

8 pin 2x2 mm DFN Package

General Description

The TQL9093 is a flat-gain, high-linearity, ultra-low noise amplifier in a small 2 x 2 mm surface-mount package. The LNA provides a gain flatness of 2 dB (peak-to-peak) over a wide bandwidth from 1.5 to 4 GHz. At 2.6 GHz, the amplifier typically provides 20 dB gain, +41.5 dBm OIP3 at a 120 mA bias setting, and 0.6 dB noise figure. The LNA can be biased from a single positive supply ranging from 3.3 to 5 volts. The device is housed in a green/RoHS-compliant industry-standard 2x2 mm package.

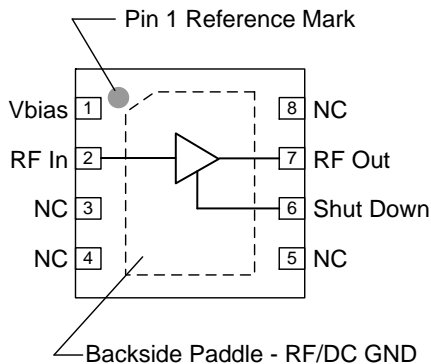
The TQL9093 is internally matched using a high performance E-pHEMT process and only requires five external components for operation from a single positive supply: an external RF choke and blocking/bypass capacitors and a bias resistor going to pin 1. This LNA integrates a shut-down biasing capability to allow for operation in TDD applications.

The TQL9093 is optimized for linear performance across the 1.5 to 4 GHz frequency band but can operate down to 600 MHz.

Product Features

- 0.6-4.2 GHz Operational Bandwidth
- Ultra low noise figure, 0.67 dB NF @ 2.6 GHz
- >19 dB gain across 1.5 to 4 GHz
- Flat 2 dB gain variation across 1.5 to 4 GHz
- Bias adjustable for linearity optimization
- 41.5 dBm OIP3 at 120mA I_{DD}
- Shut-down mode pin with 1.8V TTL logic
- Unconditionally stable
- Integrated shutdown control pin
- Maintains OFF state with high Pin drive
- +3V to +5V supply; does not require -V_{gg}

Functional Block Diagram



Applications

- Repeaters / DAS
- Mobile Infrastructure
- LTE / WCDMA / CDMA / GSM
- General Purpose Wireless
- TDD or FDD systems

Ordering Information

| Part No. | Description |
|-------------|--------------------------------|
| TQL9093 | Ultra low noise, Flat Gain LNA |
| TQL9093-PCB | 0.6-4.2 GHz Evaluation Board |

Standard T/R size = 2500 pieces on a 7" reel

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 | +33 dBm |
| RF Input Power, WCDMA, 10dB PAR | +27 dBm |
| RF Input Power, CW, OFF State | +33 dBm |

Operation of this device outside the parameter ranges given above may cause permanent damage.

Recommended Operating Conditions

| Parameter | Min | Typ | Max | Units |
|--|-----|-----|------|-------|
| Supply Voltage (V _{DD}) | 3.3 | 5.0 | 5.25 | V |
| T _{CASE} | -40 | | +105 | °C |
| T _j 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

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

| Parameter | Conditions | Min | Typ | Max | Units |
|---------------------------------------|---|------|-------|-----------------|-------|
| Operational Frequency Range | | 600 | | 4200 | MHz |
| Test Frequency | | | 2600 | | MHz |
| Gain | | 18.5 | 20 | 21.7 | dB |
| Gain Flatness | 1500-4000MHz | | 2.0 | | dB |
| Input Return Loss | | | 14 | | dB |
| Output Return Loss | | | 14.5 | | dB |
| Noise Figure ⁽¹⁾ | | | 0.67 | 1.0 | dB |
| Output P1dB | | | +21.7 | | dBm |
| Output IP3 | P _{out} =+4 dBm/tone, Δf=1 MHz | +35 | +41.5 | | dBm |
| Power Shutdown Control (pin 6) | On state | 0 | | 0.63 | V |
| | Off state (Power down) | 1.17 | | V _{DD} | V |
| Current, I _{DD} | On state | 80 | 120 | 160 | mA |
| | Off state (Power down) | | 4 | 8 | mA |
| Shutdown pin current, I _{SD} | V _{PD} ≥ 1.17 V | | 140 | | μA |
| Switching Speed | LNA ON to OFF | | 315 | | ns |
| | LNA OFF to ON | | 290 | | ns |
| Thermal Resistance, θ _{jc} | channel to case | | 44 | | °C/W |

Note: 1) Noise figure data has input trace loss de-embedded.

S-Parameters

Test Conditions: $V_{DD}=+5\text{ V}$, $I_{DD}=120\text{ mA}$ (typ.), $T=+25^{\circ}\text{C}$, unmatched 50 ohm system, calibrated to device leads

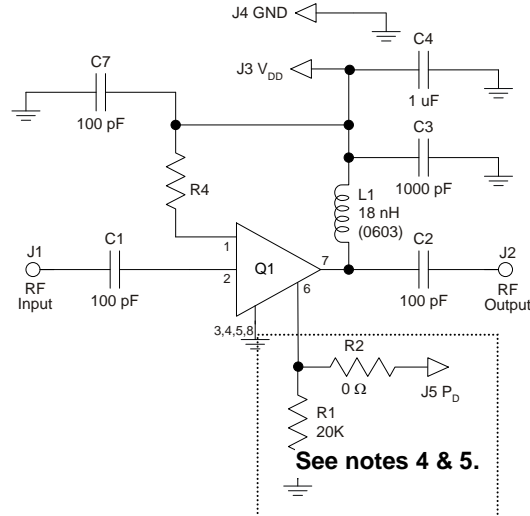
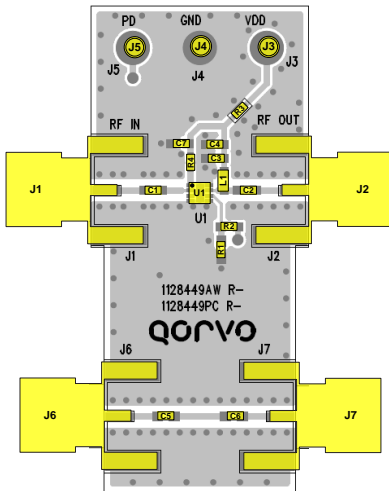
| Freq (GHz) | S11 (dB) | S11 (ang) | S21 (dB) | S21 (ang) | S12 (dB) | S12 (ang) | S22 (dB) | S22 (ang) |
|------------|----------|-----------|----------|-----------|----------|-----------|----------|-----------|
| 0.6 | -8.86 | -139.90 | 22.74 | 78.61 | -31.50 | 39.70 | -13.38 | 64.84 |
| 0.7 | -10.03 | -150.92 | 21.91 | 63.87 | -30.56 | 31.41 | -15.86 | 54.42 |
| 0.8 | -11.16 | -160.19 | 21.18 | 50.66 | -29.82 | 23.53 | -18.47 | 45.38 |
| 0.9 | -12.30 | -167.88 | 20.55 | 38.60 | -29.22 | 16.00 | -21.30 | 37.43 |
| 1 | -13.47 | -174.08 | 20.00 | 27.41 | -28.74 | 8.73 | -24.56 | 30.37 |
| 1.1 | -14.68 | -178.79 | 19.54 | 16.90 | -28.34 | 1.70 | -28.65 | 23.93 |
| 1.2 | -15.95 | 178.14 | 19.16 | 6.93 | -28.02 | -5.13 | -34.78 | 17.33 |
| 1.3 | -17.27 | 176.97 | 18.84 | -2.59 | -27.77 | -11.79 | -53.16 | -8.30 |
| 1.4 | -18.61 | 178.14 | 18.59 | -11.76 | -27.57 | -18.31 | -38.00 | -164.49 |
| 1.5 | -19.88 | -177.81 | 18.38 | -20.63 | -27.41 | -24.71 | -31.62 | -170.37 |
| 1.6 | -20.90 | -170.59 | 18.23 | -29.26 | -27.30 | -31.03 | -28.04 | -174.65 |
| 1.7 | -21.40 | -160.85 | 18.12 | -37.70 | -27.22 | -37.28 | -25.46 | -178.62 |
| 1.8 | -21.22 | -150.56 | 18.05 | -45.99 | -27.17 | -43.48 | -23.37 | 177.38 |
| 1.9 | -20.46 | -141.99 | 18.01 | -54.16 | -27.16 | -49.67 | -21.56 | 173.19 |
| 2 | -19.37 | -136.18 | 18.01 | -62.25 | -27.18 | -55.86 | -19.93 | 168.70 |
| 2.1 | -18.17 | -133.02 | 18.04 | -70.28 | -27.22 | -62.08 | -18.42 | 163.85 |
| 2.2 | -16.98 | -131.95 | 18.09 | -78.29 | -27.30 | -68.34 | -17.00 | 158.61 |
| 2.3 | -15.86 | -132.43 | 18.16 | -86.29 | -27.42 | -74.67 | -15.66 | 152.97 |
| 2.4 | -14.82 | -134.07 | 18.26 | -94.33 | -27.56 | -81.10 | -14.38 | 146.93 |
| 2.5 | -13.85 | -136.59 | 18.37 | -102.41 | -27.75 | -87.65 | -13.16 | 140.50 |
| 2.6 | -12.96 | -139.82 | 18.50 | -110.56 | -27.98 | -94.34 | -11.99 | 133.68 |
| 2.7 | -12.14 | -143.64 | 18.64 | -118.81 | -28.27 | -101.20 | -10.88 | 126.50 |
| 2.8 | -11.39 | -147.97 | 18.78 | -127.18 | -28.61 | -108.26 | -9.81 | 118.95 |
| 2.9 | -10.69 | -152.76 | 18.92 | -135.68 | -29.02 | -115.55 | -8.80 | 111.05 |
| 3 | -10.06 | -157.97 | 19.06 | -144.32 | -29.52 | -123.10 | -7.84 | 102.80 |
| 3.1 | -9.48 | -163.59 | 19.20 | -153.12 | -30.12 | -130.93 | -6.93 | 94.23 |
| 3.2 | -8.96 | -169.58 | 19.31 | -162.07 | -30.84 | -139.11 | -6.08 | 85.35 |
| 3.3 | -8.50 | -175.91 | 19.41 | -171.17 | -31.72 | -147.67 | -5.29 | 76.17 |
| 3.4 | -8.11 | 177.42 | 19.47 | 179.59 | -32.77 | -156.70 | -4.57 | 66.73 |
| 3.5 | -7.77 | 170.47 | 19.51 | 170.24 | -34.06 | -166.35 | -3.91 | 57.07 |
| 3.6 | -7.50 | 163.28 | 19.50 | 160.81 | -35.66 | -176.88 | -3.32 | 47.23 |
| 3.7 | -7.29 | 155.88 | 19.46 | 151.35 | -37.66 | 171.13 | -2.81 | 37.25 |
| 3.8 | -7.14 | 148.34 | 19.37 | 141.90 | -40.23 | 156.33 | -2.37 | 27.20 |
| 3.9 | -7.05 | 140.71 | 19.23 | 132.51 | -43.53 | 135.06 | -1.99 | 17.13 |
| 4 | -7.02 | 133.03 | 19.05 | 123.24 | -46.99 | 97.87 | -1.69 | 7.10 |
| 4.1 | -7.03 | 125.37 | 18.83 | 114.11 | -47.01 | 45.50 | -1.45 | -2.86 |
| 4.2 | -7.08 | 117.75 | 18.58 | 105.17 | -43.87 | 10.27 | -1.27 | -12.69 |

Noise Parameters

Test conditions unless otherwise noted: $V_{DD}=+5\text{ V}$, $I_{DD}=120\text{ mA}$ (typ.), $\text{Temp}=+25^{\circ}\text{C}$, 50 Ohm system

| Freq (GHz) | NF _{min} (dB) | GammaOpt (mag) | GammaOpt (deg) | Rn (Ω) |
|------------|------------------------|----------------|----------------|--------|
| 1.5 | 0.50 | 0.07 | 4.37 | 3.50 |
| 1.6 | 0.47 | 0.06 | 19.31 | 3.18 |
| 1.7 | 0.46 | 0.07 | 37.40 | 3.22 |
| 1.8 | 0.48 | 0.05 | 32.41 | 3.47 |
| 1.9 | 0.47 | 0.06 | 66.76 | 3.15 |
| 2 | 0.47 | 0.06 | 74.72 | 3.28 |
| 2.1 | 0.50 | 0.06 | 68.71 | 3.46 |
| 2.2 | 0.53 | 0.06 | 96.07 | 3.20 |
| 2.3 | 0.55 | 0.07 | 122.98 | 3.12 |
| 2.4 | 0.59 | 0.26 | 40.10 | 5.04 |
| 2.5 | 0.58 | 0.09 | 152.96 | 3.11 |
| 2.6 | 0.59 | 0.09 | 172.99 | 2.90 |
| 2.7 | 0.61 | 0.10 | 170.84 | 3.08 |
| 2.8 | 0.62 | 0.14 | -179.62 | 2.80 |
| 2.9 | 0.63 | 0.16 | -162.35 | 2.80 |
| 3 | 0.65 | 0.17 | -160.56 | 3.00 |
| 3.1 | 0.67 | 0.20 | -168.07 | 2.57 |
| 3.2 | 0.68 | 0.23 | -159.49 | 2.62 |
| 3.3 | 0.68 | 0.25 | -145.84 | 2.83 |
| 3.4 | 0.71 | 0.27 | -144.78 | 2.89 |
| 3.5 | 0.73 | 0.31 | -134.10 | 3.67 |
| 3.6 | 0.73 | 0.28 | -134.75 | 3.37 |
| 3.7 | 0.73 | 0.31 | -122.22 | 4.03 |
| 3.8 | 0.76 | 0.40 | -106.08 | 7.09 |
| 3.9 | 0.77 | 0.45 | -123.38 | 3.37 |
| 4 | 0.79 | 0.42 | -125.62 | 3.60 |

TQL9093-PCB 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. For TDD Applications: R1 = 20K & R2 = 0 Ω
5. For FDD Applications: R1 = 20K 'OR' Pin 6 tied to ground. R2 = DNP/Omitted
6. A through line is included on the evaluation board to de-embed the board losses.
7. R4 sets the current draw. Can be changed for the desired bias point. See table below.

Bill of Material – TQL9093-PCB

| Reference Des. | Value | Description | Manuf. | Part Number |
|----------------|------------|------------------------------------|-----------|---------------|
| N/A | N/A | Printed Circuit Board | Qorvo | |
| U1 | n/a | Ultra Low Noise, Flat Gain LNA | Qorvo | TQL9093 |
| R4 | 3K | Resistor, Chip, 0402, 5%, 1/16W | various | |
| R1 | 20K | Resistor, chip, 0402, 5%, 1/16W | various | |
| R2, 3 | 0 Ω | Resistor, Chip, 0402, 5%, 1/16W | various | |
| L1 | 18 nH | Inductor, coil, 0603, 5% | Coilcraft | 0603CS-18NXJL |
| C4 | 1.0 uF | Cap., Chip, 0402, 10%, 10V, X5R | various | |
| C1, C2, C5, C6 | 100 pF | Cap., Chip, 0402, 5%, 50V, NPO/COG | various | |
| C3 | 1000 pF | Cap, chip, 0402 | various | |

R4 Resistor Values for Various I_{DD} settings

| I _{DD} (mA) | 80 | 90 | 100 | 110 | 120 | 130 | 140 | 150 |
|----------------------|------|------|------|------|------|------|------|------|
| R4 | 9.2K | 6.5K | 5.1K | 3.9K | 3.1K | 2.6K | 2.2K | 1.8K |

Typical Performance – TQL9093-PCB

Test conditions unless otherwise noted: $V_{DD} = +5\text{ V}$, $I_{DD} = 120\text{ mA}$ (typ.), Temp = $+25^\circ\text{C}$

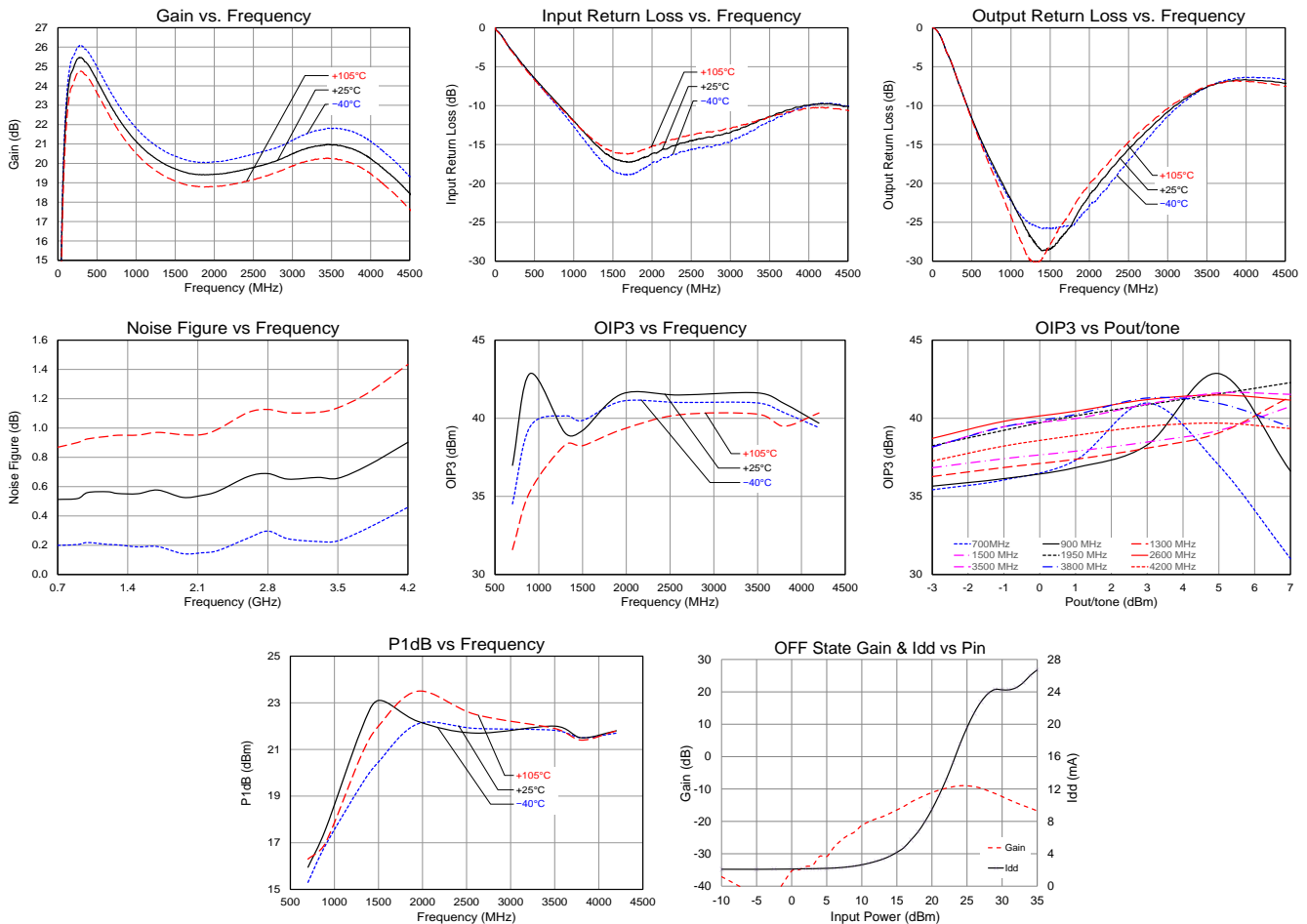
| Parameter | Conditions | Typical Values | | | | | | Units |
|-----------------------------|--|----------------------|-------|-------|-------|-------|-------|-------|
| Frequency | | 600 | 900 | 1950 | 2600 | 3500 | 4200 | MHz |
| Gain | | 23.4 | 21.6 | 19.4 | 19.9 | 20.9 | 19.6 | dB |
| Input Return Loss | | 8.1 | 10.8 | 16.5 | 14 | 11.5 | 9.7 | dB |
| Output Return Loss | | 13.4 | 20 | 23 | 14.5 | 7.6 | 6.7 | dB |
| Output P1dB | | +16.1 | +17.6 | +22.2 | +21.7 | +22 | +21.8 | dBm |
| OIP3 | $P_{out}=+5\text{ dBm/tone}$, $\Delta f=1\text{ MHz}$ | +37.2 ⁽²⁾ | +42.8 | +41.5 | +41.5 | +41.6 | +39.7 | dBm |
| Noise figure ⁽¹⁾ | | 0.52 | 0.54 | 0.54 | 0.67 | 0.67 | 0.91 | dB |

Note: 1) Noise figure data has input trace loss de-embedded.

2) $P_{out}=+3\text{ dBm/tone}$, $\Delta f=1\text{ MHz}$

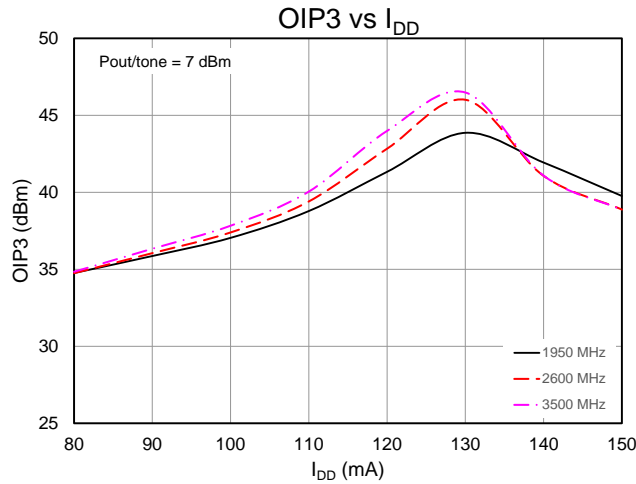
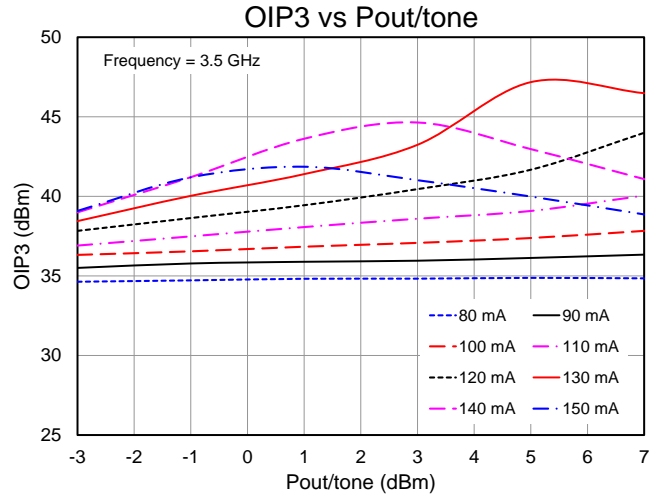
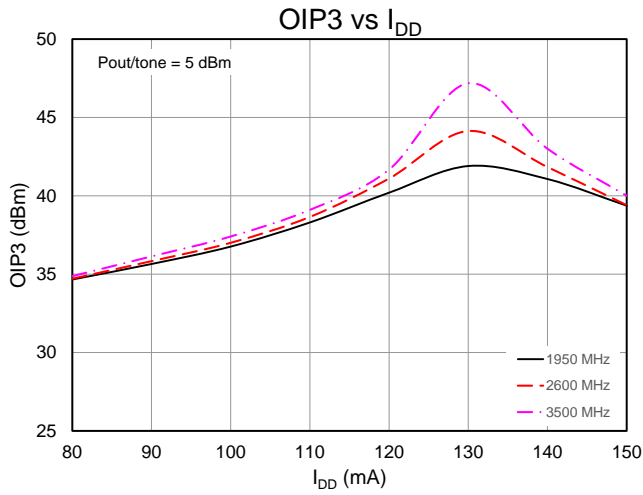
Performance Plots – TQL9093-PCB

Test conditions unless otherwise noted: $V_{DD} = +5\text{ V}$, $I_{DD} = 120\text{ mA}$, Temp = $+25^\circ\text{C}$. Noise figure data has input trace loss de-embedded.

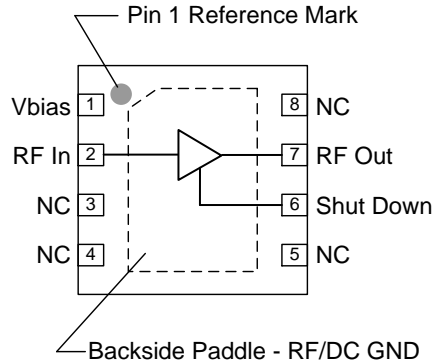


Performance Plots – TQL9093-PCB

Test conditions unless otherwise noted: $V_{DD} = +5\text{ V}$, $\text{Temp} = +25^\circ\text{C}$. Noise figure data has input trace loss de-embedded.



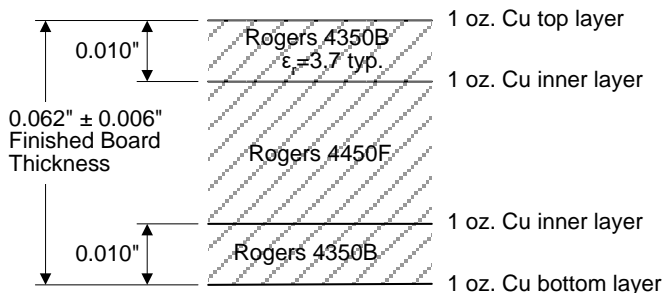
Pin Configuration and Description



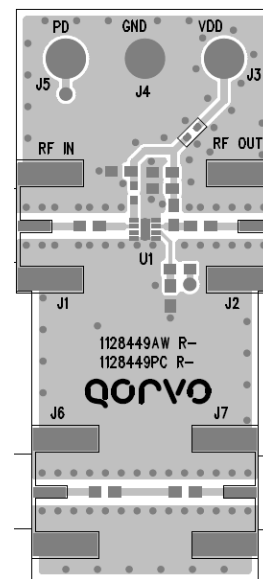
| Pin No. | Label | Description |
|-----------------|-----------------|--|
| 1 | Vbias | Sets the Icq bias point for the device. |
| 2 | RF In | RF Input pin. A DC Block is required. |
| 6 | Shut Down | A high voltage(>1.17V) turns off the device. If the pin is pulled to ground or driven with a voltage less than 0.63V, then the device will operate under LNA ON state. |
| 7 | RF Out / DCBias | RF Output pin. DC bias will also need to be injected through a RF bias choke/inductor for operation. |
| 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 1128449 Material and Stack-up

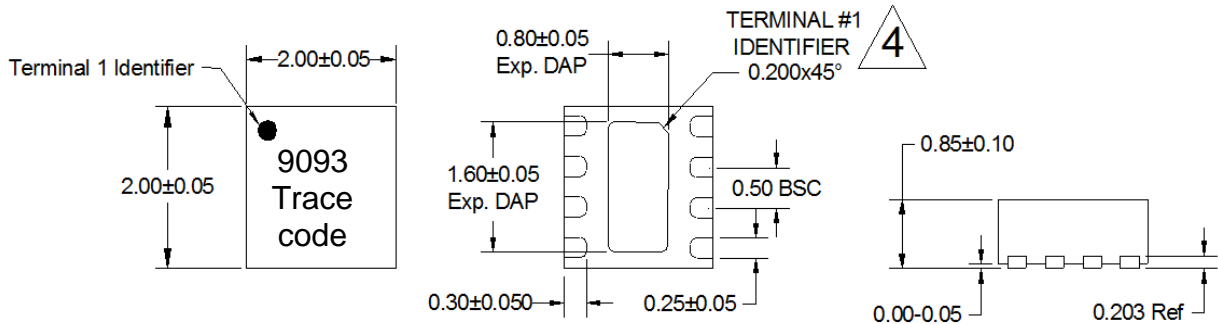


50 ohm line dimensions: width = 0.020", spacing = 0.032"



Mechanical Information

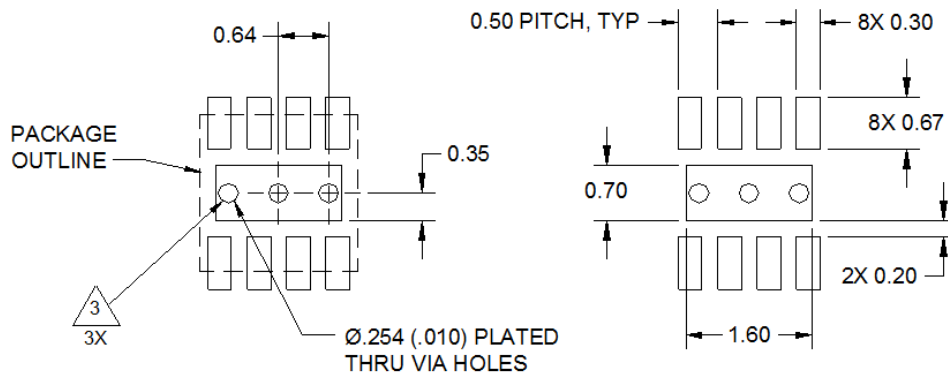
Package Marking and Dimensions



Notes:

1. All dimensions are in millimeters. Angles are in degrees.
2. Except where noted, this part outline conforms to JEDEC standard MO-220, Issue E (Variation VCCD) for thermally enhanced plastic very thin fine pitch quad flat no lead package (QFN).
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.

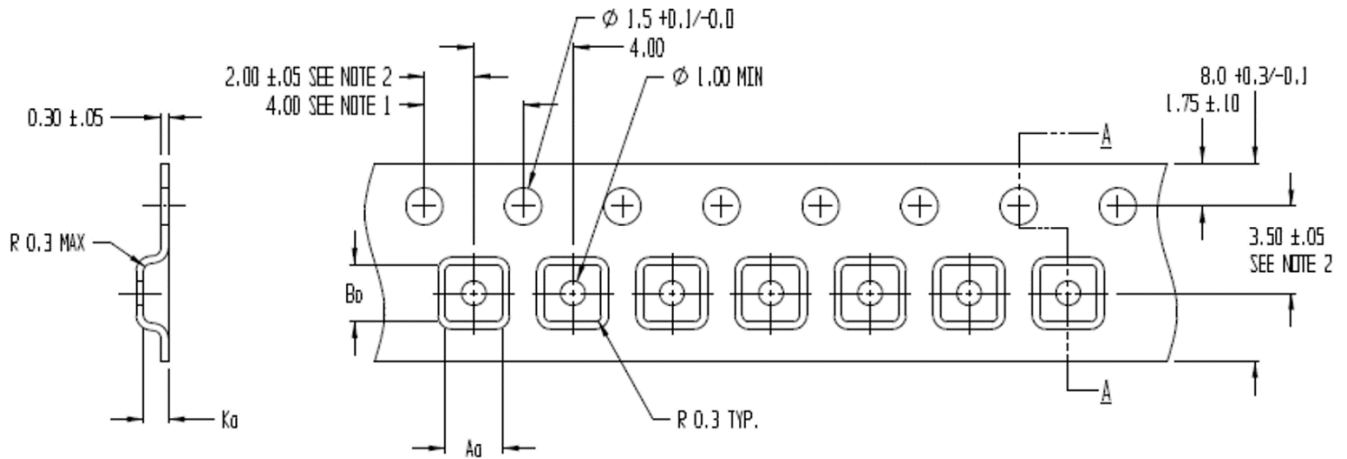
PCB Mounting Pattern



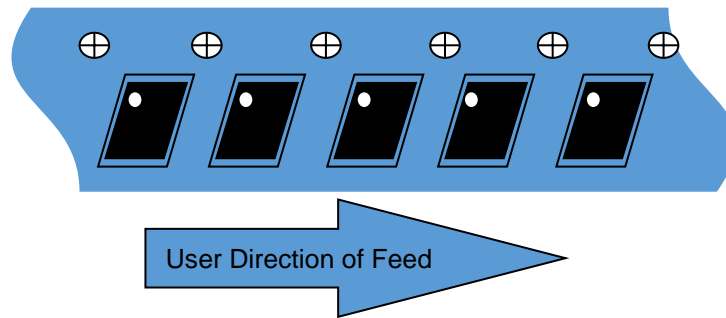
Notes:

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 0.35 mm ($\#80/.0135$ ") 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

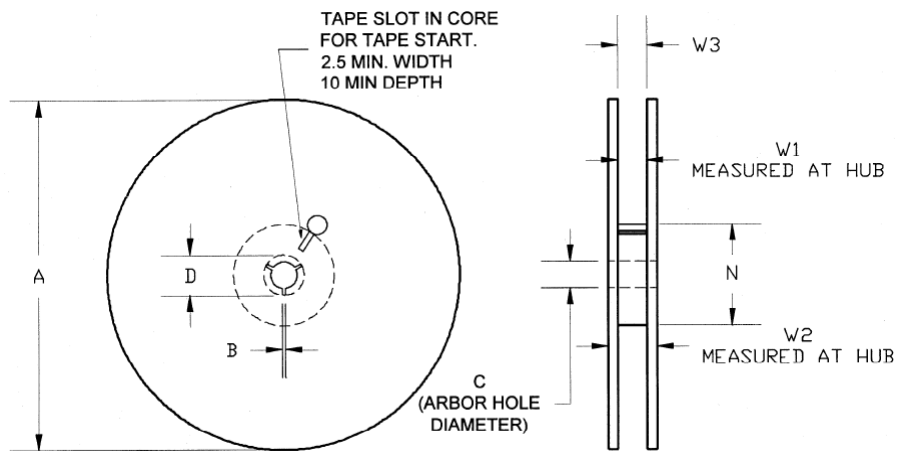


| Feature | Measure | Symbol | Size (in) | Size (mm) |
|---------------------|--|--------|-----------|-----------|
| Cavity | Length | A0 | 0.091 | 2.30 |
| | Width | B0 | 0.091 | 2.30 |
| | Depth | K0 | 0.039 | 1.30 |
| | Pitch | P1 | 0.157 | 4.00 |
| Centerline Distance | Cavity to Perforation - Length 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 |

Handling Precautions

| Parameter | Rating | Standard |
|----------------------------------|----------|--------------------------|
| ESD – Human Body Model (HBM) | Class 1B | ESDA / JEDEC JS-001-2014 |
| ESD – Charged Device Model (CDM) | Class C3 | ESDA / JEDEC JS-002-2014 |
| MSL – Moisture Sensitivity Level | Level 1 | IPC/JEDEC J-STD-020 |



Caution!
ESD-Sensitive Device

Solderability

Compatible with lead-free (260°C max. reflow temp.) soldering process.
Solder profiles available upon request.
Contact plating: NiPdAu

RoHS Compliance

This part is compliant with 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 (C₁₅H₁₂Br₄O₂) Free
- PFOS Free
- SVHC Free



Contact Information

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

Web: www.qorvo.com

Tel: 1-844-890-8163

Email: customer.support@qorvo.com

For technical questions and application information: Email: appsupport@qorvo.com

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