SP3100: Wireless Power Controller for Fast Charging Transmitter

1 Feature

- Input Voltage: 4.5V to 5.5V
- Compliant with WPC 1.2.3 to Work with A11 Coils
- Reliable and Accurate Foreign Object Detection (FOD)
- LED for Charging Status and Fault Reporting
- Built-In Demodulation Circuit for Communications
- Built-in Frequency Shift Keying modulate(FSK)
- Built-in fast charge protocol
- PWM Output from 110KHz to 205KHz with 100Hz Step
- Input Low Voltage Detection
- Limited Power to Prevent Overloading Input Sources
- Over-current Protection
- Over-temperature Protection with NTC Input
- Buzzer Output for Charging Status
- Internal Oscillator
- Interface with NU1007 to Form High Performance Total Solution
- 28 Pin 4mm ×4mm QFN Package

2 Applications

- Wireless Power Transmitter Compliant with WPC V1.2.3
- Wireless Power for Smart Phones
- General Wireless Power Transmitter for Consumer, Industrial and Medical Applications

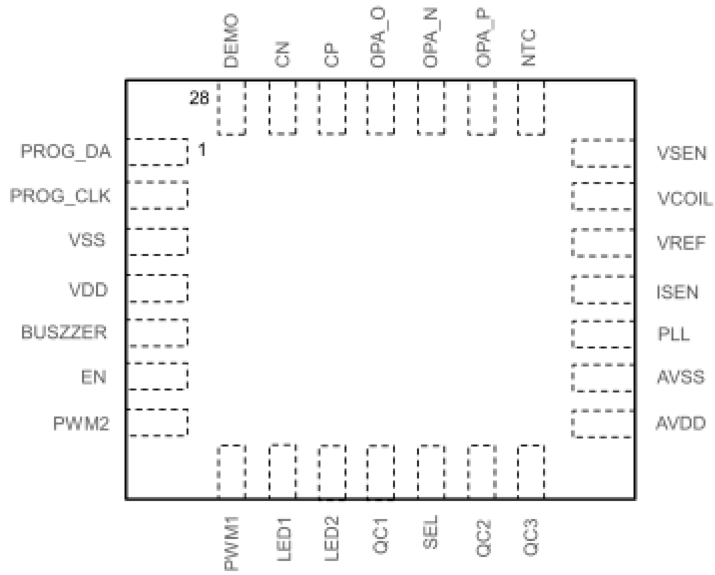
3 Descriptions

SP3100 is a highly integrated digital controller for wireless power transmitter compliant with WPC 1.2.3 standard. This device and NU1007, the companion power IC, form simple, high-performance and cost-effective wireless power transmitter solutions suitable for a wide range of applications.

SP3100 integrates all essential functions to deliver regulated power and maintain robust communications with WPC compliant receivers. The integrated demodulation circuit removes external amplifiers and comparators. The device is housed in a 4mm×4mm QFN package, making it a compact transmitter controller. Used with NU1007, the smallest and most integrated power IC, the two-chip turnkey design provides the most space saving solutions.

SP3100 also emphasizes on providing reliable and robust charging experience by preventing any transient conditions, such as receiver load variations and Rx/Tx coupling changes, from disrupting communications and continuous charging. The device adopts a proven foreign object detection (FOD) scheme to detect metal objects and prevent harmful heating. The device also integrates the protection features such as over-temperature and over-current protections, input low-voltage detection and input power limit

4 Pin Configuration and Functions



Top View 28-Pin QFN

Pin		I/O	O/T	Description
Name	No.			
PROG_DA	1	I	-	Data input for flash memory program pin. Make the pin accessible for potential need for firmware update.
PROG_CLK	2	I	-	Clock input for flash memory program pin. Make the pin accessible for potential need for firmware update.
VSS	3	-	-	Digital GND pin.
VDD	4	-	-	Digital power input pin. Connect a decoupling capacitor of 0.1uF to 1uF between VDD and VSS pins.
BUZZER	5	O	Analog	Buzzer output pin to indicate charge status.
EN	6	O	CMOS	Enable output to connect to NU1007 EN input pin through a 1KΩ resistor.
PWM2	7	O	CMOS	PWM output to NU1007. Connect this pin to the PWM2 pin of NU1007. When the MODE pin of NU1007 is set to logic low, this pin is not used.
PWM1	8	O	CMOS	PWM output to NU1007. Connect this pin to the PWM1 pin of NU1007.
LED1	9	I	-	LED1 driver input.
LED2	10	I	-	LED2 driver input.
QC1	11	O	CMOS	Fast charge data1 line output

SEL	12	O	CMOS	Select output pin to select input signal for voltage or current demodulation.
QC2	13	O	CMOS	Fast charge data2 line output
QC3	14	O	CMOS	Fast charge data3 line output
AVDD	15	-	-	Analog power input pin. Connect a decoupling capacitor of 0.1uF to 1uF between AVDD and AVSS pins.
AVSS	16	-	-	Analog GND pin.
PLL	17	I	-	PLL input pin for the internal PLL circuit. Connect this pin to a RC network circuit recommended by **Typical Application Circuit** (Sec. 8).
ISEN	18	I	-	Current signal input pin for FOD and Overcurrent Protection. The ISNS current signal from the NU1007 feeds into this pin as shown in **Typical Application Circuit** (Sec. 8).
VCOIL	20		-	Coil voltage sense pin.
VREF	19	I	-	2.5V reference input pin. Connect this pin to the VREF pin of NU1007.
VSEN	21	I	-	Voltage signal input pin for FOD and Low-Voltage Detection. Connect this pin to the input power source.
NTC	22	I	-	Connect this pin to an external NTC thermistor.
OPA_P	23	I	-	Positive input of the internal operational amplifier used for demodulation circuit.
OPA_N	24	I	-	Negative input of the internal operational amplifier used for demodulation circuit.
OPA_O	25	O	Analog	Output of the internal operational amplifier used for demodulation circuit.
CP	26	I	-	Positive input to the internal comparator. It is typically connected to the OPA_O pin through a low pass filter of 50ns time constant.
CN	27	I	-	Negative input to the internal comparator. It is typically connected to the OPA_O pin through a low pass filter of 1us time constant.
DEMO	28	I	–	Output to the internal comparator. It is the demodulation signal.

5 Specifications

5.1 Absolute Maximum Ratings

	MIN	MAX	UNIT
VDD, AVDD	-0.3	6	V
All Input Pins	-0.3	VDD+0.3	V
Operating Temperature	-40	85	ºC
Storage Temperature	-50	125	ºC

5.2 ESD Ratings

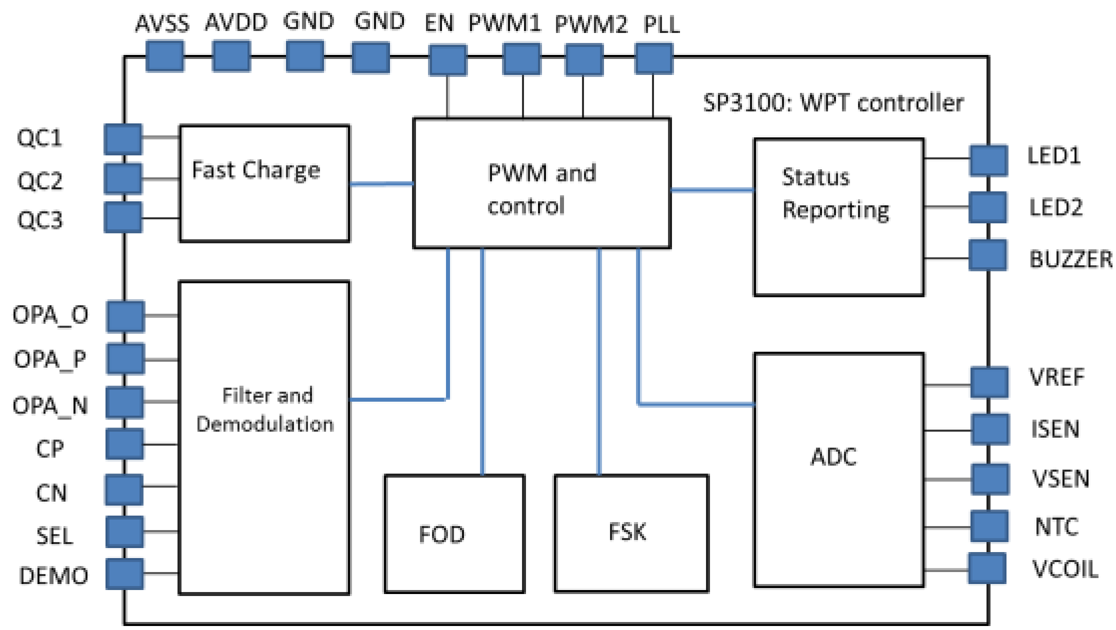
		UNIT
Human Body Model	+/-8000	V
Charged Device Model	+/-2000	V

5.3 Electrical Characteristics

VDD=AVDD=5V, Ta=25ºC(unless otherwise noted)

PARAMETERS		TEST CONDITIONS	MIN	TYP	MAX	UNIT
INPUT						
I_{VDD}	Input operating current	No PWM output		5.0	7.5	mA
I_{SLEEP}	Sleep input current	Controller in sleep mode		2.5	5.0	µA
V_{LVD}	Input low voltage detection			4		V
DRIVERS Output						
I_{LED}	LED1 and LED2 sink current		10	20		mA
I_{BUZZER}	Buzzer source current		40	80		mA
VIN, IIN and NTC INPUTS						
V_{ADI}	ADC input voltage range	V_{REF}=2.5V	0		2.5	V
V_{NTC}	NTC trigger threshold	V_{REF}=2.5V		2		V

6 Block Diagram



7 Application Descriptions

7.1 General Descriptions

The WPC wireless charging system is essentially a flat form of transformer. It transfers power from transmitter to receiver by coupling magnetic field between two coils. The following figure shows the block diagram of a typical WPC 10W transmitter.

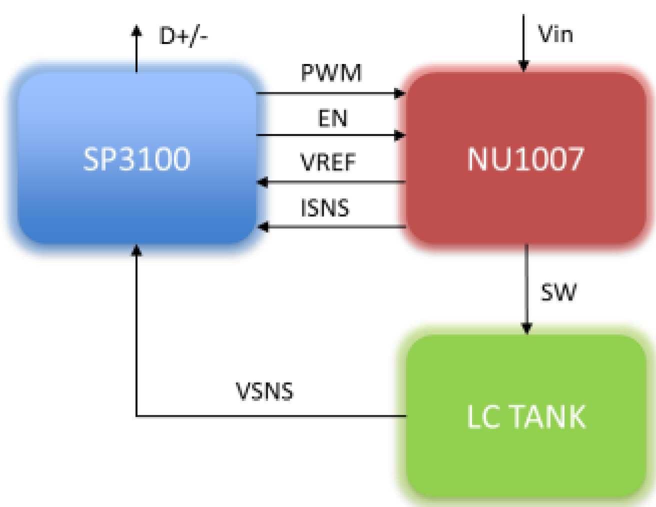


Figure 1 system block diagram

Upon power up, SP3100 communicates and identifies the output power of adaptor using fast charge protocol. If a fast charge adaptor is applied, SP3100 will communicate with the adaptor side to raise the input voltage to 9V, and the maximum wireless transfer power is 10W. In case of non-fast charge adaptor is applied, the transmitter uses 5V input for 5W wireless transfer power.

SP3100 periodically applies analog pings to look for the presence of a receiver. In case of non-existence, SP3100 enters sleep mode by powering down all its logic and NU1007 through the EN signal to minimize the idle power.

If a receiver is detected, SP3100 prolongs the analog ping, monitors communication link and prepares the handshake with the receiver. Once the receiver is identified and authenticated, SP3100 starts to regulate output power by varying PWM frequency according to the power request from the receiver. If the receiver has fast-charger requirement, SP3100 will negotiate with receiver to increase the charging power.

The PWM signal generated by SP3100 is connected to the full-bridge inverter integrated inside NU1007, which converts DC input to AC output and drives the LC tank. The WPC protocol defines a one-way communication link from the receiver to the transmitter. It is an in-band communication link using the same inductive link between the transmitter and receiver and adopting the back-scatter modulation principle. Essentially, the receiver modulates its R or C load which in-turn reflects to the transmitter side in the coupled inductor system. The transmitter receives this communication by measuring coil voltage or current signal.

WPC protocol also define the Power Transmitter communicates to the Power Receiver using Frequency Shift Keying (FSK), in which the Power Transmitter modulates the Operating Frequency of the Power Signal. The Power Transmitter shall switch its Operating Frequency between the Operating Frequency F_{OP} in the unmodulated state and the Operating Frequency F_{MOD} in the modulated state.

NU1007 integrated a low power and high accuracy current sensing circuit. After amplifying, filtering and averaging, ISNS signal from current sensing circuit is connected to ADC channels of SP3100 for current measurement used for FOD. The current signal is also used for communication through the integrated demodulation circuit.

SP3100 includes protection functions to prevent system from damaging under abnormal situations, such as over-current/temperature and low input voltage.

Two LED and one Buzzer pins are included in SP3100 as system status indicator to improve the user experience.

7.2 Low Voltage Detection and Limited Power

After establishing the power transfer contract, SP3100 keeps monitoring the input voltage of the transmitter. If it drops below 4.5V, SP3100 will limit the output power and stop decreasing the PWM frequency even if a positive Control Error packet is received. If the input voltage reaches Input-Low-Voltage-Detect Threshold (V_{LVD}) of typical 4V to maintain the power transfer, SP3100 will stop power transfer until the input voltage recovers above V_{LVD} .

7.3 Overcurrent and Over-Temperature Protections

If an over-current or over-temperature situation is detected, SP3100 will stop power transfer to ensure safety. The current signal is measured at the ISEN pin voltage. When the effective current rises above 2.5A repeatedly, the over-current protection is triggered and PWM outputs are disabled. Removing and replacing the receiver can reset this fault condition. The over-temperature condition is detected at the NTC pin. When the temperature exceeds 65°C, the over-temperature protection is enabled, and the PWM outputs are disabled. The temperature drops below 40°C, the fault condition is cleared and the system will restart.

7.4 Demodulations

SP3100 has an integrated high-performance demodulation circuit. With the help of external RC filters, the envelope of the AC voltage over the transmitter coil or the ISNS signal output from NU1007 can be detected and decoded. In the **Typical Application Circuit** (Sec. 8), an external multiplexer is controlled by the SEL pin, and used to select the voltage and current signal fed into the internal demodulation circuit. The external resistors and capacitors connected to pin 23 to pin 27 are optimized for reliable demodulation using the integrated amplifiers and comparators. Use the recommended design and component values shown in the **Typical Application Circuit** (Sec. 8).

7.5 FSK modulations

SP3100 has an integrated high-performance Frequency-Shift-Keying modulation circuit. It modulates the PWM frequency, and uses a differential bi-phase encoding scheme to modulate data bits.

In the modulated state, the PWM frequency switches between operating frequency in the unmodulated state and the modulation frequency. The difference between these two frequencies is characterized by Polarity and Depth.
Polarity: It determines whether the difference between F_{MOD} and F_{OP} is positive or negative. The Power Receiver encodes the positive polarity as a ZERO and the negative polarity as a ONE.
Depth: It determines the magnitude of the difference between F_{OP} and F_{MOD}.

7.6 Fast charge

SP3100 supports and integrates fast charge protocol. It controls the FETs Q1 ,Q2 and Q3, to communicate with adaptor through the USB D+/D- interface. Use the recommended design and component values shown in the In the **Typical Application Circuit** (Sec. 8).

7.7 Foreign Object Detection

SP3100 implements a low cost, reliable FOD algorithm to assure foreign objects detection. It calculates the power losses between transmitted power and received power reported by the receiver. The FOD parameters need to be calibrated if the coil used is different from the standard A11 coils. Consult the factory if a non-standard transmitter coil is used.

7.8 Buzzer and LED Operation

There are two LED pins on SP3100 which are used as system status indicators, such as idle, charging, and error. The following table lists the LED functions used in the reference design**.**

LED #	LED Operational States					
	Idle	**Charging**	**Charging Complete**	**Error**	**FOD**	**Power Limit**
LED1(Green)	Off	Blink Slow	Solid On	Off	Off	Blink Slow
LED2(Red)	Off	Off	Off	Blink Three Times	Blink Slow	Blink Slow

The BUZZER Pin on SP3100 is designed to connect to an external AC Buzzer for audible notifications. Once SP3100 decides to start power transfer, a tone is generated through this pin at 2.5kHz frequency.

7.9 Layout Guidelines

Careful PCB layout is critical to system operation. Many references are available on proper PCB layout techniques.

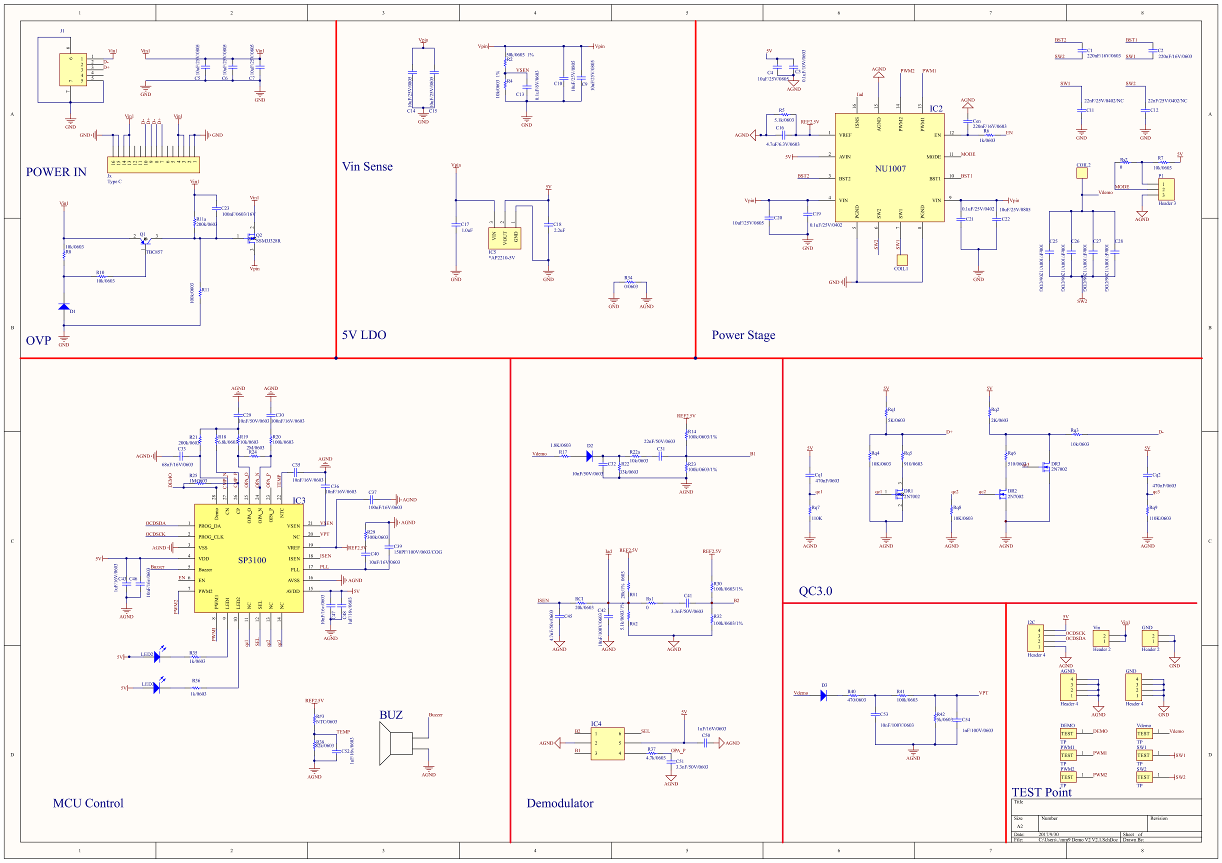
The SP3100 and NU1007 design requires a 4-layer PCB layout for adequate ground plane. A 2-layer PCB can also be achieved at the cost of larger PCB size.

- Layer 1: Component placement and major routing. Use as much ground plane as possible
- Layer 2: Minor routing, a clean power-ground plane below NU1007 and power trace; a clean analog-ground plane below SP3100 and signal trace
- Layer 3: Minor routing, power trace routing, and signal-trace routing. Use as much ground plane as possible
- Layer 4: Minor routing, a clean power-ground plane below NU1007 and power trace; a clean analog ground plane below SP3100 and signal trace

Additionally, here are the guidelines to follow.

- Make routing loop as small as possible, especially the power loop, to minimize EMI noises.
- Place power and signal traces on Middle layer 3 to avoid noise coupling.
- Widen the copper between SW1, SW2 and LC tank, because ~~the~~ high current in the LC tank can cause power losses on the traces and hence low efficiency. Moreover, the Vin routing should be as wide as possible.
- Separate the analog-ground plane from the power-ground plane, and use only one point to join them. Please refer to the R34 of Figure 2.
- The full-bridge power stage is integrated in NU1007, so thermal vias are needed to provide a thermal path for the NU1007.
- Place small-size ~~of~~ input capacitors as close as possible between the Vin pin and PGND pin. These capacitors can effectively filter out high-frequency noises due to their low ESR and ESL. Please refer to C19 and C21 in Figure 2.
- Keep analog-ground plane and power-ground plane low impedance. Use as much copper as possible and an appropriate number of vias.

8 Typical Application Circuit



9 Layout Examples

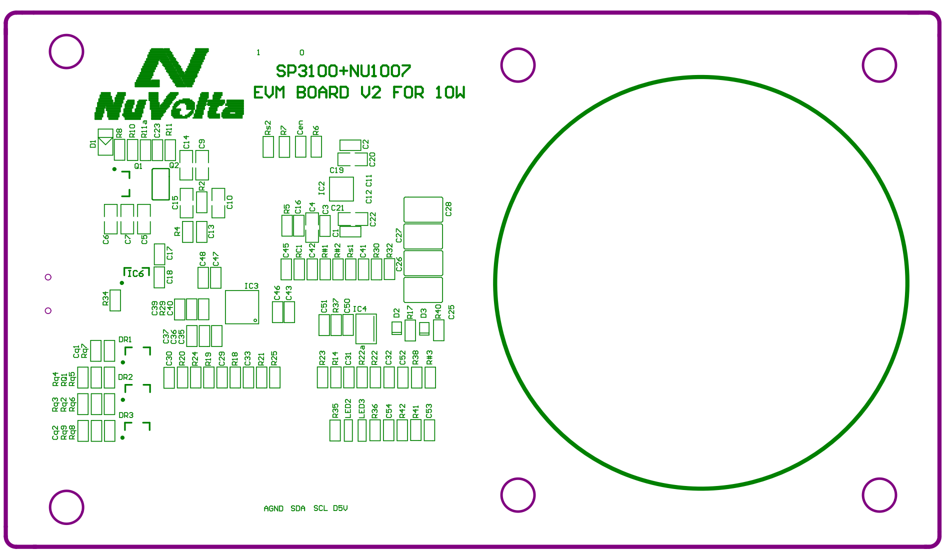


Figure 2. Top Overlay

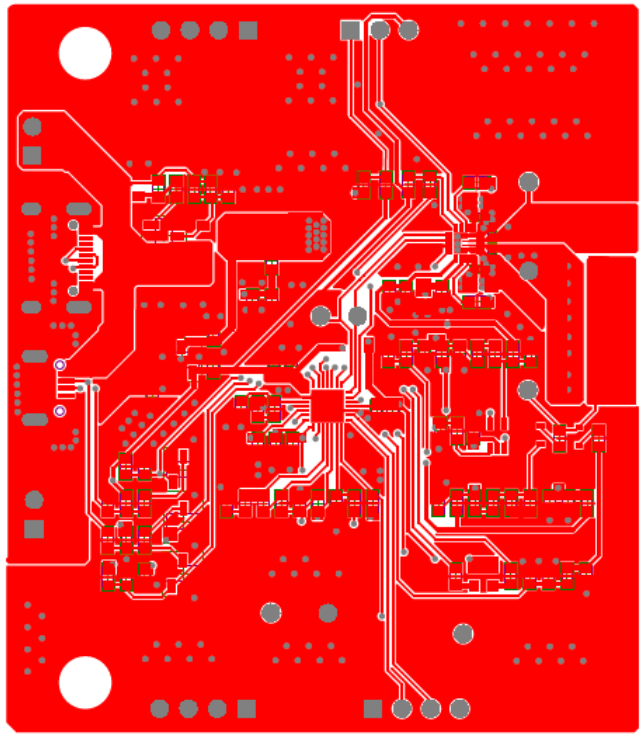


Figure 3. Top Layouts

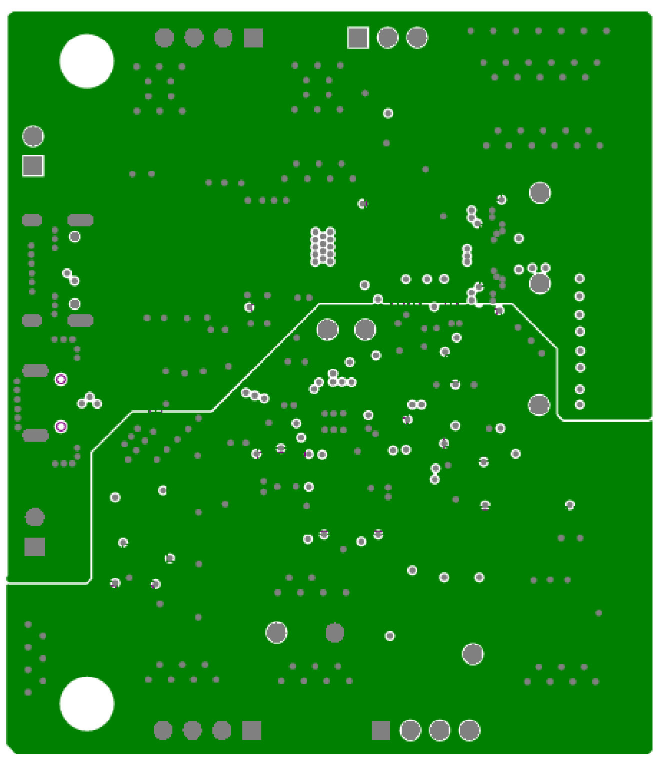


Figure 4. Middle Layer2

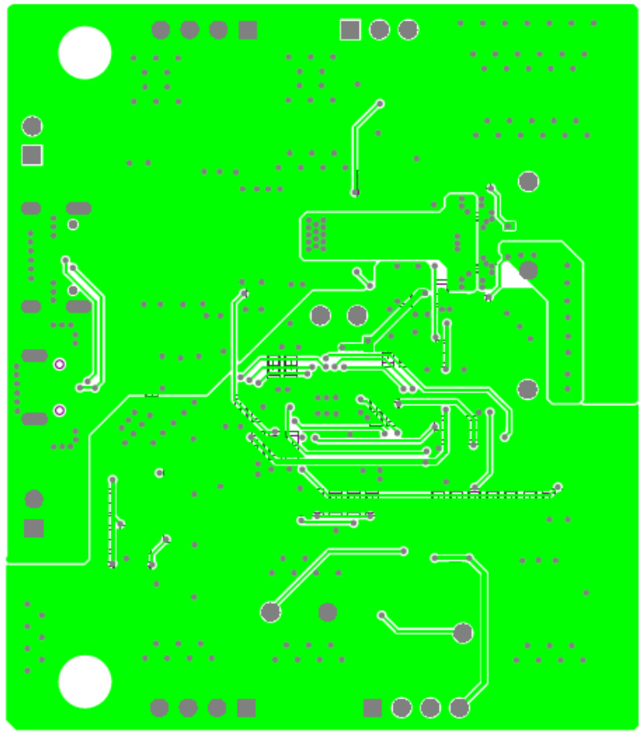


Figure 5. Middle Layer3

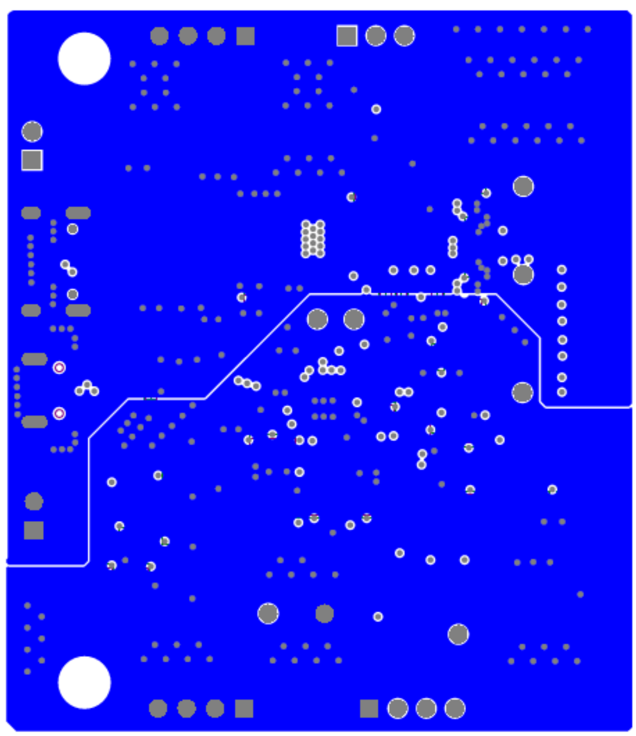
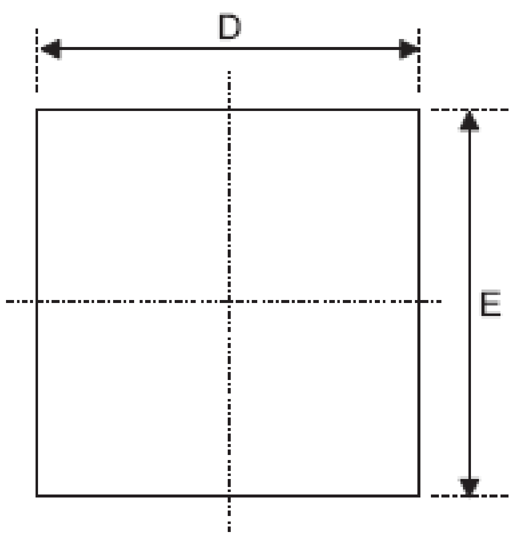


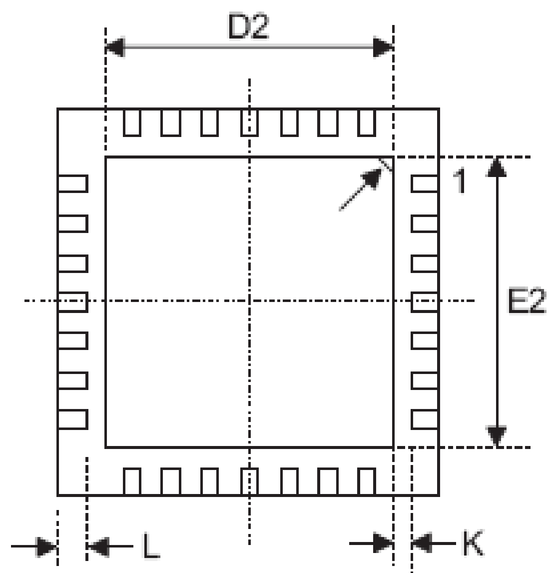
Figure 6. Bottom Layer

10 Package Information

Orderable Device	Status	Package Type	Package Drawing	Pins	Package Quantity	Eco Plan	Lead Finish	MSL Peak Temp	Op Temp ©	Device Marking
SP3100QDEB	ACTIVE	QFN	QDE	28	3000	Green (RoHS & no Sb/Br)	Pure Tin	Level-2	-40 to 85	SP310001QDE SP310002QDE

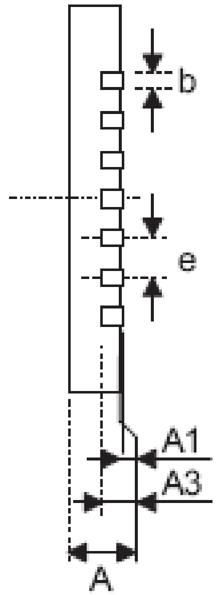
11 Mechanical Data





Top view

Bottom view



Side view

Symbol	Dimensions In Millimeters	
	Min	Max
A	0.700	0.800
A1	0.000	0.050
A3	0.203 BSC	
b	0.150	0.250
D	4.000 BSC	
E	4.000 BSC	
D2	2.550	2.650
E2	2.550	2.650
e	0.400 BSC	
L	0.300	0.500
k		

12 Revision Histories

Revision No.	Date	Changes
V0.7	5/18/17	First Draft
V0.71	6/01/17	Update the diagram
V0.72	6/07/17	polishing and correcting English writing
V1.0	9/10/17	Update PCB layout