TECHNICAL NOTES

Sound Level Meter

NA-28

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http://www.rion.co.jp/english/

Organization of the NA-28 Documentation

The documentation for the Sound Level Meter NA-28 consists of three separate manuals.

- Instruction Manual

Describes operating procedures for the Sound Level Meter NA-28, connection and use of peripheral equipment such as a level recorder and printer, and use of the memory card.

- Serial Interface Manual

Describes how to use the serial interface built into the Sound Level Meter NA-28. The manual covers the communication protocol, use of control commands for the sound level meter, format of data output by the sound level meter, and other topics.

- Technical Notes (this document)

This document provides in-depth information about the performance of the sound level meter, microphone construction and characteristics, influence of extension cables and windscreen on the measurement, and other topics.

* Company names and product names mentioned in this manual are usually trademarks or registered trademarks of their respective owners.

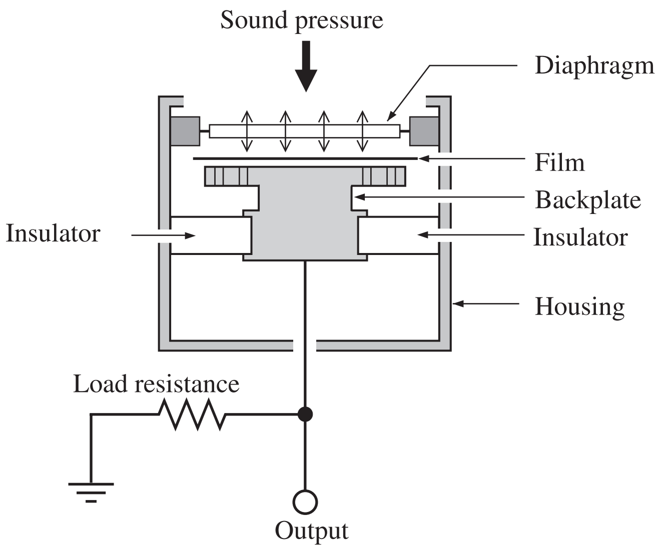
Contents

Microphone

Measurements of sound pressure level can be carried out with a variety of microphone types. The sound level meter NA-28 employs the prepolarized condenser microphone UC-59 that is compact and delivers stable and reliable response.

Construction and Operation Principle

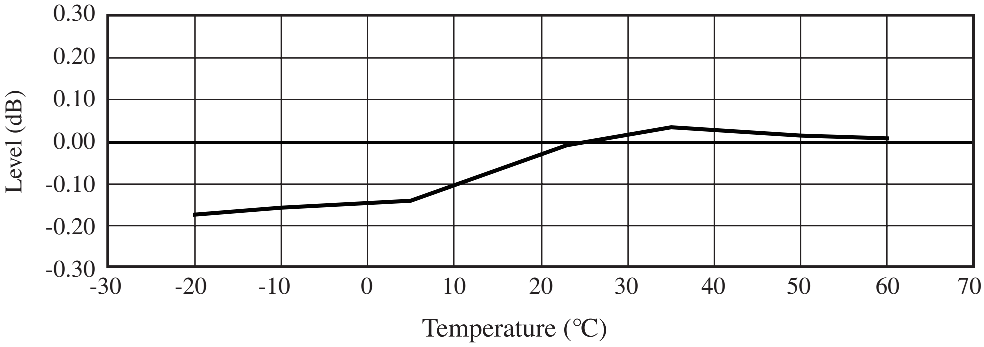
As shown in the drawing below, an electret condenser microphone consists of four main parts: diaphragm, backplate, insulator, and housing. The surface of the backplate is covered by a film holding an electrical charge. When sound pressure is applied to the diaphragm, the distance between the diaphragm and the backplate changes, thereby altering the capacitance. Using a load resistor, this change can be turned into a voltage change. The frequency response as well as the temperature and humidity characteristics of an 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.



Construction of prepolarized condenser microphone

Thermal Characteristics

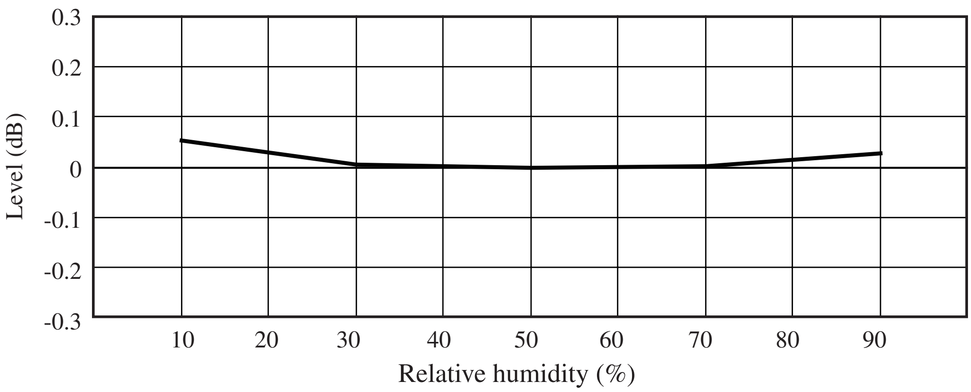
The thermal characteristics of a microphone indicate how sensitivity changes at various temperatures. This is influenced by the choice of materials and the design of the microphone. Normally, materials with a linear expansion coefficient are used. The diagrams below show the thermal characteristics of the microphone UC-59.



Thermal characteristics (at 250 Hz)

Humidity Characteristics

The humidity characteristics of a microphone indicate how sensitivity changes at various humidity levels. The diagrams below show the microphone UC-59.



Humidity characteristics (at 250 Hz)

Microphone Specifications

Model:	UC-59
Nominal diameter:	1/2 inch
Sensitivity:	-27 dB ±2 dB (re. 1 V/Pa)*
Frequency response:	10 to 20000 Hz
Capacitance:	13 pF ±1.5 pF
Temperature dependent sensitivity level fluctuation:	
	±0.35 dB max. from -10 to +50ºC referenced to 23ºC (at 1 kHz)
	±0.5 dB max. from -20 to +60ºC referenced to 23ºC (at 1 kHz)
Humidity dependent sensitivity level fluctuation:	
	±0.14 dB max. referenced to 23ºC, 50%RH 90%RH max. (at 1 kHz no condensation)
Ambient temperature/humidity range for operation:	
	-20 to +60ºC, 90%RH max. (no condensation)
Ambient temperature range for storage:	
	-20 to +60ºC
Dimensions, weight:	13.2 dia × approx. 14.3 mm, approx. 4.7 g
*Reference environment conditions:	
	Temperature: 23ºC, Humidity: 50%RH
	Atmospheric pressure: 101.325 kPa

Preamplifier

Preamplifier Requirement

Since the condenser microphone is a small-capacity transducer, it has 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.

$$f_0 = \frac{1}{2\pi \times Zin \times Cm}$$

f_0:	Low-range cutoff frequency (Hz)
Zin:	Preamplifier input impedance (Ω)
Cm:	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.

$$M_0 = \frac{Cm}{Cm + Cc} \cdot Ms$$

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

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

Preamplifier Specifications

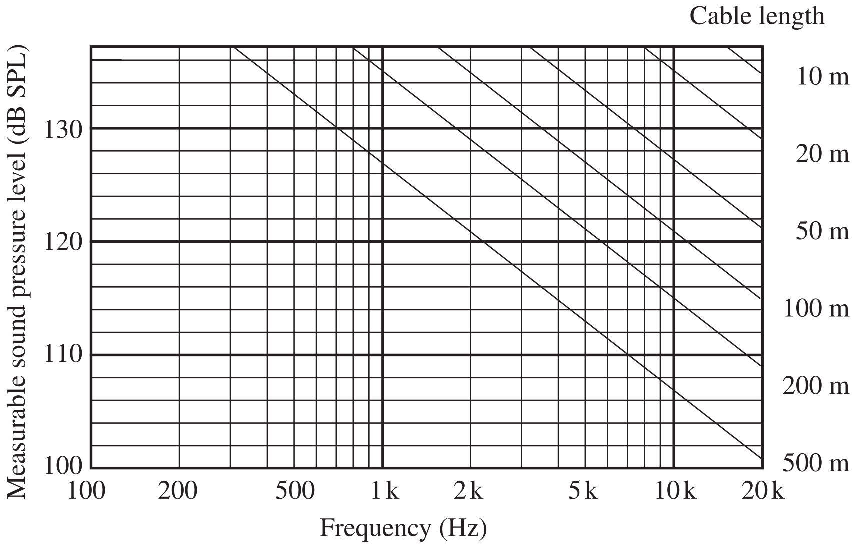
Model name:	NH-23
Input impedance:	3 GΩ
Output impedance:	100 Ω or less

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 among cable length, measurable sound pressure level, and frequency.

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

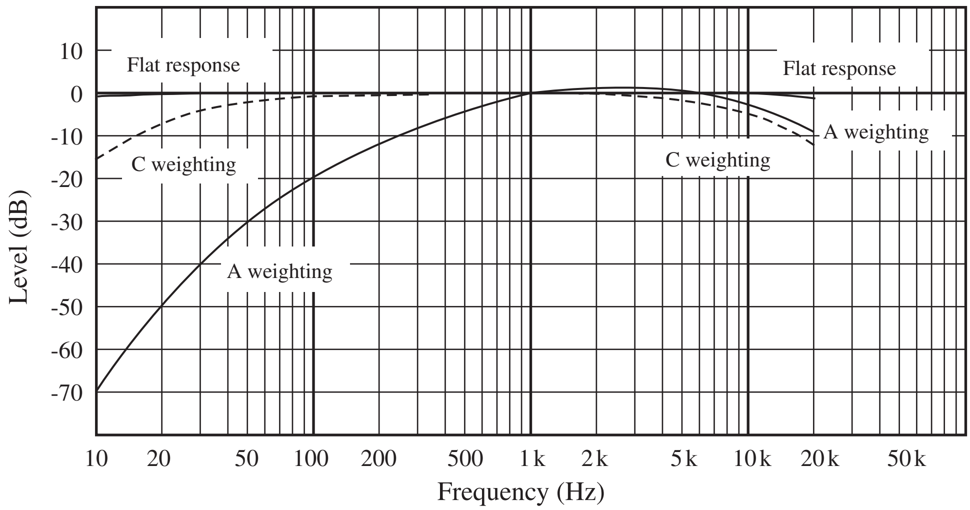
Extension cable EC-04 series



If for example a sound pressure level of 123 dB is to be measured up to 8 kHz, an extension cable length of up to 100 meters can be used.

Frequency Weighting Network

The NA-28 provides frequency weightings A, C and FLAT. The electrical characteristics of the weighting network at AC output connector 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 frequency weighting A 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 sound level evaluation.

With the frequency weighting FLAT, frequency response is linear, which is suitable for sound pressure level measurements and for using the sound level meter output for frequency analysis.

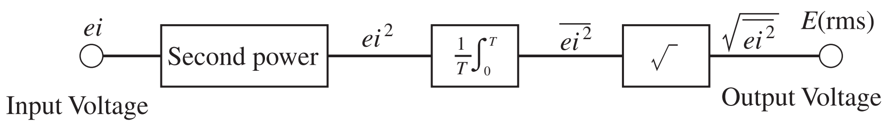
The frequency weighting C curve produces almost flat response, but with a roll off below 31.5 Hz and above 8 kHz. This is suitable for sound pressure level measurements in situations with unwanted low-frequency or high-frequency components.

RMS Detection Circuit and Time Weighting

The sound level meter uses rms detection. The effective value E (rms) is defined by the following equation.

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

The voltage e which changes over time is raised to the second power, 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.
The NA-28 uses digital processing to determine the rms value.



During sound level measurements, the level often fluctuates drastically, which would make it difficult to evaluate readings if some kind of averaging is not applied. Sound level meters therefore provide the capability for index weighting (index averaging) using the rms circuit. The parameters of this weighting process are called the time weightings, determined by the time constant (see next page).

Sound level meters usually have a F (Fast) and S (Slow) setting for the time weighting. The time range that is considered for averaging is narrow in the F (Fast) setting and wide in the S (Slow) setting. In the F (Fast) setting, the instantaneous level has a larger bearing on the displayed value than in the S (Slow) setting. From the point of view of the measurement objective, the F (Fast) setting is more suitable to situations with swiftly changing sound level, whereas the S (Slow) setting yields a more broadly averaged picture.

The F (Fast) setting is more commonly used, and sound pressure level values given without other indication are usually made with F (Fast) characteristics.

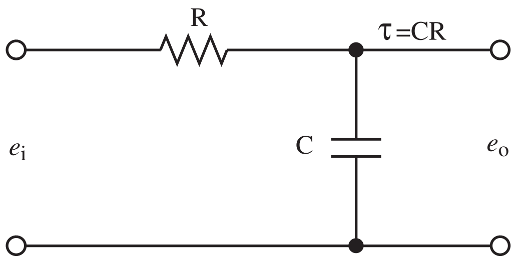
The S (Slow) setting is suitable for measuring the average of sound with fairly constant levels. For example, in Japan aircraft noise and high-speed train noise is usually transient noise with high fluctuation, but the S (Slow) setting is used to determine the maximum level for each noise event.

The I (Impulse) setting enables the meter to track noise bursts of very short duration.

Time weightings and time constant

Time Weighting	Time constant	
	Rise time	Decay time
F (Fast)	125 msec	125 msec
S (Slow)	1 s	1 s
10 msec	10 msec	10 msec
I (Impulse)	35 msec	1.5 sec

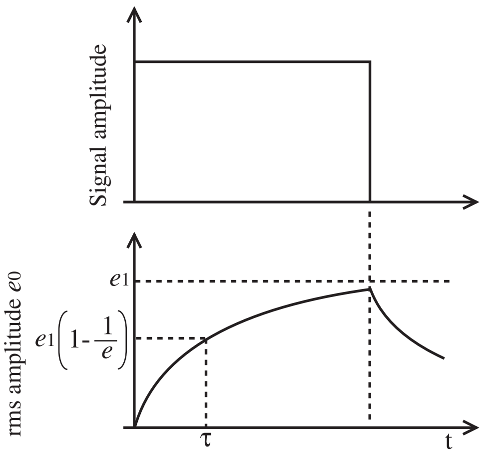
The time weighting network of the sound level meter performs index averaging on the square of the sound pressure signal. The equivalent circuit is shown below. τ is the time constant, which equals CR.



e_i : Input voltage (proportional to square of sound pressure)
e_o : Output voltage

Equivalent electrical circuit

The response of the index averaging circuit to a single burst signal is shown below.



$e1$: Burst signal voltage
e : Logarithm base
τ : Time constant
t : Time

Burst signal response

Measurement Functions

L_{Aeq} (Time average sound level, equivalent continuous sound level)

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

$$L_{AeqT} = 20 \log_{10}\left\{\left[\left(\frac{1}{T}\right)\int_{t1}^{t2} p_A^2(t)\, dt\right]^{1/2} \Big/ p_0\right\}$$

t: Time variable of integration from an arbitrary start time at $t1$ to the end of the interval at $t2$

T: Time interval $T = t2 - t1$

$p_A(t)$: A-weighted instantaneous sound pressure at running time t

p_0: Reference sound pressure (20 μPa)

In sound pressure level meter NA-28, the digital processing to determine L_{Aeq} is carried out according to the following equation.

$$L_{Aeq} = 20 \log_{10}\left\{\left(\frac{1}{N}\sum_{i=1}^{N} p_A^2(i)\right)^{1/2} \Big/ p_0\right\}$$

N: Number of samples

In NA-28, the sampling interval for A/D conversion is 20.8 μs (48000 samples per second).

L_{AE} (sound exposure level)

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

$$L_{AE} = 10 \log_{10}\left\{\left[\int_{t_1}^{t_2} p_A^2(t)\,dt\right] \Big/ p_0^2 T_0\right\} = L_{Aeq} + 10 \log_{10}(T/T_0)$$

t: Time variable of integration from an arbitrary start time at t_1 to the end of the interval at t_2

T: Time interval $T = t_2 - t_1$

T_0: Reference time (1 second)

$p_A(t)$: A-weighted instantaneous sound pressure at running time t

p_0: Reference sound pressure (20 μPa)

In NA-28, the digital processing to determined L_{AE} is carried out according to the following equation.

$$L_{AE} = 10 \log_{10} \frac{1}{N_0} \sum_{i=1}^{N} \frac{p_A^2(i)}{p_0^2}$$

N_0: Number of samples per second

In NA-28, the sampling interval for A/D conversion is 20.8 μs (48000 samples per second).

L_N (percentile sound level)

The L_N (percentile sound level) is the sound level which was exceeded for N percent of the measurement time. The NA-28 allows the user to select five values for N (from 1 to 99, in 1 steps). The sampling interval for L_N processing is 100 ms (10 samples per second).

L_{max}, L_{min} (maximum and minimum time-weighted sound level)

L_{max} is the maximum time-weighted sound level and L_{min} the minimum time-weighted sound level encountered during a measurement.
In NA-28, the sampling interval for A/D conversion is 20.8 μs (48000 samples per second). The maximum and minimum values since the start of the measurement are stored. Therefore the L_{max} and L_{min} readings up to the current point can be displayed already during measurement.

L_{Atm5} (Takt-max sound level)

For the duration of the measurement, the maximum level within a 5-second interval is sampled and the power average is determined. L_{Atm} is calculated according to the following equation.

$$L_{tm} = 10 \log_{10} \frac{1}{N} \sum_{i=1}^{N} 10^{Lm/10}$$

L_m: Maximum level within interval (5 seconds)

N: Number of samples

The number of samples is determine according to the following equation.

For L_{tm5}: $$N = \frac{(t_2 - t_1)}{5}$$

t_1: Measurement start time

t_2: Measurement end time

L_{peak} (peak sound level)

The peak sound level is a maximum absolute value of frequency weighted instantaneous sound pressure level during the measuring time.

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 10 dB or more, 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

<table>
<tr><td>Display reading difference with and without target sound (dB)</td><td>4</td><td>5</td><td>6</td><td>7</td><td>8</td><td>9</td></tr>
<tr><td>Compensation value (dB)</td><td colspan="2">- 2</td><td colspan="4">- 1</td></tr>
</table>

If for example the measured sound 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 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.

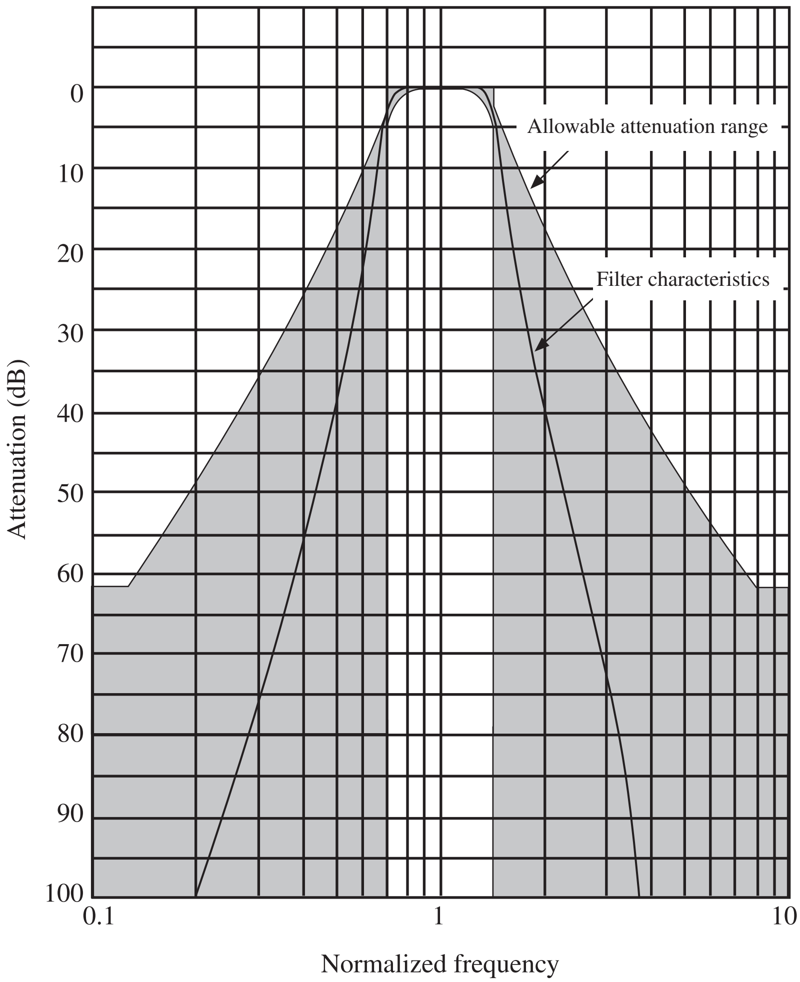
Octave, 1/3 octave Band Filter

Octave, 1/3 octave Band Filter Characteristics

The characteristics of the octave, 1/3 octave band filter in the NA-28 correspond to the JIS C 1513:2002 Class 1, ANSI S1.11 2004 Class 1, and IEC 61260: 1995 Class 1 specifications.

Octave band filter characteristics (Oct mode: Sampling frequency 64 kHz)

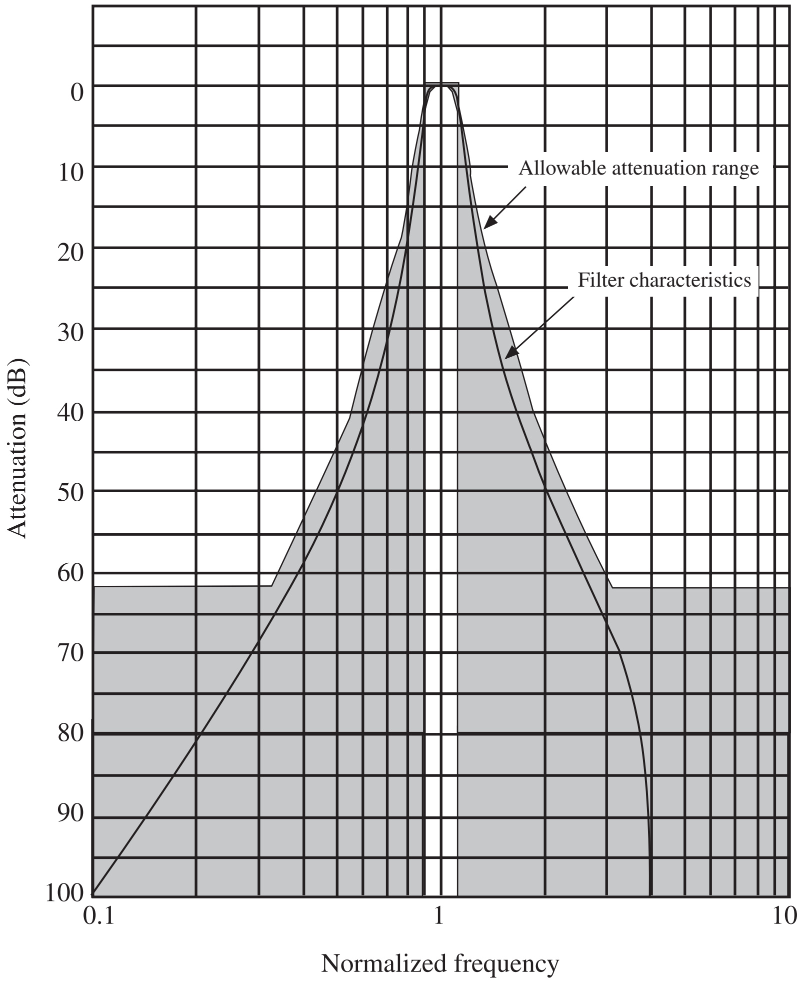
The graph below shows the allowable attenuation tolerance according to JIS and IEC, and the actual characteristics of the octave band filter in the NA-28.



Frequency ratio f/fc (f: Frequency, fc: Center frequency at 1 kHz)
Attenuation tolerance according to IEC 61260:1995 Class 1
and octave band filter characteristics of NA-28

1/3 octave band filter characteristics
(Oct mode: Sampling frequency 64 kHz)

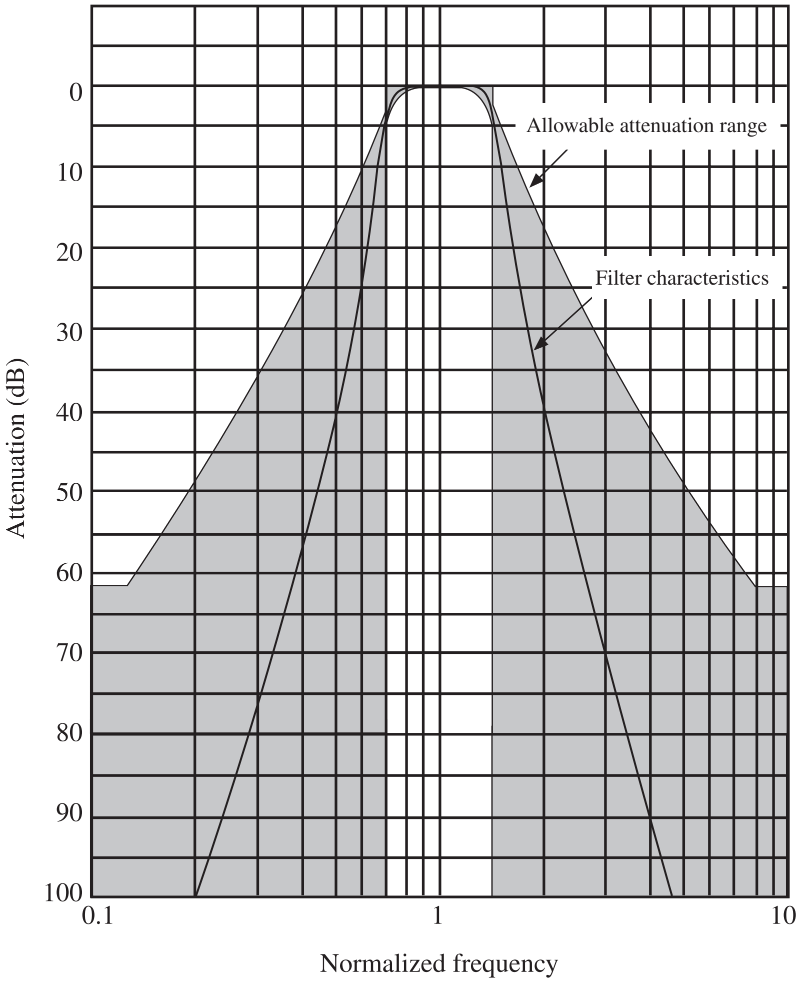
The graph below shows the allowable attenuation tolerance according to JIS and IEC, and the actual characteristics of the 1/3 octave band filter in the NA-28.



Frequency ratio f/fc (f: Frequency, fc: Center frequency at 1 kHz)
Attenuation tolerance according to IEC 61260:1995 Class 1
and 1/3 octave band filter characteristics of NA-28

Octave band filter characteristics
(Oct mode: Sampling frequency 48 kHz)

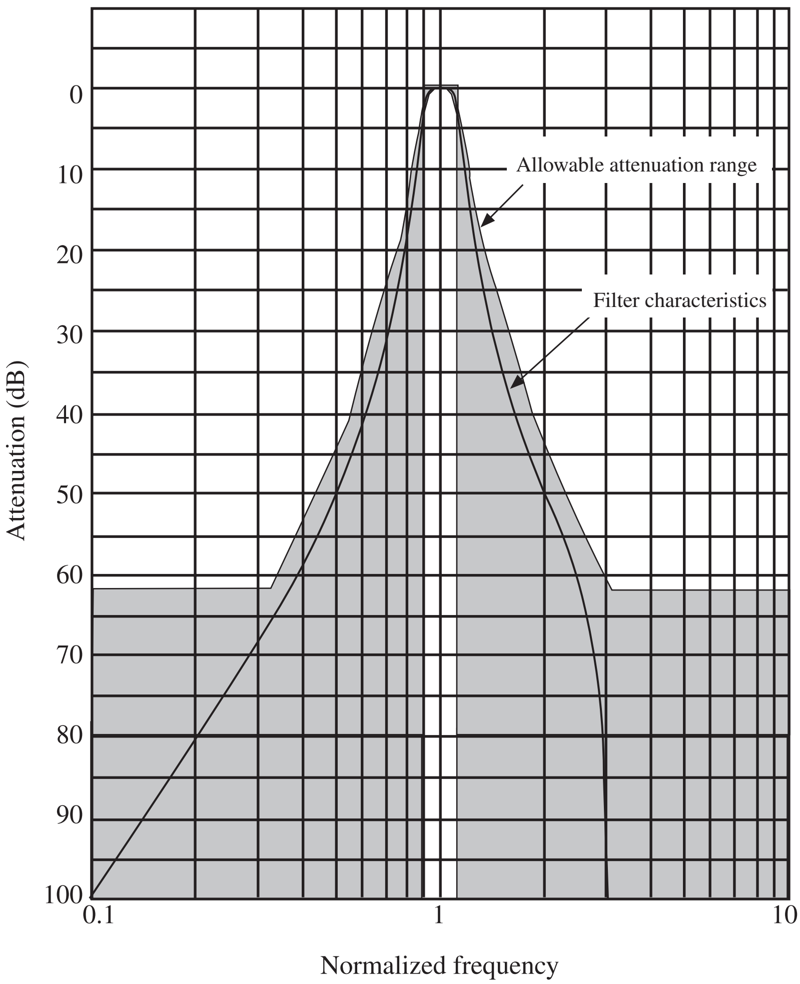
The graph below shows the allowable attenuation tolerance according to JIS and IEC, and the actual characteristics of the octave band filter in the NA-28.



Frequency ratio f/fc (f: Frequency, fc: Center frequency at 1 kHz)
Attenuation tolerance according to IEC 61260:1995 Class 1
and octave band filter characteristics of NA-28

1/3 octave band filter characteristics (Oct mode: Sampling frequency 48 kHz)

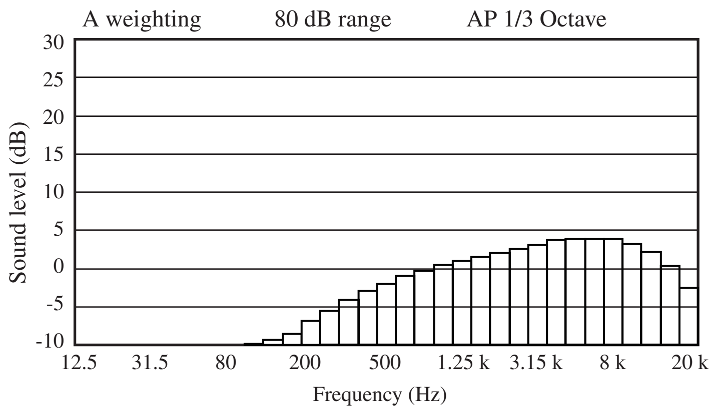
The graph below shows the allowable attenuation tolerance according to JIS and IEC, and the actual characteristics of the 1/3 octave band filter in the NA-28.

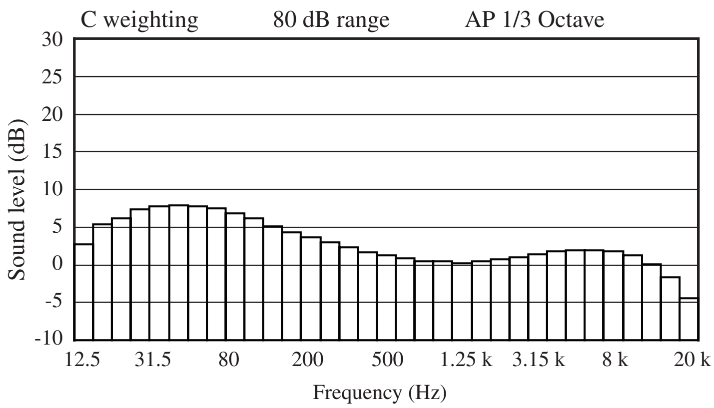


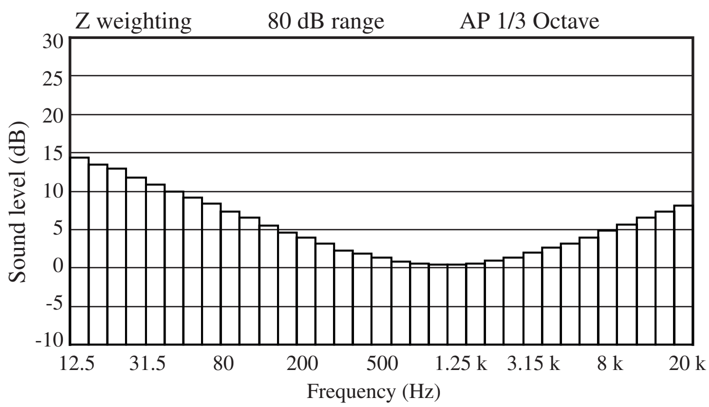
Frequency ratio f/fc (f: Frequency, fc: Center frequency at 1 kHz)
Attenuation tolerance according to IEC 61260:1995 Class 1
and 1/3 octave band filter characteristics of NA-28

Noise Floor

The diagrams below show the residual noise of the NA-28, in the frequency weighting "A", "C" and "Z" positions. The measurement was made with a 1/3 octave band filter and a frequency analyzer.







Description for IEC 61672-1

9.2.1 General	
a) Susceptibility to radio frequency fields (group and performance class)	Group X, Class 1
b) Overall configuration, Normal operation configuration (including windscreen)	➔ Controls and Functions ➔ Preparations
c) Microphone model	UC-59
d) Microphone extension required for standard conformity	Not specified
e) Multi-channel capability and operation	N/A

9.2.2 Design Features	
a) Measurement items	L_p, L_{eq}, L_{max}, L_{min}, L_E, L_N, L_{peak}, L_{tm5}
b) Directivity	➔ Fig. 1-1, 1-2, Tab. 1-1, 1-2
c) Frequency weighting characteristics	A, C, Z
d) Time weighting characteristics	F, S, 10 ms, I
e) Level range	➔ Tab. 2
f) Level range switching	Level △/▽ keys ➔ Controls and Functions, Operation key panel
g) Display device	Numeric indication, Memory data, USB output data
h) Sound level linear operation range (1 kHz)	25 to 140 dB
i) L_{Cpeak} measurement level range	➔ Tab. 2, L_C column
j) Computer software (configuration element)	(not a configuration element)
k) Design target specifications and limit values for measurement quantities	➔ Specifications, Measurement level range, Upper limit for peak sound level measurement

9.2.3 Power supply	
a) Recommended battery types and continuous operation capability under normal conditions	R14PU × 4, approx. 6 hours (23ºC) LR14 × 4, approx. 14 hours (23ºC)
b) Power supply voltage monitoring	➔ Reading the Display, Battery status
c) Operation with external power supply	Preparations, Power
d) Operation conditions and tolerances for AC power supply	Preparations, Power; Specifications

9.2.4 Adjustment to indicated level	
a) Sound calibrator to be used for calibration	NC-74 (RION)
b) Calibration frequency	1 kHz
c) Calibration procedure, target value	➔ Calibration, Acoustic calibration with Sound Calibrator NC-74
d) Microphone characteristics (free-field, chassis refraction effects, etc.)	➔ Fig. 2-1, 2-2

9.2.5 Operating the sound level meter	
a) Reference direction and reference point position	➔ Fig. 4
b) Measurement procedure, Influence of chassis and operator	➔ Measurement, Sound Level Measurement Fig. 2-2, 5-1, 5-2, 5-3
c) Optimum level range selection	Level △/▽ keys ➔ Controls and Functions, Operation key panel
d) Procedure for measurements in low-level sound field	➔ Technical Reference, Influence of Background Noise
e) Initial warm up and stabilizing interval (from power-on to measurement enabled condition)	< 30 seconds
f) Time to measurement result display	< 1 second
g) Integration time, clock time setting procedure	➔ Preparations, Setting the date and time Measurement, Sound level Measurement
h) Integration time minimum value and maximum value	Minimum value: 1 second Maximum value: 24 hours
i) Level hold function enable/cancel	➔ Measurement, Maximum Sound Level and Minimum Sound Level Measurement
j) Measurement result reset function, time required from reset to measurement initialization	Measurement results (measurement values, overload indication, under-range indication) are reset when a new measurement is started Time required for measurement initialization: max. 1 second
k) Overload indication, under-range indication	➔ Reading the Display, Signal overload indication, Signal under-range indication
l) Threshold function	N/A
m) Digital data download method	See Serial Interface Manual
n) Recommended length and type of cable	Output cable CC-24 (2.5 m)
o) Inherent noise level (Specification)	A: < 17 dB C: < 25 dB Z: < 30 dB
p) Electrical output connector (DC output)	Frequency weighting characteristics: A, C, Z Voltage: 3.0 V (at full-scale point), 25 mV/dB Output impedance: approx. 50 Ω Load impedance: > 10 kΩ
Electrical output connector (AC output)	Frequency weighting characteristics: A, C, Z Voltage: 1.0 V (at full-scale point) Output impedance: approx. 600 Ω Load impedance: > 10 kΩ

9.2.6 Accessories	
a) Influence of supplied windscreen on microphone performance	➔ Fig. 6-1, 6-2, 6-3, 6-4, 6-5 * Unit with windscreen (WS-10) mounted meets IEC 61672-1 requirements (with compensation)
b) Measurement result compensation for microphone extension	N/A
c) Use of bandpass filters	Switched with SLM/RTA key: (SLM → OCT → 1/3OCT → OCT · 1/3OCT → SLM)
d) Connection of accessories Influence of connection on performance of sound level meter	➔ Controls and Functions, Bottom View

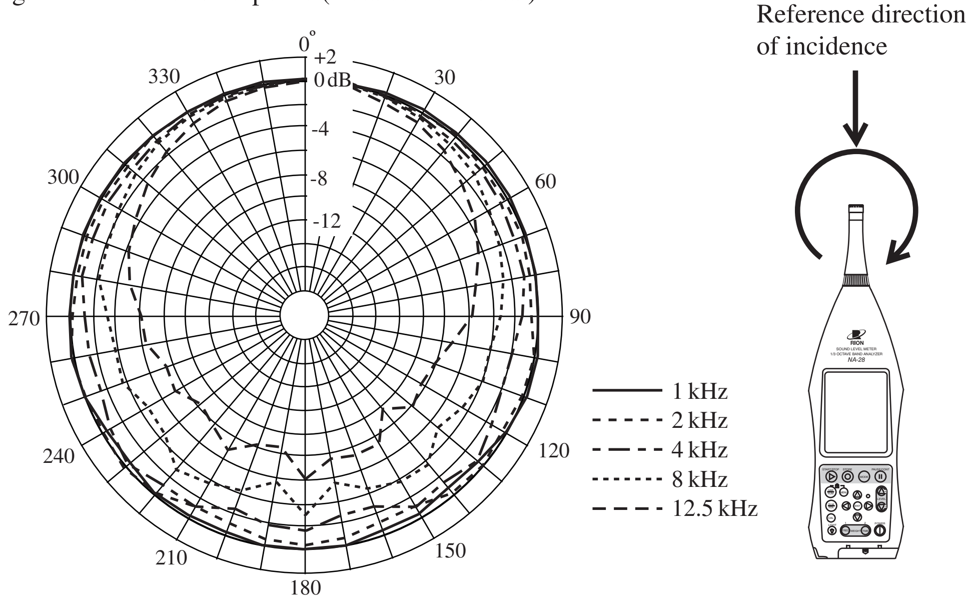
9.2.7 Influence of variations in environmental conditions	
a) Configuration elements operating only under special environmental conditions	None
b) Influence of electrostatic discharge (degradation or loss of performance/functions)	Measurement value may be affected, but effect is temporary
c) Immunity against AC power frequency magnetic fields and radio frequency electromagnetic fields	➔ Tab. 3

9.3 Information for sound level meter testing	
a) Reference sound pressure level	94 dB
b) Reference level range	30 to 120 dB range
c) Microphone reference point	Center point on diaphragm
d) Sound pressure level compensation value for sound calibrator (for planar sinusoidal wave equivalent)	➔ Tab. 4
e) Sound level linear operating range top and bottom limit	➔ Tab. 5-1, 5-2, 5-3
f) Start point on reference level range for linearity error testing	➔ Tab. 5-1, 5-2, 5-3
g) Design target value and tolerance limit for electrical signal input device	Capacitance of dummy microphone: 13 pF Tolerance: ±1.5 pF or less
h) Inherent noise (typical value)	Microphone UC-59 (-27 dB: re. 1 V/Pa) A: Typ. 14.9 dB (L_{Aeq}) C: Typ. 16.0 dB (L_{Ceq}), 32.8 dB (L_{Cpeak}) Z: Typ. 23.0 dB (L_{Zeq}), 39.4 dB (L_{Zpeak}) Dummy microphone A: Typ. 10.5 dB (L_{Aeq}) C: Typ. 14.8 dB (L_{Ceq}), 31.2 dB (L_{Cpeak}) Z: Typ. 21.6 dB (L_{Zeq}), 37.2 dB (L_{Zpeak})
i) Maximum sound pressure level supported by microphone Maximum voltage supported by electrical signal input device	158 dB 18 Vp-p
j) Maximum/minimum power supply voltage for operation	Maximum: 7 V Minimum: 5 V
k) Testing of level linearity error outside of display range	N/A
l) Adaption speed to change in environmental conditions	Temperature change: < 1 hour Humidity change: < 1 hour Static pressure change: < 5 minutes
m) Operation capability in electric field strength above 10 V/m rms	N/A
n) Operation/configuration with maximum radio frequency emissions	Level range: 120 dB range Operation mode: SLM Cable: AC out (CC-24), DC out (CC-24), Trigger (CC59+CC-24) Comparator (CC59+CC-24) USB (Standard USB A-USBmini B)
o) Operation mode/connection status where influence from AC power frequency magnetic fields and radio frequency electromagnetic fields is maximum	Fig. 7 Operation mode: SLM Cable: AC out (CC-24), DC out (CC-24), Trigger (CC59+CC-24) Comparator (CC59+CC-24) USB (Standard USB A-USBmini B)

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 NA-28 is a pressure-sensitive type, it should be equally sensitive in all directions. However, refraction and cavity effects cause a certain microphone directional response at high frequencies.
The diagram below shows the directional response of NA-28.

Fig. 1-1   Directional response (Rotated horizontal)

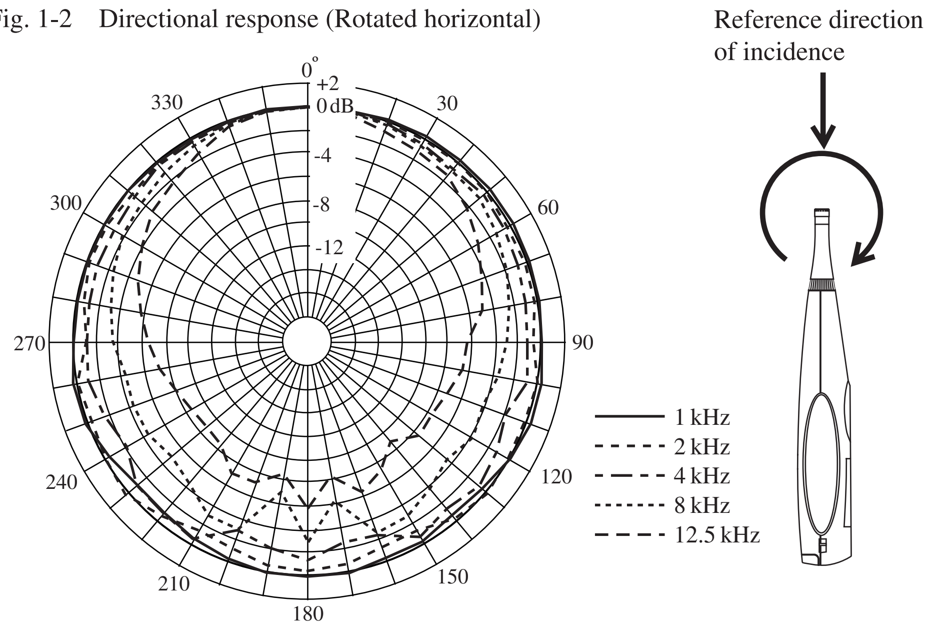


Tab. 1-1 Directional response (Rotated horizontal)

Angle	Frequency (Hz) 1 k	2 k	4 k	8 k	12.5 k
0°	0.00	0.00	0.00	0.00	0.00
10°	0.04	0.08	0.05	-0.03	-0.06
20°	0.04	0.05	0.02	-0.25	-0.48
30°	0.13	0.14	-0.34	-0.53	-1.16
40°	0.19	0.03	-0.67	-0.99	-1.62
50°	0.17	-0.29	-0.69	-1.27	-2.44
60°	0.16	-0.39	-0.81	-1.91	-3.33
70°	0.20	-0.29	-0.88	-2.34	-4.09
80°	0.15	-0.46	-0.97	-2.64	-5.07
90°	0.20	-0.58	-1.38	-3.18	-5.59
100°	0.42	-0.15	-1.96	-3.88	-7.05
110°	0.35	-0.15	-1.99	-3.63	-8.23
120°	-0.07	-0.42	-1.50	-4.43	-8.29
130°	-0.56	-0.14	-0.79	-5.04	-7.95
140°	-0.85	-0.40	-1.58	-3.40	-9.61
150°	-0.75	-1.31	-1.30	-3.67	-7.27
160°	-0.41	-1.28	-2.92	-4.42	-7.30
170°	-0.22	-0.86	-2.74	-5.57	-7.64

Angle	Frequency (Hz) 1 k	2 k	4 k	8 k	12.5 k
180°	-0.06	-0.52	-1.66	-3.23	-6.19
190°	-0.16	-0.77	-2.10	-5.61	-8.57
200°	-0.30	-1.30	-2.61	-4.26	-8.36
210°	-0.58	-1.44	-1.38	-3.86	-6.39
220°	-0.77	-0.56	-1.45	-3.13	-8.00
230°	-0.65	-0.20	-0.73	-4.65	-8.53
240°	-0.24	-0.43	-1.15	-4.67	-7.55
250°	0.11	-0.33	-1.86	-3.66	-7.83
260°	0.20	-0.19	-1.68	-3.84	-6.56
270°	0.03	-0.59	-1.51	-3.42	-6.41
280°	0.00	-0.75	-1.02	-2.57	-5.20
290°	0.05	-0.56	-1.00	-2.49	-4.38
300°	0.13	-0.47	-0.83	-1.99	-3.67
310°	0.14	-0.48	-0.74	-1.29	-2.76
320°	0.11	-0.23	-0.68	-1.03	-1.92
330°	0.06	-0.11	-0.37	-0.64	-1.30
340°	0.00	-0.01	-0.12	-0.33	-0.76
350°	0.02	0.04	-0.02	-0.14	-0.42

Fig. 1-2 Directional response (Rotated horizontal)



Tab. 1-2 Directional response (Rotated perpendicularly)

Angle	Frequency (Hz)				
	1 k	2 k	4 k	8 k	12.5 k
0°	0.00	0.00	0.00	0.00	0.00
10°	-0.01	-0.05	0.07	-0.09	-0.37
20°	0.02	-0.11	-0.24	-0.11	-0.84
30°	0.02	-0.17	-0.69	-0.58	-1.26
40°	0.19	-0.03	-0.90	-0.98	-1.61
50°	0.21	-0.35	-0.40	-1.06	-2.27
60°	0.19	-0.44	-0.77	-1.43	-3.32
70°	0.07	-0.40	-1.10	-2.02	-4.20
80°	-0.10	-0.48	-1.13	-2.60	-4.95
90°	-0.09	-0.71	-1.21	-3.02	-6.31
100°	0.10	-0.12	-1.05	-3.54	-6.51
110°	0.18	-0.20	-2.10	-4.13	-7.44
120°	-0.22	-0.39	-1.39	-3.88	-7.87
130°	-0.81	-0.01	-0.99	-4.46	-7.59
140°	-0.95	-0.43	-1.46	-3.78	-9.05
150°	-0.70	-1.44	-0.81	-3.13	-7.45
160°	-0.48	-1.44	-2.61	-2.83	-6.41
170°	-0.12	-0.88	-2.73	-6.60	-8.35

Angle	Frequency (Hz)				
	1 k	2 k	4 k	8 k	12.5 k
180°	0.01	-0.56	-1.51	-3.30	-5.80
190°	-0.06	-0.76	-2.19	-7.09	-8.55
200°	-0.39	-1.35	-3.12	-2.85	-7.27
210°	-0.77	-1.54	-0.76	-3.23	-7.21
220°	-1.16	-0.78	-1.04	-4.52	-8.63
230°	-1.11	0.04	-1.01	-4.90	-8.65
240°	-0.52	-0.13	-2.31	-4.38	-8.63
250°	0.04	-0.40	-1.67	-4.35	-8.20
260°	0.17	-0.28	-1.18	-4.37	-7.26
270°	-0.09	-1.22	-1.30	-3.50	-6.56
280°	-0.15	-0.74	-1.14	-3.07	-5.76
290°	-0.06	-0.20	-0.98	-2.62	-4.75
300°	0.10	-0.15	-1.09	-1.88	-3.80
310°	-0.04	-0.54	-0.70	-1.50	-2.84
320°	-0.06	-0.39	-0.48	-1.28	-2.17
330°	-0.09	-0.30	-0.39	-0.90	-1.54
340°	0.01	-0.04	-0.15	-0.44	-0.56
350°	0.02	0.10	-0.03	-0.01	-0.15

Measurement ranges

Tab. 2 Measurement range at each level range setting

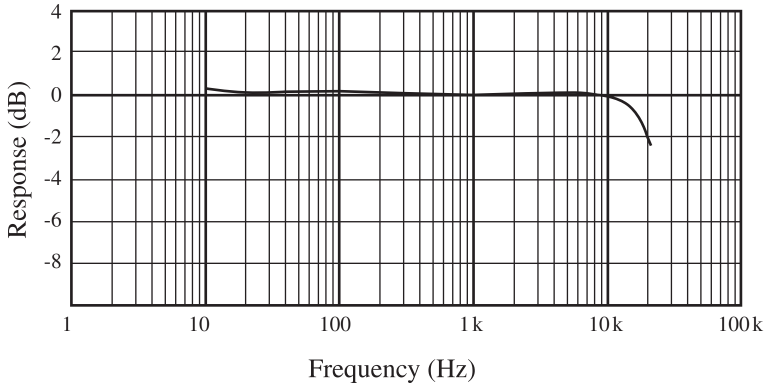
Bar graph level range		L_A (dB)	L_C (dB)	L_Z (dB)	L_{Cpeak} (dB)	L_{Zpeak} (dB)
30 to 130 dB	Max	140	140	140	143	143
	Min	30	38	43	60	65
20 to 120 dB	Max	130	130	130	133	133
	Min	25	33	38	55	60
20 to 110 dB	Max	120	120	120	123	123
	Min	25	33	38	55	60
20 to 100 dB	Max	110	110	110	113	113
	Min	25	33	38	55	60
20 to 90 dB	Max	100	100	100	103	103
	Min	25	33	38	55	60
20 to 80 dB	Max	90	90	90	93	93
	Min	25	33	38	55	60

Frequency Response

The frequency response of a sound field microphone is expressed as the frequency response in the reference direction of incidence (0°).

The diagram below shows an example for the frequency response of the microphone UC-59.

Fig. 2-1

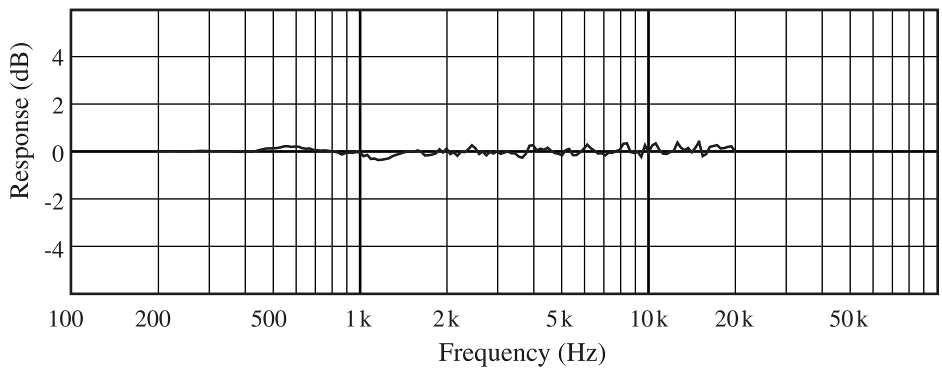


Frequency response sample of microphone UC-59

Influence of Body reflection

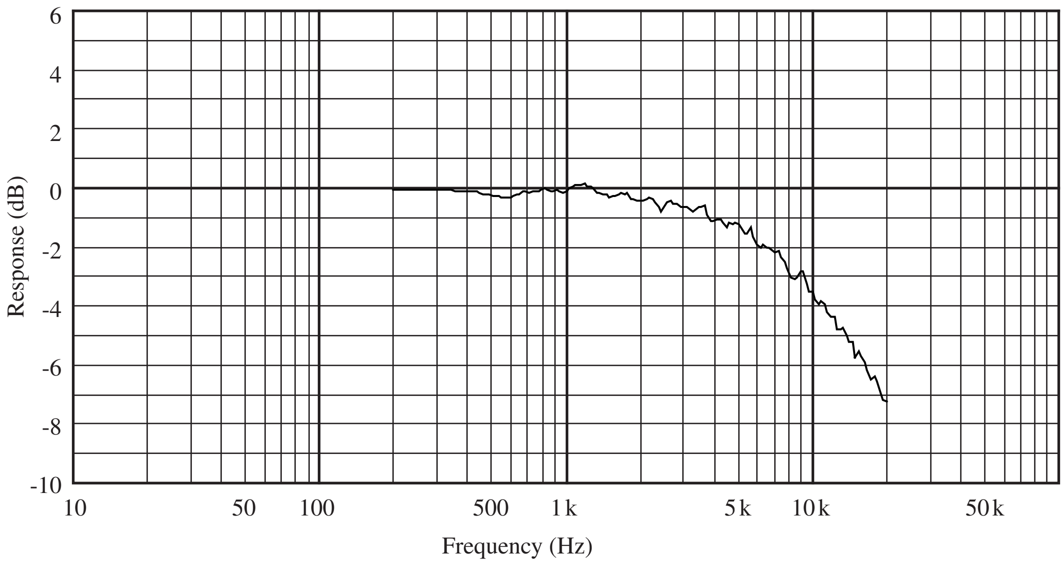
The NA-28 is designed to minimize reflections caused by the body of the unit.
The charts below show the influence on the measurement.

Fig. 2-2



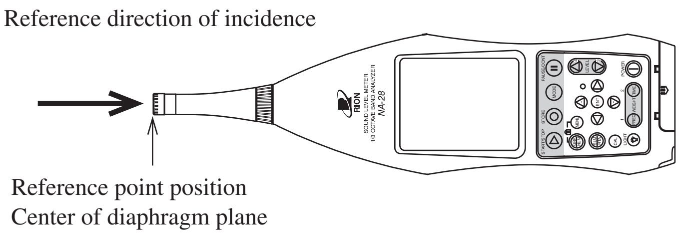
Random incidence response

Fig. 3 Random incidence response



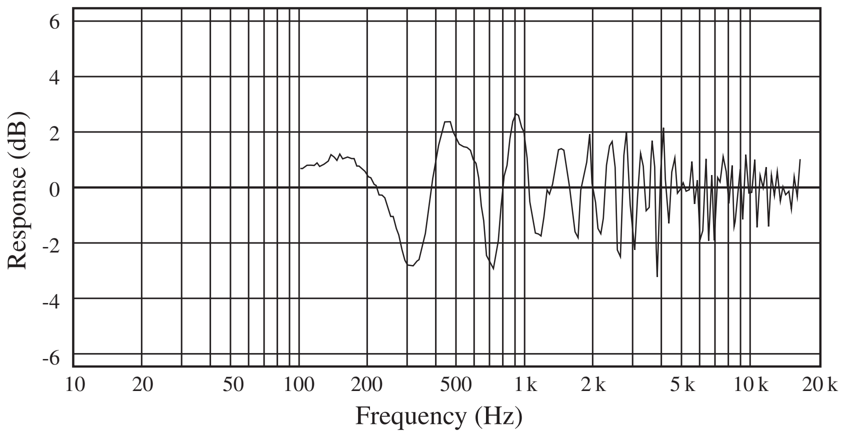
Reference incidence direction and reference point position

Fig. 4



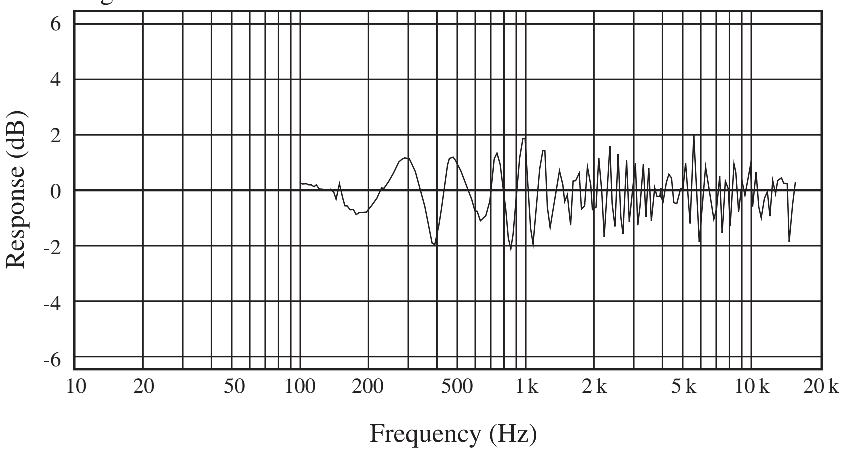
Acoustical influence of operator

Fig. 5-1



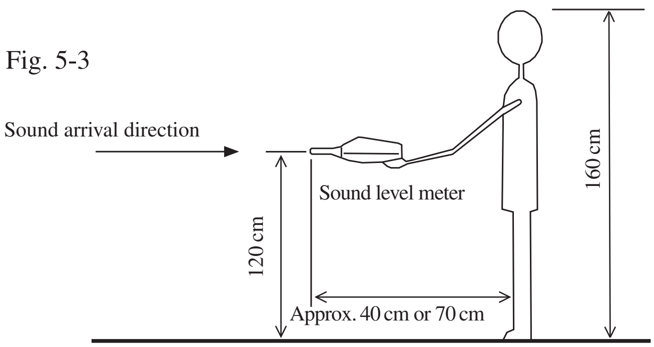
Acoustical influence of operator (the distance from the top of the microphone to the operator is approx. 40 cm)

Fig. 5-2



Acoustical influence of operator (the distance from the top of the microphone to the operator is approx. 70 cm)

Fig. 5-3

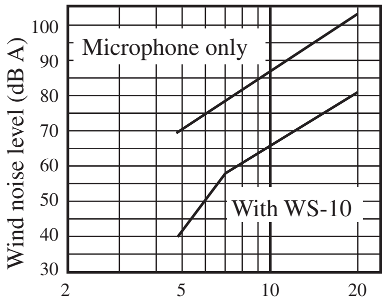


Measurement conditions for acoustical influence of operator

Reduction of Wind Noise by Windscreen

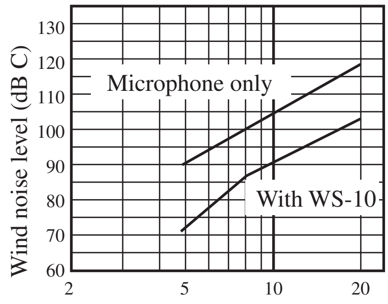
During outdoor measurements or measurement of ventilation devices, wind noise can falsify measurement results. To counter such problems, the supplied windscreen WS-10 should be mounted on the microphone. The characteristics of the WS-10 are shown below. The attenuation of wind noise produced by the windscreen is about 25 dB with frequency weighting A and 15 dB with frequency weighting C.
The influence of the windscreen WS-10 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.

Fig. 6-1



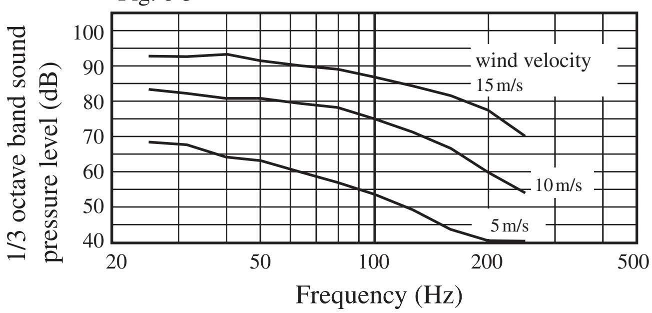
Frequency weighting A

Fig. 6-2



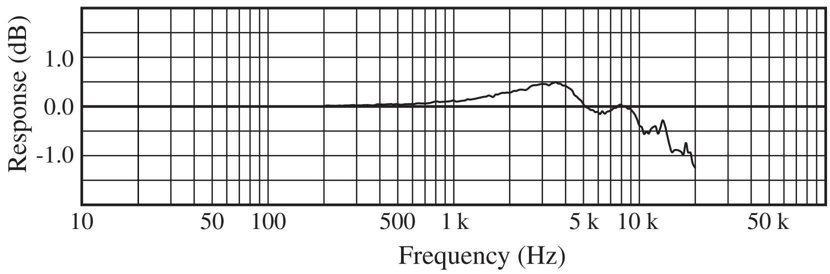
Frequency weighting C

Fig. 6-3



Frequency response of wind noise measured with windscreen WS-10 mounted microphone

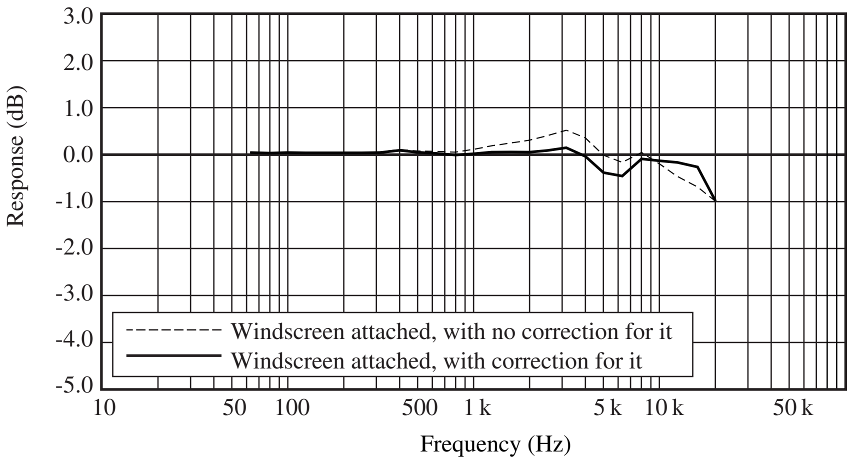
Fig. 6-4



Influence of windscreen WS-10 on acoustical properties of microphone (referred to microphone response without windscreen)

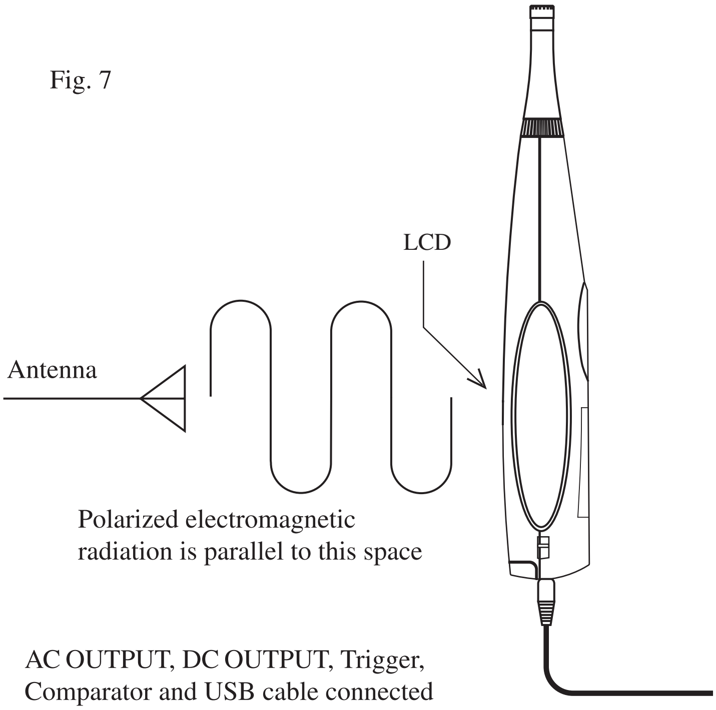
Frequency response of correction for windscreen

Fig. 6-5 Windscreen frequency response



The greatest susceptibility configuration for radio frequency fields

Fig. 7



Statement of conforming to the basic statement

Tab. 3 Statement of conforming to the basic statement

Immunity (AC power frequency magnetic field)	The specification of IEC 61672-1 Class 1 is satisfied
Immunity (Radio frequency electromagnetic field)	The specification of IEC 61672-1 Class 1 is satisfied
Emission	The specification of IEC 61672-1 Class 1 is satisfied

Frequency response adjustment data for periodic test

Tab. 4 Adjustment data for sound calibrator

Frequency (Hz)	Correction (dB)	Frequency (Hz)	Correction (dB)
31.5	0.0	2000	+0.2
63	0.0	4000	+0.9
125	0.0	8000	+3.0
250	0.0	12500	+5.9
500	0.0	16000	+7.3
1000	0.0		

The lower and upper limits of the linear operating range

Fig. 5-1 Upper and lower limit of the linear operating range (dB)
(For sound level meter set to A-weighting)

		31.5 Hz	1 kHz	4 kHz	8 kHz	12.5 kHz
130 to 30 dB	Upper	100.0	140.0	141.0	138.0	135.0
	Start	64.0	104.0	104.0	104.0	104.0
	Lower	30.0	30.0	30.0	30.0	30.0
120 to 20 dB	Upper	90.0	130.0	131.0	128.0	125.0
	Start	54.0	94.0	94.0	94.0	94.0
	Lower	25.0	25.0	25.0	25.0	25.0
110 to 20 dB	Upper	80.0	120.0	121.0	118.0	115.0
	Start	44.0	84.0	84.0	84.0	84.0
	Lower	25.0	25.0	25.0	25.0	25.0
100 to 20 dB	Upper	70.0	110.0	111.0	108.0	105.0
	Start	34.0	74.0	74.0	74.0	74.0
	Lower	25.0	25.0	25.0	25.0	25.0
90 to 20 dB	Upper	60.0	100.0	101.0	98.0	95.0
	Start	34.0	64.0	64.0	64.0	64.0
	Lower	25.0	25.0	25.0	25.0	25.0
80 to 20 dB	Upper	50.0	90.0	91.0	88.0	85.0
	Start	34.0	54.0	54.0	54.0	54.0
	Lower	25.0	25.0	25.0	25.0	25.0

Fig. 5-2 Upper and lower limit of the linear operating range (dB)
(For sound level meter set to C-weighting)

		31.5 Hz	1 kHz	4 kHz	8 kHz	12.5 kHz
130 to 30 dB	Upper	137.0	140.0	139.0	137.0	133.0
	Start	104.0	104.0	104.0	104.0	104.0
	Lower	48.0	38.0	38.0	38.0	38.0
120 to 20 dB	Upper	127.0	130.0	129.0	127.0	123.0
	Start	94.0	94.0	94.0	94.0	94.0
	Lower	43.0	33.0	33.0	33.0	33.0
110 to 20 dB	Upper	117.0	120.0	119.0	117.0	113.0
	Start	84.0	84.0	84.0	84.0	84.0
	Lower	43.0	33.0	33.0	33.0	33.0
100 to 20 dB	Upper	107.0	110.0	109.0	107.0	103.0
	Start	74.0	74.0	74.0	74.0	74.0
	Lower	43.0	33.0	33.0	33.0	33.0
90 to 20 dB	Upper	97.0	100.0	99.0	97.0	93.0
	Start	64.0	64.0	64.0	64.0	64.0
	Lower	43.0	33.0	33.0	33.0	33.0
80 to 20 dB	Upper	87.0	90.0	89.0	87.0	83.0
	Start	54.0	54.0	54.0	54.0	54.0
	Lower	43.0	33.0	33.0	33.0	33.0

Fig. 5-3 Upper and lower limit of the linear operating range (dB)
(For sound level meter set to Z-weighting)

		31.5 Hz	1 kHz	4 kHz	8 kHz	12.5 kHz
130 to 30 dB	Upper	140.0	140.0	140.0	140.0	140.0
	Start	104.0	104.0	104.0	104.0	104.0
	Lower	53.0	43.0	43.0	43.0	43.0
120 to 20 dB	Upper	130.0	130.0	130.0	130.0	130.0
	Start	94.0	94.0	94.0	94.0	94.0
	Lower	48.0	38.0	38.0	38.0	38.0
110 to 20 dB	Upper	120.0	120.0	120.0	120.0	120.0
	Start	84.0	84.0	84.0	84.0	84.0
	Lower	48.0	38.0	38.0	38.0	38.0
100 to 20 dB	Upper	110.0	110.0	110.0	110.0	110.0
	Start	74.0	74.0	74.0	74.0	74.0
	Lower	48.0	38.0	38.0	38.0	38.0
90 to 20 dB	Upper	100.0	100.0	100.0	100.0	100.0
	Start	64.0	64.0	64.0	64.0	64.0
	Lower	48.0	38.0	38.0	38.0	38.0
80 to 20 dB	Upper	90.0	90.0	90.0	90.0	90.0
	Start	54.0	54.0	54.0	54.0	54.0
	Lower	48.0	38.0	38.0	38.0	38.0

No. 50862 09-05