Solid State

By Lou Garner

AN IC THAT IS ALSO DANDY

DISCUSSING a voltage-tuned FM broadcast-band front end in last February's column, I referred to it as a DANDY circuit, explaining that "DANDY" was my acronym for "Discretes Are Not Dead Yet." If we broaden the basic meaning a little, the LM389 might well qualify as a *DANDY IC*, for it combines the versatility of discrete transistors with the wiring density and compactness of an integrated circuit. Manufactured by the National Semiconductor Corporation (2900 Semiconductor Drive, Santa Clara, CA 95051), the LM389 is supplied in a molded 18-pin DIP. As shown in Fig. 1, the device comprises three uncommitted npn transistors and a low-power integrated audio amplifier in a single package.

With its uncommitted transistors and overall electrical characteristics, the LM389 is one of the most versatile devices you're likely to encounter in some time and almost seems to have been "custom-designed" specifically for the experimenter/hobbyist. It can be used in hundreds of applications ranging from simple toys to sophisticated communications equipment. Its versatility, in fact, is limited only by the imagination and capabilities of the individual designer. Typically, the device might be used for such exciting and useful projects as AM or FM receivers, walkie-talkies, tape recorders, portable phonographs, games, power converters, musical instruments, and control systems. Depending on the equipment designer's skill, it may be the *only* active device needed for most of the projects in which it is used.

The LM389's three transistors are general-purpose npn types capable of operating from dc to 100 MHz. They are reasonably well matched and can function effectively at current levels from 1 µA to their maximum ratings of 25 mA. With a maximum V_{CEO} of 12 volts and a maximum power dissipation of 150 mW, each transistor has a typical dc beta of 275. As long as their currents and voltages are kept within the absolute maximum ratings and the collectors are never at a negative potential with respect to the common substrate (pin 17), there is virtually no limit to the ways in which the transistors can be used. For example, they can be employed as conventional transistors, in a Darlington configuration for increased gain, as diodes, and even as zeners, utilizing their emitter-base break-down voltage of 7.1 volts at currents of from 1 µA to 5 mA. In addition, with a V_{SAT} of only 150 mV when sinking 10 mA, they make excellent LED drivers.

The device's amplifier section comprises the equivalent of five npn and five pnp transistors together with two diodes and features a quasi-complementary power output stage capable of delivering up to 500 mW to a 16-ohm load with only 10% total harmonic distortion (THD). At the 125-mW level with an 8-ohm load, the THD drops to a typical value of 0.2%. The amplifier has a nominal bandwidth of 250 kHz, a power supply rejection ratio of 50 dB, and input impedances of, typically, 50,000 ohms. The input(s) are ground referenced while the output is biased automatically to one-half the supply voltage. The circuit's quiescent current (zero input signal) is typically a low 6 mA. Although the voltage gain is set internally at 20 (26 dB), external shunt components can be used to raise this to as much as 200 (46 dB).

Overall, the LM389 has a maximum supply voltage rating of 15 volts, a maximum power dissipation of 825 mW, and an operating temperature range of from 0°C to +70°C.

Referring to Fig. 1, the following tips are among the practical application hints suggested by the manufacturer in the 8-page technical brochure describing the LM389:

(1) The amplifier section's voltage gain is fixed at 20 by the 1350-ohm resistor between pins 4 and 12. Bypassing this resistor will raise the overall gain. With a 10-µF, 12-V capacitor here, the gain will increase to 200. Gain values between 20 and 200 may be obtained by connecting a fixed or variable resistor in series with the shunt capacitor. Gain control also can be achieved by capacitively coupling a resistor or FET between pin 12 and circuit ground (pin 17).

(2) The circuit's overall frequency response can be tailored to meet individual requirements. For example, bass boost can be added to compensate for a small loudspeaker's poor bass response by connecting a blocking capacitor (say, 10 µF) and series shunt resistor between pins 1 and 12, paralleling the internal 15,000-ohm resistor. A shunt resistor of 15,000 to 10,000-ohms here will provide an effective 6-dB bass boost. If pins 4 and 12 are bypassed for increased gain, shunt values as low as 2,000 ohms can be used without affecting overall stability.

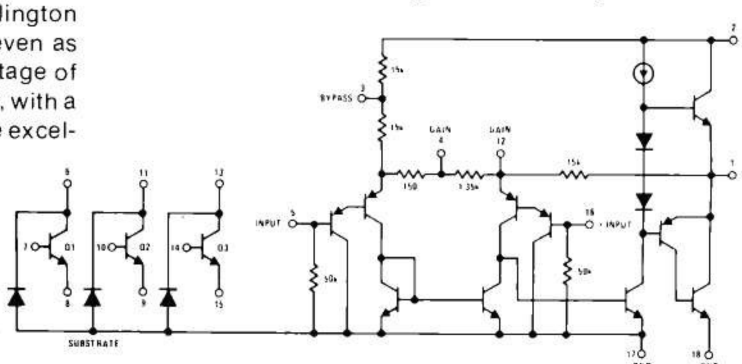

Fig. 1. The equivalent circuit diagram for the LM389 shows its versatility.

(3) Normally, both amplifier inputs (pins 5 and 16) are biased to ground via 50,000-ohm internal resistors. If capacitive coupling is used to either input or if direct coupling with a dc source resistance of more than 250,000 ohms is used, no modifications to the input circuits are needed. If direct coupling with a dc source resistance of between 10k and 250k is used, then the unused input terminal should be shunted to circuit ground with a resistor equal to the source resistance to minimize the effects of offset biasing. If the dc source resistance is less than 10k, the unused input terminal should be shorted directly to ground. In addition, when the LM389 is used at higher gain levels, it is necessary to bypass the unused input with a 0.1-µF capacitor to ground to prevent degradation of gain.

(4) If oscillation or circuit instability occurs due to specific load characteristics, these may be eliminated by connecting a 2.7-ohm and 0.05-µF series RC network from output pin 1 to circuit ground.

(5) Although the LM389 has excellent power supply rejection and does not require a well-regulated dc source, the supply should be decoupled to ground with a 0.1-µF bypass capacitor to eliminate possible instability.

(6) Separate ground returns to the dc power source from the small signal (pin 17) and power stages (pin 18) are recommended to minimize possible parasitic coupling.

(7) If desired, the amplifier may be muted (turned off) without affecting the input signal either by shorting pin 3 to the supply voltage or shorting pin 12 to ground.

Typical circuit applications for the LM389 are illustrated in Figures 2 through 4. Abstracted from the company's technical bulletin, these are but representative of the hundreds of ways in which the device may be used. All the circuits employ standard, readily available components, all utilize a single LM389 as their *only* active device, and all may be duplicated quite easily in the home workshop using conventional construction methods, such as perf board or pc techniques. Neither layout nor lead dress should be critical but, of course, good wiring practice should be observed, with all signal carrying leads kept short and direct, dc polarities maintained, and adequate separation provided between the input and output circuits. Unless otherwise noted, all resistors, except for potentiometers, can be either half-or quarter-watt types, at the builder's option. The smaller capacitors can be either low-voltage ceramic, paper or plastic film types, while the higher value units, identified by polarity markings, are low-voltage electrolytics. The loudspeakers are PM types with either 8- or 16-ohm voice coils. Finally, the dc power sources may be either series connected penlight or flashlight cells or well-filtered, line-operated power supplies, as preferred.

Designed for use with standard ceramic pick-ups, the phono amplifier circuit shown in Fig. 2 uses one of the uncommitted transistors as an emitter-follower preamp to achieve a high input impedance, while the other two are wired in a high-gain Darlington configuration. Parallel-tee and bridged-tee RC networks are used to provide treble and bass control, respectively. A 10k potentiometer, capacitively coupled to the Darlington's output load through a 1-µF capacitor, serves as the circuit's gain control. The LM389's amplifier section is capacitively coupled to the loudspeaker. The output (pin 1) to ground series RC network is optional.

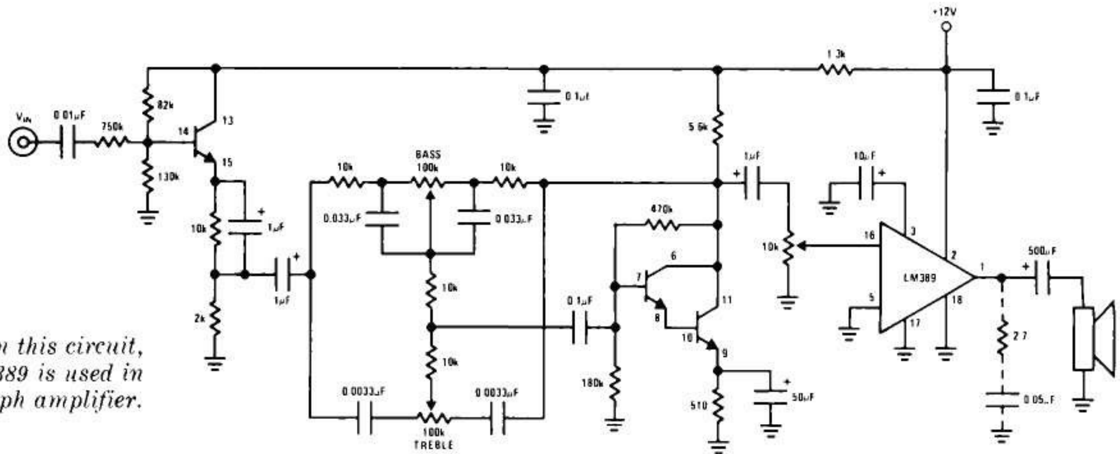

Fig. 2. In this circuit, the LM389 is used in a phonograph amplifier.

A portable tape recorder circuit is illustrated in Fig. 3. Here, two of the uncommitted transistors are cascaded as a voltage amplifier while the third serves as a variable resistor in the automatic level control (ALC) circuit used when the instrument is in its RECORD mode. A portion of the amplified signal is rectified by a general-purpose diode and applied back as dc bias to the control transistor's base through a two-stage L-type RC decoupling filter network. The transistor's collector-emitter circuit forms a voltage divider in conjunction with the 22k resistor in series with the instrument's microphone and acts to reduce or increase the input signal as necessary to maintain an optimum output voltage to the recording head. The recording/playback head's electrical characteristics are specified as 200-mH, 300 ohms, while the microphone is a conventional high-output electrodynamic type. A six-pole, two-position rotary or slide switch serves as the *Record/Playback* control and is shown in its RECORD position in the schematic diagram. The ALC feature is not used in the PLAYBACK mode; instead, a conventional gain control is switched into the circuit just ahead of the integrated amplifier section. The component values specified are for optimum performance with a 6-volt dc power source.

Chosen to demonstrate the LM389's great versatility, the circuits given in Fig. 4 include an electronic siren, Fig. 4(A), a voltage-controlled amplifier or tremolo circuit suitable for use in electronic musical instruments, Fig. 4(B), and a noise generator with potential applications in experimental test and research work, Fig. 4(C). All three designs feature loudspeaker outputs and utilize both the individual transistor and amplifier sections of the integrated circuit, with the noise generator, alone, requiring but two of the three available transistors. The siren uses two transistors as a low-frequency collector-coupled multivibrator to modulate the amplifier section through the third transistor, with the amplifier itself wired for operation as a higher frequency oscillator. The voltage-controlled amplifier circuit can be used as a tremolo when its gain control stage is driven by an external capacitively-coupled signal, as shown in the schematic diagram. The tremolo's maximum frequency is limited by the amplifier's interstage coupling network; with the component values specified, the maximum tremolo frequency should not exceed 160 Hz. Finally, the noise generator circuit is unique in that it uses the emitter-base junction of one of the transistors as a zener diode to form the basic noise source. The zener's output signal is amplified by a second transistor and applied to the amplifier section.

The circuits we've examined are but a sampling of the designs which can be developed using the LM389, and the average reader should have little or no difficulty devising additional applications for this extremely versatile device.

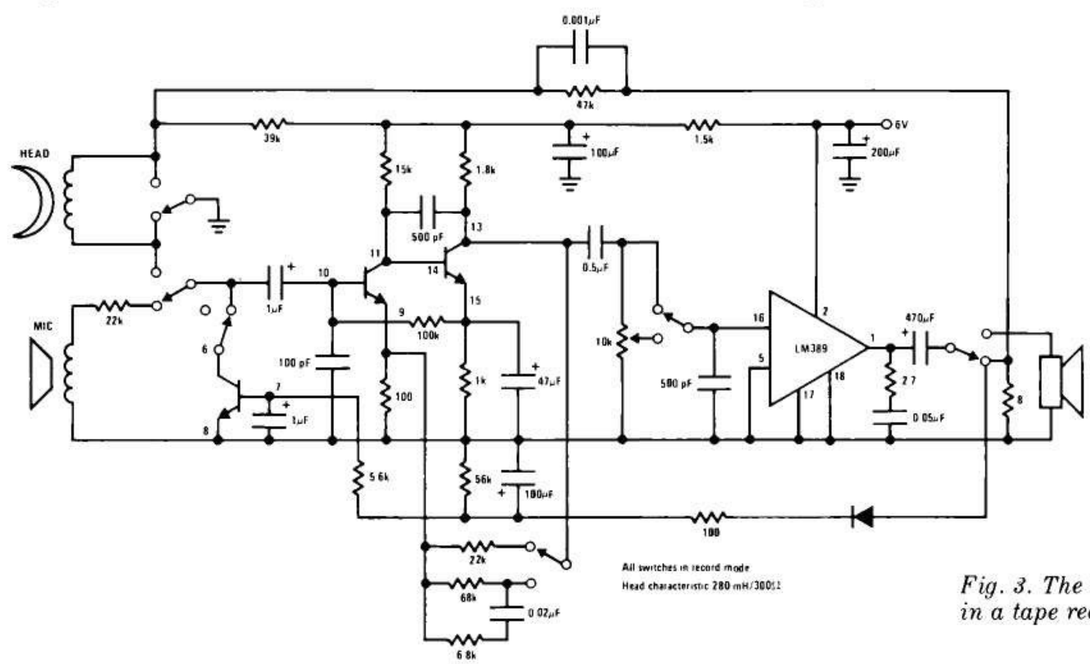

Fig. 3. The LM389 used in a tape recorder circuit.

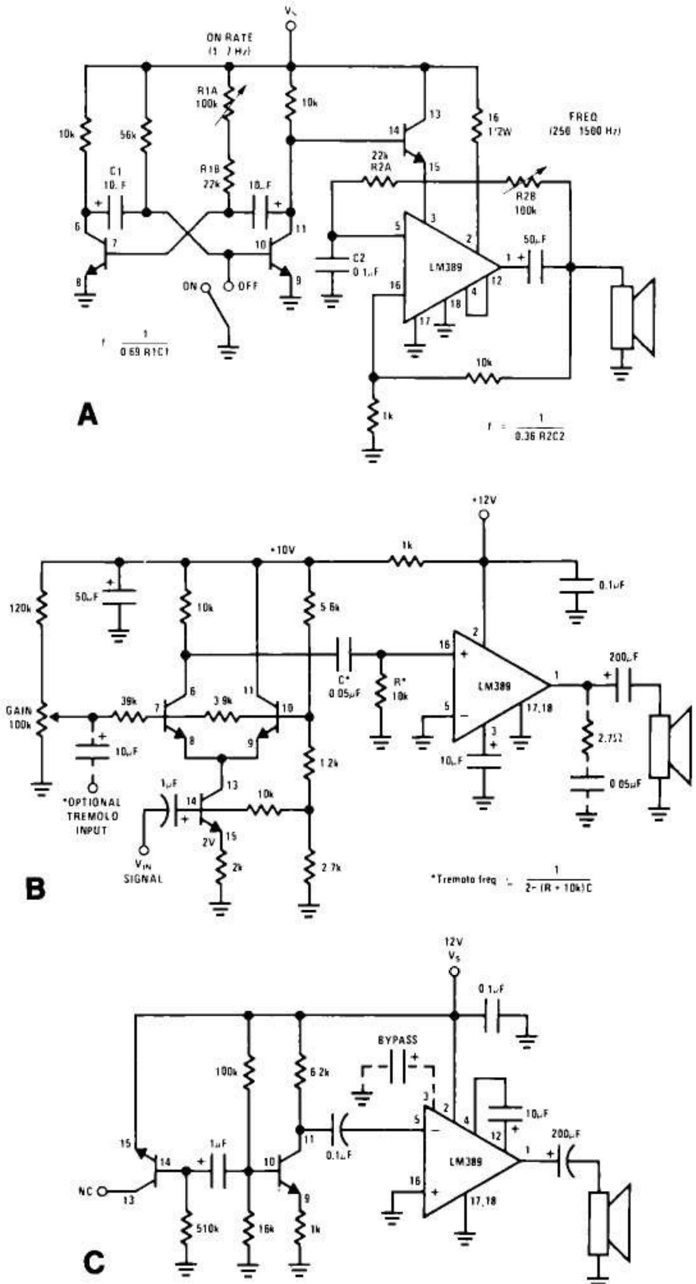

Fig. 4. Additional applications for the LM389 include: (A) a siren circuit; (B) a voltage-controlled amplifier with tremolo; and (C) a noise generator circuit.

The phonograph circuit (Fig. 2), for example, could be modified quite easily for use as an intercom. In addition, since the transistors have excellent high-frequency characteristics, the device is well suited for receiver and walkie-talkie projects. Add a suitable sensor, such as a photocell or thermistor, wire the amplifier section for operation as an oscillator (as in the siren circuit), and the LM389 can become the active part of a burglar or fire alarm system. The applications are there waiting—*all that's needed is your imagination!*

Reader's Circuit. Suitable for use in games, ESP experiments, and other applications, the random 4-digit number generator circuit illustrated in Fig. 5 was submitted by reader Michael S. Pyska (934 Seneca St., Lewiston, NY 14092). Requiring relatively few components, the design should be a good single evening's or weekend's project for the average hobbyist. The "heart" of Mike's design is a four-digit counter containing integral multiplexed 7-segment output drivers. In operation, a free-running pulse generator or "clock," *IC1*, drives the counter continuously. Since the instantaneous count in *IC2*'s register is changing rapidly, it is essentially a random number. Depressing and releasing the latch switch, *S2*, permits this number to be displayed on the readouts.

Standard components and devices are specified for the project. The clock, *IC1*, is a familiar type 555 timer while the counter/driver, *IC2*, is National Semiconductor's MM74C925. The four readouts are 7-segment common-cathode types, with the driver transistors, *Q1* through *Q4*, type 2N2222 general-purpose npn devices. All resistors are one-quarter or one-half watt types, with the series readout current limiters, *Rs*, 100 to 220 ohm units (the exact value is not critical). Power switch S1 is a spst toggle, slide, or rotary unit, while the latch switch, S2, is a spdt, spring return pushbutton or lever type. Finally, the power pack consists of three or four series-connected penlight or flashlight cells.

With neither parts arrangement nor wiring dress critical, the random number generator can be assembled using any standard construction technique from simple perfboard to a carefully designed PC card. If desired, it can be used as a two or three, rather than four, digit generator, and common-anode instead of common-cathode readouts can be used by adding a pair of hex inverters.

Device/Product News. Motorola Semiconductor Products, Inc. (P.O. Box 20294, Phoenix, AZ 85036) has introduced its popular *switchmode* power transistor in low-cost plastic packages. First in the new series are the MJE13002 and MJE13003 devices, rated at 1.5 amperes and 600/700 V blocking voltage. Switchmode transistors are designed especially for switching power supplies and other circuits requiring very fast turnoff time. They are characterized at 100°C operation with *limit* specifications for critical parameters—including a complete inductive-load switching performance matrix for collector currents ranging from 0.5 to 1.5 A., and reverse biased SOA for various turn-off voltages. The devices are housed in TO-126 packages.

A new line of inexpensive GE-MOV® varistors has been announced by GE's Semiconductor Products Department (Electronics Park, Bldg. 7-49, Syracuse, NY 13201). Ten models are available covering 14 to 250 V ac and 14 to 56 V dc. Typically, these devices are used for light-duty transient protection, such as relay-coil spike suppression.

Several products of potential interest to hobbyists and experimenters have been introduced by the Fairchild Camera and Instrument Corporation. Its Optoelectronics Division (4001 Miranda Ave., Palo Alto, CA 94304) is offering a complete digital clock module, a group of 8/10-inch high 3½- and 4-digit clock displays, and a family of 5-kV optical couplers, while its Linear Integrated Circuits Division (464 Ellis St., Mountain View, CA 94042) is manufacturing a new 5-watt, high-voltage audio amplifier IC in a molded 12-lead plastic package. The clock module, type FCS8100, contains a MOS circuit which features 10-second protection against power interruptions as well as a power failure indication, a display with a.m., p.m. and alarm set indicators and a colon in a solid-state assembly that measures only 3.5 × 1.75 inches and is 1-inch thick. The unit also incorporates power supply and output drive