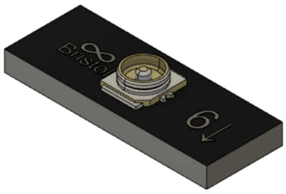
GHz BANDWIDTH AC CURRENT SENSOR

Features and Benefits

- > 1 GHz Bandwidth
- Ultra-low insertion inductance of less than 0.2 nH
- Negligible conductor resistance gives low power loss
- High isolation voltage, suitable for line-powered applications
- Overall low insertion impedance results in minimal effect on circuit performance – measure switching events without changing circuit behaviour
- Small footprint 8 mm × 3.5 mm package

Package: 2-pin leadless surface mount with MHF 4 output connector



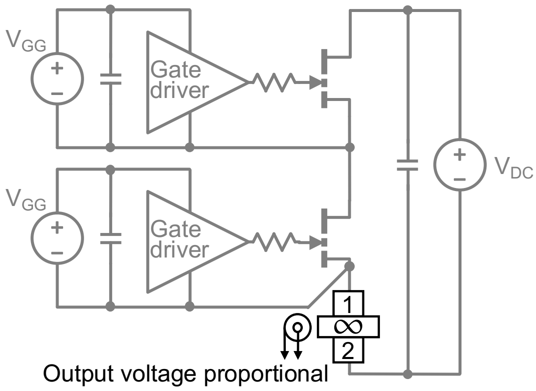
Description

The Infinity Sensor is ideal for sensing current in fast switch-mode applications such as SiC or GaN-based power electronics. When mounted in accordance with the provided guidelines, its insertion inductance is less than 200 pH, meaning that it can be added to the critical loop of a power electronic switching cell without altering circuit behaviour.

The Infinity Sensor consists of an isolated sense coil located close to an integrated copper conductor. The sense coil output voltage is directly proportional to *di/dt* in the integrated current-carrying conductor. The output is provided via a 50 ohm coaxial connection (using an MHF 4 connector). Short MHF 4 to SMA tails are provided with each sensor to facilitate connection to a measurement circuit or oscilloscope.

A current measurement can be derived from the provided output voltage by mathematical integration.

Typical Application

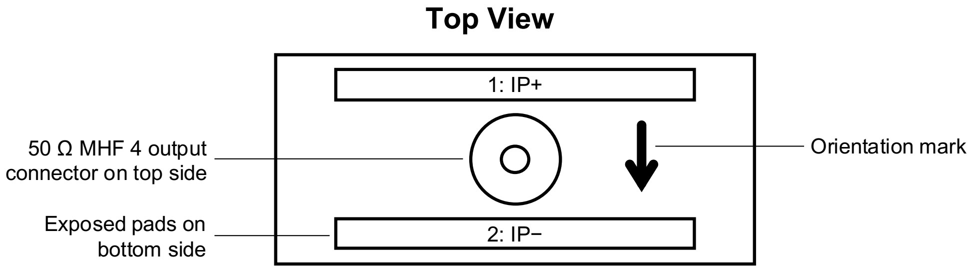


Absolute Maximum Ratings

Characteristic	Notes	Max	Unit
Isolation voltage with unprotected output connector	Limited by creepage distance to connector; according to IEC 60664 with pollution degree 2	250	V
Isolation voltage with silicone-insulated output connector	Limited by breakdown voltage of package from conductor to sense coil	2	kV
Case temperature	Limited by solder connection of output connector	180	°C
di/dt of measured current(1)	Limited by voltage rating of output connector	600	A/ns
Continuous current rating	Maximum allowable RMS current for 100 °C temperature rise	20	A

(1) If connecting to an oscilloscope, note that most 50 Ω inputs are limited to 5 V maximum, which would imply a maximum recommended *di/dt* of 50 A/ns.

Pin Configuration and Functions



Pin no.	Name	Function
1	IP+	Sensed current copper conduction path pins
2	IP−	
-	Output	Provides output voltage proportional to *di/dt* of current flowing from IP+ to IP−

Performance Characteristics

Parameter	Min.	Typ.	Max.	Units
Sensitivity(1)	0.08	0.1	0.12	V/(A/ns)
Low frequency −3dB cut-off			1	MHz
High frequency −3dB cut-off	1			GHz
Insertion inductance			200	pH

(1) When mounted according to the guidelines shown in Figure 2

Application Guidelines

Recommended sense locations

As the sensor is sensitive to *dv/dt*, it should not be placed at circuit nodes that experience high-speed voltage transitions. For example, the recommended sense locations in a standard half-bridge switching cell are illustrated in Figure 1.

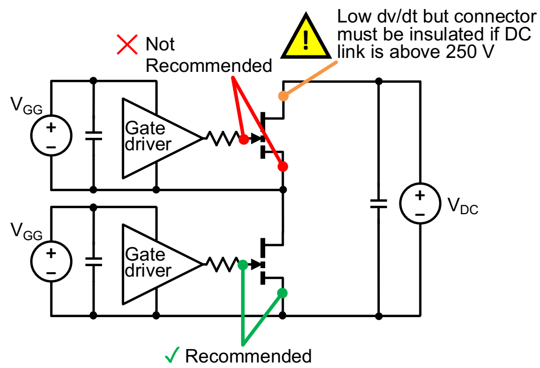
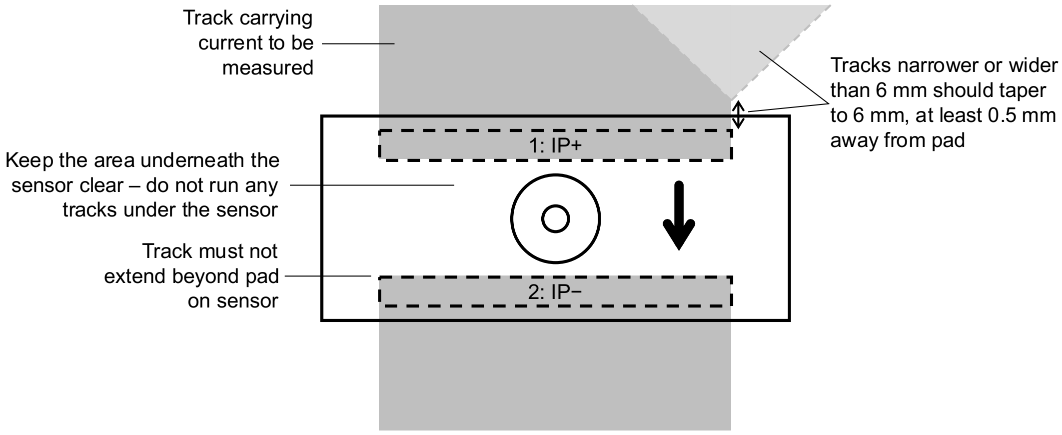


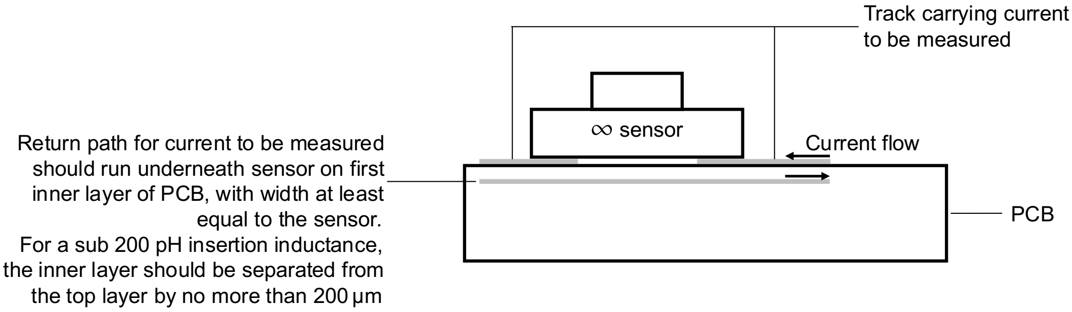
Figure 1: Recommended sense locations when using Infinity Sensor in a switch-mode half-bridge circuit

Circuit layout

In order to achieve the specified performance characteristics, including the insertion inductance of under 200 pH, and to keep potentially interfering currents away from the sensor, it is important to follow the circuit board layout guidelines as shown in Figure 2.



(a)



(b)

Figure 2: Circuit board layout guidelines – (a) top view, (b) side view

Connecting to MHF 4 output connector

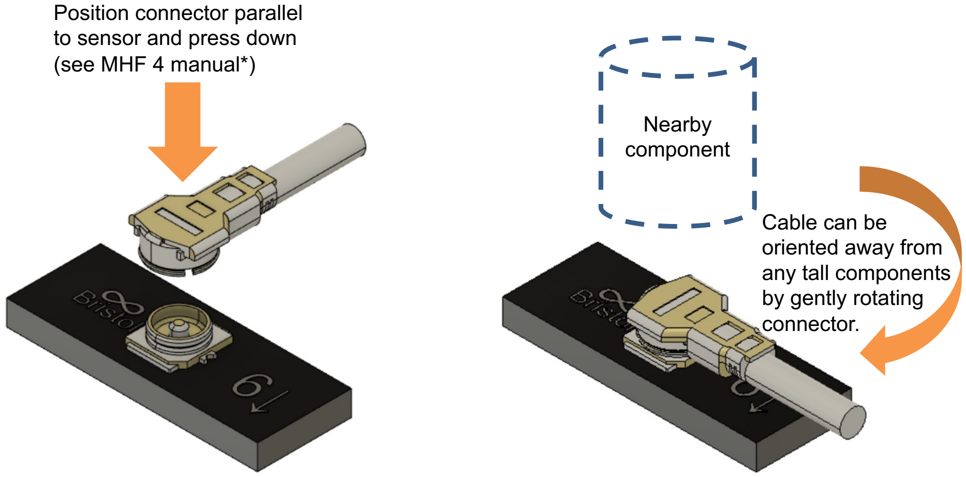


Figure 3: Connecting to MHF4 output socket

A connector attach and detach tool is available, part no. I-PEX 90435-001. More information is available in the manual*.

When using this tool for disconnections, the manual suggests to pull straight up, but this exerts excessive force on the connector and risks compromising the solder connection. Gentle side to side movement will loosen the connection whilst exerting significantly less force on the connector. Using this method, the connector survived in excess of forty mating cycles, but it should be noted that the spring contact of the female connector in the MHF-4 to SMA lead becomes significantly weaker after approximately five mating cycles.

* https://www.i-pex.com/sites/default/files/downloads/pdf/MANUAL_MHF_4_HIM-10003-08EN.pdf

Insulating for high voltage (> 250 V)

Due to the creepage distance from the underside of the sensor to the exposed metal of the top-side connector, if the sensor is connected to a circuit node that can exceed 250 V relative to the output reference ground, the connector must be covered with silicone sealant, after the sensor has been soldered in place. This increases the voltage insulation rating to 2 kV. Suitable silicone sealant is provided with the Infinity Sensor samples.

Before applying the sealant, ensure that the MHF 4 to SMA connector tail is correctly mated to the connector, and has been oriented as desired. Then, apply the sealant such that all exposed metal parts are covered by a layer at least 1 mm thick, and allow 1 – 2 hours for the sealant to cure.

Post-processing output signal to obtain a current measurement

For maximum fidelity, the sensitivity and offset of the channel measuring the Infinity Sensor output should be set such that the peaks of the output signal fill the range. It may be necessary to use the scope's "fine" sensitivity adjustment mode to achieve this.

The mathematical process to derive the current from the measured *di/dt* signal is very simple. Most high-bandwidth oscilloscopes offer sufficiently powerful maths functions that the procedure can be performed on-scope. The procedure is as follows:

1. Ensure that the scope trigger and time offset are configured such that the output signal from the sensor is zero at the start time of the signal trace.
2. Zoom-in on a portion of the measured signal where no current switching event is taking place.
3. Take the average of the signal over the zoomed-in period. This is the DC offset.
4. Activate a maths channel on the oscilloscope and enter the function:
   `10e9*integral(CH_sense - DC offset)`,
   where CH_{sense} is the reference for the channel that is being used to capture the sensor's output voltage.
   Note that the multiplier is ten billion, not one billion.

Please note that, as the Infinity Sensor is only sensitive to *di/dt* and does not respond to low-frequency currents, it is only suitable for observing short current transients, up to 1 microsecond in length. For the integral function to give a sensible output, the total timespan of the scope's timebase should not exceed 1 microsecond.

Mechanical Data

Dimensions

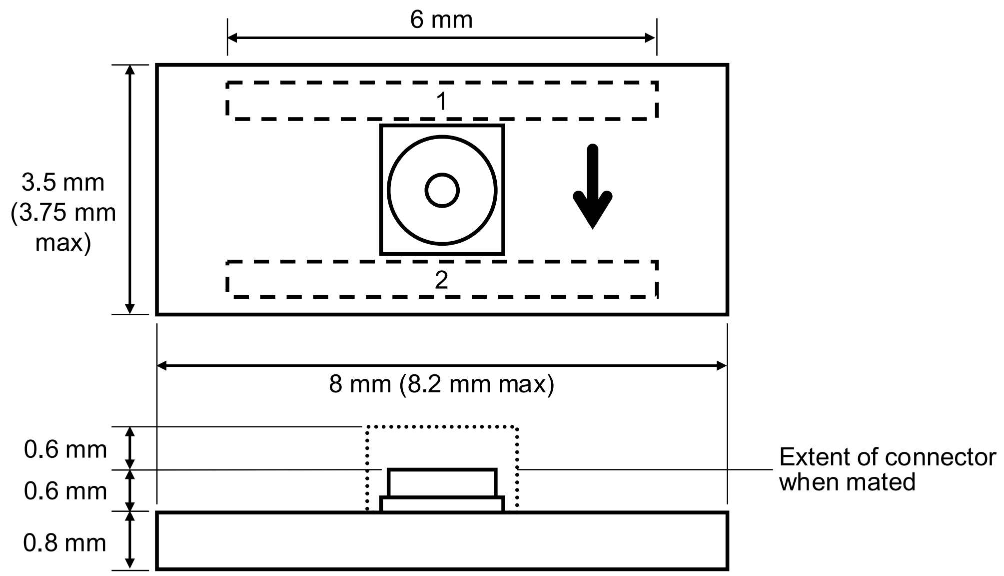


Figure 4: Dimensions of Infinity Sensor V2

Mounting and soldering

Recommended land pattern

The pads for the Infinity Sensor PCB footprint should be solder-mask defined, meaning that the opening in the solder resist layer should be smaller than the pad copper area, such that the solder resist overlaps the copper. This helps to ensure the sensor seats correctly during solder reflow. The recommended land pattern is shown in Figure 5, where the dotted lines represent the perimeter of the solder resist openings.

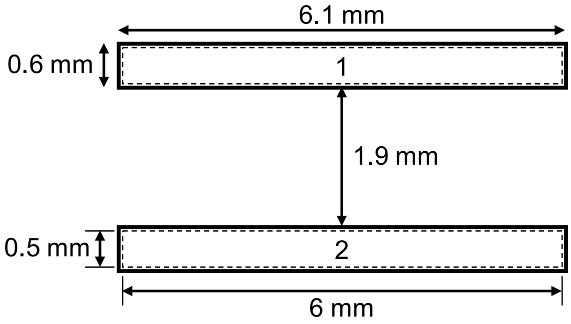
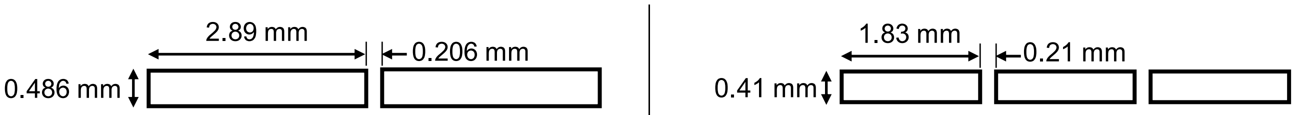


Figure 5: Recommended land pattern for mounting of Infinity Sensor V2

Solder paste stencil design

The recommended stencil design depends on the thickness of stencil used. Figure 6 shows stencil designs for stencils with 120 µm or 150 µm thickness.



(a) 120 µm stencil thickness *(b) 150 µm stencil thickness*

Figure 6: Recommended stencil design for each pad of the Infinity Sensor

PCB footprint and stencil design files

The PCB footprint, including a 3D sensor model, solder-mask openings, and solder-paste stencil designs according to the guidelines in this datasheet, is available in Altium format from the website at infinitysensor.com.

Solder reflow procedure

The connector on the top side of the sensor is attached using conventional lead-free solder with a 217 °C melting point. If you wish to be able to solder and rework the sensor manually, without disturbing the top-side connector, you can use a low melting-point solder to attach the sensor to your PCB. For example, tin-bismuth-silver $Sn_{42}Bi_{57.6}Ag_{0.4}$ solder has a melting point of 138 °C and can be reflowed using the temperature profile provided in Figure 7.

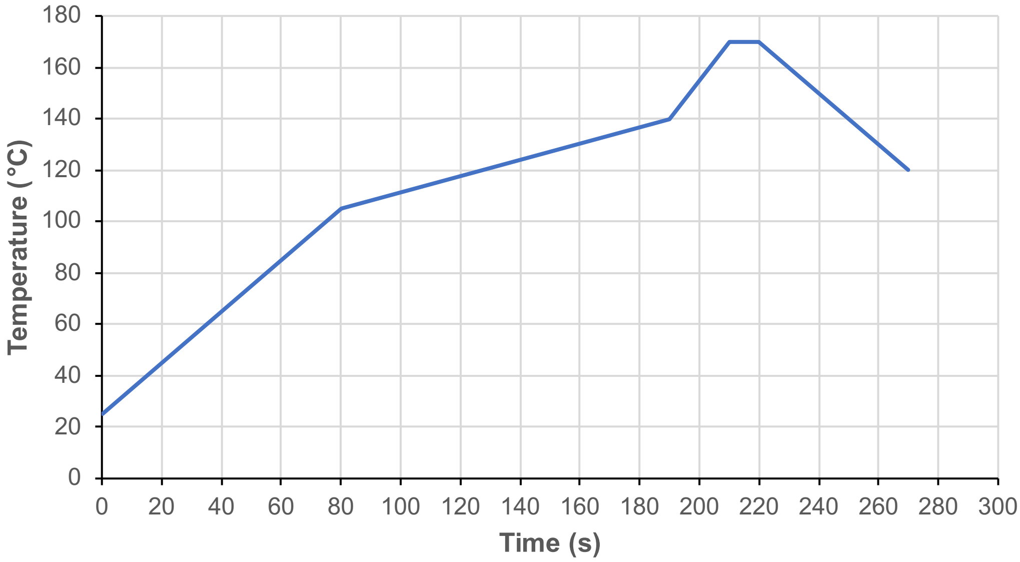


Figure 7: Solder reflow profile for low-temperature Sn42Bi57.6Ag0.4 solder

Further reading

More information regarding the Infinity Sensor can be found in our published papers listed below. If you use the sensors in published research, please cite these papers.

[1] Jianjing Wang, Mohammad H. Hedayati, Dawei Liu, Salah-Eddine Adami, Harry C. P. Dymond, Jeremy J. O. Dalton, and Bernard H. Stark: "Infinity Sensor: Temperature Sensing in GaN Power Devices using Peak *di/dt*", *2018 IEEE Energy Conversion Congress and Exposition (ECCE)*, 2018, pp. 884-890, doi: 10.1109/ECCE.2018.8558287

[2] Harry C. P. Dymond, Yushi Wang, Saeed Jahdi, and Bernard H. Stark, "Probing Techniques for GaN Power Electronics: How to Obtain 400+ MHz Voltage and Current Measurement Bandwidths without Compromising PCB Layout", *PCIM Europe 2022; International Exhibition and Conference for Power Electronics, Intelligent Motion, Renewable Energy and Energy Management*, Nuremberg, Germany, May 10-12, 2022, pp. 1-10. doi: 10.30420/565822010