SGM447
1.5V Dual-Gain Analog Temperature Sensor with Class-AB Output

GENERAL DESCRIPTION

The SGM447 is a high-accuracy analog output CMOS integrated-circuit temperature sensor with tiny WLCSP package. It can operate with a supply voltage of 1.5V in the lowest gain configuration while measuring the temperature of -55℃ to +150℃.

The SGM447 is capable of strong output source and sink current while driving heavy loads in that it has class-AB output. Therefore, it is available for sourcing the input of a sample-and-hold analog-to-digital converter requiring transient load. Without using external components such as resistors and buffers on the output, the SGM447 can deliver the output voltage inversely proportional to measured temperature from -55℃ to +150℃. Low supply current makes it suitable for application in general temperature sensors and battery-powered systems.

The gain of the temperature-to-voltage output transfer function is set by the gain selection input (GS) pin with two selectable slopes, (-5.4mV/℃ at GS = 0 or -8.1mV/℃ at GS = 1). If the GS pin is connect to logic high, the transfer function will achieve the maximum temperature sensitivity gain. The GS pin can be connected to VDD or GND without any components such as pull-up or pull-down resistors to minimize the board area. During operation or system diagnostics, if the input is driven by a logical signal, then the system will optimize the gain.

The SGM447 is available in a Green WLCSP-0.8×0.8-4B-A package. It is specified over a wide temperature range of -55℃ to +150℃.

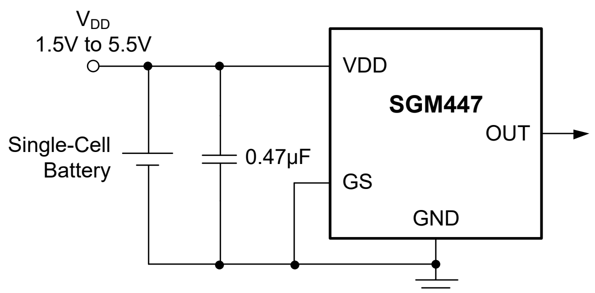
FEATURES

- **Power Supply Voltage: 1.5V to 5.5V**
- **Low Quiescent Current**
- **Temperature Accuracy:**
  - **-20℃ to +85℃: ±2.5℃ (MAX)**
  - **-55℃ to +150℃: ±3.5℃ (MAX)**
- **Two Selectable Gains**
- **300μA (MAX) Source Current**
- **Push-pull Output**
- **Output Short-Circuit Protection**
- **Operating Temperature Range: -55℃ to +150℃**
- **Available in a Green WLCSP-0.8×0.8-4B-A Package**

APPLICATIONS

Temperature Sensing and Compensation
Battery Management
Automotive Equipment

TYPICAL APPLICATION



Available Detected Temperature Range from -55℃ to +150℃ Powered by Battery.

Figure 1. Typical Application Circuit

PACKAGE/ORDERING INFORMATION

MODEL	PACKAGE DESCRIPTION	SPECIFIED TEMPERATURE RANGE	ORDERING NUMBER	PACKAGE MARKING	PACKING OPTION
SGM447	WLCSP-0.8×0.8-4B-A	-55℃ to +150℃	SGM447TG/TR	1X X	Tape and Reel, 5000

MARKING INFORMATION

NOTE: X = Date Code.

YY — Serial Number
X
└── Date Code - Quarter

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 .... -0.3V to 6V
Voltage at Output Pin .... -0.3V to (V_{DD} + 0.3V)
Output Current .... ±7mA
Voltage at GS Input Pin .... -0.3V to 6V
Input Current at Any Pin [(1)] 5mA
Package Thermal Resistance
WLCSP-0.8×0.8-4B-A, θ_{JA} .... 122℃/W
Junction Temperature .... +150℃
Storage Temperature Range .... -65℃ to +150℃
Lead Temperature (Soldering, 10s) .... +260℃
ESD Susceptibility
HBM 4000V
CDM 1000V

RECOMMENDED OPERATING CONDITIONS

Supply Voltage Range, V_{DD} .... 1.5V to 5.5V
Operating Ambient Temperature Range .... -55℃ to +150℃
Supply Voltage Ramp Rate Range .... 0.2V/ms to 20V/ms
Supply Voltage Ramp Rate Range(C_{OUT} = 1nF) .... 0.2mV/μs to 5V/μs

NOTE:
1. When the input voltage (V_{IN}) at any pin exceeds power supplies (V_{IN} < GND or V_{IN} > V+), the current at that pin should be limited to 5mA.

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.

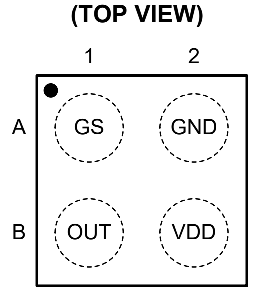
ESD SENSITIVITY CAUTION

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



WLCSP-0.8×0.8-4B-A

PIN DESCRIPTION

PIN	NAME	FUNCTION
A1	GS	Gain Selection Input Pin. It is used for selecting the slope of the analog output response, -5.4mV/℃ (GS = 0) or -8.1mV/℃ (GS = 1).
A2	GND	Ground Pin.
B1	OUT	Output Voltage Pin. The Output voltage is inversely proportional to measuring temperature.
B2	VDD	Positive Power Supply.

ELECTRICAL CHARACTERISTICS

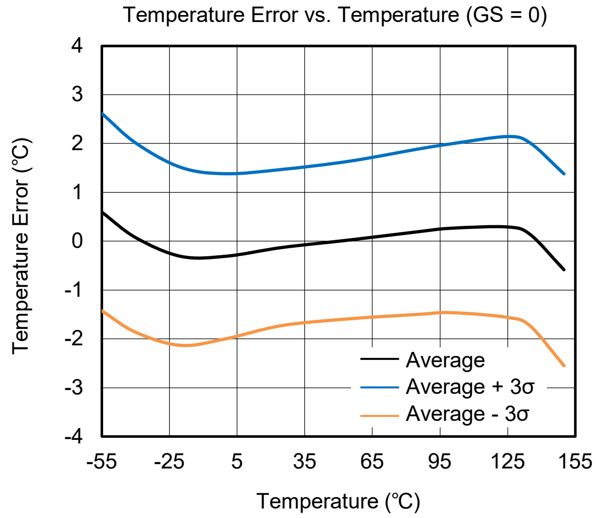
(V_{DD} = 1.5V to 5.5V, T_A = T_J = -55℃ to +150℃, typical values are at T_A = T_J = +25℃, unless otherwise noted.)

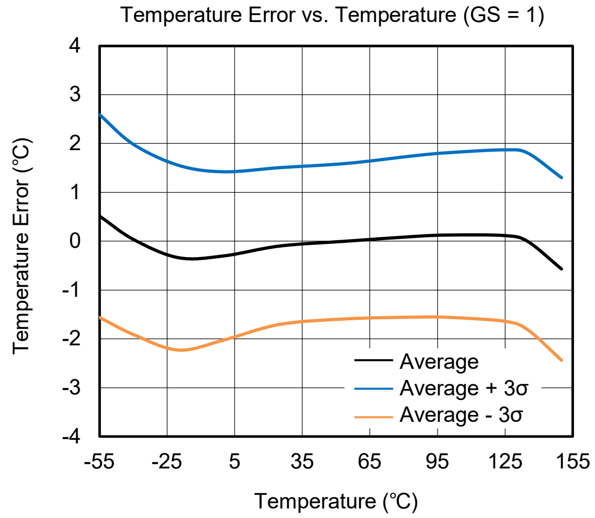
PARAMETER	SYMBOL	CONDITIONS		MIN	TYP	MAX	UNITS
Temperature Accuracy	T_{ACC}	T_A = +25℃	using parabolic transfer function, GS = 0, V_{DD} - V_{OUT} ≥ 300mV		±1		℃
		T_A = -20℃ to +85℃		-2.5	±1	2.5	
		T_A = -55℃ to +150℃		-3.5	±1	3.5	
		T_A = +25℃	using parabolic transfer function, GS = 1, V_{DD} - V_{OUT} ≥ 300mV		±1		℃
		T_A = -20℃ to +85℃		-2.5	±1	2.5	
		T_A = -55℃ to +150℃		-3.5	±1	3.5	
Sensor Gain		GS = 0			-5.4		mV/℃
		GS = 1			-8.1		
Load Regulation (1)		V_{DD} = 1.5V to 5.5V	I_{SOURCE} ≤ 300μA, (V_{DD} - V_{OUT}) ≥ 200mV		0.03	0.5	mV
			I_{SINK} ≤ 300μA, V_{OUT} ≥ 200mV		0.07	0.5	
Line Regulation (2)	$\Delta V_{OUT}/\Delta V_{DD}$				60	800	μV/V
Supply Current	I_Q	GS = 0	V_{DD} = 1.5V		3.0	6.5	μA
			V_{DD} = 3.3V		3.4	7.1	
			V_{DD} = 5.5V		3.7	7.7	
		GS = 1	V_{DD} = 1.5V		3.4	7.0	μA
			V_{DD} = 3.3V		3.8	7.5	
			V_{DD} = 5.5V		4.1	8.0	
Output Load Capacitance	C_L				1100		pF
Power-On Time		C_L = 0pF to 1100pF			0.54	1.5	ms
Input Threshold Voltage for GS Pin	V_{IH}			V_{DD} - 0.4			V
	V_{IL}					0.4	
Input Current	I_{IH}	Logic high		-1	0.001	1	μA
	I_{IL}	Logic low		-1	0.001	1	

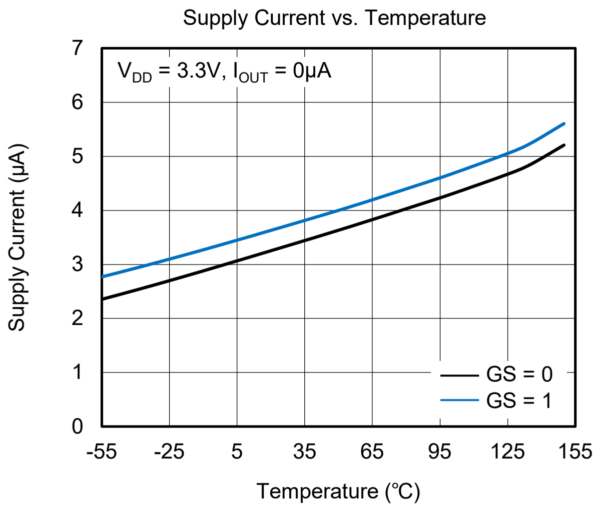
NOTES:

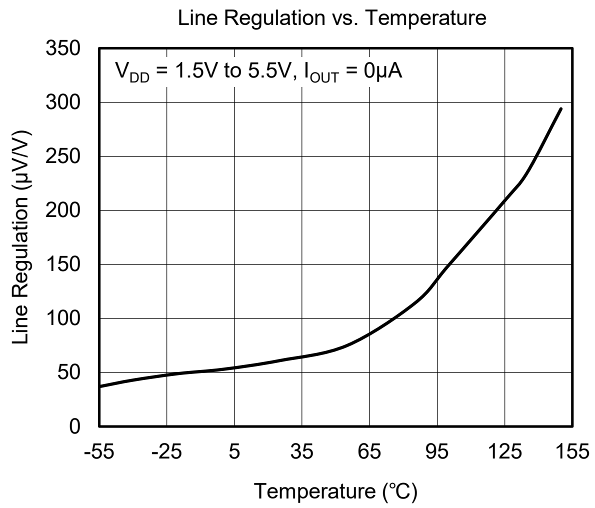
1. The currents flowing out of the SGM447 are source currents, and flowing into the SGM447 are sink currents.
2. The line regulation in DC is calculated as the output voltage when the supply voltage reaches its maximum value and its minimum value. Also, the line regulation is not the output change which is illustrated in output voltage shift section.

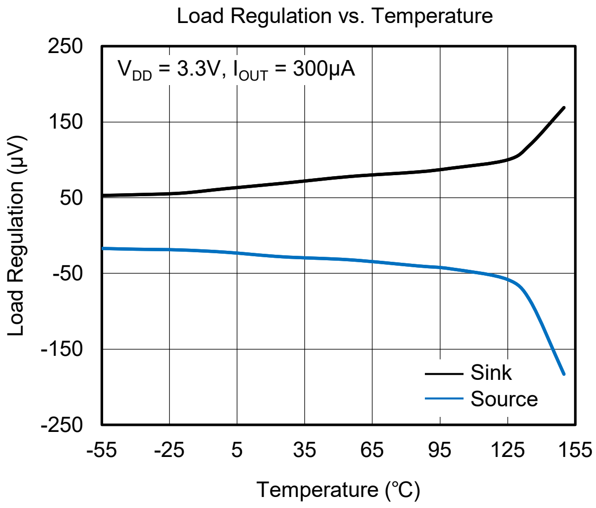
TYPICAL PERFORMANCE CHARACTERISTICS

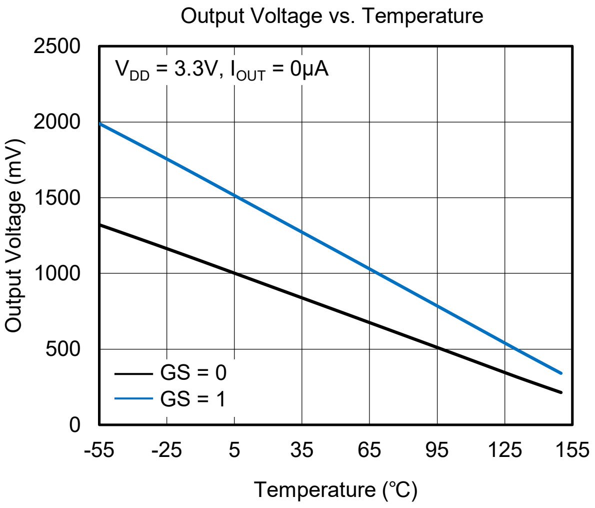






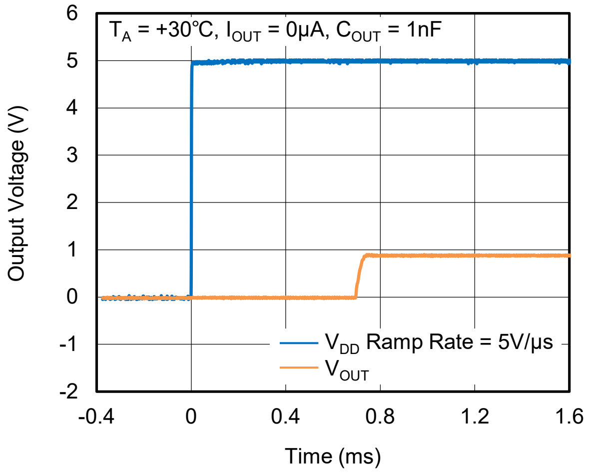




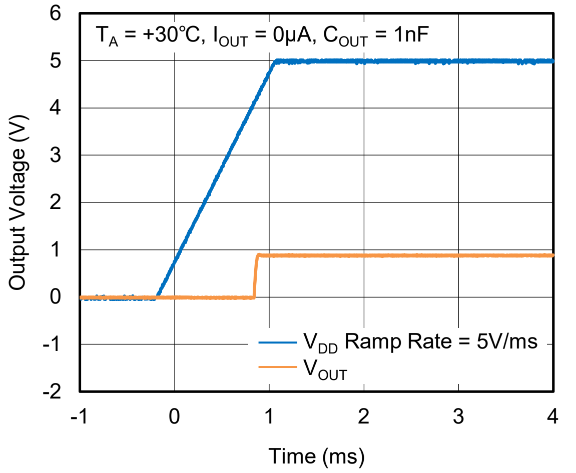


TYPICAL PERFORMANCE CHARACTERISTICS (continued)

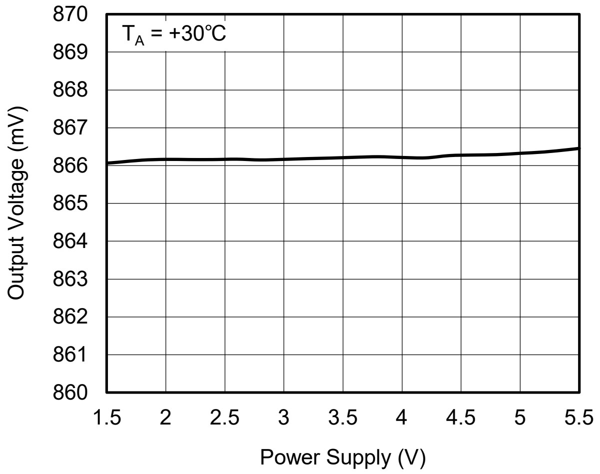
Output Voltage vs. Settling Time to Step V_{DD} (GS = 0)



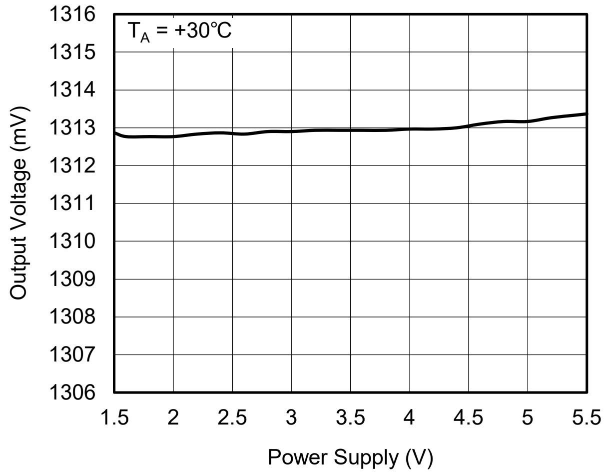
Output Voltage vs. Settling Time to Ramp V_{DD} (GS = 0)



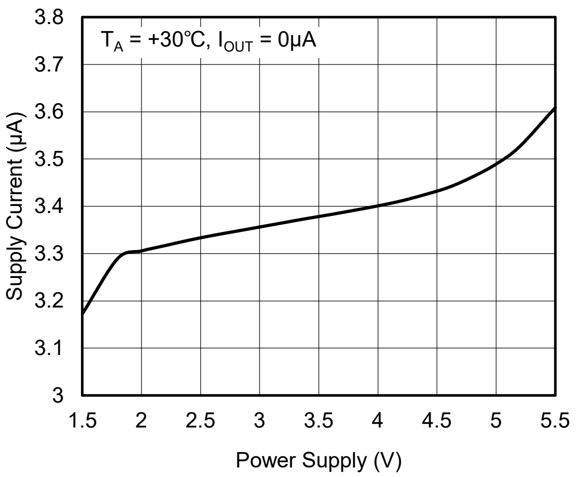
Output Voltage vs. Supply Voltage (GS = 0)



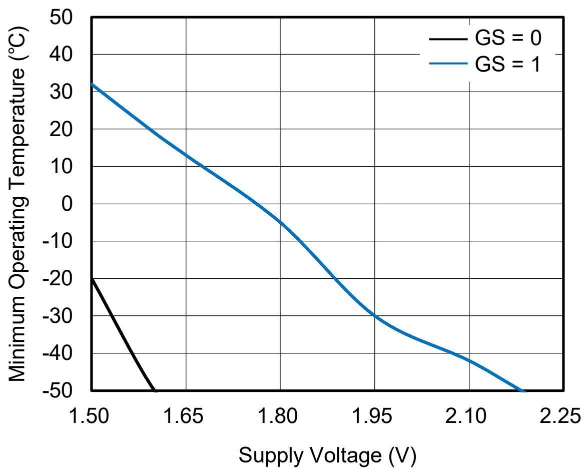
Output Voltage vs. Supply Voltage (GS = 1)



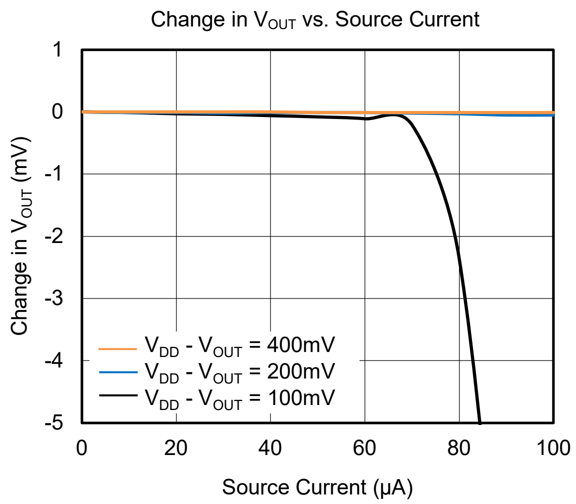
Supply Current vs. Supply Voltage

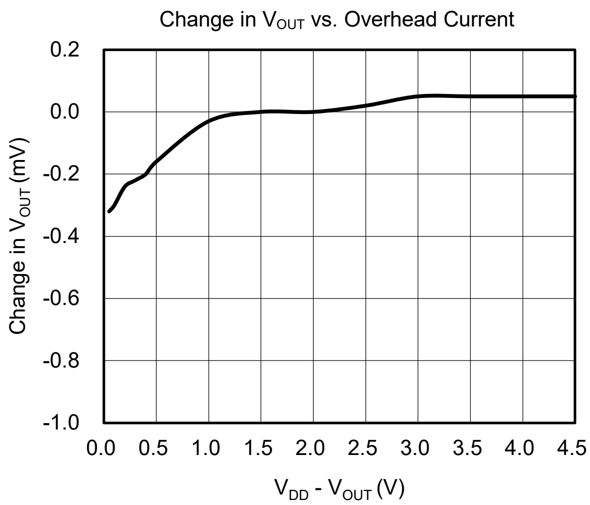


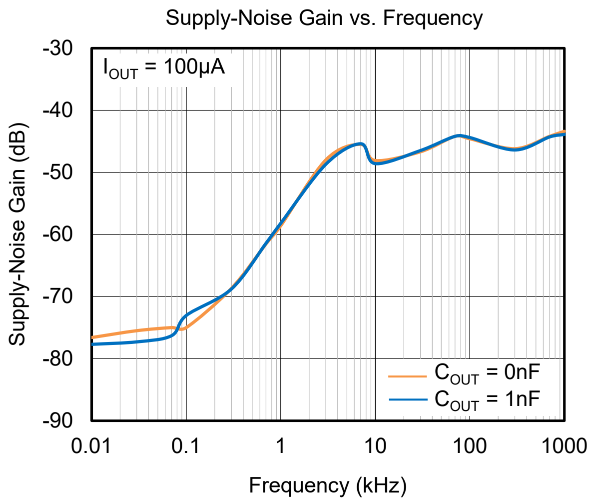
Minimum Operating Temperature vs. Supply Voltage



TYPICAL PERFORMANCE CHARACTERISTICS (continued)







APPLICATION INFORMATION

Transfer Function

The two gains of the SGM447 can be selected by GS pin. The following table shows the output voltage for different corresponding gain and temperature in Celsius, and it is also the reference for the accuracy of the temperature sensor. Table 1 is a loop-up table for the users of the SGM447.

Table 1. SGM447 Temperature-Voltage Transfer Table

TEMP	GS = 0	GS = 1	TEMP	GS = 0	GS = 1	TEMP	GS = 0	GS = 1	TEMP	GS = 0	GS = 1	TEMP	GS = 0	GS = 1	TEMP	GS = 0	GS = 1
(℃)	(mV)	(mV)	(℃)	(mV)	(mV)	(℃)	(mV)	(mV)	(℃)	(mV)	(mV)	(℃)	(mV)	(mV)	(℃)	(mV)	(mV)
-55	1328	2000	-18	1129	1704	19	928	1406	56	727	1107	93	525	806	130	322	503
-54	1323	1992	-17	1123	1696	20	923	1398	57	722	1099	94	520	798	131	317	495
-53	1318	1984	-16	1118	1688	21	918	1390	58	716	1091	95	514	789	132	311	487
-52	1312	1976	-15	1113	1680	22	912	1382	59	711	1082	96	509	781	133	306	479
-51	1307	1968	-14	1107	1672	23	907	1374	60	705	1074	97	503	773	134	300	470
-50	1302	1960	-13	1102	1664	24	901	1366	61	700	1066	98	498	765	135	295	462
-49	1296	1952	-12	1096	1656	25	896	1358	62	694	1058	99	492	757	136	289	454
-48	1291	1944	-11	1091	1648	26	890	1350	63	689	1050	100	487	749	137	284	446
-47	1285	1936	-10	1086	1640	27	885	1342	64	684	1042	101	481	740	138	278	437
-46	1280	1928	-9	1080	1632	28	880	1333	65	678	1034	102	476	732	139	273	429
-45	1275	1920	-8	1075	1624	29	874	1325	66	673	1026	103	470	724	140	267	421
-44	1269	1912	-7	1069	1615	30	869	1317	67	667	1017	104	465	716	141	262	413
-43	1264	1904	-6	1064	1607	31	863	1309	68	662	1009	105	459	708	142	256	405
-42	1258	1896	-5	1059	1599	32	858	1301	69	656	1001	106	454	700	143	251	396
-41	1253	1888	-4	1053	1591	33	852	1293	70	651	993	107	448	691	144	245	388
-40	1248	1880	-3	1048	1583	34	847	1285	71	645	985	108	443	683	145	240	380
-39	1242	1872	-2	1042	1575	35	841	1277	72	640	977	109	437	675	146	234	372
-38	1237	1864	-1	1037	1567	36	836	1269	73	634	969	110	432	667	147	229	364
-37	1231	1856	0	1031	1559	37	831	1261	74	629	961	111	427	659	148	223	355
-36	1226	1848	1	1026	1551	38	825	1253	75	624	952	112	421	651	149	218	347
-35	1221	1840	2	1021	1543	39	820	1245	76	618	944	113	416	642	150	212	339
-34	1215	1832	3	1015	1535	40	814	1236	77	613	936	114	410	634			
-33	1210	1824	4	1010	1527	41	809	1228	78	607	928	115	405	626			
-32	1204	1816	5	1004	1519	42	803	1220	79	602	920	116	399	618			
-31	1199	1808	6	999	1511	43	798	1212	80	596	912	117	394	610			
-30	1194	1800	7	994	1503	44	793	1204	81	591	904	118	388	601			
-29	1188	1792	8	988	1495	45	787	1196	82	585	895	119	383	593			
-28	1183	1784	9	983	1487	46	782	1188	83	580	887	120	377	585			
-27	1177	1776	10	977	1479	47	776	1180	84	574	879	121	372	577			
-26	1172	1768	11	972	1471	48	771	1172	85	569	871	122	366	569			
-25	1167	1760	12	966	1463	49	765	1164	86	563	863	123	361	561			
-24	1161	1752	13	961	1455	50	760	1155	87	558	855	124	355	552			
-23	1156	1744	14	956	1446	51	754	1147	88	552	847	125	350	544			
-22	1150	1736	15	950	1438	52	749	1139	89	547	838	126	344	536			
-21	1145	1728	16	945	1430	53	744	1131	90	542	830	127	339	528			
-20	1140	1720	17	939	1422	54	738	1123	91	536	822	128	333	520			
-19	1134	1712	18	934	1414	55	733	1115	92	531	814	129	328	511			

APPLICATION INFORMATION (Continued)

From the above table, although the output voltage is nearly linear with the change of temperature, the transfer function between the voltage and temperature is parabolic, which can reflect the accuracy of the SGM447. Equation 1 is the parabolic transfer function reflecting the output voltage in Table 1.

G0: V_{TEMP} (mV) = 868.6mV - 5.434mV/℃ × (T - 30℃) - 0.0003mV/℃ × (T - 30℃)^2

G1: V_{TEMP} (mV) = 1317.3mV - 8.081mV/℃ × (T - 30℃) - 0.0006mV/℃ × (T - 30℃)^2 (1)

For simplicity, the two-point equation can be easily calculated the output voltage for the corresponding temperature.

$$V - V_1 = \left(\frac{V_2 - V_1}{T_2 - T_1}\right) \times (T - T_1) \quad (2)$$

where:

V is in mV,

T is in ℃,

T_1 and V_1 are measured in the lowest temperature,

T_2 and V_2 are measured in the highest temperature.

The following steps are the examples for calculating the corresponding voltage, if the users decide to express the corresponding value of voltage for the temperature which is in the range of +20℃ to +50℃ at GS = 0, the calculation is shown as below:

$$V - 923\text{mV} = \left(\frac{760\text{mV} - 923\text{mV}}{50℃ - 20℃}\right) \times (T - 20℃) \quad (3)$$

$$V - 923\text{mV} = -5.43\text{mV}/℃ \times (T - 20℃) \quad (4)$$

$$V = -5.43\text{mV}/℃ \times T + 1032\text{mV} \quad (5)$$

Users can approximate the needed temperature ranges by using the above method.

Mounting and Thermal Conductivity

The SGM447 can be easily applied to the PCB board like other temperature sensors. Cementing and gluing are also allowed.

For conducting the thermal, the backside of the die is connecting to GND. However, the temperature of trances and lands will also affect the reading of temperature for the temperature sensor.

The SGM447 can be also mounted into a sealed-end metal tube, dipped into a bath or screwed into a threaded hole in a tank. To avoid leakage and corrosion, it is recommended that the corresponding circuit should be kept dry enough. For cold temperature where condensation and moisture may occur, it will affect the operation of the SGM447 because of short circuit. To protect the temperature sensor from moisture, a printed-circuit coating can be used.

Thermal resistance junction to ambient (θ_{JA}) can be approximated as the temperature rise for the power dissipation of SGM447. The following equation is used for calculating the die temperature of SGM447:

$$T_J = T_A + \theta_{JA} \times [(V_{DD} \times I_Q) + (V_{DD} - V_{OUT}) \times I_L] \quad (6)$$

where:

I_Q is the quiescent current,

I_L is the load current,

V_{OUT} is the output voltage,

θ_{JA} is 122℃/W.

For example, if the users substitute T_A = +25℃, V_{DD} = 5.5V, I_Q = 4.1μA, GS = 1, V_{OUT} = 2.5mV, and I_L = 2μA in the above equation, T_J will be +25.0041℃, which means that the temperature error due to the power dissipation is 0.0041℃. One way to reduce the junction temperature of SGM447 is to reduce the load current.

Output and Noise Considerations

Because of the structure of push-pull output stage, the ability of sink and source current is enhanced due to the low output resistance, which means that it can drive the dynamic loads such as Analog-to-Digital Converter (ADC). In some applications, the SGM447 can provide a current source directly to the input capacitance of an ADC. It can also be widely used in situations where strong sink and source current are required.

Because of the ripple of the power supply, the supply-noise gain may have an impact on the results, and the output capacitance can be used to filter the noise.

A 0.47μF ceramic bypass capacitor should be placed closely on the power supply pin to avoid interference of noise.

APPLICATION INFORMATION (Continued)

Capacitive Loads

For noisy conditions, such as driving a SAR ADC, an output capacitor is necessary to filter out output noise due to the switching input of the load. The SGM447 has outstanding capacitive loading capability. In Figure 2, the SGM447 can handle a 1100pF capacitive load. However, if the load capacitance is larger than 1100pF, a series resistor should be used to compensate for the SGM447 in Figure 3. If the C_L value is 1.1nF to 99nF, the minimum value of R_S should be 3kΩ. If the C_L value is 100nF to 999nF, the minimum value of R_S should be 1.5kΩ. And if the C_L value is 1μF, the minimum value of R_S should be 800Ω. Meanwhile, if the VDD ramp rate is between 0.02V/μs and 5V/μs, a 1nF load capacitor is recommended to connect to OUT pin.

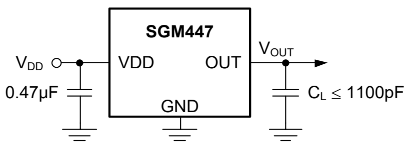


Figure 2. Application Circuit when Capacitive Loads are Less than 1100pF

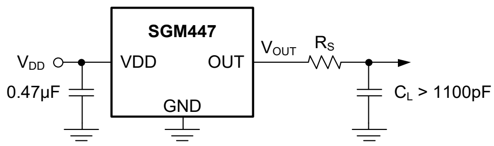


Figure 3. SGM447 with Series Resistor for Capacitive Loading Greater than 1100pF

Output Voltage Shift

The characteristic of output voltage of the SGM447 is linear within the proper temperature range. However, a slightly output shift may occur when the supply voltage ramps to the typical voltage range of the device. This phenomenon is caused by the rail to rail PMOS or N-MOS buffer in the output stage of the temperature sensor. The output voltage shift will also occur when V_{DD} is 1.0V greater than V_{OUT}.

The output voltage shift always takes place if the change of output voltage or supply voltage is approximately equal to 200mV. This voltage shift will also happen if the temperature is from +5℃ to +20℃ and the output voltage is also monotonic. In summary, the data for the entire temperature range of the two optional gains in the electrical characteristics table already includes possible voltage shifts.

Selectable Gains for Optimization

The GS pin of the SGM447 can be driven by the GPIO pins of microcontroller or simply tied to the rails of the system. For low power supply system, the SGM447 can also measure the temperature from -55℃ to +150℃ with the gain of -5.4mV/℃. For large power supply system, the corresponding gain should be set to -8.1mV/℃. And if the users desire to reduce the output noise, selecting larger gain is a good choice (for example, the coupling noise at the output or quantization noise which is from ADC).

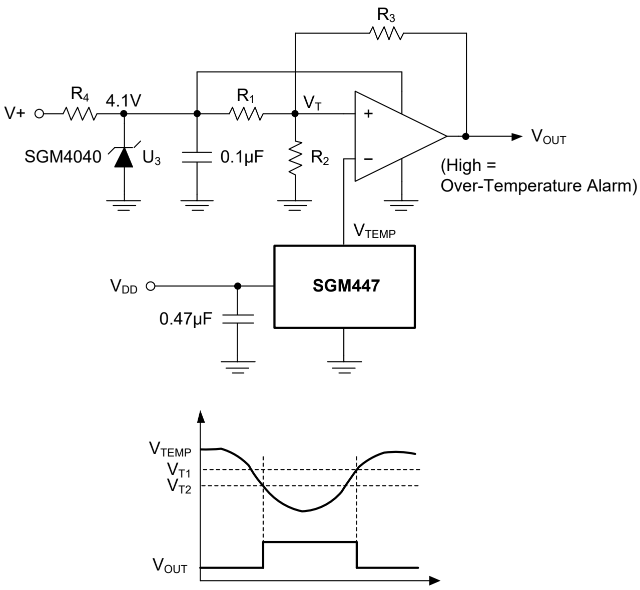
Another advantage of digital selectable gains is that the dynamic testing of the SGM447 will be enhanced when operating. Users can use their host equipment (microcontroller) to modify the gain of temperature sensor to check the functionality.

APPLICATION INFORMATION (Continued)

Other Application Circuits

Centigrade Thermostat Application

The hysteresis comparator can be used to indicate high or low state for different temperatures as shown in Figure 4.



$$V_{T1} = \frac{4.1 \times R_2 \| R_3}{R_1 + R_2 \| R_3} \quad V_{T2} = \frac{4.1 \times R_2}{R_2 + R_1 \| R_3}$$

Figure 4. Celsius Thermostat

Conserving Power Dissipation with Shutdown

The SGM447 can be shutdown with an output of a logic gate because of its ultra-low power dissipation as shown in Figure 5.

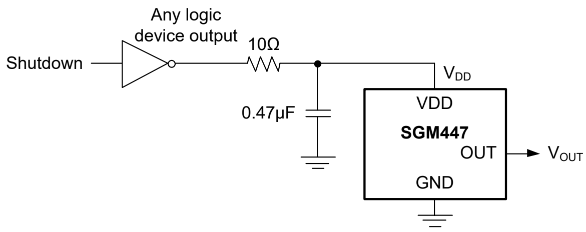


Figure 5. Conserving Power Dissipation with Shutdown

Connection for the Input Stage of SAR ADC

Most of the CMOS-based ADCs are integrated in microcontroller and have a sampling capacitor input structure. In addition, for charging the sampling capacitor of ADC, it needs the instantaneous charge from the output of the source. Adding an output capacitor (C_{FILT}) can satisfy this requirement. For the size of C_{FILT}, it depends on the sampling frequency and the size of sampling capacitor. However, the input stages of the ADCs are not exactly the same, and thus the conditions of charge are also different. Figure 6 is just one example to show what the input stage of SAR ADC looks like.

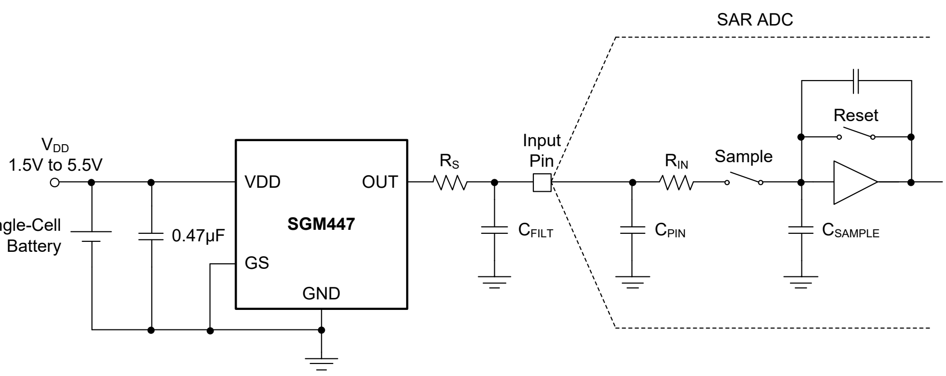


Figure 6. Suitable Connection for the Input Stage of SAR ADC

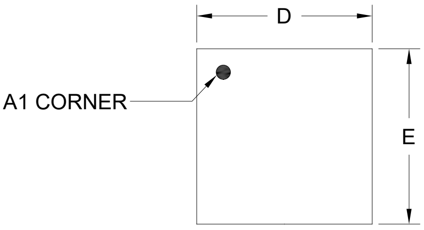
REVISION HISTORY

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

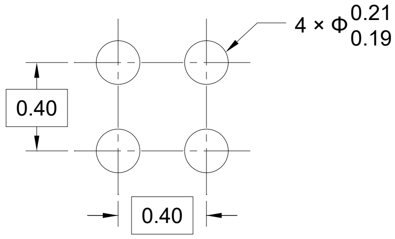
Changes from Original (NOVEMBER 2022) to REV.A	Page
Changed from product preview to production data	All

PACKAGE OUTLINE DIMENSIONS

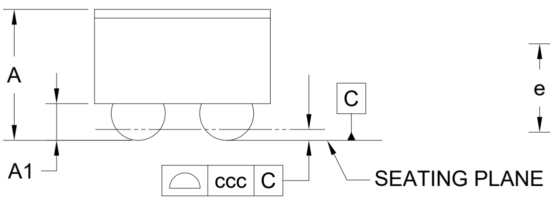
WLCSP-0.8×0.8-4B-A



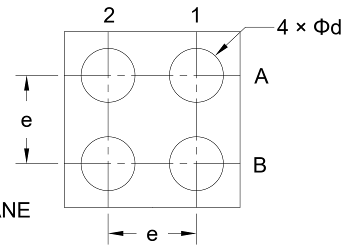
TOP VIEW



RECOMMENDED LAND PATTERN (Unit: mm)



SIDE VIEW



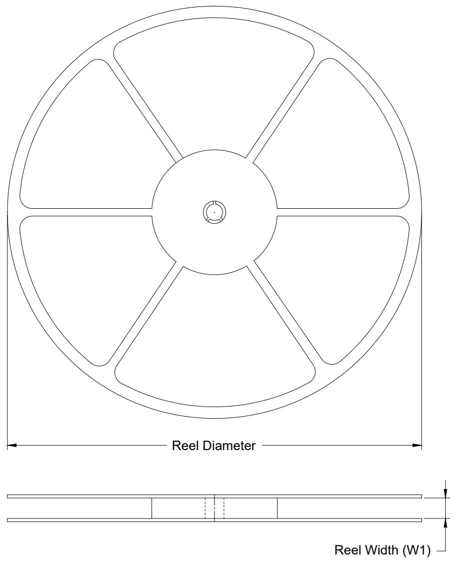
BOTTOM VIEW

Symbol	Dimensions In Millimeters		
	MIN	MOD	MAX
A	-	-	0.638
A1	0.148	-	0.188
D	0.775	-	0.835
E	0.775	-	0.835
d	0.217	-	0.277
e	0.400 BSC		
ccc	0.050		

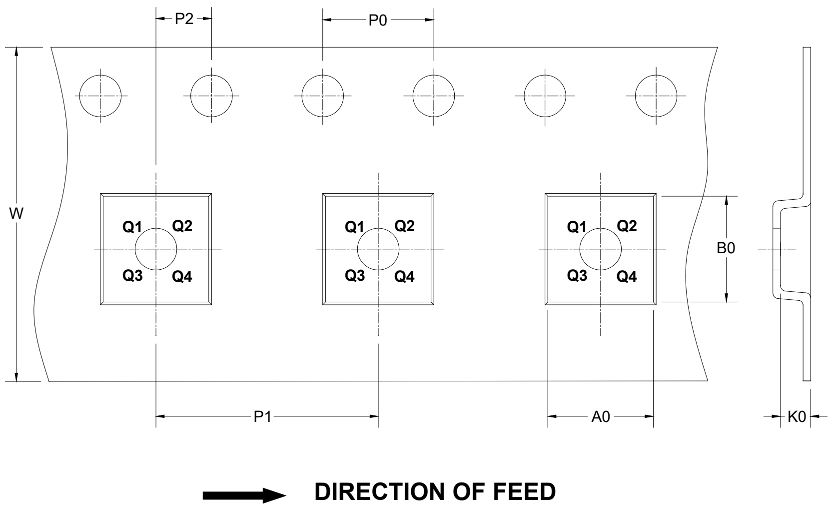
NOTE: This drawing is subject to change without notice.

TAPE AND REEL INFORMATION

REEL DIMENSIONS



TAPE DIMENSIONS



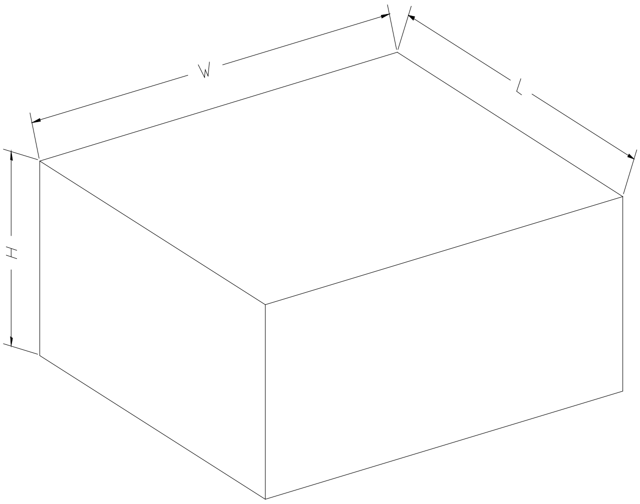
NOTE: The picture is only for reference. Please make the object as the standard.

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
WLCSP-0.8×0.8-4B-A	7″	9.5	0.89	0.89	0.70	4.0	2.0	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