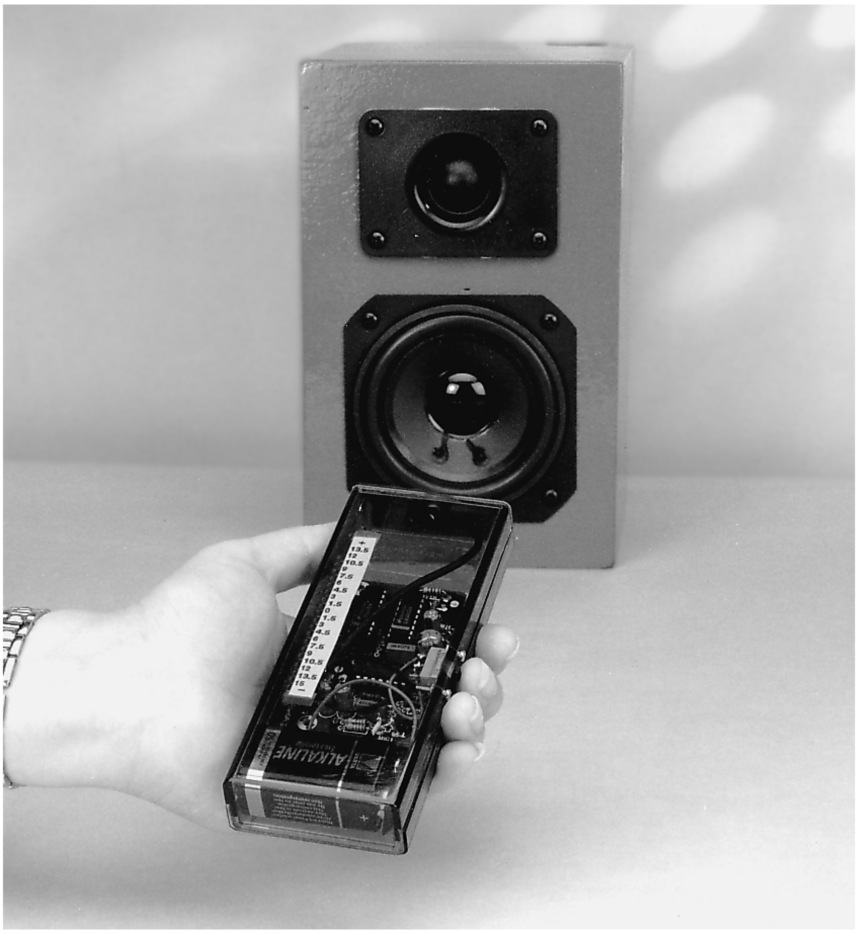
portable sound-pressure meter

sound analysis with LED indication

Few audio enthusiasts possess, or have access to, equipment required for accurately measuring the performance of a loudspeaker or the acoustics of a given hall or room. The unit described in this article is an instrument that does not give the performance of a professional meter but, in conjunction with a test CD, makes possible fairly accurate sound level measurements that enable the frequency response of an acoustic system to be ascertained. Moreover, its small size makes it a very handy unit to carry about.

Design by H. Baggen



Most home workshops have facilities for measuring current, voltage and resistance as well as other generated electrical signals with the aid of an oscilloscope and a function generator. However, equipment for measuring the frequency response of a loudspeaker, consisting of at least a sweep-oscillator system, a level recorder and a standard microphone, is in most cases not available.

Because of this lack, many amateurs would like a simple, inexpensive instrument with which the performance of a loudspeaker in a given hall or room can be assessed. Such an instrument, which, of course, cannot have the accuracy of a professional meter, is presented in this article. It consists of a simple-to-build sound pressure meter, equipped with a 20-LED display and has a resolution of 1.5 dB. In conjunction with a suitable test CD, it forms a very useful, compact and affordable miniature sound-level meter.

** In music and audio engineering, a third is a melodic and harmonic interval, taking three steps in a scale (major or minor) counting top and bottom notes. So, major third (C up to E), minor third (C up to Eb), and diminished third (C# up to Eb).*

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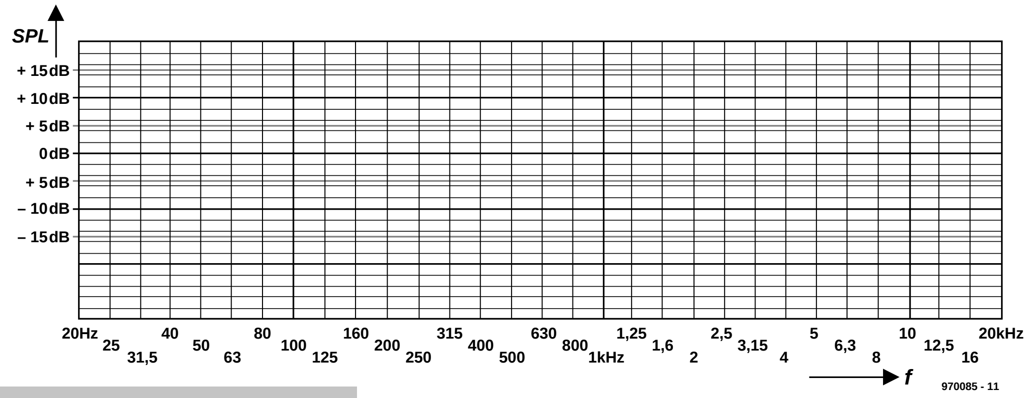

Figure 1. Model of a suitable graph paper to trace the measured frequency response of an acoustic system.

TEST SIGNALS

The circuit in **Figure 2** is, in essence, a fairly accurate sound level meter intended for carrying out relative, not absolute, measurements. Absolute sound levels are not of great import for determining the frequency response of a loudspeaker. What is of import is how the level of one sound compares with that of another, and that is a relative measurement.

In professional sound measurements, the sound source normally consists of an amplifier fed by a sweep-oscillator. Such a system is, however, not cheap and in the present circuit a much less expensive source, a test CD, is used. Most test CDs contain 30 discrete third-octave signals in the range 20 Hz to 20 kHz. When the output level produced by each of these signals is measured in identical conditions and plotted on graph paper as shown in **Figure 1**, a somewhat coarse, but nevertheless usable, frequency characteristic is obtained of the loudspeaker being tested.

It should be noted that the 30 signals available from the CD are recorded from a sweep-oscillator system generating third-octave warbled sine waves or noise (since, for measurement purposes, noise is much more to music). The frequency of a swept signal is not constant but swings between two values that are separated by 1/3 octave, that is, a third*. Third-octave noise is pink noise filtered to such a degree that only the frequencies at intervals of a third are retained.

Third-octave noise signals are used to eliminate the effects of the hall or room in which the loudspeaker is tested. Since many frequencies are generated simultaneously, the standard (test) microphone registers their mean level and this results in the averaging of the room (hall) resonances, which makes them less obtrusive.

CIRCUIT DESCRIPTION

Designing a circuit that picks up sounds and displays their relative level with reasonable accuracy is not very difficult – see Figure 2. This circuit consists of three sections: a microphone preamplifier (IC$_{1a}$), a full-wave rectifier

Figure 2.The circuit of the sound-pressure meter consists of a pre-amplifier, a full-wave rectifier, and an LED display. The microphone is an electret type.

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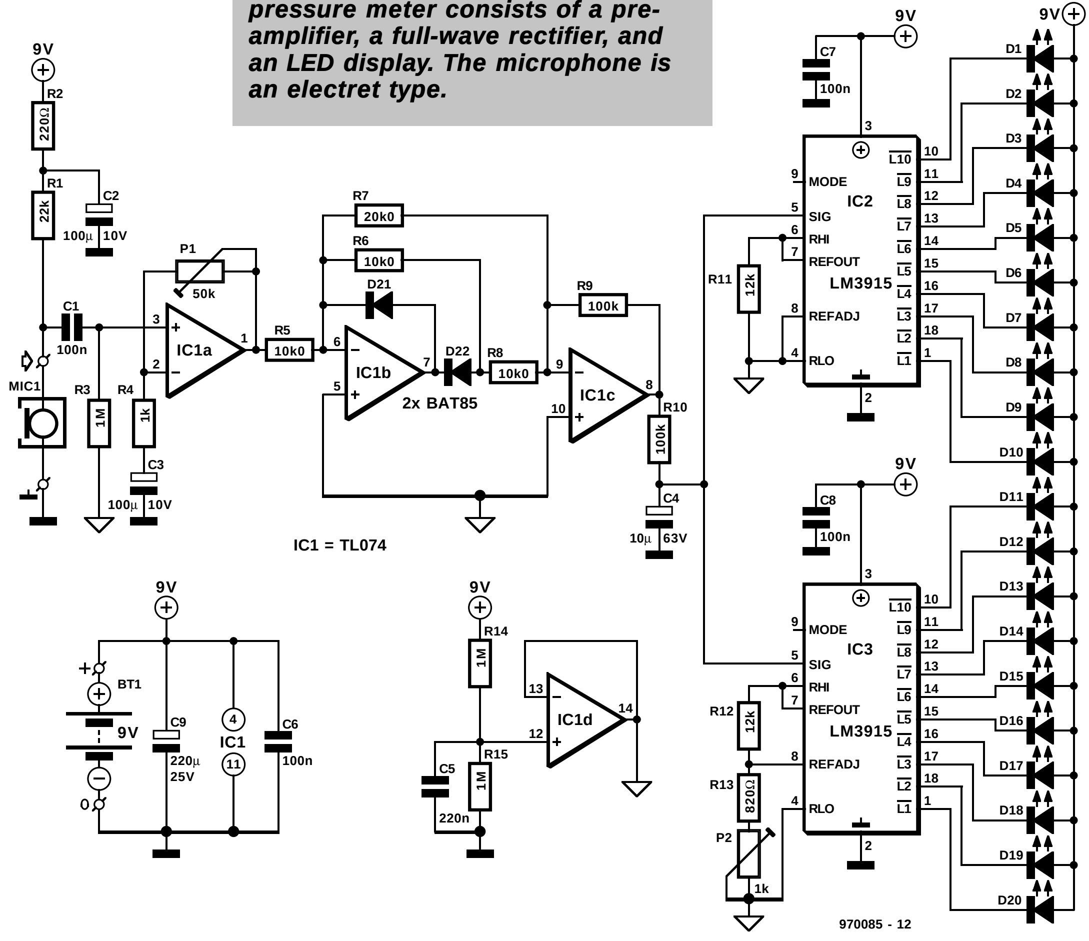

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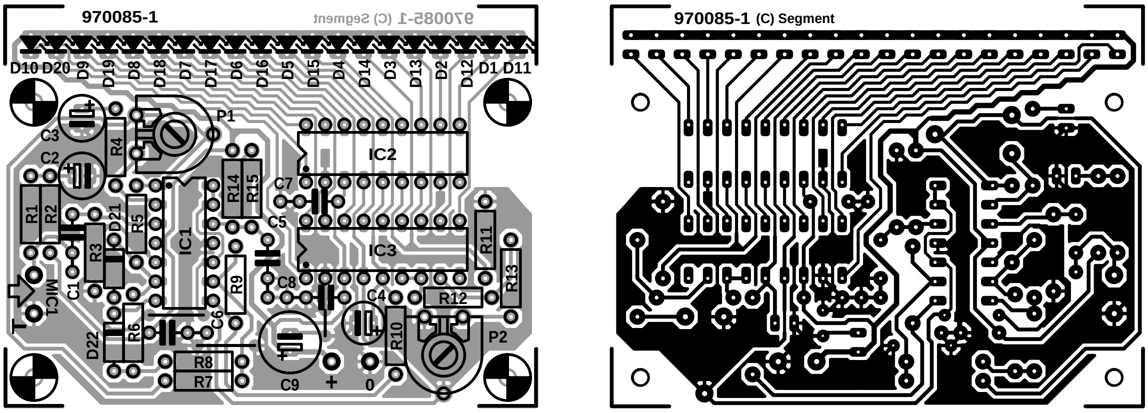

Figure 3. Printed-circuit board for the sound-pressure meter. Special care is needed when mounting the LED display.

Parts list

Resistors:
R_1 = 22 kΩ
R_2 = 220 Ω
R_3, R_{14}, R_{15} = 1 MΩ
R_4 = 1 kΩ
R_5, R_6, R_8 = 10.0 kΩ, 1% (but see text)
R_7 = 20.0 kΩ, 1% (but see text)
R_9, R_{10} = 100 kΩ
R_{11}, R_{12} = 12 kΩ
R_{13} = 820 Ω
P_1 = 47 kΩ (50 kΩ) preset
P_2 = 1 kΩ preset

Capacitors:
C_1, C_6, C_7, C_8 = 0.1 µF
C_2, C_3 = 100 µF, 10 V, radial
C_4 = 10 µF, 63 V, radial
C_5 = 0.22 µF
C_9 = 220 µF, 25 V, radial

Semiconductors:
D_1–D_{20} = LED, 3 mm, high efficiency
D_{21}, D_{22} = BAT85

Integrated circuits:
IC_1 = TL074CN
IC_2, IC_3 = LM3915N

Miscellaneous:
MIC_1 = electret microphone with rubber surround (e.g., MCE2000 from Monacor †)
BT_1 = 9 V battery with terminal clips
1 off single-pole on/off switch
Case: as desired - see text
PCB Order no 970085-1 (see Readers Services towards the end of this issue)

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(IC_{1b} and IC_{1c}), and the LED display (IC_2, IC_3, and D_1–D_{20}). Op amp IC_{1d} is used for creating a virtual earth at half the supply voltage.

The microphone in this application must meet certain requirements, of course, even though it is used in a low-budget version of a sound level meter. It must, for instance, be fairly linear, otherwise the circuit cannot perform very well. It is therefore out of the question to use microphones of unknown origin with vague or uncertain properties. On the other hand, an expensive standard (test) microphone is a superfluous luxury. A good, linear electret microphone is a very good compromise between these extremes. The prototype instrument uses a type that is linear within ±2 dB over the

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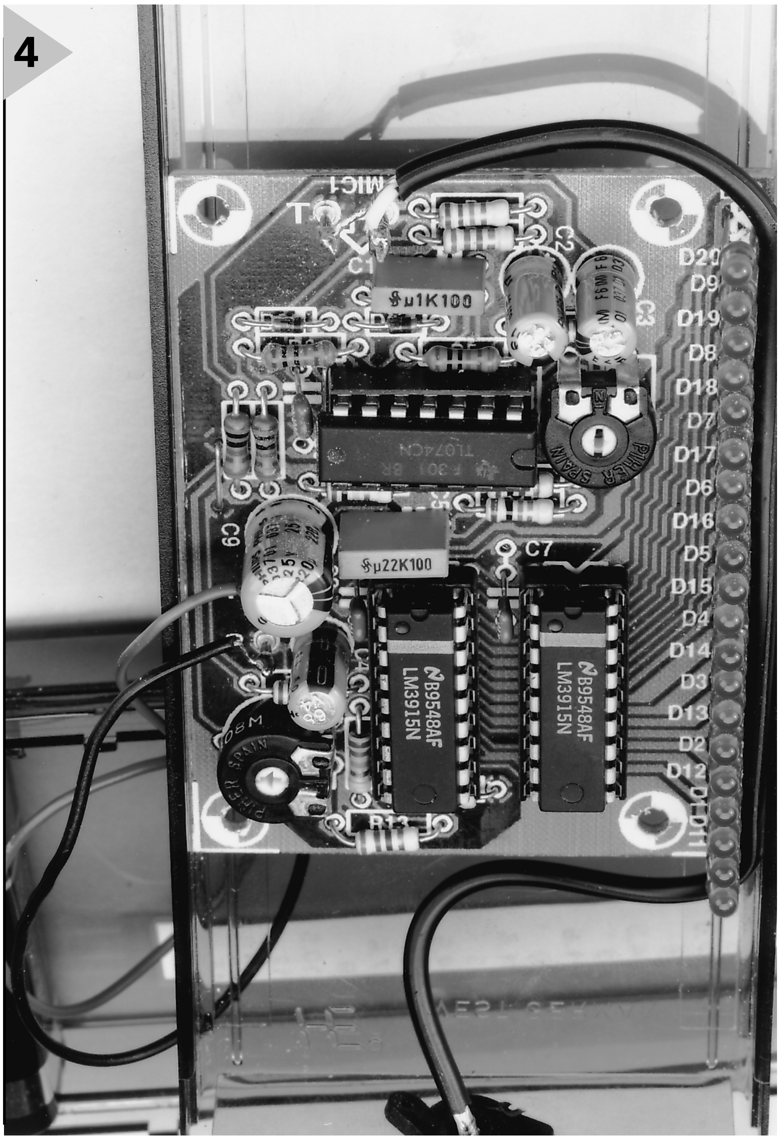


Figure 4. Inside view of the prototype sound-pressure meter in translucent case.

20 Hz to 20 kHz range.

The integral amplifier of microphone MIC_1 is held at about half the supply voltage with the aid of R_1. Network R_2-C_2 decouples the supply line.

The microphone signal is applied to preamplifier IC_{1a} via C_1. The cut-off frequencies of networks R_3-C_1 and R_4-C_3 are sufficiently low to result in a measurement error at 20 Hz of not more than 0.1 dB. The amplification, and thus the sensitivity of the microphone, is set with P_1.

The output of the preamplifier is applied to a conventional full-wave rectifier, IC_{1b} and IC_{1c}, So as to obtain a reasonable sensitivity without degrading the bandwidth of the instrument, IC_{1c} provides additional ×5 amplification. This results in an enhancement of the accuracy of the measurements at high frequencies.

To ensure a stable display, the rectified signal is differentiated by network R_{10}-C_4 (which constitutes a large time constant) before it is applied to the LED display.

The display is driven by the well-known Type LM3915 drive (IC_2). This IC contains a voltage reference source, a precise potential divider, and ten comparators, each of which can drive an LED directly. The level of the input voltage to the driver is displayed by the LED array in ten steps of 3 dB each.

Of course, 3 dB-steps are rather coarse and the resolution has, therefore, been enhanced by the addition of a second driver, IC_3, whose reference has been shifted by 1.5 dB. This is done by making the potential at the REFADJ(ust) pin (8) ×1.1885 higher than that at the corresponding pin of IC_2. This makes D_{11} the top of the decibel scale, followed by D_1, D_{12}, D_2, D_{13}, and so on. In other words, the LEDs driven by IC_2 and IC_3 are interlaced. This method has a slight drawback in that during measurements two LEDs light simultaneously: the correct test result lies somewhere between them. However, it was found that the operator quickly gets used to this.

POWER SUPPLY

Since the meter is intended for use as a portable instrument, the power supply must be battery-operated. The current drain is not greater than 19 mA, so that a 9-V battery will give about 100 hours service under normal conditions.

To ensure that op amps IC_{1a}–IC_{1c} remain within their common-mode range for as long as feasible, all three are powered by half the supply voltage. This is effected with the aid of a fourth op amp, IC_{1d}, and potential divider R_{14}-R_{15}, which is decoupled by C_5. The output of the op amp, pin14, constitutes a virtual earth at half the supply voltage above the real earth.

The reference pins of IC_2 and IC_3 are also connected to the virtual earth.

CONSTRUCTION

The instrument is best built on the printed-circuit board shown in **Figure 3**. The length of the board is determined by the dimensions of the display and the transparent case specified. It is, nevertheless, compact so that great care is required during soldering.

Potentiometer P_1 has intentionally been connected the wrong way around, that is, it has to be turned clockwise to reduce the amplification.

Note that although E96 type resistors are specified for R_5–R_8, E24 types may also be used if unavoidable. Their values should then be 11 kΩ instead of 10.0 kΩ or 22 kΩ instead of 20.0 kΩ as the case may be.

The prototype is housed in a translucent case, which has the advantage of not needing a cutout for the display. But, of course, any suitable or available case may be used, as long as the battery and finished board can be fitted comfortably inside.

Do not omit the rubber surround supplied with the microphone when fitting this on to the case. This surround damps spurious vibrations and makes the microphone less susceptible to reflections in or of the case.

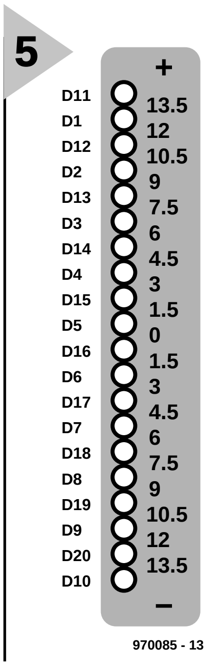
The display must, of course, be given a suitable scale of ±15 dB. The scale should have a 0 at its centre and this may be placed halfway between D_5 and D_{16} as shown in **Figure 5**. The other markings at 1.5 dB steps are placed accordingly.

SHIFTING THE REFERENCE OF IC_3

Preset P_1 is set according to the test CD used, and this will be discussed in the next section.

Preset P_2 sets the 1.5 dB shift of the reference voltage to IC_3, for which an accurate digital voltmeter is needed. Measure the potential, U_{REF1}, across pins 2 and 7 of IC_2 and then connect the voltmeter across pins 2 and 7 of IC_3. Adjust P_2 until a meter reading of $1.1885U_{REF1}$ is obtained.

Figure 5. Example of two usable scales for the sound-pressure meter. The total measuring range spans 30 dB.



USAGE

Usable test signals to obtain a frequency characteristic as described earlier may be obtained from the following test CDs: *The Test* (Stax, AXCD 92001); *Compact Test* (Pierre Verany, PV 784031); *Hi-fi Check* (Stereoplay); and *CD-2Check* (Monacor 30.0180).

When the frequency response is being measured, it is advisable to place the loudspeaker well away (≥ 1 metre) from reflecting walls or other objects. Set the volume of the audio system to a level where the test signals are well above the ambient noise level at all times. When a suitable level has been found, adjust P_1 on the sound-pressure meter to obtain a 0 reading on the LED display.

Bear in mind that at frequencies below about 200 Hz, effects of the room or hall are so strong that the measured levels say hardly anything about the performance of the loudspeaker being tested. This may be checked by holding the microphone right in front of the loudspeaker. It will be found that a number of peaks and troughs measured earlier (at the normal test distance of 1 metre) disappear.

An impression of the acoustic performance of the room or hall may be obtained by repeating the response measurement at a distance of 3–4 metres from the loudspeaker. At that distance, there is no question any longer of a flat response!

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