5-V, THREE-PHASE, SENSORLESS BLDC MOTOR DRIVER

FEATURES

- **Input Voltage Range: 1.65 V to 5.5 V**
- **Six Integrated MOSFETS With 680-mA Peak Output Current**
- **Ultralow Quiescent Current: 5 µA (typ) in Standby Mode**
- **Total Driver H+L R_{DSOn} 900 mΩ**
- **Sensorless Proprietary BMEF Control Scheme**
- **150° Commutation**
- **Synchronous Rectification PWM Operation**
- **Selectable FG and ½ FG Open-Drain Output**
- **PWM_{IN} Input from 15 kHz to 50 kHz**
- **Lock Detection**
- **Voltage Surge Protection**
- **UVLO**
- **Thermal Shutdown**

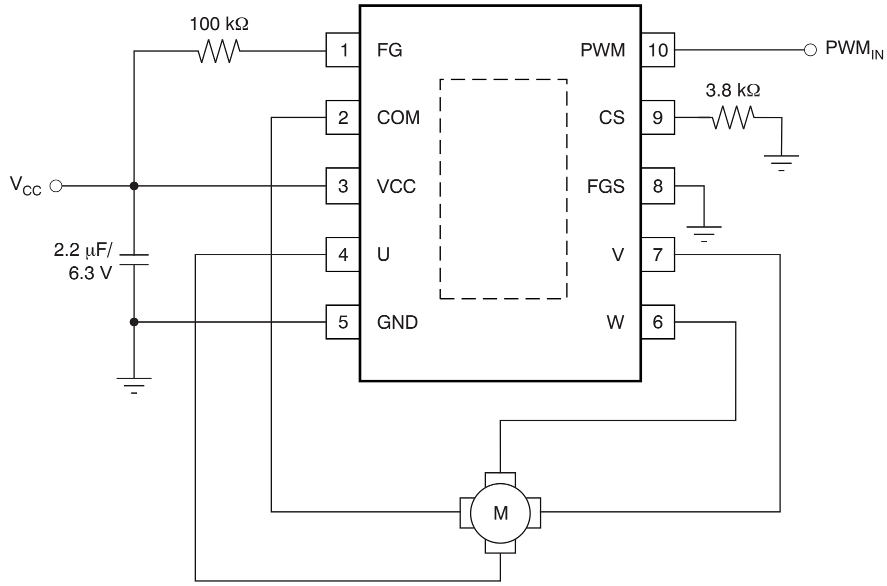
APPLICATIONS

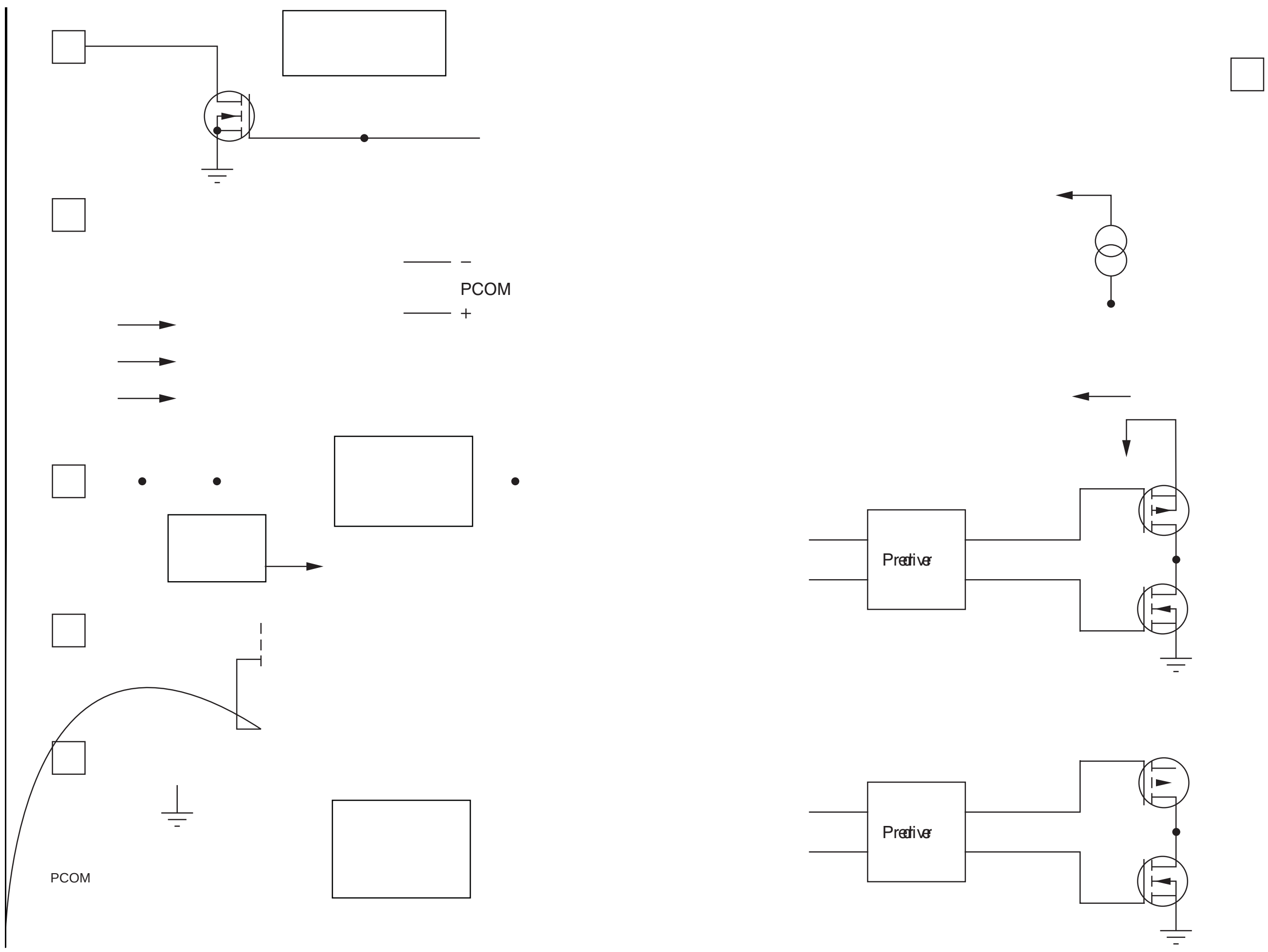
- **Notebook CPU Fans**
- **Game Station CPU Fans**
- **ASIC Cooling Fans**

DESCRIPTION

DRV10866 is a three phase, sensorless motor driver with integrated power MOSFETs with drive current capability up to 680 mA peak. DRV10866 is specifically designed for low noise and low external component count fan motor drive applications. DRV10866 has built in over-current protection with no external current sense resistor needed. The synchronous rectification mode of operation achieves increased efficiency for motor driver applications. DRV10866 outputs either FG or ½ FG to indicate motor speed with open drain output. A 150° sensorless BEMF control scheme is implemented for a three phase motor. DRV10866 is available in the thermally efficient 10-pin, 3-mm x 3-mm x 0.75-mm SON (DSC) package. The operating temperature is specified from -40°C to 125°C.

TYPICAL APPLICATION

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PCOM
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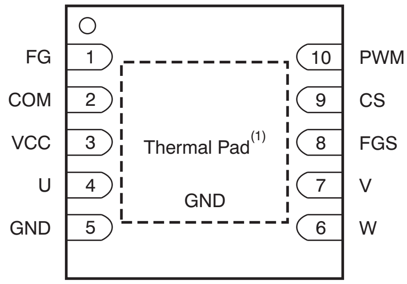
PIN DESIGNATION

DSC PACKAGE
3-mm × 3-mm SON
(TOP VIEW)



(1). Thermal pad connected to ground.

Table 1. PIN DESCRIPTIONS

TERMINAL			
NAME	**NO.**	**I/O**	**DESCRIPTION**
FG	1	O	Frequency generator output. If the FGS pin is connected to ground, the output has a period equal to six electrical states (FG). If the FGS pin is connected to VCC, the output has a period equal to 12 electrical states (1/2FG).
COM	2	I	Motor common terminal input
VCC	3	I	Input voltage for motor and chip-supply voltage; the internal clamping circuit clamps the V_{CC} voltage.
U	4	O	Phase U output
GND	5	—	Ground pin
W	6	O	Phase W output
V	7	O	Phase V output
FGS	8	I	FG and 1/2FG control pin. Latched upon wake-up signal from the PWM pin. For details, refer to the FG pin description section.
CS	9	I	Overcurrent threshold setup pin. The constant current of the internal constant current source flows through the resistor connected to this pin. The other side of the resistor is connected to ground. The voltage across the resistor compares with the voltage converted from the bottom MOSFET current. If the MOSFET current is high, the part enters the overcurrent protection mode by turning off the top PWM MOSFET and holding the bottom MOSFET on. I (mA) = 3120/R_{CS}(kΩ). Equation valid range: 300 mA < I_{LIMIT}< 850 mA
PWM	10	I	PWM input pin. The PWM input signal is converted to a fixed 156-kHz switching frequency on the MOSFET driver. The PWM input signal resolution is less than 1%. This pin can also control the device and put it in or out of standby mode. After the signal at the PWM stays low (up to 500 µs), the device goes into low-power standby mode. Standby current is approximately 5 µA. The rising edge of the PWM signal wakes up the device and puts it into active mode, where it is ready to start to turn the motor.

ABSOLUTE MAXIMUM RATINGS

Over operating free-air temperature range (unless otherwise noted).

		VALUE		UNIT
		MIN	MAX	
Input voltage range(1)	VCC	–0.3	+6.0	V
	CS, FGS, PWM	–0.3	+6.0	V
	GND	–0.3	+0.3	V
	COM	–1.0	+6.0	V
Output voltage range(1)	U, V, W	–1.0	+7.0	V
	FG	–0.3	+6.0	V
Temperature	Operating junction temperature, T_J	–40	+125	°C
	Storage, T_{stg}	–55	+150	°C
Electrostatic discharge (ESD)	Human body model, HBM		4	kV
	Charge device model, CDM		500	V

(1) All voltage values are with respect to network ground terminal unless otherwise noted.

THERMAL INFORMATION

THERMAL METRIC(1)		DRV10866	UNITS
		DSC	
		10 PINS	
θ_{JA}	Junction-to-ambient thermal resistance(2)	42.3	°C/W
θ_{JCtop}	Junction-to-case (top) thermal resistance(3)	44.5	
θ_{JB}	Junction-to-board thermal resistance(4)	17.1	
ψ_{JT}	Junction-to-top characterization parameter(5)	0.3	
ψ_{JB}	Junction-to-board characterization parameter(6)	17.3	
θ_{JCbot}	Junction-to-case (bottom) thermal resistance(7)	4.3	

(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_{JT}, estimates the junction temperature of a device in a real system and is extracted from the simulation data for obtaining θ_{JA}, using a procedure described in JESD51-2a (sections 6 and 7).
(6) The junction-to-board characterization parameter, ψ_{JB}, estimates the junction temperature of a device in a real system and is extracted from the simulation data for obtaining θ_{JA} , using a procedure described in JESD51-2a [illegible]

RECOMMENDED OPERATING CONDITIONS

Over operating free-air temperature range (unless otherwise noted).

		MIN	NOM	MAX	UNIT
Supply voltage	VCC	1.65		5.5	V
Voltage range	U, V, W	–0.7		6.5	V
	FG, CS, FGS, COM	–0.1		5.5	V
	GND	–0.1		0.1	V
	PWM	–0.1		5.5	V
Operating junction temperature, T_J		–40		+125	°C

ELECTRICAL CHARACTERISTICS

Over operating free-air temperature range (unless otherwise noted).

PARAMETER		TEST CONDITIONS	DRV10866 MIN	TYP	MAX	UNIT
SUPPLY CURRENT						
I_{Vcc}	Supply current	T_A = +25°C; PWM = V_{CC}; V_{CC} = 5 V		2.5	3.5	mA
$I_{Vcc\text{-}Standby}$	Standby current	T_A = +25°C; PWM = 0 V; V_{CC} = 5 V		5	10	µA
UVLO						
$V_{UVLO\text{-}Th\_r}$	UVLO threshold voltage, rising	Rise threshold, T_A = +25°C		1.80	1.9	V
$V_{UVLO\text{-}Th\_f}$	UVLO threshold voltage, falling	Fall threshold, T_A = +25°C	1.6	1.65		V
$V_{UVLO\text{-}Th\_hys}$	UVLO threshold voltage, hysteresis	T_A = +25°C	75	150	225	mV
INTEGRATED MOSFET						
R_{DSON}	Series resistance (H+L)	T_A = +25°C; V_{CC} = 5 V; I_O = 0.5 A		0.8	1.2	Ω
		T_A = +25°C; V_{CC} = 4 V; I_O = 0.5 A		0.9	1.4	Ω
		T_A = +25°C; V_{CC} = 3 V; I_O = 0.5 A		1.1	1.7	Ω
PWM						
$V_{PWM\text{-}IH}$	High-level input voltage	V_{CC} ≥ 4.5 V	2.3			V
$V_{PWM\text{-}IL}$	Low-level input voltage	V_{CC} ≥ 4.5 V			0.8	V
F_{PWM}	PWM input frequency		15		50	kHz
$I_{PWM\text{-}Source}$		Standby mode, V_{CC} = 5 V		5		µA
		Active mode, V_{CC} = 5 V		100		µA
T_{STBY}		PWM = 0		500		µs
FG AND FGS						
$I_{FG\text{-}Sink}$	FG pin sink current	V_{FG} = 0.3 V	5			mA
$V_{FGS\text{-}Th}$	FG set threshold voltage	FG pin output, full FG signal, V_{CC} ≥ 4.5 V			0.8	V
		FG pin output, one-half FG signal, V_{CC} ≥ 4.5 V	2.3			V
LOCK PROTECTION						
$T_{LOCK\text{-}On}$	Lock detect time	FG = 0	2	3	4	s
$T_{LOCK\text{-}Off}$	Lock release time		2.5	5	7.5	s
CURRENT LIMIT						
	Current limit	CS pin to GND resistor = 3.9 kΩ	680	800	920	mA
THERMAL SHUTDOWN						
T_{SHDN}	Shutdown temperature threshold			+160		°C
		Hysteresis		10		°C

DETAILED DEVICE DESCRIPTION

DRV10866 is a three phase, sensorless motor driver with integrated power MOSFETs with drive current capability up to 680-mA peak. DRV10866 is specifically designed for low noise, low external component count fan motor drive applications. DRV10866 has built in over current protection with no external current sense resistor needed. The synchronous rectification mode of operation achieves increased efficiency for motor driver applications. DRV10866 can output either FG or ½ FG to indicate motor speed with open drain output through FGS pin selection. A 150° sensorless BEMF control scheme is implemented for a three phase motor. Voltage surge protection scheme prevents input V_{CC} capacitor from over charge during motor acceleration and deceleration modes. DRV10866 has multiple built-in protection blocks including UVLO, over current protection, lock protection and thermal shut down protection.

Speed Control

DRV10866 can control motor speed through either the PWM_{IN} or V_{CC} pin. Motor speed will increase with higher PWM_{IN} duty cycle or V_{CC} input voltage. The curve of motor speed (RPM) vs PWM_{IN} duty cycle or V_{CC} input voltage is close to linear in most cases. However, motorIN

$$RPM = \frac{(FG \times 60)}{\text{pole pairs}}$$

Voltage Surge Protection

The DRV10866 has a unique feature to clamp the V_{CC} voltage during lock protection and standby mode. If the lock mode condition is caused by an external force that suddenly stops the motor at a high speed, or the device goes into standby mode from a high duty cycle, either situation releases the energy in the motor winding into the input capacitor. When a small input capacitor and anti-reverse diode are used in the system design, the input voltage of the IC could rise above the absolute voltage rate of the chip. This condition either destroys the device or reduces the reliability of the device. For this reason, the DRV10866 has a voltage clamp circuit that clamps the input voltage at 5.95 V, and has a hysteresis of 150 mV. This clamp circuit is only active during the lock protection cycle or when the device enters standby mode. It is disabled during normal operation.

Overcurrent Protection

The DRV10866 can adjust the overcurrent point through an external resistor connected to the CS pin (pin 9) and ground. Without this external current sense resistor, the DRV10866 senses the current through the power MOSFET. Therefore, there is no power loss during the current sensing. The current sense architecture improves the overall system efficiency. Shorting the CS pin to ground disables the overcurrent protection feature. During overcurrent protection, the DRV10866 only limits the current to the motor; it does not shut down the device. The overcurrent limit can be set by the value of current sensing resistor through Equation 2.

$$I\ (A) = \frac{3120}{R_{CS}\ (\Omega)} \quad (2)$$

UVLO (Undervoltage Lockout)

The DRV10866 has a built in UVLO function block. The hysteresis of UVLO threshold is 150 mV. The device will be locked out when V_{CC} reaches 1.65 V and woke up at 1.8 V.

Thermal Shutdown

The DRV10866 has a built in thermal shunt down function, which will shut down the device when the junction temperature is over 160°C and will resume operating when the junction temperature drops back to 150°C.

APPLICATION INFORMATION

The DRV10866 only requires three external components. A 2.2-µF or higher ceramic capacitor connected to V_{CC} and ground is needed for decoupling purposes. This capacitor must be placed close to the VCC pin (pin 3) and GND pin (pin 5). During normal operation, a sudden drop in motor speed (caused by changing the PWM duty from high to low immediately) causes the V_{CC} voltage to rise to a very high level, especially when an anti-reverse diode is added on the V_{CC} side. In order to avoid this condition, a larger input capacitor between V_{CC} and GND is needed, along with removing the anti-reverse diode. The DRV10866 is simple to design with a single-layer printed circuit board (PCB) layout. During layout, the strategy of ground copper pour is very important to enhance the thermal performance. Refer to Figure 1 for an example of PCB layout.

Figure 1. Single-Layer PCB Layout

PACKAGING INFORMATION

Orderable Device	Status (1)	Package Type	Package

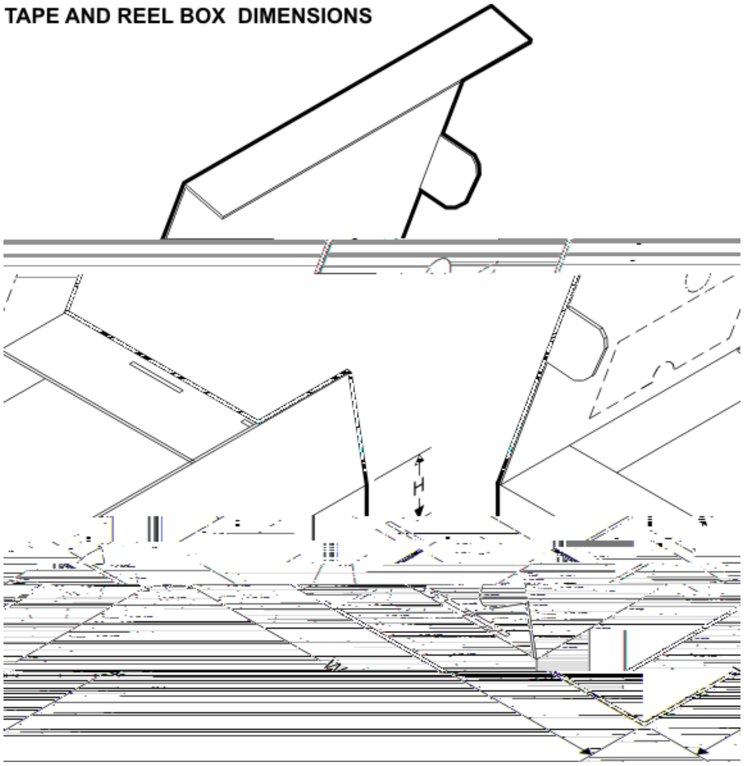
TAPE AND REEL INFORMATION

[redacted]

*All dimensions are nominal

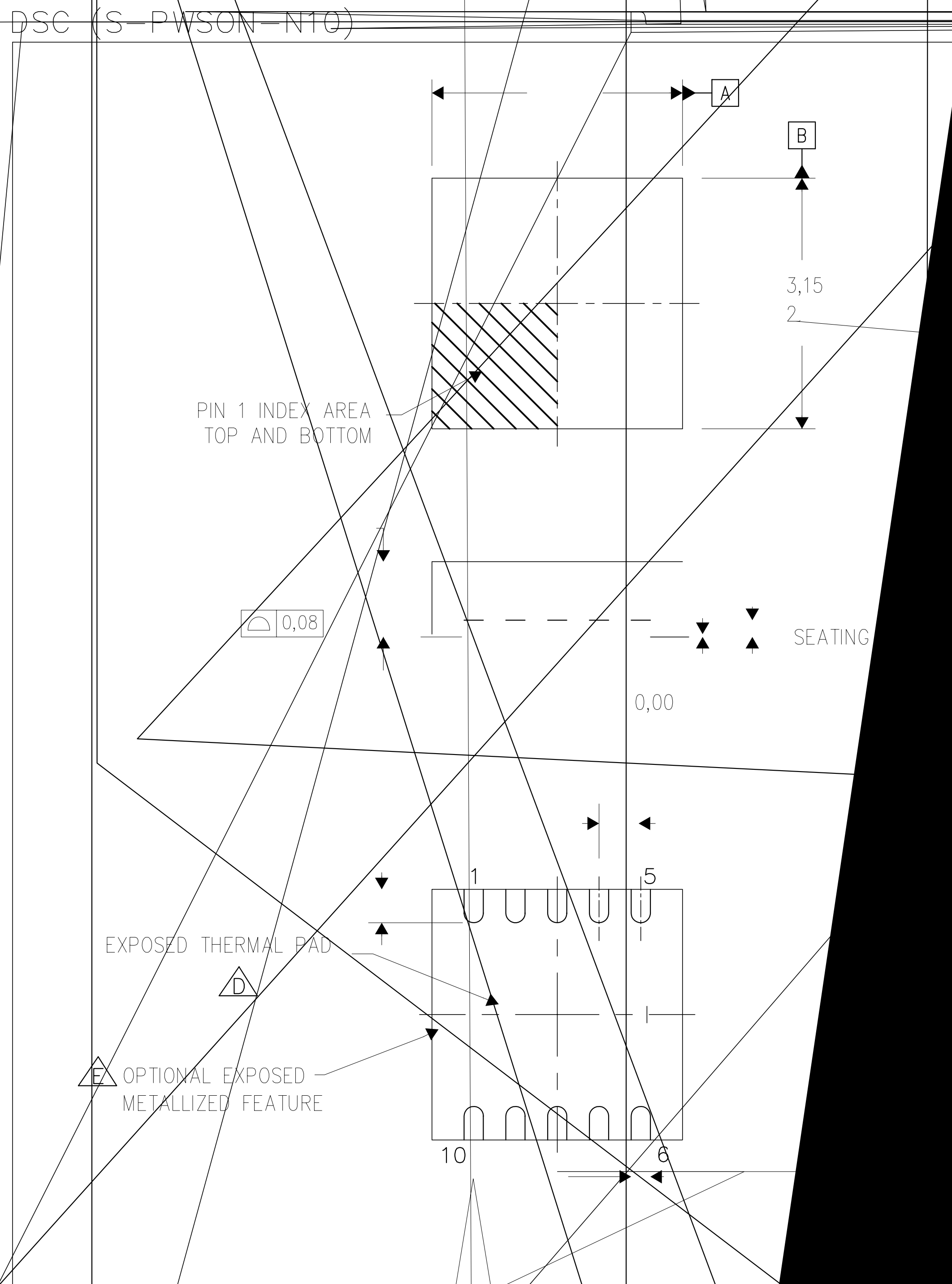
Device	Package Type	Package Drawing	Pins	SPQ	Reel Diameter (mm)	Reel Width W1 (mm)	A0 (mm)	B0 (mm)	K0 (mm)	P1 (mm)	W (mm)	Pin1 Quadrant
DRV10866DSCR	WSON	DSC	10	3000	330.0	12.4	3.3	3.3	1.1	8.0	12.0	Q2

TAPE AND REEL BOX DIMENSIONS



*All dimensions are nominal

Device	Package Type	Package Drawing	Pins	SPQ	Length (mm)	Width (mm)	Height (mm)
DRV10866DSCR	WSON	DSC	10	3000	367.0	367.0	35.0



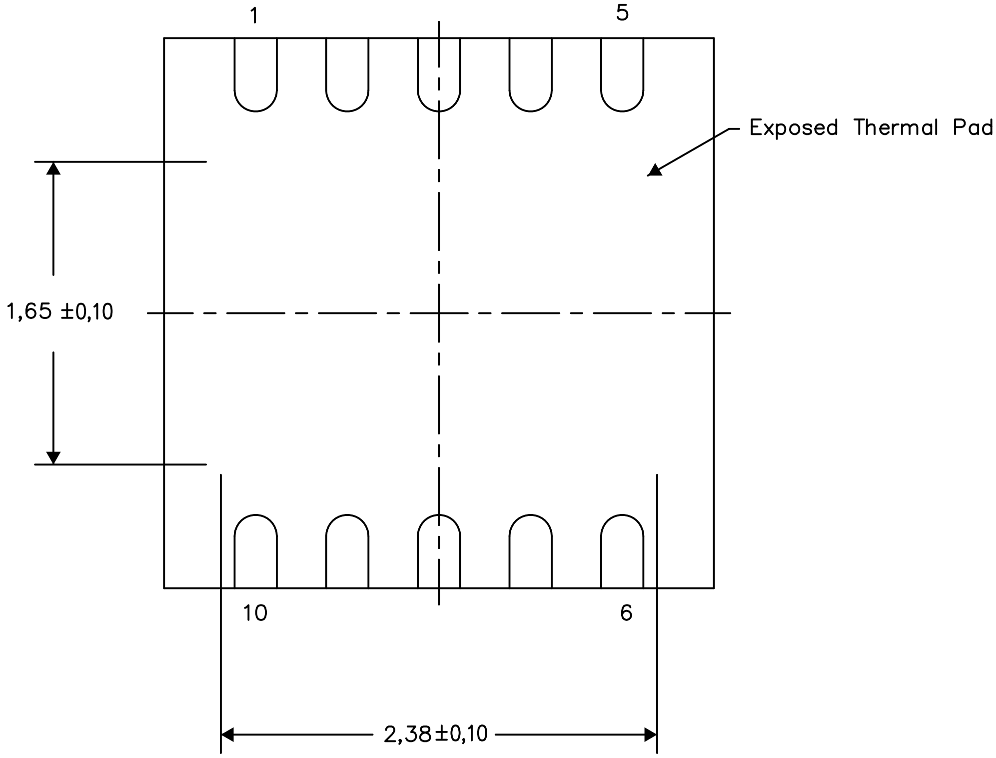
NOTES:

thermal pad must be soldered to the board for therm[redacted]

E. See the Product Data Sheet for details regarding the exposed the[redacted]

QFN/SON PCB Attachment, Texas Instruments Literature No. SLUA271. This document is available at www.ti.com.

The exposed thermal pad dimensions for this package ank. The thermal pad must be soldered directly to the t



NOTE: A. All linear dimensions are in millimeters

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