United Monolithic Semiconductors

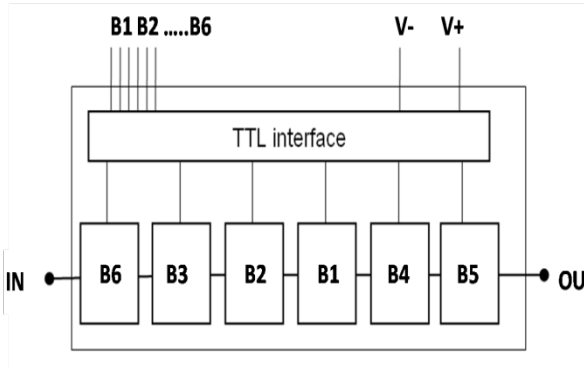
CHP3015-99F

X-Band 6-Bit Digital Phase Shifter

GaAs Monolithic Microwave IC

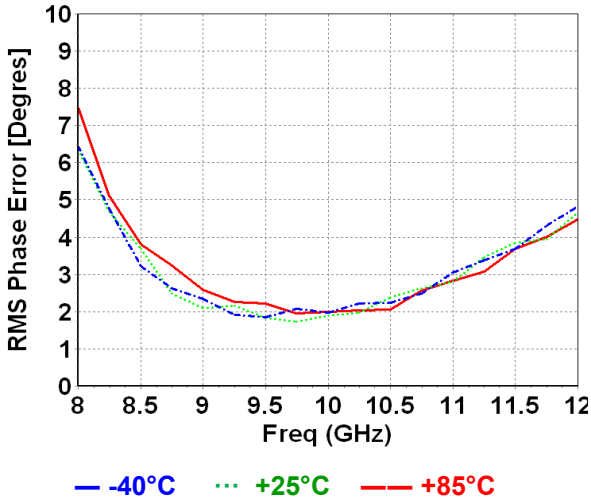
Description

The CHP3015-99F is an X-Band (8.5-11.5GHz) monolithic 6-bit digital phase-shifter with a 0-360° range and high phase accuracy. The average RMS phase error is 2.5°.The circuit provides 7.5dB insertion loss associated with input and output return losses better than 13dB under all states. An on-chip DC-interface is compatible with both CMOS (0/+3.3V) and TTL (0/+5V) logics.
The circuit is mainly dedicated to defense and space systems and is also well suited for a wide range of microwave applications.
The MMIC is developped on a robust pHEMT process.



Main Features

- 2.5 deg average RMS phase error
- Low I/O return losses (all states)
- 24dBm Input P1dB
- CMOS/TTL compatibility: V+ = +3.3/5V
- DC-decoupled I/O
- Chip size 2.41x2.41x0.1mm



Main Characteristics

Tbackside= +25°C

Symbol	Parameter	Min	Typ	Max	Unit
Freq	Frequency range	8.5		11.5	GHz
PPE	Peak Phase Error		(-3, +5)		deg
RMS_PE	RMS Phase Error		2.5		deg

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Main Characteristics

Tbackside= +25°C

Symbol	Parameter	Min	Typ	Max	Unit
Fop	Operating frequency range	8.5		11.5	GHz
PhS	Phase Shifting Range	0		360	deg
PhS step	Phase Shifting Step		5.625		deg
PPE	Peak Phase Error		(-3, +5)		deg
RMS_PE	RMS Phase Error		2.5		deg
IL	Insertion Loss		7.5		dB
Av	Amplitude Variation		(-0.5, +1)		dB
RMS_Av	RMS Amplitude Variation		0.4		dB
VSWR_In	Input Return Loss		14		dB
VSWR_Out	Output Return Loss		13		dB
P1dB	Input power @ 1dBcomp		24		dBm
OP1dB	Output power @ 1dBcomp		15.5		dBm
Vlow	Control Voltage – low level	0		0.4	V
Vhigh	Control Voltage – high level	2.4		6	V
V+	Positive Supply Voltage		5 or 3.3		V
V-	Negative Supply Voltage		-5		V
I+	Positive Supply Current		4		mA
I-	Negative Supply Current		3.5		mA
t_R	Rise time			10	ns
t_F	Fall time			10	ns
t_{ON}	On time			25	ns
t_{OFF}	Off time			25	ns
Top	Operating temperature	-40		+85	deg

These values are representative of the chip's typical performances with two parallel and one single bonding wire respectively at the input and output RF ports, each approximately 400um long.

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Definitions

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)

Tbackside= +25°C

Symbol	Parameter	Values	Unit
V+	Maximum DC positive supply voltage	+6	V
V-	Maximum DC negative supply voltage	-6	V
Vlow	Minimum control voltage	-2	V
Vhigh	Maximum control voltage	+6	V
Tj	Maximum junction temperature	175	°C
Ta	Operating temperature range	-40 to +85	°C
Tstg	Storage temperature range	-55 to +150	°C
Pin	Maximum Input Power	26	dBm

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

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Typical Bias Conditions

Two options are possible for the positive value of the biasing circuit without impact on the RF performances.

Option 1

Symbol	PAD #º	Parameter	Values	Unit
V+	9, 15	Positive Supply Voltage	+5	V
V-	10, 13	Negative Supply Voltage	-5	V
V+	11, 14	Positive Supply Voltage	NC	
Bit1 to Bit6	8 to 3	Control Voltage	0 / +3.3	V

Option 2

Symbol	PAD #º	Parameter	Values	Unit
V+	9, 15	Positive Supply Voltage	NC	V
V-	10, 13	Negative Supply Voltage	-5	V
V+	11, 14	Positive Supply Voltage	+3.3	V
Bit1 to Bit6	8 to 3	Control Voltage	0 / +3.3	V

Note: The Control Voltage of high level (Vhigh) for the above options is +3.3V as typical value, but any voltage between +2.4V and +6.0V can be used.

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Phase shifter control table

Voltage to apply on Bit 1 to Bit 6 (pads 11 to 16):

State	Phase (deg)	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	State	Phase (deg)	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1
0	0	0	0	0	0	0	0	32	180	3.3	0	0	0	0	0
1	5.625	0	0	0	0	0	3.3	33	185.625	3.3	0	0	0	0	3.3
2	11.25	0	0	0	0	3.3	0	34	191.25	3.3	0	0	0	3.3	0
3	16.875	0	0	0	0	3.3	3.3	35	196.875	3.3	0	0	0	3.3	3.3
4	22.5	0	0	0	3.3	0	0	36	202.5	3.3	0	0	3.3	0	0
5	28.125	0	0	0	3.3	0	3.3	37	208.125	3.3	0	0	3.3	0	3.3
6	33.75	0	0	0	3.3	3.3	0	38	213.75	3.3	0	0	3.3	3.3	0
7	39.375	0	0	0	3.3	3.3	3.3	39	219.375	3.3	0	0	3.3	3.3	3.3
8	45	0	0	3.3	0	0	0	40	225	3.3	0	3.3	0	0	0
9	50.625	0	0	3.3	0	0	3.3	41	230.625	3.3	0	3.3	0	0	3.3
10	56.25	0	0	3.3	0	3.3	0	42	236.25	3.3	0	3.3	0	3.3	0
11	61.875	0	0	3.3	0	3.3	3.3	43	241.875	3.3	0	3.3	0	3.3	3.3
12	67.5	0	0	3.3	3.3	0	0	44	247.5	3.3	0	3.3	3.3	0	0
13	73.125	0	0	3.3	3.3	0	3.3	45	253.125	3.3	0	3.3	3.3	0	3.3
14	78.75	0	0	3.3	3.3	3.3	0	46	258.75	3.3	0	3.3	3.3	3.3	0
15	84.375	0	0	3.3	3.3	3.3	3.3	47	264.375	3.3	0	3.3	3.3	3.3	3.3
16	90	0	3.3	0	0	0	0	48	270	3.3	3.3	0	0	0	0
17	95.625	0	3.3	0	0	0	3.3	49	275.625	3.3	3.3	0	0	0	3.3
18	101.25	0	3.3	0	0	3.3	0	50	281.25	3.3	3.3	0	0	3.3	0
19	106.875	0	3.3	0	0	3.3	3.3	51	286.875	3.3	3.3	0	0	3.3	3.3
20	112.5	0	3.3	0	3.3	0	0	52	292.5	3.3	3.3	0	3.3	0	0
21	118.125	0	3.3	0	3.3	0	3.3	53	298.125	3.3	3.3	0	3.3	0	3.3
22	123.75	0	3.3	0	3.3	3.3	0	54	303.75	3.3	3.3	0	3.3	3.3	0
23	129.375	0	3.3	0	3.3	3.3	3.3	55	309.375	3.3	3.3	0	3.3	3.3	3.3
24	135	0	3.3	3.3	0	0	0	56	315	3.3	3.3	3.3	0	0	0
25	140.625	0	3.3	3.3	0	0	3.3	57	320.625	3.3	3.3	3.3	0	0	3.3
26	146.25	0	3.3	3.3	0	3.3	0	58	326.25	3.3	3.3	3.3	0	3.3	0
27	151.875	0	3.3	3.3	0	3.3	3.3	59	331.875	3.3	3.3	3.3	0	3.3	3.3
28	157.5	0	3.3	3.3	3.3	0	0	60	337.5	3.3	3.3	3.3	3.3	0	0
29	163.125	0	3.3	3.3	3.3	0	3.3	61	343.125	3.3	3.3	3.3	3.3	0	3.3
30	168.75	0	3.3	3.3	3.3	3.3	0	62	348.75	3.3	3.3	3.3	3.3	3.3	0
31	174.375	0	3.3	3.3	3.3	3.3	3.3	63	354.375	3.3	3.3	3.3	3.3	3.3	3.3

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Typical on-wafer Sij parameters (state 0)

Tbackside= +25°C, V+ = +5V, V- = -5V

Freq (GHz)	S11 (dB)	PhS11 (°)	S12 (dB)	PhS12 (°)	S21 (dB)	PhS21 (°)	S22 (dB)	PhS22 (°)
5	-14,1	-41,3	-6,38	109	-6,38	109	-23,6	-40,3
5.2	-13,2	-48	-6,41	93	-6,41	93,2	-24,4	-19,3
5.4	-12,8	-54,4	-6,51	77,4	-6,51	77,4	-22,8	-1,55
5.6	-12,5	-61,9	-6,69	61,7	-6,69	61,8	-20,9	8,14
5.8	-12,3	-70,8	-7,06	46,4	-7,06	46,3	-19,9	13,3
6	-12,4	-86,3	-7,64	34,3	-7,66	34,3	-18,5	28,1
6.2	-14,5	-105	-7,46	24,1	-7,46	24,2	-15	26,8
6.4	-18	-115	-7,16	10,2	-7,16	10,3	-13,2	16,1
6.6	-22,6	-120	-7,07	-4,33	-7,07	-4,31	-12,4	6,63
6.8	-31	-106	-7,08	-18,7	-7,07	-18,7	-11,8	-0,352
7	-30	-5,47	-7,11	-32,7	-7,11	-32,7	-11,6	-6,88
7.2	-22,8	3	-7,13	-46,7	-7,12	-46,8	-11,4	-13,5
7.4	-19	-2,12	-7,17	-60,7	-7,18	-60,7	-11,4	-19,6
7.6	-16,4	-10,9	-7,2	-74,3	-7,2	-74,3	-11,4	-26,2
7.8	-14,8	-19,9	-7,22	-88,2	-7,22	-88,2	-11,5	-32,4
8	-13,6	-30,4	-7,23	-102	-7,24	-102	-11,8	-39,5
8.2	-12,9	-40,2	-7,26	-116	-7,25	-116	-12,1	-45,9
8.4	-12,4	-50,1	-7,28	-130	-7,28	-130	-12,6	-53,8
8.6	-12,2	-59,8	-7,31	-144	-7,29	-144	-13,2	-61,7
8.8	-12,1	-69,8	-7,28	-158	-7,29	-158	-13,9	-71,8
9	-12,1	-79	-7,28	-172	-7,29	-172	-15	-82,7
9.2	-12,3	-87,6	-7,31	174	-7,32	174	-16,2	-94,6
9.4	-12,6	-96	-7,35	160	-7,36	160	-17,8	-110
9.6	-12,8	-104	-7,41	145	-7,4	145	-19,6	-129
9.8	-13,1	-112	-7,49	131	-7,49	131	-21,2	-155
10	-13,2	-120	-7,57	116	-7,55	117	-22	172
10.2	-13,3	-128	-7,67	102	-7,64	102	-21,3	140
10.4	-13,3	-136	-7,78	87,6	-7,78	87,5	-19,8	112
10.6	-13,1	-145	-7,91	73,2	-7,89	73,1	-18,3	90,2
10.8	-13,1	-154	-8,04	58,9	-8,05	58,8	-17,1	73,2
11	-13	-164	-8,17	44,6	-8,17	44,7	-16,1	57,4
11.2	-12,9	-173	-8,3	30,3	-8,3	30,4	-15,5	43
11.4	-12,9	177	-8,43	16,2	-8,42	16,3	-15,2	28,7
11.6	-12,9	167	-8,53	2	-8,52	1,98	-15,3	14,2
11.8	-13	157	-8,64	-12,2	-8,63	-12,2	-15,7	-0,137
12	-13,1	147	-8,71	-26,5	-8,7	-26,5	-16,5	-17
12.2	-12,9	134	-8,81	-41,3	-8,8	-41,4	-18,2	-30,7
12.4	-13,1	126	-8,86	-55,8	-8,87	-55,8	-19,7	-55,8
12.6	-13,3	118	-8,93	-70,4	-8,94	-70,5	-21,2	-88,5
12.8	-13,5	110	-9,02	-85,2	-9,02	-85,2	-21	-128
13	-13,8	103	-9,09	-100	-9,08	-100	-19,1	-162
14	-16,5	75,4	-9,68	-173	-9,68	-173	-10,5	117
15	-29,3	43,8	-9,53	113	-9,52	113	-9,76	82,8

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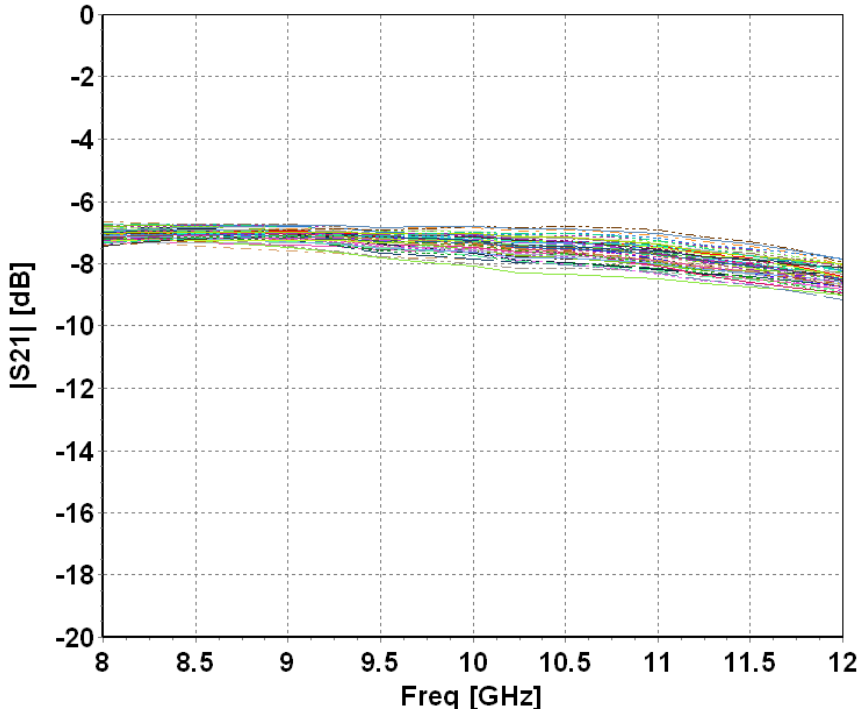
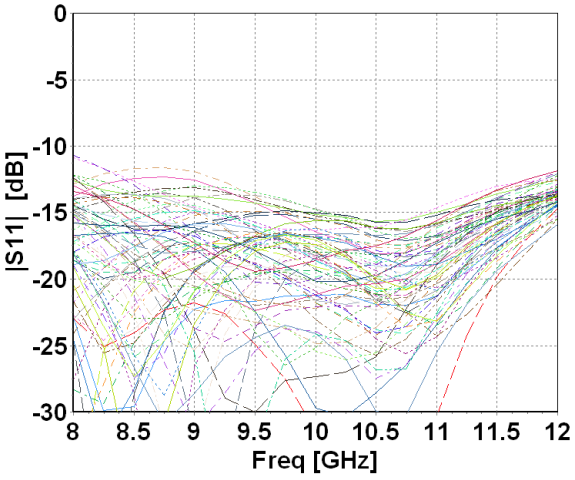
Typical Board Measurements

Tbackside= +25°C, V+ = +5V, V- = -5V

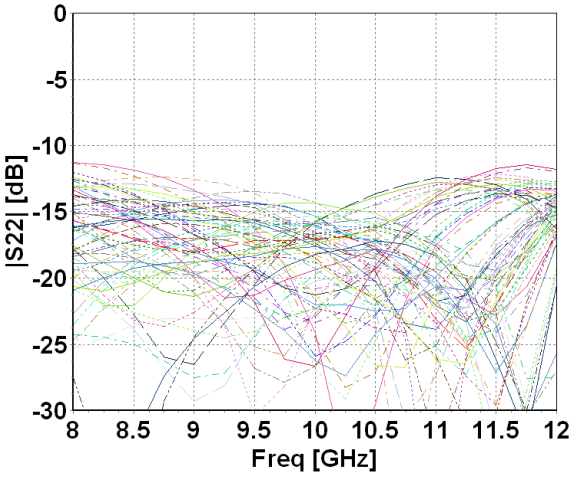
Insertion Loss vs. Frequency @ All States
(after de-embedding of test-fixture insertion loss)



Input Return Losses @ All States



Output Return Losses @ All States



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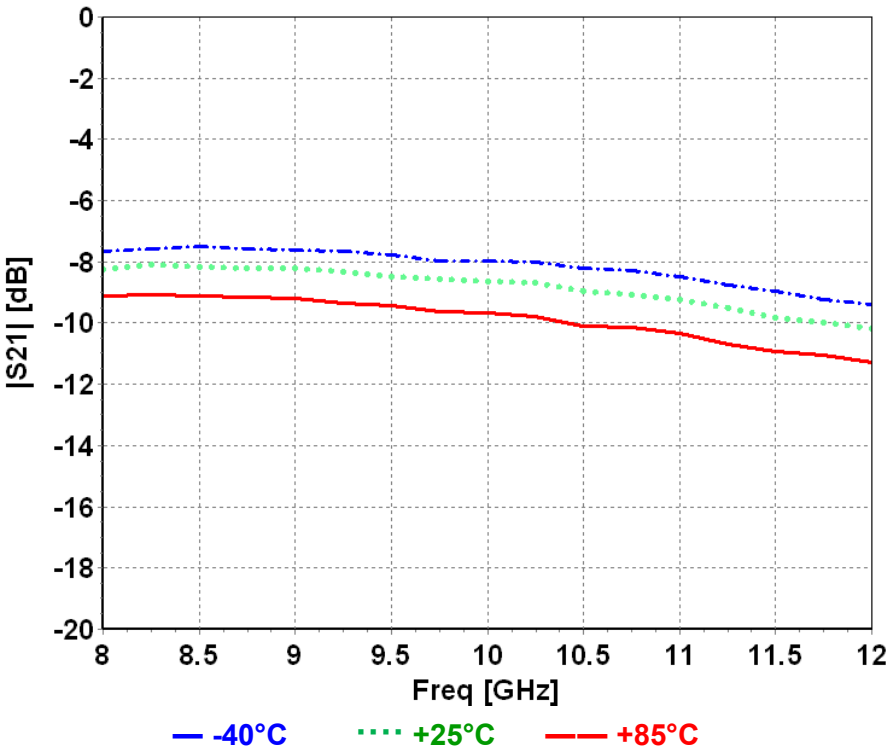
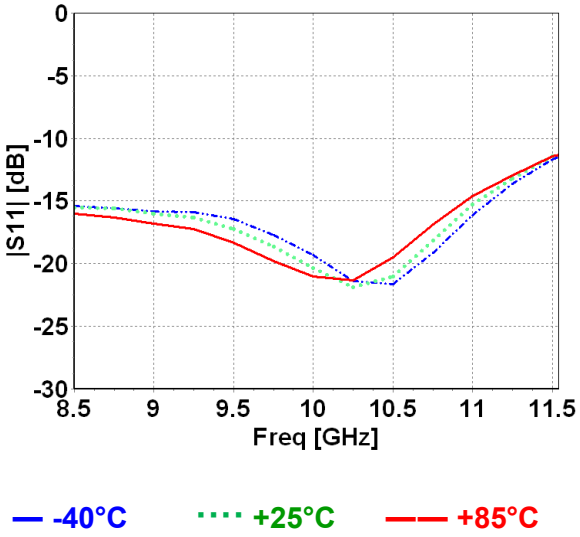
Typical Board Measurements

Temperature .-40°C,+25°C, +85°C V+ = +5V, V- = -5V

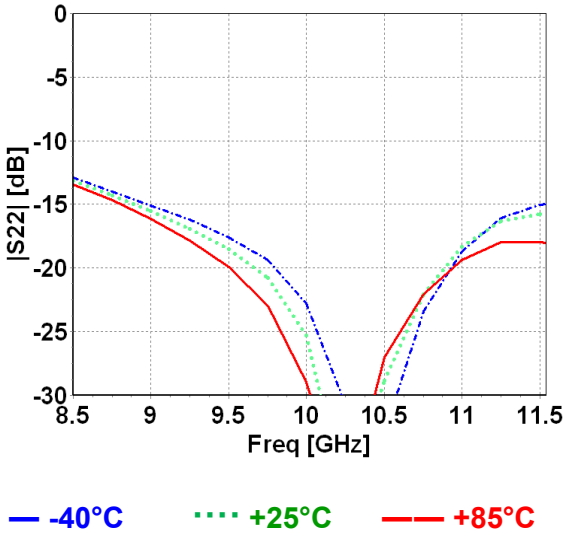
Insertion Loss vs. Frequency @ State 0
(after de-embedding of test-fixture insertion loss)



Input Return Loss @ State 0



Output Return Loss @ State 0



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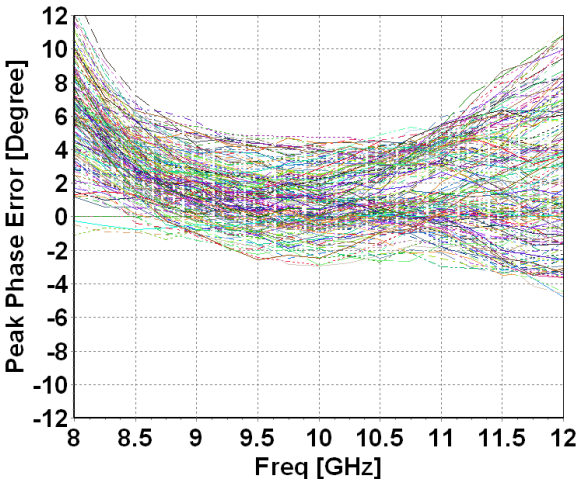
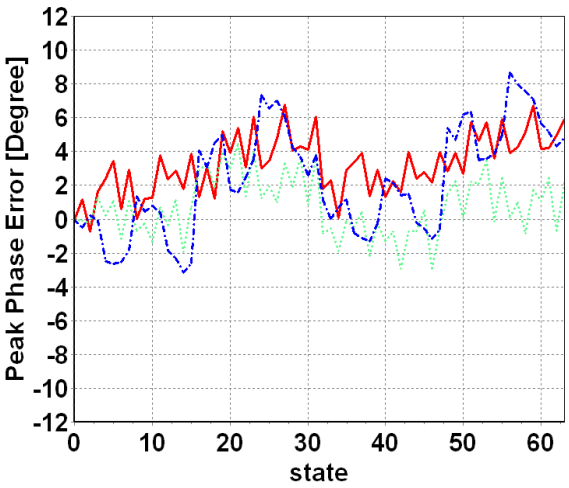
Typical Board Measurements

Tbackside= +25°C, V+ = +5V, V- = -5V

Peak Phase Error vs. Frequency (all states)

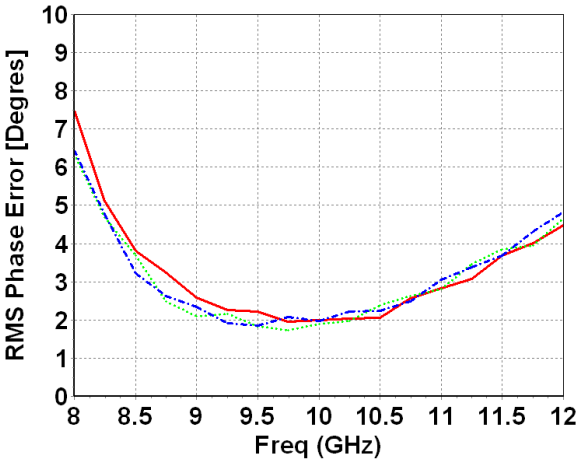


Peak Phase Error vs. State



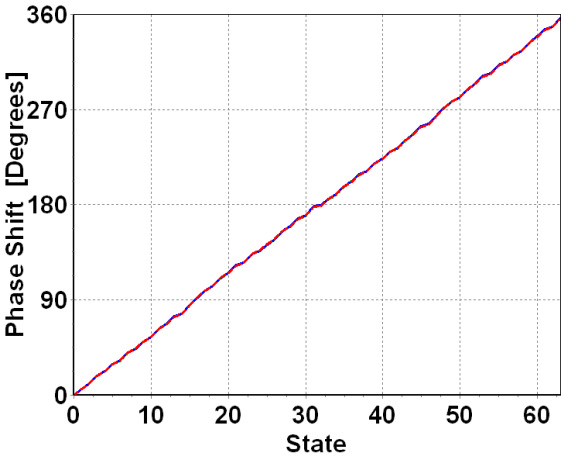
— 8.5GHz ····· 10 GHz — · — 11.5GHz

RMS Phase Error vs. Frequency



— -40°C ··· +25°C —— +85°C

Phase Shift vs. State (@ 10GHz)



— -40°C +25°C —+85°C

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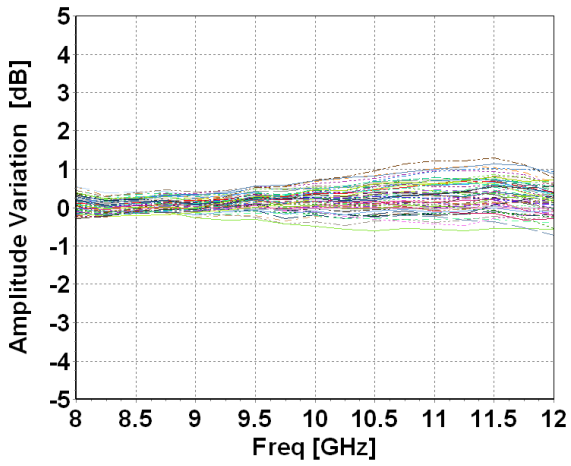
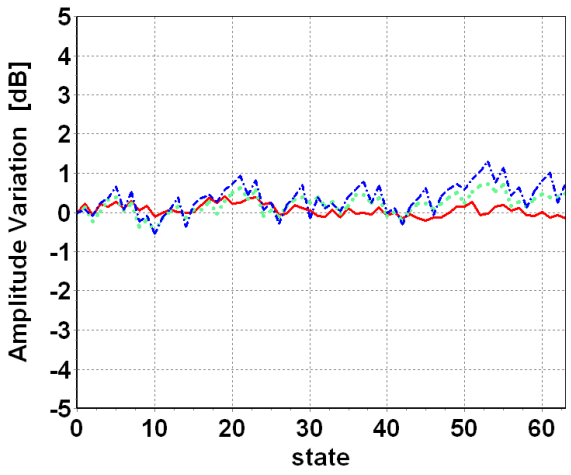
Typical Board Measurements

Tbackside= +25°C, V+ = +5V, V- = -5V

Amplitude Variation vs. Frequency (all states)

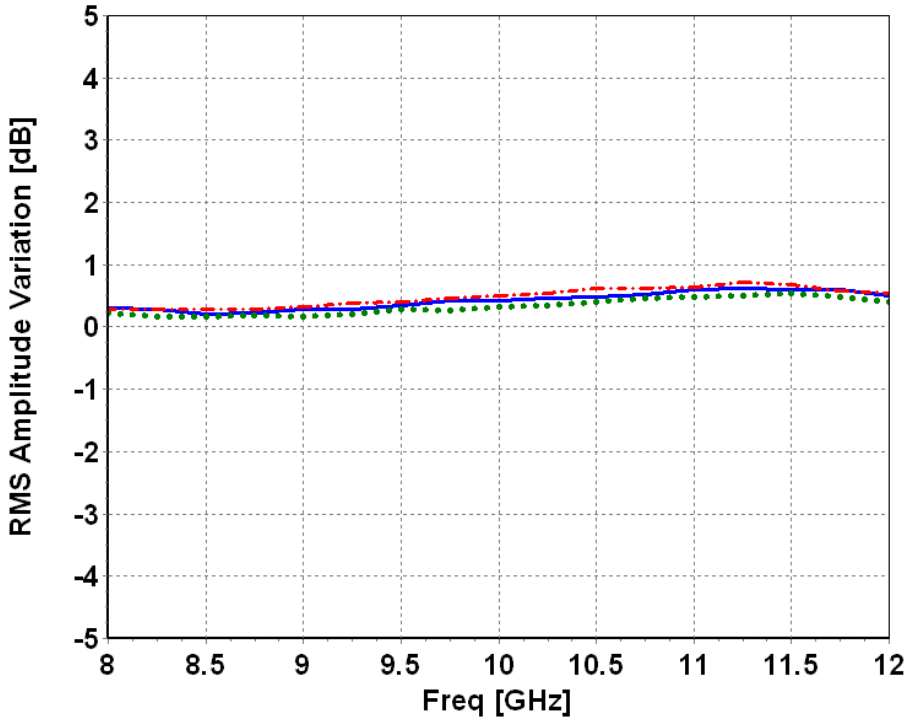


Amplitude Variation vs. State



— 8.5GHz ····· 10 GHz — - — 11.5GHz

RMS Amplitude Variation vs. Frequency



— -40°C ···· +25°C — - — +85°C

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Typical Board Measurements

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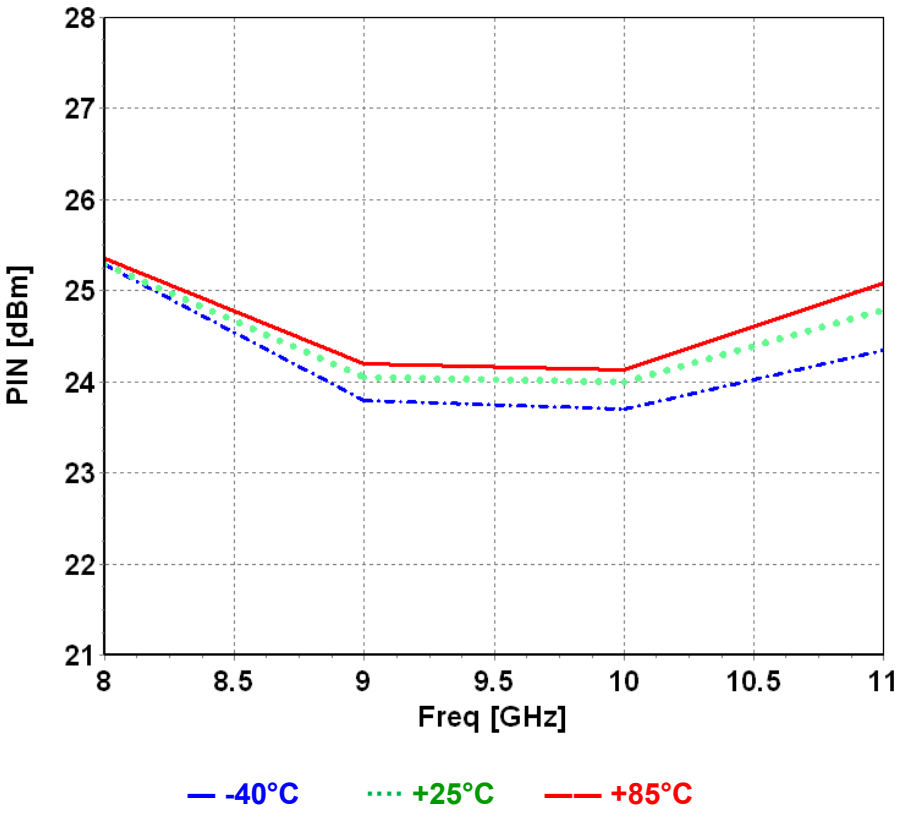
Input Power @ 1dB compression (reference state)



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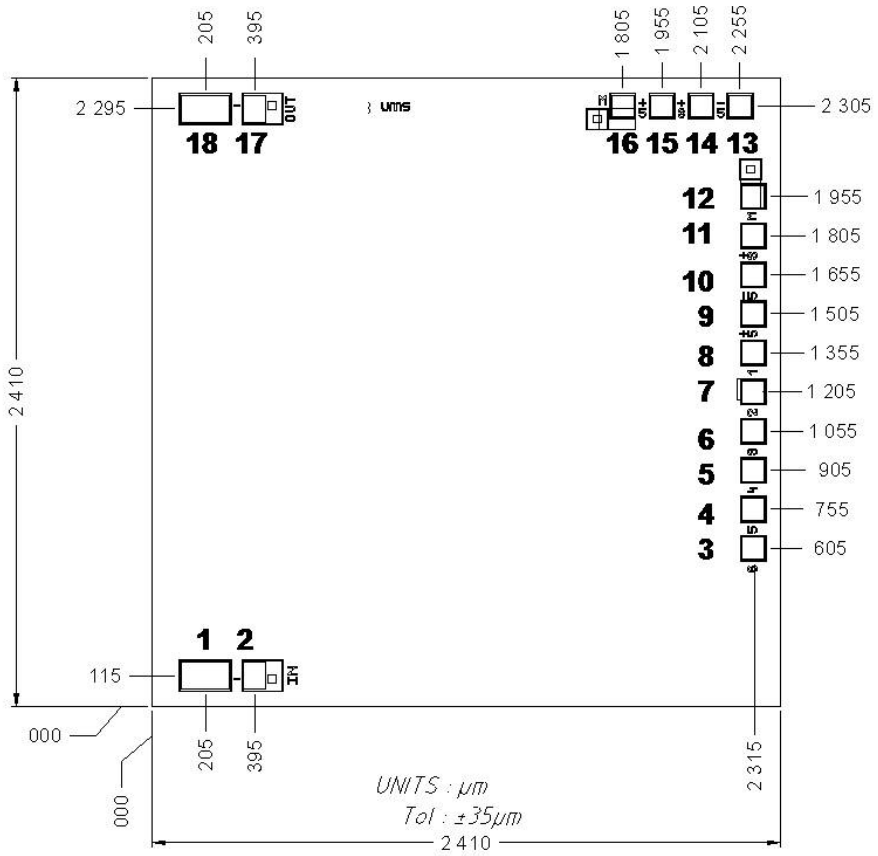
Mechanical data



Chip thickness: 100µm.
Chip size: (2410 ±35)µm x (2410 ±35)µm
All dimensions are in micrometers

Pad number	Pad name	Description
12, 16	M	Ground
2, 17		RF pad Ground
1	IN	RF input
9, 15	+5	+5V interface supply voltage (V+) *
11, 14	+3	+3.3V interface supply voltage (V+) *
10, 13	-5	-5V interface supply voltage (V-)
8	1	Bit 1
7	2	Bit 2
6	3	Bit 3
5	4	Bit 4
4	5	Bit 5
3	6	Bit 6
18	OUT	RF output

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

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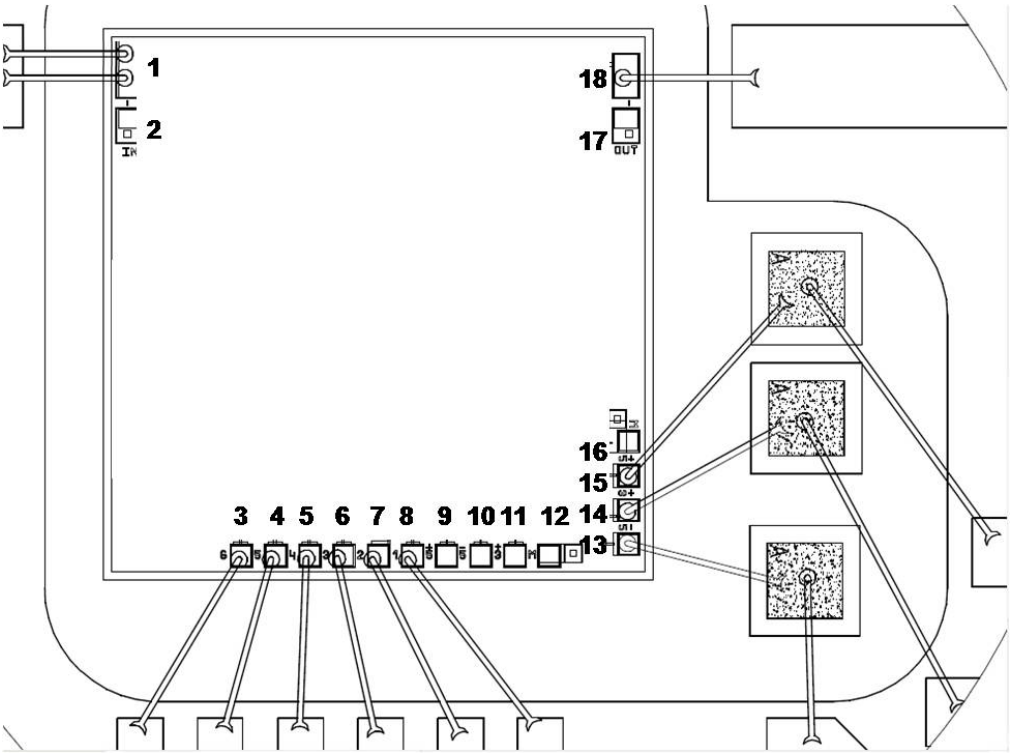
Recommended assembly plan



25µm wedge bonding is preferred

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

Pad number	Decoupling	Connection
1		2 parallel bonding wires (diameter=25µm, length=0.4mm)
18		1 bonding wire (diameter=25µm, length=0.4mm)
from 3 to 8		1 bonding wire (diameter=25µm, length=0.4mm)
13, 14, 15	120pF	1 bonding wire (diameter=25µm, length=0.4mm)

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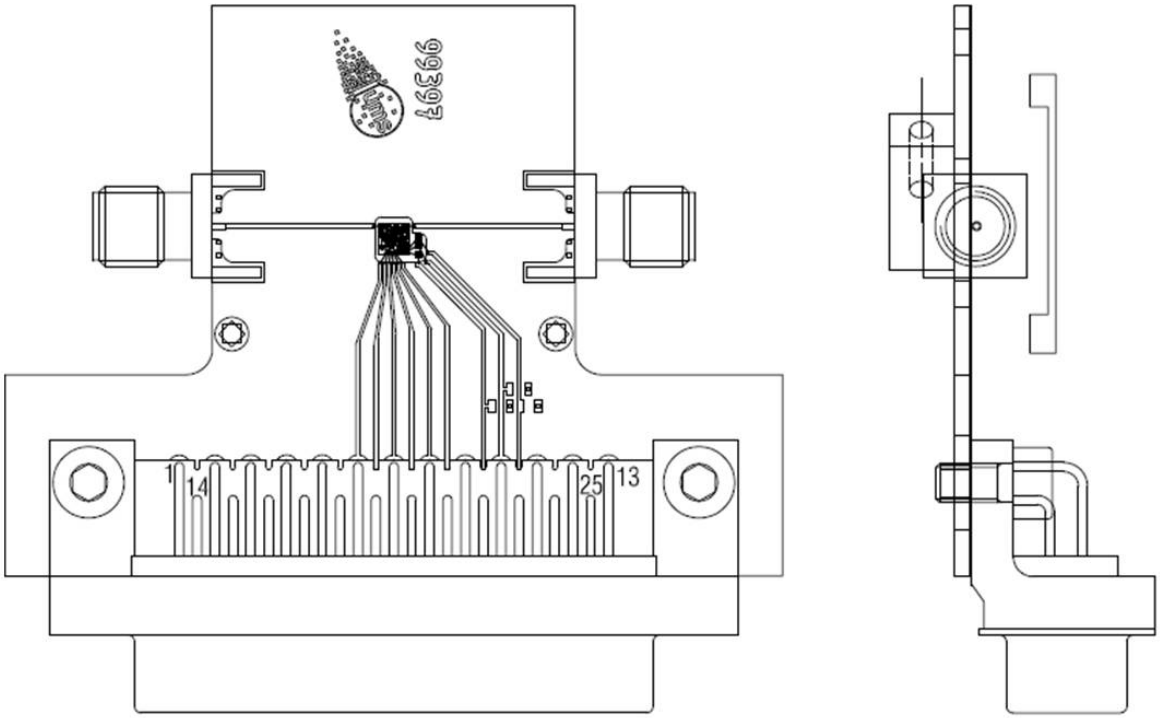
Evaluation mother board

- Based on typically Ro4003 / 8mils or equivalent.



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Notes

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Recommended die assembly process

Refer to the application note AN001 available at https://www.ums-rf.com for die attach.

Recommended ESD management

Refer to the application note AN0020 available at https://www.ums-rf.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 https://www.ums-rf.com.

Ordering Information

Chip form:	CHP3015-99F/00

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