$1.25

1973 POPULAR ELECTRONICS ELECTRONIC EXPERIMENTER'S HANDBOOK

Build a...

Digital Measurements Lab
3-Channel Time Receiver
Light-Operated Switch
Hi-Fi Power Amplifier
Moisture Sensor
SCA Adapter
Time-Period Module
Time-Base Calibrator
Liberator
Digital Thermometer
Digital VOM
Leslie-Effect Simulator
Transistor Tester
Combination Lock
Exposure Lightmeter
40-Meter Transmitter
Timbre Gate

Plus...

The Numbers Game
Electro-Culture
The JK Flip-Flop
Fatal Current
Reactance Chart
Color Codes Chart

Build the New E-V "Universal" 4-Channel Decoder

18141

The best time to upgrade your component system is before you buy it.

If you're a typical reader of this magazine, you most likely have a sizeable investment in a component system. So our advice about upgrading might come a little late.

What you might have overlooked, however, is the fact that your records are the costliest and most fragile component of all. As well as the only one you will continue to invest in.

And since your turntable is the only component that handles these valuable records, advice about upgrading your turntable is better late than never.

Any compromise here will be costly. And permanent. Because there is just no way to improve a damaged record.

If the stylus can't respond accurately and sensitively to the rapidly changing contours of the groove walls, especially the hazardous peaks and valleys of the high frequencies, there's trouble. Any curve the stylus can't negotiate, it may lop off. And with those little bits of vinyl go the high notes and part of your investment.

If the record doesn't rotate at precisely the correct speed, musical pitch will be distorted. No amplifier tone controls can correct this distortion.

If the motor isn't quiet and free of vibration, an annoying rumble will accompany the music. You can get rid of rumble by using the bass control, but only at the expense of the bass you want to hear.

Experienced component owners know all this. Which is why so many of them, especially record reviewers and other music experts, won't play their records on anything but a Dual. From the first play on.

Now, if you'd like to know what several independent test labs say about Dual, we'll send you complete reprints of their reports. Plus a reprint of an article from a leading music magazine telling you what to look for in record playing equipment. Whether you're upgrading or not.

Better yet, just visit your franchised United Audio dealer and ask for a demonstration.

You'll find Dual automatic turntables priced from $109.50 to $199.50. That may be more than you spent on your present turntable, or more than you were intending to spend on your next one.

But think of it this way. It will be a long, long time before you'll need to upgrade your Dual. **Dual**®

Dual 1215 S $109 50

Dual 1218, $155.00

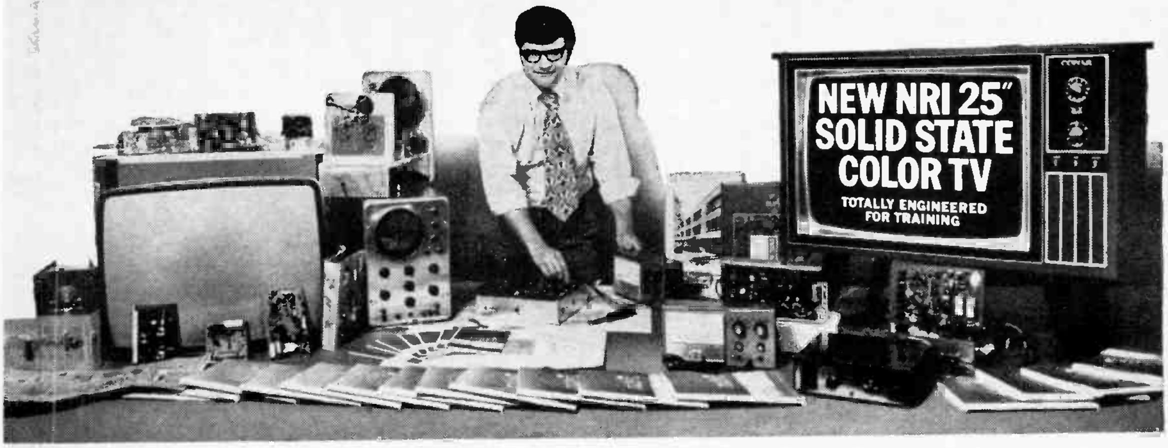
Dual 1229, $199.50

United Audio Products, Inc., 120 So. Columbus Ave., Mt. Vernon, N.Y. 10553

Exclusive U S Distribution Agency for Dual

CIRCLE NO. 17 ON READER SERVICE CARD

ou get more for your money from NRI



SOLID STATE TRAINING—*Learn-by-doing with NRI equipment. TV-Radio Servicing course includes 25" color TV, with handsome woodgrained cabinet at no extra cost; wide-band service type oscilloscope, color bar crosshatch generator, transistorized volt-Ohm meter, and solid-state radio kit. Other courses equally complete.*

NRI Programmed Equipment Gives You Priceless Confidence, Makes Learning TV-Radio, Electronics Fast and Fascinating

NRI pioneered the idea of supplying home-study students with custom designed training kits to give practical on-the-job experience as you learn. Today, NRI's "3-Dimensional" training can't be equalled. You get more value—from the exclusive Achievement Kit sent the day you enroll, to "bite-size" texts and custom training equipment. Learning TV-Radio, Electronics or Communications at home is easy, exciting, the NRI simplified, dramatized way.

BE A SKILLED TECHNICIAN IN AMERICA'S FASTEST GROWING INDUSTRY

Regardless of your educational background, you can learn the Electronics field of your choice the practical NRI way. The NRI color catalog, sent to you free and without obligation, tells you how you can qualify quickly to be a part of the fast growing Electronic Age; about engineering jobs in business, industry, broadcasting, government, now offered to men without college degrees. It will open your eyes to the great number of success opportunities available right now in the high-pay world of TV-Radio Servicing, Broadcasting-Communications and Industrial-Military Electronics. With NRI technical training, you can take your choice of a wide variety of career openings or have a business of your own. And if you choose one of five NRI courses that include FCC License preparation, *you must earn your FCC License or NRI refunds your tuition!*

MAKE $5 TO $7 AN HOUR EXTRA IN SPARE TIME STARTING SOON

Tens of thousands of NRI graduates are proof it is practical to train at home in your spare time. Keep your present job while preparing for a better one, and earn $5 to $7 an hour extra in spare time while you train, fixing sets for friends and neighbors. NRI shows you how. Equipment you build and keep becomes useful in your work.

STEP UP TO BETTER PAY, A BRIGHTER FUTURE

NRI can help you, but the decision to act must come from you. Decide now to move ahead . . . mail the postage-free card today for your FREE NRI color catalog. No obligation. No salesman will call. NATIONAL RADIO INSTITUTE, Electronics Division, Washington, D.C. 20016.

APPROVED UNDER GI BILL

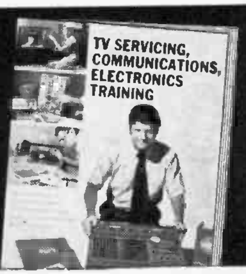
If you served since January 31, 1955, or are in service, check GI line on postage-free card or in coupon.

CASH IN ON THE BOOM IN COLOR TELEVISION

The NRI TV-Radio Servicing course includes your choice of black and white or color TV training equipment. Color TV needs thousands of trained men to keep pace with millions of sets being sold every year. NRI prepares you quickly. Cash in on the boom.

Mail insert card for your FREE NRI color CATALOG

No salesman will call



1973 POPULAR ELECTRONICS ELECTRONIC EXPERIMENTER'S HANDBOOK

COLOR CODE CHARTS 7

REACTANCE CHART 9

ASSEMBLING A UNIVERSAL TIGER .... Dan Meyer 11

Need a good stereo amp? Build this professional-quality, low- or high- (up to 125 watts per channel) power amplifier to meet all your audio needs. Hirsch-Houck Labs rates it among the "best."

BUILD A MOISTURE SENSOR .... H. St. Laurent 22

ASSEMBLE A DIGITAL MEASUREMENTS LAB .... Daniel Meyer 25

This low-cost, accurate, and flexible instrument can be used alone or expanded to provide additional functions using the circuits shown on pages 50 (Time-Period Module), 76 (Digital Thermometer Module), and 96 (Digital Volt-Ohmmeter). Although its construction takes time and care, the completed unit will provide you with a sophisticated "test bench" for present as well as future projects.

BUILD THE E-V 4-CHANNEL UNIVERSAL DECODER .... Fred Nichols 38

Join the ranks of those experimenting with "quadrasonic" sound reproduction. Build the new "Stereo-4" universal decoder, developed by Electro-Voice, which will work with tapes and discs encoded by the E-V, CBS/Columbia SQ, and Sansui processes. The chip needed to construct the decoder is now available, for the first time, to our readers.

BUILD A THREE-CHANNEL TIME RECEIVER .... Charles Caringella 43

TIME-PERIOD MODULE FOR THE DIGITAL MEASUREMENTS LAB .... Daniel Meyer 50

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Increase your odds of beating a burglar by constructing this lock which can provide 10,000 different combinations, in any four-digit code, and is self-protecting to foil random operation of the unit.

WINDING YOUR OWN OUTPUT TRANSFORMERS....Ed Francis **91**

ASSEMBLE A DIGITAL VOLT-OHMMETER PLUG-IN MODULE....Daniel Meyer **96**

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GETTING TO KNOW THE JK FLIP-FLOP....Frank H. Tooker **107**

Just because they are to be found in complex and sophisticated computers, there is no reason for you to think you can't understand and use them.

EXPERIMENTAL ELECTRO-CULTURE....L. George Lawrence **114**

LIGHT-OPERATED BISTABLE SWITCH....David C. Conner **120**

LESLIE EFFECT SIMULATOR....John S. Simonton, Jr. **122**

This all-electronic organ accessory, designed to be inserted between the keyed tone generators and the power amplifier, duplicates the acoustic effects of vibrato, tremolo, and Leslie.

CHEMICALS FOR ELECTRONICS....Lon Cantor **128**

BUILD AN SCA ADAPTER FOR FM RECEPTION....Vincent Wood **133**

THE QRP THING....Hank Olson, W6GXN **139**

A solid-state, battery-operated 40-meter transmitter that puts out a clean signal. Author reports that he has worked the entire West Coast of North America on or near 7135 kHz.

BUILDING A PRINTING EXPOSURE LIGHTMETER....A. A. Mangieri **146**

BUILDING AND USING THE XY CALIBRATOR....George Windolph **151**

Cover Photo by Bruce Pendleton
For complete details on how to build the new Electro-Voice
4-channel Universal Decoder, see page 38.

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COLOR CODE CHARTS

COLOR BAND SYSTEM

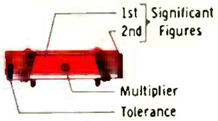
Resistors With Black Body Color Are Composition, Non-Insulated.
Resistors With Colored Bodies Are Composition, Insulated.
Wire-Wound Resistors Have The 1st Digit Color Band Double Width.

RESISTOR CODES (RESISTANCE GIVEN IN OHMS)

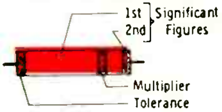
COLOR	DIGIT	MULTIPLIER	TOLERANCE
BLACK	0	1	±20%
BROWN	1	10	±1%
RED	2	100	±2%
ORANGE	3	1000	±3% •
YELLOW	4	10000	GMV•
GREEN	5	100000	±5% (EIA Alternate)
BLUE	6	1000000	±6%•
VIOLET	7	10000000	±12 1/2%•
GRAY	8	.01 (EIA Alternate)	±30% •
WHITE	9	.1 (EIA Alternate)	±10% (EIA Alternate)
GOLD		.1 (JAN and EIA Preferred)	±5% (JAN and EIA Preferred)
SILVER		.01 (JAN and EIA Preferred)	±10% (JAN and EIA Preferred)
NO COLOR			±20%

•GMV = guaranteed minimum value, or -0 + 100% tolerance.
±3, 6, 12 1/2, and 30% are ASA 40, 20, 10, and 5 step tolerances.

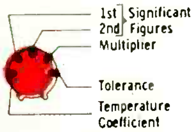
BODY-END-DOT SYSTEM



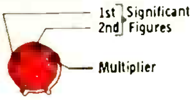
BODY - END BAND SYSTEM



DISC CERAMICS (5-DOT SYSTEM)



DISC CERAMICS (3-DOT SYSTEM)

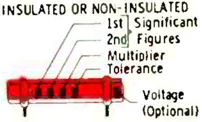


CERAMIC CAPACITOR CODES (CAPACITY GIVEN IN pF)

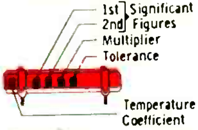
COLOR	DIGIT	MULTIPLIER	TOLERANCE		TEMPERATURE COEFFICIENT PPM/°C	EXTENDED RANGE TEMP. COEFF.	
			10 pF or LESS	OV 10MMF		SIGNIFICANT FIGURE	MULTIPLIER
BLACK	0	1	±2.0 pF	±20%	0(NPO)	0.0	-1
BROWN	1	10	±0.1 pF	±1%	-33(N033)		-10
RED	2	100		±2%	-75(N075)	1.0	-100
ORANGE	3	1000		±2.5%	-150(N150)	1.5	-1000
YELLOW	4	10000			-220(N220)	2.2	-10000
GREEN	5		±0.5 pF	±5%	-330(N330)	3.3	+1
BLUE	6				-470(N470)	4.7	+10
VIOLET	7				-750(N750)	7.5	+100
GRAY	8	.01	±0.25 pF		+30(P030)		+1000
WHITE	9	.1	±1.0 pF	±10%	General Purpose Bypass & Coupling		+10000
SILVER							
GOLD					+100 (P100, JAN)		

Voltage ratings are standard 500 volts for some manufacturers, but 1000 volts for other companies.

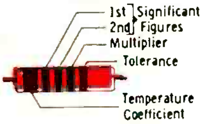
HIGH CAPACITY TUBULAR CERAMIC INSULATED OR NON-INSULATED



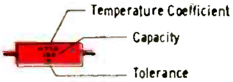
TEMPERATURE COMPENSATING TUBULAR CERAMICS



MOLDED-INSULATED AXIAL LEAD CERAMICS

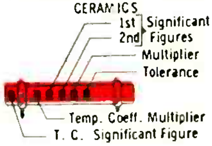


TYPOGRAPHICALLY MARKED CERAMICS



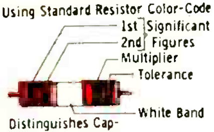
JAN LETTER	TOLERANCE	
	10 pF or LESS	OVER 10pF
C	±0.2 pF	
D	±0.5 pF	
F	±1.0 pF	±1%
G	±2.0 pF	±2%
J		±5%
K		±10%
M		±20%

EXTENDED RANGE T.C. TUBULAR CERAMICS



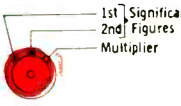
MOLDED CERAMICS

Using Standard Resistor Color-Code



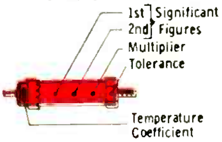
Distinguishes Capacitor From Resistor

BUTTON CERAMICS

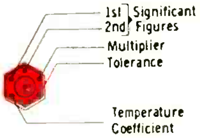


Viewed From Soldered Surface

STAND-OFF CERAMICS



FEED-THRU CERAMICS



MOLDED MICA CAPACITOR CODES

(Capacity Given In pF)

COLOR	DIGIT	MULTIPLIER	• TOLERANCE	CLASS OR CHARACTERISTIC
BLACK	0	1	20%	A
BROWN	1	10	1%	B
RED	2	100	2%	C
ORANGE	3	1000	3%	D
YELLOW	4	10000		E
GREEN	5		5% (EIA)	F(JAN)
BLUE	6			G(JAN)
VIOLET	7			
GRAY	8			I(EIA)
WHITE	9			J(EIA)
GOLD		.1	5%(JAN)	
SILVER		.01	10%	

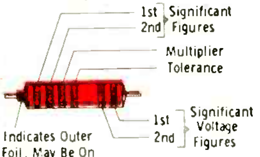
Class or characteristic denotes specifications of design involving Q factors, temperature coefficients, and production test requirements.
All axial lead mica capacitors have a voltage rating of 300, 500, or 1000 volts.
•or ±1.0 pF whichever is greater.

MOLDED PAPER CAPACITOR CODES

(Capacity Given In pF)

COLOR	DIGIT	MULTIPLIER	TOLERANCE
BLACK	0	1	20%
BROWN	1	10	
RED	2	100	
ORANGE	3	1000	
YELLOW	4	10000	
GREEN	5	100000	5%
BLUE	6	1000000	
VIOLET	7		
GRAY	8		
WHITE	9		10%
GOLD			5%
SILVER			10%
NO COLOR			20%

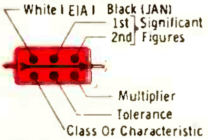
MOLDED PAPER TUBULAR



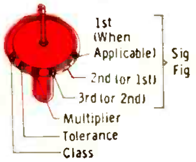
Indicates Outer Foil. May Be On Either End. May Also Be Indicated By Other Methods Such As Typographical Marking Or Black Stripe.

Add Two Zeros To Significant Voltage Figures. One Band Indicates Voltage Ratings Under 1000 Volts.

CURRENT STANDARD JAN AND EIA CODE

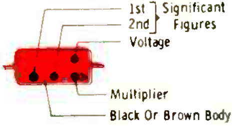


BUTTON SILVER MICA



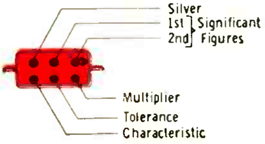
MOLDED FLAT PAPER CAPACITORS

(COMMERCIAL CODE)



MOLDED FLAT PAPER CAPACITORS

(JAN CODE)



To get more from your high fidelity system...put more of yourself in it.

In these days of instant everything, the idea behind Electro-Voice Custom Loudspeakers is a refreshing change of pace.

The custom loudspeaker concept asks you to do more than buy. It suggests that you participate directly in choosing the very best speaker system for your own special listening needs, speaker by speaker.

There's a complete, logical range of woofers, tweeters, mid-range drivers and accessories. And, with the help of your E-V dealer, you create the performance that suits you best.

You have the option of installing the speakers in new or existing furniture, or building them into walls, closets, or wherever.

Write today for our literature and list of E-V Custom Loudspeaker dealers.

CIRCLE NO. 5 ON READER SERVICE CARD

Either way you get the world's first universal four-channel decoder.

EVR-4X4
Four-Channel
AM/FM Receiver
$249.95

EVX-44
Universal
Four-Channel
Decoder $99.95

Now Electro-Voice offers our new universal decoder circuit built into both a stereo receiver and a 4-channel decoder.

The EVR-4X4 Receiver has every needed feature for 2- and 4-channel sound. Yet it costs no more than many 2-channel units that offer half the pleasure. And it will properly decode any matrix 4-channel input without switching. Ideal for playing SQ*, Stereo-4†, or any other matrixed records, tape, or FM sources.

The EVX-44 Universal Decoder creates a 4-channel control center for existing stereo equipment. Just add a second stereo amp and two more speakers. Unique separation enhancement circuit automatically adjusts front-back separation as required by program material.

Both the receiver and the decoder are also designed to accommodate 'discrete' inputs like 8-track tape if you wish. Hear the finest in four-channel sound at your Electro-Voice showroom. Where the excitement is!

E-V 4-channel products are produced under U.S. Patent No. 3,632,886
**T.M. CBS, Inc. †T.M. Electro-Voice, Inc.*

CIRCLE NO. 19 ON READER SERVICE CARD

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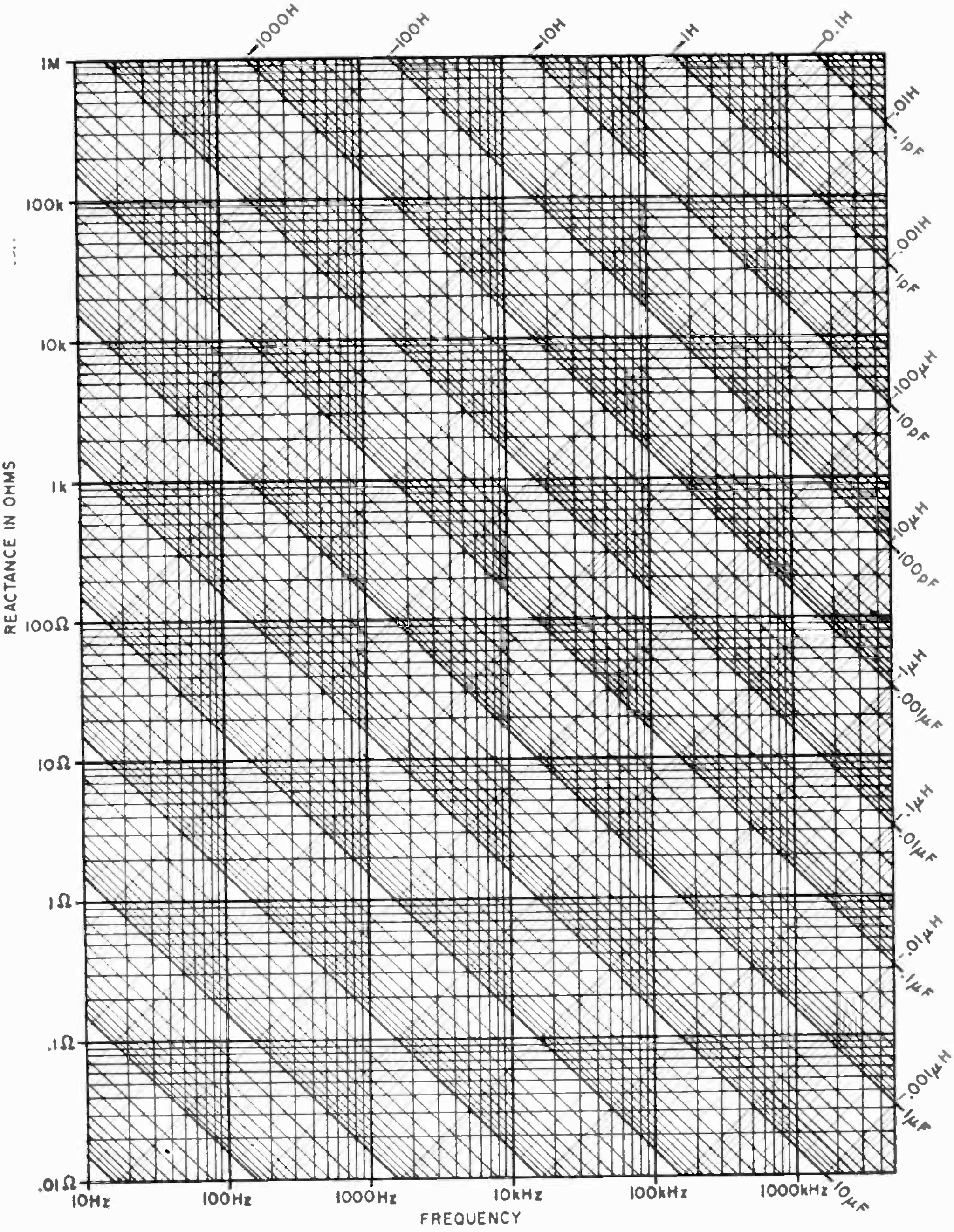
In Europe: Electro-Voice, S.A., Römerstrasse 49, 2560 Nidau, Switzerland
In Canada: EV of Canada, Ltd., Gananoque, Ontario

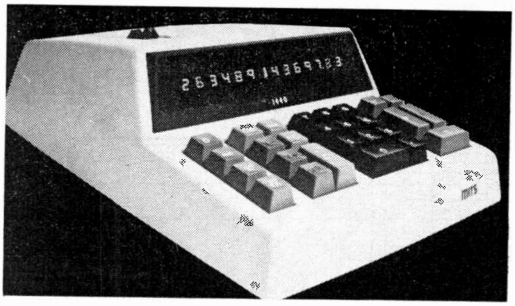
a Gulton
COMPANY

Electro-Voice®

REACTANCE CHART



our fourth generation family...



Square root operation and fourteen digit LED display makes this machine the choice of those who want the very best.

Sophisticated functions (made possible by unique MOS-LSI circuitry) include a constant data memory, 14 digit independent data memory, negative number entry, and exchange of operands . . . all are one touch operations!

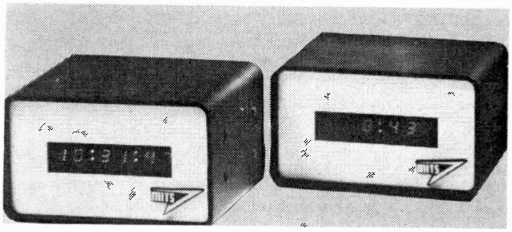
MITS has provided expanding capability for the 816 and 1440 by providing interfacing for the soon to be released programming module and printer to convert the basic unit into an impressive desk top computer.

1440 Kit	$199.95
1440 Assembled . . .	$249.95

16 digits, the highest output capacity of any MITS calculator, are available on the 816 models only. Constant data memory and computed fixed decimal system makes the 816 a useful tool for business or home use.

Human-engineered color coded keyboard and large electro-flourescent display gives both 816 models a degree of operating ease and flexibility unmatched in machines costing hundreds more.

816A Kit	$149.95
816A Assembled . .	$179.95
816B Kit	$159.95
816B Assembled . .	$189.95



Here are two new members in our fourth generation family of MITS digital products. MITS digital clocks feature large LED displays, 12 or 24 hour operation, highest quality components, A.C. operation, and individual time set buttons.

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CIRCLE NO. 9 ON READER SERVICE CARD

BY
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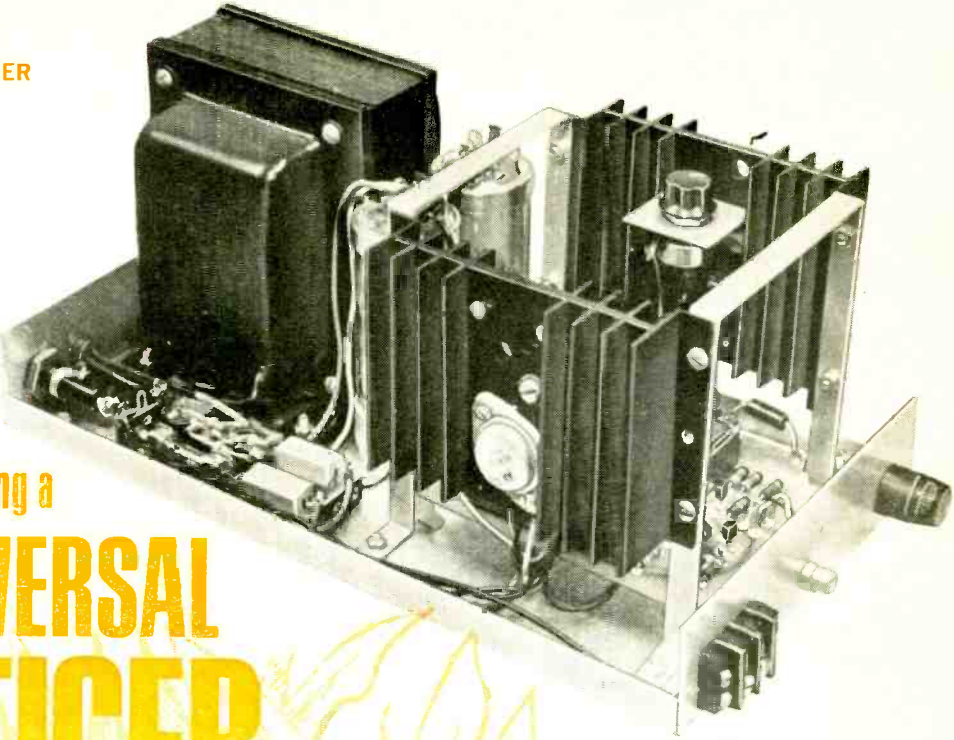


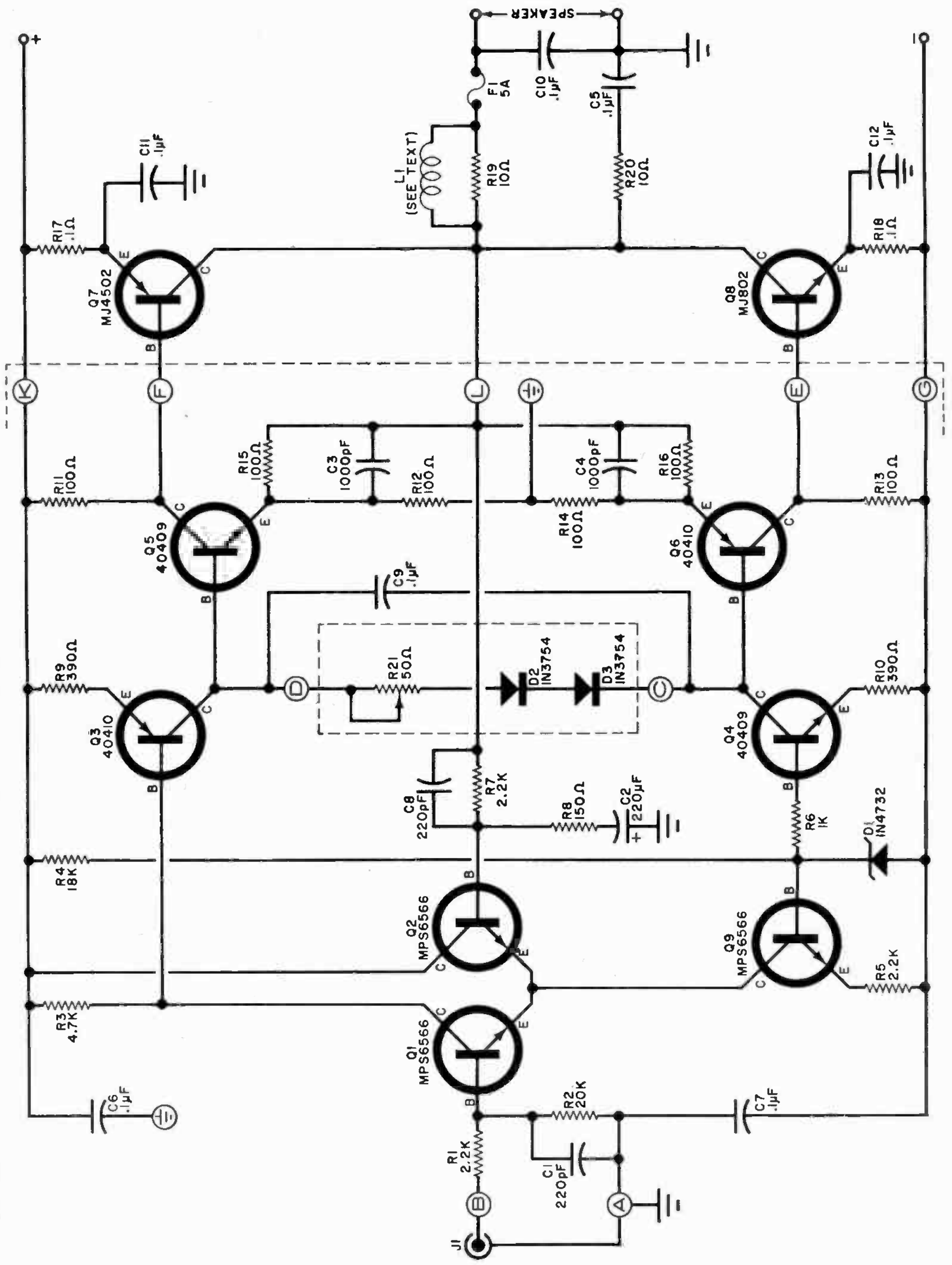
Assembling a UNIVERSAL TIGER

A UBIQUITOUS, 125-WATT-PER-CHANNEL DESIGN

This power amplifier design is the culmination of various "Tiger" amplifier projects developed by the same author. It is virtually indestructible and our exhaustive tests reveal that no combination of input-output mismatching and short circuits can cause amplifier failure. The performance specifications equal or better numerous commercial quality hi-fi power amplifiers.

NO HI-FI power amplifier can be all things to all men, but the "Universal Tiger" comes closer to the ideal than you might think. Consider the following: The output power of the Universal Tiger can be set to any level between 10 and 125 watts rms/channel by connecting to the amplifier circuit an appropriate power supply (15-40 volts dc). Over the audio spectrum, distortion is never more than 0.5% and it can be reduced to less than 0.5% at the user's option. The bandwidth between the 3-dB down points is 1-100,000 Hz!

And that's not all. No external load, short circuit, or input condition can cause amplifier failure. The most that will happen is a blown fuse. Thermal stability is so good that the output transistors operate with a heat sink temperature of 100° C (the boiling point of water) with no tendency to self-destruct. Nor is there any danger of speaker damage due to a starting transient since there are no large capacitors in the circuit that must charge up before normal operation can begin. When the Universal Tiger is


SPEAKER
+
−
C11 .1µF
R17 .1Ω
Q7 MJ4502
C10 .1µF
F1 5A
C5 .1µF
L1 (SEE TEXT)
R19 10Ω
R20 10Ω
C12 .1µF
R18 .1Ω
Q8 MJ802
K
F
L
E
G
R11 100Ω
R15 100Ω
C3 1000pF
R12 100Ω
R14 100Ω
C4 1000pF
R16 100Ω
R13 100Ω
Q5 40409
Q6 40410
C9 .1µF
R9 390Ω
R21 50Ω
D2 1N3754
D3 1N3754
D
C
R10 390Ω
Q3 40410
Q4 40409
C8 220pF
R7 2.2K
R8 150Ω
C2 220µF
R6 1K
D1 1N4732
R4 18K
Q2 MPS6566
Q9 MPS6566
R5 2.2K
R3 4.7K
Q1 MPS6566
C6 .1µF
R2 20K
C7 .1µF
R1 2.2K
C1 220pF
B
A
J1
B
C
E

turned on a small click is heard in the speaker system, then instant sound.

Construction. The driver and voltage amplifier stages of the Universal Tiger are assembled on a printed circuit board. The actual size etching guide and component placement diagram are shown in Fig. 2.

For those who have followed previous "Tiger" amplifiers, this design is an improved version of the "Tigers That Roar" which appeared in the July 1969 issue of POPULAR ELECTRONICS. Much of the design (including parts layout) is the same and conversion is rather simple.

The power supply circuit is simple and straightforward. However, depending on the amount of power you want from your amplifier, you will have to select the proper secondary voltage-current rating for transformer *T1* and the current rating of fuse *F1* from the table shown in Fig. 3.

If you want a lower output power, one of the low-voltage transformers listed in the table should be used. And with a 4-ohm load and a heavy-duty power supply (see Fig. 3) for *each* channel, a 125 watts rms/channel stereo system can be built.

Bear in mind that this circuit covers a mono version—for stereo two identical systems (including power supplies) should be built.

The power supply mounts directly on the steel chassis that accommodates the amplifier circuits. Point-to-point wiring is used

PARTS LIST
AMPLIFIER

C1, C8—220-pF capacitor
C2—220-µF, 6.3-volt electrolytic capacitor
C3, C4—1000-pF capacitor
C5-C7, C9—0.1-µF capacitor
C10-C12—0.1-µF disc capacitor
D1—4.7-volt zener diode (1N4732 or HEP602)
D2, D3—1N3754 or HEP 156 silicon diode
F1—5 ampere standard—NOT slow-blow—fuse
J1—Phono Jack
Q1, Q2, Q9—MPS-6566 transistor
Q3, Q6—Transistor (RCA 40410)
Q4, Q5—Transistor (RCA 40409)
Q7—Transistor (Motorola MJ4502)
Q8—Transistor (Motorola MJ802)
R1, R5, R7—2200-ohm, ½-watt
R2—20,000-ohm, ½-watt
R3—4700-ohm, ½-watt
R4—18,000-ohm, 1-watt
R6—1000-ohm, ½-watt
R8—150-ohm, ½-watt
R9, R10—390-ohm, ½-watt
R11-R16—100-ohm, ½-watt
R17, R18—0.1-ohm, 5-watt
R19, R20—10-ohm, 1-watt
R21—50-ohm potentiometer
All resistors 10% tolerance

Misc.—Steel chassis (6" x 11"); Wakefield Semiconductor No. NC403C or Thermalloy Co. No. 6403B heat sinks (2); two-lug ungrounded terminal block; four-lug terminal strip; 22-18-gauge aluminum stock for U and L brackets; #18 or larger stranded hookup wire; fuse holder; #6 and #4 machine hardware; diode clamps (2); solder lugs (2); three-lug terminal strips (2); transistor mounting hardware; solder; etc.

Note—The following items are available from Southwest Technical Products Corp., Box 32040, San Antonio, TX 78216; circuit board (No. 175B) for $2.75; complete amplifier as listed, but excluding chassis (No. 175C) for $30 plus shipping and insurance on 3 lb; complete stereo version with punched chassis and power supply (No. 2S-175) for $80 plus shipping and insurance on 17 lb; complete single-channel version with punched chassis and power supply (No. S-175) for $60 plus shipping and insurance on 14 lb.

Fig. 1. Circuit of power amplifier is simple and foolproof in design. Note absence of "weak link" large-value capacitors. Two such amplifier circuits are required for stereo system.

TECHNICAL SPECIFICATIONS

Output power: Up to 80 watts/channel with 8-ohm load; to 125 watts/channel with 4-ohm load

Distortion: Less than 0.5% from 20 to 20,000 Hz standard; less than 0.5% from 20 to 20,000 Hz with optional low distortion adjustment

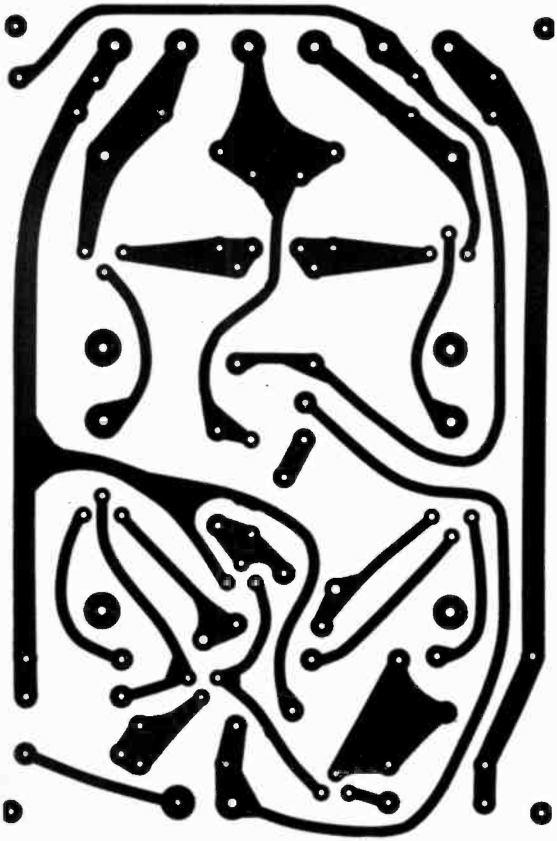
Frequency response: 3 dB down at approximately 1 and 100,000 Hz

Hum and noise: Better than 80 dB below 1 watt rms output

Damping factor: Better than 100 with 8-ohm load

Sensitivity: 1.5 volts rms input for full output

Stability: Completely stable with any source impedance; can be used with any load impedance as low as 3 ohms or capacitive loads to 1 µF.



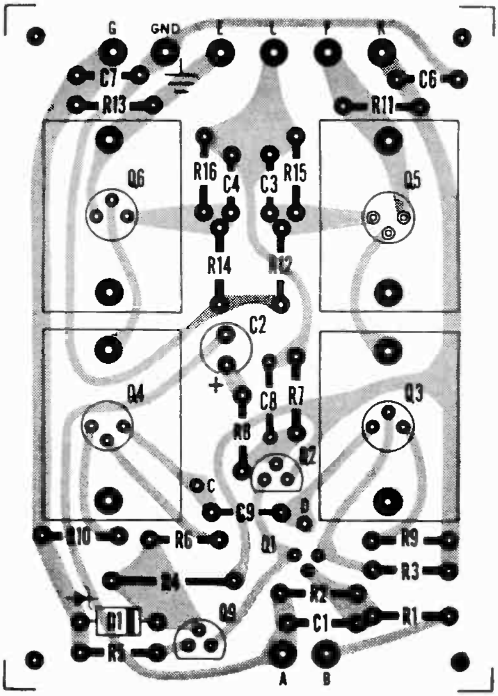


Fig. 2. Actual size etching guide is shown at left. In component layout and orientation diagram (above), boxes around Q3-Q6 represent outlines of heat sinks on these transistors. Note: connect the minus side of C2 to R8.

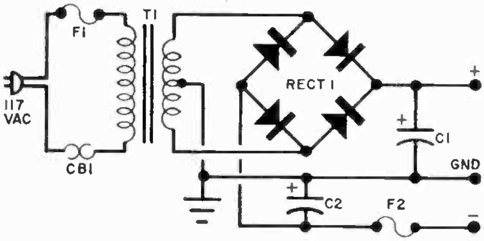


Fig. 3. Negative dc supply voltage is taken from right side of F2. Table lists ratings of F1 and T1 for desired amplifier output.

POWER SUPPLY COMPONENTS

Output Power	F1 Current	T1 Secondary Voltage & Current	DC Output
125 W*	2.6 A	62 V ct, 3 A	±40 V
80 W	2.6 A	62 V ct, 3 A	±40 V
40 W	1.5 A	45 V ct, 2 A	±28 V
20 W	1.0 A	34 V ct, 1.5 A	±20 V
10 W	1.0 A	24 V ct, 1 A	±15 V

**At 4-ohm load; all other power ratings referenced to 8-ohm load impedance.*

POWER SUPPLY PARTS LIST

C1, C2—4000-μF, 50-volt electrolytic capacitor

CB1—200° thermostat (No. L200 88-4, available for $5 from Elmwood Sensors, Inc., 1655 Elmwood Ave., Cranston, RI 02907)

F1—Slow-blow fuse (see table for rating)

F2—5-ampere standard—NOT slow-blow—fuse

RECT1—Full-wave bridge rectifier assembly (Motorola MDA962-3), or substitute four 3-ampere, 200 PIV silicon diodes

T1—117-volt primary (see table for secondary voltage and current ratings) power transformer

Misc.—Fuse holder; fuse block; ac line cord with plug; line cord strain relief; #18 or larger stranded hookup wire; #6 and #8 machine hardware; two-lug—neither grounded—terminal strips (2); five lug—center lug grounded—terminal strip; solder; etc.

Note—All above items available from Southwest Technical Products Co. as part of kits S-175 and 2S-175 (see Amplifier Parts List).

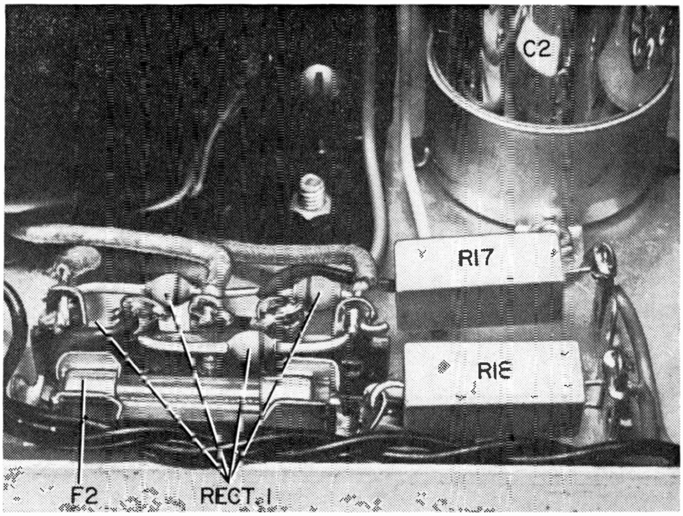


Fig. 4. Power supply secondary fuse and bridge rectifier assembly diodes mount on fuse block and terminal strip. Resistors R17 and R18 connect output of power supply to Q7 and Q8 in amplifier circuit.

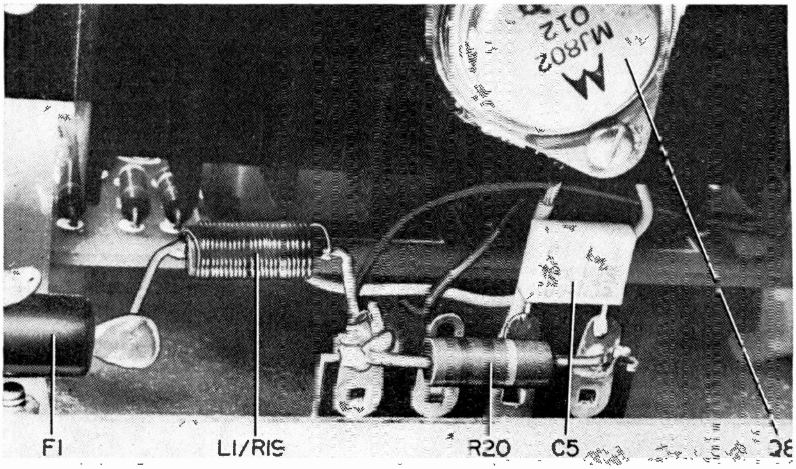
throughout, but be extremely careful during wiring to make sure diode and capacitor polarities are correct.

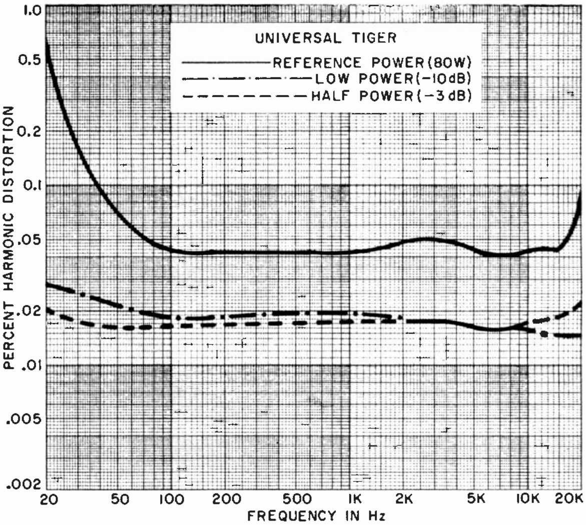
Unless you purchase the steel chassis with the complete kit from the source listed in the Amplifier Parts List, you will have to machine your own, using the photos given in this article to guide you.

After mounting and soldering into place the components on the circuit board, solder 8″ lengths of #18 or larger stranded hookup wire at hole locations C and D from the *foil* side of the board and at locations G, GND, E, L, F, and K from the component side. Twist together 2½″ lengths of black and white wires. Solder the black wire to A and the white wire to B on the component side. Then mount the circuit board in its proper location on the chassis.

At the opposite end of the chassis, anchor the power transformer with #8 hardware and the filter capacitors with #6 hardware. Fasten the power supply primary fuse holder and line cord with strain relief in their appropriate holes on the rear apron of the chassis. Then bolt down the secondary fuse block and the terminal strips associated with the power supply (see Fig. 4). Now, referring to Fig. 3, wire together the power supply circuit, using #18 or larger stranded hookup wire. (Note: Where #18 or larger wire is specified, do not substitute a smaller

Fig. 5. Close-wind a single layer of #22 enameled wire along the entire length of R19 and solder the wire ends to the resistor leads to make the L1/R19 assembly.





HIRSCH-HOUCK LABORATORIES

Project Evaluation

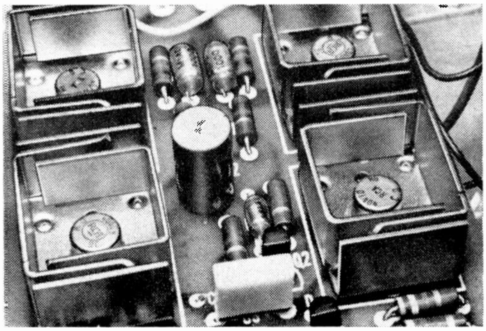
This is a very impressive basic amplifier for a home-brew project. The schematic diagram of the "Universal Tiger" is reminiscent of the Harman-Kardon "Citation 12," with an operational amplifier input configuration and overall direct-coupled feedback to maintain the speaker at dc ground. However, unlike the Citation 12, the Tiger uses complementary symmetry output transistors, and opposite polarities on the other transistors.

In general, we confirmed Mr. Meyer's specification figures. Where he claims a 0.01% or less distortion under most operating conditions, we feel that he is a trifle optimistic, but he certainly comes close. At 80 watts, the distortion is typically less than 0.05% from 70 to 17,000 Hz, rising to slightly in excess of 0.5% at 20 Hz. At half power or less, the distortion is typically less than 0.02% from 20 to 20,000 Hz.

At 1000 Hz, distortion falls from 0.15% at 0.1 watt to a minimum of 0.009% at 20 watts and rises to 0.1% at 85 watts, which is just below clipping level. These powers were measured with an 8-ohm load and a 117-volt line.

Intermodulation distortion was slightly higher. But at most power levels greater than one watt, it was less than 0.1%. We did not have enough voltage from our IM analyzer to drive the amplifier to more

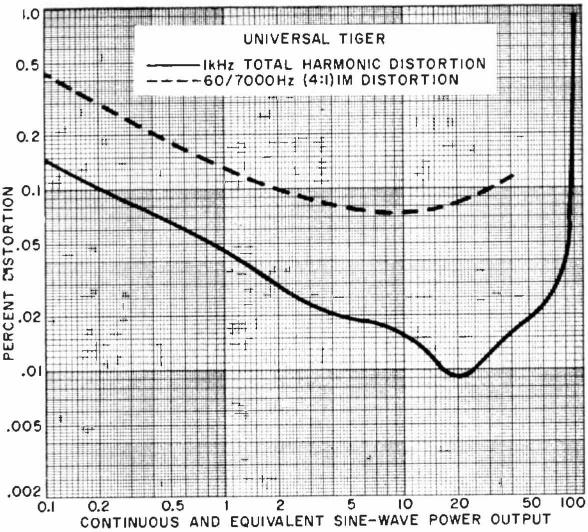
When mounting Q3-Q6 on printed circuit board, make certain that triangular lead configurations and heat sink tabs line up with holes in circuit board.



size wire. The circuits to which these wires connect carry as much as 10 amperes when the amplifier is driven to full power. If too small a wire size is used, power will be sacrificed and damping will suffer.)

Returning to the amplifier end of the chassis, mount input jack *J1*, the speaker fuse holder, and the output terminal block on the front apron. Solder the white wire from hole B on the circuit board to the center contact of *J1* and the black wire from hole A to the other lug on *J1*. Bolt a four-lug terminal strip (one lug grounded) to the chassis at the right of the circuit board and in line with the speaker fuse holder.

Close-wind one layer of #26 enameled



than 40 watts. These figures were measured with the bias adjust control set as received with best thermal stability. The low-level distortion could be reduced substantially with this control set at its opposite limit, where the measured reduction was from 0.045% to 0.023% at one watt and from 0.15% to 0.047% at 0.1 watt. However, it is hardly worth the bother to play with the bias adjust control, since we doubt that many people have the test equipment needed to make the adjustment.

Into 4 ohms, the maximum power at the clipping point was 97 watts; into 8 ohms, it was 92 watts; and into 16 ohms, it was 53 watts. An input of 0.9 volt was needed for a 10-watt output (our standard reference level) and hum and noise were 86 dB below 10 watts—a very low figure.

The frequency response of the Universal Tiger was ±0.2 dB from less than 10 Hz to beyond 20,000 Hz. It was down 0.3 dB at 5 Hz and 50,000 Hz, and the higher end was slightly better than claimed, being down 1.1 dB at 100,000 Hz and 3.9 dB at 200,000 Hz. Square wave tests showed a rise time of about 2.5 microseconds.

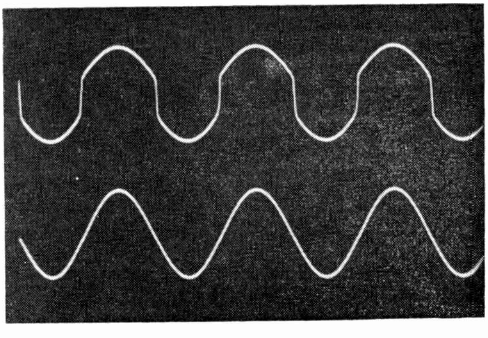
In all, the Universal Tiger is one of the best power amplifiers we have had the pleasure of testing. Short-circuiting the output at full power blew only the speaker fuse, while full power square-wave drive at 100,000 Hz blew only the power supply fuse after a few moments. But nothing damaged the amplifier circuit itself.

wire along the entire length of the body of *R19* (10-ohm, 1-watt resistor). Scrape the ends of the wire and solder them to the leads of the resistor. Then solder one lead of this *L1/R19* assembly to the center lug on the output fuse holder and connect the other lead to the lug nearest the fuse holder on the last terminal strip mounted.

As shown in Fig. 5, connect *C5* and *R20* to the terminal strip near *R19/L1*. Solder only the ground lug that serves as the tie point for both *C5* and *R20*. Temporarily set aside the chassis assembly.

Spread a film of silicone paste on the bottom of the case of *Q7* (MJ4502) and slip onto the pasted side a mica insulator. Spread

In upper waveform, crossover distortion at base of Q4 can be seen; lower trace shows undistorted waveform (F= 1000 Hz at 0.25 watt into 8-ohm load).



THEORY OF CIRCUIT DESIGN

The circuit of the Universal Tiger is a combination of operational amplifier and complementary output techniques. As shown in Fig. 1, transistors *Q1* and *Q2* form a differential amplifier. The input signal is applied to the base of *Q1*, with negative feedback on the base of *Q2*.

Zener diode *D1* maintains a constant bias voltage on *Q9* so that the current is constant through the base-emitter circuit of the transistor for any supply potential exceeding 4.7 volts. Hence, the *Q9* circuit functions as a constant-current source for *Q1* and *Q2*. Since *C2* provides for 100 percent negative feedback in the circuit, the output voltage offset is on the order of a few millivolts; any unbalance is immediately corrected by the *Q1/Q2* differential stage. And the ratio of *R7* to *R8* determines the amount of overall ac negative feedback. (Note that *C2* is the only element in the circuit that prevents the amplifier from responding down to dc)

From the collector of *Q1*, the amplified signal goes to the base of *Q3*. Normally, *Q3* would be the voltage amplifier that supplies the large voltage swing needed to drive the impedance-matching driver/output circuit. Here, however, it is limited in voltage gain and, working with *Q4*, it provides some unique characteristics.

In most of the common amplifier circuits, the voltage amplifier load resistor is split (as in Fig. A), and a "bootstrap" capacitor is connected to the output. This causes the voltage across collector load resistor R_L to remain at a constant value so that collector current is constant. If a constant-current circuit were not used, the amount of current available to drive the output circuit would drop to zero as the positive peaks of the waveform approach the peak positive potential of the power supply. This would result in a considerable amount of distortion on positive peaks that would be difficult or impossible to correct no matter how much degenerative feedback was used.

In the circuit of the Universal Tiger, an active current source is used instead of the more common bootstrap system. The results are the same with one important exception. The driver is not affected by supply voltage variations, due to the use of a constant load resistance, and a solution is provided for the crossover distortion problem because the active current source supplies a *constant* current to *Q3* at all times. The bootstrap circuit, obviously, does not.

Consider what happens if a portion of the output waveform is flat, as from A to B in Fig. B, due to an underbiased condition in the output stage. During this portion of the cycle, there is no increase in output voltage, and, as a result, no bootstrap action by the capacitor. And during this time the circuit does not provide the driver transistor with a constant current. With the active current source, this does not occur.

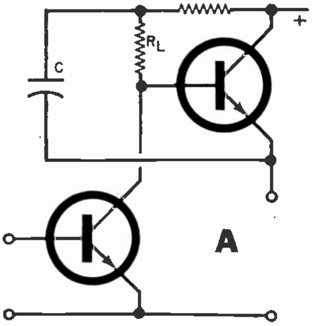
The active current source actually eliminates most of the crossover distortion that can occur due to an underbiased condition in the output circuit. We can see why if we consider what a constant current source does. It adjusts the voltage to keep the current through the circuit constant. But what happens if an underbiased condition exists in which *Q5* and *Q6* are both cut off?

As the driving voltage approaches zero, the active driver begins to turn off, but the voltage is not yet sufficient to cause the other driver to conduct. The loading on the current source becomes far less during this period since no current can be supplied to either driver while both are cut off. Hence, the current source increases the voltage in an attempt to maintain a constant current through the amplifier circuit. And the driving voltage jumps very quickly from the cutoff point of one driver to the conduction point of the other driver, resulting in minimum effect on the output waveform during the crossover period.

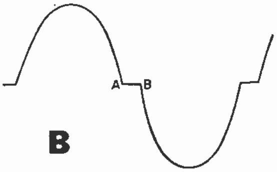
In a case like this, the bias on the output stage would normally be adjusted so that both output transistors are conducting at a low level to avoid crossover distortion. However, if it is possible to avoid having to make a critical bias adjustment, so much the better. Without making this adjustment, a considerable problem in thermal stability will result. As the transistor's temperature increases, the same bias voltage will cause a considerable increase in collector current, opening the way to possible thermal runaway. The use of diodes *D2* and *D3* in the Universal Tiger provides automatic adjustment which helps to eliminate the thermal problem.

The diodes are actually mounted on the heat sinks used for *Q7* and *Q8*. Now, any temperature changes in the output transistors are detected by the diodes, whose resistances vary with temperature. As the diode resistances change, so do the bias voltages to driver transistors *Q5* and *Q6*. Hence, if *Q7* and *Q8* begin to operate abnormally hot, the diodes increase the bias voltage to *Q5* and *Q6* and indirectly lower the operating temperature of *Q7* and *Q8*.

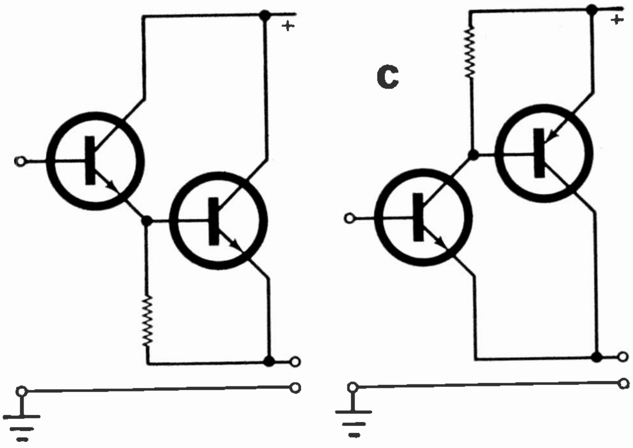
There are two types of compound connections commonly employed in the output stages of transistor power amplifiers. These are shown in Fig. C. The quasicomplementary circuits which use only one polarity of power transistors have one of each type in their output stage. The double emitter follower compound system requires two diode drops to bias it on, while the double common emitter



A



B



C

compound requires only one diode. This is a slight advantage since one less diode must be included in the temperature-compensated bias network.

Neither compound has any voltage gain: both require a driving signal voltage swing equal to the needed output. Since the common emitter driver compound at the right in Fig. C has 100 percent degenerative feedback, gain matching is not required in the output transistors, just as in the double emitter compound also shown.

Comparison of the two circuits as a power output stage gives the circuit at the right a slight advantage in lowest distortion and other areas if the circuit has overall negative feedback.

While testing a full complementary circuit using the common emitter compound, it appeared that there was really no reason why 100 percent degenerative feedback should be necessary or even desirable in the driver transistor. With a complementary circuit it is not necessary to rely on a double emitter follower for half of the output—which requires a second half with matching drive voltage requirements. A complementary circuit allows the use of any amount of degenerative feedback from zero to 100 percent in the driver portion of the circuit. A circuit with no degeneration can provide the maximum amount of voltage gain from two transistors, but it requires matched gains in the output transistors.

Since there is plenty of gain available elsewhere in the circuit of the Universal Tiger, a 50 percent feedback arrangement was selected for the driver stage. This gives a gain of two in the output stage and enough feedback to make transistor matching unnecessary.

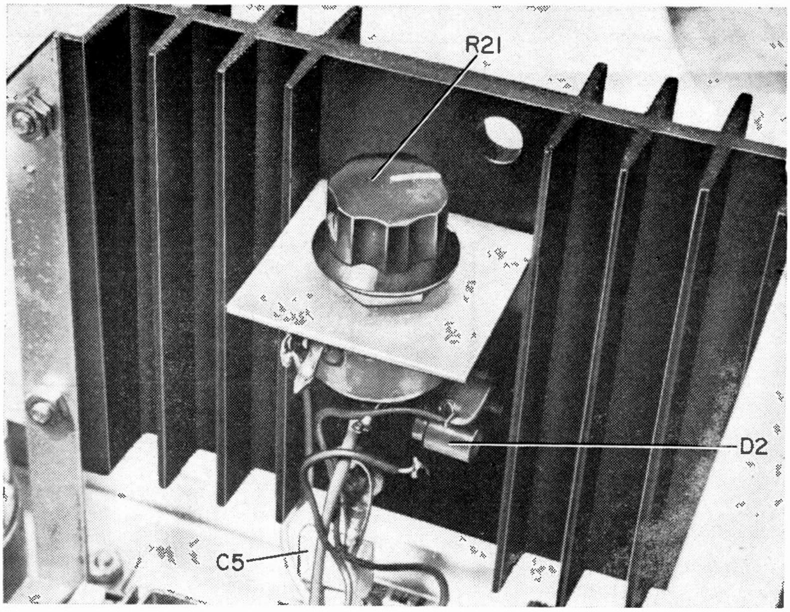
The gain of only two might appear to be too small, but it does provide several substantial benefits. First, the peak-to-peak drive voltage excursion need be only half that of the peak supply voltage. This simplifies design demands. Second, it is possible to keep distortion down to much lower levels in the driver circuit if it does not have to develop full supply positive and negative excursions. Additional temperature stability, by using 50 percent feedback in the output stage, is yet another advantage.

Even without the current drive system, the circuit of the Universal Tiger would have been many times more stable than circuits employing 100 percent degeneration in the driver. Another bonus is that the output stage is virtually failure proof.

If the output of the circuit in Fig. C is short circuited, or too low an impedance load is connected to it, the driver transistor would attempt to put enough current through the base-emitter junction of the output stage to bring the voltage up (due to overall feedback effects). This can cause the collector current rating of the driver transistor or the base-emitter rating of the power transistor, or both, to be exceeded. The same thing can also happen in the second circuit, but in a slightly different manner; therefore elaborate protection circuits must be designed to prevent this.

This situation cannot occur with a 50 percent feedback arrangement. The driver's emitter resistor limits the amount of current that can pass through the emitter-collector circuit and into the base of the output transistor. The base current is limited to a value that does not allow collector current in the output transistor to exceed its rating. Hence, short-proof protection is built in and works automatically.

Since the output transistors specified in Fig. 1 have a 30-ampere rating, a fuse in the output line and another in the primary circuit of the power supply transformer will circumvent any possible damage that might otherwise result from overloading. ◆



Distortion control R21 fastens to heat sink on which Q8 is mounted with small L bracket and machine hardware. Terminal strip for D2 mounts directly below R21.

another film of the paste on one of the heat sinks in the area over which *Q7* is to be mounted. Then seat *Q7* on the heat sink. Push a #4 machine screw through the mounting hole tabs in the case of the transistor, turn over the assembly, and slide onto each screw a shoulder fiber washer. Make sure that the shoulders engage the oversize holes in the heat sink. Then place a solder lug over the screw nearest the edge of the heat sink and a three-lug terminal strip and a diode case clamp over the other screw. Fasten the screws with appropriate nuts. Use #4 hardware to bolt *CB1* in place.

Repeat the above procedure for the second heat sink and *Q8* with the following changes. Anchor only the diode clamp and solder lug to the hold-down screws for *Q8*. Mount *R21* on an L bracket and fasten the bracket and a three-lug terminal strip to the heat sink with #4 hardware and shoulder fiber washers.

Slide *D2* and *D3* into the diode clamps and push onto the diode leads 1″ lengths of plastic tubing. Connect the leads to the *ungrounded* lugs of the terminal strips. Solder a 10″-long wire to the lug to which the *anode* lead of *D3* is connected and a 1″ wire from lug 3 of *R21* to the *anode* lug of *D2*. Then solder an 8″-long, #18 or larger wire to the solder lug on *Q7* and a 3″-long wire to the solder lug on *Q8*.

Use #6 hardware to bolt the U brackets to the chassis. Mount the heat sink assembly on which *Q7* is mounted to the left sides of the brackets. Solder the wire from hole C on the circuit board to the *cathode* lug of *D3* on the terminal strip. Connect and solder a 6″-long, #18 or larger wire between *R17* and the emitter lead of *Q7*. Then solder the lead from hole F on the circuit board to the base lead of *Q7*. Route the lead connected to the solder lug on *Q7* under the board, and connect it to the lug at the junction of *L1/R19* and *R20*.

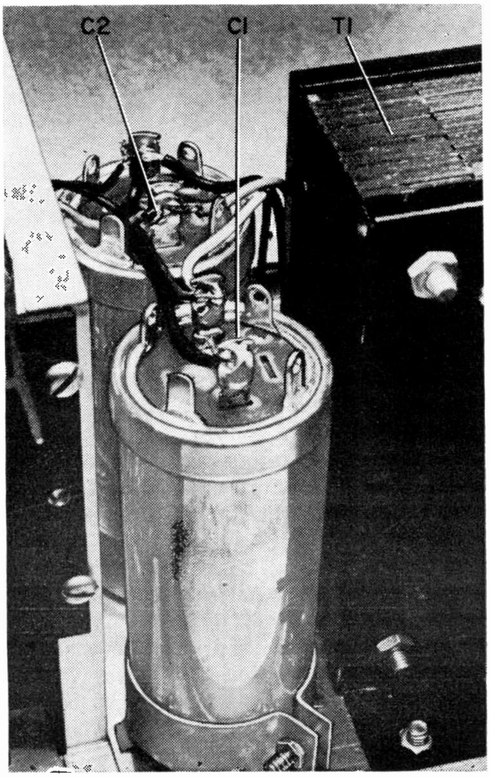
Now, mount the other heat sink assembly in place. Connect and solder the lead from the solder lug on *Q8* to the *L1/R19* and *R20* junction lug. (There should now be five wires connected to this lug.) Locate the lead from hole D on the circuit board and remove ¾″ of insulation from the free end. Connect and solder this wire to lugs 1 and 2 of *R21*. Route an 8″-long, #18 wire from the emitter of *Q8*, under the board, and to *R18*. Solder both connections. Then route the 10″ wire from the anode connection lug of *D3* under the board and connect the free end to the *cathode* connection lug for *D2*. Solder the wire from hole E on the board to the base lead of *Q8*.

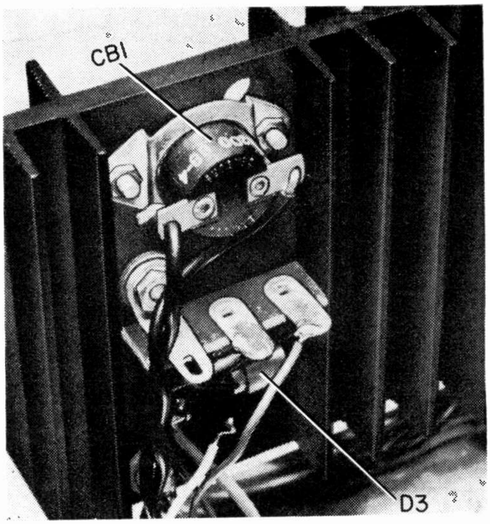
Finish the wiring as follows. Solder a 6″ wire between the side lug on the speaker fuse holder and the lug nearest the fuse holder on the output terminal block, and an 8″ wire from the ground lug on the rectifier bridge terminal strip to the other lug on the terminal block. Cut two wires to 12″ lengths, strip the ends, twist them together, and connect one end of the pair to the lugs on *CB1* and the other end to the lugs on the terminal strip located between the two fuse holders in the power supply. Finally, solder the free ends of the wires on the circuit board to the appropriate points in the power supply filter section.

Insert a 5-ampere *standard* fuse in both the speaker fuse holder and the power supply secondary fuse block. For the rating of the primary fuse, refer to the table in the power supply sidebar for the particular output power selected.

Adjustment and Use. If the Universal Tiger is to be used with any but the very best speaker system, the circuit can be assembled without distortion control *R21*. (In this event, simply connect the wire from hole D on the circuit board directly to the lug to which the anode of *D2* is connected.) However, with a first-rate speaker system where there is a possibility of noticing the difference between 0.1% and 0.01% distortion, *R21* should be added as shown.

Filter capacitors C1 and C2 in power supply mount between amplifier assembly and power transformer.





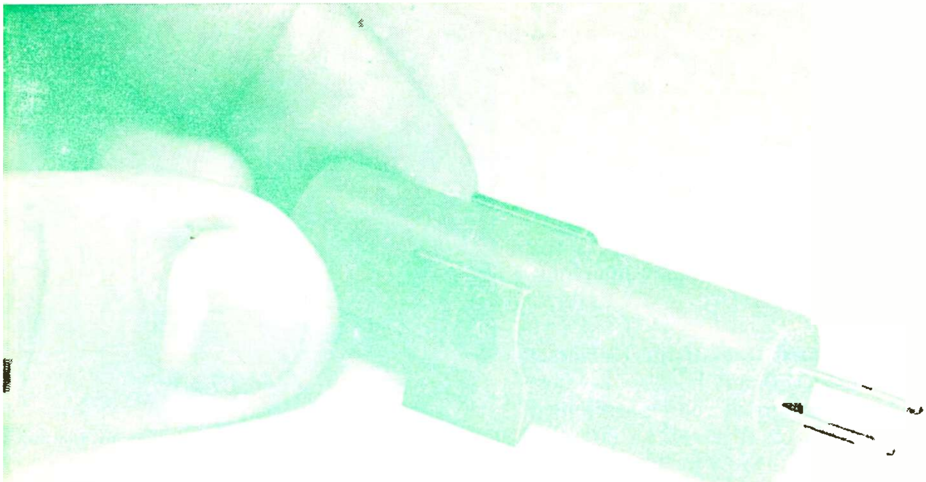
For proper operation, sensing element of thermal circuit breaker CB1 must contact Q7's heat sink.

Control *R21* allows adjustment of the bias to eliminate crossover distortion completely. Thermal stability will not be quite as good, but with a sound system there is little danger of overheating since few people would operate the amplifier continuously at its full rated power.

To set *R21*, adjust the potentiometer for minimum resistance and the amplifier for approximately a 1-watt output into a load. Observe the waveform at the base of *Q5* on an oscilloscope. Increase the resistance of *R21* until the waveform is distortion free. Check the idle current of the amplifier; it should be approximately 50 mA. Then seal the adjustment.

The Universal Tiger should give years of trouble-free operation if it is properly assembled. It is doubtful that any improvements in amplifier design during the next few years will produce an improvement in sound quality when compared with this amplifier. With distortion levels as low as they are in the Universal Tiger, speaker, cartridge, and tuner distortion will have to be reduced by a factor of at least ten to make the amplifier distortion a significant contributor to overall distortion.

If you decide to build any of the high-power versions of the Universal Tiger, remember that most speaker systems are rated for *peak* power handling ability. This means that in most cases you have to divide the peak power by two to determine roughly the amount of *rms* power the speaker can tolerate without damage. Other than this, there are no precautions that have to be taken. ◆



Build A
Moisture Sensor

DETECT PRESENCE OF WATER IN ANY LOCATION

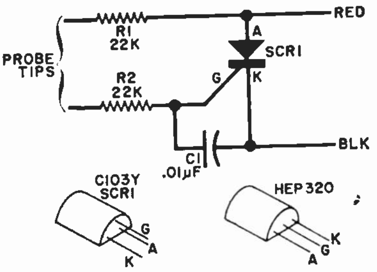
BY H. ST. LAURENT

DETECTING leakage or overflow in any system involving liquid storage or transmission is not as easy as it sounds without spending a lot of money. Detection devices on the market range in price from $40.00 to $100.00 (or more) depending on the packaging. On the other hand, the sensor described here can be built for about $4.00. The sensor itself is the heart of an efficient and accurate detection system. The cost of the external warning and power components will vary depending on how the sensor is applied.

Applications for the moisture sensor are myriad. It can detect water leaks in aquariums, basements, boats, freezers, humidifiers, sprinkler systems, boilers, etc. It will locate moisture in lumber, silos, or any stored material susceptible to moisture damage. Another important use is in the detection of condensation in fuel tanks since, in this sensor, no power is present at the probe tip (even when activated) so that there is no danger of an explosion.

One of the best features of this sensor is that it uses no power when on standby. This makes it possible to use dry cells such as lantern batteries to monitor remote, hard-to-reach areas. The sensor is not voltage sensitive; operating voltage can be varied as much as 25% without adversely affecting the operation. A number of sensors can be coupled to a central control panel for covering wide areas.

Theory of Circuit Design. The circuit of the moisture sensor is shown in Fig. 1. When any moisture is present between the probe tips, a low-level positive voltage passes from the red lead, through the two resistors, to the gate of the SCR. This fires the SCR and causes it to appear as a very



PARTS LIST

C1—0.01-μF miniature capacitor
R1,R2—22,000-ohm, ½-watt resistor
SCR1—Silicon controlled rectifier (GE C103Y or Motorola HEP320)
Misc.—Plastic tube, perf board, non-corrosive wire, cable, potting compound, solder, etc.
Note—A complete set of parts including perf board, plastic tube and matching mounting clip, but excluding potting compound, is available for $4.00 from Lectromek Co., Box 824, Warwick, RI 02888.

Fig. 1. The moisture sensor is a simple circuit that operates very readily. Color-coded leads indicate the applied dc voltage, red for positive, black for negative.

low resistance across the two power leads.

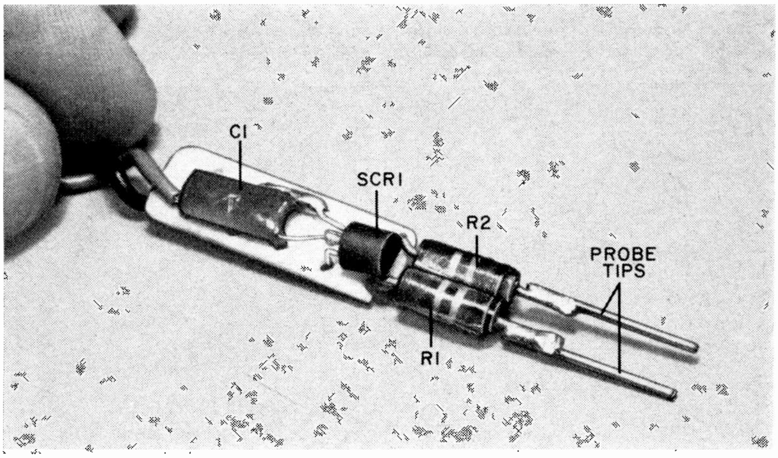
When a suitable power source and alarm are connected to the power leads as shown in Fig. 2A, the alarm is activated when the SCR fires. The particular SCR used in this sensor operates best with supplies between 6 and 18 volts. The maximum allowable load when fired is 800mA for this particular SCR.

Either dc or ac may be used for the power supply. If dc is used, once the SCR fires, it must be reset (with the probes in the clear) by disabling the power source momentarily. If ac is used, (a 6- or 12-volt filament transformer works well) then reset occurs automatically when the probes are in the clear and the ac voltage passes through zero.

Construction. The sensor can be housed in any type of narrow plastic tube—even a small pill bottle. Cut a piece of perf board shorter in length than the plastic tube to be used and just wide enough to fit within the tube. Mount the components on the perf board, making sure that only one end of each of the resistors is attached to the board (see photo). If the sensor is to be used in a corrosive atmosphere, cut the loose ends of *R1* and *R2* short and solder about ¾ to 1" lengths of 0.040" Monel (or other type of non-corrosive wire) to the loose ends. For non-corrosive use, leave the loose ends of the resistors their natural lengths. These are the probe tips.

Connect lengths of red and black wires to the appropriate points on the board. A con-

The plastic circuit board should fit snugly within a plastic tube. The probe tips are either the resistor leads or short lengths of any type corrosion-proof wire.



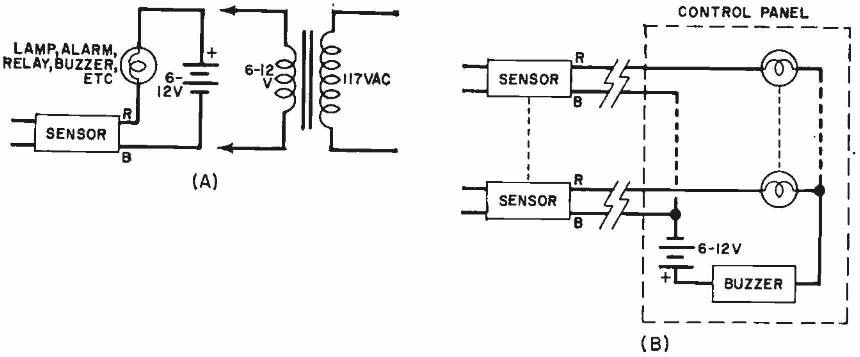


Fig. 2. The probe can be powered either from a battery or an ac source. (A). A multi-sensor system (B) can activate either visual or aural indicators as desired.

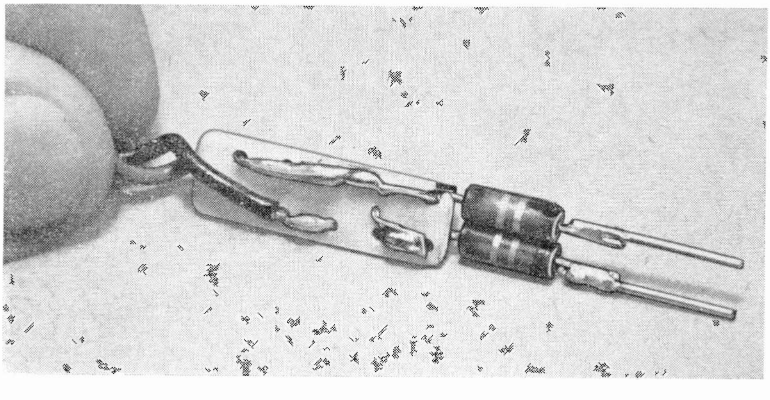
nector can be used to join the sensor to a longer set of leads to run back to the power supply and control panel.

Slide the finished board into the plastic tube so that the two tips protrude about ¾". Connect the sensor to the test circuit shown in Fig. 2A and wet your fingertips and jumper the two probe tips. The alarm should operate when the contact is made.

Once you know the probe is operating, remove it from the test circuit and plug both ends of the tube using paraffin, sealing wax, or any commercially available non-conducting potting compound which will harden to make a liquid-tight seal.

Operation. Mount the sensor using a suitable clip so that the probe tips are in the area of interest: bilge of a boat, slightly off of a basement floor, near the top of a storage tank, or any place where the presence of moisture or liquid is to be detected. The circuit diagram of Fig. 2B shows how to couple a number of sensors to a control panel. You can use either visual or audio signaling, or both. ◈

Photo of underside of the sensor plastic board shows how component leads are soldered together to form the circuit and provide a solid mechanical mounting.



ASSEMBLE A DIGITAL MEASUREMENTS LAB

MAIN FRAME POWER SUPPLY AND READOUT WITH 20-MHz FREQUENCY COUNTER MODULE

THE PRIMARY PURPOSE of most electronic measuring instruments is to provide a numerical indication of the level or value of the quantity being measured. It matters little whether the measurement is in volts, amperes, ohms, Hz, or elapsed time; only the accuracy of the measurement is important. Since the readout device and the measuring instruments do not necessarily have to be connected, why not have a "modularized" type of measurement system—with a highly accurate digital readout (with a power supply) on a main frame and measurement modules that can be plugged in?

The "Digital Measurements Lab" is such a system; and its hallmarks are economy, accuracy and flexibility.

The Digital Measurements Lab employs transistor-transistor-logic (TTL) integrated circuits and other modern design techniques to provide maximum accuracy and reliability. The readout system consists of decoders, drivers, and Nixie® neon-glow tubes to provide 3½ decades and, thus, 3-place accuracy.

The cost of the parts for the main frame is estimated at less than $75; while the Frequency Counter module is about $42.

The Main Frame. The Digital Measurements Lab can be built around almost any type of decimal counting system capable of responding to 20 MHz or more. For example, you can use either of the two decoder/driver systems that have previously appeared in POPULAR ELECTRONICS (see "Build Numeric Glow Tube DCU," Feb. 1970 and "Assembling The Popular Electronics Mini DVM," Sept. 1970). However, since the "Utilogic" three-and-a-half-digit display and counter assembly was designed specifically for the Lab's main frame, its use is recommended (see Main Frame Parts List).

The first step in putting together the main frame is to assemble the readout system from

For other modules that can be built at limited cost, see articles "Time-Period Module," on page 50; "Digital Thermometer Module," on page 76; and "Digital Volt-Ohmmeter," on page 96.

BY DANIEL MEYER

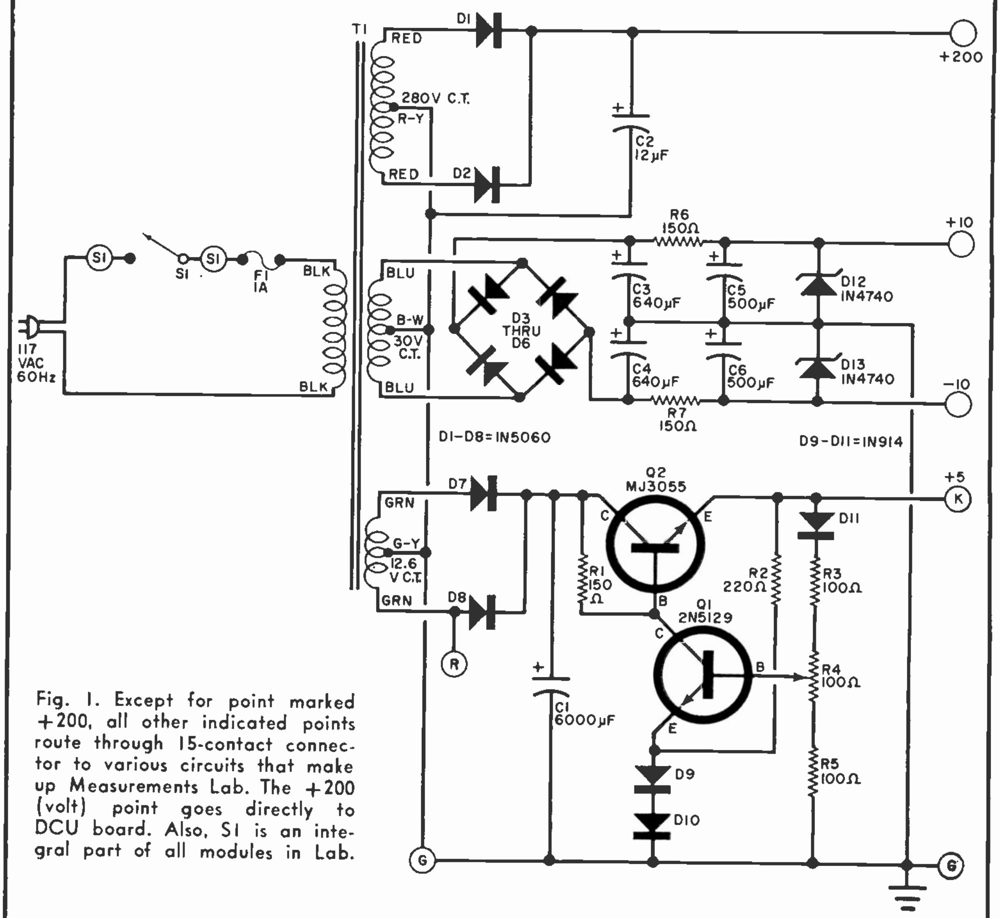


Fig. 1. Except for point marked +200, all other indicated points route through 15-contact connector to various circuits that make up Measurements Lab. The +200 (volt) point goes directly to DCU board. Also, S1 is an integral part of all modules in Lab.

PARTS LIST
MAIN FRAME

C1—6000-µF, 10-volt electrolytic capacitor

C2—12-µF, 250-volt electrolytic capacitor

C3,C4—640-µF, 250-volt electrolytic capacitor

C5,C6—500-µF, 15-volt electrolytic capacitor

D1-D8—400-PIV, 1-ampere silicon rectifier (1N5060 or similar)

D9-D11—DHD800 (General Electric) or IN914 silicon rectifier

D12,D13—1N4740 zener diode

F1—1-ampere fuse

Q1—2N5129 transistor (National Semiconductor or Fairchild)

Q2—MJ3055 transistor (Motorola)

R1,R6,R7—150-ohm, ½-watt, 10% tolerance resistor

R2—220-ohm, ½-watt, 10% tolerance resistor

R3,R5—100-ohm, ½-watt, 10% tolerance resistor

R4—100-ohm printed circuit type potentiometer

S1—Spst switch (see Frequency Counter Parts List)

T1—Power transformer (117-volt primary/280-volt, center-tapped (at 20 mA); 30-volt, center-tapped (at 100 mA); and 12.6-volt. center-tapped (at 1.5 ampere) secondaries

1—"Utilogic" 3½-digit display and counter kit

Misc.—Main frame chassis and cowling; control knob; power supply printed circuit board; ac line cord and strain relief; fuse holder; 15-contact socket; solid and stranded hookup wire; machine hardware; spacers; solder; etc.

Note—The following items are available from Southwest Technical Products Corp., Box 32040, San Antonio, TX 78216: power supply circuit board No. 170-Pb for $2.85; complete power supply kit, including board, No. 170-C for $14.55 plus postage on 4 lb; complete main frame kit, including chassis and cowling, display time control, reset switch, etc., but minus readout assembly, No. 170-CP for $19.55 plus postage on 8 lb; "Utilogic" display-counter kit No. MNX-1 for $39.50.

the plans provided with the "Utilogic" kit. Next, assemble the power supply circuit, the schematic diagram for which is shown in Fig. 1, on its printed circuit board. In the event you plan to etch and drill your own circuit board, an actual size etching guide and components location and orientation diagram are given in Fig. 2. When assembling the power supply circuit board, pay close attention to the orientations of the diodes, transistors, and electrolytic capacitors. (Note: Capacitors *C3* and *C4* are mounted vertically.)

Once the boards are assembled, they must be wired to each other and to a 15-contact connector. The connector provides a means for routing the signal and power lines to and from the plug-in modules. The wiring procedure is greatly simplified by the fact that all wiring holes in the circuit boards are assigned a letter-code designation. This code is set up so that like letters mate with each other and with the coding on the connector as shown in Fig. 3. Between the boards, you can use solid hookup wire, but between the boards and connector, it is recommended that you use stranded wire.

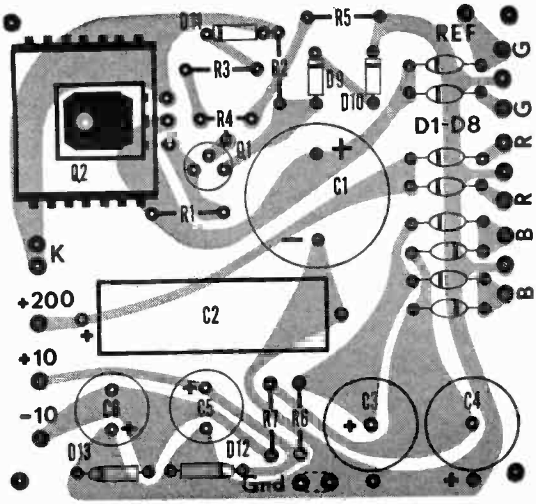


Fig. 2. Actual size etching guide for power supply printed circuit board is provided above. At left is components location and orientation diagram. Carefully follow color coding when secondary leads of T1 are connected to circuit board (holes at near left).

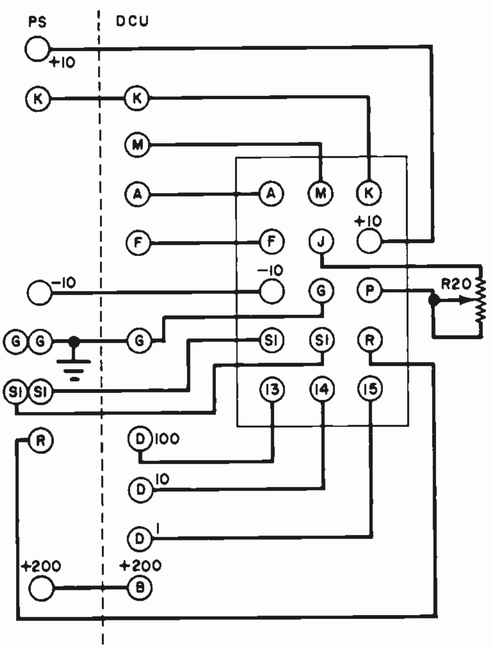


Fig. 3. Power supply (PS) and readout (DCU) boards and 15-contact connector are wired together as shown. Potentiometer R20 is display time control.

After the wiring is completed, bolt the readout circuit board to the chassis with machine hardware and 3/8" spacers. Then use #6 hardware to bolt the power transformer (*T1*) to the floor of the main frame's chassis (see Fig. 4) and temporarily set the power supply board in its appropriate location. Measure the secondary leads from *T1* to their respective holes in the power supply board. Add about an inch to each measurement and trim away any excess lead lengths. Strip away 1/4" of insulation from each lead, push the leads through the holes in the power supply board, and solder them to the foil pattern.

Mount the RATE control and the RESET switch on the front panel of the main frame. Then, on the rear apron, mount the fuse holder and pass through its entry hole the ac line cord and fasten it in place with a strain relief. Then finish wiring the power supply primary circuit, referring back to Fig. 1 and Fig. 3 for details.

Solder one end of a length of hookup wire to one of the lugs on the RESET switch; the other end goes to hole **M** on the DCU board. Cut a length of stranded hookup wire to size, and connect and solder its ends to the same lug on the RESET switch and contact M on the connector. Then connect and solder a final length of wire between the free lug of the switch and chassis ground.

Testing the Main Frame. Temporarily connect a jumper wire between the two **S1** contacts on the connector (see Fig. 3). Plug the line cord into a convenient 117-volt, 60-Hz ac outlet. Use a voltmeter to check the +10-volt, —10-volt and +200-volt outputs from the power supply. Your readings should be within 10% of these values. Then connect the meter to point **K** in the power supply and chassis ground and adjust *R4* for an exact 5-volt reading.

Now, check the front panel of the main frame; with power applied, the readout tubes

THEORY OF POWER SUPPLY DESIGN

The power supply used in the Digital Measurements Lab and shown schematically in Fig. 1 is designed to provide all of the voltages required by the circuits that make up the Lab. The +200-volt output is used for firing the readout tubes and neon lamps in the multi-decade readout assembly. This output is not critical and is, therefore, unregulated.

The various transistor circuits in the Lab are powered by the +10- and —10-volt outputs which are voltage regulated by zener diodes *D12* and *D13*. For the more critical demands of the IC's, the +5-volt output is derived from a special regulator circuit that maintains the output voltage within 5% of the 5-volt level at point K. The regulator circuit consists of series-pass transistor *Q2* and error amplifier transistor *Q1*. In operation, a sample of the output voltage is applied to the base of *Q1* by the wiper of voltage level control *R4*. If any loading condition attempts to force the output voltage to increase, the base voltage of *Q1* will also increase slightly and cause *Q1* to draw more collector current. The increase in collector current then causes a decrease in the base voltage of *Q2* of sufficient magnitude to maintain the output voltage at its original +5-volt level. If, on the other hand, loading conditions attempt to decrease the output voltage level below 5 volts at point K, the opposite action will occur.

The positive and negative 10-volt outputs are obtained from the bridge rectifier assembly made up of diodes *D3-D6* and filter capacitors *C3-C6*. The +200-volt output is obtained from a separate *T1* secondary winding, diodes *D1* and *D2*, and filter capacitor *C2*.

The +5-volt output is obtained from a third secondary winding, *D7* and *D8*, and *C1*. Potentiometer *R4* is a voltage level control, capable of varying the output voltage between approximately 4 and 6 volts. This control would normally be set to provide a 5-volt output.

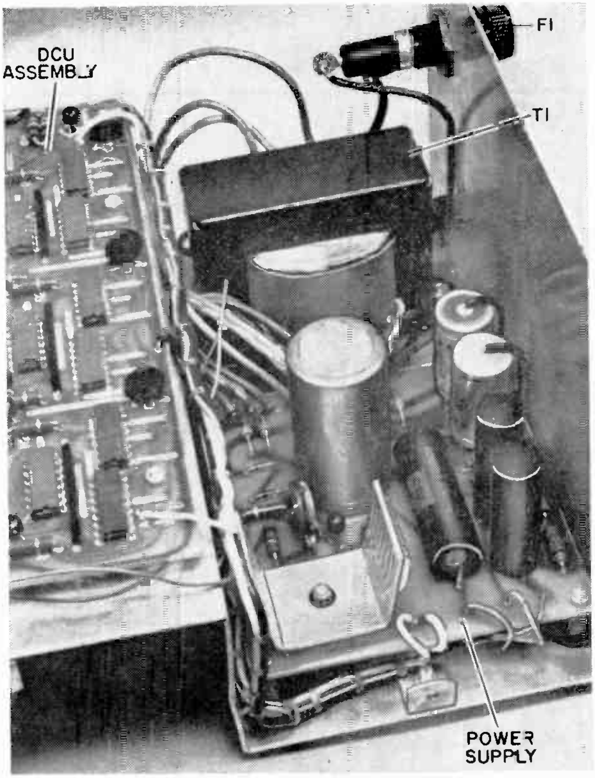
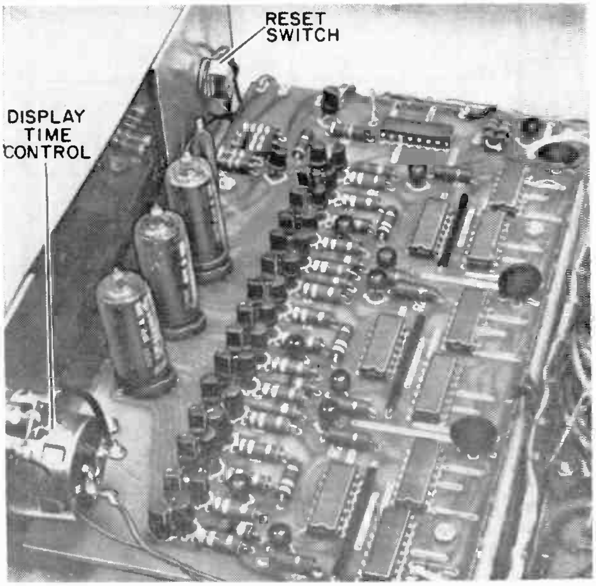
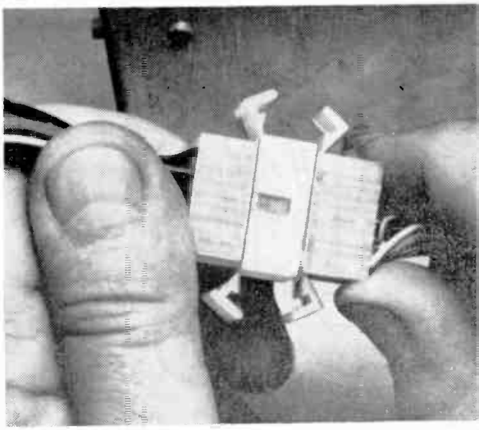


Fig. 4. Locations of power supply and 3½-digit decoder/driver assembly, reset switch, and display time control (below) are shown mounted on respective sections of main frame chassis.





A 15-contact Molex connector is recommended for use in Digital Measurements Lab for positive electrical contact.

and neon lamps should glow. If so, depress and release the RESET switch. If the main frame is operating properly, all tubes should immediately reset to "0". Then set the main frame aside.

Frequency Counter Module. As mentioned earlier, the first in the series of integrated plug-in construction plans is a 20-MHz Frequency Counter. The module, employing TTL integrated circuits, consists of two basic circuit assemblies: one is the Time Base and the other is the Scaler, shown schematically in Fig. 5 and Fig. 6, respectively.

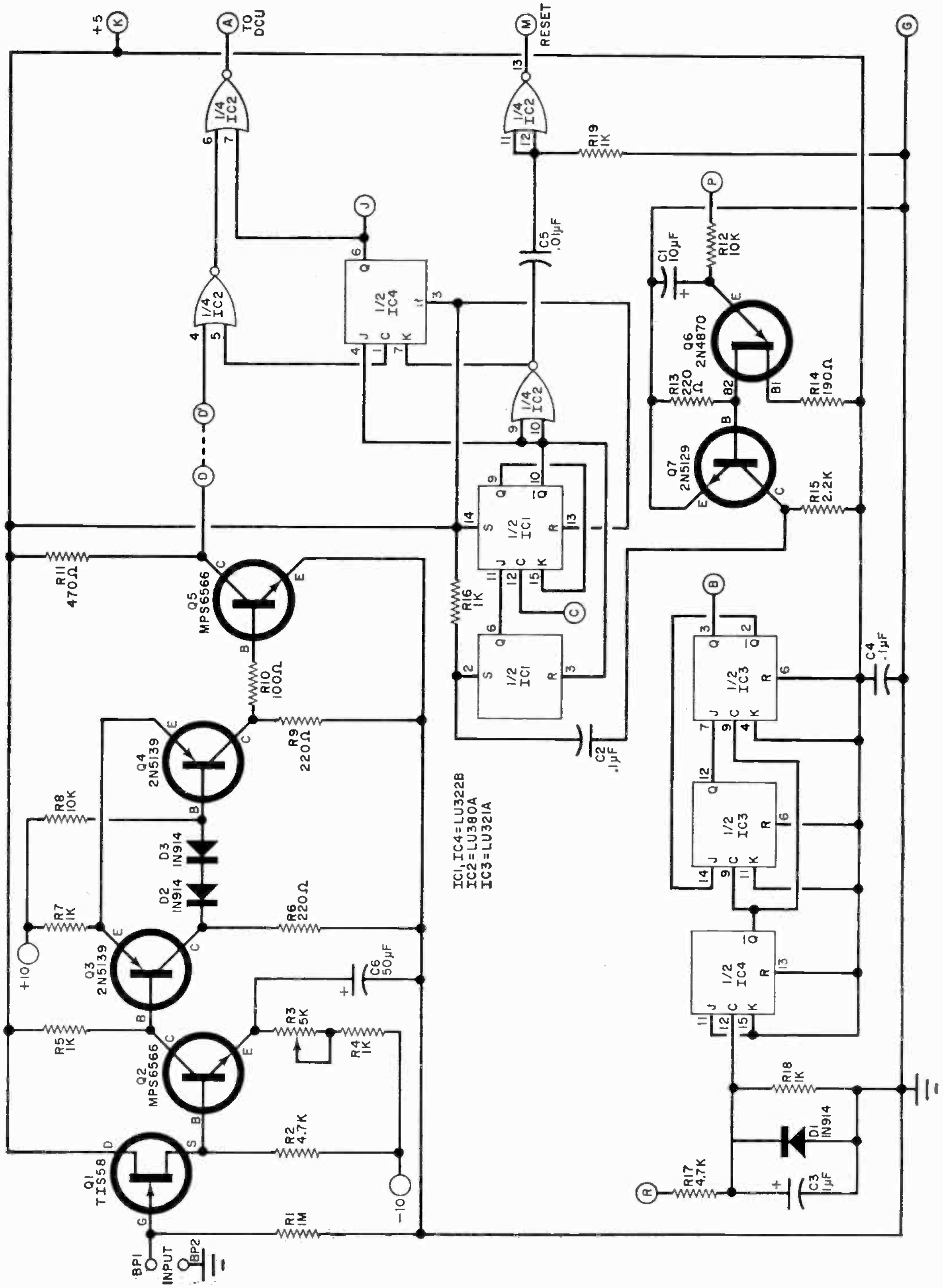
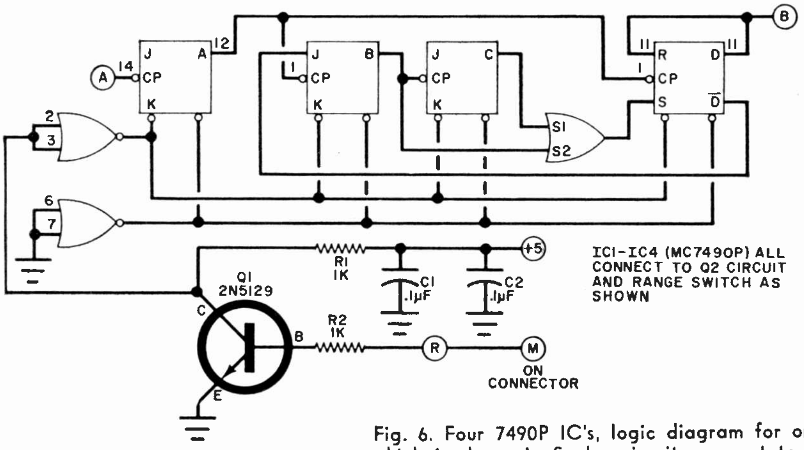


Fig. 5. By connecting D to D' and B to C, basic Time Base circuit shown can provide single 2000-Hz range. To obtain full 20-MHz, five-range capability, Scaler/switching arrangement would be connected to these points.



IC1-IC4 (MC7490P) ALL CONNECT TO Q2 CIRCUIT AND RANGE SWITCH AS SHOWN

Fig. 6. Four 7490P IC's, logic diagram for only one of which is shown in Scaler circuit, connect to Q1 stage.

For minimum loading on the circuit under test, the counter module is equipped with a high-impedance source-follower field effect transistor input circuit.

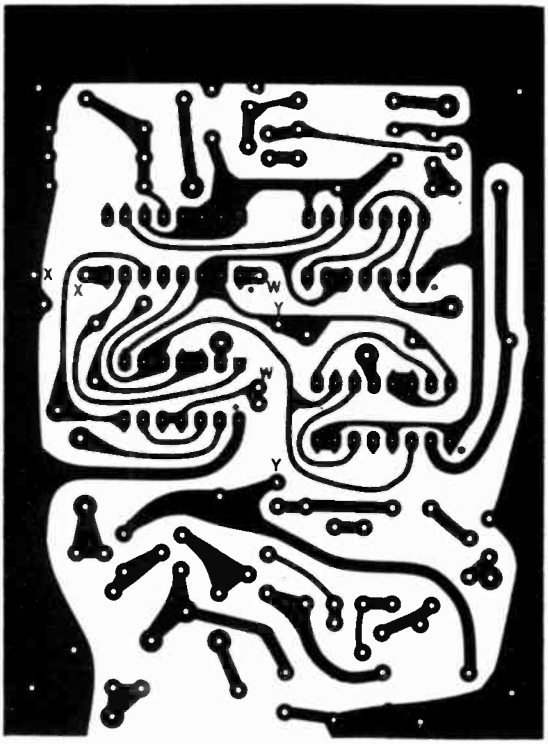
The Frequency Counter module has full-scale ranges of 1000 Hz, 10 kHz, 100 kHz, 1 MHz, and 10 MHz with a 100 percent over-range capability. This means that it will count pulses up to a frequency of 19.99 MHz directly when the module is used with the main frame. Also, the counter has a built-in TEST circuit to which you can switch at any time to check the operational status of the Lab.

Assembling the Module. The use of integrated circuits in the Time Base and Scaler subassemblies makes it necessary that the circuits be assembled on printed circuit boards. If you want to make your own boards, you can do so with the aid of the etching guides given in Fig. 7.

Mount the components on their respective circuit boards (see Fig. 8), paying careful attention to the orientations of the IC's, tran-

PARTS LIST
FREQUENCY COUNTER

Time Base:
BP1,BP2—Five-way binding post (one black, one red)
C1—10-µF, 15-volt electrolytic capacitor
C2,C4—0.1-µF, 12-volt disc capacitor
C3—1-µF, 15-volt electrolytic capacitor
C5—0.01-µF, 12-volt disc capacitor
C6—50-µF, 15-volt electrolytic capacitor
D1-D3—1N914 diode
IC1,IC4—LU322B integrated circuit (Signetics)
IC2—LU380A integrated circuit (Signetics)
IC3—LU321A integrated circuit (Signetics)
Q1—TIS58 transistor (Texas Instruments)
Q2,Q5—MPS6566 transistor (Motorola)
Q3,Q4—2N5139 transistor (Fairchild)
Q6—2N4870 or 2N4871 unijunction transistor
Q7—2N5129 transistor (Fairchild)
R1—1-Megohm
R2—4700-ohm
R4,R5,R7,R16, R18,R19—1000-ohm
R6,R9,R13—220-ohm
R8,R12—10,000-ohm
R10—100-ohm
R11—470-ohm
R14—190-ohm
R15—2200-ohm
R17—4700-ohm
All resistors ½-watt, 10% tolerance
R3—5000-ohm linear-taper potentiometer
S1—10-position, 4-deck non-shorting rotary switch with spst switch attachment for S1 in power supply
Scaler:
C1,C2—0.1-µF, 10-volt disc capacitor
IC1-IC4—MC7490P integrated circuit (Motorola)
Q1—2N5129 transistor (National Semiconductor or Fairchild)
R1,R2—1000-ohm, ⅛-watt, 10% tolerance resistor
Misc.—Time Base and Scaler printed circuit boards; 33,000-ohm, ½-watt, 10% tolerance resistor (see text); control knobs (2); L bracket chassis; 15-contact plug to match socket in main frame; 4-40 machine hardware, ¼"-long spacers (8); solid and stranded hookup wire; solder; etc.
Note—The following items are available from Southwest Technical Products Corp.. Box 32040, San Antonio, TX 78216: complete Time Base kit, including circuit board, No. TB-2, for $17.50; Complete Scaler kit, including circuit board, No. S-410 for $14.95. both kits plus chassis and 15-contact plug, No. FC-2 for $29.95 plus postage on 3 lb.



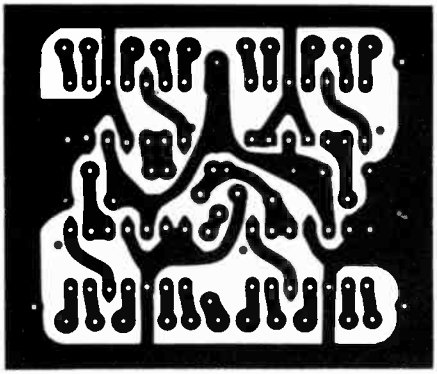
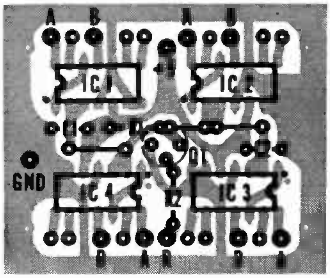


Fig. 7. Actual size etching guides for Time Base and Scaler printed circuit boards are shown at left and above, respectively. Use etching guides to check for solder bridges between closely spaced conductors after all components are soldered to circuit boards.



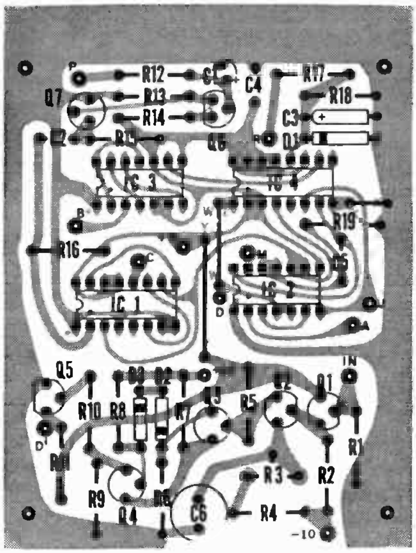
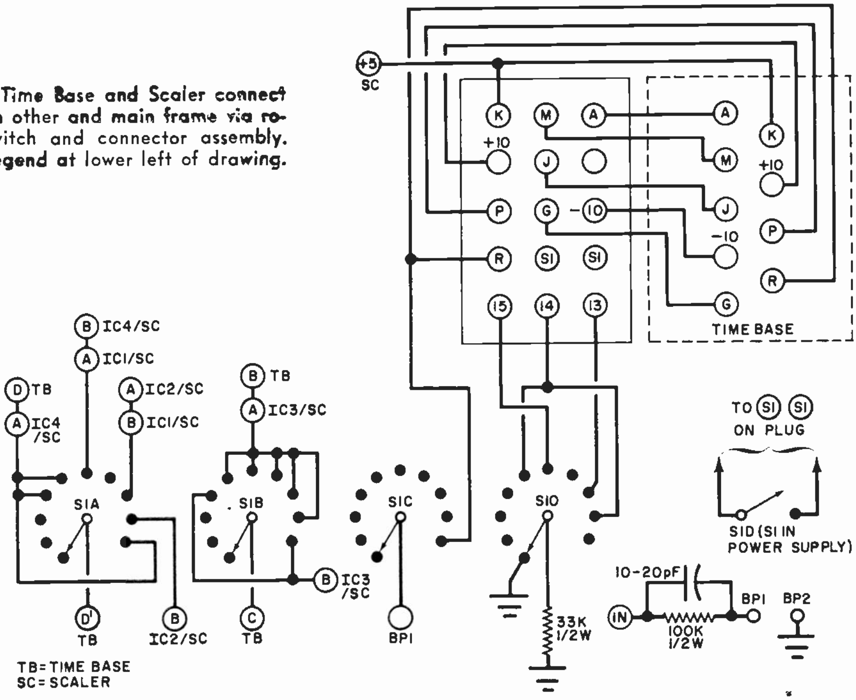


Fig. 8. When mounting electrolytic capacitors, diodes, IC's, and transistors on circuit boards carefully orient them exactly as shown here.

sistors, diodes, and electrolytic capacitors. When you finish soldering, examine the foil sides of the boards, comparing them against the guides in Fig. 7, to determine if any solder bridges exist between the closely spaced foil conductors. If you locate a solder bridge, reheat the connection adjacent to it and remove the excess solder.

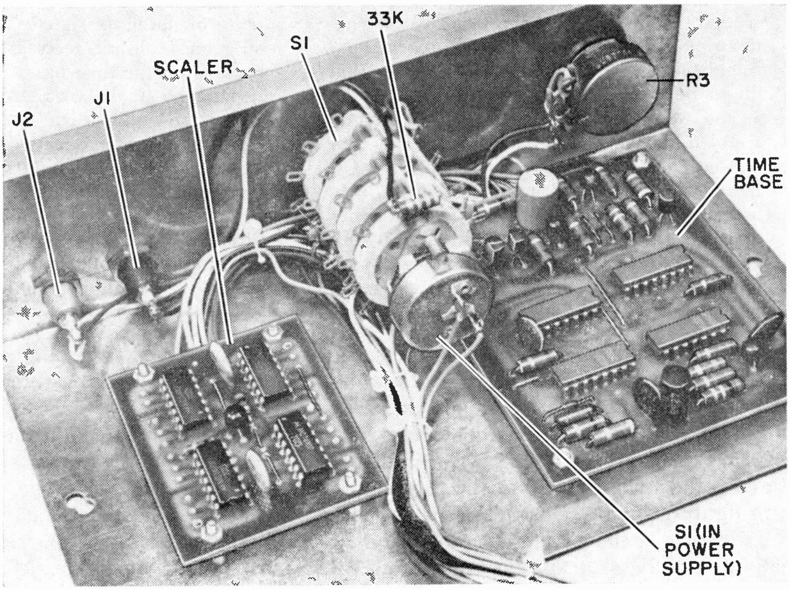
Now, referring to Fig. 9, wire up range selector switch *S1*, and make all necessary connections between *S1*, the two circuit boards, and the 15-contact plug. (Note: Make absolutely certain that the wiring to the plug conforms with the wiring to the socket in the main frame. Use stranded hookup wire to and from the socket.) Then mount the circuit boards, TRIGGER LEVEL control, range switch, and input binding posts on the L bracket chassis as shown in Fig. 10. Before tightening the hex nut on *S1* (in the module) position it so that lugs 1 and 11 point upward; this way the index on the control knob will conform with the dial markings. Wire the TRIGGER LEVEL control and binding posts into the circuit. Then neatly lace together the wiring and put the control knobs on.

Fig. 9. Time Base and Scaler connect to each other and main frame via rotary switch and connector assembly. Note legend at lower left of drawing.



Testing the Counter Module. Connect the plug on the module to the socket in the main frame and turn on the power by rotating the range switch to the 1000-Hz position. Rotate the DISPLAY RATE control on the main frame to its fully clockwise position and observe the readout display. With no input signal to the module, the readout tubes should reset to "0" as soon as the reset pulse occurs. Now, apply an input signal of 0.1 volt or more to the binding post input on the module and again observe the readout display. After

Fig. 10. Time Base and Scaler circuit boards fasten to chassis with 4-40 machine hardware and spacers. A 33,000-ohm resistor (½-watt) is used to limit current through decimal point in readouts. Wires connect to foil sides of boards.



THEORY OF COUNTER DESIGN

The 20-MHz Frequency Counter Module is divided into two basic sections—the Time Base circuit shown in Fig. 5, and the Scaler circuit in Fig. 6. The Time Base circuit employs a high-impedance source-follower FET input stage (*Q1*) to minimize loading the circuit under test. The signal, fed first through *Q1*, is direct-coupled to *Q2* where it is amplified to a level sufficient to drive the *Q3-Q4* Schmitt trigger. The driving signal level to the *Q3-Q4* circuit is primarily a function of the TRIGGER LEVEL control *R3*.

The purpose of the Schmitt trigger is to condition the signal, giving it fast rise and fall times. This is necessary to prevent false counts on low-frequency signals. Although the TTL gates and flip-flops in *IC1*, *IC2*, and *IC4* will operate at almost any frequency, the gates can produce multiple counts if the signal passes through the trigger point too slowly. The Schmitt trigger, as a result of shaping the signal, eliminates the possibility of multiple counts.

Every time the input signal at the base of *Q3* fires the Schmitt trigger, the output at the collector of *Q4* changes state, producing a series of square waves. After this, the square-wave pulses are amplified by *Q5* and fed to the sync circuits.

To obtain a readout in Hertz, the signal must be gated into the counter for a specific period of time. This is accomplished with the time base made up of *IC3* and half of *IC4*. The time base network is a divide-by-six circuit that counts down from the 60-Hz power frequency (applied at point R and obtained from one side of the 12.6-volt secondary winding in the power supply) to provide at point **B** a series of pulses that occur every 0.1 second. Diode *D1* clips the negative alternations of the 6.3-volt input, and capacitor *C3* filters out any high-frequency noise that might be present on the ac line.

The output at point **B** can be directly coupled into the sync circuit at point **C** to provide a single counting range of 1000 Hz. Or, it can be coupled through the Scaler subassembly (see Fig. 6) through *S1* for further divisions to provide the 10-kHz, 100-kHz, 1-MHz, and 10-MHz ranges. The signal can now be applied to point **C** in the sync circuit.

In the sync circuit, the input and timing signals are synchronized in such a manner that the count always starts at the same point in the input cycle to avoid any "one count" ambiguities in the reading. The "one and only one" circuit formed by *IC1*, when armed with a pulse, allows only one timing cycle to occur.

The display time setting of *R20* determines the firing rate of unijunction transistor *Q6*. When *Q6* fires, a sharp pulse appears across *R13*. After amplification through *Q7*, this pulse is applied to the S input of the R-S flip-flop in *IC1*, causing the Q output to go to "high." The high signal is next applied to the J input of the JK flip-flop in *IC1*, setting the flip-flop to change state with the next clock pulse from the time base network.

The first clock pulse that occurs after the display time circuit is fired switches the JK flip-flop. The Q output goes to high and is fed into the K input of the same flip-flop. This will result in the flip-flop going back to its original state on next clock pulse. The not Q output goes to low (0 volt) on the first clock pulse, since it is the Q output's complement, and resets the S-R flip-flop and sets the sync switch of *IC4* to switch with the next clock pulse. The clocking pulse in this case is the input signal.

Now, the following occurs: On the first negative-going pulse that occurs in the input signal, *IC4* switches so that the Q output goes to low and opens the gate in *IC2* for signals to pass into the counter. The negative-going pulse that switched the flip-flop is inverted before being applied to the gate so that it becomes a positive-going pulse that does not pass through the gate to the counter.

The first count occurs on the next negative pulse of the input signal. When the "one and only one" circuit receives the second clock pulse from the time base, it switches back to its standby state to await another display generator pulse. This causes the sync switch to close on the first negative-going input pulse that occurs after the inputs change state. The leading edge of the pulse that opens the synchronizing circuit is applied to the inverter through *C5* to the reset buss in the counter, resetting the counter just before the next pulse train to be counted is applied to point **A**.

a discrete interval, determined by the setting of the DISPLAY RATE control, the readout system should display the frequency of the applied signal. Let the instrument reset itself several times and if the numerical indication remains the same for two of the three significant figures, this range is operating properly.

Test each of the remaining ranges individually as described, using an appropriate frequency signal to produce a readout display. Then, on any of the ranges, feed in a signal that exceeds the range capability by more than 100 percent and check to see that the over-range indicator lamp glows.

Finally, set the range switch to the TEST position and observe the readout display. You should obtain a 60-Hz reading every time the instrument automatically resets itself. ◆

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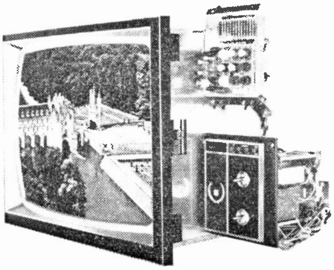

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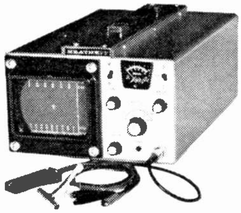

Analyzes standard, transistor, or capacitive discharge systems on 3, 4, 6, or 8 cyl. engines to find bad plugs, points, wiring or distributor parts, incorrect dwell time, coil, condenser, transistor or CD circuitry problems. Built-in tach, 0-1000 & 0-5000 rpm ranges for carb. adjustments. Constant width patterns, primary or secondary, parade or superimposed, plus expanded. Optional 12VDC supply for road checks, $24.95*.

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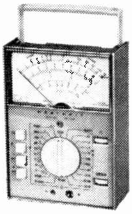

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CIRCLE NO. 6 ON READER SERVICE CARD

BUILD THE NEW E-V 4-CHANNEL UNIVERSAL DECODER

Designed specifically to play back CBS "SQ," Sansui and E-V matrixed 4-channel program material.

BY FRED NICHOLS/*Electro-Voice, Inc.*

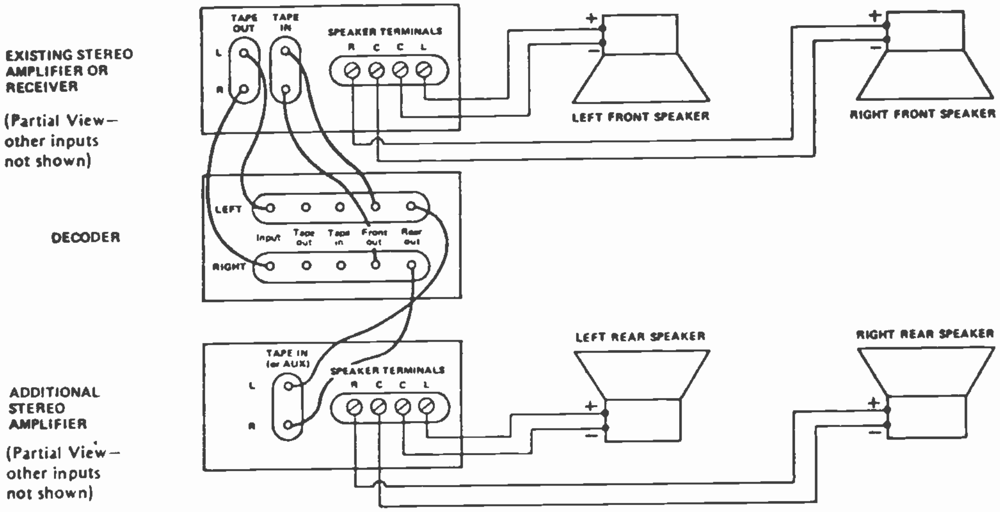
IN the two years or so since matrix four-channel systems were introduced, an impressive degree of sophistication has been obtained. Continuing development of the Electro-Voice "Stereo-4" system has resulted in a "universal" decoder which properly decodes all commercially available encoded material. The entire decoding circuitry has been reduced to an integrated circuit, which operates with various external phase-shift networks.

Because the integrated circuit involves simpler and more accurate circuitry than discrete components, a decoder built around this IC makes an ideal home construction project which offers performance equal to that of commercial units. Such a decoder is presented here for use as a separate unit or the decoder circuitry can be built into another piece of equipment, such as a back-channel stereo amplifier. The integrated circuit with close-tolerance phase-shift network components is available from Electro-Voice, as well as a more complete set of specialized parts, including an etched-circuit board. How the decoder board can be mounted in a professional-looking, commercially available enclosure is shown, although the unit can be housed in any manner the builder desires.

Construction. The entire decoder, including power supply, is built on a single printed-circuit board. See Figs. 1 & 2. Use of PC-mount controls greatly simplifies unit wiring. If the controls as shown are not needed, appropriate wire jumpers may be inserted in the board.

Mounting the power transformer, volume control, and selector switch first provides support, making it easy to perform the balance of the assembly. Be sure these parts are fully seated before you start soldering. Use a low-wattage iron and small-diameter rosin-core solder. "Tinning" the copper foil first will speed the component soldering job and reduce the amount of heat required. Special care is required when installing the integrated circuit and phase-shift components—which should be done after all other parts are mounted.

Observe the polarity of the electrolytic capacitors and the identifying notch of *IC1* when installing.

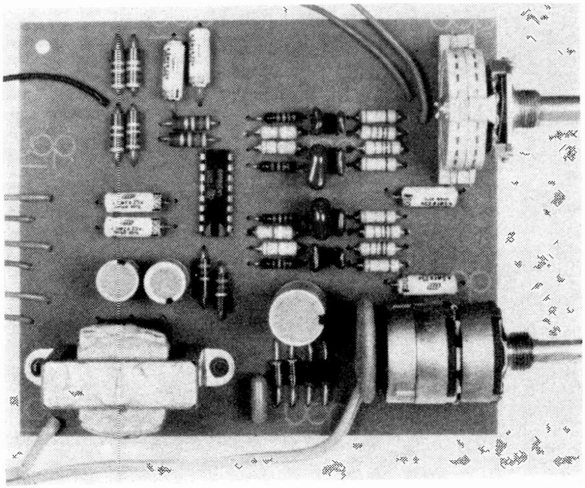


Rear panel connections for both inputs and outputs.

Housing. The assembled PC board may be mounted in any suitable enclosure, using ¼-inch standoffs. The board should be supported at the two transformer mounting holes, plus another hole provided at the back corner, by 4-40 hardware. The front of the board is secured by the two control shafts.

Ten phono jacks, providing inputs and outputs, should be mounted on the back of the chassis. Insulated jacks, or insulating washers, are recommended. The line cord should be knotted and then exit the back of the chassis through a grommet.

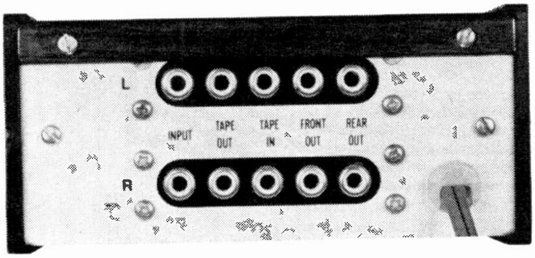
Control functions and the order in which the phono jacks should be installed are shown in the diagram and photos. Appropriate labels may be applied with a tape marker or press-on lettering.



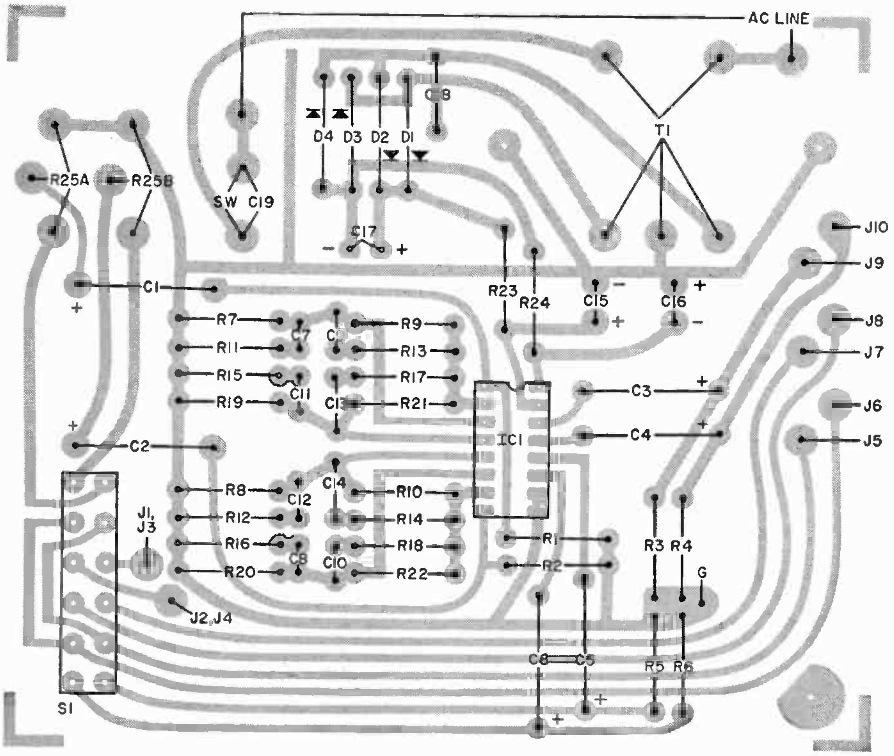
Top view of the decoder PC board.

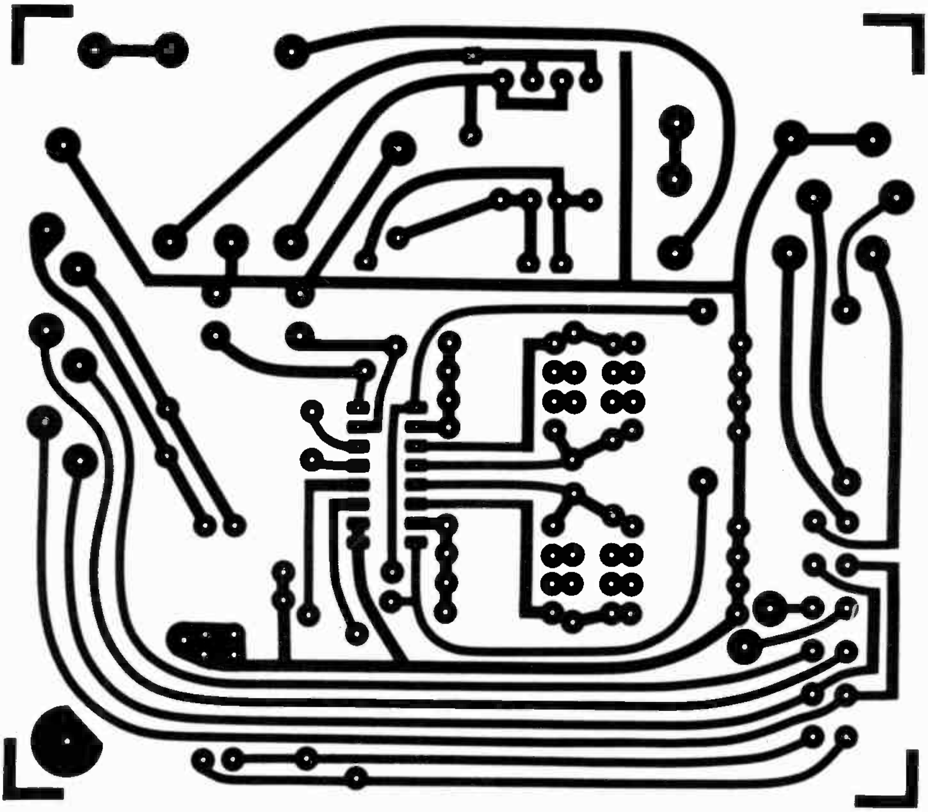
Connections. This decoder is designed to operate with signals in the 0.1 to 1-volt range. Maximum input is 4 volts rms. Normally a set of "tape-monitor" connections provides the proper signal source, plus a way to return the decoded front signals to the existing power amplifiers. The rear-channel signals may then be connected to an additional stereo power amplifier and a pair of rear speakers. Of course, the decoder may be connected between separate preamps and power amplifiers as well.

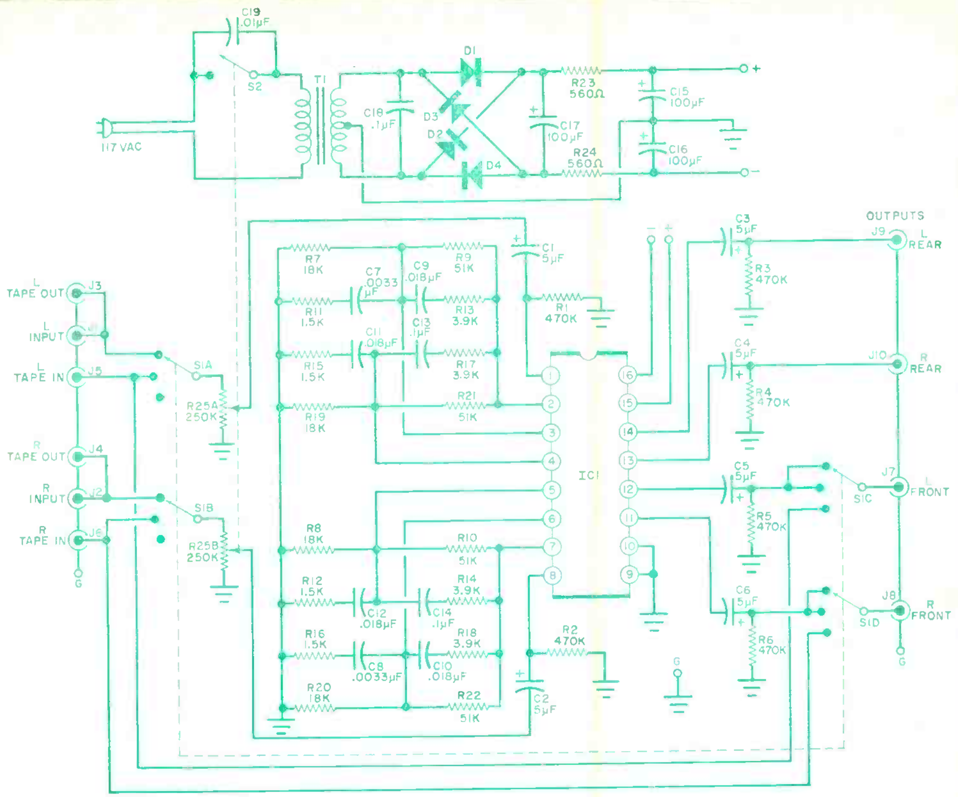
Suggested jack layout on rear panel.



Operation. As shown in the diagram of Fig. 3, the Selector switch allows a choice of decoding from the Source or Tape inputs, or playing the Tape inputs "straight-through." This latter position restores the tape-monitor function to the system.


AC LINE
C18
D4 D3 D2 D1
T1
R25A
R25B
SW C19
C17
J10
J9
J8
J7
J6
J5
C1
R23
R24
C15
C16
R7
R9
C7
C9
R11
R13
R15
R17
C11
R19
C13
R21
C3
C4
IC1
C2
R8
R10
C14
C12
R12
R14
J1, J3
R16
R18
C6
C10
R20
R22
R1
R2
R3 R4
G
J2, J4
C8
C5
R5 R6
S1





R1, R2, R3, R4, R5, R6—470,000 ohm, ½ W res.
*R7, R8, R19, R20—18,000 ohm, ½ W res., 2%
*R9, R10, R21, R22—51,000 ohm, ½ W res., 2%
*R11, R12, R15, R16—1500 ohm, ½ W res., 2%
*R13, R14, R17, R18—3900 ohm, ½ W res., 2%
R23, R24—560 ohm, ½ W res.
R25—250,000 ohm, dual-section audio-taper pot (with a.c. switch, S2)
C1, C2, C3, C4, C5, C6—5 µF, 25 V electrolytic capacitor
*C7, C8—0.0033 µF, 25 V polystyrene capacitor, 2½%
*C9, C10, C11, C12—0.018 µF, 25 V polystyrene capacitor, 2½%
*C13, C14—0.1 µF, 25 V Mylar capacitor, 5%
C15, C16—100 µF, 16 V electrolytic capacitor
C17—100 µF, 50 V electrolytic capacitor
C18—0.1 µF, 100 V ceramic or Mylar capacitor
C19—0.01 µF, 150 V a.c.—1400 V d.c. ceramic capacitor
J1—J10—Phono jack
D1, D2, D3, D4—1 A, 100 PIV diode
S1—4 pole, 3-pos. selector switch
S2—"On-off" switch (on R25)
T1—Power transformer: 40 V center-tapped, 30 mA.
IC1—E-V 87743 decoder integrated-circuit
Misc.—Chassis, line cord, grommet, mounting hardware, etc.
*Indicates close-tolerance phase-shift components. Do not substitute.
Note: The following parts are available from Electro-Voice, Buchanan, Mich. 49107:
Complete set of phase-shift components marked *plus IC1 decoder chip. $16.00 ppd.
Etched and drilled PC board with all parts shown in schematic except line cord and phono jacks) plus knobs and control hardware. $32.00 ppd. PC board is NOT available separately.
Michigan residents add 4% sales tax.
Enclosure shown on front cover is Ten-Tac Model JW-5; available from electronic parts distributors or Ten-Tec, Inc., Sevierville, Tenn. 37862.

Fig. 1. Schematic diagram and parts list for the "Universal" decoder.

←

Fig. 2. Diagrams show both sides of PC board. The one directly to left is full-size template of copper etching which can be used to make PC board. The top diagram shows how the various parts are to be placed.

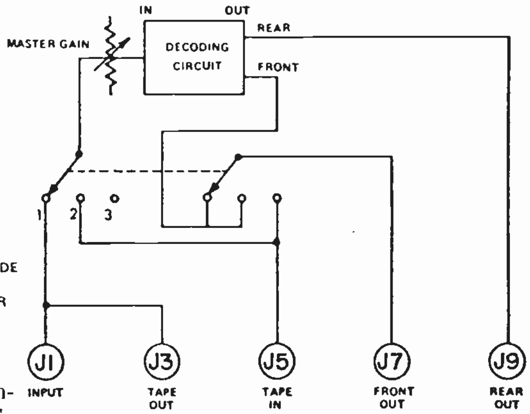


Fig. 3. Block diagram of decoder. Only left channel is shown; both the same.

SWITCH POSITION	FUNCTION
1	SOURCE DECODE
2	TAPE DECODE
3	TAPE MONITOR

The Master volume control provides control of all four channels when decoding. To start, turn this control fully clockwise. Then advance the volume controls of the front and rear amplifiers to the loudest level you expect to use. The decoder's Master volume control may then be used to lower the level of all four channels for normal listening. ◆

Our Cover Photo shows a design engineer developing the original prototype for this particular 4-channel decoder. The final version differs slightly from the original design. The circuit used is the simplest and obviously least expensive design for decoding 4-channel program material.

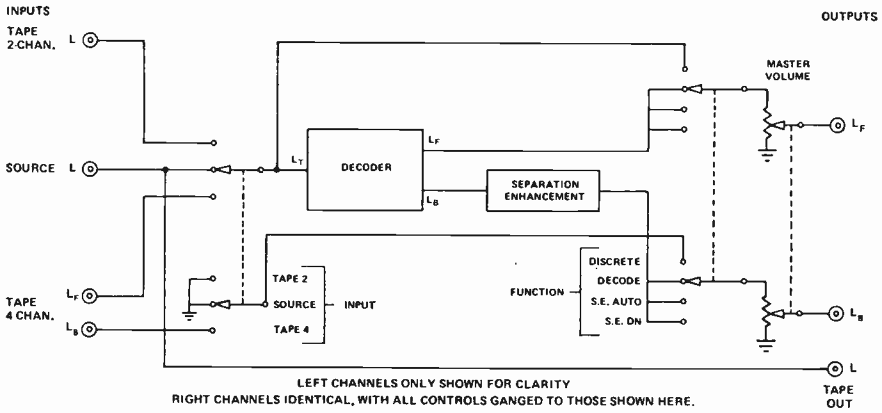
The design differs somewhat from the new Electro-Voice EVX44 decoder, which is a more sophisticated unit. While it offers the same decoding circuits, the EVX44 employs a 4-gang master volume control just ahead of the output jacks which can be incorporated by eliminating the input volume control, *R25*. Outputs *J7*, *J8*, *J9*, and *J10* would then go to the inputs of a 4-section, 50,000-ohm audio-taper pot. With this arrangement, the master volume control will affect output in all functions, including the tape monitor (tape 2).

Input and function selection are separate switches in the EVX44. This permits decoding or playing any input discretely. In addition, a 4-channel discrete tape input is provided.

The EVX44 incorporates a Separation Enhancement circuit which follows the universal decoder and permits some personal control of playback effect. Incorporating four op amps, the circuitry senses the presence of a front-center soloist. Back separation is decreased and front-to-back isolation is increased to firmly localize the soloist in the front speakers. Separation Enhancement in the EVX44 operates automatically and can be manually switched "off" or "on" as well. The EVX44 retails for $99.95.

The Heath Company has a model, AD-2022, that is almost identical to our own design. The only difference is that it incorporates a Separation Enhancement circuit similar to the EVX44, but can only be operated manually. The kit sells for $39.95.

Functional diagram of the Electro-Voice EVX44 decoder.



LEFT CHANNELS ONLY SHOWN FOR CLARITY
RIGHT CHANNELS IDENTICAL, WITH ALL CONTROLS GANGED TO THOSE SHOWN HERE.

Build A
Three-Channel Time Receiver

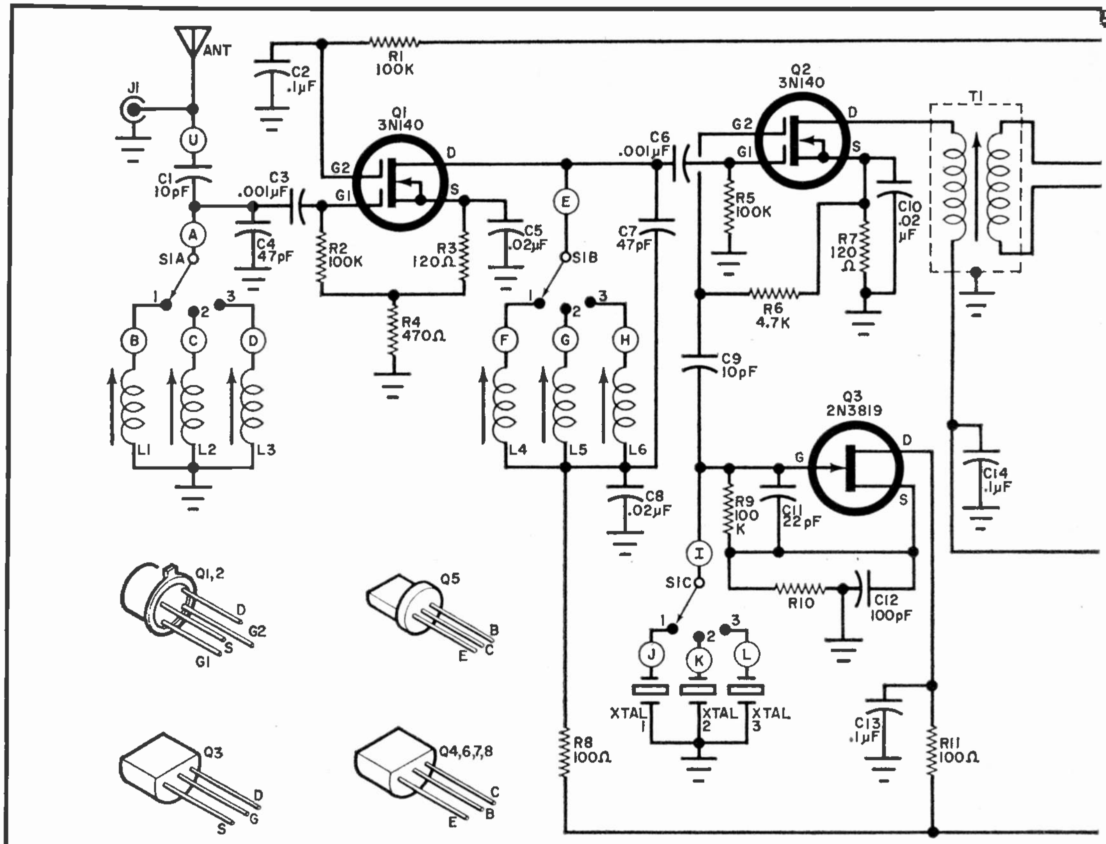
ACCURATE TIME SIGNALS FROM WWV OR CHU

Using dual-gate MOSFET's, this receiver has a sensitivity of 0.25 microvolt for a 10-dB (S + N)/N ratio. Self-contained (except for power) it offers the selection of one of three possible crystal-controlled receive channels. The version illustrated is set up for WWV, but the builder can adapt the circuit for a "mix" of WWV and CHU frequencies.

WHAT DO amateur astronomers, jewelers, boat owners, and radio and TV stations have in common? The need for accurate time. How about radio amateurs, 2-way radio service shops, and electronics labs? Many of them must also make accurate frequency measurements. If your requirements are for accurate time or frequency, build this supersensitive receiver and tune in on the standard time/frequency broadcasts of WWV or CHU (in Eastern Canada and along the East Coast). A choice of three crystal-controlled frequencies assures uninterrupted reception, day or night. You can build this sophisticated 10-transistor superhet receiver in just a few hours and you don't need any test equipment.

The National Bureau of Standards transmits standard time and frequency information continuously on several frequencies via stations WWV in the continental United States and on identical frequencies from WWVH in Hawaii. In Canada, the Dominion Observatory station, CHU, transmits standard time continuously. The program format of WWV varies from that of CHU. While WWV transmits a "tick" each second and a digital and voice time announcement every minute, CHU broadcasts a tone-type "beep" each second and a voice time an-

BY CHARLES CARINGELLA



PARTS LIST

C1,C9—10-pF, dipped silvered mica capacitor

C2,C13-C17—0.1-μF miniature disc capacitor

C3,C6—0.001-μF ceramic disc capacitor

C4,C7—47-pF dipped silvered mica capacitor

C5,C8,C10,C20—0.02-μF miniature disc capacitor

C11—22-pF dipped silvered mica capacitor

C12,C19—100-pF dipped silvered mica capacitor

C18,C21—100-μF, 15-volt miniature PC electrolytic capacitor

C22,C23—1000-μF, 15-volt miniature PC electrolytic capacitor

D1—6-volt, 500-mW zener diode (Motorola 1N5233 or similar)

D2,D3—1N914 silicon diode

J1—Phono jack

J2—Miniature phone jack

L1,L4—For 50-MHz WWV, 10.0-18.7 μH adjustable PC r-f coil (J.W. Miller 23A155-RPC); for 7.335-MHz CHU, 5.6-10-μH adjustable PC r-f coil (J.W. Miller 23A826-RPC)

L2,L5—For 10.0-MHz WWV, 2.4-4.1-μH adjustable PC r-f coil (J.W. Miller 23A336-RPC)

L3,L6—For 15.0-MHz WWV, 1.65-2.75-μH adjustable PC r-f coil (J.W. Miller 23A226-RPC); for 14.670-MHz CHU, 1.65-2.75-μH adjustable PC r-f coil (J.W. Miller 23A226-RPC)

M1—I-f amplifier module (J.W. Miller 8902-B)

Q1-Q2—Dual-gate MOSFET (Motorola 3N-140 or similar)

Q3—N-channel FET (Texas Instruments 2N3819)

Q4,Q6—Transistor (Motorola MPS6517)

Q5—Transistor (GE 2N2925)

Q7—Transistor (Motorola MPS6560)

Q8—Transistor (Motorola MPS6562)

R1,R2,R5,R9,R21—100,000-ohm

R3,R7—120-ohm

R4,R10,R13,R17—470-ohm

R6,R24—4700-ohm

R8,R11,R15—100-ohm

R12—3300-ohm

R14—1500-ohm

R16,R22—10,000-ohm

R19—220,000-ohm

R20—330,000-ohm

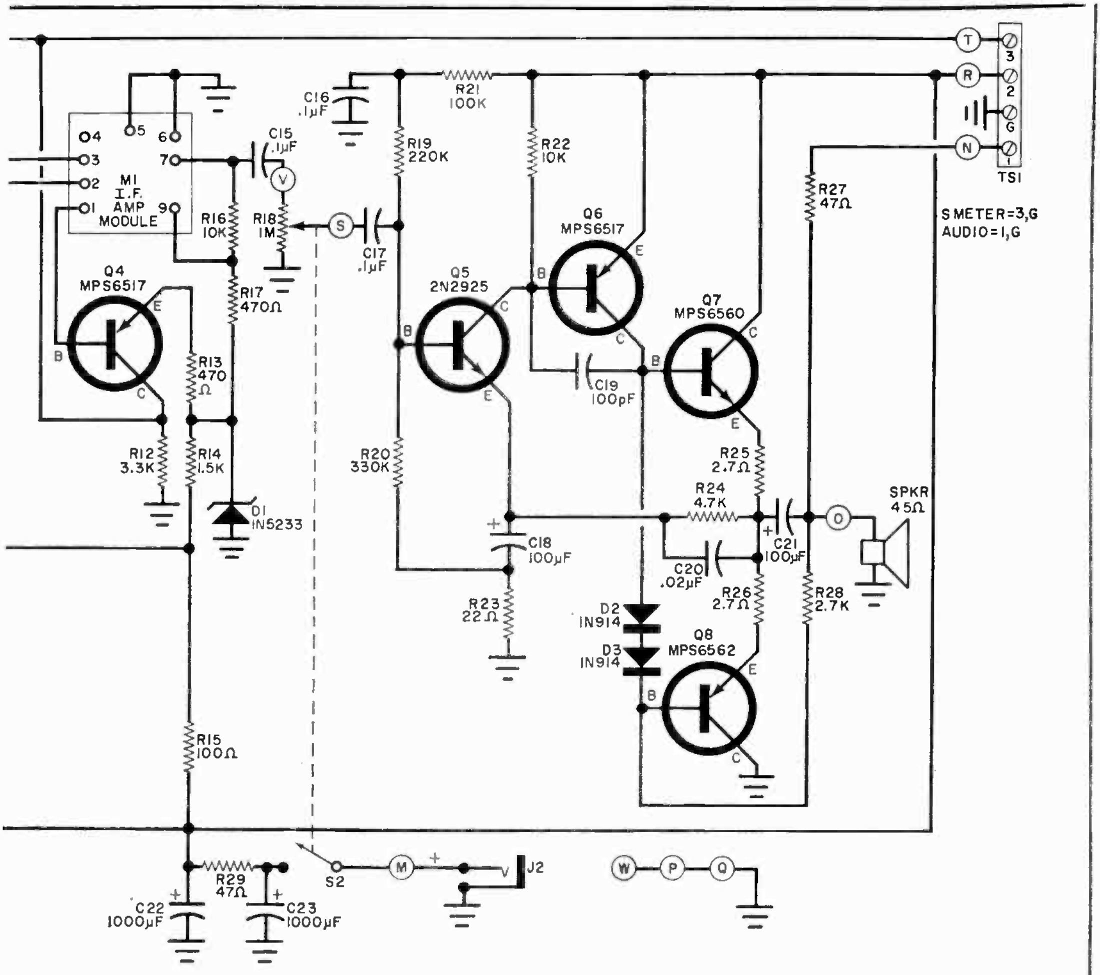
R23—22-ohm

R25,R26—2.7-ohm

R27,R29—47-ohm

R28—2700-ohm

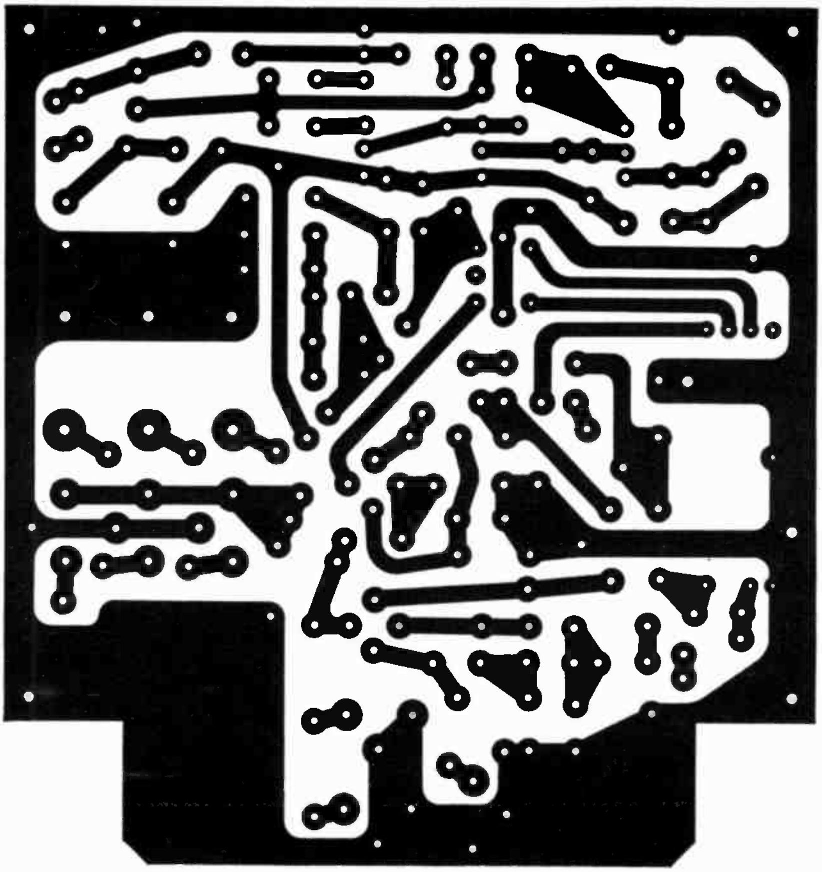
All resistors ½-watt 10% tolerance



R18—1-megohm potentiometer with spst switch (S2)
S1—Special 2-section rotary switch with shield between sections; 3-pole, 3-position switch, first section 1 pole, second section 2 poles
S2—Spst switch, part of R18
SPKR—3" PM speaker, 45-ohm coil (Quam 3A07Z45 or similar)
T1—I-f transformer (J.W. Miller 8901-B)
XTAL1—For 5.0-MHz WWV, 5.455-MHz 0.01% crystal, HC/6U holder; for 7.335-MHz CHU, 7.790-MHz 0.01% crystal, HC/6U holder
XTAL2—For 10.0-MHz WWV, 9.545-MHz 0.01% crystal, HC/6U holder
XTAL3—For 15.0-MHz WWV, 14.545-MHz 0.01% crystal, HC/6U holder; for 14.670-MHz CHU, 14.215-MHz 0.01% crystal, HC/6U holder
Misc.—Crystal sockets, telescoping antenna, knobs, angle brackets, 1/8" spacers, terminal strip, chassis, solder lug, insulating washers, rubber feet, hardware, solder, etc.

Note—The following are available from Caringella Electronics, Inc., P.O. Box 327, Upland, CA 91786: special 2-section rotary switch at $3.95; etched and drilled printed circuit board at $6.95; complete kit of all parts for receiver, including PC board, cabinet, antenna, AC power supply, coils and crystals for three channels (specify frequencies) at $74.95; complete kit of parts for S-meter, including matching cabinet at $14.95. All prices postpaid. California residents add 5% sales tax.

Fig. 1. The receiver uses dual-gate MOSFET's for minimum noise, highest gain, and lowest cross modulation. All of this contributes to extremely good sensitivity and selectivity of the receiver. Crystal-controlled local oscillator (Q3) eliminates tuning problems.



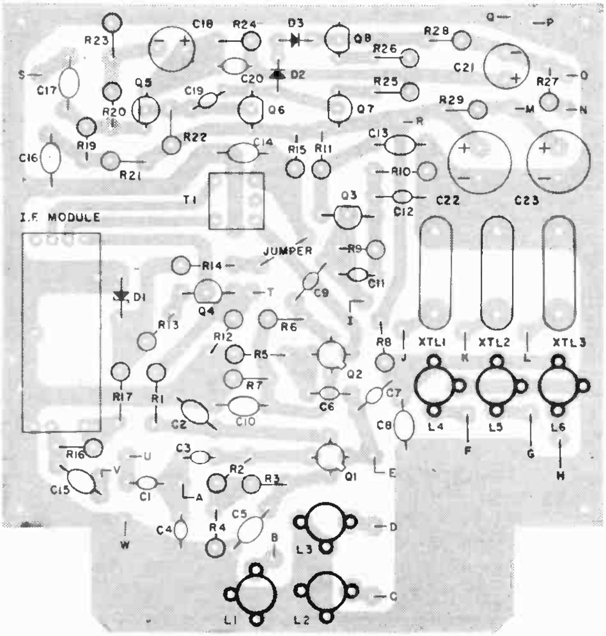


Fig. 2. Actual-size foil pattern and component installation for the receiver. Note that many components are mounted "on end" with the other lead bent over to the appropriate hole in the board. Observe the polarities of electrolytics and diodes and re-read the precautions before wiring the MOSFET's into the circuit (see text).

nouncement every minute in both English and French.

The complete Standard-Time Receiver can be built for about $75, with power supply, crystals, telescoping antenna, and built-in speaker. The circuit (see Fig. 1) consists of an r-f amplifier, mixer, crystal-controlled oscillator, pre-assembled i-f amplifier with built-in detector, and push-pull complementary-symmetry audio amplifier.

The receiver operates from any 12-volt dc source and, therefore, can be used in an automobile, boat or airplane. It will also operate on 12 volts from flashlight batteries, making it completely portable. Power consumption is 70 mA. For ac operation on the workbench all that is required is a conventional 12-volt filament transformer and four silicon rectifiers in a full-wave bridge configuration. Filtering is provided within the receiver.

A sensitivity of 0.25 microvolt for 10-dB (S+N)/N ratio makes this unit one of the hottest receivers around. A 2′ telescoping antenna is all that is needed in most locations. A jack on the back panel can be used for an external antenna should one be required for mobile operation. Provision has also been made for an external S-meter circuit.

Construction. The receiver is constructed on a printed circuit board as shown in Fig. 2. You can make your own board or purchase it as mentioned in the Parts List. Start by cutting off pin 8 on the preassembled i-f module; this pin is not used. Mount the i-f module and i-f transformer *T1* on the circuit board. To avoid damaging the MOSFET's, use a low-power (50 watts or less) soldering iron—not a gun.

Next, install the coils, crystal sockets, and the jumper wire. Mount all resistors at right angles to the board with one end of the resistor in contact with the board and the lead on the other end folded down to the other hole. After all resistors have been installed, start on the capacitors, being careful to observe the polarities on the electrolytics. Diodes *D1*, *D2*, and *D3* are also mounted vertically with a heat sink to protect them during the soldering operation. Using care, install transistors *Q3* through *Q8*, again with a heat sink on the leads during soldering. Transistors *Q1* and *Q2* require special handling. Note that they are supplied with a shorting ring on the four leads. Substitute a wire loop for the shorting ring, and remove the loop after the transistor has been soldered in the board. Handling or soldering MOSFET's with the leads unshorted can cause permanent damage.

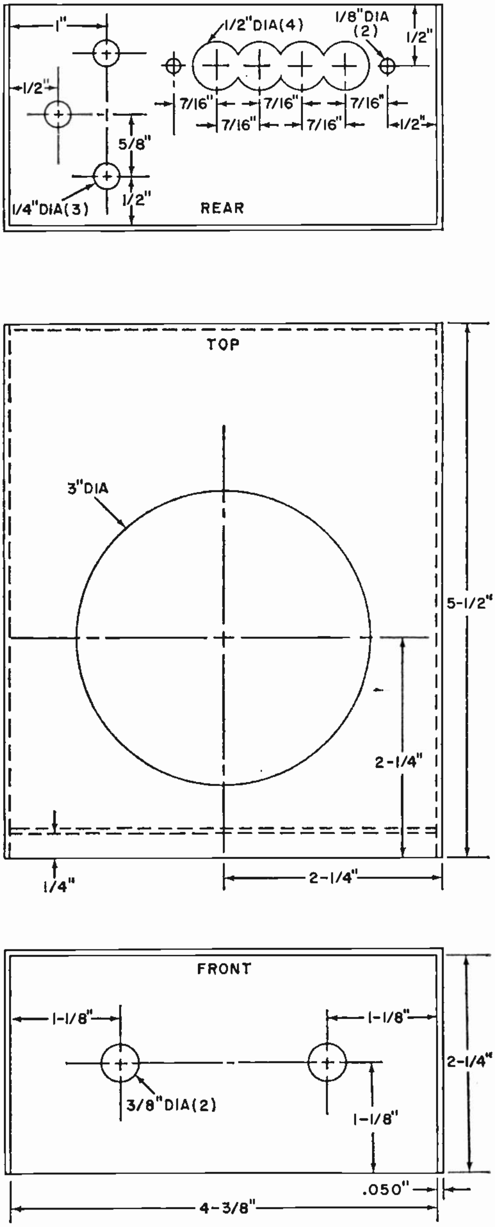
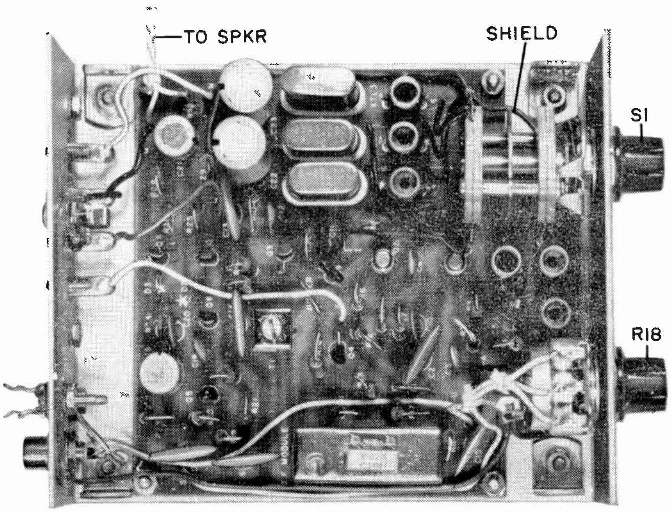


Fig. 3. If you want to duplicate the author's prototype, a metal chassis can be created using the construction information shown above. Thin sheet aluminum was used for the original two-piece chassis, which was formed in two U-shaped sections.

The prototype receiver shown in the photos was fabricated from 0.050″ sheet aluminum formed into two U-shaped pieces. The front panel, rear apron, and top are



It is recommended that a shield be located between the two segments of S1 to avoid coupling. The collapsible antenna is attached to a pair of insulated fuse clips mounted on the rear apron. The speaker is fixed to the upper part of the chassis, while the four angle brackets secure the two chassis sections.

dimensioned and machined as shown in Fig. 3. Small threaded angle brackets in each corner hold the two parts of the chassis together. The speaker, on the top, is protected by a piece of perforated metal. Other components are mounted as shown in the photos. The antenna mounting clips can be made from a fuse holder, insulated from the metal chassis. No matter what type of chassis is used, make the distance between the board and selector switch *S1* as short as possible to keep the leads to a minimum.

Connect the various leads to the PC board as shown in Fig. 1 and mount the board on ⅛" spacers on the bottom of the chassis. Recheck all wiring and then plug in the crystals making sure the *XTAL1* operates with *L1* and *L4*, *XTAL2* with *L2* and *L5*, and *XTAL3* with *L3* and *L6*.

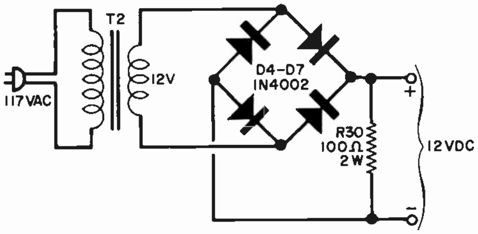


Fig. 4. This simple power supply can be used to power the receiver. No filter is shown as this is provided by components mounted on the PC board.

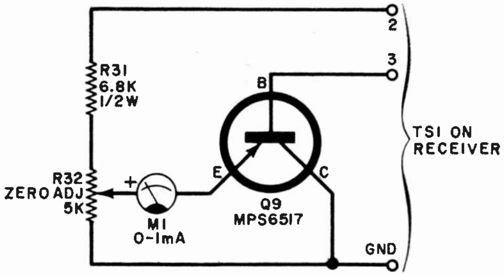


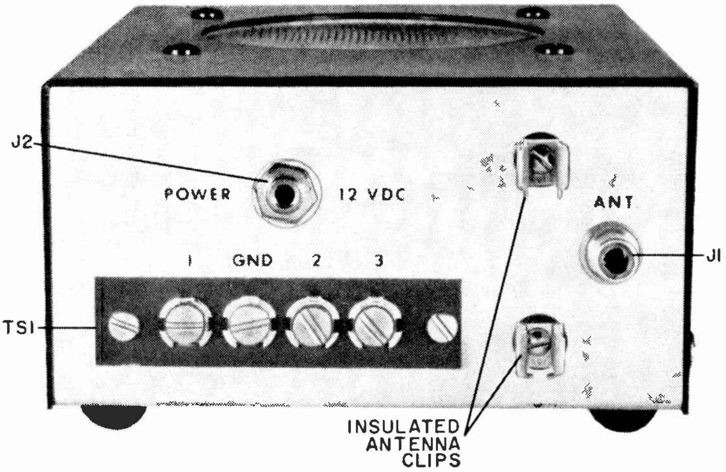
Fig. 5. This simple S-meter circuit is used when aligning an external oscillator with selected WWV.

TECHNICAL SPECIFICATIONS

Sensitivity: 0.25 microvolt for 10-dB S + N/N
Frequency: 5.0 MHz WWV or 7.335 MHz CHU
10.0 MHz WWV
15.0 MHz or 14.670 MHz CHU
Audio Power: Approximately ⅓ watt into built-in 45-ohm speaker
Selectivity: 5 kHz at 6 dB
I-F Frequency: 455 kHz
Power Requirement: 12 volts dc at 70 mA

CHU Conversion. The 5-MHz WWV channel can be converted to receive CHU on 7.335 MHz by replacing *XTAL1* with a 7.790-MHz crystal and *L1* and *L4* with 5.6-10-μH printed circuit adjustable r-f coils (see Parts List). The 15-MHz WWV channel can be converted to receive CHU on 14.670 MHz by replacing *XTAL3* with a 14.215-MHz crystal and realigning *L3* and *L6*.

Although the author used a conventional phone jack for connecting to the external power supply, almost any type of two-terminal connector may be used. The terminal strip may be omitted if you have no need for either the external audio or optional S-meter.



Power Supply and S-Meter. Any type of 12-volt dc power supply may be used with the receiver. One suitable circuit is shown in Fig. 4. Note that no filtering is shown since there are filters on the receiver PC board.

An optional S-meter attachment is shown in Fig. 5. This meter circuit provides a visual aid to obtain precise zero beat when calibrating external oscillators to the extremely accurate WWV signals. The connections shown in Fig. 5 mate with those of TS1 in Fig. 1.

Alignment and Operation. Attach the telescoping antenna to the clips on the rear of the receiver and connect the power source. The receiver can be aligned directly from "on the air" signals as the local oscillator is crystal-controlled. Tune each pair of coils for maximum signal or background noise if the signal is not present. There are also tuning adjustments on the tops of the i-f module and the i-f transformer. They should be touched up to get maximum volume.

Signal strength will depend on the propagation conditions at the time. If the 2′ telescoping antenna does not provide satisfactory reception, attach a longer antenna to *J1*. Reception of WWV on 5, 10, and 15 MHz should be reasonably good throughout most of the U.S.A., and at least one of these frequencies should be audible day or night. Reception of CHU on 7.335 MHz is confined primarily to the East Coast of North America, while reception of CHU on 14.670 MHz extends into the Midwest during daylight hours and into the Far West in the evening.

◆

THEORY OF CIRCUIT DESIGN

The pair of dual-gate MOSFET's (*Q1*, *Q2*) used in the front end offer high gain with low noise, as well as lower cross modulation and greater dynamic range than either conventional bipolars or single-gate FET's. MOSFET *Q1* serves as the r-f amplifier with the incoming signal applied to gate 1 and the agc voltage applied to gate 2. The crystal-controlled local oscillator *(Q3)* consists of a conventional n-channel FET used as an untuned crystal-controlled oscillator.

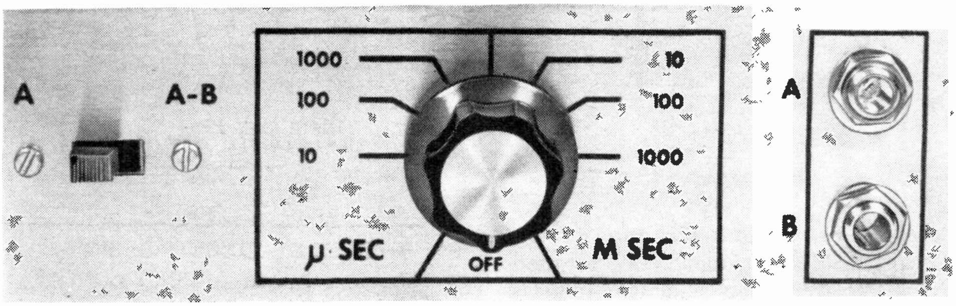
Switch *S1* selects the desired tuned circuits and the crystal for the selected channel. This switch should have a shield between the switch sections to isolate the input tuned circuit from the output circuit in the r-f amplifier. Otherwise, the r-f amplifier could become extremely unstable and might possibly oscillate due to the high gain within the stage.

After the i-f transformer *(T1)*, the signal is amplified by a commercial miniature preassembled and pre-aligned module that contains two transistors, three i-f transformers, and a diode detector. Transistor *Q4* serves as the agc amplifier for the r-f stage as well as providing the driving voltage for an optional. external S-meter circuit.

The recovered audio signal is developed across volume control *R18* and fed to a four-transistor audio amplifier that can deliver about ⅓ watt to the speaker. The audio is also available at a rear apron terminal strip for headphones.

The external 12-volt dc source need not be filtered since *C22*, *C23* and *R29* perform this function.

Time-Period Module for the Digital Measurements Lab



ELAPSED TIME MEASURED DOWN TO 0.01 SECOND

This is the second plug-in module designed to be used with the Digital Measurements Lab described on page 25. Easy to assemble, it has many applications in sporting events, photography, and electronics experiments. A 1.00-MHz crystal-controlled oscillator provides the timing base.

THE original article on page 25 was the first of a series of articles on the construction of a group of test instruments to be used with a common main frame. This article's contribution to the Digital Measurements Lab is a Time-Period module. As with the readout assembly and Frequency Counter plug-in presented previously, the Time-Period module takes advantage of TTL integrated circuits.

The Time-Period module is similar to the Frequency Counter in some ways. However, its function is the inverse of the counter in that it is designed to measure accurately the duration, rather than the frequency, of an event. The function is 1/F and it is often used to measure very-low-frequency signals which would have to be counted for an excessive length of time to obtain an accurate readout with a frequency counter.

The Time-Period module can be used as a timer, for velocity measurements, and any other related start/stop function. The wide range of the module makes it possible to time events occurring within a range of 0.01-15 seconds with a 0.1 percent accuracy.

The practical uses for the Time-Period module include measurements of bullet velocities, slot car lap times, and camera shutter speeds. In fact, the Time-Period function can measure the duration of any event that can be converted into an electrical signal. This is done by switching the counter input into one of the six scaled outputs that are

BY DANIEL MEYER

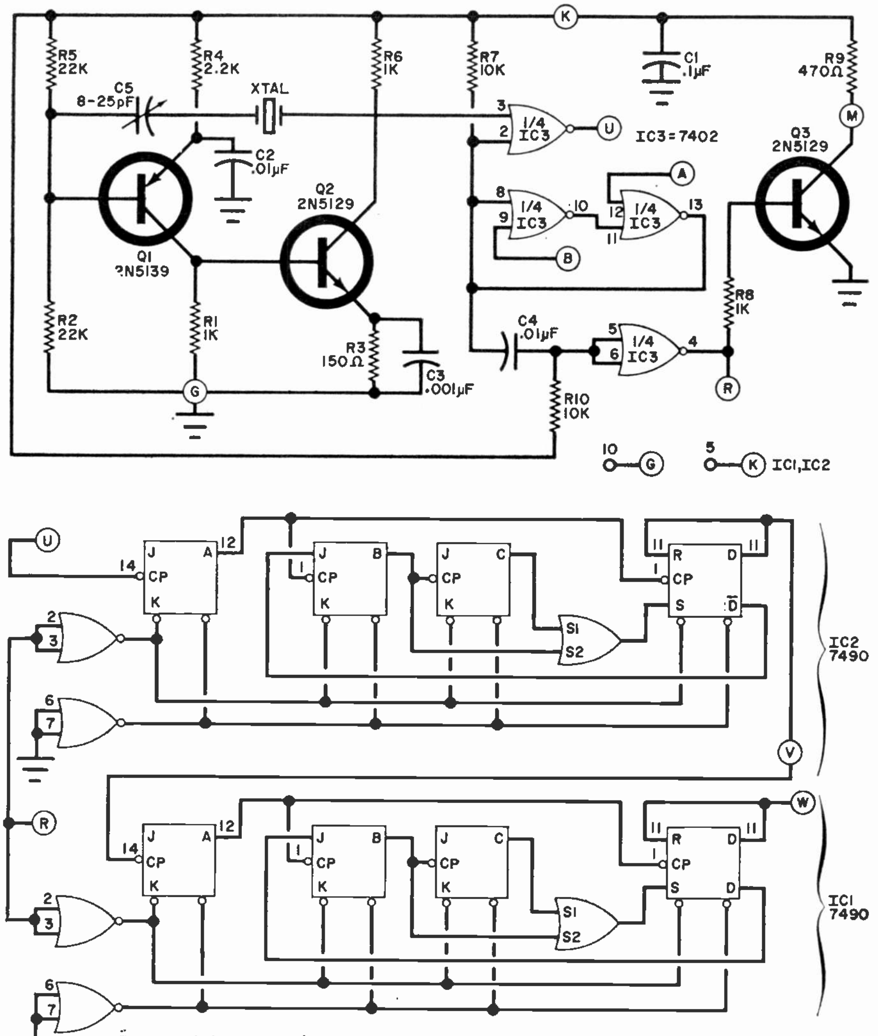


Fig. 1. Schematic diagram at top is circuit of Time Base section, while directly above is diagram of Scaler circuit used in plug-in.

PARTS LIST

C1—0.1-µF disc capacitor
C2,C4—0.01-µF disc capacitor
C3—0.001-µF disc capacitor
C5—8—25-pF trimmer capacitor
IC1,IC2—7490 integrated circuit
IC3—7402 integrated circuit
J1,J2—Two-circuit phone jack (insulated)
Q1—2N5139 transistor
Q2,Q3—2N5129 transistor
R1,R6,R8—1000-ohm
R2,R5—22,000-ohm
R3—150-ohm
R4—2200-ohm
R7,R10—10,000-ohm
R9,R11,R12—470-ohm
R13—33,000-ohm
All resistors ½-watt, 10% tolerance
S1—Two-pole, 10-position rotary switch with spst attachment (S1 in main frame power supply)
XTAL—Crystal (1.00 MHz or 100.00 kHz as desired—see text)
1—Scaler kit
Misc.—15-contact connector; control knob; printed circuit boards for time period and scaler circuits; chassis; spacers; solid and stranded hookup wire; #4 machine hardware; solder; etc.
Note—The following items are available from Southwest Technical Products Corp., Box 32040, San Antonio, TX 78216: Time Period board No. RPTb for $2.35; all Time Period circuit parts including 1.00-MHz crystal but minus Scaler, chassis, switch, etc. for $21.50; Scaler circuit board No. SC-10-4b for $1.90; circuit board and parts for Scaler for $14.55; complete kit of parts for Time Period plug-in module includes all above parts plus switch, chassis, etc. for $38.75 plus postage on 3 lb. and insurance.

generated by a 1.00-MHz crystal-controlled oscillator. Thus, the frequencies that can be counted (in terms of time) range from 100 kHz to 1.0 Hz. The circuit has an automatic reset which properly sets up the system every time a new count or measurement is made. Operation can be from a mechanical switch, microphone, photocell, or break wire.

Theory of Circuit Design. The basic timing circuit consists of a 1.00-MHz crystal-controlled oscillator made up of *Q1* and *Q2* in Fig. 1. The frequency can be set precisely with trimmer capacitor *C5* with the aid of an accurate 1-MHz signal source or by zero beating with WWV.

The output of the oscillator goes to one input of a dual-input gate (part of *IC3*). However, the oscillator's signal cannot pass through the gate until the second input on this gate goes to ground or logic "0." The gate is controlled by a latching circuit consisting of two more of the gates in *IC3*. This latch, or set-reset, circuit is, in turn, controlled by the input signal or signals.

A positive signal at input A in the form of a logic "1" opens the gate and allows the oscillator pulses to pass into the scaler chain, continuing to do so until a positive-going signal is applied to the B input to close the gate again. If a positive signal is permanently applied to input B, the A input becomes a duration gate. This input will open the gate and allow oscillator pulses to pass into the scalers as long as the A input is at logic 1. When the input is removed from gate input A, however, the gate again closes.

The remaining gate in *IC3* and *Q3* are used to reset the circuit and the counter at the beginning of each cycle. When the output of the latch circuit goes to a logic 0 to open the gate, capacitor *C4* causes the reset gate to generate a pulse which resets *IC1* and *IC2*, two divide-by-ten circuits. This pulse is connected to the scaler circuit at point R.

The counter is reset by an inverted pulse at the output of transistor *Q3*. This is necessary if the counter is made up of individual flip-flop and gate packages as in the "Utilogic" decade counting system in the main

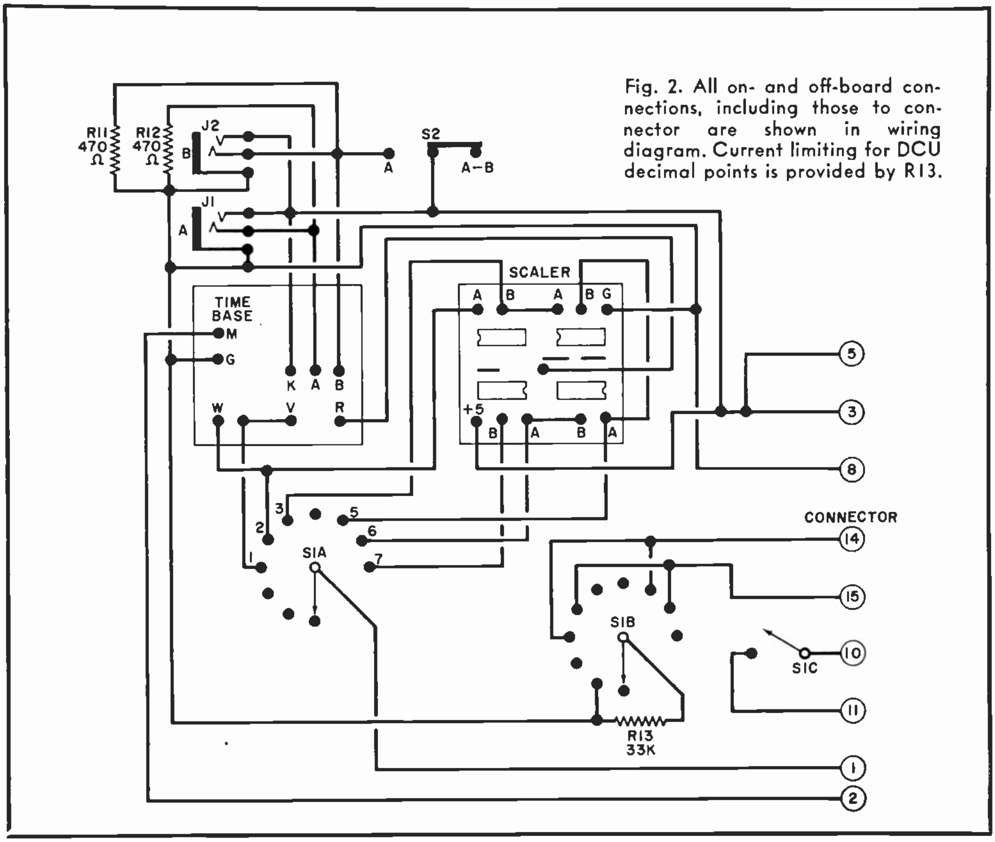
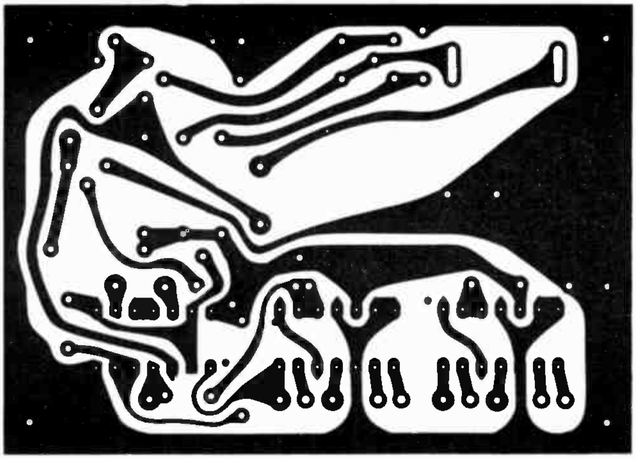


Fig. 2. All on- and off-board connections, including those to connector are shown in wiring diagram. Current limiting for DCU decimal points is provided by R13.



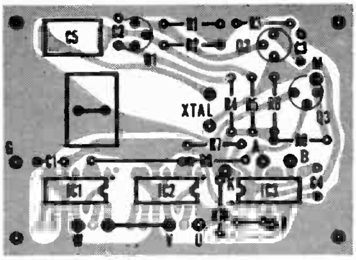


Fig. 3. Actual size etching guide (left) and components placement and orientation diagram (above) are for the Time-Period assembly.

frame. If, however, the readout system uses medium-scale IC's of the 7490 type, then the reset would be taken directly from point **R** (these decade counters require a positive reset pulse).

Rotary switch *S1* (see Fig. 2) selects the pulse frequency to be fed into the counter and also switches the decimal point to the proper position. Resistor *R13* is the ground return for the decimal point and limits the current to the proper level for this part of the readout.

Construction. Most of the assembly work involved in the Time-Period plug-in is performed by wiring the Time-Period and Scaler circuit boards. An actual-size etching guide and a components placement and orientation diagram for the Time-Period assembly are given in Fig. 3. (For additional details refer to the Frequency Counter Module on page 31 for Scaler information.) When mounting the IC's, transistors, and electrolytic capacitors on the circuit boards, make sure that they are properly oriented.

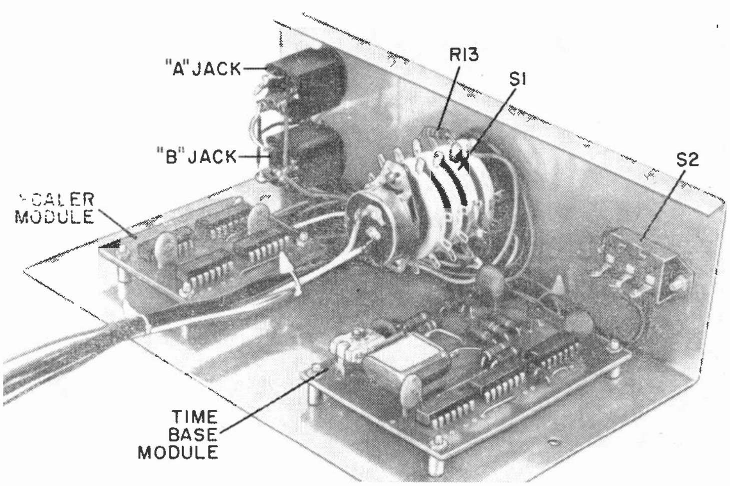
Once the boards are assembled, turn them foil side toward you and compare their foil patterns against the etching guides for solder bridges. If you are satisfied that all is in order, interconnect the boards via rotary switch *S1* and the 15-contact connector as shown in the diagram, Fig. 2. If possible, use #22 stranded hookup wire for the connector cable assembly.

Next, mount the boards to the floor of the chassis with eight sets of #4 machine hardware and eight ¼"-⅜"-long spacers. Then mount the switches and jacks to the front panel and complete the wiring. Neatly bundle the wiring together and lace it.

Now, connect the Time-Period module to the main frame via the connector assembly and turn on the system by rotating the range switch in the plug-in one or more positions to the right. Use a high-impedance voltmeter to check the potential at point **K** on the Time Period board and the +5-volt point on the Scaler board. In both cases, you should obtain readings of exactly +5 volts dc; if not, adjust the setting of the appropriate control in the power supply. Then adjust trimmer capacitor *C5* so that the oscillator is operating at exactly 1.00 MHz. Use an accurate signal source (WWV, for example) to beat against the oscillator signal. This done, seal the adjustment of *C5*.

Set the range switch on the Time-Period plug-in to the 1000 M SEC position and the mode switch to position A. Insert a phone plug in jack A and connect the input to the +5-volt power supply source. The counter should begin to count at a rate of one count per second for as long as the +5 volts is applied to the input. Moving the range switch to any other position with the input still connected to the 5-volt source, the counting rate should increase until the numbers in the readout tubes are just blurs.

Set the mode switch to the A-B position and the range switch to the 1000 M SEC position. Start the counter by connecting the A input to the +5-volt source. The counter should begin counting and stop only when the +5-volt source is connected to the B input. If everything checks out, the Time-Period module is ready to use.



Controls and input jacks mount on front panel and circuit boards fasten to floor of chassis with 4-40 hardware and spacers.

Applications and Use. To test the speed of a camera shutter with the Time-Period instrument, a high-speed photo pickoff of the type shown in Fig. 4 is required. Note that the pickup device is a photo Darlington because of its rapid response to stimulus. Do not attempt to substitute a cadmium-sulfide cell in place of the photo-Darlington pickup since such devices respond far too slowly.

The pickup should be mounted in an opaque tube to exclude as much ambient light as possible. When the circuit is assembled, connect the negative output of the pickoff circuit to the A input of the Time-Period module. Open the camera's shutter and direct the beam of a flashlight through the lens into the photo pickup. With the mode switch in position A, the counter should begin to run when the light is focused onto the photo-transistor. If it does not, adjust the potentiometer until operation does begin. (The proper setting of the sensitivity control is just slightly beyond the threshold point at which the ambient light causes the counter to operate.)

Most shutter speeds can be checked by the use of the 100-μSEC range position of *S1* in the module. The reading obtained can be converted to seconds by multiplying the display count by the switch position. For example, if the switch is in the 100-μSEC position and a reading of 200 is obtained, simply multiply 200 × 0.0001 for a result of 0.02 second (1/50 second). A reading of 200 on the 10-μSEC range would yield a figure of 0.002 second (1/500 second).

The same pickoff circuit in Fig. 4 can also be used as an input for start-stop applications, such as timing a lap in a race. In this

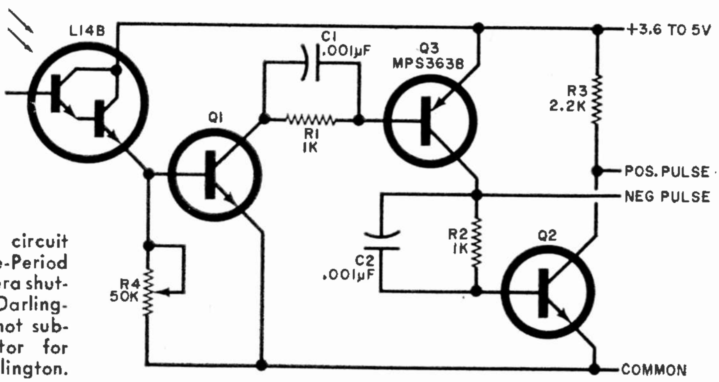


Fig. 4. Photo pickoff circuit of type used with Time-Period plug-in to measure camera shutter speed uses photo Darlington as transducer. Do not substitute a photo resistor for high-speed L14B Darlington.

case, the inputs of the Time-Period module would be connected to the positive output of the pickoff circuit. The light beam would be adjusted to keep the counter turned off until the beam is blocked or interrupted. A simple mechanical switch or a break-wire arrangement can also be used in timing applications.

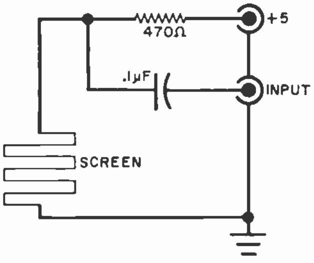


Fig. 5. Transducer circuit used for determining bullet velocity employs a continuous-conductor break screen.

A system for measuring the velocity of a bullet is shown in Fig. 5. When the bullet breaks the wire at the start screen, a positive pulse is generated by the charging action of the capacitor. Similarly, a positive pulse is generated at the stop terminal (where a duplicate circuit is employed) when the stop screen is broken by the bullet. The bullet's velocity is then equal to (screen spacing in feet X 1000) / (counter range X readout value) in feet/sec.

For example, if the screens were 4 ft apart and a reading of 200 were obtained with the selector switch in the 10 M SEC position, velocity would be equal to (4 X 1000)/(0.01 X 200), or 2000 ft/sec. Since the counter is accurate to within 0.1%, the screen spacing must be quite accurate to prevent this from affecting the accuracy of the reading obtained. At a 4-ft spacing, the screens must be placed within 1/32 in. of the correct distance.

The Time-Period circuit board assembly can also be combined with a readout system to produce a "Sports Timer" (Popular Electronics, Oct. 1968). Changing the crystal to a 100.00-kHz type will produce pulses at 1/1000 second intervals at the output of the second scaler. This output can be applied directly to a 4½-digit readout to give readings up to 10 minutes with an accuracy of ±0.001 second.

The circuit could also be used as a portable time base for electronic digital clocks that would normally be driven by the 60-Hz ac line. In this case, both the Time-Period and Scaler circuits would be needed to produce pulses at exact 1-second intervals. ◆

BUILD A TIME BASE CALIBRATOR

CLEAN SQUARE WAVES FROM 1 HZ TO 1 MHZ

This is a laboratory-style electronic construction project that would have been impossible to build without integrated circuits. With IC's, it becomes relatively simple and easy to duplicate. Uses for this project are varied and range from research to shortwave listening.

A SQUARE WAVE of known frequency is one of the most useful waveforms that the serious electronics experimenter, audiophile, or engineer can have in his workshop. It can be used to check out audio systems, align probes and check attenuators of oscilloscopes. When it is differentiated, a square wave can be used to generate accurate time markers on a scope trace for making precise measurements. It can also be used to keep tabs on the accuracy of a triggered sweep scope. In experimenting with logic circuits, a square wave makes an ideal trigger.

The time base, square-wave generator or calibrator described here is crystal controlled and can deliver any of 13 selected timing periods from 1 microsecond to 1 second. Other specifications are given in the Table.

Theory of Circuit Design. The circuit of the calibrator is shown in Fig. 1. Field-effect transistor *Q1*, with *XTAL1* and other components, forms a 1000-kHz oscillator. The signal generated at the junction of *L1* and *R2* feeds a shaper (*Q2*) which is biased to operate in the saturation region. The shaper provides the necessary square-edged signal for driving the DTL (diode-transistor logic) frequency divider chain.

The divider chain, consisting of 12 dual-JK flip-flops, is arranged to divide in a series of 2 and 5. The basic logic circuit for such division is shown in Fig. 2, which is similar to the actual division using the IC's.

The output of each divider is fed to one position of a 13-position rotary switch (*S1*). The selected signal from the switch is coupled to an output buffer (*Q3*), which also operates in the saturation region. The output is split by *R5* and *R6* to provide an output termination of 50 ohms.

BY RICHARD J. VALENTINE

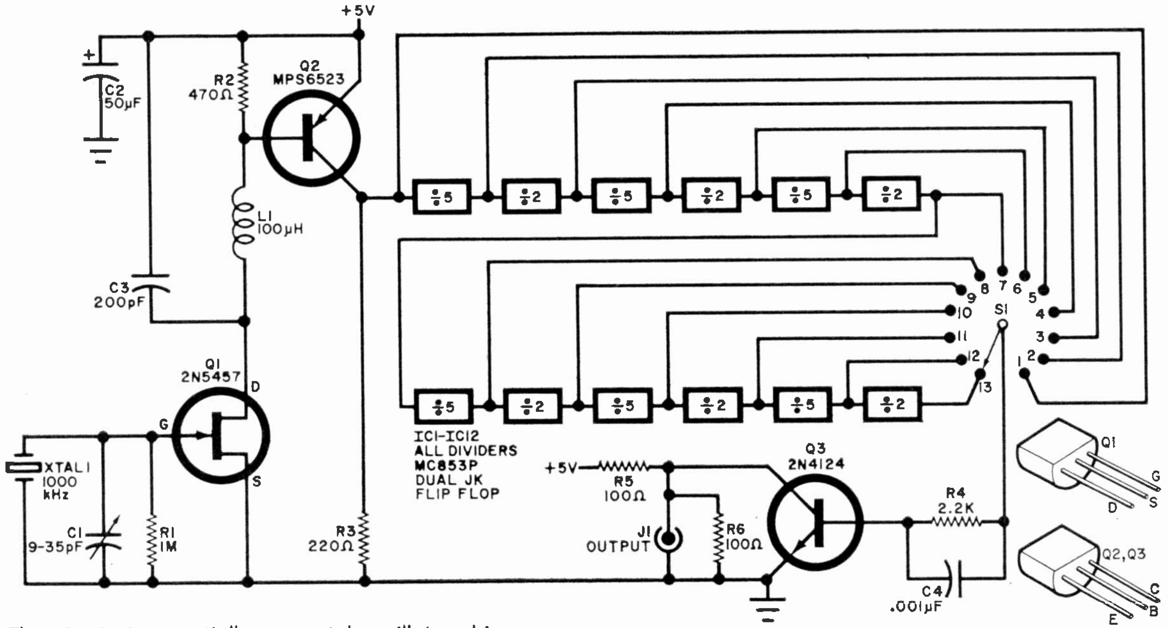


Fig. 1. The circuit is essentially a crystal oscillator driving a shaper circuit, fed to a string of digital dividers. If desired, other frequencies can be obtained either by changing the crystal frequency, the divider chain arrangement, or both.

NOTE: The calibrator circuit board is available from Southwest Technical Products Corp., Box 32040, San Antonio, Texas 78216 for $4.35 plus postage.

S1 POSITIONS

1—1 µS, 1 MHz
2—5 µS, 200 kHz
3—10 µS, 100 kHz
4—50 µS, 20 kHz
5—100 µS, 10 kHz
6—500 µS, 2 kHz
7—1 mS, 1 kHz
8—5 mS, 200 Hz
9—10 mS, 100 Hz
10—50 mS, 20 Hz
11—.1 S, 10 Hz
12—.5 S, 2 Hz
13—1 S, 1 Hz

PARTS LIST CALIBRATOR

C1—9—35-pF miniature trimmer capacitor
C2—50-µF, 6-volt electrolytic capacitor
C3—200-pF disc capacitor
C4—0.001-µF disc capacitor
IC1-IC12—Dual JK flip-flop (Motorola MC853P or HEP C1053P)
J1—BNC jack and mating plug
L1—100-µH molded choke
Q1—2N5457 or HEP 802 transistor
Q2—MPS6523 or HEP57 transistor
Q3—2N4124 or HEP53 transistor
R1—1-megohm
R2—1000-ohm
R3—220-ohm
R4—2200-ohm
R5,R6—100-ohm
all resistors ¼-watt
S1—13-pole rotary switch
XTAL1—1000-kHz crystal
Misc.—Suitable chassis, knob, stand-offs, wire, solder, etc.

Construction. Because of the high frequencies involved, the use of a printed circuit board is recommended. An actual size foil pattern and component installation diagram are shown in Fig. 3.

The power requirements are 5 volts dc at about 220 mA, which can be obtained either from a power supply such as that shown in Fig. 4 or, for a portable unit, from three D cells connected in series. If you build the ac supply, use a 2 sq in. heat sink for *Q1*.

The completed PC board and power supply can be mounted in any type of metal chassis.

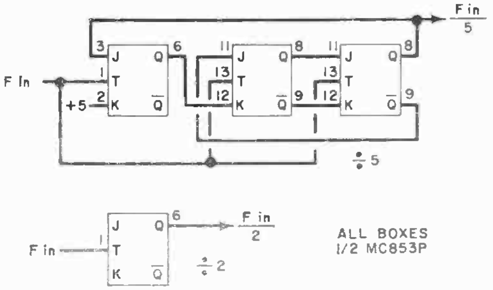
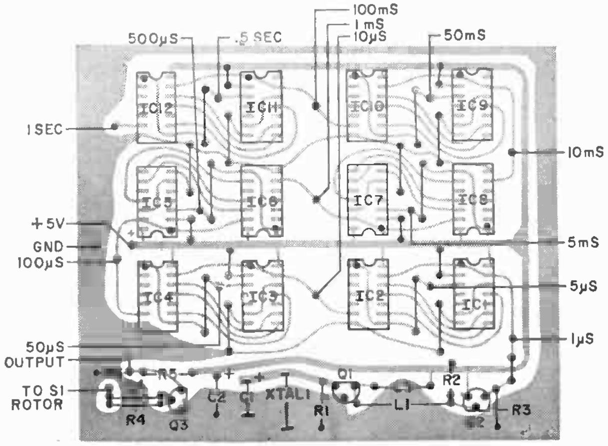
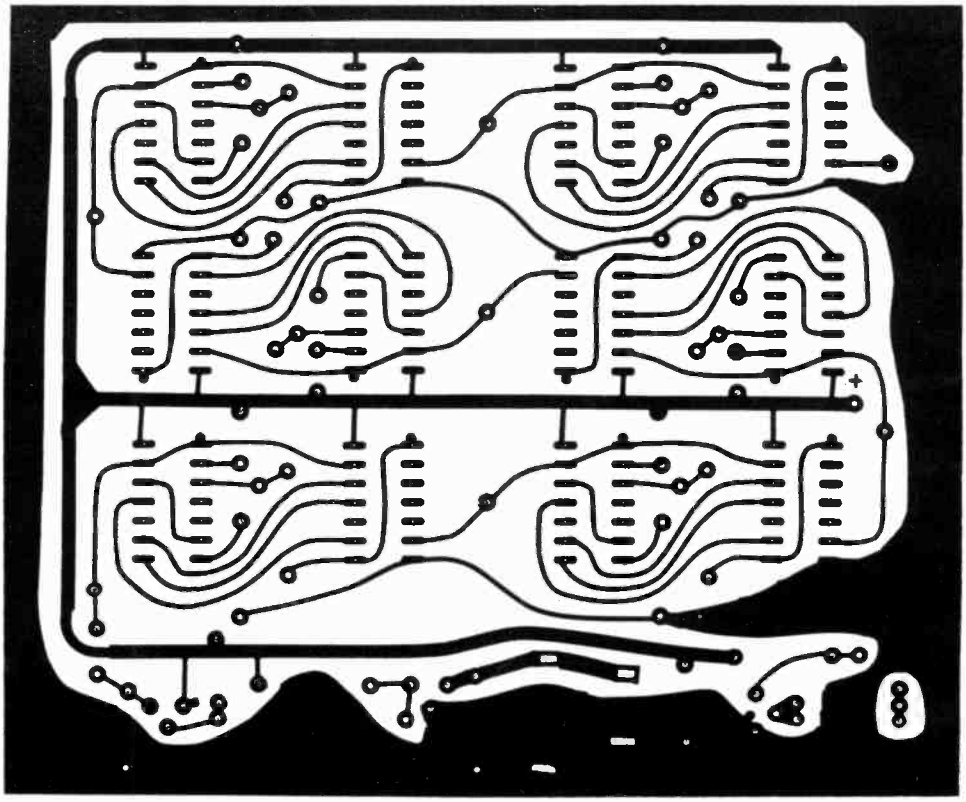


Fig. 2. Minimum hardware divide-by-5 and divide-by-2 circuits used in the calibrator. Because each IC contains a pair of JK flip-flops, a pair of IC's contains the two divide circuits shown at the left.

Fig. 3. The actual size PC board foil pattern shown below simplifies the wiring of the calibrator. Once fabricated, the components are installed as shown at the right. Observe the coding of all components, and make sure that all jumpers are placed properly. Due to the delicacy of this PC pattern all of the drill holes for installing the IC's may not show in this reproduction. Drill holes in each of the 14 contact points for all 12 IC's.





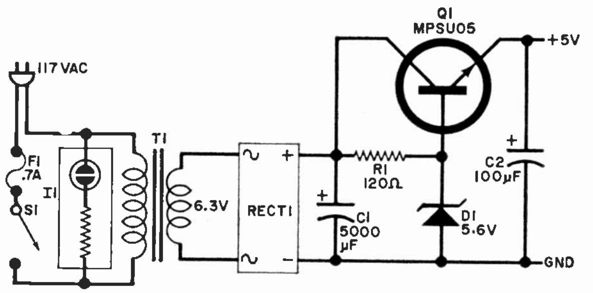


Fig. 4. This regulated power supply can easily handle the calibrator. If you want portability, use three 1½-volt D cells in series for the power supply. The slightly reduced voltage will not affect operation.

PARTS LIST
POWER SUPPLY

C1—5000-µF, 10-volt electrolytic capacitor
C2—100-µF, 6-volt electrolytic capacitor
D1—1N5232 diode
F1—0.7A fuse and holder
I1—120-volt neon lamp indicator assembly
Q1—MPSU05 transistor
R1—120-ohm, ½-watt resistor
RECT1—MDA920-1 or HEP175 25-volt, 1A bridge
S1—Spst switch
T1—Filament transformer, secondary 6.3 volts at 600 mA
Misc.—optional power-on indicator, heat sink, terminal strip, mounting hardware, line cord, grommet, etc.

Operation. To calibrate the generator accurately, put *S1* in the 1 MHz position and connect a short length of wire to the output jack. With the wire and the calibrator near a shortwave receiver tuned to WWV (5, 10 or 15 MHz), adjust capacitor *C1* to obtain a zerobeat between the generator and WWV. If you have a frequency meter, adjust *C1* to obtain an exact 1-MHz indication on the meter. However, if you have neither a WWV receiver nor a frequency meter, the inherent accuracy of the 1-MHz crystal will be sufficient for most purposes.

In using the calibrator, the output connection should be made through a 50-ohm coaxial cable terminated in a 50-ohm load.

Spiker. If you need a sharp spike signal of known frequency, use the circuit shown in Fig. 5 to develop the required signal. The input impedance is 50 ohms; the output is 1000 ohms. The switch is used to select the proper capacitor for each group of frequencies.

Applications. Although primarily designed for the calibration of oscilloscopes with triggered sweeps, this square-wave generator and spiker combination has a number of other important laboratory and experimental applications.

First, the generator makes an excellent frequency calibrator for use with general purpose shortwave receivers. For this appli-

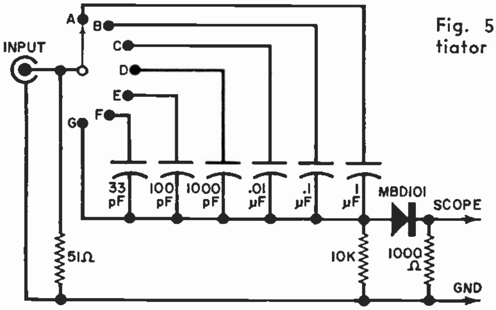


Fig. 5. The spiker is essentially a differentiator whose series capacitor can be selected.

SWITCH POSITIONS
A—1 S-50 mS
B—10 ms-5 mS
C—1 mS-500 µS
D—100 µS-50 µS
E—10-µS-5 µS
F—1 µS
G—direct

TECHNICAL SPECIFICATIONS

Rise and fall times: 25 nanoseconds
Time period: 13 selectable times in 1 and 5 steps from 1 μs to 1 second
Accuracy: 0.005%
Amplitude (output): 1 volt into 50 ohms
DC offset: less than 0.3 volt
Noise and ripple: 20 mV
Power required: 5 volts at 220 mA

cation, connect the spiker to the generator and attach a short antenna to the spiker output. Set the front panel switch to 1 MHz (1 μS). This will produce a train of "birdies," 1 MHz apart. With the receiver tuned to WWV on 5, 10, or 15 MHz, the crystal oscillator in the generator can be trimmed to the exact frequency. Use other dial positions and the calibrator will generate the frequencies shown in Fig. 1. Suitable selection of frequencies will permit a very accurate determination of the frequency of an incoming signal.

Due to the fact that the square waves generated have very rapid rise and fall times, they can be used as a source of pulses for triggering many types of IC logic, especially RTL, where steep edges are required. Having complete control of the output frequency means that the logic can be triggered at almost any desired rate.

The square waves are also ideal for testing amplifiers—from conventional audio to broad-bandwidth video. High- and low-frequency response, as well as ringing, can be detected when using the square-wave generator in conjunction with a wideband scope. Simply driving the amplifier under test with a square wave of suitable frequency and observing the changes (if any) that the amplifier produces on the square wave will show the characteristics of the amplifier. For example, to provide a clean square-wave output, the amplifier response must be from about 1/10 to 10 times the fundamental frequency of the square wave. Thus, if an amplifier can cleanly reproduce a 10-kHz waveform, then its response is good from about 1 kHz (usually much lower) to about 100 kHz.

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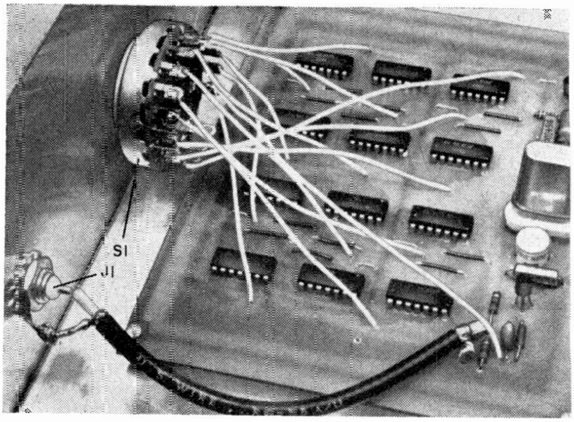
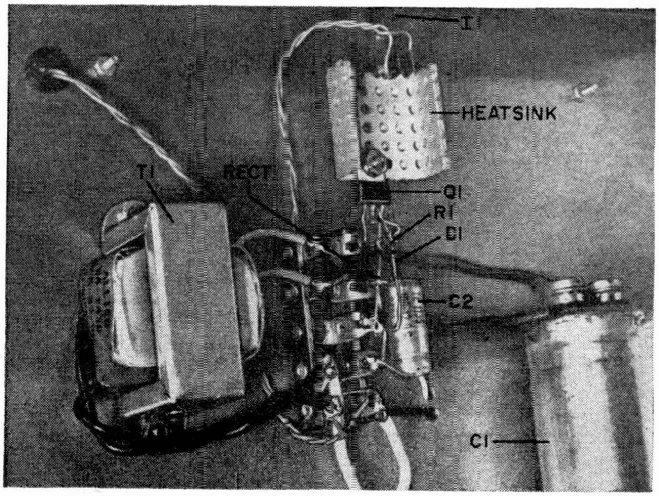


The connections from the PC board to the selector switch should be made as short as possible. A short length of coaxial cable serves as the output lead.



Use a 2-square-inch piece of scrap aluminum as the heat sink for Q1. Isolate the heat sink from the chassis using an insulated spacer.

THE NUMBERS GAME

IF FOUR IS BETTER THAN TWO, IS SIXTEEN BETTER THAN EIGHT?

In 1961, POPULAR ELECTRONICS turned loose an avalanche and has lived through a storm of brickbats and bouquets. At that time, the "Sweet Sixteen" represented a hi-fi system that many readers wanted to build and find out first hand if the multiple-speaker idea would work. Sometimes it did, many times it didn't. In this article, our specialist on speaker systems tells why.

TO THOSE SYMPTOMS of national madness, such as the tulipmania craze in the 1600's, most knowledgeable audio enthusiasts usually add the multiple-cheap speaker epidemic of the early 1960's. POPULAR ELECTRONICS[1,2] instigated the construction of thousands of speaker systems, each containing 16, or more, small 5" permanent magnet speakers. Although the heyday of the craze has abated, hundreds of these systems are still being constructed—usually for the wrong reasons.

According to the builders of the multiple speaker systems, the obvious advantages could be summarized as follows:

A. The system produces noticeably

BY DAVID B. WEEMS

lower distortion because the amplifier power is divided among many speakers.

B. The use of multiple speakers extends the bass range since mutual coupling permits all speaker cones to work together in unison at the lower frequencies.

C. The dips and peaks in the response of individual speakers are averaged out and the overall frequency response of the system is very smooth.

D. The use of small cones in the multiple speaker system insures the generation of a good treble response.

E. The multiple small speaker system does not require a crossover network and thus eliminates phase shift effects.

F. There is a noticeably "bigger" sound due to the expanded area of the source.

G. The multiple small speaker system can be built for a very low dollar figure.

All of the above qualities represent worthy goals. The reasons supporting each goal seem clear and logical. Yet, the manufacturers of high fidelity speaker systems have failed to exploit the use of multiple cheap speakers. It is natural to ask why. A hard look at the various concepts and the advantages claimed for them may disclose the answer.

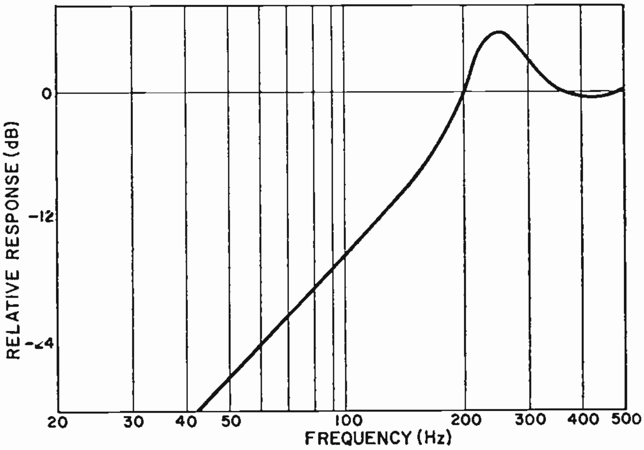
Distortion. The sound output from a loudspeaker is usually not a true representation of the electrical signal input. The production of harmonic and intermodulation distortion is mentioned most often in considering loudspeaker system performance.

Harmonic distortion, frequency doubling, tripling, etc., can be produced in a speaker by either a nonlinear cone suspension or a nonuniform magnetic field surrounding the voice coil. Most speaker cone suspensions exert an increasing force on the cone as the cone moves away from its rest position. By intentional design, the suspension of a high-quality speaker tends to exert the same restoring force on the cone throughout its normal movement range. The magnet and voice coil structure of a good speaker is usually deep enough to always keep the voice coil operating in a field of uniform flux density.

Cheap speakers are made for applications where the normal power handling requirement can be measured in a fraction of a watt. At such sound intensity levels the cone movement—and distortion—is kept within tolerable limits. Since an array divides the power among all speakers, harmonic distortion should not be a major problem in normal use.

However, if the speaker array is used to generate a high level of sound intensity at low frequencies, the cone movement can become excessive—producing distortion. In this case, the nonlinear suspension can be relieved of part of its distortion producing effects by installing the speaker array in a sealed enclosure. The captive air in the enclosure acts as a restoring force and tends to limit cone movement. Unfortunately, the creation of this "pressure box" treatment causes another problem that is discussed later on in this article.

Intermodulation distortion is the modulation of one audio frequency by another audio frequency. Low frequencies can



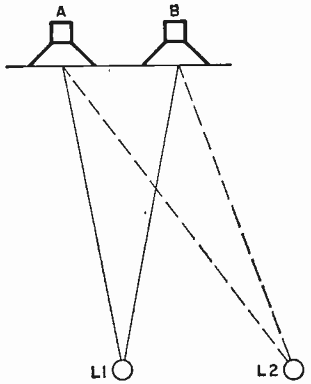
Generalized response curve of a cheap speaker in a sealed box has a resonance peak at 245 Hz. Amplitude of peak would depend upon speaker and enclosure properties.

modulate high frequencies when both are being produced by the same speaker. High quality speaker systems reduce intermodulation distortion through the separation of bass and treble ranges. Thus, these two-way or three-way systems are not as severely limited in their power handling capacity through a limitation of cone movement. Excessive cone movement aggravates and increases intermodulation distortion.

Bass Response. The bass response of any speaker falls off below the frequency of the fundamental cone resonance. The frequency of cone resonance is lowered as the compliance and mass of the cone are increased. The simplest and most obvious method of obtaining extended bass response has always been to choose a speaker with a low fundamental cone resonance frequency.

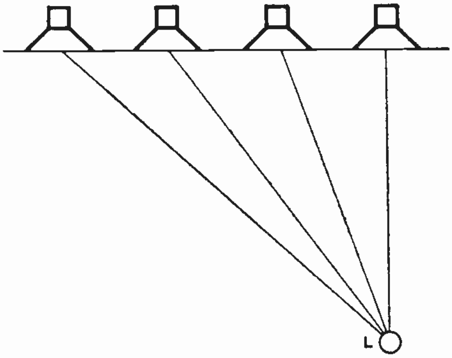
The idea of using a number of speakers to generate low audio frequencies at very high power levels was suggested as early as 1931.[3] Because of this suggestion, there have been claims that mutual coupling extends the bass response to a degree that is limited only by the number of speakers used. However, subsequent to the publication by POPULAR ELECTRONICS of the "Sweet Sixteen" system, James F. Novak[4] presented a mathematical analysis showing that coupling occurs at certain bands of frequencies and that these bands are determined by the separation between individual speakers. For example, when the center-to-center spacing between speakers is less than ⅛ wavelength, the air mass offers a reactance to the sound output. For the usual separation—about 6″ to 8″—this puts a lower limit of about 200 Hz on the coupling range of an array of small speakers. To lower this frequency, the speakers should be moved farther apart; but confusing the issue, to make the coupling more effective, speakers must be close together.

Besides contending with the problem of spacing between speakers, the builder must also decide whether the enclosure holding the speaker array is to have an open back or be built as a sealed enclosure. Since mutual coupling increases the air load, the effective mass of the speaker cones is increased, tending to lower the resonant frequency of the array below that of a single speaker. However, when the array of speakers is mounted in an airtight enclosure, the fundamental resonance of the speaker system is raised. In this trade-off, if the enclosure is small enough to add some restoring force to the cones and reduce distortion, it will also have the effect of raising the array resonance probably far above the original frequency of an individual speaker. Theoretically, a cheap speaker in a sealed enclosure should have its amplitude of peak resonance vary inversely with the damping on the speaker (see illustration). Cheap speakers are notoriously poorly damped, both electrically and mechanically. Of course, the point of resonance can be lowered by omitting the enclosure back, but the distortion increases and the frequency response curve of the speaker system becomes dependent on the shape of the open-backed box.



Effect of changing listener position from L1, on-axis with two speakers, to L2, off-axis. Difference in sound path lengths at L2 makes phase shift. Cancellation occurs if difference is ½ wavelength (phase shift of 180°).

A large, shallow open-backed box produces less peak amplitudes and more extended ended response than a small, deep open-backed



Off-axis listener to multiple speaker system is at different path lengths from various speakers. Differences change as he moves from location to location. (Drawing not to scale.)

box. Unless distortion becomes a major problem, the back should always be removed from the enclosure of a multiple cheap speaker system to improve the bass response.

Synthetic Bass. Distortion, especially that caused by driving the speakers to the limits of their suspensions or magnetic fields, may produce the illusion of more bass frequency response. Griffiths[5] experimented with electronically induced distortion and seems to have confirmed the existence of this illusion.

In the Griffiths experiment, clipping and distortion, similar to that produced by overdriven cheap speakers, was purposely designed into an audio system with a 200-Hz low-end cutoff. The percentage of distortion was controlled by the listener until the bass was thought to be "equal" to that produced by a low-distortion full-range audio system. Experimental results indicated that most listeners heard more "bass" when the distortion in the filtered system was increased to certain arbitrary values.

Another kind of synthetic bass occurs in speaker systems that have a prominent resonance. A resonant frequency in the upper bass range—say about 250 Hz—may make the system sound full and bassy, although music played through it has a distinct one-note quality. The earliest vacuum-tube amplifier juke boxes were noted for their generous bass response—most of it at one frequency.

Listeners can also be deceived into hearing bass frequency response that isn't there in the first place! A land line telephone system doesn't reproduce the fundamentals of a known voice, but the harmonic structure is recognized by the listener and the ear and brain supply the missing information. This tendency to hear the missing fundamental notes often leads the owner of a miniature transistor radio receiver with a 2″ speaker to compliment the product on its "fine tone."

Some types of synthetic bass may sound satisfactory—even impressive—at first hearing. But if the listener becomes accustomed to hearing true fundamental bass response, he won't be happy with synthetic bass again.

Smooth Response vs Phase Shift. One of the qualities attributed to the multiple speaker system is that of a smoothed response—considered to be an absolute requirement for high-fidelity sound reproduction. Many authorities claim that a medium-range speaker system with a smooth response is preferable to a wide-range system that has numerous peaks and dips in the audio response curve. And, peaks are worse than dips.

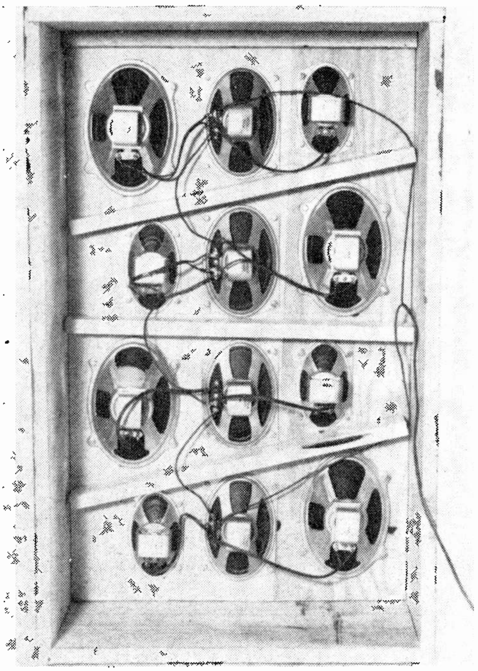
It is now well accepted that a speaker's response curve is always smoother when the speaker is operated at a reduced volume level.[6] For example, a 10″ full-range speaker may have a high-level response curve embracing the spectrum between 40-20,000 Hz at ±12.5 dB. When the input is reduced by 75%, the response curve is within ±5.0 dB. Presumably, operating a number of speakers at low volume should flatten the overall response curve. Unfortunately, what sounds good in theory does not produce acceptable results in practice.

The audio enthusiast who has built several multiple-speaker systems soon realizes that the results are fairly unpredictable. A system using only four speakers may sound pretty good, although the builder has a feeling that the sound could be improved. The number of speakers is doubled, but the sound is still not right. The number is doubled again and the system sounds terrible. The faults are numerous, and are difficult to identify—except for some obvious peaks in the mid-range.

The mid-range peaks are due to mutual coupling between speakers. The maximum coupling and boost is at the sound frequency corresponding to a separation of one-quarter wavelength. In a multiple-speaker system with center-to-center spacing of 7″ to 8″, the coupling peak is at about 500 Hz. This peak is insidious and even if not immediately noticeable, makes the system sound "loud" even at low volume levels and eventually proves quite tiring to the listener.

The problem is amplified when speakers are mounted so that there are many identical center-to-center distances and for this reason the square pattern of mounting multiple speakers is one of the worst possible arrangements. This also helps explain why larger numbers of smaller speakers sometimes sound much worse than a similar system with only four to six speakers.

In addition to the boost in the mid-range by the multiple-speaker system, the same arrangement produces sharply defined peaks and dips at the higher frequencies. These upper-range deviations are noticeable to the listener who is sitting off-axis of the system. They occur at frequencies where the sound waves from adjacent speakers reach the listener at various phase angles (see illustra-



Speakers of different sizes permit unequal spacing between speakers and staggered resonances, alleviating two of worst faults of multiple speaker systems. But problem of restricted fundamental bass response and high-frequency dispersion remains.

tions). Researcher Joel Julie[7] calculated that for a listener 10° off-axis of two speakers separated by center-to-center distance of only 8″, the 180° phase shift occurs at 4200 Hz. As the listener moves farther off center, the frequency of cancellation decreases and at 30° it is down to 1650 Hz.

For the two listening positions cited above, the listener would also receive in-phase sound boosting at 8400 Hz and 3300 Hz, respectively. At frequencies other than those specified, the sound waves mix with varying degrees of phase shift and the result is sound-wave phase distortion.

Since the broad results represent what happens with only two speakers, the reader can imagine that the phase interference situation becomes incredibly complex in a multiple-speaker situation.

Phase interference can occur in an ordinary two-speaker woofer-tweeter arrangement, but only at frequencies near the crossover point where both the woofer and tweeter are producing the same tones. Phase shift in crossover networks may be more of a problem than generally recognized, but it could hardly produce the nightmare that is generated from multiple speakers mounted on a single baffle.

The Big Sound. The feeling of spaciousness from a sound source depends, in part at least, upon good dispersion. Large speakers are notoriously directional devices at the higher audio frequencies. At frequencies above that at which the wavelength of the sound is equal to the diameter of the speaker cone, the dispersion is poor. Thus, when several speakers are mounted on a square baffle and all of them reproduce the high audio frequencies, the source is spread over the baffle, and dispersion suffers.

Cost. Since the introduction of the "Sweet Sixteen" in the early 1960's, the cost of building such a system now militates against its construction. Numerous manufacturers now offer a variety of woofers with resonant frequencies and prices far under comparable models available 10 years ago. Meanwhile, the cost of plywood and other lumber has skyrocketed and when this material cost is added to the price of obtaining 16 speakers, the multiple-speaker array is no longer cheap.

To make such an investment in an essentially cheap speaker system defeats one of the main purposes of assembling a multiple-speaker system.

It would be unfair not to mention in this article that there are useful purposes to be served by multiple speaker systems. Several good-quality woofers in a multiple system will handle far more power with much lower distortion than a single woofer. The use of multiple speakers in a line radiator provides good horizontal dispersion and the omni-directional speaker system can frequently be used to definite advantage.

The ordinary multiple-speaker system has seen its day. It was a good idea—but, the facts of life are catching up with it. ◈

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[1] Jim Kyle, "Sweet Sixteen," POPULAR ELECTRONICS, January 1961, p 55.

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[3] E. W. Kellogg, "Means of Radiating Large Amounts of Low-Frequency Sound," *Journal of the Acoustical Society of America*, July 1931, p 94.

[4] James F. Novak, "Performance of Series-Parallel Speaker Arrays," *Audio*, September 1961, p 23.

[5] John D. Griffiths, "Apparent Bass and Nonlinear Distortion," *IRE Transactions on Audio*, July-August 1961, p 117.

[6] H. A. Hartley, *Audio Design*, Gernsback Library, 1958, p 151.

[7] Joel Julie, "Minimizing Interference Effects in Tweeters and Tweeter-Woofer Combinations," *IEEE Trans. on Audio*, March-April 1964, p 30.

NON-DESTRUCTIVE TRANSISTOR TESTER

Check or Match Transistors and Diodes

BY JOHN L. KEITH

BUYING SURPLUS or bargain-package transistors is a little like buying a pig in a poke. Especially if you get one of those so-called "computer boards" to which several transistors, usually unmarked, are connected. You may get some real high-quality, expensive units—some others may be completely useless. For the most part, the transistors that are in operating condition can be put to good use by the experimenter, provided he can sort them out as to type and identify their parameters. This can be done of course with a good transistor checker but not everyone has one of those so the simple transistor tester described here comes in very handy and saves time and money.

The transistor tester can be used to check either npn or pnp transistors and will measure leakage down to 10 μA and collector current to 10 mA. You can measure I_{CO}, I_C (with 20 or 100 μA of base current), I_{CEO}, I_{CES}, and I_{EO} (see sidebar for definitions). Diodes can also be checked by connecting them between the collector and emitter pins of the test socket. The tester is also useful for checking two transistors that must be matched for a specific application.

The tester has been designed so that it will check almost any type of transistor and cannot harm a unit regardless of the switch positions or the way the transistor is connected to the test socket.

Construction. As shown in the photographs, the prototype was built in a conventional plastic utility box with all components except the batteries mounted on the cover and with point-to-point wiring. The circuit is shown in Fig. 1.

The internal resistance of the meter move-

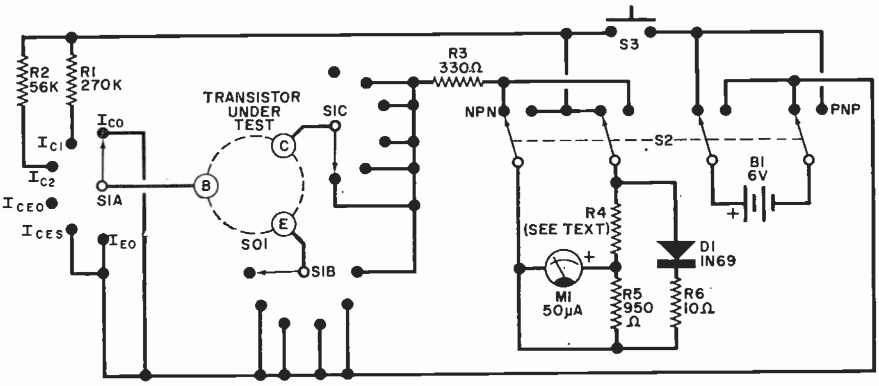


Fig. 1. All major transistor parameters can be checked using this tester since the novel circuit enables measurements from a low of 10 microamperes to high of 10 milliamperes.

PARTS LIST

B1—6-volt battery (4 flashlight cells)
D1—1N69 diode
M1—50-µA meter (Calectro D1-910 or similar)
R1—270,000-ohm, ½-watt resistor
R2—56,000-ohm, ½-watt resistor
R3—330-ohm, ½-watt resistor
R4—See text
R5—950-ohm, ½-watt resistor
R6—10-ohm, ½-watt resistor
S1—Three-pole, six-position rotary switch
S2—Four-pole, two-position rotary switch (Calectro E2-167 or similar)
S3—Spst, normally open pushbutton switch (Calectro E2-140 or similar)
SO1—Transistor socket
Misc.—Suitable cabinet with cover (Calectro J4-726), knobs (2), battery holder, mounting hardware, wire, solder, etc.

ment is an integral part of the circuit. The combined resistance of the meter, *R5*, and *R4* must be 12,000 ohms. The value of *R4* must be chosen to obtain this value as closely as possible. With the meter specified in the Parts List, *R4* should be about 11,000 ohms. This insures full compression and. with the circuit of *D1* and *R6*, provides a full-scale reading of 10 mA.

Operation. Insert the transistor to be tested in the test socket, place *S1* on either I_{C1} or I_{C2}, and depress pushbutton switch *S3*. The meter should deflect upscale when *S2* is in the proper position. The position of the switch for upscale deflection determines whether the transistor is npn or pnp.

To check the dc gain (H_{FE}) of the transistor, place *S1* on either I_{C1} or I_{C2}, depress *S3*, and note the meter indication. Then determine the gain from the conversion table. Note that position I_{C1} is for a base current of 20 µA while position I_{C2} supplies a base current of 100 µA. The gain is different for the different base currents.

The other four positions of *S1* are to test

PARAMETER DEFINITIONS

I_{CEO}—Collector current with base open. The polarity of the applied voltage is such that the collector-base junction is biased in a reverse direction.

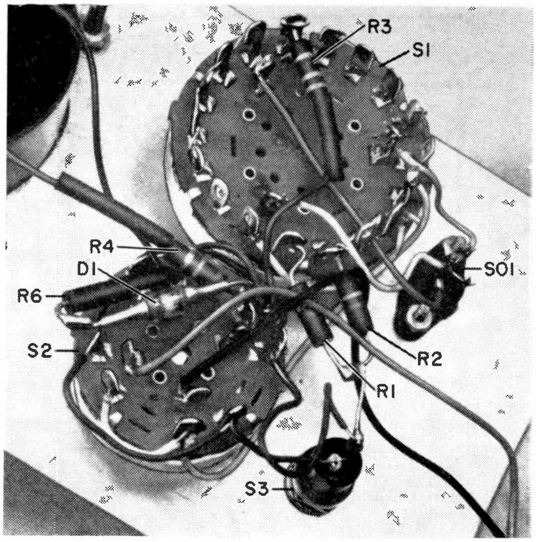
I_{CES}—Collector leakage current with base shorted to emitter. Equivalent to the leakage current of collector diode if emitter junction were not present. The polarity of the applied voltage is such that the collector-base junction is biased in a reverse direction.

I_{EO}—Sometimes called I_{EBO}. Emitter-base current with collector open. The polarity of the applied voltage is such that the emitter-base junction is biased in the reverse direction.

I_{CO}—Sometimes called I_{CBO}. Collector-base current with emitter open. The polarity of the applied voltage is such that the collector-base junction is biased in the reverse direction.

I_C—Collector current—depends on the amount of base current supplied. A measure of dc gain (H_{FE}).

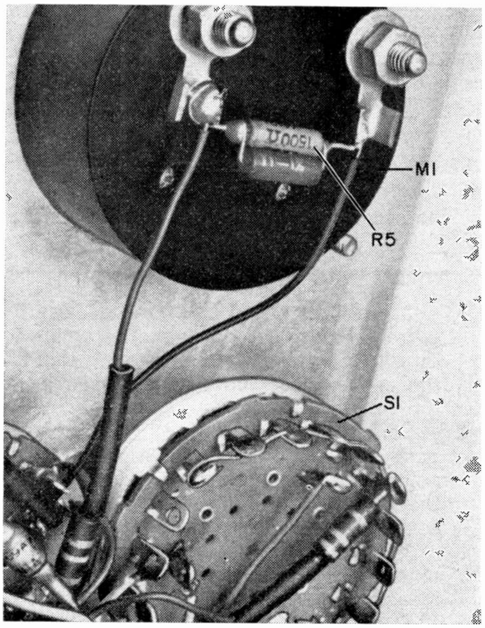
All the components except the battery are mounted on the front panel. The small parts such as resistors, capacitors and diodes are soldered directly to the two switches.



for leakage currents. The less leakage in any case, the better. In these tests, the meter indicates directly in microamperes.

To check a diode, connect it between the emitter and collector pins of the test socket and place *S1* in either the I_{C1} or I_{C2} position. Depress *S3* and note the meter readings when *S2* is in the npn and pnp positions. Ideally, in one position, the meter should indicate full scale and it should give no indication in the other position—indicating that the diode conducts in one direction and not the other. The lower the ratio between the two readings, the poorer the diode. ◈

Two resistors in parallel are used to make up the meter shunt resistor (R5) in order to obtain the required resistance value. Here again the components are mounted directly on the meter terminals.



GAIN CONVERSION TABLE

Meter Indication	Current	H_{FE}	
		I_{C1}	I_{C2}
2	10 μA	0.5	0.1
3	15	0.75	0.15
4	30	1.5	0.3
5	50	2.5	0.5
6	100	5	1.0
7	140	7	1.4
8	200	10	2
9	300	15	3
10	400	20	4
12	600	30	6
14	900	45	9
16	1.2 mA	60	12
18	1.6	80	16
20	2.0	100	20
22	2.36	118	23
24	2.75	137	27
26	3.26	163	32
28	3.48	174	35
30	4.05	200	40
32	4.55	228	45
34	5.1	255	51
36	5.75	277	57
38	6.17	308	62
40	6.63	332	66
42	7.30	365	73
44	7.85	382	78
46	8.43	420	84
48	9.26	463	93
50	9.85	494	99

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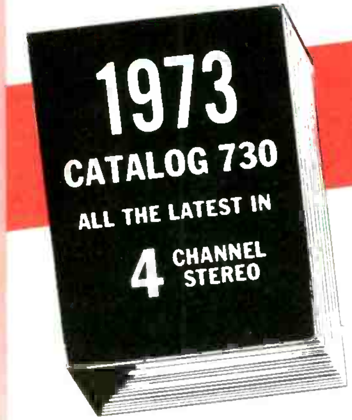

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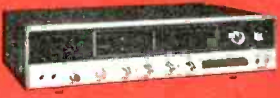

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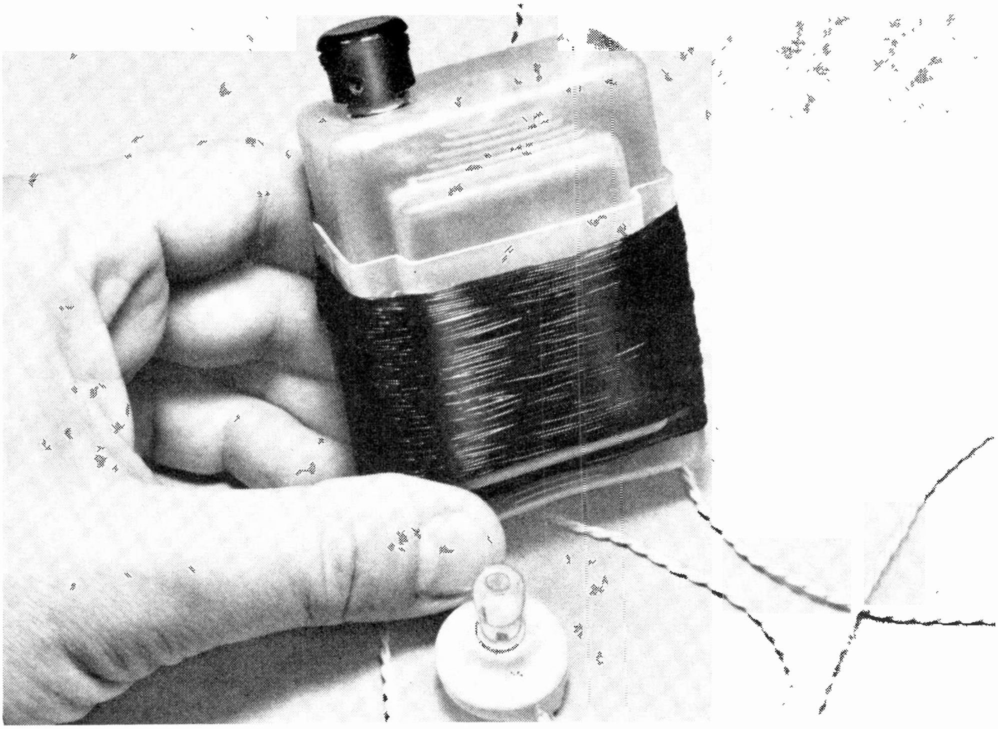


BUILD THE LIBERATOR

KEEPS YOU IN TOUCH WHILE ON THE GO

Built inexpensively and easily in a plastic cigarette case, this handy project "liberates" you from the necessity of sticking by your receiver when calls are few and far between. An integrated circuit and printed circuit board make construction foolproof.

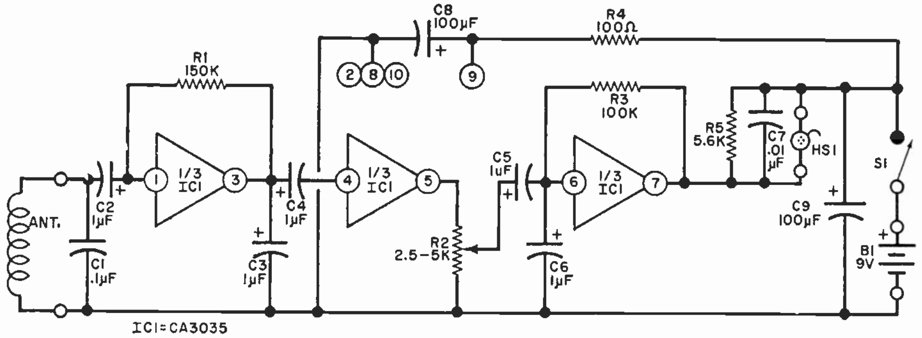
THERE ARE TIMES when it becomes an impossible task to remain glued to a communications receiver if you are a ham, CB'er or SWL. Having to sit waiting for an identification to be made or a call to come through can be quite boring. The "Liberator," a shirt-pocket-size induction (not r-f) receiver, permits you to move about the house, office, or even a large area away from the receiver and still hear everything that is going on at the receiver.

The Liberator can also be used for private, individual listening to conventional radios or audio systems. This is a particular advantage if one person in a group likes to hear loud music and the others don't.

Theory of Circuit Design. The complete system can be considered to be a form of audio transformer. The receiver or amplifier drives current through an ordinary wire transmission loop that is strung around the area of interest and produces a magnetic field that varies at the audio rate. This forms the primary of the transformer.

The receiver (see Fig. 1) has an "antenna" which forms the secondary of the transformer and detects the varying magnetic field. This

BY C. P. TROEMEL



PARTS LIST

B1—9-volt battery
C1—0.1--0.47-µF capacitor (see text)
C2-C6—1-µF, 10-volt electrolytic capacitor
C7—0.01-µF capacitor
C8, C9—100-µF, 10-volt electrolytic capacitor
HS1—Crystal earphone (Lafayette 99E25512 or similar)
IC1—Integrated circuit (RCA CA3035)
R1—150,000-ohm, ½-watt resistor
R2—2500-5000-ohm miniature replacement potentiometer with switch S1 (Lafayette 99E60-196 or similar)
R3—100,000-ohm, ½-watt resistor
R4—100-ohm, ½-watt resistor
R5—5600-ohm, ½-watt resistor
Misc.—Battery clip, plastic cigarette case, #24 or #26 enameled wire, knob, wire for loop, switch for loop.

Fig. 1. The circuit is basically a high-gain IC amplifier whose input is a loop "antenna," which forms the secondary of the induction system. With the transmitting loop wound around the main floor, excellent reception was obtained from basement to attic of a typical three-story brick structure.

signal is then amplified by an integrated circuit (*IC1*) to drive an earphone. The antenna and *C1* resonate within the audio range to reduce the effect of interference from nearby r-f transmitters. The frequency response is limited to reduce noise from both 60-Hz power lines and emissions from TV receiver sweep circuits. A crystal earphone is used to prevent feedback between it and the receiving antenna. The IC contains three independent amplifiers and has an overall gain of approximately 100,000 (100 dB). Resistors *R1* and *R3* bias the first and last amplifiers for linear operation.

Transmitter. The transmitting loop consists of a length of insulated wire surrounding the area to be covered. Inside a building, the loop may be concealed in the wall moldings, under a large rug, or taped to the walls or ceiling. For outside use, the wire can be supported on insulators on posts or just simply strung (off the ground) around the area. The actual configuration depends on the location. Keep the coil off the ground and make sure it is insulated from metal surfaces. If the loop is to be located some distance from the amplifier, connect the two with ordinary two-conductor lamp cord or TV twin lead.

Usually, one turn of wire around the area should be enough. However, two things should be kept in mind: the current in the loop and the number of turns determine the strength of the field: and do not overload or short circuit the transmitting amplifier by connecting a loop having too low a resistance.

Survey the area to be covered by the loop and calculate how long the wire will have to be to make the loop. Then determine the output impedance of the amplifier used (usually specified on the amplifier or in the instruction manual). The loop dc resistance can then be made approximately equal to the amplifier output impedance by choosing the correct wire size. Resistances of the more common wire sizes are given in the Table. Pick the wire whose resistance for the length required

RESISTANCE (OHMS) OF WIRE

Wire Length	Wire Size			
feet	#20	#22	#24	#26
25	0.26	0.40	0.64	1.0
50	0.51	0.80	1.3	2.0
100	1.0	1.6	2.6	4.1
150	1.5	2.4	3.9	6.1
200	2.0	3.2	5.1	8.2
300	3.0	4.8	7.7	12.2
400	4.1	6.4	10.2	16.3
500	5.1	8.0	12.9	20.4

comes closest to the output impedance of the amplifier. If the finished loop has less resistance than that required, a small fixed resistor can be added in series with the loop to make up the difference. However, since signal will be lost in this resistor, consider using a double loop around the area, with a larger-diameter wire.

To power the transmitting loop, simply switch the normal output leads that go to the speaker to the loop (see Fig. 2).

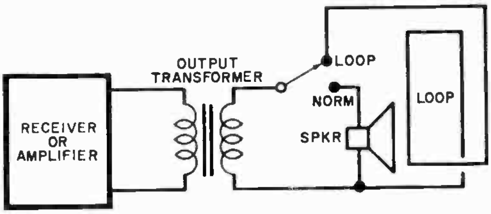


Fig. 2. If you wish simultaneous loop and speaker operation, hook a low-impedance speaker in series with the loop, so that the total load is the same as normally used with the particular transformer.

Receiver. The circuit of the receiver is shown in Fig. 1. It can be constructed on a printed circuit board using the foil pattern shown in Fig. 3. Once the board has been made, install the components, taking care to observe the polarity of the electrolytic capacitors and the orientation of the IC.

The prototype was built in a common plastic cigarette case with the board supported by the mounting hardware of potentiometer *R2*. A small hole, just large enough to accommodate the twisted-lead cable from the earphone, is made on the same side as the *R2* mounting.

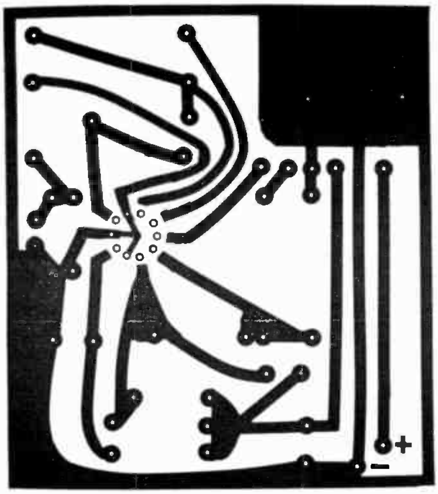
Before installing the board in the case, the receiving antenna must be made. Drill two small holes at the end of the larger of the two plastic halves and feed about six inches of the end of #24 or #26 enameled wire through one hole. Wind 150 to 200 turns of the wire around the plastic case and feed the other end of the wire in through the second hole. Leave about six inches on this end also. Coat the winding with cement or tape to hold it in place.

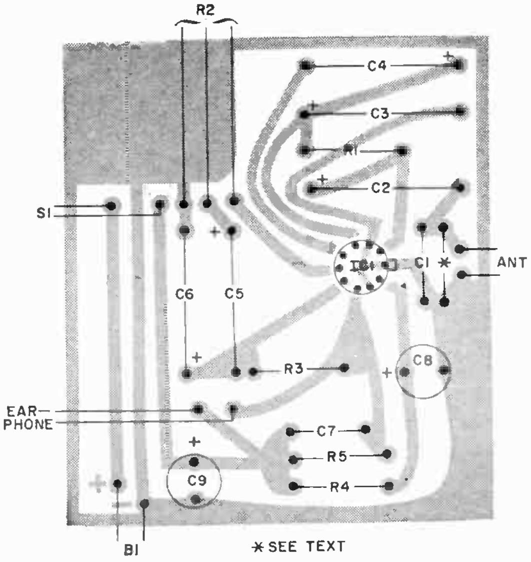
After connecting the earphone and battery leads and the two antenna wires to their proper holes on the PC board, slide the board into the plastic case. Locate the position of the shaft of *R2* and drill a suitable hole for it. Insert the board and secure it in place with the mounting hardware of *R2*. Put a knob on the potentiometer and turn the switch off. The battery is stored in the antenna half of the case.

Operation. With the earphone in your ear, turn on the Liberator. You should hear some hum, which can be made a maximum by orienting the antenna in different directions. The hum will be loudest when the Liberator is held near a fluorescent lamp.

Apply power to the transmitting loop by having some program material properly set up on the transmitter amplifier. Turn the

Fig. 3. Actual size foil pattern and component installation. Observe the placement of IC1 and the polarity of the electrolytic capacitors.





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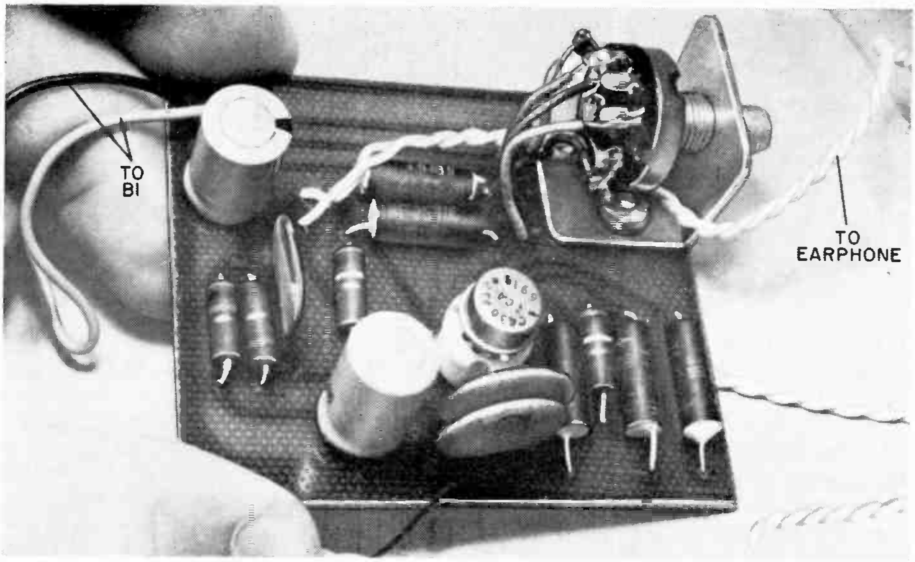
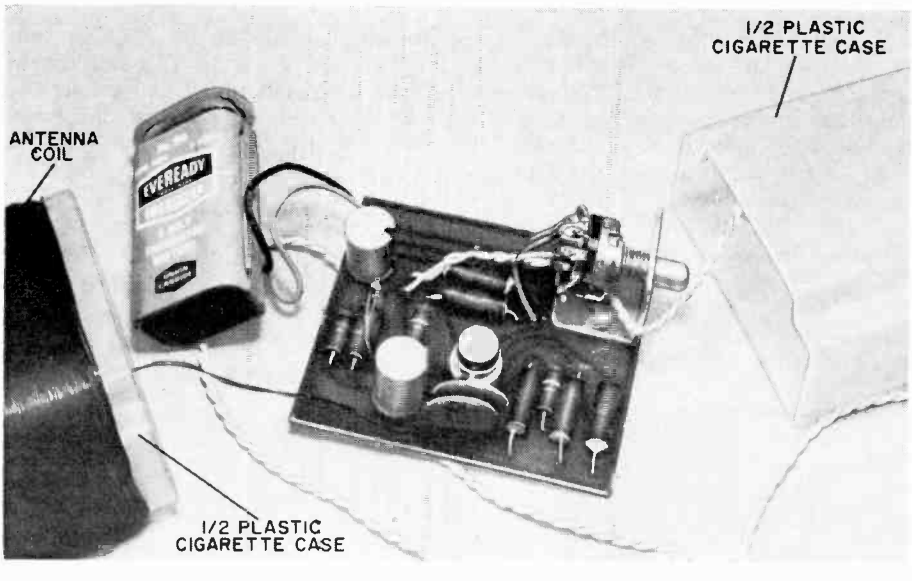


Although presently as small as a cigarette pack, the receiver can be made smaller by tightening up on the foil pattern, eliminating the IC socket, and using smaller physical sizes for C8, C9 and R2. A hearing-aid battery can be substituted for the 9-volt transistor radio battery, and a ferrite loopstick can be tried in place of the coil. Any number of receivers can be used on one loop.



amplifier gain up slightly. Switch its output to the loop position. If the Liberator is turned on, you should hear the program on the earphone. You will get the best reception when the plane of the Liberator antenna coincides with the plane of the transmitting loop, and you are within the loop. Adjust the transmitting amplifier's volume for minimum distortion; gain can be adjusted on the Liberator. If you are using battery powered gear for the transmitter, keep its volume conrtol down to conserve power.

Modifications. To improve low-frequency response, the values of coupling capacitors *C2*, *C4*, and *C5* can be increased. However, the pickup of unwanted 60-Hz noise will be increased. Shunting capacitors *C3*, *C6*, and *C7* control the high-frequency gain and amplifier noise. Smaller values here will improve the high-frequency response, but will also increase the noise.

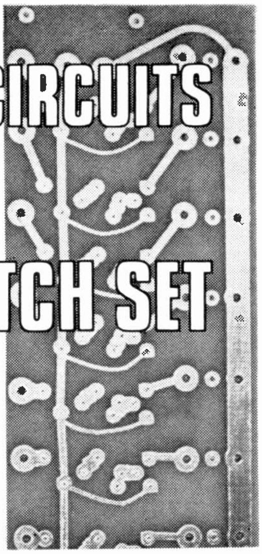
Do not substitute a magnetic earphone for the crystal unit. If you do, oscillations may set up and possible serious damage to the IC can result.

If 60-Hz pickup is a serious problem, wrap the antenna with aluminum foil, leaving a small gap somewhere so that the antenna is not completely shielded, and connect the foil to the circuit ground. To optimize signal pickup, the antenna may have to be tuned. Experiment with various capacitors in parallel with *C1* (provisions for this are made on the PC board) to get best results with the antenna on the package. If you want to remove the 200-turn antenna from the outside of the plastic case, try a common ferrite loopstick in its place, experimenting with various values of *C1* to get maximum signal.

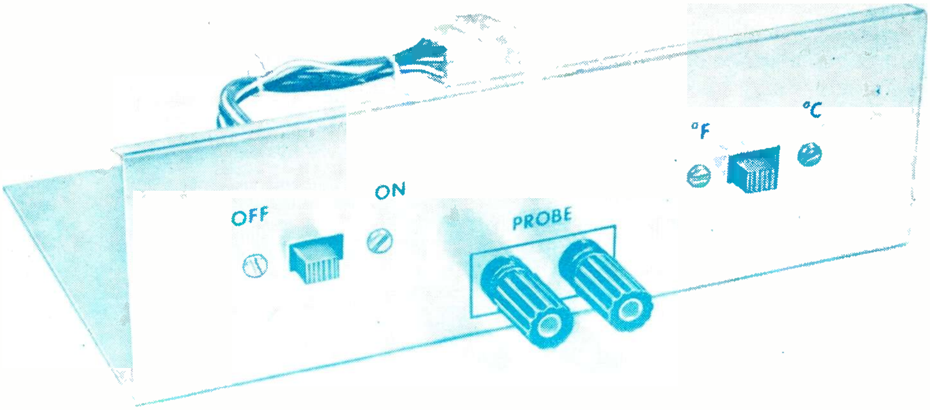
How much power do you need to cover an area? The author used a conventional transistor pocket radio to power a 30′ by 50′ loop. The 100-mW audio output from the radio was more than sufficient to do the job and a good magnetic field was found 25′ above the loop. (It might have been higher but the house wasn't.)

If you want speaker and loop operation at the same time, select a speaker with a lower impedance than normally used and couple it in series with the loop so that the total resistance is approximately the same as the output impedance of the amplifier. ◆

"—And stop referring to me as a walkie-talkie!"



Digital Thermometer Module



for the Digital Measurements Lab

FROM FREEZING TO BOILING— FAHRENHEIT OR CENTIGRADE

BY DANIEL MEYER

THIS exciting new construction project is designed as a plug-in module to be used with a main frame assembly described in the article, "Assemble a Digital Measurements Lab," (see page 25). This digital thermometer is capable of measuring temperature between the freezing and boiling points of water in °C and °F. The module is essentially a variable frequency oscillator that converts resistance changes that result from temperature variations into frequency changes.

The Thermometer's sensing element is a Texas Instruments Sensistor® silicon resistor. The Sensistor has a linear positive temperature coefficient. Its resistance increases linearly with increasing temperature. Sealed in a glass tube, the Sensistor can be mounted in any location and wired to the plug-in module via a cable and banana jack assembly.

If a reasonable wire length is used to connect the sensor to the module, the temperature readings will be unaffected. Wire lengths up to several thousand feet can be used if the circuit is calibrated with the wire length you plan to use for your measurements.

Theory of Circuit Design. The resistance change of sensing resistor *R21* (see Fig. 1) is converted to a frequency change by the oscillator circuit built around unijunction transistor *Q6*. The frequency of oscillation in this circuit is a direct function of the value of *C2* and the level of the current supplied to the oscillator by transistor *Q5*. The voltage level at the base of *Q5*, and thus the current through the transistor, are controlled by the combined resistances of *R11*, either *R12* or *R13* (depending on the position of *S1*), and *R21*.

The current supplied to *Q6* is a linear function of the resistance of *R21* just as long as this current does not have to go completely to zero. The linearity is arranged by the *Q3* circuit which acts as a current sink and draws a constant 100 μA from the collector of *Q5*.

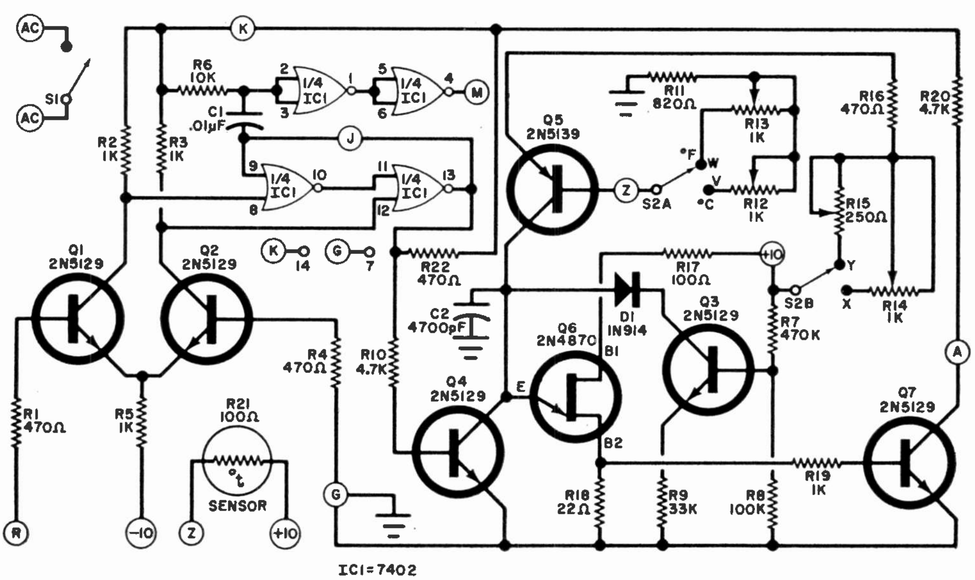


Fig. 1. Variations in temperature cause corresponding variations in output frequency of oscillator Q6 as result of changing RC control component (sensor R21/C2). Gating is controlled by 60-Hz reference, differential amplifier Q1/Q2, and integrated circuit IC1.

PARTS LIST

C1—0.01-μF disc capacitor
C2—4700-pF disc capacitor (see text)
D1—1N914 diode
IC1—7402 quad two-input gate integrated circuit
Q1-Q4,Q7—2N5129 bipolar transistor
Q5—2N5139 bipolar transistor
Q6—2N4870 or 2N4871 unijunction transistor
R1,R4,R16,R22—470-ohm
R2,R3,R5,R19—1000-ohm
R6—10,000-ohm
R7—470,000-ohm
R8—100,000-ohm
R9—33,000-ohm
R10,R20—4700-ohm
R11—820-ohm
R17—100-ohm
R18—22-ohm
All resistors ½ watt, 10% tolerance
R12-R14—1000-ohm trimmer potentiometer (Type IRC-CTS X-201 or similar)
R15—250-ohm trimmer potentiometer (Type IRC-CTS X-201 or similar)
R21—100-ohm Sensistor (Texas Instruments No. TG⅛ silicon resistor)
S1—Dpdt switch (part of power supply in main frame)
S2—Dpst switch
1—15-contact Molex connector to mate with connector in main frame
Misc.—Printed circuit board; five-way binding posts (2); chassis; spacers; hardware; solid and stranded hookup wire: solder; etc.
Note: The following are available from Southwest Technical Products Corp., Box 32040, San Antonio, TX 78216: etched and drilled printed circuit board No. THR-1b for $2.15; complete kit of parts including chassis, connector, and hardware No. THR-1C for $16.80 plus postage on 5 lb and insurance.

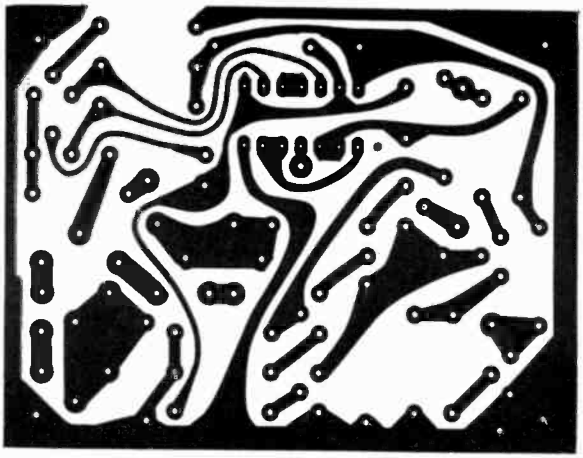
The value of *C2* will be affected to some extent by the characteristics of *Q6*. It can vary between 3900 pF and 5600 pF.

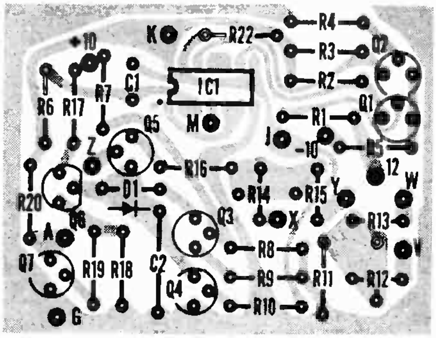
The output pulse from *Q6* is amplified by the *Q7* circuit to provide a high enough output level to drive virtually any type of readout system you may wish to use. All that is necessary now is to gate the oscillator off and discharge *C2* at the end of each conversion period. Since a 60-Hz signal is available from the power line (via the transformer in the main frame's power supply), and this rate is high enough so that flicker will not be present, a 60-Hz gate system is used in the Thermometer module.

The 60-Hz signal from the transformer is amplified and squared by the differential amplifier made up of *Q1* and *Q2*. The resulting signal at the collectors of these two transistors is used to operate a set-reset flip-flop, or latch, circuit. The SR flip-flop is made up of two of the gates in *IC1*.

This system is not affected by line voltage variations or by line noise due to the high

Fig. 2. At right is shown actual size etching/drilling guide for fabricating printed circuit board. When installing components on circuit board (see below), carefully orient transistors and IC1.





gain and the use of a latch system to generate the gate signal. The output from the latch drives *Q4* which, in turn, shorts the emitter of *Q6* to ground for 8.33 milliseconds and then allows the circuit to oscillate for another 8.33 milliseconds.

During the time that the oscillator is running, point J—which is connected to the blanking input of the readout—is at a logic "0" and the display readouts are off. As soon as the conversion cycle is complete, the blanking input returns to a logic "1" and the total number of pulses that occurred in this cycle is displayed by the readout tubes in the main frame. Connected to the fourth gate in *IC1, C1* and *R6* cause a reset pulse to be generated, resetting the display to zero at the beginning of each conversion portion of the cycle.

Construction. Assembling the Thermometer module is quite simple. Most of the components mount on a compact printed circuit board, the actual size etching guide and components placement and orientation diagram for which are shown in Fig. 2. Be careful to orient the transistors and integrated circuit properly on the board before soldering them to the foil pattern. Use a low-wattage, fine-pointed soldering iron and work carefully to avoid solder bridges between closely spaced foil conductors.

Next, mount the five-way binding posts and *S1* and *S2* on the front panel of the module chassis (see Fig. 3). Then wire the post and switch lugs, circuit board, and a 15-contact connector together (see connector wiring diagram in "Digital Measurements Lab," page 25). Point Z on the circuit board does

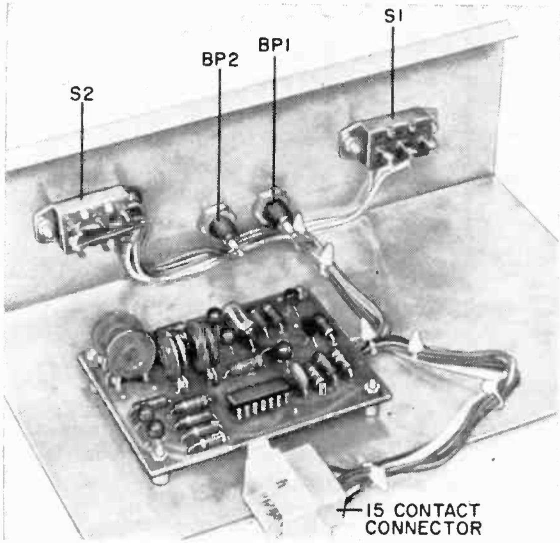


Fig. 3. Interconnections between circuit board and connector should be made with stranded hookup wire. When wiring is complete, use 4-40 machine hardware and 1/4" spacers to mount circuit board.

not go to the connector; solder a wire from this point to the wiper of *S2A*.

The sensing resistor can be mounted on a lug strip at the desired monitor location, or you can make it into a probe by covering or coating the resistor package and the resistor leads with a waterproofing material. If you coat the resistor, keep the coating material as thin as possible so that the time required to reach a stable temperature reading does not become excessive.

Calibration. After assembling the Thermometer module, plug it into the main frame via the connector assembly and turn on the system. The readout should immediately indicate some numerical value which should change slightly if you hold the probe in your hand.

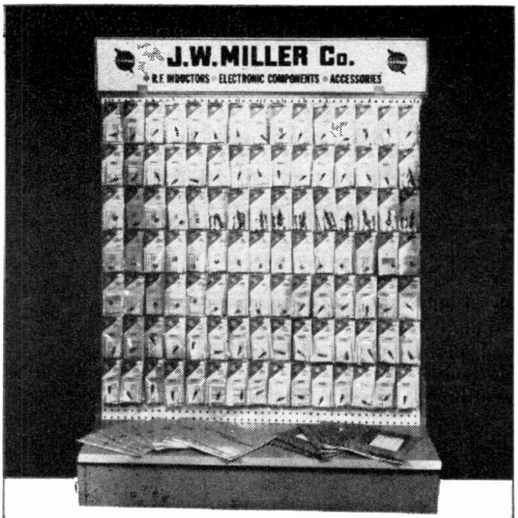
Since no two Sensistors will have exactly the same value or respond in exactly the same way to temperature changes, the Thermometer circuit must be calibrated with the resistor you intend to use if you expect maximum accuracy. The most accurate calibration will be obtained if you use a thermometer that is known to be accurate to within 1% of its reading. However, if such a thermometer is not readily available, you can obtain fairly accurate calibration with a cup of crushed ice and a pan of boiling water to obtain freezing (32°F) and boiling point (212°F) calibrations.

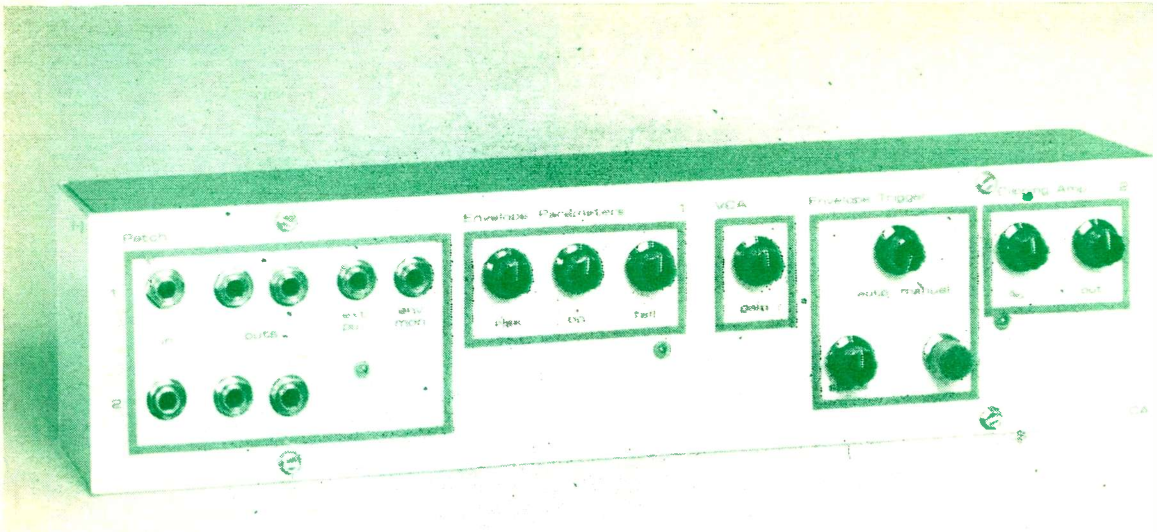
Using the second method of calibration, proceed as follows. First push the probe into the crushed ice. After the temperature has had a minute or two to stabilize, adjust trimmer pot *R12* for a "1" numeric readout in the °C position of *S2*. Flip *S2* to °F, and adjust *R13* for a reading of 32. Now, plunge the probe into *boiling* water and adjust *R15* for a reading of 212 with *S2* set to °F and adjust *R14* for a reading of 100 with switch *S2* set to °C.

Go back to the ice with the probe and recheck calibration on the low end. The controls interact slightly; so, calibration will be much more accurate if performed more than once.

The Sensistor's resistance change with temperature is not absolutely linear so the instruments should be calibrated to be correct at the high and low extremes of temperature that you wish to measure for best accuracy. It will be within ±1% over any 60° to 70°F range selected. Over the full 0° to 212°F range, accuracies of ±3% would be considered typical.

◆





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ENVELOPE GENERATOR FOR GREAT NEW SOUNDS

BY CRAIG ANDERTON

WHAT is the quality that distinguishes the sound of one musical instrument from another? The answer, of course, is timbre; and timbre is determined primarily by the geometry of the sound wave generated by the instrument—be it mechanical, electronic, or human.

Electronic synthesizers have added new dimensions to the creation of music because they can generate sounds of many different timbres—some closely resembling known instruments, others previously unknown. They do this by producing amplitude envelopes of various shapes and sizes. The "Timbre Gate" described here is an envelope generator that creates any number of different timbre qualities and will be a valuable addition to your sound setup at a fraction of the cost of commercially available generators.

As shown in Fig. 1, the amplitude envelope of a musical note consists of an imaginary line drawn from T = 0 across the peaks of each successive cycle of the note. The amplitude envelope shows rise time (time required for the envelope to go from initial zero to maximum), on time (envelope remains at maximum), and fall time (envelope goes from maximum to zero). These three parameters—rise, on, and fall times—geometrically describe the shape of the amplitude envelope and, hence, the timbre of the actual sound.

In addition to his writing, Craig Anderton is active in electronic music as a recording artist and producer.

Theory of Circuit Design. The schematic diagram of a strictly manual version —which can be used where economy is important and complexity is unimportant— is given in Fig. 2. Field effect transistor *Q1* operates as a voltage-controlled amplifier where the gain of the stage is a function of the magnitude of the bias voltage. Applying a negative bias to the gate of *Q1* allows the stage to conduct until at about −4 volts bias, *Q1* ceases to conduct current from source to drain. This cutoff action is the key to envelope generation.

With momentary-action switch *S1* in its

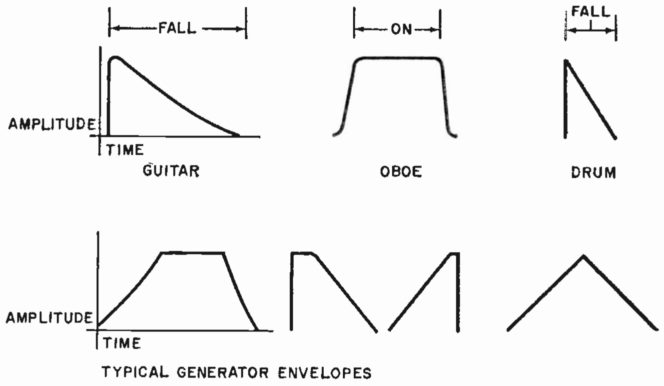


Fig. 1. Shown at top left are amplitude envelopes of various well known musical instruments. Some typical amplitude envelopes capable of construction by Timbre Gate, shown at bottom.

normal position (shown), negative bias current flows through *R1* and is stored in *C1*. The charge on *C1* maintains *Q1* at cutoff. Depressing *S1* to its alternate position allows the charge on *C1* to be dumped to ground through *R2*. The resistance setting of *R2* determines the amount of time required for *C1* to lose its negative charge and thus controls the rise time of the envelope. With *R2* set at maximum resistance, rise times of a few seconds are obtained.

For the duration of the time *S1* is in its depressed position, there will be no negative bias on *Q1* and the stage will operate at full gain. Consequently, the length of time *S1* remains in this position determines the duration of the on time of the envelope being generated.

Releasing *S1* allows *C1* to again charge up to the −4 volt level required to cut off *Q1* and reduce stage gain to zero. The larger the resistance setting of *R1* through which the charging current for *C1* flows, the longer will be the fall time of the envelope. Consequently, simply by depressing and releasing *S1*, a complete envelope can be generated. Of course, as has just been demonstrated, the geometry of the envelope must be constructed by setting *R1* and *R2* and holding *S1* depressed for a discrete interval of time.

When pitch and level controls must be operated, having to operate a switch to generate the envelope as well can become a bother. To alleviate this problem, the trigger process section shown in Fig. 3 which allows a single short-duration pulse to initiate the envelope action was designed. The trigger processor is used in conjunction with the basic generator circuit. Connected to the generator via a relay, *K1*, which replaces *S1*, the processor provides both automatic and manual modes of operation. Here, AUTO/MANUAL switch *S2* is used to select the desired mode of operation.

In the MANUAL mode momentary-action pushbutton switch *S3* is briefly depressed to initiate envelope generation. The pulse delivered by closing this switch charges *C5* which, in turn, applies a bias voltage to *Q2*. With the bias applied, *Q2* cuts off and de-energizes *K1*, allowing the upper contact circuit to be completed and initiating the rise and on time characteristics of the envelope. The charge on *C5* now slowly discharges through ON time control *R9* until sufficient bias is removed from *Q1* to allow *K1* to again energize and initiate the fall time characteristic, thus completing the cycle.

Setting *S2* to the AUTO position allows pulses to be developed at the B1 terminal of unijunction transistor *Q3* to provide the trigger. The speed of the pulse generator is adjustable over a wide range.

A second optional attachment that can be used with the envelope generator system is shown schematically on page 84. This circuit consists of a dual-gate IC and operates as a fuzz box used with guitars.

Construction. Straightforward design makes assembling the envelope generator, trigger processor, and clipper a relatively uncomplicated operation. As shown in the photos, the circuits were assembled on perforated phenolic boards. But if you are enterprising, you might want to design printed circuits boards for your project.

Since the prototype shown in the photos employed all three subassemblies, one board was used for mounting both the generator

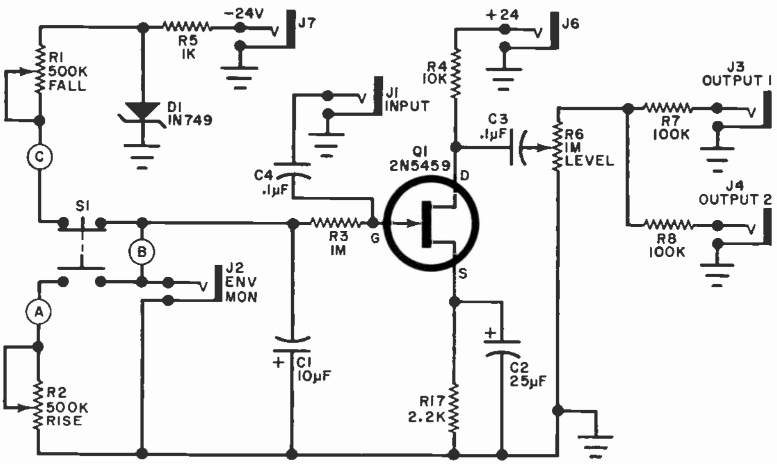


Fig. 2. Fall and rise times of the envelope are controlled by R1 and R2, respectively; on time is determined by the time S1 is in alternate position.

PARTS LIST

C1—10-µF, 10-volt electrolytic capacitor
C2—25-µF, 20-volt electrolytic capacitor
C3,C4—0.1-µF ceramic disc capacitor
C5,C6—20-µF, 20-volt electrolytic capacitor
C7—200-µF, 20-volt electrolytic capacitor
D1—1N749 zener diode (see text)
D2—1N914 or similar silicon diode
J1-J7—Single circuit phone jack
K1—4.5-volt spdt relay with 1000-ohm, 3.5-mA coil (Calectro D1-962 or similar)
Q1—2N5459 field effect transistor
Q2—Bipolar transistor (Motorola MPS2926)
Q3—Unijunction transistor (GEX10)
R1,R2—500,000-ohm linear-taper potentiometer
R6—1-megohm logarithmic-taper potentiometer
R9—100,000-ohm linear-taper potentiometer
R15—50,000-ohm linear-taper potentiometer
R3—1-megohm
R4—10,000-ohm
R5—1000-ohm
R7,R8—100,000-ohm
R10—4700-ohm
R11—1500-ohm
R12—100-ohm
R13—470-ohm
R14—3300-ohm
R16,R17—2200-ohm

All resistors ½ watt 10% tolerance.

S1—Spdt switch (see text)
S2—Spdt switch
S3—Spst normally-open momentary-action pushbutton switch
S4—Spst switch (part of R15)
Misc.—Perforated phenolic board with flea clips; 17" × 4" × 3" aluminum chassis; cover for chassis (see text); control knobs; machine hardware; hookup wire; solder; etc.

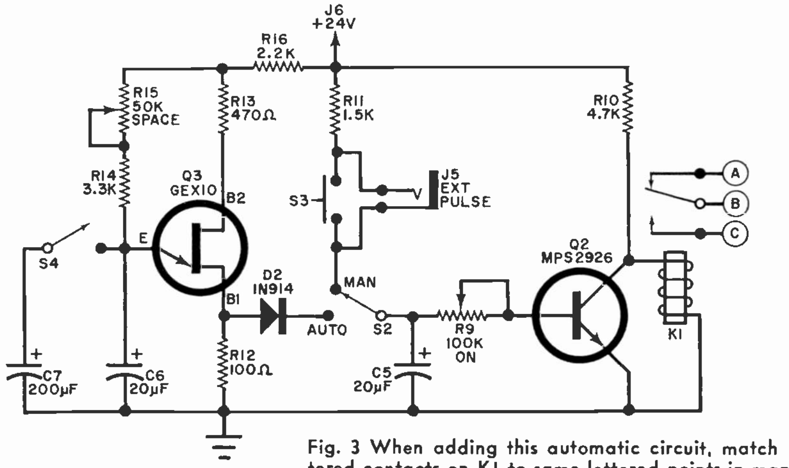
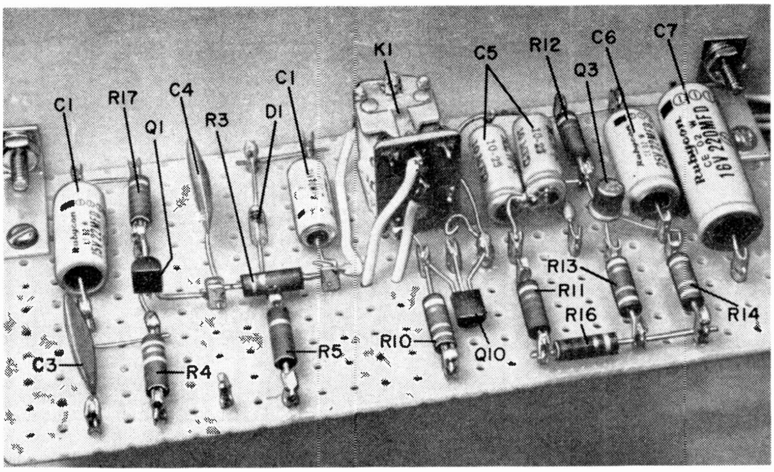


Fig. 3 When adding this automatic circuit, match lettered contacts on K1 to same lettered points in manual circuit and eliminate S1. Use S3 to initiate envelope.



Single piece of perforated board was used in prototype to accommodate all parts (except jacks and controls) in basic circuit and auto/manual add-on.

and trigger processor, while the clipper was assembled on a separate board. If you plan to use perf board, mount the components and make connections—from the under side of the board—via flea clips. And be as neat as you possibly can when laying out the components.

Certain precautions must be exercised when soldering transistors and diodes into the circuit. Use a low-wattage soldering iron with a clean tip and a heat sink. Remember that excessive heat can damage solid-state components rather easily. So, use the heat sink on all transistor and diode leads and apply the iron tip long enough only for the solder to flow over the connection.

The prototype project was built into a 17″ × 4″ × 3″ aluminum chassis, fitted with a white Plexiglas® front panel on which were mounted all controls and input, output, and monitor jacks. This size chassis is more than adequate to accommodate all of the components. If you wish, you can considerably reduce the size of the chassis required.

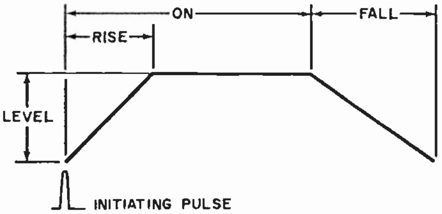


Fig. 4 Diagram shows influence each control has on geometry of envelope. Momentarily closing S3 generates initiating pulse.

Setup and Use. Connect a suitable power supply to the circuit. If a dual-polarity 24-volt dc power supply cannot be obtained, a single-polarity 24-volt supply will provide most of the voltages needed, and a 9-volt transistor battery can be used to supply the negative voltage required for biasing *Q1*.

Connect the output of the envelope generator to an instrument or hi-fi amplifier. Then feed into *J1* a signal from an electric

(Continued on page 85)

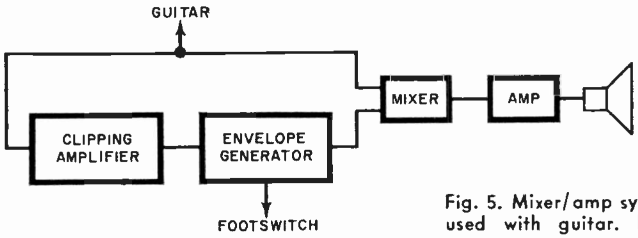
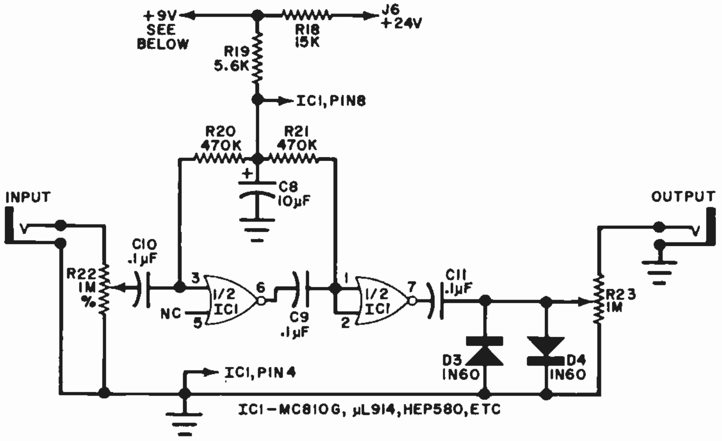


Fig. 5. Mixer/amp system allows Timbre Gate to be used with guitar. Footswitch initiates envelope.



CLIPPING AMPLIFIER

In its simplest form, the envelope generator consists of the circuit shown in Fig. 2. Incorporating the circuit in Fig. 3 merely adds an automatic/manual feature. For additional signal processing, the clipping amplifier shown here can greatly increase the versatility of the system. The clipping amplifier is similar to the fuzztone circuits often used with electric guitars and can, in fact, be used separate from the envelope generator by having a 9-volt battery at the point indicated instead of the 24-volt supply.

The clipping amplifier consists of an inexpensive dual two-input gate RTL integrated circuit, *IC1*, in which each of the gates is biased into linear operation. The gates are then cascaded.. The output from the second gate is clipped by *D3* and *D4*.

Two controls are provided in the clipping amplifier. Potentiometer *R22* allows you to adjust the percent of clipping you desire, while potentiometer *R23* lets you adjust the output signal level from the subassembly.

When the clipping amplifier is connected at the output of the envelope generating system, the percent (%) control can be adjusted so that clipping occurs only after a certain amplitude has been exceeded. Hence, the signal would start clean, but past a certain level would start to sound "fuzzy." If, however, the clipping amplifier were connected at the input of the envelope generator, the signal from the input source should be clipped regardless of amplitude. Then it would be given an envelope.

When assembling the clipping amplifier, use the same techniques employed with the two circuits that make up the envelope generator. Be particularly careful when installing *IC1* to make the proper orientation of the indexing tab. Also, use caution when soldering the IC leads in place.

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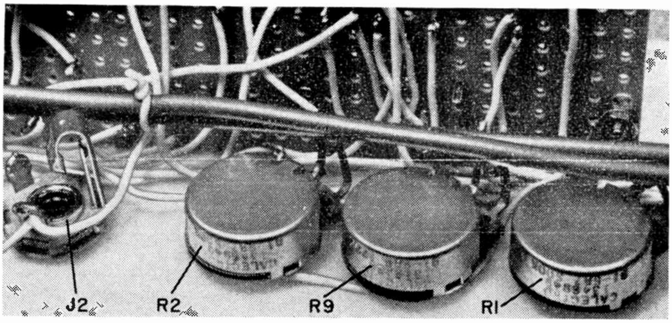
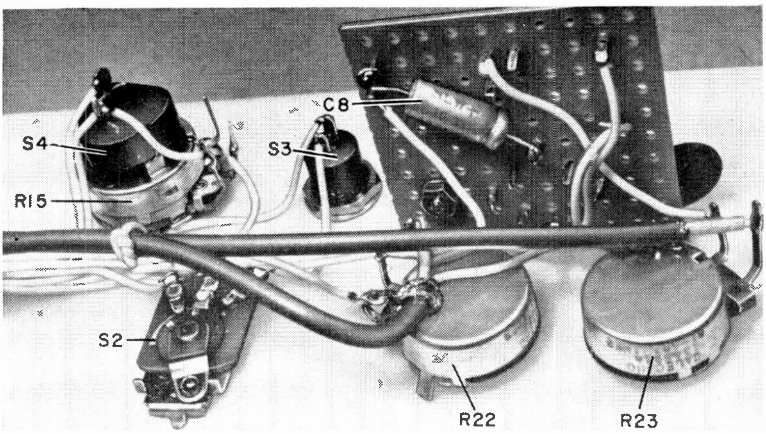
Operation of system is greatly simplified when rise, on, and fall controls (R2, R9, and R1) are grouped together as shown.





Solder shields of audio cables to the housings of potentiometers R22 and R23. Also note that capacitor C8 mounts on the bottom of clipper amp circuit board.

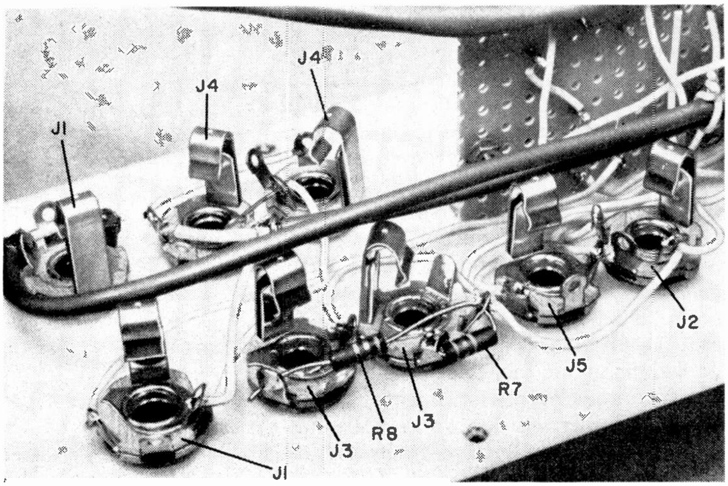
guitar or audio generator. Set the AUTO/MANUAL switch to the MANUAL position and the RISE, ON, and FALL time controls to zero. With the LEVEL control set for midposition, there should be no sound coming out of the system. If *Q1* is not being overloaded and you hear sound, not enough bias is available to cut off Q1; use a higher voltage zener diode for D1 in this case.

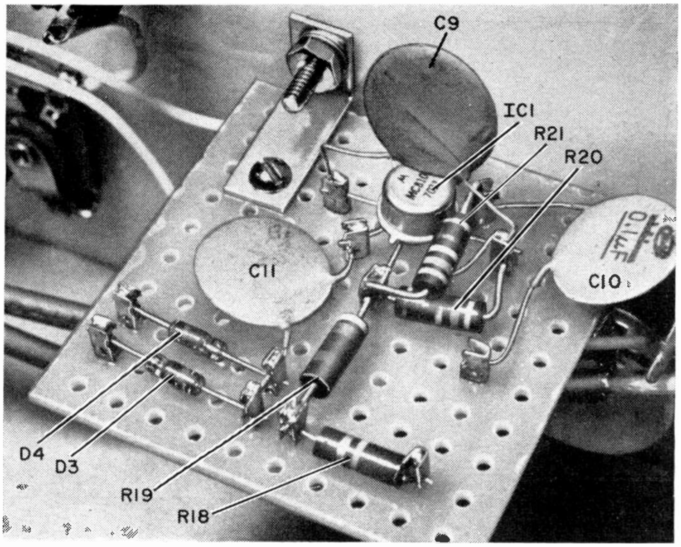
Depress and hold down *S3*; you should hear whatever signal is connected to the input of the system. In Fig. 4 are shown the effects the various controls have on the shape of the envelope being generated. Bear in mind that the on and rise times overlap.

Try various adjustments until you become familiar with each control. Plug into *J2* an oscilloscope or VTVM if you have either of these items, and you can monitor the effect each control has on the envelope. Set *S2* to AUTO and the RATE control fully clockwise. You should now hear a pulsing sound. (Note: if the on or fall time is longer than the period of the pulse generator, the signal will remain on indefinitely.)

External pulse jack *J5* is another handy built-in feature of the envelope generator. It allows you to use a footswitch to initiate the envelope generating cycle while your hands are busy playing your musical instrument. This feature is typically used with a guitar setup as shown in the block diagram

For operating convenience, all jacks (except those used for power) are best located in a group. Power jacks J6 and J7 can be located on side of box.





Wired clipper amp board fastens to front panel with 4-40 machine hardware and small L bracket. Wires connecting subassembly into system are soldered to terminals on the bottom side of the circuit board.

in Fig. 5. The straight sound of the guitar feeds to one input of a two-input mixer, while the output of the envelope generator connects to the second mixer input. When the envelope generator is triggered, a slowly rising wave of fuzz can be initiated—or, for that matter, a burst of fuzz can be initiated by presetting a fall time with zero rise and on times.

The system can also be set in the automatic cycling mode, with rise and fall times adjusted so that the end of a fall coincides with the beginning of a rise. Under these conditions, the sound generated is like a super tremolo with adjustable amplitude slope.

Sometimes the slowest pulse generator range will appear not to be working at the low end. To remedy this, turn the SPACE control fully clockwise for a few seconds. Then return the control to the low end again.

The values of certain key components in the envelope generator can be changed to tailor the system to your needs. To double the maximum rise and fall times, *R2* and *R1* can be increased in value to 1 megohm. Increasing *C5* to 50-μF will yield on times of up to 20 seconds. Lastly, if the low end of the pulse generator is too slow for your particular application, reduce *C7* to 100 μF.

Several controls interact in the envelope generator. So, if at first the system does not seem to be operating correctly, make sure that the problem is not a misadjusted control or switch or an incorrectly installed diode, transistor, or electrolytic capacitor.

Space limits the description of what can be done with the envelope generator when a little imagination and a lot of experimenting are applied. So far, the system has been used successfully with guitar, organ and bass—as well as both commercial and homemade music synthesizers. Even an audio-oscillator can become a musical instrument with the aid of the envelope generator.

Remember that an electronic musical instrument is really no different from the more conventional musical instruments with which you are familiar. The more practice you put in, the better will be your technique. The number of controls on the envelope generator means that it may take you several hours just to figure out how everything works. But at the end of that time, you will feel the effort well worth while. ◆

ELECTRONIC COMBINATION LOCK

UP TO 1 MILLION COMBINATIONS CAN BE CREATED

BY J. A. NUNLEY

ELECTRONIC COMBINATION locks are not what you would call earth-shaking novelties these days. But many of them leave something to be desired when it comes to flexibility of combinations and self protection against being opened accidentally. The solid-state lock (patent pending) described here is capable of having 10,000 different combinations and, with slight modifications, can have a million or more. The basic circuit can be programmed to accept any four-digit combination—even four of the same number—while the simple encoding process permits changing the code within a few seconds if it is suspected that the code has been detected.

The circuit is self-protecting in that the combination cannot be entered too rapidly and if an incorrect combination is entered, a wait of about four seconds is required before a second try can be made. Trials of various combinations in an attempt to break the code take about six seconds each.

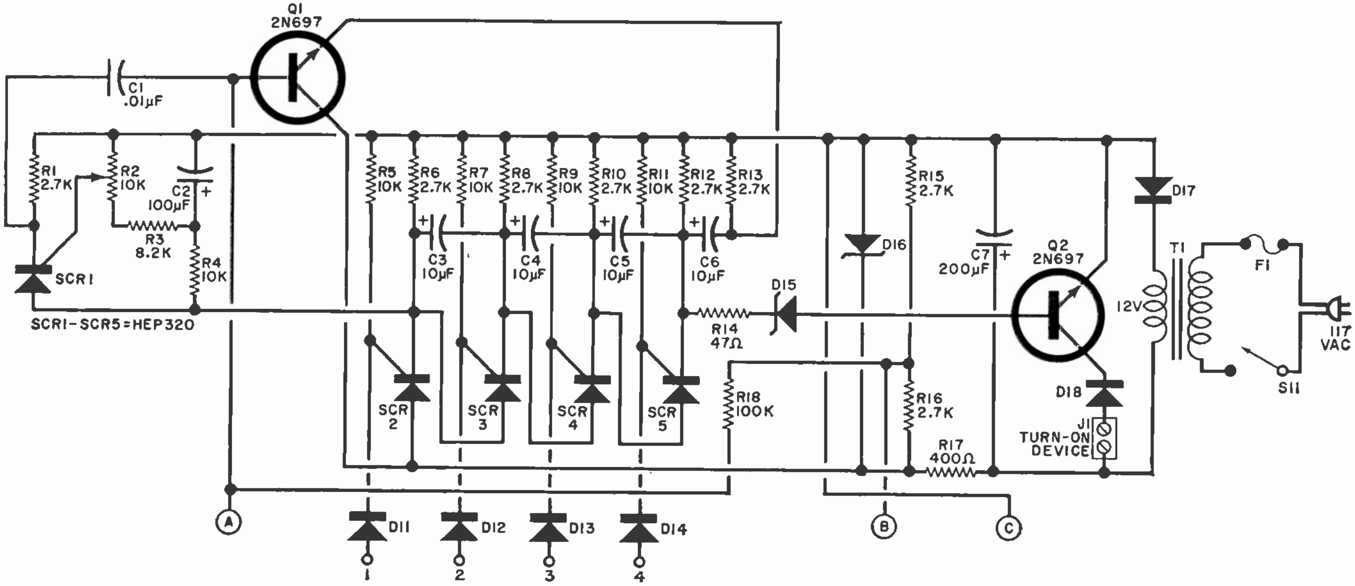
Any wrong digit, even if preceded by correct ones, cancels the stored information so that, even if the first three digits are guessed correctly, a wrong fourth one negates the attempt. Pressing several buttons at once is also useless since only the lowest number registers and is effective only if correct.

The power supply for the lock can be 117-volt line power or a 12-volt battery such as those found in cars, boats, and trailers.

Construction. The circuit of the lock (see Fig. 1) is divided into two sections. One part is the pushbutton keyboard and the other is the de-ciphering circuit. The two can be located as near or as far from each other as necessary. Any type of packaging can be used though the circuits should be enclosed so that they can't be tampered with. The mounting of the keyboard depends upon the application. The 14 gate diodes, *D1* through *D14*, can be of any type as long as they have a reverse breakdown of at least 12 volts.

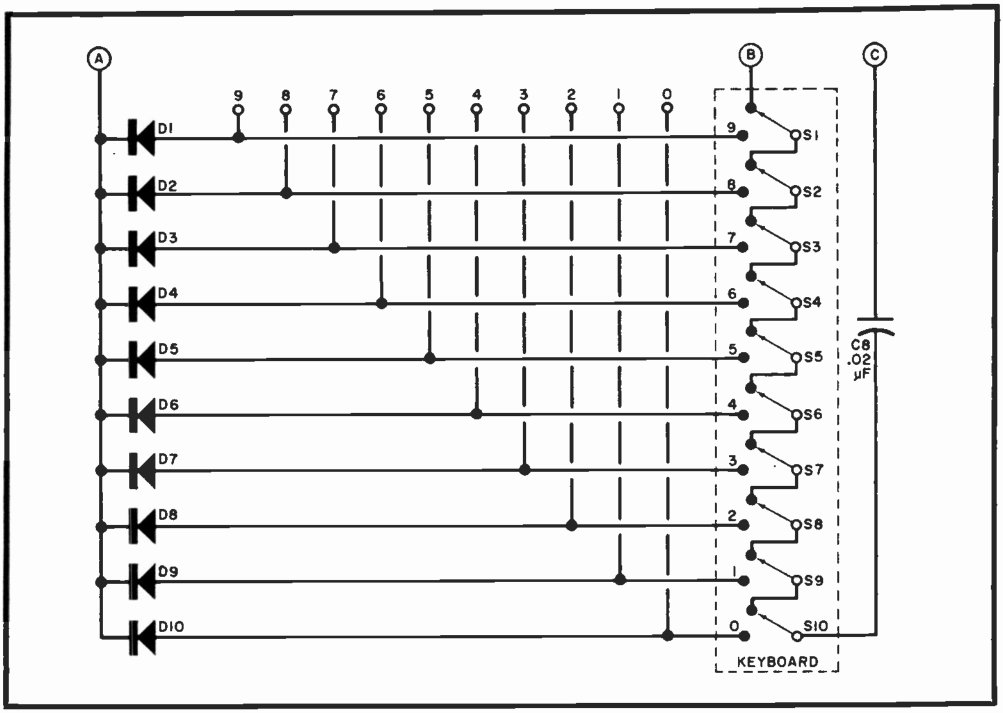
The connections between the electronic circuit (terminals 1 to 4) and the keyboard (terminals 0 to 9) determine the combination. In the prototype, simple spring-loaded wire clips were used for these connections. This does not provide an ideal low-resistance circuit but will suffice. If desired, four independent,

Fig. 1. Terminals 1 through 4 (below) represent the four sequential inputs. These are connected to any four of the 0 through 9 terminals (right). When the correct pushbuttons (S1-S10) are depressed in right order, Q2 turns on. SCR1 is the timing generator.



PARTS LIST

C1—0.01-µF capacitor
C2—100-µF, 15-volt electrolytic capacitor
C3-C6—10-µF, 15-volt electrolytic capacitor
C7—200-µF, 35-volt electrolytic capacitor
C8—0.02-µF capacitor
D1-D14—Diode with 12-volt PIV
D15—6-to-8-volt, 1-watt zener diode
D16—12-volt, 10-watt zener diode
D17—35PIV, 0.5A silicon rectifier diode
D18—200PIV, 0.5A silicon diode
F1—1A fuse and holder
J1—Two-pin connector
Q1,Q2—2N697, HEP53 (or similar) transistor
R1,R6,R8,R10,R12,R13,R15,R16—2700-ohm, ¼-watt resistor
R2—10,000-ohm subminiature potentiometer
R3—8200-ohm, ¼-watt resistor
R4,R5,R7,R9,R11—10,000-ohm, ¼-watt resistor
R14—47-ohm, ½-watt resistor
R17—400-ohm, 5-watt resistor
R18—100,000-ohm, ¼-watt resistor
S1-S10—Spdt pushbutton switch
S11—Spst slide or toggle switch
SCR1-SCR5—HEP320 silicon controlled rectifier
Misc.—Suitable enclosure, multi-conductor cable, spring-loaded clips (10), line cord, solenoid, press-on type, etc.



single-circuit, 10-position rotary switches can be used. At any rate, diodes *D11* through *D14* must be connected to four of the leads from the keyboard matrix. To change any digit at any time, one of the four is moved to another location.

Theory of Circuit Design. The keyboard has 10 (or more) spdt pushbutton switches in series. One end of the series is connected to a source of approximately 6 volts dc and the other end to a higher voltage through capacitor *C8*. When all switches are in the off position, *C8* is charged up to the voltage difference. If one of the pushbuttons is depressed, the charge on *C8* is applied to one of the silicon controlled rectifiers *SCR2* through *SCR5* through one of the diodes *D11* through *D14*. Simultaneously, it is connected to the timing circuit *(SCR1)* through one of diodes *D1* through *D10*. When a pushbutton is depressed, all pushbuttons of a higher number are disconnected and have no effect until *C8* is recharged.

Consider the operation in the most difficult case—when all numbers are the same. Assume the combination is 4444. All four digit register stages are connected to terminal 4 on the keyboard. When *S6* is depressed (to apply the 4), the charge on *C8* is applied to *SCR2* through *SCR5* simultaneously. However, only *SCR2* turns on since they are connected together by coupling capacitors. The latter appear as low impedances across the SCR's during their charging period and prevent the establishment of a minimum holding current. The discharge pulse from *C8* is much shorter than the charging pulse across C3 through C5 so by the time the latter are charged up, the gate current available from *C8* is gone. Pushbutton *S6* is then released and *C8* is allowed to recharge. When *S6* is again depressed, the second digit register comes on but the rest are still inhibited by the coupling capacitors. Each subsequent operation of *S6* turns on another stage until the complete code has been entered. For other, non-similar combinations, the inhibition principle of the coupling capacitors is not used but their charging rate determines the fastest rate at which discrete digits can be entered.

Once turned on, the SCR's remain in the conducting state as long as they have the minimum holding current. When cancellation stage *Q1* is turned on, a voltage pulse is applied to capacitors C3 through C6 and the SCR's *(SCR1* through *SCR5)*

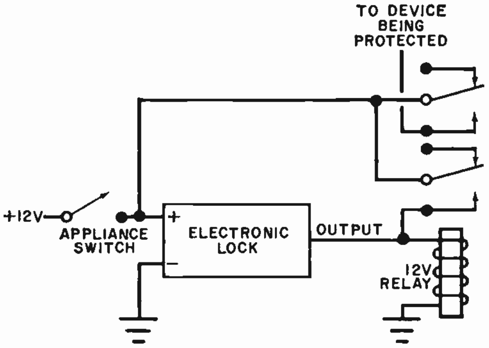


Fig. 2. This circuit is for use with a heavy load. It is also suitable for car or boat use.

are turned off. This occurs when any pushbutton is depressed. However, when the correct pushbutton is depressed *Q1* is inhibited by the charging of one of the capacitors through an SCR. Thus, "good" numbers do not cause cancellation, but any false number cancels everything. Also, if only four numbers are being used, and a fifth number is selected, the register is cancelled.

The timing circuit (*SCR1*) operates on the basis of the time constant of the combination of *R4* and *C2*. When the first correct digit is entered (*SCR2* is turned on), a positive voltage is applied to the anode of *SCR1* and to *R4*. This puts a charge on *C2* so that when the voltage at the junction of *R4* and *C2* reaches the correct potential, *SCR1* is turned on. The timing can be adjusted by potentiometer *R2* to vary between 5 to 15 seconds after *SCR2* is turned on. Capacitor *C6* and resistor *R13* are an extension of the timing chain to permit proper operation of the cancellation stage.

The solenoid driver stage (*Q2*) is a simple transistor switch that is turned on by the final register stage (*SCR5*). Zener diode *D15* prevents the short pulses that result from the turning on of previous stages from actuating Q2. Diode D18 protects the transistor from damaging back emf from an inductive load.

Applications. If the power requirements of the solenoid that operates the door exceed 24 volts at 300 mA, then a power relay must be used as the turn-on device.

If it is desired to use the lock in a 12-volt application (car, boat, etc.) eliminate *T1* and *D17* and reduce the value of *R16* to about 25 ohms. Remove the lead from the 12-volt supply to the device to be protected, and add the circuit shown in Fig. 2. When the normally used appliance switch is turned on, only the combination lock is energized. The correct combination must be entered to activate the external latching relay. The latter, in turn, applies 12 volts to the device being protected. In an ignition system, for example, substitute the ignition switch for the appliance switch so that the relay applies power to the ignition coil. Be sure the relay is wired to latch in. Otherwise, it will reopen in a few seconds.

Increasing Combinations. To increase the number of possible combinations, increase the number of keyboard pushbuttons or the number of digit register stages. The latter procedure is more effective. If the number of digit register stages is n and the number of pushbuttons is p, the total number of possible combination is p^n. It might be argued that the number of combinations is (p^n—1) but the combination 0000 is acceptable.

For 10 pushbuttons and four register stages, the number of possible combination is 10^4 or 10,000. With one more register stage, the number is 100,000, etc. By contrast, if two pushbuttons alone are added, there are 20,736 combinations.

One interesting possibility is to use 26 pushbuttons labelled A through Z. The number of combinations is then 456,976 and a four-letter word can be used as the code. At six seconds per try, it would take 761 hours to try all possible combinations.

Digit register stages identical to stages *SCR3* and *SCR4* can be added easily. The circuit shown in Fig. 1 can take only two more register stages without some circuit modifications to provide reliable operation.

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Winding Your Own Output Transformers

BY
ED FRANCIS

Circuits involving solid-state components frequently require "non-standard" audio output transformers. This article describes simplified methods of calculating the primary/secondary ratios, wire sizes, and numbers of turns for low-impedance matching transformers wound on "salvaged" cores.

PROJECT BUILDERS and experimenters occasionally need a small impedance matching audio transformer with an uncommon impedance ratio. When such a transformer is specially wound, its cost is usually prohibitively high compared to the total cost of the project in which it is to be used. However, with a few calculations and a little work on your part, you can duplicate many unusual transformers or any special audio coupling or matching transformer to suit your needs. The techniques described in this article are limited to transformers of average size and low-to-medium impedance. It is impractical to duplicate subminiature transformers that normally cost only $1 or less and high-impedance transformers that require many turns of very fine wire.

Throughout this article, you will find the term "volt amperes" (VA) used in the same manner that "watts" is used for power. This usage involves an assumption which is not quite true. However, for this type of work, if you accept the assumption that the two are equal, the results will be acceptable.

Calculations involved in designing an audio transformer are covered by the nine steps outlined in the box on page 94. To see how these steps work, let's design a typical transformer.

Assume that a transistor output transformer with a 130-ohm primary and a 4/8/16-ohm secondary is needed to match the output of an RCA CA3020 IC to a loudspeaker. By referring to the mail-order catalogs, we find that the full output of the IC is 0.5 watt. The nearest thing you can find in the catalog

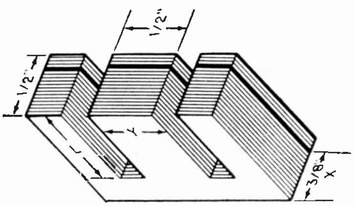


Fig. 1. Calculate X dimension needed to provide core area when multiplied with Y dimension; then, as indicated by heavy lines, remove required number of metal laminations.

is a 125-ohm center-tapped transformer rated at 300 mW. This transformer could be used, but you can make one that will be just as good and design it for a full watt if space and weight requirements permit.

First calculate the core area required. Note, however, that the core area applies only to the cross-sectional area of the core's center leg as shown in Fig. 1. Referring to Fig. 2, we find that the graph shows an approximate core area of 0.18 sq in. will suit our requirements. (We can use an approximation since the actual core area is not too critical.)

Determine the turns ratio from the impedance ratio. Since we know the primary and lowest secondary impedances to be used, plug 130 and 4 into the equation: Ratio = the square root of (130/4):1 = 5.7:1. Hence, the actual turns ratio required shows 5.7 turns in the primary winding for every turn in the secondary winding.

Next, determine the dc voltage to be applied to the transformer's primary. In this case, we desire 9-volt operation. The CA3020 employs a push-pull output. So, bear in mind that an 18-volt figure must be used in all primary calculations.

Calculate the wire size needed for the primary winding. Since we have decided to design the transformer to handle 1 watt of power, let us first determine how much current will be handled by the primary: I = (VA/Vcc) = 1/9 = 0.111 A. Now, because of the push-pull division of the current, we divide the primary current by two for determining the wire size; this gives us 55 mA in each half of the primary winding. If 700 circular mils/ampere is desired, refer to the Wire Table (column four) on page 93, and locate the current at or greater than 55mA. Column one shows that #34 wire will safely handle 57 mA, the nearest figure to 55 mA. This size is quite small and difficult to work with, so choose #28 wire for ease of winding.

We will have to make some assumptions now in determining the number of primary turns to be used. For this calculation, we will use 2Vcc, or 18 volts, and an area of 0.18 sq in. for our 1-watt transformer. The frequency we will arbitrarily settle on as being 100 Hz. For flux density BM in lines/sq in., any figure between 40,000 and 90,000 can be used; we'll settle on 70,000 to be conservative:

$$\text{Primary Turns} = \frac{2\text{Vcc} \times 10^8}{4.44 \times A \times f \times BM}$$

$$= \frac{18 \times 10^8}{4.44(0.18)(100)(70,000)} = 321$$

so, 320 turns will be close enough.

Having calculated the number of primary turns, we use the turns ratio formula to calculate the number of secondary turns needed. This is a step-down-type transformer, so we divide the number of primary turns by the turns ratio: Secondary Turns = Primary Turns/Turns Ratio = 320/5.7 = 56 turns.

Secondary wire size is determined by the current ratio method. Secondary current is equal to the primary current multiplied by the turns ratio: 0.111 × 5.7 = 0.64 A. The secondary wire size is determined by the same method as used for the primary. At 700 circular mils/ampere, the Wire Table indicates a 577-mA current capacity for #24 and 728 mA for #23 wire. Since 640 mA is about midway between the two sizes, we settle on #23 wire.

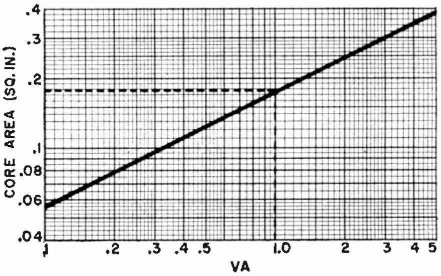


Fig. 2. Lengthy mathematical computations for determining the transformer core area can be avoided with the aid of the graph shown here.

Finally, the 8- and 16-ohm taps must be calculated. Again, refer to the turns ratio formula, and determine the turns ratio for

8 and 16 ohms separately. Then use these ratios with the primary turns to determine the exact number of turns required for each impedance: 16-ohm ratio = the square root of (130/16):1 = 2.86:1; 8-ohm ratio = the square root of (130/8) :1 = 4.04:1. Secondary turns = 320/2.86 = 112 turns for the 16-ohm ratio; Secondary turns = 320/4.04 = 79 turns for the 8-ohm ratio.

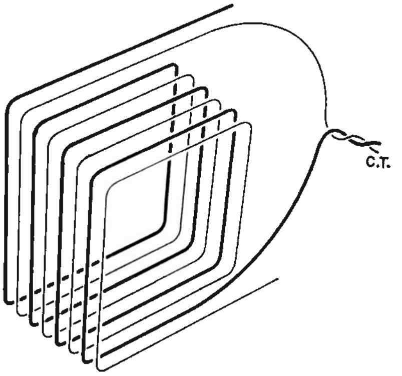


Fig. 3 Bifilar winding technique precisely locates center-tap. Center-tap is derived by twisting together opposite ends of winding.

Hence, the composite secondary will consist of 112 turns of wire with taps at the 56th and 79th turns.

Now that we have all of the design parameters, we can proceed to assembling our special-purpose transformer.

Assembling the transformer from the design parameters derived from the above procedure is easy. We know that the core area must be about 0.18 sq in. The simplest and least expensive way of obtaining a suitable core is to salvage an old audio output transformer. Many such transformers have a core area of 0.25 sq in. If about a quarter of the laminations are removed, approximately the correct dimensions will be obtained (about 0.185 sq in.).

Disassemble the salvaged transformer, and remove and discard the windings, but reserve the plastic winding bobbin if it has one. If no bobbin is available, you can make one from an index card or heavy waxed (butcher's) paper. This bobbin should easily slide over the core leg and be a little shorter than the center leg of the laminations.

WIRE TABLE

AWG B&S	Area (circular mils)	Current capacity at 600 c.m. per ampere	Current capacity at 700 c.m. per ampere	Current capacity at 800 c.m. per ampere	Turns linear inch, enamel insulation
14	4107	6.85	5.87	5.14	15.0
15	3257	5.43	4.65	4.07	16.8
16	2583	4.31	3.69	3.24	18.9
17	2048	3.42	2.93	2.56	21.2
18	1624	2.71	2.32	2.03	23.6
19	1288	2.14	1.84	1.61	26.4
20	1022	1.71	1.46	1.28	29.4
21	810	1.35	1.16	1.02	33.1
22	642	1.07	.918	.804	37.0
23	509	.848	.728	.636	41.3
24	404	.674	.577	.505	46.3
25	320	.534	.458	.400	51
26	254	.424	.363	.318	58
27	201	.336	.288	.252	64
28	160	.265	.228	.199	72
29	126	.210	.181	.158	81
30	100	.167	.144	.125	90
31	79	.133	.114	.096	101
32	63	.105	.090	.079	113
33	50	.083	.072	.063	127
34	39	.065	.057	.049	143
35	31	.053	.045	.039	158
36	25	.042	.036	.031	175
37	20	.033	.028	.025	198
38	15	.025	.022	.019	224
39	12	.020	.018	.015	248
40	10	.017	.014	.012	282

Slide the bobbin onto a length of wood to serve as a winding handle. Then begin winding the primary turns onto the bobbin, starting and ending along the ½" side of the bobbin to avoid having the ends exit from the core "windows" when the bobbin is in place. Ordinary "scatter" winding is acceptable in most cases; but if space is limited, you might have to close-wind the

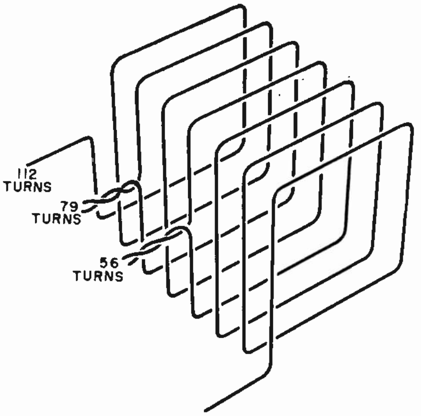


Fig. 4. Individual taps are obtained by twisting short pigtails from continuous length of wire. Attach stranded wire leads to pigtails.

NINE-STEP AUDIO TRANSFORMER DESIGN

In approaching something like the design of your own special-purpose audio matching or output transformer, you should use a practical, realistic procedure. The nine steps outlined here are set up so that you will not overlook time and work-saving steps and will lead you from start to finish without a lot of messy mathematical calculations.

Step (1). Refer to the catalogs for all available data (such as primary and secondary impedances and power and voltage ratings) concerning the transformer needed.

Step (2). Determine the transformer core area, from the transformer power rating (VA), area is equal to the square root of VA divided by 5.58. A quicker method is to refer to the graph in Fig. 2. Read up from the selected volt-amperes figure to the diagonal line, project to the left and read the core area in square inches.

Step (3). Calculate the turns ratio. From the impedance ratio, the turns ratio is equal to the square root of (Z1/Z2), where Z1 is the larger and Z2 the smaller impedance.

Step (4). Determine the voltage for which the transformer primary is to be used. For single-ended operation, use supply voltage Vcc; for push-pull operation use 2Vcc.

Step (5). Compute the size of the wire needed for the primary turns. Using the transformer power rating and the dc operating voltage (Vcc), primary current equals VA/Vcc. For audio service, a minimum of 600 circular mils/ampere is recommended; winding space permitting, it would be better to figure on using 700-1000 circular mils/ampere. A center-tapped primary would have only half of the total current flowing through each half of the winding at any one time, so the metric area can be reduced by half.

Step (6). Calculate the number of primary turns needed:

$$\text{Primary Turns} = \frac{\text{Vcc X } 10^8}{4.44\ (A)\ (f)\ (BM)}$$

where Vcc is supply voltage; A is core area in square inches; f is the lowest frequency to be passed without loss; and BM is flux density in lines/square inch.

Step (7). Determine the number of secondary turns required. If the transformer is to be an impedance-step up type, multiply the turns ratio by the number of primary turns calculated; if step-down, divide the primary turns by the turns ratio.

Step (8). Calculate the secondary wire size by the turns ratio method. Current transfer is inversely proportional to the turns ratio. Hence, if the transformer is a 10:1 step-down type, the secondary should be capable of handling ten times as much current as the primary. Once the current capacity is determined. You can refer to the Wire Table to find the smallest diameter wire that will suit your needs. It is, however, advisable to use the largest practical size wire to obviate a large dc voltage drop in the windings.

Step (9). If the center tap is required, use the "bifilar" method of winding (see text). For multi-impedance outputs, recalculate the turns ratios. secondary currents, etc., for each output impedance.

turns. Our hypothetical transformer has a further complication: The primary winding is center-tapped. It must be wound so that both sides of the winding are balanced. To do this we will use the "bifilar" winding method shown in Fig. 3.

For our 320-turn primary winding. we wind two wires onto the bobbin simultaneously, side by side until there are 160 double turns on the bobbin. Then to complete the bifilar winding, we connect one end of one wire to the *opposite* end of the other wire and solder a 5″ length of stranded hookup wire to make the center tap. Two more stranded wires soldered to the free ends of the primary windings complete the primary assembly. Color code the wires so that the center tap is easily identifiable. Make sure that each soldered connection is well insulated from the others; then wrap a layer or two of plastic tape over the windings.

Now wind the secondary turns onto the bobbin. Count the turns as you go, and make a pig-tail tap lead at the 56th and 79th turns for the 4- and 8-ohm taps (see Fig. 4). Use color coded stranded hookup wires for the winding ends and taps so that each can be

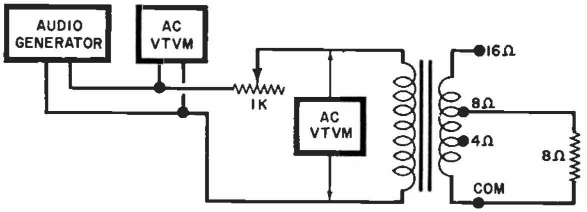


Fig. 5. Although not really necessary if you followed all steps carefully, the finished transformer can be tested as shown in drawing at left.

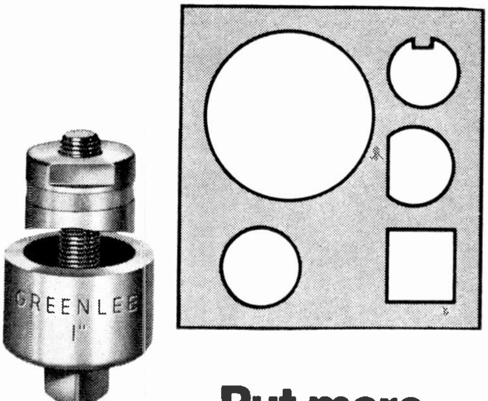
easily identified. Again, make sure that the solder connections are well insulated from each other, and wrap a layer or two of electrical tape over the assembly to prevent the windings from unraveling.

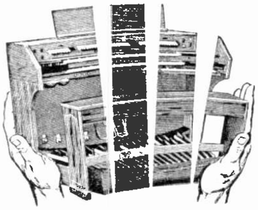
Slip the bobbin assembly off the winding handle. Orient the primary leads to one side and the secondary leads to the other side of the bobbin. Then slip the bobbin onto the center leg of the transformer core laminations. Assemble the transformer.

Testing the completed transformer is not really necessary if you exercised care during assembly and followed each step exactly as described. However, if you want to be on the safe side, you can test the transformer with the aid of an audio signal generator, two ac VTVM's or FET VOM's, an 8-ohm load resistor, and a 1000-ohm potentiometer as shown in Fig. 5. Set the generator's amplitude control for an output of several volts at 1000 Hz. Adjust the potentiometer for minimum resistance so that both meters have an identical reading.

Now, increase the resistance of the potentiometer until meter #2 indicates exactly one half its original indication while making sure that meter #1 remains at the original voltage setting. Since changing the resistance of the potentiometer decreases the load on the audio generator, meter #1 will indicate an increase in voltage. Simply reduce the generator's output level to return meter #1 to the original voltage setting.

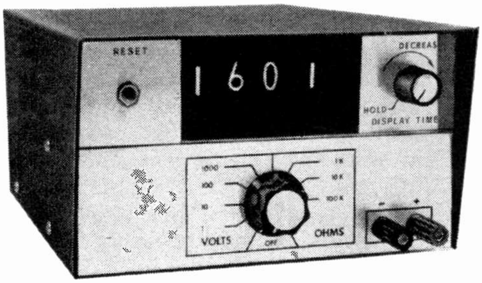
After jockeying back and forth between the generator's amplitude control and the potentiometer a few times, you should be able to arrive at settings where meter #1 indicates the original voltage and meter #2 indicates exactly half of its original voltage. When this occurs, remove the potentiometer from the circuit without upsetting its final setting and measure its resistance. This resistance should be equal (or as near as possible) to the transformer's input impedance, or 130 ohms. However, if the transformer is loaded with an incorrect impedance (say, the 8-ohm load resistor connected across the 4- or 16-ohm output leads), it will reflect an incorrect impedance into the primary. As a matter of fact, if you use a 3.2-ohm speaker on the 4-ohm transformer output, a primary impedance somewhat lower than that for which the transformer was designed will be reflected. But if you plan to use such a speaker with the transformer, you could easily have plugged into the equations the 3.2-ohm figure for the 4-ohm figure. ◈





ASSEMBLE A

DIGITAL VOLT-OHMMETER PLUG-IN MODULE



AND ADD TWO MORE FUNCTIONS TO YOUR LOW-COST DIGITAL MEASUREMENTS LAB

BY DANIEL MEYER

CONTINUING details on modules for our low-cost Digital Measurements Lab (see page 25), here is construction and assembly data on a digital volt-ohmmeter (DVOM) plug-in module. When used with the Lab main frame, the DVOM module provides measuring capabilities for dc potentials to a maximum 1999 volts in four ranges, and resistance from 1 ohm to 199,000 ohms in three ranges.

The accuracy of the DVOM plug-in module is not specified in the lower 5 percent of the instrument's range. Even so, after several months of using it on the test-bench, the DVOM module/mainframe combination proved to be an extremely versatile and easy-to-operate test center.

Converter Design. The basic circuit used in DVOM's is a voltage-to-frequency converter. Several approaches are used to change a voltage to a frequency. The most common one employed in digital instruments uses some type of capacitor-discharge analog-to-digital conversion process which depends on digitally representing the time needed to charge a capacitor to some reference voltage or to the value of the input voltage being measured. An elementary system of this type compares the voltage to be measured to the voltage across a charged capacitor as shown in Fig. 1.

The comparator is a high-gain differential amplifier, the output of which changes very rapidly from zero to maximum when a difference exists between the two input voltages. The conversion begins when *S1* is opened and *C* begins to charge toward the level of the input voltage. The charge rate of the capacitor is linear due to the use of a constant current for charging. When *S2* is closed and *S1* is opened, the counter begins counting the pulses from the clock at the same time the capacitor begins to charge.

Now, when *C* charges to a slightly greater level than the voltage being converted, the comparator changes state and closes the gate through which the clock pulses pass into the counter. Therefore, a reading directly proportional to the charging time of *C* is obtained.

This type of system, although simple, is prone to errors. Any change in clock frequency or in the value of *C* directly affects the reading obtained. Any ac voltage, hum included, riding on the dc voltage being measured affects the point at which the comparator switches. These problems can be minimized by use of a crystal-controlled oscillator, a charging capacitor with very stable characteristics, and an input filter. The same results, however, can be obtained with a dual-slope integrator such as the basic system shown in Fig. 2.

Here, an operational amplifier is connected with the charging capacitor, *C*, from the output to the inverting input to form the integrator. The input voltage is applied to *R* and the resulting current into the input of the op amp charges *C* at a constant rate. The op amp itself is used as a constant charging source.

As soon as the voltage across *C* at the output of the op amp rises above ground, the comparator changes state and opens the gate to allow clock pulses to enter the counter. The input current, the value of *C*, and the clock frequency are designed to allow the counter to reach full scale before the capacitor can fully charge.

Since the amount of time required to run the counter to full scale with a given clock frequency is a constant, there is at this point a charge on C that is proportional to the input voltage. If at the time the counter reaches full scale, it is reset to zero and the op amp input is switched to a reference voltage, *C* can be discharged at a constant rate to provide a counter reading proportional to the capacitor voltage and, thus, directly proportional to the input voltage.

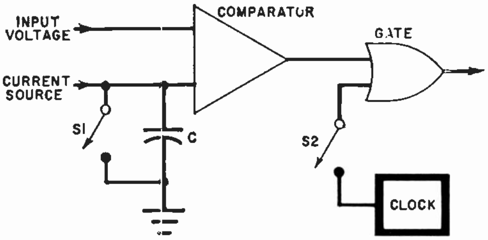
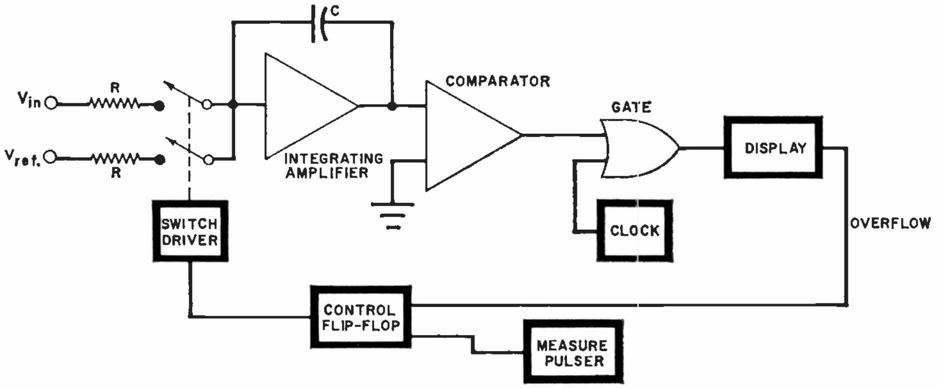


Fig. 1. Elementary capacitor-discharge analog-to-digital converter is typical of those used in digital instruments.

Circuit Operation. In the DVOM Module circuit shown in Figs. 3 and 4, the input voltage is applied to range selector switch *S1* and attenuator network *R33-R36*. If this voltage is greater than the basic 0-2-volt input range of the converter, it is reduced to this range by the attenuator resistors. The voltage obtained is then applied to *Q1* which acts as an impedance converter. This FET has a very high input impedance which makes possible the 10-megohm input impedance of the plug-in, and the low output impedance needed to drive the circuits which follow. Resistor *R1* and diodes *D1* and *D2* protect *Q1* from overloads that might occur if *S1* were not set to the proper range position and a high voltage were applied.

The voltage at the source of *Q1* is ap-

Fig. 2. Improved stability and immunity to ac noise on dc voltage being measured are obtained with this dual-slope integrator.



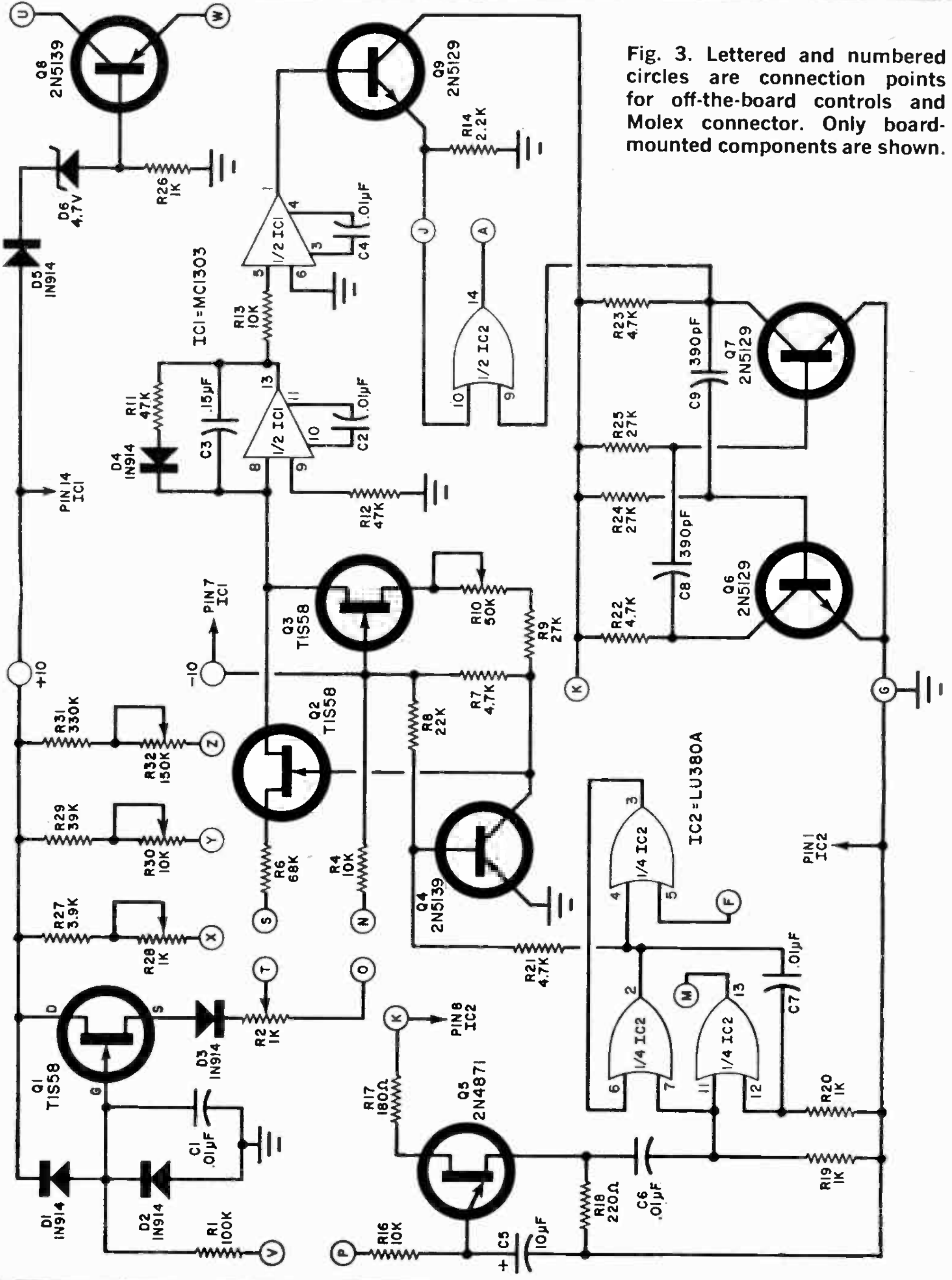


Fig. 3. Lettered and numbered circles are connection points for off-the-board controls and Molex connector. Only board-mounted components are shown.

plied to the integrator resistors. *R5* and *R6* through ZERO set control *R2* and *D3*. Transistors *Q2* and *Q3* act as switches for the integrator and reference currents.

Now, if we consider the beginning point of the cycle to be the "measure" signal, the following action takes place. Transistor *Q3* is discharging the integrator, *IC1*, which is prevented from going positive by more than 0.5 volt by diode *D4* in the feedback loop. Transistor *Q3* is connected as a constant-current

PARTS LIST

C1, C2, C4, C6, C7, C10—0.01-µF disc capacitor
C3—0.15-µF disc capacitor
C5—10-µF, 15-volt electrolytic capacitor
C8, C9—390-pF polystyrene capacitor
D1-D5—1N914 diode
D6—4.7-volt zener diode
IC1—Integrated circuit (Motorola MC1303)
IC2—Integrated circuit (Signetics LU 380A)
J1,J2—Banana jack or five-way binding post (one black, one red)
Q1-Q3—TIS58 field-effect transistor
Q4,Q8—2N5139 bipolar transistor
Q5—2N4871 unijunction transistor
Q6,Q7,Q9—2N5129 bipolar transistor
R1—100,000-ohm, ½-watt, 10% resistor
R4,R13,R16—10,000-ohm, ½-watt, 10% resistor
R6—68,000-ohm, ½-watt, 10% resistor
R7,R21-R23—4700-ohm, ½-watt, 10% resistor
R8—22,000-ohm, ½-watt, 10% resistor
R9,R24,R25—27,000-ohm, ½-watt, 10% resistor
R11,R12—47,000-ohm, ½-watt, 10% resistor
R14—2200-ohm, ½-watt, 10% resistor
R17—180-ohm, ½-watt, 10% resistor
R18—220-ohm, ½-watt, 10% resistor
R19,R20,R26—1000-ohm, ½-watt, 10% resistor
R27—3900-ohm, ½-watt, 10% resistor
R29—39,000-ohm, ½-watt, 10% resistor
R31—330,000-ohm, ½-watt, 10% resistor
R33—9-megohm, 1% precision resistor
R34—900,000-ohm, 1% precision resistor
R35—90,000-ohm, 1% precision resistor
R36—10,000-ohm, 1% precision resistor
R37—33,000-ohm, ½-watt, 10% resistor
R10—50,000-ohm trimmer potentiometer
R2, R28—1000-ohm trimmer potentiometer
R30—10,000-ohm trimmer potentiometer
R32—150,000-ohm trimmer potentiometer
R3, R5—1000-ohm standard potentiometer
R15—500,000-ohm standard potentiometer
S1—4-pole, 10-position rotary switch with spst add-on
Misc.—Printed circuit board; metal chassis; 15-contact Molex connector; solid and stranded hookup wire; control knob; 33,000-ohm, ½-watt resistor for current limiter on decimal point); machine hardware; solder; lacing cord; insulated spacers; etc.
Note—The following items are available postpaid from Southwest Technical Products Corp., Box 32040, San Antonio, TX 78216: etched and drilled printed circuit board No. VM-1b for $2.65; complete kit of parts, including chassis and connector, No. VM-1 for $29.95.

source. The −10 volts applied to the gate and a resistor in the source circuit determines the bias voltage and, therefore, the amount of current that passes through Q3. Variations in the −10-volt source have really no effect on the current. Pin 2 of *IC2* is at a 0 logic level at this point in the cycle.

Transistor Q5 is a simple UJT generator, producing pulses at a rate governed by display control *R15*. When the voltage across C5 reaches the breakover point of Q5, a sharp pulse is supplied to pin 11 of *IC2* through C6. This portion of *IC2* is connected to form an RS flip-flop, or latch, circuit.

The pulse at pin 7 causes the output at pin 2 to go to a logic 1 at approximately 4 volts. This causes Q4 to conduct and brings the Q4 collector voltage to near ground potential, in addition to resetting the counter. In turn, this causes Q3 to go into cutoff and allows Q2, cut off until now, to conduct. At this point, the input voltage begins to charge integrator capacitor C3.

The output of the op-amp section switches into the circuit the comparator portion of *IC1* as soon as the integrator output goes slightly negative. When the comparator switches, the voltage at pin 10 of *IC2* goes to logic 0 and opens the gate, allowing clock pulses to enter the counter. This same logic signal is also applied to the blanking input of the counter to keep the display off during the measurement cycle.

When the counter reaches full-scale, the logic level at the overflow point changes and this signal is coupled to pin 5 of *IC2*. The pulse from the overflow indicator resets the RS flip-flop to its original state and resets the counter to zero. At this point, Q4 cuts off and Q3 begins supplying current to bring the integrator back to zero.

Counts are entered into the counter until the op-amp integrates back to zero, at which point the comparator changes state and closes the gate to the counter. The number displayed is proportional to the input voltage level. After a period of time, determined by the setting of *R15*, the cycle repeats.

The clock oscillator is a simple multivibrator operating at approximately 70 kHz. As already pointed out, the exact frequency is not critical, nor is stability. The only requirement is that it remain within 0.1 percent during the 0.1-second measurement interval.

Adding an ohmmeter circuit to the basic digital voltmeter is quite simple. All that is needed is a constant-current

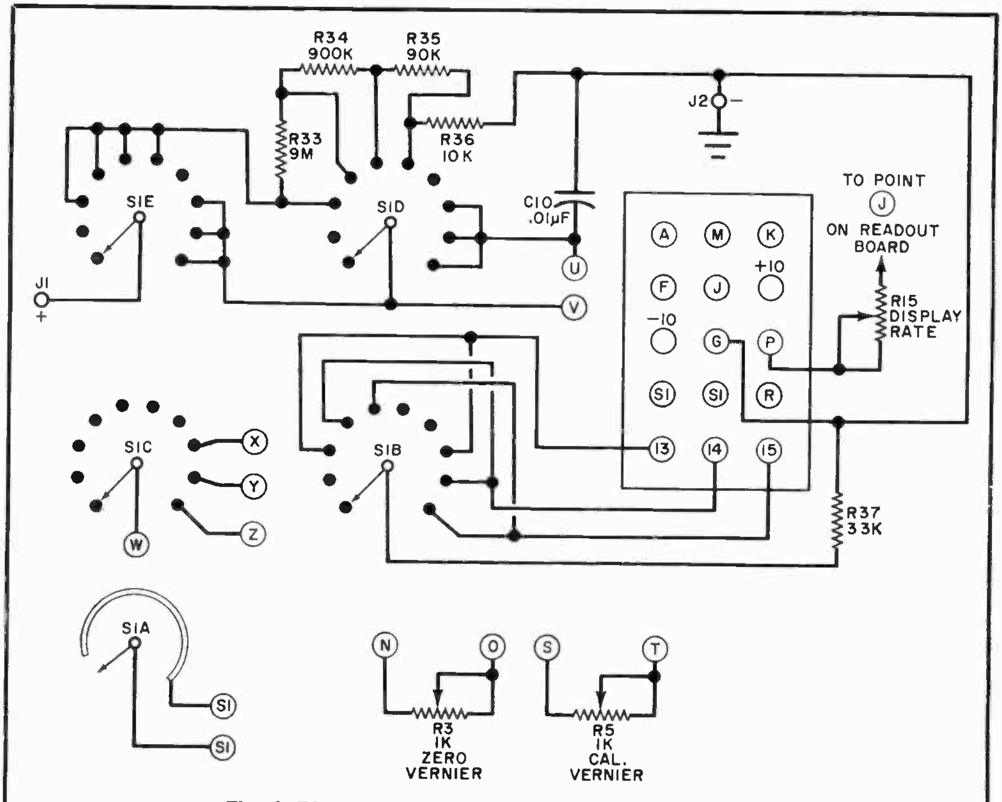
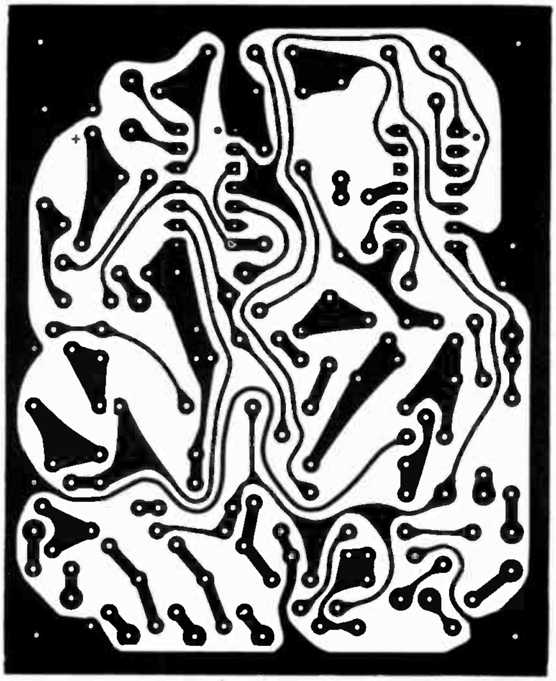


Fig. 4. Diagram shows how outboard controls, Molex connector, and range/function switch go together.



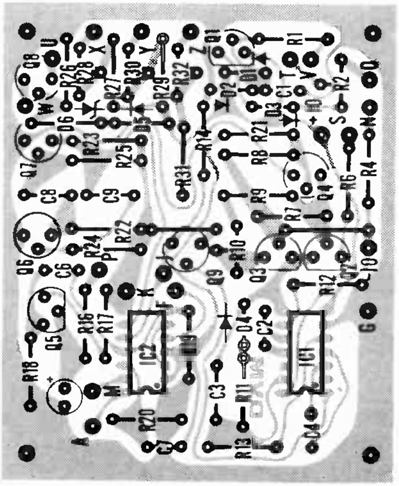


Fig. 5. Actual size drilling and etching guide and component placement and orientation diagram are shown left and below, respectively.

source to produce a dc voltage across the resistor under test. This current can be selected to provide a constant voltage that is directly proportional to the resistance. The voltmeter can then measure the voltage drop across the resistor. To accomplish this, the selector switch (*S1*) changes the emitter resistance in the current source circuit to provide the proper current for the 1999, 19.99k, and 199.9k ohm, full-scale, ranges. Transistor *Q8* is the constant-current source.

Construction. Since all of the components that make up the DVOM Module mount on a single printed circuit board (see Fig. 5 for actual size etching and drilling guide and components placement diagram), assembly is very simple. The only off-the-board components are *S1*. the attenuator resistors, and a pair of potentiometers as shown in Fig. 6.

After wiring the PC board. connect and solder to the lettered holes 8" lengths of stranded hookup wire. Next, connect and solder the attenuator resistors to the multi-deck range/function switch. Mount the switch assembly, *J1* and *J2*. and *R3* and *R5* on the chassis. Then connect and solder the appropriate wires from the circuit board to the switch. Likewise, connect and solder the appropriate wires from the board to the Molex connector contacts. Neatly bundle and tie the wires from the PC board to the switch and from the board to the connector.

Connect and solder the wires to *R3* and *R5* on the floor of the chassis. Then, using insulated spacers, mount the circuit board assembly on the floor of the chassis. Note that the circuit should not be grounded to the chassis at any point. The only ground connection to the case should be back to the dc power line.

Calibration. Plug the DVOM Module into the Mainframe via the connector. Turn on the power and check to make sure that the supply voltages are within 10 percent of their proper values. Set the control in the regulated 5-volt power supply section for between 4.5 and 5 volts output to the IC's.

Now, connect a shorting wire from *J1* to *J2* in the DVOM Module and place the range/function switch in the 1-volt position. Set *R3* and *R5* to midpoint. The display should show a reading as *R2* is rotated. Set *R15* for a 1-2 second display rate.

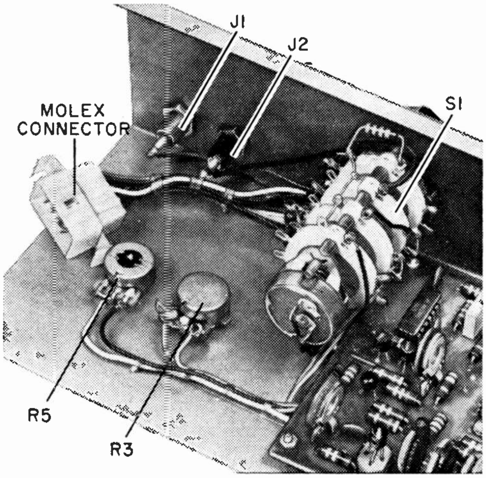


Fig. 6. Photo shows parts mounting details for off-board components.

Now, adjust *R2* for as close as possible to a zero reading. Remove the short from *J1* and *J2*, and apply a known voltage to the input terminals. A mercury reference cell is probably the most commonly available voltage reference accurate enough to be used with this instrument. Remember that your readings are only as accurate as your calibration—which is only as good as the accuracy of the reference used.

With the reference voltage applied to *J1* and *J2*, set *R10* for as close as possible to the correct reading. Then set *R3* and *R5* with the voltage reference and with the short applied to the input terminals. Check the zero setting by rotating the range/function switch to the 100-volt range. If the reading obtained is not zero with a short across the input terminals, readjust *R3* until it is. This calibration procedure should provide the voltmeter with a 1-percent or better accuracy.

The resistance ranges are set simply by connecting 1-percent tolerance precision resistors to *J1* and *J2* and adjusting *R28*, *R30*, and *R32* to provide values that reflect those stamped on the resistors. If you can obtain 0.1-percent wirewound multiplier resistors, these make excellent standards to use for calibrating the resistance ranges.

This completes the calibration procedure for the DVOM Module. You are now ready to use the instrument. ◆

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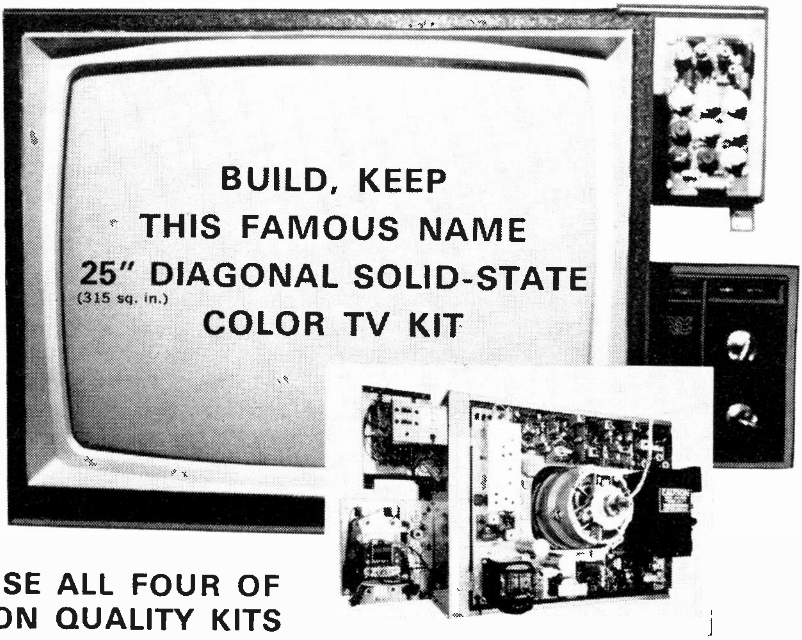

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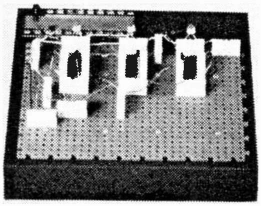

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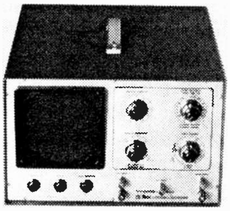

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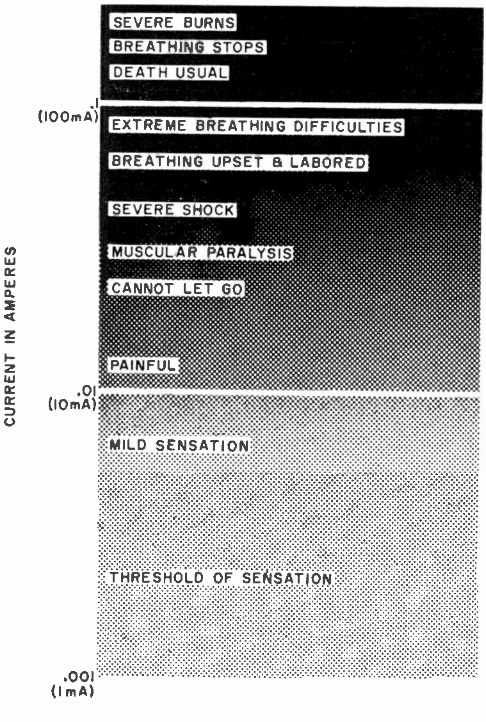
How Much Current Is Fatal?

THE FOLLOWING information, supplied by Tektronix Inc., is something we feel should be read and understood by all electronics experimenters, technicians, hams, and engineers, regardless of what area of electronics or electrical work they are in.

Unfortunately, most of us think that a shock of 10 kV would be more deadly than one of 100 volts. This is not so. People have been electrocuted by ordinary 117-volt appliances and by voltages as low as 42 volts d.c.! The real measure of the degree of shock is not the voltage applied, but the amount of current forced through the body—and that need not be very much.

While any amount of current over 10 mA is capable of producing a painful to a severe shock (as shown in the chart), current between 100 and 200 mA can be considered lethal. Currents above 200 mA, while producing severe burns and unconsciousness, do not usually cause death if the victim is given *immediate* resuscitation (artificial respiration).

It's not the voltage that causes the big problems, but the current level being driven through body tissues.



Voltage is not a consideration; it is important only because its level and the body resistance between the points of contact determine how much current flows. Since resistance varies greatly, it is impossible to predict a dangerous voltage. The resistance may vary from 1000 ohms for wet skin to over 500,000 ohms for dry skin—remembering that the resistance from point to point under the skin may be only a few hundred ohms. Also remember that the contact resistance decreases with time and the fatal current may be reached rapidly.

As shown on the chart, a current as low as 20 mA is very dangerous and painful, and the victim can't let go of the circuit. As the current approaches 100 mA, ventricular fibrillation of the heart usually occurs. Above 200 mA, the muscular contractions are so severe that the heart is often forcibly clamped during the shock. This clamping sometimes protects the heart from going into ventricular fibrillation and the victim's chances for survival are good.

Now, what lesson can we learn from all of this? First, regard *all* voltage sources (even some batteries) as potential killers. When working around electrical equipment make sure you know where you are with respect to the voltage source. Don't lunge after fallen tools. Kill all power before diving into circuits. Don't work when you are mentally or physically fatigued. Keep one hand in your pocket when investigating live electrical equipment. Be particularly observant of what you are standing on—don't work on a metal floor, damp concrete, or any other well-grounded surface. Don't handle electrical equipment while wearing damp clothing—particularly shoes—or when the skin is wet from water or perspiration.

In the event of an accident, either cut the voltage or get the victim away from his contact—using some form of insulation to do the job or you will get caught too. If the victim is unconscious and has stopped breathing, start artificial respiration at once. Do not stop until proper medical aid has arrived. ◆

GETTING TO KNOW THE JK FLIP-FLOP

BETTER UNDERSTANDING OF A MISUNDERSTOOD CIRCUIT

JUST BECAUSE the JK flip-flop is one of the basic devices on which today's complex and sophisticated computers are based is no reason for you to jump to the conclusion that it is too complicated for you to understand and use. Much of the mystery can be dispelled if you view the JK flip-flop for what it is: nothing more nor less than a very clever and extremely versatile switch.

On this and the following pages, we will trace the evolution of the JK flip-flop to its present integrated circuit form and explain how it operates. Then we will describe a few basic circuits which employ JK flip-flops as dividers.

Bistable Multivibrators. The JK flip-flop is a sophisticated and highly versatile form of the bistable multivibrator. As shown in Fig. 1, a bistable multivibrator is simply a pair of amplifier stages whose inputs and outputs are cross-coupled to each other.

When power is applied to the circuit in Fig. 1, a state in which one transistor conducts heavily and the other transistor is held at cutoff is forced upon the circuit. A heavily conducting transistor has a collector-to-emitter resistance that is very low (on the order of between 10 and 20 ohms). If the collector load resistance is about 40 times this value (typically 640 ohms in an IC package), virtually the entire supply voltage

BY FRANK H. TOOKER

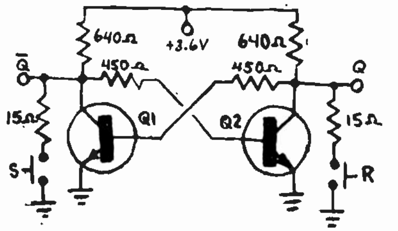


Fig. 1. A bistable multivibrator consists of a pair of amplifier stages whose inputs and outputs are cross-coupled to each other.

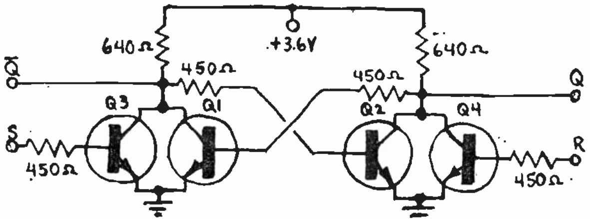
is dropped across the load resistor, and the collector is essentially at ground potential. When a transistor is cut off, its collector-to-emitter resistance is so high that it can be considered as an open circuit. The transistor's no-load collector potential will then approach the amplitude of the supply voltage.

For the purposes of positive computer logic, when a transistor's collector is very close to ground, its output (taken between collector and ground) is said to be a logical "0." Conversely, when the collector is at some potential higher than zero volts, the transistor's output is said to be a logical "1."

With *Q2* conducting heavily, the circuit's output is Q = 0; and *Q1*, held at cutoff, produces an output of $\bar{Q}$ = 1. (The vinculum or bar over the Q, as in $\bar{Q}$, means, "not." Hence, $\bar{Q}$ means "not Q." Whenever the vinculum appears, it is an indication that the logic level at that symbol is the opposite or complement of the logic where the symbol is unaccompanied by the vinculum.) This can be defined as the reset or preset state of the circuit and, unless the circuit is deliberately made to change, it will maintain this state indefinitely for as long as power is applied.

To change the state, "set" pushbutton switch *S* must be momentarily pressed. This lowers the collector potential of *Q1* to near ground level, depriving *Q2* of base bias. Transistor *Q2* ceases conducting, its collector rises to the supply voltage value, and provides base bias to *Q1*. Therefore, *Q1* turns on and remains conducting while *Q2* is cut off until "reset" switch *R* is momentarily pressed to make the circuit change state again.

The 15-ohm resistors connected in series with switches S and R simply simulate the approximate collector-to-emitter resistances of heavily conducting transistors. If it is desired to trigger the bistable multivibrator into changing state electrically with a pulse (instead of mechanically with a switch), a transistor and a 450 ohm resistor are used in place



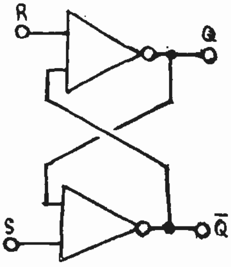
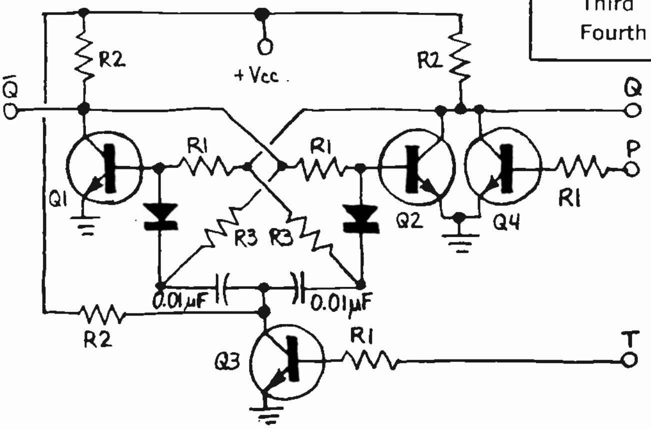


Fig. 2. Schematic and logic diagrams of SR flip-flop are shown above. All possible circuit states are indicated in truth table.

Qb	R	S	Qa
0	0	0	0
1	1	0	0
0	1	0	0
1	0	1	1
0	0	1	1
0	1	1	*
1	1	1	*

For R and S, 1 indicates a positive pulse.
Qb and Qa indicate state of Q before and after pulse, respectively.
*Doubtful state (see text).

Fig. 3. Positive pulses at toggle (T) input go through inverter Q3 and are steered to proper flip-flop stage through diode gates. Note absence of doubtful states in table.



Input Pulse Sequence	Q	$\bar{Q}$
Preset	0	1
First	1	0
Second	0	1
Third	1	0
Fourth	0	1

of each switch and 15-ohm resistor (Fig. 2).

In Fig. 2, making the input of *Q3* positive (S = 1) has the same effect as pressing switch *S* in Fig. 1. Similarly, making the input of *Q4* positive (R = 1) has the same effect as pressing switch *R*. The circuit in Fig. 2 is known as an RS (for reset-set) flip-flop or a latch, the latter term derived from its operational resemblance to a latching relay.

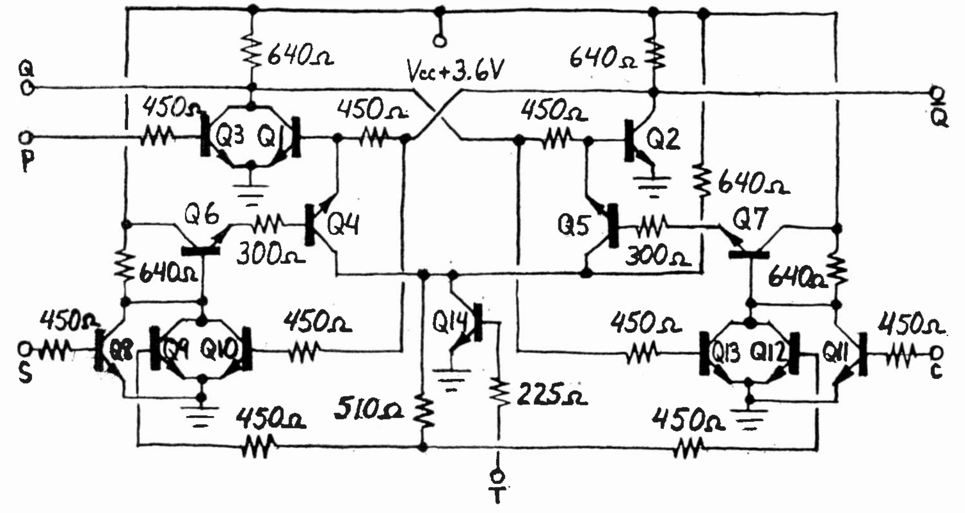
Also shown in Fig. 2 are a "truth table" and a "logic diagram" for the schematic. The truth table lists all possible inputs and the outputs resulting from these inputs. Two states not previously described are those on the bottom two lines of the table. With inputs S and R both pulsed positive, the resulting output state of the flip-flop can be either 0 or 1, depending primarily on which of the two inputs is the last to occur. Because the output is doubtful, S and R inputs are never pulsed simultaneously in practical applications.

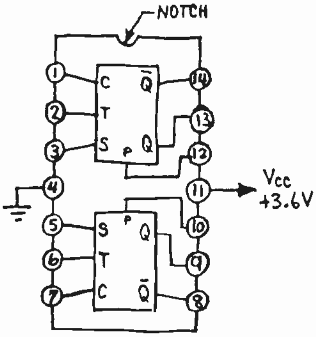
The logic diagram is a symbolic representation of the flow of logic through the circuit. The triangles are amplifier symbols. Here they are shown with two inputs, while the small circles at the apexes indicate that the outputs are inverted versions of the inputs. So, if the input is a logical 1, the output will be a logical 0. If no circle is shown, the output is non-inverted.

The RS flip-flop is not as versatile as the JK flip-flop, nor is it used as often. It does, however, find use as a start/stop switch in such instruments as digital voltmeters, frequency meters, and as a bounceless contact for the toggle input of a JK flip-flop.

The Toggled Flip-Flop. There are certain advantages to having a flip-flop that can be made to toggle or shift from state to state with the application of a pulse to a single input point and without having any doubtful states. The circuits in Fig. 1 and 2 cannot accomplish this. What is needed is a circuit like that shown in Fig. 3, in which diode gates are used to "steer" the input pulse to the side of the circuit where it will be effective. (The diodes in this circuit are biased according to the conductive states of their respective transistors. This means that one of the diodes will be biased in such a way that it cannot pass the pulse, while the other diode, more appropriately biased, can at any given instant.)

Toggle pulses are applied to the circuit at the junction between the two 0.01-µF capacitors. Because the pulses must be negative-going, transistor *Q3* is included in the circuit to demonstrate the principle of negation or inversion and to make the circuit responsive to positive-going pulses applied to toggle input T.





If Q Is:	And Prior S Is:	to CP C Is:	After CP Q Will Be:
0	0	0	1
1	0	0	0
0	0	1	0
1	0	1	0
0	1	0	1
1	1	0	1
0	1	1	0
1	1	1	1

Fig. 4. Half of a Motorola MC790P or HEP572 dual JK flip-flop is shown schematically at top, while directly above is top view IC pin identification diagram. Truth table is given above right, and logic terminology for output states is at right.

State	Level	Positive Logic
0	Low	False
1	High	True

The Truth Table for Fig. 3 shows that, for successive pulses, the Q output is alternately toggled between 0 and 1: the $\overline{Q}$ output is the Q output complement (or as Q goes from 0 to 1, $\overline{Q}$ goes from 1 to 0). A T input at the base of *Q3* becomes a T at its collector; when a T input goes to 1, the output at the collector goes to 0 at the instant of toggling.

A study of the truth table shows that the circuit in Fig. 3 divides by two. So, for the four input pulses listed, there will be two output pulses in each of the Q and $\overline{Q}$ columns.

Transistor *Q4*, with its input terminal P, is used for presetting the toggled flip-flop to Q = 0. Hence, input terminal P in Fig. 3 is used for exactly the same purpose and in the same identical manner as terminal R shown in Fig. 2.

The JK Flip-Flop. A typical JK flip-flop circuit (see Fig. 4, which is a schematic diagram of one section of a Motorola HEP-572 IC) seems a far cry from the simple circuits thus far described, but they have much in common with each other. Familiar circuits can be found in Fig. 4. And the JK flip-flop has much the same features—toggling and presetting—plus a couple of others that are essential but have not yet been described, such as set and clear (S and C) inputs.

Transistors *Q1* and *Q2* make up the bistable multivibrator proper, while *Q3* performs

FLIP-FLOP SYMBOLOGY

Because many electronic notations are extremely repetitive, an easily identifiable symbology, or shorthand, for these notations has evolved. For example, vacuum (and even gas) tubes are identified by the letter V, transistors by Q, integrated circuits by IC, etc. Symbols have also been applied to IC logic devices—sometimes with seeming abandon. However, since the symbology has become standardized throughout the industry, you should be familiar with the letter symbols used. Here is how they are derived:

RS—Reset/Set
J and K—Arbitrarily chosen designations
T—Toggle input
S—Set input
C—Clear input
P—Preclear input
Q—Arbitrarily chosen output designation
$\bar{Q}$—Complement of Q

the preset function, exactly as in the preceding circuits. Transistors *Q4* and *Q5* take the place of the capacitors shown in Fig. 3. The charges stored in the base-to-collector junctions of these transistors toggle the flip-flop when the toggle input is sufficiently fast. (The charge capacity of a transistor's base-to-collector junction is small, so toggle transit must be rapid.)

The toggle input is applied to terminal T and enters the circuit via transistor *Q14*. The pulse must be negative-going (the "fall" of a square wave, known as "trailing edge triggering," is a typical T input) and fall time must be within the range of 10-100 nanoseconds. Any T input that meets these requisites is called a "clock" or "toggle" pulse.

Inputs to terminals S and C are valuable features of the JK flip-flop. They determine whether or not the flip-flop will change state and, if so, in which direction in response to a clock pulse. In divider applications, they are essential to obtaining division ratios other than 2, 4, 8, etc., which are strictly binary.

When inputs at *Q8-Q10* are 0, a CP (clock pulse) at T sends the Q output to 0. Similarly, when inputs at *Q11-Q13* are 0, a CP at T produces a Q output of 1. Thus, steering is obtained by connecting the input of *Q10* to the output of *Q2*, and the input of *Q13* to the output of *Q1*. The states mentioned, in which S = 0 and C = 0, are shown on the first two lines of the truth table in Fig. 4.

On the third and fourth lines, note that if S = 0 and C = 1 at the time a CP arrives at T, the Q output will go to or remain at 0. Similarly, on the fifth and sixth lines, if S = 1 and C = 0 when a CP arrives at T, the Q output will go to 1 or remain at 1 if it is already there. If S = 1 and C = 1, the flip-flop does not change state in response to a CP, as demonstrated on the last two lines of the table.

A 1 input to S or C cannot independently cause the JK flip-flop to change state. It simply prepares the JK flip-flop so that operations described in the statements in the truth table can occur coincidentally with a CP input. Unlike inputs at S and C, a 1 input at P sends the Q output to 0 independently.

Inputs at S and C must be applied sufficently before a CP arrives (setup time) to assure that they are well established at the time toggling takes place. A definite release time is also required. Minimum intervals

FAN-IN AND FAN-OUT

The terms "fan-in and "fan-out" refer to the input load and output drive factors, respectively, of digital-logic devices. Fan-in is associated with the required power to the input terminals, while fan-out is related to the maximum power available at the output terminals. These two terms apply to any digital logic device and must be taken into consideration whenever you are interconnecting digital devices.

When a JK flip-flop is connected to one or more additional JK F/F's and/or other devices, the sum of the load factors must not exceed the drive factor. For example, a Fairchild 9923 single JK flip-flop, or each of the two JK flip-flops in the Motorola MC790P or HEP572, has a fan-out of 10. (The fan-in and fan-out of other digital devices can be found by examining their specification sheets.) The T input and the P input of each JK F/F has a fan-in of 5, while the S input and C input each has a fan-in of 3. Thus, the Q or $\bar{Q}$ output of one JK flip-flop can drive two T inputs (5+ 5), or three S and/or C inputs (3 + 3 + 3) with a little to spare.

The HEP-571 is an inverting dual-buffer. In medium-power service. It has a fan-in of 6 and a fan-out of 80, or about 8 times the fan-out of a typical medium-power JK flip-flop (such as one section of the HEP572). A buffer is actually a current amplifier It can be an emitter-follower; in this case, it is noninverting, but its voltage output is lower by the amount of the base-emitter drop in the transistor involved. Each section of the HEP571 involves three transistors, and the circuit more nearly resembles a power amplifier. The output is inverted.

JK flip-flops are sensitive to capacitive loads. Where such loads are unavoidable, a buffer should be used, with the JK flip-flop driving the buffer's input and the buffer's output driving the load. Some JK F/F's have buffers built-in as part of the IC. The Motorola MG791P is of this type.

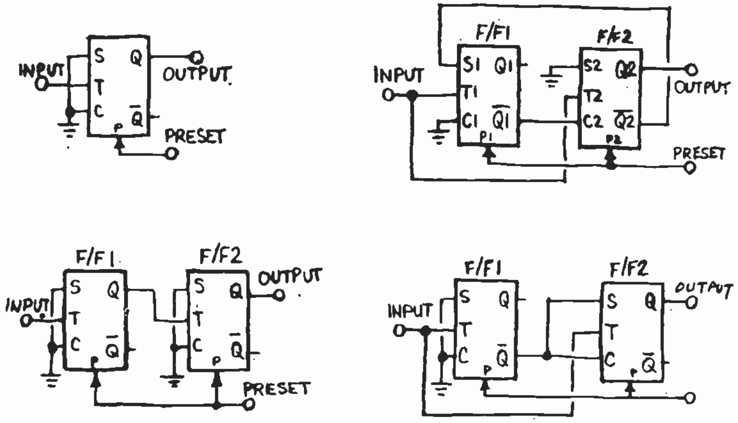


Fig. 5. Clockwise from top left are shown a divide-by-two; synchronous divide-by-three; synchronous divide-by-four; and asynchronous divide-by-four logic schemes for JK flip-flop hookups. Truth table at right is for the divide-by-three scheme.

After	Q1	S1	Q2	C2
Preset	0	1	0	1
CP1	1	1	0	0
CP2	1	0	1	0
CP3	0	1	0	1

equal to about twice the propagation delay, or 60 nanoseconds, should be sufficient for the average medium-power JK flip-flop.

The JK flip-flop is not responsive to positive-going pulses or to steady-state signals of either polarity at the T input.

While the S, C, and P inputs of a JK flip-flop are not particularly sensitive to rate or multiple pulsings, the input at T is very much so. At the T input, a CP must be fast, singular, negative-going, and have at least a 1.5-volt peak amplitude. Ordinary mechanical contacts bounce on closure, producing a ragged signal that will toggle a JK flip-flop an indefinite and random number of times instead of just once at each closing. For accurate performance, a JK flip-flop must be toggled electronically, preferably with an RS flip-flop, a Schmitt trigger, or a monostable multivibrator. Sine waves must be clipped severely to convert them into essentially square waves with fast fall times to make them suitable for clock pulses.

Simple Divider Circuits. Now that the evolution and theory concerning the JK flip-flop are out of the way, let us go to a few examples of practical circuits. The JK flip-flops thus far described are used with resistor-transistor logic, or in engineering shorthand, RTL. A single JK flip-flop divides only by two, which means that for each output pulse there must be two input or trigger pulses.

Greater division ratios can be obtained by connecting the output (Q or $\overline{Q}$) of one JK flip-flop to the toggle input of another JK flip-flop in a chain of as many JK F/F's as desired. This connection is often called a "ripple divider," because the toggling of each flip-flop (except the first) is produced by an output pulse provided by the preceding flip-flop. The maximum division ratio of a string of JK flip-flops connected in this manner is equal to 2^n, where the n is the number of JK F/F's in the chain. In simpler terms this means that two JK flip-flops divide by four, three divide by eight, and so on.

A divider made up of JK flip-flops connected in this manner is called an asynchronous divider because all JK flip-flops in the chain are not clocked at their T inputs simultaneously. Each JK flip-flop exhibits a certain delay between the arrival of a CP and the appearance of a pulse at the output.

For a medium-power JK flip-flop, like each section of a HEP572, this amounts to a delay of about 36 nanoseconds per JK flip-flop. Called propagation delay time, it accumulates in a chain of asynchronous connected JK flip-flops. In complex circuits, it can limit the maximum operating speed. In contrast, in a synchronous divider, all JK flip-flops are clocked simultaneously. So, the total propagation delay is equal to that of a single JK flip-flop.

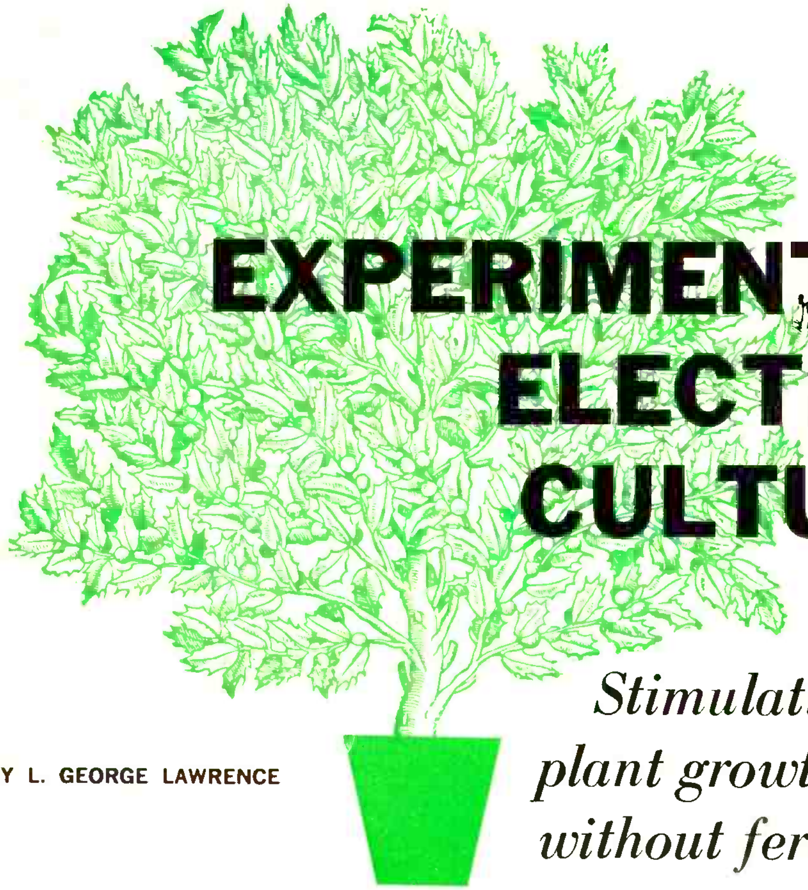
A few simple divider circuits that make use of the JK flip-flop are given in Fig. 5. Note how the S and C inputs are used to return the circuits to the same state as preset at the occurrence of the desired count.

The "divide-by-three" circuit, for example, is a synchronous divider; so both T inputs are pulsed simultaneously with each CP. After preset, Q1 of F/F1 is at 0, and Q2 of F/F2 is also at 0; S1 is at 1 ($\overline{Q}2$ output) and C2 is at 1 ($\overline{Q}1$ output). Thus, F/F1 can change state when it receives a CP, but F/F2 cannot.

After the first CP, Q1 is at 1 and Q2 remains at 0. With Q1 = 1 and S1 = 1, and Q2 = 0 and C2 = 0, F/F1 cannot change state upon receipt of a CP, but F/F2 can. Thus, after the second CP, Q2 = 1 and Q1 remains at 1. With S1 = 0 and C2 = 0, both JK F/F's can change state upon receipt of a CP. After the third CP, Q1 is at 0 and Q2 is at 0. This is the same as the preset state, so the cycle is completed at the count of 3. A concise resume of these events is given in the truth table in Fig. 5.

Pin connections and numbers for the Motorola MC790P and HEP572 RTL dual-JK flip-flop integrated circuits are also provided in Fig. 5. ◆

Boy, I sure hope they bring some more of these on their next trip up here!



EXPERIMENTAL ELECTRO-CULTURE

Stimulating plant growth without fertilizers

BY L. GEORGE LAWRENCE

This is an experimental arrangement developed by the author to test certain theories relative to stimulating plant growth in a very high voltage electro-static field. Details on the equipment built for the experiment are given and some of the background on the "why" of electro-culture is discussed.

HANGING your pet geranium upside down in the cellar all winter isn't necessarily all it takes to grow a beautiful plant next spring. Of course, amateur horticulturists—as well as professionals—have any number of theories about how you can automatically have a green thumb; but several historical and many more recent experiments have shown that successful gardening isn't just a matter of fertilizing, watering, and tender loving care.

Indeed, only a handful of people realize the role that natural electricity plays in the development of plant life. Yet, in 1902, physics professor S. Lemstroem of Finland, after a trip to the northern polar regions, decided that the rapid growth of vegetation during the short arctic summer was due to the unique electrical conditions of the atmosphere in those latitudes. Back in his laboratory, Professor Lemstroem reproduced the assumed arctic conditions by increasing the atmospheric current (which normally flows from the air to the plant) by placing a wire with a high static charge on it (generated by a Wimshurst machine) over a plant. An increase in plant yield was noticed.

Study of electro-culture (as the science is called) began with basic experiments by a Dr. Mambray in England in 1746. Later, in 1879, a French scientist, L. Grandeau, saw dramatic possibilities in the field which he described in a paper "Influence de l'Electricite Atmospherique sur la Nutrition des Vegetaux." But the real break came in 1902 with the Lemstroem experiments.

In more recent times, other experimenters extended the work to treatment of viable seeds using radio-frequency and ultrasonic methods. The r-f techniques involved frequencies above 30 MHz applied for a few seconds to seed bags placed into r-f tank circuits. Ultrasonic schemes involved the brief dipping of bags into baths agitated at frequencies up to 1 MHz. Plants grown from seeds treated in this way had yield profiles ranging from fair to excellent.

Fertilizers Spoil Picture. It was the invention and use of cheap chemical fertilizers that effectively suppressed electro-cultural engineering. Today, however, we are in the position where nitrate pollution by these very fertilizers threatens not only our water supply but the entire ecological panorama as well. Thus it would appear that the revival of electro-culture is not only desirable but imminently necessary.

Experimenting with electro-culture is hardly the same as building a stereo amplifier or a digital voltmeter. For one thing, high, static voltages are involved and a good degree of professionalism is required to obtain good results. (Keep in mind that we are concerned with living plants, which have their own peculiarities and may not *always* respond as expected—only large-scale trends are important.)

Typical electro-culture systems frequently operate unattended for long periods of time in an open-air environment. This requires heavy-duty construction in both the electrical and mechanical aspects of the equipment. However, expenditures can be kept low by using surplus-type materials. In the case of an experimental electro-culture system using high-voltage discharge, the cost of a typical exciter unit can be below $35.00.

MORE INFORMATION?

See:

"Electronics and the Living Plant," L. G. Lawrence, *Electronics World*, October 1969.

Plant Physiology, E. C. Miller, McGraw-Hill Book Co., New York, 1938.

Basic System. A schematic of a Lemstroem type of electro-culture system is shown in Fig. 1. Here, the positive terminal of the high-voltage power supply is connected to the overhead wire, with current return through a ground path. Potentials are as high as 20,000 volts—up to 60,000 volts for short periods of time. While natural atmospheric currents range between 10^{-16} and 10^{-15} ampere, the excitation provided by the high-voltage wire provides currents around 10^{-12} or 10^{-11} A, as measured by a sensitive electrometer. In open-air experimental fields, the height of the overhead discharge wires with respect to ground may be from 3 to 10 feet. The height above ground naturally affects the amount of atmospheric current. Remember that the high voltage serves as a "current carrier"—appropriate current values cannot be generated under other than high-tension conditions.

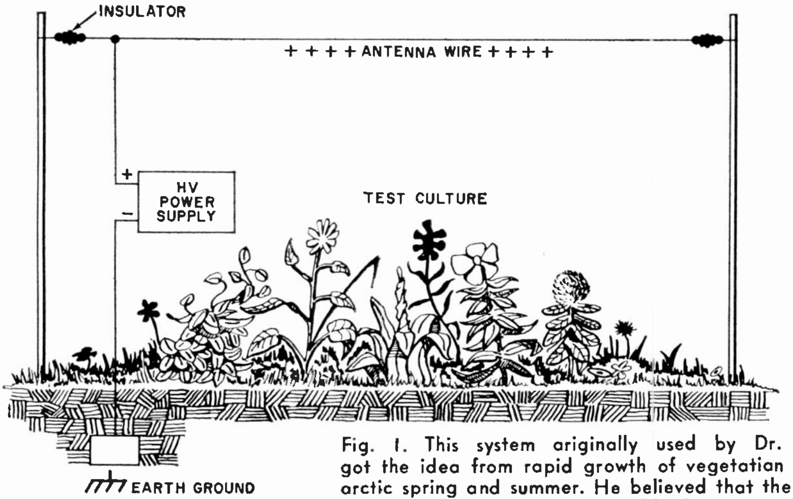


Fig. 1. This system originally used by Dr. Lemstroem who got the idea from rapid growth of vegetation during the short arctic spring and summer. He believed that the natural high atmospheric current was responsible for extremely rapid growth.

Fig. 2. Provision must be made to prevent animals, children, or strangers from touching the high-voltage lead. A simple wooden barrier is sufficient.

High-voltage electro-culture systems may take the form shown in Fig. 2. The apparatus was designed to investigate the susceptibility of many different plants to stimulation. The equipment generates ozone (O_3) and must be used in well-ventilated areas only.

An electrical schematic of this system is shown in Fig. 3. Transformer *T1* has an output of 3000 volts rms. After rectification, the effective dc is approximately 4200 volts. A dropping resistor may be necessary on the filament winding to obtain the correct voltage for the rectifier. If leakage current in the reverse mode can be tolerated, a high-voltage rectifier diode may be used instead of the tube and filament winding.

The 3000 volts dc generated is highly dangerous to touch.

Resistor *R1* (made up of several resistors in series) serves as a current limiter and can be anywhere from 5 to 20 megohms, the latter value limiting the current to 210 μA in the event of an accidental short circuit. Resistor *R1* may be in series with either the positive or negative output terminal.

Resistor *R2* is connected to two pieces of high-voltage cable with the connections and resistor thoroughly wrapped with high-voltage insulation so that the resistor is actually imbedded in the cable. Put insulated alligator clips on each end of the cable. This resistor

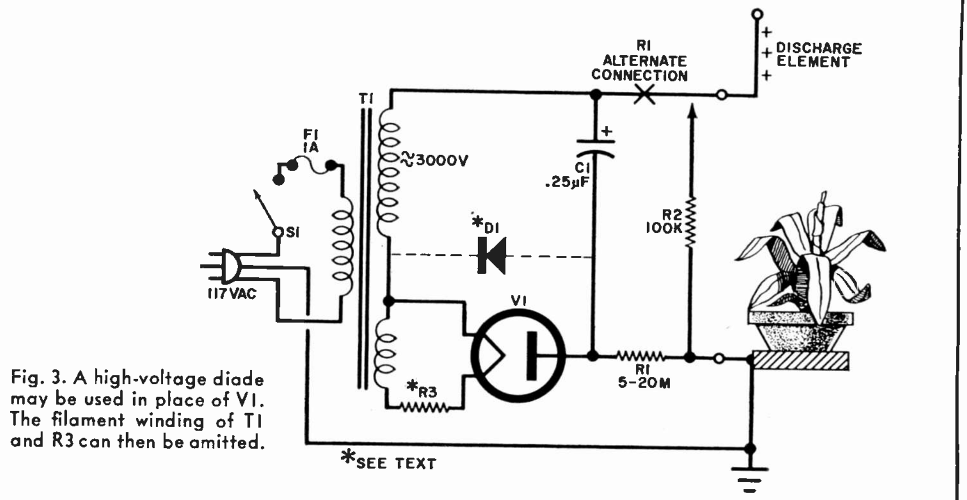


Fig. 3. A high-voltage diode may be used in place of V1. The filament winding of T1 and R3 can then be omitted.

PARTS LIST

C1—0.25-μF, 7500-volt capacitor
F1—1-ampere fuse with holder
R1—5-to-20-megohm resistor (see text, ½-watt each)
R2—100,000-ohm, 2-watt resistor
R3—See text
S1—Spst slide or toggle switch
T1—Oscilloscope transformer; secondaries: 3000 volts and 6.3 volts
V1—Half-wave, high-voltage rectifier tube
Note—Alternate rectifier diode D1 (IR 67 D-050H55FNN) can be used as shown by dotted line. See text.
Misc.—Large plastic container, 3-lead power line, mounting plate, insulators, high-voltage cable (10-kV test), hookup wire, hardware, ground plate for pot.

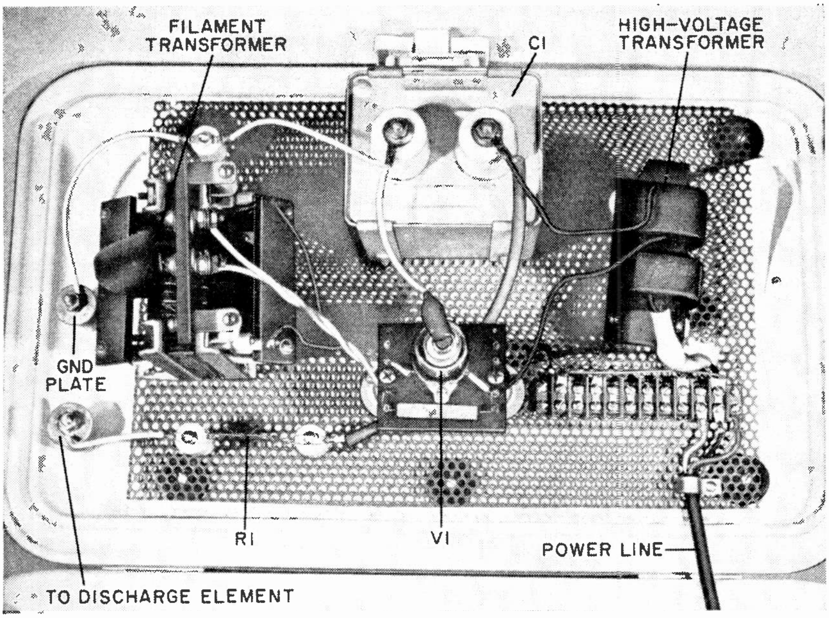


Fig. 4. Because the weak plastic chest cover will not support much weight, a perforated metal base plate is used to mount the heavy components. Feedthroughs are used to couple to the "antenna" and the main ground plate that supports the flower pot.

forms a safety discharge shunt and *must* be connected across the output terminals when the apparatus is shut off to discharge capacitor *C1* and the antenna structure ("discharge element" in Fig. 3).

The power supply's physical layout is shown in Fig. 4. For safety's sake and good appearance, the entire power unit is mounted on the lid of a plastic camping chest. Ceramic insulators are fastened to the lid to provide connections for the discharge element and ground wires. A simple ground electrode is inserted into the moist dirt (earth mixed with moss is good) in the pot and the pot sits in a metallic basket which is connected to the negative terminal of the supply. The antenna or discharge element is connected to the positive terminal and consists of a simple metal rod.

The 117-volt line cord is a grounded 3-wire type, with the green (ground) wire connected to the perforated-steel mounting plate on which the plant basket sits. The high-voltage transformer is mounted on insulators and the rectifier tube socket is mounted on insulators on a Bakelite terminal board. The string of resistors comprising *R1* is fastened to standoff insulators of the ceramic type. In the model shown in Fig. 4, a separate transformer was used for the tube filament supply with dropping resistor *R3* mounted on the Bakelite terminal board. The entire high-voltage section is wired with high-voltage cable tested to 10,000 volts dc.

R-F High-Voltage Supply. A schematic for a radio-frequency high-voltage unit is shown in Fig. 5. It is an inexpensive and slightly less dangerous alternate to the supply described above.

Effective dc output of this supply is 5000 volts at 200 microamperes maximum. Thus, should the supply's output electrodes be touched accidentally, an unpleasant, but nonlethal, shock will be experienced.

Electronically, the supply is comprised of a straightforward feedback oscillator. Optimum oscillator frequency is approximately 225 kHz. Tube *V2* is a half-wave rectifier. The supply may be constructed on a simple chassis and installed in a manner similar to the one shown in Fig. 2.

Note, however, that the transformer specified for *T1* does not have a filament winding for the rectifier. A filament loop may be added simply by placing one turn of No. 20 insulated high-voltage wire around *T1*'s ceramic base, being careful to maintain spacing from the tuned r-f circuit. (Follow the instructions packaged with the transformer.) A VTVM or similar high-impedance meter may be used

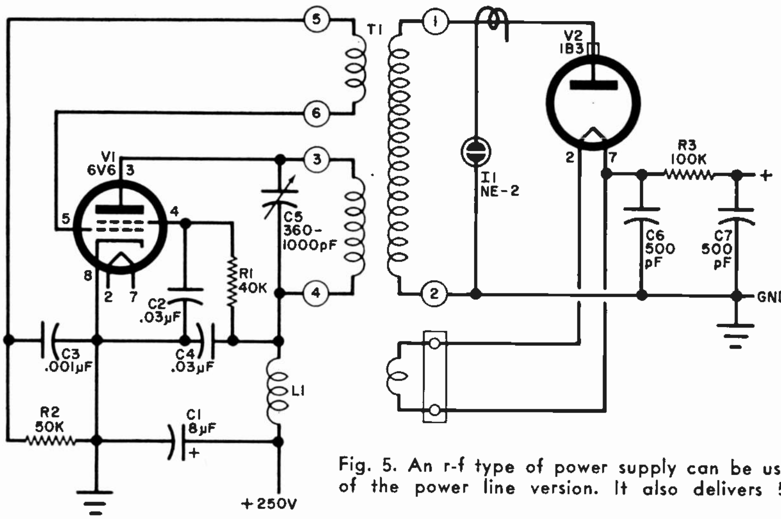


Fig. 5. An r-f type of power supply can be used instead of the power line version. It also delivers 5000 volts.

PARTS LIST

C1—8-µF, 350-volt electrolytic capacitor
C2,C4—0.03-µF, 600-volt capacitor
C3—0.001-µF, 600-volt capacitor
C5—360-1000-pF tuning capacitor (J.W. Miller 160-A or similar)
C6,C7—500-pF, 10-kV capacitors (TV-type)
I1—NE-2 neon lamp
L1—2.5-mH r-f choke (J.W. Miller 4537 or similar)
R1—40,000-ohm, 1-watt resistor
R2—50,000-ohm, 1-watt resistor
R3—100,000-ohm, 1-watt resistor
T1—High-voltage, r-f transformer (J.W. Miller 4525 or similar)
V1—6V6 tube
V2—1B3 tube
Misc.—Suitable high-voltage and filament supply, insulated chassis, tube sockets, high-voltage wire for 1B3 filament winding (see text), cap for 1B3.

to measure output voltages without excessive loading. After wiring is complete, remove rectifier tube *V2* and adjust the oscillator for maximum output power by tuning capacitor *C5* with an insulated alignment tool. Place a "gimmick" or single-turn coupling loop with a neon lamp on the output of *T1* as shown in Fig. 5 and tune the circuit until the lamp attains maximum brilliance. Remove the neon lamp and gimmick after tuning is complete. In operation, it is proper for the filament of the 1B3 to glow a dull red.

Safety Precautions. Due to the inherent shock hazards involved in either of the systems described here, they should be operated behind a simple wooden barrier marked to keep away "unauthorized personnel." The experiment may then be operated near a window or other well-lit area indoors.

The equipment may also be operated outdoors, preferably in a fenced-in private garden, provided it is protected from rain and moisture and the proper precautionary measures are employed. With component values shown, an "antenna" height of three feet is suggested—depending on local wind conditions and ambient aerobic moisture content.

When it is necessary to work on a plant or water it, turn off the power and connect safety shunt *R2* across the high-voltage terminals. When watering, avoid wetting the electronic equipment and the high-voltage discharge element. When you are through working on the plant, remove the safety shunt, get out of the way, and turn the power back on.

Always keep safety uppermost in your mind. Physically protect the electro-culture experiment from strangers, children and animals.

What Can You Expect? According to data advanced by Dr. K. Stern and others, a true increase in yield of 45 percent for a well-cultivated field can be expected. Yield differences are determined by comparing results against non-treated control cultures of the same type. Some plants give very low yield unless well-watered. Peas and carrots are in this group. Further, electric treatment must be stopped if days are hot and sunny. A simple photoelectric relay circuit, connected in series with the power line, provides adequate control for this purpose. Organic fertilizer may be used to provide basic plant nutrients.

Note that plants are mavericks in many ways and do not necessarily show uniform yield patterns. Electronically speaking, being living organisms, species utilize the energy contained in the phosphate bonds of adenosine triphosphate (ATP) to drive reactions which lead to maintenance and growth of cells, tissues, etc. This ATP is produced from adenosine diphosphate (ADP) by processes involved in aerobic respiration, fermentation, and electromagnetic bionuclear constituents of photosynthesis. In many ways, plants are *organic* semiconductors and apparently feature electron transport systems which, in higher plant mitochondria, are exactly the same as those for animal mitochondria in ways of generating enzymes.

However, taken together, science has only a vague idea why plants react to applied electro-culture and related methods mentioned earlier. The field is wide open for experimentation and improvement, and it certainly has exceptional hopes for the future. ◆

"I've been dreading the day this guy taking a correspondence course in electronics would mail in his lesson on antennas!"

Light-Operated Bistable Switch

BY DAVID C. CONNER

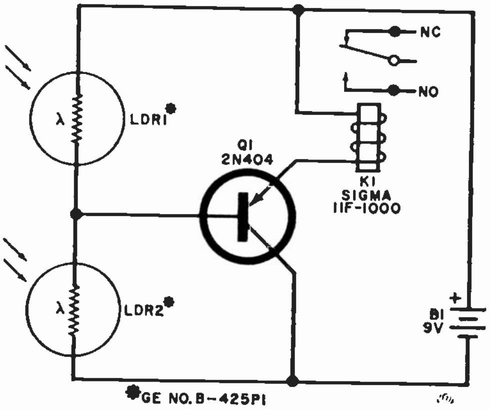
A SWITCH that can be operated by a light beam from remote locations at up to 30 feet is a handy device to have around the house or in the workshop. Such a switch, especially if it can be operated under wide ambient light extremes, is used to turn appliances on and off, silence the audio on a TV receiver during commercials, and serve as a remote switch in a garage or basement. You can readily see how much of a work saver and safety provider a light-operated remote switch can be.

As shown in the schematic diagram, the remote switch described here is a simple device, employing a pair of light-dependent resistors (*LDR1* and *LDR2*) which provide standby bias and control for an emitter follower transistor amplifier (*Q1*). The amplifier load is a 1000 ohm relay which is energized or de-energized depending on the ratio of the two LDR's. The relay has a double-throw contact arrangement so that an appliance or device can be connected to either the normally open or normally closed contacts, depending on the operating condition desired. (These contacts will handle up to 1 ampere of current at 117 volts ac. If higher power is required for a particular device, *K1* can be used as a control relay to drive an appropriately rated power relay.)

In operation, illumination of *LDR2* causes *Q1* to conduct enough extra current to energize *K1*. Once *K1* is pulled in, it remains energized even after the light is removed from *LDR2* because the solenoid of the relay is normally biased near its pull-in point. Hence, although the energizing current must exceed a certain level, the holding current is within the biasing current range. The entire circuit draws about 4.0ma.

Now, by illuminating *LDR1*, the bias condition at the base of *Q1* changes, causing the transistor to conduct less heavily—this time sufficiently below the holding current of *K1* to allow it to drop out. Again, the situation is such that the normal standby current through *Q1* and *K1* allows the relay to remain de-energized even after the light is removed from *LDR1*.

Background changes from total darkness to full brightness will not cause false operation of the remote switch since the resistance ratio between *LDR1* and *LDR2* will not change and, as a result, the biasing scheme is unaltered. However, the amount of light reaching both LDR's must be the same at any given time for this to be true.



Relay K1 closes and opens when LDR2 and LDR1, respectively, are illuminated. Sufficient current is normally available to latch K1 in desired state.

When assembling the remote switch, bear in mind that the LDR's must be physically separated so that they can be illuminated selectively (by a flashlight, for instance). Experimentally, a separation of about 7 inches provided reliable operation at distances up to 30 feet. ◆

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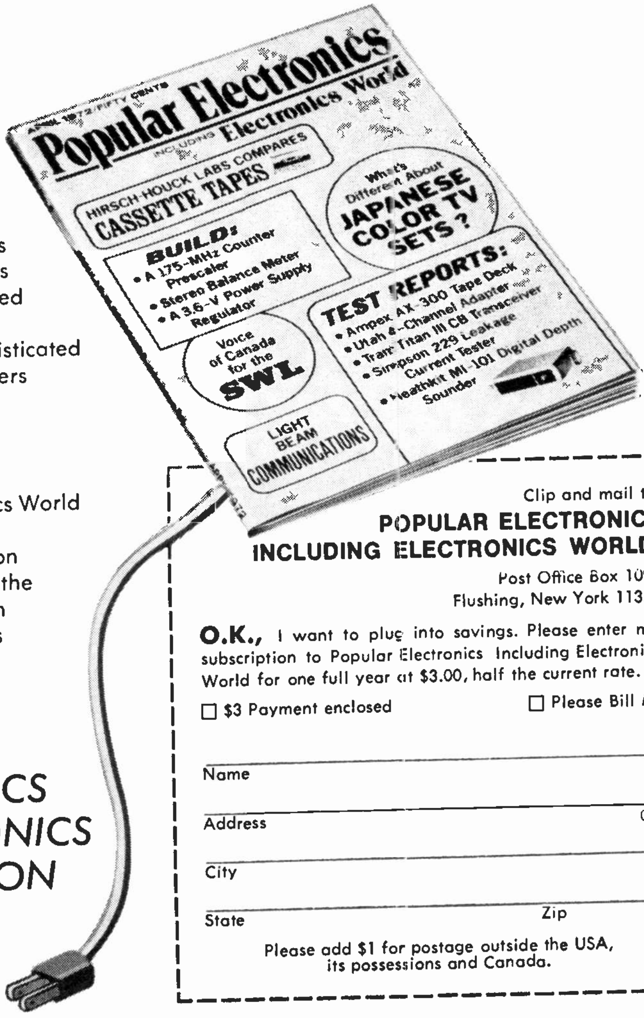

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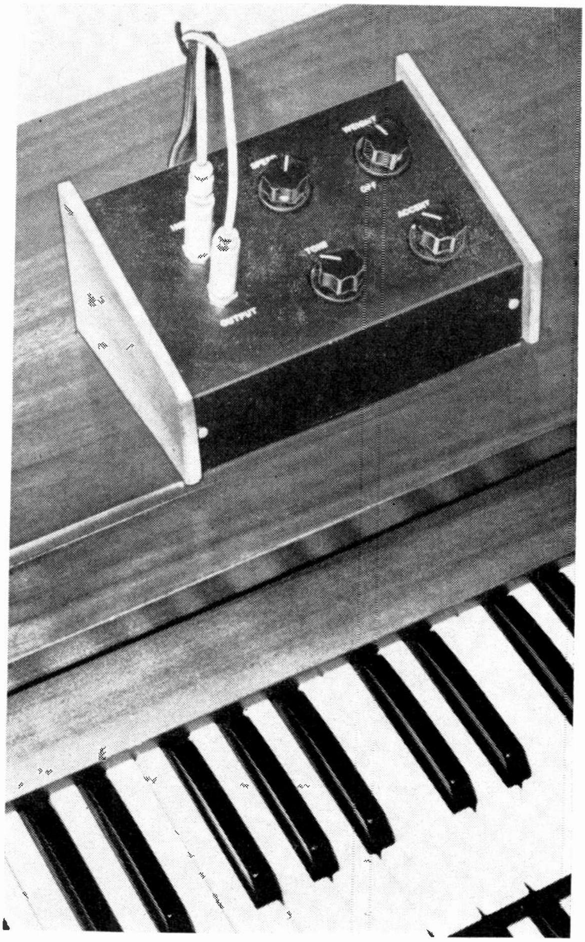


BY JOHN S. SIMONTON, JR.

LESLIE EFFECT SIMULATOR

All-Electronic Organ Accessory That Sounds Like A Leslie

The true Leslie speaker system is a cumbersome and costly organ accessory. The almost identical sound effect can be achieved by inserting the device described here between the keyed tone generators and the power amplifier in your electronic organ. Through use of a wobbulated bandpass filter, the Leslie effect is reproduced by the main amplifier and speaker. Adjustments on the simulator permit the operator to duplicate roughly the acoustic effects of vibrato, tremolo, and Leslie.

THE SPECIAL EFFECTS Leslie speaker system is a popular addition to any organ—acoustic or electronic. Usually a "Leslie" system refers to a mechanical means of obtaining a vibrato-like sound effect—a gentle undulation of intensity at a rate of 8 to 12 Hz. Even in modern electronic organs, the Leslie uses a massive rotating diffuser to disperse the sound from an extra speaker. It is effective, but also massive, noisy, and costly. Described here is a system which achieves nearly the same results with an adjustable all-electronic simulator.

While cost and size are definite advantages, perhaps the best part of the electronic Leslie Effect Simulator is its versatility. With the controls cranked back, the Simulator adds an interesting, subtle effect to conservative music. But if you're a wild man, you can really twiddle the knobs and wail! Control adjustments can produce anything from "super" bass or treble boost to sounds listeners describe as "shimmering, bubbly or out of sight!"

Theory of Circuit Design. While the frequency shift, or vibrato, effect of a Leslie

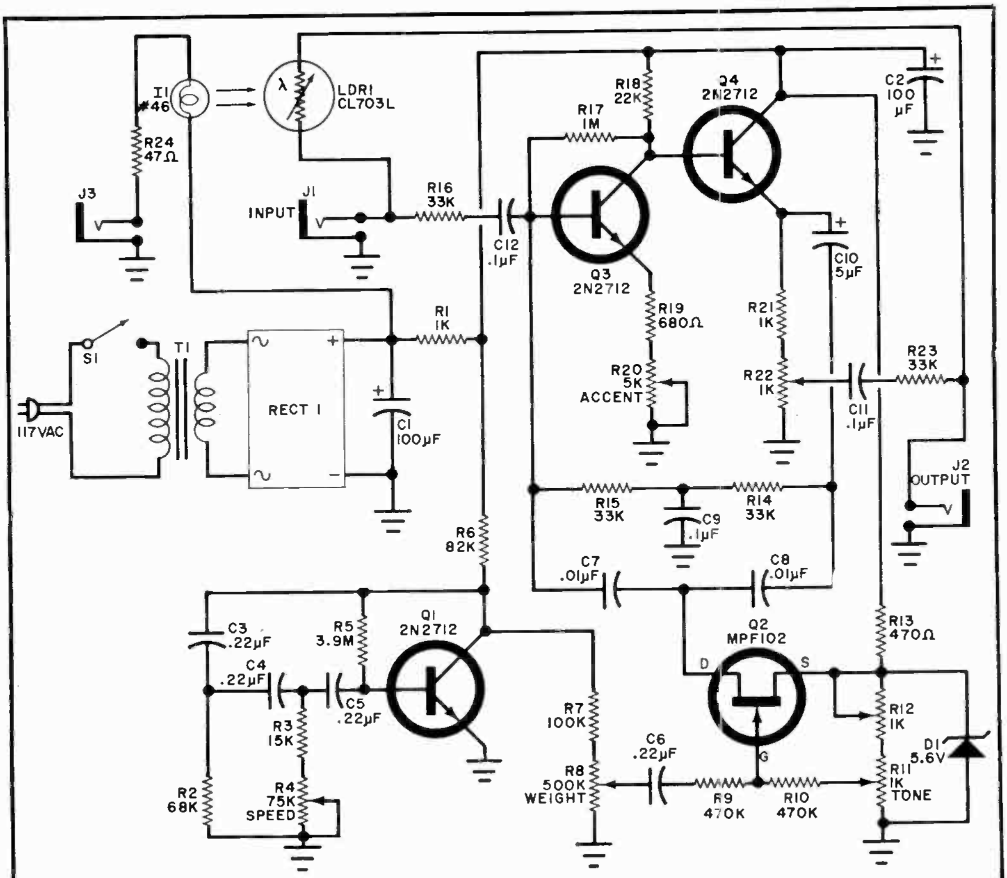


Fig. 1. Footswitch plugs into J3; when closed, footswitch powers I1 which illuminates LDR1. With LDR1 illuminated, input signal at J1 goes directly to J2.

PARTS LIST

C1—100-µF, 15-volt electrolytic capacitor
C2—100-µF, 10-volt electrolytic capacitor
C3-C6—0.22-µF Mylar capacitor
C7,C8—0.01-µF disc capacitor
C9,C11,C12—0.1-µF disc capacitor
C10—5-µF. 6-volt electrolytic capacitor
D1—5.6-volt zener diode (Motorola HEP603 or similar)
I1—#46 incandescent panel lamp
J1-J3—Open-circuit phone jack
LDR1—Light-dependent resistor (Clairex CL703L or similar)
Q1,Q3,Q4—2N2712 bipolar transistor
Q2—MPF102 or HEP802 field-effect transistor
R1,R21—1000-ohm
R2—68,000-ohm
R3—15,000-ohm
R5—3.9-megohm
R6—82.000-ohm
R7—100.000-ohm
R9.R10—470.000-ohm
R13—470-ohm
R14-R16,R23—33,000-ohm
R17—1-megohm
R18—22.000-ohm
R19—680-ohm

All transistors ½-watt, 10% tolerance

R24—47-ohm, 10% tolerance, 1-watt resistor
R4—75,000-ohm, reverse audio-taper potentiometer
R8—500,000-ohm linear-taper potentiometer with integral switch
R11—1000-ohm linear-taper potentiometer
R12,R22—1000-ohm trimmer potentiometer with printed circuit solder terminals
R20—5000-ohm linear-taper potentiometer
RECT1—1-ampere, 50 PIV. full-wave rectifier bridge module (Motorola MDA942A-1 or similar)
S1—Spst switch (part of R8)
T1—12.6-volt, 300-mA filament transformer
Misc.—Circuit board; line cord with a strain relief; cabinet: 3-lug terminal strip; control knobs (4); spacers (4); rubber feet (4); 4-40 machine hardware; hookup wire; solder: etc.

Note—The following items are available from PAIA Electronics, Inc.. P.O. Box 14359. Oklahoma City, OK 73114: etched and drilled printed circuit board (#5702pc) for \$3.50; complete kit of parts, including circuit board, case, and all parts (#5702 K) for \$22.50. Plus postage 3 lb. Separate parts are also available; send itemized listing.

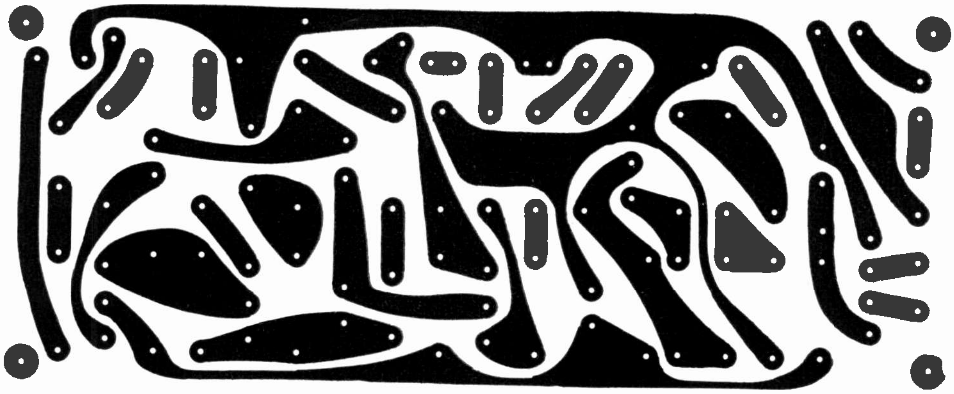
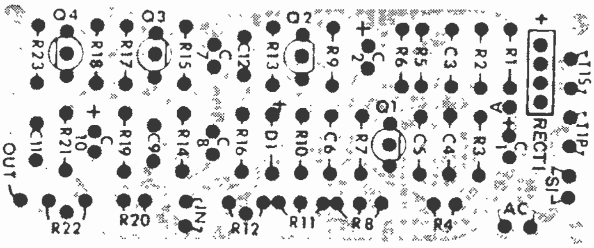


Fig. 2. Actual size printed circuit board etching and drilling guide is shown above. At right is components placement and orientation guide. Note orientations of flats on transistors and plus sign on rectifier assembly.



speaker system (see box) is expensive to generate electronically, the total effect can be convincingly simulated simply by placing a bandpass filter between the musical instrument and its amplifier and sweeping back and forth across the bandpass. This is the principle employed in the Leslie Effect Simulator circuit shown in Fig. 1.

At the heart of the Simulator is an active bandpass filter composed of *R14*, *R15*, *Q2*, and *C7* through *C9* in the feedback loop of the amplifier/buffer combination made up of *Q3* and *Q4*. Transistor *Q1* and its associated components form a low-frequency phase-shift oscillator, the output frequency of which can be set from between about 4 Hz to 12 Hz through the use of speed control *R4*. The signal from *Q1* is attenuated by weight control *R8* and applied to the gate of *Q2* to change the source-to-drain impedance of the FET and, consequently, the center frequency of the pass band.

Photoelectric system *I1/LDR1* is used to bypass the Simulator when the system is not in use. Closing a footswitch plugged into *J3* powers *I1* which, in turn, illuminates *LDR1*. Once illuminated, *LDR1's* internal resistance drops and forms a signal bypass loop around the filter circuit.

Construction. Since only low frequencies are involved in the operation of the Leslie Effect Simulator, parts layout during assembly of the project is not critical. Just adhere to the general rules of neatness and good soldering. In particular, keep signal leads as short as possible.

Begin assembly by etching and drilling the printed circuit board, carefully following the actual size etching guide provided in Fig. 2. (If you prefer, you can obtain a ready-to-use

THE "LESLIE EFFECT"

In principle, the Leslie speaker system is nothing more than one or more loudspeakers mounted at the end of an arm which is rotated by means of a motor. (other variations use a fixed speaker and employ a rotating "paddle" or baffle, but the principle is the same.) As the loudspeakers swing around in an arc, several things happen to the sound. First, a doppler shift in the apparent pitch of the sound is caused as the motion toward and away from the listener takes place. Next, a variation in sound level is produced as the speaker alternately faces toward and away from the listener. Finally, there occurs a great variety of effects which stem from changes in the acoustics of the system enclosure and the room in which the system is being used.

circuit board from the source listed in the Parts List.) Once the board is prepared, mount the parts in their respective locations, paying particular attention to the orientations of diodes, transistors, and electrolytic capacitors. Use a low-wattage soldering iron to solder the component leads to the circuit board's foil pattern. It is also a good idea to heat sink the leads of the solid-state component to prevent heat damage.

After all components are mounted on the board, solder in place the primary and secondary leads of power transformer *T1* and pieces of hookup wire sufficiently long to reach the front panel controls when the project is fully assembled. Then carefully check the foil side of the board, particularly around the transformer connections, for solder bridges. If any exist, reheat and remove any excess solder to eliminate the bridge.

You can use just about any type of case that suits your fancy to house the circuit. If you wish to duplicate the case shown in the photos, all you need are some 22-gauge sheet aluminum, lumber, glue, and fasteners. No special tools are needed for forming and fabricating the metal parts.

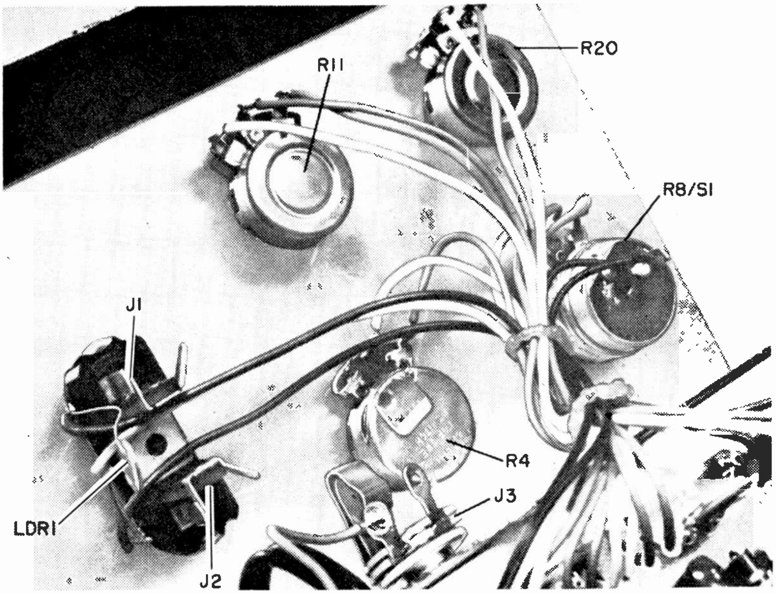
The top, front, and back of the case are made from a single sheet of aluminum, machined on the front and back panels to accommodate the controls, jacks, and entry for the line cord. It is then bent to shape to form a friction fit over the side panels. While you're at it, you can also cut to size the bottom plate, using the same sheet aluminum.

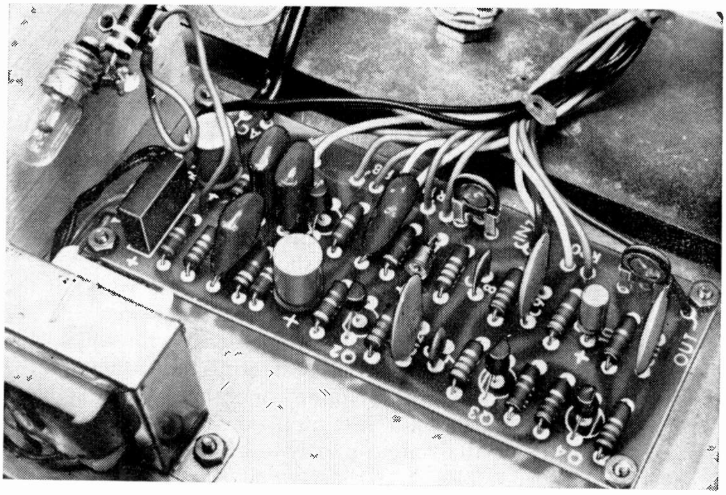
To make the side panels, you will need one walnut and one white pine panel for each. Cut the walnut pieces ¼″ longer in their length and width dimensions than the height and depth dimensions of the metal pieces. The pine pieces should be ⅜″ shorter in both dimensions than the length and width of the walnut pieces. Now, make a "sandwich" of the pine and walnut pieces with white glue and wire brads, centering the former on the latter. This done, smoothly sand and hand rub paste wax on the outer face and edges of the walnut panels to bring out a dull sheen. Then use short wood screws to fasten the bottom plate to both side panels and temporarily set the assembly aside.

Next, paint the front, top, and back assembly with a color to contrast with the dark shade of the walnut panels. When the paint has thoroughly dried, use a dry-transfer lettering kit to label the controls and jacks. Mount the controls and jacks in their respective holes; then pass the free end of the line cord through its entry hole and secure it to the rear panel with a strain relief.

Referring back to Fig. 1, connect and solder the free ends of the wires coming from

Input and output jacks J1 and J2 should be located close to each other if separate jacks are used to allow LDR1 to be mounted between them as shown here.





Neatly dress control and jack wiring to one side of circuit board and lace together with cable ties or lacing cord. Secure power transformer to chassis with 4-40 machine hardware; add ¼" spacers when mounting board in place.

the circuit board to the lugs of the appropriate control and jack lugs. Tin the free ends of the line cord and solder them to the hole locations marked AC on the board. Now, interconnect with lengths of hookup wire the ground leads of *J1-J3* and connect and solder the leads of *LDR1* directly to the signal lugs of *J1* and *J2*. Neatly dress the leads along one edge of the circuit board.

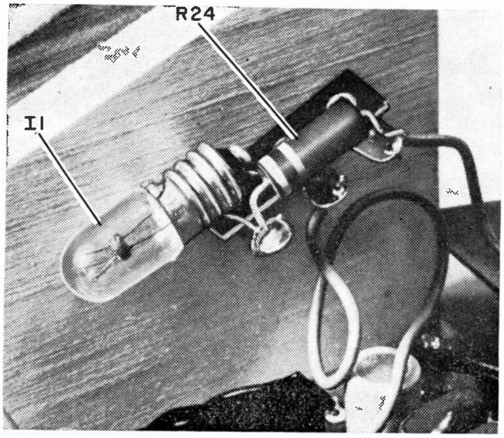
Now, mount *R24* and *I1* on a three-lug terminal strip (no lugs grounded). Position the assembly near *LDR1* so that when the lamp is lit it will illuminate effectively the LDR. Mount the assembly in place with 4-40 machine hardware. Connect this assembly via one wire to the positive side of the power supply on the circuit board.

Finally, mount the circuit board with 4-40 hardware and spacers, and power transformer *T1* with 4-40 hardware only. The project is now ready to be tested.

Setup and Use. Plug the line cord of the Leslie Effect Simulator into a 117-volt ac outlet. Connect an input and amplifier to *J1* and *J2*, respectively, and a footswitch to *J3*. Turn on the system by rotating *R8* clockwise just past the click. Close the footswitch to test the bypass circuit; *I1* should immediately come on.

Temporarily cover the sensitive face of *LDR1* with a piece of black electrical tape to keep ambient light from interfering with the adjustments to be made. Advance ACCENT

Current limiting resistor R24 and I1 are mounted on terminal strip fastened to side panel in line with LDR1 when cabinet is assembled. If side panel is metal, use four-lug terminal strip and do not connect R24 or I1 to mounting lug.



control *R20* to about two-thirds of its clockwise rotation and set weight control *R8* fully counterclockwise—but do not click the power off. The maximum effect of TONE control *R11* occurs over about one-quarter of its travel. The extra travel is useful in some effects when the weight control is fully advanced. Adjust *R12* so that the most sensitive area of the TONE control is at the center of the TONE control's travel. You can check out your settings by striking a chord and noting the action of the TONE control as it is rotated.

Trimmer potentiometer *R22* should be swept over its entire range to check the gain of the Simulator. It should then be set so that there is minimum change in volume level as the Simulator is switched in and out of the system (by operating the footswitch). While adjusting *R22*, be sure to remove the tape from over the LDR to permit switching out the Simulator.

To a certain extent, ACCENT control *R20* changes the overall gain of the Simulator. It should be adjusted for unity gain at the accent setting you intend to use most often or for whatever compromise suits your taste. When both internal adjustments (*R12* and *R22*) have been made, uncover *LDR1* and assemble the case.

In use, the best way to get the feel of the controls of the Simulator is simply to play with them. However, a few simple hints will get you started. First, to obtain the Leslie Effect, set the ACCENT control to approximately the center of its travel and rotate the WEIGHT control a small fraction of a turn clockwise. Set the TONE control to the center of its travel and adjust the SPEED control as desired.

Now, when the instrument plugged into *J1* is played, you should get an effect that is something like a tremolo, except that there will be a touch of sweeping pass band in the background. If the effect is not pronounced enough, advance the ACCENT control.

For super bass/treble boost, turn up the WEIGHT control as far as it will go without turning off the Simulator. Advance the ACCENT control all the way. Now the TONE control can be rotated clockwise for treble boost and counterclockwise for bass boost. Somewhere between the two extremes, the amplifier might break into oscillation, but this can be readily remedied simply by backing off on the ACCENT control slightly.

In prototype, top of case slopes downward. Top, front, and rear panels are painted flat black to contrast with rich tones of walnut side panels. Controls and jacks are lettered in white, using dry-transfer lettering kit.

Advancing the WEIGHT control past its mid-point and setting the TONE slightly treble of center can produce an effect quite similar to reverberation if the ACCENT control is advanced to the point that just causes oscillation when a note is struck.

If, during the operation of the Simulator, you notice a loud ac hum level, try reversing the ac line cord plug. This should effectively curb the hum loop.

Beyond the very rough hints outlined above, familiarizing yourself with the Leslie Effect Simulator will depend on your experimental nature. You will certainly want to experiment to determine just what the Simulator is capable of doing. Go to it. ◆

Chemicals for Electronics

Getting to know degreasers, cleaners, and polishing agents

IT IS SURPRISING that so few electronic experimenters make use of the many chemical aids available to them from innumerable jobbers and distributors. Store shelves hold a wide variety of chemicals and cleaners in either convenient aerosol cans or bottles. Many of these chemical tools should be as important to the experimenter as a good screwdriver or a pair of pliers. Chemicals can be used for everything from heat sinks to troubleshooting, although this particular article will concentrate on control and contact cleaners, chemicals for the audiophile, and tuner or bandswitch spray cleaners.

Types of Cleaners. Sooner or later every electronics hobbyist encounters problems with "noisy" contacts, raspy potentiometers, erratic switching and/or sticking relays. If you know what is behind the advertising claims and verbiage, you can pick the right cleaner off the shelf to solve each problem.

In the very early days of radio and electronics, carbon tetrachloride was the most universally used cleaner. Many experimenters think carbon tet is still the basis for most cleaning chemicals—but in 9 cases out of 10, this is not so. Carbon tet is both an inefficient and dangerous cleaner. Fumes from carbon tet are approximately 200 times as toxic as those of most modern electronic cleansing compounds.

Today, cleaners are usually blends of Freon solvents. Freon is Du Pont's registered trademark for chlorofluora derivatives of methane and ethane. There are two types of Freon generally used in aerosol contact and control cleaners: Freon 12— a propellant that provides only slight cleaning power, but supplies the necessary pressure to spray the cleansing formula out of the can. Freon 11, on the other hand, is similar, but in itself is an excellent cleaning agent.

BY LON CANTOR

Freon is nonflammable, relatively nontoxic and stable in use. Freon 11 is a selective solvent meaning that it dissolves oils and greases, yet will not affect most metal contacts, common plastics, or carbon-type potentiometers. In cleansing action Freon 11 ranks above hydrocarbons and just below chlorinated solvents.

Besides dissolving oils and greases, Freon 11 also provides a "washing" action, especially if sprayed on the target area under high pressure. The high density and low surface tension of Freon 11 enables this solvent to thoroughly wet the surface of most materials thereby washing away dirt and "gunk."

The Allied Chemical name for a solvent roughly equivalent to Freon 11 is Genesolv-D. In fact, Genesolv-D has the same mouthful of a name as Freon—trichlorotrifluoroethane. The Dow Chemical Company sells two similar types of chemicals used by some manufacturers in the electronics industry—Chlorothen NU and Dow Clene EC.

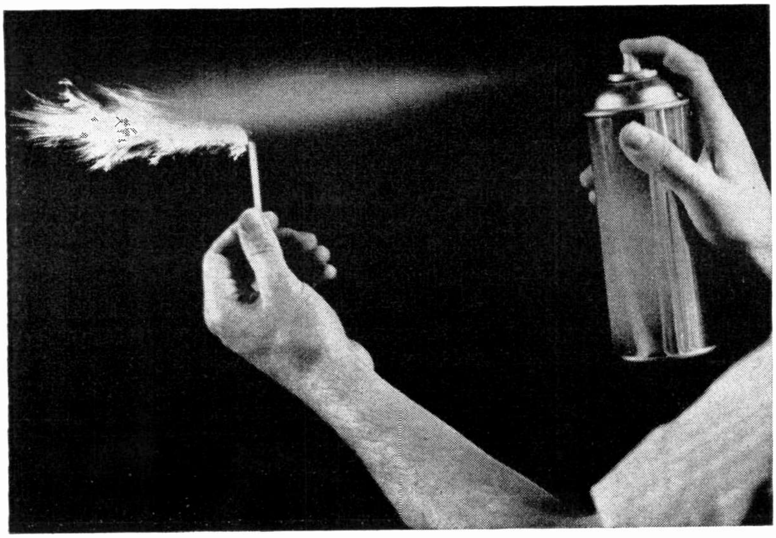
The above basic chemicals are blended by the various manufacturers of electronic cleansing chemicals to produce commercial products. None of these manufacturers is willing to reveal the formulation of its cleaners, so it is impossible to know—by true chemical definition—exactly what you're buying. Nevertheless, any cleaner incorporating any of the above mentioned chemicals is good. The problem in electronics is to avoid the cheaper products which use kerosene, benzine, or denatured alcohol as solvents. You can usually detect any of these products by the smell. They are also flammable and should be so identified on the can or bottle. These products may also be cheaper, but you pay for this cost saving through detuned circuits and deformation of soft plastic parts. For every experimental application you are better off to pay a little more money for a better and safer cleaner.

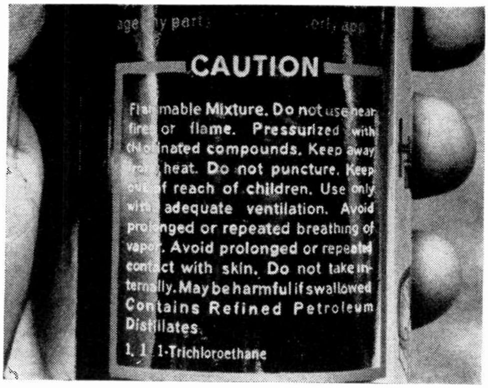
To Lubricate or Not to Lubricate. Aside from the cleansing action, some electronic aerosol chemicals also include lubricants. Lubricants not only reduce the friction of moving contacts, they may also minimize arcing and provide a protective coating to inhibit further corrosion.

Lubrication, however, is not an undisguised and unmixed blessing. A heavy residue of a lubricant can detune a critical circuit and for this reason, most electronics technicians prefer non-lubricating cleaners for work around critical tuned circuits.

Some of the newer electronic chemical cleaners use silicone lubricants. Organic lubricants are hydrocarbon polymers, but silicone lubricants are derived from silicon-oxygen linkages which should give this sort of lubricant better high temperature capabilities. Silicone lubricants generally last longer and are inert. Whereas hydrocarbon lubricants sometimes break down under application of high voltage or heat, leaving a

This is exactly what you want a cleaner in an aerosol can NOT to do—be flammable. Though spectacular, a test like this is relatively safe in a wide open area.





CAUTION

Flammable Mixture. Do not use near fire or flame. Pressurized with chlorinated compounds. Keep away from heat. Do not puncture. Keep out of reach of children. Use only with adequate ventilation. Avoid prolonged or repeated breathing of vapor. Avoid prolonged or repeated contact with skin. Do not take internally. May be harmful if swallowed Contains Refined Petroleum Distillates.

1, 1, 1-Trichloroethane

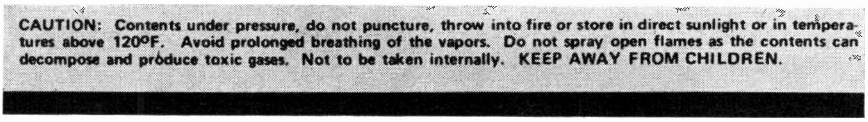
WILL NOT HARM INSULATORS NOR AFFECT ELECTRICAL PROPERTIES

LEAVES NO RESIDUE

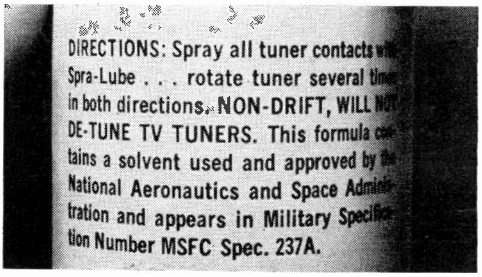
NON-CONDUCTIVE

NON-FLAMMABLE

Caution: Contents under pressure. Read precautions before using.



CAUTION: Contents under pressure, do not puncture, throw into fire or store in direct sunlight or in temperatures above 120°F. Avoid prolonged breathing of the vapors. Do not spray open flames as the contents can decompose and produce toxic gases. Not to be taken internally. KEEP AWAY FROM CHILDREN.



DIRECTIONS: Spray all tuner contacts with Spra-Lube . . . rotate tuner several times in both directions. NON-DRIFT, WILL NOT DE-TUNE TV TUNERS. This formula contains a solvent used and approved by the National Aeronautics and Space Administration and appears in Military Specification Number MSFC Spec. 237A.

Read the label before buying. For most cleansing operations around tuned circuits you will probably be better off with a non-flammable chemical that leaves no residue. Look for a possible warning about use around plastics and if in doubt check as described on the next page. As with all aerosol cans, be circumspect about disposing the empty can.

carbon residue, synthetic silicone lubricants seem to withstand greater variation of voltage and temperature without noticeable ill effects.

Polishing. Recently a new dimension has been added to switching contact sprays: polishing. In addition to cleansing and lubrication, these new products attempt chemically to assist the polishing of switching contacts through the normal wiping action of the switch itself. However, cleaners containing polishing compounds must be used with care. Many switch contacts in electronic equipment use a precious metal plated on a base metal. It is quite possible for the polishing agent—if it is abrasive—gradually to scrape away the thin precious metal plating—along with the dirt. Once the base metal is exposed, it tends to corrode rapidly, ruining the contact.

Various manufacturers are currently emphasizing the incorporation of polishing compounds in their cleaners. One manufacturer calls polishing, "the continuous cleaning method," while another emphasizes the non-abrasive polishing agent in his cleaner. Regardless of the advertising claims, all cleaners that clean, lubricate and polish have particular applications. The basic ground rule calls for a moderately thick permanent lubricant that is less likely to "run" into adjacent circuitry. These cleaner/polishers must be applied with considerable care—just on the contacts—and in the case of TV tuners or band switching components in receivers or transmitters—never near capacitive, sensitive devices.

Making Your Own Tests. A few "recommendations" prepared by the Editors of POPULAR ELECTRONICS appear in conjunction with this article. However, if you encounter an unknown chemical cleaner, here's a quicky test you can use to get an idea of just what you have bought:

1. Spray the cleaner onto a clean piece of white paper. Smell it carefully to see if you can detect the odor of alcohol, kerosene, or camphor. If any of these odors are detected, use this cleaner ONLY on equipment that you can sacrifice.

2. Feel the paper you have just sprayed with your fingertips. If the product is advertised as including a lubricant, you should be able to feel it. Rub the paper between your thumb and forefinger to see if there is any decrease in lubricating action. Simultaneously, if the product is supposed to contain a polishing agent, you should be able to feel an initial grittiness. This grittiness should disappear after a few rubs. If the grittiness persists, this product should be rejected or used with care.

3. If in doubt as to the action of the unknown cleaner on plastic, lightly spray it on several types of scrap plastic. A good cleaner will have no effect on plastic—neither dissolving it or making it turn cloudy.

4. As illustrated in the photograph carefully spray the unknown cleaner directly at a lighted match. There should not be a "flame thrower" effect and if the product supports combustion it should be rejected. However, certain reputable products will decompose in a flame and produce toxic gasses. Do this experiment last—and do it carefully.

Chemicals for Audio Epuipment Maintenance. Chemicals can be very useful in maintaining hi-fi and stereo equipment. The most obvious use is in cleaning. Aerosol chemicals can be used to wash away dust and dirt from records and a few chemicals leave an antistatic charge which tends to repel the accumulation of future dust. It pays to clean your discs before use.

For effective spraying many aerosols have hollow extension tubes that plug into the release button.

WHAT TO USE WHERE

Work to Be Performed	Suggested Products
Cleaning (washing) around rf circuits	Chemtronics Tun-O-Wash Miller-Stephenson Freon TF Degreaser "No Noise" Super Spray Bath Rawn Powder Degreaser Tech Spray Blue Shower
Cleaning bandswitches	Chemtronics Tun-O-Brite CRC Contact Cleaner GC Magic Vista Krylon Tuner Cleaner "No Noise" Super Lube Quietrole Tech Spray Blue Stuff
Cleaning noisy potentiometers	Chemtronics Super Trol Aid Miller-Stephenson Contact Re-Nu Workman Lubrite
Cleaning relay contacts	Chemtronics Contact Kleen GC Spra Kleen "No Noise" Spray Lube
Cleaning tape heads	Ampex Tape Head Cleaner Chemtronics Tape Head Cleaner GC Audio/Video Magnetic Tape Head Cleaner Miller-Stephenson Magnetic Head Cleaner Tech Spray Tape Head Spray
Cleaning PC Boards	Miller-Stephenson Flux Remover Print-Kote Solvent Tech Spray Rosin Flux Remover

Record changers and turntables should be cleaned with a good washing type degreaser that leaves no residue. Spindles on changers often "gunk up" and refuse to drop records properly, but this problem is easily resolved with an application of a good Freon 11 or equivalent spray.

One of the more important uses of chemicals for audio is to clean tape recorder heads.

Recorder heads accumulate the oxidized coatings of tapes and if they are not cleaned periodically, the hears will wear excessively and eventually ruin the tapes themselves. Some technicians still use alcohol to clean tape heads, but this is not a good idea. Alcohol is flammable, is not a particularly good cleaner, and has an adverse effect on some plastics Even today, some commercial tape head cleaners are based on the use of isopropynal alcohol, but the better products use blends of fluorocarbons (Freons).

Cleaner chemical manufacturers are at odds as to whether or not a tape head cleaner should include a lubricant. At least one manufacturer has a cleaner containing a minor amount of silicone. The claim is made that this product leaves a thin coating which permits the tape to slide freely across the head. But other manufacturers, while acknowledging this good effect, say that lubricants tend to accumulate excessive oxide coating particles. Oddly enough, tape equipment manufacturers appear to have no firm views on the subject saying that any good effect may result from a lessening of wear from excessive tape tension (a mechanical defect).

Tape head cleaners are available both bottled and in aerosol cans. It is generally preferable to use a bottled compound and to apply it with a clean cotton swab and then wipe the tape head clean. Where space is not available (in compact cassette recorders, for example) a high pressure aerosol cleaner will do a fairly good job of flushing away oxide without leaving residue.

As above, choose your tape head cleaner by the smell and feel. Reject anything that feels abrasive or smells like alcohol.

Chemicals for Cleaning R-F Circuits. Many hams and SWL's tolerate erratic bandswitches when these defects could be readily cured through the application of a TV tuner spray cleanser. Generally speaking, although these products are advertised for TV tuners, they will obviously have the same beneficial effect in a receiver, transceiver, or transmitter.

Tuner sprays usually fall into one of four relatively distinct categories:

1. Pure cleaners. Sometimes referred to as "wash" cleaners, these products are generally based on a blend of Freons and may be sprayed on TV tuner contacts or band switches with the assurance that they will leave no residue. These cleaners are especially recommended where foreign matter of any kind might unbalance a critical r-f circuit.

2. Cleaners with light lubricants. It's probably safe to say that these are the traditional TV tuner spray cleaners. These products work reasonably well, but may need to be reapplied to the same switching or contact area within a year.

3. Cleaners with heavy lubricants. This type of spray cleaner is becoming increasingly popular. They may usually be distinguished by the "foaming" action. Many technicians believe these products to be preferable, since they tend to keep tuners and bandswitches in good operating condition for longer periods of time.

4. Cleaners with heavy lubricants and polishing agents. This is a relatively new category and may well eventually replace those cleaners mentioned above in category 3.

Any cleaner should be applied to a tuner or a bandswitch with care and the degree of care should follow the numerical order indicated above, with category 4 being applied only to switching contact surfaces. Virtually any bandswitch or tuner cleaner will temporarily detune an r-f circuit, but if the cleaner is a good one, the chemical preparation will evaporate in about three minutes and unless the cleaner has been misapplied, no touching up of tuning adjustments should ever be necessary. ◆

HEAT-ELIMINATING GEL

One of the "strangest" chemicals that the hobbyist/experimenter may want to try is "Cool-It-Gel" sold by Dynatek Industries, Box 24268, Cleveland, Ohio 44124.

This jelly-like substance is a pale blue, viscous mix that is brushed, dipped, or fashioned like putty to make a heat sink! If, for example, some of the Cool-It-Gel is "puttied" around transistor leads ready for soldering, the Gel will protect the transistor by dissipating heat. The Gel itself gradually disappears and will not run, drip, be toxic or create fumes.

The manufacturer recommends Cool-It-Gel for electricians and welders working in tight quarters or with delicate components. A trial pint container of this Gel is available for $2.95 postpaid from the firm.

BUILD AN SCA ADAPTER FOR FM RECEPTION

Phase-Locked Loop Technique Simplifies Design

One of the inherent advantages of integrated circuits is the manufacturer's ability to design a complex circuit that would otherwise necessitate scores of discrete components on a single chip. This circuit is built around the Signetics NE-565 IC in a phase-locked loop configuration.

MANY FM STATIONS broadcast special educational material and music (without commercials) on the SCA subcarrier. This programming material is used (on a subscription basis) by commercial insitutions for background music. The normal home receiver cannot pick up the SCA program without a special adapter. It is illegal to use such an adapter in a commercial establishment; but you can do so for your personal pleasure at home.

The SCA subcarrier frequency is 67 kHz–which is high enough not to interfere with either the main carrier or the stereo subcarrier sidebands. A suitable filter and detector may be used to extract the SCA subcarrier, but because the modulated frequency deviation of the SCA subcarrier is such a large percentage of the subcarrier center frequency, it is difficult to make an FM detector using tuned circuits. In most cases, the very low Q that would be required to get linear demodulation using this method would result in a very low detected output. Also, the exacting alignment of the filter and detector requires special equipment and critical adjustments. All of these problems can be alleviated by using a "phase-locked loop" (PLL) detector to demodulate the SCA subcarrier. Using such a concept and taking advantage of a new integrated circuit to simplify the design and construction, it is possible to construct a modern SCA adapter that has no critical adjustments and is easily coupled to any good FM receiver.

Theory of Circuit Design. A phase-locked loop such as as that shown at Fig 1A consists of three elements: a phase comparator or detector, a low-pass filter, and a voltage controlled oscillator. The phase detector compares the phase of the incoming signal with the phase of the signal from the voltage-

BY VINCENT WOOD

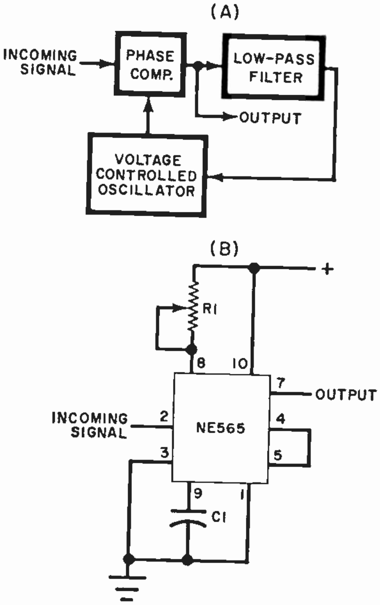


Fig. 1. The VCO tries to lock to the frequency of the incoming signal because of error voltage coming from the phase comparator. The filter removes the audio leaving the dc component. Error voltage varies with the SCA signal and becomes the audio.

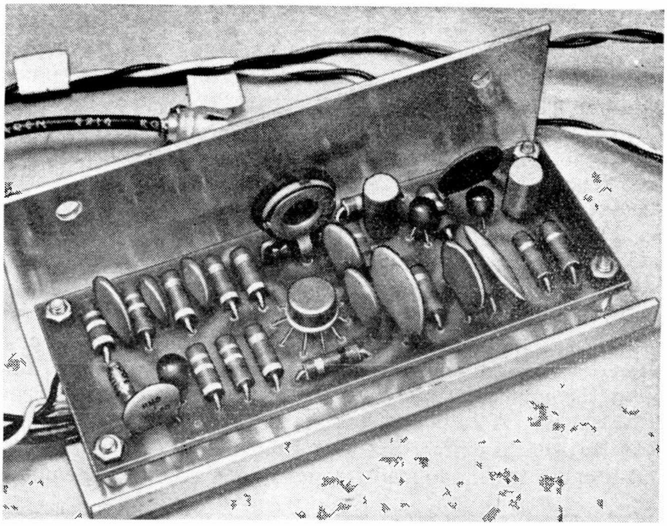
controlled oscillator and generates an output voltage that is proportional to the phase difference between the two. This voltage is filtered and applied to the oscillator so that it always tries to reduce the phase difference between the two signals. The loop is "locked" when the control voltage causes the oscillator frequency to equal the average frequency of the input signal.

Most television receivers use a similar phase-locked loop in the horizontal sync section. The phase detector in the TV set compares the frequency of the horizontal oscillator with a large number of horizontal sync pulses and adjusts the horizontal oscillator frequency so that the average phase difference is very small. The effect of any noise that may be present is greatly reduced by the phase-locked loop since it is an averaging process.

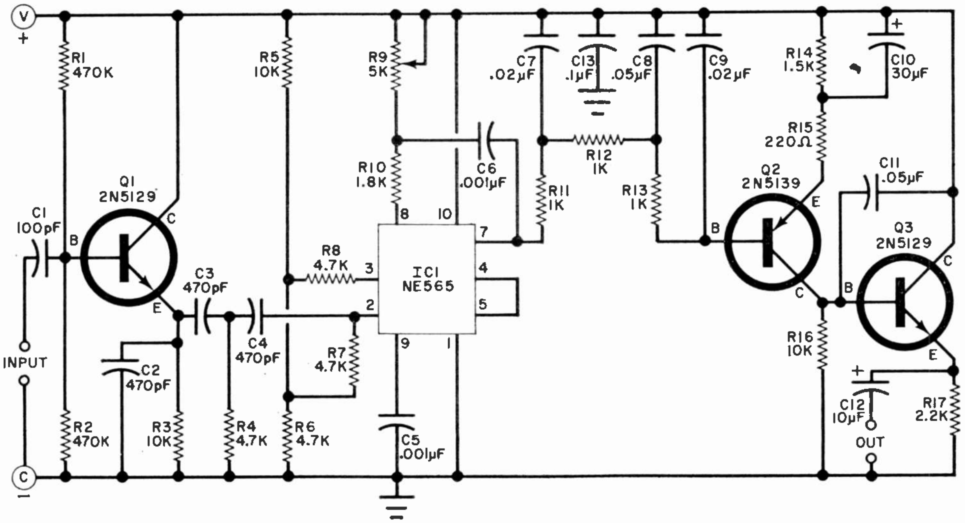
Note that the oscillator frequency tries to track the incoming frequency if the latter should change for any reason. Since the input to the PLL SCA system is a signal with some noise and the output of the VCO is clean, noise coming in is rejected.

The integrated circuit used in this project contains all of the elements necessary for the phase-locked loop and can provide highly linear FM demodulation over a range of 60% of the center frequency. Linearity is typically within 0.5% and the IC can be used to 300 kHz.

The VCO portion is set to oscillate at approximately the frequency we desire to demodulate by changing the values of *R1* and *C1* as shown in the simplified circuit in Fig. 1B. When a frequency-modulated input is applied to pin 2, the output at pin 7 consists of the error signal generated by the phase difference between the VCO and the incoming signal. This error signal is exactly the same as the frequency modulation of the incoming signal, less noise; and, after proper de-em-



The SCA adapter is small enough to be mounted within the FM receiver being used, with a small bracket for support. The low power requirements enable this unit to be directly connected to the 9-to-18 volts usually used in solid-state receivers. The text explains a simple circuit to be installed if you use a vacuum-tube unit.



PARTS LIST

C1—100-pF polystyrene capacitor
C2-C4—470-pF ceramic disc capacitor
C5,C6—0.001-μF ceramic disc capacitor
C7,C9—0.02-μF ceramic disc capacitor
C8,C11—0.05-μF ceramic disc capacitor
C10—30-μF, 6-volt electrolytic capacitor
C12—10-μF, 15-volt electrolytic capacitor
C13—0.1-μF ceramic disc capacitor
IC1—NE565 integrated circuit (Signetics)
Q1,Q3—2N5129 transistor
Q2—2N5139 transistor
R1,R2—470,000-ohm
R3,R5,R16—10,000-ohm
R4,R6-R8—4700-ohm
R10—1800-ohm
R11-R13—1000-ohm
R14—1500-ohm
R15—220-ohm
R17—2200-ohm
R9—5000-ohm trimmer potentiometer (IRC X-201 or similar)
Note—The following are available from Southwest Technical Products Corp., Box 32040, San Antonio, TX 78216: etched and drilled printed circuit board #179 at $2.15, postpaid; complete kit of parts #179C including PC board at $14.50 plus postage and insurance for 8 oz.

Fig. 2. Phase-locked loop IC is connected through an emitter follower (Q1) to remove any loading on the FM detector. Once R9 is properly adjusted, there are no further adjustments to be made.

phasis, it can be used to drive an audio amplifier.

Transistor *Q1* is a high-input-impedance emitter follower which prevents loading on the tuner output. The signal is filtered by *R3*, *R4*, *C3*, and *C4* to remove as much signal below 50 kHz as possible. This makes it much easier for the PLL system to lock on and retain the SCA subcarrier at 67 kHz.

The demodulated output at pin 7 is passed through another filter to remove any high-frequency noise and provide de-emphasis, before voltage amplification (to 1 volt) by *Q2*. Transistor *Q3* is a conventional emitter follower used to drive the outboard audio system. The top of the frequency range of the entire system is approximately 7 kHz, which is sufficient for the type of programming usually carried on the SCA subcarrier.

Construction. The schematic of the adapter is shown in Fig. 2. The entire circuit is assembled on a printed circuit board as shown in Fig. 3. All parts, with the exception of the transistors and the IC, should be pulled down firmly against the board with their leads bent over and soldered to the foil. Leave about ⅛″ of lead exposed on each transistor and be sure pin arrangement is correct before soldering them in place. The leads of the IC must be separated and bent to form a "spider" arrangement. Again be sure the leads are properly oriented before soldering it in place. The "T" on the foil pattern indicates where the tab should be. Use a low-power soldering iron and fine solder.

The adapter circuit board can be mounted on a support within the existing tuner or receiver or it can be mounted separately on a

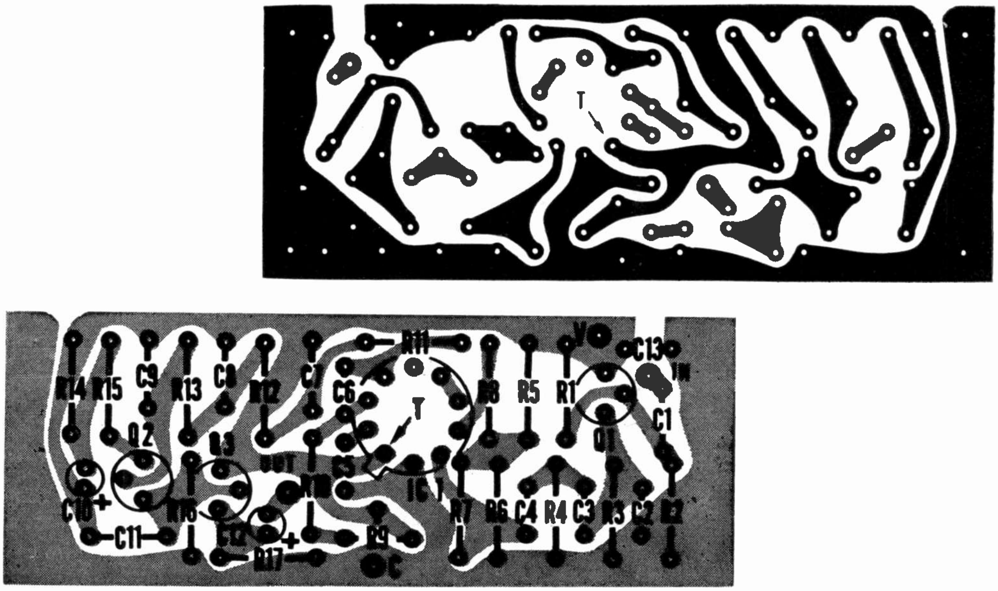


Fig. 3. When installing the components on the board, make sure the IC is oriented properly by noting exactly where the tab is located. Also observe the polarity of the electrolytics and the transistors.

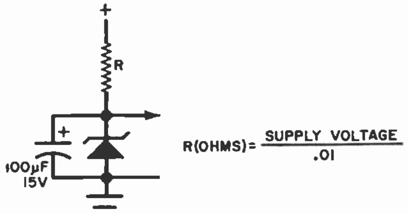


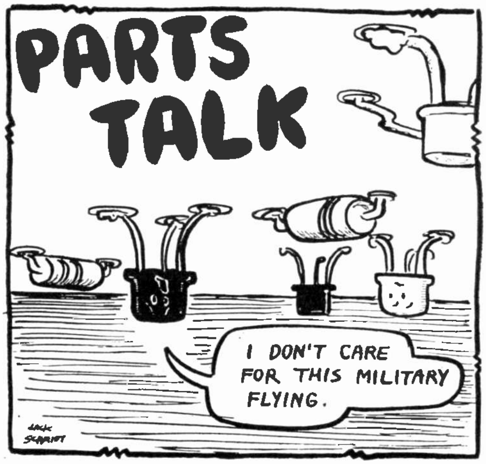
Fig. 4. This circuit is used if you happen to have a vacuum-tube receiver with its high dc voltage. After selecting a 9-to-18-volt zener, and allowing about 10 mA for it, calculate the resistor value.

small metal support. It requires 9 to 18 volts dc at 5 mA, which can be obtained from almost any solid-state tuner or receiver. If you have an older tube-type receiver, a voltage-dropping network such as that shown in Fig. 4 will be necessary. The resistor should be selected to supply approximately 10 mA to the zener diode with the available voltage supply. The zener can be any type within the 9-to-18-volt range.

Operation. The adapter is connected to the FM tuner at the output of the FM detector, before the internal de-emphasis network. It will not work on either stereo output jack. If the tuner or receiver contains a stereo multiplex circuit, the adapter can be connected to the same point where the multiplex circuit is connected.

The output of the adapter is connected to one of the high-level inputs of the audio amplifier. Tune in a station known to have SCA and adjust *R9* until the sound is clear. Once the center of lock range is found, the control may be left alone for all other stations. If you hear some feedthrough during pauses in the SCA transmission, the cause is probably insufficient bandwidth, improper alignment of the tuner i-f strip, or FM detector nonlinearity. In some areas, stations often turn off their SCA subcarrier when not in use. When this happens, the adapter will produce typical interstation noise.

◆



The QRP Thing

BATTERY-OPERATED 40-METER TRANSMITTER

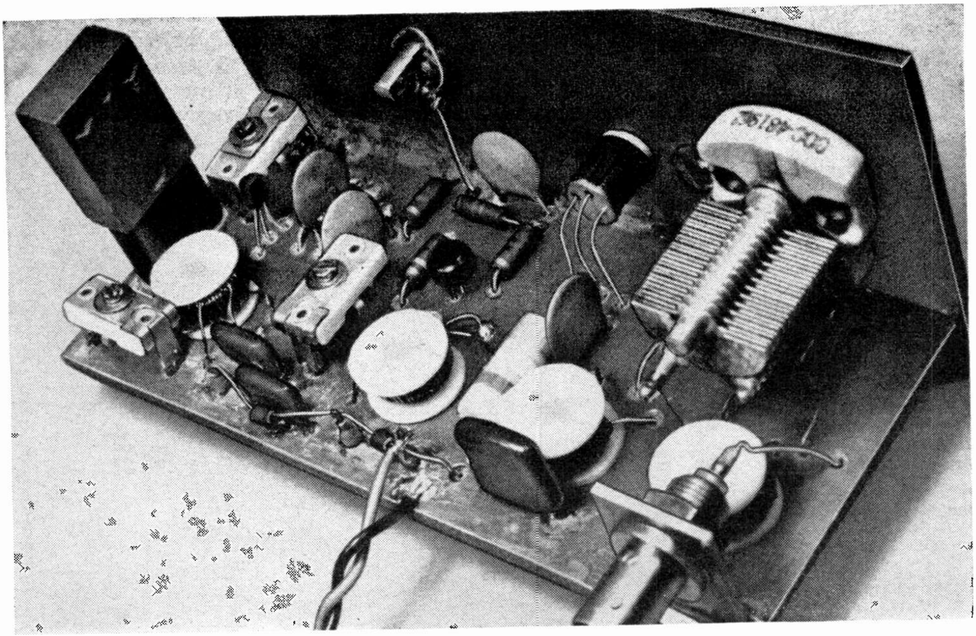
BY HANK OLSON, W6GXN

This solid-state amateur radio transmitter overcomes some of the evils of low-power transistorized designs—chirpy keying and plenty of harmonic radiation. Through the use of a FET crystal-oscillator and ferrite toroid core coils, this transmitter puts out a clean signal and has been used by the author on 7135 kHz to work most of the West Coast.

THERE HAS ALWAYS been an interest in low power operation among radio amateurs. During the first days of high-frequency radio, the very early QRP rigs were low-powered because the more powerful tubes were either rare or too costly. Even after the arrival of "war surplus" and a 100-watt tube became cheaper than a new 3Q4, there was a continuous stream of home-built QRP rigs—considered quite fashionable.

Most new QRP rigs are transistorized and therefore capable of low battery drain. [1,2,3,4,5,6,7] Such rigs run easily for long periods of time from inexpensive dry batteries or from a 12-volt auto battery.

Pretty Good, But! A rather surprising percentage of transistorized QRP rigs use crystal oscillators with designs that leave much to be desired. In fact, many of the circuits either key the oscillator or drive the output transistor directly from the crystal



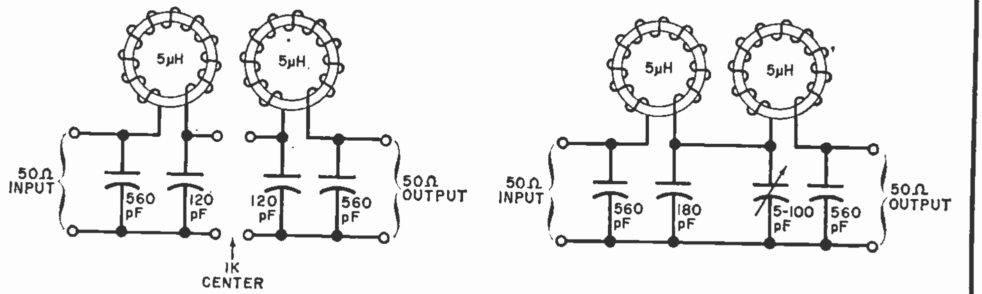


Fig. 1. A double pi-network was designed to be used with this transmitter. At the left, note that an untuned pi-network can be easily constructed using commonly available parts values to operate at 40 meters with 50 ohms input and 1000 ohms output. Two of these pi-networks placed back-to-back presents the ideal impedance. The operating Q of each pi section was chosen to be about 10.

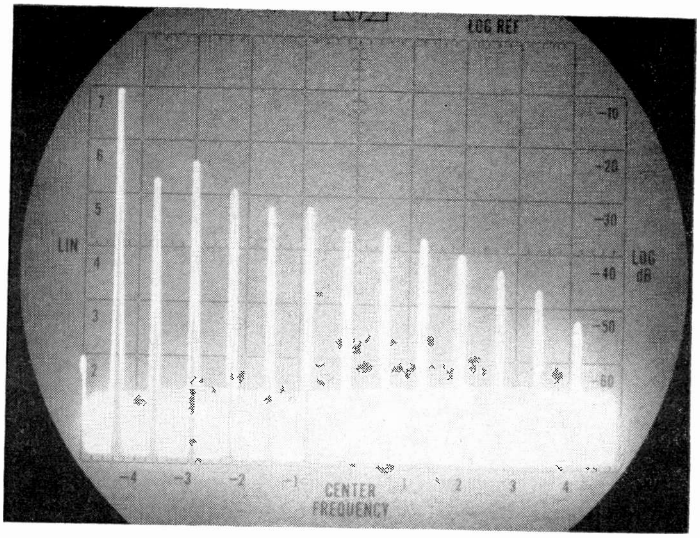
oscillator—both are acknowledged to be relatively poor circuit practices.

Pre-World War II ham operators will recall some of the simple crystal-oscillator transmitters similar to the famous 6L6 Tri-tet circuit. These transmitters used a #49 incandescent bulb in series with a crystal as a fuse to prevent cracking the quartz crystal due to excessive currents. Radiating directly from a crystal oscillator—and keying it to boot—was bad pratice in that era, and it is *still* bad practice in 1972. The only consolation is that a chirpy 2N3053 single stage running at 100 mW input isn't causing as much interference as a chirpy 6L6 running at 50 watts!

Most QRP crystal oscillator designs examined by the author used bipolar transistors. The bipolar transistor does not make a good crystal oscillator—except perhaps for use with crystals that are cut for series-mode operation. This is because of the low impedances associated with a bipolar transistor.[8] In many QRP circuits, the crystal either doesn't oscillate reliably, or does so considerably lower in frequency than it is marked—since most amateur band crystals are ground for use in parallel resonant circuits (around 32 pF).

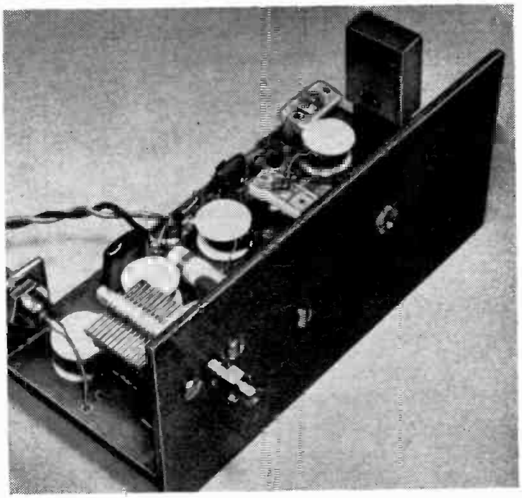
FET Crystal Oscillator. The QRP transmitter discussed in this article solves several of the problems inherent in circuits published in the past. This circuit uses an FET in a standard Colpitts configuration that presents 32 pF to the crystal. Amateur band crystals in this circuit oscillate at the frequencies marked. Furthermore, the low drive assures thermal stability of the crystal to reduce frequency drift. Since the crystal oscillator stage is not keyed, chirping is no longer a problem. Keying is accomplished in the

Fig. 2. This is the display of output from the 2N3053 stage without dual pi-network. Note the excessive generation of harmonics that would go right into the antenna. Each horizontal division is 10 MHz and the 3rd harmonic is only 14 dB down. With dual pi-network above in circuit, the 3rd harmonic was suppressed about 55 dB.



emitter of the second (driver) stage which is running in class A. The final stage of this QRP transmitter runs at zero bias—or class C—and only conducts current when its base-emitter junction is forward-biased by positive swings of the r-f drive.

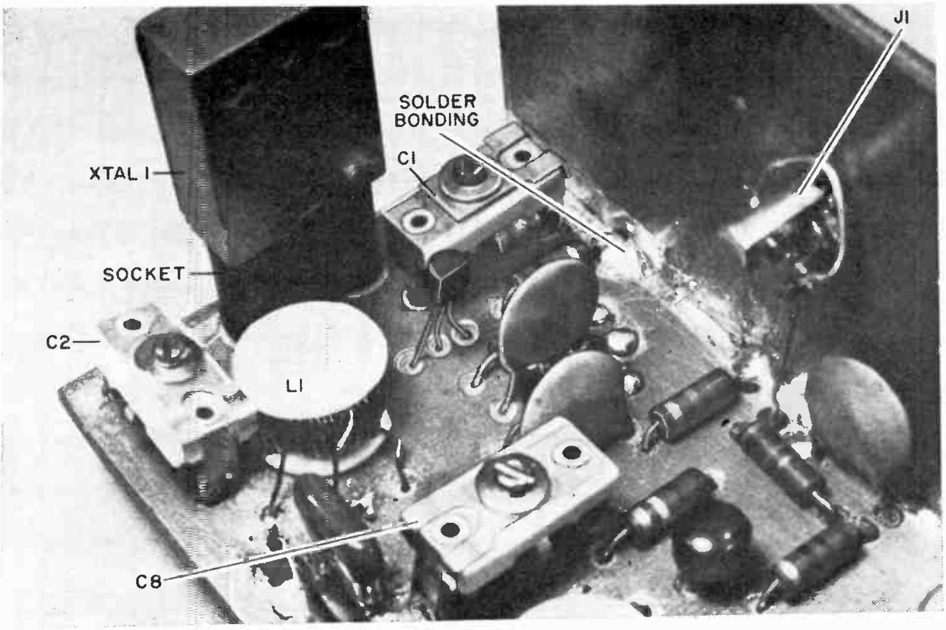
Those familiar with transistor circuits are probably now reading this with raised eyebrows. Certainly the most nonlinear gadget in the history of ham radio is a transistor operating in class C. After all, driving a diode (base-emitter junction) into forward conduction is reminiscent of antique 100-kHz calibrators, where a diode was inserted in the output to enhance harmonic production. Since the final of the QRP transmitter does have such a large harmonic content, it is necessary to insert an output network having a highly effective operating Q. This is no real burden in design since the output impedance of our transistor final is quite low and a two-section matching network is easier to realize than a single-section network.



For a front panel for transmitter, prototype had a second sheet of double-faced copper clad board.

A double-pi network is shown in Fig. 1. The point at which the two pi-sections interconnect was chosen to be 1000 ohms and the operating Q of each section was chosen to be 10. Since the input and output impedance are both 50 ohms, it is possible to show the effectiveness of this network on a spectrum analyzer—see Fig. 2. Note that the analyzer pattern shows the third harmonic at 21 MHz to be only 14 dB down from the fundamental when operating the collector directly into 50 ohms. A similar spectrum oscillogram taken with the double-pi inserted in the circuit would show the only harmonic visible (second) to be 55 dB down.

Note how the front panel was soldered to the circuit board to make prototype unit. Copper on top of board must be removed so that component leads can go through to foil pattern without shorting.



PARTS LIST

C1,C2,C8,C14—5—100-pF trimmer capacitor
C3,C6—0.047-µF capacitor
C4,C7,C9,C11—0.01-µF capacitor
C5—120-pF capacitor
C10—0.22-µF capacitor
C12,C15—560-pF capacitor
C13—180-pF capacitor
J1—Normally closed miniature phone jack
*L1—Coil: 34 turns #24 enameled wire; 5-turn link**
*L2—Coil: 34 turns #26 enameled wire; tap at 5 turns; 3-turn link**
*L3,L4—Coil: 34 turns #24 Formvar**
Q1—MPF102 or HEP802 transistor
Q2—2N3641 or HEP53 transistor
Q3—2N3053 transistor
R1—1-megohm, ½-watt resistor
R2—1000-ohm, ½-watt resistor
R3—10,000-ohm, ½-watt resistor
R4—1500-ohm, ½-watt resistor
R5—10-ohm, ½-watt resistor
R6—100-ohm, ½-watt resistor
RFC1—47-µH choke
XTAL1—7.135-MHz crystal
Misc.—Ferrite beads, heat sink for Q3, 1000-pF feedthrough capacitor (3), BNC connector, suitable copperplated PC board, crystal socket, mounting hardware, etc.*
**The following are available from Amidon Associates, 12033 Otsego St., North Hollywood, CA 91607: T-50-6 toroid coil forms at 50¢ each; packet of ferrite beads at $2.*

A kit of parts (less crystal) and etched circuit board are available from Red Johnson Electronics, 440 Pepper St., Palo Alto, Calif., for $15.00 postpaid in U.S. California residents include 5% sales tax.

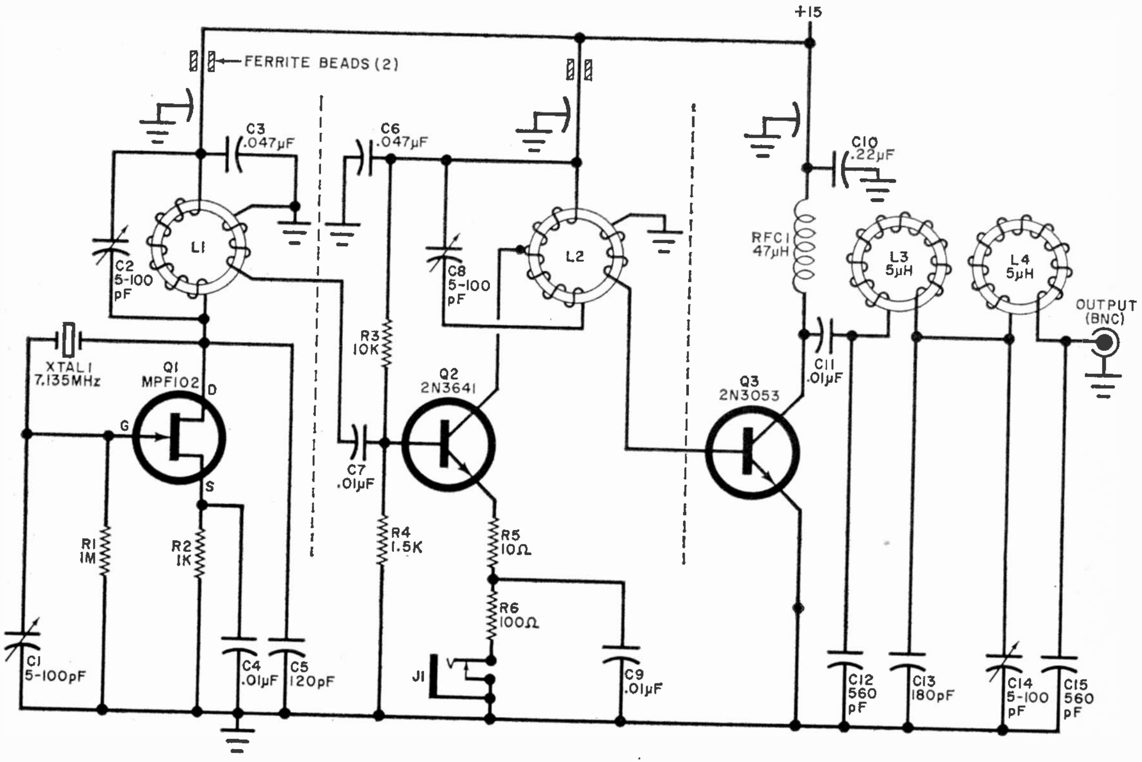
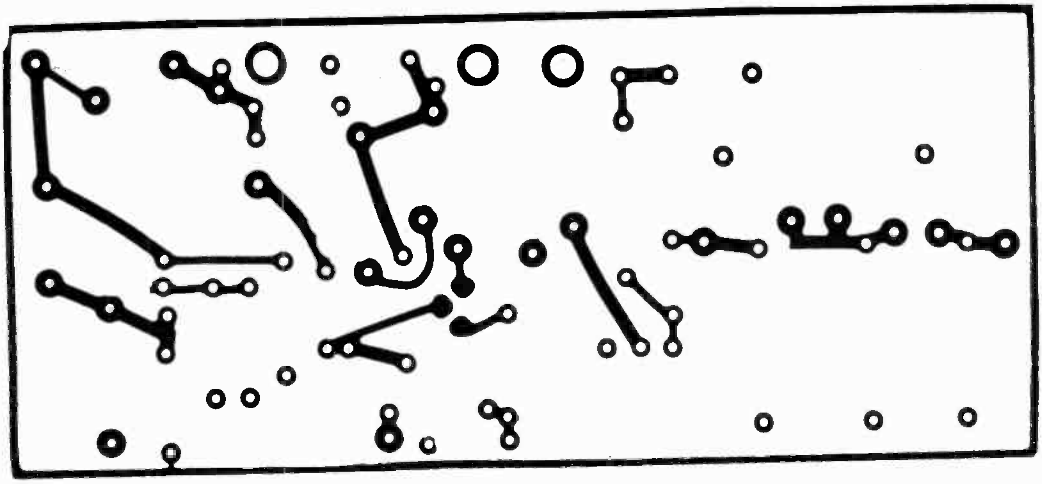


Fig. 3. Final circuit for the QRP transmitter accomplished all of the author's design objectives—better keying and less harmonic radiation.



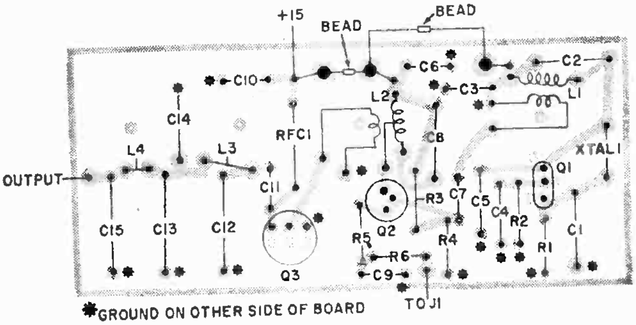
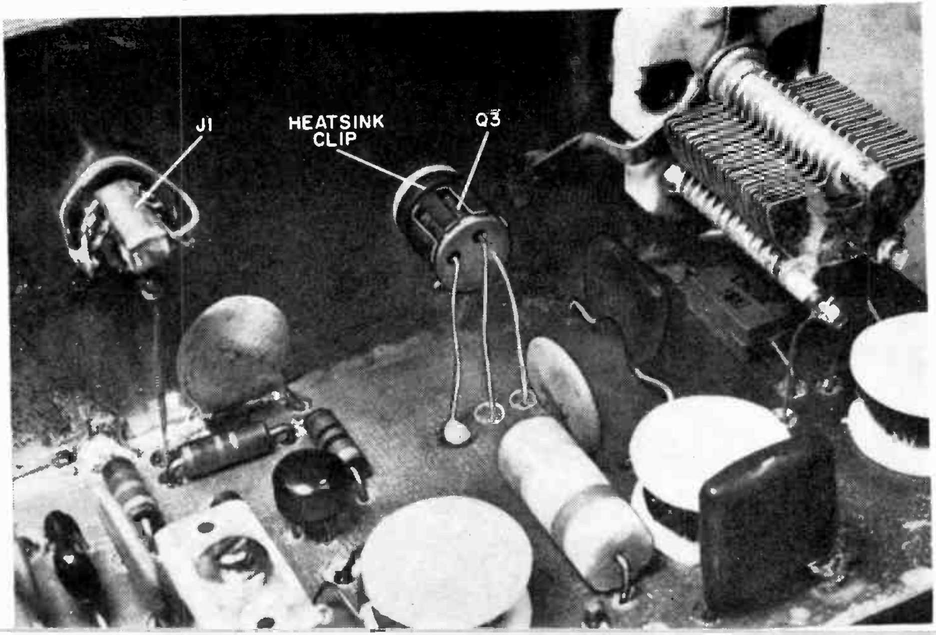


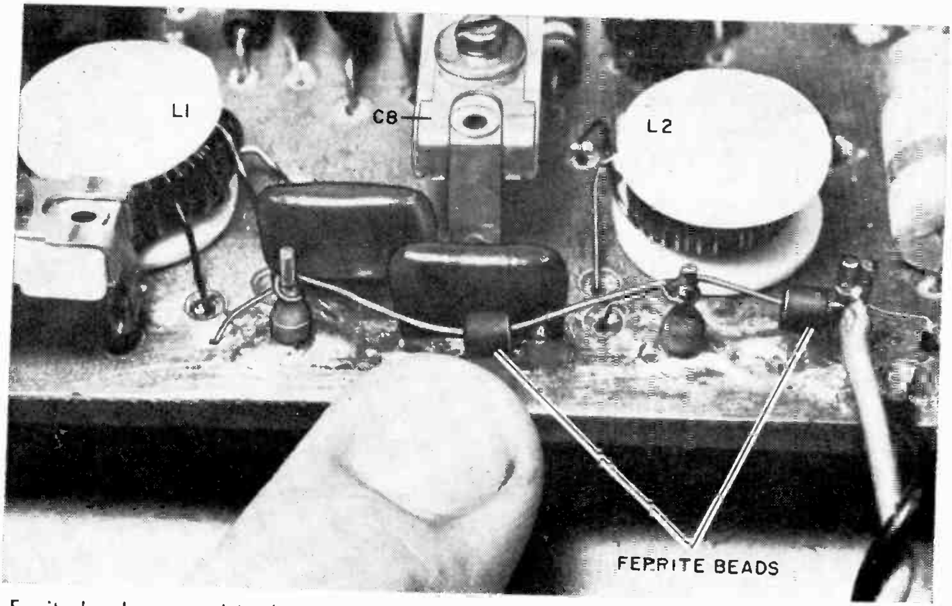
Fig. 4. Above is printed circuit foil pattern for underside of the double-faced board. Parts placement is shown at left. Note that this is a view looking up through both copper foils. Terminations that are not marked with an asterisk go through the top side of the board and are soldered to remaining etched foil pattern.

After experimentation, the final circuit for the QRP rig is shown in Fig. 3. The overall circuit is straightforward and uses readily available components with the sole exception of the two toroids, *L1* and *L2*. If any coil types other than the toroids are substituted, considerable additional shielding will be required.

As a convenience to the constructor a printed circuit foil pattern is shown in Fig. 4.

The heat sink which holds transistor Q3 is fastened by a bolt through the front panel. Note how two of Q3's leads go through circuit board to foil pattern while the third is soldered to the top.



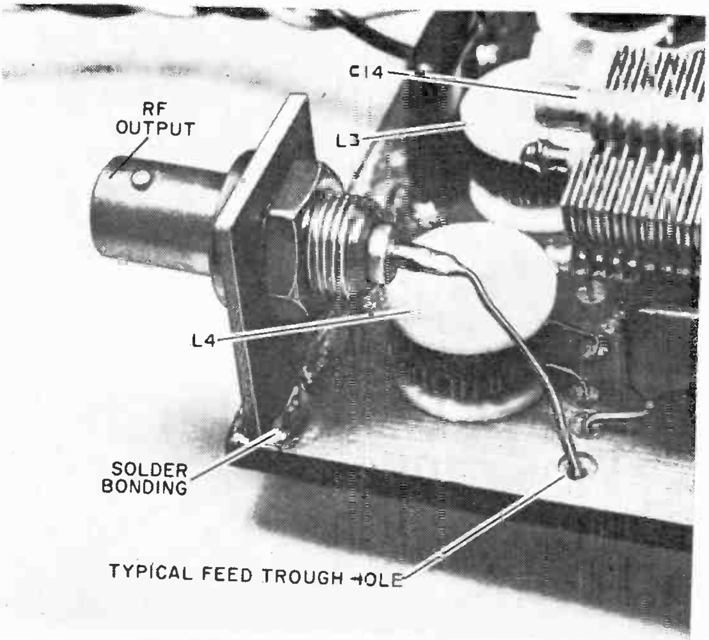


Ferrite beads are used in the plus 15-volt line to be sure harmonic radiation is kept down. The beads are slipped over the wires between the feedthru capacitors which are soldered on the board.

Parts arrangement on the PC board may be seen in the photographs and in Fig. 4. The author suggests that the board be etched from double-sided laminate and that one side be left completely unetched as a ground plane. The ground plane side of the PC board is the "parts" side and clearance holes must be drilled in the solid copper for those part leads not grounded. These clearance holes are only in the copper—not the insulation.

Operation. To tune up the QRP transmitter, the tuning capacitors should be set so that *C1* is about three-quarter turn from maximum capacitance, *C2* about 1½ turn from maximum, *C3* at maximum, and *C4* at half capacitance.

A milliammeter should be inserted in the +18-volt lead to monitor current flow. The full-scale reading for this meter should be 300-plus mA. A dummy load consisting of a 2-watt, 50-ohm carbon resistor should be put across the output. The 18-volt battery supply may be made up of three 6-volt lantern cells



The author used a BNC output connector, though any coax connector could be substituted. Capacitor C14 is adjusted by screwdriver from the front panel for operation on QRP frequency most used in your locality.

connected in series or if you prefer use any 15 to 18 volt power supply.

With the key up, only transistor *Q1* draws current and the meter indication should be about 5 mA. With the key down, tune *C3* toward minimum capacity and observe how the meter indication rises to 100 mA or more as the driver stage tunes to 7 MHz and *Q3* is fed r-f power. Now, tune *C4* in the pi-section for a dip in current and then retune *C3*, *C2* and *C1* in that order for maximum current. It should be found that *C1* and *C2* have a very slow-to-respond effect on the output or current drawn from the battery supply. Minor juggling of *C1* will "rubber" the crystal oscillator.

Although maximum r-f power output corresponds closely, in tuning, to the dip (of *C4*) in current, it is more satisfying to measure actual r-f output. This can be done with any convenient directional power output meter.[9]

After tuning up with the 50-ohm dummy load, the transmitter can be connected to a resonant 40-meter antenna fed by a 50-ohm coax cable.

Results. The QRP rig has been the recipient of nothing but good reports (consistently *T9*) and most hams on the other end of a QSO are unwilling to believe that they are listening to a signal running about 0.5 watt output. The entire West Coast of North America has been worked on 40 meters on or close to 7135 kHz—the most-used QRP frequency in the band. ◆

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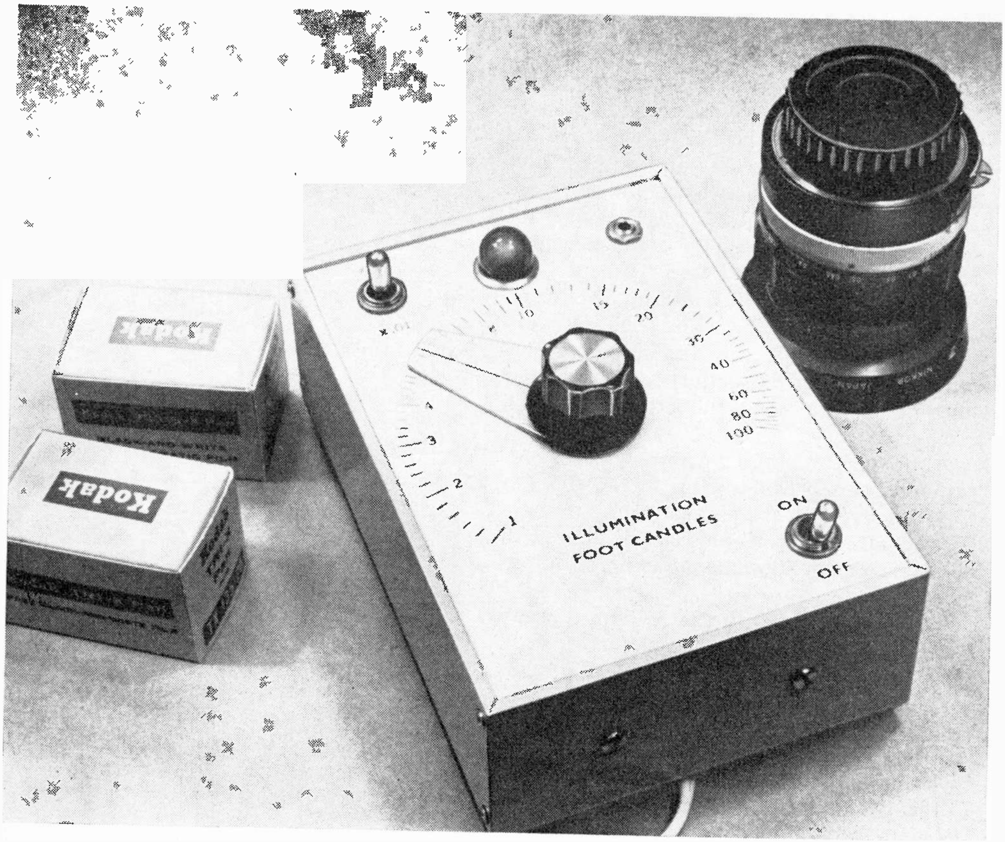

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FOR THE PHOTOGRAPHY enthusiast who does his own enlarging, an enlarger lightmeter is a must if he expects to work efficiently and economically. By standardizing his enlarger exposures, he can just about eliminate paper waste.

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BY A. A. MANGIERI

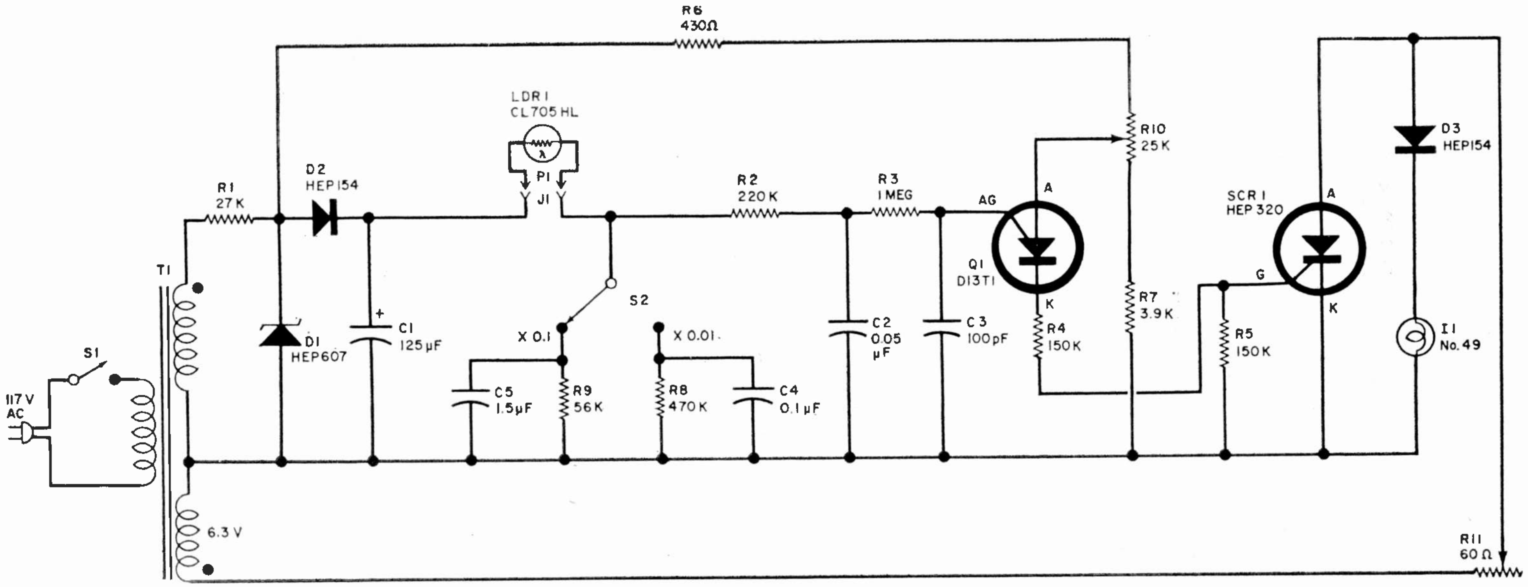


Fig. 1. The setting of R10 and resistance value of LDR1 (under various lighting levels) determine triggering time of Q1.

PARTS LIST

C1—125-μF, 20-volt electrolytic capacitor
C2—0.05-μF disc capacitor
C3—100-pF disc capacitor
C4—0.1-μF disc capacitor
C5—1.5-μF, 20-volt electrolytic capacitor
D1—15-volt, 1-watt zener diode (Motorola HEP607 or similar)
D2,D3—1-ampere, 50-volt silicon diode (Motorola HEP154 or similar)
I1—#49 panel lamp
J1—Miniature phone jack
LDR1—Light dependent resistor (Clairex CL705HL)
P1—Miniature phone plug
Q1—Programmable UJT (GE D13T1)
R1—27,000-ohm, 1-watt resistor
R2—220,000-ohm, ½-watt resistor
R3—1-megohm, ½-watt resistor
R4,R5—150,000-ohm, ½-watt resistor
R6—430-ohm, ½-watt, 5% resistor
R7—3900-ohm, ½-watt, 5% resistor
R8—470,000-ohm, ½-watt resistor
R9—56,000-ohm, ½-watt resistor
R10—25,000-ohm wirewound potentiometer (Centralab WW-253 or similar)
R11—60-ohm trimmer potentiometer (Centralab VS-60 or similar)
S1—Spst slide or toggle switch
S2—Spdt slide or toggle switch
SCR1—HEP 320 0.8A, 30V SCR
T1—Transformer; secondaries: 125 V, 15 mA; 6.3 V, 300 mA (Knight 6-K-27VF or similar)
Misc.—Lamp socket with red dome (Dialco 95-9110-0931-102 or similar), chassis (Vector Multi-Mod W20-66-46 or similar), 51 panel lamp, line cord, earphone cable, transistor socket (2), PC board terminals (18, Vector T42-1), clear plastic for cursor, etc.

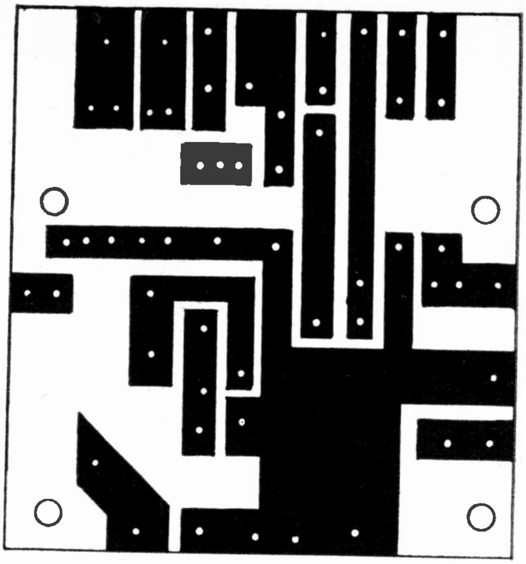
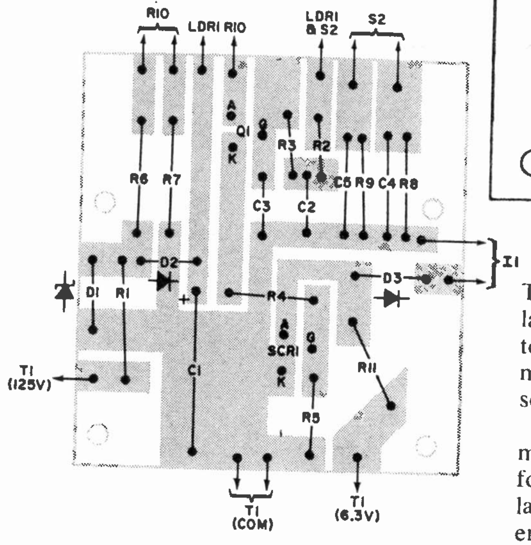


Fig. 2. Actual size printed circuit etching guide is shown at right; while below is the component location and orientation diagram.



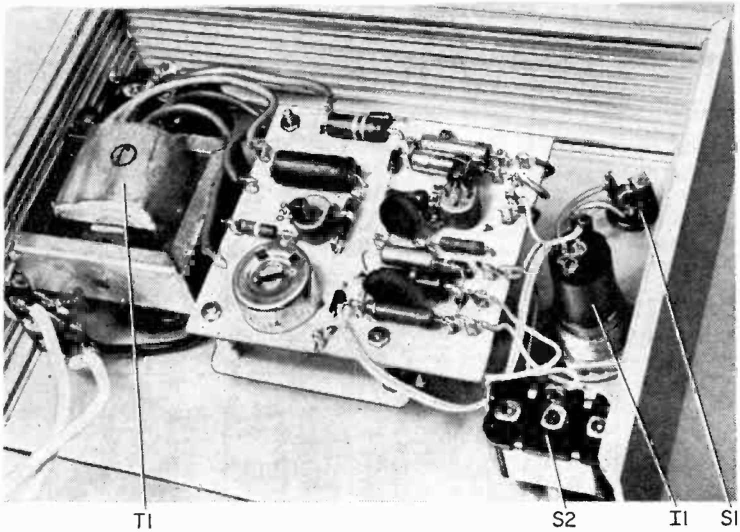
scale for high resolution readout. It should also have precise resettability and repeatability. The meter described here has a low range from 0.01 to 1 footcandle over an eight-inch scale, plus a 10X multiplier to increase the range to 10 footcandles. Light-level variations just a few percent above or below the set point of the calibrated dial cause snap action turn-on or turn-off of a panel lamp. A stabilized bridge circuit affords long-term repeatability and 100:1 light coverage per range, while a nonlinear scale provides readability to several percent at any setting.

Construction. The schematic of the enlarger lightmeter is shown in Fig. 1. The photoresistor (light dependent resistor) *LDR1*, is mounted in a thin plate-like package which is connected to the rest of the circuit by a long two-conductor cable as shown in the photos. Most of the electronic circuit is built on a printed circuit board, the foil pattern for which is shown in Fig. 2. This figure also shows the component installation and the external connections. Transistor sockets should be used to prevent thermal damage to the semiconductors during soldering.

For the prototype a 4½" × 6½" × 2" metal case was used to provide ample room for the components with enough space for a large, easy-to-read scale. Almost any type of enclosure can be used, as long as sufficient panel space is provided.

Mounted on the top panel are the calibration potentiometer *R10*, power switch *S1*, range switch *S2*, indicator lamp *I1*, and input jack *J1*. The latter should be insulated from the metal case. When all of these components have been assembled, mount the power transformer *T1* on one wall of the case; and after soldering the required leads to the PC board, mount the board on four spacers. Connect the circuit as shown in Fig. 1.

Using a piece of 1/16" thick transparent plastic, make up a cursor (or pointer) as shown in the photos to fit on the shaft of *R10*. Scratch a hairline at the center of the cursor and fill it with black ink. The knob selected for use on *R10* should preferably have a large diameter for easy handling. Cement the cursor to the knob. Prepare the upper surface of the panel for the calibration marks and with the knob temporarily installed on *R10*, make sure that the cursor can swing from limit to limit of the potentiometer. Install four rubber feet on the base of the chassis.

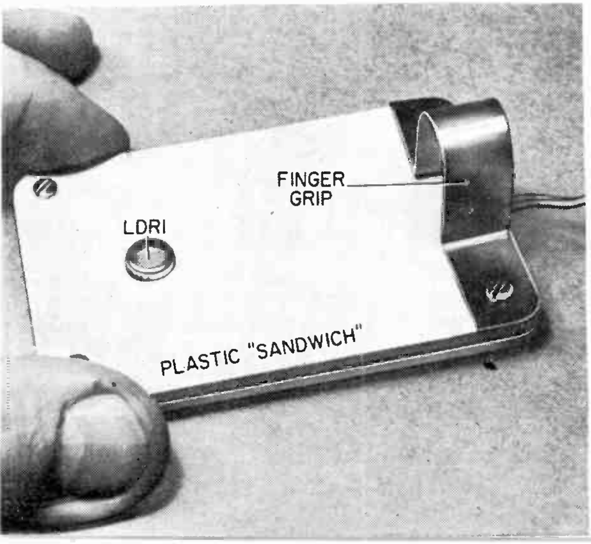


Interconnecting wires from chassis-mounted components can be soldered to appropriate points on the circuit board through use of "flea" clips.

The photoresistor is placed either within a thin plastic case or sandwiched between two pieces of thin insulation board. A slot is made in one board to provide room for the connecting cable (which can be made from old earphone cabling). A hole in the other board permits light to reach *LDR1*. Some form of finger grip should be fabricated and attached to the upper board. Use small hardware to finish off the insulation board sandwich.

Calibration. With the circuit wired as shown in Fig. 1, turn on the power. Remove *Q1* from its socket and note that indicator lamp *I1* comes on. If *I1* remains off, progressively decrease the value of *R5* to keep *SCR1* from turning on by itself. Re-insert *Q1* in its socket and with *S2* set to the X0.1 position, connect a 390,000-ohm resistor in place of *LDR1*. Lamp *I1* should go on and off as *R10* is varied about its mid-position. If it does not, reverse the leads of either secondary of *T1*. If the problem still exists, progressively decrease the value of *R4* to increase the drive to *SCR1*. Remove the 390,000-ohm resistor and note that *I1* remains off at all settings of *R10*. If it does not, slightly increase the value of *R7*. Set *R11* to about 30 ohms. Then adjust to desired lamp brightness but do not exceed 2 volts across lamp.

A simple plastic "sandwich" provides a convenient means of mounting light dependent resistor LDR1.



A 0-100 dial plate can be used as a logging scale. However, it's well worth the effort to prepare a calibrated scale for maximum versatility of the meter. The calibrating procedure makes use of the inverse square law relating to light radiating from point sources. Illumination in footcandles (FC) is equal to lamp candle power (CP) divided by the square of the distance in feet (D) from lamp to LDR location. Thus, $FC = CP/D^2$.

For the light source, use a new #51 panel lamp operated at 7.5 volts ac from a filament transformer. Use a powerstat on the primary side or a rheostat in series with the lamp on the secondary side to adjust the lamp voltage. Mount the lamp rigidly, base down, and positioned so that its filament is broadside to the LDR, facing it squarely.

Tape the mounted LDR to a wooden L bracket and mount a black card having a ½" hole several inches in front of the cell to block off most of the stray room light. Run tests at night in a large dark-walled room. At lamp-

THEORY OF CIRCUIT DESIGN

Photoresistor (light dependent resistor) *LDR1* and selected range resistors *R8* and *R9* form two sides of a bridge energized by filtered dc. Resistors *R6*, *R7*, and *R10* make up the remaining arms of the bridge, energized by a dc square wave developed at zener diode *D1*. The square wave resets *Q1* to off at each cycle.

When the voltage at the anode of *Q1* exceeds the voltage at the anode-gate (AG), *Q1* turns on thus energizing the gate of *SCR1*. This turns the SCR on and simultaneously turns pilot lamp *I1* off. Averaging filter *R2-C2* bypasses moderately large ac components of light present in cold light sources and the comparatively small components from incandescent sources.

As the resistance of *LDR1* takes on different values when exposed to different light levels, the turn-on (or trip point) of *Q1* occurs at different settings of potentiometer *R10*. Circuit action provides a snap action, rather than a gradual turn on, of *I1* at the trip point. Resistors *R3* and *R4* determine the bridge loading and are proportional in values so that turn-on and turn-off of *Q1* occur with minimum hysteresis or deadband on *R10*.

to-LDR distances of 3″, 6″, 9″, 1′, 2′, etc. to 10′, measure LDR resistance at each point with an accurate ohmmeter.

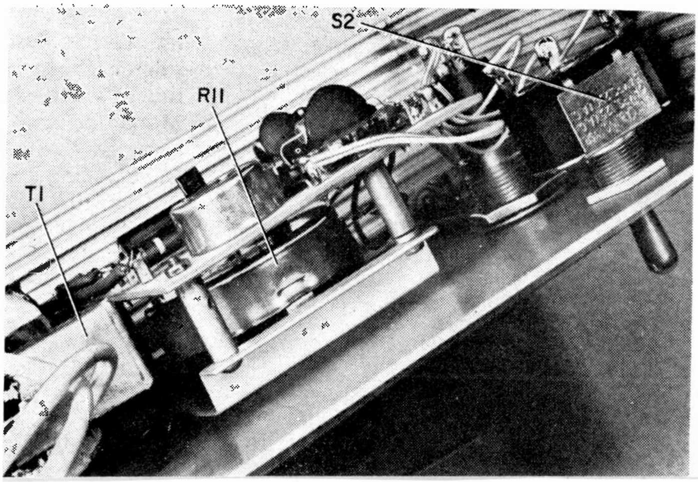
Next, using the inverse square law calculate the illumination in foot candles—using 1.2 for the lamp's candle power. (This value is 20% higher than the rated value to allow for higher radiation broadside to the lamp filament.) Plot cell resistance vs foot candles on 1 X 1 cycle logarithmic graph paper.

From the graph, read cell resistances at 0.01, 0.02, 0.03 etc. foot candles. Using a potentiometer set to these resistance values substituted for *LDR1*, locate division marks on the panel from 0.01 to 1 FC. If the 0.01 to 1.0 range does not fit over the available range of *R10*, use a different value of resistor for *R8* to account for LDR variations. With resistors equivalent to 1 and 10 FC, use a different value of resistor for *R9* so that the high range tracks the low range with as little tracking error as possible. You may prepare a second, separate scale for the high range if desired. Scale numbers may be direct reading or they can be as shown on the prototype with X0.01 and X0.1 multipliers selected by *S2*.

Application. When measuring light levels of a projected image, adjust *R10* CCW so that *I1* goes from off to on. Also, when adjusting light level through lens opening, decrease the aperture so that the lamp goes on at the trip point. This eliminates any stray light contribution from the panel lamp itself. All darkroom lights must be off during use of the meter.

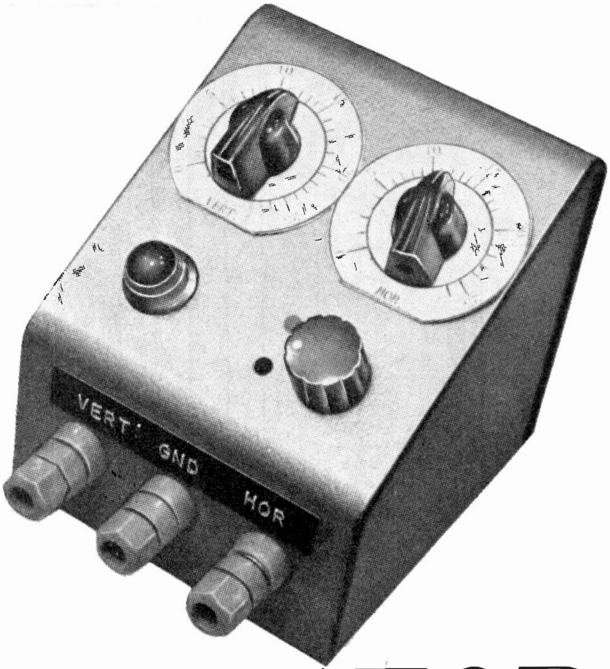
Standardize the meter by making test runs with the various enlarging papers that you use. Make a perfect print by the usual cut-and-try procedure. Using the meter, measure and record the setting of *R10* when the lamp turns on at the lightest and darkest portions of the image, as well as at the important parts of the image. For negatives and paper of the same or similar contrast and with the same or different enlarger magnifications, all you have to do is adjust the lens aperture to match the standardized settings and expose the print as before.

Since readings on the calibrated scale have a known relationship to each other, you can double the standardized readings and cut the exposure in half—and vice versa. Also, the highest and lowest readings provide an indication of the contrast on a negative, which is an aid in selecting paper contrast. For enlarging, you may prefer to read the calibrated scale as 1 to 100 on the low range and 10 to 1000 on the high to avoid use of decimals. ◆



Circuit board mounts on U bracket with aid of four spacers. Potentiometer R11 then fastens entire assembly to front panel of case via its mounting bushing.

BY GEORGE WINDOLPH



Building and Using The XY CALIBRATOR

DOUBLE-AXIS OSCILLOSCOPE CALIBRATOR USES ZENER DIODES

This circuit involves the use of a pair of matched zener diodes to obtain true horizontal or vertical oscilloscope scale calibration. The author designed the circuit for a diode and transistor curve tracer, but its ease of construction and versatility make the calibrator useful for many functions. Details on matching zener diodes for the circuit are also given.

MANY TIMES in using an oscilloscope, it is advantageous to have the vertical and/or horizontal traces calibrated so that accurate values of the quantity being measured can be determined. There are several ways in which this calibration can be performed but you will find the simple double-axis calibrator described here to be an easy, accurate instrument that permits adjustment of either axis calibration voltage to almost any level.

The circuit of the calibrator is based on the simple phase-shift network shown in Fig. 1A. In this circuit, the voltages at the two ends of the transformer secondary are 180° out of phase. With the addition of the resistor-capacitor circuit the voltages at V and H are made to have a phase difference of 90°. When connected to an oscilloscope (and with the gain controls properly adjusted), these V and H outputs produce a circle (or ellipse) on the scope. The vertical and horizontal diameters correspond to the respective peak-to-peak voltages. One shortcoming of this circuit is that the output cannot be varied in level since a potentiometer connected across the output would change the phase relationship.

If a pair of diodes is added as shown in Fig. 1B, the negative portions of both vertical and horizontal signals are cut off so that the scope pattern becomes a quarter circle. Finally, if the diodes are zeners, the positive voltage is also cut off but at a higher voltage corresponding to the zener voltage. Thus a square pattern is obtained on the scope as shown in Fig. 1C.

The actual circuit of the double-axis calibrator is shown in Fig. 2. With the high-resistance potentiometers across the outputs,

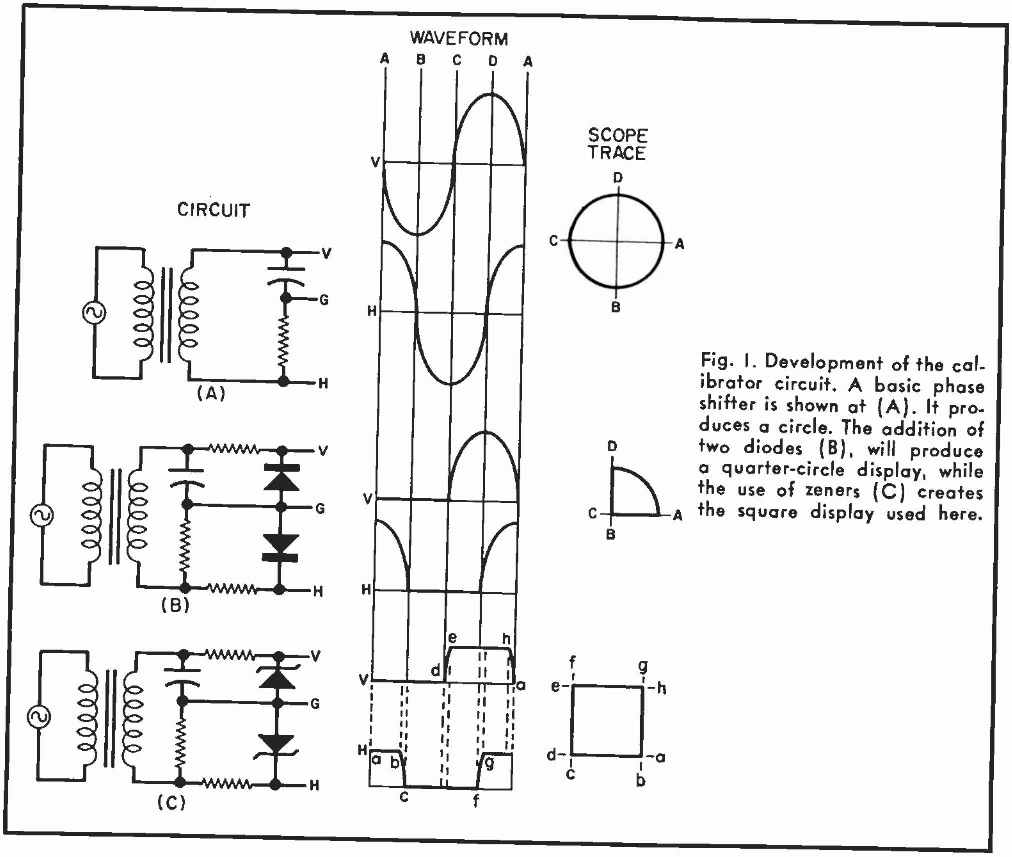


Fig. 1. Development of the calibrator circuit. A basic phase shifter is shown at (A). It produces a circle. The addition of two diodes (B), will produce a quarter-circle display, while the use of zeners (C) creates the square display used here.

the voltage can be preset from zero to the maximum determined by the zener diodes.

Construction. The circuit can be built in any type of chassis or possibly within the cabinet of the oscilloscope—as long as the potentiometers and calibrated dials are available. Wiring can be point-to-point, using terminal strips to support the various components. Parts placement is not critical. If a transformer with a higher voltage on the secondary is used, increase the wattage rating of *R1*. If the transformer secondary voltage is lower, the zener diodes and resistance values for *R2* and *R3* must be selected accordingly.

Any zener diodes with ratings of 25 volts or less may be used in the circuit as shown. If diodes rated above 25 volts are used, increase the transformer secondary or lower the value of resistors *R2* and *R3*. If one

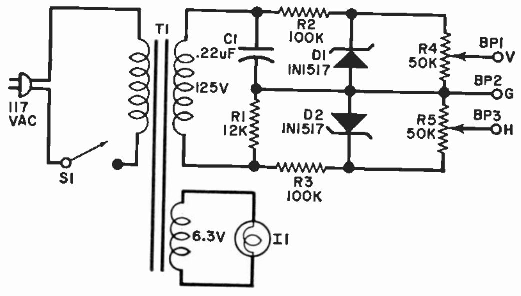


Fig. 2. The final circuit uses calibrated output potentiometers, and an optional power on-off lamp to indicate when the calibrator is in operation.

PARTS LIST

BP1-BP3—Five-way binding post
C1—0.22-µF, 200-volt capacitor
D1,D2—1N1517 zener diode (see text)
I1—6.3-volt pilot lamp
R1—12,000-ohm, 1-watt resistor
R2,R3—100,000-ohm, ½-watt resistor
R4,R5—50,000-ohm linear taper potentiometer
S1—Spst slide or toggle switch
T1—Transformer: secondaries: 125V at 15mA, 6.3V at 600 mA.
Misc.—Pointer knob (2), dials (2), line cord, suitable chassis, pilot lamp holder and lens, terminal strips, mounting hardware, etc.

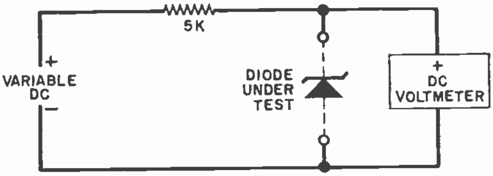
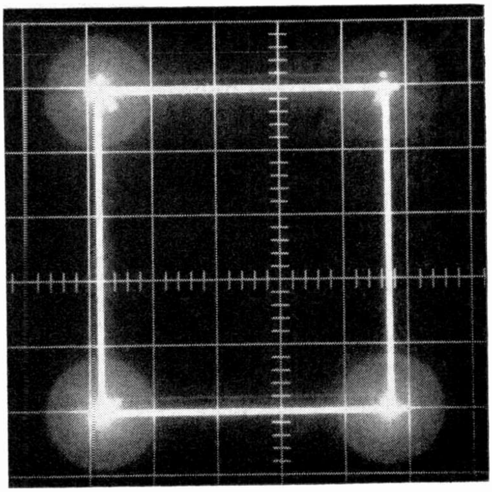


Fig. 3. This circuit can be used to check the operating voltage of any zener diode as long as the applied voltage is above actual diode requirement.

corner of the displayed pattern is rounded, it can be squared off by slightly decreasing the value of *R2* and *R3*. Resistance of *R4* and *R5* is not critical, but it should not be lower than that specified.

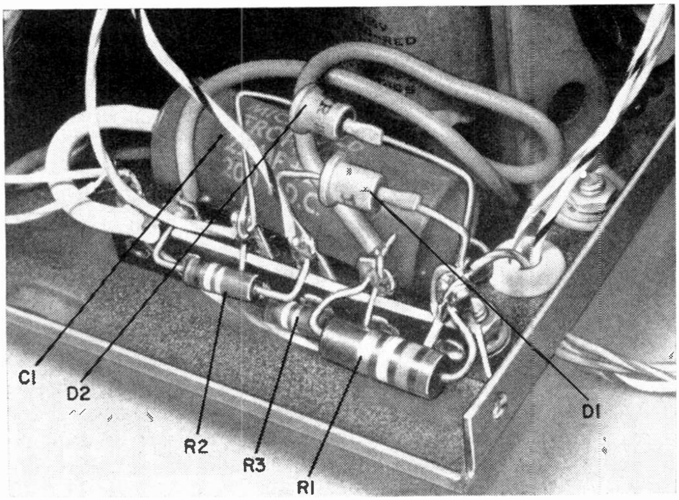
Diode Calibration. The specified operating voltage of a zener diode is usually a nominal value. To determine the exact value for a specific diode, connect it in the circuit shown in Fig. 3. As the dc voltage is increased from zero, the voltmeter will indicate upscale until the zener goes into conduction. A further increase of the applied voltage will not change the meter reading. Note the point at which the meter just peaks. Reverse the diode and repeat the process, placing the voltmeter on a lower range. The indicated voltage will be very much less (approximately 0.5 volt) since the diode is now forward biased. Add the two voltages to obtain the voltage represented on one side of the square pattern at the maximum setting of the potentiometer. Repeat the calibration procedure for the other diode.

Diode Matching. Unless you are lucky, two zener diodes will have slightly different voltages. This can be tolerated since the two potentiometers will be calibrated independently. If you prefer to have the maximum indications of the potentiometers the same, or if you want to use a dual precision potentiometer, the diode circuits will have to be matched.



This is a typical calibration square as seen on a scope. The bright spot at each corner is due to the relatively long dwell period of the trace.

Connect the ground and either of the calibrator outputs to the scope horizontal input. Set both calibrator potentiometers to maximum; then adjust the scope horizontal gain until the trace occupies some given number of divisions on the horizontal axis. Now leave the horizontal gain control where it is and remove the calibrator output from the horizontal input and connect it to the vertical input. Adjust the scope vertical gain until the trace occupies the same number of divisions



The entire circuit can be built up on a single terminal strip with the circuit wired point-to-point. The three leads are optional scope input connectors.

ELECTRONIC

EXPERIMENTER'S

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on the vertical axis. Do not disturb the scope vertical gain control after this.

Connect the calibrator to the scope in the correct way; i.e., V to vertical and H to horizontal. The ground should still be connected. The display should be a square if the diodes are closely matched. If not, insert a trimmer potentiometer between the higher voltage potentiometer (the longer side of the oblong pattern) and the associated diode, and adjust the trimmer until a square is obtained. If the proper value can be found, you can now replace the trimmer with a fixed resistor.

Dial Calibration. Both potentiometers should have pointer knobs and matching blank dials. The maximum full position should be marked with the voltage value found in calibrating the diode (see above). Assume this is 27 volts; then the maximum clockwise mark should be 27. Adjust the scope horizontal and vertical gain controls until the square is 27 divisions on a side. This produces a one-volt-per-division condition on the scope. Now, without touching the scope controls, set both calibrator potentiometers to obtain a square that is 25 divisions on a side. Mark the dials accordingly. Work your way down the scale in 5-volt steps until zero is reached.

If you have zeners with odd voltage values, add equal-value resistors between each potentiometer and its associated zener until a more convenient voltage is reached. For example, assume your zener voltage value is 19.5. You may prefer a more convenient maximum of 15 volts. Set both calibrator potentiometers at maximum and the scope gain controls so that the square trace is 19.5 divisions on each side. Insert resistance between each potentiometer and its associated zener until the trace drops to exactly 15 divisions (15 volts) on a side. This resistance is in addition to the matching resistor previously added. Calibrate the dials as described.

Using the Calibrator. The calibrator was originally designed for use with diode and transistor curve tracers and permits the calibration of both the horizontal and vertical scales of the scope. In this case, it is often desirable to have the horizontal scale compressed relative to the vertical scale. This can be done easily using the calibrator to provide one or two volts per division on the horizontal and 5 volts or more per division on vertical. Any type of calibrations can be obtained on the scope. ◆

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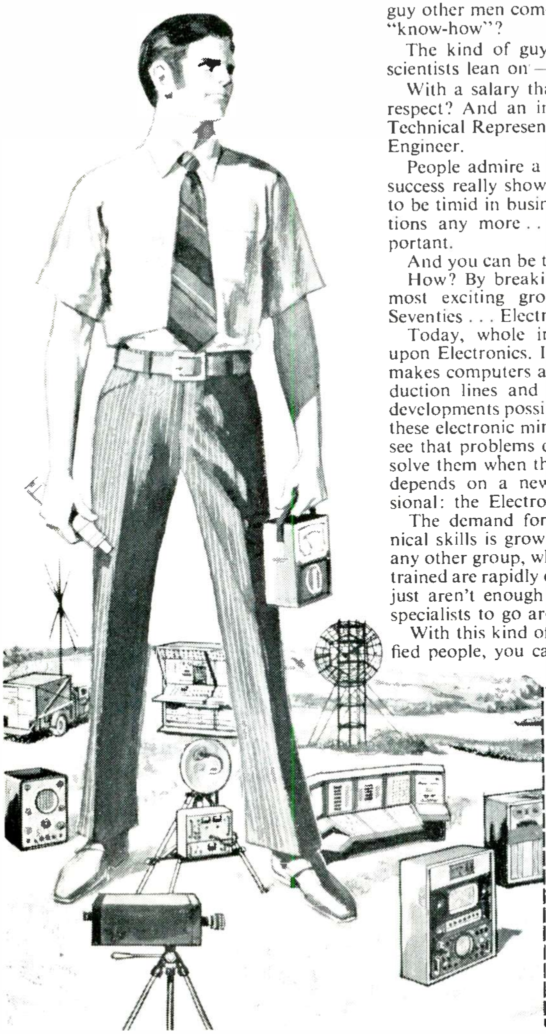

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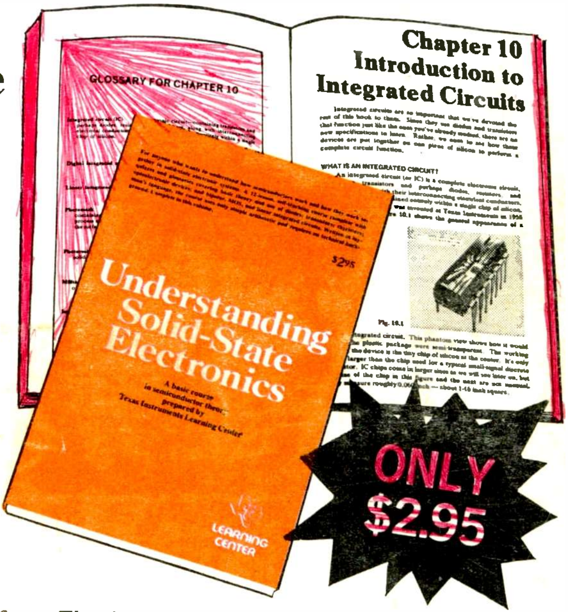

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