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Electronix Handbook

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Sound Level Meter

Use it to find out how safe your surroundings are for your hearing.

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While still in the womb, we are first exposed to the sounds of our mothers' breathing as well as the pounding of their hearts. From that point, through birth and on, we are constantly surrounded with sound. But not all of the sounds we are exposed to each day are completely safe for our hearing.

It is common today, for example, to see people jogging while immersed in sound from headphones connected to a portable CD player. However, chances are you will also be able to hear their music selection as they pass by, which is a good indication that they might be damaging their hearing. Similarly, while car manufacturers have tried to reduce road noise and wind noise, they have also surrounded drivers and passengers with multi-speaker stereo systems that can achieve levels dangerous to hearing.

What can you do to make sure your surroundings are safe for your ears? Well, you can either walk around with earplugs on, or build the practical *Sound-Level Meter* from our plans and accurately test the environs you enter. The unit provides a visual readout of just how many decibels (dB) you're absorbing, using a solid-state LED bargraph with a dynamic range from 30 to 120 dB. It is shirt-pocket-sized and highly portable, so you can take it with you to work, to a club, or even to the theater.

Sound and Hearing

Just about everything that moves through the air produces vibrations that we perceive as sound. In nature, the loudest sounds are produced by hurricanes, volcanic eruptions, and, of course, lightning with its ensuing thunder. Sounds made by humans are the most intense as well as the most persistent, though. Anyone who listens to a jack hammer for half an hour or who goes to a rock concert can attest to that.

At frequencies below 500 Hertz, almost any part of the body can detect vibrations; the fingertips are especially sensitive to such vibrations. But the vibration required to stimulate the hearing threshold is still far more sensitive. At the human-hearing threshold, the vibration of the eardrum causes a displacement of one-billionth of a centimeter, less than the diameter of a single hydrogen atom. The sensitivity of a high-impedance Sound Level Meter microphone is generally expressed as so many dB down from a reference. Usually that reference is:

$$0 \text{ dB} = 1V_{rms}/\mu\text{Bar}$$

where 1 atmosphere of air pressure equals 1 Bar at 1 kHz. The Panasonic WM-52BM microphone used in the Sound-Level Meter has a rated sensitivity of –64 ± 2 dB, and it will provide 631 ± 147 $\mu V_{rms}/\mu$Bar. Today, the proper unit for that microphone is –44 ± 2 dB where the reference is 0 dB = $1V_{rms}$/Pa(Pascal) at 1 kHz. Pascal units increase the older µBar units by exactly +20 dB.

A human ear operates exactly like a microphone to detect sound-pressure waves and convert them to electrical signals that are sent to the brain for processing. The intensity of those pressure waves is interpreted as loudness while the frequency of the wave produces the tone of the sound. Now, the sound intensity perceived by the ear cannot be directly measured, but it has been related to a sound-pressure level (SPL) through careful measurements.

The threshold at which we can

Table 1

Perceived Sound and the Decibel Scale	
Decibel	Description
0	Threshold of hearing
10	Ordinary breathing (barely audible)
20	Rustling leaves in a gentle breeze
30	Country house (quiet)
40	City house
50	Classroom, quiet restaurant (moderate)
60	Large store, ordinary conversation
70	Factory, inside car in heavy traffic (noisy)
80	Downtown street at rush hour, vacuum cleaner
90	Large truck that is 45 feet away (very noisy)
100	Subway train
110	Construction site (nearly intolerable)
120	Jet plane taking off from 180 feet away
130	Machine gun fire at close range (intolerable)
140	Space launch, thunder with nearby lightning strike (painful)

Table 2

Acceptable Noise Levels (U.S. Department of Labor)	
Sound Level (db(A))	Duration per day (Hours)
90	8
92	6
95	4
97	3
100	2
102	1.5
105	1
110	0.5
115	0.25 or less

Table 3

Increase in distance	Sound pressure reduction (dB)
2 times	–6.02
3 times	–9.54
4 times	–12.04
5 times	–13.98
6 times	–15.56
7 times	–16.90
8 times	–18.06
9 times	–19.08
10 times	–20.00

perceive a l-kHz tone is taken as the 0-dB SPL that corresponds to 0.0002 µBars. That is a remarkably small pressure change that indicates the extreme sensitivity of human hearing.

Table 1 illustrates the SPL levels of typical sounds and environments. Ordinary breathing at 10 dB corresponds to a pressure change of 0.0006 µBar. At the other extreme, a space launch produces a pressure vibration of 140 dB, over three million times larger, or 0.002 Bar. Sounds above 100 dB are disagreeable to most people, and prolonged exposure to intensities above 80-90 dB can produce noise-induced hearing loss. Those losses begin with the higher frequencies and progress downward to lower frequencies. A person might recover from such noise-induced hearing loss after a period of rest in a quiet environment, but routine exposure to that condition over a prolonged duration will lead to permanent hearing damage.

At an SPL level of 100 dB, the pressure changes become 100,000 times larger (20 µBars). It is not surprising, then, that sound pressures of extreme intensity can damage our hearing. The level at which damage is sustained is also a function of duration. Federal, state. and local agencies have established standards on acceptable levels and duration. Table 2 presents one standard from the U.S. Department of Labor for noise regulation. Amplified rock music can easily exceed those limits at just 100 dB(A) for a couple hours.

Note that in Table 2 and in several places in this article, the dB measurements are given in terms of dB(A). Here's what that term refers to: The greatest sensitivity of human hearing occurs just above 1 kHz; that sensitivity decreases as frequencies go lower or higher. A device designed to follow the response of the human ear works on a weighted curve(an A-weighted curve. Therefore, the unit is dB(A).

Because sound waves generally radiate spherically outward in all directions, the SPL decreases as the square of the distance. The distance between the source of sound and the point of measurement is, therefore, very important. Table 3 gives the dB attenuation for several convenient measuring distances. Notice that when the distance increases ten times, the dB attenuation is just -20 dB (that relationship only holds for spherical waves in a large room without reflections). The l0-dB-per-segment display of the Sound-Level Meter and its large dynamic range can be easily used to demonstrate that relationship.

Logarithmic Amplifiers

The design of the Sound-Level Meter is based upon the successive log-detection amplifier used in the Signetics NE614 high-frequency IF amplifier. That IC was originally designed for cellular telephone applications. It belongs to a family of related devices, one of which also includes an NF602-type H mixer on a single die to make a complete, low-power, single-chip, high-performance receiver.

The successive log amplifier provides a detected output signal, referred to as the RSSI (Received Signal Strength Indicator), which is proportional to the received signal strength over about a 90-dB dynamic range. In cellular telephones, that feature is valuable to indicate the operating extremes of the communications channel and to indicate the proper times to exchange cells to maintain a solid signal-to-noise ratio.

Logarithmic amplifiers fall into a category between linear amplifiers that can handle perhaps a 20-dB dynamic range and limiting amplifiers, where most of the amplitude information is lost through clipping action. What also makes a logarithmic amplifier ideal for this project is that it offers instantaneous signal compression with fast response as compared to an automatic gain-control stage or a range-changing amplifier.

Circuit Description

Figure 1 shows the schematic diagram of the Sound Level Meter. Power for the circuit is provided by B1, a 9-volt battery. Total battery current is 14.5 mA, so an alkaline battery should last about 40 hours.

Audio signals are picked up by microphone MIC1. The output of MIC1 is buffered by Q1 to maintain the 3000-ohm load of resistor R2. The input impedance at pin 16 of the NE614 (U1) is 1600 ohms; R4 provides an additional 1600 ohms of resistance to reduce the gain on the high end and preserve the RSSI linearity. Capacitors C2 and C3 provide low- and high-frequency roll-off, respectively (that allows the unit to follow an A-weighted curve).

Capacitors C4 and C7-C9 are used as filters to bypass internal bias voltages within U1. An external coupling scheme is used between pins 14 and 12 of U1 to couple the first, internal, IF-amplifier stage to the second-stage limiter amplifier.

The RSSI signal is a current source that flows through R6 to establish a voltage at pin 5 of U1; the RSSI output voltage is a function of the input SPL. Capacitor C10 filters that voltage to remove high-frequency components. The slope of the RSSI line is nominally 0.084 V_{CC}/10 dB. Op-amp U2-b is configured as a non-inverting voltage buffer with a gain of 1.2: that gain multiplied by the RSSI slope produces a slope of 0.1V_{CC}/10 dB to the remaining circuitry, which includes the display and the power supply.

The components connected between U2-b and U2-a make up a low pass filter to give the meter a slow response. A slow response is desirable so that the unit responds to an average of the noise and not the peak.

The display, DISP1, is a ten-LED bar that is used to indicate sound level in 10-dB increments from 30 to 120 dB(A). The display is driven by an LM3914 linear bar-graph driver, U5. The internal voltage regulator of U5 functions by establishing a constant current through R15, because the voltage between pins 7 and 8 is maintained at 1.25 volts. The resulting voltage at the emitter of Q2 is about 5 volts, which powers U1, U3, and the internal voltage-divider string of U5 at pin 6.

While the overall divider string is temperature dependent, the division ratio determined by the divider's resistors is very stable and accurate. When powered from Q2 at a constant voltage (V_{CC}), U5's voltage steps remain stable at a slope of Vcc divided by the ten resistor steps. The resulting slope is therefore 0.1 V_{CC}/step which compares nicely with the RSSI signal slope of 0.1 V_{CC}/10 dB. Therefore, each LED segment of display SP1 will come on (indicate an increase) by 10 dB, independent of the exact magnitude of V_{CC}.

While the slopes of the display driver and the RSSI signal are the same, they might not have the same offset. For that reason, an LM334, U4, is used to source a constant l0-microamp current through R17 to generate a fixed offset voltage on top of

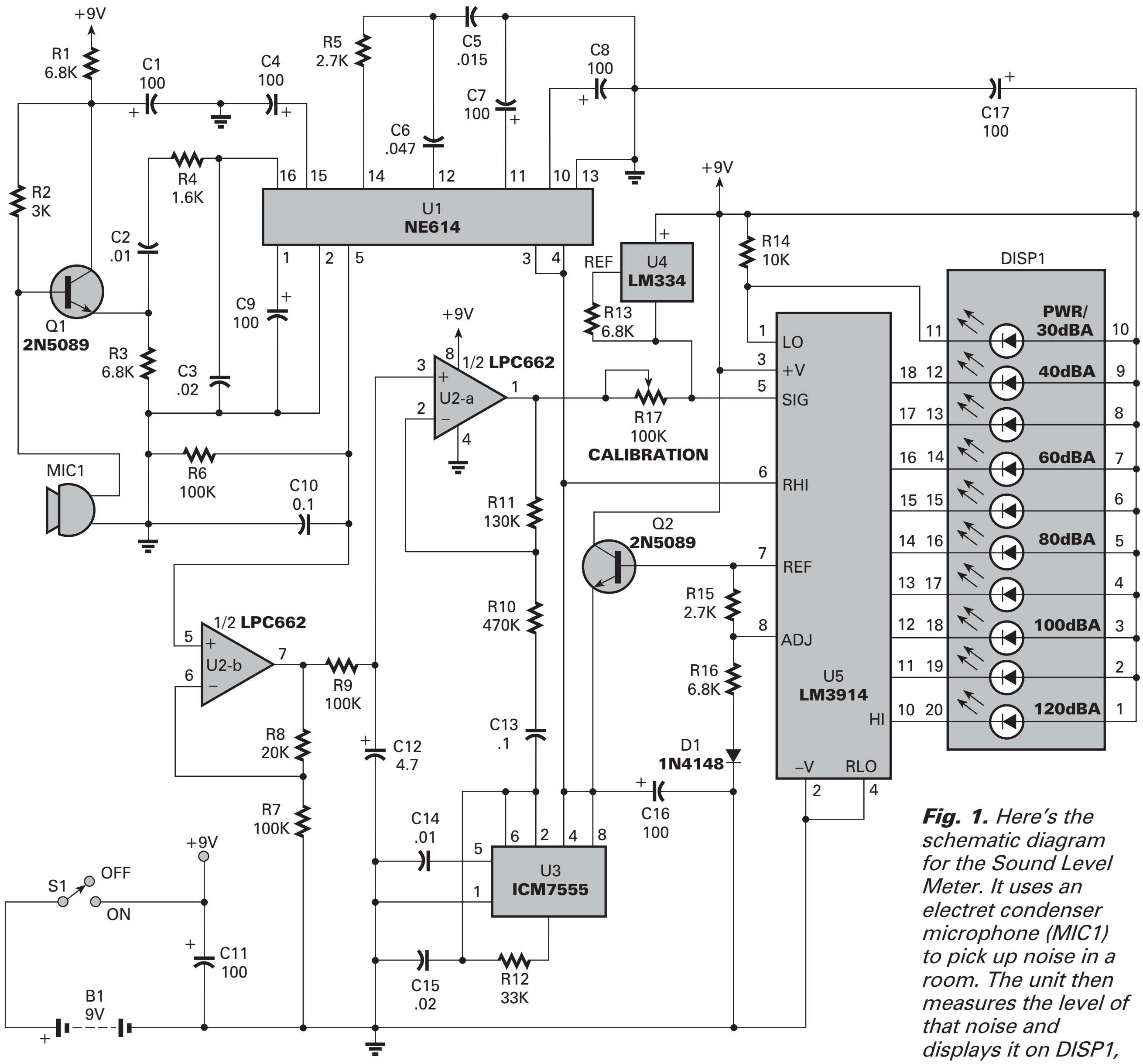
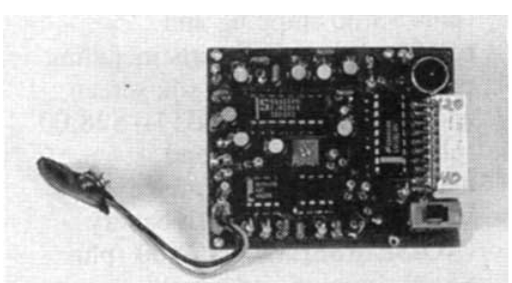


Fig. 1. *Here's the schematic diagram for the Sound Level Meter. It uses an electret condenser microphone (MIC1) to pick up noise in a room. The unit then measures the level of that noise and displays it on DISP1, an LED bargraph display.*



This board shot shows how DISP1 looks when mounted properly.

the composite RSSI voltage at the output of U2-a. By adjusting the value of potentiometer R17, differences in microphone sensitivity can be accommodated so that the display reads properly from 30 to 120 dB(A). The proper readout of the display is also ensured by an ICM7555 timer, U4, which is configured as a self-excited, squarewave oscillator; the resulting peak-to-peak, l-kHz signal of the timer is almost one step size of DISP1 (that is the equivalent of an LED bar).

Construction

The author's prototype for the Sound-Level Meter was built on a double-sided printed-circuit board. Building the Meter

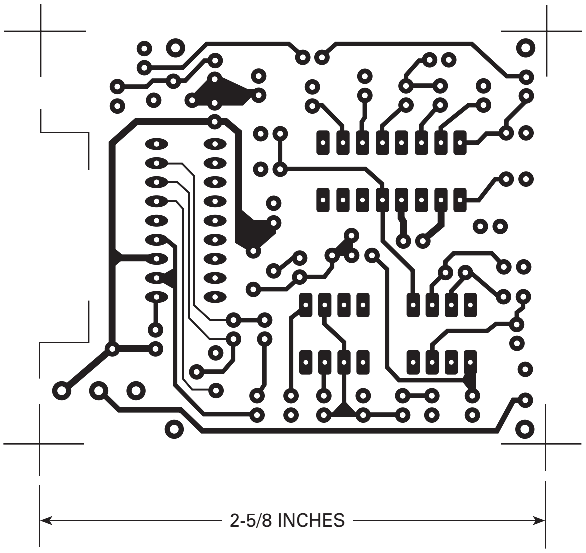


Fig. 2. *This is the foil pattern for the solder side of the double-sided PC board.*

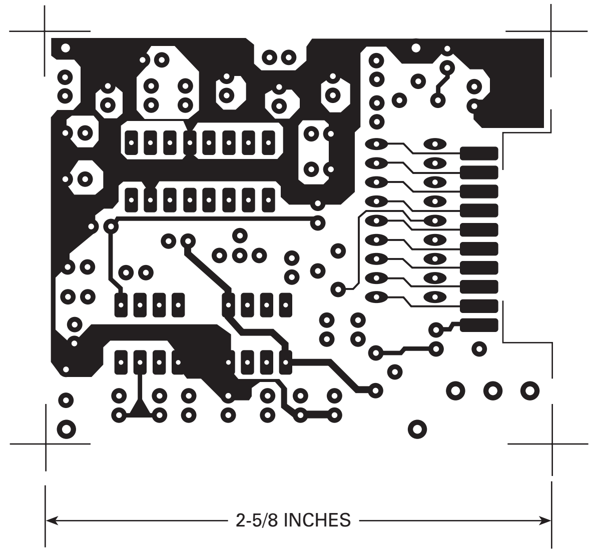


Fig. 3. *Here's the foil pattern for the component side of the board. Be sure cross hairs on Figs. 2 and 3 align when etching your own board.*

on a PC board with a good ground is strongly recommended because the NE614 is a high-frequency IC. If you would like to make your own PC board, you can use the solder-and component-side templates shown in Figs. 2 and 3, respectively. An etched and drilled board is also available from the source mentioned in the Parts List.

A parts-placement diagram is shown in Fig. 4. Cut the pins of the LED display to a length of approximately 3/16-inch. Mount the LED display sideways with pins 11 through 20 lined up with the pads along the component side of the board. The face of the display should be pointing away from the board, and pins 1 through 10 should be located above the component side of the board. Solder those free pins together with a wire and connect that wire to the solder pad closest to pin 11 of the LED display (see Fig. 4).

Mount the sockets for the U1-U4, making sure to observe proper orientation for each. The smaller, monolithic capacitors should be mounted next. Do not substitute other values for the capacitors, as most of the values tailor the bandwidth. Next, vertically (axial) mount the fixed resistors.

Mount the trimmer potentiometer, diodes, transistors, and the constant current source (U4). The electrolytic capacitors should be mounted next; make sure to match the proper polarity as shown in Fig. 4. Next install slide switch S1 so that about 1/16 inch of the leads protrude through the PC board. That will give the switch the proper height and clearance for the SerPac M6 case that comes with the Sound Level Meter kit.

Trim the battery-snap leads to approximately 2-1/2 inches, and solder them to the board, using the parts placement diagram as a guide. You might want to apply silicone rubber to where the leads attach to the board to reduce the strain on the joint.

Clean the board of residual flux before installing the microphone (make sure that the component doesn't make contact with any cleaning solvents). The microphone used is a Panasonic WM-52BM (Digi-Key part number P9970-ND) electret condenser element specified at (44 dB sensitivity into a 3000-ohm resistive load (the frequency response is flat within 3 dB to 16 kHz). It should be mounted with the leads just protruding through the board for maximum height. A small drop of silicone rubber can be mounted under the front edge of the microphone to support it more

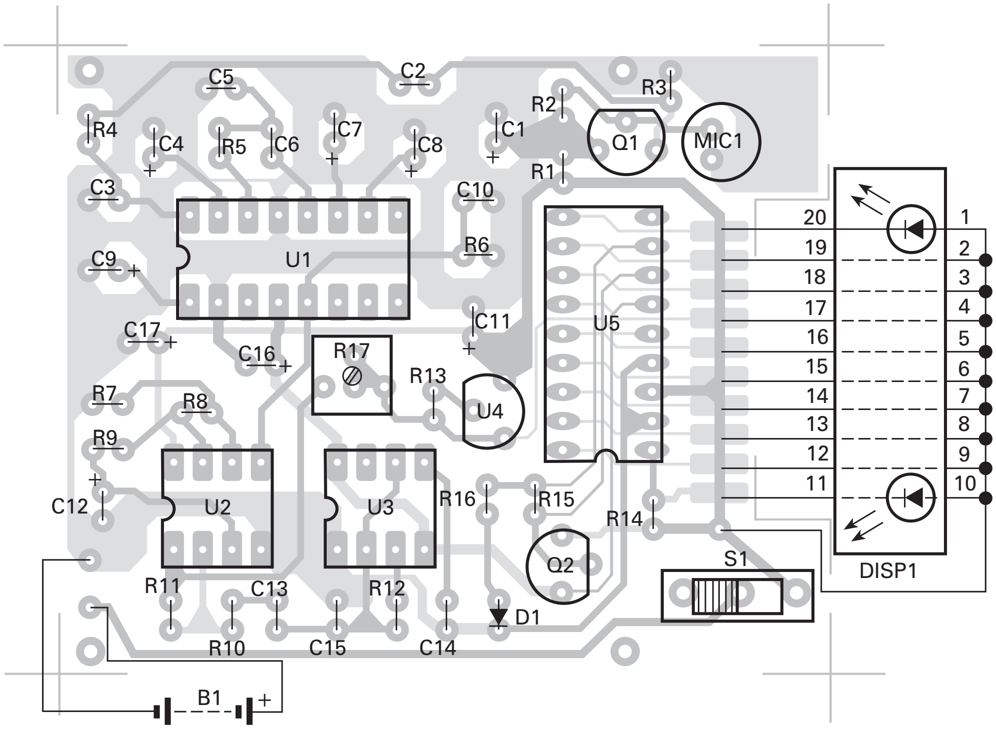


Fig. 4. *When installing components to the PC board, use this parts-placement diagram as a guide. The LED display, DISP1, is mounted sideways, off board. The row of pins not connected to pads are connected together by a wire that is then soldered to the pad as diagrammed.*

securely.

When the board is completed, mount it in its enclosure. The four internal mounting posts of the SerPac M6 case fit through the four larger, outer corner holes. If you use a different case, you will have to come up with an alternative method.

Testing and Calibration

Measure the V_{CC} voltage; it should be approximately 5 volts. Under very quiet conditions, the RSSI voltage should be under 0.2 volts at pin 5 of U1. Sounds should drive the RSSI voltage upward and light the bar graph progressively. Note that the low end of the display is located closest to the switch, so that the display reads properly (left to right) when the microphone is facing away from the user and towards the source.

Calibration is performed by adjusting R17, the offset potentiometer, so that a given signal level coincides with the proper bar display. Because the slope of the RSSI signal and the display are already equal, only one point of the display need be calibrated. The lowest point (the first LED) is almost in the noise of the amplifier, so that merely adjusting R17 to just fully light the first bar in a very quiet room will generally be adequate. The voltage measured across R17 should be about 0.44 volts. Of course, should you come across a professional, calibrated sound level meter, check your readings against it.

■

PARTS LIST FOR THE TV TRANSMITTER

SEMICONDUCTORS

D1—1N4148 silicon diode
DISP1—Ten-LED bargraph
Q1, Q2—2N5089 NPN transistor
U1—NE614 high-frequency IF amplifier, integrated circuit
U2—LPC662 dual operational amplifier, integrated circuit
U3—ICM7555 timer, integrated circuit
U4—LM334 constant-current source, integrated circuit
U5—LM3914 linear bar-graph driver, integrated circuit

RESISTORS

(All fixed resistors are 1/4-watt, 5% units .)
R1, R3, R13, R16—6800-ohm
R2—3000-ohm
R4—1600-ohm
R5, R15—2700-ohm
R6, R7, R9—100,000-ohm
R8—20,000-ohm
R10—470,000-ohm
R11—130,000-ohm
R12—33,000-ohm
R14—10,000-ohm
R17—100,000-ohm trimmer potentiometer

CAPACITORS

C1, C4, C7, C8, C9, C11, C16, C17—100-µF, 10-WVDC, electrolytic
C2, C10, C13—0.1-µF ceramic-disc
C3, C15—0.02-µF ceramic-disc
C5—015-µF ceramic-disc
C6—0.047-µF ceramic-disc
C12—4.7-µF, 10-WVDC, electrolytic
C14—0.01-µF ceramic-disc

ADDITIONAL PARTS AND MATERIALS

MIC1—Electret condenser element (Digi-Key part no. P9970-ND or equivalent)
S1—SPST slide switch
B1—9-volt battery
Printed-circuit materials, project enclosure, battery snap with leads, IC sockets, wire, solder, hardware, etc.

Note: The following items are available from
Vista
P.O. Box 1425
Bolingbrook, IL 60440
Tel. 708-378-5534)

NE614 IF Amplifier($4.50 (plus $3.00 shipping and handling); pre-etched PC board (NOISE-BRD) ($10.00 (plus $3.00 shipping and handling); kit of all parts including prepunched case with silk screen and battery (NOISE-K1T) ($48.00 (plus $5.00 shipping and handling); a fully assembled version is available with battery (NOISE-ASSEM)-$59,00 (plus $5.00 shipping and handling). Illinois residents please add 7.5% sales tax. Check, money order, and credit cards are accepted. For fast check verification, please provide street address (no PO boxes), telephone number, and driver's license number and state of issue.

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