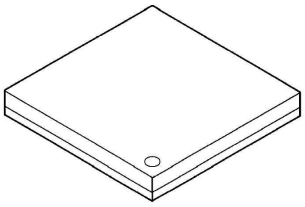
TOSHIBA CMOS Integrated Circuit Silicon Monolithic

TC94B06WBG

Stereo Headphone Amplifier with Electronic Volume

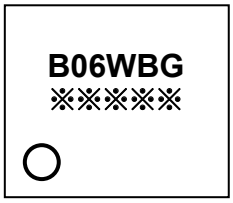
The TC94B06WBG is a G-class stereo headphone amplifier IC with electronic volume function.
It is built in a charge pump circuit, so output coupling capacitor isn't needed. And it is suitable for portable audio and mobile phone etc.



S-UFBGA16-0202-0.40A02

Weight : 3.53mg (typ.)

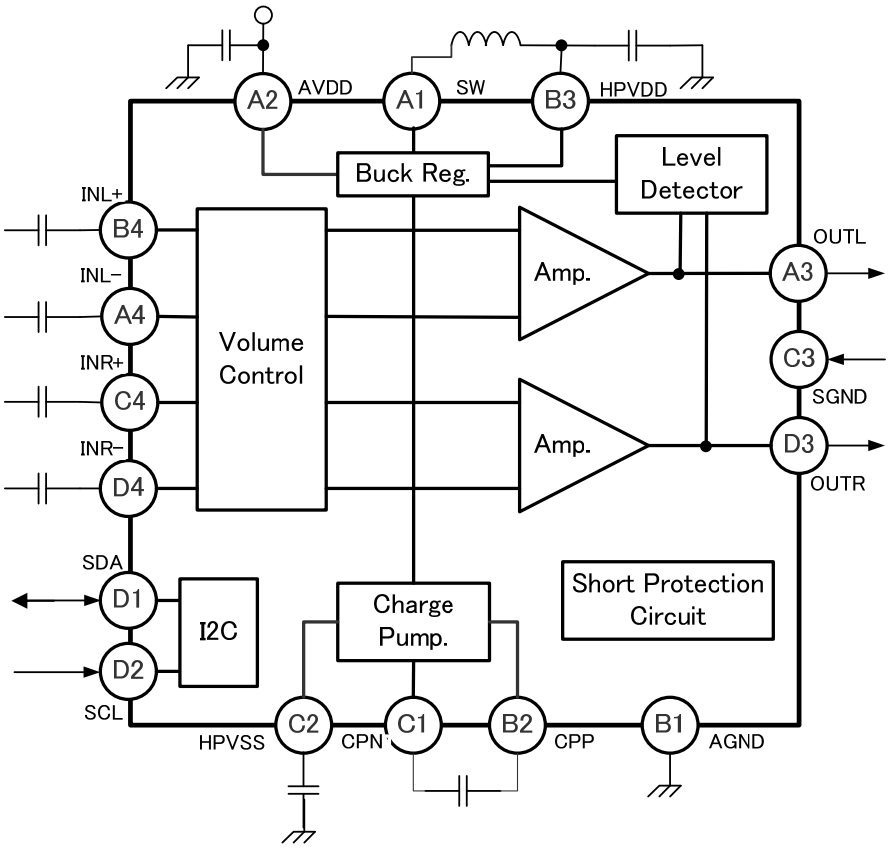
Marking:



Features

- It is high efficiency according to headphone circuit adoption of G-Class type.
- Differential inputs
- Capability to drive : RL=16 to 600 ohm
- SGND for Tuner application
  It prevents deterioration by channel separation when a headphone GND is used as FM tuner antennae.
- I2C Bus
- Volume control -59 to +4dB, 32 steps, Mute function
- Channel independent shutdown control and short-circuit protection
- High SNR (AVDD=3.6V, A-weighting)
  S/N=102dB (Typ.)
- Package WCSP 16pin , 0.4mm pitch
- Operating supply voltage range: Ta = 25°C
  AVDD (opr) = 2.3 to 4.8 V

Block Diagram



Some of the functional blocks, circuits, or constants in the block diagram may be omitted or simplified for explanatory purpose.

Pin Assignment (Top View)

A1 SW	A2 AVDD	A3 OUTL	A4 INL−
B1 AGND	B2 CPP	B3 HPVDD	B4 INL+
C1 CPN	C2 HPVSS	C3 SGND	C4 INR+
D1 SDA	D2 SCL	D3 OUTR	D4 INR−

Pin Descriptions

The equivalent circuit diagrams maybe simplified or some parts of them may be omitted for explanatory purpose.

Pin No. and name		I/O	Function
A1	SW	–	Buck converter switching node
A2	AVDD	–	Power supply for the device; connected to battery
A3	OUTL	O	Left channel output
A4	INL-	I	Left channel input, negative terminal
B1	AGND	–	Main GND
B2	CPP	–	Charge pump flying capacitor, positive terminal
B3	HPVDD	–	Power supply for headphone amplifier (DC/DC output)
B4	INL+	I	Left channel input, positive terminal
C1	CPN	–	Charge pump flying capacitor, negative terminal
C2	HPVSS	–	Charge pump output
C3	SGND	–	GND sense; connect to headphone jack GND
C4	INR+	I	Right channel input, positive terminal
D1	SDA	I/O	I2C SDA line
D2	SCL	I	I2C SCL line
D3	OUTR	O	Right channel output
D4	INR-	I	Right channel input, negative terminal

Functional Description
1. I2C control

1-1. Slave address
0xC0(Binary 11000000) : Writing mode
0xC1(Binary 11000001) : Reading mode

1-2. Register map

Register	D7	D6	D5	D4	D3	D2	D1	D0	Preset
0x01	HP_EN_L	HP_EN_R	0	0	0	0	Over current	SWS	0000 0001
0x02	Mute_L	Mute_R	Volume					0	1100 0000
0x03	0	0	0	0	0	0	Hi-Z_L	Hi-Z_R	0000 0000

Table 1 Resister map

Note
The register address is for TOSHIBA testing from 0x04. Under no circumstances must any data be written to these registers. Writing to these bits may change the function of the device, or cause complete failure. If read, these bits may assume any value.

0x01

Bit	Name	Value	Description
D7	HP_EN_L	0	Headphone amp. Lch disabled
		1	Headphone amp. Lch enabled
D6	HP_EN_R	0	Headphone amp. Rch disabled
		1	Headphone amp. Rch enabled
D1	Thermal	0	Protection circuit not activated (read only)
		1	Protection circuit activated (read only)
D0	SWS	0	Device enabled (Charge pump circuit enabled)
		1	Device disabled (Software shutdown)

Table 2 Resister explanation : 0x01

0x02

Bit	Name	Value	Description
D7	Mute_L	0	Headphone amp. Lch mute off
		1	Headphone amp. Lch mute on
D6	Mute_R	0	Headphone amp. Rch mute off
		1	Headphone amp. Rch mute on
D5:D1	Volume	-	These bits set the volume level See volume table

Table 3 Resister explanation : 0x02

0x03

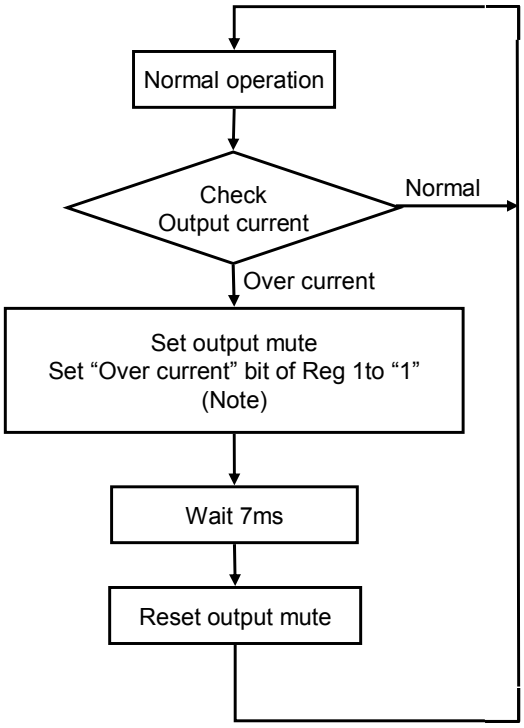
Bit	Name	Value	Description
D1	Hi-Z_L	0	Normal impedance of Lch output
		1	High impedance of Lch output
D0	Hi-Z_R	0	Normal impedance of Rch output
		1	High impedance of Rch output

Table 4 Resister explanation : 0x03

1-3. Volume table

Gain control Mute[7:6], Volume[5:0]	Gain [dB]	Gain control Mute[7:6], Volume[5:0]	Gain [dB]
10xx xxxx	Mute_Lch	0001 111x	-13
01xx xxxx	Mute_Rch	0010 000x	-11
0000 000x	-59	0010 001x	-10
0000 001x	-55	0010 010x	-9
0000 010x	-51	0010 011x	-8
0000 011x	-47	0010 100x	-7
0000 100x	-43	0010 101x	-6
0000 101x	-39	0010 110x	-5
0000 110x	-35	0010 111x	-4
0000 111x	-31	0011 000x	-3
0001 000x	-27	0011 001x	-2
0001 001x	-25	0011 010x	-1
0001 010x	-23	0011 011x	0
0001 011x	-21	0011 100x	+1
0001 100x	-19	0011 101x	+2
0001 101x	-17	0011 110x	+3
0001 110x	-15	0011 111x	+4

2. Over current protection circuit.
This IC built in the over current detection type of protection circuit.
The flow chart of the protection circuit is the following.



(Note) Over current bit is reset Reg 1 is read by I2C-bus.

Figure 1 : Flow of over current protection circuit

3. I2C Timing Characteristics

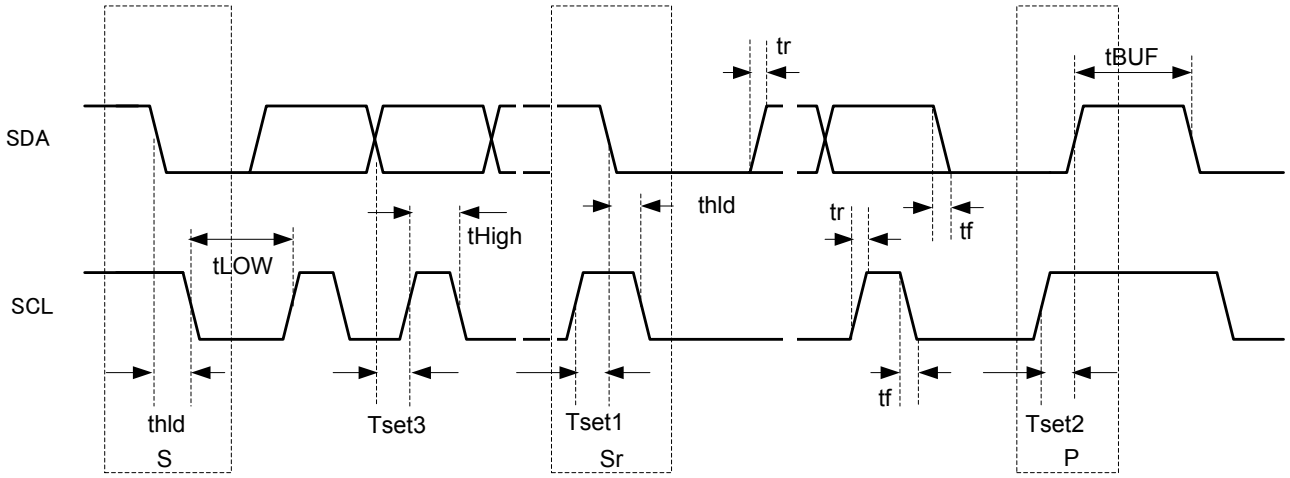


Figure 2 : I2C timing

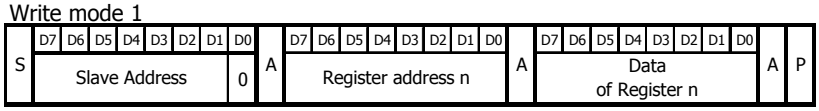
Characteristics	Symbol	Test Condition	Min.	Typ.	Max.	Unit
SCL Clock frequency	fSCL	—	—	—	400	kHz
Hold time, start condition to SCL	thld	—	0.6	—	—	μs
Setup time, SCL to start condition	Tset1	—	0.6	—	—	μs
Setup time, SCL to stop condition	Tset2	—	0.6	—	—	μs
Data setup time	Tset3	—	100	—	—	ns
Bus free time between stop and start condition	tBUF	—	1.3	—	—	μs
SCL clock width “Low”	tLOW	—	1.3	—	—	μs
SCL clock width “High”	tHigh	—	0.6	—	—	μs
SCL/SDA rise time	tr	—	—	—	300	ns
SCL/SDA fall time	tf	—	—	—	300	ns

4. I2C BUS format

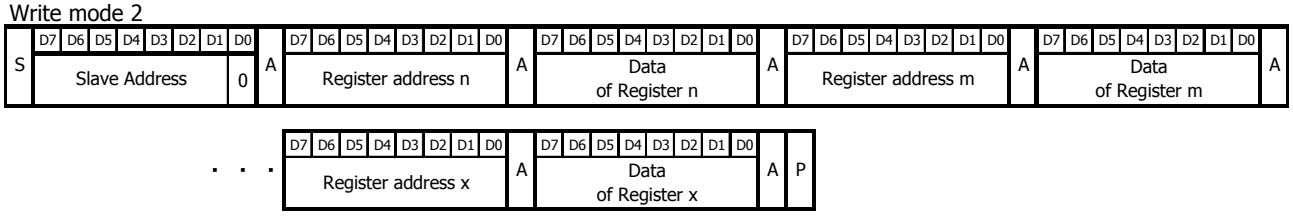
4-1. Write mode

This IC support the 3 formats.

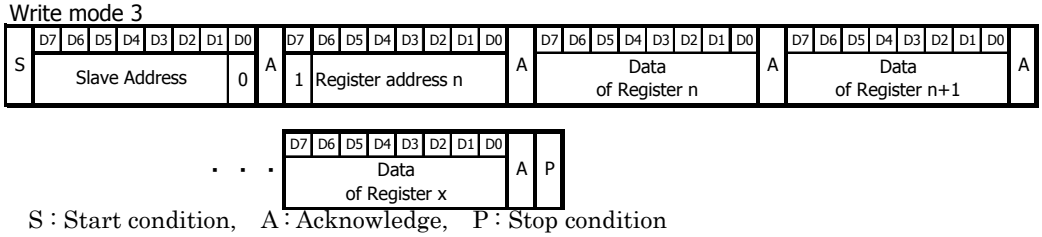
Write mode 1



Write mode 2



Write mode 3



S : Start condition, A : Acknowledge, P : Stop condition

Figure 3 : Format of write mode

4-2. Read mode
This IC support the following format.

	D7 D6 D5 D4 D3 D2 D1	D0		D7 D6 D5 D4 D3 D2 D1 D0		D7 D6 D5 D4 D3 D2 D1 D0		D7 D6 D5 D4 D3 D2 D1 D0		D7 D6 D5 D4 D3 D2 D1 D0		
S	Slave Address	1	A	Data of Register 1	A	Data of Register 2	A	Data of Register 3	A	Data of Register 4	A	P

S : Start condition, A : Acknowledge, P : Stop condition

Figure 4 : Format of read mode.

5. Hi-Z mode
This is built in a high impedance mode of amplifier output.
When this function is operated, HP_EN of resister 1 is set "0" and Hi-Z of resister 3 is set "1".

6. SGND
This terminal is used when it is combined as an FM tuner antenna and the headphone GND.
A current connection is showed in figure 5.
In case of this connection, the separation characteristic becomes bad by inductor.
But this IC can prevent deterioration of separation by a connection of Figure 6.

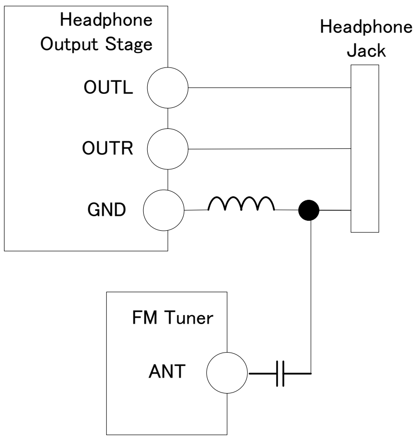


Figure 5 : Current system

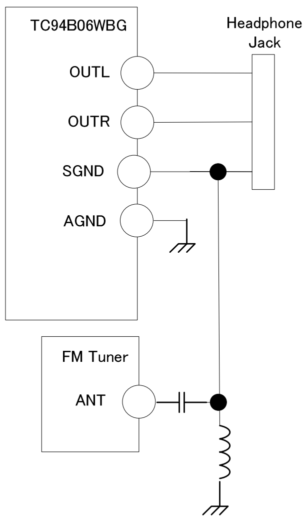


Figure 6 : Connection of this IC

Timing charts may be simplified for explanatory purpose.
These protection functions are intended to avoid some output short circuits or other abnormal conditions temporarily. These protect functions do not warrant to prevent the IC from being damaged.
In case of the product would be operated with exceeded guaranteed operating ranges, these protection features may result in the IC being damaged.
The over current protection feature is only intended to protect the IC from a temporary short circuit.
Long time short circuit may stress excessively on the IC to be damaged. The system must be configured so that any over current condition will be eliminated as soon as possible.

Absolute Maximum Ratings (Ta = 25°C)

Characteristics	Symbol	Rating	Unit
Supply voltage range	AVDD	-0.3 to 5.5	V
Differential input voltage	Vin (rms)	HPVss+0.5V to HPVDD-0.5	V
I2C voltage range	V_{I2C}	-0.3 to AVDD	V
Breakdown Voltage at amplifier outputs	Vo	5.5	V
Output protection diodes breakdown current	Io	200	mA
Power dissipation	P_D (Note)	1.4	W
Operating temperature	T_{opr}	−30 to 85	°C
Storage temperature	T_{stg}	-55 to 85	°C

Note: Derated by 14mW/°C above Ta = 25°C

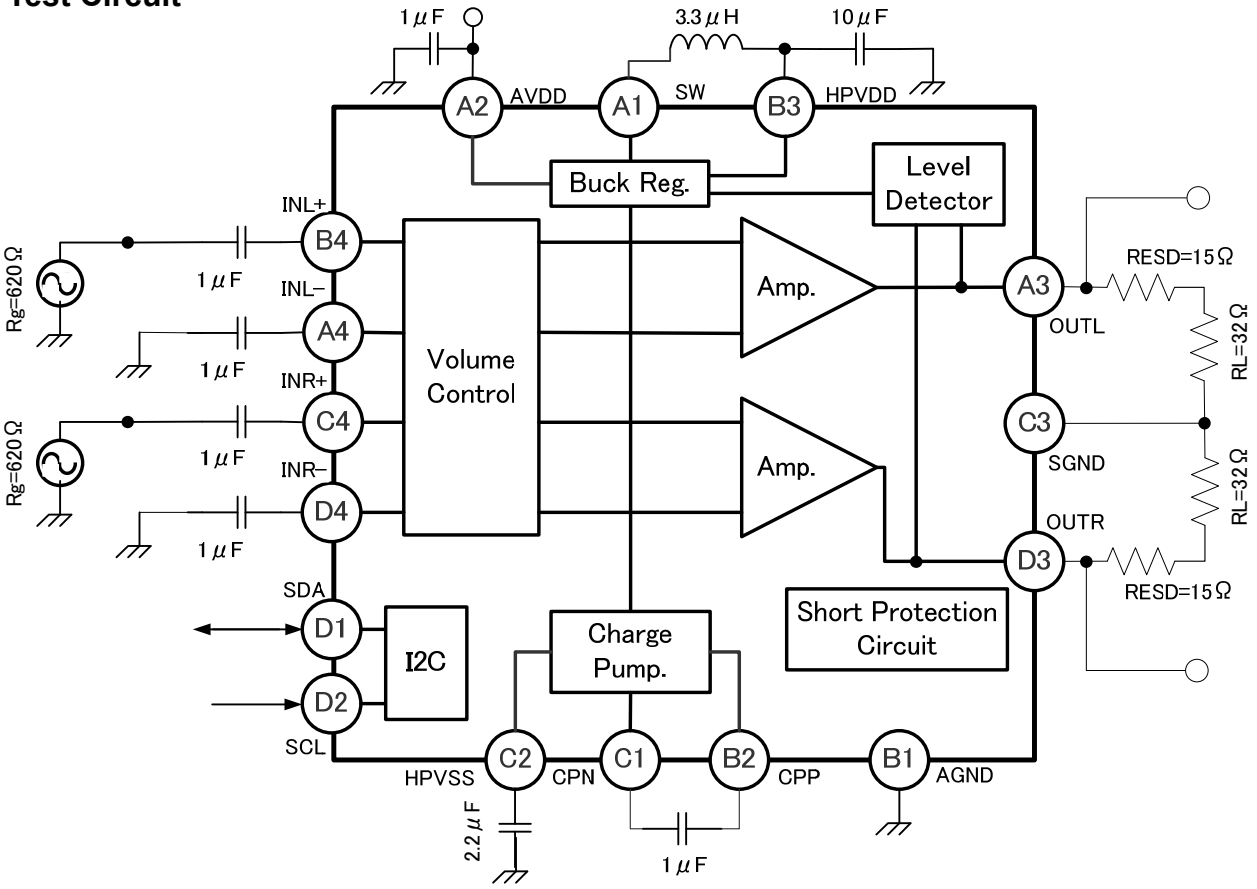
The absolute maximum ratings of a semiconductor device are a set of specified parameter values, which must not be exceeded during operation, even for an instant.
If any of these rating would be exceeded during operation, the device electrical characteristics may be irreparably altered and the reliability and lifetime of the device can no longer be guaranteed.
Moreover, these operations with exceeded ratings may cause break down, damage and/or degradation to any other equipment.
Applications using the device should be designed such that each absolute maximum rating will never be exceeded in any operating conditions.
Before using, creating and/or producing designs, refer to and comply with the precautions and conditions set forth in this documents.

Electrical Characteristics

Unless otherwise specified, AVDD = 3.6 V, Rg = 600 Ω, RL = 15 Ω+32 Ω, f = 1 kHz, Ta = 25°C

Characteristics	Symbol	Test Condition	Min	Typ.	Max	Unit
Shutdown Current	Isd	SW shutdown	—	—	5	μA
Quiescent Current	IDDQ	Both channels enabled. No audio signal	—	1.3	1.5	mA
Supply Current	Is	0.1mW*2ch, 3dB@Crest Factor	—	2.9	3.5	mA
		0.5mW*2ch, 3dB@Crest Factor	—	4.8	5.5	mA
		1mW*2ch, 3dB@Crest Factor	—	6.2	7.5	mA
Amplifier Output Voltage (rms)	Vo1	RL=16Ω only, Gv=+4dB THD+N=1%, L+R in phase	0.62	0.76	—	V
	Vo2	RL=32Ω only, Gv=+4dB THD+N=1%, L+R in phase	0.9	0.95	—	V
Total Harmonic Distortion + Noise	THD+N	Vo=500mVrms	—	0.015	0.02	%
Power Supply Rejection Ratio	PSRR	Gv=0dB, fr=217Hz(Square), 300mVrms	90	102	—	dB
Common-mode Rejection Ratio	CMRR	Gv=0dB, Vin=0.7Vrms	—	50	—	dB
Signal to Noise Ratio	S/N	f=1kHz, Vo=1Vrms, A-Weight	100	102	—	dB
Channel Separation	SEP1	RL=16Ω, Vo=0.63Vrms	60	82	—	dB
	SEP2	RL=10kΩ, Vo=0.63Vrms	80	85	—	dB
Output Noise (rms)	Vno	Gv=0, Rg=0, A-weight	—	7.5	9	μV
Output DC offset	⊿Vo	Both channels enabled, Mute on	-500	0	500	μV
Input Impedance	Zin	Differential	50	97	—	kΩ
Wake-up time	Tstart		—	2	3	ms
Output Impedance	Zout1	HiZ mode, f<40kHz	10	45	—	kΩ
	Zout2	HiZ mode, f=6MHz	500	640	—	Ω
	Zout3	HiZ mode, f=36MHz	—	135	—	Ω
Control Voltage (H)	Vih	AVDD=2.9～4.5V	1.2	—	—	V
Control Voltage (L)	Vil	AVDD=2.9～4.5V	—	—	0.6	V
Input Current (H)	Iih	SCL/SDA, Vih=AVDD	—	—	1	μA
Input Current (L)	Iil	SCL/SDA, Vil=0V	—	—	1	μA
Buck Regulator Switching Frequency	fBUCK		—	2	—	MHz
Charge pump Switching Frequency 1	fPUMP1	Po=0.1mW	—	250	—	kHz
Charge pump Switching Frequency 2	fPUMP2	Po=10mW	—	500	—	kHz
IC protection operating Current	IPRT	IC output stage current	—	150	—	mA
Common mode Voltage Range	VCM		0		1.2	V

Test Circuit



Inductor
Type No. MDT2520-CR3R3M (TOKO)

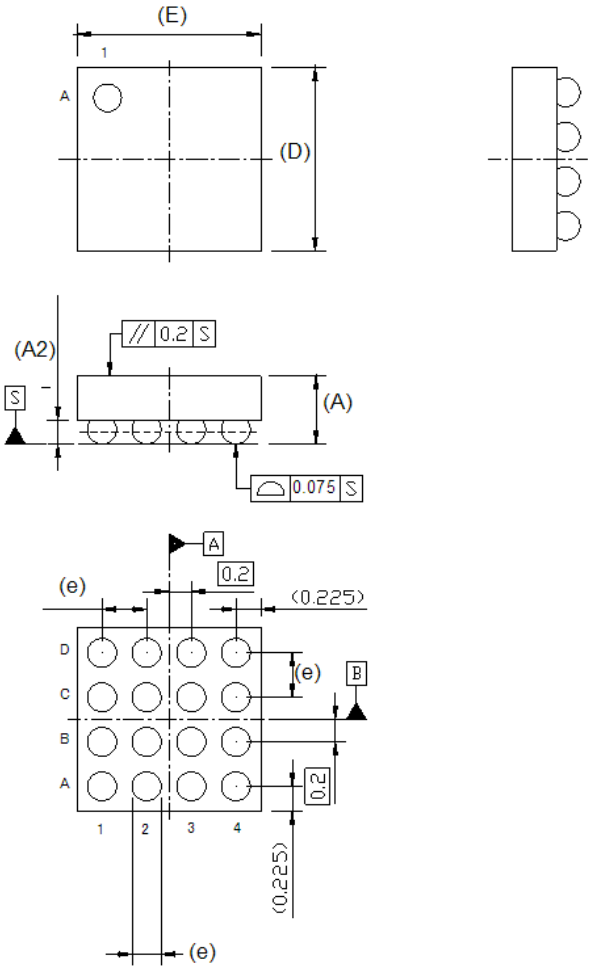
It is necessary to connect RESD to keep the oscillation margin in the application.

Components in the test circuits are only used to obtain and confirm the device characteristics.
These components and circuits do not warrant to prevent the application equipment from malfunction or failure.

Package Dimensions

Unit : mm

S-UFBGA16-0202-0.40A02



Description	Min	Nom	Max
Body size (E, mm)	1.60	1.65	1.70
Body size (D, mm)	1.60	1.65	1.70
Overall thickness (A, mm)	0.57	0.61	0.65
Terminal pitch (e, mm)	-	0.40	-
Ball / terminal diameter (b, mm)	0.23	0.26	0.29
Body height (A1, mm)	0.39	0.41	0.44
Ball height (A2, mm)	0.17	0.20	0.23
Coplanarity at terminal / ball side (mm)	-	-	0.08

- Use an appropriate power supply fuse to ensure that a large current does not continuously flow in case of over current and/or IC failure. The IC will fully break down when used under conditions that exceed its absolute maximum ratings, when the wiring is routed improperly or when an abnormal pulse noise occurs from the wiring or load, causing a large current to continuously flow and the breakdown can lead smoke or ignition. To minimize the effects of the flow of a large current in case of breakdown, appropriate settings, such as fuse capacity, fusing time and insertion circuit location, are required.
- If your design includes an inductive load such as a motor coil, incorporate a protection circuit into the design to prevent device malfunction or breakdown caused by the current resulting from the inrush current at power ON or the negative current resulting from the back electromotive force at power OFF. For details on how to connect a protection circuit such as a current limiting resistor or back electromotive force adsorption diode, refer to individual IC datasheets or the IC databook. IC breakdown may cause injury, smoke or ignition.
- Use a stable power supply with ICs with built-in protection functions. If the power supply is unstable, the protection function may not operate, causing IC breakdown. IC breakdown may cause injury, smoke or ignition.
- Carefully select external components (such as inputs and negative feedback capacitors) and load components (such as speakers), for example, power amp and regulator. If there is a large amount of leakage current such as input or negative feedback condenser, the IC output DC voltage will increase. If this output voltage is connected to a speaker with low input withstand voltage, overcurrent or IC failure can cause smoke or ignition. (The over current can cause smoke or ignition from the IC itself.) In particular, please pay attention when using a Bridge Tied Load (BTL) connection type IC that inputs output DC voltage to a speaker directly.
- Over current Protection Circuit
  Over current protection circuits (referred to as current limiter circuits) do not necessarily protect ICs under all circumstances. If the Over current protection circuits operate against the over current, clear the over current status immediately. Depending on the method of use and usage conditions, such as exceeding absolute maximum ratings can cause the over current protection circuit to not operate properly or IC breakdown before operation. In addition, depending on the method of use and usage conditions, if over current continues to flow for a long time after operation, the IC may generate heat resulting in breakdown.•

RESTRICTIONS ON PRODUCT USE

- Toshiba Corporation, and its subsidiaries and affiliates (collectively “TOSHIBA”), reserve the right to make changes to the information in this document, and related hardware, software and systems (collectively “Product”) without notice.
- This document and any information herein may not be reproduced without prior written permission from TOSHIBA. Even with TOSHIBA’s written permission, reproduction is permissible only if reproduction is without alteration/omission.
- Though TOSHIBA works continually to improve Product’s quality and reliability, Product can malfunction or fail. Customers are responsible for complying with safety standards and for providing adequate designs and safeguards for their hardware, software and systems which minimize risk and avoid situations in which a malfunction or failure of Product could cause loss of human life, bodily injury or damage to property, including data loss or corruption. Before customers use the Product, create designs including the Product, or incorporate the Product into their own applications, customers must also refer to and comply with (a) the latest versions of all relevant TOSHIBA information, including without limitation, this document, the specifications, the data sheets and application notes for Product and the precautions and conditions set forth in the “TOSHIBA Semiconductor Reliability Handbook” and (b) the instructions for the application with which the Product will be used with or for. Customers are solely responsible for all aspects of their own product design or applications, including but not limited to (a) determining the appropriateness of the use of this Product in such design or applications; (b) evaluating and determining the applicability of any information contained in this document, or in charts, diagrams, programs, algorithms, sample application circuits, or any other referenced documents; and (c) validating all operating parameters for such designs and applications. **TOSHIBA ASSUMES NO LIABILITY FOR CUSTOMERS’ PRODUCT DESIGN OR APPLICATIONS.**
- Product is intended for use in general electronics applications (e.g., computers, personal equipment, office equipment, measuring equipment, industrial robots and home electronics appliances) or for specific applications as expressly stated in this document. Product is neither intended nor warranted for use in equipment or systems that require extraordinarily high levels of quality and/or reliability and/or a malfunction or failure of which may cause loss of human life, bodily injury, serious property damage or serious public impact (“Unintended Use”). Unintended Use includes, without limitation, equipment used in nuclear facilities, equipment used in the aerospace industry, medical equipment, equipment used for automobiles, trains, ships and other transportation, traffic signaling equipment, equipment used to control combustions or explosions, safety devices, elevators and escalators, devices related to electric power, and equipment used in finance-related fields. Do not use Product for Unintended Use unless specifically permitted in this document.
- Do not disassemble, analyze, reverse-engineer, alter, modify, translate or copy Product, whether in whole or in part.
- Product shall not be used for or incorporated into any products or systems whose manufacture, use, or sale is prohibited under any applicable laws or regulations.
- The information contained herein is presented only as guidance for Product use. No responsibility is assumed by TOSHIBA for any infringement of patents or any other intellectual property rights of third parties that may result from the use of Product. No license to any intellectual property right is granted by this document, whether express or implied, by estoppel or otherwise.
- **ABSENT A WRITTEN SIGNED AGREEMENT, EXCEPT AS PROVIDED IN THE RELEVANT TERMS AND CONDITIONS OF SALE FOR PRODUCT, AND TO THE MAXIMUM EXTENT ALLOWABLE BY LAW, TOSHIBA (1) ASSUMES NO LIABILITY WHATSOEVER, INCLUDING WITHOUT LIMITATION, INDIRECT, CONSEQUENTIAL, SPECIAL, OR INCIDENTAL DAMAGES OR LOSS, INCLUDING WITHOUT LIMITATION, LOSS OF PROFITS, LOSS OF OPPORTUNITIES, BUSINESS INTERRUPTION AND LOSS OF DATA, AND (2) DISCLAIMS ANY AND ALL EXPRESS OR IMPLIED WARRANTIES AND CONDITIONS RELATED TO SALE, USE OF PRODUCT, OR INFORMATION, INCLUDING WARRANTIES OR CONDITIONS OF MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE, ACCURACY OF INFORMATION, OR NONINFRINGEMENT.**
- Do not use or otherwise make available Product or related software or technology for any military purposes, including without limitation, for the design, development, use, stockpiling or manufacturing of nuclear, chemical, or biological weapons or missile technology products (mass destruction weapons). Product and related software and technology may be controlled under the Japanese Foreign Exchange and Foreign Trade Law and the U.S. Export Administration Regulations. Export and re-export of Product or related software or technology are strictly prohibited except in compliance with all applicable export laws and regulations.
- Please contact your TOSHIBA sales representative for details as to environmental matters such as the RoHS compatibility of Product. Please use Product in compliance with all applicable laws and regulations that regulate the inclusion or use of controlled substances, including without limitation, the EU RoHS Directive. TOSHIBA assumes no liability for damages or losses occurring as a result of noncompliance with applicable laws and regulations.