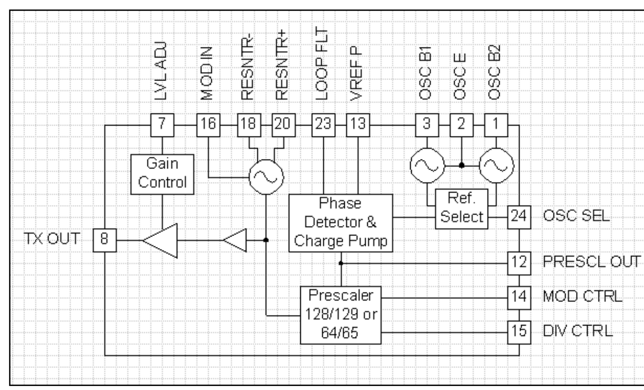
Low Cost UHF/VHF Transmitter ICs

Integrated circuits simplify design of low power FM/FSK or AM/ASK transmitters

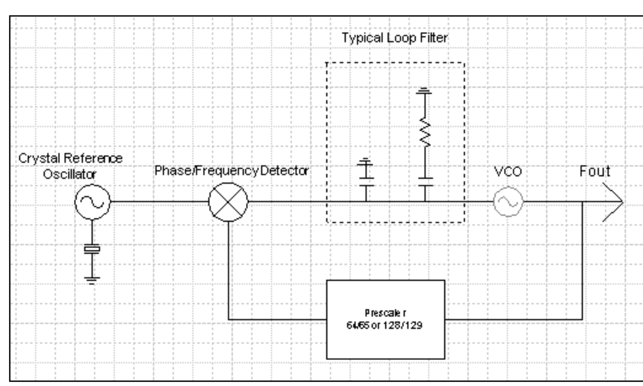
By Alan Nicol
RF Micro Devices

The RF2512 and RF2513 are low-cost monolithic frequency synthesizer and transmitter ICs that provide all the functions necessary to implement low power FM/FSK or AM/ASK transmitter or local oscillator operation in commercial wireless products. The devices can be used in the US 915 MHz ISM band and European 433 MHz or 868 MHz ISM band. Typical applications include wireless security systems, wireless meter reading and wireless data link.

The parts are provided in a 24-pin plastic SSOP package and operate from a 2.2 to 5 volt DC supply. The Optimum Technology Matching™ approach taken by RF Micro Devices in all of its designs leads to the choice of a 15 GHz silicon bipolar process technology for these parts. The process features a f_T of 15 GHz at less than a 3 volts and a 0.5 mA operating point. The only difference between the RF2512 and RF2513 is that the RF2513 has on-chip tuning varactors. The RF2513 is a more cost effective integrated solution but has lower output power, smaller tuning range and higher phase noise than the RF2512.



▲ **Figure 1. RF2512 functional block diagram.**



▲ **Figure 2. PLL block diagram.**

Operating features

The RF2512 and RF2513 operate as FM/FSK or AM/ASK transmitters or local oscillators. The integrated VCO, dual modulus/dual divide prescaler and reference oscillator only require the addition of an external crystal oscillator to complete a fully integrated phase-locked loop (PLL) system. A functional block diagram of the RF2512 is shown in Figure 1. A second reference oscillator is available to support two channel applications. In sleep mode, when only V_{cc} is applied, the part draws less than 1 μA. The PLL enable pin powers the VCO and PLL while the TX enable powers the transmitter stages. The level adjust control allows the transmitter output power to be varied over a 15 dB range. The dc transmitter current is also reduced with output power. The level adjust pin must be set low if the transmitter output is disabled. The dual modulus/dual divide prescaler provides divider ratios of 64/65 or 128/129. This allows for a certain amount of flexibility in the choice of reference frequency.

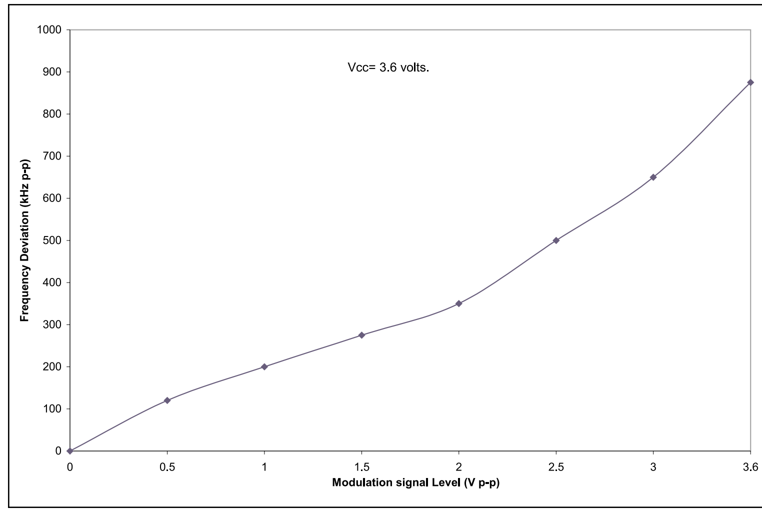
PLL functionality

A block diagram of the PLL section is shown in Figure 2. The VCO design is based on a balanced configuration that utilizes cross coupling between the bases and collectors of a transistor pair. A pair of external inductors and a hyperabrupt varactor diode form the tank resonator for the RF2512. The RF2513 uses on-chip varactors, which are the base-collector junctions of bipolar devices. The base collector junction was chosen because although the base emitter junction has more capacitance, the breakdown voltage of the base-emitter is much lower than the base-collector. The VCO tuning ranges at the ISM band frequencies are shown in Table 1, where the reduced range of the on-chip varactors is evident. A balanced configuration was used instead of a single ended design since it provides differential drive to the prescaler section and has better rejection of unwanted modulation signals. There must be a DC path to V_{cc} on the VCO resonators.

The dual modulus prescaler is implemented using a master/slave flip-flop divider architecture. A current mode phase/frequency detector using D-type flip-flops and charge pumps provide the control signal to the varactors. A 2nd or 3rd order passive loop filter is typically used to set the loop parameters.

Crystal oscillator

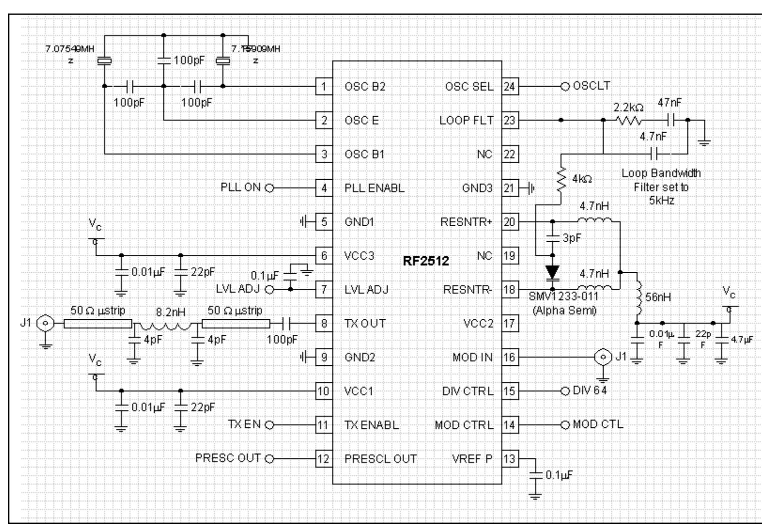
The crystal reference oscillator is a fundamental mode common emitter Colpitts design that operates in a parallel resonant circuit. The crystal is calibrated with a 32 pF load. The on-chip amplifier is an emitter follower, which gives a voltage gain of one. The values of the external feedback capacitors can be adjusted for optimal performance at different frequencies. The capacitors provide most of the phase shift and set the loop gain. The crystal can be replaced by an external source. The signal must be AC coupled and the drive level should be at least 200 mV peak to peak.



▲ **Figure 3. Frequency deviation vs. modulation signal level.**

Frequency (MHz)	VCO Sensitivity (MHz/volt)	
	RF2512	RF2513
915	45	23
868	44	23
433	27	10

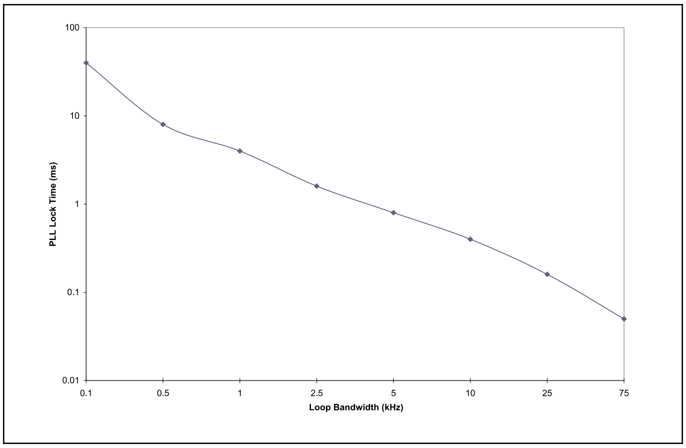
▲ **Table 1. VCO tuning ranges at Cvv = 3.6 volts.**



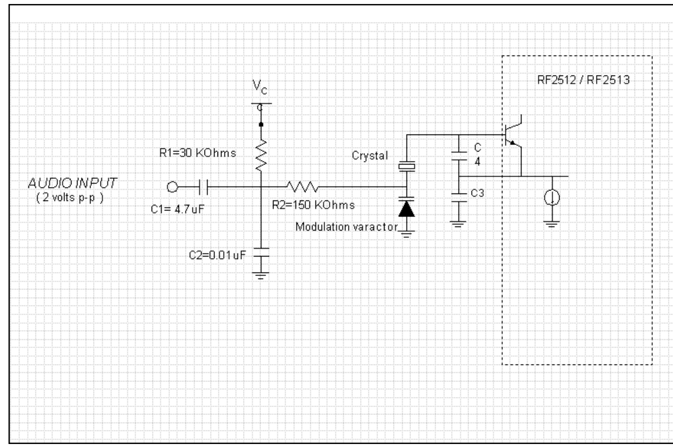
▲ **Figure 4. 915 MHz application schematic.**

Modulation and PLL characteristics

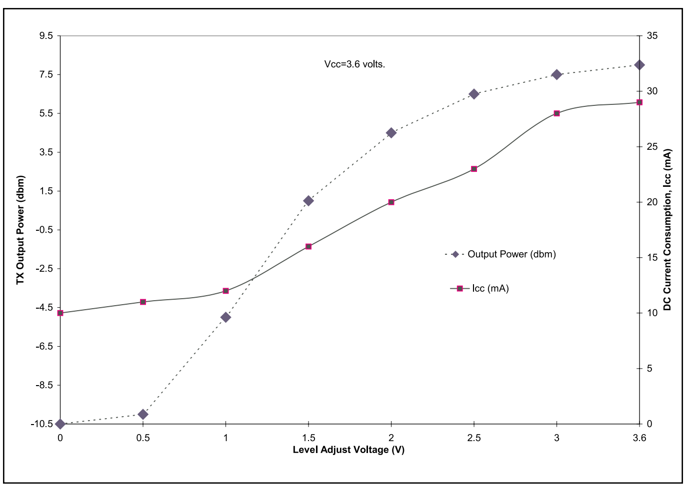
The RF2512 and RF2513 can support wireless applications with data rates up to 1 Mb/s using FSK or ASK digital modulation or linear modulation using FM or AM. The FM/FSK modulation is imparted directly to the VCO using on-chip modulation varactors. The diodes are formed in a similar way to the tuning varactors on the RF2513. The main difference is that the base-collector junction of a smaller bipolar device is used since less capacitance is required. The TX enable and level adjust control can be used to implement AM modulation. The level adjust control and TX enable need to be tied together to provide on-off keying functionality when ASK operation is required. The level adjust control does not provide enough range. The frequency deviation is



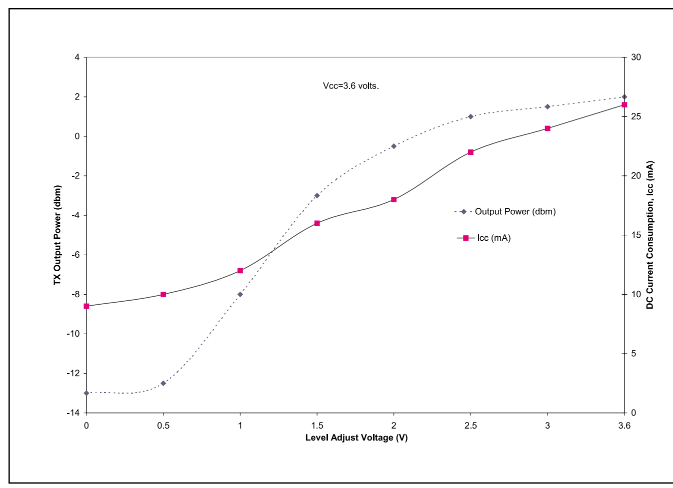
▲ **Figure 5. PLL lock time vs. loop bandwidth.**



▲ **Figure 6. Audio modulation using the reference frequency crystal.**



▲ **Figure 7. Transmitter output power and I_{cc} vs level adjust voltage for the RF2512.**



▲ **Figure 8. Transmitter output power and I_{cc} vs. level adjust voltage for the RF2513.**

proportional to the amplitude of the modulation signal. A typical graph of frequency deviation versus input modulation level for a 40 kHz signal with no DC offset is shown in Figure 3.

Direct modulation is a simple method of applying FM/FSK modulation. However, care must be taken since the modulation rate needs to be higher than the PLL bandwidth otherwise the PLL will track out the modulation. Another situation that can cause these errors is when the modulation data has long strings of ones or zeros. The minimum modulation frequency should always be greater than the PLL bandwidth and a Manchester encoding scheme is recommended to avoid the modulation tracking problem.

The external second order passive filter using capacitors and a resistor as shown in the 915 MHz application schematic typically sets the PLL bandwidth, Figure 4. The series resistor and capacitor set the loop parameters while the single capacitor helps to suppress the reference sidebands. Classical PLL loop analysis can be used to determine the loop component values for a specific loop bandwidth. The graph of PLL lock time versus loop bandwidth is shown in Figure 5.

This graph shows that if direct modulation is used for low frequency modulation, such as audio, then the PLL lock time could become excessively large for certain applications. A solution to this problem is to modulate outside the loop by modulating the reference crystal. A simple implementation with typical component values is shown in Figure 6. Low frequency modulation can then be applied without having a very small loop bandwidth.

The turn on time of the RF2512 or RF2513 is affected by the PLL lock times but mainly by the start-up time of the reference oscillator. The appropriate choice of crystal and prescaler parameters can help reduce the turn-on time. The start-up time is inversely proportional to the crystal oscillator reference frequency. This means that if start-up time is a critical parameter then the lowest possible divider ratio in the prescaler should be used since this would use the highest possible crystal reference frequency. The amplitude of the reference oscillator signal is another factor, which can affect the start-up time. The on-chip phase/frequency detector requires a certain amplitude of reference signal before locking can occur. It is possible to decrease the start-up time by changing the feedback capacitors on the crystal oscillator to increase the reference signal swing. The maximum drive level of the crystal must be taken into consideration, however, when doing this. A start-up time of around 1 ms is achievable with these parts.

Transmitter output characteristics

The RF2512 and RF2513 both consume less than 1 µA in the sleep mode at 3.6 volts and around 10 mA at 3.6 volts and level adjust low. This rises to around 28 µA when the level adjust is brought up to 3.6 volts. The RF2513 draws about 2 µA less than the RF2512 since the drive level from the VCO to the output PA is lower than in the RF2512.

Transmitter output levels and dc current consumption versus level control voltage for the RF2512 and RF2513 at 915 MHz are shown in Figures 7 and 8 respectively. The RF2513 is typically 3 to 5dB lower than the RF2512 with maximum output levels being around +8 dBm for the RF2512 and +2 dBm for the RF2513. The second and third order harmonic levels are typically 23 dBc, therefore the evaluation boards have a low pass filter on the transmitter output. Higher output levels are obtainable when the part is used at lower frequencies, 433 MHz for instance. The phase noise at a 10 kHz offset and a 10 kHz loop bandwidth is –80 dBc/Hz for the RF2512 and –75 dBc/Hz for the RF2513. These two parts are now available in volume at a low cost. ■

Author information

Alan Nicol received his B.S. degree in Electrical Engineering in 1979 from Edinburgh University. From 1983 to 1986, he served as a Microwave Research Assistant at Paisley University, Scotland, where he received his M.Phil. in Microwave Engineering. He currently is a staff engineer for RF Micro Devices in Greensboro, NC. He may be reached by telephone at 336-931-6654.

For more information, contact:

RF Micro Devices
7628 Thorndike Road
Greensboro, NC 27409-9421
Tel: 336-664-1233
Email: info@rfmd.com
Internet: www.rfmd.com

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