

## OVERVIEW

The SM6451BV is a 3-wire serial-controlled electronic variable volume IC for audio applications. It provides electronic volume control for a stereo system (left and right channels), and independent channel attenuation and muting, with greatly enhanced digital zip noise suppression. The chip address function allows up to four SM6451BV devices to be connected and individually controlled over the 3-wire control interface from a single CPU. It is available in 16-pin VSOP packages.

## FEATURES

- Stereo inputs and outputs
- Attenuation function
  - 2-channel independent control
  - 1.0 dB/step over 80 steps
  - 0 to -80 dB range
- Mute function
- 3-wire serial data control (MDT, MCK, MLEN)
- Chip addressing (up to 4 devices can be connected in parallel)
- Low noise
  - 0.003 % THD + noise
  - 12  $\mu$ Vrms residual noise
- 2.5 to 3.6 V single power supply
- Silicon-gate CMOS process

## APPLICATIONS

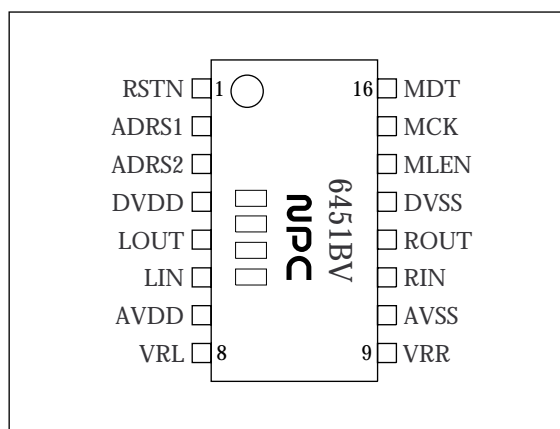
- Audio equipment

## ORDERING INFORMATION

Device	Package
SM6451BV	16-pin VSOP

## PINOUT

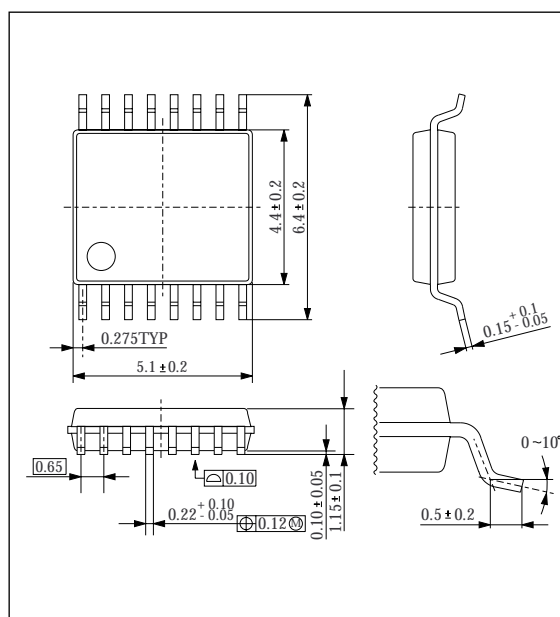
(Top View)



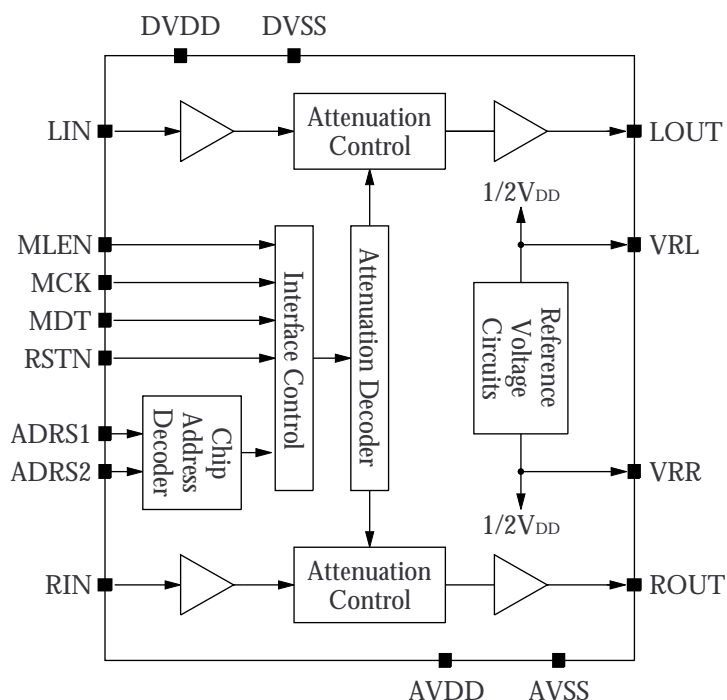
## PACKAGE DIMENSIONS

(Unit: mm)

16 pin VSOP



## BLOCK DIAGRAM



## PIN DESCRIPTION

Number	Name	I/O <sup>1</sup>	A/D <sup>1</sup>	Description
1	RSTN	I <sub>p</sub>	D	System reset input (LOW-level reset)
2	ADRS1	I <sub>p</sub>	D	Chip address set 1
3	ADRS2	I <sub>p</sub>	D	Chip address set 2
4	DVDD	-	D	Digital supply
5	LOUT	O	A	Left-channel audio output
6	LIN	I	A	Left-channel audio input
7	AVDD	-	A	Analog supply
8	VRL	O	A	Left-channel reference voltage (0.5V <sub>DD</sub> ). Connect a 10 μF capacitor between VRL and AVSS.
9	VRR	O	A	Right-channel reference voltage (0.5V <sub>DD</sub> ). Connect a 10 μF capacitor between VRR and AVSS.
10	AVSS	-	A	Analog ground
11	RIN	I	A	Right-channel audio input
12	ROUT	O	A	Right-channel audio output
13	DVSS	-	D	Digital ground
14	MLEN	I <sub>p</sub>	D	Microcontroller latch enable input
15	MCK	I <sub>p</sub>	D	Microcontroller clock input
16	MDT	I <sub>p</sub>	D	Microcontroller data input

1. I<sub>p</sub> = input pin with pull-up, A = analog, D = digital

## SPECIFICATIONS

### Absolute Maximum Ratings

DVSS = AVSS = 0 V, DVDD = AVDD = V<sub>DD</sub>

Parameter	Symbol	Rating	Unit
Supply voltage	V <sub>DD</sub>	-0.3 to 7.0	V
Input voltage	V <sub>IN</sub>	V <sub>SS</sub> - 0.3 to V <sub>DD</sub> + 0.3	V
Power dissipation	P <sub>D</sub>	150	mW
Storage temperature	T <sub>stg</sub>	-55 to 125	°C
Soldering temperature	T <sub>slid</sub>	255	°C
Soldering time	t <sub>slid</sub>	10	s

### Recommended Operating Conditions

DVSS = AVSS = 0 V, DVDD = AVDD = V<sub>DD</sub>

Parameter	Symbol	Rating	Unit
Supply voltage	V <sub>DD</sub>	2.5 to 3.6	V
Supply voltage deviation	DV <sub>DD</sub> - AV <sub>DD</sub> , DV <sub>SS</sub> - AV <sub>SS</sub>	±0.1	V
Operating temperature	T <sub>opr</sub>	-40 to 85	°C

### DC Characteristics

DVDD = AVDD = V<sub>DD</sub> = 2.5 to 3.6 V, V<sub>SS</sub> = 0 V, Ta = -40 to 85 °C

Parameter	Symbol	Condition	Rating			Unit
			min	typ	max	
DVDD Current consumption	I <sub>DD1</sub>	Data transfer stopped, MDT, MCK, MLEN, RSTN, ADRS1, ADRS2 = V <sub>DD</sub>	-	0.2	1.0	μA
	I <sub>DD2</sub>	ADRS1 = ADRS2 = 0V, 0.8V <sub>rms</sub> analog input, ATT = 0 dB, data transfer active	-	0.4	1.0	mA
AVDD Current consumption	I <sub>DDA</sub>		-	1.9	5.5	mA
HIGH-level input voltage <sup>1</sup>	V <sub>IH</sub>		0.7V <sub>DD</sub>	-	-	V
LOW-level input voltage <sup>1</sup>	V <sub>IL</sub>		-	-	0.3V <sub>DD</sub>	V
Input current <sup>1</sup>	I <sub>IL</sub>	V <sub>IN</sub> = 0 V	-	70	150	μA
Input leakage current <sup>1</sup>	I <sub>IH</sub>	V <sub>IN</sub> = V <sub>DD</sub>	-	-	1.0	μA

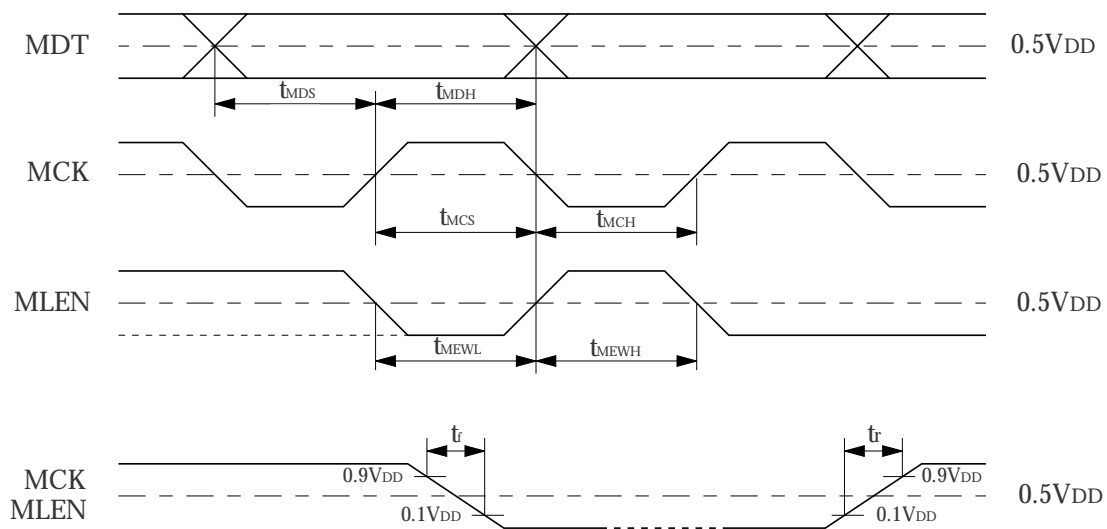
1. MDT, MCK, MLEN, RSTN, ADRS1, ADRS2

## AC Digital Characteristics

DVDD = AVDD = V<sub>DD</sub> = 2.5 to 3.6 V, V<sub>SS</sub> = 0 V, Ta = -40 to 85 °C

### Serial inputs (MDT, MCK, MLEN)

Parameter	Symbol	Rating			Unit
		min	typ	max	
MCK, MLEN rise time	$t_r$	-	-	100	ns
MCK, MLEN fall time	$t_f$	-	-	100	ns
MDT setup time	$t_{MDS}$	50	-	-	ns
MDT hold time	$t_{MDH}$	50	-	-	ns
MLEN setup time	$t_{MCS}$	50	-	-	ns
MLEN hold time	$t_{MCH}$	50	-	-	ns
MLEN LOW-level pulsewidth	$t_{MEWL}$	50	-	-	ns
MLEN HIGH-level pulsewidth	$t_{MEWH}$	50	-	-	ns



### Reset input (RSTN)

Parameter	Symbol	Rating			Unit
		min	typ	max	
RSTN LOW-level pulsewidth	$t_{RSTN}$	100	-	-	ns

## AC Analog Characteristics

$V_{DD} = 3.0\text{ V}$ ,  $0.8\text{ V}_{rms}$  amplitude,  $1\text{ kHz}$  input frequency,  $100\text{ k}\Omega$  output load resistance,  $T_a = 25\text{ }^\circ\text{C}$ , AC-coupled inputs

### Analog inputs (LIN, RIN)

Parameter	Symbol	Condition	Rating			Unit
			min	typ	max	
Reference input amplitude	$V_{AI}$		-	0.8	-	V <sub>rms</sub>
Input resistance	$R_{IN}$		40	50	60	k $\Omega$
Input clipping voltage	$V_{CLP}$	THD + N = 1%, ATT = 0 dB	-	1.1	-	V <sub>rms</sub>

### Analog outputs (LOUT, ROU)

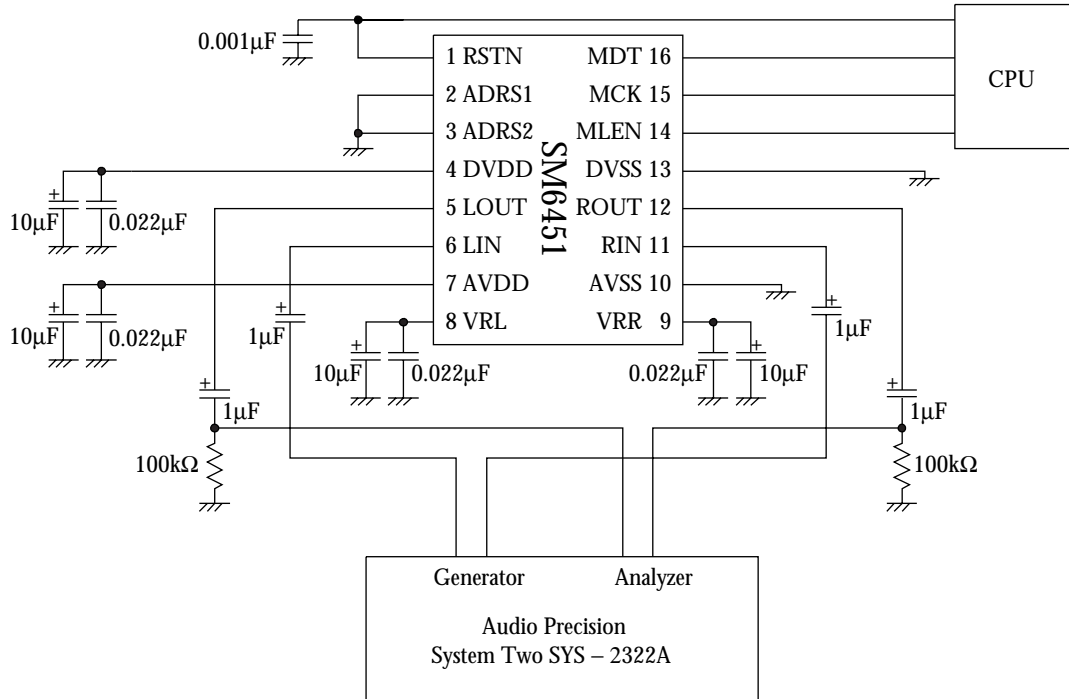
Parameter	Symbol	Condition	Rating			Unit
			min	typ	max	
Residual noise voltage	$V_{NS}$	Input signal: $0\text{ V}_{rms}$ , A-weight filter, $0\text{ dB}$ = $0.8\text{ V}_{rms}$ , ATT = $0\text{ dB}$	-	12	20	$\mu\text{V}_{rms}$
Signal-to-noise ratio	SNR		92	96	-	dBr
Total harmonic distortion + noise	THD + N	ATT = $0\text{ dB}$ , $20\text{ kHz}$ lowpass filter	-	0.0025	0.005	%
Gain control range	$R_{CNT}$		- 80	-	0	dB
Step size	Step		0.8	1.0	1.8	dB
Attenuation error (1k to 20kHz)	ERR <sub>1</sub>	0 to -60 dB	- 2	-	1	dB
	ERR <sub>2</sub>	-61 to -80 dB	- 6	-	0	dB
Absolute attenuation (1 kHz)	AT <sub>0</sub>	ATT = $0\text{ dB}$	-	- 0.0	-	dB
	AT <sub>2</sub>	ATT = -20 dB	-	- 20.0	-	dB
	AT <sub>4</sub>	ATT = -40 dB	-	- 40.0	-	dB
	AT <sub>6</sub>	ATT = -60 dB	-	- 60.4	-	dB
	AT <sub>8</sub>	ATT = -80 dB	-	- 84.2	-	dB
Mute attenuation (1 kHz)	Mute	ATT = Mute	- 85.0	- 88.0	-	dB
Channel crosstalk	CT	ATT = $0\text{ dB}$	- 103	- 105	-	dB
Frequency response	FR	ATT = $0\text{ dB}$ , $f = 200\text{ kHz}$	- 10	- 8	-	dB
Quiescent output zip noise voltage (while ATT value adjusting)	$N_J$	$0\text{ V}_{rms}$ input	-	-	3	mV
Minimum driver load resistance	$R_{ML}$	ATT = $0\text{ dB}$ , THD + N = 1%	-	8	12	k $\Omega$

### Reference voltage (VRL, VRR)

Parameter	Symbol	Condition	Rating			Unit
			min	typ	max	
Reference voltage output	$V_{REF}$		$0.45V_{DD}$	$0.5V_{DD}$	$0.55V_{DD}$	V

## MEASUREMENT CIRCUIT

Chip address: ADRS1 = LOW, ADRS2 = LOW



## MICROCONTROLLER INTERFACE

The SM6451BV uses a 3-wire serial interface comprising MDT (data), MCK (clock) and MLEN (latch enable) to select channels and attenuation levels for the addressed device.

### Input Timing

The microcontroller data input timing is shown in figure 1.

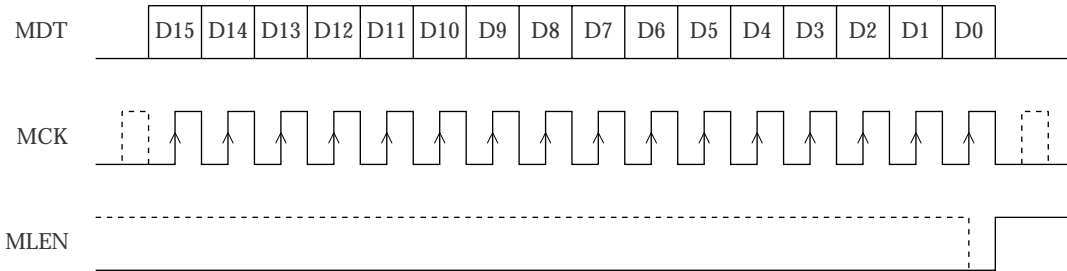


Figure 1. Microcontroller data input timing

Data is shifted into the internal shift register on the rising edge of MCK, and the attenuation value is updated on the rising edge of MLEN. Accordingly, data on MDT should be changed on the falling edge of MCK. The dotted lines for MCK and MLEN also indicate valid timing.

Note, however, a minimum of 16 MCK input pulses are required.

### Data Format

The format of microcontroller input data is shown in figure 2.

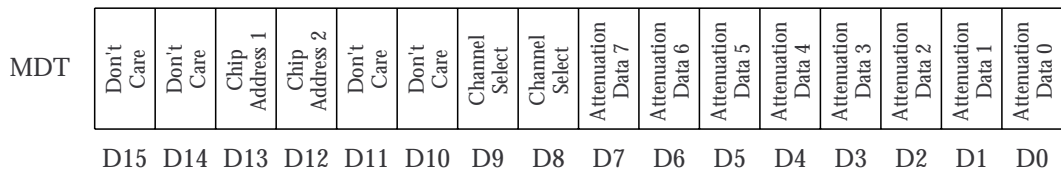


Figure 2. Microcontroller data format

#### D15, D14

Don't care.

#### D13, D12

Chip address bits. D13 corresponds to ADRS1 and D12 corresponds to ADRS2. The device is addressed only when ADRS1:ADRS2 matches D13:D12.

Example 1: If D13 = LOW, D12 = HIGH and ADRS1 = LOW, ADRS2 = LOW, then the device is not addressed since ADRS2 and D12 do not match.

Example 2: If D13/D12 = LOW and ADRS1/ADRS2 = LOW, then the device is addressed and all input data is read and the attenuation settings updated.

#### D11, D10

Don't care.

**D9, D8**

Channel select bits. The selected channel(s) are shown in table 1.

Table 1. Channel select

D9	D8	Selected channel
LOW	LOW	Both left and right channels
LOW	HIGH	Left channel
HIGH	LOW	Right channel
HIGH	HIGH	No change

**D7 to D0**

Attenuation register (ATT) set bits.

Table 2. Attenuation setting<sup>1</sup>

Attenuation	ATT <sub>H</sub>	D7	D6	D5	D4	D3	D2	D1	D0
0 dB	00	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW
-1 dB	01	LOW	LOW	LOW	LOW	LOW	LOW	LOW	HIGH
-2 dB	02	LOW	LOW	LOW	LOW	LOW	LOW	HIGH	LOW
:	:	:	:	:	:	:	:	:	:
-15 dB	0F	LOW	LOW	LOW	LOW	HIGH	HIGH	HIGH	HIGH
-16 dB	10	LOW	LOW	LOW	HIGH	LOW	LOW	LOW	LOW
-17 dB	11	LOW	LOW	LOW	HIGH	LOW	LOW	LOW	HIGH
:	:	:	:	:	:	:	:	:	:
-63 dB	3F	LOW	LOW	HIGH	HIGH	HIGH	HIGH	HIGH	HIGH
-64 dB	40	LOW	HIGH	LOW	LOW	LOW	LOW	LOW	LOW
-65 dB	41	LOW	HIGH	LOW	LOW	LOW	LOW	LOW	HIGH
:	:	:	:	:	:	:	:	:	:
-79 dB	4F	LOW	HIGH	LOW	LOW	HIGH	HIGH	HIGH	HIGH
-80 dB	50	LOW	HIGH	LOW	HIGH	LOW	LOW	LOW	LOW
Mute	51	LOW	HIGH	LOW	HIGH	LOW	LOW	LOW	HIGH
Mute	52	LOW	HIGH	LOW	HIGH	LOW	LOW	HIGH	LOW
:	:	:	:	:	:	:	:	:	:
Mute	FE	HIGH	HIGH	HIGH	HIGH	HIGH	HIGH	HIGH	LOW
Mute	FF	HIGH	HIGH	HIGH	HIGH	HIGH	HIGH	HIGH	HIGH

1. Outputs are muted after system reset.

Attenuation error is changed dependent on the supply voltage when attenuation level is under - 60dB. In the case of the supply voltage being under 2.6V, mute level inverses up to the same level of - 80dB setting or more. (see Figure 6)



**ANALOG PERFORMANCE CHARACTERISTICS**

DVDD = AVDD = 3.0 V, 100 kΩ output load resistance, Ta = 25 °C

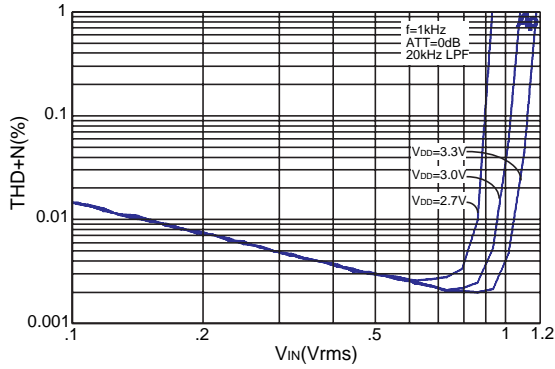


Figure 3. THD + N vs. input amplitude

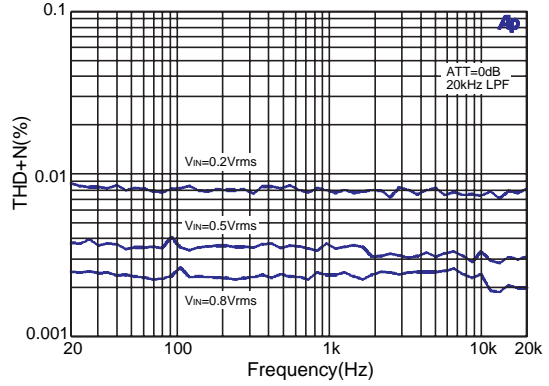


Figure 4. THD + N vs. input frequency

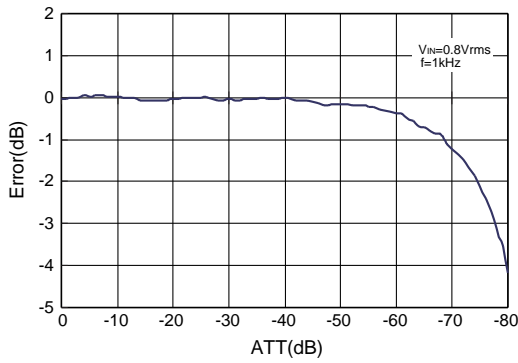


Figure 5. Attenuation error

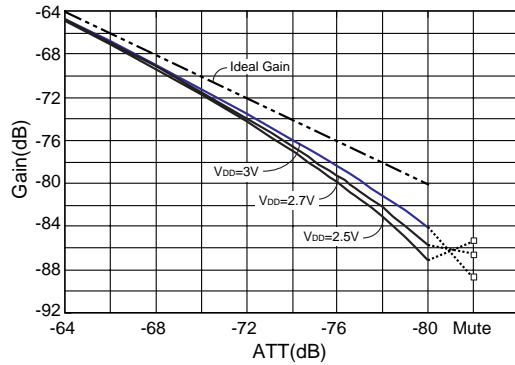


Figure 6. Attenuation characteristic (-64dB to MUTE)

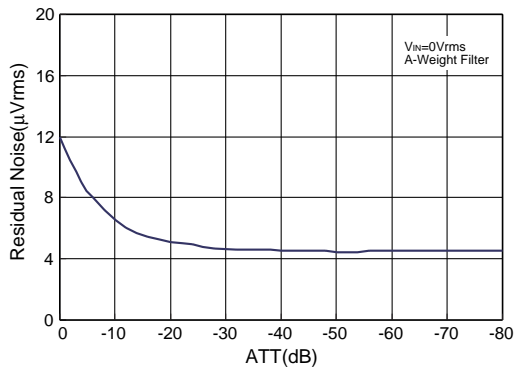


Figure 7. Residual noise vs. ATT

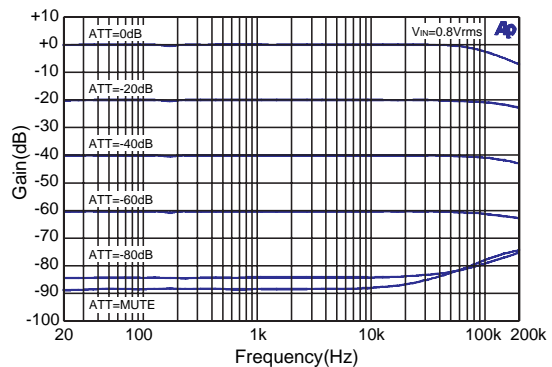


Figure 8. Frequency response

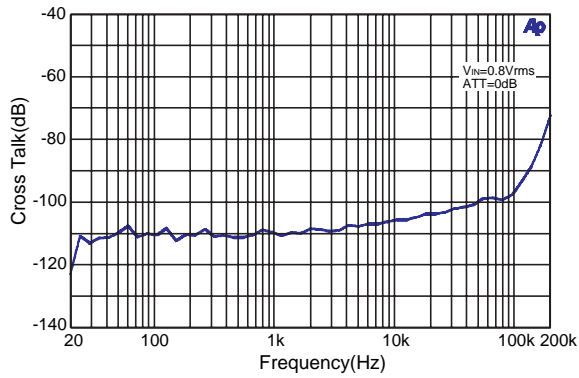


Figure 9. Crosstalk frequency response

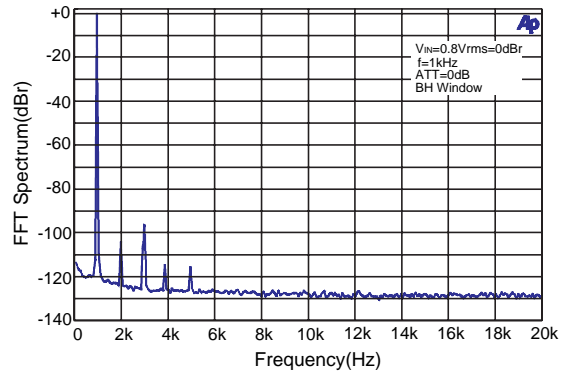


Figure 10. FFT spectrum

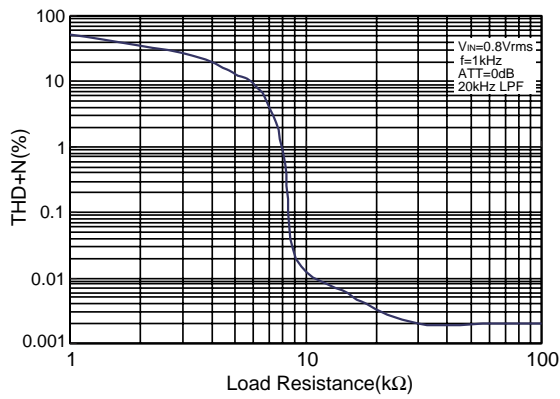


Figure 11. THD + N vs. load resistance

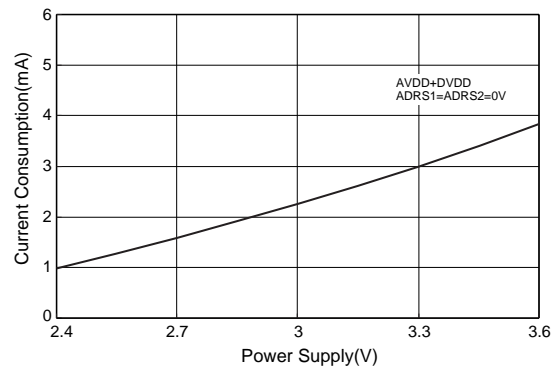


Figure 12. Current consumption vs. supply voltage

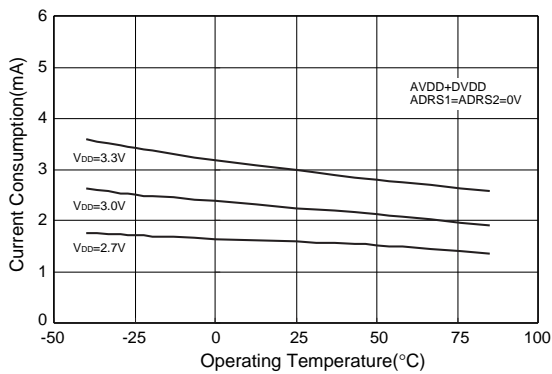


Figure 13. Current consumption vs. operating temperature

## TYPICAL APPLICATIONS

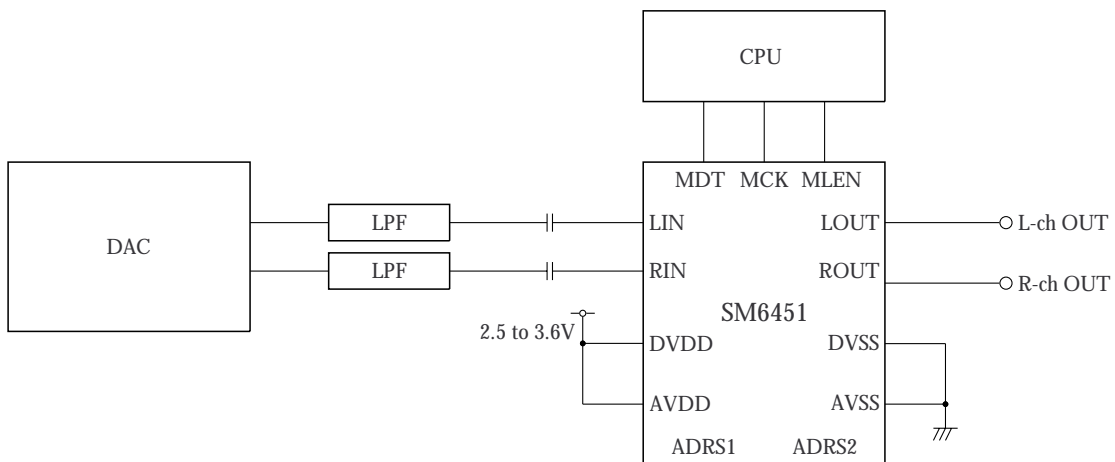
### Connection Guidelines

Decoupling capacitors of approximately 10  $\mu\text{F}$  should be connected from AVDD, VRL, VRR to AVSS, and from DVDD to DVSS.

In addition, approximately 0.01  $\mu\text{F}$  capacitors should also be connected from AVDD, VRL, VRR to AVSS, and from DVDD to DVSS to suppress digital switch noise.

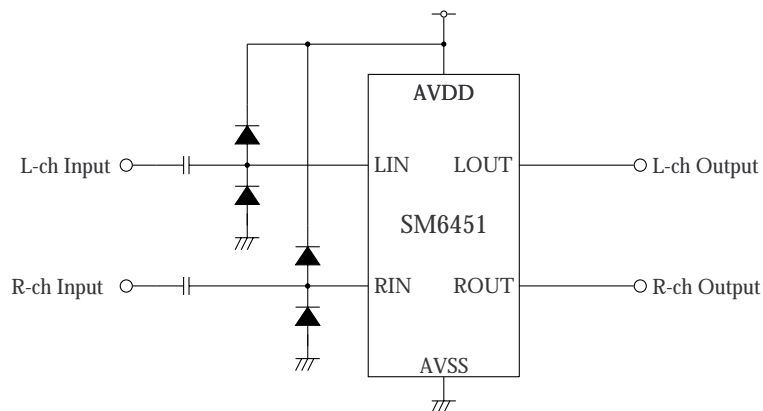
An approximately 0.001  $\mu\text{F}$  capacitor connected from RSTN to DVSS will force a system reset when power is applied.

### Connection 1 (to DAC)



### Connection 2

When there is a possibility that the input peak-to-peak amplitude will exceed the supply voltage, input protection diodes should be connected to prevent device breakdown.



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