Engineering News

ALTEC

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TECHNICAL LETTER NO. 213

USING THE G.R. 1564 ANALYZER TO MEASURE THD

ALTEC professional loudspeakers exhibit gratifyingly low acoustic distortion at typical auditorium program levels. This can be measured by using the G.R. 1564 analyzer as a 1/10-octave wave analyzer. The "skirts" on the 1/10-octave tunable bandpass filter in the G.R. 1564 analyzer are better than -45 dB at $\frac{f}{2}$ and 2f, thereby allowing measurements down to 1%. 40 dB = 100/1 ratio.

Acoustic Conditions Necessary for Measurement

At least 50 dB of signal-to-ambient-noise ratio is required over the frequency range of the measurements. The input level to the loudspeaker should be at least 10 dB below full rated input power. Normally, the measurement must be made in the audience area so that distances up to 100 feet from the loudspeaker are encountered. This means the attenuation from 4 feet to the distance at which the measurement is to be made should be ascertained either by measurement or by calculation.

An Example of a Typical Measurement Environment

Figure 1 shows the ambient noise level in an auditorium. From 100 Hz upward, the ambient noise level in 1/3-octave bands is not more than 48 dB SPL and is below 40 dB SPL over much of the range. This means the signal level at the measuring point in the audience area should be 48 dB SPL + 50 dB to obtain a signal-to-noise-ratio = 98 dB SPL.

EXAMPLE — In a room with the following parameters:

$V = 500{,}000 \text{ ft}^3$

$S = 42{,}500 \text{ ft}^2$

$\bar{a} = 0.12$

Measuring distance = 70 ft

Loudspeaker Q = 10

Litho in USA CP-872-2.5K

then the SPL at 4' from the loudspeaker would need to be:

$$10 \log_{10} \left[\left(\frac{10}{4 \pi 16}\right) + \left(\frac{4}{5795.45}\right) \right] = \Delta 4' = -12.97 \text{ dB}$$

$$10 \log_{10} \left[\left(\frac{10}{4 \pi 4900}\right) + \left(\frac{4}{5795.45}\right) \right] = \Delta 70' = -30.69 \text{ dB}$$

$$\Delta 70' - \Delta 4' = (-30.69) - (-12.97) = -17.72 \text{ dB}$$

The required SPL at the measuring point must be added to the attenuation between four feet and the measuring point to obtain the required SPL at 4' from the loudspeaker:

$$98 + 17.72 = 115.72 \text{ dB SPL}$$

If an 803B with a 291-16 driver is used, Technical Letter 203 shows that its maximum input power is 40 watts and that 10 dB below 40 watts is four watts. It is rated at 110 dB SPL at 4' with 1 electrical watt input. Therefore, with 4 electrical watts input, it will generate $10 \log_{10} \left(\frac{4}{1}\right) = 6.02$ dB more SPL or a total of 110 dB + 6 dB - 116 dB SPL. This figure allows a 1 dB margin in meeting the dynamic range requirement (50 dB signal-to-noise ratio) at a power level 10 dB below full rated input power (4 watts).

Measuring the Fundamental and Its Harmonics

Figure 2 shows the equipment setup for the measurement of harmonic distortion.

EXAMPLE: Choose 1000 Hz as the initial test frequency. Adjust the oscillator and power amplifier level controls until 116 dB SPL is read at the measuring point, (or whatever other level is required to meet the 50 dB signal-to-noise at 10 dB below full rated input power). Adjust the G.R. 1564 wave analyzer in its 1/10-octave mode until the full-scale reading on the meter is obtained. If a graphic level recorder is used, adjust for full scale on the chart (see Figure 3). Next, turn only the frequency dial on the G.R. 1309A to 2000 Hz (2f) and using the attenuators on the G.R. 1564 wave analyzer get as near a full-scale reading on the meter as possible. Record how many dB below the reference signal this signal is. The graphic level recorder is mechanically interconnected to the wave analyzer and swept at low speed to obtain an automatic readout such as that shown in Figure 3.

Calculating THD, Method 1

Having obtained how far below the fundamental each harmonic lies in dB, this information must then be converted into total harmonic distortion (THD) in percent. First, combine levels in dB. Use the graph of Figure 4 to combine levels in dB. Since 1% = 40 dB down, harmonic 1 is either -36 dB compared to the fundamental or 4 dB above 1%. Harmonic 2 is either -25 dB compared to the fundamental or 15 dB above 1%. Therefore, 15 dB - 4 dB = a difference of 11 dB. Figure 4 shows the THD is then 15 + 0.3 dB or 15.3 dB above 1% as a result of combining harmonic 1 with harmonic 2. When combined, -40 dB + 15.3 dB = -24.7 dB below the fundamental. Use Figure 5 to find that -24.7 dB = 5.82% THD. Method 1 was developed by Hannon Engineering, Los Angeles, for use by their field engineers.

Calculating THD, Method 2

Method 2 uses the same basic data in a slightly different way. Figures 6 and 7 detail this second method (Bruel & Kjaer).

Formulas used in THD Calculations

The formula for combining levels expressed in dB is:

$$CNL = 10 \log_{10} \left[\left(\text{antilog}_{10} \frac{db}{10} \right)_1 + \left(\text{antilog}_{10} \frac{db}{10} \right)_2 + \cdots \left(\text{antilog}_{10} \frac{db}{10} \right)_n \right]$$

The formula for THD after levels in dB have been combined is:

$$THD = \sqrt{\frac{10{,}000}{\text{antilog}_{10} \frac{dB}{10}}}$$

For those users of the H.P. 35 pocket calculator, Figures 8 and 9 detail these calculations.

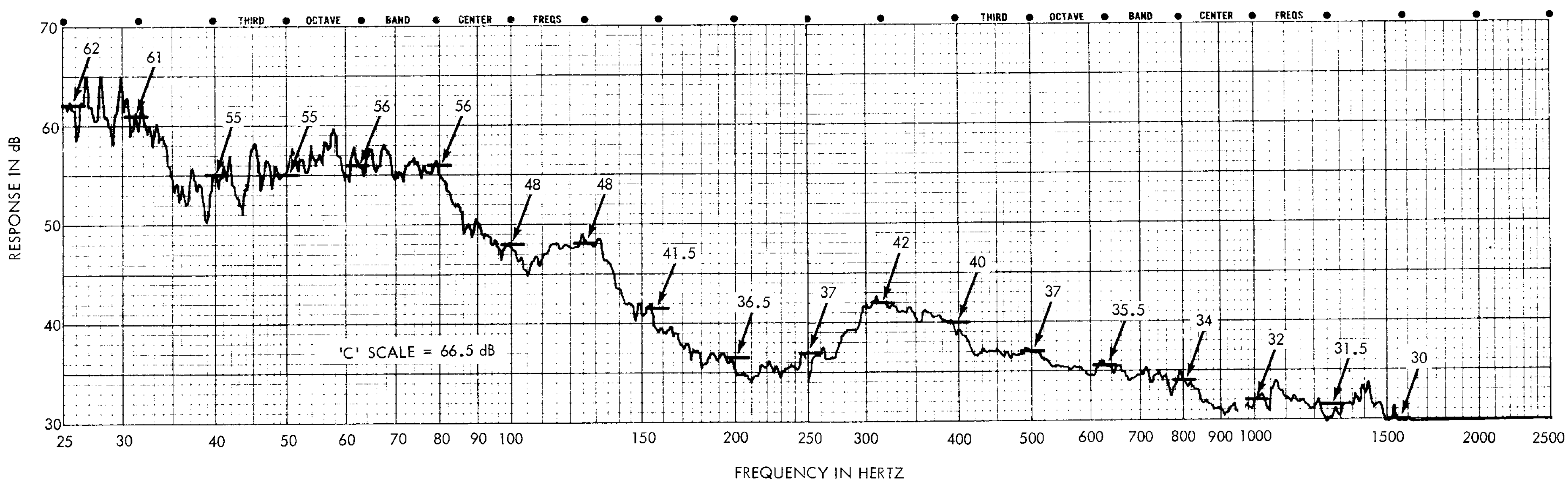


Figure 1. Ambient Noise Level in an Auditorium

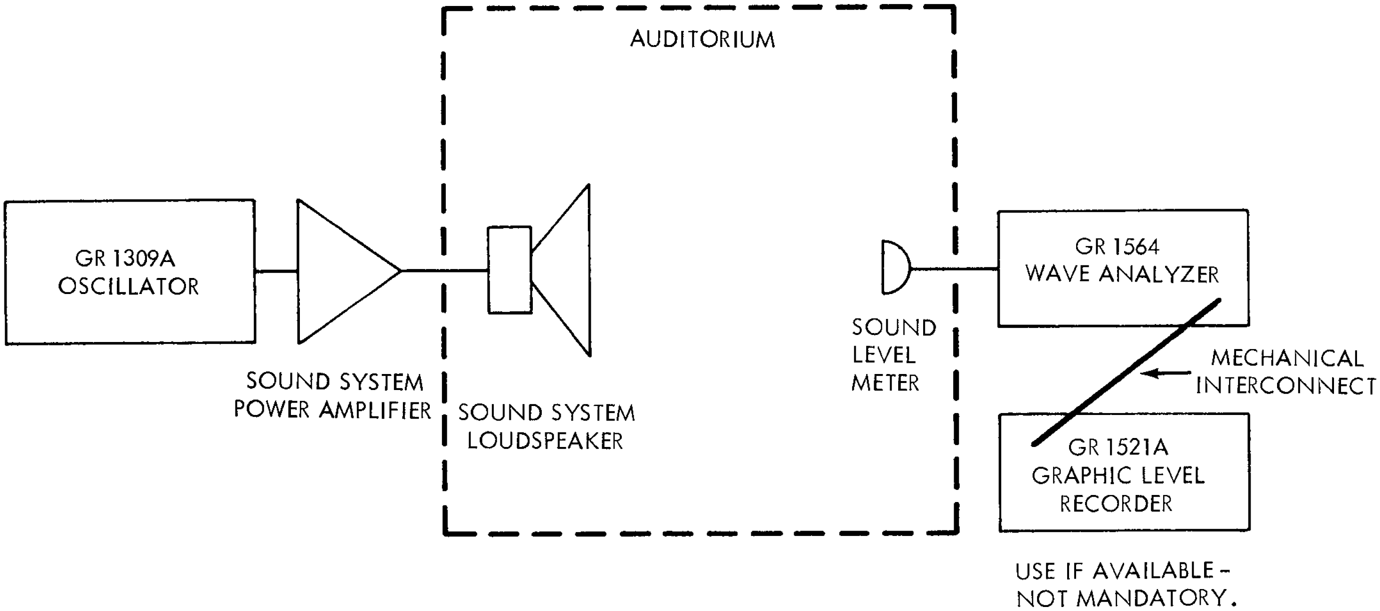


Figure 2. Measuring Harmonic Distortion

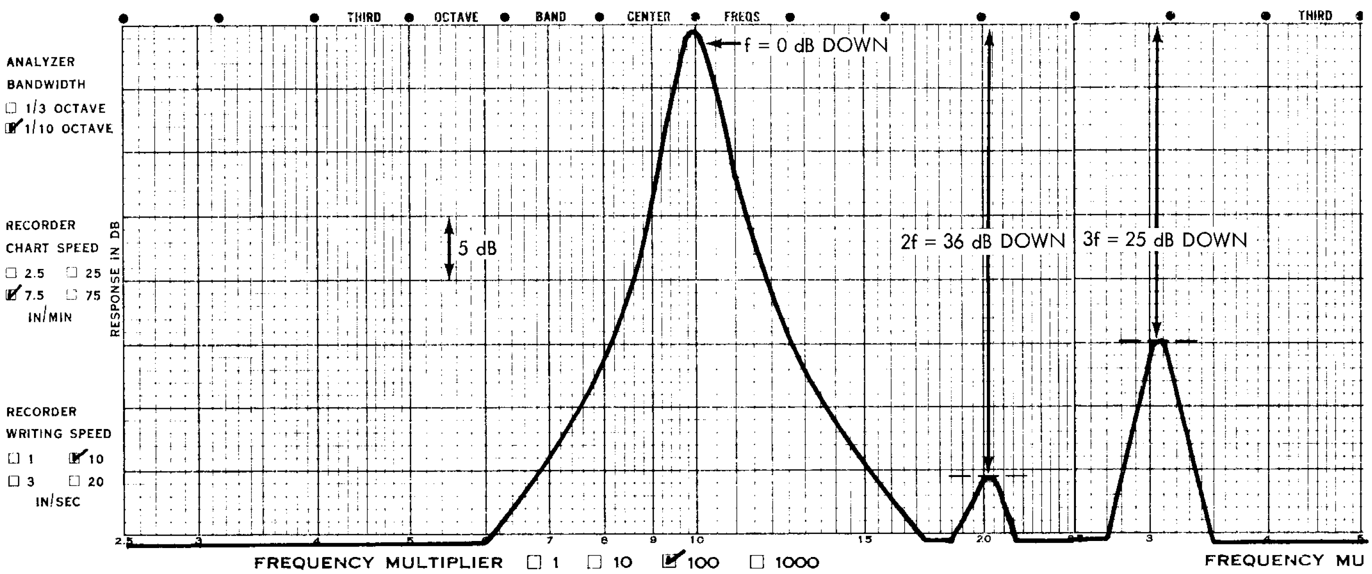


Figure 3. Readout from Graphic Level Recorder

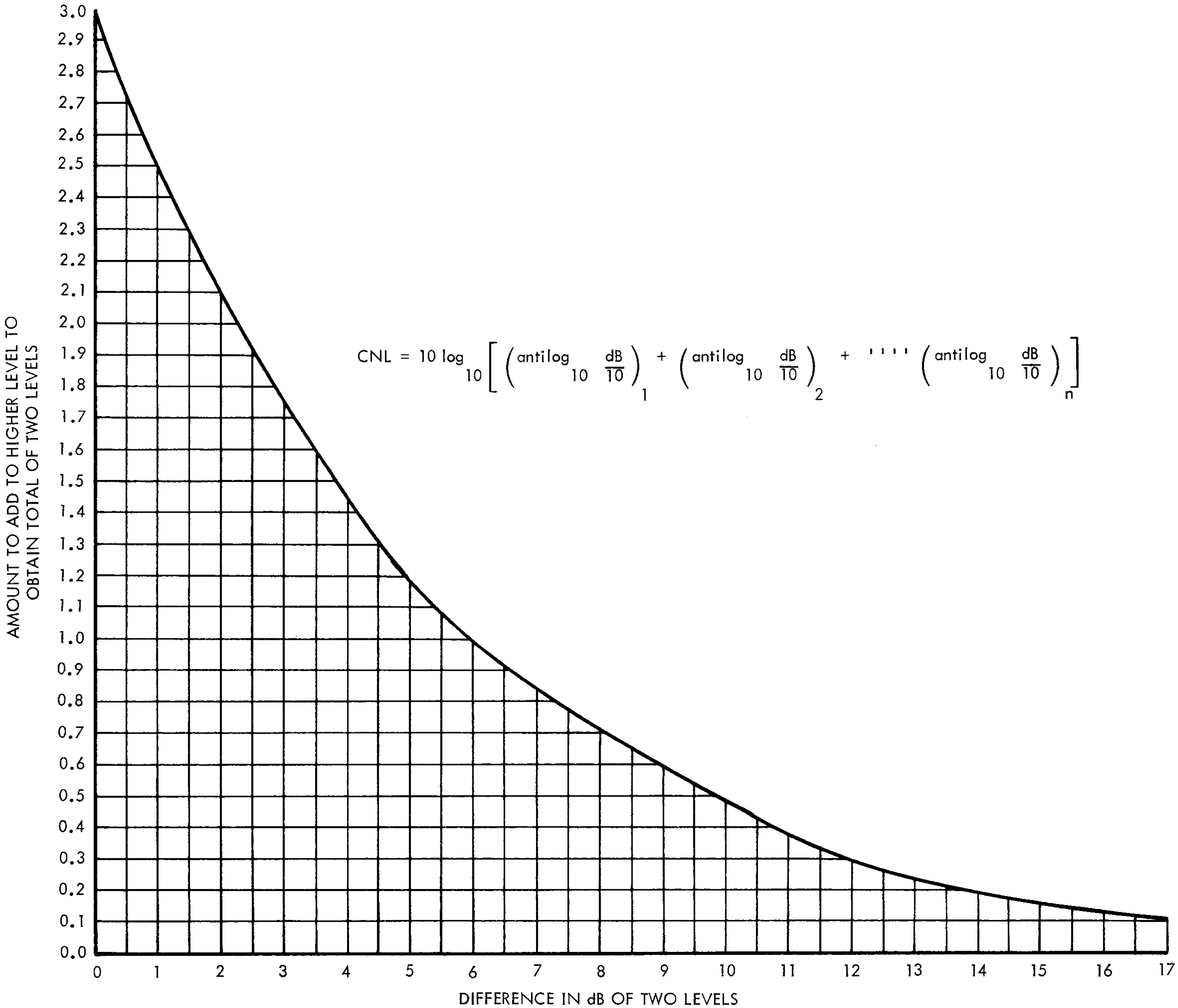


Figure 4. Combining Graph for Two Levels in dB

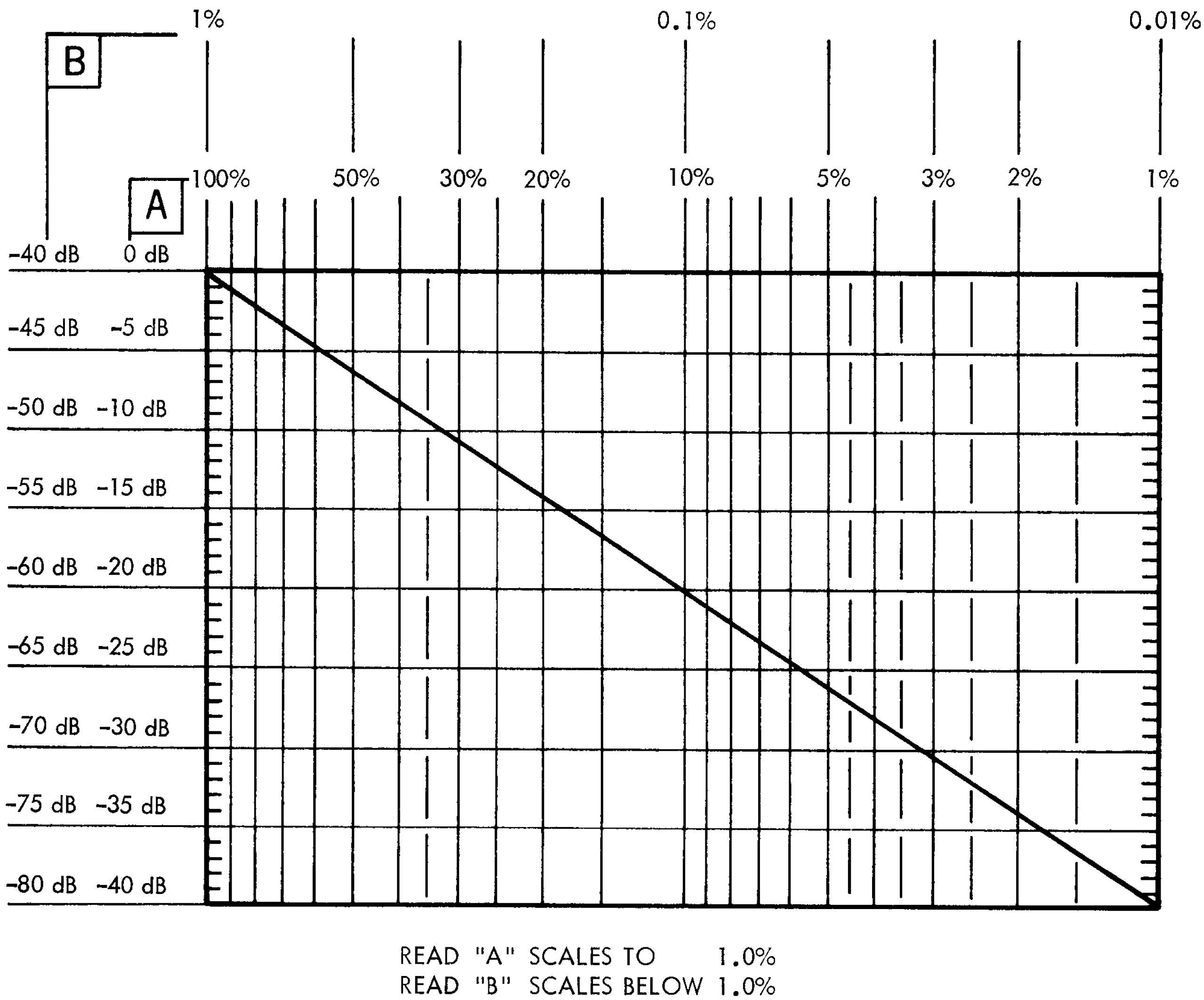
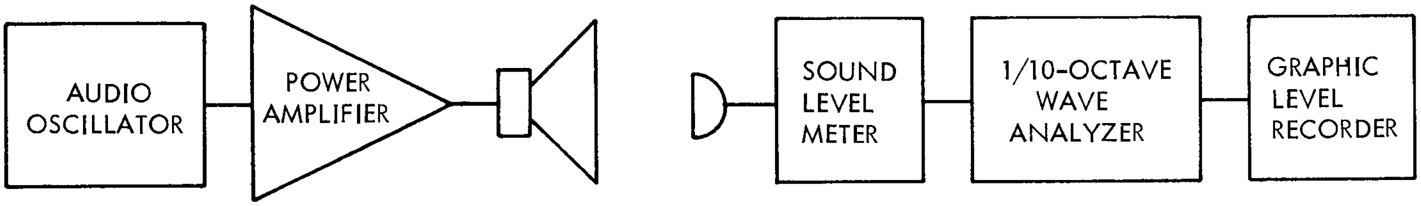
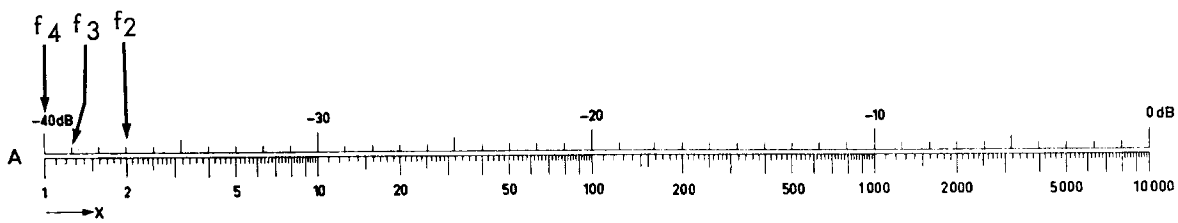


Figure 5. Conversion Chart, dB Below Signal to Percent of Signal



SET AUDIO OSCILLATOR TO f_x. ADJUST LEVEL FOR FULL-SCALE READING ON WAVE ANALYZER OR FOR TOP OF CHART (40 dB POTENTIOMETER) ON GRAPHIC LEVEL RECORDER. SWEEP WAVE ANALYZER VERY SLOWLY THROUGH EACH HARMONIC FREQUENCY AND NOTE HOW MANY dB BELOW FUNDAMENTAL EACH HARMONIC IS.

EXAMPLE: f_2 = -37 dB, f_3 = -39 dB and f_4 = -40 dB



f_2 = 2
f_3 = 1.25
f_4 = 1

4.25

4.25 IS CONVERTED TO 2.06 PERCENT ACOUSTIC DISTORTION BY USING SCALE "B".

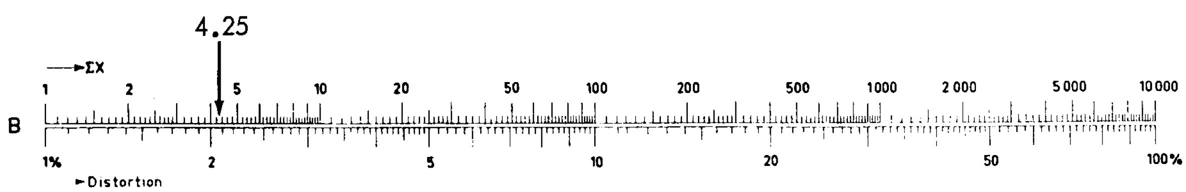


Figure 6. Measuring Acoustic Distortion

$$\text{Nonlinear distortion: } d = \frac{\sqrt{a_2^2 + a_3^2 + a_4^2 + \dots a_n^2}}{\sqrt{a_1^2 + a_2^2 + a_3^2 + \dots a_n^2}} \times 100\% = \frac{\sqrt{a_2^2 + a_3^2 + a_4^2 + \dots a_n^2}}{\text{rms value of complete signal}} \times 100\%$$

The harmonic distortion d in percent for sine-waves can be calculated from the number of dB the individual harmonics lie below the rms value of the complete signal containing the fundamental and all harmonics.

EXAMPLE: The harmonics of a signal are found to be the following number of dB below the rms value of the complete signal:

2. harmonic a_2 = -68 dB

3. harmonic a_3 = -62 dB

4. harmonic a_4 = -76 dB

From scale A: the value X for the individual harmonics is found to be:

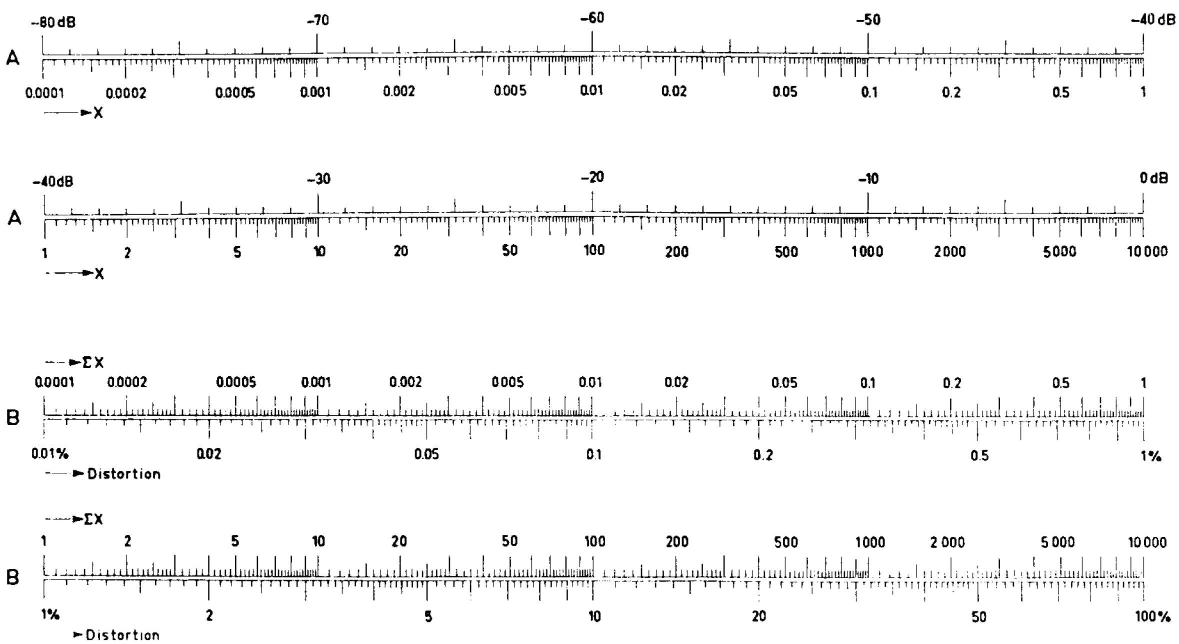
2. harmonic X_1 = 0.0016

3. harmonic X_2 = 0.0064

4. harmonic X_3 = 0.00025

$\sum X$ = 0.00825

From scale B it is now found that for $\sum X$ = 0.00825, the distortion d in % will be: d = 0.09%



$$\text{THD} = \sqrt{\left[\frac{10{,}000}{\text{antilog}_{10}\left(\frac{dB}{10}\right)}\right]_1 + \left[\frac{10{,}000}{\text{antilog}_{10}\left(\frac{dB}{10}\right)}\right]_2 + \dots \left[\frac{10{,}000}{\text{antilog}_{10}\left(\frac{dB}{10}\right)}\right]_n}$$

Figure 7. Harmonic Distortion Conversion Scales

$$CNL = 10LOG_{10}\left[\left(antilog_{10}\frac{dB}{10}\right)_1 + \left(antilog_{10}\frac{dB}{10}\right)_2 + \ldots.\left(antilog_{10}\frac{dB}{10}\right)_n\right]$$

		DISPLAY					
		ENTER	READ	STORAGE			
STEP	KEY	x	x	y	z	t	s
1		dB	dB				
2	↑		dB	dB			
3	1		1				
4	0		10				
5	÷		$\frac{dB}{10}$				
6	1		1	$\frac{dB}{10}$			
7	0		10	$\frac{dB}{10}$			
8	x^y		$10^{\left(\frac{dB}{10}\right)}$				
9	REPEAT (START AGAIN AT STEP 1)						
10	+	(AFTER 1ST REPEAT USE + AND THEN)					
11	REPEAT						
12	+	ETC. (WHEN LAST + IS MADE THEN)					
13	LOG						
14	1						
15	0						
16	X						

Figure 8. Calculating CNL on HP35 Calculator

$$THD = \sqrt{\frac{10,000}{\text{antilog}_{10}\left(\frac{dB}{10}\right)}}$$

STEP	KEY	DISPLAY ENTER x	READ x	STORAGE y	z	t	s
1	1		1				
2	0		10				
3	0		100				
4	0		1000				
5	0		10000				
6	↑		10000	10000			
7		dB	dB	10000			
8	↑		dB	dB	10000		
9	1		1	dB	10000		
10	0		10	dB	10000		
11	÷		$\frac{dB}{10}$	10000			
12	1		1	$\frac{dB}{10}$	10000		
13	0		10	$\frac{dB}{10}$	10000		
14	x^y		$10^{\left(\frac{dB}{10}\right)}$	10000			
15	÷		$\frac{10000}{10^{\left(\frac{dB}{10}\right)}}$				
16	$\sqrt{X}$		$\sqrt{X}$				

Figure 9. Calculating THD on HP35 Calculator