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Biasing MSA Series RF Integrated Circuits

Application Note S003

Bias Point Selection

Like discrete transistors, the MSA Series of RF Integrated Circuits can be operated at different bias points to achieve different performance results. These Monolithic Silicon Amplifiers have an internal structure consisting of a Darlington connected pair of bipolar transistors embedded in a matrix of resistors. Since this structure is current controlled, the bias point of an MSA can best be described by specifying the total device current, I_d.

Both power and gain can be adjusted by varying I_d. Curves of typical performance as a function of bias are shown on the individual MSA data sheets. Table 1 lists the range of bias currents over which the various MSAs can be expected to operate. The column labeled "Minimum Recommended Operation" represents the lowest level at which HP recommends operating the MSA. Operation of the MSA below this threshold causes the IC to be partially turned off; performance becomes unpredictable, and stability problems can result when the device is operated over temperature. There is no intrinsic reliability problem associated with operation below this bias level, however. The column labeled "Guaranteed Performance" lists the bias level at which HP specifies and tests device performance. It represents a "typical" operating bias point. The "Maximum Recommended Operation" column lists HP's recommendation for the highest level of bias for the MSA. In particular, significant improvements in P_{1dB} and (to a lesser extent) gain can be obtained for the MSA-06 and

Table 1. MSA Typical Operating Currents

Geometry	Minimum Recommended Current (mA)	Guaranteed Performance (mA)	Maximum Recommended Current (mA)	Absolute Maximum (mA)
01	13	17	25	40
02	18	25	40	60
03	20	35	50	80
04	30	50	70	85–100
0420	30	90	110	120
05	60	80	100	135
0520	80	165	200	225
06	12	16	20–25	40–50
07	15	22	30–40	60–50
08	20	36	40	80–65
09/99	25	35	45	80
10	150	325	400	425
11	40	60	70–75	80–100
20	—	32	—	50
31	—	29	—	50

MSA-07 geometries when operated at higher currents – refer to the product data sheets for more information. Typically operation at currents above the "maximum recommended" level yields minimal returns in terms of improved performance, and causes a noticeable decrease in device life expectancy. HP suggests that this value be used as an upper limit when selecting device operating point. The "Absolute Maximum" column lists the value of I_d beyond which catastrophic device failure can be anticipated. It represents the most current the MSA can ever be expected to handle without being destroyed.

In general, the maximum device current ratings are thermally limited. The thermal conductivity properties of the 200 mil BeO (20) package are good enough to allow a chip mounted in this package to be rated significantly higher in current handling capability than the same chip mounted in any of the other package options. Conversely, the thermal properties of the plastic packages (04, 05, 85, 86, and especially 11) requires a lowering of the maximum allowable current. For this reason some devices have ranges of "maximum recommended" and "absolute maximum" currents; refer to the individual product data sheets for details. The style 20 package performance is sufficiently different to be listed separately in Table 1.

Bias Circuitry Options

Once an appropriate bias point has been chosen, circuitry must be provided to ensure that the MSA operates at that bias point. To be effective, this circuitry must establish an appropriate bias point across the entire operating temperature range the MSA will experience. The internal resistors on the MSA have a temperature coefficient of –0.08%/°C; the on-chip transistors increase in β at a rate of +0.7%/°C. If the bias current I_d is to remain constant over a broad temperature range, the bias circuitry must decrease the device voltage V_d at higher temperatures and increase V_d at lower temperatures.

A number of possible biasing schemes are described in detail below.

Voltage Source On Collector

The simplest bias scheme available is to provide a fixed voltage to the "collector" or output terminal of the MSA. This voltage can be supplied either from a voltage regulator or from a power supply. It must be provided through an RFC (Radio Frequency "Choke," or high-value inductor) to keep the high frequency signal isolated from the DC circuitry. A large-value capacitor (e.g., 1 μF) should be connected from the DC side of the RFC to Ground to provide a low-impedance path to any signal that does get past the RFC. DC blocking capacitors (or alternatively transformers, if the MSA is to be operated at very low frequencies or at DC) must be used to isolate both the input of the MSA from the drive source and the output of the MSA from the load. The entire circuit is shown in Figure 1.

Because of its very narrow temperature operating range and sensitivity to V_d this bias scheme is not appropriate for most production circuits. It finds its major applications in laboratory testing of devices utilizing variable power supplies to provide the bias. With this bias scheme, temperature variations on the order of 25°C will cause significant alterations in performance; temperature variations on the order of 75°C can destroy devices by causing them to draw too much current. Device-to-device variations may also yield a MSA that draws an excessively high current if V_d is fixed, even at room temperature.

Collector Bias Stabilization Resistor

The fixed collector voltage bias circuit described above can be changed into a temperature-compensated bias circuit with the addition of a bias stabilization resistor in the collector feed. This resistor acts as a simple feedback element. As the temperature increases, the MSA tries to draw more and more current. Since this current is supplied through a resistor, the MSA bias voltage V_d decreases as I_d tries to increase: V_{CC} stays fixed; I_d increases with temperature causing the voltage drop $I_d R_C$ across R_C to increase, thus lowering V_d and "throttling back" on the bias current I_d.

Note that the amount of feedback is proportional to the voltage drop across R_C, and hence to the value of R_C. For effective compensation over normal operating temperature ranges (–25°C to +100°C), a voltage drop of at least 4 volts is recommended.

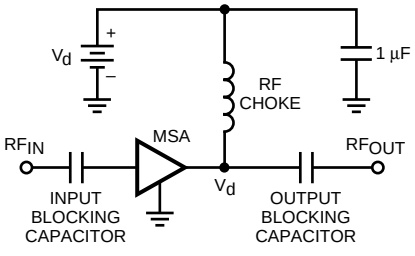


Figure 1. Fixed Collector Voltage Bias Circuit

Remember that R_C itself will change in resistance as the temperature changes. By selecting a bias resistor with an appropriate temperature coefficient the temperature compensation of this circuit can be "fine tuned." Carbon composite resistors typically have a temperature coefficient of +0.10%/°C, and work particularly well as bias stabilization resistors.

A side benefit of using a bias stabilization resistor is that it is often of high enough impedance that an RFC is no longer needed to keep the high frequency signal out of the DC bias. It is recommended that an RFC still be used if the MSA is being used near saturation; otherwise R_C appears in parallel with the load resistance and can cause enough of a shift in load impedance to reduce both gain and saturated power by 1 to 2 dB.

The circuitry needed for a bias stabilization resistor scheme is shown in Figure 2. MSAs were designed with this bias scheme in mind and many of the devices are available with R_C built onto the amplifier chip. Since devices incorporating internal bias stabilization resistors require independent access to the V_{CC} port, one ground lead is given up to make room for the extra connection that must now be provided. Some high-frequency performance is therefore sacrificed with these devices due to their increased common lead inductance.

± Supply Bias

Sometimes the designer does not have available the higher voltages necessary to use the bias stabilization resistor method described above, but does have available both positive and negative voltages. Under these circumstances the MSA may be DC "floated" and the difference between the two voltage supplies used to provide the voltage drop necessary to use a stabilization resistor. A schematic showing this technique is shown in Figure 3.

An RFC is needed in the path to the negative voltage supply, again to keep the RF signal separated from the DC. The most critical elements are the capacitors used to "float" the MSA. These must provide excellent high frequency grounding throughout the entire frequency range of operation. This means that large valued capacitors must be used to ensure good low frequency operation ($1/(2\pi fC) < 1\ \Omega$ at f_{min}), and that low parasitic inductance capacitors must be used to ensure good high frequency grounding ($2\pi fL < 1\ \Omega$ at f_{max}). These requirements sometimes necessitate the use of multiple bypass capacitors. Typically, it is not possible to avoid some degradation in gain at higher frequencies if this bias scheme is used.

Active Bias

Active bias circuitry can be used to provide temperature stability without requiring the large voltage drop or relatively high dissipated power needed with a bias stabilization resistor. A simple realization using a resistively-biased PNP transistor as a current source is shown in Figure 4.

In this circuit R_1 and R_2 form a resistive divider that establishes the bias point of the PNP bias transistor. R_3 provides a "bleed path" for any excess bias current;

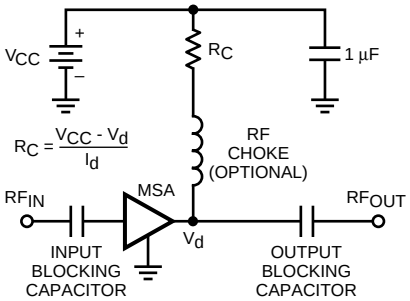


Figure 2. Collector Bias Stabilization Resistor Bias Circuit

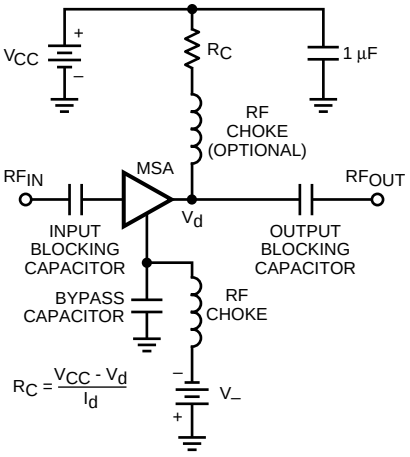


Figure 3. ± Power Supplies Bias Circuit

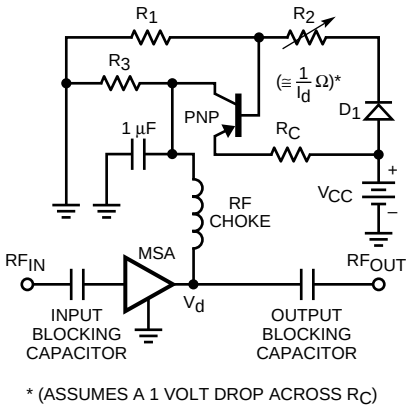


Figure 4. Active Bias Circuit

it is a safety feature that can be omitted from minimum element realizations of this circuit. D_1 is also an optional element; its purpose is to provide temperature compensation by tracking the voltage variation with temperature of the emitter-to-base junction of the PNP bias transistor. For this reason, when it is included it is often realized using the E-B junction of a second PNP transistor identical to the bias transistor, connected with its collector-base junction shorted.

R_C is a feedback element that keeps I_d constant. If the device current starts to increase, the voltage drop across R_C also increases, turning off the E-B junction of the PNP transistor, and hence decreasing the bias voltage V_d applied to the MSA. For best circuit operation, there should be at least a 0.5 to 1 volt drop across R_C. The PNP transistor is acting in the saturated mode with both junctions forward biased. The voltage drop needed across the emitter to collector junction of this transistor will therefore be equal to its $V_{CE\,sat}$ - typically only several tenths of a volt. Thus, the total voltage difference needed between V_{CC} and V_d is only about 1.3 volts for this circuit, as compared to the 4 volts or so needed by the bias stabilization resistor for good bias stability over temperature.

A side effect of the PNP bias transistor operating in the saturated mode is that this bias requires some extra "charge up" time at turn-on and "discharge" time at turn-off. How much extra time is required will depend on the time constants of the PNP transistor.

Systems requiring wide dynamic range operation or AGC (automatic gain control) often require that the MSAs operate at variable operating points. If R_2 is made variable, this bias scheme will work well for such applications.

Current Adjust Passive Bias

It is possible to design a simple passive bias circuit that allows the designer to adjust the MSA bias current I_d while using a fixed voltage power supply. This allows operation of the MSA at bias points other than those established by its internal bias circuitry, e.g., operation at the data sheet value of I_d but with a lower V_d than specified on the device data sheet. The schematic for such a circuit is shown in Figure 5.

This circuit works by supplying an external "base" voltage to the MSA that can be adjusted by using a variable resistor, R. Decreasing R will raise the voltage on the input of the IC, and hence increase its bias current. R must be connected in series with an RFC to prevent it from degrading the input impedance of the MSA.

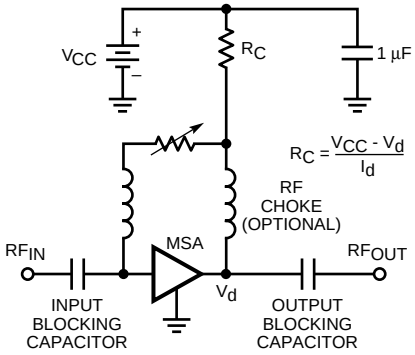


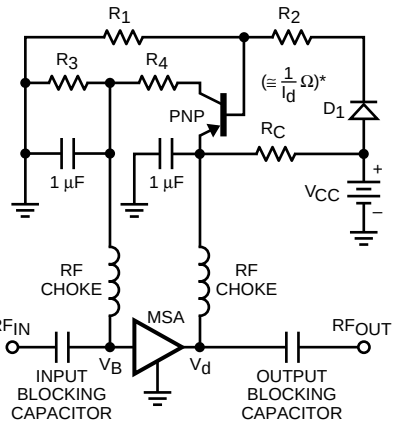
Figure 5. Current Adjust Passive Bias

Note that this circuit works only to increase the MSA bias current beyond some minimum value established by the device's internal bias resistors and the voltage V_d. If R were connected from the input of the MSA to ground (instead of to R_C), an analogous circuit that would decrease bias current as R was decreased in value would result.

Current Adjust Active Bias

Figure 6 shows a circuit that combines the features of adjustable (offset) bias current and active bias. The "base" voltage applied to the MSA is set by the output voltage of the PNP bias transistor. The bias applied to this PNP transistor is established by the voltage divider formed by R_1 and R_2. Adjusting the value of R_2 therefore determines the MSA bias current I_d.

R_4 is present to decrease the power dissipation of the bias transistor. Given the relatively low "collector" to "base" voltages required to operate most MSAs, this element can be omitted at the designer's discretion. R_3 once



* (ASSUMES A 1 VOLT DROP ACROSS R_C)

Figure 6. Current Adjust Active Bias Circuit

again serves as a bias current "safety bleed path."

RF chokes and bypass capacitors are used in both "collector" and "base" feeds to keep the DC and RF circuitry separate.

This circuit provides excellent bias stability over temperature. Due to the feedback function of R_C, increases in I_d resulting from rises in temperature are compensated for by a lowering of V_B. This results from the increased voltage drop across R_C turning off the PNP bias transistor.

Note that the "base" current provided to the MSA by the PNP is much less than the "collector" current of the MSA. This indicates that the PNP transistor is not operating in the saturated mode in this circuit, as it was in the active bias circuit described above. This circuit will therefore have a much faster response time than will the previously described active bias circuit.

An important consideration when using this circuit is that it changes bias point by changing bias load line, that is, it adjusts V_d and I_d simultaneously. This circuit is therefore not readily adaptable to situations where the designer wishes to continuously vary the operating point of the MSA. It is best suited for situations where the designer has a specific "non-standard" bias point in mind that must be closely maintained over temperature.

A saturated variant of this bias results if the RFC connecting the output of the MSA to the emitter of the PNP is moved to connect the output of the MSA to the collector of the PNP. Such a bias functions as a hybrid between the active bias scheme of Figure 4 and the current adjust passive bias of Figure 5. It allows operation from low voltage power supplies (minimum voltage drop required for the PNP, ability to raise I_d by decreasing R_4) while simultaneously allowing a sweeping of bias points for AGC type operation by varying R_2.

Conclusions

A variety of bias circuits that can be used with MSAs have been shown. The simplest scheme (a constant voltage source) is not acceptable for most applications because of poor temperature stability. The next simplest scheme (the bias stabilization resistor) is the most widely used bias method due to its low cost and stable performance over temperature. Its major drawback is the relatively large voltage drop required across the stabilization resistor for good bias stability over temperature. Bias schemes that address this problem by using two power supplies (± supply bias) or active bias (active bias circuit) were also shown. Finally, bias schemes that allow the user to alter the MSA operating point from the design operating point have been included (current adjust passive bias, current adjust active bias).

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