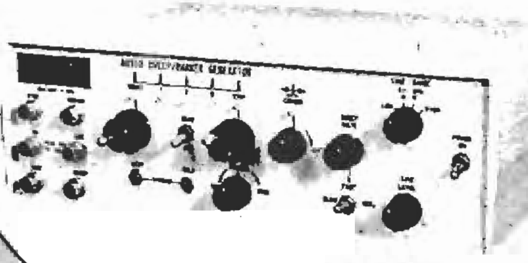
AUDIO SWEEP/MARKER GENERATOR

JOHN WANNAMAKER

Build this sweep/marker generator and discover the audio-range frequency response of your amplifier or filter design.



A PICTURE IS WORTH A THOUSAND words—especially when you're trying to determine the frequency response of an audio amplifier or filter design. Our sweep/marker generator lets you create an oscilloscope display that shows the response of an of an audio system. It can be a useful tool for designing and analyzing amplifier and filter circuits.

With the sweep/generator, the user programs a desired frequency range that is swept into the input of the device under test. The response curve of the frequency sensitive circuit is displayed on the scope screen. When using a conventional storage scope, multiple response curves can be superimposed for a helpful comparison of waveform characteristics.

The sweep/generator can be used to examine the tuning response of an amplifier, check circuit stability or even be used by acoustic engineers. Let's take a closer look into the operation of this versatile unit.

Operating features

The sweep/generator operates in two basic modes; READ or RUN. In the READ mode, the frequency sweep range can be programmed by adjusting the START and STOP multi-turn potentiometers on the front panel. Three user adjustable frequency ranges can be swept into the device under test—3 Hz to 1000 Hz, 35 Hz to 20 kHz, and 3 kHz to 100 kHz. The user adjusts the exact beginning and end of the frequency range to be swept.

While in the RUN mode, each of the frequency ranges may be swept in its entirety, or any portion of the range, as low as 0.4%, may be swept. The upper 100-kHz frequency range may have up to 12% error over the entire band, the amount of error is roughly reduced in proportion to the amount of the band being swept.

There is also a SWEEP RATE potentiometer, which can be adjusted from 50 milliseconds to 30 seconds per ten graticule divisions in each of the three frequency ranges. The SWEEP output provides a sawtooth ramp for the X input to an oscilloscope.

The frequency range that is being swept uses five markers, or brightened spots, equally spaced at 25% intervals along the horizontal graticules. The first and fifth markers are adjusted to the outer most graticule lines. The frequency at each graticule line can then be determined by taking the difference between the start and stop frequencies and dividing by ten. All markers are indicated on the front panel LED's. Figure 1 shows a swept sine output of the sweep/generator displaying such markers at 25% intervals along the horizontal graticule lines.

When you are in the RUN mode, the markers should be turned off when sweeping. A momentary overshoot could occur that is not actually present if the marker switch was on during sweeping. That effect is less likely to happen at higher frequencies.

The amplitude level of the swept sine-wave output may be varied from 10 millivolts to 5 volts peak-to-peak by the SINE LEVEL control. The output impedance is about 700 ohms, and the output level is maintained within 0.5 dB from 10 Hz to 100 kHz. Two on-board trimmer potentiometers allow adjustment of the sine shape to as little as 0.5% total harmonic distortion. The very act of sweeping generates its own type of distortion, which can be minimized by using a long-duration sweep.

Another feature of the READ mode is its capability to move between the five markers and cursor with the SKIP button, and stay at a position with the HOLD button. When held at a particular position, the frequency of that marker or cursor can be read on the front panel display. The initial display is dim, when it brightens after a few seconds you'll have an accurate frequency reading.

The cursor is an additional marker which can be adjusted to a particular point of interest while in the RUN mode. The user can move the cursor marker with the CURSOR potentiometer to any point on the swept frequency. The CURSOR is best used to determine the frequency of a point before going to the memory mode. The cursor frequency is read in the READ mode the same way as the marker frequency is read.

Input and output jacks are located on the front panel for connection to an audio amplifier or

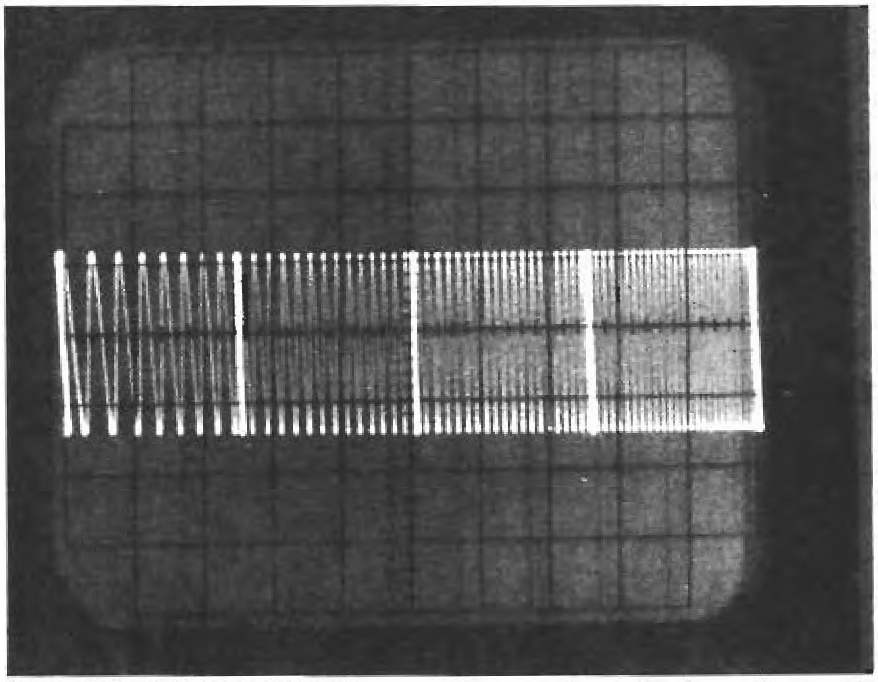


FIG. 1—THE AUDIO OUTPUT SINE wave of the sweep/generator shows five equally spaced markers.

filter device and an oscilloscope. A conventional, digital memory or storage scope may be used with the sweep/generator, however the connections are different. Figure 2 shows a basic connecting diagram that can be used with a conventional scope. The swept sine output connects to the audio input jack, the audio output jack connects to the peak-hold input jack of the sweep/generator. The sweep output and peak-hold outputs of the sweep/generator connect to channels X and Y of the scope, respectively. The scope must be used in the X-Y mode for a proper display.

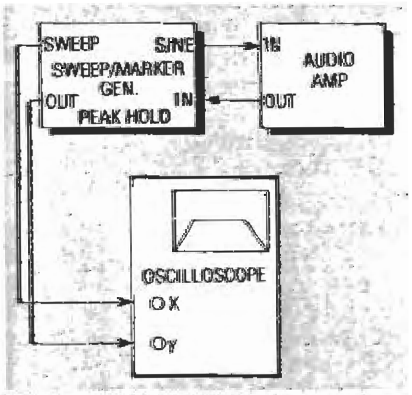


FIG. 2—A CONNECTING diagram shows how the sweep/generator can be used with a conventional scope.

Conventional analog storage scopes are best suited for use with the sweep/generator. When that type of scope is used, the SWEEP output connects to the scope's external trigger. Some digital-memory scopes, unfortunately, do not have the memory capability when used in the X–Y mode, nor can they remember superimposed sweeps of different shapes. To use the storage mode of a digital-memory scope, the sweep/generator must be synchronized with the scope's internal sweep, and the sweep rates must be adjusted for similar times. When a digital-memory scope is used, the SYNC output of the sweep/generator connects to the external trigger of the scope. The dual-trace feature of a digital-memory scope must be used in order to achieve a suitable display. Those various connections are shown in the side bar under Operating Instructions.

A peak-hold circuit is incorporated in the sweep/generator to create a clear base line reference of the frequency response curve. The output signal from the product to be tested may be fed directly into the scope's Y input, but there will be no well-defined base line because of the mirror-image of the audio response. The peak-hold circuit overcomes that problem by momentarily holding the peak value of each positive alternation of the signal, and then quickly reducing to zero. The output from the tested device is connected to the peak-hold input, the peak-hold output is then connected to the scope's Y input. The scope will display a contour line that follows the positive "envelope" of the response curve. That rather nice feature has a nearly flat frequency response from 20 Hz to 20 kHz (within 0.25 dB) and can be used up to 50 kHz.

The input to the peak-hold circuit should not exceed 3.5 volts peak-to-peak. The circuit works adequately with an input as low

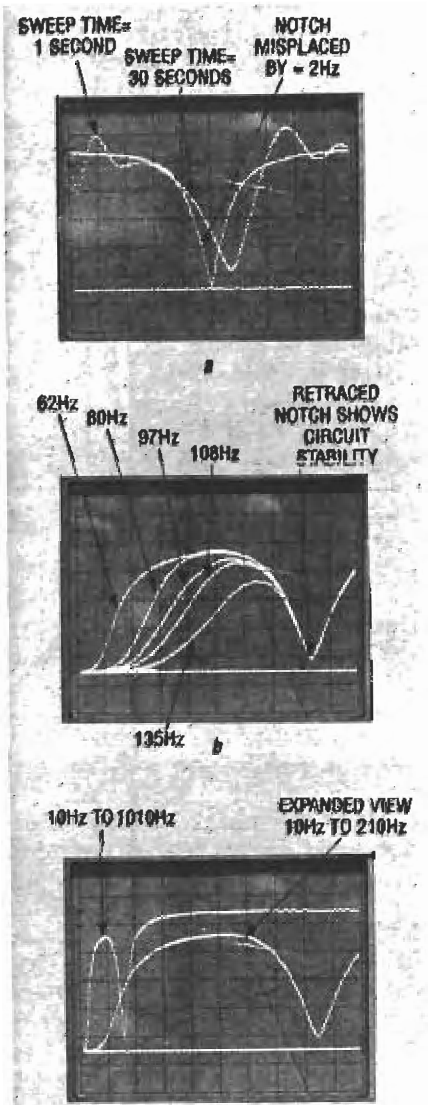


FIG. 3—FILTER RESPONSES: (*a*) shows a 60-Hz notch filter, a smooth response is displayed with a slow sweep of 30 seconds, a faster sweep of 1 second gives overshoots and misplaces the notch by almost 2 Hz; (*b*) shows a 180-Hz notch filter with selectable low-end gains, note the same notch is retraced, indicating circuit stability; and (*c*) shows a low-end response of an amplifier with a 180 Hz notch filter, one trace covers a 10- to 1010-Hz range, the expanded view covers a 10- to 210-Hz range.

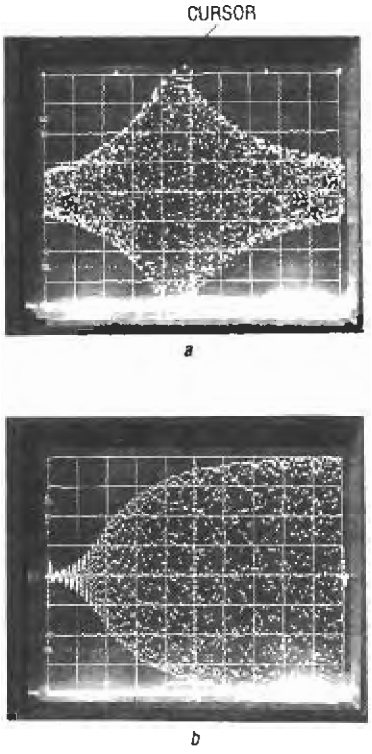


FIG. 4—PEAK-HOLD CIRCUIT not in use, note how the mirror image is displayed: (*a*) shows an L–C tuned circuit, the frequency sweep is 50 kHz at 5 kHz per division, with the CURSOR marker at the curve peak, 52.48 kHz; (*b*) shows an audio amplifier frequency response from 20 Hz to 120 Hz.

as 35 millivolts peak-to-peak, but any value below 20 millivolts peak-to-peak will come out as a base-line value of about +5 millivolts peak-to-peak.

Now that we've introduced you to some of the operating features of the sweep/generator, let's examine some of the scope displays it can produce.

Sweep/generator uses

An example of the sweep/generator being used to determine the frequency response of a notch filter is shown in Fig. 3-*a*. The advantage of a slow sweep with its inherent little distortion of the sine wave is seen in the two superimposed sweeps. The smoothest response is at a sweep time of 30 seconds. The faster sweep of 1 second shows overshoots and a displacement of the notch frequency that are not present at the slower sweep rate.

Two interesting displays are shown in Figs. 3-*b* and -*c*. Figure 3-*b* shows five superimposed response curves of a 180-Hz notch filter with variable low-end gains selected at 62 Hz, 80-Hz, 97 Hz, 108 Hz and 135 Hz. The filter's stability is illustrated by retracing the same notch at the various frequencies. Figure 3-*c* shows a low-end response of an amplifier with a 180-Hz notch filter. One trace ranges over a frequency of 10 Hz to 1010 Hz, the other trace is an expanded view with a frequency range of 10 Hz to 210 Hz.

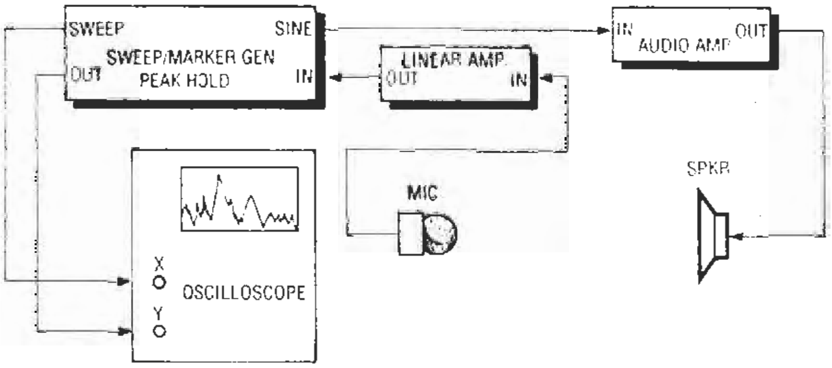


FIG. 5—THE SWEEP/GENERATOR CAN BE USED as a tool in testing the acoustic response of a room. The amplified swept sine wave is projected into a room, and is picked up by a microphone, whose signals are then amplified with a linear amp and fed into the peak-hold circuit.

Figure 4-*a* shows the use of a cursor in an L-C circuit. The total frequency sweep is 50 kHz, at 5 kHz per CRT graticule division. The CURSOR marker, at 52.5 kHz, is at the peak of the curve.

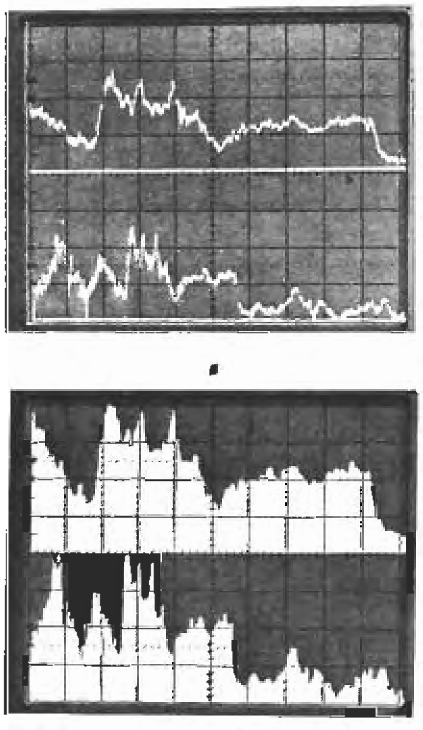


FIG. 6—SCOPE DISPLAYS show an acoustic response of a room: (*a*) shows a line-contour display where the top is swept over 1 kHz to 3 kHz, the bottom is swept over 45 Hz to 5045 Hz; (*b*) shows a filled-in display which is achieved by increasing the scope's intensity.

Figure 4-*b* shows an audio amplifier's frequency response from 20 to 120 Hz. The mirror image of the response curve is displayed in both Figs. 4-*a* and -*b* because the peak-hold circuit is not in use.

An unusual application of the sweep/generator is in the field of acoustic engineering. The generator can be used as an aid in acoustic design by amplifying a swept sine wave into a speaker, and projecting that sound into a room, or perhaps an auditorium. The acoustic response of the room is picked up by a microphone, whose signals are fed into a linear amplifier. The output of the linear amplifier is connected into the peak-hold circuit of the sweep/generator. A block diagram showing the connections for an acoustic response arrangement is shown in Fig. 5. A high quality linear amplifier should be used to pick up microphone signals. Also, the frequency response of the audio amplifier and speaker should be known to avoid misinterpretation of the amplifier response with that of the acoustic response of the room.

Figure 6-*a* shows a line contour-display of an acoustic response of a room with the peak-hold circuit in use. The upper display is swept over a frequency range of 1 kHz to 3 kHz (200 Hz per graticule division), while the lower display varies over a 45 Hz to 5045 Hz range (500 Hz per

PARTS LIST

All resistors are ¼-watt, 5%, unless otherwise indicated.
R1—3900 ohms
R2, R5, R15, R19, R24, R25, R26, R39, R41, R58, R59, R77, R99—10,000 ohms
R3, R47—3300 ohms
R4, R28, R31—50,000-ohm potentiometer
R6—10,000-ohm multiturn potentiometer
R7—2000-ohm 10-turn potentiometer
R8—2200 ohms
R9—2000-ohm multiturn potentiometer
R10—6800 ohms
R11—10,000-ohm 10-turn potentiometer
R12, R13—1 megohm, 1%
R14, R17—47,000 ohms, 1%
R16—5000-ohm multiturn potentiometer
R18, R80, R90—100,000 ohms
R20, R79—1000 ohms
R21, R23—10,000-ohm potentiometer
R22—12,000 ohms
R27—500-ohm potentiometer
R29, R32, R33, R36, R49, R54, R56, R67–R71, R92, R102, R103—4700 ohms
R30, R34, R38, R48, R50, R51, R53, R73, R76, R78, R81, R82—47,000 ohms
R35, R40—68,000 ohms
R37—15,000 ohms
R42—1.5 megohms
R43, R83, R87—150 ohms
R44, R46, R91, R100, R101—1500 ohms
R45—50,000-ohm potentiometer with SPST switch
R52—270,000 ohms
R55—4.7 megohms
R60–R66, R94, R95—100 ohms
R72—68 ohms
R74—1 megohm
R75—10 megohms
R85, R86—10 ohms
R84, R87–R89—unused
R93, R97—4.7 ohms
R98—330 ohms

Capacitors
C1, C2, C17, C26, C29, C32, C66, C68, C69—10 μF, 25 volts, electrolytic
C3, C6, C7, C15, C30, C31, C36, C37, C65, C91, C94—0.001 μF, Mylar
C5, C9, C11, C14, C23, C28, C33, C61—0.01 μF, Mylar
C4, C13, C16, C25, C60, C73, C74, C75—0.1 μF, Mylar
C8, C64—22 pF, ceramic disc
C10—470 pF, ceramic disc
C12, C39-C59, C76-C89—unused
C18—100 μF, electrolytic
C19—.0068 μF, Mylar
C20—0.004 μF (four 0.001 μF 1% capacitors in parallel), Mylar
C21—0.8 μF (0.33μF and 0.47μF wired in parallel), Mylar
C22—0.033 μF, Mylar
C24, C27, C35—0.005 μF, Mylar
C34, C38, C62, C67—47 μF, 16 volts, electrolytic
C63, C95—100 pF, ceramic disc
C70—3300 μF, 25 volts, electrolytic
C71, C72—1000 μF, 25 volts, electrolytic
C90—10 μF nonpolar, electrolytic
C92—470 μF, 16 volts, electrolytic
C93—see text
C95—47 pF, ceramic disc
C96—0.05 μF, Mylar
C97—2200 μF, electrolytic

Semiconductors
IC1, IC14, IC15—XRL555 timer
IC2—CD4040, 12-stage binary ripple counter
IC3—DAC1222LCN D/A converter
IC4, IC6, IC7, IC8, IC9, IC23–IC25—CA3140E op-amp
IC5—LM336Z 2.5-volt reference diode
IC10, IC26—CA3130E op-amp
IC11—CD4068 8-input NAND gate
IC12—CD4538BCN/BCP or MM14538BCN dual-precision monostable multivibrator
IC13—CD4017 decade counter/divider
IC16—XR2206 monolithic function generator
IC17, IC18—RDD104 timebase
IC19—74C926 counter
IC20—7812 12-volt positive regulator
IC21—7912 12-volt negative regulator
IC22—7805, 5-volt positive regulator
Q1-Q13—2N4401 transistor
Q14—2N2219 transistor or VN0300M MOSFET (see text)
D1–D7—1N914 diode
D8, D9, D10—1N4001 diode
DSP1—NSB3881, 4-digit, 7-segment LED display
LED1-7—LN28CAL(US) Panasonic high-efficiency light emitting diodes

Other components
S1, S2—momentary contact pushbutton switch, SPST
S3—ON-OFF-ON toggle switch, SPDT
S4—SPST switch mounted on R45
S5—3PDT toggle switch
S6—3-pole, 4-position rotary switch
S7—SPST toggle switch, 1.0 amp, 125 volts AC
T1—120 volts primary, 12.6 volts secondary, 0.6 amps
J1–J6—RCA chassis mount phono jacks
XTAL1—5-MHz crystal
F1—0.5-amp fuse
Miscellaneous: Fuseholder, 3-conductor 18 AWG line cord, Jameco enclosure type H2507, DIP sockets and hardware.

Note: A set of 2 PC boards is available from John Wannamaker, Route 4, Box 550, Orangeburg, S.C. 29115: $43.00, postage paid, S.C. residents add 5% sales tax.

graticule division).

An alternate filled-in display is shown in Fig. 6-*b*. The area under the response curve is filled-in, rather than having only a base line and contour line. A filled-in display can be achieved by increasing the intensity level on the scope. The main disadvantage of that type of display is its inability to display multiple traces.

Theory of operation

Two PC boards are used in the sweep/generator: a main board, consisting of a function generator, counter, and analog-to-digital conversion circuitry, and a power supply board, which also includes the peak-hold circuit. A schematic of the main PC board is shown in Fig. 7. On this board, an XR2206 function generator chip, IC16, is used as a current-controlled oscillator. A low-to-high frequency sweep occurs when current flow from ground into pin 7 varies from near zero to about 3 milliamps. That current change takes place when a digitized ramp, or sweep voltage, is applied to the base of Q1.

The ramp voltage is created by applying pulses from an astable multivibrator, IC1, into a 12-stage binary counter, IC2. The resulting binary-coded outputs are converted into an analog voltage by a 12-bit digital-to-analog converter, IC3. The output of the converter at pin 1 must feed into the virtual ground of op-amp IC4. The output of IC4 has an apparent straight-line voltage rise, but

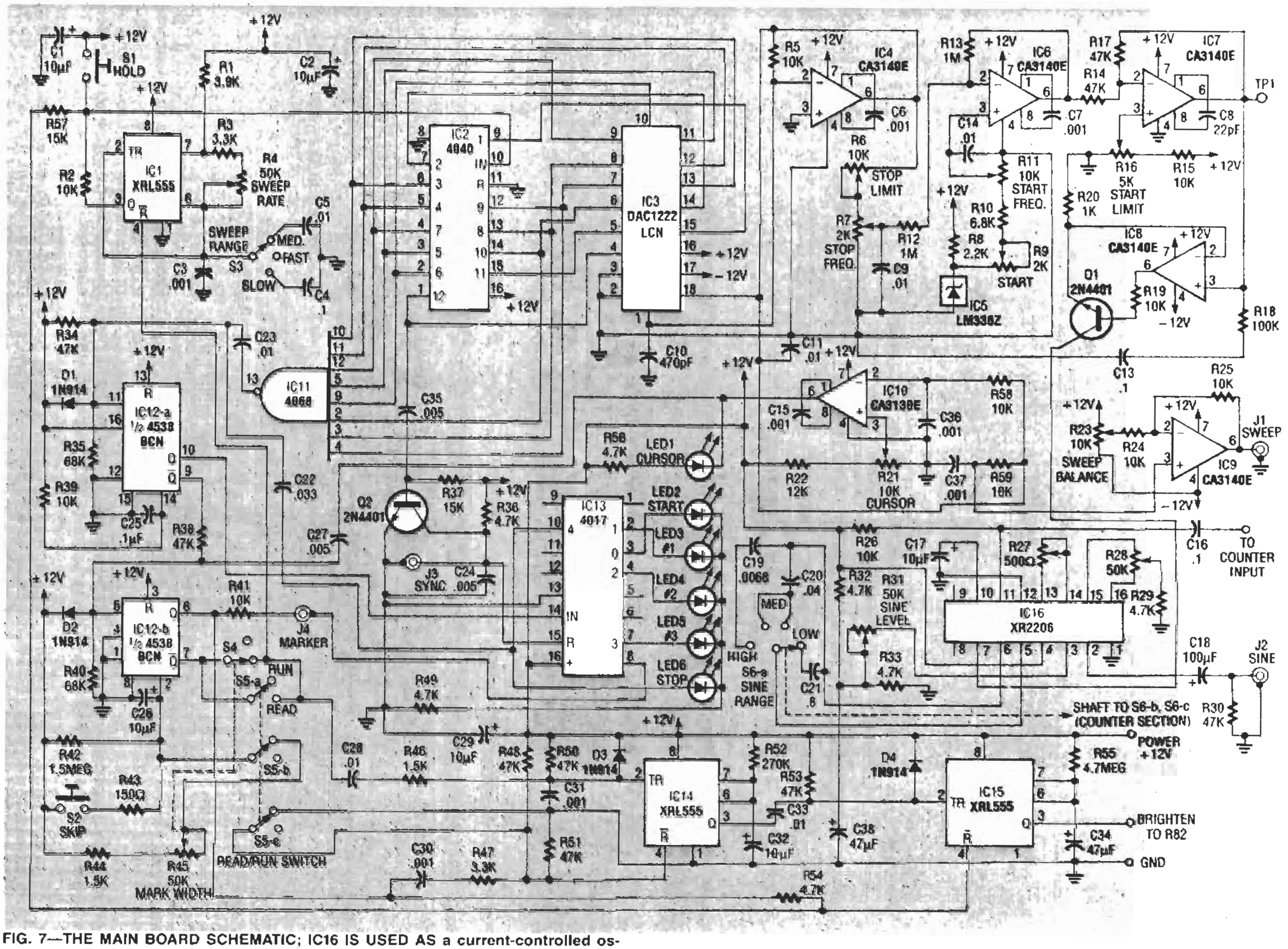


FIG. 7—THE MAIN BOARD SCHEMATIC; IC16 IS USED AS a current-controlled oscillator—a frequency sweep is generated when current flow from ground to pin 7 varies from 0 to 3 milliamps. IC5 is a 2.5-volt precision voltage regulator used to minimize frequency drift

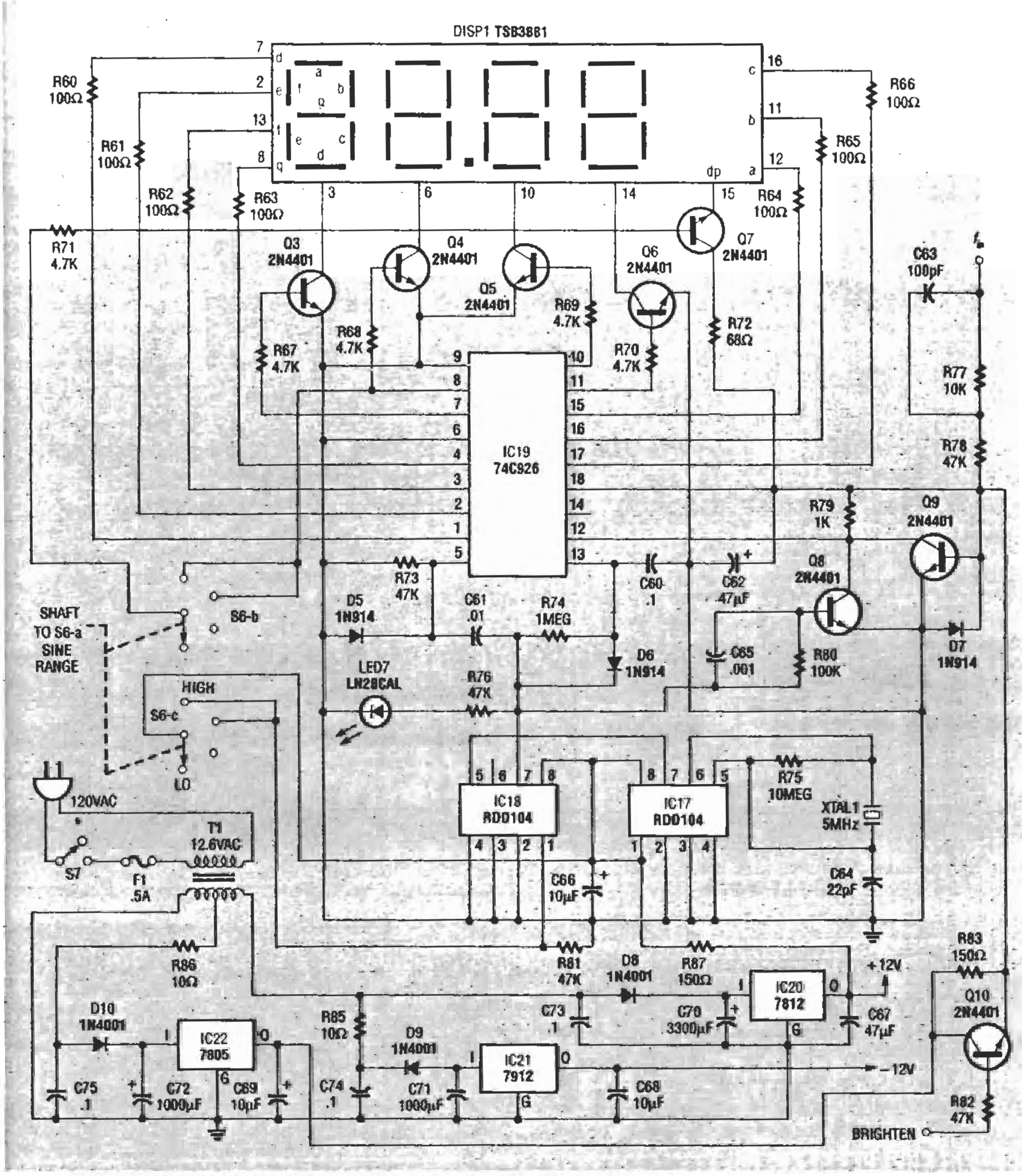


FIG. 8—THE COUNTER AND POWER-SUPPLY BOARD SCHEMATIC; The time-base for the counter originates from IC17 and IC18. A 5-MHz crystal oscillator is used by IC17 and is programmed via pins 1 and 2. The output of IC18 is a square wave which provides a 0.1 or 1 second sampling of the frequency to be measured by the shorting or non-shorting action of Q8.

in reality it is composed of 4,096 small steps. When the frequency of IC1 changes, the ramp's slope and duration change.

Two inverting unity-gain op-amps, IC6 and IC7, provide level-shifting controls for adjusting both ends of the ramp. That permits adjustable start and stop points as well as some limit-setting to protect IC16.

Op-amp IC8 and transistor Q1 act as a voltage-to-current converter for the most linear control over the frequency of the IC16. Frequency drift is a problem, especially within the true audio range, which is at the low end of the middle range. When a device operates in the audio range, a 1-millivolt drift can cause a change of 18 Hz. To minimize frequency drift, a 2.5 volt precision voltage regulator, IC5, is used, and after one hour of warmup time, the

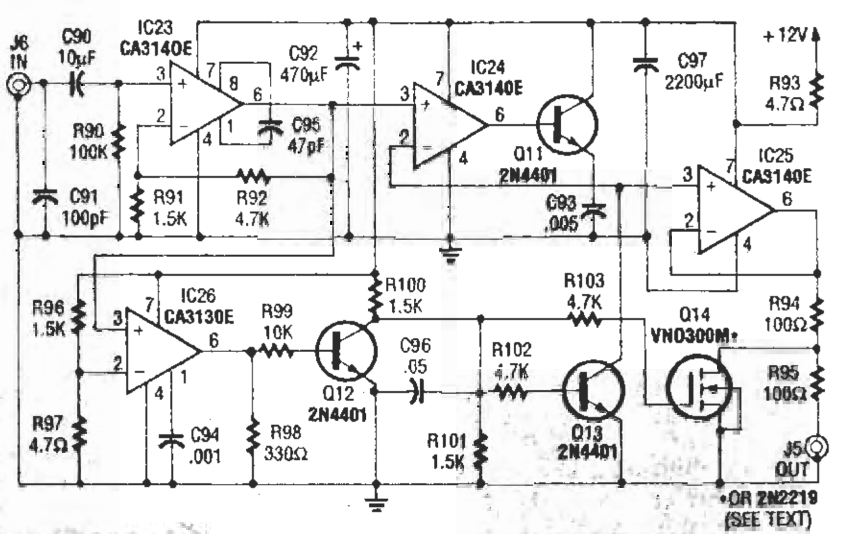


FIG. 9—A SCHEMATIC OF THE PEAK-HOLD CIRCUIT; IC23 AMPLIFIES the signal from the tested device, and reproduces only the positive alternation of the waveform. Transistors Q13 and Q14 act as switches—when open, C93 charges to the peak value of the positive alternation, then holds the peak value. The top portion of that charge is one segment of the positive contour line.

drift averages about 5 or 6 Hz per hour.

An 8-input NAND gate, IC11, provides a falling edge output at 25% increments as the ramp is taking shape. That falling voltage triggers IC12-a, a one-shot monostable multivibrator, which then applies a 10-millisecond input pulse to decade counter, IC13, which has one-of-ten decoded outputs. Each of the five counts light separate LED's to indicate which marker is in progress.

The highlighted marker frequency is established by the technique described below. The pin 9 output of IC12-a triggers a one-shot monostable multivibrator, IC12-b. Its pulse width may be either fixed at 15 seconds or variable from 10 to 150 milliseconds depending on whether the unit is in the READ or RUN mode. During the time that the voltage at pin 7 has dropped to zero, astable IC1's $\overline{\text{RESET}}$ pin is held and cannot furnish pulses to the 12-stage counter. The counter holds whatever count exists at that time which ultimately translates into a steady control current at IC16, and a steady frequency out of it. The continuous frequency out of IC16 is the marker frequency. Each time the ramp stops, the sweep applied to the scope's X input holds a steady value. That stops the trace in its tracks and the unmoving electron beam creates a bright spot which is the marker. If there is a signal at the Y input, the marker becomes a brightened vertical line.

The STOP marker is generated on the count of 4,092. After its completion, four more counts return the 12-stage counter to an all-zeros output condition, the ramp returns to its starting point, and a synchronized pulse is generated by transistor Q2. That same pulse resets IC13, the LED markers counter, and the voltage that had previously lit the STOP LED falls to zero. That fall retriggers IC12-a and a new sequence begins.

The built-in counter that displays the marker frequency cannot give a meaningful readout when it is in the RUN mode because the frequency is continually changing. A valid frequency readout can be displayed only in the READ mode, where a one-second sampling of an unchanging frequency can be taken. To keep the user aware of that, the display is dimmed until the readout is valid. An accurate readout may not be available to the user until three seconds after stopping on a marker. A three-second delay is provided for all automatic stops before the display is brightened.

Integrated circuit IC14 is used as the one-shot, three-second delay for the automatic stops. A three-second delay is triggered every time the marker one-shot, IC12-b, is activated. The delayed falling edge out of IC14 at pin 3 triggers another one-shot, IC15, which produces a long duration "brighten" pulse to Q10 in the power supply. Once the brighten one-shot is triggered, it has the capacity to remain on for several minutes, but its time is cut short by IC12-b, which resets after 15 seconds. The HOLD pushbutton can extend this time if held pressed. The HOLD pushbutton also applies a positive voltage to the input of the 12-stage counter and prevents pulses from entering. Timers IC14 and IC15 are type XRL555 made by Exar. Standard 555 IC's do not work in this application.

The CURSOR marker is generated in a totally different manner from all other markers. A single op-amp, IC10, is used as a comparator. A digitized ramp is applied to the inverting input and an adjustable DC voltage from the CURSOR potentiometer is applied to the non-inverting input. When the ramp rises to equal the DC voltage, the op-amp's output falls to zero and actuates IC12-b to provide an added marker. The reason for the complexity of having two one shots to generate markers is that the cursor marker must be counted by all markers, not just by IC13. The CURSOR marker must hold the astable IC1 reset for a period of time.

The MARKER WIDTH control is a variable resistor with an attached switch, S4. When S4 is turned off, there are no markers, but the sweep will cover the same frequencies as if the markers were present.

The frequency sweep for the middle range, or audio spectrum range, presents a problem for a four-digit counter display. Resolution is poor at the low end if the readout is in kHz, and if the readout is in Hz, the most significant digit would be missing on the high end. To overcome that problem, the middle range occupies two positions on the SINE RANGE switch, and the user may select a readout in either hertz or kilohertz.

The counter and power-supply circuit is shown in Fig. 8. The timebase for the counter comes from IC17 and IC18, both are

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SWEEP/MARKER

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RDD104 IC's made by LSI Computer Systems, Inc. A 5-MHz crystal oscillator used by IC17 is programmed via pins 1 and 2 to divide by 1000. Its output at pin 7 is fed to the input of IC18 which divides by either 1,000 or 10,000, depending on the position of the SINE RANGE switch. The output is a square wave and provides either 0.1 second or 1.0 second sampling of the frequency to be measured by the shorting or nonshorting action of transistor Q8. The same precision square wave is differentiated by C61 and R73 to originate a positive updating spike at pin 5 of the counter chip, IC19. The same square wave is integrated by C60 and R74 to provide a reset voltage a few milliseconds after the update. The RDD104 IC needs about 12 volts to oscillate at 5 MHz, and since the counter IC requires 5 volts, dual-voltage supplies are really necessary.

The schematic of the peak-hold circuit is shown in Fig. 9. In that circuit, op-amp IC23 amplifies the signal from the device under test about four times.

The positive alternation of the waveform is squared and inverted by op-amp IC26. That near-square wave is applied to the bases of transistors Q13 and Q14, both of which act as switches and behave as either open circuits or shorts to ground. If Q14 is a 2N2219 transistor, it shorts to within 5 millivolts with reference to ground. If a VN0300M power MOSFET is used, it shorts to within 1 millivolt to ground.

When Q13 and Q14 act as open circuits, C93 charges to the peak value of the positive alternation, following the rising edge of the alternation and then holding the peak value because there is no discharge path. The flat-top portion of that charge is one segment of the positive contour line. Transistor Q13 discharges C93, and the next time it acts as a short circuit. This varying between charge-time and short-circuit time continues for each cycle.

We're going to have to stop at this point. Next month we'll build and test out the unit. **R-E**

AUDIO SWEEP/MARKER GENERATOR

Build this sweep/marker generator and discover the audio-range frequency response of your amplifier or filter design.

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LAST MONTH WE DISCUSSED ALL OF the operating theory concerning the audio sweep/marker generator. Now let's build the unit.

Construction and checkout

There are two PC boards in this unit: the power-supply board, which includes the peak-hold circuit, and the main sweep/generator board. Etched and drilled PC boards are available from the source in the parts list. The prototype uses a Jameco enclosure type H2507, but any thermoplastic or metal enclosure with the proper openings for control shafts and jacks will serve the purpose. An internal view of the sweep/generator is shown in Fig. 10.

Assemble the power supply/peak-hold board according to the parts layout shown in Fig. 11 and mount near the rear of the enclosure. Three mounting holes in the board match the mounting bosses molded onto the enclosure's bottom half. Prior to mounting, solder the transformer leads and 6-inch leads to all the outputs. Those leads can be cut to length later. Mount the transformer about an inch away from the power-supply section, leaving room for a line cord and fuseholder to pass through the plastic rear panel. If a three-conductor line cord is used, connect the ground wire to a closed-loop connector and connect it to the transformer mounting screw.

The type of capacitor, C93, used in the peak-hold circuit is critical, and must be a low-leakage type. *Only* a polystyrene or a polypropylene dielectric capacitor, rated .0033 µF to .005 µF, should be used in this application. The prototype uses a .0047 µF capacitor. You should also use a type 2N4401 transistor for Q11. Substituting an equivalent component for that transistor will cause unusual almost-peak-hold effects. Play it safe and use only recommended components.

All IC's, except IC5, use DIP sockets. Solder all DIP sockets, resistors and capacitors to the main PC board according to Fig. 12. The following instructions will prepare the board for connection of the display and six marker LED's.

Cut away that portion of the board where the word "CUT" indicates so that the display may be recessed. Cut precisely up to the thirteen foil fingers that must mate with the connections on the display.

Three foil fingers are reserved for hookup wire to be looped through two pads. Press those three wires flat against their fingers and let them extend one-sixteenth inch beyond the board. Solder along the length of the fingers. Use the extending wire ends as indexing pins to mate with the holes in the display. Hold the display at a right angle to the board and form solder bridges between board and display to connect all fingers.

Hold the PC board with the display along the inside of the front panel to determine where the cutout for the display should be. Mark points where each of the six LED's must insert through the panel to be soldered to the wide fingers along the board's edge. Use low-current, high-efficiency LED's or the CMOS circuitry will not be able to light them. Drill holes for the LED's with a number 33 or 7/64-inch bit. Lay out the rest of the panel and cut all other necessary holes.

Make an "L"-shaped metal bracket to help hold the board in place before the LED's are inserted through the front panel and soldered in place. The letters L and S are etched on the board to indicate long and short leads from the LED's. The cathode is the short lead of the LED.

Attach the metal supporting bracket to the board with a 4-40 machine screw. A hole is provided between IC11 and IC12. Connect the other end of the bracket to the front panel and solder the LED's for additional support.

Add front-panel controls which are closest to the board first, and then complete the connections to the board. It is easier to bring the leads from the controls to the foil side rather than insert them through holes from the component side.

The 8 volts peak-to-peak SWEEP output from the sweep/generator may be too much for some scopes to adequately handle. If that is the case, a voltage divider may be needed. A voltage divider can be made by soldering resistors to the SWEEP jack terminal. Solder a 1K resistor from the positive terminal to ground and a 4.7K resistor in series with the lead wire to the PC board.

A long jumper wire must be added to the board to make the connection between the counter input and one end of C16. Solder the leads from the power-supply board to the main board. Complete the connections to the ON/OFF switch and insert a 0.5-amp fuse. Don't forget to drill a hole in the top enclosure, directly above R9, so that a trimming tool can be inserted after the enclosure is assembled.

Now it's time to install the IC's on the main board. The IC's are inserted in DIP sockets, and certain waveforms are monitored at test points in a sequence of stages. That way all circuits and components are properly adjusted before proceeding to the next step. Check the power-supply voltages before any IC's are installed. The right most pin of each voltage regulator chip is the output. When checked with a scope, any ripple should be less than 1 millivolt. Make sure you unplug the power-supply cord before proceeding to each subsequent step.

Insert IC17, IC18, and IC19 in the counter area and turn the power on. The on-board LED near the crystal should blink dimly at either 1- or .1-second intervals depending on the position of the SINE RANGE switch. If it does not blink, turn off the power and interchange IC17 and IC18. Troubleshoot the IC by checking the voltage on the appropriate pins first. If an IC is installed backwards and power is applied, the IC may be damaged.

When the LED blinks properly, the frequency display should dimly indicate 0000. The decimal will probably not be visible in any position of the SINE RANGE switch.

Clip a jumper lead from either end of any 10-ohm resistor in the power supply to the side of R26 closest to potentiometer R28. Turn the power on. The readout should be 0060, ± 1 Hz, on the two lowest positions of the SINE RANGE switch. There may be an occasional erratic readout such as 0067. On the two higher positions of the switch, the readout should be 0006 or 0007.

Insert IC14 and IC15 and keep the jumper between the power supply and R26 in place. Turn the power on. Select the lowest position of the SINE RANGE switch, then select the READ mode. Short pin 2 of IC14 to ground with one quick momentary touch. After three seconds the display should brighten and be easy to read. Select either of the two highest positions of the SINE RANGE switch. The decimal should be visible between the two middle digits. Set the SWEEP RATE switch to slow before proceeding.

Insert IC1 into the PC board. Disconnect only that end of the jumper that goes to the 10-ohm resistor in the power supply and connect it to either end of R2 (R2 is jumped to R26). Select the lowest position of the SINE RANGE switch and turn the power on. The counter should display the frequency of the pulses generated by IC1. Sample the three positions of the SWEEP RATE toggle switch and vary the SWEEP RATE adjustment. You should see the

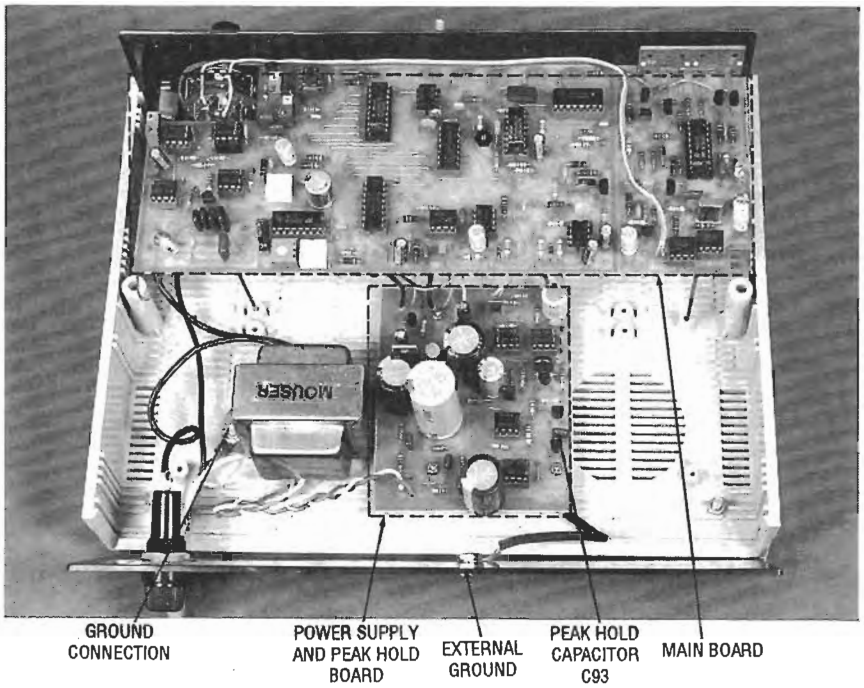


FIG. 10—INTERNAL VIEW OF MARKER/SWEEP GENERATOR.

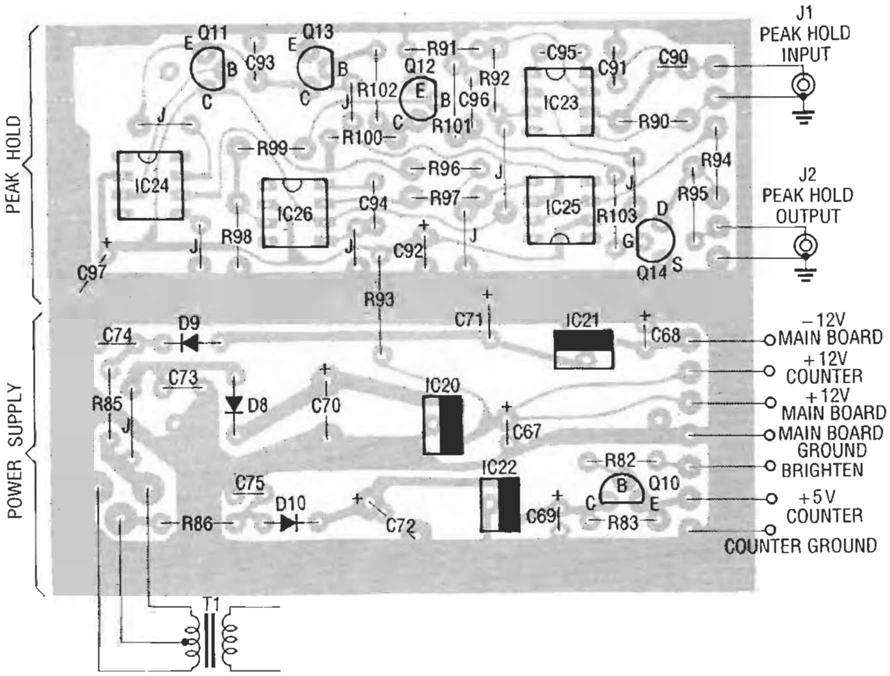


FIG. 11—PARTS PLACEMENT DIAGRAM OF THE PEAK-HOLD and power supply board.

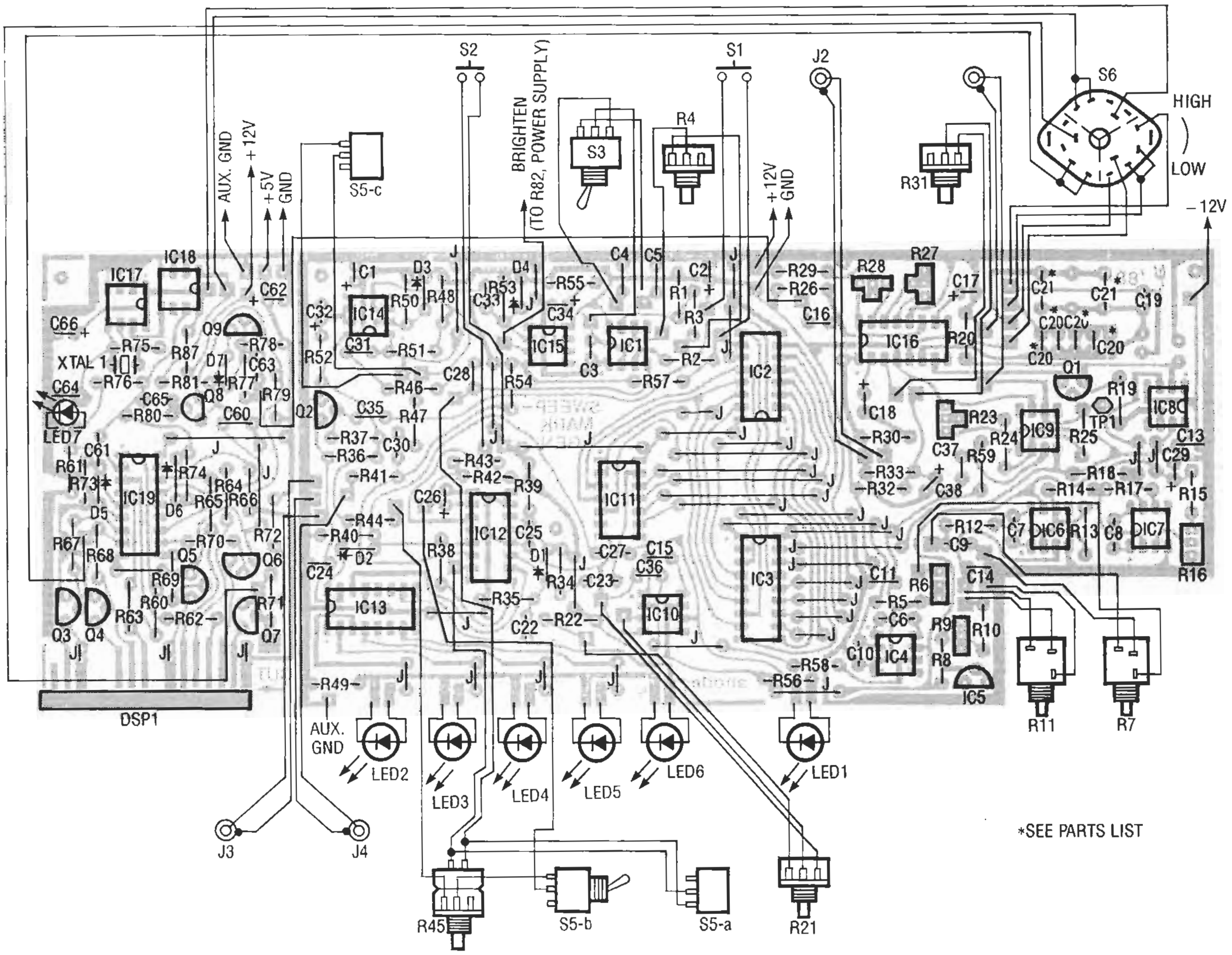
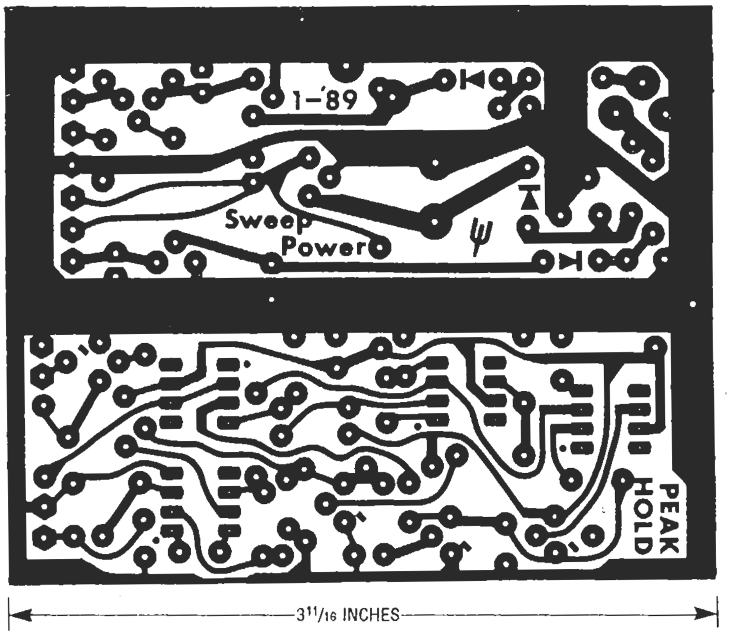


FIG. 12—PARTS PLACEMENT DIAGRAM OF THE MAIN BOARD.



THIS IS THE FOIL PATTERN for the power-supply and peak-hold PC board.

frequency vary from about 160 Hz to more than 80 kHz. Select a high position of the SINE RANGE switch to read any value above 9999 Hz. There may be small frequency gaps where the three ranges do not overlap. If the jumper wire is connected to the side of R2 closest to the DIP socket for IC2, the HOLD button may be pressed and held to reset the count to 0000. If troubleshooting must be done, pulses varying from zero to +11 volts should be seen at the end of R2 nearest IC1. The checkout waveform is shown in Fig. 13-*a*.

Remove the jumper wire between R2 and R26. Insert IC2, IC3, and IC4. Select the FAST position of the SWEEP RATE switch (middle position) and set the SWEEP RATE adjustment to the middle position. Turn the power on. Adjust the scope for DC input, 1 volt per division, and either 20 or 50 milliseconds per division. You should observe a linear ramp varying from near 0 to about 4.5 volts at either end of R58, between IC3 and IC4. That waveform is shown in Fig. 13-*b*.

PARTS LIST

All resistors are ¼-watt, 5%, unless otherwise indicated.
R1—3900 ohms
R2, R5, R15, R19, R24, R25, R26, R39, R41, R58, R59, R77, R99—10,000 ohms
R3, R47—3300 ohms
R4, R28, R31—50,000-ohm potentiometer
R6—10,000-ohm multiturn potentiometer
R7—2000-ohm 10-turn potentiometer
R8—2200 ohms
R9—2000-ohm multiturn potentiometer
R10—6800 ohms
R11—10,000-ohm 10-turn potentiometer
R12, R13—1 megohm, 1%
R14, R17—47,000 ohms, 1%
R16—5000-ohm multiturn potentiometer
R18, R80, R90—100,000 ohms
R20, R79—1000 ohms
R21, R23—10,000-ohm potentiometer
R22—12,000 ohms
R27—500-ohm potentiometer
R29, R32, R33, R36, R49, R54, R56, R67–R71, R92, R102, R103—4700 ohms
R30, R34, R38, R48, R50, R51, R53, R73, R76, R78, R81, R82—47,000 ohms
R35, R40—68,000 ohms
R37—15,000 ohms
R42—1.5 megohms
R43, R83, R87—150 ohms
R44, R46, R91, R100, R101—1500 ohms
R45—50,000-ohm potentiometer with SPST switch
R52—270,000 ohms
R55—4.7 megohms
R60–R66, R94, R95—100 ohms
R72—68 ohms
R74—1 megohm
R75—10 megohms
R85, R86—10 ohms
R84, R87–R89—unused
R93, R97—4.7 ohms
R98—330 ohms

Capacitors
C1, C2, C17, C26, C29, C32, C66, C68, C69—10 µF, 25 volts, electrolytic
C3, C6, C7, C15, C30, C31, C36, C37, C65, C91, C94—0.001 µF, Mylar
C5, C9, C11, C14, C23, C28, C33, C61—0.01 µF, Mylar
C4, C13, C16, C25, C60, C73, C74, C75—0.1 µF, Mylar
C8, C64—22 pF, ceramic disc
C10—470 pF, ceramic disc
C12, C39-C59, C76-C89—unused
C18—100 µF, electrolytic
C19—.0068 µF, Mylar
C20—0.004 µF (four 0.001 µF 1% capacitors in parallel), Mylar
C21—0.8 µF (0.33µF and 0.47µF wired in parallel), Mylar
C22—0.033 µF, Mylar
C24, C27, C35—0.005 µF, Mylar
C34, C38, C62, C67—47 µF, 16 volts, electrolytic
C63, C95—100 pF, ceramic disc
C70—3300 µF, 25 volts, electrolytic
C71, C72—1000 µF, 25 volts, electrolytic
C90—10 µF nonpolar, electrolytic
C92—470 µF, 16 volts, electrolytic
C93—see text
C95—47 pF, ceramic disc
C96—0.05 µF, Mylar
C97—2200 µF, electrolytic

Semiconductors
IC1, IC14, IC15—XRL555 timer
IC2—CD4040, 12-stage binary ripple counter
IC3—DAC1222LCN D/A converter
IC4, IC6, IC7, IC8, IC9, IC23–IC25—CA3140E op-amp
IC5—LM336Z 2.5-volt reference diode
IC10, IC26—CA3130E op-amp
IC11—CD4068 8-input NAND gate
IC12—CD4538BCN/BCP or MM14538BCN dual-precision monostable multivibrator
IC13—CD4017 decade counter/divider
IC16—XR2206 monolithic function generator
IC17, IC18—RDD104 timebase
IC19—74C926 counter
IC20—7812 12-volt positive regulator
IC21—7912 12-volt negative regulator
IC22—7805, 5-volt positive regulator
Q1-Q13—2N4401 transistor
Q14—2N2219 transistor or VN0300M MOSFET (see text)
D1–D7—1N914 diode
D8, D9, D10—1N4001 diode
DSP1—NSB3881, 4-digit, 7-segment LED display
LED1-7—LN28CAL(US) Panasonic high-efficiency light emitting diodes

Other components
S1, S2—momentary contact push-button switch, SPST
S3—ON-OFF-ON toggle switch, SPDT
S4—SPST switch mounted on R45
S5—3PDT toggle switch
S6—3-pole, 4-position rotary switch
S7—SPST toggle switch, 1.0 amp, 125 volts AC
T1—120 volts primary, 12.6 volts secondary, 0.6 amps
J1–J6—RCA chassis mount phono jacks
XTAL1—5-MHz crystal
F1—0.5-amp fuse
Miscellaneous: Fuseholder, 3-conductor 18 AWG line cord, Jameco enclosure type H2507, DIP sockets and hardware.

Note: A set of 2 PC boards is available from John Wannamaker, Route 4, Box 550, Orangeburg, S.C. 29115: $43.00, postage paid, S.C. residents add 5% sales tax.

The falling edge of the ramp may appear to have 6 to 10 short steps as it descends. The SWEEP RATE adjustment should vary the ramp's duration from about 40 milliseconds to 280 milliseconds. If there is a problem with the ramp's amplitude or duration, check pins 4 through 15 of IC3. You should observe a 12-volt square wave at each pin. Start at pin 15 and work in descending order to pin 3 and note that the square wave duration doubles at each pin. Proceed only when the ramp is correct, then check to make sure that the middle pin of IC5 is +2.5 volts DC.

Insert IC5, IC6, IC7, IC8 and IC9 into the board. Adjust the on-board trimmer potentiometer R23 (the SWEEP BALANCE control) to the middle position. Turn the power on. You should see a ramp of about 8-volts peak-to-peak at the SWEEP output jack, J1. That waveform is shown in Fig. 13-*c*. Now adjust R23 for a true AC ramp with an equal positive and negative distribution.

Some of these next adjustments are preliminary, and will be more finely adjusted later. Look at TP1 with the oscilloscope. Turn the START control fully counter clockwise, with the STOP control fully clockwise. Set the SWEEP RATE toggle switch to FAST and turn the SWEEP RATE control fully clockwise for th fastest sweep possible. Preset the on-board multiturn potentiometers R6, R9, and R16 fully clockwise. Turn the power on and adjust R16 clockwise until a

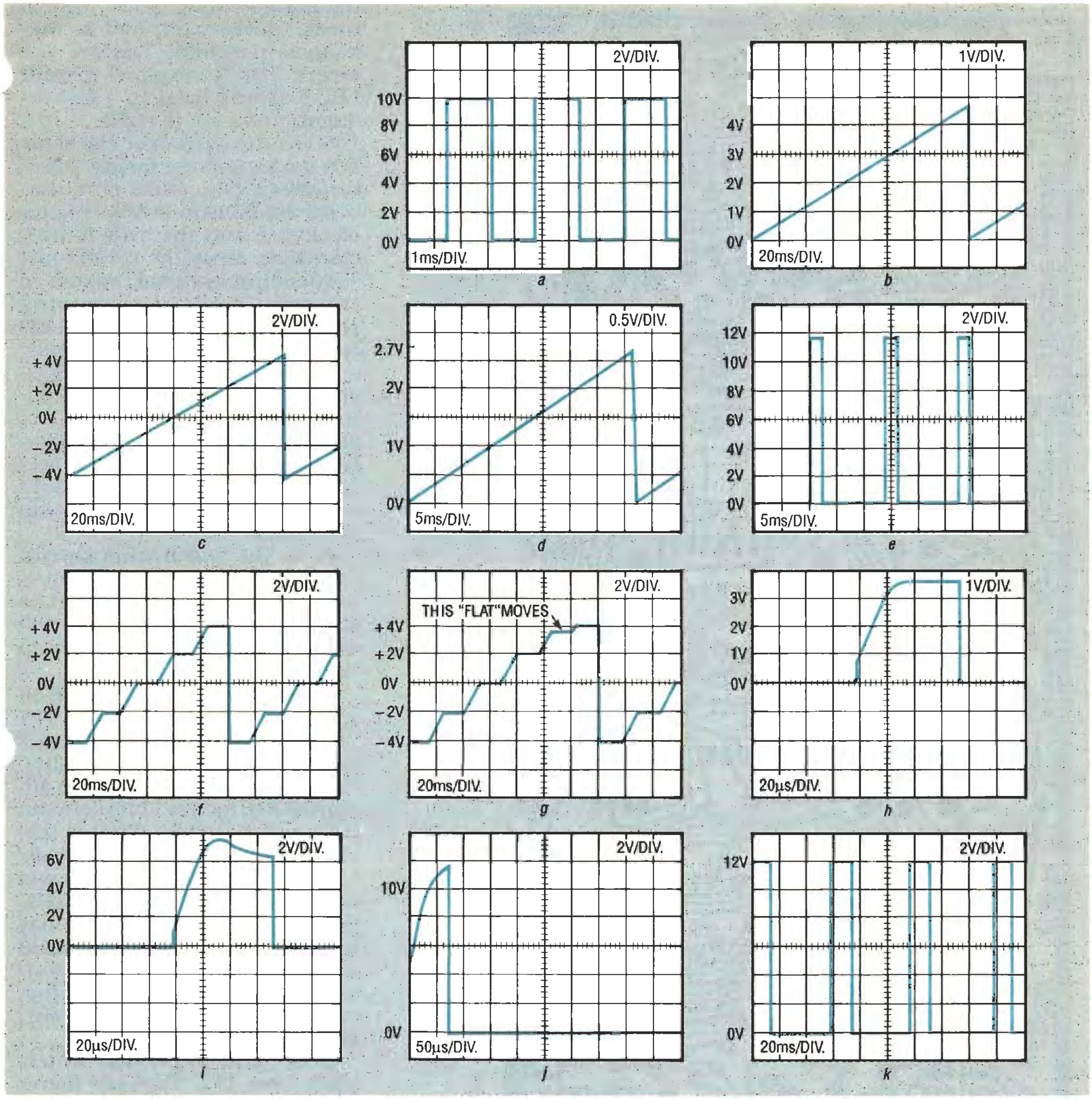


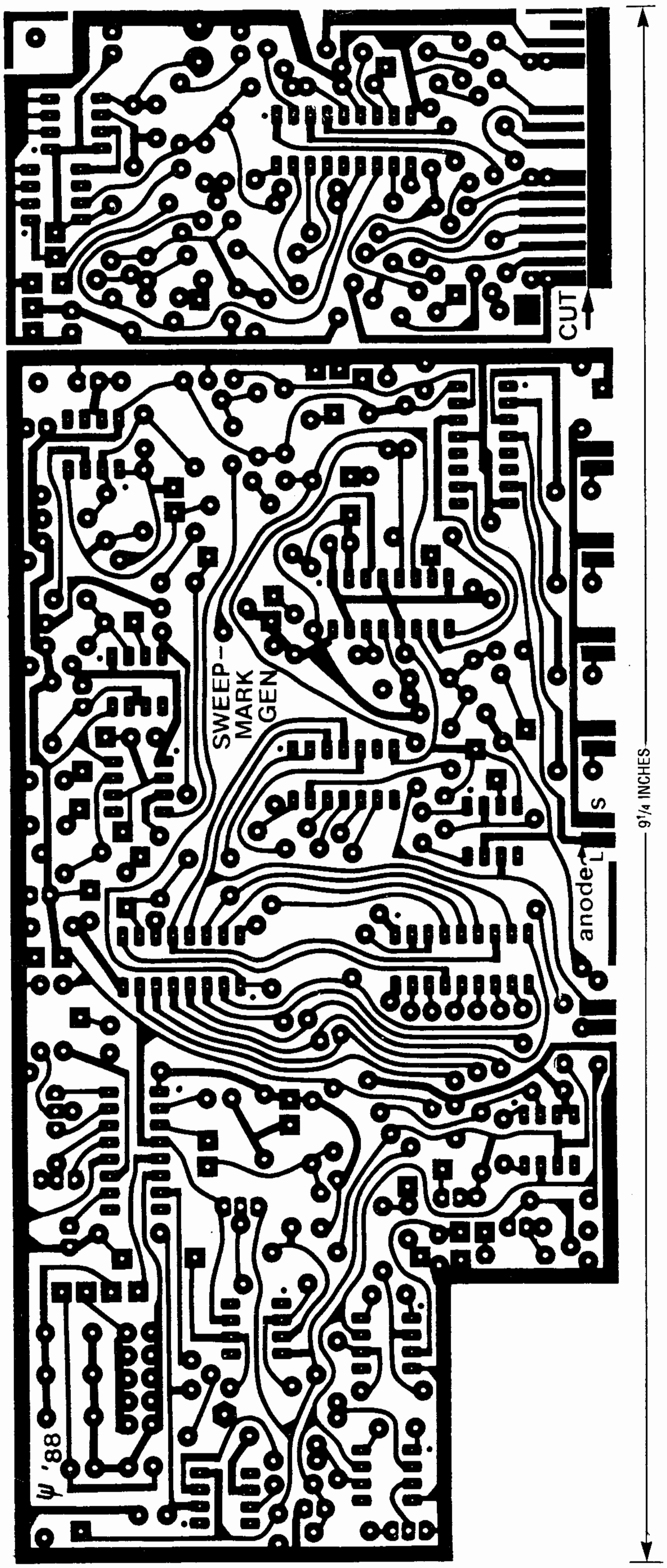
FIG. 13—CHECKOUT WAVEFORMS: (*a*) shows pulses at the end of R2 closest to IC2, SWEEP RATE on LOW and adjusted to mid-range; (*b*) shows a ramp at either end of R58, SWEEP RATE on FAST and adjusted to mid-range; (*c*) shows an AC ramp at jack J1, SWEEP RATE on FAST and adjusted to mid-range; (*d*) shows a saw-tooth ramp, at TP1, adjusted for 0 to 2.7 volts, SWEEP RATE on FAST and adjusted fully clockwise; (*e*) shows a ramp at pin 13 of IC11 adjusted to fill the CRT; (*f*) shows a sweep with marker flats at J1, SWEEP RATE on FAST and adjusted fully clockwise; (*g*) shows a sweep with markers and cursor at J1, SWEEP RATE on FAST and adjusted fully clockwise; (*h*) shows the peak-hold output at 6.3 kHz; (*i*) shows the peak-hold output overdriven at 6.3 kHz; (*j*) shows the sync pulse at J3, SWEEP RATE on FAST and adjusted for mid-range and (*k*) shows markers at J4, synchronize the scope with SYNC, J3, SWEEP RATE on FAST and adjusted to mid-range.

ramp-like waveform appears. Continue adjusting R16 until the positive peak is no more than +2.70 volts, as shown in the Fig. 13-*d* waveform. The positive peak may be flattened. The lower portion of the ramp may become flattened as the adjustment is made.

Adjust R9 clockwise until any flattened lower portion of the ramp disappears and the bottom has a sharp sawtooth-like transition at the 0-volt line. Adjust R6 clockwise until any flattened upper portion of the waveform disappears and the top has a sharp sawtooth transition. Adjust the SWEEP RATE so that one ramp spans the entire CRT graticule from left to right with the scope adjusted for 5 milliseconds per division in preparation for the next step.

Insert IC11 and turn the power on. A positive 12 volts should be present at pin 13 of IC11 with four spike-like pulses that fall to zero during each ramp cycle. That waveform is shown in Fig. 13-*e*. The scope may show five such pulses, as one will be the first spike of a new cycle.

Insert IC12 and IC13. Make sure you use a 4538 IC with a BCN or BCP suffix, as others are



THIS IS THE FOIL PATTERN for the main PC board.

not likely to work. Select the RUN mode, markers on, and in the NARROW position. Restore the power. The front-panel marker LED's should flash in a fast sequence from left to right.

Select the narrowest markers, RUN mode, and the fastest possible sweep rate. Make sure the START adjustment is fully counter clockwise and the STOP is fully clockwise. Once the correct fast sequencing is noted, switch to the READ mode. Sequencing should be very slow as each LED remains lit for about 15 seconds.

As soon as the display brightens, press the HOLD button continually for about one minute to see that it extends the brightening time beyond the usual 12 seconds. The same LED should remain lit while the HOLD button is pressed.

Press the SKIP button several times at about one second intervals. A new LED should light as soon as SKIP is pressed. That will not happen at a slower sweep rate.

Connect a digital voltmeter, on the 20-volt scale, between TP1 and ground. Cycle with the SKIP button until the STOP LED lights. Press HOLD continually while adjusting R16 for a reading between 2.67 and 2.71 volts. Release the HOLD button. When the START LED lights, again press HOLD and adjust R9 to obtain 0.006 volts, using the 2-volt scale. There may be some interaction between R9 and R16. Repeat both adjustments as necessary for the proper readings of 0.006 volts (START) and 2.67 to 2.71 volts (STOP).

Insert IC16 and remove all test leads from TP1. Turn the power on. Make sure the START adjustment is fully counter clockwise and the STOP is fully clockwise. Select the frequency readout position in the middle range of SINE RANGE. Select the FAST SWEEP RATE. Cycle for the START LED to light and press the HOLD button. Retrim R9 for a frequency readout between 0030 and 0035. Release the HOLD button. Resistor R9 may need adjustment from time to time, due to frequency drift.

Select the kilohertz readout position in the middle range of SINE RANGE. Cycle until the STOP LED lights. Press the HOLD button. If the readout is between 20.10 and

OPERATING INSTRUCTIONS

1. Plug the marker/sweep generator in and turn the power on. Allow one half to one full hour of warm-up time in the RUN mode to minimize frequency drift.

2. Select the FAST position of the SWEEP RATE switch, and select the READ mode.

3. Select the proper frequency range with the SINE RANGE switch. The low range is from 3 Hz to 1 kHz. Both medium positions (M) cover the same range of 35 Hz to 20 kHz. The frequency display will be in Hz or kHz depending on which (M) position is selected. The high frequency range is 3 kHz to 100 kHz.

4. Wait until the unit automatically cycles so that the start LED is lit, or manually cycle by pressing the SKIP button.

5. When the START LED lights and the frequency readout brightens, press the HOLD button continuously while adjusting the START frequency. When the START frequency control is fully counter clockwise, with the middle (M) Hz range selected, the frequency readout should be between 0030 and 0035 Hz. If it is not, adjust potentiometer R9 through the hole in the top of the enclosure. Now, adjust the START frequency as desired.

6. Manually cycle the LED's with the SKIP button until the STOP LED is lit. When the frequency readout brightens, press HOLD and adjust to the desired STOP frequency.

7. The START and STOP frequencies interact somewhat. Repeat both adjustments once, adjusting the START first and STOP last.

8. Connect the SWEEP output of the generator to the X input of the scope. Connect the SINE output of the generator to the Y input of the scope. Turn the SINE level down counter clockwise. Select the FAST SWEEP RATE, RUN mode and NARROW MARKERS. The CURSOR should be fully clockwise.

9. Adjust the scope for X-Y operation. A horizontal line with five equally spaced dots, or bright spots, should be seen. Adjust the scope's X gain and positioning so that the line-ends, with bright spots at each end, exactly match the left and right CRT graticule lines.

10. Adjust the SINE LEVEL control for the desired peak-to-peak output voltage desired. A MEDIUM or SLOW position of the SWEEP RATE control may be more convenient to use when adjusting the amplitude.

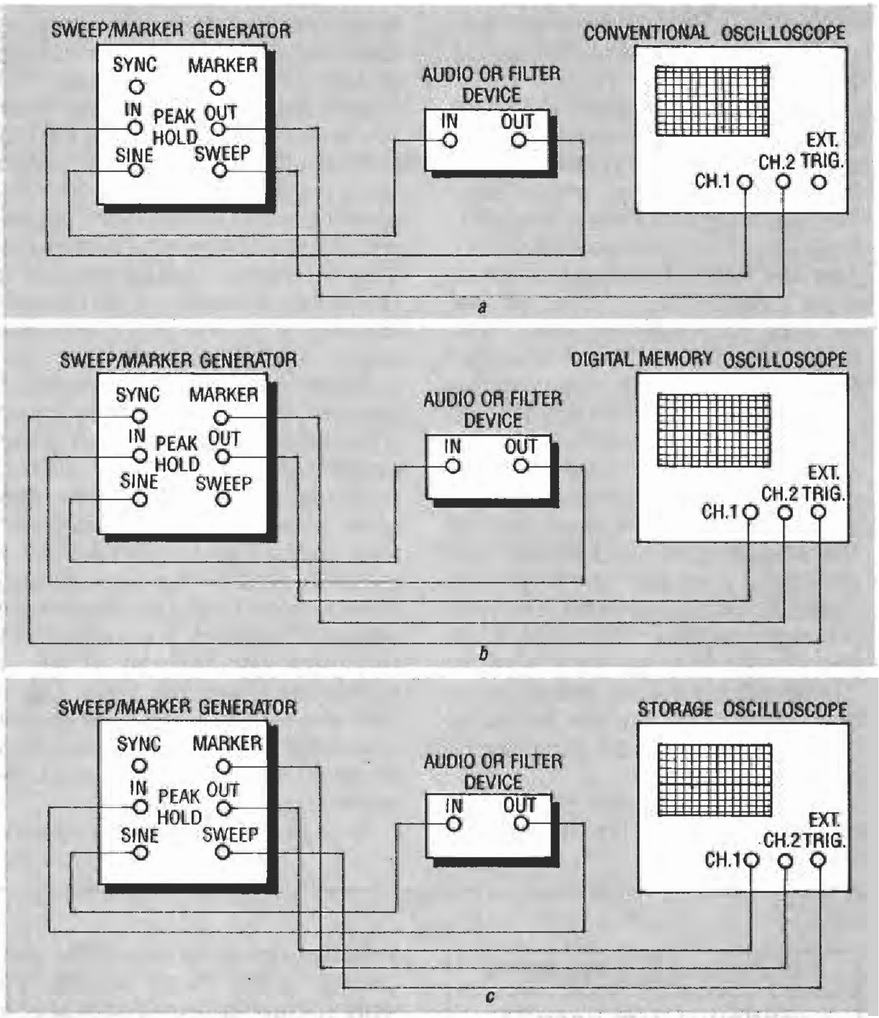
11. Disconnect the cable from the SINE jack and connect it to the peak-hold OUT (the peak-hold OUT connects to the scope's Y input.)

12. Connect the SINE output of the generator to the input of the device to be tested. Connect the device's output into the peak-hold IN of the generator.

13. Adjust the SWEEP RATE, switch, and control for the desired sweep rate.

14. Adjust the scope's volts/division control (Y input) as required.

15. The scope's brightness should be turned down for a satisfactory contour-line display of the response curve. The peak-hold will not operate properly with an input signal of more than 3.75 volts peak-to-peak. Inputs of 0.2 volts to 3.75 volts work best.



THESE ARE SWEEP/GENERATOR CONNECTIONS for a conventional, digital-memory or a storage scope.

21.20, no adjustment is necessary. If the readout is only off slightly, adjust R6 and R16 just a little. Recheck to see that the low end still has a frequency reading of 0030 to 0035 Hz. Three potentiometers, R6, R9, and R16, all interact, and if a little adjustment cannot correct for proper readouts, all the steps after inserting IC6–IC9 may have to be repeated. If the .04 µF timing capacitor, C20 (four .01 µF's in parallel), is not within 1 percent, you may have to find your own adjustment values, or settle for a slightly different range span.

The low and high ranges of the SINE RANGE have no separate adjustment; only the timing capacitors C19 and C21 can change their ranges. Extra space is provided on the PC board for paralleling capacitors in order to find a proper range more easily.

Insert IC10, a CA313OE, and turn the power on. Select the RUN mode with a fast sweep, MARKER on NARROW and CURSOR turned fully clockwise. With the scope on DC input, observe the SWEEP waveform at J1. A ramp waveform interrupted with five flats, or markers, should be seen as in Fig. 13-*f*. Adjust the CURSOR control slowly counter clockwise and observe an additional flat moving smoothly among the others. That waveform is shown in Fig. 13-*g*. With the CURSOR fully clockwise, there should be no extra marker.

Set the range of the SINE RANGE, SLOW SWEEP RATE, and SWEEP RATE adjustment at mid-position. Select WIDE MARKERS, place the CURSOR fully clockwise, and the SINE LEVEL at mid-position. Adjust the STOP fully counter clockwise. With the START control initially fully counter clockwise, turn it clockwise three turns. Select the RUN mode. The display will be dim, but it should indicate a frequency of about 6500 Hz. Set the scope for 0.5 volts per division and 20 microseconds per division. Observe the waveform at the SINE jack, J2, and adjust triggering for a steady waveform. Adjust the two on-board trimmer potentiometers, R27 and R28, for the best sine-wave shape. Those adjustments interact, so you should alternate between them until a good sine-wave shape is achieved.

Now, remain triggered on the sine wave but switch the scope's time base to 0.2 milliseconds per division. Turn the START control slowly counter clockwise. The frequency should become lower and may drop to less than 1 Hz, or stop oscillation altogether. Turn the STOP fully clockwise. The frequency should become higher while the STOP control is turning. The waveform should change in frequency from about 30 Hz to 20 Hz over a period of 12 seconds. Adjust R16 if necessary.

When the SWEEP RATE switch or control is changed, the sweep from 30 Hz to 20 kHz will either speed up or slow down accordingly. Adjust for the slowest possible SWEEP RATE. Connect the SINE output to the peak-hold IN jack, J6. Reduce the SINE LEVEL to about one-third the maximum output. Look at the peak-hold OUT jack, waveform at J5. It should look like Fig. 13-*h*. Figure 13-*i* shows the peak-hold output overdriven, causing a downward slope of the flat portion of the waveform.

A +11-volt synchronization pulse should be seen at the SYNC jack, J3, as shown in Fig. 13-*j*. The pulse will have an RC time constant-like rise and a fast fall, with a duration of about 70 microseconds. Use the fastest possible SWEEP RATE. Set the scope for 2 volts per division, 50 microseconds per division, and use (+) slope triggering.

To observe the output at the MARKER jack, J4, select the RUN mode, SWEEP RATE switch set to FAST, SWEEP RATE adjustment to mid-position and the markers set on and NARROW. Synchronize the scope with the output of the SYNC jack, J3. Adjust the scope's triggering for external input, (−) slope triggering, and use a 20 millisecond per division sweep rate. Four markers, consisting of positive pulses, should be seen with a peak value of 12 volts, and a duration of about 15 milliseconds each. That waveform is shown in Fig. 13-*k*. The MARKER control should increase the pulsewidth. That completes the checkout. **R-E**

AUDIO SWEEP/MARKER GENERATOR UPDATE

Anyone building my "Audio Sweep/Marker Generator" (**Radio-Electronics**, February and March 1991) might encounter a problem that we cannot explain. It concerns IC11, an 8-input NAND gate. Two sources of information on the pinout arrangement show that there is no internal connection to pin 1. In the PC layout, pin 1 is connected to pin 2 to make the foil pattern layout a little simpler. That arrangement worked well with my prototype. However, I am indebted to Mr. Gordon La Grange of Baytown, TX, for pointing out that he had to snip off pin 1 before he could get a proper output from the NAND gate. That output is not shown properly in Fig. 13-*e* on page 59 in the March issue. The correct output is properly described in the paragraph almost directly below Fig. 13-*k*. If you invert the pulses in Fig. 13-*e* and make them no wider than a single line width, you'll have a correct picture.

JOHN WANNAMAKER