16-Bit Stereo Audio DAC Integrated Headphone Driver with Volume Control

FEATURES

- Operation range: 2.7V~5.5V
- Volume control range : 6dB to –39dB, 1.5dB/step
- Low power consumption, 17mW at V_{DD}=3.3V (Audio code = 0000H)
- Mute function
- Flexibility power management
- No pop-noise
- No zero crossing distortion

- Audio format : Right justified, I^2S
- Serial control interface : I^2C, SPI
- Output voltage adjusted by the external resisters
- Excellent Power Supply Rejection Ratio(PSRR)
- Component less
- Cost effective
- Housed in SSOP20, SSOP16, QFN16 package

APPLICATIONS

Multimedia system, MP3, PDA, Portable Digital Audio.

DESCRIPTION

The MS6334 is a 16-bits voltage-output Digital-to-Analog Converter (DAC) integrated class AB stereo headphone driver with volume control. It is fabricated in a CMOS process and features extremely low power dissipation, small package size and easy application. The accuracy of the matched coarse current sources, combined with the unique symmetrical decoding method, preclude zero-crossing distortion and ensures high quality audio reproduction.

The MS6334 has good feature for portable equipment, these features include the low voltage operation, low power consumption, flexible power management, component less and small package SSOP20, make the MS6334 ideally suited for use in portable digital audio equipments.

The MS6335 only has I^2C interface, the smaller package SSOP16, QFN16 , and other functions are the same as the MS6334.
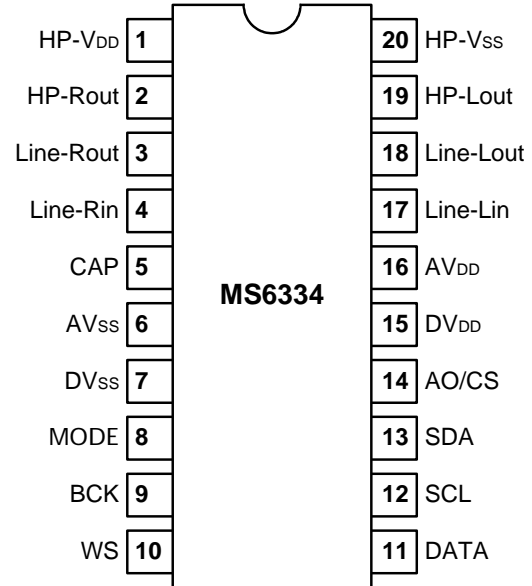
BLOCK DIAGRAM
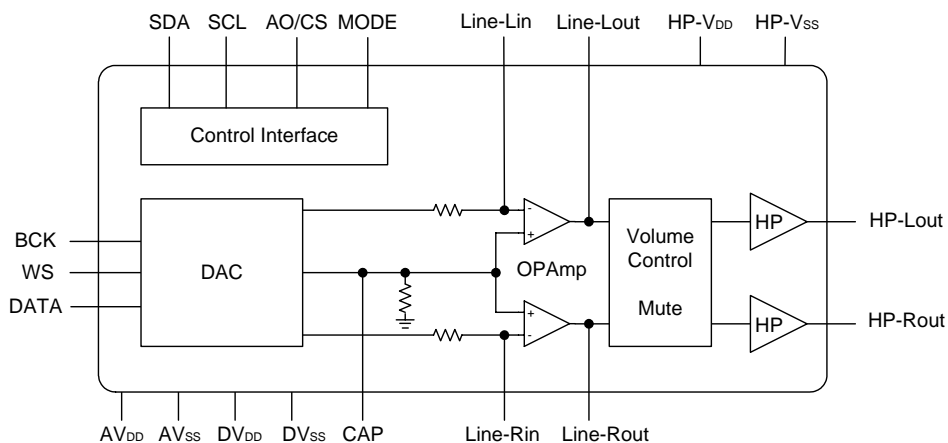
PIN CONFIGURATION

MS6334

Symbol	Pin	Description
HP-V$_{DD}$	1	Headphone supply voltage
HP-Rout	2	Right channel headphone output
Line-Rout	3	Right channel line output
Line-Rin	4	Right channel line input
CAP	5	Capacitor connected
AV$_{SS}$	6	Analog ground
DV$_{SS}$	7	Digital ground
MODE	8	Control interface selection Low : I^{2}C, High : SPI
BCK	9	Audio bit clock input
WS	10	Audio word select input
DATA	11	Audio data input
SCL	12	I^{2}C clock input SPI clock input
SDA	13	I^{2}C data input SPI data input
AO/CS	14	I^{2}C address option SPI chip select
DV$_{DD}$	15	Digital supply voltage
AV$_{DD}$	16	Analog supply voltage
Line-Lin	17	Left channel line input
Line-Lout	18	Left channel line output
HP-Lout	19	Left channel headphone output
HP-V$_{SS}$	20	Headphone ground

Pin diagram (MS6334, SSOP20):
- 1 HP-V$_{DD}$ / 20 HP-V$_{SS}$
- 2 HP-Rout / 19 HP-Lout
- 3 Line-Rout / 18 Line-Lout
- 4 Line-Rin / 17 Line-Lin
- 5 CAP / 16 AV$_{DD}$
- 6 AV$_{SS}$ / 15 DV$_{DD}$
- 7 DV$_{SS}$ / 14 AO/CS
- 8 MODE / 13 SDA
- 9 BCK / 12 SCL
- 10 WS / 11 DATA

SSOP20, I^{2}C / SPI interface

Note: 1. MODE = low, the interface is I^{2}C and pin14 is address option (AO).
  AO = low, the address code is 8CH (10001100B).
  AO = high, the address code is 88H (10001000B).
 2. MODE = high, the interface is SPI and pin14 is chip selection (CS).

MS6335

| Symbol	Pin	Description
HP-V_{DD}	1	Headphone supply voltage
HP-Rout	2	Right channel headphone output
Line-Rout	3	Right channel line output
Line-Rin	4	Right channel line input
CAP	5	Capacitor connected
V_{SS}	6	Ground
BCK	7	Audio bit clock input
WS	8	Audio word select input
DATA	9	Audio data input
SCL	10	I^2C clock input
SDA	11	I^2C data input
V_{DD}	12	Supply voltage
Line-Lin	13	Left channel line input
Line-Lout	14	Left channel line output
HP-Lout	15	Left channel headphone output
HP-V_{SS}	16	Headphone ground
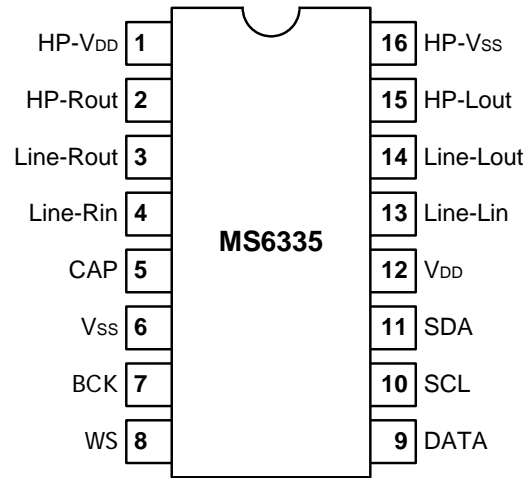
SSOP16, I^2C interface

Note: The control interface is I^2C only. The address code is 8CH (10001100B).

MS6335

Symbol	Pin	Description
Line-Rout	1	Right channel line output
Line-Rin	2	Right channel line input
CAP	3	Capacitor connected
V_{SS}	4	Ground
BCK	5	Audio bit clock input
WS	6	Audio word select input
DATA	7	Audio data input
SCL	8	I^2C clock input
SDA	9	I^2C data input
V_{DD}	10	Supply voltage
Line-Lin	11	Left channel line input
Line-Lout	12	Left channel line output
HP-Lout	13	Left channel headphone output
HP-V_{SS}	14	Headphone ground
HP-V_{DD}	15	Headphone supply voltage
HP-Rout	16	Right channel headphone output
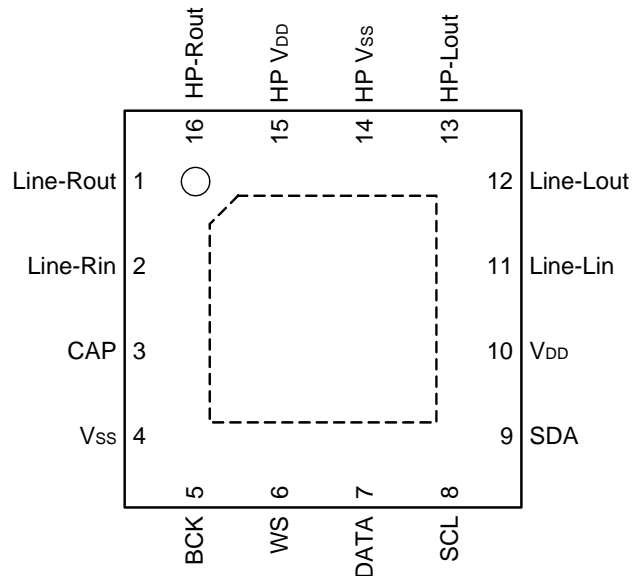
QFN16, I^2C interface

Note: The control interface is I^2C only. The address code is 88H (10001000B).

ORDERING INFORMATION

Package	Part number	Packaging Marking	Transport Media
20-Pin SSOP	MS6334TR	MS6334	2.5k Units Tape and Reel
20-Pin SSOP	MS6334U	MS6334	50 Units Tube
20-Pin SSOP (lead free)	MS6334GTR	MS6334G	2.5k Units Tape and Reel
20-Pin SSOP (lead free)	MS6334GU	MS6334G	50 Units Tube
16-Pin SSOP	MS6335TR	MS6335	2.5k Units Tape and Reel
16-Pin SSOP	MS6335U	MS6335	100 Units Tube
16-Pin SSOP (lead free)	MS6335GTR	MS6335G	2.5k Units Tape and Reel
16-Pin SSOP (lead free)	MS6335GU	MS6335G	100 Units Tube
16-Pin QFN (lead free)	MS6335QTR	6335	5k Units Tape and Reel
16-Pin QFN (lead free)	MS6335Q	6335	490 Units Tray

ABSOLUTE MAXIMUM RATINGS

Symbol	Parameter	Rating	Unit
V_{DD}	Positive Supply Voltage	6	V
V_{ESD}	Electrostatic Handling	-3000 to 3000	V
T_{STG}	Storage Temperature Range	-65 to 150	℃
T_A	Operating Ambient Temperature Range	-40 to 85	℃
T_J	Maximum Junction Temperature	150	℃
T_S	Soldering Temperature, 10 seconds	260	℃
R_{THJA}	Thermal Resistance from Junction to Ambient in Free Air SSOP20 SSOP16 QFN16	210 210 210	℃/W

OPERATING RATINGS

Symbol	Parameter	Min	Typ	Max	Unit
V_{DD}	Supply Voltage	2.7	-	5.5	V

3.3V ELECTRICAL CHARACTERISTICS

(Ta=25℃, V_{DD}=3.3V, V_{SS}=0V, f=1kHz, R_L=32Ω; unless otherwise specified)

| Symbol	Parameter	Conditions	Min	Typ	Max	Unit
DC Characteristics						
V_{CAP}	Voltage at CAP		1.60	1.65	1.70	V
V_{DC}	Output DC level		1.60	1.65	1.70	V
V_{FS}	Full scale output voltage	V_{FS}=0.02* R_F *V_{DD}	V_{FS}-10%	V_{FS}	V_{FS}+10%	V
I_Q	Quiescent current	Audio code 0000H	-	5.4	-	mA
I_{PD}	Power down current		-	11	-	uA
PSRR	Power supply rejection ratio	CAP=2.2uF (100Hz)	58	63		dB
		CAP=10uF (100Hz)	67	72		dB
CS	Channel separation		76	82	-	dB
ATT	Mute attenuation		100	110	-	dB
A_{GA}	Gain/Attenuation	Max gain	-	6	-	dB
		Max attenuation	-	-39	-	dB
A_{STEP}	Gain/Attenuation step		-	1.5	-	dB
E_{GA}	Gain/Attenuation step error		-	0.3	-	dB
E_{IGA}	Interchannel gin/attenuation error		-	0.3	-	dB
AC Characteristics						
Res	Resolution		-	-	16	bits
THD+N	Total harmonic distortion plus noise		-	-65	-60	dB
			-	0.056	0.1	%
S/N	Signal-to-noise ratio		86	92	-	dB
Po	Maximum output power	(THD+N)/S < 0.1%, 2 ch	-	52	-	mW
Vo	Maximum output voltage swing	(THD+N)/S < 0.1%	-	2.6	-	Vpp
Bus Characteristics						
V_{IH}	Bus high input level		-	-	$0.7V_{DD}$	V
V_{IL}	Bus low input level		$0.3V_{DD}$	-	-	V

Note:
R_F : Feedback resistor

TYPICAL PERFORMANCE CHARACTERISTICS

(Ta=25℃, R_L=32Ω, R_F=22k, sampling rate=4fs; unless otherwise specified)
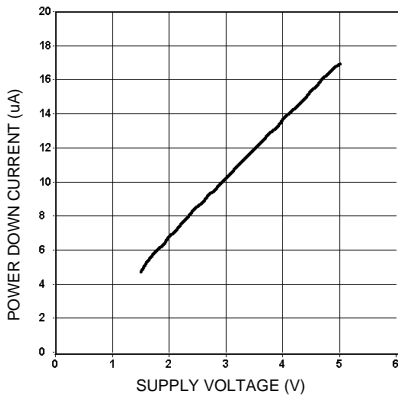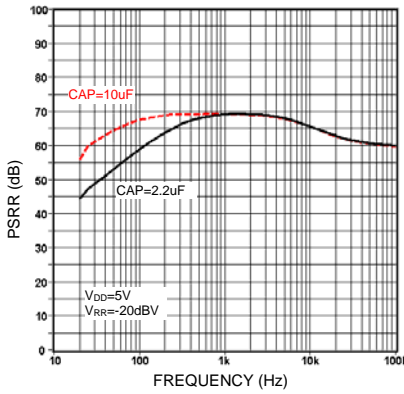

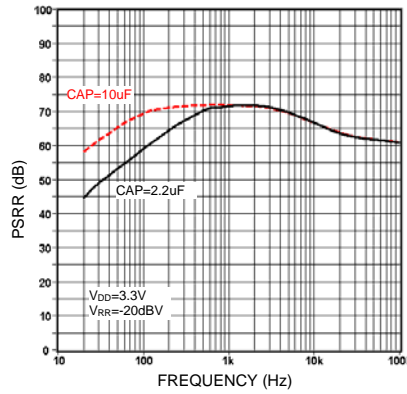**Power down current vs. supply voltage**
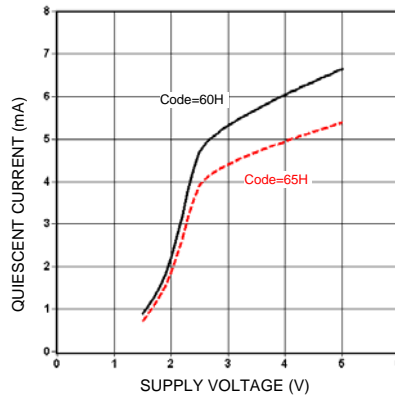
Quiescent current vs. supply voltage
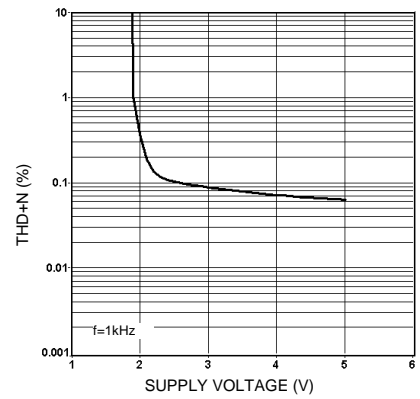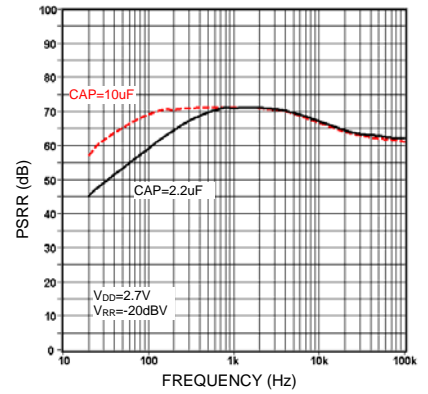

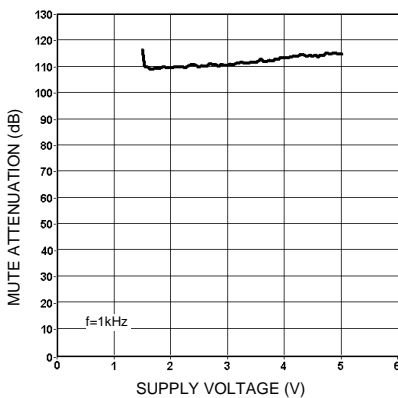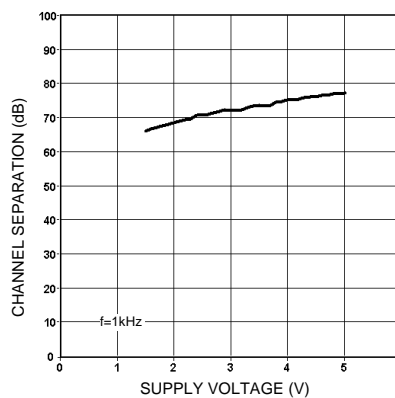**THD+N vs. supply voltage**

PSRR vs. frequency

PSRR vs. frequency

PSRR vs. frequency

Mute attenuation vs. supply voltage

Channel separation vs. supply voltage
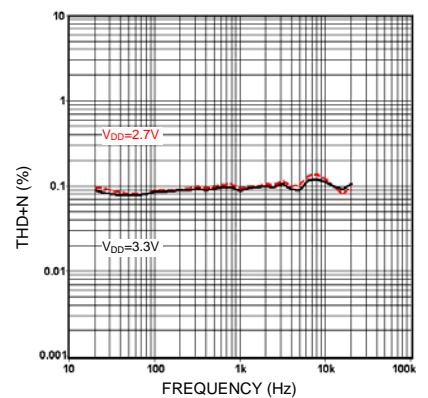
THD+N vs. frequency

AUDIO TIMING AND FORMAT

The MS6334 accepts input serial data formats of 16-bit word length. Left and right data words are time multiplexed. The MSB must always be first.
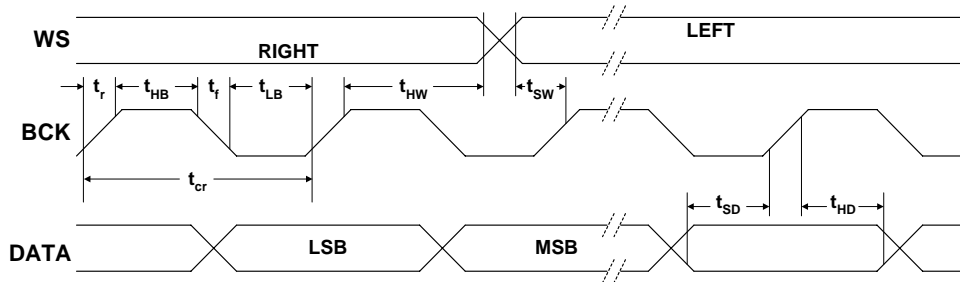
Fig.1   Timing of input signals

Audio data format (BCK, WS, DATA)

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
V_{IL}	Input LOW level		-	-	$0.3V_{DD}$	V
V_{IH}	Input HIGH level		$0.7V_{DD}$	-	-	V
f_{BCK}	Input Clock Frequency		-	-	18.4	MHz
BR	Bit Rate Data Input		-	-	18.4	Mbits/s
f_{WS}	Word Select Input		-	-	384	kHz
t_r	Rise Time		-	-	12	ns
t_f	Fall Time		-	-	12	ns
t_{Cr}	Bit Clock Cycle Time		54	-	-	ns
t_{HB}	Bit Clock High Time		15	-	-	ns
t_{LB}	Bit Clock Low Time		15	-	-	ns
t_{SD}	Data Set-up Time		12	-	-	ns
t_{HD}	Data Hold Time to Bit Clock		2	-	-	ns
t_{HW}	Word Select Hold Time		2	-	-	ns
t_{SW}	Word Select Set-up Time		12	-	-	ns
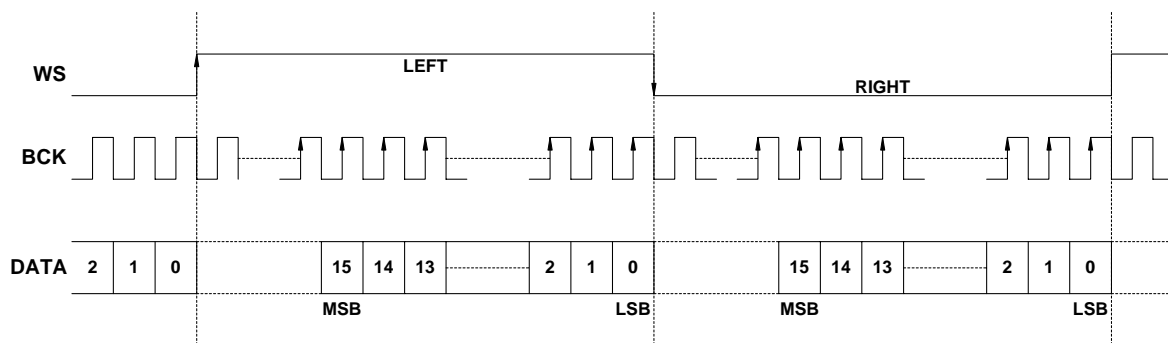
Fig.2   Right justified format (Normal format)
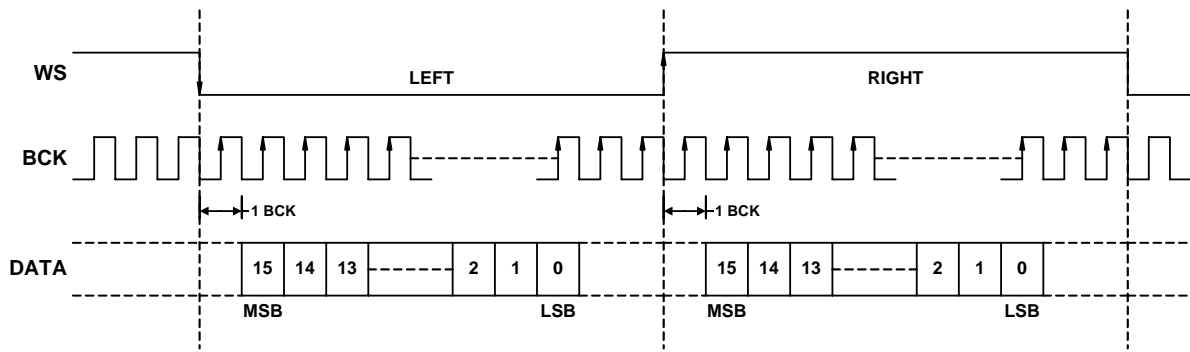
Fig.3   I²S format

I²C BUS INTERFACE

I²C interface protocol

The format consists of the following
 ・ A START condition
 ・ A chip address byte including the chip address. (7bits)
 ・ The 8th bit of the byte must be "0".(write=0, read=1)
 ・ The chip must always acknowledge the end of each transmitted byte.
 ・ A data sequence (N-bytes + Acknowledge)
 ・ A STOP condition
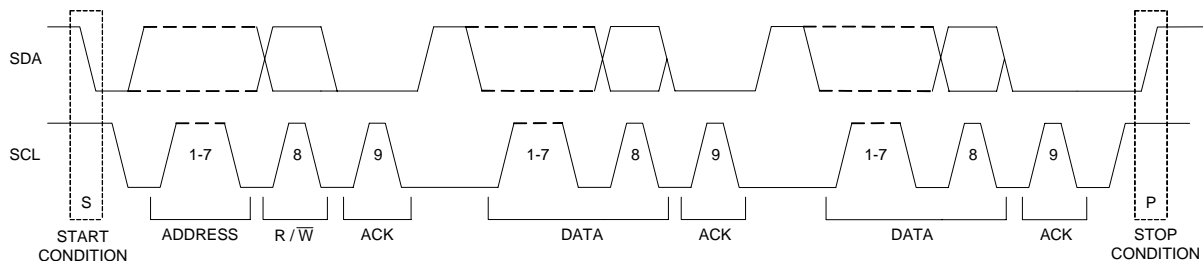
Fig.4   I²C format

I²C chip address

88H

| 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 |

7 bits address → W ←
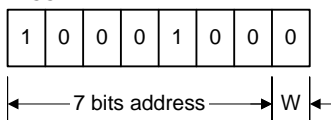
For MS6334, MODE=Low, AO/CS=High,
For MS6335 QFN16 package only

8CH

| 1 | 0 | 0 | 0 | 1 | 1 | 0 | 0 |

7 bits address → W ←
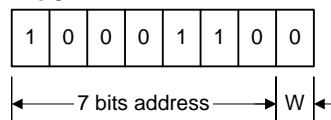
For MS6334, MODE=Low, AO/CS=Low
For MS6335 SSOP16 package only

I²C data bytes description

Volume control												
MSB						**LSB**	**Function**					
0	0	0	**b4**	**b3**	**b2**	**b1**	**b0**	2-channel, 1.5dB/step				
0	0	1						Left channel, 1.5dB/step				
0	1	0						Right channel, 1.5dB/step				
Gain / Attenuation bits												
b4	**b3**	**b2**	**b1**	**b0**	**Value (dB)**							**Value (dB)**
0	0	0	0	0	Mute	1	0	0	0	0		-16.5
0	0	0	0	1	-39	1	0	0	0	1		-15
0	0	0	1	0	-37.5	1	0	0	1	0		-13.5
0	0	0	1	1	-36	1	0	0	1	1		-12
0	0	1	0	0	-34.5	1	0	1	0	0		-10.5
0	0	1	0	1	-33	1	0	1	0	1		-9
0	0	1	1	0	-31.5	1	0	1	1	0		-7.5
0	0	1	1	1	-30	1	0	1	1	1		-6
0	1	0	0	0	-28.5	1	1	0	0	0		-4.5
0	1	0	0	1	-27	1	1	0	0	1		-3
0	1	0	1	0	-25.5	1	1	0	1	0		-1.5
0	1	0	1	1	-24	1	1	0	1	1		0
0	1	1	0	0	-22.5	1	1	1	0	0		+1.5
0	1	1	0	1	-21	1	1	1	0	1		+3
0	1	1	1	0	-19.5	1	1	1	1	0		+4.5
0	1	1	1	1	-18	1	1	1	1	1		+6

Initial state: Mute

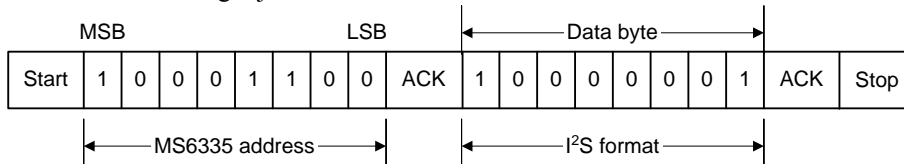| Power down mode							
MSB						**LSB**	**Function**
0	1	1	**b4**	**b3**	**b2**	**b1**	**b0**	Power down mode selection
Power down bits							
b4=1, Pull down CAP pin to ground (CAPGD) b4=0, Set the voltage of CAP to middle of supply voltage (CAPGD)							
b3=1, Enable OPAmp power down (OPAPD) b3=0, Disable OPAmp power down (OPAPD)							
b2=1, Enable DAC power down (DACPD) b2=0, Disable DAC power down (DACPD)							
b1=1, Enable headphone power down (HPPD) b1=0, Disable headphone power down (HPPD)							
b0=1, Enable DAC mute (DACM) b0=0, Disable DAC mute (DACM)							

Initial state: b0=b1=b2=b3=b4=1

Audio format and power off								
MSB						**LSB**		**Function**
1	0	0	0	0	0	**b1**	**b0**	Audio format selection and preparation for power off
Audio format and power off bits								
b1=1, Enable preparation for power off b1=0, Disable preparation for power off								
b0=1, I^{2}S format b0=0, Right justified format (normal format)								

Initial state: b0=b1=0. Power off : V_{DD} down to 0V

I^{2}C example

The audio format is selected I^{2}S format. Audio format code = 81H.
The initial state is right justified format.

MSB					LSB							Data byte							
Start	1	0	0	0	1	1	0	0	ACK	1	0	0	0	0	0	0	1	ACK	Stop

MS6335 address ← → I^{2}S format

DAC active. Code = 7BH.
The initial state is enabled all power down mode when power on.

Start	Chip Address	ACK	0	1	1	1	1	0	1	1	ACK	Stop

DACPD = 0
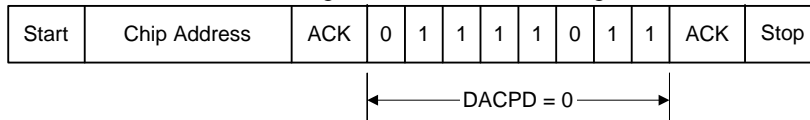
HP active, OPAmp active, CAP to 1/2 V_{DD}, DAC keep active. Code = 61H.
Set the voltage of CAP to middle of supply voltage, the charge time is approximately 1 second.

Start	Chip Address	ACK	0	1	1	0	0	0	0	1	ACK	Stop

CAPGD = 0
HPPD = 0
OPAmp = 0
DACPD = 0
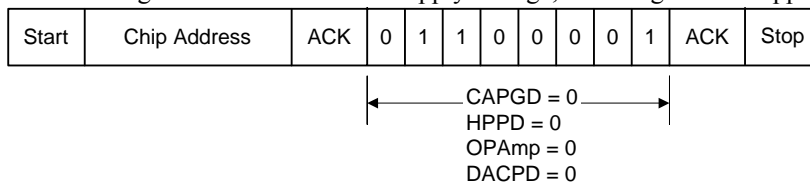
DAC mute off. Code = 60H.
The chip entered active mode.

Start	Chip Address	ACK	0	1	1	0	0	0	0	0	ACK	Stop

DACM = 0
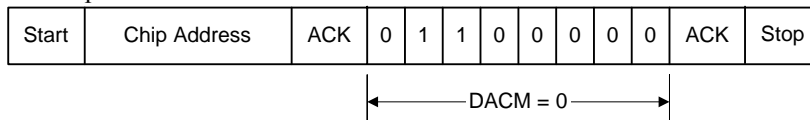
Set gain of 2 channel at 0dB. Volume control code = 1BH.

Start	Chip Address	ACK	0	0	0	1	1	0	1	1	ACK	Stop

2-ch, 0dB
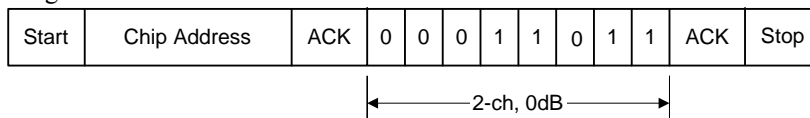
Set attenuation of left channel at –22.5dB. Volume control code = 2CH.

Start	Chip Address	ACK	0	0	1	0	1	1	0	0	ACK	Stop

L-ch, -22.5dB
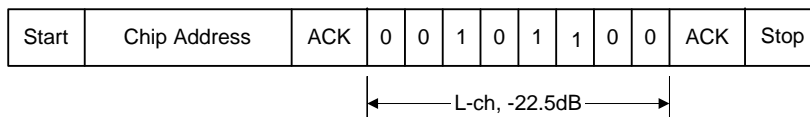
Set attenuation of right channel at –22.5dB. Volume control code = 4CH.

Start	Chip Address	ACK	0	1	0	0	1	1	0	0	ACK	Stop

← R-ch, -22.5dB →
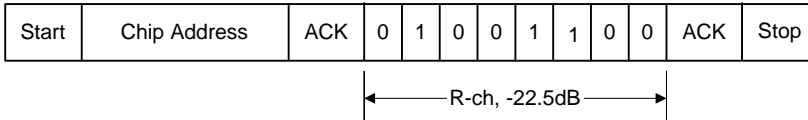
Preparation for power off. Code = 82H or 83H.

Start	Chip Address	ACK	1	0	0	0	0	0	1	x	ACK	Stop

← Power Off Preparation = 1 →
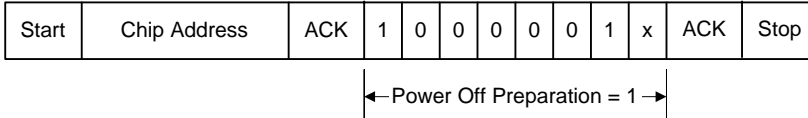
FM application. OPAmp active, HP active. DAC inactive, DAC mute off. Code = 65H.
The chip enters line-in mode.

Start	Chip Address	ACK	0	1	1	0	0	1	0	1	ACK	Stop

HPPD = 0
OPAmp = 0
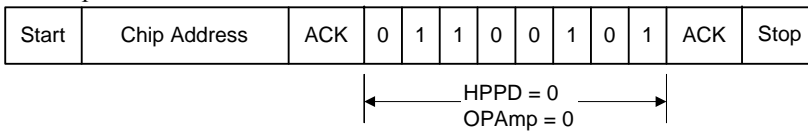
Power down mode (shut down mode). Code = 6FH
The chip enters power down mode. The shut down current is approximately 11uA.

Start	Chip Address	ACK	0	1	1	0	1	1	1	1	ACK	Stop

DACM = 1
DACPD = 1
HPPD = 1
OPAmp = 1
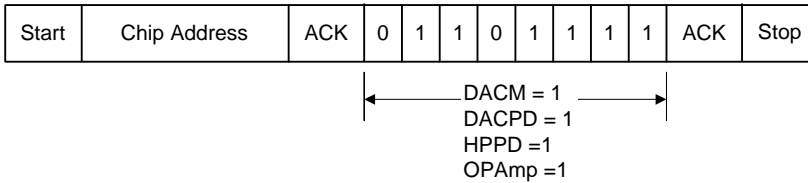
SPI BUS INTERFACE

In SPI mode, SCL is serial clock, SDA is serial data and AO/CS latches the data word into the MS6334. A control word consist of 16bit, starting with the MSB. The data bits are latched on the rising edge of SCL. A rising edge of AO/CS latches the data into the MS6334 after sixteenth rising clock edge.
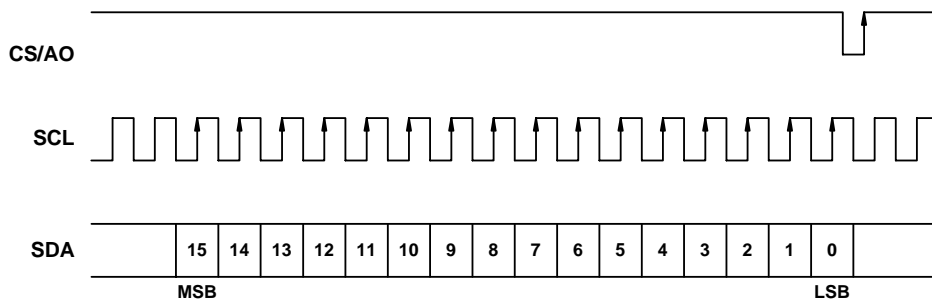
Fig.5   SPI format

SPI data word description

MSB															LSB
b15	b14	b13	b12	b11	b10	b9	b8	b7	b6	b5	b4	b3	b2	b1	b0
0	0	0	0	0	0	0	0	Reference to I²C data bytes description The initial state is the same as I²C							

OPERATION PROCEDURE

The sequence of operation: power on→ active → power down → active → power off. The basic flowcharts are as follows:

Power Turn On

Active

Power Off

Power Down (Shut Down)

All the Digital Interface Signals Pull Low
 I2C pull low
 Audio inputs pull low
 (BCK, WS, DATA)
 V_{DD} = GND

↓

Power On
 V_{DD} = Supply voltage

Default Codes Inside The Chip
 Volume control : *00H*
 Power down : *7FH*
 Audio format : *80H*

Default Status
 The chip is in the power down mode, all devices are not active
 Volume Mute On

Audio Format Selection
 Right justified: *80H* (default)
 I²S: *81H*

↓

Power up
 Code : *6DH*

 Wait 1sec

 Code : *61H*
 All Devices are active

↓

DAC Mute Off
 Code : *60H*

↓

Volume Control
 Default volume = mute
 Volume up/down step by step

Active mode
 All Devices are active

↓

Volume Control
 volume down to mute
 both 2 channels mute on

↓

Power Off Preparation
 code : *82H* or *83H*
 wait 0.2 sec

↓

Power Down
 code : *6FH*
 All devices are not active except CAPPD keep active

↓

All the Digital Interface Signals Pull Low
 I2C pull low
 Audio inputs pull low
 (BCK, WS, DATA)

↓

Power Off
 Disconnect V_{DD}
 V_{DD} will be down to 0V

Volume Control
 volume down to mute
 both 2 channels mute on

↓

Power Down
 code : *6FH*
 All devices are not active except CAPPD keep active

↓

Keep All the Digital Interface Signals unchanged

Fig.6   Operational procedure

APPLICATION INFORMATION

A MP3 with FM application

The analog and digital power can be supplied as single voltage.
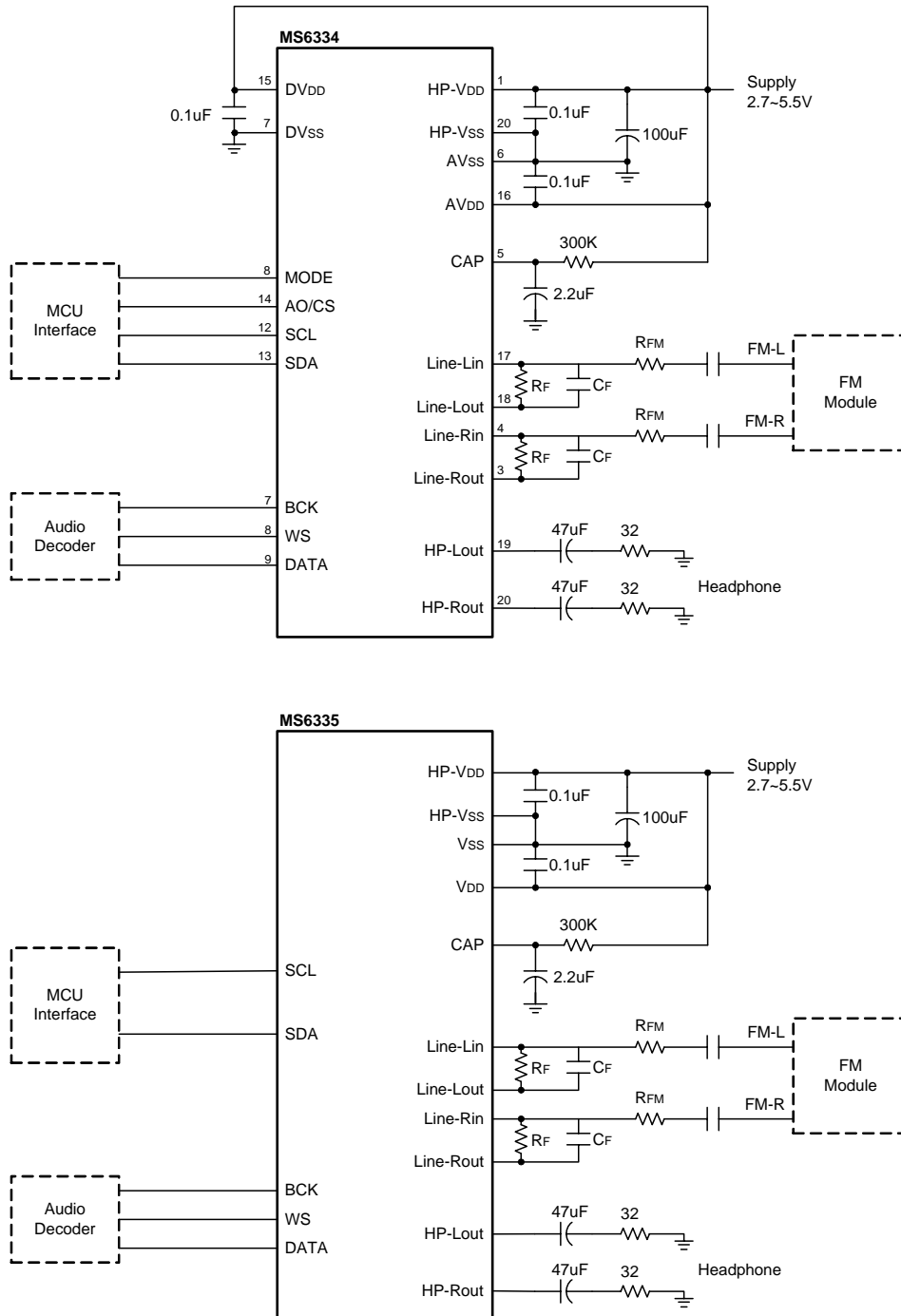
Note : $Vo = 0.02269 * R_F * V_{DD}$ Vpp at 0dB gain

$R_F // C_F$ to decide $-3dB$ point

For $V_{DD} = 3V$, $R_L = 32\Omega$, $R_F = 24k$, $C_F = 390pF$, $Vo = 1.63Vpp$

$R_L = 16\Omega$, $R_F = 22k$, $C_F = 470pF$, $Vo = 1.50Vpp$

FM mode, V_{Line} DC Gain = R_F / R_{FM}

Fig.7   MP3 with FM application circuit.

EXTERNAL DIMENSIONS

SSOP20

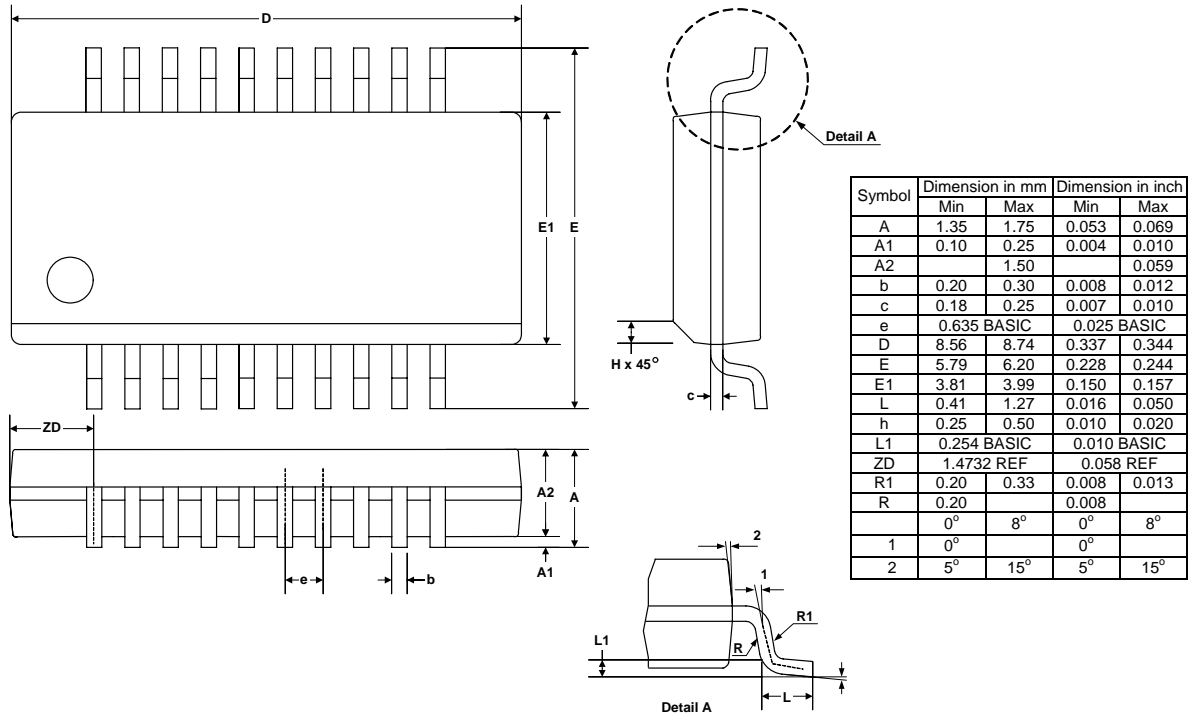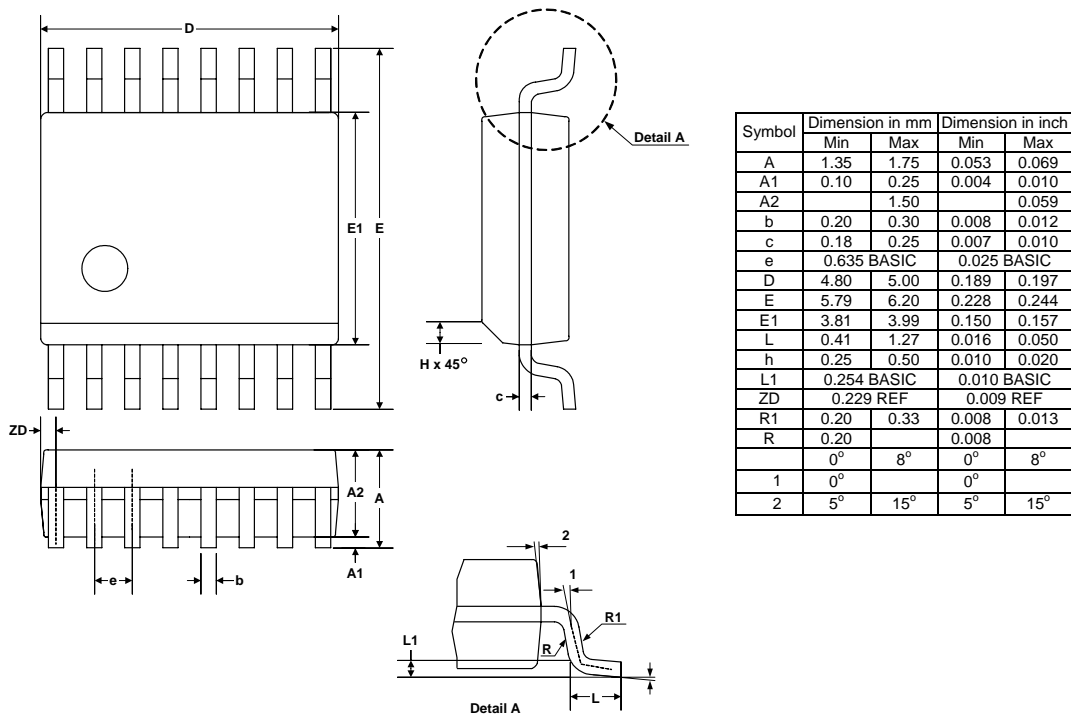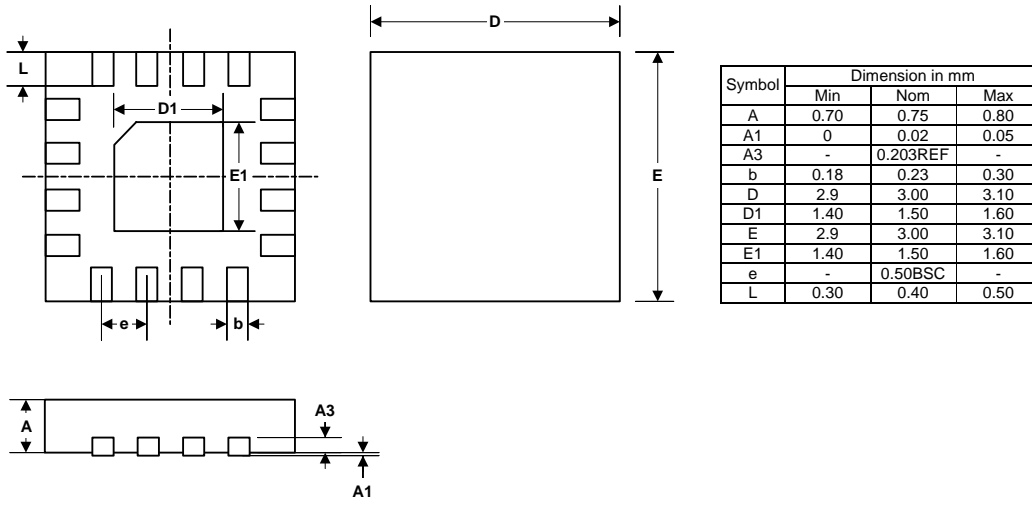| Symbol	Dimension in mm		Dimension in inch	
	Min	Max	Min	Max
A	1.35	1.75	0.053	0.069
A1	0.10	0.25	0.004	0.010
A2		1.50		0.059
b	0.20	0.30	0.008	0.012
c	0.18	0.25	0.007	0.010
e	0.635 BASIC		0.025 BASIC	
D	8.56	8.74	0.337	0.344
E	5.79	6.20	0.228	0.244
E1	3.81	3.99	0.150	0.157
L	0.41	1.27	0.016	0.050
h	0.25	0.50	0.010	0.020
L1	0.254 BASIC		0.010 BASIC	
ZD	1.4732 REF		0.058 REF	
R1	0.20	0.33	0.008	0.013
R	0.20		0.008	
	0°	8°	0°	8°
1	0°		0°	
2	5°	15°	5°	15°

SSOP16

Symbol	Dimension in mm		Dimension in inch	
	Min	Max	Min	Max
A	1.35	1.75	0.053	0.069
A1	0.10	0.25	0.004	0.010
A2		1.50		0.059
b	0.20	0.30	0.008	0.012
c	0.18	0.25	0.007	0.010
e	0.635 BASIC		0.025 BASIC	
D	4.80	5.00	0.189	0.197
E	5.79	6.20	0.228	0.244
E1	3.81	3.99	0.150	0.157
L	0.41	1.27	0.016	0.050
h	0.25	0.50	0.010	0.020
L1	0.254 BASIC		0.010 BASIC	
ZD	0.229 REF		0.009 REF	
R1	0.20	0.33	0.008	0.013
R	0.20		0.008	
	0°	8°	0°	8°
1	0°		0°	
2	5°	15°	5°	15°

QFN16 (3x3mm)

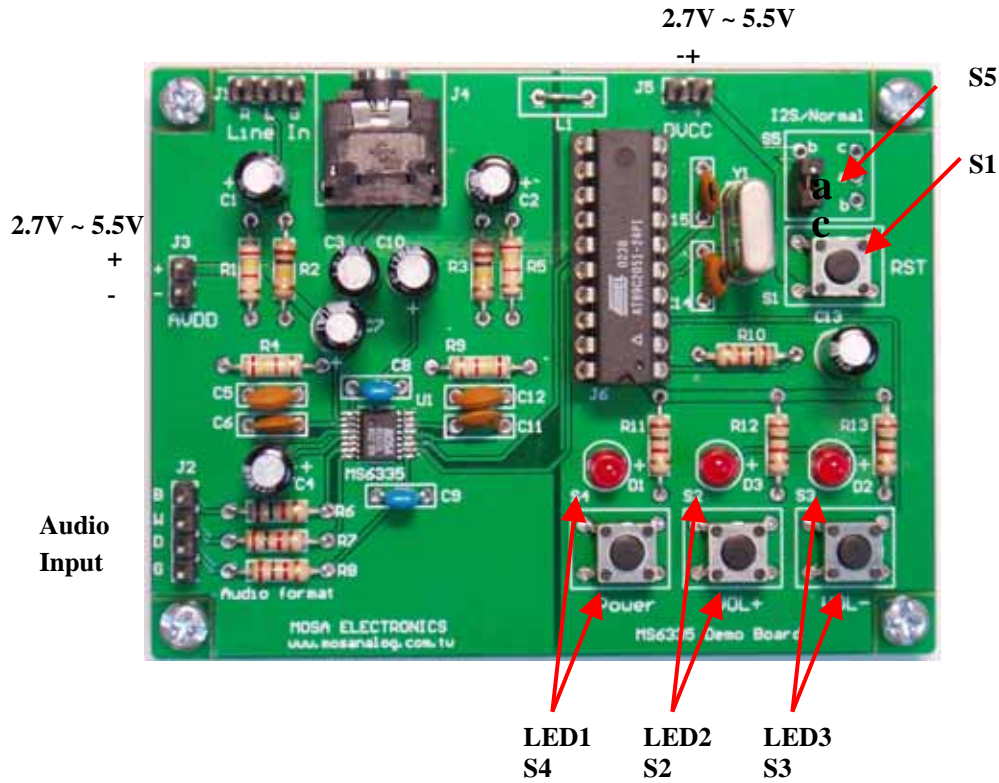| Symbol	Dimension in mm		
	Min	Nom	Max
A	0.70	0.75	0.80
A1	0	0.02	0.05
A3	-	0.203REF	-
b	0.18	0.23	0.30
D	2.9	3.00	3.10
D1	1.40	1.50	1.60
E	2.9	3.00	3.10
E1	1.40	1.50	1.60
e	-	0.50BSC	-
L	0.30	0.40	0.50

MS6335 DEMO BOARD

S4 (Power): POWER On/Off

Power On: If this key is pressed until the LED1 power on(about 3 sec),then system is Power On.
Power Off: If this key is pressed until the LED1 power off(about 3 sec),then system is Power Off.

S2 (UP) & S3 (Down): Volume Control

The volume key is used to adjust the volume of playing, and the segment is divided to 31 levels(-39dB～+6dB).
The prime value is level 5(-33dB).
Express full volume when LED3 is bright continuously.
Express mute on when LED2 is bright continuously.

S1: Reset

All I/O pins are reset to high.

S5: I²S/Normal

This PIN is used to switch the mode of audio format.
I²S : a & c open.
Normal : a & c short.

MOSA

Circuit :