5 GHz to 11 GHz GaAs, pHEMT, MMIC, Low Noise Amplifier

Data Sheet

**FEATURES**

- Noise figure: 1.6 dB typical
- Small signal gain: 20 dB typical
- P1dB output power: 16 dBm typical
- Supply voltage: 3.5 V at 80 mA typical
- Output IP3: 28 dBm typical
- 50 Ω matched input/output
- Self biased with optional bias control for quiescent drain current (I_{Q0}) reduction with no radio frequency (RF) applied
- Die size: 1.33 mm × 1.04 mm × 0.102 mm

**APPLICATIONS**

- Point to point radios
- Point to multipoint radios
- Military and space
- Test instrumentation
- Industrial scientific and medical (ISM) radio band
- Unlicensed national information infrastructure (UNII)
- Wireless communication service (WCS)

**GENERAL DESCRIPTION**

The HMC902 is a gallium arsenide (GaAs), pseudomorphic (pHEMT) monolithic microwave integrated circuit (MMIC), low noise amplifier (LNA), which is self biased with optional bias control for I_{Q0} reduction. The HMC902 operates between 5 GHz and 11 GHz. This LNA provides 20 dB of small signal gain, 1.6 dB noise figure, and output IP3 of 28 dBm, requiring only 80 mA from a 3.5 V supply. The P1dB output power of 16 dBm enables the LNA to function as a local oscillator (LO) driver for balanced, I/Q, or image rejection mixers. The HMC902 also features inputs/outputs that are matched to 50 Ω for ease of integration into multichip modules (MCMs). All data is taken with the HMC902 in a 50 Ω test fixture connected via two 0.025 mm (1 mil) diameter wire bonds of 0.31 mm (12 mil) length.
## SPECIFICATIONS

### ELECTRICAL SPECIFICATIONS

\( T_a = 25^\circ C, V_{DD1} = V_{DD2} = 3.5 \, V, \, I_{DO} = 80 \, mA. \, V_{GG1} = V_{GG2} = \) no connection for nominal, self biased operation.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Symbol</th>
<th>Test Conditions/Comments</th>
<th>Min</th>
<th>Typ</th>
<th>Max</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>FREQUENCY RANGE</td>
<td></td>
<td></td>
<td>5</td>
<td>11</td>
<td>11</td>
<td>GHz</td>
</tr>
<tr>
<td>SMALL SIGNAL GAIN</td>
<td></td>
<td></td>
<td>17</td>
<td>20</td>
<td>0.012</td>
<td>dB</td>
</tr>
<tr>
<td>Gain Variation over Temperature</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>dB/°C</td>
</tr>
<tr>
<td>RETURN LOSS</td>
<td></td>
<td></td>
<td>12</td>
<td></td>
<td></td>
<td>dB</td>
</tr>
<tr>
<td>Output</td>
<td></td>
<td></td>
<td>15</td>
<td></td>
<td></td>
<td>dB</td>
</tr>
<tr>
<td>OUTPUT</td>
<td></td>
<td></td>
<td>16</td>
<td></td>
<td></td>
<td>dBm</td>
</tr>
<tr>
<td>Output Power for 1 dB Compression</td>
<td>P_{1dB}</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>dBm</td>
</tr>
<tr>
<td>Saturated Output Power</td>
<td>P_{SAT}</td>
<td></td>
<td>17.5</td>
<td></td>
<td></td>
<td>dBm</td>
</tr>
<tr>
<td>Output Third-Order Intercept</td>
<td>IP3</td>
<td></td>
<td>28</td>
<td></td>
<td></td>
<td>dBm</td>
</tr>
<tr>
<td>NOISE FIGURE</td>
<td>NF</td>
<td></td>
<td>1.6</td>
<td>2.1</td>
<td></td>
<td>dB</td>
</tr>
<tr>
<td>SUPPLY CURRENT</td>
<td>I_{DO}</td>
<td>Quiescent drain current, no RF applied</td>
<td>80</td>
<td></td>
<td></td>
<td>mA</td>
</tr>
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</table>
ABSOLUTE MAXIMUM RATINGS

Table 2.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Rating</th>
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<tbody>
<tr>
<td>Drain Bias Voltage</td>
<td>4.5 V</td>
</tr>
<tr>
<td>Radio Frequency (RF) Input Power</td>
<td>10 dBm</td>
</tr>
<tr>
<td>Gate Bias Voltages</td>
<td></td>
</tr>
<tr>
<td>$\text{V}_{\text{G1}}$</td>
<td>$-2 \text{ V to } +0.2 \text{ V}$</td>
</tr>
<tr>
<td>$\text{V}_{\text{G2}}$</td>
<td>$-2 \text{ V to } +0.2 \text{ V}$</td>
</tr>
<tr>
<td>Channel Temperature</td>
<td>175°C</td>
</tr>
<tr>
<td>Continuous Power Dissipation, $P_{\text{Diss}}$ ($T = 85^\circ \text{C}$, Derate 7 mW/°C Above 85°C)</td>
<td>0.63 W</td>
</tr>
<tr>
<td>Thermal Resistance (Channel to Die Bottom)</td>
<td>143.8°C/°W</td>
</tr>
<tr>
<td>Storage Temperature Range</td>
<td>$-65^\circ \text{C to } +150^\circ \text{C}$</td>
</tr>
<tr>
<td>Operating Temperature Range</td>
<td>$-55^\circ \text{C to } +85^\circ \text{C}$</td>
</tr>
<tr>
<td>Electrostatic Discharge (ESD) Sensitivity, Human Body Model (HBM)</td>
<td>Class 1A, Passed 250 V</td>
</tr>
</tbody>
</table>

Stresses at or above those listed under Absolute Maximum Ratings may cause permanent damage to the product. This is a stress rating only; functional operation of the product at these or any other conditions above those indicated in the operational section of this specification is not implied. Operation beyond the maximum operating conditions for extended periods may affect product reliability.

ESD CAUTION

ESD (electrostatic discharge) sensitive device. Charged devices and circuit boards can discharge without detection. Although this product features patented or proprietary protection circuitry, damage may occur on devices subjected to high energy ESD. Therefore, proper ESD precautions should be taken to avoid performance degradation or loss of functionality.
PIN CONFIGURATION AND FUNCTION DESCRIPTIONS

Table 3. Pad Function Descriptions

<table>
<thead>
<tr>
<th>Pad No.</th>
<th>Mnemonic</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>RFIN</td>
<td>Radio Frequency Input. This pin is matched to 50 Ω. See Figure 3 for the interface schematic.</td>
</tr>
<tr>
<td>2, 3</td>
<td>VDD1, VDD2</td>
<td>Power Supply Voltages. Power supply voltage for the amplifier; see Figure 24 and Figure 25 for required external components. See Figure 4 for the interface schematic.</td>
</tr>
<tr>
<td>4</td>
<td>RFOUT</td>
<td>Radio Frequency Output. This pad is matched to 50 Ω. See Figure 5 for the interface schematic.</td>
</tr>
<tr>
<td>5, 6</td>
<td>VGG2, VGG1</td>
<td>Gate Control Voltages. Optional gate control for the amplifier. When left open, the amplifier is self biased. Applying a negative voltage reduces the current. See Figure 6 for the interface schematic.</td>
</tr>
<tr>
<td>Die Bottom</td>
<td>GND</td>
<td>Ground. Die bottom must be connected to RF/dc ground. See Figure 7 for the interface schematic.</td>
</tr>
</tbody>
</table>

INTERFACE SCHEMATICS

Figure 3. RFIN Interface Schematic

Figure 4. VGG1, VGG2 Interface Schematic

Figure 5. RFOUT Interface Schematic

Figure 6. VGG1, VGG2 Interface Schematic

Figure 7. GND Interface Schematic
TYPICAL PERFORMANCE CHARACTERISTICS

Figure 8. Broadband Gain and Return Loss vs. Frequency

Figure 9. Input Return Loss vs. Frequency at Various Temperatures

Figure 10. Noise Figure vs. Frequency at Various Temperatures

Figure 11. Gain vs. Frequency at Various Temperatures

Figure 12. Output Return Loss vs. Frequency at Various Temperatures

Figure 13. Output IP3 vs. Frequency at Various Temperatures
Figure 14. P1dB vs. Frequency at Various Temperatures

Figure 15. Reverse Isolation vs. Frequency at Various Temperatures

Figure 16. PSAT vs. Frequency at Various Temperatures

Figure 17. P_OUT, Gain, and Power Added Efficiency (PAE) vs. Input Power at 7 GHz

Figure 18. Gain, P1dB, and Noise Figure vs. Supply Voltage (VDD) at 7 GHz
THEORY OF OPERATION

The HMC902 is GaAs, pHEMT, MMIC, low noise amplifier. The HMC902 amplifier uses two gain stages in series. The basic schematic for the amplifier is shown in Figure 19, which forms a low noise amplifier operating from 5 GHz to 11 GHz with excellent noise figure performance.

The HMC902 has single-ended input and output ports with impedances nominally equaling 50 Ω over the 5 GHz to 11 GHz frequency range. Consequently, the device can be directly inserted into a 50 Ω system with no required impedance matching circuitry, meaning multiple HMC902 amplifiers can be cascaded back to back without the need for external matching circuitry.

The input and output impedances are sufficiently stable vs. variations in temperature and supply voltage so no impedance matching compensation is required.

It is critical to supply very low inductance ground connections to the exposed pad to ensure stable operation. To achieve optimal performance from the HMC902 and to prevent damage to the device, do not exceed the absolute maximum ratings.

Figure 19. Basic Schematic for the HMC902
APPLICATIONS INFORMATION

The HMC902 has VGG1 and VGG2 optional gate bias pads. When these pads are left open, the amplifier runs in self biased operation with typical IDQ = 80 mA. Figure 25 shows the basic connections for operating the HMC902 in self biased operation mode. Both the RFIN and the RFOUT ports of the HMC902 have on-chip dc block capacitors, which eliminates the need for external ac coupling capacitors.

When using the VGG1 and the VGG2 gate bias pads, follow bias sequencing to prevent damage to the amplifier.

The recommended bias sequence during power-up is as follows:

1. Connect to GND.
2. Set VGG1 to −0.8 V.
3. Set VDD1 and VDD2 to 3.5 V.
4. Increase VGG1 to achieve typical IDQ = 80 mA.
5. Apply the RF signal.

The recommended bias sequence during power-down is as follows:

1. Turn off the RF signal.
2. Decrease VGG1 to −0.8 V to achieve typical IDQ = 0 mA.
3. Decrease VDD1 and VDD2 to 0 V.
4. Increase VGG1 to 0 V.

The bias conditions previously listed (VDD1 and VDD2 = 3.5 V and IDQ = 80 mA) are the recommended operating points to achieve optimum performance. The data used in this data sheet is taken with the recommended bias conditions listed in the Electrical Specifications section. If the HMC902 is used with different bias conditions than what is recommended, a different performance than what is shown in the Typical Performance Characteristics section can result. Decreasing the VDD level has a negligible effect on gain and NF performance, but reduces P1dB. This behavior is seen in Figure 18. For applications where the P1dB requirement is not stringent, the HMC902 can be down biased to reduce power consumption.
MOUNTING AND BONDING TECHNIQUES FOR MILLIMETERWAVE GaAs MMICS

The die is attached directly to the ground plane eutectically or with conductive epoxy (see the General Handling section, the Mounting section, and the Wire Bonding section).

The 50 Ω microstrip transmission lines on 0.127 mm (5 mil) thick alumina thin film substrates are recommended for bringing RF to and from the HMC902 (see Figure 20). When using 0.254 mm (10 mil) thick alumina thin film substrates, the die is raised 0.150 mm (6 mil) so the surface of the die is coplanar with the surface of the substrate. One way to accomplish this is to attach the 0.102 mm (4 mil) thick die to a 0.150 mm (6 mil) thick molybdenum heat spreader (moly tab), which then attaches to the ground plane (see Figure 21).

Microstrip substrates are placed as close to the die as possible to minimize bond wire length. Typical die to substrate spacing is 0.076 mm to 0.152 mm (3 mil to 6 mil).

HANDLING PRECAUTIONS

Follow the precautions detailed in the following sections to avoid permanent damage to the device.

Storage

All bare die are placed in either waffle or gel-based ESD protective containers and then sealed in an ESD protective bag for shipment. After opening the sealed ESD protective bag, store all die in a dry nitrogen environment.

Cleanliness

Handle the chips in a clean environment. Do not attempt to clean the chip using liquid cleaning systems.

Static Sensitivity

Follow ESD precautions to protect against ESD strikes.

Transients

Suppress instrument and bias supply transients while bias is applied. Use the shielded signal and bias cables to minimize inductive pickup.

General Handling

Handle the chip along the edges with a vacuum collet or with a sharp pair of bent tweezers. The surface of the HMC902 has fragile air bridges and must not be touched with the vacuum collet, tweezers, or fingers.

Mounting

The HMC902 is back metallized and can be die mounted with gold tin (AuSn) eutectic preforms or with electrically conductive epoxy. The mounting surface must be clean and flat.

Eutectic Die Attach

An 80% gold/20% tin preform is recommended with a work surface temperature of 255°C and a tool temperature of 265°C. When hot 90% nitrogen/10% hydrogen gas is applied, the tool tip temperature is 290°C. Do not expose the chip to a temperature greater than 320°C for more than 20 sec. No more than 3 sec of scrubbing is required for attachment.

Epoxy Die Attach

Apply a minimum amount of epoxy to the mounting surface so that a thin epoxy fillet is observed around the perimeter of the HMC902 after it is placed into position. Cure epoxy per the schedule of the manufacturer.

Wire Bonding

RF bonds made with two 1 mil wires are recommended. These bonds are thermosonically bonded with a force of 40 g to 60 g. DC bonds of 0.001 in (0.025 mm) diameter, thermosonically bonded, are recommended. Create ball bonds with a force of 40 g to 50 g and wedge bonds at 18 g to 22 g. Create bonds with a nominal stage temperature of 150°C. A minimum amount of ultrasonic energy is applied to achieve reliable bonds. All bonds are as short as possible, less than 12 mil (0.31 mm).
TYPICAL APPLICATION CIRCUITS

Figure 22. Typical Application Circuit with Gate Control Option

Figure 23. Typical Application Circuit with Self Biased Option
**Figure 24. Assembly Diagram with Gate Control Option**

**Figure 25. Assembly Diagram with Self Biased Option**
OUTLINE DIMENSIONS

*This die utilizes fragile air bridges. Any pickup tools used must not contact this area.

Figure 26. 6-Pad Bare Die [CHIP]
(C-6-9)
Dimensions shown in millimeters

ORDERING GUIDE

<table>
<thead>
<tr>
<th>Model</th>
<th>Temperature Range</th>
<th>Package Description</th>
<th>Package Option</th>
</tr>
</thead>
<tbody>
<tr>
<td>HMC902</td>
<td>−55°C to +85°C</td>
<td>6-Pad Bare Die [CHIP]</td>
<td>C-6-9</td>
</tr>
<tr>
<td>HMC902-SX</td>
<td>−55°C to +85°C</td>
<td>6-Pad Bare Die [CHIP]</td>
<td>C-6-9</td>
</tr>
</tbody>
</table>

1 The HMC902-SX is a sample order of two devices.