Applications of Audio Amplifier—Transistor Array ICs

National Semiconductor
Application Note 264

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The availability of extremely low cost audio amplifier ICs with on-chip transistor arrays allows designers a great deal of flexibility in designing audio circuits. The availability of the uncommitted transistors on the chip makes it easier and more economical to implement audio functions. One chip, the LM389, features a 250 mW audio amplifier and a 3 NPN transistor array (see "The LM389 Audio Amplifier—Transistor Array IC" drawing). The amplifier has differential inputs, separate pins for setting the gain via a resistor and runs from a single supply which may range from 4V to 15V. The 3 transistors have good beta over a wide range of collector currents and current handling capability of 25 mA. This combination of devices and features on a single, low priced chip suggests that application areas unrelated to audio can be served. A good example appears in *Figure 1*.

DC-DC CONVERTER

The circuit in *Figure 1* uses the LM389 to provide a fully isolated ±15V supply from a 5V line. This is useful in powering op amps and related circuitry in a primarily digital system. This circuit is intended for use in a digital system where it is necessary to supply ±15V power to a small, low power load. Although units are available which will do this, they are designed to supply much more power than is required for many applications and are quite expensive. In this circuit, the LM389 amplifier is set up to oscillate at 20 kHz (Trace

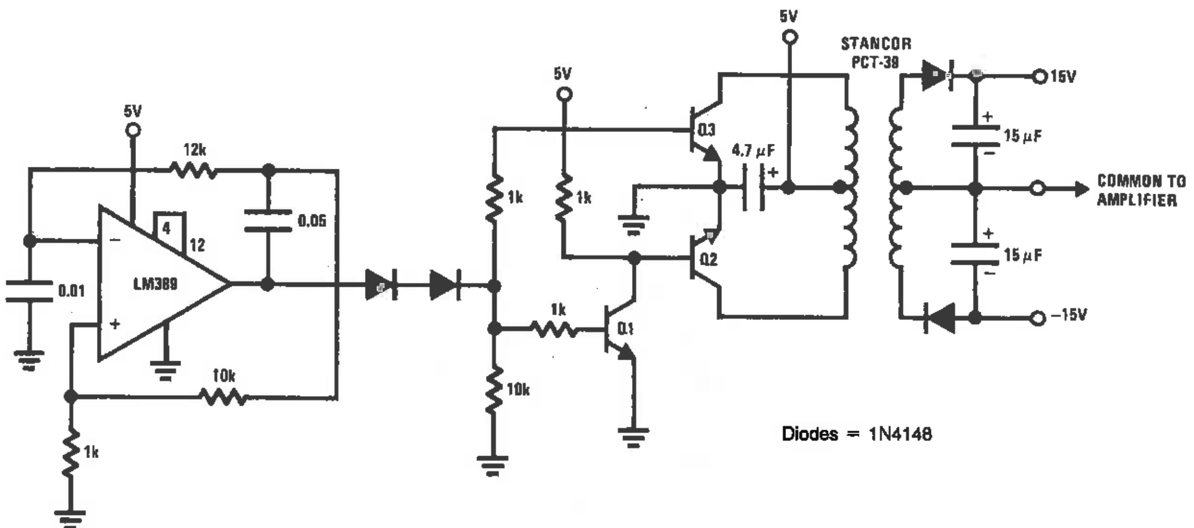

FIGURE 1

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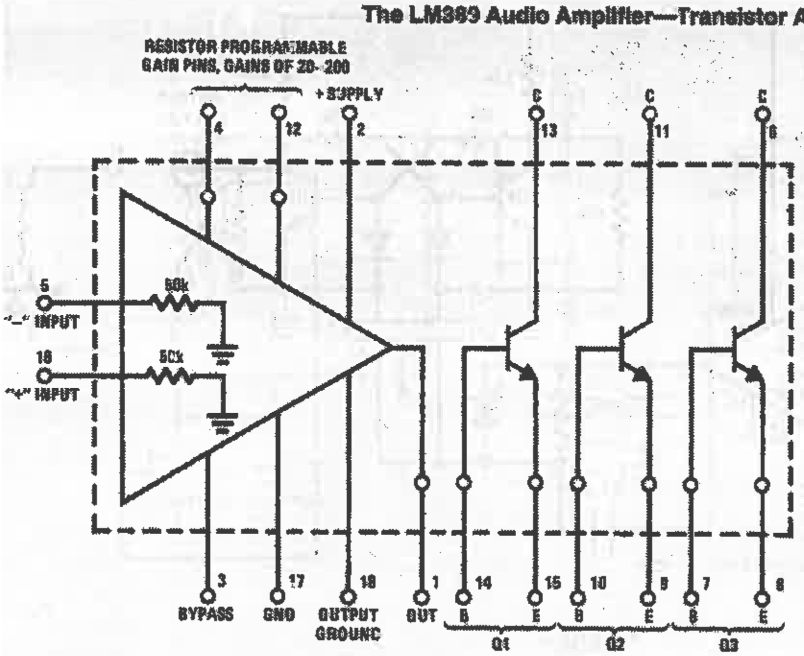
The LM389 Audio Amplifier—Transistor Array IC



- The gain pins allow resistive programming of gains from 20 to 200
- The bypass pin may be connected to ground through a 10 µF capacitor for increased supply rejection
- The three transistors have a minimum beta of 100 over a wide range of collector current. V_{CE} = 12V minimum
- Output (high current) ground should be returned directly to power supply ground

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A, *Figure 2*). Each time the amplifier output changes state, the charging voltage supplied to the 0.01 μF capacitor reverses polarity, resulting in a triangle at the amplifier's negative input (Trace B, *Figure 2*). When the triangle potential crosses the voltage at the positive input, the output again changes state. The 20 kHz square wave output is fed to Q1 and Q3. The series diodes insure clean turn-off for Q1 and Q3. Q1's inverted output drives Q2 while Q3 is used to drive half the transformer primary (Trace C, *Figure 2*). Q2 drives the other half of the transformer primary out of phase because of Q1's inversion (Trace D, *Figure 2*). The saturated switching of Q3 and Q2 is fast and clean (Q2 = Trace E, *Figure 2*; Q3 = Trace F, *Figure 2*; note horizontal sweep speed change) and results in an efficient voltage step-up across the transformer. The transformer output is rectified and filtered to produce complementary voltages which may be used to power the required linear components. This circuit will deliver ±1.5 mA, enough to power an op amp or instrumentation amplifier in a signal conditioning application.

BI-STABLE TOUCH SWITCH

The circuit of *Figure 3* allows a 115 V_{AC} powered load to be controlled from a touch plate. The circuit's output is bi-stable and changes state each time the plate is touched. In operation, each time the touch plate is contacted the Q1 emitter follower conducts and its output is amplified by the LM389's amplifier, whose normally positive output (note the 10 MΩ bias resistor to "+" input) becomes a 60 Hz square wave. This causes the potential at the output of the 10 kΩ-4.7 μF filter to jump sharply negative and remain there as long as the plate is touched. This negative step triggers a toggling flip-flop comprised of the remaining Q2 and Q3 LM389 transistors. In this manner, each time the touch plate is contacted the output of the flip-flop changes state. The flip-flop output is used to control a Triac or SCR which switches AC power to the load.

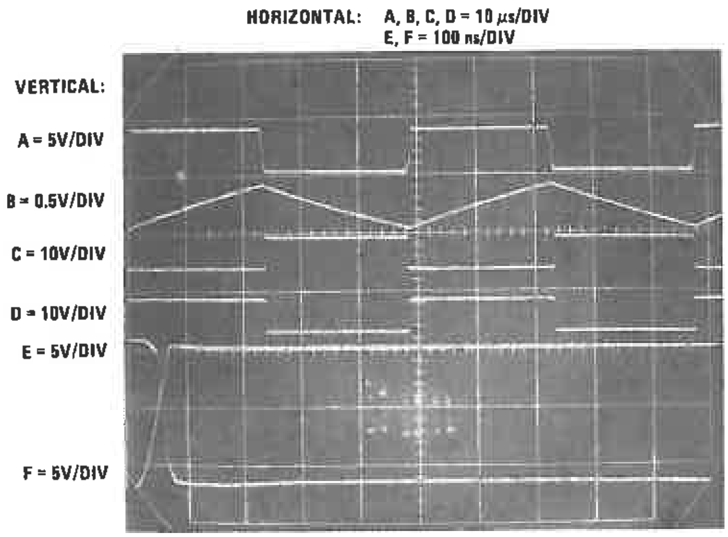

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FIGURE 2

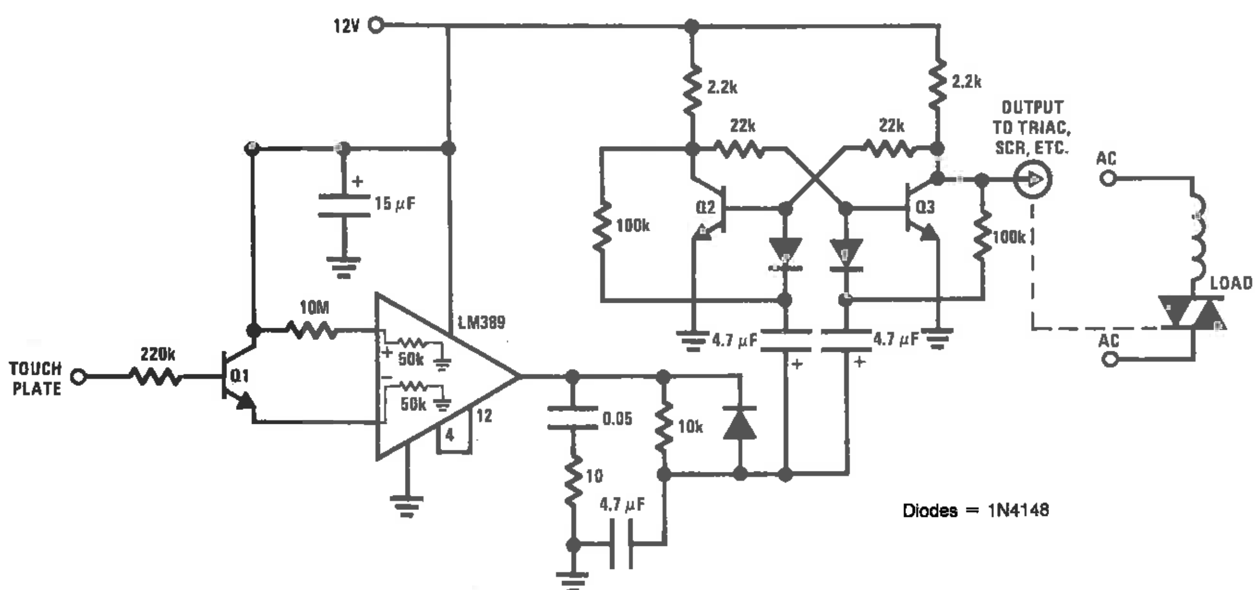

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FIGURE 3

PORTABLE OSCILLOSCOPE CALIBRATOR

The circuit shown in *Figure 4* allows a quick check of an oscilloscope's time base and vertical calibration. It may be built into a small hand-held box and powered by a 12.5V battery, such as an Eveready type E-289. In this circuit the amplifier oscillates at 1 kHz. The 30 kΩ value should be trimmed for a precise (±5 Hz) 1 kHz output. The amplifier output drives Q1 which provides very fast edges at Q2's base. Q2, an emitter follower, is used to drive Q3, which is connected in inverse mode and functions as a zener diode. Q3's breakdown potential is scaled by the 2k potentiometer to provide a 5.00V high square wave at the 5V output tap. The remaining resistors in the string furnish the 1V and 0.1V outputs. The 1 MΩ oscilloscope impedance does not introduce any appreciable loading error.

TUNING FORK STABILIZED FREQUENCY STANDARD

Figure 5 shows a circuit which provides a low frequency tuning fork stabilized output. Both sine wave and TTL compatible outputs are available. The circuit runs from 5V, which could be battery derived, due to the low power consumption. The tuning fork provides a direct low frequency output with very high stability (typically 5 ppm/°C) with an initial accuracy of 0.01%. It will withstand vibration and shock which would fracture a quartz crystal. Q3 is set up in a feedback configuration which forces the tuning fork to oscillate at its resonant frequency. The signal at Q3's collector is squared up by Q1 and Q2, which provide a TTL compatible square wave at Q2's collector (Trace A, *Figure 6*). This square wave is also used to drive an LC filter whose output is a sine wave. The filter's output is unity gain amplified

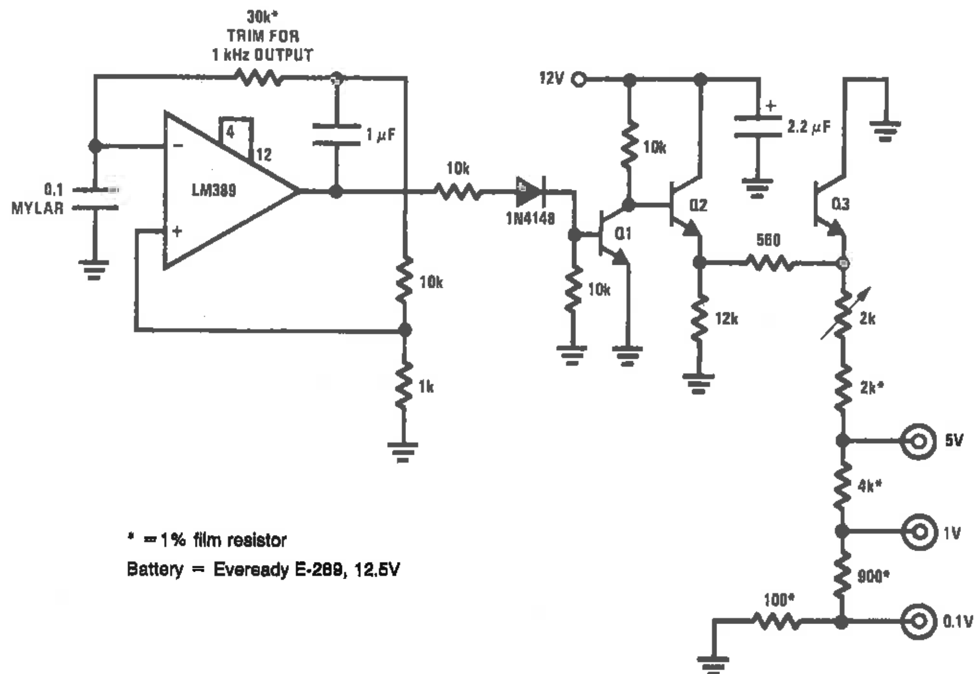

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FIGURE 4

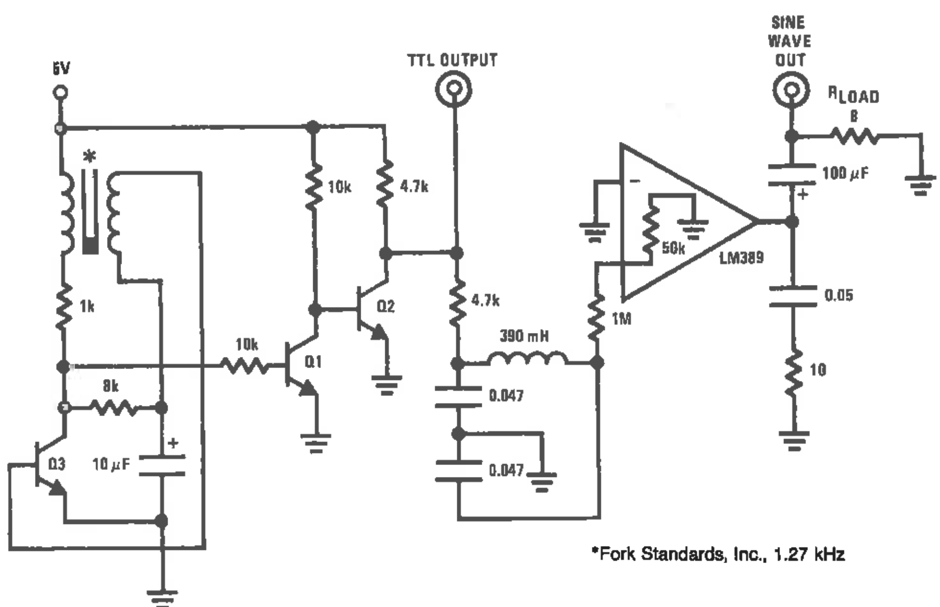

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FIGURE 5

by the amplifier to provide a low impedance output (Trace B, *Figure 6*). The amplifier, which has a minimum gain of 20, is made to achieve apparent unity gain by the voltage divider created between the internal 50 kΩ resistor and the 1 MΩ unit in series with the positive input. The circuit's sine wave output, which will drive an 8Ω load, has less than 1% distortion. Trace C, *Figure 6* shows the output of a distortion analyzer connected to the sine wave output.

LOW DISTORTION OSCILLATOR

In *Figure 7*, the LM389 is used to produce a low distortion sine wave and a synchronous in-phase wave output is also provided. The circuit's 1/4W output drive capability allows it to drive loads such as transducer bridges. In such applications, the in-phase square wave output can be used to drive synchronous demodulation switches. The oscillator's low distortion (0.2%) is directly traceable to the use of a light bulb which provides smooth amplitude limiting for the Wein bridge network at the amplifier. In this example, oscillation frequency is 1 kHz. The in-phase square wave output is provided by the three transistors. Q1, operating in the common base configuration, is based by the diode drop and the 100Ω potentiometer. The resultant square wave at Q1's collector is used to drive the Q2-Q3 common emitter stages which provide edge speed-up. The potentiometer is adjusted so that the edges of the output square wave precisely line up with the zero crossings of the sine wave.

HORIZONTAL: 500 μs/DIV

VERTICAL:

A = 5V/DIV

B = 2V/DIV

C = 0.2V/DIV

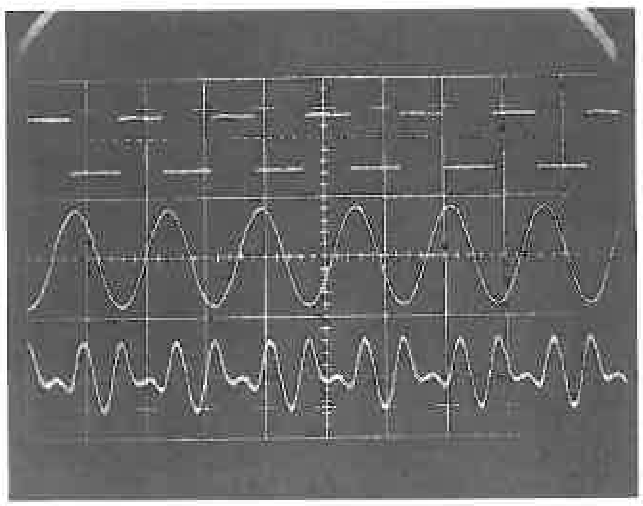

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FIGURE 6

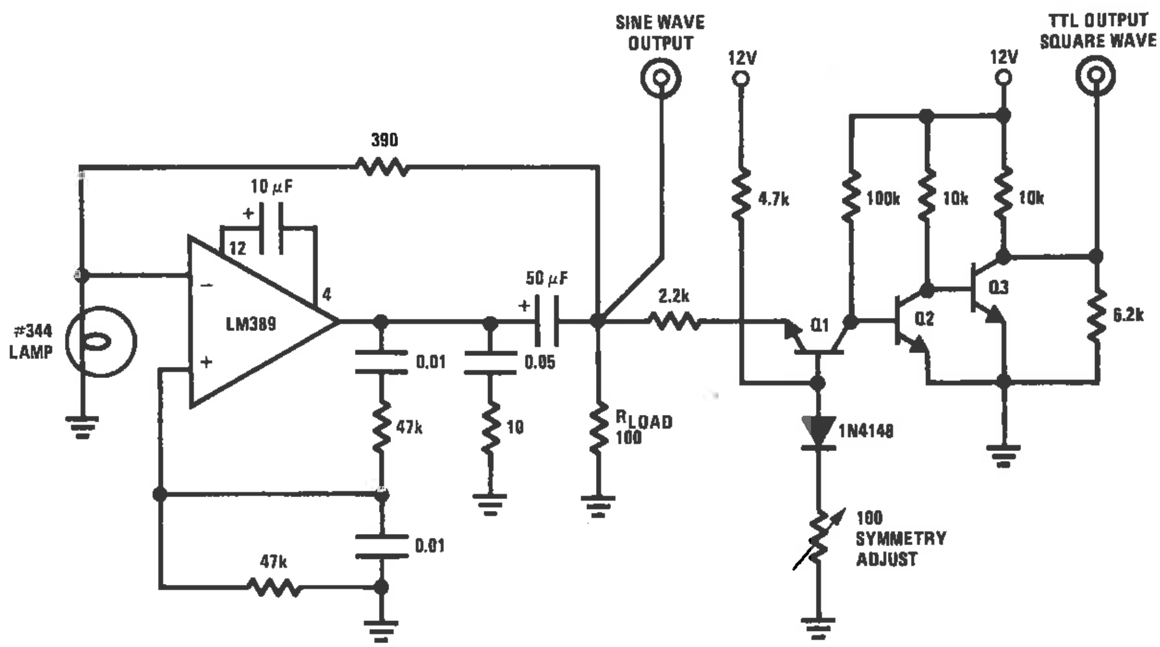

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FIGURE 7

LOGARITHMIC AMPLIFIER

In *Figure 8*, the LM389 is used in an unorthodox fashion to build a logarithmic amplifier which eliminates the usual complex and expensive temperature compensation associated with such circuits. This allows the cost of the logarithmic amplifier function to be reduced by an order of magnitude compared to conventional approaches. Q3 functions as a chip temperature sensor while Q2 serves as a heater. The amplifier senses the temperature dependent V_{BE} of Q3 and drives Q2 to servo the chip temperature to the set point established by the 10 kΩ-1 kΩ divider string. The LM329 reference insures power supply independence of the temperature control. Q1, the logging transistor, operates in this tightly controlled thermal environment (typically 50°C) and is immune to ambient temperature shifts. The LM340L 12V regulator insures safe operation of the LM389, a 12V device. When the circuit is first turn ON, the voltage Q2's emitter is about 3.3V resulting in a current flow of 120 mA. This forces Q2 to dissipate about 1.5W which raises the chip to operating temperature very rapidly. At this point the thermal servo takes control and backs the power down. The LM340L regulator has only 3V across it, so dissipation never exceeds more than about 0.3W. The zener at the base of Q2 prevents servo lock-up during circuit start-up. Because of the small size of the chip, warmup is quick and power consumption low.

To adjust this circuit, ground the base of Q2, apply circuit power and measure the collector potential of Q3 at known room temperature. Next, calculate what Q3's collector potential will be at 50°C, allowing −2.2 mV/°C. Select the 1k value to yield a voltage close to the calculated 50°C potential at the LM389's negative input. This can be a fairly loose trim, as the exact chip temperature is unimportant, so long as it is stable. Finally, unground Q2's base and the circuit will servo. This may be functionally checked by reading Q3's collector voltage and noting stability within 100 µV (0.05°C) while blowing on A3.

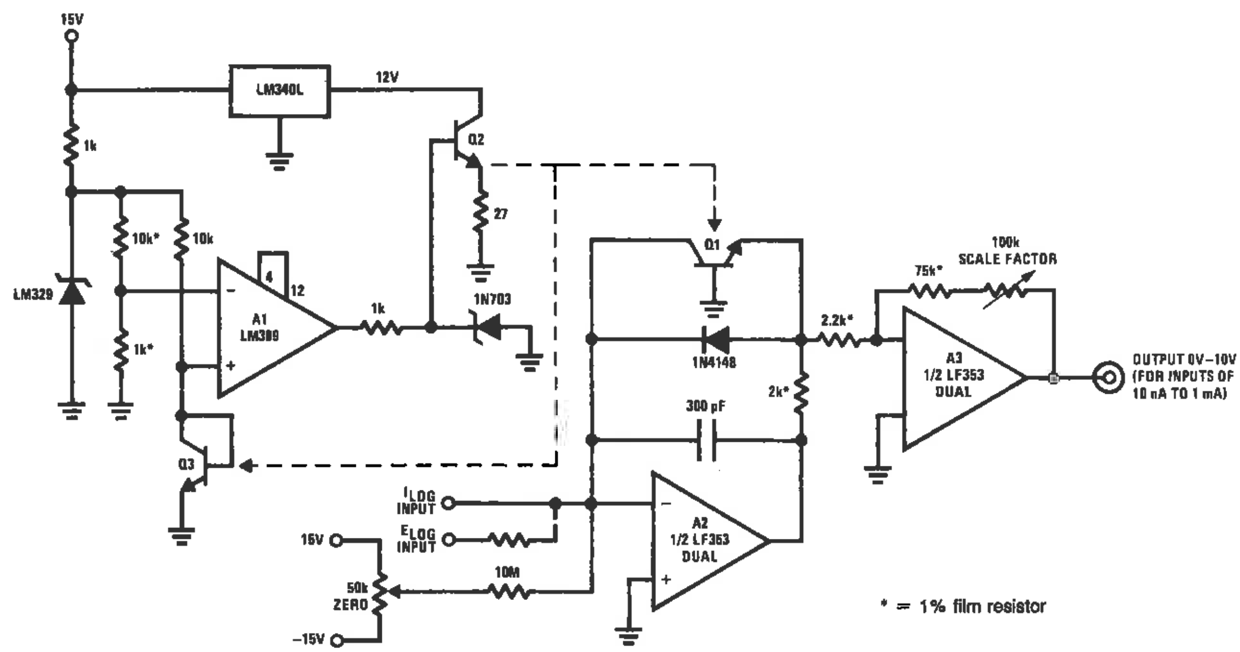

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FIGURE 8