♦ PRECISION INSTRUMENTS FOR TEST AND MEASUREMENT ♦

GR 1988
Precision Integrating Sound-Level Meter and Analyzer

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VIIM-700/cover.p65

Contents

This instrument is capable of making sound-level measurements required under Part 1910.95 "Occupational Noise Exposure," (Dept of Labor) of the Code of Federal Regulations, Chap. XVII of Title 29 (36 F.R. 7006).

GR 1988
Precision Integrating Sound-Level Meter and Analyzer

Form 1988-0100-B

Warranty

GenRad

WARRANTY

We warrant that this product is free from defects in material and workmanship and, when properly used, will perform in accordance with GenRad's applicable published specifications. If within one (1) year after original shipment it is found not to meet this standard, it will be repaired or at the option of GenRad, replaced at no charge when returned to a GenRad service facility.

CHANGES IN THE PRODUCT NOT APPROVED BY GENRAD SHALL VOID THIS WARRANTY.

GENRAD SHALL NOT BE LIABLE FOR ANY INDIRECT, SPECIAL, OR CONSEQUENTIAL DAMAGES, EVEN IF NOTICE HAS BEEN GIVEN OF THE POSSIBILITY OF SUCH DAMAGES.

THIS WARRANTY IS IN LIEU OF ALL OTHER WARRANTIES, EXPRESS OR IMPLIED, INCLUDING, BUT NOT LIMITED TO, ANY IMPLIED WARRANTY OF MERCHANTABILITY OR FITNESS FOR A PARTICULAR PURPOSE.

SERVICE POLICY

Your local GenRad office or representative will assist you in all matters relating to product maintenance, such as calibration, repair, replacement parts and service contracts.

GenRad policy is to maintain product repair capability for a period of five (5) years after original shipment and to make this capability available at the then prevailing schedule of charges.

Specifications

CATALOG NUMBERS.

1988-9700 Precision Integrating Sound-Level Meter and Analyzer (supplied with ½-in. flat random-incidence response electret-condenser microphone).

1988-9710 Precision Integrating Sound-Level Meter and Analyzer (supplied with ½-in. flat perpendicular-incidence response electret-condenser microphone).

INTEGRATION CHARACTERISTICS: The 1988 measures and displays sound-pressure level (SPL or LEQ) or sound-exposure level (SEL) integrated over selectable times ranging from 1 s to 24 h. Integration can be timed manually or automatically. Two time ranges are available: 1 s to 600 s in 1-s steps and 10 min to 24 h in 1-min steps. A pause feature permits exclusion of events not wanted in the integrated result. Short-time standard FAST and SLOW sound levels over range of more than 70 dB are included in integrated result. Long-time integrated sound-pressure levels (LEQ) ranging from 25 to 150 dB and sound-exposure levels (SEL) ranging from 25 to 190 dB are displayed. The maximum detected level (Fast, Slow or Impulse) during integration period can be displayed at any time.

STANDARDS: Meets the following (use 1987 or 1986 Sound-Level Calibrator):

ANSI Standard Specifications for Sound-Level Meters S1.4-1971, Type 1 (Precision).

IEC Standard 651-1979, Sound-Level Meters (Type 1).

ANSI Standard Specification for Octave, Half-Octave, and Third-Octave Band Filter Sets S1.11-1966, Type E, Class II.

IEC Recommendation Publication 225-1966, Octave, Half-Octave, and Third-Octave Band Filters for the Analysis of Sound and Vibration.

REFERENCE CONDITIONS: Reference conditions as required by IEC Standard 651-1979 are as follows:

Reference Direction of Incidence: 1988-9700 – random
1988-9710 – perpendicular to plane of diaphragm

Reference Sound Pressure Level: 94 dB

Reference Range: 100 dB full scale

Reference Frequency: 1 kHz

LEVEL RANGE (Preamplifier GAIN set to X1): 30 to 130 dB re 20 μPa* (140 dB pk). May be extended to 140 dB rms (150 dB pk) using 10-dB microphone attenuator (1962-3210) supplied.

Minimum Measurable Levels**

Weighting or Octave Band	A	B	C	F	31	63	125	250	500	1k	2k	4k	8k	16k
Level (dB)	39	41	46	55	44	41	38	36	33	32	31	30	29	29

FREQUENCY WEIGHTING AND FILTERS: A, B and C weighting per referenced standards. Flat response from 5 Hz to 20 kHz. Response is down −3 dB ±3 dB at 5 Hz and 20 kHz relative to 1-kHz level (electrical only, microphone not included). Ten octave-band filters ranging from 31.5 Hz to 16 kHz (center frequencies).

DETECTOR CHARACTERISTICS: Detector Response: Fast, Slow, Impulse (per IEC 651) and absolute peak (<50-μs detector rise time) switch selectable. Precise rms detection for signals with crest factors up to 20 dB at 120 dB,† (10 dB at 130 dB). Crest-factor capacity increases below full scale.

DETECTION OF OVERLOAD AND UNDERLOAD: Signal peaks monitored at 2 critical points to provide positive indication of peak overload on panel LED. If, during integration, upper limit of detector range is exceeded for more than 0.1% of integration period, overload warning on digital display indicates that result may be in error. If integrated level is less than lower limit corresponding to 5 dB below bottom scale on panel meter, underload warning is given on digital display.

DISPLAY: ANALOG: 3-in. panel meter graduated in 1-dB increments; four ranges: 30–80 dB, 50–100 dB, 70–120 dB, and 90–140 dB; displays continuous level (i.e., Fast, Slow, Impulse and Peak). DIGITAL:Display is 4-digit LED type with 0.1-dB resolution for level display; can display continuous level, maximum level, integrated sound level (LEQ) or sound-exposure level (SEL); display is updated once per second when integrating, 7 times per second in continuous mode.

FILTERS: Octave-band filters have attenuation of 3.5 ± 1 dB at nominal cutoff frequency, more than 18-dB attenuation at ½ and 2X center frequency, and more than 70-dB ultimate attenuation.

MICROPHONE AND PREAMPLIFIER: TYPE: ½-in. Electret-Condenser Microphone with flat response to random (–9700) or perpendicular (– 9710) incidence; response curve supplied. MOUNTING: Detachable preamplifier (1560-3410) that plugs into nose of instrument or can be remoted with 10-ft cable (1933–0220) supplied or 60-ft cable (1933–9601) available. Preamplifier has selectable X1 or X10 gain, normally set for X1. INPUT IMPEDANCE: Approximately 2 GΩ in parallel with <6 pF. Switchable 200-V polarizing supply allows use with air-condenser microphones.

OUTPUTS: AC OUTPUT: 0.4 V rms nominal, behind 5 kΩ, corresponding to full-scale deflection; any load permissible. DC OUTPUT: 3 V nominal, behind 30 kΩ, corresponding to full scale meter deflection. Output is linear in dB at 60 mV/dB over 70-dB range (50-dB panel-meter display range plus 20-dB crest-factor allowance). Any load permissible. OUTPUT TO PRINTER: RS232C with TTL-logic levels (0–5 V), 25-pin-connector optional printer cable available for use with most TTL-compatible printers. Serial output rate at EIA standard 110 baud. Dwell time of 5 s permits use with buffered-input printers. Elapsed integration time, selected integration level (LEQ or SEL) and maximum level during each integration period are printed.

CALIBRATION: FACTORY: Calibrated and fully tested to all specifications. Sensitivity measured in free field by comparison with laboratory-standard microphone that has calibration traceable to U.S. National Bureau of Standards. FIELD: GR 1987 or 1986 Sound-Level Calibrators are available for field calibration.

ENVIRONMENT: TEMPERATURE: −10 to +50°C operating, −40 to +60°C storage with batteries removed, 15°C to 50°C during battery charging. HUMIDITY: 0–95% RH operating. MAGNETIC FIELD: 1-oersted (80 A/m) 60-Hz field causes 50-dB, C-weighted indication and negligible A-weighted indication, when meter is oriented for maximum sensitivity to field. Equivalent A-weighted response to 1-oersted 400-Hz field is approximately 55 dBA with meter oriented for maximum sensitivity to field. VIBRATION: When sound-level meter, with attached microphone, is vibrated at acceleration of 1 m/s^2 (0.1/G) in direction perpendicular to plane of microphone diaphragm, the indicated flat-weighted level does not exceed 80 dB in frequency range from 20 Hz to 1 kHz. Reference instrument that is not being vibrated indicates maximum level of 65 dB.

POWER: May be operated from any of following 4 sources of power: 1) 100–125 or 200–250 V line with power pack supplied. 2) Supplied AA-size rechargeable battery pack provides at least 2-h continuous operation. Battery pack is recharged in about 4 h from power pack. 3) 3 AA-size alkaline (non-rechargeable) batteries in place of rechargeable AA battery pack. 4) Remote 12-V battery or any remote battery of sufficient capacity and voltage in range from 3.3 to 14 V. Cable and plug for connection are supplied.

MECHANICAL: 1988–9700, 1988–9710 DIMENSIONS (WXHXD): 3.9X20.2X2.322 in. (99X513X59 mm). WEIGHT: 3 lb (1.36 kg) net, 11 lb (5.0 kg) shipping.

Description	Catalog Number
1988 Precision Integrating Sound-Level Meter and Analyzer	1988-9700
1988 Precision Integrating Sound-Level Meter and Analyzer	1988-9710

U.S. Patent Numbers 3,681,618 and 4,070,741.

* In the international system of units (S1) the unit of pressure is the pascal (Pa); 1 Pa = 1 N/m^2 = 10 $dynes/cm^2$ = 10^{-2} mbar. REF: "The International System of Units (S1)," U.S. Dept. of Commerce, National Bureau of Standards, NBS Special Publication 3320. SD Cat. No. C13. 10:330/2, U.S. GPO, Washington, D.C. 20402.

** Noise floor is at least 5 dB below Minimum Measurable Levels with ½-in. electret-condenser microphone having sensitivity of −45 dB re 1 V/Pa. Power levels can be measured by setting preamplifier to X10 gain and using microphone with greater capacitance, such as GR 1961 or 1971 microphone. Refer to para 3.7.3 for nominal noise floors with various microphones.

† 10 dB higher when 10-dB microphone attenuator is used.

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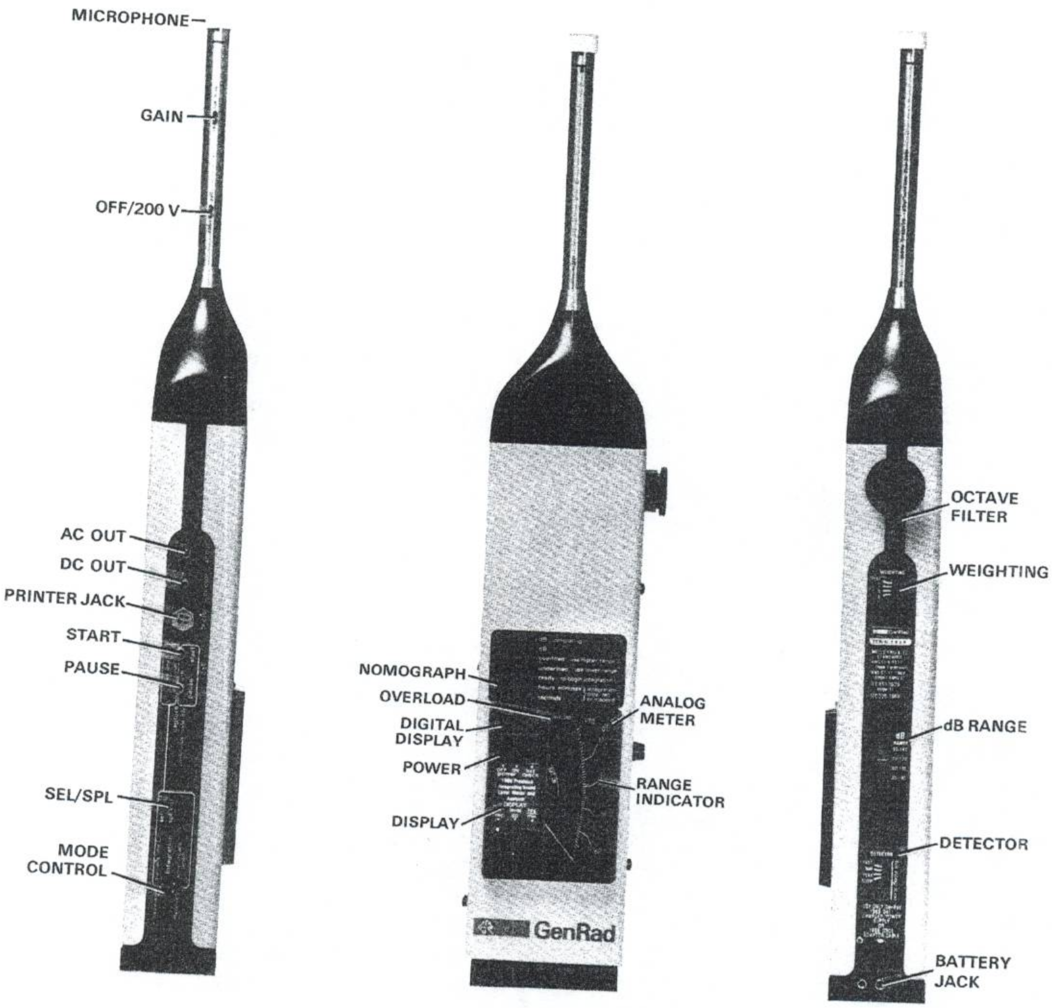


1988 Integrating Sound-Level Meter

Display Information

CONTINUOUS SPL.

Instantaneous sound-pressure level (SPL), in dB. Indicated on analog meter at all times. Selectable on digital display, where updated 7 times per second, with "capture" (display-freeze) capability at any update. Display is used for: duplication of meter reading, capture of time-varying SPLs, and calibration.

LEQ.

"Equivalent constant SPL" (dB). Selectable on digital display, where updated once per second. Represents *steady* SPL that would produce same total energy during Elapsed Time (t) as sum of all *time-varying* SPLs actually measured during t. Computed by integrating circuitry, for long-term periods, as "time-averaged root-mean-square SPL". Usage of LEQ: replaces manual averaging of instantaneous SPL's (by operator) with automatic and precise computation; good predictor of hearing damage from environmental noise; satisfies noise-study criteria for LEQ, "equivalent continuous level," "average sound level," and "integrated sound level."

SEL.

"Sound Exposure Level" (dB). Selectable on digital display, where updated once per second. Represents total sound-level energy measured during Elapsed Time (t). Computed by integrating circuitry, for long-term periods, as "summed mean-square SPL". Relationship of SEL to SPL (LEQ) is: SEL = LEQ + 10 log10 t. Usage of SEL: indicator of "noise exposure level" or "total noise accumulation" of an individual; measures total energy rather than power level measured by LEQ of transient (short-duration) signal, e.g., "passby" measurement of a moving noise source.

ELAPSED TIME (t).

Time accrued during current measurement period. Cumulative integrating time since instrument was last "reset", omitting any suspended-integration interruptions. Selectable on digital display, where indicated as follows: for t from 0 to 599 s, updated each second with readout in "seconds" (no decimal point); for t from 10 min (600 s) to 24 h, updated each minute with readout in "hours.minutes" (decimal point separates h from min). Usage: record of integration period's cumulative duration in computing LEQ/SEL.

MAXIMUM SPL.

Highest instantaneous SPL (dB) since last "reset". Selectable on digital display, where updated each time higher SPL is measured, with capability to suspend measurement (display-freeze) at any update. Display is used for indication of maximum rms/impulse/peak level (dB) during Elapsed Time (t).

Condensed Operating Instructions

CHECK OF POWER SOURCE AND INDICATORS.

Slide *power* switch to BAT CHECK. Analog-meter reading above BAT OK line on scale and digital-display reading of "8.8.8.8." indicate satisfactory power source and properly functioning indicators. Refer to paras 2.3 through 2.6 for power-source replacement procedure.

CALIBRATION (Use GenRad 1986, 1987, 1562, or 1567 Sound-Level Calibrator).

a. Release 1988 *power* switch from BAT CHECK to ON.

b. Set 1988 controls: DISPLAY to *level dB*, left panel 4-position slide switch (hereafter called "Mode" control) to *continuous*, OCTAVE FILTER FREQ to WTG, WEIGHTING to A, dB RANGE to 70-120, DETECTOR to FAST. Set preamplifier controls (on microphone post): GAIN to X1, OFF/200 V to OFF.

c. Turn on calibrator power and set for 1-kHz, 114-dB output (on 1986, set VARIABLE SPL to CALIBRATED SPL).

d. Place calibrator (or transducer), with 1/2-in. microphone adaptor installed, over 1988 microphone.

e. Observe readings on 1988 meter and display; adjust 1988 CAL (left panel) for reading of 114 ± 0.5 dB. Refer to calibrator's instruction manual for appropriate corrections, if needed, due to altitude/pressure variations or microphone type used.

f. To ensure accuracy, perform calibration in measurement environment before and after measurements.

INITIAL SETTINGS.

a. To select desired weighting, set WEIGHTING to A, B, C, or FLAT, with OCTAVE FILTER FREQ set to WTG.

b. To select desired detector response, set DETECTOR to FAST, IMP, PEAK or SLOW. Use FAST for integrated measurement of SEL/LEQ.

c. With DISPLAY set to *level dB* and Mode to *continuous*, set dB RANGE for mid-scale meter readings of sound levels to be measured.

SELECTION OF OPERATIONAL MODE.

Five operational modes are selectable. Choice of mode determines type of information available on digital display. "Automatic 10-s Mode" is primarily intended for quick integration measurement (LEQ/SEL); "Automatic Preset-Time Mode" for any automatically timed integration measurement (LEQ/SEL) up to 24 h, "Manual Mode" for manually timed integration measurement (LEQ/SEL) that requires temporary interruption(s) of integration, "Maximum Mode" for instantaneous updates of Maximum SPL on display, and "Continuous Mode" for instantaneous updates of Continuous SPL on display. Operating procedure for each mode follows.

OPERATION IN "AUTOMATIC 10-s MODE".

Following procedure provides automatic 10-s integration:

a. Set DISPLAY to *level dB*, Mode to *automatically timed*, *sel/spl(leq)* to desired position for display of SEL or LEQ.

b. Simultaneously press and release 2 *reset* buttons to clear memory registers (switching *power* from OFF to ON produces same result). Observe "ready to integrate" indication: ("- - - -").

c. Press *start* to initiate 10-s integration. Observe "integrating" indication ("blinks"). Display's reading of SEL/LEQ is updated once per second with each blink.

d. Observe that, after 10 blinks, integration automatically stops (blinks cease). Display now reads 10-s measurement of SEL/LEQ.

e. For a new 10-s measurement, press *start* (automatically clears registers). Repeat this step as often as desired.

f. To record all data upon completion of 10-s measurement: switch *sel/spl(leq)* to its other position for display of LEQ or SEL, switch Mode to *maximum* for display of Maximum SPL, switch Mode to *continuous* for frozen display of final update of Continuous SPL, and switch DISPLAY to either *sec* or *hrs/min* for display of Elapsed Time (t).

OPERATION IN "AUTOMATIC PRESET-TIME MODE".

Following procedure provides automatically timed integration for any predetermined period up to 24 h:

a. Set Mode to *automatically timed* and *sel/spl(leq)* to desired position for display of SEL or LEQ.

b. To preset "Set Integration Time (T)": set DISPLAY to *sec* for T between 0-600 s, or to *hrs/min* for T between 10 min (600 s) and 24 h. (Note: Do not use internal battery pack for T that exceeds 2 h).

c. Simultaneously press and release 2 *reset* buttons. In *sec* position, "default" T of 10 s ("10" on display) is established by re- execution; in *hrs/min* position, T of 1 h

("1.00" on display) is established. If default T is to be used, proceed to step e; if not, proceed to step d.

d. To select desired T, use 2 *set time* buttons one at a time; *start* button (→) increments T, *pause* button (←) decrements T. If either button is held depressed, display's incrementation/decrementation of T increases at rate proportional to button-depression time. In *sec* position, T is displayed in "seconds" (no decimal point) and can be selected to resolution of 1 s; in *hrs/min* position, T is displayed in "hours.minutes" (decimal point separates h from min) and can be selected to resolution of 1 min.

e. After T is preset, switch DISPLAY to *level dB*. Observe "ready to integrate" indication ("- - - -" for *sec*, "- - .- -" for *hrs/min*).

f. Press *start* to initiate integration. Observe "integrating" indication ("blinks"). Display's reading of SEL/LEQ is updated once per second with each blink.

g. When Elapsed Time (t) reaches T, integration automatically stops (blinks cease). Display then reads final SEL/LEQ.

h. For a new measurement of same duration (T), press *start* (clears all registers except "T" register). Repeat this step as often as desired.

i. To record all data upon completion of integration period, perform step f of preceding procedure.

OPERATION IN "MANUAL MODE".

Following procedure provides manually timed integration for any desired period (SEL cannot exceed 190 dB). Integration can be temporarily suspended at any time to exclude extraneous event(s) or record interim data. When integration is resumed, computation "picks up where left off" (at last update on display) to provide *cumulative* measurement.

a. Set DISPLAY to *level dB*, Mode to *manually timed*, *sel/spl(leq)* to desired position for display of SEL or LEQ.

b. Simultaneously press and release 2 *reset* buttons. Observe "ready to integrate" indication ("- - - -") on display.

c. Press *start* to initiate integration. Observe "integrating" indication ("blinks"). Display's reading of SEL/LEQ is updated once per second with each blink.

d. To suspend integration, press *pause* (blinks cease).

e. To record interim data while integration is suspended, perform step f of *Automatic 10-s Mode* procedure. After data is recorded, return controls as in step a above, then proceed to next step.

f. To resume integration, press *start* (blinks reappear). Perform "pause-start" interruptions (steps d and f) as often as desired during measurement period. Display always indicates *cumulative* reading of LEQ/SEL.

g. To terminate integration (no more suspensions), press *pause*.

h. To record final cumulative data, perform step f of *Automatic 10-s Mode* procedure.

OPERATION IN "MAXIMUM MODE".

Following procedure provides instantaneous updates of Maximum SPL on display, with capability to interrupt measurement (and freeze display) at any update.

a. Set DISPLAY to *level dB* and Mode to *maximum*.

b. Set DETECTOR to PEAK for display of sound's "maximum-peak" level (dB), to FAST or SLOW for display of "maximum-rms" level, or to IMPULSE for display of "maximum-impulse" level.

c. Simultaneously press and release 2 *reset* buttons. Observe "ready to integrate" indication ("- - - -"). Note: Although LEQ and SEL (integrated functions) are computed in this mode, it is primarily intended for display of Maximum SPL (instantaneous function).

d. Press *start* to begin measurement and display of Maximum SPL. Display's reading is updated whenever higher instantaneous SPL is measured. Note: Disregard "blinks" that indicate 1988 is integrating.

e. To stop (or interrupt) measurement, press *pause*. This freezes display at present update, but does not clear register. Record level (dB) of Maximum SPL.

f. If resumption of measurement (at level of frozen update) is desired, press *start*. Perform "pause-start" interruptions as often as desired during measurement of Maximum SPL.

g. To clear register and start new measurement, press *reset* ("- - - -" on display), then press *start*.

OPERATION IN "CONTINUOUS MODE".

Following procedure provides display of Continuous SPL, with "capture" capability at any update.

a. Set DISPLAY to *level dB* and Mode to *continuous*. Display now indicates discrete updates of Continuous SPL. (If 1988 was previously in Integration Mode, press *start* to unfreeze display.)

b. To "capture" an update (freezes display), press and hold *pause* ("capture") button. After reading is recorded, release button to resume display's updates of Continuous SPL.

GR P/N 5301-8111

Introduction—Section 1

1.1 PURPOSE.

The GenRad 1988 Precision Integrating Sound-Level Meter and Analyzer is a multi-functional instrument that can measure and display both instantaneous levels and long-term integrated levels of sound energy, and can analyze this energy in 10 octave-frequency bands. When the 1988 is properly calibrated, its measurements conform to ANSI* and IEC** standards for a Type 1 ("Precision") impulse sound-level meter.

1.2 SOUND; THE ISLM.

Sound pressure is air pressure that oscillates above and below atmospheric pressure at the instant a sound is generated. A sound can also be thought of as a particle of air that is displaced from its equilibrium position and bumps into surrounding particles. These surrounding particles are set in motion by the bumping and then in turn bump into adjacent particles. In this manner, sound is transmitted through the atmosphere. This displacement of the air is detected by the ear and subsequently converted into the sensation referred to as "sound."

The sound-level meter (SLM) is the conventional instrument used to measure the instantaneous sound-pressure level (SPL), in decibels (dB), of sound energy. Basically, and SLM contains a microphone, an amplifier, weighting and filter networks, detector networks and an indicator.

An integrating sound-level meter (ISLM) has the added capability to compute the long-term root-mean-square (rms) level of time varying sound energy. The time-averaged mean square (SPL) is referred to as the LEQ (Equivalent constant SPL). The total accumulation (or "sum") of mean-square sound energy is referred to as the SEL (Sound-Exposure Level). Thus, an ISLM contains integrating circuitry to compute LEQ and SEL, in addition to the components that comprise an SLM.

The requirement for an ISLM arises, in part, from the fact that LEQ is a good predictor of hearing damage, annoyance, and other subjective responses to environmental noise. Although LEQ can be measured with a conventional SLM, either by "eyeball averaging" or by computing the average of values obtained from repeated "winks" at the panel meter, the ISLM provides greater ease and accuracy of LEQ measurement. What is accomplished manually with an SLM is accomplished automatically and precisely with an ISLM.

The DETECTOR network of an SLM/ISLM contains an "averaging" circuit that determines the speed of response of the indicator(s) to the time-varying SPLs being measured. A "slow" speed of response provides more averaging of the instantaneous SPLs than a "fast" speed of response. Some SLM/ISLMs contain more than one DETECTOR network, providing a choice of indicator responses. FAST and SLOW networks both average time-varying sound energy to determine its "rms" level (dB), but with different response speeds of the indicator(s). A FAST response produces an rms indication that includes more of the time-varying fluctuations in sound-level energy, whereas a SLOW response produces a smoother rms indication with greater "averaging." An IMPULSE network conforms to IEC Standard 651 for "impulse" measurements; it averages time-varying sound energy to produce a non-rms "impulse" level (dB), which more closely predicts the effect of "impulsive" noises (such as produced by forging hammers, punch presses, stamping machines, etc.) than an rms measurement. A PEAK network produces a very fast indicator-response speed in order to measure the "absolute peak" level (dB) of sound energy, without averaging it.

The averaging process accomplished on a "short-term" basis by a DETECTOR network is computed over a "long-term" basis by the integrating circuitry of an ISLM. This circuitry performs successive "mean-square" computations of time-varying sound energy for integration periods up to 24 h, thus providing long-term measurements of LEQ and SEL. Since LEQ and SEL are both defined in terms of "mean square (rms) SPL", only an rms DETECTOR is normally applicable to their measurement. Also, for short integration periods (10 s or less), the different responses of a FAST and SLOW network can produce slightly different levels of LEQ and SEL; this discrepancy usually "averages out" and disappears after 20 s of integration.

*American National Standards Institute, Inc., 1430 Broadway, New York, NY 10018.
**International Electrotechnical Commission, 1 Rue de Varembe, Geneva, Switzerland.

A FAST response is recommended for integrated measurements of LEQ/SEL in order to include the faster responses to time-varying instantaneous SPLs.

Some SLM/ISLMs include a "maximum register" that holds in memory the highest instantaneous SPL measured since the register was last cleared ("reset"). If the operator selects this function ("Maximum SPL") for a readout on the digital display, and if the PEAK DETECTOR network is concurrently selected, the display will then indicate the "maximum absolute peak" level (dB) of noise measured since the instrument was reset. This function is sometimes referred to as the noise's "MAX-PEAK"; its measurement is specified in noise studies prescribed by OSHA*. It is extremely useful for "capturing" (on the display) the highest peak level of a short-duration ("transient") noise or a vehicle "passby" sound.

Many plant and environmental noise surveys are concerned with hearing-impairment risks. Most standards that define the criteria for such surveys specify an "A-weighting" network in the noise-measuring instrument. This network alters the frequency response of the instrument so that it is comparable to the response of the human ear. The criteria are defined in terms of an A-weighted sound level (measured in the unit "dBA") and the duration of exposure to that level. Noise reduction or control consists primarily of barriers erected to shield an operator from a noise source, walls and ceilings treated to reduce reflected sound, or of ear protectors provided for workers. Since the effectiveness of these methods varies with the frequency, it is necessary to determine which frequency components comprise the offending noise. A detailed analysis of these components can be quickly accomplished via use of a sound-measuring instrument that contains octave-band filters to provide an "analyzer" capability.

1.3 DESCRIPTION.

The GenRad 1988 Precision ISLM and Analyzer contains the integrating circuitry, detector networks, memory registers, weighting networks and octave-band filters to perform all the sound-level measurements and analyses discussed in preceding para 1.2. The instrument's integrating circuitry performs successive integrations every 9.09 ms to continually update computations of LEQ and SEL; the readout of either of these integrated functions is then updated once per second on the display. Four detector networks provide a selection of FAST, SLOW, PEAK or IMPULSE indicator response; the FAST network is recommended for integrated measurements of LEQ/SEL. A "maximum" memory register holds the "Maximum SPL" encountered, which can be selected for display at any time. The 1988 incorporates 4 weighting networks (A, B, C and FLAT) that cover the frequency range from 5 Hz to 20 kHz, and 10 octave-band filters (from 31.5 Hz to 16 kHz) for noise analysis.

*Occupational Safety and Health Act (OSHA), 1970 (84 Stat. 1593), U.S. Dept. of Labor.

The front-panel analog meter has a 50-dB linear scale to provide a continuous indication of the instantaneous ambient SPL ("Continuous SPL"). The front-panel digital display provides discrete 4-LED readouts of Continuous SPL, Maximum SPL, LEQ, SEL or Elapsed Time; the display's information is selectable by the operator. A single LED on the meter's scale lights when an instantaneous overload level (above selected dynamic range) is recorded. A front-panel nomograph illustrates special information given on the display to indicate the operating status of the 1988.

A single range switch provides selection of 4 ranges: 30-80, 50-100, 70-120 and 90-140 dB. The 10-dB attenuator can be used to extend the upper limit to 150 dB with the PEAK or IMPULSE detector network. An LEQ ranging from 25 to 150 dB can be displayed, and an SEL from 25 to 190 dB can be displayed.

The microphone and preamplifier are detachable and can be used with cables up to 60-ft long without additional equipment. A 20-dB gain is selectable on the preamplifier to account for low signal levels or signal losses due to long cable runs.

Five operational modes are selectable. In the "Continuous Mode", the display reads discrete updates of Continuous SPL; a reading can be "captured" (frozen) on the display at any precise instant required, while the meter continues to track the instantaneous SPLs. In the "Maximum Mode", the display reads instantaneous updates of Maximum SPL; measurement can be suspended at any time, whereupon the latest reading is frozen on the display. In the "Manually Timed Integration Mode", the integration period is manually controlled by the operator; integration can be suspended at any time (to exclude extraneous events) and, when resumed it "picks up where it left off" (at last update on display) to produce a cumulative computation of LEQ/SEL. In the "10-s Automatically Timed Integration Mode", the integration automatically stops after 10 s to produce a quick computation of LEQ/SEL. In the "Preset Automatically Timed Integration Mode", the operator presets a "Set Integration Time (T)" up to 24 h via 2 "set-time" buttons; once integration is started, the operator can leave the instrument, and integration will automatically stop when the "Elapsed Time (t)" reaches T, whereupon the display will read the final computation of LEQ/SEL for the time t.

Output connectors are provided on the 1988 for a dc recorder, an ac device (recorder, oscilloscope, amplifier, etc), and a printer. The printer must have an RS 232C format with TTL-logic levels (0-5V).

The 1988 is operable from an internal rechargeable battery pack, internal non-rechargeable (alkaline) cells, ac line power, or an external battery. The internal rechargeable pack can be recharged with the supplied charger.

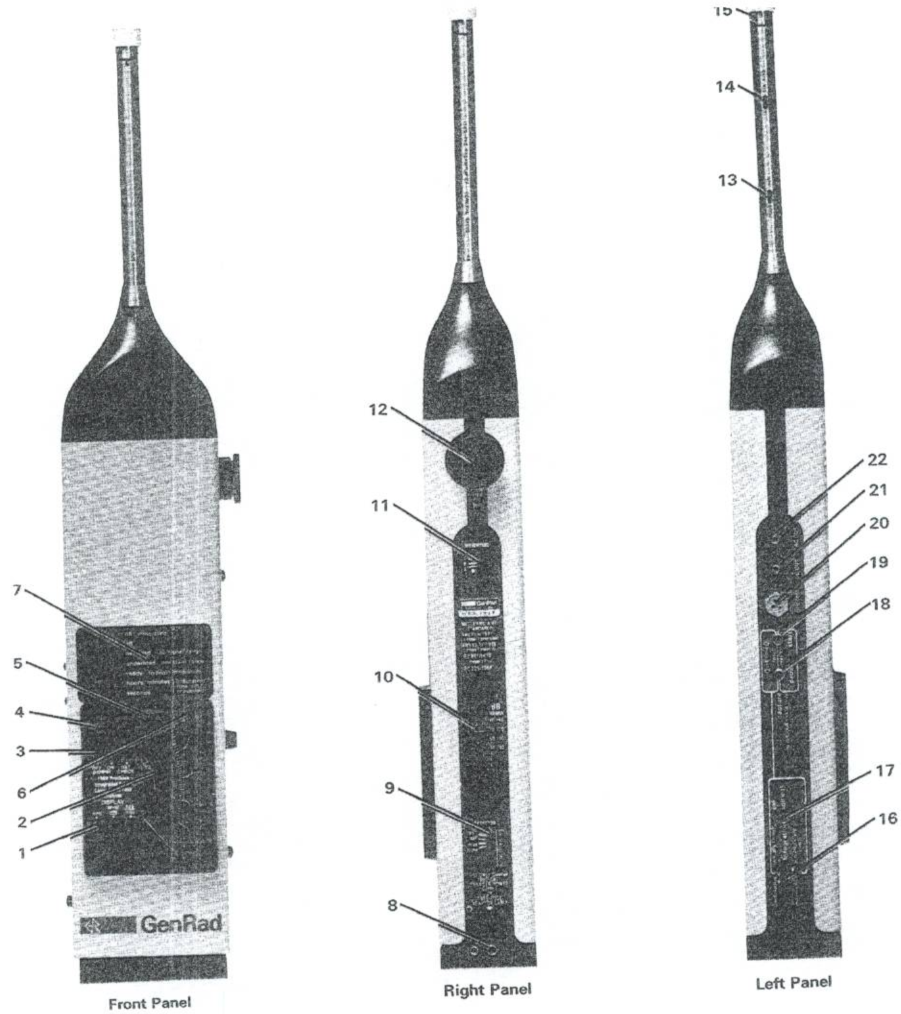


Figure 1-1. Controls, Indicators, and Connectors.

1.4 CONTROLS, INDICATORS, AND CONNECTORS.

Figure 1-1 and Table 1-1 illustrate and describe the controls, indicators, and connectors on the 1988.

Table 1-1

CONTROLS, INDICATORS, AND CONNECTORS

Figure 1-1 Reference	Name	Description	Position(s)	Function(s)
1	DISPLAY	3-position slide switch	level dB	Activates "Mode Control" (item 16).
			sec,hrs/min	Selects indication of Elapsed Time or Set Integration Time on display (refer to item 4).
2	Analog Meter	Pointer and 3-in. 50-dB scale, graduated in 1-dB increments, with BAT OK mark on scale		Indicates continuous instantaneous SPL (dB) of ambient sound energy, unless power control set to BAT CHECK, whereupon indicates condition of power source.
3	power	3-position slide switch, with spring return from BAT CHECK to ON position	OFF	Disengages instrument from power source.
			ON	Activates power from power source.
			BAT CHECK	Checks condition of power source, meter and display.
4	Digital Display	4 red LED (Light-Emitting Diode) indicators	DISPLAY switch set to level dB:	Indicates level (dB) of function selected by "Mode Control" (item 16).
			DISPLAY switch set to sec or hrs/min, set time buttons not activated (item 18, 19)	Indicates "Elapsed Time" (t) in "seconds" for t from 0 through 599 s or in "hours.minutes" for T between 0 min through 24 h.
			DISPLAY switch set to sec, set time buttons activated:	Indicates "Set Integration Time (T)" in "seconds" for T between 0 and 600 s.
			DISPLAY switch set to hrs/min, set time buttons activated:	Indicates Set Integration Time (T) in "hours.minutes" for T between 10 min and 24 h.
				Displays all indications illustrated on Nomograph for applicable situations.
5	OVERLOAD	Single red LED indicator		Lights when instantaneous SPL is above peak limit of selected range.
6	Range Indicators	6 windowed markers on meter's scale		Indicate decade positions of selected range (item 10). Top marker indicates upper rms limit of selected range.
7	Nomograph	Front-panel label		Interprets various operating-status indications given on digital display.
8	External Power/ Battery Charge	Connector consisting of 1 miniature banana jack and 1 miniature phone jack	Connected to 1988-0411 Power Pack and Charger:	If power set to OFF, recharges internal rechargeable batteries; if power set to ON, simultaneously charges batteries and powers instrument.
			Connected to external battery:	Provides external power when power switch set to ON.

Table 1-1

CONTROLS, INDICATORS, AND CONNECTORS (CONTINUED)

Figure 1-1 Reference	Name	Description	Position(s)	Function(s)
9	DETECTOR	4-position slide switch	FAST, IMP, PEAK, SLOW	Selects fast-rms, slow-rms, peak or impulse detector response.
10	dB RANGE	4-position slide switch	90-140, 70-120, 50-100, 30-80	Selects rms range of instantaneous levels (dB) that can be measured (absolute peak level can exceed upper limit by 10 dB).
11	WEIGHTING	4-position slide switch	A, B, C, FLAT	When item 12 is set to WTG, selects A, B, C or flat frequency weighting.
12	OCTAVE FILTER FREQ HZ	11-position rotary switch	WTG, 31.5, 63, 125, 250, 500, 1000, 2000, 4000, 8000 and 16,000	WTG position activates WEIGHTING control. Other 10 positions select center frequency of octave band to be analyzed.
13	GAIN	2-position slide switch	X1, X10	X1 position selects unity gain; X10 position selects 20-dB gain.
14	OFF/200 V	2-position slide switch	OFF, 200 V	200 V position provides polarizing voltage of +200 V for air-condenser microphones; OFF position removes polarizing voltage for all other microphones.
15	Microphone	1/2-in. electret-condenser transducer		Transforms acoustic energy into electrical energy.
16	Mode Control*	4-position slide switch	Continuous, maximum, manually timed, automatically timed	Position at time of reset determines operational mode. Position during operation determines level mode of digital-display information (if DISPLAY set to level dB).
17	sel/spl(leq)	2-position slide switch	sel, spl(leq)	Activated when Mode Control (item 16) set to manually timed or automatically timed. Selects digital-display indication of SEL or LEQ.
18	capture	Single pushbutton	Held depressed	Freezes display's reading of instantaneous SPL in Continuous Mode.
18	pause	Single pushbutton	Pressed and released	Suspends integration during Integration Mode.
19	start	Single pushbutton	Pressed and released	Initiates integration when pressed after reset. Resumes integration when pressed after pause.
18,19	reset	2 adjacent pushbuttons	Pressed and released simultaneously	Initializes (clears) all memory registers (SEL, LEQ, Maximum SPL, Elapsed Time, Integration Time).
18,19 (cont.)	set time	2 adjacent pushbuttons	< or > (depressed one-at-a-time)	Activated as set time buttons if Mode Control set to automatically timed, DISPLAY to sec or hrs/min and reset then pressed; pause button (<) decrements "Set Integration Time (T)" and start button (>) increments T. In sec position, buttons select T between 0-600 s; in hrs/min position, buttons select T between 10 min and 24 h.

*Referred to as "Mode Control" in this manual, but not labelled as such on instrument.

Table 1-1

CONTROLS, INDICATORS, AND CONNECTORS (CONTINUED)

Figure 1-1 Reference	Name	Description	Position(s)	Function(s)
20	printer	4-pin jack		Available cable interfaces this jack to 25-pin RS 232C printer with TTL-logic levels (0-5 V). Can be used with most TTL-compatible printers.
21	DC OUT	Subminiature phone jack		Provides output for dc recorder. Output of 3 V corresponds to full-scale meter indication.
22	AC OUT	Subminiature phone jack		Provides output for ac recorder, oscilloscope, amplifier, etc. Output of 0.4 V rms corresponds to full-scale meter indication.

Figure 1-2. Accessories supplied with 1988-9700/-9710.

Table 1-2

ACCESSORIES SUPPLIED WITH 1988-9700/-9710

Quantity	Name/Description/Purpose	GenRad Part Number
1	Precision Integrating Sound-level Meter and Analyzer, instrument only.	1988-3000
1	Microphone, 1/2-in., Electret-Condenser: • Random-Incidence (1988-9700). • Perpendicular-Incidence (1988-9710).	 1962-3300 1962-3310
1	Microphone Extension Cable; 10-ft; mates with preamplifier's output connector at one end and instrument's input connector (inside nose cone) at other end.	1933-0220
1	Preamplifier; provides impedance match between microphone and input connector of instrument (in nose cone); offers optional input gain (20 dB) and 200-V polarizing voltage for an air-condenser microphone.	1560-3410
1	Battery-Pack Assembly; contains 3 rechargeable NiCd batteries; built-in jumper on side of pack assures that charging current will affect rechargeable batteries only.	1981-2050
1	Power Pack and Charger; accepts 100-125 or 200-250 Vac (50-60 Hz) line source via 7-ft. 4200-0220 power cord; outputs 5.0 Vdc for instrument power and 4.5 Vdc for recharging internal rechargeable batteries via 40-in. cable and plug that mates with External Power/Battery Charge jack on right panel.	1988-0411
1	Power Cable; 3 conductor; 7-ft. long; Belden No. PH-267 3-pin male plug; Belden No. SPH-386 3-wire female connector; connects 120 or 220-Vac (50-60 Hz) line source to input of 1988-0411 power pack/charger.	4200-0220
1	Support; 8-in. long; threads into rear-panel socket; supports instrument at 70° angle of tilt to horizontal surface.	1988-1015
1	10-dB Attenuator; threads between microphone and input of preamplifier; extends instrument's upper limit of measurement from 130 dB to 190 dB rms (150 dB pk).	1962-3210
2	Subminiature Phone Plug; mates with DC OUT and AC OUT jacks; provides connection for patch cable.	4270-1110
1	Calibration Screwdriver; used to adjust CAL control, preamplifier's "slide" switches, or internal adjustments.	7985-1000
1	Microphone Windscreen; reticulated polyurethane foam; fits over 1/2-in. microphone; attenuates up to 20 dB of ambient wind noises.	1560-7551
1	Battery Tag.	5301-1561
1	Pouch; accommodates instrument, microphone/preamplifier and support.	1988-0157
1	Wrist Strap; attaches to instrument for convenient carrying.	1981-0410
1	Instruction Manual.	1988-0100

1.5 ACCESSORIES.

Figure 1-2 and Table 1-2 illustrate and describe the accessories supplied with the 1988.

Table 1-3 lists typical accessories, available upon order from GenRad, which can be used to comprise a sound-analysis system that includes the 1988. A carrying case is available for such a system; this case has an interior configuration to accommodate any of GenRad's calibrators, as indicated in Table 1-3. Figure 1-3 shows a typical 1988 sound-analysis system that utilizes the 1986 calibrator.

Table 1-4 lists additional accessories, available upon order from GenRad, which can further enhance the capabilities of the 1988. Para 3.8 describes the use of these accessories with the 1988.

Table 1-3

ACCESSORIES AVAILABLE FOR SOUND-ANALYSIS SYSTEM*

Name	Description	GenRad Catalog Number
Sound-Level Calibrator	Generates 5 SPLs from 74 dB; 6 frequencies from 125 Hz to 4 kHz; 3 tone burst signals for check of fast-response, and crest-factor characteristics.	1986-9700
Sound-Level Calibrator	Generates 1 kHz at either 94 or 114 dB.	1987-9700
Sound-Level Calibrator	Generates 114 dB at 5 frequencies from 125 Hz to 2 kHz.	1562-9701
Carrying Case	Contains compartments to accommodate GenRad Calibrators and other accessories shown in Figure 1-3.	1982-9630
Tripod	Mounts either the entire 1988 ISLM, or the detachable preamplifier and microphone; telescopic legs provide height adjustment; tilting sleeve adaptor swivels 360° and tilts 90° in one direction or 20° in other direction.	1560-9590
Extension Cable, 60-ft.	Connects detachable preamplifier and microphone to nose cone of 1988.	1933-9601

*In addition to supplied accessories listed in Table 1-2.

Figure 1-3. Typical 1988 Sound-Analysis System.

Table 1-4

ACCESSORIES AVAILABLE*

Name	Description/Purpose	GenRad Catalog Number
Audiometer Calibration Accessory Kit	Consists of microphone, earphone coupler (NBS Type 9-A), calibration stand, calibration data and instruction manual. Allows 1988 to check the acoustic output and attenuator linearity of an audiometer.	1560-9619
Auto Power Cable	4.6 m (15 ft.) long; 2-pin connector at one end mates with External Battery jack on 1988 right panel, "charger plug" at other end plugs into vehicle's cigarette-lighter receptacle; allows 1988 to be powered externally from automotive battery.	1988-9606
DC Recorder	DC strip-chart recorder with 10-cm scale for 50-dB span of sound levels (full scale can be set to 500 mV) and 12 feed rates from 2 cm/h to 60 cm/min; uses z-fold paper.	1985-9700
Dummy Microphone	22-pF capacitance simulates 1962-9610/-9611 microphone; BNC input with optional shorting cap.	1962-9620
Extended-Life Battery and Charger Set	Consists of rechargeable battery (126 Vdc, 5 Ah) in simulated leather case with shoulder strap, ac charger (input of 120 or 220 Vac at 50-60 Hz, output of 520 mA at 12.6 Vdc), and 1-ft. coiled cord (extendable to 4-ft.) with cigarette-lighter plug at one end and 2-pin plug at other end that mates with external-battery connector on 1988. Allows operation of 1988, remote from ac line source, for period greater than 24 h.	1988-9610
Patch Cables	Adaptor cables that connect 1988 DC OUT and AC OUT jacks to applicable connectors; d1 0.9 m (3-ft.) long:	
	Miniature phone plug to GenRad 274 double banana plug.	1560-9677
	Miniature phone plug to BNC male connector.	1560-9679
	Miniature phone plug to standard (0.250-in. diameter) phone plug.	1560-9678
	Miniature phone plug to standard phone jack.	1560-9680 1988-9605
Printer Cable	2 m (6-2/3-ft.) long; 4-pin connector at one end mates with 4-pin jack on 1988 left panel, 25-pin connector on other end mates with most TTL-compatible printers. Female dB 25 connector also supplied.	1988-0300
Vibration Integrator System	Consists of vibration pickup (accelerometer), vibration integrator, 8-ft. cable, slide-rule calculator, storage case and instruction manual. Allows 1988 to make vibration measurements of acceleration, velocity and displacement.	1933-9610
Windscreen Set	Package of four 1560-7551 windscreens.	1560-9522

*In addition to accessories listed in Table 1-3.

Installation—Section 2

2.1 UNPACKING AND INSPECTION.

If the shipping carton is damaged, ask that the carrier's agent be present when the instrument is unpacked. Inspect the instrument and supplied accessories for damage (scratches, dents, broken parts, etc). If the instrument or an accessory is damaged or fails to meet specifications, notify the carrier and the nearest GenRad office (see list at back of this manual). Retain the shipping carton and padding material for the carrier's inspection.

The shipping weight of the 1988 is 2.43 kg (5.4 lb). The weight of the unpacked instrument is 1.36 kg (3 lb). If the instrument passes inspection, proceed with the ensuing installation procedures.

2.2 DIMENSIONS.

The overall dimensions of the 1988 (including preamplifier, microphone, and support) are shown in Figure 2-1.

2.3 POWER-SOURCE CONFIGURATIONS.

The 1988 can be operated from 4 optional power-source configurations.

- Line Power via 1988-0411 Power Pack and Charger ("Power Pack").
- Internal Battery Power via 1981-2050 Battery Pack (rechargeable).
- Internal Battery Power via 3 AA-size alkaline cells (non-rechargeable).
- External Battery Power via 1988-9606 Auto Power Cable (available) or 1988-9610 Extended-Life Battery and Charger Set (available).

The 2-pin jack on the 1988 battery compartment (right panel) provides connection to the 1988-0411 power pack or to either of the external-battery accessories (1988-9606 or 1988-9610).

The installation/removal procedures for these power sources are given in ensuing paras 2.4, 2.5, and 2.6.

2.4 LINE POWER.

2.4.1 General.

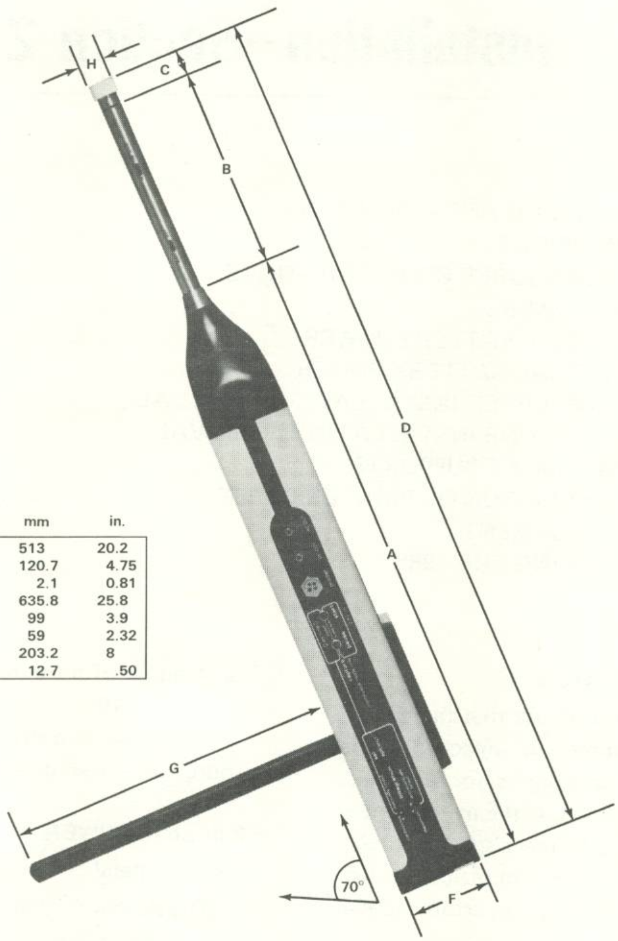
The supplied 1988-0411 Power Pack and Charger (hereafter referred to as "power pack") enables the 1988 to be operated from any line voltage between 100-125 or 200-250 Vac, at 50/60 Hz. A 2-position slide switch on the power pack's front panel provides selection of the appropriate nominal voltage (120 or 220 Vac) for the line source being used. The power pack is connected to a line source via the supplied 3-conductor 2.1-m (7-ft) 4200-0220 Power Cable.

The power pack is connected to the 1988 via its 0.9-m (3-ft) output cord, which is terminated with a 2-pin plug. This plug mates with the battery compartment's external-power jack on the 1988 right panel. The 2-pin plug contains a miniature phone pin and a miniature banana pin. The phone pin's tip provides 5.0 Vdc for instrument power, and its sleeve provides a 150-mA (at 4.5 Vdc) charging current to the internal rechargeable battery pack. The banana pin provides a common line between the power pack and the 1988.

2.4.2 Installation/Removal of Power Pack.

To connect the 1988-0411 power pack to the 1988, proceed as follows (see Figure 2-2).

a. Use the supplied calibration screwdriver to slide the power pack's voltage-range switch to the appropriate position (120 or 220 Vac) for the line source being used.



	mm	in.
A	513	20.2
B	120.7	4.75
C	2.1	0.81
D	635.8	25.8
E	99	3.9
F	59	2.32
G	203.2	8
H	12.7	.50

Figure 2-1. Dimensions of 1988 with support, preamplifier, microphone.

b. Set the 1988 *power* switch to OFF.

c. Plug the 2-pin output plug from the power pack into the external-power jack of the battery compartment, located on the right panel of the 1988.

d. Connect the female connector of the 4200-0220 power cable to the 3-pin power-input connector on the power pack.

e. Connect the male plug of the 4200-0220 power cable to the line source being used.

f. Switch the 1988 *power* control to BAT CHECK. If the meter's pointer indicates above the BAT OK line on the scale, the 1988 is satisfactorily powered by the power pack.

NOTE

1981-2050 battery pack contains build-in interlock to ensure that charging circuit will only be engaged when this rechargeable battery pack is installed. If non-rechargeable cells are installed, or if battery compartment is empty, charging circuit will not be engaged.

g. If the 1988 *power* control is set to OFF, the power pack's charging circuit is still engaged to recharge an internal 1981-2050 battery pack (if installed). If the *power* control is set to ON, the power pack's charging and power circuit are both engaged to simultaneously power the instrument and recharge an internal battery pack.

To disconnect the power pack from the 1988, reverse the above procedure.

2.5 INTERNAL BATTERY POWER.

2.5.1 General.

The supplied 1981-2050 Battery Pack enables the 1988 to be portably operated from a rechargeable internal power source. The battery pack contains 3 AA-size, 1.5-Vdc, NiCd rechargeable cells that comprise a 4.5-Vdc power source. When fully charged, the battery pack provides at least 2 h of continuous operation for any operation mode of the 1988. A full recharge of the 1981-2050 battery pack from the 1988-0411 power pack takes 4 h.

NOTE

Do not use internal battery power if a continuous integration time greater than 2 h is required.

Figure 2-2. Proper connection of 1988-0411 Power Pack and Charger to 1988 battery-compartment jack. If the 1988 power switch is set to ON, 1988-0411 simultaneously powers the 1988 and recharges internal battery pack; if set to OFF, battery pack is recharged while 1988 power is disengaged.

The 1988 can also be powered by 3 AA-size, 1.5-Vdc alkaline (non-rechargeable) cells.* Three fresh cells provide at least 3.5 h of continuous operation for any 1988 operational mode. When discharged, these cells must be replaced with new ones.

The 150-mA charging current from the 1988-0411 power pack is engaged by a built-in interlock contained on the 1981-2050 battery pack. This interlock ensures that the charging circuit is only completed when the rechargeable pack is installed, and not when individual non-rechargeable cells are installed or when the battery compartment is empty.

CAUTION

Do not attempt to recharge any battery other than the 1981-2050 battery pack, and do not attempt to defeat the interlock. Any attempt to charge non-rechargeable cells can cause them to overheat and explode.

*Mallory MN1500 or equivalent.

2.5.2 Installation of Internal Batteries.

To install 1981-2050 Rechargeable Battery Pack:

a. Hold the 1988 as shown in Figure 2-3 and slide the bottom cover off the instrument.

b. Remove any batteries that may be in the battery compartment, as described in para 2.5.3 below.

c. Hold the new battery pack so that the words THIS SIDE UP are exposed, and the "+" signs are at the opposite end from the coiled springs (see Figure 2-4).

d. Place the battery pack against the springs; push to compress the springs, and simultaneously push the "+" end of the pack down into the battery compartment.

e. Slide the battery-compartment cover (notch end first and bow up) back into the grooves on the bottom of the battery compartment (see Figure 2-3).

f. Slide the 1988 *power* switch to the BAT CHECK position. If the meter's pointer reads above the BAT OK line on the scale, and if the display reads "8.8.8.8.", the battery pack is satisfactorily charged to power the 1988.

To Install Alkaline Batteries:

a. Perform steps a and b above.

b. Place each of the 3 new cells individually into the battery compartment, as described in step d above. Be sure to observe the correct polarity printed on the battery-compartment case.

2.5.3 Removal of Internal Batteries.

NOTE

Batteries should be removed whenever 1988 will not be used for 1 week or more.

To Remove 1981-2050 Rechargeable Battery Pack:

a. Hold the 1988 as shown in Figure 2-3 and slide the bottom cover off the instrument.

b. Place the finger tips on the end of the battery pack in contact with the coil springs; push down and toward the springs such that the other end of the pack raises from the battery compartment, as shown in Figure 2-5.

c. Remove the battery pack from the battery compartment.

To Remove Alkaline Batteries:

a. Perform step a above.

b. Remove each cell individually as described in step b above, and as shown in Figure 2-5 for the battery pack.

2.5.4 Charging 1981-2050 Battery Pack.

NOTE

The GenRad Battery Pack (P/N 1981-2050) supplied with the 1988 may arrive partially or completely discharged.

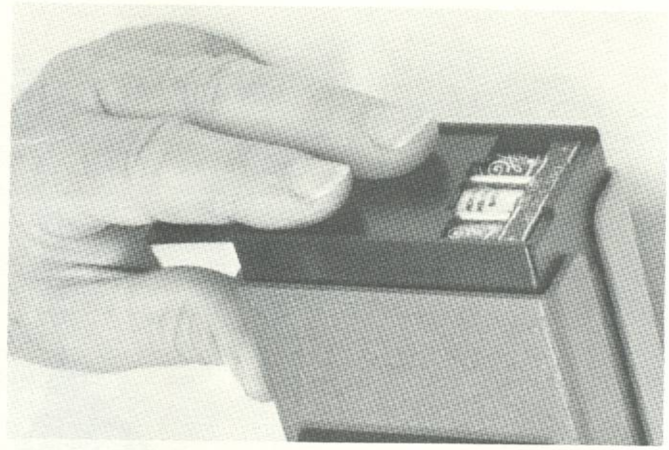


Figure 2-3. Removal of battery-compartment cover.

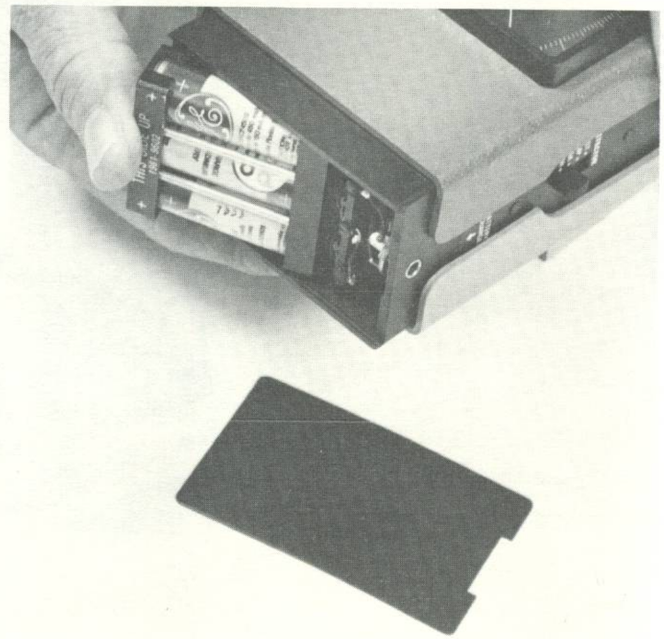


Figure 2-4. Installation of battery pack (1981-2050).

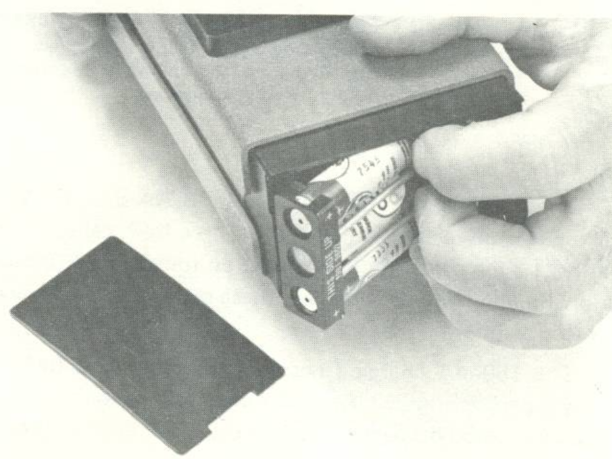


Figure 2-5. Removal of 1981-2050 battery pack.

When the 1981-2050 battery pack is installed in the 1988, it can be recharged with the 1988-0411 power pack. No attempt should be made, however, to recharge batteries other than the rechargeable battery pack supplied with the 1988. The built-in interlock on the 1988-2050 pack is intended to prevent damage that could result from recharging AA-size non-rechargeable cells.

CAUTION

Any attempt to recharge non-rechargeable cells can cause them to overheat and explode.

To Charge the 1988-2050 Battery Pack, Pack, Proceed as Follows:

a. Install the battery pack, as described in para 2.5.2.

b. Connect the 1988-0411 power pack to the 1988, as described in para 2.4.2.

c. To simultaneously power the 1988 and recharge the battery pack, set the 1988 *power* control to ON. To recharge the battery pack only, set the *power* control to OFF.

d. Observe the following precautions when charging internal batteries.

Avoid Overcharging. Optimum battery-charge time should about equal discharge time, but remain within the specified 4 to 5-h limit. All charge beyond optimum is overcharge and is excess energy dissipated as heat. Within the cells, the heat produces gas, raising internal pressure. Normally, the cell's chemicals reabsorb the gas as pressure increases, and a safety vent protects against the possibility of bursting. However, the overcharge does strain the battery and it must, therefore, be avoided.

Temperature has some effect on the capacity of the battery pack and on the length of time it will provide power. If the battery is recharged at 40 degrees C (104 degrees F), it will provide only 60 percent of the capacity available after a room-temperature or low-temperature charge. Also, if the 1988 is operated in temperatures below 0 degrees C (32 degrees F), the battery will produce only about 90 percent of its rated capacity.

Avoid very cold charging. There is a low-temperature limit for charging because the gas-absorbing chemical reactions do not work at low temperatures. Even moderate charging below a temperature of 15 degrees C (59 degrees F) can generate enough gas to open the safety vent. Therefore, be sure to keep the temperature above 15 degrees C (59 degrees F) while charging the battery.

If the safety vent opens, (an occurrence difficult to detect), the battery loses some of its electrolyte. The result is degradation and ultimate failure of the battery, i.e., loss of capacity to store electrical energy.

Extreme Discharge. Do not allow the battery to become fully discharged. Perform battery checks (refer to para 3.1.2) at recommended intervals. Slide the power switch to OFF upon completion of each test. The decimal point in the digital display remains visible to serve as a reminder while power is ON.

Memory. Nickel-cadmium (NiCd) batteries tend to lose charge capacity with disuse or after many cycles of very light use. This phenomenon, called "memory", results in a condition where the battery will appear to be fully charged, but will fail to perform for a specified minimum period. Fortunately, a "memory" condition can be remedied by reconditioning the battery. Proceed as follows to recondition the battery:

- Discharge the battery fully by operating the 1988 for about 24 h.
- Perform a charge, with power ON, for 24 h.
- Repeat this cycle as necessary to restore full charging capacity.

Extending Battery Life. Nickel-cadmium batteries respond best to moderation in usage and handling. Avoid excess discharge and overcharging. Limit exposure to temperature extremes. During charge periods, be sure line voltage stays within the selected range of the line-voltage switch on the battery charger.

Storage. Nickel-cadmium batteries may be stored in either a charged or partially charged condition. They undergo self-discharge at a rate of 10 to 25% per month. Thus, after prolonged storage (3 months or more), they require a new charge. If "memory" becomes a problem, perform the reconditioning process (see *Memory* above).

WARNING

Never discard batteries in a fire or in trash to be burned, as they can explode and cause serious injury.

2.6 EXTERNAL BATTERY POWER.

2.6.1 General.

The external-power jack, located on the 1988 battery compartment, is accessible on the 1988 right panel; it enables the instrument to be powered from an external battery. This capability is particularly useful for a field measurement that requires a continuous integration time greater than the 2-h life of the internal battery pack.

The 1988 will accept an external battery that has a voltage between 3.3 and 14 Vdc. The current that the 1988 draws from an external battery depends on the battery's voltage and the operating status of the instrument. The range of operating currents varies from approximately 300 mA (for a 3.3-V battery) to 50 mA (for a 14-V battery). The particular external battery used should have a sufficient A-h capacity to satisfy the application under consideration. Generally, it is safe to assume an operating current of 200 mA when determining how long a fully charged external battery can power the 1988 before becoming discharged. For example, a fully charged 5-Ah battery could be expected to provide 40 h of continuous operation (at 200 mA) before requiring a recharge.

NOTE

Maximum continuous integration time in Automatically Timed Integration Mode is 24 h. In Manually Timed Integration Mode, there is no limit on cumulative integration time as long as level of SEL does not exceed 190 dB.

GenRad offers 2 available accessories to power the 1988 from an external battery. The Auto Power Cable (P/N 1988-9606) provides external-battery power to the 1988 via a vehicle's cigarette-lighter receptacle. The 1988-9610 Extended-Life Battery and Charger Set contains all the necessary components for a complete external-power system; it allows long-term portable and mobile measurements. The installation/removal of these 2 accessories follows.

2.6.2 Auto Power Cable 1988-9606.

This available accessory enables the 1988 to be connected to an automative battery via the vehicle's cigarette-lighter receptacle. The cable is 4.6 m (15 ft) long. On one end, it is terminated with a 2-pin connector that mates with the 2-pin external-power jack on the battery compartment (right panel of 1988); on the other end, it is terminated with a universal "charger plug"* that mates with a standard automative cigarette-lighter receptacle.

A wiring diagram of the 1988-9606 auto power cable is shown in Figure 2-6. The cable contains a fuse receptacle (1 A, "Normal Blow") to prevent overheating from excessive currents. The cable is intended only for vehicles that contain a negative-ground battery with a voltage between 3.3 and 14 Vdc. To install the cable, proceed as follows.

CAUTION

Charger plug on 1988-9606 cable is wired for automotive system with battery's negative terminal grounded. Do not use on positive-grounded vehicle.

a. Check the 1-A fuse in the cable's fuse receptacle.

b. Ensure that the vehicle's battery has a voltage between 3.3-14 Vdc, is fully charged, and has a negative-terminal ground. Leave the battery properly connected to the vehicle, and make sure the engine and all accessories are turned off.

c. Remove the cigarette lighter from its receptacle.

d. Push the cable's "charger-plug" into the vehicle's cigarette-lighter receptacle.

e. Plug the cable's 2-pin connector into the external-power jack on the 1988 battery compartment (right-panel).

f. Slide the 1988 *power* switch to the BAT CHECK position. If the meter's pointer indicates above the BAT OK line on its scale, and if the display reads "8.8.8.8 ", the 1988 is satisfactorily powered from the vehicle's battery. If there is no indication on the meter and display, set the vehicle's ignition switch to the "accessories" or "on" (but not "start") position, and check again for a BAT OK indication. If satisfactory power is still not verified, the vehicle's circuitry needs to be checked.

NOTE

Full-scale BAT OK indication is about 6.6 V. Therefore, this is basically a go/no go test. If full-scale indication is not attained battery is seriously discharged.

g. Once a BAT OK indication is given, the 1988 is properly powered for operation.

To disconnect the external battery, reverse the above procedure.

2.6.3 1988-9610 Extended-Life Battery and Charger Set.

This available accessory includes the components listed in Table 2-1 and illustrated in Figure 2-7. The external battery pack, which can be readily carried via its shoulder strap, provides at least 24 h of continuous operation when fully charged. The coiled cable provides an extendable power connection between the external battery pack and the 1988. Thus, the operator can use this portable external-battery set to make long-term continuous field measurements.

Two installation/removal procedures are described below. The first procedure is for powering the 1988 with the external battery pack; the second is for recharging the external battery pack with the ac charger.

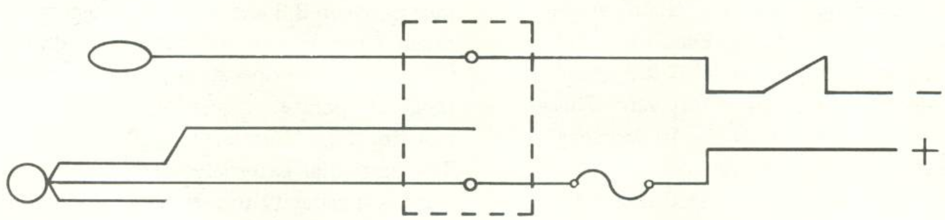


Figure 2-6. Wiring diagram — 1988-9606 auto power cable.

*Safco No. 20 Charger Plug (with No. 20-3 End Cap), or equivalent.

Table 2-1

COMPONENTS OF BATTERY AND CHARGER SET

Qty.	Description	GenRad Part No.
1	Battery Pack; 12.6 Vdc; 5 Ah; rechargeable; in-line fuse holder; in simulated leather carrying case with shoulder-carrying strap.	1988-4001
1	Charger; 120/220-Vac, 50/60-Hz input; 12.6-Vdc, 520-mA output; in plastic case.	1988-0431
1	Coiled Cable; 2-conductor; extendable from 30.5 cm (1 ft) to 122 cm (4 ft).	1988-0315
1	Fuse; Type 3AG; 5 A; "Normal Blow."	5330-3500
1	Power Cable; 3-conductor; Belden No. KH7267; 213 cm (7 ft) long.	4200-0220

To Power the 1988 with the 1988-4001 Battery Pack:

a. Plug the "charger plug" on the 1988-0315 coiled cable into its mating socket on the 1988-4001 battery pack.

b. Check the in-line fuse (5 A, "Normal Blow," Type 3AG) located inside the battery pack.

c. Plug the 2-pin connector on the 1988-0315 coiled cable into the external-power jack on the 1988 battery compartment (right panel of instrument).

d. Slide the 1988 *power* switch to the BAT CHECK position. If the meter's pointer indicates above the BAT OK line on its scale, and if the display reads "8.8.8.8", the 1988 is satisfactorily powered from the external battery pack. If the meter reads below the BAT OK line, the battery pack needs to be recharged.

e. Once a BAT OK indication is given, the 1988 is properly powered for operation. If desired, the battery pack can be personally carried via its shoulder strap for portable field measurements.

To Recharge 1988-4001 Battery Pack with 1988-0431 AC Charger:

a. On the 1988-0431 ac charger, set the voltage-range switch to the appropriate nominal position (120 or 220 Vac) for the line source being used.

b. Plug the "charger plug" on the ac charger's 1.8-m (6-ft) output cord into the "charger socket" on the 1988-4001 battery pack.

c. Connect the ac charger to the line source via the 4200-0220 power cord.

d. Refer to Table 2-2 for the recommended charging time.

e. After the charging time from Table 2-2 has been completed, disconnect the ac charger, first from the line source, and then from the battery pack.

f. Slide the 1988 *power* switch to BAT CHECK. If the meter's pointer reads above the BAT OK mark on the scale, and if the display reads "8.8.8.8", the battery pack is satisfactorily charged. If not, repeat the above charging procedure until the meter reads BAT OK.

Figure 2-7. Components of 1988-9610 extended-life battery and charger set.

Table 2-2

CHARGING TIMES FOR 1988-0431 AC CHARGER*

Voltage-Range Setting (Vac)	Line-Source Voltage (Vac)	Charging Time (h)
120	104	24
	127	8
220	198	24
	242	8

*To charge 1988-4001 battery pack.

2.7 PREAMPLIFIER INSTALLATION/REMOVAL.

CAUTION

Be sure to proceed with care when installing or removing preamplifier into/from nose cone. Small connector pins can be damaged if proper procedure is not followed.

2.7.1 General.

The 1560-P42 Preamplifier provides impedance matching between the microphone and instrument, and an optional gain of 20 dB (refer to para 3.6.2). Its 4-pin output connector, which is recessed in one end of its casing, mates with the instrument's 4-pin input connector, which is recessed inside its nose cone. Figure 2-8 shows the pin-out functions of the preamplifier; Section 6 contains component-layout and schematic diagrams of the preamplifier.

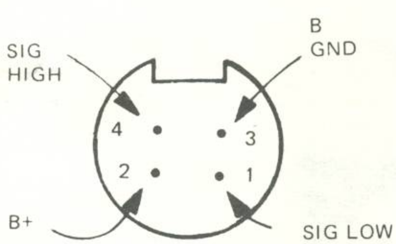


Figure 2-8. Pinout functions of 1560-P42 preamplifier.

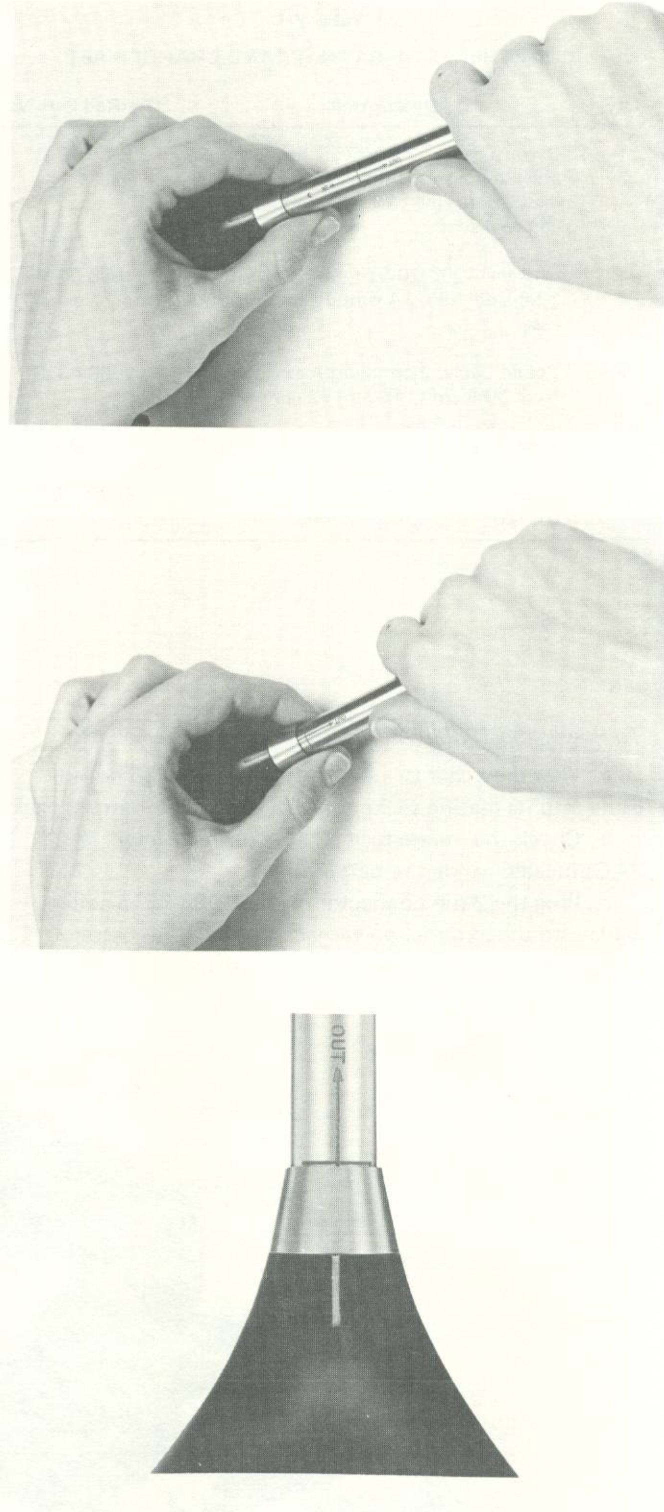


Figure 2-9. Installation of preamplifier into 1988 nose cone.

The preamplifier must be removed from the instrument each time it is placed in its pouch or a carrying case, or when it is used to make measurements remote from the instrument via an extension cable. The casing of the preamplifier contains red markings that aid in the installation, or removal, of the preamplifier to/from the 1988 nose cone. Two red ''axial'' arrows (parallel to preamplifier's axis) are used to properly align the connector pins during installation and removal of the preamplifier (see Figure 2-9). The arrow that points toward the nose-cone connector is for use during installation of the preamplifier, and the arrow that points toward the microphone is for use during removal of the preamplifier. A red ''circumferential'' marking (parallel to preamplifier's circumference), located between the 2 red axial arrows, is for use during installation to indicate when the preamplifier has been inserted sufficiently far enough into the nose cone to ensure a complete engagement of connectors.

2.7.2 Installation of Preamplifier.

CAUTION

Observe red alignment markings on preamplifier and nose cone as described below. Connector pins can be damaged from improper alignment.

To install the preamplifier in the nose cone of the 1988, proceed as follows:

a. Slide the 1988 *power* switch to OFF and the preamplifier's OFF/200 V switch to OFF (unless air-condenser microphone is being used).

CAUTION

200-V polarizing voltage is for use only with air-condenser microphone. Always set OFF/200 V switch to OFF when supplied 1962-3300/3310 microphone is used.

b. Place the rear panel of the 1988 flat on a level surface (1988-1015 support must be removed), with its front panel facing upward.

c. Orient the preamplifier such that its 4-pin-connector end will enter the nose cone, and with the red markings on its casing facing upward.

d. Before inserting the preamplifier into the nose cone, align the red axial arrow on the preamplifier's casing with the red marking on the nose cone.

e. Without twisting or rotating the preamplifier, insert it about 1/4 in. into the nose cone opening until it encounters some resistance from spring guides attached to the interior casing of the nose cone (see Figure 2-9). Make sure the axial markings on the preamplifier and nose cone are still aligned.

f. Exert a little more force on the preamplifier to carefully slide it through the spring guides. It should slide approximately 3/4 in. further into the nose cone until its 4-pin connector encounters the 4-pin socket recessed in the nose cone. The circumferential red marking on the preamplifier's casing should now be approximately 1/8 in. above the top of the nose cone, which indicates that the 2 connectors have encountered each other, but are not yet fully engaged or "seated" (see Figure 2-11).

g. Make sure the red axial markings on the preamplifier's casing and nose-cone housing are still in alignment, and then push the preamplifier with a slight force to see if its connector pins are indexed in the nose cone socket. If they are, the preamplifier should enter about another 1/8 in. into the nose cone until its connector seats, whereupon the circumferential marking on its casing should coincide with the top of the nose-cone opening (see Figure 2-11). The preamplifier may need to be rotated a slight amount for its 4-pin connector to index on the input socket, whereupon it can then be pushed to its seated position.

2.7.3 Removal of Preamplifier.

CAUTION

Do not rotate or twist the preamplifier to remove it. It should only be pulled with a force parallel to its axis, as described below.

a. Set the 1988 *power* control to OFF.

b. Repeat step b of para 2.7.2.

c. With one hand, hold the top section of the 1988 securely. With the other hand, grasp the casing of the preamplifier such that the thumb and forefinger overlap onto the front of the 1988 nose cone; use the thumb and forefinger to guide the preamplifier as it is pulled directly away from the instrument (in the direction of the red arrow on its casing) with a force parallel to its axis (see Figure 2-10).

d. If the preamplifier is to be used remotely with an extension cord, refer to para 2.9.3. If it is to be stored in the pouch or a carrying case, refer to para 2-12.

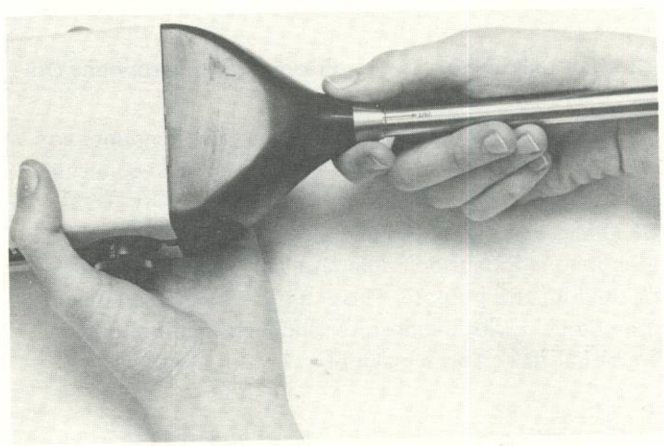


Figure 2-10. Removal of preamplifier. Use thumb and forefinger on nose cone, as shown, to guide preamplifier's casing.

2.8 MICROPHONE INSTALLATION/REMOVAL.

Either the 1/2-in. 1962-3300 Random-Incidence Microphone (Model 1988-9700) or the 1/2-in. 1962-3310 Perpendicular-Incidence Microphone (Model 1988-9710) threads directly (clockwise) onto the threaded end of the preamplifier; no adaptor is required. The supplied plastic microphone cap should always be inserted over the microphone when it is not in use to protect its front grid and diaphragm.

2.9 INSTRUMENT SUPPORTS.

2.9.1 General.

The 1988 can be hand-held, surface-supported or tripod-supported (total instrument or detachable preamplifier/microphone) when used to make measurements. Para 3.4 describes the procedures to properly orient the microphone to the sound field being measured. The paragraphs below describe the installation procedures to prepare the 1988 for surface-supported or tripod-mounted measurements.

2.9.2 Surface-Supported Instrument.

The 1988-1015 Support (supplied) threads into the grounded socket on the rear panel of the 1988; when installed, this support rod is perpendicular to the rear panel (see Figure 2-1). The supnort props the instrument such that its axis tilts 70 to the surface upon which it is placed. This angle provides convenient front-panel viewing and a stable mounting position; also, it is the optimum angle for uniform frequency response when the random-incidence microphone is used to measure unidirectional sound energy (refer to para 3.4.2).

Another accessory that can be used to support the 1988 on a surface is the Weatherproof Enclosure Adaptor (P/N 1988-9600). This available accessory is primarily intended for supporting the instrument at an inclined viewing angle inside a weatherproof enclosure box, but it also provides a very stable inclined support for bench applications or surface-supported measurements. Para 3.8.5 describes the procedure for use of the 1988 with this accessory.

2.9.3 Installation of Remote Preamplifier/Microphone On Tripod.

The 1988 preamplifier/microphone can be mounted on the 1560-9590 Tripod (available accessory) and connected remotely to the instrument via the supplied 10-ft 1933-0220 Microphone Extension Cable. The 60-ft 1933-9601 Microphone Extension Cable (available accessory) can also be used for this purpose. This setup allows measurement of a sound field with the operator and instrument removed from that field. The installation procedure follows.

Connection of Preamplifier/Microphone to Cable. To connect the preamplifier/microphone assembly to the microphone extension cable (1933-0220 or 1933-9601), proceed as follows:

a. Remove the preamplifier/microphone assembly from the nose cone of the 1988, as described in para 2.7.3.

b. Hold the preamplifier in the right hand, with the hole in the end of the preamplifier's casing pointing upward, as shown in Figure 2-11.

c. Hold the plug end of the cable in the left hand, such that its spring clip is aligned with the hold in the preamplifier's casing.

d. Depress the clip on the cable connector, as shown in Figure 2-11, to allow the connector to slide inside the preamplifier's casing; then, insert the cable connector into the preamplifier's casing until the ball of its clip is underneath the hole of the preamplifier's casing.

e. Release the clip, and ensure that its ball protrudes fully through the hole for a secure connection.

Mounting Preamplifier/Microphone to Tripod. After the preamplifier has been connected to the microphone extension cable (above procedure), it can be mounted on the 1560-9590 tripod as follows:

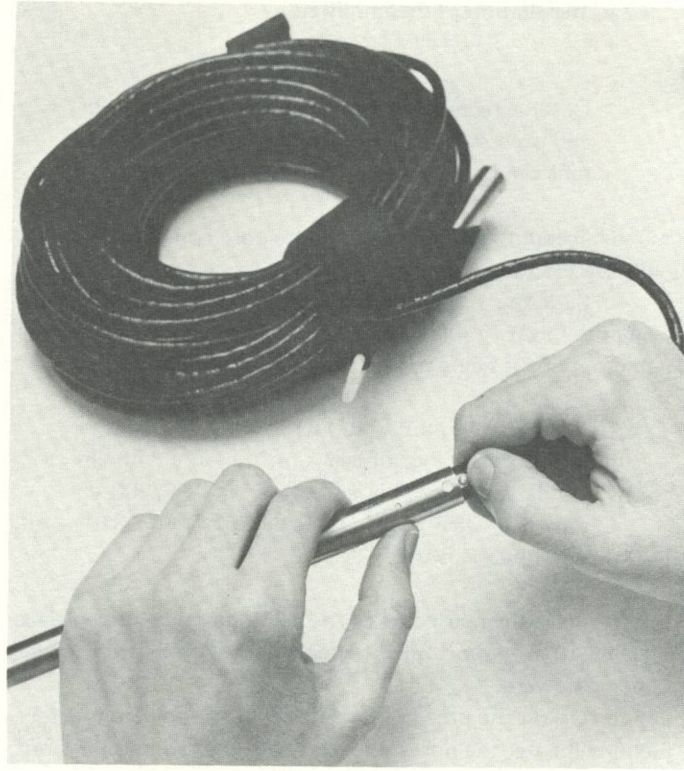


Figure 2-11.
Connection of preamplifier-to-microphone extension cable.

a. On the tripod, extend the telescopic legs to the desired lengths; make sure the knurled nut on each telescopic section is tightened after the lengths are established.

b. Set the tripod in the measurement area with its legs properly spread out.

c. Make sure the "center post" is installed on the tripod as shown in Figure 2-12.

d. Make sure the "tilting sleeve adaptor" (see Figure 2-13) is tightened securely to the top of the "center post."

e. The "tilting sleeve adaptor" has collars for 2 different sized sleeves: a "1/2-in. sleeve" and a "3/4-in. sleeve." The sleeve to be used depends on the size of the preamplifier that fits inside of it. Since the 1988 preamplifier/microphone assembly fits inside the 1/2-in. sleeve, the 3/4-in. sleeve is not needed. If the 3/4-in. sleeve is attached to the tilting sleeve adaptor, loosen the "large knurled collar" (see Figure 2-13C) and remove this sleeve by pulling it away from the loosened collar.

f. If the 1/2-in. sleeve is not installed in the tilting sleeve adaptor, loosen the "small knurled collar" (see Figure 2-13B). Then orient the 1/2-in. sleeve so that the open end of its "cable slot" (see Figure 2-12) faces away from the tilting sleeve adaptor, and insert the closed end of the 1/2-in. sleeve into the recess inside the small knurled collar. Tighten the small knurled collar to secure the 1/2-in. sleeve.

g. Take the 1988 preamplifier/microphone assembly (attached to cable), and insert its cable (at junction to the

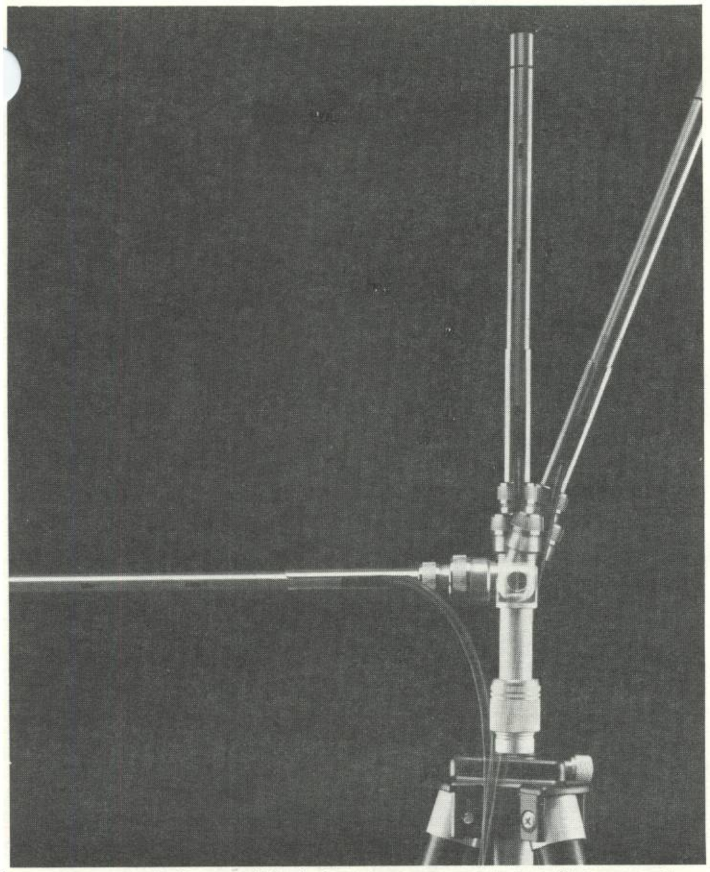


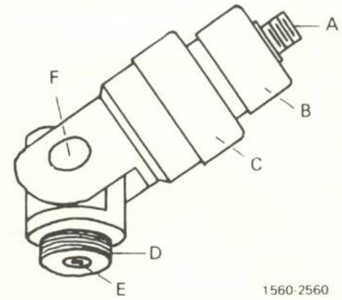
Figure 2-12. Preamplifier/microphone assembly installed remotely on tripod. Three "tilts" of the microphone are shown by triple-exposure photography (90 degrees, 70 degrees, and 0 degrees to horizontal).

preamplifier) into the cable slot of the 1/2-in. sleeve; then slide the preamplifier/microphone assembly into the 1/2-in. sleeve until its cable encounters the base of the sleeve (see Figure 2-12).

h. The *tilt*, *swivel* and *elevation* of the microphone can now be set via tripod adjustments, as described in ensuing steps i, j and k.

i. The tripod's tilting sleeve adaptor swivels upon a pivot (see Figure 2-13F); the friction of the pivot can be adjusted, when the adaptor is removed from the center post, via an Allen-head screw (see Figure 2-13E) in the adaptor's base (Allen wrench supplied with tripod). Most sound-measurement applications require that the microphone's axis be either exactly vertical (90 degrees from horizontal), 20 degrees from the vertical (70 from horizontal), or 90 degrees from the vertical (0 degrees from horizontal). Figure 2-13 shows the microphone in these 3 positions. The tilting sleeve adaptor tilts to a 20 degree "stop" in one direction and a 90 degree "stop" in the other direction. Para 3.4 describes the criteria to determine the microphone's orientation to the sound field being measured.

j. The tripod's center post can be swiveled 360° to adjust the microphone's orientation to the sound field. To swivel the center post, loosen the screw that secures the post



A – Top stud that screws into rear panel.
B – Small knurled collar (clamping nut).
C – Large knurled collar (clamping nut).
D – Bottom stud that screws onto top of tripod.
E – Allen-head screw that adjusts pivot friction.
F – Pivot.

Figure 2-13. Tilting sleeve adaptor for tripod.

inside the tripod, swivel the post to the desired position, and then secure this screw (see Figure 2-12).

k. The elevation of the microphone can be raised or lowered by adjusting the tripod's telescopic center post. To adjust the elevation, loosen the post's telescopic clamping nut, set the microphone to the desired height, and then secure the clamping nut.

l. Make sure all tripod adjustments are tightened securely.

Connection of Cable to 1988. To connect the microphone extension cable to the 1988 nose-cone connector proceed as follows:

CAUTION

Perform following procedure carefully. Small connector pins can be damaged if proper procedure is not followed.

a. Observe the 4-pin recessed socket inside the nose cone of the 1988. Note that the socket has an "alignmei notch" to ensure only one orientation for pin engageme Note also that this notch faces the rear panel of the 198

b. Observe the recessed 4-pin male connector inside t metal casing on the end of the microphone extension ca Note that this connector also has a small, rectangular "alignment notch" (see Figure 2-8) that mates with the notch on the recessed nose-cone connector.

c. Set the 1988 *power* control to OFF; place the fro panel of the 1988 flat on a surface, such that its rear pa faces upward.

CAUTION

Make sure preamplifier's OFF/200 V switch is set to OFF for use with supplied 1962-3300/-3310 microphone. The 200-V polarizing voltage is intended only for air-condenser microphone.

d. Rotate the cable connector's metal casing until the ıll hole faces upward. Align this hole with the center of 1988 rear panel, such that the "alignment notches" of h connectors are lined up for engagement.

e. Carefully insert the cable connector's casing about -in. into the nose-cone opening, keeping the casing's e aligned with the rear panel's center, until it encounters resistance of spring guides located on the inside of the e-cone housing.

f. Keeping the same alignment, exert a little more force the cable connector to slide it through the spring guides il its 4-pin connector encounters the face of the instru-ıt's recessed input connector.

g. If the cable connector is properly aligned, a slight ease in pushing force will engage it with the input con-tor until it seats. Otherwise, gently rotate the cable con-tor's casing back and forth until it indexes on the 4 pins, then push it into the socket until it seats.

.4 Removal of Remote Preamplifier/Microphone from Tripod.

To remove the set-up established in para 2.9.3, proceed ollows.

Removal of Cable from 1988. Refer to para 2.7.3 and ure 2-10. Remove the microphone extension cable from 1988 nose cone in the same manner that the preampli-is removed from the nose cone. Be sure not to twist or ıte the cable connector when disengaging it from the e-cone connector.

CAUTION

Only pull cable connector with force in line with its axis, or damage to pins can result.

noval of Preamplifier/Microphone from Tripod.

ı. Slide the preamplifier/microphone assembly out of 1/2-in. sleeve of the tripod.

). To detach the microphone extension cable from the ımplifier, use the tip of the thumb to depress the ball of clip that protrudes through the casing's hole; then pull cable connector away from the preamplifier's casing.

:. To remove the 1/2-in. sleeve from the tripod's tilting ve adaptor, loosen the small knurled collar (see Figure 3B) and pull the sleeve away from the collar.

l. To disassemble the tripod, remove the tilting sleeve otor by unthreading it from the top of the center post. n, contract the telescopic center post and telescopic , and close up the 3 legs to the center. The tripod is ready for storage.

5 Mounting Complete Instrument on Tripod.

The complete 1988 instrument, with the preamplifier/ ophone assembly installed on its nose cone (refer to 2.7.2), can be attached to the 1560-9590 tripod. set-up provides a stable support for the 1988, with capability to adjust the microphone's axis for:

- *Tilt* — via tilting sleeve adaptor.
- *Swivel* — via swivelling center post.
- *Elevation* — via telescopic center post.

To install the instrument on the tripod, proceed as follows:

a. Perform steps a through d of the *Mounting Preamplifier/Microphone to Tripod* procedure of para 2.9.3.

b. If either or both of the sleeves (1/2-in., 3/4-in.) are attached to the "tilting sleeve adaptor," remove them as follows: first, loosen the "large knurled collar" (see Figure 2-13C) and pull the 3/4-in. sleeve from this collar, then loosen the "small knurled collar" (see Figure 2-13B) and pull the 1/2-in. sleeve from this collar.

c. The "top stud" of the tilting sleeve adaptor should now be exposed (see Figure 2-13A). To mount the instru-ment, this stud threads into a mating socket on the rear panel of the 1988 (support rod must be removed). Tighten the instrument securely onto the stud.

d. The *tilt*, *swivel* and *elevation* of the instrument can now be adjusted, as described in steps i, j, k and l of the *Mounting Preamplifier/Microphone to Tripod* procedure of para 2.9.3.

e. To remove the instrument, reverse the above procedure.

2.10 INSTALLATION OF PRINTER CABLE.

2.10.1 Interface Structure.

Figure 2-14 shows the pinout functions of the GenRad 1988-0300 Printer Cable, an accessory available upon order from GenRad. This 6-ft cable interfaces the 4-pin printer connector, at the top of the left panel of the 1988, to an RS-232 25-pin connector. It is usable with most TTL-compatible printers.

NOTE

Although RS-232 defines a minimum signal level of -3 to +3 V, most printers will accept 0 to 5 V.

The printer to be used must have an RS-232-C format with TTL-logic blocks (0 — 5 V). Since the input configura-tion of an RS-232-C printer varies with the manufacturer, it is not always possible to make a direct connection via the 1988-0300 cable without first making some wiring changes within the cable and/or setting DIP switches within the printer to the appropriate positions. This procedure follows.

CAUTION

Do not install the printer cable without first ensuring that the cable and/or DIP switches are properly set to conform the printer input to the output of the 1988.

The 1988 incorporates a serial interface to a printer. This 2-wire interface operates at the EIA standard 110 baud, which works with any RS-232C printer that accepts TTL-level signals. A dwell time of about 5 seconds permits use of the 1988 with buffered-output printers.

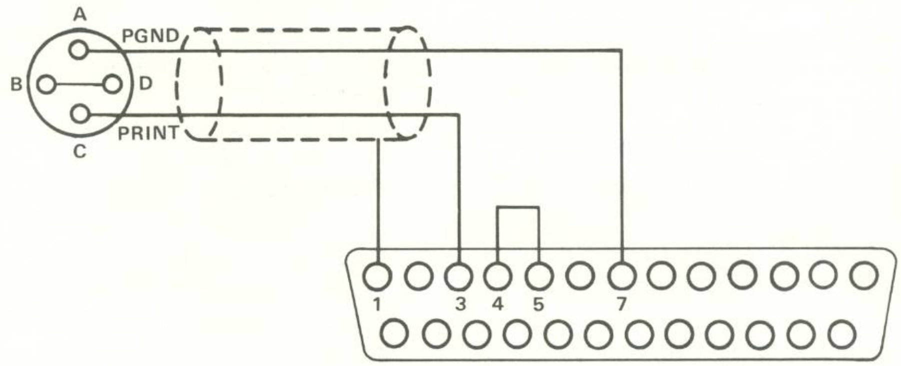


Figure 2-14. Pinout functions of 1988-0300 Printer Cable.

NOTE

Pin 1 is wired to the cable shield and serves as the earth ground.

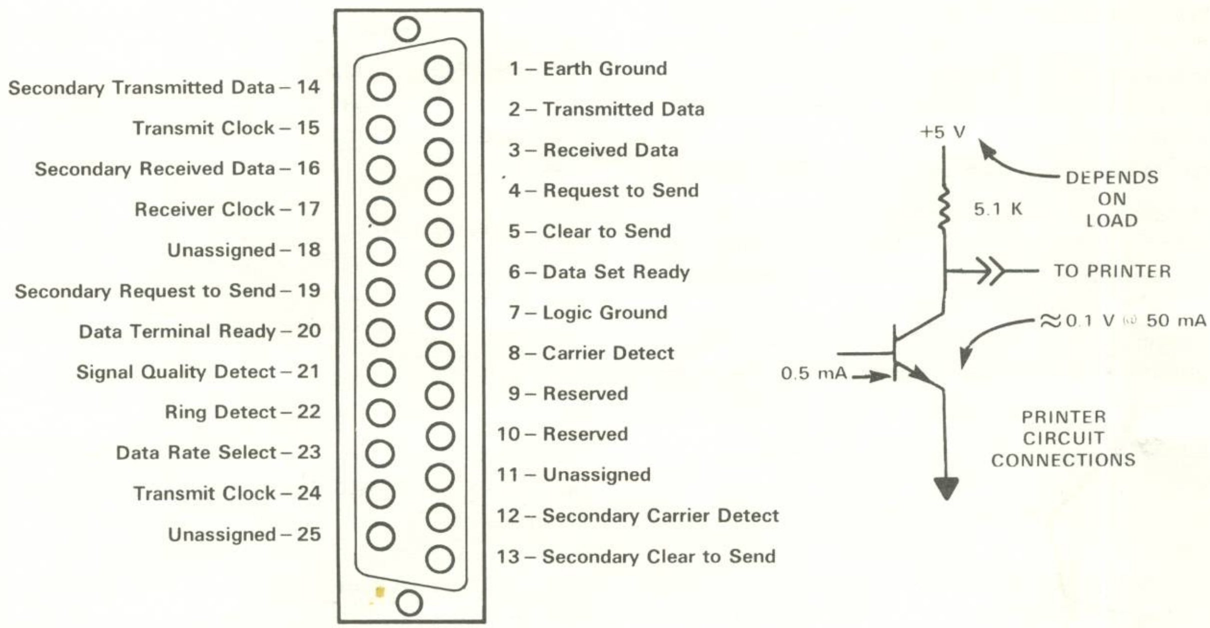


Figure 2-15. Printer interface signal designations.

A problem arises when trying to apply the EIA standard RS-232-C interface between the 1988 and a strip printer. The standard was developed to govern the connection between data terminal equipment (DTE) and data communication equipment (DCE). Neither the 1988 nor the printer fits these definitions, however. Most printer manufacturers assume their units to play the role of the DTE. For those applications, the female EIA DB25-type plug supplied with the cable will suffice as the interface.

Other printer manufacturers, among them Telpar, Inc. consider their equipment to be the DCE in this arrangement. For interfacing with devices of this type, a male EIA DB25-type plug is also supplied with the printer cable kit. This plug can be wired in the same configuration shown in Figure 2-14, with the following exception.

Figure 2-15 shows the signal designations across the printer interface. Pins 2 and 3 are the primary unidirectional data transfer lines. For most applications, pin 3 is used for the transfer of data from the 1988 (DCE) to the printer (DTE). For the Telpar printer, which is considered the DCE in the interface, pin 2 should be used as the transmit line from the ISLM to the printer.

*Telpar, Inc., 4132 Billy Mitchell Road, Box 796, Addison, TX 75001.

In addition, in some applications, pin 20 (Data Terminal Ready) must be jumpered with pins 4 and 5 to ensure that line 20 always shows a high state to the 1988. Hence, the printer is always ready to accept data.

A general printer installation procedure follows:

a. Determine the required connector type. Install the supplied female plug if needed.

b. Set the printer to 110 baud, using 2 stop bits and 7 serial bits. Set parity bit to off (don't-care state).

NOTE

The printer will operate with 1 stop bit with slight delays for stammer.

c. Determine the receive-data pin (pin 2 or 3) and wire the connector accordingly.

d. Determine whether the printer requires a clear-to-send (CTS) enable. If so, jumper pin 5 to pin 4, 6, or 20 (whichever is tied high by the printer).

e. Determine whether the logic level is sufficient to drive the printer. If not, add a 1 to 2 K resistor to the printer 5-V supply line. If a true + or -3 V transition is required, install a logic-level converter between the 1988 and the printer.

f. Test the cable output signal as shown in para 5.6.4.

The character set used with all these printers is the standard 7-bit ASCII code (upper case only). Although the parity is not important, the number of stop bits must be the same in both the printer and the 1988.

When using the Telpar PS-48C 20-column thermal printer, the DIP switches on SW1 (under the cover beneath the print head) must be strapped as shown in Table 2-3.

Table 2-3

TELPAR PRINTER STRAPPING

SW1 Switch	On/Off	Function
1	Off	Low Active Strobe
2	On	Serial Mode
3	On	Half Duplex
4	Off	PSN High
5	Don't Care	No Application
6	Off	Serial 110 Baud
7	Off	PON High
8	Off	RS-232-C TTL Serial/TTL Parallel

For further information, consult the Telpar manual supplied with the equipment.

When a printer is connected, the 1988 microprocessor receives an internal logic indication of the instrument's present status. If the 1988 is set up in the Automatic Integration Mode when the printer is connected, the instrument automatically repeats integrations of the present duration (as if the START button was pressed upon completion of each integration period). At the end of each integration period, a message is printed, containing the following information:

- Total elapsed time since the start of the first integration period.
- LEQ or SEL, depending on the position of the sel/spl(leq) control.
- Maximum SPL.

The elapsed time is printed in an "HH:MM:SS" format. The same message is printed in the Manual Integration Mode when the PAUSE button is pressed. This function allows for manually controlled sampling. If an overload occurs during an integration period, it is signified in the printer output by a number that is equal to "LEQ/SEL plus 800." Header messages are supplied in the printer output to label the printed information. An example of a printer output giving the LEQ in the Manual Integration Mode follows:

HR:MN:S	MAX	LEQ M
00:05:00	089.2	069.7
00:06:54	101.7	073.2

NOTE

When the 1988 is being used to measure sel levels, the LEQ in the above message is replaced by SEL. The M indicates the manual-timed mode. Automatic-timed mode is indicated by a T in the header.

This example shows that 5 minutes after the START button was first pressed, the PAUSE button was pressed, at which time the maximum SPL was 89.2 dB and the LEQ was 69.7 dB. Then, 6 minutes and 54 seconds after the first press of the START button (minus any pause-start interruption time), the PAUSE button was again pressed, at which time the maximum SPL was 101.7 dB and the LEQ was 73.2 dB.

2.10.2 Signal Designations.

All control data for the 1988, except for weighting and detector information, is presented to the processor through 3 input-data multiplexers on the 1988-4705 board. These units allow 24 signals to be multiplexed on the 8-bit data bus. Each input multiplexer has 4 selectable inputs for each of its 2 outputs. Table 2-4 shows the mapping configuration of the input information.

In a similar fashion, the output data latches supply information to 16 output lines when they are gated by the appropriate output (Y1 – Y3) of the address decoder U7. Output latch U11 serves the special function of controlling the wake-up and sleep of the microprocessor.

Table 2-4

1988 MEMORY MAP
I/O BIT ASSIGNMENTS*

	Hex Address	MSB 7	6	5	4	3	2	1	LSB 0
Data	0080	MAX	AD4	AD3	AD2	AD1	AD0	–	–
Inputs	0081	LEVEL	AD9	AD8	AD7	AD6	AD5	–	–
From	0081	PAUSE	START	PREN	RNG140	RNG120	RNG100	–	–
U9-U11 (4705)	0083	CONT	AUTO	–	OVLD	BATCK	SEL	–	–
Data	0084	SEGA	SEGB	SEGC	SEGD	SEGE	SEGF	SEGG	PRINT
Outputs	0088	–	–	–	–	DS4	DS3	DS2	DS1
U8-U11 (4710)	008C	CONV	–	–	RESET	–	WAKEUP	–	DP

*For signal names, refer to signals on the 1988-4705 and 1988-4710 schematics in Section 6. An unassigned bit is identified by "–."

The 4.54-ms rate of wake-up in the processor is fundamental to the transfer rate of information from the output data latches. Many operations are performed on alternate wake-up cycles to balance "ON" processing time of the microprocessor.

If the printer output is enabled, a new bit is shifted out every other wake-up for a 9.08-ms rate, which is equal to 110 Baud. The four digital readout digital-select lines are scanned sequentially during each wake-up. Therefore, a complete display scan takes 18 ms.

Refer to para 4.8.4 for a detailed description of the 1988 data I/O latches.

2.11 ENVIRONMENT.

The 1988 performs within the environmental parameters listed in the "Specifications" section at the beginning of this manual. For measurements under wet conditions, the 1988-9600 Weatherproof Enclosure Adaptor (available accessory) allows the instrument to be placed within a weatherproof box; refer to para 3.8.5 for details.

2.12 HANDLING THE 1988.

2.12.1 General.

The 1988 can be carried by its wrist strap, in its pouch, or in an available carrying case that accommodates a complete sound-analysis system.

2.12.2 1988-0410 Wrist Strap. (See Figure 1-2.)

This supplied accessory screws into the threaded socket on the rear panel of the 1988. It provides a convenient means to transport the instrument separate from its pouch or carrying case.

2.12.3 1988-0461 Pouch. (See Figure 1-2.)

This supplied accessory accommodates the 1988 instrument, preamplifier/microphone and 1988-1015 support. To pack the instrument in the pouch, proceed as follows:

a. Remove the preamplifier/microphone from the 1988 as described in para 2.7.3. Be sure to observe the proper procedure in order to avoid damage to the connector's small pins. Place the preamplifier/microphone in one of the pouch's two side pockets.

b. Unthread (counter-clockwise) the support from the 1988 rear panel, and place the support in one of the pouch's side pockets.

c. Seal the velcro flap that covers the two side pockets.

d. To place the instrument inside the pouch, insert its nose cone into the foam block at the non-zippered end of the pouch, and then position the instrument within the pouch.

e. Close the zipper. The pouch can now be carried by its two straps.

2.12.4 1982-9630 Carrying Case.

A GenRad carrying case is available to accommodate a sound-analysis system that includes the 1988. A typical system consists of the 1988 ISLM and all of its supplied accessories (see Figure 1-2 and Table 1-2), a sound-level calibrator, a tripod and microphone extension cable, extra batteries, appropriate instruction manuals, and pertinent documents.

The interior configuration of the carrying case contains a specifically shaped compartment to accommodate GenRad calibrators. Figure 1-3 illustrates the placement of components in a 1982-9630 carrying case and Table 1-3 describes typical components that can comprise a sound-analysis system.

Operation – Section 3

3.1 IMPORTANT INITIAL CHECKS.

3.1.1 General.

After the installation procedures of the previous section have been performed, the 1988 ISLM is ready to be set up for operation. The following procedures comprise important initial checks that should be performed during each day's use, both *before* and *after* the measurement period. Validation of these checks ensures optimum accuracy of sound-level measurements made with the 1988.

3.1.2 Check of Power Source, Meter, and Display.

The following procedure ensures that the 1988 is satisfactorily powered, and that the analog meter and digital display are functional.

a. Make sure one of the following four power options is properly installed, as described in paras 2.3 through 2.6:

- Rechargeable Internal Battery Pack.
- Non-rechargeable (Alkaline) Internal Batteries.
- Line Power via AC Power Pack and Charger (P/N 1988-0411).
- External Battery via 1988-0315 or -9606 Battery Cable.

NOTE

The internal battery pack (rechargeable) provides at least 2 h of continuous operation. For continuous integration periods that exceed 2 h, use only ac power pack or external battery to avoid battery rundown during integration period.

b. Slide the front-panel *power* switch to the BAT CHECK position, and hold it there to verify the following 2 indications:

- Analog-meter reading above BAT OK line on scale.*
- Digital display of "8.8.8.8".

c. If the meter reading is below the BAT OK line on the scale, the power source is unsatisfactory. Refer to Section 2 for removal/installation procedures.

d. If the meter reading is verified, but the digital display does not read "8.8.8.8", the 4 LED (Light-Emitting Diode) segments that comprise the display need to be checked by a qualified service person (refer to Section 6).

e. If both indicator readings are verified, the power source is satisfactory, and the next check can be performed.

3.1.3 Calibration of Sensitivity.

This calibration procedure checks the sensitivity and overall gain (dB) of the 1988 to ensure optimum accuracy of measurements. It should be performed before and after each day's use in the same environment (temperature, humidity) where measurements are performed.

The total measurement system should be calibrated. If a microphone extension cable (1933-0220, -9601, or -9614) is being used, the calibration should be conducted with the microphone and preamplifier connected to the cable. Similarly, if an output device such as a printer is being used it should be included in the system that is calibrated.

It is recommended that the GenRad 1986, 1987 or 1562 Sound-Level Calibrator be used to calibrate the 1988; the 1567 can also be used. For a more comprehensive calibration procedure that checks other characteristics of the 1988 (in addition to sensitivity), refer to para 5.1.

The procedure for the daily check of sensitivity follows:

a. Verify the calibrator's battery, as described in its instruction manual. Verify the 1988 power source, as described in para 3.1.2.

*On early-production models, BAT OK region is indicated by curved vertical line on top portion of scale; if meter's pointer indicates anywhere on this line, power source is satisfactory (if below line, unsatisfactory). On later-production models, BAT OK region is indicated by horizontal mark with an "up arrow"; if meter's pointer indicates anywhere above the horizontal mark, as indicated by the "up arrow", power source is satisfactory (if below mark, unsatisfactory).

b. If the calibrator generates more than a single frequency, set its appropriate control for a 1-kHz output. (If the 1986 calibrator is used, set the VARIABLE SPL control to CALIBRATED SPL.)

c. If the calibrator produces more than a single output level (dB), set its appropriate control to the level that best approximates the levels to be measured by the 1988. If this is not known, set the control to either 94 dB (preferable) or 114 dB.

d. Set 1988 controls as follows:

OCTAVE FILTER FREQ HZ
(right panel) . . . . WTG
WEIGHTING (right panel) . . . . A
DETECTOR (right panel) . . . . SLOW
Left-Panel 4-Position Slide Switch . . . .continuous
sel/spl(leq) (left panel) . . . . spl(leq)
Preamplifier GAIN X1
DISPLAY (front panel) . . . . dB
power (front panel) . . . . ON

e. On the 1988, simultaneously press and release the 2 left-panel *reset* buttons to clear its memory registers.

f. Set the 1988 dB RANGE control for an analog-meter reading just below full scale; that is, select the lowest possible range that has an upper limit above the calibrator's output level (dB) selected in step c.

g. Insert the calibrator's 1/2-in. microphone adaptor into its microphone cavity so that it will conform to the 1988 1/2-in. microphone. (Use 1987-7061 adaptor on the 1986/1987 calibrator, or 1562-6130 adaptor on 1562/1567 calibrator.)

h. Remove the protective microphone cover from the 1988, and carefully place the calibrator's cavity over the 1988 microphone (see Figure 3-1).

i. Read the level (dB) indicated by the 1988 meter and digital display; add the appropriate correction factor from Table 3-1 to obtain a "corrected reading (dB)". (This correction accounts for difference between "free-field incidence" for which microphone is intended and actual "pressure incidence" within calibrator's cavity.)

Table 3-1

PRESSURE-TO-FREE-FIELD CORRECTION FACTORS

Microphone Type on 1988	GenRad Calibrator Used	1-kHz Correction Factor (dB)*
Random Incidence	1986	0.0
(P/N 1962-9610)	1987	0.0
	1562 or 1567	0.0
Perpendicular Incidence	1986	0.1
(P/N 1962-9611)	1987	0.1
	1562 or 1567	0.0

*To be added to 1988 reading when 1-kHz calibration signal is applied to microphone; e.g., correction factor of 0.1 dB, when applied to 1988 reading of 113.9 dB, produces "corrected reading" of 114.0 dB.

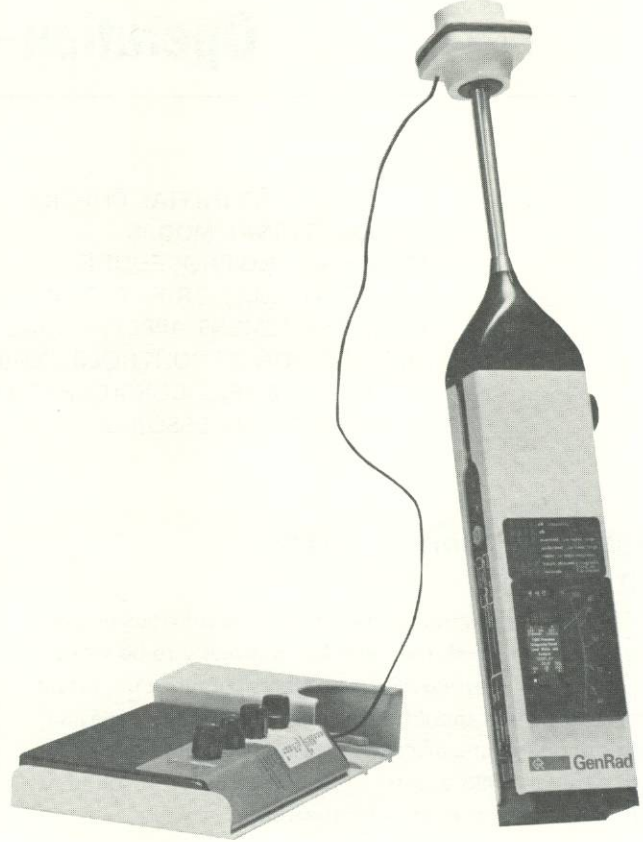


Figure 3-1. Set-up for calibration of the 1988 with the 1986.

j. Compare the "corrected reading (dB)" obtained in step i with the output level (dB) of the calibrator and, if they're not the same, use the supplied calibration screwdriver to adjust the 1988 CAL control (left panel) for the proper reading (see Figure 3-2).

NOTE

If atmospheric pressure varies significantly from 760 mm of Hg, refer to calibrator's instruction manual for appropriate correction factor to apply to calibrator's output level (dB).

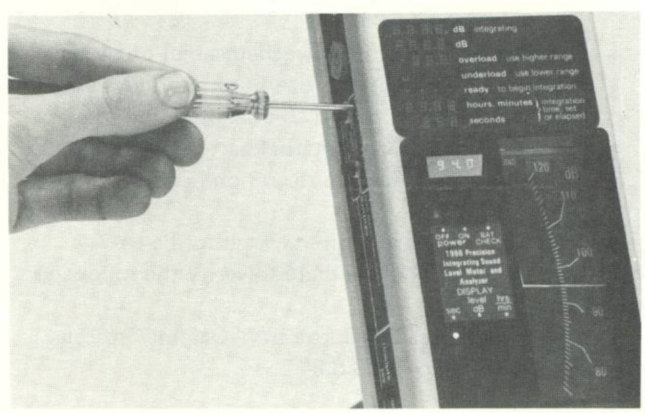


Figure 3-2. Adjustment of left-panel CAL control.

k. When the "corrected reading (dB)" of the 1988 matches the calibrator's output level (dB), the sensitivity and overall gain (dB) are calibrated for accurate measurements.

3.2 FUNCTIONAL MODES OF 1988.

3.2.1 Operational Modes.

The 1988 has 2 basic operational modes: the Continuous Mode and the Integration Mode. When the instrument is operated in the Continuous Mode, it functions similar to a conventional SLM (Sound-Level Meter) in that it measures and displays only instantaneous levels (dB). When operated in the Integration Mode, the 1988 functions as an ISLM (Integrating Sound-Level Meter) to compute 2 integrated functions (SEL and LEQ), which can be displayed in this mode in addition to the instantaneous functions. The integration period for the Integration Mode can be either manually timed via the operator's intervention, automatically timed for 10 s, or automatically timed for any period up to 24 h. The operational procedure for each mode is described in para 3.3.

3.2.2 Display Mode.

The front-panel analog meter always reads the continuous instantaneous level (dB) of the ambient sound energy being measured. The front-panel digital-display reading is a function of the instrument's control settings. The display can provide discrete updates of any of the instrument's measurement functions (described in ensuing para 3.2.3), it can indicate the Elapsed Time (t) of measurement since the 1988 was last reset, it can indicate the Set Integration Time (T) that is established for an automatically timed integration, and it can indicate any of the presentations shown on the front-panel nomograph.

3.2.3 Measurement Functions.

The 1988 can measure 4 distinct functions of sound-level energy. These 4 functions are described below.

Continuous SPL. This is the current instantaneous SPL (dB) of sound-level energy being measured. It is indicated continuously on the analog meter during any operating mode of the 1988, and it can be concurrently indicated on the digital display in discrete readings that are updated 7 times per second.

Maximum SPL. This is the highest instantaneous SPL (dB) that has been measured since the instrument was last reset (memory registers cleared). It is updated on the display whenever an instantaneous SPL is measured that is higher than the current Maximum SPL.

LEQ. This is the "Equivalent constant SPL" that would produce the same total sound-level energy during the elapsed integration time (t) as the sum of all time-varying SPLs actually measured during t. The 1988 integrating circuitry allows a long-term computation of LEQ; this circuitry computes the time average of successive 9-ms integrations that determine the mean-square SPL. LEQ is updated each second on the digital display. Thus, each 1-s update of LEQ on the display represents the time-averaged, mean-square SPL for the elapsed integration time (t).

SEL. This is the Sound-Exposure Level, or the total sound-level energy measured during the elapsed integration time (t). The 1988 integrating circuitry allows a long-term computation of SEL; this circuitry computes the sum of successive 9-ms integrations that determine the mean-square SPL. That is, the later computed 9-ms mean-square SPL is summed (rather than time-averaged, as for LEQ) with all previous 0.9-ms mean-square SPLs to produce SEL, which is updated once per second on the digital display. Thus, each 1-s update of SEL on the display represents the summed mean-square SPL for the elapsed integration time (t).

3.2.4 Functions of Controls, Indicators and Connectors.

The functions of individual controls and connectors on the 1988 are described in Table 1-1 and para 3.6.

3.3 OPERATING PROCEDURE.

3.3.1 General.

Two controls on the left panel of the 1988 serve multiple functions. The 4-position slide switch (hereafter referred to as "Mode Control") is used to select the instrument's operational mode and, after measurement/integration is initiated, to select the digital-display information. The 2 adjacent pushbuttons are used to : (1) reset the 1988 for any operational mode (clears all memory registers), (2) "capture" an instantaneous measurement in the Continuous Mode, (3) interrupt integration in an Integration Mode, or (4) set the integration time for the Automatically Timed Integration Mode. Because of the multiple functions of these controls, it is important to observe the procedural sequences described below.

The following paragraphs describe the general procedure to operate the 1988 for any measurement. Para 3.5 describes procedures for specific measuring applications of the 1988.

3.3.2 Initial Installations and Checks.

a. Install the desired power-source configuration (internal battery pack, ac power pack or external battery) as described in paras 2.3 through 2.6.

b. Install the preamplifier and microphone as described in paras 2.7 and 2.8.

c. Check the power source, meter, and digital display as described in para 3.1.2.

d. Calibrate the sensitivity as described in para 3.1.3.

3.3.3 Initial Settings.

a. Set the preamplifier's GAIN control to X1, unless levels below 30 dB are to be measured (refer to para 3.6.2).

b. Set the preamplifier's 200 V control to OFF, unless an air-condenser microphone is used (refer to para 3.6.2).

c. Set the OCTAVE FILTER FREQ control to WTG, unless an analysis is to be performed (refer to para 3.6.3).

d. The setting of the WEIGHTING control depends on the purpose of the measurement. For most noise studies concerned with hearing damage, this control is set to A (refer to para 3.6.4).

e. The setting of the DETECTOR control depends on the speed of response desired for the meter and display. For a measurement of LEQ/SEL, the FAST setting is recommended. For an instantaneous measurement in the Continuous or Maximum Mode, the desired response should be selected (refer to para 3.6.6).

f. To select the appropriate dB RANGE position, set:

power . . . . ON
DISPLAY . . . . *level dB*
Mode Control . . . . *continuous*

Then, select the dB RANGE position that provides mid-scale meter readings of the sound levels to be measured.

3.3.4 1988 Operation Modes.

Any of the following 5 operational modes can be selected:

- Automatic 10-s Mode – primarily for automatically timed 10-s measurement of SEL/LEQ.
- Automatic Preset-Time Mode – primarily for any automatically timed measurement of SEL/LEQ up to 24 h, without interruption of integration.
- Manual Mode – primarily for manually timed measurement of LEQ/SEL (cannot exceed 190 dB) that requires interruption(s) of integration to exclude extraneous events.
- Maximum Mode – primarily for measurement of highest instantaneous rms/peak/impulse level (dB) during period controlled by operator.
- Continuous Mode – primarily for calibration, or for "capture" of display's latest update of instantaneous ambient SPL.

The operating procedure for each operational mode is described in ensuing paras 3.3.5 through 3.3.9 and illustrated in Figures 3-3 through 3-8.

3.3.5 Operation in "Automatic 10-s Mode".

This operational mode is primarily intended for a quick measurement of LEQ or SEL, with automatic termination of integration after 10 s. The digital display reads 1-s updates of LEQ or SEL when integration is in process, and then reads the final update of LEQ/SEL when integration automatically stops after 10 s. The procedure is described below and illustrated in Figure 3-3.

OCTAVE FILTER FREQ, WEIGHTING,
DETECTOR . . . . as desired
DISPLAY . . . . *level dB*
Mode . . . . *automatically timed*
sel/spl (leq) . . . . as desired
(for SEL or LEQ)
power . . . . ON

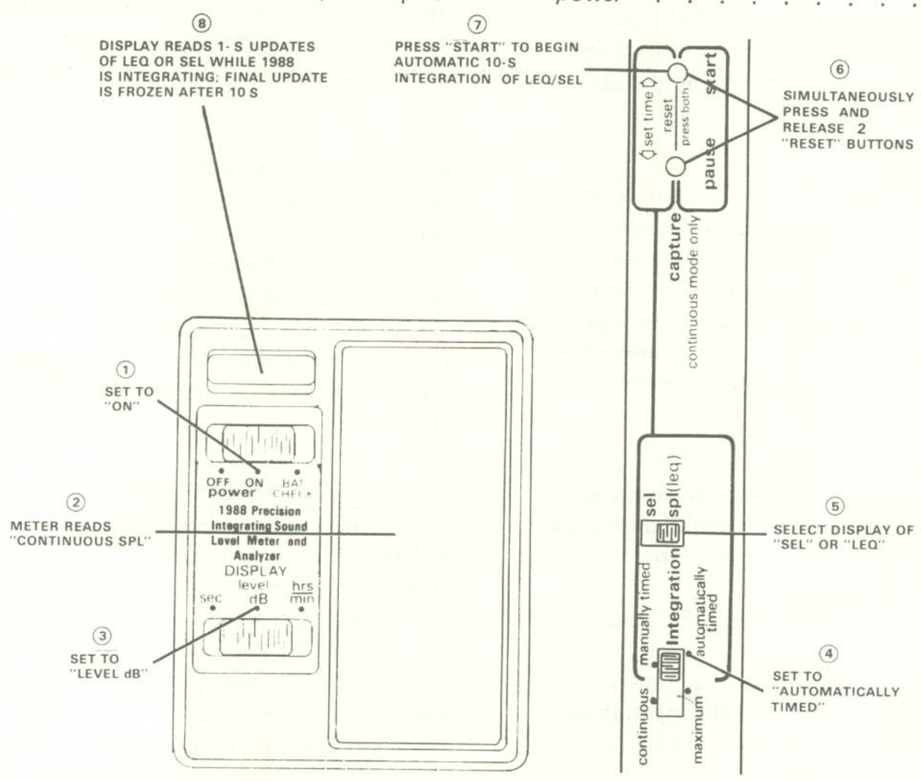


Figure 3-3. Control settings for "automatic 10-s mode". Perform steps 1 through 8 in sequence shown. Final reading on digital display represents 10-s computation of LEQ/SEL.

b. Simultaneously press and release the 2 *reset* buttons to clear the memory registers and automatically establish a "Set Integration Time (T)" of 10 s (sliding the *power* switch from OFF to ON accomplishes the same result when controls are set as in step a). Observe the "ready to integrate" indication ("––––") on the display.

c. Press *start* to initiate the 10-s integration period. Observe the "integrating" indication (blinking decimal point) on the far-right side of the display. The display's reading of LEQ or SEL is updated once per second with each "blink".

d. Observe that, after 10 blinks, integration automatically stops (blinks cease). The reading on the display now represents the final 10-s computation of SEL or LEQ.

e. If a new measurement of SEL/LEQ is desired, press *start* again (automatically clears registers and starts new 10-s computation). This step can be performed as often as desired.

f. To record other data upon completion of a 10-s measurement, proceed as follows:

- Slide *sel/spl (leq)* switch to its other position for display of LEQ or SEL (not chosen in step a).
- Slide Mode switch to *maximum* for display of Maximum SPL during 10-s measurement period.
- Slide Mode switch to *continuous* for "frozen" display of *last* instantaneous SPL measured during 10-s period.
- Slide DISPLAY switch to *either sec* or *hrs/min* for display of Elapsed Time (t) of measurement.

3.3.6 Operation in "Automatic Preset-Time Mode."

This operational mode is primarily intended for a continuous (uninterrupted) computation of LEQ and SEL, which is automatically terminated when a preset integration time is completed. The operator presets the "Set Integration Time (T)" and then initiates integration, which continues until the "Elapsed Time (t)" reaches T, whereupon integration automatically stops. Thus, the operator can leave the 1988 in its measurement area, where it will automatically stop integrating without manual intervention. The maximum T that can be preset in the Automatic Mode is 24 h; the Manual Mode must be used for an integration period longer than 24 h. Once T is preset, it remains in the memory register after the integration period is completed; this allows the same T to be performed as often as desired without presetting it again each time. When the 1988 is reset in this mode, the instrument automatically reverts to a "default" T of 10 s or 1 h, depending on the position of the DISPLAY switch. The operational procedure for the Automatic Preset-Time Mode is illustrated in Figures 3-4 and 3-5, and it is described below.

a. Set 1988 controls as follows:

OCTAVE FILTER FREQ, WEIGHTING, DETECTOR	as desired
Mode	*automatically timed*
sel/spl (leq)	as desired (for SEL or LEQ)
power	ON

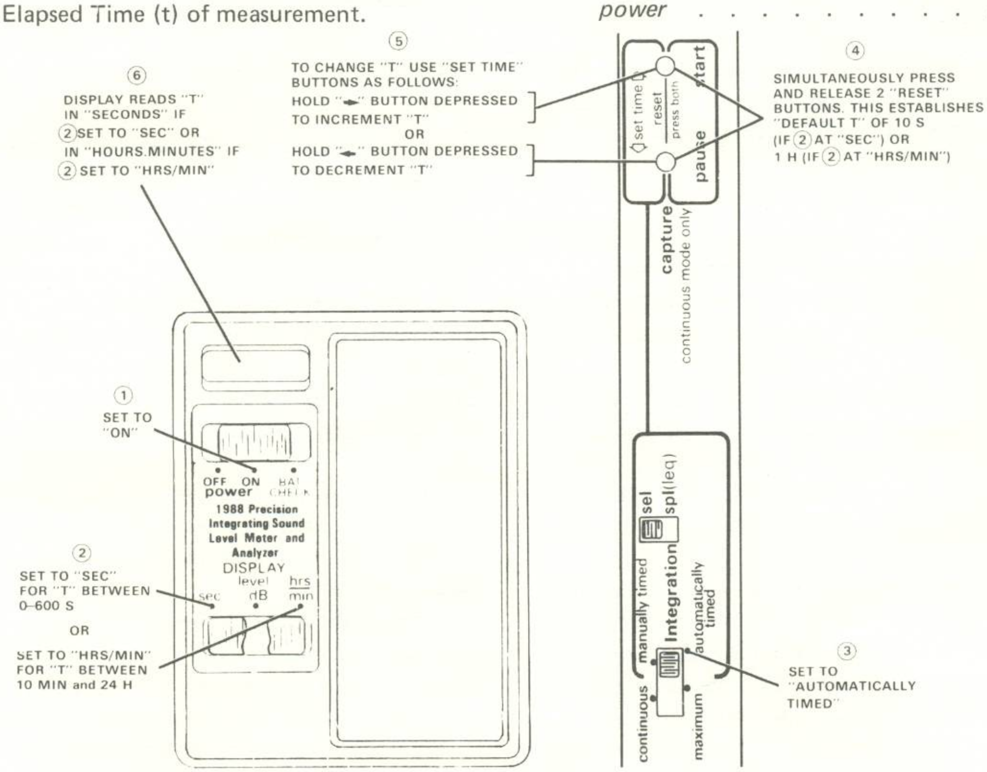


Figure 3-4. Operational procedure to establish "Set Integration Time" ("T") for "Automatic Preset-Time Mode". Perform steps 1 through 6 in sequence shown. Final reading on digital display represents time (T) for integration. Proceed to Figure 3-9.

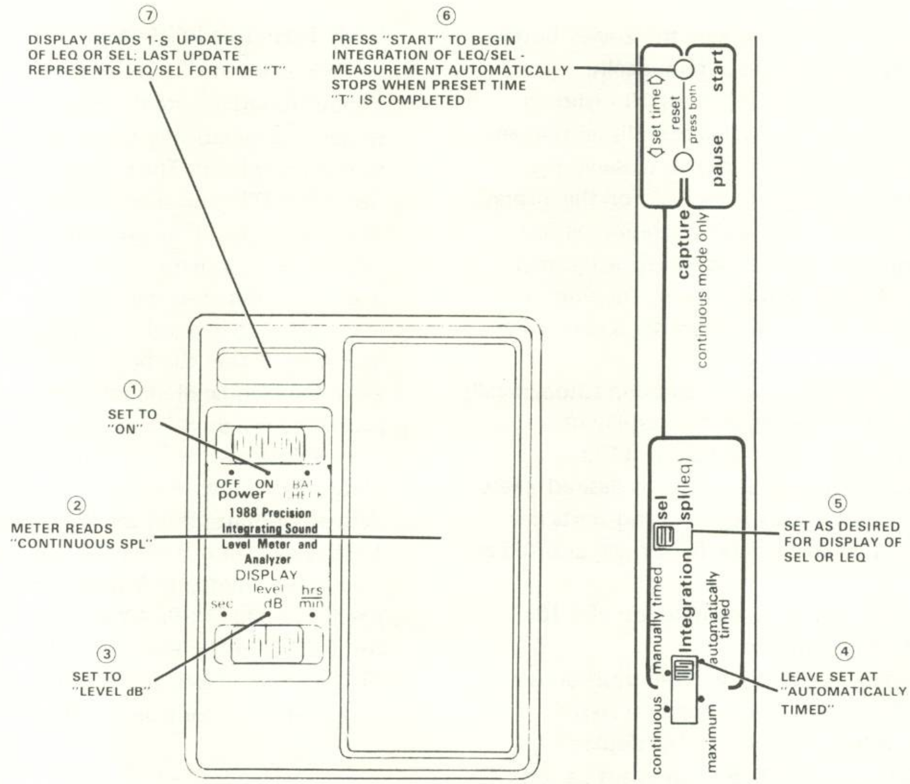


Figure 3-5. Operation procedure in "Automatic Preset-Time Mode" after "T" is established (Figure 3-8). Perform steps 1 through 7 in sequence shown. 1988 performs computation of LEQ/SEL for preset period "T", and automatically stops integrating when "T" is completed.

b. For a Set Integration Time (T) between 0-600 s, set the DISPLAY control to the *sec* position; for a T between 10 min (600 s) and 24 h, set DISPLAY to *hrs/min.*

NOTE

If a continuous integration period greater than 2 h is to be performed, do not use internal battery pack. Use ac power pack or external battery with sufficient A-h capacity (refer to para 2.6).

c. Simultaneously press and release the 2 *reset* buttons. If the DISPLAY control is in the *sec* position, the display should indicate a default T of 10 s; if DISPLAY is set to *hrs/min*, a default T of 1 h should be displayed ("1.00"). If the default T is to be used, proceed to step e; if not, proceed to step d.

d. Use the 2 *set time* buttons one-at-a-time to preset the Set Integration Time (T). The *pause* button decrements T and the *start* button increments T. If the DISPLAY control is set to the *sec* position, T is indicated on the display in "seconds" (no decimal point), and any T between 0 and 600 s can be preset to a resolution of 1 s, if DISPLAY is set to *hrs/min*, T is indicated in "hours.minutes" (decimal point separates hours from minutes), and any T between 10 min (600 s) and 24 h can be preset to a resolution of 1 min (refer to para 2.7).

e. Switch the DISPLAY control to the *level dB* position. If T was established in the *sec* position of the DISPLAY control, a "ready to integrate" indication of "————" should appear on the display; if T was established in the *hrs/min* position, a "——.——" indication should appear.

f. When ready to start measurement, press the *start* button to initiate integration. The "integrating" indication (blinking decimal point) should appear in the right-most LED of the display; the display's reading of LEQ or SEL (selected in step a) is updated once per second with each "blink".

g. Although the Automatic Mode is primarily intended for noninterrupted measurements, if a suspension of integration is required, perform step d of the preceding Manual Mode procedure.

h. When the Elapsed Time (t) reaches T, integration is automatically terminated ("blinks" on display cease). To record the final data, repeat step f of para 3.3.5.

i. To perform a new automatically timed integration measurement of the same duration T, repeat step a, then steps e through h; to perform a new measurement with a different T, repeat steps a through h.

3.3.7 Operation in Manual Mode.

This operational mode is primarily intended for an integrating measurement that requires the operator to suspend integration during the measurement period to exclude extraneous events. The operator presses the *pause* button to stop integration, whereupon the computations of LEQ/SEL and Elapsed Time (t) are suspended; then, when *start* is pressed to restart integration, measurement and timekeeping resume at the exact juncture of suspension to provide cumulative computations of LEQ/SEL and t. The *pause* button must also be pressed to stop integration when the measurement period is completed; thus the integration period is *manually timed*. The 1988 is capable of computing LEQ/SEL for any t up to 99 h; however, since the maximum t that the display can indicate is 24 h (whereupon it "wraps around" to 0 s and continues to update t), the operator must make a note of each "wrap around" in order to know the final t. The operating procedure for the Manual Mode is illustrated in Figure 3-6 and described below.

NOTE

The Manual and Maximum Modes function identically. Maximum Mode is primarily intended for display of Maximum SPL; Manual Mode is primarily intended for cumulative display of LEQ/SEL.

a. Set 1988 controls as follows:

OCTAVE FILTER FREQ, WEIGHTING, DETECTOR	as desired
DISPLAY	*level dB*
Mode	*manually timed*
sel/spl (leq)	as desired (for SEL or LEQ)
power	ON

NOTE

If a continuous integration period greater than 2 h is to be performed, do not use internal battery pack. Use ac power pack or external battery with sufficient A-h capacity (refer to para 2.6).

b. Simultaneously press and release the 2 *reset* buttons to clear the memory registers. The "ready to integrate" indication ("————") should appear on the display.

c. Press *start* to initiate integration. The "integrating" indication (blinking decimal point) should appear in the right-most LED of the display; the display's reading of LEQ or SEL (selected in step a) is updated once per second with each "blink".

d. To suspend integration, press the *pause* button; note that the display's "integrating" indication (blinks) ceases. To resume integration, press the *start* button (blinks reappear). This procedure of using the *pause* and *start* but-

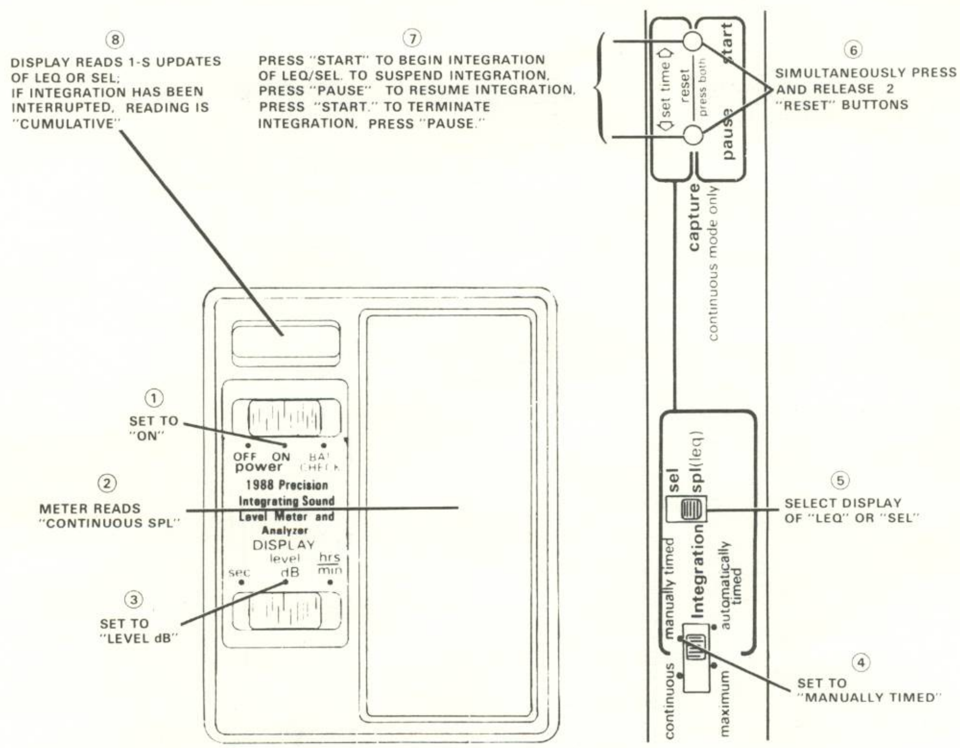


Figure 3-6. Operational procedure in "Manual Mode". Perform steps 1 through 8 in sequence shown. Final reading on display represents "Cumulative LEQ/SEL" for elapsed time of integration.

tons to interrupt integration can be performed as often as desired during the measurement period; the final indications of LEQ, SEL and Elapsed Time will be cumulative readings that represent the total "integrating" time (blinks) of one continuous period.

NOTE

If readings of LEQ, SEL, Maximum SPL, Continuous SPL, or Elapsed Time are desired during the suspension of integration, perform step f now.

e. To stop integration and terminate the measurement period, press the *pause* button.

f. To record final readings on the display, perform step f of para 3.3.5.

NOTE

Elapsed Time (t) is displayed in "seconds" (no decimal point) for $0 \leqslant t \leqslant 599$ s, and in "hours.minutes" (decimal point separates hours from minutes) for t between 10 min (600 s) and 24 h. If t exceeds 24 h, be sure to include the elapsed 24-h period(s) in the final value of t.

g. To clear the memory registers and start a new manually controlled integration period, repeat steps a through f above.

3.3.8 Operation in Maximum Mode.

This operational mode is primarily intended for instantaneous updates of Maximum SPL on the display. The display of Maximum SPL in this mode differs from its display in the Continuous Mode (ensuing procedure) in that there is no switching necessary in this mode. Maximum SPL is updated on the display whenever a higher instantaneous SPL is measured, and measurement can be suspended at any time to freeze the latest update of Maximum SPL on the display. If the DETECTOR is set to PEAK, "PEAK-MAX" measurements of short-duration sounds (transient sound's maximum peak) can be made to conform with OSHA specifications. It should be noted that, although integration is performed in the Maximum Mode, the display of Maximum SPL is still an instantaneous function. (This mode functions identically to the Manually Timed Integration Mode.) The operational procedure for the Maximum Mode is described below and illustrated in Figure 3-7.

a. Set 1988 controls as follows:

OCTAVE FILTER FREQ, WEIGHTING,
DETECTOR . . as desired (use PEAK DETECTOR for "PEAK-MAX")
DISPLAY . . . . *level dB*
Mode . . . . *maximum*
power . . . . ON

b. Simultaneously press and release the 2 *reset* buttons to clear the memory registers. The "ready to integrate" indication ("– – – –") should appear on the display.

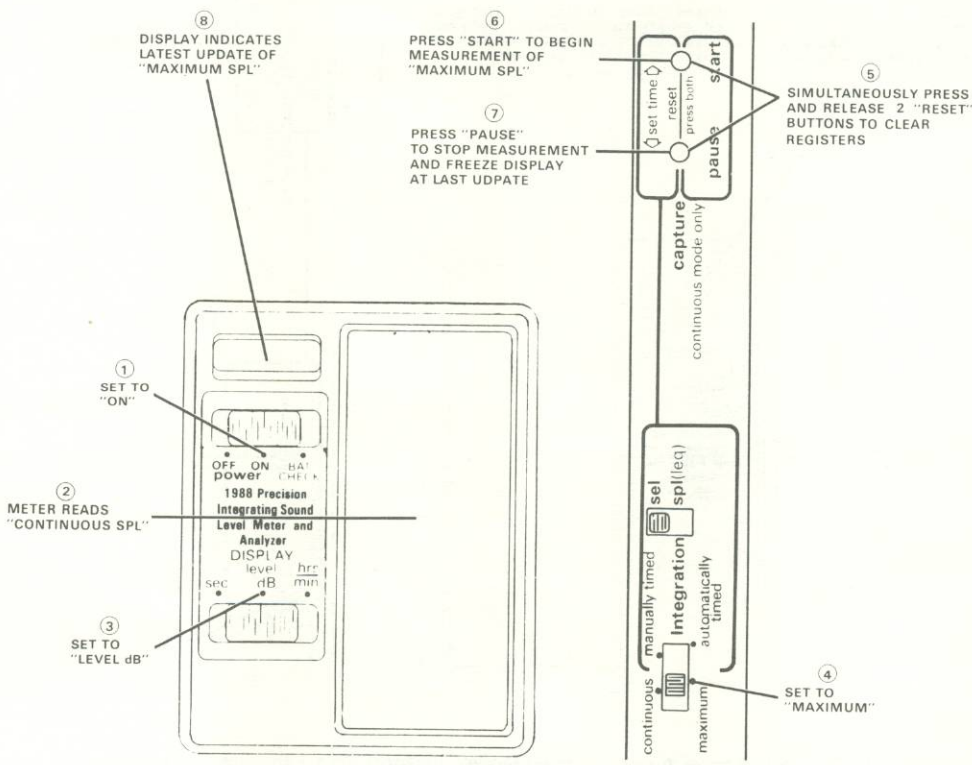


Figure 3-7. Operational procedure in "Maximum Mode." Perform steps 1 through 8 in sequence shown. Digital display then indicates updates of "Maximum SPL."

c. When ready to start recording Maximum SPL, press and release the *start* button. The "integrating" indication (blinking decimal point) should appear in the right-most LED of the display; however, the integrated functions (LEQ and SEL) are not used in this mode.

NOTE

Display of Maximum SPL is an instantaneous function, even though Maximum Mode is an integrating mode.

d. To freeze a Maximum-SPL readout on the display, press and release the *pause* button. If a transient sound, such as an impulsive or impact-type noise, is being measured, be sure to press *pause* as soon as the sound has diminished; this avoids recording extraneous sounds.

e. If updates of the Maximum SPL recorded in step d are desired, press and release *start* (does not clear Maximum-SPL register); the display will not be updated if an instantaneous SPL is measured that is higher than the Maximum SPL recorded in step d. If it is desired to clear the Maximum-SPL register, simultaneously press and release the 2 *reset* buttons; then press and release *start* to begin new measurements of Maximum SPL.

f. Repeat steps d and e as often as desired.

3.3.9 Operation in Continuous Mode.

This is the only instantaneous (non-integrating) operational mode; it is primarily intended for the "capture" of a discrete update of Continuous SPL on the display. Maximum SPL can also be displayed in this mode. The operating procedure for the Continuous Mode is described below and illustrated in Figure 3-8.

a. Set 1988 controls as follows:

OCTAVE FILTER FREQ, WEIGHTING, DETECTOR	as desired
DISPLAY	*level dB*
Mode	*continuous*
power	ON

b. Observe the meter and digital display. Continuous SPL is indicated continuously on the meter and discretely (7/s updates) on the display.

c. To freeze an instantaneous SPL on the display, press and hold the *capture* (*pause*) button; note that the meter still indicates Continuous SPL. After the frozen digital readout is recorded, release the *capture* button to resume the display's updates of Continuous SPL.

d. To read Maximum SPL in this mode, perform the following procedural sequence:

- Simultaneously depress 2 *reset* buttons (clears memory register for Maximum SPL) – hold *pause* button depressed and release *start* button.
- Hold *pause* depressed (omits transient switch noise) while Mode Control is switched to *maximum*.
- To begin measurement of Maximum SPL, release

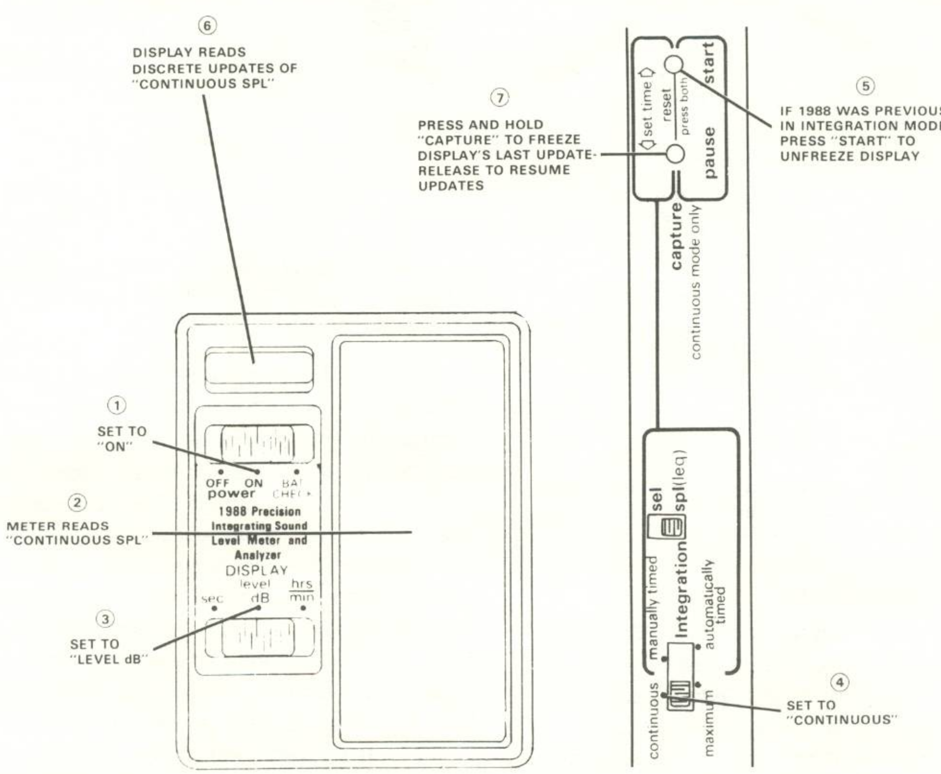


Figure 3-8. Operational procedure in Continuous Mode. Perform steps 1 through 7 in sequence shown. Digital display then indicates updates of Continuous SPL.

pause and read Maximum SPL updates on display (meter still indicates Continuous SPL).

- Press and hold *pause* to freeze display of Maximum SPL – release *pause* to resume updates on display (does not clear register).
- To clear Maximum SPL register, hold *pause* depressed while Mode is switched to *continuous*, release *pause*, and repeat above procedure.

NOTE

To stay in Continuous Mode, *reset* can only be pressed with Mode Control set to *continuous*.

3.4 MICROPHONE ORIENTATION/RESPONSE.

3.4.1 General.

Two models of the 1988 ISLM are available. Model 1988-9700 includes a 1/2-in. 1962-3300 Random-Incidence Microphone. Model 1988-9710 includes a 1/2-in. 1962-3310 Perpendicular-Incidence Microphone. Figure 3-9 indicates the typical directional response for either microphone when it is extended on a 10-ft extension cable with the preamplifier. Figure 3-10 indicates the directional response for either microphone when it is installed on the mast of the 1988. The procedure to orient either microphone in the sound field being measured is described below.

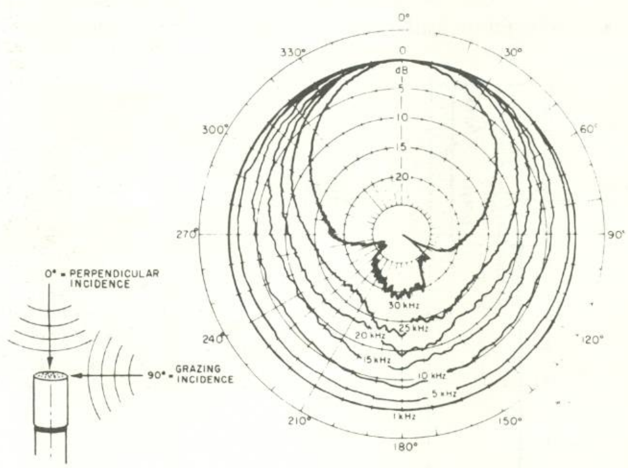


Figure 3-9. Typical directional response for either random-incidence or perpendicular-incidence microphone, when microphone is extended on 10-ft extension cable with preamplifier.

3.4.2 Random-Incidence Microphone.

The 1962-3300 microphone conforms to ANSI-Standard specifications for random response. This microphone is intended for use in a "diffuse sound field" where sound-energy incidence is equally probable from all directions (random incidence). In such a diffuse field, any orientation of the random-incidence microphone provides approximate uniform frequency response. Figure 3-9 illustrates the characteristic frequency response of a 1962-3300 microphone to a random-incidence sound field.

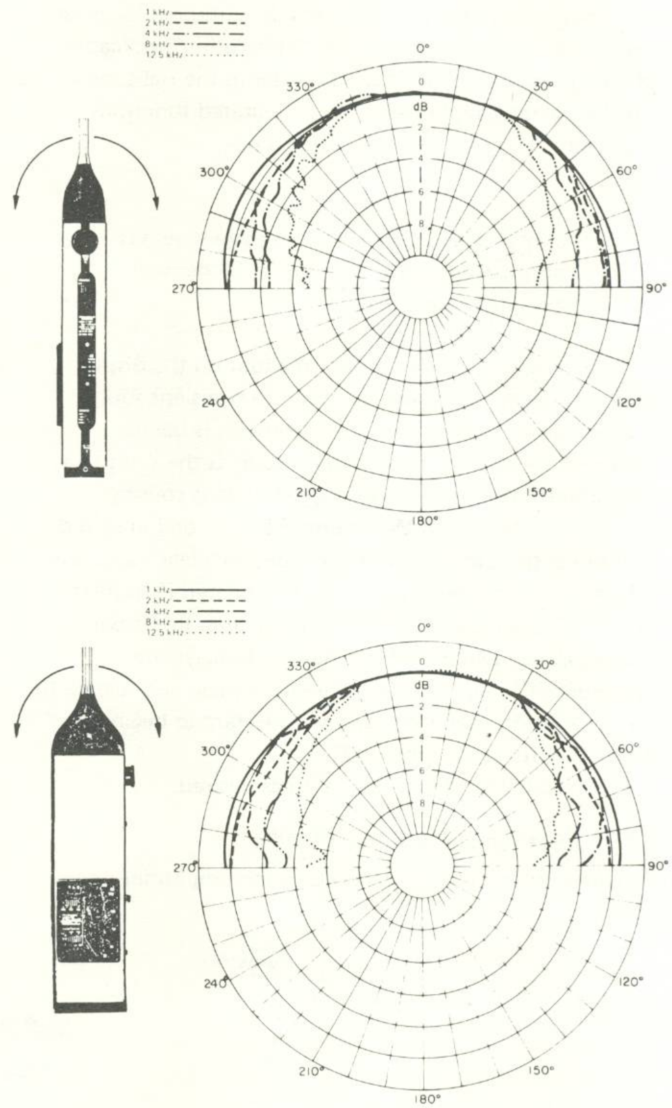


Figure 3-10. Typical directional results for either random-incidence or perpendicular-incidence microphone, when microphone is installed on instrument's mast.

The 1962-3300 microphone can also be used to measure uni-directional sound energy that enters directly into the microphone (perpendicular incidence). However, a correction factor must be applied to the response level (dB) for such applications. Figure 3-12 gives the correction factor (dB) vs frequency that must be added algebraically to determine the perpendicular-incidence response level (dB) when a random-incidence microphone is used.

For sound with a known direction of propagation, the 1962-3300 microphone's design provides a uniform frequency response when its axis (the axis of the preamplifier's mast) makes a 70 degree angle with the line-of-sight direction from the sound source. The 3 procedures below describe, respectively, the correct orientation of a hand-held, surface-mounted, and tripod-mounted random-incidence microphone to a known direction of sound propagation.

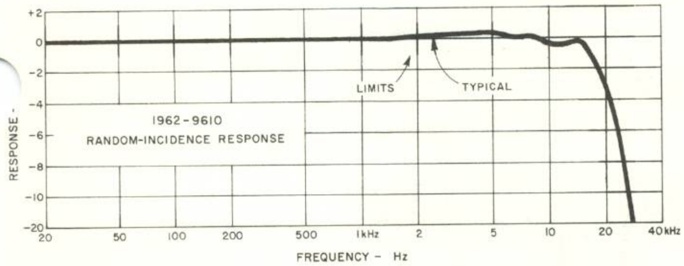


Figure 3-11. Characteristic frequency response of 1962-3300 microphone to random-incidence sound (acceptable in gray area).

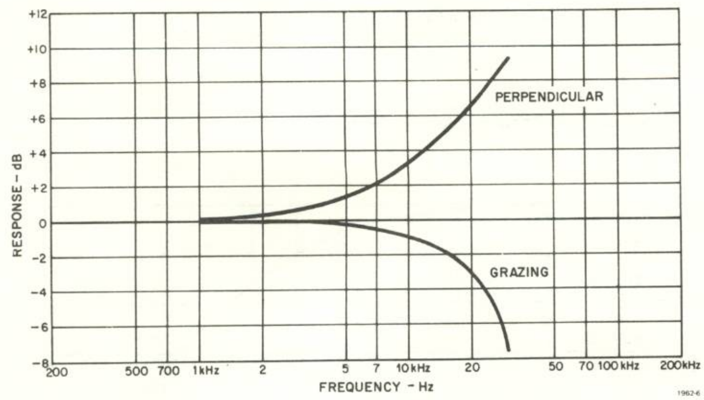


Figure 3-12. Corrections to be added algebraically to the response level (dB) obtained when a random-incidence microphone is used to measure uni-directional perpendicular-incidence sound energy.

Hand-Held Measurement (Figures 3-13 and 3-14):

a. Hold the instrument in the left hand (reverse the following procedure for the right hand).

b. Stand such that the line-of-sight from the directional sound source intersects the left shoulder.

c. Hold the instrument at arm's length, with the front panel directly in view. The instrument can be held at any angle of elevation.

d. Move the instrument (or arm, or body) 20 degrees toward the sound source, such that the instrument's axis intersects the line-of-sight from the sound source at an angle of 70 degrees. Notice that the instrument's angle of elevation does not affect the 70 degree angle.

Surface-Mounted Measurement (Figure 3-15):

a. Thread the supplied 1988-6000 support rod into its socket on the rear panel of the 1988. When the instrument is mounted on a level surface with this support, its axis tilts at an angle of 70 degrees.

b. Orient the supported instrument (or sound source) such that the microphone and sound source are in the same horizontal plane, and the 1988 rear panel faces directly toward the sound source. The line-of-sight from the sound source now intersects the microphone at a 70 degree angle of incidence.

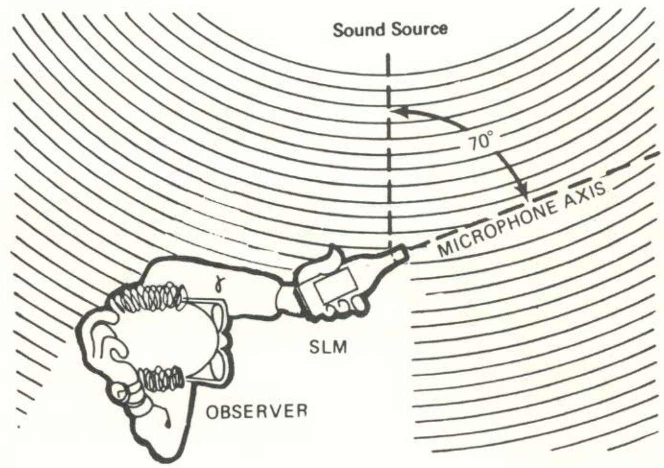


Figure 3-13. Orientation of hand-held random-incidence microphone in a known sound field.

Figure 3-14. Random-incidence microphone in use.

Tripod-Mounted Measurement:

a. Mount either the total instrument or the detachable microphone/preamplifier (via extension cable) on the tripod, as described in para 2.9. Use the "70 degree stop" on the tilting sleeve adaptor (1560-2560) horizontal plane. Tilt the microphone's axis at an angle of 70 degrees to the direction defined.

3.4.3 Perpendicular-Incidence Microphone.

The 1962-3310 microphone conforms to IEC standard specifications for perpendicular-incidence. This microphone is intended for use in a "free-field" where the sound

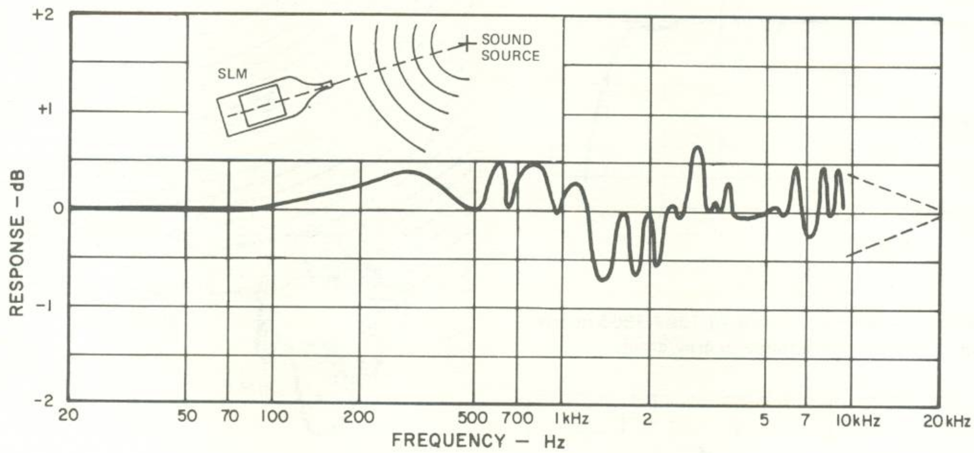


Figure 3-15. Surface-mounted random-incidence microphone orientation that provides uniform response to a uni-directional sound source.

energy's direction of propagation is perpendicular to the microphone's diaphragm. A free-field is, ideally, uniform and free from boundaries; such a field is approximated by a flow of sound in one direction only.

For the perpendicular-incidence microphone, such a free field should flow directly into the microphone to provide a uniform frequency response. Figure 3-16 illustrates the characteristic frequency response of a 1962-3310 microphone to a perpendicular-incidence sound field.

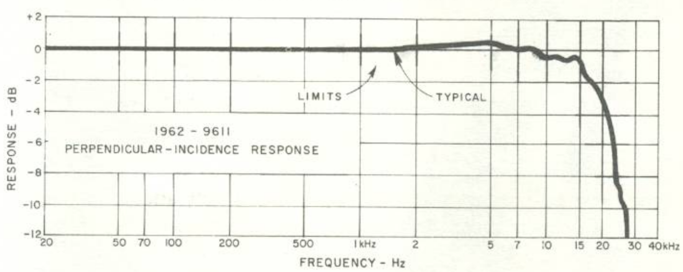


Figure 3-16. Characteristic frequency response for 1962-3310 microphone to perpendicular-incidence sound (acceptable in gray area).

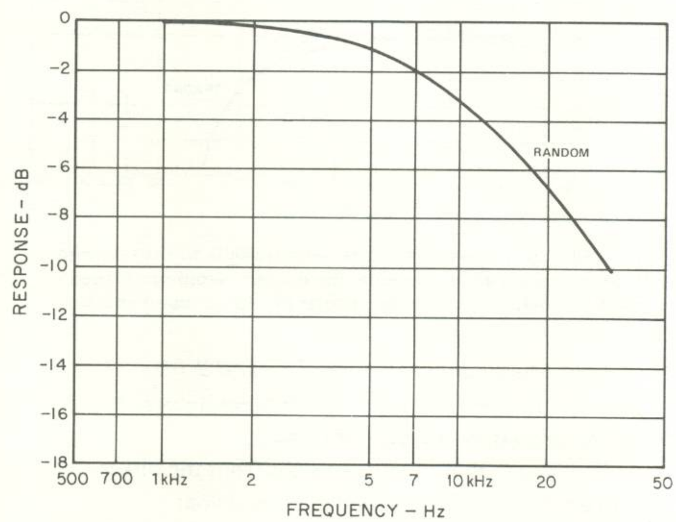


Figure 3-17. Corrections to be used algebraically to the response level (dB) obtained when a perpendicular-incidence microphone is used to measure random-incidence sound energy.

The 1962-3310 microphone can also be used to measure random-incidence sound energy. However, a correction factor must be applied to the response level (dB) for such applications. Figure 3-17 gives the correction factor (dB) vs frequency that must be added algebraically to determine the random-incidence response level (dB) when a perpendicular-incidence microphone is used.

The 2 procedures below describe, respectively, the correct orientation of a hand-held and tripod-mounted perpendicular-incidence microphone to a directional sound source's field.

a. Hold the instrument in the left hand (reverse the following procedure for the right hand).

b. Stand so that the sound source is to the left and slightly to the front.

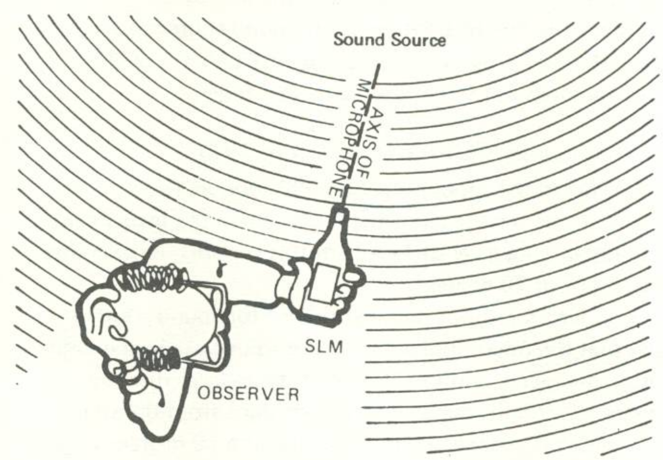


Figure 3-18. Orientation of hand-held perpendicular-incidence microphone in a known sound field.

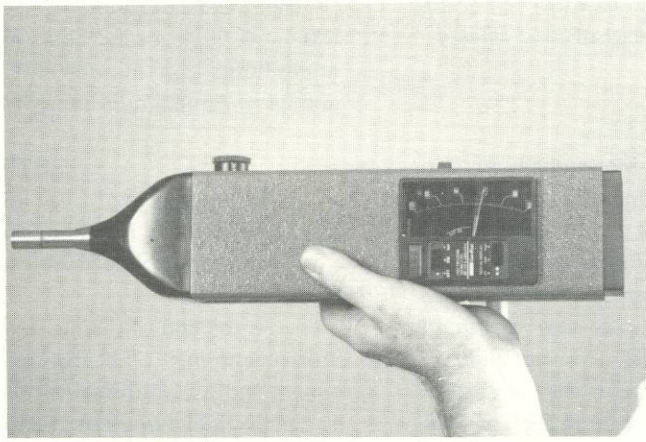


Figure 3-19. Perpendicular-Incidence Microphone in use.

c. Extend the 1988 to arm's length and point the microphone toward the sound source, such that the unidirectional sound enters directly into the microphone.

Tripod-Mounted Measurement:

a. Repeat step a from the tripod-mounted procedure of para 3.4.2.

b. Orient the tripod such that the uni-directional sound enters directly into the microphone.

c. Tilt the head of the tilting sleeve adaptor 90 degrees from the vertical, such that the axis of the 1988 is in a horizontal plane.

d. Swivel the tilting sleeve adaptor, by rotating the center post of the tripod, until the microphone points directly toward the sound source.

e. Adjust the tripod legs and center post such that the height of the microphone and sound field are the same.

3.5 MEASUREMENT APPLICATIONS.

3.5.1 General.

Para 3.4 contained the general operating procedure for each of the instrument's 4 operational modes. In the following paragraphs, specific measuring procedures are given for:

- General Noise Survey, Continuous Mode.
- General Noise Survey, Manual Mode.
- General Noise Survey, Automatic Mode.
- "MAX-PEAK" Measurement.
- Transient-Sound Measurement.
- Crest-Factor Measurement.
- Octave-Band Analysis.

3.5.2 Noise Survey in Continuous Mode.

A plant or general noise survey in the Continuous Mode gives manually controlled samples of the 2 instantaneous functions, Continuous SPL and Maximum SPL. Four frequency weightings and four detector-integrator responses are available in this mode. The procedure follows:

a. Perform the initial checks described in para 3.1.

b. Set 1988 controls as follows:

OCTAVE FILTER FREQ HZ. . . . . . . .WTG
WEIGHTING . . . . A
DETECTOR . . . . . FAST/SLOW (as desired)
DISPLAY . . . . .level dB
Mode Control . . . . .continuous
power . . . . ON

NOTES

If SLOW DETECTOR is used, response to a 500-ms tone burst, at 1000 Hz, is nominally 4.5 dB down from a reference steady-state signal at the same level and frequency.

Overshoot response to a signal suddenly applied and then held constant, over frequency range of 63-8000 Hz, is nominally 0 dB.

c. Press reset to clear the memory registers; release *reset* to start measurement.

d. Orient the microphone to the noise field as described in para 3.4.

WARNING

If a level of 115 dB(A) or higher is observed, put ear protectors on immediately to avoid temporary hearing loss.

NOTE

If OVERLOAD indicator lights at any time during measurement, switch dB RANGE control to higher range and disregard readings observed while indicator is lit.

e. Perform the procedure of para 3.3.5.

f. To record the Elapsed Time (t) of a measurement in the Continuous Mode, (since reset): hold pause depressed while the DISPLAY control is switched to either sec or hrs/min, observe t, return DISPLAY to level dB and release pause.

3.5.3 Noise Survey in Manual Mode.

In the Manually Timed Integration Mode, the integration period is manually controlled by the operator. Integration can be suspended as often as necessary, via the pause and start buttons, to exclude intrusive or undesirous events. Each time pause is pressed, measurement and timekeeping are temporarily suspended until start is pressed, whereupon they resume exactly where they left off. This capability allows cumulative SEL/LEQ measurements that omit the unwanted events. An integration period up to 99 h can be performed in the Manual Mode, but since the display of Elapsed Time (t) reverts back to 0 s each time it reaches 24 h, the operator must keep track of the number of 24-h "wrap arounds".

A noise survey in the Manual Mode can provide instantaneous recordings of Continuous SPL and Maximum SPL, as well as the cumulative recordings of LEQ and SEL. Four frequency weightings are available, and integration should usually be performed with a FAST detector-integrator response. The procedure follows:

a. Repeat steps a and b of preceding para 3.5.2, except set the DETECTOR control to FAST and the Mode Control to manually timed.

b. Press reset, and observe the "ready to integrate" indication ("- - - -") on the digital display. The instrument will not begin integration until start is pressed; after start is pressed, pause can be pressed again at any time to suspend integration.

c. Press start to initiate the manually-timed integration period.

NOTE

If the digital display gives an "overload" indication ("-"), switch the dB RANGE control to a higher range; if it gives an "underload" indication ("U"), switch the control to a lower range.

d. Perform the procedure of para 3.3.7.

e. If desired, press pause to interrupt integration ("blinking decimal point" ceases). This function can eliminate undesirous events from being included in the integration process. To resume integration, press start.

f. If desired, switch the Mode Control to maximum to observe the noise's Continuous SPL. Return the control to manually timed.

g. If desired, switch the DISPLAY control to either sec or hrs/min to observe the Elapsed Time (t) since start was first pressed.

NOTE

Elapsed time is not recorded during "pause-start" interruptions of integration.

The time is indicated in "seconds" on the digital display if $0 \leqslant t \leqslant 600$ s, or in "hours.minutes" (decimal point separates hours from minutes) if t is between 10 min (600 s) and 24 h. A maximum time of 24 h is permissible.

NOTE

Maximum life of fresh internal batteries is 2 h. Use external power source for continuous integration time greater than 2 h.

h. At the end of the measurement period, press pause to stop measurement. Set the Mode Control to manually timed, and switch the sel/spl (leq) control to both positions to obtain final cumulative readings (dB) of the noise's SEL and LEQ.

i. To obtain the final reading of the noise's Maximum SPL, switch the Mode Control to maximum, and observe the reading (dB) on the display.

j. To obtain a reading of the final instantaneous SPL recorded during the integration period, switch the Mode control to continuous, and observe the last update of Continuous SPL frozen on the display.

k. To obtain the total Elapsed Time over which the cumulative computation of LEQ/SEL was performed, repeat step g.

NOTE

If t exceeds 24 h, display reverts back to 0 s and continues to update, but operator must keep track of 24 h completions to determine final t.

3.5.4 Noise Survey in Automatic Mode.

The Automatically-Timed Integration Mode allows measurements of a noise's SEL and LEQ over a preset, automatically-timed integration period. This mode is most useful for an integration measurement (up to 24 h) that will be performed within interruptions. Since the integration period is automatically terminated when the Elapsed Time (t) reaches the Set Integration Time (T), it is not necessary for an operator to stop the measurement as in the Manual Mode.

A noise survey in the Automatic Mode can also provide the noise's Maximum SPL measured during T. Four frequency weightings are available, and integration is usually performed with a FAST detector-integrator response. The procedure follows.

a. Repeat steps a and b of para 3.5.2, except set the DETECTOR control to FAST and the Mode Control to automatically timed.

NOTE

As long as the 1988 is not reset, the last-set T will remain in the memory to allow as many automatically timed measurements as desired with the same integration time.

b. Repeat step d of para 3.5.3 (observe "NOTE").

c. Perform the procedure of para 3.3.8.

NOTE

If desired, "pause-start" interruption can be executed (in same manner as described for Manual Mode) during T. All computations will be performed cumulatively to omit such interruptions.

3.5.5 Transient-Sound Measurement.

A transient sound is one that repeats itself less than once each second. It is most often produced by an impact of impulsive force such as a hammer, punch press, stamping machine, etc. The procedure to measure such a short-duration pulse depends upon the information that is desired. The PEAK detector can be used in the Maximum Mode to measure the absolute peak ("MAX-PEAK") of the transient sound. Also, either Integration Mode (Automatic or Manual) can be used to measure the SEL (total energy) or LEQ (Equivalent Continuous SPL) of the transient sound. The procedure follows:

Measurement of Transient-Sound's Absolute Peak:

a. Set the 1988 as follows:

OCTAVE FILTER FREQ Hz	.WTG
WEIGHTING	FLAT
dB RANGE	90-140
DETECTOR	PEAK
DISPLAY	level dB
Mode Control	maximum
power	ON

b. Press reset to clear the memory registers. Then switch the Mode Control to maximum.

c. Orient the microphone, with respect to the transient-sound source as described in para 3.4.

Measurement of Transient Sound's SEL or LEQ:

a. Set the 1988 as follows:

OCTAVE FILTER FREQ Hz	.WTG
WEIGHTING	A
DETECTOR	FAST
DISPLAY	level dB
Mode Control	manually timed
sel/spl (leq)	.spl (leq)
power	ON

b. Press reset. The digital display should indicate "ready to integrate" ("----").

c. Orient the microphone, with respect to the transient-sound source as described in para 3.6.

d. Wait for a time when the transient sound will not occur for at least 30 s, and then press start to measure the "background LEQ". Observe the readings of background LEQ on the digital display; when the readings stabilize, record the background LEQ (dB).

e. Press reset.

f. To measure the transient LEQ, start must be pressed just before the occurrence of the transient sound; then, pause must be pressed as soon as the Continuous SPL of the transient sound (indicated on the analog meter) decreases to 0-6 dB above the background LEQ recorded in step d. Perform this procedure a few times for practice; each time after pause is pressed, observe the transient LEQ on the digital display, and then switch the DISPLAY control to sec to observe the Elapsed Integration Time (t). (The value of t for a transient sound frequently ranges up to 10 or even 30 s, in which case there is little difficulty in selecting the start of the integration period to include the full energy of the transient sound during t.)

NOTE

Be sure to press reset each time before a new measurement of LEQ is made.

g. Perform the procedure of step f, and record the reading (dB) of transient LEQ that is indicated on the display. If desired, switch the sel/spl (leq) control to sel to obtain a reading (dB) of transient SEL.

h. Switch the DISPLAY control to either sec or hrs/min, and record the Elapsed Time (t) of the transient measurement.

i. If desired, the same measurement can be performed in the Automatic Mode, using the Elapsed Time (t) from step h as the Set Integration Time (T). Refer to para 3.8.4 for the procedure to make a measurement in the Automatic Mode.

3.5.6 Crest-Factor Measurement.

The noise most commonly found in industrial surroundings consists of many complex sounds. Many of these sounds have peak levels that are read with the SLOW response of the detector. It is often useful to know the difference between the average rms and peak levels to calculate the noise-dose exposure. This difference is known as "crest factor".

To measure the crest factor of a noise, proceed as follows:

a. Use the Manual Mode, with the DETECTOR control set to SLOW, to measure the LEQ (Equivalent Continuous rms Level) of the noise being measured (refer to para 3.3.7). Record the LEQ (dBA-rms/FAST) obtained.

b. To measure the absolute peak levels of the noise, perform the procedure described under *Measurement of Transient Sound's Absolute Peak* in para 3.5.5. Record the absolute peak of Maximum SPL (dBA-pk).

c. The difference between the LEQ (dBA-rms/slow) and Maximum SPL (dBA-pk) is the crest factor.

3.5.7 Octave-Band Analysis.

The 1988 contains 10 octave-band filter networks that cover the audible frequency range for acoustic measurements. The center frequency of each octave band is labeled on the OCTAVE FILTER FREQ Hz control (see para 3.6.3).

The 10 octave-band networks allow the 1988 to analyze the frequency components of a noise. In order to understand the source of a noise problem and to make a decision concerning possible corrective action, the noise characteristics must be analyzed in these octave bands. It is essential to know the level of contribution in each frequency band in order to select effective hearing protectors, sound-barrier material, or to determine the source of the noise.

When the OCTAVE FILTER FREQ Hz control is set to WTG, the 1988 measures the total spectrum of acoustic energy according to the particular weighting selected (see Figure 3-21). Each octave band has a certain amount of energy that is contributed toward the overall acoustic energy. Figure 3-20 illustrates 8 of the 10 octave-band noise components of 2 noise sources that have the same overall A-weighted SPL (dB). As can be seen, the octave-band components of noise are quite different, even though the total A-weighted levels are the same. For one noise, the dominant band-pressure level (BPL) is at 500 Hz, while the other noise has dominant BPL's at 63 Hz and 2000 Hz. Hence, the solution for each noise problem requires a different approach.

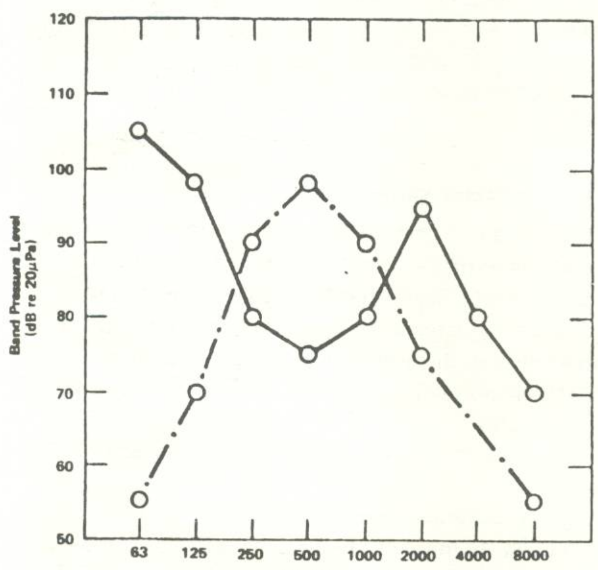


Figure 3-20. Octave-band analyses of 2 noises with the same overall A-weighted SPL (dB); 8 octave-band components of BPL (dB) are shown for each noise.

To generate the types of curves shown in Figure 3-19, the octave-band analyzer is used. The octave-band data gives the FLAT (no weighting) level of noise in each frequency band. This data enables a plant engineer to select the proper absorptive material for an enclosure or barrier. Also, it enables the engineer to isolate the source of noise in a machine so that engineering changes can be implemented. Perhaps, the data will indicate that the machine's bearings are worn or that the machine needs servicing.

An octave-band analysis can be performed in either the Continuous Mode or the Integration Mode. In the Continuous Mode, the Continuous SPL and Maximum SPL for each octave band can be measured. In an Integration Mode, the LEQ and SEL can be measured for each octave band, in addition to the Continuous SPL and Maximum SPL. The procedure follows:

Octave-Band Analysis in Continuous Mode:

a. To measure the A-weighted Continuous SPL and Maximum SPL for the total noise spectrum, perform the procedures of paras 3.5.2 and 3.3.8, and record the A-weighted levels (dBA).

b. Switch the OCTAVE FILTER FREQ Hz control to each of the 10 octave-band center frequencies and, for each octave band, repeat step a above to obtain the 10 flat (no weighting) BPLs.

c. Plot the BPLs obtained in step b, as shown in Figure 3-19, for either/both Continuous SPL or/and Maximum SPL.

Octave-Band Analysis in Integration Mode:

a. Repeat steps a, b, and d of para 3.5.2, except set the DETECTOR control to FAST and the Mode Control to automatically timed.

b. Set the DISPLAY control to sec, and press reset to establish the default Set Integration Time of 10 s.

c. Switch the DISPLAY control to level dB.

d. Press start and, during the 10-s integration period, set the dB RANGE control for mid-scale meter readings.

e. To measure the A-weighted levels for the total noise spectrum, press start again. After the 10-s integration period is completed (no more blinks), switch the sel/spl(leq) control to both positions and record the A-weighted SEL an LEQ (dBA). Also, if desired switch the Mode Control to maximum, and record the A-weighted Maximum SPL (dBA). Return the Mode Control to automatically timed.

f. Switch the OCTAVE FILTER FREQ Hz control to each of the 10 octave-band center frequencies and for each band, repeat step e above to obtain the 10 flat (no weighting) BPLs.

g. Plot the BPLs obtained in step f, as shown in Figure 3-19, for any or all of the following: LEQ, SEL, and Maximum SPL.

3.6 FUNCTIONS OF CONTROLS, INDICATORS, CONNECTORS.

3.6.1 Mode of Input Signal.

The Sound-Pressure-Level (SPL) input is first converted to an electrical signal by the microphone. The microphone's output is connected to the preamplifier, where it undergoes impedance matching (for the 1988 input circuitry) and possible gain. The preamplifier's output is connected to the 1988 input circuitry at the input connector located inside the nose cone.

Several accessories can be used at the input stage of the 1988. Supplied accessories include a 10-dB attenuator, a 10-ft extension cable, and a microphone windscreen; available accessories include a dummy microphone, a 20-ft or 60-ft extension cable, a tripod, a weatherproof enclosure adaptor set, a vibration-integrator system, and an audiometer calibration kit. Refer to paras 1.5 and 3.8 for input configurations that involve the use of any of these accessories.

3.6.2 Preamplifier Controls.

The preamplifier contains 2 slide-switch controls that should be correctly set before a measurement is performed. The blade of the supplied calibration screwdriver fits in a notch in the slides of each switch, and should be used to set these switches to their proper settings.

GAIN Control. This control allows the gain of the total operating system (ISLM, preamplifier, microphone, optional extension cable, optional input/output device) to be increased by 20 dB. For normal signal levels, the X1 position should be used to provide unity gain. In the X10 position, the preamplifier supplies a 20-dB gain. Usually, a gain of X1 should be used for cable lengths of 150 m (500 ft) or less, and for microphones with sensitivities of -40 dB re 1V/Pa or greater. For extremely low signal levels (30 dB or less) and/or long cable runs, set the gain to X10 to eliminate the influence of internal 1988 noise on the signal. If the underload indication ("U") of the 1988 is given for its lowest range (30-80 dB), the GAIN should be set to X10. The instrument should be recalibrated for a calibration reading that is 20 dB higher if the GAIN control is switched from X1 to X10, or for a reading that is 20 dB lower if it is switched.

OFF/200 V Control. In the 200 V position, this control provides a polarized voltage of +200 V for an air-condenser microphone. It should be set to OFF for all transducers other than an air-condenser microphone. The available current from the 200-V supply is extremely low and nonhazardous. However, left on with the standard 1988 electret-condenser microphone, it will produce a temporary change in sensitivity and frequency response, but the microphone will recover a few minutes after the polarized voltage is removed.

CAUTION

Use the 200-V position only with an air-condenser microphone.

3.6.3 Octave-Filter-Frequency Control.

The OCTAVE FILTER FREQ Hz control is an 11-position rotary switch located on the right panel. In the WTG position, the instrument's WEIGHTING control (para 3.4) is activated, and a 5-Hz to 20-kHz spectrum of frequencies is measured by the 1988 according to the particular weighting selected. The other 10 positions of the control provide frequency filtering when the 1988 is used as an analyzer; the WEIGHTING control is disabled in these positions.

The 1988 contains 10 ANSI-preferred octave-band filter networks that cover the audible range from 5 Hz to 20 kHz. The pass-band center frequencies of these networks are 31.5, 63, 125, 250, 500, 1000, 2000, 4000, 8000 and 16,000 Hz. The nominal frequency range of each band has a 2-to-1 ratio; e.g., 1000 Hz is the center frequency for the octave band that extends from 707 Hz to 1414 Hz. The procedure to analyze a particular noise source in the 10 octave-frequency bands is given in para 3.5.7.

3.6.4 Weighting Control.

The WEIGHTING control is a 4-position slide switch located on the right panel. It is activated when the OCTAVE FILTER FREQ Hz control is set to WTG. The control is used to select one of the instrument's 3 weighting networks (A, B, or C), which "shapes" the measured noise to discriminate against lower frequencies, or to select the nonweighting FLAT network, which has a flat frequency response from 5 Hz to 20 kHz re 1 kHz. Figure 3-21 graphically illustrates the frequency response of the 4 networks, as specified by ANSI and IEC standards.

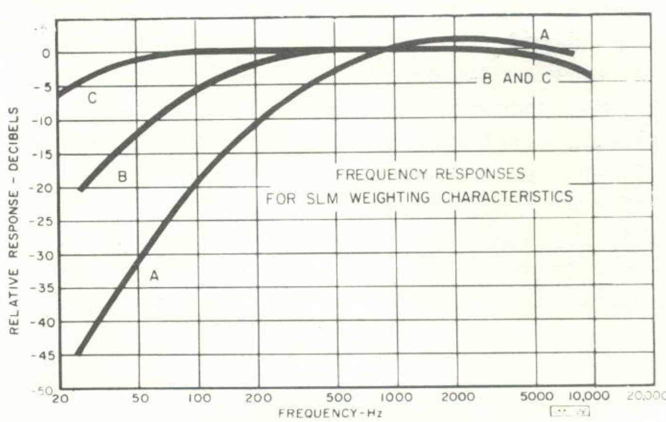


Figure 3-21. Frequency-response characteristics for the 1988 ISLM, based on a 22-pF source impedance with and without standard weighting networks. Curves exclude the possible acoustical effects of a microphone, and are based on a 22-pF source impedance.

The A-weighting network simulates the response of the human ear. Thus, it is often specified by acoustic standards for surveys that are designed to locate noises hazardous to the hearing. When an A-weighting measurement is made, it is indicated by the unit dB(A) or dBA.

Very low frequencies are discriminated against quite severely by the A network, moderately by the B network, hardly at all by the C network, and not at all by the FLAT network. Therefore, if a measured SPL of noise is much of the noise, it is contributed by the low frequencies.

The FLAT network measures the SPL with no frequency weighting. This flat, unweighted frequency response is not a good indicator of subjective response. It is used primarily when the measured noise is to be recorded for analysis at a future time.

3.6.5 Range Control.

The dB RANGE control is a 4-position slide switch located on the right panel. Its position determines the dynamic operating range of the 1988 re the reference range of 50-100 dB. The upper and lower limits of the selected range are indicated on the scale of the front-panel meter.

For either a FAST or SLOW detector determination of rms level, each range has a dynamic span of 50 dB rms and the total dynamic range of the instrument is 30-130 dB rms re 20 μPa. For a PEAK detector response, the upper limit of each range is extended by 10 dB, and total dynamic range of the instrument is 30-140 dB pk re 20 μPa. An OVERLOAD indicator lights when the absolute peak of a signal is above the PEAK limit of the selected range.

For the 2 integrated level modes – LEQ and SEL – FAST-response levels over a range of more than 70 dB are included in the integrated result. Computations of LEQ ranging from 25 dB to 150 dB are indicated on the digital display, and computations of SEL ranging from 25 dB to 190 dB are displayed. An overload indication ("-") is given in an Integration Mode if the PEAK detector is overloaded for more than 0.1% of the elapsed integrated time, and an underload indication ("U") is given for instantaneous measured levels that are more than 5 dB below the bottom limit of the selected range.

For noise levels above the highest dynamic range of the 1988, the 10-dB attenuator (supplied accessory) can be used (refer to para 3.8.2). For low noise levels, the preamplifier's GAIN control can be set to X10 (refer to para 3.6.2).

WARNING

If a level of 115 dBA or higher is observed, put on ear protectors immediately to avoid a temporary hearing loss (refer to para 3.7.8).

3.6.6 Detector Control.

The DETECTOR control is a 4-position slide switch located on the right panel. It is used to select the desired detector response to the sound-level energy being measured. Only the FAST detector network is recommended for measurement of LEQ/SEL.

The FAST and SLOW networks determine the rms level (dB rms) of time-varying sound energy, with either a fast or slow speed of indicator response. Precise rms detection is provided for signals with a crest factor of 20 dB at 120 dB; this crest-factor capacity increases below full scale.

The PEAK network determines the absolute peak level (dB pk) of a sound. Precise peak detection is provided for a signal with less than 50 μs rise time (electrical).

The IMPULSE network conforms to the specifications of IEC 651 SLM Standard for impulse measurements. It provides an indicator "rise" speed faster than the FAST detector, and a "decay" speed slower than the SLOW detector.

In the Continuous Mode, either the FAST or SLOW detector-integrator is used to measure the rms level of time-varying sound-level energy. The SLOW response is specified by ANSI and IEC SLM standards for surveys that study hearing-damage risk. The PEAK detector is used in the Maximum Mode to measure the absolute peak of a sound, while the IMPULSE detector is used to measure the non-rms "impulse" level (dB) of an impulsive sound such as made by forging hammers, punch presses, stamping machines, etc.

3.6.7 Display Control.

The DISPLAY control is a 3-position slide switch located on the front panel. In the level dB position, it activates the left-panel Mode Control. In the sec or hrs/min position, it provides a display of either Elapsed Time (t) or Set Integration Time (T). If set to sec or hrs/min while the Mode Control is set to automatically timed, and if reset is then pressed, it provides a display of T; otherwise, it provides a display of t when set to sec or hrs/min.

3.6.8 Mode Control.*

The Mode Control is the 4-position slide switch located on the left panel. It is activated whenever the DISPLAY control is set to level dB, and it serves 2 functions:

- Selection of operational mode.
- Selection of digital-display information.

The first function is to select one of the 4 modes of operation: Continuous, Maximum, Manually-Timed Integration ("Manual") or Automatically-Timed Integration ("Automatic"). To accomplish mode selection, the Mode Control is set to the applicable position, and then reset is pressed to establish that mode. If the Continuous Mode is selected, measurement begins as soon as reset is released. If an Integration Mode is selected, integration does not begin until start is pressed.

Once the operating mode is selected and measurement is initiated, the Mode Control performs its second function. The control cannot change the mode of operation at this

*Referred to as "Mode Control" in this manual, but not labeled as such on the instrument.

point, but now it selects the level (dB) of digital-display information. If the Continuous Mode is in effect, the Mode Control can be switched between continuous and maximum to display either Continuous SPL or Maximum SPL. If an Integration Mode is in effect, and the Mode Control is set to either manually timed or automatically timed, the sel/spl(leq) control is activated to display either SEL or LEQ; the Mode Control can also be switched, during an Integration Mode, to maximum and continuous to display Maximum SPL and Continuous SPL.

3.6.9 Sel/Spl(leq) Control.

The sel/spl(leq) control is located on the left panel. It is a 2-position slide switch that is activated during an Integration Mode when the Mode Control is set to either manually timed or automatically timed, and the DISPLAY control is set to level dB. When this control is activated, its position selects an indication of either SEL or LEQ on the digital display.

3.6.10 Reset/Start/Pause/Set-Time Controls.

The 2 adjacent pushbuttons on the left panel serve several distinct functions. The particular function performed depends upon the manner in which the buttons are used, and the status of the instrument at the time of use. These functions are described below, and are outlined in Table 3-2.

Reset Control. When the 2 buttons are simultaneously pressed and released, they always function as a reset control, regardless of the instrument's status. A reset execution initializes (clears) the registers used to compute LEQ and SPL, resets the Elapsed Time to 0 s, initializes the register used to hold Maximum SPL in memory, and resets the Set Integration Time to one of the 2 "default" times (10 s or 1 h) in the Automatic Mode (described under Set Time Control).

If the Mode Control is set to continuous when reset is pressed, measurement begins as soon as the buttons are released. If the Mode Control is set to manually timed (or maximum) when reset is pressed, start must subsequently be pressed to begin integration. If the Mode Control is set to be automatically timed when reset is pressed, the Set Integration Time must next be selected by the set time controls (DISPLAY set to sec or hrs/min) before start is pressed (DISPLAY set to level dB) to begin integration. The procedure for setting integration time in the Automatic Mode is given in para 3.3.8.

Capture Control. In the Continuous Mode, the pause button can be used to "capture" an instantaneous measurement. If the button is held depressed while the Mode Control is set to continuous, the instantaneous Continuous SPL is frozen on the digital display until the button is released; if it is pressed while the Mode Control is set to maximum, the last instantaneous Maximum SPL is frozen until the button is released. This "capture" function allows manually controlled sampling in the Continuous Mode. The start button is disabled in the Continuous Mode.

Pause/Start Controls. After reset is pressed in an Integration Mode, the start button must always be pressed to initiate the integration. In the Manual Mode, start can be pressed immediately after reset is pressed. In the Automatic Mode, the correct sequence is to first press reset, then use the set time controls (DISPLAY set to sec or hrs/min) to establish the Set Integration Time (T), and then press the start button (DISPLAY set to level dB) to initiate integration.

The pause control is primarily intended for use during the Manual Mode to exclude undesirous events that are not the subject of the measurement, although it functions identically in the Automatic Mode also. When pause is pressed, integration is suspended until start is pressed, whereupon integration resumes. In the Manual Mode, integration doesn't cease until the operator intervenes to press pause; in the Automatic Mode, integration automatically ceases without operator intervention (unless pause is pressed) when the Set Integration Time (T) is reached.

When the pause-start function is used to interrupt an integrating measurement, the measurement and timekeeping (Elapsed Time) are suspended as soon as start is pressed. This allows cumulative measurements in the Manual Mode.

NOTE

All measurements of LEQ, SEL, Maximum SPL and Elapsed Time are suspended when pause is pressed, and resumed at the suspended point when start is pressed.

Set-Time Controls. The 2 pushbuttons are activated as set time controls by setting controls in the following sequence:

- Mode Control to automatically timed.
- DISPLAY control to either sec or hrs/min.
- Press and release 2 reset buttons simultaneously.

Once this sequence is executed the 2 buttons function as set time controls when pressed one-at-a-time. The left button decrements the Set Integration Time (T), and the right button increments T. If a button is held depressed, T increments or decrements at a rate that depends on the button-depression time; the rate increases from 2 times per second, to 2.3, then 2.6, up to a maximum rate of 73 times per second. When the button is released and then pressed again, the rate reverts to the slowest rate. A quick press, a release of a button allows a single-step incrementation or decrementation.

If the DISPLAY control is set to sec in the preceding sequence, a "default" T of 10 s is automatically established as soon as reset is released. If, in this sec mode, a T other than 10 s is desired, the set time buttons must be used to select any time between 0 and 600 s. In the sec mode, T is

Table 3-2

FUNCTIONS OF LEFT-PANEL PUSHBUTTONS

Position of Mode Control	Position of Display Control	Two Buttons Simultaneously	Left Button Individually	Right Button Individually	Comments
continuous	any position	reset	non-functional	pause	1. New Measurement period begins as soon as reset is released. 2. To capture on instantaneous measurement, pause must be held depressed.
manually timed	any position	reset	start	pause	1. New Measurement/integration period is initiated when reset is first pressed, then start. 2. Measurement/integration is interrupted when pause is pressed, and resumed when start is pressed.
automatically timed	level dB	reset	start	pause	1. Default T of 10 s established when reset is pressed; integration begins when start is pressed. 2. Measurement/integration is interrupted when pause is pressed, and resumed when start is pressed.
automatically timed	sec	reset	set time (1-sec decrements)	set time (1-sec decrements)	1. Default T of 10 s established when reset is pressed. 2. Any T between 0-600 s can be established by use of set time buttons. 3. After T is established, DISPLAY must be switched to level dB to execute start.
automatically timed	hrs/min	reset	set time (1-min decrements)	set time (1-min decrements)	1. Default T of 1 h established when reset is pressed. 2. Any T between 10 min and 24 h established by use of set time buttons. 3. After T is established, DISPLAY must be switched to level dB to execute start.

incremented or decremented in 1-s intervals by the set time buttons, and T is indicated on the digital display by a 1-3 digit reading in "seconds" (no decimal point). A complete cycle of 0-600 s takes 15 s when either button is held depressed. However, since T "wraps around" (i.e., 600 s increments to 0 s, or 0 s decrements to 600 s), the worst-case time to reach any point is one half of 15 s.

If the DISPLAY control is set to hrs/min in the preceding sequence, a default T of 1 h is automatically established. The set time buttons are used in the hrs/min mode to select a T between 10 min (600 s) and 24 h, which is the maximum integration time of the instrument. In the hrs/min mode, T is incremented or decremented in 1-min intervals by the set time buttons, and T is indicated on the digital display by a 1-4 digit reading in "hours.minutes" (decimal point separates hours from minutes). A complete cycle from 10 min to 24 h takes 45 s, but any T can be reached in half of 45 s because the times wrap around as in the sec mode.

3.6.11 Analog Meter.

The analog meter is located on the front panel. Its 3-in. scale is graduated in 1-dB increments. The meter's needle gives a continuous (analog) indication of the current instantaneous SPL (Continuous SPL) being measured. Its response is determined by the setting of the DETECTOR control. The meter is unaffected by the front-panel DISPLAY control and the controls on the left panel of the 1988.

3.6.12 Digital Display.

The digital display is located on the front panel. It consists of 4 LED (Light-Emitting Diode) segments that allow a 4-digit reading of level (dB) or time. The level is displayed with a 0.1-dB resolution.

The display can indicate Continuous SPL, Maximum SPL, LEQ, SEL, Elapsed Time, or Set Integration Time. Readings of Continuous SPL are updated 7 times per second, and readings of LEQ and SEL are updated once per second. Readings of Maximum SPL are updated whenever a higher instantaneous SPL is measured.

3.6.13 Overload Indicator.

The OVERLOAD indicator is a single LED located in the top portion of the meter's scale. It lights automatically whenever an instantaneous SPL is measured with an absolute peak above the dynamic range of the instrument (see para 3.6.5). Signal peaks are measured at 2 critical points by the peak-detector circuit to provide a positive LED indication of peak overload.

When the OVERLOAD indicator lights in the Continuous Mode, a higher range should be selected with the dB RANGE control. In an Integration Mode, a separate overload indication ("-") is given on the digital display for the non-instantaneous measurements in this mode (see Table 3-3).

NOTE

> If, at any time, either the OVERLOAD indicator lights during a Continuous Mode, or the digital-display overload indication ("-") occurs during an Integration Mode, switch to a higher range and disregard readings observed during the overload indication.

3.6.14 Nomograph.

The nomograph is located on the front panel above the indicators. It illustrates various types of status information that are given on the digital display. The nomograph illustrations are described in Table 3-3.

3.6.15 Printer Connector.

The printer connector is a 4-pin jack located on the left panel. It mates with the 4-pin plug on the 1988-0300 Printer Cable (supplied accessory). The cable interfaces the 1988 printer connector to a standard 25-pin RS232C printer connector. Most TTL-compatible printers can be used with the 1988, which produces a serial output rate at EIA standard 110 baud. A dwell time of 4 s permits use with buffered-output printers. The following parameters are printed: Elapsed Time, Level (dB), and Maximum SPL (dB). The procedure to install the cable is given in para 2.10, and the procedure to use a printer with the 1988 is given in para 3.3.9.

3.6.16 DC-OUT Connector.

The DC OUT connector is a subminiature phone jack located on the left panel. It mates with a subminiature phone plug to a dc recorder. A digital output of 3 Vdc behind 30K (ohms) corresponds to a full-scale meter deflection (upper limit of selected range) on the 1988. The dc output is linear in dB at 60 mV/dB over a 70-dB range. (50-dB range of meter, plus 20-dB crest-factor allowance.) The procedure to use a dc recorder with the 1988 is given in para 3.8.8.

3.6.17 AC-OUT Connector.

The AC OUT connector is a subminiature phone jack located on the left panel. It mates with a subminiature phone plug to oscilloscope, amplifier, headphone set, ac recorder, etc. An analog output of 0.4 V rms nominal behind 5K (ohms) corresponds to a full-scale meter deflection (upper limit of selected range) on the 1988. Any load is permissible. Refer to para 3.8.9.

3.7 MEASUREMENT CONSIDERATIONS.

3.7.1 General.

Much care is exercised in the design and manufacture of Type-1 instruments, but this only assures that the use of a "Precision" instrument will contribute negligible error to the measurement results. In order to make valid, repeatable measurements, it is helpful to recognize that the results of a measurement are determined by a number of factors, among which are the following:

- The phenomenon being measured.
- The effect of the measurement process on the phenomenon being measured.
- The environmental conditions.
- The calibrations of the transducers and instruments at the time they are used.
- The way the transducers and instruments are used.
- The observer.

Table 3-3

NOMOGRAPH ILLUSTRATIONS

Location (From Top) on Nomograph	LED Indications* #1	#2	#3	#4	Description	Interpretation
1	X	X	X	X	1-4 digit reading with constant decimal point at right of LED #3, and blinking decimal point at right of LED #4.	Measured functions dB level, 1988 is presently integrating.
2	X	X	X	X	Same as above, but no blinking decimal point on far right.	Measured function's dB level, 1988 not presently integrating.
3	–				Negative sign at left of LED #1.	Overload during integrating mode of operation. Select higher range.
4	U				Letter "U" at left of LED #1.	Underload. Measured function's instantaneous level (dB) is more than 5 dB below bottom limit of range. Select lower range.
5	-	-	-	-	Four hyphens.	1988 has been reset, is ready to begin integration.
6		X	X	X	1-3 digit reading with no decimal point.	Elapsed Time (t) or Set Integration Time (T), in "seconds", for a time between 0 and 600 s.
7	X	X	X	X	2-4 digit reading; decimal point at right of LED #2.	Elapsed Time (t) or Set Integration Time (T), in "hours.minutes", for a time between 10 min and 24 h.

*"X" is any digit from 0 to 9 or a null display if zero is a leading digit.

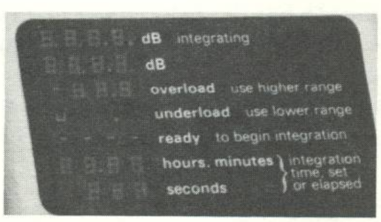


Figure 3-21a. 1988 Front-panel nomograph.

It is generally a good policy to measure sound in accordance with a standard procedure. The standards have been prepared to help obtain valid data. They are useful guides for the inexperienced user, and can help the experienced user by listing the steps required in a measurement procedure. Standards help to make comparisons of measured results more meaningful.

NOTE

The general standard ANSI S.13-1971, "Standard Methods for Measurement of Sound-Pressure Levels," is particularly recommended.

An obvious and important step in any measurement task is to verify that the results are reasonable. If they are not, try to determine possible causes of inconsistencies. Some common causes include: background noise, poor connections of plugs, no power, partially discharged batteries, incorrectly set controls, damaged equipment, stray grounds, and electrical-interference pickup.

The results of a noise measurement may be a key factor in resolving a noise problem. In addition, the experience and data can help to solve other noise problems. Careful records of noise measurements can be a valuable reference in the solution of subsequent noise problems.

A recognition of the accuracy limitations of acoustic and vibration measurements is important in the solution of any measurement problem. Thus, consistency to ±0.1 dB or better is attainable in only a few laboratory calibration procedures and, generally, not in acoustical measurements. Field calibrations of sound-level meters at one frequency with a calibrator can be consistent to ±0.5 dB or slightly better. In general, a consistency of ±1.0 dB is difficult to attain, even under carefully controlled conditions.

3.7.2 Effects of Instrument Case and Observer.

NOTE

For precise measurements in a very dead room, such as an anechoic chamber, the instruments and the observer should be outside, with only the source, microphone, preamplifier, extension cable, and a minimum of supporting structure in the room.

An observer close to the microphone can affect the measured data. When measurements are made in a live room (an ordinary room) and not close to a source, the effect is usually not important. But, if measurements are made near a source, it is advisable that the observer stand well to the side of the direct path between the source and the microphone.

For many measurements, it is most convenient to carry the ISLM. In order to obtain the best results when making hand-held measurements, hold the ISLM as described in para 3.4.

NOTE

If the microphone and preamplifier are mounted on the ISLM, do not make measurements with the hand on the top part of the housing. Support the main chassis for best results.

Figure 3-9 illustrates the effect of the instrument case upon frequency response.

3.7.3 Noise Floors.

The dynamic range (full scale to noise floor) of the 1988 is a function of the range selected by the dB RANGE control and the capacitance of the microphone used. The lowest level that can be measured by an ISLM is usually taken to be a level 5 dB above the absolute noise floor of the instrument. The table in "Specifications" (at beginning of this manual) gives the minimum levels according to this criterion for A, B, and C weighting, no weighting (FLAT), and the 10 octave bands; levels are given for various microphone types.

The minimum measurable noise levels in the "Specifications Table" are for a typical instrument; the actual noise floor of a particular 1988 can be determined by replacing the microphone with a dummy microphone that has the same capacitance. The 1962-9620 Dummy Microphone (available accessory) has a capacitance of 22 pF, which simulates the capacitance of either the 1962-9610 or -9611 microphone for noise-floor determination (see para 3.8.4). Table 3-4 shows the minimum measurable levels in each range.

Table 3-4

NOMINAL MINIMUM MEASURABLE NOISE LEVELS*

		1-in. Electret Condenser (dB)	.5-in. Electret Condenser (dB)	1-in. Ceramic (dB)
Nominal Sensitivity		−38	−40	−40
Wide Band	A	21	32	19
	B	23	35	18
	C	31	39	30
	FLAT	38	48	28
Octave Band	31.5 Hz	24	37	13
	63 Hz	22	34	11
	125 Hz	19	31	10
	250 Hz	17	32	10
	500 Hz	15	26	10
	1 kHz	13	24	9
	2 kHz	12	23	9
	4 kHz	13	22	12
	8 kHz	15	22	15
	16 kHz	16	22	16

*All dB levels re 20 μPa.

3.7.4 Background-Noise Considerations.

Ideally, when a sound source is measured, the measurement should determine only the direct airborne sound from that source, without any appreciable contribution from noise produced by other sources. In order to ensure such a separation, the measurement space may need to be isolated from external noise and vibration. As a test to determine that this requirement has been met, the American National Standard Method for the Physical Measurement of Sound, S1.2, specifies the following:

"If the increase in the sound-pressure level . . . , with the sound source operating, compared to the ambient sound-pressure level alone, is 10 dB or more, the sound-pressure level due to both the sound source and ambient sound is essentially the sound-pressure level due to the sound source. This is the preferred criterion."

If both the background noise level and the noise level being measured are steady, a correction can be applied to the measured data as indicated in the graph in Figure 3-22. Proceed as follows:

a. Select the test position for the microphone in accordance with the specifications of the pertinent code or procedure.

NOTE

Refer to the Handbook of Noise Measurement ,
for additional sound-measurement information.

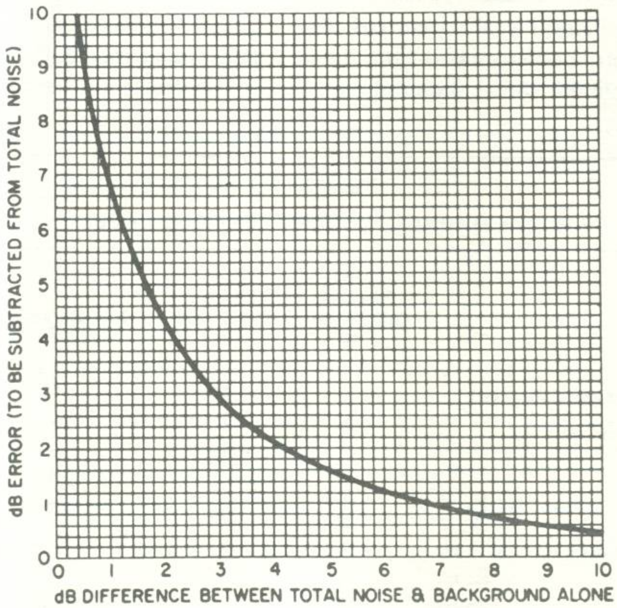


Figure 3-22. Background-noise correction for SPL measurement.

b. Orient the microphone as described in para 3.4.

c. Measure the background noise with the "device under test" (DUT) quiescent.

d. Measure the "total" sound-level with the DUT operating.

e. Evaluate the significance of background noise in the measurement and take steps to reduce it, if necessary, as discussed below.

The difference between the sound-level with the DUT operating and the background noise level determines the correction to be used. If this difference is less than 3 dB, the noise contribution of the DUT is less than the background noise; then the level obtained by use of the correction should be regarded as only indicative of the true level and not as an accurate measurement. If the difference is greater than 10 dB, the background noise is negligible and the reading with the DUT operating is the desired measurement.

The following is an example of a situation that falls between those two extremes. The background noise level is 77.5 dB, and the total noise with the DUT operating is 83.5 dB. The correction factor, obtained from Figure 3-22 for a 6.0-dB difference, is 1.2 dB, so that the corrected level is 82.3 dB.

If this difference between background level and total noise level is small, an attempt should be made to lower the background level. Usually, the first step is to isolate the source or sources of this background noise to reduce the noise directly. The second step is to analyze the transmission path between the source and the point of measurement. This step may mean simply closing doors and windows, if the source is external to the room, or it may mean erecting barriers, applying acoustical treatment to the room, and opening doors and windows, if the source is in the room. The third step is to improve the difference by the method of measurement. It may be possible to select a point closer to the apparatus, or an exploration of the background noise field may indicate that the microphone position can be shifted (see para 3.4) within the specifications to a point where this noise is at a minimum (yet allowing proper orientation with respect to the device under test). The Handbook of Noise Measurement by Peterson and Gross contains particularly useful information about sound measurements and sound fields.

3.7.5 Extension-Cable Effects.

The 10-ft Microphone Extension Cable (P/N 1933-0220) allows mounting of the microphone and preamplifier remote from the instrument. This cable can be increased in length (see para 2.9) to certain limits, whereupon the cable's length up to 150 m (500 ft) can be used without degrading the performance of the system. For longer cable lengths, consult GenRad.

3.7.6 Microphone-Windscreen Effects.

Microphone windscreens are used to reduce the effects of ambient wind noise. Wind flowing across the surface of the microphone generates low-frequency noise, which can lead to erroneous measurements. The windscreen also protects the microphone from accumulations of vapor and dust in the work environment.

This accessory fits snugly over the microphone. It is made of reticulated polyurethane foam and can be conveniently removed and washed, or replaced, if it becomes soiled. This is in addition to the obvious advantage of attenuating up to 20 dB of ambient wind noises, such as might emanate from a fan blowing cooling air or outdoor winds blowing across the site being monitored. Figure 3-23 indicates the effect of a windscreen on microphone response.

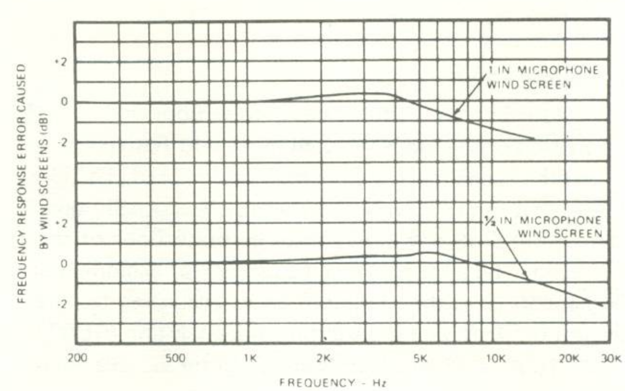


Figure 3-23. Effect of windscreens.

The procedure to use the 1560-7551 Microphone Windscreen supplied with the 1988, is described in para 3.8.4. This windscreen fits the 1/2-in. microphone provided with the 1988.

3.7.7 Overload-Level Tolerances.

Figure 3-24 illustrates the maximum SPL, in dB, that can be applied to the 1988 for each setting of the dB RANGE and WEIGHTING controls.

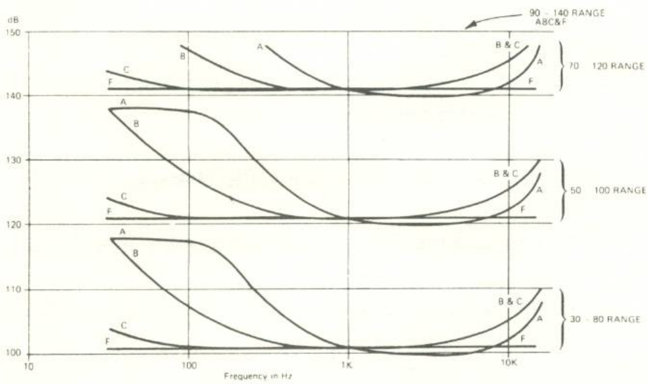


Figure 3-24. Peak SPL, in dB, for each range and weighting of the 1988.

3.7.8 Ear-Protector Ratings.

Ear protectors will only be effective if they attenuate the frequency of the unwanted noise. Therefore, to use them, the octave-band frequency levels of the area must be known (refer to para 3.5.7). As an example, the noise levels (at 7 octave bands) in a wood-and-pulp processing plant are as follows:

Octave Band	125 Hz	250 Hz	500 Hz	1 kHz	2 kHz	4 kHz	8 kHz
Level	108	114	114	112	111	106	97

To determine if hearing protectors are useful for the above examples, first make a measurement of the overall A-weighted level in the plant; this is the level existent without ear protectors, in dB(A). Then, using Table 3-6, proceed as follows:

a. Place the OBA readings on line 1.

b. Subtract the A-weighting correction on line 2 and write results on line 3.

c. Enter the ear-protector standard deviation (times 2) on line 4.

d. Add lines 3 and 4.

e. Enter ear-protector attenuation on line 6.

f. Subtract line 6 from line 5 and enter on line 7.

g. Reassemble the results on line 7 in descending order.

h. Combine dB, as described in para 3.7.10, using Figure 3-19.

As can be seen from this example, the hearing protector selected did not solve the noise problem. This type of procedure must also be utilized to evaluate absorbative material.

NOTE

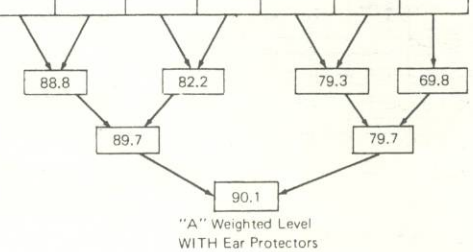
Table 3-6 can be used as a sample for other applications.

Table 3-5

EAR PROTECTOR RATING FORM

	– Frequency –						
	125 Hz	250 Hz	500 Hz	1 kHz	2 kHz	4 kHz	8 kHz
(1) Octave Band Level @ Worker's Ear (dB)	108	114	114	112	111	106	97
(2) "A" Weighting Correction (dB)	–16	–9	–3	0	+1	+1	–1
(3) Combine (1) and (2)	92	105	111	112	112	107	96
(4) Ear Protector Standard Deviation x 2 (dB)	3.8	3.8	6.3	8.6	7.4	10.8	10.8
(5) Add (3) and (4)	95.8	108.8	117.3	120.6	119.4	117.8	108.2
(6) Ear Protector Attenuation (dB)	15	22	33	44	43	48	32
(7) Subtract (6) from (5) For Corrected Level	80.8	86.8	84.3	76.6	76.4	69.8	76.2
Reassemble Corrected Levels (7) in descending Order	86.8	84.3	80.8	76.6	76.4	76.2	69.8

Combine dB Using Chart Below:



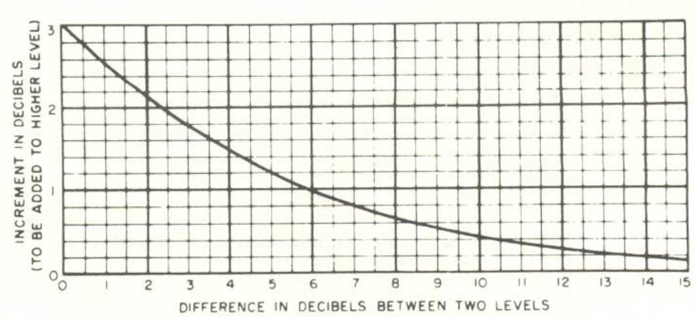
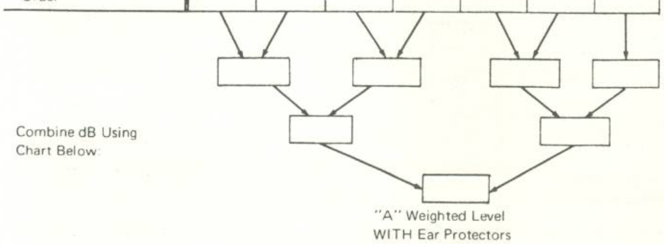
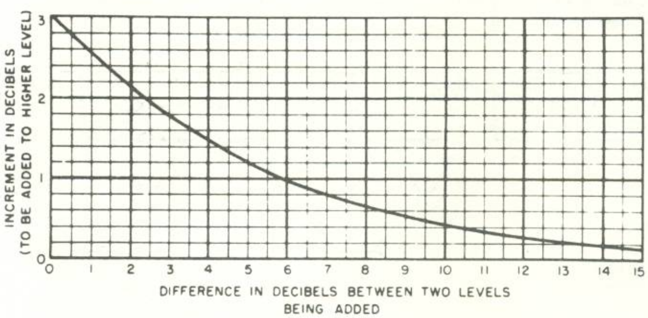


Table 3-6

EAR PROTECTOR RATING FORM

	– Frequency –						
	125 Hz	250 Hz	500 Hz	1 kHz	2 kHz	4 kHz	8 kHz
(1) Octave Band Level @ Worker's Ear (dB)							
(2) "A" Weighting Correction (dB)	–16	–9	–3	0	+1	+1	–1
(3) Combine (1) and (2)							
(4) Ear Protector Standard Deviation x 2 (dB)							
(5) Add (3) and (4)							
(6) Ear Protector Attenuation (dB)							
(7) Subtract (6) from (5) For Corrected Level							
Reassemble Corrected Levels (7) in descending Order							





3.7.9 Data-Recording Parameters.

An important part of any measurement program is obtaining and recording meaningful data. The use of data sheets designed specifically for a noise problem ensures that the desired information will be recorded. Below is a list of items that can be useful in recording measurement data or preparing suitable data sheets:

- Description of space in which measurements are made. Nature and dimensions of floor, walls, and ceiling. Description and location of nearby objects and personnel.
- Description of DUT (primary noise source). Dimensions, name-plate information and other pertinent facts including speed and power rating. Kinds of operations and operating conditions. Location of device and type of mounting.
- Description of secondary noise sources. Location, types, and kinds of operations.
- Type and serial numbers on all microphones, sound-level meters, and accessories used. Length and type of microphone cable.
- Position of observer.
- Positions of microphone. Direction of arrival of sound with respect to microphone orientation. Tests of standing-wave patterns and decay of sound level with distance.
- Ambient temperature, humidity, barometric pressure and resultant corrections, if any.
- Results of maintenance and calibration tests.
- Weighting network and dynamic characteristics of indicator.
- Measured sound levels at each microphone position. Extent of meter fluctuation.
- Background-noise levels at each microphone position, with DUT not operating.
- Cable and microphone corrections.
- Date and time.
- Name of observer. When the measurement is being made to determine the extent of noise exposure of personnel, the following items are also of interest.
  - Personnel exposed — directly and indirectly.
  - Time pattern of exposure.
  - Actions taken to control noise and to protect personnel.
  - Audiometric examinations — dates, methods, equipment, etc.

3.7.10 Mathematics of Decibels.

Often, in noise surveys, the noise levels of 2 or more sources are measured separately, and it is desirous to know the overall noise level (in dB) of the sources. Since a decibel (dB) is a logarithmic function, this can only be accomplished in a special, non-arithmetic manner.

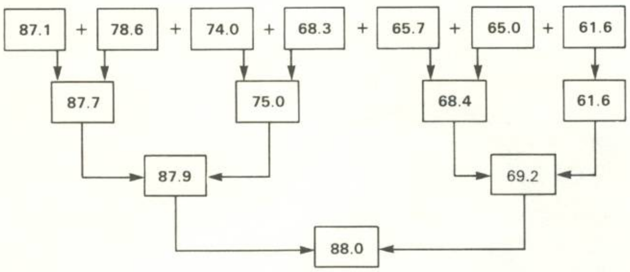
Figure 3-25 can be used to add decibel levels. The first step is to subtract the 2 dB levels to obtain the difference.

Locate this number along the horizontal axis. Move up the chart until the curve is intersected, and then read the increment along the vertical axis. This increment is added to the larger decibel value to determine the new level. As can be seen, if two sources are 10 dB or more apart, the lower source adds very little to the overall noise level. For this reason, most laws require the ambient level to be at least 10 dB below the level being measured.

The following is an example of adding decibels. The readings listed are from various noise sources in an area. To find the overall level, proceed as follows:

a. Arrange the numbers in descending order.

b. Combine two at a time, then again two at a time, until only one number remains.



The first two numbers (87.1 and 78.6) are 8.5 apart. From Figure 3-19, it can be seen that the difference of 8.5 dB indicates that an increment of 0.6 dB should be added to the larger value. Continuing on, the final answer will be 88 dB. This is not significantly higher than the dominant level of 87.1, since all other levels are more than 10 dB apart.

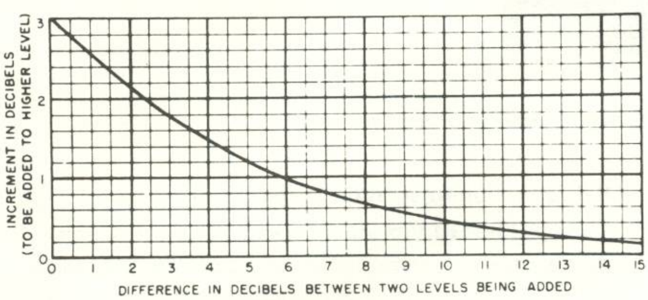


Figure 3-25. Decibel manipulation graph.

If a room contains a number of noise sources that produce the same noise level, it is simpler to multiply the dB levels than to add them to obtain the overall level. Table 3-7 gives the dB increment to be added to the level of the multiple sources.

3.8 USE WITH ACCESSORIES.

3.8.1 General.

Figure 1-2 illustrates the 1988 ISLM with its supplied accessories; Table 1-2 describes each supplied accessory. Table 1-3 lists additional accessories that are available upon order from GenRad. The following paragraphs describe the use of the 1988 with these supplied and available accessories.

3.8.2 Attenuator.

The GenRad 1962-3210 10-dB Attenuator is supplied with the 1988. It is used to attenuate high input-signal levels. The attenuator extends the upper limit of measurement from 130 dB rms re 20 μPa (140 dB pk) to 140 dB rms (150 dB pk). When the 10-dB attenuator is installed, the 1988 will indicate 10 dB less than the actual sound level that is measured.

The 1962-3210 attaches between the microphone and preamplifier of the 1988. To install the 1962-3210, place the 1988 flat on a surface, and unscrew its microphone from the preamplifier.

Thread the 1962-3210 attenuator to the preamplifier, and then thread the microphone to the attenuator. Figure 3-26 shows the microphone, attenuator, and preamplifier in their mating sequence before connection.

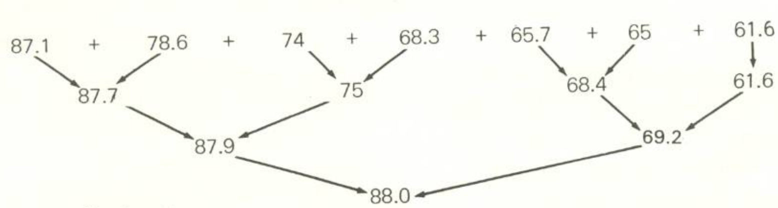
After the 10-dB attenuator is installed, the 1988 should be recalibrated for a reading 10-dB lower than normal. Refer to para 3.1.3 for the procedure.

3.8.3 Microphone Windscreen.

The Microphone Windscreen (P/N 1560-7551) is supplied with the 1988. A package of 4 additional windscreens (1560-9522) is available upon order from GenRad.

Table 3-7

MULTIPLYING DECIBELS



Number of equal levels	2	3	4	5	6-7	8	9-10	N
Add dB	3 dB	5 dB	6 dB	7 dB	8 dB	9 dB	10 dB	10 Log N dB

Figure 3-26. Mating configuration for connection of microphone, attenuator and preamplifier.

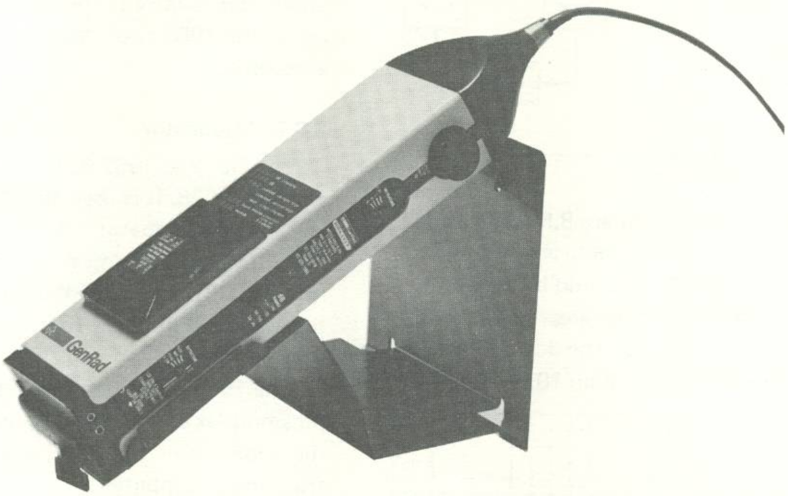


Figure 3-27. Mounting for use of 1988-9600 weatherproof enclosure adaptor.

3.8.4 Dummy Microphone.

The Dummy Microphone (P/N 1962-9620) is an accessory available upon order from GenRad. It connects directly to the input side of the preamplifer in place of the regular microphone, and provides BNC coupling at its input end.

The 1962-9620 has the same capacitance, 22 pF, as the 1962-9610 or -9611 microphone to provide impedance simulation. A signal generator can be connected to the input end of the 1962-9620 whenever a known signal-input level is desired without using the microphone. A "shorting cap" is also supplied with the dummy microphone in order to provide a capacitor-to-ground input to determine the noise floor of the preamplifer and instrument (see para 3.7.3).

The windscreen fits snugly over the 1/2-in. microphone, as shown in Figure 3-27. The effect of the windscreen upon frequency response is described in para 3.9.6.

3.8.5 Extension Cables.

The 1933-0220 Microphone Extension Cable is supplied with the 1988. A 20-ft cable (1933-9614) and a 60-ft cable (1933-9601) are available upon order from GenRad. These cables allow the preamplifier/microphone to be placed in the sound field being measured, while the instrument is operated in an external location where it does not affect the sound energy that is incident upon the microphone. The procedure for installation/removal of a cable is given in para 2.9.

3.8.6 Vibration-Integration System.

The 1933-9610 Vibration-Integration System is an accessory available upon order from GenRad. It expands the capabilities of the 1988 to include vibration measurements with readouts of acceleration, velocity, and displacement. The system consists of a vibration pickup (accelerometer) with a magnetic clamp and keeper, a vibration integrator that mounts on the 1988 preamplifier in place of the microphone, an 8-ft cable to connect the pickup to the integrator, a storage case, a slide rule, and an instruction manual. Figure 3-28 shows the 1933-9610 connected to the 1988.

Noise exposure in an industrial environment can be caused by air-borne or structure-borne sources. The structure-borne noise is caused by vibrating parts of machines. Some vibration is tolerable and necessary with a machine. However, if this vibration becomes excessive, machine wear and damage can result. When attempting to solve a noise problem, it is necessary to measure the level of vibration in terms of velocity, acceleration, and displacement in one part of the machine. When performing preventive maintenance on machines, it is necessary to take periodic vibration measurements to determine whether maintenance is necessary.

When the 1988 is used with the 1933-9610 Vibration Integrator System, the system can be used for vibration measurement. A 1557-9702 Vibration Calibrator is required to calibrate the 1988/1933-9610 system to ensure accurate measurements. After each measurement is made, the slide

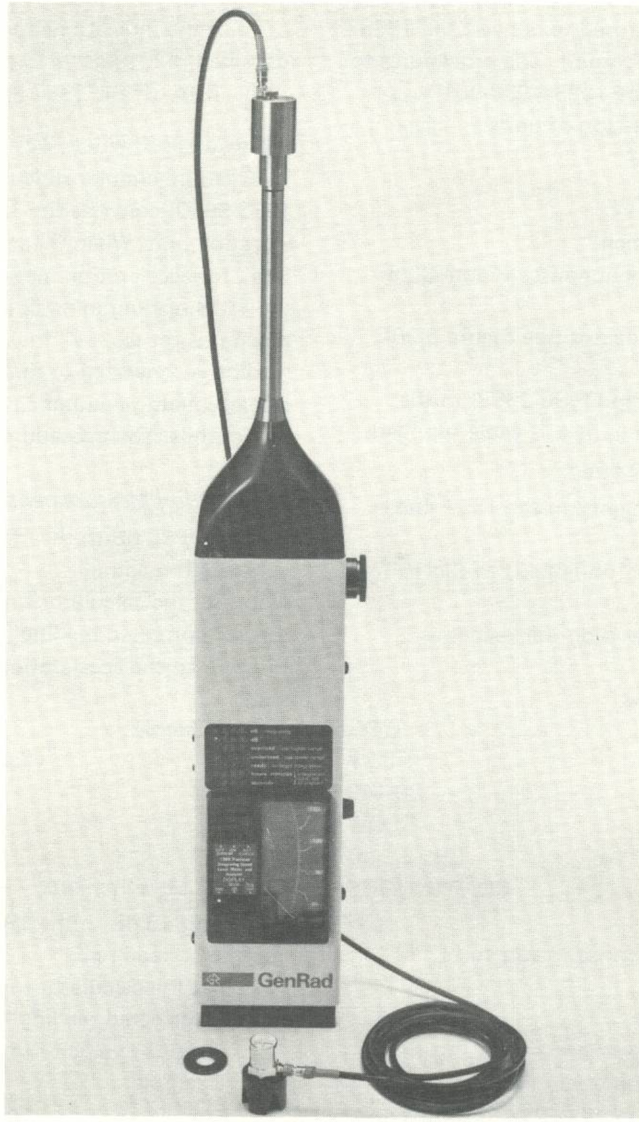


Figure 3-28. Vibration Integrator System connected to the ISLM.

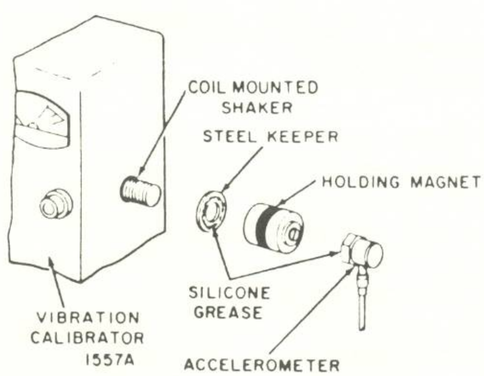


Figure 3-29. Configuration to mount the 1560-9653 pickup on the 1557-9802 calibrator.

rule (supplied with 1933-9610) is used to convert the 1988 reading to the appropriate vibration unit. The procedures to install the 1933-9610, calibrate the 1988/1933-9610 system, and perform slide-rule conversion of units are given below.

Installation of GenRad 1933-9610:

a. Place the 1988 flat on a bench.

b. Carefully remove the microphone (see Figure 3-25) and set it aside.

c. Thread the 1933-3030 connector (see Figure 3-26) onto the 1988 preamplifier.

d. Connect the vibration pickup (1560-9653) to the vibration-integrator assembly using the 8-ft cable supplied.

Calibration of 1988/1933-9610 System:

a. Remove one of the 50-g weights on the 1557 shaker (see Figure 3-29).

b. Thread the magnet-keeper (1560-6641) to the 1557 shaker.

c. Mount the magnet and pickup on the keeper as shown in Figure 3-29.

d. Set 1988 controls as follows:

OCTAVE FILTER FREQ	WTG
WEIGHTING	FLAT
dB RANGE	90-140
DETECTOR	SLOW
DISPLAY	LEVEL dB
MODE	CONTINUOUS
POWER	ON

e. Set the 1933-3030 Vibration Integrator to "La" (acceleration).

f. Press RESET on the 1988.

g. Turn on the 1557 and allow a few seconds for the shaker in the calibrator to build up to amplitude.

h. Adjust the LEVEL control on the 1557 until the 1557 panel meter indicates 143.

i. The 1988 should read 109.8 dB. Add 10 dB to this reading to obtain 119.8 dB, which is the corresponding acceleration level (La) in dB re 10-5 m/s2. Use the 5-in. circular slide rule (described below) to convert 119.8 dB to a corresponding acceleration, i.e., 1-g = 9.8 m/s2 = 386 in./s2.

j. If necessary, adjust the CAL control (on the 1988) if the meter reading is above 110.3 dB or below 109.3 dB.

k. Turn the integrator selector knob to Lv; the reading on the 1988 should be 83.9 dB. Add 40 dB to this reading to obtain 123.9 dB, which is the velocity level (Lv) in dB re 10-8 m/s for the shaker output of 1-g at 100 Hz. (Use the slide rule to convert 123.9 dB to a corresponding velocity of 0.015 m/s = 0.59 in./s.)

l. Turn the integrator selector to Ld; the 1988 reading should be 57.9 dB. Add 30 dB to this to obtain 87.9 dB, which is the displacement level (Ld) in dB re 10-9 for the shaker output of 1-g at 100 Hz. (Use the slide rule to convert 87.9 dB to a corresponding displacement of 0.0249 mm = 0.979 mils.)

m. If the indications specified in steps g through l are obtained, the 1988/9610 system is ready for use.

n. Turn off the 1557 and remove the magnet keeper.

Use of Slide-Rule Calculator:

The 5-in. circular slide-rule calculator (provided with the 1933-9610) converts the 1988 reading to the applicable vibration unit. When the integrator's selector knob is set to "La" for acceleration measurements, the slide rule converts the 1988 reading to m/s2 (metric) and in./s2 (English). When it is set to "Lv" for velocity measurements, the 1988 reading is converted to m/s and in./s; when set to "Ld" for displacement measurements, the reading is converted to mm or mils. The procedure to use the calculator follows.

Acceleration Measurements:

a. Add 10 dB to the 1988 indicator reading to obtain a "corrected reading".

b. Set the calculator's main index (1933 dB READING) to the "corrected reading" obtained in step a.

c. Read the acceleration (m/s2 or in./s2) on the outer scale.

Example:	1988 reading	= 90 dB
	"corrected reading"	= 100 dB
	Acceleration	= 1 m/s2
		= 39.4 in./s2

Velocity Measurements:

a. Add 10 dB to the 1988 indicator reading to obtain a "corrected reading".

b. Set the calculator's main index (1933 dB READING) to the "corrected reading" obtained in step a.

c. Read the velocity (m/s or in./s) on the outer scale.

Example:	1988 reading	= 80 dB
	"corrected reading"	= 90 dB
	Velocity	= 0.01 m/s
		= 0.39 in./s

Displacement Measurements:

a. Add 10 dB to the 1988 indicator reading to obtain a "corrected reading".

b. Set the calculator's main index (1933 dB READING) to the "corrected reading" obtained in step a.

c. Read the displacement (mm or mils) on the outer scale.

Example:	1988 reading	= 50 dB
	"corrected reading"	= 60 dB
	Displacement	= 0.01 mm
		= 0.39 mils

3.8.7 Printer.

The *printer* output connector is located on the left panel of the 1988. This 4-pin connector mates with the 4-pin connector on the printer cable (1988-0300). The

25-pin connector (dB-25S) on the other end of the 1988-0300 cable mates with most TTL-compatible printers. Para 2.10 describes the wiring of the printer cable.

The 1988 incorporates a serial interface to a printer. This 2-wire interface operates at the EIA standard 110 baud, which works with any RS-232C printer that accepts TTL-level signals. A dwell time of 4 s permits use with buffered-output printers.

When a printer is connected, the 1988 microprocessor receives an internal logic indication of the instrument's present status. If the 1988 is set up in the Automatic Integration Mode when a printer is connected, the instrument automatically repeats integrations of the same preset duration (as if *start* was pressed upon completion of each integration period). At the end of each integration period, a message is printed that consists of:

- Total Elapsed Time since start of first integration period.
- LEQ or SEL, depending on the position of the *sel/spl(leq)* control.
- Maximum SPL.

The Elapsed Time is printed in a "HH:MM:SS" format. The same message is printed in the Manual Integration Mode when the *pause* button is pressed; this function allows manually controlled sampling. If an overload occurs during an integration period, it is signified on the printer output by a number that is "LEQ/SEL plus 800". Header messages are supplied on the printer output to label the printed information. An example of a printer output that gives LEQ in the Manual Mode follows:

HH:MM:SS	MAX	LEQ	(MANUAL)
00:05:00	89.2	69.7	
00:06:54	101.7	73.2	

This example shows that 5 min after *start* was first pressed, *pause* was pressed, at which time the Maximum SPL was 89.2 dB and the LEQ was 69.7 dB; then, 6 min and 54 s after the first press of *start* (minus any pause-start interruptions), *pause* was again pressed, at which time the Maximum SPL was 101.7 dB and the LEQ was 73.2 dB.

3.8.8 DC Recorder.

The left-panel DC OUT jack provides a dc electrical output of the sound levels measured by the 1988 (refer to para 3.6.17). This output can be connected to a dc recorder to provide a permanent hard-copy record of level-vs-time measurements made by the 1988.

The 1985 dc Recorder is a portable strip-chart recorder that is ideal for use with the 1988. It has a pen response fast enough to conform to ANSI and IEC specifications for fast and slow indicator response when used with a Type-1 ISLM. And, the 1985 has a 50-dB recording range that makes it directly compatible with the 1988; thus, the recorder's full scale automatically coincides with the full-scale setting of the 1988. The dc output of the 1988 is linear over a 70-dB range (50-dB range setting plus a 20-dB crest-factor allowance. factor allowance).

To use the 1985 to record the levels measured by the 1988, proceed as follows:

a. Calibrate the 1988 in accordance with the procedures in para 3.1.3.

b. Perform the initial setups described in para 1.5 of the 1985 manual and para 3.1 of this manual.

c. With the 1988 and 1985 power off, connect the 1985-0200 cable (supplied with the 1985) between the DC OUT jack of the 1988 and the DC INPUT jack on the 1985. The gold pin (+) on the banana-connection end of the cable is inserted in the (+) terminal on the 1985.

d. On the 1985, set the GenRad instrument no. switch to the F position.

e. Set the 1985 controls as follows:

Chart Speed	15
Centimeters per	MINUTE
CHART	ON
POWER	ON

f. The pen on the 1985 should be writing along the right-hand, wide-grid mark (baseline).

g. If the results in step f are not obtained, adjust the ZERO control using the screwdriver supplied with the 1985.

3.8.9 AC Recorder.

The 1935 Cassette Data Recorder can be used with the 1988 as a data-recording system. In order to record data from the 1988, the AC OUT jack on the 1988 left panel must be connected via a cable to the CHAN A AUX IN jack on the right side of the 1935. This cable can be fabricated by using two 4270-11 sub-miniature phone plugs (accessories available from GenRad), or the 1560-9678 and 1560-9680 cables (available from GenRad) can be used. Playback is accomplished by connecting a 1560-9679 cable (accessory available from GenRad) between the A OUTPUT jack on the left side of the 1935 and the 1988 preamplifier input through the 1962-9620 dummy microphone and the 10-dB attenuator (1962-3210).

To Set Up the Equipment:

Refer to para 3.1, and perform the initial-setup procedures for the 1988. For a complete description of the 1935 setup, refer to its instruction manual. A brief set-up procedure follows:

a. Depress the PLAY button on the top of the 1935.

b. Slide the BAT CHECK/CHAN B switch on the front of the 1935 to the BAT CHECK position.

c. Observe that the CHANNEL B meter indicates to the right of the BAT CHECK mark.

d. If the indication in step c is not obtained, proceed as follows:

- Press and release the STOP button.

- Slide the battery-compartment cover (located at the rear of the 1935) off the instrument to expose the battery compartment.
- If batteries are installed in the instrument, remove them.
- Observe the proper polarity and install 5 alkaline C-size cells in the battery compartment.
- Replace the battery-compartment cover.

e. Depress the STOP button far enough to cause the tape deck to open. Release the switch.

f. Hold the tape cassette with the tape toward you and the side with the name plate up; insert the tape into the tape deck.

g. Close the tape-deck door.

h. If necessary, press the REWIND button to rewind the tape.

i. Press the tape-counter reset button on top of the 1935 to reset the counter to zero.

j. The 1935 is now ready for use.

To Record Data:

Set up the 1988 and 1935 as described above. To record data on the 1935, proceed as follows:

a. Connect the AC OUT jack on the 1988 to the CHAN A AUX IN jack on the 1935.

b. Position the 1988 Controls as follows:

OCTAVE FILTER FREQ HZ	WTG
WEIGHTING	FLAT
dB RANGE	70-120
DETECTOR	SLOW
DISPLAY	*level dB*
Mode	*continuous*
power	ON
reset	press 2 buttons

c. Position the 1935 controls as follows:

RANGE CODE CHANNEL B	ON
dB FULL SCALE	120
FROM SLM-dB FULL SCALE	ON
PAUSE	Depressed
PLAY	Depressed
RECORD	Depressed

d. Apply a 1-kHz, 114-dB calibrated signal to the 1988 microphone, as described in para 3.1.3.

e. Adjust the CAL control on the 1988 with the calibration screwdriver to obtain an indication of 117 dB on the 1988.

f. Adjust the CAL A control on the right side of the 1935 to obtain an indication of −10 on the CHANNEL A meter on the front of the 1935.

g. Reset the 1935 counter to zero.

h. Depress and release the 1935 PAUSE button.

i. Record the calibration tone for at least a count of 10 on the counter.

j. Depress and release the STOP button on the 1935.

k. Recalibrate the 1988 to 114 dB. Remove the calibrator from the 1988.

l. The system is now ready to record data.

m. When the dB RANGE switch on the 1988 is set to a different range, the dB FULL SCALE switch on the 1935 should be set to the full-scale value. This data will be recorded on Channel B of the 1935.

When recording data, ensure that the dynamic range of the 1935 is not exceeded, as the full 50-dB scale cannot be used. Record on only the following portions of the 1988 scale:

1988 dB RANGE Setting	1935 Recording Range (dB)
30–80	39–80
50–100	61–100
70–120	79–120
90–140	99-140

To Play Back Data:

To play back data, which was recorded on the 1935, into the 1988, proceed as follows:

a. Remove all cables between the 1988 and 1935 and rewind the tape in the 1935.

b. Place the 1988 flat on a bench, unscrew the microphone (Figure 3-26) from the preamplifier, and place it gently on the bench. Thread the 10-dB attenuator (1962-3210) onto the preamplifier, and thread the 1962-9620 dummy microphone onto the attenuator.

c. Connect the BNC end of the 1560-9679 cable to the dummy microphone. Connect the other end of the cable to the OUTPUT A jack on the left side of the 1935.

d. Set the 1988 as in step b of the "To Record Data" procedure.

e. On the 1935, depress the PLAY buttons.

f. While the calibration tone is playing on the 1935, calibrate the 1988 to indicate 117 dB.

g. The 1988 will now be direct reading on the 70-120 dB scale from 79 to 120 dB. On playback, the maximum record level on the 1935 will indicate 120 dB on the 1988. If the data was recorded with the 1988 set on the 90-140 dB range, on playback the 1988 indication of 120 dB will represent 140 dB. In this case, add 20 dB to the 1988 reading. However, if the data was recorded with the 1988 set to the 50-100 dB range, a 120-dB indication on the 1988 during playback will represent 100 dB. In this situation, subtract 20 dB from the 1988 reading. A summary for all 1988 ranges is shown below.

1988 Range (dB) When Recording	Correction Factor For 1988 Reading On Playback
30–80	-40 dB
50–100	-20 dB
70–120	Direct Reading
90–140	+20 dB

The data on the tape can now be analyzed in octave bands or with A-weighting. With the 1935-9601 earphone (supplied with the 1935) connected to the 1988 AC OUT jack, the user can listen to the recorded data while it is being played back into the 1988.

3.8.10 Audiometer Calibration Kit.

The 1560-9619 Audiometer Calibration Accessory Kit expands the measurement capabilities of the 1988 to include audiometer calibration. The 1988/1560-9619 system checks the acoustic output and attenuator linearity of an audiometer. The 1560-9619 includes a 1-in. electret-condenser microphone, an NBS Type 9-A earphone coupler, a calibration-stand assembly, appropriate calibration data, and an instruction manual that describes the calibration procedure.

Theory—Section 4

4.1 GENERAL.

As the name indicates, the 1988 is both a sound-level meter and a spectrum analyzer. It includes the sound-level weighting networks A, B, and C, an octave-band filter that is tunable to the 10 standard center frequencies from 31.5 Hz to 16 kHz and a flat or "all pass" characteristic that extends in frequency from 5 Hz to 20 kHz.

The 1988 comprises four main elements as shown in the block diagram, Figure 4-1. The microphone produces an electrical signal proportional to the applied sound pressure. This ac electrical signal is applied to an amplifier with frequency-selective networks that establish the "weighting" and octave-band filter characteristics. The amplification is adjustable in order to accommodate the four input sound pressure level ranges and to provide a precise means for calibration.

After amplification and filtering or weighting, the ac signal is applied to the detector where it is converted to a dc signal suitable for application to the indicator. The detector has closely controlled response-time characteristics to produce a dc signal proportional to the effective, or root mean square (rms) value, or to the peak value of the filtered ac input signal. The detector output signal is applied to the indicator which may be a meter, digital display, or both as in the case of the 1988.

NOTE

The purpose of this section is to provide a comprehensive description of the circuits which comprise the 1988. This material should prove to be especially useful if any repair or trouble-shooting is to be performed. It is recommended that the reader refer to the appropriate schematic diagram (Section 6) and to the block diagram (Figure 6-2) during this discussion.

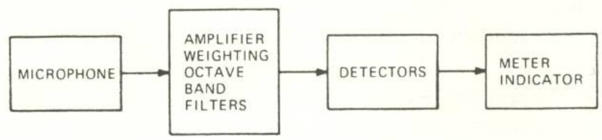


Figure 4-1. Elementary Sound-Level Meter block diagram.

4.2 MICROPHONE AND PREAMPLIFIER.

The microphone is an electret-condenser microphone. Its basic design is similar to the conventional air-condenser microphone, but it has a permanently charged diaphragm and does not require a polarizing voltage. The electret-condenser microphone retains the advantages of conventional air-condenser microphones with high sensitivity, flat frequency response and wide dynamic range. In addition, it does not become noisy in a humid environment. The analyzer is supplied with either "flat random incidence" response microphone or "flat perpendicular incidence" response microphone. Typical frequency response and directional response characteristics are shown in Figures 3-9 to 3-12.

The preamplifier (1560-P2) is a wide-band, low-noise amplifier that features high input impedance and low output impedance and selected gain of unity or X10. It serves as an interface between the high source impedance of the microphone and the input to the SLM. If the microphone is connected directly to a long cable (capacitive load) without a preamplifier, the long cable merely reduces the sensitivity of the microphone by forming a capacitive voltage attenuator. However, when the removable *preamplifier* and microphone are connected to the same end of the cable, the low output impedance of the preamplifier eliminates any losses due to the cable. Hence, there is no need for any cable correction factors.

In addition, the length of the preamplifier makes it generally unnecessary to use an extension cable to avoid the influence of body reflections from the user and 1988 housing itself.

Also, the preamplifier incorporates a +200-V supply, making it useful for air condenser microphones.

4.3 INPUT AMPLIFIER/ATTENUATOR STAGE.

Refer to Figure 6-8, Filter Board Schematic diagram. The input stage from the microphone and preamplifier has four levels of amplification or attenuation which provide the ranging function of the SLM. The input amplifier and electronic attenuator comprise U1, U3, Q1, Q2 and associated circuit components. A "high" level on one of the electronic switch control lines at J4, which are controlled by the dB RANGE switch, selects one of the 20-dB steps formed by the resistive attenuator, R1-R3. In the most sensitive range, 30-80 dB, the input amplifier provides an additional 20 dB of signal gain through R6. Q1 and Q2 form a low-noise, differential input to the output stage, U3.

CAL potentiometer, R10, provides continuous gain adjustment of the input stage to permit overall instrument calibration. This is necessary to compensate for sensitivity variations among different microphones.

4.4 OCTAVE-BAND FILTERS AND WEIGHTING NETWORK.

Refer to Figure 6-8, Filter Board Schematic diagram. The signal from the input stage discussed in the previous paragraph drives the filter networks. The octave-band filters in the 1988 are resistance-capacitance-amplifier types (U4, U5, and U6) using the Sallen and Key configuration with three two-pole sections cascaded. U4 is a low pass filter, U5 is a high-pass filter, and U6 is a band-pass filter. The octave-band center frequencies are selected by switching resistor values in the hybrid circuits, Z1 through Z6 with the octave-filter switch, S1.

The weighting networks A, B and C, selected in the CCW position of S1, use much of the same circuitry as the octave-band filters. C12, C15, and R21 bypass the filters to provide the FLAT response. One of the three weightings, A, B, C, or FLAT is selected with an electronic switch, U2, by a "high" level on the appropriate control line at J2. These lines are controlled by the 4-position weighting switch.

Refer to Figure 4-2 for a simplified drawing of a typical filter network. Figure 4-3 shows the frequency response characteristics of the 1988 weighting networks. Figures 4-3a and b show a normalized magnitude and phase response of a typical octave filter.

4.5 DETECTOR SYSTEM.

Refer to Figure 6-10, Detector Board Schematic diagram. The circuits located on the Detector Board consist of an rms detector, a peak detector in cascade, separate overload peak detector and analog-to-digital (A/D) converter. The rms detector circuit, U1, U2, and U3, provides a dc output voltage proportional to the logarithm of the rms value of the input signal. The name of this ac input signal is FILTO and is derived from the output of the filter and weighting circuit. The dc output voltage from the detector, U3 pin 3, is proportional to the input, i.e., 6 mV/dB.

NOTE

The electronic switch, U7, momentarily shorts the detector averaging capacitor to ground when the instrument is turned on to eliminate transients.

The detector response times for FAST, SLOW, and IMPULSE are established by C14 and C15 and C16 respectively. They are selected by a "high" level on the appropriate control line at J6. For example, when the detector is set for a SLOW response, the SLOW control line is set "high" to turn on Q2 and to connect C15 to ground. In the FAST response mode, the FAST control line is set "high" to turn on Q1 and connect C14 to ground.

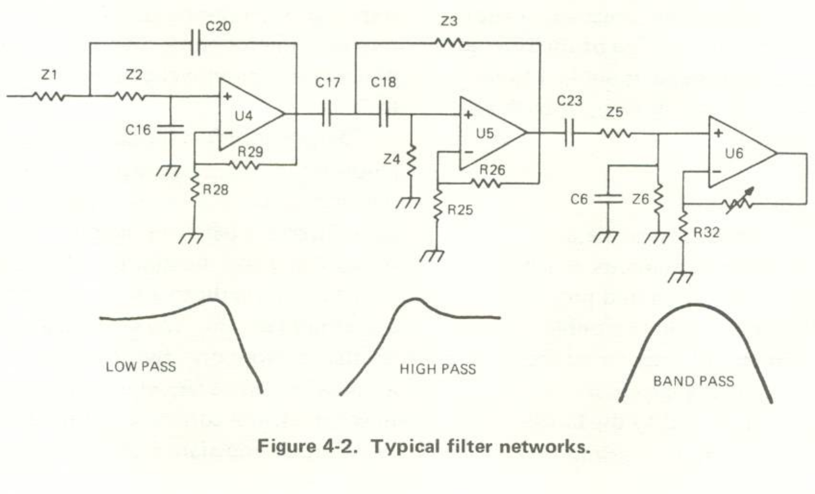


Figure 4-2. Typical filter networks.

Curves exclude the possible acoustical effects of a microphone and are based on a 20-pF source impedance.

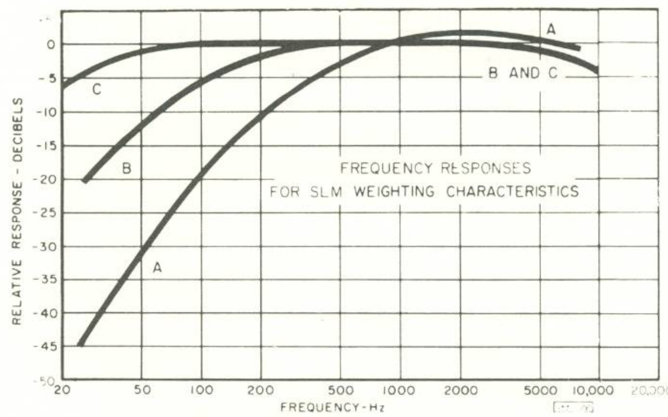


Figure 4-3. Frequency-response characteristic for 1988 SLM.

The PEAK detector is U5 and Q6. In the FAST and SLOW modes, the PEAK detector function is bypassed, i.e., CR6 is shorted by the electronic switch, U4. In these modes the PEAK detector circuit serves as a dc amplifier only.

In the PEAK mode, the FAST and SLOW time constants in the RMS detector are bypassed, i.e., neither Q1 nor Q2 are enabled. However, the PEAK detector circuit is enabled, i.e., switch U4 is open and C17 charges to the absolute signal peak through CR6 (50 μs rise time). The 3 dB/s decay time is established by the time constant of C17 and R25.

The PEAK detector is reset by the microprocessor when the reset function is performed (pause and start buttons pressed simultaneously). This generates a positive RESET pulse at J8 (which originates on the Digital Board) and momentarily closes the bypass switch, U4 in the PEAK detector to discharge C17.

Both the RMS detector and PEAK detector are employed in the IMPULSE mode to provide an indication proportional to the peak of the short duration rms value of the signal. In this case Q3 is turned on to employ C16 in the RMS detector circuit and U4 is open to employ CR6 in the PEAK detector circuit. Rise time for the IMPULSE detector function is 35 ms.

The dc output of the peak detector amplifier U5 and Q4 is proportional to the detector input at approximately 20 mV/dB, but is uncompensated for the predictable temperature effects in the rms converter circuit.

Temperature compensation in panel meter M1 is performed by the meter's copper resistance as the meter is driven from a voltage source U5A and *meter cal.* control R50 establish the proper signal level for the meter.

Driven from a voltage source, the meter response time is sufficiently fast that the detector time constant is the dominant time constant for the meter indicating system.

Temperature compensation for the digital circuit and dc output is performed by U5d and copper resistor RT1. Dc cal. control R33 sets the full scale level which drives the A/D converter on the Detector Board.

Overload PEAK detector circuit U6 monitors the ac signal at two points, before and after the filter and weighting networks. Signal OVLD1 monitors the input to the filter and weighting circuits and signal FLTO is monitored. If the peak value of either signal exceeds the + or − overload threshold, the comparator (U6) output is pulled low making Q5 conduct, shorting out C20 and C18 and pulling the gate of Q6 high.

As long as gate Q6 exceeds the threshold voltage of 2 V, Q6 will conduct, turning on front-panel "overload" LED DS1. In addition, a parallel "OVLD" output is provided to the digital circuitry for processing during integrating calculations. The front panel LED will stay on for 0.5 to 1 s for single transients as little as 25 μs or continuously for continuous overloads.

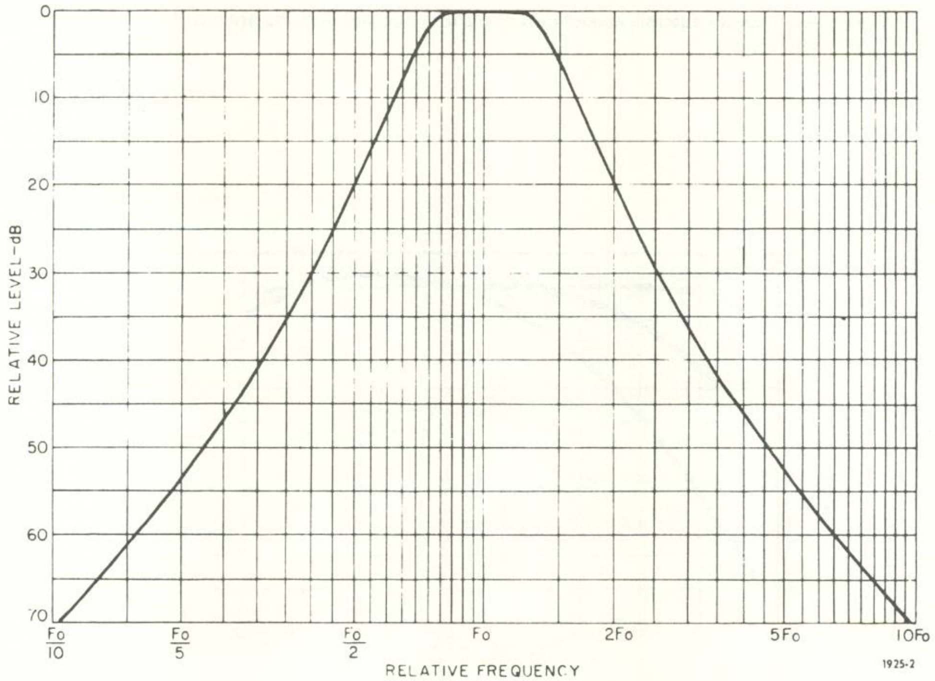


Figure 4-3a. Normalized magnitude response.

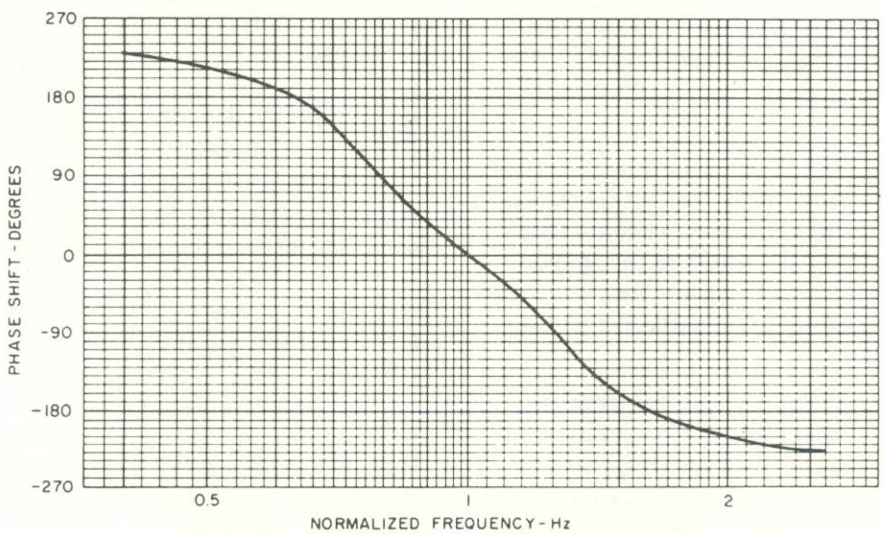


Figure 4-3b. Normalized phase response.

The OVLD signal will remain on for ≈10 ms for a single overload, allowing the digital circuits to "count" the overloads. (See theory of microprocessor operation further on in this section.)

4.6 METER AND BATTERY CHECK CIRCUIT.

The meter circuit is comprised of U5A and the meter A-M1. When power switch S1 is pressed to the BAT position, the battery voltage is checked under full load and generally must be greater than +3.3 V.

During battery check, "BATCK" at J7 goes high converting meter amplifier U5a from a non-inverting amplifier to inverting amplifier through the switch action of U4. The actual battery voltage is converted into a current and applied to the inverting terminal of U5. BAT CAL control R46 sets the low meter scale indication. If the battery is checked during an integration, the effect is to press "pause" for the time of the battery check, so no data is ruined. During the battery check, the digital display is checked by indicating all 8's, as described in Section 3.

4.7 A/D CONVERTER.

Refer to Figure 6-13 for the A/D converter schematic. The A/D converter consists of a single-chip 10-bit binary A/D converter and precision negative voltage reference, with conversion control directed from the microprocessor on the digital board.

The DC-out signal is applied continuously to the A/D as an input current, "I_{IN}". Conversion is initiated by a positive pulse on the CONV line at J8 from the microprocessor. During conversion, the sum of I_{IN} and pulses of reference current (-)I_{ref} (derived from the precision voltage references) is integrated for a fixed time determined by the converter's internal clock. I_{ref} is switched in just frequently enough to maintain a zero sum at the integrator input. The total number of I_{ref} pulses needed during the conversion period is counted and latched at the output at the end of the conversion. Total conversion time is 6.0 ms with a new conversion made each 9.09 ms.

The binary value of the A/D output is such that one bit has the value of 0.1 dB. Since the converter does not count negative, an offset current is applied at the input of the converter, via R64 so that the counted output is 114 (decimal) with zero volts at the "Dc out," representing 30.0 dB. 30.0 dB is *always* the bottom scale level, and 18.6 is the effective "digital noise floor" due to this offset.

The microprocessor adds 18.6 dB (186 counts in decimal) to the converter output to obtain the correct dB values (e.g., 186 + 114 = 300 dB at bottom scale). In addition, the microprocessor scales the converted value by 20, 40 or 60 dB, with information supplied by the RANGE switch.

Table 4-1 lists the equivalent values of the A/D output vs dB reading.

The A/D converter output lines are presented to multiplexers U9-U11 along with other data lines which are made available to the microprocessor data bus during appropriate times in the program execution.

Table 4-1

EQUIVALENT VALUES

SPL (dB)	Decimal	Hex*
100	814	32E
90	714	2CA
80 (full scale)	614	266
70	514	202
60	414	19E
50	314	13A
40	214	D6
30 (bottom scale)	114	72
25	64	40
20	14	0E
18.6	0	0

A/D converter output representation of equivalent SPL.

*Hexadecimal notation is a convenient means of representing binary data using base 16 where A – F represent values 10 – 15 respectively.

4.8 DIGITAL PROCESSING.

4.8.1 General.

The 1988 incorporates microprocessor circuitry to provide control and computation necessary for the integration functions. The processor is also used to simplify the display and printing functions.

Simplified block diagram, Figure 4-4, shows the basic circuit blocks used in the 1988 digital board.

The central processor is a 6503 NMOS microprocessor that communicates to interfacing circuits through a 12-bit address bus, an 8-bit data bus, and several control circuits. The program for the processor is stored in the 4K x 8 NMOS PROM, U2. Working memory is provided by CMOS RAMs U3 and U4.

All input information, panel control, and A/D converter data is presented to the processor data bus through input data multiplexer (MUX) U9-U11, which is buffered by U15. All output, digital display, printer output, A/D control and peak detector reset information is transmitted through output latches U8-U11.

Address decoder U7 directs which I/O device is to be selected. Master clock U5 is crystal controlled for stable and accurate timing of the integration process. The clock also sets the printer serial output timing of 110 BAUD.

To conserve power in the 1988, certain high-current-consuming circuits are shut off when they are not needed. U1, U2, U7 and U14 have their power pulsed on by Q7 and Q9 every 4.5 ms and will stay on as long as required by the function being performed, but generally for no more than 0.5 ms, reducing the average current required to about 10% nominal.

4.8.2 Clock.

U5 is an integrated crystal-controlled CMOS oscillator and divider. The crystal frequency of 901.12 kHz is the microprocessor clock timing frequency. All processor operations, instruction selecting, data and address bus timing read and write operations are set by this clock. A synchronous output of U5 at a 220-Hz rate is used to reset the "wakeup" latch, which turns on the microprocessor every 4.5 ms, and also "resets" the microprocessor each "wakeup."

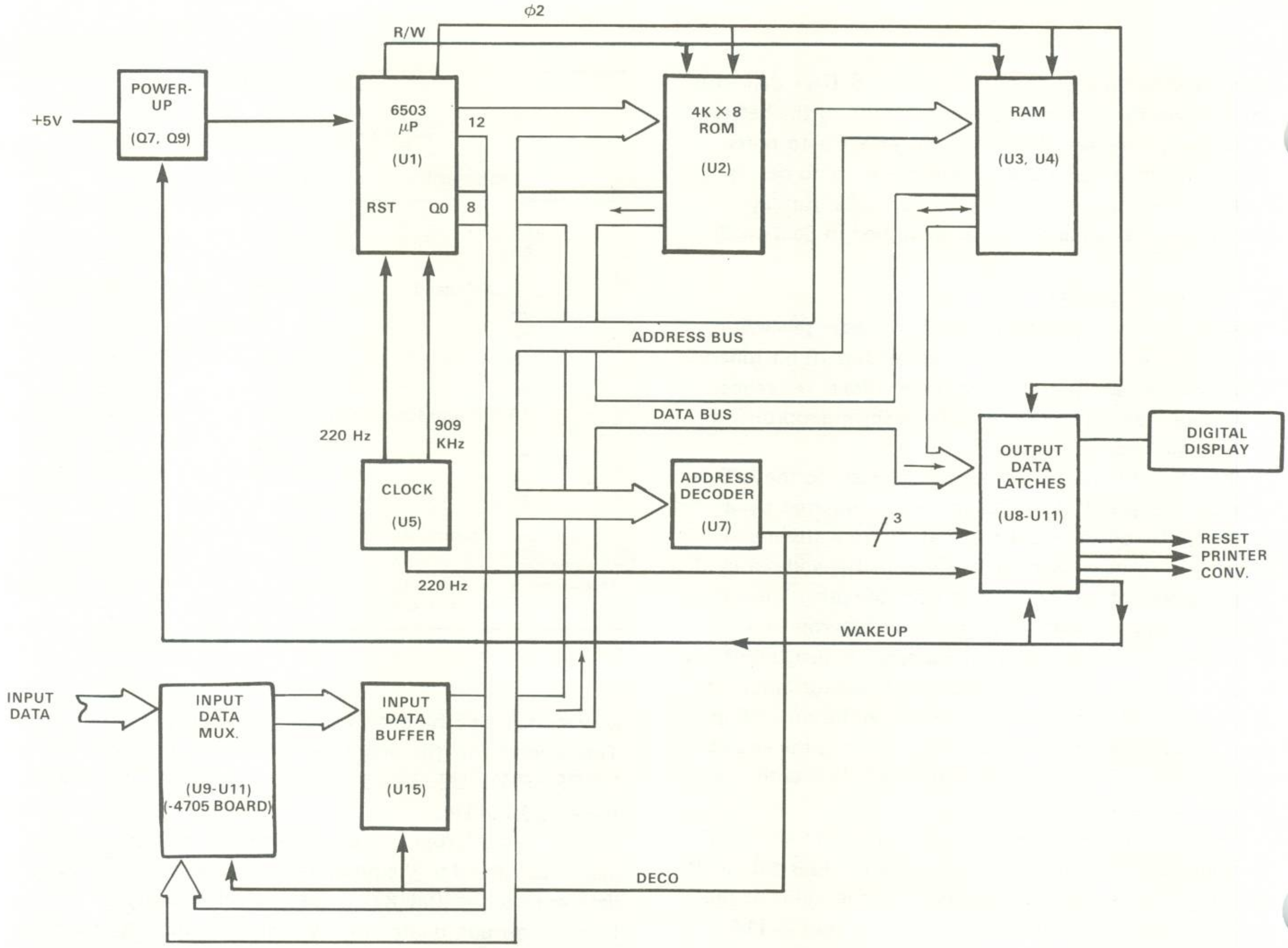


Figure 4-4. Simplified block diagram of digital circuits.

4.8.3 Microprocessor.

The microprocessor used in the 1988 is the MOS technology 6503, shown as U1. It is similar to a Mostek 6502 but has four less address lines, so there are only 4K bytes of addressable memory.

This processor has clock phases $\phi 1$ and $\phi 2$; $\phi 1$ is used internally to the processor and is transparent to the user.

During the period when the $\phi 1$ clock is high or the $\phi 2$ clock is low, the address of the next instruction or memory fetch is sent out on the address lines. During the period when the $\phi 2$ clock is high, the memory (RAM, ROM or I/O latches) is responding with data during a read cycle, or accepting data during a write cycle. At the falling edge of the 02 clock phase, the microprocessor latches the information on the data lines.

Bus Structure. There are basically 3 buses emanating from the microprocessor:

1. The address bus, 12 lines
2. The data bus, 8 lines
3. The control bus, 7 lines

These buses are unbuffered on the board, and only two address lines leave the board to select the data input mux.

The address bus is unidirectional and always leaves the processor. It goes directly to the 3 memory elements on the board: 4K words MOS ROM (U2), 256 words CMOS RAM (U3 and U4), and I/O interface chips latches U8-U11, and buffer U15.

The program PROM, U2, is selected whenever the upper three bits of the address bus are asserted true at U14 pin 9-11, equivalent to address 0200-OFFF. While U2 is connected to all address bits, addresses 0000 to 01FF are never selected in the ROM.

The ROM is power strobed like the processor, to conserve power. CMOS RAMs U3 and U4 are selected only when the four high-order address bits are *not* true, making the RAM have an effective address of 0000-007F. (Only addresses 000 to 003F are used in the 1988.) While locations 40 and 7F are used by the RAM, they are "dummy" locations, being addressed during the microprocessor "sleep" cycle to avoid any possibility of spurious writing to the used portion of the RAM at that time.

Address placement for the I/O latches is set for convenient decoding, which is performed by U7. Input data multiplexers are selected by successive addresses, starting at 0080. Output data latches are selected by successive jumps of 4 by three outputs of decoder U7, starting with 0084. See Table 4-2.

Table 4-2

I/O DECODING

Address Bus		Hex Value			
		80	84	88	8C
AB2	0	0	1	0	1
AB3	0	0	0	1	1
AB4	0	0	0	0	0
AB7	0	1	1	1	1
AB9	0	0	0	0	0
AB10	0	0	0	0	0
AB11	0	0	0	0	0
U7 output	open	Y0 ↓ Input data mux selected	Y1 ↓ U8, 9 selected	Y2 ↓ U10 selected	Y3 ↓ U11 selected

The data bus is bidirectional at the processor, but is unidirectional to all memory elements except the CMOS RAM. Data is read only from the input data buffer and program ROM and written only to the output latches. Thus the addressing of the I/O devices and ROM defines the data direction for those devices whereas the CMOS RAM may be read or written.

Output data latches U8-U11 are inputs only; therefore, they never load the data bus. When input data buffer U25 and ROM U2 are deselected, their outputs go to a high impedance state so that they do not load the bus. CMOS ROM U3 and U4 load the data bus only when selected and set in the read mode. Table 4-3 contains a map of the various memory functions.

The several control bus functions are as follows:

1. RES (pin 1) is the normal power-up reset control of the microprocessor; however, it is used differently in the 1988. As described before, the microprocessor is turned on every 4.5 ms and shut down when its work is done. During each "wakeup," the RES line is held low to reset the internal registers of the microprocessor; however, the stack is not reset, so there is continuity to memory operations. After RES goes high, the program commences at the same spot at the beginning of each wakeup as directed by the RESET interrupt vector at FFFC and FFFD.
2. NMI and IRQ (pins 3 and 4) provide interrupt functions that direct the program to start at the very beginning, initializing all registers and the stack. These, in effect, are the powerup reset vectors during instrument turn on. So long as the 1988 power switch is on, NMI and IRQ stay high and are in operation. If the power supply regulator ceases operation, NMI goes low and shuts down the processor.

Except for the power supply shutdown, there are no external interrupts to the operation of the 1988.

3. The R/W line (pin 26) from the processor goes low during a write operation. Since it is low during a portion of the $\phi 1$ clock cycle, as well as during all of $\phi 2$, it is ANDed with $\phi 2$ before controlling the write input on the RAMs. R/W is ANDed at U14 with -02LA from U14 pin 12 and reinverted at U6 to produce the 02 R/W necessary to control CMOS RAMs U3 and U4.

Table 4-3

1988 MEMORY MAP

Hex Address		Function
0000-003F	RAM	Zero page temporary storage, stack
↓		(unused)
0080-0083	LATCHES	Input data Mux
0084, 0088, 008C	↓	Output data latches
↓		(unused)
F200-F84B*	ROM	Main program and subroutine
F84C-F889		tables (printer, BIN-to-BCD conversion, etc)
F88A-FE85		LEQ Conversion Table
		(unused)
FFFA, FFFB		NMI vector → F200
FFFC, FFFD		Reset vector → F38A
FFFE, FFFF	↓	IRQ/BRK vector → F200

*Since the microprocessor has only 4K of addressable memory, the upper 4 address bits are ignored during processing so that program memory structured at F200-FFFF is in reality 0200-0FFF.

Output latches U8 to U11 need no R/W signal since they are write-only devices. Writing occurs when they are properly chip-selected by the address decoder and when ϕ2LB goes positive, clocking the latches. Similarly, data is accepted from input data latches and ROM when these devices are appropriately chip-selected and addressed. Data is transferred to the processor after the positive transition of ϕ2 (internal to the processor in this instance). Figures 4-5 through 4-7 show the processor read/write timing.

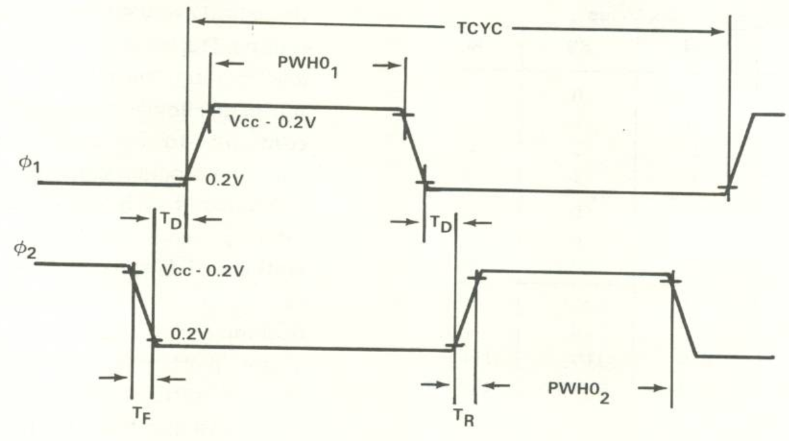


Figure 4-5. Two phase clock timing.

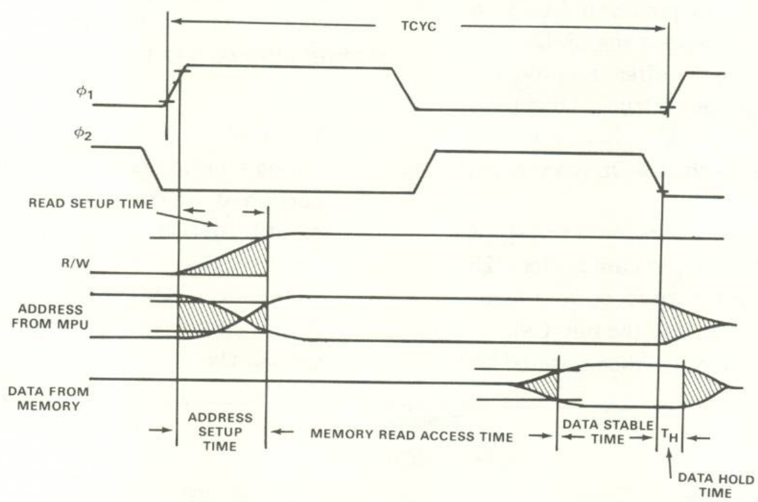


Figure 4-6. Timing for reading data from memory.

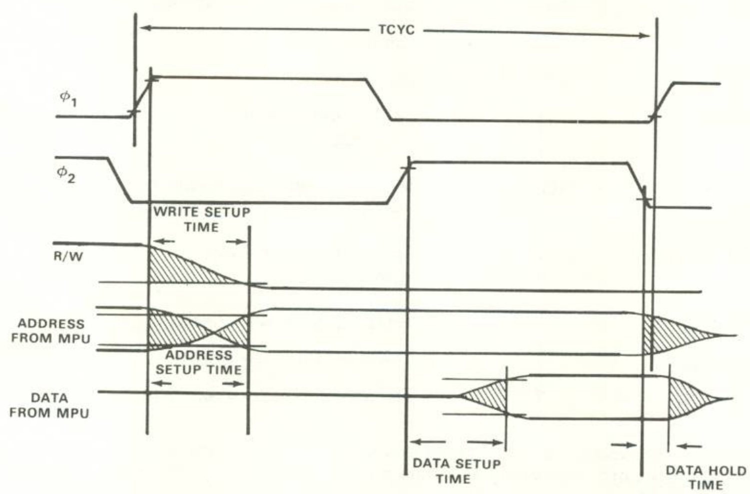


Figure 4-7. Timing for writing data to memory.

4. CLK line $\phi 0$ (pin 27) is the source of the processor timing, derived from the clock oscillator and divider U5. Q2 (pin 28) is the processor clock output which times the address and data transfers on the respective bus lines. Q1 is internal outside the chip.

4.8.4 Data I/O Latches.

The manner in which the data I/O latches are addressed has already been discussed. The purpose of the latches is to allow apparent continuous communication with the world outside the processor while it is essentially "asleep." All control data for the 1988 except for weighting and detector information is presented to the processor through the input data multiplexer.

These input data multiplexers on the -4705 board allow 24 signals to be applied to the 8-bit data bus. These bits of input information have been "mapped" as shown on Table 4-4. Each of the three input data multiplexers has four possible selected inputs for both of its two outputs. The data selection is performed by sequencing AB0 and AB1 through the possible combinations while the address decoder, U7, output Y0 is asserted.

In a similar manner, the output data latches supply information to 16 output lines when they are gated by the appropriate output Y1-Y3 of address decoder U7.

Output latch U11 has the special function of controlling the "wakeup" and "sleep" of the microprocessor.

Every 4.54 ms, the 220-Hz clock signal from U5 resets output latch U11 at pin 15, setting all outputs low. This signal is at the same time the input-enabler for U11 and the turn-on for processor power wakeup circuit Q9 and Q7. Since the decoder U7 is "asleep," with the processor output select line Y3 (pin 12, which is a second input enabler for U11) low, as the system "wakes up," U11 is ready to receive data. The "wake up" output from U11 is latched "ON" until the processor completes its task, at which point DB2 goes high and U11 is selected. Power to the processor ROM, and decode "LS" circuits is turned off and the processor goes to "sleep."

The 4.54-ms rate of wakeup in the processor is fundamental to the transfer rate of information from the output data latches. Many operations are performed on alternate wakeup cycles to balance "on" processing time of the microprocessor. Alternately, the A/D converter is strobed and read; thus, a measurement is made every 9.09 ms. If the printer output is enabled, a new bit is shifted out every other wakeup for a 9.09-ms rate, which is 110 baud. The four digital readout digit-select lines are scanned sequentially each wakeup so that it takes 18 ms for a complete display scan.

4.9 POWER SUPPLY.

4.9.1 Introduction.

The power supply consists of two basic parts; a dc-to-dc converter and a pulse-width-modulated switching regulator that surrounds the dc-to-dc converter.

4.9.2 DC to DC Converter.

Refer to Figure 6-15, Digital Board schematic, sheet 1. The dc input to the converter is a constant +2.8 V at the emitter of Q2 and Q3. Q2 and Q3 and transformer T1 are connected as a self-excited oscillator with a frequency of approximately 40 kHz. Positive feedback to the base of Q2 and Q3 is taken from the secondary of step-up transformer T1. CR 3-6 provide full-wave rectified positive and negative voltages of 6.4 V. The negative voltage is regulated directly; the positive voltage tracks the negative regulated voltage as a result of tight coupling in transformer T1. A voltage tripler composed of CR7, CR8 and C7 provide +18 V for the the preamplifier supply. Final regulation of this supply to +16 V is accomplished by series pass regulator Q8, Q13, and reference diode VR3. A second series pass regulator,

Table 4-4

1988 MEMORY MAP
I/O BIT ASSIGNMENTS*

	Hex Address	MSB 7	6	5	Bits 4	3	2	1	LSB 0
Data	0080	MAX	AD4	AD3	AD2	AD1	AD0	–	–
Inputs	0081	LEVEL	AD9	AD8	AD7	AD6	AD5	–	–
from	0082	PAUSE	START	PREN	RNG140	RNG120	RNG100	–	–
U9-U11 (1988-4705)	0083	CONT	AUTO	–	OVLD	BATCK	SEL	–	–
Data	0084	SEGA	SEGB	SEGC	SEGD	SEGE	SEGF	SEGG	PRINT
Outputs	0088	–	–	–	–	DS4	DS3	DS2	DS1
at U8-U11 (1988-4710)	008C	CONV	–	–	RESET	–	WAKEUP	–	DP

*For signal names, refer to signals on the 1988-4705 and 1988-4710 schematics (Section 6). Unassigned is indicated by –.

formed by Q6 and reference diode VR2 and CR10, supply the +5 V for the digital circuits.

4.9.3 Switching Regulator.

Refer to simplified Power Supply schematic, Figure 4-8. The output of the dc-to-dc converter is regulated by a switching regulator consisting of Q1, L1, CR2, C2, Q4, Q5, VR1 and C6. This type of regulator is a constant power supply and allows a wide range of battery input voltages. It is a step-down regulator that supplies a constant +2.8 V to the dc-dc regulator and to the digital display for constant brightness over the range of battery voltages. The regulating action is described as follows.

At power turn-on, Q4 is turned on with a small current from the battery (not shown with simplified schematic), which in turn switches on pass transistor Q1, slowly charging up filter capacitor C2 through inductor L1. As the +2.8 V line rises, the dc-dc converter is free to oscillate. A portion of these square-wave oscillations is fed to Q4 base through C6, which turns on Q4 at the positive edge of the oscillation period. As the negative 6.4 V rises to the sum of Q5 emitter-base voltage and Zener VR1, Q5 will conduct. This action removes base current from Q4, which in turn turns off pass transistor Q1. The inductor current cannot change instantly and the voltage at Q1 collector falls to -0.6 V; diode CR2 turns on to provide a path for inductor current. The inductor current falls gradually until Q1 is turned on again by the next dc-to-dc converter. The on-time of Q1 is determined by the amount of charge required to maintain constant voltage on C2 such that the negative voltage is held at -6.4 V. For a given load, which is relatively constant in the 1988, the input current reduces as the battery voltage increases.

4.10 COMPUTATIONAL ALGORITHMS

4.10.1 General.

The 1988 does much of its signal processing digitally. It operates on samples of the output of a short-time, rms-level detector. This detector has a response identical to FAST in a sound-level meter.

The 1988 integrates these samples digitally for longer integration times. The algorithms for this calculation are described below.

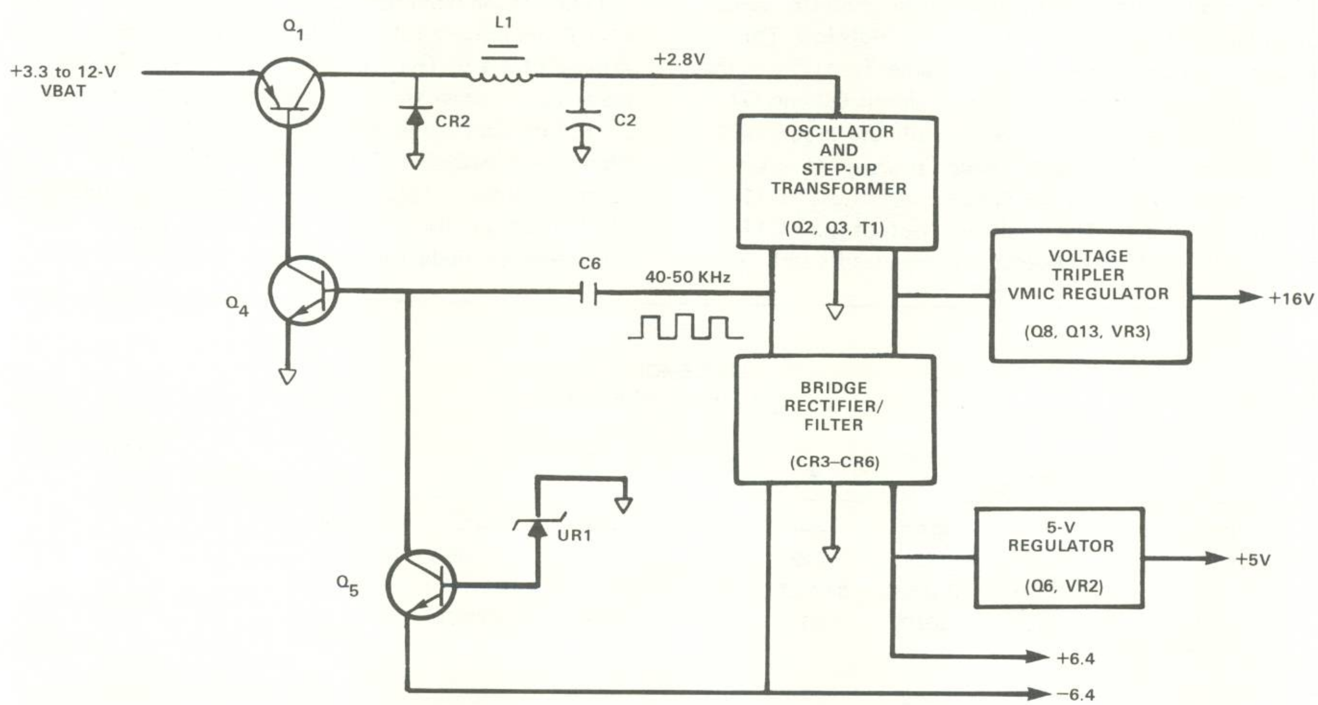


Figure 4-8. Simplified power supply schematic.

4.10.2 Integration Algorithms.

Sound-Pressure Level, SPL, is normally expressed in dB, relative to a reference pressure. The equation is given by:

$$SPL = 10 \log_{10} \frac{< p^2(t) >}{p_o^2}$$

Where $p(t)$ = instantaneous pressure variations in Pascals
p_o = the reference pressure of 20 μPa
and $< >$ denotes an averaging process.

In a practical application, either linear or exponential averaging can be used. Frequently, the pressure signal that is averaged is not the full bandwidth signal, but is first passed through a filter or weighting network. Then the result is called "sound level," and must be further qualified to indicate what filtering operation was performed.

The averaging performed by the 1988 is a two-stage process. The microprocessor performs computations equivalent to an integrator or RC averager operating on the output of a short-term RC averager, as shown in Figure 4-9.

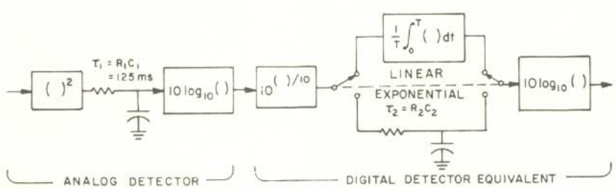


Figure 4-9. Block diagram of 1988 two-stage averaging.

For averaging times shorter than one second, the two-stage averaging gives results slightly different from the results produced by a single-stage averaging process, but for averaging times longer than one second, (the shortest integrating time in the 1988), the averaging performed by the microprocessor dominates.

4.10.3 Averaging Computations.

The primary computation performed by the microprocessor is to average the sound level over the prescribed period.

Linear averaging of the squared-pressure signal is performed by integrating the squared pressure for a time T, and dividing the integral by T to yield an average. This is usually referred to as the Equivalent Continuous Level, denoted by the symbol L_{eq}, and is defined by:

$$L_{eq}(T) = 10 \log_{10} \left[\frac{1}{T} \int_0^T \frac{p^2(t)\, dt}{p_o^2} \right]$$

Where $p(t)$ = instantaneous sound pressure
p_o = reference pressure of 20 μPa
T = integration time

This calculates a level only for a block of time. However, T may be treated instead as a variable; this allows a "running" L_{eq} to be calculated as T grows from 0 to some preset upper limit. That technique is used for the 1988 to allow intermediate results to be displayed.

The computation in the 1988 is actually performed with samples of the short-term sound level as

$$L_{eq}(T) = 10 \log_{10} \left[\frac{1}{N} \sum_{i=1}^{N} 10^{L_i/10} \right]$$

Where L_i = the i-th sample of sound level
N = total number of samples, which is given by $N = Tf_s$ where f_s is the sampling frequency.

The physical interpretation of L_{eq} is that it is the constant sound level, present for the integration time, T, which would have the same total energy as the sound being measured.

The linearly averaged sound level, L_{eq}, can be used to characterize short transients, but has a limitation in that application. If the integration time is longer than the transient, and the background noise is negligible, then the integral of squared pressure in the above formula is constant, but the average level will (decrease) if the integration time is increased. This result is physically correct, but hampers the comparison of transient signals which are measured with different integration times. A solution is to modify the calculation to produce a measure known as sound exposure level (SEL). Squared pressure is integrated over a time T, as above; however, the integral is divided by a reference time, T_{ref}, of one second instead of the integration time T

$$SEL = 10 \log_{10} \left[\frac{1}{T_{ref}} \int_0^T \frac{p^2(t)\, dt}{p_o^2} \right]$$

Where T_{ref} = 1 second

or from sound level samples:

$$SEL = 10 \log_{10} \left[\frac{1}{N_{ref}} \sum_{i=1}^{N} 10^{L_i/10} \right]$$

Where N_{ref} = f_s, the number of samples per second

4.11 1988 PROGRAM FLOW.

Figure 4-9 depicts the simplified general program flow for the 1988 processor. The main entry point occurs at power up only. Once the basic function has been established, the program loops through the preset path. When the user "resets" the function, the program flow changes to accept new mode setup information.

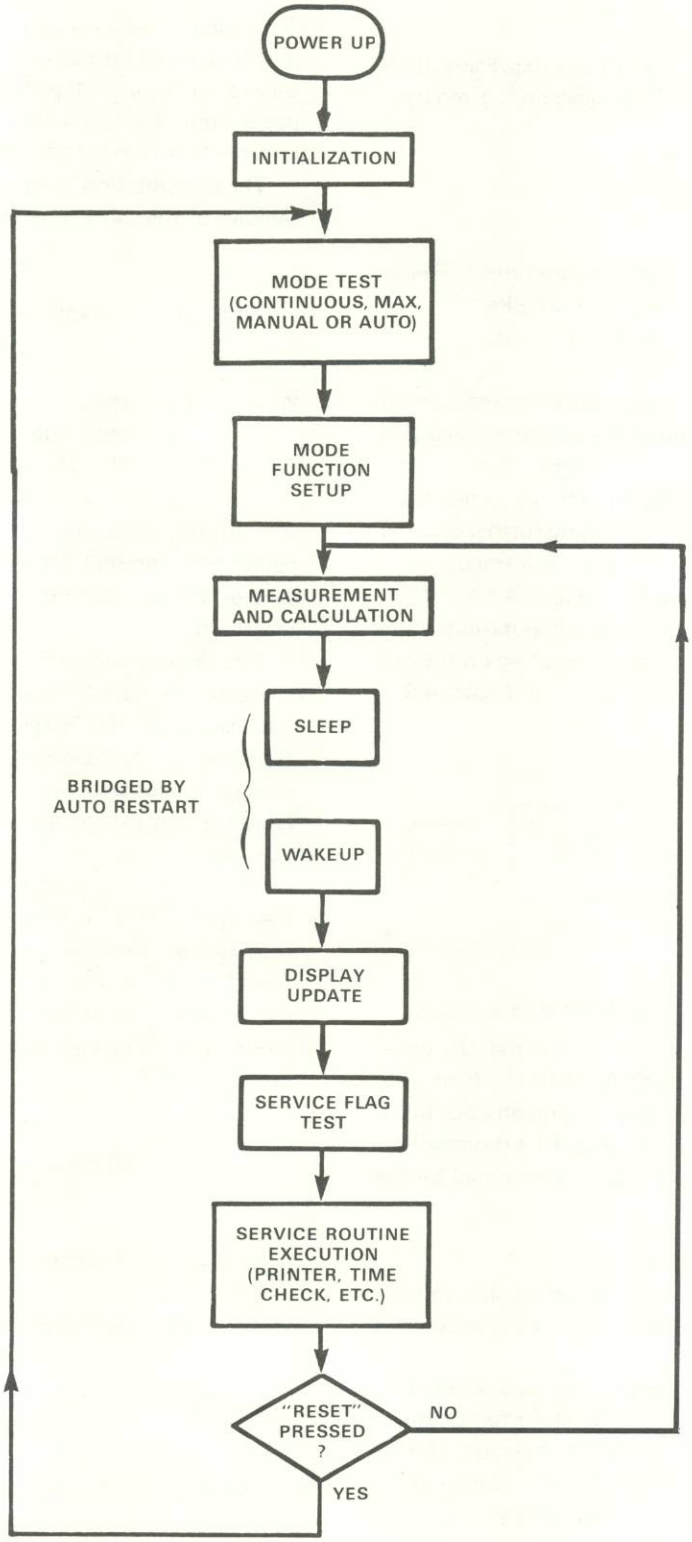


Figure 4-10. Program flow chart.