SGM48522Q
Automotive Dual 5V, 7A/6A Low-side GaN and MOSFET Driver

GENERAL DESCRIPTION

The high-speed, dual-channel low-side driver SGM48522Q is designed to drive GaN FETs and logic level MOSFETs. The application areas include LiDAR, time of flight, facial recognition, and power converters using low-side drivers. The SGM48522Q provides 7A source and 6A sink output current capability. Split output configuration allows individual turn-on and turn-off time optimization depending on FET. The Flip-Chip TQFN package and pinout minimize parasitic inductances to reduce the rise and fall time and limit the ringing. Additionally, the 2ns propagation delay with minimized tolerances and variations allows efficient operation at high frequencies.

The driver has internal under-voltage lockout and over-temperature protection against overload and fault events.

This device is AEC-Q100 qualified (Automotive Electronics Council (AEC) Standard Q100 Grade 1) and it is suitable for automotive applications.

The SGM48522Q is available in a Green TQFN-2×2-10AL package.

FEATURES

- **AEC-Q100 Qualified for Automotive Applications**
  Device Temperature Grade 1
  T_A = -40℃ to +125℃
- **5V Supply Voltage**
- **7A Peak Source and 6A Peak Sink Currents**
- **Ultra-Fast, Low-side Gate Driver for GaN and Si FETs**
- **Minimum Input Pulse Width: 1ns**
- **Up to 60MHz Operation**
- **Propagation Delay: 2ns (TYP)**
- **Rise Time: 720ps (TYP)**
- **Fall Time: 570ps (TYP)**
- **Protection Features:**
  - **Under-Voltage Lockout (UVLO)**
  - **Over-Temperature Protection (OTP)**
- **Available in a Green TQFN-2×2-10AL Package**

APPLICATIONS

Automotive Applications
Laser Distance Measuring System (LiDAR)
5G RF Communication System
Wireless Charging System
GaN DC/DC Conversion System

TYPICAL APPLICATION

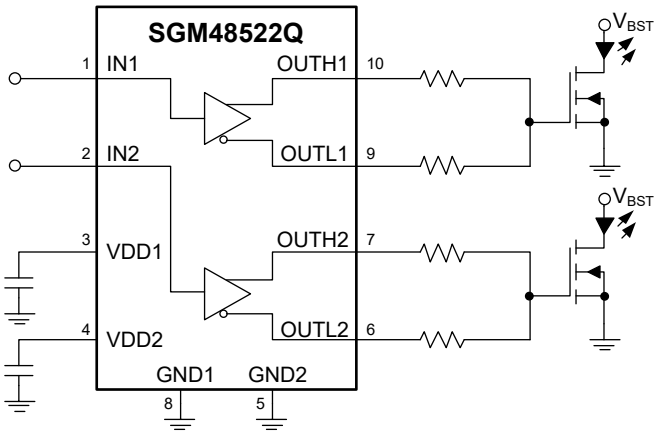


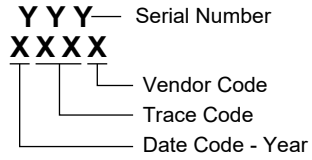
Figure 1. Typical Application Circuit

PACKAGE/ORDERING INFORMATION

MODEL	PACKAGE DESCRIPTION	SPECIFIED TEMPERATURE RANGE	ORDERING NUMBER	PACKAGE MARKING	PACKING OPTION
SGM48522Q	TQFN-2×2-10AL	-40℃ to +125℃	SGM48522QTSV10G/TR	0HT XXXX	Tape and Reel, 3000

MARKING INFORMATION

NOTE: XXXX = Date Code, Trace 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_{DD1}, V_{DD2} ..... -0.3V to 6V
IN1, IN2 Pin Voltage, V_{INx} ..... -0.3V to 6V
OUTH1, OUTH2 Pin Voltage, V_{OUTHx} .....-0.3V to V_{DD} + 0.3V
OUTL1, OUTL2 Pin Voltage, V_{OUTLx}
DC ..... -0.3V to 6V
Repetitive Pulse < 5ns ..... -2V to 7V
Package Thermal Resistance
TQFN-2×2-10AL, θ_{JA}..... 81.8℃/W
TQFN-2×2-10AL, θ_{JB}..... 18.9℃/W
TQFN-2×2-10AL, θ_{JC} ..... 57.3℃/W
Junction Temperature.....+150℃
Storage Temperature Range .....-65℃ to +150℃
Lead Temperature (Soldering, 10s).....+260℃
ESD Susceptibility
HBM.....4000V
CDM 1500V

RECOMMENDED OPERATING CONDITIONS

Supply Voltage, V_{DD1}, V_{DD2} .....4.5V to 5.5V
IN1, IN2 Pin Voltage, V_{INx} .....0V to 5.5V
Operating Ambient 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

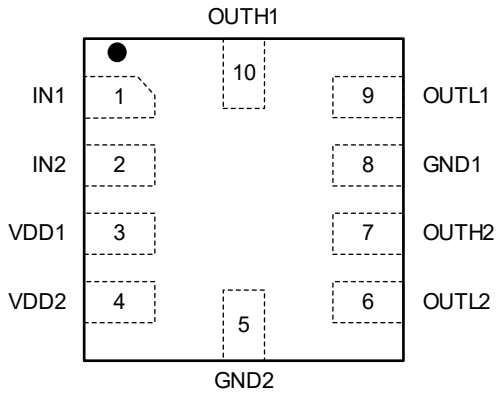
This integrated circuit can be damaged if ESD protections are not considered carefully. SGMICRO recommends that all integrated circuits be handled with appropriate precautions. Failure to observe proper handling and installation procedures can cause damage. ESD damage can range from subtle performance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



TQFN-2×2-10AL

PIN DESCRIPTION

PIN	NAME	I/O	FUNCTION
1	IN1	I	Channel 1 Control Logic Input (Non-Inverting).
2	IN2	I	Channel 2 Control Logic Input (Non-Inverting).
3	VDD1	I	Channel 1 Input Voltage Supply. Bypass to GND with a low inductance ceramic capacitor.
4	VDD2	I	Channel 2 Input Voltage Supply. Bypass to GND with a low inductance ceramic capacitor.
5	GND2	—	Channel 2 Ground. Internally connected to GND1 by anti-parallel diodes.
6	OUTL2	O	Channel 2 Pull-Down Gate Drive Output. Connect it to the gate of the target transistor with an optional resistor.
7	OUTH2	O	Channel 2 Pull-Up Gate Drive Output. Connect it to the gate of the target transistor with an optional resistor. Internally connected to GND2 by anti-parallel diodes.
8	GND1	—	Channel 1 Ground.
9	OUTL1	O	Channel 1 Pull-Down Gate Drive Output. Connect it to the gate of the target transistor with an optional resistor.
10	OUTH1	O	Channel 1 Pull-Up Gate Drive Output. Connect it to the gate of the target transistor with an optional resistor.

NOTE: I = input, O = output.

FUNCTION TABLE

INx Pin	OUTHx Pin	OUTLx Pin
L	Open	L
H	H	Open

ELECTRICAL CHARACTERISTICS

(V_{DD} = 4.5V to 5.5V, T_A = -40℃ to +125℃, typical values are at T_A = +25℃, unless otherwise noted.)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
DC Characteristics						
VDD Quiescent Current	I_{VDDQ}	V_{IN1} = V_{IN2} = V_{DD}		50	100	μA
		V_{IN1} = V_{IN2} = 0V		50	100	
VDD Operating Current	I_{VDD_OP}	f_{SW} = 30MHz, no load		48		mA
		f_{SW} = 30MHz, 100pF load		63		
Under-Voltage Lockout Threshold	V_{DD_UVLO}	V_{DDx} rising. Per channel	3.95	4.18	4.40	V
UVLO Hysteresis	ΔV_{DD_UVLO}			97		mV
Over-Temperature Shutdown, Rising Edge Threshold	T_{OTP}	Per channel		175		℃
Over-Temperature Hysteresis	ΔT_{OTP}			23		℃
Input DC Characteristics						
IN1, IN2 High Threshold	V_{IH}		1.7	2.1	2.6	V
IN1, IN2 Low Threshold	V_{IL}		1.1	1.4	1.8	V
IN1, IN2 Hysteresis	V_{HYS}		0.38		1	V
Input Pull-Down Resistance	R_{INx}	INx to GNDx	100	200	250	kΩ
Input Pin Capacitance	C_{INx}	INx to GNDx		2.3		pF
Output DC Characteristics						
Output Low Voltage (OUTLx)	V_{OL}	I_{OUTLx} = 100mA, V_{INx} = 0V			36	mV
Output High Voltage (OUTHx)	V_{DDx} - V_{OHx}	I_{OUTHx} = 100mA, V_{INx} = 5V			50	mV
Peak Source Current	I_{OH}	V_{OUTHx} = 0V, V_{INx} = 5V		7		A
Peak Sink Current	I_{OL}	V_{OUTLx} = 5V, V_{INx} = 0V		6		A

SWITCHING CHARACTERISTICS

(V_{DD} = 4.5V to 5.5V, T_A = -40℃ to +125℃, typical values are at T_A = +25℃, unless otherwise noted.)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
Startup Time, V_{DDx} Rising above UVLO	t_{START}	INx = VDDx, V_{DDx} rising to 4.4V to OUTHx rising		57	78	μs
ULVO Falling	$t_{SHUTOFF}$	INx = VDDx, V_{DDx} falling below 3.9V to OUTLx falling	0.7	2.5	3.5	μs
Turn-On Propagation Delay	t_{PDR}	INx to OUTHx, 100pF load		2.1	4	ns
Turn-Off Propagation Delay	t_{PDF}	INx to OUTLx, 100pF load		1.7	4	ns
Pulse Positive Distortion (t_{PDR} - t_{PDF})	Δt_{PD}			400		ps
Output Rise Time	t_{RISE}	0Ω series 100pF load (1)		720		ps
Output Fall Time	t_{FALL}	0Ω series 100pF load 1)		570		ps
Minimum Input Pulse Width	t_{MIN}	0Ω series 100pF load (1)		1		ns

NOTE:

1. Rise and fall are calculated as a 20% to 80%.

FUNCTIONAL BLOCK DIAGRAM

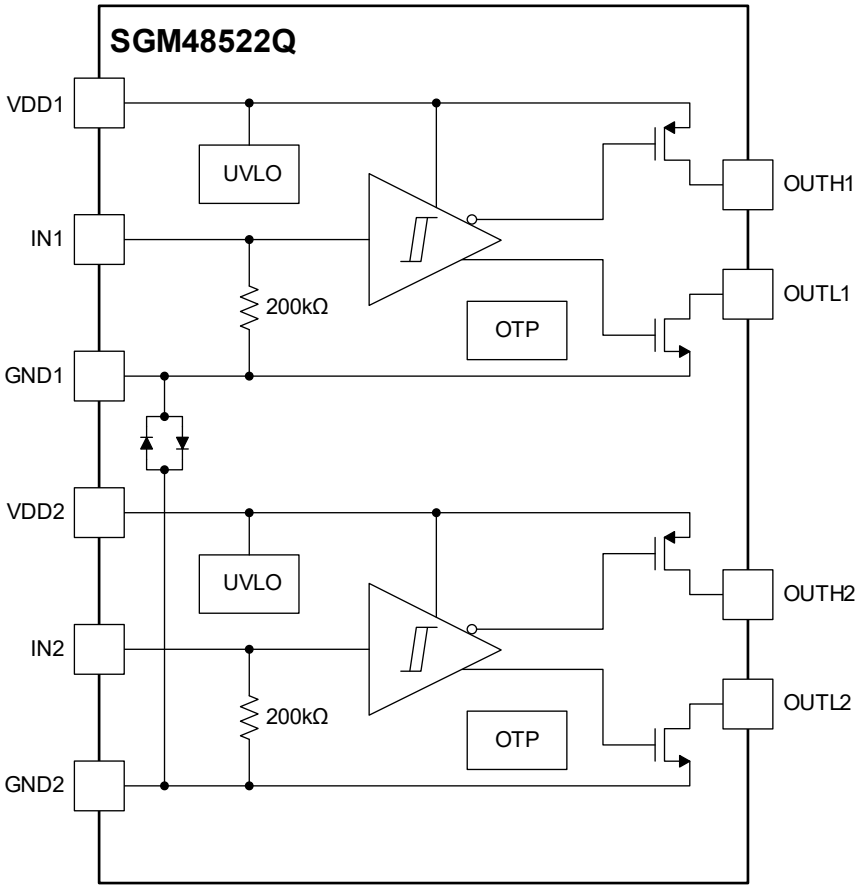
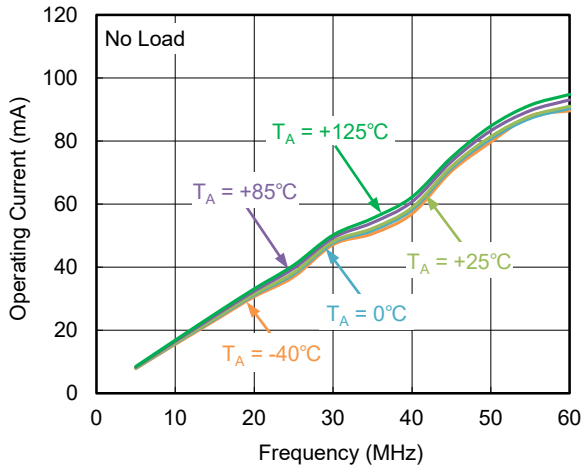


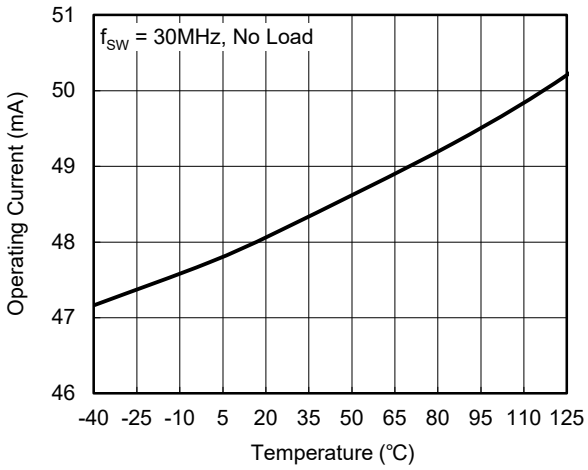
Figure 2. Functional Block Diagram

TYPICAL PERFORMANCE CHARACTERISTICS

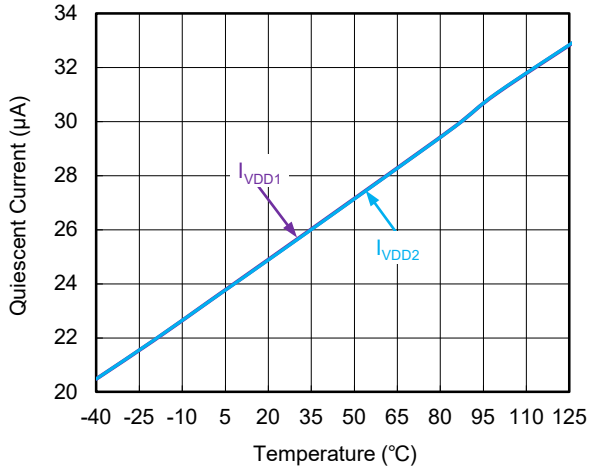
Operating Current vs. Frequency



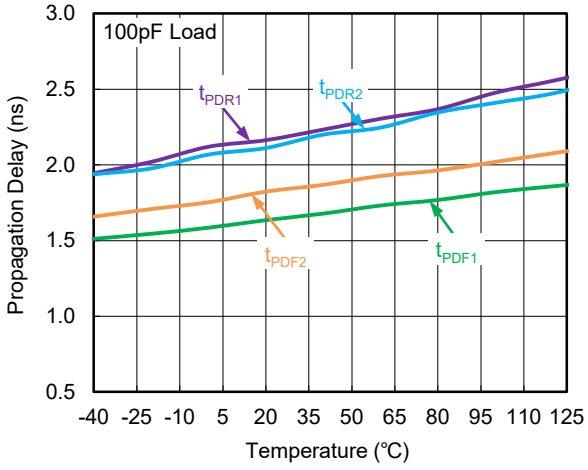
Operating Current vs. Temperature



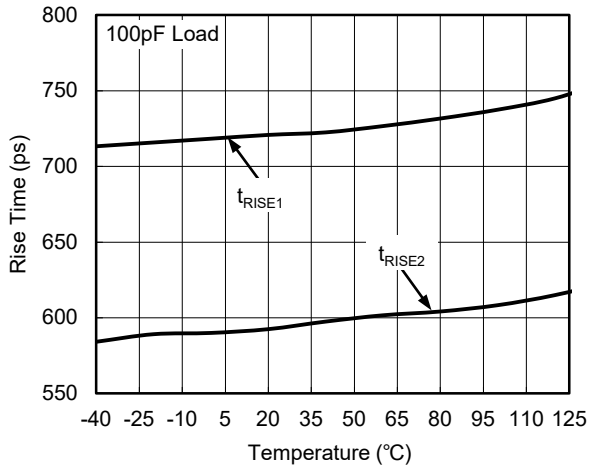
Quiescent Current vs. Temperature



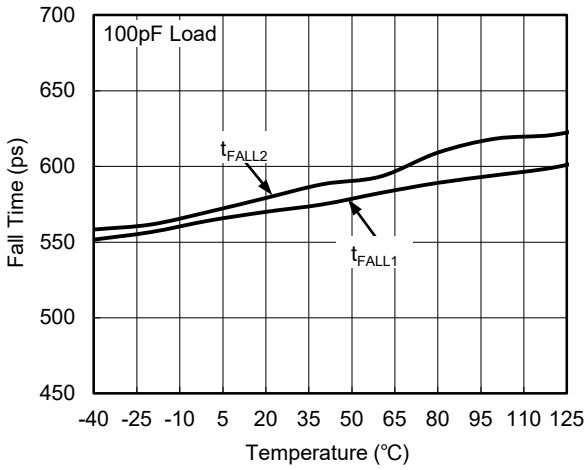
Propagation Delay vs. Temperature



Rise Time vs. Temperature

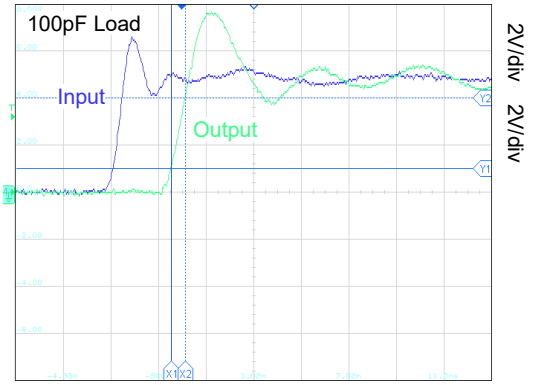


Fall Time vs. Temperature



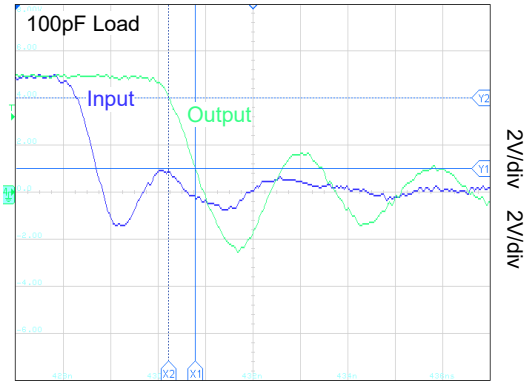
TYPICAL PERFORMANCE CHARACTERISTICS (continued)

Rising Edge



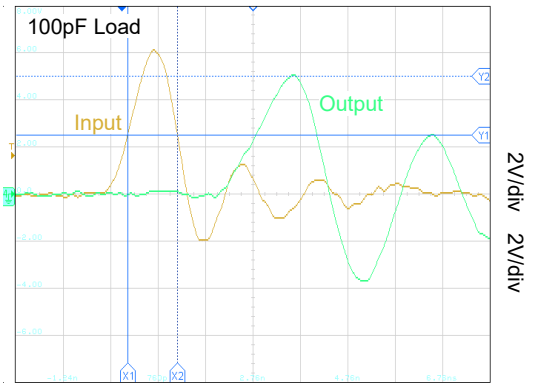
Time (2ns/div)

Falling Edge



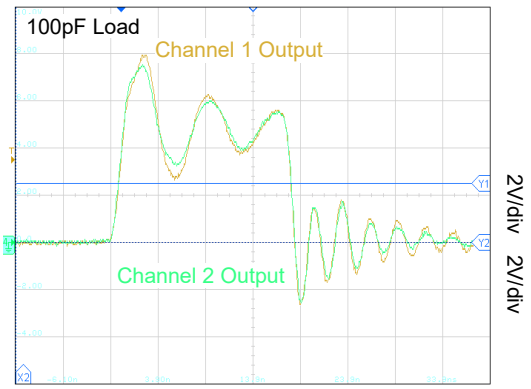
Time (1ns/div)

1ns Minimum Input Pulse Width



Time (1ns/div)

Channel Mismatch



Time (5ns/div)

DETAILED DESCRIPTION

The high-speed, dual low-side driver SGM48522Q is designed to drive GaN FETs and logic level MOSFETs. The application areas include LiDAR, time of flight, facial recognition, and power converters using low-side drivers.

SGM48522Q provides the lowest propagation delay of 2ns from the drivers to the power transistors.

Input Stage

There are Schmitt triggers at the input pins IN1 and IN2 to improve noise immunity. In order to prevent the output from accidentally turning on when the input is in the floating state, IN1 and IN2 are internally connected to pull-down resistors.

Output Stage

SGM48522Q provides 7A peak source and 6A sink currents, and the outputs are separated to allow custom pull-up and pull-down drive strength to suit the application. The OUTHx and OUTLx pins can be severally connected to transistor gates with separate drive resistors, adjusting the driving speed of turning on and off to control the slew rate and EMI of the driving signal and the ringing on the gate signal. Controlling ringing as much as possible reduces the stress on the driver and switch device, which is very important for high-performance applications and reliability of GaN FETs. In order to prevent the device C_{ISS} from turning the FET on by mistake, the OUTLx pins will be pulled low in under-voltage conditions.

VDD and Under-Voltage Lockout

The rated working voltage of SGM48522Q is 5V ± 0.5V. In the application, the error of the power supply of the driver chip needs to be ensured within 0.5V, and the transient overshoot voltage of the power supply cannot exceed the absolute maximum voltage of the part. In the VDD Overshoot Solution section, there are more specific design details.

SGM48522Q provides independent under-voltage lockout (UVLO) function on each channel to protect the circuits in the event of a fault condition. The UVLO rising trigger point is typically set at 4.18V, and the hysteresis voltage point is 97mV. This UVLO level ensures that the GaN FET operates in the low R_{DSON} region. When UVLO is triggered, the output is low.

Over-Temperature Protection (OTP)

The SGM48522Q provides independent over-temperature protection (OTP) function for each channel with a trigger point of +175℃. The hysteresis temperature is 23℃. If the OTP is triggered, switching action is stopped for the channel with the corresponding OUTLx held low. Then when the junction temperature of the device falls below +152℃, normal operation resumes.

APPLICATION INFORMATION

Since the output of the PWM controller cannot often provide the voltage required by the gate of the power device, a high-performance gate driver is usually required between the PWM output of the controller and the gate of the GaN transistor, so that the GaN transistor can operate at correct gate voltages. In addition, the gate driver can reduce switching losses and maximize the performance of GaN transistors in high-frequency applications. Especially in the field of digital power control, it is common for the PWM signal of the digital controller to be a 3.3V logic signal, and GaN transistors cannot work optimally with this gate voltage. The gate driver boosts the 3.3V signal to the preferred gate drive voltage of 5V, which fully turns on the power device and minimizes conduction losses.

The good noise immunity of the SGM48522Q gate driver also minimizes the effects of high frequency switching noise when the driver is placed near the power switch. Adding a gate driver also transfers the gate charge power loss from the controller to the driver, which effectively reduces the power consumption and thermal stress in the controller.

The SGM48522Q is a low-side high-speed gate driver with a maximum operating frequency of 60MHz and an operating voltage of 5V. It is optimized to drive GaN FETs. The output has an independent configuration architecture, which can flexibly adjust the turn-on and turn-off speed, while providing a strong current sinking and sourcing capabilities.

The SGM48522Q is primarily used to drive GaN transistors, which are used in various power converters, LiDAR, wireless chargers, and synchronous rectifiers. The SGM48522Q can be used as a driver for high-speed pulsed laser diodes.

Typical Application

A typical application circuit for the SGM48522Q is shown in Figure 1, with a dual-channel, 5V drive voltage, specifically designed to drive GaN transistors or logic-level Si FETs. The output has a separated structure, so that the turn-on and turn-off speeds can be controlled separately by driving resistors. If it is not necessary to adjust the turn-on and turn-off speeds separately, OUTHx and OUTLx may be connected directly together (with a single gate drive resistor added if necessary).

In order to avoid voltage overstress caused by the parasitic inductance of the drive circuit, SGMICRO recommends using at least 2Ω resistors at OUTHx and OUTLx.

For applications requiring a smaller resistance value, please contact SGMICRO E2E for guidance.

Design Requirements

There are some key factors to consider when designing with the SGM48522Q gate driver and GaN power FETs, especially for high MHz frequency (or nanosecond pulse) applications. These factors include circuit layout, PCB trace design, passive component selection, and maximum operating frequency.

Detailed Design Procedure

Handling Ground Bounce

Place the ground pin of the SGM48522Q as close as possible to the source of the low-side FET to get the smallest gate current loop, the smallest parasitic inductance, and maximize the switching performance. However, this can cause ground bounce on the SGM48522Q, resulting in incorrect switching logic at the input and wrong level at the output.

In order to eliminate this effect, SGM48522Q has built-in Schmitt triggers on the input terminals to increase the input hysteresis. Equation 1 shows the relationship between the input hysteresis and the maximum allowable di/dt:

$$\frac{di}{dt} = \frac{V_{HYS}}{L_P} \quad (1)$$

where

L_P: Parasitic inductance between source and Ground.

V_{HYS}: Hysteresis voltage of the input port.

di/dt: Current slew rate.

APPLICATION INFORMATION (continued)

Assuming that the parasitic inductance is 0.7nH and the hysteresis voltage is 0.7V, the maximum allowable current slew rate is 1A/ns by calculation. If the current slew rate generated in the application is higher than 1A/ns, this exceeds the hysteresis voltage range and causes the output signal to be unstable. Using the inverting input to accept the PWM signal and connecting the non-inverting input to VDD reduce the possibility of false pulses or oscillations and improve stability. High di/dt produces high transient voltage spikes that affect the input of the SGM48522Q. In order to protect the device from a large current spike at INx, a 100Ω current limiting resistor can be placed before the INx input.

If the current slew rate is not too high, and the pulse width is not very short (for example, 1ns range), the extra delay can be accepted. The parasitic capacitance of the SGM48522Q input can be used as a good advantage to create an RC filter to reduce high-frequency noise by adding a resistor in series with the input pin. The SGM48522Q has stable input capacitance of about 2.3pF at the input pins, which is convenient for this purpose.

In applications that use current sensing resistors, the ground bounce phenomenon is particularly serious. In the application circuit with current sense resistor, the ground of the SGM48522Q is connected to the source of the GaN FET, and one side of the current sense resistor is connected to the controller ground. In the case of high-speed switching and large current, the potential rebound due to the parasitic inductance of the current detection resistor will cause the circuit to turn on/off by mistake, and in severe cases may cause damage to the device. When the pulse width is not extremely narrow, a resistor can also be added to the signal output line before SGM48522Q to form an RC filter as a supplement. Although the circuit can improve the ground bounce problem by connecting the ground of the driver to the signal ground after the current sense resistor, this circuit is not recommended. The drawback of this circuit is that the voltage drop across the current sense resistor and its parasitic inductance reduce the transient and DC gate drive voltage to the FET, thus reducing efficiency. In severe cases, the voltage ringing caused by the inductance of the sense resistor path can even cause the FET to spuriously turn on and off.

VDD Overshoot Solution

Due to the existence of PCB parasitic inductance, inductance ringing and transient overshoot voltage are prone to occur under high current switching conditions. In the PCB design process, it is necessary to evaluate and control the overshoot caused by the ringing, so as not to exceed the stress of the device. The strength of the overshoot voltage and the percentage of the overshoot duration to the switching time are parameters that affect the stress. Keeping the overshoot below maximum allowable pin voltage is the best solution. The parasitic inductance can be decreased by optimizing PCB layout. To limit the voltage overshoot, low ESL components and series resistance can be helpful as well. If the overshoot is too large, the accuracy of the power supply needs to be considered. For example, if the overshoot voltage is 0.5V, the maximum error voltage of the power supply cannot exceed 5.5V (10% accuracy). Therefore, if the overshoot voltage is large, a power supply with higher accuracy is necessary.

APPLICATION INFORMATION (continued)

Applications at High Frequencies

SGM48522Q has a rise/fall time of 720ps/570ps, and provides a minimum output capability of 1ns pulse width and a maximum operating frequency of 60MHz. According to the capacitive load, different output modes and frequencies can be selected. Under the working condition of high-frequency pulse, in order to prevent the device from overheating, a high-frequency pulse train with a certain interval time can be used. This can increase the transient frequency and keep the effective value of the output current unchanged. At this time, a larger decoupling capacitor is needed to charge the capacitive load at a high frequency.

Power Supply Recommendations

In order to provide high peak current when the FET is turned on and improve the stability of the VDD pin supply voltage, a low ESR/ESL ceramic capacitor needs to be used as a bypass capacitor placed as close as possible to the IC's VDD and GND pins. To avoid ringing at the IC pins as much as possible, the decoupling capacitors need to be placed on the same side as the IC, and vias cannot be used.

In order to achieve the best transient performance, SGMICRO recommends choosing a three-terminal capacitor and a capacitor with a larger capacitance in parallel. The three-terminal capacitor needs to be placed close to the VDD and GND pins of the IC, and the other capacitor is placed close to the three-terminal capacitor. The three-terminal capacitor has the lowest ESL, and the larger capacitor provides enough drive peak current. Under normal circumstances, it is recommended to use 0.1μF 0402 or through-core capacitors in parallel with 1μF 0603 capacitors.

Layout Guidelines

Proper PCB layout is extremely important in a high-current, fast-switching circuit to provide appropriate device operation and design robustness.

In order to achieve the best performance, a PCB with at least four routing layers is recommended to minimize the parasitic inductance. Using resistors and capacitors in a smaller package (0201) can also minimize inductance and PCB space. It is necessary to calculate the resistor power of a small package to meet the requirements of gate drive power loss.

Drive Loop Inductance and Grounding

SGM48522Q should be placed as close to the GaN FET as possible, and the trace of the gate drive circuit should be as wide as possible to reduce parasitic inductance.

To achieve minimum drive loop inductance, it is recommended to use the second layer of the PCB as the source loop of the GaN FET, near the bottom of the device (top layer). Both the vias connected to the GND pin and the source of the FET are connected to this layer with minimal impedance. Please note that the coupling of the ground plane will be decreased only when the GND plane is connected to the source power plane at the FET.

Bypass Capacitor

The VDD pins require bypass capacitors connected to their respective GND pins, placed as close to the pins of the SGM48522Q as possible. The capacitor should be connected to VDD and GND power planes, which should be large and as close to the top layer of the PCB as possible. Due to the high operating frequency of the IC, the inductance of the bypass capacitor is critical, so the value of the bypass capacitor should be between 0.1μF and 1μF, and the material should be X7R or better. The best capacitors for the application are low inductance chip capacitors (LICC), interdigital capacitors (IDC), feedthrough and LGA capacitors. Finally, in order to meet the demand of driving peak current, an extra 1μF capacitor between VDD and GND should be added in parallel close to the IC.

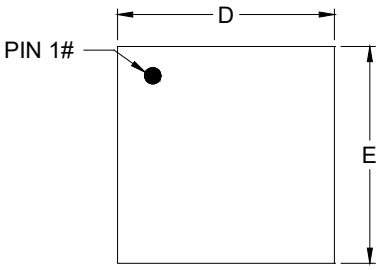
REVISION HISTORY

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

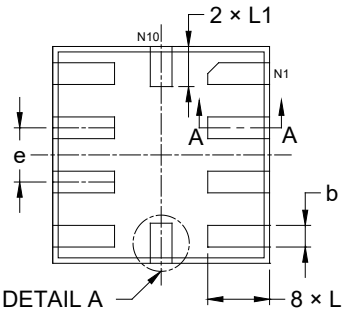
Changes from Original (AUGUST 2024) to REV.A	Page
Changed from product preview to production data	All

PACKAGE OUTLINE DIMENSIONS

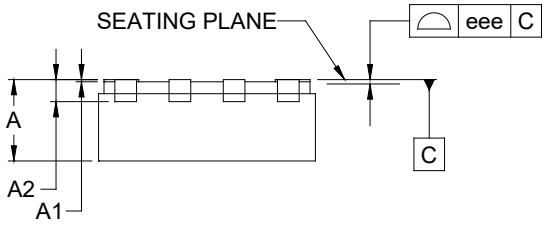
TQFN-2×2-10AL



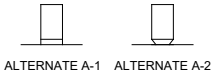
TOP VIEW



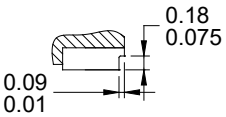
BOTTOM VIEW



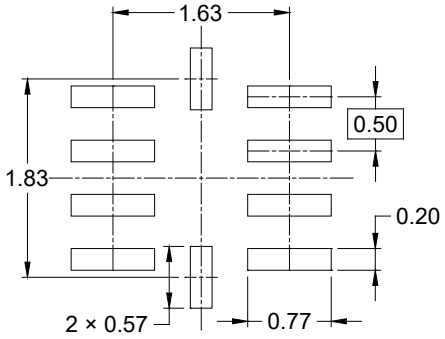
SIDE VIEW



DETAIL A
ALTERNATE TERMINAL CONSTRUCTION



SECTION A-A
TERMINAL CROSS SECTION



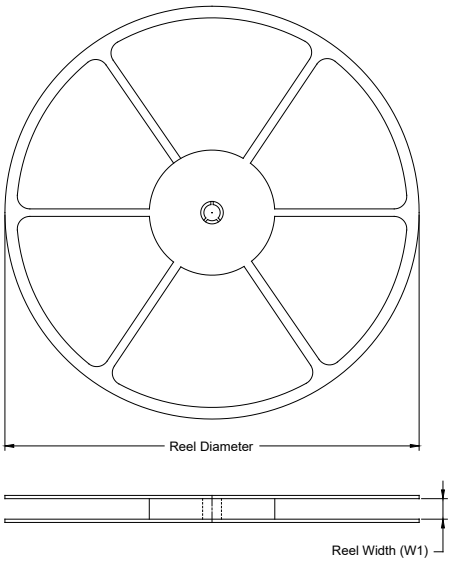
RECOMMENDED LAND PATTERN (Unit: mm)

Symbol	Dimensions In Millimeters		
	MIN	NOM	MAX
A	0.700	-	0.800
A1	0.000	-	0.050
A2	0.203 REF		
b	0.150	-	0.250
D	1.900	-	2.100
E	1.900	-	2.100
e	0.500 BSC		
L	0.470	-	0.670
L1	0.270	-	0.470
eee	0.080		

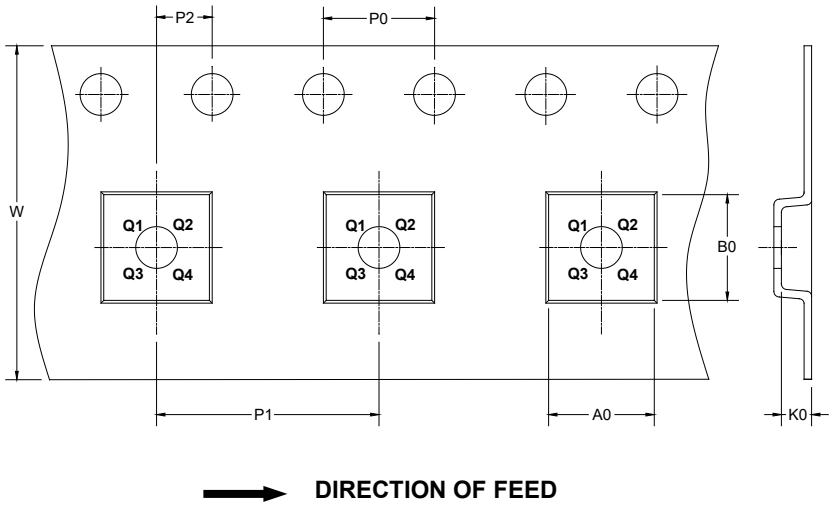
NOTE: This drawing is subject to change without notice.

TAPE AND REEL INFORMATION

REEL DIMENSIONS



TAPE DIMENSIONS



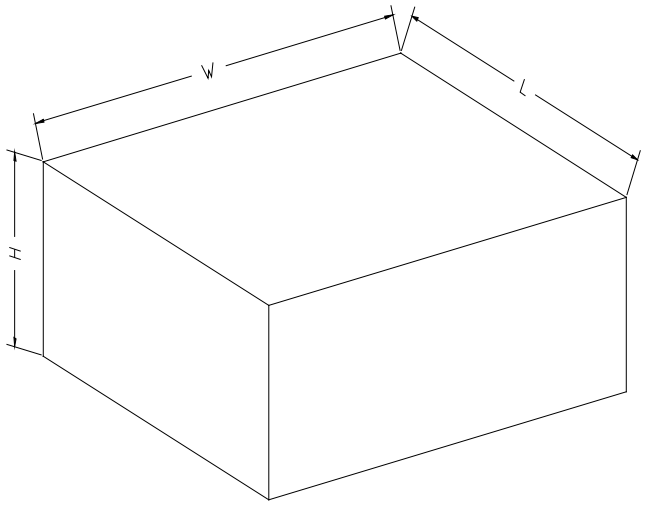
NOTE: The picture is only for reference. Please make the object as the standard.

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
TQFN-2×2-10AL	7"	9.5	2.30	2.30	1.10	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