# AlGaAs SPST Non-Reflective PIN Diode Switch

# MA4AGSW1A
### Rev 2.0

## FEATURES

- Ultra Broad Bandwidth: 10 GHz to 50 GHz
- Functional Bandwidth: 100 MHz to 70 GHz
- 1.0 dB Insertion Loss, 35 dB Isolation at 50 GHz
- M/A-COM's unique patent pending AlGaAs hetero-junction anode technology.
- Silicon Nitride Passivation
- Polymide Scratch protection

## DESCRIPTION

M/A-COM's MA4AGSW1A is an Aluminum-Gallium Arsenide anode enhanced, SPST Non-Reflective PIN diode switch. AlGaAs anodes, which utilize M/A-COM's patent pending hetero-junction technology, produce less loss than conventional GaAs processes, by as much as a 0.3 dB reduction in insertion loss at 50 GHz. These devices are fabricated on a OMCVD eptaxial wafer using a process designed for high device uniformity and extremely low parasitics. The diodes themselves exhibit lower series resistance, lower capacitance, and faster switching speeds than Silicon based devices. They are fully passivated with silicon nitride and have an additional layer of a polymer for scratch protection. The protective coating prevents damage to the junction and the anode airbridges during handling. Off-chip bias circuitry is required and allows for maximum design flexibility.

## APPLICATIONS

The output port of this device ( J2 ), is 50 Ω terminated during Isolation mode, which allows this signal to be absorbed rather than reflected back. This functionality makes it ideal for instrumentation and radar applications. This absorptive switch can be added to available reflective AlGaAs switches to improve isolation VSWR and increase isolation magnitude.

The ultra low capacitance of the PIN diodes makes it ideal for usage in lower loss and higher isolation microwave and millimeter wave switch designs through 70 GHz. The lower series resistance of the AlGaAs diodes reduces the total insertion loss and distortion of the devices. These AlGaAs PIN switches are used as the switching arrays for radar systems, radiometers, and other multi-function components.

## MA4AGSW1A LAYOUT
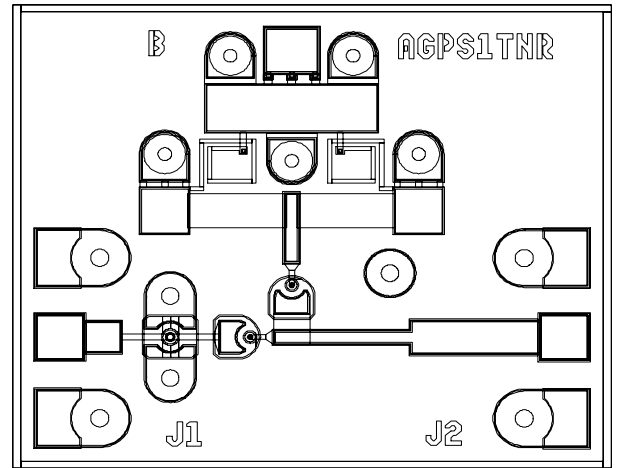


## ABSOLUTE MAXIMUM RATINGS

### @$T_A$ = +25°C ( Unless otherwise specified )

| Parameter | MAXIMUM RATING |
|---|---|
| Operating Temperature | -55° TO +125°C |
| Storage Temperature | -65°C TO +150°C |
| Junction Temperature | +175°C |
| Assembly Temperature | +300°C for < 10 sec |
| Incident C.W. RF Power | +23 dBm C.W. |
| Reverse Voltage | \| - 25 V \| |
| Forward Bias Current | +/-25 mA |

**Note: Exceeding ANY of these values may result in permanent damage**

**Maximum Operating Conditions forCombination of RF Power, D.C. Bias, and Temperature:**
**+ 23 dBm C.W. @ 10 mA ( per Diode ) @ + 85 °C.**

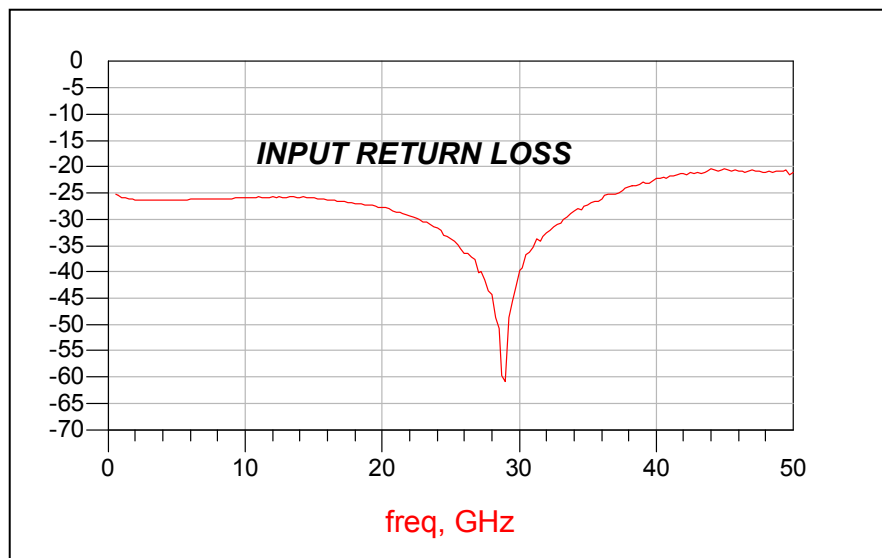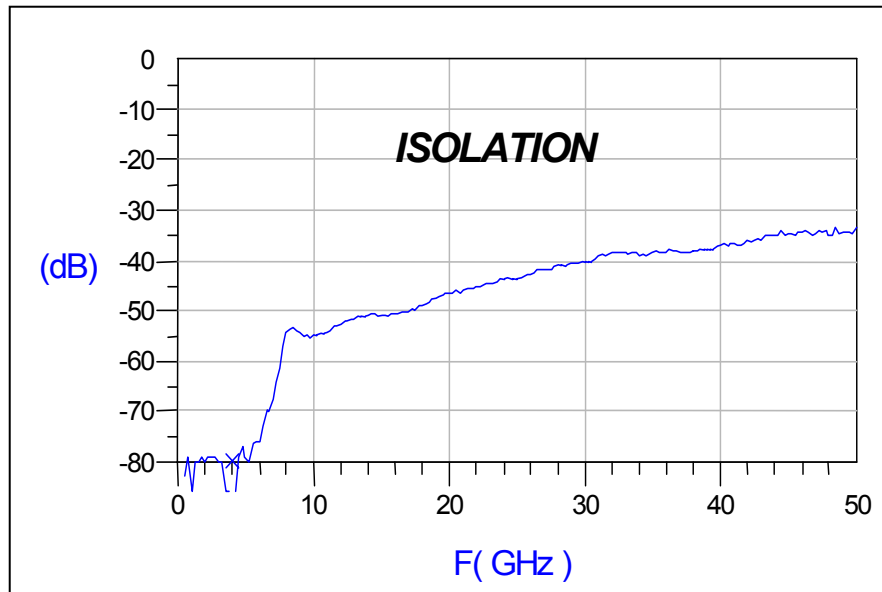**Electrical Specifications @ 25 ° C (On Wafer Measurements )**

| Frequency Range = 10 – 50 GHz | | | | |
| --- | --- | --- | --- | --- |
| **Parameter** | **Ports** | **Bias Conditions** | **Specification** | **Comments** |
| Insertion Loss | J1 – J2 | D.C. Bias 1 = -1.35 V @ -10 mA D.C. Bias B = -1.35 V @ 0 mA | 1.2 dB Typical | Value at 50 GHz |
| Input Return Loss | J1 ( Terminate J2 into 50Ω ) | D.C. Bias 1 = -1.35 V @ -10 mA D.C. Bias B = -1.35 V @ 0 mA | 15 dB Typical | Value at 50 GHz In Insertion Loss State |
| Output Return Loss ( Insertion Loss ) | J2 (Terminate J1 into 50Ω ) | D.C. Bias 1 = -1.35 V @ -10 mA D.C. Bias B = -1.35 V @ 0 mA | 18 dB Typical | Value at 50 GHz In Insertion Loss State |
| Output Return Loss ( Isolation ) | J2 | D.C. Bias 1 = +1.35 V @ +10 mA D.C. Bias B = +1.35 V @ +10 mA | 18 dB Typical | Value at 50 GHz In Isolation State |
| Isolation | J1 – J2 | D.C. Bias 1 = +1.35 V @ +10 mA D.C. Bias B = +1.35 V @ +10 mA | 30 dB Typical | Value at 50 GHz |
| Switching Speed ( 10 % - 90 % RF Voltage ) | J1 – J2 | +/- 5V PIN Diode TTL Driver @ 1 MHz Rep Rate | 10 nS Typical | Value at 10 GHz |

Notes:

1.  " D.C. Bias 1" and " D.C. Bias B "  Nodes can be connected together.

Error!

**Typical Performance ( On Wafer Measurements )**



INSERTION LOSS



ISOLATION



INPUT RETURN LOSS

3

**Typical Performance ( On Wafer Measurements )**



OUTPUT RETURN LOSS
INSERTION LOSS STATE
(dB)
freq, GHz



OUTPUT RETURN LOSS
ISOLATION STATE
(dB)
freq, GHz
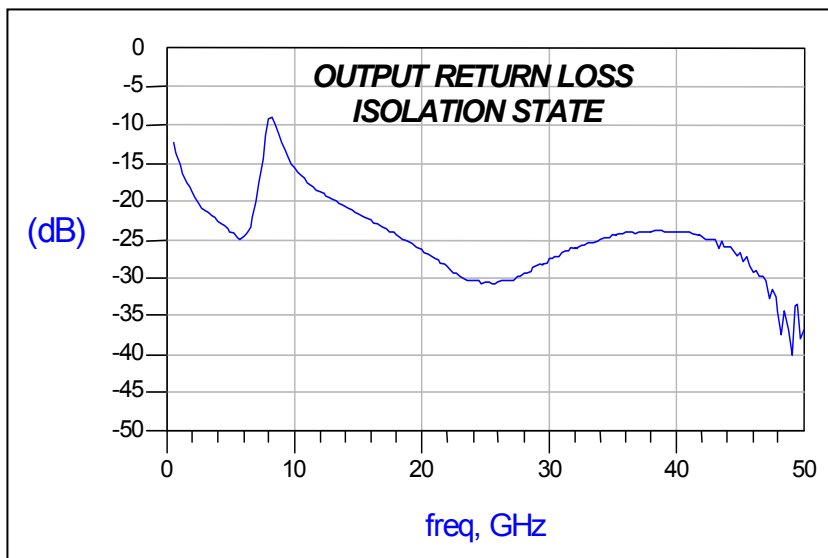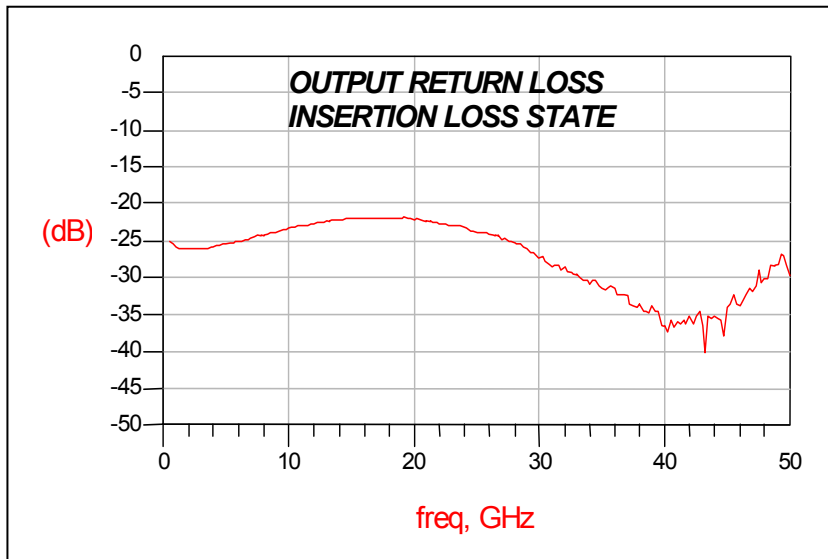
**Outline Dimensions**
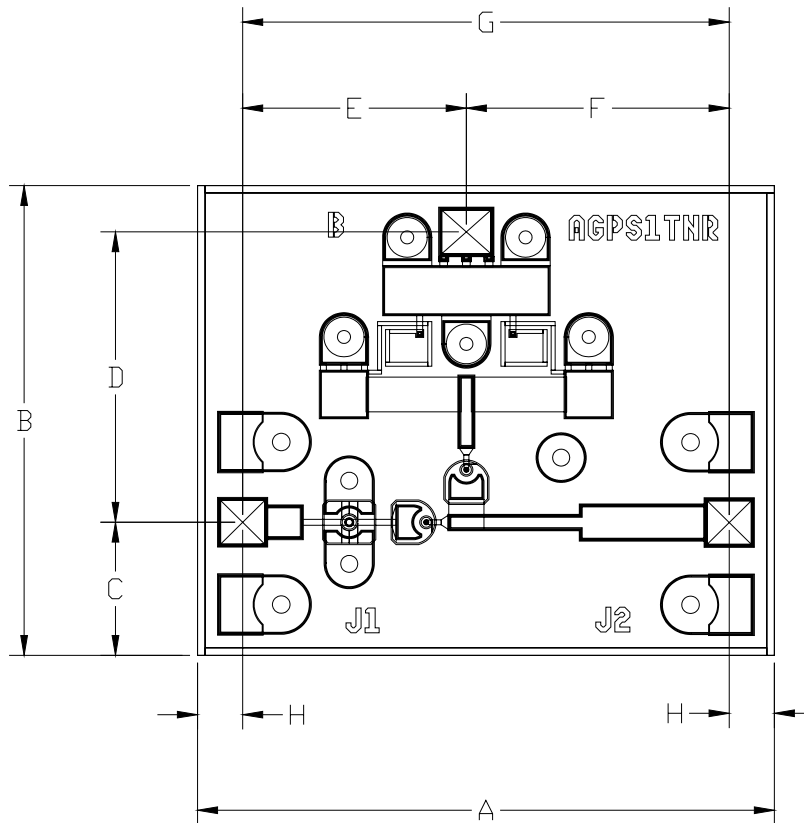


| Dimensions | | | | |
|---|---|---|---|---|
| | **mm** | | **mils** | |
| | **min** | **max** | **min** | **max** |
| **A** | 1.14 | 1.19 | 44.9 | 46.9 |
| **B** | 0.94 | 0.99 | 36.9 | 38.9 |
| **C** | 0.26 | 0.29 | 10.4 | 11.4 |
| **D** | 0.58 | 0.59 | 22.8 | 23.4 |
| **E** | 0.44 | 0.45 | 17.3 | 17.9 |
| **F** | 0.52 | 0.53 | 20.3 | 20.9 |
| **G** | 0.96 | 0.98 | 37.9 | 38.5 |
| **H** | 0.09 | 0.11 | 3.4 | 4.4 |
| **Thickness** | 0.09 | 0.11 | 3.5 | 4.5 |

## ASSEMBLY INSTRUCTIONS

The following precautions should be observed to avoid damaging these chips.

## CLEANLINESS

These chips should be handled in a clean environment. Clean die after solder die attach installation with care.

## STATIC SENSITIVITY

These Devices are considered ESD Class1. Proper ESD techniques should be used when handling these devices.

## GENERAL HANDLING

The protective polymer coating on the active areas of these die provides scratch and impact protection, particularly for the metal air bridge, which contacts the diode's anode.  Die should primarily be handled with vacuum pickups, or alternatively with plastic tweezers.

## MOUNTING TECHNIQUES

These AlGaAs devices are designed to be mounted with electrically conductive silver epoxy or with a solder that does not excessively scavenge gold.

## SOLDER DIE ATTACH

All die attach and bonding methods should be compatible with gold metal. Solders which do not excessively scavenge gold, such as 80Au/20Sn or Sn62/Pb36/Ag2 are acceptable for usage. Do not expose die to a temperature greater than 300 °C for more than 10 seconds.

## ELECTRICAL CONDUCTIVE EPOXY DIE ATTACH

Assembly can be preheated to approximately 125°C. Use a controlled thickness of approximately 2 mils for best electrical and thermal conductivity. Cure epoxy as per manufacturer's schedule. For extended cure times, temperatures should be kept below 150°C.

## RIBBON/WIRE BONDING

Wedge thermo compression bonding or ball bonding may be used to attach gold ribbons or gold wires to bonding pads. 1 Mil diameter gold wire or 1/4 x 3 mil sq. gold ribbons should be used for all RF ports for lower inductance and best mmwave performance.

**Successful Operation of the MA4AGSW1A Switch**

One External Bias Network and One External D.C Return is required for successful operation of the MA4AGSW1A Absorptive SPST AlGaAs PIN Diode Switch. The Backside Area of the Die is the RF and D.C. Return Ground Plane. In the Low Loss State, the Series Diode is Forward Biased with -1.35V, - 10 mA, at " D.C. Bias 1 " and the Match Diode is Reverse Biased at -1.35V, 0 mA at " D.C. Bias B ". In the Isolation State, both the Shunt Diode and the Match Diode are Both Forward Biased at + 1.35 V, + 10 mA at " D.C. Bias 1" and " D.C. Bias B ". This Isolation State condition makes the Series Diode Reverse Biased by 1.35V.  This Isolation State Results in a Good 50 Ω Match into Port J2 Only. The RF to D.C. Bias Truth table is shown in Table I. The Bias Network Design should yield > 30 dB RF to DC Isolation.

**MA4AGSW1A Schematic for 10 – 30 GHz Operation**

**DC Bias 1**



**AlGaAs Switch Die Shown in Dotted Outline**
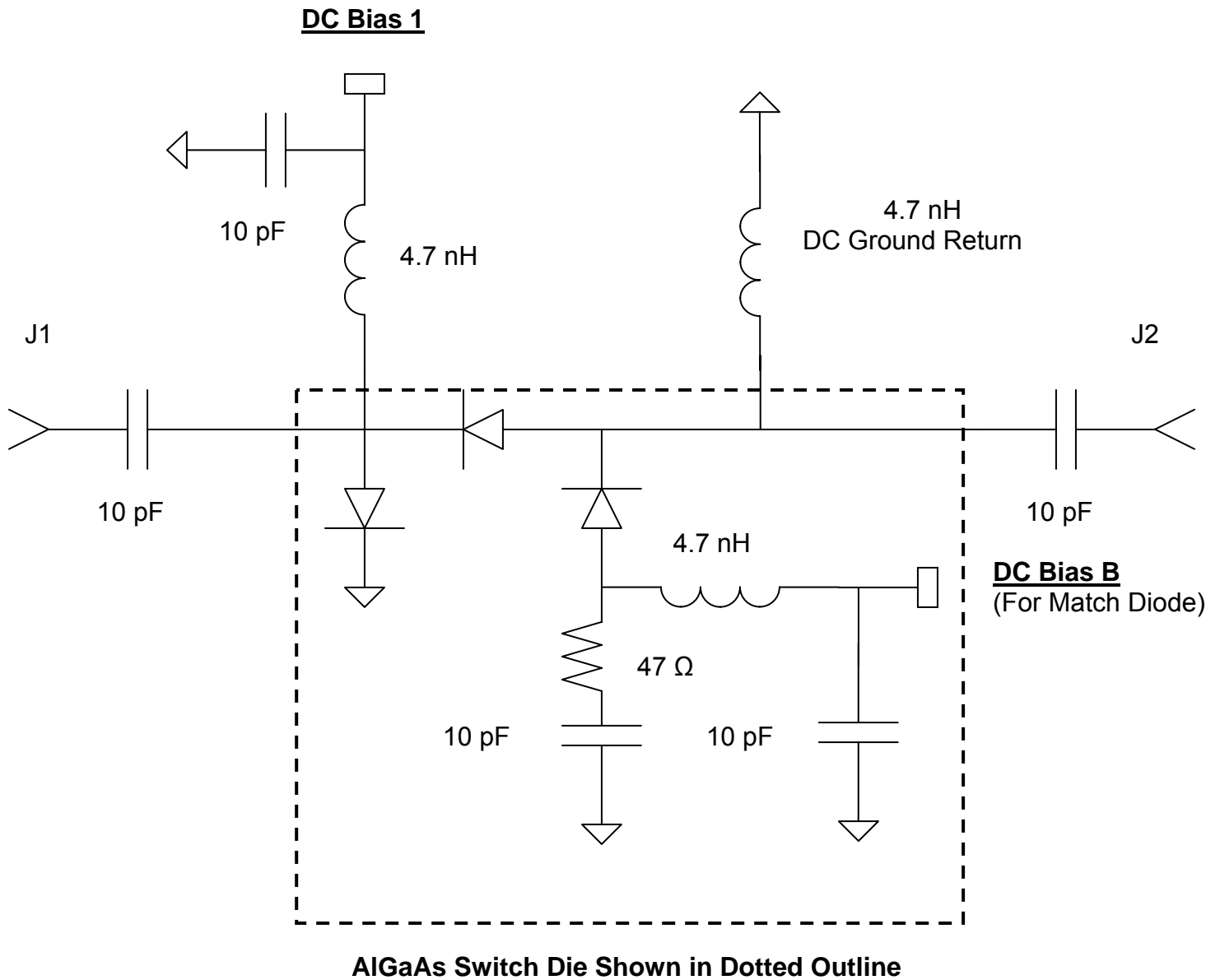
Notes:
1. " D.C. Bias 1" and " D.C. Bias B " Nodes can be connected together.
2. Diode Junction Forward Bias Voltage, Δ Vf @ 10 mA ~ 1.35 V @ + 25 ° C.

**Table I: D.C. to RF Truth Table**

| J1-J2 Low Loss :<br>Good VSWR at J1 & J2 | J1-J2 Isolation :<br>Good VSWR at J2 |
|---|---|
| D.C. Bias 1 = -1.35V @ - 10mA | D.C. Bias 1 = = + 1.35V @ + 10mA |
| D.C. Bias B = -1.35V @ 0mA | D.C. Bias B = + 1.35V @ + 10mA |

**On Wafer S Parameters @ + 25C**

**Insertion Loss State**

| F ( GHz ) | S11 Mag | S11 Ang | S21 Mag | S21 Ang | S12 Mag | S12Ang | S22 Mag | S22 Ang |
|---|---|---|---|---|---|---|---|---|
| .500 | .05547 | -14.13 | .94244 | -1.66 | .94244 | -1.66 | .05571 | -15.03 |
| .750 | .05276 | -15.15 | .94469 | -2.85 | .94469 | -2.85 | .05296 | -16.45 |
| 1.000 | .05100 | -16.32 | .94581 | -4.01 | .94582 | -4.01 | .05141 | -18.07 |
| 1.250 | .05002 | -17.71 | .94690 | -5.15 | .94690 | -5.15 | .05052 | -19.73 |
| 1.500 | .04930 | -18.98 | .94720 | -6.30 | .94719 | -6.30 | .04990 | -21.64 |
| 1.750 | .04888 | -20.46 | .94743 | -7.42 | .94744 | -7.42 | .04960 | -23.41 |
| 2.000 | .04855 | -22.18 | .94773 | -8.55 | .94772 | -8.55 | .04940 | -25.51 |
| 2.250 | .04825 | -23.61 | .94770 | -9.68 | .94770 | -9.68 | .04939 | -27.46 |
| 2.500 | .04819 | -25.59 | .94781 | -10.79 | .94781 | -10.79 | .04944 | -29.45 |
| 2.750 | .04803 | -27.32 | .94767 | -11.90 | .94768 | -11.90 | .04950 | -31.40 |
| 3.000 | .04786 | -29.12 | .94768 | -13.02 | .94769 | -13.02 | .04991 | -33.36 |
| 3.250 | .04767 | -30.73 | .94749 | -14.13 | .94749 | -14.13 | .05019 | -35.62 |
| 3.500 | .04780 | -32.68 | .94759 | -15.23 | .94759 | -15.23 | .05041 | -37.75 |
| 3.750 | .04775 | -34.70 | .94733 | -16.34 | .94734 | -16.34 | .05081 | -39.42 |
| 4.000 | .04771 | -36.36 | .94719 | -17.46 | .94720 | -17.46 | .05130 | -41.80 |
| 4.250 | .04775 | -38.07 | .94687 | -18.55 | .94688 | -18.55 | .05170 | -43.92 |
| 4.500 | .04777 | -40.07 | .94680 | -19.65 | .94679 | -19.65 | .05213 | -45.94 |
| 4.750 | .04779 | -41.76 | .94672 | -20.75 | .94673 | -20.75 | .05279 | -48.04 |
| 5.000 | .04795 | -43.78 | .94649 | -21.85 | .94650 | -21.85 | .05339 | -50.25 |
| 5.250 | .04800 | -45.67 | .94607 | -22.96 | .94607 | -22.96 | .05397 | -52.34 |
| 5.500 | .04830 | -47.51 | .94580 | -24.07 | .94579 | -24.07 | .05437 | -54.42 |
| 5.750 | .04842 | -49.57 | .94552 | -25.16 | .94552 | -25.16 | .05496 | -56.37 |
| 6.000 | .04862 | -51.49 | .94528 | -26.26 | .94527 | -26.26 | .05553 | -58.29 |
| 6.250 | .04876 | -53.47 | .94492 | -27.36 | .94492 | -27.36 | .05626 | -60.29 |
| 6.500 | .04906 | -55.55 | .94469 | -28.46 | .94469 | -28.46 | .05698 | -62.30 |
| 6.750 | .04918 | -57.56 | .94413 | -29.55 | .94412 | -29.55 | .05763 | -64.01 |
| 7.000 | .04936 | -59.68 | .94366 | -30.65 | .94367 | -30.65 | .05854 | -66.06 |
| 7.250 | .04956 | -61.79 | .94320 | -31.74 | .94320 | -31.74 | .05933 | -68.16 |
| 7.500 | .04980 | -64.04 | .94284 | -32.84 | .94283 | -32.84 | .06000 | -70.19 |
| 7.750 | .04953 | -66.39 | .94217 | -33.93 | .94217 | -33.93 | .06059 | -72.19 |
| 8.000 | .04910 | -67.89 | .94164 | -34.98 | .94164 | -34.98 | .06070 | -74.05 |
| 8.250 | .04936 | -69.47 | .94176 | -36.06 | .94177 | -36.06 | .06165 | -75.54 |
| 8.500 | .04995 | -71.42 | .94211 | -37.14 | .94211 | -37.14 | .06272 | -77.49 |
| 8.750 | .04988 | -73.21 | .94174 | -38.24 | .94175 | -38.24 | .06383 | -79.06 |
| 9.000 | .04991 | -75.30 | .94134 | -39.34 | .94133 | -39.34 | .06463 | -80.92 |
| 9.250 | .05047 | -77.42 | .94082 | -40.44 | .94081 | -40.44 | .06529 | -83.14 |
| 9.500 | .05039 | -79.49 | .94076 | -41.53 | .94077 | -41.53 | .06640 | -84.75 |
| 9.750 | .05091 | -81.50 | .94036 | -42.62 | .94037 | -42.62 | .06683 | -86.86 |
| 10.000 | .05083 | -83.80 | .93997 | -43.71 | .93998 | -43.71 | .06757 | -88.54 |
| 10.250 | .05091 | -85.51 | .93996 | -44.79 | .93996 | -44.79 | .06853 | -90.45 |
| 10.500 | .05114 | -87.75 | .93919 | -45.89 | .93920 | -45.89 | .06922 | -92.47 |
| 10.750 | .05090 | -90.05 | .93895 | -46.97 | .93896 | -46.97 | .07012 | -94.37 |
| 11.000 | .05120 | -91.94 | .93842 | -48.06 | .93842 | -48.06 | .07083 | -95.91 |
| 11.250 | .05099 | -93.81 | .93822 | -49.15 | .93821 | -49.15 | .07141 | -97.43 |
| 11.500 | .05116 | -95.76 | .93787 | -50.23 | .93788 | -50.23 | .07227 | -99.34 |
| 11.750 | .05101 | -97.99 | .93732 | -51.32 | .93733 | -51.32 | .07270 | -101.21 |
| 12.000 | .05121 | -99.58 | .93730 | -52.41 | .93729 | -52.41 | .07350 | -102.81 |
| 12.250 | .05107 | -102.22 | .93689 | -53.49 | .93688 | -53.49 | .07417 | -104.59 |
| 12.500 | .05127 | -103.70 | .93650 | -54.58 | .93651 | -54.58 | .07473 | -106.64 |
| 12.750 | .05104 | -105.60 | .93619 | -55.67 | .93619 | -55.67 | .07532 | -107.89 |
| 13.000 | .05098 | -107.69 | .93575 | -56.76 | .93575 | -56.76 | .07567 | -109.84 |
| 13.250 | .05126 | -109.70 | .93536 | -57.84 | .93536 | -57.84 | .07633 | -111.50 |
| 13.500 | .05122 | -111.78 | .93501 | -58.93 | .93501 | -58.93 | .07685 | -113.29 |
| 13.750 | .05090 | -113.66 | .93469 | -60.01 | .93469 | -60.01 | .07730 | -114.82 |
| 14.000 | .05101 | -115.78 | .93426 | -61.11 | .93426 | -61.11 | .07754 | -116.72 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 14.250 | .05135 | −117.82 | .93360 | −62.18 | .93361 | −62.18 | .07818 −118.39 |
| 14.500 | .05072 | −119.86 | .93268 | −63.26 | .93268 | −63.26 | .07866 −120.21 |
| 14.750 | .05029 | −122.22 | .93219 | −64.35 | .93219 | −64.35 | .07842 −121.93 |
| 15.000 | .05035 | −123.94 | .93205 | −65.41 | .93205 | −65.41 | .07873 −123.48 |
| 15.250 | .04974 | −126.15 | .93161 | −66.44 | .93160 | −66.44 | .07886 −125.02 |
| 15.500 | .04930 | −127.96 | .93136 | −67.53 | .93136 | −67.53 | .07885 −126.75 |
| 15.750 | .04890 | −129.91 | .93060 | −68.61 | .93061 | −68.61 | .07905 −128.27 |
| 16.000 | .04828 | −132.57 | .93060 | −69.71 | .93060 | −69.71 | .07913 −130.07 |
| 16.250 | .04781 | −133.30 | .93115 | −70.77 | .93114 | −70.77 | .07898 −131.09 |
| 16.500 | .04747 | −135.09 | .93082 | −71.82 | .93083 | −71.82 | .07911 −132.44 |
| 16.750 | .04722 | −137.29 | .93002 | −72.89 | .93002 | −72.89 | .07899 −133.80 |
| 17.000 | .04648 | −138.80 | .92938 | −74.00 | .92939 | −74.00 | .07907 −135.59 |
| 17.250 | .04615 | −140.25 | .92975 | −75.09 | .92975 | −75.09 | .07920 −136.98 |
| 17.500 | .04579 | −142.31 | .92939 | −76.13 | .92940 | −76.13 | .07901 −138.57 |
| 17.750 | .04510 | −144.14 | .92954 | −77.22 | .92955 | −77.22 | .07954 −139.88 |
| 18.000 | .04494 | −145.56 | .92922 | −78.30 | .92922 | −78.30 | .07864 −141.39 |
| 18.250 | .04381 | −146.84 | .92860 | −79.33 | .92861 | −79.33 | .07887 −142.22 |
| 18.500 | .04408 | −148.73 | .92854 | −80.45 | .92854 | −80.45 | .07894 −143.32 |
| 18.750 | .04302 | −149.07 | .92959 | −81.51 | .92960 | −81.51 | .07949 −144.35 |
| 19.000 | .04367 | −151.64 | .92987 | −82.62 | .92987 | −82.62 | .07949 −146.12 |
| 19.250 | .04322 | −153.43 | .92969 | −83.72 | .92970 | −83.72 | .07988 −147.83 |
| 19.500 | .04224 | −155.94 | .92920 | −84.83 | .92920 | −84.83 | .07948 −149.96 |
| 19.750 | .04122 | −157.50 | .92851 | −85.90 | .92850 | −85.90 | .07878 −150.95 |
| 20.000 | .04047 | −159.50 | .92738 | −87.00 | .92738 | −87.00 | .07820 −152.52 |
| 20.250 | .04126 | −160.65 | .92871 | −88.13 | .92870 | −88.12 | .07894 −153.62 |
| 20.500 | .03950 | −163.02 | .92780 | −89.17 | .92781 | −89.17 | .07713 −155.37 |
| 20.750 | .03792 | −164.93 | .92768 | −90.23 | .92769 | −90.23 | .07648 −156.95 |
| 21.000 | .03703 | −166.23 | .92743 | −91.32 | .92743 | −91.32 | .07545 −157.55 |
| 21.250 | .03687 | −169.11 | .92745 | −92.46 | .92745 | −92.46 | .07632 −159.61 |
| 21.500 | .03612 | −169.75 | .92707 | −93.55 | .92707 | −93.55 | .07497 −160.38 |
| 21.750 | .03469 | −171.50 | .92661 | −94.69 | .92661 | −94.69 | .07506 −161.96 |
| 22.000 | .03388 | −174.32 | .92657 | −95.70 | .92658 | −95.70 | .07343 −162.86 |
| 22.250 | .03278 | −173.13 | .92540 | −96.84 | .92540 | −96.84 | .07269 −164.03 |
| 22.500 | .03246 | −175.92 | .92512 | −97.90 | .92513 | −97.90 | .07269 −165.49 |
| 22.750 | .03116 | −177.64 | .92558 | −98.98 | .92559 | −98.98 | .07197 −166.52 |
| 23.000 | .03004 | −179.26 | .92554 | −100.10 | .92554 | −100.10 | .07171 −167.65 |
| 23.250 | .02936 | −179.07 | .92572 | −101.18 | .92572 | −101.18 | .07092 −168.56 |
| 23.500 | .02813 | 178.58 | .92534 | −102.23 | .92533 | −102.23 | .07046 −169.57 |
| 23.750 | .02676 | 177.73 | .92584 | −103.35 | .92584 | −103.35 | .07063 −170.54 |
| 24.000 | .02586 | 172.53 | .92492 | −104.46 | .92493 | −104.46 | .06864 −173.06 |
| 24.250 | .02491 | 169.29 | .92445 | −105.59 | .92445 | −105.59 | .06737 −174.15 |
| 24.500 | .02221 | 169.87 | .92442 | −106.64 | .92441 | −106.64 | .06523 −174.92 |
| 24.750 | .02164 | 171.46 | .92422 | −107.72 | .92421 | −107.72 | .06536 −175.12 |
| 25.000 | .02067 | 170.82 | .92467 | −108.80 | .92467 | −108.80 | .06414 −176.00 |
| 25.250 | .01930 | 168.87 | .92409 | −109.92 | .92409 | −109.92 | .06410 −176.35 |
| 25.500 | .01809 | 166.52 | .92325 | −111.04 | .92324 | −111.04 | .06310 −178.70 |
| 25.750 | .01662 | 171.49 | .92352 | −112.07 | .92351 | −112.07 | .06255 −177.66 |
| 26.000 | .01508 | 167.27 | .92416 | −113.17 | .92415 | −113.17 | .06155 179.99 |
| 26.250 | .01486 | 168.72 | .92389 | −114.35 | .92389 | −114.35 | .06101 −179.71 |
| 26.500 | .01374 | 165.44 | .92325 | −115.43 | .92326 | −115.43 | .06032 178.10 |
| 26.750 | .01327 | 161.55 | .92271 | −116.55 | .92270 | −116.55 | .06022 177.13 |
| 27.000 | .00979 | 162.46 | .92142 | −117.60 | .92142 | −117.60 | .05732 175.28 |
| 27.250 | .01014 | 163.35 | .92217 | −118.67 | .92217 | −118.67 | .05831 175.01 |
| 27.500 | .00830 | 159.53 | .92256 | −119.74 | .92255 | −119.74 | .05557 174.44 |
| 27.750 | .00664 | 160.87 | .92300 | −120.89 | .92301 | −120.89 | .05575 173.51 |
| 28.000 | .00614 | 168.15 | .92190 | −122.01 | .92191 | −122.01 | .05387 172.52 |
| 28.250 | .00363 | −173.81 | .92131 | −123.10 | .92131 | −123.10 | .05308 172.00 |
| 28.500 | .00288 | 148.73 | .92179 | −124.19 | .92179 | −124.19 | .05272 170.13 |
| 28.750 | .00104 | −145.83 | .92134 | −125.32 | .92133 | −125.32 | .05077 170.32 |
| 29.000 | .00090 | 1.99 | .92106 | −126.43 | .92107 | −126.43 | .04922 169.01 |
| 29.250 | .00364 | −45.19 | .92065 | −127.54 | .92065 | −127.54 | .04685 169.74 |
| 29.500 | .00534 | −33.10 | .92099 | −128.60 | .92099 | −128.60 | .04639 167.93 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 29.750 | .00737 | −52.54 | .92025 | −129.75 | .92026 | −129.75 | .04480 | 167.59 |
| 30.000 | .01042 | −51.45 | .92005 | −130.85 | .92005 | −130.85 | .04220 | 168.67 |
| 30.250 | .01103 | −52.47 | .92037 | −131.95 | .92037 | −131.95 | .04379 | 166.90 |
| 30.500 | .01450 | −52.20 | .92014 | −133.06 | .92015 | −133.06 | .04087 | 166.79 |
| 30.750 | .01526 | −57.64 | .92000 | −134.19 | .92000 | −134.19 | .03937 | 169.08 |
| 31.000 | .01702 | −56.76 | .91895 | −135.35 | .91895 | −135.35 | .03727 | 169.08 |
| 31.250 | .02046 | −61.02 | .91790 | −136.44 | .91789 | −136.44 | .03743 | 172.14 |
| 31.500 | .01941 | −62.63 | .91781 | −137.46 | .91780 | −137.46 | .03766 | 168.38 |
| 31.750 | .02183 | −61.74 | .91763 | −138.58 | .91762 | −138.58 | .03553 | 170.71 |
| 32.000 | .02358 | −66.97 | .91603 | −139.56 | .91603 | −139.56 | .03689 | 172.52 |
| 32.250 | .02454 | −66.70 | .91628 | −140.72 | .91627 | −140.72 | .03503 | 168.60 |
| 32.500 | .02649 | −67.85 | .91614 | −141.86 | .91613 | −141.86 | .03401 | 168.85 |
| 32.750 | .02845 | −68.93 | .91586 | −143.00 | .91587 | −143.00 | .03306 | 169.13 |
| 33.000 | .02925 | −69.39 | .91522 | −144.06 | .91522 | −144.06 | .03295 | 170.81 |
| 33.250 | .03109 | −71.49 | .91516 | −145.12 | .91516 | −145.12 | .03197 | 170.08 |
| 33.500 | .03280 | −71.36 | .91552 | −146.22 | .91552 | −146.22 | .03049 | 171.26 |
| 33.750 | .03564 | −71.29 | .91549 | −147.41 | .91549 | −147.41 | .03001 | 172.88 |
| 34.000 | .03820 | −72.84 | .91592 | −148.40 | .91592 | −148.40 | .02857 | 175.60 |
| 34.250 | .03999 | −78.19 | .91495 | −149.59 | .91495 | −149.59 | .03042 | 177.15 |
| 34.500 | .03937 | −79.44 | .91481 | −150.59 | .91480 | −150.59 | .03005 | 174.66 |
| 34.750 | .04189 | −78.53 | .91594 | −151.75 | .91594 | −151.75 | .02800 | 174.69 |
| 35.000 | .04353 | −80.36 | .91578 | −152.93 | .91578 | −152.93 | .02671 | 178.53 |
| 35.250 | .04579 | −82.73 | .91494 | −154.03 | .91494 | −154.03 | .02576 | 178.82 |
| 35.500 | .04682 | −84.78 | .91425 | −155.10 | .91426 | −155.10 | .02709 | −179.94 |
| 35.750 | .04622 | −85.88 | .91384 | −156.14 | .91384 | −156.14 | .02797 | 176.67 |
| 36.000 | .04971 | −85.18 | .91378 | −157.41 | .91379 | −157.41 | .02629 | −179.71 |
| 36.250 | .05284 | −86.30 | .91517 | −158.53 | .91518 | −158.53 | .02420 | −179.98 |
| 36.500 | .05429 | −88.89 | .91179 | −159.57 | .91178 | −159.57 | .02438 | −178.91 |
| 36.750 | .05450 | −92.31 | .91307 | −160.59 | .91306 | −160.59 | .02442 | 175.95 |
| 37.000 | .05468 | −93.14 | .91358 | −161.62 | .91358 | −161.62 | .02367 | 172.97 |
| 37.250 | .05675 | −91.05 | .91425 | −162.80 | .91424 | −162.80 | .02107 | 178.53 |
| 37.500 | .05972 | −91.65 | .91401 | −164.02 | .91402 | −164.02 | .02010 | −179.72 |
| 37.750 | .06328 | −93.85 | .91361 | −165.17 | .91360 | −165.17 | .01992 | −176.77 |
| 38.000 | .06425 | −95.80 | .91331 | −166.23 | .91331 | −166.23 | .02110 | −175.82 |
| 38.250 | .06571 | −97.91 | .91227 | −167.29 | .91228 | −167.29 | .01840 | −170.91 |
| 38.500 | .06627 | −99.92 | .91261 | −168.50 | .91261 | −168.50 | .01839 | −162.74 |
| 38.750 | .06823 | −99.92 | .91327 | −169.67 | .91327 | −169.67 | .01795 | −163.97 |
| 39.000 | .07049 | −102.45 | .91155 | −170.75 | .91154 | −170.75 | .02028 | −160.62 |
| 39.250 | .06891 | −104.42 | .91182 | −171.75 | .91183 | −171.75 | .01833 | −170.43 |
| 39.500 | .06953 | −103.43 | .91175 | −172.89 | .91174 | −172.89 | .01890 | −165.72 |
| 39.750 | .07356 | −105.61 | .91138 | −174.07 | .91139 | −174.07 | .01488 | −163.30 |
| 40.000 | .07811 | −106.97 | .91226 | −175.31 | .91227 | −175.31 | .01488 | −153.47 |
| 40.250 | .07747 | −110.27 | .91134 | −176.38 | .91134 | −176.38 | .01367 | −159.72 |
| 40.500 | .07912 | −111.07 | .91039 | −177.51 | .91040 | −177.51 | .01613 | −146.34 |
| 40.750 | .07739 | −112.63 | .90898 | −178.48 | .90898 | −178.48 | .01441 | −143.62 |
| 41.000 | .08135 | −114.01 | .90813 | −179.74 | .90814 | −179.74 | .01596 | −137.37 |
| 41.250 | .08198 | −113.58 | .90898 | 179.10 | .90898 | 179.10 | .01515 | −141.38 |
| 41.500 | .08473 | −115.16 | .90999 | 177.88 | .90999 | 177.88 | .01635 | −125.93 |
| 41.750 | .08513 | −118.56 | .90805 | 176.90 | .90805 | 176.90 | .01530 | −129.70 |
| 42.000 | .08704 | −119.99 | .90639 | 175.79 | .90638 | 175.79 | .01727 | −128.37 |
| 42.250 | .08470 | −121.72 | .90599 | 174.71 | .90599 | 174.71 | .01530 | −130.53 |
| 42.500 | .08776 | −121.37 | .90755 | 173.30 | .90754 | 173.30 | .01724 | −119.61 |
| 42.750 | .08662 | −123.61 | .90748 | 172.25 | .90747 | 172.25 | .01830 | −127.00 |
| 43.000 | .08853 | −124.91 | .90686 | 171.11 | .90686 | 171.11 | .01497 | −120.81 |
| 43.250 | .08671 | −126.34 | .90481 | 170.17 | .90482 | 170.17 | .00973 | −130.14 |
| 43.500 | .08882 | −129.64 | .90477 | 169.05 | .90477 | 169.05 | .01745 | −119.89 |
| 43.750 | .09094 | −132.31 | .90554 | 167.87 | .90554 | 167.87 | .01670 | −120.93 |
| 44.000 | .09485 | −131.16 | .90269 | 166.59 | .90269 | 166.59 | .01727 | −108.56 |
| 44.250 | .09330 | −134.10 | .90349 | 165.59 | .90349 | 165.59 | .01690 | −104.18 |
| 44.500 | .09103 | −135.89 | .90163 | 164.52 | .90164 | 164.52 | .01619 | −102.26 |
| 44.750 | .09222 | −138.67 | .90045 | 163.42 | .90045 | 163.42 | .01282 | −94.74 |
| 45.000 | .09507 | −139.16 | .89873 | 162.31 | .89872 | 162.31 | .01968 | −94.77 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 45.250 | .09349 | –141.00 | .89982 | 161.16 | .89983 | 161.16 | .02088 | –86.34 |
| 45.500 | .09172 | –139.48 | .90057 | 160.09 | .90057 | 160.09 | .02429 | –88.17 |
| 45.750 | .09272 | –141.90 | .89873 | 158.89 | .89873 | 158.89 | .02057 | –86.38 |
| 46.000 | .09182 | –145.28 | .89885 | 157.89 | .89884 | 157.89 | .02037 | –77.52 |
| 46.250 | .09127 | –145.01 | .89855 | 156.77 | .89855 | 156.77 | .02217 | –87.65 |
| 46.500 | .08861 | –145.45 | .90021 | 155.64 | .90020 | 155.64 | .02469 | –82.06 |
| 46.750 | .09153 | –146.93 | .89816 | 154.44 | .89817 | 154.44 | .02642 | –77.57 |
| 47.000 | .09193 | –148.69 | .89791 | 153.49 | .89791 | 153.49 | .02526 | –72.32 |
| 47.250 | .09059 | –150.41 | .89818 | 152.43 | .89818 | 152.43 | .02790 | –69.92 |
| 47.500 | .08933 | –153.02 | .89471 | 151.28 | .89471 | 151.28 | .03564 | –75.22 |
| 47.750 | .08815 | –152.11 | .89924 | 150.14 | .89924 | 150.14 | .02920 | –70.47 |
| 48.000 | .08779 | –154.64 | .89714 | 148.97 | .89713 | 148.97 | .03124 | –63.97 |
| 48.250 | .08938 | –152.91 | .89581 | 148.00 | .89581 | 148.00 | .03121 | –60.84 |
| 48.500 | .08828 | –153.56 | .89680 | 146.49 | .89680 | 146.49 | .03800 | –67.82 |
| 48.750 | .08988 | –158.15 | .89474 | 145.59 | .89474 | 145.59 | .03744 | –61.92 |
| 49.000 | .08956 | –153.58 | .89810 | 144.52 | .89810 | 144.52 | .03900 | –73.07 |
| 49.250 | .09103 | –154.40 | .89997 | 143.34 | .89998 | 143.34 | .04552 | –60.49 |
| 49.500 | .09230 | –162.24 | .89318 | 142.54 | .89319 | 142.55 | .04440 | –53.86 |
| 49.750 | .08425 | –159.25 | .89215 | 141.45 | .89216 | 141.45 | .03763 | –60.17 |
| 50.000 | .08818 | –155.34 | .89448 | 140.01 | .89448 | 140.01 | .03229 | –52.56 |

## On Wafer S Parameters @ + 25C

**Isolation State**

| F ( GHz ) | S11 Mag | S11 Ang | S21 Mag | S21 Ang | S12 Mag | S12Ang | S22 Mag | S22 Ang |
|---|---|---|---|---|---|---|---|---|
| .500 | .88147 | −179.25 | .00011 | 64.17 | .00006 | 90.73 | .24284 | −53.34 |
| .750 | .88853 | 179.93 | .00014 | 46.08 | .00015 | 60.12 | .20284 | −69.33 |
| 1.000 | .89183 | 179.19 | .00011 | 27.97 | .00003 | 27.97 | .17097 | −84.56 |
| 1.250 | .89489 | 178.52 | .00014 | 46.74 | .00018 | −6.39 | .14758 | −96.01 |
| 1.500 | .89634 | 177.92 | .00011 | 28.65 | .00010 | 62.34 | .12856 | −105.54 |
| 1.750 | .89771 | 177.28 | .00016 | 20.85 | .00013 | 2.42 | .11649 | −114.32 |
| 2.000 | .89890 | 176.70 | .00014 | 47.75 | .00006 | 86.41 | .10701 | −123.25 |
| 2.250 | .89965 | 176.11 | .00011 | 29.64 | .00014 | 156.51 | .09692 | −131.58 |
| 2.500 | .90134 | 175.55 | .00016 | 21.85 | .00016 | 11.23 | .08813 | −138.66 |
| 2.750 | .90063 | 174.97 | .00014 | 48.75 | .00014 | 78.50 | .08119 | −144.42 |
| 3.000 | .90145 | 174.44 | .00011 | 30.64 | .00020 | −25.67 | .07662 | −149.71 |
| 3.250 | .90146 | 173.82 | .00010 | 94.40 | .00012 | 57.53 | .07378 | −155.81 |
| 3.500 | .90166 | 173.29 | .00010 | 94.75 | .00025 | 41.62 | .07051 | −162.78 |
| 3.750 | .90169 | 172.70 | .00011 | 68.52 | .00017 | −7.44 | .06667 | −169.96 |
| 4.000 | .90214 | 172.20 | .00016 | 77.01 | .00028 | 122.01 | .06280 | −176.75 |
| 4.250 | .90215 | 171.68 | .00015 | 95.80 | .00015 | 109.83 | .05921 | 176.57 |
| 4.500 | .90253 | 171.11 | .00015 | 96.17 | .00023 | 15.63 | .05655 | 169.60 |
| 4.750 | .90210 | 170.57 | .00020 | 96.52 | .00025 | 85.21 | .05447 | 161.21 |
| 5.000 | .90302 | 170.04 | .00021 | 82.85 | .00022 | 54.77 | .05230 | 151.18 |
| 5.250 | .90275 | 169.50 | .00020 | 111.29 | .00026 | 117.00 | .04977 | 139.96 |
| 5.500 | .90329 | 168.94 | .00030 | 97.62 | .00032 | 77.06 | .04798 | 127.87 |
| 5.750 | .90278 | 168.43 | .00030 | 97.98 | .00026 | 106.11 | .04821 | 114.94 |
| 6.000 | .90321 | 167.91 | .00035 | 98.38 | .00037 | 98.38 | .05149 | 99.29 |
| 6.250 | .90288 | 167.37 | .00040 | 98.75 | .00035 | 94.67 | .05744 | 81.43 |
| 6.500 | .90286 | 166.86 | .00050 | 99.16 | .00053 | 97.48 | .06655 | 63.14 |
| 6.750 | .90290 | 166.31 | .00060 | 90.10 | .00060 | 88.31 | .07988 | 46.78 |
| 7.000 | .90306 | 165.79 | .00074 | 80.34 | .00073 | 83.98 | .10200 | 32.48 |
| 7.250 | .90269 | 165.26 | .00102 | 71.39 | .00104 | 70.07 | .13872 | 17.55 |
| 7.500 | .90227 | 164.76 | .00133 | 52.93 | .00135 | 53.15 | .19562 | −.07 |
| 7.750 | .90275 | 164.21 | .00172 | 28.25 | .00172 | 28.25 | .27708 | −23.68 |
| 8.000 | .90296 | 163.72 | .00214 | −4.71 | .00213 | −4.82 | .34830 | −55.24 |
| 8.250 | .90240 | 163.20 | .00200 | −39.57 | .00199 | −40.36 | .35014 | −86.38 |
| 8.500 | .90326 | 162.72 | .00177 | −68.64 | .00179 | −68.86 | .31422 | −110.07 |
| 8.750 | .90278 | 162.17 | .00162 | −88.76 | .00165 | −87.00 | .26986 | −127.82 |
| 9.000 | .90289 | 161.67 | .00149 | −103.50 | .00148 | −102.60 | .23124 | −140.11 |
| 9.250 | .90298 | 161.13 | .00137 | −118.00 | .00136 | −118.90 | .20335 | −149.00 |
| 9.500 | .90292 | 160.59 | .00126 | −128.37 | .00127 | −128.81 | .18318 | −155.99 |
| 9.750 | .90281 | 160.09 | .00128 | −134.15 | .00129 | −135.26 | .16757 | −162.04 |
| 10.000 | .90336 | 159.60 | .00134 | −142.46 | .00134 | −143.13 | .15490 | −167.17 |
| 10.250 | .90306 | 159.08 | .00127 | −150.17 | .00124 | −149.71 | .14488 | −171.67 |
| 10.500 | .90357 | 158.56 | .00140 | −153.34 | .00139 | −154.24 | .13673 | −175.72 |
| 10.750 | .90179 | 158.19 | .00148 | −157.44 | .00146 | −155.39 | .12967 | −179.42 |
| 11.000 | .90329 | 157.52 | .00152 | −159.10 | .00156 | −158.00 | .12354 | 177.42 |
| 11.250 | .90281 | 157.04 | .00161 | −165.96 | .00161 | −166.19 | .11821 | 174.21 |
| 11.500 | .90284 | 156.54 | .00172 | −170.35 | .00171 | −171.25 | .11361 | 171.06 |
| 11.750 | .90339 | 156.01 | .00179 | −174.45 | .00179 | −174.00 | .10925 | 168.14 |
| 12.000 | .90385 | 155.50 | .00194 | 179.41 | .00195 | 178.52 | .10551 | 165.46 |
| 12.250 | .90391 | 154.98 | .00197 | 177.12 | .00197 | 176.22 | .10197 | 162.82 |
| 12.500 | .90395 | 154.48 | .00207 | 174.18 | .00206 | 174.40 | .09895 | 160.34 |
| 12.750 | .90412 | 153.93 | .00211 | 169.19 | .00210 | 169.19 | .09564 | 157.72 |
| 13.000 | .90421 | 153.46 | .00216 | 167.32 | .00214 | 166.87 | .09289 | 155.25 |
| 13.250 | .90467 | 152.91 | .00226 | 163.52 | .00225 | 163.29 | .09008 | 153.15 |
| 13.500 | .90457 | 152.42 | .00240 | 159.21 | .00238 | 160.34 | .08744 | 150.66 |
| 13.750 | .90533 | 151.89 | .00230 | 158.98 | .00232 | 157.88 | .08503 | 148.54 |
| 14.000 | .90503 | 151.38 | .00253 | 156.68 | .00252 | 156.90 | .08294 | 146.20 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 14.250 | .90562 | 150.86 | .00265 | 148.86 | .00267 | 148.86 | .08062 | 144.24 |
| 14.500 | .90471 | 150.33 | .00258 | 147.62 | .00259 | 146.95 | .07825 | 141.96 |
| 14.750 | .90525 | 149.80 | .00253 | 142.33 | .00252 | 141.77 | .07647 | 139.84 |
| 15.000 | .90514 | 149.31 | .00240 | 144.53 | .00240 | 144.75 | .07431 | 137.87 |
| 15.250 | .90606 | 148.86 | .00255 | 144.11 | .00255 | 144.23 | .07225 | 135.68 |
| 15.500 | .90582 | 148.31 | .00247 | 139.24 | .00242 | 138.90 | .07027 | 133.25 |
| 15.750 | .90512 | 147.81 | .00245 | 141.13 | .00243 | 141.58 | .06829 | 131.26 |
| 16.000 | .90639 | 147.31 | .00249 | 143.46 | .00248 | 142.78 | .06685 | 128.99 |
| 16.250 | .90709 | 146.81 | .00258 | 145.22 | .00256 | 145.67 | .06464 | 127.05 |
| 16.500 | .90789 | 146.35 | .00276 | 142.23 | .00278 | 142.11 | .06277 | 124.83 |
| 16.750 | .90670 | 145.79 | .00276 | 138.19 | .00275 | 138.08 | .06074 | 122.81 |
| 17.000 | .90745 | 145.24 | .00273 | 139.94 | .00272 | 140.39 | .05936 | 120.50 |
| 17.250 | .90778 | 144.72 | .00292 | 139.61 | .00295 | 138.95 | .05760 | 118.52 |
| 17.500 | .90841 | 144.24 | .00273 | 140.79 | .00272 | 140.12 | .05583 | 116.48 |
| 17.750 | .90937 | 143.74 | .00288 | 140.90 | .00287 | 140.68 | .05419 | 114.57 |
| 18.000 | .90941 | 143.21 | .00308 | 143.46 | .00306 | 143.57 | .05270 | 112.33 |
| 18.250 | .90913 | 142.73 | .00307 | 141.12 | .00309 | 141.46 | .05061 | 110.11 |
| 18.500 | .90977 | 142.13 | .00349 | 141.88 | .00348 | 141.99 | .04935 | 107.76 |
| 18.750 | .91043 | 141.60 | .00359 | 140.71 | .00361 | 140.82 | .04762 | 105.69 |
| 19.000 | .91066 | 141.09 | .00367 | 139.94 | .00367 | 139.82 | .04647 | 103.16 |
| 19.250 | .91226 | 140.62 | .00374 | 139.16 | .00374 | 138.93 | .04459 | 100.99 |
| 19.500 | .91258 | 140.02 | .00414 | 135.46 | .00415 | 135.57 | .04345 | 97.89 |
| 19.750 | .91185 | 139.47 | .00403 | 132.79 | .00401 | 132.68 | .04152 | 95.71 |
| 20.000 | .91237 | 138.92 | .00423 | 130.67 | .00421 | 130.45 | .04036 | 92.97 |
| 20.250 | .91299 | 138.51 | .00413 | 130.66 | .00416 | 130.55 | .03864 | 91.02 |
| 20.500 | .91266 | 137.95 | .00456 | 127.15 | .00455 | 127.01 | .03736 | 87.26 |
| 20.750 | .91379 | 137.38 | .00426 | 126.11 | .00428 | 125.77 | .03629 | 84.59 |
| 21.000 | .91384 | 136.85 | .00451 | 128.77 | .00451 | 128.82 | .03471 | 81.36 |
| 21.250 | .91426 | 136.33 | .00474 | 128.30 | .00474 | 128.30 | .03364 | 77.95 |
| 21.500 | .91480 | 135.75 | .00476 | 123.05 | .00475 | 123.05 | .03194 | 74.77 |
| 21.750 | .91529 | 135.24 | .00471 | 123.42 | .00471 | 123.45 | .02977 | 72.84 |
| 22.000 | .91624 | 134.72 | .00480 | 125.07 | .00480 | 125.07 | .03002 | 68.47 |
| 22.250 | .91527 | 134.04 | .00494 | 122.71 | .00492 | 122.82 | .02819 | 64.30 |
| 22.500 | .91518 | 133.56 | .00504 | 120.04 | .00504 | 119.95 | .02711 | 60.60 |
| 22.750 | .91512 | 133.09 | .00508 | 121.59 | .00508 | 121.59 | .02635 | 56.80 |
| 23.000 | .91633 | 132.54 | .00524 | 119.61 | .00523 | 119.75 | .02531 | 52.29 |
| 23.250 | .91650 | 131.97 | .00542 | 117.27 | .00542 | 117.42 | .02407 | 47.36 |
| 23.500 | .91711 | 131.46 | .00554 | 118.45 | .00551 | 118.41 | .02340 | 42.58 |
| 23.750 | .91759 | 130.90 | .00563 | 116.17 | .00563 | 116.17 | .02270 | 37.94 |
| 24.000 | .91757 | 130.36 | .00554 | 116.45 | .00555 | 116.63 | .02252 | 32.80 |
| 24.250 | .91824 | 129.76 | .00602 | 114.59 | .00603 | 114.73 | .02135 | 26.82 |
| 24.500 | .91807 | 129.21 | .00606 | 113.74 | .00606 | 113.70 | .02203 | 21.17 |
| 24.750 | .91716 | 128.67 | .00613 | 111.61 | .00613 | 111.57 | .02114 | 16.28 |
| 25.000 | .91753 | 128.11 | .00606 | 112.44 | .00607 | 112.48 | .02126 | 10.75 |
| 25.250 | .91725 | 127.51 | .00634 | 111.91 | .00633 | 111.96 | .02086 | 4.67 |
| 25.500 | .91722 | 127.05 | .00629 | 112.24 | .00629 | 112.20 | .02083 | .49 |
| 25.750 | .91726 | 126.48 | .00667 | 109.50 | .00667 | 109.74 | .02130 | −7.54 |
| 26.000 | .91872 | 125.93 | .00661 | 110.26 | .00662 | 110.35 | .02140 | −10.60 |
| 26.250 | .91707 | 125.38 | .00667 | 110.47 | .00668 | 110.44 | .02220 | −19.05 |
| 26.500 | .91827 | 124.90 | .00701 | 110.00 | .00701 | 109.97 | .02223 | −22.17 |
| 26.750 | .91766 | 124.35 | .00708 | 109.08 | .00709 | 109.06 | .02216 | −27.03 |
| 27.000 | .91923 | 123.75 | .00741 | 105.94 | .00739 | 105.74 | .02349 | −30.52 |
| 27.250 | .91861 | 123.27 | .00715 | 105.35 | .00715 | 105.39 | .02376 | −36.24 |
| 27.500 | .91805 | 122.70 | .00768 | 105.20 | .00769 | 105.31 | .02499 | −38.03 |
| 27.750 | .92100 | 122.12 | .00775 | 105.55 | .00774 | 105.44 | .02532 | −44.98 |
| 28.000 | .91853 | 121.55 | .00805 | 101.81 | .00805 | 101.84 | .02699 | −46.54 |
| 28.250 | .91896 | 120.95 | .00798 | 102.39 | .00800 | 102.53 | .02699 | −51.38 |
| 28.500 | .91976 | 120.47 | .00830 | 99.24 | .00831 | 99.19 | .02856 | −52.83 |
| 28.750 | .91877 | 119.85 | .00840 | 99.33 | .00839 | 99.26 | .02946 | −57.80 |
| 29.000 | .91954 | 119.31 | .00826 | 99.53 | .00825 | 99.40 | .03056 | −60.74 |
| 29.250 | .91880 | 118.71 | .00857 | 96.84 | .00859 | 96.92 | .03140 | −62.84 |
| 29.500 | .92098 | 118.21 | .00882 | 98.27 | .00881 | 98.24 | .03196 | −65.45 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 29.750 | .92023 | 117.58 | .00873 | 94.87 | .00873 | 94.92 | .03327 | −66.21 |
| 30.000 | .91982 | 116.96 | .00896 | 93.02 | .00895 | 92.95 | .03501 | −68.99 |
| 30.250 | .92040 | 116.39 | .00899 | 93.73 | .00899 | 93.91 | .03540 | −74.51 |
| 30.500 | .92100 | 115.87 | .00911 | 91.92 | .00911 | 91.96 | .03647 | −74.81 |
| 30.750 | .91981 | 115.22 | .00953 | 95.90 | .00953 | 95.91 | .03770 | −76.14 |
| 31.000 | .91961 | 114.64 | .01006 | 92.42 | .01006 | 92.39 | .03936 | −77.83 |
| 31.250 | .91920 | 114.12 | .01019 | 90.46 | .01018 | 90.40 | .04069 | −81.74 |
| 31.500 | .91942 | 113.54 | .01067 | 86.84 | .01067 | 86.82 | .04059 | −83.72 |
| 31.750 | .91874 | 112.92 | .01053 | 86.99 | .01053 | 87.04 | .04152 | −83.09 |
| 32.000 | .91691 | 112.39 | .01105 | 82.45 | .01105 | 82.50 | .04320 | −87.82 |
| 32.250 | .91823 | 111.85 | .01088 | 80.11 | .01088 | 80.18 | .04350 | −90.04 |
| 32.500 | .91806 | 111.29 | .01090 | 77.85 | .01089 | 77.90 | .04395 | −91.15 |
| 32.750 | .91851 | 110.66 | .01128 | 80.12 | .01128 | 80.15 | .04492 | −93.06 |
| 33.000 | .91616 | 110.11 | .01104 | 77.17 | .01103 | 77.19 | .04588 | −95.58 |
| 33.250 | .91684 | 109.51 | .01061 | 71.09 | .01061 | 71.07 | .04699 | −95.91 |
| 33.500 | .91656 | 108.98 | .01065 | 73.64 | .01065 | 73.58 | .04700 | −98.13 |
| 33.750 | .91620 | 108.28 | .01047 | 73.33 | .01047 | 73.33 | .04769 | −99.18 |
| 34.000 | .91586 | 107.72 | .01078 | 73.08 | .01078 | 73.11 | .04927 | −100.17 |
| 34.250 | .91411 | 107.07 | .01094 | 71.96 | .01094 | 71.84 | .05135 | −102.77 |
| 34.500 | .91288 | 106.62 | .01053 | 69.93 | .01053 | 69.91 | .05075 | −104.61 |
| 34.750 | .91278 | 105.91 | .01060 | 67.75 | .01060 | 67.77 | .05111 | −104.80 |
| 35.000 | .91149 | 105.23 | .01081 | 72.16 | .01082 | 72.16 | .05189 | −106.63 |
| 35.250 | .91155 | 104.72 | .01108 | 71.78 | .01108 | 71.84 | .05276 | −107.66 |
| 35.500 | .91049 | 104.18 | .01161 | 68.33 | .01161 | 68.33 | .05307 | −110.14 |
| 35.750 | .90881 | 103.65 | .01102 | 62.17 | .01102 | 62.22 | .05399 | −111.52 |
| 36.000 | .90870 | 103.12 | .01209 | 64.42 | .01209 | 64.47 | .05698 | −113.98 |
| 36.250 | .90954 | 102.67 | .01195 | 65.65 | .01195 | 65.63 | .05678 | −113.44 |
| 36.500 | .90737 | 101.98 | .01187 | 62.75 | .01187 | 62.78 | .05538 | −116.43 |
| 36.750 | .90682 | 101.52 | .01185 | 57.96 | .01185 | 57.97 | .05556 | −119.29 |
| 37.000 | .90987 | 101.03 | .01148 | 55.82 | .01148 | 55.79 | .05546 | −120.24 |
| 37.250 | .90920 | 100.33 | .01147 | 58.36 | .01147 | 58.36 | .05585 | −121.92 |
| 37.500 | .90734 | 99.68 | .01154 | 59.20 | .01153 | 59.20 | .05662 | −122.01 |
| 37.750 | .90359 | 99.14 | .01092 | 63.42 | .01092 | 63.46 | .05669 | −123.45 |
| 38.000 | .90251 | 98.58 | .01160 | 57.05 | .01160 | 57.06 | .05686 | −123.59 |
| 38.250 | .90400 | 98.06 | .01152 | 55.64 | .01152 | 55.60 | .05627 | −124.97 |
| 38.500 | .90711 | 97.45 | .01211 | 55.76 | .01211 | 55.79 | .05806 | −126.29 |
| 38.750 | .90357 | 96.78 | .01162 | 57.39 | .01162 | 57.35 | .05774 | −128.46 |
| 39.000 | .90484 | 96.02 | .01160 | 55.88 | .01160 | 55.86 | .05784 | −129.56 |
| 39.250 | .90320 | 95.69 | .01192 | 54.41 | .01193 | 54.37 | .05648 | −133.19 |
| 39.500 | .90212 | 94.85 | .01282 | 50.97 | .01283 | 50.97 | .05544 | −133.99 |
| 39.750 | .90222 | 94.37 | .01239 | 52.51 | .01239 | 52.49 | .05493 | −134.76 |
| 40.000 | .89882 | 93.94 | .01302 | 54.02 | .01302 | 54.02 | .05698 | −133.43 |
| 40.250 | .90193 | 93.62 | .01287 | 54.48 | .01287 | 54.48 | .05565 | −137.01 |
| 40.500 | .90087 | 92.80 | .01275 | 50.73 | .01275 | 50.72 | .05670 | −136.49 |
| 40.750 | .90172 | 92.09 | .01311 | 46.94 | .01311 | 46.93 | .05300 | −141.00 |
| 41.000 | .90095 | 91.55 | .01434 | 47.97 | .01434 | 47.97 | .05473 | −139.10 |
| 41.250 | .89982 | 90.99 | .01385 | 46.06 | .01384 | 46.06 | .05387 | −143.41 |
| 41.500 | .89697 | 90.29 | .01309 | 49.46 | .01309 | 49.46 | .05313 | −142.17 |
| 41.750 | .90063 | 89.83 | .01409 | 48.88 | .01409 | 48.89 | .05285 | −144.68 |
| 42.000 | .89610 | 88.96 | .01480 | 45.53 | .01480 | 45.49 | .05357 | −145.77 |
| 42.250 | .89174 | 88.57 | .01436 | 41.76 | .01436 | 41.79 | .05060 | −147.85 |
| 42.500 | .89827 | 87.77 | .01474 | 45.61 | .01474 | 45.62 | .05082 | −147.75 |
| 42.750 | .89377 | 87.42 | .01510 | 45.47 | .01509 | 45.45 | .05084 | −148.75 |
| 43.000 | .89370 | 86.97 | .01617 | 45.72 | .01617 | 45.73 | .04702 | −151.51 |
| 43.250 | .88419 | 85.92 | .01579 | 39.21 | .01578 | 39.19 | .04638 | −153.83 |
| 43.500 | .89400 | 85.87 | .01534 | 32.53 | .01534 | 32.52 | .05028 | −155.99 |
| 43.750 | .89849 | 85.00 | .01793 | 35.43 | .01793 | 35.42 | .04426 | −156.34 |
| 44.000 | .88778 | 84.46 | .01646 | 34.58 | .01646 | 34.58 | .04224 | −155.20 |
| 44.250 | .88322 | 84.11 | .01685 | 32.39 | .01685 | 32.40 | .04415 | −158.65 |
| 44.500 | .88747 | 83.25 | .01736 | 31.37 | .01736 | 31.37 | .04027 | −161.39 |
| 44.750 | .88749 | 83.13 | .01834 | 28.00 | .01834 | 28.00 | .03925 | −163.03 |
| 45.000 | .88364 | 82.31 | .01674 | 27.19 | .01674 | 27.20 | .03731 | −159.73 |

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45.250    .88817   81.86   .01867   24.67   .01867   24.66   .03495  -164.75
45.500    .88906   81.15   .01756   24.56   .01756   24.55   .03577  -164.30
45.750    .87946   80.34   .01878   22.75   .01878   22.74   .02962  -165.35
46.000    .88375   79.52   .01908   20.50   .01908   20.51   .02558  -171.18
46.250    .88489   79.27   .01856   19.00   .01856   19.01   .02677  -171.87
46.500    .88585   78.37   .01868   16.71   .01868   16.71   .02601  -171.42
46.750    .88322   78.04   .01937   10.12   .01937   10.12   .02571   179.04
47.000    .88351   77.97   .01760   12.10   .01760   12.10   .02333   178.07
47.250    .88479   77.22   .01887   15.77   .01887   15.77   .01479   166.91
47.500    .88159   76.92   .02033   12.08   .02033   12.08   .01822  -174.44
47.750    .87769   76.14   .01972    8.67   .01972    8.66   .01535   166.18
48.000    .87898   75.15   .01654    5.78   .01654    5.78   .00877   150.90
48.250    .88740   74.32   .01797   10.38   .01798   10.38   .00688   135.18
48.500    .88169   73.52   .01842    -.69   .01842    -.69   .00346   129.61
48.750    .88029   73.32   .01864    4.16   .01864    4.17   .00576    78.42
49.000    .88487   72.80   .01965    -.91   .01965    -.91   .00479    56.34
49.250    .86841   72.20   .01774    3.71   .01773    3.70   .01132    29.70
49.500    .87164   71.80   .02049     .36   .02049     .35   .00945    26.52
49.750    .87549   70.74   .01992   -6.32   .01992   -6.33   .01368    30.04
50.000    .86901   69.62   .01982   -1.00   .01982   -1.00   .01961    21.35
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