Engineering News

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A Division of LTV LING ALTEC, INC.

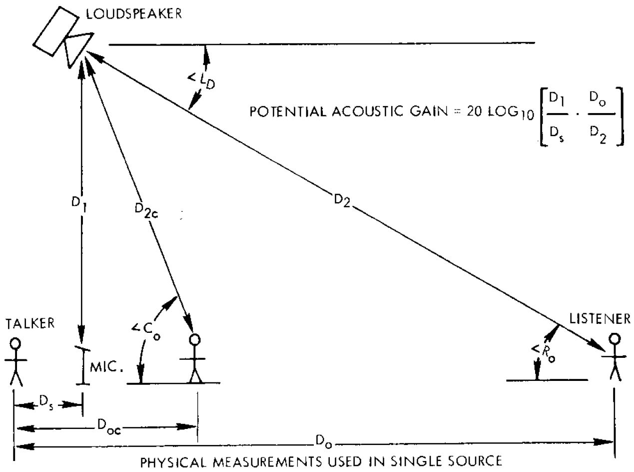
TECHNICAL LETTER NO. 181

INVERSE SQUARE LAW CALCULATOR

By Don Davis

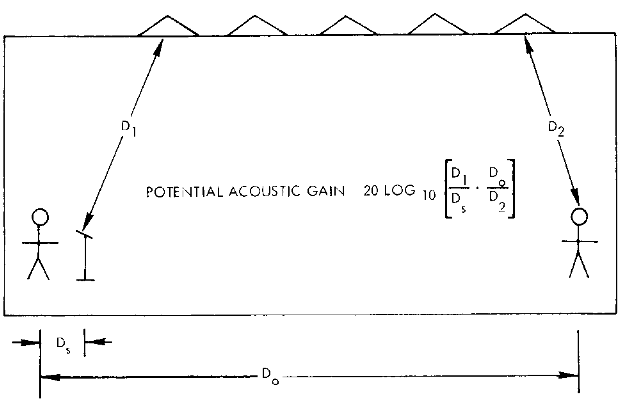
SOLVING TYPICAL SOUND SYSTEM PROBLEMS WITH THE ALTEC INVERSE SQUARE LAW CALCULATOR

The Altec inverse square law calculator can be used to quickly find each of the parameters shown in Figures 1 and 2.



PHYSICAL MEASUREMENTS USED IN SINGLE SOURCE SOUND SYSTEM PERFORMANCE CALCULATIONS

Figure 1



PHYSICAL MEASUREMENTS USED IN DISTRIBUTED SOUND SYSTEMS PERFORMANCE CALCULATIONS

Figure 2

For ease of identification, the side of the calculator containing the title "Inverse Square Law Calculator" is herein referred to as Side One (see Figure 3).

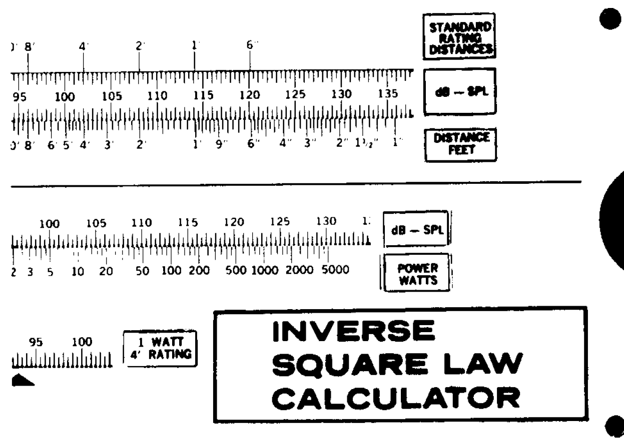


Figure 3

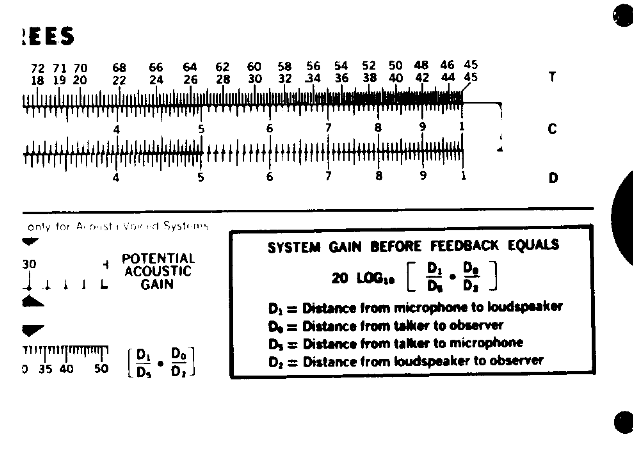


Figure 4

And the side containing the system-gain-before-feedback formula in the lower right hand corner is herein referred to as Side Two (see Figure 4).

Solving D_0 Loss in dB

1. With a tape measure, physically measure the distance in feet from the talker to the listener (usually the most remote listener).

2. Using Side One of the calculator, select an arbitrary reference point (100 on the dB-SPL scale) and place it opposite 2' on the Distance Feet scale.

3. On the Distance Feet scale, find the distance in feet equal to the measured D_0 distance (100' for example). Directly above this distance on the dB-SPL scale read the dB figure (see Figure 5).

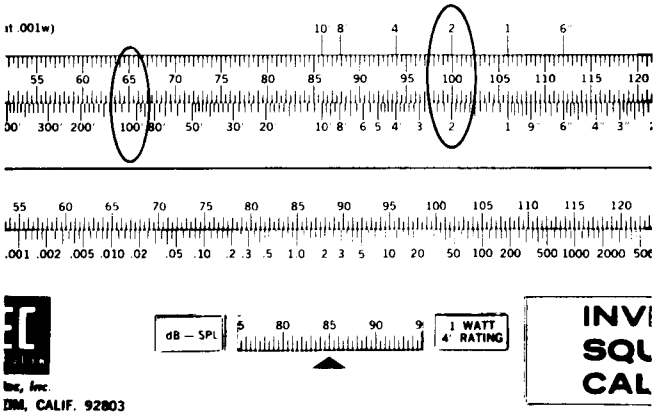


Figure 5

The D_0 loss is 100 dB - 66 dB = 34 dB.
The reference distance of 2' is used because it is the normal talker-to-microphone reference distance for the initial calculation of the potential acoustic gain of any sound system.

Solving D_2 Loss in dB

Because in many cases the proposed loudspeaker location is often inaccessible, it is necessary to calculate the D_2 distance from a set of physical measurements that can be acquired with the tools at hand. By using the tape measure and an inclinometer to make the physical measurements, and by using the calculator to solve the equation for D_2, the unknown distance can be quickly found.

1. Find a convenient spot in the audience area from which to view the proposed loudspeaker location through the view-finder of the inclinometer. Center the inclinometer bubble in the cross hair of the view-finder and record the angle (37 degrees, for example).

2. Using Side Two of the calculator find 37 degrees on the "T" scale. Opposite this angle read the number on the "D" scale — 37 degrees = 0.75 (see Figure 6).

3. With a tape measure, measure the distance in feet from the viewing position to a point directly under the proposed loudspeaker location (40 feet, for example). The tangent of 37 degrees is therefore equal to $\frac{x}{40}$, where x equals the height of the proposed loudspeaker array

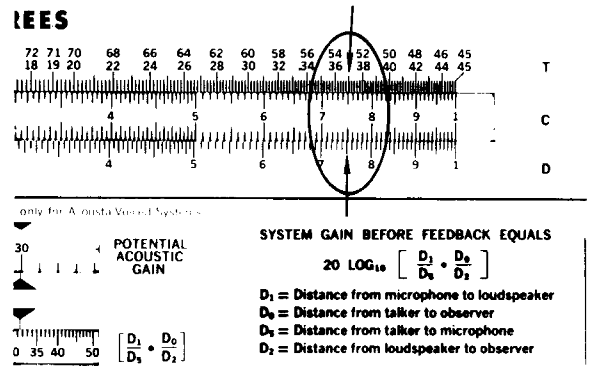


Figure 6

above the height of the viewer's eye level. Since it was already found from the calculator that the tangent of 37 degrees = 0.75, then 0.75 = $\frac{x}{40}$.

4. Again, using Side Two of the calculator, place 100 on the "C" scale opposite 75 on the "D" scale and then find what number appears on the "D" scale opposite 40 on the "C" scale (see Figure 7).

NOTE

1 on the slide rule scale can equal 1, 10, 100, 1000, or 0.1, 0.01, 0.001, etc.

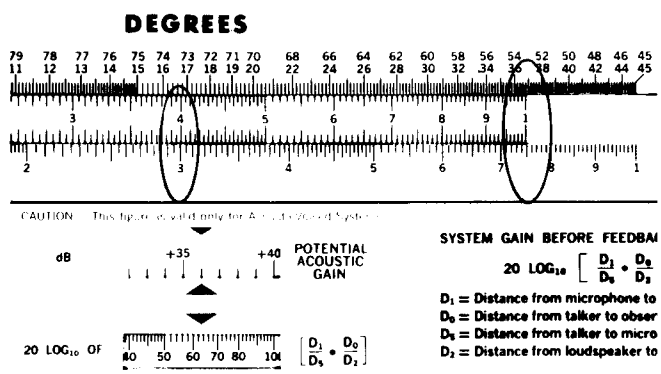


Figure 7

5. Be sure to add the distance from the floor to the viewer's eye (5 feet in this case), making the total height of the array 35 feet above the floor.

6. 40' and 35' provide the base and height respectively of a right triangle. Use Pythagoras' theorem to find D_2. This theorem states that the sum of the squares of the two sides of a right triangle are equal to the square of the hypotenuse; therefore $35^2 + 40^2 = (D_2)^2$.

Use nomograph of Figure 8 to solve this equation.

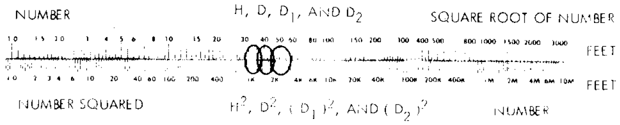


Figure 8

$35^2 = 1225$, $40^2 = 1600$; $1225 + 1600 = 2825$. The $\sqrt{2825} = 53.15$ feet. Therefore, $D_2 = 53$ feet. Accuracy to within a foot or so is more than adequate for the purpose for which the measurement is being used.

7. The final calculation of distance D_2 into dB loss is accomplished by using Side One of the calculator and placing 100 on the dB-SPL scale opposite 4' on the Distance Feet scale. (Four feet is used here because that is the distance at which Altec speaker efficiency is quoted.)

8. Finding 53 feet on the Distance Feet scale, read directly above it on the dB-SPL scale 77.5 dB. 100 dB - 77.5 dB = 22.5 dB loss for a D2 distance of 53 feet. (see Figure 9).

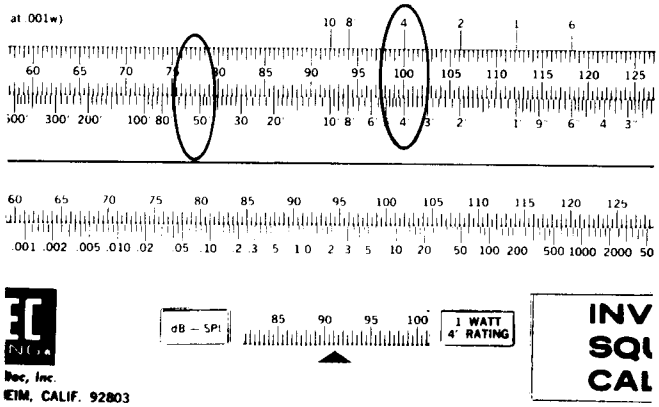


Figure 9

Solving Variations of D_1 and D_2 Losses in dB

D_{2c} and D_1 distances can be solved in the same manner as D_2 distance by first calculating the height of the array from the floor, followed by finding the length of the hypotenuse that constitutes the D_1 or D_{2c} distance.

Calculation of Potential Acoustic Gain

1. Using Side Two of the calculator, place 1 on the "C" scale over the D_1 distance on the "D" scale. Find the D_o distance on the "C" scale and record the figure that appears directly below it on the "D" scale. For example, $D1 = 35'$, $D_o = 40'$, number = 1400. (see Figure 10).

2. Now, place the 1 on the "C" scale over the 2 on the "D" scale. Find the D_2 distance on the "C" scale and read directly below it the number on the "D" scale. For example, $2 \times 53 = 106$ (see Figure 11).

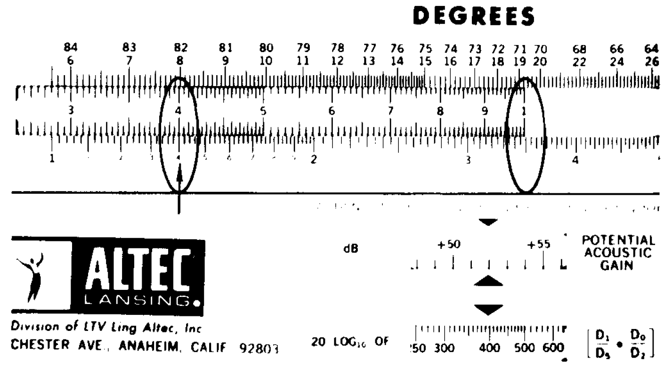


Figure 10

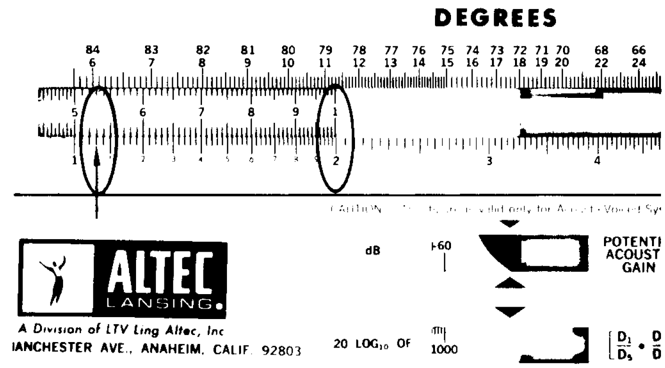


Figure 11

3. Find 1400 on the "D" scale and place 106 on the "C" scale directly above it. Opposite 1 on the "C" scale, read the number on the "D" scale. For example, $\frac{1400}{106} = 13.2$ (see Figure 12).

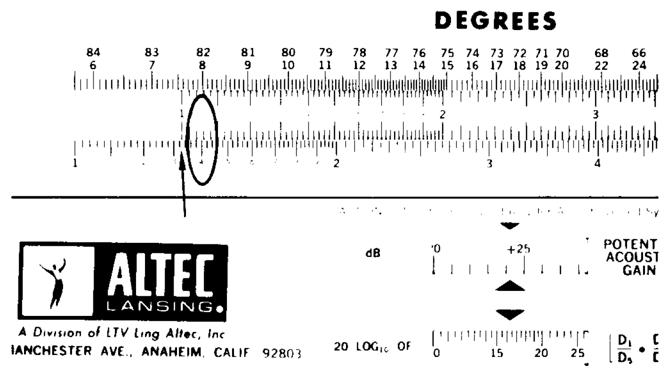


Figure 12

4. Enter this number in the window marked

$$20 \log_{10} \text{ of } \boxed{} \left[\frac{D_1}{D_s} \cdot \frac{D_o}{D_2}\right]$$

and read the potential acoustic gain in dB in the window so marked. Potential acoustic gain in this case ≅ 22 dB (See Figure 13).

> **CAUTION**
>
> This figure is easily achieved when Altec Acousta-Voicing™ filters are correctly tuned. It cannot be obtained in untuned systems where the actual gain is usually from 10 dB to 20 dB less than the calculated figure.

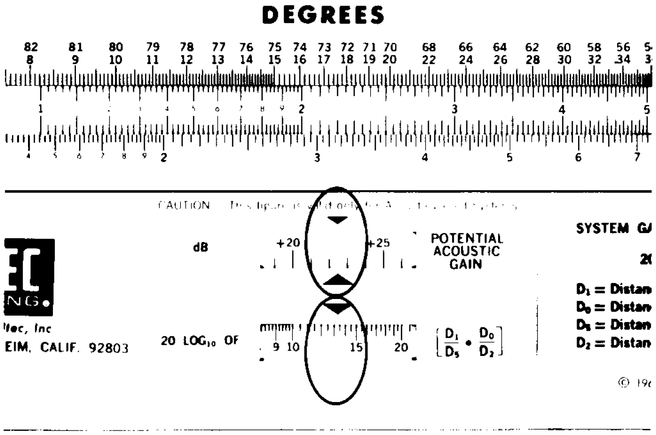


Figure 13

Calculation of Loss from use of Multiple Microphones open Simultaneously

Since the loss incurred from opening a number of microphones at the same time follows the same mathematical rule as does power ($10 \log_{10} \frac{N_1}{N_2}$), use the dB-SPL scale and the Power Watts scale to calculate this loss in dB. For example, a conference room needs 12 open microphones. What must be subtracted from the potential acoustic gain figure to accommodate this condition?

Using Side One of the calculator, place 100 on the dB-SPL scale opposite 12 on the Power Watts scale. Read the dB figure in the window marked dB-SPL [ ] 1 Watt 4' Rating. Subtract this figure from 100 dB. Then 100 dB - 89 dB = 11 dB loss for 12 open microphones (see Figure 14).

This is the number of dB that must be subtracted from the potential acoustic gain figure to insure realistic calculations of available amplification gain.

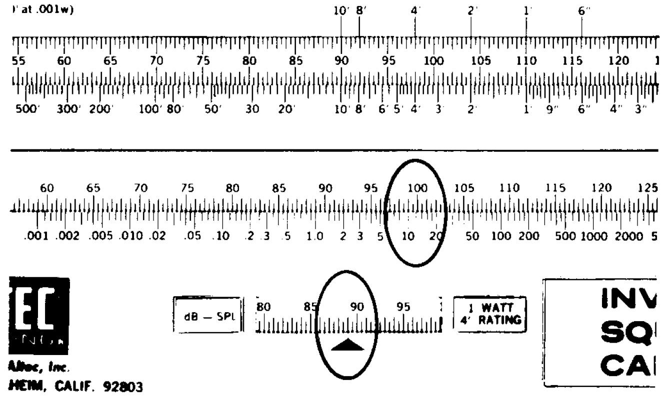


Figure 14

Calculating Increases or Decreases in Acoustic Gain for D_s Distances other than Two Feet

1. Using Side One of the calculator, place 100 on the dB-SPL scale opposite 2' on the Distance Feet scale.

2. For D_s distances greater than 2' on the Distance Feet scale, subtract the number on the dB-SPL scale opposite the number on the Distance Feet scale from 100. This is the additional loss caused by increasing the D_s distance (see Figure 15).

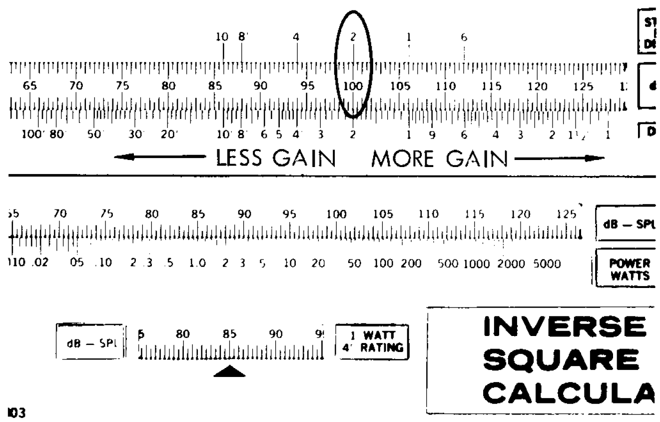


Figure 15

3. For D_s distances less than 2', follow the same procedure as step "1" above and opposite the shorter D_s distance on the Distance Feet scale, read the dB on the dB-SPL scale. The figure reading, minus 100, is the additional acoustic gain available due to the shorter D_s distance.

> **CAUTION**
>
> Note that for distances of less than one foot, the Distance Feet scale is calibrated in inches rather than feet.

Calculation of Electrical Power Required to Achieve Needed Acoustic Level

The power that any loudspeaker will require is a function of its own efficiency rating and the D_2 loss in dB to the furthest seat it must cover. Knowing the D_2 distance enables calculation of the D_2 distance loss in dB as shown above. Knowing the talker's level at a microphone diaphragm placed two feet in front of him gives the desired acoustic level at the most remote seat. For example, desired acoustic level = 80 dB-SPL, and D_2 distance loss = -23 dB. The loudspeaker has a true efficiency rating of 99 dB-SPL at 4' from one watt.

Using Side One of the calculator, set 99 dB at the arrow in the window marked dB-SPL [ ] 1 Watt 4' Rating. Add the desired acoustic level (80 dB) plus the D_2 distance loss in dB (23 dB) plus the peaking factor (10 dB) for a total figure of 113 dB-SPL. This is the acoustic level required at 4' from the loudspeaker. Locate 113 dB on the dB-SPL scale associated with the Power Watts scale. Directly below 113 dB on the Power Watts scale, (see Figure 16) read the required electrical power necessary to achieve this acoustic level at 4' (approximately 25 watts).

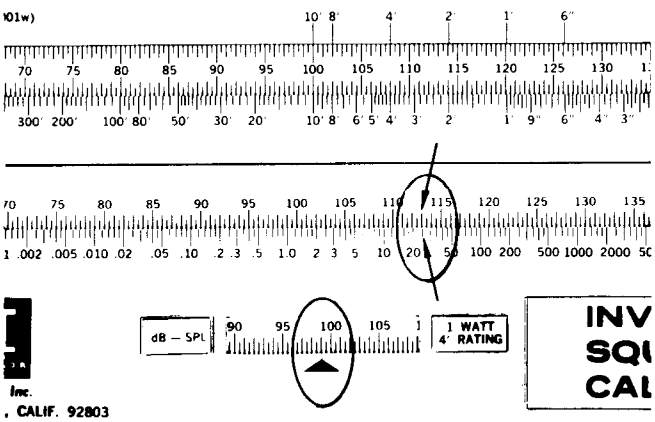


Figure 16

Calculating Delay Time in Milliseconds

The difference in arrival time of the sound from the talker and the reinforced sound from the loudspeaker can be handled by measuring the distance (in feet) from the loudspeaker to the listener (D_2 distance) and the distance from the talker to the listener (D_0 distance). The difference in feet between these two measurements can then be converted into time difference in milliseconds by using Side Two of the calculator (see Figure 17).

1. Sound travels 1130'/sec; therefore, 1' equals 0.885 milliseconds. Place 1 on the "D" scale opposite 885 on the "C" scale.

2. For a path length difference of 70' on the "D" scale, read opposite it on the "C" scale 62 milliseconds.

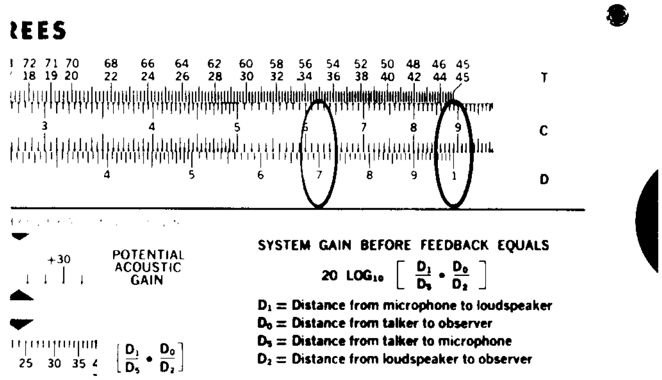


Figure 17

It should always be remembered that delay time alone is not the only factor to consider before installing a time delay device. The relative acoustic levels must also be examined (see "Engineering Loudspeaker Locations").

CAUTION

Delays occasioned by the talker being closer than the loudspeaker cannot be corrected with time delay devices.

SUMMARY

The foregoing examples are only a few of the many types of calculations for which this calculator can be used. Like all similar devices, persistent initial practice soon makes it a thoroughly familiar and very useful tool. This Altec Inverse Square Law Calculator, used in conjunction with Altec's Power Equation Calculator (designed by Paul B. Spranger of Altec's Engineering Department) equips you to solve any calculation pertinent to the proper design of an Altec Lansing engineered sound system.