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CONVERSION OF OCTAVE-BAND NOISE DATA TO EQUIVALENT A-WEIGHTED LEVELS

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FOREWORD

This research was conducted in the Audiology and Hearing Conservation Function of the Otolaryngology Branch under task No. 775508 during the period November 1970 through September 1971. The manuscript was submitted for publication on 5 October 1971.

This report has been reviewed and is approved.

EVAN R. GOLTRA, Colonel, USAF, MC
Commander

ABSTRACT

Bioacoustic criteria incorporating A-weighted sound levels have been widely adopted in industry and government; yet much of the noise data currently stored or in use by the Air Force is expressed in octave bands. The Air Force is finding it increasingly necessary to convert these data to equivalent A-weighted values. This report describes and illustrates a simple device--a dial-type calculator--with which such conversion can be made. Five different A-weighted conversions are provided: two for data expressed in the old octave bands, and three for data expressed in the newer set (preferred) of octave bands.

GLOSSARY

Octave band - The octave is the interval between two sounds having a basic ratio of 2. The interval, in octaves, between any two frequencies is the logarithm of the base 2 (or 3,322 times the logarithm to the base 10) of the frequency ratio.

Sound level - The apparent loudness we attribute to sound varies not only with sound pressure but also with the frequency (spectrum) of the sound. Acoustic measurements can be accomplished by using certain frequency "weighting" networks so that psychophysical attributes of sounds can be specified.

A-weighting (dBA, or A-level) - Selective frequency weighting that closely parallels human ear responses near threshold.

B-weighting (dBB, or B-level) - Selective frequency weighting that closely parallels human ear responses at loudness levels ranging from 45 to 70 dB.

C-weighting (dBC, or C-level) - Selective frequency weighting that closely parallels human ear responses at loudness levels ranging from 75 to 90 dB.

Flat response - (commonly referred to as "all pass" - AP) - The electroacoustic response of the noise measuring instrument that is essentially flat (equal) within the frequency range from 25 through 12,500 Hz.

Center frequency - The geometric center (in frequency) specified for a given octave range; i.e., the octave band from 707 to 1414 Hz has a center frequency of 1000 Hz.

I.E.C. - International Electrotechnical Commission. One of two international bodies that provide specifications for use by manufacturers of noise measurement instruments.

I.S.O. - International Organization for Standardization. One of two international bodies that provide specifications for use by manufacturers of noise measurement instruments.

A.N.S.I. - American National Standards Institute.

IEC-123 - An international standard currently employed for sound-level meters.

IEC-179 - An international specification for precision sound-level meters.

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I. INTRODUCTION

Many methods are available for measuring and specifying acoustic noise (2, 4, 5). Although acoustic noise measurements may be very detailed and third-, half-, or full-octave measurements used to define a given noise, use of a single numerical value such as the A-weighted sound level has gained considerable acceptance during the past decade. In fact, the use of dBA (A-weighted sound level) is increasing with each passing year. This unit of measure, dBA, is widely used to indicate differing degrees of speech interference, to identify potentially hazardous noises, to predict differing degrees of annoyance, and for many other applications.

Young (5), in an excellent review of some 60 different sound measurements, expresses the opinion that the dBA unit is the most valuable, especially when attempting to express human (community) responses to sounds or noises found within transportation media. The extent to which dBA has been accepted as a primary expression of noise is evidenced by the fact that a group of experts recently charged by the U.S. Department of Commerce to investigate "noise pollution" in the United States adopted dBA as the preferred unit of noise measurement (2).

Most of the noise measurements available to biomedical personnel are reported by octave bands. The need to convert octave-band data to equivalent dBA units is self-evident. The procedures and the dial-type calculator which are described here decrease the complexity of the task.

II. PROCEDURES FOR CONVERTING OCTAVE BANDS TO dBA

Generally, the following steps must be performed to convert octave-band data to equivalent dBA levels: First, the octave-band levels are noted. Second, correction values (as shown in table I) are entered (using octave-band corrections for appropriate overall level, either flat or C-weighted response). Third, the appropriate weightings are added or subtracted. Fourth, the corrected levels are combined to derive the equivalent dBA.

TABLE I

Octave-band weightings for octave-band data (old and new octaves). Octaves identified by center frequency in Hz. Correction factors are provided for flat and/or C-weighted levels. (Note: levels rounded to nearest 1.0 dB)

	Old octave bands								
Center frequency (Hz)	26	53	106	212	425	850	1700	3400	6800
Flat	-41	-28	-17	-10	-4	0	+1	+1	-1
C-weighted	-37	-26	-17	-10	-4	0	+1	+2	+2
	New octave bands								
Center frequency (Hz)	32	63	125	250	500	1000	2000	4000	8000
Flat	-37	-25	-15	-8	-3	0	+1	+1	-1
C-weighted	-34	-24	-15	-8	-3	0	+1	+2	+2
IEC-123/179*	-39	-26	-16	-9	-3	0	+1	+1	-1

*Corrections re B & K Instruments, Inc. (1).

The data shown in table I (except line 7, IEC-123/179) represent corrections provided by General Radio Company. The levels are relative to the overall measurements, either C-weighted or flat (AP) (3). The General Radio Company corrections were chosen because this company supplies the Air Force with most of its noise instruments.

Once the correct weighting has been applied to the octave-band data, the next step involves combining the levels (in pyramid fashion) into the equivalent A-weighting. Decibel combinations provided by General Radio (3) are shown in table II.

TABLE II

Combining levels for different octave bands

dB difference	"add"	dB difference	"add"
0	3.0	5.0	1.2
0.5	2.8	5.5	1.1
1.0	2.6	6.0	1.0
1.5	2.3	6.5	0.9
2.0	2.1	7.0	0.8
2.5	2.0	7.5	0.7
3.0	1.8	8.0	0.6
3.5	1.6	8.5	0.6
4.0	1.5	9.0	0.5
4.5	1.3	9.5	0.5

The values shown in table II can be used to determine the overall A-weighted level from the individual levels found within the different octave levels that have already been corrected according to the appropriate A-weightings.

Figures 1 and 2 show the calculator that we use to simplify the task of converting octave-band data to equivalent dBA. The outer dial, or base (see fig. 1), contains a scale for decibels. A table is provided (top) for use in combining dB levels. The task of laying out the calculator can be facilitated by using Codex Book Company, Inc. (Norwood, Mass.) polar coordinate chart No. 3224. The inner part of the dial (fig. 2) is divided into halves. One half provides two sets of dB weightings for older octaves, and the other half provides three sets of dB weightings for newer octaves. The five sets of dB weightings correspond to those listed in table I. The larger arrow tip shown on each of the five weightings identifies the "reference" point that is used when dialing the octave-band level to be considered. This arrow is moved to the octave-band level being considered. Once the arrow is positioned on the appropriate level for a given octave, the dB level (weighted) that appears next to the center frequency of the octave can be read. For example, if the level for the octave band centered at 26 Hz is 100 dB as measured with a flat-response instrument, the arrow for General Radio "flat," old octave bands, should be rotated to 100 dB. The level adjacent to "26" is then noted and found to be 59 dB (see table I — the amount of weighting is −41 dB for this octave; thus, 41 dB subtracted from 100 dB yields a weighted value of 59 dB).

Table III provides an example of the steps used to determine equivalent dBA levels. In this example, the noise measured within the cockpit of a reciprocating-engine aircraft is used.

TABLE III

Sample of octave-band noise measurements obtained with an analyzer that yielded an overall flat response of 120.8 dB

	Octave bands by center frequency								
Octaves (Hz)	26	53	106	212	425	850	1700	3400	6800
Levels (dB)	100	110	120	110	105	99	86	80	76

The levels shown in table III are dialed to the respective octave-band level for each, and the weighted dBA levels are read as follows. For the octave 26 Hz, the arrow is turned to 100 dB. The reading next to 26 Hz shows a weighted value of 59 dB (a level 41 dB less than 100 dB, see table I). The level of 110 dB is dialed for the octave 53 Hz and the resulting weighted level is 82 dB (-28 dB). This procedure is continued for the remaining octaves. Table IV shows the resulting weighted values.

COMBINING dB LEVELS

dB DIFF.	"ADD"	dB DIFF.	"ADD"	dB DIFF.	"ADD"
0	3	3.5	1.6	7.0	.8
.5	2.8	4.0	1.5	7.5	.7
1.0	2.6	4.5	1.3	8.0	.6
1.5	2.3	5.0	1.2	8.5	.6
2.0	2.1	5.5	1.1	9.0	.5
2.5	2.0	6.0	1.0	9.5	.5
3.0	1.8	6.5	.9		

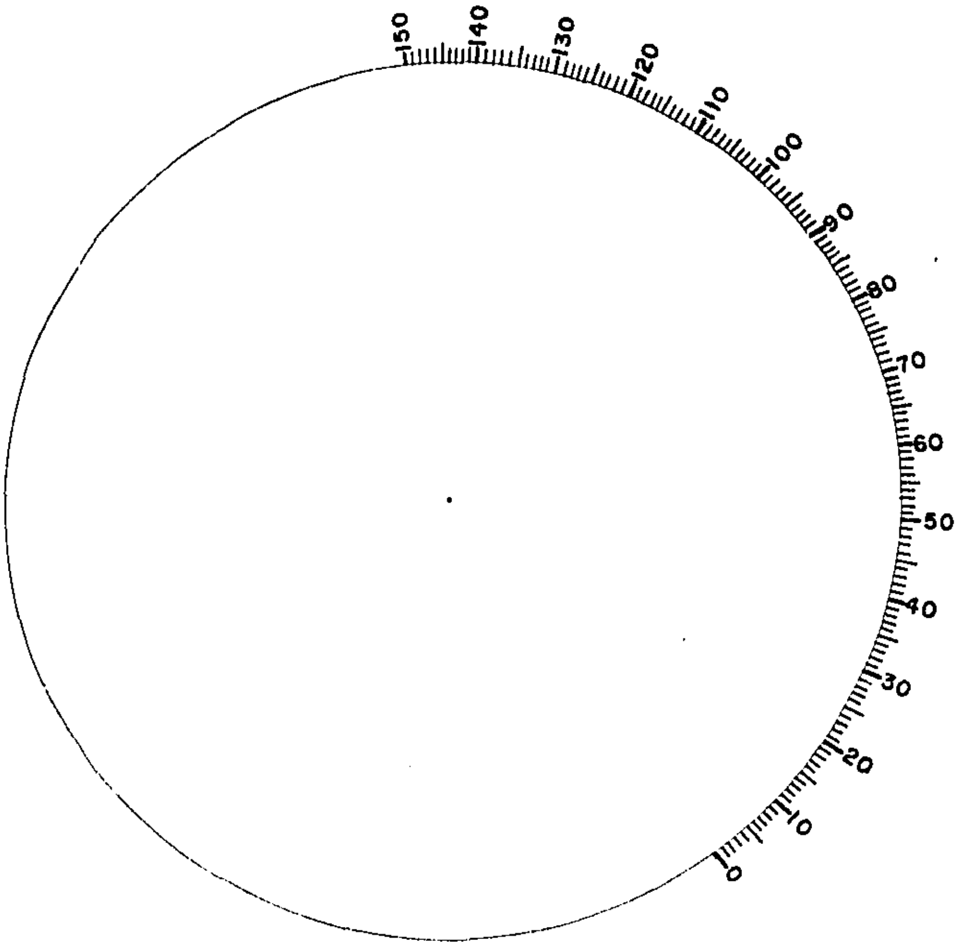

FIGURE 1

Base part of calculator used to convert octave-band data to equivalent dBA levels.

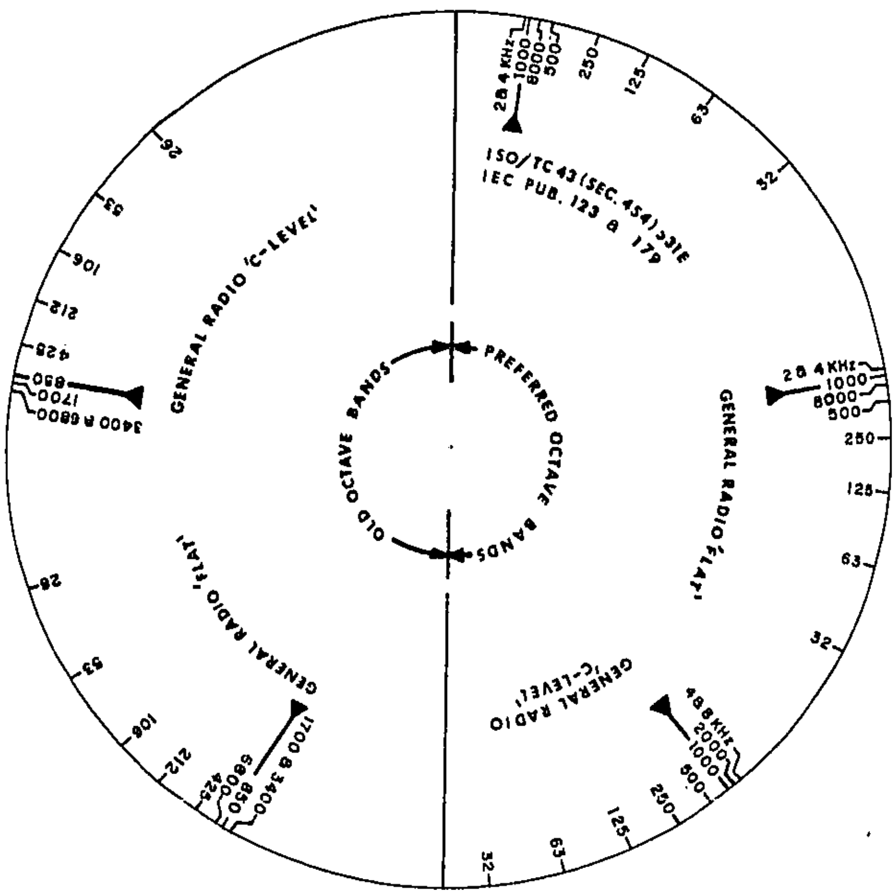

FIGURE 2

Dial part of calculator.

TABLE IV

Levels shown in table III corrected for A-weightings

	Octave bands by center frequency								
Octaves (Hz)	26	53	106	212	425	850	1700	3400	6800
dBA (weighted)	59	82	103	100	101	99	87	81	75

The levels shown in table IV are entered on a sheet of paper, and the levels are combined (added) using dB differences shown in figure 1 (also table II). This procedure can best be illustrated by the following:

```
59     82     103     100     101     99     87     81     75
               103.6     (1 dB diff., add 2.6 dB to higher level;
                          i.e., +2.6 to 101 = 103.6)
               106.4      .6 diff., add 2.8 dB to 103.6
               107.1     7.4 diff., add 0.7 dB to 106.4
```

Since other corrected octave levels are greater than 10 dB (difference), the increment is negligible.

Using the dB combinations provided, the equivalent dBA is found to be 107.1 dBA.

This procedure, although it appears complicated, can be used with considerable ease. It reduces the steps (pencil-paper) required to determine selective A-weighted corrections for each octave band, and, more important, the procedure reduces the chance of error associated with adding and subtracting.

The calculator parts shown in figures 1 and 2 have been printed at the end of this report so that the reader can cut them out and brad the inner dial with the base part of the calculator to make a workable model.

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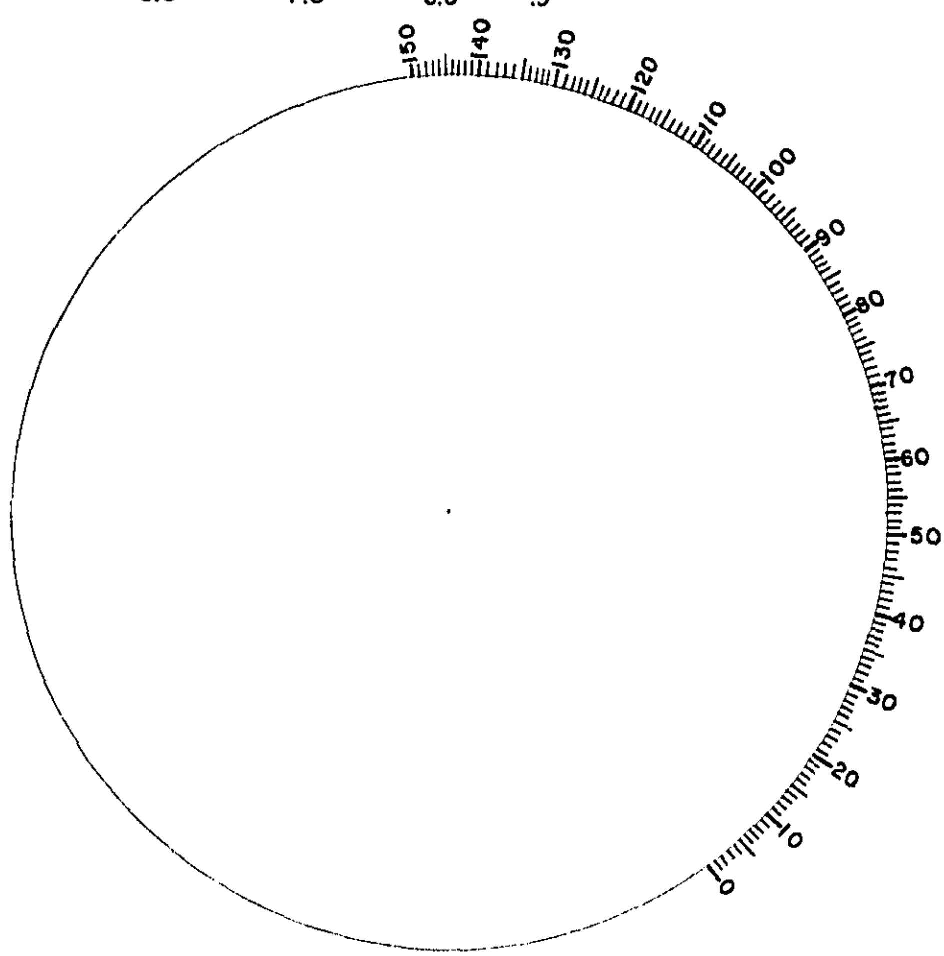
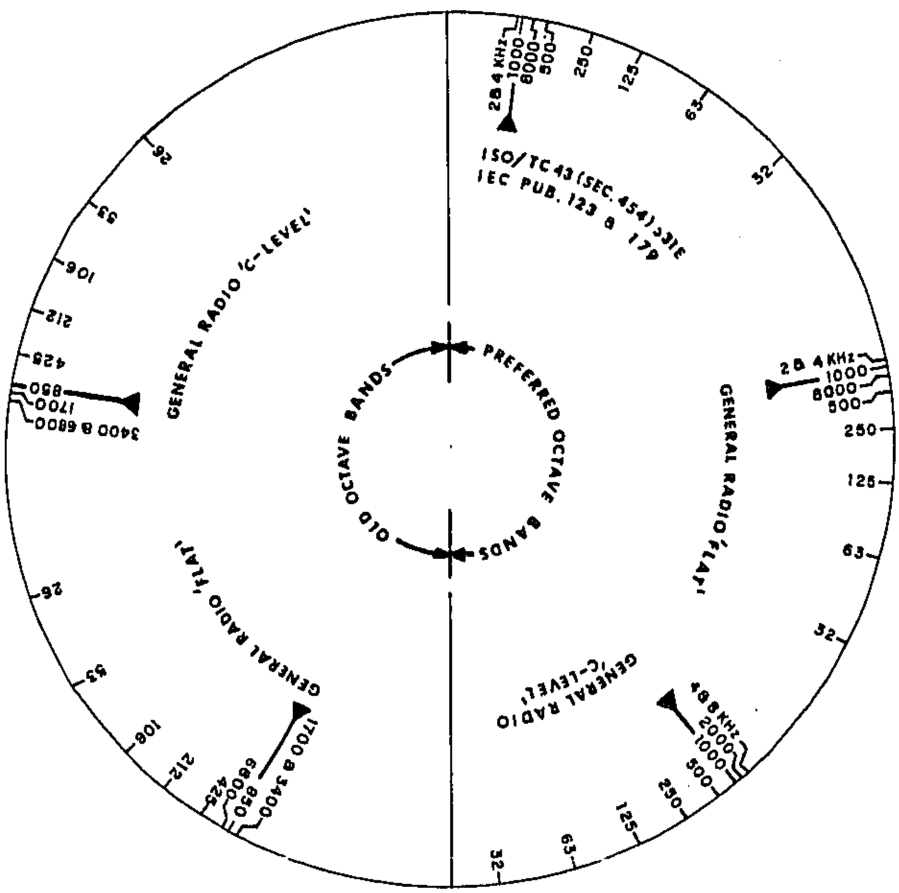


CUT-OUT

Base part of calculator used to convert octave-band data to equivalent dBA levels.



CUT-OUT

Dial part of calculator.

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