# RF Amplifier Design Using HFA3046, HFA3096, HFA3127, HFA3128 Transistor Arrays

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## Introduction

This application note is focused on exploiting the RF design capabilities of HFA3046/3096/3127/3128 transistor arrays. Detailed design procedures, using these transistor arrays, for a matched (800MHz to 2500MHz) high-gain low-noise amplifier and a 10MHz to 600MHz wideband feedback amplifier are described.

The HFA3046, HFA3096, HFA3127, HFA3128 transistor arrays are fabricated in a complementary bipolar bonded wafer silicon-on-insulator (SOI) technology, dubbed UHF-1 [1]. All four products make use of the same die, which has both NPN and PNP transistors on it. Figure 1 shows the pinouts of the four different products. Typical NPN and PNP transistor characteristics are shown in Table 1.

**TABLE 1. UHF-1 DEVICE CHARACTERISTIC**

| PARAMETERS | NPN | PNP | UNITS |
|---|---|---|---|
| $BV_{CEO, MIN}$ | 8 | 8 | V |
| $BV_{CBO, MIN}$ | 12 | 10 | V |
| $BV_{EBO, MIN}$ | 5.5 | 4.5 | V |
| $I_{CBO}$ | 0.1 | 0.1 | nA |
| $h_{FE}$ | 70 | 40 | |
| $C_{CB}$ | 500 | 600 | fF |
| $f_T$ | 9 | 5.5 | GHz |
| $P_{1DB}$ ($I_C$ = 10mA, $V_{CE}$ = 5V, $f_O$ = 1GHz) | 7.6 | 6.2 | dBm |
| IP3 ($I_C$ = 10mA, $V_{CE}$ = 5V, $f_O$ = 1GHz) | 17.6 | 16.2 | dBm |
| NF ($R_S$ = 50Ω, $I_C$ = 5mA, $V_{CE}$ = 3V, $f_O$ = 1GHz) | 3.5 | 3.0 | dB |

The SOI process has the advantage of lower DC and AC parasitic leakage currents as opposed to junction isolation, which leads to good isolation between transistors. Furthermore, an SOI process provides substantially lower collector to substrate capacitance, immunity to any possible latch-up between the devices, and superior radiation hardness.

The HFA3127 is used for the two stage matched (800MHz to 2500MHz) high-gain amplifier design, while the HFA3096 is used for the 10MHz to 600MHz wideband feedback amplifier.

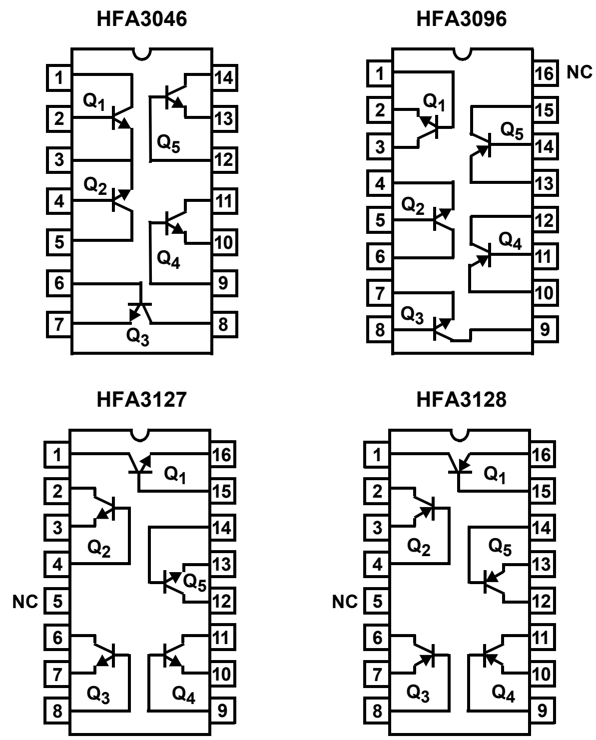


**FIGURE 1. PINOUTS OF HFA3046/3096/3127/3128 SOIC PACKAGED TRANSISTOR ARRAYS**

## Circuit Design

### High-Gain Low-Noise Amplifier

One important design requirement for an RF amplifier is the accurate control of input and output impedance levels. This is especially important if the amplifier is to interface with matched source and load impedances.

Based on S-parameter measurements, for a common-emitter configuration, transistors of HFA3127 exhibit a prematched condition on the input side over a wide range of frequencies. The package lead and bond wire inductances for these transistors make the input impedance close to 50Ω. For $I_C$ = 5mA - 10mA, $V_{CE}$ = 2V - 5V, the input VSWR of $Q_2$ and $Q_5$ was less than -10dB for frequencies of 800MHz to 3000MHz. Furthermore, for these transistors, a good output match, output VSWR < -10dB for frequencies 300MHz to 3000MHz, could be accomplished through bypassing the collector with a 100Ω resistor. As the single stage amplifiers built with $Q_2$ and $Q_5$ both show good input and output matching, they can be cascaded for higher gain without requiring an impedance transforming network. Figure 2 shows the final two stage amplifier. The advantage of this circuit is its simplicity. This design does not use any tuning inductors or capacitors which would tend to increase the cost of the circuit. Furthermore, this circuit accomplishes higher gain by cascading two amplifier stages built with integrated transistors.

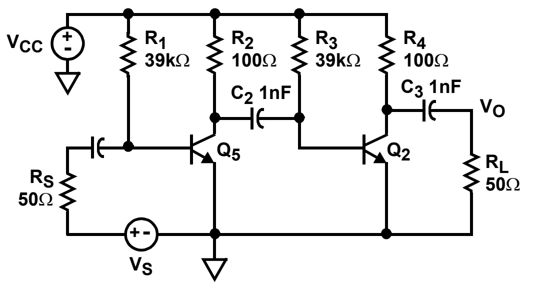


FIGURE 2. HIGH-GAIN LOW-NOISE AMPLIFIER REALIZED WITH HFA3127

Figure 3 shows the measured characteristics of the amplifier under two different bias conditions: $V_{CC}$ = 3V, $I_{C2}$ = $I_{C5}$ = 5mA; and $V_{CC}$ = 5V, $I_{C2}$ = $I_{C5}$ = 10mA. As can be seen from Figure 3, the input and output VSWR is less than -10dB for frequencies greater than 800MHz. The amplifier shows better performance at the expense of higher power dissipation ($I_C$ = 10mA and $V_{CC}$ = 5V) except the noise figure. For $I_{C2}$ = $I_{C5}$ = 10mA, the amplifier gains are 18.7, 8.8, and 6.6dB at frequencies of 900MHz, 1800MHz, and 2200MHz, respectively.

From Figure 2, the noise figure of the whole circuit is mainly controlled by the noise characteristics of the transistor $Q_5$. As shown in Figure 3D, this high-gain amplifier demonstrates good noise performance. For $I_{C2}$ = $I_{C5}$ = 5mA, the measured noise figure is 3.9dB at 900MHz, making this useful as a high-gain, low-noise amplifier.

The complete microstrip board layout is shown in Figure 4. A 0.031 inch thick FR-4 (G-10) glass epoxy board is used for the layout. The dielectric constant of the material is 4.7 at 1000MHz.

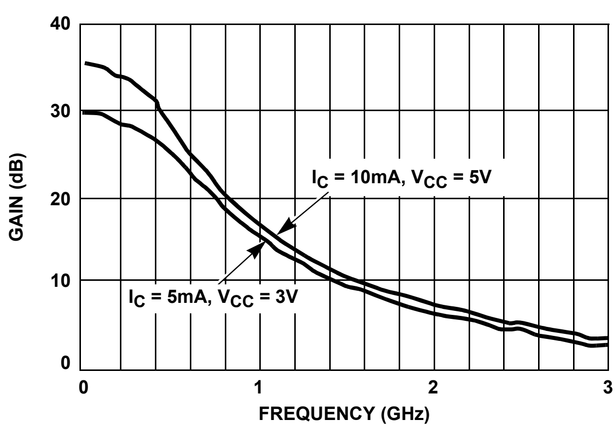


FIGURE 3A. GAIN

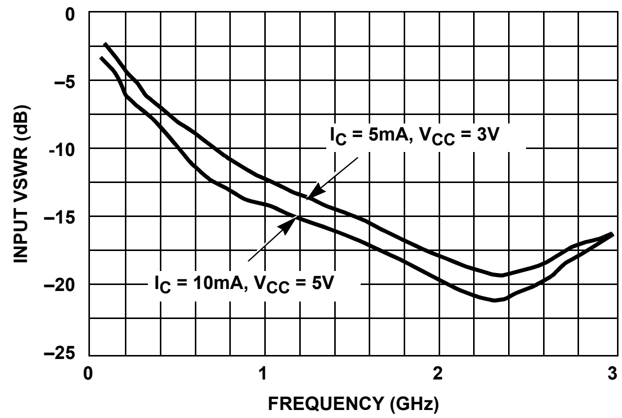


FIGURE 3B. INPUT VSWR

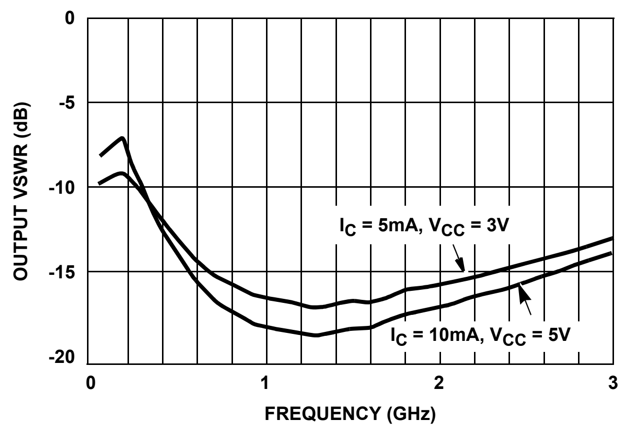


FIGURE 3C. OUTPUT VSWR

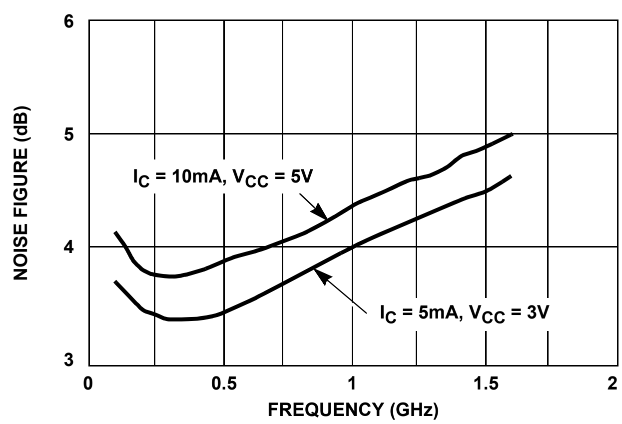


FIGURE 3D. NOISE

FIGURE 3. MEASURED CHARACTERISTICS OF THE HIGH GAIN LOW-NOISE AMPLIFIER

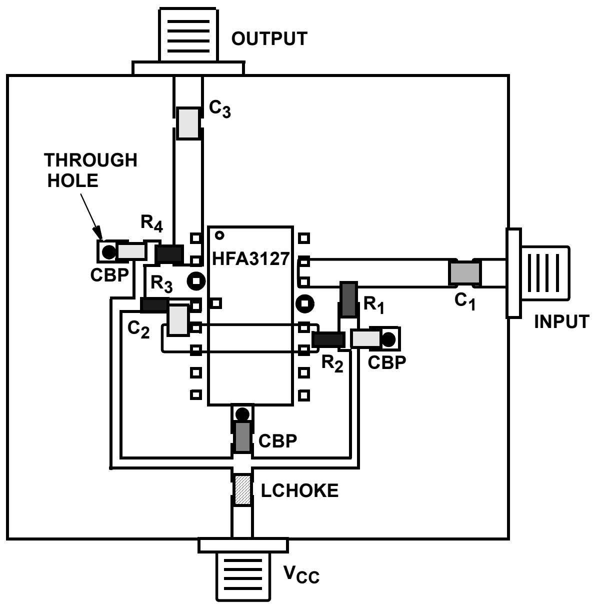


FIGURE 4. MICROSTRIP BOARD LAYOUT FOR THE HIGH-GAIN LOW-NOISE AMPLIFIER

The key rule for the circuit board layout is to make the physical length of the conductors as short as possible where the RF signal is involved. Although it seems obvious, it is easy to forget that the impedance looking into a microstrip line, that has load attached at the end, can be totally different from the attached load impedance depending on the length of the microstrip line and frequency. Outside the RF signal path, it does not matter.

At RF frequencies, the value of chip resistors, capacitors, and inductors should not be taken for granted. In general, the smaller the size of the component, the better the performance. However, it is important to evaluate the components before use. For the RF frequencies, these components can be evaluated easily using a network analyzer by mounting them as shown in Figure 5. The SMA connector itself contributes about 0.7pF of capacitance between the signal and ground terminals.

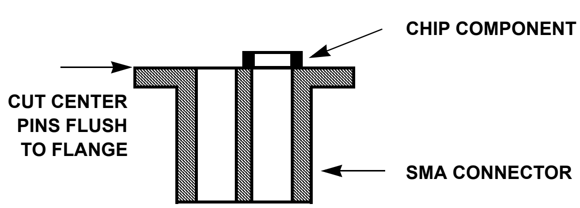


FIGURE 5. A CHIP COMPONENT MOUNTED ON AN SMA CONNECTOR

### *Wideband Amplifier*

A well known simple amplifier configuration which achieves flat gain and broadband matching without losing excessive signal power is shown in Figure 6. The simultaneous use of both shunt and series feedback gives rise to broadband resistive input and output impedances [2, 3].

Figure 7 shows a similar version of the double feedback wideband amplifier circuit realized with the HFA3096. This design takes advantage of the PNP transistors ($Q_4$ and $Q_5$) available on the HFA3096, to bias amplifying transistor $Q_2$ for good temperature stability.

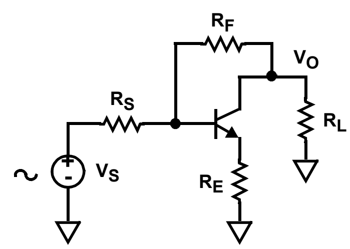


FIGURE 6. SINGLE STAGE SHUNT AND SERIES FEEDBACK CIRCUIT

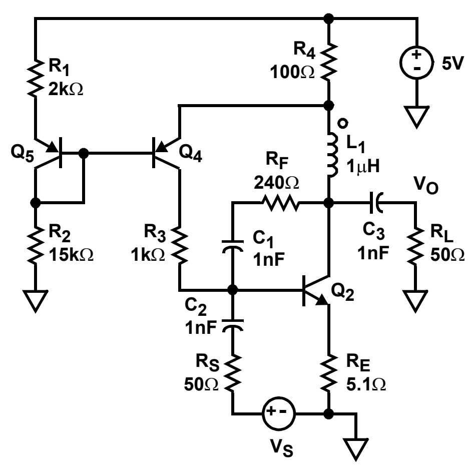


FIGURE 7. WIDEBAND AMPLIFIER REALIZED WITH HFA3096

The frequency response of the wideband amplifier is shown in Figure 8. As can be seen from Figure 8, the amplifier shows 10dB of flat gain with 600MHz bandwidth.The input and output matching is very good over the range of frequency where gains are flat. The low frequency performance is limited by the 1000pF capacitor.

The microstrip board layout for the wideband amplifier is shown in Figure 9. A 0.031 inch thick FR-4 (G-10) glass epoxy board is used for the layout.

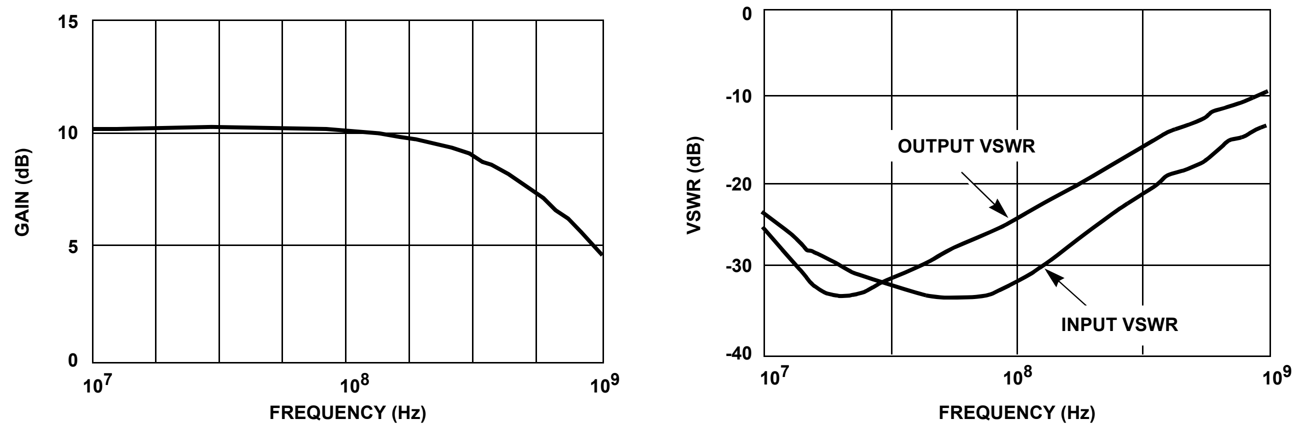


FIGURE 8A. GAIN

FIGURE 8B. INPUT-OUTPUT VSWR

FIGURE 8. MEASURED CHARACTERISTICS OF THE WIDEBAND AMPLIFIER

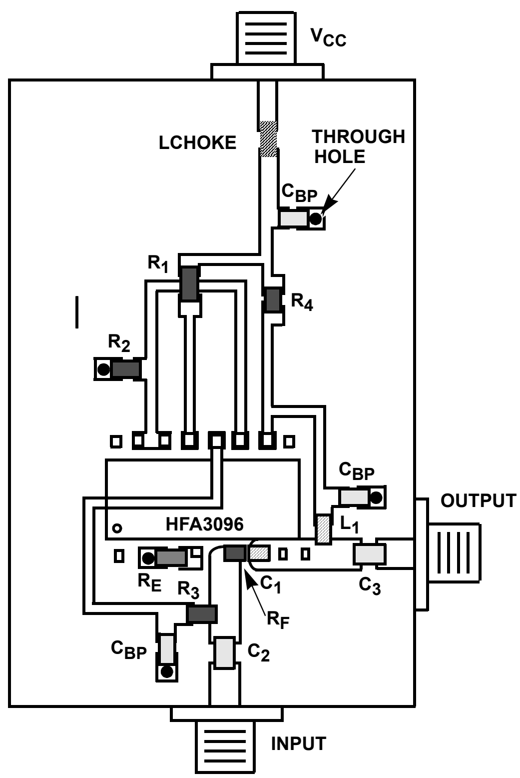


FIGURE 9. MICROSTRIP BOARD LAYOUT FOR THE WIDEBAND

## Summary

A detailed process of designing a high-gain low-noise and a wideband amplifier using the Intersil UHF transistor arrays is summarized.

A two-stage, high-gain, low-noise amplifier built with the HFA3127 demonstrates 50Ω input and output impedance over a wide frequency range of 800MHz to 2500MHz without the use of external matching networks. The gain at 900MHz is in excess of 17dB with a noise figure of 3.9dB.

A wideband amplifier built with the HFA3096 demonstrates excellent input and output matching with 10dB of constant gain. The -3dB bandwidth of this amplifier is 600MHz. PNP transistors available on the HFA3096 are used for temperature stable biasing of the amplifying transistor.

## References

[1] [1]C. Davis, et al, “UHF-1: A High Speed Complementary Bipolar Analog Process on SOI,” Proceeding of BCTM 92, pp260-263, Oct. 1992.

[2] [2]J. B. Couglin, et al, “A Monolithic Silicon wideband Amplifier from DC to 1 GHz,” IEEE J. Solid-State Circuits, vol. SC-8, pp414-419, Dec. 1973.

[3]R. G. Meyer, et al, “A wideband Ultralinear Amplifier from 3 to 300 MHz,” IEEE J. Solid-State Circuits, vol. SC-9, pp167-175, Aug. 1974.

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