HMC313 BAISING and IMPEDANCE MATCHING TECHNIQUES

General Description

The HMC313 is a DC - 6 GHz GaAs Heterojunction Bipolar Transistor (HBT) MMIC amplifier that operates from a single voltage supply. The surface mount SOT26 amplifier can be used as a broadbad gain stage or used with external matching for optimized narrow band applications. This amplifier is ideal as a driver amplifier for 2.2 - 2.7 GHz MMDS, 3.5 GHz Wireless Local Loop Applications (WLL), 5.0 - 6.0 GHz UNII an dHiperLAN applications. This application note describes proper operation and an explanation of the external components needed in order to insure maximum performance from the HMC313.

Circuit Diagram

Figure 1 shows the recommended circuit configuration for the HMC313 used as a wideband amplifier.

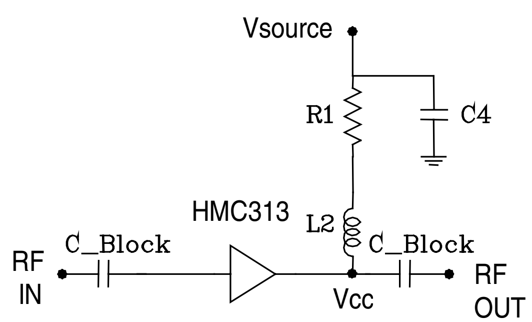

FIGURE 1 - *Recommended Wideband Circuit Configurattion*

In figure 1, L2, R1, and C4 form the external baising network, which will be described in detail in the following section. Capacitors C_Block are required at the input and output for DC blocking.

Selection of DC blocking capacitors

The value of the DC blocking capacitors at the input and output of the HMC313 should be selected based on the lowest frequency of operation required. In addition, the quality factor (Q) and the self resonant frequency (SRF) of the capacitors must be adequate to effectively pass the higest frequency of operation without excessive loss or mismatch to the external circuit. A low impedance blocking capacitor does not affect matching and consequently, the insertion loss and VSWR of the input and output ports. For example, at 900 MHz a 35 pF capacitor has an impedance of 5 Ohms, which is sufficiently small compared to a source impedance of 50 Ohms. Table 1 lists recommended blocking capacitor values for various minimum operating frequencies.

Frequency (GHz)	Capacitor Value (pF)
0.2	160
0.4	82
0.6	56
0.8	43
1.0	33
1.2	27
1.4	24
1.6	20
1.8	18
2.0	16
2.2	15
2.4	13
2.8	12
3.0	11
3.2	10
3.6	9.1
4.0	8.2
4.5	7.5
5.0	6.8
5.5	6.2
6.0	5.6

TABLE 1 - *Recommended C_Block Values*

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Bias Network

Bias current for the HMC313 is delivered from a voltage supply (Vsource) through a resistor (R1) and RF choke inductor (L2) as shown in Figure 1. Capacitor C4 is a RF bypass capacitor added to decouple the Vsource voltage supply.

Bias resistor R1 reduces the effect of temperature variation on the amplifier bais current. The bais resistor value is determined by equation1,

$$R_1 = \frac{V_{source} - Vcc}{I_{total}}$$

Equation 1 *- Bias Resistor Value*

The voltage at the output pin of HMC313 (Vcc) should be set to 5V or 7V depending on the specific application requirements and available voltage sources. Table 2 show appropriate R1 resistor values for Vcc = 5V @ 50 mA and Vcc = 7V @ 85 mA, calculated from equation 1. It is recommended that a bias resistor always be present. Operation in the shaded area of Table 2 is not recommended.

Vsource (V)	Vcc = 5V R1 (V)	Vcc = 5V PdissR1 (mW)	Vcc = 7V R1 (Ohm)	Vcc = 7V PdissR1 (mW)
5				
6	20	50		
7	39	100		
8	62	150	12	85
9	82	200	24	170
10	100	250	36	255
11	120	300	47	340
12	150	350	62	425

TABLE 2 - *Bias Resistor Selection*

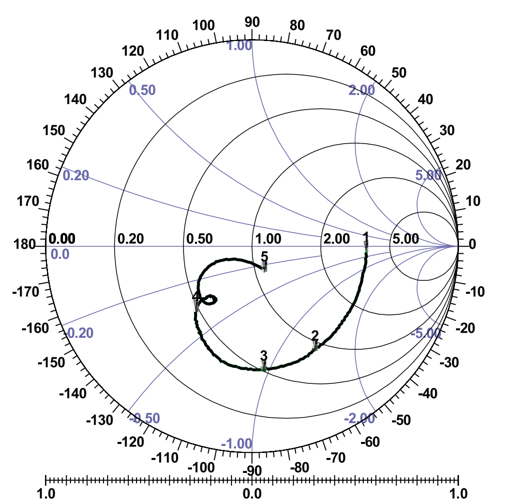
The Rf choke, L2 isolates the HMC313 RF circuit from the bias network. The impedance of the Rf choke inductor should be approximately 10 times the impedance of the load. For the 50 Ohms load case, this requires an inductive reactance of at least 500 Ohms for the RF choke. Table 3 gives maximum inductor values for a variety of popular frequencies. Choice of Rf choke inductors must also consider the parasitic effects of capacitance associated with the inductor wingdings that act to bypass the inductor. At the inductor's series self-resonant frequency, the parasitic capacitance completely cancels the inductive reactance. Therefore an inductor with a self-resonant frequency significantly higher than the maximum operating frequency of the amplifier must be used.

Frequency (MHz)	RF Choke Inductance Value (nH)
900	91
1900	43
2400	36
3500	24
5200	16
5800	15

TABLE 3 *- RF Choke Inductor Values*

Application Specific Impedance Matching Networks

Since the HMC313 is a broadband amplifier, it is often desirable to optimize the amplifier return loss over application specific frequency bands. Figure 2 and 3 show the unmatched broadband input and output impedance of the HMC313 measured at the pins of the device.



M1= 0.552 P1= -2.374 0.100GHz | M2= 0.586 P2= -58.612 2.400GHz | M3= 0.601 P3= -84.538 3.500GHz | M4= 0.413 P4= -131.535 5.800GHz | M5= 0.132 P5= -62.879 10.100GHz

FIGURE 2 - *Unmatched Input Impedance*

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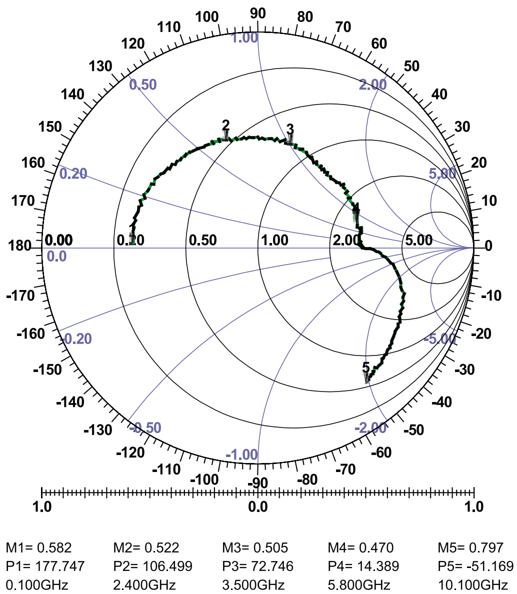

FIGURE 3 - *Unmatched Output Impedance*

Element	Value	Part Number
L1	2.2 nH	04CS2N2
L2	7.5 nH	04CS7N5
C1	0.4 pF	C06CF0R4B5UX
C2	0.4 pF	C06CF0R4B5UX
C3	0.8 pF	C06CF0R4B5UX
C4	330 pF	C17AH331J6UX
C_Block	12 pF	C06CF120J5UX
R1	28 Ohm	ERJ14YJ280B

NOTE - *Vsource = +9V, Vcc = +7V*

TABLE 4 - *Matching Circuit Component Values*

The circuit in Figure 4 enhances the basic baising circuit by providing input and output matching networks for the amplifier. In figure 4 L1, C1, and C2 are added to provide a narrow band impedance match for the amplifier input. Similarly, C3 is added to provide a narrow band impedance match for the amplifier output.

The input and output matching networks shown above are only one realization for narrow band matching the HMC313. Depending on the desired frequency bandwidth, external board space, or external matching netowrk loss requiements, othe rmatching network topologies may be preferred. Table 4 shows matching circuit element values for the components in the circuit in Figure 4 for a 2.4 GHz application,

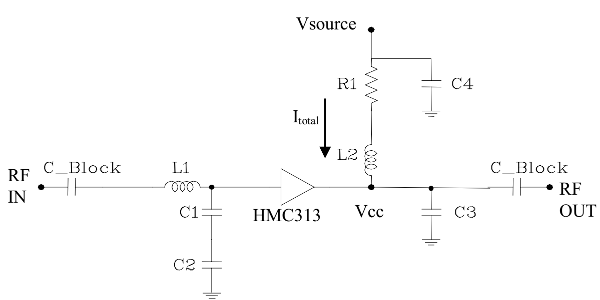

FIGURE 4 - *Application Specific Matching Networks*

Amplifier Matching Example

A matching circuit was synthesized for the HMC313 amplifier for a 2.4 GHz application using commercially available chip inductors and chip capacitors. Since physical chip inductors and chip capacitors are not ideal, equivalent circuits were generated for the components based on manufactures supplied circuit models and S-parameters.

In Figure 5, the complete matching equivalent circuit for the amplifier is depicted. In this circuit, the input match consists of a shunt 0.2 pF capacitor (realized as a series combination of two 0.4 pF capacitors) and a 2.2nH series inductor. The capacitors are modeled using a series/parallel resonant circuit with the element values determined by the manufacturer's data sheet. The series inductor is provided directly as a 2-port S Parameter file from the manufacturer. The output matching circuit consists of a single shunt 0.8 pF capacitor. Once again, the capacitor is modeled as a series/parallel resonant circuit. The HMC313 amplifier is inserted as a2-port with S Parameter data based on de-embedded measurements.

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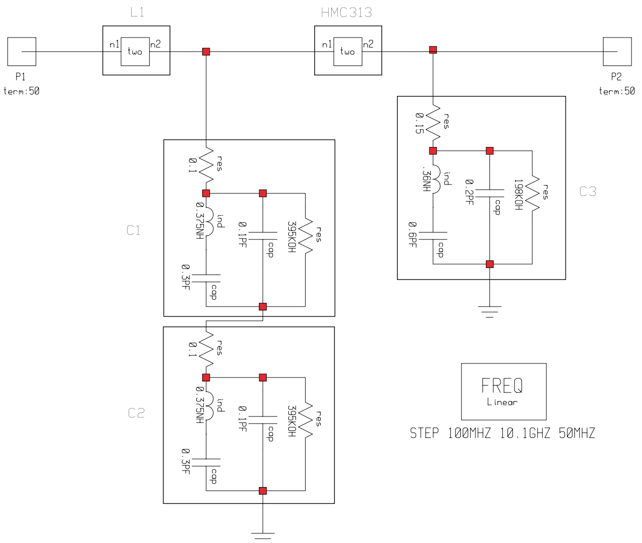

FIGURE 5 - *Amplifier Matching Equivalent Circuit at 2.4 GHz*

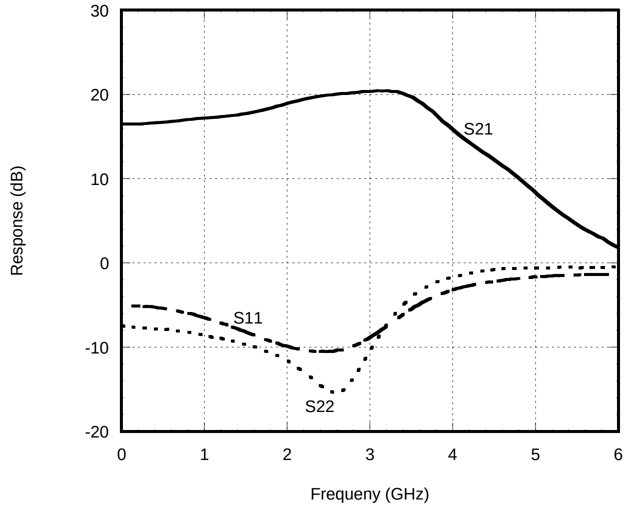

FIGURE 7 - *2.4 GHz Matched Circuit Response (measured*

In Figure 6, the simulated gain, imput match and output match are plotted for the circuit in Figure 5. The simulation predicts a narrow band match centered at approximately 2.7 GHz. In Figure 7, the measured response of the matched circuit shows good agreement with the simulated values.

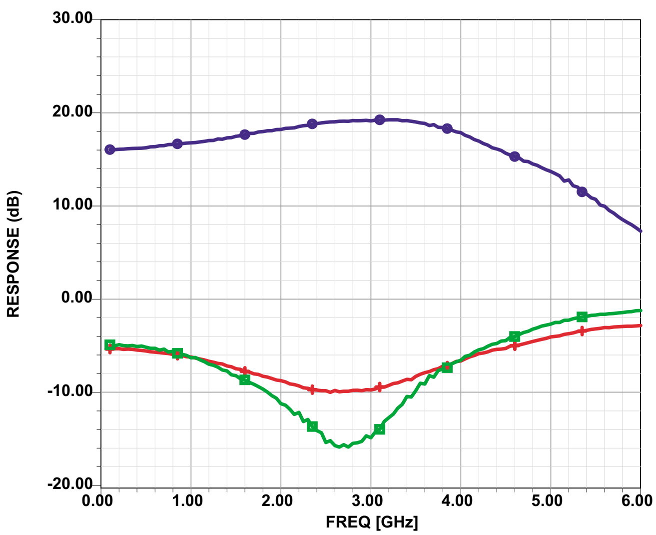

FIGURE 6 - *2.4 GHz Matched Circuit Response (simulated)*

Conclusion

A method of baising and impedance matching the general purpose HMC313 DC - 6 GHz GaAs HBT amplifier has been discussed. Proper selection of DC baising elements including bais resistor, RF choke and bypass capacitors was optimized for specific application frequencies. Furthermore, narrow-band impedance matching networks have been demonstrated with an example for a 2.4 GHz application. The matching circuit networks can be extended to cover different frequency ranges and accomodate physical layout constraints.