APPLICATION NOTE
ANE202607001

Multi-Channel Parallel Operation of High-Side and Low-Side Drivers

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Jul. 15, 2026

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ABSTRACT

High-side and low-side drivers that integrate multiple protection and diagnostic functions are widely used in automotive electronics and industrial control as replacements for traditional discrete MOSFET solutions. They are capable of adapting to various application scenarios commonly found in different systems, including resistive load heating, capacitive load fast startup, and inductive load turn-off clamping. For different systems, in multi-channel applications, the load currents of different channels often exhibit certain variations. When the current requirement of a particular channel exceeds the maximum load capability of a single channel of the driver, the system will fail to operate properly. One feasible solution is to parallel multiple channels of a multi-channel high-side driver to increase the load current capability. This application note will provide a detailed introduction to the key considerations and limitations that need to be taken into account in channel-parallel applications of high-side drivers.

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1 Introduction to Multi-Channel Parallel Operation

In practical applications, when multi-channel high-side and low-side drivers operate at room temperature, the current capability of a single channel is typically sufficient to meet load requirements and drive the load stably without triggering the chip's thermal shutdown protection. However, when the ambient temperature rises, the load current required remains unchanged, but the driver's on-resistance increases with temperature. This physical characteristic leads to increased power dissipation, such that a load current that is acceptable at room temperature may exceed the thermal shutdown threshold at high temperatures due to intensified self-heating of the chip.

One effective way to address this issue is to add an external heatsink to dissipate the heat from the power device in a timely manner, ensuring that the overall junction temperature of the chip operates below the thermal shutdown protection threshold. However, the introduction of an external heatsink undoubtedly increases system cost and layout design complexity. In contrast, multi-channel parallel operation reduces the on-resistance to lower the power dissipation during normal driving, thereby effectively controlling temperature rise and allowing the chip to operate stably within the over-temperature protection threshold even at higher ambient temperatures. SG Micro Corp offers a variety of high-side and low-side driver products that can be used for channel paralleling, with representative models listed in Table 1.

Table 1 High-Side and Low-Side Driver Products Available for Channel Paralleling

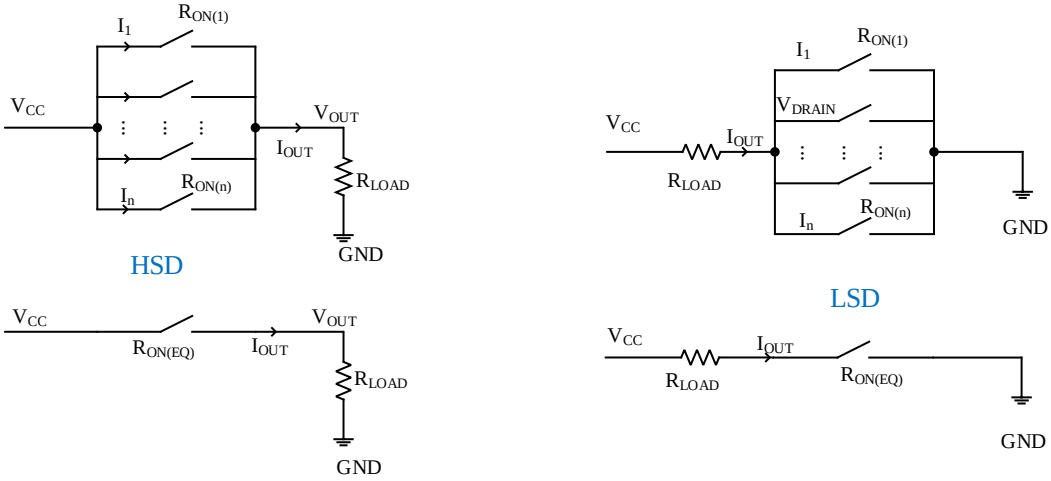
Type	No. of channels	Product Model
High-Side Driver	Dual-Channel	SGM42203、SGM42203Q
	Quad-Channel	SGM42214xQ
Low-Side Driver	Dual-Channel	SGM42402Q
	Quad-Channel	SGM42403、SGM42403Q、SGM42404A/B
	Eight-Channel	SGM42406、SGM42408Q

These multi-channel high-side and low-side drivers are specifically designed for automotive systems and industrial applications, integrating short-circuit protection, over-temperature protection, over-voltage clamping, and open-circuit diagnostics, as well as internally and externally configurable current limiting. Among them, the high-side drivers also integrate high-precision current sensing circuits. This family of devices supports multiple load driving modes: all channels can be paralleled to drive a single high-current load, or partially paralleled to handle medium-current loads, or used as independent single channels to drive lighter loads with lower current requirements. Parallel channel output is achieved by connecting multiple power MOSFETs integrated within a single device in parallel to provide higher current to the load. In this configuration, the load current, originally borne by a single channel, is shared among the paralleled channels, with the theoretical current carried by each paralleled channel equal to the total load current divided by the number of paralleled channels. This parallel configuration enables these high-side and low-side drivers to drive loads that exceed the capability of a single channel, such as high-power halogen lamps, solenoids, electromagnetic valves, and motors.

2 Current and Voltage Output Relationship in Parallel Configuration

When multi-channel high-side and low-side drivers operate in parallel, the voltage drop (V_{DS}) from the supply pin V_{CC} to the output pin OUT is identical for all channels. For a high-side driver, the voltage drop is (V_{CC} − V_{OUT}); for a low-side driver, it is (V_{DRAIN} − V_{SOURCE}). The total output current after paralleling multiple channels equals the sum of the currents from each channel, and the total resistance equals the parallel equivalent of the on-resistances of all channels. Figure 1 illustrates the connection scheme for high-side and low-side drivers with n channels in parallel, showing the V_{CC} node and the V_{OUT} node connections for each channel. The upper portion of the figure shows the on-resistance $R_{ON(x)}$ and corresponding current for each of the n independent channels, while the lower portion shows the equivalent on-resistance $R_{ON(EQ)}$ and total output current I_{OUT} after paralleling.

Under ideal conditions, when multiple channels are used in parallel, the load current is evenly distributed among the channels, and the expected total output current I_{OUT} is n times that of a single channel. This requires the channels of the device to have highly consistent on-resistance. In actual manufacturing, due to process variations and bond-wire length differences within the same device, there are certain deviations in on-resistance among channels, resulting in uneven distribution of total output current across the paralleled channels. Within a single device, process variation can reach up to 10%. Taking SG Micro Corp's quad-channel high-side driver SGM42214xQ as an example, mass production test data shows that the single-channel on-resistance has a minimum value of 143mΩ, a typical value of 150mΩ, and a maximum value of 164mΩ, indicating a certain degree of manufacturing process variation.



(a) High-Side Driver (b) Low-Side Driver

Figure 1 Connection Scheme for High-Side and Low-Side Drivers with n Channels in Parallel (n = 2、4、6、8 Channels)

Taking a 12V system application with a total load current of 6A required at +85°C ambient temperature as an example, the quad-channel high-side driver SGM42214xQ from SG Micro Corp can be selected for 4-channel parallel driving. Referring to the SGM42214xQ Datasheet[1], the typical single-channel on-resistance at +25°C ambient temperature is 150mΩ; at +125°C ambient temperature (V_{CC} > 13.5V), the maximum on-resistance is 270mΩ. The junction-to-ambient thermal resistance parameter θ_{JA} is 25.7°C/W. With 4 channels in parallel, each channel needs to drive a typical current of 1.5A to meet the 6A total load current requirement. Theoretically, the maximum power dissipation generated during normal operation with

a 6A load current is:

$$P = \frac{R_{ON@+125℃}}{4} \times I_{OUT}^2 = \frac{270m\Omega}{4} \times 6A^2 = 2.43W \quad (1)$$

The temperature rise generated by the paralleled power devices is:

$$\Delta T = \theta_{JA} \times P = 25.7℃/W \times 2.43W = 62.451℃ \quad (2)$$

The junction temperature at +85°C ambient temperature is:

$$T_J = \Delta T + T_A = 62.451℃ + 85℃ = 147.451℃ < T_{SD}（Typical + 158℃） \quad (3)$$

Since the on-resistance R_{ON} among channels can have a maximum deviation of ±10%, the actual load current per channel may vary between 1.35A and 1.65A. This current variation among channels remains within the current capability and temperature rise limits specified in the device datasheet. As shown in Figure 2, Probe 1 measures the output voltage, Probe 3 measures the supply voltage, and Probe 4 is set to 1A/DIV, measuring a total load current of 6A. As shown in Figure 3, Channel 2 (Current Probe 1) measures a maximum single-channel current of 1.6A, while Channel 4 (Current Probe 2) measures a minimum single-channel current of 1.41A. The measurement results indicate that the current and voltage of each channel are within the design target range.

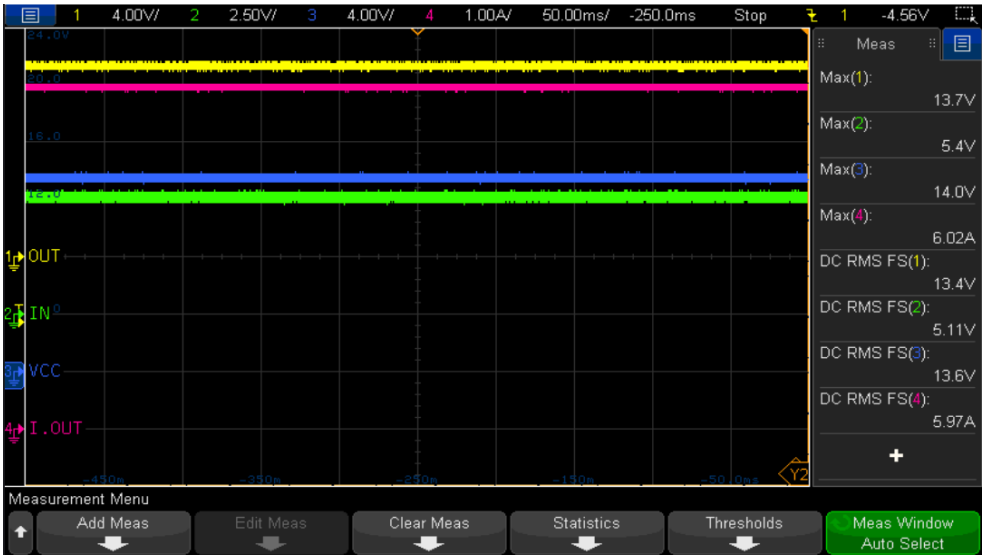


Figure 2 Four-Channel Parallel Driving: 6A Current and Voltage Waveforms

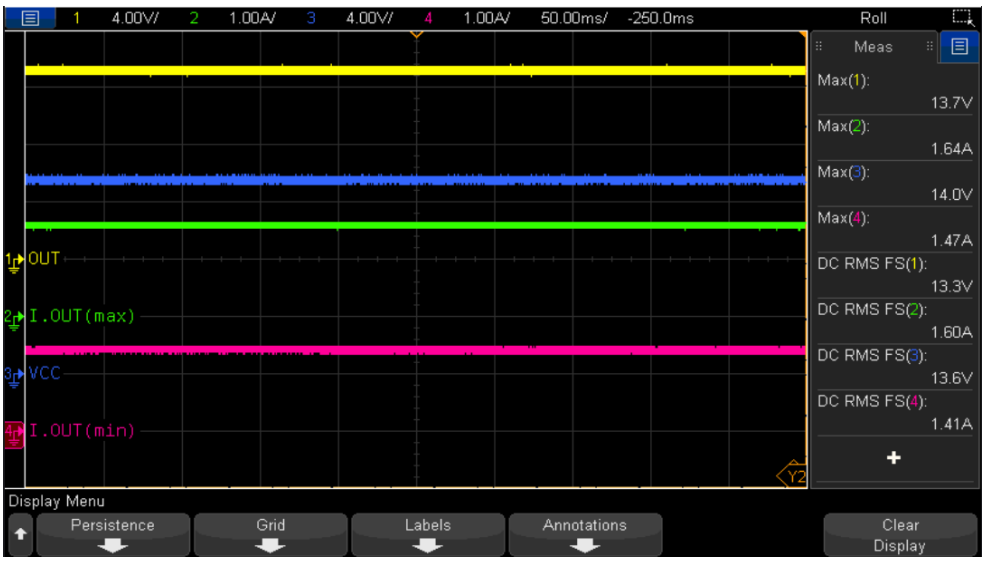


Figure 3 Maximum and Minimum Single-Channel Currents in Four-Channel Parallel Operation

3 Design Considerations for Parallel Channel Applications

In multi-channel parallel applications, the protection and diagnostic functions of the paralleled configuration are approximately equivalent to those of a single channel. To ensure synchronous output of all paralleled channels, for direct PWM-controlled high-side and low-side drivers, the input pins INx of all parallel channels must be connected together, and the output pins OUTx should be paralleled and connected close to the load to reduce parasitic inductance effects. Additionally, design considerations must fully account for parameter deviations among channels, including on-resistance, current sensing gain K, and inductive load turn-off clamping. Figure 4 illustrates the input and output connection scheme for multi-channel parallel operation. For SPI-controlled switches, it is necessary to ensure synchronous setting of the switch commands for the paralleled channels. Furthermore, the STx pins (with single-channel fault status indication function) should be connected in parallel and pulled up externally before being fed back to the microcontroller. For parallel driving, the CSx pins (with multi-channel independent current sensing capability) should also be connected in parallel to the sense resistor R_{SENSE} for total load current detection.

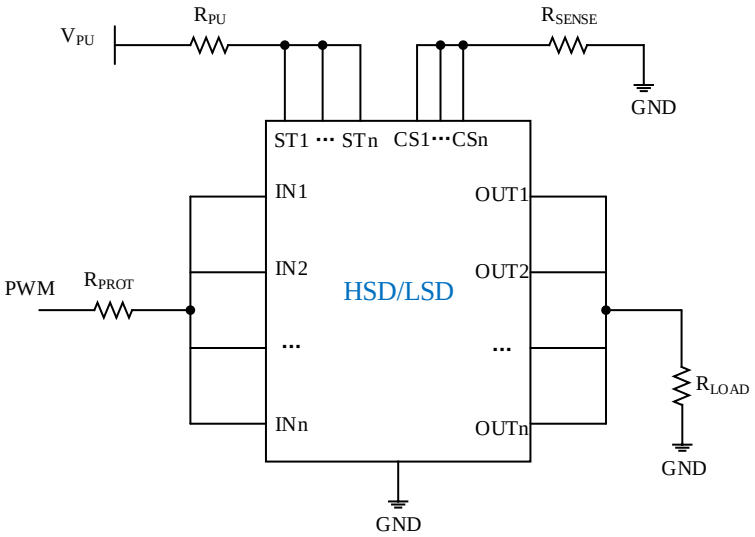


Figure 4 Input and Output Connection Scheme for Multi-Channel Parallel Operation

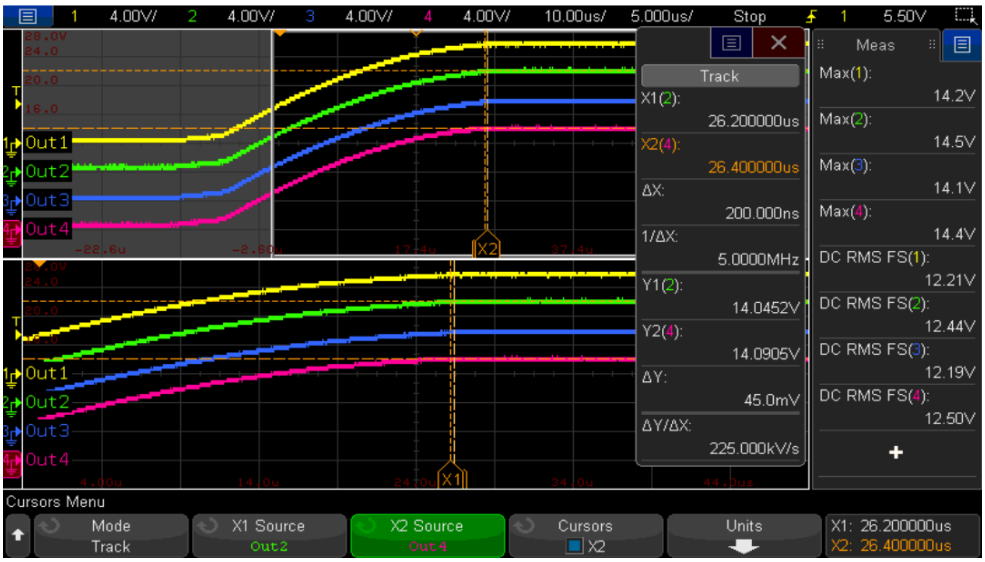


Figure 5 Direct-Control Input Parallel Connection and Output Switching Delay for SGM42214xQ

Figure 5 shows the switching delay measurement results between output channels when multiple inputs are shorted together in direct-drive mode for the SGM42214xQ. Since the internal four channels share the same charge pump circuit for driving, the switching delay error among channels is only from the internal clock, with delay times on the order of microseconds. Measurements show that the output delay between Channel 2 and Channel 4 is 0.2μs. Compared to the tens-of-microseconds rise/fall times of the switching transitions, this delay has essentially no impact on parallel-driving load applications. Similarly, Figure 6 shows the synchronous command settings for parallel driving channels in SPI-controlled mode, referencing the SGM42404A/B Datasheet[2]. Figure 7 shows the measured output delay times among individual channels during multi-channel synchronous turn-on. The measurement shows that the output delay between Channel 2 and Channel 4 is 3.6ns, which meets the allowable delay error range for synchronous switching among channels.

SPI Write

SI

Field	C	R/W	Address						1	0	1	0	Data in	1	0	1	0
Bit	[15]	[14]	[13]	[12]	[11]	[10]	[9]	[8]	[7]	[6]	[5]	[4]	[3]	[2]	[1]	[0]	
Data	0	0	A5	A4	A3	A2	A1	A0	D7	D6	D5	D4	D3	D2	D1	D0	

Bits	CHx	Output and Protection Circuit Status			
		Output	OCP	TSD	OLD
[7:6], [5:4] [3:2], [1:0]	00	Off	Disable	Disable	Disable
	01	NA	NA	NA	NA
	10	On	Enable	Enable	Disable
	11	Off	Disable	Disable	Enable

Figure 6 Four-Channel Parallel Driving SPI Settings for SGM42404A/B



Figure 7 SGM42404A/B SPI-Synchronized Input and Output Switching Delay Among Channels

4 Impact on Functional Parameters in Parallel Channel Applications

The protection function parameters in multi-channel parallel applications are essentially consistent with those of single-channel independent driving. Table 2 summarizes the characteristics and considerations for high-side and low-side drivers in parallel applications, and Table 3 summarizes the differences in diagnostic functions between single-channel and parallel-channel applications.

Table 2 Characteristics of High-Side and Low-Side Drivers

Characteristic	Single-Channel Application	Multi-Channel Parallel Application
Load Current (I_{OUT})	Limited load current capability I_{OUTx}	Maximum load current capability up to ($n \times I_{OUTx}$)
On-Resistance (R_{ON})	Typical value $R_{ON(x)}$	Paralleled $R_{ON(x)}$: $R_{ON(1)}//R_{ON(2)}//...//R_{ON(n)}$
Current Limit (I_{CL})	Fixed or controlled by external resistor	Same as single-channel application, each channel has the same current limit value
Current Sensing (V_{CS})	Each channel indicated separately	Indicates a single channel. Full load current equals the sum of individual channel current sensing values
Short-Circuit Protection (SC)	Each channel detected independently	Global detection; a short circuit in any channel affects other channels simultaneously
Over-Voltage Clamp	Each channel clamped independently	Clamp voltage does not multiply; each channel has the same clamp voltage
Inductive Load Demagnetization (E_{AS})	Single-channel maximum demagnetization E_{AS}	Demagnetization energy does not multiply; external freewheeling circuit is recommended for high-inductance loads

It should be noted that:

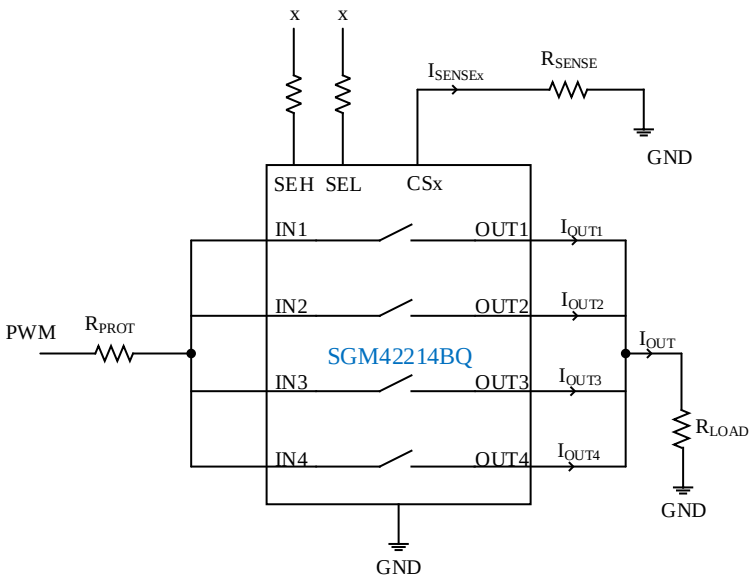
1) For devices that perform current sensing through channel-switching polling (e.g., SGM42214xQ), in parallel applications, the current sensing reports only the current flowing through a single output channel, and the total current sensing value equals the sum of the current sensing readings from each

channel. The CS pin application diagram is shown in Figure 8. The CS pin voltage that can be detected by the microcontroller is:

$$V_{CSx} = I_{SENSEx} \times R_{SENSE} \quad (4)$$

2) For devices with independent current sensing for each channel (e.g., SGM42203/42203Q), in parallel applications, all CS pins can be shorted together and connected to the sense resistor R_{SENSE} for total current detection. The CS pin application diagram is shown in Figure 9. The CS pin voltage that can be detected by the microcontroller is:

$$V_{CS_Total} = (I_{SENSE1} + I_{SENSE2}) \times R_{SENSE} \quad (5)$$



SEH	SEL	CSx
0	0	CS1
0	1	CS2
1	0	CS3
1	1	CS4

Figure 8 CS Pin Application Diagram for SGM42214BQ

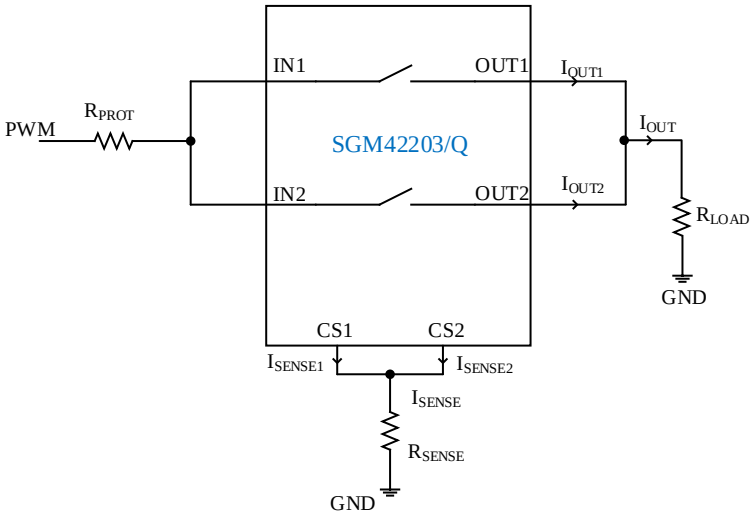


Figure 9 CS Pin Application Diagram for SGM42203/Q

In multi-channel high-side and low-side driver parallel applications driving inductive loads, the back-EMF generated during turn-off due to the inductive current's inability to change instantaneously must be safely clamped within the device's safe voltage capability. Each channel internally integrates drain-source voltage clamp protection, but in parallel applications, the clamp voltage does not multiply and remains the same as for a single channel. When turning off high-current, high-inductance loads, the demagnetization energy E_{AS}

to be dissipated is not evenly distributed among all channels. Due to device process variations, there are also certain deviations in clamp voltage among channels. In the worst-case scenario, the channel with the lower clamp voltage will be the first to activate clamp protection and conduct slightly, causing all demagnetization energy to flow through that single channel, and the resulting transient stress may damage that channel. If the demagnetization energy required for turning off a parallel-driven inductive load (E_{AS} = 1/2 × L × I²) is estimated to be higher than the turn-off demagnetization energy that a single channel can withstand, SG Micro Corp recommends referring to the application notes in the datasheet and adding an external clamp circuit to dissipate the excess demagnetization energy during design.

Table 3 Diagnostic Function Differences for High-Side and Low-Side Drivers

Characteristic	Single-Channel Application Behavior	Multi-Channel Parallel Application Behavior
Open-Circuit Detection	Each channel detected independently	Channels are not distinguished; faults appear simultaneously across all channels
Under-Voltage Lockout Protection	Each channel detected independently	Channels are not distinguished; faults appear simultaneously across all channels
Output Short to Supply or Ground	Each channel detected independently	Channels are not distinguished; faults appear simultaneously across all channels
Over-Current Fault Indication V_{CS}	Each channel detected independently	Channels are not distinguished; faults appear simultaneously across all channels
Loss of Supply/Ground Protection	Each channel detected independently	Channels are not distinguished; faults appear simultaneously across all channels
Battery Reverse Connection Detection	Each channel detected independently	Channels are not distinguished; faults appear simultaneously across all channels
Overload Thermal Cycle Restart	Each channel detected independently	Channels are distinguished; a specific channel may trigger thermal cycling independently of other channels
Thermal Shutdown Protection	Each channel detected independently	Channels are distinguished; a specific channel may trigger thermal shutdown before other channels

The fault diagnostic functions integrated in high-side and low-side drivers are fed back to the microcontroller through pins such as nFAULT, STATUS, CS, and SDO. The diagnosable fault types include: open-circuit detection, output short to supply or ground, over-current, overload, thermal shutdown, etc. When channels are paralleled with outputs shorted together, for devices that use analog current-sensing CS pins for fault reporting, any single channel can be selected via logic input pins to feedback load current status and device fault diagnostic information. Referring to the single-channel diagnostics and multi-channel parallel application diagnostics summarized in Table 3, in most cases when channels are paralleled, faults are not distinguished by channel and are reported through a single channel. Notably, in cases such as overload thermal restart or thermal shutdown protection in multi-channel driving, the fault can be identified through the corresponding channel's fault reporting. This is because process variations cause parameters such as current limit and on-resistance among paralleled channels to not be perfectly consistent. Once one channel reaches its current limit threshold, or its power dissipation triggers the thermal shutdown threshold and causes shutdown, that channel's current is forcibly redistributed to the other paralleled channels, which may subsequently trigger overload thermal shutdown in those channels as well.

5 Conclusion

By paralleling the outputs of multi-channel high-side and low-side drivers, output currents exceeding the maximum capability of a single channel can be achieved. From the perspective of multi-channel parallel applications, this article has introduced the current and voltage relationships of inputs and outputs, and elaborated on design considerations, functional parameter impacts, and differences in diagnostic fault reporting for parallel channel applications. In practical applications, to ensure system stability, reliability, and necessary safety margins, full consideration must be given during design to parameter deviations among channels and to all specifications outlined in the device datasheets.

6 References

[1] SG Micro Corp. SGM42214AQ_SGM42214BQ Datasheet [EB/OL].
https://www.sg-micro.com/rect/assets/d89e17e9-ee5e-4c9a-a256-78034f4336e8/SGM42214AQ_SGM42214BQ.PDF.
[2] SG Micro Corp. SGM42404A_SGM42404B Datasheet [EB/OL].
https://www.sg-micro.com/rect/assets/fa04f901-dd9b-48a7-894a-33e0a56eb681/SGM42404A_SGM42404B-Brief.pdf.

7 Appendix

The following is a series of driver products recently provided by SG Micro Corp. Welcome to call us for further discussion!

Table 4 High-Side and Low-Side Driver Product Portfolio

Product Type	Product Model	No. of channels	Output Clamp Voltage (V)	$R_{DS(ON)}$ @ +25°C (mΩ)	Output Peak Current (A)	Continuous Drain Current @ +25°C (A)	Package
Low Side Driver	SGM42401Q	1	42	90	8.5	3.5	SOT-223-3
	SGM42402Q	2	42	110	8.8*2	3.2/2.2, 1CH/2CH	SOIC-8
						4.2/3.1, 1CH/2CH	SOIC-8 (Exposed Pad)
	SGM42411Q/NQ	1	44	130	6	2	SOT-223-3
	SGM42403	4	50	350	3*4	1.5/0.8, 1CH/4CH	SOIC-20
						2/1, 1CH/4CH	TSSOP-16 (Exposed Pad)
	SGM42403Q	4	50	350	3*4	2/1.1, 1CH/4CH	TSSOP-16A (Exposed Pad)
	SGM42404A/B	4	51	300	3*4	2/1, 1CH/4CH	TSSOP-16 (Exposed Pad) TSSOP-20 (Exposed Pad)
	SGM42406	8	38	780	1.16*8	0.93/0.31, 1CH/8CH	TSSOP-16
						1/0.51, 1CH/8CH	TSSOP-16 (Exposed Pad)
	SGM42408Q	8	56	570	1.2*8	1/0.5, 1CH/8CH	TSSOP-24 (Exposed Pad)
High Side Driver	SGM42210Q	1	48.5	6	88	15	SSOP-16 (Exposed Pad), SSOP-14 (Exposed Pad)
	SGM42210NQ	1	48.5	7	88	15	SSOP-14 (Exposed Pad)
	SGM42203	2	70	80	22*2	3.5/2.5, 1CH/2CH	TSSOP-16A (Exposed Pad)
	SGM42203Q	2	70	86	22*2	3.5/2.5, 1CH/2CH	TSSOP-16A (Exposed Pad)
	SGM42214AQ/SGM42214BQ	4	40	150	4.6*4	2.5/1.5, 1CH/4CH	TSSOP-28 (Exposed Pad)

REVISION HISTORY

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

Date	Rev	Description
2026-07-15	REV.A	Initial Release

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