

Galvanically isolated 4 A single gate driver for SiC MOSFETs



Features

- High voltage rail up to 1700 V
- Driver current capability: 4 A sink/source @25 °C
- dV/dt transient immunity ± 100 V/ns in full temperature range
- Overall input-output propagation delay: 75 ns
- Separate sink and source option for easy gate driving configuration
- 4 A Miller CLAMP dedicated pin option
- UVLO function
- Gate driving voltage up to 26 V
- 3.3 V, 5 V TTL/CMOS inputs with hysteresis
- Temperature shutdown protection
- Standby function
- 4.8 kV_{PK} isolation
- Narrow body SO8

Application

- Motor driver for home appliances, factory automation, industrial drives and fans.
- 600/1200 V inverters
- Battery chargers
- Induction heating
- Welding
- UPS
- Power supply units
- DC-DC converters
- Power Factor Correction

Description

The **STGAP2SICSN** is a single gate driver which provides galvanic isolation between the gate driving channel and the low voltage control and interface circuitry.

The gate driver is characterized by 4 A capability and rail-to-rail outputs, making the device also suitable for mid and high power applications such as power conversion and motor driver inverters in industrial applications. The device is available in two different configurations. The configuration with separated output pins allows to independently optimize turn-on and turn-off by using dedicated gate resistors. The configuration featuring single output pin and Miller CLAMP function prevents gate spikes during fast commutations in half-bridge topologies. Both configurations provide high flexibility and bill of material reduction for external components.

The device integrates protection functions: UVLO with optimized value for SiC MOSFETs and thermal shutdown are included to easily design high reliability systems. Dual input pins allow choosing the control signal polarity and also implementing HW interlocking protection in order to avoid cross-conduction in case of controller malfunction. The input to output propagation delay results are contained within 75 ns, providing high PWM control accuracy. A standby mode is available in order to reduce idle power consumption.

Product status link

[STGAP2SICSN](#)

Product label



1 Block diagram

Figure 1. Block diagram - Single output and Miller Clamp configuration

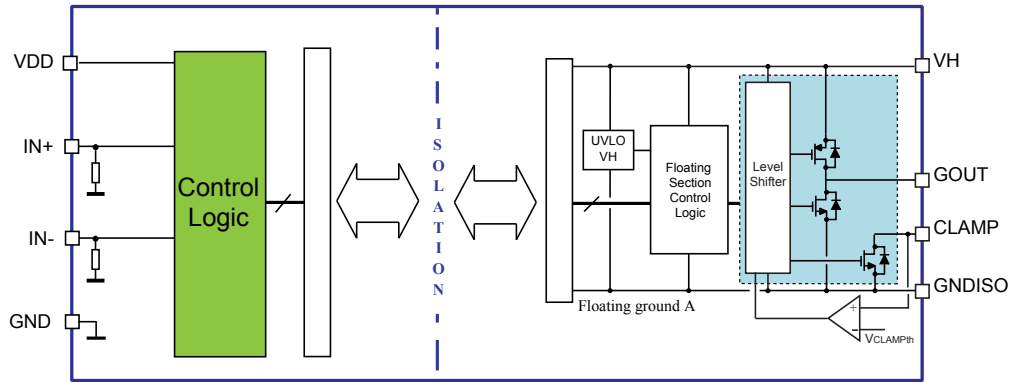
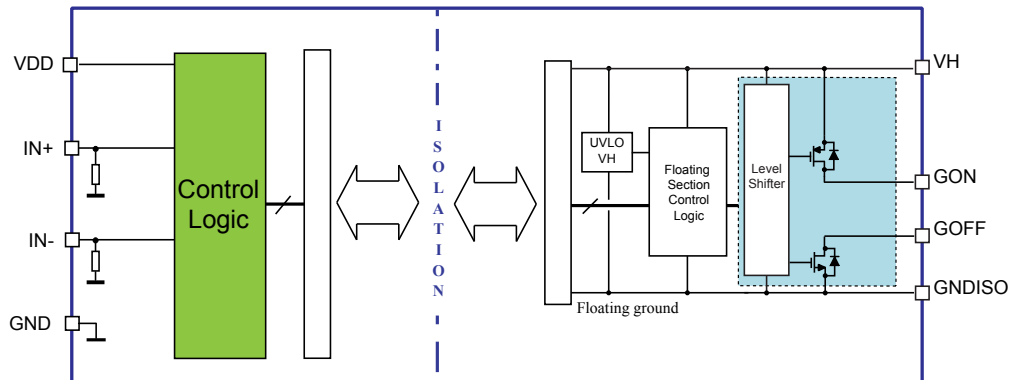


Figure 2. Block diagram - Separate outputs configuration



2 Pin description and connection diagram

Figure 3. Pin connection (top view), Separated outputs option

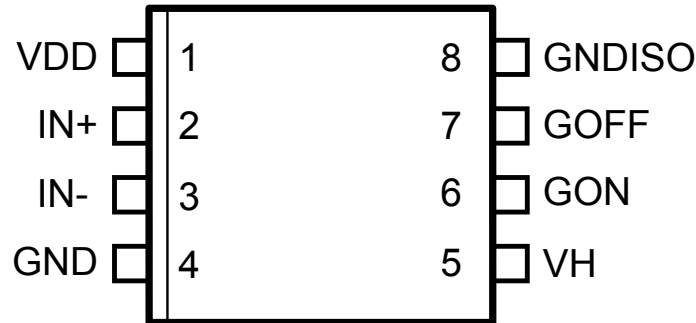


Figure 4. Pin connection (top view), Single output and Miller CLAMP option

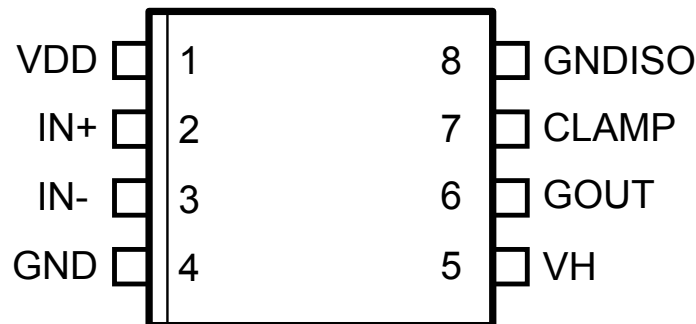


Table 1. Pin Description

| Pin # | | Pin name | Type | Function |
|----------|----------|----------|---------------|---------------------------------------|
| Figure 3 | Figure 4 | | | |
| 1 | 1 | VDD | Power supply | Driver logic supply voltage. |
| 2 | 2 | IN+ | Logic input | Driver logic input, active high. |
| 3 | 3 | IN- | Logic input | Driver logic input, active low. |
| 4 | 4 | GND | Power supply | Driver logic ground. |
| 5 | 5 | VH | Power supply | Gate driving positive voltage supply. |
| | 6 | GOUT | Analog output | Sink/Source output. |
| | 7 | CLAMP | Analog output | Active Miller Clamp. |
| 6 | | GON | Analog output | Source output. |
| 7 | | GOFF | Analog output | Sink output. |
| 8 | 8 | GNDISO | Power supply | Gate driving Isolated ground. |

3 Electrical data

3.1 Absolute maximum ratings

Table 2. Absolute maximum ratings

| Symbol | Parameter | Test condition | Min. | Max. | Unit |
|--------------------|--|----------------|------|----------|------|
| VDD | Logic supply voltage vs. GND | | -0.3 | 6.5 | V |
| V _{LOGIC} | Logic pins voltage vs. GND | | -0.3 | 6.5 | V |
| VH | Positive supply voltage (VH vs. GNDISO) | | -0.3 | 28 | V |
| V _{OUT} | Voltage on gate driver outputs (GON, GOFF, CLAMP vs. GNDISO) | | -0.3 | VH + 0.3 | V |
| T _J | Junction temperature | | -40 | 150 | °C |
| T _S | Storage temperature | | -50 | 150 | °C |
| ESD | HBM (human body model) | | | 2 | kV |

3.2 Thermal data

Table 3. Thermal data

| Symbol | Parameter | Package | Value | Unit |
|---------------------|--|---------|-------|------|
| R _{th(JA)} | Thermal resistance junction to ambient | SO-8 | 123 | °C/W |

3.3 Recommended operating conditions

Table 4. Recommended operating conditions

| Symbol | Parameter | Test conditions | Min. | Max. | Unit |
|---------------------|---|-----------------|------------------------|-------|------|
| VDD | Logic supply voltage vs. GND | | 3.1 | 5.5 | V |
| V _{LOGIC} | Logic pins voltage vs. GND | | 0 | 5.5 | V |
| VH | Positive supply voltage (VH vs. GNDISO) | | Max(V _{Hon}) | 26 | V |
| V _{ISO-OP} | Input to output operative voltage (GND to GNDISO) | DC or peak | -1700 | +1700 | V |
| F _{SW} | Maximum switching frequency. ⁽¹⁾ | | | 1 | MHz |
| t _{OUT} | Output Pulse width | | 100 | | ns |
| T _J | Operating Junction Temperature | | -40 | 125 | °C |

1. Actual limit depends on power dissipation and T_J

4 Electrical characteristics

Table 5. Electrical characteristics

| Symbol | Pin | Parameter | Test conditions | Min. | Typ. | Max. | Unit |
|--------------------------------|-------------|--|-------------------------------------|---------------------|---------------------|---------------------|------------|
| Dynamic characteristics | | | | | | | |
| t_{Don} | IN+, IN- | Input to output propagation delay ON | | 50 | 75 | 90 | ns |
| t_{Doff} | IN+, IN- | Input to output propagation delay OFF | | 50 | 75 | 90 | ns |
| t_r | | Rise time | $C_L = 4.7$ nF see Figure 12 | | 30 | | ns |
| t_f | | Fall time | | | 30 | | ns |
| PWD | | Pulse Width Distortion $t_{Don} - t_{Doff}$ | | | | 20 | ns |
| $t_{deglitch}$ | IN+, IN- | Inputs deglitch filter | | | 20 | 40 | ns |
| CMTI ⁽¹⁾ | | Common-mode transient immunity, $ dV_{ISO}/dt $ | $V_{CM} = 1500$ V, see Figure 13 | 100 | | | V/ns |
| Supply voltage | | | | | | | |
| $V_{H_{on}}$ | VH | VH UVLO turn-on threshold | | 14.6 | 15.5 | 16.4 | V |
| $V_{H_{off}}$ | VH | VH UVLO turn-off threshold | | 13.9 | 14.8 | 15.7 | V |
| $V_{H_{hyst}}$ | VH | VH UVLO hysteresis | | 600 | 750 | 950 | mV |
| $I_{QH_{U}}$ | VH | VH undervoltage quiescent supply current | $V_H = 7.0$ V | | 1.3 | 1.8 | mA |
| I_{QH} | VH | VH quiescent supply current | | | 1.3 | 1.8 | mA |
| $I_{QH_{SBY}}$ | VH | Standby VH quiescent supply current | Standby mode | | 400 | 550 | μ A |
| SafeClp | GOUT / GOFF | GOFF active clamp | $I_{GOFF} = 0.2$ A; VH floating | | 2 | 2.3 | V |
| I_{QDD} | VDD | VDD quiescent supply current | | | 1.0 | 1.3 | mA |
| $I_{QDD_{SBY}}$ | VDD | Standby VDD quiescent supply current | Standby mode | | 40 | 65 | μ A |
| Logic inputs | | | | | | | |
| V_{il} | IN+, IN- | Low-level logic threshold voltage | | $0.29 \cdot V_{DD}$ | $0.33 \cdot V_{DD}$ | $0.37 \cdot V_{DD}$ | V |
| V_{ih} | IN+, IN- | High-level logic threshold voltage | | $0.62 \cdot V_{DD}$ | $0.66 \cdot V_{DD}$ | $0.70 \cdot V_{DD}$ | V |
| I_{INh} | IN+, IN- | INx logic "1" input bias current | $INx = 5$ V | 33 | 50 | 70 | μ A |
| I_{INl} | IN+, IN- | INx logic "0" input bias current | $INx = GND$ | | | 1 | μ A |
| R_{pd} | IN+, IN- | Inputs pull-down resistors | $INx = 5$ V | 70 | 100 | 150 | k Ω |
| Driver buffer section | | | | | | | |
| I_{GON} | GOUT / GON | Source short-circuit current | $T_J = 25$ °C | | 4 | | A |

| Symbol | Pin | Parameter | Test conditions | Min. | Typ. | Max. | Unit |
|-----------------------------------|-------------|---------------------------------------|--|---------|----------|------|------------------|
| I_{GON} | GOUT / GON | Source short-circuit current | $T_J = -40 \div +125 \text{ }^\circ\text{C}^{(1)}$ | 3 | | 5 | |
| V_{GONH} | GOUT / GON | Source output high-level voltage | $I_{GON} = 100 \text{ mA}$ | VH-0.15 | VH-0.125 | | V |
| R_{GON} | GOUT / GON | Source R_{DS_ON} | $I_{GON} = 100 \text{ mA}$ | | 1.25 | 1.5 | Ω |
| I_{GOFF} | GOUT / GOFF | Sink short-circuit current | $T_J = 25 \text{ }^\circ\text{C}$ | | 4 | | A |
| | | | $T_J = -40 \div +125 \text{ }^\circ\text{C}^{(1)}$ | 3 | | 5.5 | |
| V_{GOFFL} | GOUT / GOFF | Sink output low-level voltage | $I_{GOFF} = 100 \text{ mA}$ | | 110 | 120 | mV |
| R_{GOFF} | GOUT / GOFF | Sink R_{DS_ON} | $I_{GOFF} = 100 \text{ mA}$ | | 1.1 | 1.2 | Ω |
| Miller clamp function | | | | | | | |
| $V_{CLAMPth}$ | CLAMP | CLAMP voltage threshold | V_{CLAMP} vs. GNDISO | 1.3 | 2 | 2.6 | V |
| I_{CLAMP} | CLAMP | CLAMP short-circuit current | $V_{CLAMP} = 15 \text{ V}$ | | | | A |
| | | | $T_J = 25 \text{ }^\circ\text{C}$ | | 4 | | |
| | | | $T_J = -40 \div +125 \text{ }^\circ\text{C}^{(1)}$ | 2 | | 5 | |
| V_{CLAMP_L} | CLAMP | CLAMP low-level output voltage | $I_{CLAMP} = 100 \text{ mA}$ | | 96 | 115 | mV |
| R_{CLAMP} | CLAMP | CLAMP R_{DS_ON} | $I_{CLAMP} = 100 \text{ mA}$ | | 0.96 | 1.15 | Ω |
| Overtemperature protection | | | | | | | |
| T_{SD} | | Shutdown temperature ⁽¹⁾ | | 170 | | | $^\circ\text{C}$ |
| T_{hys} | | Temperature hysteresis ⁽¹⁾ | | | 20 | | $^\circ\text{C}$ |
| Standby | | | | | | | |
| t_{STBY} | | Standby time | See Section 5.7 | 200 | 280 | 500 | μs |
| t_{WUP} | | Wake-up time | See Section 5.7 | 10 | 20 | 35 | μs |
| t_{awake} | | Wake-up delay | See Section 5.7 | 90 | 140 | 200 | μs |
| $t_{stbyfilt}$ | | Standby filter | See Section 5.7 | 200 | 280 | 800 | ns |

1. Characterization data, not tested in production.

Table 6. Isolation related package specifications

| Parameter | Symbol | Value | Unit | Conditions |
|---|--------|------------|------|--|
| Clearance (Minimum External Air Gap) | CLR | 4 | mm | Measured from input terminals to output terminals, shortest distance through air |
| Creepage (*) (Minimum External Tracking) | CPG | 4 | mm | Measured from input terminals to output terminals, shortest distance path along body |
| Comparative Tracking Index (Tracking Resistance) | CTI | ≥ 400 | V | DIN IEC 112/VDE 0303 Part 1 |
| Isolation Group | | II | | Material Group (DIN VDE 0110, 1/89, Table 1) |

Table 7. Isolation characteristics

| Parameter | Symbol | Test conditions | Characteristic | Unit |
|--|------------|----------------------------------|----------------|------------|
| Input to Output test voltage In accordance with VDE 0884-11 | V_{PR} | Method a, Type test | 2720 | V_{PEAK} |
| | | $V_{PR} = 2720$, $t_m = 10$ s | | |
| | | Partial discharge < 5 pC | | |
| | | Method b1, 100 % Production test | 3200 | V_{PEAK} |
| | | $V_{PR} = 3200$, $t_m = 1$ s | | |
| Partial discharge < 5 pC | | | | |
| Transient Overvoltage (Highest Allowable Overvoltage) | V_{IOTM} | $t_{ini} = 60$ s, Type test | 4800 | V_{PEAK} |
| Maximum Surge Test Voltage | V_{IOSM} | Type test | 4800 | V_{PEAK} |
| Isolation Resistance | R_{IO} | $V_{IO} = 500$ V, Type test | $>10^9$ | Ω |

Table 8. UL 1577 Tests

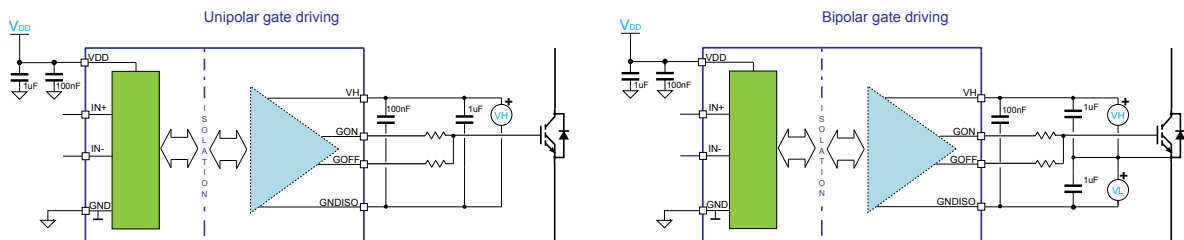
| Description | Symbol | Characteristic | Unit |
|---|---------------|----------------|--------------------|
| Isolation Withstand Voltage, 1min (Type test) | V_{ISO} | 2828/4000 | V_{rms}/ P_{EAK} |
| Isolation Voltage, 1sec (100% production) | $V_{ISOtest}$ | 3394/4800 | V_{rms}/ P_{EAK} |

5 Functional Description

5.1 Gate driving power supply and UVLO

The STGAP2SiCSN is a flexible and compact gate driver with 4 A output current and rail-to-rail outputs. The device allows implementation of either unipolar or bipolar gate driving.

Figure 5. Power supply configuration for unipolar and bipolar gate driving



Undervoltage protection is available on VH supply pin. A fixed hysteresis sets the turn-off threshold, thus avoiding intermittent operation.

When VH voltage goes below the VH_{off} threshold, the output buffer goes into “safe state”. When VH voltage reaches the VH_{on} threshold, the device returns to normal operation and sets the output according to actual input pins status.

The VDD and VH supply pins must be properly filtered with local bypass capacitors. The use of capacitors with different values in parallel provides both local storage for impulsive current supply and high-frequency filtering. The best filtering is obtained by using low-ESR SMT ceramic capacitors, which are therefore recommended. A 100 nF ceramic capacitor must be placed as close as possible to each supply pin, and a second bypass capacitor with a value in the range between 1 μ F and 10 μ F should be placed close to it.

5.2 Power-up, power-down and ‘safe state’

The following conditions define the “safe state”:

- GOFF = ON state;
- GON = High Impedance;
- CLAMP = ON state (for STGAP2SiCSNC);

Such conditions are maintained at power-up of the isolated side ($VH < VH_{on}$) and during whole device power-down phase ($VH < VH_{off}$), regardless of the value of the input pins.

The device integrates a structure which clamps the driver output to a voltage not higher than SafeClp when VH voltage is not high enough to actively turn the internal GOFF MOSFET on. If VH positive supply pin is floating or not supplied, the GOFF pin is therefore clamped to a voltage smaller than SafeClp.

If the supply voltage VDD of the control section of the device is not supplied, the output is put into *safe state*, and remains in such condition until the VDD voltage returns within operative conditions.

After power-up of both isolated and low voltage side, the device output state depends on the input pins’ status.

5.3 Control inputs

The device is controlled through the IN+ and IN- logic inputs, in accordance with the truth table described in Table 9.

Table 9. Inputs truth table (applicable when device is not in UVLO or "safe state")

| Input pins | | Output pins | |
|------------|-----|-------------|------|
| IN+ | IN- | GON | GOFF |
| L | L | OFF | ON |
| H | L | ON | OFF |
| L | H | OFF | ON |
| H | H | OFF | ON |

A deglitch filter allows input signals with duration shorter than t_{deglitch} to be ignored, thereby preventing noise spikes potentially present in the application from generating unwanted commutations.

5.4 Miller Clamp function

The Miller Clamp function allows the control of the Miller current during the power stage switching in half-bridge configurations. When the external power transistor is in the OFF state, the driver operates to avoid the induced turn-on phenomenon that may occur when the other switch in the same leg is being turned on, due to the C_{GD} capacitance.

During the turn-off period the gate of the external switch is monitored through the CLAMP pin. The CLAMP switch is activated when gate voltage goes below the voltage threshold, V_{CLAMPth} , thus creating a low impedance path between the switch gate and the GNDISO pin.

5.5 Watchdog

The isolated HV side has a watchdog function in order to identify when it is not able to communicate with LV side, for example because the VDD of the LV side is not supplied. In this case the output of the driver is forced in "safe state" until communication link is properly established again.

5.6 Thermal shutdown protection

The device provides a thermal shutdown protection. When junction temperature reaches the T_{SD} temperature threshold, the device is forced into "safe state". The device operation is restored as soon as the junction temperature is lower than $T_{SD} - T_{\text{hys}}$.

6 Typical application diagram

Figure 7. Typical application diagram - Separated outputs

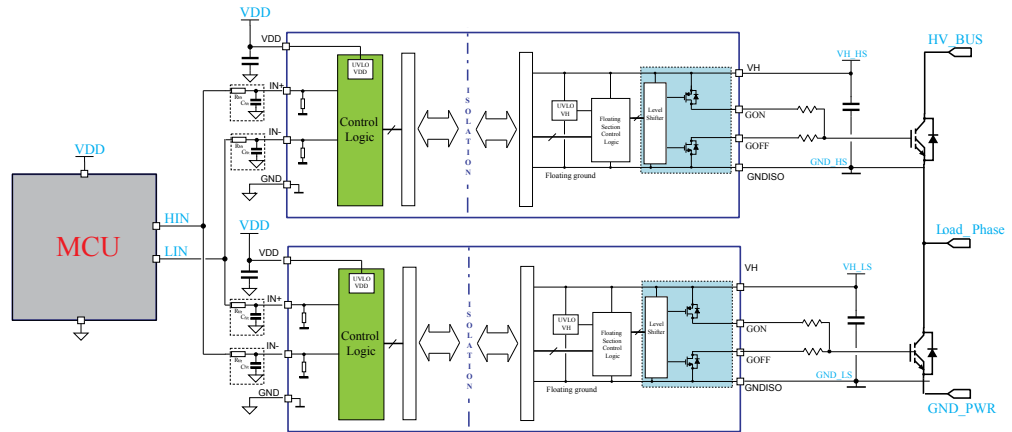


Figure 8. Typical application diagram - Separated outputs and negative gate driving

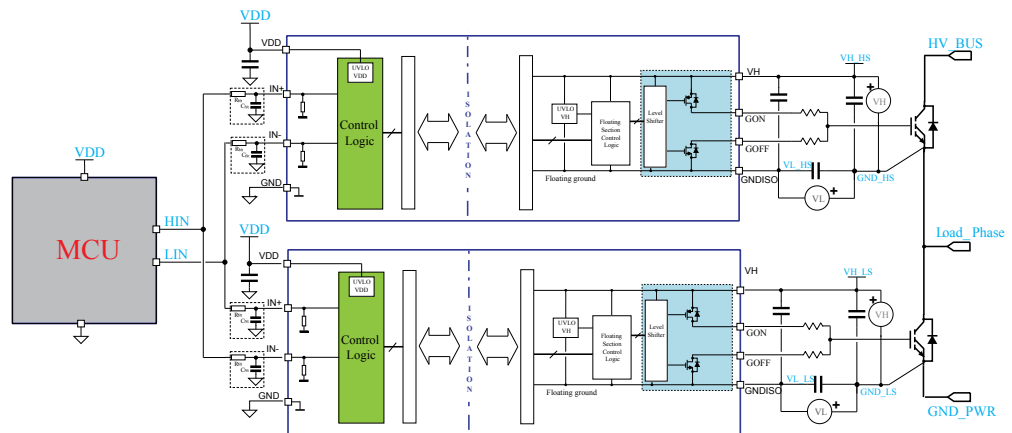


Figure 9. Typical application diagram - Miller Clamp

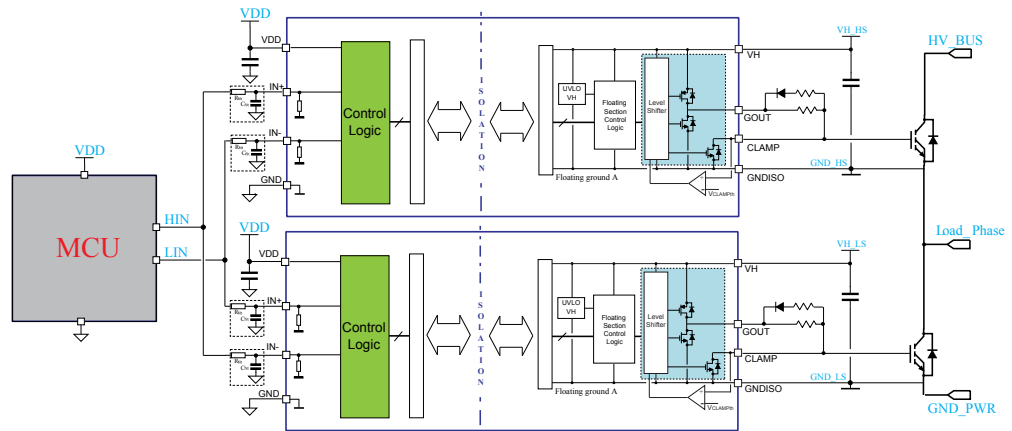
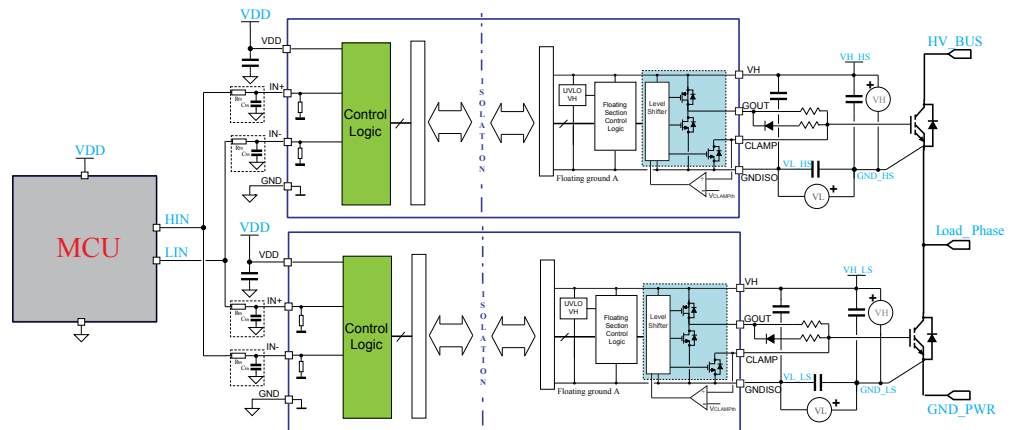


Figure 10. Typical application diagram - Miller Clamp and negative gate driving



7 Layout

7.1 Layout guidelines and considerations

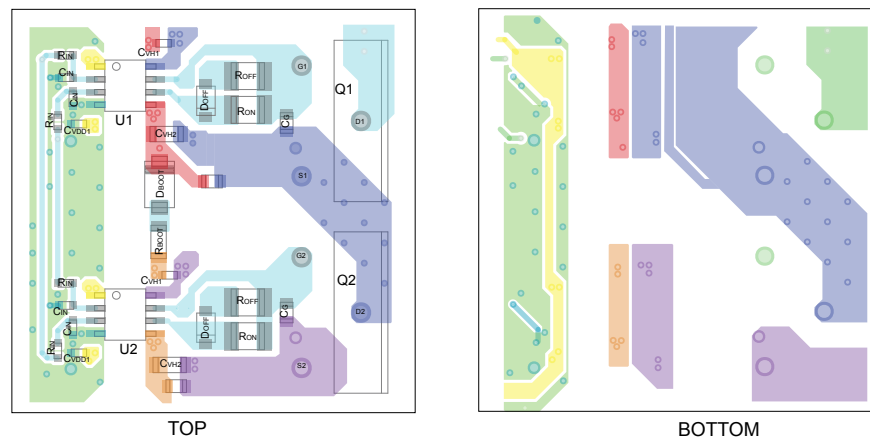
In order to optimize the PCB layout, the following considerations should be taken into account:

- SMT ceramic capacitors (or different types of low-ESR and low-ESL capacitors) must be placed close to each supply rail pin. A 100 nF capacitor must be placed between VDD and GND and between VH and GNDISO, as close as possible to device pins, in order to filter high-frequency noise and spikes. In order to provide local storage for pulsed current a second capacitor with value in the range between 1 μ F and 10 μ F should also be placed close to the supply pins.
- As a good practice, it is suggested to add filtering capacitors close to logic inputs of the device (IN+, IN-), in particular for fast switching or noisy applications.
- The power transistors must be placed as close as possible to the gate driver, so to minimize the gate loop area and inductance that might lead to noise or ringing.
- To avoid degradation of the isolation between the primary and secondary side of the driver, there should not be any trace or conductive area below the driver.
- If the system has multiple layers, it is recommended to connect the VH and GNDISO pins to internal ground or power planes through multiple vias of adequate size. These vias should be located close to the IC pins to maximize thermal conductivity.

7.2 Layout example

An example of the STGAP2SiCSN half-bridge suggested PCB layout with main signals highlighted by different colors is shown in Figure 11. It is recommended to follow this example for proper positioning and connection of filtering capacitors.

Figure 11. Half-bridge suggested PCB layout



8 Testing and characterization information

Figure 12. Timings definition

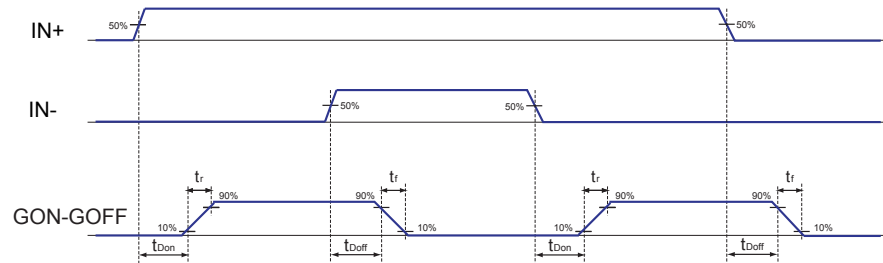
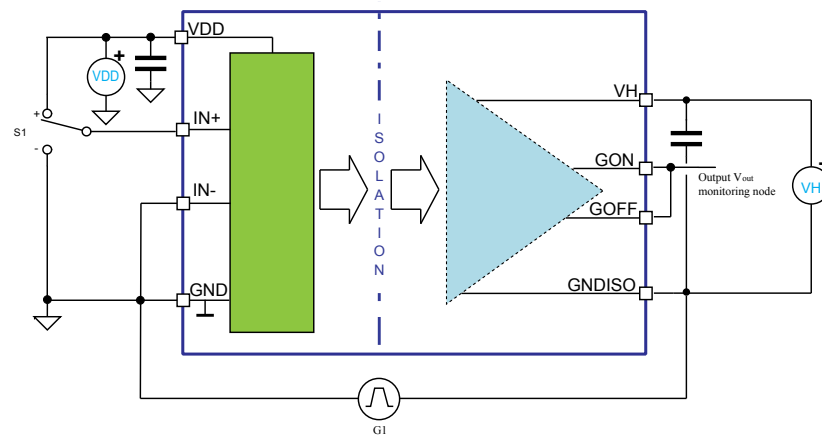


Figure 13. CMTI test circuit



9 Package information

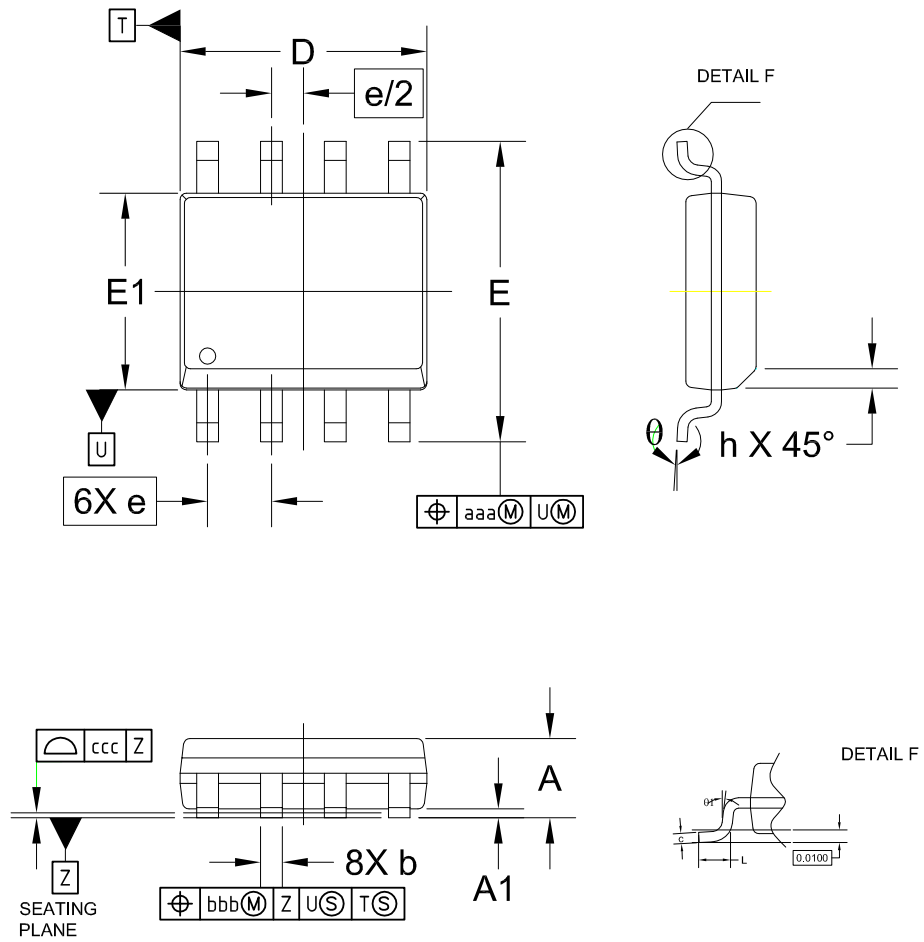
In order to meet environmental requirements, ST offers these devices in different grades of **ECOPACK** packages, depending on their level of environmental compliance. ECOPACK specifications, grade definitions and product status are available at: www.st.com. ECOPACK is an ST trademark.

9.1 SO-8 package information

| Dim. | mm | | | NOTES |
|------------------|----------|------|------|-------|
| | Min. | Typ. | Max. | |
| A | 1.35 | - | 1.75 | |
| A1 | 0.10 | - | 0.25 | |
| b | 0.35 | - | 0.49 | |
| c | 0.19 | - | 0.25 | |
| D ⁽¹⁾ | 4.8 | - | 5 | |
| E1 | 3.8 | 3.9 | 4 | |
| E | 5.8 | 6 | 6.2 | |
| e | 1.27 BSC | | | |
| L | 0.4 | - | 1.25 | |
| h | 0.25 | - | 0.50 | |
| θ | 0° | | 7° | |
| Θ1 | 2° | | 12° | |
| aaa | 0.25 | | | |
| bbb | 0.25 | | | |
| ccc | 0.1 | | | |

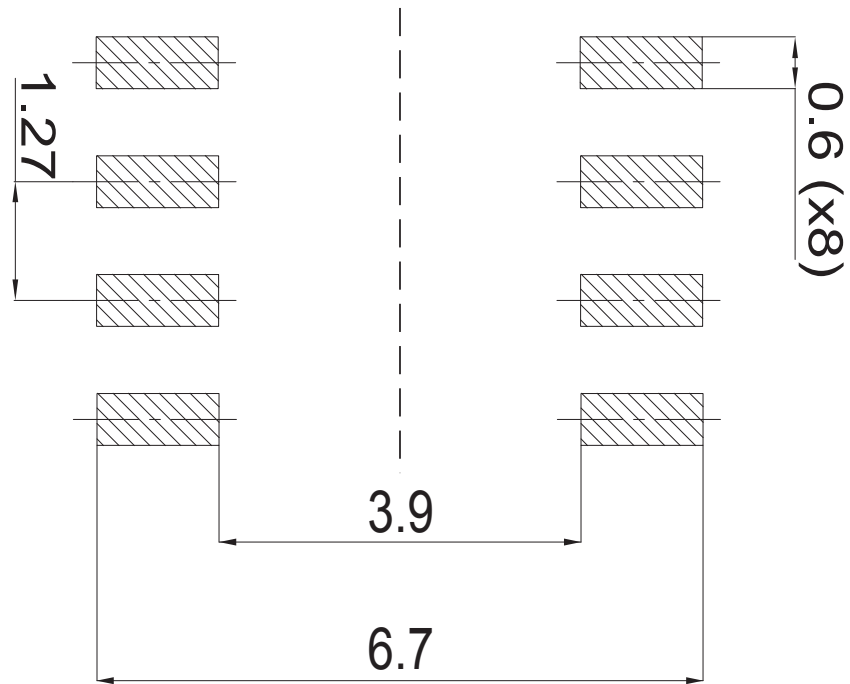
1. Dimension "D" does not include mold flash, protrusions, or gate burrs. Mold flash, protrusions or gate burrs shall not exceed 0.15 mm per side.

Figure 14. SO-8 mechanical data



9.2 SO-8 Suggested land pattern

Figure 15. SO-8 suggested land pattern



10 Ordering information

Table 10. Device summary

| Order code | Output configuration | Package | Package marking | Packaging |
|--------------|----------------------|---------|-----------------|---------------|
| STGAP2SiCSN | GON-GOFF | SO-8 | GAP2ISN | Tape and Reel |
| STGAP2SiCSNC | GOUT-CLAMP | SO-8 | GAP2ISCN | Tape and Reel |

Revision history

Table 11. Document revision history

| Date | Version | Changes |
|-------------|---------|------------------|
| 13-Aug-2021 | 1 | Initial release. |

Contents

| | | |
|------------|---|-----------|
| 1 | Block diagram | 2 |
| 2 | Pin description and connection diagram | 3 |
| 3 | Electrical data | 4 |
| 3.1 | Absolute maximum ratings | 4 |
| 3.2 | Thermal data | 4 |
| 3.3 | Recommended operating conditions | 4 |
| 4 | Electrical characteristics | 5 |
| 5 | Functional Description | 8 |
| 5.1 | Gate driving power supply and UVLO | 8 |
| 5.2 | Power-up, power-down and 'safe state' | 8 |
| 5.3 | Control inputs | 9 |
| 5.4 | Miller Clamp function | 9 |
| 5.5 | Watchdog | 9 |
| 5.6 | Thermal shutdown protection | 9 |
| 5.7 | Standby function | 10 |
| 6 | Typical application diagram | 11 |
| 7 | Layout | 13 |
| 7.1 | Layout guidelines and considerations | 13 |
| 7.2 | Layout example | 13 |
| 8 | Testing and characterization information | 14 |
| 9 | Package information | 15 |
| 9.1 | [Package name] package information | 15 |
| 9.2 | SO-8 Suggested land pattern | 17 |
| 10 | Ordering information | 18 |
| | Revision history | 19 |
| | Contents | 20 |
| | List of tables | 21 |
| | List of figures | 22 |

List of tables

| | | |
|------------------|--|----|
| Table 1. | Pin Description | 3 |
| Table 2. | Absolute maximum ratings | 4 |
| Table 3. | Thermal data | 4 |
| Table 4. | Recommended operating conditions | 4 |
| Table 5. | Electrical characteristics | 5 |
| Table 6. | Isolation related package specifications | 6 |
| Table 7. | Isolation characteristics | 7 |
| Table 8. | UL 1577 Tests | 7 |
| Table 9. | Inputs truth table (applicable when device is not in UVLO or "safe state") | 9 |
| Table 10. | Device summary | 18 |
| Table 11. | Document revision history | 19 |

List of figures

| | | |
|-------------------|---|----|
| Figure 1. | Block diagram - Single output and Miller Clamp configuration | 2 |
| Figure 2. | Block diagram - Separate outputs configuration | 2 |
| Figure 3. | Pin connection (top view), Separated outputs option | 3 |
| Figure 4. | Pin connection (top view), Single output and Miller CLAMP option | 3 |
| Figure 5. | Power supply configuration for unipolar and bipolar gate driving | 8 |
| Figure 6. | Standby state sequences | 10 |
| Figure 7. | Typical application diagram - Separated outputs | 11 |
| Figure 8. | Typical application diagram - Separated outputs and negative gate driving | 11 |
| Figure 9. | Typical application diagram - Miller Clamp | 12 |
| Figure 10. | Typical application diagram - Miller Clamp and negative gate driving | 12 |
| Figure 11. | Half-bridge suggested PCB layout | 13 |
| Figure 12. | Timings definition | 14 |
| Figure 13. | CMTI test circuit | 14 |
| Figure 14. | SO-8 mechanical data | 16 |
| Figure 15. | SO-8 suggested land pattern | 17 |

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