Combination Oscillator/Buffer Amplifier ICs Simplify LO Design

Abstract

Two new combination oscillator/buffer amplifier ICs are introduced by RF Micro Devices to make the task of designing an LO for wireless applications simpler. The RF2501 and RF2502 are combination oscillator/buffer amplifier ICs with a power down feature that operate anywhere from 750MHz to 1500MHz with the help of an external resonator. The RF2501 offers low current consumption and low output power, while the RF2502 offers higher output power. These ICs are flexible, yet easy to use, and can reduce the load pulling, overall size, and cost of an LO for wireless applications.

Introduction

Local oscillators are very important components of wireless systems, yet the task of designing and building an LO can be very challenging, particularly to those who have not previously designed one. Two new ICs, the RF2501 and RF2502 from RF Micro Devices, are combination oscillator/buffer amplifier ICs that simplify the task of building an LO. They cover the frequency range of 750 MHz to 1500 MHz, which is just right for many wireless applications, including the 902MHz to 928MHz ISM band.

The RF2501 and RF2502 are made to be flexible and easy to use by utilizing an external resonator to set the frequency of oscillation. Both ICs incorporate several integrated buffer amplifiers to minimize load pulling and flatten the output power response. They operate off of a single 5 V supply and have a power down feature that is great for applications that have to conserve battery power.

The RF2501 is a low current, low power integrated oscillator/buffer amplifier. It typically draws approximately 2.6mA and sources -14dBm into a 50Ω load at room temperature and VCC of 5V.

The RF2502 is a higher current, higher power integrated oscillator/buffer amplifier. It typically draws approximately 4.5mA and sources -6dBm into a 50Ω load at room temperature and VCC of 5V.

The ICs are made with silicon BJT technology, which produces good phase noise for an integrated oscillator. Operating at 1500MHz and room temperature, phase noise at 100kHz offset has been measured at -96dBc and at 10kHz offset has been measured at -76dBc for both ICs when used with a microstrip resonator on FR4 board. At lower frequencies, the phase noise will improve, 6dB lower phase noise has been measured at 750MHz.

The RF2501 and RF2502 are offered in a standard SOIC-8 package. When used in a design, they can reduce the overall size and cost of the LO, which are important considerations for wireless applications.

Functional Description

A functional block diagram of the RF2501 is shown in Fig. 1. It includes an oscillator, four buffer amplifiers

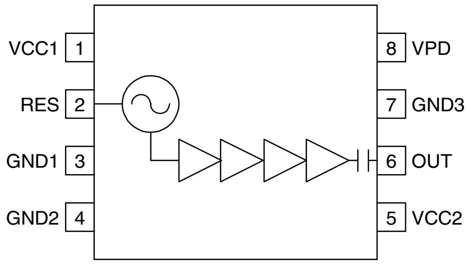

Figure 1. RF2501 Functional Block Diagram

and power down circuitry. Pins 1-4 supply the oscillator, and pins 5-7 supply the buffer amplifiers. Pin 8 is the power down pin, Vpd, that controls the bias to both.

A high voltage on Vpd turns on the IC, and a low voltage on Vpd turns off the IC. When Vpd is 0V, the supply current is less than 1µA. Vpd should be less than 0.7V to fully turn off the IC. To fully turn on the IC, Vpd should be 3.0V or higher, but should not exceed the maximum rating of 5.5V.

The external resonator input is pin 2 and requires a dc blocking capacitor. The resonator is an inductive element. Changing the effective inductance either physically or with a varactor tuned circuit, will change the frequency of oscillation. It should be noted that all parasitics on the circuit board will contribute to the effective inductance and will influence the oscillation frequency. These effects become more pronounced at higher frequencies.

The output of the RF2501 has an internal choke and dc blocking capacitor. This feature reduces the overall size and parts count of the resulting LO.

A functional block diagram of the RF2502 is shown in Fig. 2. The oscillator portion of the IC is the same as

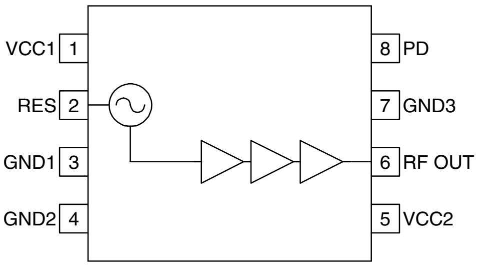

Figure 2. RF2502 Functional Block Diagram

the RF2501. The differences are in the buffer amplifiers. There are three buffer amplifiers instead of four, to increase the available output voltage swing, and the required supply current is greater. The output is open collector, which requires an external choke and blocking capacitor. The result is more available power into a 50Ω load.

Theory of Operation

Each IC has two functional parts: an oscillator and buffer amplifier. The functional blocks have separate ground and VCC pins to increase the isolation and reduce load pulling, one of the key design objectives. An external resonator is utilized to add design flexibility, and the loaded Q of this resonator will impact the performance of the resulting oscillator.

To create an oscillation, negative resistance is generated at pin 2 with a circuit similar to a Colpitts oscillator. Figure 3 shows the input impedance at pin 2 measured with a vector network analyzer, it looks like a negative resistance in series with a capacitor. The negative resistance decays as the frequency increases. An oscillator is created when an inductive element is placed on pin 2 that is the conjugate of the capacitive reactance. A greater inductive element will create a lower frequency of oscillation.

Figure 4 shows the S11 looking into pin 2. It has return gain from 500MHz to 2200MHz at room temperature. The specified frequency range of 750MHz to 1500MHz defines the region where the output power is relatively flat. At lower and higher frequencies, the power will tend to roll off from the nominal value. The specified frequency range is conservatively set to ensure oscillation and maintain performance, but the RF2501 and RF2502 can be used over a broader frequency range with degraded performance.

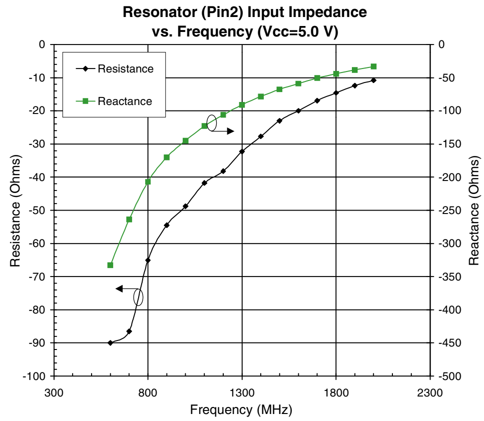

Figure 3. RF2501/2 Input Impedance

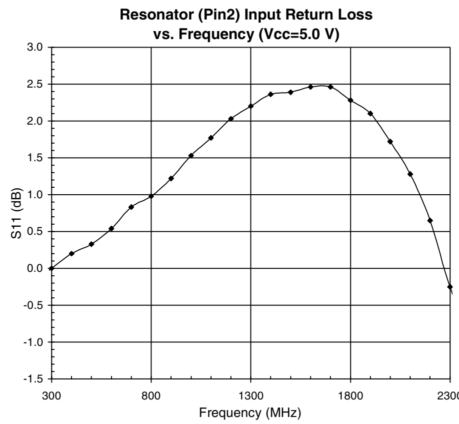

Figure 4. RF2501/2 Input S11 versus Frequency

The overall Q of the external resonator will impact performance. Lower Q means lower power, higher phase noise, and more load pulling. If the Q is too low, the circuit will not oscillate. The ICs are designed to oscillate into a resonator with Q>10. The performance is measured with a microstrip resonator or high quality inductor, which usually have a Q>50. These measurements define the best performance that can be expected from the ICs, a later section describes typical performance and specifications. Lower Q resonators, particularly those including a lossy varactor, might have degraded performance.

The specified output power is measured into a 50Ω load. Both ICs have a high output impedance, and if desired, output matching can be used to obtain more power by transforming 50Ω into a higher impedance. On the RF2502, this could be accomplished by simply changing the values of the external output inductor and capacitor.

Applications

In order to demonstrate the use of the RF2501 and RF2502, several application circuits are built and tested. The ICs are used to build VCOs at the 902MHz to 928MHz ISM band, and the RF2502 is used to build a VCO near 1500MHz.

The schematic of a VCO built with the RF2501 is shown in Fig. 5. The resonator is a 15nH coil and varactor connected to pin 2. The zero bias capacitance of the varactor is 15pF, and it is biased through a low cost resistor. Besides the external resonator, the only other external parts required are by-pass capacitors.

The tuning curve and output power for this circuit are shown in Fig. 6. The typical measured performance for this circuit at room temperature into a 50Ω load and VCC of 5V are -12dBm output power, 2.9mA supply current, harmonics less than -12dBc, VCC pushing of 1.7MHz/V, less than 76 kHz of load pulling into a 1.67 VSWR load, and phase noise of -102dBc at 100kHz offset, -89dBc at 25kHz offset, and -81dBc at 10kHz offset.

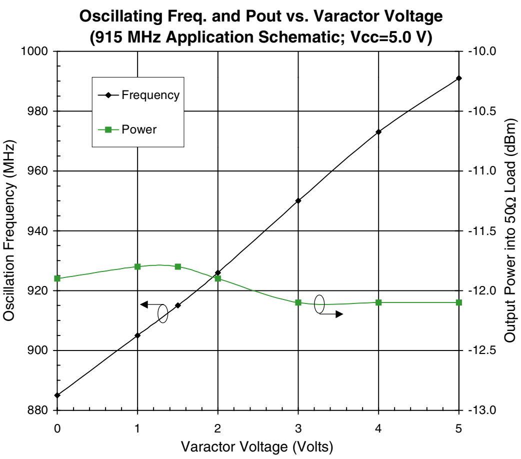

Figure 6. RF2501 915MHz ISM Band Tuning Curve and Output Power

A similar schematic for a VCO operating in the 902MHz to 928MHz ISM band using the RF2502 is shown in Fig. 7. The resonator is the same, and it has an additional 27nH external output choke and output blocking capacitor. The tuning curve and output power for this circuit are shown in Fig. 8. The typical measured performance for this circuit at room temperature into a 50Ω load and VCC of 5V are -5.0dBm output power, 4.8mA supply current, harmonics less than -9.5dBc, VCC pushing of 1.55MHz/V, less than 140kHz of load pulling into a 1.67 VSWR load, and phase noise of -101dBc at 100kHz offset, -88dBc at 25kHz offset, and -80dBc at 10kHz offset.

A last application circuit using the RF2502 in a VCO that operates from 1331MHz to 1607MHz is shown in Fig. 9. The resonator coil is smaller, the varactor zero bias capacitance is 10pF, and the external output choke is 18nH. The external output choke is selected from the manufacturers data to have a self-resonant frequency above the frequency of operation.

The tuning curve and output power for this VCO are shown in Fig. 10. The typical measured performance for this circuit at room temperature into a 50Ω load and VCC of 5V are -5.6dBm output power, 4.2mA supply current, harmonics less than -13 dBc, VCC pushing of 1.8MHz/V, less than 535kHz of load pulling into a 1.67 VSWR load, and phase noise of -96dBc at 100kHz offset, -83dBc at 25kHz offset, and -75dBc at 10kHz offset. The load pulling is measured at 1500MHz.

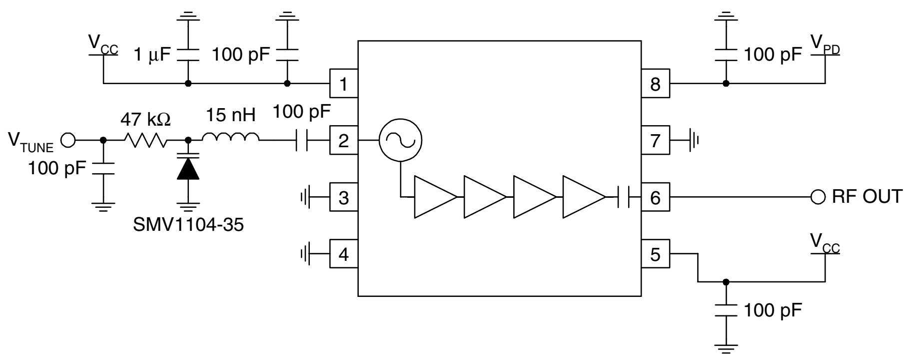

Figure 5. RF2501 915MHz Application Schematic

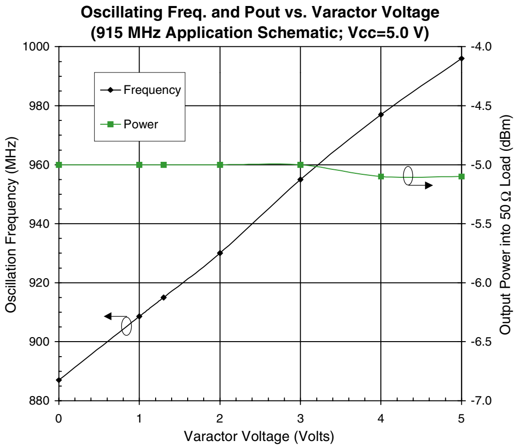

Figure 8. RF2502 915MHz ISM Band Tuning Curve and Output Power

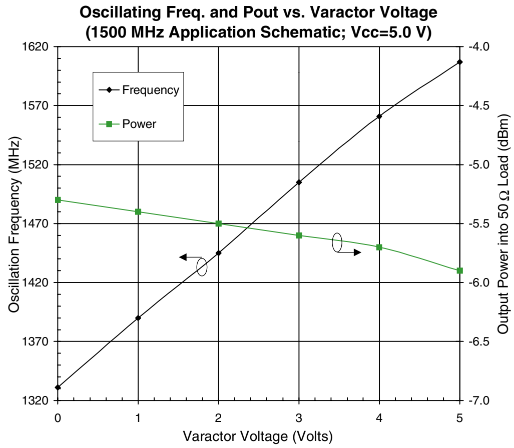

Figure 10. RF2502 1500MHz ISM Band Tuning Curve and Output Power

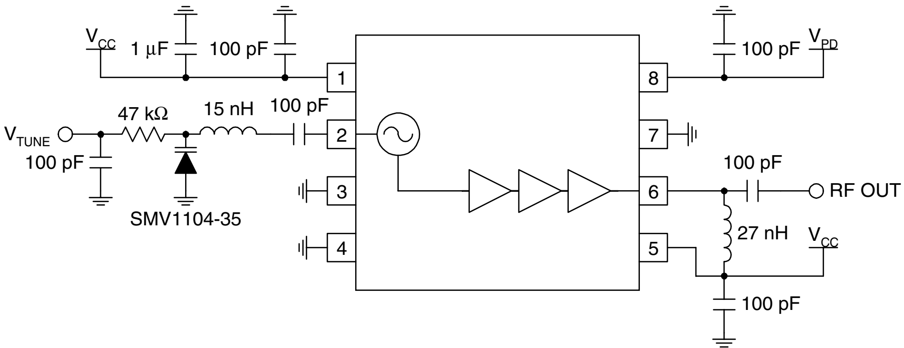

Figure 7. RF2502 915MHz Application Schematic

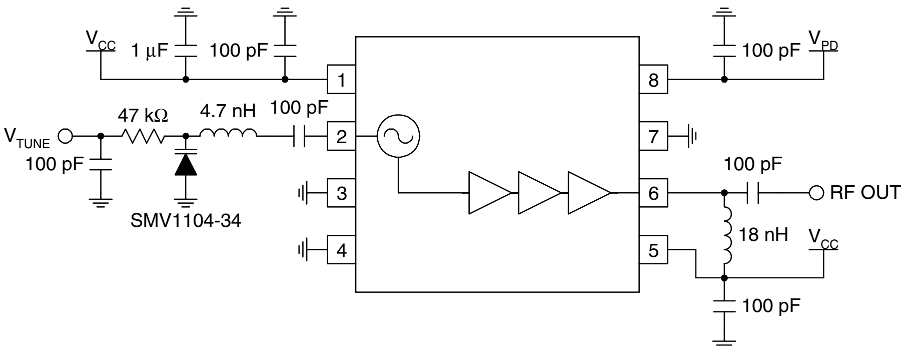

Figure 9. RF2502 1500MHz Application Schematic

Parameter	Measured Performance			Units
IC	RF2501	RF2502	RF2502	
Frequency	885 to 991	887 to 996	1331 to 1607	MHz
Tuning Voltage	0 to 5	0 to 5	0 to 5	V
Supply Current	2.9	4.8	4.2	mA
P_{OUT}	-12	-5	-5.6	dBm
2nd Harmonic	-15	-9.5	-13	dBc
3rd Harmonic	-12	-18	-23	dBc
V_{CC} Pushing	1.7	1.6	1.8	MHz/V
Load Pulling[A]	76	140	535	kHz
Phase Noise:				
100kHz Offset	-102	-101	-96	dBc
25kHz Offset	-89	-88	-83	dBc
10kHz Offset	-81	-80	-75	dBc
Schematic	Figure 5	Figure 7	Figure 9	
[A]Load Pulling is measured into a 1.67 VSWR load.				

Table 1. Typical measured performance of application circuits at room temperature

Parameter	RF2501	RF2502	Units
VCC	5	5	V
Frequency	750-1500	750-1500	MHz
ICC (on)	2.6	4.8	mA
ICC (off)	<1	<1	mA
VPD (on)	5	5	V
VPD (off)	0	0	V
IPD (on)	<100	<100	nA
IPD (off)	<0.1	<0.1	nA
Output Power	-14	-6	dBm
Load Pulling[A]:			
750 MHz	<100	<200	kHz
1500 MHz	< 1	<1	MHz
VCC Pushing	<3	<3	MHz/V
Phase Noise[B]:			
100 kHz Offset	-96	-96	dBc
10 kHz Offset	-76	-76	dBc
Temperature	-40 to 85	-40 to 85	°C
[A]Load Pulling is measured into a 1.67 VSWR [B]Phase noise is measured at 1500MHz at room temperature with a low loss microstrip resonator. Phase noise generally improves by 6dB/octave as the frequency is lowered.			

Table 2. Summary of specifications and typical performance into a 50Ω load at room temperature using a microstrip resonator

A summary of the measured performance at room temperature for these three application circuits is shown in Table 1. The values quoted are typical across the band, there will be some variation with frequency and component variation.

Specifications

The specifications and typical performance of the RF2501 and RF2502 are summarized in Table 2. The parameters are typical values at room temperature for a microstrip resonator or a similar high Q inductor. The specific performance of a circuit using the RF2501 or RF2502 will vary depending on the Q of the resonator and frequency. In particular, low Q resonators will result in degraded performance.

There are some general trends in performance with the frequency of operation. It can be expected that the load pulling will be greater at higher frequencies than at lower frequencies due to the greater effects of parasitic package coupling. Phase noise is greater at higher frequencies due to device physics, and can generally be estimated using the factor of 6dB/octave. Phase noise in Table 2 is typical performance at 1500MHz, and an oscillator built at 750MHz will generally have 6dB better phase noise.

Summary and Conclusions

Two new oscillator/buffer amplifier ICs are introduced by RF Micro Devices. The RF2501 and a higher power version, the RF2502, are flexible building blocks that can be used to build an LO from 750MHz to 1500MHz. They offer a power down feature, low current consumption, reduced load pulling, and can be used to reduce the size and cost of building an LO.