7-9GHz 6-Bit Digital Phase Shifter

GaAs Monolithic Microwave IC

Description

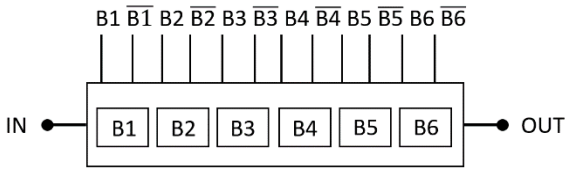
The CHP4010-99F is an X-Band (7-9GHz) monolithic 6-bit digital Phase-Shifter with a 0-360° range and high phase accuracy.

The average RMS phase error is 1.5°. The circuit provides 9dB insertion loss associated with input and output return losses better than 10dB under all states.

The circuit is mainly dedicated to defense and space systems and is also well suited for a wide range of microwave applications.

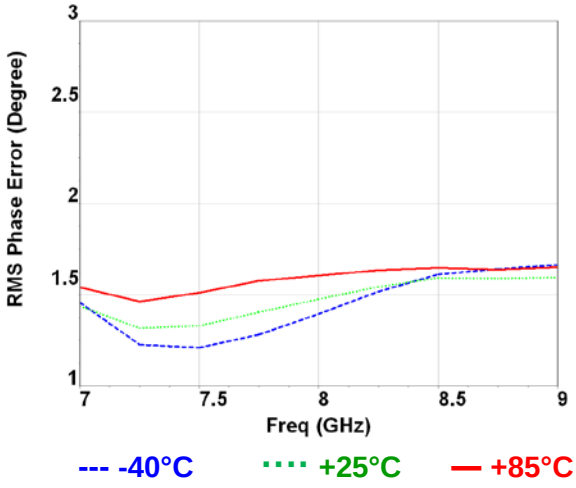
The circuit is manufactured with a pHEMT process, 0.25µm gate length, via holes through the substrate, air bridges and electron beam gate lithography.

It is available in chip form.



Main Features

- Frequency range: 7-9GHz
- 5.625° phase shifter step
- 0-360° phase shift range
- RMS phase error: 1.5°
- Low I/O return losses (all states)
- 26dBm input power at -1dB comp.
- I/O reversible
- Chip size: 2.41x2.41x0.07mm
- DC-decoupled I/O



Main Electrical Characteristics

Tamb.= +25°C

Symbol	Parameter	Min	Typ	Max	Unit
Freq	Frequency range	7.0		9.0	GHz
IL	Insertion losses		9		dB
RMS_PE	RMS Phase Error		1.5		°
Pin	Input Power @1dB comp.		26		dBm

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Specifications

Tamb.= +25°C

Symbol	Parameter	Min	Typ	Max	Unit
Freq	Frequency range	7.0		9.0	GHz
PhS	Phase Shifting Range	0		360	deg
PhS step	Phase Shifting Step		5.625		deg
PPE	Peak Phase Error		-4/4.5		deg
RMS_PE	RMS Phase Error		1.5		deg
IL	Insertion Loss		9		dB
Av	Amplitude Variation		-1.2/0.9		dB
RMS_Av	RMS Amplitude Variation		0.4		dB
VSWR_In	Input Return Loss		-13		dB
VSWR_Out	Output Return Loss		-13		dB
P1dB	Input power @ 1dBcomp		26		dBm
Vlow	Control Voltage – low level		0		V
Vhigh	Control Voltage – high level		-3.5		V
t_R	Rise time			7	ns
t_F	Fall time			7	ns
t_{ON}	On time			12	ns
t_{OFF}	Off time			12	ns

These values are representative of on-board measurements that are made with bonding wires at the RF ports.

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Peak Phase Error (PPE) definition

PPE(i) = measured_Phase(S21)@state(i) - measured_Phase(S21)@state(0) - theoreticalPhaseValue@State(i)

Amplitude Variation (Av) definition

Av(i) = Measured_dB(S21)@state(i) - Measured_dB(S21)@state(0)

RMS Phase Error (RMS_PE) definition

$$\text{RMS\_PE} = \sqrt{\frac{\sum_{i=0}^{63} PPE^2(i)}{64}}$$

where i is the state number (from 0 to 63)

RMS Amplitude variation (RMS_Av) definition

$$RMS\_AV = \overline{Av} = \frac{\sum_{i=0}^{63} Av(i)}{64}$$

where i is the state number (from 0 to 63)

Absolute Maximum Ratings (1)

Tamb.= +25°C

Symbol	Parameter	Values	Unit
Vlow	Control Voltage – low level	0.4	V
Vhigh	Control Voltage – high level	-6	V
Tj	Maximum Junction temperature (2)	175	°C

(1) Operation of this device above anyone of these parameters may cause permanent damage.

Temperature Range

Ta	Operating temperature range	-40 to +85	°C
Tstg	Storage temperature range	-55 to +150	°C

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Voltage to apply on Bit 1 to Bit 6 (pads 4 to 21):

State	Phase (deg)	Bit 1	Bit 1 N	Bit 2	Bit 2 N	Bit 3	Bit 3 N	Bit 4	Bit 4 N	Bit 5	Bit 5 N	Bit 6	Bit 6 N
0	**0**	-3.5	0	-3.5	0	-3.5	0	-3.5	0	-3.5	0	-3.5	0
1	**5.625**	0	-3.5	-3.5	0	-3.5	0	-3.5	0	-3.5	0	-3.5	0
2	**11.25**	-3.5	0	0	3.5	-3.5	0	-3.5	0	-3.5	0	-3.5	0
3	**16.875**	0	-3.5	0	-3.5	-3.5	0	-3.5	0	-3.5	0	-3.5	0
4	**22.5**	-3.5	0	-3.5	0	0	-3.5	-3.5	0	-3.5	0	-3.5	0
5	**28.125**	0	-3.5	-3.5	0	0	-3.5	-3.5	0	-3.5	0	-3.5	0
6	**33.75**	-3.5	0	0	-3.5	0	-3.5	-3.5	0	-3.5	0	-3.5	0
7	**39.375**	0	-3.5	0	-3.5	0	-3.5	-3.5	0	-3.5	0	-3.5	0
8	**45**	-3.5	0	-3.5	0	-3.5	0	0	-3.5	-3.5	0	-3.5	0
9	**50.625**	0	-3.5	-3.5	0	-3.5	0	0	-3.5	-3.5	0	-3.5	0
10	**56.25**	-3.5	0	0	-3.5	-3.5	0	0	-3.5	-3.5	0	-3.5	0
11	**61.875**	0	-3.5	0	-3.5	-3.5	0	0	-3.5	-3.5	0	-3.5	0
12	**67.5**	-3.5	0	-3.5	0	0	-3.5	0	-3.5	-3.5	0	-3.5	0
13	**73.125**	0	-3.5	-3.5	0	0	-3.5	0	-3.5	-3.5	0	-3.5	0
14	**78.75**	-3.5	0	0	-3.5	0	-3.5	0	-3.5	-3.5	0	-3.5	0
15	**84.375**	0	-3.5	0	-3.5	0	-3.5	0	-3.5	-3.5	0	-3.5	0
16	**90**	-3.5	0	-3.5	0	-3.5	0	-3.5	0	0	-3.5	-3.5	0
17	**95.625**	0	-3.5	-3.5	0	-3.5	0	-3.5	0	0	-3.5	-3.5	0
18	**101.25**	-3.5	0	0	-3.5	-3.5	0	-3.5	0	0	-3.5	-3.5	0
19	**106.875**	0	-3.5	0	-3.5	-3.5	0	-3.5	0	0	-3.5	-3.5	0
20	**112.5**	-3.5	0	-3.5	0	0	-3.5	-3.5	0	0	-3.5	-3.5	0
21	**118.125**	0	-3.5	-3.5	0	0	-3.5	-3.5	0	0	-3.5	-3.5	0
22	**123.75**	-3.5	0	0	-3.5	0	-3.5	-3.5	0	0	-3.5	-3.5	0
23	**129.375**	0	-3.5	0	-3.5	0	-3.5	-3.5	0	0	-3.5	-3.5	0
24	**135**	-3.5	0	-3.5	0	-3.5	0	0	-3.5	0	-3.5	-3.5	0
25	**140.625**	0	-3.5	-3.5	0	-3.5	0	0	-3.5	0	-3.5	-3.5	0
26	**146.25**	-3.5	0	0	-3.5	-3.5	0	0	-3.5	0	-3.5	-3.5	0
27	**151.875**	0	-3.5	0	-3.5	-3.5	0	0	-3.5	0	-3.5	-3.5	0
28	**157.5**	-3.5	0	-3.5	0	0	-3.5	0	-3.5	0	-3.5	-3.5	0
29	**163.125**	0	-3.5	-3.5	0	0	-3.5	0	-3.5	0	-3.5	-3.5	0
30	**168.75**	-3.5	0	0	-3.5	0	-3.5	0	-3.5	0	-3.5	-3.5	0
31	**174.375**	0	-3.5	0	-3.5	0	-3.5	0	-3.5	0	-3.5	-3.5	0

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Voltage to apply on Bit 1 to Bit 6 (pads 4 to 21):

State	Phase (deg)	Bit 1	Bit 1 N	Bit 2	Bit 2 N	Bit 3	Bit 3 N	Bit 4	Bit 4 N	Bit 5	Bit 5 N	Bit 6	Bit 6 N
32	180	-3.5	0	-3.5	0	-3.5	0	-3.5	0	-3.5	0	0	-3.5
33	185.625	0	-3.5	-3.5	0	-3.5	0	-3.5	0	-3.5	0	0	-3.5
34	191.25	-3.5	0	0	3.5	-3.5	0	-3.5	0	-3.5	0	0	-3.5
35	196.875	0	-3.5	0	-3.5	-3.5	0	-3.5	0	-3.5	0	0	-3.5
36	202.5	-3.5	0	-3.5	0	0	-3.5	-3.5	0	-3.5	0	0	-3.5
37	208.125	0	-3.5	-3.5	0	0	-3.5	-3.5	0	-3.5	0	0	-3.5
38	213.75	-3.5	0	0	-3.5	0	-3.5	-3.5	0	-3.5	0	0	-3.5
39	219.375	0	-3.5	0	-3.5	0	-3.5	-3.5	0	-3.5	0	0	-3.5
40	225	-3.5	0	-3.5	0	-3.5	0	0	-3.5	-3.5	0	0	-3.5
41	230.625	0	-3.5	-3.5	0	-3.5	0	0	-3.5	-3.5	0	0	-3.5
42	236.25	-3.5	0	0	-3.5	-3.5	0	0	-3.5	-3.5	0	0	-3.5
43	241.875	0	-3.5	0	-3.5	-3.5	0	0	-3.5	-3.5	0	0	-3.5
44	247.5	-3.5	0	-3.5	0	0	-3.5	0	-3.5	-3.5	0	0	-3.5
45	253.125	0	-3.5	-3.5	0	0	-3.5	0	-3.5	-3.5	0	0	-3.5
46	258.75	-3.5	0	0	-3.5	0	-3.5	0	-3.5	-3.5	0	0	-3.5
47	264.375	0	-3.5	0	-3.5	0	-3.5	0	-3.5	-3.5	0	0	-3.5
48	270	-3.5	0	-3.5	0	-3.5	0	-3.5	0	0	-3.5	0	-3.5
49	275.625	0	-3.5	-3.5	0	-3.5	0	-3.5	0	0	-3.5	0	-3.5
50	281.25	-3.5	0	0	-3.5	-3.5	0	-3.5	0	0	-3.5	0	-3.5
51	286.875	0	-3.5	0	-3.5	-3.5	0	-3.5	0	0	-3.5	0	-3.5
52	292.5	-3.5	0	-3.5	0	0	-3.5	-3.5	0	0	-3.5	0	-3.5
53	298.125	0	-3.5	-3.5	0	0	-3.5	-3.5	0	0	-3.5	0	-3.5
54	303.75	-3.5	0	0	-3.5	0	-3.5	-3.5	0	0	-3.5	0	-3.5
55	309.375	0	-3.5	0	-3.5	0	-3.5	-3.5	0	0	-3.5	0	-3.5
56	315	-3.5	0	-3.5	0	-3.5	0	0	-3.5	0	-3.5	0	-3.5
57	320.625	0	-3.5	-3.5	0	-3.5	0	0	-3.5	0	-3.5	0	-3.5
58	326.25	-3.5	0	0	-3.5	-3.5	0	0	-3.5	0	-3.5	0	-3.5
59	331.875	0	-3.5	0	-3.5	-3.5	0	0	-3.5	0	-3.5	0	-3.5
60	337.5	-3.5	0	-3.5	0	0	-3.5	0	-3.5	0	-3.5	0	-3.5
61	343.125	0	-3.5	-3.5	0	0	-3.5	0	-3.5	0	-3.5	0	-3.5
62	348.75	-3.5	0	0	-3.5	0	-3.5	0	-3.5	0	-3.5	0	-3.5
63	354.375	0	-3.5	0	-3.5	0	-3.5	0	-3.5	0	-3.5	0	-3.5

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Typical on-wafer Sij parameters

Tamb.= +25°C, Vlow = 0 V, Vhigh = -3.5 V, State=0

Freq (GHz)	S11 (dB)	PhS11 (°)	S12 (dB)	PhS12 (°)	S21 (dB)	PhS21 (°)	S22 (dB)	PhS22 (°)
4	-2.9	-50.2	-11.6	-161.4	-11.6	-161.6	-16.1	148.3
4.25	-2.9	-50.8	-11.7	173.1	-11.7	172.6	-15.6	131.4
4.5	-3.1	-53.2	-11.1	151.3	-11.1	150.8	-15.5	113.2
4.75	-3.2	-54.9	-10.8	126.5	-10.8	126.1	-14.4	84.7
5	-3.3	-57.6	-10.6	102.8	-10.6	102.4	-13.6	51.1
5.25	-3.4	-61.1	-10.4	80.1	-10.4	79.8	-12.8	19.5
5.5	-3.7	-65	-10.2	58.1	-10.2	57.9	-12.2	-9
5.75	-4.1	-69.2	-10	35.9	-10	35.7	-11.9	-33.4
6	-4.6	-73.6	-9.7	13.9	-9.7	13.6	-12.2	-53.9
6.25	-5.4	-77.6	-9.4	-8.2	-9.5	-8.5	-13.1	-70.2
6.5	-6.3	-80.4	-9.2	-31	-9.2	-31.4	-14.6	-79.6
6.75	-7.5	-81.2	-9	-54	-9	-54.4	-16	-79.6
7	-8.6	-79.3	-8.9	-77.4	-8.9	-77.7	-16.1	-73
7.25	-9.4	-75.5	-8.9	-100.7	-8.9	-101	-14.8	-69.5
7.5	-9.8	-70.9	-8.9	-123.6	-8.9	-123.9	-13.5	-74.9
7.75	-9.9	-67.6	-9	-146.4	-9	-146.6	-12.9	-84.7
8	-9.9	-65.7	-9.1	-169	-9.1	-169.2	-13.1	-94.6
8.25	-9.9	-64.5	-9.3	168.6	-9.3	168.5	-14.2	-102.1
8.5	-9.9	-63.7	-9.4	146.4	-9.4	146.2	-16	-102.2
8.75	-9.8	-63.3	-9.6	124.1	-9.6	123.9	-17.4	-89.1
9	-9.7	-63.5	-9.8	101.7	-9.8	101.4	-16.3	-71.8
9.25	-9.5	-65.2	-10	79.4	-10.1	79.2	-13.7	-66.9
9.5	-9.4	-69.5	-10	57.6	-10.4	57.4	-11.7	-71.8
9.75	-9.5	-76	-10.7	36.5	-10.7	36.2	-10.7	-80.5
10	-10.4	-84.4	-11	16.9	-11	16.6	-10.4	-87.5
10.25	-12.2	-90.3	-10.9	-3.1	-10.9	-3.1	-10.5	-92.4
10.5	-14.2	-92.1	-10.8	-24.3	-10.8	-24.4	-10.6	-91.9
10.75	-17.3	-95.1	-10.6	-45	-10.6	-45	-9.9	-91.9
11	-23	-71.3	-10.2	-68.3	-10.2	-68.2	-9.5	-95.3
11.25	-21	-21.6	-10.2	-93.1	-10.2	-93.1	-9.4	-96.8
11.5	-17	-13.2	-10.3	-117.5	-10.3	-117.5	-8.9	-97.4
11.75	-15.2	-15.5	-10.5	-141.6	-10.5	-141.5	-8.5	-99.6
12	-14.6	-16.2	-10.8	-165.2	-10.8	-165	-8.1	-102.4

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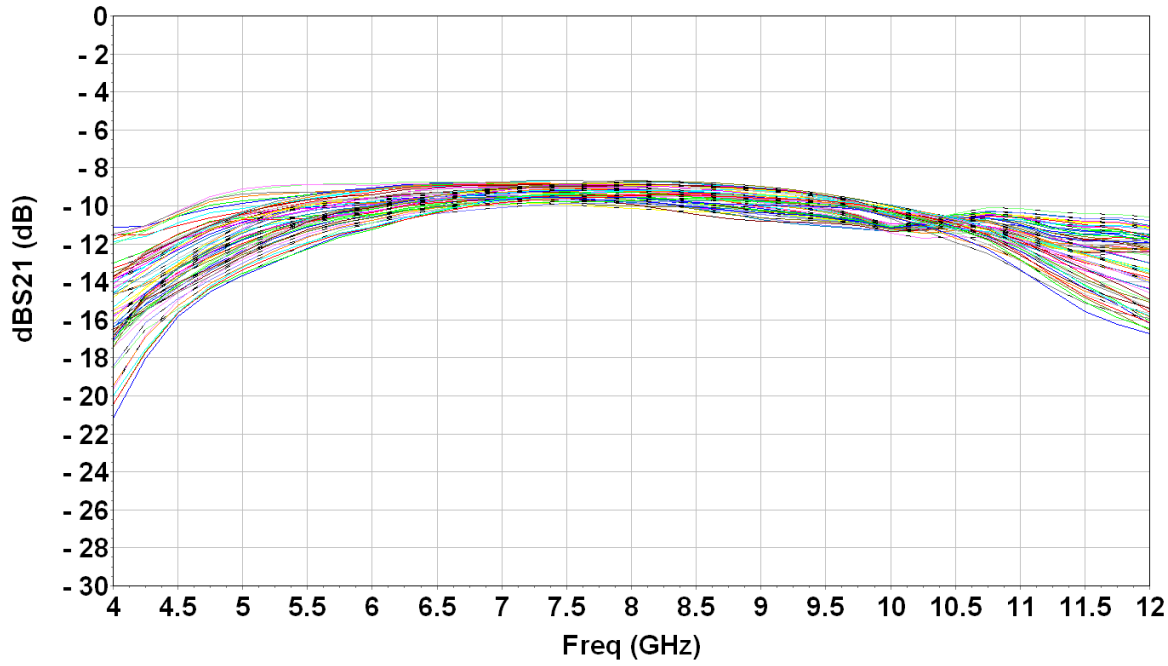
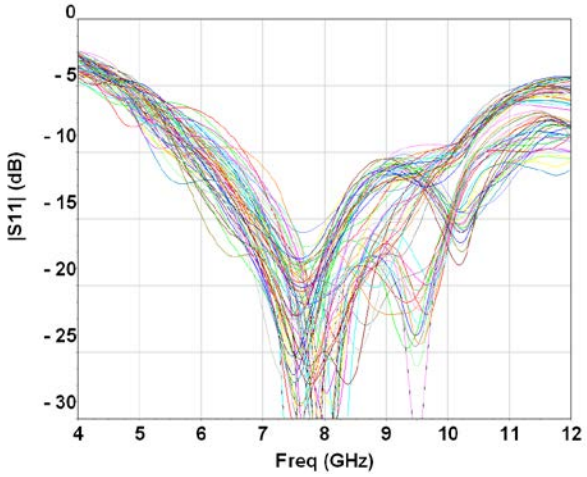
Typical Board Measurements

Tamb.= +25°C,

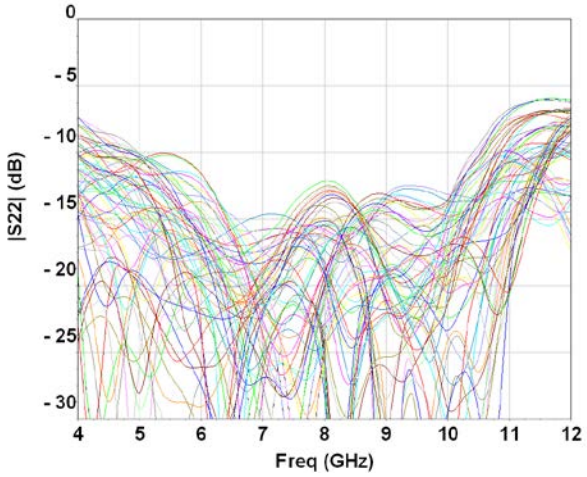
Insertion Loss versus Frequency @ All States
(after de-embedding of test-fixture insertion loss)



Input Return Losses @ All States



Output Return Losses @ All States



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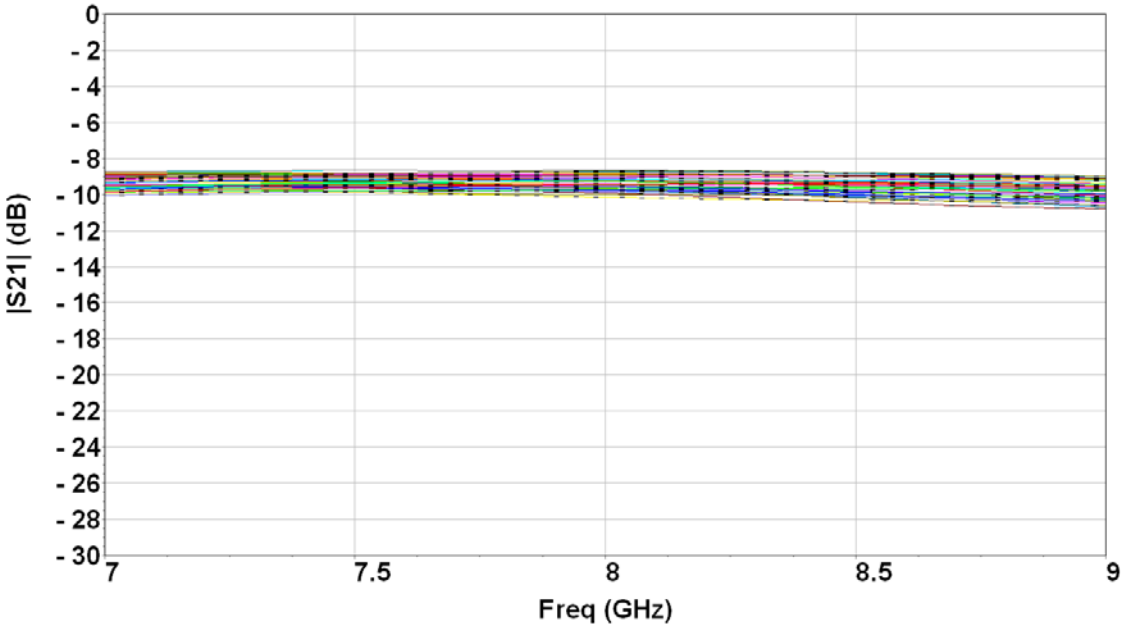
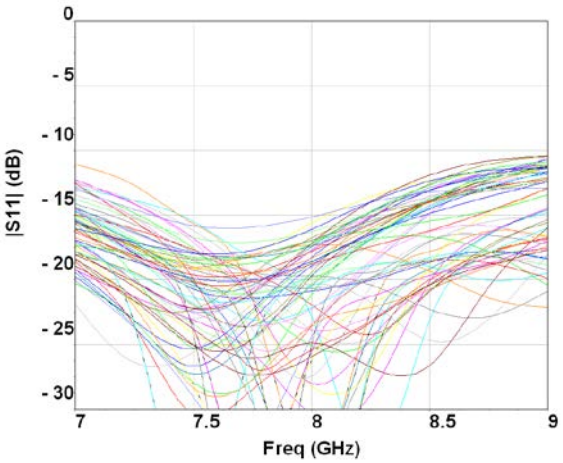
Typical Board Measurements

Tamb.= +25°C,

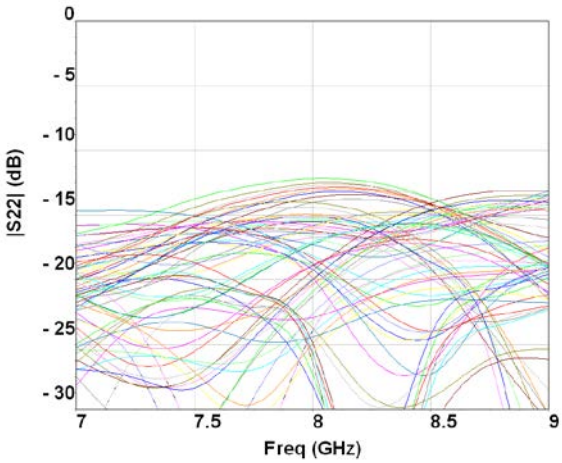
Insertion Loss versus Frequency @ All States
(after de-embedding of test-fixture insertion loss)



Input Return Losses @ All States



Output Return Losses @ All States



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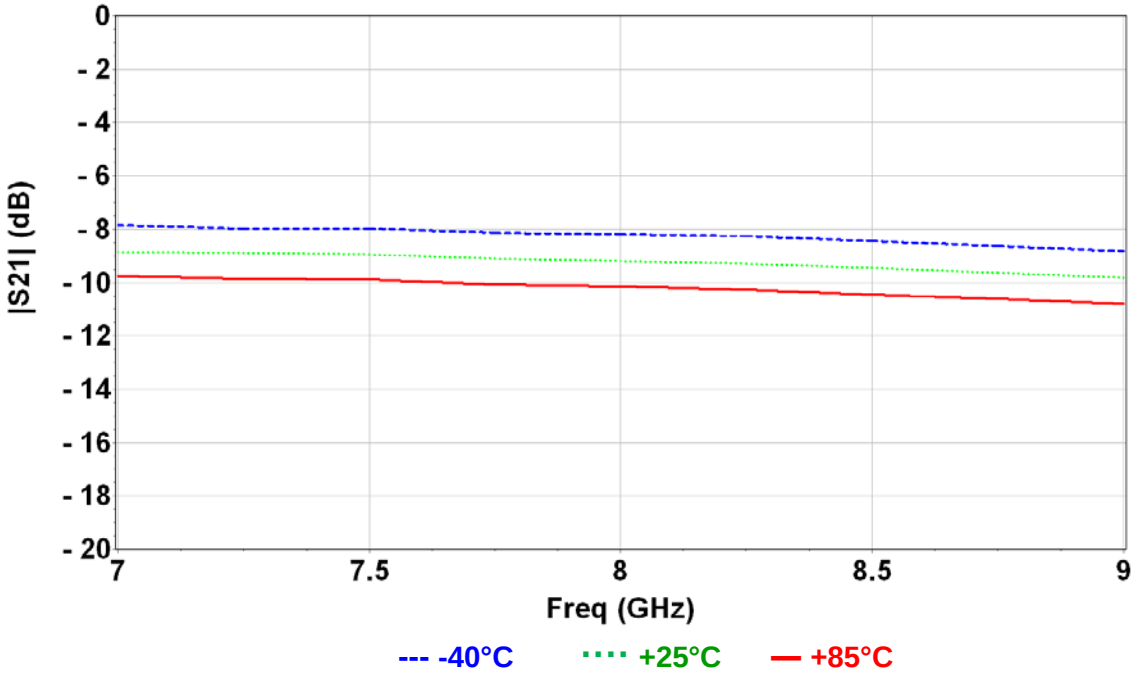
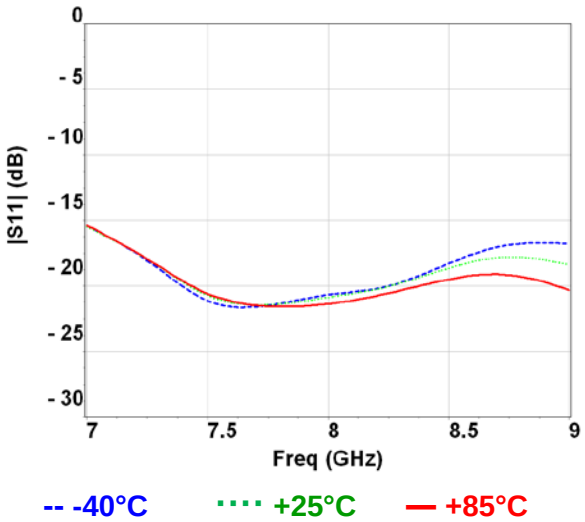
Typical Board Measurements

Tamb : -40°C,+25°C, +85°C

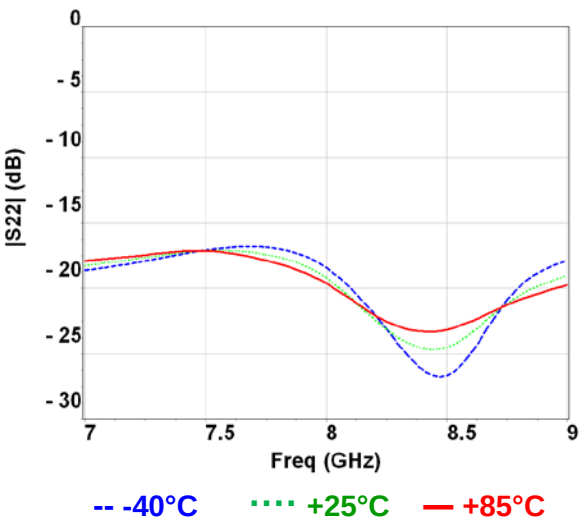
Insertion Loss versus Frequency @ State 0
(after de-embedding of test-fixture insertion loss)



Input Return Loss @ State 0



Output Return Loss @ State 0



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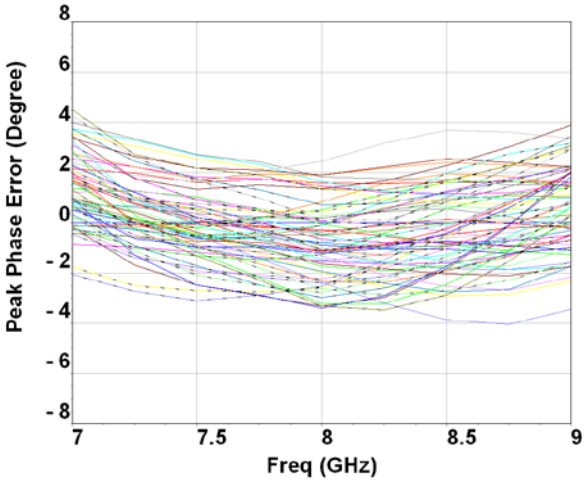
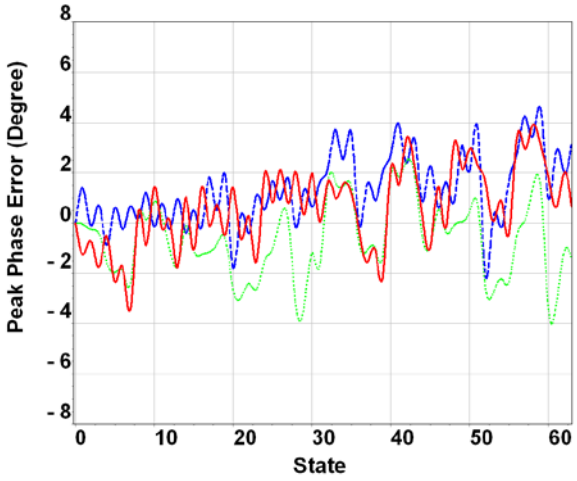
Typical Board Measurements

Tamb.= +25°C,

Peak Phase Error versus Frequency (all states)

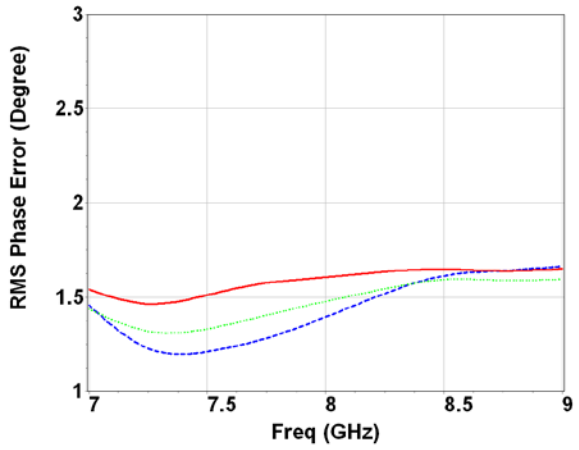


Peak Phase Error versus State



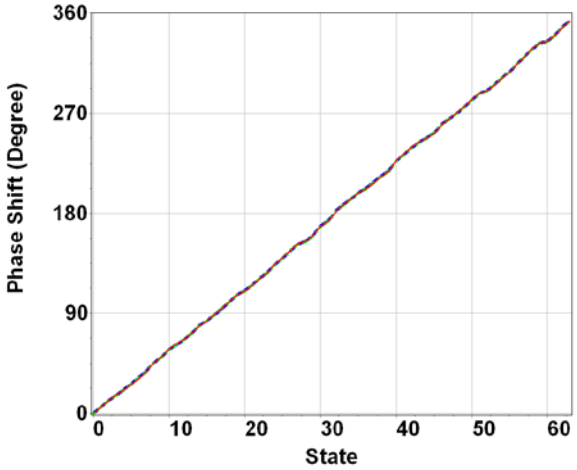
-- 7GHz ··· 8 GHz — 9GHz

RMS Phase Error versus Frequency



-- -40°C ··· +25°C — +85°C

Phase Shift versus State (@8 GHz)



-- -40°C ··· +25°C —+85°C

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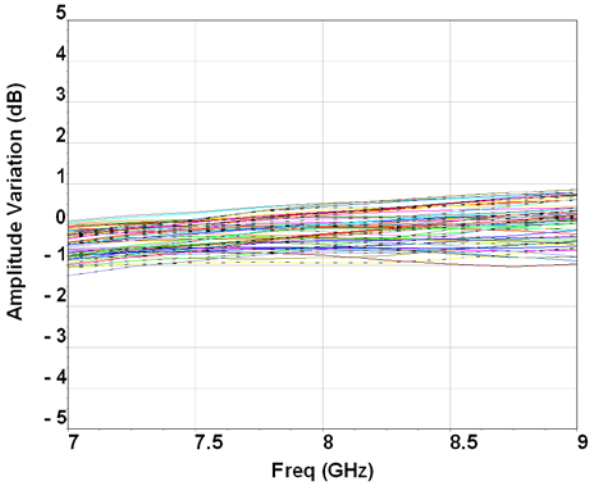
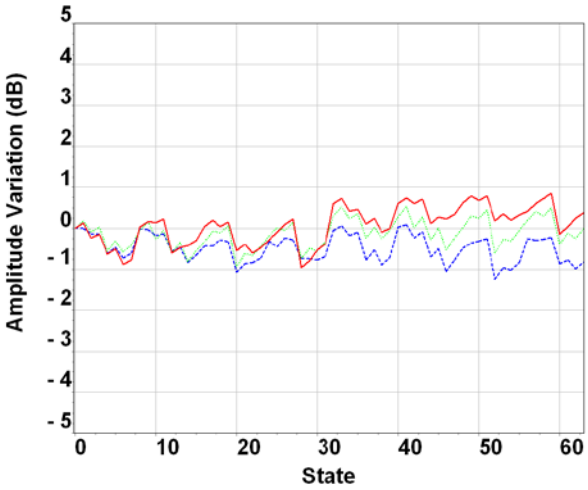
Typical Board Measurements

Tamb.= +25°C

Amplitude Variation versus Frequency (all states)

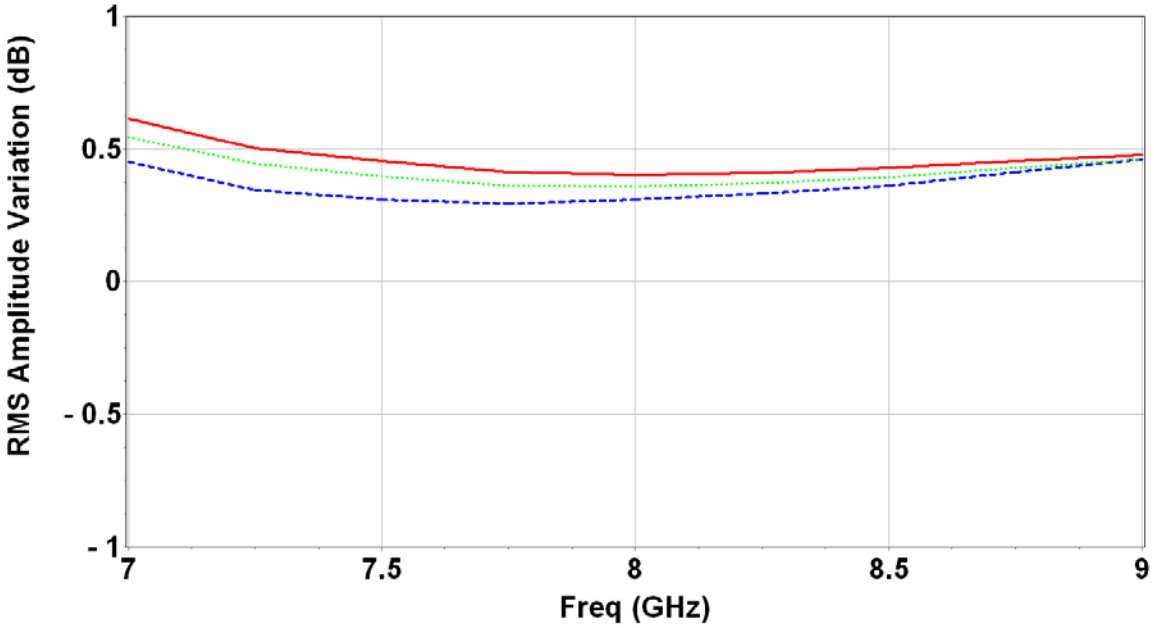


Amplitude Variation versus State



-- 7GHz ··· 8 GHz — 9GHz

RMS Amplitude Variation versus Frequency



-- -40°C ···· +25°C — +85°C

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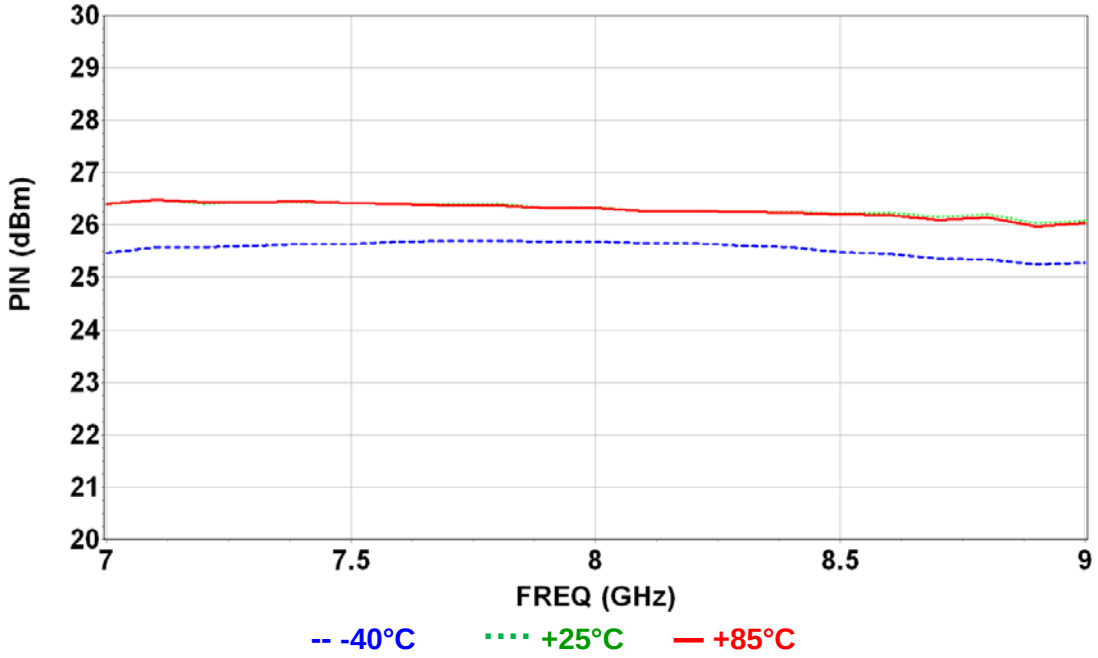
Typical Board Measurements

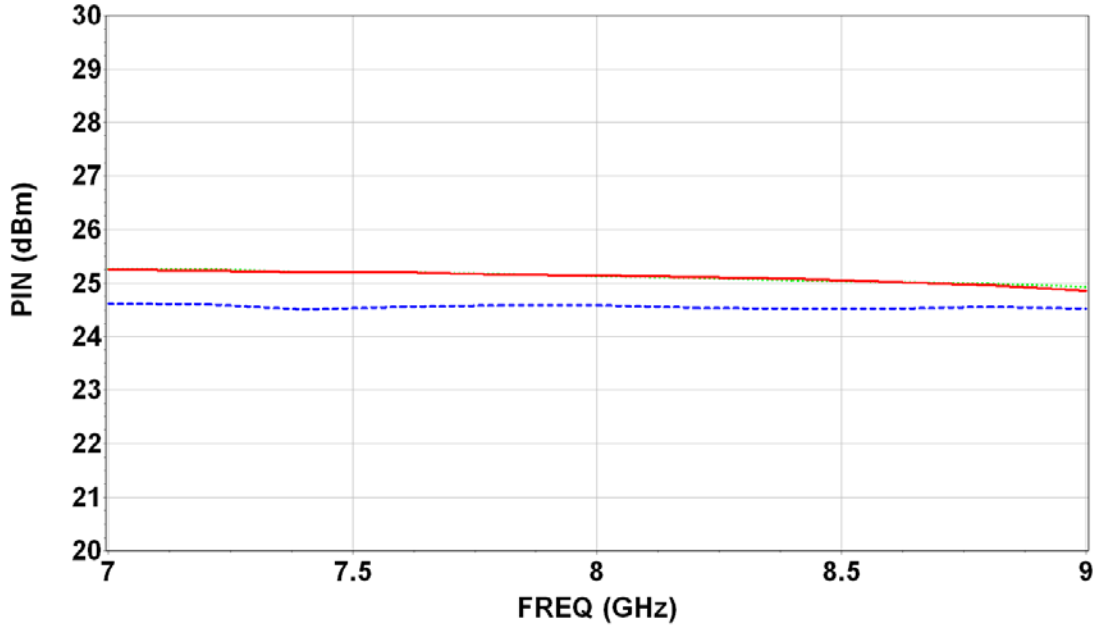
Tamb.= +25°C, V+ = +5V, V- = -5V

Input Power @ 1dB compression (reference state) IN -> OUT



-- -40°C ···· +25°C — +85°C

Input Power @ 1dB compression (reference state) OUT -> IN



-- -40°C ···· +25°C — +85°C

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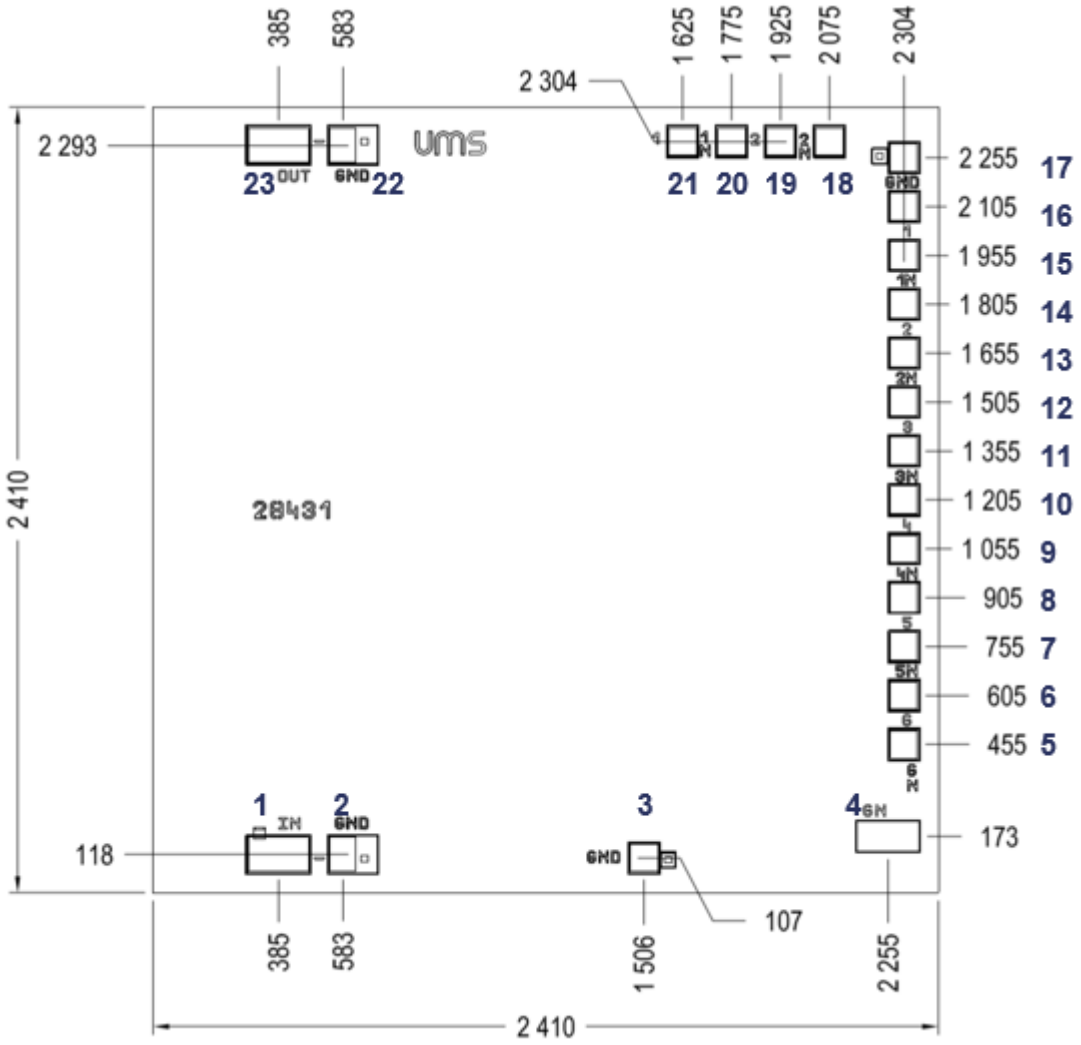
Mechanical data



Chip thickness: 70µm ±10µm.
Chip size: (2410 ±35)µm x (2410 ±35)µm
All dimensions are in micrometers

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Pad number	Pad name	Description
1	IN	RF input
23	OUT	RF output
16 or 21	1	Bit 1
15 or 20	1N	$\overline{\text{Bit 1}}$
14 or 19	2	Bit 2
13 or 18	2N	$\overline{\text{Bit 2}}$
12	3	Bit 3
11	3N	$\overline{\text{Bit 3}}$
10	4	Bit 4
9	4N	$\overline{\text{Bit 4}}$
8	5	Bit 5
7	5N	$\overline{\text{Bit 5}}$
6	6	Bit 6
5 or 4	6N	$\overline{\text{Bit 6}}$
4, 18, 19, 20	6N, 2N, 2, 1N	NC if 4, 21, 13, 14, 15 are used
2, 3, 17, 22	GND	GND = NC

* only one of the two pads must be connected to the DC supply

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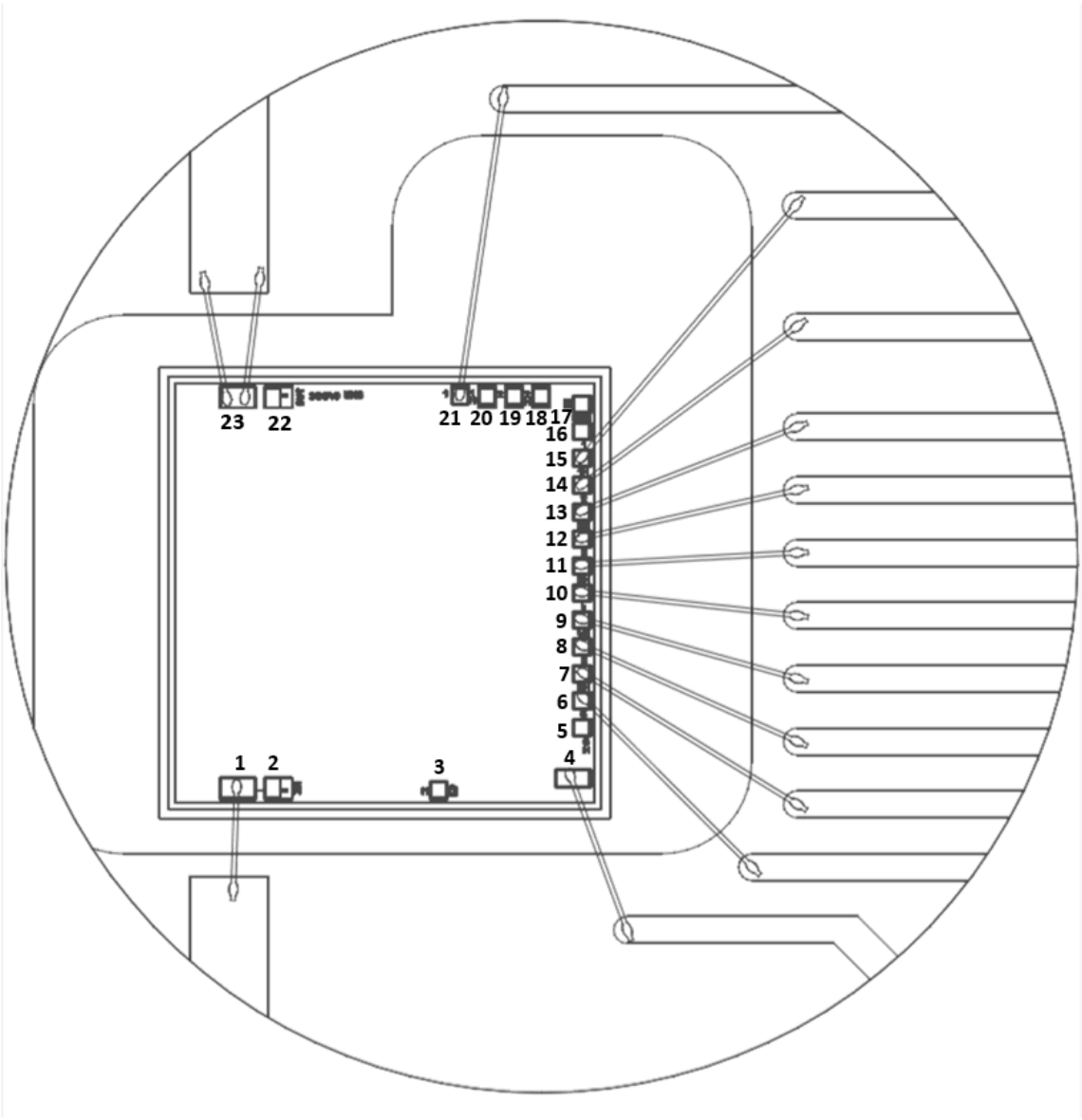
Recommended assembly plan



Notes: Supply feed should be bypassed : 25µm diameter gold wire is to be preferred

Pad number	Decoupling	Connection
23	/	2 parallel bonding wires (diameter=25µm, length=0.65mm, self-inductance equivalent = 0.5nH)
1	/	1 bonding wire (diameter=25µm, length=1.1mm, self-inductance equivalent = 0.98nH)

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Recommended ESD management

Refer to the application note AN0020 available at http://www.ums-gaas.com for ESD sensitivity and handling recommendations for the UMS products.

Recommended environmental management

UMS products are compliant with the regulation in particular with the directives RoHS N°2011/65 and REACh N°1907/2006. More environmental data are available in the application note AN0019 also available at http://www.ums-gaas.com.

Ordering Information

Chip form:	CHP4010-99F/00

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