SGM8604-1/SGM8604-2/SGM8604-3/SGM8604-5
15MHz, High Output Drive, High Precision, Low Noise Operational Amplifiers

GENERAL DESCRIPTION

The SGM8604-1 (single), SGM8604-3 (single with shutdown), SGM8604-2 (dual) and SGM8604-5 (dual with shutdown) high output drive CMOS operational amplifiers feature a peak output current of 232mA, rail-to-rail output capability from a single 2.7V to 5.5V supply. These amplifiers exhibit a high slew rate of 7V/μs and a gain-bandwidth product (GBP) of 15MHz. The SGM8604-1/2/3/5 can drive typical headset levels (32Ω), as well as bias an RF power amplifier in wireless handset applications.

These operational amplifiers are designed to be part of the power amplifier control circuitry, biasing RF power amplifiers in wireless headsets. The SGM8604-3/5 offer a shutdown feature that drives the output low. This ensures that the RF power amplifier is fully disabled when needed, preventing unconverted signals to the RF antenna.

The SGM8604-1/2/3/5 offer low input offset voltage, low input offset voltage drift, wide bandwidth and high output drive.

The SGM8604-1/3 are available in Green UTDFN-1.45×1-6L package. The SGM8604-2 is available in Green TDFN-2×3-8AL package. The SGM8604-5 is available in Green TDFN-3×3-10L package. They operate over an ambient temperature range of -40℃ to +125℃.

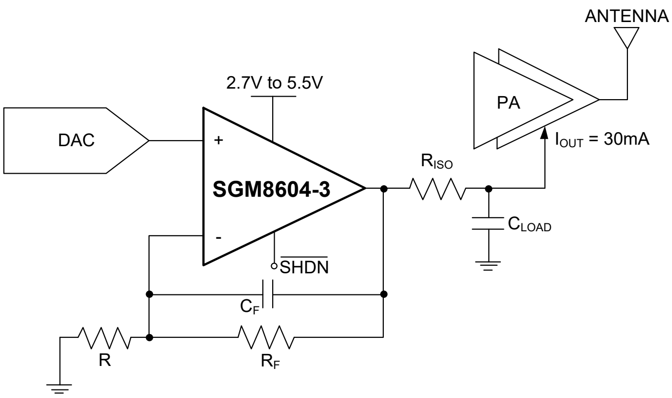
APPLICATIONS

RF Power Amplifier Biasing Controls
Portable/Battery-Powered Audio Applications
Portable Headphone Speaker Drivers (32Ω)
Audio Hands-Free Car Phones (Kits)
Laptop/Notebook Computers/TFT Panels
Sound Ports/Cards
Set-Top Boxes
Digital-to-Analog Converter Buffers
Transformer/Line Drivers
Motor Drivers

FEATURES

- **232mA Output Drive Capability**
- **Rail-to-Rail Output**
- **Low Input Offset Voltage: 10μV (MAX)**
- **Low Input Offset Voltage Drift: 17nV/℃ (TYP)**
- **Low Noise: 22nV/$\sqrt{Hz}$ at 1kHz**
- **Over-Temperature Protection**
- **Supply Voltage Range: 2.7V to 5.5V**
- **Quiescent Supply Current:**
  1.2mA/Amplifier (TYP)
  0.1μA Shutdown Current for SGM8604-3/5 (TYP)
- **Gain-Bandwidth Product: 15MHz**
- **High Slew Rate: 7V/μs**
- **Voltage Gain (R_L = 2kΩ): 145dB**
- **Power Supply Rejection Ratio: 127dB**
- **No Phase Reversal for Overdriven Inputs**
- **Small Packaging:**
  SGM8604-1 Available in Green UTDFN-1.45×1-6L
  SGM8604-2 Available in Green TDFN-2×3-8AL
  SGM8604-3 Available in Green UTDFN-1.45×1-6L
  SGM8604-5 Available in Green TDFN-3×3-10L

TYPICAL APPLICATION



PACKAGE/ORDERING INFORMATION

MODEL	PACKAGE DESCRIPTION	SPECIFIED TEMPERATURE RANGE	ORDERING NUMBER	PACKAGE MARKING	PACKING OPTION
SGM8604-1	UTDFN-1.45×1-6L	-40℃ to +125℃	SGM8604-1XUDL6G/TR	D1X	Tape and Reel, 5000
SGM8604-2	TDFN-2×3-8AL	-40℃ to +125℃	SGM8604-2XTDC8G/TR	GD0 XXXX	Tape and Reel, 3000
SGM8604-3	UTDFN-1.45×1-6L	-40℃ to +125℃	SGM8604-3XUDL6G/TR	D2X	Tape and Reel, 5000
SGM8604-5	TDFN-3×3-10L	-40℃ to +125℃	SGM8604-5XTD10G/TR	SGM 86045D XXXXX	Tape and Reel, 4000

NOTE: XXXX = Date Code. XXXXX = Date 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

Supply Voltage, $+V_S$ to $-V_S$ 6V
All Other Pins............................. ($-V_S$ - 0.3V) to ($+V_S$ + 0.3V)
Output Short-Circuit Duration to $+V_S$ or $-V_S$.......................10s
Junction Temperature...+150℃
Storage Temperature Range ....-65℃ to +150℃
Lead Temperature (Soldering, 10s)............................+260℃
ESD Susceptibility
HBM...7000V
MM...400V
CDM 1000V

RECOMMENDED OPERATING CONDITIONS

Operating Temperature Range.....................-40℃ to +125℃
Operating Supply Voltage Range ....2.7V to 5.5V

OVERSTRESS CAUTION

Stresses beyond those listed may cause permanent damage to the device. Functional operation of the device at these or any other conditions beyond those indicated in the operational section of the specification is not implied. Exposure to absolute maximum rating conditions for extended periods may affect reliability.

ESD SENSITIVITY CAUTION

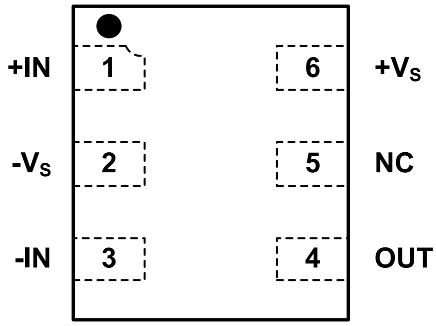
This integrated circuit can be damaged by ESD if you don’t pay attention to ESD protection. SGMICRO recommends that all integrated circuits be handled with appropriate precautions. Failure to observe proper handling and installation procedures can cause damage. ESD damage can range from subtle performance degradation to complete device failure. Precision integrated circuits may be more susceptible to damage because very small parametric changes could cause the device not to meet its published specifications.

DISCLAIMER

SG Micro Corp reserves the right to make any change in circuit design, specification or other related things if necessary without notice at any time.

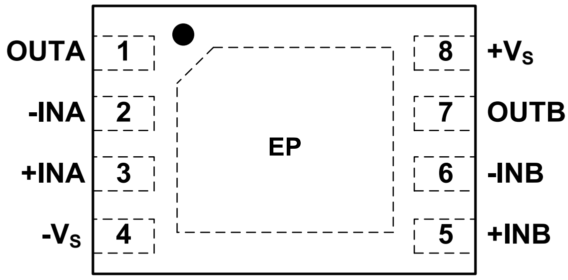
PIN CONFIGURATIONS

SGM8604-1 (TOP VIEW)



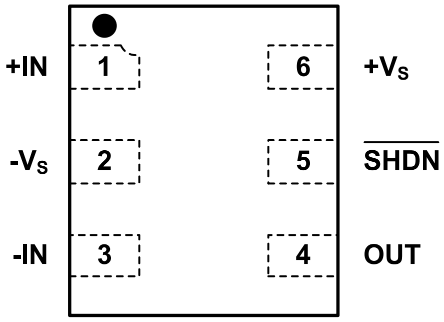
UTDFN-1.45×1-6L

SGM8604-2 (TOP VIEW)



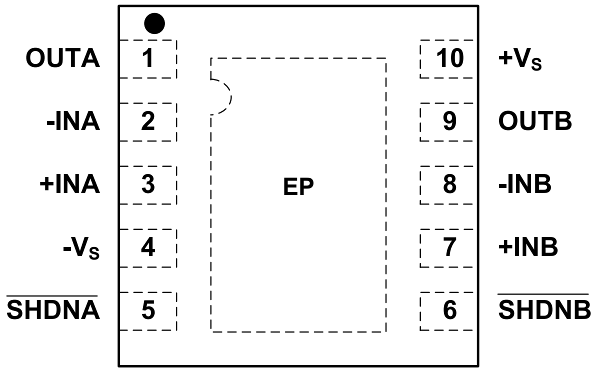
TDFN-2×3-8AL

SGM8604-3 (TOP VIEW)



UTDFN-1.45×1-6L

SGM8604-5 (TOP VIEW)



TDFN-3×3-10L

NOTE: For all packages, connect thermal die pad to $-V_S$ or floating. Soldering the thermal pad improves heat dissipation and provides specified performance.

ELECTRICAL CHARACTERISTICS

(At T_A = +25℃, Full = -40℃ to +125℃, $+V_S$ = 2.7V to 5V, $-V_S$ = 0V, V_{CM} = $+V_S/2$, V_{OUT} = $+V_S/2$, R_L = ∞ connected to $+V_S/2$, $V_{\overline{SHDN}}$ = $+V_S$, unless otherwise noted.)

PARAMETER	SYMBOL	CONDITIONS		TEMP	MIN	TYP	MAX	UNITS
INPUT CHARACTERISTICS								
Input Offset Voltage	V_{OS}	$+V_S$ = 2.7V		+25℃		2.4	8	μV
		$+V_S$ = 5V		+25℃		2.4	10	
Input Offset Voltage Drift	$\Delta V_{OS}/\Delta T$	$+V_S$ = 2.7V		Full		25	126	nV/℃
		$+V_S$ = 5V		Full		17	130	
Input Bias Current	I_B	$+V_S$ = 2.7V, V_{CM} = $+V_S/2$		+25℃		50		pA
		$+V_S$ = 5V, V_{CM} = $+V_S/2$		+25℃		200		
Input Offset Current	I_{OS}	$+V_S$ = 2.7V, V_{CM} = $+V_S/2$		+25℃		50		pA
		$+V_S$ = 5V, V_{CM} = $+V_S/2$		+25℃		200		
Input Common Mode Voltage Range	V_{CM}	Inferred from CMRR test		+25℃	$-V_S$-0.1		$+V_S$+0.1	V
Common Mode Rejection Ratio	CMRR	$+V_S$ = 2.7V, $(-V_S) - 0.1V < V_{CM} < (+V_S) + 0.1V$		+25℃	104	120		dB
				Full	100			
		$+V_S$ = 5V, $(-V_S) - 0.1V < V_{CM} < (+V_S) + 0.1V$		+25℃	108	120		
				Full	90			
Large Signal Voltage Gain	A_{VOL}	$+V_S$ = 2.7V, $(-V_S) + 0.2V < V_{OUT} < (+V_S) - 0.2V$	R_L = 2kΩ	+25℃	112	145		dB
				Full	110			
			R_L = 200Ω	+25℃	109	142		
				Full	106			
		$+V_S$ = 5V, $(-V_S) + 0.2V < V_{OUT} < (+V_S) - 0.2V$	R_L = 2kΩ	+25℃	115	145		
				Full	112			
			R_L = 200Ω	+25℃	110	145		
				Full	108			
OUTPUT CHARACTERISTICS								
Output Voltage Swing from Rail	V_{OUT}	$+V_S$ = 2.7V	R_L = 32Ω	+25℃		245	300	mV
				Full			370	
			R_L = 200Ω	+25℃		45	60	
				Full			73	
			R_L = 2kΩ	+25℃		5	10	
				Full			12	
			I_{OUT} = 10mA	+25℃		62	100	
			I_{OUT} = 10mA	Full			122	
		$+V_S$ = 5V	R_L = 32Ω	+25℃		400	485	mV
				Full			585	
			R_L = 200Ω	+25℃		72	95	
				Full			113	
			R_L = 2kΩ	+25℃		8	15	
				Full			18	
			I_{OUT} = 10mA	+25℃		62	85	
			I_{OUT} = 10mA	Full			102	
Short Circuit Current Limit	I_{SC}	$+V_S$ = 2.7V		+25℃	85	120		mA
				Full	58			
		$+V_S$ = 5V		+25℃	185	240		
				Full	154			

ELECTRICAL CHARACTERISTICS

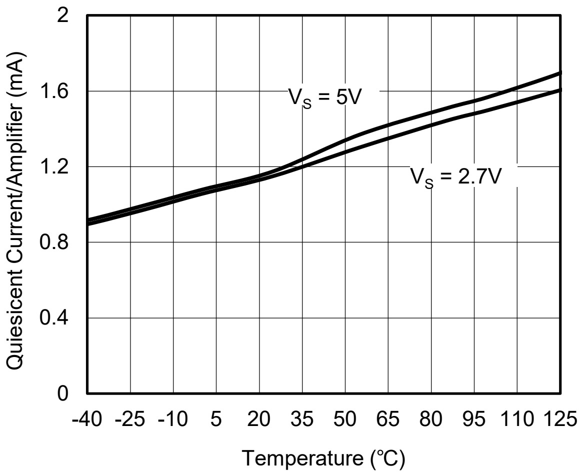
(At T_A = +25℃, Full = -40℃ to +125℃, $+V_S$ = 2.7V to 5V, $-V_S$ = 0V, $V_{CM} = +V_S/2$, $V_{OUT} = +V_S/2$, $R_L = \infty$ connected to $+V_S/2$, $V_{\overline{SHDN}} = +V_S$, unless otherwise noted.)

PARAMETER	SYMBOL	CONDITIONS	TEMP	MIN	TYP	MAX	UNITS
POWER-DOWN DISABLE (SGM8604-3/5 Only)							
Shutdown Supply Current/Amplifier	$I_{Q(\overline{SHDN})}$	$V_{\overline{SHDN}}$ = 0V, $R_L = \infty$	+25℃		0.1	2.5	μA
$\overline{SHDN}$ Logic Threshold	V_{IL}	Shutdown mode	+25℃			0.5	V
	V_{IH}	Normal mode	+25℃	1.6			
$\overline{SHDN}$ Input Bias Current		$-V_S < V_{\overline{SHDN}} < +V_S$	+25℃		50		pA
Shutdown Output Impedance	R_{OUT}	$V_{\overline{SHDN}}$ = 0V	+25℃		10		Ω
Output Voltage in Shutdown	$V_{OUT(\overline{SHDN})}$	$V_{\overline{SHDN}}$ = 0V, R_L = 200Ω	+25℃		10		mV
Shutdown Time	$t_{\overline{SHDN}}$		+25℃		7		μs
Enable Delay Time	t_{ENABLE}		+25℃		10		μs
POWER SUPPLY							
Supply Voltage Range	$+V_S$	Inferred from PSRR test	+25℃	2.7		5.5	V
Power Supply Rejection Ratio	PSRR		+25℃	102	127		dB
			Full	94			
Quiescent Supply Current/Amplifier	I_Q	$+V_S$ = 2.7V, $V_{CM} = +V_S/2$	+25℃		1.1	1.55	mA
		$+V_S$ = 5V, $V_{CM} = +V_S/2$	+25℃		1.2	1.6	
			Full			2.1	
DYNAMIC PERFORMANCE							
Gain-Bandwidth Product	GBP	$V_{CM} = +V_S/2$	+25℃		15		MHz
Slew Rate	SR		+25℃		7		V/μs
Total Harmonic Distortion + Noise	THD+N	$+V_S$ = 5V, R_L = 32Ω, f = 10kHz, $V_{OUT} = 2V_{P-P}$, A_{VCL} = 1V/V	+25℃		0.008		%
Input Capacitance	C_{IN}		+25℃		20		pF
Channel-to-Channel Isolation		f = 1kHz, R_L = 100kΩ	+25℃		-125		dB
Capacitive-Load Stability		A_{VCL} = 1V/V, no sustained oscillations	+25℃		780		pF
Power-Up Time	t_{ON}		+25℃		50		μs
NOISE PERFORMANCE							
Input Voltage Noise Density	e_n	f = 1kHz	+25℃		22		$nV/\sqrt{Hz}$
		f = 10kHz	+25℃		20		
Input Voltage Noise		f = 0.1Hz to 10Hz	+25℃		0.5		μV_{P-P}

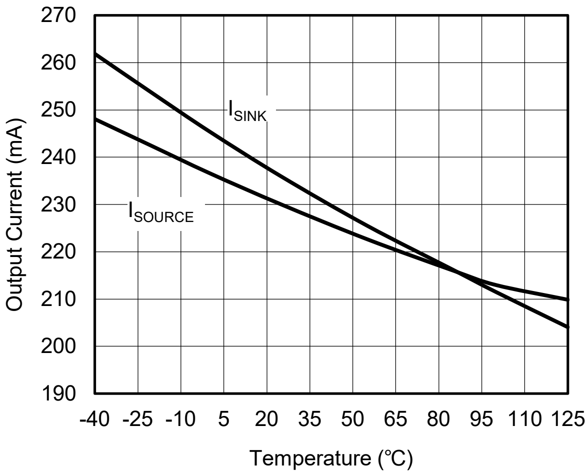
TYPICAL PERFORMANCE CHARACTERISTICS

At T_A = +25℃, V_S = 5.0V, unless otherwise noted.

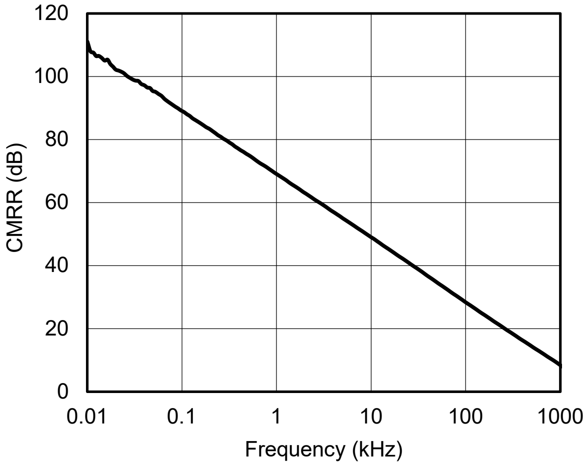
Quiescent Current vs. Temperature



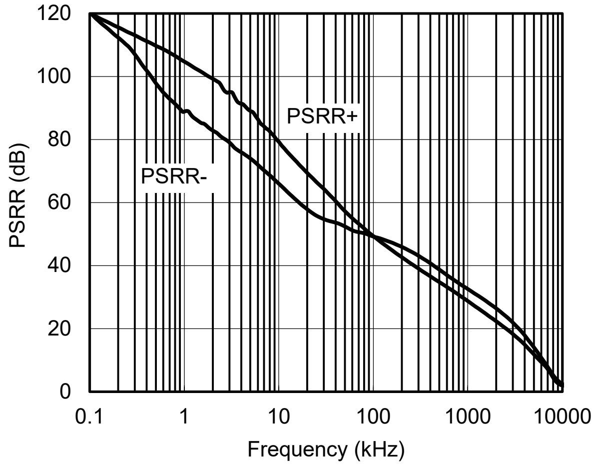
Output Current vs. Temperature



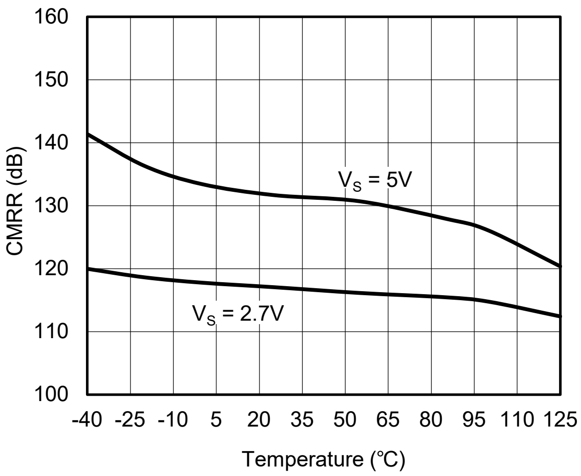
Common Mode Rejection Ratio vs. Frequency



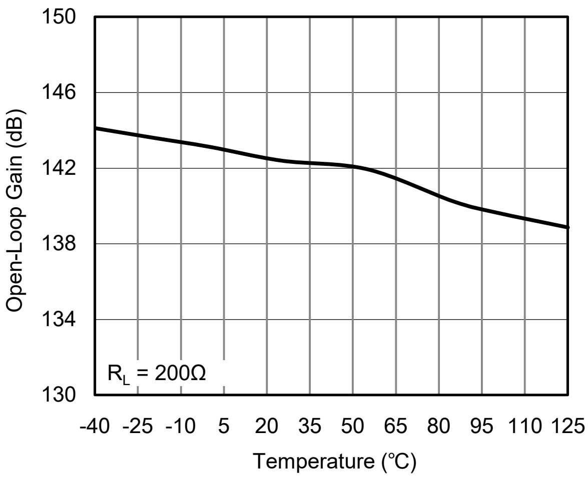
Power Supply Rejection Ratio vs. Frequency



Common Mode Rejection Ratio vs. Temperature



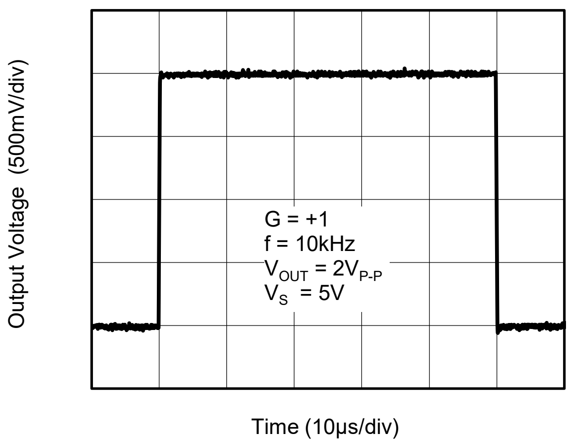
Open-Loop Gain vs. Temperature



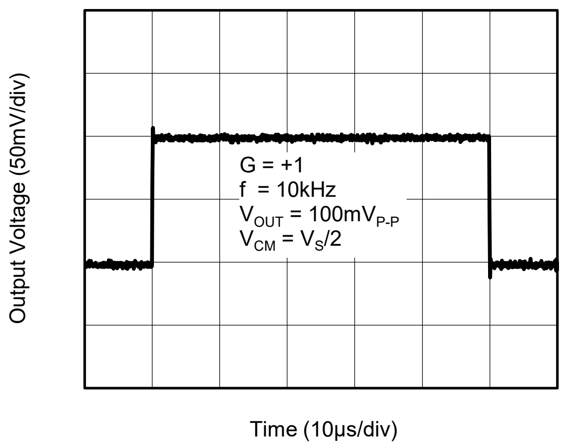
TYPICAL PERFORMANCE CHARACTERISTICS (continued)

At T_A = +25℃, V_S = 5.0V, unless otherwise noted.

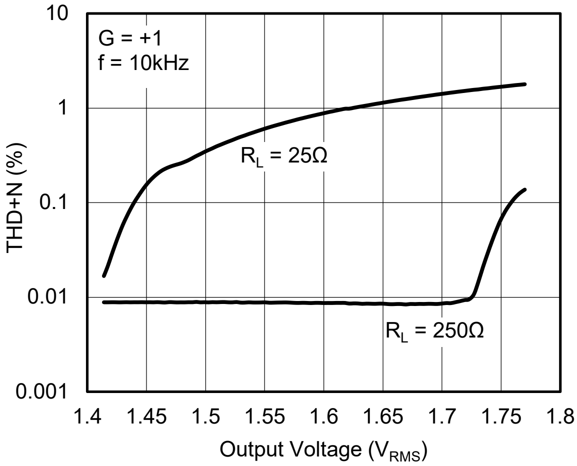
Large Signal Step Response



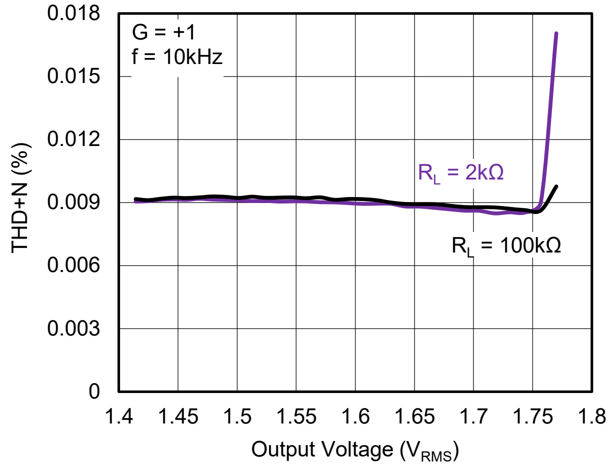
Small Signal Step Response



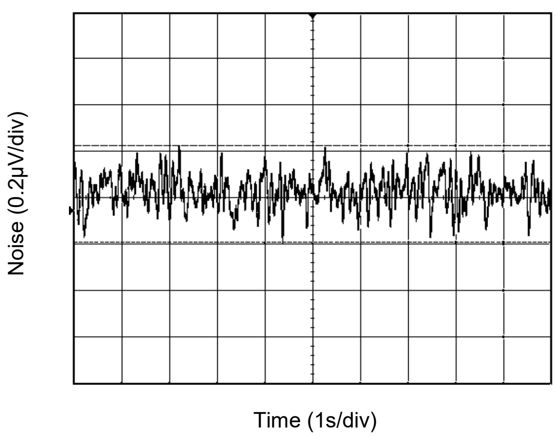
THD+N vs. Output Voltage



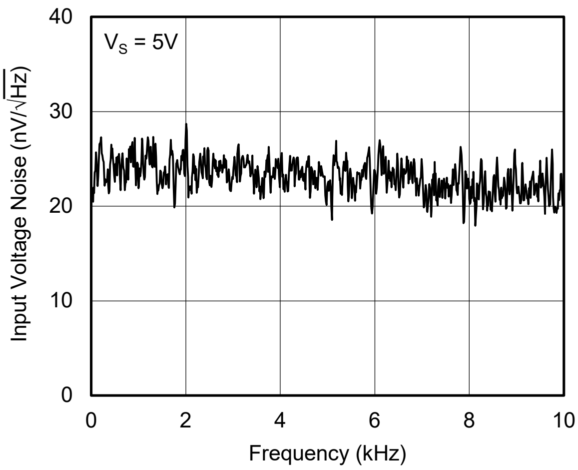
THD+N vs. Output Voltage



0.1Hz to 10Hz Noise

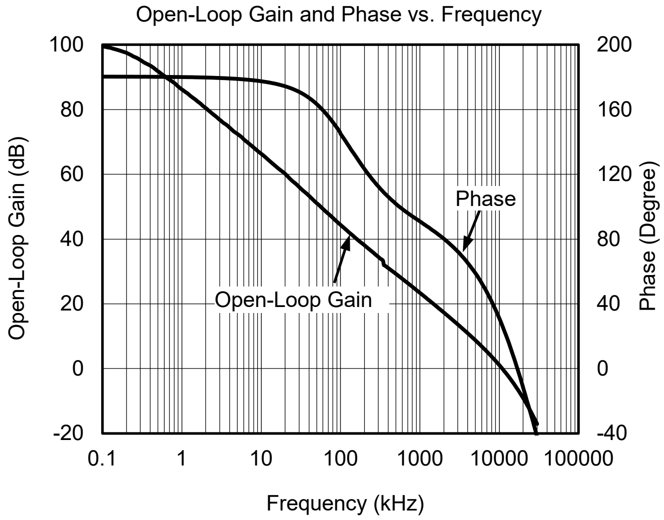


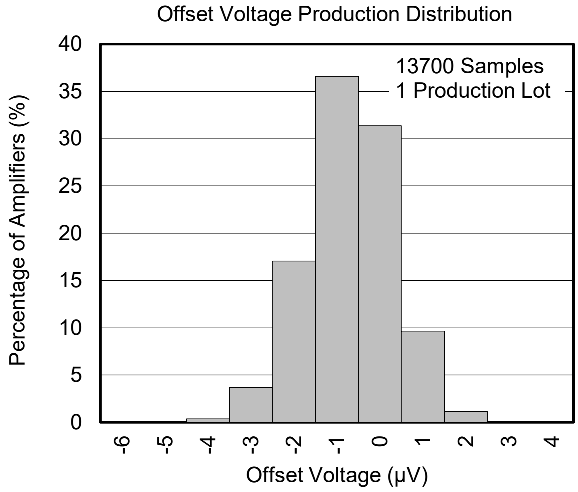
Input Voltage Noise Density



TYPICAL PERFORMANCE CHARACTERISTICS (continued)

At T_A = +25℃, V_S = 5.0V, unless otherwise noted.





APPLICATIONS INFORMATION

60mW Single-Supply Stereo Headphone Driver

The SGM8604-2 can be used as a single supply, stereo headphone driver. The circuit shown in Figure 1 can deliver 60mW per channel with 1% distortion from a single 5V supply.

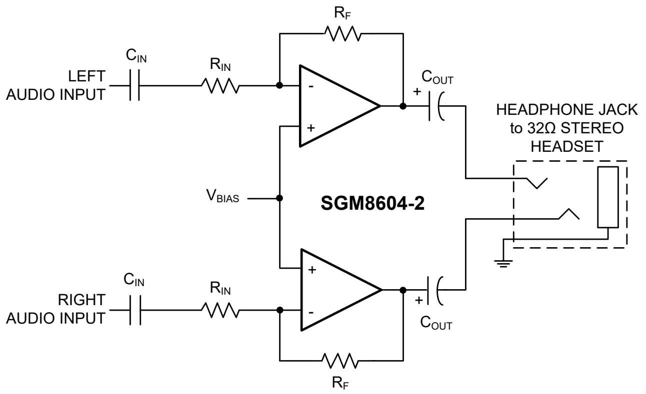


Figure 1. Circuit Example: A Single Supply, Stereo Headphone Driver

The input capacitor (C_{IN}), in conjunction with R_{IN}, forms a high-pass filter that removes the DC bias from the incoming signal. The -3dB point of the high-pass filter is given by:

$$f_{-3dB} = \frac{1}{2\pi R_{IN} C_{IN}}$$

Choose gain-setting resistors R_{IN} and R_F according to the amount of desired gain, keeping in mind the maximum output amplitude. The output coupling capacitor (C_{OUT}), blocks the DC component of the amplifier output, preventing DC current flowing to the load. The output capacitor and the load impedance form a high-pass filer with the -3dB point determined by:

$$f_{-3dB} = \frac{1}{2\pi R_L C_{OUT}}$$

For a 32Ω load, a 100μF aluminum electrolytic capacitor gives a low-frequency pole at 50Hz.

Rail-to-Rail Output Stage

The minimum output is within millivolts of ground for single-supply operation, where the load is referenced to ground ($-V_S$). The maximum output voltage swing is load dependent.

Observe the Absolute Maximum Ratings for power dissipation and output short-circuit duration because the output current can exceed 232mA.

Bridge Amplifier

The circuit shown in Figure 2 uses an SGM8604-2 to implement a 3V, 200mW amplifier suitable for use in size-constrained applications. This configuration eliminates the need for the large coupling capacitor required by the single operational amplifier speaker driver when single-supply operation is necessary. Voltage gain is set to 10V/V; however, it can be changed by adjusting the 82kΩ resistor value.

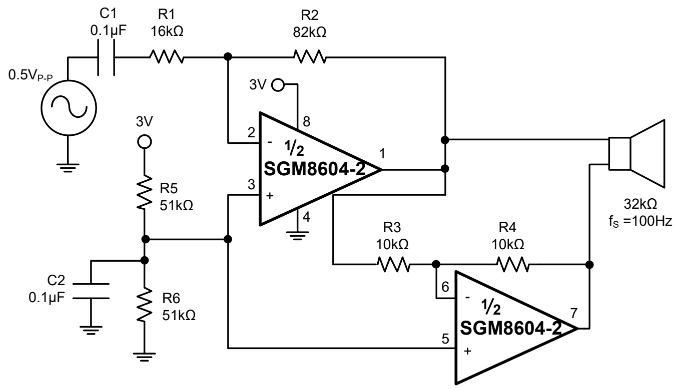


Figure 2. SGM8604-2 Bridge Amplifier for 200mW at 3V

APPLICATIONS INFORMATION (continued)

Input Capacitance

One consequence of the parallel-connected differential input stages is a relatively large input capacitance C_{IN} (20pF TYP). This introduces a pole at frequency $(2\pi R'C_{IN})^{-1}$, where R′ is the parallel combination of the gain-setting resistors for the inverting or non-inverting amplifier configuration (Figure 3). If the pole frequency is less than or comparable to the unity-gain bandwidth (15MHz), the phase margin is reduced, and the amplifier exhibits degraded AC performance through either ringing in the step response or sustained oscillations. The pole frequency is 10MHz when R′ = 2kΩ. To maximize stability, R′ << 2kΩ is recommended.

To improve step response when R′ > 2kΩ, connect small capacitor C_F between the inverting input and output. Choose C_F as follows:

$$C_F = 8(R/R_F)\ [pF]$$

where R_F is the feedback resistor and R is the gain-setting resistor (Figure 3).

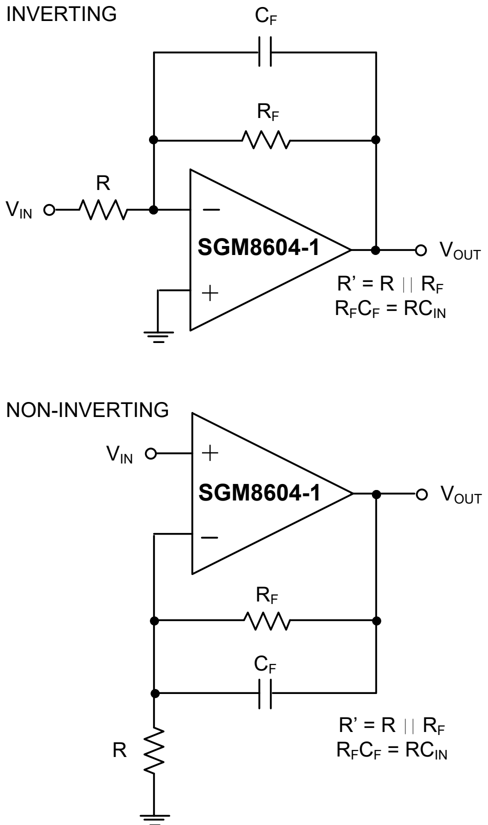


Figure 3. Inverting and Non-Inverting Amplifiers with Feedback Compensation

Driving Capacitive Loads

The SGM8604-1/2/3/5 have a high tolerance for capacitive loads. They are stable with capacitive loads up to 780pF. Figure 4 shows the transient response with excessive capacitive loads (780pF), with and without the addition of an isolation resistor in series with the output. Figure 5 shows a typical non-inverting capacitive-load-driving circuit in the unity-gain configuration.

The resistor improves the circuit’s phase margin by isolating the load capacitor from the op amp’s output.

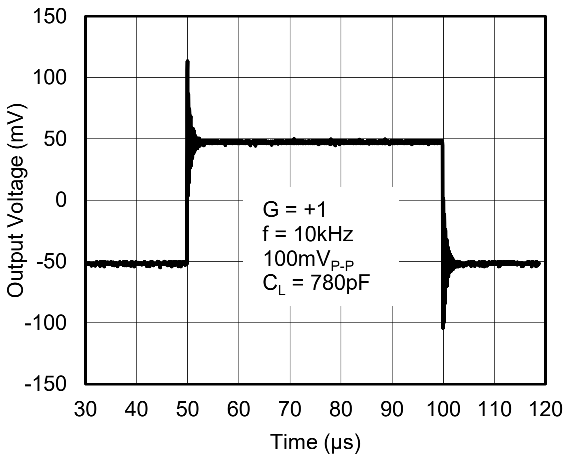


Figure 4. Small-Signal Transient Response with Excessive Capacitive Load

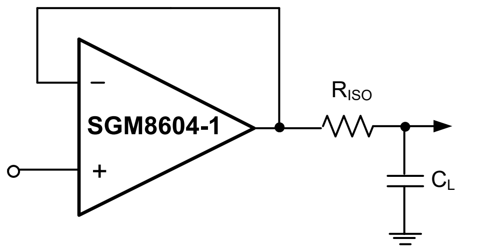


Figure 5. Capacitive-Load-Driving Circuit

APPLICATIONS INFORMATION (continued)

Power-Up and Shutdown Modes

The SGM8604-3/5 have a shutdown option. When the shutdown pin ($\overline{SHDN}$) is pulled low, supply current drops to 0.5μA per amplifier (+V_S = 5V), the amplifiers are disabled, and their outputs are driven to -V_S. Since the outputs are actively driven to -V_S in shutdown, any pull-up resistor on the output causes a current drain from the supply. Pulling $\overline{SHDN}$ high enables the amplifier. In the dual SGM8604-5, the two amplifiers are shut down independently. Figure 6 shows the SGM8604-3's output voltage to a shutdown pulse. The SGM8604-1/2/3/5 typically settle within 50μs after power-up.

When exiting shutdown, there is a 6μs delay before the amplifier's output becomes active (Figure 6).

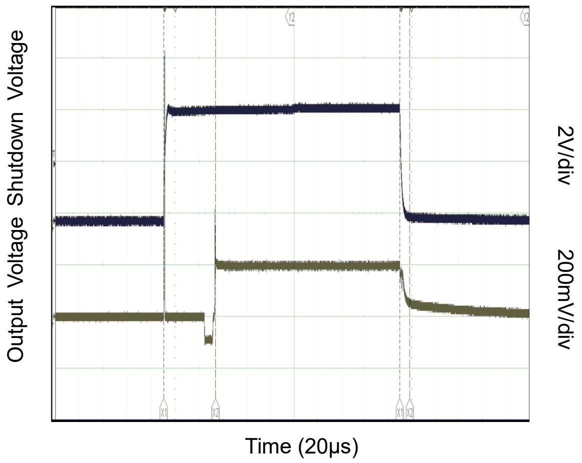


Figure 6. Shutdown Output Voltage Enable/Disable

Power Supplies and Layout

The SGM8604-1/2/3/5 can operate from a single 2.7V to 5.5V supply, or from dual ±1.35V to ±2.75V supplies. For single-supply operation, bypass the power supply with a 0.1μF ceramic capacitor. For dual supply operation, bypass each supply to ground. Good layout improves performance by decreasing the amount of stray capacitance at the operational amplifiers' inputs and outputs. Decrease stray capacitance by placing external components close to the operational amplifiers' pins, minimizing trace and lead lengths.

REVISION HISTORY

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

APRIL 2018 – REV.A.1 to REV.A.2

Changed Package/Ordering Information section........ 2

NOVEMBER 2017 – REV.A to REV.A.1

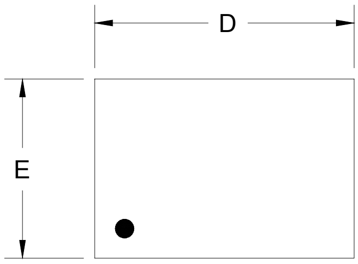
Changed Electrical Characteristics section........ 4
Changed Typical Performance Characteristics section........ 7, 8

Changes from Original (DECEMBER 2016) to REV.A

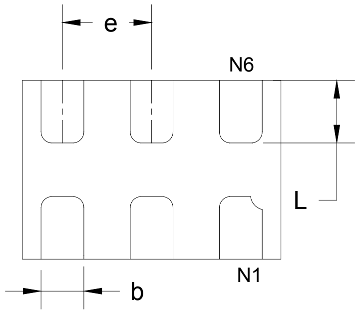
Changed from product preview to production data........ All

PACKAGE OUTLINE DIMENSIONS

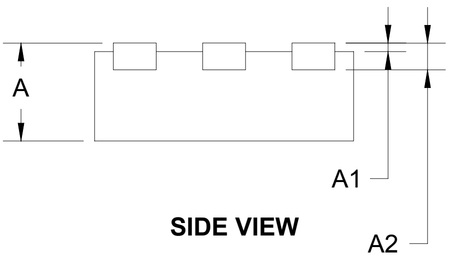
UTDFN-1.45×1-6L



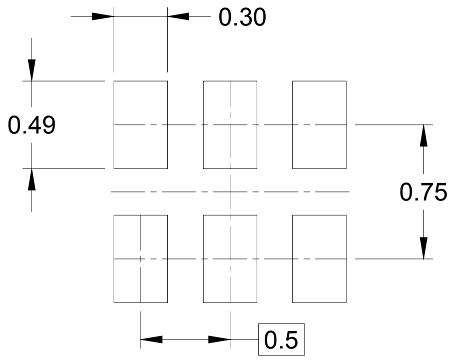
TOP VIEW



BOTTOM VIEW



SIDE VIEW

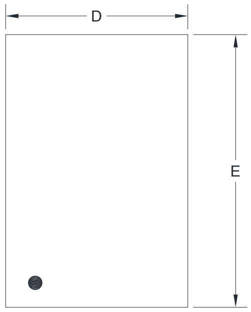


RECOMMENDED LAND PATTERN (Unit: mm)

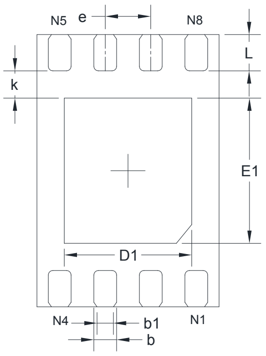
Symbol	Dimensions In Millimeters		Dimensions In Inches	
	MIN	**MAX**	**MIN**	**MAX**
A	0.450	0.550	0.018	0.022
A1	0.000	0.050	0.000	0.002
A2	0.150 REF		0.006 REF	
D	1.374	1.526	0.054	0.060
E	0.924	1.076	0.036	0.042
b	0.180	0.300	0.007	0.012
e	0.500 TYP		0.020 TYP	
L	0.274	0.426	0.011	0.017

PACKAGE OUTLINE DIMENSIONS

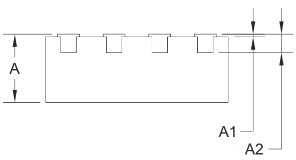
TDFN-2×3-8AL



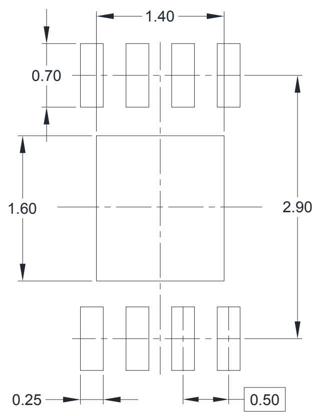
TOP VIEW



BOTTOM VIEW



SIDE VIEW

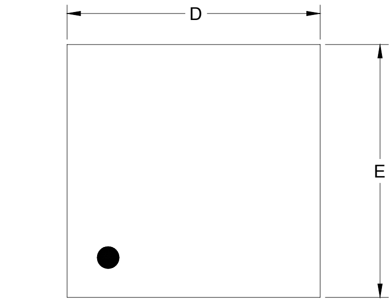


RECOMMENDED LAND PATTERN (Unit: mm)

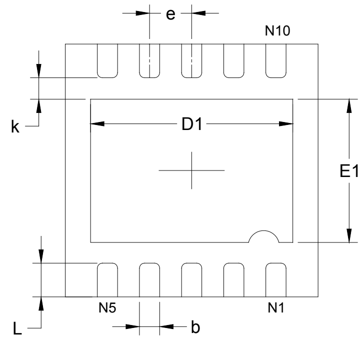
Symbol	Dimensions In Millimeters		Dimensions In Inches	
	MIN	**MAX**	**MIN**	**MAX**
A	0.700	0.800	0.028	0.031
A1	0.000	0.050	0.000	0.002
A2	0.203 REF		0.008 REF	
D	1.900	2.100	0.075	0.083
D1	1.300	1.500	0.051	0.059
E	2.900	3.100	0.114	0.122
E1	1.500	1.700	0.059	0.067
k	0.300 REF		0.012 REF	
b	0.200	0.300	0.008	0.012
b1	0.180 REF		0.007 REF	
e	0.500 BSC		0.020 BSC	
L	0.300	0.500	0.012	0.020

PACKAGE OUTLINE DIMENSIONS

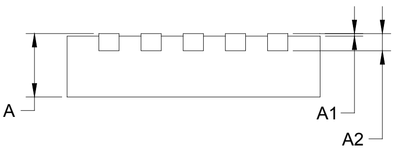
TDFN-3×3-10L



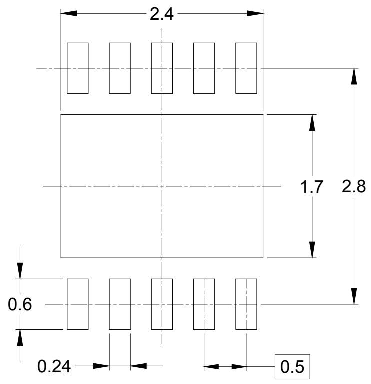
TOP VIEW



BOTTOM VIEW



SIDE VIEW

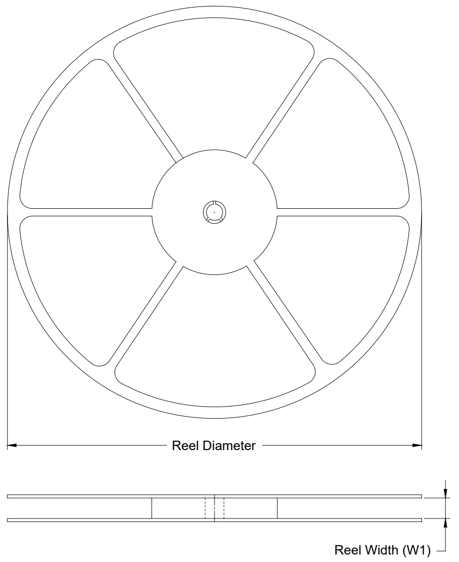


RECOMMENDED LAND PATTERN (Unit: mm)

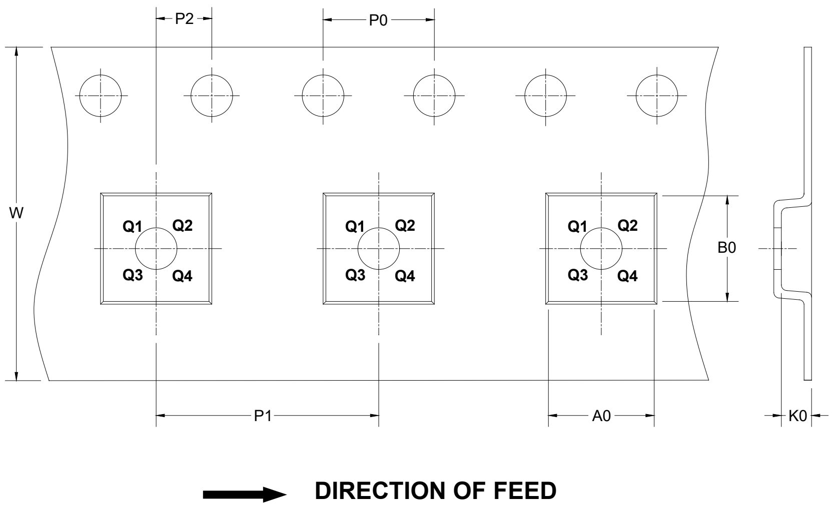
Symbol	Dimensions In Millimeters		Dimensions In Inches	
	MIN	MAX	MIN	MAX
A	0.700	0.800	0.028	0.031
A1	0.000	0.050	0.000	0.002
A2	0.203 REF		0.008 REF	
D	2.900	3.100	0.114	0.122
D1	2.300	2.600	0.091	0.103
E	2.900	3.100	0.114	0.122
E1	1.500	1.800	0.059	0.071
k	0.200 MIN		0.008 MIN	
b	0.180	0.300	0.007	0.012
e	0.500 TYP		0.020 TYP	
L	0.300	0.500	0.012	0.020

TAPE AND REEL INFORMATION

REEL DIMENSIONS



TAPE DIMENSIONS



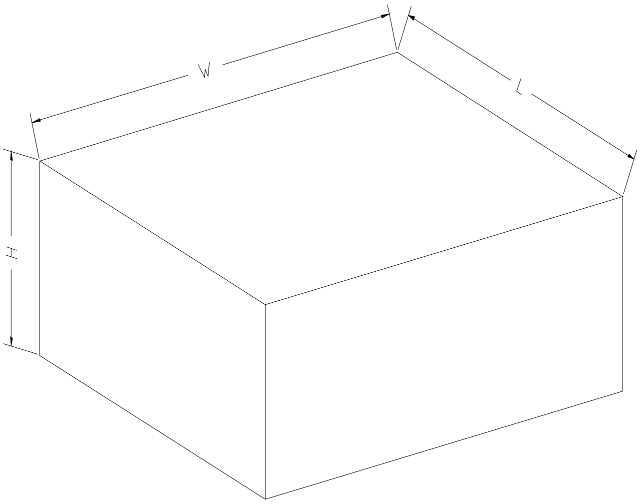
NOTE: The picture is only for reference. Please make the object as the standard.

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
UTDFN-1.45×1-6L	7″	9.5	1.15	1.60	0.75	4.0	4.0	2.0	8.0	Q1
TDFN-2×3-8AL	7″	9.5	2.30	3.30	1.10	4.0	4.0	2.0	8.0	Q2
TDFN-3×3-10L	13″	12.4	3.35	3.35	1.13	4.0	8.0	2.0	12.0	Q1

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
7″ (Option)	368	227	224	8
7″	442	410	224	18
13″	386	280	370	5

DD0002