On-chip transistors extend audio amp's design flexibility

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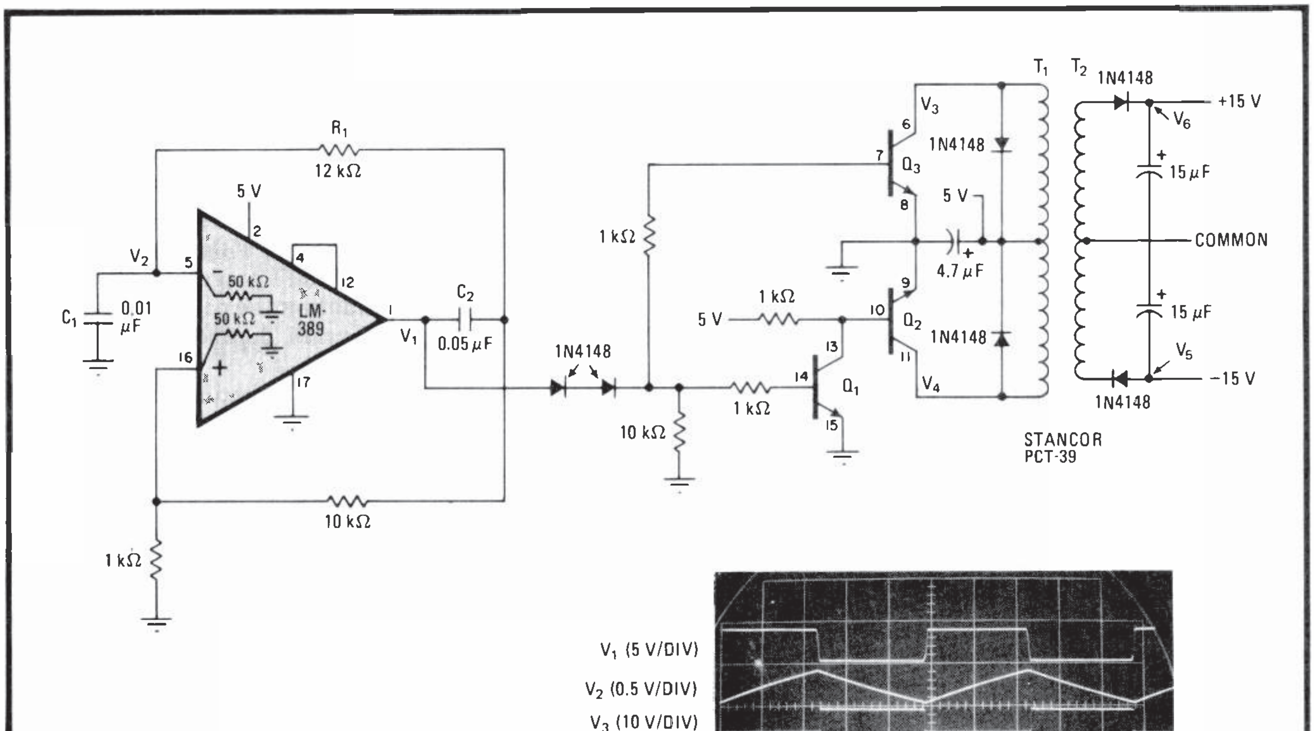
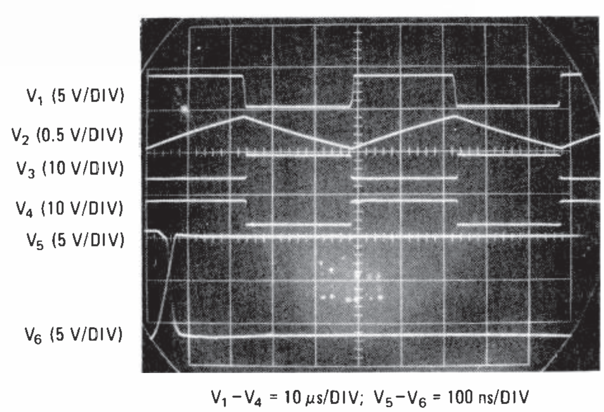
The availability of extremely low-cost audio-amplifier integrated circuits with on-chip transistor arrays, such as National's LM389, gives designers a great deal of flexibility in designing audio circuits. They make it much easier to develop low-cost versions of circuits unrelated to basic audio amplification, such as dc-dc converters, touch switches, stabilized frequency standards, scope calibrators, low-distortion oscillators, and logarithmic amplifiers. The designs of the often-needed converter, a bistable touch switch, and a tuning-fork frequency standard are discussed here in the first part of this two-part presentation.

The LM389 contains a 250-milliwatt audio amplifier and an array of three npn transistors, each of which is uncommitted. The amp has differential inputs and separate pins for setting its gain (from 20 to 200) via a resistor and runs off a single supply that may range from 4 to 15 volts. The three transistors have a minimum current-handling capability of 25 milliamperes and a minimum current gain of 100 for $V_{ce\,max}$ = 12 V and for a wide range of collector currents. The chip is therefore ideal for general use.

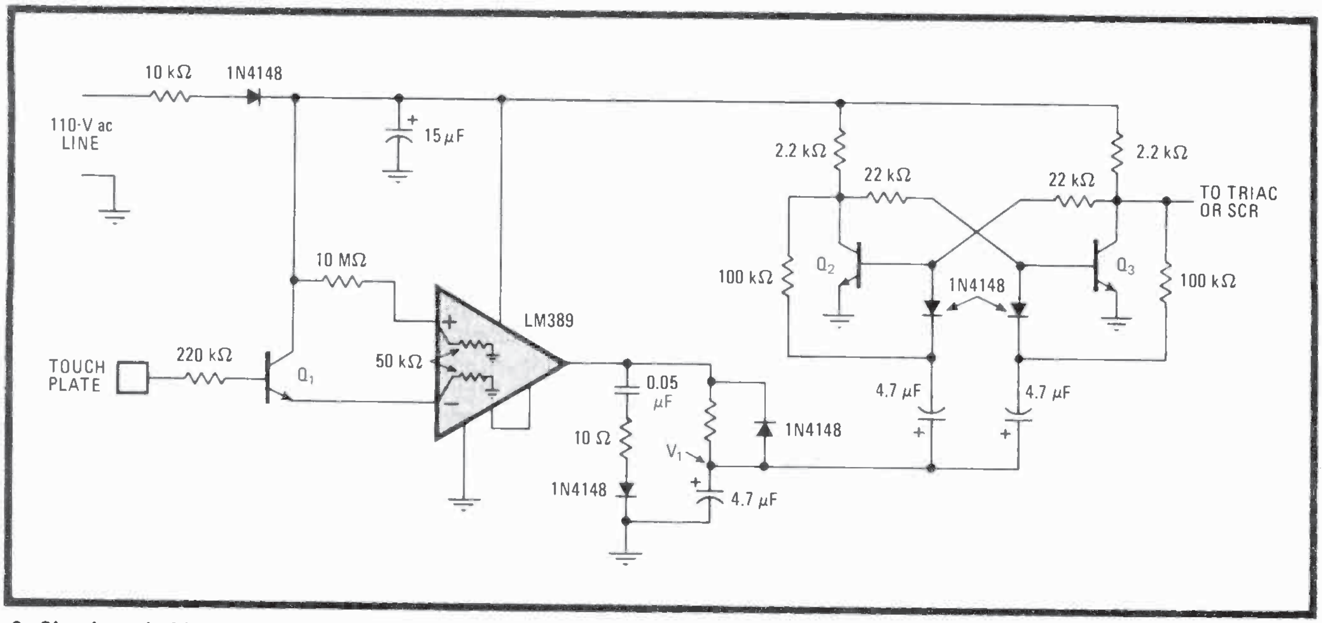
One area in which the chip will be useful is in dc-dc switching conversion. The device in Fig. 1 is intended for use as a power supply in a digital system where it is necessary to supply ±15 V to a low-power load. As can be seen from the oscilloscope photograph, the LM389 switches at 20 kilohertz. That rate is determined by the triangular-wave feedback signal, whose time constant is set by $R_1C_1C_2$, and its square-wave output is applied to transistors Q_1 and Q_3. The series diodes ensure clean turn-off for Q_1 and Q_3.

Q_1's inverted output drives one half of the transformer primary through Q_2, while Q_3 drives the other half. The diodes across Q_2 and Q_3 suppress spikes. Thus there is an

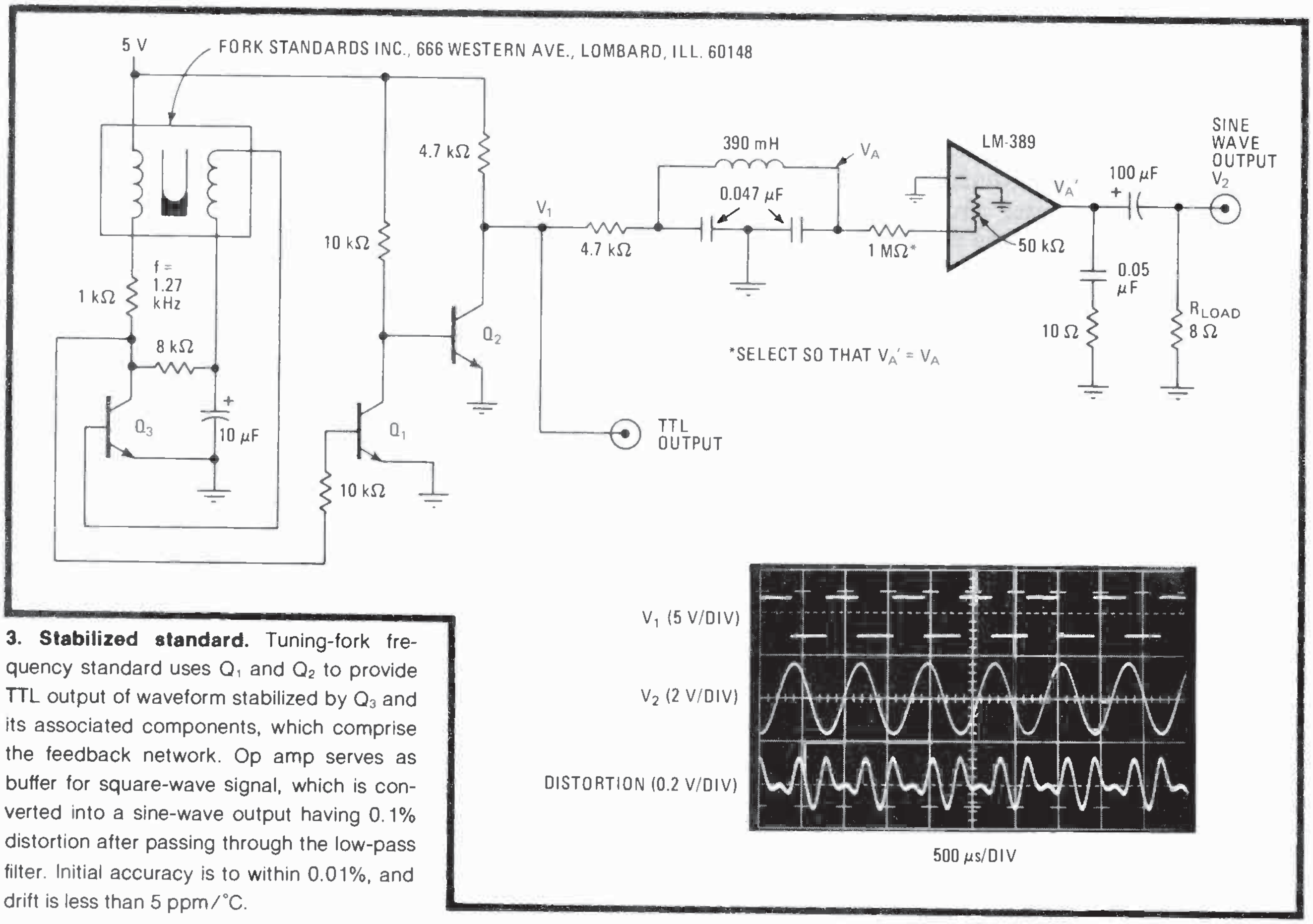




1. Condensed converter. Op amps with an on-chip transistor array, such as National's LM389, make inexpensive one-chip switching converters. Costing under $10, unit shown provides ±1.5 mA at ±15 V for instrumentation amplifier. Scope photo displays waveforms at various points in circuit. Use of diodes in driver side of circuit allows spike suppression, plus clean switching.



2. Simple switching. Simple bistable touch switch may be similarly constructed. Op amp works as comparator and trigger for flip-flop Q_2–Q_3, which changes state each time plate is contacted. Thus, SCR at output may be alternately fired and switched off on command.



3. Stabilized standard. Tuning-fork frequency standard uses Q_1 and Q_2 to provide TTL output of waveform stabilized by Q_3 and its associated components, which comprise the feedback network. Op amp serves as buffer for square-wave signal, which is converted into a sine-wave output having 0.1% distortion after passing through the low-pass filter. Initial accuracy is to within 0.01%, and drift is less than 5 ppm/°C.

efficient step-up of voltage across T_2. This ac signal is rectified and filtered to produce complementary output voltages that may be used to power the desired linear components, in this case delivering ±1.5 mA, enough to power an operational or instrumentation amplifier.

The bistable touch switch (Fig. 2) allows a line-powered load to be controlled from a touch plate by means of a thyristor. Each time the plate is contacted, emitter-follower Q_1 conducts, permitting a fraction of the 60-hertz input signal to be applied to the inverting input of the amplifier. Consequently, the normally high output of the op amp follows the 60-Hz line input, causing V_1 to drop sharply.

This negative transition triggers a toggling flip-flop formed by Q_2 and Q_3. In this manner, the output of the flip-flop changes state each time the touch plate is contacted, prompting the firing of the silicon controlled rectifier or triac that switches ac power to the load.

Figure 3 shows a tuning-fork frequency standard that is stabilized by appropriate feedback. Both sine-wave and TTL-compatible outputs are available. As the circuit needs only 5 V, it can run off a battery.

The tuning fork proper supplies a low-frequency output that is very stable (typically to within 5 ppm/°C) and has an initial accuracy of within 0.01%. Moreover, it will withstand vibration and shock that would fracture a quartz crystal. Here, Q_3 is set up in a feedback configuration that forces the fork to oscillate at its resonant frequency. Q_3's output is squared up by Q_1 and Q_2, which provide a TTL-compatible output. When passed through an LC filter and the op amp, which provides a low-impedance (8-ohm) output, the signal is converted into a sine wave having less than 1% distortion, as shown in the figure.

Several other useful circuits also can be built. The second part of this article will deal with the chip's use in a portable scope calibrator, a low-distortion oscillator, and as a logarithmic amplifier. □

On-chip transistors add versatility to op amp

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Low-cost audio-amplifier chips containing uncommitted transistor arrays are widely applicable, as discussed in part 1 of this article [*Electronics*, Jan. 27, 1981, p. 118]. Besides uses in nonaudio applications such as dc-dc converters, touch switches, and stabilized frequency standards, array amplifiers like National's LM 389 are especially suited for general service in portable oscilloscope calibrators, low-distortion oscillators, and logarithmic amplifiers.

For example, the circuit in Fig. 1 allows a quick check of an oscilloscope's time base and vertical calibration. It can be built into a small hand-held enclosure and may be powered by a 12.5-volt battery.

When suitably trimmed, the amplifier will oscillate at 1 kilohertz ± 5 hertz. Transistor Q_1 serves as a switch to provide fast, sharp edges to Q_2's base. This transistor drives Q_3, which functions as a zener diode so that a relatively constant 10-V square wave is applied across the resistive divider at the output. Q_3's breakdown potential is scaled by the 2-kilohm potentiometer to provide a 5-, a 1-, and a 0.1-V square wave at the appropriate output taps. Loading of the circuit by a 1-megohm oscilloscope impedance will not introduce any appreciable error.

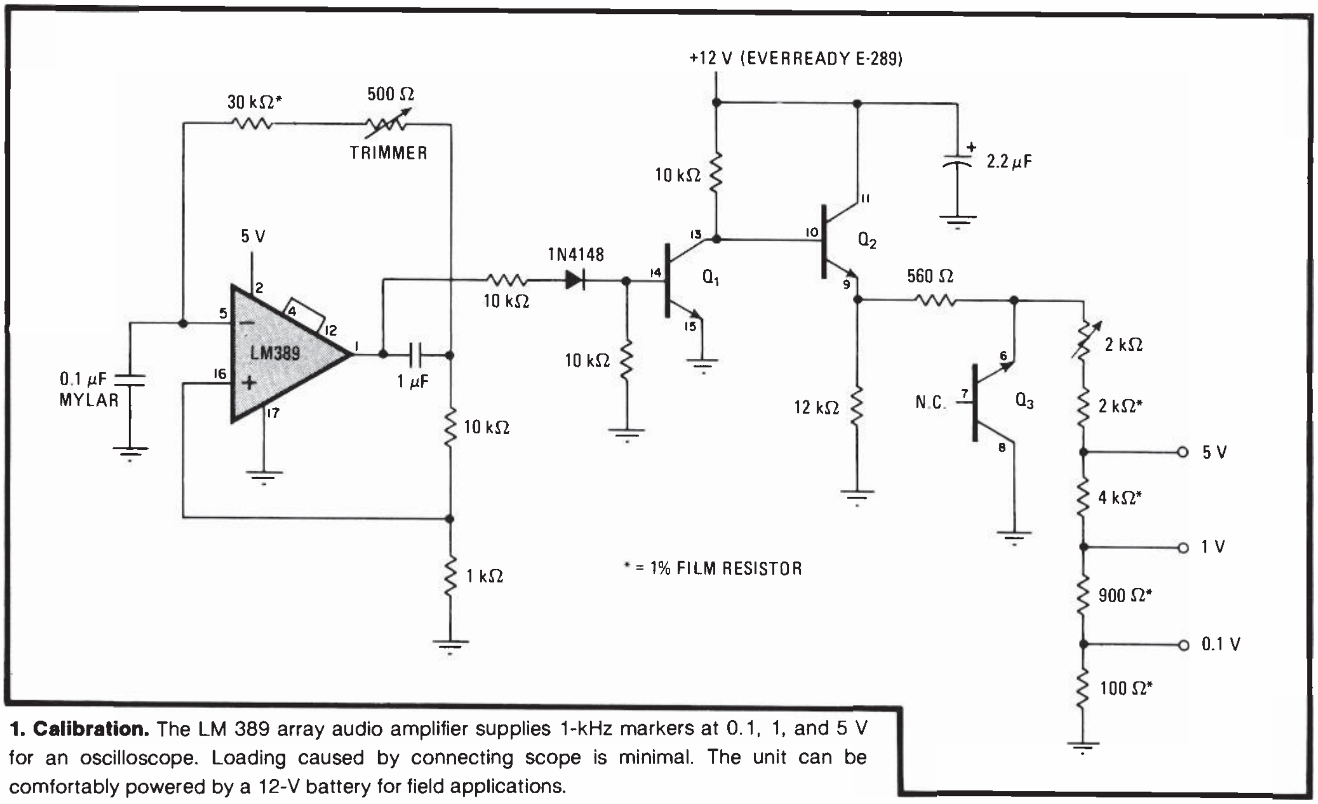
In Fig. 2, the LM389 is called on to provide a low-distortion sine wave and a synchronous in-phase square wave. The circuit's 0.25-watt output capability enables it to drive such loads as a transducer bridge. In such an application, the in-phase square-wave output can be used to drive a set of synchronous demodulation switches.

The oscillator's low distortion (0.2%) is directly traceable to the use of a light bulb that provides smooth amplitude-limiting for the Wien-bridge network of the amplifier. The oscillation frequency is 1 kHz. The in-phase square-wave output is ensured by Q_1–Q_3 and the potentiometer R_1, with Q_2 and Q_3 speeding up the waveform's edges. Calibration for synchronism is simply performed by adjusting R_1 so that the edges of the square wave line up precisely with the zero-crossings of the sine-wave output.

As shown in Fig. 3, the LM389 is used in an unorthodox fashion to build a logarithmic amplifier that eliminates the complex and expensive means by which temperature compensation is usually achieved. Thus, the cost of the log amp is reduced by some 90% compared with that of conventional approaches.

Q_2–Q_3 operate in a heat-generating and -sensing feedback network, with Q_2 serving as the heater and Q_3 the temperature sensor. This combination keeps the temperature virtually constant, so that the LF353 op amp's transfer function, as determined solely by logging transistor Q_1 and the 1N4148 diode, will be independent of any variation in temperature.

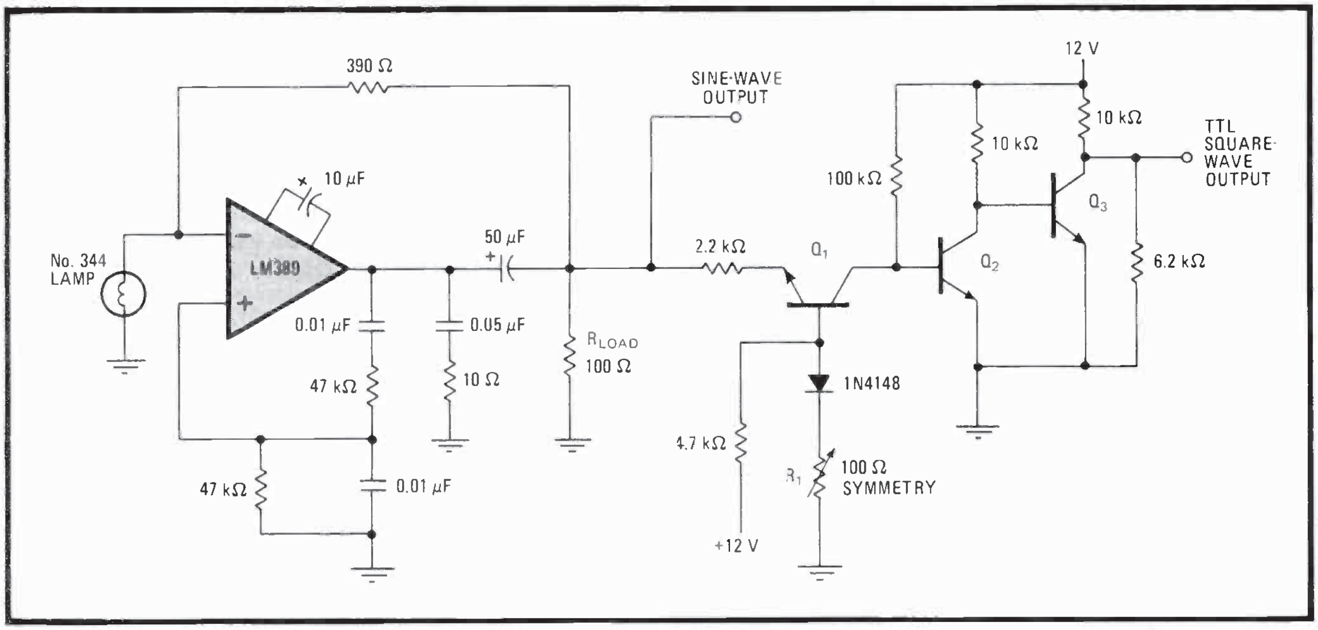
When power is first applied, Q_2's emitter voltage rises to about 3.3 V and a current of 120 milliamperes flows. This current forces Q_2 to dissipate about 1.5 W, which raises the chip to operating temperature very rapidly because of its small size. At this time, the thermal servo Q_2–Q_3 takes over, because the LM389 senses the depen-



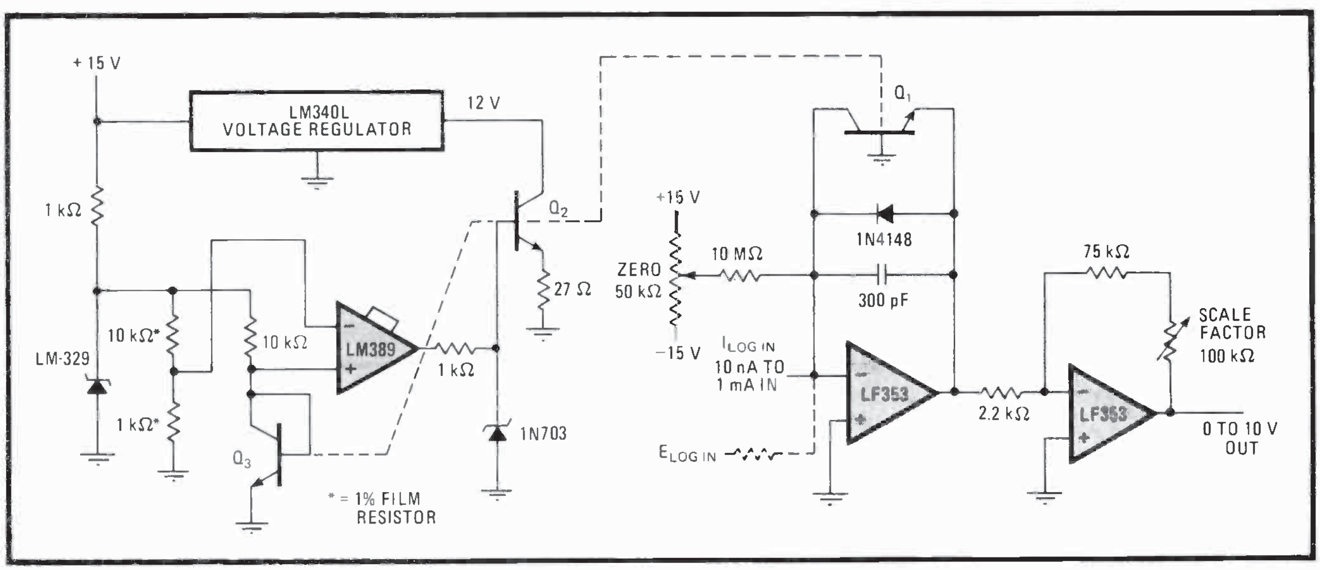
1. Calibration. The LM 389 array audio amplifier supplies 1-kHz markers at 0.1, 1, and 5 V for an oscilloscope. Loading caused by connecting scope is minimal. The unit can be comfortably powered by a 12-V battery for field applications.

dence of Q_3's base-to-emitter voltage drop on temperature and drives Q_2 to a temperature (50°C) corresponding to the setting of the 10-kΩ-to-1-kΩ divider string. Since the LM340 never has a voltage of more than 3 v across it, the power dissipation never exceeds 0.3 w. Note that the zener diode at the base of Q_2 will prevent servo lock-up when the circuit is initialized.

To calibrate the temperature servo, the base of Q_2 must first be grounded. The collector potential of Q_3 must then be measured at a known room temperature. Calculate what Q_3's potential should be at 50°C, assuming a temperature coefficient of −2.2 millivolts/°C. Next, trim the 1-kΩ resistor in the resistive divider so that the voltage at the LM389's inverting port approximates the calculated potential. Finally, unground Q_2's base. The Q_2–Q_3 servo loop should then be functional. As a check, note Q_3's collector voltage stability (within 100 mv) and temperature change (0.05°C maximum) as cool air is applied to the LM389. □



2. Sines and squares. This oscillator provides a 1-kHz sine-wave output and synchronous in-phase square waves. The amplitude-limited Wien bridge contributes to low distortion (0.2%). Single-knob calibration for synchronization is provided by potentiometer R_1.



3. Holding heat. The LM389's servo loop, Q_2–Q_3, performs low-cost temperature compensation for the LF353 op amp, which is configured as a logarithmic amplifier. The chip temperature, initially determined by current through Q_2, is set with the 1-kΩ-to-10-kΩ resistive divider.