SGM8188
Tiny Package, Nano-Power, Precision Current-Sense Amplifier

GENERAL DESCRIPTION

The SGM8188 series is a nano-power, high precision, high-side current-sense amplifier. The device consumes only 1.2μA (MAX) quiescent current. It features a 60μV (MAX) low offset voltage, which allows for 12-bit resolution at a very low 50mV full-scale current measurement. The device can sense the voltage across a current-sense resistor in a common mode voltage range from 1.6V to 28V. The SGM8188 series provides four fixed gains: 25V/V, 50V/V, 100V/V and 200V/V, which allows flexible selection of the external current-sense resistor.

The SGM8188 is available in a Green WLCSP-1×1-4B-A package. The tiny package makes the device an excellent choice for portable and battery-powered applications with limited size. The SGM8188 is rated over the -40℃ to +125℃ temperature range.

FEATURES

- **Ultra-Low Quiescent Current: 1.2μA (MAX)**
- **Input Common Mode Range: 1.6V to 28V**
- **Low Input Offset Voltage: 60μV (MAX)**
- **Choice of Gains:**
  - **SGM8188A0 Gain: 25V/V**
  - **SGM8188A1 Gain: 50V/V**
  - **SGM8188A2 Gain: 100V/V**
  - **SGM8188A3 Gain: 200V/V**
- **Low Gain Error: ±0.4% (MAX)**
- **Voltage Output**
- **-40℃ to +125℃ Operating Temperature Range**
- **Available in a Green WLCSP-1×1-4B-A Package**

APPLICATIONS

Portable Equipment
Battery-Powered Equipment
Mobile Phones
Laptops
Personal Digital Assistants
Power Management

TYPICAL APPLICATION

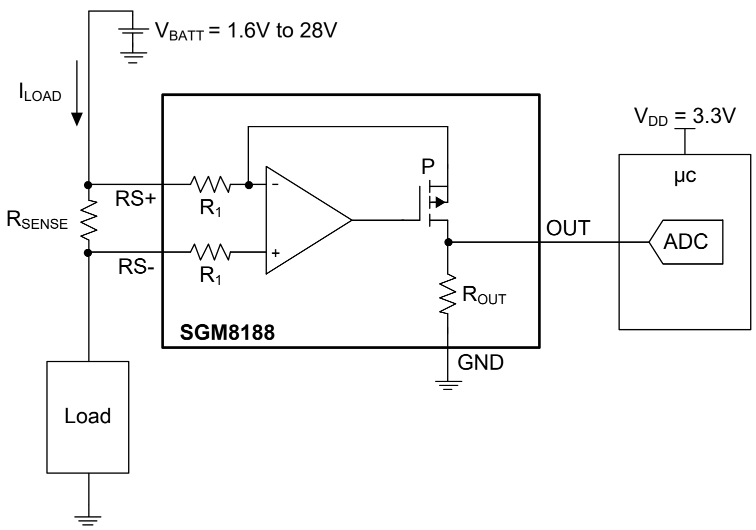


Figure 1. Typical Application Circuit

PACKAGE/ORDERING INFORMATION

MODEL	PACKAGE DESCRIPTION	SPECIFIED TEMPERATURE RANGE	ORDERING NUMBER	PACKAGE MARKING	PACKING OPTION
SGM8188A0 (Gain = 25V/V)	WLCSP-1×1-4B-A	-40℃ to +125℃	SGM8188A0XG/TR	01 XX	Tape and Reel, 3000
SGM8188A1 (Gain = 50V/V)	WLCSP-1×1-4B-A	-40℃ to +125℃	SGM8188A1XG/TR	02 XX	Tape and Reel, 3000
SGM8188A2 (Gain = 100V/V)	WLCSP-1×1-4B-A	-40℃ to +125℃	SGM8188A2XG/TR	00 XX	Tape and Reel, 3000
SGM8188A3 (Gain = 200V/V)	WLCSP-1×1-4B-A	-40℃ to +125℃	SGM8188A3XG/TR	03 XX	Tape and Reel, 3000

MARKING INFORMATION

NOTE: XX = Date Code.

YY — Serial Number
X X
Date Code - Week
Date Code - Year

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

RS+, RS- to GND.. -0.3V to +30V
OUT to GND .... -0.3V to +6V
RS+ to RS- ....±30V
Short-Circuit Duration, OUT to GND.................. Continuous
Continuous Input Current (Any Pin)............................±20mA
Package Thermal Resistance
WLCSP-1×1-4B-A, θ_{JA}.. 232℃/W
Junction Temperature...+150℃
Storage Temperature Range.......................-65℃ to +150℃
Lead Temperature (Soldering, 10s)............................+260℃
ESD Susceptibility
HBM..4000V
CDM..1000V

RECOMMENDED OPERATING CONDITIONS

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

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

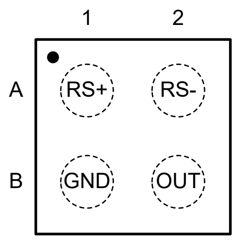
This integrated circuit can be damaged if ESD protections are not considered carefully. SGMICRO recommends that all integrated circuits be handled with appropriate precautions. Failure to observe proper handling and installation procedures can cause damage. ESD damage can range from subtle performance 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)



WLCSP-1×1-4B-A

PIN DESCRIPTION

PIN	NAME	FUNCTION
A1	RS+	Power-Side Pin for the Sense Resistor.
A2	RS-	Load-Side Pin for the Sense Resistor.
B1	GND	Ground.
B2	OUT	Output Voltage. V_{OUT} and $V_{SENSE} = V_{RS+} - V_{RS-}$ are in direct proportion.

ELECTRICAL CHARACTERISTICS

($V_{RS+} = V_{RS-} = 3.6V$, $V_{SENSE} = (V_{RS+} - V_{RS-}) = 0V$, Full = -40℃ to +125℃, typical values are at T_A = +25℃, unless otherwise noted.)

PARAMETER	SYMBOL	CONDITIONS	TEMP	MIN	TYP	MAX	UNITS
Input Characteristics							
Input Offset Voltage [1]	V_{OS}		+25℃		10	60	μV
			Full			160	
Input Common Mode Voltage Range	V_{CM}	Guaranteed by CMRR	+25℃	1.6		28	V
		Guaranteed by CMRR	Full	1.8		28	
Common Mode Rejection Ratio	CMRR	$1.6V < V_{RS+} < 28V$	+25℃	106	120		dB
		$1.8V < V_{RS+} < 28V$	Full	100			
Output Characteristics							
Gain	G	SGM8188A0	+25℃		25		V/V
		SGM8188A1	+25℃		50		
		SGM8188A2	+25℃		100		
		SGM8188A3	+25℃		200		
Gain Error [2]	GE		+25℃		±0.15	±0.4	%
			Full			±0.6	
Output Resistance [3]	R_{OUT}	SGM8188A0/SGM8188A1/SGM8188A2	Full	7	10	13	kΩ
		SGM8188A3	Full	15.5	20	24	
Low Output Voltage	V_{OL}	SGM8188A0	Full		0.5	5	mV
		SGM8188A1	Full		0.5	6	
		SGM8188A2	Full		1	12	
		SGM8188A3	Full		2	25	
High Output Voltage [4]	V_{OH}	$V_{OH} = V_{RS-} - V_{OUT}$, SGM8188A0/ SGM8188A1/ SGM8188A2	Full		0.14	0.35	V
		$V_{OH} = V_{RS-} - V_{OUT}$, SGM8188A3	Full		0.07	0.2	

NOTES:

1. V_{OS} is inferred from the measured value of gain error test.
2. Gain error is the difference between the ideal gain and the gain obtained by calculating two V_{SENSE} measured values.
   G = 25V/V, V_{SENSE} = 20mV and 120mV.
   G = 50V/V, V_{SENSE} = 10mV and 60mV.
   G = 100V/V, V_{SENSE} = 5mV and 30mV.
   G = 200V/V, V_{SENSE} = 2.5mV and 15mV.
3. The device can keep stable with all external capacitance values.
4. V_{OH} is defined as the voltage difference between V_{RS-} and V_{OUT} with V_{SENSE} = 3.6V/gain.

ELECTRICAL CHARACTERISTICS (continued)

(V_{RS+} = V_{RS-} = 3.6V, V_{SENSE} = (V_{RS+} - V_{RS-}) = 0V, Full = -40℃ to +125℃, typical values are at T_A = +25℃, unless otherwise noted.)

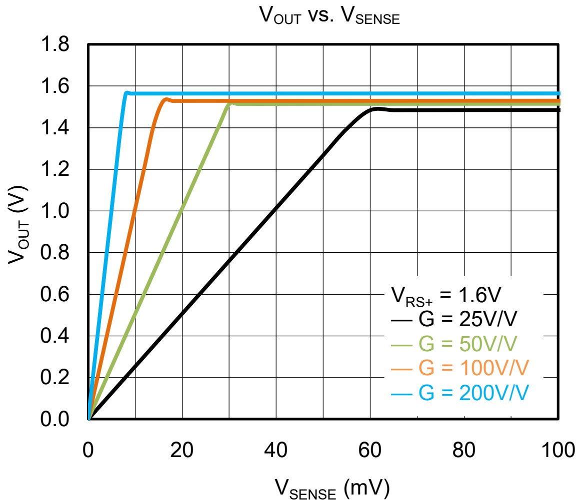
PARAMETER	SYMBOL	CONDITIONS	TEMP	MIN	TYP	MAX	UNITS
Dynamic Performance							
Small-Signal Bandwidth (1)	BW	V_{SENSE} = 100mV, SGM8188A0	+25℃		280		kHz
		V_{SENSE} = 50mV, SGM8188A1	+25℃		220		
		V_{SENSE} = 25mV, SGM8188A2	+25℃		160		
		V_{SENSE} = 12.5mV, SGM8188A3	+25℃		125		
Output Settling Time	t_S	1% final value, V_{SENSE} = 100mV	+25℃		10		μs
		1% final value, V_{SENSE} = 50mV	+25℃		20		
		1% final value, V_{SENSE} = 25mV	+25℃		20		
		1% final value, V_{SENSE} = 12.5mV	+25℃		20		
Overload Recovery Time (2)	t_{RC}	1% final value, V_{SENSE} from 3.6V/gain to 0.5V/gain	+25℃		300		μs
Input-Referred Voltage Noise	e_n		+25℃		275		$nV/\sqrt{Hz}$
Power Supply							
Supply Current (3)	I_{CC}	1.6V < V_{RS+} < 28V	+25℃		0.85	1.2	μA
		1.8V < V_{RS+} < 28V	Full			2.2	

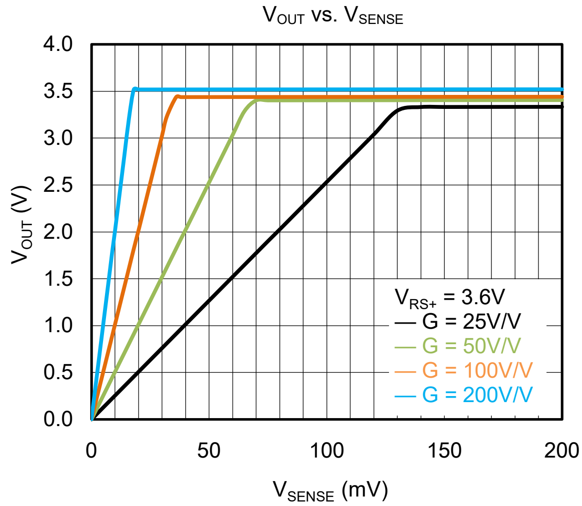
NOTES:

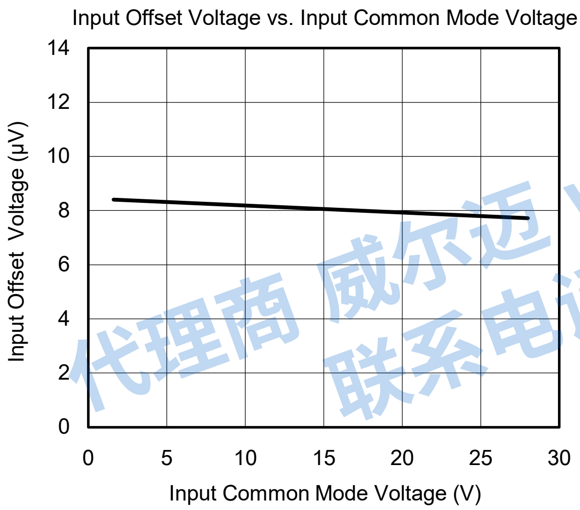
1. The device can keep stable with all external capacitance values.
2. Overload recovery is measured by applying V_{SENSE} equal to 3.6V/gain, then transitioning to 0.5V/gain, and waiting for V_{OUT} to settle within 1% of the final value.
3. I_{CC} is defined as the total current of I_{RS+} and I_{RS-} when V_{OUT} = 0V.

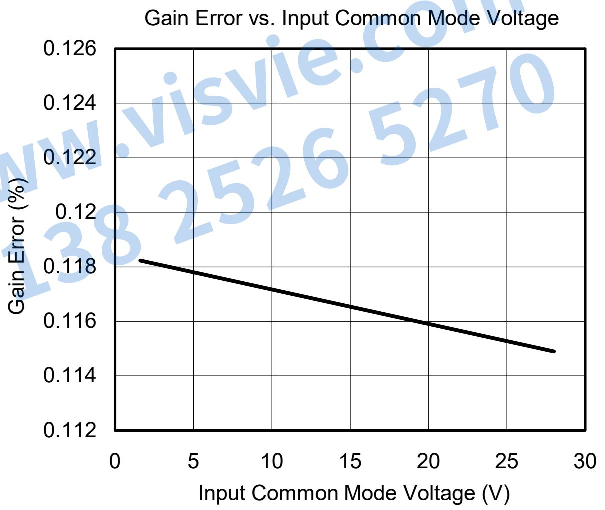
TYPICAL PERFORMANCE CHARACTERISTICS

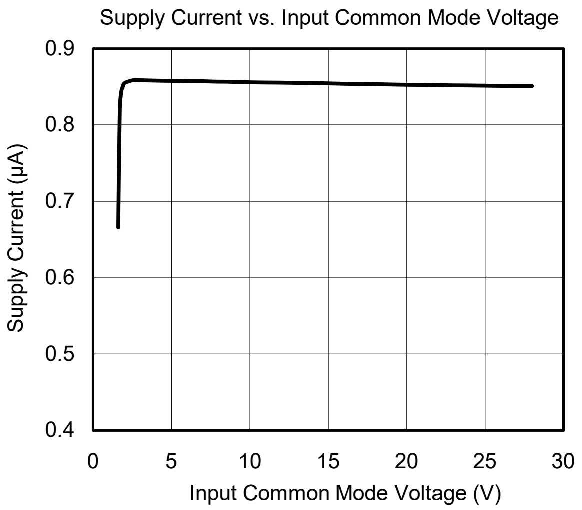
At T_A = +25℃, V_{RS+} = V_{RS-} = 3.6V, unless otherwise noted.

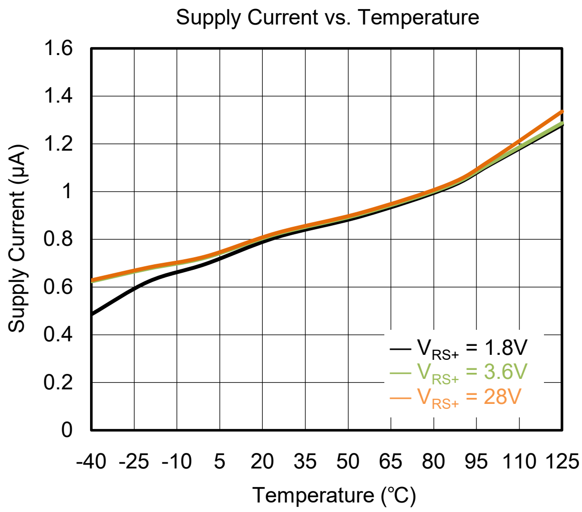








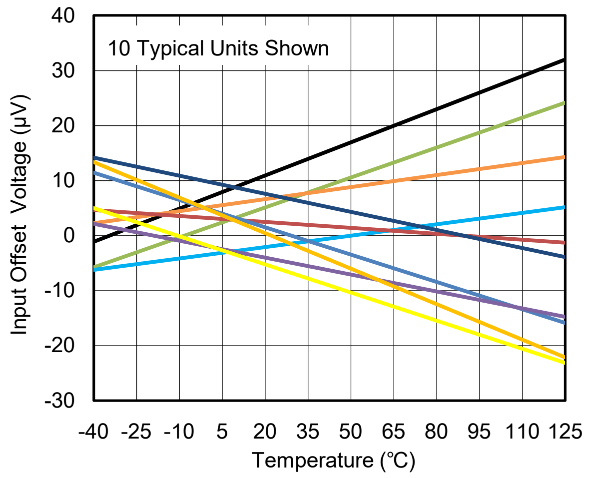




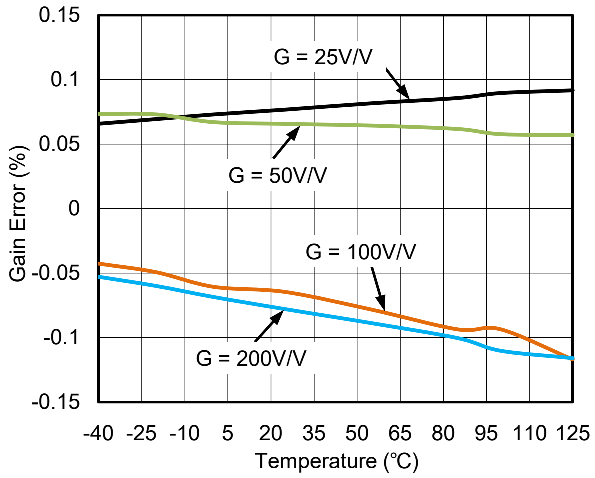
TYPICAL PERFORMANCE CHARACTERISTICS (continued)

At T_A = +25℃, V_{RS+} = V_{RS-} = 3.6V, unless otherwise noted.

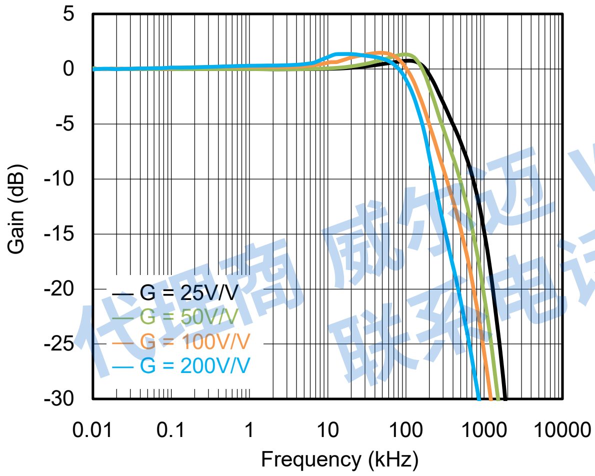
Input Offset Voltage vs. Temperature



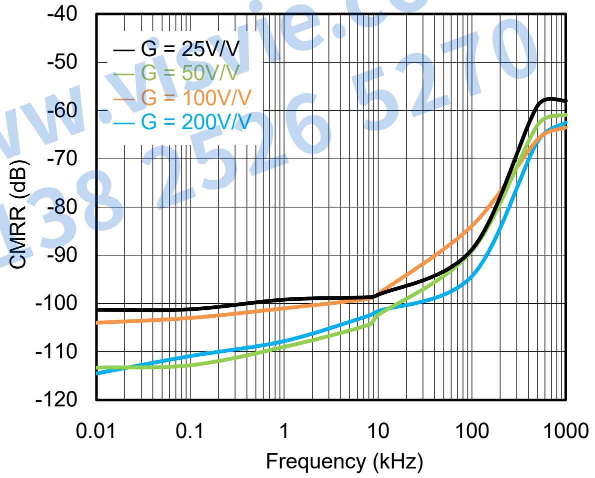
Gain Error vs. Temperature



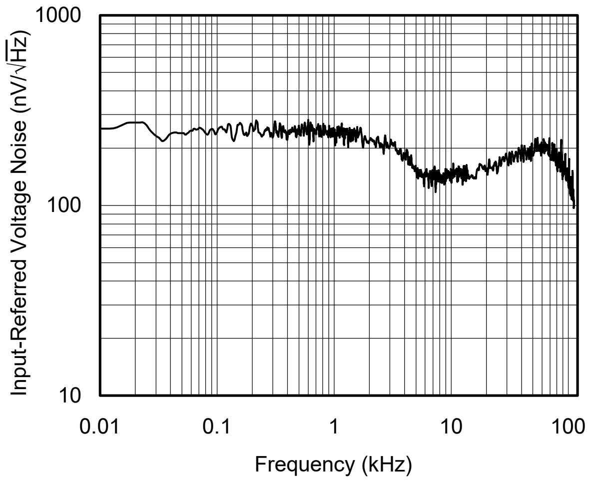
Small-Signal Gain vs. Frequency



CMRR vs. Frequency



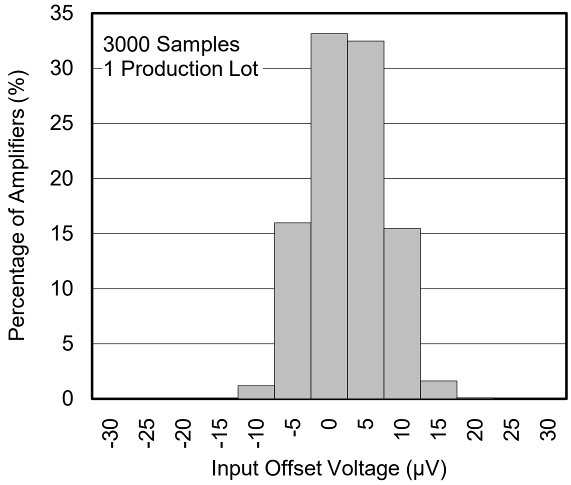
Input-Referred Voltage Noise vs. Frequency



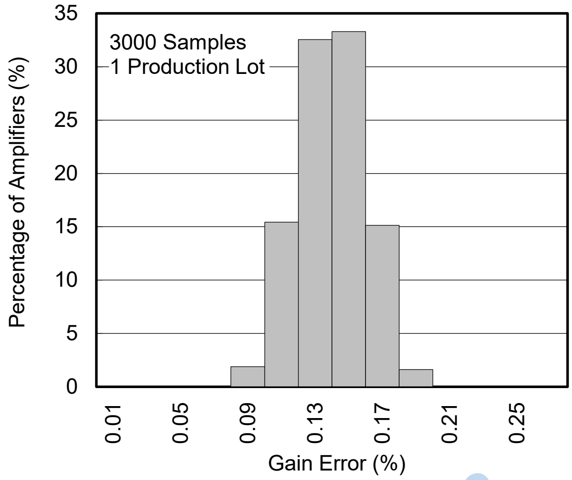
TYPICAL PERFORMANCE CHARACTERISTICS (continued)

At T_A = +25℃, V_{RS+} = V_{RS-} = 3.6V, unless otherwise noted.

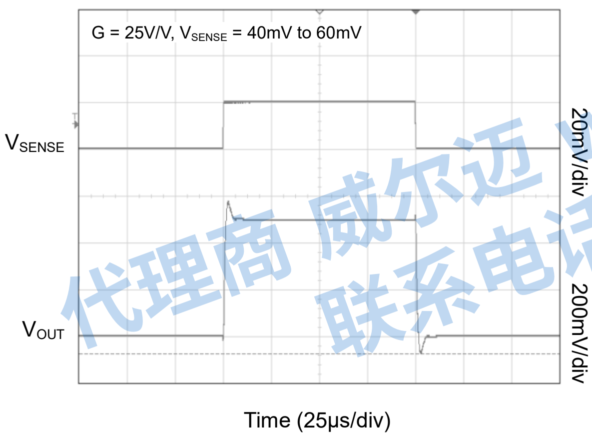
Input Offset Voltage Production Distribution



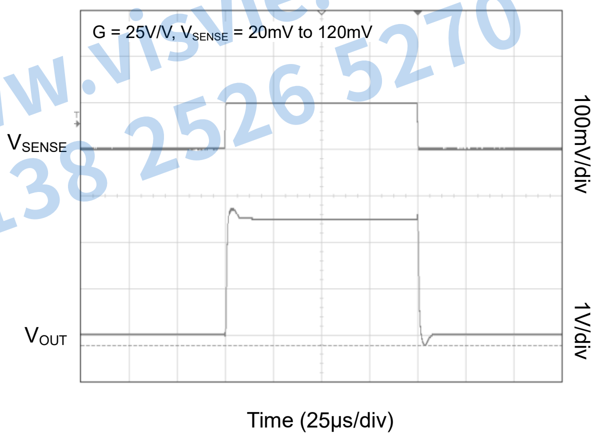
Gain Error Production Distribution



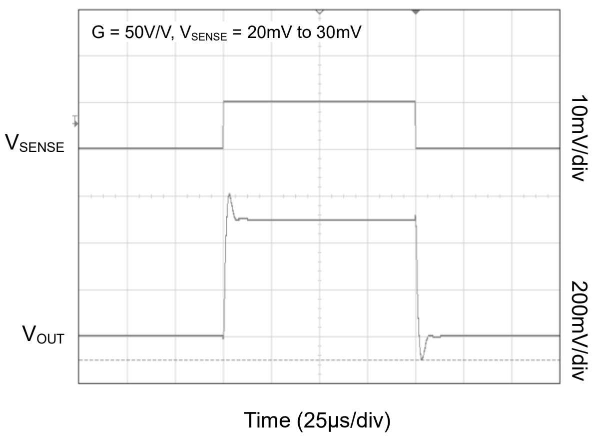
Step Response



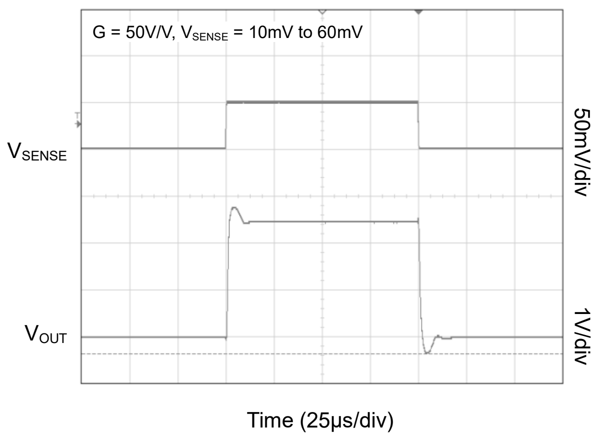
Step Response



Step Response



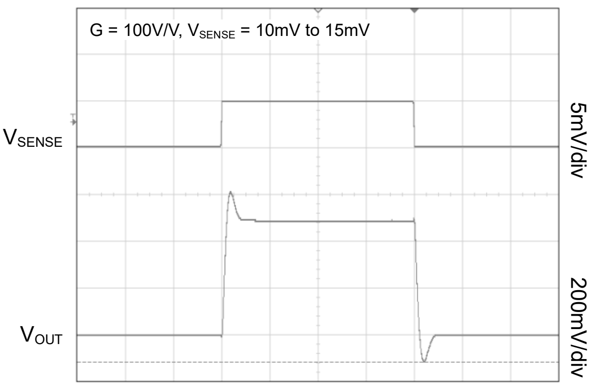
Step Response



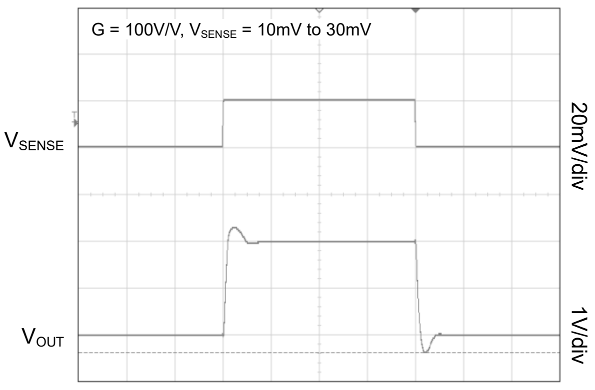
TYPICAL PERFORMANCE CHARACTERISTICS (continued)

At T_A = +25℃, V_{RS+} = V_{RS-} = 3.6V, unless otherwise noted.

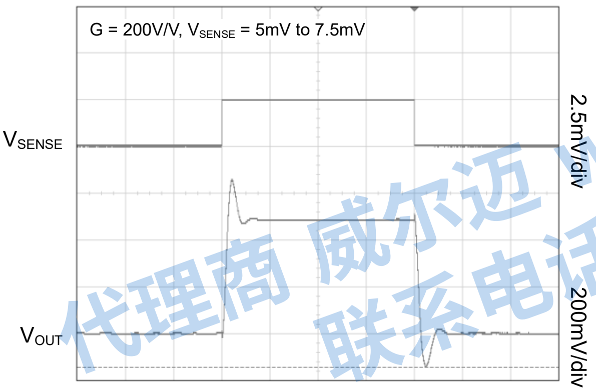
Step Response



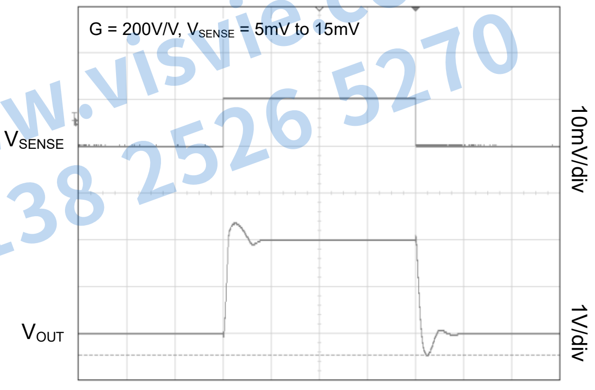
Step Response



Step Response



Step Response



FUNCTIONAL BLOCK DIAGRAM

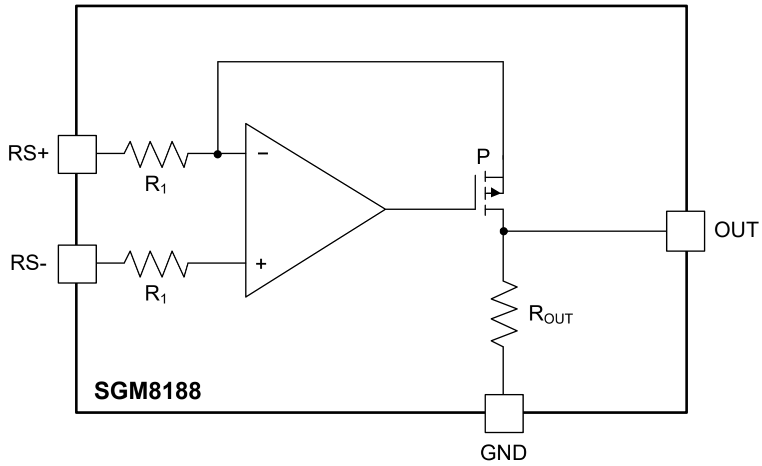


Figure 2. Block Diagram

DETAILED DESCRIPTION

The SGM8188 is a unidirectional high-side current-sense monitor with an input common mode range from 1.6V to 28V. This common mode voltage range allows measuring of a 1.8V battery system. The load current that flows through the external resistor R_{SENSE} generates a corresponding sense voltage that is amplified by the current-sense monitor.

The internal amplifier will force the load current through the resistor R_1 such that the voltage dropping over R_1 is equal to the sense voltage across the external resistor. To minimize the offset voltage, there is also a resistor connecting to the positive input of the internal operational amplifier. The PMOS, which is integrated inside the device, forces the current through R_1 to also flow through R_{OUT}, such that V_{OUT} is equal to $I_{LOAD} \times R_{SENSE} \times R_{OUT}/R_1$. Therefore, the two resistors R_1 and R_{OUT} will determine the gain, which is 25V/V for the SGM8188A0, 50V/V for the SGM8188A1, 100V/V for the SGM8188A2 and 200V/V for the SGM8188A3 (see Table 1). The output current-limit and a 6V clamp protection circuit are used for protecting the output from input overdrive.

Table 1. Internal Gain-Setting Resistors (Typical Values)

Device	Gain (V/V)	R_1 (Ω)	R_{OUT} (kΩ)
SGM8188A0	25	400	10
SGM8188A1	50	200	10
SGM8188A2	100	100	10
SGM8188A3	200	100	20

APPLICATIONS INFORMATION

Choosing the Sense Resistor

The sense resistor should be selected by the following steps.

R_{SENSE} Voltage Loss

Due to Ohm's Law, the voltage drop across R_{SENSE} will be increased if the customer prefers higher R_{SENSE}. However, for obtaining the minimum voltage drop, the lowest R_{SENSE} should be taken into account.

OUT Swing vs. V_{RS+} and V_{SENSE}

The SGM8188 is powered through its RS+ pin, which means that there is no supply voltage pin. Therefore, the maximum output swing value is limited by the minimum voltage level of RS+.

$$V_{OUT(MAX)} = V_{RS+(MIN)} - V_{SENSE(MAX)} - V_{OH} \qquad (1)$$

$$R_{SENSE} = \frac{V_{OUT(MAX)}}{G \times I_{LOAD(MAX)}} \qquad (2)$$

Moreover, when the SGM8188 is powered by a 3.6V power supply, the largest dynamic range will be achieved if R_{SENSE} is chosen such that the maximum V_{SENSE} voltage is 30mV (gain of 100V/V).

Accuracy

Within the linear region of the SGM8188 ($V_{OUT} < V_{OUT(MAX)}$), the input offset voltage and the gain error are the two main issues that affect the accuracy of the output voltage. For the SGM8188, the maximum offset voltage (V_{OS}) is 60μV and the maximum gain error (GE) is ±0.4%. The following equation illustrates the actual output voltage according to the gain error and offset voltage:

$$V_{OUT} = (G \pm GE) \times V_{SENSE} \pm (G \times V_{OS}) \qquad (3)$$

It is recommended to use a larger R_{SENSE} when measuring a small load current, as this minimizes the effect of the input offset voltage on the output error.

Efficiency and Power Dissipation

If the current level is increasing, the I^2R loss will be increased. So the trade-off between power dissipation and the value of resistor is significant. In addition, the resistance will be changed if the corresponding temperature is higher due to the power dissipation. The SGM8188 allows using lower external resistor so that the power dissipation and the hot spots are decreased dramatically.

Kelvin Connections

The current flowing through the R_{SENSE} will be significantly high, so that the external voltage drop caused by the PCB trace should also be considered. Use the sense resistor with four terminals or use Kelvin connections.

Optional Output Filter Capacitor

For the sample and hold stage in the ADC, the sampling capacitor would instantly load the output of the SGM8188 and thusly the output voltage will be decreased. If the sampling time of the ADC is short (less than 1μs), the ceramic capacitor will keep the output voltage stable. Also, the small-signal bandwidth and the corresponding noise are also reduced by using an additional capacitor at the output stage of the SGM8188.

APPLICATIONS INFORMATION (continued)

Using the SGM8188 in Bidirectional Application

For the applications which are powered by battery, the bidirectional measurement is required as the customer needs to know the charging and discharging current of the battery. The following circuit provides an accuracy measurement for charging and discharging current, which is shown in Figure 3.

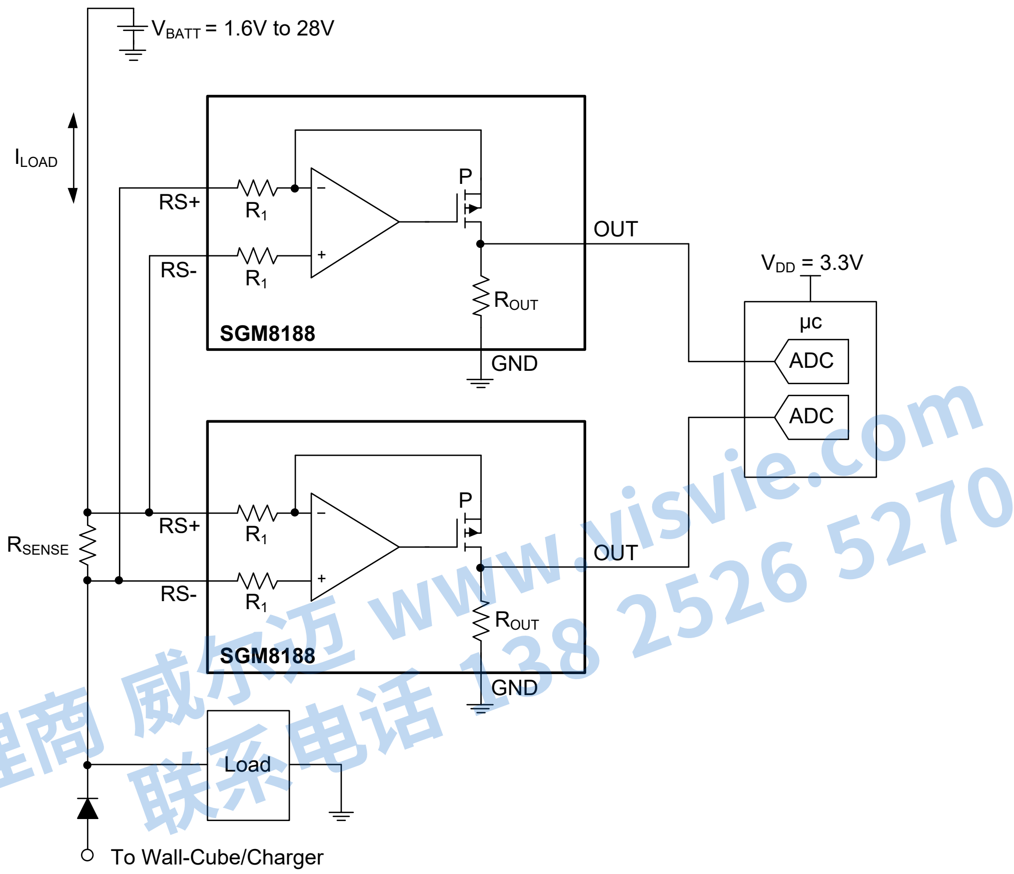


Figure 3. Bidirectional Application

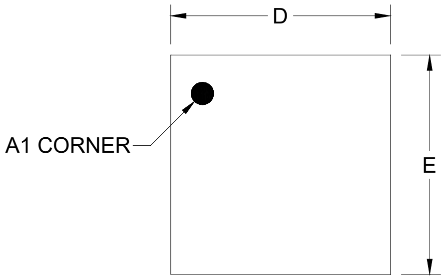
REVISION HISTORY

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

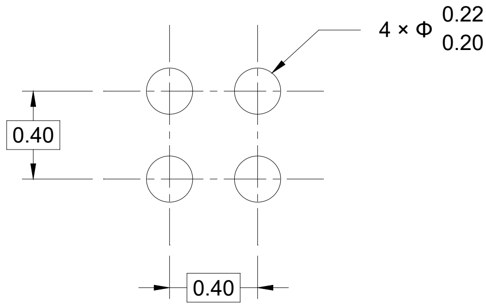
Changes from Original (JUNE 2023) to REV.A	Page
Changed from product preview to production data	All

PACKAGE OUTLINE DIMENSIONS

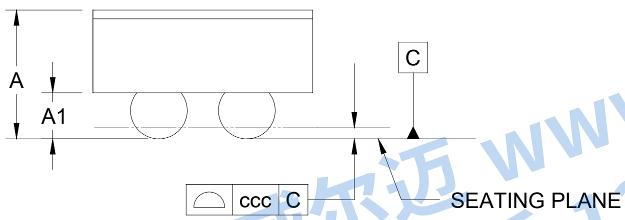
WLCSP-1×1-4B-A



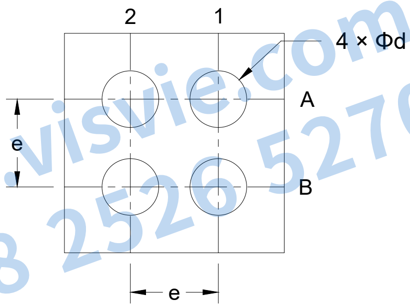
TOP VIEW



RECOMMENDED LAND PATTERN (Unit: mm)



SIDE VIEW



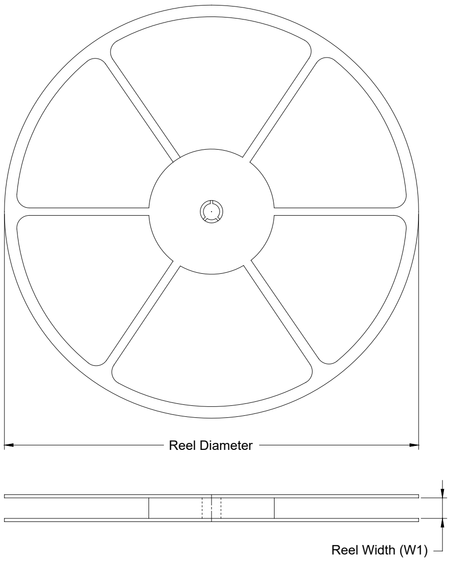
BOTTOM VIEW

Symbol	Dimensions In Millimeters		
	MIN	MOD	MAX
A	-	-	0.625
A1	0.190	-	0.230
D	0.975	-	1.035
E	0.975	-	1.035
d	0.228	-	0.288
e	0.400 BSC		
ccc	0.050		

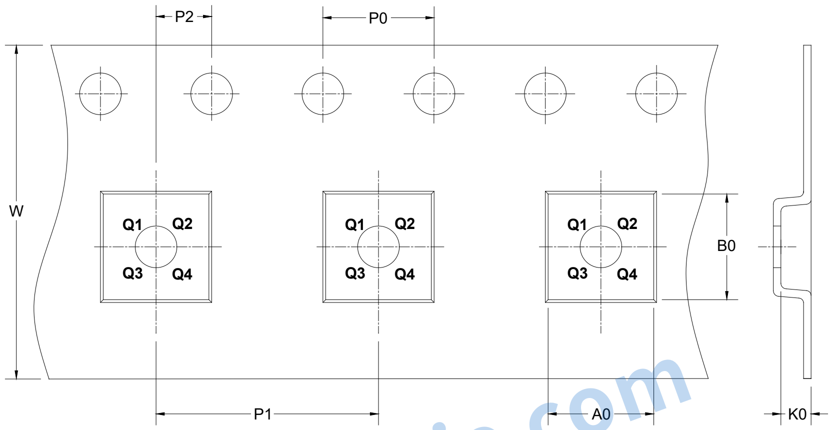
NOTE: This drawing is subject to change without notice.

TAPE AND REEL INFORMATION

REEL DIMENSIONS



TAPE DIMENSIONS



DIRECTION OF FEED

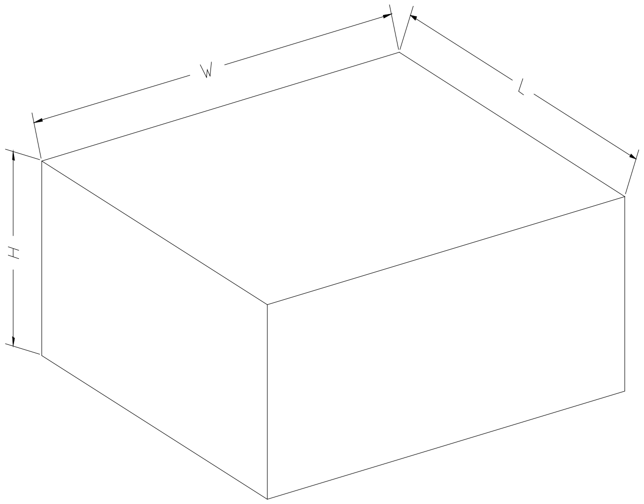
NOTE: The picture is only for reference. Please make the object as the standard.

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
WLCSP-1×1-4B-A	7"	9.5	1.07	1.07	0.72	4.0	4.0	2.0	8.0	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

DD0002