# SGM8603
# 1.1mA, 11MHz, Low Noise, Rail-to-Rail I/O Tiny Package, CMOS Operational Amplifier

## GENERAL DESCRIPTION

The SGM8603 (single with shutdown) is a low noise, low voltage and low power operational amplifier that can be designed into a wide range of applications. The SGM8603 has a high gain-bandwidth product of 11MHz, a slew rate of 8.5V/μs, and a quiescent current of 1.1mA at 5V. The SGM8603 has a power-down disable feature that reduces the supply current to less than 1μA.

The SGM8603 is designed to provide optimal performance in low voltage and low noise systems. It provides rail-to-rail output swing into heavy loads. The input common mode voltage range includes ground, and the maximum input offset voltage is 4.9mV for SGM8603. The operating supply range is from 2.1V to 5.5V.

The SGM8603 is available in Green TDFN-2×2-6L package. It is specified over the extended industrial temperature range (-40℃ to +125℃).

## FEATURES

- **Rail-to-Rail Input and Output**
  **1.1mV Typical $V_{OS}$**
- **High Gain-Bandwidth Product: 11MHz**
- **High Slew Rate: 8.5V/μs**
- **Settling Time to 0.1% with 2V Step: 0.21μs**
- **Overload Recovery Time: 0.6μs**
- **Low Noise: 8.5nV/$\sqrt{Hz}$ at 10kHz**
- **Supply Voltage Range: 2.1V to 5.5V**
- **Input Common Mode Voltage Range:**
  **-0.1V to +5.6V with $V_S$ = 5.5V**
- **Low Power**
  **1.1mA Typical Supply Current**
  **Less than 1μA when Disabled**
- **-40℃ to +125℃ Operating Temperature Range**
- **Available in Green TDFN-2×2-6L Package**

## APPLICATIONS

Sensors
Audio
Active Filters
A/D Converters
Communications
Test Equipment
Cellular and Cordless Phones
Laptops and PDAs
Photodiode Amplification
Battery-Powered Instrumentation

## PACKAGE/ORDERING INFORMATION

| MODEL | PACKAGE DESCRIPTION | SPECIFIED TEMPERATURE RANGE | ORDERING NUMBER | PACKAGE MARKING | PACKING OPTION |
|---|---|---|---|---|---|
| SGM8603 | TDFN-2×2-6L | -40℃ to +125℃ | SGM8603XTDI6G/TR | 8603<br>XXXX | Tape and Reel, 3000 |

NOTE: XXXX = Date 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
Input Common Mode Voltage Range
....................................................($-V_S$) - 0.3V to ($+V_S$) + 0.3V
Storage Temperature Range ....................... -65℃ to +150℃
Junction Temperature .................................................. 150℃
Lead Temperature (Soldering 10sec) .......................... 260℃
ESD Susceptibility
HBM............................................................................ 4000V
MM................................................................................ 400V
CDM ........................................................................... 1000V

### RECOMMENDED OPERATING CONDITIONS

Input Voltage Range .......................................... 2.1V to 5.5V
Operating Temperature Range .................... -40℃ to +125℃

### 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.

### OVERSTRESS CAUTION

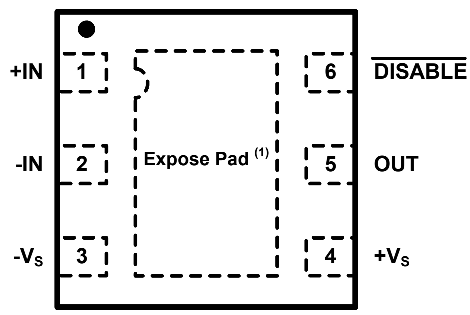
Stresses beyond those listed may cause permanent damage to the device. Functional operation of the device at these or any other conditions beyond those indicated in the operational section of the specification is not implied. Exposure to absolute maximum rating conditions for extended periods may affect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

## PIN CONFIGURATION

SGM8603 (TOP VIEW)




TDFN-2×2-6L

NOTE 1: Exposed pad can be connected to $-V_S$ or left floating.

## ELECTRICAL CHARACTERISTICS

(At $T_A$ = +25℃, $V_S$ = +5V, $V_{CM}$ = $V_S$/2, $R_L$ = 600Ω, unless otherwise noted.)

| PARAMETER | CONDITIONS | SGM8603 | | | | | |
|---|---|---|---|---|---|---|---|
| | | TYP | MIN/MAX OVER TEMPERATURE | | | | |
| | | +25℃ | +25℃ | -40℃ to 85℃ | -40℃ to 125℃ | UNITS | MIN/ MAX |
| **INPUT CHARACTERISTICS** | | | | | | | |
| Input Offset Voltage ($V_{OS}$) | | 1.1 | 4.9 | 5.1 | 5.4 | mV | MAX |
| Input Bias Current ($I_B$) | | 1 | | | | pA | TYP |
| Input Offset Current ($I_{OS}$) | | 1 | | | | pA | TYP |
| Input Common Mode Voltage Range ($V_{CM}$) | $V_S$ = 5.5V | -0.1 to +5.6 | | | | V | TYP |
| Common Mode Rejection Ratio (CMRR) | $V_S$ = 5.5V, $V_{CM}$ = - 0.1V to 4V | 83 | 67 | 66 | 65 | dB | MIN |
| | $V_S$ = 5.5V, $V_{CM}$ = - 0.1V to 5.6V | 77 | 61 | 60 | 56 | dB | MIN |
| Open-Loop Voltage Gain ($A_{OL}$) | $R_L$ = 600Ω, $V_O$ = 0.15V to 4.85V | 91 | 85 | 73 | 62 | dB | MIN |
| | $R_L$ = 10kΩ, $V_O$ = 0.05V to 4.95V | 105 | 97 | 84 | 69 | dB | MIN |
| Input Offset Voltage Drift ($\Delta V_{OS}/\Delta_T$) | | 2.7 | | | | μV/℃ | TYP |
| **OUTPUT CHARACTERISTICS** | | | | | | | |
| Output Voltage Swing from Rail | $R_L$ = 600Ω | 78 | 102 | 123 | 144 | mV | MAX |
| | $R_L$ = 10kΩ | 7 | 12 | 14 | 20 | mV | MAX |
| Output Current ($I_{OUT}$) | | 64 | 52 | 25 | 19 | mA | MIN |
| Closed-Loop Output Impedance | f = 1MHz, G = 1 | 8.5 | | | | Ω | TYP |
| **POWER-DOWN DISABLE** | | | | | | | |
| Turn-On Time | | 1.1 | | | | μs | TYP |
| Turn-Off Time | | 0.3 | | | | μs | TYP |
| $\overline{DISABLE}$ Voltage-Off | | | 0.8 | | | V | MAX |
| $\overline{DISABLE}$ Voltage-On | | | 2 | | | V | MIN |
| **POWER SUPPLY** | | | | | | | |
| Operating Voltage Range | | | 2.1 | 2.1 | 2.1 | V | MIN |
| | | | 5.5 | 5.5 | 5.5 | V | MAX |
| Power Supply Rejection Ratio (PSRR) | $V_s$ = +2.1V to +5.5V, $V_{CM}$ = (-$V_S$) + 0.5V | 80 | 68 | 67 | 64 | dB | MIN |
| Quiescent Current ($I_Q$) | $I_{OUT}$ = 0 | 1.1 | 1.4 | 1.6 | 1.75 | mA | MAX |
| Supply Current when Disabled | | 0.5 | 8 | 9 | 10 | μA | MAX |
| **DYNAMIC PERFORMANCE** | | | | | | | |
| Gain-Bandwidth Product (GBP) | $R_L$ = 10kΩ | 11 | | | | MHz | TYP |
| Phase Margin ($\varphi_O$) | | 62 | | | | ° | TYP |
| Full Power Bandwidth ($BW_P$) | < 1% distortion | 400 | | | | kHz | TYP |
| Slew Rate (SR) | G = 1, 2V output step | 8.5 | | | | V/μs | TYP |
| Settling Time to 0.1% ($t_S$) | G = 1, 2V output step | 0.21 | | | | μs | TYP |
| Overload Recovery Time | $V_{IN}$ × Gain = $V_S$ | 0.6 | | | | μs | TYP |
| **NOISE PERFORMANCE** | | | | | | | |
| Voltage Noise Density ($e_n$) | f = 1kHz | 12.5 | | | | nV/$\sqrt{Hz}$ | TYP |
| | f = 10kHz | 8.5 | | | | nV/$\sqrt{Hz}$ | TYP |

## ELECTRICAL CHARACTERISTICS

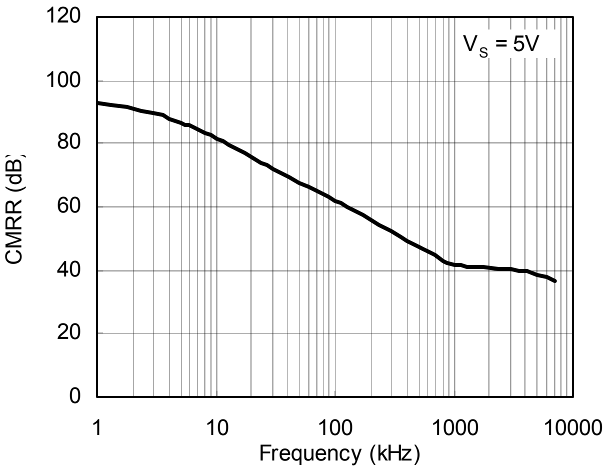
(At $T_A$ = +25℃, $V_S$ = +2.1V, $V_{CM}$ = $V_S$/2, $R_L$ = 600Ω, unless otherwise noted.)

| PARAMETER | CONDITIONS | SGM8603 | | | | | |
|---|---|---|---|---|---|---|---|
| | | TYP | MIN/MAX OVER TEMPERATURE | | | | |
| | | +25℃ | +25℃ | -40℃ to 85℃ | -40℃ to 125℃ | UNITS | MIN/ MAX |
| **INPUT CHARACTERISTICS** | | | | | | | |
| Input Offset Voltage ($V_{OS}$) | | 1 | 5.2 | 5.5 | 5.6 | mV | MAX |
| Input Bias Current ($I_B$) | | 1 | | | | pA | TYP |
| Input Offset Current ($I_{OS}$) | | 1 | | | | pA | TYP |
| Input Common Mode Voltage Range ($V_{CM}$) | $V_S$ = 2.1V | -0.1 to +2.2 | | | | V | TYP |
| Common Mode Rejection Ratio (CMRR) | $V_S$ = 2.1V, $V_{CM}$ = - 0.1V to 0.6V | 77 | 60 | 59 | 51 | dB | MIN |
| | $V_S$ = 2.1V, $V_{CM}$ = - 0.1V to 2.2V | 70 | 55 | 53 | 49 | dB | MIN |
| Open-Loop Voltage Gain ($A_{OL}$) | $R_L$ = 600Ω ,$V_O$ = 0.15V to 1.95V | 88 | 78 | 68 | 58 | dB | MIN |
| | $R_L$ = 10kΩ ,$V_O$ = 0.05V to 2.05V | 100 | 89 | 82 | 67 | dB | MIN |
| Input Offset Voltage Drift ($\Delta V_{OS}/\Delta_T$) | | 2.9 | | | | μV/℃ | TYP |
| **OUTPUT CHARACTERISTICS** | | | | | | | |
| Output Voltage Swing from Rail | $R_L$ = 600Ω | 38 | 50 | 59 | 66 | mV | MAX |
| | $R_L$ = 10kΩ | 4 | 9 | 11 | 12 | mV | MAX |
| Output Current ($I_{OUT}$) | | 28 | 23 | 17 | 14 | mA | MIN |
| Closed-Loop Output Impedance | f = 1MHz, G = 1 | 9.3 | | | | Ω | TYP |
| **POWER-DOWN DISABLE** | | | | | | | |
| Turn-On Time | | 7.7 | | | | μs | TYP |
| Turn-Off Time | | 0.5 | | | | μs | TYP |
| $\overline{DISABLE}$ Voltage-Off | | | 0.4 | | | V | MAX |
| $\overline{DISABLE}$ Voltage-On | | | 1.8 | | | V | MIN |
| **POWER SUPPLY** | | | | | | | |
| Quiescent Current ($I_Q$) | $I_{OUT}$ = 0 | 1.1 | 1.4 | 1.6 | 1.75 | mA | MAX |
| Supply Current when Disabled | | 0.5 | 8 | 9 | 10 | μA | MAX |
| **DYNAMIC PERFORMANCE** | | | | | | | |
| Gain-Bandwidth Product (GBP) | $R_L$ = 10kΩ | 11.5 | | | | MHz | TYP |
| Phase Margin ($\varphi_O$) | | 59 | | | | ° | TYP |
| Full Power Bandwidth ($BW_P$) | < 1% distortion | 400 | | | | kHz | TYP |
| Slew Rate (SR) | G = 1, 2V output step | 8 | | | | V/μs | TYP |
| Settling Time to 0.1% ($t_S$) | G = 1, 2V output step | 0.23 | | | | μs | TYP |
| Overload Recovery Time | $V_{IN}$ × Gain = $V_S$ | 1 | | | | μs | TYP |
| **NOISE PERFORMANCE** | | | | | | | |
| Voltage Noise Density ($e_n$) | f = 1kHz | 15 | | | | nV/ $\sqrt{Hz}$ | TYP |
| | f = 10kHz | 9 | | | | nV/ $\sqrt{Hz}$ | TYP |

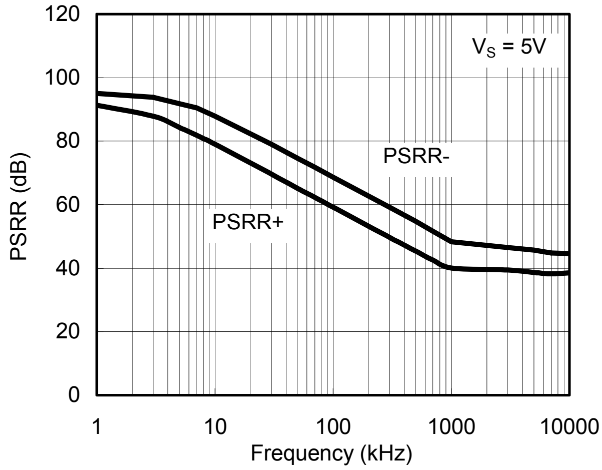
## TYPICAL PERFORMANCE CHARACTERISTICS

At $T_A$ = +25℃, $V_{CM}$ = Vs/2, $R_L$ = 600Ω, unless otherwise noted.

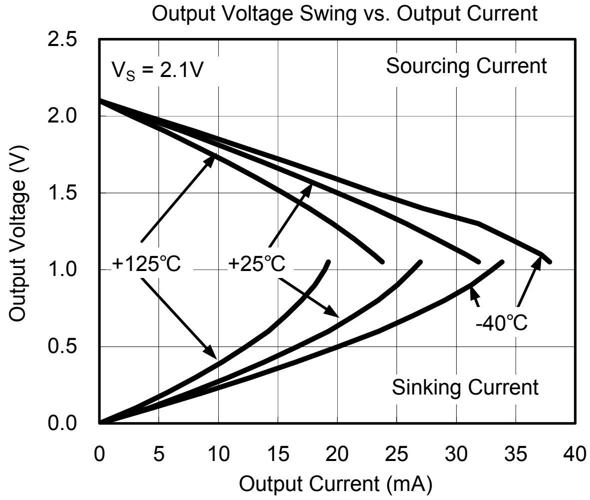
CMRR vs. Frequency



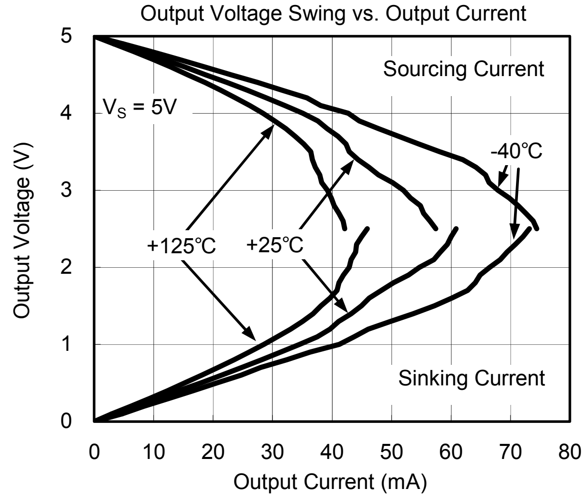

PSRR vs. Frequency



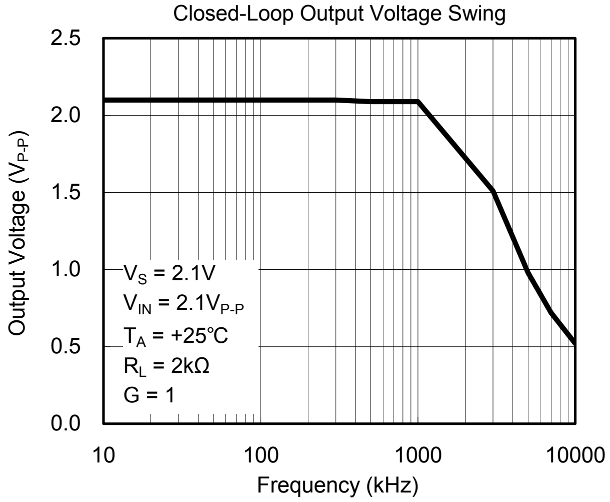

Output Voltage Swing vs. Output Current



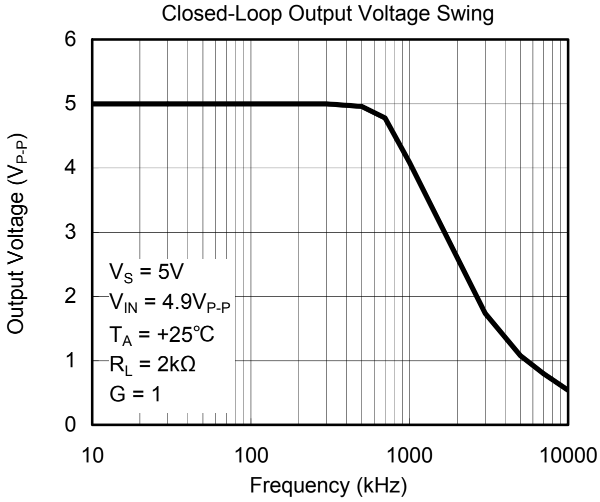

Output Voltage Swing vs. Output Current




Closed-Loop Output Voltage Swing

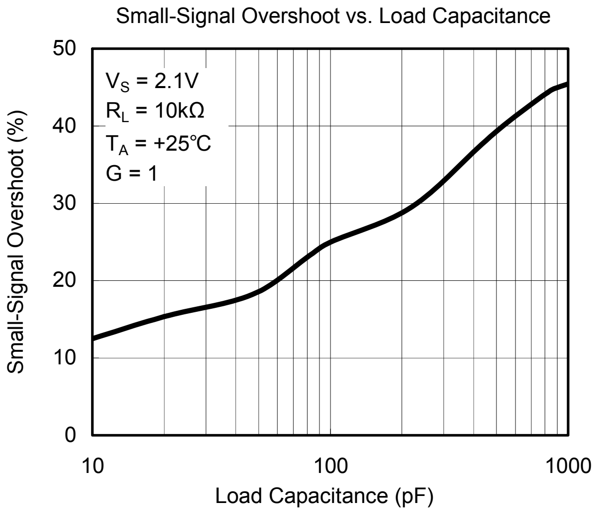


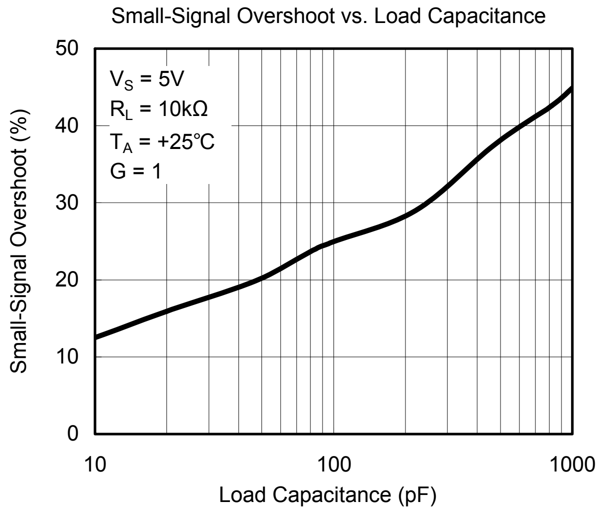

Closed-Loop Output Voltage Swing

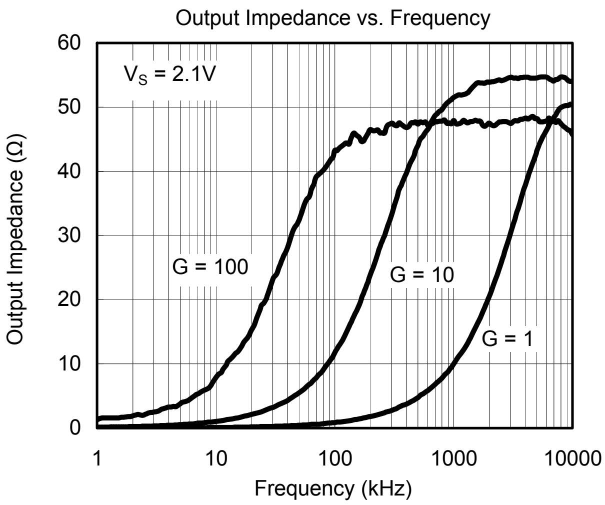


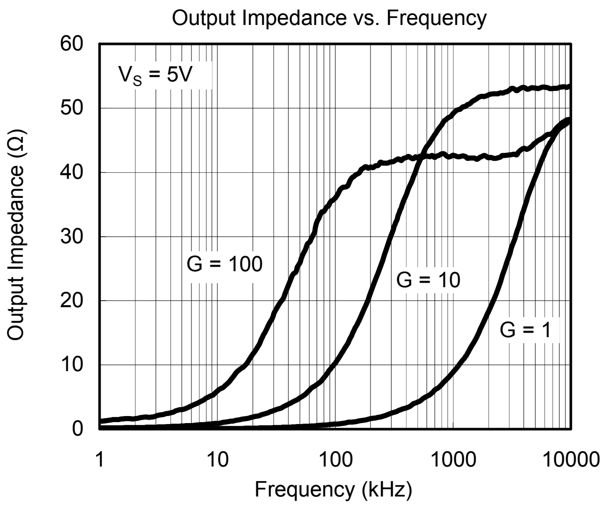
## TYPICAL PERFORMANCE CHARACTERISTICS

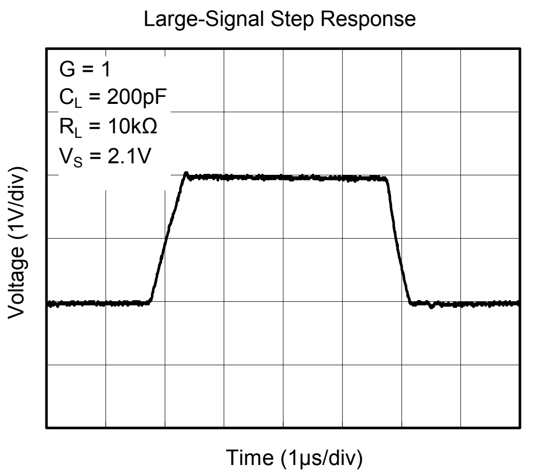
At $T_A$ = +25°C, $V_{CM}$ = $V_S$/2, $R_L$ = 600Ω, unless otherwise noted.

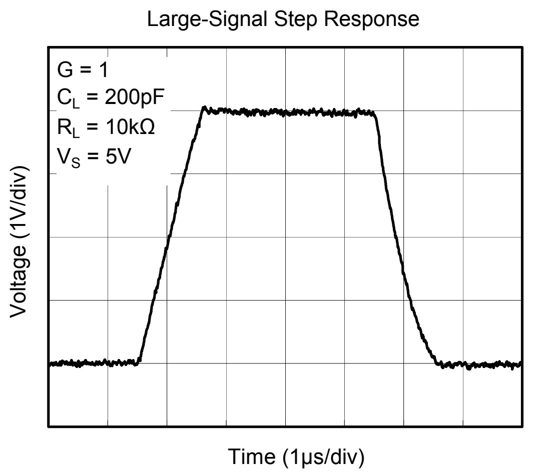


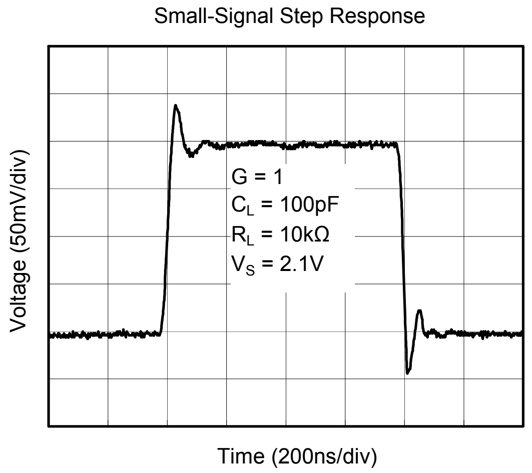



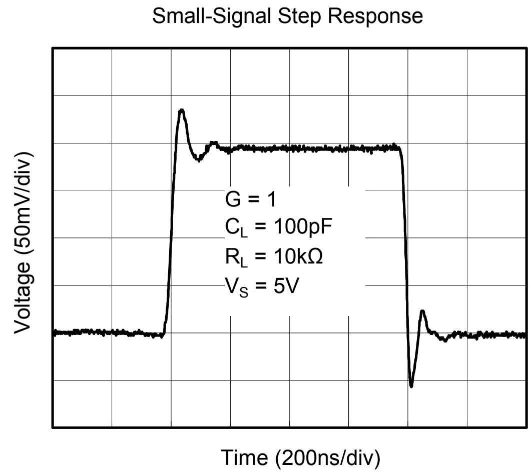



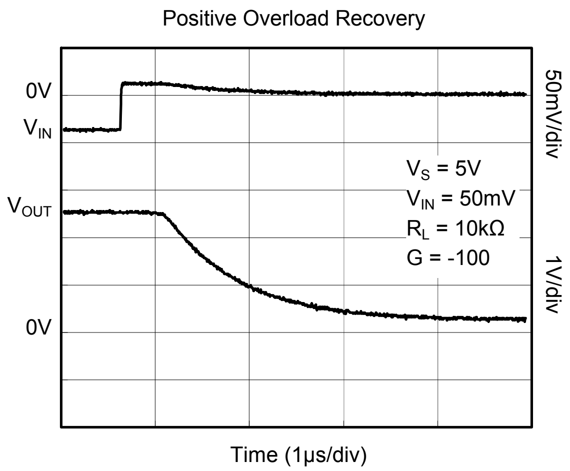



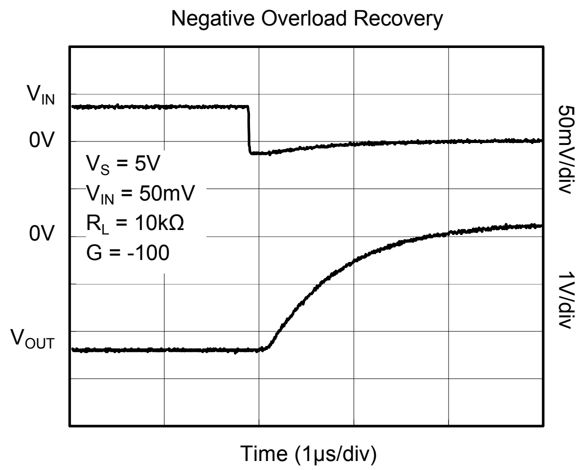
## TYPICAL PERFORMANCE CHARACTERISTICS

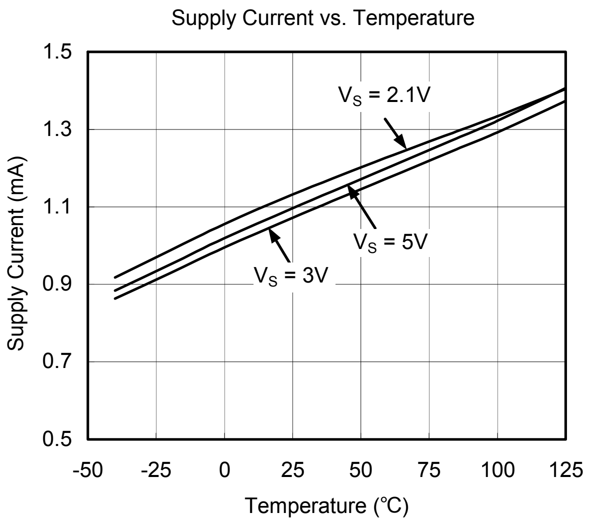
At $T_A$ = +25℃, $V_{CM}$ = $V_S$/2, $R_L$ = 600Ω, unless otherwise noted.

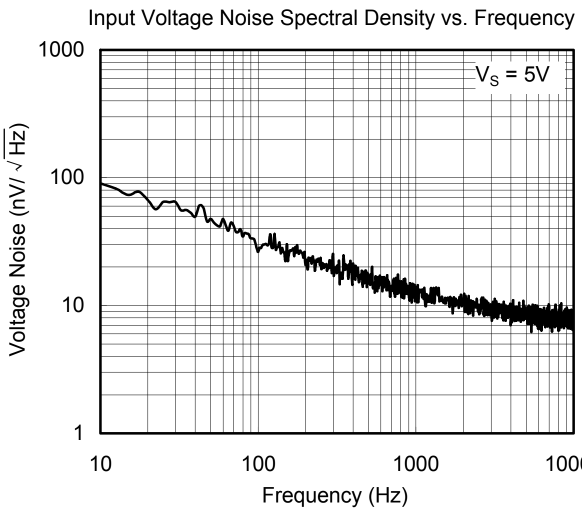


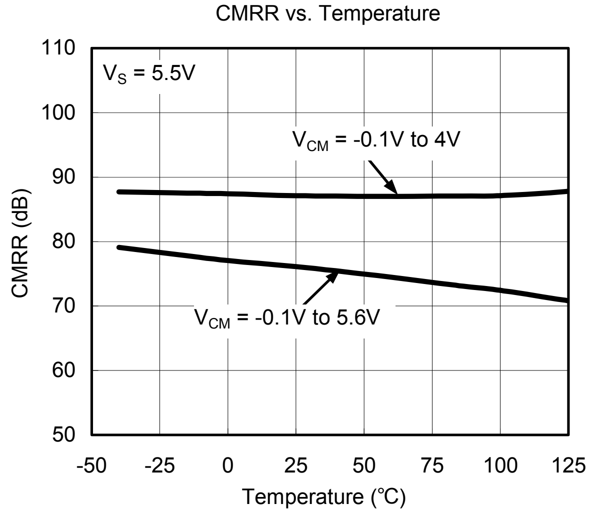



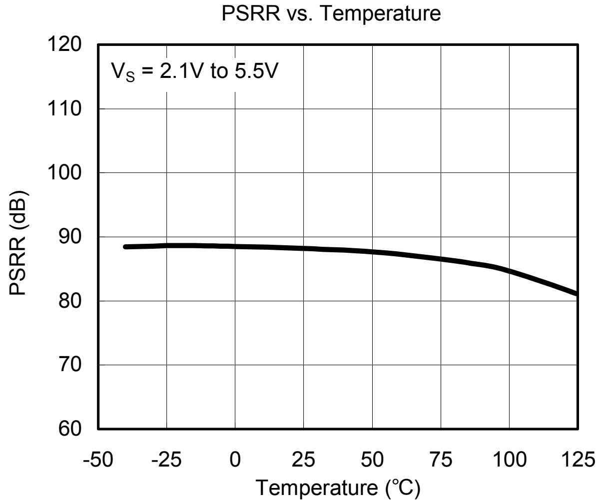



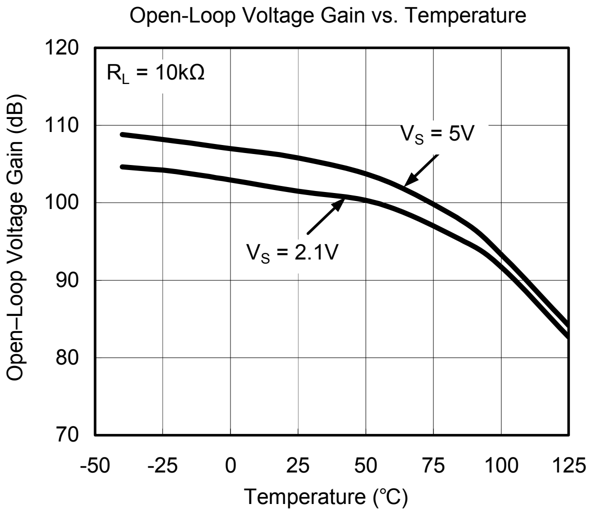



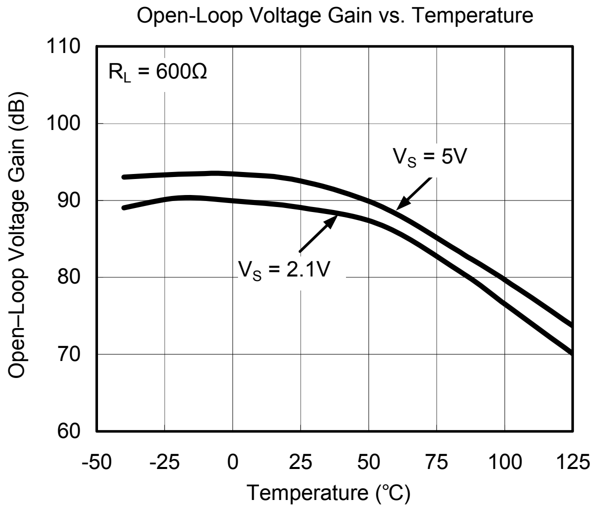
## TYPICAL PERFORMANCE CHARACTERISTICS

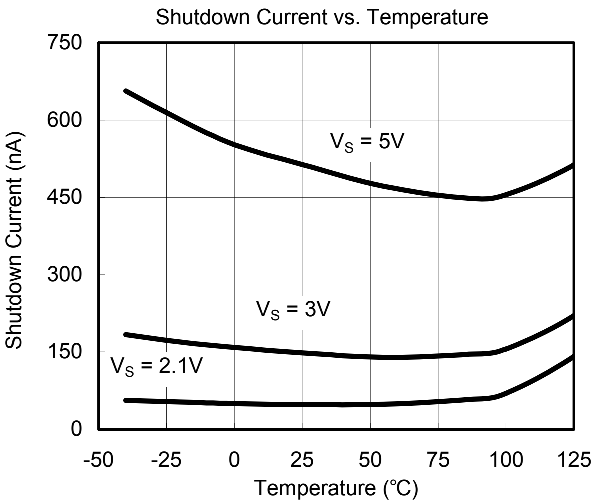
At $T_A$ = +25℃, $V_{CM}$ = $V_S$/2, $R_L$ = 600Ω, unless otherwise noted.

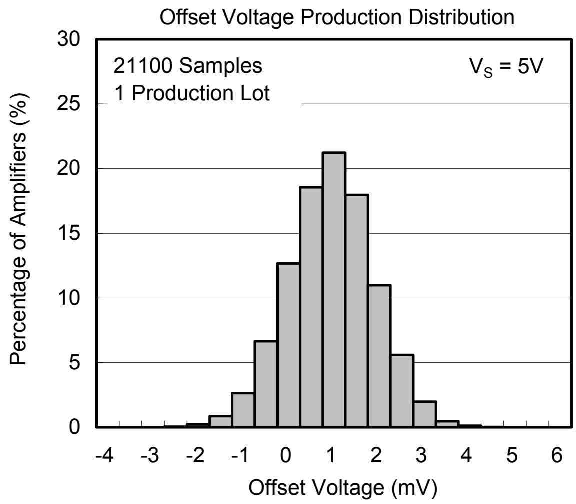


# APPLICATION INFORMATION

## Driving Capacitive Loads

The SGM8603 can directly drive 4700pF in unity-gain without oscillation. The unity-gain follower (buffer) is the most sensitive configuration to capacitive loading. Direct capacitive loading reduces the phase margin of amplifiers and this results in ringing or even oscillation. Applications that require greater capacitive driving capability should use an isolation resistor between the output and the capacitive load like the circuit in Figure 1. The isolation resistor $R_{ISO}$ and the load capacitor $C_L$ form a zero to increase stability. The bigger the $R_{ISO}$ resistor value, the more stable $V_{OUT}$ will be. Note that this method results in a loss of gain accuracy because $R_{ISO}$ forms a voltage divider with the $R_{LOAD}$.

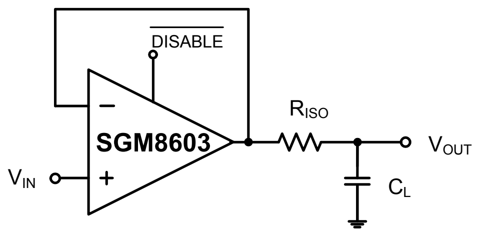



**Figure 1. Indirectly Driving Heavy Capacitive Load**

An improved circuit is shown Figure 2. It provides DC accuracy as well as AC stability. $R_F$ provides the DC accuracy by connecting the inverting input with the output. $C_F$ and $R_{ISO}$ serve to counteract the loss of phase margin by feeding the high frequency component of the output signal back to the amplifier's inverting input, thereby preserving phase margin in the overall feedback loop.

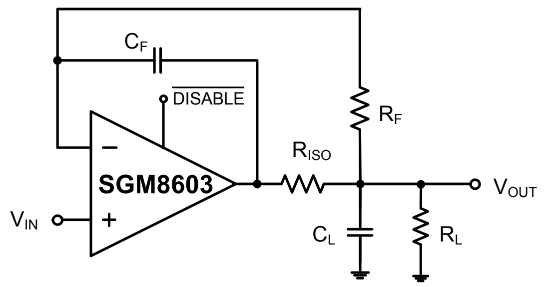



**Figure 2. Indirectly Driving Heavy Capacitive Load with DC Accuracy**

For non-buffer configuration, there are two other ways to increase the phase margin: (a) by increasing the amplifier's closed-loop gain or (b) by placing a capacitor in parallel with the feedback resistor to counteract the parasitic capacitance associated with inverting node.

## Power-Supply Bypassing and Layout

The SGM8603 operates from either a single +2.1V to +5.5V supply or dual ±1.05V to ±2.75V supplies. For single-supply operation, bypass the power supply $+V_S$ with a 0.1μF ceramic capacitor which should be placed close to the $+V_S$ pin. For dual-supply operation, both the $+V_S$ and the $-V_S$ supplies should be bypassed to ground with separate 0.1μF ceramic capacitors. 2.2μF tantalum capacitor can be added for better performance.

Good PC board layout techniques optimize performance by decreasing the amount of stray capacitance at the op amp's inputs and output. To decrease stray capacitance, minimize trace lengths and widths by placing external components as close to the device as possible. Use surface-mount components whenever possible.

For the operational amplifier, soldering the part to the board directly is strongly recommended. Try to keep the high frequency current loop area small to minimize the EMI (electromagnetic interfacing).

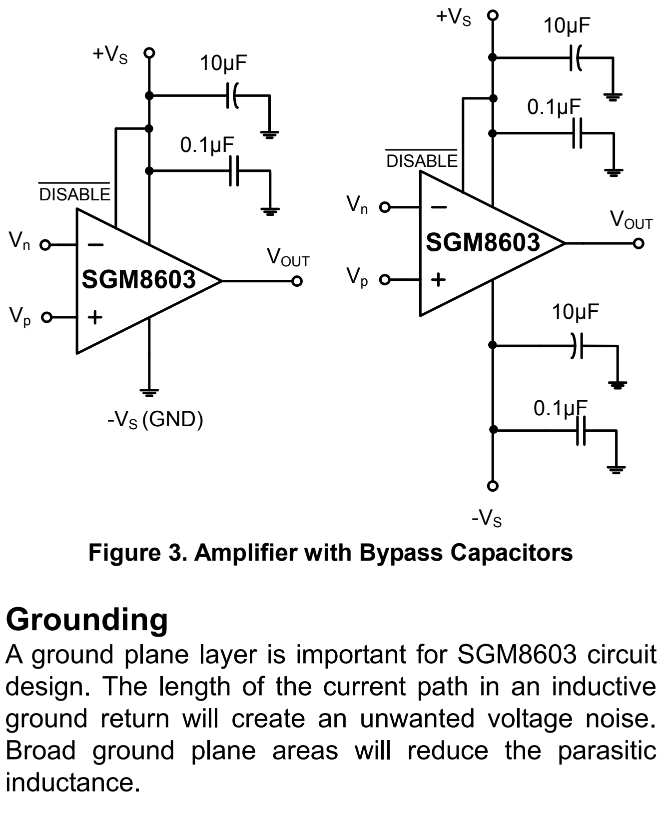



**Figure 3. Amplifier with Bypass Capacitors**

## Grounding

A ground plane layer is important for SGM8603 circuit design. The length of the current path in an inductive ground return will create an unwanted voltage noise. Broad ground plane areas will reduce the parasitic inductance.

## Input-to-Output Coupling

To minimize capacitive coupling, the input and output signal traces should not be in parallel. This helps reduce unwanted positive feedback.

## TYPICAL APPLICATION CIRCUITS

### Differential Amplifier

The circuit shown in Figure 4 performs the difference function. If the resistor ratios are equal ($R_4/R_3 = R_2/R_1$), then $V_{OUT} = (V_p - V_n) \times R_2/R_1 + V_{REF}$.

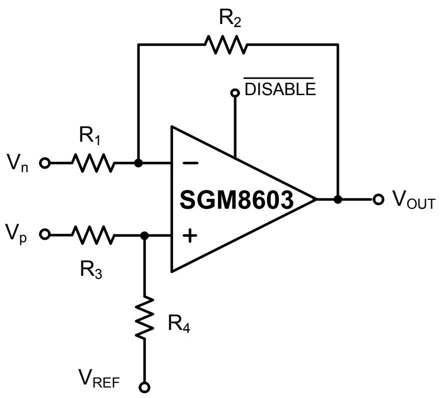



**Figure 4. Differential Amplifier**

### Instrumentation Amplifier

The circuit in Figure 5 performs the same function as that in Figure 4 but with a high input impedance.

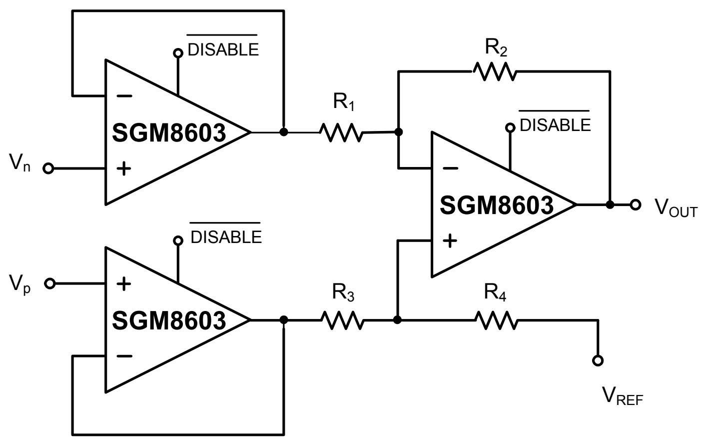



**Figure 5. Instrumentation Amplifier**

### Low-Pass Active Filter

The low-pass filter shown in Figure 6 has a DC gain of ($-R_2/R_1$) and the -3dB corner frequency is $1/2\pi R_2C$. Make sure the filter bandwidth is within the bandwidth of the amplifier. The large values of feedback resistors can couple with parasitic capacitance and cause undesired effects such as ringing or oscillation in high-speed amplifiers. Keep resistor values as low as possible and consistent with output loading consideration.

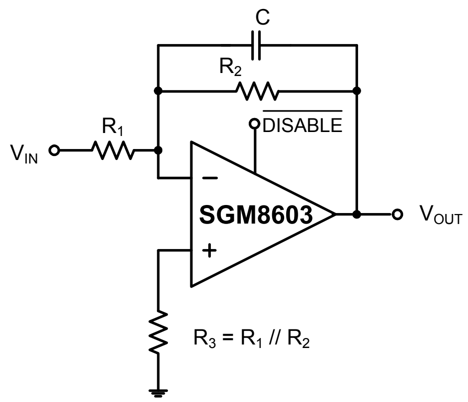
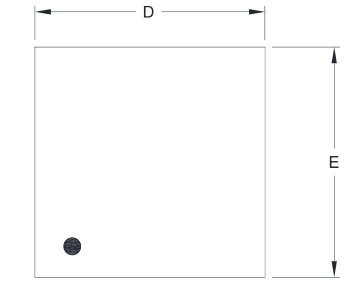


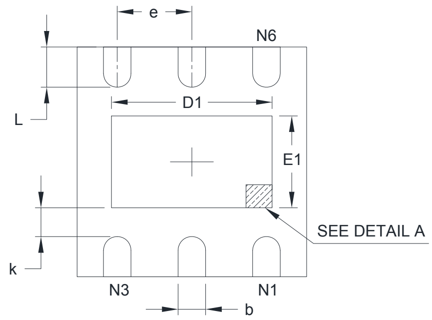

**Figure 6. Low-Pass Active Filter**

# PACKAGE OUTLINE DIMENSIONS

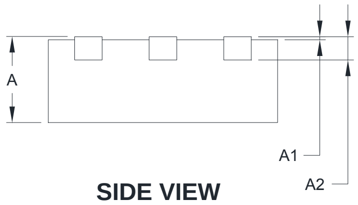
## TDFN-2×2-6L



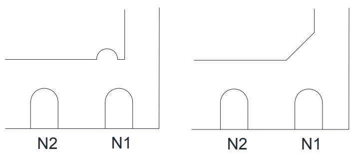

TOP VIEW




BOTTOM VIEW



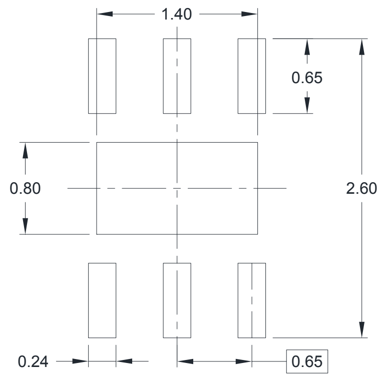

SIDE VIEW




DETAIL A

Pin #1 ID and Tie Bar Mark Options

NOTE: The configuration of the Pin #1 identifier is optional, but must be located within the zone indicated.

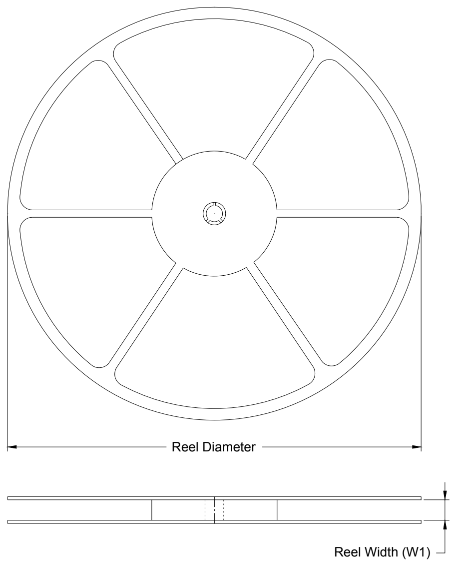



**RECOMMENDED LAND PATTERN** (Unit: mm)

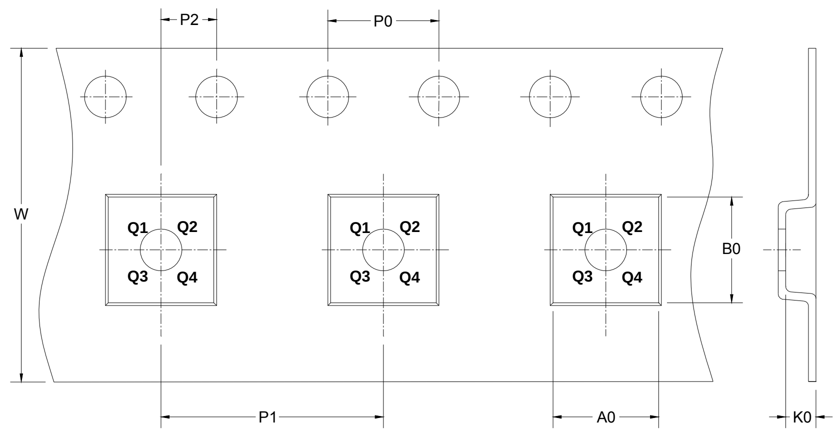
| Symbol | Dimensions In Millimeters | | Dimensions In Inches | |
|---|---|---|---|---|
| | MIN | MAX | MIN | MAX |
| A | 0.700 | 0.800 | 0.028 | 0.031 |
| A1 | 0.000 | 0.050 | 0.000 | 0.002 |
| A2 | 0.203 REF | | 0.008 REF | |
| D | 1.900 | 2.100 | 0.075 | 0.083 |
| D1 | 1.100 | 1.450 | 0.043 | 0.057 |
| E | 1.900 | 2.100 | 0.075 | 0.083 |
| E1 | 0.600 | 0.850 | 0.024 | 0.034 |
| k | 0.200 MIN | | 0.008 MIN | |
| b | 0.180 | 0.300 | 0.007 | 0.012 |
| e | 0.650 TYP | | 0.026 TYP | |
| L | 0.250 | 0.450 | 0.010 | 0.018 |

# 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 |
|---|---|---|---|---|---|---|---|---|---|---|
| TDFN-2×2-6L | 7″ | 9.5 | 2.30 | 2.30 | 1.10 | 4.00 | 4.00 | 2.00 | 8.00 | Q1 |

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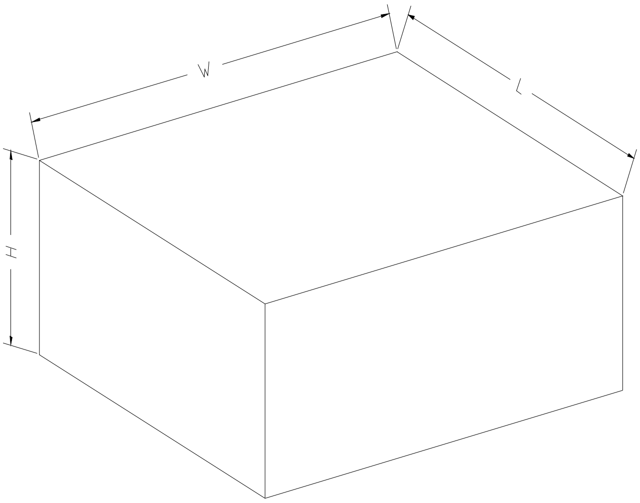
## CARTON BOX DIMENSIONS




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 |

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