60¢ ■ SEPT. 1972

Radio-Electronics

FOR MEN WITH IDEAS IN ELECTRONICS

BUILD THIS $40 IC FUNCTION GENERATOR

ELECTRONIC WATCHDOGS
To Protect Your Home

EXORCISE TV GHOSTS
Caused By Mismatch

IC DUO-TROUBLESHOOTER
Generator—Tracer

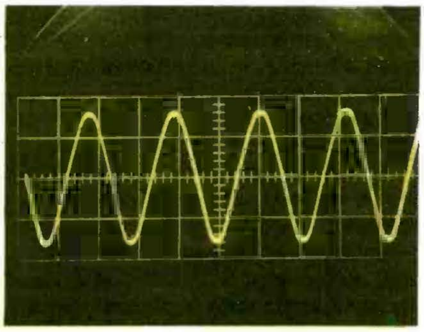
NEW TV SERVICE SERIES
Step-By-Step Fix-It Guide
This Month Art Margolis
Probes The AGC Keyer

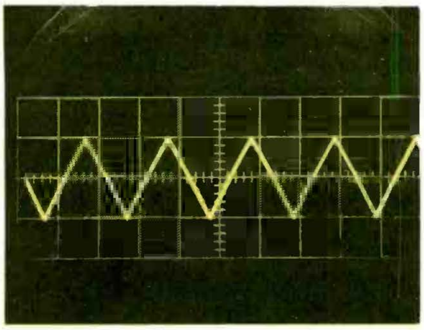
OP-AMPS AT WORK
Using The 709

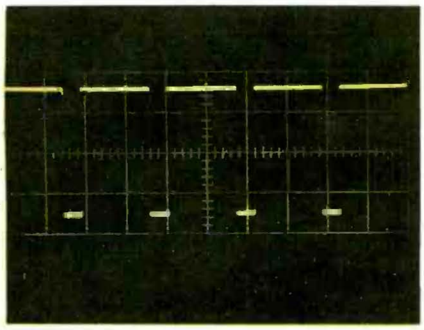
PLUS
State Of Solid State
TV Service Clinic
Solid-State Amplifier Design
Appliance Clinic

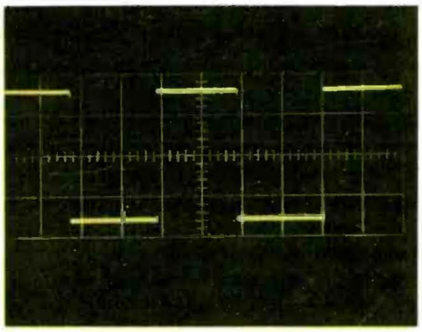
A GERNSBACK PUBLICATION

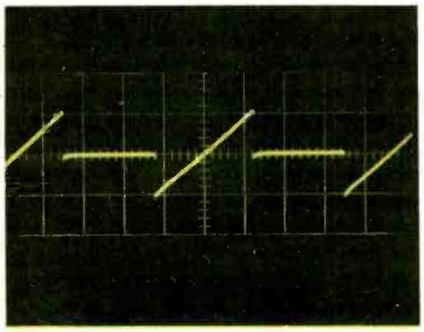
THESE FIVE WAVEFORMS, all at 1 kHz, are typical of the kinds of outputs the generator will deliver. From top to bottom they are, obviously; sine wave, triangle wave, pulses, square wave, and at the bottom, a ramp. While the patterns shown are at 1 kHz, all of these signals are available over the full range of the generator—1 Hz to 1 MHz.











BUILD THIS $40 IC

Build this 30-range universal signal square, pulse, and ramp

ASK ANYONE WHO'S EVER BEEN ABLE TO afford one, and they'll tell you that a function generator is the handiest and most versatile signal source you can own, regardless of your particular electronic interest. Function generators produce various test waveforms—sine, triangle, and square at the very least, and sometimes much more. Function generators are often the number one choice for digital logic testing and experiments, electronic music, radio, TV, and hi-fi service, servo experiments, network synthesis, general electronics service and repair, ultrasonics, analog computation, and virtually anywhere else you need a flexible and stable wide-range signal source.

The problem is that today's function generators cost at least $400, and sometimes much more. This puts them beyond the range of the student, service technician, experimenter, or serious electronic hobbiest. But, thanks to a brand new $15 integrated circuit and some simplified switching circuitry, you can now duplicate most, if not all, the capabilities of a commercial function generator for less than $40.

The **Radio-Electronics** function generator has 30 pushbutton ranges that give you sine, triangle, square, pulse, and ramp outputs over a six-decade frequency range from 1 hertz to 1 megahertz. Output amplitude is adjustable from 0 to 2 volts and may be either ac coupled, or dc coupled with an adjustable offset from -2 to +2 volts, nicely giving you pulses and other test signals of either polarity. Output impedance is around 70 ohms, and the circuit drives TTL directly.

The complete specs appear in the table. Complete kits and any and all individual parts are commercially available and you can put this instrument together in a few evenings. Thanks to special printed-circuit boards, switch wiring is greatly simplified, eliminating one of the biggest assembly headaches on any piece of test equipment. An unbreakable impact plastic case is used. If you like, you can easily add external AM, FM, pulse modulation as well as voltage control, remote gating, the whole bit. You can also use two generators—one to control the other one for really wild waveforms. Typical waveform photos of the basic instrument appear in Fig. 1.

How it works

A single function-generator integrated circuit does the whole job practically by itself, helped along only with a transistor used to compensate amplitudes. Fig. 2 shows us, in simplified form, that we can think of the circuit as made up of seven blocks. The four most complicated ones are inside the IC. The basic object of the game is to generate a waveform of the desired frequency. Then you select or alter its shape, control its amplitude, and then you control its offset, or how much dc there is to be in the output. Finally, you amplify it so it will drive a low-impedance output.

Fig. 5 shows us more details on each block. In Fig. 5-a, we see that the waveform generator is a fancy version of a multivibrator called an *emitter-coupled astable.* It has two stable states, one with Q3 conducting heavily and one with Q3 off and Q4 conducting heavily. Let's say that Q3 has just turned on, conducting heavily. Its collector voltage is low. This in turn holds the base voltage of Q4 low, temporarily insuring that Q4 is indeed off. If Q4 is off, all of the available current that normally flows through Q4 goes into the capacitor instead, charging the right end of the capacitor *negatively.* Since the charging takes place from a current source instead of a resistor, the charge on the capacitor is constantly changing with time, resulting in a *linear* ramp or a straight-line charging action.

The capacitor keeps charging until it gets to -1.2 volts. At this point, Q4 will begin to conduct, and through snap-action feedback, the circuit will flip over, and Q4 snaps ON and Q3 snaps OFF.

Now things have reversed, and the capacitor starts charging in the *other* direction. It does so until the left side goes negative enough to flip things back the way they initially were, and you have a continuous back and forth oscillation.

We note there are three outputs available. A ramp output from Q4, an out-of-phase ramp output from Q3 and a square wave from Q6. If we take the Q6 output, we have our square wave. If we take either the Q3 or Q4 output, we have our ramp. Now, if we take the *difference* between Q3 and Q4, we get a triangle wave. And finally, if we take the difference between Q3 and Q4 and round off the sharp corners, we come up with a sinewave.

Changing frequency

We can obviously change frequency by changing capacitor values, for the charging time for a constant current is directly proportional to how big a capacitor you hang on the circuit. So, looking at Fig. 3, we switch select a series of capacitors that are decade multiples (10X) of each other. This takes care of range switching.

To get a 10:1 vernier range, we have to somehow change the value of the current source at the bottom of the circuit. We can't change what's inside an IC, but we can add to or subtract from this current by sourcing or sinking some extra current at pin 13. We do this with an external potentiometer and current-limiting resistor. In the middle of the range, the pot does nothing. Make it more negative, and it *adds* to the available circuit current, and thus *increases* frequency. Make it more positive, and it steals some of the available current, leaving *less* for the circuit and *lowering* the frequency. We get a 10:1 operating range with reasonable care, and, except for some pot loading, the voltage versus frequency curve is very linear.

We can also shunt some current around Q1 and Q2 and get some added features. Normally the currents through Q1 and Q2 are very nearly 50-50, but they can go one way or the other by a few percent. This makes the square wave slightly asymmetrical, which isn't too bad. Trouble is that when we get to the sinewave output, anything but a 50-50 duty cycle will give us a bunch of second harmonic distortion in a hurry. So, we set up a high impedance pot and some big resistors (R21,R22,R23 of Fig. 6) around Q1 and Q2 to give us a symmetry control that lets us touch things up to an exactly 50-50 duty cycle.

If we shunt a bunch of current around one side, we get a very low duty cycle. This is how we get our pulse waveform. We use the square-wave output, but we unbalance things badly enough to get a 1:5 or 20:80 duty cycle. By the way, this also changes frequency, so the dial readings for the pulse output will be around half the actual pulse repetition rate.

So, the wave generator directly generates a square wave and a pair of out-of-phase ramp waveforms. If we take the difference between the ramps, we get a triangle wave. If we polish the tops of the triangle wave, we get a sinewave. Finally, if we pick the squarewave and unbalance the symmetry, we get a pulse output.

Wave shaping

The shaping circuit of Fig. 5-b is called a *variable-gain differential amplifier.* The gain is controlled by resistor R_x, and the *difference* between the two input signals gets amplified and appears as an output. A differential amplifier is a linear amplifier for small input signals or low gains. Its also a limiter or clipper for large input signals or high gains, for you can get no more current out than is available at the bottom of the circuit, nor less than zero. Converted to voltages across the load resistor, this means you get a smooth clipping or clamping action for high input levels or high gains.

So, we change both the gain and drive level to improve upon our basic waveforms. Triangle and ramp are sent through at low level and low gain; they come out the way they went in. The differential amplifier nicely converts the two out-of-phase ramps into a uniform triangular wave. For square and pulse, we heavily overdrive the differential amplifier and run the gain up very high. This gives us a constant amplitude, lots of output, and sharp rise and fall times for these waveforms.

For the sine wave, we use a moderate amount of gain and start with a triangle wave generated as the difference between the two ramps. What this

FUNCTION GENERATOR

source that generates sine, triangle, waveforms from 1 Hz to 1 MHz.

by DON LANCASTER

does is knock the sharp corners off the triangle waveshape, giving us the familiar sinewave shape, with a distortion typically around 2%. This technique is far simpler than those normally used in function generators, and this level of distortion is not even noticeable for anything but critical audio testing.

Biasing is critical on any differential amplifier. Both *inputs must be returned to the same dc level,* or the circuit goes into limiting and ignores the input signal due to the unbalance in currents caused by improper biasing.

There are two ways we use the differential amplifier in the **Radio-Electronics** function generator. For triangle and sine, we connect the inputs directly to the ramp and out-of-phase ramp outputs. These are both at the same dc level and thus give us proper bias. At the same time, the differential amplifier takes the *difference* between these two waveforms, generating a triangle wave at low gain and a rounded top triangle approximation to a sine wave at higher gain.

The rest of the waveshapes must be capacitor-coupled. To do this, we return both inputs of the differential amplifier to ground and bypass one input. This gives us a single-ended amplifier into which we can couple these square, pulse, and ramp inputs. We run the ramp at low gain, so the same signal comes out we put in. In square and pulse, we run very high gain by shorting R_x. This gives us a bigger output with completely flat tops and fast risetimes. Two small refinements complete the square and pulse coupling. The coupling capacitor is a compromise, since one that gives no droop on the 1-Hz range also gives objectionably long transients on the higher ranges as frequency is suddenly changed. To beat this, we use a relatively small coupling capacitor C6 for the higher ranges and switch in a larger C10 for the 1-Hz range. The pulse waveform has a large dc component due to its duty cycle. If we capacitor-couple, we end up with linear amplification on the bottom of the pulse and limiting on the top. This reduces pulse amplitude, but worse yet, it makes the bottom noisy and rounds the edges of the rise and fall times. To beat this, we purposely unbalance the differential amplifier slightly with R27, but *only during pulse operation.* This nicely limits both the bottom and the top of the pulse, giving us an output as big and as clean as the square-wave.

Amplitude compensation

There is a slight change of wave generator output amplitude when we operate over a 10:1 current range. Most obvious is a dropoff at the high current, high frequency and caused by larger drops in Q3 and Q4. The high-end voltage drop gets eliminated automatically in the square and pulse modes since the shaper heavily limits, and you get a constant output level. The problem isn't too bad in triangle and ramp, but in the sine position, the waveshape changes pretty drastically as you reduce the amplitude, giving you "pointy" sinewaves at the high end of any frequency range. To beat this, we raise the gain of the shaper slightly at the far end of the frequency pot. The drop in input amplitude gets made up by the increase in shaper gain, and the output sine wave amplitude and waveshape stays constant over the pot's range.

Since the pot's going the wrong

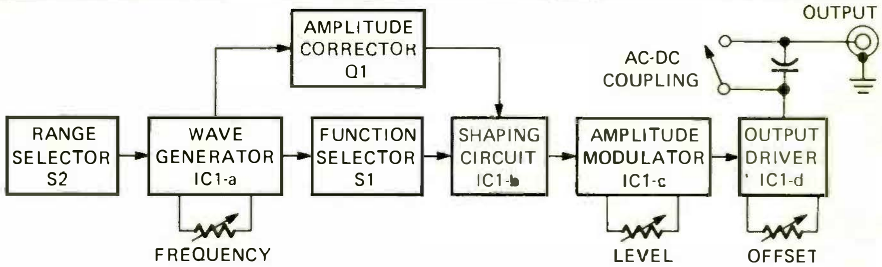
SPECIFICATIONS

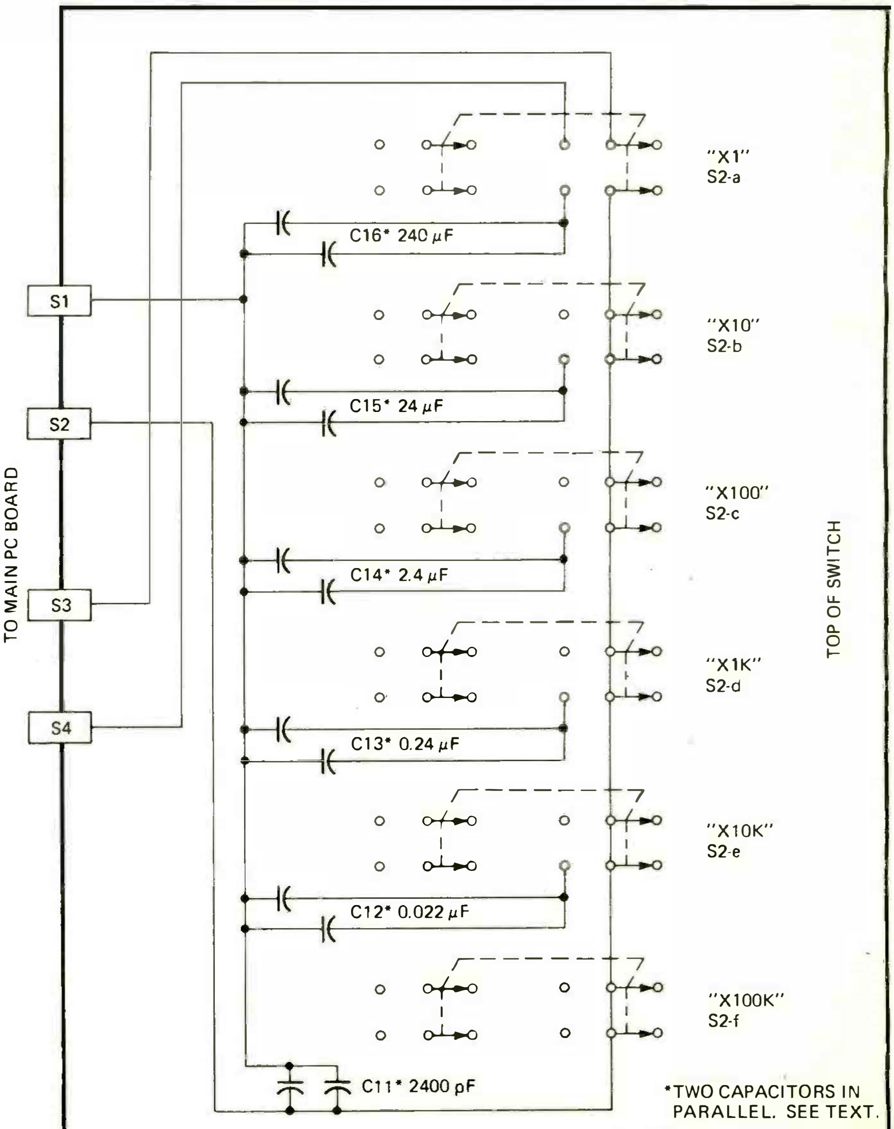
FREQUENCY RANGE: 1 Hz to 1 Mhz, pushbutton selected by decades and vernier adjusted over any one decade. Overall accuracy 2-5%

FUNCTIONS: Sine, Triangle, Square, Pulse, and Ramp

AMPLITUDE: Variable 0-2 volts Sine, Square, Pulse; 0-1.75 volts Triangle and Ramp. TTL compatable output using +0.6-volt baseline offset.

OFFSET: In DC Mode, adjustable from −2 to +2 volts giving high, centered, or low baseline. Capacitor coupled in ac mode.





S2 IS 6 STATION 4 PDT INTERLOCKING ALL SECTIONS SHOWN IN "UP" POSITION

SPECIFIC...ONS

DISTORTION: S...2%; 3% over vernier ...frequency sine wave, less ... range.

DUTY CYCLES: Pulse 20% typical; Square adjustable to 50%. Dial calibration not accurate on pulse range.

OUTPUT IMPEDANCE: 70 Ohms. Zener protected

SIZE: 2½" x 5" x 6½"; grey impact plastic case.

WEIGHT: 2 pounds

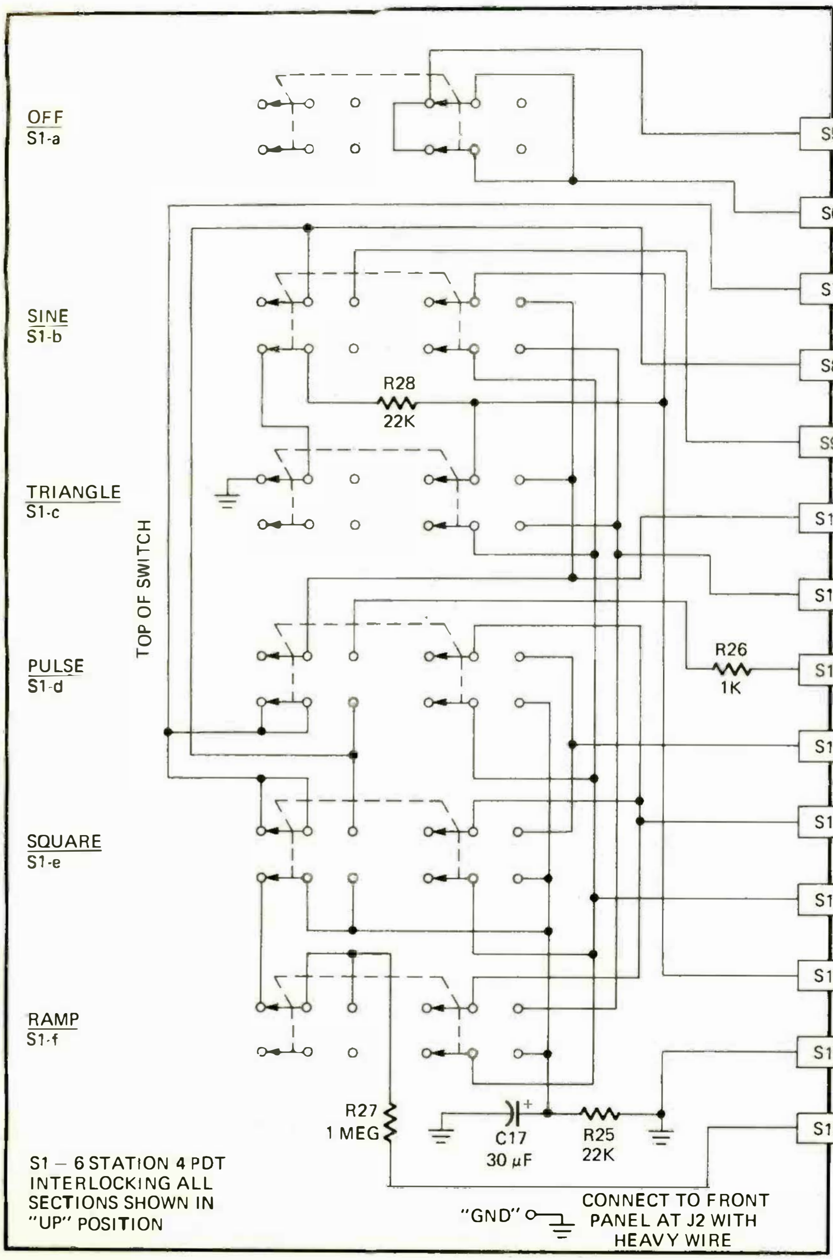
MODULATION: None in basic unit; AM, FM, VCO, remote gain, keying, etc. are easily added to the basic circuit.

way to do us any good, we invert it with a transistor and use this control voltage to steal a small amount of the shaper's current source. This increases the shaper gain as R_x is now smaller with respect to the circuit currents than it was before. By keeping the transistor saturated for part of the pot's range, we don't start any correction till we need it. More and more gain is added as we get to the end of the pot. Looking ahead at Fig. 6, we see that R31 and R32 decide *how much* gain we add at the high end, while the *ratio* of R29 to R30 decides *when* in the pot's rotation the gain correction is to begin.

FIG. 2—(left) BLOCK DIAGRAM OF GENERATOR gives an overall look at how the unit operates. The one IC does the lion's share of the work.

FIG. 3—(bottom left) RANGE-SWITCHING CIRCUIT is on a separate printed-circuit board. An interlocking push-button switch, that mounts on this board, is used.

FIG. 4—(below) FUNCTION-SELECTOR SWITCH forms another subassembly on a separate circuit board. Again an interlocking pushbutton switch is used and is mounted on the board.



We control the gain with an electronic modulator as shown in Fig. 5-c. We can also inject signals here for amplitude modulation, remote volume control, keying, etc. If we like. The circuit is a true multiplier, which means it doubles as a balanced modulator. The circuit works by letting both the input and the control provide only a fraction of the available current to the output. Since the two fractions are cascaded, the *product* of the input and control appears at the output. Polarity may be controlled by reversing the difference in voltage on the control inputs. Zero difference gives zero gain, and one volt gives full gain, the polarity of the input determining which side of the waveshape ends up on top. The electronic gain control is internally directly connected to the shaper; all we have to do is connect up an external gain control or signal. Note that no waveforms have to travel through the pot and we can easily and safely use long leads without worrying about high frequency response falling off and causing misleading conclusions from the tests you are performing.

Output buffer

A Darlington differential amplifier converts the output signal to one with enough current drive to handle a short circuit or another low-impedance load without damage. To adjust the offset, or how much dc we get out in addition to the waveshape, we capacitor-couple the buffer's input and add a variable bias that we control with the offset potentiometer. We also provide an output coupling capacitor that we short out when we want variable offset and insert for ac work.

Circuit of the generator

The complete schematic is shown in Figs. 3, 4 and 6. Capacitors C11 to C16 select the decade frequency ranges, while R17 selects the vernier frequency and drives amplitude compensator Q1. Pots R9 and R11 put limits on the frequency control, so we can calibrate the upper and lower frequencies on the dial. Selector S1 picks the function we want and controls power to the +10,–10 volt conventional Zener supply.

R19 controls the triangle waveshape, while R19 and R20 together control the sine waveshape. R21 to R23 provide the symmetry control, while R13 controls offset. Square, pulse, and ramp coupling is handled by C6, helped along C10 on the 1-Hz range. R27 switches in only during pulse operation to give a good pulse waveform.

The switching may seem complicated, but its really simple, particularly since the switches mount directly on the board, S1-a controls the ac power. If this button is *up,* the power is on. S1-b handles the sine wave. It first connects the shaper differentially to the

...d ou...
...ate a tr...phase ramp outputs to switches in enough... wave. Then it shaper with R20 to giv...increase in the output. Finally, it prevents the sine wave getting into the circuit. R22 is used to bias the shape.

That's all we have room for in this issue. Next month we will conclude the story by presenting the remaining text on construction and operation along with a complete set of circuit-board patterns, both foil and parts placement diagrams.

R-E

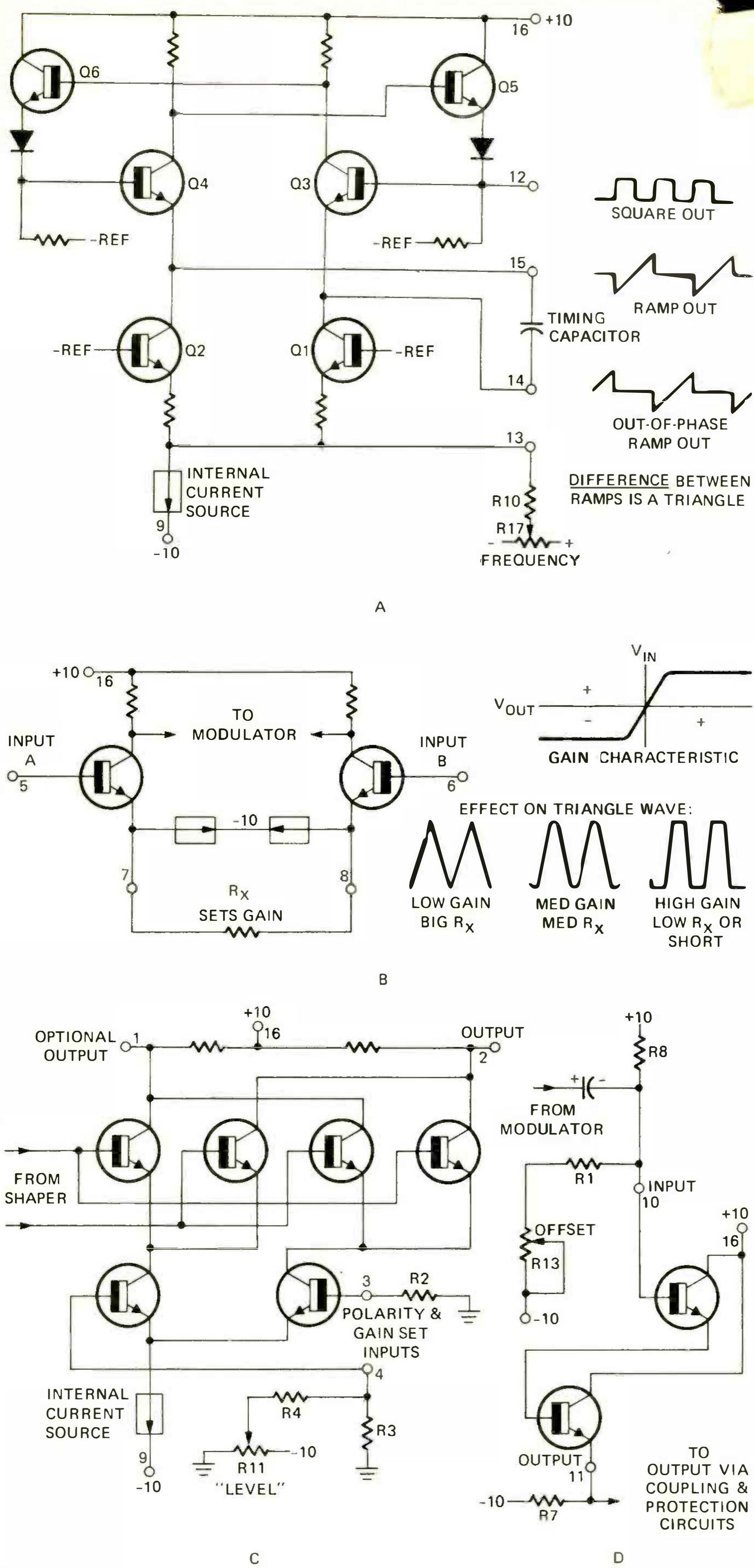


FIG. 5—SIMPLIFIED DIAGRAMS OF PORTIONS of the waveform generator's circuitry. a—basic emitter-coupled astable multivibrator. b—shaping circuit is called a variable-gain differential amplifier. c—electronic modulator controls the gain. d—output driver.

PARTS LIST

C1—1 μF, 400 volts, mylar
C2,C7—0.22 μF, mylar
C3,C9—500 μF, 12-volt electrolytic
C4,C5—1000 μF, 25-volt electrolytic
C6—3 μF, 6-volt tantalum
C8—6000 μF, 10-volt electrolytic
C10—50 μF, 6-volt tantalum
C11—Two parallel capacitors, 2400 pF, 2%
C12—Two parallel capacitors, .022 μF, 2%
C12—Two parallel capacitors, 0.24 μF, 2%
C14—Two parallel capacitors, 2.4 μF, 2%
C15—Two parallel capacitors, 24 μF, 2%
C16—Two parallel capacitors, 240 μF, 2%
C11—C16 Value shown is total capacitance
See October issue for capacitor selection details
C17—30-μF, 12-volt electrolytic
C18—0.1 μF, disc ceramic
D1,D2—Silicon power diode, 1 amp, 50 PIV, 1N4001 or equiv.
D3,D4—10-volt Zener, 1N4740 or equivalent
D5—15- to 20-volt Zener, 1N4744 or equivalent
F1—0.1-ampere fuse
IC1—XR-205 Function Generator IC (Exar)
J1,J2—5-way binding posts, 1 black, 1 blue
Q1—2N5129 transistor, silicon npn
R1,R25,R28—22,000 ohms, ¼ watt
R2,R3,R29—4700 ohms
R4,R31,R32—47,000 ohms
R5,R21,R22,R30—10,000 ohms
R6,R24—12 ohms
R7—1500 ohms
R8—33,000 ohms
R9—1000 ohms upright PC potentiometer
R10—680 ohms, ¼ watt
R11—1000 ohms upright PC potentiometer
R12,R18—330 ohms, ¼ watt
R13—50,000 ohms linear potentiometer with spst pull switch
R14—5000 ohms linear potentiometer
R15,R16—100 ohms, ½ watt
R17—1000 ohms linear potentiometer
R19—5000 ohms upright PC potentiometer
R20—5000 ohms upright PC potentiometer
R23—250,000 upright PC potentiometer
R26—1000 ohms, ¼ watt
R27—1 megohm, ¼ watt
S1,S2—six station, 4PDT interlocking
S3—spst pull switch on R13
T1—Power transformer: 20 Vct @ 60 mA, PC mount, *Signal* PC-20-60

MISC: Main, Selector, and Range PC boards, punched front panel; impact plastic case; line cord; ¾" knobs (2); skirted 2¼" knob with special calibration; flat cable or wiring harness; capacitor clip; no skid feet; fuse clips; PC terminals; angle brackets (4); mounting hardware; plastic machine screws for front panel; mylar button callouts; ground lug; wire; sleeving; solder.

NOTE: The following are available from Southwest Technical Products, 219 West Rhapsody, San Antonio, Texas, 78216
Set of three PC boards, etched and drilled FGb, $8.25
Complete kit of all above parts FG-1, $39.95

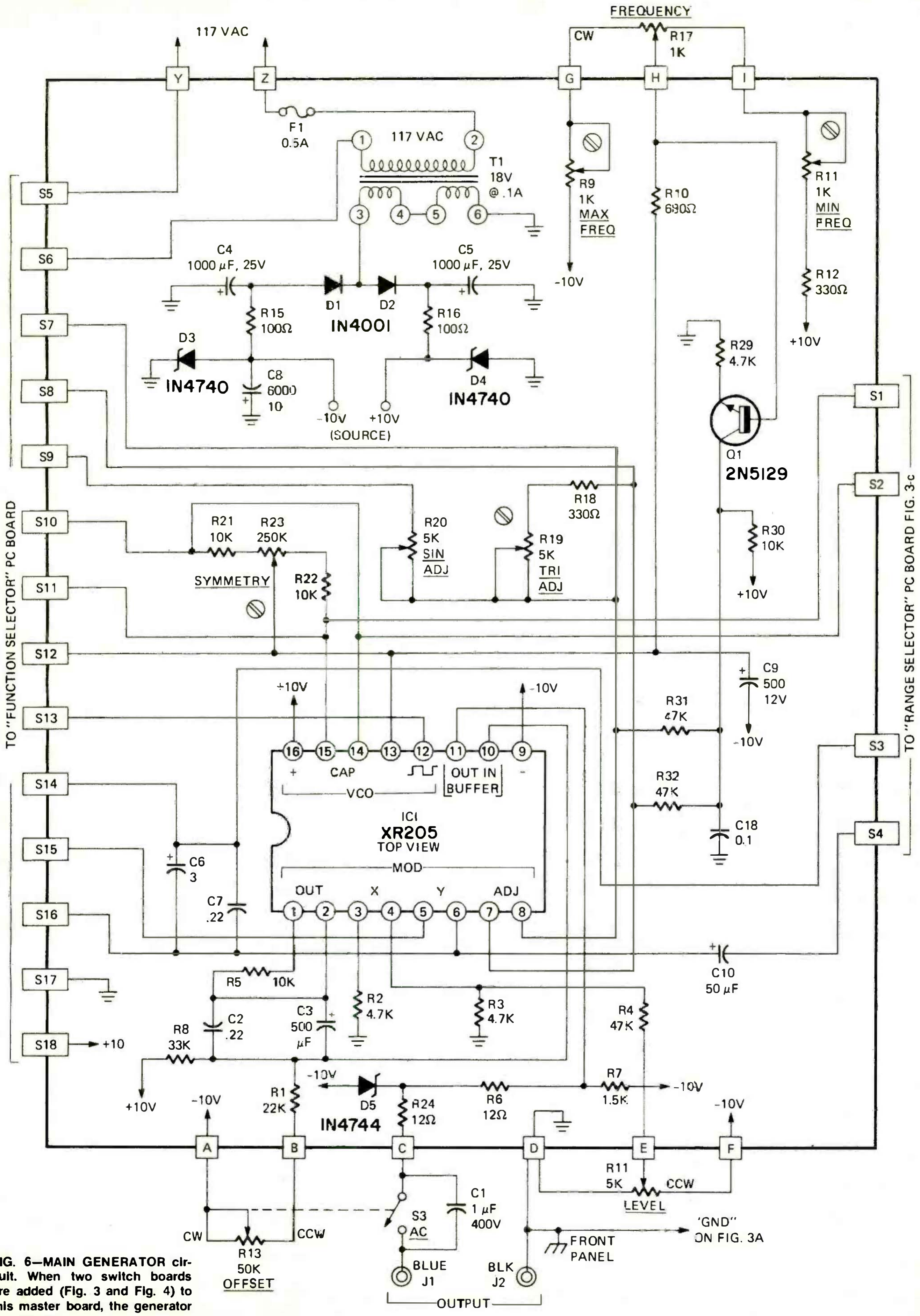
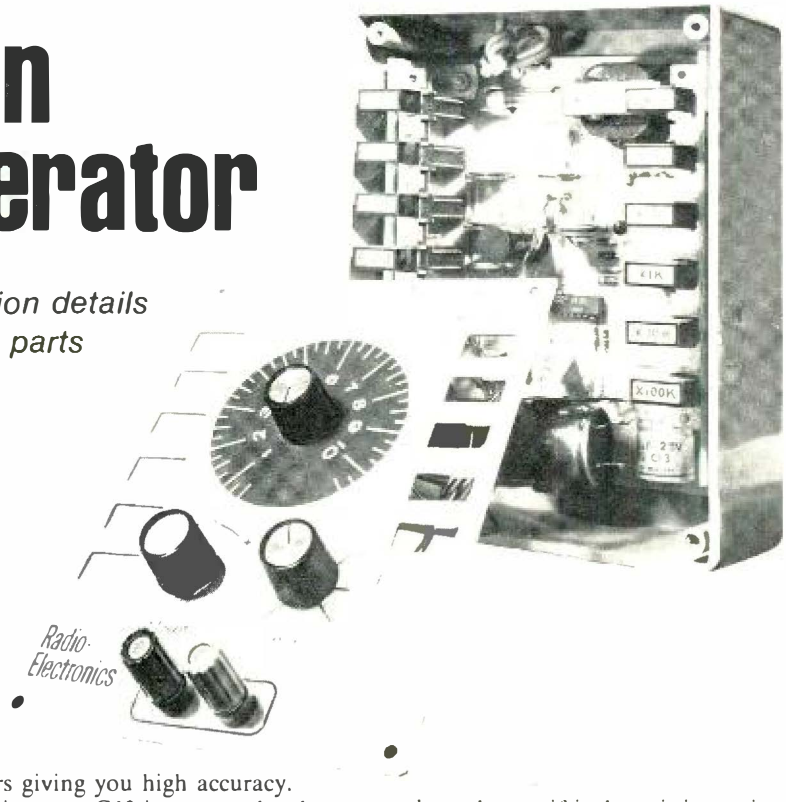


FIG. 6—MAIN GENERATOR circuit. When two switch boards are added (Fig. 3 and Fig. 4) to this master board, the generator is complete.

R-E's Function Generator



Part II: Final assembly and construction details including printed-circuit patterns and parts placement diagrams

by DON LANCASTER

LAST MONTH WE PRESENTED THE FIRST part of this article on a $40 function generator build around a single IC that could deliver five different waveforms. This issue we complete that article by presenting the remaining text and diagrams.

The pulse is handled by S1-d. It first sets up the shaper for single-ended capacitor-coupled operation. Next it shorts the shaper's gain control, giving full limiting. Finally, it unbalances the wave generator with R26 to get the pulse duty cycle. *If* we had a fifth deck on S1-d, we'd use it to switch in the shaper unbalancer R27 needed for good pulse amplitude and risetimes. We don't have this switch available, so we use the *normally closed* contacts of S1-e and S1-f, the SQUARE and RAMP selectors. Thus if the PULSE switch is depressed, SQUARE and RAMP obviously are not, and the resistor is switched in.

S1-e is the SQUARE select which connects the shaper for a single-ended capacitor-coupled input. It also runs the shaper gain wide open, and prevents R27 from being in the circuit. Finally, it connects the wave generator's square-wave output to the shaper.

S1-f is identical to S1-e, except it connects the ramp output to the shaper.

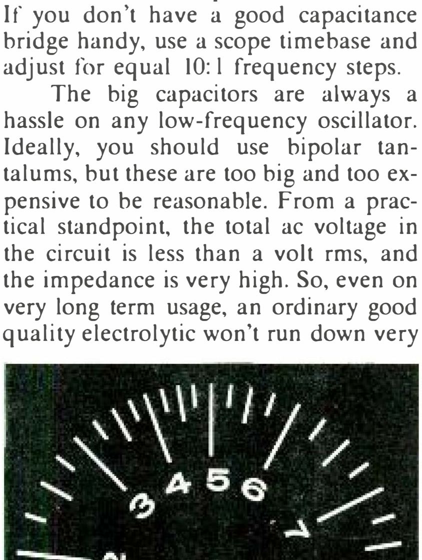
S2 is much simpler. All it does is switch in a selected capacitor for each frequency range. It also switches in an anti-droop capacitor C10 only on the X1 range.

About the capacitors

The instrument will be a no more accurate than the capacitors you select. 2% tolerance or better yet 1% tolerance is needed for range-to-range accuracy. To beat buying very expensive capacitors, you use a parallel pair of capacitors with roughly a 10:1 range of value. Measure the big one and select the small one, and you get by with plain old capacitors giving you high accuracy.

For instance C13 is supposed to be 0.24μF. Virtually any 0.22-μF capacitor you get will be lower than this value, so get one and measure it. If it is exactly 0.22μF, put a plain old 0.02-μF in parallel with it. If it's 0.23μF, use an 0.01μF. If it's 0.21μF, use a parallel 0.03μF, etc. If you don't have a good capacitance bridge handy, use a scope timebase and adjust for equal 10:1 frequency steps.

The big capacitors are always a hassle on any low-frequency oscillator. Ideally, you should use bipolar tantalums, but these are too big and too expensive to be reasonable. From a practical standpoint, the total ac voltage in the circuit is less than a volt rms, and the impedance is very high. So, even on very long term usage, an ordinary good quality electrolytic won't run down very much, and even if it does, it just raises the frequency a bit. So the reasonable thing to do is to use ordinary high-quality electrolytics, and if extreme accuracy is needed, check up on them every six months or so.



FOLLOW THIS PATTERN to make the dial for your unit. Final size is 2 9/16-in. wide.

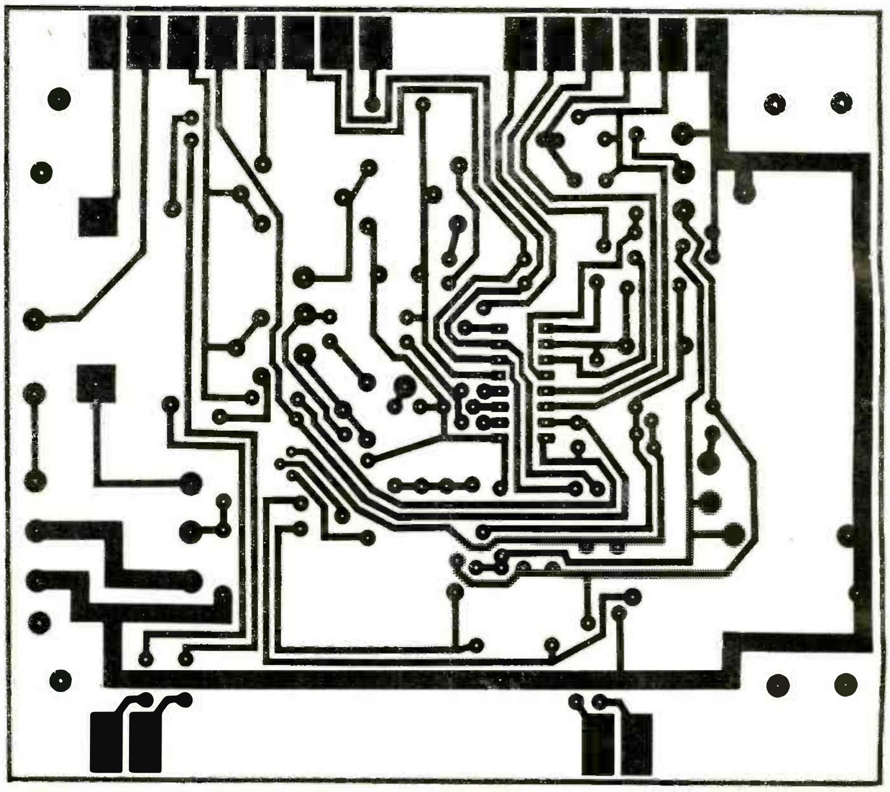
Note that C11, the X100K capacitor is in the circuit all the time, and that C12 is slightly smaller as a result. This prevents the function generator from taking off at a very high frequency in-between button pressings, and also eliminates a minor starting problem.

Building it

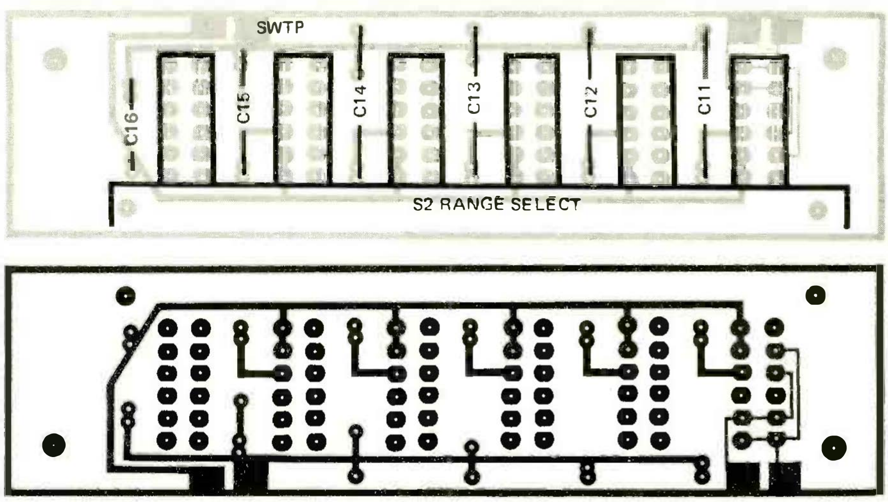
Three PC boards are needed for assembly. Two of them support the switches, while the third holds almost everything else. These are commercially available, but if you are building your own, complete details appear in the following pages. You can start assembly with the switch boards, placing the smaller components and wire jumpers exactly as shown. The switches are then soldered in place. After that, any terminals that may interfere with the main circuit board may be clipped short. Wire the switch assemblies to the main board last.

To put together the main board, start with the input and control terminals, followed by the jumpers, fuseholder, resistors, and finally the major components. Use sleeving on the jumpers where indicated. IC1 is identified by

(continued on page 50)



FOIL PATTERN OF THE MAIN CIRCUIT BOARD. Actual size of this board is 5 inches high and 5¾ inches wide. Two other boards plug into this one. They are the range-select and mode-select assemblies, also shown on these two pages.



RANGE-SELECTOR BOARD DETAILS. Foil pattern of board must be enlarged to 5¼ inches wide. Top diagram shows parts placement on this circuit board.

a code dot and notch beside pin *one*. Its shown *top view* everywhere. Be sure pins 1 and 2 of the power transformer go to the 110 volt line side or you'll have extensive damage on your hands. Also be sure to watch out for diode and capacitor polarities.

After the main board is complete, *loosely* bolt the switch boards in place with right angle brackets. Be sure the function selector is on the left and the frequency selector is on the right. The main circuit board may then be bolted temporarily into the impact plastic case. Now, check the front panel alignment with the pushbuttons to make sure everything works smoothly. If you have to, adjust the angle brackets slightly to get smooth operation. Once everything fits nicely, tighten the switch circuit boards down firmly and remove everything from the case.

Wire jumpers or resistor ends may now be used to solder together the pads on both switch boards to the main board. You can then mount things back into the case, adding the line cord and an anti-strain knot. No-skid feet may also be added.

Mount the front panel components and wire them to the main circuit using a small harness or flat cable if you have it; or neatly laced cable if you do not.

The frequency dial is slightly nonlinear; a suitable replica is on page 45, or you may prefer to calibrate your own dial for extra accuracy. Either way, be sure the dial markings coincide with the pot's range when you push the knob in place.

A single heavy ground lead must be added from the terminal provided on the function selector board to the front panel and output Black terminal. Be sure to connect this wire exactly this way. Other grounding schemes (or a lack of them) can give you a little glitch in the top and bottom center of the sinewave. After applying stick-on Mylar callouts to the pushbuttons, your unit should be complete and ready for test.

Preliminary checkout

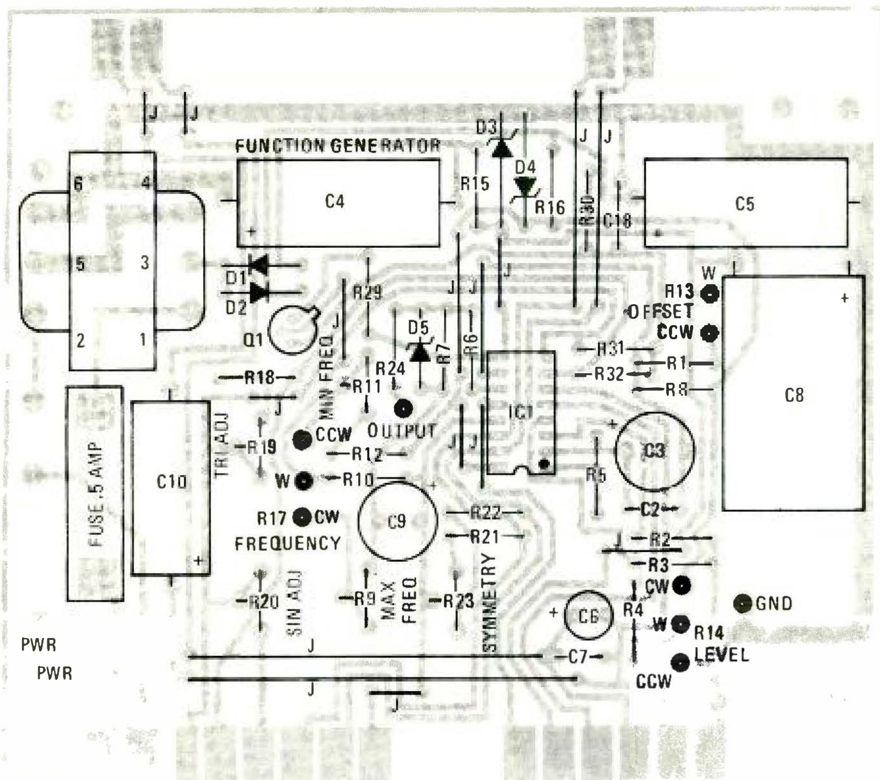
Center all the controls, and apply power *very briefly*, measuring the voltages across Zener diodes D3 and D4, and looking for the +10 and -10 values. If the voltages are low or if a scope shows hum at this point *stop and find out what is causing the excess current flow*. If things look OK, apply power again for 15 seconds and measure any temperature rise in IC1 with your finger. It should be negligible or only very slightly warm. Again, if its too hot, stop and find out why.

Now, set the unit to a 400-hertz square wave and with a scope, check pin 12 of IC1 for a 2-volt square wave. Check for out-of-phase ramps at pins 14 and 15. Turn up the level. You should get a 2-volt square wave here, verifying that the shaper and modulator are also working. Finally, check the output for the same 2-volt square wave.

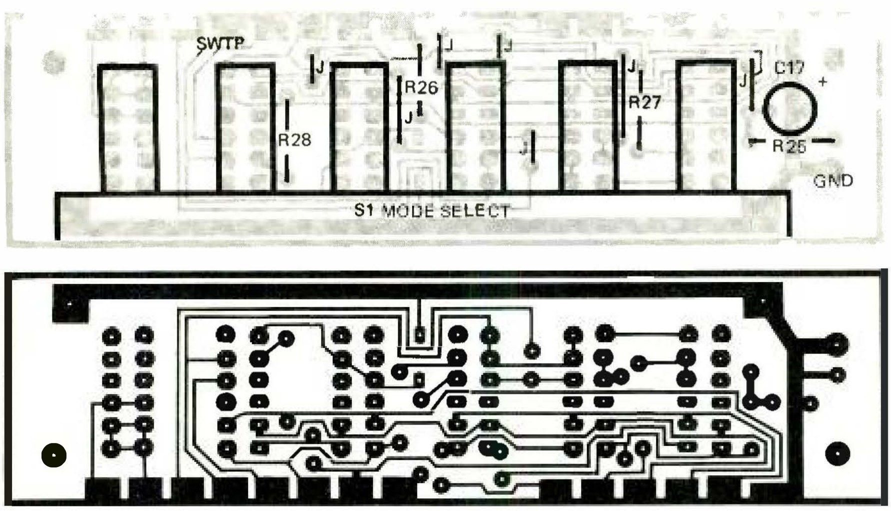
Next, check out the offset adjustment and proper operation of the pull switch. With the switch OUT, you should get dc coupling and variable offset. With the switch IN, you should get ac coupling. Check the frequency pot over its range. Don't worry if funny things happen at either end unless they're still there after you go through the calibration procedure. Check for droop on the 1-Hz range. Now, check the other functions. Pulse should look like square, only with a 5:1 duty cycle. Triangle may be rather small or may have bent tops; calibration will fix this. The same thing is true of the sine; and ramp; while they might look funny before calibration, the important thing here and now is that they exist. If everything seems to be there, you're ready for calibration. If there's any problem, go back to figure two and isolate where the problem seems to be. Don't attempt to calibrate an instrument that doesn't seem to be working right.

Calibration steps

For top-notch performance, you should calibrate your function generator. You'll need a good oscilloscope for this and, while not essential, a counter



MAIN CIRCUIT BOARD SHOWING WHERE PARTS ARE MOUNTED. In addition, the mode-select board and the range-select board are connected to the main "mother" board. The only wiring external to these boards connects to the front panel of the instrument.



MODE-SELECTOR BOARD DETAILS. Foil pattern of this board must be enlarged to 5¼ inches wide. Top diagram shows parts placement on this circuit board.

would also be handy.

To start the calibration, center all pots. Select dc coupling with zero offset, maximum amplitude and a 400-Hz square wave. Now:

1. Adjust the SYMMETRY control for exactly a 50% duty cycle of the output when viewed with a good scope.

2. Switch to TRIANGLE and adjust for the largest *undistorted* triangle output you can get and then back it off just a bit. Use TRIANGLE ADJUST control R19 for this step.

3. Switch to SINE and adjust for the best looking sine wave using SINE ADJUST R20. If you ever readjust the TRIANGLE ADJUST, you'll also have to readjust SINE ADJUST.

4. Switch back to SQUARE, and set the frequency knob to "1" on the 100-Hz range. Now adjust the MIN FREQ potentiometer R11 for a 100-Hertz squarewave or a 100-millisecond period.

5. Change the FREQUENCY knob to "10" and adjust MAXIMUM FREQUENCY potentiometer R9 for a 1-KHz squarewave or a 1-millisecond period.

6. Redo steps 4 and 5 as often as you have to till there's no more interaction. Twice through is usually all it takes.

7 Verify operation of the other frequency ranges and the PULSE and RAMP outputs.

Your instrument is now fully calibrated and ready for use. If you have no means of calibration at all, just set all the internal pots to their mid range, and you'll still have a reasonably useful, if somewhat inaccurate piece of test gear.

After you've gone through the calibration, any end effects that showed up on the frequency knob should now be gone. You might like to doublecheck the amplitude compensator Q1. To do this, switch to X100 and a triangle wave and compare the "1" and the "10" amplitude on a scope. They should be very nearly the same. If the "10" is smaller, try lowering R31 and R32 slightly, and vice versa. If there is a hump in the middle, try lowering R30. If there is a dip in the middle, lower R29. Optimum compensation should be a very slight dip followed by a very slight rise. Finally switch to sine and note an undistorted and uniform sinewave over the whole range. Adjustment of the amplitude compensator is a very fine point and shouldn't be necessary in a properly working unit.

Operating hints

Use the dc position with zero offset unless you have to couple into a high-voltage, tube-type circuit or something similar. Note also that the ac-coupling capacitor is rather small and forms a high-pass filter whose lower cutoff is determined by the load you hang on the generator. For very-low-frequency work or very heavy loads, you'll want to substantially increase the value of this capacitor.

To drive TTL, use the pulse or square output and turn it up to the full 2 volts. Now adjust the offset control for a positive baseline offset of 0.6 volts. This gives you a signal that exceeds the TTL 1-0 requirements and you can easily drive any TTL logic circuit. DTL and RTL are also easy to drive, and a simple interface works with MOS logic. For MECL logic, simply use some negative offset and you're home free.

If you need some of the fancier capabilities of professional function generators, you can easily pick them up. For instance, you can apply a differential control voltage to pins 3 and 4. This gives you an amplitude modulator, a remote volume control, a phase control (reverse the polarity for an upside down waveform, or a way of off-on keying.) You can also use this for single sideband modulation or ordinary AM by capacitor-coupling a suitable signal to the present level control input. Or, a voltage replacing the frequency control gives you a VCO (Voltage Controlled Oscillator), a frequency modulator, or a way of frequency shift keying. For high modulation frequencies, you'll want to reduce C9 or delete it entirely. Its in there to keep from hum modulating with external pickup. **R-E**

letters

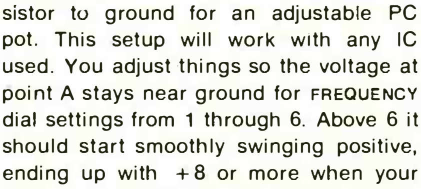
MORE ON THE FUNCTION GENERATOR

Several problems crept into the **Radio-Electronics** Function Generator story (September and October 1972). The pulse waveform is shown upside down in the photos. On the overlays, timing capacitors C11 through C16 are shown interchanged; the largest capacitor goes with the lowest frequency at the top of the instrument. The input POWER callouts should, of course, go up with the input terminals on the fuse and power transformer.

Resistor R27, the 1-megohm pulse unbalancing resistor should go to +10 volts as called out in the schematic. The PC overlay and master has this going to −10, which gives you one-third amplitude and very noisy pulse putput. Carve and jumper the PC board so that this resistor runs to +10.

There is enough linearity variation from IC to IC that you'll want to custom calibrate your frequency dial to match the particular IC you are using. A larger value resistor for R10, perhaps 1000 ohms or 1200 ohms should be used unless your particular IC will not provide enough range. This improves linearity and makes the control setting easier and more stable.

The amplitude compensator shown seems to work only with certain XR-205 chips. A better circuit looks like this:



Note that all we've done is add a series resistor to the base of Q1 and exchange the old 4700-ohm R29 fixed resistor to ground for an adjustable PC pot. This setup will work with any IC used. You adjust things so the voltage at point A stays near ground for FREQUENCY dial settings from 1 through 6. Above 6 it should start smoothly swinging positive, ending up with +8 or more when your frequency dial reads 10. For more correction at the high end, reduce R31 and R32, and vice versa. The new pot decides when in the FREQUENCY dial rotation the correction begins. Amplitude compensation only affects the sinewave distortion and the high frequency triangle and ramp size; it is bypassed in the square and pulse modes.

All of the commercially available kits have picked up all of these additions and corrections and include a slightly heavier power supply than the original called for.

DON LANCASTER
Phoenix, Ariz.

NEED SERVICE DATA

They have opened a new Radio & TV Repair Course here in high school for juniors and seniors. We are in need of a complete set of Sams Service notes from 1 to date, or we would accept 500 to date. We are also in need of used test equipment of all kinds. We will be glad to pay a reasonable price and will answer all letters.

RALPH DOROUGH, *Instructor*
Killeen High School
Vocational Building
3101 Clinkenbeard Dr.
Killeen, Texas

WHO ARE THEY?

I have a question about the article "State Of Solid State." **Radio-Electronics,** October, 1972. At one point the text mentions Signetics and Integrated Systems Inc. At another point the text mentions EXAR IC's. Are EXAR and Integrated Systems the same? I am most interested in building a low-cost speedometer and tachometer. Could you provide information on a source for IC circuits?

ROBERT N. SLEGHT
Laramie, Wyo.

EXAR and Integrated Systems are indeed the company. The correct full name and address is EXAR Integrated Systems Inc., 733 North Pastoria Ave., Sunnyvale, Calif. 94086.

I have not, at this date, seen any circuit diagrams that would meet your needs for the speedometer. We are, however, negotiating with an author for the purchase of his article on a digital IC tachometer. Tentatively, this story is scheduled for publication in our April 1973 issue.—Editor

NO MORE SUPPLIERS?

I recently ordered some parts from Newark Electronics. Their reply to me was "We no longer accept orders from individuals. Therefore we are returning your order."

STEVEN W. RUSSELL **R-E**