# MODAMP Silicon MMIC Chip Use

## Application Note S009

## Introduction

This Application Note supplies information needed to layout and assemble circuits when using Hewlett-Packard's MODAMP silicon MMIC amplifiers in chip form. Section I gives an overview of the product, including what to expect in the way of appearance and performance. Section II discusses the use of optional on-chip bias resistors. Section III covers assembly information – die handling, die attach, and wire bonding. Section IV gives several sample layouts, and delineates what other components will be needed to construct a MODAMP chip based amplifier.

## Section I: About The Die

### Die Topography

MODAMP is a trade name for HP's line of bipolar based, resistive feedback MMIC gain blocks. These devices share a common topology, shown in Figure 1. Two bipolar transistors ($Q_1$ and $Q_2$) are connected in Darlington configuration. Shunt ($R_F$) and series ($R_E$) resistive feedback are used to set both the gain and the impedance match of the structure. Resistors connecting the bases of $Q_1$ ($R_B$) and $Q_2$ ($R_{bias}$) to ground complete the DC bias network. Some geometries have additional resistors ($RC_1$ , $RC_2$ ) connected to the collector of $Q_2$ to allow for optional on-chip biasing. More information about these resistors is provided in Section II. Figure 2 identifies these components on a typical MODAMP MMIC chip outline drawing (outline drawings for other MODAMP MMIC chips are presented in Appendix I of this note).

The bond pad connected to the base of $Q_1$ is the input to the circuit. The bond pad connected to $R_E$, $R_B$ and $R_{bias}$ is the amplifier's common (or ground) terminal. Electrically, the output of the circuit is the collector of $Q_2$. Since the MMIC is built with conventional vertical bipolar technology, the entire bottom surface of the chip is a shared collector contact for the two transistors of the Darlington, and therefore serves as the output terminal of the MMIC. For convenience, a topside collector contact is also provided for designers who would rather wire bond the output connection to the chip. The remaining bond pads are bias options that are not normally connected in typical chip use.

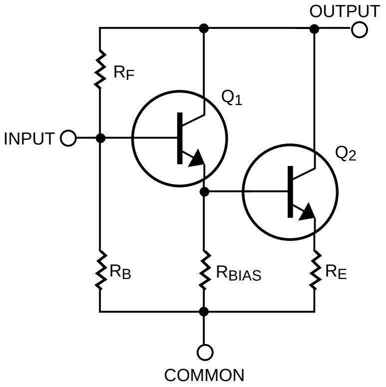


Figure 1. MODAMP Equivalent Circuit Schematic

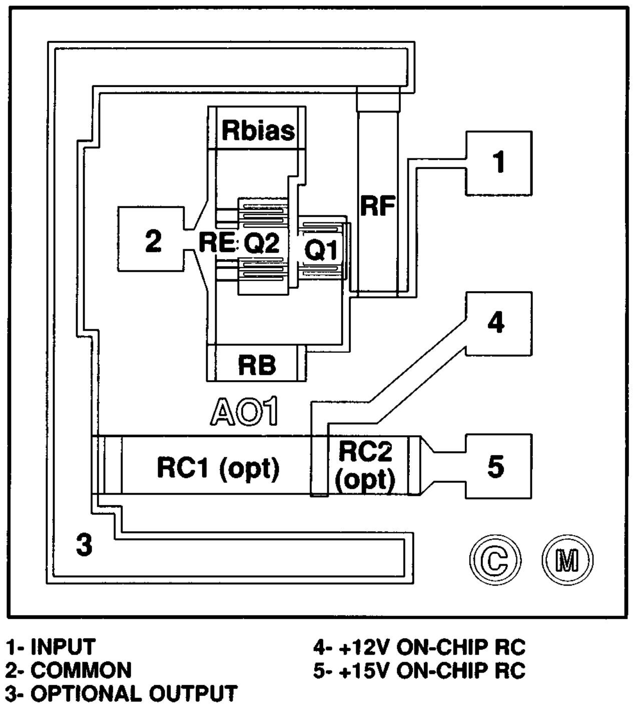


**Figure 2. Typical MODAMP Chip Outline Labeling Components and Bond Pads. (MSA-0100 shown as an example)**

### Packaging, Shipment, And Storage

Hewlett-Packard MODAMP MMIC chips are supplied in two inch trays that use an elastomer as a carrier medium. The chips are held in place by the surface tension of the elastomer. One corner of the tray is beveled to provide orientation for chip selection. Each chip tray is enclosed in a plastic box to protect the die during shipping. Up to 300 chips can be contained in a tray.

MODAMP MMIC die can be stored in the trays in which they are shipped. Die that will be stored for long periods of time (greater than 1 to 2 weeks) should be kept in a dry nitrogen atmosphere for optimum reliability. The MODAMP MMIC chips use a gold based metal system that is very resistant to deterioration; none the less, the best practice is to always store die in an inert atmosphere.

### Product Guarantees

Visual Inspection Criteria: MODAMP MMIC chips are inspected to grade B visual, equivalent to MIL-STD-883 Method 2010, before shipping. Probe marks from the DC sort operation may be visible on the optional output, optional on-chip bias resistor, or common bond pads.

DC Guarantees: Each MODAMP MMIC die is probed for compliance with all DC guaranteed parameters (any parameter listed with a minimum or a maximum rating in the catalog or on the product data sheet).

RF Guarantees: RF typical performance is verified by wafer sampling 10 die per candidate wafer. RF performance is measured on die mounted in an appropriate minimum parasitic package (typically the 70 mil gold-ceramic stripline package).

## Section II:
## Use of Optional On-chip Bias Resistors

MODAMP MMICs are current controlled devices. The most common way of biasing them is through a dropping resistor from a fixed voltage supply. The biasing resistor acts as a feedback element that stabilizes the DC operating point over temperature. For more information see HP Application Note AN-S003: *Biasing MODAMP MMICs*.

As mentioned in Section I, several of the MODAMP MMIC geometries include optional on-chip resistors that can be used to bias the MMIC from a fixed voltage supply. The chips incorporating this option are the MSA-0100, MSA-0200, MSA-0300, MSA-0600, and MSA-0700. For most designs, these on-chip resistors are left unconnected, and the bias is supplied through an external (off-chip) bias resistor. To make use of the on-chip bias option, wire bond the appropriate bond pad on the MMIC to a circuit trace that will supply the appropriate voltage. The bond pad nearest to the RF input bond pad is for use with a nominal +12 volt supply; the remaining bond pad is for use with a nominal +15 volt supply (see Figure 3). The MSA-0600 and MSA-0700 geometries have 3 bond pad options: a +5 volt pad which is nearest to the RF input bond pad, a +12 volt pad, and a +15 volt pad which is furthest from the RF input pad. The length of the bond wire is not critical. A long wire is, if anything, preferable as the added series inductance it provides improves the effectiveness of the bias feed as

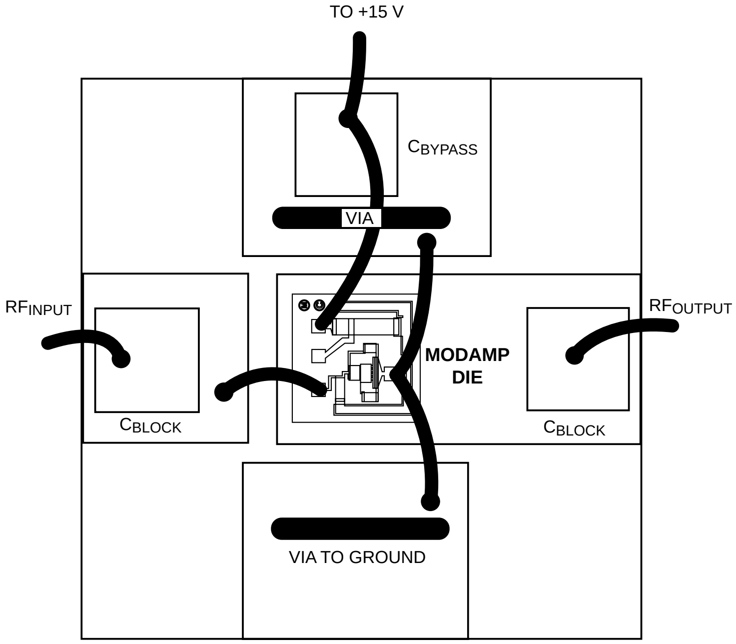


**Figure. 3. Representative Bond Scheme For Use Of On-chip Bias Resistor (+15 V option)**

an RF choke. The circuit will no longer require external bias resistors or chokes for biasing the MODAMP MMIC, although an external inductor in series with the bias resistor usually improves $P_{1dB}$ and gain performance. A bypass capacitor at the power supply rail is still recommended.

Several factors should be considered before using the on-chip bias resistors. First, tolerance of the resistor values is ± 15%. HP does not guarantee either the values of these resistors or the performance that will be obtained if they are used. Next, these resistors are made of poly-silicon, which has a temperature coefficient of -0.0008 ppm/°C. Since this coefficient is negative, the on-chip resistors provide less feedback at high temperatures (and hence less bias stability) than would an external carbon resistor possessing a positive temperature coefficient. Finally, using these resistors creates a significant new on-chip heat source that will raise the operating temperature of the transistors in the MODAMP MMIC. This will decrease some aspects of RF performance (especially $P_{sat}$) and reduce the MTTF of the MMIC.

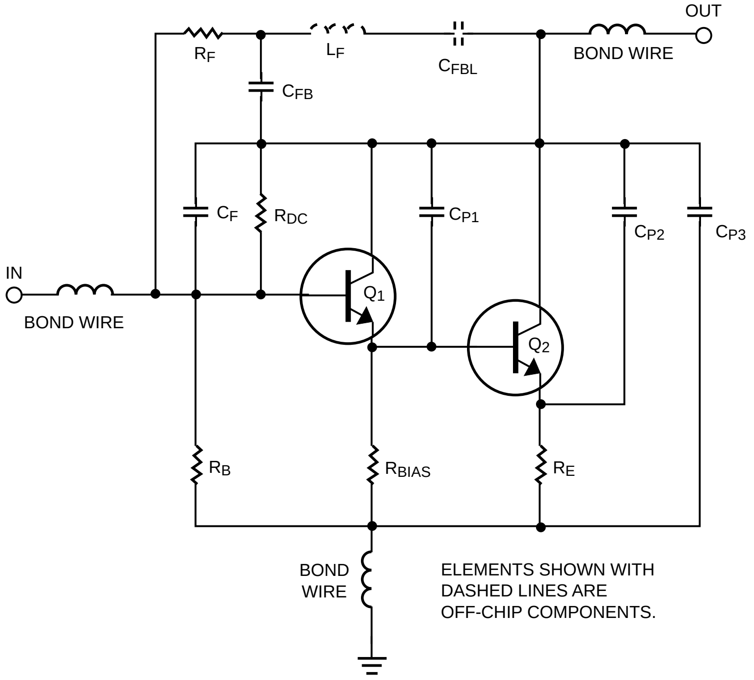
## Section III.
## MSAs Requiring External Feedback Blocking Capacitors

Some MODAMP MMIC chips require the use of an external capacitor in the feedback loop. This need arises with geometries where DC current flow through the shunt feedback resistor RF would otherwise result in excessive on-chip power dissipation. The specific products requiring this capacitor are the MSA-0500, MSA-0900, MSA-1000, and MSA-1100.

### Circuit Background

MODAMP MMICs requiring a feedback blocking capacitor use the circuit topology shown in Figure 4. In this circuit, a high valued resistor, $R_{DC}$, is connected from output to input to form the voltage divider which creates the base bias voltage on Q1. Since the value of $R_{DC}$ is typically in the kilo ohm range, it carries little current and dissipates little power. A capacitor $C_{FBL}$ is connected in series with the shunt feedback resistor $R_F$ to prevent DC current flow through this relatively low valued (typically several hundred ohms) resistor.

The value of $C_{FBL}$ sets the lowest frequency at which this kind of MSA will act as a matched gain block. At frequencies where the impedance of the feedback blocking capacitor is low, the



ELEMENTS SHOWN WITH DASHED LINES ARE OFF-CHIP COMPONENTS.

**Figure 4. Equivalent Circuit for MODAMP MMICs with DC Blocking Capacitor in Feedback Path**

shunt feedback will be connected and performance will be like that of a standard MODAMP MMIC. At very low frequencies however, $C_{FBL}$ will “open circuit” and break the shunt feedback path. The MSA will then become unmatched. Both input and output VSWRs will increase, but the gain will also increase (and in fact approach the open loop gain of the semiconductor devices). At these low frequencies an MSA requiring a feedback blocking capacitor acts more like an unmatched transistor than a matched-to-50-ohm gain block.

The performance trends described above are shown on the individual MSA data sheets, both in the s-parameter data and the performance graphs. Note also that for this class of MSAs the “Gain flat to DC” comment is removed from the $G_P$ versus frequency graph.

### Capacitor Selection

The relatively large value of $C_{FBL}$ required to extend performance into the low MHz frequency range forces the feedback blocking capacitor to be an off-chip element. The value selected for packaged versions of these products is limited by the space available in the package used. These “standard” values are listed in Table 1. Chip data sheet characterization for the geometries listed assumes the use of a $C_{FBL}$ of the value shown.

**Table 1. Standard Capacitor Values for MSAs Using $C_{FBL}$**

| Geometry | $C_{FBL}$ |
|---|---|
| MSA-0500 | 45 pF |
| MSA-0900 | 45 pF |
| MSA-1000 | 80 pF |
| MSA-1100 | 200 pF |

When a designer works with these MSA chips, the option of extending low frequency performance by increasing the value of the feedback blocking capacitor becomes available. Larger capacitor values than “standard” can be used, as the size constraint imposed by the package cavity dimensions is no longer present. The MSAs will work with flat gain and good match down to frequencies where the feedback blocking capacitor provides an impedance of 50 ohms or less. The impedance of $C_{FBL}$ can be calculated from the relationship $Z_{cfbp} = 1 / \{2\pi fC\}$ ohms, where f is the frequency of operation in Hz and C is the capacitance in Farads.

The capacitor selected must have a voltage breakdown adequate for the voltage that will appear across it. A capacitor with a breakdown of 30 volts or more is sufficient for use with any of the MSAs requiring a feedback blocking capacitor.

HP does not sell MOS capacitors, but these components are readily available from a number of vendors. Two such suppliers are listed to the right. This listing does not constitute an endorsement of these vendors by HP, and is for reference only.

MPulse Microwave
576 Charcot Ave.
San Jose, CA 95131

Metelics
975 Stewart Ave.
Sunnyvale, CA 94086

## Assembly

The mechanical connections needed for the feedback blocking capacitor are simple. A MOS capacitor, with the bottom of the chip forming one electrode and the top of the chip the other, should be used. Since the bottom of the MSA chip is also the RF output, when the MOS capacitor and MSA chip are die-attached onto the same metalization area the connection from MSA output to one side of the capacitor is made. The remaining connection between capacitor and shunt feedback resistor is accomplished with a single wire bond connecting the top of the die to the appropriate bond pad on the MODAMP chip. To prevent resonances that can result in high frequency ripple, this bond wire should be kept relatively short.

Bonding diagrams showing typical connection schemes for the MSA geometries requiring feedback blocking capacitors are shown in Figures 5 through 8. These drawings use the same pad numbering scheme as is used in Appendix I of this Application Note and on the chip outline drawing on the individual data sheets.

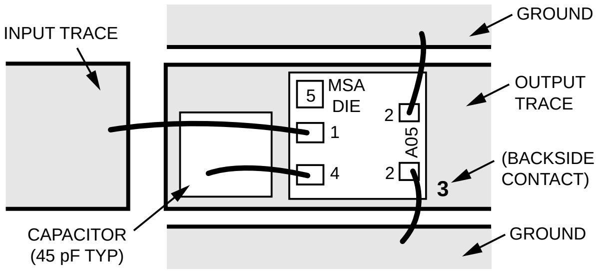


**Figure 5. Representative Bond Scheme for MSA-0500**

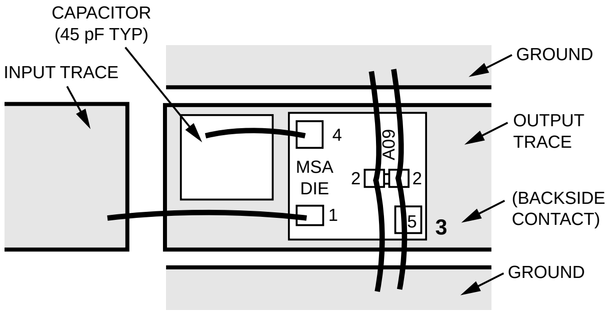


**Figure 6. Representative Bond Scheme for MSA-0900**

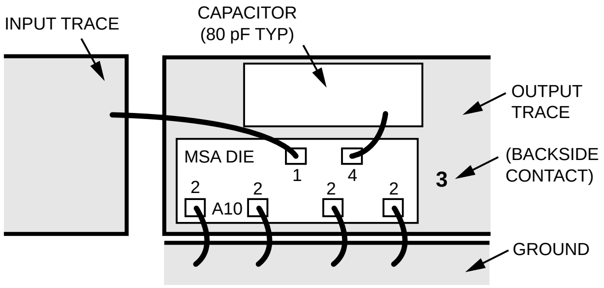


**Figure 7. Representative Bond Scheme for MSA-1000**

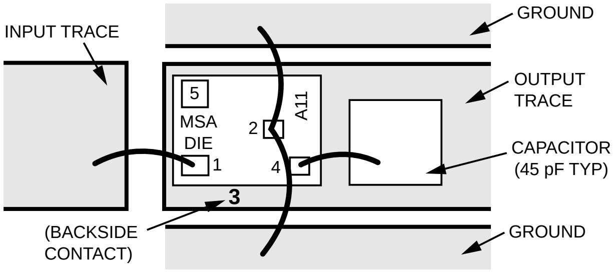


**Figure 8. Representative Bond Scheme for MSA-1100**

# Section IV:
# Assembly Information

### Die Handling

Normal die handling is with tweezers to prevent contamination of the die attach surface. The brittleness of silicon makes the sharp edges of the MMIC chip susceptible to damage if too much pressure is applied. A good precaution is to use only very sharp tweezers with excellent point alignment when handling die (e.g. EREM type 5 SA). Inexperienced operators should practice with bonding samples, which can be obtained from Hewlett-Packard.

The surface of the die is protected with a layer of silicon nitride passivation. This layer provides sufficient scratch protection to allow vacuum picks to also be used for moving die, as long as reasonable care is taken in die handling.

Silicon bipolar devices are far less sensitive to electrostatic discharge (E.S.D.) than are GaAs devices. MODAMP MMICs enjoy an added degree of protection due to their resistive feedback, which tends to “bleed” charge from around the junction. None the less, even MODAMP MMICs can be damaged if sufficient potential is generated across the device terminals. It is therefore always prudent to use standard ESD prevention techniques when handling microwave die.

HP uses and recommends the following procedures to prevent ESD damage.

1. Operators use wrist straps connected to earth ground through 1 megaohm (for operator safety).

2. All equipment is grounded to earth ground, including heater blocks, bonders, and test equipment.

3. Work surfaces are covered with anti-static mats (not metal) which are grounded to earth ground.

4. Operators wear anti-static smocks made of material woven with 1 stainless steel wire.

5. Floors and seat cushions are treated periodically with an anti-static solution.

6. A periodic survey of work areas is conducted with a static potential meter to monitor potential build-ups or grounding failures.

For more information on ESD damage prevention, see HP Application Note AN-A004R: *Electrostatic Damage Discharge and Control.*

### Die Attach

The die attach process serves three functions. First, it mechanically attaches the die to the circuit substrate. Second, it electrically connects the output of the circuit to the trace on which the die is mounted.

Third, it establishes the thermal path by which excess heat leaves the die. All three factors must be considered when selecting a die attach process.

The best procedure for die attaching a MODAMP MMIC chip is to eutectically bond it to a gold plated mounting surface. For this process, the chip and mounting surface are heated sufficiently for the gold on the mounting surface to mix with the gold backside of the chip, and then melt into the silicon of the chip, forming a gold-silicon eutectic bond. The process should be carried out under an inert atmosphere blanket to prevent die attach contamination. This procedure produces a bond that is mechanically very strong, has low contact resistance, and provides the best thermal transfer out of the die.

Alternate die attach procedures include low temperature “solder-down” attaches using gold-tin or indium preforms, and conductive epoxy attach. In general these methods are inferior to eutectic die attach for thermal transfer, and can introduce added contact resistance that will degrade high frequency operation. Their advantage is that they can be performed at lower temperatures than eutectic die attach. Excellent thermal transfer is particularly important for MODAMP MMICs with power dissipations above 100 mW. Poor die attach on such parts means that waste heat is trapped in the die, unnecessarily raising the junction operating temperature. This can degrade device performance in several ways. First, RF performance will be limited, with the most dramatic effect being a reduction in $P_{1dB}$. Second, since the device operating voltage varies with temperature by dV/dT (provided for each device on its data sheet) there will be a shift in DC bias point. Finally, since electromigration (the most common long-term failure mechanism for microwave semiconductor devices) occurs faster at elevated temperatures, the MTTF of the device will be reduced.

**Recommended MODAMP MMIC Eutectic Die Attach Procedure**

1. Set the heater block temperature to 410°C ± 10°C. This temperature should be measured at the point on the die attach stage where the package is to be heated; often there is a significant difference between the dial reading and the actual stage temperature.

2. Place the circuit or package into which the MODAMP MMIC will be attached on the heater block. Allow sufficient time for it to heat thoroughly – typically 5 to 15 seconds depending on thermal mass.

3. Using tweezers or a vacuum collet, pick up the MODAMP MMIC chip and orient it properly for placement on the mounting surface.

4. Place the chip directly on the mounting surface (in general preforms are not needed for eutectic die attach). Scrub with a back-and-forth motion, being careful not to scratch the top surface of the chip. Continue scrubbing until wetting occurs; this should occur within three to four scrubs.

5. If wetting does not occur, check that the heater block is at the

correct temperature, that the inert atmosphere is present, and that all gold surfaces are free of contamination. The inert atmosphere should be heated to around 250°C to prevent it from cooling the die to below the gold-silicon eutectic forming temperature of 387°C.

6. When wetting occurs, perform one circular scrub to insure wetting of the chip perimeter. 100% flow should be visible around the die. Carefully remove the tweezers or collet from the die.

7. Remove the circuit or package from the heater block and allow it to cool in air. The total time for die attach should be less than 10 seconds. Maintaining the die at the 410°C die attach temperature for longer than this can lead to reduced device reliability.

**Equipment**
The following companies supply die attach equipment. These vendors are listed for reference only and their listing here does not constitute an endorsement by HP.

Alphasem
520 Weddell Dr.
Sunnyvale, Ca 94089
(408) 745-1079

Mullen Equipment Company
500 Alaska Ave.
Torrance, Ca 90503
(213) 320-9462

**Wire Bonding**
The electrical connections to the input and common (ground) terminals of the MODAMP MMIC die are made by wire bonds. The output electrical connection is most often made through the die attach, but can also be made through a topside wire bond (e.g. in instances where the MODAMP MMIC chip is die attached onto an electrically isolated “island”, and contact must be made to the output of the circuit).

At microwave frequencies, bond wires become important impedance matching elements, and can significantly effect the RF performance. MODAMP MMIC chips are designed to be 50 Ω structures at the bond pads; the added parasitic inductance of the bond wires degrades this impedance match and should therefore be minimized.

MODAMP MMIC chips are designed to use a single input wire bond. This wire bond should be as low and as short as possible without contacting the edge of the die. Recommended clearance is 1 mil minimum. Contact between the bond wire and the edge of the die can produce a short circuit to the device output, and also can stress the bond wire sufficiently to result in an unreliable connection. If an output wire is used, it should also be kept low and short to have minimal impact on device impedances.

The most critical bond on the chip is the common bond. The inductance of the common bond is a major contributor to high frequency gain roll-off.

Since the common bond is in a series feedback connection with the MODAMP MMIC chip, it not only influences impedance matching, it can also change device stability characteristics. Most MODAMP MMICs are unconditionally stable when properly bonded; however, any MODAMP MMIC can become potentially unstable if enough inductive feedback (i.e. a long enough common bond) is added to the device.

For these reasons the common bond is kept as low and as short as possible while avoiding contact with the edge of the die. It is typically stitch bonded to provide a dual ground configuration. Some MODAMP MMICs (for example, the MSA-0800 geometry) have multiple common bond pads to further reduce common bond inductance.

It is also important that the contact point of the common bond on the mounting surface be an excellent RF ground. This is accomplished through the use of vias or wrap-arounds on the substrate to create a minimum length path to the bottom side ground of the RF circuit.

Bias circuitry, such as an external bias stabilization resistor, can at the designer’s option be connected directly to the MODAMP MMIC chip instead of to the circuit substrate. In such cases the optional output bond pad is used as the bond attachment point. The length of such bond wires will not be critical, as added length merely improves the effectiveness of the connection as an RF choke. For bonding schemes using the on-chip bias resistors, refer to Section II of this note.

**Bonding Techniques And Equipment**
The bond pad size and metal adhesion strength of the MODAMP MMIC chips are compatible with both gold-ball bonding and wedge bonding. Either technique may be used when building MODAMP MMIC chip assemblies.

**Recommended Ball Bonding Procedure**

1. Set the heater block temperature to 300° ± 10°C if thermo-compression ball bonding, or to 150° ± 10°C if thermosonic (ultrasonic) ball bonding.

2. Use prestressed (annealed) gold wire between 0.0007 to 0.001 inches in diameter.

3. Calibrate the bond force as follows:

| Wire Diameter | Bond Force | MWB |
|---|---|---|
| 0.0007" | 15 - 20 grams | 20 ± 2 |
| 0.011" | 20 - 30 grams | 25 ± 2 |

4. Proceed with bonding according to machine specifications. For the common wire, start with the ball on the circuit bonding surface and bond to the common bond pad on the chip, then continue (stitch

bond) to a second contact with the circuit bonding surface. Keep both loops of this common bond low and short. For the input wire, bond a single low short loop from the circuit bonding surface to the input bond pad of the MMIC. If an output wire is used, bond a single low short loop from the circuit bonding surface to the output bond pad of the MMIC. If an on-chip bias resistor is to be used, bond a comfortable loop from the voltage supply trace to the appropriate voltage option bond pad.

**Recommended Wedge Bonding Procedure**

1. Set the heater block temperature to 300° ± 10°C.(Note: If the wedge is heated, the heater block temperature should be lowered slightly from this setting. The exact temperature setting will need to be determined empirically, and will vary from machine to machine.)

2. Use prestressed (annealed) gold wire between 0.0007 to 0.001 inches in diameter.

3. Tip bonding pressure should be between 15 and 20 grams, and should not exceed 20 grams. The footprint that the wedge leaves on the gold wire should be between 1.5 and 2.5 wire diameters across for a good bond.

4. Proceed with bonding according to machine specifications. Refer to step 4 of the Ball Bonding Procedure for information on loop shapes and bonding direction.

**Wire Bonding Equipment**

The following companies supply wire bonding equipment and / or supplies. These vendors are listed for reference only and their listing here does not constitute an endorsement by HP.

| | |
|---|---|
| Ball Bonding: | West Bond 7700 (Thermosonic)<br>West Bond 7716 (Thermocompression)<br>West Bond<br>1551 E. Pacifico Ave. Anaheim, CA 92805<br>(714) 978-1551 |
| Wedge bonding: | West Bond K + S<br>2210 Martin Ave. Santa Clara, Ca 95050<br>(408) 727-5040 |
| Bond Wire | MWS<br>0.0007 inch, P/N 453-18496, EL 1-3<br>Hydrostatics, Inc.<br>0.001 inch, P/N 453-010977-001, EL 3-8 |
| Bonding Wedge: | Deweyl Tool<br>K-1/16-L-60-F1507-T1 |
| Bonding Capillary: | Gaiser 1/8", P/N 1251-15-35, (3-4-3)<br>1/16", P/N 1551-15-375P-39, (3-5-5) |

## Section V: Sample Circuits

Since MODAMP MMICs are matched 50 Ω gain blocks, no special RF circuit design is required when using these chips. The “matching networks” for a typical amplifier consist of 50 Ω input and output transmission lines. For convenience, a graph of line width versus substrate thickness for 50 Ω line on alumina is shown in Figure 9.

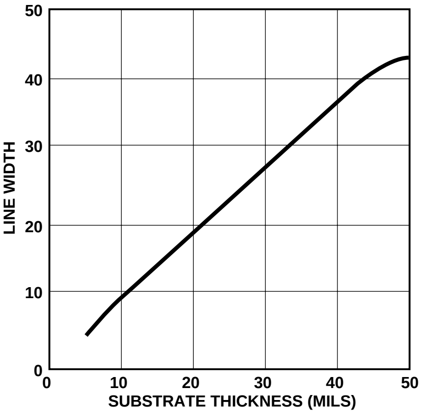


**Figure 9. Line Width vs. Substrate Thickness for 50 Ohm Line on Alumina (k = 9.8)**

The MODAMP MMIC chip is die attached directly on the output trace, and the input connection is made by a wire bond. The ground connections are also made by wire bonds. Solid metalization should be brought up on either side of the die to allow for stitch bonding on the common bond. The bond attach points should be connected to the backside ground of the circuit through multiple vias.

Both input and output transmission lines need to be DC blocked; blocking capacitors should be of a high enough value to present a low series impedance across the frequency range over which the amplifier will operate. Remember to include the effect of parasitic inductance when calculating capacitor impedance. MOS capacitor die, ceramic chip capacitors, or gap capacitances in the transmission line traces can all be used as blocking capacitors. Figure 10 presents a graph of impedance versus frequency for chip capacitors between 1 and 1000 pF, assuming a bonding inductance of 0.5 nH.

MODAMP MMIC circuits require bias circuitry that provides a temperature stable DC operating point; most commonly this takes the form of a dropping resistor between the power supply and the chip. The use of optional on-chip bias resistors has been discussed in Section II. More commonly, the bias resistor will be either a thin film resistor or a chip resistor. Keep in mind that bias resistors with ***positive*** temperature coefficients provide increased feedback and therefore better bias stability over temperature. Other possible bias circuits are discussed in HP Application Note AN-S003: *Biasing MODAMP MMICs.*

Inductive chokes in series with the bias resistor will further reduce any loading effects of the bias on the RF termination presented to the die. The combination of bias resistor plus choke should present a shunt impedance of at least 500 Ω if loading effects are to be minimal. If chokes are used, they may be printed high impedance transmission lines, bond wires, chip inductors, or a combination of these.

The bias network is completed with a bypass capacitor that AC grounds the end of the bias-resistor-plus-choke that is away from the MODAMP MMIC. This capacitor must present a low impedance (less than 5 ohms) throughout the frequency band in which the MODAMP MMIC will be used. Typical bypass capacitors are in the 500 – 1000 pF range; ceramic chip capacitors with their higher capacitance ranges are most commonly used. A sample layout for a one stage MODAMP MMIC amplifier is shown in Figure 11. A sample layout for a two stage cascade is shown on Figure 12. These layouts use MOS chips for blocking capacitors, ceramic chips for bypass capacitors, and thin film

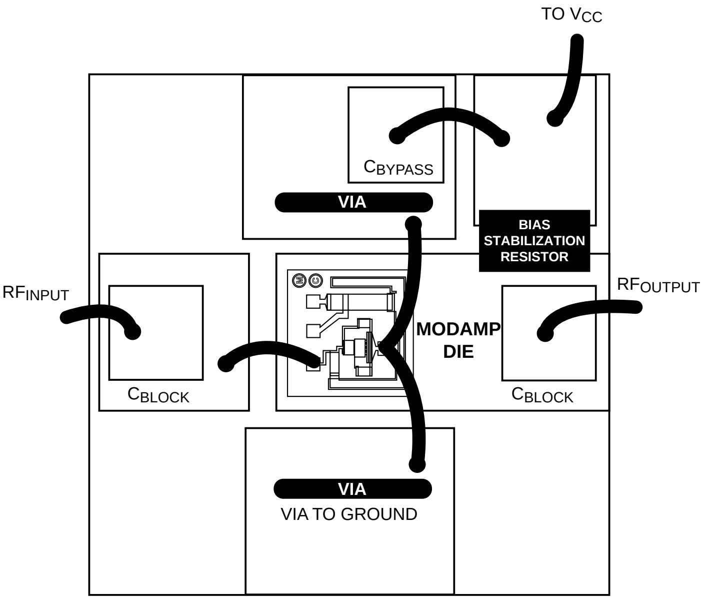


Figure 11. Typical One Stage MODAMP MMIC Circuit

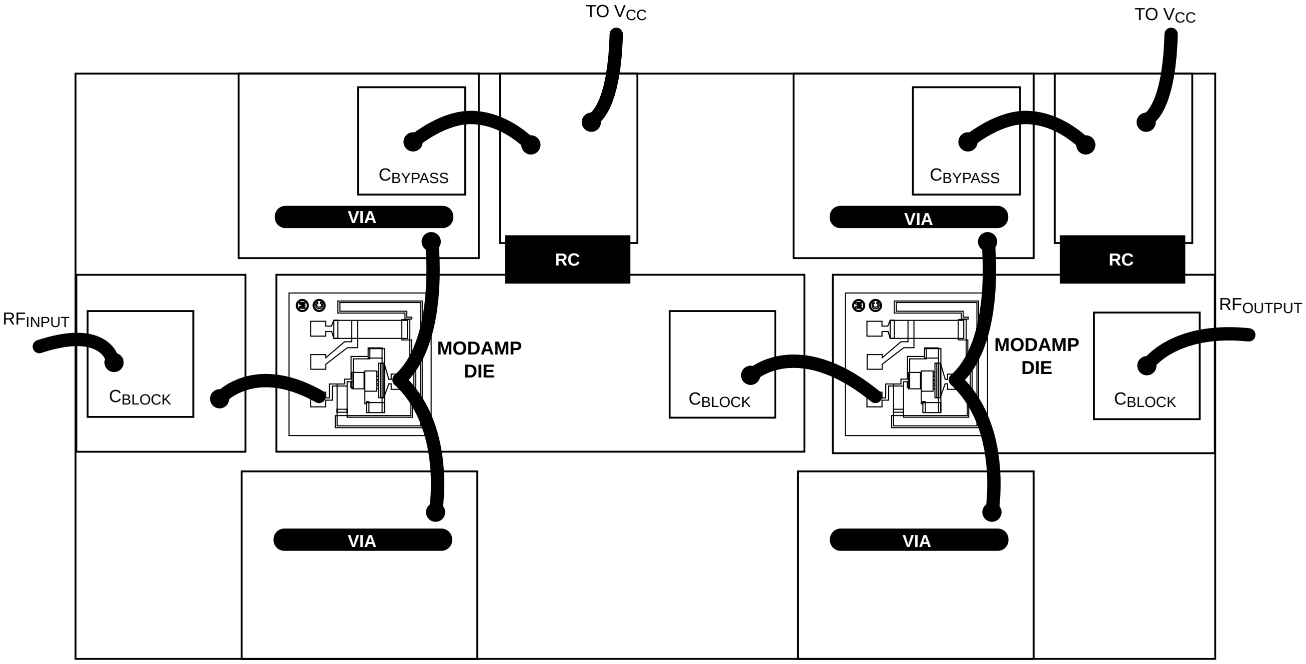


Figure 12. Typical Two Stage MODAMP MMIC Cascade

resistors for the bias feed. No additional choke inductance is used. Note that in a cascade, only one blocking capacitor is needed between devices (not one capacitor per device).

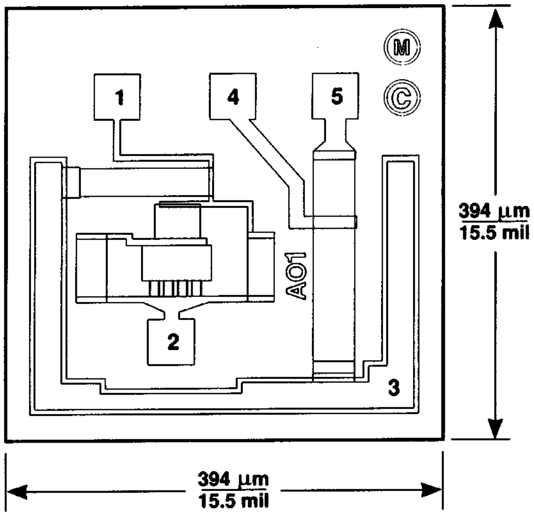
Separate bias feeds are always recommended for each stage. This ensures the best bias stability, reduces device to device feedback, and prevents imbalance that can result if devices with device voltages at opposite ends of the guaranteed range are combined.

## Conclusion

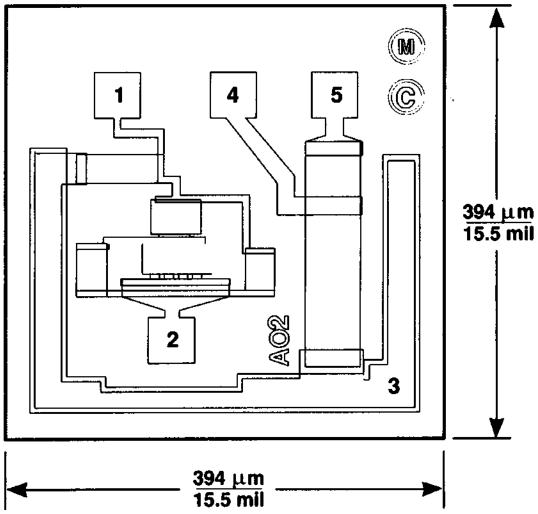
Packaged MODAMP MMIC products have provided microwave circuit designers with effective, easy to use solutions to many of their problems. These same solutions now become available to the designer of hybrid circuits using the MODAMP MMIC chip family. The simplicity and performance offered by these MMICS, combined with the reduced size and lower parasitics of chip-and-wire assembly technology, create microwave circuitry with superior performance. The guidelines and procedures detailed in this Application Note provide the hybrid designer with the information needed to realize such circuits.

## Appendix I:
## MODAMP MMIC Chip Outlines, Labeling Bond Pads

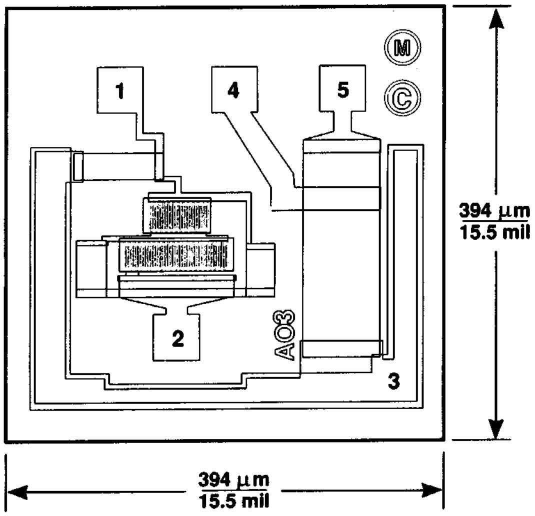
**MSA-0100**



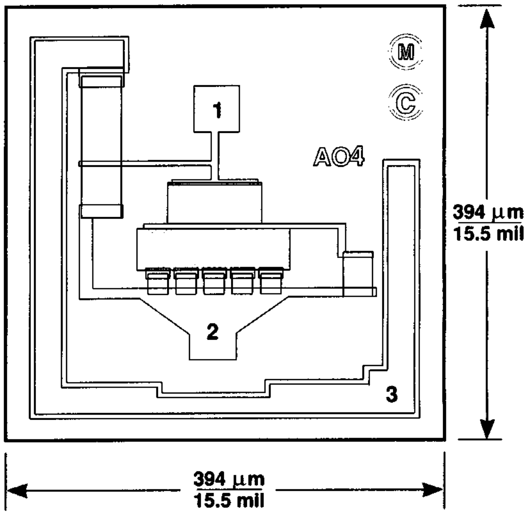
**MSA-0200**



**MSA-0300**



**MSA-0400**



**Bond Pad Code:**

1 – Input

2 – Common

3 – Optional Output

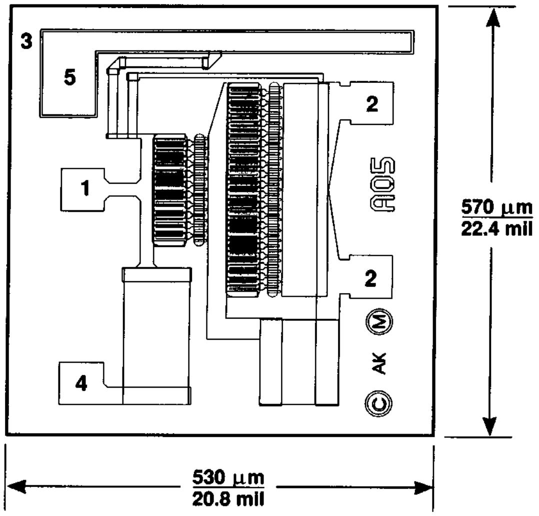
4 – +12V On-Chip Optional Bias Resistor

5 – +15V On-Chip Optional Bias Resistor

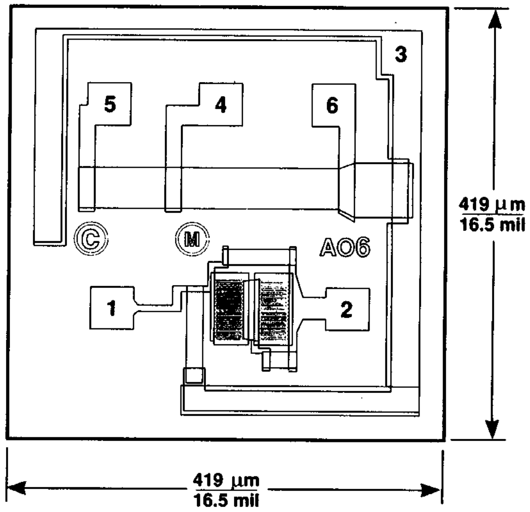
6 – +5V On-Chip Optional Bias Resistor

## Appendix I: (continued)
## MODAMP MMIC Chip Outlines, Labeling Bond Pads

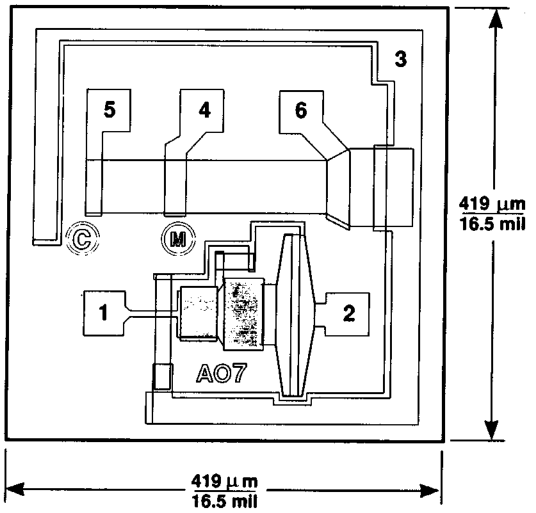
**MSA-0500**



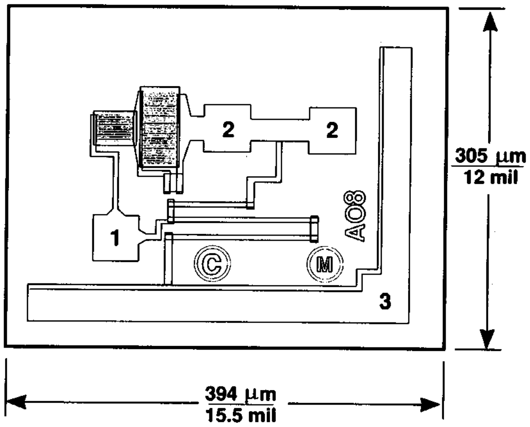
**MSA-0600**



**MSA-0700**



**MSA-0800**



**Bond Pad Code:**

1 – Input

2 – Common

3 – Optional Output

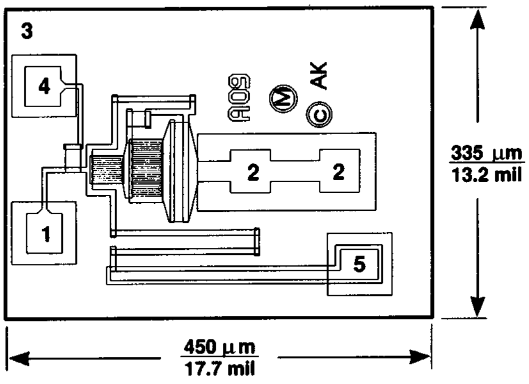
4 – +12V On-Chip Optional Bias Resistor

5 – +15V On-Chip Optional Bias Resistor

6 – +5V On-Chip Optional Bias Resistor

## Appendix I: (continued)
## MODAMP MMIC Chip Outlines, Labeling Bond Pads

**MSA-0900**



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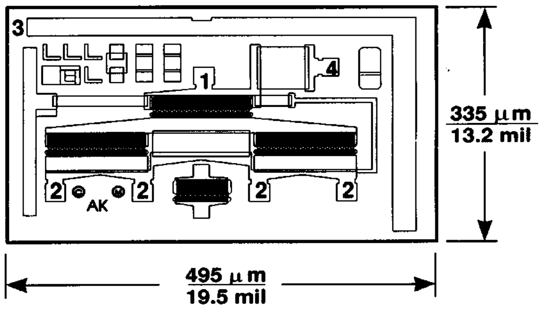

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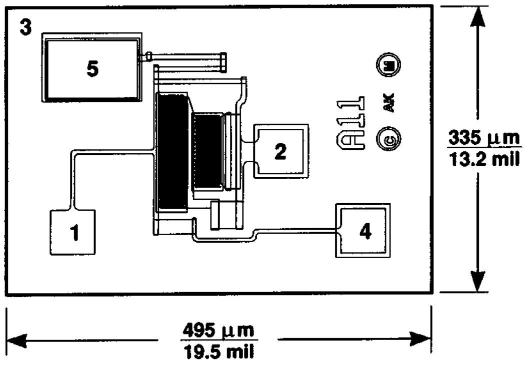

**Bond Pad Code:**

1 – Input
2 – Common
3 – Optional Output
4 – +12V On-Chip Optional Bias Resistor
5 – +15V On-Chip Optional Bias Resistor
6 – +5V On-Chip Optional Bias Resistor

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Printed in U.S.A. 5091-9054E (9/93)