TECHNICAL NOTES

INTEGRATING SOUND LEVEL METER NL-04
PRECISION INTEGRATING SOUND LEVEL METER NL-14

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ORGANIZATION OF THE MANUALS

The documentation for the integrating sound level meter NL-04 and precision integrating sound level meter NL-14 consists of the three manuals listed below.
Although there are certain differences in performance and functions, the NL-04 and NL-14 are essentially identical in operation. The manuals therefore apply to both units. When there are differences between the two models, this is indicated in the manuals.

- **Instruction Manual**
  Describes connections, setup, and general operation of the NL-04/NL-14 as well as the optional filter units and printer.

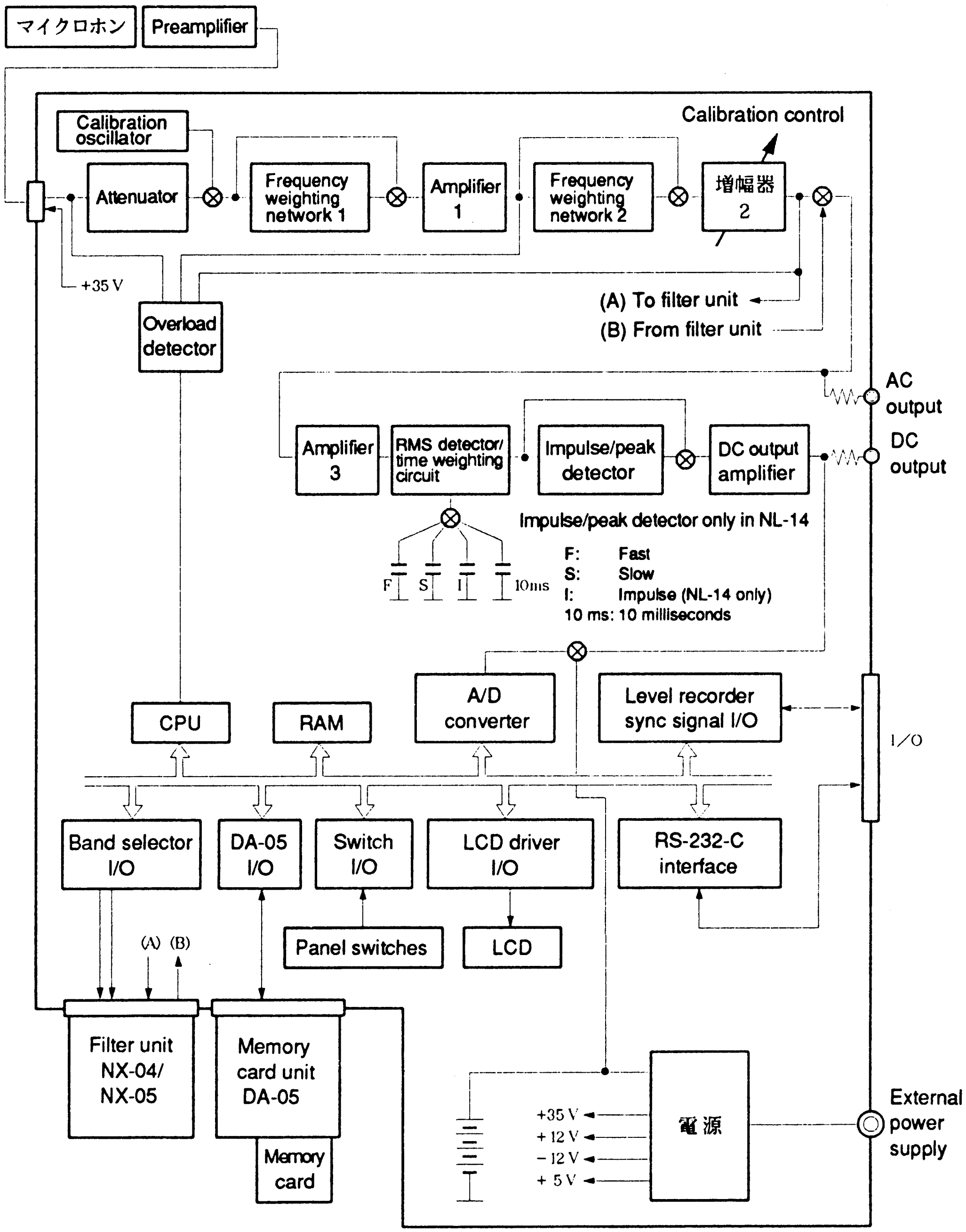
- **RS-232-C Interface Manual**
  Describes communication with a personal computer using the integrated RS-232-C interface of the NL-04/NL-14. Transfer protocols, commands for controlling the sound level meter, format of the sound level meter output data etc. are explained.

- **Technical Notes**
  Gives technical background information covering circuit configuration and performance characteristics of the sound level meter, microphone principles and performance, influence of extension cables and windscreen on the measurement and other topics.

CONTENTS

CONFIGURATION OF THE NL-04/NL-14

A block diagram of the NL-04/NL-14 is shown below.



Block Diagram

● Microphone, preamplifier

The unit employs a 1/2-inch prepolarized condenser microphone. The following microphone and preamplifier combinations are used.

NL-04: Microphone UC-52, preamplifier NH-19
NL-14: Microphone UC-53A, preamplifier NH-20

● Attenuator

Depending on the level range setting, the signal from the preamplifier is attenuated by 0 dB or 20 dB (⇒ p. 13).

● Frequency weighting network (1, 2)

After passing the attenuator, the signal is weighted according to the setting selected with the front panel keys.

A weighting: The signal passes frequency weighting network 1, amplifier 1, and frequency weighting network 2.
C weighting: The attenuator output is supplied directly to amplifier 1, and then to frequency weighting network 2.
Flat: No frequency weighting is carried out. The attenuator output passes amplifier 1 and then amplifier 2.

● Amplifier 1

Depending on the level range setting, the signal is amplified by 0 dB to 50 dB, in 10-dB steps (⇒ p. 13).

● Amplifier 2

Depending on the setting of the calibration control, the signal is further amplified by amplifier 2. The output of this amplifier is connected to amplifier 3 and the AC output jack.

● Amplifier 3

The output of amplifier 2 is further amplified by amplifier 3 and supplied to the rms detector and time weighting circuit.

● RMS detector, time weighting circuit

This circuit performs rms detection and logarithmic compression of the output signal from amplifier 3, resulting in a level-converted DC signal that is supplied to the A/D converter and the DC output jack. The available time weighting characteristics for rms detection are as follows.

NL-04: Fast, Slow, 10 ms
NL-14: Fast, Slow, 10 ms, Imp (impulse), Peak (peak hold)

● Overload detector

This circuit monitors the signal waveform. If an overload condition is detected, the indication "Over" appears on the display.

- **A/D converter, CPU, LCD**

  The output signal from the rms detector and time weighting circuit (level-converted DC signal) is converted into a digital signal by the A/D converter. The CPU then processes this signal depending on the level range setting, to determine the sound pressure level and other values for display on the LCD.

- **Calibration oscillator**

  A 1000-Hz sine-wave signal is used for calibration. This signal is output when the Cal key has been pressed.

- **Power supply**

  The voltage from the batteries or external power supply (AC adapter) is fed to a DC-DC converter which provides the voltages required by the various sections. The input voltage range of the DC-DC converter is 4 to 7 V, and the output voltages are +35 V, +12 V, –12 V, and +5 V.

- **Filter unit**

  The octave filter NX-04 or the 1/1, 1/3 octave filter NX-05 is connected here and becomes active when the Filter key has been pressed. The output signal from amplifier 2 is supplied to the filter unit. Depending on the band setting, the signal is routed through the corresponding bandpass filter before being supplied to amplifier 3 and the AC output jack.

- **Memory card unit**

  The memory card unit DA-05 allows storage of measurement data on memory cards.

- **I/O connector**

  Serves for input of control signals and output of data. The connector has the following functions.

  - Measurement data output to printer CP-11 (including data stored in memory)
  - Measurement parameter output to level recorder LR-06
  - Filter control input from level recorder LR-06 and LR-04
  - Communication with a computer (RS-232-C interface)
  - Input of external signal for start/stop control of auto store function or L_{eq}, L_E, L_x, L_{max} measurements

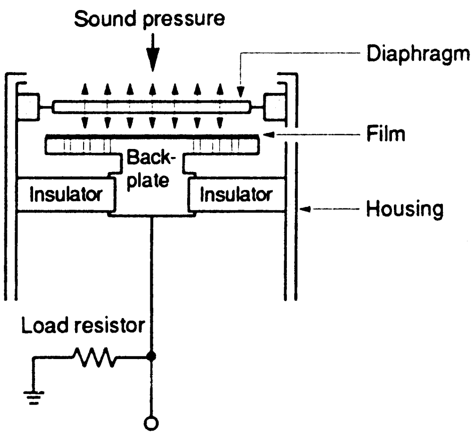
MICROPHONE

Measurements of sound pressure level can be carried out with a variety of microphone types. The NL-04/NL-14 employs a prepolarized condenser microphone that is compact and delivers stable and reliable response.

NL-04: 1/2-inch prepolarized condenser microphone UC-52
NL-14: 1/2-inch prepolarized condenser microphone UC-53A

Construction and Operation Principle

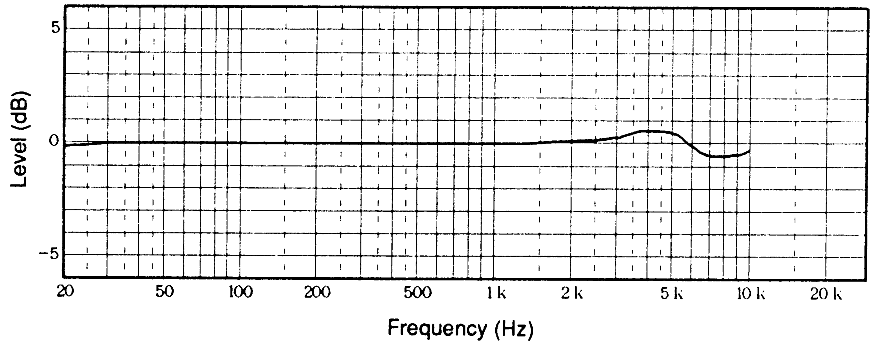
As shown in the drawing below, a prepolarized condenser microphone consists of four main parts: diaphragm, backplate, insulator, and housing. The surface of the backplate is covered by a film holding an electrical charge. When sound pressure is applied to the diaphragm, the distance between the diaphragm and the backplate changes, thereby altering the capacitance. Via a load resistor, this change can be turned into a voltage change. The frequency response as well as the temperature and humidity characteristics of a prepolarized condenser microphone depend considerably on the type and properties of the materials used. The frequency range is determined by the resonance frequency of the diaphragm assembly.



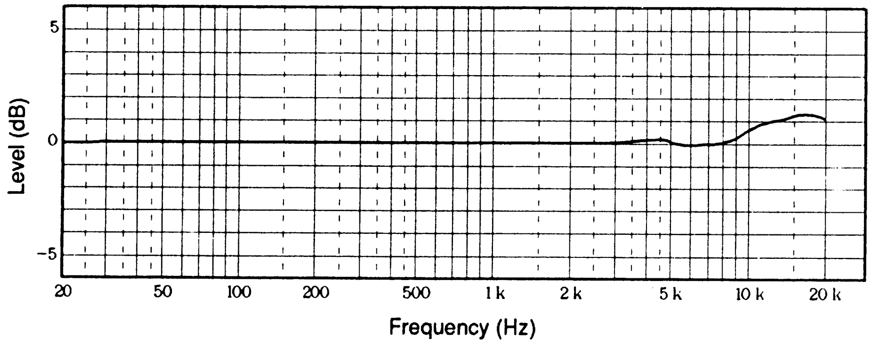
Prepolarized condenser microphone

Frequency Response

The frequency response of a sound field microphone is expressed as the frequency response in the reference direction of incidence. The diagram below shows an example for the frequency response of the microphone UC-52 used in the NL-04 and the microphone UC-53A used in the NL-14.



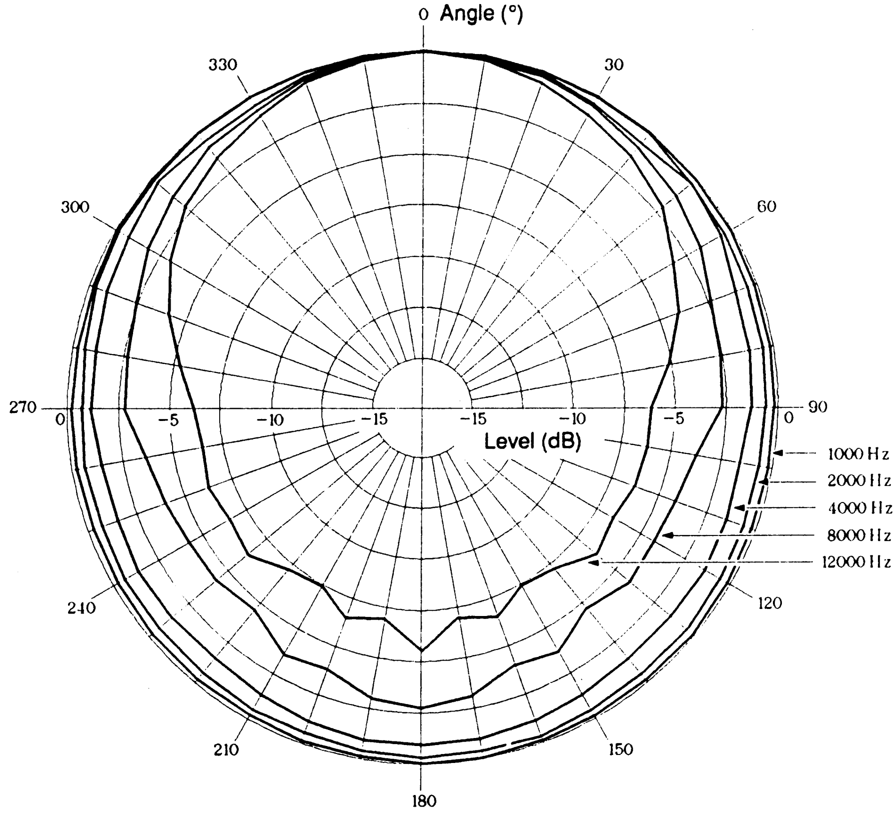
Frequency response sample of microphone UC-52



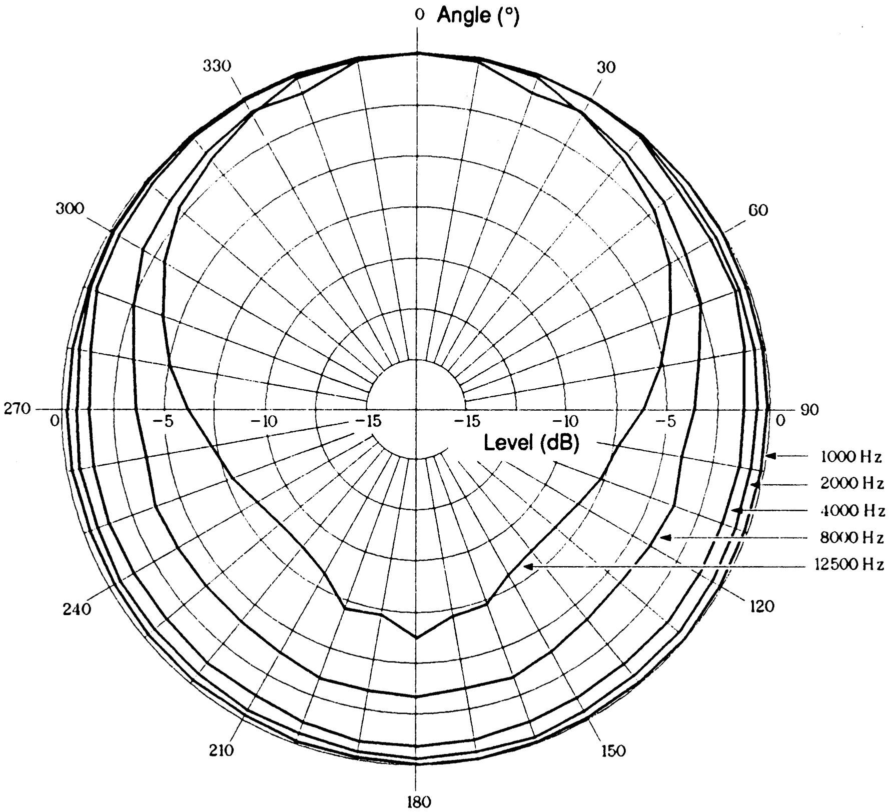
Frequency response sample of microphone UC-53A

Directional Characteristics

The directional characteristics of a microphone is a measure of its differing sensitivity for sound waves arriving from various angles. Since the prepolarized condenser microphone used in the NL-04/NL-14 is a pressure-sensitive type, it should be equally sensitive in all directions. However, at high frequencies diffraction and cavity effects cause a certain microphone directivity. The diagram below shows the directional characteristics of the microphone UC-52 used in the NL-04, and the diagram on the next page shows the directional characteristics of the microphone UC-53A used in the NL-14.



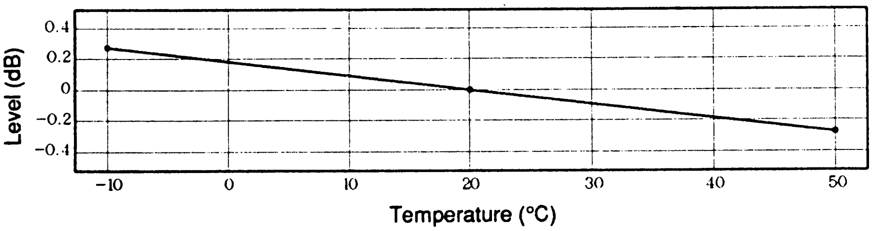
Directional characteristics of microphone UC-52



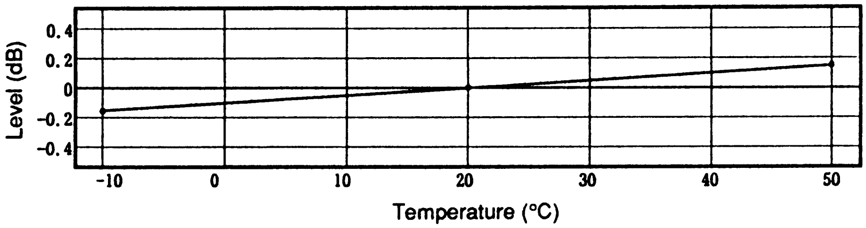
Directional characteristics of microphone UC-53A

Thermal Characteristics

The thermal characteristics of a microphone indicate how sensitivity changes at various temperatures. This is influenced by the choice of materials and the design of the microphone. Normally, materials which are identical in linear expansion coefficient are used. The diagrams below show the thermal characteristics of the microphone UC-52 used in the NL-04 and the microphone UC-53A used in the NL-14.



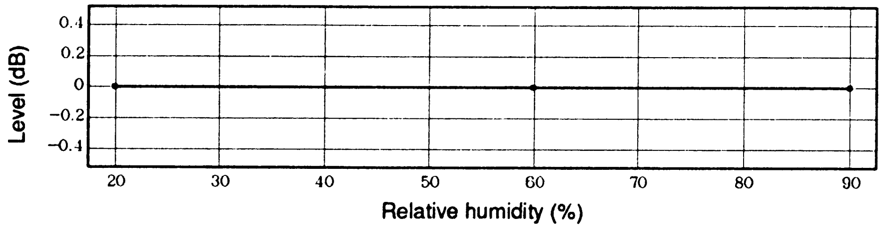
Thermal characteristics of microphone UC-52 (at 250 Hz)



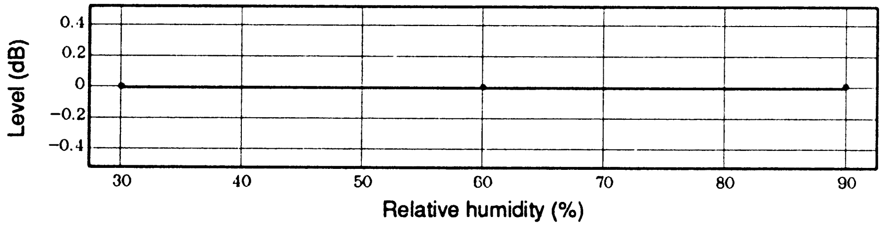
Thermal characteristics of microphone UC-53A (at 250 Hz)

Humidity Characteristics

The humidity characteristics of a microphone indicate how sensitivity changes at various humidity levels. The diagrams below show the humidity characteristics of the microphone UC-52 used in the NL-04 and the microphone UC-53A used in the NL-14.



Humidity characteristics of microphone UC-52 (at 250 Hz)



Humidity characteristics of microphone UC-53A (at 250 Hz)

Microphone Specifications

Model	UC-52 (in NL-04)	UC-53A (in NL-14)	
Nominal diameter	1/2 inch	1/2 inch	
Sensitivity	–33 dB	–28 dB	(0 dB = 1 V/Pa)
Frequency response	20 - 8000 Hz	10 - 12500 Hz	
Capacitance	19 pF	12 pF	
Diaphragm type	Titan alloy film	Titan alloy film	
Temperature coefficient	–0.008 dB/°C	+0.005 dB/°C	(at 250 Hz)
Humidity-dependent sensitivity change	0.1 dB or less	0.1 dB or less	(at 250 Hz, RH below 95%, no condensation)
Dimensions	13.2 dia. x 12 mm	13.2 dia. x 12 mm	

PREAMPLIFIER

Preamplifier Requirement

Since the condenser microphone is a small-capacity transducer, it has a high impedance, especially at low frequencies. Therefore, a very high load resistance is required to ensure uniform response extending to the low frequency range. The relationship between the microphone capacitance and the low-range cutoff frequency can be expressed as follows.

$$f_0 = \frac{1}{2\pi \cdot Z_{in} \cdot C_m}$$

f_0: Low-range cutoff frequency (Hz)
Z_{in}: Preamplifier input impedance (Ω)
C_m: Capacitance of condenser microphone (F)

If the output of the microphone were directly routed through a long shielded cable, the capacitance between the cable conductors would cause a sharp drop in sensitivity, as is evident from the following equation.

$$M_0 = \frac{C_m}{C_m + C_c} \cdot M_s$$

M_0: Output voltage into directly connected shielded cable (V)
M_s: Output voltage in microphone open condition (V)
C_c: Cable capacitance of shielded cable (F)

For the above reasons, a preamplifier is connected directly after the microphone, to provide a low-impedance output signal.

Preamplifier Specifications

The NL-04 uses the preamplifier NH-19 and the NL-14 uses the preamplifier NH-20. Both are specially designed preamplifiers for use with 1/2-inch condenser microphones. Major specifications are as follows.

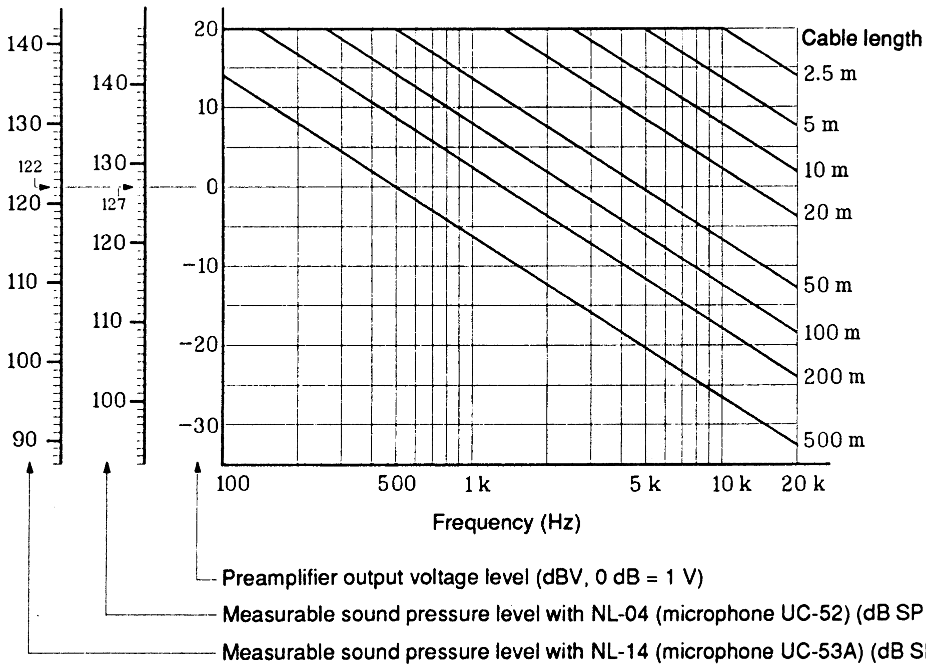
Input impedance:	3 GΩ
Output impedance:	Less than 300 Ω
Maximum output current:	2 mA

INFLUENCE OF MICROPHONE EXTENSION CABLE

When the output of the microphone/preamplifier is routed through an extension cable, certain limitations regarding measurable sound pressure level and frequency range will apply. This is due to the influence of the cable capacitance. The longer the cable, the lower the measurable sound pressure level and the lower the frequency limit. The diagram below shows the relationship between cable length, measurable sound pressure level, and frequency.

Extension cable EC-04 series

Model	Length
EC-04	2 m
EC-04A	5 m
EC-04B	10 m
EC-04C	30 m (with reel)
EC-04D	50 m (with reel)
EC-04E	100 m (with reel)



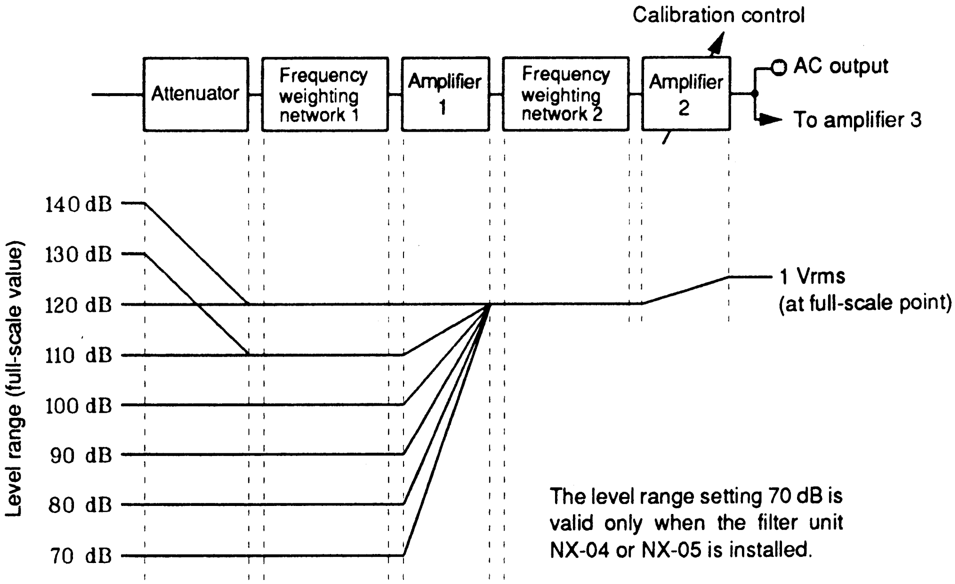
Microphone sensitivity level (0 dB = 1 V/Pa)
UC-52: –33 dB
UC-53A: –28 dB

Relationship between extension cable length and measurable sound pressure level/frequency

If for example a sound pressure level of 120 dB is to be measured up to 5 kHz using the NL-04 (microphone UC-52), an extension cable length of up to 100 meters can be used.

AMPLIFIER CIRCUIT CONFIGURATION AND LEVEL DIAGRAM

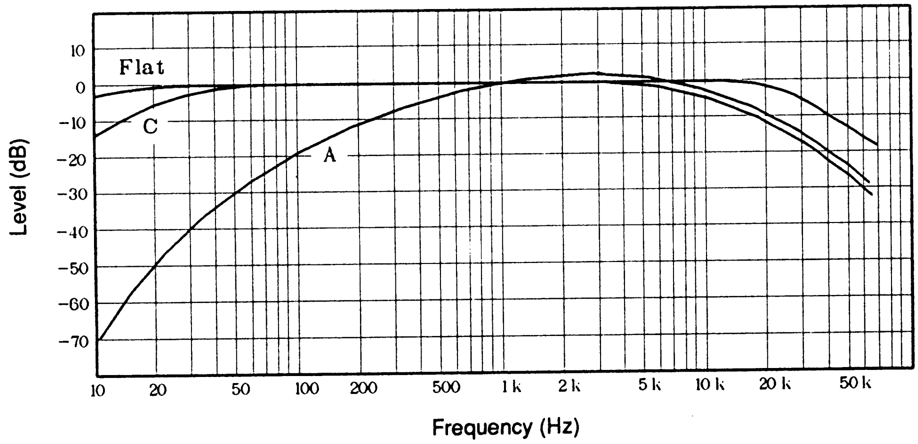
The amplifier circuit configuration and level diagram of the NL-04/NL-14 are shown below. The combination of attenuation and amplifier 1 stages depends on the level range setting. The gain of amplifier 2 depends on the calibration control setting.



Level diagram

FREQUENCY WEIGHTING NETWORK

The NL-04/NL-14 provide a choice between A and C weighting and flat frequency response. The electrical characteristics of the weighting networks are as shown below.



Frequency weighting characteristics

The volume impression (loudness) of a sound depends not only on the sound pressure level, but also on the frequency. At high or low frequencies, a sound is felt to be less loud than a sound of equal level in the midrange. The "A" weighting curve compensates for this effect and produces measurement results which are close to the actual impression of loudness. For this reason, this type of frequency weighting is widely used for purposes such as noise level evaluation.

With the "Flat" characteristic, frequency response is linear, which is suitable for straight sound pressure level measurements and for using the sound level meter output for frequency analysis.

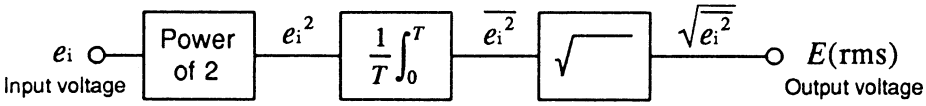
The "C" weighting curve produces almost flat response, but with a roll-off below 31.5 Hz and above 8 kHz. This is suitable for sound pressure level measurements in situations with unwanted low-frequency or high-frequency components.

RMS DETECTION CIRCUIT

The sound level meter uses rms detection as defined by the following equation.

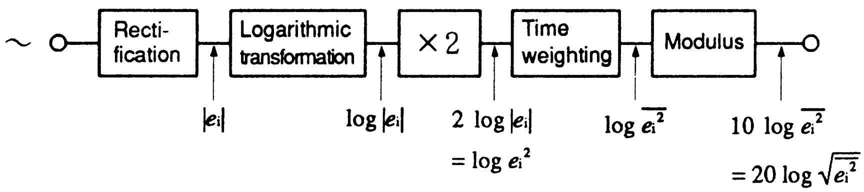
RMS value $E(\mathrm{rms}) = \sqrt{\frac{1}{T}\int_0^T e^2 dt}$

The voltage *e* which changes over time is raised to the power of 2, and integration for the time interval *T* is performed. The result is divided by *T* and the square root is extracted.
The circuit configuration for performing the above mathematical operation looks as follows.



Output voltage $E(\mathrm{rms}) = \sqrt{\overline{e_i^2}}$

The rms detection circuit in the NL-04/NL-14 employs logarithmic transformation and is configured as follows.



For measurement and evaluation of the rms detection circuit, a signal with known crest factor is used. The crest factor is defined as crest value divided by rms value. If the signal type is known, the crest factor can be calculated precisely. The rms detection error of the NL-04/NL-14 is about ±0.2 dB for an input signal with a crest factor of 3.

L_{Aeq}, L_{AE}, L_{Ax}, L_{Amax} PROCESSING

L_{Aeq} (Equivalent Continuous A-weighted Sound Pressure Level)

For a sound pressure level signal that changes over time, the L_{Aeq} is a hypothetical constant A-weighted sound pressure level that has the same energy as the actually measured signal in the measurement interval. It is determined by the following equation.

$$L_{Aeq} = 10 \log_{10} \frac{1}{T_m} \int_{t1}^{t2} \frac{p_A^2(t)}{p_0^2} dt$$

t_1: Measurement start time
t_2: Measurement end time
T_m: Measurement time interval (integrated time) $T_m = t_2 - t_1$
p_0: Reference sound pressure 20 μ Pa (2×10^{-5} N / m²)
$p_{A(t)}$: Instantaneous A-weighted sound pressure

Expressing the above equation for sound pressure level yields the following.

$$L_{Aeq} = 10 \log_{10} \frac{1}{T_m} \int_{t1}^{t2} 10^{L_{A(t)}/10} dt$$

$L_{A(t)}$: Instantaneous sound pressure level

In the sound level meter NL-04/NL-14, this statement is used as reference, and digital processing is carried out according to the following equation.

$$L_{Aeq} = 10 \log_{10} \frac{1}{N} \sum_{i=1}^{N} 10^{L_{A(i)}/10}$$

Using the output signal of the rms detection circuit, digital processing is performed to determine the L_{Aeq} value. For this purpose, a suitable rms detection time constant and sampling interval for L_{Aeq} processing must be chosen. In the NL-04/NL-14, the sampling interval for A/D conversion is 10 ms (100 samples per second), and L_{Aeq} processing is carried out every interval. The L_{Aeq} reading can therefore be displayed already during measurement.

L_{AE} (A-weighted Sound Exposure Level)

The L_{AE} is a hypothetical constant 1-second sound pressure level that has the same energy as a single-event sound pressure level measured with A weighting. It is determined by the following equation.

$$L_{AE} = 10 \log_{10} \frac{1}{T_0} \int_{t1}^{t2} \frac{p_A{}^2(t)}{p_0{}^2} dt$$

t_1: Measurement start time
t_2: Measurement end time
T_0: Reference time interval (1 second)
p_0: Reference sound pressure 20 μ Pa (2×10^{-5} N / m^2)
$p_{A(t)}$: Instantaneous A-weighted sound pressure

Expressing the above equation for sound pressure level yields the following.

$$L_{AE} = 10 \log_{10} \frac{1}{T_0} \int_{t1}^{t2} 10^{L_{A(t)}/10} dt$$

$L_{A(t)}$: Instantaneous sound pressure level

In the sound level meter NL-04/NL-14, this statement is used as reference, and digital processing is carried out according to the following equation.

$$L_{AE} = 10 \log_{10} \frac{1}{N_0} \sum_{i=1}^{N} 10^{L_{A(i)}/10}$$

N_0: Number of samples per second

In the NL-04/NL-14, the sampling interval for A/D conversion is 10 ms (100 samples per second), and L_{AE} processing is carried out every interval. The L_{AE} reading can therefore be displayed already during measurement.

L_{Ax} (Percentile A-weighted Sound Pressure Level)

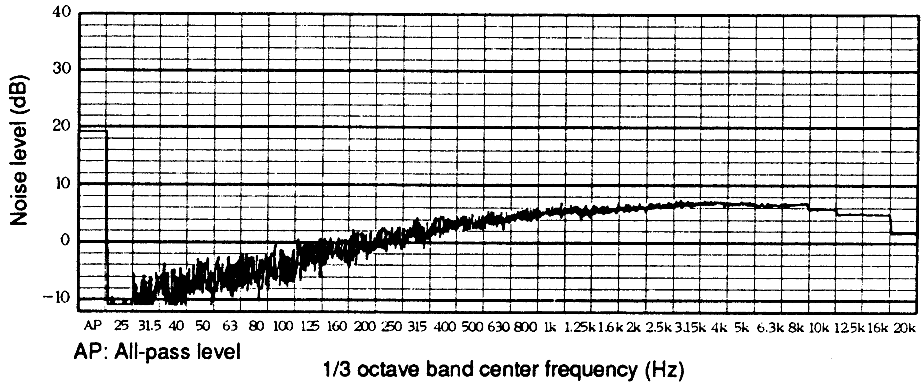
The L_{Ax} is the A-weighted sound pressure level which was exceeded for x percent of the measurement time. The NL-04/NL-14 calculates the percentile level for 5, 10, 50, 90, and 95 percent simultaneously. The sampling interval for L_{Ax} processing is 100 ms (10 samples per second), and processing is carried out after the measurement is completed. L_{Ax} readings shown during measurement therefore are not meaningful.

L_{Amax} (Maximum A-weighted Sound Pressure Level)

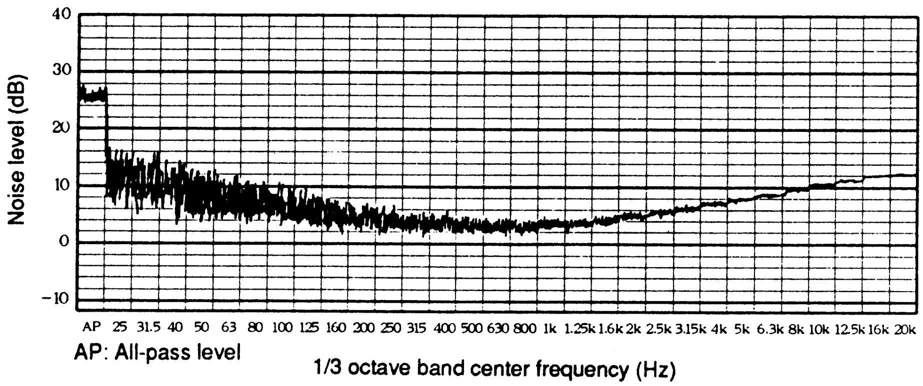
L_{Amax} is the maximum sound pressure level with the frequency weighting "A" encountered during a measurement. In the NL-04/NL-14, the sampling interval for A/D conversion is 10 ms (100 samples per second), and the L_{Amax} value since the start of the measurement is stored. Therefore the L_{Amax} reading up to the current point can be displayed already during measurement.

INHERENT NOISE

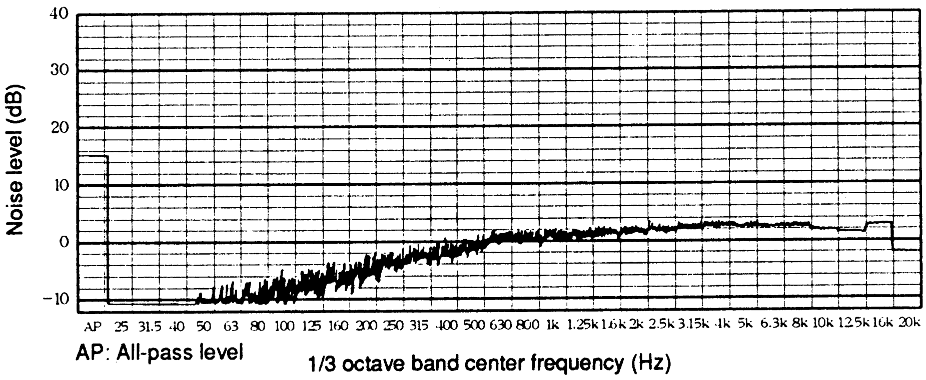
The diagrams below show the inherent noise of the NL-04/NL-14, in the frequency weighting "A" and "Flat" positions. The measurement was made with a 1/3 octave filter.



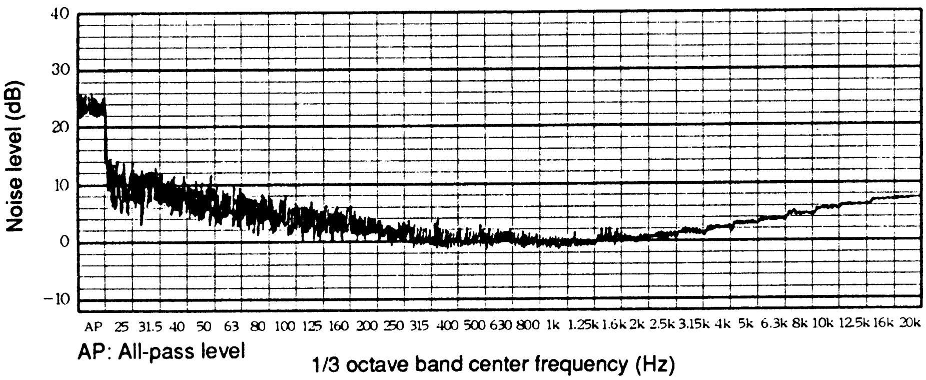
Inherent noise of NL-04 in frequency weighting A position



Inherent noise of NL-04 in Flat position



Inherent noise of NL-14 in frequency weighting A position



Inherent noise of NL-14 in Flat position

INFLUENCE OF BACKGROUND NOISE

When measuring a certain sound in a certain location, all other sounds present at that location except the measurement target sound are background noise (also called ambient noise or dark noise). Since the sound level meter will display the combination of target sound and background noise, the amount of background noise must be taken into consideration when determining the level of the target sound.

If the difference between the meter reading in absence of the target sound and the reading with the target sound is more than 10 dB, the influence of background noise is small and may be disregarded. If the difference is less than 10 dB, the values shown in the table below may be used for compensation, to estimate the level of the target sound.

Background noise compensation

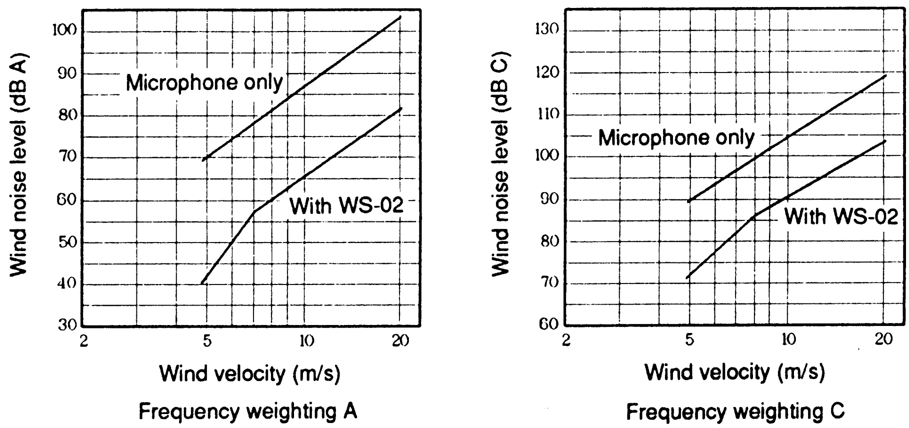
Display reading difference with and without target sound (dB)	4	5	6	7	8	9
Compensation value (dB)	–2		–1			

If for example the measured sound pressure level when operating a machine is 70 dB, and the background noise level when the machine is not operating is 63 dB, the compensation value for the difference of 7 dB is –1 dB. Therefore the sound pressure level of the machine can be taken to be 70 dB + (–1 dB) = 69 dB.

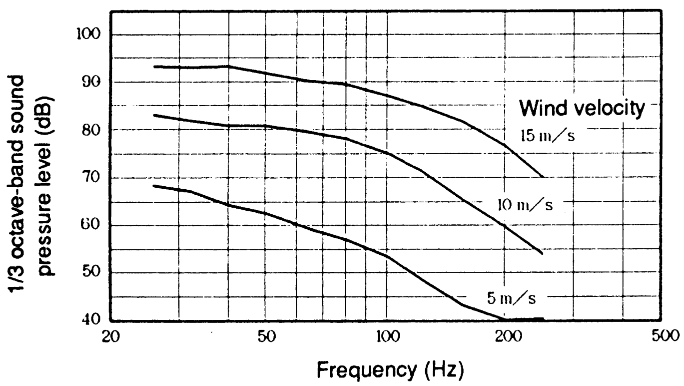
The above principle for compensating the influence of the background noise assumes that both the background noise and the target sound are approximately constant. If the background noise fluctuates, and especially if it is close in level to the target sound, compensation is difficult and will often be meaningless.

REDUCTION OF WIND NOISE BY WINDSCREEN

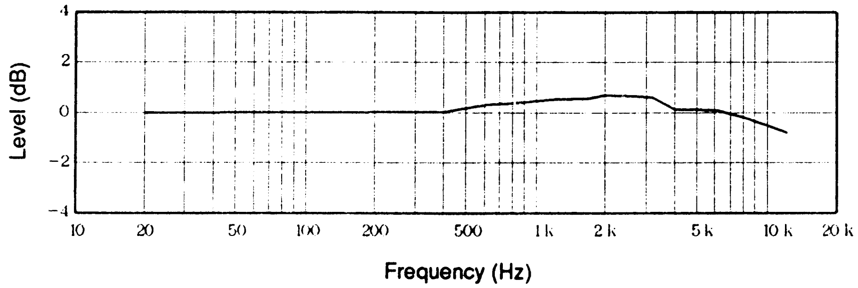
During outdoor measurements or measurement of ventilation devices, wind noise can falsify measurement results. To counter such problems, the supplied windscreen WS-02 should be mounted on the microphone. The characteristics of the WS-02 are shown below. The attenuation of wind noise produced by the windscreen is about 25 dB with "A" frequency weighting and 15 dB with "C" frequency weighting.
The influence of the windscreen WS-02 on the acoustic performance of the microphone is within ±1.0 dB up to 12.5 kHz, as shown in the diagram on the next page.



Wind noise reduction with windscreen WS-02



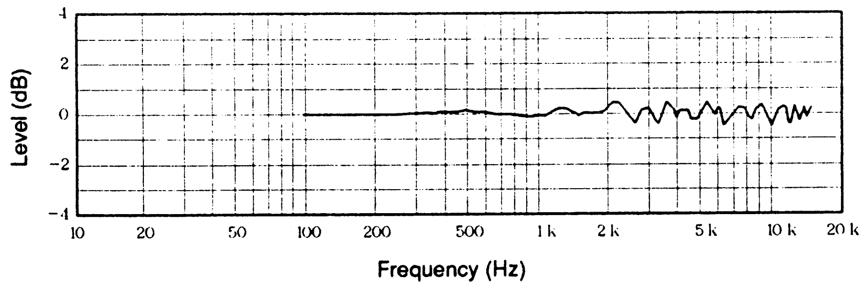
Frequency response of wind noise measured with windscreen WS-02 mounted on microphone



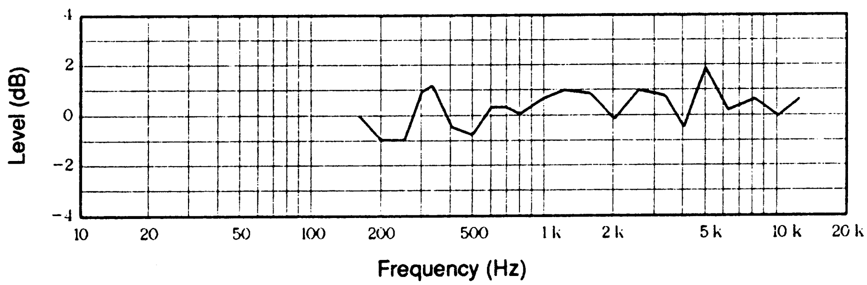
Influence of windscreen WS-02 on acoustical properties of microphone (referred to microphone response without windscreen)

INFLUENCE OF SOUND LEVEL METER BODY AND OPERATOR

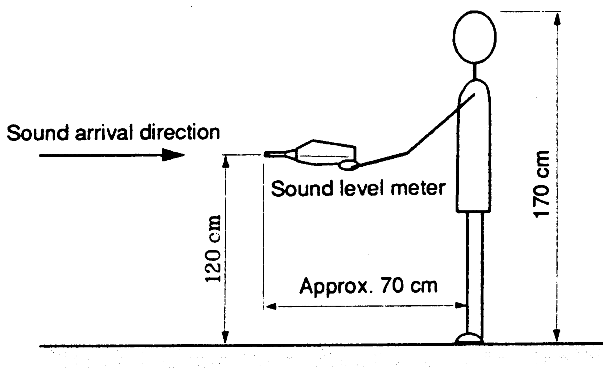
The NL-04/NL-14 is designed to minimize body reflections. The charts below show the influence of the sound level meter body and the operator on the measurement.



Acoustical influence of sound level meter body (on tripod mount)



Acoustical influence of operator (in conditions as shown below)



Measurement conditions for acoustical influence of operator

I/O CONNECTOR

The I/O connector on the NL-04/NL-14 serves for input of control signals and input/output of data. It has the following functions.

- Measurement data output to printer CP-11
  (with printer cable CC-90)

- Measurement parameter output to level recorder LR-06
  (with NL data transmission cable CC-31)

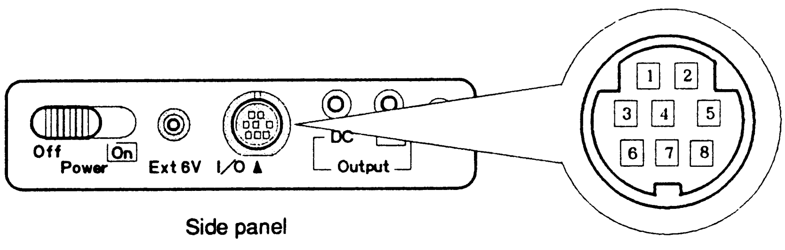
- Filter control input from level recorder LR-06 and LR-04
  (with sync cable CC-91)

- Communication with a computer (RS-232-C interface)
  (with RS-232-C interface cable CC-87E)

- Input of external signal for start/stop control of auto store function or L_{eq} and other measurements
  (with connector and switch wiring)

The pin layout of the I/O connector and the wiring of the printer cable CC-90 and the RS-232-C interface cable CC-87E are shown below. The wiring for switch control of auto store or L_{eq} and other measurements is also described.

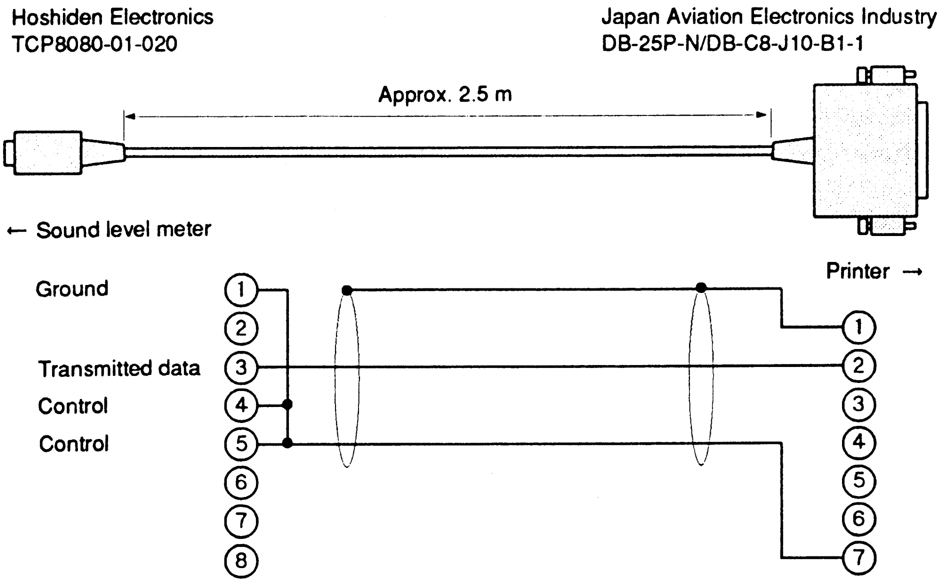
• I/O connector pin layout



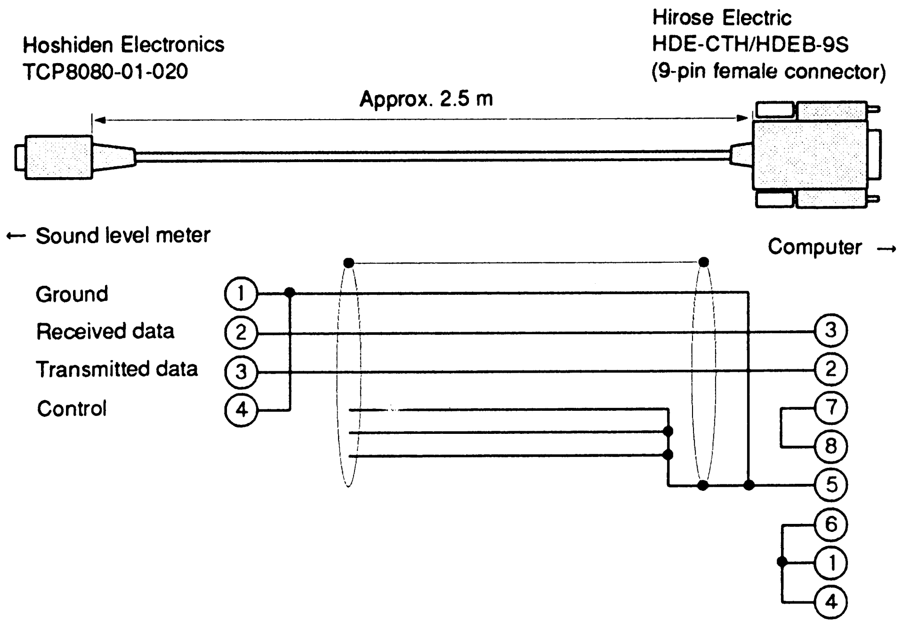
Side panel

I/O connector pin layout

- **Printer cable CC-90 wiring**

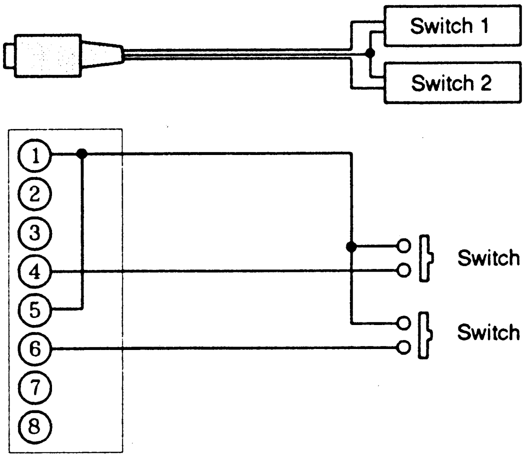


- **Interface cable CC-87E wiring**



• Wiring for external switch control of auto store or L_{eq} and other measurements

Connector:
Hoshiden Electronics
TCP8080-01-020



Switch 1: Measurement or auto store STOP

Switch 2: Measurement or auto store START
If store mode "Man" is selected, this switch causes start of *L*eq or other measurements. If store mode "Auto 1" through "Auto 6" is selected, the switch causes start of the respective auto store operation.
If the sound level meter is in the recall mode, the switch has no effect.
When measuring waveform peak value with Peak setting, switch 2 is used to reset the peak value and start new measurement (NL-14 only).

Important

Set the ON time of every switch from 50 to 100 ms.

FILTER UNIT NX-04/NX-05 CHARACTERISTICS

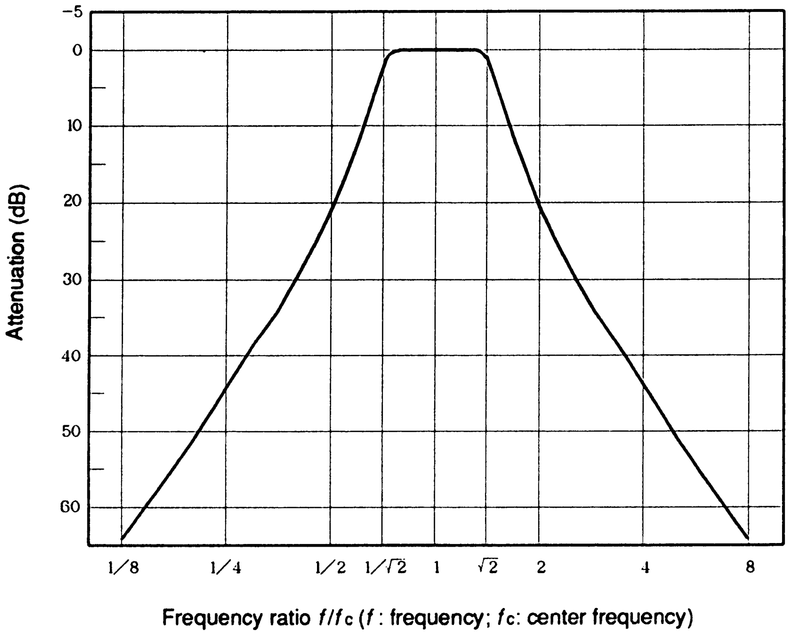
The characteristics of the octave filter NX-04 and the 1/1, 1/3 octave filter NX-05 are shown below.

1/1 octave filter

Center frequencies (Hz)

16	31.5	63	125	250	500	1000	2000	4000	8000	16000

Attenuation characteristics: According to IEC Pub. 225: 1966, JIS C 1513-1983 type II



Characteristics of NX-04/NX-05 1/1 octave filter

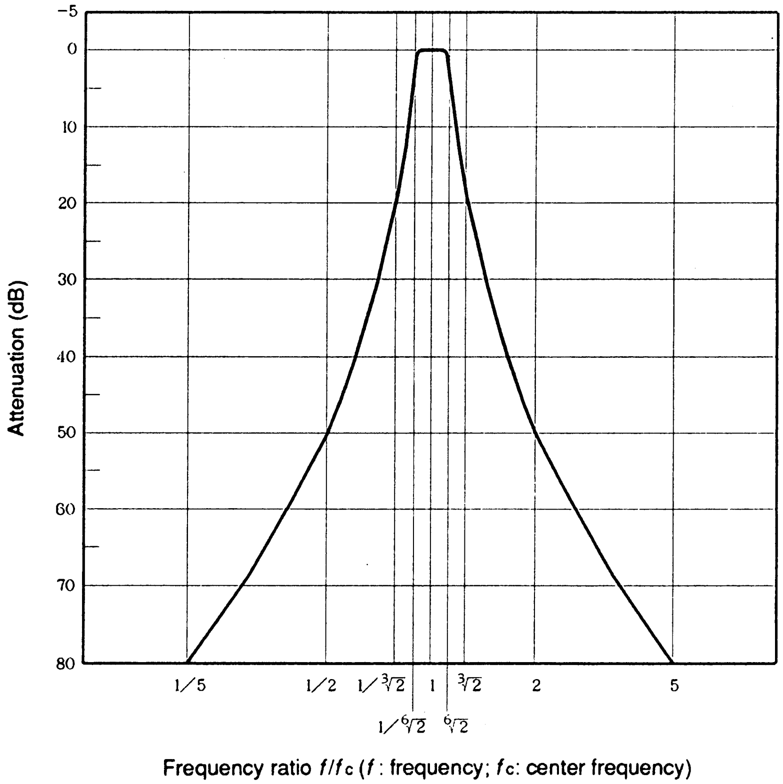
Note: The frequency range of the sound level meter NL-04 is 20 to 8000 Hz and that of the sound level meter NL-14 20 to 12500 Hz. Measurements at center frequencies outside of this range may not be reliable.

1/3 octave filter

Center frequencies (Hz)

	12.5	16	20	25	31.5	40	50	63	80
100	125	160	200	250	315	400	500	630	800
1000	1250	1600	2000	2500	3150	4000	5000	6300	8000
10000	12500	16000	20000						

Attenuation characteristics: According to IEC Pub. 225: 1966, JIS C 1513-1983 type III



Characteristics of NX-05 1/3 octave filter

No.19713 00-01