TGP2109

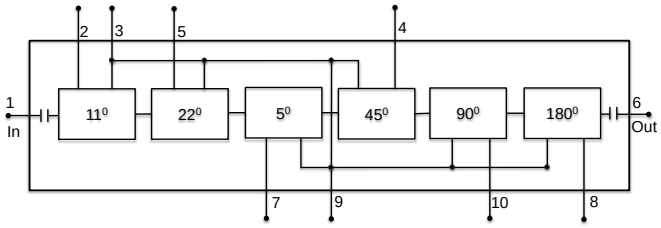
8-12 GHz 6-Bit Digital Phase Shifter

Product Description

The Qorvo TGP2109 is a 6-bit digital phase shifter fabricated on Qorvo's high performance 0.15µm GaAs pHEMT process. It operates over 8 to 12 GHz and provides 360° of phase coverage with a LSB of 5.625°. It also achieves a low RMS phase error of 4° with 6 dB of insertion loss.

The TGP2109 was developed for simply system integration. It uses positive only switch logic; eliminating the need for a negative voltage rail. In addition, both ports are matched to 50 ohms with DC blocking capacitors. Ease of use along with low insertion loss and a high degree of resolution makes the TGP2109 ideally suited for a variety of x-band phased array applications including commercial and military radars and phase array communication systems.

Block Diagram



Product Features

- Frequency Range: 8 to 12 GHz
- 6-Bit Digital Phase Shifter
- Bi-Directional
- 360° Coverage, LSB = 5.625°
- RMS Phase Error: 4°
- RMS Amplitude Error: 0.5 dB
- Insertion Loss: 6 dB
- Return Loss: 10 dB IRL; 15 dB ORL
- Input P1dB: 29 dBm
- Input IP3: >40 dBm
- IM3: <-50 dBc
- Control Voltage: 0/5 V
- Chip Dimensions: 2.2 x 2.2 x 0.1 mm

Performance is typical across frequency. Please reference electrical specification table and data plots for more details

Applications

- X-Band Radar
- Satellite Communication Systems

Ordering Information

Part No.	Description
TGP2109	8-12 GHz X-Band 6 Bit Digital Phase Shifter
TGP2109 EVB	TGP2109 Evaluation Board

Absolute Maximum Ratings

Parameter	Value
Control and Reference Voltage	6 V
Control Current	0.5 mA
Power Dissipation	1.5 W
Input Power, CW, 50 Ω, 85°C	33 dBm
Channel Temperature	200 °C
Mounting Temperature (30 Seconds)	320 °C
Storage Temperature	-55 to 150 °C

Operation of this device outside the parameter ranges given above may cause permanent damage. These are stress ratings only, and functional operation of the device at these conditions is not implied. Extended application of Absolute Maximum Rating conditions may reduce device reliability.

Recommended Operating Conditions

Parameter	Value
Control Voltage	0/+5 V
Reference Voltage (V_{REF})	+5 V
Current (I_{REF}, I_{CTRL})	< 50 µA

Electrical specifications are measured at specified test conditions. Specifications are not guaranteed overall operating conditions.

Electrical Specifications

Test conditions unless otherwise noted: 25°C. Control Voltage (REF, 5^0, 11^0, 22^0, 45^0, 90^0, 180^0) = 0/+5 V; see Bias Truth Table.

Parameter	Min	Typical	Max	Units
Operational Frequency Range	8		12	GHz
Insertion Loss		6		dB
Input Return Loss		10		dB
Output Return Loss		15		dB
RMS Phase Error		4		deg
RMS Amplitude Error		0.5		dB
Input P1dB		29		dBm
Input IP3 (Tone Spacing = 10 MHz, Pin/Tone = 16 dBm)		> 40		dBm
IM3 (Tone Spacing = 10 MHz, Pin/Tone = 16 dBm)		< -50		dBc
Insertion Loss Temperature Coefficient		0.004		dB/°C

Bias Truth Table

Logic “0” = 0 V, Logic “1” = V_{REF} = +5 V

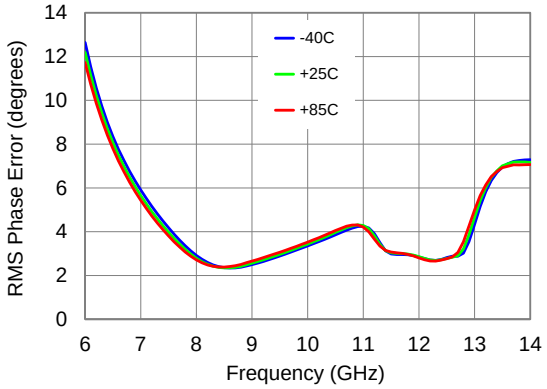
Phase Shifter	B1	B2	B3	B4	B5	B6	VREF
0° (Reference)	0	0	1	1	1	1	1
5°	1	0	1	1	1	1	1
11°	0	1	1	1	1	1	1
22°	0	0	0	1	1	1	1
45°	0	0	1	0	1	1	1
90°	0	0	1	1	0	1	1
180°	0	0	1	1	1	0	1
355°	1	1	0	0	0	0	1

Performance Plots – Small Signal

Test conditions unless otherwise noted: 25 °C; 5V and 3V

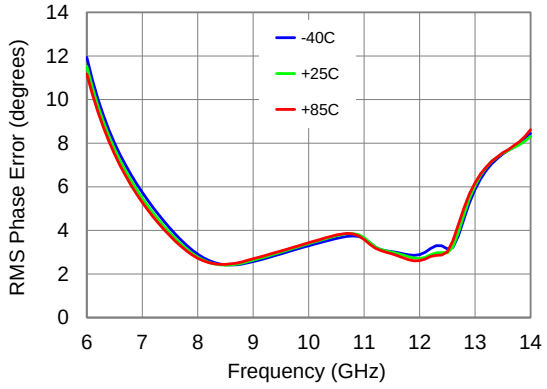
RMS Phase Error vs. Freq. vs. Temp

V_{REF} = 5 V, All Phase States



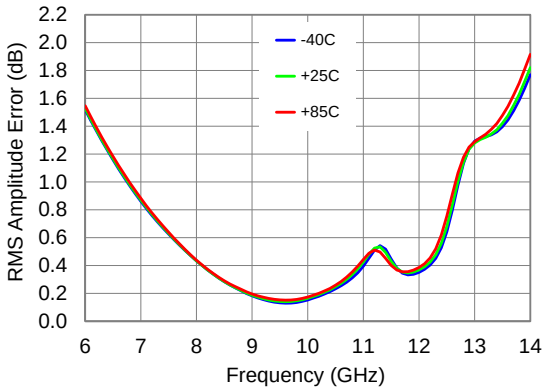
RMS Phase Error vs. Freq. vs. Temp

V_{REF} = 3 V, All Phase States



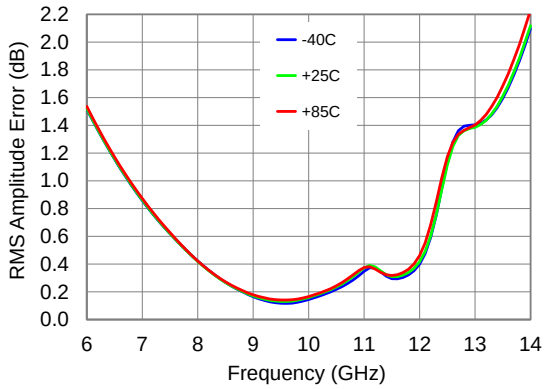
RMS Amplitude Error vs. Freq vs. Temp.

V_{REF} = 5 V, All Phase States



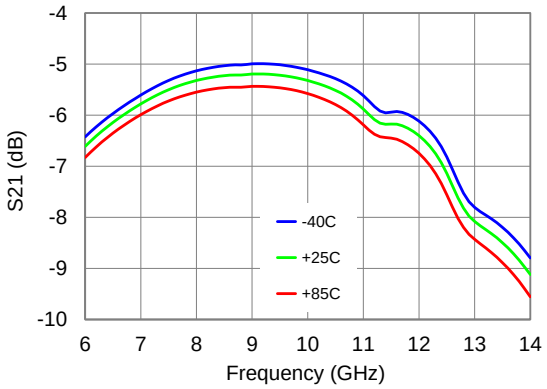
RMS Amplitude Error vs. Freq vs. Temp.

V_{REF} = 3 V, All Phase States



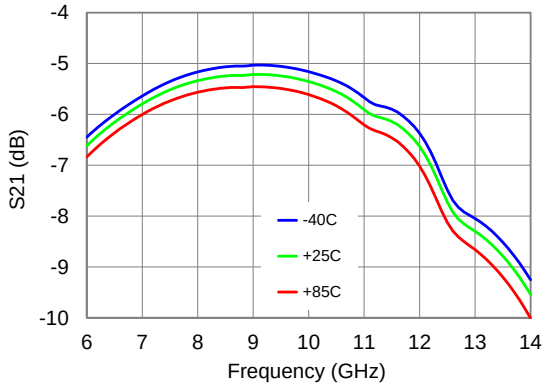
Avg. Insertion Loss vs. Freq. vs. Temp.

V_{REF} = 5 V, All Phase States



Avg. Insertion Loss vs. Freq. vs. Temp.

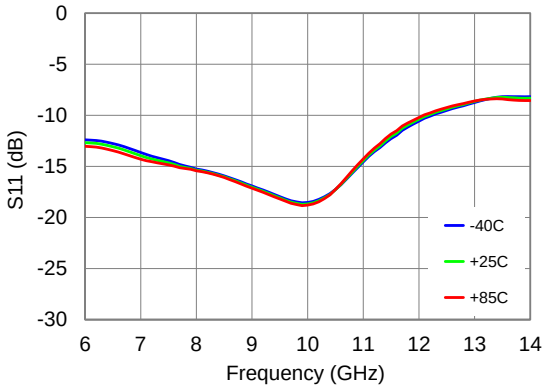
V_{REF} = 3 V, All Phase States



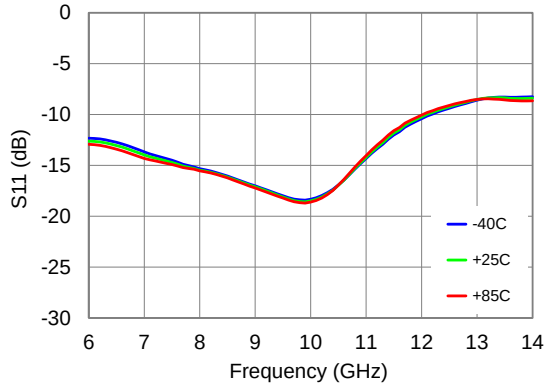
Performance Plots – Small Signal (Cont.)

Test conditions unless otherwise noted: 25 °C; 5V and 3V

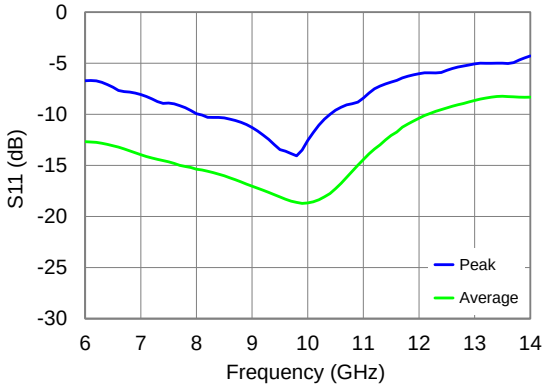
Avg. IRL vs. Freq. vs.Temp.
V_{REF} = 5 V, All Phase States



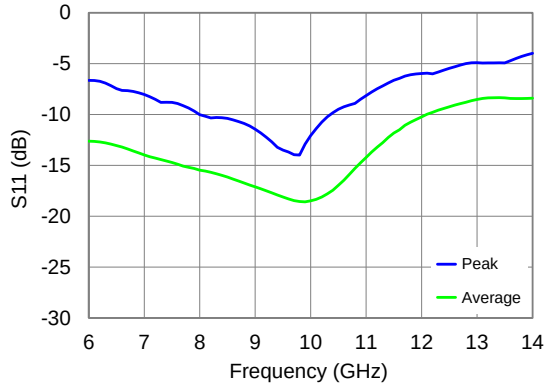
Avg. IRL vs. Freq. vs.Temp.
V_{REF} = 3 V, All Phase States



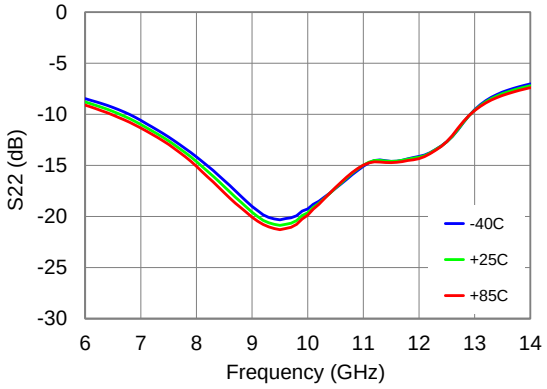
IRL vs. Freq.
V_{REF} = 5 V, All Phase States, 25 °C



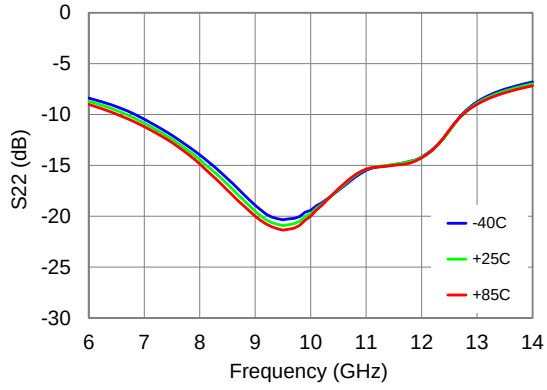
IRL vs. Freq.
V_{REF} = 3 V, All Phase States, 25 °C



Avg. ORL vs. Freq. vs. Temp
V_{REF} = 5 V, All Phase States

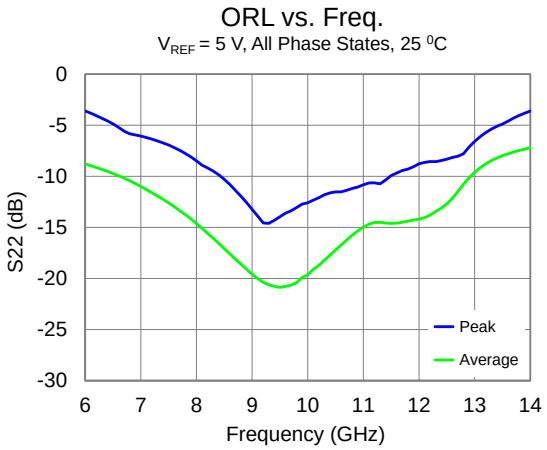


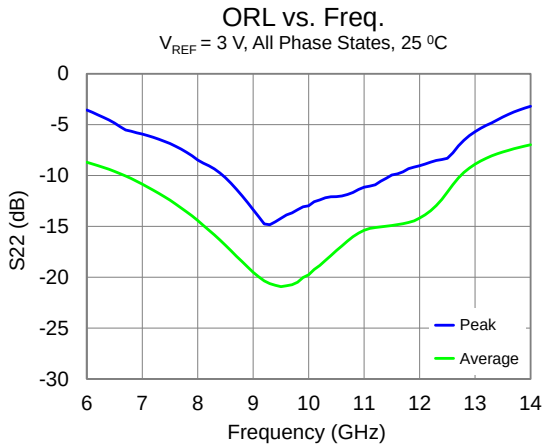
Avg. ORL vs. Freq. vs. Temp
V_{REF} = 3 V, All Phase States



Performance Plots – Small Signal (Cont.)

Test conditions unless otherwise noted: 25 °C; 5V and 3V, 25

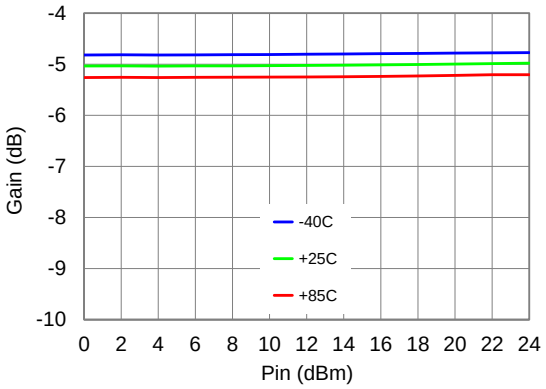




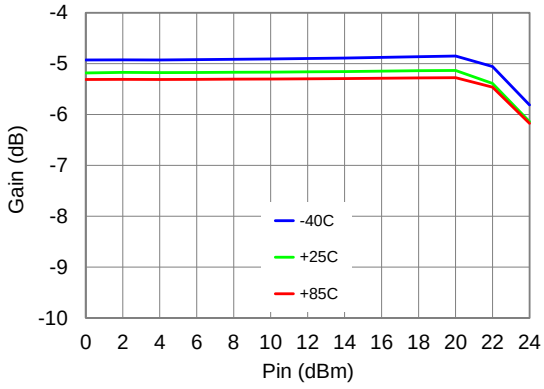
Performance Plots – Large Signal

Test conditions unless otherwise noted: 25 °C; 5V and 3V

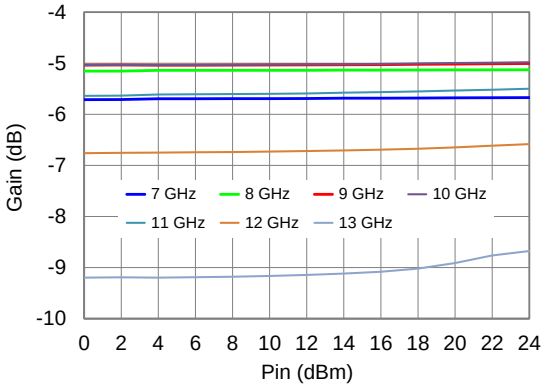
Gain vs. Pin vs. Temperature
V_{REF} = 5 V, Freq. = 10 GHz, Phase State = 0 deg



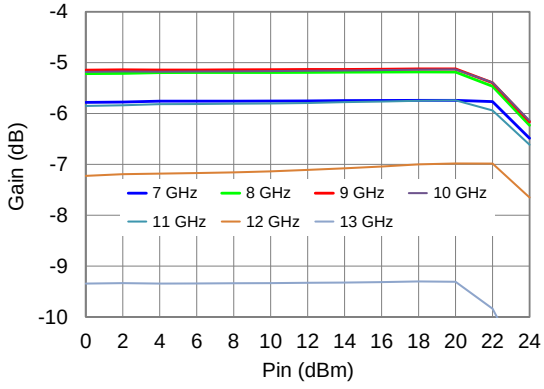
Gain vs. Pin vs. Temperature
V_{REF} = 3 V, Freq. = 10 GHz, Phase State = 0 deg



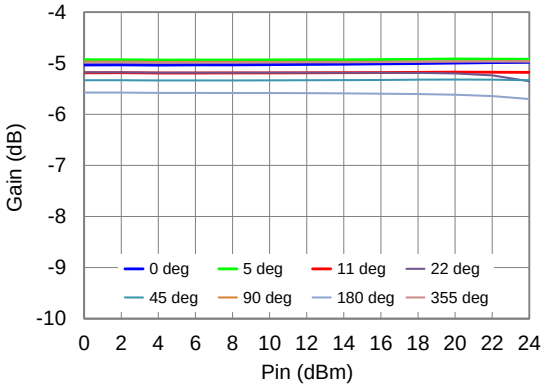
Gain vs. Pin vs. Frequency
V_{REF} = 5 V, 25 °C, Phase State = 0 deg



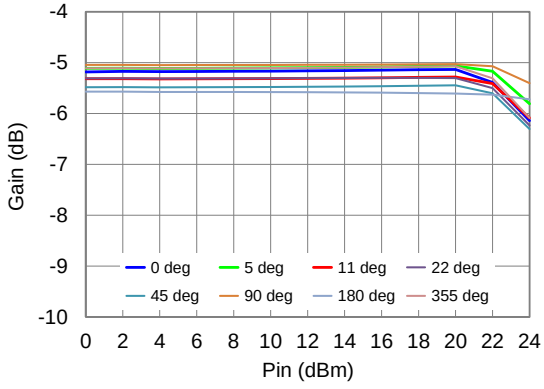
Gain vs. Pin vs. Frequency
V_{REF} = 3 V, 25 °C, Phase State = 0 deg



Gain vs. Pin vs. Major Phase States
V_{REF} = 5 V, Freq. = 10 GHz, 25 °C



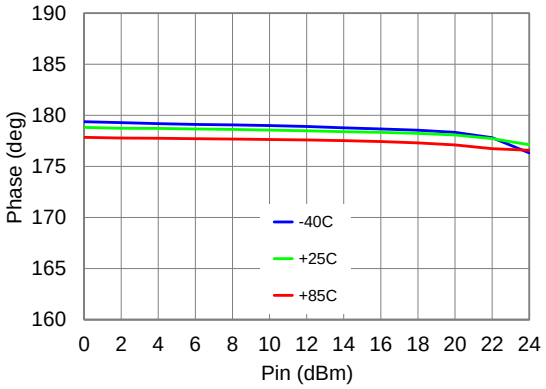
Gain vs. Pin vs. Major Phase States
V_{REF} = 3 V, Freq. = 10 GHz, 25 °C



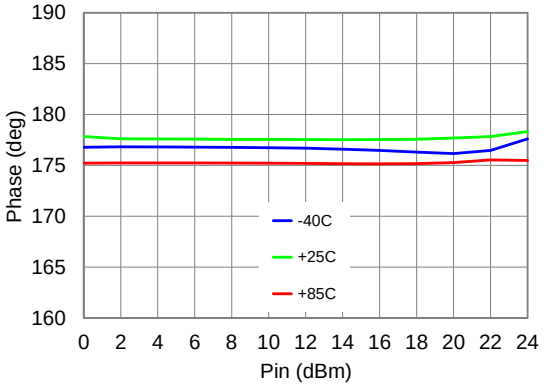
Performance Plots – Large Signal (Cont.)

Test conditions unless otherwise noted: 25 °C; 5V and 3V

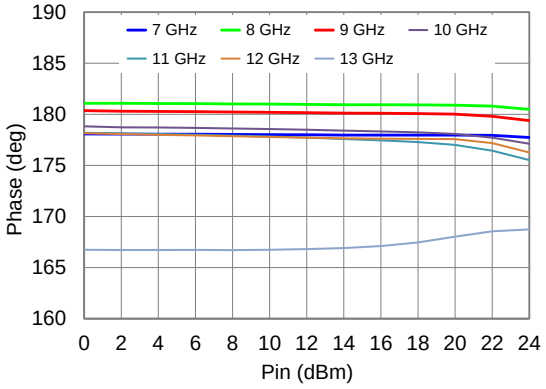
Phase vs. Pin vs. Temperature
V_{REF} = 5 V, Freq. = 10 GHz, Phase State = 0 deg



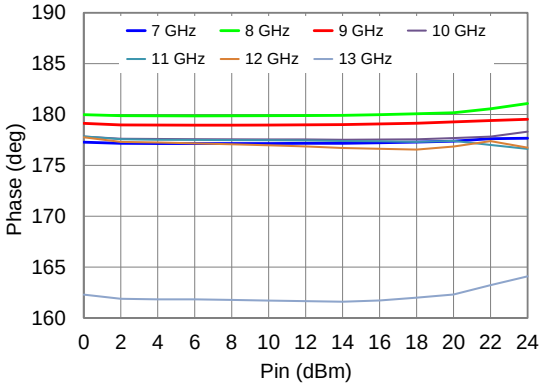
Phase vs. Pin vs. Temperature
V_{REF} = 3 V, Freq. = 10 GHz, Phase State = 0 deg



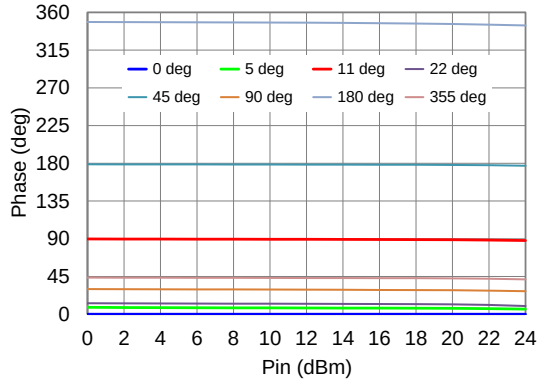
Phase vs. Pin vs. Frequency
V_{REF} = 5 V, 25 °C, Phase State = 0 deg



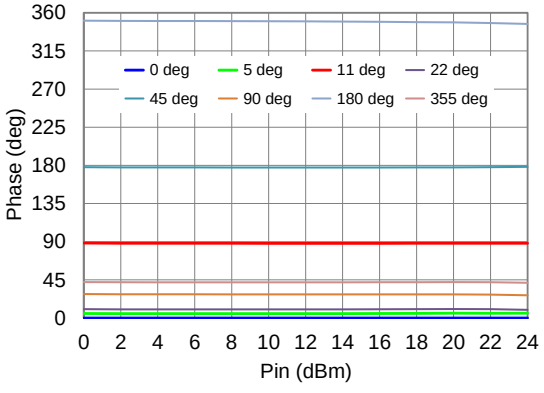
Phase vs. Pin vs. Frequency
V_{REF} = 3 V, 25 °C, Phase State = 0 deg



Phase vs. Pin vs. Major Phase States
V_{REF} = 5 V, Freq. = 10 GHz, 25 °C



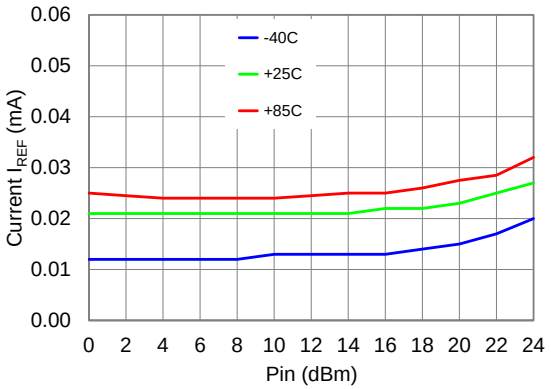
Phase vs. Pin vs. Major Phase States
V_{REF} = 3 V, Freq. = 10 GHz, 25 °C



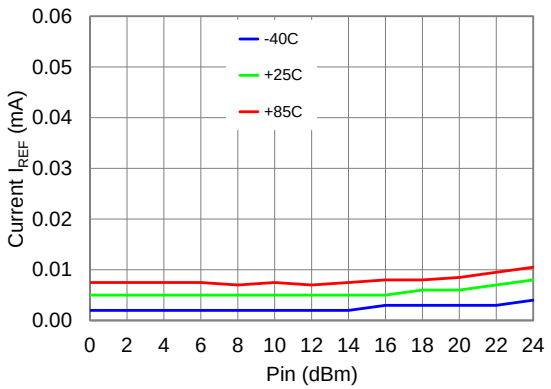
Performance Plots – Large Signal (Cont.)

Test conditions unless otherwise noted: 25 °C; 5V and 3V

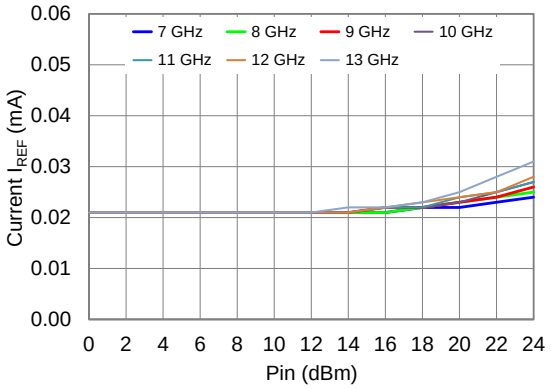
Current I_{REF} vs. Pin vs. Temperature
V_{REF} = 5 V, Freq. = 10 GHz, Phase State = 0 deg



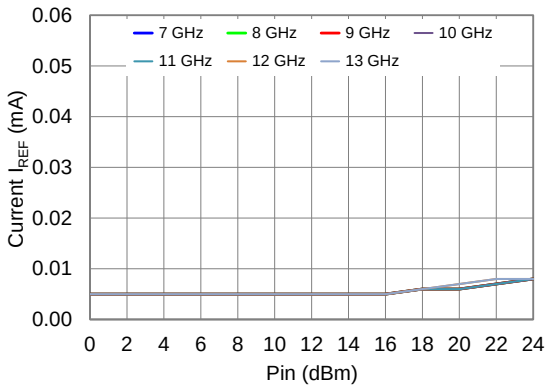
Current I_{REF} vs. Pin vs. Temperature
V_{REF} = 3 V, Freq. = 10 GHz, Phase State = 0 deg



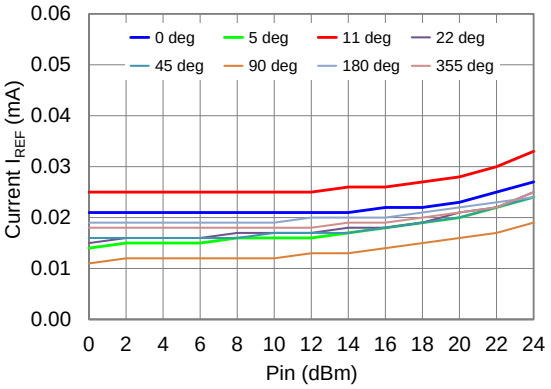
Current I_{REF} vs. Pin vs. Frequency
V_{REF} = 5 V, 25 °C, Phase State = 0 deg



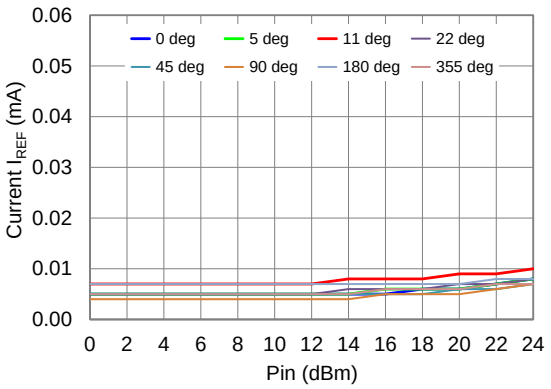
Current I_{REF} vs. Pin vs. Frequency
V_{REF} = 3 V, 25 °C, Phase State = 0 deg



Current I_{REF} vs. Pin vs. Phase States
V_{REF} = 5 V, Freq. = 10 GHz, 25 °C



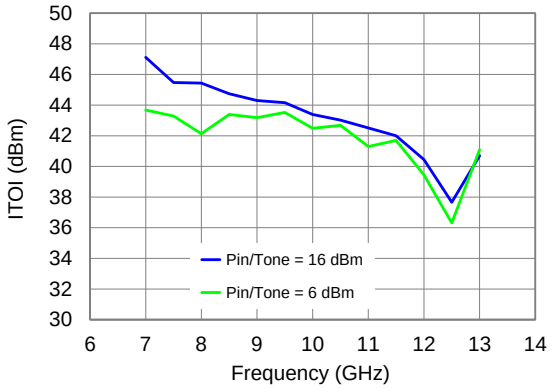
Current I_{REF} vs. Pin vs. Phase States
V_{REF} = 3 V, Freq. = 10 GHz, 25 °C



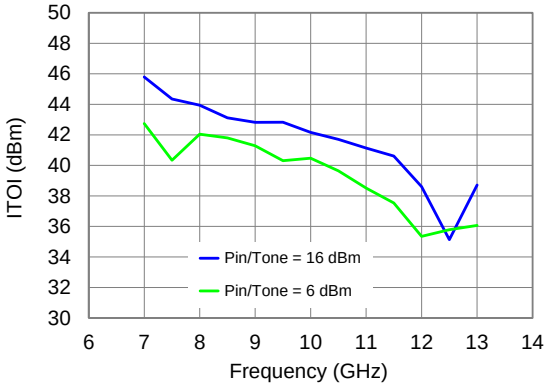
Performance Plots – Linearity

Test conditions unless otherwise noted: 25 °C; 5V and 3V, Tone Spacing = 10 MHz

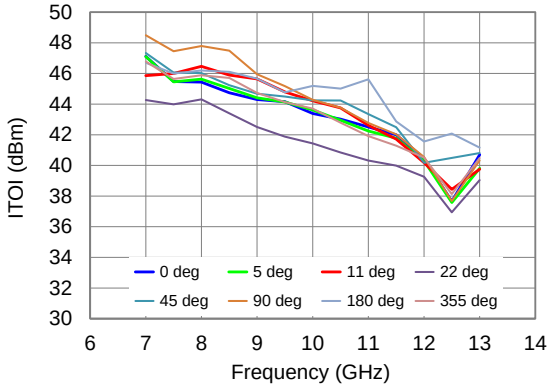
ITOI vs. Freq. vs. Pin/Tone
V_{REF} = 5 V, 25 °C, Phase State = 0 deg



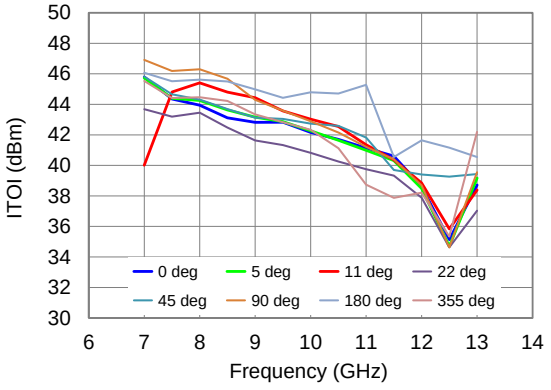
ITOI vs. Freq. vs. Pin/Tone
V_{REF} = 3 V, 25 °C, Phase State = 0 deg



ITOI vs. Freq. vs. Major Phase States
V_{REF} = 5 V, Pin/Tone = 16 dBm, 25 °C



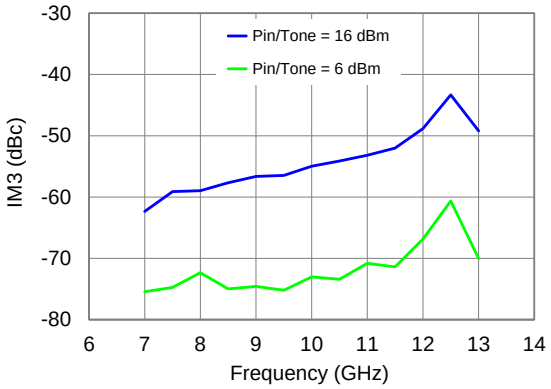
ITOI vs. Freq. vs. Major Phase States
V_{REF} = 3 V, Pin/Tone = 16 dBm, 25 °C



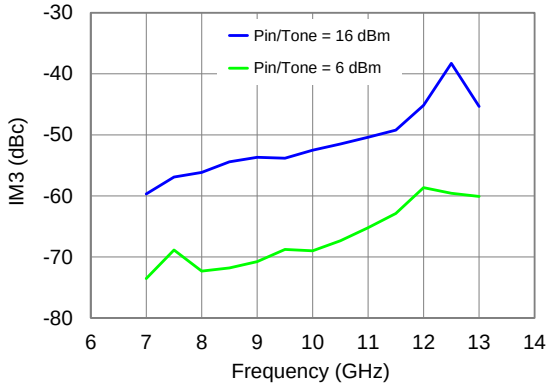
Performance Plots – Linearity (Cont.)

Test conditions unless otherwise noted: 25 °C; 5V and 3V, Tone Spacing = 10 MHz

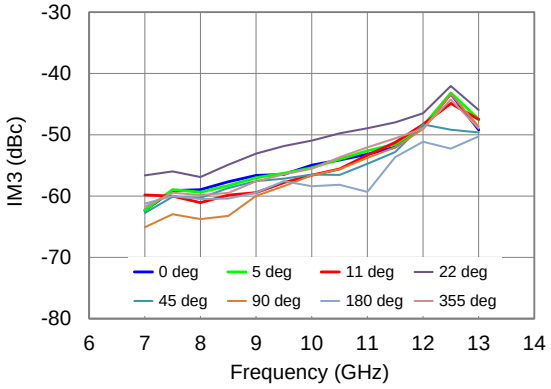
IM3 vs. Freq. vs. Pin/Tone
V_{REF} = 5 V, 25 °C, Phase State = 0 deg



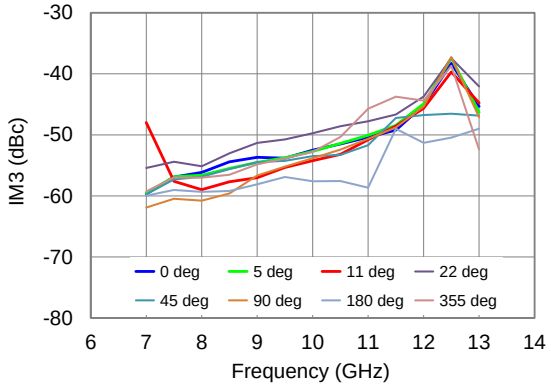
IM3 vs. Freq. vs. Pin/Tone
V_{REF} = 3 V, 25 °C, Phase State = 0 deg



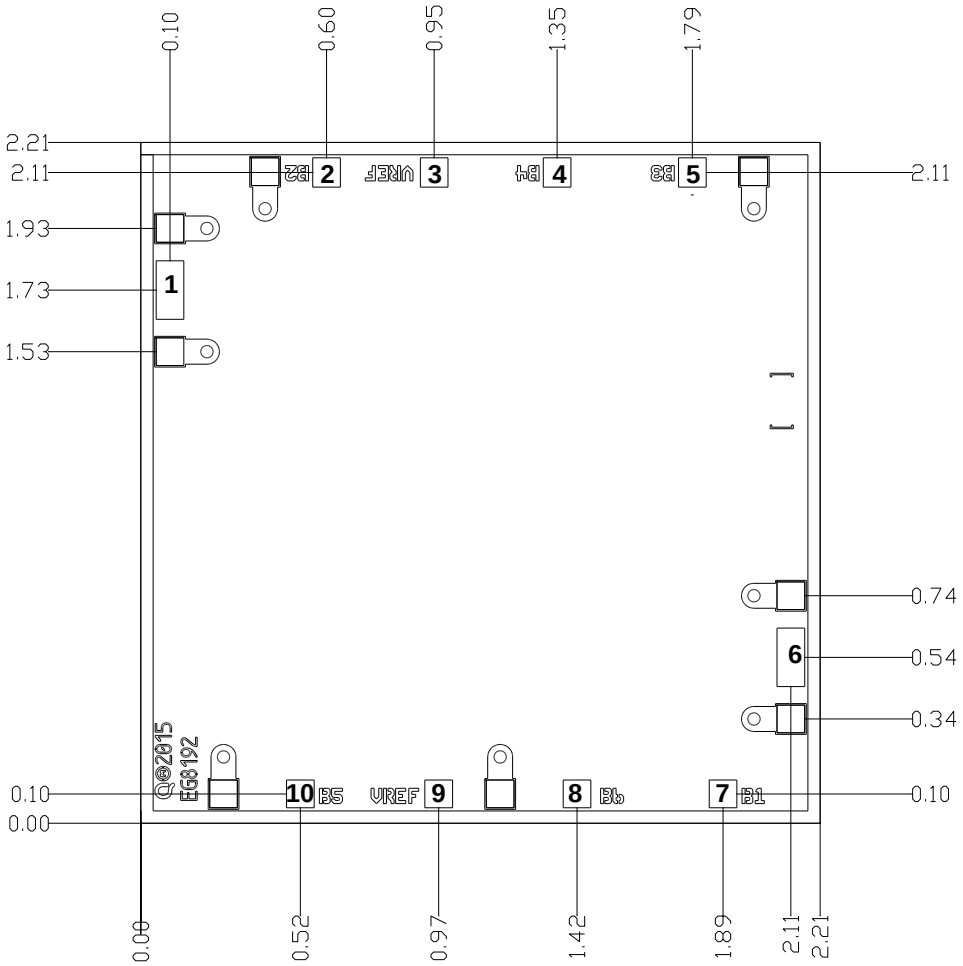
IM3 vs. Freq. vs. Major Phase States
V_{REF} = 5 V, Pin/Tone = 16 dBm, 25 °C



IM3 vs. Freq. vs. Major Phase States
V_{REF} = 3 V, Pin/Tone = 16 dBm, 25 °C



Mechanical Information and Bond Pad Description

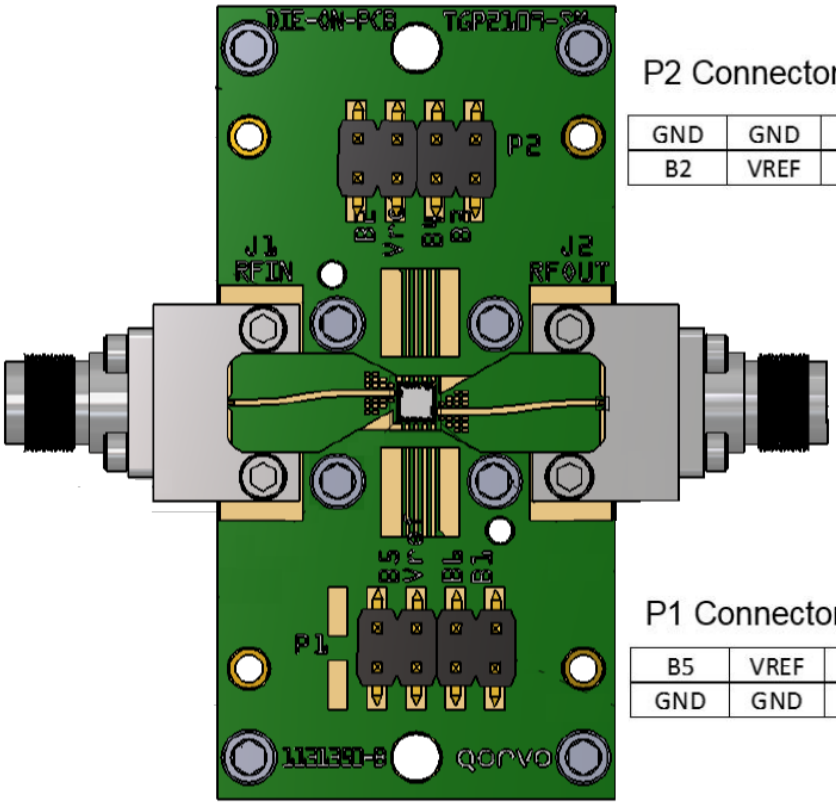


Unit: millimeters, Die thickness: 0.10, Die x, y size tolerance: ± 0.050
Chip edge to bond pad dimensions are shown to center of pad, Ground is backside of die

Bond Pad	Symbol	Description	Pad Size
1	RF In	Input; matched to 50 Ω; DC blocked; interchangeable to RF Output	0.200 x 0.100
2	B2	11º Bit	0.100 x 0.100
3, 9	REF	Reference; V_{REF} can be applied to either pad	0.100 x 0.100
4	B4	45º Bit	0.100 x 0.100
5	B3	22º Bit	0.100 x 0.100
6	RF Out	Output; matched to 50 Ω; DC blocked; interchangeable to RF Input	0.200 x 0.100
7	B1	5º Bit	0.100 x 0.100
8	B6	180º Bit	0.100 x 0.100
10	B5	90º Bit	0.100 x 0.100

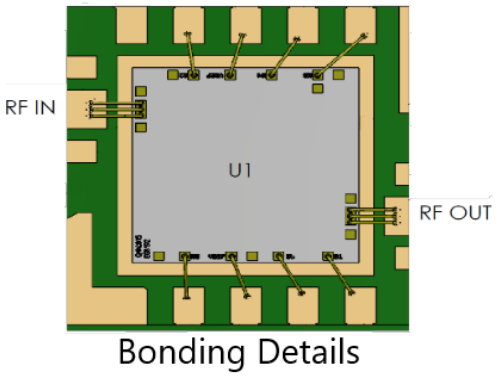
Assembly Notes

1. De-Quing network is not required; V_{REF} can be applied to either side of the MMIC (pad # 3 or #9)
2. The spacing between MMIC and TFN at RF In and RF Out is <5 mils typical.
3. RF connections: Bond three 1-mil diameter, <20 mils length gold bond wires at RF In and RF Out for optimum RF performance.



P2 Connectors (Top)

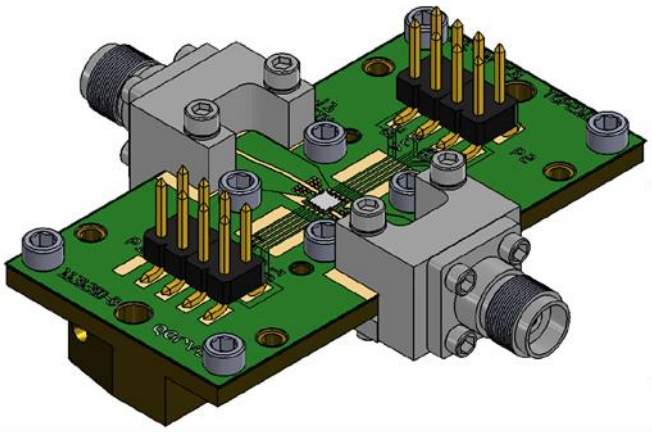
GND	GND	GND	GND
B2	VREF	B4	B3



Bonding Details

P1 Connectors (Bottom)

B5	VREF	B6	B1
GND	GND	GND	GND



Assembly Notes

Component placement and adhesive attachment assembly notes:

- Vacuum pencils and/or vacuum collets are the preferred method of pick up.
- Air bridges must be avoided during placement.
- The force impact is critical during auto placement.
- Organic attachment (i.e., conductive epoxy) can be used in low-power applications.
- Curing should be done in a convection oven; proper exhaust is a safety concern.

Reflow process assembly notes:

- Use AuSn (80/20) solder and limit exposure to temperatures above 300°C to 3-4 minutes, maximum.
- Conductive epoxy die attach is recommended for PCB mounting.
- Bonding pads plating: Au.
- An alloy station or conveyor furnace with reducing atmosphere should be used.
- Do not use any kind of flux.
- Coefficient of thermal expansion matching is critical for long-term reliability.
- Devices must be stored in a dry nitrogen atmosphere.

Interconnect process assembly notes:

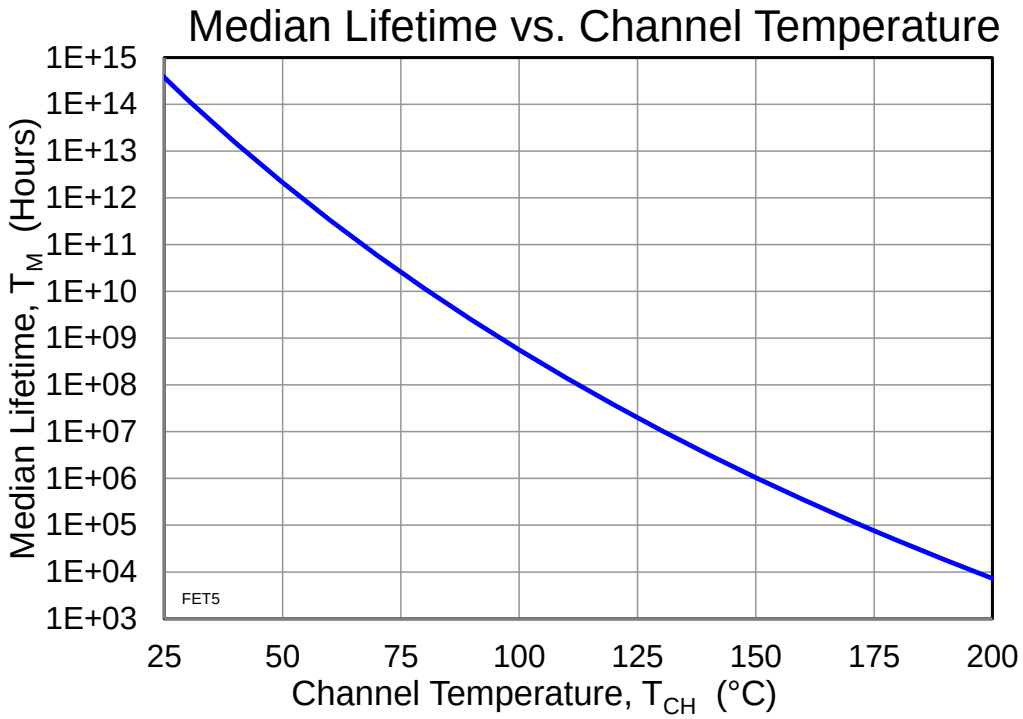
- Thermosonic ball bonding is the preferred interconnect technique.
- Force, time, and ultrasonics are critical parameters.
- Aluminum wire should not be used.
- Devices with small pad sizes should be bonded with 0.0007-inch wire.

Thermal and Reliability Information

Parameter	Test Conditions	Value	Units
Channel Temperature, T_{CH} (Under RF)	$T_{BASEPLATE}$ = 85°C	85	°C
Median Lifetime (T_M)		5.2E09	Hrs

Notes:
Under normal (lifetime) operating conditions, self-heating is not a significant contributor to channel temperature.

Median Lifetime



Handling Precautions

Parameter	Rating	Standard
ESD – Human Body Model (HBM)	Class 0	ESDA / JEDEC JS-001-2012

Caution!
ESD-Sensitive Device

RoHS Compliance

This product is compliant with the 2011/65/EU RoHS directive (Restrictions on the Use of Certain Hazardous Substances in Electrical and Electronic Equipment), as amended by Directive 2015/863/EU. This product also has the following attributes:

- Lead Free
- Halogen Free (Chlorine, Bromine)
- Antimony Free
- TBBP-A ($C_{15}H_{12}Br_4O_2$) Free
- PFOS Free
- SVHC Free

Contact Information

For the latest specifications, additional product information, worldwide sales and distribution locations:

Tel: **1-844-890-8163**

Web: **www.qorvo.com**

Email: customer.support@qorvo.com

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