"SQUARE DEAL" AUDIO GENERATOR

PROFESSIONAL-TYPE TEST EQUIPMENT FROM INEXPENSIVE INTEGRATED CIRCUITS

By DON LANCASTER

LOOKING for a good audio generator? Here's a portable space-age, transformerless, integrated-circuit instrument with performance features not found even in commercial test gear. The *Square Deal* puts out symmetrical, high-rise-time square waves ranging in amplitude from 0 to 2.5 volts and in frequency from 10 Hz to 1 MHz. The output signal can be a.c.- or d.c.-coupled to equipment being tested, timed, triggered, or sounded.

Signal frequency is entirely independent of output loading; you can drive a speaker directly, or place a dead short across the output without "phasing" this project. You can use the *Square Deal* for general-purpose audio work—to make tone and hearing studies, and to test amplifiers and speakers. Add a phone jack and a speaker, and you'll come up with a code practice oscillator that is loud enough for group practice. And if you want to use the *Square Deal* as a remote annunciator, or as the heart of a burglar alarm, you can.

It will also serve as an oscilloscope calibrator to give you time and amplitude references accurate enough for practically all experimental purposes. When used with a scope, it easily reveals such dynamic amplifier characteristics as frequency response, damping, overshoot, ringing, and phase distortion. You'll also find it handy for digital logic experiments and demonstrations where you need a d.c.-coupled trigger source.

Best of all, the *Square Deal* is unexcelled for field operation; you can use it to check out those tricky mobile or marine installations. Only two D-size flashlight batteries will power the unit continuously for 40 hours or more.

Inside the case you'll find $2.30 worth of semiconductors and a special $2 potentiometer in a simple circuit easily put together in a few hours. Depending upon how fancy you get, and the parts you have on hand, your parts cost will run from $6 to $18. A professional precalibrated and imprinted aluminum front panel is available. (See Parts List.)

How It Works. Two of the four transistors "housed" in an integrated circuit (*IC1*), no larger than a few match heads, are hooked up in an astable multivibrator circuit that puts out a good, clean square wave which is direct-coupled to *Q1*, as shown in Fig. 1. Transistor *Q1*, hooked up as an emitter follower, serves as a buffer to prevent output loading conditions from affecting the oscillator frequency.

The signal from *Q1* is direct-coupled to the base of transistors *C* and *E* in *IC2*, where it is further isolated from the oscillator. Transistor *C* reverses the phase of the signal and passes it on to transistor *D*. Transistors *D* and *E* drive the load in a push-push manner. Operation is similar to a push-pull class B amplifier, but a push-push circuit is single-ended. The output signal appears across

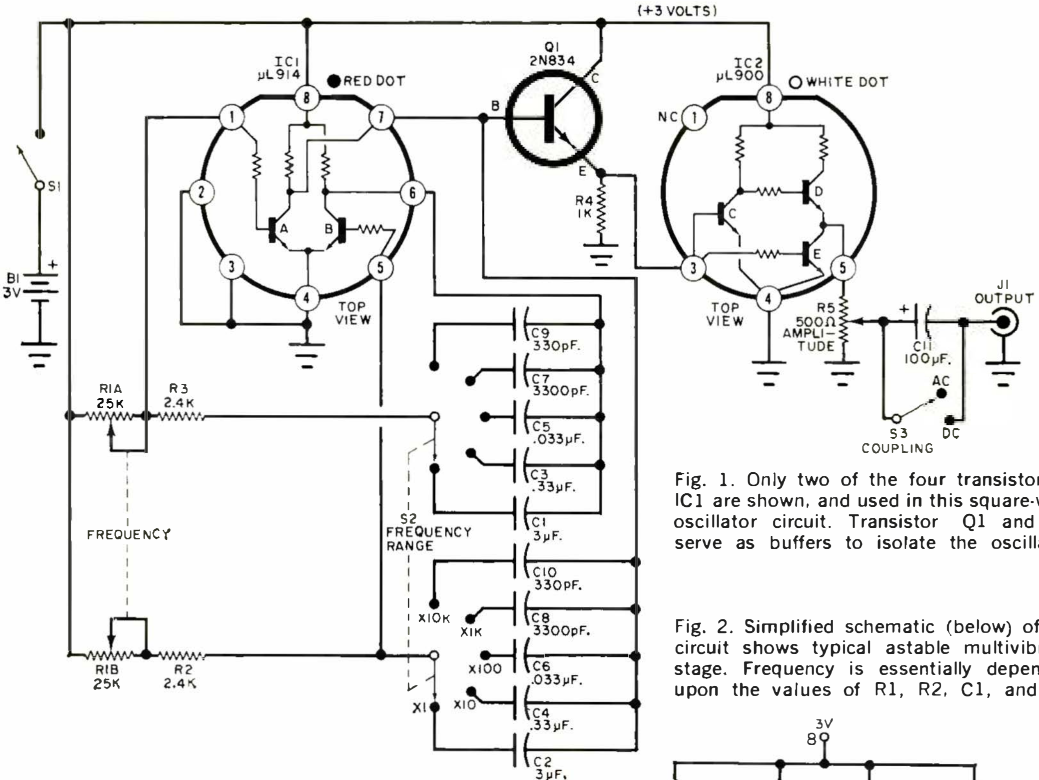
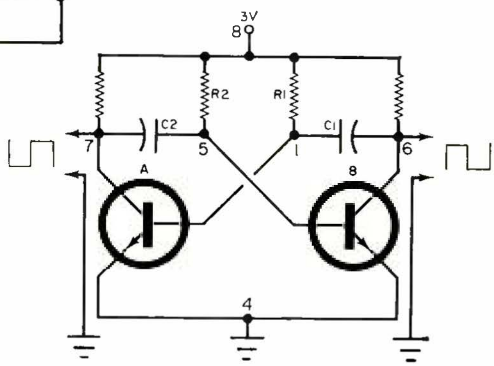


Fig. 1. Only two of the four transistors in IC1 are shown, and used in this square-wave oscillator circuit. Transistor Q1 and IC2 serve as buffers to isolate the oscillator.

Fig. 2. Simplified schematic (below) of IC2 circuit shows typical astable multivibrator stage. Frequency is essentially dependent upon the values of R1, R2, C1, and C2.



R5, and is fed out directly or through coupling capacitor *C11*, depending upon the position of *S3*. Integrated circuit *IC2* contains the equivalent of three transistors and five resistors.

Figure 2 is a simplified drawing of the multivibrator and some of the waveforms it generates. The multivibrator is free-running and does not require an external signal. When transistor *A* is conducting. transistor *B* is cut off. and when transistor *B* is conducting. transistor *A* is cut off.

The signals at the collectors of transistors *A* and *B* are identical, but of opposite polarity, as shown at terminals 6 and 7. Capacitors *C1*, *C3*, *C5*, *C7*, and *C9* in the project are represented by *C1* in the simplified drawing, and *C2*, *C4*, *C6*, *C8*, and *C10* are represented by *C2*. The length of time each transistor remains in the off state is a function of the values of *C1* and *R1* (for transistor ***A***), and *C2* and *R2* (for transistor *B*). Because the values of the components are the same in both transistor circuits, the output waveform is symmetrical.

To change the repetition rate or frequency of operation, simply change the values of either or both of the capacitors or the resistors. In the actual circuit, capacitors *C1* through *C10* provide different frequency ranges in five decade steps from *X 1* to *X 10,000,* and the ganged potentiometer (*R1a* and *R1b*) provides a continuously variable selection of frequencies within each range.

Construction. Almost any type of chassis construction can be used to assemble the *Square Deal.* A deep-drawn aluminum case and a homemade aluminum chassis are shown in the photos. The chassis is a 10" x 6 3/8" x 3/64" piece of aluminum, cut, bent, and drilled as shown in Fig. 3.

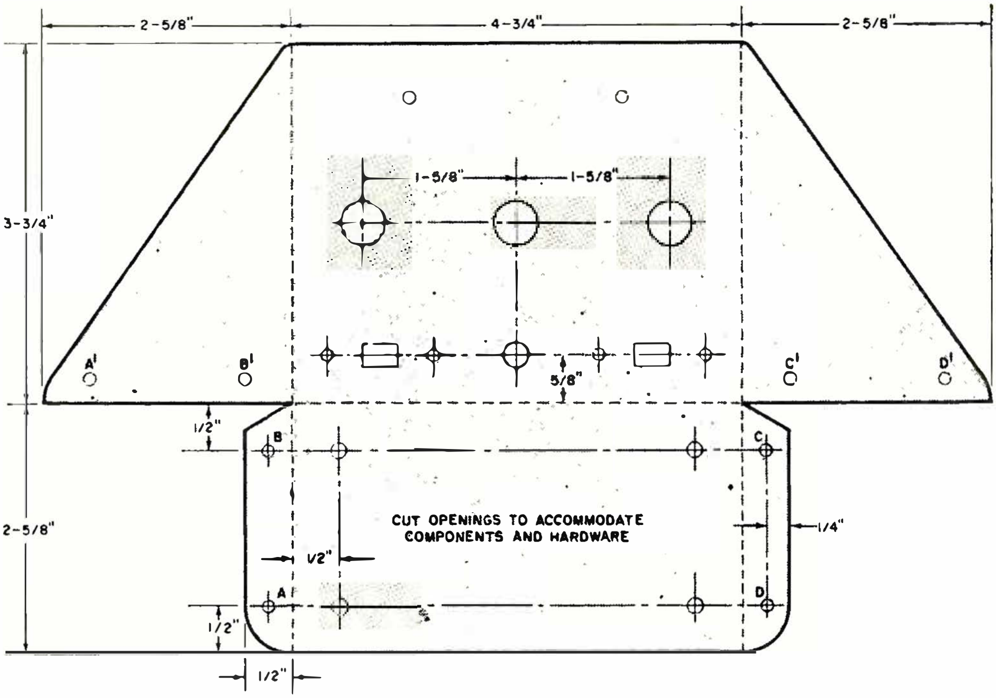


Fig. 3. Chassis can be formed from a thin piece of sheet aluminum. Drill and shape to size as shown.

Layout is not critical. If you get the ready-made front panel, you can use it to locate the holes on the front of the chassis. Pop rivets, or 6-32 x ⅜" machine screws and nuts can be used to hold things together. A 4½" x 1½" x ⅛" piece of aluminum is used as a spacer to "pull" back the controls so that the control knobs will fit closer to the panel, but you can mount an extra nut on the bushings before installing the controls, and adjust the nuts to obtain the proper spacing.

If you wish to conceal the screw heads or rivets that hold the terminal strip and switches in place, you will have to

PARTS LIST

B1—Two 1.5-volt, D-size cells
C1, C2—3-μF, 6-volt electrolytic or Mylar capacitor
C3, C4—0.33-μF, 100-volt Mylar capacitor
C5, C6—0.033-μF, 100-volt Mylar capacitor
C7, C8—3300-pF mica or polystyrene capacitor, any working voltage
C9, C10—330-pF mica or polystyrene capacitor, any working voltage
C11—100-μF, 6-volt electrolytic capacitor
IC1—μL914 epoxy micrologic dual two-input gate (Fairchild)*
IC2—μL900 epoxy micrologic buffer (Fairchild)*
J1—Phono jack (RCA type)
Q1—2N834 transistor (Motorola MPS 834)
R1—Dual 25,000-ohm carbon potentiometer, linear taper (similar to IRC 45-D253-MD253)
R2, R3—2400-ohm, ½-watt resistor
R4—1000-ohm, ½-watt resistor
R5—500-ohm, ½-watt potentiometer, linear taper
S1, S3—S.p.s.t. slide switch
S2—Two-pole, five-position, rotary switch, nonshorting type (similar to Mallory 2236J)
1—3" x 4" x 5" case (similar to Zero Z64-80A-48 or Bud Minibox CU-2105A)
1—10" x 6⅛" piece of 3/64" aluminum stock
1—1½" x 4½" piece of ⅛" aluminum stock (optional—see text)
1—Front panel (an anodized hard-aluminum METAL-PHOTO dialplate is available from Reill's Photo Finishing, 4627 N. 11 St., Phoenix, Ariz. 85014; in silver color for $2.75; in red, blue, or copper for $3.25, postpaid in USA)
Misc.—Insulated Teflon standoffs (3) optional; Sealectro's 8-lead IC sockets for TO-5 case (2), optional, available from Arrow Electronics or Joseph Kurzan, Inc., both in New York City; 5-lug terminal strip; battery holder for 2 D-size cells; small knobs (3); nylon cup washers for feet (4), wire, solder, spacers, screws, etc.

*Appropriate data sheets and distributor lists are available from Fairchild Semiconductors, 313 Fairchild Dr., Mountain View, Calif., and Motorola Semiconductor, P.O. Box 955, Phoenix, Ariz. 85001

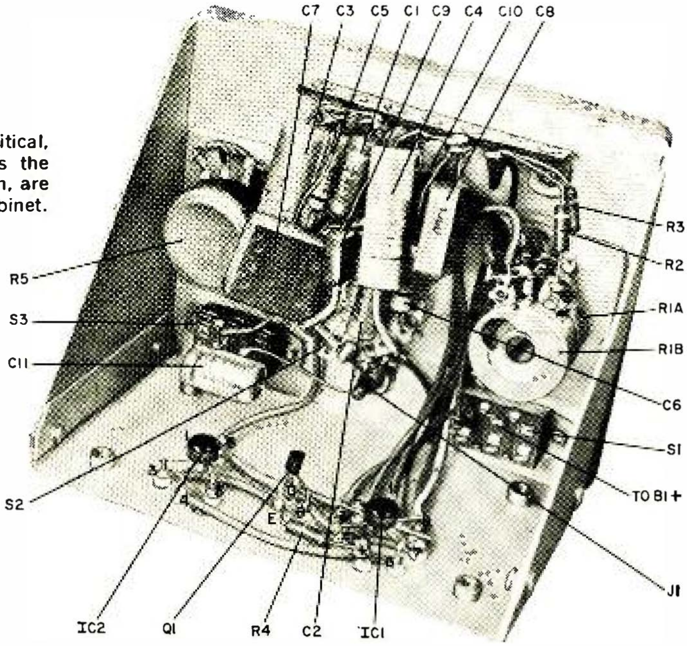


Fig. 4. Layout of parts is not critical, but be careful not to crisscross the connections. Batteries, not shown, are mounted on the back of the cabinet.

indent (dimple) the chassis sufficiently to clear the panel. Use flat-headed machine screws and countersink the holes if you are not equipped to do a good dimpling job. It's worth the extra effort . . . the front panel will lie flat, hide the hardware, and will provide you with a neat, professional-looking instrument.

Temporarily place the chassis inside the cabinet and drill four holes through the bottom of the cabinet and the chassis to accommodate suitable protective feet; nylon cup washers can be used. By drilling the cabinet and the chassis at the same time, you simplify hole alignment when the job is completed. You can use self-tapping screws, or install threaded rivet-on spacers on the chassis. Either way, the size of the holes should be appropriate for the hardware used. The screws that hold the feet in place also hold the cabinet and chassis together.

Mount a two-cell flashlight battery holder on the back of the cabinet in any convenient manner, but be alert to any clearance problems that may arise when the components are installed. Press-fit terminals, sockets, or a perforated board can be used to hold the transistor and the integrated circuits—modify the chassis to accommodate your fittings. Note: the flat, or color dot, on the integrated components identifies terminal 8; the other terminals are numbered clockwise when you're looking at them from the bottom of the epoxy case. The IC's are not interchangeable.

Rotary switch *S2* and a five-lug terminal strip anchor the capacitors. Be particularly careful not to confuse the circuit by wiring *S2* or *R1* to *IC1* improperly. If your project fails to operate, there's a good chance that you crossed the wires to these components. Follow the schematic and you won't have any trouble.

Instrument accuracy depends upon proper values of *C1* through *C10*. Without a special selection, you'll probably wind up with a full-scale accuracy of about ±15%. You can improve this figure by making a careful selection of capacitors. The *AMPLITUDE* scale is relative, and depends upon output loading and battery conditions.

Do not allow the instrument's output circuit to come across any external voltage while in the *DC* position, nor more than the rated voltage of *C11* while in the *AC* position. If you must couple into higher voltage ridden circuits, insert a suitable capacitor in series with *J1*.

Operation. There is a slight difference between *AC* and *DC* outputs. In the *DC* position, the signal is direct-coupled, and the square wave is clamped to the instrument's ground (0 volt). In the *AC* position, the signal is made to pass through a capacitor (*C11*), and the d.c. component is lost. There is as much signal above the zero-reference line as there is below it. In either case, the peak-to-peak voltage is the same.

If the d.c. component is not needed for your application, take advantage of the built-in coupling capacitor—it serves as a d.c. block, and minimizes upsetting voltage and resistance conditions in the input circuits of the equipment being worked by the *Square Deal,* as well as in the instrument's own output circuit. Audio equipment, amplifiers, speakers, etc., can be driven from the *AC* position. For logic experiments, counter circuits, and other pulse circuits, you will most likely use the *DC* position.

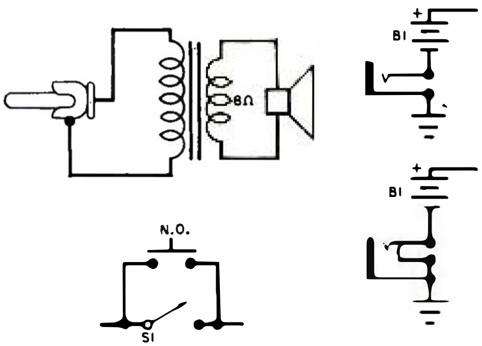


Fig. 5. Simple modifications you can make to extend the utility of the "Square Deal." See text below.

Modifications. If you add a phone jack in series with the battery, you can turn the multivibrator on and off with almost any switching device, for use in a code practice rig, annunciator, burglar alarm, or to make tone-burst tests (see Fig. 5). If you use a non-shorting type jack, the circuit will work only when the key, switch, thermostat, etc., is plugged in and completes the circuit. However, if a shorting-type jack is used, the circuit will work both ways.

Of course, you will have to plug a speaker or a set of headphones into *J1* to be able to hear the signal. Speaker volume can be increased by the use of a matching transformer. If the output of the instrument is allowed to "look" into, say, a 50-ohm load instead of an 8-ohm load, its amplitude will be significantly greater. You can use a multitapped transformer such as Stancor's TA39 for this purpose. -30-

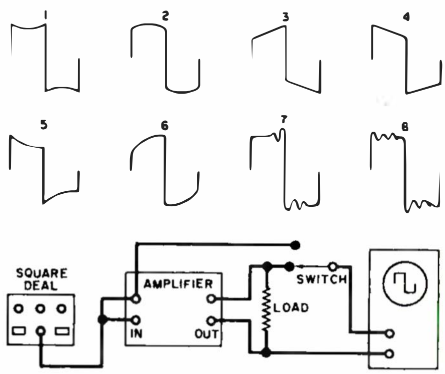
TESTING WITH SQUARE WAVES

A rapid indication of frequency response can be obtained by using two test frequencies; one low enough to reveal low frequency response and phase shift, and one high enough for some of the harmonics in the square wave to reach the upper limits of the amplifier under test. Other characteristics such as ringing or parasitics, damping, phase shift, and transient response can be determined.

Frequency response ranging from 1/10 to 10 times the fundamental frequency of the square wave can be predicted in one "shot." For example, if a 1000-Hz square wave is passed through the amplifier without distortion, the frequency response is at least 100 Hz to 10,000 Hz. To check the scope, to see that it does not distort the waveform, connect the scope directly to the generator. If the scope distorts the waveform, you can overcome this shortcoming by feeding the signal directly to the vertical deflection plates of the CRT.

An easy way to interpret the waveforms is to look for tilt and curvature. Tilt is primarily an indication of phase shift of the fundamental frequency. Square-wave testing for phase shift is quite sensitive. A 10% slope represents about a 2° phase shift. Curvature shows frequency response; a convex shape indicates good lows, a concave shape shows loss of lows. It is not unusual for the waveform to show both tilt and curvature.

Ringing is a piggyback oscillation (parasitic) sometimes caused by overboost of highs or other resonant conditions in the circuit. Not all ringing is parasitic. Some circuits, such as the horizontal deflection stage in a TV set, purposely set up a ringing condition. Damping is simply the ability of the amplifier to suppress ringing when it does occur.



Basic waveforms. Ideal shape is shown on scope. Other shapes are: (1) loss of lows; (2) boosted lows; (3) low-frequency phase lag; (4) low-frequency phase lead; (5) combination of loss of lows and phase shift; (6) combination of loss of highs and phase shift; (7) ringing, with good damping; and (8) ringing, with poor damping.