INSTRUCTION LETTER

SOUND SYSTEM DESIGN CALCULATOR
OPERATING INSTRUCTIONS

By
Mark Engebretson

The Altec Sound System Design Calculator is designed for calculation of the following factors:

1. **Sensitivity (dB SPL)** of a transducer at distances other than those for which it may have been rated.

2. **Inverse Square Law Problems** involving free-field attenuation at any distance from a sound source (as might be encountered out-of-doors).

3. **Power Change Required** to raise or lower a reference sound pressure level (SPL) when input power is known.

4. **Directivity Factor (Q)** of a sound source when Directivity Index (D_I) is known.

5. **Directivity Index (D_I)** of a sound source when Directivity Factor (Q) is known. (Directivity Index is the relative on-axis SPL of a sound source compared to the same sound source if it were radiating the same power omnidirectionally.)

6. **Room Constant (R)** of a space when the Surface Area (S) and Average Absorption Coefficient ($\overline{a}$) are known.

7. **Average Absorption Coefficient ($\overline{a}$)** of a space when Surface Area (S) and Room Constant (R) are known.

8. **Critical Distance (D_c)** from a sound source where an equal proportion of direct and reverberant energy exists, when Room Constant (R) and Directivity Factor (Q) are known.

9. **Required Q** for a space when Room Constant (R) and desired Critical Distance (D_c) are known.

10. **dB Loss** for any distance (r) in reverberant spaces having a given Room Constant (R) when the Directivity Factor (Q) of the sound source is known.

The scales for Surface Area (S) and Room Constant (R) on the side labeled **SOUND SYSTEM DESIGN CALCULATOR** and the scale for (R) on the **dB LOSS** side, use exponential notation to allow large numbers to be represented on the scale.

$10^1 = 10$

$10^2 = 100$

$10^3 = 1000$

$10^4 = 10,000$

$10^5 = 100,000$

$10^6 = 1,000,000$

HOW TO USE THE SIDE LABELED "SOUND SYSTEM DESIGN CALCULATOR"

This side can be used for the calculation of the factors normally assembled prior to calculation of Needed Acoustic Gain (NAG) and Potential Acoustic Gain (PAG).

AL-1110-1
LITHO IN U.S.A. CP-174-2K

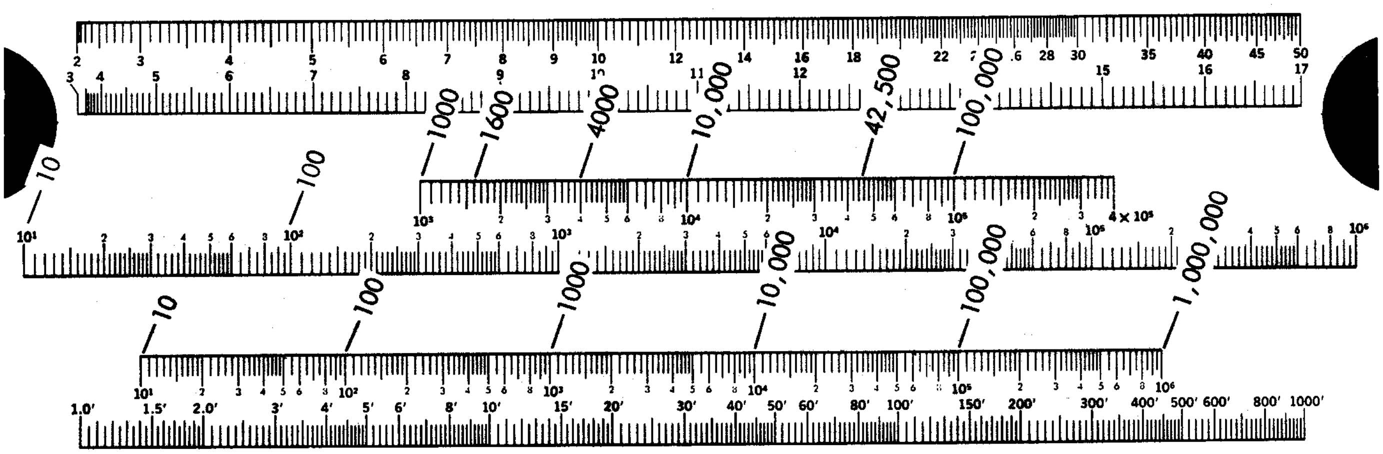
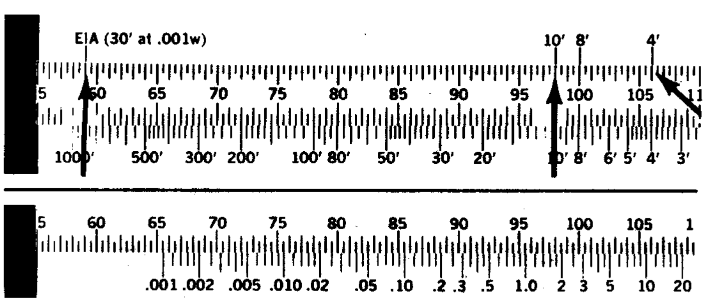


Figure 1. Scale Notation

Conversion of Sensitivity Data (dB SPL)

Assume a loudspeaker is rated to produce 106 dB SPL at 4 ft with 1 watt input. To convert this rating to a 10 ft sensitivity rating, set 106 on the scale marked **dB-SPL** below 4 ft on the scale marked **STANDARD RATING DISTANCES.** Read 98 on the scale marked **dB-SPL** below 10 ft on the scale marked **STANDARD RATING DISTANCES.** Similarly, the EIA sensitivity of the loudspeaker is read as 59 on the scale marked **dB-SPL** below **EIA (30' at .001w)** on the scale marked **STANDARD RATING DISTANCES.**



Set 106 dB SPL opposite 4 ft.

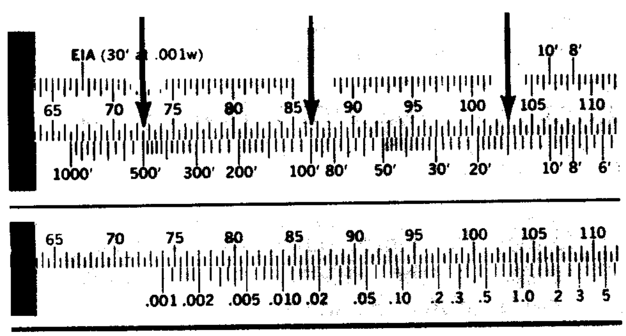
Below 10 ft, read 98 dB SPL.

Below EIA, read 59 dB SPL.

Figure 2. Conversion of Sensitivity Data

Inverse Square Law Problems

Use scales marked **dB-SPL** and **DISTANCE FEET** to determine free-field attenuation at any distance from a sound source. Set the reference sound pressure level on the **dB-SPL** scale over the near distance on the **DISTANCE FEET** scale. (For this example, assume 103 dB SPL at 15 ft).

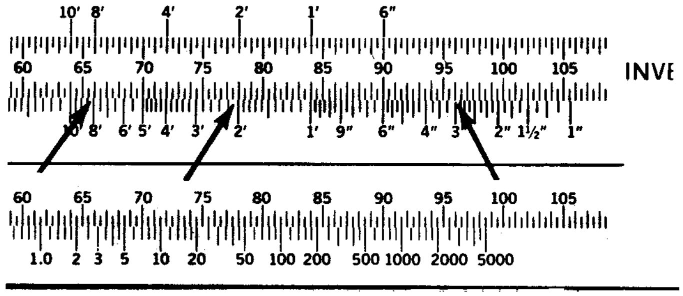


Set 103 dB SPL opposite 15 ft.

Read 86.5 dB SPL above 100 ft, 72.5 dB SPL above 500 ft, etc.

Figure 3. Calculating Free-Field Attenuation at Any Distance from A Sound Source

Microphone input levels may be similarly calculated. Assume an average of 78 dB SPL were measured 2 ft from a vocalist's lips. If a microphone were substituted for the sound level meter and moved to distances other than 2 ft, the resultant SPL at the microphone diaphragm may be calculated at any distance.



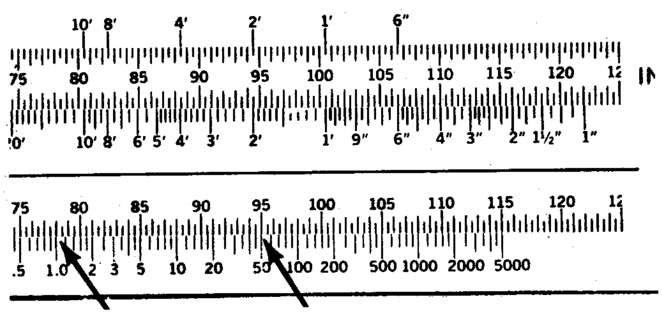
Set 78 dB SPL opposite 2 ft.

Read 96 dB SPL above 3 inches, 66 dB SPL above 8 ft, etc.

Figure 4. Calculating Microphone Input Level at Any Distance from A Sound Source

Power Change Required to Alter A Reference SPL

Use the scales marked **dB-SPL** and **POWER WATTS** to determine the power change required to raise or lower a reference SPL when input power is known. Assume a loudspeaker is producing 78 dB SPL with 1 watt of electrical input and 95 dB SPL is required. Set 78 on the scale marked **dB-SPL** over 1.0 on the scale marked **POWER WATTS.** Below 95 on the scale marked **dB-SPL,** read 50 on the scale marked **POWER WATTS.** 50 watts is the power required to raise the reference SPL from 78 dB to 95 dB.



Set 78 dB SPL opposite 1 watt.

Below 95 dB SPL, read 50 watts required.

Figure 5. Power Change Required to Alter A Reference SPL

Assume the physical conditions shown in Table I and Figure 6 exist in an actual building.

Table I. Physical Measurements

Parameter	Symbol	Value
Total Volume	V	= 500,000 ft^3
Total Surface Area	S	= 42,500 ft^2
Average Absorption Coefficient	$\bar{a}$	= 0.085
D_o Distance	D_o	= 155 ft
D_1 Distance	D_1	= 45 ft
D_2 Distance	D_2	= 150 ft
D_s Distance	D_s	= 2 ft
Equivalent Acoustic Distance	EAD	= 8 ft
Number of Open Microphones	NOM	= 1

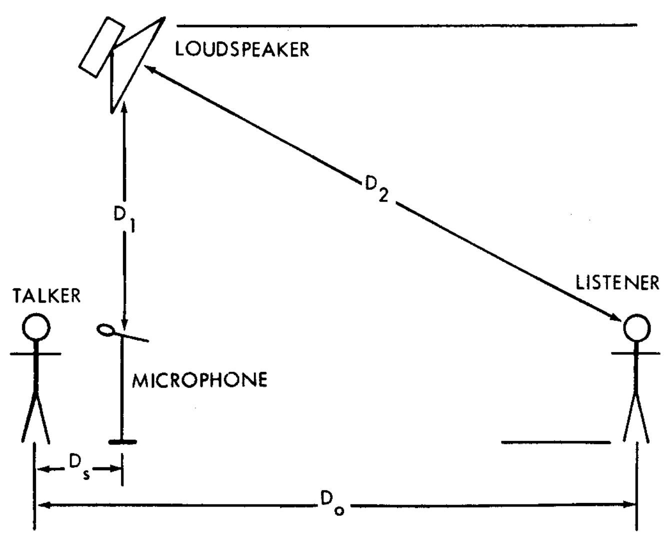
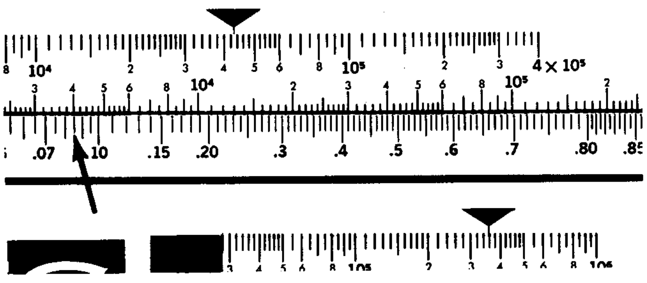


Figure 6. Physical Measurements Used in Single-Source Sound System Performance Calculations

Calculation of Room Constant (R)

Use the **ROOM CONSTANT** scale and set the Surface Area (**S**) of 42,500 square feet at the arrow. Locate .085 on the ($\bar{a}$) scale and read Room Constant of 4000 directly above on the (**R**) scale.



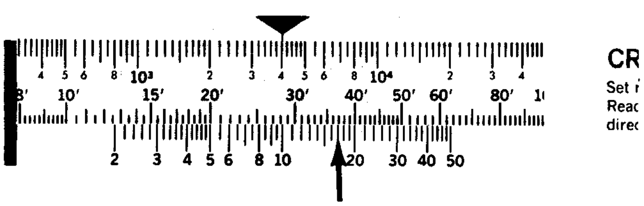
Set S = 42,500

Opposite the point where $\bar{a}$ = .085, read **R** = 4000.

Figure 7. Calculating **R**

Determination of Required Q

Since $D_2 \leqq 4D_c$ for acceptable articulation in the majority of cases, then for the purpose of determining the minimum Q for acceptable articulation, D_c can be assumed to be 1/4 of D_2. Use the **CRITICAL DISTANCE** scale and set the Room Constant (**R**) of 4000 at the arrow. Locate D_c of 37 ft (¼D_2) on the scale marked $\mathbf{D_c}$ and read required Q of 17 directly below on the scale marked **Q**. This value may be assumed as the lower limit or minimum value for Q.



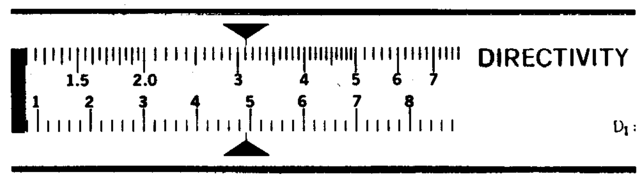
Set **R** = 4000.

Opposite the point where D_c = 37 feet, read Q = 17.

Figure 8. Determining Minimum Q Required

Directivity Index and Q

Set the value for Q (17) opposite the upper arrow on the **DIRECTIVITY** scale. The Directivity Index (**D_I**) of 12.3 dB may be read directly opposite the lower arrow.



Set **Q** = 17.
Read **D_I** = 12.3 dB directly opposite lower arrow.

Figure 9. Determining Directivity Index or Directivity Factor

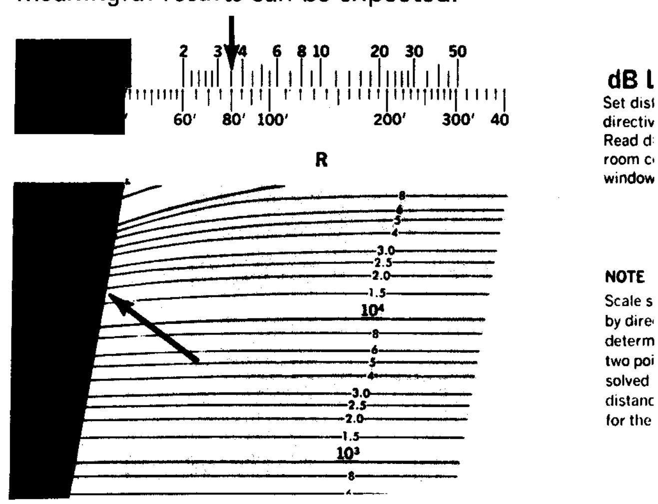
HOW TO USE THE REVERSE SIDE OF THE CALCULATOR

Determining dB Loss in Reverberant Environments

Reference side two of the calculator and use the **dB LOSS** scale to determine loss in dB for any distance (**r**) from a sound source when the Directivity Factor (**Q**) and the Room Constant (**R**) are known.

Assume a loudspeaker with a Q of 3.5 and a Room Constant (R) of 20,000. To determine the relative loss at 80 ft, set 80 ft on the (**r**) scale opposite 3.5 on the (**Q**) scale in the upper window. Select the curved line that represents a Room Constant (**R**) of 20,000 (2.0 x 10^4). Follow the line to the **dB LOSS** scale to read relative loss of – 36 dB.

Remember, this is a *relative* loss value, and assumes that inverse square law will prevail to a distance less than 1 ft from the actual source. In actual circumstances, this would place the reference well within the near field of the loudspeaker, and hence the value in dB will be useful *only* when it is compared to a loss value taken at a distance where meaningful results can be expected.



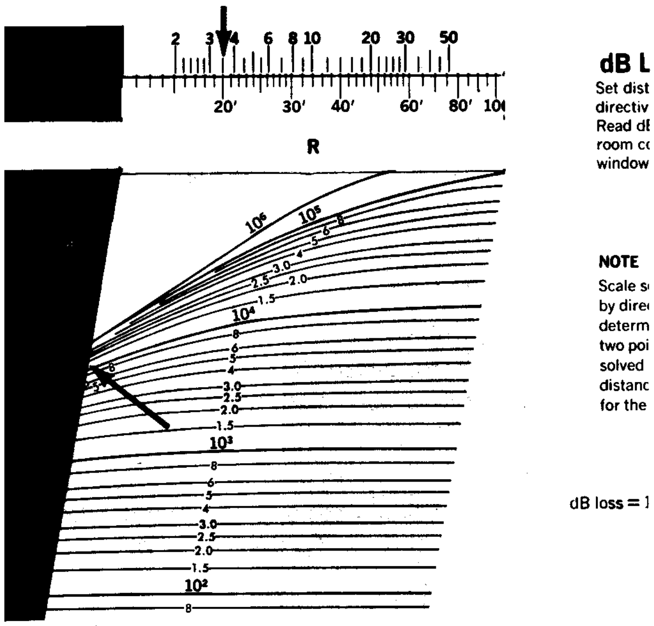
Set **r** = **80 ft opposite Q = 3.5**

Enter scale **R** at 20,000 (2.0 x 10^4)

At intersection of R = 20,000 and **dB LOSS**, read – **36 dB**

Figure 10. Relative dB Loss

Assume the same loudspeaker was generating 80 dB SPL at a distance of 20 ft, in the same space.



Set **r** = 20 ft opposite **Q** = 3.5

Enter scale **R** at 20,000 (2.0 x 10^4)

At intersection of **R** = 20,000 and **dB LOSS**, read – 30 dB

Figure 11. Relative dB Loss

Because both distances assume the same acoustic center for the source, the absolute loss in dB under these conditions will be:

SPL at D_F = SPL at D_N – (Relative Loss at D_F – Relative Loss at D_N

where D_F = Far Distance and D_N = Near Distance.

In the example, these values become:

SPL at D_F = 80 dB SPL – (36 dB – 30 dB) = 74 dB SPL

The above equation may be transposed to find the dB increase at distances shorter than the reference distance.

NOTE

The dB LOSS scale solves the attenuation formula:

$$\text{dB LOSS} = 10 \log_{10} \left[\left(\frac{Q}{4\pi r^2}\right) + \left(\frac{4}{R}\right)\right]$$

The term $f(D_x)$ implies the use of this formula in calculating Potential Acoustic Gain **(PAG)** and Needed Acoustic Gain **(NAG)** for indoor sound systems. For outdoor (free-field) calculation of **PAG** and **NAG**, the term $f(D_x)$ implies use of the following formula:

$$\text{dB LOSS} = 20 \log_{10} \left(\frac{D_N}{D_F}\right)$$

Use of the dB LOSS Scale for Sound System Design Equations

The equations for Needed Acoustic Gain **(NAG)** and Potential Acoustic Gain **(PAG)** add and subtract dB values for distances that assume a common reference distance. The relative loss values may therefore be used directly to find **NAG** and **PAG**.

Using the physical measurements from Table I and Figure 6, calculate Needed Acoustic Gain **(NAG)** and Potential Acoustic Gain **(PAG)**.

STEP 1

First, determine the values for Room Constant (**R**). See Figure 3.

Set **S** = 42,500.

Opposite the point where $\bar{a}$ = .085, read **R** = 4000.

STEP 2

Determine the required Directivity Factor (**Q**) that will allow the distance between the loudspeaker and listener (**D_2**) to be equal to four times Critical Distance (**D_c**).

Critical Distance may be assumed to be ¼D_2 for calculation of minimum Directivity Factor (**Q**). See Figure 8.

D_c = ¼D_2.

Set **R** = 4000.

Opposite the point where **D_c** = 37 ft, read **Q** = 17.

STEP 3

Given the factors of Room Constant (R) and Directivity Factor (Q), relative losses for the various distances that appear in the gain formulas may be calculated. Using the method described in Figure 10, convert the factors of D_o, D_1, D_2, D_s and EAD from feet to relative losses in dB.

D_o = 155 ft = – 30 dB

D_1 = 45 ft = – 28 dB

D_2 = 150 ft = – 30 dB

D_s = 2 ft = – 5 dB

EAD = 8 ft = – 17 dB

Needed Acoustic Gain (NAG) may be found by substituting the dB relative loss values.

NAG = $f(D_o) - f(EAD)$

NAG = 30 dB – 17 dB = 13 dB

Potential Acoustic Gain (PAG) may be found by a similar calculation.

PAG = $f(D_1) + f(D_o) - f(D_s) - f(D_2) -$ 10 log NOM – 10 dB

PAG = 28 dB + 30 dB – 5 dB – 30 dB – 0 dB – 10 dB = 13 dB

NOTE

10 log NOM may be calculated using the Altec Inverse Square Law Calculator, or by the following rule-of-thumb.

Number of Open Microphones	dB Gain Reduction
1	0
2	3
3	4 ½
4	6
8	9
16	12
etc.	etc.

Since **PAG** is equal to **NAG**, the proposed sound system will be capable of meeting the owner's requirements.

SUMMARY

The examples illustrated are intended as a brief introduction to the Sound System Design Calculator. A wide variety of sound system design problems can be quickly and accurately solved with practice.