MGA-62563

High Performance GaAs MMIC Amplifier

Application Note 5011

Application Information

The MGA-62563 is a high performance GaAs MMIC amplifier fabricated with Avago Technologies E-pHEMT process and is targeted for commercial wireless application from 100 MHz to 3 GHz. The MGA-62563 runs on only 3 V and is typically biased at around 60 mA to deliver approximately 22 dB of gain and about 17 dBm P_{1dB} @ 500 MHz. It has an internal current mirror bias circuitry built in. An external resistor adjusts the device's bias current and therefore it's P_{1dB} and linearity performance. The internal bias circuit regulates the internal current to enable the MGA-62563 to operate over a wide temperature range with single, positive power supply of 3 V.

In addition, the device uses the voltage drop across the bias resistor to set the gate voltage of the amplifying device and therefore acts more like a MMIC than a FET.

The MGA-62563 offers several benefits to both designers and manufacturers :

1. Flexibility of design – easy trade-off between power consumption and RF performance by changing the bias resistor.
2. Easy to design with, resulting in faster time to market.
3. One size fits all – MGA-62563 can be used to design out many fixed bias driver amplifiers thereby reducing the number of parts manufacturers need to carry.

The MGA-62563 uses resistive feedback to simultaneously achieve low input and output VSWR over a fairly wide range of operating frequency. In most cases, an input series inductor is the only matching component required to bring the input impedance sufficiently close to 50 Ohms. It offers superior linearity and low noise figure suitable for application requiring high dynamic range such as receivers operating in dense signal environment. A wide dynamic range amplifier such as the MGA-62563 can often be used to relieve the requirements of bulky, lossy filters at the receiver's input.

The MGA-62563 is also a suitable candidate for IF amplification where linearity requirements are typically higher than front end amplifiers in most modern digital communication systems. In transmitter chain design, the MGA-62563 is extremely useful for signal amplification in pre-driver and driver stages and it provides approximately +18 dBm of saturated output power.

Test Circuit

The circuit shown in Figure 1 is used for 100% RF testing of Noise Figure and Gain. The test board is fix-tuned at 500 MHz with a series 6.8 nH inductor at the input.

The MGA-62563 requires only a RF choke at the output to deliver the required bias current to the device under test. Tests in this circuit are used to guarantee the NF_{test}, OIP_3 and G_{test} parameters shown in the table of Electrical Specifications.

Phase Reference Planes

The positions of the reference planes used to specify the S-parameters for this device are shown in Figure 2. As seen in the illustration, the reference planes are located at the point where the package leads contact the test circuit.

Parameters

Several categories of parameters appear within this data sheet. Parameters may be described with values that are either minimum or maximum, typical or standard deviations.

The values for parameters are based on comprehensive product characterization data, in which automated measurements are made on a minimum of 500 parts taken from 3 nonconsecutive process lots of semiconductor wafers. The data derived from product characterization tends to be normally distributed, e.g., fits the standard "bell curve".

Parameters considered to be the most important to system performance are bounded by minimum or maximum values. For the MGA-62563, these parameters are Gain (G_{test}), Noise Figure (NF_{test}), OIP_3 and Device Current (I_d).

Each of these guaranteed parameters is 100% tested.

Values for most of the parameters in the table of Electrical Specifications that are described by typical data are the mathematical mean of the normal distribution taken from the characterization data. For parameters where measurements or mathematical averaging may not be practical, such as the noise and S-parameter tables or performance curves, the data represents a nominal part taken from the center of the characterization distribution. Typical values are intended to be used as a basis for electrical design.

To assist designers in optimizing not only the immediate circuit using the MGA-62563, but to also optimize and evaluate trade-offs that affect a complete wireless system, the standard deviation is provided for many of the Electrical Specification parameters in addition to the mean. The standard deviation is a

Specification and Statistical

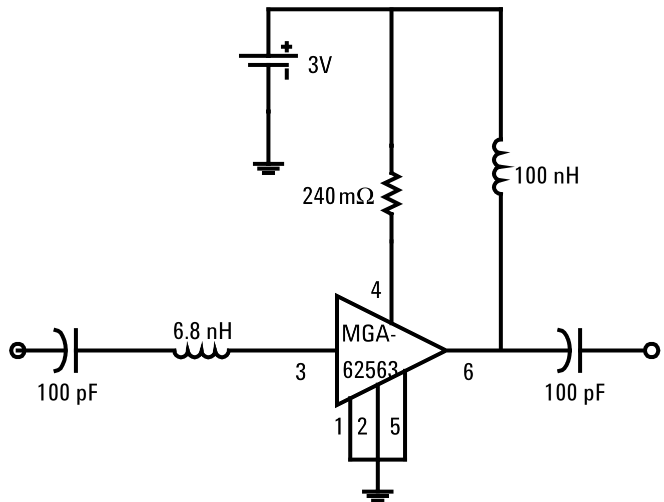

Figure 1. MGA-62563 test circuit

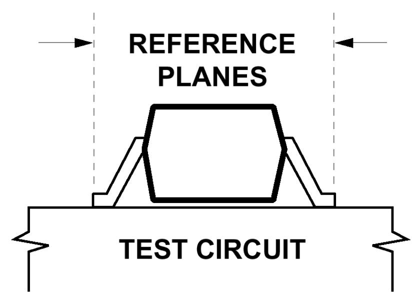

Figure 2. Reference Plane

measure of the variability about the mean. It will be recalled that a normal distribution is completely described by the mean and standard deviation.

Standard statistics tables or calculations provide the probability of a parameter falling between two values, usually symmetrically located about the mean. Referring to Figure 3 for example, the probability of a parameter being between ± 1σ is 38.3%, between ± 2σ is 95.4% , and between ±3σ is 99.7%.

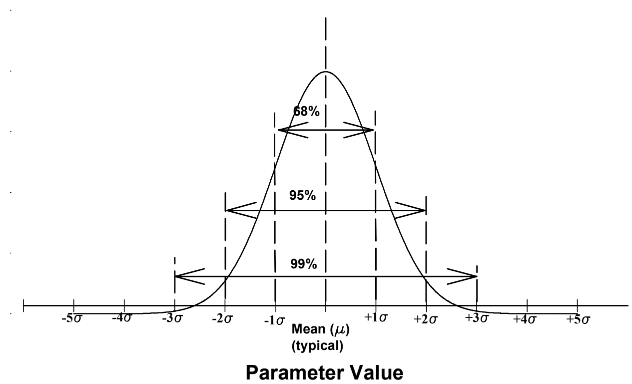

Figure 3. Normal Distribution

RF Layout

The RF layout in Figure 5 is suggested as a starting point for microstripline designs using the MGA-62563.

Adequate grounding is needed to obtain optimum performance and to maintain stability. All of the ground pins of the MMIC should be connected to the RF groundplane on the backside of the PCB by means of plated through holes (vias) that are placed near the package terminals. For MGA-62563, preferably, the dielectric thickness of the PCB should be kept as thin as possible to minimize inductance introduced by via holes. As a minimum, one via should be located next to each ground pin to ensure good RF grounding. It is a good practice to use multiple via holes to further minimize ground path inductance.

PCB Material

FR-4 or G-10 PCB materials are a good choice for most low cost wireless applications. Typical board thickness is 0.020 to 0.03 inches. The width of the 50 Ohm microstriplines on a PCB in this thickness range is also very convenient for mount chip components such as dc blocking and bypass capacitors of 0402 and 0603 sizes.

For higher frequencies or for noise figure critical applications, the additional cost of PTFE/glass dielectric materials may be warranted to minimize transmission line loss at the amplifier's input. A 0.5 inch length of 50 Ohm microstripline on FR4, for example, has approximately 0.3 dB loss at 4 GHz. This loss will add directly to the noise figure of the MGA-62563. Therefore, it is important to use low loss dielectric materials for PCB when operating the MGA-62563 at higher frequencies (4-6 GHz).

Biasing and Power Dissipation

The MGA-62563 is a voltage biased device and is designed to operate from a single, +3 V power supply. The biasing current of the device can be set externally by mean of a resistor connecting a voltage source of pin 4 of the device. The resistor is internally connected to a current mirror circuit which will set the bias current flowing in the amplifying transistor. The bias current flowing in the amplifying transistor is then related to the reference bias and the relative size of the amplifying FET to the FET setting the reference current. For a desired bias current, the approximate value of resistance value (R_{bias}) connecting to pin 4 can be estimated using the chart shown in Figure 4.

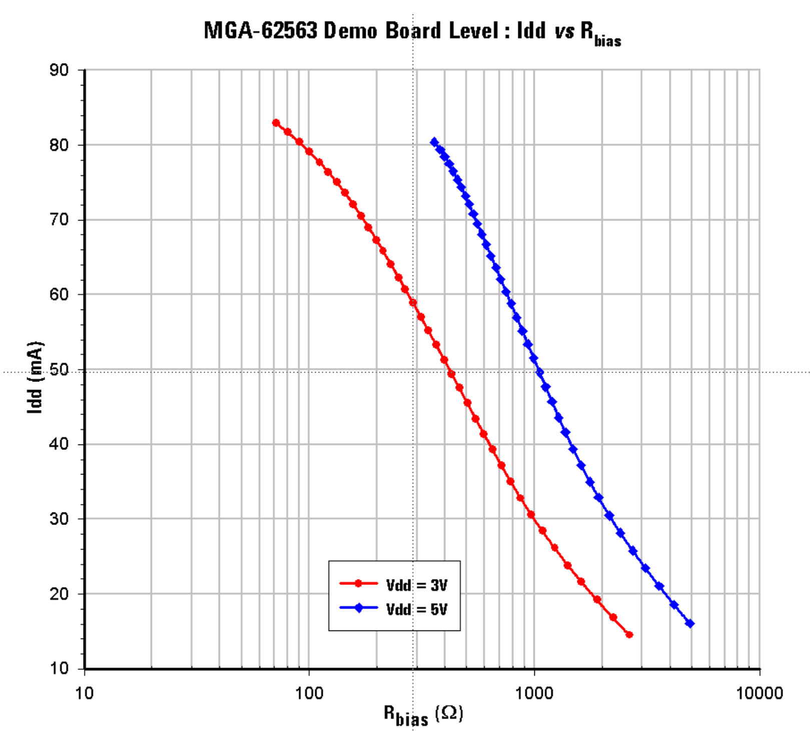

Figure 4. Drain current vs R_{bias} in MGA-62563

Typical Application Example

An application demo board for MGA-62563 is available and the layout is as shown in Figure 5. It is fabricated on Rogers 4350B material with the dielectric thickness of 10 mils. The stacking structure of the PCB is as shown in Figure 6. The FR4 layer was included merely to improve the mechanical strength of the PC board and does not affect the RF performance of the circuit as there is a ground plane separating the FR4 and the RO-4350B dielectrics. The bottom RO-4350B layer was to ensure that any thermal expansion or contraction will have the same effect on both sides of the PC board and does not cause any warping.

The printed circuit layout in Figure 5 can serve as a PCB design guide. This layout is a microstripline design (solid groundplane on the backside of the circuit board) with a 50 ohm input and output. Width of the 50 ohm microstrip is about 22 mil on the 10 mil thick RO-4350B dielectric. For ground connections, multiple vias are used to reduce the inductance of the paths to ground (refer to Figure 20). A schematic diagram of the 500 MHz application circuit is shown in Figure 7. DC blocking capacitors (C1 and C3) are used at the input and output of the MMIC to isolate the device from the preceding stage and subsequent stage respectively. Due to internal resistive termination use at the output of the MGA-62563, high output return loss can be achieved at board level without any matching. This can be seen from the S22 plot of the MGA-62563 alone. From the S11 plot of the device, it is obvious that the input match requires a series inductor.

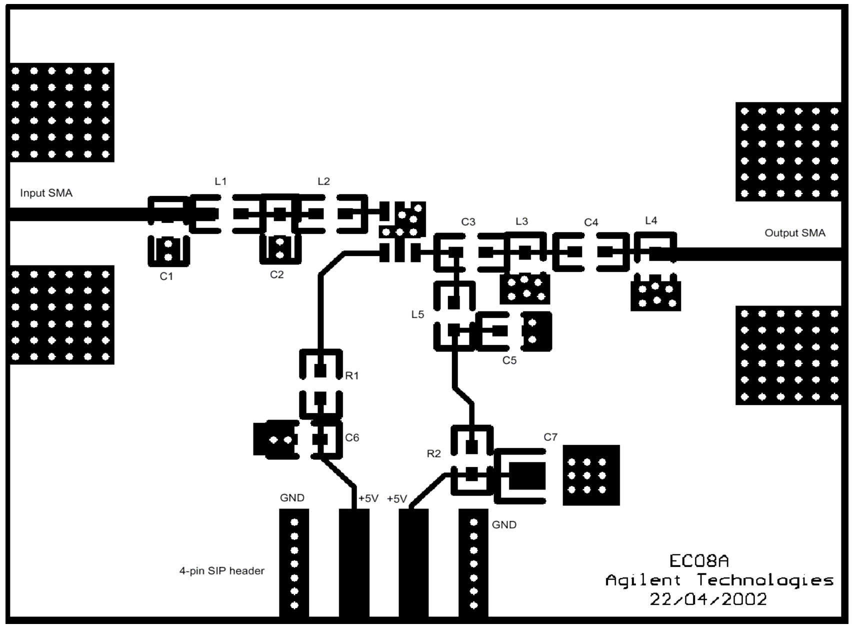

Figure 5. An application demo board for MGA-62563.

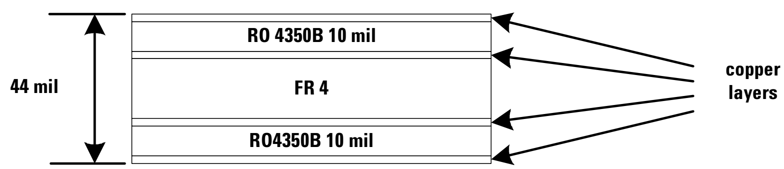

Figure 6. Stacking structure of the demo board PCB.

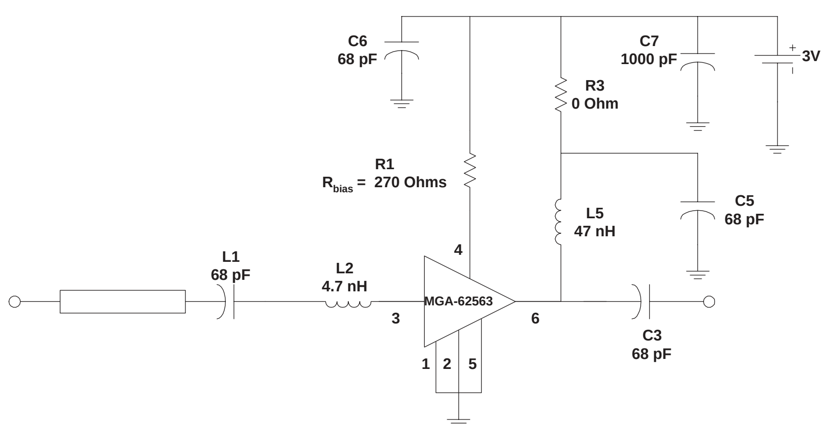

Figure 7. Schematic of a typical 500 MHz application of MGA-62563.

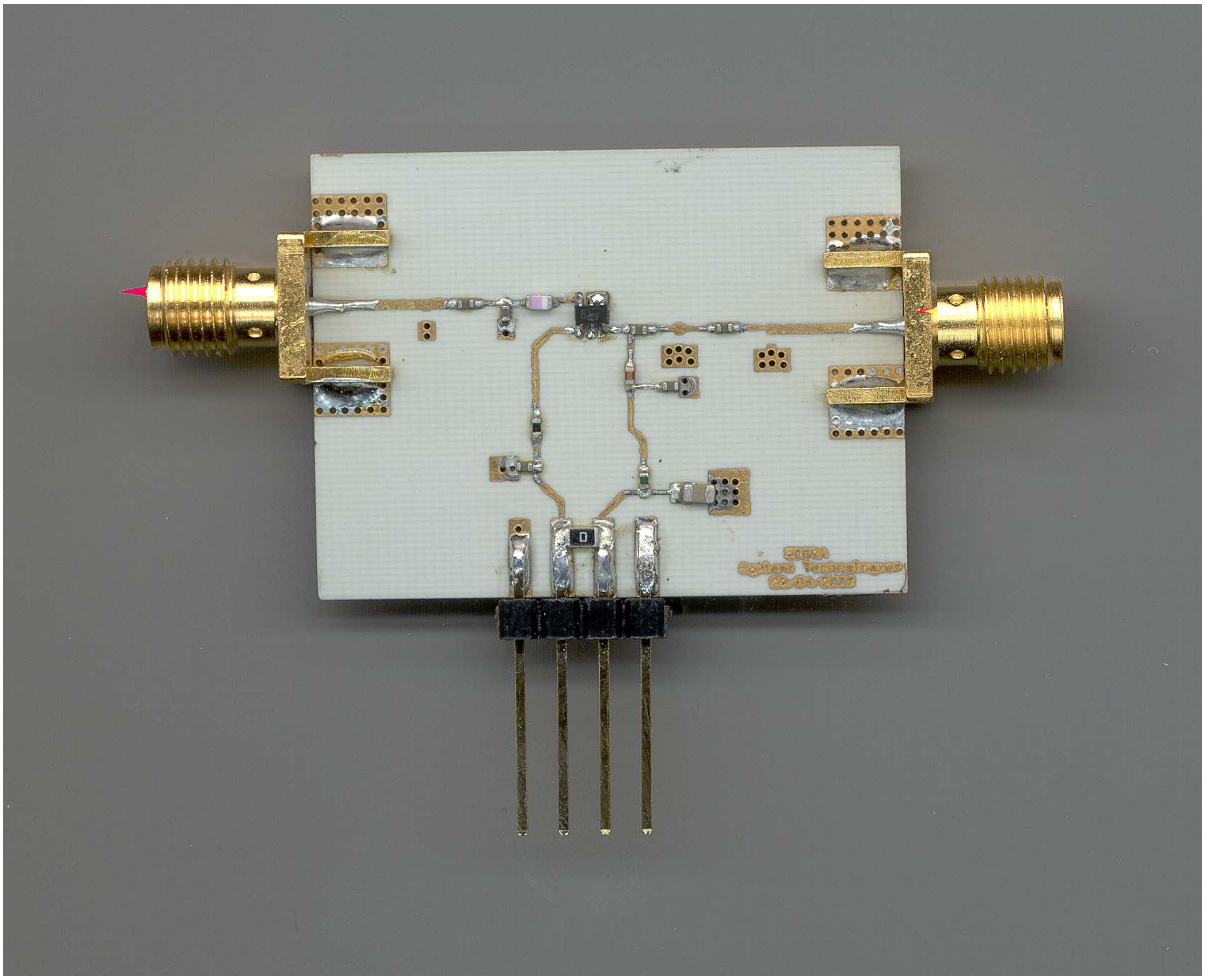

Figure 8. A completed demo board for MGA-62563 operating at 500 MHz

When matching the MGA-62563 on the demo board at 500 MHz, a 4.7 nH series inductor at the input is all that is required to simultaneously match the input of the device for low VSWR and low noise (approximately 0.65 dB). A 6.8 nH inductor should be used to replace the series 4.7 nH when the circuit is to be tuned down to operate at 200 MHz. As the frequency of operation lowers to VHF region, the values of the drain inductor (delivering the bias) and RF coupling and bypass capacitors need to be adjusted accordingly. A schematic showing an application operating at 200 MHz is also given in Figure 15.

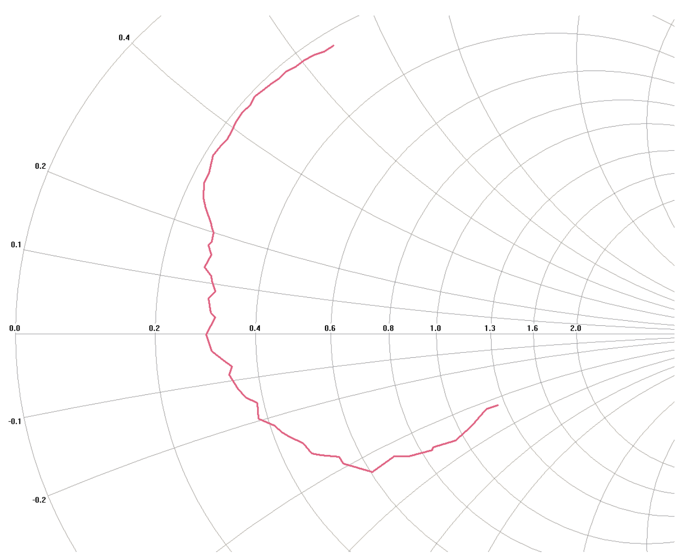

Figure 9. S11 of MGA-62563 at 60 mA, from 0.1 GHz to 6 GHz

Performance on Application Demo Board

The typical performance of the MGA-62563 measured on the application demo board is shown in this application note. The board provides about 22 dB of insertion gain at 500 MHz (Figure 12). The return loss is better than 10 dB at both input and output port. The rest of the performance across input power and frequency are shown in Figure 14. Performance obtainable from the board when tuning down to 200 MHz is also provided in Figures 16-18.

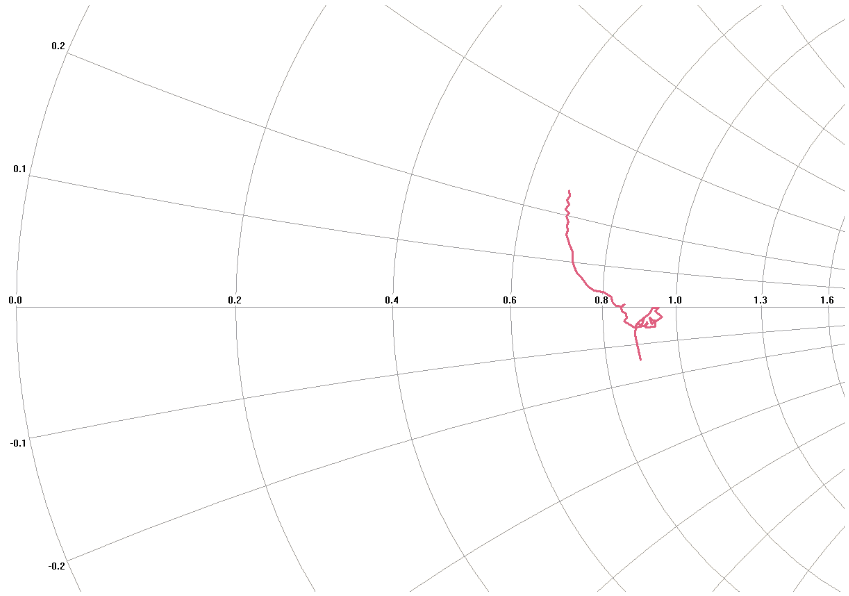

Figure 10. S22 of MGA-62563 at 60 mA, from 0.1 GHz to 6 GHz

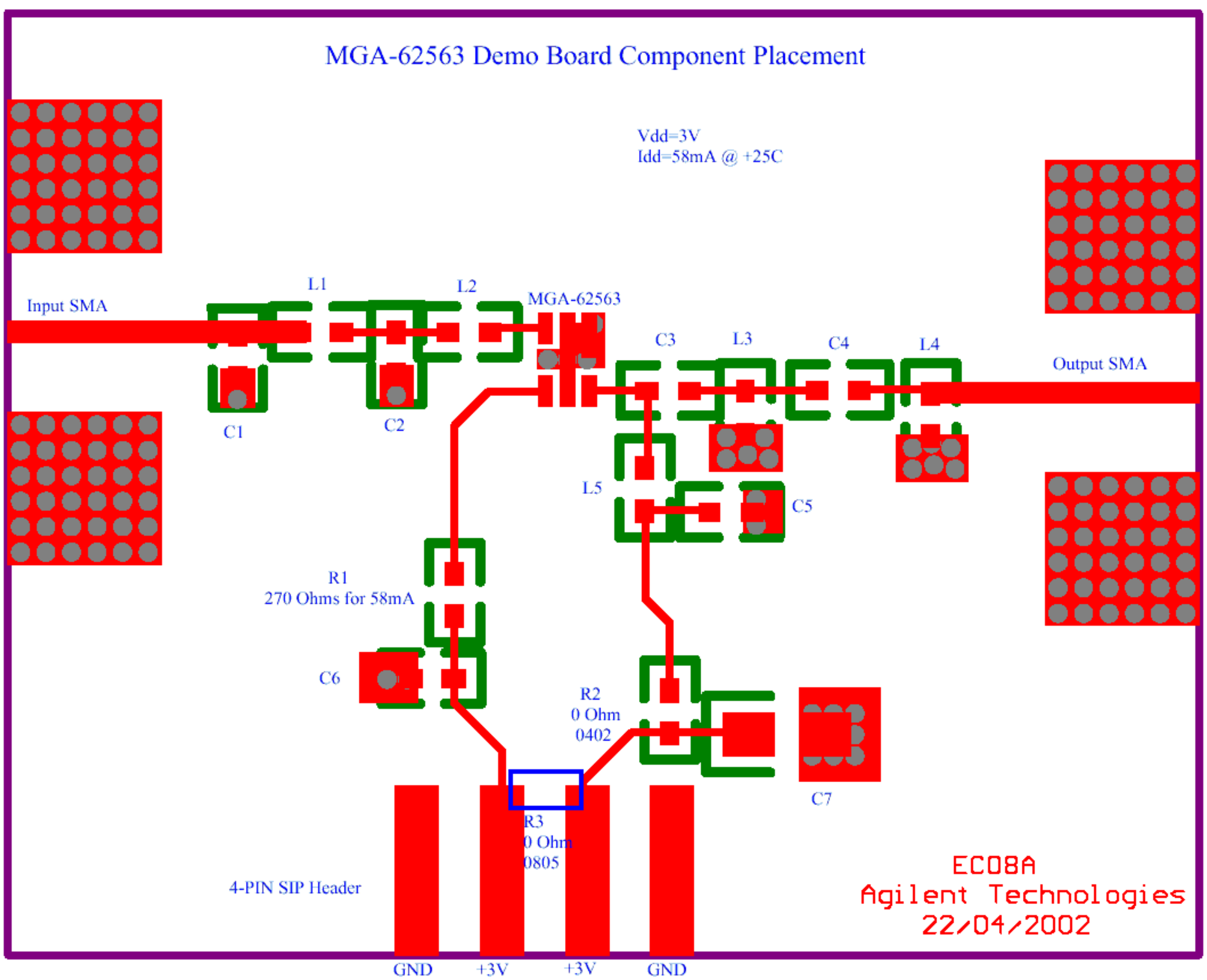

Figure 11. Component placement on the application demo board.

Table 1. Component list and manufacturer part number.

Component Designator	Manufacturer and Part Number
C1	Not used
C2	Not used
C3	68 pF 0402 ROHM MCH155A680JK
C4	68 pF 0402 ROHM MCH155A680JK
C5	68 pF 0402 ROHM MCH155A680JK
C6	68 pF 0402 ROHM MCH155A680JK
C7	1000 pF 0805 MURATA GRM40X7R102K50
L1	68 pF 0402 ROHM MCH155A680JK
L2	4.7 nH 0603 TOKO LL1608-FS4N7S
L3	Not used
L4	Not used
L5	47 nH 0603 TOKO LL1608-FS47NJ
R1	270 Ohms 0402 ROHM MCR01J271[1]
R2	0 Ohms 0402 ROHM MCS01J271
R3	0 Ohms 0805
SMA (Input and Output)	JOHNSON COMPONENTS 142-0711-881
Avago Technologies device	Avago Technologies MGA-61563
Demoboard	Avago Technologies DEMO-MGA-6x563 blank demo board

Note:

1. 270 Ohms was used to set the total current consumption to 58 mA at 3 V supply. Exact resistance required may vary from one unit to another.

SOT-363 PCB Footprint

A recommended PCB pad layout for the miniature SOT-363 (SC-70) package used by the MGA-62563 is shown in Figure 13 (dimensions are in inches). This layout provides ample allowance for package placement by automated assembly equipment without adding parasitics that could impair the high frequency RF performance of the MGA-62563. The layout is shown with a nominal SOT-363 package footprint superimposed on the PCB pads.

SMT Assembly

Reliable assembly of surface mount components is a complex process that involves many material, process, and equipment factors including : method of heating (e.g., IR or vapor phase reflow, wave soldering, etc) circuit board material, conductor thickness and pattern, type of solder allow, and the thermal conductivity and thermal mass of components. Components with a low mass, such as the SOT-363 package, will reach solder reflow temperatures faster than those with a greater mass.

The MGA-62563 has been qualified to the time-temperature profile shown in Figure 19. This profile is representative of an IR reflow type of surface mount assembly process.

After ramping up from room temperature, the circuit board with components attached to it (held in place with solder paste) passes through one or more preheat zones. The preheat zones increase the temperature of the board and components to prevent thermal shock and begin evaporating solvents from the solder paste. The reflow zone briefly elevates the temperature sufficiently to produce a reflow of the solder.

The rates of change of temperature for the ramp-up and cool-down zones are chosen to be low enough to not cause deformation of the board or damage to components due to thermal shock. The maximum temperature in the reflow zone (T_{MAX}) should not exceed +260 °C.

These parameters are typical for a surface mount assembly process for the MGA-62563 . As a general guideline, the circuit board and components should be exposed only to the minimum temperature and times necessary to achieve a uniform reflow of solder.

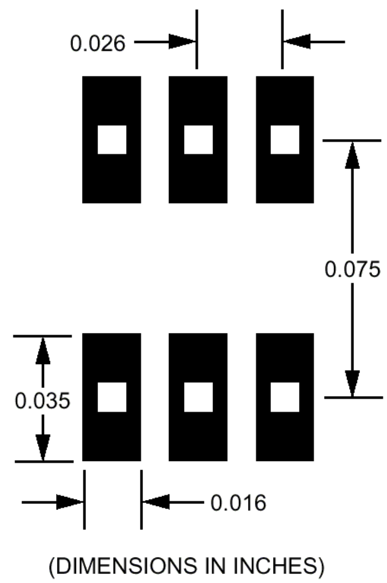

Figure 13. PCB pad layout

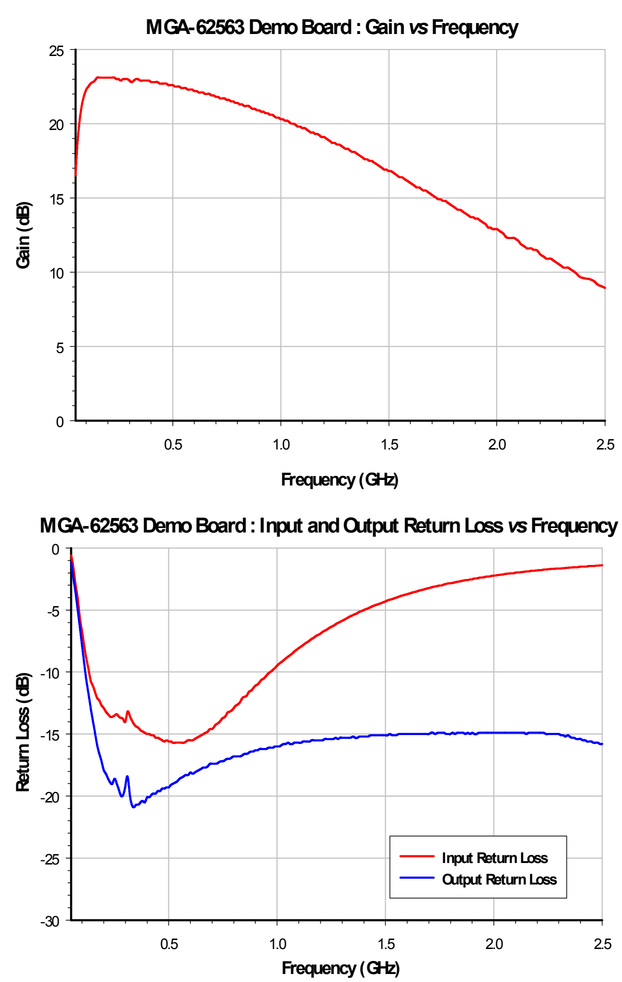

Figure 12. Gain and return loss of MGA-62563 on demo board.

Electrostatic Sensitivity

GaAs MMIC are electrostatic discharge (ESD) sensitive devices. Although the MGA-62563 is robust in design, permanent damage may occur to these devices if they are subjected to high energy electrostatic discharges. Electrostatic charges as high as several thousand volts (which readily accumulate on the human body and on test equipment) can discharge without detection and may result in degradation in performance or failure. The MGA-62563 is an ESD class 2 device. Therefore, proper ESD precautions are recommended when handling, inspecting and assembling these devices to avoid damage.

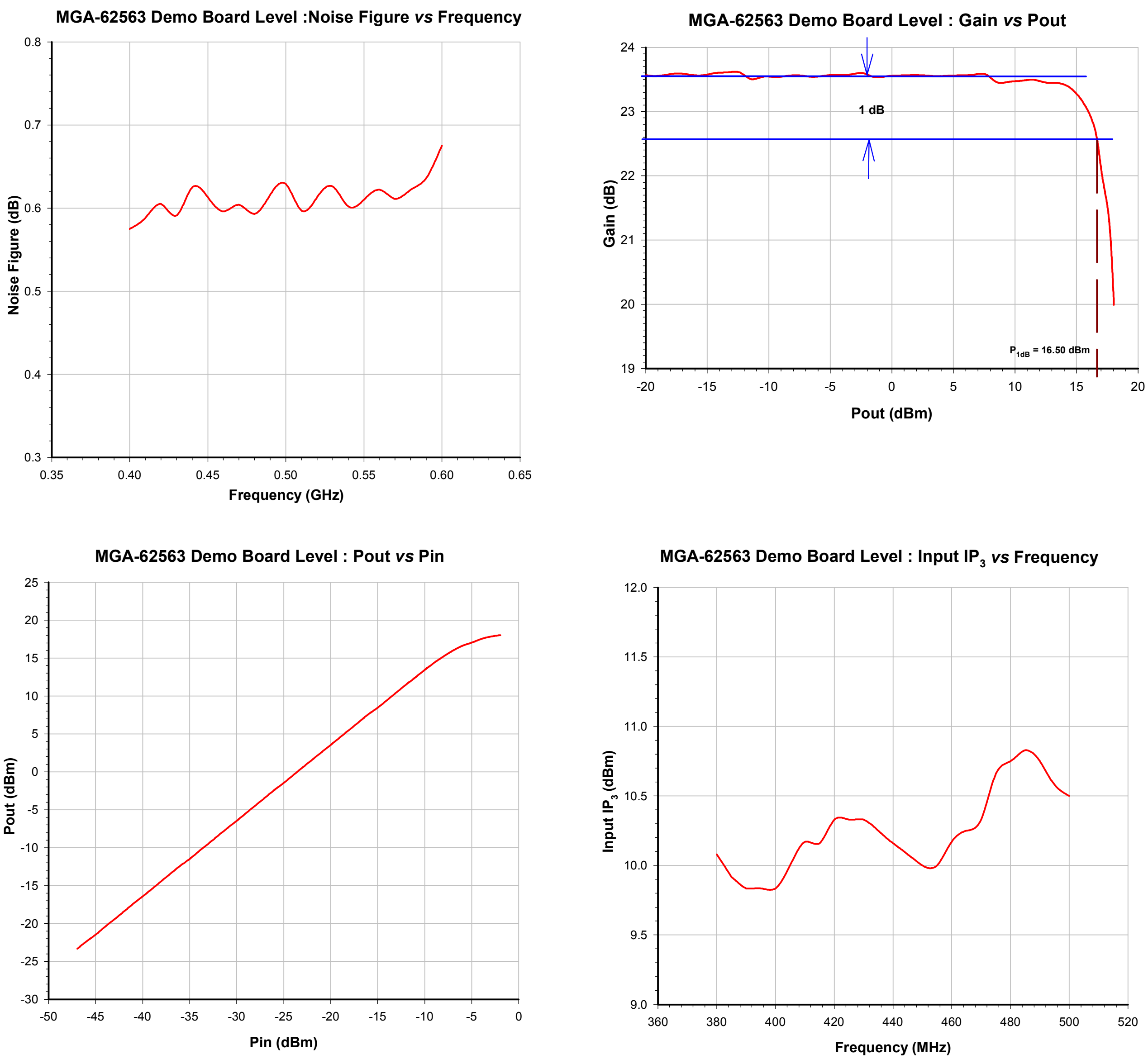

Figure 14. Noise Figure, P_{1dB} @ 500 MHz and Input IP_3 performance of MGA-62563 on demo board.

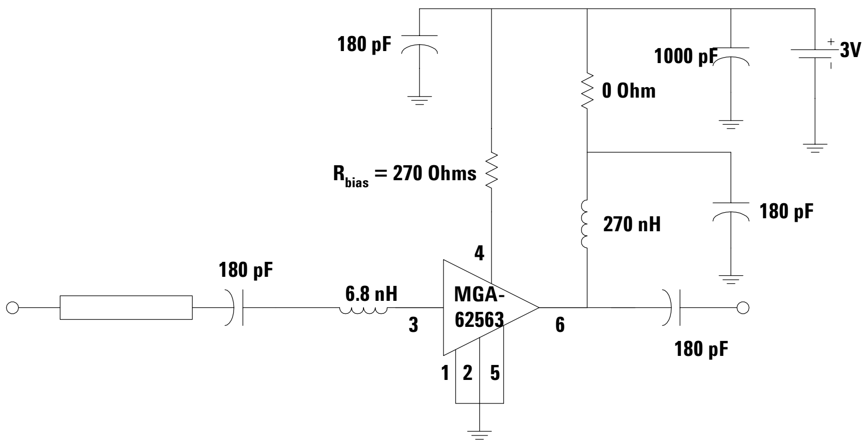

Figure 15. Schematic of a 200 MHz amplifier with MGA-62563 on the demo board.

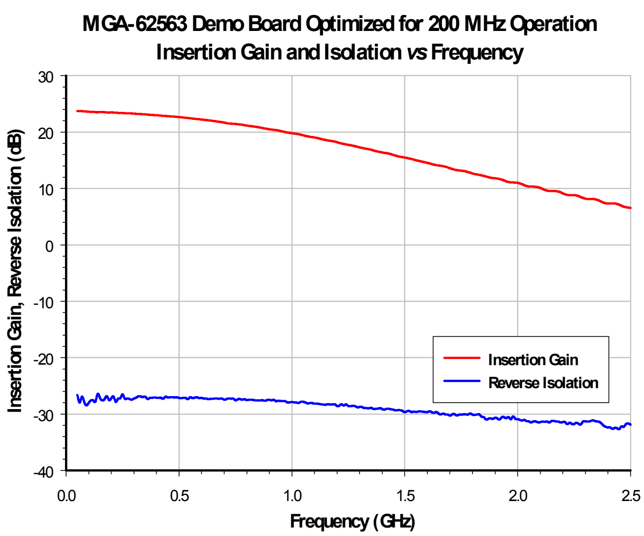

Figure 16. Gain and reverse isolation of a MGA-62563 amplifier tuned to 200 MHz on demo board.

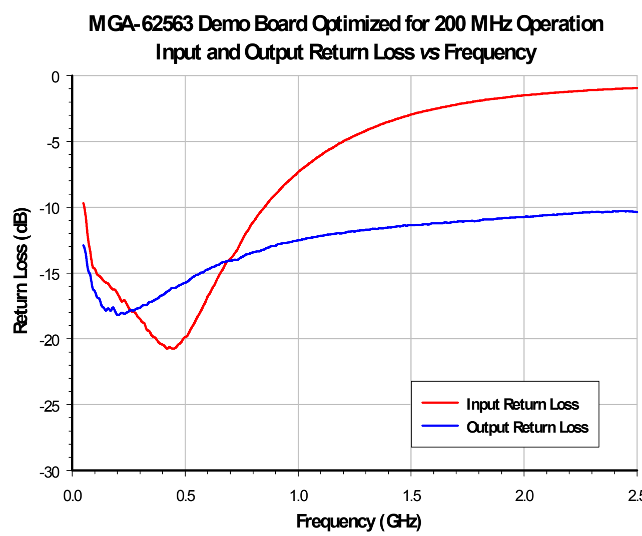

Figure 17. Return loss of a MGA-62563 amplifier tuned to 200 MHz on demo board.

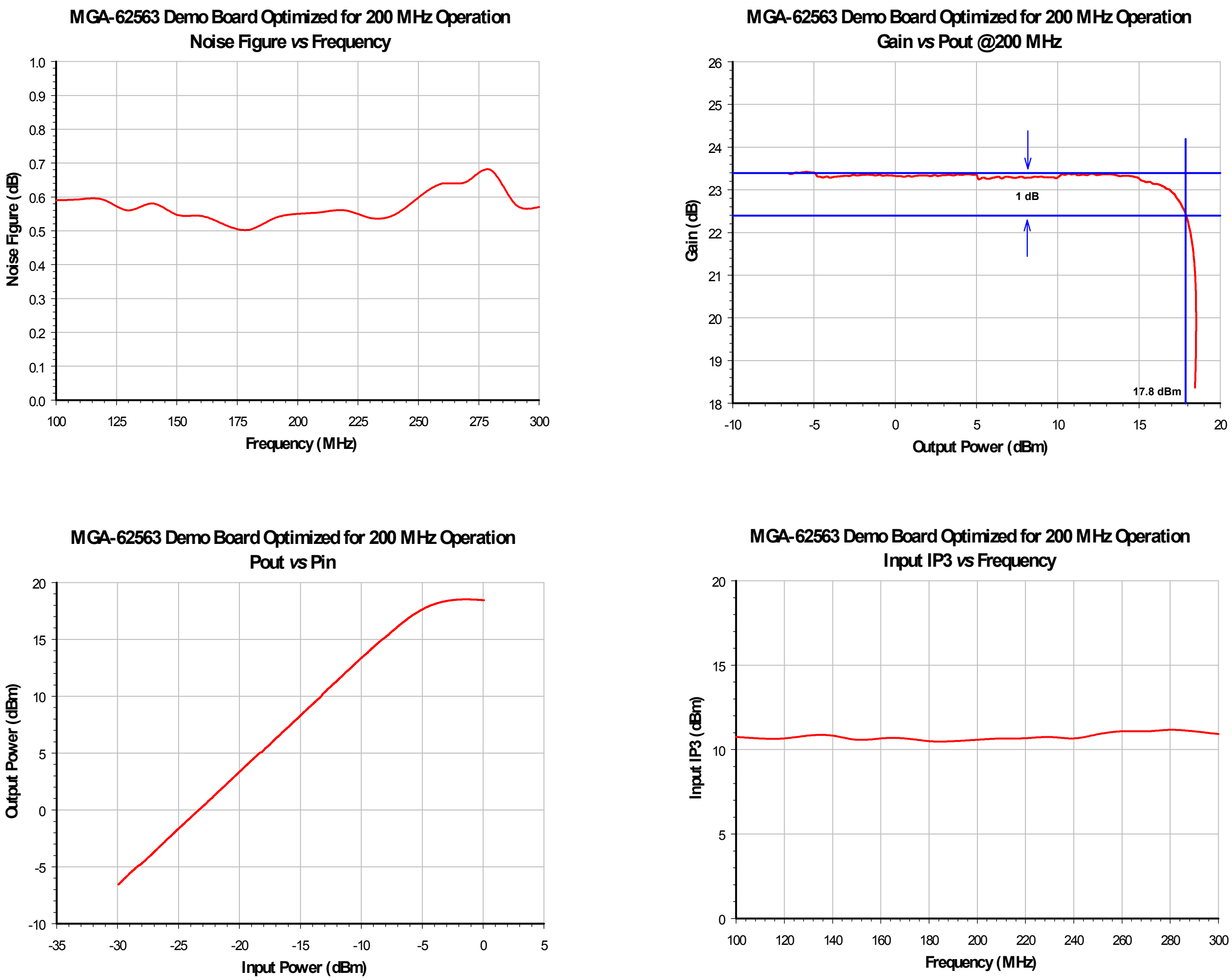

Figure 18. Noise Figure, P_{1dB} @ 200 MHz and Input IP_3 performance of MGA-62563 on demo board.

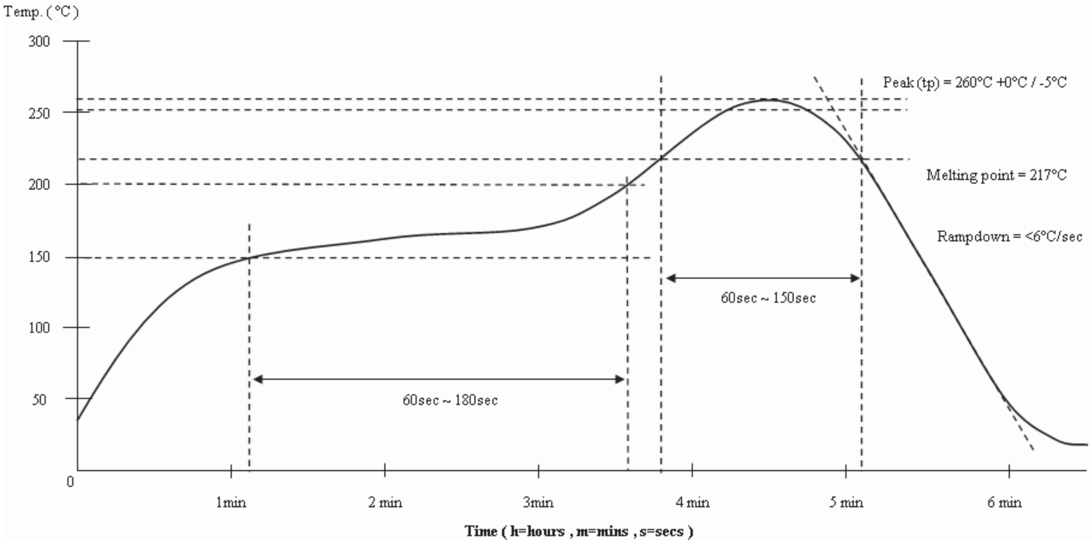

Figure 19. Surface Mount Assembly Profile.

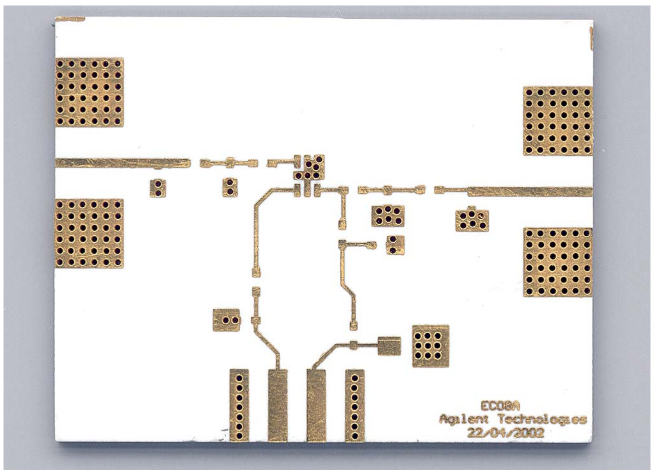

Figure 20. Picture of an unpopulated demo board for MGA-62563.

For product information and a complete list of distributors, please go to our web site: **www.avagotech.com**

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