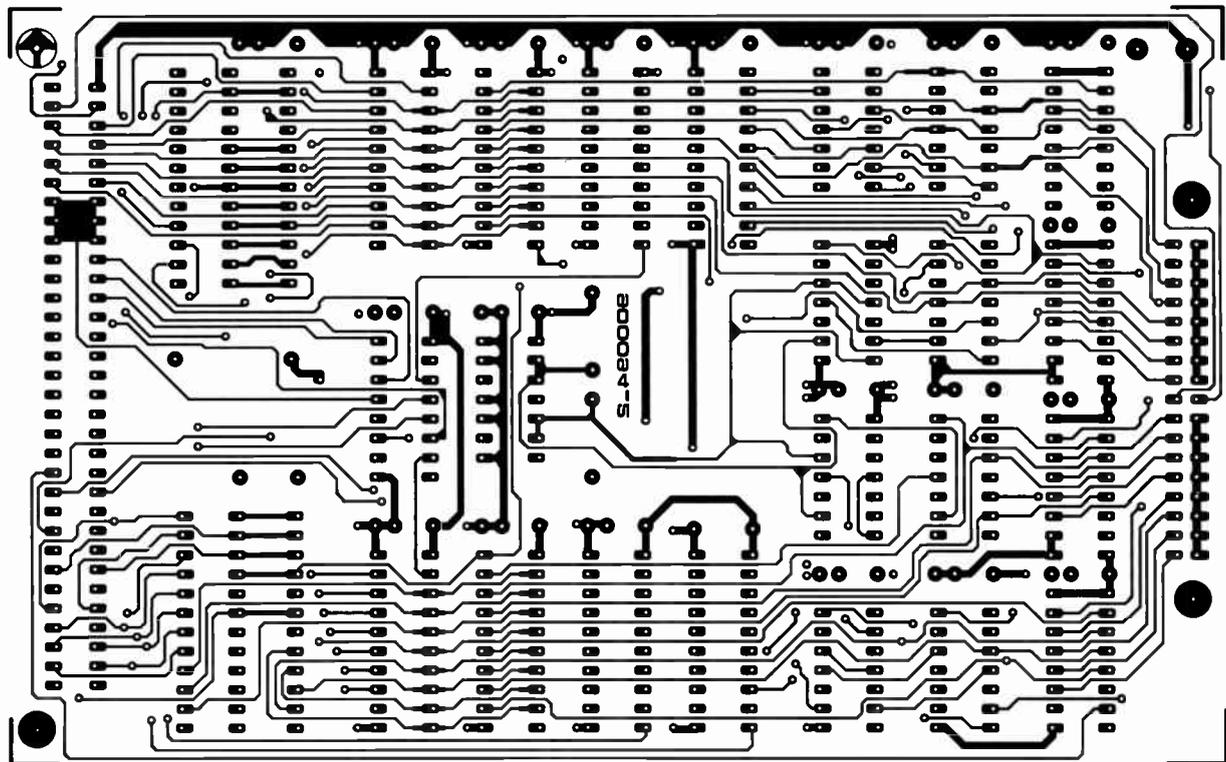
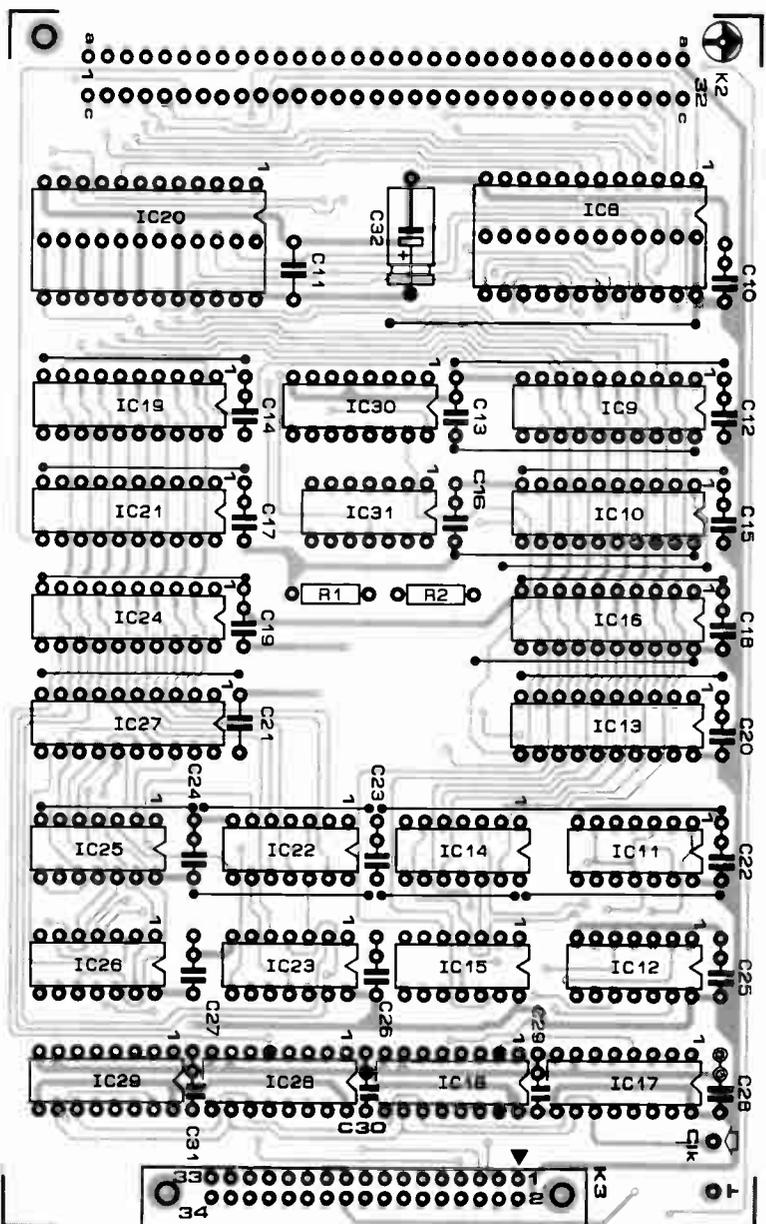


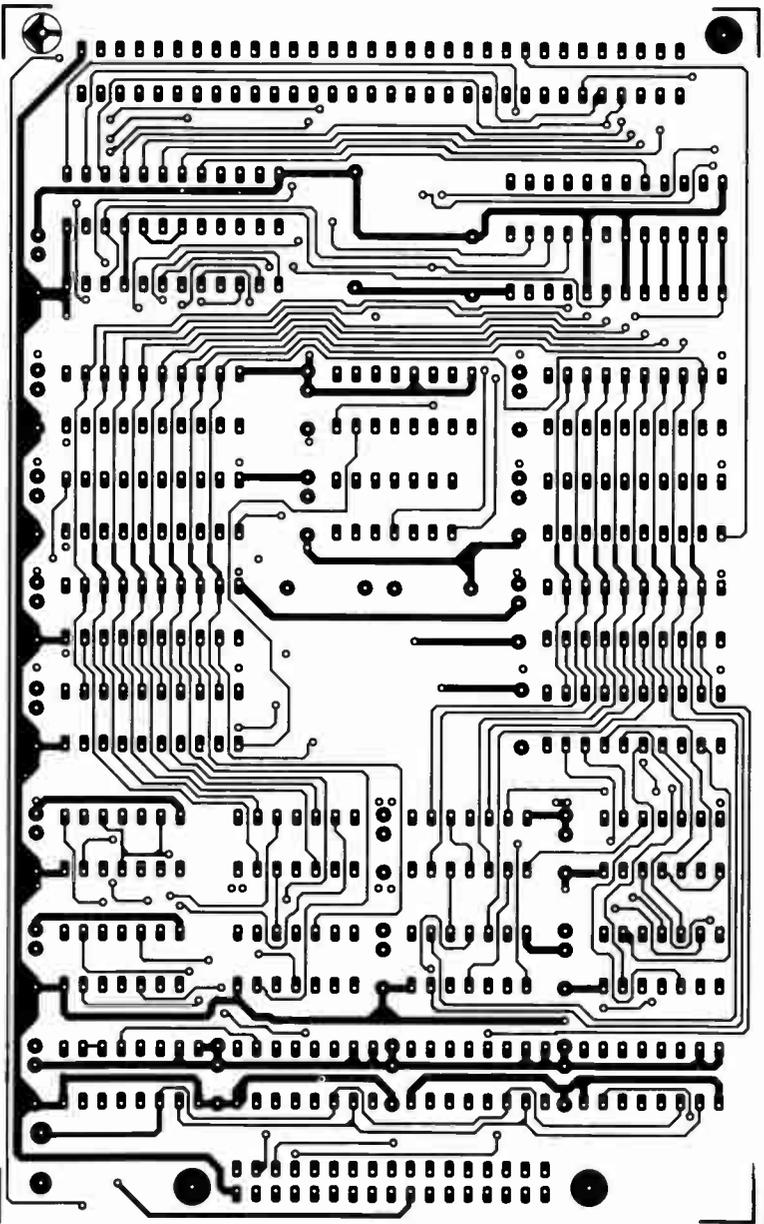
Fig. 11. Printed-circuit board for the RAM card

Register address	Read	Write
0	low byte RAM	trigger nibble 0
1	high byte RAM	trigger nibble 1
2	no address	trigger nibble 2
3	no address	trigger nibble 3

Table 1. Address arrangement for the RAM card.



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OPTICAL-FIBRE COMMUNICATION

Modern telecommunications increasingly uses photonics, the technology of using photons instead of electrons to convey information in a controlled manner. The United Kingdom is a world-leader in this technology and both British Telecom and Mercury Telecommunications already have substantial lengths of optical-fibre cable in everyday use.

THE basic principles of using photons for communication via optical-fibre cable were established by Hockam and Kao, working at the Standard Telecommunication Laboratories at Harlow, Essex, in 1966.

A photon is an elementary particle of light in the frequency range of 3×10^8 MHz to 6×10^{10} MHz, corresponding to wavelengths of 1000–5 nm.

A ray of light is the direction along which photons, that is, light energy, travel. A beam of light is a collection of rays. According to the Principle of Reversibility of Light, if a light ray is reversed, it always travels along its original path. Light waves may be refracted or reflected.

In reflection, some or virtually all of the light is thrown back into the original medium when the light strikes the boundary surface between two media. Highly polished metals reflect most of the light incident on them, whereas, for instance, plate glass reflects only about five per cent.

In reflection, the incident ray, the normal, and the reflected ray lie in the same plane. Also, the angle of incidence with the normal is equal to the angle of reflection with the normal—see Fig. 1.

Refraction is the change of direction that a ray of light undergoes when it enters another transparent medium. In refraction, the incident ray, the normal, and the refracted ray lie in the same plane. Snell, a Dutch scientist, found in 1620 that the ratio $\sin\alpha:\sin\beta$ is a constant, where α is the angle of incidence and β is the angle of refraction. Snell's Law is usually expressed as

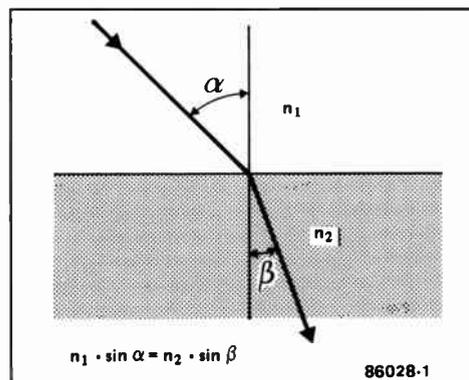


Fig. 2. Illustrating Snell's Law.

$$\sin\alpha/\sin\beta = n_2/n_1 = \mu, \quad [1]$$

where n_1 and n_2 are the refractive indexes of the two media and μ is a constant.

Light is refracted because it has different velocities in different media. The Wave Theory of Light shows that the refractive index n_2 for two given media 1 and 2 is given by

$$n_2 = c_1/c_2, \quad [2]$$

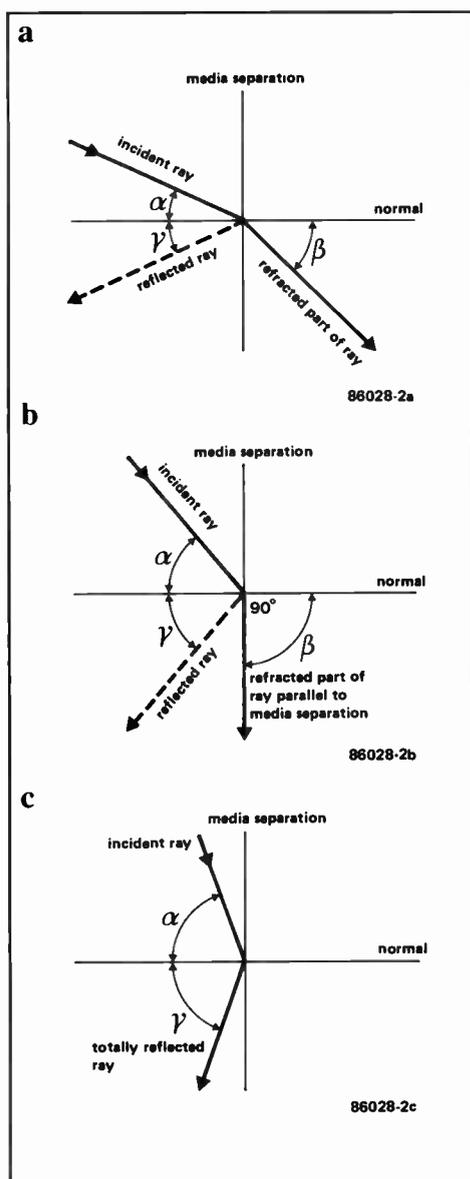


Fig. 1. Depending on the angle of incidence of the light ray, the transmission path is called low- or high-order mode; the greater the angle, the lower the mode.

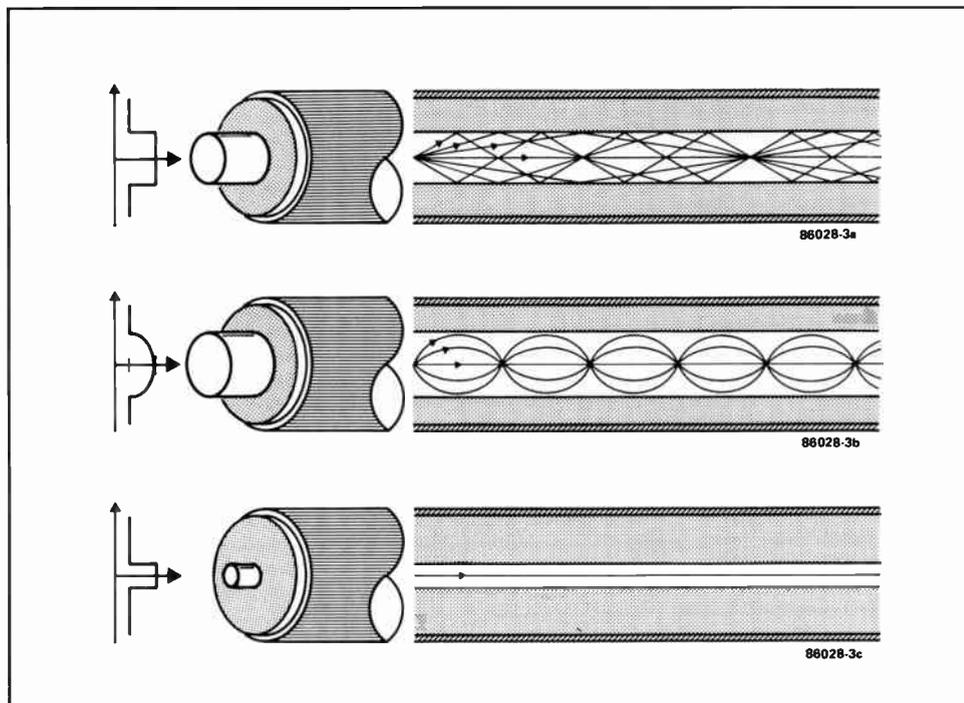


Fig. 3. Top: stepped index multimode cable; centre: graded index multimode cable; bottom: monomode cable. At the left of the drawings are the profiles of the refractive index.

where c_1 and c_2 are the velocities of light in media 1 and 2 respectively.

If medium 1 in [2] is a vacuum, the value is the absolute refractive index. The value for any other two media is the relative refractive index. The absolute refractive index, n , of a medium is then $n=c/v$, where c is the velocity of light in a vacuum and v is the velocity of light in the medium. As the absolute index of air is 1.000 29, in practice the velocity of light in air can replace that in vacuum.

There are, of course, situations where there is a partial reflection and a partial refraction of the light. For instance, in Fig. 1a the angle of incidence is so small that a large

part of the incoming light is refracted. In optical fibre, this would mean that a large part of the light would be lost in the cladding of the cable. Figure 1b shows the critical angle of incidence: the refracted light here is at an angle of 90° with the normal. At the critical angle, the refracted light may cause interference. It is, therefore, essential that the angle of incidence is greater than the critical angle—see Fig. 1c—when total reflection takes place. Note that the angle of incidence, α , is equal to the angle of reflection, γ . The condition for total reflection is that the ray of light travels from an optically dense medium with a relatively large refractive index to a less dense one with a smaller refractive index.

Rays of light that fall upon the media boundary at an angle smaller than the critical angle are called high-order modes: they take relatively longer to reach the end of the cable. Rays of light that travel almost parallel to the optical axis, that is, at an angle greater than the critical, are called low-order modes. Low-order modes travel faster because they are reflected less often than high-order modes. Low-order modes are far less prone to losses than high-order ones.

The sine of the angle of incidence of the ray of light is called the numerical aperture: this is the prime factor where two optical waveguides are to be linked. The numerical aperture is also an indication of the difference

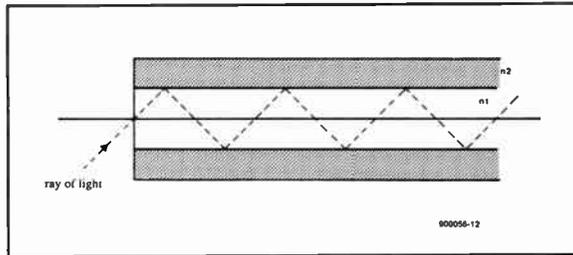


Fig. 4. Longitudinal cross-section of an optical fibre cable. The refractive index of the core is slightly higher than that of the cladding.

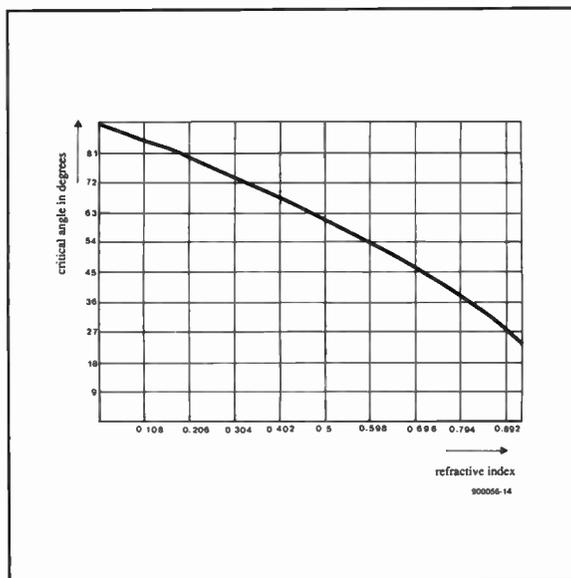


Fig. 6. Relationship between the critical angle and the refractive index n_2 with n_1 given a value of 1.

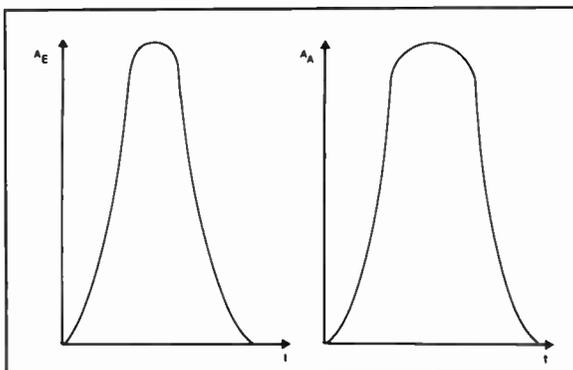


Fig. 8. Dispersion causes the width of the light pulses to be increased.

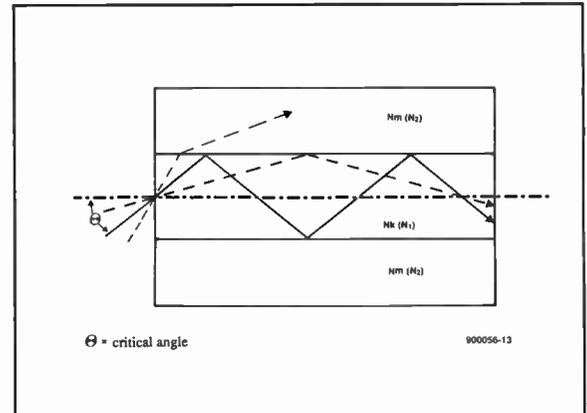


Fig. 5. If the ray of light is input at an angle greater than the critical angle θ , it is not reflected internally but absorbed in the cladding.

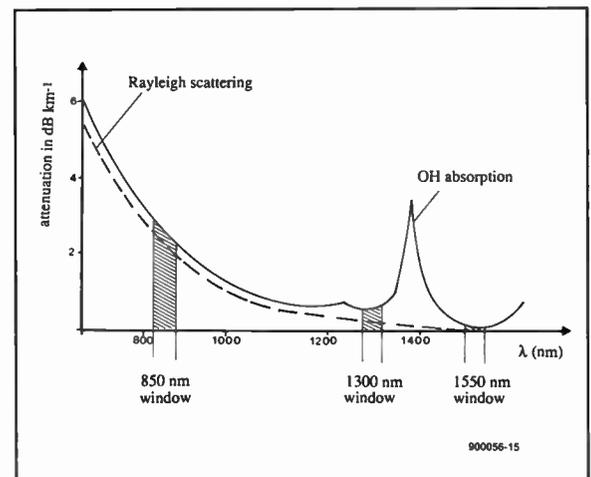


Fig. 7. Relationship between attenuation presented by an optical-fibre cable and the wavelength of the input light.

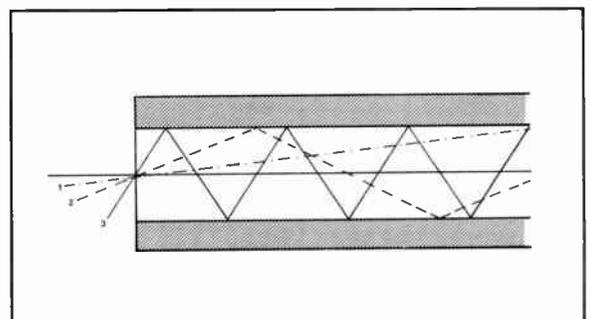


Fig. 9. Depending on the input angle, different rays of light travel different distances, and this causes their transit times to be of different duration.

between the refractive indexes of the core and the cladding: the smaller it is, the greater the bandwidth of the optical signal.

In mono-mode (also called single-mode) optical-fibre cables (Fig.3) the core diameter is comparable to the wavelength of the light, so that there can be only one electromagnetic mode of propagation and spreading of the pulse, called multi-path dispersion, is eliminated.

In multi-mode optical fibre cables—see Fig. 3—the ray paths of the different modes are of different lengths and have, therefore, difference transmission times. Because the modes are divided by a pulse, this is subject to progressive spreading as it travels along the fibre, causing it to interfere with adjacent pulses.

Its small core size makes mono-mode fibre more difficult to use, but it has a smaller attenuation than multi-mode fibre cables.

Optical fibre cable in practical use consists of a light-conductive cylindrical core of doped silica clad in pure silica—see Fig. 4. The refractive index, n_2 , of the cladding is

about 1% smaller than that of the core, n_1 . This makes total internal reflection possible at the boundary between core and cladding of all rays of light that enter the cable at an angle smaller than the critical (Fig. 5). The critical angle, θ , is

$$\theta = \arcsin \sqrt{(n_1^2 - n_2^2)},$$

and it depends therefore only on the refractive indexes n_1 and n_2 . If $n_1 = 1$ (vacuum) the characteristic curve in Fig. 6 pertains. Often, the numerical aperture, NA, is given instead of the critical angle:

$$NA = \sin \theta = \sqrt{(n_1^2 - n_2^2)}.$$

Cable characteristics

The transient response of an optical-fibre cable depends, apart from its geometrical characteristics pertaining to the core and cladding, on its optical attenuation and scattering. The attenuation is largely dependent on the wavelength of the input light. It consists of

two components: one caused by absorption and the other by dispersion.

The absorption component is specific to the glass fibres and can be kept to a minimum during manufacture, when, for example, oxygen-hydrogen (OH) ions may get trapped in the material. Such impurities absorb light at a number of wavelengths as shown in Fig.7. Note that the attenuation of wavelengths around 1300 nm and 1150 nm is very small.

The dispersion component depends on the properties of the cable. It manifests itself as a variation of refractive index with the wavelength of the light.

Some spurious particles will always be present in the glass; they come about during the melting process. The dispersion caused by these particles, which are small compared to the wavelength of the light used, is called Rayleigh scattering, which reduces with increasing wavelength—Fig. 7. Scattering is an intrinsic property of the glass: it cannot be eliminated. It is partly caused by the glass fibres and partly by properties of the

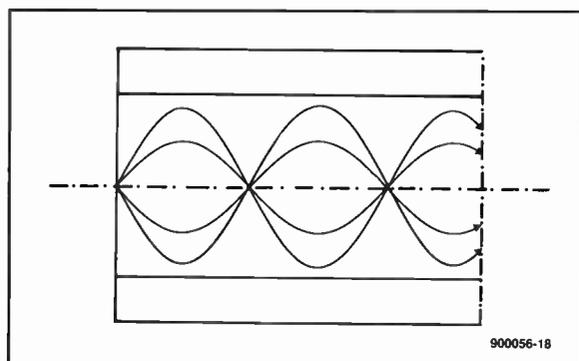


Fig. 10. Because of the continuously varying refractive index of graded index optical-fibre cables, rays of light in these cables travel along helical instead of linear paths.

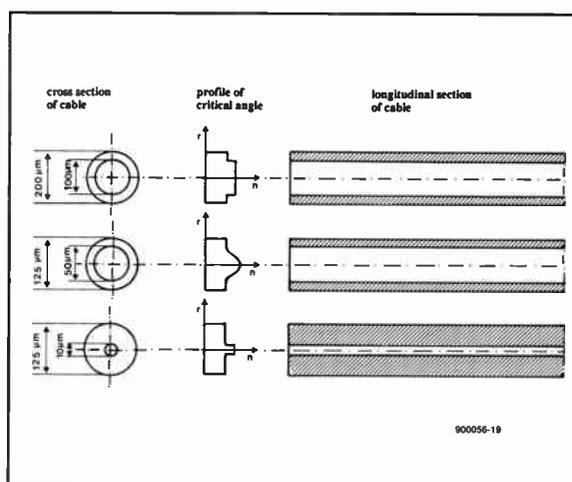


Fig. 11. Diagrammatic representation of the three types of optical-fibre cable. That at the top, a stepped index mode type, is virtually out of production.

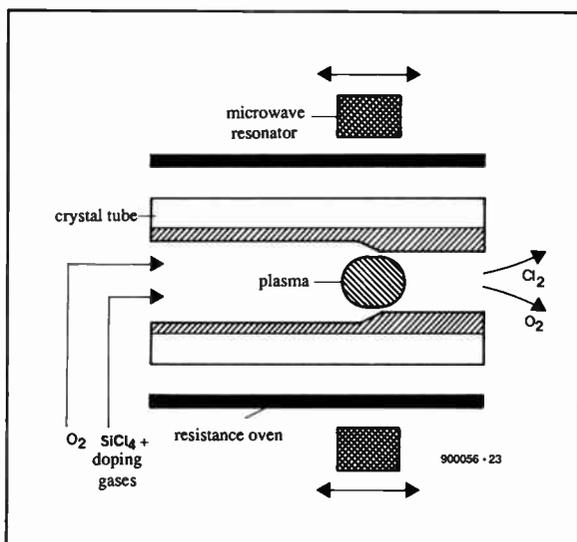


Fig. 12. Simplified diagram of production set-up.

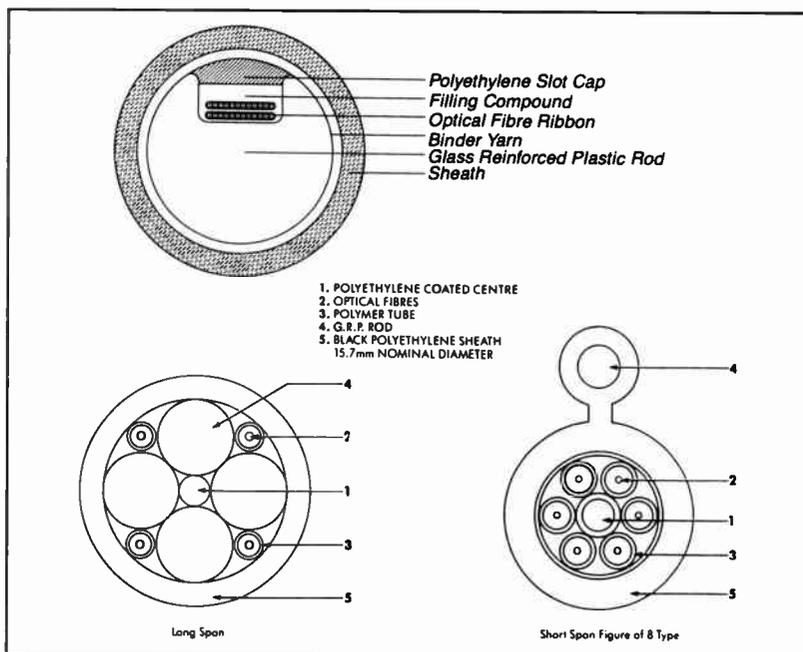


Fig. 13. Some multi-core optical-fibre cables: top: Fibrespan (made by STC) and below: Translite (made by TCL, a subsidiary of General Electric).

light input.

Dispersion results in an increase in pulse width of the light during its travel through the cable (see Fig. 8). The increase is proportional to the distance between sender and receiver, that is, the length of the cable. It is normally given in picoseconds per kilometre (ps km^{-1}).

Mode scattering is caused by the various light rays entering the cable at slightly different angles—see Fig. 9. It is clear that different rays travel different distances through the cable and this leads to attenuation of the input signal. The difference between the shortest and longest transit times, Δt , is

$$\Delta t = n_k(n_k n_m) / cn_m,$$

where n_k is the refractive index of the core material, n_m the refractive index of the cladding and c the speed of light.

The smaller the dispersion attenuation of an optical-fibre cable, the larger the trans-

mission bandwidth. In practice, the bandwidth, B , is $B = 0.44/T$, with T determined at the -3 dB pulse amplitude.

Practical cables

A multimode cable is one with a core diameter sufficiently larger than the wavelength of light to allow propagation of light energy in a large number of different modes. Multimode cables embrace stepped index and graded index types. Stepped index types have a core whose refractive index is constantly higher than that of the cladding, that is, the index changes abruptly at the boundary of core and cladding. Owing to mode dispersion, the attainable bandwidth of this type of cable is limited to about 100 MHz km^{-1} .

The refractive index of the core of graded index cables reduces parabolically by 1% from the centre of the core to that of the cladding. This results in the light rays travelling along helical instead of linear paths in the cable—see Fig. 10. This results in a noticeable reduction in transit times and dispersion attenuation. Dispersion attenuation values of 0.2 ns km^{-1} and corresponding bandwidths of 1 GHz km^{-1} are attainable.

The graded index cable has become an international (CCITT) standard with a core diameter of $50 \mu\text{m}$, a cladding diameter of $125 \mu\text{m}$, and a numerical aperture of 0.2 (Fig. 11).

A monomode cable is a stepped index type whose inner core diameter (of higher refractive index) is comparable with the wavelength of light; this results in there being only one mode of light propagation. Mode dispersion is thus eliminated. Monomode cables do not cause transit delays, which results in very large bandwidths of more than 10 GHz km^{-1} . Since the attenuation of these cables is also small, they are eminently suitable for wide-band and long-distance communication.

Diagrammatic representa-

tions of the three types of cable are shown in Fig. 11. The most commonly used is the graded-index type. The transfer capacity of this type of cable is normally greater than required. Moreover, the in- and out-coupling of light is easier with this cable than with the mono-mode type. The attenuation of commercially available graded-index cable is $5\text{--}10 \text{ dB km}^{-1}$, which is not a lot worse than that of mono-mode cable. On the other hand, the dispersion in mono-mode cable is much smaller than in multi-mode cable. Owing to its high attenuation of $10\text{--}30 \text{ dB km}^{-1}$ and its smaller transfer capacity, the stepped index multimode type of cable is now virtually out of production.

Cable manufacture

Glass fibres are normally manufactured by the plasma activated chemical vapour deposition (PCVD) technology. In this, a mixture of silicon chloride, germanium chloride and oxygen is passed through a very pure quartz tube. This gas mixture causes a plasma reaction zone in the field of a microwave generator, which results in the deposition of a doped quartz layer (SiO_2) at the internal surface of the tube (see Fig. 12). By axially shifting the microwave generator along the tube, an even thin layer is deposited. The core is built up of some hundreds of such layers. By varying the Ge doping of individual layers it is possible to obtain a very exact refractive index profile, which is a prerequisite for large transmission bandwidths.

The quartz tube is then heated to a temperature where it collapses into a solid 1.5 m long glass rod. This rod is then heated to near its melting point and drawn into a fibre some 15 km long with a diameter of $125 \mu\text{m}$. To prevent damage to this fragile strand, it is immediately given a primary coating of man-made fibre. Later, a secondary coating of man-made fibre is applied to give it the tensile and mechanical strength required for processing it into a cable. The protective sheathing of the cable does not affect the optical properties. Over the past few years, multi-core optical-fibre cables as shown in Fig. 13 have become available, which have opened up enormous possibilities for improving and expanding communications systems.

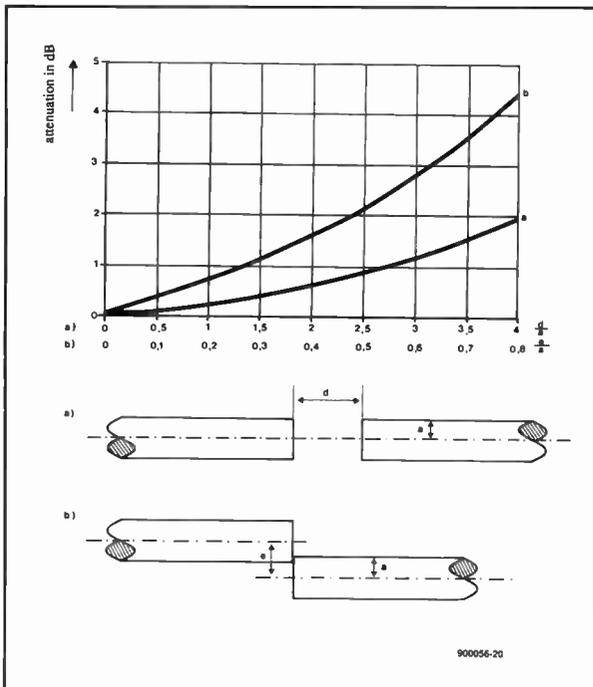


Fig. 14. Attenuation as function of (a) the distance between the cable ends, and (b) radial displacement between the cores.

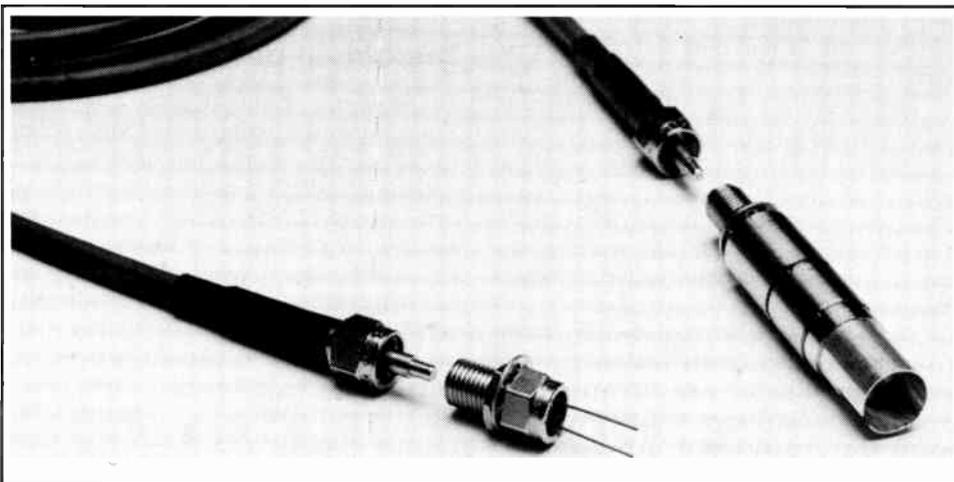


Fig. 15. Some commercially available couplers for use with optical-fibre cable.

Coupling techniques

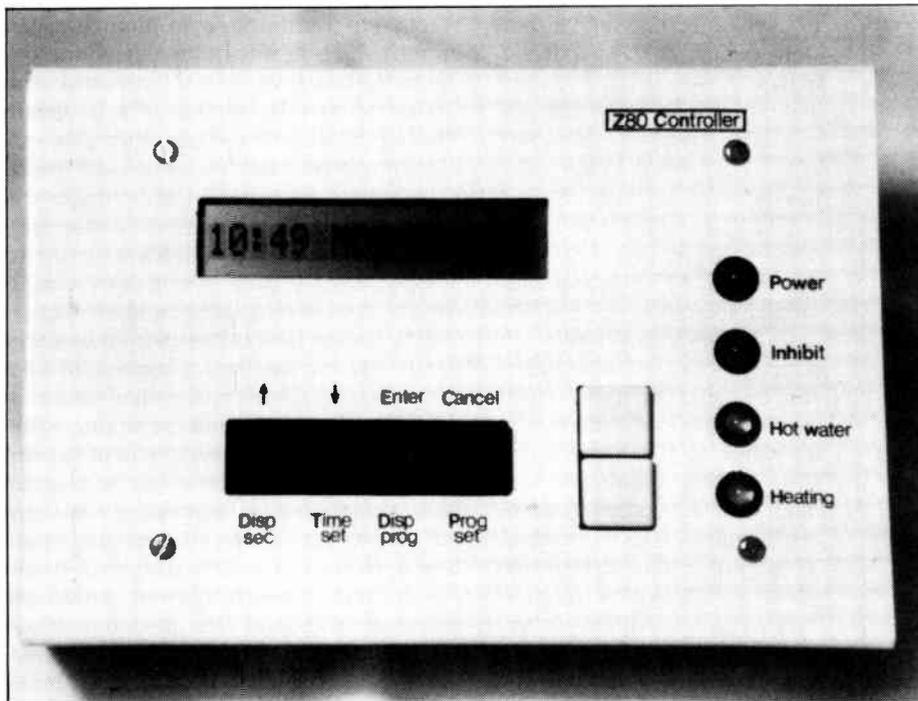
Couplers are, of course, required for connecting the optical fibre cables to transmitters, receivers and repeaters, although cables may also be lengthened by splicing. Whether a coupler or a spliced joint is used, additional attenuation is the result, which depends on the distance between the cable ends, and the radial as well as the angular displacement between the two cores. In a spliced joint the cables ends are fused so this type of coupling therefore gives the lower attenuation as shown by curve *a* in Fig. 14. In many cases, however, removable connections are required and for these there are now a number of optical couplers available commercially (see Fig. 15).

CENTRAL HEATING CONTROLLER

PART 1: SYSTEM OUTLINE AND CIRCUIT DESCRIPTION

Most householders these days employ timeswitches to control their central heating systems. Many of these switches, however, are of the mechanical type, with a limited number of switching steps, and with no facilities to vary the program from one day to the next. It is only fairly recently that electronic controllers have appeared on the scene, and the one described here is designed to give a wide range of programming options, which can easily be changed.

K. Browne



MAIN FEATURES

- Microprocessor-controlled
- Programs can be selected on an individual day, weekdays only, weekend only, or on an every day basis
- One-shot or repeating programs
- Separate control of heating and hot water systems
- Override and inhibit functions
- Battery backup in the event of power failure

The key switches and display unit are mounted on a separate PCB. The 6 keys interface with the data bus via diodes, and perform multiple functions to enable the user to program the timeswitch.

The display unit is a 1-line, 16-character LCD (liquid crystal display) module from Seiko-Epson. The unit contains its own ROM character generator and display RAM. Care should be taken when handling the LCD as it is quite expensive and easily damaged.

THE block diagram of the system is shown in Fig. 1. The CPU (central processing unit) is a CMOS version of the popular Z80 8-bit microprocessor. This is connected to the ROM (read-only memory), RAM (random-access memory), display unit, key switches and output latch via a common 8-bit data bus.

The ROM contains the control program, enabling the CPU to perform the timeswitch operations. This IC is a CMOS version of the perhaps more common 2764 8K×8 bit EPROM. The control program would actually fit in the smaller 2732 4K×8 bit EPROM. At the time of writing, however, the 2732 was not available in a CMOS version at a reasonable price.

The RAM is a 2-Kbyte CMOS memory

chip, which is used to store the switching program, the current time and other system variables.

Two bits of the output latch are used to control the switching relays. A further three bits control LED indicators on the front panel.

A mains-derived 50 Hz signal is provided for the CPU by the timing section of the circuit. This signal is required for timekeeping purposes.

The power supply provides a stabilized 5 V rail for all the circuits. This supply is either derived from the mains, or, in the event of a mains failure, from a stand-by battery source. The battery can be of the rechargeable type, since the PSU also supplies a charging current.

The circuit details

Power supply section (Fig. 2)

Transformer Tr1 reduces the mains voltage to 12 V, which is rectified by diodes D1 to D4, and smoothed by capacitor C2 to provide approximately 12 VDC. This voltage is used, via resistor R6 and diode D8, to charge the stand-by battery, if required. The 12-V supply is also fed, via D7, to a 5-V fixed voltage regulator, IC2.

Resistor R1 feeds the positive half-cycles of the mains frequency to an optocoupler, IC1, whose output drives a pulse-shaping circuit formed by C1-R3. The resulting short-duration positive pulses are inverted by IC3F, and subsequently used as a reference

by the CPU to synchronize the timekeeping function. Transistor T1, diode D6 and resistor R5 form a monitor circuit for the 12-V supply. T1 is normally on. In the event of a mains failure, R4 discharges smoothing capacitor C2. When the voltage across C2 falls to about 8 V, T1 is turned off, providing a power fail signal to the rest of the circuit.

The timing section (Fig. 3)

As previously mentioned, the CPU requires a timing or interrupt signal of 50 Hz. The normal supply of this signal is from IC3f in the power supply circuit. The pulses are applied to the interrupt input of the CPU. To prevent the system losing its timing reference when the mains fails, a second source of 50 Hz pulses is implemented in the form of an oscillator circuit based on IC9. The frequency of oscillation is set by resistors R12, R13 and capacitor C7. Preset P13 allows fine tuning of the frequency to exactly 50 Hz. The power fail indication from T1 in the PSU circuit is connected to the oscillator circuit by diode D9. The result is that IC9 provides an output signal only when a mains failure occurs.

The CPU circuit (Fig. 4)

A clock supply for the CPU is generated by the circuit around IC3c. The quartz crystal in

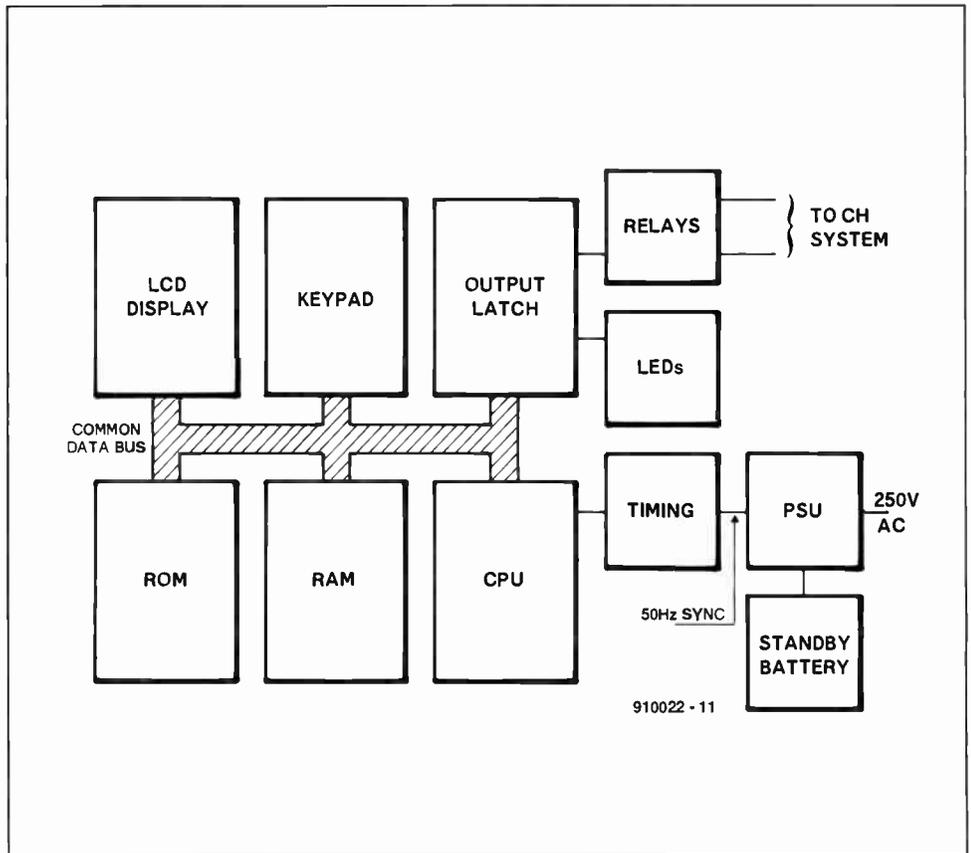


Fig. 1. Block diagram of the Z84C00-based central heating controller.

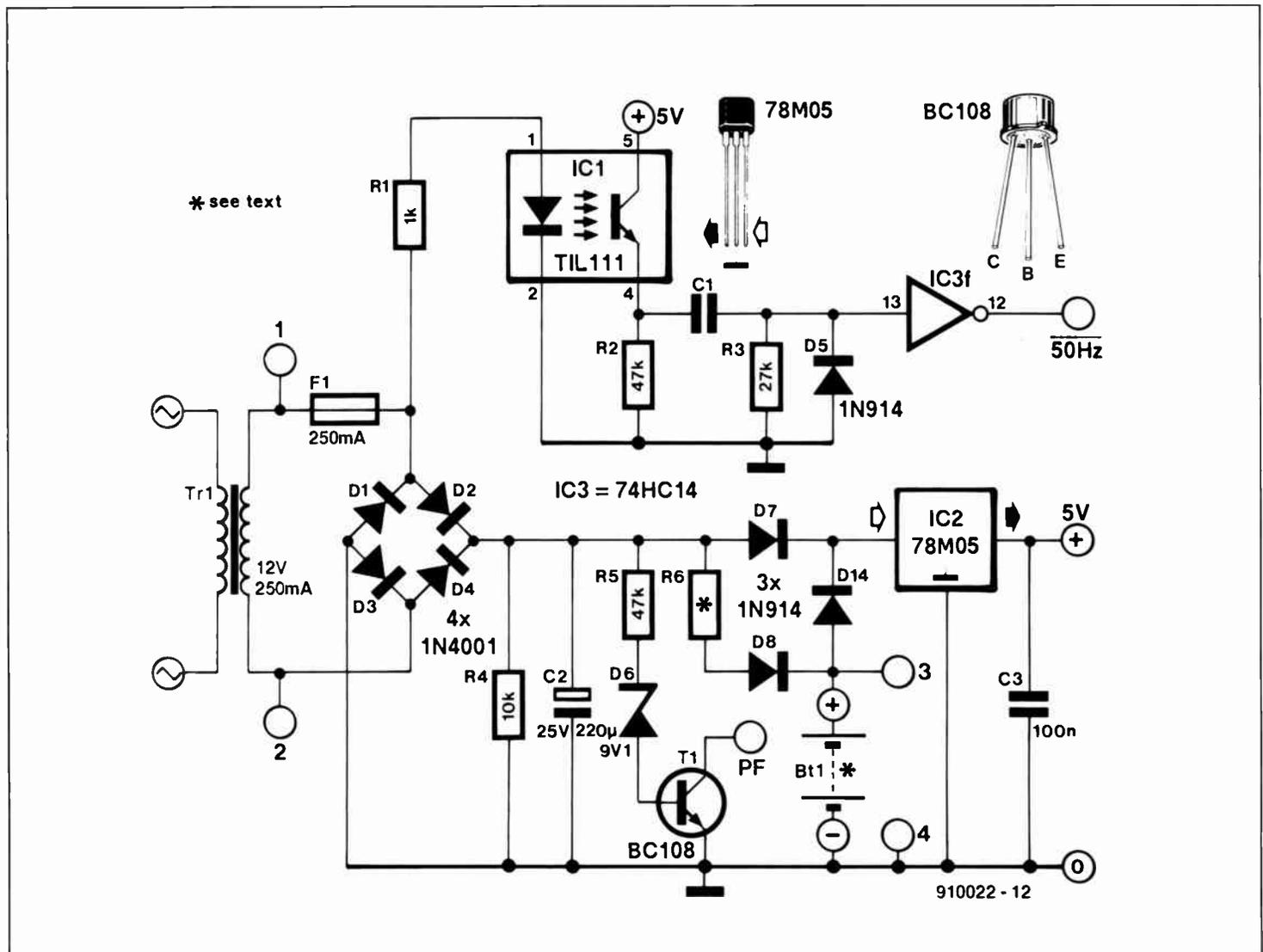


Fig. 2. Circuit diagram of the power supply and the 50 Hz timebase, which derives its accuracy from the mains.

this circuit is a 2-MHz type. A lower frequency than the maximum specification of the CPU is used in view of the LCD unit, which can only operate with signals up to 3 MHz. The 8-bit data bus is connected to the ROM, IC5, the RAM, IC6, and the output latch, IC7. Twelve of the address lines, A0 to A11, are also connected both to the ROM and the RAM ICs. The remaining address lines, A12 to A15, are used to select various ICs connected to the data bus. A number of gates in IC8 'AND' these address lines with the MRQ (memory request) output from the CPU, to provide the correct timing. A truth table of the address decoding logic is shown in Table 1.

Display module and key switches (Fig. 5)

The 8-bit data bus from the CPU, along with two of the address lines, A0 and A1, is extended through to the display PCB. The six key switches, SW20 to SW25, are connected direct to individual lines of the data bus. Pressing a key, however, has no effect unless the $\overline{\text{IORQ}}$ (input/output request) line of the CPU is low. This terminal is normally high, and only taken low when the CPU requires to read the key switches. It does this periodically under software control. When a key is pressed during a CPU read cycle, the appropriate data line is pulled low via one of the diodes D20 to D25. If two or more switches are pressed at the same time, this prob-

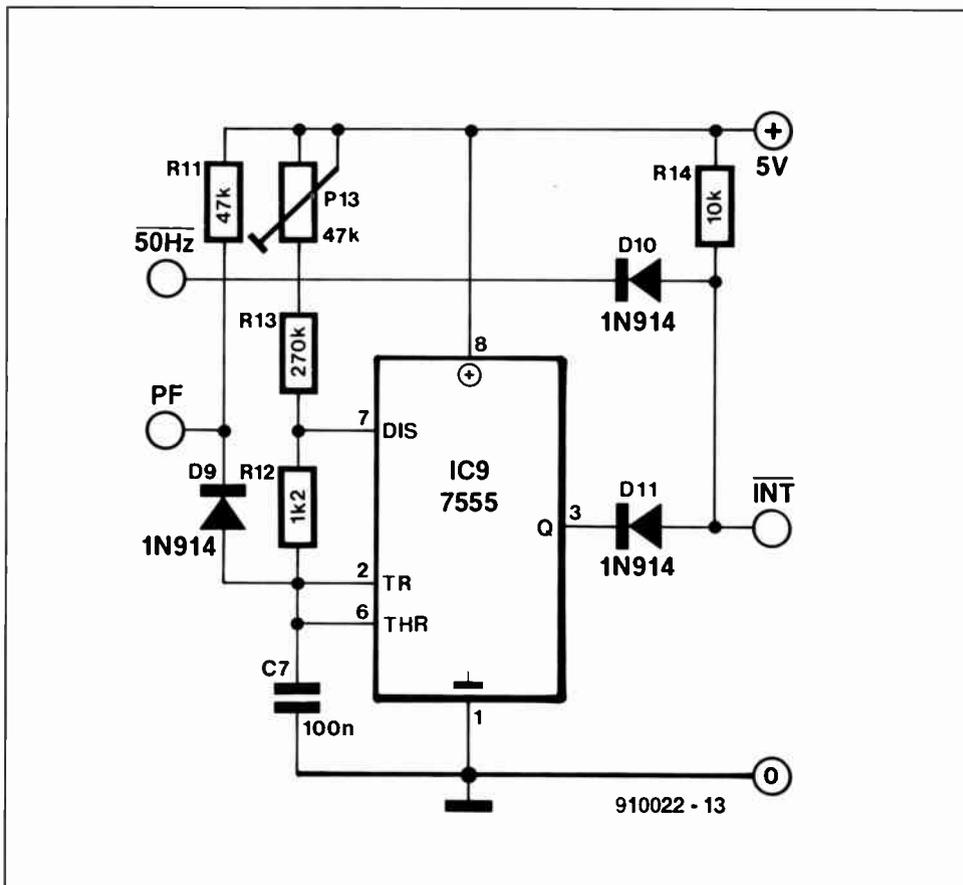


Fig. 3. Circuit diagram of the mains-synchronized timebase. The interrupt pulses supplied by this circuit are fed to the microprocessor.

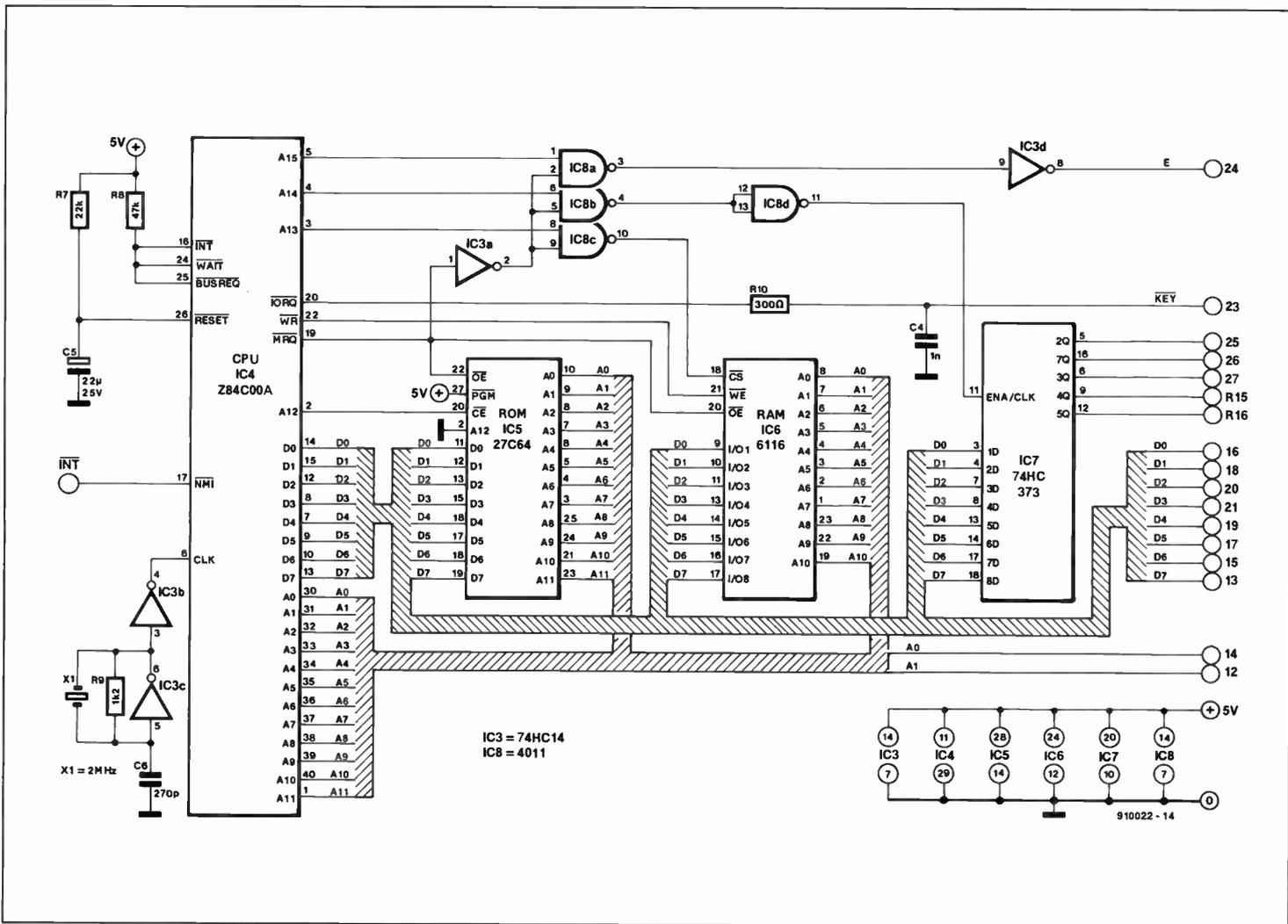


Fig. 4. The heart of the controller is formed by a computer system based on Zilog's Z84C00 8-bit CMOS microprocessor.

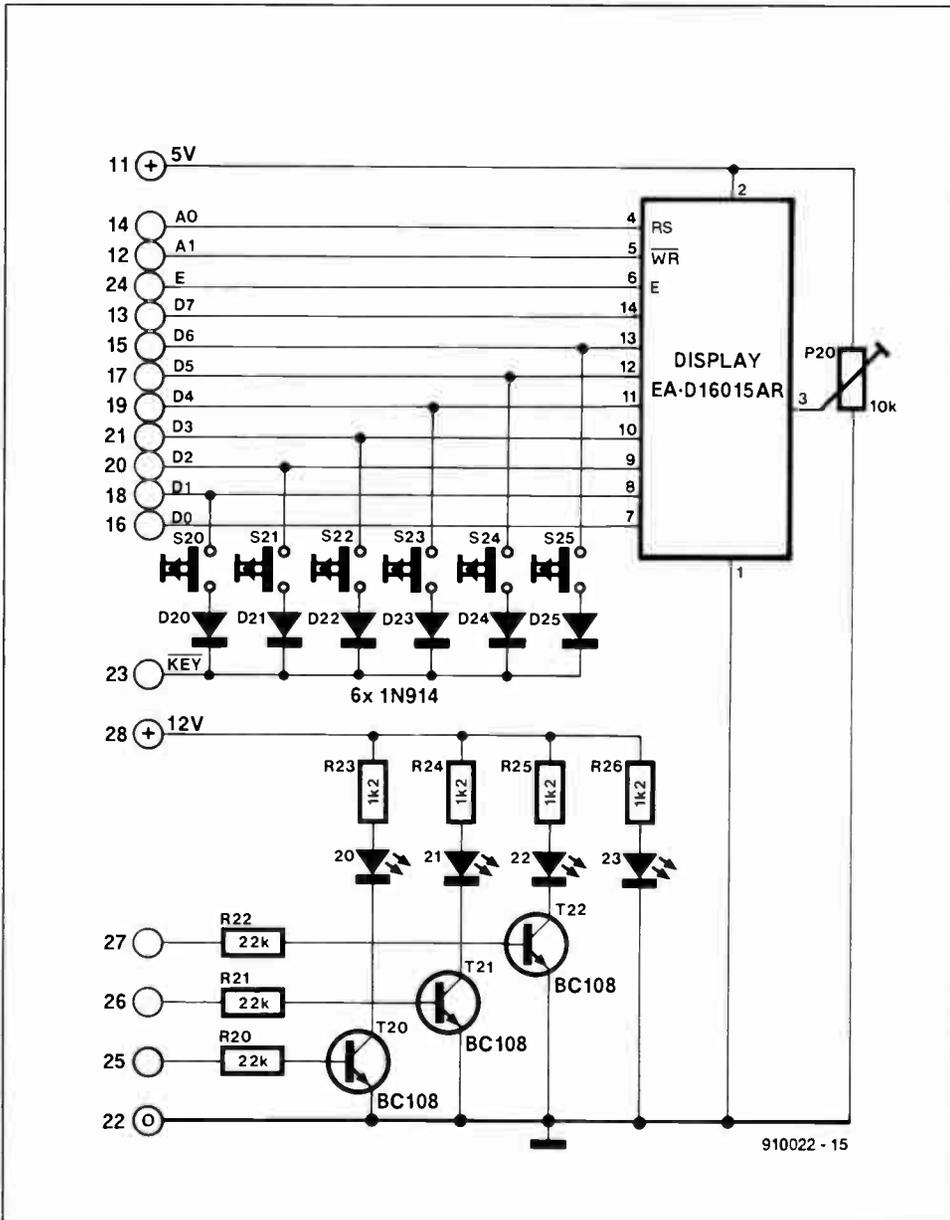


Fig. 5. The display circuit of the CH controller is based on an intelligent LCD module from Seiko-Epson.

CPU/Address lines					IC selected	Base address (hex)
MREQ	A15	A14	A13	A12		
0	0	0	0	0	ROM	0000
0	0	0	1	1	RAM	3000
0	0	1	0	1	Output latch	5000
0	1	0	0	1	Display module	9000

Table 1. Address decoding in the microprocessor system.

CPU/Address lines							Address (hex)	Display module register selected
MREQ	A15	A14	A13	A12	A1	A0		
0	1	0	0	1	0	0	9000	Instruction Register (write)
0	1	0	0	1	0	1	9001	Data Register (write)
0	1	0	0	1	1	0	9002	Instruction Register (read)
0	1	0	0	1	1	1	9003	Data Register (read)

Table 2. Display module register selection.

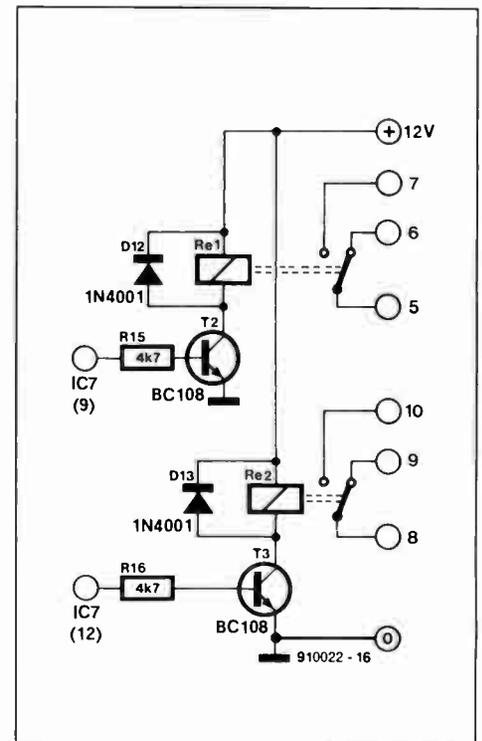


Fig. 6. The relay driver circuit that forms the link between the controller and the CH pumps, valves and the boiler.

lem is sorted out by the software.

The display module proper is self-contained. The CPU writes data to, or reads data from, either the control or the data registers in the display module. Access to the registers is controlled by the two lower address lines, A0 and A1, and by address line A15 (see Table 2). A summary of the control codes and character set available in the display module is detailed in Table 3.

Preset P20 is provided to adjust the contrast of the display. Four LEDs are also accommodated on the display PCB. LED20 and LED21 indicate the state of the 'hot water' and the 'heating system' respectively. LED22 is used to indicate the state of the inhibit control. These three LEDs are controlled by the CPU via the output latch and driver transistors T20, T21 and T22. LED23 indicates that mains power is present to the unit.

Relay section (Fig. 6)

Two changeover relays, RL1 and RL2, control the actual central heating system. They are operated by the CPU via the output latch and the drivers, T2 and T3.

Continued next month.

INTERMEDIATE PROJECT

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

SIMPLE FUNCTION GENERATOR

The test instrument presented here is capable of supplying sine-wave, square-wave and triangular-wave signals with an adjustable amplitude of 0 to 12 V. The square-wave output in addition offers a fixed 5-V level for easy use with digital circuits. The frequency range of the generator is 2 Hz to 25 kHz.

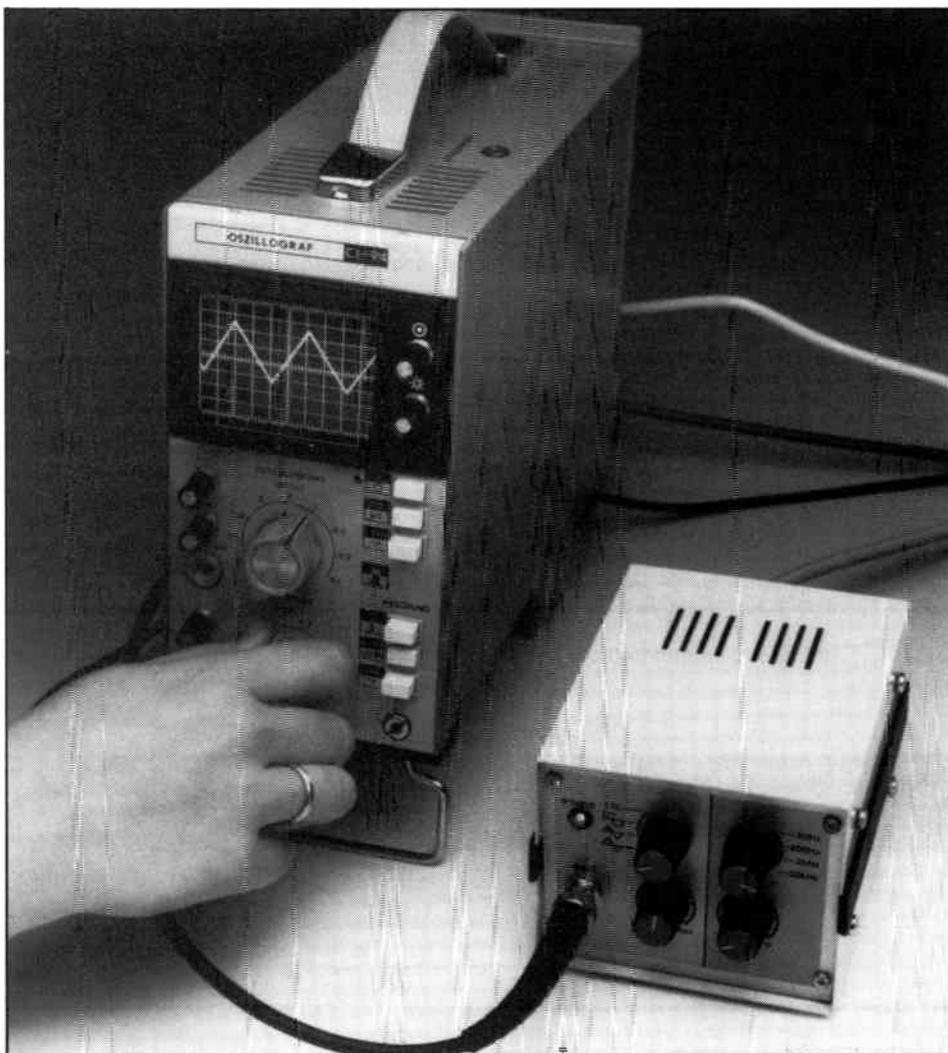
D. Harkema

IF you are into testing and designing electronic circuits at almost any level, a function generator and an oscilloscope are indispensable instruments on the work bench. Sine-wave signals produced by a function generator are typically used to check the frequency response and power output of audio amplifiers, and to align filters. The triangular waveform, often mistakenly referred to as 'ramp' or 'sawtooth', enables you to measure the cross-over distortion of a balanced amplifier. The square-wave output has the widest application range: it is generally used for overshoot, frequency response and pulse response measurements on audio amplifiers. Applied to digital circuits, the square-wave function is often used to provide a variable clock generator. For this purpose, the generator output level is either 5 V for TTL circuits, or 12 V (generally) for CMOS circuits. In any case, make sure you know the supply voltage of the digital circuit connected to the generator, and the required drive level of the logic ICs.

Integrator

To help you in locating the individual circuits that together form the function generator, and understanding the basic function of each of these circuits, the simplified schematics are first discussed with reference to Fig. 1. For convenience, the part reference numbers in the simplified schematics correspond to those in the full circuit diagram, discussed further on.

The first sub-circuit is an integrator (Fig. 1a). When a constant voltage is applied



to the input, capacitor C_1 is charged with a constant current. Hence, the voltage across C_1 rises, in principle, linearly as a function of time, and not according to a logarithmic function (e -curve) as in a resistor-based charging circuit. The opamp is responsible for this linearization of the charge voltage. Since the inverting input of the opamp forms a virtual ground, all input current is, in principle, sent into the capacitor. This means that the capacitor charge current is equal to the current that flows through the input resistor. This current is simple to calculate since the value of the resistor is known, and the voltage across the resistor equals the input voltage. In the present circuit, there are only two voltage levels, 'high' and 'low'. You have guessed it: the integrator is driven by a square-wave signal.

The capacitor is charged by the 'high' voltage level, and discharged by the 'low' voltage level. Because of the integrating operation of the capacitor, its right-hand terminal supplies a triangular voltage, which corresponds to the charge voltage (remember that the left-hand terminal of the capacitor is at 'virtual' ground). If you want to demonstrate the operation of the integrator, use a large time constant by fitting a capacitor of say, $1\ \mu\text{F}$, for C_1 , and a resistor of $1\ \text{M}\Omega$ at the opamp input. These component values make the integrator so slow that a simple multimeter connected to the output will clearly indicate a slowly rising and falling voltage when the input is taken low and high (in that order because of the inverting function of the opamp).

Schmitt trigger

The previously mentioned square-wave signal that drives the integrator is supplied by an oscillator based on a Schmitt-trigger. The basic schematic of this circuit is given in Fig. 1b. Like the integrator, the Schmitt-trigger is based on an operational amplifier. Resistor junction R_{12} - R_{13} is connected to the non-inverting opamp input and causes positive feedback instead of negative feedback as with the integrator. Contrary to a 'normal' circuit with positive feedback, however, the Schmitt-trigger sees its output voltage reach the full positive and negative supply level. When the input voltage is sufficiently positive, the output voltage reaches the positive supply level. When a negative input voltage is applied, the opamp output voltage is nought. The feedback resistor between the input and the output of the opamp also enables the circuit to settle in one of two stable states, like a flip-flop. The opamp can be made to change state by applying a sufficiently high reverse voltage to the +input. This happens when the voltage at the resistor junction exceeds that at the inverting input of the opamp. Hence, there is a certain degree of hysteresis. If we apply a sine-wave to the circuit, the output will not go high until the instantaneous amplitude of the input signal is a little higher than $0\ \text{V}$. Similarly, the output goes low when the input signal is a little below $0\ \text{V}$. The upshot is that

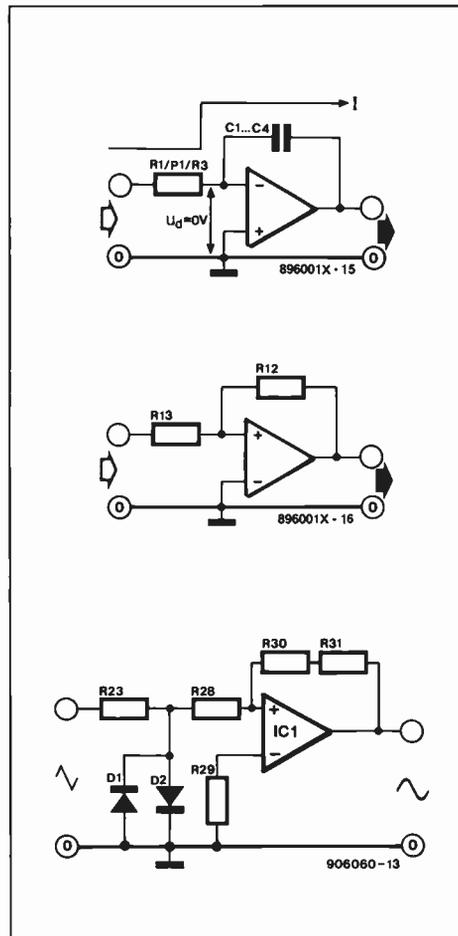


Fig. 1. The main sections of the circuit are formed by an integrator (Fig. 1a), a Schmitt-trigger (Fig. 1b), and a sine-wave shaper (Fig. 1c).

the circuit in Fig. 1b converts a sine-wave into a square-wave.

Generator

A signal generator is created by combining the circuits in Fig. 1a and Fig. 1b. In principle, all that is required is to connect the output of one circuit to the input of the other. This results in positive and negative levels at the input of the integrator, enabling the capacitor to be charged and discharged. The Schmitt trigger receives positive and negative levels from the integrator. In this configuration, the inverting function of the integrator, the delaying effect of the capacitor, and the hysteresis of the Schmitt-trigger together ensure that the circuit oscillates. In other words, what we have on paper at this stage can be used as a signal generator.

Sine-wave shaper

As already noted, the function generator is capable of supplying a sine-wave signal. Here, the sine-wave output is obtained from the triangular waveform. The circuit that performs this function is shown in Fig. 1c. The two anti-parallel diodes, D_1 and D_2 , play a crucial role. Their non-linear current-voltage characteristic causes the peak excursions of the triangular signal to be 'crushed'. The resulting waveform is a crude approximation of a sine-wave that needs to be passed

through a low-pass filter to clean up the signal.

The two diodes and R_{23} form a potential divider (p.d.). Since the lower branch of the p.d. has a non-linear behaviour (it is not a pure resistance), the ratio of the resistance in the upper branch to that in the lower branch is voltage-dependent. This is caused by the internal resistance of the two diodes, which is low at a high input voltage, and high at a low input voltage. The effect of the non-linear p.d. is that the difference between the maximum and minimum levels of the input voltage (a triangular waveform) becomes smaller. That is precisely what we are after: the peaks of the triangular wave must be 'crushed' to give the round parts of the sine-wave, and the part around the $0\ \text{V}$ potential must be 'stretched'. The circuit in Fig. 1c achieves this goal, although its output waveform is not a perfect sine-wave.

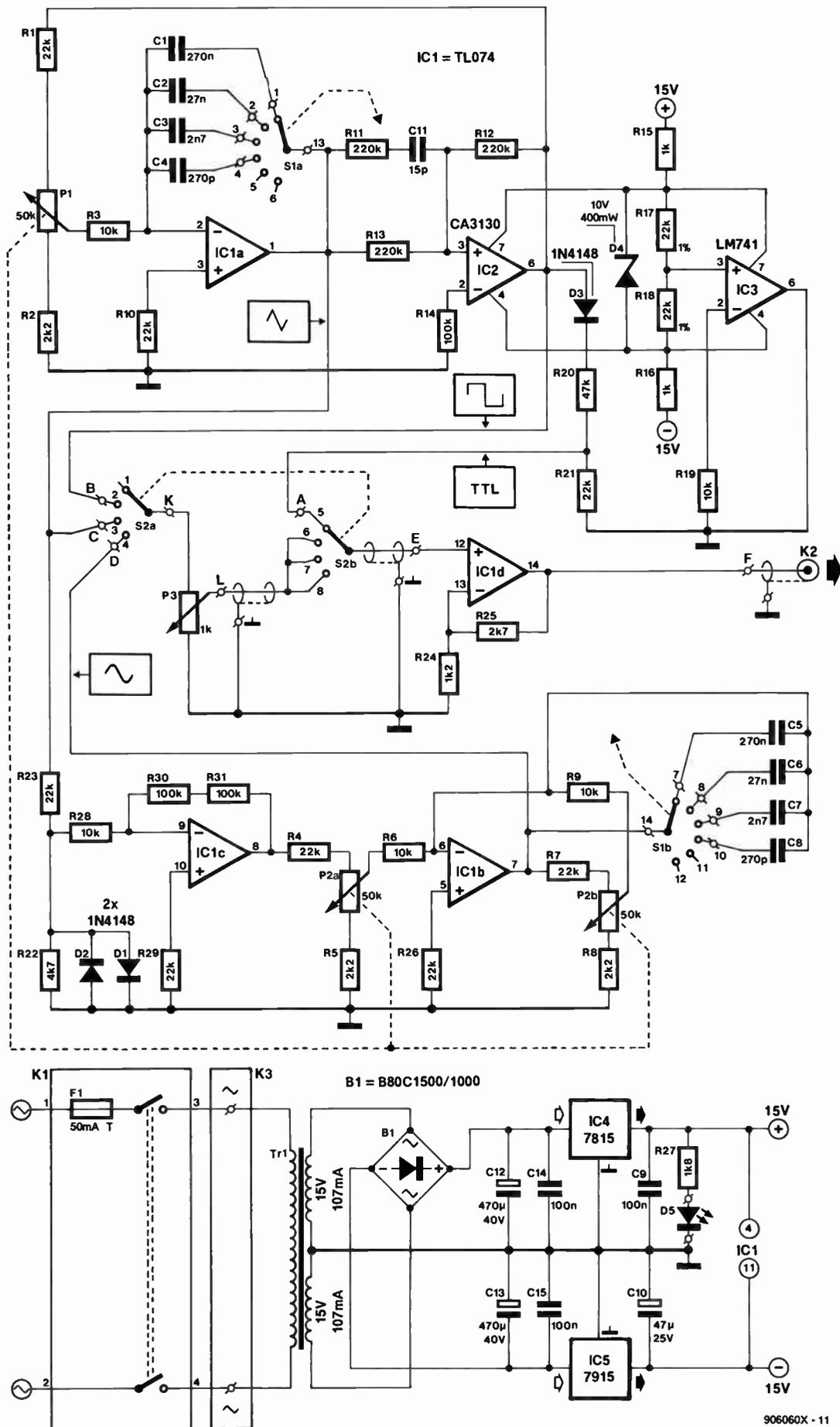
The complete circuit

In the circuit diagram in Fig. 2 we find the integrator, IC_{1a} , in the top left-hand corner. The Schmitt-trigger, IC_2 , is seen to the right of the integrator. The circuit around IC_3 provides the Schmitt-trigger, IC_2 , with an accurate symmetrical supply voltage. IC_{1d} is a standard amplifier set up to function as a buffer.

The power supply of the function generator is symmetrical with output voltages of $+15\ \text{V}$ and $-15\ \text{V}$ with respect to ground. The previously mentioned low-pass filter is formed by the circuit based on opamp IC_{1b} . Referring back to the basic circuit diagram of the integrator, Fig. 1a, the series combination of a resistor and a capacitor makes the response dependent on the frequency of the input signal. In essence, this creates a filter function. If we want to use the capacitor to enable the circuit to 'remember' the applied voltage, its function is that of an integrator. Conversely, if we want the capacitor to introduce more attenuation for high frequencies than for low frequencies, its use in combination with a resistor creates a low-pass filter. Hence, the circuit in Fig. 1a functions as an integrator as well as a low-pass filter.

For the moment, we will consider the circuit in Fig. 1a as a low-pass filter. If a resistor were fitted in the position of the capacitor, the circuit would function as a normal, opamp-based amplifier, of which the voltage gain is not dependent on the frequency. However, because of its reactance, the capacitor makes the voltage gain of the circuit frequency-dependent. Since the reactance of a capacitor drops with frequency, the circuit functions as a low-pass filter that suppresses some of the higher harmonics of the converted triangular signal.

In the circuit diagram of the function generator, the feedback capacitor in the low-pass filter, IC_{1b} , is selected by a switch, S_{1a} . The frequency determining capacitor are C_5 - C_8 . The integrator capacitors, C_1 - C_4 , are also selected by a switch, in this case S_{1b} . The switches that select the components are coupled to make sure that the frequency ran-



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Fig. 2. Complete circuit diagram of the function generator. Note the special symmetrical power supply for integrator opamp IC2.

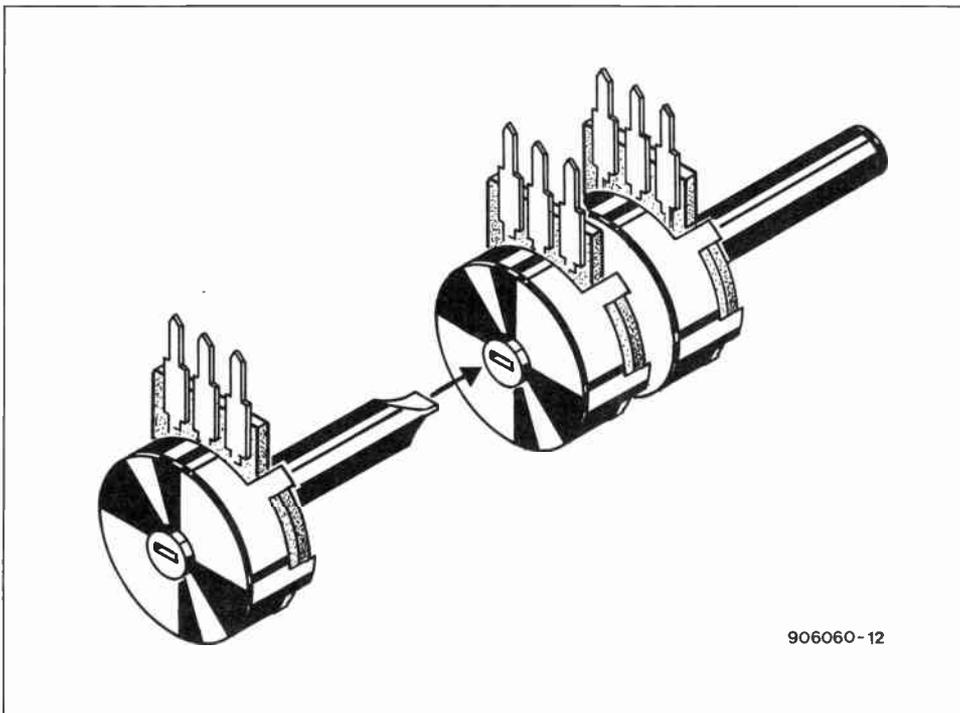


Fig. 3. A little cutting and filing does the trick: how to turn a single potentiometer and a stereo potentiometer in a ganged triple type.

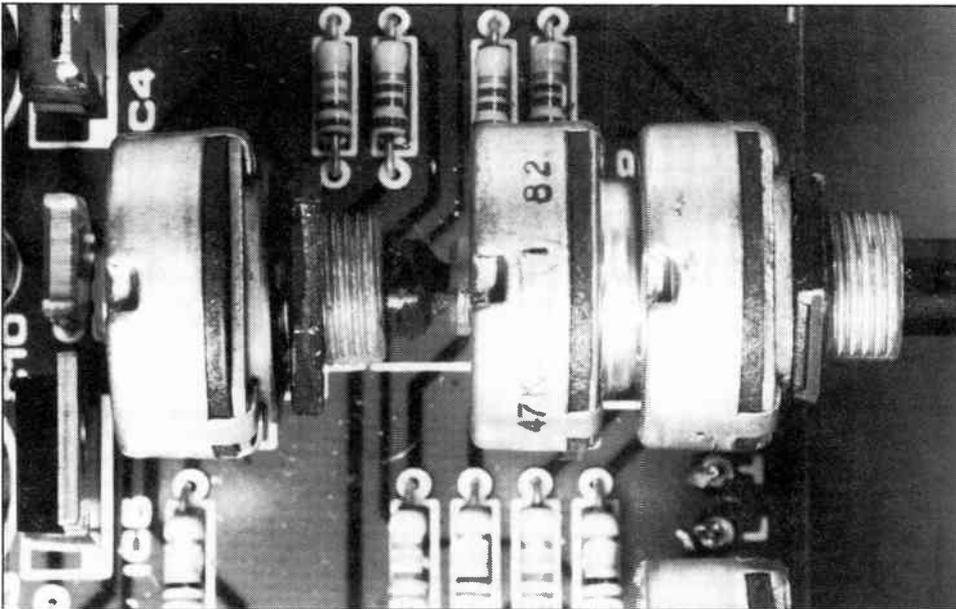
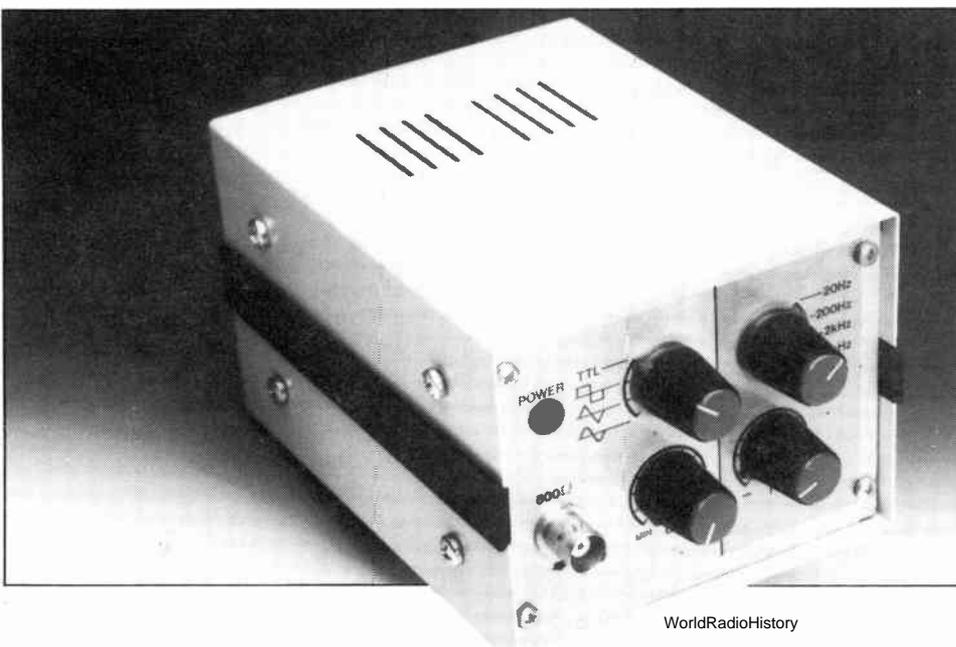


Fig. 4. Practical realization of the triple ganged potentiometer on the generator PCB.



WorldRadioHistory

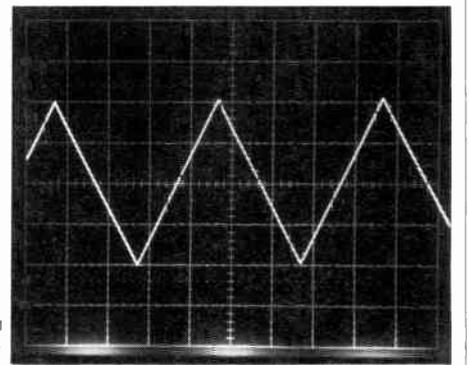
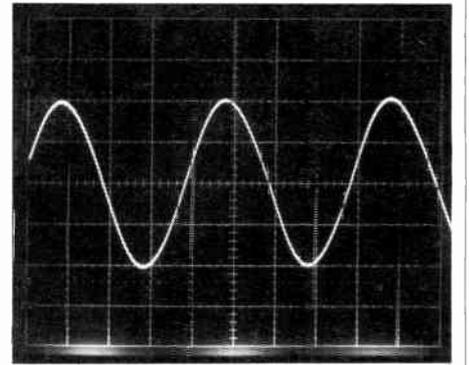
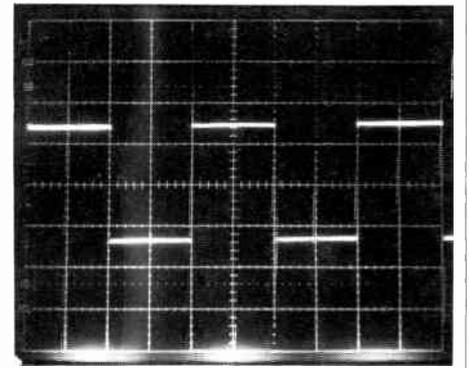


Fig. 5. Oscilloscope photographs of the waveforms produced by the function generator. Top: square wave; centre: sine wave; below: triangular wave.

ges of the low-pass filter: correspond those of the square-wave/triangular-wave generator based on IC1a and IC2.

The frequency of the signal produced by the square wave/triangular wave oscillator is determined by the charge/discharge rate of the integrator capacitor, the capacitor value and the charge voltage. The coarse frequency setting is effected by selecting a capacitor with the aid of a rotary switch. A potentiometer, P1, is used for the 'fine' frequency adjustment. Two further potentiometers, P2a and P2b, are used to adjust the low-pass filter. Since the low-pass filter must track the generator frequency, P2 is coupled mechanically to P1 (see the drawing in Fig. 3 and the photograph in Fig. 4.)

The power supply of the function generator is conventional with a symmetrical 15 V output. The ± 15 V supply voltages are used for all parts of the circuit except opamp IC2, which requires a more accurate symmetrical supply voltage to ensure that its output signal is an exact square wave. Opamp IC3 forms a stabilizer for IC2. Normally, pin 3 of

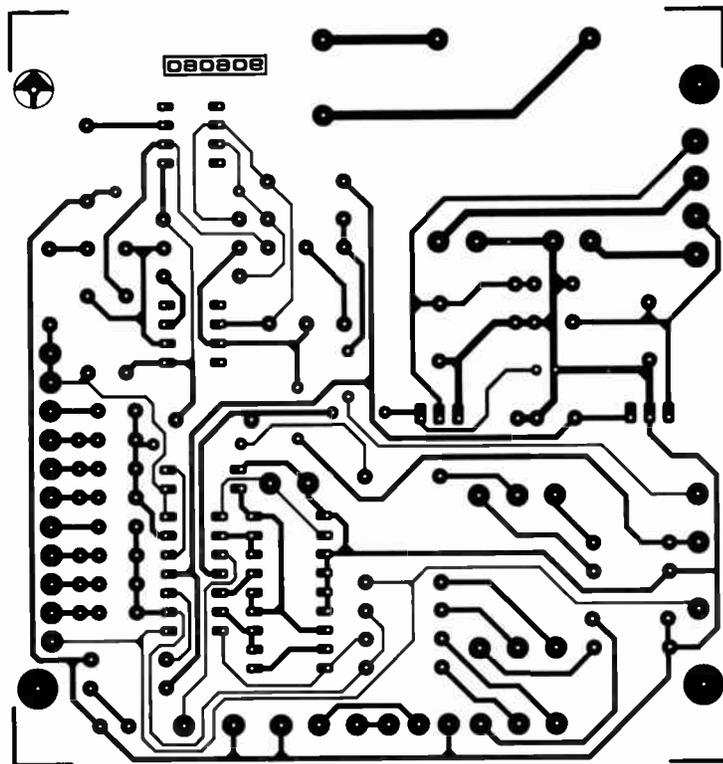
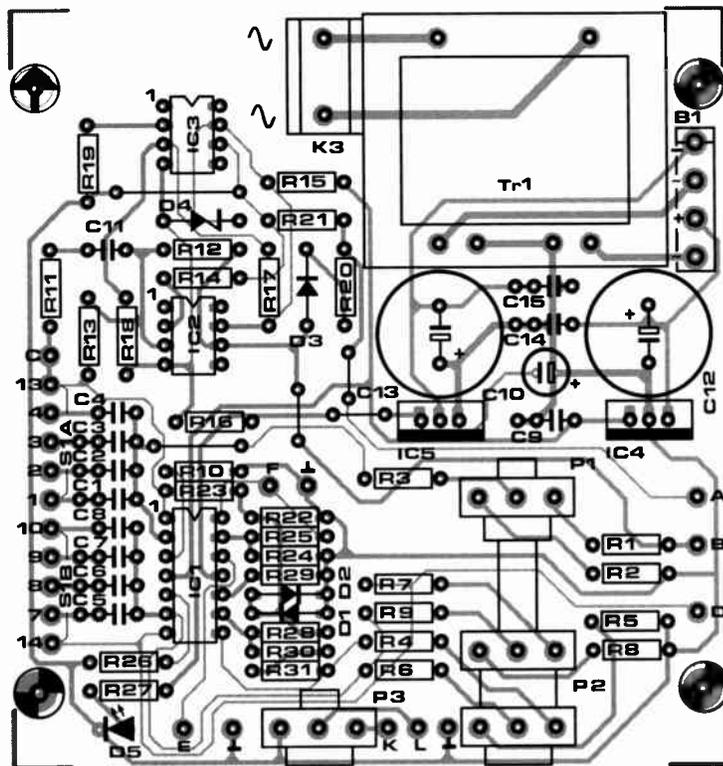


Fig. 6. Design of the single-sided printed-circuit board for the function generator. Note that the complete power supply, including the mains transformer, is accommodated on this board.

COMPONENTS LIST

Resistors:

8	22k Ω	R1, R4, R7, R10, R21, R23, R26, R29
3	2k Ω	R2, R5, R8
5	10k Ω	R3, R6, R9, R19, R28
3	220k Ω	R11, R12, R13
3	100k Ω	R14, R30, R31
2	1k Ω	R15, R16
2	22k Ω 1%	R17, R18
1	47k Ω	R20
1	4k Ω 7	R22
1	1k Ω 2	R24
1	2k Ω 7	R25
1	1k Ω 8	R27
1	50k Ω linear potentiometer	P1
1	50k Ω linear stereo potentiometer	P2
1	1k Ω linear potentiometer	P3

Capacitors:

2	270nF	C1, C5
2	27nF	C2, C6
2	2nF7	C3, C7
2	270pF	C4, C8
3	100nF	C9, C14, C15
1	47 μ F 25V radial	C10
1	15pF	C11
2	470 μ F 40V radial	C12, C13

Semiconductors:

3	1N4148	D1; D2; D3
1	10V 400mW zener diode	D4
1	LED 5mm red	D5
1	B80C1500	B1
1	TL074	IC1
1	CA3130	IC2
1	LM741	IC3
1	7815	IC4
1	7915	IC5

Miscellaneous:

1	PCB-mount transformer 2 \times 15V @ 2 \times 107mA	Tr1
2	2-pole 6-way rotary switch	S1; S2
1	mains appliance socket w. built-in fuseholder and 50mA fuse	K1
1	BNC socket	
1	2-way PCB terminal block	K3
1	enclosure LC730 (manufacturer: Telet; supplier: C-1 Electronics)	

IC3 is held at ground potential by a symmetrical potential divider, R15–R18. The output of IC3, pin 6, is therefore also at ground potential. However, when the ± 15 V input voltage is not exactly symmetrical (for example, when the +15 V voltage is a little higher than the –15 V voltage), the voltage at pin 3 of IC3 rises. Consequently, the output of IC3 will try to track this change by raising the output voltage. This is not possible, however, since the output is connected to ground. The result is that a positive current flows from the output of IC3 into the ground line. Since this current is supplied via R15, the voltage drop across R15 rises, so that the positive supply voltage of IC2 (pin 7) drops. In this way, the too high supply voltage is re-

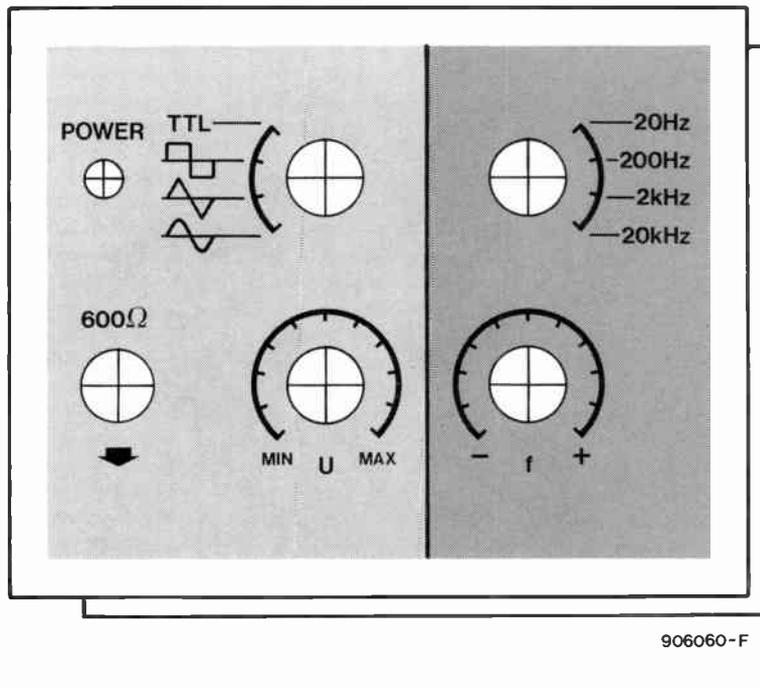


Fig. 7. Suggested design of a front panel for the function generator.

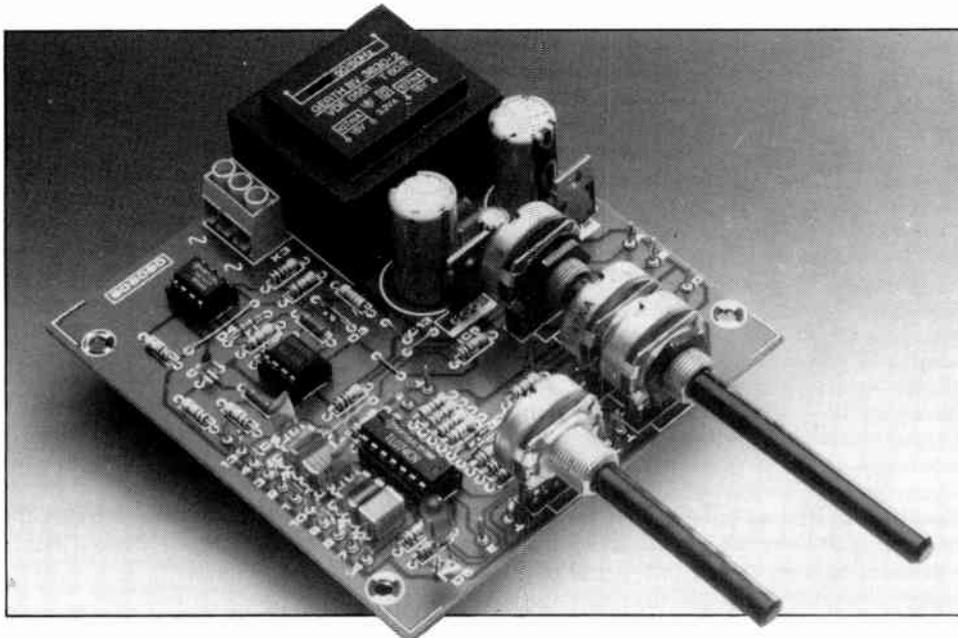


Fig. 8. Completed printed-circuit board viewed from the component side.

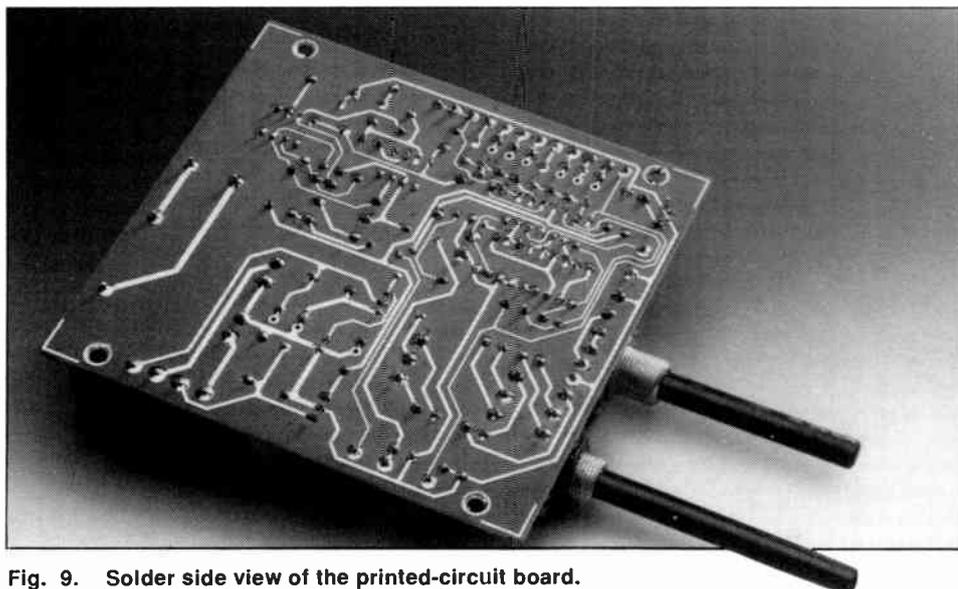


Fig. 9. Solder side view of the printed-circuit board.

duced and stabilized. The operation of the stabilizer is the same for too high levels of the negative supply voltage, -15 V . The zener diode in the stabilizer, D_4 , limits the output voltage of IC_2 to 10 V_{pp} .

The circuit based on IC_{1d} is a buffer with a short-circuit resistant output (connector K_2). The potentiometer at the input of the buffer, P_3 , forms the output level control of the function generator. The output voltage available at K_2 can be set between 0 V and 12 V .

The waveform selection is accomplished with a four-way, 2-pole switch, $S_{2a/2b}$, connected ahead of the buffer. The square-wave setting has two options: a fixed output voltage of 5 V for TTL circuits, or 0 V to 12 V (variable) for all other applications. The positive half-cycles of the 5-V square wave are obtained from the output voltage of IC_2 . A diode, D_3 , passes only the positive half-cycles to a potential divider, $R_{20}\text{-}R_{21}$ and a buffer, IC_{1d} . The photographs in Fig. 5 show the waveforms produced by the generator.

Construction

The function generator is best built on the printed-circuit board shown in Fig. 6. A suggested front-panel design is shown in Fig. 7. The connection of the range select switches to the board involves quite a few wires, so make sure you understand the pinning of the rotary switches. Keep all wires as short as possible. Also note that the connections to the output buffer, IC_{1d} , are made with three screened cables (refer back to the circuit diagram in Fig. 2). The photographs in Figs. 8 and 9 show the completed circuit board, viewed from the component side and the track side respectively. The board is fitted on four short plastic PCB spacers to avoid any risk of the mains-carrying PCB tracks touching the bottom cover of the metal enclosure

SERIAL VIDEO CARD

This design, based on a 6847 video display generator and the 8031 single-chip microcontroller, provides a simple solution to the problem of interfacing serial ASCII data for display on a monitor.

R. Grodzik

THE unit proposed here is basically a simple terminal for use with small computer systems that do not have their own display interface, but are capable of supplying serial RS-232 or inverted TTL ASCII data. The serial video card is capable of working at a selectable bit rate, and has a RAM (random-access memory) with storage capacity for up to 16 pages (or screens) of information.

As shown in the block diagram, Fig. 1, the system has two push-buttons; one is used to leaf forward through the pages of text, while the other, the reset key, is used to initialize the system, to home to the first text page, and to configure the bit rate on the serial input channel.

The unit has been designed as a minimum text display device with a reduced character set displaying upper-case characters only. Lower-case characters sent by the computer are displayed as upper case. The available character set is listed in Table 1, along with the line and page control codes.

The RAM in the system allows 16 screens of alpha-numeric data to be stored and displayed one at a time, providing a total capacity of 8,000 characters. The screen mode is

organized as 16 lines with 32 characters per line, giving 512 characters per screen. If the amount of data received at the serial input exceeds the screen capacity, the next page is automatically selected, until all 16 pages have been filled. Furthermore, there is an

automatic wrap-around facility when the earlier data in the first page is overwritten.

Applications

I am often asked "What is it for?" or "What does it do?", when completing a design. Well, the answer is: it depends on you. Here are a few examples of what my colleagues have come up with:

- A serial keyboard which provides an ASCII encoded output (note that IBM PC keyboards are not suitable as they produce their own unique codes). The serial keyboard is connected to the input of the video card to give a basic text display terminal.
- Connected between a modem and a television receiver, incoming computer data can be displayed on your TV set. This application may be of interest to the deaf and hard of hearing.
- A video answering machine?
- A teaching aid.
- With additional battery back-up for the video RAM, text can be downloaded from a computer station for subsequent

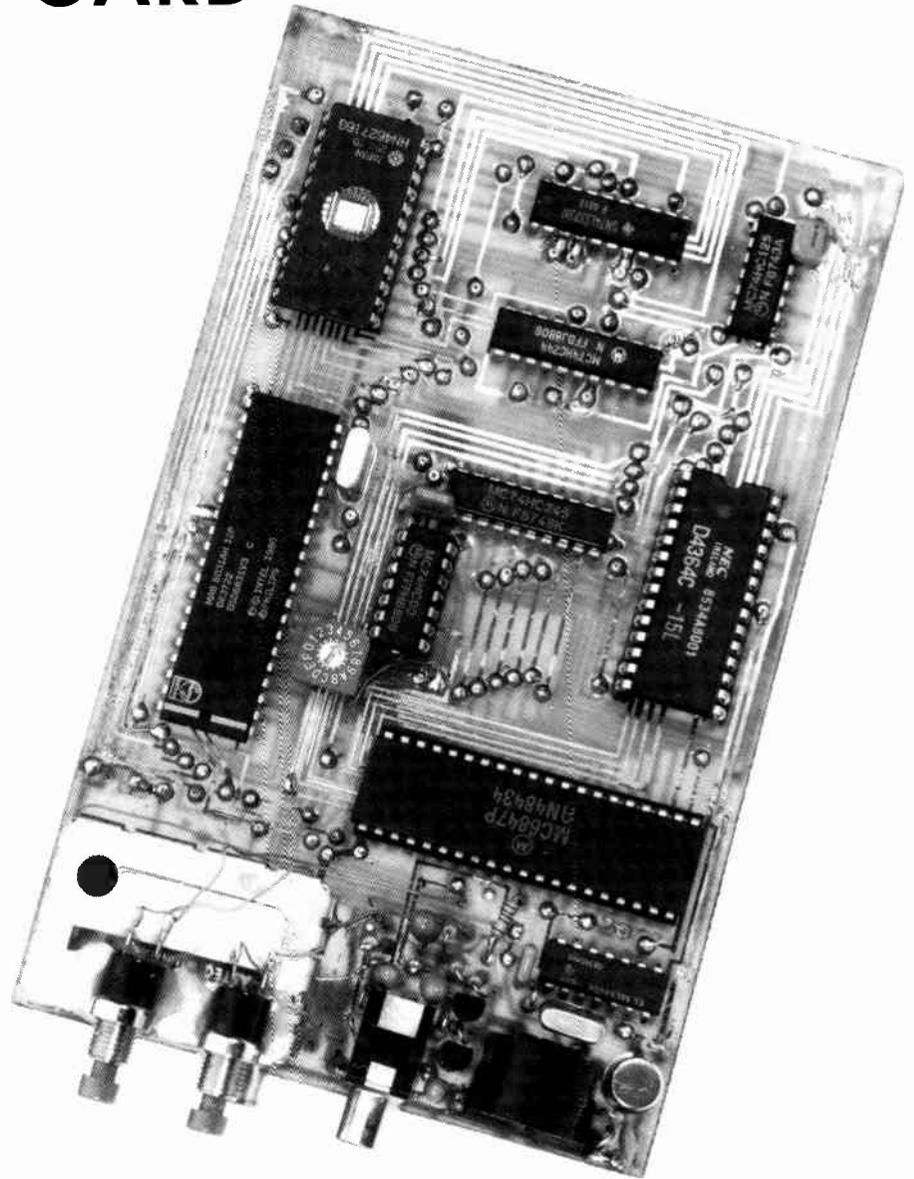


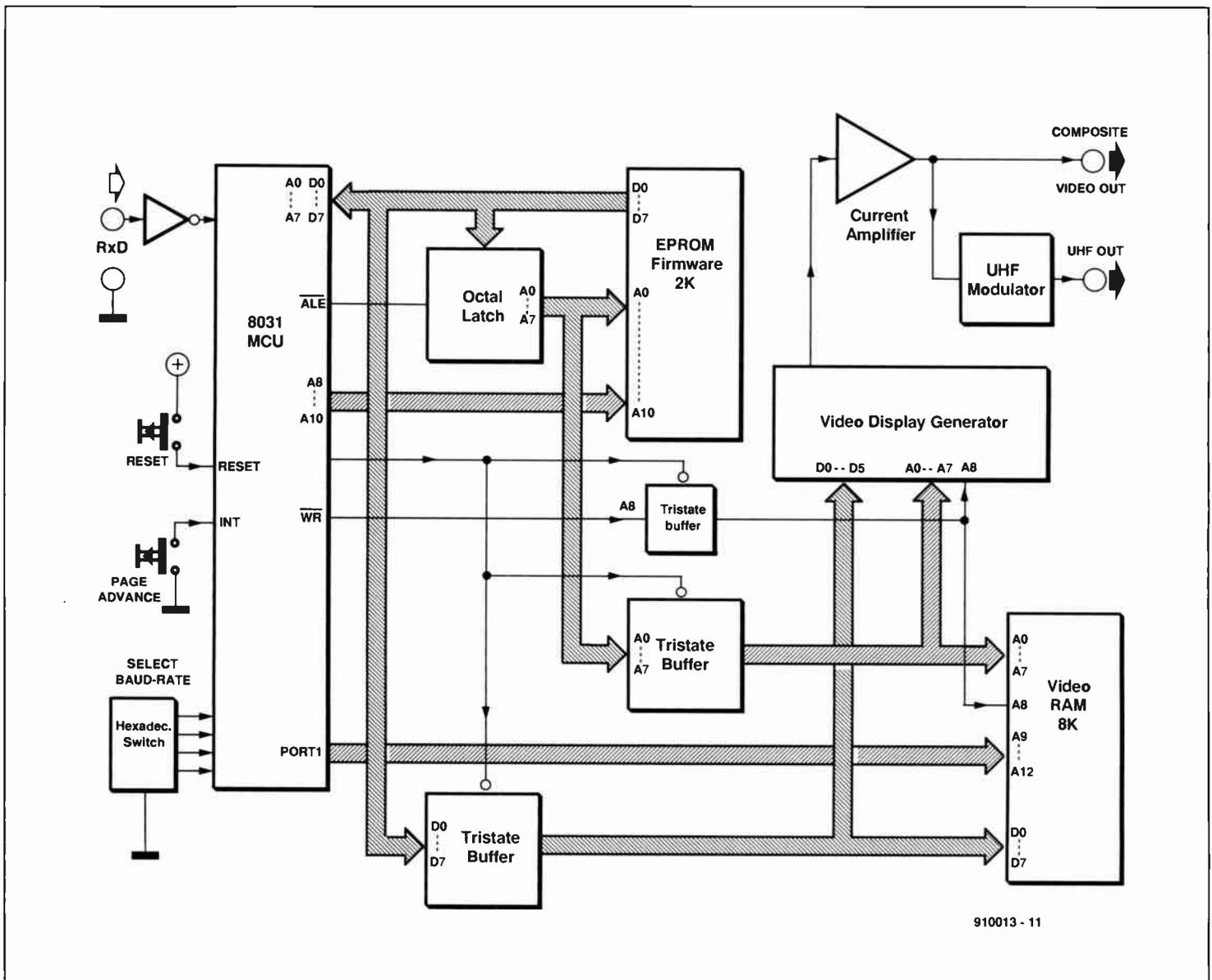
Table 1. The character set

A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	
0	1	2	3	4	5	6	7	8	9	!	"	\$	%	&	'	()	=	-	.	:	;	/	?	+ [/]	
→ ↑ ← (space)																										

Control codes:

0DH	carriage return
08H	backspace
09H	horizontal tab
0AH	linefeed
0CH	next page (form feed)
0FH	clear screen

all other codes are ignored



910013 - 11

Fig. 1. Block diagram of the serial video card. At the heart of the circuit is a 8031 single-chip microcontroller.

- remote display on a TV set or a monitor.
- A video carousel for promotional and advertising purposes.

Circuit description

The complete circuit diagram of the serial video card is given in Fig. 2. On power-up, or pressing RESET button SW1, the hexadecimal switch SW3 is read by IC2, a single-chip computer, and the bit rate on the serial input channel is initialised. Table 2 lists the bit rates that can be selected by SW3. The word protocol follows the most commonly used format with 1 start bit, 8 data bits, 1 stop bit and no parity.

The serial data applied to the circuit is converted into parallel data by the system firmware, and subsequently sent to the video RAM, IC10. For this to be accomplished, the tri-state buffers IC4, IC5 and IC6 are enabled by address line A15 and \overline{WR} lines of the 8031. At the same time, the video generator, IC9, and the data and address buses are switched to a high impedance state by IC8D, and the system EPROM, IC1, is disabled by A15. One databyte is thus transferred from the 8031 on to datalines D0-D5. Databit D6 is

lost since it not required by the character generator. Dataline D7 on IC10 provides a reverse video facility during the power-up self test, when the entire available character set is generated, a screenful of each character. This test feature is useful if an address or data line is open or shorted, since the monitor will show up either fault.

Once the video RAM has been updated, the tri-state buffers IC4, IC5 and IC6 are disabled, the IC9 buses are enabled, and address lines A0-A8 are strobed by IC9 to access the

ASCII data. Data goes into IC9 on lines DD0-DD5, and is converted into a composite serial video signal on pin 28 of IC9.

The video signal is inverted by transistor T1, and buffered by T2 to drive the 75 Ω load formed by the monitor input. Two outputs are provided: K2 supplies the 1 V_{pp} 75- Ω composite video to the monitor, while K1, the phono-type socket on the TV modulator, supplies a modulated RF signal at 591.5 MHz in the UHF TV band, for connection to the aerial socket of a domestic television receiver.

Subsequent serial asynchronous data words are fed to the video RAM. After 512 characters, port address P1.0-P1.3 on the 8031 increments, which, in turn, selects the next block of 512 locations in IC10. Address lines A9-A12 of IC10 provide 16 pages of text storage capacity.

About the Video Generator

Each character on the screen is consists of a pattern of light and dark dots. Dot patterns for the desired characters are stored permanently in the character generator, as illustrated in Fig. 3. This simplified block

Table 2. Bit rate settings (SW3)

Position	Bit rate/Function
0	150
1	300
2	600
3	1200
4	1800
5	2400
6	power-on self test

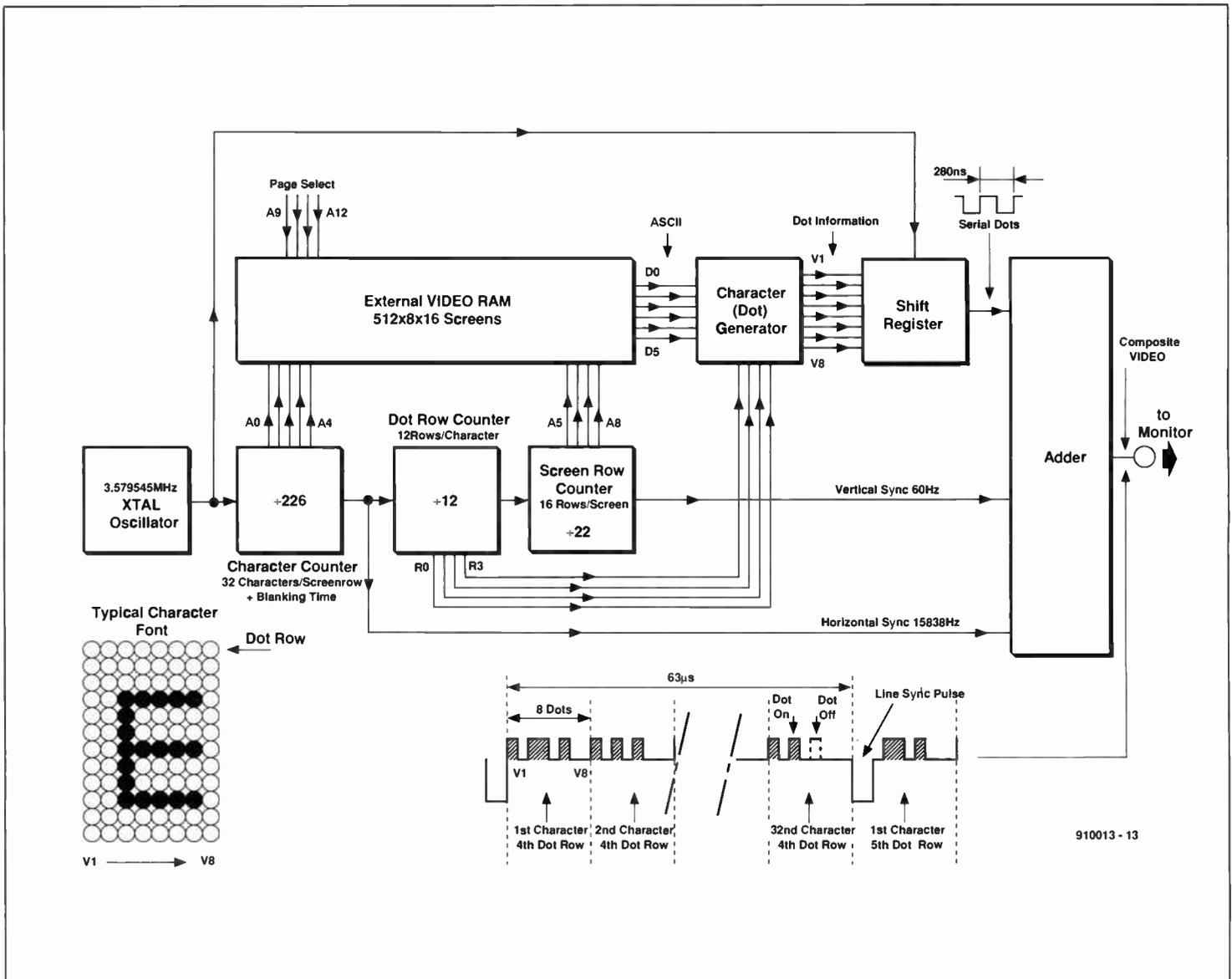


Fig. 3. Simplified block schematic of the video generator.

diagram shows how a chain of counters are cascaded to provide the timing required for the monitor circuitry.

The clock signal for the video generator is derived from an inexpensive 3.579 MHz (NTSC subcarrier) quartz crystal. The dot clock signal enables the video dots to be clocked out of the shift register. As the first ASCII character in RAM is accessed by the +226 counter, the character generator is addressed via data lines D0-D5. The dot information required to produce the first dot row of the character resident in the character generator is presented to the parallel-in, serial-out shift register. The dot clock is used to shift out the eight dots required to turn the CRT (cathode ray beam) beam in the monitor on or off, which produces the first line of dots for the character.

The address on lines A0-A4 increments once every eight dot clock cycles to address the next ASCII character in RAM, and the first dot row of this character is clocked out to the CRT. Address lines A0-A4 can select one of 32 characters needed for a complete line of text on the screen.

The output of the +226 counter produces a line sync pulse after the first dot row of all 32 characters is clocked out. The +12 counter

COMPONENTS LIST

Resistors:

1	47k Ω	R1
1	4k Ω	R2
1	8k Ω	R3
2	470 Ω	R4;R5
1	6k Ω	R6
1	2k Ω	R7
1	1k Ω	R8
2	270 Ω	R9;R10
1	82 Ω	R11
1	3k Ω	R12

Capacitors:

1	10 μ F tantalum bead	C1
1	10nF	C2
3	22 μ F tantalum bead	C3;C4;C5
2	33pF	C6;C7
10	100nF ceramic	IC decoupling capacitors

Semiconductors:

1	1N4148	D1
1	2N3053	T1
2	BC547	T2;T3
1	27C16	IC1
1	80C31	IC2

1	74HC373	IC3
1	74HC244	IC4
1	74HC245	IC5
1	74HC125	IC6
1	74HC00	IC7
1	74HC04	IC8
1	6847	IC9
1	6264	IC10

Miscellaneous:

1	12 MHz quartz crystal	X1
1	3.579 MHz quartz crystal	X2
2	push-to-make button	SW1;SW2
1	PCB-mount hex switch	SW3
1	UHF TV modulator UM1233	
1	5-way DIN socket for PCB mounting	
1	PCB-mount phono socket	
	0.8 mm PCB pins	
	DIL turned pin sockets	

Note: the pre-programmed EPROM and the PCB artwork for this project are available from R. Grodzik • 53 Chelmsford Road • BRADFORD BD3 8QN • ENGLAND. The price of the EPROM is £15.00 inclusive of P&P.

```

00000: 02 00 40 02 04 31 FF FF
00010: FF FF D2 8E A3 32 FF FF FF FF FF FF 02 03 00 FF FF FF FF
00020: C0 D0 C0 E0 7E FF 1E 7F FF 1F BF 00 FC BE 00 F0 F6
00030: D0 E0 D0 D0 22 75 09 00 75 08 00 32 FF FF FF FF FF
00040: 31 00 31 05 11 B0 31 05 D2 A8 C2 BC D2 B8 00 00
00050: FF FF
00060: E5 90 FB F5 90 BB F0 02 7C 30 BB E0 02 7C 98 BB
00070: D0 02 7C CC BB C0 02 7C E6 BB B0 02 7C EF BB A0
00080: 02 7C F3 BB 90 06 12 02 00 02 00 40 31 16 11 20
00090: 11 20 11 20 11 20 11 20 11 20 31 09 31 05 8C 8D
000A0: 75 98 50 75 89 20 D2 8E D2 AF D2 AB 80 FE 80 FC
000B0: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
000C0: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
000D0: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
000E0: 00 00 00 00 00 00 00 00 00 00 00 00 00 02 02 C0
000F0: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
00100: 74 F0 F5 90 22 90 80 00 22 90 80 00 74 20 F0 A3
00110: A8 83 B8 82 F7 22 90 80 E6 74 0A C0 E0 83 F0 A3
00120: D0 E0 04 B4 1D F5 80 14 53 59 53 54 45 4D 20 49
00130: 4E 49 54 49 41 4C 49 53 45 44 20 20 BB F0 14 74
00140: 0B C0 E0 83 F0 A3 00 D0 E0 04 B4 0F F4 80 04 31
00150: 35 30 20 BB E0 14 74 0B C0 E0 83 F0 A3 00 D0 E0
00160: 04 B4 0F F4 80 04 31 30 30 20 BB D0 14 74 0B C0
00170: E0 83 F0 A3 00 D0 E0 04 B4 0F F4 80 04 36 30 30
00180: 20 BB C0 14 74 0B C0 E0 83 F0 A3 00 D0 E0 04 B4
00190: 0F F4 80 04 31 32 30 30 BB B0 14 74 0B C0 E0 83
001A0: F0 A3 00 D0 E0 04 B4 0F F4 80 04 31 38 30 30 BB
001B0: A0 14 74 0B C0 E0 83 F0 A3 00 D0 E0 04 B4 0F F4
001C0: 80 04 32 34 30 30 22 FF FF FF FF FF FF FF FF FF
001D0: E5 90 04 54 0F F5 90 22 FF FF FF FF FF FF FF FF
001E0: FF FF
001F0: FF FF
00200: 74 80 C0 E0 F0 A3 A8 83 B8 82 F9 11 20 11 20 31
00210: 09 31 05 D0 E0 04 B4 00 E9 22 02 04 80 00 00 00
00220: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 A8 82
00230: B8 00 02 80 03 B8 20 02 80 03 B8 40 02 80 03 B8
00240: 60 02 80 03 B8 00 02 80 03 B8 A0 02 80 03 B8 C0
00250: 02 80 03 B8 E0 03 D2 8E 32 15 82 D2 8E 32 A8 82
00260: B8 1F 02 80 03 B8 3F 02 80 03 B8 5F 02 80 03 B8
00270: 7F 02 80 03 B8 9F 02 80 03 B8 BF 02 80 03 B8 DF
00280: 02 80 03 BF 0F 03 D2 8E 32 05 82 D2 8E 32 74 20
00290: A3 14 B4 00 FB A8 83 B8 82 0D 90 80 00 E5 90 04
002A0: 54 0F F5 90 D2 8E 32 D2 8E 32 00 00 00 E5 90 04
002B0: 54 0F F5 90 D2 8E 31 05 32 74 20 02 02 1A FF FF
002C0: C0 90 75 F0 10 E5 90 54 0F 04 F5 90 31 09 D5 F0
002D0: F4 D0 90 22 FF FF
002E0: FF FF
002F0: FF FF
00300: 30 98 FD C2 8E C2 98 E5 99 A2 D0 B2 D7 54 7F B4
00310: 20 03 02 02 B9 C0 E0 54 60 60 05 D0 E0 02 02 1A
00320: D0 E0 B4 08 03 02 02 2E B4 09 03 02 02 5E B4 0A
00330: 03 02 02 8E 00 00 00 00 00 00 00 B4 0C 03 02 02 AD
00340: B4 0D 03 02 04 00 00 00 00 00 00 00 00 B4 0F 06 12
00350: 01 09 90 80 00 D2 8E 32 FF FF FF FF FF FF FF FF
00360: FF FF
00370: FF FF
00380: FF FF
00390: FF FF
003A0: FF FF
003B0: FF FF
003C0: FF FF
003D0: FF FF
003E0: FF FF
003F0: FF FF
00400: E5 82 54 1F B4 00 02 80 05 15 82 14 80 F6 D2 8E
00410: 32 B8 60 02 80 03 B8 80 02 80 03 B8 A0 02 80 03
00420: B8 C0 02 80 05 B8 E0 05 80 03 D2 8E 32 15 82 80
00430: CF C2 8E C2 A8 11 20 C0 E0 E5 90 04 54 0F F5 90
00440: D0 E0 00 00 00 00 00 00 00 00 00 00 31 05 11 20
00450: 11 20 D2 A8 D2 8E 32 FF FF FF FF FF FF FF FF FF
00460: FF FF
00470: FF FF
00480: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
00490: 00 00 00 00 00 00 00 00 00 30 E6 02 C2 E5 00 00
004A0: 00 A8 83 B8 82 0F C0 E0 E5 90 04 54 0F F5 90 00
004B0: 00 31 05 D0 E0 F0 A3 D2 8E 32 FF FF FF FF FF FF
004C0: FF FF
004D0: FF FF
004E0: FF FF

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910013-14

tional circuitry is needed to produce a blanking (beam retrace) signal for the monitor, and also to combine the vertical and horizontal sync signals with the serial dot stream. The combination of these signals is called the composite video signal.

The complex functions described in relation to the video generator circuitry are accomplished by a VLSI (very large scale integration) IC, the 6847 from Motorola. This chip thus performs the definitely non-trivial task of interfacing a microprocessor to a computer monitor or television set.

Construction notes

The serial video card is built on a double-sided, not through-plated printed circuit board of Eurocard size (10x16 cm). The author's prototype is shown in the introductory photograph. For constructors wishing to burn their own EPROM for this project, the content of the 27C16 is given in Fig. 4.

It is recommended that all ICs be fitted in sockets, particularly IC9, which is static sensitive. The usual precautions, such as grounding the circuit board and yourself, should be taken. Be sure not to wear a nylon shirt or pullover when handling any of the ICs.

All logic ICs must be devices from one and the same family, in this case the HC series. Mixing HC series with standard 74 series ICs will produce timing errors and random display of information, since the input and output voltage thresholds are incompatible.

Ceramic decoupling capacitors should be fitted directly on the supply pins of the ICs, at the track side of the board.

Printed circuit linking pins, totalling over 150, are inserted from the component side during the initial stages of construction. The holes for these pins are drilled at a diameter of 0.8 mm. Care should be taken while soldering, since solder bridges are easily made. A watchmakers' eyepiece is useful for inspecting the board, since solder whiskers can easily evade the human eye. Once the linking pins are in place, the IC sockets are soldered in. Next, fit the discrete analogue video components. Then follows the ready-made UHF modulator, which is also static sensitive.

Finally, the power supply to the board is 5 V, at a total current consumption of about 200 mA. ■

Fig. 4. Hexdump of the control program that resides in the system EPROM, a 27C16.

then increments to point to the next lower row of dot patterns for the same 32 characters. As the CRT beam sweeps across the screen, the dot information of the subsequent 11 rows of each character is traced on to the screen after every line sync pulse.

When all 12 rows of all 32 characters are traced, the +22 counter increments the address on lines A5-A8, and the next screen row of 32 RAM-resident characters is addressed. The dot information for these characters is clocked out as described above. When 16 lines of characters have been dis-

played on the monitor, the final output of the +22 counter issues a vertical sync pulse required by the monitor circuitry to restart the raster scan, by which time all the counters have been re-initialized to zero. Thus, all 512 characters are continuously refreshed to the monitor, 60 times per second, corresponding to about three million dots per second.

External lines A9-A12 on the 8031 allow one of 16 different blocks of 512 characters to be addressed, providing a total of 16 screens of information.

In addition to the chain of counters, addi-

MIDI-TO-CV INTERFACE

Older monophonic synthesizers have the disadvantage that they cannot be controlled via a Musical Instrument Digital Interface—MIDI. Since most owners of these synthesizers, which are rightly renowned for their excellent sound, would be loath to get rid of them just yet, this article describes an interface that enables these units to be controlled via a MIDI, provided they conform to the 1 V/octave logarithmic standard.

CONNECTION to the MIDI is made via a standard MIDI IN socket that is located on the printed-circuit board of the present interface. A MIDI THRU/OUT socket enables additional MIDI compatible equipment to be controlled. The MIDI receive channel of the present interface is set via a 4-pole DIP switch.

Connection from the interface to the synthesizer is via two 6.3 mm audio connectors: one for the control voltage—CV (1 V/octave) and the other for the gate signal. Either a positive or a negative gate signal may be selected.

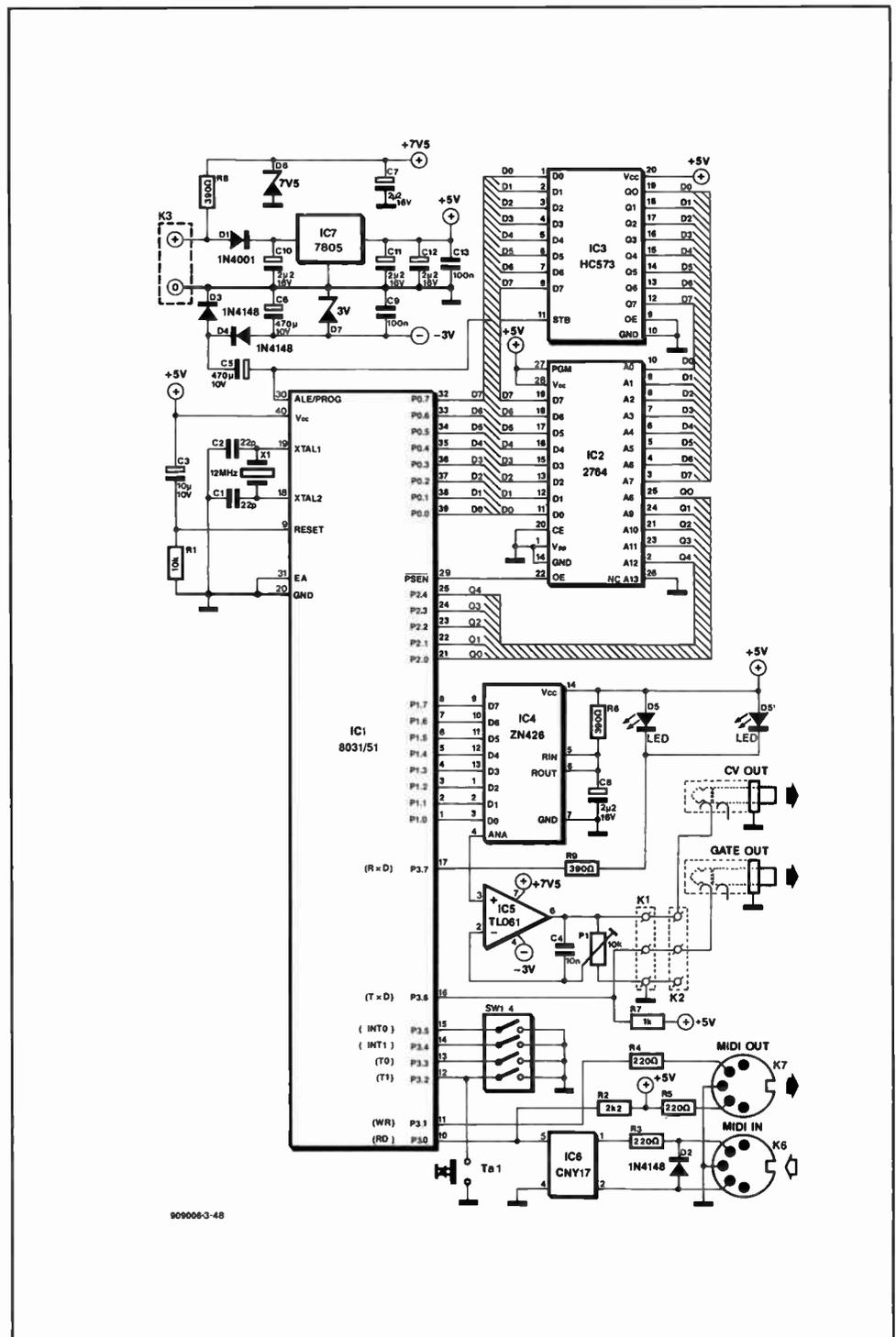
The interface receives MIDI note-on and note-off instructions from which it gathers the control voltage and status of the gate needed to be supplied to the synthesizer so that this produces the tones associated with the MIDI data. The MIDI code for the touch control is not involved and is of no further interest here.

In conformity with accepted standards, the interface software uses MIDI controller no. 36 as the reference tone for 0 V, that is, MIDI tone value 36, equivalent to low C on a standard 5-octave keyboard, is produced when the CV output is 0 V. The maximum tone range is 5 octaves, produced by a control voltage range of 0–5 V.

The interface is powered by an external mains-operated supply: the three required voltages are derived on the interface board.

Circuit description

The MIDI signal is applied to serial input P3.0 (pin 10) of microcontroller IC₁ via the obligatory optocoupler, IC₆. The program, stored in IC₂, responds to note-on and note-off commands in the MIDI channel selected with switches SW₁–SW₄. It computes from the MIDI data the corresponding analogue voltage, later converted into digital form, and the status of the gate. The voltage is available in digital form at the 8-bit port P1, which is connected with the digital inputs of 8-bit analogue-to-digital converter IC₄. The output of this converter is a voltage that is directly proportional to the digital value at port P1. The scale of the control voltage is set by opamp IC₅, whose gain is varied with the aid of preset P₁.



The status of the gate is available simultaneously at port lines P3.6 and P3.7. Depending on the software, P3.6 is active high (i.e., +5 V with key depressed) or active low (i.e., 0 V with key depressed).

The heart of the interface is microcontroller IC₁, which consists of an 8-bit microprocessor, 128 byte RAM, four ports of eight lines (bits) each, P0–P3, a serial interface with programmable baud rate, and two 16-bit counter/clocks. Note that the difference between a Type 8031 and a Type 8051 IC is that the former has on-board ROM. If, therefore, an 8051 is used, its internal ROM must be switched off via pin 31 (EA), since the program is stored in an external ROM. A more

detailed description of the 8031/8051 may be found in Ref. 1.

Since the 8051 has no separate terminals for address and data buses, ports P0 and P2 are used for this purpose. Port P0 serves as a multiplexed address-cum-data bus for the eight lowest bits, and P2 as that for the eight highest bits.

Circuit IC₂, an eight-fold latch, assumes the eight lowest addresses from port P0 at the trailing edge of the ALE (address latch enable) signal. The eight highest addresses are provided by P2.0–P2.4. From the leading edge of the ALE signal onwards, P0 functions again as data bus.

The program is stored in IC₃, an EPROM

Type 2764. Although this is available ready-programmed, it may, of course, be programmed to individual requirements.

The 8031/8051 has a complete serial interface, i.e., input and output, as required for MIDI operation. When a 12 MHz clock is used, the internal baud rate generator is adjusted via the software to operate at 31.25 kHz. The input of the interface is P3.0 (RD=read) and the output is P3.1 (WR=write).

The MIDI input circuit is based on optocoupler IC₆. Input resistor R₃ limits the current through the photodiode, while D₂ protects the LED against negative input voltages. The open-collector output of the optocoupler is connected to serial input P0.3 and to

PARTS LIST

Resistors:

R₁=10 kΩ
R₂=2k2
R₃–R₅=220 Ω
R₆, R₈, R₉=390Ω
R₇=1 kΩ
P₁=10 kΩ, 25-turn preset

Capacitors:

C₁, C₂=22 pF, ceramic
C₃=6.8–10 μF, 16 V, tantalum
C₄=10 nF, ceramic
C₅, C₆=100–470 μF, 10 V, upright
C₇, C₈=1.5–6.8 μF, 16 V
C₉=100 nF
C₁₀–C₁₂=1.5–6.8 μF, 16 V, or
10–100 nF, ceramic

Semiconductors:

D₁=1N4001–1N4007
D₂, D₃, D₄=1N4148
D₅ (D₅')=LED
D₆=zener, 7.5 V (ZPD 7V5)
D₇=zener, 3 V (ZPD 3V0)
IC₁=SAB8031 or SAB8051
IC₂=2764 EPROM
IC₃=74HC573, 74HCT573
IC₄=ZN426E-8
IC₅=TL061
IC₆=CNY17/II
IC₇=7805

Miscellaneous:

X₁=12 MHz crystal
SW₁–SW₄=4-way DIP switch
K₁, K₂=3-way pin header,
2.54 mm grid
K₃=low-voltage socket for PCB
K₄, K₅=6.3 mm (stereo) audio
connector for PCB
K₆, K₇=5-pin DIN socket for PCB
IC socket 40-pin
IC socket 28-pin
IC socket 20-pin
IC socket 14-pin
2× IC socket 8-pin
2× insulated jumper (J₁ and J₂)
Heat sink for IC₇
Unregulated 9–12 V, 300 mA mains
adaptor

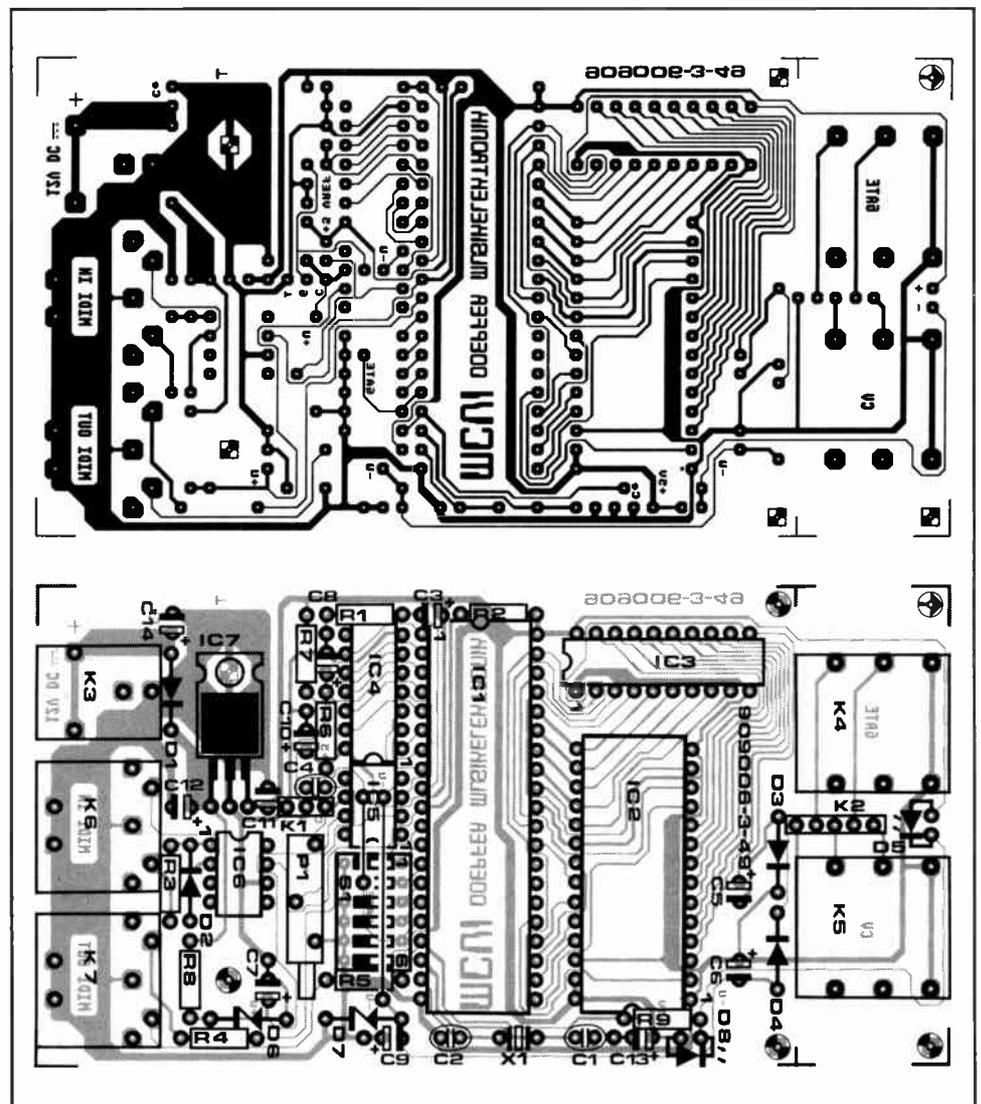
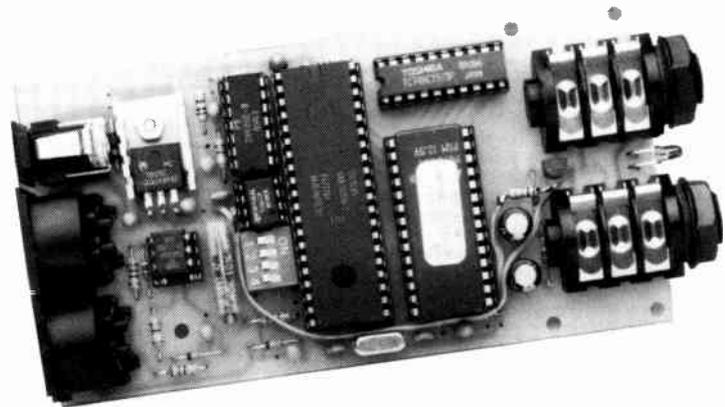


Fig. 2. Printed-circuit board for the MIDI-to-CV interface.(not available ready-made).

the +5 V supply via pull-up resistor R_2 .

The MIDI OUT socket is connected via the obligatory 220- Ω resistors, R_4 and R_5 , to P3.1 and the +5 V line respectively.

Components X_1 , C_1 , and C_2 are the external elements for the internal clock oscillator of the 8031/8051; their values are as specified by the manufacturers.

Resistor R_1 and capacitor C_3 provide the reset signal at power-on. The EA terminal, pin 31 of IC_1 , is connected to earth to ensure that when an 8051 is used, its internal ROM is switched off.

Port terminals P1.0–P1.7 are connected to the digital inputs of digital-to-analogue converter—DAC— IC_4 . The analogue output of this device has a potential that is directly proportional to the digital value at P1.0–P1.7 and the reference voltage at the RIN input, pin 5, of IC_4 .

At the reference voltage output (ROUT), pin 6, of IC_4 a constant, temperature-stable reference voltage of 2.5 V is available. The output is connected according to manufacturers' specification to ground via C_8 , to the +5 V line via R_6 , and directly to RIN.

Since the analogue voltage range of IC_4 is only 0–2.5 V, and cannot be preset, the output voltage is applied to opamp IC_5 . The gain of this amplifier is preset with P_1 to obtain the wanted voltage range of 0–5 V, corresponding to a tone range of five octaves. Preset P_1 is a 25-turn helical type to ensure precise setting of the control voltage.

The outputs of switches SW_1 – SW_4 are monitored by ports P3.2–P3.5. Since these ports are connected internally to the +5 V line via resistors, pull-up resistors are not needed at their input terminals.

When the relevant switch is open, the associated port is high; when the switch is closed, the port is low.

The switches serve as channel selectors (MIDI channels 1–16). When the unit is switched

on, the software ascertains the position of each of the switches, which is translated into a MIDI channel number. Switch SW_1 has the lowest value, i.e., 1, and SW_4 the highest, i.e., 8. The MIDI channel numbers 1–16 result from the addition of 1 to the (converted) digital values 0–15, since the counting in MIDI technology is from 1 to 16.

Port P3.6 provides the gate signal. To ensure that its potential is high enough, the port is connected to the +5 V line via pull-up resistor R_7 .

Port P3.7 provides the gate indication signal: it is connected to an LED, D_5 , via R_9 . The other terminal of the diode is at +5 V. This way of operating the diode is advantageous, since the 8031/8051 ports can draw higher currents when they are low than when they are high. The LED lights when P3.7 is low.

The +5 V supply for the digital part of the circuit is derived from an unregulated voltage of 9–12 V, available at K_3 , via protection diode D_1 and integrated voltage regulator IC_7 . The interface also needs a negative and a higher positive voltage for opamp IC_5 . In the present circuit, these were chosen at –3 V and +7.5 V: both these voltages are stabilized by appropriate zener diodes. Note that the –3 V line can provide a current of only 0.5 mA maximum. It is therefore impossible to replace the Type TL061 by an 'equivalent' type, such as the $\mu A741$, TL081 or TL071, since all these draw a higher current and this would damage the –3 V part of the power supply.

Construction

The entire interface is housed on the printed-circuit board shown in Fig. 2. Only two wire bridges are needed: 'U' and 'gate'.

If audio connectors are used for CV-OUT and Gate-OUT, two jump leads (J_1 and J_2) must be connected between K_1 and K_2 . Diode D_5 must be soldered between K_4 and K_5 . The terminals of this LED should be bent by 90°.

If audio connectors are not used, the CV and gate take-off, as well as the ground connection, are at K_1 . Diode D_5 must be fitted next to R_9 . The relevant part of the board not used may then be cut off along the dashed line to make the board smaller and more suitable for fitting into an existing equipment.

Note that K_2 has two additional soldering points to enable the use of stereo connectors for both

CV and gate.

Test

Do not yet plug in the ICs and switch on the mains. Check that the +5 V ($\pm 5\%$) and +7.5 V ($\pm 10\%$) supplies are present. If not, a short-circuit, a defect capacitor, or one that is connected with incorrect polarity, may be the cause.

Switch off the mains and insert all ICs into their sockets. Switch on the mains and check that the 3 V ($\pm 20\%$) supply is present. Also, when the mains is switched on, D_5 or D_5' should light briefly to indicate that the reset routine is effected. If it does not, there is a short-circuit, defect component, or the LED has been connected with incorrect polarity.

Set the DIP switch to the required MIDI channel as shown in Fig. 3 and connect a suitable MIDI sender to the MIDI-IN socket on the interface board. When the sender transmits on the selected channel, diode D_5 or D_5' , as the case may be, should light when an note-on instruction activates the gate signal. When the relevant key is released, and a note-off command is thus given, the LED should go out.

Next, press the reference key, which is normally C_2 (MIDI code 36), and check that the control voltage is 0 V. If it is not, jot down the difference. Then, press a key five octaves higher (C^3) and adjust P_1 until the control voltage is exactly 5.000 V (or 4.000 V if a four-octave keyboard is used) plus or minus the difference noted before.

If the circuit does not operate satisfactorily and no apparent fault can be found, check whether there is a 12 MHz signal at pins 18 and 19 of the microprocessor (showing that the internal oscillator functions) and whether at reset pin 9 the level briefly becomes +5 V and then drops back to zero when the mains is switched on. Also, check the board for short-circuits or breaks of the tracks, whether all ICs have been inserted properly into their sockets, and whether the EPROM is of the correct type.

Switched trigger modification

Some synthesizers do not operate with a gate signal but with a switched trigger. The waveform generator in these is not started by a voltage pulse but by a switched contact. To control such synthesizers via the present interface, an additional 10 k Ω resistor and a general-purpose n-p-n transistor should be connected as shown in Fig. 4.

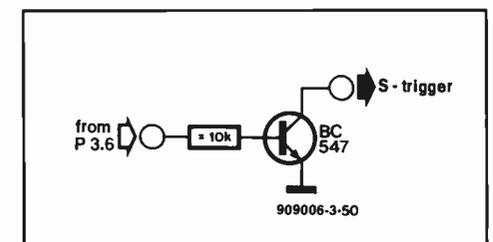


Fig. 4. Extension circuit for working with switched trigger equipment.

Reference: The 8031/8731 microcontroller *Elektor Electronics* – July 1990, p. 36. ■

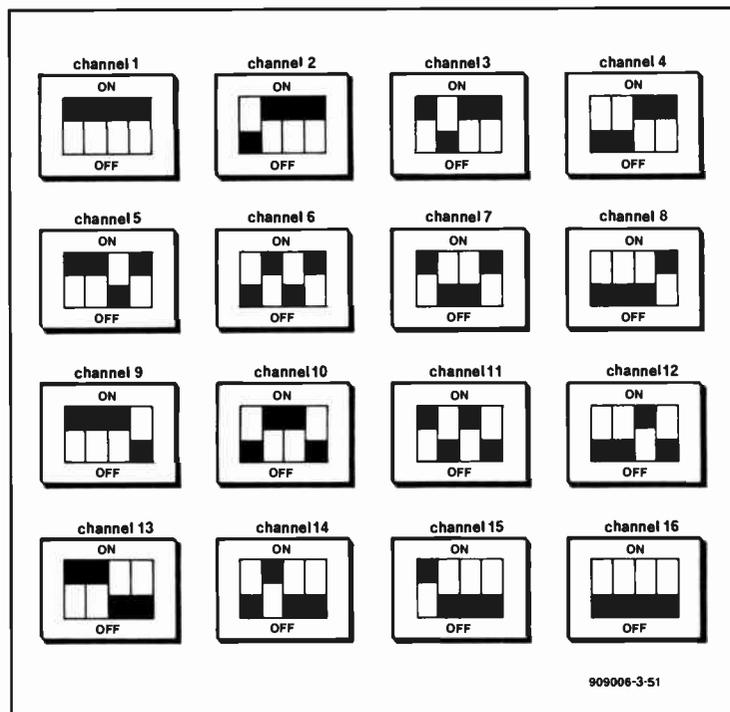


Fig. 3 Setting of MIDI channels with the DIP switches.

HIGH-CURRENT h_{FE} TESTER

A conventional current gain tester is too unreliable for measuring and comparing the d.c. gain of power transistors because it fails to set the collector current at a value that reflects the actual working conditions in, say, the output stage of an audio power amplifier. The tester described here measures the large-signal gain, h_{FE} , of n-p-n as well as p-n-p transistors at a collector current of up to 10 A, yet does not require a bulky power supply.

from an idea by C. Sanjay

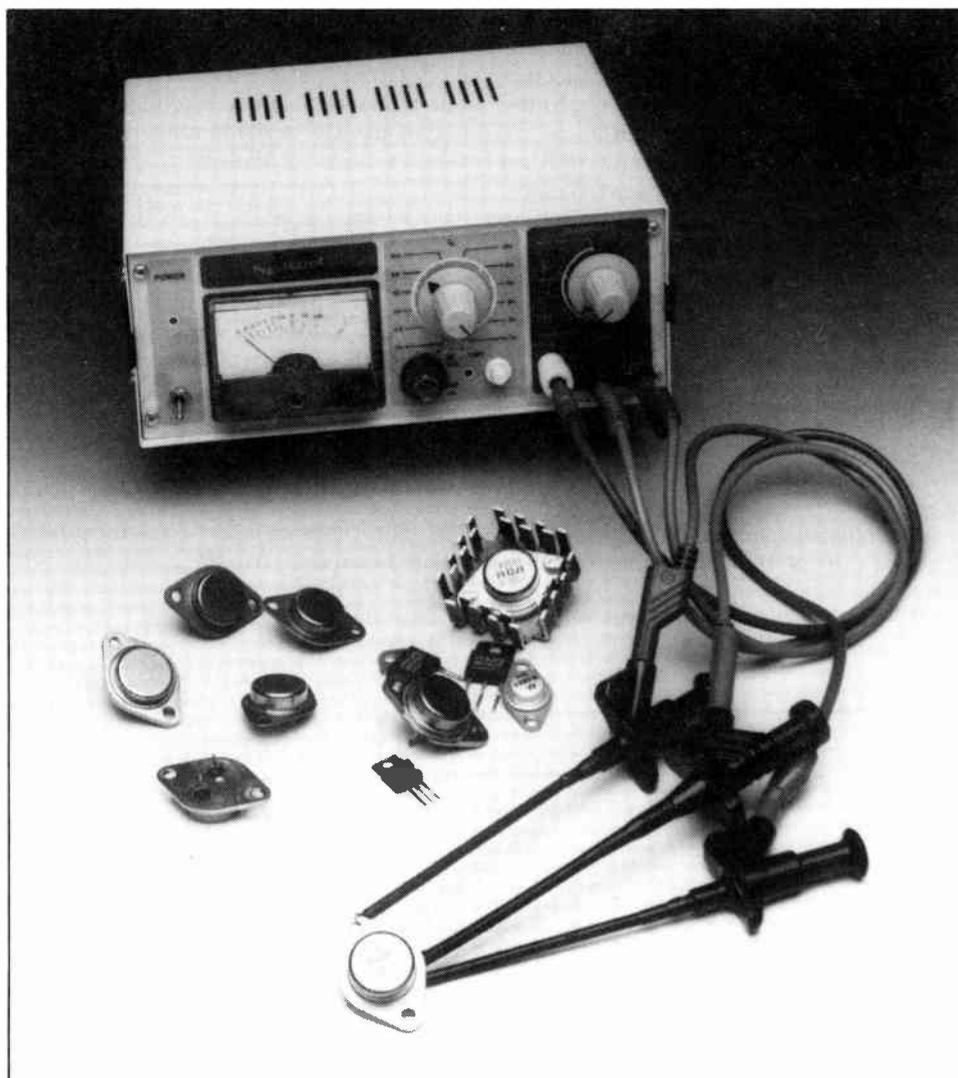
Complementary power transistors with matching d.c. gain characteristics are often used in power amplifiers to prevent problems with thermal drift, unbalanced operation and, worst of all, unacceptable distortion. Similarly, in series-regulated power supplies, it is often required that two or more parallel-connected power transistors have virtually the same gain to ensure equal current distribution.

Selecting power transistors with matching gains from a batch is definitely worthwhile for the above applications. Two problems may arise, however. First, the conditions under which the power transistors are to operate differ considerably from those presented by a conventional h_{fe} tester. The tester typically measures the small-signal gain of the transistor at a collector current not higher than 100 mA or so, while in 'real life' the power transistor may carry up to 100 times more current, causing its junction temperature to rise and the d.c. gain to change. This makes low-signal h_{fe} testing of little use for power transistors.

The second difficulty follows from the first: assuming there is a need to test at high collector currents (several ampères), the cost and size of a suitable power supply and a heat-sink for the transistor under test may be prohibitive factors. Also, an ammeter to read the collector current during the test may not be available.

Principle of operation

The present circuit overcomes the above problems in an elegant way by pulsing the collector current at a duty factor of about 0.01. This enables the circuit to be powered by a supply of modest current rating—say, 1 A or so. An impractical collector current meter is also avoided by reversing the principle of current gain measurement: set a certain collector current and measure the (much smaller) base current that produces it (see the inset column on the design background). This measurement is performed during the 'on' time of the collector current, and the values obtained are processed by a



sample-and-hold circuit whose timing is controlled by the same generator that supplies the pulses to the transistor under test.

Basic test circuit

The basic test circuit for n-p-n transistors is shown in Fig. 1. Pulses with a duty factor of about $1/100$ cause T1, T4, T5 and the TUT (transistor under test) to conduct for about 1.5 ms and block for about 150 ms. Because of the presence of a 3.9-V zener

diode, Dz, transistor T4 limits the voltage across the collector resistor, Rc, of the TUT to about 3.3 V. If the voltage rises above this level, T5 is blocked and consequently the TUT also. The maximum voltage allowed across Rc thus establishes a constant collector current, at which the base current may be measured to obtain the h_{FE} value.

Capacitor Cp between the base and the collector of T4 prevents oscillation in the current source by allowing some time for T5 to start conducting. The disadvantage

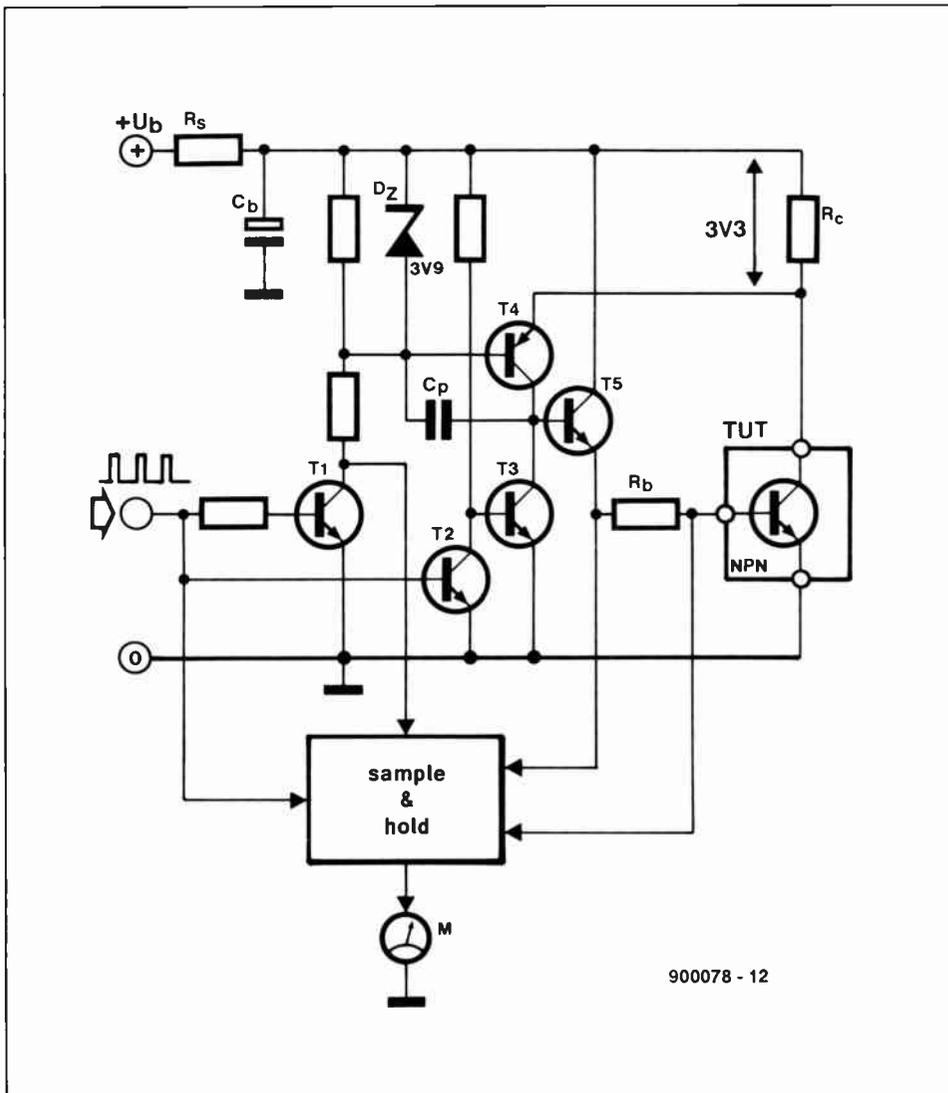


Fig. 1. Basic circuit of the current-gain tester configured for n-p-n transistors. The transistor under test is allowed to draw a relatively high current with a small duty factor from buffer capacitor C_b via collector resistor R_c . A sample-and-hold measurement circuit derives the current gain parameter, h_{FE} , from the level of the pulsed base voltage. The test circuit is in principle the same for p-n-p transistors.

of this form of compensation is that C_p is briefly connected to a higher voltage when T_4 switches off. However, transistors T_2 and T_3 prevent current surges through T_5 and the TUT by pulling the base of T_5 to ground in between pulses.

The (high) current that flows through the TUT during the 1.5-ms long 'on' time is supplied by a reservoir capacitor, C_b .

For p-n-p transistors, the basic test circuit is duplicated with complementary transistor types. The same zener diode D_z and the same power resistor R_c are used, however, to enable comparative gain tests to be carried out on pairs of complementary TUTs.

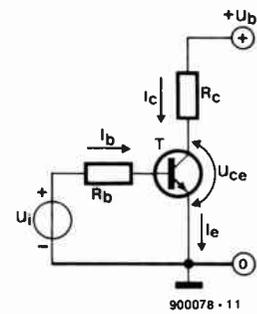
A sample-and-hold circuit measures the voltage drop across the base resistor, R_b , of the TUT. This measurement is performed under the control of the generator pulses. The output voltage produced by the sample-and-hold circuit is fed to a moving-coil meter, M , provided with a 1-to-infinite scale. The indicated value is multiplied by two factors, the collector current multiplier and the sensitivity, to arrive at the h_{FE} value.

Circuit description

Figure 2 shows the circuit diagram of the h_{FE} tester for n-p-n and p-n-p power transistors. The pulse generator is formed by opamp IC_{1a} , which is wired as an astable multivibrator. Two series-connected LEDs, D_3 and D_4 , supply the 3.9-V reference voltage for the current source. The red LED, D_3 , drops about 1.8 V, and the green LED, D_4 , about 2.1 V.

The base current drive circuits consist of T_1 - T_5 for n-p-n TUTs, and T_1 - T_6 - T_{10} for p-n-p TUTs. Depending on the range selected, the base of the TUT develops a voltage across one of the six resistors connected to the contacts of switch S_3 . During the 1.5-ms long measurement period, electronic switches IC_{3c} and IC_{3d} are closed, while IC_{3a} and IC_{3b} are open. This results in the voltage developed across the base resistor being stored in capacitor C_3 . The electronic switches change state during the 'off' period of the generator output signal, so that the measured voltage exists with reference to ground and can be fed to the meter driver, opamp IC_{1b} . Capacitor C_4 smooths the output voltage supplied

DESIGN BACKGROUND



The static forward current transfer ratio, h_{FE} , of a bipolar transistor in a common-emitter circuit is defined as the ratio of d.c. output current to the d.c. input current, or

$$h_{FE} = \frac{I_c}{I_b}$$

provided that I_{ce0} , the collector current with the base open-circuited, is much smaller than I_c .

In the test circuit,

$$I_c = \frac{3.3V}{R_c} \quad \text{and} \quad I_b = \frac{U_{Rb}}{R_b}$$

Substituting:

$$h_{FE} = \frac{I_c \times R_b}{U_{Rb}}$$

The values of R_c result in I_c values of 1 A, 2 A, 3 A, 4 A, 6 A and 10 A.

Examples:

1. When $I_c = 1$ A; $R_b = 10 \Omega$ and $U_{Rb} = 2.5$ V (full-scale deflection):

$$h_{FE} = \frac{1 \times 10}{2.5} = 4$$

2. When $I_c = 1$ A; $R_b = 24.9 \Omega$ and $U_{Rb} = 2.5$ V (full-scale deflection):

$$h_{FE} = \frac{1 \times 24.9}{2.5} \approx 10$$

3. When $I_c = 3$ A; $R_b = 249 \Omega$ and $U_{Rb} = 1.75$ V:

$$h_{FE} = \frac{3 \times 249}{1.75} \approx 427$$

Note:

The d.c. gain parameter, h_{FE} , must not be confused with the common-emitter small-signal short-circuit forward current transfer ratio, h_{fe} , which is defined in terms of a.c. as

$$h_{fe} = \frac{\delta I_c}{\delta I_b}$$

with the output short-circuited to a.c.

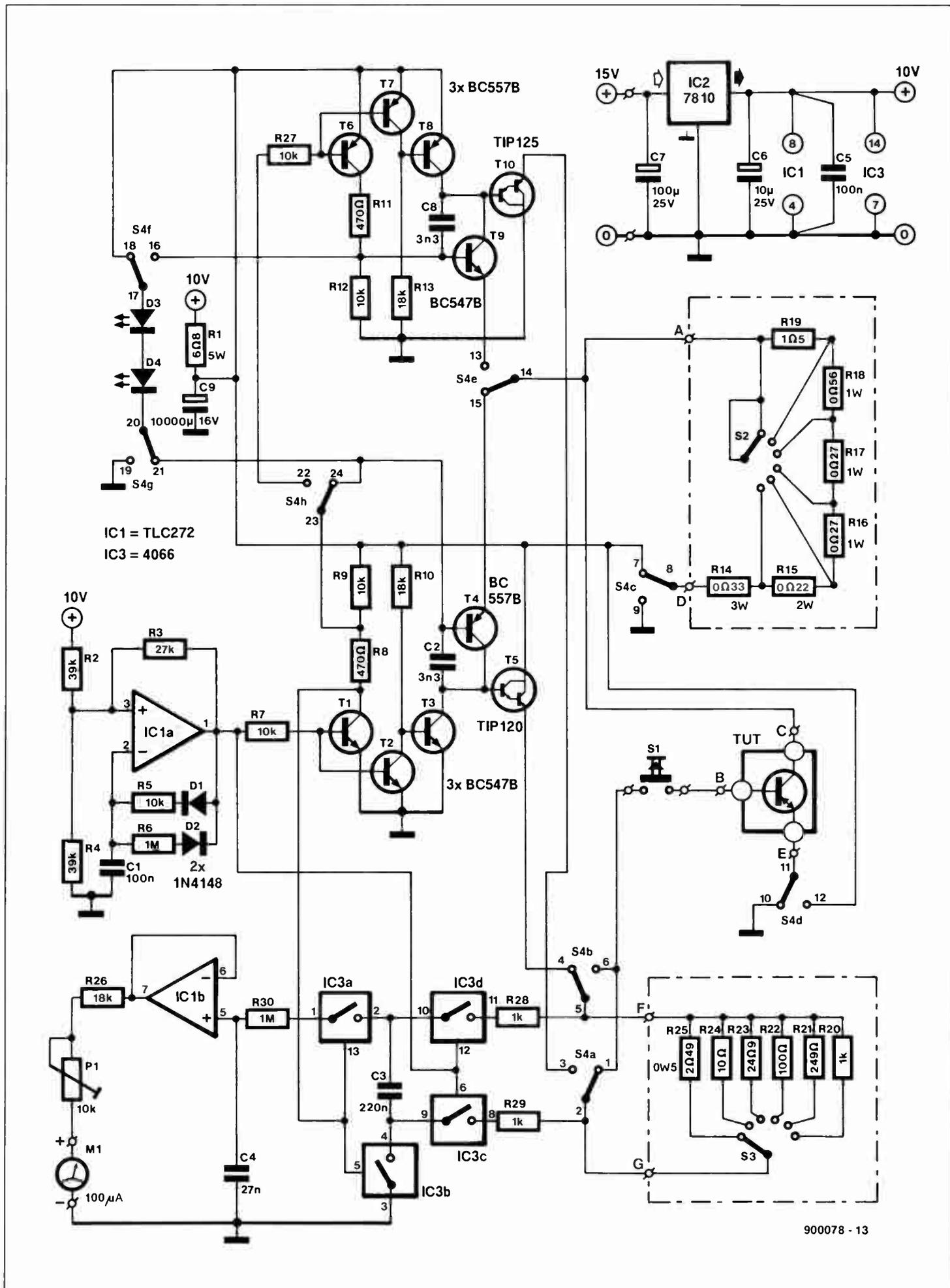


Fig. 2. Circuit diagram of the h_{FE} tester. The contacts of push-button S4 serve to configure the circuit for use with n-p-n and p-n-p transistors.

by the sample-and-hold circuit.

Preset P1 at the output of IC1B serves to set full-scale deflection on the moving-coil meter when the base resistor drops 2.5 V. Note that the meter deflection is inversely related to the h_{FE} value, creating the need for a meter scale from infinite (no deflection) to 1 (full deflection), similar to that used on an analogue ohm-meter.

The collector currents for the six available ranges are determined by power resistors connected to the contacts of switch S2. The circuit is switched from n-p-n testing to p-n-p testing by eight toggle contacts on switch S4.

The power supply of the h_{FE} tester is conventional and based on a three-terminal 10-V regulator Type 7810 (IC2). The unregulated input voltage to the circuit should be between 15 V and 20 V.

Construction

Start the construction by fitting the six base resistors (1% types from the E96 series) on the 'sensitivity' switch, S3. Each of the resistors is soldered between its terminal on the switch and a common junction. Resistor R25 goes to the switch terminal marked '1', R24 to switch terminal '2' and so on. Next, connect approximately 10-cm long light-duty wires to the pole and the resistor junction.

The collector current switch, S2, also has the associated resistors, in this case R14-R19, fitted direct at its terminals. Resistor R19 is connected between switch terminals '1' and '2', resistor R18 between switch terminals '2' and '3', and so on. The pole of the switch and the last resistor, R14, are connected to the circuit board by two 5-cm long insulated wires. The respective

PCB terminals are marked 'A' and 'D'.

Fit the ten wire links on the printed-circuit board as indicated by the component overlay (see Fig. 4). Next, fit all parts on the board as indicated by the parts list and the component overlay.

LED D4 is not fitted on the board, but

COMPONENTS LIST

Resistors:

1	6 Ω 5W	R1
2	39k Ω	R2;R4
1	27k Ω	R3
5	10k Ω	R5;R7;R9;R12;R27
2	1M Ω	R6;R30
2	470 Ω	R8;R11
3	18k Ω	R10;R13;R26
1	0 Ω 33 3W	R14
1	0 Ω 22 2W	R15
2	0 Ω 27 1W	R16;R17
1	0 Ω 56 1W	R18
1	1 Ω 5	R19
1	1k Ω 1%	R20
1	249 Ω 1%	R21
1	100 Ω 1%	R22
1	24 Ω 9 1%	R23
1	10 Ω 1%	R24
1	2 Ω 49 1%	R25
2	1k Ω	R28;R29
1	10k Ω preset H	P1

Capacitors:

2	100nF	C1;C5
3	3nF3	C2;C8
1	220nF	C3
1	27nF	C4
1	10 μ F 25V radial	C6
1	100 μ F 25V radial	C7
1	10,000 μ F 16V radial	C9

Semiconductors:

2	1N4148	D1;D2
1	green LED (3 mm)	D3
1	high-efficiency red LED (3 mm)	D4
4	BC547B	T1;T2;T3;T9
4	BC557B	T4;T6;T7;T8
1	TIP120	T5
1	TIP125	T10
1	TLC272	IC1
1	7810	IC2
1	4066	IC3

Miscellaneous:

1	push-button with 1 make contact	S1
2	1-pole 6-way rotary switch	S2;S3
1	locking 8 \times changeover switch Schadow type F-8U/EE.	S4
Accessory parts: indicator button FA200, upper and lower cap half M14, spring washer, plastic nut and front panel cap (parts set type ZFA)		
1	100- μ A moving-coil meter e.g. Monacor (Monarch) type PM-2	M1
1	printed-circuit board	900078
1	front-panel foil	900078-F
1	enclosure Telet LC850	

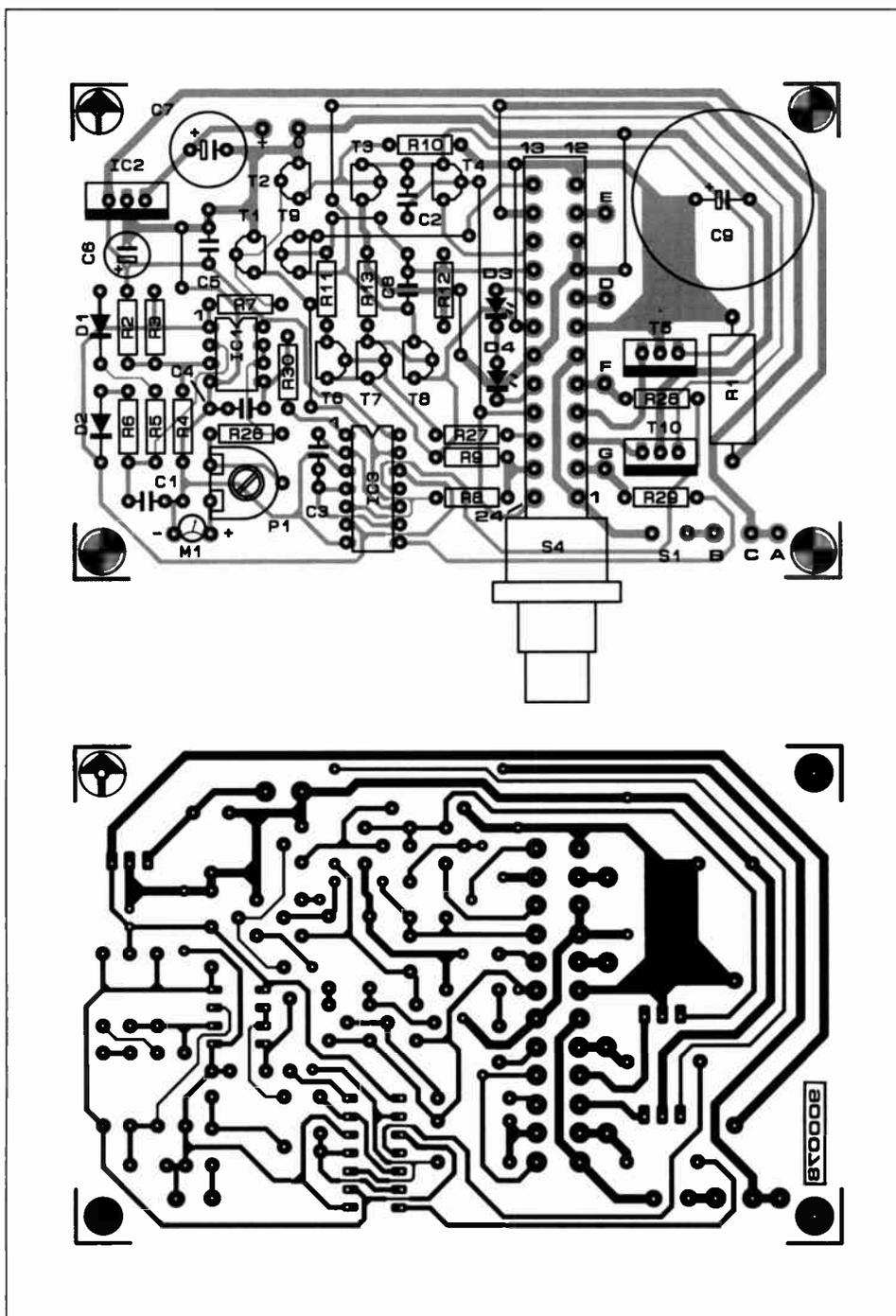


Fig. 3. Track lay-out (mirror image) and component mounting plan.

connected to it via 10-cm long wires. The LED is used on the front panel as a 'test' indicator that flashes when the associated button is pressed.

The vertically mounted power transistors, T5 and T10, and the voltage regulator, IC2, do not require heat-sinks. Use IC sockets for the TLC272 and the 4066. The completed printed-circuit board and the wired range switches are shown in Fig. 5. All wires are soldered direct to the board—solder terminals must not be used.

Testing

It is recommended to test the completed board before fitting it into an enclosure. Connect the moving-coil meter, the three switches and the power supply (15-20 VDC) to the board.

Temporarily disconnect R30 from pin 1 of IC3, and connect it to the junction of a voltage divider that supplies 2.5 V (e.g., a 1-kΩ resistor and a 500Ω preset connected between the +10-V line and ground). Switch on and check the output voltage of the potential divider. Adjust the preset until +2.5 V is produced. Next, adjust P1 for full-scale meter deflection. Remove the potential divider.

Connect an oscilloscope and check the presence of a 10-V_{pp} rectangular signal at pin 13 (negative-going) and pin 12 (positive-going) of IC3. Because of the small duty factor of the signal, it may be necessary to switch the input of the scope to DC-coupled.

Connect a test transistor to the circuit. Check that the two LEDs drop 3.9 V or a voltage within 10% of that value. If they

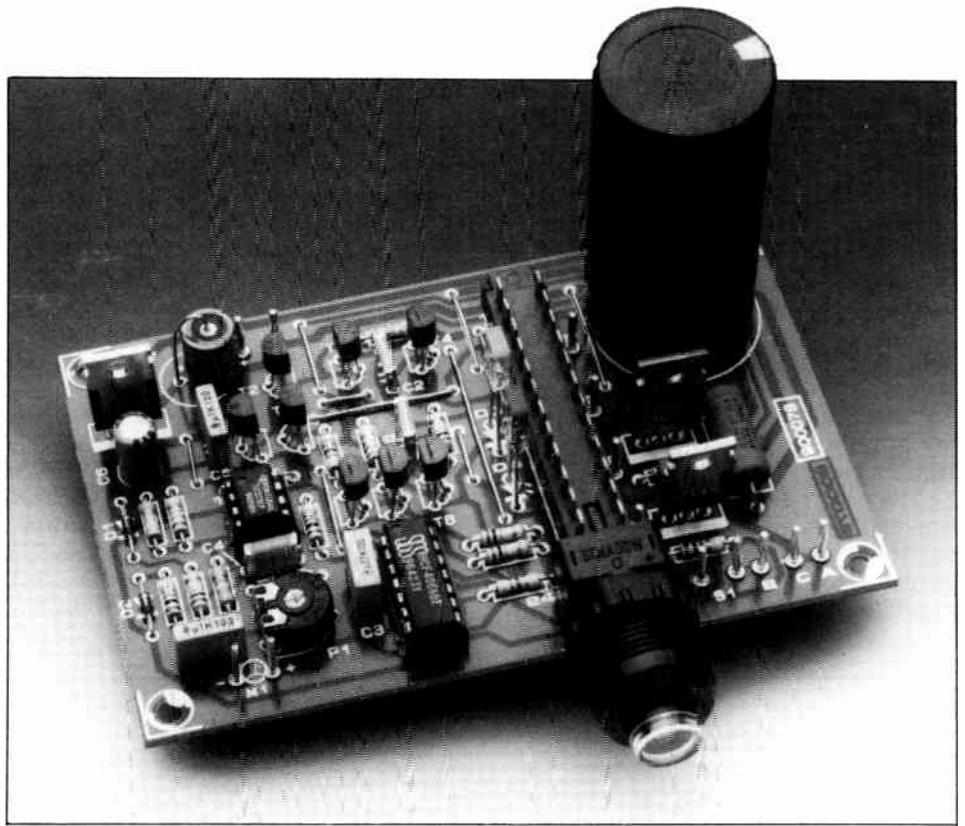


Fig. 4. Completed PCB ready for fitting into the enclosure.

do not, use other LEDs (e.g., a high-efficiency type for the red one).

Finally, connect R30 to pin 1 of IC3 again.

Assembly

The instrument is relatively simple to build in an aluminium enclosure Type LC850 from Telet. A ready-made front panel (Fig. 7) finished in light and dark

blue is available to give the tester an attractive appearance, in line with previous instruments in this series.

First, remove the existing scale from your moving-coil meter and replace it with the scale cut out from the front panel foil. Carefully re-assemble the meter and connect short wires to it.

Next, cut and drill the metal front panel of the LC850 case, using the drilling template supplied with the front panel foil

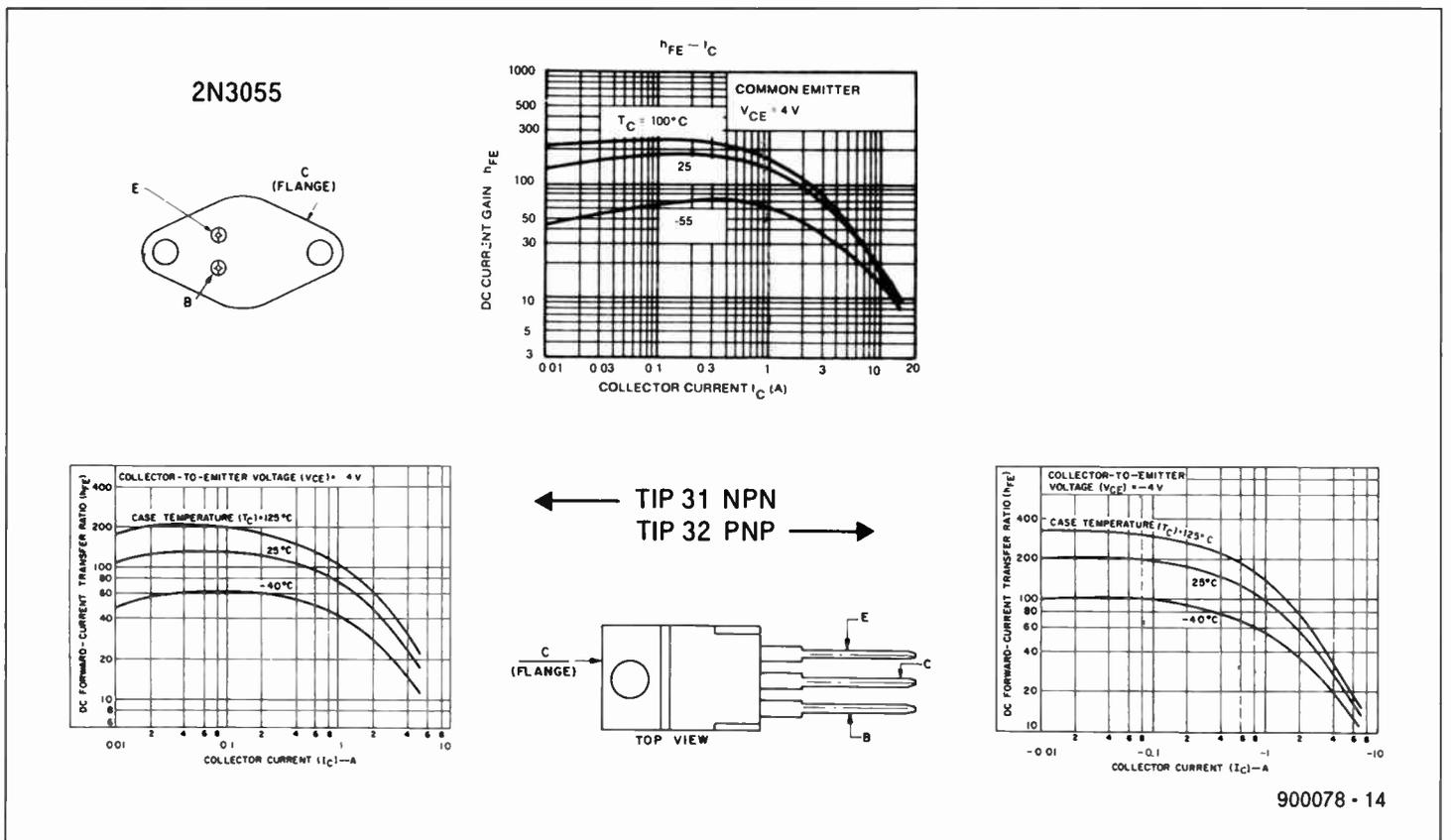


Fig. 5. For your reference: h_{FE} curves of three well-known power transistors (courtesy Harris Semiconductor, formerly RCA).

to mark the holes.

Before applying the self-adhesive foil to the metal front panel, make sure all drilled holes have the right diameter. This is easily checked by temporarily fitting the front panel controls, the two LEDs (the 'power' indicator and the 'test' indicator), the three wander sockets and the meter.

The pnp/npn switch, S4, secures the PCB to the front panel. Determine how far the PCB can be moved towards the front panel without the rear side of the meter touching any component on the board. Check that you can secure the switch to the front panel with the aid of the locking nut at the inside and the threaded cap at the outside. Mark the final position of the board on the bottom plate and drill the four holes for the M3 screws in the corners. Use short PCB spacers or a couple of nuts and washers to fit the board at the correct height above the bottom plate.

Next, remove all parts from the front panel, and carefully apply the self-adhesive foil. The two 3-mm LEDs are glued in position at the rear side of the panel. They do not protrude from the front panel foil.

Fit the range switches (complete with the resistors soldered at the terminals), the wander sockets, the 'test' push-button, the on/off switch and the meter on the front panel. Cut the spindles of the range switches to the required length, and fit the collet knobs. The second pointer on the collector current switch, a small solid triangle, is applied as a rub-off symbol on the collet.

Secure the PCB on the bottom plate of the enclosure. Next, fit the front panel with all parts on it. Secure it to the case with the four self-tapping screws supplied. Finally, tighten the threaded cap of the npn/pnp switch.

The remainder of the wiring work is straightforward. The 'power' indicator, a 3-mm LED, and the associated on/off switch are connected to a DC adapter socket on the rear panel of the enclosure. A 1-k Ω series resistor is used for the LED.

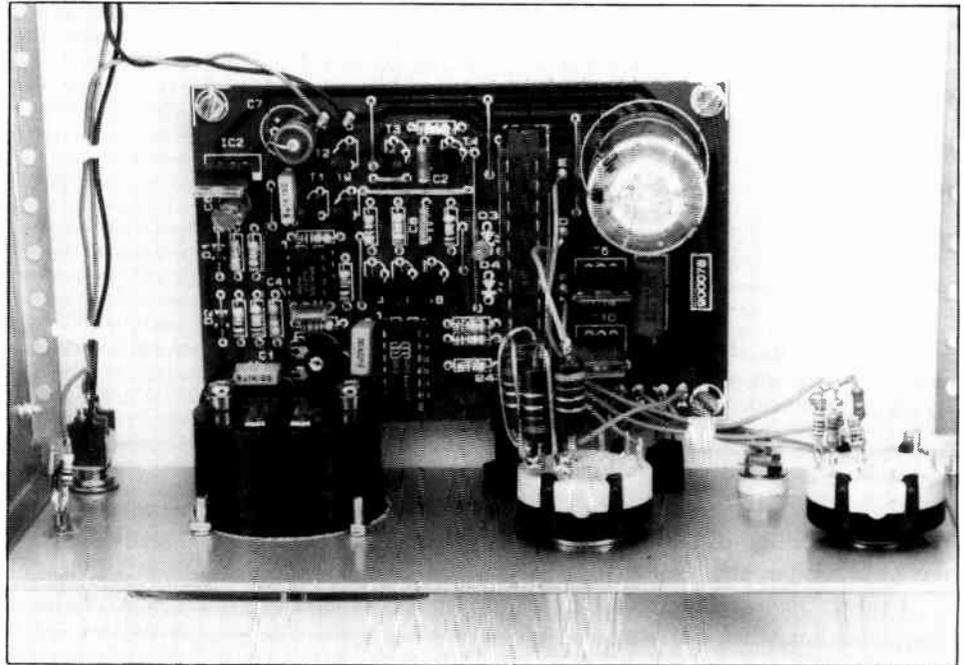


Fig. 5. A look inside the completed prototype. Note that the resistors are soldered direct to the terminals of the rotary switches.

The input voltage connections are made in light-duty red and black wires.

Practical use

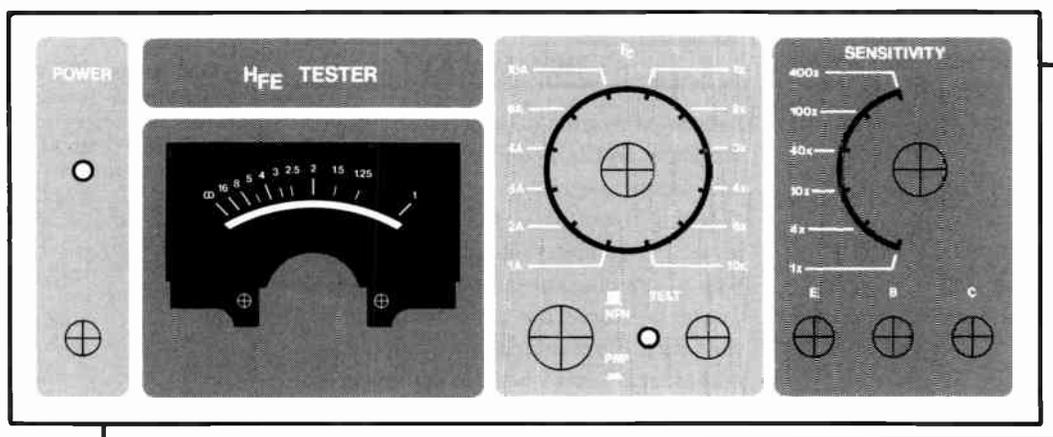
A few points must be made as regards the use of the h_{FE} tester. First, always make sure the n-p-n/p-n-p switch is in the right position. You may destroy a transistor if you do not stick to this rule. Second, make sure you get the emitter, base and collector terminals right. Third, always start the test in the lowest collector current range, 1 A, and the lowest sensitivity, 1 \times . Increase the sensitivity until a usable meter indication is produced. The h_{FE} value is calculated from

$$\text{meter value} \times I_c \text{ multiplier} \times \text{sensitivity}$$

Familiarize yourself with the operation of

the instrument by measuring the current gain of a few power transistors from your junkbox. The curves in Fig. 6 show the relation between the collector current and the current gain of the well-known 2N3055 and the complementary pair TIP31/TIP32. Bear in mind the maximum collector current of the transistor under test—a medium-power transistor such as the BD139, for instance, will almost certainly be destroyed when the tester is set to the 10 A range.

Having built the instrument you are in a position to select matching pairs of complementary power transistors for your next power supply or AF amplifier. Because of the low duty factor of the collector current passed through the transistor under test, it is not normally required to fit this on a heat-sink, not even while testing in the 10 A range. ■



900078-F

Fig. 7. This front panel foil (shown here at 66% of true size) is available ready-made to give your current gain tester a professional appearance. The meter scale is cut out from the foil and applied to the moving-coil meter.

SUGGESTED TOPICS

I received the invitation to subscribe to your publication. There are some things I wish to see published in your magazine and possibly presented as kits. I have worked on sophisticated communications and airborne navigational systems and have used a lot of expensive test equipment, such as Tektronics, Hewlett-Packard, Ballentine Labs, and Western Electric. I long for the day when I can own such gear, but the cost is too high.

I would like to see articles on a spectrum analyzer, a good AC voltmeter, a frequency selective voltmeter, an intermodulation distortion meter, a digital VSWR meter, a low-distortion audio frequency generator, and an FM deviation meter. Other items of interest would include anything that will use the flat, square 12GHz antenna to pick up satellite communications.

Maybe some readers have developed ways to adapt consumer electronic devices for other uses. I have a tuner from a television receiver that tunes the whole VHF TV spectrum. It uses the ever popular varactor diodes. I have always wondered if it could be the heart of a spectrum analyzer. I have been unable to get any information about this tuner.

Since my recent return to the US, I have tried to get training in consumer electronics. Most of the consumer devices I have repaired are quite simple compared to what I am used to working on. I have found one consumer device that puzzles me, though. This is the VCR. Although it uses sophisticated electronics and servo systems, the mechanisms are Stone Age. This is where 80% or better of all VCR problems originate. Do you plan to do any articles on VCR technology? Or even video equipment?

Computers are nice, but for me, the only computer I own is a video game. I hope my letter may suggest articles and kits helpful for techs like me.

Richard McCleary
Jacksonville, FL 32210-8202

Fair Radio Sales (Box 1105, Lima, OH 45802) and other outlets offer fine choices in used, high quality military test gear. [Ed.]

A HAPPY READER

Thank you for your unique publications. Since subscribing to your various maga-

READERS' FORUM

zines in 1987, I have learned much about high fidelity and electronics in general. *Glass Audio* is especially impressive, and should be published quarterly.

Your new journal, *Elektor Electronics*, is long overdue. If it is anything like *Audio Amateur*, it should give the serious builder more challenging and useful projects than what is currently offered by magazines such as *Popular Electronics*.

Your Old Colony book service is also excellent. I recently purchased the first three volumes of *Audio Anthology*. These books contain some of the best information on valve (tube) circuits that I have seen. Would it be possible for Old Colony to print a valve data manual? They are hard to find.

In the future, would you consider articles on musical equipment modification and design? There are many samplers, drum boxes, and keyboards that could benefit from such projects. An article on digital reverb construction would also be useful.

Peter Carli
York, PA 17403

Having learned that Howard Sams & Company was allowing the Tube Substitution Handbook to go out of print, and as usual carrying utmost in its heart the well-being of tube enthusiasts such as Peter, Old Colony snapped up reprint rights for that venerable classic (\$6.95). [Ed]

THEM vs. US

I recently became a subscriber to your magazine and in general I like what I see. I particularly agree with the editorial "Getting Evolved" in the December 1990 issue. I have always liked the European way of drawing schematics; I believe theirs far eclipse the often confusing and convoluted presentations we call schematics, and I have been in the engineering world about 36 years, although I am now retired.

The Europeans also come up with much more imaginative projects than we seem to have in the US. I have been a ham for 46 years (W6VAT) and get tired of seeing

dozens of articles on Pi-networks, three-terminal regulator supplies, and vertical antennas in the usual run-of-the-mill amateur magazines.

As an author myself (since 1961), I have always tried to make my articles interesting, attractive, and above all buildable when they involve project construction. Here is where I have a criticism about using European parts. Most letters I receive on my construction articles ask, "Where can I get such and such a part(s)?"

I know this frustration well. I am interested in building the "Milliohmmeter" by A. Rigby in your December 1990 issue (p. 27). But where do I find BD139s, BC547Bs, TLC271s, 272s, and LM336-2.5s? I may be able to find NTE equivalents for the transistors, but even though I live near National Semiconductor in Silicon Valley, I know of no local store that stocks the LM336-2.5 diodes.

I know you plan to publish a cross-reference list between our parts and theirs, but it has been my experience that space limitations keep these lists shorter than they should be. Please accept this criticism in the vein offered. Your magazine is certainly not the first, nor the last, to be guilty of this omission.

I also recommend you keep your articles on theory coming. The two on transmission lines, Hart and Whitehead, in your December issue will find eager readers, particularly those who do not lean heavily on mathematics. I have received any number of letters asking for just this kind of information.

Again, your magazine appears to be heading in a good direction. You are to be complimented on it.

James G. Lee
San Jose, CA 95129

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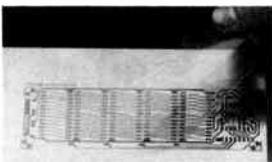
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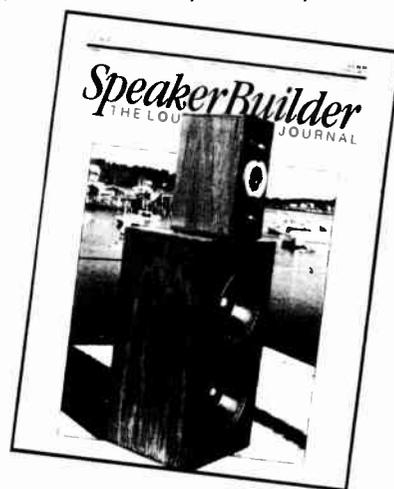
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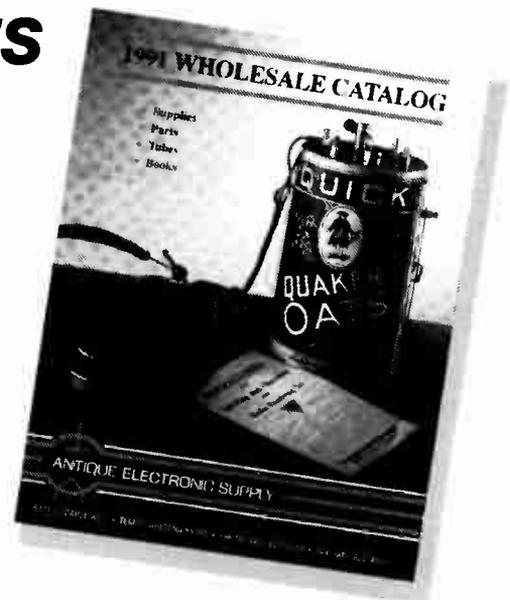
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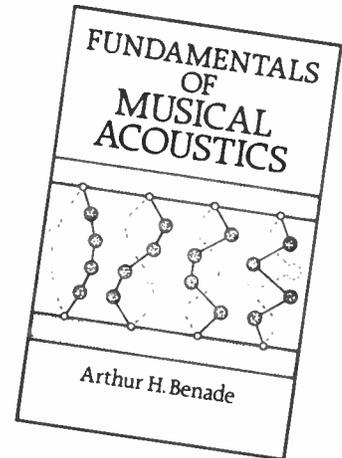
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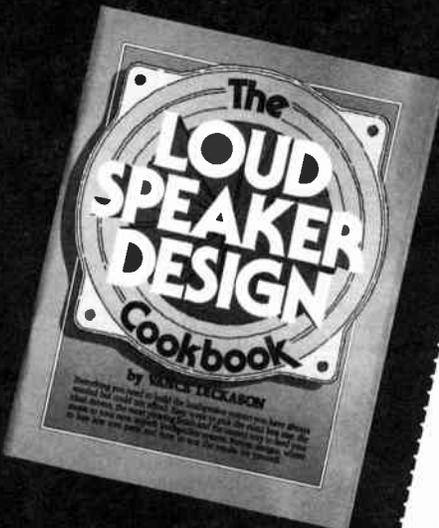
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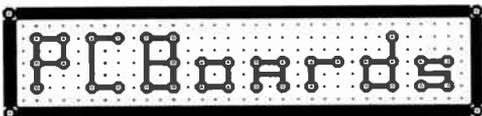
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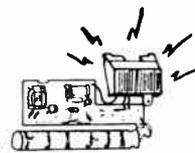
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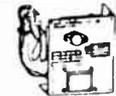
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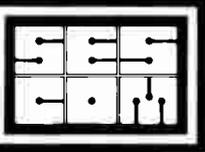
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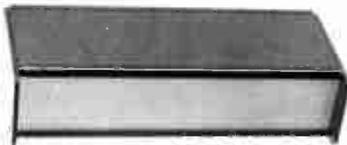
Rack Chassis



MODEL #.	DESCRIPTION (Width x Depth x Height)	PRICE \$
1RU5	19 x 5 x 1.75 in. (482.6 x 127 x 44.45mm)	28.00
1RU7	19 x 7 x 1.75 in. (482.6 x 177 x 44.45mm)	30.00
1RU10	19 x 10 x 1.75 in. (482.6 x 254 x 44.45mm)	32.00
2RU5	19 x 5 x 3.50 in. (482.6 x 127 x 88.9mm)	30.00
2RU7	19 x 7 x 3.50 in. (482.6 x 177.8 x 88.9mm)	32.00
2RU10	19 x 10 x 3.50 in. (482.6 x 254 x 88.9mm)	34.00
3RU5	19 x 5 x 5.25 in. (482.6 x 127 x 133.35mm)	38.00
3RU7	19 x 7 x 5.25 in. (482.6 x 177.8 x 133.35mm)	40.00
3RU10	19 x 10 x 5.25 in. (482.6 x 254 x 133.35mm)	42.00

The above rack chassis are made of .063 aluminum. The front and rear panels are clear brushed anodized. All hardware is included. Assembly Required.

Metal Cabinets



MODEL #.	DESCRIPTION (Width x Depth x Height)	PRICE \$
MC-1A	4 x 3 x 2 in. (101.6 x 76.2 x 50.8mm)	15.00
MC-2A	6 x 3 x 2 in. (152.4 x 76.2 x 50.8mm)	17.00
MC-3A	8 x 3 x 2 in. (203.2 x 76.2 x 50.8mm)	19.00
MC-4A	4 x 5 x 3 in. (101.6 x 127 x 76.2mm)	17.00
MC-5A	6 x 5 x 3 in. (152.4 x 127 x 76.2mm)	19.00
MC-6A	8 x 5 x 3 in. (203.2 x 127 x 76.2mm)	21.00
MC-7A	4 x 7 x 4 in. (101.6 x 177.8 x 101.6mm)	19.00
MC-8A	6 x 7 x 4 in. (152.4 x 177.8 x 101.6mm)	21.00
MC-9A	8 x 7 x 4 in. (203.2 x 177.8 x 101.6mm)	23.00

The above cabinets are made of .063 aluminum. The front and rear panels are clear brushed anodized. All hardware and rubber feet are included. Assembly Required.

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Model #.	Description	Price \$
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HP-3	BENCH MOUNT	15.00
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PD-2	ROUND 5/64"	6.00
PD-3	ROUND 3/32"	6.00
PD-4	ROUND 7/64"	6.00
PD-5	ROUND 1/8"	6.00
PD-6	ROUND 9/64"	6.00
PD-7	ROUND 5/32"	6.00
PD-8	RDUND 11/64"	6.00
PD-9	ROUND 3/16"	6.00
PD-10	ROUND 13/64"	6.00
PD-11	ROUND 7/32"	6.00
PD-12	ROUND 15/64"	6.00
PD-13	ROUND 1/4"	6.00
PD-14	ROUND 17/64"	6.00
PD-15	ROUND 9/32"	6.00
PD-16	SQUARE 1/8"	66.90
PD-17	SQUARE 5/32"	66.90
PD-18	SQUARE 3/16"	66.90
PD-19	REC. 1/8 x 3/16"	66.90
PD-20	REC. 1/8 x 7/32"	66.90
PD-21	REC. 1/8 x 15/64"	66.90
HP-2	XX TODL KIT	129.75
HP-4	BENCH MDUNT	15.00
PD-30	RDUND 1/16"	9.50
PD-31	RDUND 5/64"	9.50
PD-32	RDUND 3/32"	9.50
PD-33	ROUND 7/64"	9.50
PD-34	RDUND 1/8"	9.50
PD-35	ROUND 9/64"	9.50
PD-36	RDUND 5/32"	9.50
PD-37	RDUND 11/64"	9.50
PD-38	ROUND 3/16"	9.50
PD-39	ROUND 13/64"	9.50
PD-40	ROUND 7/32"	9.50
PD-41	ROUND 15/64"	9.50
PD-42	ROUND 1/4"	9.50
PD-43	RDUND 17/64"	9.50
PD-44	ROUND 9/32"	9.50
PD-45	ROUND 19/64"	9.50
PD-46	ROUND 5/16"	9.50
PD-47	ROUND 21/64"	9.50
PD-48	ROUND 11/32"	9.50
PD-49	RDUND 23/64"	9.50
PD-50	RDUND 3/8"	9.50
PD-51	ROUND 25/64"	9.50
PD-52	ROUND 13/32"	9.50
PD-53	ROUND 27/64"	9.50
PD-54	ROUND 7/16"	9.50
PD-55	ROUND 29/64"	9.50
PD-56	ROUND 15/32"	9.50
PD-57	ROUND 31/64"	9.50
PD-58	ROUND 1/2"	6.00
PD-59	ROUND 33/64"	6.00
PD-60	ROUND 17/32"	6.00
PD-61	SQUARE 1/8"	66.90
PD-62	SQUARE 5/32"	66.90
PD-63	SQUARE 3/16"	66.90
PD-64	REC. 1/8 x 3/16"	83.10
PD-65	REC. 1/8 x 1/4"	83.10
PD-66	REC. 1/8 x 5/16"	83.10
PD-67	REC. 1/8 x 3/8"	83.10
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PUNCH 4	9/16"	ROUND 7/32"	11.95
PUNCH 5	5/8"	ROUND 7/32"	11.95
PUNCH 6	11/16"	ROUND 7/32"	11.95
PUNCH 7	3/4"	ROUND 7/32"	11.95
PUNCH 8	13/16"	ROUND 7/32"	11.95
PUNCH 9	7/8"	ROUND 7/32"	11.95
PUNCH 10	1"	RDUND 5/16"	12.95
PUNCH 11	1-1/16"	RDUND 5/16"	12.95
PUNCH 12	1-1/8"	RDUND 5/16"	12.95
PUNCH 13	1-3/16"	RDUND 5/16"	12.95
PUNCH 14	1-1/4"	RDUND 5/16"	13.95
PUNCH 15	1-3/8"	RDUND 5/16"	13.95
PUNCH 16	1-1/2"	RDUND 5/16"	15.95
PUNCH 17	1-5/8"	RDUND 5/16"	20.95
PUNCH 18	1-3/4"	RDUND 5/16"	23.95
PUNCH 19	2-5/8"	ROUND 1/2"	59.95
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2N3906	PNP T092	.12	.10	.08
2N2102	PNP T039	.80	.67	.54
2N4037	PNP T039	.90	.75	.60
PN2219A	NPN T0237	.40	.34	.28
PN2905A	PNP T0237	.40	.34	.28

DIODES:

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

LINEAR INTEGRATED CIRCUITS:

PART NO.	DESCRIPTION	1-9	10-99	100+
LF351N	SINGLE DP-AMP	.60	.54	.48
LF353N	DU-L DP-AMP	1.05	.95	.84
NE5534N	SINGLE DP-AMP	1.28	1.15	1.02
NE5534AN	LDW NDISE	1.80	1.62	1.44
NE5532N	SINGLE DP-AMP	1.85	1.67	1.48

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SDC-14	14 PIN TIN	.12	.11	.10
SDC-16	16 PIN TIN	.13	.12	.11
SDC-18	18 PIN TIN	.15	.14	.13
SDC-20	20 PIN TIN	.19	.16	.15

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XLR F CH	3 PIN CHASSIS FEMALE	3.60	3.24	2.88
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RCA	RCA PHONO JACK CHASSIS	.65	.59	.52

CAPACITORS: Axial Lead Electrolytic

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

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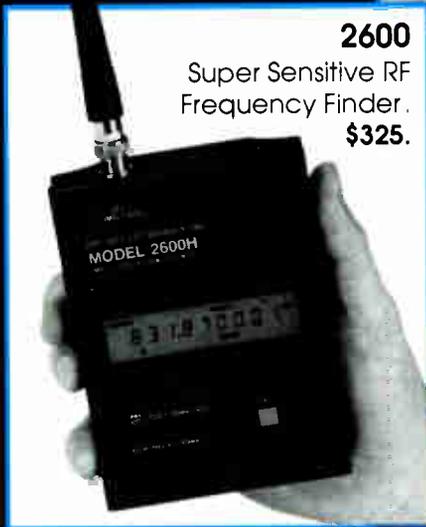
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