Monolithic Microwave Integrated Circuits

Part 1: Wait! Even if you're not interested in microwaves, you can still use these low-level gain blocks in your next RF project. They work from dc to nearly daylight!

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Monolithic microwave integrated circuits (MMICs) are sure to revolutionize receiver and transmitter design, just as low-noise GaAsFET devices did 10 years ago. Just what is an MMIC? The field is expanding so rapidly that the answer to that question changes every month. In this article, I will concentrate on low-level amplifier MMICs, useful in many ham projects, that are available in small quantities to individuals. This type of MMIC is a chip that contains a single-stage, Darlington-connected bipolar transistor pair with internal biasing. A combination of series and shunt feedback establishes input and output impedance, sets the device gain and ensures stability. The chip is contained in one of a variety of standard low-power, stripline transistor packages.

The state of the art is progressing rapidly in the fabrication of single-package RF ICs, and the term MMIC applies to devices other than single-stage amplifiers as well. Manufacturers have demonstrated that complete receiver front-end assemblies—including RF amplifier, mixer and even the local oscillator—are possible on a single chip. With current technology, MMICs are usable to 18 GHz!

The MMICs that I've used in my projects are from a family of silicon MODAMP™ MMICs manufactured by Avantek. Similar devices are available from NEC, Siemens (MSC) and others. The MODAMP is a modular gain-block amplifier with nominal 50-ohm input and output impedance. With the exception of one special series, these devices are unconditionally stable. Some versions provide usable broadband gain at frequencies above 4 GHz. Low-frequency performance is limited only by the value of the series blocking capacitors used at the input and output of the device.

An MMIC chip can replace an entire amplifier stage that uses the standard hybrid approach with discrete transistors, capacitors and resistors. Size is reduced dramatically, as is manufacturing assembly time. An MMIC chip is merely mounted to the case housing, and small bond wires tie the input and output to the appropriate pins on the device case. Since inductive elements and large bias decoupling capacitors are sometimes best done "off chip" because of their physical size, these are generally the only additional components needed to build a complete MMIC amplifier stage.

A Typical Circuit

The schematic of a typical MMIC amplifier stage is shown in Fig 1. A circuit like this is usable with most MMICs over a frequency range from dc to 3 or 4 GHz. The only thing that changes with frequency is the value of C1, C2 and RFC1.

Everything inside the shaded lines is contained inside the MMIC package! Series and shunt feedback resistors are shown as R_E and R_B, respectively. R1 and R2 are used in addition to R_E and R_B to set the quiescent operating point of each device.

The standard MODAMP MMIC requires an external resistor, R3, to complete the bias network for the device. An external RF choke, RFC1, is often used to isolate R3 from the RF path. Some versions of the MODAMP MMIC include R3 inside the device. While at first this may seem convenient, the external resistor/RF choke combination offers greater bandwidth and gain capability.

Choosing the right values for RFC1 and R3 is important to obtain maximum gain and power output from the MMIC. The combination of RFC1 and R3 should have a high reactance, greater than 500 ohms, at the frequency of operation. Carbon resistors work fine for R3. The RF choke is important—depending on the value of R3, amplifier gain can drop as much as 1 dB if RFC1 is eliminated. This is caused by the parallel loading of the resistor across the nominal 50-ohm output impedance of the MMIC.

The value of R3 can be calculated from a simple equation:

$$R3 = \frac{V_{cc} - V_{MMIC}}{I_{MMIC}} \qquad \text{(Eq 1)}$$

where V_{cc} is the available supply voltage.

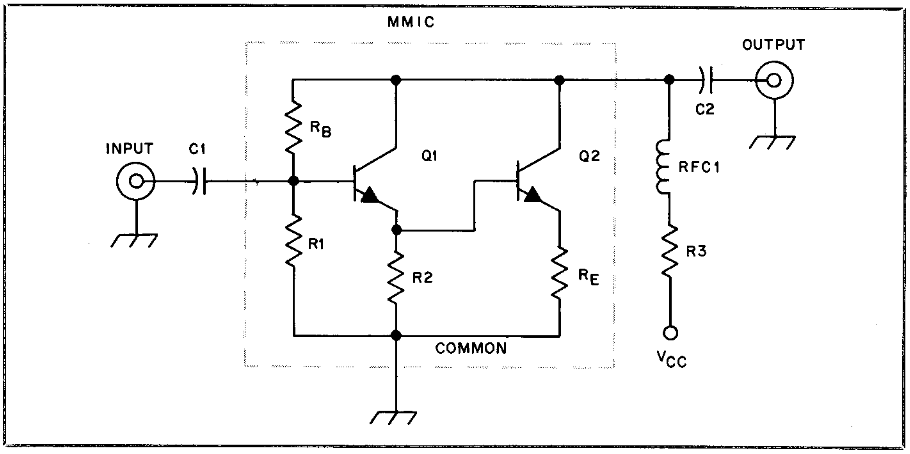

Fig 1—A complete MMIC amplifier stage uses only a few parts and no tuned circuits. Everything inside the shaded lines is contained inside the MMIC package.

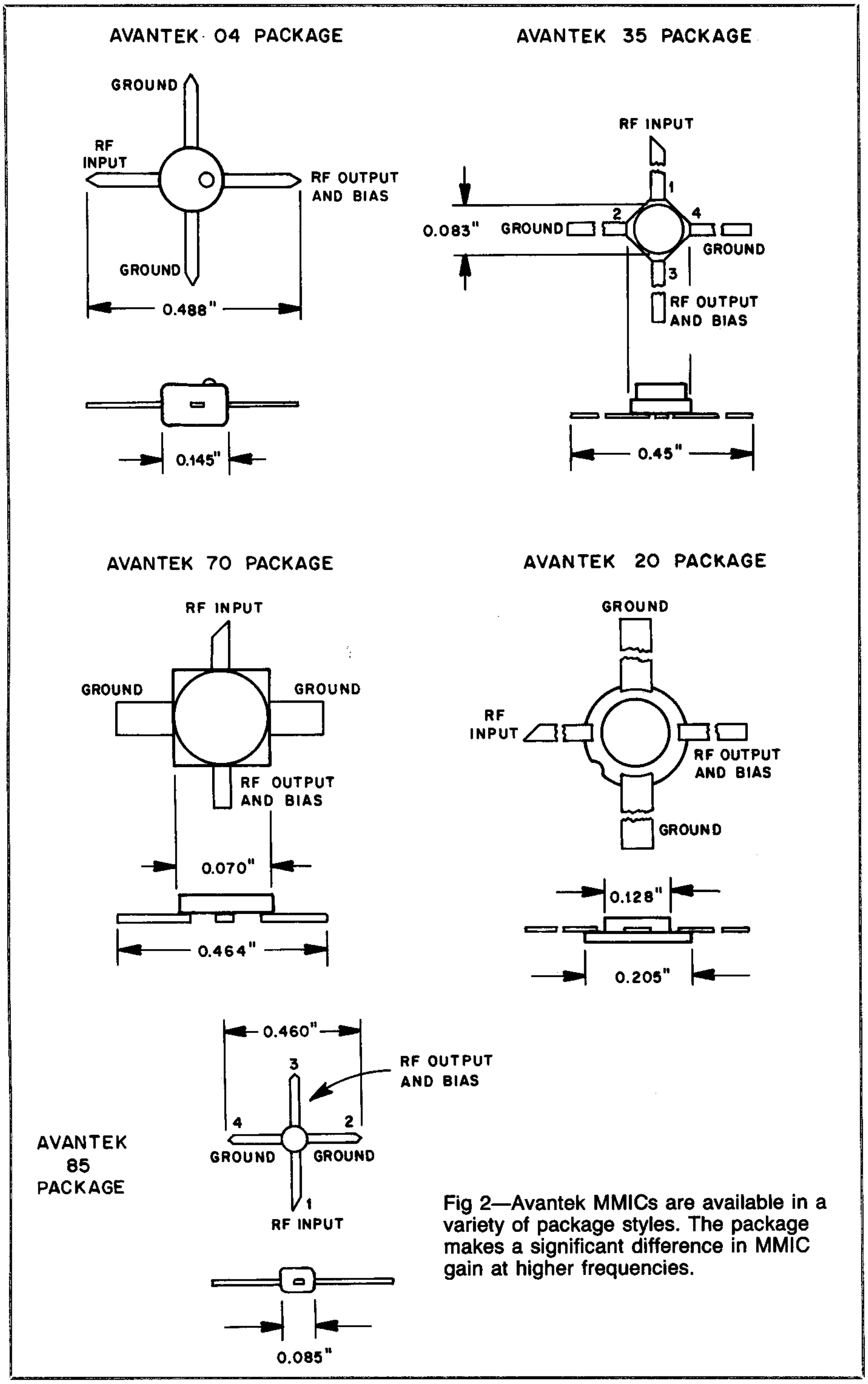

Fig 2—Avantek MMICs are available in a variety of package styles. The package makes a significant difference in MMIC gain at higher frequencies.

V_{MMIC} and I_{MMIC} are specified on the data sheet for the specific device being used.

As Eq 1 indicates, the higher the supply voltage, the higher the value for R3. This is advantageous from the standpoint that a higher value for R3 will load the output of the MMIC less and allow the MMIC to produce greater gain.

R3 also serves as a temperature-compensating element for the MMIC. As the device beta (β) increases with temperature, collector current will increase. Increased collector current causes an increased voltage drop across R3, which tends to decrease the voltage to the MMIC. This in turn decreases MMIC current. An additional advantage of using an external carbon resistor is that the carbon resistor has a positive temperature coefficient, whereas an MMIC with the internal resistor for R3 has a negative temperature coefficient. (A positive-temperature-coefficient resistor is one whose value increases with temperature.)

The manufacturer suggests a 2-V differential between the MMIC operating voltage and the supply voltage for best gain performance over a wide range of temperatures. If V_{cc} was applied directly to the MMIC, with R3 equal to 0, the device would self-destruct when the ambient temperature was increased to +100 °C. Even though a 2-V differential is optimum, a differential of up to 7 V is still acceptable, especially when you consider the relatively narrow temperature range over which typical amateur equipment operates.

The only other components needed to complete the amplifier circuit are C1 and C2, which act as dc blocking capacitors. C1 and C2 should be chosen for low reactance at the frequency of operation, preferably several ohms. For an HF or VHF MMIC amplifier, silver-mica capacitors will work fine. For frequencies above 1 GHz, however, good low-loss ceramic chip capacitors are a must.

MMIC Device Families

The part numbers established by Avantek categorize MODAMP devices by performance. A typical Avantek MMIC has a part number like this: MSA-AABB-CD. Table 1 shows the various Avantek device types and explains how MMIC characteristics are given by the part number.

Outline drawings for some popular Avantek MMIC packages are shown in Fig 2. Generally, the plastic 04 package may be most desirable for commercial or amateur applications where temperature extremes vary from −25 °C to +75 °C. The "micro-x" 35 package is an industry standard for microwave transistors. It is hermetically sealed and offers acceptable performance over a wider temperature range (−55 °C to +125 °C). The "micro-x" package also offers improved RF performance above 2 GHz because the package parasitics are lower than those of the plastic 04 package. Recently introduced by Avantek, the 85 "micro-plastic" package combines the low cost advantages of the 04 package with the high-frequency advantages of the 35 package. The thermal resistance, θ_{jc} (the ability of the device to dissipate power), is rated at 200 °C/W for the 04 package and 140 °C/W for the "micro-x" package. For the 85 package, θ_{jc} is rated at 150 °C/W. Single-unit prices are in the $8, $3 and $4 price range for the 35, 04 and 85 packages, respectively.

For more rugged environments that require military screening, the Avantek 0.200-inch-square disc package (type 20 package) or the 70-mil stripline package (type 70) are available. The 20 package has a θ_{jc} of 65 °C/W, making it capable of greater power dissipation and hence greater power output than the other package types. For the 70 package, θ_{jc} is 130 °C/W. Prices for these "high rel" parts start at $30, so they are generally not used for amateur applications.

Another new release that probably won't see much amateur use is the 86 style package. This one takes advantage of

Table 1
MMIC Nomenclature

The Avantek MODAMP MMICs each have a part number like the following: MSA-AABB-CD. The part number gives some important information about the device. Here's a guide to some characteristics of the various device families.

The number designated by AA defines which MODAMP die is used. The primary differences among the die types are maximum power output, gain and noise figure (NF). The performance numbers given here are approximate and will vary with package style and frequency. Presently there are six available types:

Type	*Characteristics*
01	Low power (+1 dBm), high gain (18 dB) and moderate NF (5 dB)
02	Medium power (+4 dBm), medium gain (10 dB) and moderate NF (6 dB)
03	High power (+10 dBm), medium gain (10 dB) and moderate NF (5.5 dB)
04	Highest power (up to +17 dBm), low gain (8 dB) and moderate NF (6 dB)
07	Similar to 02 except lower operating voltage and lower NF (4.5 dB)
08	Highest gain (30 dB at 100 MHz), medium power (+12 dBm) and low noise figure (3 dB) (Note: This device is not unconditionally stable and care must be given to bias decoupling design.)

BB designates package configuration. Presently there are five available package options.

Style	*Package*	*Comments*
04	Plastic	145-mil-diameter package, low cost; reduction in high-frequency performance
20	BeO	200-mil-square beryllium-oxide package (ceramic); excellent thermal conductivity for higher power applications
35	Micro-x	100-mil-square, economical glass-sealed package with excellent high-frequency performance
70	Stripline	70-mil-square, gold-plated package for "high rel" applications
85	Micro-plastic	85-mil-diameter, low-cost package with excellent high-frequency performance; similar to the micro-x package
86	Surface-mount	Version of 85 package with leads formed for surface-mounting techniques; decreased high-frequency performance

Options

Some of the ceramic-style MMIC families have a suffix (-CD) tacked on to the end of the part number. An example is the MSA-0335-21. A -1 for the first number of the suffix indicates that the series-bias resistor (R3 of Fig 1) is built in. The -1 series require an operating voltage of about 12 V. A -2 indicates that an external bias resistor is required, and the operating voltage is typically 5 to 6 V. In the -1 series with the built-in bias resistor, one of the common leads is a V_{cc} terminal. In the -2 style, there are two ground leads.

The second digit of the suffix is used to designate a premium part which typically has a better high-frequency response. For example, the gain of the MSA-0235-11 is 1 dB less at 1 GHz than it is at 100 MHz. For the MSA-0235-12, however, the frequency at which the gain is 1 dB lower is 800 MHz. This is quite a difference in performance!

These options apply to the 01, 02 and 03 geometries in the 35 and 70 packages. The 04 series (for example, the MSA-0470 or MSA-0435) has no bias or frequency-response options and therefore no suffix.

The 04 and 85 package styles are designed such that both common leads are grounded for best high-frequency performance. Dc is then fed in via the bias network arrangement discussed earlier, and there is no internal-bias-resistor option. This is the standard arrangement, so these styles have no suffix after the package style (for example, MSA-0104).

surface-mount technology, but generally requires mounting to a ceramic substrate to attain adequate heat sinking.

For most amateur applications the 04, 35 and 85 packages are most appropriate. Later in this article I will describe amplifiers that use the 04 and 85 packages since they are the least expensive and are readily available from local distributors in any quantity desired.

MMIC Manufacturing Processes

MMIC chip manufacturing processes are very similar to those for silicon bipolar transistors. An excellent series on these manufacturing processes appeared in *QEX.*[1] The technology necessary for building MMIC chips didn't exist until a few years ago. For example, state-of-the-art nitride self-alignment and ion-implantation techniques are used for precise doping control. This guarantees a high degree of uniformity among wafers of MMIC chips. Nitride passivation assures high reliability by minimizing oxidation buildup on the chip. Precision thin-film resistors are fabricated directly onto the chip so that on most versions only one external resistor is needed to set the bias point. The small reactances associated with the internal feedback resistors enhance the high-frequency characteristics of the MMIC. All of these factors result in high-volume production and low manufacturing cost.

[1]Notes appear on page 32.

Performance

There are so many different MMIC versions that sometimes it's not easy to decide which to use for a given application. In Tables 2 through 4, I have summarized typical gain and 1-dB-gain-compression performance data for the various MMIC families. The data, which covers popular amateur frequencies, was obtained from Avantek specification sheets and represents performance at optimum current for continuous operation.

Performance figures for the popular MSA-0104 through MSA-0404 plastic-package MMICs are shown in Table 2. Since it's often necessary to cascade or parallel units for additional gain or power output, I've included information on various combinations as well.

Table 3 shows performance data for several of the "micro-X" 35 versions. By comparing these figures with those of Table 2, it is evident that the microwave packages do offer superior performance above 2 GHz and should even be considered for work in the 1296-MHz band.

Table 4, for devices with the 85-type package, shows that this series is a good compromise between price and performance at higher frequencies. It's readily apparent that gain above 902 MHz is approximately 1 to 2 dB greater with the 85 package than the 04 package. The 85 and 35 packages offer similar gain above 902 MHz. The 85 package is certainly the choice for economy, yet it still retains the high-frequency performance of the 35 package style.

Input and output SWR is typically less than 2:1 for all of the MMICs. Noise figure ranges from about 5 to 7.5 dB for the 01 through 04 series, with the 01 having the lower noise figure. The 08 series devices have minimal internal feedback and therefore have a lower noise figure—typically 3 to 4 dB up to 3 GHz. Gain of the 08 series is the highest of any of the MODAMP MMICs, but care must be taken in the layout and bias network design since this series is not unconditionally stable. This point will be covered in the practical construction section.

Applications

These MMICs can find many uses in receiving and transmitting equipment in both the RF and IF sections. Since they require no tuned circuits and the 01 through 04 series are unconditionally stable, MMIC amplifiers can be built quickly and easily in a minimum of space. In a test setup, for example, an MMIC can be used as a broadband scope or counter preamplifier when low-level gain is needed. In a receiver, MMICs can be used as RF and IF amplifi-

Table 2

Typical Gain and 1-dB Compression Point (P_{1dB}) Performance for 04 Style Avantek MMICs

Type (MSA-)	*30*	*50*	*144*	*220*	*432*	*902*	*1296*	*2304*	*3456*	
				Frequency (MHz)						
0104	19	19	19	18	17	14	12	9	6	dB Gain
	+8	+8	+7	+6	+4	†	†	†	†	dBm P_{1dB}
0204	13	13	13	13	12	11	10	8	6	dB Gain
	> +7	> +7	> +7	> +7	+7	+5	+4	+2	†	dBm P_{1dB}
0304	13	13	13	13	12	11	10	8	6	dB Gain
	> +13	> +13	> +13	> +13	+13	+11	+10	+5	†	dBm P_{1dB}
0404	8	8	8	8	8	8	7	6	5	dB Gain
	> +13	> +13	> +13	> +13	> +13	+13	+13	+13	†	dBm P_{1dB}
For Cascaded 04 Type Devices:										
02/03	26	26	26	26	24	22	20	16	12	dB Gain
	> +13	> +13	> +13	> +13	+13	+11	+10	+5	†	dBm P_{1dB}
02/03/04	34	34	34	34	32	30	28	††	17	dB Gain
	> +13	> +13	> +13	> +13	+13	+13	+13	††	†	dBm P_{1dB}
03/04/04	†††	†††	†††	†††	†††	†††	†††	22	16	dB Gain
	†††	†††	†††	†††	†††	†††	†††	+13	†	dBm P_{1dB}
For Four 0404 Devices in Parallel:										
4-0404	> +19	> +19	> +19	> +19	> +19	+19	+19	+19	†	dBm P_{1dB}

†Not specified.
††Not recommended for 2304 MHz because of compression of the 03 stage.
†††Not analyzed.
Note: This information was obtained from Avantek data sheets and represents typical performance at the current specified for continuous operation.

Table 3

Typical Gain and 1-dB Compression Point (P_{1dB}) Performance For 35 Style Avantek MMICs

Type (MSA-)	*902*	*1296*	*2304*	*3456*	
		Frequency (MHz)			
0135	17	15	11	9	dB Gain
	†	†	†	†	dBm P_{1dB}
0235	12	11	10	8	dB Gain
	+11	+9	+6	†	dBm P_{1dB}
0335	12	12	10	7	dB Gain
	+12	+10	+6	†	dBm P_{1dB}
0435	8	8	7	5	dB Gain
	+12	+10	+6	+5	dBm P_{1dB}
0835	24	20	15	12	dB Gain
	+13	+14	+12	+10	dBm P_{1dB}

†Not specified.
Note: This information was obtained from Avantek data sheets and represents typical performance at the current specified for continuous operation.

ers. For applications where a low noise figure is not critical, an MMIC can be used as a front end. In transmitters, MMICs can be used for all low-level stages up to 50 mW or so, depending on the device chosen.

Practical Construction

This part of the article is for those of you who have a practical application for an MMIC amplifier or just want to experiment to see how they really behave. Here, I will describe the construction of single and cascaded MMIC amplifiers and show the measured performance of several popular combinations.

Since there are so few parts in an MMIC amplifier, it won't take too long to gather them and it won't break the bank either. Study Tables 2 through 4 and pick the MMIC best suited for the frequency range and power level you need. For most appli-

Table 4

Typical Gain and 1-dB Compression Point (P_{1dB}) Performance for 85 Style Avantek MMICs

Type (MSA-)	*30*	*50*	*144*	*220*	*432*	*902*	*1296*	*2304*	*3456*	
				Frequency (MHz)						
0185	18	18	18	17	17	15	14	10	7	dB Gain
	> +7	> +7	+7	+5	+4	+3	+2	†	†	dBm P_{1dB}
0285	12	12	12	12	12	12	11	10	8	dB Gain
	> +9	> +9	+9	+7	+5	+5	+5	†	†	dBm P_{1dB}
0385	12	12	12	12	12	12	11	10	7	dB Gain
0485	8	8	8	8	8	8	8	7	6	dB Gain

†Not specified.
Note: This information was obtained from Avantek data sheets and represents typical performance at the current specified for continuous operation.

cations, I'd recommend the 85 series because they work well and cost only a few dollars each. Avantek components are available through a number of distributors nationwide. Contact Avantek for the name and address of the distributor for your area.[2] You should have no trouble buying MMICs in small quantities from any distributor.

You'll also need some small-diameter wire, around no. 26 or 28, to make the RF chokes. For the external bias resistor, you'll need an assortment of ¼- and ½-W resistors with values of up to about 400 ohms. The circuit also contains a few capacitors for bypassing and dc blocking. The dc blocking capacitors can be good-quality silver-mica or ceramic units for frequencies through the VHF range. Ceramic chip capacitors are highly recommended for UHF work and above, though. One source of ceramic chips in small quantities is Microwave Components of Michigan.[3] Last, you'll need to decide what type of connectors to use to mate your amplifier to the outside world. I prefer SMA connectors because they are small and they work well at 900 MHz and above, where I do most of my experimenting these days. You can put the finished unit in an enclosure if you wish.

A Simple VHF Amplifier

A simple VHF test amplifier using an MSA-0204 and MSA-0304 can be built from the schematic of Fig 3. C1 through C7 are all common silver-mica or miniature-ceramic capacitors. The 0.1-μF capacitors are used along with the 0.001-μF bypass capacitors to suppress low-frequency oscillations occurring in the bias decoupling network. Remember that the MMICs have a significant amount of low-frequency gain, so good bypassing is a must.

R1 and R2 are ½-W carbon types. The exact value will depend on the type of device used. Table 5 shows typical bias-resistor values (for a 12-V supply) for popular MMICs. These values assume continuous operation at the specified current level. If you use a different supply voltage, you can calculate the resistor value from Eq 1. The optional RFC for each MMIC was not used in this circuit.

I built one version of the amplifier on a piece of 0.015-inch-thick hobby brass bolted to the inside of a standard aluminum box, as shown in Fig 4. Both MMIC common leads are soldered directly to the brass ground plane.

Another version was built using a scrap piece of double-sided, 0.062-inch-thick, glass-epoxy circuit-board material instead of the brass sheet. To assure a good ground for the MMIC common leads, drill a hole in the board and solder them to the ground plane side (which is pressed flat against the case ground). The best way to do this is to use the lead of a 1-W resistor as a bending fixture so that the leads don't break off.

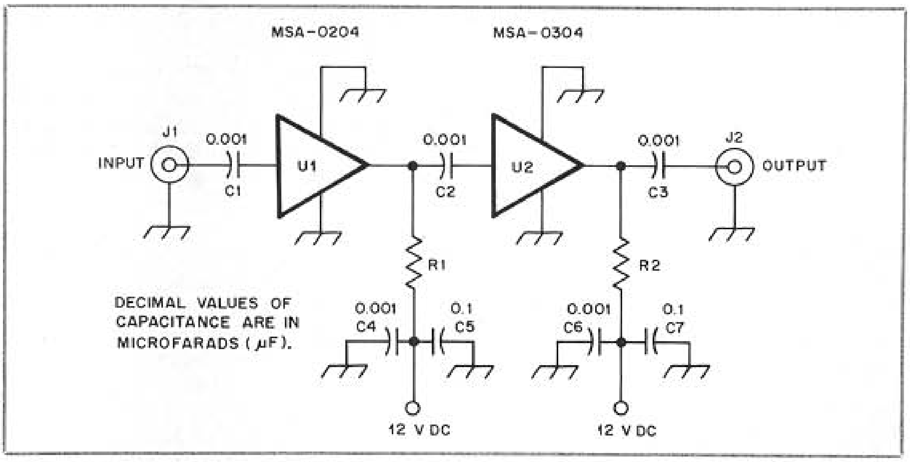

Fig 3—Schematic diagram of the simple HF and VHF MMIC amplifier. Capacitors are silver-mica or ceramic types, and values are expressed in μF. The resistors are ½-W carbon units.

J1, J2—Female, chassis-mount BNC connector.

U1—Avantek MSA-0204.
U3—Avantek MSA-0304.

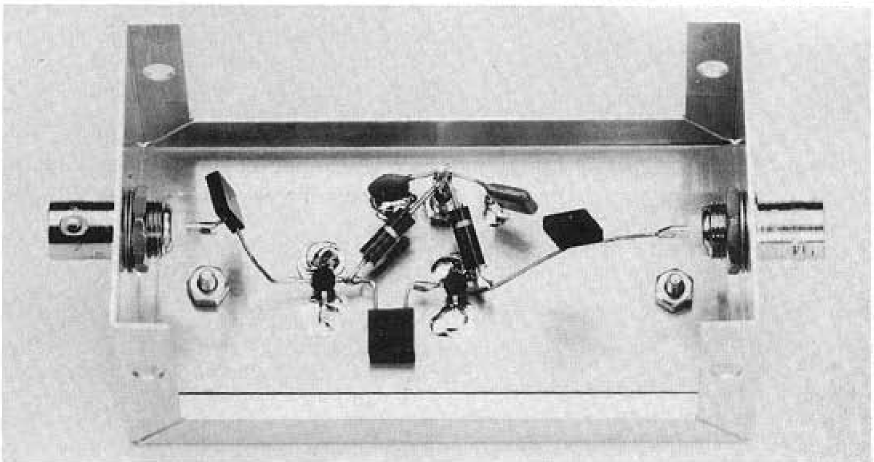

Fig 4—The amplifier of Fig 3 is built on a brass sheet inside a small aluminum box. All ground points are soldered to the brass sheet.

Table 5

Bias Resistor Information For Various Avantek MMICS

Type (MSA-)	*Optimum Current (mA)*	*Resistor Value for V_{CC} = 12V dc (Ohms)*	*Resistor Dissipation (Watts)*
0104	20	330	0.13
0204	30	220	0.20
0304	40	180	0.29
0404	50	130	0.33
0135	22	270	0.13
0235	40	150	0.24
0335	50	120	0.30
0435	50	130	0.33
0835	35	120	0.15
0185	17	410	0.12
0285	25	280	0.18
0385	35	200	0.25
0485	50	140	0.35

Bend the common leads down and then away from the package so the device will lay flat when soldering to the groundplane. See Fig 5. Other construction details are the same as for the amplifier shown in Fig 4.

The gain plots in Fig 6 show that both versions have usable gain well above 1 GHz. Measurements were made on a swept network analyzer. Curve A is for the brass-sheet amplifier, while curve B is for the PC-board version. Lead lengths were purposely made longer on the brass-sheet version (3/8 inch versus 1/4 inch) to see the effect on high-frequency performance.

Since the swept network analyzer plots only characterized the amplifier down to 50 MHz, additional point-by-point data was taken to evaluate performance at specific HF frequencies. This data is shown in Table 6. The 0.001-μF blocking capacitors begin to roll off the gain below about 7 MHz. For improved gain performance at

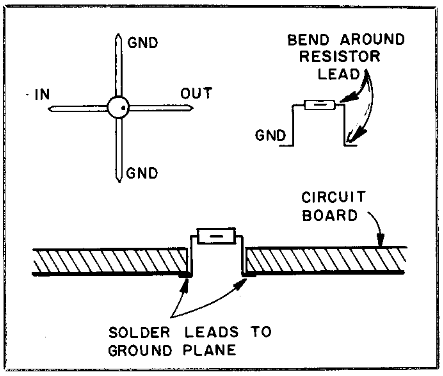

Fig 5—Mounting details for the MMIC. Double-sided PC board material is used instead of brass sheet for the amplifier of Fig 4.

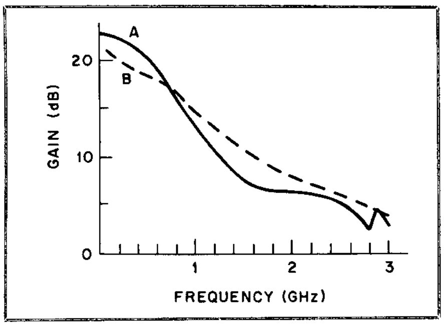

Fig 6—Gain versus frequency for the simple VHF MMIC amplifier. The curve at A is for an amplifier built with brass sheet for the ground plane, while curve B is for the PC-board version. See text.

low frequencies, the blocking capacitors were changed to 0.1 μF. Calculations predict a 1-dB gain reduction to occur at a frequency below about 100 kHz when using 0.1-μF capacitors. High-frequency performance above 50 MHz may suffer, depending on capacitor parasitics.

The basic test amplifier will find many uses around the amateur station. Some possibilities include use as an IF amplifier for a converter or receiver or as an IF amplifier for an automatic noise figure meter. With the 0204/0304 combination, noise figure will be around 6 dB below 1 GHz and 1-dB gain compression at the output will typically be +10 dBm or greater.

Techniques for Using MMICs at UHF and Above

To realize the total gain potential of MMICs at frequencies above 902 MHz, microstripline techniques are required. A cross-sectional view of a microstrip transmission line is shown in Fig 7. The actual impedance of the microstripline depends on the line width (W), the height of the line above the ground plane (h), and the dielectric constant (ϵ_r) of the material separating the line from the ground plane. Microstripline impedance calculations are beyond the scope of this article, but you can learn more about them from several good articles that have appeared in the amateur literature.[4-6]

The microstripline PC board can be etched, or you can use a sharp knife and hot soldering iron to create isolated pads on any piece of scrap board. Common glass-epoxy material is fine for most applications below 2 or 3 GHz; we'll cover this in detail later.

An amplifier built on microstripline is shown in Figs 8, 9 and 10. Standard 0.062-inch-thick, double-sided, glass-epoxy PC-board material has a dielectric constant about 5.0. A microstripline with a characteristic impedance of 50 ohms is about 0.10 inch wide on this material. The line lengths needed for an MMIC amplifier are short enough that the loss of glass-epoxy material is acceptable, even at 3456 MHz.

The board layout shown in Figs 9 and 10 lends itself rather nicely to using 2- or 4-hole flange-mount SMA-type connectors. Gold-plated SMA connectors can be easily soldered to the bottom ground plane. Remember to clear away a circle of copper 0.150 inch in diameter around each SMA center pin on the ground-plane side of the board. This will prevent the center pin from shorting to the ground plane and also ensures a smooth RF transition between the connector and the board.

To ensure a low-loss, low-inductance path to ground for the common leads of the MMIC, pieces of thin copper or brass foil (preferably no greater than 0.005 inch thick) are used to tie the ground areas on the top of the board to the bottom ground plane. First wrap the edges of the board. Then drill a hole where the MMIC mounts that is big enough to wrap a piece of this foil under the common leads, through the hole, down to the ground plane. Solder the foil on both sides of the board. Alternatively, drill a small hole through the board under the ground leads of each device. Bend the leads down, through the small holes, and solder them to the top and bottom ground areas.

In the UHF amplifier, good-quality 0.050-inch- or 0.100-inch-square ceramic-chip capacitors are used as dc blocks. These capacitors are necessary for good gain performance at frequencies around 1 GHz and higher. Use a 15-W soldering iron when installing the chip capacitors to avoid removing the metallization during assembly. An excellent article on the selection and use of chip capacitors appeared in *QEX*.[7]

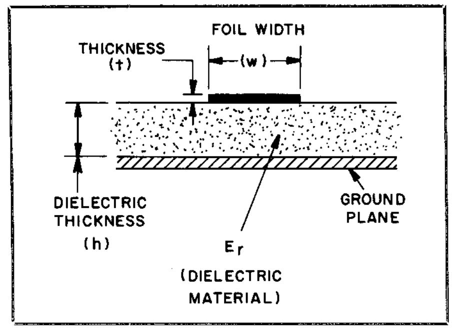

Fig 7—Cross-sectional view of typical microstripline construction.

Table 6

MMIC Amplifier Performance at HF

With 0.001-μF Blocking Capacitors:

Frequency (MHz)	*Gain (dB)*
28	21.4
7	20.6
3.5	19.0
1.2	19.0

With 0.1-μF Blocking Capacitors:

Frequency (MHz)	*Gain (dB)*
28	21.7
7	21.4
3.5	21.5
1.2	22.0

Table 7

Performance of Various Microstripline MMIC Amplifiers

MMICs Used (MSA-)	*Frequency (MHz)*	*Gain (dB)*
0104/0104	500	30.42
	900	28.07
	1300	24.75
	2300	16.65
	3400	11.25
	4000	7.15
0204/0304	500	22.70
	900	21.52
	1300	19.50
	2300	14.40
	3400	10.00
	4000	8.49
0404/0404	500	14.45
	900	14.48
	1300	12.46
	2300	10.80
	3400	6.65
	4000	5.79

RFC1 and RFC 2 are made from no. 26 or 28 enameled wire. The chokes offer a high impedance to RF at UHF and microwave frequencies. At lower VHF frequencies, the reactance of the RF chokes is rather small, and R1 and R2 appear as terminations for low frequencies.

Bypassing is similar to that used in the VHF amplifier. The 0.1-μF capacitors can be used to reduce low-frequency oscillations in the bias decoupling network. When cascading two or more MMICs in a typical receiver or transmitter strip, it may be advantageous to use additional decoupling. Remember that MMICs, especially the 01 and 08 series, have significant gain at low frequencies (several megahertz). If the bias decoupling is not adequate, the amplifier may oscillate from feedback in the bias network. If you experience low-frequency oscillations, try adding a 1-μH RF choke in series between V_{cc} and each bias resistor, and then bypassing each end of the 1-μH choke with a 0.001-μF capacitor.

I built several amplifiers with combina-

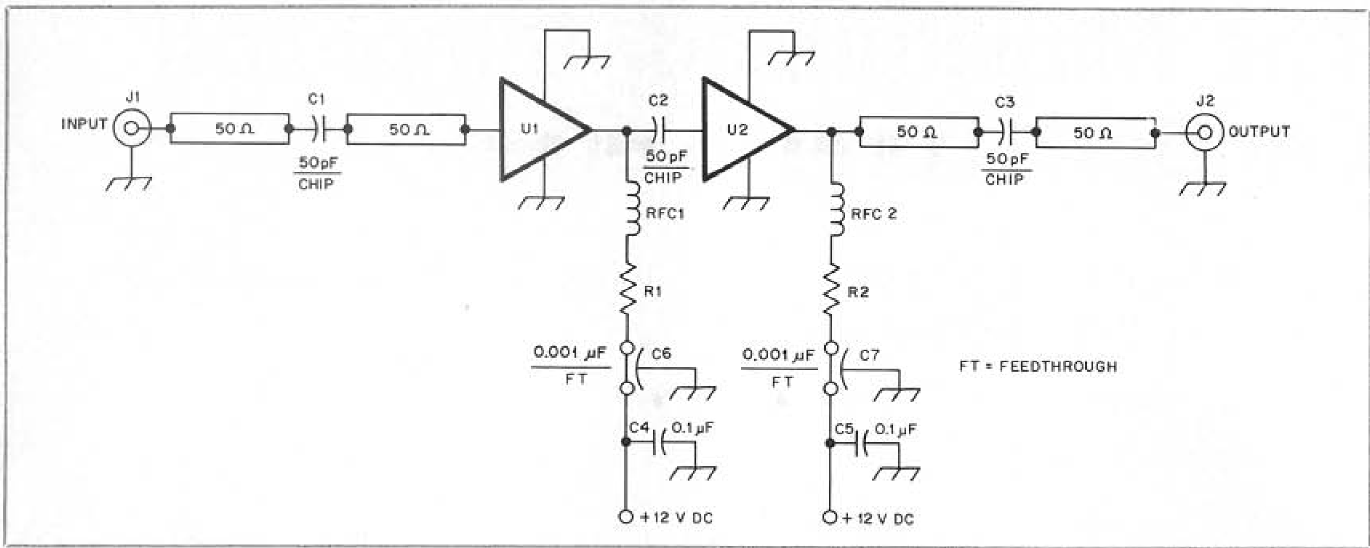

Fig 8—Schematic diagram of the microstripline MMIC amplifier.

C1-C3—50- to 100-pF ceramic chip capacitor. Good quality, 50-mil- or 100-mil-square units are preferred. See text.
C4, C5—0.1-μF, 25-V ceramic disc.
C6, C7—470- to 1000-pF feedthrough capacitor.
J1, J2—Female, flange-mount SMA connector.
R1, R2—Carbon bias resistors. See text and Table 5 for values.
RFC1, RFC2—4 turns no. 26 or 28 enam wire, 0.125-in ID, spaced 1 wire diam.
U1, U2—Avantek 04 series MMIC. See text.

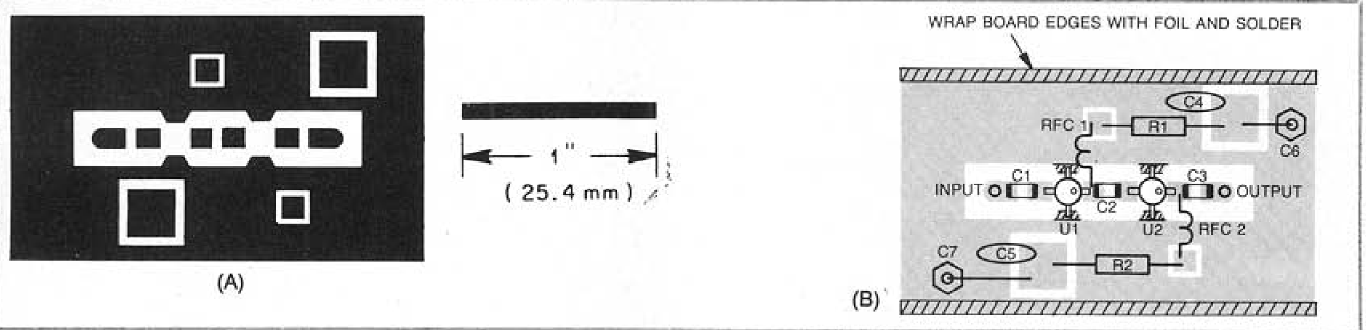

Fig 9—Etching pattern and PC-board layout information for the microstripline MMIC amplifier of Fig 8. All components mount on the circuit-trace side of the board. A PC board can be etched from the pattern shown at A, or a sharp knife and hot soldering iron can be used to clear away unwanted copper. Black areas represent unetched copper.

tions of the 04 series MMICs and measured the performance of each. The configurations are: (1) 0104 driving 0104; (2) 0204 driving 0304; and (3) 0404 driving 0404. Gain for these amplifiers is shown in Table 7.

Notice the vastly improved performance of the microstrip 02/03 combination as compared to the VHF version shown in Fig 3. This is because the 50-ohm transmission lines match the MMIC to its 50-ohm source and load. The gain obtained was slightly less than advertised in the data sheets, but is probably caused in part by the use of lossy glass-epoxy material. It is possible to enhance the high-frequency performance above 2 GHz by using low-loss, Rogers® 5880 circuit-board material. For 0.031-inch-thick board with a dielectric constant of 2.17, a 50-ohm line would be about 0.10 inch wide. For 0.062-inch-thick board, a 50-ohm line is about 0.20 inch wide.

Some gain reduction can be attributed to mismatch loss caused by SWR interactions between the output port of one MMIC and the input port of the second MMIC. This effect is more pronounced at higher frequencies where SWR is typically higher. This subject will be covered in Part 2 of this article.

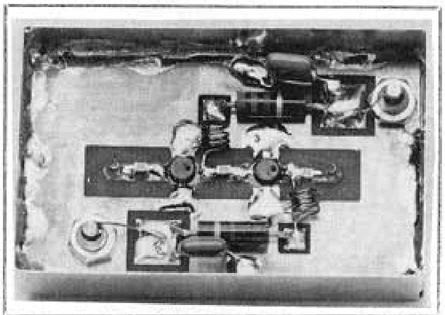

Fig 10—Here is the completed MMIC amplifier, ready for testing. If desired, it can be mounted in an enclosure such as an aluminum box, or you could solder together side and bottom plates made from scrap circuit-board stock or from sheet brass.

Noise figure for the 0104/0104 configuration was measured at 4.7 dB at 1296 MHz and 5.3 dB at 2304 MHz. Noise figure below 1296 MHz will typically be 4.5 dB. The 1-dB-gain-compression point of the 02/03 combination was measured at +10 dBm at 1296 MHz and +5 dBm at 2304 MHz, referenced to the output port. For the 04/04 combination, the 1-dB-gain-compression point was +13 dBm at 1296 MHz and +12 dBm for 2304 MHz. Slightly improved gain performance can be expected by using the 85 package style MMICs.

A High-Gain, Low-Noise MMIC Amplifier

A similar microstripline test amplifier was built using a single MSA-0835 MMIC. Since this particular series is not unconditionally stable, there are a few special considerations. I chose a 200-ohm, ½-W carbon resistor to bias the MMIC at 25 mA for the lowest possible noise figure.

(continued on page 32)

Monolithic Circuits

(continued from page 29)

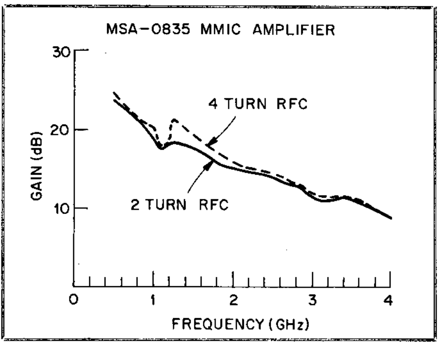

Fig 11—This graph compares the gain of a single-stage MSA-0835 amplifier with 2-turn and 4-turn RFCs. Although the use of a 4-turn choke enhances gain, a 2-turn choke is preferred for amplifier stability.

The RF choke was made from 2 turns of no. 28 wire, 0.125-inch ID, spaced one wire diameter. When the 2-turn RF choke was added in series with the bias resistor, the amplifier exhibited a slight increase in gain in the 500-2500 MHz frequency range without compromising stability. Experimentation with up to 6-turn RF chokes yielded greater gain, but stability was marginal. The 2-turn choke is a good compromise for maximum gain and stability. Depending on the inductance of the bias resistor, the series RF choke may need to be deleted to ensure stability under all circuit conditions.

Actual measured gain response with 2-turn and 4-turn RF chokes in place is shown in Fig 11. Gain (for a single device!) is 24 dB at 500 MHz, while the gain at 3500 MHz drops to 9 dB. Gain was not measured above 3500 MHz. Noise figure as measured at 2304 MHz is in the vicinity of 4 dB with an associated gain of 13 dB—not bad for an untuned microwave amplifier using glass-epoxy PC board material! Gain performance comparable to that shown in Table 3 may be achieved if a lower-loss dielectric material such as Rogers Duroid® were used.

In Part 2 of this article, I will show how to combine MMICs in parallel for increased power output. I will also discuss important parameters such as gain, compression point, third-order IMD products and noise figure and how they should be considered when designing MMICs into your next project.

Notes

[1]B. Olson, ">50: Focus on Technology above 50 MHz," *QEX*, Apr 1986, pp 12-15; May 1986, pp 12-14; June 1986, pp 10-11.

[2]Avantek, 3175 Bowers Ave, Santa Clara, CA 95051, tel 408-727-0700.

[3]Microwave Components of Michigan, 11216 Cape Cod, Taylor, MI 48180, tel 313-941-8469 (evenings).

[4]D. Mitchell, "Microstrip Impedance Program," *Ham Radio*, Dec 1984, pp 84-86.

[5]J. Fisk, "Simple Formulas for Microstrip Impedance," *Ham Radio*, Dec 1977, p 72.

[6]J. Fisk, "Microstrip Transmission Line," *Ham Radio*, Jan 1978, pp 28-37.

[7]B. Olson, ">50: Chip Capacitors," *QEX*, Sep 1986, pp 14-15.