# TQL9047

## High Linearity Gain Block

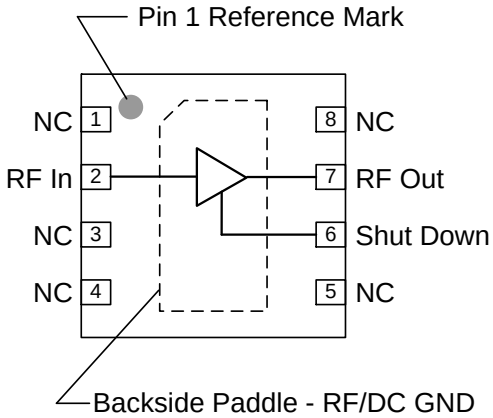
## Product Overview

The TQL9047 is a cascadable, high linearity gain block amplifier in a low-cost surface mount package. At 1.9 GHz, the amplifier typically provides 14.5 dB gain, +35.5 dBm OIP3 and 1.6 dB Noise Figure while drawing 70 mA current from a 5V supply.

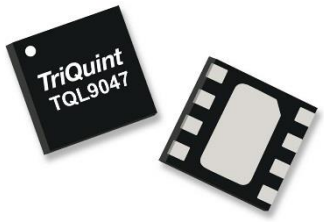
The TQL9047 features medium gain across a broad range of frequencies with the integration of a shut-down biasing capability to allow for operation for TDD applications. The low noise figure and high linearity performance allows the device to be used in both receiver and transmitter chains for high performance systems. The internal active bias circuit also enables stable operation over bias and temperature variations and can be biased from a single positive supply ranging from +3.3 to +5 volts. The amplifier is internally matched using a high performance E-pHEMT process and is housed in a small 2 x 2 mm surface-mount package.

The TQL9047 covers the 700 – 4200 MHz frequency band and is targeted for wireless infrastructure or other applications requiring high linearity and/or low noise figure.

## Functional Block Diagram




Top View




8 pin 2x2 mm DFN Package

## Key Features

- 50 – 4200 MHz Operational Bandwidth
- Flat Gain (14.5 ± 1 dB) from 0.7 to 2.7 GHz
- High Linearity, +35.5 dBm Output IP3
- 1.6 dB Noise Figure
- Integrated On-chip Matching, 50 ohm In/Out
- Integrated Active Bias
- Integrated Shutdown Control Pin

## Applications

- Base Station Transceivers and Repeaters
- Defense Communications
- General Purpose Wireless
- Test Instrumentation
- TDD or FDD systems

## Ordering Information

| Part No. | Description |
|---|---|
| TQL9047 | 2,500 pieces on a 7” reel (standard) |
| TQL9047-PCB_RF | 0.5 – 4.0 GHz Evaluation Board |
| TQL9047-PCB_IF | 50 – 500 MHz Evaluation Board |

## Absolute Maximum Ratings

| Parameter | Rating |
|---|---|
| Storage Temperature | −65 to +150 °C |
| Supply Voltage ($V_{DD}$) | +7 V |
| RF Input Power, CW, 50Ω, T=25°C | +20 dBm |

Exceeding any one or a combination of the Absolute Maximum Rating conditions may cause permanent damage to the device. Extended application of Absolute Maximum Rating conditions to the device may reduce device reliability.

## Recommended Operating Conditions

| Parameter | Min | Typ | Max | Units |
|---|---|---|---|---|
| Supply Voltage ($V_{DD}$) | +3.0 | +5.0 | +5.25 | V |
| $T_{CASE}$ | −40 | | +105 | °C |
| Tj at $T_{CASE}$ max | | | +138 | °C |
| Tj for >$10^6$ hours MTTF | | | +190 | °C |

Electrical specifications are measured at specified test conditions. Specifications are not guaranteed over all recommended operating conditions.

## Electrical Specifications

| Parameter | Conditions[1] | Min | Typ | Max | Units |
|---|---|---|---|---|---|
| Operational Frequency Range | | 50 | | 4200 | MHz |
| Test Frequency | | | 1900 | | MHz |
| Gain | | 13.0 | 14.5 | 16.0 | dB |
| Input Return Loss | | | 11 | | dB |
| Output Return Loss | | | 13 | | dB |
| Noise Figure | | | 1.6 | 3.0 | dB |
| Output P1dB | | +18 | +20.8 | | dBm |
| Output IP3 | Pout = +4 dBm / tone, Δf = 1 MHz | +32 | +35.5 | | dBm |
| Power Shutdown Control (Pin 6) | On state | 0 | | +0.5 | V |
| | Off state (Power down) | +1.4 | +3.3 | $V_{DD}$ | V |
| Current, $I_{DD}$ | On state | | 70 | 100 | mA |
| | Off state (Power down) | | 3 | 5 | mA |
| Shutdown pin current, $I_{SD}$ | $V_{PD}$ ≥ +1.4 V | | 250 | | µA |
| Thermal Resistance, $\theta_{jc}$ | Channel to case | | | 62 | °C/W |

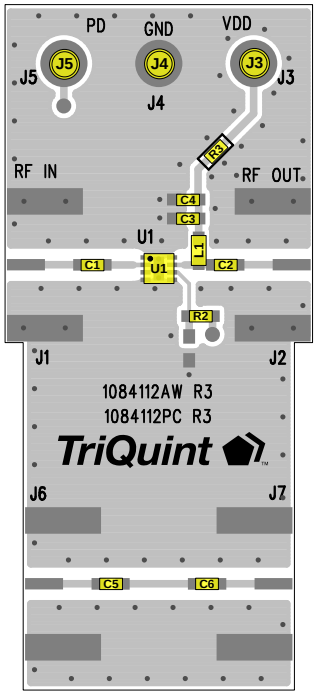
Notes:
1. Test conditions unless otherwise noted: $V_{DD}$ = +5 V, Temp. = +25 °C, 50 Ω system.

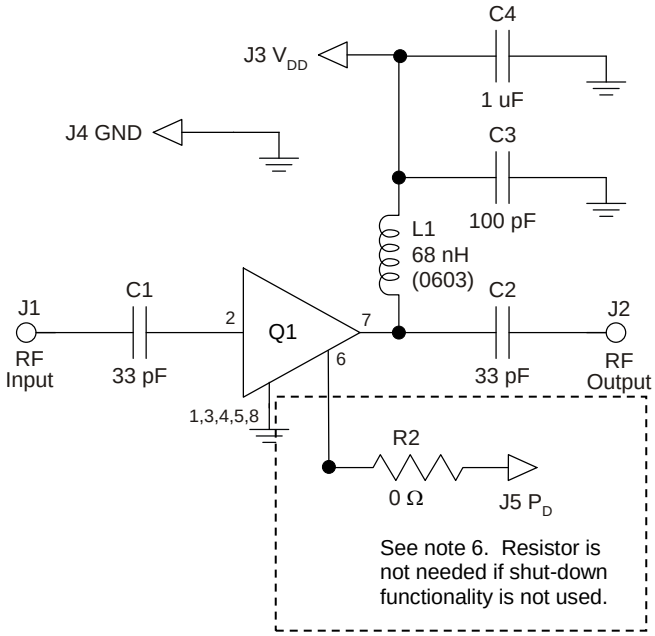
## S-Parameters

| Freq (GHz) | S11 (dB) | S11 (ang) | S21 (dB) | S21 (ang) | S12 (dB) | S12 (ang) | S22 (dB) | S22 (ang) |
|---|---|---|---|---|---|---|---|---|
| 0.05 | -14.7 | -82.4 | 17.5 | 163.7 | -20.4 | 10.7 | -24.7 | -89.6 |
| 0.1 | -19.4 | -117.5 | 16.9 | 164.3 | -20.0 | 3.6 | -18.2 | -156.9 |
| 0.2 | -22.9 | -146.3 | 16.7 | 159.8 | -19.8 | -2.1 | -18.6 | 173.6 |
| 0.3 | -25.2 | -165.5 | 16.6 | 153.1 | -19.8 | -6.1 | -19.2 | 153.6 |
| 0.4 | -26.5 | -174.9 | 16.5 | 145.7 | -19.7 | -9.4 | -19.1 | 137.5 |
| 0.5 | -29.3 | 179.8 | 16.4 | 138.2 | -19.7 | -12.5 | -19.1 | 121.5 |
| 0.6 | -32.8 | 172.9 | 16.3 | 130.7 | -19.7 | -15.7 | -19.5 | 107.6 |
| 0.7 | -40.1 | -174.1 | 16.2 | 123.1 | -19.7 | -18.7 | -19.7 | 93.5 |
| 0.8 | -43.3 | -61.6 | 16.1 | 115.6 | -19.6 | -21.9 | -19.8 | 78.8 |
| 0.9 | -33.6 | -45.7 | 16.0 | 108.1 | -19.6 | -25.0 | -20.0 | 64.2 |
| 1.0 | -28.8 | -45.4 | 15.9 | 100.6 | -19.6 | -28.3 | -20.2 | 50.0 |
| 1.1 | -25.7 | -48.8 | 15.8 | 93.1 | -19.6 | -31.5 | -20.3 | 35.7 |
| 1.2 | -23.3 | -51.6 | 15.6 | 85.7 | -19.6 | -34.8 | -20.3 | 21.1 |
| 1.3 | -21.4 | -55.3 | 15.5 | 78.3 | -19.6 | -38.1 | -20.4 | 6.1 |
| 1.4 | -19.9 | -59.1 | 15.4 | 71.0 | -19.6 | -41.4 | -20.3 | -8.8 |
| 1.5 | -18.7 | -63.2 | 15.3 | 63.6 | -19.6 | -44.8 | -20.0 | -23.9 |
| 1.6 | -17.6 | -67.2 | 15.2 | 56.4 | -19.6 | -48.2 | -19.7 | -38.4 |
| 1.7 | -16.7 | -71.3 | 15.1 | 49.1 | -19.6 | -51.7 | -19.2 | -52.2 |
| 1.8 | -15.9 | -75.5 | 14.9 | 41.9 | -19.7 | -55.2 | -18.7 | -65.6 |
| 1.9 | -15.3 | -79.7 | 14.8 | 34.6 | -19.7 | -58.6 | -18.1 | -78.2 |
| 2.0 | -14.7 | -84.0 | 14.7 | 27.4 | -19.7 | -62.1 | -17.5 | -89.8 |
| 2.1 | -14.2 | -88.2 | 14.6 | 20.1 | -19.8 | -65.6 | -16.9 | -100.9 |
| 2.2 | -13.8 | -92.5 | 14.5 | 12.8 | -19.8 | -69.1 | -16.3 | -111.1 |
| 2.3 | -13.5 | -96.8 | 14.4 | 5.5 | -19.8 | -72.6 | -15.8 | -120.8 |
| 2.4 | -13.2 | -101.1 | 14.3 | -1.8 | -19.8 | -76.2 | -15.3 | -130.2 |
| 2.5 | -13.0 | -105.5 | 14.3 | -9.2 | -19.9 | -79.8 | -14.8 | -138.9 |
| 2.6 | -12.9 | -109.9 | 14.2 | -16.7 | -19.9 | -83.6 | -14.4 | -147.7 |
| 2.7 | -12.8 | -114.3 | 14.1 | -24.2 | -19.9 | -87.2 | -13.9 | -156.5 |
| 2.8 | -12.7 | -118.6 | 14.1 | -32.0 | -19.9 | -91.0 | -13.6 | -165.2 |
| 2.9 | -12.7 | -122.8 | 14.0 | -39.7 | -19.9 | -94.7 | -13.2 | -173.9 |
| 3.0 | -12.7 | -126.9 | 13.9 | -47.6 | -19.9 | -98.7 | -13.0 | 177.1 |
| 3.1 | -12.7 | -130.7 | 13.8 | -55.7 | -19.9 | -102.7 | -12.7 | 168.1 |
| 3.2 | -12.8 | -134.3 | 13.8 | -64.0 | -19.9 | -106.8 | -12.4 | 158.8 |
| 3.3 | -12.9 | -137.7 | 13.7 | -72.4 | -19.8 | -111.0 | -12.2 | 149.4 |
| 3.4 | -13.0 | -140.3 | 13.6 | -81.0 | -19.8 | -115.4 | -12.0 | 139.8 |
| 3.5 | -13.0 | -142.4 | 13.5 | -89.7 | -19.7 | -119.9 | -11.8 | 129.8 |
| 3.6 | -13.0 | -143.9 | 13.3 | -98.8 | -19.7 | -124.7 | -11.7 | 119.6 |
| 3.8 | -12.8 | -144.2 | 13.0 | -117.3 | -19.5 | -134.7 | -11.5 | 98.0 |
| 4.0 | -11.8 | -143.1 | 12.5 | -136.6 | -19.4 | -145.8 | -11.5 | 75.3 |
| 4.2 | -10.1 | -140.1 | 12.0 | -160.1 | -19.5 | -160.5 | -12.5 | 49.0 |

Test Conditions: $V_{DD}$=+5 V, $I_{DD}$=70 mA (typ.), Temp.=+25 °C, unmatched 50 Ohm system, reference plane at device leads

## TQL9047-PCB_RF Evaluation Board




Notes:

1. See Evaluation Board PCB Information section for material and stack-up.
2. R3 (0 Ω jumper) is not shown on the schematic and may be replaced with copper trace in the target application layout.
3. All components are of 0402 size unless stated on the schematic.
4. C1, C2, and C3 are non-critical values. The reactive impedance should be as low as possible at the frequency of operation for optimal performance.
5. The L1 value is non-critical and needs to provide high reactive impedance at the frequency of operation.
6. R2 is optional and does not need to be loaded if the shut-down functionality is not needed; i.e. FDD applications. If R2 is not loaded, the LNA will operate in its standard “ON” state.
7. A through line is included on the evaluation board to de-embed the board losses.

## Bill of Material − TQL9047-PCB_RF

| Reference Des. | Value | Description | Manuf. | Part Number |
|---|---|---|---|---|
| N/A | N/A | Printed Circuit Board | Qorvo | N/A |
| U1 | N/A | High Linearity Gain Block | Qorvo | TQL9047 |
| R1 | N/A | Do not load | N/A | N/A |
| R2 | 0 Ω | Resistor, Chip, 0402, 5%, 1/16W | various | various |
| R3 | 0 Ω | Resistor, Chip, 0402, 5%, 1/16W | various | various |
| L1 | 68 nH | Inductor, 0603, 5%, Ceramic | various | various |
| C4 | 1.0 uF | Cap., Chip, 0402, 10%, 10V, X5R | various | Various |
| C1, C2, C3, C5, C6 | 33 pF | Cap., Chip, 0402, 5%, 50V, NPO/COG | various | Various |

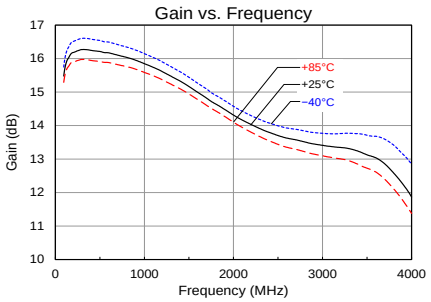
## Typical Performance – TQL9047-PCB_RF

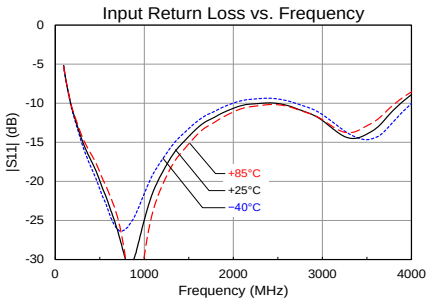
| Parameter | Conditions[1] | Typical Values | | | | | Units |
|---|---|---|---|---|---|---|---|
| Frequency | | 900 | 1900 | 2700 | 3500 | 4200 | MHz |
| Gain | | 16 | 14.5 | 13.5 | 13.0 | 11.2 | dB |
| Input Return Loss | | 28 | 11 | 10 | 14 | 8.0 | dB |
| Output Return Loss | | 19 | 13 | 13 | 20 | 10.2 | dB |
| Output P1dB | | +21 | +20.8 | +20.5 | +19.2 | +17.9 | dBm |
| OIP3 | Pout = +4 dBm / tone, Δf = 1 MHz | +35.8 | +35.5 | +35.5 | +33.3 | +31.4 | dBm |
| Noise figure [2] | | 1.5 | 1.6 | 1.9 | 2.7 | 3.7 | dB |

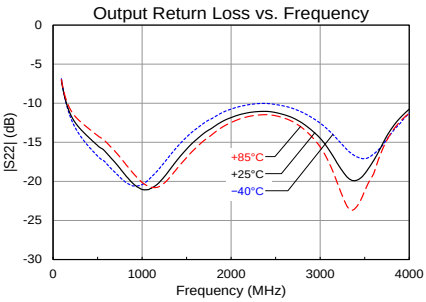
Notes:
1. Test conditions unless otherwise noted: $V_{DD}$ = +5 V, $I_{DD}$ = 70 mA (typ.), Temp. = +25 °C
2. Noise figure data shown in the table above is de-embedded from the eval board loss.

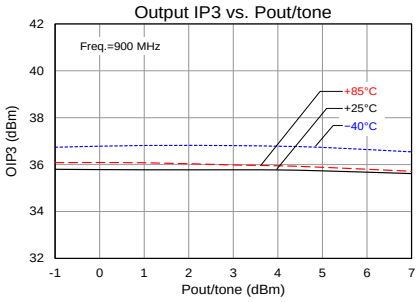
## Performance Plots – TQL9047-PCB_RF

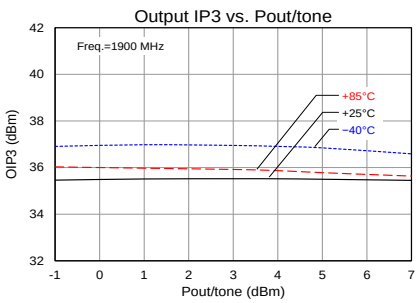
Test conditions unless otherwise noted: $V_{DD}$ = +5 V, $I_{DD}$ = 70 mA (typ.), Temp. = +25 °C

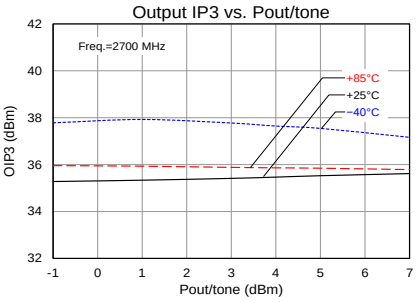


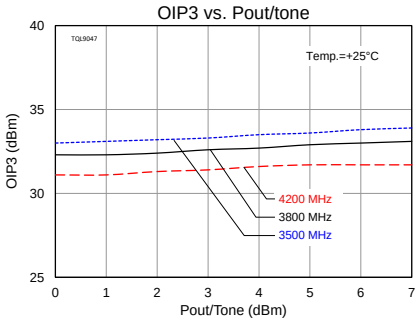



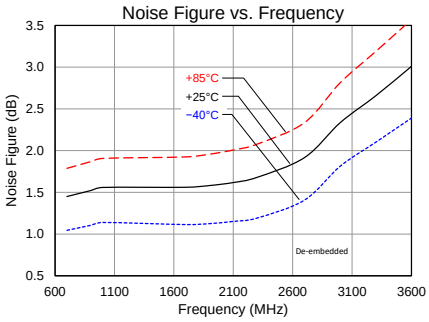



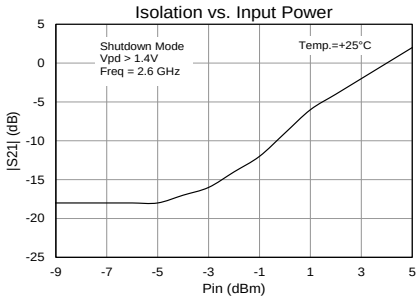



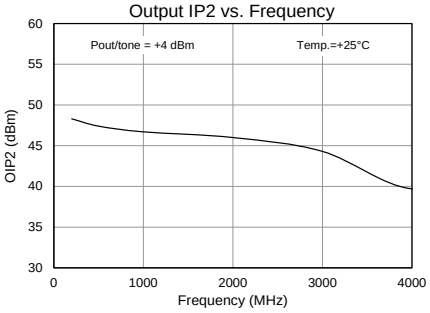
## Performance Plots − TQL9047-PCB_RF (cont'd)

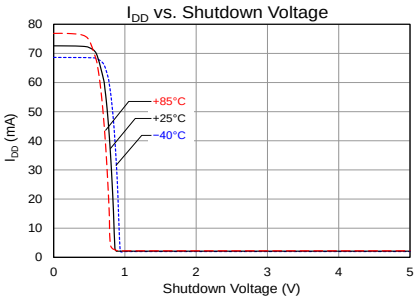
Test conditions unless otherwise noted: $V_{DD}$ = +5 V, $I_{DD}$ = 70 mA (typ.), Temp. = +25 °C



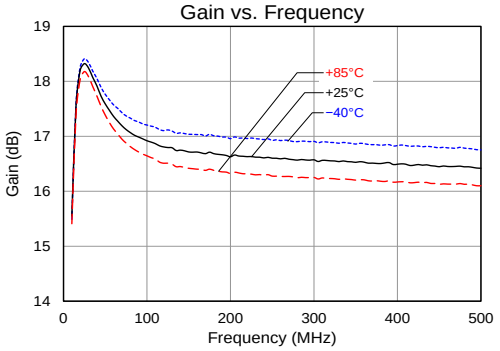
## Typical Performance – TQL9047-PCB_IF

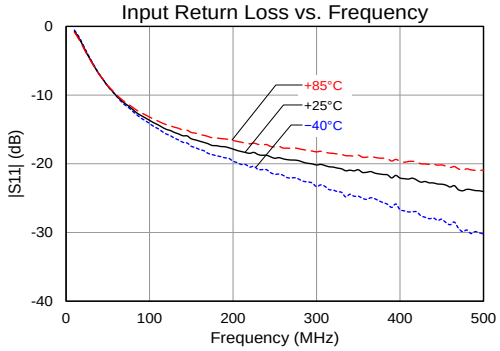
| Parameter | Conditions[1] | Typical Values | | | | Units |
|---|---|---|---|---|---|---|
| Frequency | | 50 | 100 | 150 | 500 | MHz |
| Gain | | 17.5 | 17 | 16.7 | 16.4 | dB |
| Input Return Loss | | 8 | 13 | 16 | 23 | dB |
| Output Return Loss | | 18 | 17 | 17 | 18 | dB |
| Output P1dB | | +20.4 | +20.7 | +20.8 | +20.8 | dBm |
| OIP3 | Pout = +3 dBm / tone, Δf = 1 MHz | +36.3 | +36.4 | +36.5 | +36.5 | dBm |
| Noise Figure [2] | Eval board losses de-embedded | 1.4 | 1.4 | 1.4 | 1.6 | dB |

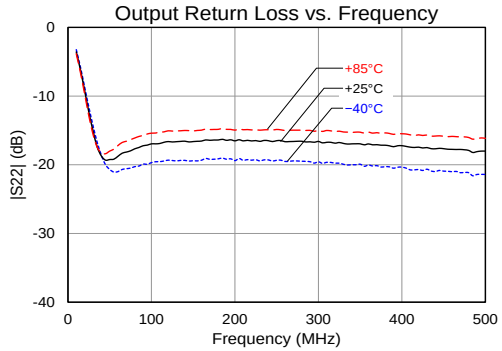
Notes:
1. Test conditions unless otherwise noted: $V_{DD}$ = +5 V, $I_{DD}$ = 70 mA (typ.), Temp. = +25 °C
2. Noise figure data shown in the table above is de-embedded from the eval board loss.

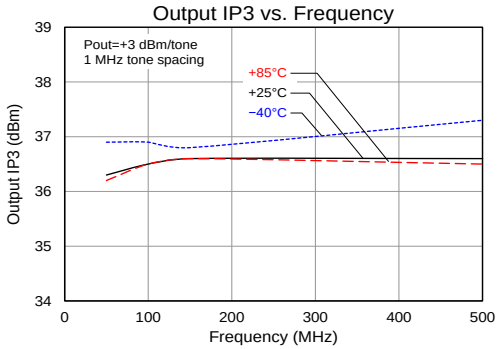
## Performance Plots – TQL9047-PCB_IF

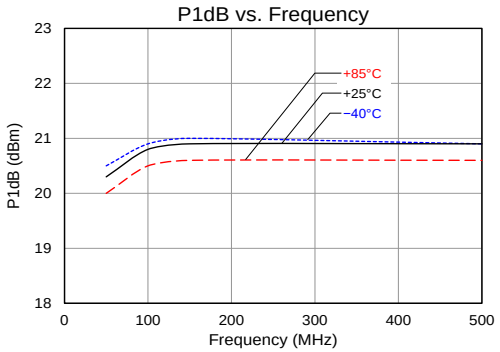
Test conditions unless otherwise noted: $V_{DD}$ = +5 V, $I_{DD}$ = 70 mA (typ.), Temp. = +25 °C, C1 and C2 = 1000 pF, L1 = 330 nH

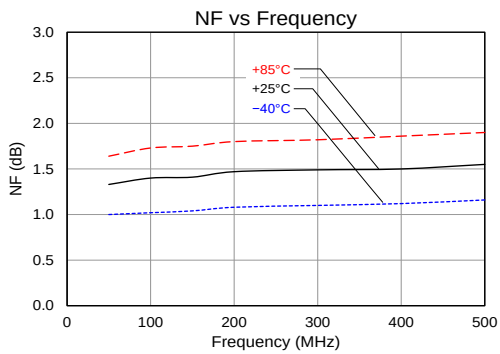


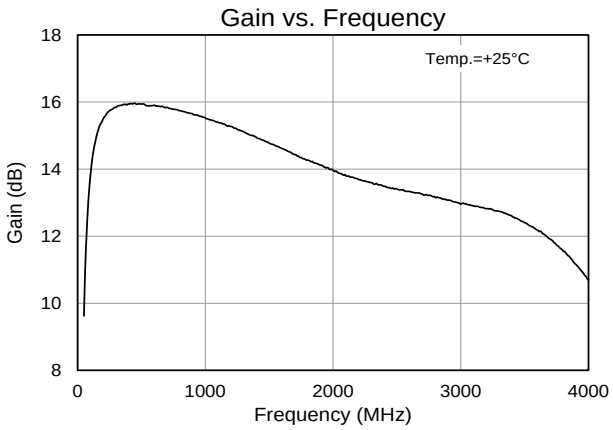
## Typical Performance – TQL9047-PCB_RF $V_{DD}$ = +3.3V

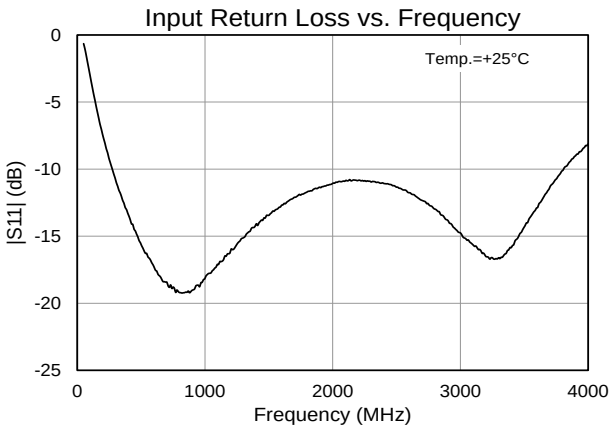
| Parameter | Conditions[1] | Typical Values | Units |
|---|---|---|---|
| Frequency | | 1900 | MHz |
| Gain | | 14.0 | dB |
| Input Return Loss | | 11 | dB |
| Output Return Loss | | 12.5 | dB |
| Output P1dB | | +16.7 | dBm |
| OIP3 | Pout = +3 dBm / tone, Δf=1 MHz | +29 | dBm |
| Noise figure [2] | | 1.7 | dB |

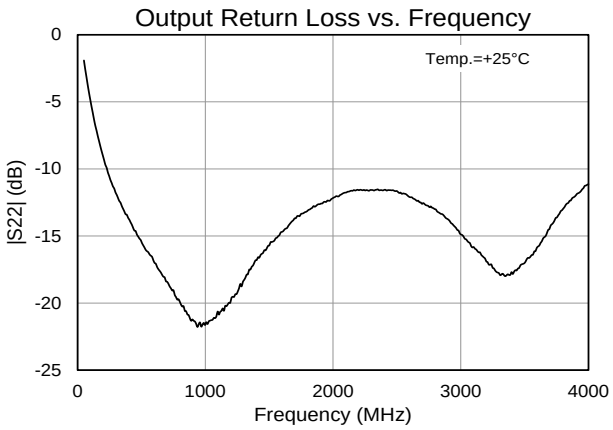
Notes:
1. Test conditions unless otherwise noted: VDD = +3.3V, IDD = 42 mA (typ.), Temp= +25°C
2. Noise figure data shown in the table above is de-embedded from the eval board loss.

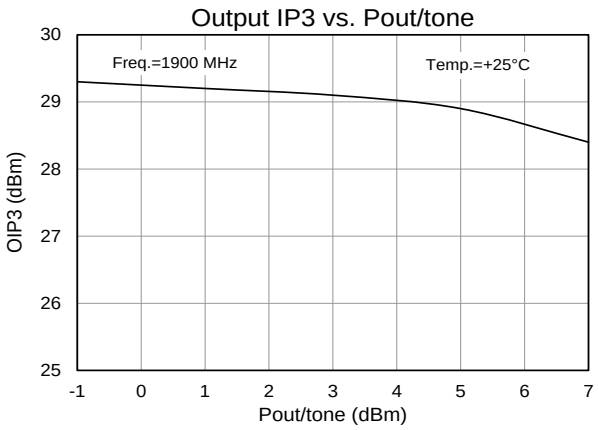
## Performance Plots – TQL9047-PCB_RF $V_{DD}$ = +3.3V

Test conditions unless otherwise noted: $V_{DD}$ = +3.3 V, $I_{DD}$ = 42 mA (typ.), Temp. = +25 °C



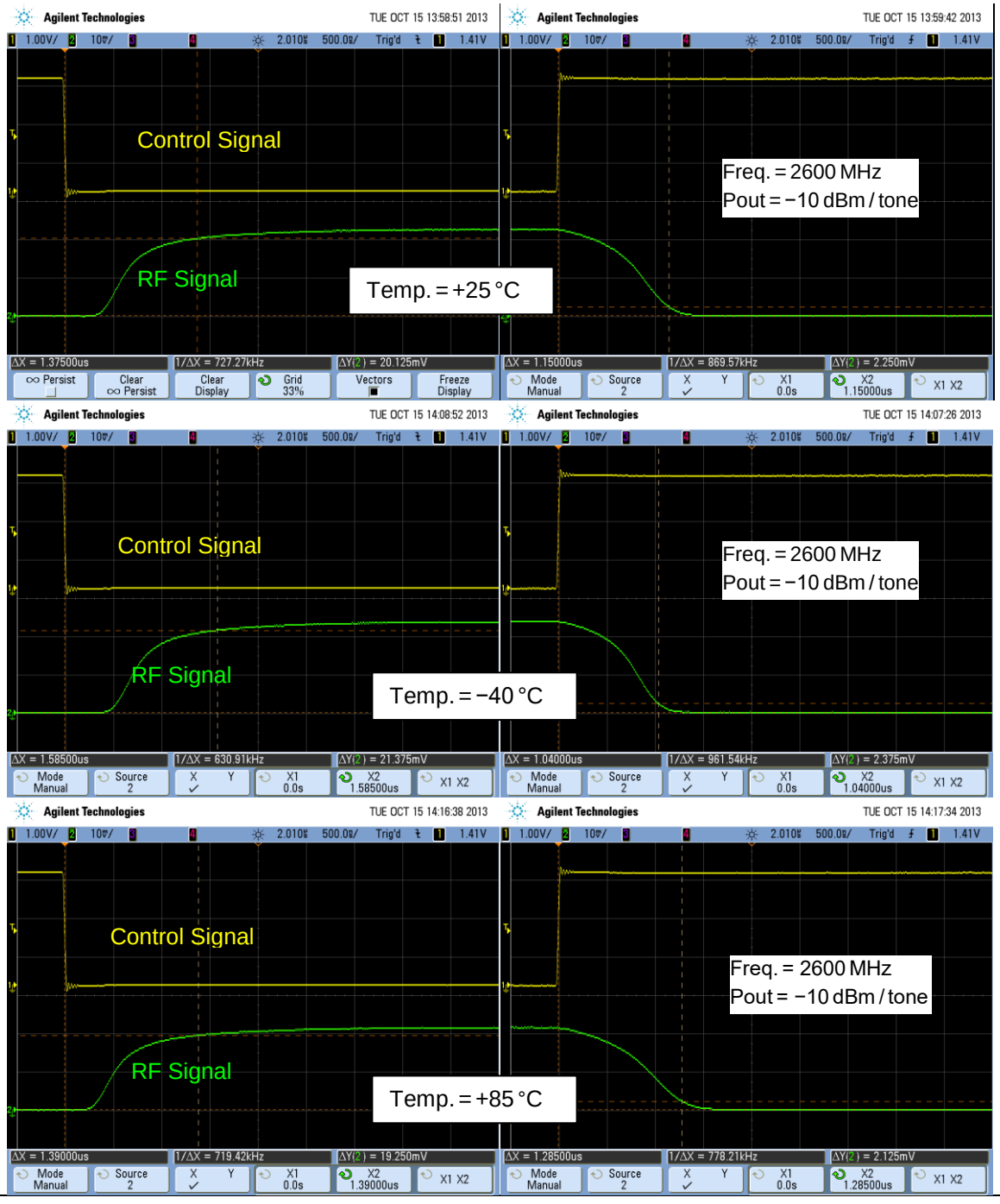



## Switching Speed

**Switching Speed Measurement based on TQS Application Board**

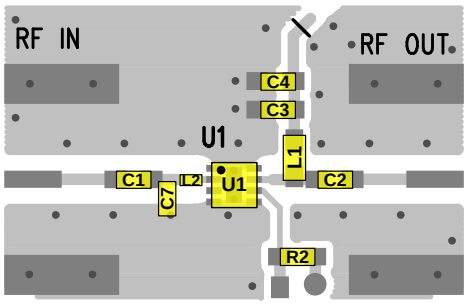
Using Shutdown Circuit: $V_{PD}$ = +3 V, $V_{DD}$ = +5 V

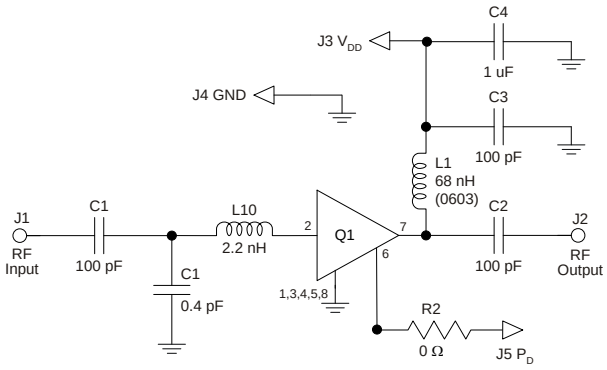
| Parameter | −40 °C | +25 °C | +85 °C |
|---|---|---|---|
| Turn-off Transition (50% CNTR – 10% RF) | 1.04 µs | 1.15 µs | 1.28 µs |
| Turn-on Transition (50% CNTR – 90% RF) | 1.58 µs | 1.37 µs | 1.39 µs |



## Reference Design – Optimized Return Loss

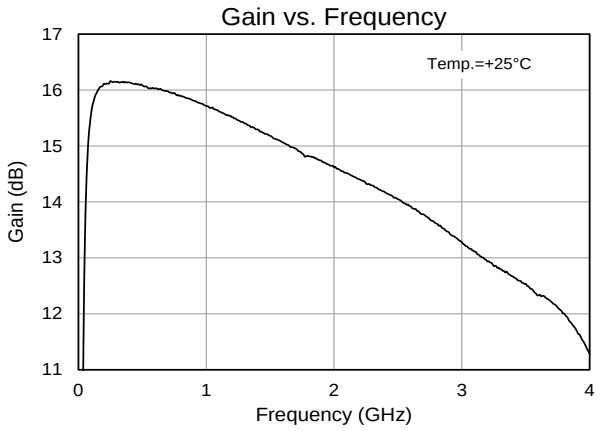
Input return loss over the 500 – 2700 MHz band can be optimized using a 2 element input tune.

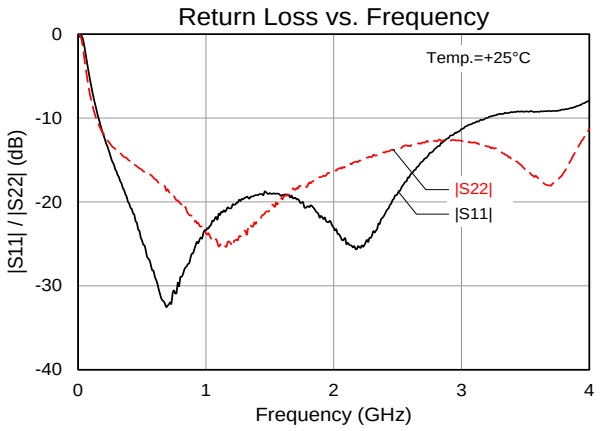


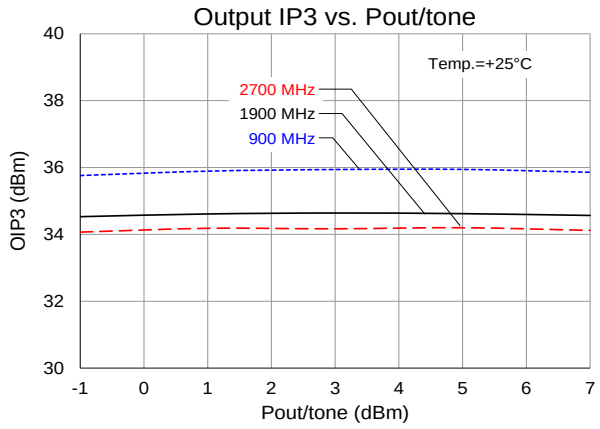



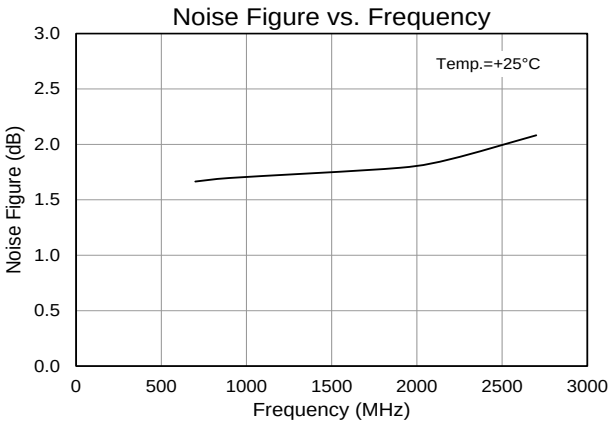

## Performance Plots

Test conditions unless otherwise noted: $V_{DD}$ = +5 V, $I_{DD}$ = 70 mA (typ.), Temp. = +25 °C

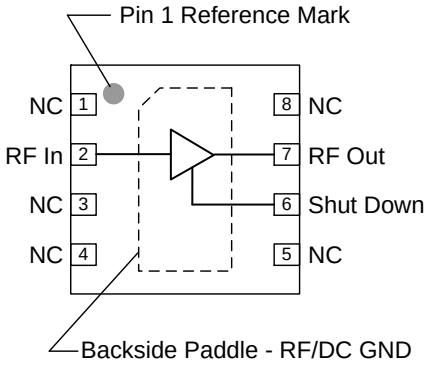


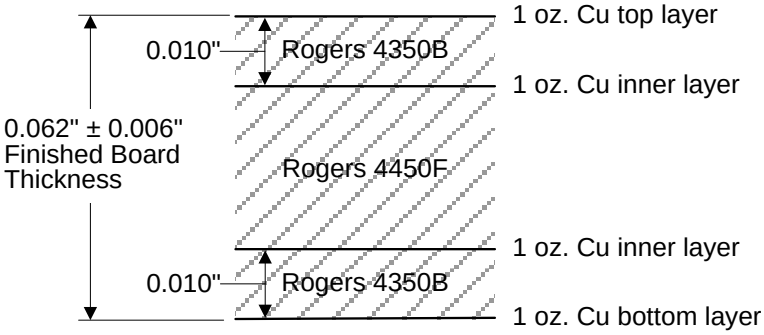
## Pin Configuration and Description



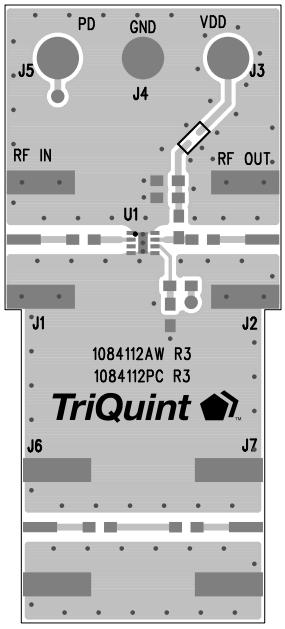

| Pin No. | Label | Description |
|---|---|---|
| 2 | RF In | RF Input pin. A DC Block is required. |
| 6 | Shut Down | A high voltage turns off the device. If the pin is not connected or is less than 0.5V, then the device will operate under its normal operating condition. |
| 7 | RF Out | RF Output pin. DC bias will also need to be injected through a RF bias choke/inductor for operation. |
| 1, 3, 4, 5, 8 | NC | No electrical connection. Provide grounded land pads for PCB mounting integrity. |
| Backside Paddle | RF/DC GND | RF/DC ground. Use recommended via pattern to minimize inductance and thermal resistance; see PCB Mounting Pattern for suggested footprint. |

## Evaluation Board PCB Information

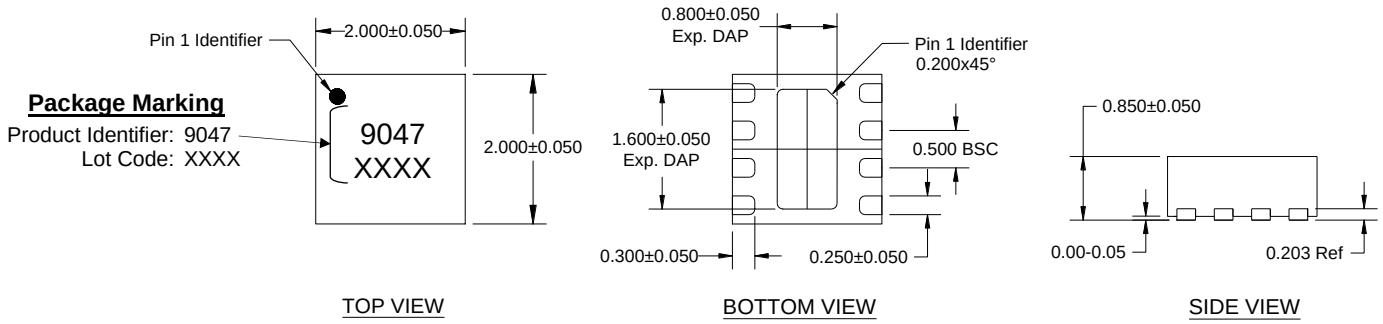
Qorvo PCB 1084112 Material and Stack-up




50 ohm line dimensions: width = 0.020”, spacing = 0.032”

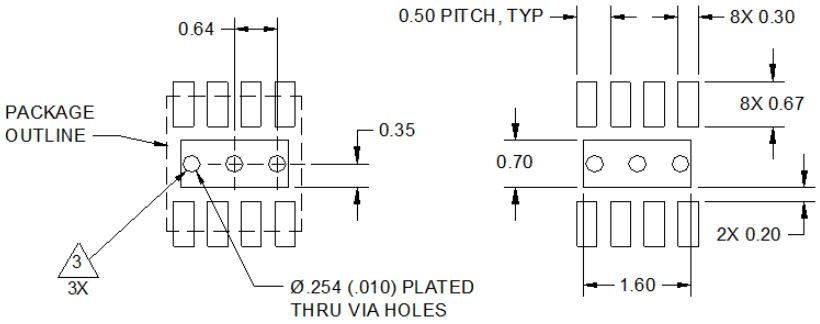


## Package Marking and Dimensions



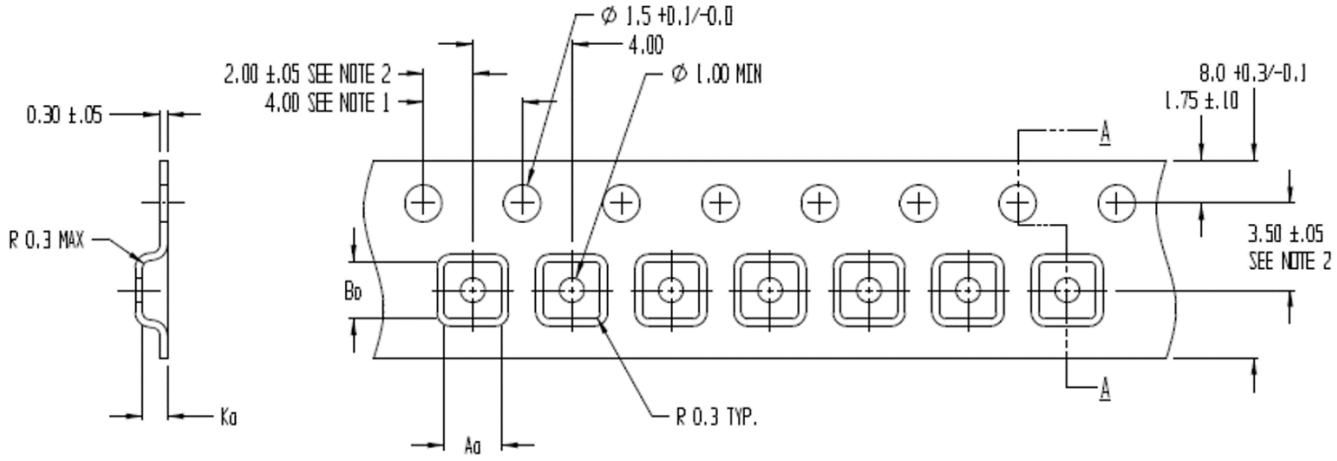

Notes:
1. All dimensions are in millimeters. Angles are in degrees.
2. Except where noted, this part outline conforms to JEDEC standard MO-229.
3. Dimension and tolerance formats conform to ASME Y14.4M-1994.
4. The terminal #1 identifier and terminal numbering conform to JESD 95-1 SPP-012.

## PCB Mounting Pattern

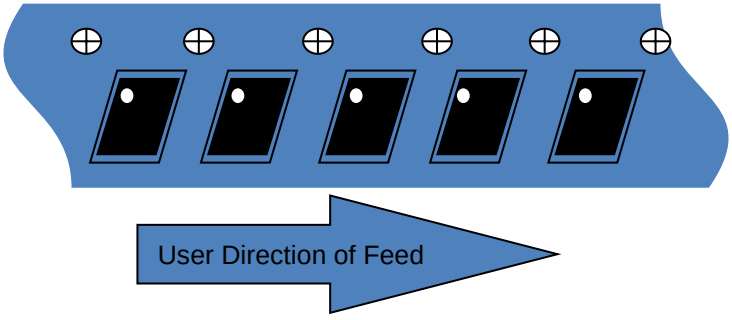



Notes:
1. All dimensions are in millimeters. Angles are in degrees.
2. Use 1 oz. copper minimum for top and bottom layer metal.
3. Vias are required under the backside paddle of this device for proper RF/DC grounding and thermal dissipation. We recommend a 0.35mm (#80/.0135") diameter bit for drilling via holes and a final plated thru diameter of 0.25 mm (0.10").
4. Ensure good package backside paddle solder attach for reliable operation and best electrical performance.

## Tape and Reel Information – Carrier and Cover Tape Dimensions

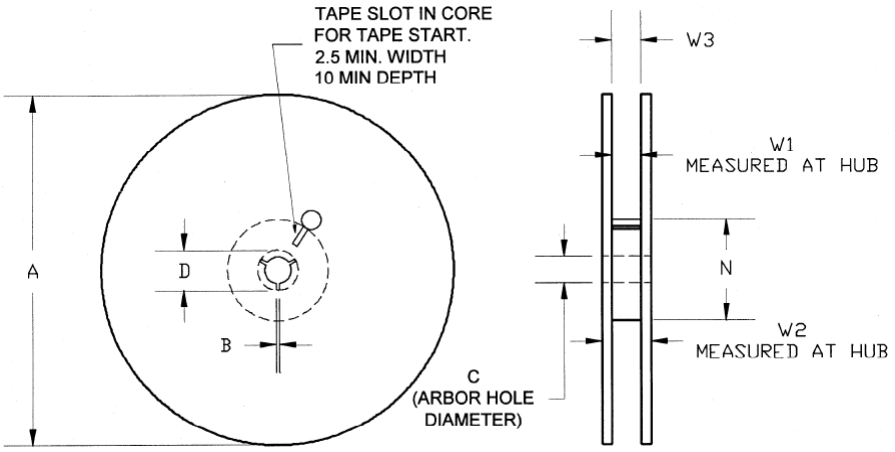



| Feature | Measure | Symbol | Size (in) | Size (mm) |
|---|---|---|---|---|
| Cavity | Length | A0 | 0.091 | 2.30 |
| | Width | B0 | 0.091 | 2.30 |
| | Depth | K0 | 0.039 | 1.30 |
| | Pitch | P1 | 0.157 | 4.00 |
| Centerline Distance | Cavity to Perforation - Length Direction | P2 | 0.079 | 2.00 |
| | Cavity to Perforation - Width Direction | F | 0.138 | 3.50 |
| Cover Tape | Width | C | 0.213 | 5.40 |
| Carrier Tape | Width | W | 0.315 | 8.00 |



## Tape and Reel Information – Reel Dimensions

Standard T/R size = 2,500 pieces on a 7” reel.




| Feature | Measure | Symbol | Size (in) | Size (mm) |
|---|---|---|---|---|
| Flange | Diameter | A | 6.969 | 177.00 |
| | Thickness | W2 | 0.559 | 14.20 |
| | Space Between Flange | W1 | 0.346 | 8.80 |
| Hub | Outer Diameter | N | 2.283 | 58.00 |
| | Arbor Hole Diameter | C | 0.512 | 13.00 |
| | Key Slit Width | B | 0.079 | 2.00 |
| | Key Slit Diameter | D | 0.787 | 20.00 |