

# Electronics Today

INTERNATIONAL

APRIL 1981

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TECHNOLOGY



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Stereo Image Co-ordinator

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## COLOUR MODULATOR Kit #1 \$24.95

This video modulator has been designed to complement the small home computer. It allows the standard colour television to be used as a high quality colour video monitor. Uses state of the art integrated circuit technology. Direct coupling is employed to provide white level compensation in the vestigial sideband output. The gain device of the LM1889's chroma oscillator is used to buffer, level shift, and invert the incoming composite colour input. The signal then passes to the RF modulator where a channel 7 carrier is provided. Requires 12 volt DC for operation.

## VIDEO TO RF MODULATOR

Kit #2 \$8.95

Converts a video signal to a RF signal. The RF output terminals connect to the antenna of your TV. Connecting in the video and supplying 5 to 10 volts DC is all that is needed. You turn your channel selector to 4, 5 or 6 (whichever is not used in your area) and tune the adjusting coil for a suitable display.

## POWER SUPPLY

Kit #3 \$6.95

This kit has been designed to satisfy the need for an economical power supply. Provides 5 volt DC at 1 amp for TTL projects plus a separate floating power supply that is variable from 5 to 35 volt DC at 1/2 amp for CMOS and other uses.

## MAD BLASTER

Kit #4 \$4.95

The MB-1 produces a loud "ear shattering" and attention getting siren like sound. This kit can supply to 4 watts of obnoxious audio into an 8 ohms speaker. Requires +5-15 volts DC for operation.

## COLOUR ORGAN

Kit #5 \$14.95

Good for home colour organ to light up your sound system. Three channel, four level controls. Up to 500 watts per channel (more with heatsinking).

## SIREN KIT

Kit #6 \$3.95

The siren kit will duplicate the sound of a police siren at a low volume (200 MW) or at a high volume (5 watts) depending upon construction. Closing of the pushbutton will produce the upward wail typical of a police siren, opening will cause the tone to fall downward. Requires 3-12 volts DC.

## LM380 AMP-SUPER SNOOP

Kit #7 \$6.95

Many applications for this kit, intercom, mini pa system, telephone amplifier, room bug amplifier and more. Uses ceramic or crystal mike for input with 8ohms output. Requires 9 DC volts for operation.

## CRYSTAL TIME BASE KIT

Kit #8 \$6.95

The crystal time base kit provides a highly accurate source of 60 HZ which is useful for operating digital clocks when there is no source of 60HZ power available.

## ELECTRONIC UNIVERSAL TIMER KIT

Kit #9 \$5.95

The universal timer kit provides the basic parts required to provide a source of precision timing and pulse generation. The U.T. makes use of the versatile 555 timer IC which is capable of both astable and monostable operation.

## TONE DECODER KIT

Kit #10 \$6.95

Can be used as a touch-tone decoder. Its frequency range is 400HZ to over 5KHZ. Bandwidth 2% to greater than 15% of center frequency. Output sink current 100ma. Requires +8-15 volts DC. Audio input level should be 50-100m volts. Useful for touch-tone burst detection, or as a stable tone encoder.

## CODE OSCILLATOR/TONE GENERATOR

Kit #11 \$2.95

Can be used as a code oscillator (1KHZ), burglar alarm, light operated oscillator, light operated burglar alarm, variable frequency audio oscillator and much much more. Runs on +3-12 volts.

## LED BLINKER

Kit #12 \$2.95

Great attention getter with many applications. Alternates flashing of two LED's. Flashing rate is determined by two capacitors which can be changed to increase or decrease the rate of flashing. Runs off voltages up to 20 volts.

## BI-POLAR LED BLINKY KIT

Kit #13 \$3.95

Another great attention getter. Same as #12, however, it uses 1 LED. The LED changes from red to green. Requires 3-9 volts DC.

## FM WIRELESS MIKE KIT

Kit #14 \$3.95

The FM-1 is a small circuit used to transmit onto the FM band. Requires crystal or dynamic mike and 3-9 volts DC. Transmits 300 feet.

## FM WIRELESS MIKE KIT (WITH PRE-AMP)

Kit #15 \$5.95

Same as #14, however, it has a sensitive mike pre-amp.

## DECISION MAKER

Kit #16 \$5.95

A random flashing of two LED's. Red for no, green for yes. Requires 9 volts DC.

## MAGNETIC PRE-AMP (ASSEMBLED)

Kit #17 \$9.95

This magnetic pre-amp provides the required pre-amplification and RIAA equalization for a magnetic cartridge. Runs on 18 to 24 volts.

## ARKON LOGIC PROBE LOGIC 1

Kit #18 \$24.95

Easy to build Logic Probe kit. A full performance logic probe. With it, the logic levels in a digital circuit translates into light from the Hi or Lo LED. Pulses as narrow as 300 nano seconds are stretched into blinks of the pulse LED's. Specs—300 Kohm imp. Power—30ma at 5 volts, 40ma at 15 volts, 15 volts max. Max. speed—300 nano seconds 1.5 MHZ. Input Protection—+50 volts DC continuous, 117 volts AC for 15 seconds. (case included).

## LED POWER METER

Kit #19 \$24.95

Uses the popular LM3915 display driver. Features switch selectable peak or average peak power level indication. The front end utilizes precision half wave rectification. LED displays included 30 db (-24 db to +3 db) dynamic range.

## LED VU/POWER METER

Kit #20 \$29.95

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# Electronics Today

INTERNATIONAL

APRIL 1981 Vol. 5 No. 4.

## Features

### Introduction To Lasers. . . . . 10

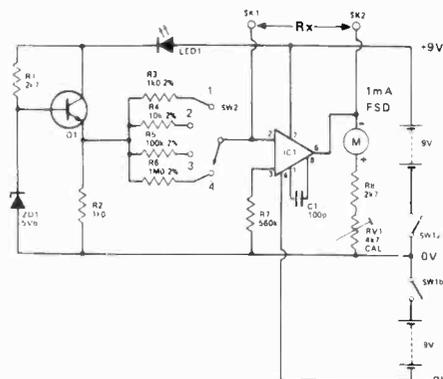
Once called the 'solution without a problem', the laser has become commonplace. Inside David Tilbrook explains the physics of their operation and describes the most common types.



Introduction to Lasers, p. 10

### Test Meter Circuits . . . . . 23

Many of the techniques used for testing electronic measurements are incorporated in this 'circuits' feature by Ray Marston.



Test Meter Circuits, p. 23

### Eddy Currents . . . . . 61

Eddy currents present peculiar problems, especially in the design of transformers yet the heating effects produced by them are used in the manufacture of semiconductors. A.S. Lipson explains.

### Into Electronics Part 7 . . . . . 70

Ian Sinclair continues on the subject of multivibrators in their various guises and leads on to other oscillator circuitry.



Stereo Image Co-ordinator, p. 16

## Projects

### Stereo Image Co-ordinator . . . . . 16

This box of tricks gives you the opportunity to try out what has up to now been predominantly a studio technique. The stereo sound image may be controlled automatically or manually. You can position the image in one place and keep it there or continually sweep the images between channels — and more.

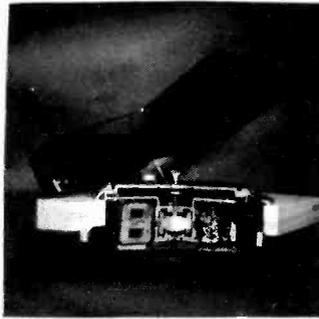
### Ultrasonic Switch . . . . . 31

This project uses a 40kHz ultrasonic frequency to switch a relay at distances up to 20 feet. Modern circuitry keeps the component count low. The relay can of course control any equipment including a 110V socket.



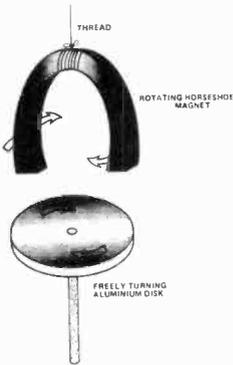
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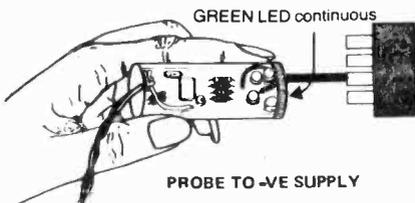
Cover: A cutaway model of a DP 2550 Turntable shows the high quality of engineering that goes into spinning the platters.

ISSN 0703-8984



Eddy Currents, p. 61

**Autoprobe . . . . . 65**  
 When it comes to finding faults—or confirm correct operation in a vehicle's electrical system, a multi-meter has disadvantages. This convenient project is very useful in those awkward places: it's also easy to build and inexpensive.



Autoprobe, p. 65

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 Firstly decimal points are dropped and substituted with the multiplier, thus 4.7uF is written 4u7. Capacitors also use the multiplier nano (one nanofarad is 1000pF). Thus 0.1uF is 100n, 5600pF is 5n6. Other examples are 5.6pF=5p6, 0.5pF=5p5.  
 Resistors are treated similarly: 1.8M ohms is 1M8, 56k ohms is the same, 4.7k ohms is 4k7, 100 ohms is 100R and 5.6 ohms is 5R6.

**PCB SUPPLIERS**  
 This magazine does not supply PCBs or kits but we do issue manufacturing permits for companies to manufacture boards and kits to our designs. Contact the following companies directly when ordering boards. NOTE, we do not keep track of what's available from who, so please don't write to us for information on kits or boards. Similarly, do not ask our PCB suppliers for project help.

K.S.K. Associates, P.O. Box 54, Morriston, Ontario N0B 2C0.  
 B&R Electronics, P.O. Box 6326F, Hamilton, Ontario, L9C 6L9  
 Wentworth Electronics, R.R. No. 1, Waterdown, Ontario L0R 2K0  
 Danocinths Inc. P.O. Box 261, Westland, MI 48185, USA.  
 Exceltronix Inc., 319 College St., Toronto, Ontario, M5T 1S2  
 Arkon Electronics Ltd., 409 Queen St. W., Toronto, Ontario, M5V 2A5.  
 A-1 Electronics, 5062 Dundas St. West, Islington, Ontario M9A 1B9. (416) 231-4331.

535 Yonge Street,  
Toronto, Ont. M4Y 1Y5  
Phone (416) 922-1818  
No collect calls please

# DOMINION

## PC BOARD SPECIALS

### Epoxy Base PC

6''x6 1/2'' ..... 25¢ ea.  
13''x4'' ..... 35¢ ea.  
13''x6'' ..... 50¢ ea.

## ETCHANT

16 oz ..... \$ 2.25  
32 oz ..... \$ 4.25  
140 oz ..... \$14.95

## RESISTORS

Values from 1 ohm to 10 meg. 1/4 or 1/2 watt. Still Only 3/4¢ each.

## CAPACITORS NISSEI POLYESTER FILM

	Price	uF	Price	uF	Price	uF
.0010	.20	.012	.20	.0027	.20	.027
.0012	.20	.015	.20	.0033	.20	.033
.0015	.20	.017	.30	.0039	.20	.039
.0018	.20	.020	.30	.0047	.20	.12
.0022	.20	.024	.30	.0056	.20	.15
.0027	.20	.028	.30	.018	.25	.18
.0033	.20	.033	.30	.022	.25	.22
.010	.20					

## CAPACITORS

### AXIAL LEAD

uF	WV(SV) 16(20)	WV(SV) 25(32)	WV(SV) 50(63)
1			.25
2			.25
3			.25
4			.25
5			.25
6			.25
7			.25
8			.25
10	.25	.25	.30
12	.30	.30	.30
15	.30	.35	.35
18	.35	.35	.35
22	.35	.40	.55
27	.40	.40	.65
33	.45	.55	.75
47	.55	1.05	
100	1.05	1.35	
220	1.65	1.95	

### TANTALUMS

DIPPED SOLID TANTALUM  
Capacitance Tolerance +/-20%

uF	WV(SV) 16(20)	WV(SV) 25(32)	WV(SV) 35(46)
0.22			.35
0.33			.35
0.47			.35
0.68			.35
1.0			.35
1.5			.35
2.2			.35
3.3			.35
4.7	.35		.35
6.8	.45		.35
10	.45	.50	.55
15	.50	.55	.85
22	.55	.65	1.35
33	.65	1.20	2.25
47	1.95	2.75	
68	2.75		
100	3.50		

## RADIAL LEAD

uF	WV(SV) 16(20)	WV(SV) 25(32)	WV(SV) 50(63)
1			.25
2			.25
3			.25
4			.25
5			.25
6			.25
7			.25
8			.25
10	.25	.25	.30
12	.30	.30	.30
15	.30	.35	.35
18	.35	.35	.35
22	.35	.40	.55
27	.40	.40	.65
33	.45	.55	.75
47	.55	1.05	
100	1.05	1.35	
220	1.65	1.95	

## POWER SUPPLY

### POWER SUPPLY

1400	16	.65	6800	Com 25	6.95
1600	16	.65	15000	RPE 10	4.50
2200	16	.75	12000	COM 40	6.95
2700	10	.65	14000	COM 40	1.50
1000	Can 16	1.50	15000	RPE 10	4.50
4700	Eiac 40	1.75	15000	CAR 25	1.50
6700	COM 100	6.95	15000	Com 50	11.95
			44000	Com 35	14.95
6800	RPE 25	6.95	80000	Com 20	14.95

## TTL

7400	.45	7423	.55	7472	.55	74123	1.10
7401	.45	7425	.65	7473	.70	74125	.98
7402	.45	7426	.65	7474	.70	74141	1.15
7403	.40	7427	.55	7475	.98	74150	2.30
7405	.75	7430	.45	7476	.70	74151	.98
7406	.85	7440	.45	7485	1.40	74154	2.50
7407	.95	7441	1.35	7486	1.50	74160	1.75
7408	.75	7442	1.35	7490	1.15	74164	1.25
7409	.45	7446	1.45	7491	1.15	74177	1.45
7410	.39	7447	1.65	7492	.85	74190	1.65
7411	.55	7448	1.75	7493	.85	74191	1.60
7412	.55	7434	.65	74121	.65	74192	1.55
7413	.85	7460	.40	74122	.90	74193	2.95
7420	.45						

## 4000 SERIES

4000	.50	4015	1.50	4026	2.35	4064	1.05
4001	.45	4016	.50	4027	.85	4065	1.78
4002	.45	4017	1.50	4028	1.50	4047	.90
4006	1.25	4018	.75	4029	1.25	4049	.45
4007	.20	4019	1.65	4030	.40	4050	1.50
4008	1.15	4020	1.25	4033	1.95	4069	.65
4010	.75	4021	1.95	4040	1.29	4310	1.95
4011	.65	4024	1.25	4041	2.05	4511	1.95
4012	.65	4025	.40	4043	1.30	4516	1.35
4013	.90						

## MICRO PROCESSOR

LS SERIES	PRICE				
74LS00	.85	74LS32	.80	74LS109	.80
74LS04	.60	74LS33	.60	74LS125	1.00
74LS08	.65	74LS38	.80	74LS132	1.40
74LS10	1.50	74LS74	.70	74LS151	1.40
74LS11	.75	74LS75	1.10	74LS155	1.10
74LS20	.70	74LS86	.70	74LS247	1.18
74LS30	.65	74LS90	.95	280	14.95
				8080	8.95
				8212	3.00
				8216	3.50
				8224	8.95
				8228	6.25
				8255	8.95
				4116	7.95



## ZENERS

TYPE #	VOLTAGE	WATTAGE			
BZK61-C75	3.7V	1W	IN758A	10	1W
IN4623	4.7	1W	IN759A	12V	1W
IN751A	5.1	1W	IN964B	13	.5
IN4733A	5.1	1W	3E21605	14	1W
IN4735A	5.6	1W	IN966	16	1W
14-515-.04	6.2	1W	BZK61-C18	18	1W
14574	6.2	.5	H220C	20	1W
IN753A	6.2	1W	BZK61-C20	20	1W
IN754A	6.8	1W	GE5028	20	1W
IN752A	5.6	1W	14-515-31	22	.5
17-515-.15	6.8	1W	IN47511	30	1W
HZ7B	7	1W	BZK61-C30	30	1W
IN755A	7.5	1W	BZK79C36	36	1W
IN74738A	7.5	1W	BZK61-C56	56	1W
IN757A	9.1	.5	IN5045	66	5W
IN4739A	9.1	.5	BZK61-C68	68	1W
BZK61-C9V1	9.1	1W	IN4764A	100	1W
IN757A	9.1	1W	IN5593B	183	1W

PART No	REPLACE	OLR PRICE			
2N2906	- ECG - 159	1.79	AD161	- ECG - 155	4.95
BF-245	- ECG - 133	1.99	25C1025	- ECG - 175	2.95
2N3391	- ECG - 199	1.15	25C1304	- ECG - 124	2.59
BF-199	- ECG - 161	1.59	25C1104	- ECG - 124	2.59
TT5-92	- ECG - 128	2.40	AD162	- ECG - 131	3.99
HD136	- ECG - 185	2.99	AD118	- ECG - 104	1.89
BD135	- ECG - 184	2.79	25C1160	- ECG - 175	3.50
25C1505	- ECG - 198	2.95	2N3614	- ECG - 121	3.95
25C1520	- ECG - 198	3.00	25C1106	- ECG - 162	9.95
25C1507	- ECG - 198	2.95	80182	- ECG - 130	4.79
25C1446	- ECG - 198	2.95	BU205	- ECG - 165	9.95
HJE2170	- ECG - 242	3.59	BU108	- ECG - 165	9.95
25C940	- ECG - 281	11.95	25C939	- ECG - 163A	12.95
BF245A	- ECG - 133	2.25	25C945	- ECG - 199	.89
25C1685	- ECG - 199	.89	25C656	- ECG - 289	1.59
25C656	- ECG - 289	1.59	25C839	- ECG - 123A	1.59
25C658	- ECG - 191	4.25	25C458	- ECG - 289	1.49
25C877	- ECG - 102A	1.99	2N1611	- ECG - 128	1.99
25C103A	- ECG - 103A	2.30			

## POTENTIOMETERS

A huge selection available. Slider controls from 99¢ to \$2.95; Single pots 49¢ (with switch 59¢) Dual pots 69¢ (with switch 79¢) See out catalogue for full range and other types.

## MINIMUM ORDER

\$10.00. All merchandise subject to prior sale. Prices subject to change without notice.

## SHIPPING.

Add 5% extra to cover shipping, excess refunded. Orders over \$75 shipped pre-paid. Ontario residents add 7% P.S.T.

# EduKit's

LOGIC TRAINER ..... \$74.95

MODEL DLT01

A new development package for a BASIC DIGITAL LOGIC COURSE. Four gates and a counter. Circuit is included along with an in-depth manual. Protoboard included.

STEREO PHONO

PREAMP KIT ..... \$11.25

MODEL EK80SP001

Anyone with a ceramic input receiver can enjoy the quality of a magnetic cartridge with this simple but very effective Stereo Phono Preamp.

Specification: Standard RIAA, Frequency Response: 20Hz to 2KHz + 1.5dB. Input Sensitivity: 5mv input for 500mv output. Maximum Output: 700mv rms. Input Overload: 100mv rms. S/N Ratio: Greater than 60dB.

16 CHANNEL MULTI-MODE LED CHASER KIT ..... \$32.95

MODEL EK80LCM16

We're proud to add this to our line. It's similar to our 15 channel LED chaser but with many extra features. There are over 60 selectable modes. A few: Up, Down, Skip, Pulse, Scramble, Single Pulse, Multi Pulse and many more. An optional 120 vac board is available. (Extra)

STROBE LITE KIT ..... \$21.95

MODEL EK80SL001

Fantastic for special effects. Variable speed Xenon flash gives you a "STILL MOTION" effect. A real attention getter.

CRYSTAL RADIO KIT ..... \$8.95

MODEL EK80CR001

A self powered radio which uses a resonant circuit and detector for AM radio reception. An ideal project for the beginners.

1.5 to 24v POWER SUPPLY KIT ..... \$24.95

MODEL EK80PS024

A variable Power Supply suitable for many digital and linear applications. Delivers an output current of 100ma, from 1.5v to 15v and 500ma, from 16v to 24v.

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MODEL EK80PS028

A true 0 to 28 volts capable of delivering 1 amp continuous. Full wave rectification, filtering and capacitance multiplication provides a clean dc source for sensitive audio and digital work. An ideal supply for the experimenter.

STEREO AUDIO MIXER KIT ..... \$49.95

MODEL EK80AM001

Inputs 2 phono, 1 aux. Master control. Expandable. Frequency response 20Hz-20kHz; 5v output, 0.01% distortion.

16 CHANNEL LED CHASER KIT ..... \$22.95

MODEL EK80LC016

A very familiar sight seen at discos, department stores, and on neon signs. 16 LED's flash in sequence up-down or alternate. Adaptable to 120 vac. (Extra)

POWER SUPPORT 120 ..... \$24.95

MODEL EK80PLC120

A 120 volt power board which allows you to connect regular lamps to our LED Chaser Kits. 8 channels are supplied per board with 150 watts per channel. They can be easily interfaced for 16 channels.

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MODEL EK80A005

A general purpose 5 watt amplifier with Thermal Overload and Short Circuit Protection. Because of its low operating voltage and high

# RADIO

## TRANSFORMERS

8801S ..... \$8.95  
 Primary 110V. Secondaries 700V @ 150mA, 250V @ 50mA,  
 13.5V @ 1.5A (Specifically designed for the 7984  
 transmitting compactron tube.)

2826500 ..... \$3.95  
 Primary 110V. Secondaries 28V @ 2A, 6V @ 500mA

24-10182-1 ..... \$14.95  
 Primary 110V. Secondaries 56V (CT) @ 8A, 2V @ 2A,  
 6.3V @ 4A

24-10182-2 ..... \$14.95  
 Primary 110V. Secondaries 58V (CT) @ 10A, 24V @ 2A,  
 6.3 @ 4A

321 TK ..... \$3.95  
 Primary 1 120V: Secondaries 10V (CT) 500mA, 14V @  
 500mA  
 Primary 2 120V: Secondaries 20V (CT) 500mA, 28V @  
 500mA

# PHILIPS



# DeForest

Quality  
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### Tweeters — Dome

	Regular Prices	
AD00400T8/4	18MM	15.40
AD00800T8/4	18MM	14.25
AD00900T8/4	18MM	15.00
AD140T8/4	Polycarbonate	15.40
AD141T8/4	Textile	15.40
AD01800T8/4/15	Exposed Textile	19.25
AD01805T8/4/15	Square Exposed	19.40
AD0182T8/4/15*	Polycarbonate	17.40
AD0183T8/4/15*	Textile	17.30
AD01830T8/4/15	Textile	18.00
AD01831T8	Textile Square	21.20
AD01832T8	Paper	21.00
AD01833T8/4/15	Paper Square	21.00
AD01835T8/15	Diamond Cut Plat.	48.00

### Tweeters — Dome — Ferro Fluid

AD01404T8/4	Available	17.30
AD01824T8/4	Early	18.00
AD01834T8/4	81	18.00

### Tweeters — Cone

AD2273T8	2" Cone	5.45
AD2298T8	2" Cone	8.40

### Squawkers (Mid Range) Dome

AD0211SQ8/4*	5" Textile	39.90
AD0211SQ8/4		37.75
AD0215SQ8/4		44.25
AD0216SQ8/4		46.50
AD02161SQ8/4	Deluxe Version	52.15

### Squawkers — (Mid Range) Cone

AD5060SQ8/4*	5" Cone	28.00
AD5061SQ8/4	5" Cone	20.00
AD5062SQ8/4	5" Cone	28.85

### Woofers

AD4060W8/4	4" 30W	22.25
AD5060W8/4	5" 10W	20.55
AD7065W8	7"	31.20
AD70652W8/4	7"	28.50
AD08120W8	8"	8.62
AD0100W8/W8W	8" 40W	43.00
AD60601W8	8" 30W	25.95
AD60651W8/4	8" 50W	32.40
AD60652W8/4	8" 50W	30.00
AD80671W8/4	8" 50W	37.50
AD80672W8/4	8" 50W	36.00
AD1065W8*	30 W 10"	56.25
AD10100W8/4*	40 W 10"	75.00
AD10240W8/W8W	70 W 10"	67.50
AD10650W8	30 W 10"	54.00
AD12200W8	80 W 12"	78.00
AG12240W8/W8W	70 W 12"	69.00
AD12250W8	100W 12"	83.50
AD12600W8	40 W 12"	46.80
AD12650W8	60 W 12"	52.00
AD15240W8/W8W	80 W 15"	69.75

### Combl Plates (Squawker & Tweeter on Aluminum Plate)

	Regular Prices	
AD21180ST8	Diamond Cut	85.00
AD21181ST8	Flat Back	85.00

### Full Range

AD5061M8	10 W 5"	20.75
AD7062M8	30 W 7"	26.25
9710MC	20 W 8"	46.00
AD12100M8	25 W 12"	80.00

### Passive Radiators ("Drone Cones")

AD6000	Rubber Surround	14.25
AD8001	Rubber Surround	12.00
AD8002	Foam Surround	14.25
AD1000	Rubber Surround	34.50
AD10000/W	Foam Surround	15.00
AD12000	Foam Surround	18.75
AD12001	Rubber Surround	35.90

### Cross-Over

ADF1500/8/4	2 way	9.75
ADF1600/8/4	2 way	9.15
ADF2000/8	2 way	9.15
ADF2400/8	2 way	7.50
ADF3000/8/4	2 way	8.85
AD3WXSP	3 way hi-Power	37.50
ADF6/SSP	3 way hi-Power	32.00
ADF7/3SP	3 way hi-Power	41.10
ADF500/4500/8	3 way	17.40
ADF700/2600/8/4	3 way	22.50
ADF700/3000/8/4	3 way	22.50
AD1SUBW	Sub Woofer	37.50

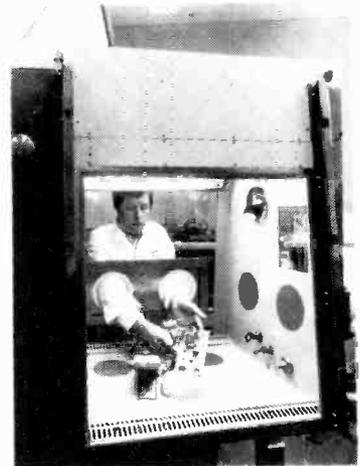
# NEWS

## Weightless Workbench

Designed and built by Lockheed Missiles & Space Co. Biotechnology Organization under contract, the portable laboratory — officially the general purpose work station — is intended to support general life sciences laboratory experiments conducted in Weightless space.

The scientists' hooded work bench is extremely versatile, according to Lockheed Project Leader Philip A. Wagner. "It is capable of being adapted to the particular requirements of many different life science experiments," Wagner says. "An important function for it is to protect experimenters as well as the specimens from biological contamination and to control liquids and chemical vapors released inside the laboratory in a zero-gravity environment."

The laboratory — really a controlled environment "clean-room" also has a camera stand available, to photograph experiments, and interior lighting and connections that bring electricity, water,



vacuum and data links to the experimenter.

The tiny laboratory can be used in one of three positions in zero gravity: (1) in its storage rack in one wall when used by a standing experimenter (2) partially pulled from the rack and used by a seated experimenter and (3) pulled entirely out of the rack, pivoted 90 degrees, and used by two experimenters seated opposite each other.

## Stores Directory

We held our collective breaths as the January 1981 issue hit the stands. We had fully expected a deluge of mail from angry retailers demanding to know why they weren't in the Directory Of Electronic Retailers.

So far only three firms came through. When we had initiated the survey, we were sure that complete coverage was impossible. However, results to date seem to indicate that we managed to include all stores. We find this hard to believe.

It's really nice to see that the 'spirit of competition' is alive in Canada.

## IUS Electronics Ltd.

P.O. Box 81, Trail, BC V1R 2T6, (604) 364-2786.

EK (speaker kits), MO, CAT, Free Assembled speaker kits for the do-it-yourselfer.

## Amtrex Electronic Inc.

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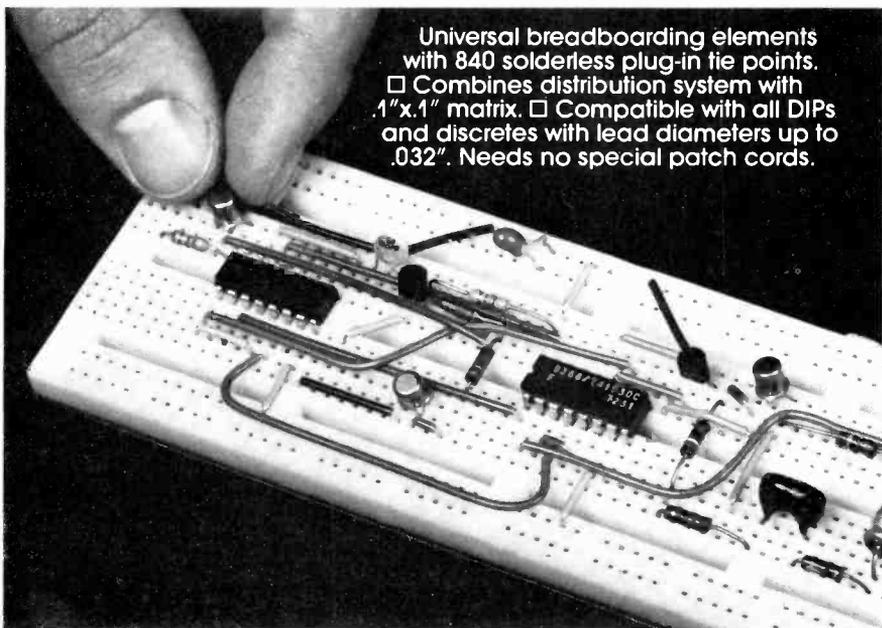
CA, MO, CAT, FREE (send stamp).

## Cat News

Needless to say, after we went to press for March, two new catalogues came through.

Firstly, Noramel's catalogue No. 18 is out. The 44 page flyer is crammed (and we mean crammed) with a diverse assortment of J.W. Miller coils, tubes, insulators, connectors, cables and more. The catalogue is available free from Noramel 2407, Ste. Catherine E., Montreal, PQ H2K 2J7. A french version should be available soon.

Also, we've been told that the long awaited Arkon cat. will be ready soon. We haven't seen it (not even the cover), but we're told it will be 150 pages long. It should be ready by the time you read this. Write Arkon Electronics Ltd., 409 Queen Street W, Toronto, Ontario M5V 2A5.



Universal breadboarding elements with 840 solderless plug-in tie points. □ Combines distribution system with .1" x .1" matrix. □ Compatible with all DIPs and discretes with lead diameters up to .032". Needs no special patch cords.

## Your breadboarding is a super-snap with a solderless A P Super-Strip.

Build a circuit almost as fast as you dream it up. Pull it apart and do another—everything's as good as new.

Our versatile Super-Strip mini-breadboards give you the same top-quality contacts you get in our full-scale ACE All-Circuit Evaluators. Not so "mini," either. You

can build circuits with as many as nine 14-pin DIPs.

Instant-mount backing and quick-removal screws make stacking and racking a snap, too.

For our complete AP catalog, The Faster and Easier Book, contact your local AP Products distributor.

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Thunder Bay . . . . . (807) 345-7334

Toronto . . . . . (416) 868-1315

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Willowdale . . . . . (416) 221-6174

### QUEBEC:

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Montreal . . . . . (514) 769-8861

### SASKATCHEWAN:

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Saskatoon . . . . . (306) 562-6424

### MAIL ORDER:

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LINES FINE

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### SHARP POCKET COMPUTER

- Programs in BASIC
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- 1424 steps, 26 memories
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- Optional cassette interface to store programs or data
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Only . . . . . \$269.00

### COMMODORE PET COMPUTERS

- 8K . . . . . \$1195.00 Full keyboard.
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- 32K . . . . . \$1795.00 keypad — 25 lines

Cassette Deck \$99.00 of 40 characters.

Memorex 5 1/4" Diskettes . . . 10 for \$49.95

Memorex C-10 Cassettes . . . . . \$1 each

PET Personal Computer Guide . . . \$19.95

Library of PET Subroutines . . . . \$24.95

BSR System X-10 Home Control System

for lighting and appliances. No special wiring needed. Starter Kit . . . \$139.95

(Includes 1 command module, 1 appliance module, 2 lamp modules)

### Scientific SHARP PRODUCTS

programmable (Model EL5813) . . \$59.95

Metric Converter . . . . . \$25.95

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## ELECTRONICS 2001

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## NEWS

### New Babani Books

Two new Babani Books this month. The first is another R.A. Penfold effort entitled 'VMOS Projects' (BP 83). The book details many practical circuits covers such areas as audio circuits, sound generator circuits, DC and signal control circuits. Price is \$8.20 including postage and handling.

Babani's second offering is Electronic Synthesiser Project (BP 81) by M.K. Berry. Projects described includes an analogue delay lines, programmable sequencer, VCOS, ADSRs etc. Sample pcb layouts have been included. Price is \$7.30 including postage and handling. All orders should be sent to the ETI Book Service care of this magazine.

### New Sprague Rep

Sprague Electric Co. has appointed Lenbrook Industries, Ltd. distributor sales representative for Sprague components a semiconductor.

Lenbrook will responsible for sales and technical support from their Montreal, Toronto and Calgary offices. Responsibility for management will be under the management of Bill Strangways.

Lenbrook Industries, Ltd. 1145 Bellamy Road, Scarborough, Ontario M1H 1H5.

### Videoland Move

Videoland have moved, not far from their old location, but moved nevertheless. The new address for the Head Office and for Mail Order is: 938 Wilson Ave, Downsview, Ont, M3K 9Z9.



### Looking Back Power To the People, January, 1981

Some readers have pointed out that the article was missing a piece. The conclusion appears on page 70.

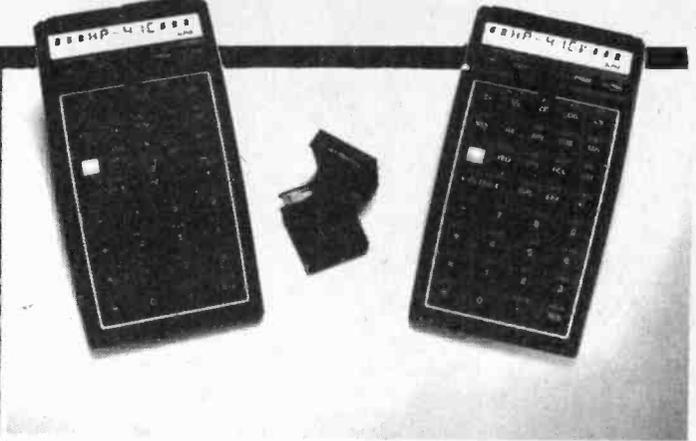
### 300W Amplifier, August 1980

Some problems may be encountered in adjusting the Class A bias. In most cases this can be traced to Q8 not having enough gain. An MPS-A18 should do a better job.

As an alternative, constructors may wish to try reducing the value of R22 until proper adjustment is possible.

### Heath Computer Contest, February 1981

A little confusion here on our part. For the record, the learning manuals and parts are designated EE-3401 and the trainer is designated ET-3400.



### Super 41C

The Hp-41CV's memory accommodates up to 2,000 program lines, five times that of its predecessor. The calculator is fully programmable, and features continuous memory, meaning that programs and data are saved even while the calculator is off. Alphanumeric display (letters and numerals) and 130 functions make it perhaps the most powerful handheld machine available.

The HP-41CV's list price is \$549.00 and it is available now from calculator dealers and HP.

Hewlett-Packard also introduced a "Super Memory Module" that plugs into the back of the company's HP-41C calculator and boosts its memory

to the same 2,000 program lines as the new HP-41CV.

The new quad memory (A random-access memory module with quadruple the memory of the HP-41C) plugs into one port while providing four times the memory of the standard memory module. So an HP-41C with quad memory has the same capacity as the Hp-41CV (about 2,000 program lines) and still has three free ports for software modules or peripherals.

The HP-82170 quad memory will be available in the first half of 1981 from calculator dealers and HP at a suggested price of \$152.95.

Write to Hewlett-Packard (Canada) Ltd., 6877 Goreway Drive, Mississauga, Ontario L4V 1M8.

### The Last Word Novel New Breadboard

Mario's Bakery (New Jersey) has just announced what they claim is the most significant step in breadboard technology.

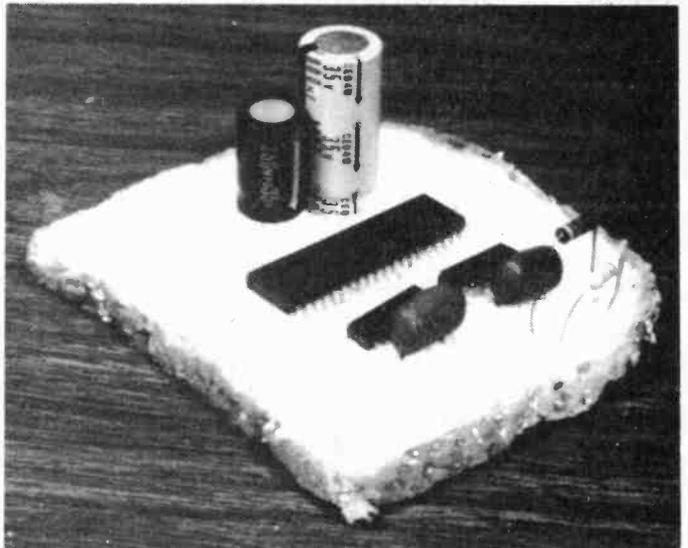
The Model W (for white) breadboard feature infinitesimal pin spacing so that a virtually endless variety of electronic packages can be accommodated. The breadboard is manufactured from purely organic and renewable materials (flour, water

etc.) and has been certified ecologically safe.

Other features include tasteful appearance and composition. Two or more Model W breadboards can be stacked to form a circuit 'sandwich'.

Two more versions, the Model CW (Cracked Wheat) and Model WW (Whole Wheat) are expected shortly. A french version will be introduced later this year.

And people say there's nothing new.



## Deputy Editor For ETI

We're looking for someone to join us in a senior editorial capacity. This is a new position and reflects the rapid growth being experienced by the magazine.

Candidates must have three qualities:

1. Interest in and knowledge of electronics.
2. Knowledge of and preferably experience in publishing.
3. A desire to communicate.

Although a degree in electronics is an advantage, it is not essential. Candidates must be literate.

The Deputy Editor must have qualities which would enable them to take on the day-to-day running of the editorial side of the magazine after a period of familiarisation.

ETI Magazine is an independent company, 100% owned, published and printed in Canada. The company has experienced rapid growth and it is anticipated that this will continue. The salary will depend initially upon experience but will ultimately depend upon the individual's contribution to the company.

Applications should be made in writing (these will be treated as confidential). Send to:

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# AN INTRODUCTION TO LASERS

A fascinating rundown on these devices,  
the physics of their operation  
and the various types by David Tilbrook.

THE FIRST LASER was built in 1960 by Theodore Maiman, a research scientist working for the Hughes Aircraft Corporation. His research paved the way for the development of a fantastic array of fascinating devices and very useful tools. Today, lasers are used in surveying, geophysical measurements, medical applications, electronic component manufacture, atomic fusion research, precise distance measurement and a host of other applications.

The word laser stands for *light amplification through stimulated emission of radiation*. Whilst this implies that lasers are amplifiers, they are generally configured as oscillators. The light radiation they produce is very 'pure' — occurring at a specific frequency (or frequencies) — and the beam is well collimated, that is, it diverges only a tiny amount rather than spreading as does the beam from a flashlight.

The unique properties of laser light

make the laser a prime candidate for wide application in technology and physical measurement. Many different types of laser have been developed but all employ the same basic principle of operation. All lasers have two fundamental components — a 'laser medium' and an energy source. The latter is used to excite the laser medium by a process called *pumping* — but I'll explain that further when I get into the physics behind the laser. First, let's

look at the various 'breeds'.

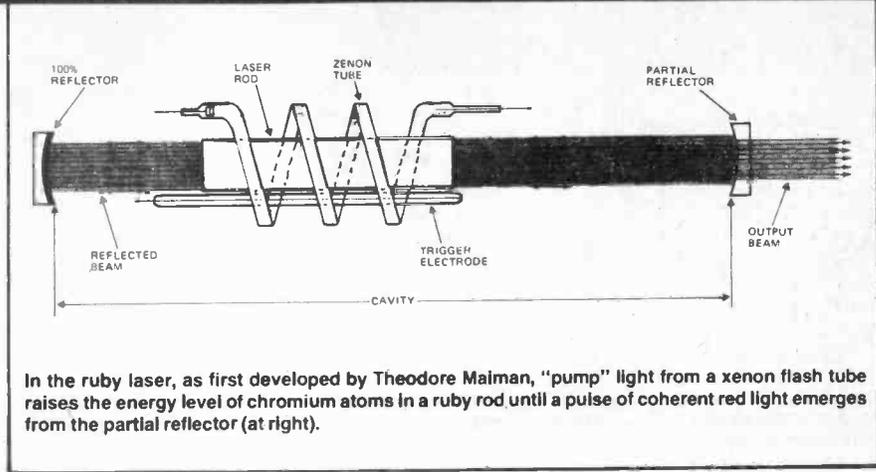
### Solid-State Lasers

In laser physics, solid-state does not refer to semiconductor lasers but to a breed having a laser medium that is formed by doping a crystalline or glass material with an impurity material which produces the laser action when pumped. The most common of these is the ruby laser.

This type of laser consists of a central, cylindrical synthetic ruby crystal made from aluminium oxide as a base material and doped with chromium as the impurity. The crystal is mounted with mirrors at each end and is surrounded by a xenon-filled flash tube (or tubes). These xenon tubes provide optical pumping—a requirement of all solid-state lasers. One of the mirrors is 100% reflective while the other is very slightly transmissive so that a small portion of the laser light produced within the crystal is tapped off.

When the xenon flash tube is fired, laser action occurs within the ruby and laser light travels back and forth down the crystal, exciting further laser action and generating an intense pulse of light that passes through the slightly transmissive mirror.

One of the early problems with solid-state lasers was to achieve a continuous output. In 1962 a solid-state laser was built at Bell



In the ruby laser, as first developed by Theodore Maiman, "pump" light from a xenon flash tube raises the energy level of chromium atoms in a ruby rod until a pulse of coherent red light emerges from the partial reflector (at right).

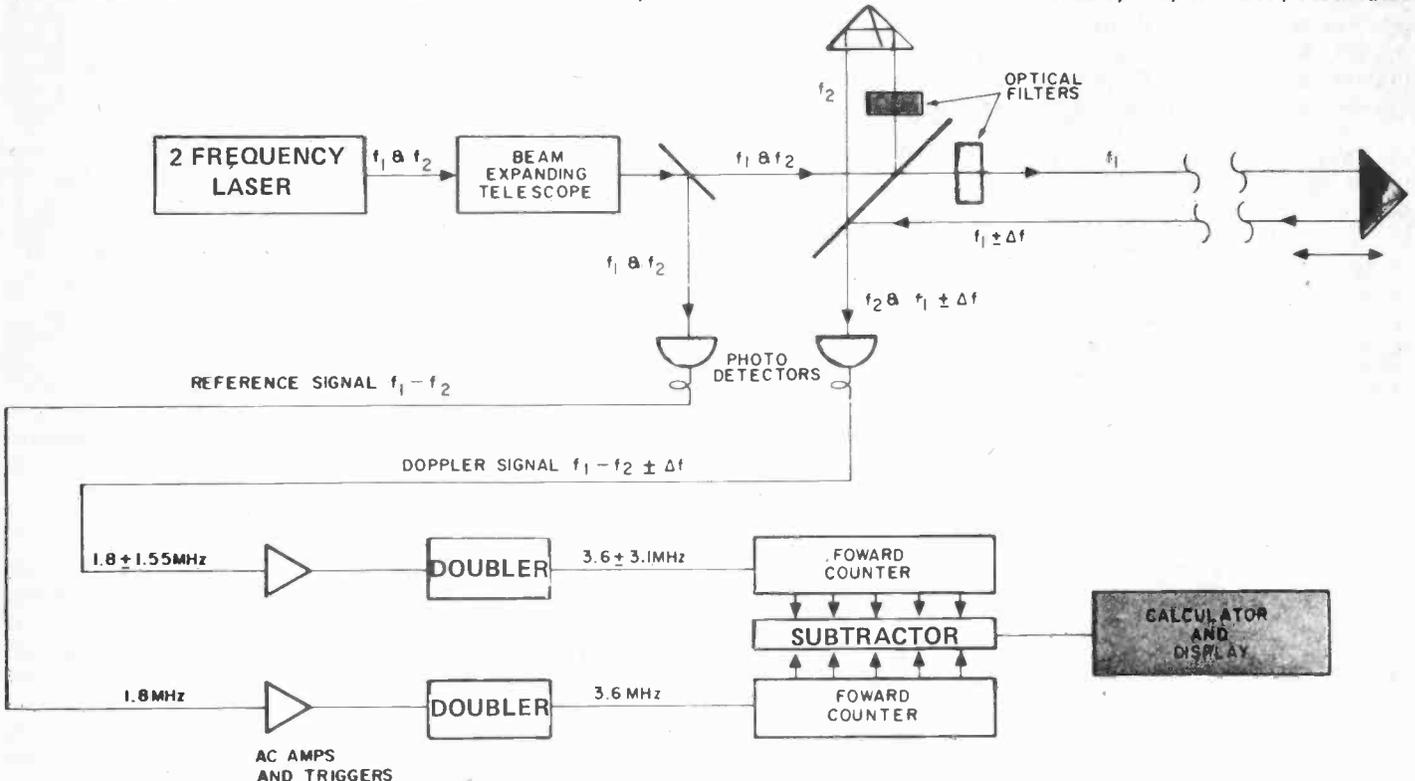
Telephone Laboratories. It consisted of the base material calcium tungstate, impregnated with neodymium. More recently, solid-state lasers have been built with continuous outputs of over 1000 watts.

Much experimenting has been done to optimise the method of pumping solid-state lasers. One means developed by RCA in 1962 used a 300 mm hemispherical mirror to focus sunlight onto a laser crystal of calcium fluoride immersed in liquid helium. This laser produced a continuous output of 50 W, and was the first laser to use sunlight to power the device directly.

### Semiconductor Lasers

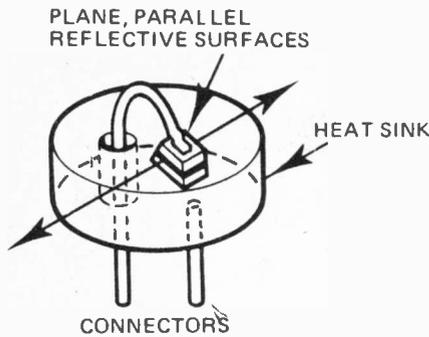
Semiconductor lasers are relatives of the common light emitting diode, or LED. The most common of these is the gallium arsenide laser, and consists of a semiconductor diode junction formed by gallium arsenide doped with two different impurities to form the p and n materials. When forward bias is applied, a large number of electrons and holes move towards the junction where they recombine and generate laser light.

Typical power outputs of gallium arsenide lasers are low, around one watt maximum, but efficiency is very high. Furthermore, they are easily modulated

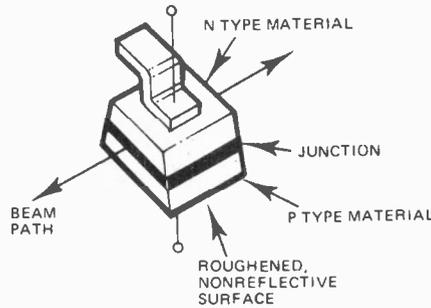


An important application of helium-neon lasers is in distance and velocity measurements using interferometric techniques. This block diagram shows a system devised by Hewlett-Packard for an instrument which has the ability to

measure length to an accuracy of 1 part in  $10^6$  over a distance of 60 metres (that's 1 mm in 1 km!).



The semiconductor laser comprises a gallium arsenide junction doped with two different impurities. Construction of the junction is illustrated on the right, this is mounted on a heatsink header in the practical device, as shown at left.



not all quantities are continuous. A dice can only show 1, 2, 3, 4, 5 or 6 on its upper face and this is a quantised quantity.

Similarly, standing waves on a violin string, resonances of a quartz crystal, or harmonics of a square wave are all quantised - they occur only at fixed frequencies.

Quantum physics is based on the discovery that a large number of quantities involved with molecular, atomic and sub-atomic physics are quantised. Many of these quantities were assumed to be continuous in "classical physics" and it has only been through the recognition of their quantised nature that modern physics has been able to achieve a reasonably workable model of atomic structure.

Most light sources today consist of either a solid (like a tungsten filament) or a gas (as in the fluorescent tube) through which an electric current is

and for this reason should be of great importance in optical communications in the future.

**Liquid Lasers**

Most liquid lasers use an organic dye as the laser medium and are optically pumped. Their big advantage over other types lies in the fact that the frequency of light generated can be varied. For this reason they are called **tunable lasers** and are being used experimentally to 'steer' chemical reactions.

Often the optical pumping of liquid dye lasers is done by other lasers, such as the nitrogen gas laser which has an output in the ultraviolet spectrum.

**Gas Lasers**

Gas lasers are probably the most important single category. The **carbon dioxide** laser for example provides the highest continuous power outputs of any breed. Furthermore, its output is in the infra-red spectrum which makes it useful commercially for cutting applications.

The most common gas laser is the **helium-neon** type. It provides a continuous output of red laser light that has been used commercially in distance measuring equipment as well as a general purpose "straight line". It is also used extensively in laboratories for

diffraction, for general optical experiments and in interferometers. It has evolved into an inexpensive and reliable device.

The HeNe laser consists of a mixture of the gases helium and neon, placed in a sealed tube at low pressure. Originally, HeNe lasers were excited by high frequency ac current (around 28 MHz) but these days high voltage dc is used. As in most other lasers, mirrors are used at each end of the tube, so that most of the light produced is trapped within the laser itself, maintaining a special condition needed for laser action called *population inversion*.

In order to understand the laser phenomenon in any greater depth it is necessary to look at some of the physics of atomic structure.

**Quantum physics**

When studying the universe we apparently find two fundamentally different types of quantities, those quantities with a continuum of values and those with only a discrete or 'quantised' number of values. For instance, the speed of an object can range from zero up to the speed of light and seems to consist of an infinite number of possibilities. Similarly, the set of all numbers is infinite. These are examples of continuous quantities, but

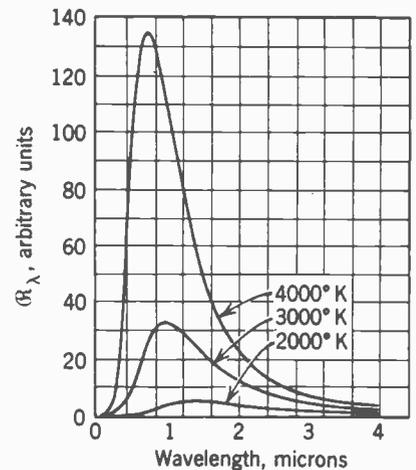
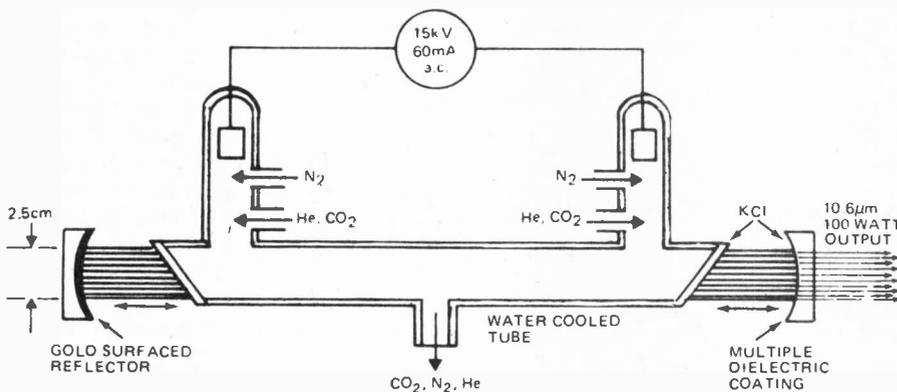


Figure 1. The spectral radiance for cavity radiation at three different temperatures. (After Halliday and Resnick, "Physics for Students of Science and Engineering".)

passed. This current heats the filament or gas to incandescence and light is emitted. Using a spectrometer, it is possible to measure the relative intensities of the different light wavelengths emitted. If the temperature of the heated objects is varied the relative intensities change. All of these results can be plotted to make a family of curves on a graph like Figure 1. Each curve represents a different temperature and the shape of these curves is related to the particular material that is being heated.

The number of variables in the case of a heated solid makes any mathematical analysis unnecessarily complicated so scientists sought an idealised



Some gas lasers can generate enormous output powers. This diagram illustrates the general construction of a carbon dioxide laser.

heated solid. They called this a *cavity radiator*, and the light emitted proved to be largely independent of the material used to make the cavity radiator. Furthermore, the light emitted was found to vary in a fairly simple way as the temperature was varied.

Practical cavity radiators simply consist of a hollow container with a small hole drilled in one side (see Figure 2). If the cavity radiator is heated,

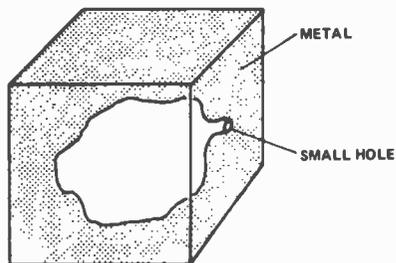


Figure 2. Representation of a cavity radiator. At a particular temperature, light emitted from the hole is brighter than that radiated by the body of the material.

more light is emitted from the hole than from the outside walls. The light emitted from the hole is called *cavity radiation* (sometimes called *black body radiation*) and was of intense interest in the later part of the nineteenth century.

The explanation of the related intensities of the various wavelengths emitted in cavity radiation was one of the outstanding problems for classical physics. Several attempts had been made but all of these had only fitted the experimental data partially.

In 1900, a German physicist, Max Planck, derived a formula that fitted cavity radiation perfectly. He was forced to the conclusion that the atoms inside the cavity radiator were acting like tiny electro-magnetic oscillators. They could emit light into the cavity and absorb light energy from it, but only at certain characteristic frequencies.

Planck was forced to make the radical assumption that an oscillator cannot have a continuum of different energies. These energies were quantised so that the only possible values were given by the equation.

$$E = nh\nu$$

where 'E' is the energy  
'n' is an integral number, i.e.: 1, 2, 3, 4, 5, etc.  
'h' is a constant (now called Planck's constant)  
and 'ν' is the frequency of the oscillator

The oscillators could not radiate light continuously but only in jumps, or 'quanta', and only when the atom jumped from a high energy state to a lower one. If the atom jumped just one energy state then 'n' in the above equation becomes equal to one, and the equation becomes:

$$E = h\nu$$

This is known as *Planck's equation* and is one of the more important equations in modern physics.

This was the start of quantum physics. A physical event could only be explained by assuming that atoms radiate integral amounts of energy.

Planck's ideas were reinforced several years later by Albert Einstein who applied the concepts of quantisation to another area of physics that was to revolutionise our understanding of the nature of light. Up to this time, light was thought of as an electromagnetic wave. Even though Planck had quantised the energies of atomic oscillators in the cavity walls, he still regarded the radiation within the cavity as a wave. This wave picture of light had been enormously successful in explaining light phenomena up to that time, but Einstein was to point out its inadequacy in some circumstances.

### The Photo-electric Effect

This effect was another experiment which had not been satisfactorily explained in terms of classical physics. Figure 3 shows a circuit diagram for the apparatus used in the photo-electric experiment. If light is shone onto a clean metal surface some electrons are liberated from the metal. If the metal is placed in an evacuated glass cylinder, the liberated electrons (called *photo-electrons*) can be made to constitute a current flow, which will register on the

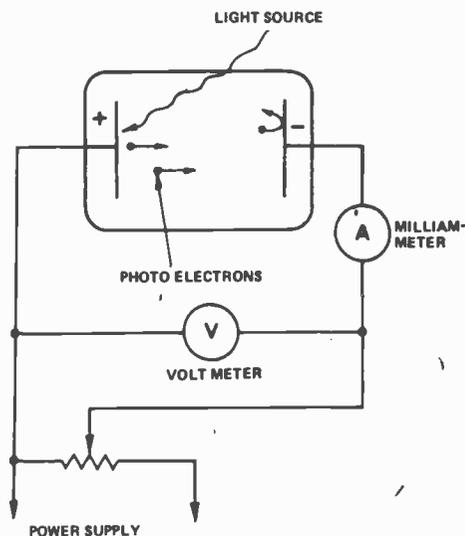


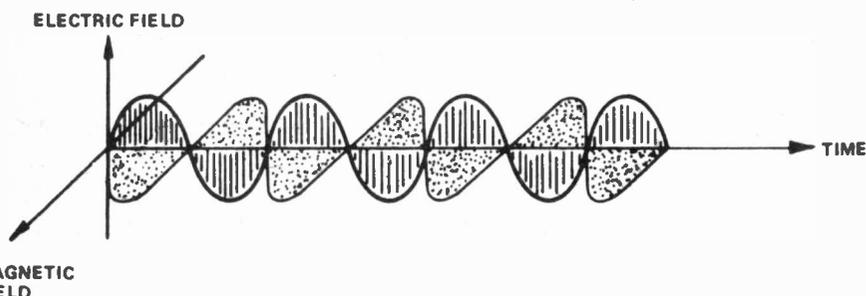
Figure 3. Circuit diagram of the apparatus used in the photo-electric experiment.

meter. If the other electrode is now made negative with respect to the first, by connecting the two to a power supply, the negative electrode will tend to repel the photo-electrons and decrease current flow. When the voltage is great enough, the photo-electrons can be brought to a stop. If the voltage is increased even further the photo-electrons are turned back toward the anode. The voltage applied to the plates is called the *retarding potential* and can be used to measure the energy of the photo-electrons.

When the experiment is carried out it is found that photo-electrons are emitted almost instantaneously when the light is turned on. If the wavelength of the incident light and the retarding potential are kept constant, then the current flowing is found to be proportional to the intensity of the light beam. Furthermore, for any particular metal the energy of the photo-electrons is found to be independent of light intensity, but varies with frequency of the light.

These results were difficult, if not impossible, to explain on the basis of the wave theory of light. Since light was thought of as a continuous wave, the energy absorbed on the photo-electric surface should have been proportional to the light intensity. If the intensity was decreased enough it should have taken a certain amount of time for sufficient energy to be absorbed by the electrons before any emission could start. So the wave theory of light could not explain why photo-electric emission starts instantaneously, even if the intensity of light is decreased.

Similarly, the fact that the energy of the photo-electrons varies with the frequency of the light and is in no way affected by the intensity of the light,



According to the electromagnetic wave theory, light is seen as a continuous wave of oscillating electric and magnetic fields.

cannot be explained by the classical theory.

**A quantum approach**

In 1905, Albert Einstein applied quantum theory to the problem of photo-electric emission and obtained a theory that explained all the observed characteristics. He postulated that light was not a continuous wave but consisted of small quanta of light called *photons*. Each photon has an energy, 'E', that is related to the wavelength of the light by Planck's equation.

Any single photon can interact with a single electron so the energy imparted to this electron will depend only on the energy of the photon, i.e: its frequency. Increasing the intensity of the light beam increases the number of photons and will only increase the number of photo-electrons emitted. Emission will start instantaneously, as all the energy needed for a photo-electron to escape the surface of the metal is contained in any single photon.

The photo-electric effect occurs because the energy imparted to the photo-electron by the photon has exceeded that needed by the electron to break bonds that normally bind it to the metal surface; but it is not the only example of electron-photon interactions. In the photo-electronic effect the electron struck is a bound electron, inside an atom. The photon disappears and the electron is dislodged. However if the electron is a free electron it will recoil and cause the generation of a second photon of lower energy. This is called *the Compton effect*.

Another set of electron-photon interactions are called *pair production* and *pair annihilation*. If a photon is given enough energy it can convert into an electron and a *positron* when passing another heavy particle. A positron is an antimatter electron. It has all the properties of a normal electron except that it has a positive instead of a negative charge. This process is called pair production. Pair annihilation occurs when a positron and an electron interact. Both are annihilated and two photons are generated.

All these electron-photon interactions are manifestations of a single process, the exchange of photons, called *virtual photons*, between charged particles. Indeed, it is this effect that gives rise to the attractive and repulsive forces between charged objects. The study of photo-electron interactions is called quantum electrodynamics and is one of the major fields of research in modern physics.

**Spontaneous and stimulated emission**

When a photon interacts with a bound electron it may not have sufficient energy to overcome the binding forces. In this case the photon is absorbed by the electron, as would happen in the photo-electric effect, but the electron is not liberated from the atom. Instead, it jumps up to a higher energy level or orbit. Quantum physics has determined that electrons cannot have a continuum of different energy levels, only energy levels that are integral multiples of a fixed amount. When the electrons of an atom are in their minimum energy states the atom is said to be in its ground state. If an atom is in its ground state, say with energy  $E_1$ , it can be forced to a higher energy level, say  $E_2$ , by absorption of a photon. If the photons absorbed have energy  $E = hv$  then the increase in electron energy will be exactly  $hv$ , i.e:  $E_2 - E_1 = hv$ .

After a certain amount of time, approximately  $10^{-8}$  seconds, the electron will drop back down to its lower energy level, automatically emitting a photon, again with energy  $hv$ .

The excited atom was initially at rest and has no preferred direction in space. As a result the photon can be radiated in any direction while the atom recoils in the opposite direction. This process is called *spontaneous emission*. If a group of atoms are excited in this way they will generate photons in all directions randomly, as excited atoms return to their ground states; see Figure 4.

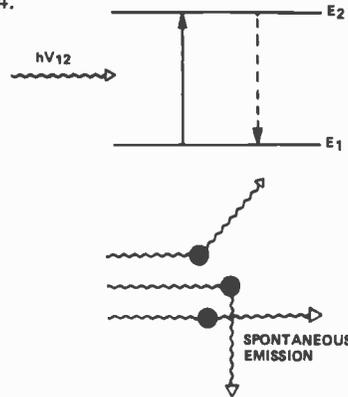


Figure 4. Energy level diagram for the process of spontaneous emission.

If an electron at energy level  $E_2$  interacts with another photon of energy  $hv$ , the electron is forced to return to its ground state with the emission of a second photon. This process is called *stimulated emission* and is the basis of laser action.

The most important point about

stimulated emission is that both photons leave the atom with the same phase and direction as the incoming photon, see Figure 5. The two photons are said to be *coherent*. It is essential that the two photons be coherent. If they were even slightly out of phase cancellation would occur between them, violating the law of conservation of energy. If a group of atoms is

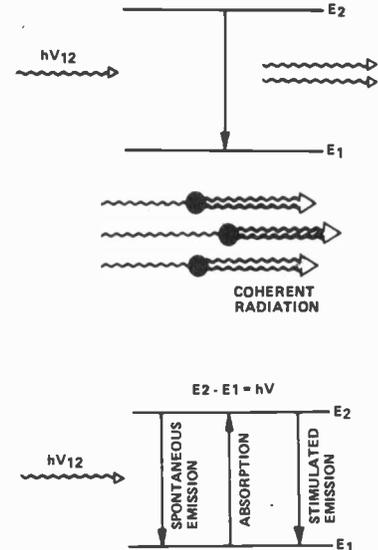


Figure 5. Energy level diagram for the process of stimulated emission.

excited in this way the initial beam of photons will be augmented by additional photons, so the beam is amplified.

**Population inversion**

If a material is in thermal equilibrium at a temperature  $T$ , the distribution of atoms in a lower energy state to those in a higher energy state is normally accented heavily toward the lower energy state. If  $N_1$  is the density of atoms in the lower state and  $N_2$  the density of atoms in the more excited state, then the ratio of  $N_2$  to  $N_1$  is given by the equation

$$\frac{N_2}{N_1} = \exp(-hv/kT)$$

where  $T$  is the temperature of the material in Kelvin and 'k' is Boltzmann's constant. If the material is at  $10^3K$ , then:

$$\frac{N_2}{N_1} = 10^{-5}$$

So, only one atom is  $10^5$  is in the excited state.

The condition in which the number of excited atoms exceeds the number of atoms at the ground state is a non-equilibrium condition called *population inversion*, but it is precisely this con-

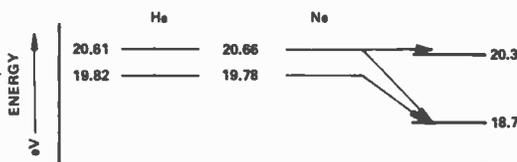


Figure 6. Energy level diagram for the helium-neon laser.

dition that is needed to maintain laser action. If the vast majority of atoms are in the non-excited state, only spontaneous absorption followed by spontaneous emission, can occur. If, on the other hand, a population inversion can be maintained then stimulated emission will occur leading to photon multiplication. *Pumping* is simply the process used to maintain the population inversion.

#### A closer look at the HeNe laser

In the helium-neon laser, population inversion is maintained by generating a glow discharge in a low pressure mixture of helium and neon gases. Figure 6 is a simplified energy diagram for a HeNe laser.

The helium energy levels at 20.61 and 19.82 electron volts (eV) are called *metastable levels*. Once at a metastable energy level an atom cannot move to a lower state by the emission of a photon. It can only be de-excited by some other process. A transition from a metastable level to a lower level is called a *forbidden transition* and the fact that these transitions are not permitted is predicted by quantum theory. So, once an atom has been excited to one of these energy levels it will stay at that energy level for a relatively long period of time, approximately  $10^{-3}$  seconds, hence large metastable populations can exist.

Two of the energy levels of neon closely coincide with those of the metastable levels of helium, these are at 20.66 and 19.78 eV. An energy transfer will occur between helium metastable atoms and neon ground state atoms, exciting neon atoms to the 20.66 and 19.78 eV energy levels. As a result, very large populations of excited neon atoms are produced. The population of neon atoms in these energy levels vastly exceeds that achievable from direct excitation by the electric discharge. Below these two highly populated energy levels there are two lower neon levels that are only populated by direct excitation and consequently have much smaller populations, and this is a population inversion.

Whenever an excited neon atom jumps to one of these lower energy levels a photon is emitted, and the frequency of the photon will depend on the difference in energy between the two levels. The three possible transitions are shown in Figure 6 and are: 20.66 eV to 20.3 eV (3391 nm in the far infrared), 19.78 eV to 18.7 eV (1152 nm in the infrared), 20.66 eV to 18.7 eV (633 nm in the visible spectrum). Figure 7 shows the basic elements of a helium neon laser. The tube contains roughly 90% helium and 10% neon gas at a pressure of one to three Torr.

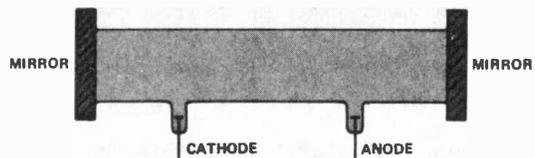
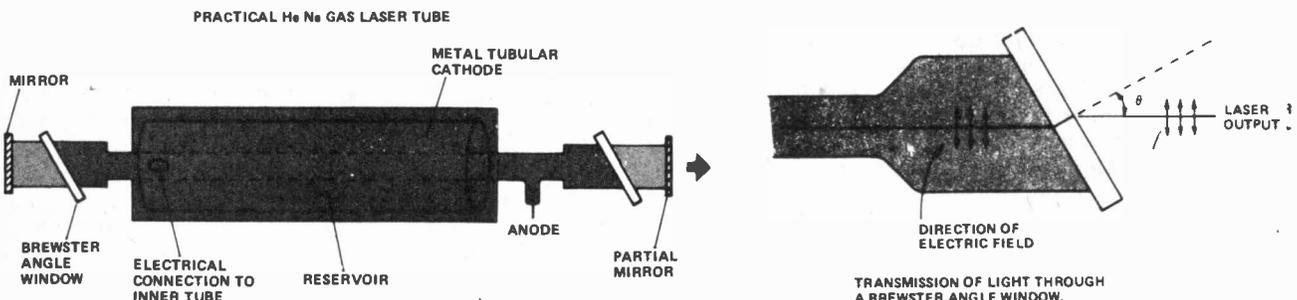


Fig. 7. Basic construction of a gas laser. A glass cylinder, containing a gas at a low pressure, has two mirrors placed at either end — one is totally reflective, the other slightly transmissive. When current is passed through the gas, population inversions of the atoms occur and laser action results.

When a current is passed through the tube a variety of collision processes take place. Among these are the collisions that lead to population inversion. As neon and helium atoms jump between higher and lower energy levels, photons are emitted randomly in all directions. However, since there are large populations of neon atoms at the 20.66 and 19.78 eV energy levels, any photon with one of the above three wavelengths has a high probability of causing stimulated emission of a second, identical, photon. Those photons travelling parallel to the axis of tube are reflected back and forth between the two end mirrors, and each pass through the tube gives rise to further identical photons by the process of stimulated emission. A limit is finally reached when the rate of production of neon atoms at the higher energy levels equals the rate of stimulated emission.

If one of the mirrors is made a few percent transparent, (i.e: slightly transmissive) a portion of the coherent radiation can escape from the tube and this is the laser output. The word laser stands for *light amplification through stimulated emission of radiation*, but the helium neon laser is not really an amplifier, it's more of an oscillator generating coherent electromagnetic radiation at three distinct frequencies. ●

### A practical HeNe laser tube



A practical HeNe laser tube is shown in the diagram. It features a number of improvements over the basic system. The cathode consists of a large metal cylinder instead of a single wire electrode. This decreases the current density around the cathode and increases the rate of excitation of helium atoms to metastable states. Plane mirrors are very difficult to align accurately and a common system used to overcome this difficulty is the use of slightly concave mirrors, separated

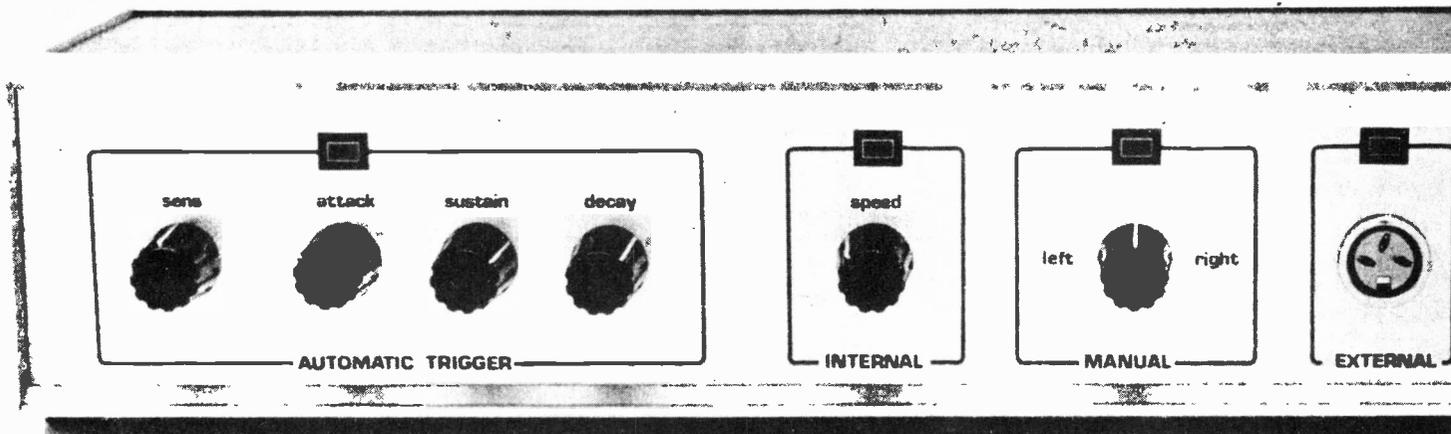
by their radius of curvature.

Another configuration employed, and the one used in the tube for the project, is referred to as a "hemispherical" configuration. This uses a totally reflective, flat-backed mirror and a concave front mirror with a radius of curvature of around 1.4 times the tube length. The mirrors used are designed specifically for laser use and constitute a significant portion of the cost of the device. The mirrors are used as bandpass filters to optimise the

particular output required. The tube specified for the project uses a system like this to enhance tube operation at the 633 nm emission wavelength and to suppress operation at the other two dominant wavelengths. The front mirror is approximately 0.9% transmissive at 633 nm but considerably less transmissive at the two longer wavelengths. The rear mirror is almost totally reflective at 633 nm, but more transmissive at longer wavelengths. HeNe tubes often employ

a "Brewster angle polarizing filter". This is a glass disc placed in the light beam at an angle determined by its refractive index. Light of the correct polarization is transmitted through the filter. All other polarizations suffer high reflections and are attenuated. This does not cause any loss in the light output of the laser since any one polarization will be amplified by stimulated emission to produce a full output intensity coherent laser beam with a single polarization.

# STEREO IMAGE CO-ORDINATOR



Keith Brindley presents the ultimate in sound control.

PERHAPS AN explanation is required! What, you may ask, is a Stereo Image Co-ordinator? Briefly it's a panning control — simple? — well, not so simple. Panning is an effect whereby you apply a single mono sound source and derive two independent adaptations of that original sound, which together form the inputs to a stereo (or 2 x mono) amplifier. By varying the amplitude of these two adaptations, the stereo image they produce can be altered providing an apparently moving sound source. It is an effect used quite often in recording studios usually with modern rock and pop music. Commercial units are now available which produce the effect live, for stage work, but in the past panning has been predominantly a studio technique.

## Not Only But Also

The ETI Stereo Image Co-ordinator produces the usual effect of panning using a manually turned pot, but added to this are the exclusive facilities of automatic control over the image produced. The use of these facilities obviously allows the musician to concentrate on the music rather than the equipment.

Control over the stereo image is provided by four methods:

Manual — a single pot positions the image wherever required.

Sweep — the image is swept from one channel to the other at a variable rate, automatically.

Automatic Trigger — the instant a note is played or sung the image is swept from one side to the other at a completely variable rate.

External — control is accorded by an externally applied voltage eg from a foot pedal.

The unit utilises the 1537A Voltage Controlled Attenuator which is a high quality (good enough for studio applications), recently introduced, integrated circuit for VCA use. All other active components used in the audio section of the circuit are high quality, low noise types which coupled with the considerations of careful PCB design should allow the builder to construct a device which is at home in the studio as well as in live stage work.

Any input signal within the range 10 mV to 10 V AC should successfully operate the device, although obviously the best signal to noise ratios will be obtained with the larger values of input signal.

The overall signal gain of the Image Co-ordinator is approximately 6 dB, which allows for a unity gain output signal when the level pot is at approximately three-quarters of its rotation.

## Construction

The project consists of two printed circuit boards which together hold all components, switches, pots, etc apart from the nine LEDs.

Roughly speaking, the right hand board includes all components to the right hand side of the circuit diagram and similarly the left hand board includes all left side components. The left hand board also contains the power supply.

PCB mounting pots and switches are used throughout eliminating the use of flying leads, therefore cutting down the possibility of pickup in the audio section. Any jumpers or wires only carry DC control voltages or power and are, therefore, of no problem. There is one exception, however, and that is the connection between the Auto Trig output on the right hand board and the Auto Trig input on the left hand board. This should be screened lead taken neatly, either under or over the boards, keeping it away from the PSU section.

The right hand board is double sided while the left hand is single sided with jump leads. Neither are too difficult to construct, although it is worthwhile when building up the project to construct each stage separately, testing as you go along eg start with the PSU then the automatic trigger, then the

This box of tricks gives you the opportunity to try out what has up to now been an effect used predominately in the studio. The stereo sound image can be controlled automatically or manually. You can position the image in one place and keep it there or continually sweep the image between channels . . . and more.



sweep, etc, etc. In this way any faults which develop can be traced to one particular area very quickly. Actually this constructional method is highly recommendable with any project! Test procedures are described in the section on Setting Up.

IC sockets are advisable though not necessary, likewise cermet presets, although more expensive, present easier setting up and a high quality than their cheaper carbon colleagues.

The signal switches which comprise SW1 a and b might be slightly difficult to get hold of so it is worthwhile taking your PCB along with you to make sure you get the right ones. If you can find transparent knobs for the switches then you may want to try to mount the LEDs behind them. Square LEDs work well in this application. Alternatively the LEDs can be panel mounted vertically above the switch front. If LED 1, a flashing LED with integral IC, cannot be obtained an ordinary can be used in its place — but replace ZD1 with a suitable limiting resistor eg. 560R.

The control marking LEDs should be positioned close to the corresponding controls in order that the user can clearly see which function is in use.

Finally use PCB pins for external connections so that when the two boards are fixed in their case side by side the nine links can be soldered into position along with input and output

connections, without removing the boards.

#### Setting Up

After the PSU section is complete, it can be tested to make sure that the correct supply rails, +15 V, 0 V and -15 V are obtained.

The components around the automatic trigger should be inserted next (R1-9, C1-7, IC1 and 2, RV1-4 and D1-3). This can be tested by applying an AC signal of about 500 mV at its input on the left hand board while watching the voltage across C7. (All four pots should be mid-position). This voltage should increase from 0 V to

about +12 volts then after a short time decrease back down to 0 V DC.

The sweep generator circuit can be built up next (R10-18, C8-14, IC and RV5-9) and tested. Set all pots and presets to mid-position. The DC output voltage at pin 7 of IC1 should be a low frequency near sine wave oscillation approximately 10 Vpk-pk (adjusted by RV8 and varying between 0 and +10 V DC (adjust by RV9). By altering RV6 and RV7 which control the charge and discharge rates of capacitor C9 (which in turn controls the overall frequency and shape) the best setting can be found whereby RV5 controls the frequency of the sine wave between approximately 0.1 Hz and 10 Hz. Fairly careful adjustment of these two presets is necessary and it is a distinct advantage if a scope is available with a slow time base so that the waveform can be studied for purest sine wave.

The manual control function circuitry is simple consisting of only two components RV11 and RV12. The DC voltage at the wiper of RV12 should vary between 0 and 10 V dependent on wiper position and is adjusted by RV11.

The external control circuit is equally as simple but an external pot is necessary in the shape of a foot pedal. RV10 adjusts for a wiper voltage of 0 to 10 V DC for different values of pot. Alternatively a control voltage of 0 to 10 V DC relative to chassis can be fed in from some external control circuit.

The control voltage phase splitter is next to be assembled and set up (R36-40, C27-30, IC5 and RV13,14). With a known input voltage of 0 to +10 V DC (derived best from the manual pot by pressing the manual switch and varying the pot) the voltage at pin 1 of IC5 should be 0 to +10 V DC the op amp

#### HOW IT WORKS

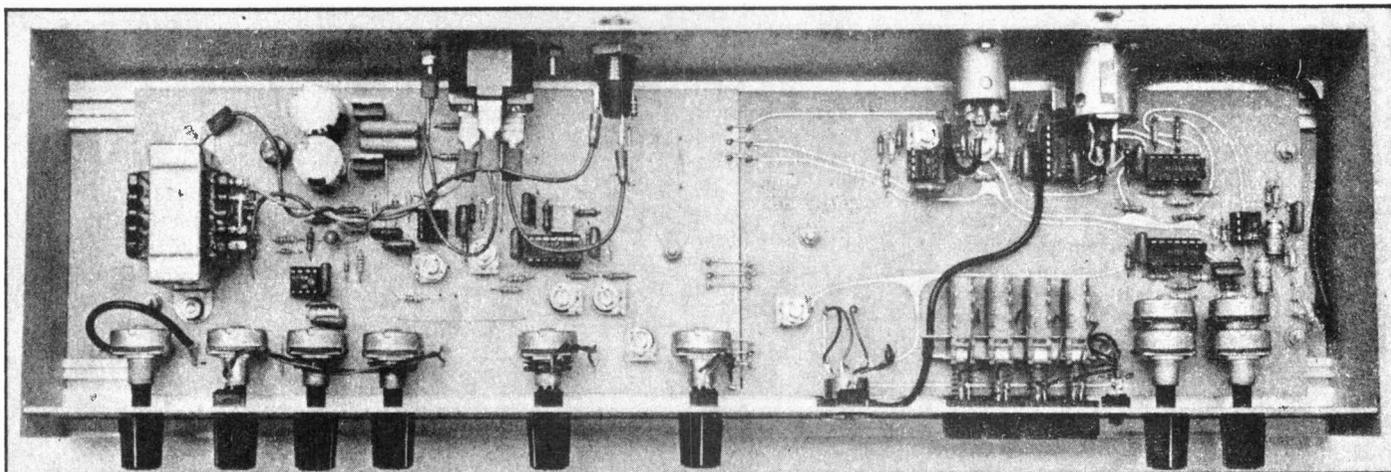
The main function of the unit is to create an impression of a stereo image from a single signal from a musical instrument. This is done by feeding the signal via IC4 (a quad op-amp) to 2 paralleled VCAs whose output amplitudes are controlled by an external control voltage. These VCAs form the output channels and are buffered by IC8a and b, providing drive for a stereo power amplifier. The stereo image is created simply by allowing the signal output from one channel to be greater than that from the other channel. The origin of the sound thus appears closer to the first side of the sound field than it does to the latter.

IC 5 provides phase split control voltages of 0 to -10 volts DC and -10 to 0 volts DC from a single input voltage of 0 to +10 volts DC. RV15 provides a depth control which simply limits the effect of the control voltages applied to the VCAs. IC5a inverts the DC control while IC5b also is a fairly high impedance buffer so as not to load the source.

SW1a gives selection of whichever source is required, there being three internal, sweep, manual and automatic trigger and one external method of controlling the stereo image. The corresponding LEDs are also switched in via SW1 allowing an indication of which function is in use at the switch and also at the function controls — see photographs. LED 1 is a special type of display. As this is in series with two other LEDs (2 and 6, 3 and 7, 4 and 8, or 5 and 9, dependent on SW1) then all three LEDs will flash on and off simultaneously.

External control of image is provided so that, for example a foot pedal can be used to control positioning of the applied signal within the stereo field. RV10 adjusts for various values of pots inside the pedal, although 100k lin is the nominal value.

RV12 acts as the manual pot in an identical fashion to an external control pedal pot but positioned on the front panel.



being a simple unity gain inverter. The output at pin 7 should be the same size pk to pk (adjusted by RV13) but 180° out of phase ie -10 to 0 DC (adjusted by RV14).

There is no further setting up to be undertaken so the rest of the circuit can be installed and testing of the whole job undertaken.

**BUYLINES**

The Aphex 1537A is available in Canada from Octopus Audio. Cost is \$22.00 each, which includes postage and handling (Ontario residents add 7% PST). Send cheque or money order to: Octopus Audio, Suite 315, 69 Sherbourne St., Toronto, Ontario M5A 3A7.

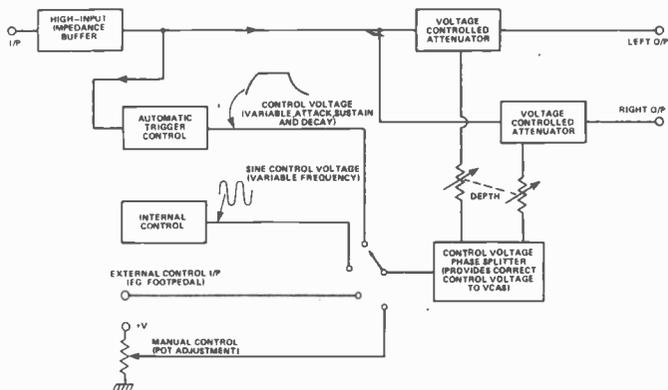


Fig. 1. Block diagram of the Stereo Image Co-ordinator.

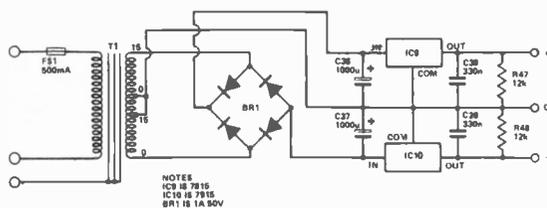


Fig. 2. Power supply producing +15,0,-15 volts output.

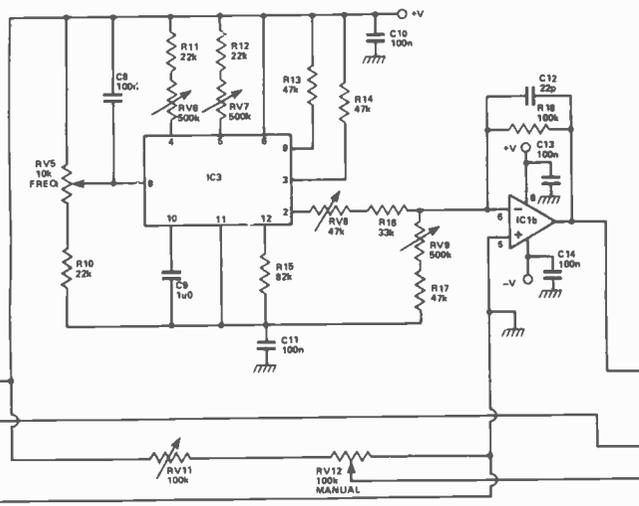
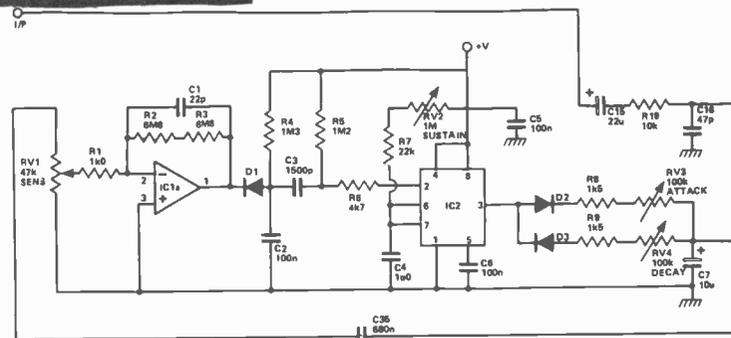


Fig. 3. Circuit diagram. Note the orientation of LEDs connected to signal switch SW1.

## PARTS LIST

### RESISTORS

All 1/4W, 5%

R1	1k0
R2,3	6M8
R4,5	1M2
R6,20,32	
35,43,45	4k7
R7,10,11	
12,25	22k
R8,9	1k5
R13,14	
17,24,39	47k
R15	82k
R16	33k
R18,36	
37,40	100k
R19,20,21	
31,33,44,46	10k
R22,23,26	
27,28,29	
41,42	3k3
R34	220R
R38	68k
R47,48	12k

### POTENTIOMETERS

RV1	47k log PCB mounting pot
RV2	1M0 lin PCB mounting pot

RV3,4,12	100k lin PCB mounting pot
RV5	10k lin PCB mounting pot
RV6,7,9	500k min horiz cermet preset

RV8,13

47k min horiz cermet preset

RV10,11

100k min horiz cermet preset

RV14

220k min horiz cermet preset

RV15

100k lin dual PCB mounting pot

RV16

47k log dual PCB mounting pot

### CAPACITORS

C1,12,17,24,27,30,33	22p polystyrene
C2,5,6,8,10,11,13,14,18,19,20,21,23,25,28,29,31	100n polyester
C3	1500p polystyrene
C4,9,26,34	1u0 25V electrolytic
C7	10u 16V electrolytic
C15	22u 25V electrolytic
C16,22,32	47p polystyrene

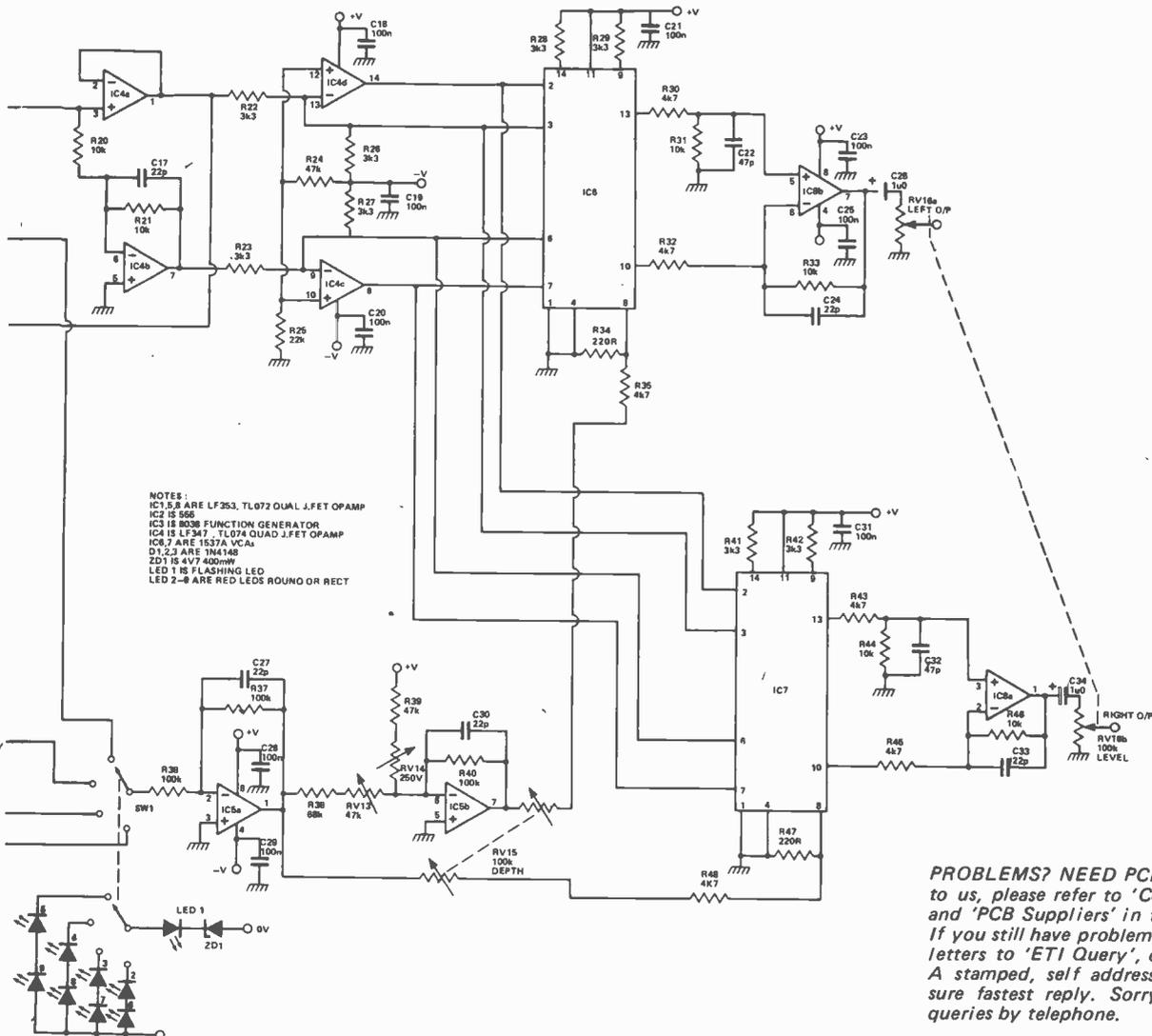
C35	680n polycarbonate
C36,37	1000u 25V PCB electrolytic
C38,39	330n polyester

### SEMICONDUCTORS

IC1,5,8	LF353, TL072 etc dual op amp
IC2	555
IC3	8038
IC4	LF347, TL074 etc quad op amp
IC6,7	1537A (Aphex)
IC9	7815
IC10	7915
ZD1	5V1 zener 400mW
LED 1	Flashing red LED Litronix FRL4403 or sim.
LED 2-9	Red LED
D1-3	1N4148

### MISCELLANEOUS

SW1	4 station interlocking DPDT push button switch with lockout. Switchcraft No. 90044B06.
T1	15-0-15 6VA transformer
FS1	500mA fuse + panel mounting holder
Case, sockets, line cord etc.	



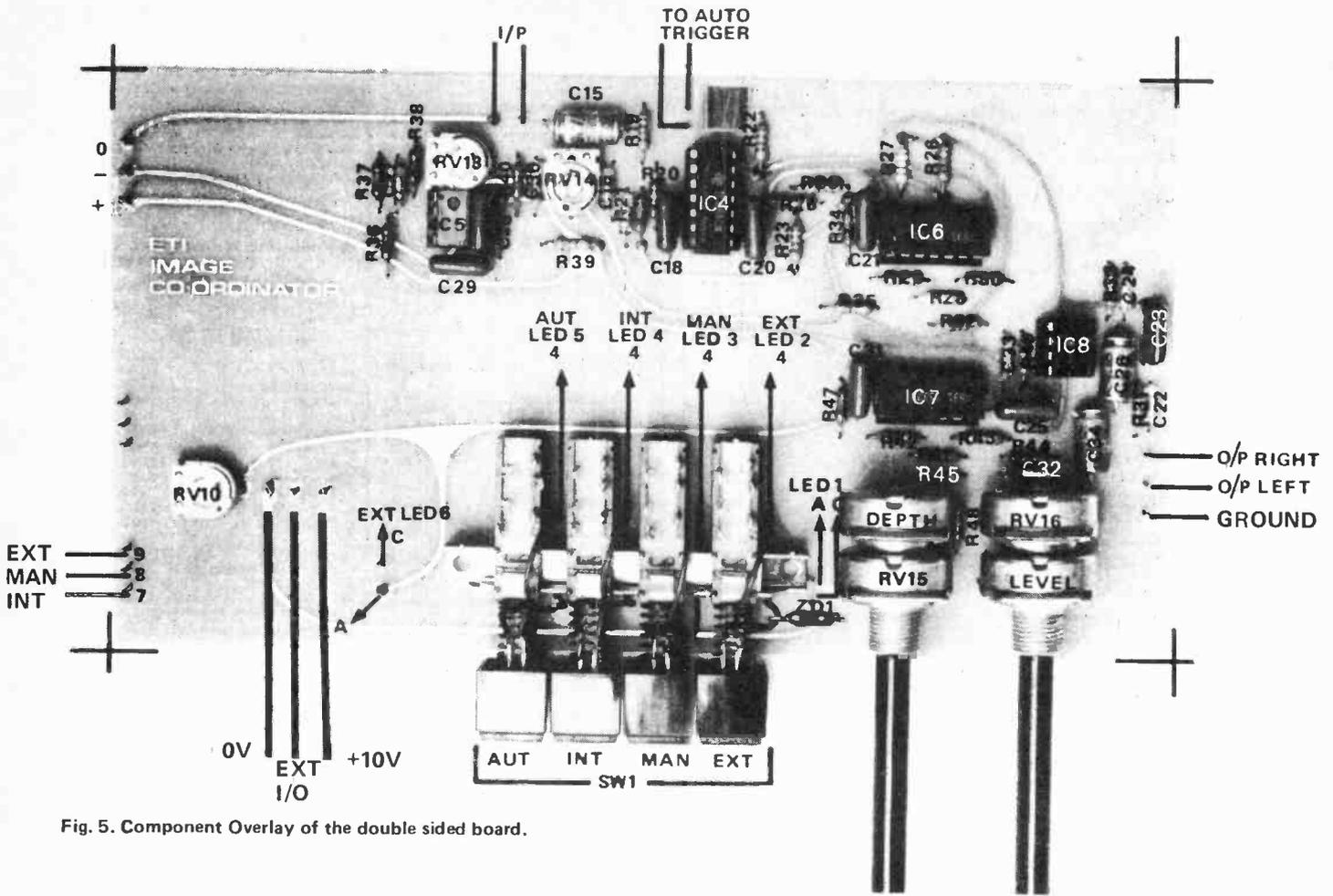


Fig. 5. Component Overlay of the double sided board.

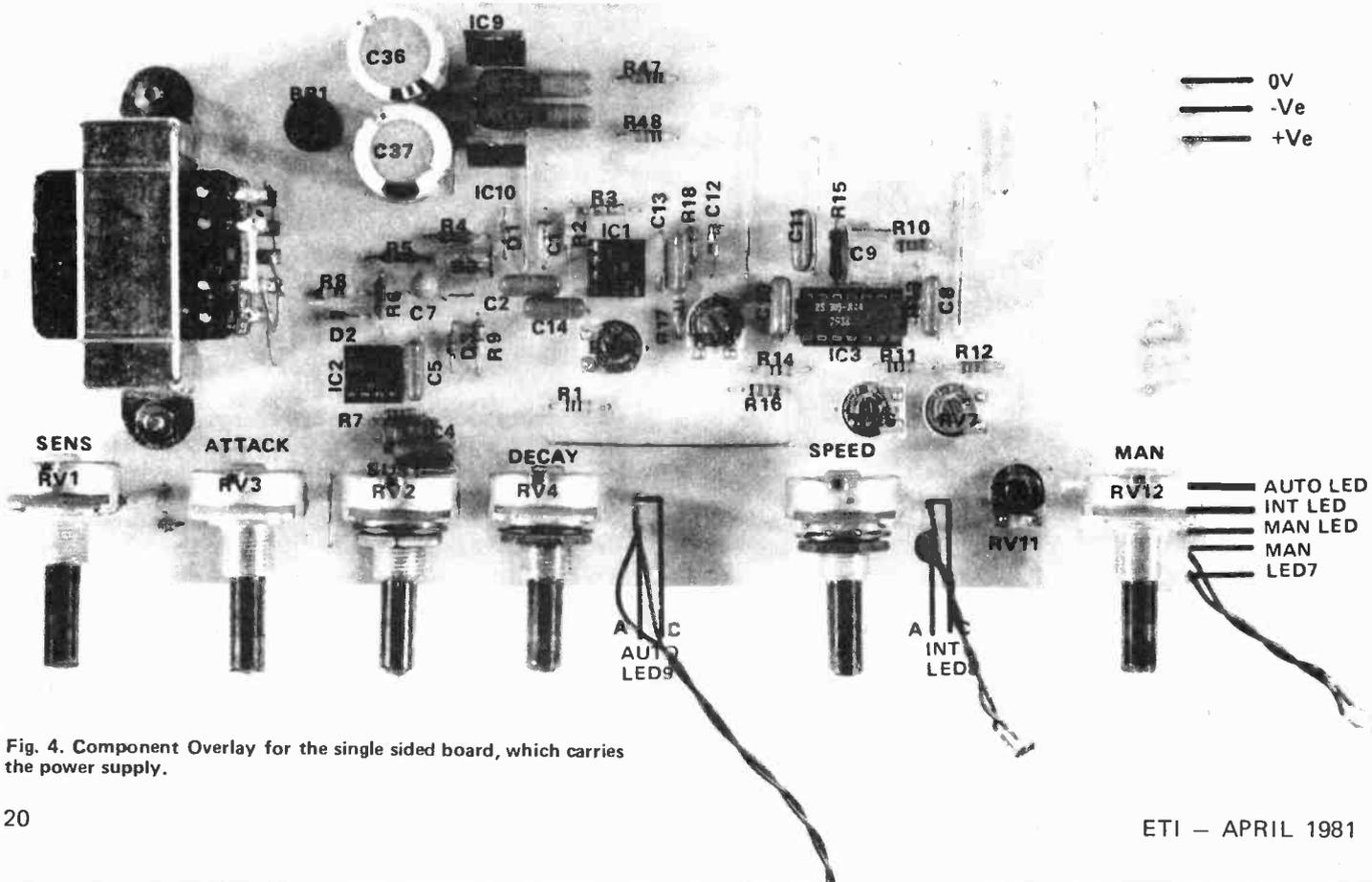
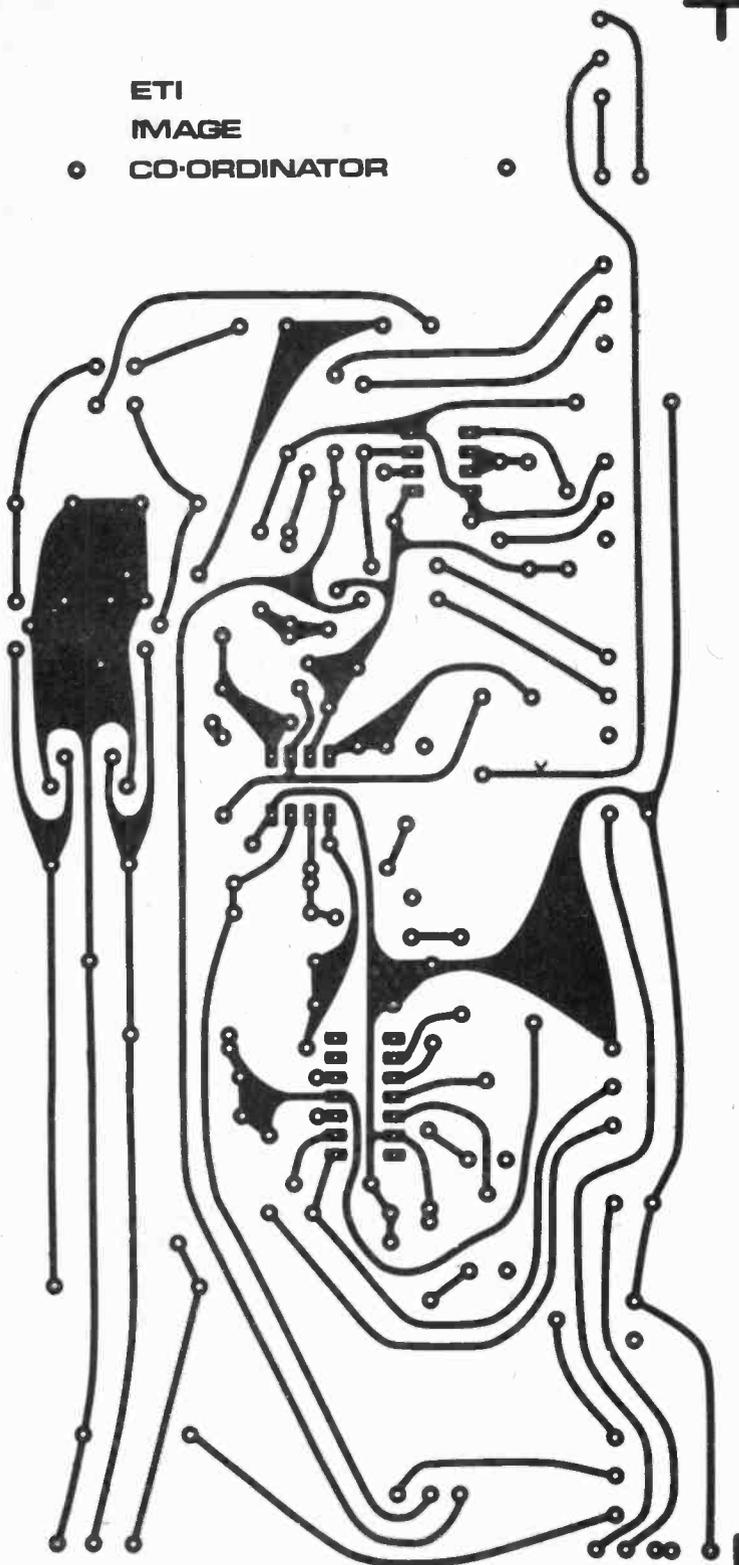
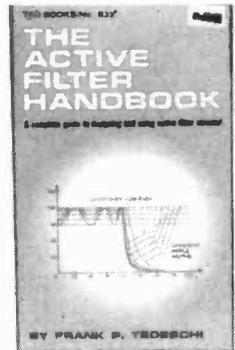


Fig. 4. Component Overlay for the single sided board, which carries the power supply.

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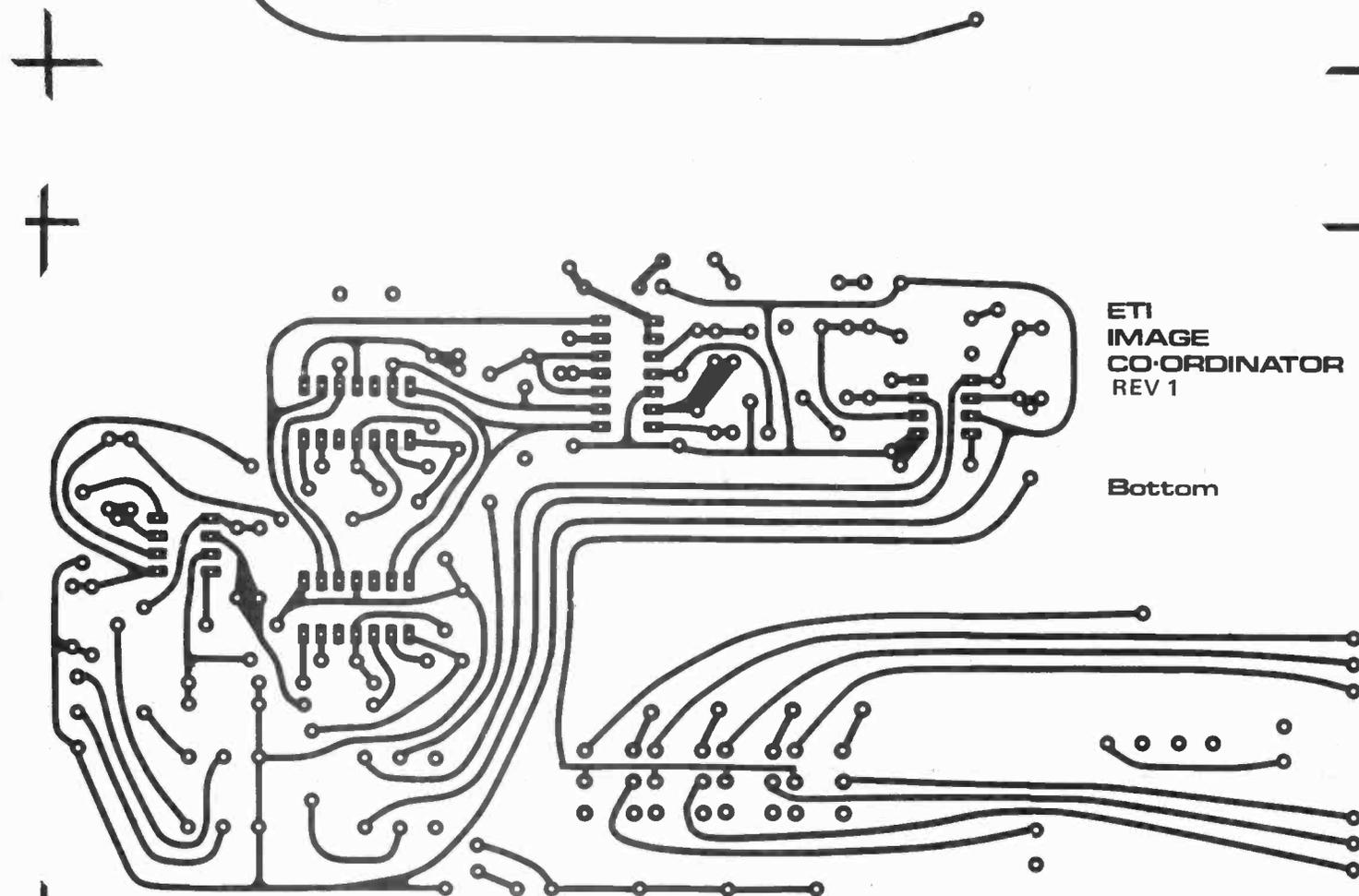
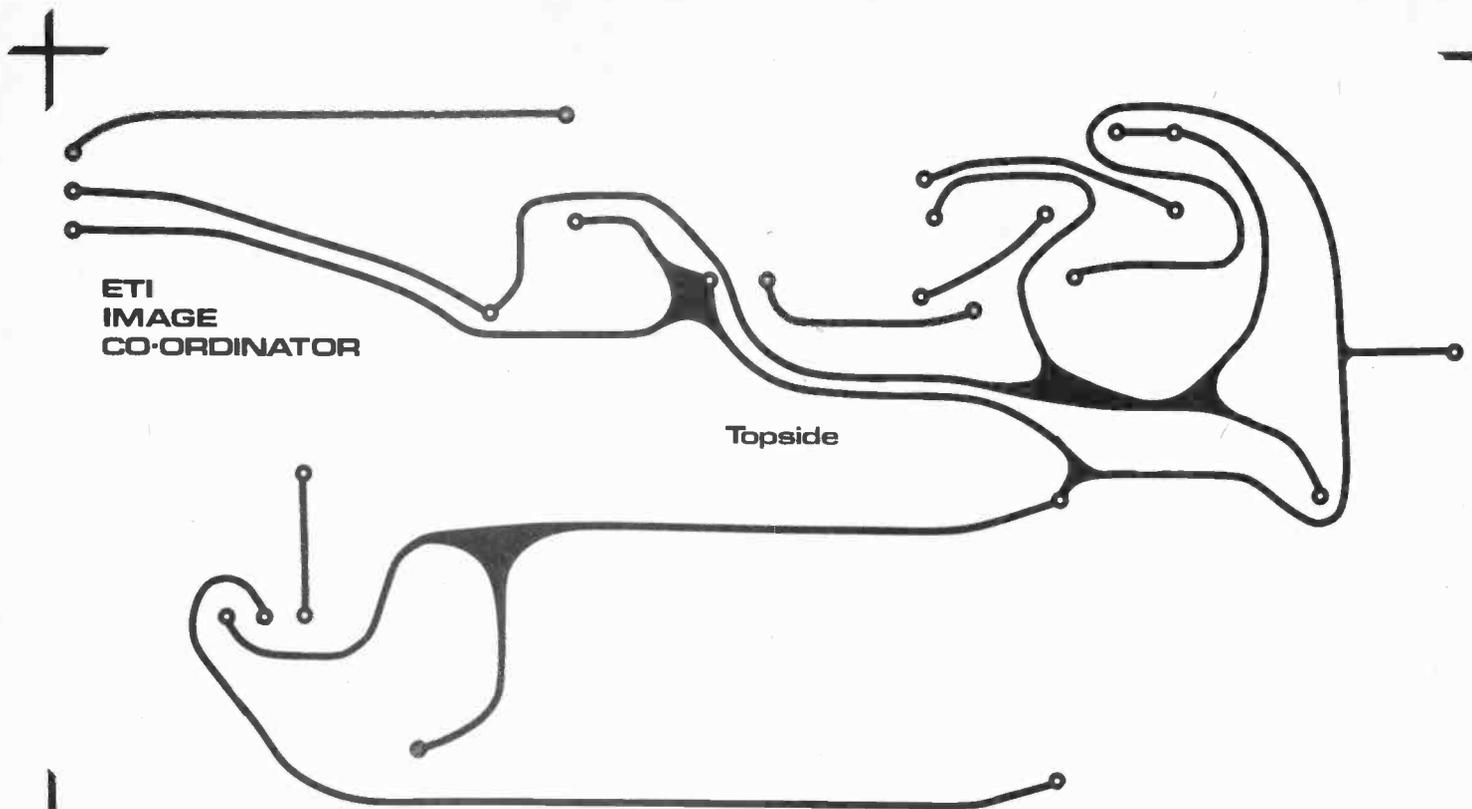


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# TEST METER CIRCUITS

Gotta a need to do some measurin? Here are seven circuits to help you. From Ray Marston.

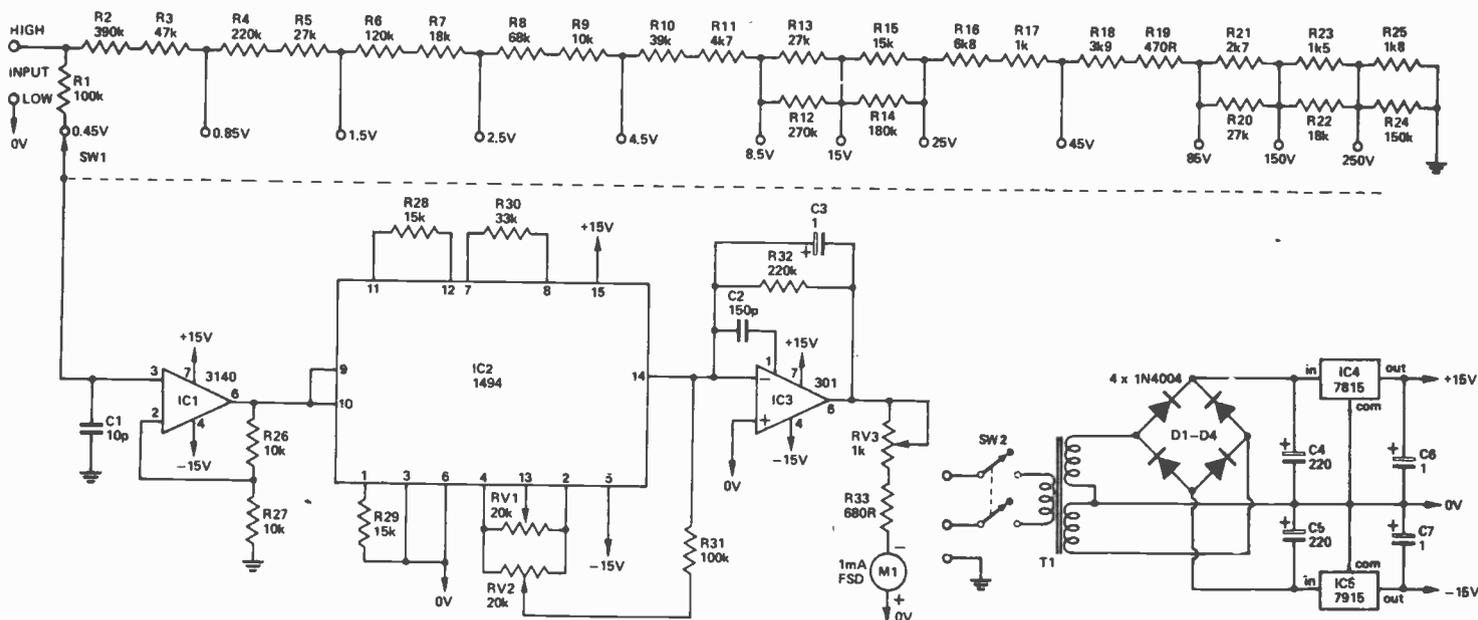


Fig. 1. A true RMS voltmeter. The input voltage is divided by the input network such that the input IC1 is 0.47 volts (DC or RMS) for full scale deflection. IC1 provides buffering and a gain of two.

Squaring of the output of IC1 is done by IC2 (1494), a four quadrant multiplier, which gives a current output proportional to the product of the voltages at its two inputs (pin 9 and 10). As we are feeding the same signal into both inputs the result is the square function.

The output of this IC is a current which is converted to a voltage by IC3 which also provides the averaging network (C3, R32). Its output drives the meter whose scale is a square root function.

Adjustments are provided for the input offset of IC2 (RV1) output offset (RV2) and overall calibration (RV3).

As the power requirement of all the ICs is  $\pm 15$  V we use a line power supply and three-terminal regulators. Current drain is about 15 mA on both supplies.

BY FAR the most important thing a hobbyist or technician needs to know is what's going on inside a circuit. Such data is usually obtained from a test meter of some sort. This month we present several circuits that measure different useful quantities.

Figure 1 shows a true RMS voltmeter. Such a meter is useful whenever one encounters complex waveforms or has to make power measurement with the latter. Ordinary AC voltmeters will give RMS readings for sine waves on specially calibrated scales. These readings, however, will not be correct for square waves or any other shape you'd care to name. The circuit shown electronically calculates the actual RMS value of the waveform under test.

If you have a large quantity of unmarked or doubtful capacitors then the capacitance meter in Figure 2 should be useful. This particular version permits operation from AC or batteries.

The measurement of phase relationships between two AC signals is important when one wishes to determine phase shifts in a circuit, a load's power factor and so on. The circuit has two outputs. One is intended for use with a meter (0-1mA should be adequate), and the other can be connected to a chart recorder and gives a output from  $-180^\circ$  to  $+180^\circ$ .

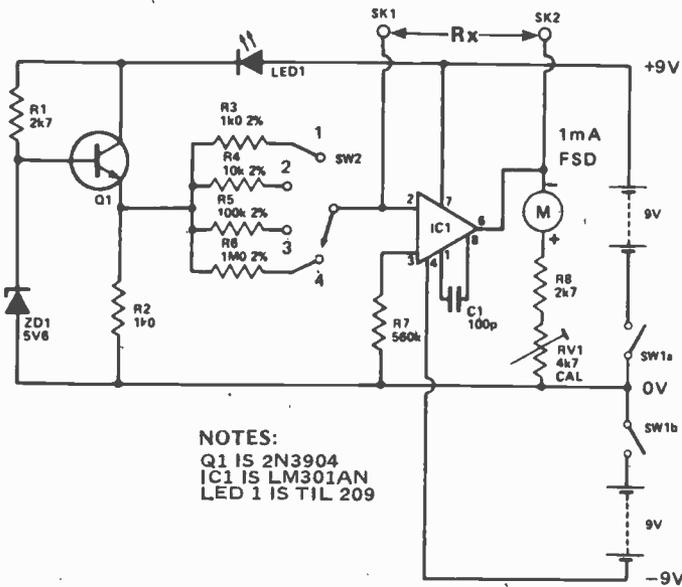
Figure 4 shows a linear scale ohmmeter. What more can we say? (Before you answer that read the caption).

Nowadays, most frequency measurements are made on

digital frequency counters. However, for audio applications the job can be done quite effectively by the analogue frequency meter in figure 5. The circuit can give a full scale reading of 100kHz with an accuracy that is limited by its range resistors and the meter used.

Figure 6 shows a sequential logic tester. Essentially this circuit does nothing more than provide a series of clean pulses to a digital circuit. With it, you can monitor a circuit's action at a greatly reduced rate. Figure 7 shows a simple logic probe that can be used with virtually any type of logic and can detect pulses as narrow as 500ns.





NOTES:  
 Q1 IS 2N3904  
 IC1 IS LM301AN  
 LED 1 IS TIL 209

Fig. 4. (Above). Linear ohm-meter circuit. The circuit is divided into two parts: a reference voltage generator and a readout unit that indicates the value of the resistor under test. The reference voltage generator section of the circuit comprises zener diode ZD1, transistor Q1, and resistors R1 and R2. The action of these components is such that a stable reference of about 5 V is developed across R2. This reference voltage is fed to the op-amp resistance-indicating circuit via range resistors R3 to R6.

The op-amp is wired as an inverting DC amplifier, with the 1 mA meter and R8-RV1 forming a voltmeter across its output, and with the op-amp gain determined by the relative values of ranging resistors R3 to R6 and by the negative feedback resistor Rx. RV1 is adjusted so that the meter reads full scale when Rx has the same value as the selected range resistor. Under this condition the op-amp circuit has a voltage gain of precisely unity. Since the values of the reference voltage and the ranging resistors are fixed, the reading of the meter is directly proportional to the value of Rx, and the circuit thus functions as a linear-scale ohm-meter and has a full scale value equal to the value of the selected range resistor.

NOTES:  
 D1,2 ARE 1N4001  
 IC1 IS 741  
 IC2 IS 555

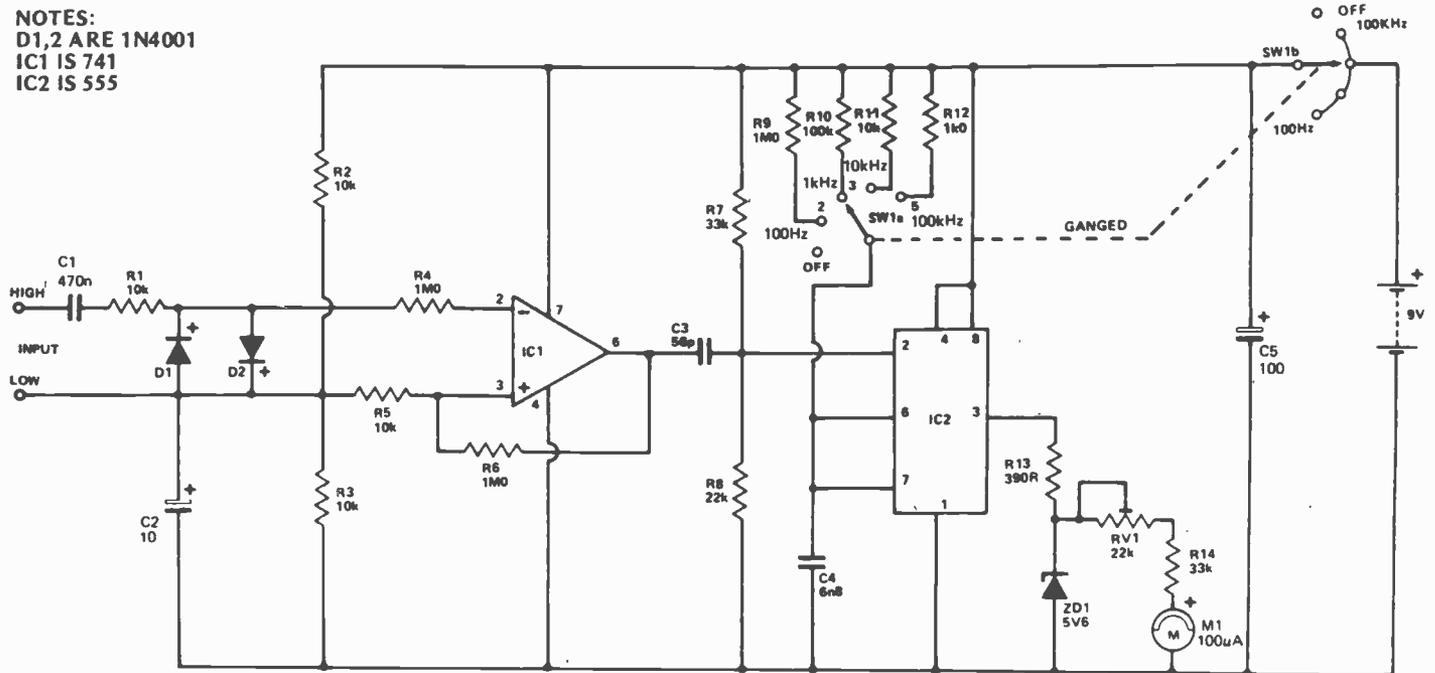


Fig. 5. Linear frequency meter. The circuit consists of an op-amp operated as a Schmitt trigger to amplify and square the input signal, followed by a 555 timer wired as a monostable, giving a short output pulse of fixed width for each cycle of input signal. This pulse drives a moving-coil meter, the reading being an average of the pulse amplitude, which is proportional to the pulse frequency. As the pulse frequency is directly related to the input frequency, the meter reading is directly proportional to the input frequency.

The input signal is coupled into IC1 via C1, which provides DC blocking. Protection from overload caused by high amplitude input signals is provided by a diode clipper consisting of D1, D2 and R1. The diodes are connected in an inverse-parallel arrangement so that both positive and negative peaks, above the diode forward conduction voltage, are clipped.

The output of IC1 is a train of square waves at the same frequency as the input. The output of IC1 is differentiated to provide

short trigger pulses for the 555 timer, IC2. The differentiating network consists of C3, R7 and R8. This network is arranged to provide a trigger pulse that is always shorter than the output pulse of the 555. Capacitor C3 is selected to give the shortest possible pulse to the 555 consistent with reliable triggering.

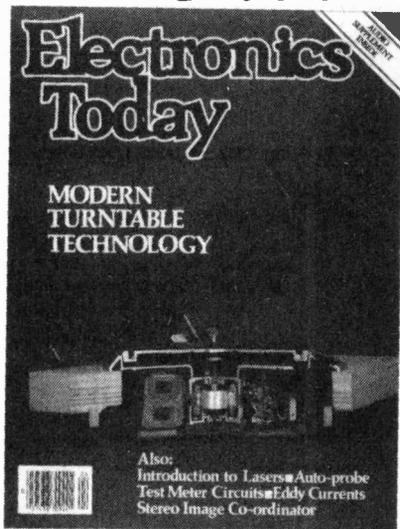
The output of the 555 monostable will be a pulse of fixed width, determined by the range resistors, R9 to R12, and capacitor C4. The ranges are arranged to give a 75% output duty cycle at frequencies of 100 Hz, 1 kHz, 10 kHz and 100 kHz on the input.

The output pulse from the 555 is clipped at 5V6 by a zener diode, ZD1, to avoid inaccuracies caused by falling battery voltage (as the battery ages). The meter responds to the average value of the clipped pulses. As the frequency increases, the duty cycle (on/off ratio) of the pulse train increases, increasing the average voltage and thus the meter current in direct proportion. Thus the reading on the meter will be linearly related to frequency.





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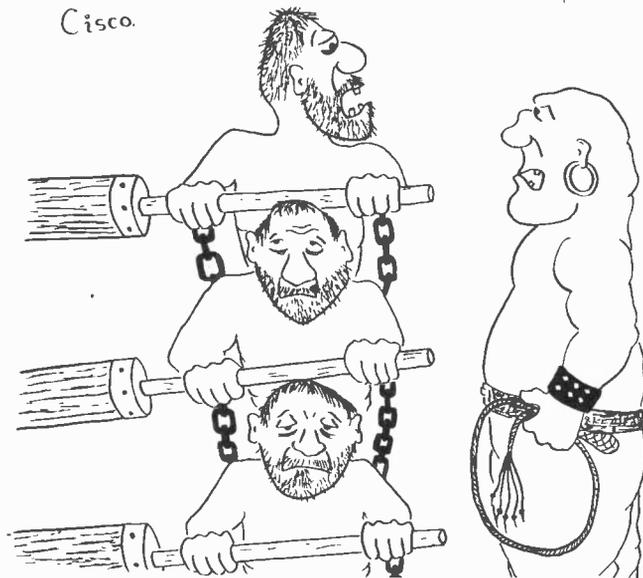
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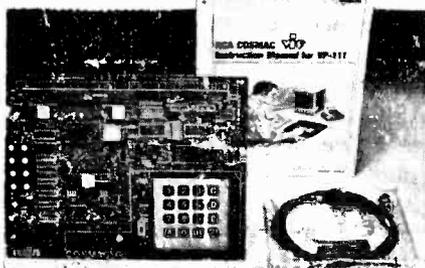


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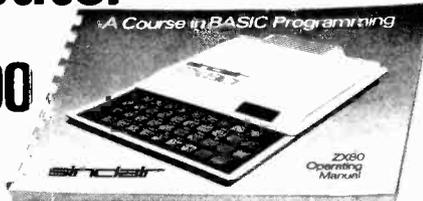
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- Instruction Manual with 5 video game listings, schematics, CHIP 8, much more.

Ideal for low-cost control applications.  
Expandable to full VIP capability with  
VP-114 Kit.

\*User needs only connect cables (included) a  
5-volt power supply and speaker.

## The ZX80 Personal Computer

\$329.00



The Sinclair ZX80 is an extraordinary personal computer. Compact and briefcase-sized, it weighs just 12 ounces. Yet in performance it matches and surpasses systems many times its size and price.

The ZX80 is an advanced example of microelectronics design. Inside, it has one-tenth the number of parts of existing comparable ma-

chine. This unique design — packing the system onto fewer, more advanced LSI chips — gives the ZX80 its remarkably low price.

Along with a complete 128-page course in BASIC programming, the ZX80 comes with all the necessary cords for connecting to standard color or B/W televisions and cassette recorders.

### Microprocessor/Memory

Z80A 3.25MHz clock  
ROM 4K bytes containing BASIC  
RAM: 1K bytes internal, externally expandable to 16K bytes.

### Keyboard

40 key touch-sensitive membrane with keyboard entry gives an equivalent of 62 keys. After entering the statement number, the next key you touch enters the keyword printed above it automatically.

### SINCLAIR ADVANCED DESIGN FEATURES

- \* 4K Integer Basic.
- \* 1 stroke entry for key words.
- \* Automatic error detection.
- \* Text editing capability.
- \* Machine code programming too.
- \* 26 string variables, any length.
- \* Random function, built-in.
- \* 1K RAM matches others 4K.

Price includes TV and cassette connectors, AC Adapter, and 128 page manual.

Please send more information on Sinclair Computers

A powerful microcomputer... a full standard 53 key typewriter style keyboard and built-in cassette recorder for use in entering and storing programs. Utilizing the versatile Intel 8080A microprocessor, the Interact computer has 16K of RAM and 2K of ROM at its disposal. Output is in color on your own TV screen. Sound is also generated through your TV set and can consist of exhilarating computer beats or two full octaves of music. This is truly a powerful computer capable of developing and handling a variety of programs, and with available software provides true educational stimulus (examples: Star Trek, Chess, Concentration, etc.). The Interact computer offers the ideal opportunity to learn BASIC, the most popular computer language for small business and hobbyists, and with the use of the 54 page manual, you learn at your own pace.

INSTALLATION: Attach to antenna terminals of your color TV set and plug into 120 VAC wall outlet. Computer includes built-in RF modulator, FCC approved and UL and CSA listed.

PROGRAMMING: Most Micro-computers start you off with an abbreviated 4K BASIC, and then later you have to relearn the more powerful language. Since this computer has 16K of RAM, we start you with Level II Microsoft 4.7 BASIC. BASIC is the most popular Micro-computer language using commands that are words we are ordinarily used to: such as, PRINT, NEW, GOTO (For go to), END, COLOR, JOY, INPUT, etc. To help you learn programming we have included an 84 page instruction manual, plus a 20 page book of program examples.

### Educational and Entertaining

ASCII Keyboard Fully encoded, 128-character ASCII alphanumeric keyboard, 58 light touch keys (2 user defined), Selectable Upper-Case-Only	VP-611	\$99.75
ASCII/Numeric Keyboard ASCII Keyboard identical to VP-601 plus 16 key numeric entry keyboard for easier entry of numbers	VP-611	\$129.95
Cable: ASCII Keyboards to VP-711 Flat ribbon cable, 24 in. length for connecting VP-601 or VP-611 and VP-711. Includes matching connector on both ends	VP-620	\$27.50
Cable: ASCII Keyboards Flat ribbon cable, 36 in. length with mating connector for VP-601 or VP-611 Keyboards. Other end is unterminated	VP-623	\$27.50

Orion Electronic Supplies Inc.  
40 Lancaster Street West  
Kitchener, Ontario N2H 4S9  
(519) 576-9902

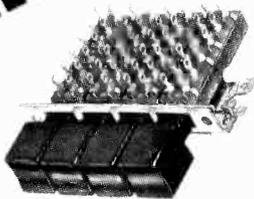
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# ULTRASONIC SWITCH

Switch from afar with this novel project. Another Hobby Electronics project.

INVISIBLE RAYS have always exerted a considerable fascination on man down the ages. Isaac Newton watched apples falling under their influence and Uri Geller bent spoons with them (or did he?)

This project falls somewhere between these two extremes of the sublime and the ridiculous. It uses ultrasound; a high frequency sound, well above the range of human hearing to control a relay. By selecting a suitable type you can control your TV, Hi-Fi or bedside light at the touch of a button or as you will see later, with a snap of the fingers.

The unit is silent in operation. As the ultrasonic carrier beam consists of very high frequency (40 kHz) waves, special transducers have to be used as ordinary microphones and loudspeakers are very inefficient at this frequency. These transducers are just like crystal microphones and earphones except that they are designed to be resonant, ie very sensitive at a particular frequency. The receiver and transmitter units have different characteristics and best results will be obtained if the correct device is used in each application.

They are usually identified with a suffix 'R' for receiver or 'T' for transmitter marked on the case.

Range obtained will depend to an extent on the sensitivity of the particular transducers used but it is also considerably affected by the conditions under which the unit is operated. Ultrasonic waves are quite directional and can be bounced from hard surfaces like walls and ceilings so that greater range will be achieved in a sparsely furnished room or a corridor and satisfactory operation can often be obtained with the transmitter pointing away from the receiver. Our unit gave a maximum effective range of about twenty feet.

Any method of construction may be used although our PCBs are recommended and no special precautions are necessary. However, if you use your unit to control a mains operated device ensure that the mains is kept safely isolated from the control circuitry and use a relay whose contacts are rated for the job.

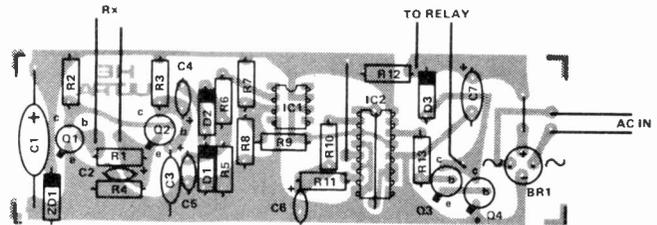
We mounted our 'Ultraswitch' in an grounded metal case. No special care was taken to protect the transducer from Mechanical shock and the unit worked quite reliably.

The transmitter was housed in a small Verobox. Ensure that the transmitter tuning control is easily accessible. It should be adjusted for maximum range. There are no other adjustments to make.

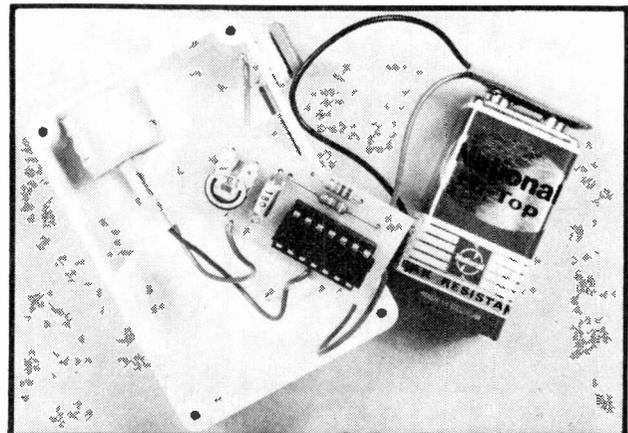
Ultrasonic waves are present in many 'natural' sounds and you will find that the switch will operate at varying range in response to jangling keys, crumpling paper and even, at close range, a snap of the fingers. A novel trick is to operate the unit with a handclap.



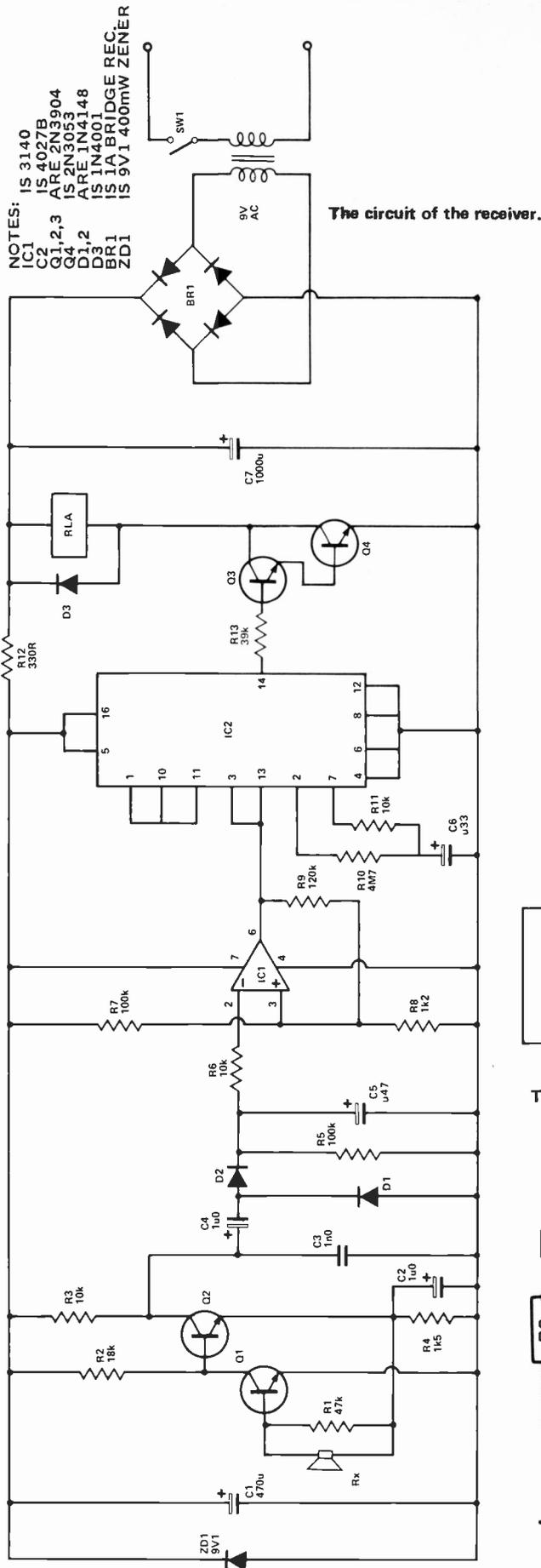
Remember to use a suitable relay for your application and make all connections safe. Then press that button and turn on.



The component overlay of the receiver.



The transmitter; the small size of the transducer can be judged from this photograph.



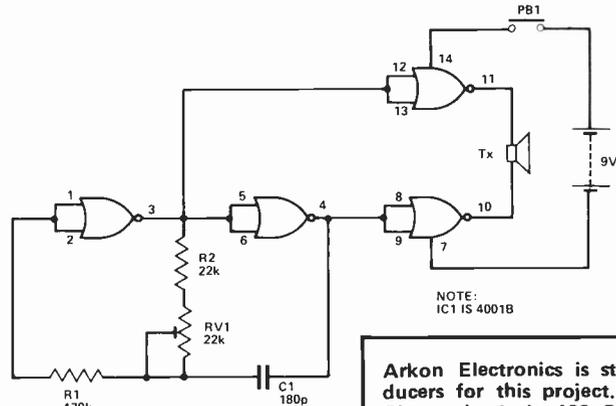
**Transmitter**

The transmitter consists of a straightforward CMOS oscillator driving the transducer via two complementary buffer stages. R2 and RV1 together comprise the timing resistance and C1 is the timing capacitor.

**Receiver**

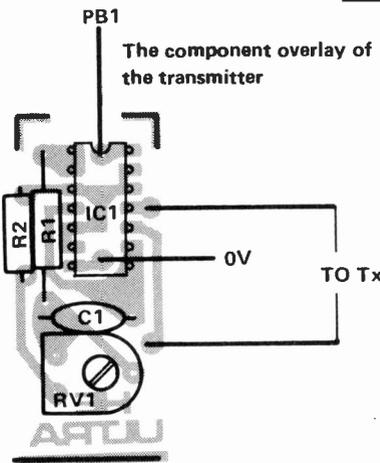
The ultrasonic signal is amplified by Q1, Q2 a direct coupled amplifier and appears at Q2 collector. C3 is a decoupling capacitor to suppress spurious RF oscillation. The amplified signal charges C5 via C4, D1, D2 and the voltage across C5 is compared with a reference provided by R7, R8 and controls the output of IC1. R9 provides some positive feedback to produce a degree of hysteresis and speed up the transition time.

The output of IC1 clocks IC2. This is a JK flip-flop whose output toggles, ie changes state with each clock pulse. The bistable is disabled for a period determined by R10, C6 to avoid erratic operation. The output of the bistable appears at pin 14 of IC2 and controls super-alpha-pair Q3, Q4 which drive the relay. R12, ZD1 and C1 provide a smooth, stabilised power supply for the amplifier and CMOS circuitry whilst C7 is the main power supply smoothing capacitor.



**The transmitter circuit.**

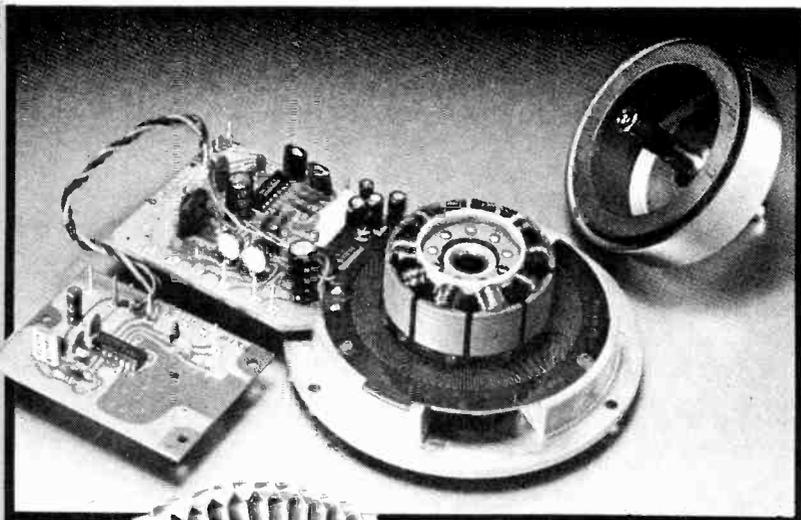
Arkon Electronics is stocking the transducers for this project. Write to Arkon Electronics Ltd., 409 Queen Street West, Toronto, Ontario M5V 2A5.



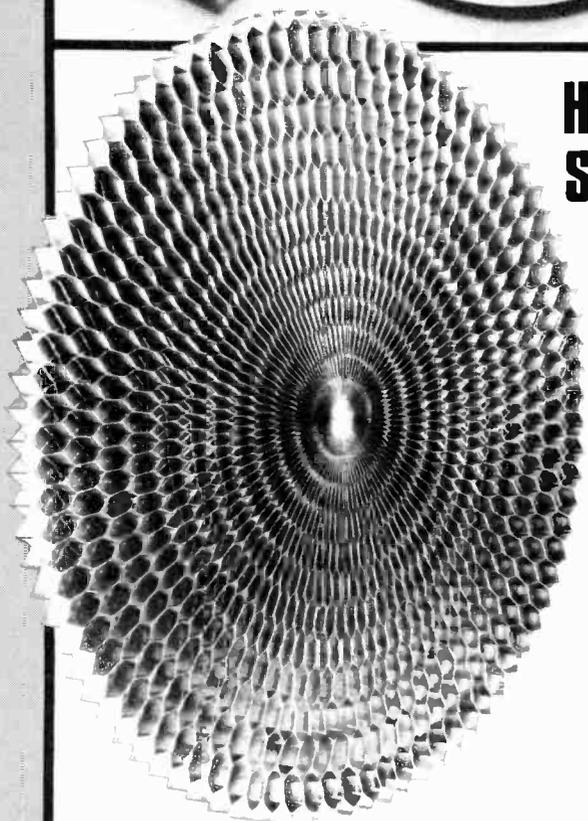
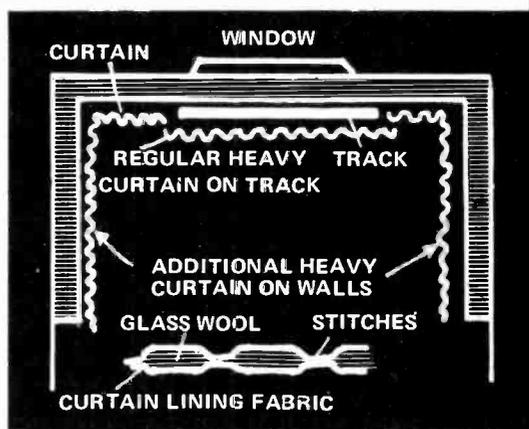
**PCB pattern of the transmitter.**



# AUDIO SUPPLEMENT



## Turntable Technology



## Honeycomb Speakers

## Acoustic Rooms



Upgrading your Hi-Fi  
Audio News

# ROLL OVER BEETHOVEN BACH, OR BRAHMS . . .



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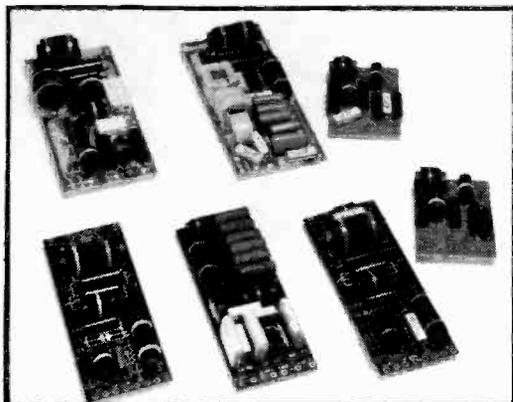


**Like a captive liquid,**  
our special dry polymer surface flows into the record grooves and lifts out even the finest micro-dust particles. Most important: that dust does not build up on the cleaner as it does on all other devices. As often as you wish, you can clean the surface of the roller completely, under the tap! Clean a record with your present cleaner system and look closely at the record surface under strong light. See that haze of micro-dust left in the grooves? We can remove it!

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For his name, phone Avalon 861-1031

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# Audio News

## Bang & Olufsen's Micro Computer

No one has ever accused Denmark's Bang & Olufsen of "me too" design. Only the multi-faceted eye of a fly could possibly confuse any of their products with those of the competition.

Performance has always received as much attention as cosmetics, and now they've incorporated microcomputer technology in the new Beocentre 7000.

Running counter to the usual trend in audio, the Beocentre 7000 is an integrated system consisting of phonograph, FM radio, and Cassette machine combined with two 30 Watt amplifiers, all controlled by a microcomputer. One button will operate any of the components, including the selection of one of six pre-set FM stations, and bring up a read-out



of user's instructions on a panel.

An infra-red remote control module allows selection of programme, volume level, make cassettes (you have to load the machine yourself) and power off from the listening position.

On the main panel, all primary functions, including

standby and power off, can be programmed for automatic recall at any time in a 24-hour period. You can also programme for off-air recording.

Connectors for external components, such as speakers, processors, etc., are accessible from the top by lifting a hinged

cover at the rear. Outputs include provision for an external power amplifier.

Headphones and an additional tape deck can be connected from the front. Write to BSR (Canada) Ltd, P.O.Box 7003, Stn B., 26 Clairville Dr., Rexdale ON M9V 4B3, Phone (416) 675-2425.

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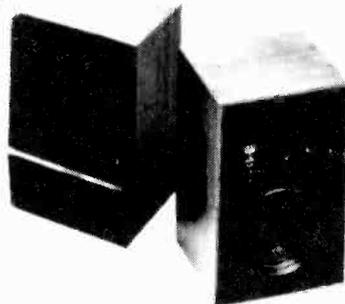
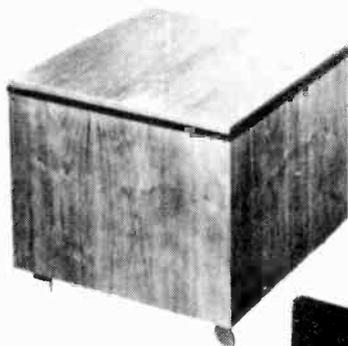
## ADC's Designer Series

Three new components from ADC include a vacuum tube pre-amplifier, designed by Mark Deneen, a Subwoofer by Mark Nazar, and a two-way satellite speaker system from Roy Cizek.

The preamp has three phono inputs, one of them for moving coil pickups and a slim black housing. Price \$2395.00.

Model B300 is a Subwoofer with built-in 120 Watt amplifier. It uses a 12" woofer and claims a response to 27 Hz, and less than 3% distortion. Priced at \$1195.00

Complementing the subwoofer is the B410 satellite speaker. This is actually a full-range two-way compact speaker with a claimed response from 65 Hz to 17 kHz. It can handle up to 250 Watts, thanks to the use of Ferrofluid in the voice coil gaps of both drivers, and the tweeter has its own circuit breaker. Suggested list: \$825.00 a pair. Contact BSR (Canada) Ltd P.O.Box 7003, Stn B, Rexdale Ontario M9V 4B3



Circle No. 35 on Reader Service Card.

## Astrion Pickups from ADC

In an increasingly machine-made world more of the good stuff is handmade. The ADC Astrion pickup is such a product, handmade from start to finish by an individual craftsman, who personally auditions it and signs the calibration sheet. Any problems and the user can call ADC and give the guy what for.

Design features include a square nude diamond stylus mounted on a laser etched sapphire cantilever. The stiffness of the resulting cantilever is said to improve the accuracy of transmission from stylus to transducer. Price is \$250.00. Write to BSR (Canada) Ltd, P.O.Box 7003 Stn B Rexdale Ontario M9V 4B3

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**Mitsubishi Receivers**

Mitsubishi has entered the receiver market with three new models with features such as fluorescent digital display, touch-sensitive lock tuning and built-in moving coil pickup preamp, along with a DC power amplifier.

Model DA-R20 offers 60 W/Ch at 8 Ohms with less than 0.02% THD., switchable IF selectivity, pilot tone cancellation and high frequency blend.

Touch-sensitive lock tuning

combines AFC with a switching system which disables AFC while tuning and restores it when tuning is accomplished.

High and Low filters, tone defeat, 10 position loudness control, record select independent of programme select and A and B speaker selection via relay, complete the operational features.

The Model DA-R10 offers 45 W/Ch, while the DA-R7 is rated at 35 W/Ch.

Contact Melco Sales at 900 Denison St, Markham Ont L3R 3K5



**New From PSB**

PSB's new line a budget speaker, a sub-woofer and new models in the Summit series.

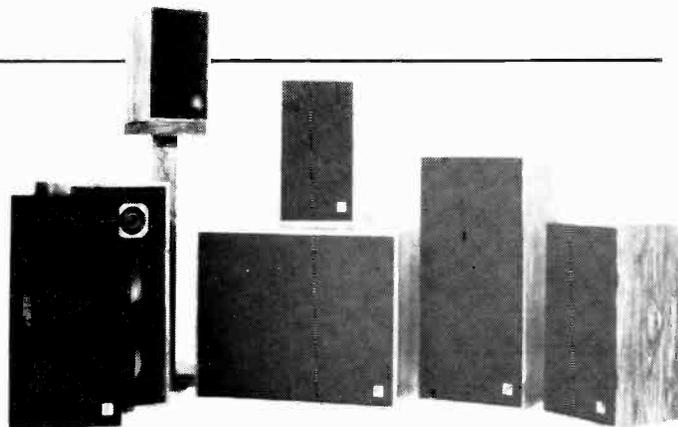
The Avette is a low priced speaker boasting high efficiency, smooth response, and an easy-to-take price tag of \$250.00/pair.

The Subwoofer consists of two 8" woofers operating in stereo in a smallish enclosure. A passive system, it has three switchable

cross-over frequencies, a gain control, and a matching switch to matching it to the user's satellites.

The Summit Seven and Summit Ten use polypropylene cone woofers and Dales'ord-ferrofluid tweeters in a phase-arrayed enclosure. They boast high efficiency and high power handling capability. Contact PSB Speakers, Inc. 480 Dutton Dr., Waterloo Ont N2L 4C6

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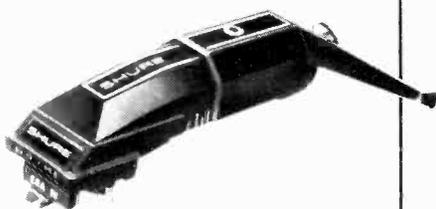
**A New Head Deserves a New Shell**

Ever since Shure introduced the V15-Type IV they've been busy turning out a whole new range of pickups based on the basic design. Specifically, the M97 Series which feature the high trackability and the damped brush of Grandad.

More specifically, the M97HE-AH offers easier installation, and lower mass than many separate pickup-shell combinations.

In addition it comes with a special arm alignment system which includes an overhang gauge and a non-operable alignment pin gauge stylus. This is used to allow precise overhang adjustment without exposing the real stylus to danger.

The pickup itself incorporates a feature from Shure's broadcast series: a stylus suspension system which allows the stylus to retract if accidentally slid across a record surface



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**A R K O N K I T S**

**LED POWER METER**  
Uses the popular LM3915 display driver. Features switch selectable peak or average peak power level indication. The front end utilizes precision half wave rectification. LED displays included 30 db (-24 db to +3db) dynamic range. **\$24.95**

**LED VU/POWER METER**  
Same as LED power meter but uses NSM series display. Two types NSM 3915 - 30 db (-24 db to +3 db power) NSM 3916 - 23 db (-20 db to +3 db VU) **\$29.95**

**THE BRUTE 300 WATT AMP**  
This kit is not recommended for beginners or inexperienced constructors. Power output, 200 watts RMS, 8 ohms, 310 watts RMS, 4 ohm. Input sensitivity, 1V for total output. This kit uses all standard parts and comes complete with instructions and printed circuit board (mono) (transformer required 100 VCT 5 amps is available for \$51.00 #167P100) **P.C. Board \$11.25**

**COLOUR MODULATOR**  
This video modulator has been designed to complement the small home computer. It allows the standard colour television to be used as a high quality colour video monitor. Uses state of the art integrated circuit technology. Direct coupling is employed to provide white level compensation in the vestigial sideband output. The gain device of the LM1889's chroma oscillator is used to butter level shift, and invert the incoming composite colour input. The signal then passes to the RF modulator where a channel 7 carrier is provided. Requires 12 volt DC for operation. **\$24.95**

**VIDEO TO RF MODULATOR**  
Converts a video signal to a RF signal. The RF output terminals connect to the antenna of your TV. Connecting in the video and supplying 5 to 10 volts DC is all that is needed. You turn your channel selector to 4, 5 or 6 (whichever is not used in your area) and tune the adjusting coil for a suitable display. **\$8.95**

**ASCII KEYBOARD KIT**  
60 Key complete ASCII character set. Highest commercial quality key switches. Uses a KR2376 ST encoder IC. Output compatible with TTL. Caps lock for upper case alpha characters. Repeat key parity/data invertable. Positive and negative key pressed and strobe signals. Requires +5 volts to +30 volts at 100ma. **\$99.95**

**ARKON LOGIC PROBE LOGIC I**  
Easy to build Logic Probe kit. A full performance logic probe. With it, the logic levels in a digital circuit translates into light from the Hi or Lo LED. Pulses as narrow as 300 nano seconds are stretched into blinks of the pulse LED's. Specs - 300K ohm imp Power - 30ma at 5 volts, 40ma at 15 volts, 15 volts max. Max Speed - 300 nano seconds 1.5 MHz. Input Protection - +50 volts DC continuous, 117 volts AC for 15 seconds (case included) **\$24.95**

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# Turntable Technology

By Brian Dance

THE BASIC REQUIREMENT of any record player assembly is that the turntable shall rotate noiselessly, at the required speed without any short-term or long-term variations in this speed. This sounds a simple enough requirement, yet sophisticated, modern players contain quite complex circuitry with large numbers of integrated circuits and discrete components; indeed, the circuitry is too complex for us to reproduce in full for any of the latest players mentioned in this article!

Turntable mechanisms have evolved a very long way from the purely mechanical gramophones of about fifty years ago where one had to wind up a spring motor with a handle. All of the audio power came from the mechanical interaction of a large steel needle with the surface of the revolving record; the steel needle moved a mica diaphragm at the narrow end of a flexible horn which provided suitable acoustic coupling to the air. The weight of the moving arm part of the horn seemed almost enough to push the needle through the record! However, it is this old type of gramophone which has set the pattern for the modern record player of today.

## Turntable speed

The rate of rotation of the turntable directly controls the frequency of the audio signal reproduced from the record track. Any slight increase or decrease in the rate of rotation will produce a proportionate increase or decrease in the pitch of the recovered audio signal. Modern recordings are made for use at either 33 1/3 or 45 revolutions per minute. How accurately must the player match these speeds of rotation in order to be acceptable? This is not a question to which one can give a definite answer, since so much depends on one's hearing, on the listening experience one has had previously and on the amount of hard cash one is willing to spend in order to obtain a constant rate of revolution.



The Pioneer PL-L1000 features a tangential tracking tone arm driven by a unique linear motor system. It employs an optical tracking sensor to maintain the arm position to within 0.2° of deflection.

Most of the fairly economical turntables employ a strobing system which enables the rate of rotation of the turntable to be set quite accurately to the required speed. The cheapest strobing system employs a lamp (normally a light emitting diode) which flashes at the line frequency frequency line.....However, if one uses the line frequency as the standard, any changes in frequency will produce errors. This problem can be avoided by driving the lamp from an astable multivibrator circuit which is operated from a stabilised supply voltage.

In the simplest systems the lamp may be placed under the edge of the turntable so that light passes through a pattern of bars on the edge; the speed is correct when the bar pattern for that speed remains stationary as the turntable rotates.

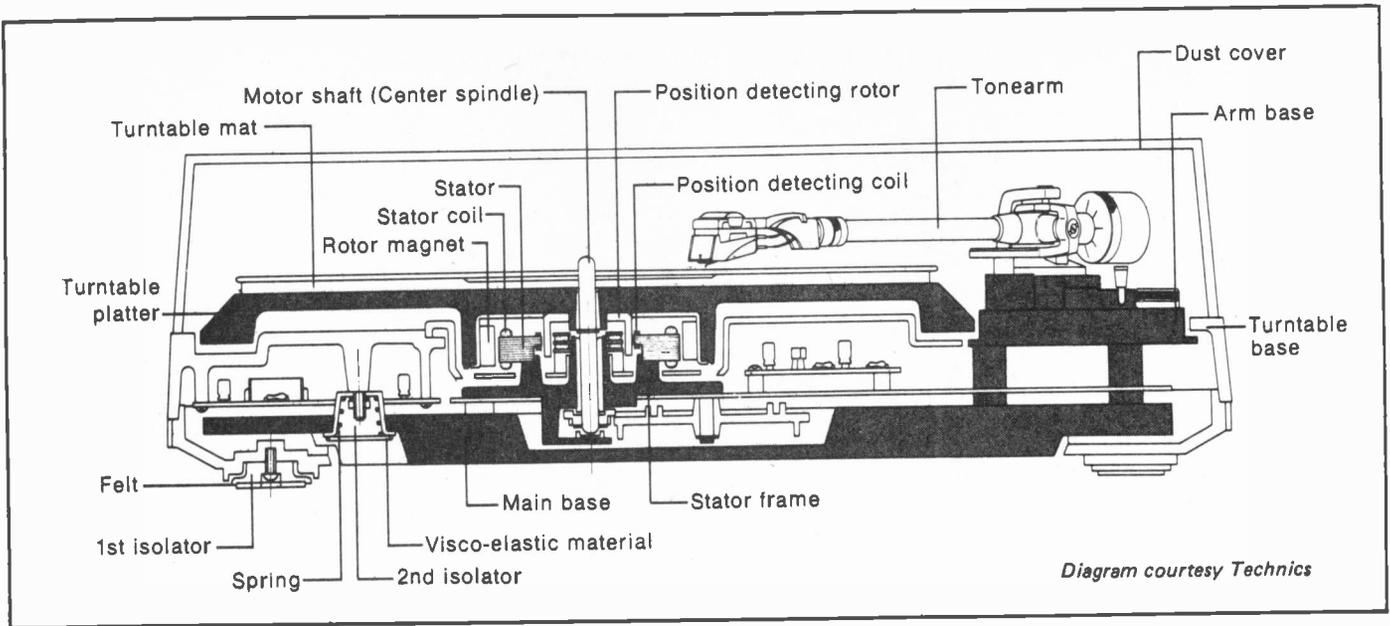
To stabilise rotation speed a tachometer and an F/V converter can be used to give a voltage proportional to rotation rate. The difference between this and a reference voltage is used to adjust the speed of rotation so that the error voltage is reduced almost to zero. The use of such a system minimises speed

variations due to changes in the line voltage or frequency or any loading on the turntable (for example the drag caused by a disc cleaning arm and changes in the tone arm effective weight). Few manufacturers quote a value for the speed stability over a fairly long period for such equipment, but generally a few tenths per cent speed variation is reasonable.

## Quartz stabilised

For more closely controlled speed stability, a turntable locked to a quartz crystal oscillator should be selected. Typical speed stabilities of such turntables are  $\pm 0.002\%$  to  $\pm 0.004\%$  or about a hundred times better than other systems. Is such high speed stability necessary? Only the user can answer this question after prolonged listening to both quartz stabilised and other equipment.

In some quartz stabilised equipment turntable speed cannot be varied without losing the advantages of quartz control. Some manufacturers of top quality decks offer quartz control systems with a digital display of the platter speed. Changes in speed of a



quartz controlled system with temperature can be as low as 0.2 parts per million per celsius degree.

**Wow and Flutter**

Wow and flutter are short term variations in the record speed. Wow is generally taken to mean changes of the recovered audio at frequencies of less than about 10 Hz, while flutter is a similar effect at frequencies above 10 Hz. Wow and flutter are normally measured together as a total percentage, but a form of weighting network is often used which attempts to take account of the degree of annoyance to the listener so that wow and flutter of particularly annoying types produces a larger contribution to the percentage figure than a similar amount of other types.

Wow and flutter can be measured in various ways. Using a test record, pickup and tone arm, will usually show a higher percentage figure than measuring the fluctuations of speed in the turntable more directly with a tachogenerator. Many of the Japanese manufacturers employ the tachogenerator technique to obtain a percentage figure for wow and flutter expressed as a WRMS figure (weighted root mean square). The German standard DIN (Deutsche Industrie Normal) is a peak weighted figure expressed as a percentage which is a *third* figure to catch the unwary.

It has been agreed that DIN peak weighted wow and flutter percentages of less than about 0.1% are probably undetectable in normal listening. However it has recently been shown that intermodulation products which can be generated by pitch fluctuations can impair the recovered audio signals,

so it is wise to select a system with the minimum wow and flutter percentage figures you can afford. The percentage figures quoted are normally in the range 0.01% to 0.1%.

Table 1 shows wow and flutter percentage figures for the Philips AF877/AS977 and AF677/AF777 turntables measured in various ways for comparative purposes. The lower values obtained for the AF877 and AF977 are due to improved control circuitry and differences in the mass of the turntable.

**Cogging**

Most turntable motors are dc electric motors which employ Hall Effect cells for commutation instead of the conventional brushes and copper commutator ring. Brush sparking can generate much noise; the use of Hall Effect cells for detecting the changes of magnetic field and for generating the switching pulses eliminates brush noise.

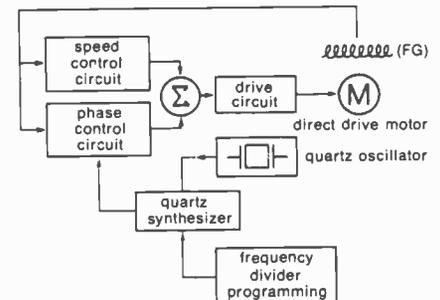
However, the problem remains that the energy is given to the motor in small discrete pulses as each coil passes through one of the magnetic fields. The uneven running due to this effect is known as 'cogging'; it can result in appreciable rumble combined with wow and flutter. Technics has developed a 20-pole, 30-slot brushless dc motor to minimise the effects of cogging. Hitachi employ their 'Unitorque' motor which incorporates a 200-pole, rotary magnet. The coils are arranged 22.5° physically or 90° electrically out of phase with each other. The torque produced by a single coil fluctuates in a linear mode between a maximum value and zero. When the coils are out of phase at a given rotor angle, the sum of the torque pro-

duced is equal to the maximum torque of a single coil. This results in a motor action which has a uniform torque and is completely free from cogging.

**Other effects**

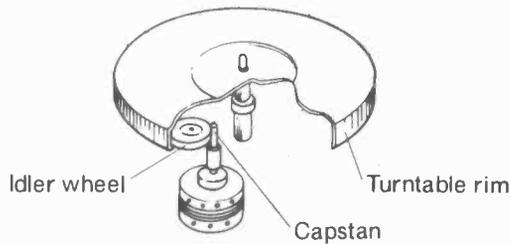
Various other effects can cause minor variations in turntable rotation. One of these is 'platter wobble' in which the turntable wobbles on its axis. It may be reduced by the use of a large diameter centre shaft, but Pioneer employs a hanging rotor system in which the main bearing is placed at the centre of gravity of the rotating system at the top of a *fixed* motorshaft. This provides a kind of gyrostatic action, increasing the stability and allowing the platter and the attached 'hanging cup rotor' to glide without any wobbling.

The actual recorded groove can cause small fluctuations in the speed of rotation of the platter. Figure 1 shows of the record. Thus the cutting path is a straight line unlike the arc of the replaying stylus. This leads to the important point that the axis of the recording head relative to the record groove is a tangent at all times. A con-



Block diagram of a quartz stabilised turntable drive circuit, as devised by Technics.

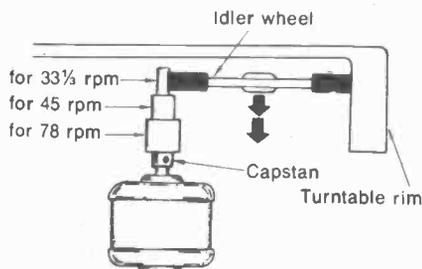
### Rim drive system



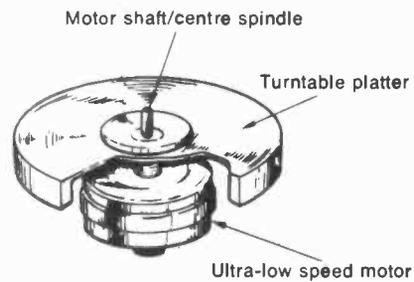
#### Rim Drive

In this system the motive power provided by the drive motor is applied to the inner or outer edge (rim) of the turntable by means of a capstan on the shaft of the motor. Since a high speed motor is used, one or more idler wheels are inserted between the capstan and the rim to reduce the speed and achieve the desired ratio to obtain the correct platter speed. (This system is also known as 'idler drive'). The rim drive system is relatively low in cost, permits the use of a low torque motor and allows mechanically simple speed changing. Its main disadvantage is rotational instability due to slippage occurring between the capstan, idler and rim.

#### Speed change of rim drive



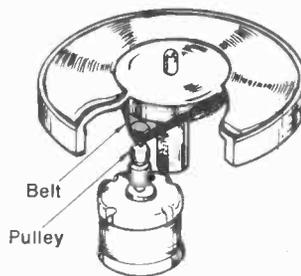
### Direct drive system



#### Direct Drive

As the name implies, this system uses no speed reduction devices to transfer the motive power from the motor to the turntable platter. Rather, the shaft of the platter is set in the centre of the motor itself and is driven directly. The motor rotates at exactly the required speeds (33 1/3 or 45 rpm) and its rotational accuracy is maintained by any one of a variety of electronic servo mechanisms. The slower rotational speeds and very high rotational accuracy of this system have brought both rumble and wow and flutter specs to levels seldom if ever before achieved. Since the introduction of the first direct drive turntable by Technics in 1970, this system has rapidly become very popular and many manufacturers have entered the market with their own models.

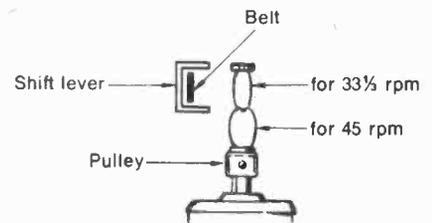
### Belt drive system



#### Belt Drive

This is a very common drive system like the rim drive. A relatively high speed motor is used and coupled to the turntable platter by a compliant belt. By moving the belt up or down over different diameter sections of the motor shaft pulley, speed changes may be effected. One of the big advantages of this system is that the belt serves to dampen motor vibrations, thereby reducing noise and rumble. Polyurethane is the preferred belt material because of its resistance to heat, humidity and oil and its low elasticity. The problems encountered with belt drive are instability due to belt slippage and a relatively large amount of vibration due to the high rotational speed of the motor.

#### Speed change of belt drive



ventional stylus cannot be tangential to the record groove at more than two places. At all other points there will be a small angle between the cutting axis and a tangent to the groove.

Many people feel that a stylus which follows the path of the cutting head across the disc as accurately as possible is likely to achieve a more faithful reproduction of exactly what is on the disc than a stylus which moves at an angle to the direction of movement of the cutting head. A few record decks

are now coming onto the market in which 'tangential' or 'parallel' tracking is achieved.

The basic idea of the tangential tracking system is shown in Figure 3. The tone arm does not swing in an arc, but moves from right to left along a fixed bar at the back of the record. The stylus moves in a straight line along a

radius of the record so that tangential tracking is achieved at all points. One of the major disadvantages of tangential tracking systems is that the arm must be moved across the record surface by some type of motor drive system. This requires very careful design of the tone arm motor if satisfactory performance is to be obtained.

Most manufacturers employ an optical feedback system to control the

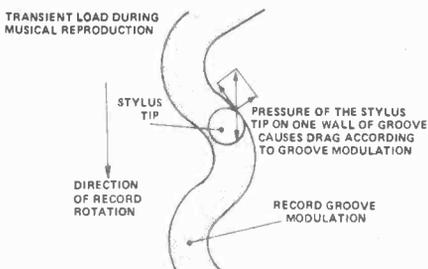


Figure 1. The groove modulation can apply a variable braking effect on turntable rotation.

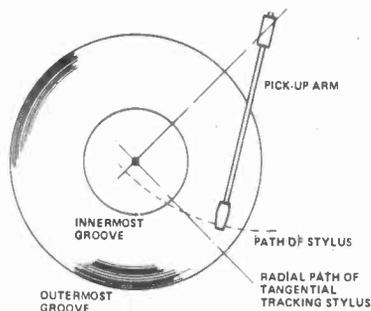


Figure 2. The path a conventional tone arm traces across the record is different to the path taken by the cutting arm of the original disc cutter. Thus, the stylus is not always tangent to the groove. Tangential tracking arms were devised to overcome this.

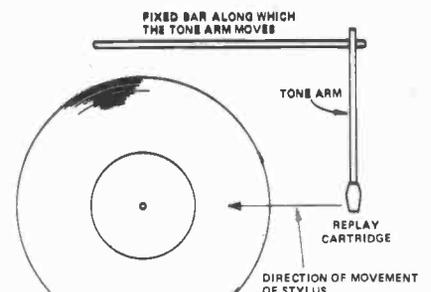


Figure 3. The basic arrangement of a tangential tracking turntable system.

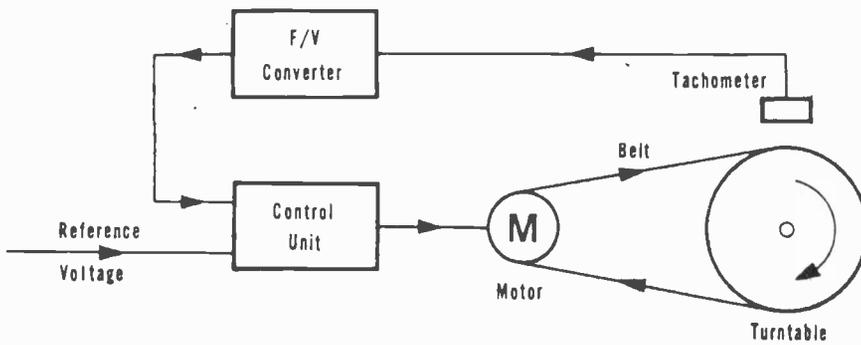


Figure 4. The Philips 'direct control' system employs belt drive for the platter and servo feedback to the motor control circuitry via a tachometer sensing the platter speed.

tone arm motor. In the normal or equilibrium position a beam of light from a lamp is blocked off by a shutter on the tone arm so that it cannot reach a photo-resistive cell. If the record now rotates so that the stylus is closer to the centre of the record, the position of the tone arm will be changed by a small amount so that the shutter no longer prevents the beam of light from reaching the photoconductive cell. The current through this cell activates the tone arm motor which moves the arm inwards towards the centre of the record until the shutter again blocks the beam of light.

A successful optical system of this type must be very accurate, since the record grooves are very small and close together. The tone arm motor system must also be carefully designed to prevent 'hunting' in which excessive or inadequate movement of the tone arm takes place and the system hunts for the correct position.

Tangential tracking systems generally provide tracking angles to within a few tenths of a degree of the desired angle, whereas conventional systems may have angles of up to a few degrees at some point on the record. But what is the practical effect? Tracking error angles tend to introduce second a stylus tip following a heavily modulated signal. It can be seen that the pressure of the stylus on the one wall of the groove acts as a variable braking effect on the rotation of the turntable. This problem can be reduced by using a turntable of high moment of inertia, but in turn this involves the use of a high torque motor which can bring the turntable up to its correct speed reasonably quickly.

Vibrations from the motor, transformer and acoustic waves from the speakers can also affect the rotational stability of the platter.

So far we've examined motors and platters, but of equal importance is the means of coupling the two together.

The inset illustrates the most commonly used methods of accomplishing this.

Although for many years rim drive, with a rubber idler wheel coupling the inner turntable rim with the motor, was the most popular, this was later supplanted by a belt coupling the two elements with considerable reduction in rumble and flutter.

Direct drive has the additional advantage of allowing high starting torque, essential for broadcast applications, and may take two forms. The form shown in the inset uses a low speed motor, with the platter mounted directly to the shaft. Alternatively, the rotor of the motor may be an integral part of the platter, while the stator assembly is fixed to the motorboard.

Whichever method is used, there is no gearing system to control mean speed, so electronics systems are mandatory.

All modern quality turntables are either belt or direct driven, but a few models, such as Philips, use a belt drive with an electronically controlled motor, whose speed is controlled by a sensor which measures turntable, rather than motor, speed, to generate a control signal.

Most direct drive turntables use quartz stabilized drive systems. Kenwood, for example, also uses a high mass platter, whose high moment of inertia minimizes transient speed fluctuations, as do Denon and Technics.

Tangential tracking

The conventional tone-arm moves across the record in an arc of a circle so that the path of the stylus is as shown in Figure 2. When a record is being cut, however, the cutting arm moves inwards along a radius towards the centre harmonic distortion which, while obviously undesirable, is not nearly so objectionable as third harmonic distortion. There seems to be some controversy as to exactly how much distortion is introduced by such tracking angle errors. Pioneer states that reduction of crosstalk between channels can be achieved by the use of tangential tracking.

The pickup arm of a conventional system will tend to 'skate' towards the centre of a record unless the correct amount of bias compensation is applied. If no bias or an incorrect bias is applied, the inner groove is likely to receive more force from the stylus which will result in signals of an unequal amplitude in the two channels and

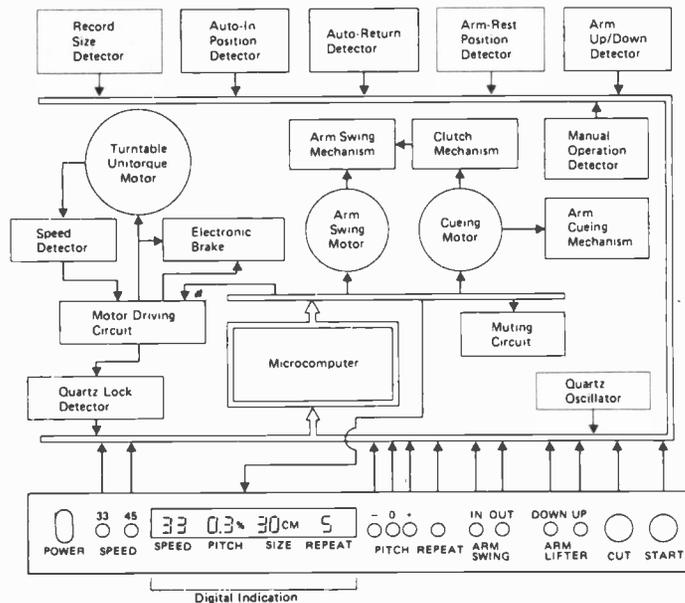


Figure 8. Block diagram of Hitachi's HT-860 microcomputer controlled deck.

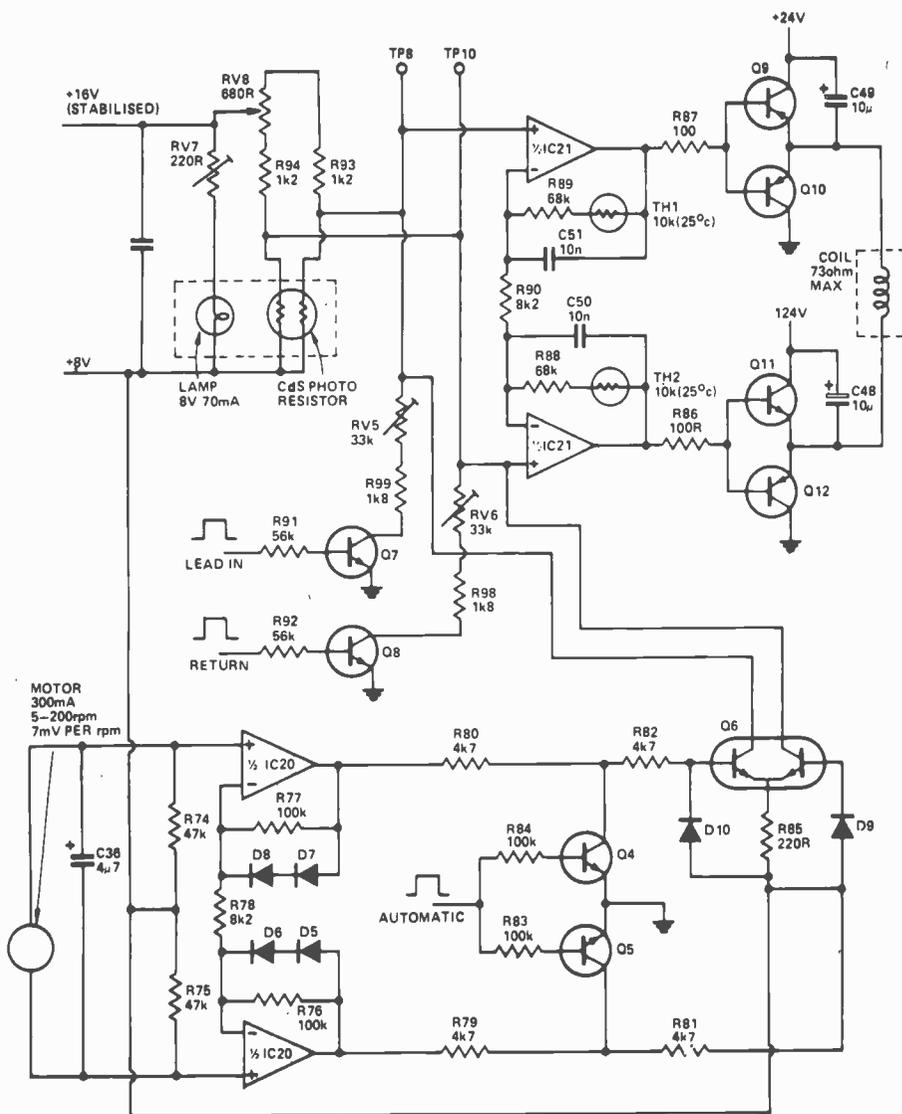


Figure 13. The Pioneer PL-L1000 turntable has a tangential tracking tone arm employing an optical tracking system. This is the optical sensor circuitry.

which is likely to cause the inner groove to wear at an increased rate. These problems are said not to arise in tangential tracking systems, whereas in conventional systems the application of bias is only a compromise, since the required bias varies with the position of the tone arm on the record and with the modulation levels.

In a tangential tracking system the effective arm length can be relatively short and the equivalent mass low even if strong materials are used to obtain a highly rigid arm. This can bring the advantages of minimum vibrational levels and small resonance patterns and hence of cleaner reproduction.

In spite of their important advantages, tangential tracking decks must be very carefully designed if they are to be better than conventional systems. Designers have not yet had

extensive experience with linear tracking, so the intending purchaser would be well advised to try any linear tracking equipment very thoroughly before committing himself to purchase. However, it may well be the system of the future for top-of-the-market systems.

The use of servo control systems in modern tangential arms makes possible considerable control automation, but some pivoted arms also feature such control.

For example, Hitachi's microcomputer system controls more than platter rotation. By shining a lamp through holes in the platter, the record size is detected, and the set-down position of the arm is controlled. In addition, the set-down instructions for a seven-inch disc automatically sets turntable speed to 45 rpm. And if no record is on the turntable the arm will not set down.

The arm can be controlled manually from the front panel, for any desired set down.

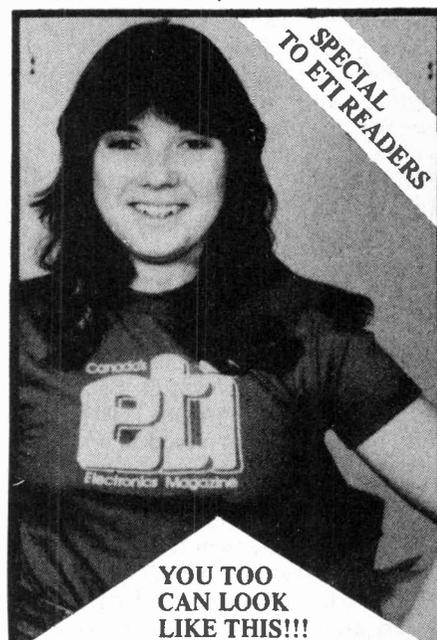
Optical sensing, coupled with micro-computer control, allows several manufacturers to provide automatic programming. By sensing the more coherent light reflected between bands on a record, such a system allows automatic playing of various cuts in any order the operator may desire.

If you believe equipment should be compact and unobtrusive, Technics has the SL10, not much larger than the record itself.

The SL10 has a record clamp built-in and the tracking force is applied by means of a fine spring, so this remarkable turntable can be used in any position, including on its side or even inverted! The arm runs along a pair of guide bars and is driven by a coreless electric motor. The motor is controlled by an optical system mounted in the shorter of the two arms near the tip of the stylus.

The SL10 will accept only the special moving coil cartridge with which it is supplied. The low output cartridge can be used with a step-up head amplifier which may be switched in and out of the circuit. However, this turntable is most remarkable for its portability.

It's enough to make the head spin. With servo control, of course.



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# ACOUSTICAL TREATMENT OF ROOMS

Often completely ignored, the audiophile's listening room requires as much consideration as any other component. Wally Parsons explains.

SOONER OR LATER anyone interested in sound reproduction will come across a reference in a book or magazine, or from a salesman about the effects of acoustics on reproduction, particularly with respect to loudspeaker performance.

By now, almost every reader probably knows that loudspeakers are usually measured in free-field conditions, which really means either outdoors or, more usually, in an anechoic chamber, a room designed to be free of any sound reflections. We are encouraged to experiment with loudspeaker positions to secure the smoothest response and sometimes advised to use equalizers to finish the job.

Sometimes we are given guidelines as to the most suitable dimensions of a room and some idea as to suitable furnishings to make it very live, very dead, or somewhere in between.

How these characteristics may be accomplished, though, is somewhat of a mystery, to which is added the confusion of mythology.

Once in a while an article appears dealing with the design of concert and, although the subject is an interesting one in itself, there is seldom any information which is actually useful in controlling home acoustics.

Consequently, most people either throw up their hands and make the best of what they have, or pile thick rugs on the floor, furnish the place with heavy upholstered furniture which they do not like, and hang heavy curtains on the wall, until the whole room becomes a claustrophobe's nightmare. They then turn up the tweeter controls and hope for the best.

There is really no need to despair, however, as the principles of acoustic control are really well understood, and materials are available which are designed to be effective, controllable in their action, and aesthetically attractive.

## Objectives

For our purposes, it is assumed that you know what you wish to accomplish acoustically, and have a pretty good idea of the decor desired. Therefore, we shall not get involved in determining what is optimum reverberation time in the room, or whether or not it should

be equal at all frequencies. We shall also assume a room of reasonable proportions: e.g. it's not a cube, nor is the length two or three times the width, and the ceilings are neither cathedral in height nor do you have to watch your head.

Essentially, the objective in acoustic treatment is to control the reflection of sound around the room so that reflections are suppressed to inaudibility in an acceptably short period of time. In practice, this is what we mean by *reverberation time*. To accomplish this we arrange for boundary surfaces — walls, ceilings, floors — to absorb part of the sound energy which strikes them. We might also install structures within the room — and this includes furniture — which will absorb part of the energy and scatter part of it.

## Mechanisms

When sound energy strikes a surface, some of that energy passes through the material, to a degree determined by its porosity, and is dissipated as heat. Part of this dissipation is the result of friction between the air and the material's structure, and part consists of actually moving the material. An example of this is the affect of passing through wool, or glass fibre. Some materials are more absorbent than others: concrete absorbs less sound energy than soft woods and velour curtains are more absorbent than silk.

Energy which is not absorbed is reflected and the greater the absorption, the less the reflection.

Obviously, one method of controlling reflections is to line all surfaces with suitably absorptive materials.

Table 1 shows that different materials not only have different coefficients of absorption, but that this coefficient varies with frequency. The absorption coefficient is simply a figure indicating what percentage of sound energy is absorbed by a surface, and total absorption is indicated by a coefficient of unity, or 1. If a surface has a coefficient of 0.5, then it absorbs 50 per cent of incident sound, while a coefficient of 0.25 describes a surface which only absorbs 25 per cent. The remainder is reflected back into the room.

## Techniques

Since we are considering a domestic listening room, in all likelihood we should consider first the furnishings. In many cases the furniture has already been purchased, and may even be in place.

Probably the floor will be carpeted. Most carpets have greater absorption at high frequencies than at low, but this is modified by the depth of pile might show significant absorption a coefficient of 0.1 or greater at around 125 Hz, but will be progressively more absorbent as frequency rises. A medium pile would show the same response shape, but shifted up about an octave.

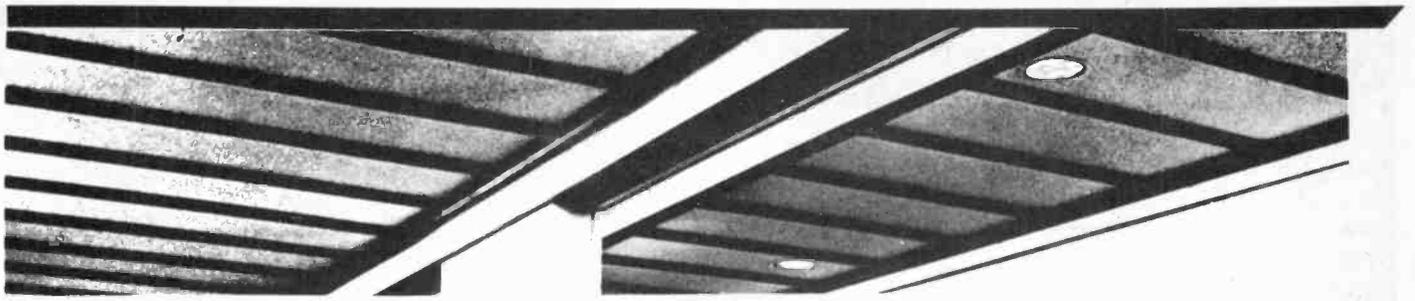
Materials such as polyester and nylon, are more nearly constant with frequency in their absorption coefficients than wool, but the overall absorption is less.

Adding a thick underpad will improve absorption at lower frequencies, and make a more comfortable walking surface.

This brings us to another characteristic of acoustic absorbents: the effect of mounting on performance. Table 2 illustrates different methods of mounting absorbents. Although each illustration except No. 6 is shown mounted on a ceiling, they are equally applicable to wall treatment. These are also the mountings referred to in Table 1 at the bottom.

As sound penetrates a fibrous material, it's energy is progressively attenuated until it reaches the surface on which the material is mounted. It will then be partially absorbed and partially reflected by that surface in accordance with its absorption coefficient at any frequency. The reflected energy will again pass through the absorbent for further attenuation. This is true whether the distance between surfaces consists entirely of the absorbent or a combination of absorbent and air space. Maximum absorption occurs when the distance is equal to or greater than a quarter wavelength.

Thus, a 2.5cm absorbent fixed to a hard wall will be most effective at about 3000 Hz and above, with progressively less attenuation at lower frequencies. If that same material is mounted 300cm



away from the surface, its effectiveness is extended to about 250 Hz and at 3 metres, it will be effective over the entire audio band. This principle is used in anechoic chambers, with the entire space filled with absorbent for maximum overall attenuation.

This gives us a clue as to effective use. Suspended ceilings use this principle to extend absorption into the upper bass region, and although at first glance this would seem to present a problem at lower frequencies, the higher hearing threshold at lower frequencies reduces the absorption requirements: instead of requiring, say, 60 dB attenuation as we might at 1000 Hz, at 50 Hz we may require only 20 dB for equivalent perceived attenuation.

Assuming we want a high level of absorption, we've taken care of floors and ceilings, but how about walls: All

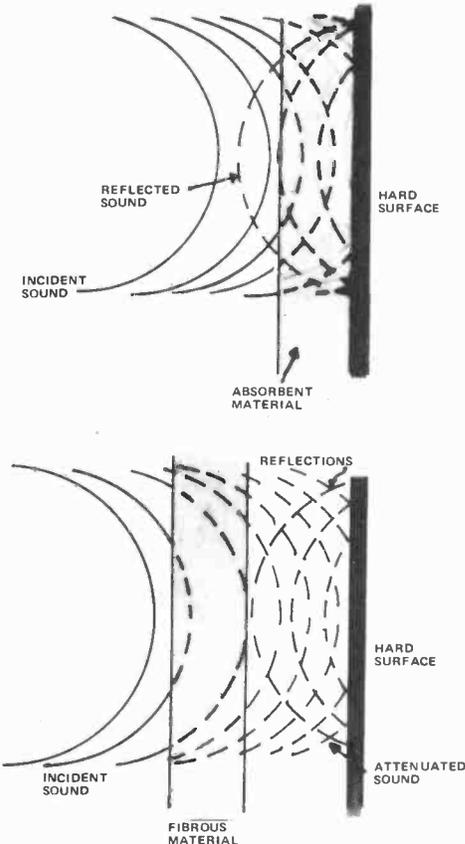


Fig 1. The attenuation mechanism.

TABLE 1

Materials	Coefficients						N.R.C.
	125 cps	250 cps	500 cps	1000 cps	2000 cps	4000 cps	
Brick, unglazed	.03	.03	.03	.04	.05	.07	.04
Brick, unglazed, painted	.01	.01	.02	.02	.02	.03	.02
Carpet, heavy, on concrete	.02	.06	.14	.37	.60	.65	.29
Same, on 40 oz. hairfelt or foam rubber	.08	.24	.57	.69	.71	.73	.55
Same, with impermeable latex backing on 40 oz. hairfelt or foam rubber	.08	.27	.39	.34	.48	.63	.37
Concrete block, coarse	.36	.44	.31	.29	.39	.25	.36
Concrete block, painted	.10	.05	.06	.07	.09	.08	.07
Fabrics							
Light velour, 10 oz. per sq. yd., hung straight, in contact with wall	.03	.04	.11	.17	.24	.35	.14
Medium velour, 10 oz. per sq. yd., draped to half area	.07	.31	.49	.75	.70	.60	.56
Heavy velour, 18 oz. per sq. yd., draped to half area	.14	.35	.55	.72	.70	.65	.58
Floors							
Concrete or terrazzo	.01	.01	.015	.02	.02	.02	.02
Linoleum, asphalt, rubber or cork tile on concrete	.02	.03	.03	.03	.03	.02	.03
Wood	.15	.11	.10	.07	.06	.07	.08
Wood parquet in asphalt on concrete	.04	.04	.07	.06	.06	.07	.06
Glass							
Large panes of heavy plate glass	.18	.06	.04	.03	.02	.02	.04
Ordinary window glass	.35	.25	.18	.12	.07	.04	.16
Gypsum board, 1/2" nailed to 2 x 4's 16" o.c.	.29	.10	.05	.04	.07	.09	.06
Marble or glazed tile	.01	.01	.01	.01	.02	.02	.01
Plaster, gypsum or lime, smooth finish on tile or brick	.013	.015	.02	.03	.04	.05	.02
Plaster, gypsum or lime							
Rough finish on lath	.02	.03	.04	.05	.04	.03	.04
Same, with smooth finish	.02	.02	.03	.04	.04	.03	.04
Plywood paneling, 3/8" thick	.28	.22	.17	.09	.10	.11	.14
Water surface, as in a swimming pool	.008	.008	.013	.015	.020	.025	.12
Air, sabines per 1000 cubic feet					2.3	7.2	
Mat-faced textured Fiberglas 5/8" #7	.63	.90	.68	.90	.96	.91	.85
Pin perforated Fiberglas 5/8" #7	.85	.86	.64	.84	.90	.89	.80
Sonacor Fiberglas 1" #7	.60	.61	.92	.83	.71	.46	.75
Sonoglas - nubby 3/4" #7	.89	.78	.83	.97	.99	.91	.90
Perforated wood fibre tiles 1/2" #7	.14	.30	.51	.67	.68	.56	.54

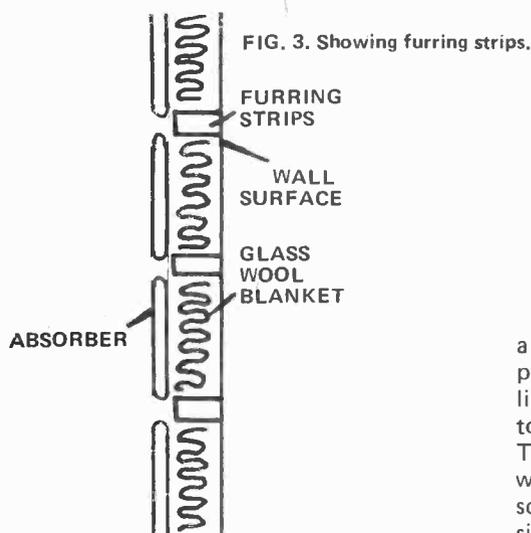
other considerations aside, if floors and ceilings alone are treated, a phenomenon known as "flutter echo" can occur, especially in long rooms, which gives the

impression of greater reverberation than actually measured. To counter this the walls must be treated, at least at ear level.

Although we can drop the ceiling,



this isn't so easily done with the walls. Fortunately, our requirements here are less stringent, and we can settle for mounting 2.5cm panels directly on the wall, or perhaps adding furring strips to the wall and mounting our absorbers on them.



Alternatively, the wall area can be covered with glass fibre and covered over with curtains. Where appropriate to the decor, this presents some interesting possibilities. For example, a common situation places speakers at one end of a room with a window between them. Windows are highly reflective, and it's desirable to damp them. Fortunately, most people use curtains on their windows, and a living room window may have a heavy curtain set on

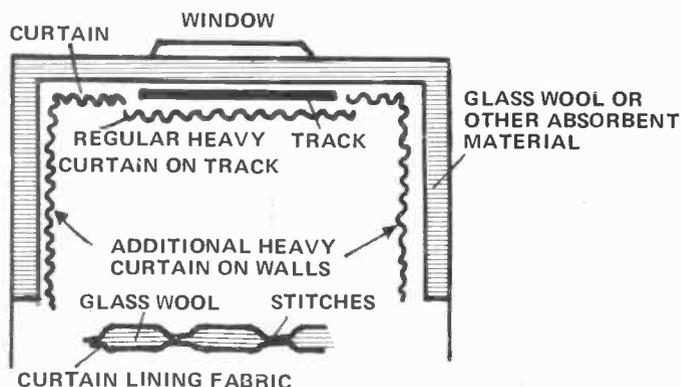


FIG. 4. Windows are highly reflective and can present problems. However, this end of the room can be treated as shown here. The curtain lining should be doubled and filled with glass wool, the walls can be lined with absorbent material and the curtains extended to cover this (they need not be on a track).

a draw track, with a back lining to protect the curtain from fading. This lining can be made of two layers, stitched together downward from the pleats. The pockets thus formed can be filled with glass fibre, such as the 1" material sold in building supply stores in rolls. A similar glass fibre layer may be attached to the walls flanking the end wall and the curtains extended, without track, along those walls. This now gives a relatively dead area for the speakers which is visually attractive, and reduces the many early reflections which produce phase problems with speakers.

With this setup, the walls behind the listener and on either side can be left bare if rear reflections are desired. Alternatively, hard furniture or wooden bookcases may be installed.

For stereo reproduction, it's desirable that the room be symmetrical between left and right sides if possible. An open doorway on one side provides 100% absorption at all frequencies, so it's a good idea to provide absorption on the opposite wall. On the other hand, if the door is normally closed it might provide substantial reflection, so either it should be treated, or the opposing wall area left untreated.

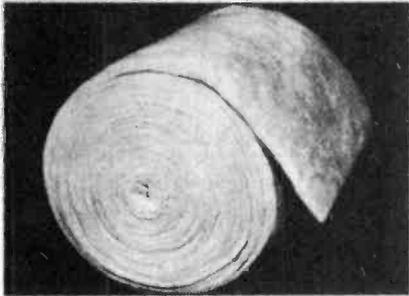
#### Diffusion

Any projection into the room, such as a piece of furniture, also provides diffusion of any energy it reflects; that is, sound is reflected from it into some different direction from which it arrived. Such projections are effective down to one eighth wavelength, in the case of rectan-

gular diffusers, and may be used as part of a suspended ceiling, perhaps in the form of a cloth covered glass fibre panel mounted edgewise to the ceiling panel grid and projecting downwards. Aesthetic considerations will have to be considered here, as well as in other alternatives, such as breaking a suspended ceiling into two parts, each suspended by a different amount. Similarly, a window can also be fitted with Venetian blinds, which would usually be visible from outside, but would also provide wonderful dispersion and diffusion behind the curtains.

### Materials

Reference has been to various materials, including glass fibre. The biggest ad-



vantage of the latter material lies in the availability of reliable data on the products of manufacturer's such as Fiberglas Canada Ltd, best known for their thermal insulation bats and rolls as well as ceiling tiles.

It should be understood that there are differences in tiles. Fiberglas, for example, produces three different types of ceiling materials. Sonoglas consists of rigid glass fibre covered with a pre-painted glass cloth facing. It features high absorption at all frequencies, is rugged but expensive.

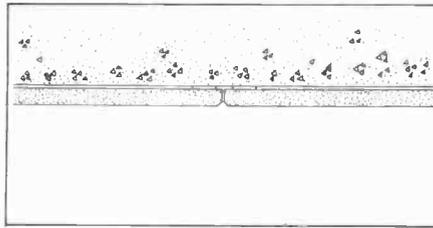
Sonoboard is somewhat less expensive, is soil resistant, but less effective as an absorber.

For home use, Sonoflex is especially suitable for shallow suspended ceilings, because its flexibility aids in installation. Absorption coefficients are quite high, but less constant with frequency.

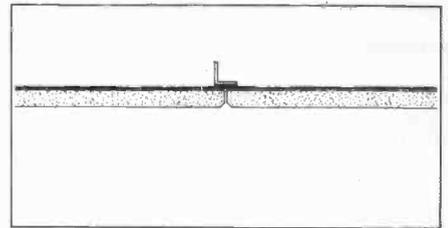
Some of these materials have pebbled surfaces, some are perforated. Unfortunately, many people thoughtlessly buy a plain white board then paint them over. This is not always satisfactory, as the characteristics of the board may be changed. This is particularly true if the paint is a latex or other finish with good bridging characteristics. The holes get covered. These holes are intended to allow sound penetration into the fibres behind the finish, where absorption takes place.

**TABLE 2**

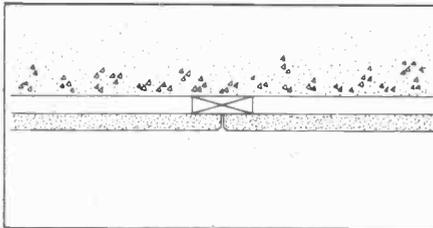
The effect of deep air spaces on low frequency absorption is most pronounced for materials like Fiberglas which are relatively porous through their entire thickness and thus allow unabsorbed sound to enter the air space rather than reflect out. That which is reflected after striking the rigid backing is again partially absorbed.



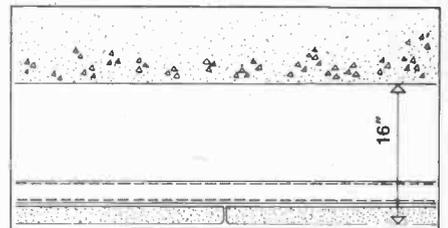
1. Cemented to plaster board with  $\frac{1}{8}$ " air space. Considered equivalent to cementing to plaster or concrete ceiling.



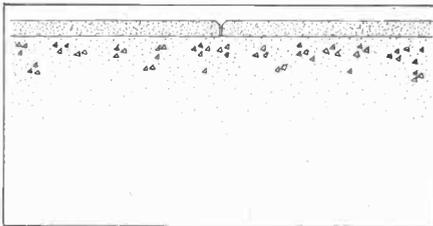
6. Attached to 24 gauge sheet iron supported by 1" x 1" x  $\frac{1}{8}$ " angle iron.



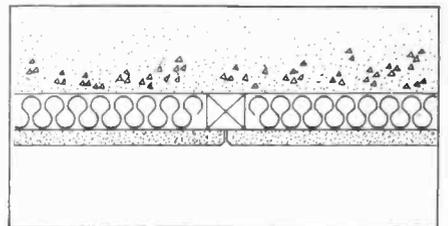
2. Nailed to nominal 1" x 3" ( $\frac{3}{4}$ " x  $2\frac{5}{8}$ " actual) wood furring 12" o.c.



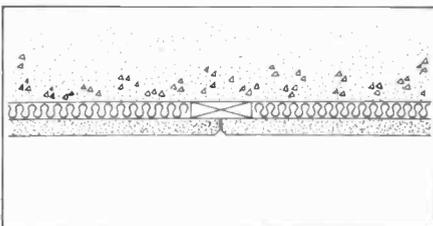
7. Mechanically mounted on special metal supports at a 16" mounting depth.



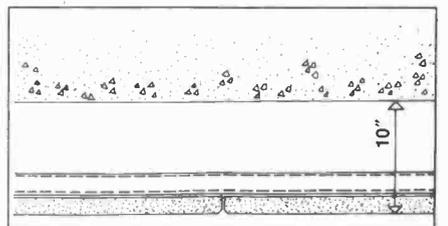
4. Laid directly on laboratory floor.



8. Wood furring 2" x 2" ( $1\frac{5}{8}$ " x  $1\frac{5}{8}$ " actual) 24" o.c. 2" mineral wool between furring. Perforated facing fastened to furring.



5. Wood furring 1" x 3" ( $2\frac{3}{4}$ " x  $2\frac{5}{8}$ " actual) 24" o.c. 1" mineral wool between furring. Perforated facing fastened to furring.



10X Mechanically mounted on special metal supports at a 10" mounting depth.

### Additional Benefits

A well damped room is wonderful in revealing the quality of a good sound system, without making a poor system sound worse.

But for sheer feeling of peace, there is nothing like a quiet room for developing a feeling of calm.

And, if you use the right materials, they're even fire-resistant! ●

# Babani Books from

BP1: First Book of Transistor Equivalents & Substitutes \$2.80

More than 25,000 transistors with alternatives and equivalents make up this most complete guide. Covers transistors made in Great Britain, USA, Japan, Germany, France, Europe, Hong Kong, and includes types produced by more than 120 different manufacturers.



BP44: IC 555 Projects \$7.55

Every so often a device appears that is so useful that one wonders how life went on before without it. The 555 timer is such a device. It is manufactured by almost every semiconductor manufacturer and is inexpensive and very easily obtainable.

Included in this book are Basic and General Circuits, Motor Car and Model Railway Circuits, Alarms and Noise Makers as well as a section on the 556, 558 and 559 timers.



BP14: Second Book of Transistor Equivalents & Substitutes \$4.80

This handbook contains entirely new material, written in the same style as the "First Book of Transistor Equivalents & Substitutes". The two complement each other and make available some of the most complete and extensive information in this field.



BP46: Radio Circuits Using IC's \$5.90

This book describes integrated circuits and how they can be employed in receivers for the reception of either amplitude or frequency modulated signals. Chapters on amplitude modulated (a.m.) receivers and frequency modulation (f.m.) receivers. Discussion on the subjects of stereo decoder circuits, the devices available at present for quadrophonic circuits and the convenience and versatility of voltage regulator devices. An extremely valuable addition to the library of all electronics enthusiasts.

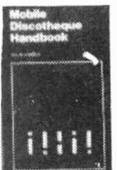
BP24: Projects Using IC741 \$4.25

The popularity of this inexpensive integrated circuit has made this book highly successful. Translated from the original German with copious notes, data and circuitry, a "must" for everyone, whatever their interest in electronics.



BP47: Mobile Discotheque Handbook \$5.90

The aim of this book is to give you enough information to enable you to have a better understanding of many aspects of "disco gear". The approach adopted is to assume the reader has no knowledge and starts with the fundamentals. The explanations given are simplified enough for almost anyone to understand.



BP33: Electronic Calculator Users Handbook \$4.25

An invaluable book for all calculator users whatever their age or occupation, or whether they have the simplest or most sophisticated of calculators. Presents formulae, data, methods of calculation, conversion factors, etc., with the calculator user especially in mind, often illustrated with simple examples.

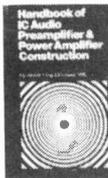


BP48: Electronic Projects For Beginners \$5.90

The newcomer to electronics, will find a wide range of easily made projects and a considerable number of actual component and wiring layouts. Many projects are constructed so as to eliminate the need for soldering. The book is divided into four sections: "No Soldering" Projects, Miscellaneous Devices, Radio and Audio Frequency Projects and Power Supplies.

BP35: Handbook of IC Audio Pre-amplifier & Power Amplifier Construction \$5.50

This book is divided into three parts: Part I, Understanding Audio ICs; Part II, Pre amplifiers, Mixers and Tone Controls; Part III, Power Amplifiers and Supplies. Includes practical constructional details of pure IC and Hybrid IC and Transistor designs from about 250mW to 100W output. An ideal book for both beginner and advanced enthusiasts alike.



BP49: Popular Electronic Projects \$6.25

A collection of the most popular types of circuits and projects which will provide a number of designs to interest the electronics constructor. The projects selected cover a very wide range. The four basic types covered are: Radio Projects, Audio Projects, Household Projects and Test Equipment.



NO.205: First Book of Hi-Fi Loudspeaker Enclosures \$3.55

The only book giving all data for building every type of loudspeaker enclosure. Includes corner reflex, bass reflex, exponential horn, folded horn, tuned port, klipschorn labyrinth, tuned column, loaded port and multi speaker panoramic. Many clear diagrams are provided showing all dimensions necessary.



BP50: IC LM3900 Projects \$5.90

The purpose of this book is to introduce the LM3900, one of the most versatile, freely obtainable and inexpensive devices available to the Technician, Experimenter and the Hobbyist. It provides the groundwork for both simple and more advanced uses.

Simple basic working circuits are used to introduce this IC. The reader should set up each of these for himself. Familiarity with these simple circuits is essential in order to understand many more complicated circuits and advanced uses.

BP37: 50 Projects Using Relays, SCR's & Triacs \$5.50

Relays, silicon controlled rectifiers (SCR's) and bi-directional triodes (TRIACs) have a wide range of application in electronics today. These may extend over the whole field of motor control, dimming and heating control, delayed, timing and light sensitive circuits and include warning devices, various novelties, light modulators, priority indicators, excess voltage breakers, etc.

The enthusiast should be able to construct the tried and practical working circuits in this book with a minimum of difficulty. There is a wide latitude in component values and types, allowing easy modification of circuits or ready adaptation of them to individual needs.



BP51: Electronic Music and Creative Tape Recording \$5.50

This book sets out to show how electronic music can be made at home with the simplest and most inexpensive of equipment. It then describes how the sounds are generated and how these may be recorded to build up the final composition.

For the constructor, several ideas are given to enable him to build up a small studio including a mixer and various sound effects units. All the circuits shown in full have been built by the author. Most of the projects can be built by the beginner.



BP39: 50 (FET) Field Effect Transistor Projects \$5.50

The projects described in this book include radio frequency amplifiers and converters, test equipment and receiver aids, tuners, receivers, mixers and tone controls, as well as various miscellaneous devices which are useful in the home. This book contains something of particular interest for every class of enthusiast - short wave listener, radio amateur, experimenter or audio devotee.

BP62: BOOK 1. The Simple Electronic Circuit & Components \$8.95

BP63: BOOK 2. Alternating Current Theory \$8.95

BP64: BOOK 3. Semiconductor Technology \$8.95

BP77: BOOK 4. Microprocessing Systems & Circuits \$12.30

Simply stated the aim of these books is to provide an inexpensive introduction to modern electronics. The reader will start on the right road by thoroughly understanding the fundamental principles involved.

Although written especially for readers with no more than ordinary mathematical skills, the use of mathematics is not avoided, and all the mathematics required is taught as the reader progresses.

The course concentrates on the understanding of the important concepts central to electronics. Each book is a complete treatise of a particular branch of the subject and, therefore, can be used on its own. However, latter books assume a working knowledge of the subjects covered in earlier books.

BOOK 1: This book contains fundamental theory necessary to develop a full understanding of the simple electronic circuit and its main components.

BOOK 2: This book continues with alternating current theory.

BOOK 3: Follows on semiconductor technology, leading up to transistors and integrated circuits.

BOOK 4: A complete description of the internal workings of microprocessors.

BP65: Single IC Projects \$6.55

All the projects contained in this book are simple to construct and are based on a single IC. A strip board layout is provided for each project, together with any special constructional points and setting up information, making this book suitable for beginners as well as more advanced constructors.



BP42: 50 Simple L.E.D. Circuits \$3.55

50 interesting and useful circuits and applications, covering many different branches of electronics, using one of the most expensive and freely available components - the Light Emitting Diode (L.E.D.). Also includes circuits for the 707 Common Anode Display. A useful book for the library of both beginner and more advanced enthusiast alike.



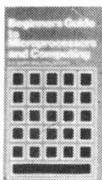
# ETI

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ETI Magazine, Unit 6, 25 Overlea Boulevard,  
Toronto, Ontario, M4H 1B1.

**BP66: Beginners Guide To Microprocessors & Computing \$7.55**

This book is intended as an introduction to the basic theory and concepts of binary arithmetic, microprocessor operation and machine language programming. The only prior knowledge which has been assumed is very basic arithmetic and an understanding of indices. A helpful Glossary is included. A most useful book for students of electronics, technicians, engineers and hobbyists.



**BP67: Counter Driver & Numeral Display Projects \$7.55**

The author discusses and features many applications and projects using various types of numeral displays, popular counter and driver IC's, etc.

**BP68: Choosing & Using Your Hi-Fi \$7.25**

The reader is provided with the fundamental information necessary to enable him to make a satisfactory choice from the extensive range of stereo equipment currently on the market. This should aid him in understanding the technical specifications of the equipment he is interested in buying. Full of helpful advice on how to use your stereo system properly so as to realise its potential to the fullest and also on buying your equipment. A Glossary of terms is included.



**BP69: Electronic Games \$7.55**

The author has designed and developed a number of interesting electronic game projects using modern integrated circuits. The book is divided into two sections, one dealing with simple games and the latter dealing with more complex circuits. Ideal for both beginner and enthusiast.

**BP70: Transistor Radio Fault-Finding Chart \$2.40**

Author Mr. Chas. Miller has drawn on extensive experience in repairing transistor radios to design this book. The reader should be able to trace most of the common faults quickly using the concise chart.



**BP71: Electronic Household Projects \$7.70**

Some of the most useful and popular electronic construction projects are those that can be used in or around the home. These circuits range from such things as '2 Tone Door Buzzer' and Intercom through Smoke or Gas Detectors to Baby and Freezer Alarms.

**BP72: A Microprocessor Primer \$7.70**

A newcomer tends to be overwhelmed when first confronted with articles or books on microprocessors. In an attempt to give a painless approach to computing, this small book will start by designing a simple computer that is easy to learn and understand. Such ideas as Relative Addressing, Index Registers, etc. will be developed and will be seen as logical progressions rather than arbitrary things to be accepted but not understood.



**BP73: Remote Control Projects \$8.58**

This book is aimed primarily at the electronics enthusiast who wishes to experiment with remote control and many of the designs are suitable for adaptation to the control of other circuits published elsewhere. Full explanations have been given so that the reader can fully understand how the circuits work and see how to modify them. Not only are Radio control systems considered but also Infra-red, Visible light and Ultrasonic systems as are the use of Logic ICs and Pulse position modulation etc.

**BP74: Electronic Music Projects \$7.70**

Although one of the more recent branches of amateur electronics, electronic music has now become extremely popular and there are many projects which fall into this category, ranging in complexity from a simple guitar effects unit to a sophisticated organ or synthesiser.

The purpose of this book is to provide the constructor with a number of practical circuits for the less complex items of electronic music equipment, including such things as Fuzz Box, Waa-Waa Pedal, Sustain Unit, Reverberation and Phaser-Units, Tremolo Generator etc.



**BP75: Electronic Test Equipment Construction \$7.30**

This book covers in detail the construction of a wide range of test equipment for both the hobbyist and radio amateurs. Included are projects ranging from a FET Amplified Voltmeter and Resistance Bridge to a Field Strength Meter and Heterodyne Frequency Meter.

Not only can the home constructor enjoy building the equipment but the finished project can also be usefully utilised in the furtherance of his hobby. An ideal book for both beginner and advanced enthusiast alike.



**BP76: Power Supply Projects \$7.30**

Power supplies are an essential part of any electronic project.

The purpose of this book is to give a number of power supply designs, including simple unregulated types, fixed voltage regulated types, and variable voltage stabilised types, the latter being primarily intended for use as bench supplies for the electronic workshop. The designs are all low voltage types for use with semiconductor circuits.

There are other types of power supplies and a number are dealt with in the final chapter, including a cassette supply, Nicad battery charger, voltage step up circuit and a simple inverter.

**BP78: PRACTICAL COMPUTER EXPERIMENTS \$7.30**

This book aims to fill in the background to microprocessors by describing typical computer circuits in discreet logic and it is hoped that this will form a useful introduction to devices such as adders, memories, etc. as well as a general source book of logic circuits.

An essential edition to the library of any computer and electronic enthusiast.



**BP79: Radio Control For Beginners \$7.30**

The aim of this book is to act as an introduction to Radio Control for beginners to the hobby. The book will commence by dealing with the conditions that are allowable for such things as frequency and power of transmission. This is followed by a "block" explanation of how control-device and transmitter operate and receiver and actuator(s) produce motion in a model.

Details are then given of actual solid state transmitting equipment that the reader can build. Plain and loaded aerials are then discussed and so is the field-strength meter to help with proper setting up.

The radio receiving equipment is then dealt with, this includes a simple receiver and a crystal controlled superhet. The book ends with electro-mechanical means of obtaining movement of the controls of the model.

**BP80: POPULAR ELECTRONIC CIRCUITS—BOOK 1 \$8.25**

Another book by the very popular author, R.A. Penfold, who has designed and developed a large number of circuits which are accompanied by a short text giving a brief introduction, circuit description and any special notes on construction and setting up that may be necessary.

The circuits are grouped under the following headings: Audio Circuits, Radio Circuits, Test Gear Circuits, Music Project Circuits, Household Circuits, and Miscellaneous Circuits.

An extremely useful book for all electronic hobbyists, offering remarkable value for the number of designs it contains.



**NO.213: Electronic Circuits For Model Railways \$4.50**

The reader is given constructional details of how to build a simple model train controller; controller with simulated inertia and a high power controller. A signal system and lighting for model trains is discussed as is the suppression of RF interference from model railways. The construction of an electronic steam whistle and a model train chuffer is also covered.

**NO.215: Shortwave Circuits & Gear For Experimenters \$3.70**

Covers constructional details of a number of projects for the shortwave enthusiast and radio "Ham". Included are: an add-in crystal filter, adding an "S" meter in your receiver, crystal locked H.F. Receiver; AM tuner using phase locked loop; converter for 2MHz to 6MHz, 40 to 800MHz RF amplifier, Aerials for the 52, 144MHz bands, Solid State Crystal Frequency Calibrator, etc.



**NO.221: Tested Transistor Projects \$5.50**

Author Mr. Richard Torrens has used his experience as an electronics development engineer to design, develop, build and test the many useful and interesting circuits in this book. Contains new and innovative circuits as well as some which may bear resemblance to familiar designs.

**NO. 223: 50 Projects Using IC CA3130 \$5.50**

In this book, the author has designed and developed a number of interesting and useful projects using the CA3130, one of the more advanced operational amplifiers that is available to the home constructor. Five general categories are covered: Audio Projects, R.F. Projects, Test Equipment, Household Projects and Miscellaneous Projects.



**NO.224: 50 CMOS IC Projects \$4.25**

CMOS IC's are suitable for an extraordinary wide range of applications and are now also some of the most inexpensive and easily available types of IC's. The author has designed and developed a number of interesting and useful projects. The four general categories discussed in the book are: Multivibrators, Amplifiers and Oscillators, Trigger Devices and Special Devices.

# Upgrading Your Hi-Fi System

By Richard Timmins

**DIGITAL TECHNIQUES.** despite their already obvious superiority to current analogue systems, still seem destined for the distant future, that is, a good ten years or more from now, which means nobody should be wondering if it's worth holding off buying a new turntable to replace an old and deficient one. Disc records will be with us for a good while yet and it's interesting to note that there is lots of evidence to suggest the disc isn't exploited to the full. Which is to say even the best modern record playing equipment doesn't extract anything like one hundred percent of the information from a disc recording.

## The turntable etc

Turntables and pickups will continue to improve, and in the next ten years it's likely they will improve by the same magnitude that they did in the last. The standard-setting Linn-Sondek, way ahead of its competition five years ago, now has strong competition in the form of new belt-drive designs. A very old design, the splendid Connoisseur DB1 can, if set up on a very solid and heavy base, give results equally satisfying as those of the Linn. Although the latter sounds definitely quite different to any other turntable, it is now not necessarily better!

Upgrading your turntable doesn't always mean buying a more expensive one. The DB1, for example, equipped with a mid-price arm such as the Hadcock GH228 or SME 11 and an appropriate cartridge — say a Decca Gold, a Grado or Ortofon MC for the Hadcock and a fairly compliant model — (a good choice would be an Ortofon moving magnet, a top grade ADC or Shure) for the SME — could still leave you with lots of change from \$700 and give you top-notch sound as well. Down the price scale there is the unbeatable Acoustic Research, simplicity personified. The main drawback with this design is its arm, which accepts only a very restricted range of cartridges,

If only for its unusual attitude, the Mitsubishi LT-5V Vertical Linear Tracking Turntable is a worthwhile addition to any audio system.

although with the trend toward very low effective tip mass but reduced compliance in the best cartridges, the AR arm becomes a more reasonable choice than it was a couple of years ago. Nevertheless it suffers from a poor headshell which is frustratingly non-standard in the sense that it can be substituted physically by any EIA-standard (SME-type) model. This substitution can well result in trouble because the arm has unsprung electrical contacts, unlike EIA-standard arms: it is the AR *beadshell* terminals that are sprung.

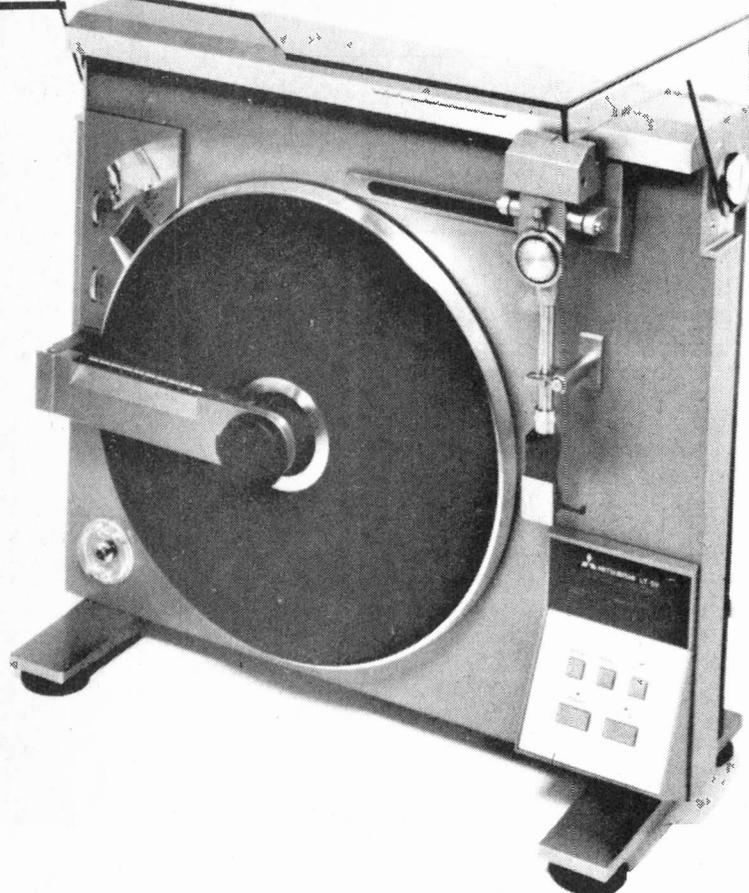
The AR arm bearings are also a little flimsy, but by and large this turntable is a very good choice for those who want top sound with economy.

Automatic turntables in general still

don't appear to offer the performance of manuals, although a couple of designs have separate motors to drive the arm whilst it performs its automatic functions. But no automatic turntable can offer the performance of a manual at the same price, so be prepared to spend more for convenience!

Cartridges have improved almost out of recognition in the past few years, and the most significant shift has been towards low-output moving coils.

Most moving coil cartridges have low-medium compliance which means, in effect, that they will not track at very low downforces. Most of them require at least 1.5 g and the majority sound best at about 2 g. This seems retrograde compared with the tracking forces of





more expensive combination arises simply because of a poor match, while the Grace and the budget FR moving-magnet come together as an excellent compromise.

Any self-respecting turntable should rarely give trouble in terms of wow and flutter, and rumble will be reduced using a good arm-cartridge system (provided the turntable is well set up) because spurious resonances will be suppressed. When you choose a new turntable, listen with particular care to the clarity of all frequencies. Rumble and other forms of noise will obscure details in music, resulting in a flat, thick sound. A good turntable system will, on the other hand, produce a fine, textured delicacy.

#### Amplifiers

There has been some considerable controversy of late concerning amplifier sound, Messrs Acoustical Manufacturing (Quad), represented by Mr Peter Walker, having instituted last year some pretty convincing 'blind' tests with some 'golden ears' of the UK hi-fi press to demonstrate that the differences between competently-designed power amplifiers are negligible. While this is no doubt true, I believe a great many listeners stretch their amplification beyond the fundamental design limits and the behaviour of an amplifier when clipping or operating into a 'difficult' loudspeaker load is really what one

0.75 and 1 g of many popular cartridges a few years ago, but record wear isn't necessarily increased. This is because the latest generation of cartridges has significantly lower tip mass than before, and the inertia of the stylus as it moves within the groove is significantly lower. The reduction of this inertia is an important factor in the reduction of record wear, and the higher tracking forces serve to reduce surface noise (because the stylus has better and more consistent contact with the groove walls) with greater overall stability. In general, heavier arms can be used — an advantage in most ways because a heavy arm will normally have fewer structural resonances than a very light arm.

An arm with reasonably low effective mass, few structural resonances and genuine flexibility is the Hadcock GH228. This gives excellent results with most moving-coil cartridges and will also accept the finicky Decca with its curious requirement of a low-mass arm that is also very rigid. The Hadcock unipivot bearing is surprisingly free of resonance and other losses, due probably to its use of only four ball-bearings which, due to the high pressure they impose on the bearing shaft, are less prone to vibration than more bearings, with reduced pressure on each.

When selecting a new pickup, due care must be taken to ensure that all performance parameters are carefully

matched. It is woeful to hear a combination such as the Stax UA-7 with an expensive Fidelity Research moving-coil cartridge being trounced by the combination of a humble Grace 707 with the cheapest of Fidelity Research moving-magnets! The inferiority of the vastly



The PL-L1000 turntable from Pioneer, features a tangential tracking tone-arm system.



The NAD 3020 Integrated Amplifier delivers excellent performance for its cost.

hears a great deal of the time. So the power amp with 'soft' clipping characteristics might well sound smoother and more expansive than one which clips 'spikily' but is otherwise more accurate and real-sounding. One of Mr Walker's provisos during his tests was that all amplifiers should be working within their limits (i.e. not clipping). But this, one feels, is out of touch with reality. The best power amplifiers seem to be those with good current drive ability, and these can almost invariably be recognised by their use of huge power transformers and large filter capacitor complements. It is interesting to compare the many high power amplifiers with otherwise excellent, but low power units. Operating into real loudspeaker loads. It is under these circumstances that the now obsolete mono Quad 2, rated at 15 watts, reveals itself as a surprisingly powerful amplifier!

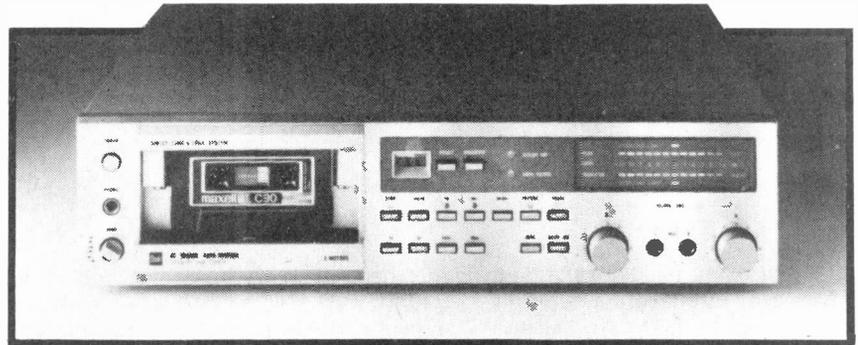
The first thing to check when you buy your new amplifier is that it has an adequate power supply. If you compare two amplifiers each with the same power output rating but one with a larger power supply and transformer, it can be predicted that invariably the unit with the bigger power supply will sound better. The power supply capacitors are a good guide, generally speaking. If they're big and there are plenty of them and the power transformer is fairly substantial (and toroidal transformers are far smaller than conventional ones) then the amplifier is almost certain to sound good. Perhaps the best way to choose between two power amps of the same rating is to check their weights; the heavier one will almost certainly sound better! All of this applies regardless of price range.

The part of the amplifier that is generally regarded as having greatest influence on sound quality is the preamp. The most critical part of the preamp is the circuitry for amplification and equalisation of the incoming signal from a pickup cartridge. Here, the preamp must compensate for the RIAA characteristic of records in which bass is attenuated and treble boosted. Correspondingly, the preamp needs to provide bass boost and treble cut, and the accuracy of this characteristic

is important. Even a deviation of as little as 1 dB or 0.5 dB can give serious colouration to sound from records, and so those preamps with highly accurate RIAA are obvious starters when you're upgrading. This usually means a separate preamp, but several recent integrated amps and receivers such as NAD and Hafler are outstanding in this respect.

handling without a size penalty, although the best of the latest generation tend to be very expensive but very good. As always there are plenty of speaker bargains to be had, and the best policy is to persuade an obliging dealer to allow you to try a few at home before choosing. The thing to avoid like the plague is spectacular-sounding speakers, for this points to peaky frequency response and colouration. Listen instead for clean, effortless dynamics and a firmly defined bass line with crisp but not over-stated treble.

In general the better a speaker, regardless of size, the simpler it will appear to be. Monstrosities with dozens of drive units look exciting but



The Dual 828 cassette deck features solenoid control, auto reverse metal tape capability.

**Speakers**

This is probably the most difficult area of all to upgrade, not because there's any shortage of variety, but because of individual characteristics being marked. Recent trends in speaker design are toward increased efficiency and power

normally don't sound good, unless those drive units are very carefully positioned for a specific radiation pattern. A very valid test, even now, is weight. The heavier the better. The little BBC-designed LS3/5A (needs a well-behaved power amplifier) the loudspeaker gives

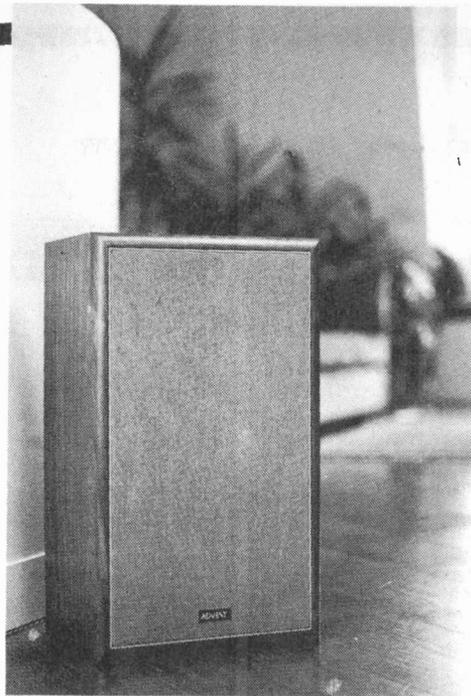
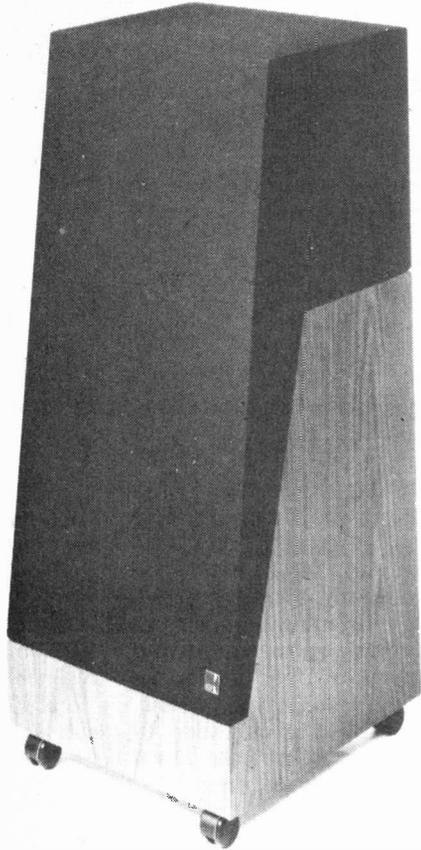


Ortofon's top-class Concorde and LM series cartridges feature a patented transducer system, top performance specifications and extremely light weight.

remarkably natural results despite its lack of deep bass.

The name of the upgrading game is compromise. It's surprising just how good a system based on fairly ordinary components can sound if each part is suitably matched to the rest. The most expensive components in the world simply won't give good results if they're not an adequate match and if you're upgrading piece by piece, it's advisable to check the compatibility of the new equipment not only with existing gear

The famous KEF Model 105.

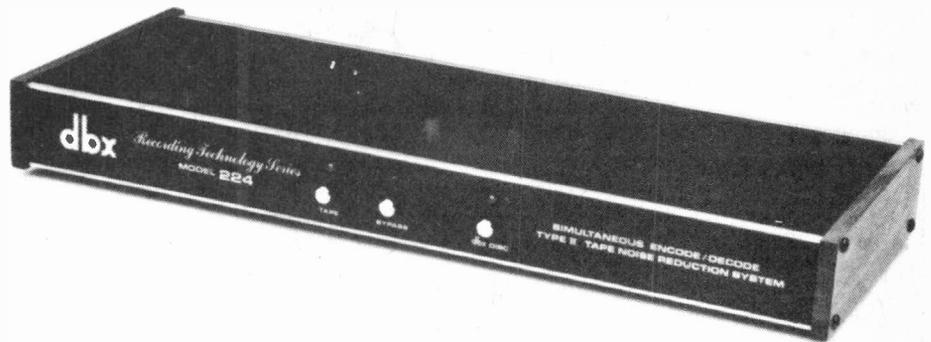


The Advent 4002 offers good reproduction at a reasonable price.

The natural complement to tape recorders is the FM tuner and here there is a very wide selection. Sound, once again, is the chief reason for selecting any particular model, but such performance features as selectivity and capture ratio (the ability of the tuner to reject unwanted broadcasts on different or similar broadcast frequencies) are equally important, especially with the existence of high power TV

broadcasts adjacent to and within the normal radio range.

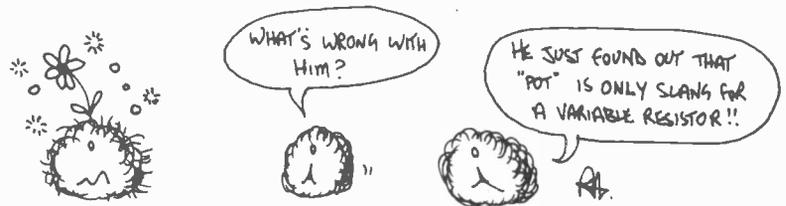
Approach upgrading with a straight-forward attitude and don't believe that the most expensive will be the best. Try the new equipment with your existing system if you can, and only settle for those items which show considerably more potential than your present ones. And, begin at the beginning. . . ●



dbx Model 224 Type II Tape Noise Reduction System, a simultaneous encode/decode system that provides up to a 40dB increase in usable dynamic range. It is suitable for use with 2-head recorders. The system also features a decoding function for specially encoded dbx Discs, offering full dynamic range and noise-free playback.

but with whatever you're likely to be using in the future.

A quick final word about tape. The new metal tape cassettes demand very special bias and equalisation arrangements and if you're planning to replace an existing cassette machine it would be wise to select one with metal tape capability, even if you don't feel you'll be able to afford the vastly superior new tapes which are, admittedly, very dear indeed. The indications are that the new machinery gives improved results with more conventional tapes, and in any event the metal formulations are certain to become cheaper within a fairly short time.



# Honeycomb Speakers

By Roger Harrison

A NEW RANGE of loudspeakers, leased recently by Technics, employs revolutionary drivers having a special flat disc construction made of a unique aluminum honeycomb 'sandwich' said to have great advantages over conventional paper cone drivers.

Claimed to represent a "significant step forward" in the quest for realistic reproduction of complex musical material, Technics' honeycomb disc drivers have been incorporated in their new SB range of loudspeakers — the SB-3, SB-5, SB-7 and SB-10.

Five honeycomb disc drivers were developed specially for this new range of speakers: a 320 mm woofer, a 250 mm woofer, a 220 mm bass mid-range, an 80 mm mid-range and a 28 mm tweeter.

Compared with conventional cone diaphragm drivers, a flat diaphragm driver excels in two vital areas according to Technics: smooth frequency response and simple alignment of acoustic centres. Let's examine how these honeycomb disc drivers are constructed and the reasons behind the claimed advantages.

## Of pistons and paper

It is not without justification that the loudspeaker has often been called the weakest link in the chain of hi-fi music recording and reproduction. For over half a century the dynamic speaker, with its magnet, voice coil and paper cone, has remained principally the same, although great improvements have been made in many constructional details leading to the high quality drivers available today.

Nevertheless, much money and time has been spent in an attempt to develop "the perfect reproducer".

The familiar conical shape of the diaphragm of conventional loudspeakers was never a virtue of the basic design but a necessity forced upon speaker designers because of the need to obtain

a rigid moving surface with a soft, pliant material — paper. The need for flat diaphragm speakers was apparent quite early in the piece, but solving the problem of obtaining a material suitable for the application, that did not exhibit significant resonances and was light, yet rigid, was beyond the technology of the times.

One of the serious limitations of a conventional paper cone speaker is the narrow frequency range over which it acts like a piston. Beyond a certain frequency, depending on the particular driver's construction, 'partial vibration' occur on the cone — known as "cone break-up". Also, the semi-enclosed air-filled cavity within the cone volume has a resonance effect known as "front cavity effect" which limits the upper frequency performance of conventional drivers. Both of these effects reduce the usable bandwidth of paper cone drivers and contribute to distortion.

A further factor contribution to the limitations of conventional speakers is that the cone, being made of wood pulp, is difficult to manufacture with close uniformity from unit to unit. Secondly, its characteristics deteriorate over time, contributing to the gradual deterioration of a loudspeaker over its lifetime.

Many manufacturers have gone to considerable lengths to overcome these failings, with varying degrees of success. They are contributing factors to the

high cost of good quality paper cone speakers.

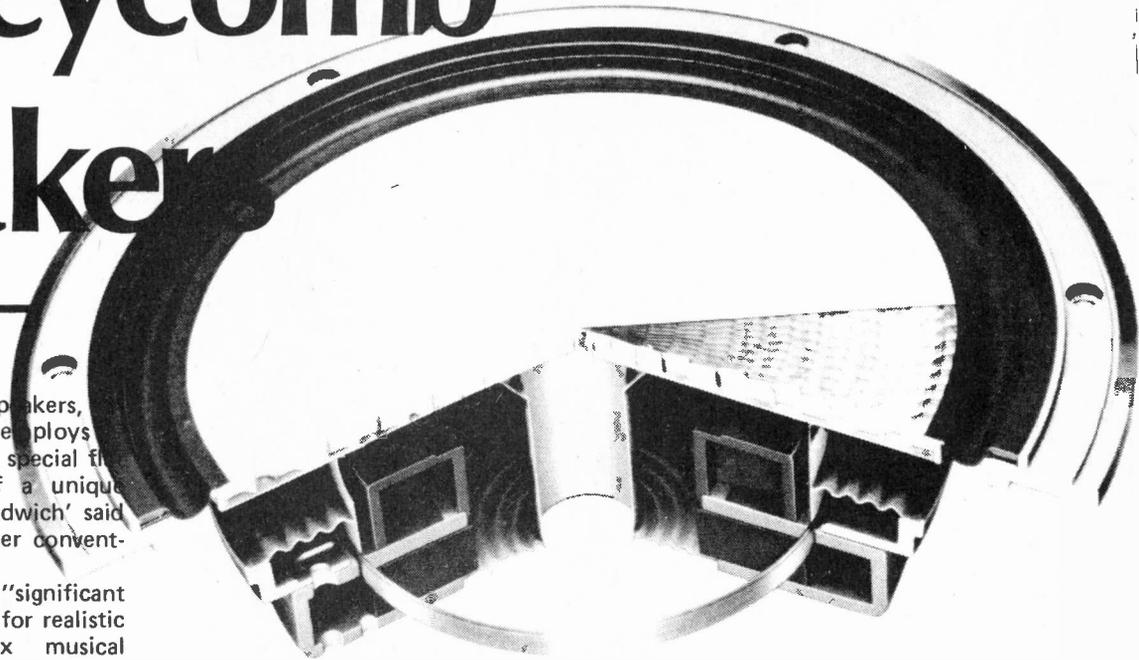
## Flat diaphragm speakers

A rigid, flat diaphragm offers inherently lower distortion, a smoother frequency response, better dispersion and wider bandwidth. Flat diaphragm drivers offer a further advantage. The acoustic centre of a flat diaphragm driver is on the front surface of the diaphragm. A linear phase loudspeaker system is readily constructed by mounting flat diaphragm speakers on a plane surface. As the acoustic centre of conventional cone drivers is located near the voice coil, they have to be mounted on a stepped surface in order to align their acoustic centres, which gives a constructional disadvantage as well as introducing possible diffraction problems with the mid-range driver and the tweeter.

One of the first successful commercially-produced flat diaphragm drivers was the well-known B139, designed by Raymond Cooke of the British KEF company. This uses an oval-shaped diaphragm made of polystyrene.

While this approach was an early solution to the problem of providing a light, rigid planar diaphragm, Technics researchers looked at various techniques used in other branches of engineering aimed at producing light, rigid surfaces.

In the aircraft industry they found that "honeycomb" structures are used in the floors, wings and other parts of



civil and military aircraft.

The honeycomb structure consists of hexagonal 'cells' of a light metal (usually aluminium) sandwiched between thin sheets of light metal — forming a 'skin' for the structure, as can be seen in figure 2, (a) and (b). The honeycomb possesses a very high bending strength, and is thus very rigid, yet very light weight.

However, this form of honeycomb construction is not ideal for a speaker diaphragm. For a number of reasons, a circular diaphragm was decided as being the optimum shape and a honeycomb structure having "axial symmetry" was developed. A 'normal' honeycomb (with linear symmetry) and Technics axial symmetry honeycomb are compared in figure 2, (b) and (c).

A normal honeycomb structure does not exhibit the same rigidity characteristics in all directions, as it bends or flexes more easily in the transverse direction than in the longitudinal direction. In a speaker having a round diaphragm, this directionality would be an unwelcome characteristic, as the diaphragm needs to be equally rigid in all directions taken from the centre. Hence the development of the axial symmetry honeycomb core. The bending strength of this type of diaphragm is the same on any radius.

Acoustic center of flat diaphragm



Acoustic center of cone driver



Figure 1. The dot shows the relative acoustic centres of a flat diaphragm driver (left) and a cone type driver (right).

Another advantage arises from this form of construction. As its mass is greater towards the centre, its vibration 'nodes' also move closer towards the centre than for a solid disc of similar weight, but uniform density.

This helps to simplify driver construction, as we shall see shortly.

### Of modes and nodes

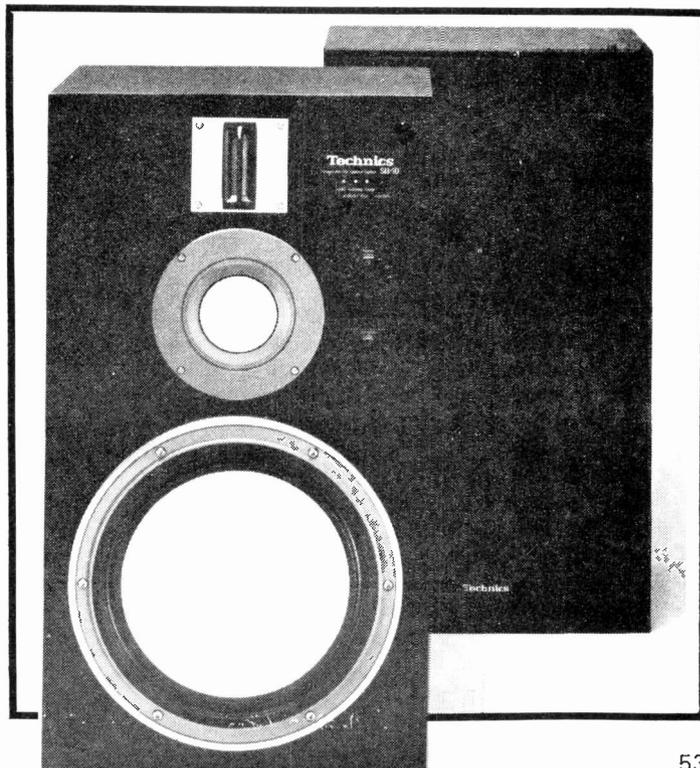
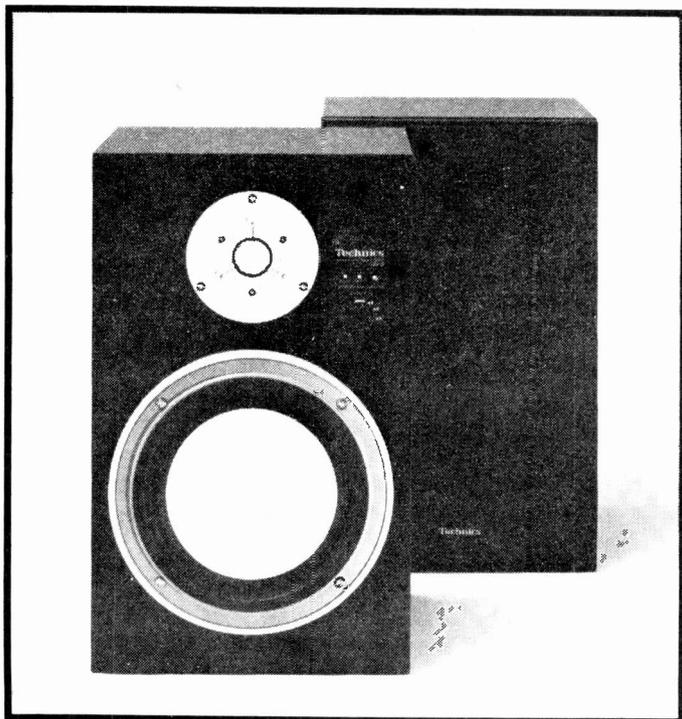
When a guitar string is made to vibrate at an octave above its fundamental frequency there will be a point, exactly half way along the string, that does not vibrate at all. Such points are called "nodes".

The same phenomenon can be observed in flat objects set to vibrate — such as drum heads and xylophone blocks. . . and speaker diaphragms. With vibrating flat objects, 'nodal lines' may be observed. In high school physics you may remember seeing this demonstrated where sand was sprinkled on a horizontal flat metal or glass plate that was supported at its centre. With the plate set to vibrate by drawing a violin bow across the edge, the sand would bounce about and settle in a characteristic pattern — along the nodal lines where it was not vibrating. A variety of patterns may be generated in this way, each representing a distinct "vibration mode". A German physicist name Walter Ritz first examined the vibration modes of square diaphragms in 1909 and calculated the many modes possible.

Such vibration modes are distinctly undesirable in a speaker diaphragm as they introduce harmonic distortion. Remember that I mentioned the term "cone break-up" previously? This is

At left is Technics' SB-3 two-way speaker system featuring a 220 mm bass/mid-range driver and a 28 mm tweeter — both employing honeycomb disc construction. At right is the SB-10

system. This is a three-way employing a 320 mm woofer, an 80 mm mid-range — both honeycomb disc types, and a special 'leaf' tweeter.



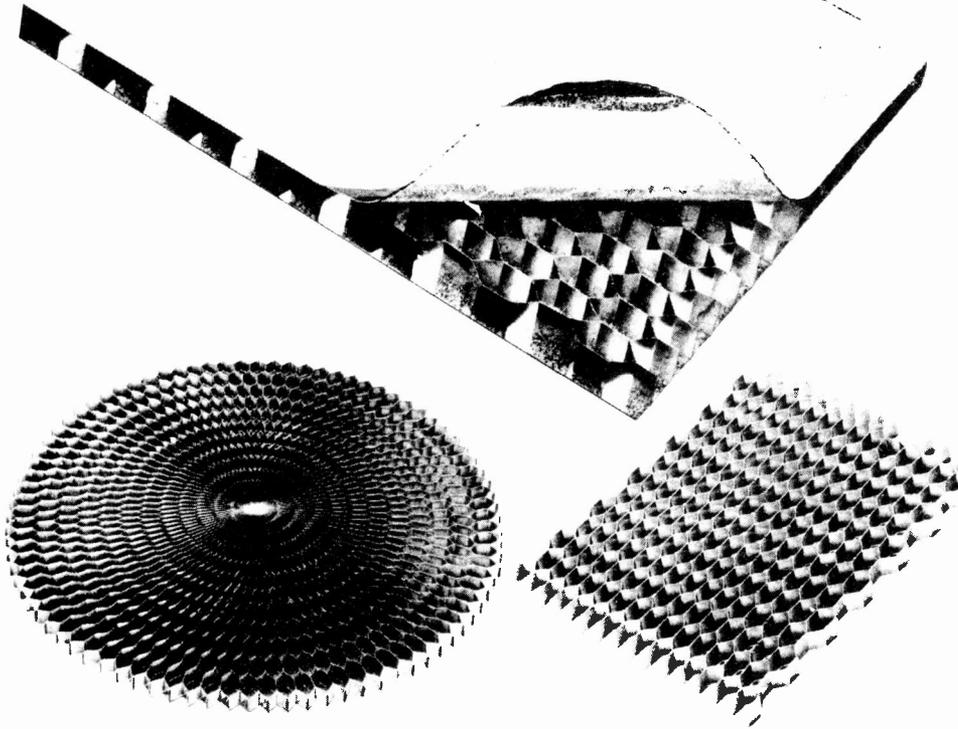


Figure 2. At top is a "honeycomb sandwich" structure (a). The basic honeycomb at bottom right (b), usually made of aluminium, is sandwiched between layers of thin metal foil. This is unsuitable for speakers however, and Technics engineers developed the circular structure shown at bottom left (c).

where the speaker diaphragm changes its mode of operation from that of a piston and goes into various vibration modes as the drive frequency is increased.

Where, and in what shapes, these nodal patterns appear on a speaker diaphragm depends on several factors, including the diaphragm's basic resonant frequency, its shape and the frequency at which it is driven.

A computer analysis of the nodal patterns of a disc and a square plate for a range of frequencies is given in the illustration here, showing that the disc has a simpler arrangement of nodal lines. This indicates that it exhibits less harmonic distortion as it is driven over a range of frequencies.

These unwelcome vibration modes can be prevented in either of two ways: by driving the diaphragm across its entire surface (which is technically extremely difficult and thus costly) or by applying the drive where it intersects the most nodal lines. Centre drive is undesirable as can be seen from Figure 4. Nodal drive prevents spurious

vibration modes forming, forcing the diaphragm to move as a rigid piston over a wide drive frequency range.

The dramatic effect on the usable frequency range of a disc diaphragm with nodal drive, compared to centre drive, is readily apparent from Figure 5. Serious resonances occur at quite low frequencies when the disc is centre driven, producing pronounced peaks and dips in the frequency response. Nodal drive moves these resonances well up in the frequency range, extending it two octaves or more.

With a square diaphragm, the more complex nodal patterns make it impossible to provide nodal drive with a single voice coil across as wide a range as with the disc diaphragm.

Now, nodal drive for a disc diaphragm requires a voice coil and magnet structure that can drive the disc at a considerable distance from the centre. Technics have solved this problem with two basic construction methods. A cross-section of the 320 mm woofer shows one form of construction. The voice coil in this driver is 160 mm in diameter! This woofer is used in the new SB-10 loudspeaker and, although crossed over to the mid-range driver at 400 Hz in this design, it can be used to 3.3 kHz, Technics claim. The reverse-rolled edge construction prevents spurious sonic radiation from the edge of the diaphragm near the upper frequency limit of the driver's range.

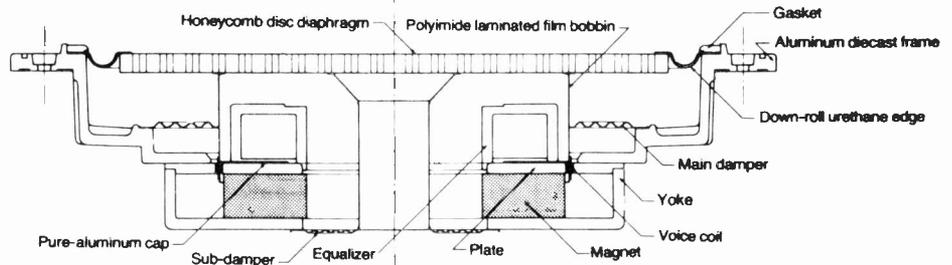


Figure 6. Cross-section of Technic's 320 mm honeycomb disc woofer.

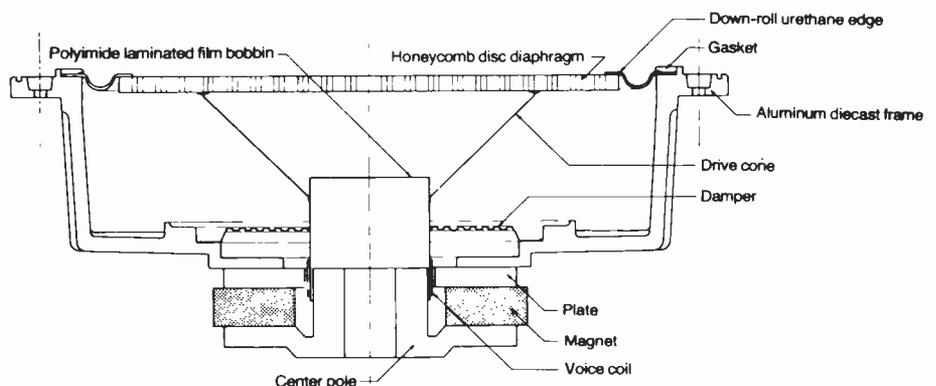


Figure 7. Cross-section of the 250 mm honeycomb disc woofer. The other honeycomb disc drivers are similar.

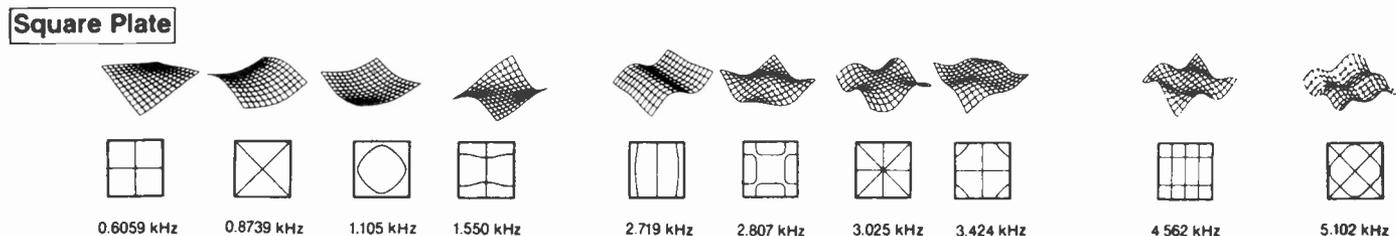
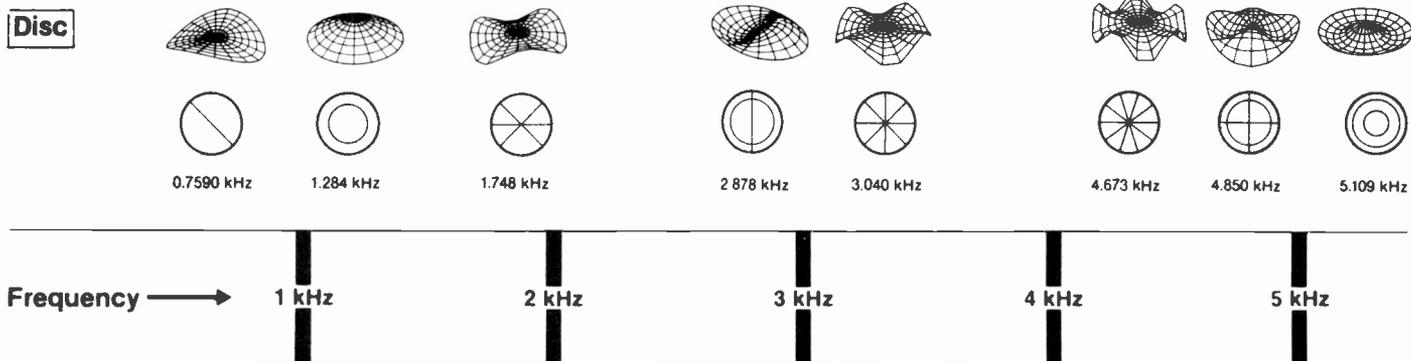


Figure 4. Computer analysis of the modes of vibration of a disc and a square plate showing the flexing patterns and the nodal lines produced (lines of least vibration) when driven at different frequencies. Clearly, a disc has the least complicated variety of vibration modes. (All diagrams courtesy National).

The other type of construction is illustrated in Figure 7. This shows the 250 mm woofer where the voice coil mounting bobbin applies nodal drive to the diaphragm via a rigid cone.

Only time and experience adjudge the success of this approach to driver design.

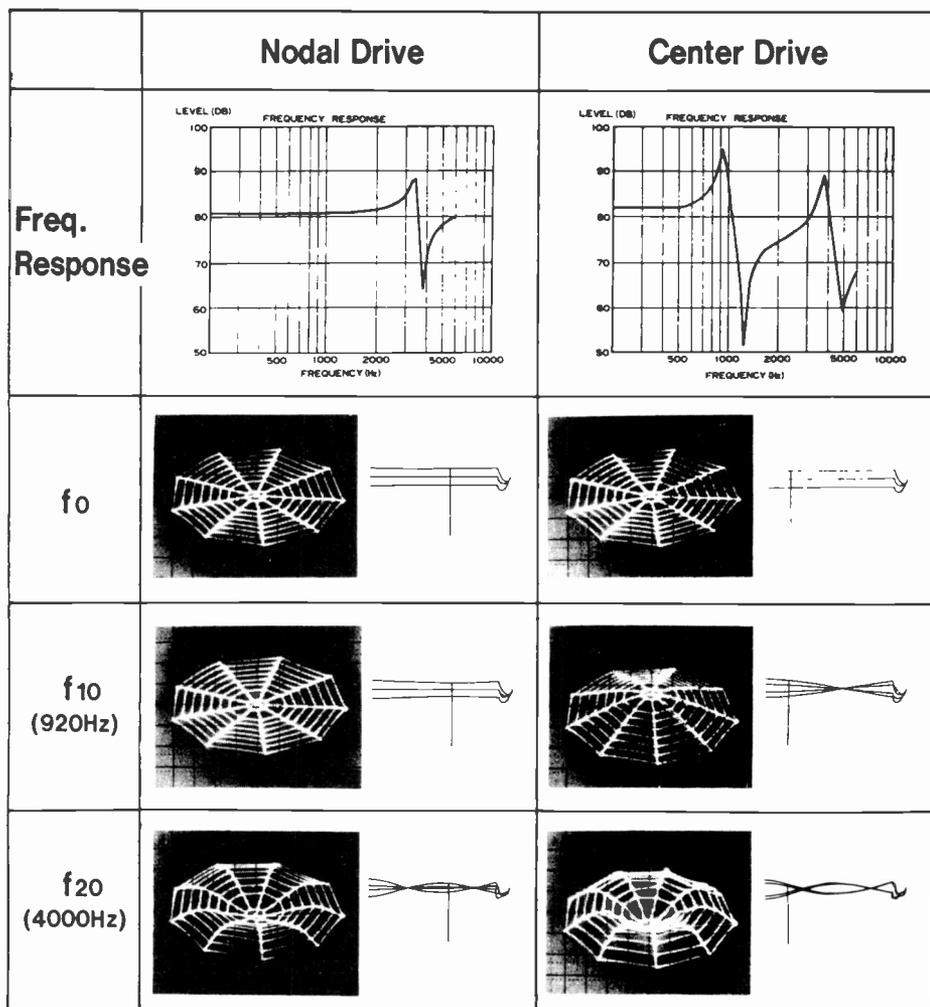
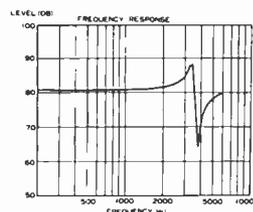
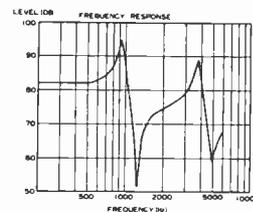
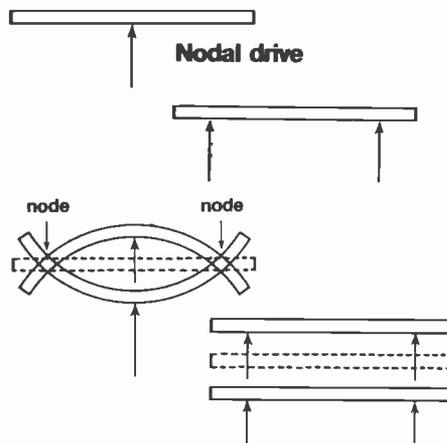


Figure 5. Illustrating how the frequency response of a disc, i.e.: its range of 'piston motion', is extended by nodal drive.

**Center drive**



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# Audio Today

What is Hi-Fi? Wally Parsons tells his story.

LAST YEAR I had occasion to devote a couple of columns to the subject of up-grading equipment in general, and an offshoot of that column, choice of capacitors and the effect on equipment performance.

In response to the latter item, I received a letter from a Physics teacher in Port Moody B.C. dealing with the subject of equipment reviews and methods of evaluation. Included with the letter was a copy of an excellent article in "The Audio Amateur", Issue No. 1, 1980, entitled "Are Those Golden Ears Really Golden", by Thomas Smith, Michael Peterson, and Peter Jackson, all of them scientists in different fields, and all of them audio enthusiasts.

The article dealt with the audibility of differences between power amplifiers with similar specifications and described some experiments to test this audibility, along with the results. As has been shown in so many experiments of this kind, no basis could be found for the claim by many reviewers that different amplifiers have a particular "sound".

In my column I had described my own experience with a preamp of my own design in which different types of capacitors were substituted for the units originally used, with some definite audible results. My correspondent states "...reading your comments on the modified preamp led me to wonder what procedures you used in your evaluation".

He goes on to say: "I am now somewhat skeptical of someone who claims to detect an audible difference in a piece of equipment, unless the conditions of comparison are quite clearly stated. So now the question is, can you back up your impressions with a methodology that forces me to conclude that the differences you describe are really detectable, and are not just a result of your believing that those capacitor changes should make an audible difference?"

"My comments above appear highly critical. I'm not trying to put you on the defensive. It's more that I'm inquiring into how tightly controlled an author's stated perceptions are, and of course trying to push a point of view that, at least in my opinion, may once and for all set limits on required distortion levels for satisfactory listening. Are those magnificently low distortion figures really necessary? Can the ear really detect what the analyzing equipment can't? I say we won't really know until a good number of studies are done to determine what the limits of our perception are."

All of these are good and valid points, and raise question which are not easily answered, especially in short snappy phrases.

## IMAGINE AN ADVERTISER ASKING IF YOU WILL STILL RESPECT YOUR SPEAKERS IN THE MORNING.

**Science, Technology, And All That Hype.**  
In view of the fact that this is the third anniversary of Audio Today, perhaps this would be as good a time as any to lay down some fundamental philosophical principles, specifically those which I bring to the process of evaluating audio equipment, technological developments, and the point of view which I try to bring to this corner every month.

I've noticed that a great many people seem to take Audiophilia very seriously; they approach it in a manner akin to that of people searching for a cure for cancer, or the means of feeding an overpopulated world, or otherwise relieving human suffering, improving man's well-being, and expanding our knowledge of the universe.

Needless to say, such people take themselves very seriously, and seem to lack a sense of humour.

Side by side with humour is a sense of proportion, and the absence of one invariably is accompanied by the absence of the other. Consequently, we see advertising copy and articles in the popular audio press written by people who seem to be dealing in some eternal truth.

In other words, Metaphysics.

Can you imagine discussing electric toasters, or washing machines in the manner some people discuss audio? Or electric blankets, or briefcases? On the whole, to many people seem to have lost touch with reality.

Imagine an advertiser asking if you will still respect your speakers in the morning. This is the kind of thing detergent advertisers do.

## A Matter Of Perspective

The truth is, what we call audio is just another of the many technologies which make up modern living. It deals with the means of recreating sound at some point in time and/or space removed from its original generation.

Many audiophiles will be surprised to learn that most original sound is generated as a basic means of communicating intelligence. In other words, speech. What matters, essentially, is the information carried by the speech, not the sound of the speech itself.

Another deliberate man-made generation of sound exists for the purpose of engendering pleasurable feelings. Although speech can be used this way, what we usually mean by pleasurable sound is music, that organized sequence of sound combinations which some people think is a universal language but is really the product of culture, and subject to evolution.

In the Western world this music has developed into a high art, and, as such, conveys considerably more than simple visceral pleasure to those attuned to its subtleties. Successful practitioners of this art are regarded highly by civilized persons, who wish to experience its expression beyond the limitations of space and time.

To this end we use several technologies which, together, form what we like to call "Audio".

**McLuhan Was Wrong**

The point to all this is that the only thing that counts is the music, or whatever else the programme content is. For the vast majority of people with any involvement with audio, other than the fringe nuts, the medium is definitely NOT the message.

All this notwithstanding, audiophiles and hobbyists tend to be people who take pleasure in getting the most out of a technology, and in making things work well. And there's no question that in reproducing anything high fidelity is more satisfying than low fidelity. Just as a car which handles well and rides comfortably, or a television receiver which gives a sharp picture with good colour, or a camera which has these qualities and allows the photographer to concentrate on the artistry of his craft. . . .these all add immeasurably to the pleasure of the activity.

But they are not ends in themselves.

**A Point Of View**

Returning now to my correspondent's letter, the point of view I have tried to present in these pages is that of an informed audiophile with a background which consists of over a quarter of a century experience, one who entered via a formal musical training, and a solid foundation in the technology involved, much of it gained informally.

I have tried to present a reasonable view of developments in the field, along with a clarification of the technology involved, in such a way as to be useful both to the hobbyist who enjoys building his own gear, and the audiophile who is interested in how things work, and realizes that knowledge is his best tool in selecting the equipment most suitable to his needs and in determining the best way of using it. With knowledge comes greater skill in sorting out the often conflicting claims made by competing manufacturers, and the kind of compromises and trade-offs which bring about the apparent conflicts.

ETI does not maintain a testing laboratory as such. As a consequence no attempt is made to verify whether or not a manufacturer's claim as to performance specifications are valid or not. Anyone who reads test reports in those publications which deal with such matters will have noticed that it's a rare thing for any product to fail in these areas. What is far more significant is the importance of the specifications claimed.

For example, my correspondent asks whether or not these low distortion figures are really necessary. If you can

hear the difference then the answer is certainly "yes". Otherwise, it's quite academic. Yet, what was considered vanishingly low distortion twenty years ago would be considered intolerable today by many people. Even in the days of accoustical recording reproduction was often described as so lifelike as to be indistinguishable from the original. This may not be very scientific, but neither is the judgement of the recording engineer when he selects a miking technique which captures the kind of sound he seeks.

Readers are not expected to purchase or reject a product strictly on the basis of my judgement of it, or my comments as to a technological approach. What I am offering is observations and insights which the less experienced may not have thought of or noticed. Thus, in the past I've described the long line contact stylus as the most nearly ideal device with which to trace a record groove. This does not relegate all pickups which do not use such a stylus to the scrap heap. I've also pointed out some problems in using the stylus which render it impractical in many installations.

Similarly, I've drawn attention to the manner in which low distortion is

accomplished, and the importance of power supplies.

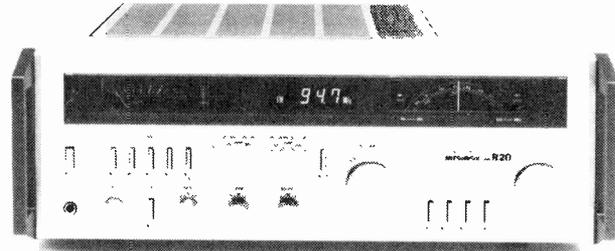
Returning to my preamp, the column in question contained observations based on other people's research, along with the theoretical considerations involved. The rationale behind my own experiments was that if the research was valid there ought to be some audible effect resulting from the application of the principles involved. No expectation as to the outcome existed, therefore the differences observed were not the result of expectation. As a matter of fact I was quite surprised at the obviousness of the differences observed.

One of the tests of the validity of any scientific experiment is its repeatability. Another test, this time of the conclusions drawn from the results of the experiment, is the ability to predict the results when such conclusion are incorporated into a design procedure.

And if the Port Moody Physics teacher has conducted experiments of his own which he feels are of interest I would certainly be anxious to hear about them.

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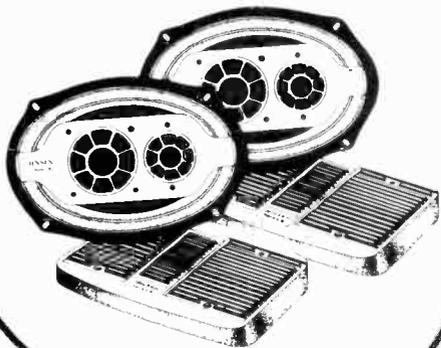
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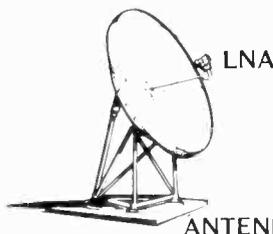
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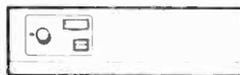
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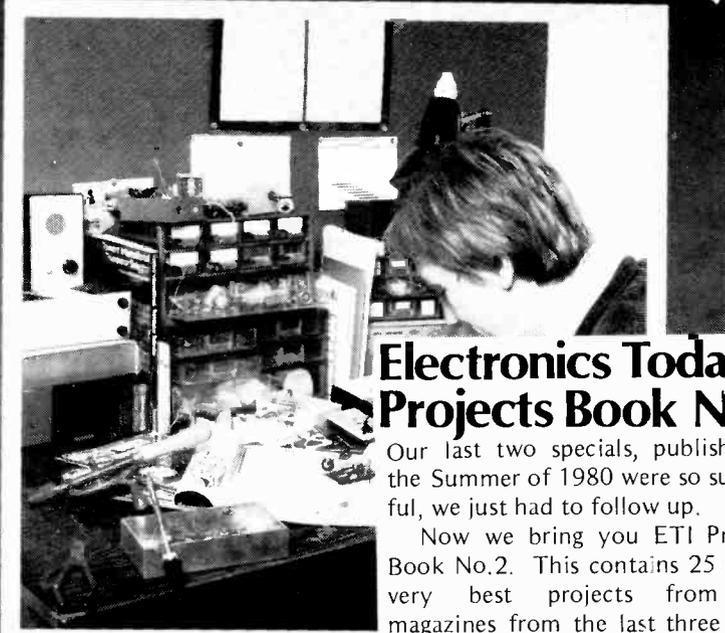
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January 1981

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# EDDY CURRENTS

A. S. Lipson brings you the life of Eddy Current, last known to be circulating in the region of transformers.

THE BRANCH OF PHYSICS now known as electromagnetism can be said to have been born in 1819. It was in that year that Professor Oersted of the University of Copenhagen discovered that electricity and magnetism are related — that a current flowing in a conductor produces a changing magnetic field — was discovered simultaneously, and quite independently, by Faraday in England and Henry in America.

Both of these effects are used, for example, in the transformer; an alternating current in a coil creates a changing magnetic field, which, in turn, is used to produce an EMF (and hence a current, should a circuit be connected) in another coil. However, rather less people are aware of another, very closely related, and extremely interesting, effect — the phenomenon of eddy currents . . . .

## What's In A Name

Magnetic fields are not usually quite as selective as we would like them to be. A changing magnetic field will not only produce an EMF in any coils in its vicinity, but it will also produce EMFs, and hence currents, in any conductor around — even any old lumps of metal that may be just hanging about. These currents don't actually go anywhere — they just circulate round and round within the conductors, like eddy currents in a liquid. Hence the name — eddy currents.

Since eddy currents are the result of induced EMFs in conductors and because resistances within conductors can be very small, the currents can on occasion be quite sizeable, and so the effects produced by them can be very significant. In fact, eddy currents are far more than just a scientific curiosity. Depending on exactly where they are, and what they are doing, they can be either a curse or a blessing. However you view them, though, they are an interesting phenomenon, and can produce some fascinating effects, not all of which are totally useless!

## Counting Your Blessings . . . . .

One of the more striking experiments on eddy currents is shown in Fig. 1a. A horseshoe magnet is suspended above an aluminum disc which is itself free to turn about its centre. If the magnet is now spun round, the aluminum disc starts to rotate with it (although it never quite catches up with the magnet). Similarly, if you spin the aluminum disc, the magnet above it also starts to turn. This obviously cannot be due to ordinary magnetic effects — aluminum is non-magnet, and if you try to pick up the disc with the magnet, you will find that you are unable to. It is apparent that something funny is going on. (No, air currents aren't dragging the disc round when the magnet rotates — you can put a sheet of paper between the two, and the effect still works!)

## Field Study

The relative movement between the magnet and disc is inducing eddy currents in the aluminum. These, in turn, create other magnetic fields, and it is these that cause the magnet and disc to move together — the magnetic field of the magnet interacting with the fields caused by the eddy currents (sounds a bit like pulling yourself up by your bootstraps, but it's correct) An interesting follow-up to this experiment is to replace the disc with one cut as shown in Fig. 1b. The slots tend to get in the way of the eddy currents and prevent them from flowing, so such a disc is not dragged round so easily by a magnet (which is another way of showing that air currents don't do the work — the slots shouldn't make any difference to them).

Interestingly enough, this apparently insignificant effect actually has some practical application. It is used, for instance, in the normal car speedometer! The rotation of the wheels is transmitted, by various means, to a magnet, which itself rotates, with a speed proportional

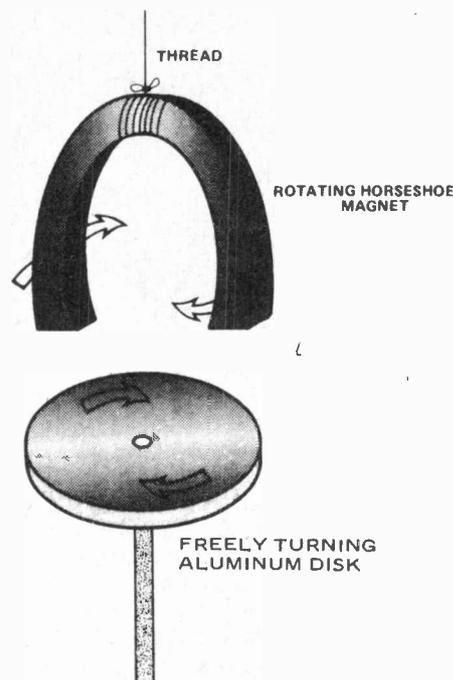


Fig. 1a. The rotating magnet induces eddy currents in the aluminum disc.

to that of the wheels. This rotating magnet induces eddy currents in an aluminum disc, (or its equivalent) and tries to drag it round. However, a spring is used to hold the disc, so it is unable to turn very far. The faster the car goes, though, the faster the magnet rotates, the greater the eddy currents, and the further round the aluminum disc is pulled. By attaching a little red or orange needle to this disc and seeing how far this needle rotates, we can work out how far the disc has turned, and hence the speed of rotation of the magnet. Thus, we find out the speed of the car. Yes, I wish I'd thought of it first, too.

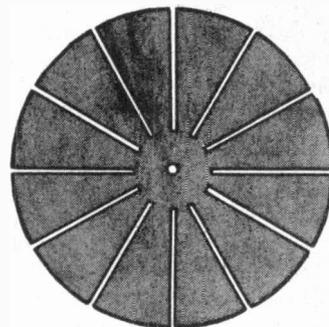
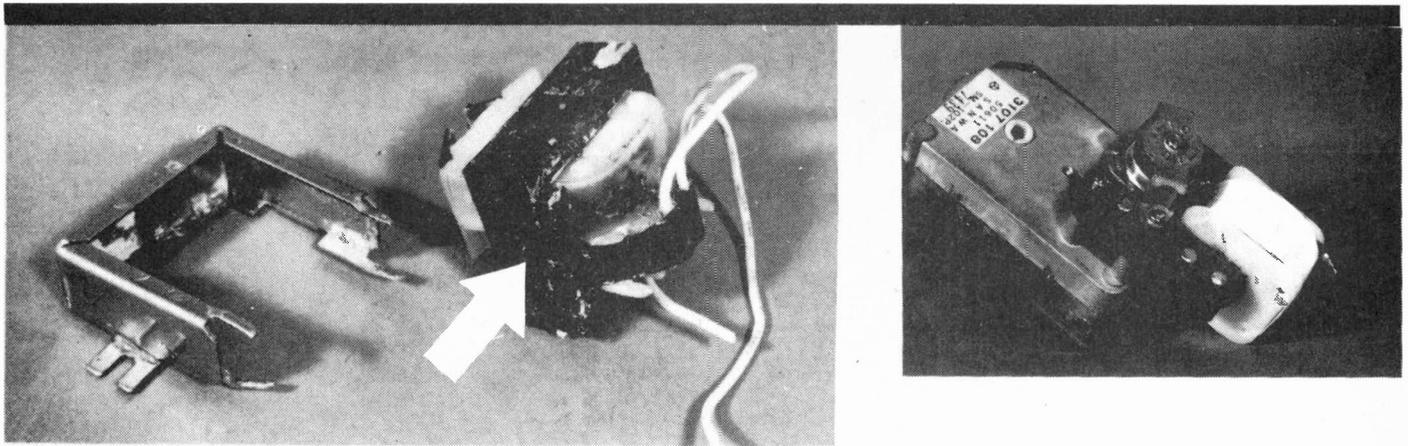


Fig. 1b. If the disc in Fig. 1a. is replaced with the one cut like this, the drag effect is greatly reduced, or even stopped.



### Cutting Your Losses

Besides being useful, though, eddy currents can also be very annoying. They could justly be called the transformer designer's nightmare. The transformer is, basically, two coils, close together. However, in the middle there's a dirty great lump of metal (the core) and it doesn't just sit there doing nothing, with all those magnetic fields about. No prizes for guessing what happens. It might not seem that eddy currents in the transformer core would be much of a problem, but they are, for two main reasons. Firstly, the eddy currents mean a loss of power in the transformer and hence reduced efficiency. It stands to reason that if power is being used to drive currents around in the core, then that much less power is going to be available for use from the secondary coil. The second problem is no less serious, especially in large-scale transformers. The power being wasted in the core, driving eddy currents round, quite naturally ends up as heat, and consequently transformers are liable to get very hot. indeed, large transformers, such as those on utility power grids, may be oil-cooled, to prevent overheating.

It is obvious that, in transformers at least, eddy currents are not wanted. So what can be done about them? Well, if you've ever taken an old transformer apart for the wire, or even just out of curiosity (naughty, naughty), you will probably have noticed that the core is not just one solid lump; it is built up of flat metal laminations. This is not because they make the cores out of flattened baked bean tins. The laminations are separated by varnish or paper of some other insulator and this greatly increases the internal resistance of the cores, reducing eddy currents. Hence, both the loss of power and the unwanted heating are reduced.

Even the heating effect of eddy currents can be put to use, though. It is used in the production of pure crystalline samples of conductors like metals or semiconductors — germanium, for

(Above) A small transformer with its frame removed. The arrow points to a loosened lamination. (Right) A synchronous induction motor. Eddy currents induced in the armature eliminate the need for expensive and noisy commutators. Motors like these are cheap and reliable but very inefficient.

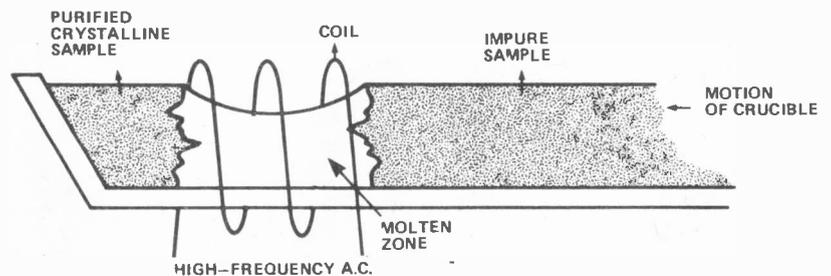


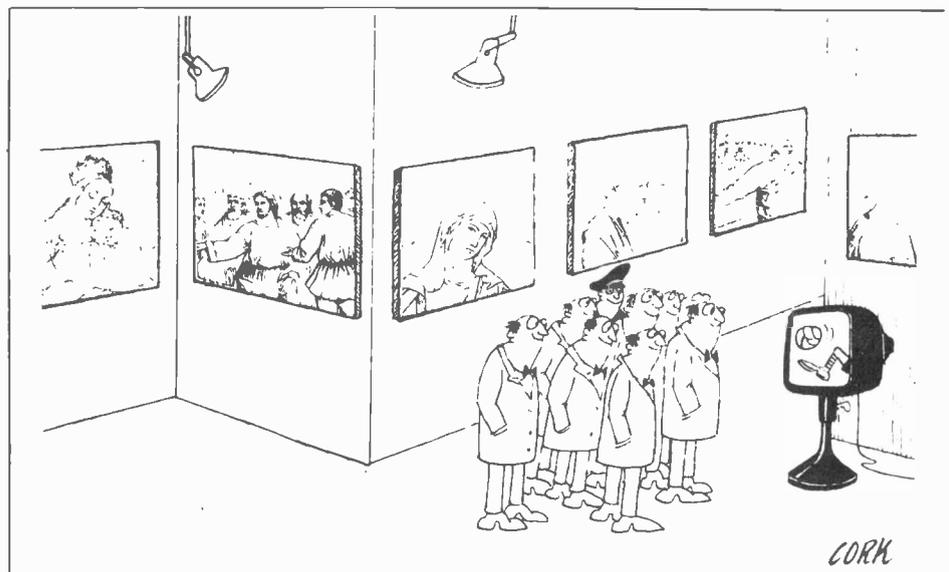
Fig. 2. The heating effects of high frequency AC can be put to good use in semiconductor material manufacture.

example. The impure sample of the material is passed, in a crucible, through a coil, which has passing through it a high frequency alternating current. The magnetic field produced by this current induces eddy currents in the specimen and the heating effect is great enough to melt it! As the sample passes through the coil, the molten zone within it is carried to one end (Fig. 2). Impurities within the sample are accumulated in the molten zone and hence get taken to one end of the specimen. This end is later removed.

What is left is a very pure, crystalline sample of the substance. So eddy currents can be surprisingly useful!

### Footnote

There is one final point which must be at least mentioned in connection with eddy currents. This is the induction motor, an indispensable servant of industry. It depends for its operation on eddy currents . . . . full explanation of that, though, is another story altogether. ●





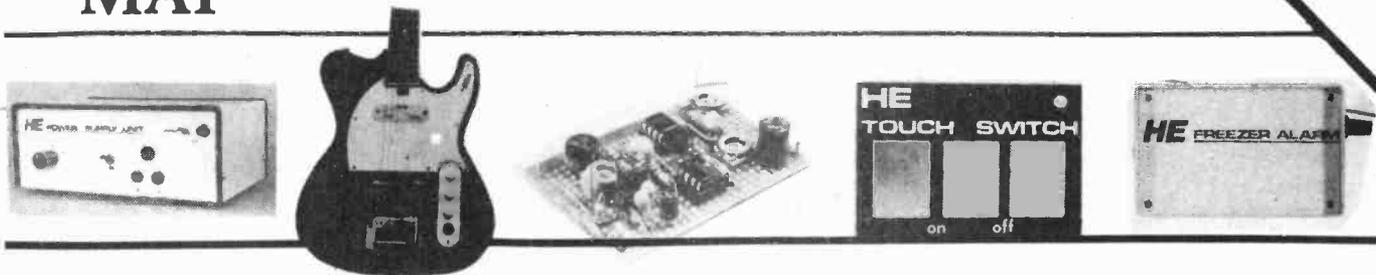
# Electronics Today

## INTERNATIONAL

At the time of going to press, the articles mentioned are in an advanced stage of preparation. However, circumstances may result in changes to the final contents of the magazine.

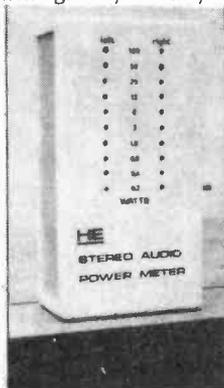
NEXT MONTH

MAY



A real bumper month for those of you who like our projects: we've got 10 of them for you covering a wide range of interests.

There's a Bench Power Supply which will give you any six voltages up to



20V at 1A — and it's regulated. The 'Nobell Doorbell' uses a synthesised electronic 'knock-knock' to replace the 'ding-dong'. For the musician there's a well designed Guitar Pickup Preamp including tone controls which can be built right into the body of the instrument itself.

A sound Operated Flash Trigger will enable you to take zany pictures of bursting balloons or popping champagne corks. Our Freezer Alarm Project will warn you automatically if the

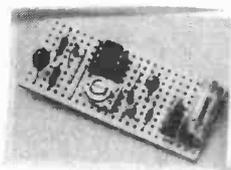
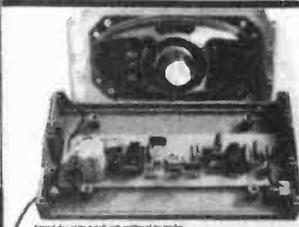
heavy investment in your freezer cabinet is in danger. A neat Touch Switch uses a VMOS FET to switch on and off practically anything.

The model railway enthusiast has two 'goodies': there's a 'chuffer' which electronically simulates the old time steam trains and a Two-tone Horn.

A stereo Power Meter lets you find

### 4017 Circuits

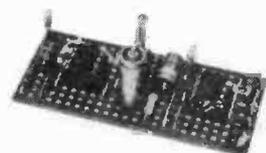
Our circuits features next month presents a whole variety of applications circuits for this inexpensive decade counter/divider.



out Watt (!) power your system is delivering while our High Impedance Voltmeter has an input impedance of eleven megohms and three ranges: 1V, 10V and 100V.

### Solder

We take solder for granted don't we? Most of us are mystified by the range available and stick with our single type. However, there's much more to it than meets the eye as you'll learn next month.

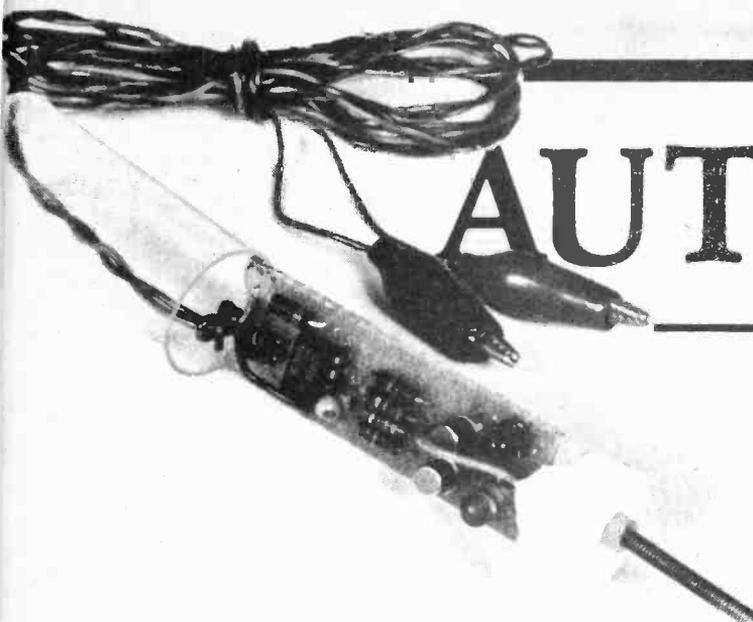


### Computing Supplement No. 2

Our computing supplement in the February issue seemed to go down well with everyone. So well that we've changed our plans and have brought it forward in our schedule to next month.

We plan to look at a Canadian micro-computer selling for under \$500, have a look at some programming techniques and do much, much more.

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# AUTO-PROBE

When it comes to probing faults or otherwise in a vehicle's electrical system, a multimeter has distinct disadvantages. This highly convenient probe is very useful in those awkward places so often encountered; it's also simple to build and inexpensive.

THE DIFFICULTIES of tracing a fault in a vehicle's electrical system using a multimeter are probably familiar to most readers. As that accursed Murphy's law generally has it, you have to contort yourself into an awkward position before you can see where to put the test prod, or prods, and having done that, find that you can't twist yourself sufficiently to see the multimeter face.

Damned annoying isn't it!

Then again, a multimeter can give you a false indication. No, not possible, you cry. It sure is though if, for some reason, you're measuring the voltage at a particular point and it happens to be connected to the battery via a low, but significant, resistance how do you detect the presence of that low resistance?

A voltmeter measurement won't show it. If that low resistance is the fault, an ohmmeter measurement may well be impossible.

Sorting out the wiring can be a nightmare — especially on motorcycles.

This project gives clear indication of the six conditions one usually finds in an automotive electrical system. These are:

- Short to +ve supply
- Short to -ve supply
- Open circuit
- Connection to +ve supply via an intermediate impedance
- Grounded via an intermediate impedance
- Connection to a fixed, intermediate (low) voltage level

The Auto-probe is smaller, cheaper, easier to interpret and easier to use and read than a multimeter. It is the sort of device that can be left in the tool kit in

the trunk of your car or stored in the glove box. It is a worthwhile addition to any mechanically-minded handyman's array of gadgets.

The Auto-probe can be used on 6 volt or 12 volt systems, with minor changes to the circuit values.

To get an idea of how it can be used, and how useful it is, let's take a look at a few typical problems encountered in vehicle electrical systems.

## The Problem

Let us consider the case of a car radio that has 'stopped working'.

Looking at the panel lights, you observe that they aren't lit up when the set's turned on. Obviously, it would seem to be a supply problem. Wriggling upside down; under the dashboard, you check the fuse and find it intact. Taking the Auto-probe, you attach its supply leads to the rear connection of the cigarette lighter or the ignition switch. Both lights should blink on and off. If they don't then you'd have to reverse the connections and mentally castigate yourself for being a twit. No worries though, it's protected against twits.

Touching the probe on the radio's B + connection, the red LED glows steadily. Aha! This shows the probe tip is connected to the supply.

Touching the probe onto the radio's ground lead results in a blinking red LED. Hmm, it's connected to supply via an impedance. It seems the ground connection isn't grounded.

Some jiggling and scraping at the radio's ground lead grounding point results in a steady green LED and a burst of music . . . well, more likely, commercials.

Suppose you wish to know if your car

has an ignition ballast resistor. This is a resistance inserted in series with the ignition coil primary during normal running, but is shorted out when the starter is operated so that the coil receives a voltage 'boost'. The resistor may be a heavy wirewound type mounted somewhere in the engine compartment or (as is common in many late-model vehicles) a resistance lead is used — they're hard to spot.

In this case, the probe tip is touched on the coil primary terminal that is not connected to the contact breaker points. With the ignition on, (engine not running) no light will show on the probe, indicating it is connected via an intermediate impedance. When you touch the starter, the red LED should burst into lusty life, indicating the resistor is shorted, as you would expect.

Tracing wiring and switch operation can be a real hassle. Does this motor-bike operate its horn by supplying power or a ground connection via the horn switch? If touching the two switch contacts in turn shows first a steady green LED then a blinking red LED, the first contact is grounded and the second is clearly connected to the positive supply via an intermediate impedance, ie: the horn. If the green LED lights and then both LEDs blink when the probe is touched to the other switch contact, this would indicate that the horn is open circuit.

The circuit will cause both LEDs to blink when the probe tip is connected to an open circuit or to either side of the supply via an impedance greater than about 1,000 ohms. In an automotive environment 1,000 ohms is a high impedance!

Simple, and easy to use, isn't it?

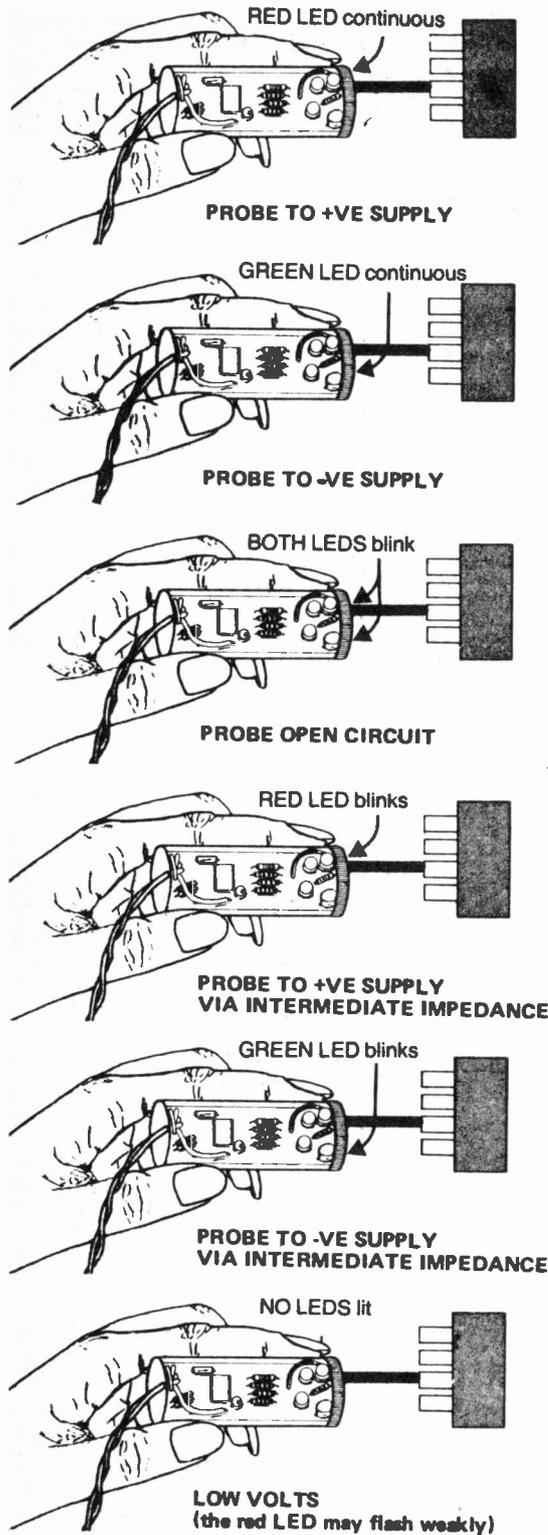


Figure 1 showing in visual form the wide variety of electrical conditions which may be encountered in automobile electric systems and how the Autoprobe detects them.

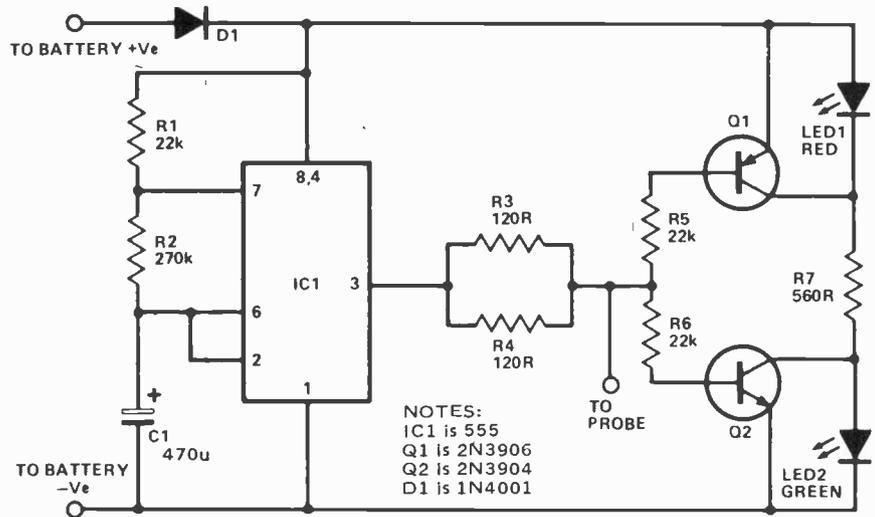


Figure 2 (above), the circuit diagram — yet another ingenious use of the 555 integrated circuit.

PROBLEMS? NEED PCBs? Before you write to us, please refer to 'Component Notations' and 'PCB Suppliers' in the Table Of Contents. If you still have problems, please address your letters to 'ETI Query', care of this magazine. A stamped, self addressed envelope will ensure fastest reply. Sorry, we cannot answer queries by telephone.

HOW IT WORKS

Consider first the 'idle' state of the device — ie: with the probe open circuit. Diode D1 protects the whole circuit against accidental reversal of supply polarity. When the battery is connected correctly, the battery voltage (less about 0.7 volts dropped across D1) is applied to the electronics.

IC1 is the familiar 555 timer IC, connected as an astable multivibrator. When C1 charges up to 2/3 of the supply voltage, via R1 and R2, the 'high' level comparator (pin 6) detects this and sends the output high, which also shorts pin 7 to near ground. C1 thus commences to discharge via R2. When it reaches 1/3 of the supply voltage, the 'low' level comparator trips (pin 2) and C1 is allowed to recommence charging as before, since the output is sent low. This cycle repeats indefinitely, with a frequency of

$$F=1/(0.692 \times C1 \times (R1 + 2R2))$$

With the values chosen, this is about 4 Hz. This may be varied by changing C1 or R2. The output on pin 3 of IC1 oscillates between nearly 0 V and V + (less 0.7 volts). It can source about 200 mA.

Consider now the circuitry surrounding the LEDs. Assume at first that the voltage on the junction of R5 and R6 is about half the supply potential. Current will flow through the bases of both transistors via R5 and R6, hence both of these transistors will conduct. Each transistor will short out the LED connected in parallel. Thus neither LED will glow. If the voltage on the resistor junction (the probe connection) were to fall below 0.6 volts, or thereabouts, Q2 would be biased off and would no longer bypass the current flowing through R7 away from the green LED. Thus the green LED would light. Similarly, if the voltage on the probe were to rise to within 0.6 volts of the battery supply, due to the action of D1)

Q1 would be biased off and the red LED would light.

Now let us put the picture together and see what happens in practice. The output of IC1 is connected to the probe and the resistor junction of the LED driver circuit: via a 60 ohm resistance made up of two 120 ohm resistors in parallel. There are two resistors rather than one 1W or larger resistor for reasons of physical size.

With no connection made to the probe, the 555 drives the probe alternately to the +ve and - ve rails, with the result that the LEDs flash alternately.

Shorting the probe to either rail of course forces the appropriate LED to stay on continuously. If a resistance is placed between the probe and ground, say, three possibilities occur:

- 1) The current flowing from pin 3 of the 555, via R3/R4, is insufficient to develop 0.6 volts across the resistance — this looks like a short and green LED stays on.
- 2) The current develops sufficient voltage to turn Q2 on & the LED extinguishes on that part of IC1's cycle when its output is high. This allows the appropriate LED (green) to blink.

However, if the resistance is not high enough to allow the junction of R5/R6 to go far enough positive the red LED will not turn on. This gives green only blinking.

3) If the resistance is high enough (over 1k) both LEDs blink, giving the open-circuit response.

The same argument applies 'upside down' for a resistance to the positive rail, but the voltage across it must be 1.3 V due to D1 being in the emitter circuit of Q1. If the voltage is fixed midway, neither LED can glow, as first assumed.

Resistor R7 fixes the LED current and R3/R4 limits the 555 output current to a safe level and defines the voltage 'turnover' points.

## PARTS LIST

### RESISTORS

(All 1/4 W, 5% unless specified)  
 R1,5,6 22k  
 R2 270k  
 R3,4 120 R 1/2 W (See text)

### CAPACITORS

C1 470u 16 V tantalum

### SEMICONDUCTORS

IC1 555  
 Q1 2N3906  
 Q2 2N3904  
 D1 1N4001  
 LED 1, 2 0.2" red, green. LEDs

### MISCELLANEOUS

Lengths of red and black wire  
 Crocodile clips  
 Pill container  
 6 - 32 nut and bolt (for probe)

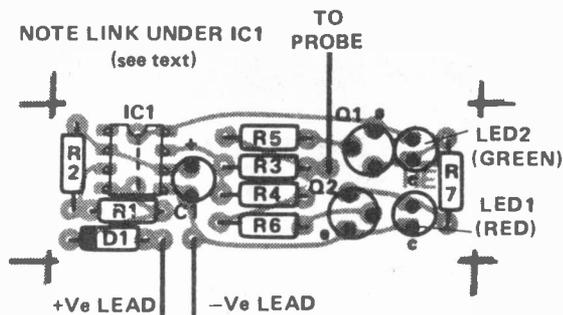
### Construction

Constructing the project on a PCB is simple. First thing to do is locate the position of IC1. A link is inserted between two pads located between the two rows of holes for the IC pins. Having done that, insert the IC. Take care that you have it correctly oriented. All the other components may now be assembled and soldered into the board. Watch the orientation of Q1 and Q2, the two LEDs and C1. Refer to the overlay picture.

Now comes the testing. You will need either a 12 V battery or a power supply that can deliver around 12 V to 14 V DC. Temporarily solder battery leads and a probe lead to the board. Connect the battery leads to the 12 V supply. The two LEDs should flash. Shorting the probe lead to the negative of the supply should cause the green LED to flash.

If you cannot obtain the correct indications at this stage, look for incorrect connections or components round the wrong way. To check that IC1 is working, connect a multimeter - set to, say, the 30 V range - between the supply negative and pin 3 of IC1 (positive meter lead to the latter). The meter needle should rise and fall at about four times per second.

The pill bottle used to house this project measured 61 mm overall length (with the cap on) by 21 mm outside diameter. A 25 mm long 6 - 32 bolt was used for the probe. This was bolted through a hole made in the cap somewhat off-centre. The photograph shows roughly where this needs to be. Just keep it out of the way of the



**Figure 3. Printed circuit board overlay. Once completed the project will, no doubt, pay for itself very quickly by savings on costly repair bills.**

board. A small solder lug under the bolt head is used to attach the probe lead from the board. The battery leads should be colour-coded to avoid confusion. The convention is: red for positive, black for negative. Twist together about one metre of each colour hookup wire.

Connect the appropriate leads to the board and tie a knot close to the board (see photograph).

Drill a hole in the end of the pill bottle, near the edge, and pass the battery leads through it. The knot

prevents the leads being pulled out of the board. Attach alligator clips to the ends of the battery leads.

Two small cutouts will have to be made in the lip of the pill bottle's cap so that the LEDs may be seen easily. All these details are clearly shown in the photograph of the completed project.

When the unit is assembled, give it a thorough work out.

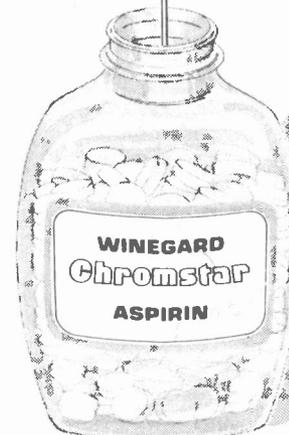
Once you have this little project working for you, you'll be amazed how quickly electrical problems in your vehicle are sorted out. ●

## FAST RELIEF FOR TV RECEPTION HEADACHES

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This book was designed as both an education text and a self-contained reference manual. This book presents a thorough introduction to machine language programming from basic concepts to advanced programming techniques. Detailed illustrative examples and numerous programs show the reader how to write clear, well-organized programs in the language of the Z8000.

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This book presents practical applications techniques for the 6502. You will build a complete home alarm system, including fire detection, as well as an electronic piano, a motor speed-regulator, a time-of-day clock, a simulated traffic control system, and a Morse code generator. You will also design an industrial control loop for temperature control, including analog-to-digital conversion, and your own simple peripherals from paper-tape reader to microprinter.

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This book is designed as an educational text on advanced programming techniques. It presents a comprehensive set of algorithms and programming techniques for common computer games. All the programs are developed for the 6502 at the assembly language level.

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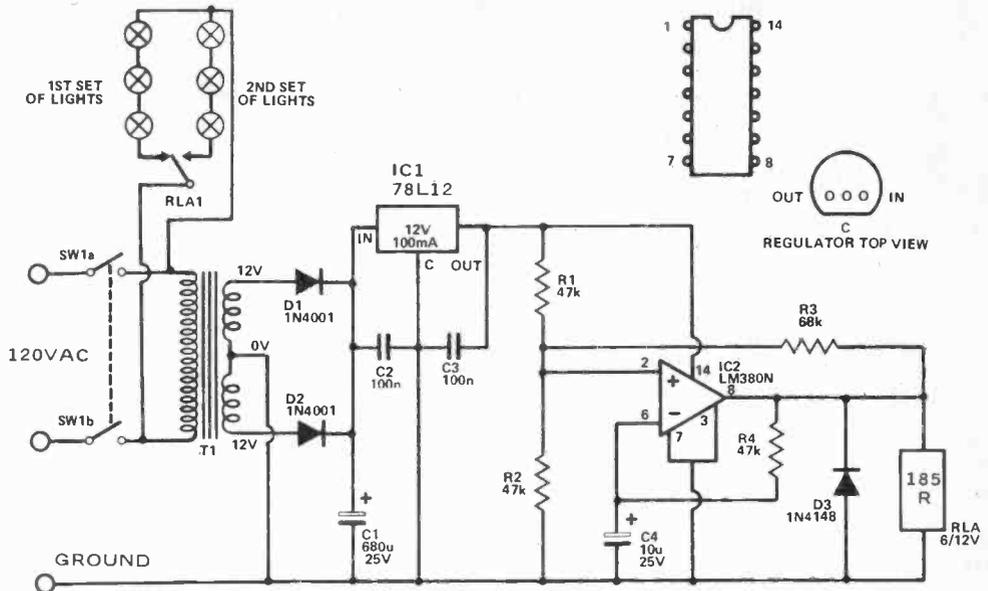
# Designer Circuits

## CHRISTMAS TREE LIGHTS FLASHER

The usual method of getting the lights on a Christmas tree to flash on and off is to use a bimetal-strip type flashing bulb in the series chain of bulbs. As this switches on and off it breaks the circuit to all the bulbs so that they switch on and off in unison. One drawback of this system is that most flashing bulbs provide a rather irregular flash rate, and another is that it cannot be used to operate two sets of lamps so that when one set switches off, the other switches on.

Both these problems can be overcome by using the simple circuit shown here. It is a low frequency oscillator (about 0.5 Hz) which controls the lights via a relay. Thus the lights are switched on for periods of about one second in duration at intervals of roughly one second in length. By using a changover relay contact it is possible to use two sets of lights with the relay switching the power alternately from one set of lights to the other. If this alternate mode of operation is not required, then one set of lights is simply omitted.

The unit is powered from a



supply having on/off switch S1, stepdown and isolation transformer T1, push-pull rectifier D1 and D2, smoothing capacitor C1, and 12 V monolithic regulator chip IC1. C2 and C3 aid the stability and transient response of IC1, and should be mounted physically close to this component.

A well known oscillator configuration is used here, but it is a little

unusual in that it employs an audio power amplifier IC, rather than the more normal operational amplifier device. However, the LM380N audio IC has, like an operational amplifier, both inverting (-) and non-inverting (+) inputs, and can be used in operational amplifier type circuits. In this application it has the advantage of having a power output stage that can

directly drive the relay with the family high current it requires. D3 is used to suppress the high back EMF which is generated across the relay coil as it de-energizes, and which could otherwise destroy IC2.

The switch on and switch off times of the circuit are proportional to the value of C4, and if desired they can be altered by changing the value of this component.

## METRONOME

There have been a great number of electronic metronome designs published over the last few years, and the majority of these are designed to simulate the sound of a mechanical metronome (Maelzel's metronome). The usual method of achieving this consists of feeding brief pulses to a loudspeaker at the appropriate beat rate, these pulses giving the required "clicking" sounds. One drawback of this system is that a normal miniature loudspeaker can only give rather limited volume from such a signal.

One way of producing a more effective metronome that is not easily masked by the sound of the music, is to feed the speaker with a pulsed tone. The diaphragm of the speaker does not then make a single backward and forward movement, but makes several such movements in rapid succession,

giving a much more noticeable and penetrating sound. The sound produced is somewhat different to that of a conventional metronome, but is nevertheless perfectly acceptable in practice.

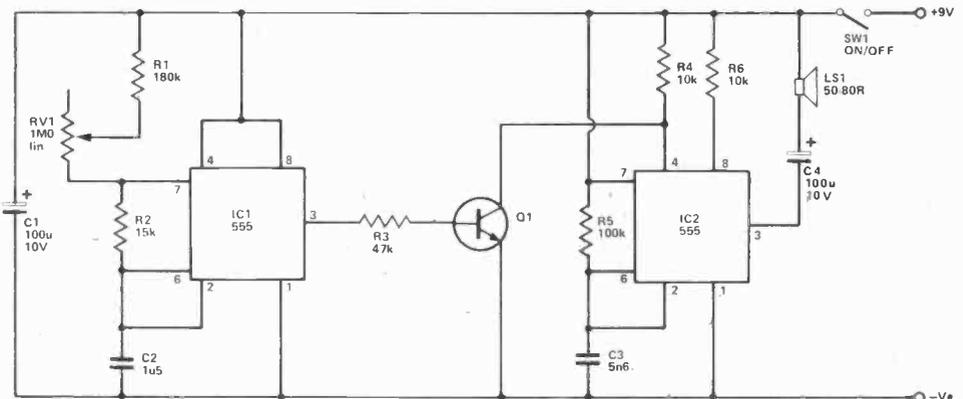
The circuit shown here is for a metronome of this type. The audio tone is produced using a 555 astable circuit based on IC2 and its associated components. The timing components (R4, R5, and C3) give a roughly squarewave

output at a frequency of about 1.24kHz. This signal is fed to the loudspeaker via DC blocking capacitor C4.

IC1 is used in another astable circuit which is used to briefly pulse on the tone generator at the required beat rate. The operating frequency of this oscillator can be varied from about 290 pulses per minute with RV1 at minimum resistance, down to about 48 per minute when it is set at maximum

resistance. The timing component values have been chosen to give very brief negative output pulses, and during these Q1 becomes cut off. Normally Q1 holds pin 4 of IC2 at only a fraction of a volt, and prevents the tone generator from oscillating, but this muting is removed when Q1 becomes cut off, and a brief tone burst is fed to the speaker.

The average current consumption of the circuit is about 20 mA.



Q1 2N3904

# INTO ELECTRONICS (PART 7)

This month Ian Sinclair continues his discussion of oscillating circuits.

LAST MONTH we started looking at astable multivibrators. This month we'll continue with our discussion as well as look into other types of oscillators.

The circuit in Fig. 13 of Part 6 will oscillate and in fact is used quite frequently in various non-critical applications, if, however, we want any sort of stability or reliable operation, we run into some problems.

## Pulse Problems

Problems? Well, the simple circuit can suffer from sticking if the bias resistors R2, R3 are either too low (around 1 k) or too high (220 k or more). Sticking means that both transistors are bottomed or cut-off together, so that oscillation will not start. The remedy is to keep to sensible values of bias resistors. Next problem — a poor wave-shape at the collector of each transistor. The cause is the time needed to charge the coupling capacitor. Looking at the collector of Q2; when Q2 cuts off, C2 has to charge from about 0.2 V up to +6 V through R4. One plate of C2 is held at about 0.5 V by the base of Q1, the other has to reach +6 V, and current must flow through R4, which takes time (a time constant of C2.R4). This makes the rising part of the wave at the collector of Q2 rather slow. The remedy is to add a resistor and a diode as shown in Fig. 1, at the collector of Q2. Now when Q2 cuts off, the voltage can rise quickly at the collector by R5, and can take its time. When the collector voltage of Q2 drops, of course, the action is quite normal because the diode now conducts.

Last problem — in the simple circuit, the frequency varies rather a lot when we change the voltage, and the theory says it shouldn't. When theory and practice disagree like this, there's usually something wrong with the practice! In this case it's the base-emitter junction of the transistors breaking down so that the base voltage cannot go as negative as the signal (through the capacitor) is trying to force it. The remedy is simple — a silicon diode connected into each base lead, using a type which can stand the reverse voltage rather better than the base-emitter junction of the transistor.

## The Serial Astable

Got your breath back? Fig. 3. shows quite a different type of astable, a *serial* type. This circuit also uses two transistors, but the type of action is quite different. Instead of switching so that the transistors conduct alternately, this circuit works so that we have either both transistors conducting together or both cut off. The output is a series of short negative pulses, and there is only one time constant. One transistor is a PNP type, the other an NPN. It all works like this:

When the circuit is switched on, C1 is uncharged and will take some time to charge through R1. As a result, the emitter voltage of Q1 is still low by the time its base voltage has reached the level set by R3 and R4 (a voltage

equal to half of supply voltage when R3 = R4). Now this ensures that Q1 is not conducting, because a PNP transistor conducts only when its emitter voltage is more positive than its base voltage (or its base voltage more negative than its emitter voltage, if you like it that way round). No current flows through Q1, then, and there's no base current flowing into Q2 either to switch that one on.

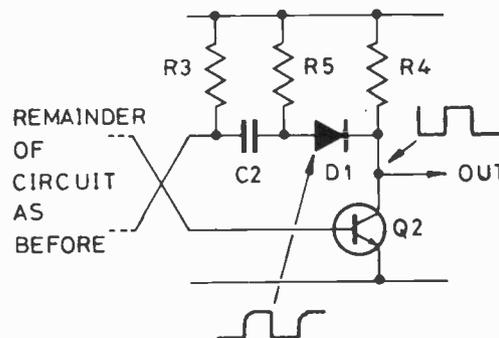


Fig. 1. Improving the basic astable.

As C1 charges up, though, the voltage at the emitter of Q1 will become higher than the voltage at the base of Q1. When this happens, Q1 conducts, current flows into the base of Q2, so that Q2 conducts and its collector voltage drops right down to about 0.2 V. The base of Q1 is connected to the collector of Q2 to complete the positive feedback loop, though, so that Q1 is now well and truly conducting, with C1 now discharging like mad through R2 and the base-emitter junction of Q1 will drop until it's too low to keep current flowing through Q1. When that happens, there's no current flowing into the base of Q2, so that it shuts off. The collector voltage of Q2 then rises, bringing the base voltage of Q1 with it, up to the value set by R3 and R4. Q1 now has its base at the voltage set by R3 and R4, and the emitter of Q1 is at a low voltage, so that Q1 is cut off. C1 now starts to charge again through R1, and the whole cycle repeats.

The waveforms at various parts of the circuit are shown in Fig. 4. The output at point A consists of short-duration negative-going pulses, and of near-sawtooth waves at B. The circuit is economical in components and takes very little current from the supply because when both transistors do conduct most of the current is supplied by the charged capacitor C1.

## The Half-Time Type

The kind of **Multivibrator** which we've just described is the **astable**, which cannot stay in any stable state but has to oscillate continuously. There's a related circuit, the **monostable**, which has one stable state. Fig. 5 shows one type of monostable. R3 keeps the base of

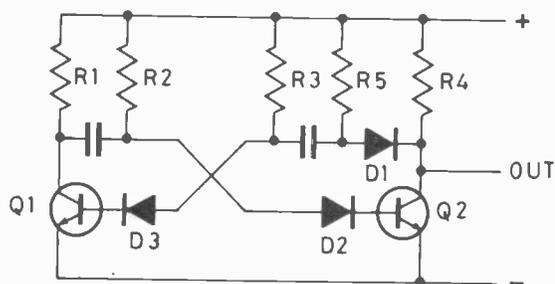


Fig. 2. Astable circuit with the modifications mentioned in the text.

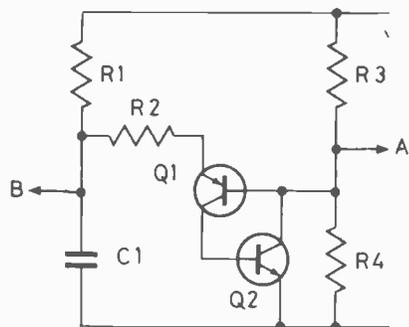


Fig. 3. Serial astable circuit. Try this out with the following values: R1=33k, C1=0.02uF, R3=R4=10k, R2=100R, Q1 =2N3905 Q2=2N3904

Q2 conducting, at a voltage of around 0.5 V to 0.6 V. With the base passing current, the collector voltage of Q2 is low because of the current through R4, and so the base of Q1, which is connected to the collector of Q2 through resistor R5 is also at a low voltage. When a collector voltage bottoms, it can go to a voltage of about 0.2 V, less than the 0.5 V, or so that is needed to make a base conduct, so that Q1 is quite definitely not conducting. There's nothing in the circuit itself, no charging capacitors, to change this so that the circuit can remain in this state (Q1 off, Q2 on) until the cows come home.

The cows come home when a short positive pulse is fed through C1 and D1 to the base of Q1. Only a small change of voltage is needed to make Q1 start to conduct, then the old positive feedback loop takes over, ending up with Q2 off (base negative) and Q1 held on with current flowing through R5. The diode D1 isolates the base of Q1 from any negative pulse which would otherwise turn off Q1 before the end of the timing period. What timing? Oh yes, there's a timing action as C2 charges up because of the current flowing through R3. During this time the collector voltage of Q2 is high, and the collector voltage of Q1 is low. When the base voltage of Q2 reaches a level of about 0.5 V (in a time of about  $0.7 - C3 \cdot R3$ ), Q2 conducts and the positive feedback ensures a quick snap back to the original conditions. There it remains, waiting again for the next trigger pulse.

The monostable is ideal for generating short pulses at long intervals, the job which cannot be done by using very unequal time constants in an astable multivibrator. The trigger pulses can be obtained from the square wave of the astable by using a differentiating circuit, as shown in Fig. 7.

#### Synchronise Your Pulses

One of the many useful points about an astable is that it's rather unstable. Now for many purposes that's about as useful as a lead life-jacket, because so many oscillators have to be very stable. Stable in this respect means that the frequency can be set and will not thereafter change when temperature changes or as components

slowly change value. The oscillator that sets the frequency of a radio or TV transmitter must, for example, be particularly stable so that the transmitter is always at its correct frequency. The oscillator of an electronic watch has to be stable so that the time can be held accurate to within a few seconds a month. We wouldn't use a plain astable for either of these jobs, but the instability of the astable is useful to us nevertheless. Take a problem — how do you generate a square wave with exactly the line frequency, but which will keep going when the line supply stops? You can generate 60 Hz wave using an astable but the frequency will change — unless it's synchronised. Synchronisation

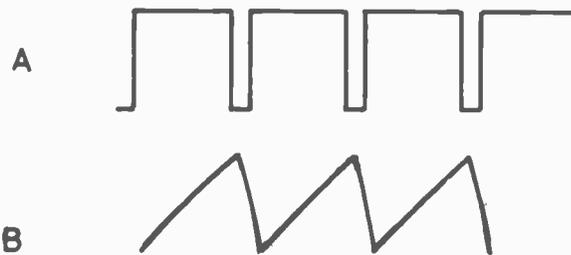


Fig. 4. Serial astable waveforms.

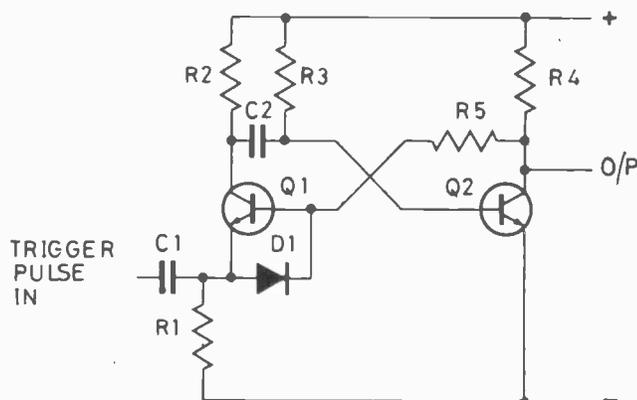


Fig. 5. A monostable circuit.

means forcing an oscillator to run at the frequency of a wave that is fed into it. If we feed a wave, say a 3 V, 60 HZ sine wave from a transformer into the base of one transistor of an astable running at some frequency between 50 Hz and 70 Hz, then the astable will be forced to run at 60 Hz. There's not much choice about it. If the frequency of the astable is higher or lower than the synchronising frequency, then at some time or other there will be a 50 Hz positive peak of the synchronising signal at the base of the transistor when that transistor is just about to switch on (Fig. 8.). The synchronising signal ensures that the transistor switches at that moment, and the next positive peak of the synchronising signal will ensure that the same happens again, and so on. The astable is synchronised, it runs at the same frequency as the synchronising signal.

A monostable will do even better, because it gives one output pulse for each synchronising pulse, no more, no less — this is called triggered operation. The difference between the two is that the monostable does not run unless it is triggered, the astable keeps running, though its speed may not be correct when the synchronising pulses are missing.

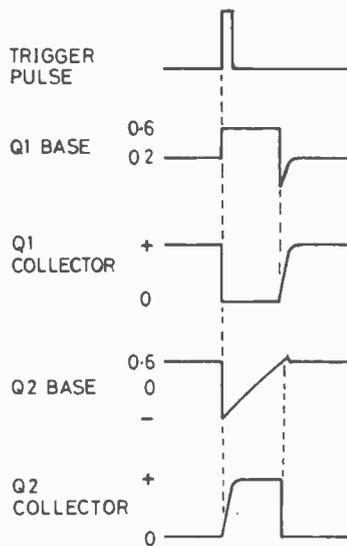


Fig. 6. Monostable waveforms.

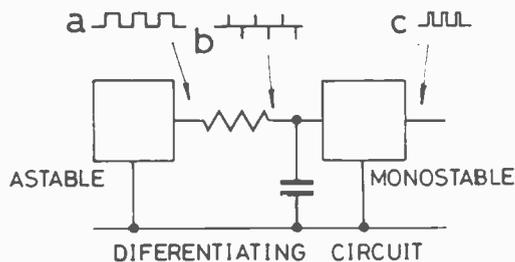


Fig. A monostable connected to an astable. The differentiating circuit converts the square wave into a set of pulses. The diode at the input of the monostable circuit selects only the positive pulses to trigger the monostable. The time of the monostable pulse (its pulse-width) is decided by the values of C2, R3 in Fig. 5.

**Sweeping up**

The square wave from an astable can be used to generate another important waveform, the timebase or linear sweep. As the name 'timebase' suggests, this is a waveform which is used for timing operations, particularly in oscilloscopes and in digital voltmeters. A simple timebase makes use of the charging and discharging of a capacitor through a resistor. If we put in a square wave at the input of the R-C circuit shown in Fig. 9. (an **integrator**), then the voltage signal across the capacitor is a sloping waveform; it's the exponential charge and discharge curve. Now if we could make the resistor a large value for the upward slope and a small value for the downward slope we would get the type of sweep waveform we need, with a slow steady rise and a rapid-fall of voltage. Say no more, we have the circuit in Fig. 10.

When the transistor is cut off by the negative part of the input wave, C charges through R, giving the slow rising part of the sweep wave. The positive part of the input wave then makes the transistor conduct, the collector-emitter part of the transistor has a low resistance that discharges C rapidly and the result is a sweep waveform. It's not perfect, but it's a start, and various improvements aimed at keeping the charging current through the resistance constant during the time of the sweep result in the good linear sweeps that we use for oscilloscope timebases. Take a look at the circuit of Fig.

11 for example, which uses a PNP transistor to control the current into C1. If you have time, construct this circuit and have a look at the waveform.

**Sines of the Times**

We've spent a lot of time on square-wave generators like astables, but what about sine-waves? Nowadays, the types of circuit that we use have less need of sinewaves, but we still need to generate waves of perfect sine shape for a lot of uses, not least the carrier waves of radio transmitters. A sinewave oscillator, like any other oscillator, uses an amplifying circuit along with positive feedback, but it needs two other important features.

One is some sort of automatic limiting action, so that the feedback does not simply whack the amplifier between the cut-off and bottomed states as happens in the astable circuits. The other requirement is a circuit that will control the frequency and shape of the sine-wave.

That excellent circuit, the **tuned circuit**, does a lot of what we want. A tuned circuit, such as the parallel connection of an inductor and a capacitor, responds only to frequencies very near to its resonant frequency of about  $1/2\pi\sqrt{LC}$ .

The type of response, as far as a parallel circuit is concerned, is its resistance to signals, which is maximum at the frequency of resonance and very small for signals at other frequencies. If we use a parallel tuned circuit as the load of an amplifier which has a little bit of positive feedback, then there will be enough amplifier gain for oscillation to start only at the frequency to which the parallel tuned circuit is tuned. The transistor itself will prevent the oscillation amplitude from becoming too great if we can arrange it so that the transistor runs out of

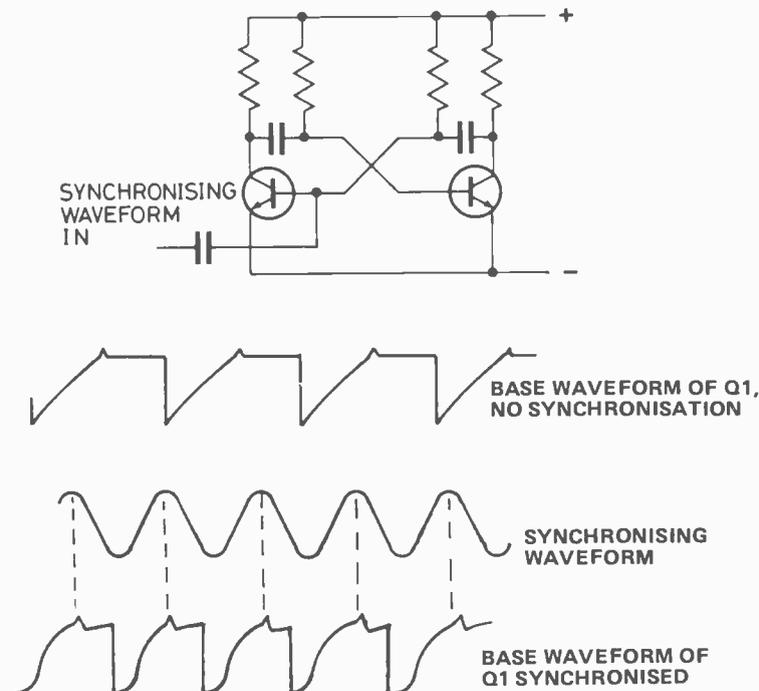


Fig. 8. Synchronisation of an astable. In this example, the astable is forced to run at the frequency of the sync. wave, but the astable can be made to run at lower frequencies, half a third a quarter etc. of the sync. wave.

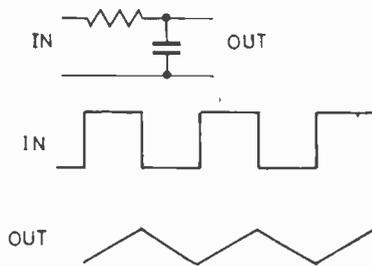


Fig. 9. Integrating circuit and waveforms.

gain when the amplitude of the oscillation becomes too large. This happens when the collector voltage is low, or if the bias is reduced. Both of these methods of controlling the amplitude would cause a distorted signal but for two things. One is that the amount of positive feedback is kept small, so that a reduction of gain stops or reduces the amplitude of oscillation rather than allowing a large and distorted signal to be generated. The other point is that the tuned circuit itself will sort out a distorted wave, and extract a well-shaped sine-wave from it.

A sinewave oscillator circuit circuit is shown in Fig. 12 This is a type called a **Colpitts** oscillator, and its trademark is the signal potential divider using two capacitors. These two capacitors are connected across the inductor  $L$ , and arranged so that a fraction of the output signal is fed back to the emitter of the transistor. This is positive feedback, because if the base voltage is held steady, then a rise in the emitter voltage causes less bias voltage between base and emitter, so less base current, therefore less collector current, and so causes a

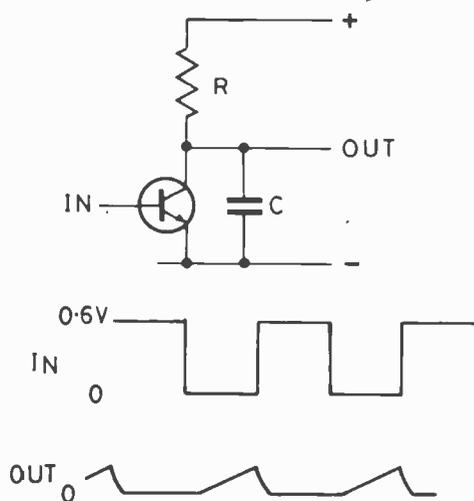


Fig. 10. A simple timebase circuit, with waveforms. The amplitude of the output sawtooth depends on the value of time-constant  $CR$  compared with the period of the square-wave. For a good wave-shape,  $CR$  should be much greater than the period of the square-wave.

rise of collector voltage. To make sure that the base voltage remains steady, a capacitor  $C3$  must be connected as shown. Without this capacitor, the base voltage can follow the emitter voltage at high frequencies so that oscillation does not occur. The tuned circuit for this oscillator consists of  $L$ , with the capacitors  $C1$  and  $C2$  in series with each other (but connected in parallel with  $L$ ).

Oscillators that use inductors and capacitors are useful for generating radio frequency waves, particularly if we need to alter the frequency. Using a variable capacitor as part of the tuned circuit lets us do just that, making the oscillator a VFO, (variable frequency oscillator).

The Colpitts oscillator is not ideal from this point of

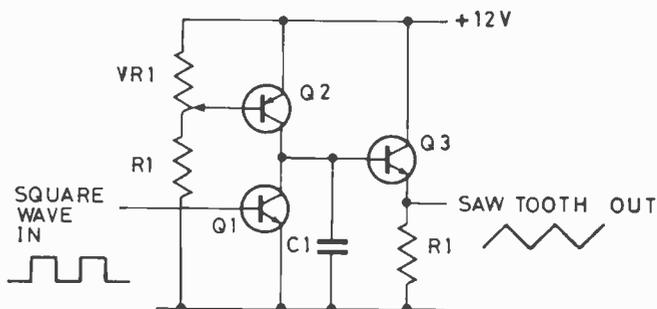


Fig. 11. A timebase circuit which gives a more linear shape of sweep when smaller values of time constant are used. The current through  $Q2$  is set by the bias on its base, and is constant for most of the sweep. Try the following values:  $RV1, 5k$ ;  $R1, 47k$ ;  $C1, 0.1 \mu F$ ;  $R2, 1k$ ;  $Q2, 2N2905$ ;  $Q1, Q3, 2N2219$ .

view because both plates of the variable capacitor would have a signal voltage on them. This makes adjustment rather difficult, because a variable capacitor is constructed with one set of plates connected to the central shaft. If this set of plates is connected to a signal voltage, then touching the control (tuning) knob will change the frequency of the oscillator even before the control is adjusted, because the capacitance between your hand and the capacitor plates is now part of the tuned circuit. When variable tuning is needed, other circuits which allow the moving plates of the tuning capacitor to be earthed are more suitable. The **Hartley** oscillator circuit is of this type, and is shown in Fig. 13.

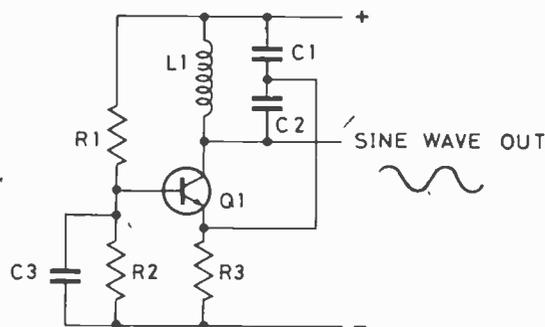


Fig. 12. One form of the Colpitts oscillator.

### The Crystal Oscillator

Sinewave oscillators which use LC tuned circuits are useful, but their frequency can be altered by small changes of supply voltage and by changes of temperature. For generating sinewaves of very precise frequency, something better than the LC circuit is needed, and that something is the quartz crystal. Quartz crystals are just what the name says they are — crystals of Quartz (silicon oxide). The quartz is carefully cut to shape, and opposite faces are coated with silver so that wire contacts can be soldered in place. With this done, the crystal will now behave like a tuned circuit. At one particular frequency, depending on the size and shape of

the crystal, the crystal can resonate to a frequency applied to its connections, vibrating mechanically at that frequency. At this resonant frequency, the crystal behaves like an LC circuit, but one with values of L and C that we could not possibly obtain when we use ordinary components. The usefulness of a tuned circuit for generating a good shape of sinewave is measured by a figure called the **Q factor**. A conventional LC tuned

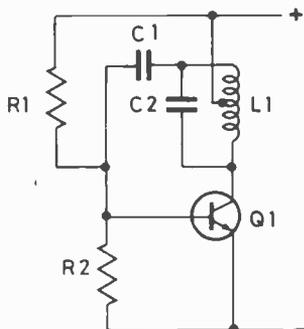


Fig. 13. One form of Hartley oscillator, which uses a tapped-coil.

circuit might have a Q factor of 150 with luck, but a quartz crystal can notch up a Q figure of 30 000. This makes crystal oscillators the natural choice when a very precise value of frequency has to be generated and when the oscillator frequency must be unaffected by changes in other components. Quartz crystals are therefore used in digital watches, radio transmitters, frequency meters and in any other application which needs a fixed frequency.

A typical crystal oscillator is shown in Fig. 14. The oscillator is of the Colpitts variety, but the frequency is controlled almost entirely by the crystal, so that the output frequency is much more stable than that of any LC Colpitts circuit.

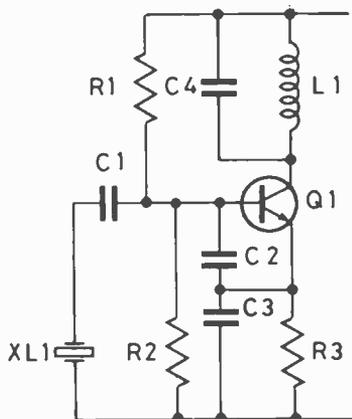


Fig. 14. A crystal oscillator, one of a large number of possible circuits.

**How Low Can You Get?**

We have a pretty satisfactory set of circuits for generating sinewaves at radio frequencies, but we run into problems if we try to use the same circuits to generate lower frequencies, audio frequencies, for example with a range of 20 Hz to 20 kHz. LC oscillators are of very little use because a very large value of inductance will be needed for the low frequencies, and the values of capacitance will also have to be large, ruling out the use of the usual 500 pF variable capacitor as a method of tuning.

There are two ways around this problem. One is the use of the beat-frequency oscillator (BFO). This type of circuit uses two oscillators, both working at radio frequencies of several hundred kHz. The output signals at frequencies  $f_1$  and  $f_2$  are fed into a mixer stage which produces (surprise, surprise) a mixture of signal frequencies including the difference frequency  $f_1 - f_2$  and the sum  $f_1 + f_2$ . Now if the frequencies  $f_1$  and  $f_2$  are close, such as 320 kHz and 325 kHz, then the difference frequency is low, 5 kHz in this example, and

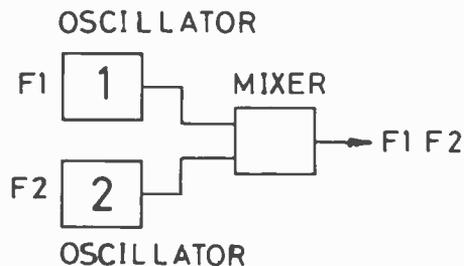


Fig. 15. Principle of the beat-frequency oscillator (BFO)

can easily be separated from all the other signal frequencies. The BFO is a simple way of generating low frequency sinewaves, but if its performance is to be good then both of its oscillators must be very stable. A frequency change of 10 Hz, may be noticeable in a 320 kHz oscillator, but it does make rather a lot of difference when the difference frequency is only 20 Hz. The BFO circuit is still used, in metal detectors for example, but not so much now as a generator of low frequency sine waves.

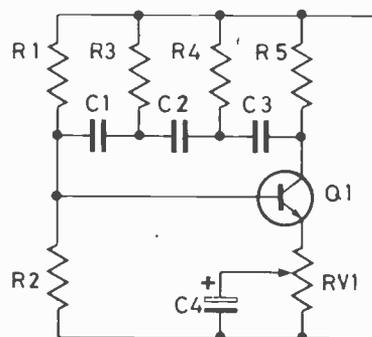


Fig. 16. Basic phase-shift oscillator. This circuit is often seen in print, but it seldom oscillates because the gain of the transistor is usually too low to overcome the losses in the CR network.

**Beat This**

The modern method of generating low frequency signals is the RC oscillator, so let's have a look at these. Like any other oscillator, the RC type consists of an amplifier, a positive feedback connection, a frequency selective circuit (tuned circuit) and a method of stabilising the amplitude. The trouble with frequency selective circuit which use resistors and capacitors only is that they are not nearly so selective as the LC circuits. The Q factor which measures how good they are at selecting a frequency is only around 2 to 6 (compare LC at about 50 to 150, crystals 5000 upwards). Because of this, we can't rely on the RC circuits to keep a sinewave looking like a sinewave, and every RC oscillator needs some other method of adjusting the feedback so that the oscillator is just oscillating with an amplitude that stops well short of bottoming or cutting off the transistor.

Figure 16 shows a phase-shift RC oscillator — probably the simplest type. It's possible to make this type of oscillator using only one transistor, but the results are rather unpredictable, and as often as not the circuit totally refuses to oscillate. The circuit shown in Fig. 17. is a bit more reliable. Q2 is an emitter follower (with unity gain) and Q1 is a common-emitter amplifier, load R4 which provides voltage gain. The phase-shift network is R1, C1, R2, C2, R3, C3 three lots of RC time constants. Each of these RC time constants has two effects on a sine wave — it reduces the amplitude and it phase shifts the current wave relative to the voltage wave. If the total phase shift in the three sections is  $180^\circ$ , then the sinewave of current into the base of Q1 is  $180^\circ$  out of phase with the voltage wave at the collector of Q2. For a sinewave, a  $180^\circ$  phase shift has the same effect as inverting the wave, so that the feedback through this network is positive. The circuit will oscillate if the gain of Q2 is just slightly more than the losses through the RC network (not forgetting RV1) and Q1. We have to adjust the gain in this simple circuit by

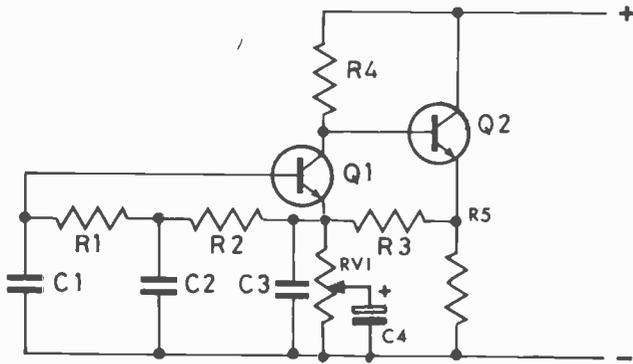


Fig. 17. A more reliable phase-shift circuit. Try this with the following values:  $R1=R2=R3=15k$ ,  $C1=C2=C3=0.01 \mu F$ ,  $R4=3k$ ,  $R5=10k$ ,  $RV1=1k$ ,  $C4=10\mu F$ , Q1, Q2=2N2219. RV1 is used to adjust the gain so that the circuit is just oscillating. The DC voltage at the emitter of Q2 should be about 1.5V, if it is much too low or much too high, adjust the value of R4.

setting RV1, which provides a bit of negative feedback. If RV1 is set so that the circuit is only just oscillating, the shape of the sinewave that is produced can be quite good.

The phase-shift circuit isn't used much, however, because it is rather difficult to provide variation of the frequency (too many quantities to change) and also because there are other networks which are more selective. Really well-shaped sinewaves are produced only if the amplifier has its gain automatically controlled.

#### A Bridge Too Far?

Figure 18 shows the circuit of a **Wein-bridge oscillator**. This circuit calls for an amplifier with two inputs so that both negative — and positive feedback loops can be connected. This, of course, can be as simple as using a transistor base as one input and the emitter of the same transistor as the other, but to avoid cluttering up the diagram, the amplifier is shown as a triangle with negative feedback going to the input marked — and positive feedback to the input marked +. The Wein bridge is actually the network consisting of C1, R1, C2, R2, connected as shown. The action of this circuit is that it has zero phase shift at one frequency, when  $f_o = 1/2\pi CR$  (with  $C = C1 = C2$  and  $R = R1 = R2$ ) (where  $f_o$  is the frequency of oscillation.)

With the Wein bridge circuit connected into the positive feedback loop, there is positive feedback only when the phase shift of the network is zero, which is at the frequency  $f_o$ . As usual, the sinewave shape is good only if the amplifier gain can be controlled so that it just compensates for the losses in the network; this requires a gain of about 3 times. The easiest way of providing the gain and regulating it is to make the amplifier a high-gain type and arrange R3 and R4 so that the negative feedback adjusts and controls the gain. One commonly-used method is to use a thermistor for R4 and a resistor with twice the thermistor resistance for R3. Twice what resistance? Well, we use a thermistor which will run at a temperature which is a bit above room temperature when signals current passes through it, and we pick the

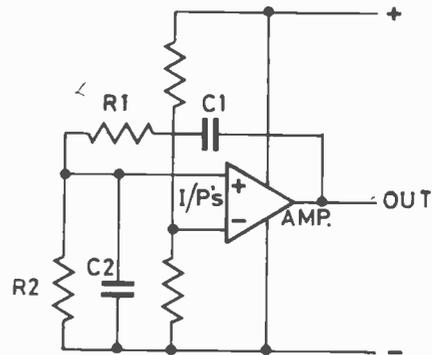


Fig. 18. Wein-bridge oscillator showing both feedback paths.

value of resistance it will have at this temperature. When the circuit is switched on at first, the oscillations quickly build up to full amplitude, but the current through the thermistor heats up the tiny element until the resistance drops, adjusting the gain of the amplifier, and reducing the amplitude of oscillation. Too small an amplitude, of course, will allow the thermistor to cool, raising its resistance, decreasing the negative feedback and increasing the gain so that the amplitude can build up. This negative feedback loop then controls the gain of the amplifier to ensure that the waveshape remains good and the amplitude constant.

Another method that is used to control the gain of the amplifier is to rectify the signal output and use the rectified signal to provide bias for a FET, using the source-drain connections of the FET as the resistor R4. This method is not affected by the temperature of the air surrounding a thermistor, so that it is a better method of stabilisation.





# WHAT'S NEW

By Steve Rimmer

In its most basic form, a music synthesizer is a wonderful and versatile machine, Steve Rimmer tells how polyphony makes it even better.

THE UBIQUITOUS conceptual Moog machine, the voltage controlled synthesizer, has but one limitation, and that is that it's monotonous, or capable of producing but a single voice. This one voice can be very complex. . . . the concept is, in theory, at least, infinitely expandable. In this respect, if the oscillators are set so as to be separated in pitch by, say, a full tone, chords could be produced, but these are rather like pseudo-chords; they are multi-voiced, to be sure, but there is not the capacity to manipulate them, as would be the case with a polyphonic keyboard, like a piano. If one has a synthesizer with three oscillators, producing a chord of C, E and G when one hits the C key, there is no way to get something like, say, C, F and A without re-adjusting the oscillators, as the intervals are different. The polyphony of the system is thus restricted to playing essentially the same chord transposed up and down the keyboard. This is highly dull, and, for this reason, never done very much.

However, multi-voiced synthesized sounds are fairly important. The monotonous instrument is really only suitable for playing lead lines, solos, and single parts in a multi-voiced piece, this last, for example, like replacing the violin in a string quartet. It can't take over the textural things done by, say, an organ. This is a drag, too, because even those relatively complex organs, with ranks of stops to simulate everything from a fractured kazoo to a nose flute with a head cold, don't give the player the sort of control available with even a fairly modest synthesizer. The lovely thing about Moog's concept is that it allows one to specify each aspect of the sound being produced. It is, therefore, possible to render a nose flute with either a simple head cold, or a head cold with inflamed sinuses.

It is a fairly simple task to devise a keyboard, which, although still essentially a linear voltage control affair, is capable of dealing with two keys simultaneously. It simply sends the first key voltage produced, the result of the first key down, to the first voltage output, and the second key voltage, to the second output. From there on, there are essentially two completely separate systems, each of which is tuneable so as to be able to produce the whole range of possible synthesized sounds.

Now this, it would seem, is quite wonderful. It's better than a polyphonic organ, because the two keys can actually be producing the sounds of two wholly different instruments. The high part can be a viol, and the low part a horn, for instance. Oh ho. This does, however, lead to a problem when one wishes to be monophonic again.

Let us say that synthesizer number one will do the viol, and synthesizer number two will handle the horn part. Now, there are two ways that the keyboard can differentiate between which key should actuate the horn, and which the viol. It can either send the first key down to the first synthesizer, or it can send the highest key down. There are hassles with each. If it sends the first key down to synth number one, that means that there always have to be two keys down to get the horn in. The horn cannot play unless the viol is wailing too. If it differentiates by deciding which one is the highest, if the horn line ever gets higher than the viol line, the horn will suddenly become the viol until it retreats back down the keyboard.

This type of poly system is not wholly uncool. It's great when both of its voices are to be the same. It's also very useful when one has the time to plan out its intricacies, and get everything nicely scored and premeditated.



However, there is, due to the wonders of high technology, clean living and psychedelic drugs, a better way.

## More Voices

Obviously, the two tone poly is a kind of intermediary in the direction of full multi-voice capability. However, it does serve to illustrate a very important tenet of polyphonic instruments. It has two voices, and it's at least twice as complex as a one voice machine. This means that it's bigger, more expensive and, most important, twice the hassle to set up. Several of these factors can be offset to a degree by making each of the two synthesizer sections somewhat simpler than they might have been in a one voice system, but this bodes ill if the initial design utilized two oscillators and the two voice scene uses only one for each section. A three voiced machine would entail fractional oscillators, which, one might suppose, would only render a portion of each waveform. Not only prone to generating a lot of unwanted harmonics, this sort of arrangement might also be expected to produce scales with fewer than twelve tones, making ol' Ludwig sound faintly oriental. Gadzooks.

The point here is that complexity increases right along with voice capacity, and a three octave, thirty seven voiced instrument would need thirty seven complete synthesizers. Each would require tuning, adjusting and voicing prior to playing the thing. Then there's the problem of where to house the power supply to run all this. A separate outbuilding may be in order.

Unfortunately, flexibility is also linked into complexity, and if we reduce the number of knobs and patches to something less than room-filling, we'll also be axing the number of sounds the synthesizer can churn out. Getting the instrument into a reasonable sized box will reduce it to doing practically only a single tonal structure, or, at best, a very narrow range.

These are the parameters involved in polyphony, and there is very little that can be done to get around them. Practical poly machines are quite common, but they embody little of the versatility of a monophonic instrument. They are, in fact, usually quite set in their ways; designed especially to play, say, a string section, synthetic fiddles, or brass, synthetic horns. The only heavy tonal alterations involved are whether one prefers big fiddles, little fiddles, or a combination thereof.

The compensation in these instruments is that they are capable of doing several tonal things that an ordinary Moog instrument cannot because it is mono voiced. To understand where this is at, it is necessary to have an idea of what goes on inside these beasts.

### String Things

To begin with, a polyphonic keyboard does not require a voltage controlled oscillator for each key. Since the pitches don't change, it's actually quite acceptable to have stationary oscillators. It's just as acceptable to use one oscillator and divide down from there. Thus, each key produces only a gating pulse, which, as we'll see, eventually affects the amplitude of some square waves kicked out of a long chain of flip flops.

The keyboard begins with a top octave, which are the twelve notes of the uppermost octave to be played. This can be generated either in a fixed temperment or an adjustable one . . . we'll get into the musical implications of this briefly just before adjournment. A fixed top octave generator consists of a single master oscillator, usually



A string synthesizer manufactured by Yamaha.

of quite a high frequency, which gets fed into a chip containing twelve sets of binary dividers set to chop the reference clock down to the right pitches. A variable one utilizes twelve separate adjustable oscillators . . . presumably fairly stable ones . . . to arrive at roughly the same result. From this point, we encounter a string of flip flops.

The word "octave" is a bit misleading, especially as it contains, at least in our music, twelve tones. Actually, four of these are semi-tones, the black keys on the keyboard, leaving eight full tones which should explain the derivation. What it actually means, though, is that to ascend an octave in pitch you must double the frequency. Descending works likewise. To shift down from, say, C' to C, the pitch must be divided by two . . . easily accomplished by pumping it through a flip flop. Thus, once one has the top octave properly in place, the octaves below it can be had simply by feeding each top octave pitch into one binary divider for each twelve keys in the keyboard.

We now have, for a three octave keyboard, thirty six separate frequencies straining at the bit, waiting to get out and be heard. We could just mix them onto a common buss through the keyboard, such that every time a key went down, it switched on its corresponding frequency. However, this wouldn't be too interesting, as there would be no dynamics to the sound. Actually, what we'd have created would be, essentially, a rock "combo" organ . . . not the most ethereal instrument known to civilization. Therefore, we shall first proceed

to do something interesting to the notes.

The first thing to happen to the frequencies is to give them envelopes. This means that, under normal circumstances their amplitudes are all zero, but, given suitable cause, one can raise the level of this or that particular pitch for a time before letting it fall back. The rate at which the note ascends in volume is called the attack. The length of time it takes to begin dropping off is called sustain. The rate at which it dies out is called decay. These factors determine the amplitude dynamics of the resulting sound.

In getting envelopes on the sounds, we find the one last vestige of the voltage controlled mono synthesizer. The gating pulses from the keyboard are sent along to a rank of envelope generators, essentially monostable multivibrators with time constants happening to round off the leading and trailing edges. These are, however, not just ordinary envelope generators. It is usually blessed under the advertising brochure to be able to vary at least the decay (and usually the attack, too) of the envelope. If they were to be adjustable individually there would be quite a brotherhood of potentiometers kicking around. Therefore, any variable factors in the envelopes must be voltage controlled, so that one knob does all.

The envelope generators feed their envelopes to a rank of thirty six voltage controlled amplifiers, which are looking at the frequencies being fed into their audio inputs. Thus, every time you hit a key, the appropriate envelope generator wakes up, produces an envelope and goes back to sleep. The envelope finds

its way to the associated VCA, ups its gain, letting the note go through for a while. The envelope dies away, the note is silenced, and placidity reigns. If all the VCA outputs were to be mixed together there would be . . . we'd actually still have a combo organ. Now we get into the neat stuff.

**Further Fiddling**

Yehudi Menuhin would probably resent being referred to as a fiddle player. However, he'd probably also resent having what comes out of a string synthesizer referred to as being the sound of violins. Actually, its supposed to be the sound of orchestral strings . . . a mass of violins and cellos . . . but it sounds more like a spacy organ sound. It's not an organ in anything like the relatively simple tonal structure of a church organ. In fact, its complexity approaches the acoustic reality it's supposed to be synthesizing. This, in itself, is very unlike the results of Moog sounds, which are invariably simpler.

What a string machine does to get its rich noises is to approach synthesizing not only the basic tones, but the effects of the acoustics beyond the body of the violin. There are cancellations due to all the phase things coming down because of many instruments being played by many bows, none of which are perfectly in time. There are a lot of musical intervals happening, because one rarely has a piece scored such that the whole string section is playing the same lines. Lastly, there are all sorts of subtle bends in the pitch of each note as the violinists glide into notes and get into vibrato finger work.

Getting harmonies added to each individual note is the easiest part. Unlike in a mono system, where in each separate pitch need to be added individually, with a separate oscillator, all the notes that might be used to enrich a fundamental tone are present somewhere in the divider. Thus, it is only necessary to get a circuit that will select which ones are desired, and switch them in. Contemporary string machines usually add quite a bit to each note in this respect, blending in intervals of fifths and sevenths.

This blend is also usually voltage controllable, so that the sound can range from a straight reed organ, basically a flat pitch generator, to a full orchestra.

The other temporal and tonal variations are handled by a chorusing circuit, which is usually in the system after all the switching has occurred and the individual notes have been mixed to a common buss. It consists of two analog delay lines, each having their delays

varied slightly by some sort of slow complex waveforms. Each one varies independently. Because the delays are constantly varying, they are also producing slight variations in the pitch of the notes, which correspond to the movement of the violinist's fingers on the strings. This, in turn, also does some phase changing trips. The two outputs of the delay lines and the original voice are combined after all the processing has happened. Because of the resulting complexity, the ear is fooled into thinking it is hearing many more voices than are actually present.

**Brief Temperments**

The pitches of the keyboard are determined by what is called temperment. The hassle here is that there isn't really an absolute series of numbers which should relate to the top octave generator . . . this can be set different ways to do different sorts of music. This is not usually the case . . . the niceties of different tunings are rarely gotten into in electronic instruments. However, some systems do use a top octave generator in which each of the twelve initial tones can be set independently . . . it is thus nice to have some idea of how to tune the things.

The "temperment" of a keyboard is, essentially, a fudge factor. You can't actually tune a piano keyboard in any way so as to make it perfectly in tune for all keys. The reason for this is a bit confusing. The interval for an octave is a doubling of pitch, or a ratio of 2:1. The next smallest interval is a fifth, which essentially means you count down five tones. This has a ratio of 3:2. Now, beginning with a low "C" on the keyboard, let's begin moving up simultaneously in octaves and fifths until we meet again.

In fact, there will never be a point where in the two ratios will produce the same pitch. They get very close seven octaves up the board, with the octave interval being 128 times higher than the initial C, and the fifth something like 129.7. However, that C can't be producing these two frequencies simul-

taneously. This will be further complicated by seeing that, in fact, none of the other intervals come out right. It is therefore necessary to fudge each key a bit to get things workable. This fudging can be done in several ways, each one a different type of "temperment".

The most common approach is to tune the octaves more or less pure, and have each of the intervals between them equal. This is called equal temperment, and is most commonly used in contemporary instruments, as it permits playing in any key with relatively uniform results, considering the clarity of the tone. By contrast, many of the other temperments are only good in one or two keys . . . however, they sound a lot better in these keys than would an equal temperment. The following chart will provide a set of intervals for three different temperments, should you wish to fool with them.

I should also point out, if you are looking for something to compare with, that the top octave generated by an I.C. top octave generator chip is not an equal temperment . . . it is a fairly rough approximation, and will not usually sound as pure as a top octave from twelve independent oscillators.



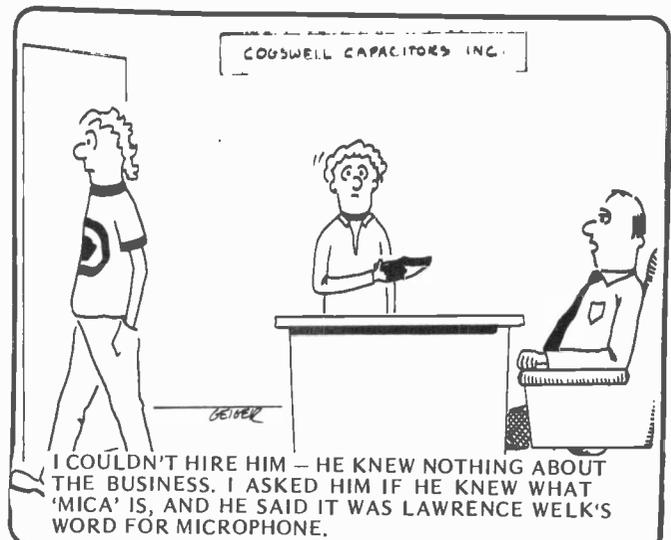
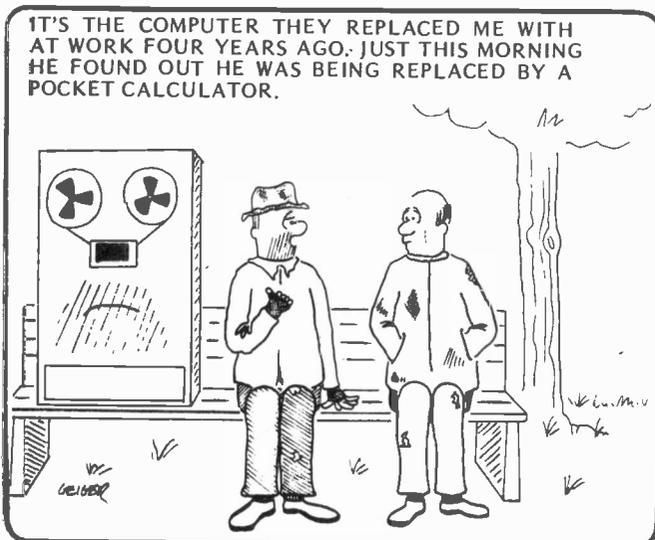
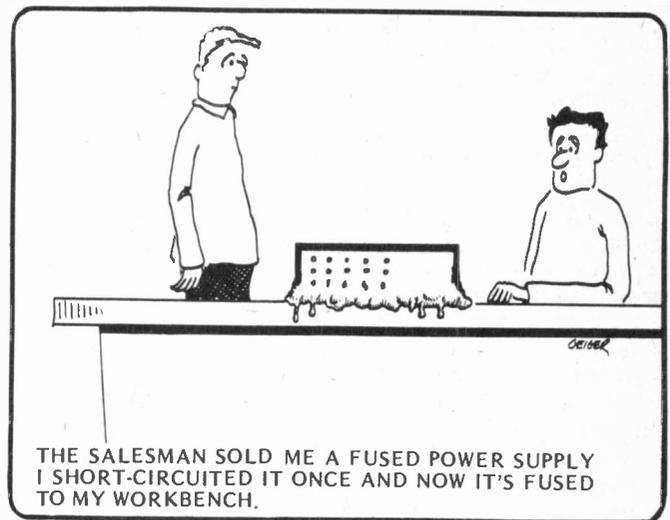
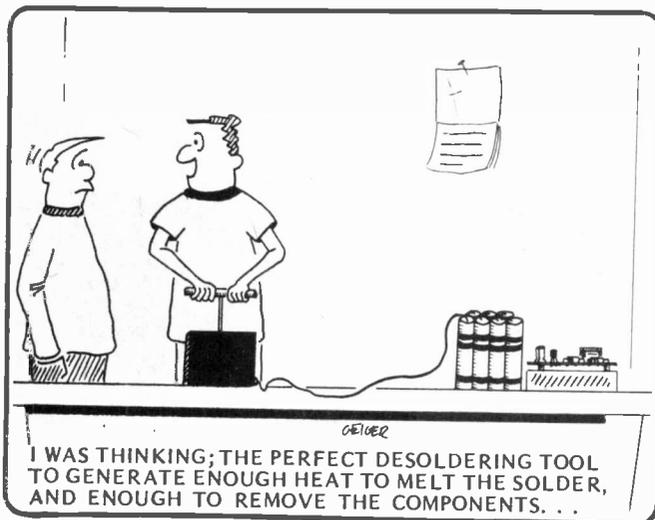
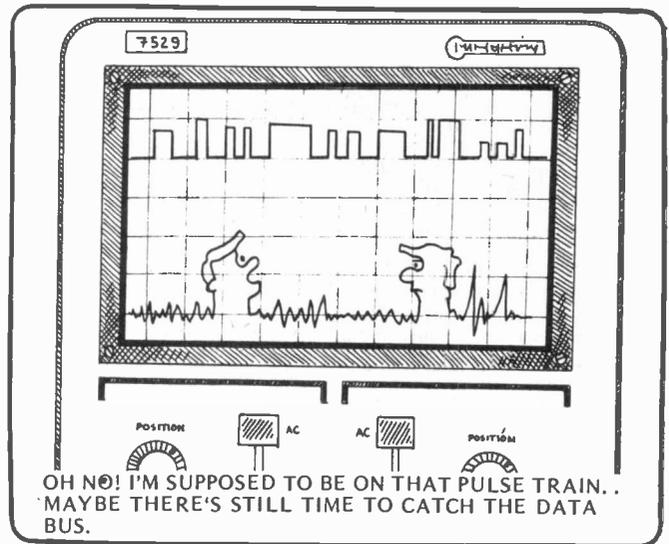
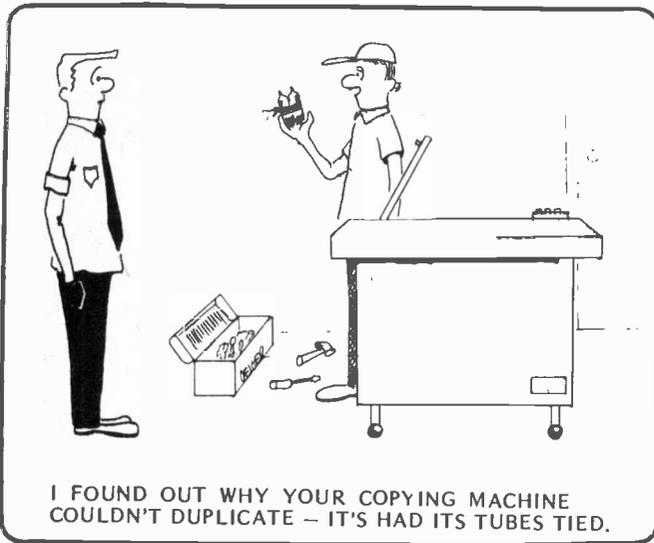
A polyphonic synthesizer manufactured by Crumar. This particular model can produce brass or string sounds.

**Next Month**

I wouldn't expect much from next month for at least thirty days. Present plans have us looking at either a four track cassette portable studio thing . . . or something else. Until then, don't let any charming blond, blue eyed, half stoned hookers near your string machines, and stay tuned.

	Equal	Perfect Fifths	Major Just
C	1.000	1.000	1.000
C #	1.05946309	1.0667	1.0667
D	1.12246204	1.1250	1.1250
D #	1.18920711	1.2000	1.2000
E	1.25992104	1.2657	1.2500
F	1.33483985	1.3333	1.3333
F #	1.41421356	1.4063	1.4222
G	1.49830707	1.5000	1.5000
G #	1.58740105	1.6000	1.6000
A	1.68179283	1.6875	1.6667
A #	1.78179743	1.7777	1.7777
B	1.88774862	1.8984	1.8750
C	2.000	2.000	2.000

*Infinite gratitude and suchlike to Tom Cuff at the Music Shoppe, Thornhill, Ontario for the use of the light reflecting from his string synthesizer.*



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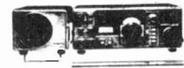
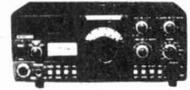


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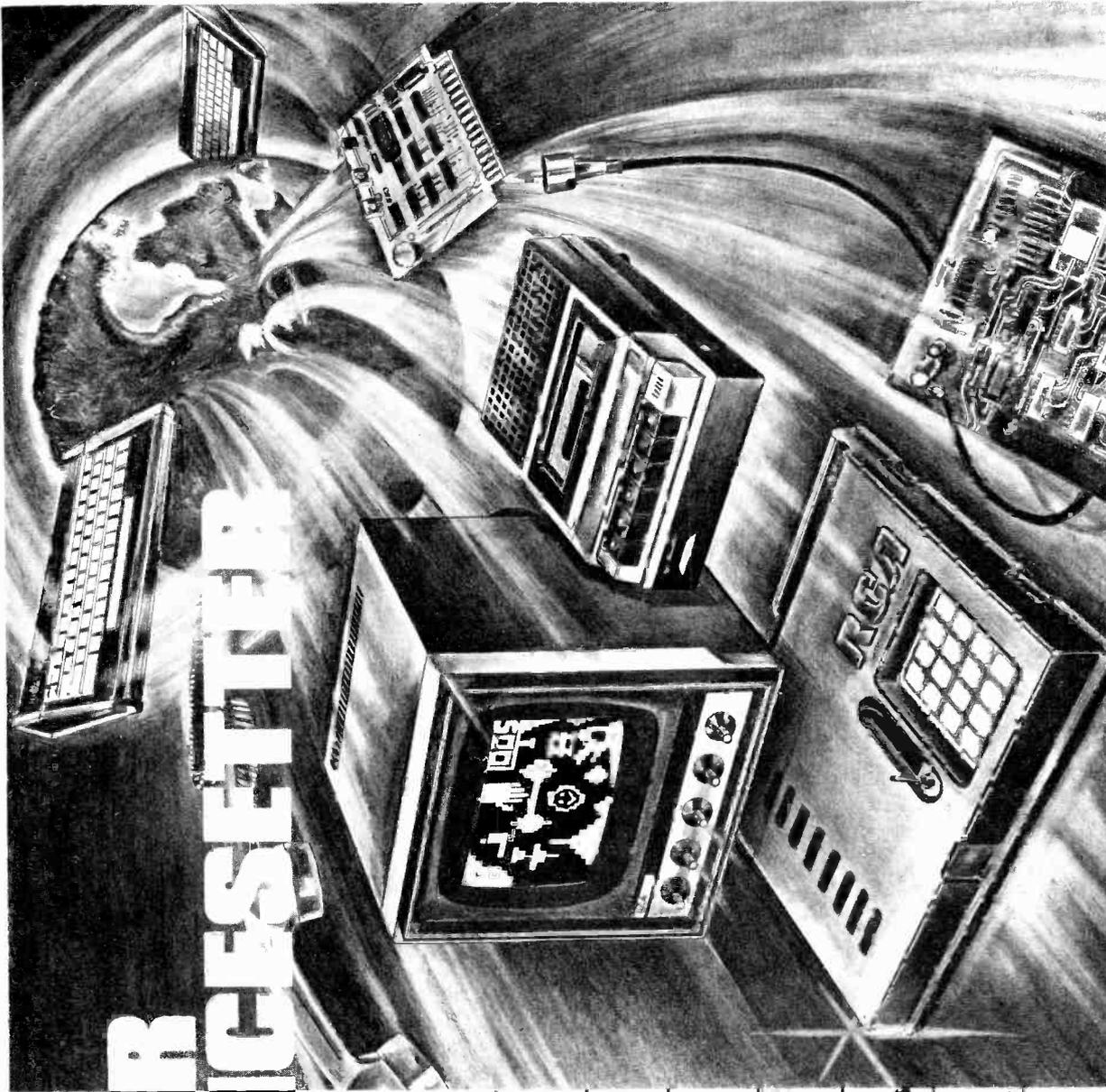
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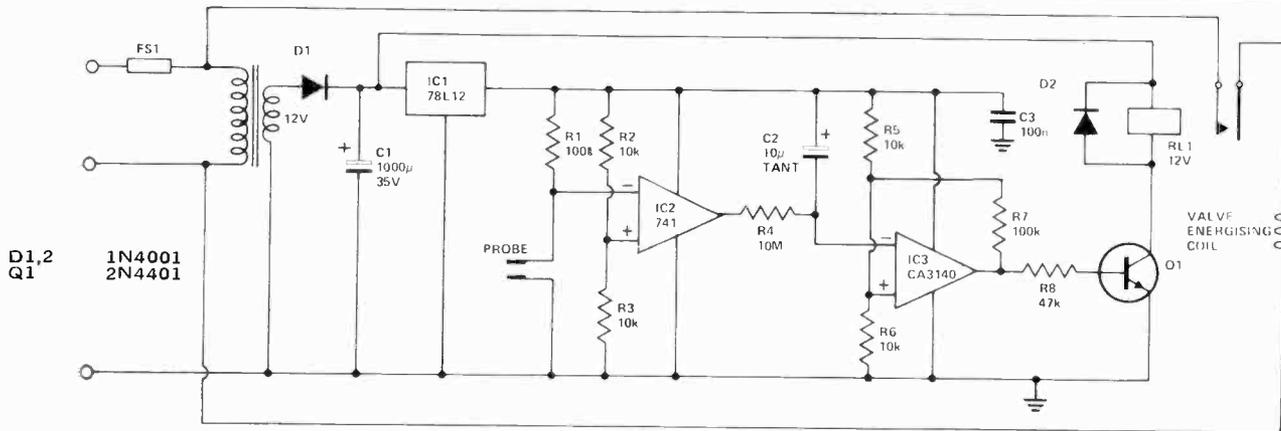


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Cliff Heath

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The inverting input of IC2 is held low by a short across the probe (which can simply be a couple of bolts through the side of a fibreglass pool). When the water level is low the probe will go open circuit and the output of IC2 will go low. C2 will begin to charge and after about 2 minutes, the output of IC3 will change state. This 2 minute delay is to

prevent waves from setting the device off prematurely.

Once triggered, IC3 (which is connected as a Schmidt trigger) will give a high output voltage for at least 20 seconds — this is the length of time needed for IC2 to change the inverting input voltage of IC3 past its hysteresis point.

While the output of IC3 is high, Q1 will turn on and energise the water supply valve coil. Care should be taken with the valve line supply — it's a good idea to put the end of the water supply hose into the pool. This will remove the possibility of line voltage

water falling into the pool due to a short inside the valve.

**Tech-Tips is an ideas forum and is not aimed at the beginner; we regret that we cannot answer queries on these items. We do not build up these circuits prior to publication.**

**ETI is happy to consider circuits or ideas submitted by readers; all items used will be paid for. Drawings should be as clear as possible and the text should be preferably typed. Anything submitted should not be subject to copyright. Items for consideration should be sent to the Editor.**

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33 PF	1000 Volt	.16	01 MFD	25 Volt	.12
47 PF	1000 Volt	.16	01 MFD	50 Volt	.17
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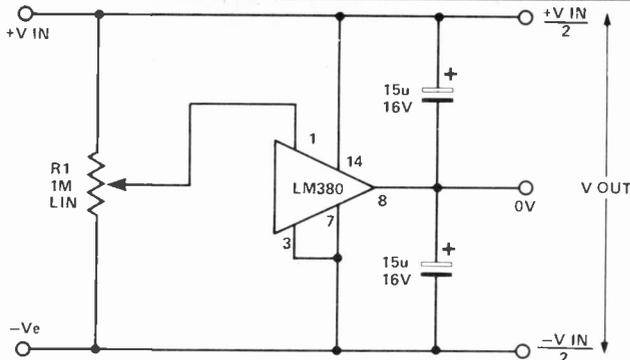
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4071	.30	4520	.80	4013	.50	4035	1.80
4072	.29	4526	1.80	4014	1.26	4040	1.16
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## TECH TIPS



### Simple Dual Power Supply

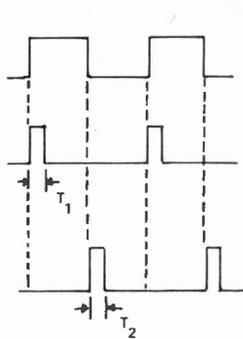
L Swann

This circuit offers a cheap and simple way of obtaining a split power supply (for Op-amps etc.), utilising the quasi-complementary output stage of the popular LM380 audio power IC.

The device is internally biased so that with no input the output is held mid-way between the supply rails.

R1, which should be initially set to mid-travel, is used to nullify any imbalance in the output. Regulation of  $V_{OUT}$  depends upon the circuit feeding the LM380, but the positive and negative outputs will track accurately irrespective of input regulation and unbalanced loads.

The free-air dissipation is a little

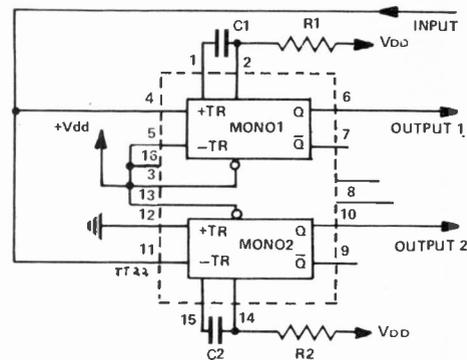


### Dual One - Shot Discriminates trailing and Falling Edges Of Data Signals

Noel Boutin, Sherbrooke University  
Many circuits have been published in the past which can be classified as transition detectors. They produce an output pulse each time a state change occurs at their input. The proposed circuit have two output ports. On the

over 1 watt, and so extra cooling may be required. The device is fully protected and will go into thermal shut-down if its rated dissipation is exceeded, current limiting occurs if the output current exceeds 1A3.

The input voltage should not exceed 20 V.



first one, a short pulse, the duration of which being adjustable by an external RC network, is produced each time a transition from a logical "0" to a logical "1" is detected at its input. In fact, the circuit is a monostable triggered by trailing edge of data input. On the second output port, a short pulse, also adjustable, is produced each time a transition from a logical "1" to a logical "0" is detected at its input. This second part of the discriminator is another monostable triggered, this time, by the falling edge of the input signal.

As shown in figure, the only components need is an IC dual monostable multivibrator such as the CD4098 or MC14538 and two RC networks.

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- 20Ω Range (MX333)

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#### CONDENSED SPECIFICATIONS: MX331 and MX333

DC VOLTS (5 RANGES): 200mV to 1000V full scale. RESOLUTION: 0.1mV. ACCURACY:  $\pm 0.1\% + 1$  digit. INPUT IMPEDANCE: 10MΩ. OVERLOAD PROTECTION: 1000V DC or peak AC + up to 6kV transients all ranges.

AC VOLTS (5 RANGES): 200mV to 1000V full scale. RESOLUTION: 0.1mV. ACCURACY:  $\pm 1\% + 2$  digits, 45 Hz to 1kHz.  $\pm 5\% + 5$  digits to 5 kHz. INPUT IMPEDANCE: 10mΩ. OVERLOAD PROTECTION: 1000V DC/750 RMS.

RESISTANCE (7 RANGES): 20Ω to 20MΩ full scale except no 20Ω range on MX331. RESOLUTION: 0.01Ω on MX333, 0.1Ω on MX331. ACCURACY:  $\pm 0.1\% + 1$  digit except 0.2% on 200Ω, 1% on 20MΩ, and 3% on 20Ω ranges. OVERLOAD PROTECTION: 500V DC on RMS all ranges plus 2A fuse on 20Ω range. TEST VOLTAGE: Low power, 0.25V max of full scale.

DIODE TEST (1 RANGE): Measures forward voltage drop across diode and transistor junctions at 2mA nominal current.

AC/DC CURRENT (5 RANGES): 2mA to 10A full scale. RESOLUTION: 1μA. ACCURACY:  $\pm 1.2\% + 1$  digit DC.  $\pm 2.5\% + 1$  digit AC. OVERLOAD PROTECTION: 250V @ 2A all ranges except 10A, max 15A on 10A range.

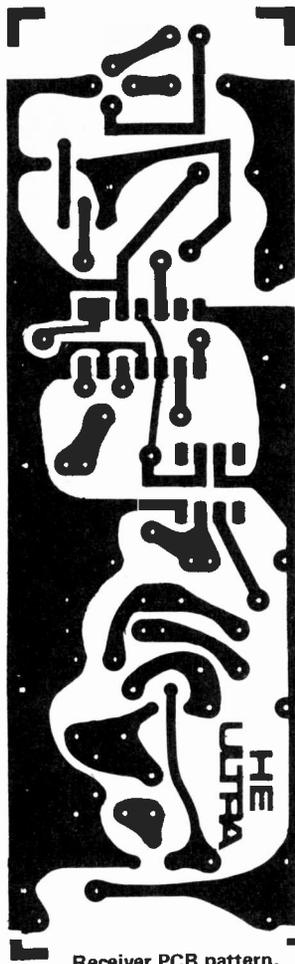
VARI-PITCH (MX333 ONLY): Variable pitch proportionate to reading, off at open circuit. Increasing frequency as resistance approaches "0" on ohms function. Increasing frequency as input increases on volts and current functions. RESPONSE: Instantaneous (less than 100 msec.)

LOGI-TRAK (MX333 ONLY): 0-20V range using Hickok SP-7 (not incl.) or other 10:1 scope probe. HI/LO INDICATION: High or low audible tone, PULSE INDICATION: Audible "chirp" plus lighted colon on display, MIN PULSE WIDTH: 5 nsec typical. MAX FREQUENCY: 80 MHz. ACCURACY:  $\pm 0.25\% + 1$  digit + probe accuracy. INPUT IMPEDANCE: 10MΩ. INPUT PROTECTION: 300V DC or RMS.

GENERAL: Dimensions: 2.2 x 6.7 x 6 in. (5.6 x 17 x 15.2 cm); Weight: 22 oz (7kg); Power: 9V battery (incl.) or Hickok AC adapter; Battery Life: 200 Hrs. typical; Temperature: 0-50°C operating, -35 to +60°C storage. INCLUDES: Deluxe safety test leads, battery, manual and belt clip.

#### ACCESSORIES

SP-7 10:1 Divider Probe for Logi-Trak Input	...	\$50.75
TP-20 (C or F) Temperature Probe	.....	\$72.50
VP-14 RF Probe (0.25V to 40V rms)	.....	\$50.75
VP-40 40KV DC Probe (0 to 40KVDC)	.....	\$56.00
CC-4 Deluxe Vinyl Carrying Case	.....	\$23.00
RC-3 AC Adapter	.....	\$12.50



Receiver PCB pattern.

ULTRASONIC SPEAKER PARTS LIST

**TRANSMITTER**

RESISTORS	(all 1/4W, 5%)
R1	470k
R2	22k
RV1	22k min horiz. preset
CAPACITORS	
C1	180p polystyrene
SEMICONDUCTORS	
IC1	4001B
MISCELLANEOUS	
Tx Ultrasonic transmitter transducer.	PB1
SPST push-button PCB.	

R12	330R
R13	39k
CAPACITORS	
C1	470μ elect.
C2, 4	1μ tant.
C3	In polystyrene
C5	μ47 tant.
C6	μ33 tant.
C7	1,000μ elect.
SEMICONDUCTORS	
IC1	3140
IC2	4027B
Q1, 2, 3	2N3904
Q4	2N3053
D1, 2	1N4148
D3	1N4001
BR1	1A Bridge Rec.
ZD1	9V1 400 mW zener

**RECEIVER**

RESISTORS	(all 1/4W, 5%)
R1	47k
R2	18k
R3, 6, 11	10k
R4	1k5
R5, 7	100k
R8	1k2
R9	120k
R10	4M7

MISCELLANEOUS	
Rx Ultrasonic receiver transducer.	Transformer 9V
	200mA. SW1 SPST switch. RLA 12V relay
	P.C.B.

Continued from page 32

PROBLEMS? NEED PCBs? Before you write to us, please refer to 'Component Notations' and 'PCB Suppliers' in the Table Of Contents. If you still have problems, please address your letters to 'ETI Query', care of this magazine. A stamped, self addressed envelope will ensure fastest reply. Sorry, we cannot answer queries by telephone.

TECH TIPS

Linear Temperature To Frequency Transducer

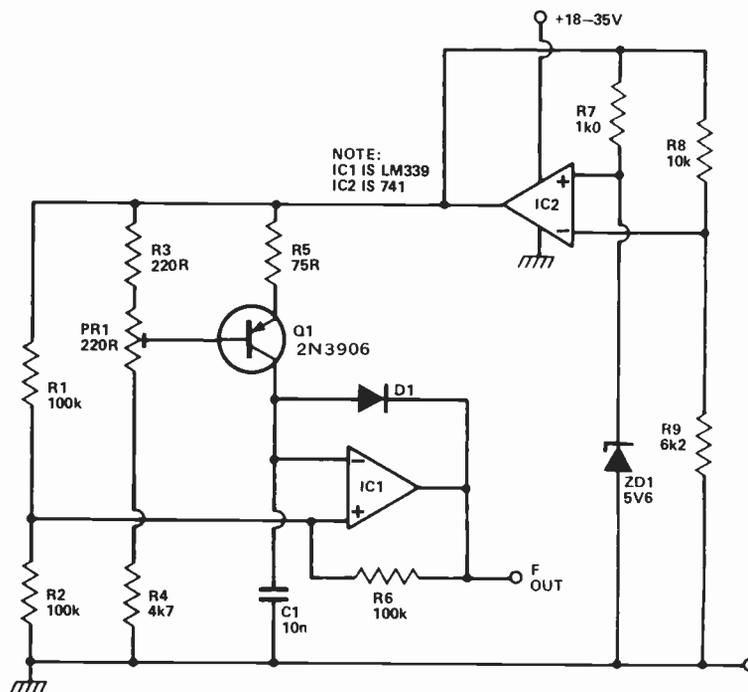
J.P. Macaulay

This circuit provides a linear increase of frequency of 10 Hz/°C over 0-100°C and can thus be used with logic systems, including microprocessors.

The heart of the system is the temperature probe Q1 whose Vbe changes at 2.2 mV/°C. Since this transistor is incorporated in a "constant" current source circuit it follows that a current proportional to temperature will be available to charge C1.

The circuit is powered via the temperature stable reference voltage supplied by the 741. Comparator IC1 is used as a Schmitt trigger, the output of which is used to discharge C1 via D1. To calibrate the circuit Q1 is immersed in boiling distilled water and PR1 adjusted to give 1 kHz output.

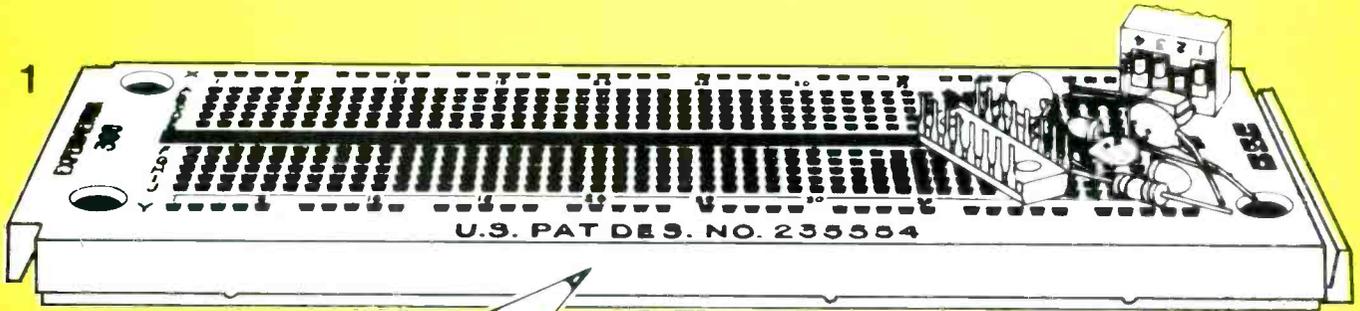
The prototype was found to be accurate to within 0.2°C.



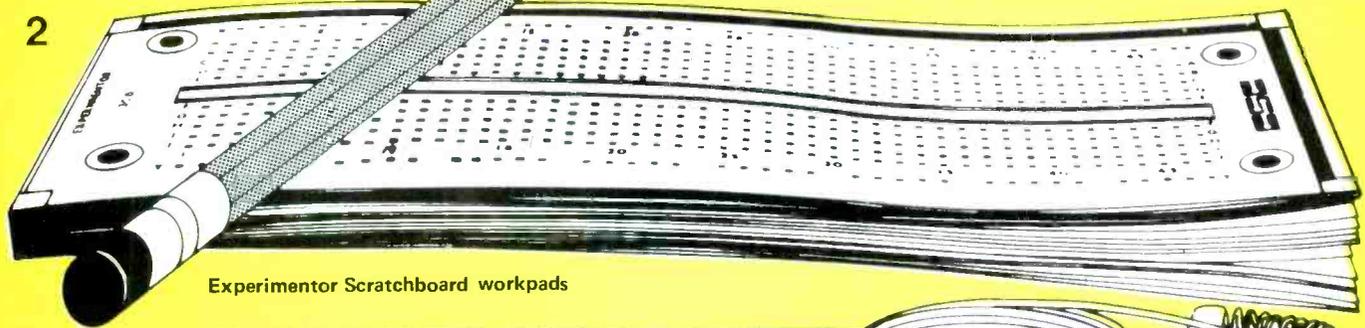
NOTE:  
IC1 IS LM339  
IC2 IS 741

# You can't beat The System!

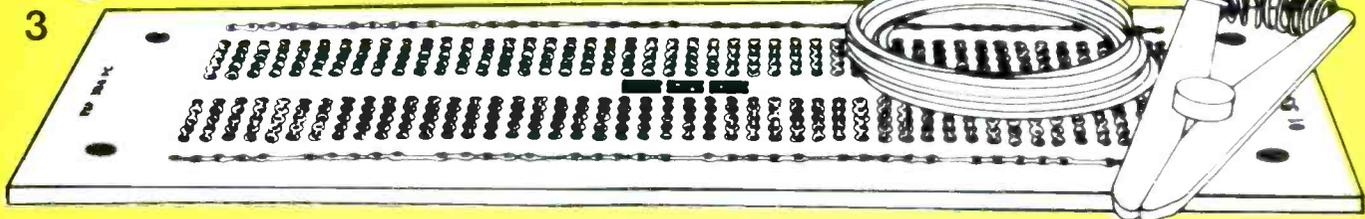
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2  
Experimenter Scratchboard workpads



3  
Experimenter Matchboard pre-drilled PCBs.

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You already know how big a help our Experimenter solderless breadboards can be. Now we've taken our good idea two steps further.

We've added Experimenter Scratchboard workpads, with our breadboard hole-and-connection pattern printed in light blue ink. To let you sketch up a layout you already have working so you can reproduce it later.

With Experimenter Matchboard you can go from breadboard to the finished product nonstop! We've matched our breadboard pattern again, this time on a printed circuit board, finished and ready to build on. All for about \$4.25.

There's even a letter-and-number index for each hole, so you can move from breadboard (where they're moulded) to Scratchboard (where they're printed) to Matchboard (where they're silkscreened onto the component side) and always know where you are.

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4	EXP-304, which includes four items Two Matchboards, an EXP-300 breadboard and a Scratchboard workpad	\$26. <sup>70</sup>

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Z80-CTC	2.5 MHz 7.77	Z80-SIO/9	2.5 MHz 21.91
Z80-CTC	4.0 MHz 9.95	Z80-SIO/9	4.0 MHz 28.00
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Z80-DMA	4.0 MHz 29.94	Z80-DART	4.0 MHz 22.88

### MICROPROCESSOR CHIP SETS

Part No.	Price	Part No.	Price
8080A CPU	6.80	6800 CPU	7.09
8085 CPU	11.67	6802 CPU	14.24
8212	2.93	6810	3.89
8214	4.75	6821	3.89
8216	2.57	6850	3.89
8224	4.49	6852	3.89
8226	2.93		
8228	6.47		
8251	7.74	6502 CPU	10.21
8253	12.25	6504 CPU	10.99
8255	7.35	6505 CPU	10.99
8257	14.24	6522	7.44
8259	14.24	6532	12.29
		6533	16.32
		6551	16.12

### EPROM'S

C1702A	\$11.64
2K 1US	
C2708	\$ 6.18
1K x 8 450 ns	
CT2716/TMS2516 (Intel version)	\$ 9.07
16K 450NS Single 5V Supply	
TMS2532 (T 1 Pin Out)	\$ 25.55
CT2732 (Intel version)	\$ 25.55
32K (4096 x 8) 450 ns	
TMS2564	\$182.00
64K (8K x 8) 450 ns	

### MOS MEMORIES

**MOS Static RAM's**

Part No.	Price
2101-35 1K (256 x 4) 350NS 22 PIN	5.14
2102-25 1K (1K x 1) 250NS 16 PIN	1.42
P2111-45 1K (256 x 4) 450NS 18 PIN	4.49
P2112-35 1K (256 x 4) 350NS 18 PIN	3.25
21144 Low Power 4K (1024 x 4) 300NS	3.87
2147 4K (4K x 1) 55NS	12.94
2147 4K (4K x 1) 70NS	11.64

### PROM'S

74S288	4.49	256 bit, 16 PIN	
74S188	4.49	256 bit, 16 PIN	
93427/82S129	4.75	1K, 16 PIN	
93417/82S126	4.75	1K, 16 PIN	
93446/7621	6.44	2K, 16 PIN	
93436/7620	6.44	2K, 16 PIN	
93453/7643	11.51	4K, 18 PIN	
93448/7641	12.94	4K, 24 PIN	
93451/82S181	25.94	4K, 24 PIN	
82S195/7128	36.34	8K, 18 PIN	
74S478/7138	25.79	8K, 24 PIN	
82S191/7138	101.40	16K, 24 PIN	

### TTL

**STANDARD, SCHOTTKY & LOW POWER SCHOTTKY**

7400N	29	74246N	1.77	74LS54N	.27
7401N	29	74247N	1.61	74LS55N	.31
7402N	31	74251N	.99	74LS73N	.42
7403N	31	74259N	2.93	74LS74N	.49
7404N	31	74273N	2.93	74LS75N	.47
7405N	31	74276N	1.61	74LS76N	.94
7406N	47	74278N	3.09	74LS78N	.38
7407N	47	74279N	7.77	74LS83N	.98
7408N	31	74283N	1.55	74LS85N	1.16
7409N	31	74293N	.94	74LS86N	.55
7410N	31	74298N	1.09	74LS90N	.51
7412N	59	74351N	2.86	74LS91N	1.16
7413N	57	74365AN	.90	74LS92N	.60
7414N	58	74366N	.90	74LS93N	.55
7416N	47	74367AN	.90	74LS95N	.62
7417N	46	74368AN	.90	74LS96N	.75
7420N	38	74390N	1.25	74LS107N	.48
7422N	47	74393N	1.77	74LS109N	.49
7423N	47			74LS112N	.49
7425N	42	74500N	.57	74LS122N	.62
7426N	57	74502N	.62	74LS123N	.83
7427N	42	74503N	.62	74LS125N	.70
7428N	59	74504N	.90	74LS126N	.60
7430N	29	74505N	.90	74LS132N	.85
7432N	73	74508N	.73	74LS133N	2.03
7433N	57	74509N	.90	74LS36N	.57
7437N	46	74510N	.73	74LS138N	.74
7438N	46	74511N	.90	74LS139N	.74
7440N	29	74520N	.73	74LS145N	1.55
7442N	57	74530N	.62	74LS147N	3.24
7445N	1.16	74532N	1.16	74LS148N	1.77
7446N	1.09	74537N	2.15	74LS151N	.55
7447AN	74	74538N	2.15	74LS153N	.47
7450N	29	74540N	.57	74LS155N	.94
7451N	42	74551N	.90	74LS156N	1.89
7453N	40	74574N	.90	74LS157N	.70
7454N	42	74585N	3.11	74LS158N	.68
7472N	47	74586N	1.77	74LS160N	.94
7473N	49	745112N	1.77	74LS161N	.90
7474N	49	745114N	1.95	74LS162N	2.05
7475N	55	745124N	3.33	74LS163N	.90
7476N	49	745132N	1.61	74LS164N	.77
7483AN	.62	745133N	1.27	74LS165N	1.42
7484AN	1.77	745134N	.90	74LS166N	2.55
7485AN	.86	745135N	.86	74LS170N	2.38
7486N	55	745138N	1.50	74LS173N	.83
7490AN	42	745139N	1.50	74LS174N	.51
7491AN	55	745140N	1.89	74LS175N	.55
7492AN	49	745151N	1.53	74LS181N	2.85
7493AN	49	745153N	1.53	74LS189N	10.21
7494AN	.88	745157N	1.53	74LS197N	1.09
7495AN	.77	745158N	1.89	74LS191N	.09
7496N	.77	745159N	3.71	74LS192N	.90
7497N	2.93	745162N	4.81	74LS193N	1.29
74100N	1.79	745163N	4.80	74LS194N	2.55
74104N	.83	745168N	6.01	74LS196N	1.14
74107AN	.82	745169N	6.44	74LS197N	1.09
74109N	.59	745174N	1.29	74LS221N	1.42
74110N	.59	745175N	1.29	74LS240N	1.27
74111N	.75	745181N	5.81	74LS241N	1.27
74116N	1.79	745182N	3.76	74LS242N	1.27
74120N	1.63	745189N	12.94	74LS243N	1.42
74121N	.70	745194N	3.07	74LS244N	1.77
74123N	.68	745195N	2.46	74LS257N	.70
74125N	.68	745200N	12.94	74LS247N	.99
74126AN	.68	745225N	8.91	74LS248N	1.56
74128N	.68	745240N	4.88	74LS249N	1.29
74129N	.90	745241N	4.88	74LS251N	1.25
74132N	.59	745244N	4.88	74LS253N	.73
74136N	.68	745251N	1.92	74LS259N	.90
74141N	1.09	745259N	9.07	74LS258N	.77
74142N	3.87	745257N	1.68	74LS259N	2.57
74143N	4.47	745258N	1.68	74LS260N	1.29
74144N	4.47	745266N	1.89	74LS266N	.57
74145N	.87	745274N	25.94	74LS273N	1.55
74147N	1.61	745275N	25.94	74LS275N	6.44
74148N	1.16	745280N	3.71	74LS279N	.70
74150N	1.87	745283N	5.06	74LS280N	2.57
74151N	.55	745289N	9.07	74LS283N	1.16
74153N	.49	745373N	4.49	74LS290N	1.01
74154N	2.18	745374N	4.49	74LS293N	.49
74155N	.68	745381N	10.34	74LS298N	1.25
74157N	.68	745412N	1.97	74LS299N	3.25
74159N	2.13	745471N	10.99	74LS320N	3.58
74160N	.62	745472N	18.93	74LS321N	5.14
74161AN	.90	745474N	19.44	74LS322N	6.44
74162N	.77	745476N	10.99	74LS323N	6.44
74163AN	.82	745478N	22.04	74LS324N	3.25
74164N	.82	745481N	1.74	74LS348N	3.45
74165N	.82	74LS00N	.22	74LS352N	.76
74166N	.94	74LS01N	.22	74LS353N	2.15
74170N	2.57	74LS02N	.29	74LS362N	12.94
74172N	7.63	74LS03N	.29	74LS365N	.88
74173N	1.03	74LS04N	.31	74LS366N	.88
74174N	.85	74LS05N	.31	74LS367N	.94
74175N	.77	74LS08N	.25	74LS368N	.94
74176N	1.03	74LS09N	.31	74LS373N	1.79
74178N	1.50	74LS10N	.25	74LS374N	1.79
74179N	1.50	74LS11N	.31	74LS375N	2.57
74180N	.98	74LS12N	.31	74LS377N	1.87
74182N	.62	74LS13N	.33	74LS378N	1.55
74184N	3.84	74LS14N	.55	74LS379N	1.55
74185N	3.84	74LS20N	.23	74LS390N	1.77
74190N	.90	74LS21N	.23	74LS393N	1.63
74191N	.99	74LS26N	.51	74LS395N	1.76
74192N	.90	74LS27N	.38	74LS447N	.48
74193N	1.14	74LS30N	.23	74LS490N	2.95
74194N	1.14	74LS32N	.47	74LS630N	110.50
74195N	.60	74LS37N	.42	74LS669N	1.55
74196N	1.01	74LS50N	.42	74LS670N	3.07
74197N	1.01	74LS42N	.57		
74198N	2.03	74LS47N	.88		
74199N	2.03	74LS48N	1.29		
74221N	.88	74LS51N	.27		

**UART'S**

AYS-1013A 40 Khz Single 5V Supply **Special 5.14**

**IK CMOS RAM**

5101 1K (256 x 4) 450NS 22 PIN Low Power 5.14

**4K CMOS RAM**

P6504 4K (4K x 1) 550NS 18 PIN 110MW 10.34

P6514 4K (1K x 4) 450NS 18 PIN 110MW 9.04

**SHIFT REGISTERS**

3341APC FIFO 1 MHz 6.47

3347PC 80 bit 5.14

### LINEAR I.C.'s

LM301AN-8	.44	LM739CN-14	1.69
LM307N-8	.38	LM741CN-8	.38
LM308N-8	1.16	LM747CN-14	.73
LM308CH	1.24	LM358N-8	.51
LM309K	2.03	LM458N-8	.51
LM310HC	1.94	LM488N-14	.86
LM311N-8	1.09	LM489N-14	.86
LM313N-8	.70	LM221CN-14	3.58
LM317T	1.29	LM734CH	5.04
LM318N-8	1.63	LM734CN-14	1.11
LM318N-8	2.03	LM732CN-14	.62
LM323K	6.44	LM733CN-14	1.77
LM324N	.60	LM733CN-14	1.77

### PROM'S

CD-1001BE	.25	CD4026BE	2.07	CD4068BE	.31	CD4516BE	1.03
CD-10							