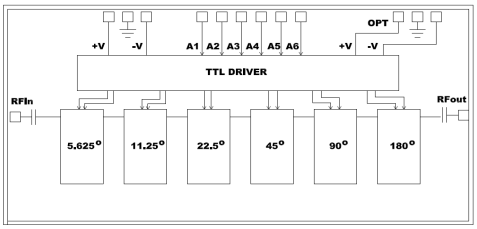
# 3.0- 4.0 GHz 6-Bit Digital Phase Shifter

## Features

- **Frequency Range: 3 to 4 GHz**
- **Low RMS Phase Error ~ 2 deg.**
- **6 dB Maximum Insertion Loss**
- **TTL Control Inputs**
- **21 dBm Input P1dB**
- **Chip Size : 4.5 mm x 2.2 mm x 0.1 mm**

**Functional diagram**




## Typical Applications

- **Military & Space**
- **Radar**

## Description

The AMT2221013 is a 6-bit digital phase shifter MMIC designed to work from 3 to 4 GHz. The phase shifter features a low RMS phase error of less than 2.0 deg over the entire operating band. The insertion loss is 6 dB maximum and varies within ±0.5 dB over the band and the 64 phase states. The phase shifter has an input P1 dB of 21 dBm at +7V & -7V supply Voltages and is capable of handling up to 1 Watt of input power. The input /output ports are well matched to 50 Ohms. The integrated TTL compatible drivers provide convenient digital interface for 6-bit control. The chip operates with +5V and -5V DC supply at a very low current. The MMIC die is fabricated using a robust 0.5µm InGaAs pHEMT technology

## Absolute Maximum Ratings(1)

| Parameter | Absolute Maximum | Units |
|---|---|---|
| RF Input Power | 30 | dBm |
| Positive Supply Voltage | +8 | V |
| Negative Supply Voltage | -8 | V |
| Control Voltage<br>ON<br>OFF | <br>+6<br>-0.5 | <br>V<br>V |
| Operating Temperature | -55 to +85 | $^{o}$C |
| Storage Temperature | -55 to +120 | $^{o}$C |

**1**. Operation beyond these limits may cause permanent damage to the component

## Electrical Specifications @ $T_A$ = 25 $^oC$, $Z_o$ =50 Ω

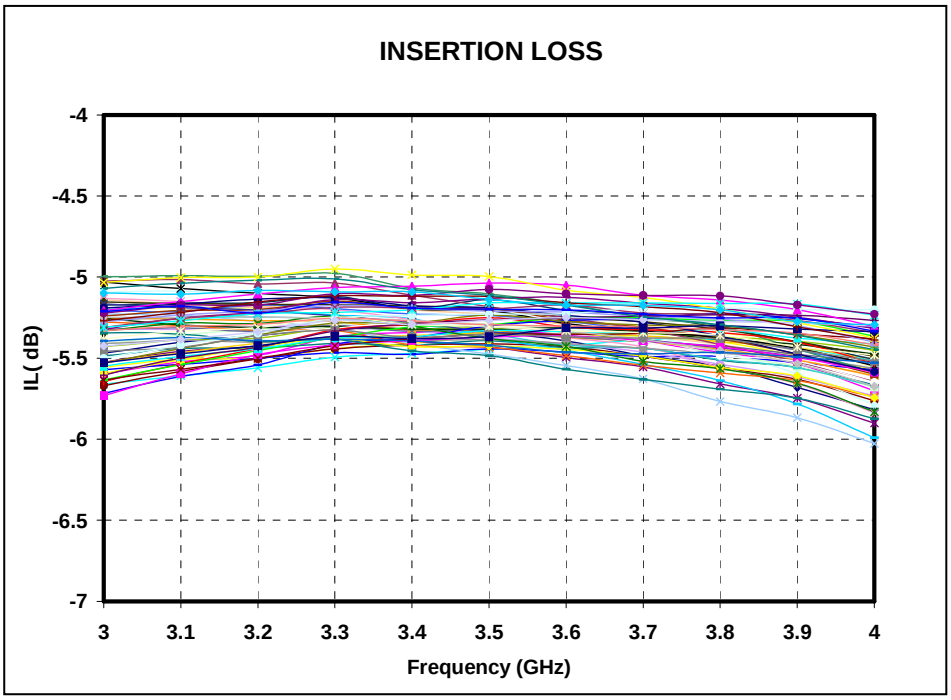
| Parameter | Value | Units |
|---|---|---|
| Bandwidth | 3 to 4 | GHz |
| Phase Shift | 0 – 360 in 64 steps | deg |
| Insertion Loss [1] | 5.5 | dB |
| Peak Amplitude Error | ±0.5 | dB |
| Peak Phase Shift Error | -2 to +4.5 | deg |
| RMS Phase Shift Error (max.) | 2.2 | deg |
| Input Return loss [2] | -9 | dB (max) |
| Output Return Loss [2] | -10 | dB (max) |
| P1 dB @ Input [3] | + 21 | dBm |
| DC Supply Voltages | +5, -5 | V |
| DC Supply Current [4] | 11 | mA |
| DC Control Voltage | | |
| ON | +5 | V |
| OFF | 0 | V |

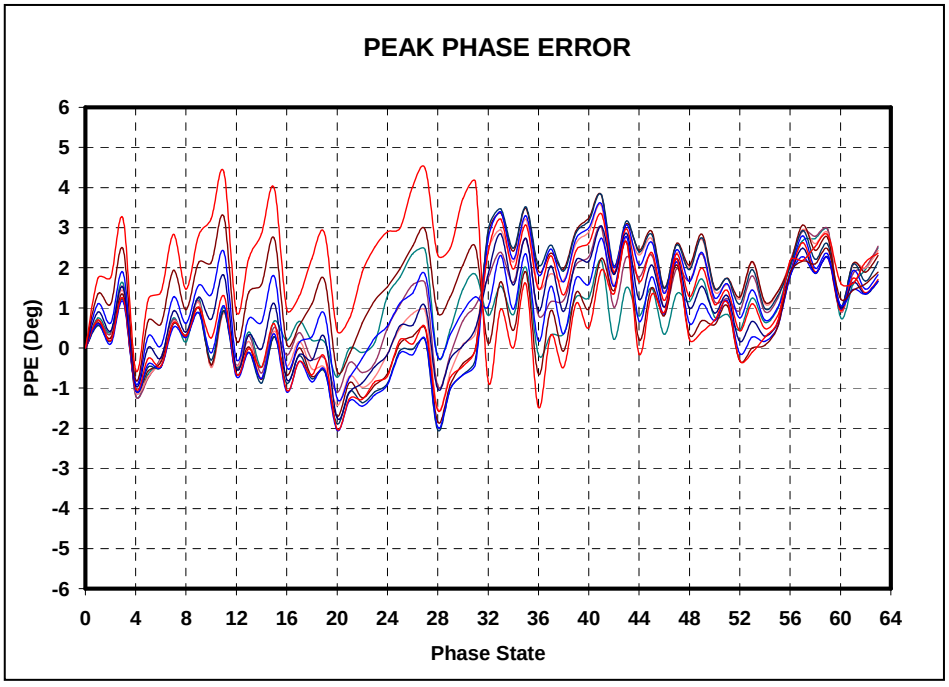
***Note:***

1. Averaged over all the 64 phase states
2. Measured over all the 64 phase states
3. Measured over prime phase states – 0, 5.625, 11.25, 22.5, 45, 90 and 180 degrees.
4. Positive supply draws 7mA, negative supply draws 3mA.

## Test fixture data

*$T_A$ = 25 $^oC$, $Z_0$ =50Ω*

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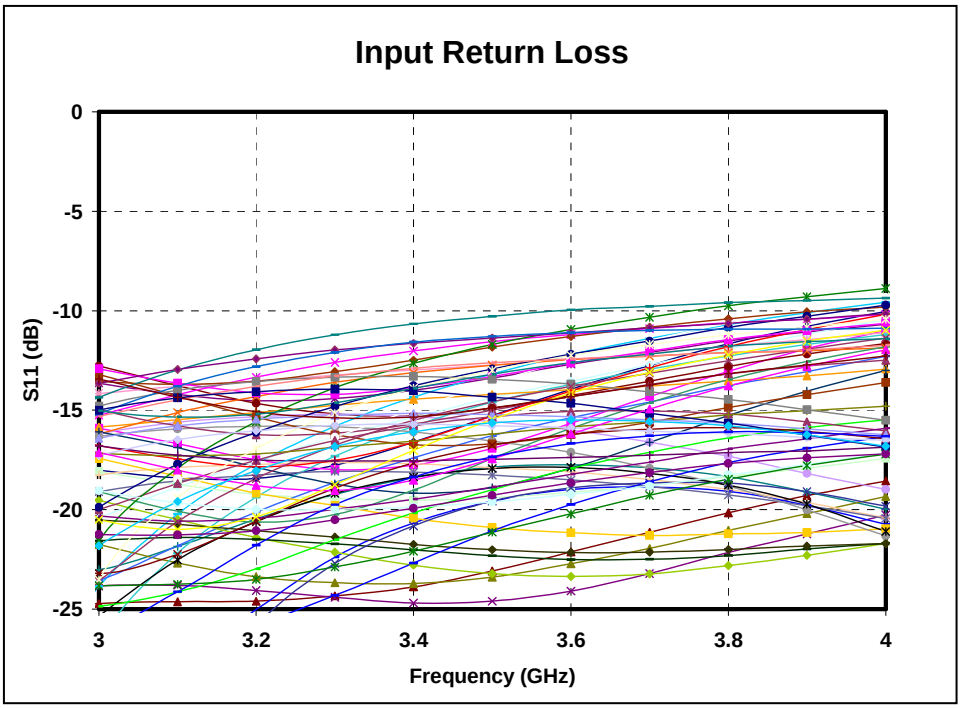


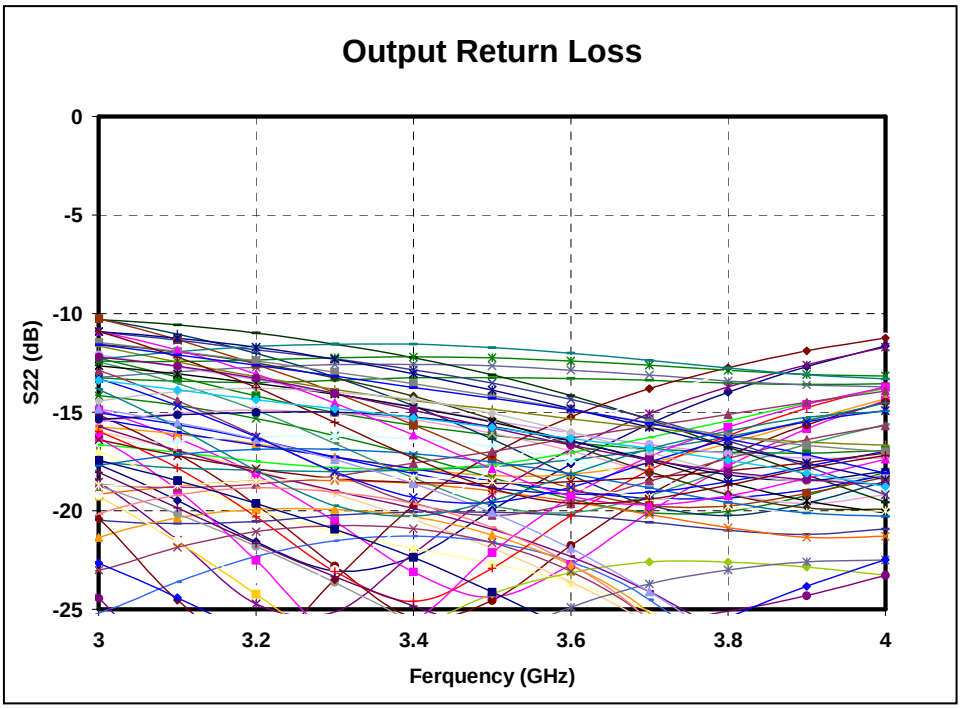


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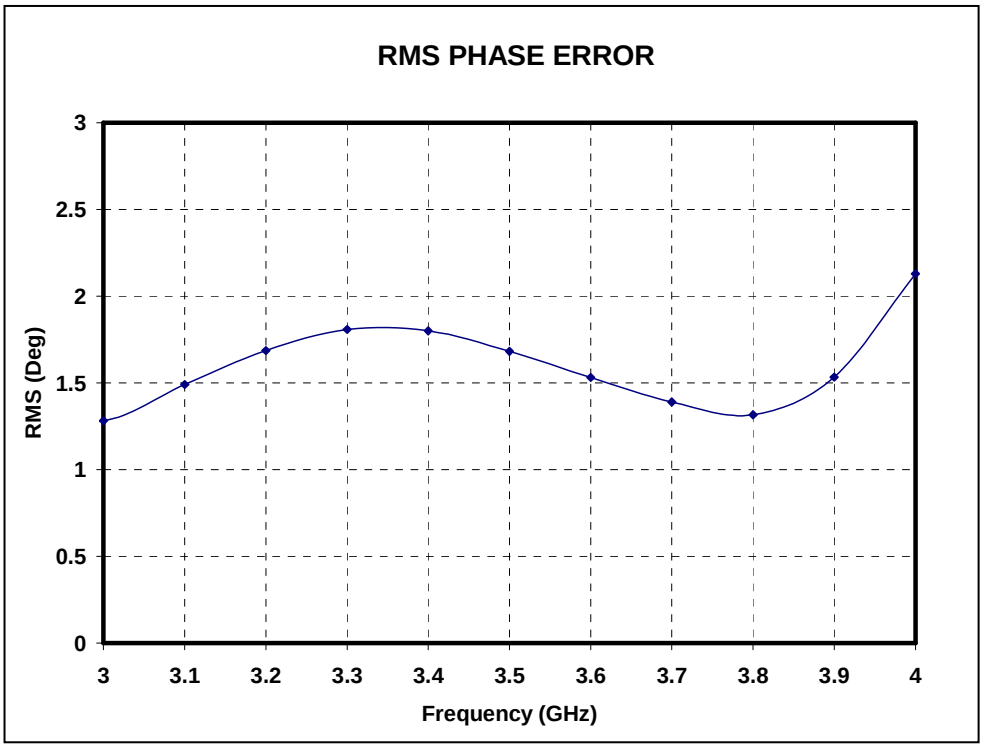

RMS PHASE ERROR
RMS (Deg)
3
2.5
2
1.5
1
0.5
0
3
3.1
3.2
3.3
3.4
3.5
3.6
3.7
3.8
3.9
4
Frequency (GHz)

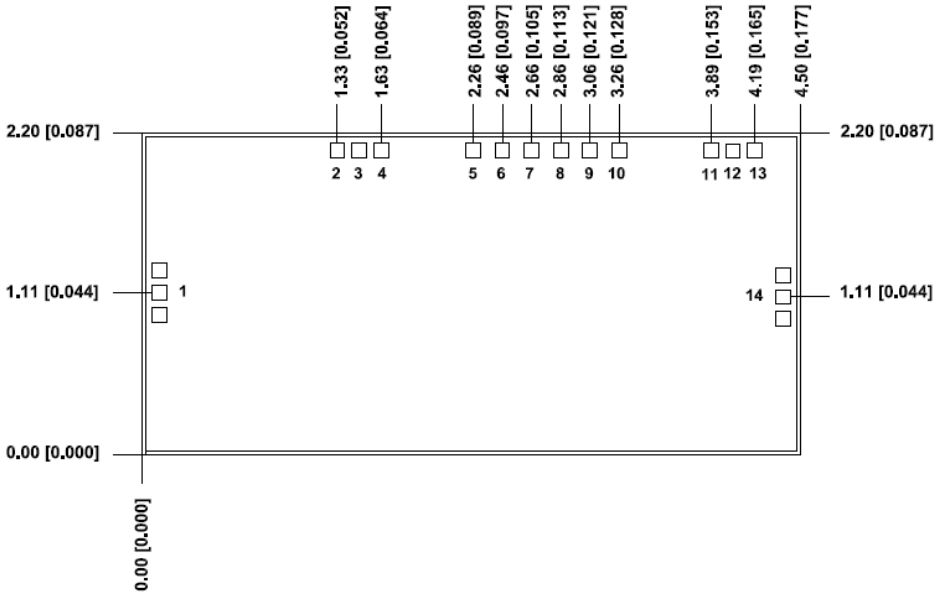
## Truth Table

| S.No. | Phase Shift (deg.) | TTL Control ( 1 = 3.5 to 5 V, 0 = 0 to 0.5 V ) | | | | | |
|---|---|---|---|---|---|---|---|
| | | 180Deg (A6) | 90Deg (A5) | 45Deg (A4) | 22.5Deg (A3) | 11.25Deg (A2) | 5.625Deg (A1) |
| 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2 | 5.625 | 0 | 0 | 0 | 0 | 0 | 1 |
| 3 | 11.25 | 0 | 0 | 0 | 0 | 1 | 0 |
| 4 | 16.875 | 0 | 0 | 0 | 0 | 1 | 1 |
| 5 | 22.5 | 0 | 0 | 0 | 1 | 0 | 0 |
| 6 | 28.125 | 0 | 0 | 0 | 1 | 0 | 1 |
| 7 | 33.75 | 0 | 0 | 0 | 1 | 1 | 0 |
| 8 | 39.375 | 0 | 0 | 0 | 1 | 1 | 1 |
| 9 | 45 | 0 | 0 | 1 | 0 | 0 | 0 |
| 10 | 50.625 | 0 | 0 | 1 | 0 | 0 | 1 |
| 11 | 56.25 | 0 | 0 | 1 | 0 | 1 | 0 |
| 12 | 61.875 | 0 | 0 | 1 | 0 | 1 | 1 |
| 13 | 67.5 | 0 | 0 | 1 | 1 | 0 | 0 |
| 14 | 73.125 | 0 | 0 | 1 | 1 | 0 | 1 |
| 15 | 78.75 | 0 | 0 | 1 | 1 | 1 | 0 |
| 16 | 84.375 | 0 | 0 | 1 | 1 | 1 | 1 |
| 17 | 90 | 0 | 1 | 0 | 0 | 0 | 0 |
| 18 | 95.625 | 0 | 1 | 0 | 0 | 0 | 1 |
| 19 | 101.25 | 0 | 1 | 0 | 0 | 1 | 0 |
| 20 | 106.875 | 0 | 1 | 0 | 0 | 1 | 1 |
| 21 | 112.5 | 0 | 1 | 0 | 1 | 0 | 0 |
| 22 | 118.125 | 0 | 1 | 0 | 1 | 0 | 1 |
| 23 | 123.75 | 0 | 1 | 0 | 1 | 1 | 0 |
| 24 | 129.375 | 0 | 1 | 0 | 1 | 1 | 1 |
| 25 | 135 | 0 | 1 | 1 | 0 | 0 | 0 |
| 26 | 140.625 | 0 | 1 | 1 | 0 | 0 | 1 |
| 27 | 146.25 | 0 | 1 | 1 | 0 | 1 | 0 |
| 28 | 151.875 | 0 | 1 | 1 | 0 | 1 | 1 |
| 29 | 157.5 | 0 | 1 | 1 | 1 | 0 | 0 |
| 30 | 163.125 | 0 | 1 | 1 | 1 | 0 | 1 |
| 31 | 168.75 | 0 | 1 | 1 | 1 | 1 | 0 |
| 32 | 174.375 | 0 | 1 | 1 | 1 | 1 | 1 |
| 33 | 180 | 1 | 0 | 0 | 0 | 0 | 0 |
| 34 | 185.625 | 1 | 0 | 0 | 0 | 0 | 1 |
| 35 | 191.25 | 1 | 0 | 0 | 0 | 1 | 0 |

## Truth Table

| S.No. | Phase Shift | TTL Control ( 1 = 3.5 to 5 V, 0 = 0 to 0.5 V ) | | | | | |
|---|---|---|---|---|---|---|---|
| | | 180Deg (A6) | 90Deg (A5) | 45Deg (A4) | 22.5Deg (A3) | 11.25Deg (A2) | 5.625Deg (A1) |
| 36 | 196.875 | 1 | 0 | 0 | 0 | 1 | 1 |
| 37 | 202.5 | 1 | 0 | 0 | 1 | 0 | 0 |
| 38 | 208.125 | 1 | 0 | 0 | 1 | 0 | 1 |
| 39 | 213.75 | 1 | 0 | 0 | 1 | 1 | 0 |
| 40 | 219.375 | 1 | 0 | 0 | 1 | 1 | 1 |
| 41 | 225 | 1 | 0 | 1 | 0 | 0 | 0 |
| 42 | 230.625 | 1 | 0 | 1 | 0 | 0 | 1 |
| 43 | 236.25 | 1 | 0 | 1 | 0 | 1 | 0 |
| 44 | 241.875 | 1 | 0 | 1 | 0 | 1 | 1 |
| 45 | 247.5 | 1 | 0 | 1 | 1 | 0 | 0 |
| 46 | 253.125 | 1 | 0 | 1 | 1 | 0 | 1 |
| 47 | 258.75 | 1 | 0 | 1 | 1 | 1 | 0 |
| 48 | 264.375 | 1 | 0 | 1 | 1 | 1 | 1 |
| 49 | 270 | 1 | 1 | 0 | 0 | 0 | 0 |
| 50 | 275.625 | 1 | 1 | 0 | 0 | 0 | 1 |
| 51 | 281.25 | 1 | 1 | 0 | 0 | 1 | 0 |
| 52 | 286.875 | 1 | 1 | 0 | 0 | 1 | 1 |
| 53 | 292.5 | 1 | 1 | 0 | 1 | 0 | 0 |
| 54 | 298.125 | 1 | 1 | 0 | 1 | 0 | 1 |
| 55 | 303.75 | 1 | 1 | 0 | 1 | 1 | 0 |
| 56 | 309.375 | 1 | 1 | 0 | 1 | 1 | 1 |
| 57 | 315 | 1 | 1 | 1 | 0 | 0 | 0 |
| 58 | 320.625 | 1 | 1 | 1 | 0 | 0 | 1 |
| 59 | 326.25 | 1 | 1 | 1 | 0 | 1 | 0 |
| 60 | 331.875 | 1 | 1 | 1 | 0 | 1 | 1 |
| 61 | 337.5 | 1 | 1 | 1 | 1 | 0 | 0 |
| 62 | 343.125 | 1 | 1 | 1 | 1 | 0 | 1 |
| 63 | 348.75 | 1 | 1 | 1 | 1 | 1 | 0 |
| 64 | 354.375 | 1 | 1 | 1 | 1 | 1 | 1 |

## Mechanical Characteristics



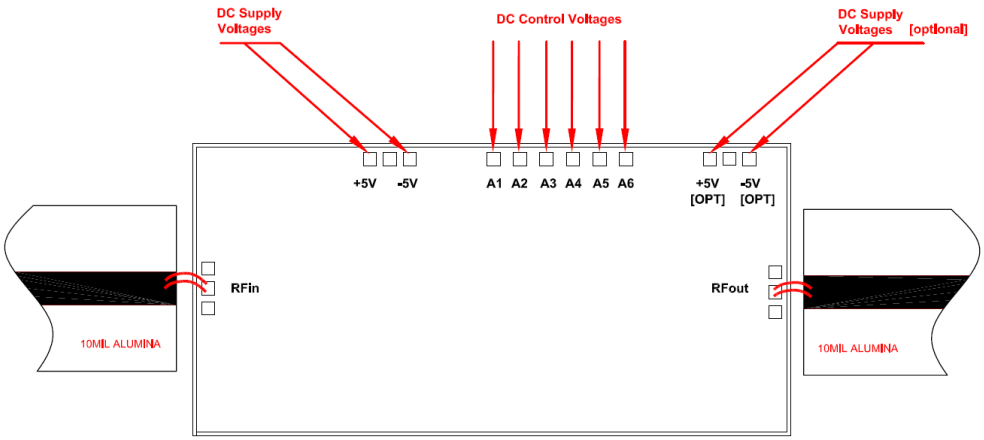

**Units: millimeters (inches)**

**All RF and DC bond pads are 100µm x 100µm**

## PAD DESIGNATIONS

| Pad No. | Function | Pad No. | Function |
|---|---|---|---|
| 1 | RF INPUT | 8 | CTRL BIT – 4 (45$^{o}$) |
| 2 | +Vcc (+5V) | 9 | CTRL BIT – 5 (90$^{o}$) |
| 3 | GND | 10 | CTRL BIT – 6 (180$^{o}$) |
| 4 | -Vcc (-5V) | 11 | +Vcc (Optional) |
| 5 | CTRL BIT – 1 (5.625$^{o}$) | 12 | GND |
| 6 | CTRL BIT – 2 (11.25$^{o}$) | 13 | -Vcc (Optional) |
| 7 | CTRL BIT – 3 (22.5$^{o}$) | 14 | RF OUTPUT |

## Recommended Assembly Diagram




**Note:**

1. It is recommended to use series resistors ~100-200 Ω at all the control inputs
2. DC Supply Pads are given on both sides of the Control Input Pads. Either of the pads can be used.
3. For giving +Vcc and –Vcc supplies, 100 pF capacitor should be used as a bypass as close to the chip as possible.

**Die attach:** For Epoxy attachment, use of a two-component conductive epoxy is recommended. An epoxy fillet should be visible around the total die periphery. If Eutectic attachment is preferred, use of fluxless AuSn (80/20) 1-2 mil thick preform solder is recommended. Use of AuGe preform should be strictly avoided.

**Wire bonding:** For DC pad connections use either ball or wedge bonds. For best RF performance, use of 150 - 200µm length of wedge bonds is advised. Single Ball bonds of 250-300µm though acceptable, may cause a deviation in RF performance.


***GaAs MMIC devices are susceptible to Electrostatic discharge. Proper precautions should be observed during handling, assembly & testing***

All information and Specifications are subject to change without prior notice