Wideband Choke Biases Amplifier Circuits To 8 GHz

This broadband RF choke can save valuable gain and output power when supplying power to monolithic microwave amplifiers.

Engineering Department

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WIDEBAND monolithic amplifiers operating to 8 GHz have become commonplace. Unfortunately, bias circuitry for these amplifiers has not been readily available until the recent introduction of the model ADCH-80A wideband microwave choke from Mini-Circuits (Brooklyn, NY). The choke supports RF/DC applications from 50 to 8000 MHz and can help to significantly reduce resistive RF signal losses in the bias circuitry of broadband microwave amplifiers.

Widespread use of wideband monolithic-microwave amplifiers, such as the ERA series from Mini-Circuits, has required circuit designers to develop broadband power-supply circuitry that supports the bias requirements of these integrated circuits (ICs). Monolithic microwave amplifiers are typically biased through current injection at the RF output port. Since DC power and RF output signals share this port, it must exhibit strong DC and RF characteristics. An inadequately designed DC biasing circuit will degrade the RF performance. One recommended bias approach involves the use of a resistor and RF choke in series with the DC supply. The RF choke serves to minimize the RF losses of the resistor.

The biasing scheme for a typical monolithic microwave amplifier is shown in Fig. 1, with the biasing resistor denoted by R_{bias}. The value of this resistor is determined by the device's required voltage, the supply voltage, and the desired operating current of the amplifier design. For example, for a model ERA-1 monolithic amplifier, the device voltage is +3.6 VDC. Assuming that the supply voltage is +12 VDC, the value of the biasing resistor will be:

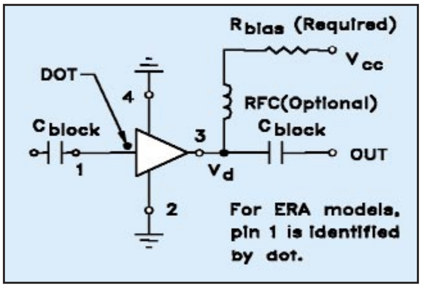
$$R_{bias} = (V_{cc} - V_d)/I_d = 210\ \Omega$$

where:

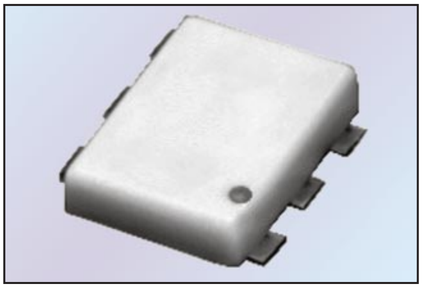
V_{cc} = the supply voltage, and

I_d = the biasing current.

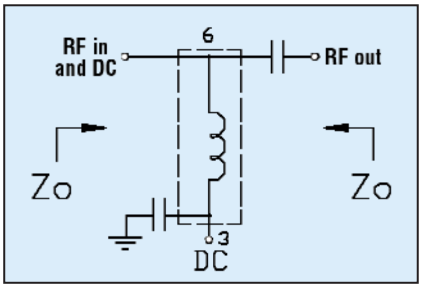
The use of a 210-Ω bias resistor without an RF choke in series results in a 1-dB loss of amplifier gain and output power. If the supply voltage is dropped to +5 VDC, then the required bias resistor, R_{bias}, will be 35 Ω. The use of this smaller resistor results in a loss of 4.6 dB in gain, a loss in output



1. This simple schematic diagram represents a basic biasing scheme for the ERA line of monolithic microwave amplifiers.



2. The model ADCH-80A RF choke is housed in a miniature surface-mount package compatible with automated assembly equipment.

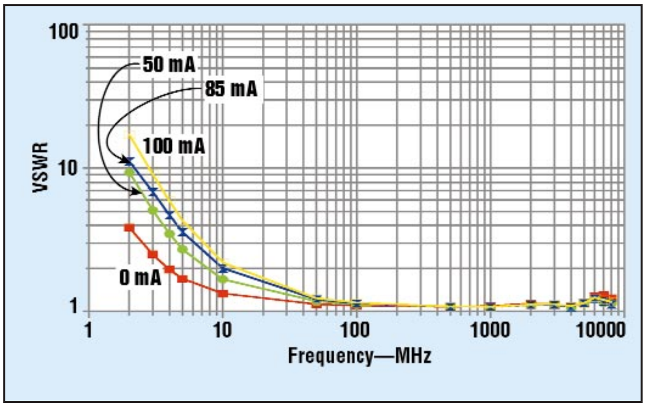


3. This simple evaluation circuit is used to interconnect the model ADCH-80A RF choke to 50-Ω test equipment.

power, and degraded return-loss performance for the amplifier. However, the addition of the RF choke in series with the bias resistor adds an inductive reactance to the resistor's shunt impedance, minimizing the effect of the resistor on the performance of the monolithic amplifier. This simple example illustrates how a wideband choke such as the model ADCH-80A can dramatically improve the performance of wideband amplifiers.

Commercially available inductors can be used as RF chokes. The low-frequency limit for this approach is determined by the component's inductance. Higher values of inductance deliver lower-frequency performance. The high-frequency limit for an inductor is determined by its series resonant frequency. The series resonant frequency tends to decrease with increasing values of inductance. Thus, when using an inductor as an RF choke, the RF bandwidth will be sharply limited by the value of inductance, complicating the job of the circuit designer. Any design changes that are performed by the inductor manufacturer will have an unknown effect on the amplifier circuitry.

The ADCH-80A (Fig. 2) was designed to optimize the performance of RF amplifiers over wide frequency ranges (Table 1). Its frequency range of 50 to 8000 MHz is wide enough to support amplifiers such as the ERA-1, which is specified to 8 GHz. The equivalent inductance of the ADCH-80A is 1 μH. In comparison, a typical commercial 1-μH inductor has a series resonant frequency as low as 90 MHz which

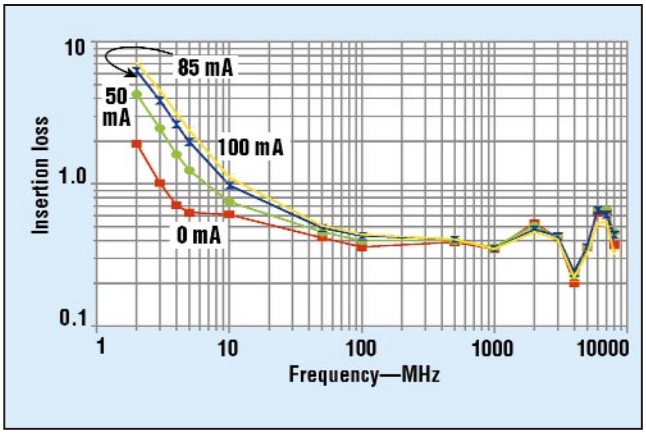


5. The return-loss performance of the ADCH-80A was evaluated through 8 GHz with applied currents of 0, 50, 85, and 100 mA.

Table 1: The ADCH-80A RF choke at a glance

Frequency (MHz)	50 to 8000
Insertion loss (dB)	0.4 typical 1.0 maximum
VSWR	1.15:1 typical, 1.35:1 maximum
DC current (μA)	100 maximum
Inductance (μH)	7 at 0 μA typical
	1.8 at 50 μA
	1at 100 μA

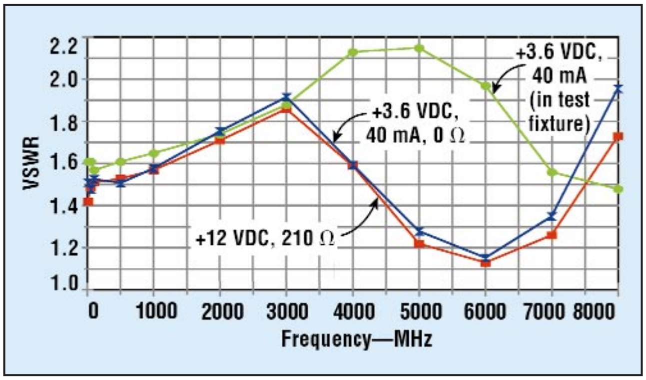
Note: Two different models ADCH-80A and ADCH-80 are available with the above specs. Choice of the model depends on the PCB layout in the application.



4. The insertion loss of the ADCH-80A RF choke was measured across a broad bandwidth with applied currents of 0, 50, 85, and 100 mA.

would severely limit the usefulness of a wideband amplifier such as the ERA-1.

The ADCH-80A was evaluated in an application test circuit designed for use with 50-Ω test equipment (Fig. 3). The microwave test equipment was used to measure insertion loss (Fig. 4) and return loss (Fig. 5) with currents up to 100 mA. The insertion loss and voltage standing-wave ratio (VSWR) were found to change very little with changes in current.

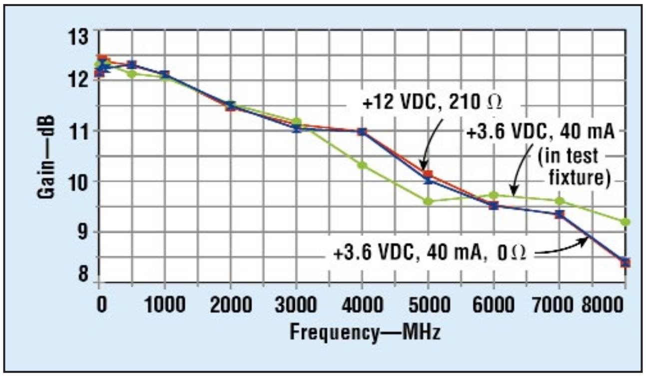


7. The input VSWR of the ERA-1SM monolithic amplifier was measured in the evaluation circuit with a bias resistor of 210 Ω and +12-VDC supply, in the evaluation circuit with a bias resistor of 0 Ω and a supply of +3.6 VDC, and in the test fixture with a supply of 40 mA and +3.6 VDC.

EVALUATING PERFORMANCE

To illustrate the use of the RF choke, evaluation boards were built using the ERA-1SM amplifier, based on the schematic diagram that appears in Fig. 1. Figure 6 shows the gain of the amplifier with two values of V_{CC}: +12 and +3.6 VDC. In the first case, the biasing resistor is 210 Ω. In the second case, the biasing resistor is 0 Ω. The gain levels in both cases are very close, demonstrating the effectiveness of the RF choke in wideband circuits. In practice, a finite biasing resistor is recommended for introducing a potential drop of a few volts to ensure bias-current stability, unless a constant-current source is used for biasing (see the Mini-Circuits publication, "Biasing ERA Amplifiers," which is available on the company's website at http://www.minicircuits.com/appnote/an60010.htm).

Figure 6 also shows the gain of the ERA-1SM amplifier in a 50-Ω test fixture. In this case, the biasing current is supplied through the bias tee that is a part of the microwave test system's S-parameter test set. Note that the gain is very close to that measured in the RF choke evaluation board except in the range of 7 to 8 GHz. Part of the difference is due to the longer transmission lines which increase the loss of the evaluation board.



6. The gain of the ERA-1SM monolithic amplifier was measured in the evaluation circuit with a bias resistor of 210 Ω and +12-VDC supply, in the evaluation circuit with a bias resistor of 0 Ω and a supply of +3.6 VDC, and in the test fixture with a supply of 40 mA and +3.6 VDC.

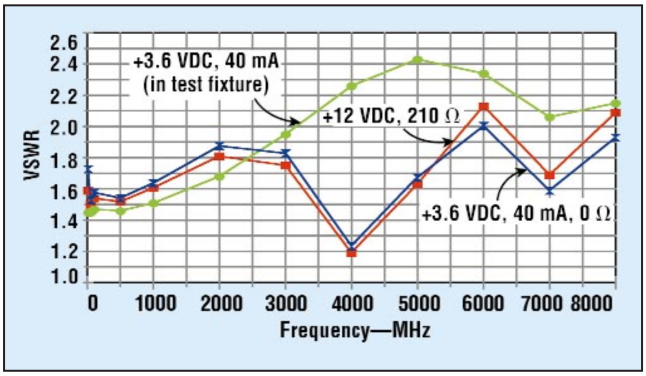
Figures 7 and 8 show input and output VSWR, respectively, for the cases with the 210- and 0-Ω resistors and the RF choke in the evaluation board as well as for the case using the test equipment's bias tee and the test fixture. The VSWR is again almost the same with the 210- and 0-Ω biasing resistors. There is

Table 2: Comparing linear performance

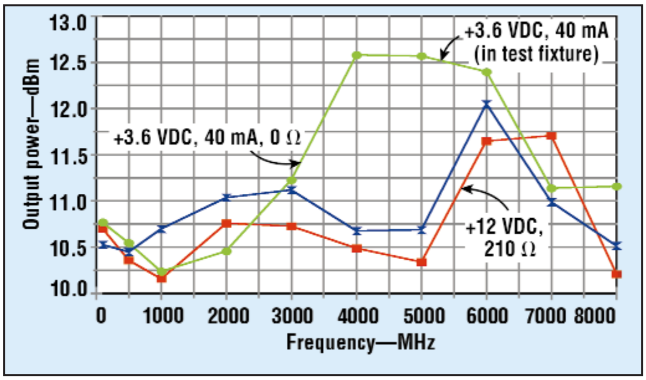
Device	Frequency (GHz)	Third-order intercept in evaluation board with RF choke (dBm)	Third-order intercept in test fixture (dB)
ERA-1	2	+25.0	+25.5
ERA-2	2	+25.5	+25.6
ERA-3	2	+23.0	+23.1
ERA-4	1	+33.2	+33.2
ERA-5	1	+33.5	+33.8
ERA-6	1	+37.5	+37.0

slight improvement in the evaluation board. Part of this improvement is due to fixed-stub matching. This is required to compensate for the difference in the ground pattern of the evaluation board compared to the test fixture. Figure 9 shows the 1-dB compression for the three cases. Another characteristic that can be affected by the RF choke, if its magnetic core is nonlinear, is the third-order intermodulation performance. Table 2 shows the third-order intercept-point (IP3) performance of the ERA-1 amplifier measured with the test fixture and with the evaluation board and the RF choke. No measurable difference was found. Table 2 also offers data on the ERA-2 through ERA-6 amplifiers, again showing the closeness of the third-order-intercept (TOI) performance in the various cases. These measurements indicate that the RF choke is not degrading the TOI performance of these amplifiers.

The ADCH-80A RF choke is designed to simplify the bias-circuit design requirements for monolithic and discrete amplifiers operating through 8 GHz. Although it is not DC coupled for use with fiber-optic amplifiers, it should serve the majority of wireless applications through 6 GHz. It is well-suited for biasing the entire Mini-Circuits ERA series and similar amplifiers operating up to 8 GHz.



8. The output VSWR of the ERA-1SM monolithic amplifier was measured in the evaluation circuit with bias resistors of 210 and 0 Ω as well as in the test fixture with an instrumentation-grade bias tee.



9. The output power at 1-dB compression for the ERA-1SM amplifier was measured in the evaluation circuit with bias resistors of 210 and 0 Ω as well as in the test fixture with an instrumentation-grade bias tee.