SGM56101

110dB, 192kHz, 32-Bit, 8-Channel Audio DAC

GENERAL DESCRIPTION

The SGM56101 is an 8-channel, 32-bit digital-to-analog converter (DAC) designed for digital audio systems. Its internal circuitry integrates a 32-bit state-of-the-art digital filter that optimizes both audio quality and performance. With support for a maximum 192kHz PCM input, it is ideal for reproducing high-resolution audio sources that are increasingly common in network audios, USB-DACs and audio systems.

Furthermore, the SGM56101 incorporates the innovative OSR-Enhancement technology, enabling it to handle a diverse range of signals while minimizing out-of-band noise and maintaining low power consumption. Additionally, the device provides three types of 32-bit digital filters, which enable sound making simple and flexible in wide range of applications. It should be noted that SGM56101 needs to input the MCLK signal in advance to execute the 3-wire serial/ I^2C-bus program.

The SGM56101 is available in a Green TQFN-5×5-32JL package.

APPLICATIONS

External Amplifiers
Audio Systems
CD Players
Headphones
Network Audios (Audio-Over-IP)
Professional Measuring Instruments
RCA Receivers
Super Audio CD Players
USB DACs

FEATURES

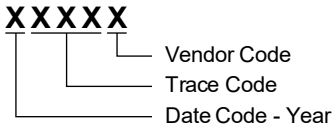
- **Power Supply Voltage Range**
  - **Analog Power Supply: AVDD = 3.0V to 3.6V**
  - **Digital Power Supply: TVDD = 2.3V to 3.6V**
  - **Digital Power Supply with Integrated LDO**
- **32-Bit, 8-Channel DAC**
  - **256× Oversampling**
  - **32-Bit, High-Performance Sound Digital Filter**
  - **THD+N: -91.5dB**
  - **DR, SNR: 110dB**
  - **Flexible Digital Volume Control System (Each Channel): Full Range 0dB to -127dB, 0.5dB per Step and Mute**
  - **Soft Mute**
  - **De-emphasis Filter Options: 32kHz, 44.1kHz and 48kHz**
  - **Audio Interface Format Options: MSB/LSB Justified, I^2S and TDM**
  - **Channel-Independent Zero Detection**
- **Sampling Frequency**
  - **Normal Speed Mode: f_S = 8kHz to 48kHz**
  - **Double Speed Mode: f_S = 48kHz to 96kHz**
  - **Quad Speed Mode: f_S = 96kHz to 192kHz**
- **Typical Master Clock Ratio**
  - **Normal Speed Mode: 256 × f_S, 384 × f_S, 512 × f_S, 768 × f_S**
  - **Double Speed Mode: 128 × f_S, 192 × f_S, 256 × f_S**
  - **Quad Speed Mode: 128 × f_S**
- **Control Interface: 3-Wire Serial, I^2C-Bus (Fast Speed Mode: 400kHz) and Parallel Mode**
- **Operating Power Consumption: 31mA (f_S = 48kHz)**
- **-40℃ to +125℃ Operating Temperature Range**
- **Available in a Green TQFN-5×5-32JL Package**

PACKAGE/ORDERING INFORMATION

MODEL	PACKAGE DESCRIPTION	SPECIFIED TEMPERATURE RANGE	ORDERING NUMBER	PACKAGE MARKING	PACKING OPTION
SGM56101	TQFN-5×5-32JL	-40℃ to +125℃	SGM56101XTYB32G/TR	SGM56101 XTYB32 XXXXX	Tape and Reel, 3000

MARKING INFORMATION

NOTE: XXXXX = Date Code, Trace Code and Vendor Code.



Green (RoHS & HSF): SG Micro Corp defines Green to mean Pb-Free (RoHS compatible) and free of halogen substances. If you have additional comments or questions, please contact your SGMICRO representative directly.

ABSOLUTE MAXIMUM RATINGS (1)

Power Supply Voltage Range (2) (3)
- AVDD ..... -0.3V to 4.3V
- TVDD ..... -0.3V to 4.3V
- Difference (VSS1 - VSS2) ..... -0.3V to 0.3V

Digital Input Voltage Range, V_{IND} (4) .....-0.3V to TVDD + 0.3V
Input Current (Except for Supply Pins), I_{IN} ..... ±10mA
Package Thermal Resistance
- TQFN-5×5-32JL, θ_{JA} ..... 27.4℃/W
- TQFN-5×5-32JL, θ_{JB} ..... 7.8℃/W
- TQFN-5×5-32JL, $\theta_{JC\ (TOP)}$ ..... 16℃/W
- TQFN-5×5-32JL, $\theta_{JC\ (BOT)}$ ..... 1.6℃/W

Junction Temperature .....+150℃
Storage Temperature Range .....-65℃ to +150℃
Lead Temperature (Soldering, 10s) .....+260℃
ESD Susceptibility (5) (6)
HBM .....±4000V
CDM .....±1000V

RECOMMENDED OPERATING CONDITIONS

Power Supply Voltage Range (2) (3)
- AVDD ..... 3.0V to 3.6V, 3.3V (TYP)
- TVDD ..... 2.3V to 3.6V, 3.3V (TYP)

Voltage Reference (7)
- High Voltage Reference, VREFH ..... AVDD - 0.5V to AVDD
- Low Voltage Reference, VREFL ..... VSS2 (TYP)

Operating Ambient Temperature Range ..... -40℃ to +125℃

NOTES:

1. All voltages referenced to ground, VSS1 and VSS2 should be connected to a unified analog ground plane, ensuring that VSS1 and VSS2 both equal 0V.

2. The sequence of powering up AVDD and TVDD is not crucial for operation.

3. Avoid powering off the SGM56101 while the peripheral device remains powered on. Additionally, when utilizing the I^2C interface, ensure that pull-up resistors for the SDA and SCL pins are connected to TVDD or a lower voltage.

4. The maximum permissible digital input voltage is the smaller value between TVDD + 0.3V and 4.3V.

5. For human body model (HBM), all pins comply with ANSI/ESDA/JEDEC JS-001 specifications.

6. For charged device model (CDM), all pins comply with ANSI/ESDA/JEDEC JS-002 specifications.

7. It is imperative to connect the VREFL pin to VSS2.

OVERSTRESS CAUTION

Stresses beyond those listed in Absolute Maximum Ratings may cause permanent damage to the device. Exposure to absolute maximum rating conditions for extended periods may affect reliability. Functional operation of the device at any conditions beyond those indicated in the Recommended Operating Conditions section is not implied.

ESD SENSITIVITY CAUTION

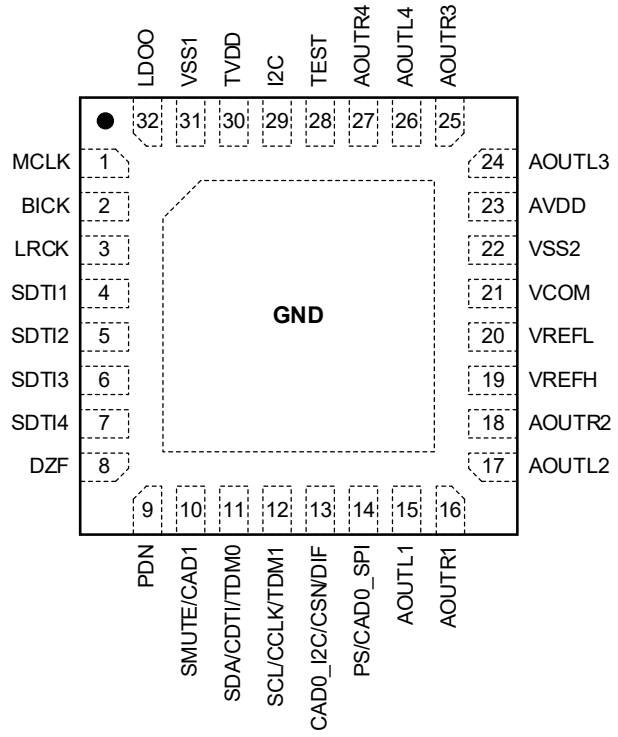
This integrated circuit can be damaged if ESD protections are not considered carefully. SGMICRO recommends that all integrated circuits be handled with appropriate precautions. Failure to observe proper handling and installation procedures can cause damage. ESD damage can range from subtle performance degradation to complete device failure. Precision integrated circuits may be more susceptible to damage because even small parametric changes could cause the device not to meet the published specifications.

DISCLAIMER

SG Micro Corp reserves the right to make any change in circuit design, or specifications without prior notice.

PIN CONFIGURATION

(TOP VIEW)



TQFN-5×5-32JL

PIN DESCRIPTION

PIN	NAME	TYPE (1) (2)	POWER-DOWN STATE	FUNCTION
1	MCLK	I	Hi-Z	Master Clock Input Pin for External.
2	BICK	I	Hi-Z	Serial Audio Input Bit Clock Pin.
3	LRCK	I	Hi-Z	Serial Audio Input Left/Right Clock Pin.
4	SDTI1	I	Hi-Z	Serial Audio Input Data Port.
5	SDTI2	I		
6	SDTI3	I		
7	SDTI4	I		
8	DZF	O	50kΩ Pull-Down	Zero Detection Function Pin. When the input data of each channel reaches zero continuously within 8192 LRCK cycles, the DZF pin becomes high level. When the input data of each channel does not reach zero, the DZF pin immediately reverts to the low level.
9	PDN	I	Hi-Z	Power-Down Mode Control Pin. When it is set low, the SGM56101 enters in a power-down mode, and its control registers revert to their default settings.
10	SMUTE	I	Hi-Z	Soft Mute Pin in Parallel Control Mode. When SMUTE pin becomes high level, the soft mute cycle is activated. When returning low level, the output mute is released.
	CAD1	I		Chip Address 1 Pin in the I^2C-Bus or 3-Wire Serial Control Mode. It serves as an identifier for the specific chip or device being addressed.
11	SDA	I/O	Hi-Z	Control I/O Data Line in I^2C-Bus Mode.
	CDTI	I		Input Data Pin. It is from the control port interface in 3-wire serial control mode.
	TDM0	I		Function Pin 0. It is used as the selector for the TDM mode in the parallel control mode.

PIN DESCRIPTION (continued)

PIN	NAME	TYPE (1) (2)	POWER-DOWN STATE	FUNCTION
12	SCL	I	Hi-Z	Serial Control Interface Clock Pin in I^2C-Bus Mode.
	CCLK	I		Serial Control Interface Clock in 3-Wire Serial Control Mode.
	TDM1	I		Function Pin 1. It is used as the selector for the TDM mode in the parallel control mode.
13	CAD0_I2C	I	Hi-Z	Chip Address 0 Pin in the I^2C-Bus Mode. It serves as an identifier for the specific chip or device being addressed.
	CSN	I		Control Port Enable Pin in 3-Wire Serial Control Mode. It is used to enable the control port interface on the SGM56101.
	DIF	I		Audio Data Format Select Pin in Parallel Control Mode. Low: 32-bit MSB. High: 32-bit I^2S.
14	PS	I	Hi-Z	Control Mode Select Pin (I2C Pin = High). Low: I^2C-bus mode. High: parallel control mode.
	CAD0_SPI	I		Chip Address 0 Pin (I2C Pin = Low) in 3-Wire Serial Control Mode. It serves as an identifier for the specific chip or device being addressed.
15	AOUTL1	O	Hi-Z	Left Channel Analog Output 1 Pin.
16	AOUTR1	O	Hi-Z	Right Channel Analog Output 1 Pin.
17	AOUTL2	O	Hi-Z	Left Channel Analog Output 2 Pin.
18	AOUTR2	O	Hi-Z	Right Channel Analog Output 2 Pin.
19	VREFH	–	Hi-Z	High Voltage Reference Input Pin. It should be connected to the AVDD.
20	VREFL	–	Hi-Z	Low Voltage Reference Input Pin. It should be connected to the VSS2.
21	VCOM	O	500Ω Pull-Down	Common Voltage Output Pin (AVDD × 1/2). Reducing power noise requires the use of large external capacitor around 2.2μF.
22	VSS2	–	–	Analog Ground Pin. Ground for the analog circuitry in the chip.
23	AVDD	P	–	Analog Power Supply Pin. The voltage range is from 3.0V to 3.6V.
24	AOUTL3	O	Hi-Z	Left Channel Analog Output 3 Pin.
25	AOUTR3	O	Hi-Z	Right Channel Analog Output 3 Pin.
26	AOUTL4	O	Hi-Z	Left Channel Analog Output 4 Pin.
27	AOUTR4	O	Hi-Z	Right Channel Analog Output 4 Pin.
28	TEST	–	21.5kΩ Pull-Down	Test Pin. It should be left floating or tied to VSS2.
29	I2C	I	Hi-Z	Control Mode Select Pin. Low: 3-wire serial control mode. High: I^2C-bus or parallel control mode.
30	TVDD	P	–	Digital Power Supply Pin. The voltage range is from 2.3V to 3.6V.
31	VSS1	–	–	Digital Ground Pin.
32	LDOO	O	630Ω Pull-Down	LDO Output Pin. The pin requires a connection to ground via a 2.2uF capacitor with a tolerance of ±50%.
Exposed Pad	GND	–	–	The exposed pad on the bottom surface of the package should be connected to the ground plane for optimized heat dissipation.

NOTES:

1. I = input, O = output, I/O = input or output, P = power.

2. All digital inputs must be securely connected and not allowed to remain unconnected or floating.

ELECTRICAL CHARACTERISTICS

(AVDD = TVDD = VREFH = 3.3V, VSS1 = VSS2 = 0V, T_A = +25℃, unless otherwise noted.) (1)

PARAMETER	SYMBOL	CONDITIONS		MIN	TYP	MAX	UNITS
DAC Analog Output							
Resolution				32			Bits
Output Voltage (2)				2.55	2.8	3.11	V_{PP}
Total Harmonic Distortion + Noise (0dBFS)	THD+N	f_S = 48kHz (3)			-91.5	-74	dB
		f_S = 96kHz (3)			-90		
		f_S = 192kHz			-86		
Dynamic Range (-60dBFS)	DR	f_S = 48kHz (A-weighted)		104	110		dB
		f_S = 96kHz			103		
		f_S = 192kHz			102		
Signal-to-Noise Ratio	SNR	f_S = 48kHz (A-weighted)		106	110		dB
		f_S = 96kHz			103		
		f_S = 192kHz			103		
Interchannel Isolation (4)		Isolation from other LR channels			120		dB
		Isolation of LR for a single channel			118		
Interchannel Gain Mismatch				-0.2	0	0.2	dB
Load Resistance (5)	R_L			10			kΩ
Load Capacitance	C_L					30	pF
Power Supply Rejection	PSR	AVDD (6)			65		dB
		TVDD (7)			88		
		VREFH (8)			82		
Power Supply							
Power Supply Current	I_{AVDD}	Normal operation (PDN pin = high)	f_S = 48kHz, 96kHz, 192kHz		14	25	mA
	I_{TVDD}		f_S = 48kHz (9)		14	28	
			f_S = 96kHz (10)		25	36	
			f_S = 192kHz (10)		35	50	
Power Supply Leakage Current	I_{AVDD} + I_{TVDD} + I_{VREFH}	Power-down mode (PDN pin = low) (11)			1	200	μA

NOTES:

1. Measurement frequency f_S = 48kHz, BICK = 64 × f_S, signal frequency = 1kHz, 32-bit data, 20Hz to 20kHz at f_S = 48kHz, 20Hz to 40kHz at f_S = 96kHz, 20Hz to 40kHz at f_S = 192kHz.

2. Full-scale output voltage is always proportional to AVDD. Specifically, it is calculated as AVDD multiplied by 0.86.

3. Test conditions 48kHz/96kHz are done in high-performance mode for optimized performance.

4. The interchannel isolation is measured by applying a 0dBFS, 1kHz sine wave output to non-measurement channel.

5. AC load = 5kΩ, DC load = 10kΩ.

6. The PSR is measured by applying a 1kHz sine wave with a peak-to-peak amplitude of 50mV to the AVDD.

7. The PSR is measured by applying a 1kHz sine wave with a peak-to-peak amplitude of 50mV to the TVDD.

8. The PSR is measured by applying a 1kHz sine wave with a peak-to-peak amplitude of 50mV to the VREFH.

9. Power supply current of TVDD is measured at I^2S mode, f_s = 48kHz, BICK = 64 × f_s, MCLK = 12.288MHz.

10. Power supply current of TVDD is measured at I^2S mode, f_s = 96/192kHz, BICK = 64 × f_s, MCLK = 24.576MHz.

11. Quiescent current is measured when all digital input pins, inclusive of clock pins, are connected to VSS.

ELECTRICAL CHARACTERISTICS (continued)

(AVDD = TVDD = VREFH = 3.3V, VSS1 = VSS2 = 0V, T_A = +25℃, unless otherwise noted.) (1)

PARAMETER	SYMBOL	CONDITIONS		MIN	TYP	MAX	UNITS
DC Characteristics							
High-Level Input Voltage	V_{IH}			0.7 × TVDD			V
Low-Level Input Voltage	V_{IL}					0.3 × TVDD	V
High-Level Output Voltage	V_{OH}	DZF pin, I_{OUT} = -100μA		TVDD - 0.5			V
Low-Level Output Voltage	V_{OL}	DZF pin, I_{OUT} = 100μA				0.5	V
		SDA pin, I_{OUT} = 3mA				0.4	
Input Leakage Current	I_{IN}			-10		10	μA
Digital Filter Characteristics with Sharp Roll-Off Filter (2)							
Pass Band (3)	PB	±0.05dB	f_S = 48kHz	0		22	kHz
		-3.0dB			23.5		
		±0.05dB	f_S = 96kHz	0		44	
		-3.0dB			47		
		±0.05dB	f_S = 192kHz	0		88	
		-3.0dB			94		
Pass Band Ripple (4)	PR	f_S = 48kHz		-0.003		0.003	dB
		f_S = 96kHz		-0.003		0.003	
		f_S = 192kHz		-0.003		0.003	
Stop Band (3)	SB	f_S = 48kHz		26.4			kHz
		f_S = 96kHz		52.8			
		f_S = 192kHz		105.6			
Stop Band Attenuation (6)	SA	f_S = 48kHz		80			dB
		f_S = 96kHz		80			
		f_S = 192kHz		80			
Group Delay (5)	GD	f_S = 48kHz			26.8		$1/f_S$
		f_S = 96kHz			26.8		
		f_S = 192kHz			26.8		
Frequency Response (Digital Filter + SCF + SMF (6))		0kHz to 20kHz	f_S = 48kHz	-0.03		0.12	dB
			f_S = 96kHz	-0.03		0.12	
			f_S = 192kHz	-0.03		0.1	

NOTES:

1. Measurement frequency f_S = 48kHz, BICK = 64 × f_S, signal frequency = 1kHz, 32-bit data, 20Hz to 20kHz at f_S = 48kHz, 20Hz to 40kHz at f_S = 96kHz, 20Hz to 40kHz at f_S = 192kHz.

2. Specified by design and characterization, not production tested.

3. The frequencies of the pass band and stop band are scalable based on the sampling frequency f_S. For instance, PB = 0.45 × f_S, SB = 0.55 × f_S.

4. The pass band gain amplitude of the double oversampling filter is exhibited during the initial stage of the interpolator operation.

5. The delay time that arises from digital filtering is the duration from the moment when 16/20/24/32-bit data for both channels is set in the input register to the point when the analog signal is outputted.

6. When a 1kHz sine wave with 0dB is inputted, the output level is presumed to be 0dB.

ELECTRICAL CHARACTERISTICS (continued)

(AVDD = TVDD = VREFH = 3.3V, VSS1 = VSS2 = 0V, T_A = +25℃, unless otherwise noted.) (1)

PARAMETER	SYMBOL	CONDITIONS		MIN	TYP	MAX	UNITS
Digital Filter Characteristics with Slow Roll-Off Filter (2)							
Pass Band (3)	PB	±0.05dB	f_S = 48kHz	0		14.58	kHz
		-3.0dB			21.74		
		±0.05dB	f_S = 96kHz	0		29.16	
		-3.0dB			43.48		
		±0.05dB	f_S = 192kHz	0		58.32	
		-3.0dB			86.96		
Pass Band Ripple (4)	PR	f_S = 48kHz		-0.003		0.003	dB
		f_S = 96kHz		-0.003		0.003	
		f_S = 192kHz		-0.003		0.003	
Stop Band (3)	SB	f_S = 48kHz		36			kHz
		f_S = 96kHz		72			
		f_S = 192kHz		144			
Stop Band Attenuation (6)	SA	f_S = 48kHz		88.66			dB
		f_S = 96kHz		88.66			
		f_S = 192kHz		88.66			
Group Delay (5)	GD	f_S = 48kHz			6.85		$1/f_S$
		f_S = 96kHz			6.85		
		f_S = 192kHz			6.85		
Frequency Response (Digital Filter + SCF + SMF (6))		0kHz to 20kHz	f_S = 48kHz	-3.2		0	dB
			f_S = 96kHz	-0.5		0	
			f_S = 192kHz	-0.16		0	

NOTES:

1. Measurement frequency f_S = 48kHz, BICK = 64 × f_S, signal frequency = 1kHz, 32-bit data, 20Hz to 20kHz at f_S = 48kHz, 20Hz to 40kHz at f_S = 96kHz, 20Hz to 40kHz at f_S = 192kHz.

2. Specified by design and characterization, not production tested.

3. The frequencies of the pass band and stop band are scalable based on the sampling frequency f_S. For instance, PB = 0.25 × f_S, SB = 0.75 × f_S.

4. The pass band gain amplitude of the double oversampling filter is exhibited during the initial stage of the interpolator operation.

5. The delay time that arises from digital filtering is the duration from the moment when 16/20/24/32-bit data for both channels is set in the input register to the point when the analog signal is outputted.

6. When a 1kHz sine wave with 0dB is inputted, the output level is presumed to be 0dB.

TIMING CHARACTERISTICS

(AVDD = TVDD = VREFH = 3.3V, VSS1 = VSS2 = 0V, T_A = +25℃, unless otherwise noted.)

PARAMETER		SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
External Master Clock Timing							
MCLK Frequency		f_{CLK}	128 × f_{SN}, 128 × f_{SD}, 192 × f_{SN}, 256 × f_{SN}	2.048		12.288	MHz
MCLK Pulse Width Low		t_{CLKL}		32			ns
MCLK Pulse Width High		t_{CLKH}		32			ns
MCLK Frequency		f_{CLK}	192 × f_{SD}, 384 × f_{SN}	3.072		18.432	MHz
MCLK Pulse Width Low		t_{CLKL}		22			ns
MCLK Pulse Width High		t_{CLKH}		22			ns
MCLK Frequency		f_{CLK}	128 × f_{SQ}, 256 × f_{SD}, 512 × f_{SN}, 768 × f_{SN}	4.096		24.576	MHz
MCLK Pulse Width Low		t_{CLKL}		16			ns
MCLK Pulse Width High		t_{CLKH}		16			ns
LRCK Timing (Slave Mode)							
LRCK Frequency	Normal Speed Mode	f_{SN}	Normal mode (TDM[1:0] bits = 00)	8		48	kHz
	Double Speed Mode	f_{SD}		48		96	kHz
	Quad Speed Mode	f_{SQ}		96		192	kHz
Duty Cycle		Duty		45		55	%
LRCK Frequency	Normal Speed Mode	f_{SN}	TDM128 mode (TDM[1:0] bits = 01)	8		48	kHz
	Double Speed Mode	f_{SD}		48		96	kHz
	Quad Speed Mode	f_{SQ}		96		192	kHz
LRCK High Time		t_{LRH}		1/128f_S			ns
LRCK Low Time		t_{LRL}		1/128f_S			ns
LRCK Frequency	Normal Speed Mode	f_{SN}	TDM256 mode (TDM[1:0] bits = 10)	8		48	kHz
	Double Speed Mode	f_{SD}		48		96	kHz
LRCK High Time		t_{LRH}		1/256f_S			ns
LRCK Low Time		t_{LRL}		1/256f_S			ns
LRCK Frequency	Normal Speed Mode	f_{SN}	TDM512 mode (TDM[1:0] bits = 11)	8		48	kHz
LRCK High Time		t_{LRH}		1/512f_S			ns
LRCK Low Time		t_{LRL}		1/512f_S			ns

TIMING CHARACTERISTICS (continued)

(AVDD = TVDD = VREFH = 3.3V, VSS1 = VSS2 = 0V, T_A = +25℃, unless otherwise noted.)

PARAMETER		SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
Audio Interface Timing							
BICK Period	Normal Speed Mode	t_{BCK}	Normal mode (TDM[1:0] bits = 00)	$1/256f_{SN}$			ns
	Double Speed Mode			$1/128f_{SD}$			ns
	Quad Speed Mode			$1/64f_{SQ}$			ns
BICK Pulse Width Low		t_{BCKL}		16			ns
BICK Pulse Width High		t_{BCKH}		16			ns
BICK Rising Edge to LRCK Edge (1)		t_{BLR}		5			ns
LRCK Edge to BICK Rising Edge (1)		t_{LRB}		5			ns
SDTI Hold Time		t_{SDH}		5			ns
SDTI Setup Time		t_{SDS}		5			ns
BICK Period	Normal Speed Mode	t_{BCK}	TDM128 mode (TDM[1:0] bits = 01)	$1/128f_{SN}$			ns
	Double Speed Mode			$1/128f_{SD}$			ns
	Quad Speed Mode			$1/128f_{SQ}$			ns
BICK Pulse Width Low		t_{BCKL}		16			ns
BICK Pulse Width High		t_{BCKH}		16			ns
BICK Rising Edge to LRCK Edge (1)		t_{BLR}		5			ns
LRCK Edge to BICK Rising Edge (1)		t_{LRB}		5			ns
SDTI Hold Time		t_{SDH}		5			ns
SDTI Setup Time		t_{SDS}		5			ns
BICK Period	Normal Speed Mode	t_{BCK}	TDM256 mode (TDM[1:0] bits = 10)	$1/256f_{SN}$			ns
	Double Speed Mode			$1/256f_{SD}$			ns
BICK Pulse Width Low		t_{BCKL}		16			ns
BICK Pulse Width High		t_{BCKH}		16			ns
BICK Rising Edge to LRCK Edge (1)		t_{BLR}		5			ns
LRCK Edge to BICK Rising Edge (1)		t_{LRB}		5			ns
SDTI Hold Time		t_{SDH}		5			ns
SDTI Setup Time		t_{SDS}		5			ns
BICK Period	Normal Speed Mode	t_{BCK}	TDM512 mode (TDM[1:0] bits = 11)	$1/512f_{SN}$			ns
BICK Pulse Width Low		t_{BCKL}		16			ns
BICK Pulse Width High		t_{BCKH}		16			ns
BICK Rising Edge to LRCK Edge (1)		t_{BLR}		5			ns
LRCK Edge to BICK Rising Edge (1)		t_{LRB}		5			ns
SDTI Hold Time		t_{SDH}		5			ns
SDTI Setup Time		t_{SDS}		5			ns

NOTE:

1. The occurrence of the BICK rising edge does not overlap with the LRCK edge, ensuring proper synchronization and avoiding potential conflicts.

TIMING CHARACTERISTICS (continued)

(AVDD = TVDD = VREFH = 3.3V, VSS1 = VSS2 = 0V, T_A = +25℃, unless otherwise noted.)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
Control Interface Timing (3-Wire Serial Mode)						
CCLK Period	t_{CCK}		200			ns
CCLK Pulse Width Low	t_{CCKL}		80			ns
CCLK Pulse Width High	t_{CCKH}		80			ns
CDTI Setup Time	t_{CDS}		40			ns
CDTI Hold Time	t_{CDH}		40			ns
CSN High Time	t_{CSW}		150			ns
CSN Falling Edge to CCLK Rising Edge	t_{CSS}		50			ns
CCLK Rising Edge to CSN Rising Edge	t_{CSH}		50			ns
Control Interface Timing (I^2C-Bus Mode)						
SCL Clock Frequency	f_{SCL}				400	kHz
Bus Free Time between Transmissions	t_{BUF}		1.3			μs
Start Condition Hold Time	t_{HD_STA}	Prior to first clock pulse	0.6			μs
Clock Low Time	t_{LOW}		1.3			μs
Clock High Time	t_{HIGH}		0.6			μs
Setup Time for Repeated Start Condition	t_{SU_STA}		0.6			μs
SDA Hold Time from SCL Falling (1)	t_{HD_DAT}		0			μs
SDA Setup Time from SCL Rising	t_{SU_DAT}		0.1			μs
Rise Time of Both SDA and SCL Lines	t_R				1.0	μs
Fall Time of Both SDA and SCL Lines	t_F				0.3	μs
Setup Time for Stop Condition	t_{SU_STO}		0.6			μs
Pulse Width of Spike Noise Suppressed by Input Filter	t_{SP}		0		50	ns
Capacitive Load on Bus	C_B				400	pF
Power-Down/Reset Timing						
PDN Pulse Width (2)	t_{APD}		800			ns
PDN Reject Pulse Width	t_{RPD}				50	ns

NOTES:

1. The data must be maintained for an adequate duration to span the 300ns transition period of SCL, ensuring stable and accurate transmission.

2. To reset the SGM56101, the PDN pin is recommended to be low during power-up, and this low state must be maintained for a duration exceeding 600ns to ensure a complete reset. Conversely, a low pulse lasting less than 50ns will not trigger a reset in the SGM56101.

TIMING DIAGRAMS

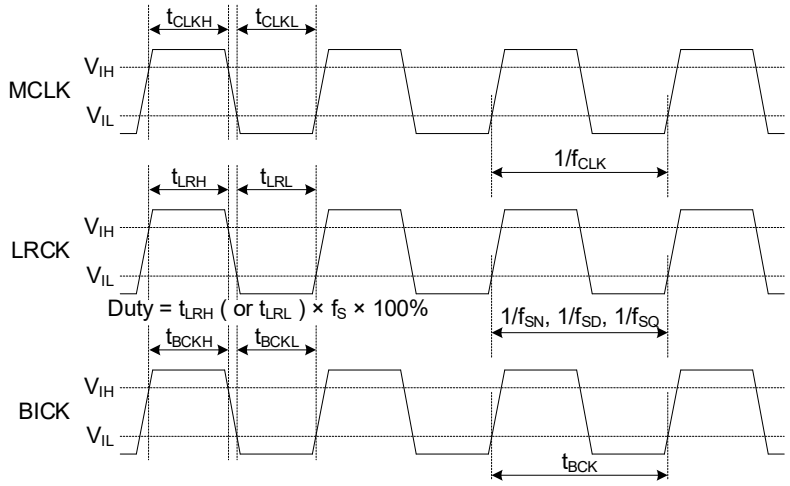


Figure 1. Non-TDM Clock Timing

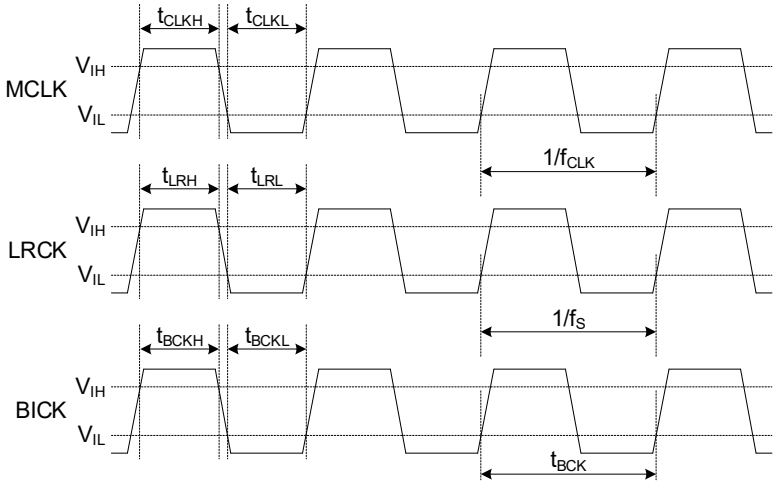


Figure 2. TDM Clock Timing

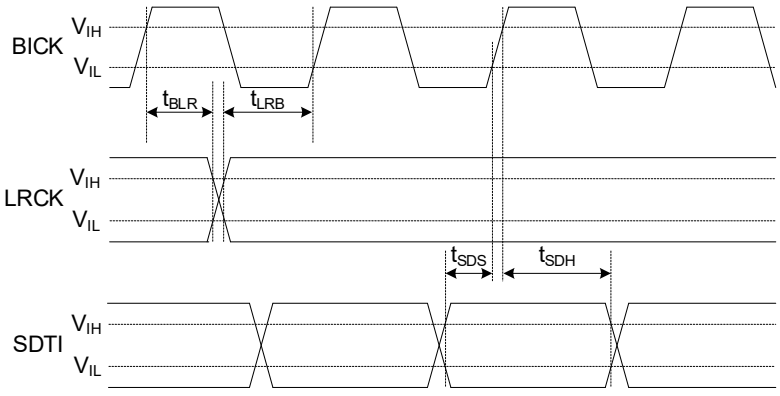


Figure 3. Non-TDM Clock Timing (Audio Interface)

TIMING DIAGRAMS (continued)

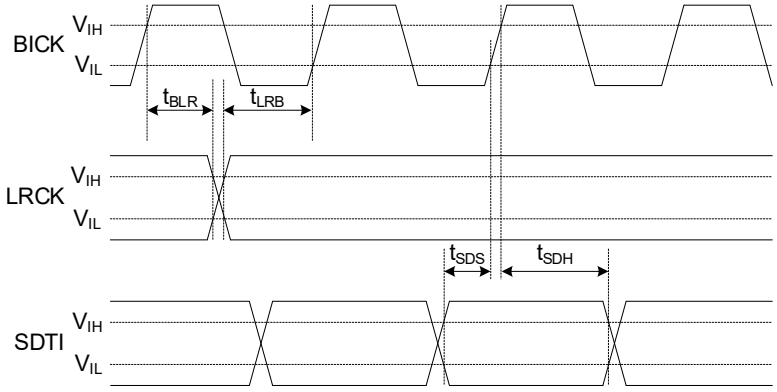


Figure 4. TDM Clock Timing (Audio Interface)

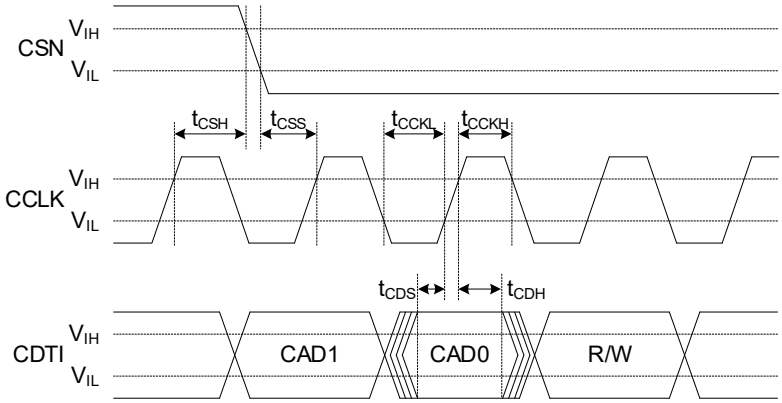


Figure 5. 3-Wire Serial Mode Command Input Timing (Write Only)

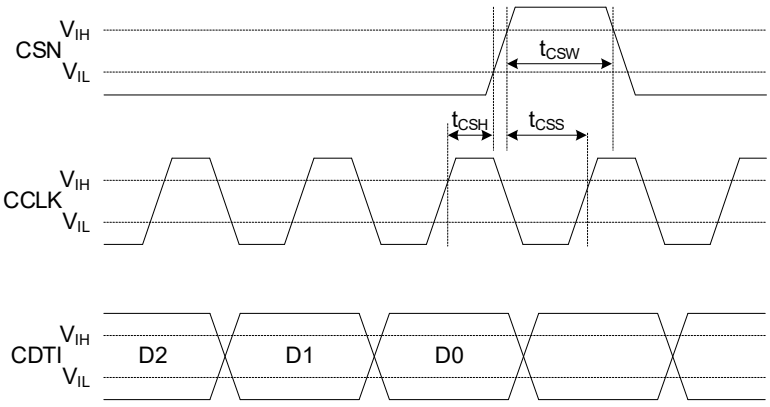


Figure 6. 3-Wire Serial Mode Data Input Timing (Write Only)

TIMING DIAGRAMS (continued)

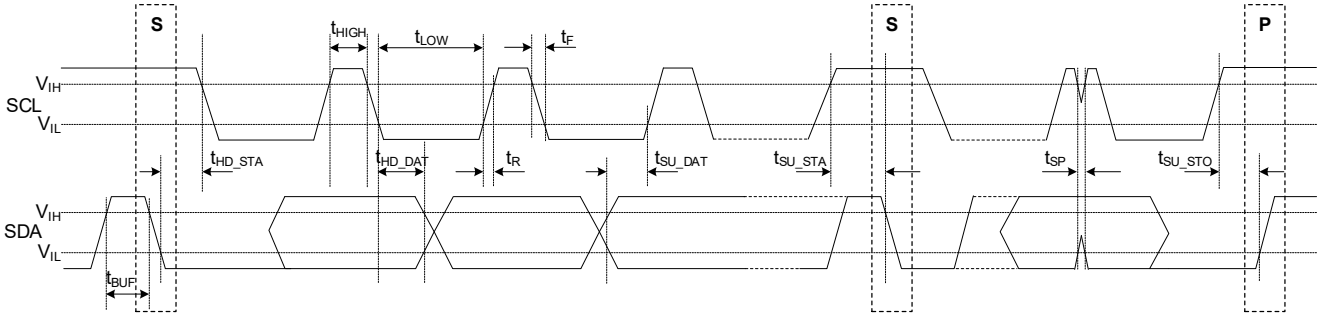


Figure 7. I²C-Bus Mode Input/Output Timing (Write/Read)

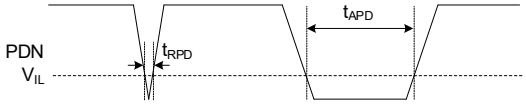
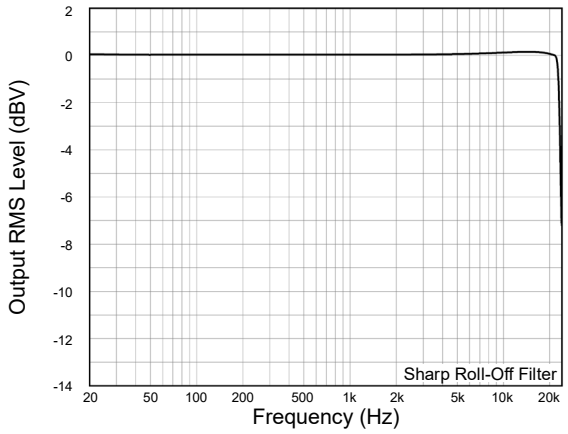


Figure 8. Power-Down/Reset Timing

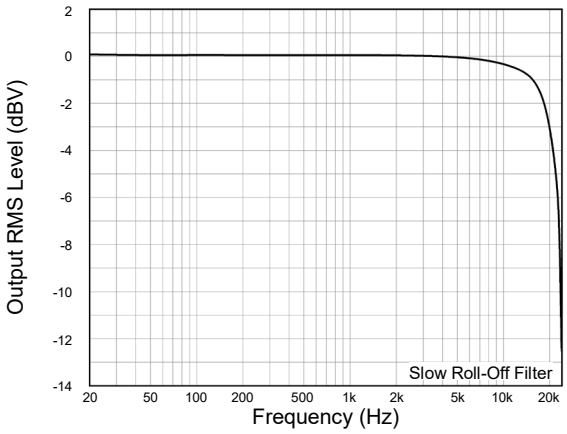
TYPICAL PERFORMANCE CHARACTERISTICS

T_A = +25℃, AVDD = TVDD = VREFH = 3.3V, VSS1 = VSS2 = 0V. Measurement frequency f_S = 48kHz, BICK = 64 × f_S = 3.072MHz, MCLK = 12.288MHz, signal frequency = 1kHz, 20Hz to 20kHz at 48kHz, 32-bit data, DFS[2:0] bits = 001, I^2S mode.

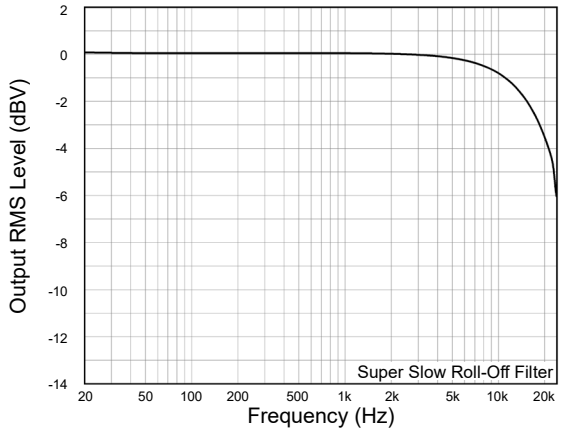
Output RMS Level vs. Frequency



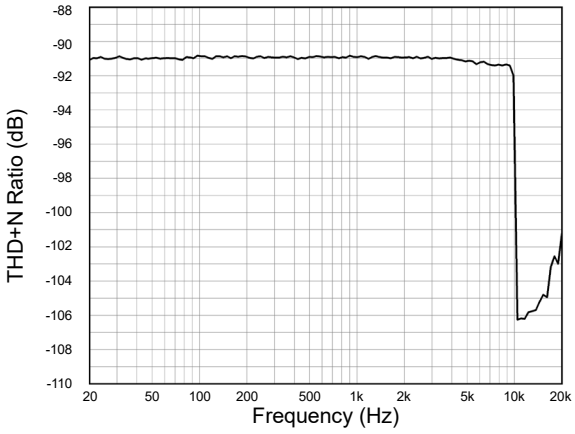
Output RMS Level vs. Frequency



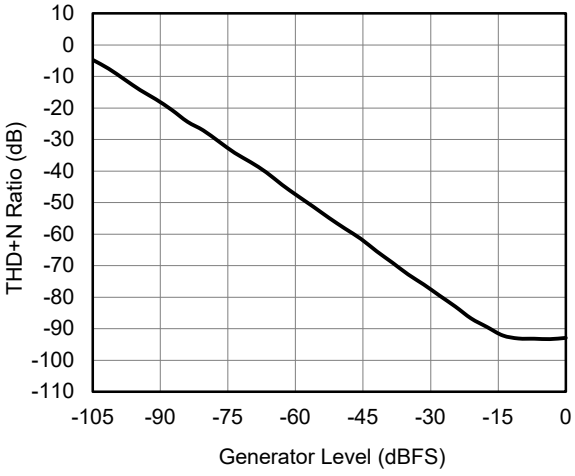
Output RMS Level vs. Frequency



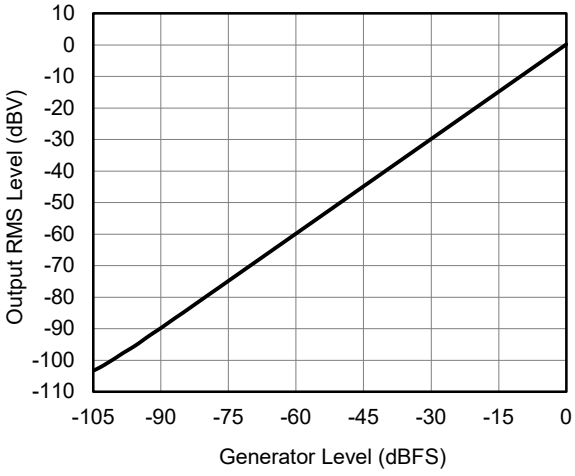
THD+N Ratio vs. Frequency



THD+N Ratio vs. Generator Level



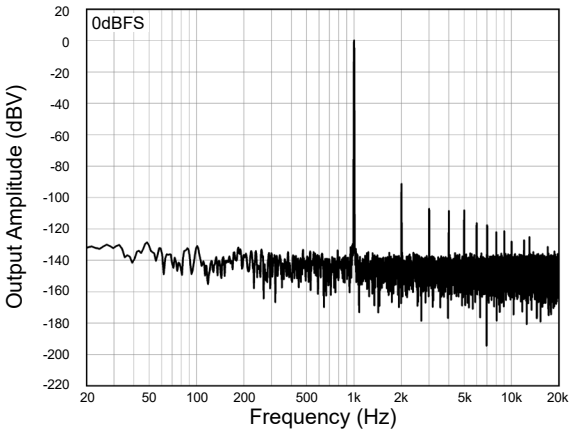
Output RMS Level vs. Generator Level



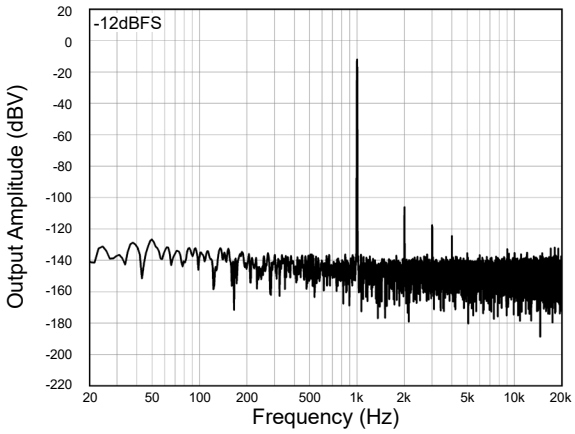
TYPICAL PERFORMANCE CHARACTERISTICS (continued)

T_A = +25℃, AVDD = TVDD = VREFH = 3.3V, VSS1 = VSS2 = 0V. Measurement frequency f_S = 48kHz, BICK = 64 × f_S = 3.072MHz, MCLK = 12.288MHz, signal frequency = 1kHz, 20Hz to 20kHz at 48kHz, 32-bit data, DFS[2:0] bits = 001, I^2S mode.

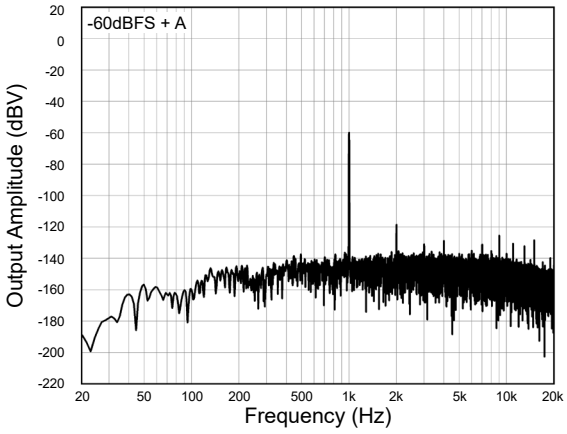
Output Amplitude vs. Frequency



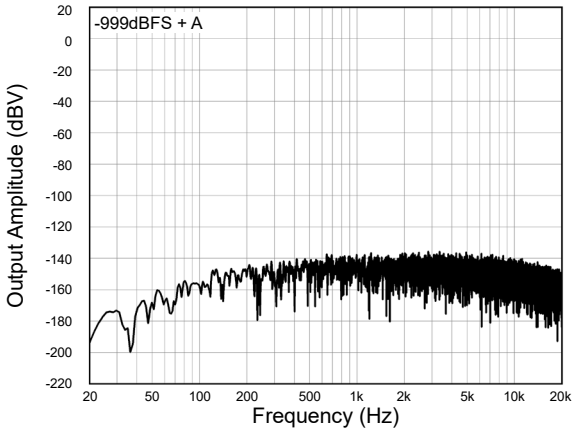
Output Amplitude vs. Frequency



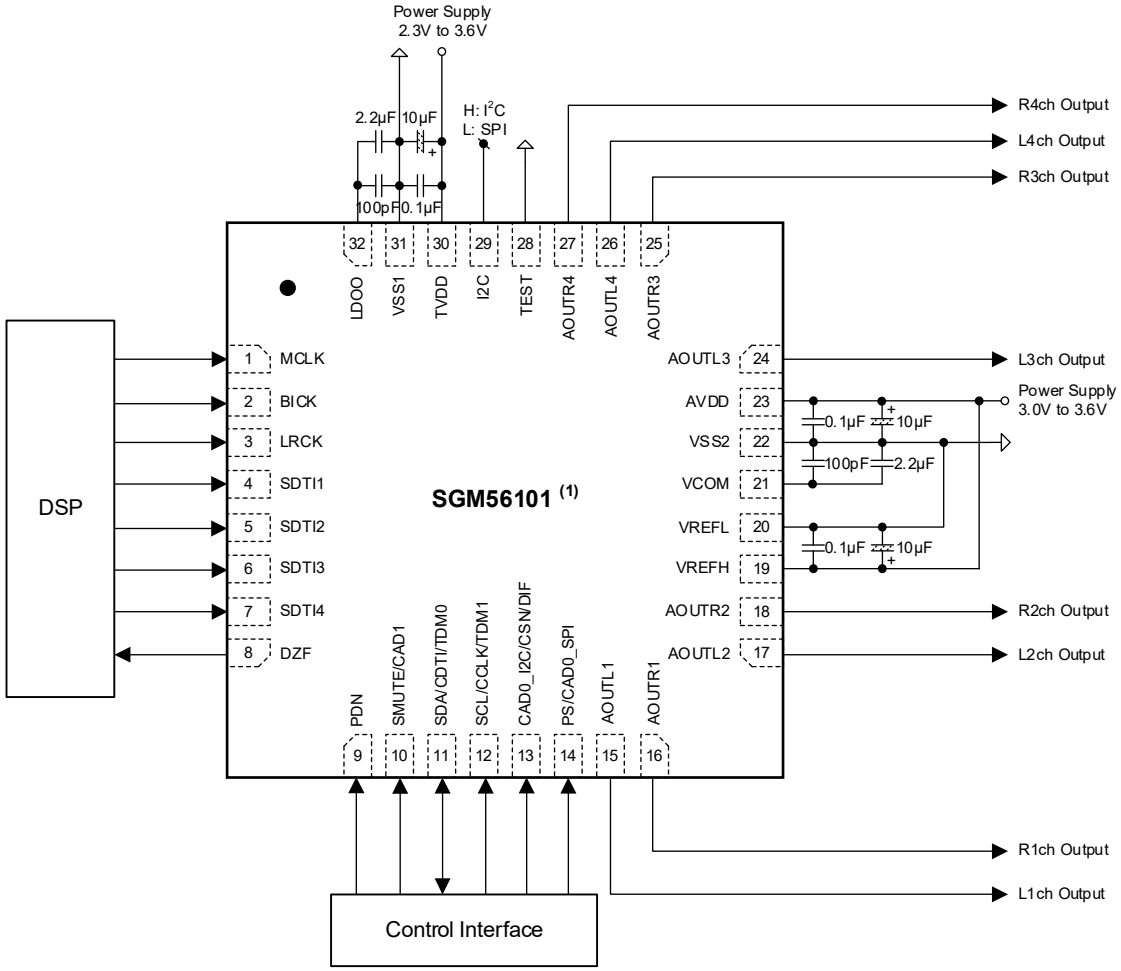
Output Amplitude vs. Frequency



Output Amplitude vs. Frequency



TYPICAL APPLICATION CIRCUIT



NOTE:

1. The off chip capacitors should be placed as close as possible to the chip pins.

Figure 9. Typical Application Circuit

FUNCTIONAL BLOCK DIAGRAM

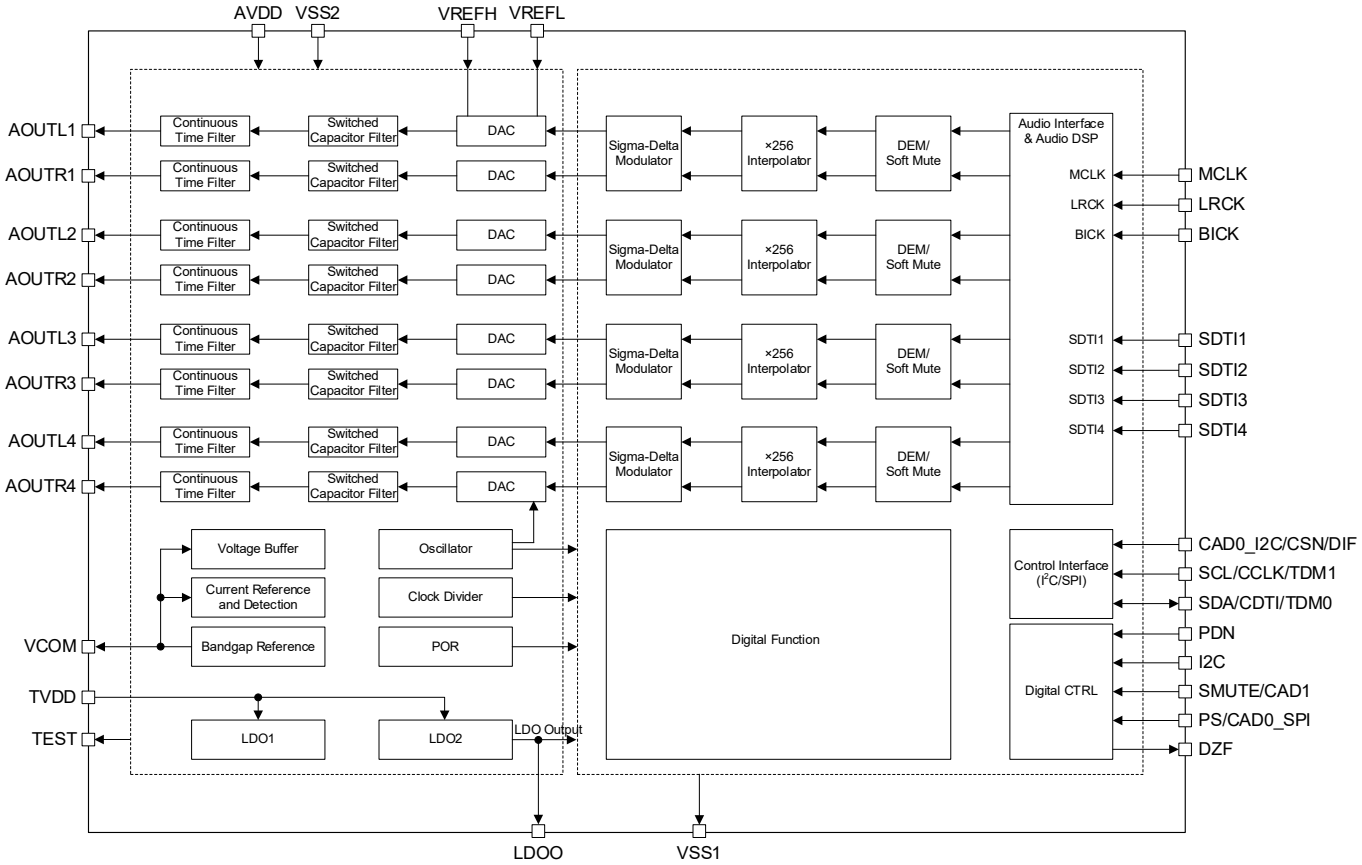


Figure 10. Block Diagram

DETAILED DESCRIPTION

System Clock

The SGM56101 requires three external clocks (MCLK, LRCK and BICK) for its operation. These clocks are crucial for ensuring the proper synchronization and transmission of data within the device. MCLK should be synchronized with LRCK and BICK, but the phase does not need to be strictly consistent. The DFS[2:0] bits in Table 1 are responsible for determining the sampling speed. At each specific sampling speed, the frequency of MCLK should be configured according to Table 2, ensuring seamless and accurate data transmission.

When the reset is exited during power-up and the PDN pin is in a low-to-high state, the SGM56101 remains in power-down mode until both MCLK and LRCK signals are entered. The SGM56101 is configured to operate in manual mode upon power-up, with the PDN pin transitioning from a low-to-high state. When it comes to adjusting the clock settings, it is crucial to reset the SGM56101 either by manipulating the PDN pin or by utilizing the RSTN bit. This reset ensures that the device can accommodate the new clock configurations and operate reliably.

In case that the clock is paused, a click noise will emit when it is restarted. If the click noise poses an issue for system applications, it is recommended to externally mute the digital output.

Manual Setting Mode

The SGM56101 automatically detects the frequency of the MCLK, and the DFS[2:0] bits in Table 1 are responsible for configuring the sampling rate. It is crucial to provide the appropriate MCLK frequency externally for each sampling speed, as specified in Table 2, to ensure accurate and reliable data transmission. The SGM56101 is configured to operate in manual mode upon power-up, with the PDN pin transitioning from a low-to-high state. When the DFS[2:0] bits undergo changes, it is necessary to reset the SGM56101 through the RSTN bit.

Table 1. Sampling Speed in Manual Setting Mode

DFS2 Bit	DFS1 Bit	DFS0 Bit	Sampling Speed Mode (f_S)	
0	0	0	Normal Speed Mode	8kHz to 48kHz (Default)
0	0	1	Double Speed Mode	48kHz to 96kHz
0	1	0	Quad Speed Mode	96kHz to 192kHz

Table 2. System Clock Example in Manual Setting Mode

LRCK (kHz)	MCLK (MHz)						Sampling Speed Mode
f_S	128 × f_S	192 × f_S	256 × f_S	384 × f_S	512 × f_S	768 × f_S	
8.0	N/A	N/A	2.0480	3.0720	4.0960	6.1440	Normal Speed Mode
44.1	5.6448	8.4672	11.2896	16.9344	22.5792	N/A	Normal Speed Mode
48.0	6.1440	9.2160	12.2880	18.4320	24.5760	N/A	Normal Speed Mode
88.2	11.2896	16.9344	22.5792	N/A	N/A	N/A	Double Speed Mode
96.0	12.2880	18.4320	24.5760	N/A	N/A	N/A	Double Speed Mode
176.4	22.5792	N/A	N/A	N/A	N/A	N/A	Quad Speed Mode
192.0	24.5760	N/A	N/A	N/A	N/A	N/A	Quad Speed Mode

DETAILED DESCRIPTION (continued)

De-emphasis Filter

The SGM56101 incorporates a digital de-emphasis filter, implemented as an IIR filter. Notably, this filter is exclusively compatible with the normal speed mode. It supports three distinct sampling frequencies (32kHz, 44.1kHz and 48kHz). Individual settings for each DAC, namely DAC1 (SDTI1), DAC2 (SDTI2), DAC3 (SDTI3) and DAC4 (SDTI4), allow for tailored de-emphasis configuration through register adjustments. This flexibility ensures that the SGM56101 can accommodate a range of audio processing needs.

Table 3. De-emphasis Filter Control

Mode	Sampling Speed Mode	DEM11/21/31/41	DEM10/20/30/40	DEM
0	Normal Speed Mode	0	0	44.1kHz
1	Normal Speed Mode	0	1	Off (Default)
2	Normal Speed Mode	1	0	48kHz
3	Normal Speed Mode	1	1	32kHz

Audio Interface Format

During operation, it is advisable not to alter the TDM[1:0] bits, DIF[2:0] bits, SDS[2:0] bits, TDM0, TDM1 pins and DIF pin settings.

Normal Mode (TDM[1:0] Bits = 00)

Audio data from eight channels is streamed into the SGM56101 through the SDTI1-4 pins, utilizing the BICK and LRCK inputs for synchronization. The SDS[2:0] bits serve to select the appropriate data stream. Furthermore, the device supports eight distinct data formats, which can be chosen by using the DIF[2:0] bits as detailed in Table 4. This versatility allows for seamless integration with a wide range of audio sources and processing requirements. Regardless of the format, the serial data is always transmitted with the most significant bit (MSB) first, in two's complement format, and is latched on the rising edge of BICK.

TDM128 Mode (TDM[1:0] Bits = 01)

Audio data from eight channels is streamed into the SGM56101 through the SDTI1-2 pins, utilizing the BICK and LRCK inputs for synchronization. The SDS[2:0] bits serve to select the appropriate data stream. The inputs to the SDTI3-4 pins are disregarded during the data streaming process. The BICK frequency remains static at 128 × f_S, providing a constant synchronization rate. Furthermore, the device supports six distinct data formats, which can be chosen by using the DIF[2:0] bits as detailed in Table 4. Regardless of the format, the serial data is always transmitted with the most significant bit (MSB) first, in two's complement format, and is latched on the rising edge of BICK.

TDM256 Mode (TDM[1:0] Bits = 10)

Audio data from sixteen channels is streamed into the SGM56101 through the SDTI1-2 pins, utilizing the BICK and LRCK inputs for synchronization. The SDS[2:0] bits serve to select the appropriate data stream. The inputs to the SDTI3-4 pins are disregarded during the data streaming process. The BICK frequency remains static at 256 × f_S, providing a constant synchronization rate. Furthermore, the device supports six distinct data formats, which can be chosen by using the DIF[2:0] bits as detailed in Table 4. Regardless of the format, the serial data is always transmitted with the most significant bit (MSB) first, in two's complement format, and is latched on the rising edge of BICK.

TDM512 Mode (TDM[1:0] Bits = 11)

Audio data from sixteen channels is streamed into the SGM56101 through the SDTI1 pin, utilizing the BICK and LRCK inputs for synchronization. The SDS[2:0] bits serve to select the appropriate data stream. The inputs to the SDTI3-4 pins are disregarded during the data streaming process. The BICK frequency remains static at 512 × f_S, providing a constant synchronization rate. Furthermore, the device supports six distinct data formats, which can be chosen by using the DIF[2:0] bits as detailed in Table 4. Regardless of the format, the serial data is always transmitted with the most significant bit (MSB) first, in two's complement format, and is latched on the rising edge of BICK.

DETAILED DESCRIPTION (continued)

Table 4. Audio Data Format

Mode		TDM1	TDM0	DIF2	DIF1	DIF0	LRCK	BICK	SDTI Format
Normal (1)	0	0	0	0	0	0	H/L	≥ 32 × f_S	16-Bit LSB Justified
	1			0	0	1	H/L	≥ 40 × f_S	20-Bit LSB Justified
	2			0	1	0	H/L	≥ 48 × f_S	24-Bit MSB Justified
	3			0	1	1	L/H	32 × f_S	16-Bit I^2S Compatible
							L/H	≥ 48 × f_S	24-Bit I^2S Compatible
	4			1	0	0	H/L	≥ 48 × f_S	24-Bit LSB Justified
	5			1	0	1	H/L	≥ 64 × f_S	32-Bit LSB Justified
	6			1	1	0	H/L	≥ 64 × f_S	32-Bit MSB Justified
	7			1	1	1	L/H	≥ 64 × f_S	32-Bit I^2S Compatible
TDM128	–	0	1	0	0	0	Rising Edge	128 × f_S	N/A
	–			0	0	1	Rising Edge	128 × f_S	N/A
	8			0	1	0	Rising Edge	128 × f_S	24-Bit MSB Justified
	9			0	1	1	Falling Edge	128 × f_S	24-Bit I^2S Compatible
	10			1	0	0	Rising Edge	128 × f_S	24-Bit LSB Justified
	11			1	0	1	Rising Edge	128 × f_S	32-Bit LSB Justified
	12			1	1	0	Rising Edge	128 × f_S	32-Bit MSB Justified
	13			1	1	1	Falling Edge	128 × f_S	32-Bit I^2S Compatible
TDM256	–	1	0	0	0	0	Rising Edge	256 × f_S	N/A
	–			0	0	1	Rising Edge	256 × f_S	N/A
	14			0	1	0	Rising Edge	256 × f_S	24-Bit MSB Justified
	15			0	1	1	Falling Edge	256 × f_S	24-Bit I^2S Compatible
	16			1	0	0	Rising Edge	256 × f_S	24-Bit LSB Justified
	17			1	0	1	Rising Edge	256 × f_S	32-Bit LSB Justified
	18			1	1	0	Rising Edge	256 × f_S	32-Bit MSB Justified
	19			1	1	1	Falling Edge	256 × f_S	32-Bit I^2S Compatible
TDM512	–	1	1	0	0	0	Rising Edge	512 × f_S	N/A
	–			0	0	1	Rising Edge	512 × f_S	N/A
	20			0	1	0	Rising Edge	512 × f_S	24-Bit MSB Justified
	21			0	1	1	Falling Edge	512 × f_S	24-Bit I^2S Compatible
	22			1	0	0	Rising Edge	512 × f_S	24-Bit LSB Justified
	23			1	0	1	Rising Edge	512 × f_S	32-Bit LSB Justified
	24			1	1	0	Rising Edge	512 × f_S	32-Bit MSB Justified
	25			1	1	1	Falling Edge	512 × f_S	32-Bit I^2S Compatible

NOTE:

1. BICK refers to the requirement that the bit input to each channel must be greater than the length of setting format.

DETAILED DESCRIPTION (continued)

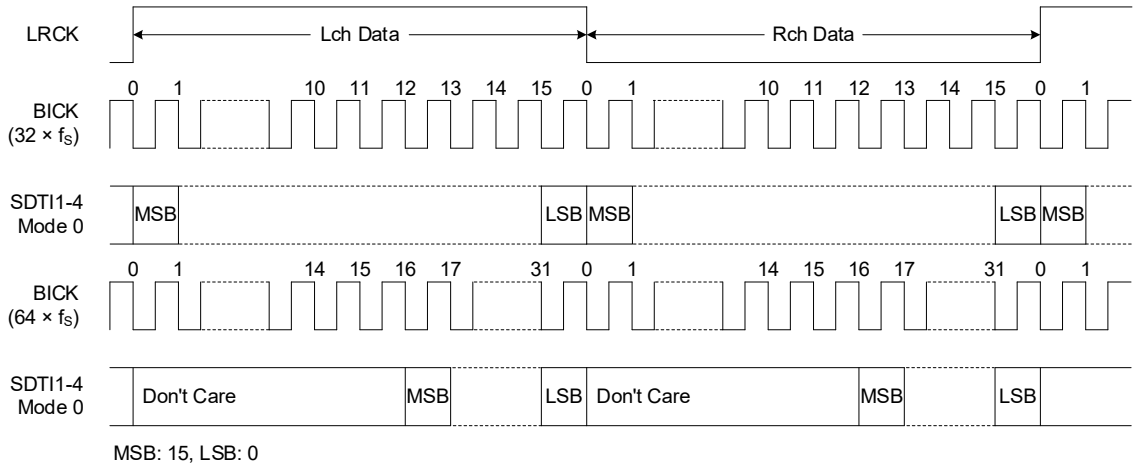


Figure 11. Audio Data Format Timing (Mode 0)

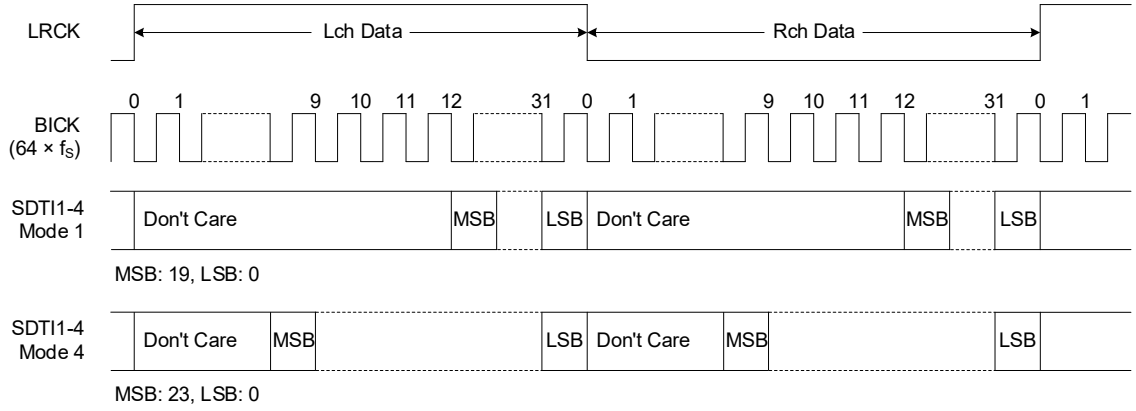


Figure 12. Audio Data Format Timing (Mode 1 and 4)

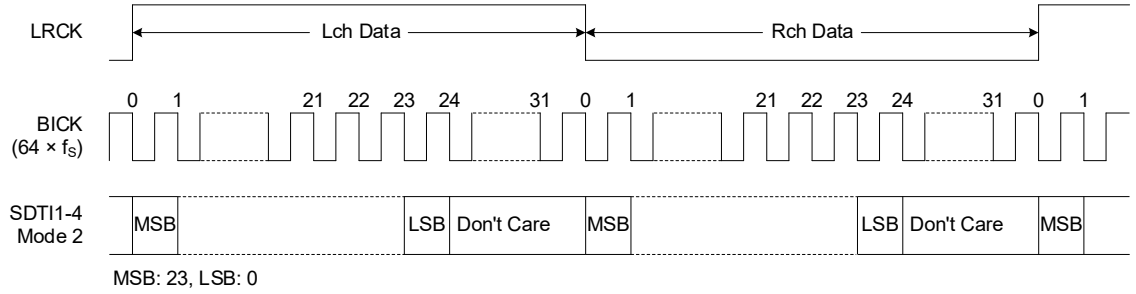


Figure 13. Audio Data Format Timing (Mode 2)

DETAILED DESCRIPTION (continued)

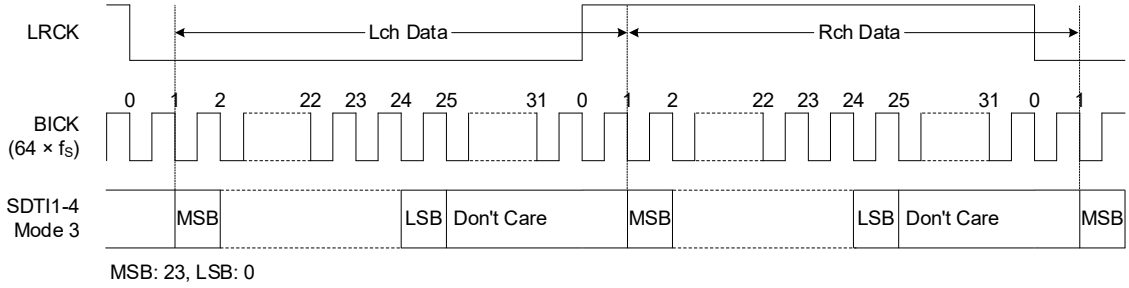


Figure 14. Audio Data Format Timing (Mode 3)

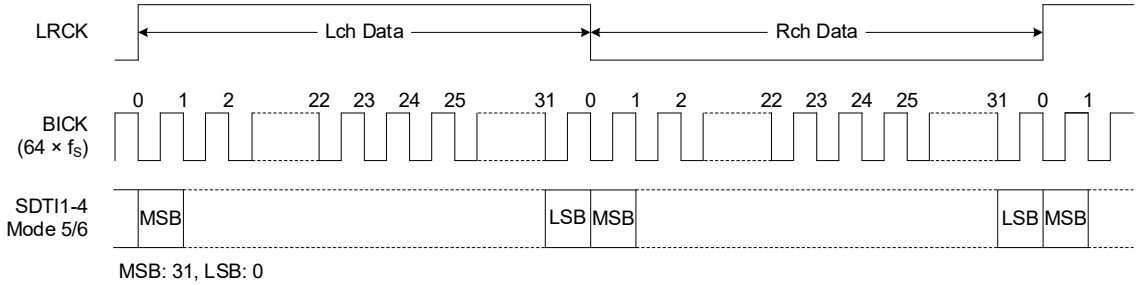


Figure 15. Audio Data Format Timing (Mode 5 and 6)

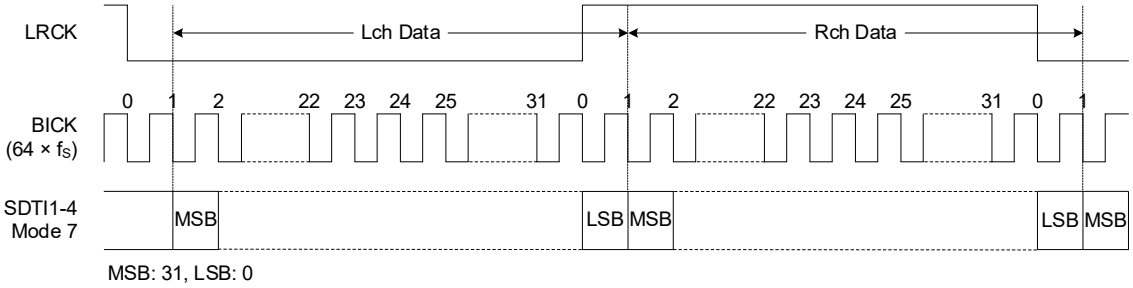


Figure 16. Audio Data Format Timing (Mode 7)

DETAILED DESCRIPTION (continued)

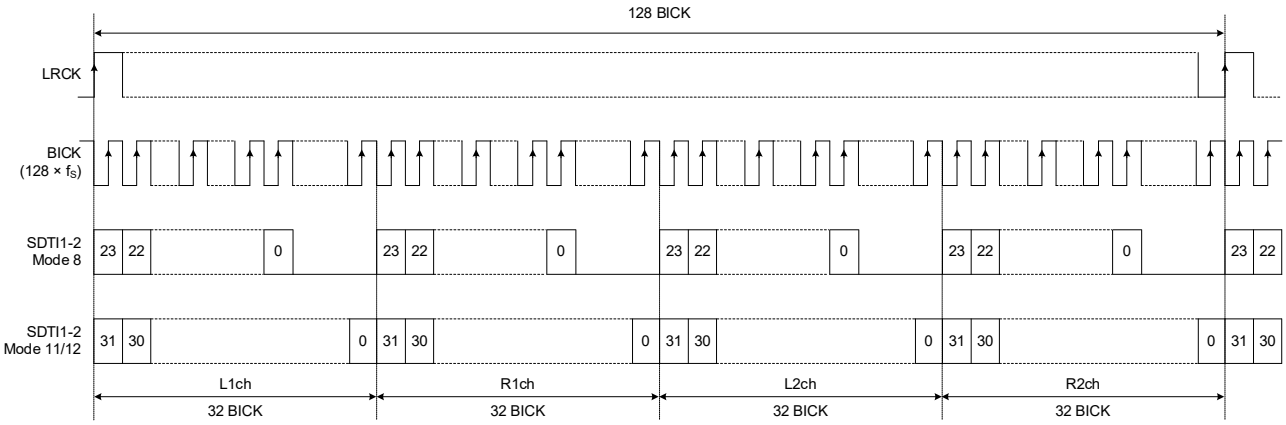


Figure 17. Audio Data Format Timing (Mode 8, 11 and 12)

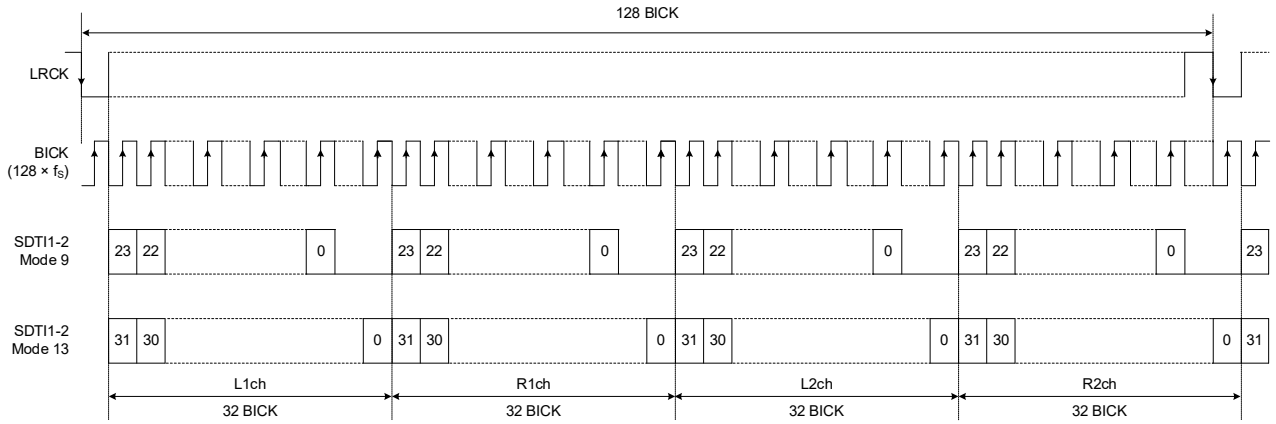


Figure 18. Audio Data Format Timing (Mode 9 and 13)

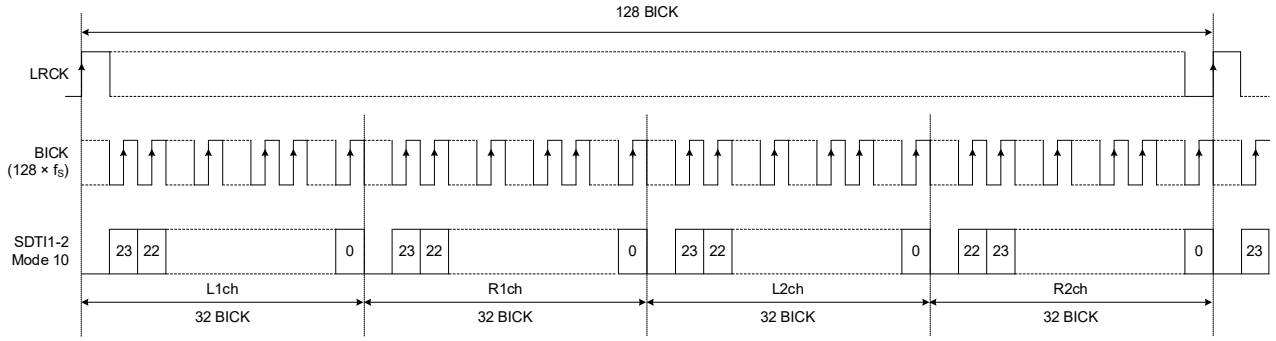


Figure 19. Audio Data Format Timing (Mode 10)

DETAILED DESCRIPTION (continued)

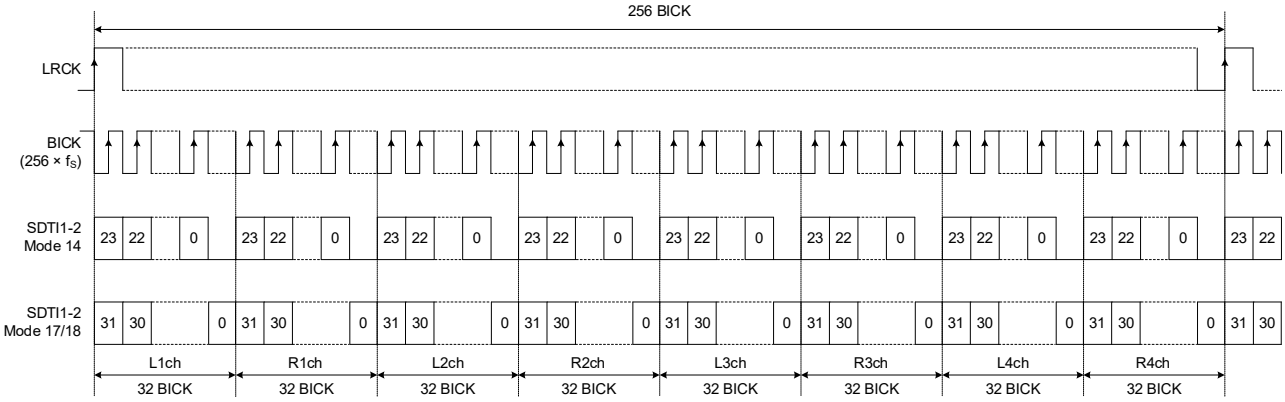


Figure 20. Audio Data Format Timing (Mode 14, 17 and 18)

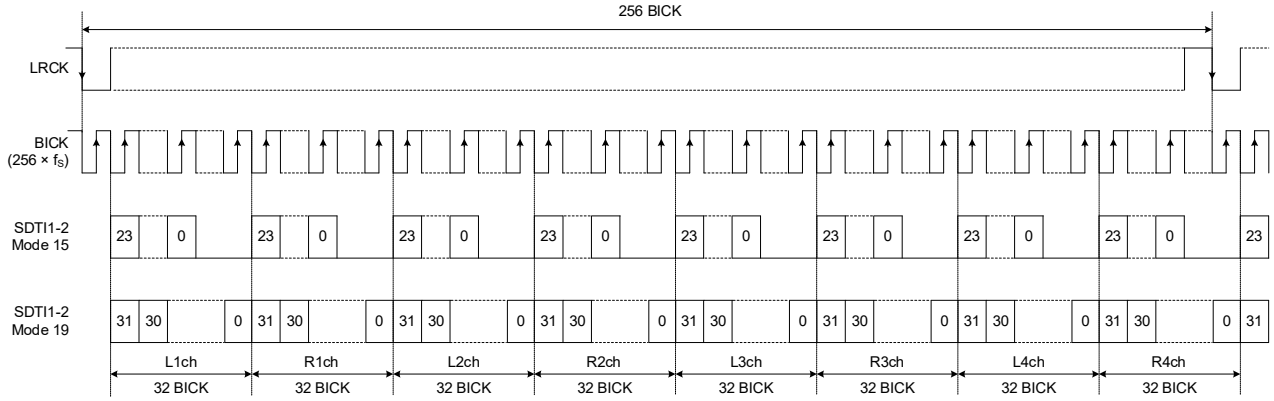


Figure 21. Audio Data Format Timing (Mode 15 and 19)

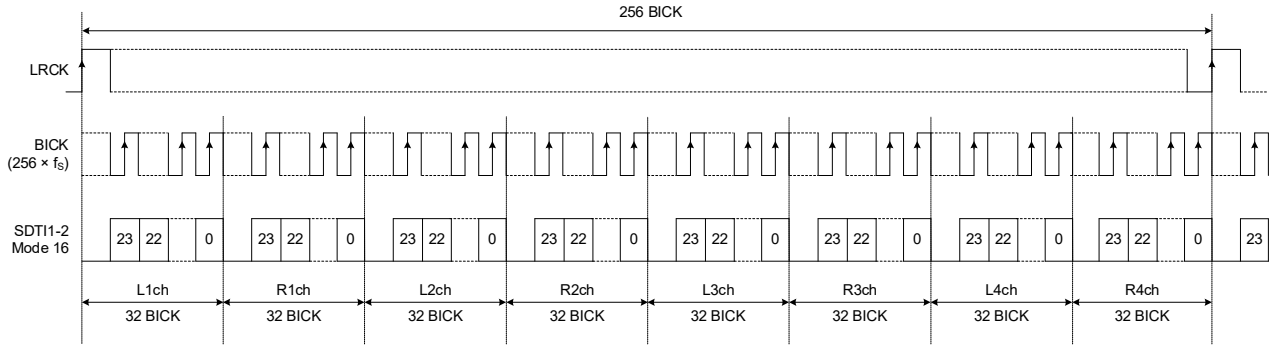


Figure 22. Audio Data Format Timing (Mode 16)

DETAILED DESCRIPTION (continued)

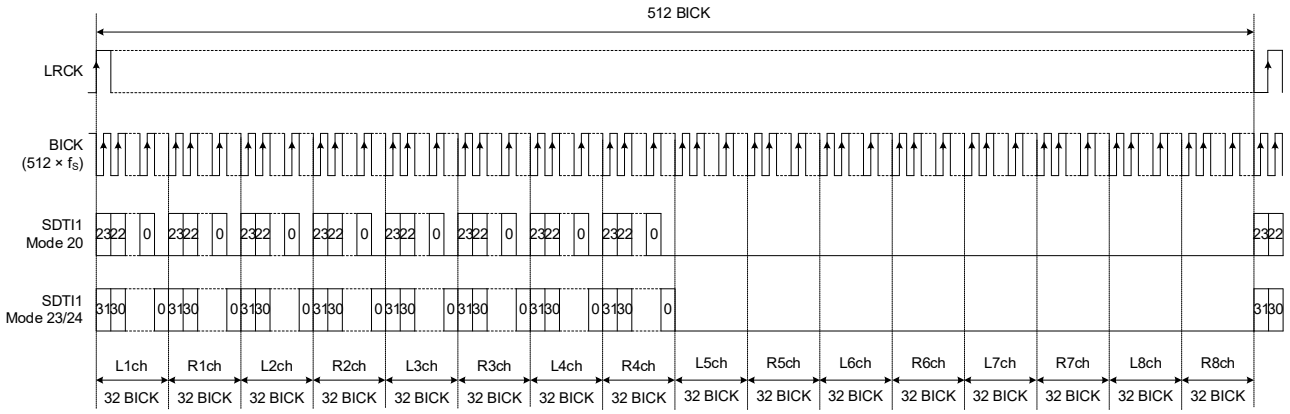


Figure 23. Audio Data Format Timing (Mode 20, 23 and 24)

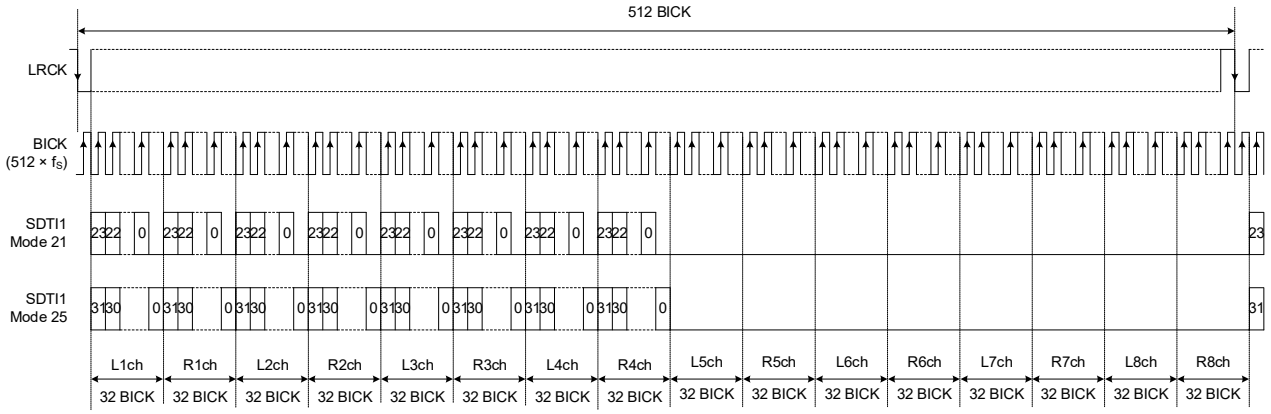


Figure 24. Audio Data Format Timing (Mode 21 and 25)

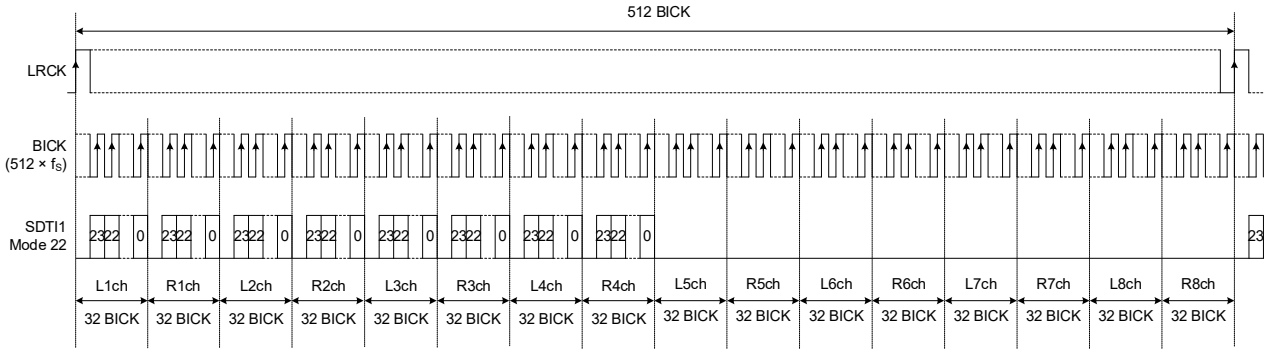


Figure 25. Audio Data Format Timing (Mode 22)

DETAILED DESCRIPTION (continued)

Data Select

The playback channel of each DAC is controlled by SDS[2:0] bits.

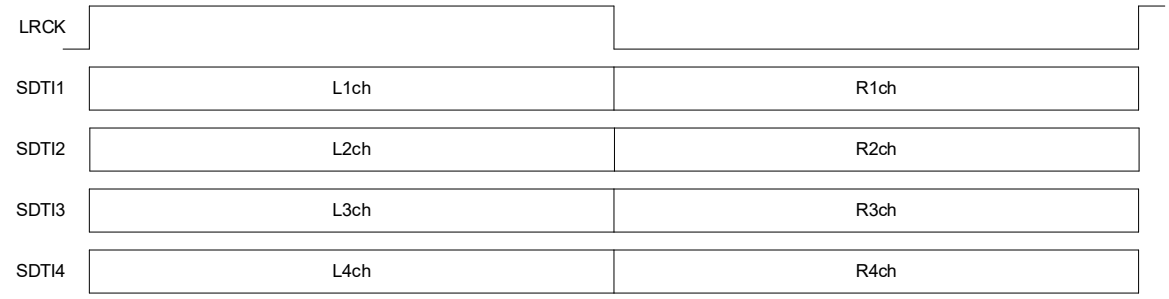


Figure 26. Normal Mode Data Slot

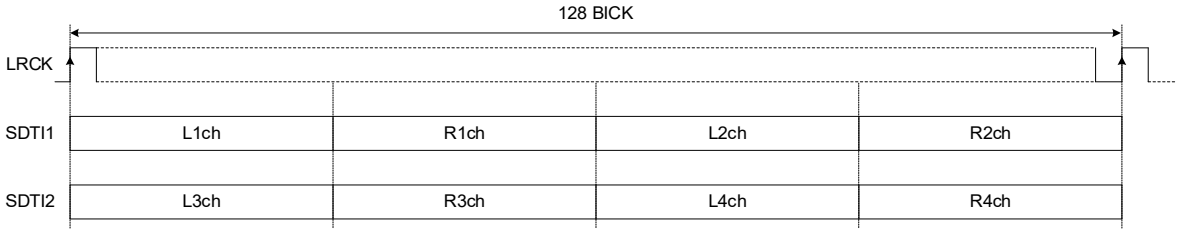


Figure 27. TDM128 Mode Data Slot

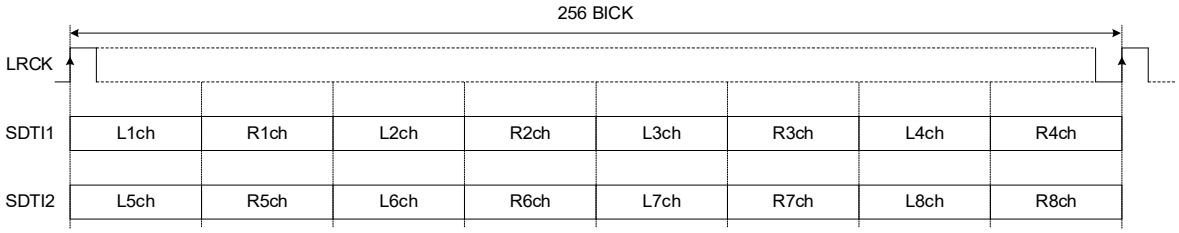


Figure 28. TDM256 Mode Data Slot

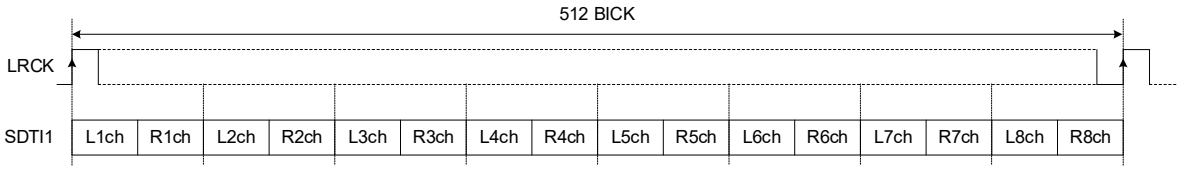


Figure 29. TDM512 Mode Data Slot

DETAILED DESCRIPTION (continued)

Table 5. Data Select (*X* = Don't Care)

Mode	SDS2	SDS1	SDS0	DAC1		DAC2		DAC3		DAC4	
				Lch	Rch	Lch	Rch	Lch	Rch	Lch	Rch
Normal	*X*	0	0	L1ch	R1ch	L2ch	R2ch	L3ch	R3ch	L4ch	R4ch
	X	0	1	L2ch	R2ch	L3ch	R3ch	L4ch	R4ch	L1ch	R1ch
	X	1	0	L3ch	R3ch	L4ch	R4ch	L1ch	R1ch	L2ch	R2ch
	X	1	1	L4ch	R4ch	L1ch	R1ch	L2ch	R2ch	L3ch	R3ch
TDM128	*X*	0	0	L1ch	R1ch	L2ch	R2ch	L3ch	R3ch	L4ch	R4ch
	X	0	1	L2ch	R2ch	L3ch	R3ch	L4ch	R4ch	L1ch	R1ch
	X	1	0	L3ch	R3ch	L4ch	R4ch	L1ch	R1ch	L2ch	R2ch
	X	1	1	L4ch	R4ch	L1ch	R1ch	L2ch	R2ch	L3ch	R3ch
TDM256	0	0	0	L1ch	R1ch	L2ch	R2ch	L3ch	R3ch	L4ch	R4ch
	0	0	1	L2ch	R2ch	L3ch	R3ch	L4ch	R4ch	L5ch	R5ch
	0	1	0	L3ch	R3ch	L4ch	R4ch	L5ch	R5ch	L6ch	R6ch
	0	1	1	L4ch	R4ch	L5ch	R5ch	L6ch	R6ch	L7ch	R7ch
	1	0	0	L5ch	R5ch	L6ch	R6ch	L7ch	R7ch	L8ch	R8ch
	1	0	1	L6ch	R6ch	L7ch	R7ch	L8ch	R8ch	L1ch	R1ch
	1	1	0	L7ch	R7ch	L8ch	R8ch	L1ch	R1ch	L2ch	R2ch
	1	1	1	L8ch	R8ch	L1ch	R1ch	L2ch	R2ch	L3ch	R3ch
TDM512	0	0	0	L1ch	R1ch	L2ch	R2ch	L3ch	R3ch	L4ch	R4ch
	0	0	1	L2ch	R2ch	L3ch	R3ch	L4ch	R4ch	L5ch	R5ch
	0	1	0	L3ch	R3ch	L4ch	R4ch	L5ch	R5ch	L6ch	R6ch
	0	1	1	L4ch	R4ch	L5ch	R5ch	L6ch	R6ch	L7ch	R7ch
	1	0	0	L5ch	R5ch	L6ch	R6ch	L7ch	R7ch	L8ch	R8ch
	1	0	1	L6ch	R6ch	L7ch	R7ch	L8ch	R8ch	L1ch	R1ch
	1	1	0	L7ch	R7ch	L8ch	R8ch	L1ch	R1ch	L2ch	R2ch
	1	1	1	L8ch	R8ch	L1ch	R1ch	L2ch	R2ch	L3ch	R3ch

The SGM56101 incorporates a high-performance mode, which can be activated by adjusting specific combinations of LRCK, BICK and MCLK frequencies in conjunction with the DFS[2:0] bits. In this mode, the THD+N dynamic performance parameters are enhanced. For detailed configuration relationships, please refer to Table 6 below.

Table 6. Detailed Configuration of High-Performance Mode

High-Performance Mode				
Mode	**DFS[2:0] Bits**	**LRCK (kHz)**	**BICK (MHz)**	**MCLK (MHz)**
Normal	001	48	3.072	12.288
TDM128	001	48	6.144	12.288
TDM256	001	48	12.288	12.288
TDM512	001	48	24.576	12.288
Normal	001	96	6.144	12.288
Normal	010	96	6.144	12.288
TDM128	001	96	12.288	12.288
TDM128	010	96	12.288	12.288
TDM256	001	96	24.576	12.288
TDM256	010	96	24.576	12.288

DETAILED DESCRIPTION (continued)

Digital Filter

Three distinct digital filters are offered for playback, offering a diverse range of sound hues to choose from. The selection of these digital filters is determined by the SLOW bit and the SSLOW bit.

Table 7. Digital Filter Setting

SSLOW Bit	SLOW Bit	Mode
0	0	Sharp Roll-Off Filter (Default)
0	1	Slow Roll-Off Filter
1	1	
1	0	Super Slow Roll-Off Mode

Zero Detection

The SGM56101 features channel-independent zero detection. This functionality allows for the selection of zero detection channels, the AOUTL1-4 and AOUTR1-4 pins, through the control 5 and 6 registers (comprising the L1 ~ L4 bits and R1 ~ R4 bits). If the input data remains constantly at zero for 8192 consecutive LRCK cycles in any given channels, the DZF pin will switch to the high state. If the input data of each channel does not reach zero, the DZF pin will promptly revert to the low state. Additionally, when the RSTN bit is set to 0, the DZF pin of both channels will be converted to high. However, when the RSTN bit returns to 1, the DZF pin of both channels will revert to low after approximately 4~5/f_S. Furthermore, the DZFB bit allows for the inversion of the polarity of the DZF pin. It is worth noting that when RSTN bit is set to 1 if all channels are disabled, the outputs of the DZF pin will not be zero.

Table 8. DZF Pin Function

DZFB Bit	DZF Pin	Data
0	Low	Not Zero (1)
0	High	Zero Detect (2)
1	High	Not Zero
1	Low	Zero Detect

NOTES:

1. Not zero: any one of the zero detection channels, which is established by L1 ~ L4 bits and R1 ~ R4 bits, fails to detect zero.

2. Zero detect: one of the zero detection channels configured through the L1 ~ L4 bits and R1 ~ R4 bits successfully detects the presence of zero.

Digital Volume Function

The SGM56101 incorporates a digital attenuator that operates independently of any specific channel, offering 256 distinct attenuation levels with increments of 0.5dB. The attenuation level for each DAC1-4 can be individually configured by using the ATT[7:0] bits located in register 03H, 04H, 0FH to 14H, as outlined in Table 9.

Table 9. Attenuation Level Applied by Digital Attenuator

ATT[7:0] Bits (Register 03H, 04H, 0FH to 14H)	Attenuation Level
FFH	+0dB
FEH	-0.5dB
FDH	-1.0dB
…	…
02H	-126.5dB
01H	-127.0dB
00H	Mute (-∞)

DETAILED DESCRIPTION (continued)

The transition time between the set values of the ATT[7:0] bits can be adjusted using the ATS[1:0] bits, as detailed in Table 10. In modes 0, 1, 2 and 3, the transition between set values is designed as a soft transition, effectively eliminating switching noise during the transition process.

Table 10. Transition Time for Digital Volume Adjustment

Mode	ATS1 Bit	ATS0 Bit	ATT Speed
0	0	0	$4080/f_S$ (Default)
1	0	1	$2040/f_S$
2	1	0	$510/f_S$
3	1	1	$255/f_S$

In mode 0, the transition between set values occurs smoothly, spanning 4080 distinct levels. Completing the transition from FFH to 00H requires a duration of $4080/f_S$, which translates to approximately 85ms when the sampling frequency (f_S) is set to 48kHz. Additionally, if the PDN pin is set to low, the ATT[7:0] bits will automatically reset to FFH.

If a change is made to the digital volume while the reset is active, the volume will revert to the newly set value once the reset is released. If the volume is modified within $5/f_S$ of the reset being lifted, the change will occur immediately without undergoing a soft transition.

LR Channel Output Signal Select

The SGM56101s input and output signal combinations can be configured by using the MONO[3:0] and SELLR[3:0] bits. Additionally, the phase of the DAC output signal can be controlled through the INVL[3:0] and INVR[3:0] bits. These settings are compatible with all audio formats supported by the SGM56101.

Table 11. Selection of Output for DAC1

MONO1 Bit	SELLR1 Bit	INVL1 Bit	INVR1 Bit	L1ch Output	R1ch Output
0	0	0	0	L1ch Input	R1ch Input
		1	0	L1ch Input Invert	R1ch Input
		0	1	L1ch Input	R1ch Input Invert
		1	1	L1ch Input Invert	R1ch Input Invert
0	1	0	0	R1ch Input	L1ch Input
		1	0	R1ch Input Invert	L1ch Input
		0	1	R1ch Input	L1ch Input Invert
		1	1	R1ch Input Invert	L1ch Input Invert
1	0	0	0	L1ch Input	L1ch Input
		1	0	L1ch Input Invert	L1ch Input
		0	1	L1ch Input	L1ch Input Invert
		1	1	L1ch Input Invert	L1ch Input Invert
1	1	0	0	R1ch Input	R1ch Input
		1	0	R1ch Input Invert	R1ch Input
		0	1	R1ch Input	R1ch Input Invert
		1	1	R1ch Input Invert	R1ch Input Invert

DETAILED DESCRIPTION (continued)

Table 12. Selection of Output for DAC2

MONO2 Bit	SELLR2 Bit	INVL2 Bit	INVR2 Bit	L2ch Output	R2ch Output
0	0	0	0	L2ch Input	R2ch Input
		1	0	L2ch Input Invert	R2ch Input
		0	1	L2ch Input	R2ch Input Invert
		1	1	L2ch Input Invert	R2ch Input Invert
0	1	0	0	R2ch Input	L2ch Input
		1	0	R2ch Input Invert	L2ch Input
		0	1	R2ch Input	L2ch Input Invert
		1	1	R2ch Input Invert	L2ch Input Invert
1	0	0	0	L2ch Input	L2ch Input
		1	0	L2ch Input Invert	L2ch Input
		0	1	L2ch Input	L2ch Input Invert
		1	1	L2ch Input Invert	L2ch Input Invert
1	1	0	0	R2ch Input	R2ch Input
		1	0	R2ch Input Invert	R2ch Input
		0	1	R2ch Input	R2ch Input Invert
		1	1	R2ch Input Invert	R2ch Input Invert

Table 13. Selection of Output for DAC3

MONO3 Bit	SELLR3 Bit	INVL3 Bit	INVR3 Bit	L3ch Output	R3ch Output
0	0	0	0	L3ch Input	R3ch Input
		1	0	L3ch Input Invert	R3ch Input
		0	1	L3ch Input	R3ch Input Invert
		1	1	L3ch Input Invert	R3ch Input Invert
0	1	0	0	R3ch Input	L3ch Input
		1	0	R3ch Input Invert	L3ch Input
		0	1	R3ch Input	L3ch Input Invert
		1	1	R3ch Input Invert	L3ch Input Invert
1	0	0	0	L3ch Input	L3ch Input
		1	0	L3ch Input Invert	L3ch Input
		0	1	L3ch Input	L3ch Input Invert
		1	1	L3ch Input Invert	L3ch Input Invert
1	1	0	0	R3ch Input	R3ch Input
		1	0	R3ch Input Invert	R3ch Input
		0	1	R3ch Input	R3ch Input Invert
		1	1	R3ch Input Invert	R3ch Input Invert

DETAILED DESCRIPTION (continued)

Table 14. Selection of Output for DAC4

MONO4 Bit	SELLR4 Bit	INVL4 Bit	INVR4 Bit	L4ch Output	R4ch Output
0	0	0	0	L4ch Input	R4ch Input
		1	0	L4ch Input Invert	R4ch Input
		0	1	L4ch Input	R4ch Input Invert
		1	1	L4ch Input Invert	R4ch Input Invert
0	1	0	0	R4ch Input	L4ch Input
		1	0	R4ch Input Invert	L4ch Input
		0	1	R4ch Input	L4ch Input Invert
		1	1	R4ch Input Invert	L4ch Input Invert
1	0	0	0	L4ch Input	L4ch Input
		1	0	L4ch Input Invert	L4ch Input
		0	1	L4ch Input	L4ch Input Invert
		1	1	L4ch Input Invert	L4ch Input Invert
1	1	0	0	R4ch Input	R4ch Input
		1	0	R4ch Input Invert	R4ch Input
		0	1	R4ch Input	R4ch Input Invert
		1	1	R4ch Input Invert	R4ch Input Invert

LDO Protection Function

The SGM56101 integrates an LDO internally, which provides separate clean power supply to key modules inside the chip. This LDO supports over-current protection (OCP) function, which is a current limiting type. The typical OCP threshold value is 80mA. When the LDO load current exceeds the OCP threshold, the OCP circuit will forcibly clamp the output current to 80mA. If the load continues to increase at this time, the LDO output current will still remain at around 80mA, but the LDO output voltage (LDOO) will continue to decrease until it reaches 0. The typical LDOO value is 1.85V. Once the chip malfunctions, it is recommended that users first check whether LDOO voltage is normal. If the LDOO voltage is found to be below 1.5V or above 2.2V, it is recommended to restart the chip through the PDN pin. Note that in principle, the LDO only supplies power to the internal circuits of SGM56101 and does not supply power to board level devices.

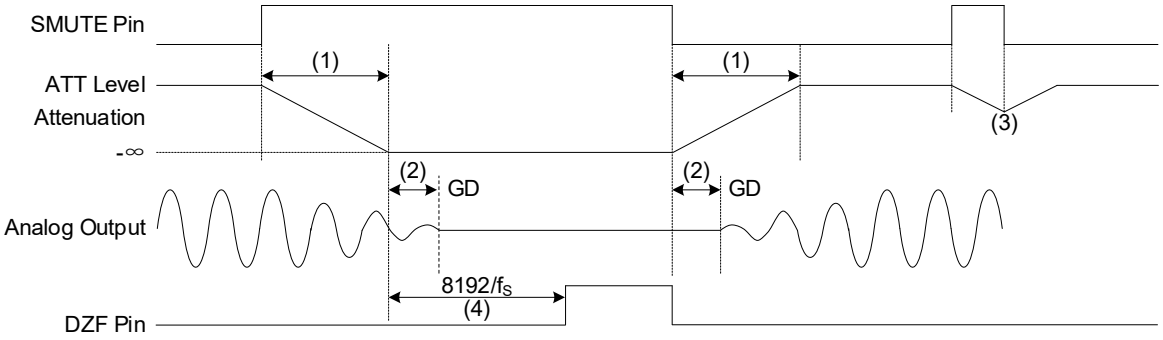
Table 15. LDO Fault Detection

LDO Fault Type	LDO Fault Conditions
LDO Over-Current Threshold	LDO Output Current: 80mA (TYP)
LDO Under-Voltage Threshold	LDO Output Voltage: 1.5V (TYP)
LDO Over-Voltage Threshold	LDO Output Voltage: 2.2V (TYP)

DETAILED DESCRIPTION (continued)

Soft Mute Operation

The soft mute function operates exclusively within the digital domain. The SMUTE pin is responsible for controlling the soft mute operation, as depicted in Figure 30. Whenever the SMUTE pin is set to high or the SMUTE bit is configured as 1, the output signal experiences an attenuation of negative infinity during the ATT_DATA × ATT transition period, commencing from the current ATT level. When the SMUTE pin is brought back to low or the SMUTE bit is reset to 0, and the output attenuation gradually turns back to the ATT level over the same ATT_DATA × ATT transition time. When the soft mute is scrapped before the attenuation reaches negative infinity, the attenuation process halts immediately, and the signal returns to the ATT level within the same ATT_DATA × ATT transition time cycle. The soft mute gains profits when it comes to switching signal sources without interrupting the signal transmission, as it ensures a smooth transition with minimal audio disruption.



NOTES:

1. The transition time for ATT_DATA × ATT is determined by the specific value of ATT_DATA. For instance, when ATT_DATA is set to 255 in the normal speed mode, the transition time spans 4080 LRCK cycles.

2. Each digital input corresponds to an analog output that exhibits a certain group delay (GD).

3. If the soft mute function is deactivated prior to attaining the negative infinity attenuation level after initiating the operation, the attenuation process will be aborted, and the volume will revert to the previous ATT level within the same transition cycle.

4. If the input data for the zero detection channel remains constantly zeros for a duration of 8192 LRCK cycles, the DZF pin transitions to the high state. If the input data ceases to be zero, the DZF pin promptly returns to the low state.

Figure 30. Function for Soft Mute and Detection of Zero Signal

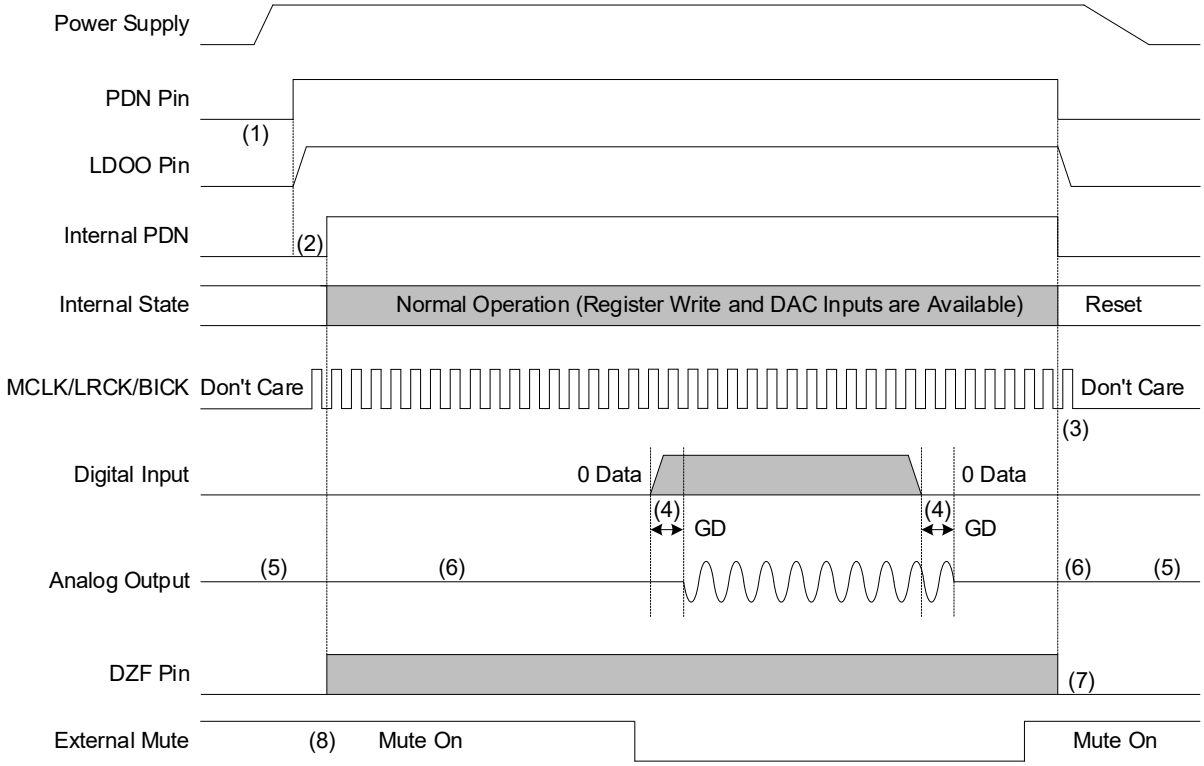
System Reset

Upon power-up, the SGM56101 should be initially reset by setting the PDN pin to low. This reset ensures that the device starts in a known and consistent state. The PDN pin must be set to high to deactivate the power-down state of the reference voltages, including LDO and VCOM. The settings will take effect within 1ms after the power-down state is lifted. The SGM56101 remains in a power-down state until both the MCLK (master clock) and LRCK (left/right clock) inputs are present and active. This ensures that the device does not commence operation until the necessary clock signals are available and stable, preventing potential issues due to incomplete or unstable initialization.

DETAILED DESCRIPTION (continued)

Power-Down Function

When the PDN pin of the SGM56101 is set to low, the device enters power-down mode, resulting in the analog outputs entering a floating (Hi-Z) state. The specific timings for both power-up and power-down operations are detailed in Figure 31.



NOTES:

1. After AVDD and TVDD have been successfully powered up, it is recommended to maintain the PDN pin at low for a duration of 800ns to ensure a stable and reliable transition into the operational state of the device.

2. Once the PDN pin is set to high, the internal LDO and VCOM will activate, initiating the power-up process. Subsequently, the internal registers will undergo initialization. Once the PDN pin is set to high, register writing becomes available within 1ms. This brief delay ensures that the SGM56101 has stabilized and is ready to accept configuration and control commands through its registers. During this period, the device performs internal initialization procedures necessary for proper operation.

3. The MCLK, BICK and LRCK clocks can be deactivated in the power-down mode (when the PDN pin is set to low).

4. Each digital input corresponds to an analog output that exhibits a certain group delay (GD).

5. During the power-down mode, the analog outputs enter a floating state (Hi-Z).

6. When the PDN signal experiences an edge transition, click noise may occur. This noise regardless of whether 0 data is input.

7. In the internal power-down mode, the DZF output pin is low.

8. In the case that click noise 5 has an impact on system performance, external analog outputs are recommended to be muted. Figure 31 refers to the timing example.

Figure 31. Example of Pin Power-Up and Power-Down Sequence

DETAILED DESCRIPTION (continued)

Power-Off and Reset Functions

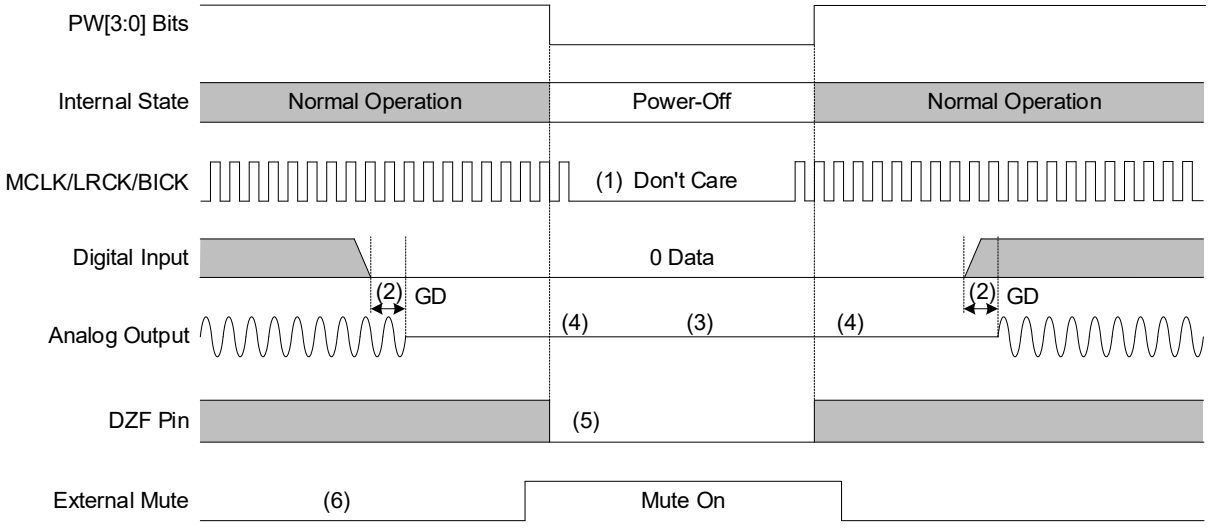
Table 16. Power-Off and Reset Functions

RSTN Bit	PW[3:0] Bits (PW4, PW3, PW2, PW1)	Analog Output			
		DAC4	DAC3	DAC2	DAC1
0	0000	Hi-Z	Hi-Z	Hi-Z	Hi-Z
0	0001	Hi-Z	Hi-Z	Hi-Z	VCOM
0	0010	Hi-Z	Hi-Z	VCOM	Hi-Z
0	0011	Hi-Z	Hi-Z	VCOM	VCOM
0	0100	Hi-Z	VCOM	Hi-Z	Hi-Z
0	0101	Hi-Z	VCOM	Hi-Z	VCOM
0	0110	Hi-Z	VCOM	VCOM	Hi-Z
0	0111	Hi-Z	VCOM	VCOM	VCOM
0	1000	VCOM	Hi-Z	Hi-Z	Hi-Z
0	1001	VCOM	Hi-Z	Hi-Z	VCOM
0	1010	VCOM	Hi-Z	VCOM	Hi-Z
0	1011	VCOM	Hi-Z	VCOM	VCOM
0	1100	VCOM	VCOM	Hi-Z	Hi-Z
0	1101	VCOM	VCOM	Hi-Z	VCOM
0	1110	VCOM	VCOM	VCOM	Hi-Z
0	1111	VCOM	VCOM	VCOM	VCOM
1	0000	Hi-Z	Hi-Z	Hi-Z	Hi-Z
1	0001	Hi-Z	Hi-Z	Hi-Z	Normal
1	0010	Hi-Z	Hi-Z	Normal	Hi-Z
1	0011	Hi-Z	Hi-Z	Normal	Normal
1	0100	Hi-Z	Normal	Hi-Z	Hi-Z
1	0101	Hi-Z	Normal	Hi-Z	Normal
1	0110	Hi-Z	Normal	Normal	Hi-Z
1	0111	Hi-Z	Normal	Normal	Normal
1	1000	Normal	Hi-Z	Hi-Z	Hi-Z
1	1001	Normal	Hi-Z	Hi-Z	Normal
1	1010	Normal	Hi-Z	Normal	Hi-Z
1	1011	Normal	Hi-Z	Normal	Normal
1	1100	Normal	Normal	Hi-Z	Hi-Z
1	1101	Normal	Normal	Hi-Z	Normal
1	1110	Normal	Normal	Normal	Hi-Z
1	1111	Normal	Normal	Normal	Normal

DETAILED DESCRIPTION (continued)

Power-Off Function (PW[3:0] Bits: PW4, PW3, PW2, PW1)

All DAC1-4 can be immediately powered down by configuring the PW[3:0] bits to 0000. During the internal power-down mode, the transition of analog outputs gets into a floating state (Hi-Z). Additionally, the DACs are reset, and the digital block is powered down by configuring the RSTN bit to 0. In the reset state, when the DAC is energized and the necessary clock signals (MCLK, LRCK and BICK) are provided, the analog outputs reach the VCOM voltage level (Table 16). It is important to note that setting the PW[3:0] bits does not initialize the internal register values, but only controls the power state of the DACs. Figure 32 exhibits a sample timing diagram depicting the process of powering on and powering down the device.



NOTES:

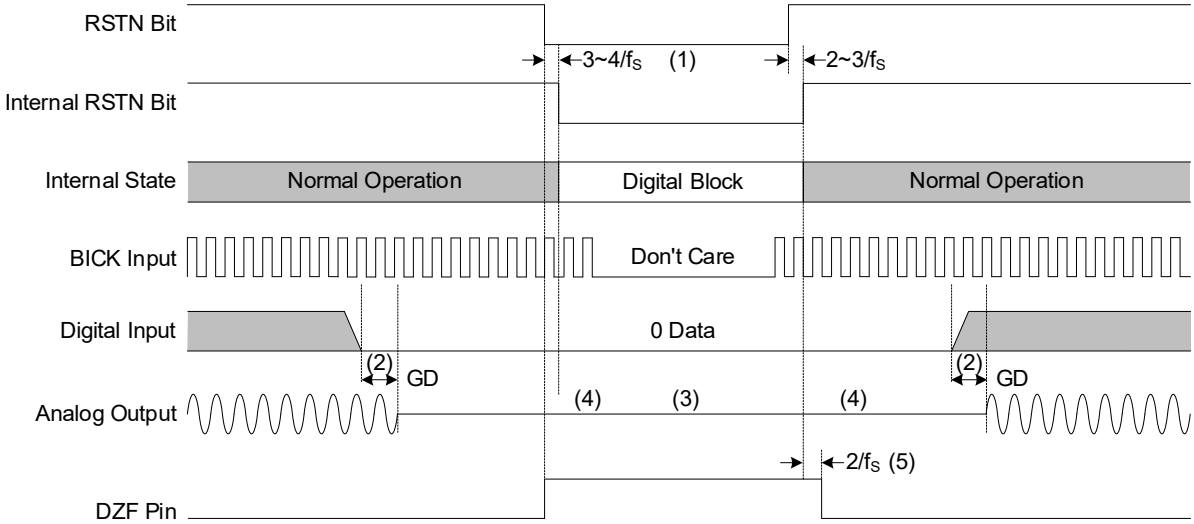
1. The MCLK, BICK and LRCK clocks can be deactivated in the power-down mode (PW[3:0] bits = 0000).
2. Each digital input corresponds to an analog output that exhibits a certain group delay (GD).
3. During the power-down mode, the analog outputs enter a floating state (Hi-Z).
4. The rising and falling edges of the internal clock timing for the PW[3:0] bits produce click noise, regardless of whether 0 data is inputted or not.
5. In the internal power-down mode, the DZF pin output is low (PW[3:0] bits = 0000).
6. In the case that click noise has a negative impact on system performance, external analog outputs are recommended to be muted.

Figure 32. Example of Pin Power-On and Power-Off Sequence

DETAILED DESCRIPTION (continued)

Reset Function (RSTN Bit)

The DAC can be reset by setting RSTN bit to 0 but this action does not automatically revert the internal registers to their default settings. During this period, the DZF pin will emit high signal whenever clocks (MCLK, BICK and LRCK) are received as inputs. As an illustration, Figure 33 depicts a sample reset sequence triggered by the RSTN bit.



NOTES:

1. There is a delay of 3~4/f_S from when the RSTN bit transitions to 0 until the internal RSTN bit also reaches 0. Similarly, there is a delay of 2~3/f_S from when the RSTN bit transitions to 1 until the internal RSTN bit reaches 1.

2. Each digital input corresponds to an analog output that exhibits a certain group delay (GD).

3. During the power-down mode, the analog outputs VCOM voltage.

4. The rising and falling edges of the internal clock timing for the PW[3:0] bits produce click noise, regardless of whether 0 data is inputted or not.

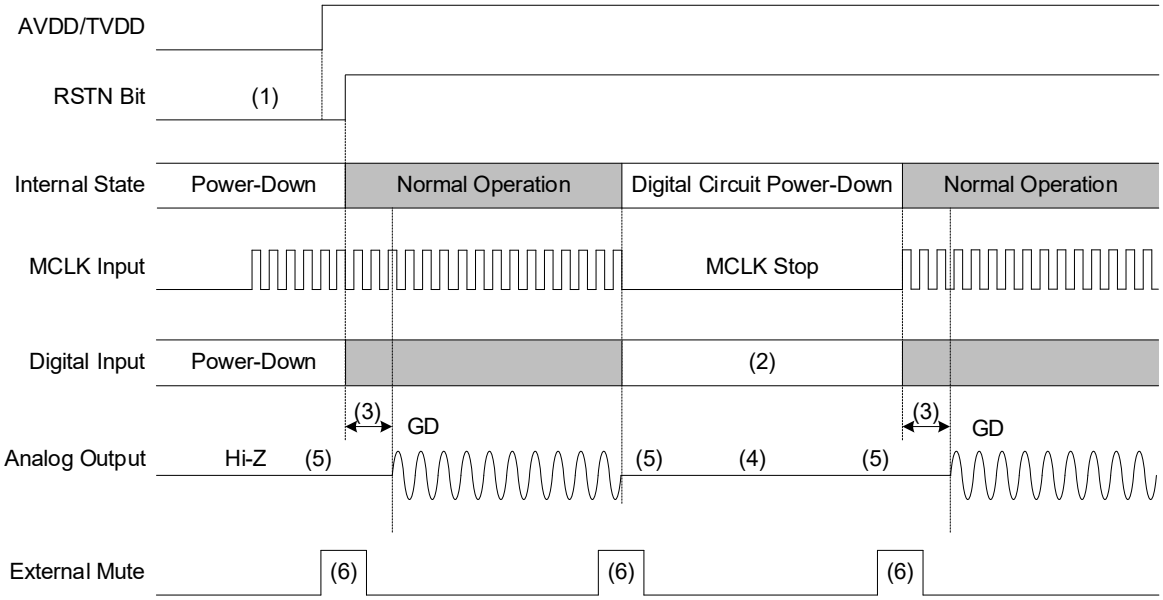
5. When the RSTN bit transitions from high to low, the DZF pin changes its state to high. Subsequently, after the internal RSTN experiences a rising edge, the DZF pin transitions to low after a duration of 2/f_S.

Figure 33. Example of Reset Sequence

DETAILED DESCRIPTION (continued)

Reset Function (MCLK)

The SGM56101 automatically enters a reset state when the MCLK is halted during normal operation, provided that the PDN pin is set to high. Under such conditions, the analog outputs transition to VCOM voltage. When the MCLK (master clock) is re-input, the SGM56101 exits the reset state and resumes its operational functions. When MCLK is stopped, zero detect function is disabled.



NOTES:

1. After AVDD and TVDD have been successfully powered up, it is recommended to maintain the PDN pin at low for a duration of 800ns to ensure a stable and reliable transition into the operational state of the device.

2. Data of digital inputs can be stopped. Inputting 0 data during the pause period can effectively mitigate the click noise that would otherwise occur upon the subsequent resumption of the MCLK input.

3. Each digital input corresponds to an analog output that exhibits a certain group delay (GD).

4. When the MCLK signal is paused, the analog outputs VCOM voltage.

5. Click noise emerges within a duration of 3 to 4 LRCK cycles, commencing from the rising edge of the PDN pin or MCLK input. It is worth noting that this noise still exists when the input data is 0.

6. In the case that click noise has a negative impact on system performance, external analog outputs are recommended to be muted. Figure 34 exhibits the sample timing diagram.

Figure 34. Example of Reset Sequence 2

Parallel Mode

By configuring the I2C pin to high and the PS pin to high, the parallel mode becomes accessible. In this operational mode, the register settings are disregarded. Instead, the audio interface format and soft mute function are directly controlled through designated pins. As for other functionalities, they operate according to the default settings programmed within the registers. The system clock is always set to operate in auto-setting mode in parallel mode.

Audio Interface

In parallel mode, the audio interface format is exclusively controlled by the TDM0, TDM1 and DIF pins (Table 17). In parallel mode, both the zero detection function and the functionalities configured through registers are not operational. This means that in parallel mode, the audio interface format is determined solely by physical pins, while other advanced features offered by register settings are unavailable.

DETAILED DESCRIPTION (continued)

Table 17. Parallel Mode

Pin			Mode
TDM1	TDM0	DIF	
0	0	0	Mode 6
0	0	1	Mode 7
0	1	0	Mode 12
0	1	1	Mode 13
1	0	0	Mode 18
1	0	1	Mode 19
1	1	0	Mode 24
1	1	1	Mode 25

Serial Control Interface

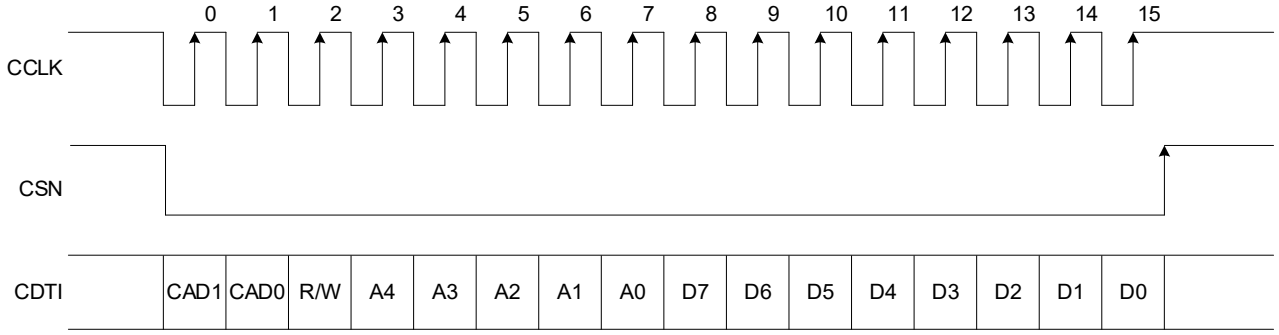
The functions of SGM56101 are managed through registers, which can be programmed by using two types of control modes. In the 3-wire serial control mode, the internal registers are regulated when the I2C pin is set to low and the PS pin is also set to low. Alternatively, when the I2C pin is set to high and the PS pin remains at low, the registers are controlled in the I^2C-bus control mode. CAD0 and CAD1 pins can determine the chip address.

To initialize the internal registers, simply set the PDN pin to low. When the RSTN bit is set to 0, the internal timing circuit undergoes a reset. However, it is important to note that this action does not initialize the register values. The registers retain their previous settings, and only the timing circuit is affected by this reset operation. When the PDN pin is at low, writing to the registers is not possible.

3-Wire Serial Control Mode (I2C Pin = Low)

Utilizing the 3-wire control interface pins of CCLK, CSN and CDTI, the internal registers can be written. The data transmitted over this interface consists of a 2-bit chip address, a fixed 1-bit read/write flag set exclusively for writing, a register address (starting with the MSB, spanning 5 bits), and control data (also starting with the MSB, totaling 8 bits). Data is latched once CSN transitions from low to high. The input of both the address and data occurs on the rising edge of CCLK, while data output happens on the falling edge. The highest clock frequency of CCLK is 5MHz, which determines the upper limit for the rate of data transfer.

To initialize the internal registers, the PDN pin must be set to low. In serial mode, the internal timing circuit can be reset by assigning the RSTN bit a value of 0, but register values are not initialized.



NOTES:

1. CAD1, CAD0: chip slave address
2. R/W: read/write (write only, fix to 1)
3. A4 to A0: register address
4. D7 to D0: control data

Figure 35. Command of 3-Wire Serial Control Timing

DETAILED DESCRIPTION (continued)

I²C Serial Interface and Data Communication

Standard I²C interface is used to program SGM56101 parameters and get status reports. I²C is well-known 2-wire serial communication interface that can connect one (or more) master device(s) to some slave devices for two-way communication. The bus lines are named serial data (SDA) and serial clock (SCL). The device that initiates a data transfer is a master. A master generates the SCL signal. Slave devices have unique addresses to identify. A master is typically a micro controller or a digital signal processor.

The SGM56101 operates as a slave device that address is 0x20. It has twenty-one 8-bit registers, numbered from REG0x00 to REG0x14.

Physical Layer

The standard I²C interface of SGM56101 supports standard mode and fast mode communication speeds. The frequency of stand mode is up to 100kHz, while the fast mode is up to 400kHz. Bus lines are pulled high by weak current source or pull-up resistors and in logic high state with no clocking when the bus is free. The SDA and SCL pins are open-drain.

I²C Data Communication

START and STOP Conditions

A transaction is started by taking control of the bus by master if the bus is free. The transaction is terminated by releasing the bus when the data transfer job is done as shown in Figure 36. All transactions begin by the master which applies a START condition on the bus lines to take over the bus and exchange data. At the end, the master terminates the transaction by applying one (or more) STOP condition. START condition is defined when SCL is high and a high-to-low transition on the SDA is generated by master. Similarly, a STOP is defined when SCL is high and SDA goes from low to high. START and STOP are always generated by a master. After a START and before a STOP the bus is considered busy.

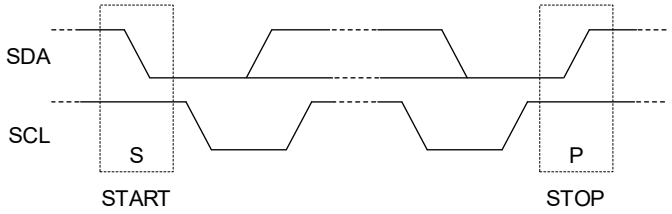


Figure 36. I²C Bus in START and STOP Conditions

Data Bit Transmission and Validity

The data bit (high or low) must remain stable during clock high period. The state of SDA can only change when SCL is low. For each data bit transmission, one clock pulse is generated by master. Bit transfer in I²C is shown in Figure 37.

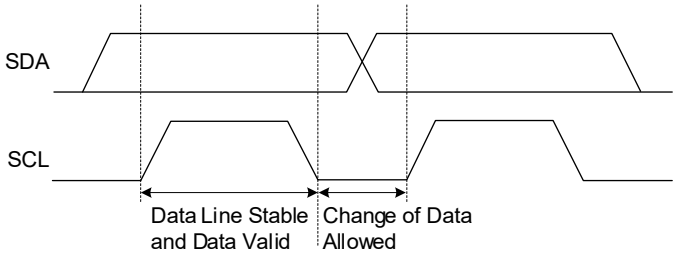


Figure 37. I²C Bus Bit Transfer

Byte Format

Data is transmitted in 8-bit packets (one byte at a time). The number of bytes in one transaction is not limited. In each packet, the 8 bits are sent successively with the most significant bit (MSB) first. An acknowledge (or not-acknowledge) bit must come after the 8 data bits. This bit informs the transmitter whether the receiver is ready to proceed for the next byte or not. If the slave is busy and cannot transfer another byte of data, it can hold the SCL line low and keep the master in a wait state (called clock stretching). When the slave is ready for another byte of data, it releases the clock line and data transfer can continue with clocks generated by master. Figure 37 shows the byte transfer process with I²C interface.

DETAILED DESCRIPTION (continued)

Acknowledge (ACK) and Not Acknowledge (NCK)

After transmission of each byte by transmitter, an acknowledge bit is replied by the receiver as the ninth bit. With the acknowledge bit, the receiver informs the transmitter that the byte is received, and another byte is expected or can be sent (ACK) or it is not expected (NCK = not ACK). Clock (SCL) is always generated by master, including the acknowledge clock pulse, no matter who is acting as transmitter or receiver. SDA line is released for receiver control during the acknowledge clock pulse. And the receiver can pull the SDA line low as ACK (reply a 0 bit) or let it be high as NCK during the SCL high pulse. After that, the master can either apply a STOP (P) condition to end the transaction or send a new START (S) condition to start a new transfer (called repeated start). For example, when master wants to read a register in slave, one start is needed to send the slave address and register address, and then, without a STOP condition, another start is sent by master to initiate the receiving transaction from slave. Master then sends the STOP condition and releases the bus.

I^2C-Bus Control Mode (I2C Pin = High)

The SGM56101 supports the fast mode I^2C-bus (maximum: 400kHz).

Write Operations

Figure 38 shows the data transfer sequence of the I^2C-bus mode. The first byte sent by master after the START is always the target slave address (7 bits) and an eighth data-direction bit (R/W). R/W bit is 0 for a write transaction and 1 for read (when master is asking for data). Data direction is the same for all next bytes of the transaction. To reverse it, a new START or repeated START condition must be sent by master (STOP will end the transaction).

After the START condition, the first byte (Figure 38) consists of the chip slave address of the SGM56101. The address consists of 7 bits followed by an eighth bit designated as the data direction bit (R/W). The five most significant bits of the slave address are permanently set to 00100. The subsequent bits, CAD[1:0] serve as device address bits, uniquely identifying a specific device on the bus. These device address bits are configured through dedicated hard-wired input pins (CAD1, CAD0) as shown in Figure 39. When the slave address matches the address of the SGM56101, the device generates an acknowledgement, initiating the execution of the corresponding operation. The master to generate the acknowledge-related clock pulse and release the SDA line to a high state during the acknowledge clock pulse, as illustrated in Figure 38. An R/W bit value of 1 signifies the execution of a read operation, while a value of 0 indicates a write operation.

The second byte comprises the control register address to the SGM56101. This format follows the rule of MSB first, and the most significant 3 bits are fixed to zeros (Figure 40).

The subsequent data, following the second byte, consists of control data in the format of MSB first, 8 bits (Figure 41). The SGM56101 generates an acknowledgement upon receiving each byte. The data transfer process is always concluded with a STOP condition initiated by the master. This STOP condition is defined by a low-to-high transition on the SDA line while SCL remains high (Figure 37).

The SGM56101 is capable of executing multiple byte write operations within a single sequence. Upon receiving the third byte, the SGM56101 generates an acknowledgment signal, indicating successful receipt, and subsequently waits for the next data to be transmitted. The master can continue to send additional bytes rather than terminate the write cycle after transmitting the first data byte. As each data packet is received, the internal address counter automatically increments by one, ensuring that the next data is stored in the consecutive address. If the address surpasses 14H before a stop condition is triggered, the address counter resets to 00H, leading to the overwriting of previous data. Therefore, it is essential to manage the data flow and stop condition carefully to avoid data error. It is worth noting that the R4ch ATT register cannot be written to individually. Instead, it must be written through a multi-byte write operation to ensure proper functionality.

During the high state period of the clock, the data on the SDA line must maintain stability. The state of the data line, whether high or low, can only be altered when the clock signal on the SCL line is in its low state, with exceptions being the START and STOP conditions (Figure 36).

DETAILED DESCRIPTION (continued)

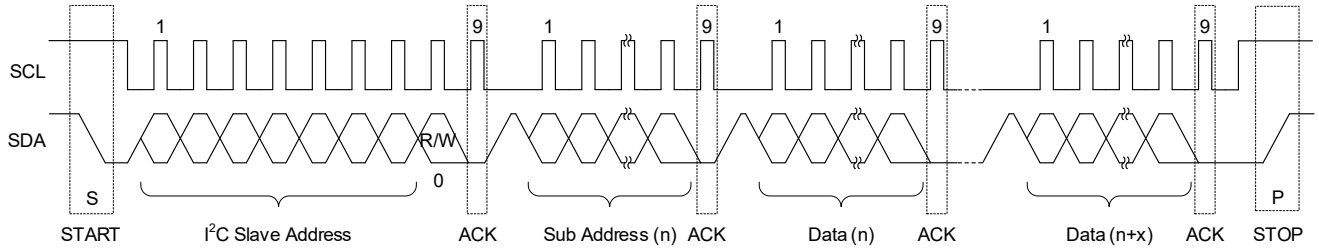


Figure 38. Data Transfer Sequence at the I²C-Bus Mode (Write)

0	0	1	0	0	CAD1	CAD0	R/W

NOTE: CAD1 and CAD0 can be controlled by pin settings.

Figure 39. Chip Slave Address

0	0	0	A4	A3	A2	A1	A0

Figure 40. Sub Address

D7	D6	D5	D4	D3	D2	D1	D0

Figure 41. Byte Data after the Sub Address

Read Operations

To initiate a read operation for the SGM56101, the R/W bit should be set to 1. The master can acknowledge receipt and initiate a read operation for the subsequent address after successfully transmitting data, instead of concluding the write cycle upon receiving the first data word. When each data packet is received, the internal address counter automatically increments by one, and the next data automatically enters the next address. If the address exceeds 14H before the stop condition is generated, the address counter will reset to 00H, resulting in the reading of data from address 00H. The SGM56101 can allow two fundamental read operations, namely current address read and random address read.

The SGM56101 incorporates an internal address counter that keeps track of the address of the last accessed word and automatically increments it by one. Consequently, the subsequent read operation for the current address would retrieve data from address n + 1, assuming the previous access (read or write) was directed to address. Once the SGM56101 receives the slave address with the R/W bit set to 1, the SGM56101 generates an acknowledgement, transmits a single byte of data from the address designated by the internal address counter, and then increments the internal address counter by 1. If the master does not generate an acknowledgement but instead triggers a stop condition, the SGM56101 will halt its transmission process.

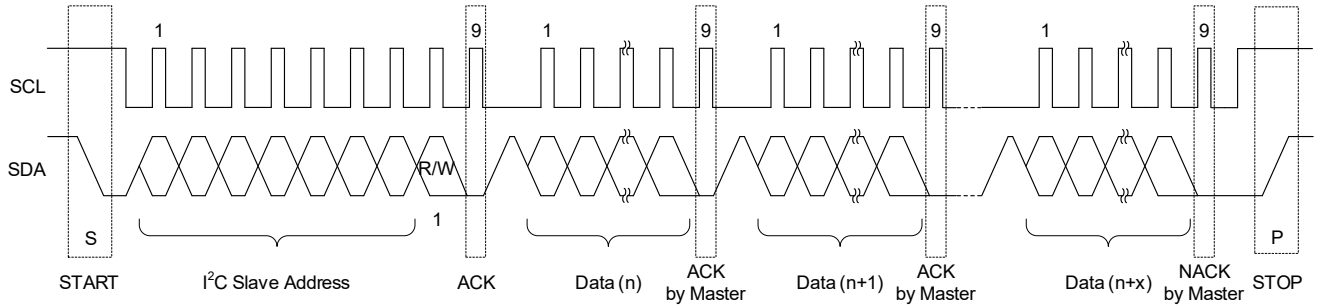


Figure 42. Data Transfer Sequence at the I²C-Bus Mode (Current Address Read)

DETAILED DESCRIPTION (continued)

The random read operation enables the master to randomly access any memory location. Before initializing a slave address and setting the R/W bit to 1, the master must implement the operation of virtual write. This involves the master sending a start request, followed by the slave address with the R/W bit set to 0, and subsequently the desired register address for reading. Once the register address is acknowledged, the master promptly repeats the start request and transmits the slave address with the R/W bit set to 1. Upon receiving this sequence, the SGM56101 responds an acknowledgement by transmitting a single byte of data from the specified address, and incrementing the internal address counter by one. If the master opts not to generate an acknowledgement but instead triggers a stop condition, the SGM56101 will halt its transmission, as previously mentioned.

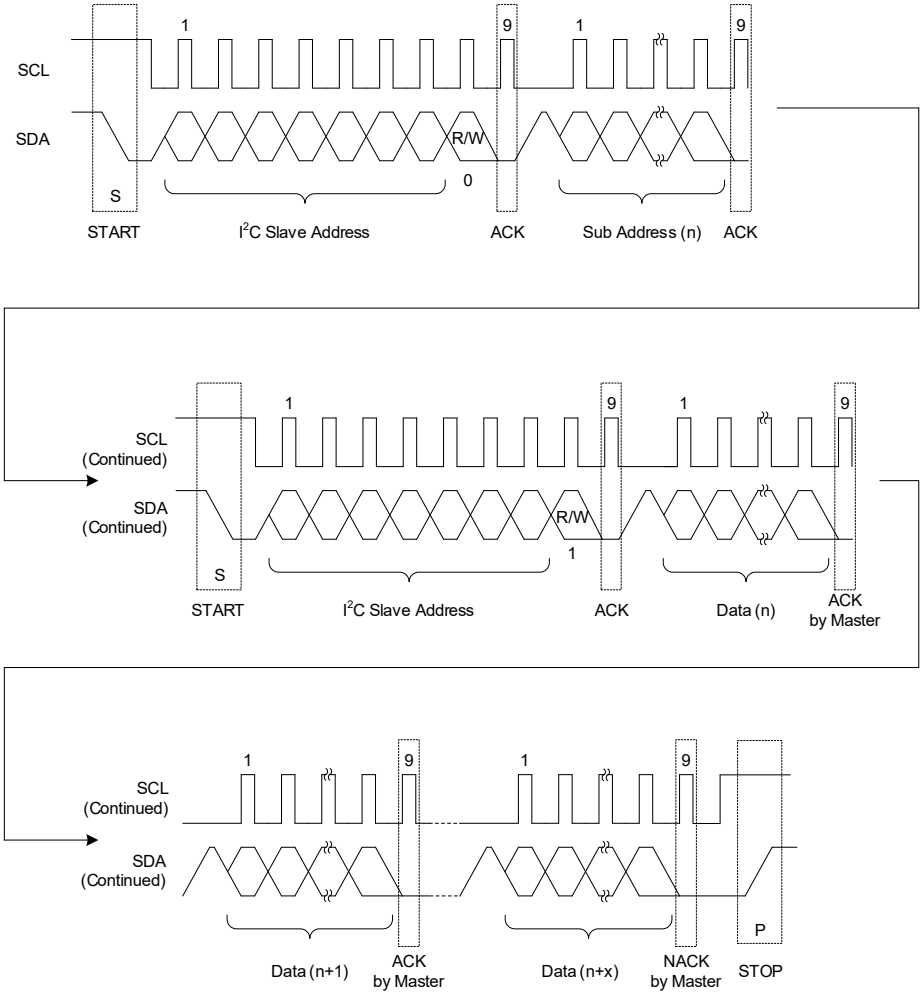


Figure 43. Data Transfer Sequence at the I²C-Bus Mode (Random Address Read)

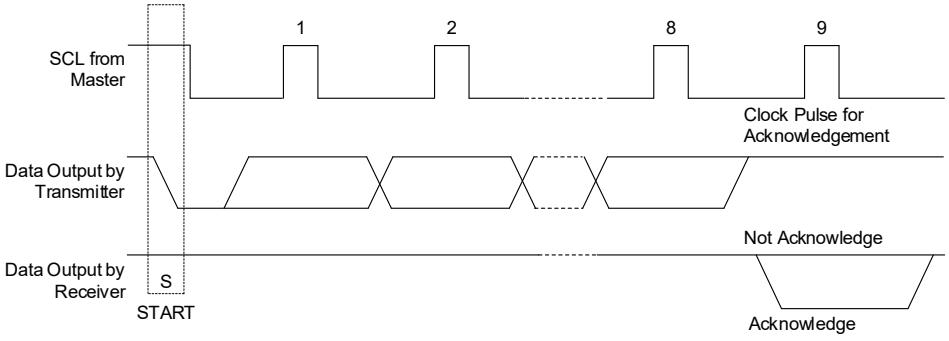


Figure 44. Acknowledge on the I²C-Bus Mode

REGISTER MAPS

All registers are 8-bit and individual bits are named from D[0] (LSB) to D[7] (MSB).

Bit Types:
R/W: Read/Write

I²C Register Address Map

Address	Register Name	D[7]	D[6]	D[5]	D[4]	D[3]	D[2]	D[1]	D[0]
00H	Control 1	0	0	0	0	DIF2	DIF1	DIF0	RSTN
01H	Control 2	0	0	1	DFS1	DFS0	DEM11	DEM10	SMUTE
02H	Control 3	0	0	0	0	MONO1	DZFB	SELLR1	SLOW
03H	L1ch ATT	ATT7	ATT6	ATT5	ATT4	ATT3	ATT2	ATT1	ATT0
04H	R1ch ATT	ATT7	ATT6	ATT5	ATT4	ATT3	ATT2	ATT1	ATT0
05H	Control 4	INVL1	INVR1	INVL2	INVR2	SELLR2	0	DFS2	SSLOW
06H	Reserved	–	–	–	–	–	–	–	–
07H	Control 5	R2	R4	L3	L1	0	0	0	1
08H	Control 6	R1	R3	L2	L4	0	0	0	0
09H	Reserved	–	–	–	–	–	–	–	–
0AH	Control 7	TDM1	TDM0	SDS1	SDS2	PW2	PW1	DEM21	DEM20
0BH	Control 8	ATS1	ATS0	0	SDS0	PW4	PW3	0	0
0CH	Control 9	INVR4	INVL4	INVR3	INVL3	0	0	0	0
0DH	Control 10	MONO4	MONO3	MONO2	0	SELLR4	SELLR3	0	0
0EH	Control 11	DEM41	DEM40	DEM31	DEM30	0	0	0	0
0FH	L2ch ATT	ATT7	ATT6	ATT5	ATT4	ATT3	ATT2	ATT1	ATT0
10H	R2ch ATT	ATT7	ATT6	ATT5	ATT4	ATT3	ATT2	ATT1	ATT0
11H	L3ch ATT	ATT7	ATT6	ATT5	ATT4	ATT3	ATT2	ATT1	ATT0
12H	R3ch ATT	ATT7	ATT6	ATT5	ATT4	ATT3	ATT2	ATT1	ATT0
13H	L4ch ATT	ATT7	ATT6	ATT5	ATT4	ATT3	ATT2	ATT1	ATT0
14H	R4ch ATT	ATT7	ATT6	ATT5	ATT4	ATT3	ATT2	ATT1	ATT0

NOTES:

1. Addresses ranging from 15H to 1FH are not writable.

2. When designated as 0, the bit must be assigned a value of zero.

3. Upon setting the PDN pin to low, the registers undergo initialization and adopt their default values.

4. Upon setting the RSTN bit to 0, the internal timing is reset, whereas the registers maintain their current state without undergoing initialization.

REGISTER MAPS (continued)

REG0x00: Control 1 Register [Reset = 0x0D]

BITS	BIT NAME	DEFAULT	TYPE	DESCRIPTION
D[7:4]	Reserved	0000	R/W	Reserved
D[3]	DIF2	1	R/W	Audio Data Interface Modes (Table 4) Default: 110 (mode 6: 32-bit MSB justified)
D[2]	DIF1	1	R/W	
D[1]	DIF0	0	R/W	
D[0]	RSTN	1	R/W	Internal Timing Reset 0 = Reset (when the DZF pin is set to high, the register values are uninitialized.) 1 = Normal operation (default)

REG0x01: Control 2 Register [Reset = 0x22]

BITS	BIT NAME	DEFAULT	TYPE	DESCRIPTION
D[7:5]	Reserved	001	R/W	Reserved
D[4]	DFS1	0	R/W	Sampling Speed Mode Control (Table 1) DFS[2:0]: DFS2, DFS1, DFS0 000 = Normal speed mode (default) 001 = Double speed mode 010 = Quad speed mode Others = N/A When adjusting the DFS[2:0] setting, a click noise is generated.
D[3]	DFS0	0	R/W	
D[2]	DEM11	0	R/W	De-emphasis Response for DAC1 (Table 3) 00 = 44.1kHz 01 = Off (default) 10 = 48kHz 11 = 32kHz
D[1]	DEM10	1	R/W	
D[0]	SMUTE	0	R/W	Soft Mute Enable 0 = Normal operation (default) 1 = Soft-muted of DAC outputs

REG0x02: Control 3 Register [Reset = 0x00]

BITS	BIT NAME	DEFAULT	TYPE	DESCRIPTION
D[7:4]	Reserved	0000	R/W	Reserved
D[3]	MONO1	0	R/W	Upon setting the MONO1 bit to 1, the DAC1 transitions to MONO output mode. (Table 11) 0 = Stereo mode (default) 1 = MONO mode
D[2]	DZFB	0	R/W	Inverting Enable of DZF (Table 8) 0 = DZF pin set to high at zero detection (default) 1 = DZF pin set to low at zero detection
D[1]	SELLR1	0	R/W	Data Selection of DAC1 (Table 11) 0 = Normal mode (default) 1 = Swap mode This bit enables or disables the channel swapping feature. When set to 0, the audio system operates in normal mode, where the left channel input is routed to the left channel output, and the right channel input is routed to the right channel output. When set to 1, the audio system enters swap mode, where the left channel input is routed to the right channel output, and the right channel input is routed to the left channel output.
D[0]	SLOW	0	R/W	Slow Roll-Off Filter Enable (Table 7) 0 = Disable (default) 1 = Enable

REGISTER MAPS (continued)

REG0x03/REG0x04: L1ch/R1ch ATT Register [Reset = 0xFF]

BITS	BIT NAME	DEFAULT	TYPE	DESCRIPTION
D[7]	ATT7	1	R/W	Attenuation Level (Table 9) 1111 1111 = 0dB (default) 1111 1110 = -0.5dB ... 0000 0001 = -127dB 0000 0000 = Mute (-∞)
D[6]	ATT6	1	R/W	
D[5]	ATT5	1	R/W	
D[4]	ATT4	1	R/W	
D[3]	ATT3	1	R/W	
D[2]	ATT2	1	R/W	
D[1]	ATT1	1	R/W	
D[0]	ATT0	1	R/W	

REG0x05: Control 4 Register [Reset = 0x00]

BITS	BIT NAME	DEFAULT	TYPE	DESCRIPTION
D[7]	INVL1	0	R/W	Output of AOUTL1 Phase Inverting Enable Bit (Table 11) 0 = Normal (default) 1 = Inverted
D[6]	INVR1	0	R/W	Output of AOUTR1 Phase Inverting Enable Bit (Table 11) 0 = Normal (default) 1 = Inverted
D[5]	INVL2	0	R/W	Output of AOUTL2 Phase Inverting Enable Bit (Table 12) 0 = Normal (default) 1 = Inverted
D[4]	INVR2	0	R/W	Output of AOUTR2 Phase Inverting Enable Bit (Table 12) 0 = Normal (default) 1 = Inverted
D[3]	SELLR2	0	R/W	Data Selection of DAC2 (Table 12) 0 = Normal mode (default) 1 = Swap mode This bit enables or disables the channel swapping feature. When set to 0, the audio system operates in normal mode, where the left channel input is routed to the left channel output, and the right channel input is routed to the right channel output. When set to 1, the audio system enters swap mode, where the left channel input is routed to the right channel output, and the right channel input is routed to the left channel output.
D[2]	Reserved	0	R/W	Reserved
D[1]	DFS2	0	R/W	Sampling Speed Mode Control (Table 1) DFS[2:0]: DFS2, DFS1, DFS0 000 = Normal speed mode (default) 001 = Double speed mode 010 = Quad speed mode Others = N/A When adjusting the DFS[2:0] setting, a click noise is generated.
D[0]	SSLOW	0	R/W	Super Slow Roll-Off Mode Enable (Table 7) 0 = Disable (default) 1 = Enable

REGISTER MAPS (continued)

REG0x07: Control 5 Register [Reset = 0x01]

BITS	BIT NAME	DEFAULT	TYPE	DESCRIPTION
D[7]	R2	0	R/W	Zero Detect Flag Enable Bit for the DZF Pin 0 = Disable (default) 1 = Enable
D[6]	R4	0	R/W	
D[5]	L3	0	R/W	
D[4]	L1	0	R/W	
D[3:0]	Reserved	0001	R/W	Reserved

REG0x08: Control 6 Register [Reset = 0x00]

BITS	BIT NAME	DEFAULT	TYPE	DESCRIPTION
D[7]	R1	0	R/W	Zero Detect Flag Enable Bit for the DZF Pin 0 = Disable (default) 1 = Enable
D[6]	R3	0	R/W	
D[5]	L2	0	R/W	
D[4]	L4	0	R/W	
D[3:0]	Reserved	0000	R/W	Reserved

REG0x0A: Control 7 Register [Reset = 0x0D]

BITS	BIT NAME	DEFAULT	TYPE	DESCRIPTION
D[7]	TDM1	0	R/W	TDM Mode Select 00 = Normal mode (default) 01 = TDM128 mode 10 = TDM256 mode 11 = TDM512 mode
D[6]	TDM0	0	R/W	
D[5]	SDS1	0	R/W	Data Selection for DAC1-4 0 = Normal operation (default) 1 = Output other slot data (Table 5) SDS[2:0] default: 000
D[4]	SDS2	0	R/W	
D[3]	PW2	1	R/W	Power-Down Control for DAC2 0 = DAC2 power-off 1 = DAC2 power-on (default)
D[2]	PW1	1	R/W	Power-Down Control for DAC1 0 = DAC1 power-off 1 = DAC1 power-on (default)
D[1]	DEM21	0	R/W	De-emphasis Response for DAC2 (Table 3) 00 = 44.1kHz 01 = Off (default) 10 = 48kHz 11 = 32kHz
D[0]	DEM20	1	R/W	

REGISTER MAPS (continued)

REG0x0B: Control 8 Register [Reset = 0x0C]

BITS	BIT NAME	DEFAULT	TYPE	DESCRIPTION
D[7]	ATS1	0	R/W	Transition Time between Value Settings of ATT7-0 Bits (Table 10) 00 = 4080/f_S (default) 01 = 2040/f_S 10 = 510/f_S 11 = 255/f_S
D[6]	ATS0	0	R/W	
D[5]	Reserved	0	R/W	Reserved
D[4]	SDS0	0	R/W	Data Selection for DAC1-4 0 = Normal operation (default) 1 = Output other slot data (Table 5) SDS[2:0] default: 000
D[3]	PW4	1	R/W	Power-Down Control for DAC4 0 = DAC4 power-off 1 = DAC4 power-on (default)
D[2]	PW3	1	R/W	Power-Down Control for DAC3 0 = DAC3 power-off 1 = DAC3 power-on (default)
D[1:0]	Reserved	00	R/W	Reserved

REG0x0C: Control 9 Register [Reset = 0x00]

BITS	BIT NAME	DEFAULT	TYPE	DESCRIPTION
D[7]	INVR4	0	R/W	Output of AOUTR4 Phase Inverting Enable Bit (Table 14) 0 = Normal (default) 1 = Inverted
D[6]	INVL4	0	R/W	Output of AOUTL4 Phase Inverting Enable Bit (Table 14) 0 = Normal (default) 1 = Inverted
D[5]	INVR3	0	R/W	Output of AOUTR3 Phase Inverting Enable Bit (Table 13) 0 = Normal (default) 1 = Inverted
D[4]	INVL3	0	R/W	Output of AOUTL3 Phase Inverting Enable Bit (Table 13) 0 = Normal (default) 1 = Inverted
D[3:0]	Reserved	0000	R/W	Reserved

REGISTER MAPS (continued)

REG0x0D: Control 10 Register [Reset = 0x00]

BITS	BIT NAME	DEFAULT	TYPE	DESCRIPTION
D[7]	MONO4	0	R/W	Upon setting the MONO4 bit to 1, the DAC4 transitions to MONO output mode. (Table 14) 0 = Stereo mode (default) 1 = MONO mode
D[6]	MONO3	0	R/W	Upon setting the MONO3 bit to 1, the DAC3 transitions to MONO output mode. (Table 13) 0 = Stereo mode (default) 1 = MONO mode
D[5]	MONO2	0	R/W	Upon setting the MONO2 bit to 1, the DAC2 transitions to MONO output mode. (Table 12) 0 = Stereo mode (default) 1 = MONO mode
D[4]	Reserved	0	R/W	Reserved
D[3]	SELLR4	0	R/W	Data Selection of DAC4 (Table 14) 0 = Normal mode (default) 1 = Swap mode This bit enables or disables the channel swapping feature. When set to 0, the audio system operates in normal mode, where the left channel input is routed to the left channel output, and the right channel input is routed to the right channel output. When set to 1, the audio system enters swap mode, where the left channel input is routed to the right channel output, and the right channel input is routed to the left channel output.
D[2]	SELLR3	0	R/W	Data Selection of DAC3 (Table 13) 0 = Normal mode (default) 1 = Swap mode This bit enables or disables the channel swapping feature. When set to 0, the audio system operates in normal mode, where the left channel input is routed to the left channel output, and the right channel input is routed to the right channel output. When set to 1, the audio system enters swap mode, where the left channel input is routed to the right channel output, and the right channel input is routed to the left channel output.
D[1:0]	Reserved	00	R/W	Reserved

REG0x0E: Control 11 Register [Reset = 0x50]

BITS	BIT NAME	DEFAULT	TYPE	DESCRIPTION
D[7]	DEM41	0	R/W	De-emphasis Response for DAC4 (Table 3) 00 = 44.1kHz 01 = Off (default) 10 = 48kHz 11 = 32kHz
D[6]	DEM40	1	R/W	
D[5]	DEM31	0	R/W	De-emphasis Response for DAC3 (Table 3) 00 = 44.1kHz 01 = Off (default) 10 = 48kHz 11 = 32kHz
D[4]	DEM30	1	R/W	
D[3:0]	Reserved	0000	R/W	Reserved

REG0x0F/REG0x11/REG0x13: L2ch/L3ch/L4ch ATT Register [Reset = 0xFF]

BITS	BIT NAME	DEFAULT	TYPE	DESCRIPTION
D[7]	ATT7	1	R/W	Attenuation Level (Table 9) 1111 1111 = 0dB (default) 1111 1110 = -0.5dB … 0000 0001 = -127dB 0000 0000 = Mute (-∞)
D[6]	ATT6	1	R/W	
D[5]	ATT5	1	R/W	
D[4]	ATT4	1	R/W	
D[3]	ATT3	1	R/W	
D[2]	ATT2	1	R/W	
D[1]	ATT1	1	R/W	
D[0]	ATT0	1	R/W	

REGISTER MAPS (continued)

REG0x10/REG0x12/REG0x14: R2ch/R3ch/R4ch ATT Register [Reset = 0xFF]

BITS	BIT NAME	DEFAULT	TYPE	DESCRIPTION
D[7]	ATT7	1	R/W	Attenuation Level (Table 9) 1111 1111 = 0dB (default) 1111 1110 = -0.5dB … 0000 0001 = -127dB 0000 0000 = Mute (-∞)
D[6]	ATT6	1	R/W	
D[5]	ATT5	1	R/W	
D[4]	ATT4	1	R/W	
D[3]	ATT3	1	R/W	
D[2]	ATT2	1	R/W	
D[1]	ATT1	1	R/W	
D[0]	ATT0	1	R/W	

APPLICATION INFORMATION

The SGM56101 needs to input the MCLK signal in advance to execute the 3-wire serial/I^2C-bus program. It can only enter its normal operating state once the power-up sequences for AVDD, TVDD and VREFH are completed, and the functional and digital logic blocks are enabled. It is crucial that the voltage at the digital input pins is synchronized with the voltage of TVDD to prevent reverse current flow, commonly known as backflow.

Grounding and Power Supply Decoupling

The SGM56101 necessitates meticulous attention to its power supply and grounding configurations. AVDD and TVDD are usually sourced from the analog power supply. When AVDD and TVDD are supplied independently, the specific power-up sequence between them is not crucial. For VSS1 and VSS2, they ought to be interconnected to a unified ground plane. It is essential to separate the analog ground from its digital ground and connect them as closely as possible to the point where the power supplies are introduced into the printed circuit board. The decoupling capacitors must be placed as close as possible to the SGM56101.

Voltage Reference

The analog output range is determined by the differential voltage between the VREFH and VREFL pins, with the VREFH pin typically connected to AVDD and the VREFL pin linked to VSS2. To mitigate the impact of high-frequency noise, it is recommended to connect a 0.1μF ceramic capacitor and a 10μF electrolytic capacitor between VREFH and VREFL, positioning them as close as possible to the respective pins.

VCOM is defined as the signal ground of the chip, and can output a voltage of AVDD × 1/2. To mitigate the impact of high-frequency noise, a 2.2μF ± 50% ceramic capacitor should be placed between the VCOM pin and VSS2, and it is crucial to position this capacitor as close to the pin as possible. It is important to note that no load current should be drawn from the VCOM pin. Additionally, it is essential to keep all signals, particularly clocks, away from the VREFH pin and the VCOM pin to prevent unwanted coupling into the SGM56101.

The LDOO produces 1.85V, which serves as the voltage source for the internal critical circuit. To ensure the stability of the internal LDO, it is necessary to connect a 2.2μF ± 50% ceramic capacitor between the LDOO pin and VSS1, positioning it as close to the pin as possible. It is crucial to note that no load current should be drawn from the VCOM pin.

Analog Output

Nominally, the output signal range is centered on the VCOM voltage and spans 0.86 × AVDD V_{PP}. The DAC employs a two's complement data format, with a positive full-scale output corresponding to 7FFFFFFFH (for 32-bit) and a negative full-scale output corresponding to 80000000H (for 32-bit). The ideal output is VCOM voltage for 00000000H (for 32-bit).

To minimize noise generated by the sigma-delta modulator of the DAC beyond the audio pass band in single-ended input mode, internal analog filters are employed. However, it's worth noting that the DAC outputs typically have DC offsets of a few millivolts relative to the VCOM voltage. Consequently, an external capacitor is normally used to eliminate this DC component. Unused input or output pins must be connected correctly. AOUTL1-4, AOUTR1-4 and DZF pins must be set to open and SDTI1-4 pins must be connected to VSS1.

External Circuits of Analog Output

The analog output of this circuit typically reaches 2.8V_{PP} (as specified for the Electrical Characteristics). Typically, due to the presence of DC offsets in the DAC outputs, which amount to a few millivolts relative to the VCOM voltage, an external capacitor is employed to eliminate the DC component. The cutoff frequency of the high-pass filter (HPF) is detailed in the following section.

$$f_C = 1/(2 \times \pi \times R \times C)\ (Hz) \quad (1)$$

The external AC coupling capacitor is denoted by C, while R represents the load resistance. Given that C equals 2.2μF and R equals 5kΩ, the resulting cutoff frequency f_C is calculated to be 14.5Hz. Note that in AC coupling mode, the maximum resistive load capacity is 5kΩ.

APPLICATION INFORMATION (continued)

Another output mode is DC coupling, as shown on the right side of Figure 45. The output is directly connected to the load without AC coupling capacitor. In this mode, there is a common mode voltage at the output terminal, which is AVDD/2 (typical value is 1.65V), and the maximum resistive load capacity is 10kΩ.

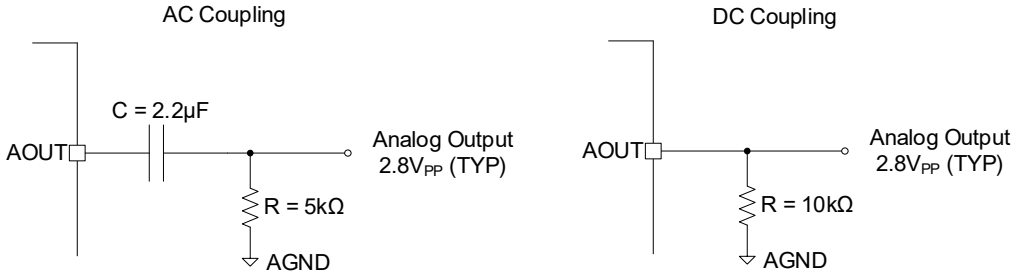


Figure 45. Example of Output Buffer Circuits

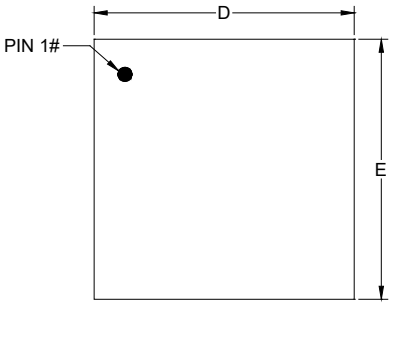
REVISION HISTORY

NOTE: Page numbers for previous revisions may differ from page numbers in the current version.

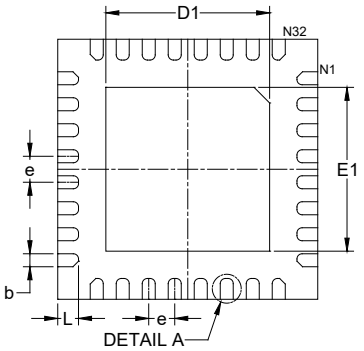
Changes from Original to REV.A (OCTOBER 2025)	**Page**
Changed from product preview to production data	All

PACKAGE OUTLINE DIMENSIONS

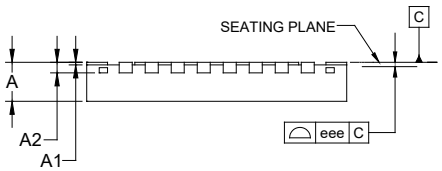
TQFN-5×5-32JL



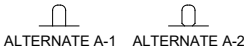
TOP VIEW



BOTTOM VIEW

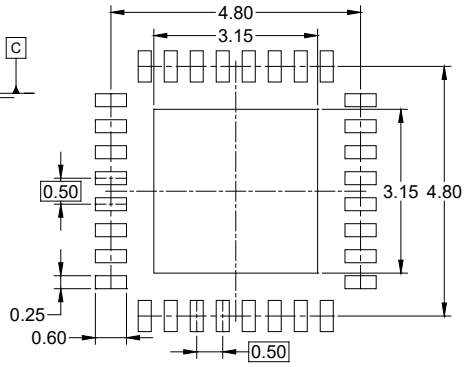


SIDE VIEW



DETAIL A

ALTERNATE TERMINAL CONSTRUCTION



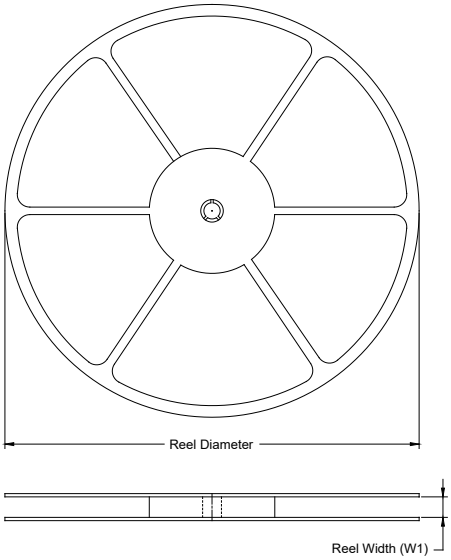
RECOMMENDED LAND PATTERN (Unit: mm)

Symbol	Dimensions In Millimeters		
	MIN	NOM	MAX
A	0.700	-	0.800
A1	0.000	-	0.050
A2	0.203 REF		
b	0.180	-	0.300
D	4.900	-	5.100
E	4.900	-	5.100
D1	3.050	-	3.250
E1	3.050	-	3.250
e	0.500 BSC		
L	0.300	-	0.500
eee	0.080		

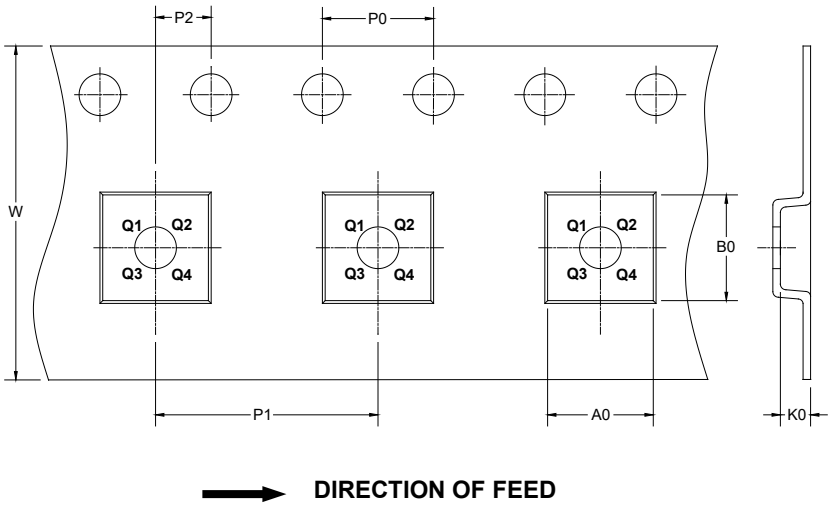
NOTE: This drawing is subject to change without notice.

TAPE AND REEL INFORMATION

REEL DIMENSIONS



TAPE DIMENSIONS



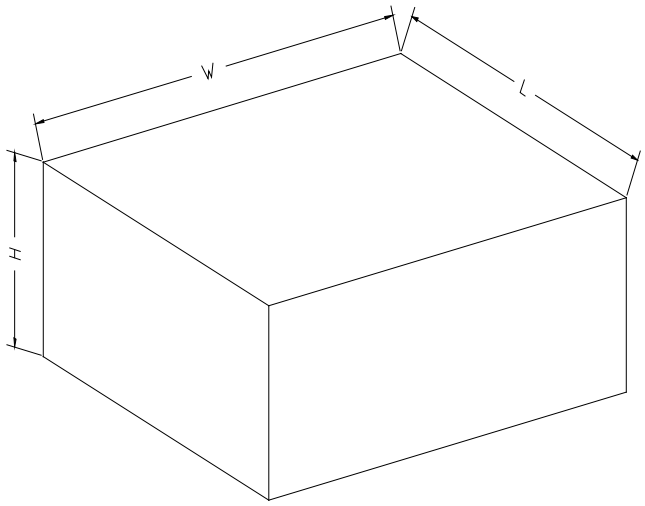
NOTE: The picture is only for reference. Please make the object as the standard.

KEY PARAMETER LIST OF TAPE AND REEL

Package Type	Reel Diameter	Reel Width W1 (mm)	A0 (mm)	B0 (mm)	K0 (mm)	P0 (mm)	P1 (mm)	P2 (mm)	W (mm)	Pin1 Quadrant
TQFN-5×5-32JL	13"	12.4	5.30	5.30	1.10	4.0	8.0	2.0	12.0	Q2

DD0001

CARTON BOX DIMENSIONS



NOTE: The picture is only for reference. Please make the object as the standard.

KEY PARAMETER LIST OF CARTON BOX

Reel Type	Length (mm)	Width (mm)	Height (mm)	Pizza/Carton
13″	386	280	370	5

DD0002