

# **AUTOMOTIVE THREE PHASE PRE-DRIVER WITH DUAL CURRENT SHUNT AMPLIFIERS AND BUCK REGULATOR**

Check for Samples: [DRV8301-Q1](#)

## **FEATURES**

- Qualified for Automotive Applications
- AEC-Q100 Tested With the Following Results:
  - Device Temperature Grade 1: –40°C to 125°C Ambient Operating Temperature Range
  - Device HBM ESD Classification Level H2
  - Device CDM ESD Classification Level C4A
- Operating Supply Voltage 6V–60V
- 2.3A Sink and 1.7A Source Gate Drive Current Capability
- Integrated Dual Shunt Current Amplifiers With Adjustable Gain and Offset
- Integrated Buck Converter to Support up to 1.5A External Load
- Independent Control of 3 or 6 PWM Inputs
- Bootstrap Gate Driver With 100% Duty Cycle Support
- Programmable Dead Time to Protect External FETs from Shoot Through
- Slew Rate Control for EMI Reduction
- Programmable Overcurrent Protection of External MOSFETs
- Support Both 3.3V and 5V Digital Interface
- SPI Interface
- Thermally Enhanced 56-Pin TSSOP Pad Down DCA Package

## **APPLICATIONS**

- Automotive 3-Phase Brushless DC Motor and Permanent Magnet Synchronous Motor
- Water, Oil, Fuel Pumps

## **DESCRIPTION**

The DRV8301-Q1 is an automotive gate driver IC for three phase motor drive applications. It provides three half bridge drivers, each capable of driving two N-type MOSFETs, one for the high-side and one for the low side. It supports up to 2.3A sink and 1.7A source peak current capability and only needs a single power supply with a wide range from 6V to 60V. The DRV8301-Q1 uses bootstrap gate drivers with trickle charge circuitry to support 100% duty cycle. The gate driver uses automatic hand shaking when high side FET or low side FET is switching to prevent current shoot through. Vds of FETs is sensed to protect external power stage during overcurrent conditions.

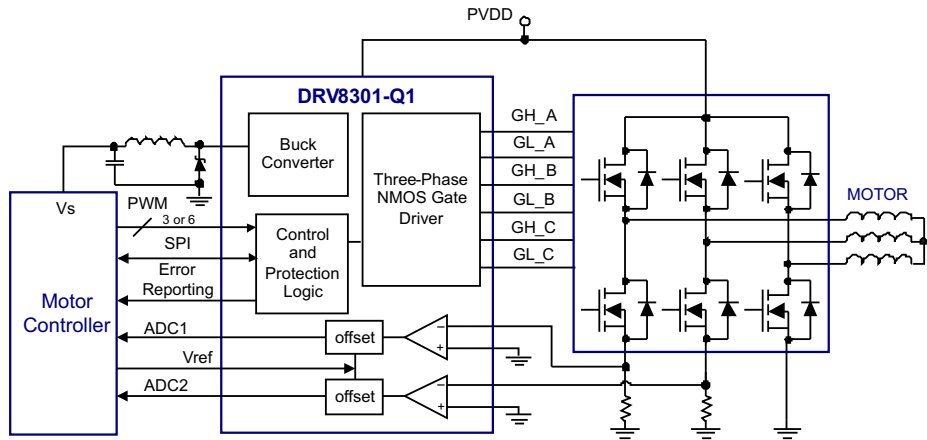
The DRV8301-Q1 includes two current shunt amplifiers for accurate current measurement. The current amplifiers support bi-directional current sensing and provide an adjustable output offset of up to 3V.

The DRV8301-Q1 also has an integrated switching mode buck converter with adjustable output and switching frequency to support MCU or additional system power needs. The buck is capable to drive up to 1.5A load.

The SPI interface provides detailed fault reporting and flexible parameter settings such as gain options for current shunt amplifier, slew rate control of gate driver, etc.



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**Figure 1. DRV8301 Simplified Application Schematic**



These devices have limited built-in ESD protection. The leads should be shorted together or the device placed in conductive foam during storage or handling to prevent electrostatic damage to the MOS gates.

## DEVICE INFORMATION

### PIN ASSIGNMENT

The DRV8301-Q1 is designed to fit the 56-pin DCA package. Here is the pinout of the device.

RT_CLK	1		56	SS_TR
COMP	2		55	EN_BUCK
VSENSE	3		54	PVDD2
PWRGD	4		53	PVDD2
OCTW	5		52	BST_BK
FAULT	6		51	PH
DTC	7		50	PH
SCS	8		49	VDD_S PI
SDI	9		48	BST_A
SDO	10		47	GH_A
SCLK	11		46	SH_A
DC_CAL	12		45	GL_A
GVDD	13		44	SL_A
CP1	14		43	BST_B
CP2	15		42	GH_B
EN_GATE	16		41	SH_B
INH_A	17		40	GL_B
INL_A	18		39	SL_B
INH_B	19		38	BST_C
INL_B	20		37	GH_C
INH_C	21		36	SH_C
INL_C	22		35	GL_C
DVDD	23		34	SL_C
REF	24		33	SN1
SO1	25		32	SP1
SO2	26		31	SN2
AVDD	27		30	SP2
AGND	28		29	PVDD1

Power Pad (57) - GND

## PIN FUNCTIONS

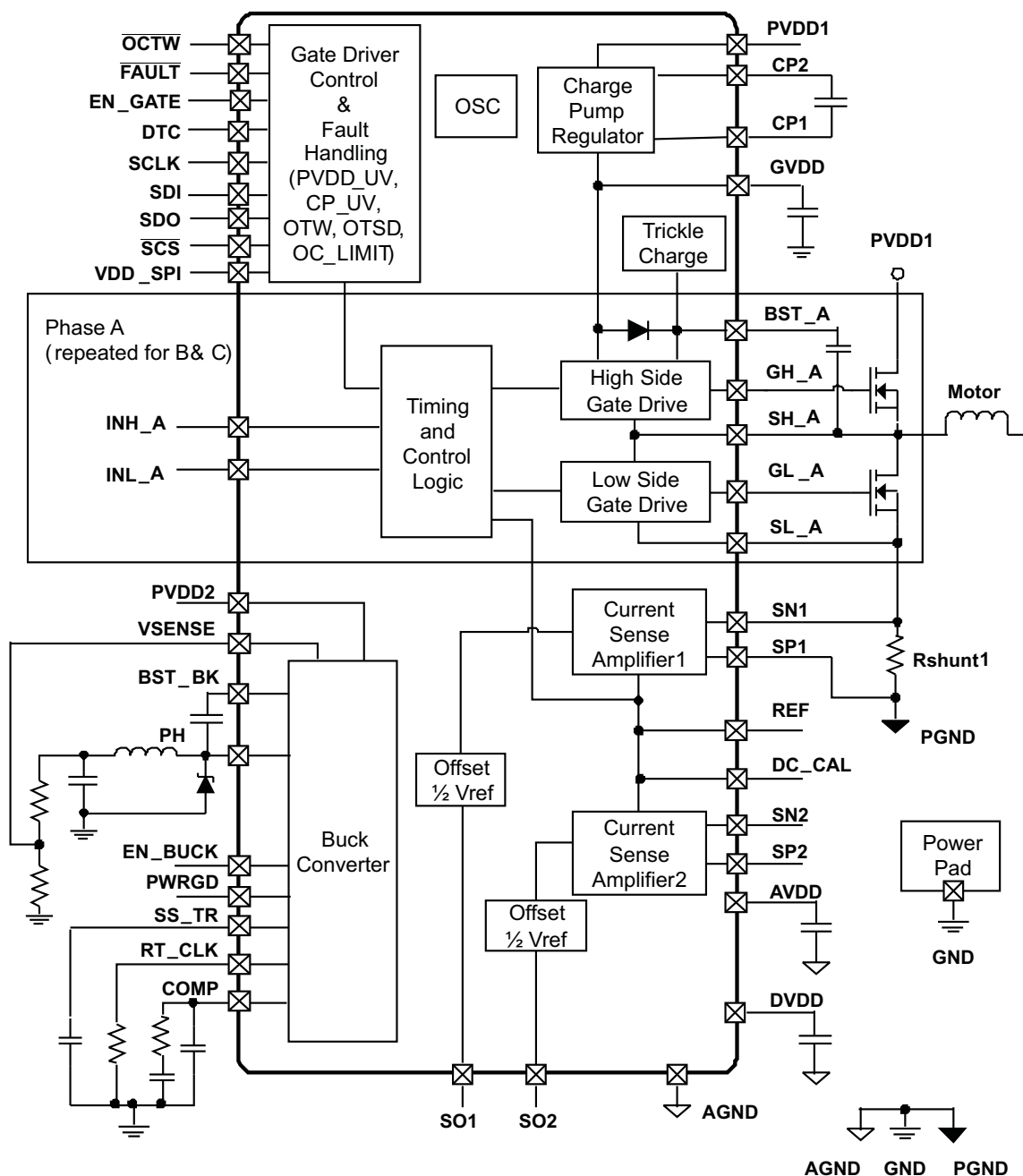
PIN		I/O <sup>(1)</sup>	DESCRIPTION
NAME	NO.		
RT_CLK	1	I	Resistor timing and external clock for buck regulator. Resistor should connect to GND (power pad) with very short trace to reduce the potential clock jitter due to noise.
COMP	2	O	Buck error amplifier output and input to the output switch current comparator.
VSENSE	3	I	Buck output voltage sense pin. Inverting node of error amplifier.
PWRGD	4	I	An open drain output with external pull-up resistor required. Asserts low if buck output voltage is low due to thermal shutdown, dropout, over-voltage, or EN_BUCK shut down
OCTW	5	O	Over current or/and over temperature warning indicator. This output is open drain with external pull-up resistor required. Programmable output mode via SPI registers.
FAULT	6	O	Fault report indicator. This output is open drain with external pull-up resistor required.
DTC	7	I	Dead-time adjustment with external resistor to GND
SCS	8	I	SPI chip select
SDI	9	I	SPI input
SDO	10	O	SPI output
SCLK	11	I	SPI clock signal
DC_CAL	12	I	When DC_CAL is high, device shorts inputs of shunt amplifiers and disconnects loads. DC offset calibration can be done through external microcontroller.
GVDD	13	P	Internal gate driver voltage regulator. GVDD cap should connect to GND
CP1	14	P	Charge pump pin 1, ceramic cap should be used between CP1 and CP2
CP2	15	P	Charge pump pin 2, ceramic cap should be used between CP1 and CP2
EN_GATE	16	I	Enable gate driver and current shunt amplifiers. Control buck via EN_BUCK pin.
INH_A	17	I	PWM Input signal (high side), half-bridge A
INL_A	18	I	PWM Input signal (low side), half-bridge A
INH_B	19	I	PWM Input signal (high side), half-bridge B
INL_B	20	I	PWM Input signal (low side), half-bridge B
INH_C	21	I	PWM Input signal (high side), half-bridge C
INL_C	22	I	PWM Input signal (low side), half-bridge C
DVDD	23	P	Internal 3.3V supply voltage. DVDD cap should connect to AGND. This is an output, but not specified to drive external circuitry.
REF	24	I	Reference voltage to set output of shunt amplifiers with a bias voltage which equals to half of the voltage set on this pin. Connect to ADC reference in microcontroller.
SO1	25	O	Output of current amplifier 1
SO2	26	O	Output of current amplifier 2
AVDD	27	P	Internal 6V supply voltage, AVDD cap should always be installed and connected to AGND. This is an output, but not specified to drive external circuitry.
AGND	28	P	Analog ground pin
PVDD1	29	P	Power supply pin for gate driver, current shunt amplifier, and SPI communication. PVDD1 is independent of buck power supply, PVDD2. PVDD1 cap should connect to GND
SP2	30	I	Input of current amplifier 2 (connecting to positive input of amplifier). Recommend to connect to ground side of the sense resistor for the best common mode rejection.
SN2	31	I	Input of current amplifier 2 (connecting to negative input of amplifier).
SP1	32	I	Input of current amplifier 1 (connecting to positive input of amplifier). Recommend to connect to ground side of the sense resistor for the best common mode rejection.
SN1	33	I	Input of current amplifier 1 (connecting to negative input of amplifier).
SL_C	34	I	Low-Side MOSFET source connection, half-bridge C. Low-side $V_{DS}$ measured between this pin and SH_C.
GL_C	35	O	Gate drive output for Low-Side MOSFET, half-bridge C
SH_C	36	I	High-Side MOSFET source connection, half-bridge C. High-side $V_{DS}$ measured between this pin and PVDD1.
GH_C	37	O	Gate drive output for High-Side MOSFET, half-bridge C

(1) KEY: I =Input, O = Output, P = Power

**PIN FUNCTIONS (continued)**

<b>PIN</b>		<b>I/O <sup>(1)</sup></b>	<b>DESCRIPTION</b>
<b>NAME</b>	<b>NO.</b>		
BST_C	38	P	Bootstrap cap pin for half-bridge C
SL_B	39	I	Low-Side MOSFET source connection, half-bridge B. Low-side $V_{DS}$ measured between this pin and SH_B.
GL_B	40	O	Gate drive output for Low-Side MOSFET, half-bridge B
SH_B	41	I	High-Side MOSFET source connection, half-bridge B. High-side $V_{DS}$ measured between this pin and PVDD1.
GH_B	42	O	Gate drive output for High-Side MOSFET, half-bridge B
BST_B	43	P	Bootstrap cap pin for half-bridge B
SL_A	44	I	Low-Side MOSFET source connection, half-bridge A. Low-side $V_{DS}$ measured between this pin and SH_A.
GL_A	45	O	Gate drive output for Low-Side MOSFET, half-bridge A
SH_A	46	I	High-Side MOSFET source connection, half-bridge A. High-side $V_{DS}$ measured between this pin and PVDD1.
GH_A	47	O	Gate drive output for High-Side MOSFET, half-bridge A
BST_A	48	P	Bootstrap cap pin for half-bridge A
VDD_SPI	49	I	SPI supply pin to support 3.3V or 5V logic. Connect to either 3.3V or 5V.
PH	50, 51	O	The source of the internal high side MOSFET of buck converter
BST_BK	52	P	Bootstrap cap pin for buck converter
PVDD2	53,54	P	Power supply pin for buck converter, PVDD2 cap should connect to GND.
EN_BUCK	55	I	Enable buck converter. Internal pull-up current source. Pull below 1.2V to disable. Float to enable. Adjust the input undervoltage lockout with two resistors
SS_TR	56	I	Buck soft-start and tracking. An external capacitor connected to this pin sets the output rise time. Since the voltage on this pin overrides the internal reference, it can be used for tracking and sequencing. Cap should connect to GND
GND (POWER PAD)	57	P	GND pin. The exposed power pad must be electrically connected to ground plane through soldering to PCB for proper operation and connected to bottom side of PCB through vias for better thermal spreading.

## FUNCTION BLOCK DIAGRAM



**ABSOLUTE MAXIMUM RATINGS<sup>(1)</sup>**

			VALUE		UNITS
			MIN	MAX	
PVDD	Supply voltage range including transient	Relative to PGND	−0.3	70	V
PVDD <sub>RAMP</sub>	Maximum supply voltage ramp rate	Voltage rising up to PVDD <sub>MAX</sub>		1	V/μs
V <sub>PGND</sub>	Maximum voltage between PGND and GND		±0.3		V
I <sub>IN_MAX</sub>	Maximum current, all digital and analog input pins except $\overline{\text{FAULT}}$ and $\overline{\text{OCTW}}$ pins		±1		mA
I <sub>IN_OD_MAX</sub>	Maximum sinking current for open drain pins ( $\overline{\text{FAULT}}$ and $\overline{\text{OCTW}}$ Pins)		7		mA
V <sub>OPA_IN</sub>	Voltage range for SPx and SNx pins		±0.6		V
V <sub>LOGIC</sub>	Input voltage range for logic/digital pins (INH_A, INL_A, INH_B, INL_B, INH_C, INL_C, EN_GATE, SCLK, SDI, SCS, DC_CAL)		-0.3	7	V
V <sub>GVDD</sub>	Maximum voltage for GVDD Pin		13.2		V
V <sub>AVDD</sub>	Maximum voltage for AVDD Pin		8		V
V <sub>DVDD</sub>	Maximum voltage for DVDD Pin		3.6		V
V <sub>VDD_SPI</sub>	Maximum voltage for VDD_SPI Pin		7		V
V <sub>SDO</sub>	Maximum voltage for SDO Pin		VDD_SPI +0.3		V
V <sub>REF</sub>	Maximum reference voltage for current amplifier		7		V
I <sub>REF</sub>	Maximum current for REF Pin		100		μA
T <sub>J</sub>	Maximum operating junction temperature range		−40	150	°C
T <sub>STORAGE</sub>	Storage temperature range		−55	150	°C
Capacitive discharge model			Per AEC-Q100		
Human body model			Per AEC-Q100		

- (1) Stresses beyond those listed under “absolute maximum ratings” may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated under “recommended operating conditions” is not implied. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.

**THERMAL INFORMATION**

THERMAL METRIC <sup>(1)</sup>		DRV8301-Q1	UNITS
		DCA	
		56 PINS	
θ <sub>JA</sub>	Junction-to-ambient thermal resistance <sup>(2)</sup>	30.3	°C/W
θ <sub>JCTop</sub>	Junction-to-case (top) thermal resistance <sup>(3)</sup>	33.5	
θ <sub>JB</sub>	Junction-to-board thermal resistance <sup>(4)</sup>	17.5	
ψ <sub>JT</sub>	Junction-to-top characterization parameter <sup>(5)</sup>	0.9	
ψ <sub>JB</sub>	Junction-to-board characterization parameter <sup>(6)</sup>	7.2	
θ <sub>JCbot</sub>	Junction-to-case (bottom) thermal resistance <sup>(7)</sup>	0.9	

- (1) For more information about traditional and new thermal metrics, see the *IC Package Thermal Metrics* application report, [SPRA953](#).
- (2) The junction-to-ambient thermal resistance under natural convection is obtained in a simulation on a JEDEC-standard, high-K board, as specified in JESD51-7, in an environment described in JESD51-2a.
- (3) The junction-to-case (top) thermal resistance is obtained by simulating a cold plate test on the package top. No specific JEDEC-standard test exists, but a close description can be found in the ANSI SEMI standard G30-88.
- (4) The junction-to-board thermal resistance is obtained by simulating in an environment with a ring cold plate fixture to control the PCB temperature, as described in JESD51-8.
- (5) The junction-to-top characterization parameter, ψ<sub>JT</sub>, estimates the junction temperature of a device in a real system and is extracted from the simulation data for obtaining θ<sub>JA</sub>, using a procedure described in JESD51-2a (sections 6 and 7).
- (6) The junction-to-board characterization parameter, ψ<sub>JB</sub>, estimates the junction temperature of a device in a real system and is extracted from the simulation data for obtaining θ<sub>JA</sub>, using a procedure described in JESD51-2a (sections 6 and 7).
- (7) The junction-to-case (bottom) thermal resistance is obtained by simulating a cold plate test on the exposed (power) pad. No specific JEDEC standard test exists, but a close description can be found in the ANSI SEMI standard G30-88.

## RECOMMENDED OPERATING CONDITIONS

			MIN	TYP	MAX	UNITS
PVDD1	DC supply voltage PVDD1 for normal operation	Relative to PGND	6		60	V
PVDD2	DC supply voltage PVDD2 for buck converter		3.5		60	V
C <sub>PVDD1</sub>	External capacitance on PVDD1 pin (ceramic cap) 20% tolerance			4.7		μF
C <sub>PVDD2</sub>	External capacitance on PVDD2 pin (ceramic cap) 20% tolerance			4.7		μF
C <sub>AVDD</sub>	External capacitance on AVDD pin (ceramic cap) 20% tolerance			1		μF
C <sub>DVDD</sub>	External capacitance on DVDD pin (ceramic cap) 20% tolerance			1		μF
C <sub>GVDD</sub>	External capacitance on GVDD pin (ceramic cap) 20% tolerance			2.2		μF
C <sub>CP</sub>	Flying cap on charge pump pins (between CP1 and CP2) (ceramic cap) 20% tolerance			22		nF
C <sub>BST</sub>	Bootstrap cap (ceramic cap)			100		nF
I <sub>DIN_EN</sub>	Input current of digital pins when EN_GATE is high				100	μA
I <sub>DIN_DIS</sub>	Input current of digital pins when EN_GATE is low				1	μA
C <sub>DIN</sub>	Maximum capacitance on digital input pin				10	pF
C <sub>O_OPA</sub>	Maximum output capacitance on outputs of shunt amplifier				20	pF
R <sub>DTC</sub>	Dead time control resistor range. Time range is 50ns (-GND) to 500ns (150kΩ) with a linear approximation.		0		150	kΩ
I <sub>FAULT</sub>	$\overline{\text{FAULT}}$ pin sink current. Open-drain	V = 0.4 V			2	mA
I <sub>OCTW</sub>	$\overline{\text{OCTW}}$ pin sink current. Open-drain	V = 0.4 V			2	mA
V <sub>REF</sub>	External voltage reference voltage for current shunt amplifiers		2		6	V
f <sub>gate</sub>	Operating switching frequency of gate driver	Qg(TOT) = 25 nC or total 30 mA gate drive average current			200	kHz
I <sub>gate</sub>	Total average gate drive current				30	mA
T <sub>A</sub>	Ambient temperature		-40		125	°C

## ELECTRICAL CHARACTERISTICS

PVDD = 6 V to 60 V, T<sub>C</sub> = 25°C, unless specified under test condition

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
<b>INPUT PINS: INH_X, INL_X, M_PWM (SCS), M_OC (SDI), GAIN(SDO), EN_GATE, DC_CAL</b>					
V <sub>IH</sub>	High input threshold	2			V
V <sub>IL</sub>	Low input threshold			0.8	V
R <sub>EN_GATE</sub>	Internal pull down resistor for EN_GATE		100		kΩ
R <sub>INH_X</sub>	Internal pull down resistor for high side PWMs (INH_A, INH_B, and INH_C)	EN_GATE high	100		kΩ
R <sub>INL_X</sub>	Internal pull down resistor for low side PWMs (INL_A, INL_B, and INL_C)	EN_GATE high	100		kΩ
R <sub>SCS</sub>	Internal pull down resistor for $\overline{\text{SCS}}$	EN_GATE high	100		kΩ
R <sub>SDI</sub>	Internal pull down resistor for SDI	EN_GATE high	100		kΩ
R <sub>DC_CAL</sub>	Internal pull down resistor for DC_CAL	EN_GATE high	100		kΩ
R <sub>SCLK</sub>	Internal pull down resistor for SCLK	EN_GATE high	100		kΩ
<b>OUTPUT PINS: <math>\overline{\text{FAULT}}</math> AND <math>\overline{\text{OCTW}}</math></b>					
V <sub>OL</sub>	Low output threshold	I <sub>O</sub> = 2 mA		0.4	V
V <sub>OH</sub>	High output threshold	External 47 kΩ pull up resistor connected to 3-5.5 V	2.4		V
I <sub>OH</sub>	Leakage Current on Open Drain Pins When Logic High ( $\overline{\text{FAULT}}$ and $\overline{\text{OCTW}}$ )			1	μA

**ELECTRICAL CHARACTERISTICS (continued)**PVDD = 6 V to 60 V,  $T_C = 25^\circ\text{C}$ , unless specified under test condition

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
<b>GATE DRIVE OUTPUT: GH_A, GH_B, GH_C, GL_A, GL_B, GL_C</b>						
$V_{GX\_NORM}$	Gate driver Vgs voltage	PVDD = 8V–60V, $I_{gate} = 30\text{mA}$ , $C_{CP} = 22\text{nF}$	9.5		11.5	V
		PVDD = 8V–60V, $I_{gate} = 30\text{mA}$ , $C_{CP} = 220\text{nF}$	9.5		11.5	
$V_{GX\_MIN}$	Gate driver Vgs voltage	PVDD = 6V–8V, $I_{gate} = 15\text{mA}$ , $C_{CP} = 22\text{nF}$	8.8			V
		PVDD = 6V–8V, $I_{gate} = 30\text{mA}$ , $C_{CP} = 220\text{nF}$	8.3			
$I_{oso1}$	Maximum source current setting 1, peak	Vgs of FET equals to 2 V. REG 0x02		1.7		A
$I_{osi1}$	Maximum sink current setting 1, peak	Vgs of FET equals to 8 V. REG 0x02		2.3		A
$I_{oso2}$	Source current setting 2, peak	Vgs of FET equals to 2 V. REG 0x02		0.7		A
$I_{osi2}$	Sink current setting 2, peak	Vgs of FET equals to 8 V. REG 0x02		1		A
$I_{oso3}$	Source current setting 3, peak	Vgs of FET equals to 2 V. REG 0x02		0.25		A
$I_{osi3}$	Sink current setting 3, peak	Vgs of FET equals to 8 V. REG 0x02		0.5		A
$R_{gate\_off}$	Gate output impedance during standby mode when EN_GATE low (pins GH_x, GL_x)		1.6		2.4	k $\Omega$
<b>SUPPLY CURRENTS</b>						
$I_{PVDD1\_STB}$	PVDD1 supply current, standby	EN_GATE is low. PVDD1 = 8V.		20	50	$\mu\text{A}$
$I_{PVDD1\_OP}$	PVDD1 supply current, operating	EN_GATE is high, no load on gate drive output, switching at 10 kHz, 100 nC gate charge		15		mA
$I_{PVDD1\_HIZ}$	PVDD1 Supply current, HiZ	EN_GATE is high, gate not switching	2	5	10	mA
<b>INTERNAL REGULATOR VOLTAGE</b>						
$A_{VDD}$	AVDD voltage	PVDD = 8V - 60V	6	6.5	7	V
		PVDD = 6V - 60V	5.5		6	
$D_{VDD}$	DVDD voltage		3	3.3	3.6	V
<b>VOLTAGE PROTECTION</b>						
$V_{PVDD\_UV}$	Under voltage protection limit, PVDD	PVDD falling			5.9	V
		PVDD rising			6	
$V_{GVDD\_UV}$	Under voltage protection limit, GVDD	GVDD falling			7.5	V
$V_{GVDD\_OV}$	Over voltage protection limit, GVDD			16		V
<b>CURRENT PROTECTION, (VDS SENSING)</b>						
$V_{DS\_OC}$	Drain-source voltage protection limit	PVDD = 8V - 60V	0.125		2.4	V
		PVDD = 6V - 8V <sup>(1)</sup>	0.125		1.491	
$T_{oc}$	OC sensing response time			1.5		$\mu\text{s}$
$T_{OC\_PULSE}$	OCTW pin reporting pulse stretch length for OC event			64		$\mu\text{s}$

(1) Reduced  $A_{VDD}$  voltage range results in limitations on settings for over current protection. See [Table 10](#).

## GATE TIMING AND PROTECTION CHARACTERISTICS

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
<b>TIMING, OUTPUT PINS</b>						
$t_{pd,lf-O}$	Positive input falling to GH_x falling	CL=1nF, 50% to 50%		45		ns
$t_{pd,lr-O}$	Positive input rising to GL_x falling	CL=1nF, 50% to 50%		45		ns
$T_{d\_min}$	Minimum dead time after hand shaking <sup>(1)</sup>				50	ns
$T_{dtp}$	Dead Time	With $R_{DTC}$ set to different values	50		500	ns
$t_{GDr}$	Rise time, gate drive output	CL=1nF, 10% to 90%		25		ns
$t_{GDF}$	Fall time, gate drive output	CL=1nF, 90% to 10%		25		ns
$T_{ON\_MIN}$	Minimum on pulse	Not including handshake communication. Hiz to on state, output of gate driver			50	ns
$T_{pd\_match}$	Propagation delay matching between high side and low side				5	ns
$T_{dt\_match}$	Deadtime matching				5	ns
<b>TIMING, PROTECTION AND CONTROL</b>						
$t_{pd,R\_GATE-OP}$	Start up time, from EN_GATE active high to device ready for normal operation	PVDD is up before start up, all charge pump caps and regulator caps as in recommended condition		5	10	ms
$t_{pd,R\_GATE-Quick}$	If EN_GATE goes from high to low and back to high state within quick reset time, it will only reset all faults and gate driver without powering down charge pump, current amp, and related internal voltage regulators.	Maximum low pulse time			10	us
$t_{pd,E-L}$	Delay, error event to all gates low			200		ns
$t_{pd,E-FAULT}$	Delay, error event to FAULT low			200		ns
OTW_CLR	Junction temperature for resetting over temperature warning			115		°C
OTW_SET/OTSD_CLR	Junction temperature for over temperature warning and resetting over temperature shut down			130		°C
OTSD_SET	Junction temperature for over temperature shut down			150		°C

- (1) Dead time programming definition: Adjustable delay from GH\_x falling edge to GL\_X rising edge, and GL\_X falling edge to GH\_X rising edge. This is a minimum dead-time insertion. It is not added to the value set by the microcontroller externally.

## CURRENT SHUNT AMPLIFIER CHARACTERISTICS

$T_C = 25^\circ\text{C}$  unless otherwise specified

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
G1	Gain option 1	$T_C = -40^\circ\text{C}-125^\circ\text{C}$	9.5	10	10.5	V/V
G2	Gain option 2	$T_C = -40^\circ\text{C}-125^\circ\text{C}$	18	20	21	V/V
G3	Gain Option 3	$T_C = -40^\circ\text{C}-125^\circ\text{C}$	38	40	42	V/V
G4	Gain Option 4	$T_C = -40^\circ\text{C}-125^\circ\text{C}$	75	80	85	V/V
Tsettling	Settling time to 1%	$T_C = 0-60^\circ\text{C}$ , $G = 10$ , $V_{\text{step}} = 2\text{ V}$		300		ns
Tsettling	Settling time to 1%	$T_C = 0-60^\circ\text{C}$ , $G = 20$ , $V_{\text{step}} = 2\text{ V}$		600		ns
Tsettling	Settling time to 1%	$T_C = 0-60^\circ\text{C}$ , $G = 40$ , $V_{\text{step}} = 2\text{ V}$		1.2		$\mu\text{s}$
Tsettling	Settling time to 1%	$T_C = 0-60^\circ\text{C}$ , $G = 80$ , $V_{\text{step}} = 2\text{ V}$		2.4		$\mu\text{s}$
Vswing	Output swing linear range		0.3		5.7	V
Slew Rate		$G = 10$		10		V/ $\mu\text{s}$
DC_offset	Offset error RTI	$G = 10$ with input shorted			4	mV
Drift_offset	Offset drift RTI			10		$\mu\text{V}/^\circ\text{C}$
Ibias	Input bias current				100	$\mu\text{A}$
Vin_com	Common input mode range		-0.15		0.15	V
Vin_dif	Differential input range		-0.3		0.3	V
Vo_bias	Output bias	With zero input current, $V_{\text{ref}}$ up to 6 V	-0.5%	$0.5 \times V_{\text{ref}}$	0.5%	V
CMRR_OV	Overall CMRR with gain resistor mismatch	CMRR at DC, gain = 10	70	85		dB

## BUCK CONVERTER CHARACTERISTICS

$T_C = 25^\circ\text{C}$  unless otherwise specified

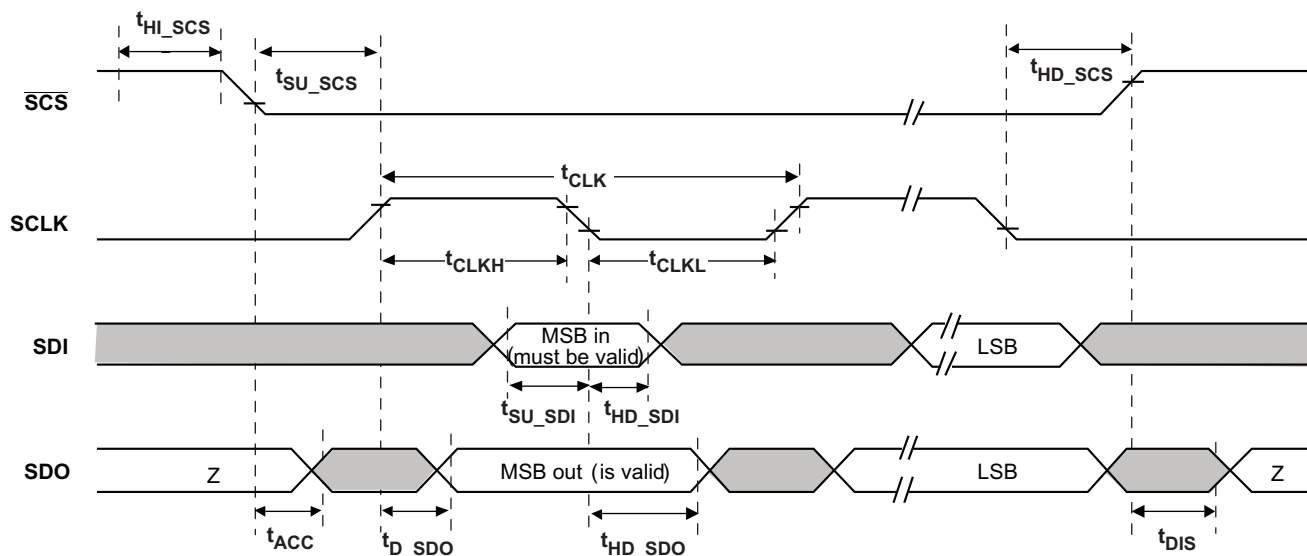
PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
V <sub>UVLO</sub>	Internal undervoltage lockout threshold	No voltage hysteresis, rising and falling		2.5		V
I <sub>SD(PVDD2)</sub>	Shutdown supply current	$\text{EN} = 0\text{ V}$ , $25^\circ\text{C}$ , $3.5\text{ V} \leq \text{VIN} \leq 60\text{ V}$		1.3	4	$\mu\text{A}$
I <sub>NON_SW(PVDD2)</sub>	Operating: nonswitching supply current	$\text{VSENSE} = 0.83\text{ V}$ , $\text{VIN} = 12\text{ V}$		116	136	$\mu\text{A}$
V <sub>EN_BUCK</sub>	Enable threshold voltage	No voltage hysteresis, rising and falling, $25^\circ\text{C}$	0.9	1.25	1.55	V
R <sub>DS_ON</sub>	On-resistance	$\text{VIN} = 3.5\text{ V}$ , $\text{BOOT-PH} = 3\text{ V}$		300		m $\Omega$
I <sub>LIM</sub>	Current limit threshold	$\text{VIN} = 12\text{ V}$ , $T_J = 25^\circ\text{C}$	1.8	2.7		A
F <sub>sw</sub>	Switching frequency	$\text{RT} = 200\text{ k}\Omega$	450	581	720	kHz
PWRGD	VSENSE threshold	VSENSE falling		92%		
		VSENSE rising		94%		
		VSENSE rising		109%		
		VSENSE falling		107%		
	Hysteresis	VSENSE falling		2%		
	Output high leakage	$\text{VSENSE} = V_{\text{REF}}$ , $\text{V(PWRGD)} = 5.5\text{ V}$ , $25^\circ\text{C}$		10		nA
	On resistance	$\text{I(PWRGD)} = 3\text{ mA}$ , $\text{VSENSE} < 0.79\text{ V}$		50		$\Omega$

## SPI CHARACTERISTICS (Slave Mode Only)

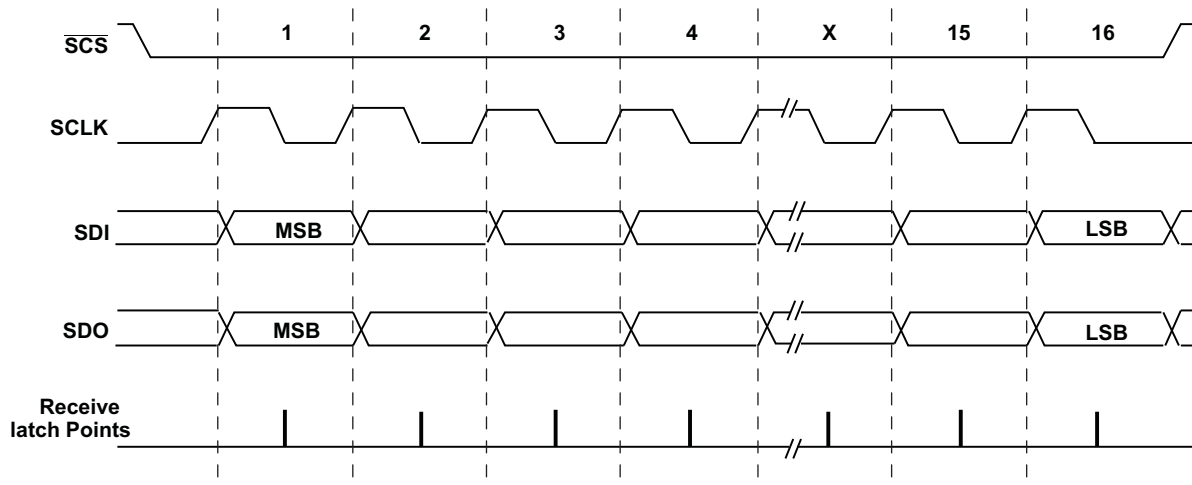
PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
t <sub>SPI_READY</sub>	SPI ready after EN_GATE transitions to HIGH	PVDD > 6 V		5	10	ms
t <sub>CLK</sub>	Minimum SPI clock period		100			ns
t <sub>CLKH</sub>	Clock high time		40			
t <sub>CLKL</sub>	Clock low time		40			
t <sub>SU_SDI</sub>	SDI input data setup time		20			ns

### SPI CHARACTERISTICS (Slave Mode Only) (continued)

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
$t_{HD\_SDI}$	SDI input data hold time	30			ns
$t_{D\_SDO}$	SDO output data delay time, CLK high to SDO valid			20	ns
$t_{HD\_SDO}$	SDO output data hold time	40			
$t_{SU\_SCS}$	SCS setup time	50			ns
$t_{HD\_SCS}$	SCS hold time	50			ns
$t_{HI\_SCS}$	SCS minimum high time before SCS active low	40			ns
$t_{ACC}$	SCS access time, SCS low to SDO out of high impedance		10		ns
$t_{DIS}$	SCS disable time, SCS high to SDO high impedance		10		ns



**Figure 2. SPI Slave Mode Timing Definition**



**Figure 3. SPI Slave Mode Timing Diagram**

## FUNCTIONAL DESCRIPTION

### THREE-PHASE GATE DRIVER

The DRV8301-Q1 provides three half bridge drivers, each capable of driving two N-type MOSFETs, one for the high-side and one for the low side.

Gate driver has following features:

- Internal hand shake between high side and low side FETs during switching transition to prevent current shoot through.
- Programmable slew rate or current driving capability through SPI interface.
- Support up to 200kHz switching frequency with  $Q_g(TOT)=25nC$  or total 30mA gate drive average current
- Provide cycle-by-cycle current limiting and latch over-current (OC) shut down of external FETs. Current is sensed through FET drain-to-source voltage and the over-current level is programmable through SPI interface
- $V_{ds}$  sensing range is programmable from 0.060V to 2.4V and with 5 bit programmable resolution through SPI.
- High side gate drive will survive negative output from half bridge up to -10V for 10ns
- During EN\_GATE pin low and fault conditions, gate driver will keep external FETs in high impedance mode.
- Programmable dead time through DTC pin. Dead time control range: 50ns to 500ns. Short DTC pin to ground will provide minimum dead time (50ns). External dead time will override internal dead time as long as the time is longer than the dead time setting (minimum hand shake time cannot be reduced in order to prevent shoot through current).
- Bootstraps are used in high side FETs of three-phase pre-gate driver. Trickle charge circuitry is used to replenish current leakage from bootstrap cap and support 100% duty cycle operation.

### CURRENT SHUNT AMPLIFIERS

The DRV8301-Q1 includes two high performance current shunt amplifiers for accurate current measurement. The current amplifiers provide output offset up to 3V to support bi-directional current sensing.

Current shunt amplifier has following features:

- Programmable gain: 4 gain settings through SPI command
- Programmable output offset through reference pin (half of the  $V_{ref}$ )
- Minimize DC offset and drift over temperature with dc calibrating through SPI command or DC\_CAL pin. When DC calibration is enabled, device will short input of current shunt amplifier and disconnect the load. DC calibrating can be done at anytime even when FET is switching since the load is disconnected. For best result, perform the DC calibrating during switching off period when no load is present to reduce the potential noise impact to the amplifier.

The output of current shunt amplifier can be calculated as:

$$V_O = \frac{V_{REF}}{2} - G \times (SN_x - SP_x) \quad (1)$$

Where  $V_{ref}$  is the reference voltage,  $G$  is the gain of the amplifier;  $SN_x$  and  $SP_x$  are the inputs of channel  $x$ .  $SP_x$  should connect to resistor ground for the best common mode rejection.

Figure 4 shows current amplifier simplified block diagram.

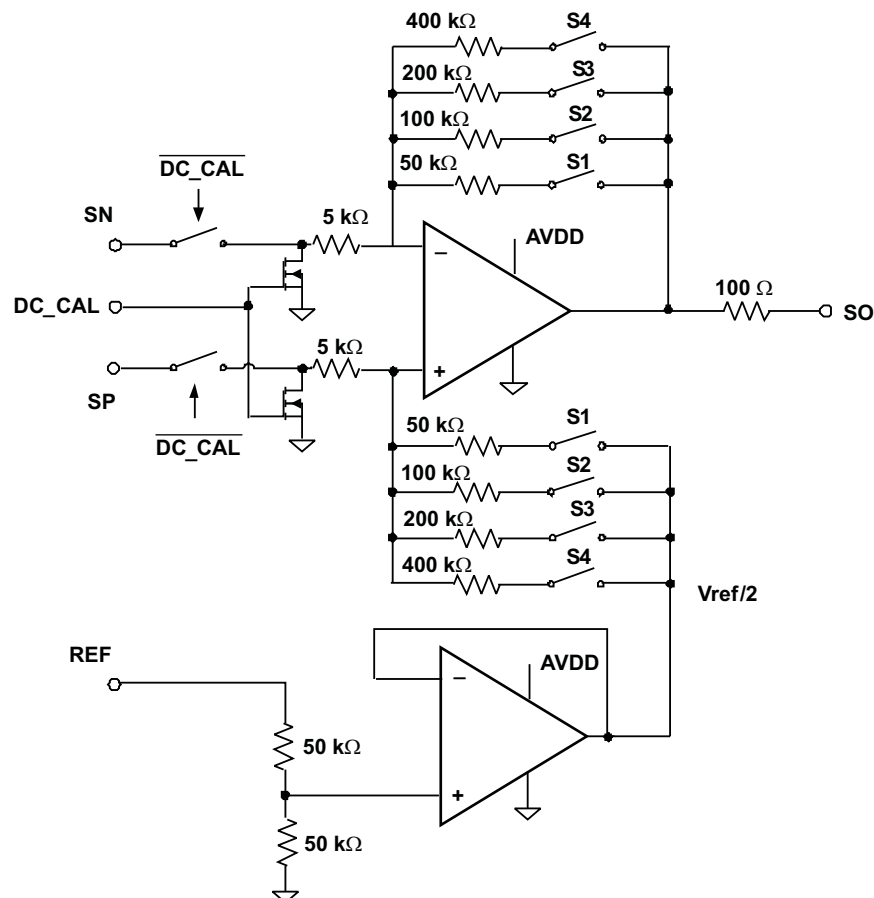


Figure 4. Current Shunt Amplifier Simplified Block Diagram

## BUCK CONVERTER

The buck converter in the DRV8301 is the same as the TPS54160 buck converter. Although integrated in the same device, buck converter is designed completely independent of rest of the gate driver circuitry. Since buck will support external MCU or other external power need, the independency of buck operation is very critical for a reliable system; this will give buck minimum impact from gate driver operations. Some examples are: when gate driver shuts down due to any failure, buck will still operate unless the fault is coming from buck itself. The buck keeps operating at much lower PVDD of 3.5V, this will assure the system to have a smooth power up and power down sequence when gate driver is not able to operate due to a low PVDD.

The buck has an integrated high side n-channel MOSFET. To improve performance during line and load transients the device implements a constant frequency, current mode control which reduces output capacitance and simplifies external frequency compensation design.

The wide switching frequency of 300kHz to 2200kHz allows for efficiency and size optimization when selecting the output filter components. The switching frequency is adjusted using a resistor to ground on the RT\_CLK pin. The device has an internal phase lock loop (PLL) on the RT\_CLK pin that is used to synchronize the power switch turn on to a falling edge of an external system clock.

The buck converter has a default start up voltage of approximately 2.5V. The EN\_BUCK pin has an internal pull-up current source that can be used to adjust the input voltage under voltage lockout (UVLO) threshold with two external resistors. In addition, the pull up current provides a default condition. When the EN\_BUCK pin is floating the device will operate. The operating current is 116μA when not switching and under no load. When the device is disabled, the supply current is 1.3μA.

The integrated 200mΩ high side MOSFET allows for high efficiency power supply designs capable of delivering 1.5 amperes of continuous current to a load. The bias voltage for the integrated high side MOSFET is supplied by a capacitor on the BOOT to PH pin. The boot capacitor voltage is monitored by an UVLO circuit and will turn the high side MOSFET off when the boot voltage falls below a preset threshold. The buck can operate at high duty cycles because of the boot UVLO. The output voltage can be stepped down to as low as the 0.8V reference.

The BUCK has a power good comparator (PWRGD) which asserts when the regulated output voltage is less than 92% or greater than 109% of the nominal output voltage. The PWRGD pin is an open drain output which deasserts when the VSENSE pin voltage is between 94% and 107% of the nominal output voltage allowing the pin to transition high when a pull-up resistor is used.

The BUCK minimizes excessive output overvoltage (OV) transients by taking advantage of the OV power good comparator. When the OV comparator is activated, the high side MOSFET is turned off and masked from turning on until the output voltage is lower than 107%.

The SS\_TR (slow start/tracking) pin is used to minimize inrush currents or provide power supply sequencing during power up. A small value capacitor should be coupled to the pin to adjust the slow start time. A resistor divider can be coupled to the pin for critical power supply sequencing requirements. The SS\_TR pin is discharged before the output powers up. This discharging ensures a repeatable restart after an over-temperature fault,

The BUCK, also, discharges the slow start capacitor during overload conditions with an overload recovery circuit. The overload recovery circuit will slow start the output from the fault voltage to the nominal regulation voltage once a fault condition is removed. A frequency foldback circuit reduces the switching frequency during startup and overcurrent fault conditions to help control the inductor current.

## PROTECTION FEATURES

### Power Stage Protection

The DRV8301-Q1 provides over-current and under-voltage protection for the MOSFET power stage. During fault shut down conditions, all gate driver outputs will be kept low to ensure external FETs at high impedance state.

### Over-Current Protection (OCP) and Reporting

To protect the power stage from damage due to high currents, a  $V_{DS}$  sensing circuitry is implemented in the DRV8301-Q1. Based on  $R_{DS(on)}$  of the power MOSFETs and the maximum allowed  $I_{DS}$ , a voltage threshold can be calculated which, when exceeded, triggers the OC protection feature. This voltage threshold level is programmable through SPI command.

There are total 4 OC\_MODE settings in SPI.

#### 1. Current Limit Mode

When current limit mode is enabled, device operates current limiting instead of OC shut down during OC event. The over-current event is reported through OCTW pin. OCTW reporting should hold low during same PWM cycle or for a max 64μs period (internal timer) so external controller has enough time to sample the warning signal. If in the middle of reporting, other FET(s) gets OC, then OCTW reporting will hold low and recount another 64μs unless PWM cycles on both FETs are ended.

There are two current control settings in current limit mode (selected by one bit in SPI and default is CBC mode).

- Setting 1 (CBC mode): during OC event, the FET that detected OC will turn off until next PWM cycle.
- Setting 2 (off-time control mode):
  - During OC event, the FET that detected OC will turn off for 64us as off time and back to normal after that (so same FET will be on again) if PWM signal is still holding high. Since all three phases or 6 FETs share a single timer, if more than one FET get OC, the FETs will not be back to normal until the all FETs that have OC event pass 64μs.
  - If PWM signal is toggled for this FET during timer running period, device will resume normal operation for this toggled FET. So real off-time could be less than 64uS in this case.
  - If two FETs get OC and one FET's PWM signal gets toggled during timer running period, this FET will be back to normal, and the other FET will be off till timer end (unless its PWM is also toggled)

## 2. OC latch shut down mode

When OC occurs, device will turn off both high side and low side FETs in the same phase if any of the FETs in that phase has OC.

## 3. Report only mode

No protection action will be performance in this mode. OC detection will be reported through OCTW pin and SPI status register. External MCU should take actions based on its own control algorithm. A pulse stretching of 64μs will be implemented on OCTW pin so controller can have enough time to sense the OC signal.

## 4. OC disable mode

Device will ignore all the OC detections and will not report them either.

## Under-Voltage Protection (UVP)

To protect the power output stage during startup, shutdown and other possible under-voltage conditions, the DRV8301-Q1 provides power stage under-voltage protection by driving its outputs low whenever PVDD is below 6V (PVDD\_UV) or GVDD is below 7.5V (GVDD\_UV). When UVP is triggered, the DRV8301-Q1 outputs are driven low and the external MOSFETs will go to a high impedance state.

## Over-Voltage Protection (GVDD\_OV)

Device will shut down both gate driver and charge pump if GVDD voltage exceeds 16V to prevent potential issue related to GVDD or charge pump (e.g. short of external GVDD cap or charge pump). The fault is a latched fault and can only be reset through a transition on EN\_GATE pin.

## Over-Temperature Protection

A two-level over-temperature detection circuit is implemented:

- Level 1: over temperature warning (OTW)  
OTW is reported through  $\overline{\text{OCTW}}$  pin (over-current-temperature warning) for default setting. OCTW pin can be set to report OTW or OCW only through SPI command. See SPI Register section.
- Level 2: over temperature (OT) latched shut down of gate driver and charge pump (OTSD\_GATE)  
Fault will be reported to  $\overline{\text{FAULT}}$  pin. This is a latched shut down, so gate driver will not be recovered automatically even OT condition is not present anymore. An EN\_GATE reset through pin or SPI (RESET\_GATE) is required to recover gate driver to normal operation after temperature goes below a preset value,  $t_{\text{OTSD\_CLR}}$ .

SPI operation is still available and register settings will be remaining in the device during OTSD operation as long as PVDD is still within defined operation range.

## Fault and Protection Handling

The  $\overline{\text{FAULT}}$  pin indicates an error event with shut down has occurred such as over-current, over-temperature, over-voltage, or under-voltage. Note that  $\overline{\text{FAULT}}$  is an open-drain signal.  $\overline{\text{FAULT}}$  will go high when gate driver is ready for PWM signal (internal EN\_GATE goes high) during start up.

The  $\overline{\text{OCTW}}$  pin indicates over current event and over temperature event that not necessary related to shut down.

Following is the summary of all protection features and their reporting structure:

**Table 1. Fault and Warning Reporting and Handling**

EVENT	ACTION	LATCH	REPORTING ON FAULT PIN	REPORTING ON OCTW PIN	REPORTING IN SPI STATUS REGISTER
PVDD undervoltage	External FETs HiZ; Weak pull down of all gate driver output	N	Y	N	Y
DVDD undervoltage	External FETs HiZ; Weak pull down of all gate driver output; When recovering, reset all status registers	N	Y	N	N
GVDD undervoltage	External FETs HiZ; Weak pull down of all gate driver output	N	Y	N	Y
GVDD overvoltage	External FETs HiZ; Weak pull down of all gate driver output Shut down the charge pump Won't recover and reset through SPI reset command or quick EN_GATE toggling	Y	Y	N	Y
OTW	None	N	N	Y (in default setting)	Y
OTSD_GATE	Gate driver latched shut down. Weak pull down of all gate driver output to force external FETs HiZ Shut down the charge pump	Y	Y	Y	Y
OTSD_BUCK	OTSD of Buck	Y	N	N	N
Buck output undervoltage	UVLO_BUCK: auto-restart	N	Y, in PWRGD pin	N	N
Buck overload	Buck current limiting (HiZ high side until current reaches zero and then auto-recovering)	N	N	N	N
External FET overload – current limit mode	External FETs current Limiting (only OC detected FET)	N	N	Y	Y, indicates which phase has OC
External FET overload – Latch mode	Weak pull down of gate driver output and PWM logic "0" of LS and HS in the same phase. External FETs HiZ	Y	Y	Y	Y
External FET overload – reporting only mode	Reporting only	N	N	Y	Y, indicates which phase has OC

## PIN CONTROL FUNCTIONS

**Table 2. Device Truth Table**

INH_X	INL_X	GH_X	GL_X
1	1	L	L
1	0	H	L
0	1	L	H
0	0	L	L

### EN\_GATE

EN\_GATE low is used to put gate driver, charge pump, current shunt amplifier, and internal regulator blocks into a low power consumption mode to save energy. SPI communication is not supported during this state. Device will put the MOSFET output stage to high impedance mode as long as PVDD is still present.

When EN\_GATE pin goes to high, it will go through a power up sequence, and enable gate driver, current amplifiers, charge pump, internal regulator, etc and reset all latched faults related to gate driver block. It will also reset status registers in SPI table. All latched faults can be reset when EN\_GATE is toggled after an error event unless the fault is still present.

When EN\_GATE goes from high to low, it will shut down gate driver block immediately, so gate output can put external FETs in high impedance mode. It will then wait for 10 $\mu$ s before completely shutting down the rest of the blocks. A quick fault reset mode can be done by toggling EN\_GATE pin for a very short period (less than 10 $\mu$ S). This will prevent device to shut down other function blocks such as charge pump and internal regulators and bring a quicker and simple fault recovery. SPI will still function with such a quick EN\_GATE reset mode.

The other way to reset all the faults is to use SPI command (RESET\_GATE), which will only reset gate driver block and all the SPI status registers without shutting down other function blocks.

One exception is to reset a GVDD\_OV fault. A quick EN\_GATE quick fault reset or SPI command reset won't work with GVDD\_OV fault. A complete EN\_GATE with low level holding longer than 10 $\mu$ S is required to reset GVDD\_OV fault. It is highly recommended to inspect the system and board when GVDD\_OV occurs.

### EN\_BUCK

Buck enable pin, internal pull-up current source. Pull below 1.2V to disable. Float to enable.

### DTC

Dead time can be programmed through DTC pin. A resistor should be connected from DTC to ground to control the dead time. Dead time control range is from 50ns to 500ns. Short DTC pin to ground will provide minimum dead time (50ns). Resistor range is 0 to 150k $\Omega$ . Dead time is linearly set over this resistor range.

Current shoot through prevention protection will be enabled in the device all time independent of dead time setting and input mode setting.

### VDD\_SPI

VDD\_SPI is the power supply to power SDO pin. It has to be connected to the same power supply (3.3V or 5V) that MCU uses for its SPI operation.

During power up or down transient, VDD\_SPI pin could be zero voltage shortly. During this period, no SDO signal should be present at SDO pin from any other devices in the system since it causes a parasitic diode in the DRV8301-Q1 conducting from SDO to VDD\_SPI pin as a short. This should be considered and prevented from system power sequence design.

### DC\_CAL

When DC\_CAL is enabled, device will short inputs of shunt amplifier and disconnect from the load, so external microcontroller can do a DC offset calibration. DC offset calibration can be also done with SPI command. If using SPI exclusively for DC calibration, the DC\_CAL pin can connected to GND.

## SPI Pins

SDO pin has to be 3-state, so a data bus line can be connected to multiple SPI slave devices. SCS pin is active low. When SCS is high, SDO is at high impedance mode.

## STARTUP AND SHUTDOWN SEQUENCE CONTROL

During power-up all gate drive outputs are held low. Normal operation of gate driver and current shunt amplifiers can be initiated by toggling EN\_GATE from a low state to a high state. If no errors are present, the DRV8301-Q1 is ready to accept PWM inputs. Gate driver always has control of the power FETs even in gate disable mode as long as PVDD is within functional region.

There is an internal diode from SDO to VDD\_SPI, so VDD\_SPI is required to be powered to the same power level as other SPI devices (if there is any SDO signal from other devices) all the time. VDD\_SPI supply should be powered up first before any signal appears at SDO pin and powered down after completing all communications at SDO pin.

## SPI COMMUNICATION

### SPI Interface

SPI interface is used to set device configuration, operating parameters and read out diagnostic information. The DRV8301-Q1 SPI Interface operates in the slave mode.

The SPI input data (SDI) word consists of 16bit word, with 11 bit data and 5 bit (MSB) command. The SPI output data (SDO) word consists of 16bit word, with 11 bit register data and 4 bit MSB address data and 1 frame fault bit (active 1). When a frame is not valid, frame fault bit will set to 1, and rest of SDO bit will shift out zeros.

A valid frame has to meet following conditions:

1. Clock must be low when /SCS goes low.
2. We should have 16 full clock cycles.
3. Clock must be low when /SCS goes high.

When SCS is asserted high, any signals at the SCLK and SDI pins are ignored, and SDO is forced into a high impedance state. When SCS transitions from HIGH to LOW, SDO is enabled and the SPI response word loads into the shift register based on 5 bit command in SPI at previous clock cycle.

The SCLK pin must be low when SCS transitions low. While SCS is low, at each rising edge of the clock, the response bit is serially shifted out on the SDO pin with MSB shifted out first.

While SCS is low, at each falling edge of the clock, the new control bit is sampled on the SDI pin. The SPI command bits are decoded to determine the register address and access type (read or write). The MSB will be shifted in first. If the word sent to SDI is less than 16 bits or more than 16 bits, it is considered a frame error. If it is a write command, the data will be ignored. The fault bit in SDO (MSB) will report 1 at next 16 bit word cycle.

After the 16th clock cycle or when SCS transitions from LOW to HIGH, in case of write access type, the SPI receive shift register data is transferred into the latch where address matches decoded SPI command address value. Any amount of time may pass between bits, as long as SCS stays active low. This allows two 8-bit words to be used.

For a read command (Nth cycle) in SPI, SP0 will send out data in the register with address in read command in next cycle (N+1).

For a write command in SPI, SPO will send out data in the status register 0x00h in next 16 bit word cycle (N+1). For most of the time, this feature will maximize SPI communication efficiency when having a write command, but still get fault status values back without sending extra read command.

### SPI Format

SPI input data control word is 16-bit long, consisting of:

- 1 read or write bit W [15]
- 4 address bits A [14:11]
- 11 data bits D [10:0]

SPI output data response word is 16-bit long, and its content depends on the given SPI command (SPI Control Word) in the previous cycle. When a SPI Control Word is shifted in, the SPI Response Word (that is shifted out during the same transition time) is the response to the previous SPI Command (shift in SPI Control Word "N" and shift out SPI Response Word "N-1").

Therefore, each SPI Control / Response pair requires two full 16-bit shift cycles to complete.

**Table 3. SPI Input Data Control Word Format**

	R/W	Address					Data									
Word Bit	B15	B14	B13	B12	B11	B10	B9	B8	B7	B6	B5	B4	B3	B2	B1	B0
Command	W0	A3	A2	A1	A0	D10	D9	D8	D7	D6	D5	D4	D3	D2	D1	D0

**Table 4. SPI Output Data Response Word Format**

	R/W	Data														
Word Bit	B15	B14	B13	B12	B11	B10	B9	B8	B7	B6	B5	B4	B3	B2	B1	B0
Command	F0	A3	A2	A1	A0	D10	D9	D8	D7	D6	D5	D4	D3	D2	D1	D0

## SPI Control and Status Registers

### Read / Write Bit

The MSB bit of SDI word (W0) is read/write bit. When W0 = 0, input data is a write command; when W0 = 1, input data is a read command, and the register value will send out on the same word cycle from SDO from D10 to D0.

### Address Bits

**Table 5. Register Address**

Register Type	Address [A3..A0]				Register Name	Description	Read and Write Access
Status Register	0	0	0	0	Status Register 1	Report occurred faults after previous reading	R (auto reset to default values after read)
	0	0	0	1	Status Register 2	Device ID and report occurred faults after previous reading	Device ID: R Fault report: R (auto reset to default values after read)
Control Register	0	0	1	0	Control Register 1		R/W
	0	0	1	1	Control Register 2		R/W

## SPI Data Bits

### Status Registers

**Table 6. Status Register 1 (Address: 0x00) (all default values are zero)**

Address	Register Name	D10	D9	D8	D7	D6	D5	D4	D3	D2	D1	D0
0x00	Status Register 1	FAULT	GVDD_UV	PVDD_UV	OTSD	OTW	FETHA_OC	FETLA_OC	FETHB_OC	FETLB_OC	FETHC_OC	FETLC_OC

**Table 7. Status Register 2 (Address: 0x01) (all default values are zero)**

Address	Register Name	D7	D6	D5	D4	D3	D2	D1	D0
0x01	Status Register 2	GVDD_OV				Device ID			
						0	0	0	0

- All status register bits are in latched mode. Read each status register will reset the bits in this register. Read fault register twice to get an updated status condition.
- EN\_GATE toggling with “low” level holding longer than 10µS will force a shut down and start up sequence and reset all values in status registers including GVDD\_OV fault.
- EN\_GATE toggling (quick fault reset) with low level holding less than 10µS or GATE\_RESET high (in SPI) will reset all values in status registers except GVDD\_OV fault which will still be latched as a fault.
- FAULT is high when any fault occurs to cause a shut down (GVDD\_UV, PVDD\_UV, OTSD, OCSD, GVDD\_OV), which is opposite to FAULT hardware pin.

### Control Registers

**Table 8. Control Register 1 for Gate Driver Control (Address: 0x02)<sup>(1)</sup>**

Address	Name	Description	D10	D9	D8	D7	D6	D5	D4	D3	D2	D1	D0
0x02	GATE_CURRENT	Gate driver peak current 1.7A (for slew rate control)										0	0
		Gate driver peak current 0.7A										0	1
		Gate driver peak current 0.25A										1	0
		Reserved										1	1
	GATE_RESET	Normal mode									<b>0</b>		
		Reset all latched faults related to gate driver, reset gate driver back to normal operation, reset status register values to default									1		
		GATE_RESET value will automatically reset to zero after gate driver completes reset											
	PWM_MODE	PWM with six independent inputs								<b>0</b>			
		PWM with three independent inputs. PWM control high side gates only. Low side is complementary to high side gates with minimum internal dead time.								1			
	OC_MODE (gate driver only)	Current limiting when OC detected						<b>0</b>	<b>0</b>				
		Latched shut down when OC detected						0	1				
		Report only (no current limiting or shut down) when OC detected						1	0				
		OC protection disabled (no OC sensing and reporting)						1	1				
	OC_ADJ_SET	See OC_ADJ_SET table	X	X	X	X	X						

(1) **Bold** is default value

**Table 9. Control Register 2 for Current Shunt Amplifiers and Misc Control (Address: 0x03)<sup>(1)</sup>**

Address	Name	Description	D10	D9	D8	D7	D6	D5	D4	D3	D2	D1	D0
0x03	OCTW_SET	Report both OT and OC at /OCTW pin										<b>0</b>	<b>0</b>
		Report OT only										0	1
		Report OC only										1	0
		Report OC Only (Reserved)										1	1
	GAIN	Gain of shunt amplifier: 10V/V								<b>0</b>	<b>0</b>		
		Gain of shunt amplifier: 20V/V								0	1		
		Gain of shunt amplifier: 40V/V								1	0		
		Gain of shunt amplifier: 80V/V								1	1		
	DC_CAL_CH1	Shunt amplifier 1 connects to load through input pins							<b>0</b>				
		Shunt amplifier 1 shorts input pins and disconnected from load for external calibration							1				
	DC_CAL_CH2	Shunt amplifier 2 connects to load through input pins						<b>0</b>					
		Shunt amplifier 2 shorts input pins and disconnected from load for external calibration						1					
	OC_TOFF	Normal CBC operation (recovering at next PWM cycle)					<b>0</b>						
		Off time control during OC					1						
	Reserved												

(1) **Bold** value is default value

### Over Current Adjustment

When external MOSFET is turned on, the output current flows the MOSFET, which creates a voltage drop  $V_{DS}$ . The overcurrent protection event will be enabled when the  $V_{DS}$  exceeds a pre-set value  $I_{OC}$ . The OC tripped value can be programmed through SPI command. Assuming the on resistance of MOSFET is  $R_{DS(on)}$ , the  $V_{ds}$  can be calculated as:

$$V_{DS} = I_{OC} \times R_{DS(on)}$$

$V_{DS}$  is measured across the SL\_x and SH\_x pins for the low-side MOSFET. For the high-side MOSFET,  $V_{DS}$  is measured across PVDD1 (internally) and SH\_x. Therefore, it is important to limit the ripple on the PVDD1 supply for accurate high-side current sensing.

It is also important to note that there can be up to a 20% tolerance across channels for the OC trip point. This is meant for protection and not to be used for regulating current in a motor phase.

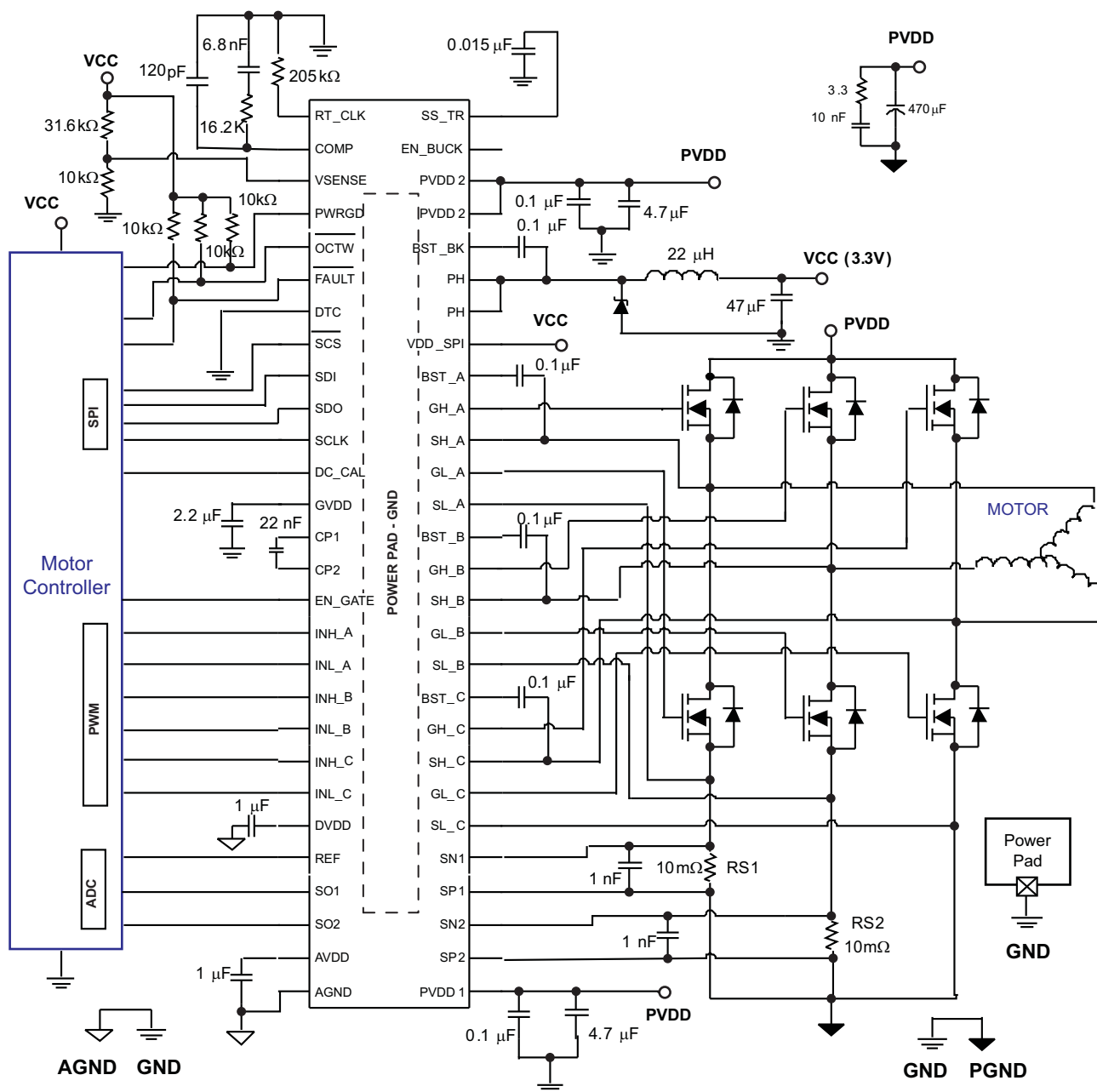
**Table 10. OC\_ADJ\_SET Table**

Control Bit (D6–D10) (0xH)	0	1	2	3	4	5	6	7
Vds (V)	0.060	0.068	0.076	0.086	0.097	0.109	0.123	0.138
Control Bit (D6–D10) (0xH)	8	9	10	11	12	13	14	15
Vds (V)	0.155	0.175	0.197	0.222	0.250	0.282	0.317	0.358
Control Bit (D6–D10) (0xH)	16	17	18	19	20	21	22	23
Vds (V)	0.403	0.454	0.511	0.576	0.648	0.730	0.822	0.926
Code Number (0xH)	24	25	26	27	28	29	30	31
Vds (V)	1.043	1.175	1.324	1.491	1.679 <sup>(1)</sup>	1.892 <sup>(1)</sup>	2.131 <sup>(1)</sup>	2.400 <sup>(1)</sup>

(1) Do not use settings 28, 29, 30, 31 for  $V_{DS}$  sensing if the IC is expected to operate in the 6V – 8V range.

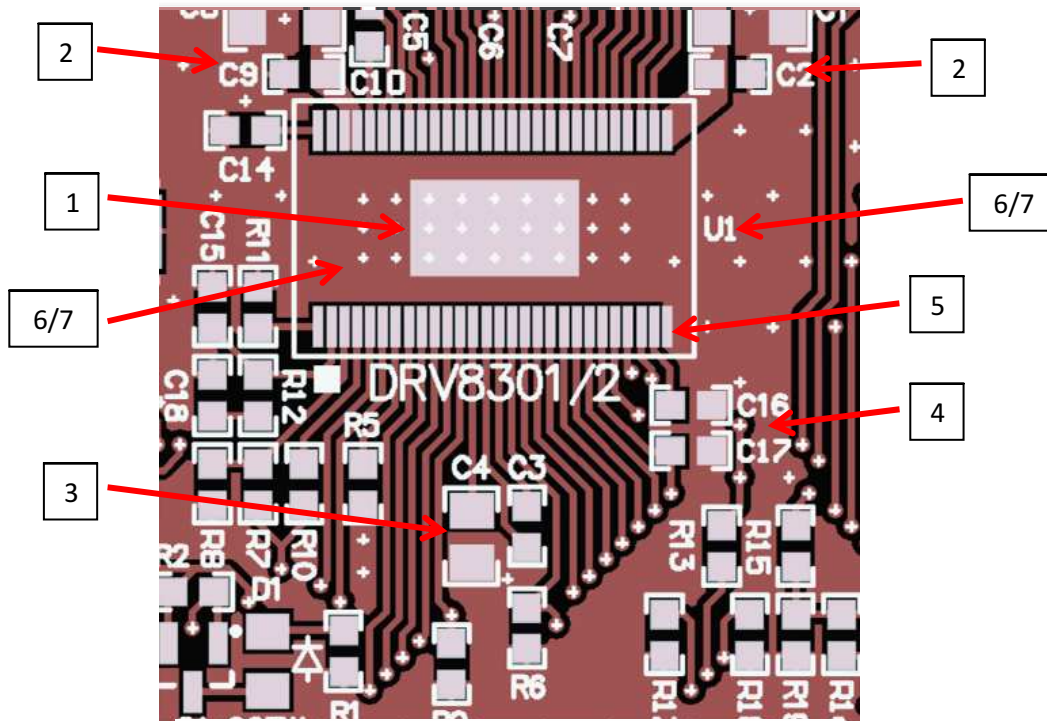
Example:

Buck: PVDD= 3.5V – 40V, Iout\_max = 1.5A, Vo = 3.3V, Fs = 570 kHz



## PCB LAYOUT RECOMMENDATIONS

Below are a few layout recommendations to utilize when designing a PCB for the DRV8301-Q1.



1. The DRV8301-Q1 makes an electrical connection to GND through the PowerPAD. Always check to ensure that the PowerPAD has been properly soldered (See PowerPAD application report, [SLMA002](#)).
2. C1/C2/C8/C9, PVDD decoupling capacitors should be placed close to their corresponding pins with a low impedance path to device GND (PowerPAD).
3. C4, GVDD capacitor should be placed close its corresponding pin with a low impedance path to device GND (PowerPAD).
4. C16/C17, AVDD & DVDD capacitors should be placed close to their corresponding pins with a low impedance path to the AGND pin. It's preferable to make this connection on the same layer.
5. AGND should be tied to device GND (PowerPAD) through a low impedance trace/copper fill.
6. Add stitching vias to reduce the impedance of the GND path from the top to bottom side.
7. Try to clear the space around and underneath the DRV8301-Q1 to allow for better heat spreading from the PowerPAD.

**Table 11. Recommended Values**

DESIGNATOR	PIN	RECOMMENDED VALUE	DESCRIPTION
C1	PVDD1 – pin 29	2.2uF	CAP CER 2.2UF 100V 10% X7R
C2	PVDD1 – pin 29	0.1uF	CAP CER 0.1UF 100V 10% X7R
C8	PVDD2 – pins 53 & 54	2.2uF	CAP CER 2.2UF 100V 10% X7R
C9	PVDD2 – pins 53 & 54	0.1uF	CAP CER 0.1UF 100V 10% X7R
C4	GVDD – pin 13	2.2uF	CAP CER 2.2UF 25V 10% X7R
C16	AVDD – pin 27	1.0uF	CAP CER 1UF 25V 10% X7R
C17	DVDD – pin 23	1.0uF	CAP CER 1UF 25V 10% X7R

## PACKAGING INFORMATION

Orderable Device	Status (1)	Package Type	Package Drawing	Pins	Package Qty	Eco Plan (2)	Lead/Ball Finish	MSL Peak Temp (3)	Op Temp (°C)	Device Marking (4/5)	Samples
DRV8301QDCAQ1	ACTIVE	HTSSOP	DCA	56	35	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-3-260C-168 HR	-40 to 125	DRV8301Q	<a href="#">Samples</a>
DRV8301QDCARQ1	ACTIVE	HTSSOP	DCA	56	2000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-3-260C-168 HR	-40 to 125	DRV8301Q	<a href="#">Samples</a>

(1) The marketing status values are defined as follows:

**ACTIVE:** Product device recommended for new designs.

**LIFEBUY:** TI has announced that the device will be discontinued, and a lifetime-buy period is in effect.

**NRND:** Not recommended for new designs. Device is in production to support existing customers, but TI does not recommend using this part in a new design.

**PREVIEW:** Device has been announced but is not in production. Samples may or may not be available.

**OBSOLETE:** TI has discontinued the production of the device.

(2) Eco Plan - The planned eco-friendly classification: Pb-Free (RoHS), Pb-Free (RoHS Exempt), or Green (RoHS & no Sb/Br) - please check <http://www.ti.com/productcontent> for the latest availability information and additional product content details.

**TBD:** The Pb-Free/Green conversion plan has not been defined.

**Pb-Free (RoHS):** TI's terms "Lead-Free" or "Pb-Free" mean semiconductor products that are compatible with the current RoHS requirements for all 6 substances, including the requirement that lead not exceed 0.1% by weight in homogeneous materials. Where designed to be soldered at high temperatures, TI Pb-Free products are suitable for use in specified lead-free processes.

**Pb-Free (RoHS Exempt):** This component has a RoHS exemption for either 1) lead-based flip-chip solder bumps used between the die and package, or 2) lead-based die adhesive used between the die and leadframe. The component is otherwise considered Pb-Free (RoHS compatible) as defined above.

**Green (RoHS & no Sb/Br):** TI defines "Green" to mean Pb-Free (RoHS compatible), and free of Bromine (Br) and Antimony (Sb) based flame retardants (Br or Sb do not exceed 0.1% by weight in homogeneous material)

(3) MSL, Peak Temp. -- The Moisture Sensitivity Level rating according to the JEDEC industry standard classifications, and peak solder temperature.

(4) There may be additional marking, which relates to the logo, the lot trace code information, or the environmental category on the device.

(5) Multiple Device Markings will be inside parentheses. Only one Device Marking contained in parentheses and separated by a "~" will appear on a device. If a line is indented then it is a continuation of the previous line and the two combined represent the entire Device Marking for that device.

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**OTHER QUALIFIED VERSIONS OF DRV8301-Q1 :**

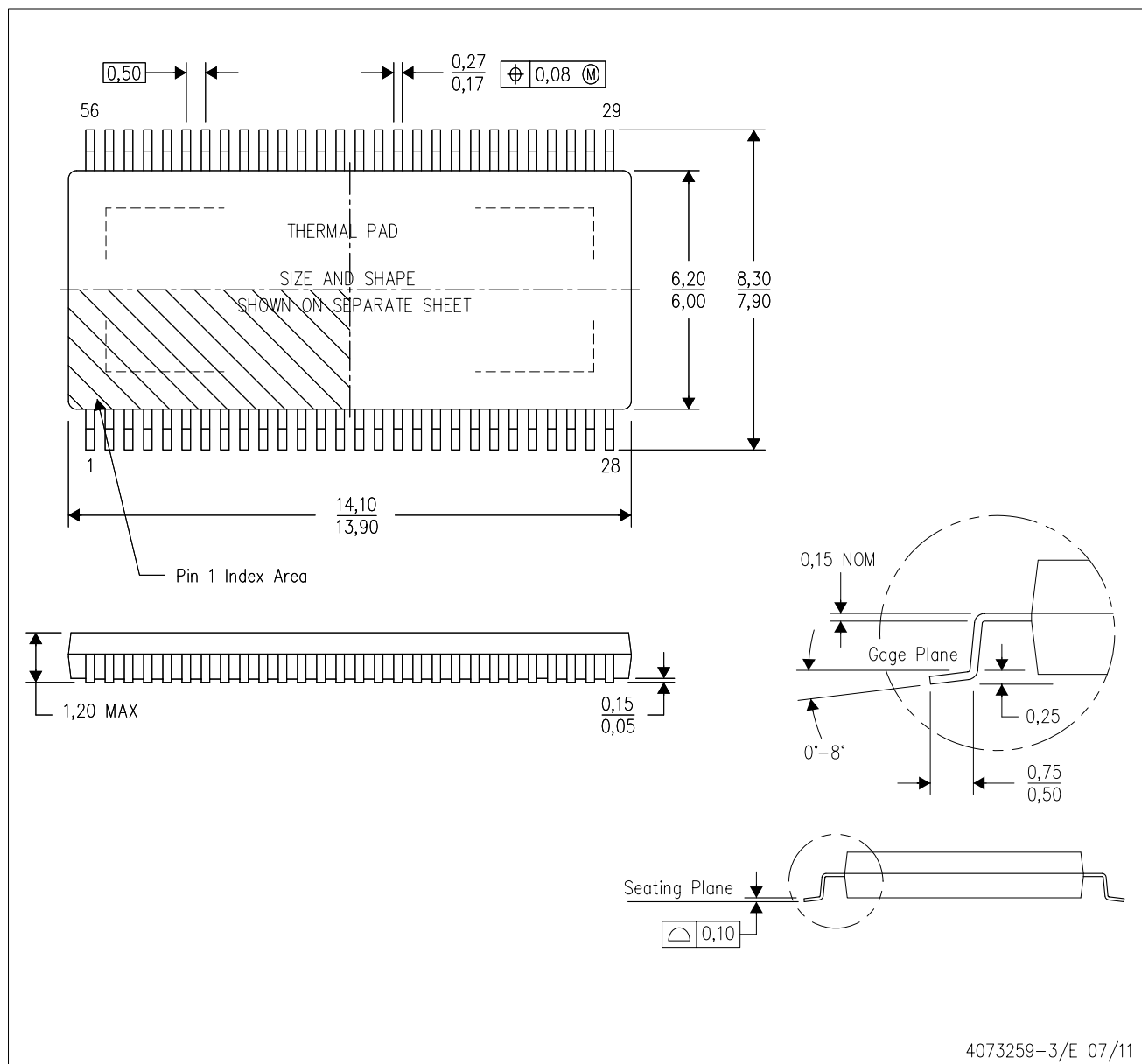
- Catalog: [DRV8301](#)

## NOTE: Qualified Version Definitions:

- Catalog - TI's standard catalog product

DCA (R-PDSO-G56)

PowerPAD™ PLASTIC SMALL-OUTLINE



- NOTES:
- All linear dimensions are in millimeters. Dimensioning and tolerancing per ASME Y14.5M-1994.
  - This drawing is subject to change without notice.
  - Body dimensions do not include mold flash or protrusion not to exceed 0.15.
  - This package is designed to be soldered to a thermal pad on the board. Refer to Technical Brief, PowerPad Thermally Enhanced Package, Texas Instruments Literature No. SLMA002 for information regarding recommended board layout. This document is available at [www.ti.com](http://www.ti.com) <<http://www.ti.com>>.
  - See the additional figure in the Product Data Sheet for details regarding the exposed thermal pad features and dimensions.
  - Falls within JEDEC MO-153

PowerPAD is a trademark of Texas Instruments.

DCA (R-PDSO-G56)

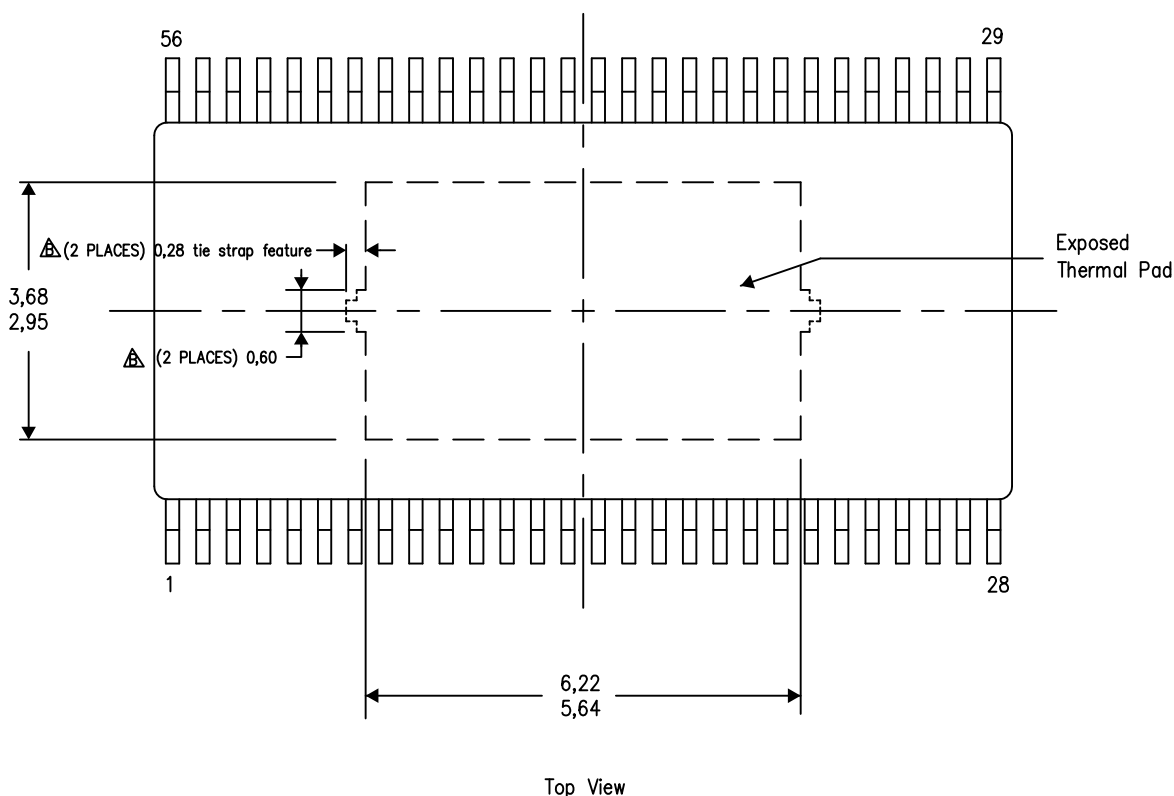
PowerPAD™ PLASTIC SMALL OUTLINE

## THERMAL INFORMATION

This PowerPAD™ package incorporates an exposed thermal pad that is designed to be attached to a printed circuit board (PCB). The thermal pad must be soldered directly to the PCB. After soldering, the PCB can be used as a heatsink. In addition, through the use of thermal vias, the thermal pad can be attached directly to the appropriate copper plane shown in the electrical schematic for the device, or alternatively, can be attached to a special heatsink structure designed into the PCB. This design optimizes the heat transfer from the integrated circuit (IC).

For additional information on the PowerPAD package and how to take advantage of its heat dissipating abilities, refer to Technical Brief, PowerPAD Thermally Enhanced Package, Texas Instruments Literature No. SLMA002 and Application Brief, PowerPAD Made Easy, Texas Instruments Literature No. SLMA004. Both documents are available at [www.ti.com](http://www.ti.com).

The exposed thermal pad dimensions for this package are shown in the following illustration.



4206320-13/S 11/14

NOTES: A. All linear dimensions are in millimeters



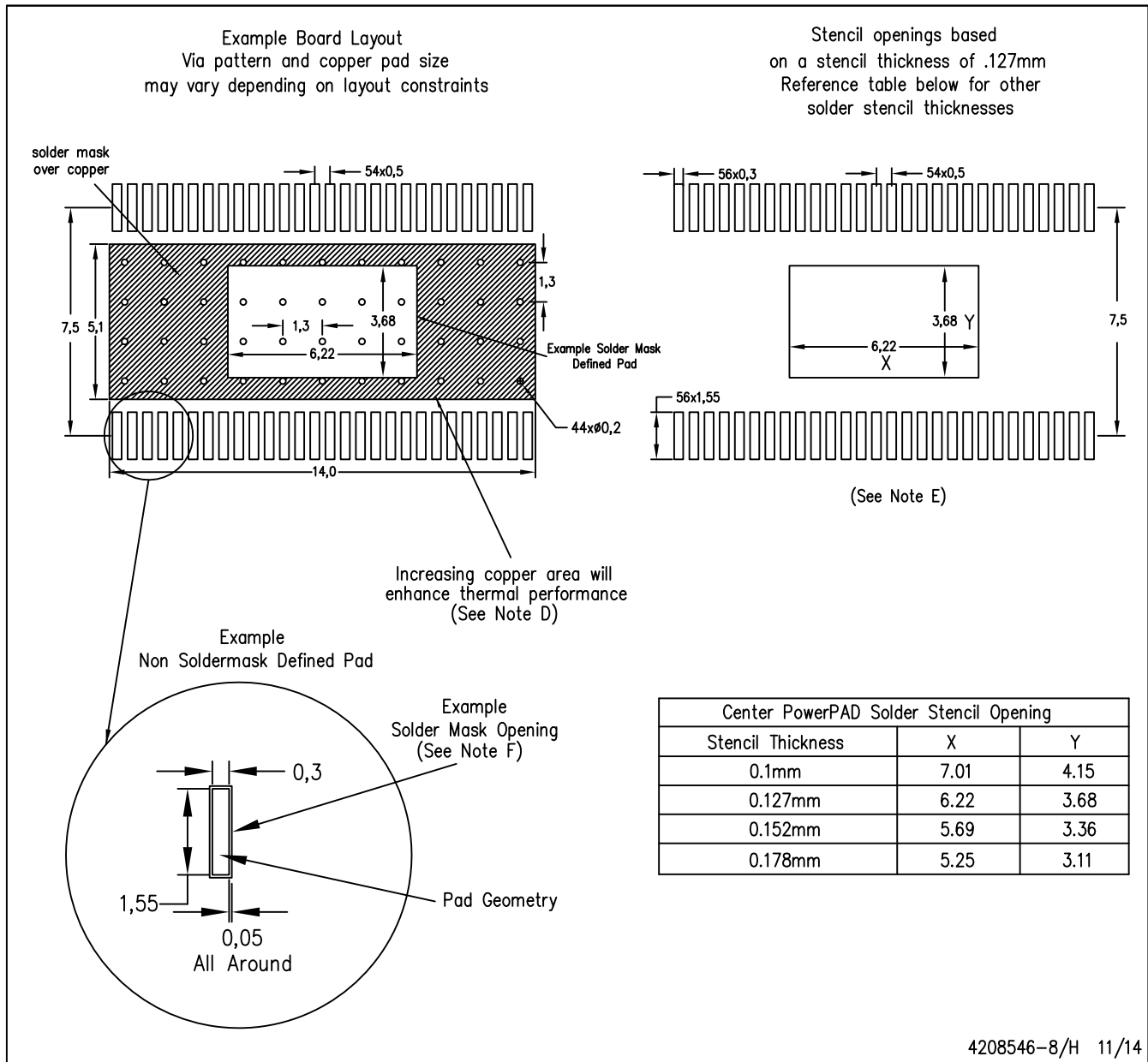
Keep-out features are identified to prevent board routing interference.

These exposed metal features may vary within the identified area or completely absent on some devices.

PowerPAD is a trademark of Texas Instruments.

DCA (R-PDSO-G56)

PowerPAD™ PLASTIC SMALL OUTLINE PACKAGE



- NOTES:
- All linear dimensions are in millimeters.
  - This drawing is subject to change without notice.
  - Customers should place a note on the circuit board fabrication drawing not to alter the center solder mask defined pad.
  - This package is designed to be soldered to a thermal pad on the board. Refer to Technical Brief, PowerPad Thermally Enhanced Package, Texas Instruments Literature No. SLMA002, SLMA004, and also the Product Data Sheets for specific thermal information, via requirements, and recommended board layout. These documents are available at [www.ti.com](http://www.ti.com) <<http://www.ti.com>>. Publication IPC-7351 is recommended for alternate designs.
  - Laser cutting apertures with trapezoidal walls and also rounding corners will offer better paste release. Customers should contact their board assembly site for stencil design recommendations. Example stencil design based on a 50% volumetric metal load solder paste. Refer to IPC-7525 for other stencil recommendations.
  - Customers should contact their board fabrication site for solder mask tolerances between and around signal pads.

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