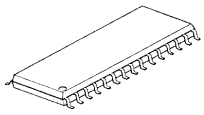
# 6-CHANNEL ELECTRONIC VOLUME

## ■ GENERAL DESCRIPTION

The **NJW1151** is a 6-CHANNEL ELECTRONIC VOLUME, which also includes tone control, balance and trim level control. The **NJW1151** is suitable for multi-channel audio system, such as AV amplifier, mini stereo component, speaker system, and others.

All of internal status and variables are controlled by $I^2C$ BUS interface.

## ■ PACKAGE OUTLINE

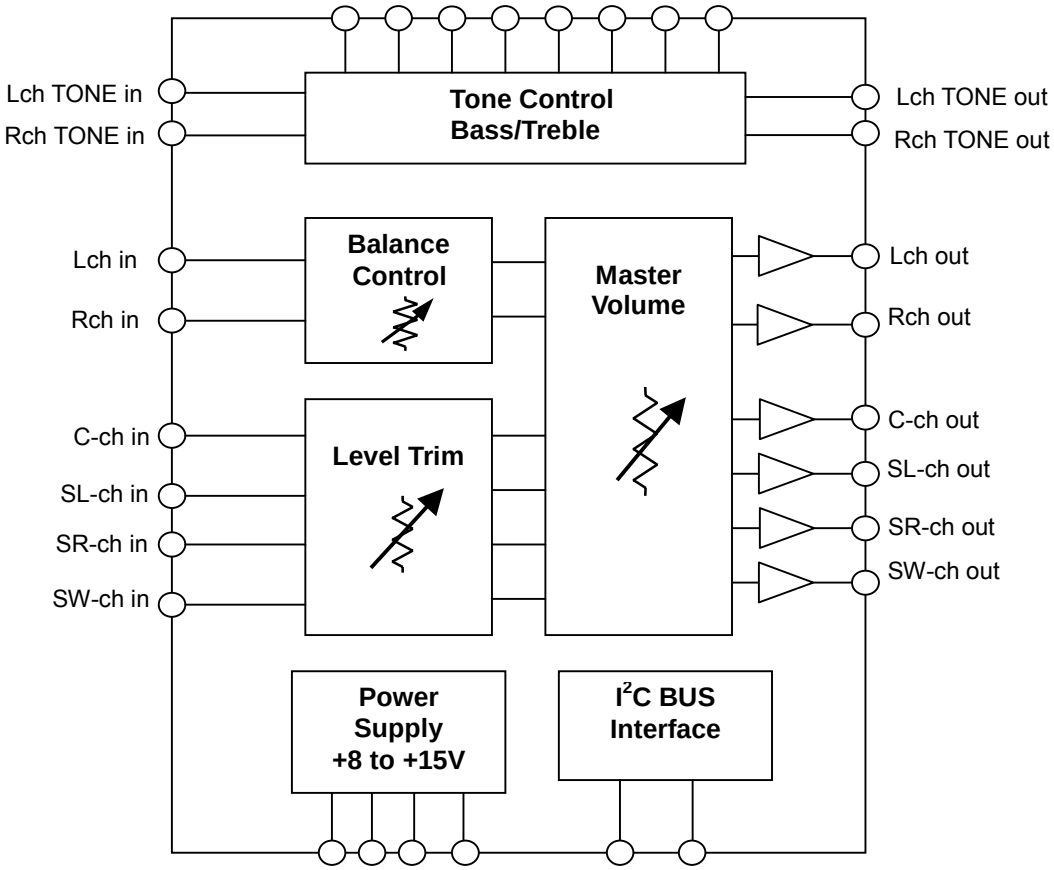


**NJW1151M**

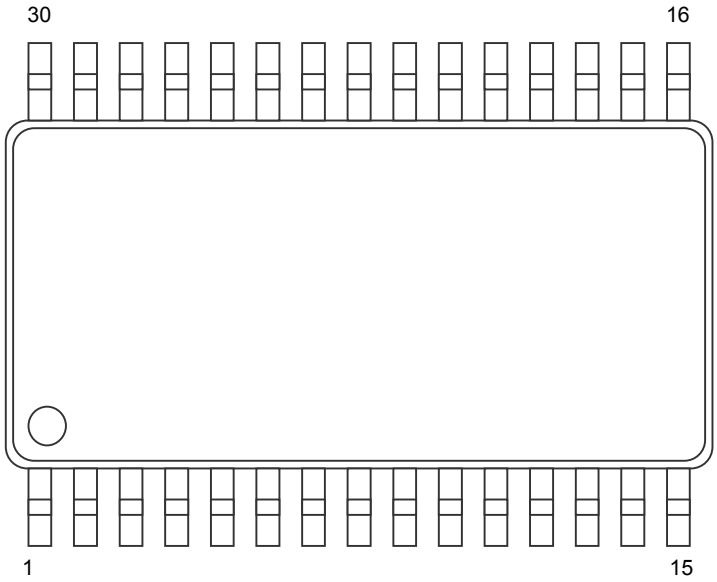
## ■ FEATURES

| | |
|---|---|
| ● Operating Voltage | +8.0 to +15.0V |
| ● $I^2C$ BUS Interface | |
| ● 6-Chnnel Master Volume | 0 to –79dB, MUTE |
| ● Balance control for L, R-ch | 0 to –30dB, MUTE |
| ● Trim Level Control for C, SL, SR, SW-ch | 0 to –20dB |
| ● Independent Tone Control (Bass, Treble) | for L, R-ch |
| ● Bi-CMOS Technology | |
| ● Package Outline | SDMP30 |

## ■ BLOCK DIAGRAM



## ■ PIN FUNCTION




| No. | SYMBOL | FUNCTION | No. | SYMBOL | FUNCTION |
|---|---|---|---|---|---|
| 1 | VREF | Reference voltage | 16 | SCL | $I^2C$ bus clock input |
| 2 | V+ | Power supply voltage | 17 | SDA | $I^2C$ bus data input |
| 3 | VREFC | Reference voltage stabilization capacitor | 18 | SWOUT | Volume Sub Woofer channel output |
| 4 | RTIN | Tone control Right channel input | 19 | SROUT | Volume Surround Right channel output |
| 5 | RTOUT | Tone control Right channel output | 20 | SLOUT | Volume Surround Left channel volume output |
| 6 | RTC | Tone control Right channel Treble filter capacitor | 21 | COUT | Volume Center channel output |
| 7 | RBC1 | Tone control Right channel Bass filter capacitor | 22 | ROUT | Volume Right channel output |
| 8 | RBC2 | Tone control Right channel Bass filter capacitor | 23 | LOUT | Volume Left channel output |
| 9 | RBC3 | Tone control Right channel Bass DC cut capacitor | 24 | LBC3 | Tone control Left channel Bass DC cut capacitor |
| 10 | LIN | Volume Left channel input | 25 | LBC2 | Tone control Left channel Bass filter capacitor |
| 11 | RIN | Volume Right channel input | 26 | LBC1 | Tone control Left channel Bass filter capacitor |
| 12 | CIN | Volume Center channel input | 27 | LTC | Tone control Left channel Treble filter capacitor |
| 13 | SLIN | Volume Surround Left channel input | 28 | LTOUT | Tone control Left channel output |
| 14 | SRIN | Volume Surround Right channel input | 29 | LTIN | Tone control Left channel input |
| 15 | SWIN | Volume Sub Woofer channel input | 30 | GND | Ground (IC substrate) |

■ **ABSOLUTE MAXIMUM RATING (Ta=25°C)**

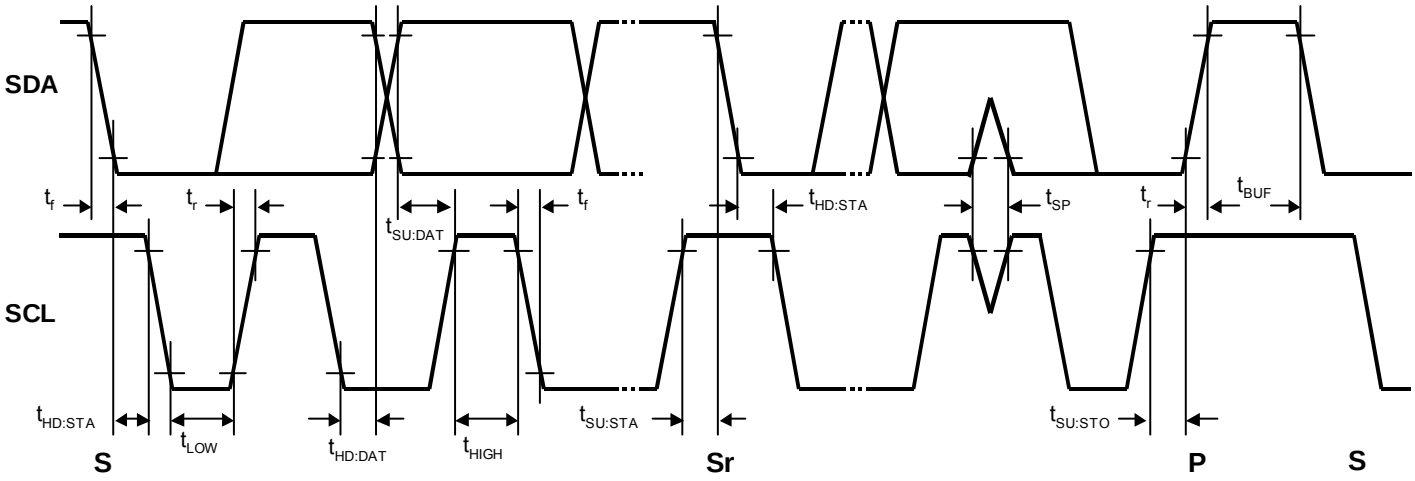
| PARAMETER | SYMBOL | RATING | UNIT |
|---|---|---|---|
| Supply Voltage | $V^+$ | +15 | V |
| Maximum Input Voltage | $V_{IM}$ | $V^{+(*)}$ | V |
| Power Dissipation | $P_D$ | 700 | mW |
| Operating Temperature Range | Topr | -40 to +85 | °C |
| Storage Temperature Range | Tstg | -40 to +125 | °C |

(✳) For the maximum input voltage less than 0 to V+

■ **ELECTRICAL CHARACTERISTICS ( Ta=25°C,$V^+$=14V, $V_{DD}$=5V)**

| PARAMETER | SYMBOL | TEST CONDITION | MIN. | TYP. | MAX. | UNIT |
|---|---|---|---|---|---|---|
| ♦**Power Supply** | | | | | | |
| Operating Voltage | $V^+$ | | 8.0 | 14.0 | 15.0 | V |
| Supply Current | $I_{CC}$ | No Signal | - | 10 | 30 | mA |
| ♦**Input/Output Characteristics** | | | | | | |
| Voltage Gain | $G_V$ | $V_{IN}$=1Vrms, f=1kHz Master=0dB, Balance=0dB Trimmer=0dB | -0.5 | 0 | 0.5 | dB |
| Voltage Gain Error | $\Delta G_V$ | $V_{IN}$=1Vrms, f=1kHz Master=0dB | -0.5 | 0 | 0.5 | dB |
| Maximum Attenuation 1 | $A_{TT1}$ | f=1kHz, $V_{IN}$=1Vrms Master=-79dB | - | -79 | - | dB |
| Maximum Attenuation 2 | $A_{TT2}$ | f=1kHz, $V_{IN}$=1Vrms Mute | - | -90 | - | dB |
| Attenuation Error | $\Delta A_{TT}$ | f=1kHz, $V_{IN}$=1Vrms Master=-50dB Trimmer=-10dB | -1 | 0 | 1 | dB |
| Maximum Output Voltage | $V_{OM}$ | f=1kHz,THD=1% Master=0dB | 3.0 | 4.0 | - | Vrms |
| Output Noise | $V_{NO}$ | Master=0dB, Rg=0,A-weight | - | -110 (3.2μ) | -100 (10μ) | dBV (Vrms) |
| Total Harmonic Distortion | T.H.D. | f=1kHz,Vo=1Vrms, Master=0dB,Trimmer=0dB | - | 0.005 | 0.05 | % |
| Channel Separation | CS | f=1kHz,Vo=1Vrms Master=0dB,A-weight | - | -90 | -80 | dB |
| ♦**Tone Control Characteristics** | | | | | | |
| Treble Boost Gain1 | $HF_{BST}$ | Vo=1Vrms f=10kHz Treble=10dB | 8 | 10 | 12 | dB |
| Treble Boost Gain2 | $HF_{CUT}$ | Vo=1Vrms f=10kHz Treble=-10dB | -12 | -10 | -8 | dB |
| Bass Boost Gain1 | $LF_{BST}$ | Vo=1Vrms f=50Hz Bass=10dB | 8 | 10 | 12 | dB |
| Bass Boost Gain2 | $LF_{CUT}$ | Vo=1Vrms f=50Hz Bass=-10dB | -12 | -10 | -8 | dB |

■TIMING ON THE I²C BUS (SDA,SCL)




■CHARACTERISTICS OF I/O STAGES FOR I²C BUS (SDA,SCL)

I²C BUS Load Conditions

STANDARD MODE: Pull up resistance 4kΩ (Connected to +5V), Load capacitance 200pF (Connected to GND)

| PARAMETER | SYMBOL | Standard mode | | | UNIT |
|---|---|---|---|---|---|
| | | MIN. | TYP. | MAX. | |
| Low Level Input Voltage | $V_{IL}$ | 0.0 | - | 1.5 | V |
| High Level Input Voltage | $V_{IH}$ | 3.0 | - | 5.0 | V |
| Low level output voltage (3mA at SDA pin) | $V_{OL}$ | 0 | - | 0.4 | V |
| Input current each I/O pin with an input voltage between $0.1V_{DD}$ and $0.9V_{DDmax}$ | $I_i$ | -10 | - | 10 | μA |

## ■CHARACTERISTICS OF BUS LINES (SDA,SCL) FOR I²C-BUS DEVICES

| PARAMETER | SYMBOL | Standard mode | | | UNIT |
|---|---|---|---|---|---|
| | | MIN. | TYP. | MAX. | |
| SCL clock frequency | $f_{SCL}$ | - | - | 100 | kHz |
| Hold time (repeated) START condition. | $t_{HD:STA}$ | 4.0 | - | - | μs |
| Low period of the SCL clock | $t_{LOW}$ | 4.7 | - | - | μs |
| High period of the SCL clock | $t_{HIGH}$ | 4.0 | - | - | μs |
| Set-up time for a repeated START condition | $t_{SU:STA}$ | 4.7 | - | - | μs |
| Data hold time NOTE) | $t_{HD:DAT}$ | 0 | - | - | μs |
| Data set-up time | $t_{SU:DAT}$ | 250 | - | - | ns |
| Rise time of both SDA and SCL signals | $t_r$ | - | - | 1000 | ns |
| Fall time of both SDA and SCL signals | $t_f$ | - | - | 300 | ns |
| Set-up time for STOP condition | $t_{SU:STO}$ | 4.0 | - | - | μs |
| Bus free time between a STOP and START condition | $t_{BUF}$ | 4.7 | - | - | μs |
| Capacitive load for each bus line | $C_b$ | - | - | 400 | pF |
| Noise margin at the Low level | $V_{nL}$ | 0.5 | - | - | V |
| Noise margin at the High level | $V_{nH}$ | 1 | - | - | V |

$C_b$ ; total capacitance of one bus line in pF.

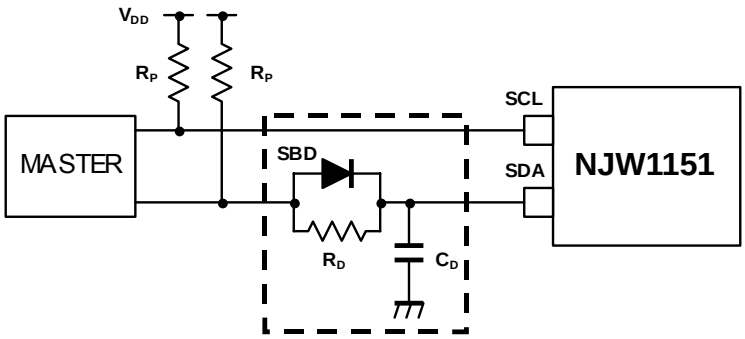
NOTE). Data hold time : $t_{HD:DAT}$

Please hold the Data Hold Time ($t_{HD:DAT}$) to 300ns or more to avoid status of unstable at SCL falling edge.

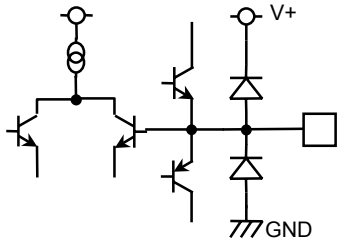
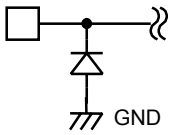
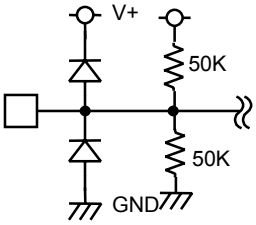
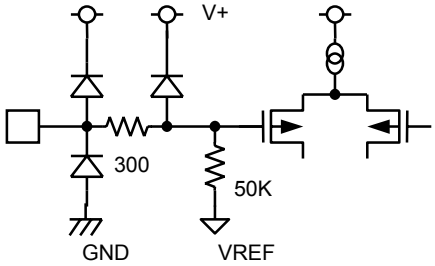
The SDA block in the NJW1151 does not hold data. Add external data-delay-circuit of the SDA terminal, in case of not providing a hold time of at least 300nsec for the SDA in the master device.
The time-consists of the data-delay-circuit of the SDA terminal are as follows.

(a) Low level → High level: $T_{LH} \approx R_P * C_D$
(b) High level → Low level: $T_{HL} \approx R_D * C_D$

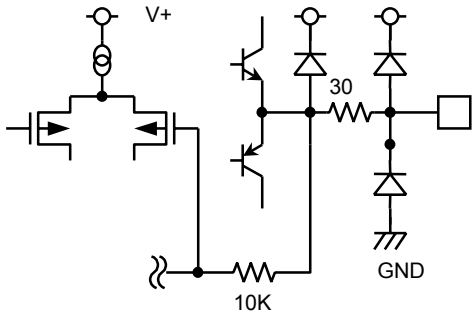
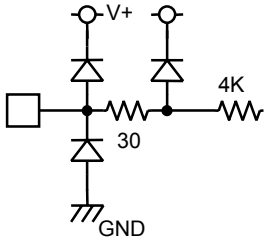
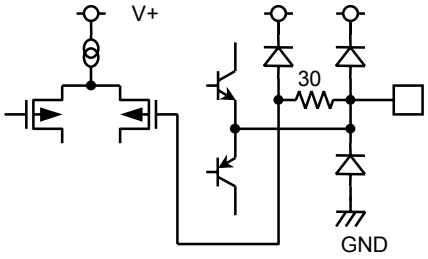
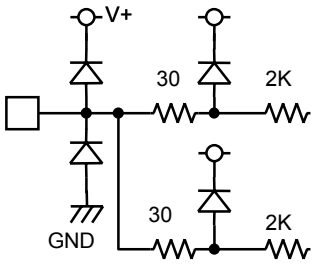
In addition, Schottky barrier diode (SBD) influences a Low level at the Acknowledge. Therefore choose the low forward voltage (Vf) as much as possible.



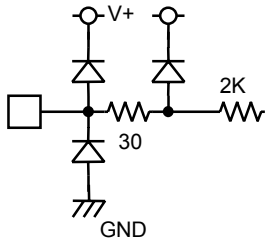
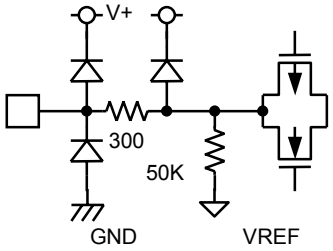
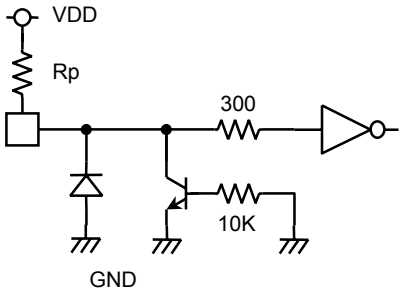
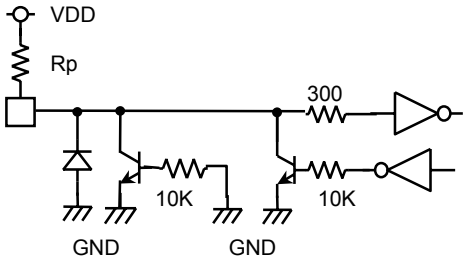
■TERMINAL DESCRIPTION

| No. | SYMBOL | FUNCTION | EQUIVALENT CIRCUIT | TERMINAL VOLTAGE |
|---|---|---|---|---|
| 1 | VREF | Reference voltage |  | V+ / 2 |
| 2 | V+ | Power supply voltage |  | $V^+$ |
| 3 | VREFC | Reference voltage stabilization capacitor |  | V+ / 2 |
| 4<br>29 | RTIN<br>LTIN | Tone control<br>Right channel input<br>Left channel input |  | V+ / 2 |

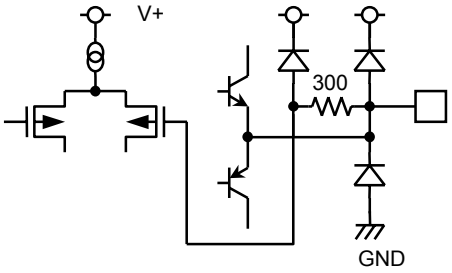
■TERMINAL DESCRIPTION

| No. | SYMBOL | FUNCTION | EQUIVALENT CIRCUIT | TERMINAL VOLTAGE |
|---|---|---|---|---|
| 5<br>28 | RTOUT<br>LTOUT | Tone control<br>Right channel output<br>Left channel output |  | V+ / 2 |
| 6<br><br>27 | RTC<br><br>LTC | Tone control<br>Right channel<br>Treble filter capacitor<br>Left channel<br>Treble filter capacitor |  | V+ / 2 |
| 7<br><br>26 | RBC1<br><br>LBC1 | Tone control<br>Right channel<br>Bass filter capacitor<br>Left channel<br>Bass filter capacitor |  | V+ / 2 |
| 8<br><br>25 | RBC2<br><br>LBC2 | Tone control<br>Right channel<br>Bass filter capacitor<br>Left channel<br>Bass filter capacitor |  | V+ / 2 |

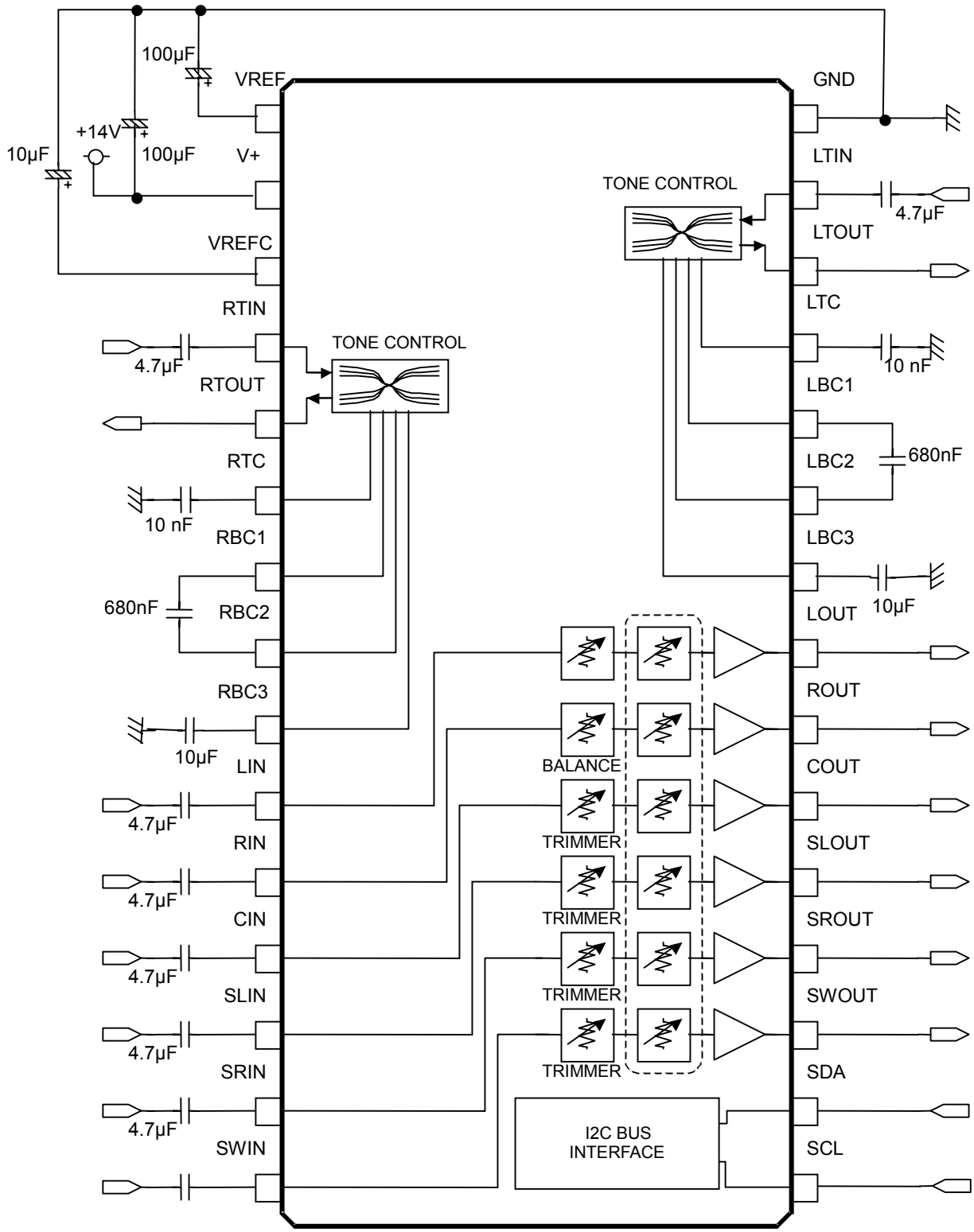
■TERMINAL DESCRIPTION

| No. | SYMBOL | FUNCTION | EQUIVALENT CIRCUIT | TERMINAL VOLTAGE |
|---|---|---|---|---|
| 9<br>24 | RBC3<br>LBC3 | Tone control<br>Right channel<br>Bass DC cut capacitor<br>Left channel<br>Bass DC cut capacitor |  | V+ / 2 |
| 10<br>11<br>12<br>13<br>14<br>15 | LIN<br>RIN<br>CIN<br>SLIN<br>SRIN<br>SWIN | Volume<br>Left channel input<br>Right channel input<br>Center channel input<br>Surround Left channel input<br>Surround Right channel input<br>Sub Woofer channel input |  | V+ / 2 |
| 16 | SCL | $I^2C$ bus clock input |  <br>( Rp ; External pull up resistor ) | - |
| 17 | SDA | $I^2C$ bus data input |  <br>( Rp ; External pull up resistor ) | - |

■TERMINAL DESCRIPTION

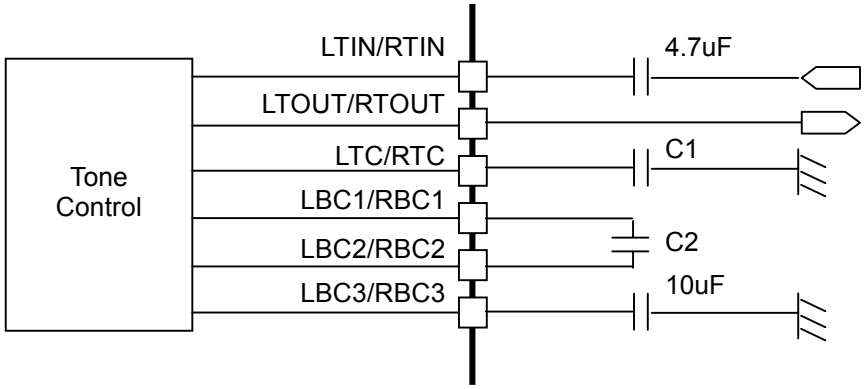
| No. | SYMBOL | FUNCTION | EQUIVALENT CIRCUIT | TERMINAL VOLTAGE |
|---|---|---|---|---|
| | | Volume |  | V+ / 2 |
| 18 | SWOUT | Left channel output | | |
| 19 | SROUT | Right channel output | | |
| 20 | SLOUT | Center channel output | | |
| 21 | COUT | Surround Left channel output | | |
| 22 | ROUT | Surround Right channel output | | |
| 23 | LOUT | Sub Woofer channel output | | |

■APPLICATION CIRCUIT



■ **Definition of cut-off frequency for Tone Control**

Cut-off frequency for Tone Control is adjustable with changing the capacitor C1, C2 in below circuit.
See the next function for the cut-off frequency.




EX) C1 =10nF, C2 = 680nF
Cut-off frequency for Treble = 3.9kHz
Cut-off frequency for Bass = 238Hz

1) TREBLE =+/-10dB

$$fc = \frac{39.2 * 10^{-6}}{C1} (kHz)$$

2) BASS =+/-10dB

$$fc = \frac{161.7 * 10^{-6}}{C2} (Hz)$$

## ■ DEFINITION OF I²C REGISTER

### ● I²C BUS FORMAT

S: Starting Term  A: Acknowledge Bit  P: Ending Term

| | MSB LSB | | MSB LSB | | MSB LSB | | |
|---|---|---|---|---|---|---|---|
| S | Slave Address | A | Select Address | A | Data | A | P |
| 1bit | 8bit | 1bit | 8bit | 1bit | 8bit | 1bit | 1bit |

### ● SLAVE ADDRESS

| MSB | | | | | | | LSB |
|---|---|---|---|---|---|---|---|
| 1 | 0 | 0 | 0 | 1 | 0 | 0 | R/W |

R/$\overline{W}$=0: Receive Only
R/$\overline{W}$=1: No Output Data

### ● CONTROL REGISTER TABLE

| Select Address | BIT | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | D7 | D6 | D5 | D4 | D3 | D2 | D1 | D0 |
| 00H | * | Master Volume | | | | | | |
| 01H | * | | | Left channel Balance | | | | |
| 02H | * | | | Right channel Balance | | | | |
| 03H | * | | | Center Channel Trimmer | | | | |
| 04H | * | | | SL Channel Trimmer | | | | |
| 05H | * | | | SR Channel Trimmer | | | | |
| 06H | * | | | SW Channel Trimmer | | | | |
| 07H | Tone (Treble) | | | | Tone (Bass) | | | |
| 08H | * | | MUTE | | | | | |

* : Don't care.
On Power up, the master volume mute is activated.

### ● CONTROL REGISTER DEFAULT VALUE

| Select Address | BIT | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | D7 | D6 | D5 | D4 | D3 | D2 | D1 | D0 |
| 00H | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 |
| 01H | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 02H | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 03H | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 |
| 04H | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 |
| 05H | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 |
| 06H | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 |
| 07H | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 08H | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

## ● CONTROL COMMAND TABLE

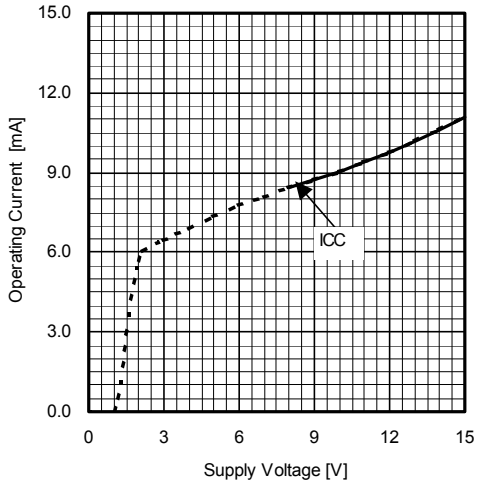
| Select Address | BIT D7 | D6 | D5 | D4 | D3 | D2 | D1 | D0 | REMARKS |
|---|---|---|---|---|---|---|---|---|---|
| 00H | * | VOL | | | | | | | VOL : Volume control for all channel (1dB/step)<br>Ex.)<br>"0000000"= 0dB<br>"0000001"=-1dB<br>"0000010"=- 2dB<br>.<br>"1001111"=-79dB<br>"1010000"=MUTE:Default Value<br>Maximum Attenuation : Master Volume :–79dB<br>Trimmer -20dB<br>Minimum Attenuation : Master Volume 0dB<br>Trimmer 0dB |
| | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| | | 0 | 0 | 0 | 0 | 0 | 0 | 1 | |
| | | 0 | 0 | 0 | 0 | 0 | 1 | 0 | |
| | | | | | : | | | | |
| | | | | | : | | | | |
| | | 1 | 0 | 0 | 1 | 1 | 1 | 1 | |
| | | 1 | 0 | 1 | 0 | 0 | 0 | 0 | |
| 01H | * | | | L-BAL | | | | | L-BAL : Balance control for Left channel (1dB/step)<br>Ex.)<br>"00000"=0dB<br>"00001"=-1dB<br>:<br>:<br>"11110"=-30dB<br>"11111"=MUTE |
| | | | | 0 | 0 | 0 | 0 | 0 | |
| | | | | 0 | 0 | 0 | 0 | 1 | |
| | | | | 0 | 0 | 0 | 1 | 0 | |
| | | | | | | : | | | |
| | | | | 1 | 1 | 1 | 1 | 1 | |
| 02H | * | | | R-BAL | | | | | R-BAL : Balance control for Right channel (1dB/step)<br>Ex.)<br>"00000"=0dB<br>"00001"=-1dB<br>:<br>:<br>"11110"=-30dB<br>"11111"= MUTE |
| | | | | 0 | 0 | 0 | 0 | 0 | |
| | | | | 0 | 0 | 0 | 0 | 1 | |
| | | | | 0 | 0 | 0 | 1 | 0 | |
| | | | | | | : | | | |
| | | | | 1 | 1 | 1 | 1 | 1 | |
| 03H | * | | | C TRIM | | | | | C TRIM :Center Channel Trimmer Control<br>Ex.)<br>"00000"=0dB<br>"00001"=-1dB<br>"00010"=-2dB<br>:<br>"10100"=-20dB "00001010"=-10dB Default Value |
| | | | | 0 | 0 | 0 | 0 | 0 | |
| | | | | 0 | 0 | 0 | 0 | 1 | |
| | | | | 0 | 0 | 0 | 1 | 0 | |
| | | | | | | : | | | |
| | | | | 1 | 0 | 1 | 0 | 0 | |
| 04H | * | | | SL TRIM | | | | | SL TRIM :SL Channel Trimmer Control<br>Ex.)<br>"00000"=0dB<br>"00001"=-1dB<br>"00010"=-2dB<br>:<br>"10100"=-20dB "00001010"=-10dB Default Value |
| | | | | 0 | 0 | 0 | 0 | 0 | |
| | | | | 0 | 0 | 0 | 0 | 1 | |
| | | | | 0 | 0 | 0 | 1 | 0 | |
| | | | | | | : | | | |
| | | | | 1 | 0 | 1 | 0 | 0 | |
| 05H | * | | | SR TRIM | | | | | SR TRIM :SR Channel Trimmer Control<br>Ex.)<br>"00000"=0dB<br>"00001"=-1dB<br>"00010"=-2dB<br>:<br>"10100"=-20dB "00001010"=-10dB Default Value |
| | | | | 0 | 0 | 0 | 0 | 0 | |
| | | | | 0 | 0 | 0 | 0 | 1 | |
| | | | | 0 | 0 | 0 | 1 | 0 | |
| | | | | | | : | | | |
| | | | | 1 | 0 | 1 | 0 | 0 | |
| 06H | * | | | SW TRIM | | | | | SW TRIM :SW Channel Trimmer Control<br>Ex.)<br>"00000"=0dB<br>"00001"=-1dB<br>"00010"=-2dB<br>:<br>"10100"=-20dB "00001010"=-10dB Default Value |
| | | | | 0 | 0 | 0 | 0 | 0 | |
| | | | | 0 | 0 | 0 | 0 | 1 | |
| | | | | 0 | 0 | 0 | 1 | 0 | |
| | | | | | | : | | | |
| | | | | 1 | 0 | 1 | 0 | 0 | |

## ● CONTROL COMMAND TABLE

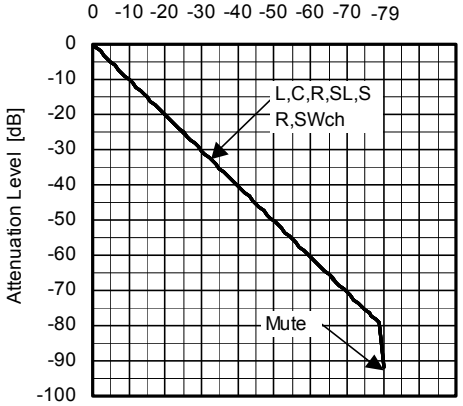
| Select Address | BIT | | | | | | | | REMARKS |
|---|---|---|---|---|---|---|---|---|---|
| | D7 | D6 | D5 | D4 | D3 | D2 | D1 | D0 | |
| 07H | TREBLE | | | | BASS | | | | TONE CONTROL<br>Ex.) "11011101"=+10dB<br>"11001100"=+8dB<br>:<br>"10001000"=0dB<br>"00000000"=0dB<br>:<br>"01000111"=-8dB<br>"01010101"=-10dB |
| | 1 | 1 | 0 | 1 | 1 | 1 | 0 | 1 | |
| | 1 | 1 | 0 | 0 | 1 | 1 | 0 | 0 | |
| | | | | | : | | | | |
| | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | |
| | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| | | | | | : | | | | |
| | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | |
| | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 1 | |
| 08H | * | | | MUTE | | | | | MUTE CONTROL<br>Ex.) "0"=OFF<br>"1"=MUTE<br>D5=L ch,D4=R ch,D3=C ch,D2=SL ch,D1=SR ch,D0=SW ch |
| | | | | 0 | | | | | |
| | | | | 1 | | | | | |

## ■ TYPICAL CHARACTERISTICS

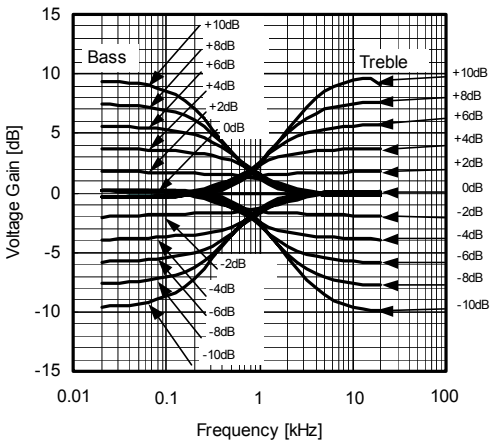
Operating Current vs. Supply Voltage
Ta=25°C



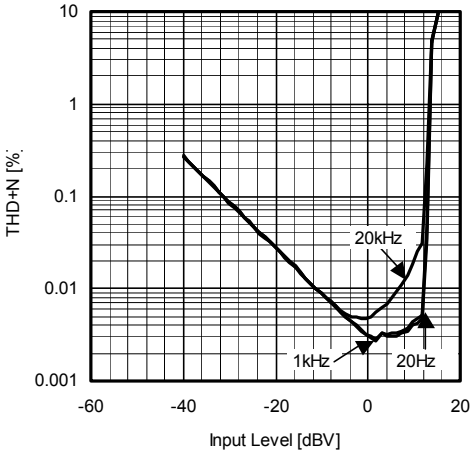

Volume Attenuation Level vs. Setting Level
V+=14V f=1kHz Ta=25°C



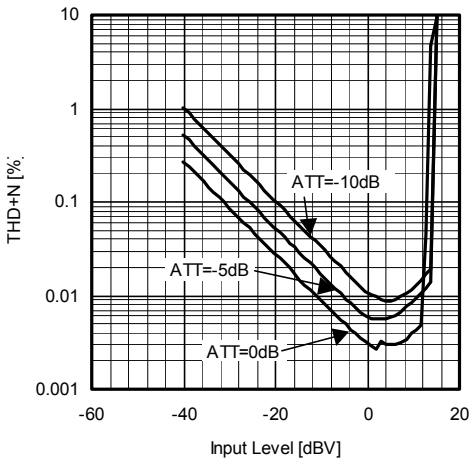

Tone Control Voltage Gain vs Frequency
V+=14V Vin=1Vrms Ta=25°C



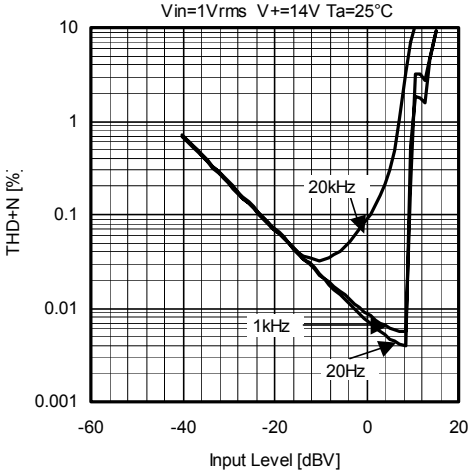

Volume THD+N vs. Input Level
Vin=1Vrms V+=14V Ta=25°C




Volume THD+N vs. Input Level
V+=14V Ta=25°C

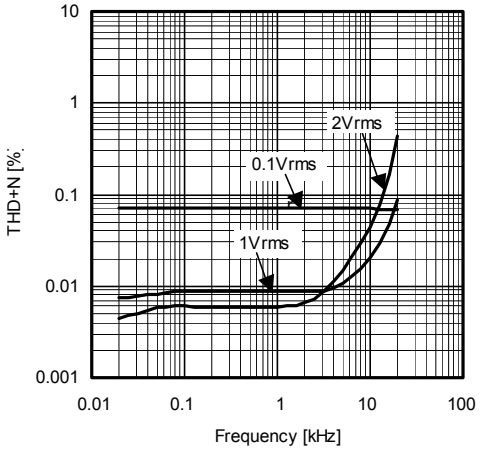



Tone Control THD+N vs. Input Level
(ATT=0dB;Flat)
Vin=1Vrms V+=14V Ta=25°C

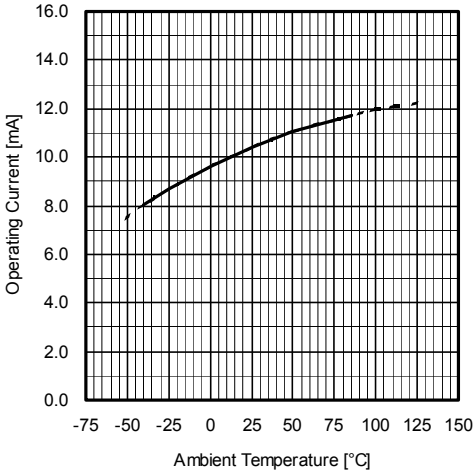


## ■ TYPICAL CHARACTERISTICS

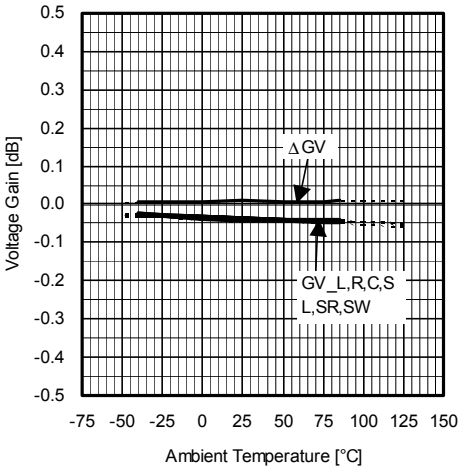
Tone Control THD+N vs. Frequency
(ATT=0dB;Flat)
V+=14V Ta=25°C



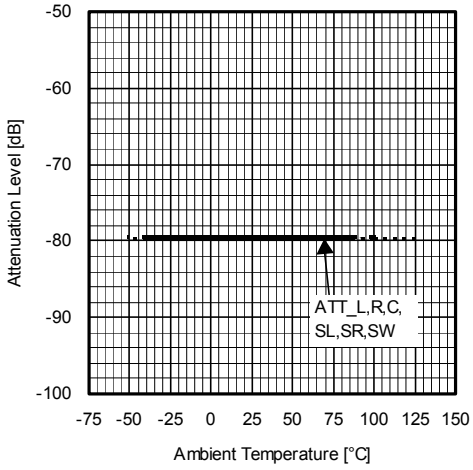

Operating Current vs. Ambient Temperature
V+=14V



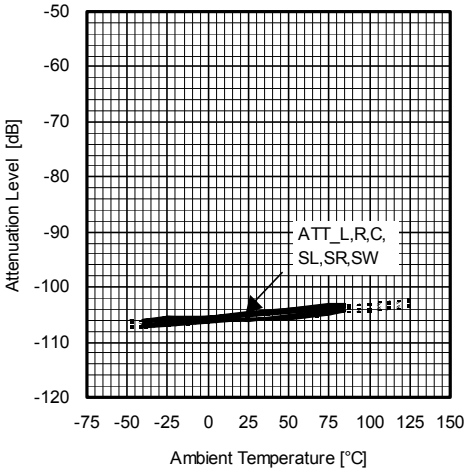

Volume Voltage Gain vs. Ambient Temperature
(Master Volume=0dB)
V+=14V Vin=1Vrms f=1kHz



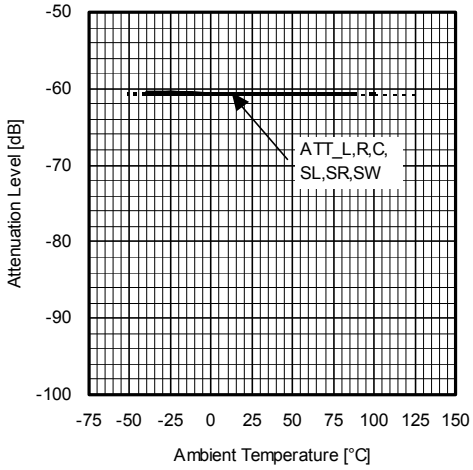

Volume Attenuation Level vs. Ambient Temperature
(Master Volume=-79dB)
V+=14V Vin=1Vrms f=1kHz




Volume Attenuation Level vs. Ambient Temperature
(Master Volume=Mute)
V+=14V Vin=1Vrms f=1kHz

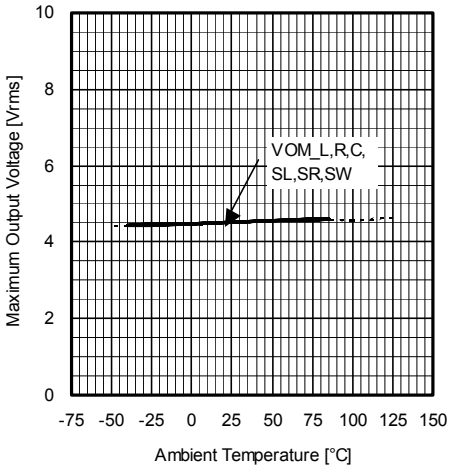



Volume Attenuation Level vs. Ambient Temperature
(Master=-50dB, Trimmer=-10dB)
V+=14V Vin=1Vrms f=1kHz

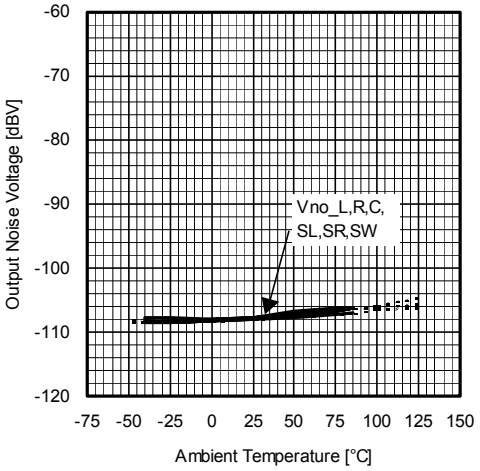


## ■ TYPICAL CHARACTERISTICS

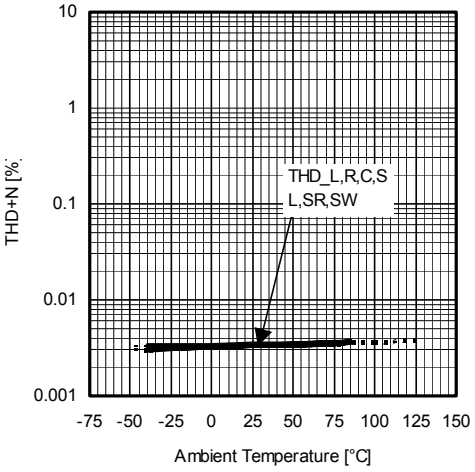
Volume Maximum Output Voltage vs. Ambient Temperature
V+=14V f=1kHz



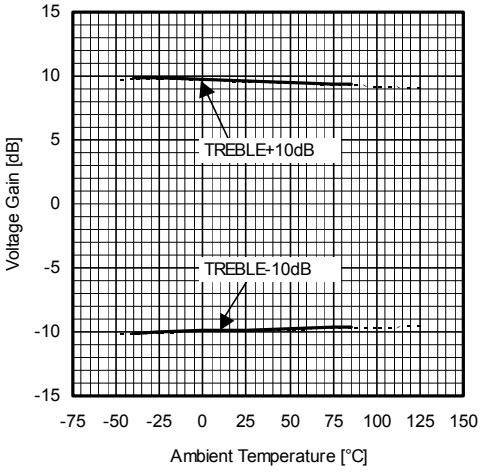

Volume Output Noise Voltage vs. Ambient Temperature
V+=14V A-Weighted



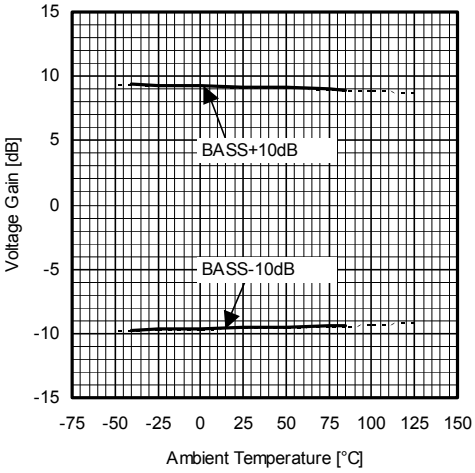

Volume THD+N vs. Ambient Temperature
V+=14V Vin=1Vrms f=1kHz



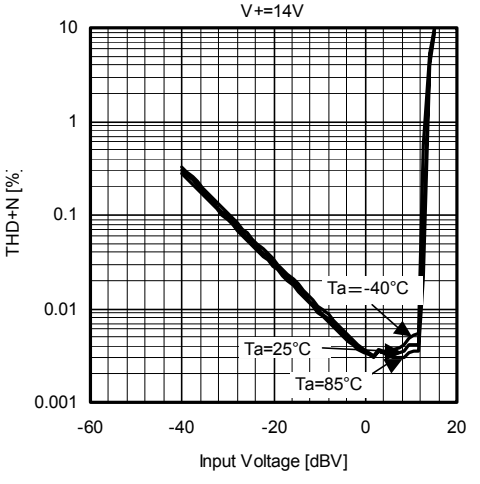

Tone Control Voltage Gain vs. Ambient Temperature
V+=14V Vin=1Vrms f=10kHz



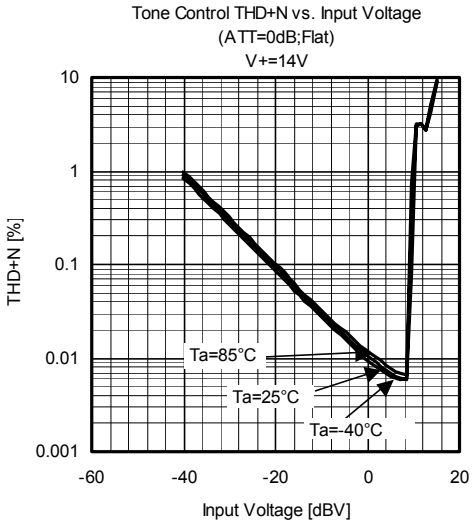

Tone Control Voltage Gain vs. Ambient Temperature
V+=14V Vin=1Vrms f=50Hz




Volume THD+N vs. Input Voltage
(Master Volume=0dB)
V+=14V



## ■ TYPICAL CHARACTERISTICS

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