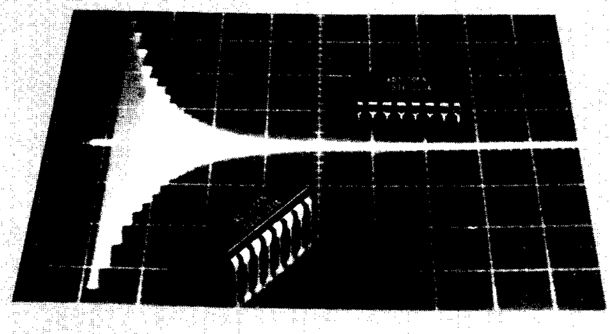
ANALOG DEVICES

CMOS LOGDAC
Digitally Controlled Audio Attenuator

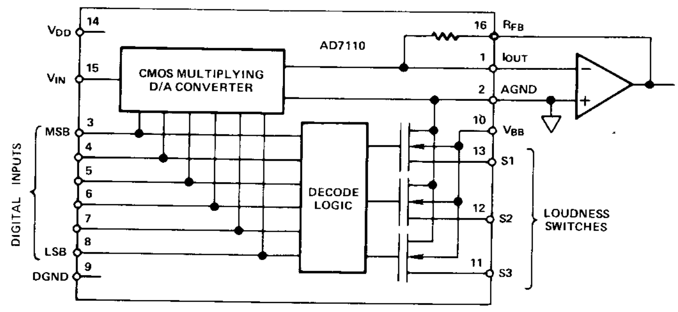
FEATURES
Attenuation Range: 0 to 88.5dB Plus Full Muting
Resolution: 1.5dB
Low Distortion: THD Better Than -98dB
IMD Better Than -92dB
Includes Switches for Loudness Compensation
Low Power Consumption
Excellent S/N Ratio: 100dB (20Hz – 20kHz)
Low Cost
Complies with DIN 45403 and DIN 45405
Latch-Proof Operation

APPLICATIONS
Digitally Controlled Audio Gain
Wide Dynamic Range D/A Converters



GENERAL DESCRIPTION
The AD7110 LOGDAC™ is a monolithic CMOS digitally controlled audio attenuator (U.S. Patent No. 4521764). With the addition of an external operational amplifier it provides 0 to 88.5dB of attenuation in 1.5dB steps, plus full muting of the audio input signal for digital input code 1111XX, where X can be 1 or 0. The audio input is applied to the V_{IN} pin and the device delivers a logarithmically related output current which is determined by a 6-bit binary input code. Loudness compensation switches are provided on the device to enable additional bass boost at low volume settings.
The device is manufactured using an advanced thin-film on CMOS monolithic wafer fabrication process and is packaged in a 16-pin DIP.

FUNCTIONAL DIAGRAM

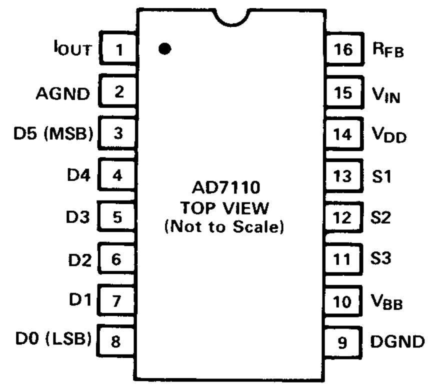


AD7110 AUDIO ATTENUATOR

ORDERING INFORMATION

Model	Package	Operating Temperature Range
AD7110KN	16-Pin Plastic DIP	0 to +50°C

PIN CONFIGURATION



*U.S. Patent No. 4521764.
LOGDAC is a trademark of Analog Devices, Inc.

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AUDIO SPECIFICATIONS (V_{DD} = +12V, V_{BB} = 0 to −12V, Pin 11-13 Open, T_A = 0 to +50°C unless otherwise noted)

PARAMETER	AD7110 WITH "IDEAL OP AMP"	AD7110 WITH TL071 OP-AMP (FIG. 1)	UNITS	TEST CONDITIONS/COMMENTS
ATTENUATION RANGE	0 to -88.5	0 to -88.5	dB	V_{IN} = 10V rms @ 1kHz
RESOLUTION	1.5 max	1.5 max	dB	Frequency Range: 20Hz to 20kHz
ATTENUATION ACCURACY (Absolute) 0dB to -48dB -48dB to -88.5dB	±0.7 max Monotonic	±0.7 max Monotonic	dB	The AD7110 is guaranteed monotonic for all attenuation settings between 0 and -88.5dB
TOTAL HARMONIC DISTORTION (THD)	-98 max	-85 typ	dB	per DIN 45403, BLATT 2 (with input level of 1V rms)
INTERMODULATION DISTORTION (IMD)	-92 max	-79 typ	dB	per DIN 45403, BLATT 4
V_{IN}	30 max	10 max	V peak	for <1% (max) THD (Note 1)
FEEDTHROUGH ERROR	Better than -85dB @ 1kHz. Feedthrough is primarily dependent upon printed circuit board layout.			
OUTPUT NOISE VOLTAGE DENSITY	30 max	70 typ	nV/$\sqrt{Hz}$	20Hz to 20kHz (Note 2)
BANDWIDTH	D.C. to 150 min	D.C. to 250 typ	kHz	0dB Attenuation

ELECTRICAL SPECIFICATIONS (V_{DD} = +12V, V_{BB} = 0 to −12V, Pin 11-13 Open, T_A = 0 to +50°C unless otherwise noted)

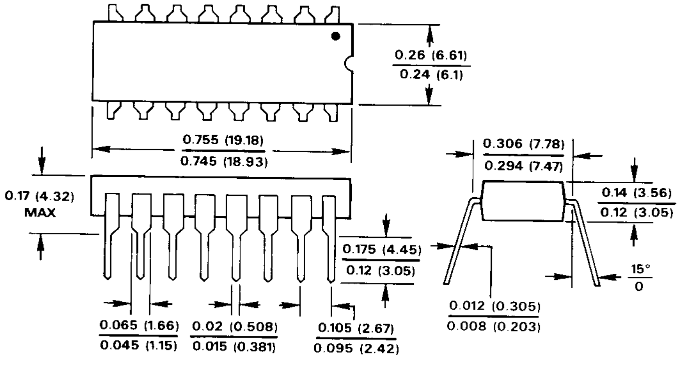
PARAMETER	LIMIT	TEST CONDITIONS/COMMENTS
ANALOG INPUT		Input resistance for a given unit is constant for all input conditions.
Input Resistance of V_{IN} (pin 15)	18kΩ max 9kΩ min	V_{OUT} = 0V
LOUDNESS SWITCHES		
Switch ON Resistance R_{ON}	600Ω max	Switch Current = 1mA
Switch OFF Leakage Current	1μA max	V_{switch} = +12V
Switch Coding	See Table 1	
DIGITAL INPUTS		
V_{INH}	11.5V min	
V_{INL}	0.5V max	
I_{INH}	1μA max	
I_{INL}	1μA max	
C_{IN}	5pF typ	
POWER REQUIREMENTS		
V_{DD}	+12V	
V_{DD} Range	+5V to +12V	Functionality with degraded performance.
V_{BB}	-12V	
I_{DD}	1mA max	Digital Inputs = V_{INL} or V_{INH}
I_{BB}	100μA max	
Total Power Dissipation	5mW typ	

NOTES
[1] Output amplifier (and amplifier supplies) must be capable of 30V peak output.
[2] Output noise voltage density includes op amp noise.
Specifications subject to change without notice.

OUTLINE DIMENSIONS

Dimensions shown in inches and (mm).

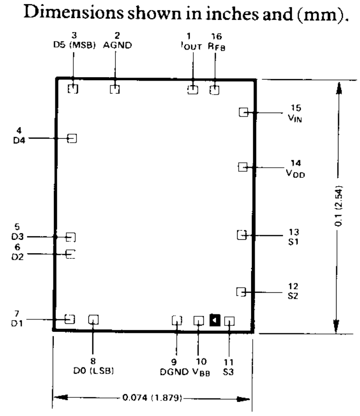
16-Pin Plastic DIP



NOTES
1. LEAD NO. 1 IDENTIFIED BY DOT OR NOTCH
2. LEADS ARE SOLDER-PLATED KOVAR

BONDING DIAGRAM

Dimensions shown in inches and (mm).



NOTES:
1. PAD NUMBERS CORRESPOND TO PIN NUMBERS SHOWN IN PIN CONFIGURATION, PAGE 1
2. PAD 9 (DGND) SHOULD BE BONDED FIRST TO MINIMIZE ESD HAZARDS.
3. PADS ARE 0.004 × 0.004 (0.102 × 0.102).

ABSOLUTE MAXIMUM RATINGS

(T_A = +25°C unless otherwise noted)

*V_{DD} (to GND) . . . . +14V
*V_{BB} (to GND). . . . . −14V
Voltage (pins 11, 12, 13) to GND. . . . . V_{BB}, +14V
V_{IN} (to GND). . . . . ±35V
Digital Input Voltage to GND . . . . −0.3V to V_{DD}
Output Voltage (Pin 1) to GND . . . . −100mV to VDD
Power Dissipation (Package) 670mW
Operating Temperature. 0 to +70°C
Storage Temperature . . . . −65°C to +150°C
Lead Temperature (Soldering, 10 seconds). . . . . +300°C

*If Loudness Compensation Switches (S1, S2, S3) are not used, the negative power supply may be omitted and V_{BB} (Pin 10) connected instead to DGND (Pin 9). In this case the absolute maximum rating of V_{DD} is +17V.

CAUTION:
ESD (Electro-Static-Discharge) sensitive device. The digital control inputs are diode protected; however, permanent damage may occur on unconnected devices subject to high energy electrostatic fields. Unused devices must be stored in conductive foam or shunts. The foam should be discharged to the destination socket before devices are removed.

TERMINOLOGY

RESOLUTION: Nominal change in attenuation when moving between two adjacent binary codes. The AD7110 resolution is 1.5dB.

MONOTONICITY: The AD7110 digitally controlled audio attenuator is monotonic if the analog output decreases (or remains constant) as the digital input code (attenuation setting) increases.

FEEDTHROUGH ERROR: That portion of the input signal which reaches the output when the digital input code is set to mute the input signal.

ANALOG CIRCUIT PERFORMANCE:

Table I gives the nominal attenuation in dB for the AD7110 for all digital input codes. It also shows the Loudness Switch states and the nominal output voltage when using an external operational amplifier (as shown in Figure 1) and a fixed −10 volt reference applied to V_{IN} (pin 15). It may be seen that the transfer function for the circuit of Figure 1 is given by

$$V_{OUT} = -V_{IN}\ 10 \exp -\left\{\frac{1.5N}{20}\right\}$$

where N is the binary input for values 0 to 59. For N = 60 through 63 the input is fully muted, that is, the attenuation is infinite.

HIGH FREQUENCY AMPLIFIERS

R_{FB} and the output capacitance of the AD7110 create a phase lag in the output amplifier's feedback circuit. This phase lag, in conjunction with the amplifier's phase lag, may cause ringing or oscillation. When using a high speed amplifier, shunting the amplifier input to output with 30−50pF of feedback capacitance (C1) ensures stability.

DC PERFORMANCE OF AD7110

For fixed-reference applications, an output amplifier with low offset voltage (less than 50µV) is required, e.g. the AD517L. This combination will provide the utmost stability at the expense of slow settling times.

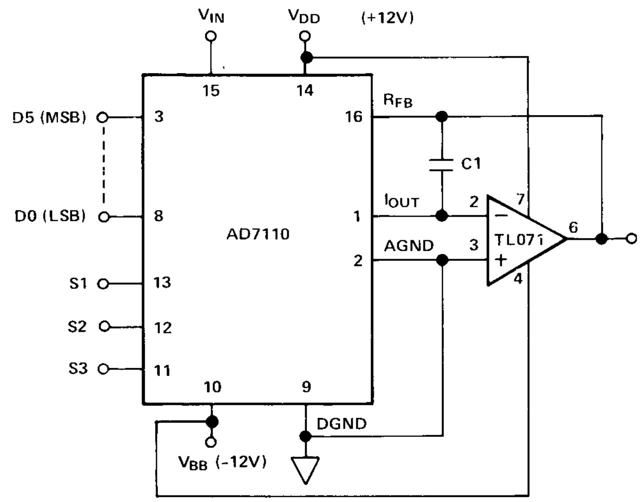


Figure 1.

Table I

N	Digital Input D5 D0	Attenuation dB	Switches[1] S1	S2	S3	V_{OUT}[2]
0	00 00 00	0.0				10.00
1	00 00 01	1.5				8.414
2	00 00 10	3.0				7.079
3	00 00 11	4.5				5.957
4	00 01 00	6.0				5.012
5	00 01 01	7.5				4.217
6	00 01 10	9.0				3.548
7	00 01 11	10.5				2.985
8	00 10 00	12.0				2.512
9	00 10 01	13.5				2.113
10	00 10 10	15.0				1.778
11	00 10 11	16.5				1.496
12	00 11 00	18.0				1.259
13	00 11 01	19.5				1.059
14	00 11 10	21.0				0.891
15	00 11 11	22.5				0.750
16	01 00 00	24.0				0.631
17	01 00 01	25.5				0.531
18	01 00 10	27.0				0.447
19	01 00 11	28.5				0.376
20	01 01 00	30.0				0.316
21	01 01 01	31.5				0.266
22	01 01 10	33.0				0.224
23	01 01 11	34.5				0.188
24	01 10 00	36.0				0.158
25	01 10 01	37.5				0.133
26	01 10 10	39.0				0.112
27	01 10 11	40.5				0.0944
28	01 11 00	42.0				0.0794
29	01 11 01	43.5				0.0668
30	01 11 10	45.0				0.0562
31	01 11 11	46.5				0.0473
32	10 00 00	48.0				0.0398
33	10 00 01	49.5				0.0335
34	10 00 10	51.0				0.0282
35	10 00 11	52.5				0.0237
36	10 01 00	54.0				0.0200
37	10 01 01	55.5				0.0168
38	10 01 10	57.0				0.0141
39	10 01 11	58.5				0.0119
40	10 10 00	60.0				0.0100
41	10 10 01	61.5				0.00841
42	10 10 10	63.0				0.00708
43	10 10 11	64.5				0.00596
44	10 11 00	66.0				0.00501
45	10 11 01	67.5				0.00422
46	10 11 10	69.0				0.00355
47	10 11 11	70.5				0.00299
48	11 00 00	72.0				0.00251
49	11 00 01	73.5				0.00211
50	11 00 10	75.0				0.00178
51	11 00 11	76.5				0.00150
52	11 01 00	78.0				0.00126
53	11 01 01	79.5				0.00106
54	11 01 10	81.0				0.000891
55	11 01 11	82.5				0.000750
56	11 10 00	84.0				0.000631
57	11 10 01	85.5				0.000531
58	11 10 10	87.0				0.000447
59	11 10 11	88.5				0.000376
60	11 11 XX[3]	∞				

NOTES:
[1] Switch closed in shaded area.
[2] V_{IN} = -10V dc
[3] X = 1 or 0. Output is fully muted for N≥60.

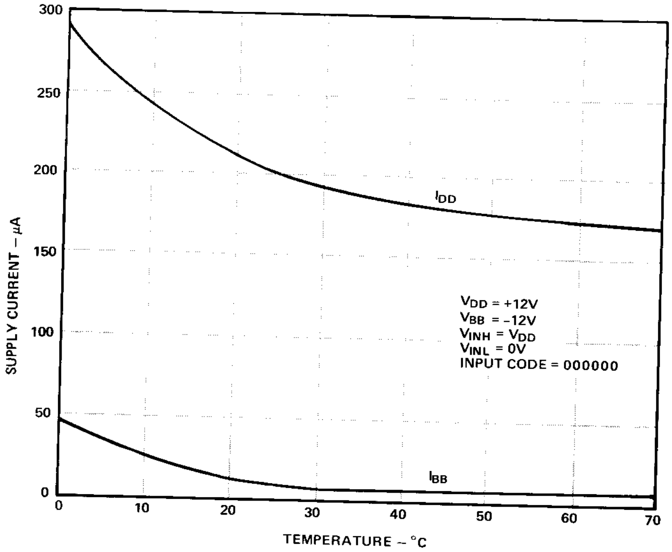


Figure 2. Power Supply Current vs. Temperature

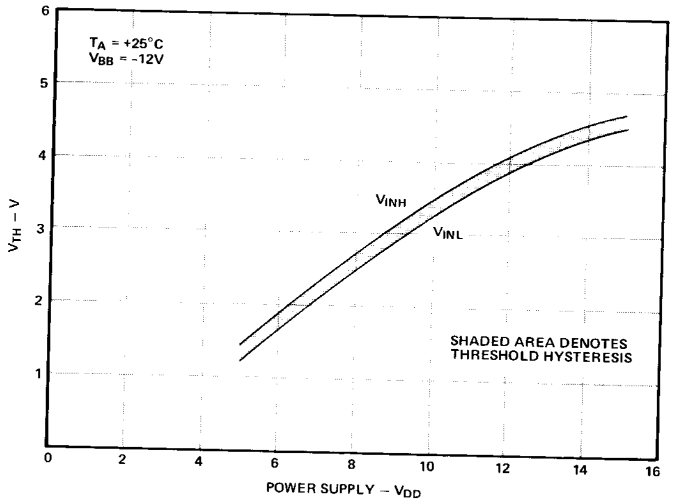


Figure 3. Digital Threshold Voltage vs. Power Supply Voltage

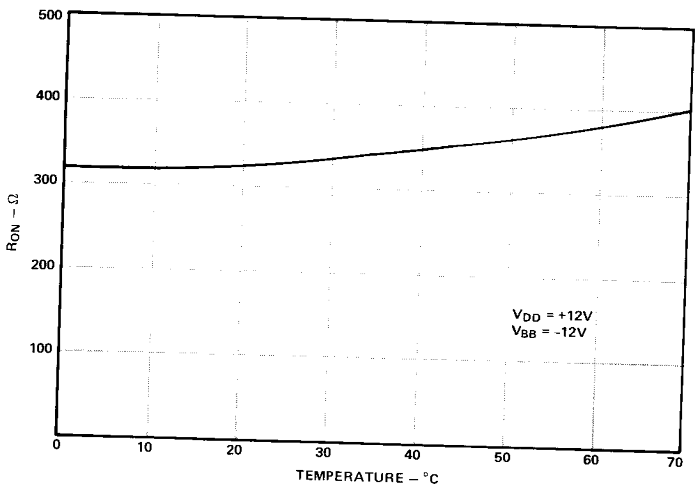


Figure 4. Loudness Switch On Resistance vs. Temperature

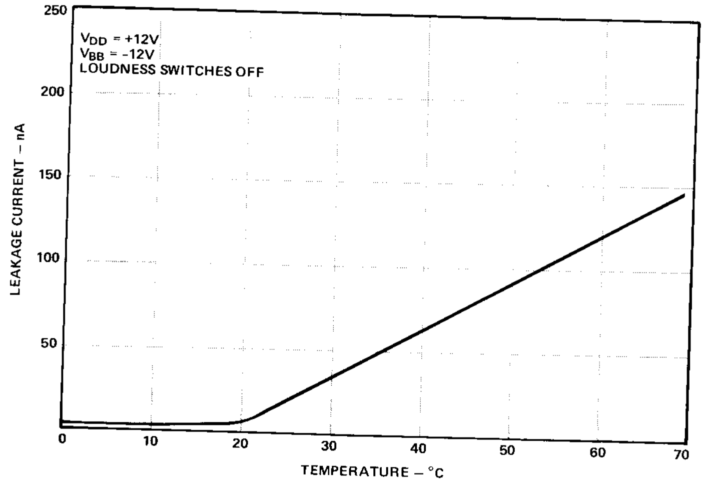


Figure 5. Loudness Switch Leakage Current vs. Temperature

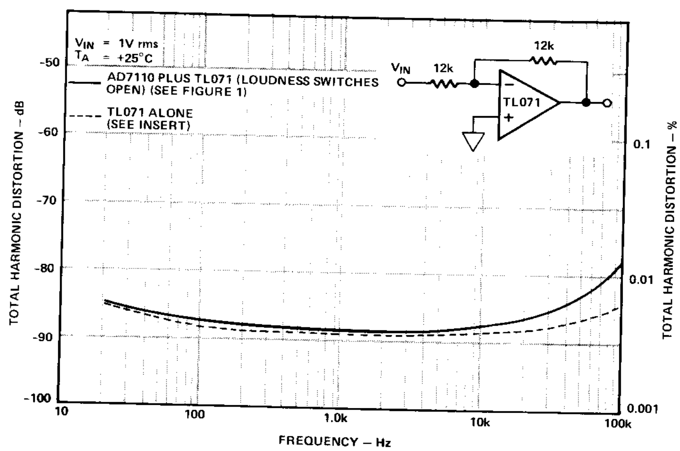


Figure 6. Total Harmonic Distortion vs. Frequency

Figure 6 shows that the total harmonic distortion of the attenuator circuit of Figure 1 is almost totally dependent on the characteristics of the operational amplifier used.

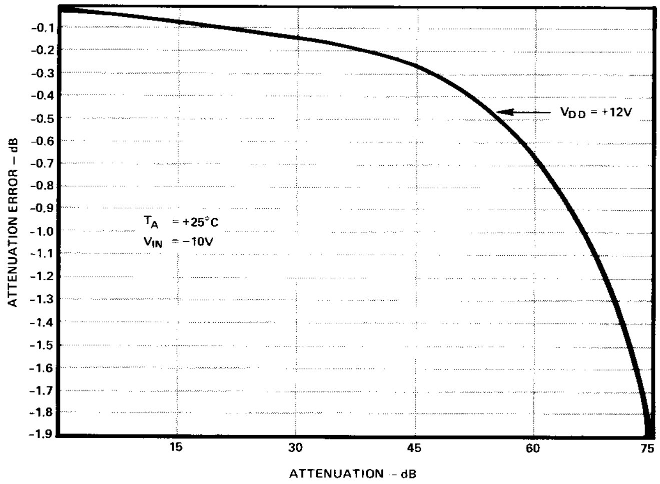


Figure 7. Typical dc Attenuation Error vs. Attenuation

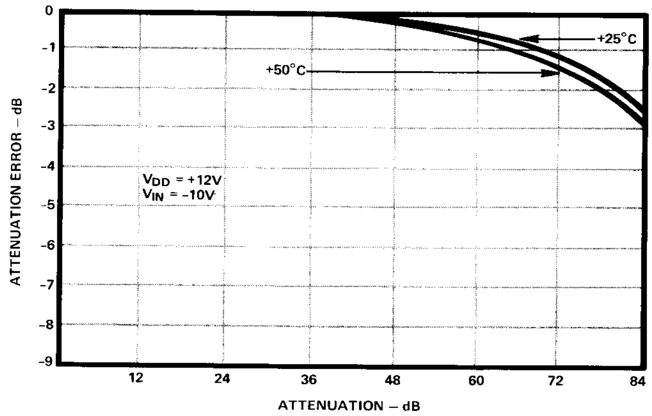


Figure 8. Typical dc Attenuation Error vs. Attenuation & Temperature

Applications Information

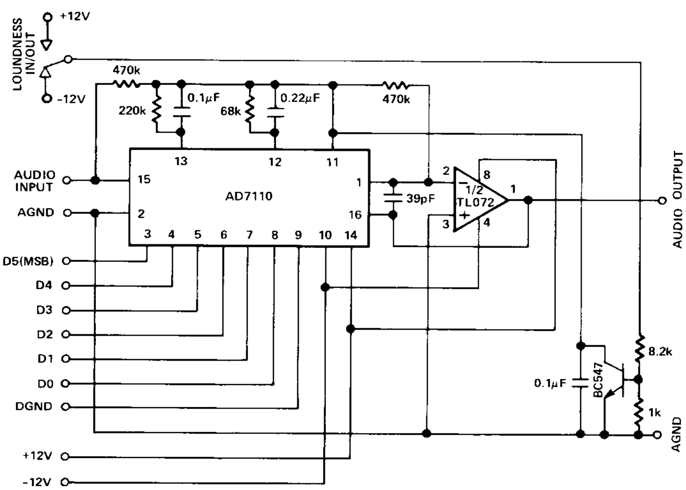


Figure 9. Single Channel Audio Attenuator with Loudness Compensation

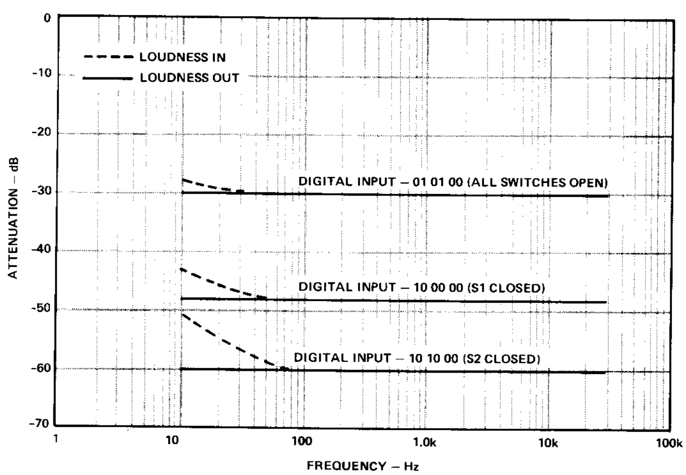


Figure 10.

Figure 10 shows the Attenuation vs. Frequency for the circuit of Figure 9. The attenuation is plotted against frequency for the two digital input codes at which the loudness compensation switches S1 and S2 are activated.

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