Using the INA-12063 RFIC Amplifier for 2.4 GHz Applications

Application Note 1147

Introduction

The versatile INA-12063 RFIC amplifier provides an effective solution for many buffer, pre-driver, and multi-purpose gain stage requirements for applications in the 2.4 GHz frequency band. The INA-12063 is especially easy to use at this frequency, as illustrated in the RF schematic in Figure 1. This amplifier solution will be particularly useful for wireless data, RFID, WLAN, and HomeRF products.

One of the unique features of the INA-12063 is the user's ability to set the device current by means of an external resistor. For applications requiring minimal current drain, the INA-12063 operates satisfactorily with currents as low as 1 to 2 mA. For buffer and pre-driver stages, the device current can be increased to 8 mA to provide a 1 dB compressed output power of approximately +6 dBm. Although the nominal supply voltage for the INA-12063 is +3 volts, the device can operate over a voltage range of 1.5 to 5 volts.

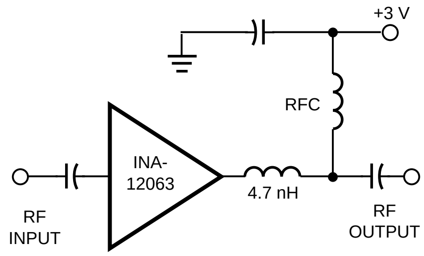

Figure 1. RF Schematic of 2.4 GHz Amplifier

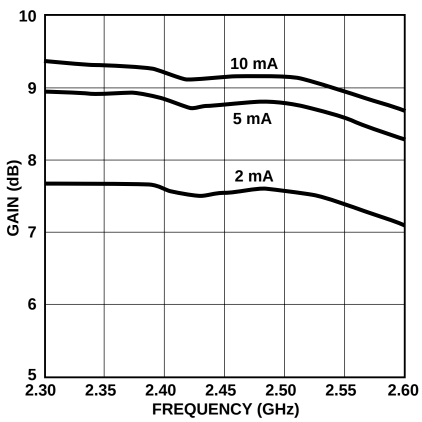

Figure 2. Gain of 2.4 GHz Circuit Using INA-12063

Setting the Bias Current

The patented,[1] active bias regulation circuit is a 10: 1 current mirror that forces the current in the RF section of the INA-12063 to be approximately 10 times the current supplied to the I_{bias} pin. Pin connections for the INA-12063 are shown in Figure 3. In normal use, a voltage between +1.5 and +5 volts is applied to both the V_d and V_c terminals of the INA-12063. The device current is then set by injecting a small control current into the I_{bias} pin that is approximately 1/10 of the desired device current. The simplest means of supplying the I_{bias} control current is to merely place a resistor, shown as R_{bias} in Figure 4, between the V_d and I_{bias} terminals. R_{bias} is sufficiently high that it simulates a current source. The value for R_{bias} is calculated as follows:

$$R_{bias} = 10 \left(\frac{V_d - 0.8}{I_c} \right) \qquad (1)$$

where V_d is the device voltage (volts), I_c is the desired device current (amps), and R_{bias} is the value of the bias-determining resistor (ohms).

[1] U.S. Patent Number 5436595

2.4 GHz Design Example

An example circuit was designed to demonstrate the use of the INA-12063 for 2.4 GHz applications. The example amplifier was designed to operate from a power supply of +3 volts with a nominal device current of 5 mA.

The integrated series feedback in the INA-12063 provides a very good input match over the entire 2 to 3 GHz frequency range. The input match is typically under a VSWR of 2:1, improving to 1.3:1 at higher device currents. Therefore, the input to the INA-12063 may be used as is without the need for any impedance-matching circuitry.

The real part of the output impedance of the INA-12063 lies near 50 ohms at 2.4 GHz. The addition of a simple series inductor is all that is needed to achieve a very reasonable output match to 50 ohms. A CAD simulation using Hewlett-Packard's *Touchstone* program predicted the output of the INA-12063 could be matched by using a 4.5 nH series inductor. A 4.7 nH chip inductor was chosen as the nearest standard value to 4.5 nH.

The only other components required to complete the circuit are: DC blocking and bypass capacitors, a RF choke, and the current setting resistor, R_{bias}. The value for R_{bias} was calculated from Equation 1 above to be 4.4 kΩ for 3 volts and 5 mA. The nearest standard value of 4.7 kΩ will be used for this design. A value of 33 nH is used for the RFC and all capacitors are 56 pF. A schematic diagram of the complete circuit is shown in Figure 4.

A demonstration circuit for the INA-12063 was assembled on an "IAM-91-A" evaluation PCB. The IMA-91-A circuit board, originally designed for use with the IAM-91563 RFIC mixer, is readily adapted to accommodate the INA-12063. The unused circuit traces are cut away and an external wire is added to connect the supply voltage to the V_d terminal at Pin 4. The completed amplifier is shown in Figure 5.

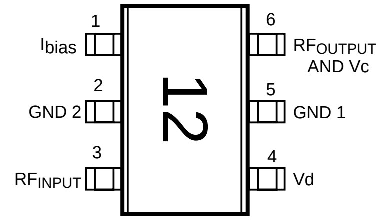

Figure 3. INA-12063 Pin Connections

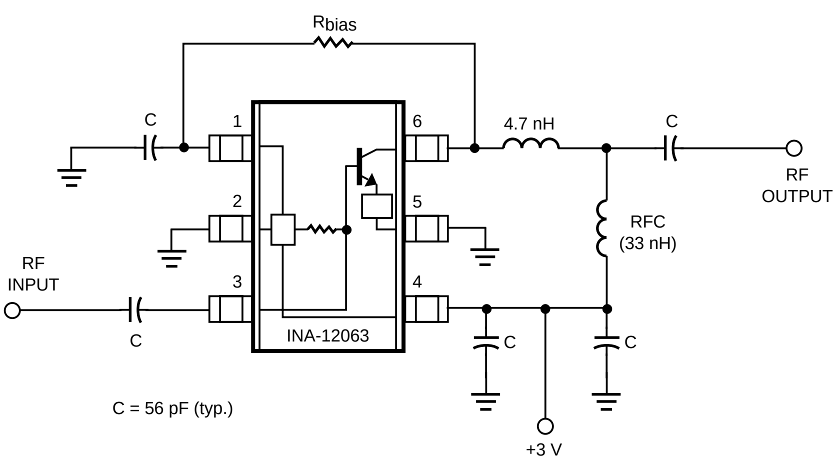

Figure 4. Complete Schematic of 2.4 GHz Amplifier

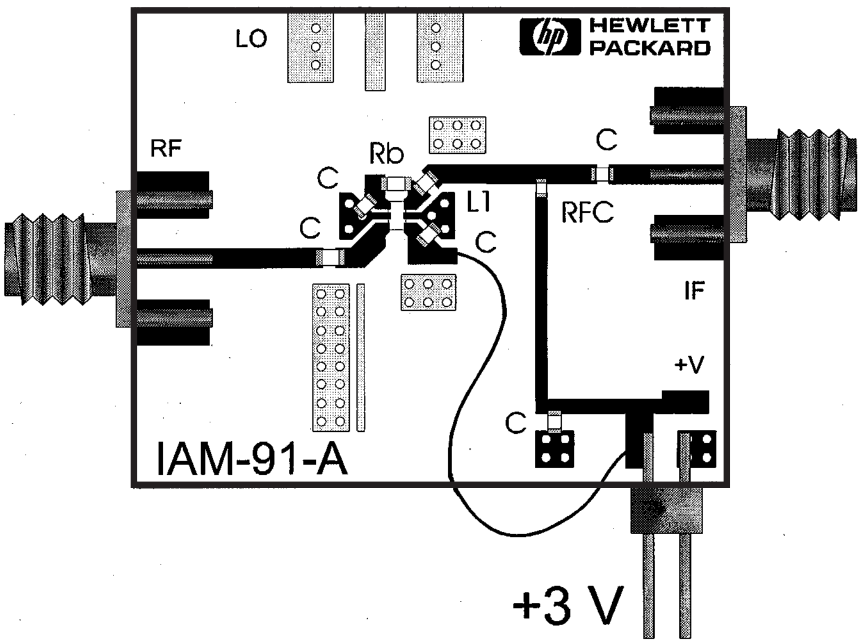

Figure 5. Example 2.4 GHz Circuit Using the HP INA-12063 RFIC Amplifier

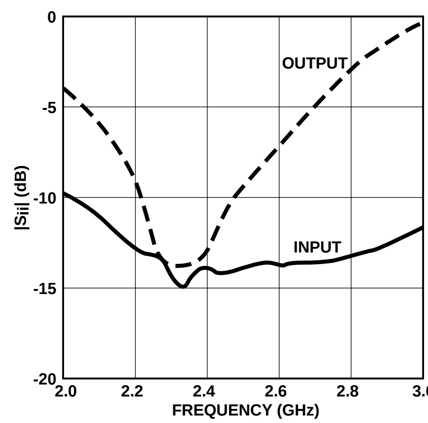

Figure 6. Input and Output Return Loss

Test Results

Actual measured gain of the completed amplifier from 2.3 to 2.6 GHz is shown in Figure 2 for three different device currents. The value of R_{bias} was changed to adjust the device current to 2, 5, and 10 mA.

Return loss for the RF input and output is plotted in Figure 6 from 2.0 to 3.0 GHz. These data are for a device current of 5 mA. The input and output VSWRs are both less than 1.6:1 over a 100 MHz bandwidth centered near 2.3 GHz. This result suggests the output match is tuned slightly low compared to the 2.4 GHz target frequency and is likely due to rounding up of the output matching inductor to a standard value.

Output power at 1 dB of gain compression was measured over a 1 to 10 mA decade of current and is plotted in Figure 7. The output power data was taken with fixed tuning, i.e., no re-tuning was done for different currents. The output power results show a point of diminishing return beyond a current of 8 mA where a maximum P_{1dB} of +6.5 dBm is obtained.

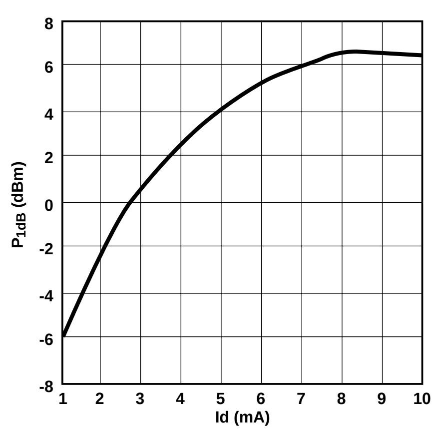

Figure 7. Output Power (P_{1dB}) vs. Device Current

The isolation (reverse gain) of the amplifier is shown in Figure 8 for a current of 5 mA. The isolation is fairly insensitive to current and varies only 1 dB over a 2 to 10 mA current range.

Noise figure for the example amplifier was measured as 3.4 dB at 2 mA, increasing to 3.8 dB at 10 mA of device current.

A measured plot of device current vs. R_{bias} is shown in Figure 9 for reference.

Refer to the Data Sheet for the INA-12063 RFIC for additional information.

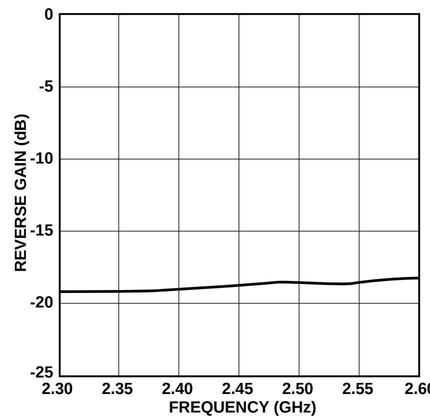

Figure 8. Amplifier Isolation vs. Frequency

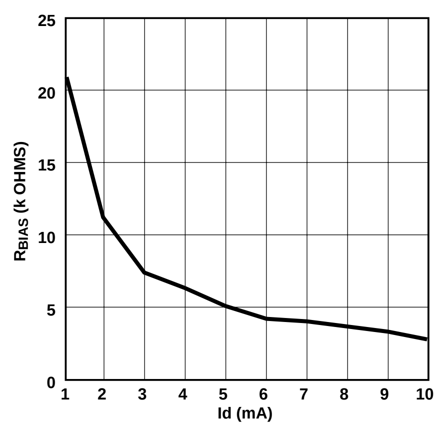

Figure 9. R_{bias} vs. I_d

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