HBT Technology Adds Power to CDMA Chip Set

These four chips provide all of the front-end functions that are needed for CDMA handsets.

Introduction

Efficient bandwidth utilization and low operating power characterize code-division-multiple-access (CDMA) transmissions, capturing the interest of several major telephone carriers in the technology. In support of future CDMA and dual-mode (analog/CDMA) handset designs, the engineers at RF Micro Devices (Greensboro, NC), in cooperation with CDMA-developer Qualcomm, Inc.(San Diego, CA) and device foundry TRW (Redondo Beach, CA), have created an RF chip set with the performance levels required by CDMA system designers.

The chip set is based on the low-power GaAs heterojunction-bipolar-transistor (HBT) device technology from TRW. The CDMA chips perform all the RF front-end functions in a handset (Fig. 1), including frequency translation, RF and intermediate-frequency (IF) amplification, and automatic gain control (AGC).

The chip set consists of the RF9906 low-noise amplifier (LNA)/mixer, the RF9908 upconverter integrated circuits (ICs), and the RF9907 and RF9909 AGC amplifier ICs. These ICs can be used in a handset design prior to second-stage frequency conversion.

The RF9906 integrates a low-noise preamplifier, double-balanced mixer, two switched variable-gain IF amplifiers, and a switched local-oscillator (LO) output buffer amplifier (Fig. 2). The IC is housed in a QSOP-24 surface-mount package and is designed to provide high dynamic range from a single +3.6 V_{DC} supply without additional external matching networks or bias circuitry.

The RF9906 is optimized for 850 to 900 MHz assuming 2.5 to 3.0 dB external image filter loss, although the wideband circuits provide similar performance from 500 to 1500 MHz. The 1 dB IF bandwidth is 110 MHz to either output port.

The overall gain of the RF9906 is 26 dB to the differential (IF1) port or 16 dB to the single-ended (IF2) port at the nominal gain setting. The gain can be tuned by (4.5 dB by adjusting a control voltage between 0.5 and 2.5 V. The IF output impedance is 1kΩ for IF1 and 750Ω for IF2 ports. The overall noise figure is 2.8 dB and the input third-order intercept point is -8 dBm at the nominal gain setting. The RF and LO input-port VSWRs are less than 1.50:1, while the LO output-port VSWR is less than 2.00:1. The LO-to-RF isolation is more than 50 dB in addition to image filter rejection.

The RF9906's LNA employs a combination of series and shunt feedback around a common-emitter amplifier to achieve excellent port impedance match without reactive elements. The gain is 16 dB, with more than 22 dB reverse isolation at 880 MHz (Fig. 3). The noise figure is less than 1.5 dB at frequencies below 1.2 GHz (Fig. 4). The input third-order intercept point is -3 dBm. The DC current drain is 7 mA.

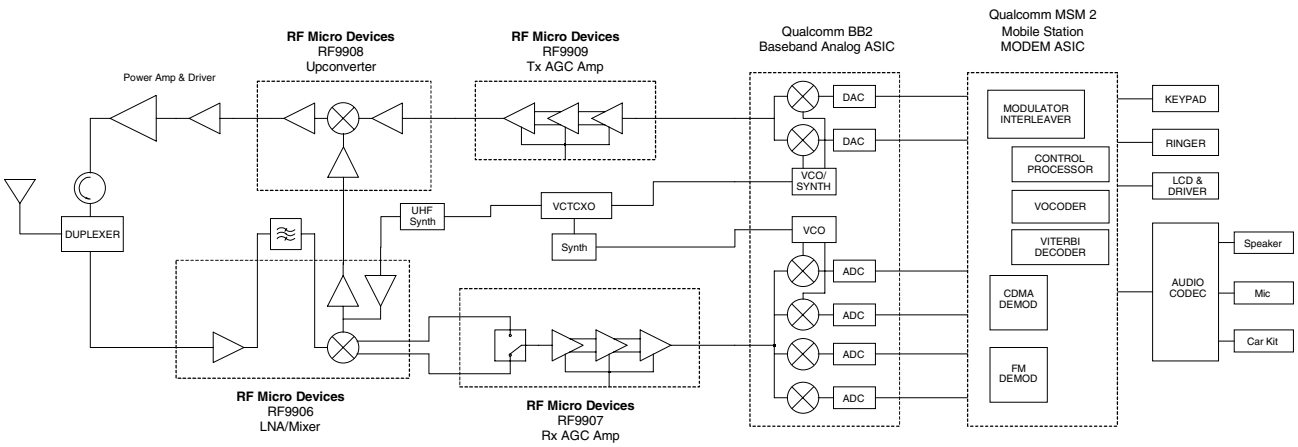

Figure 1: The CDMA chips provide the basic front-end functions required by a handset design.

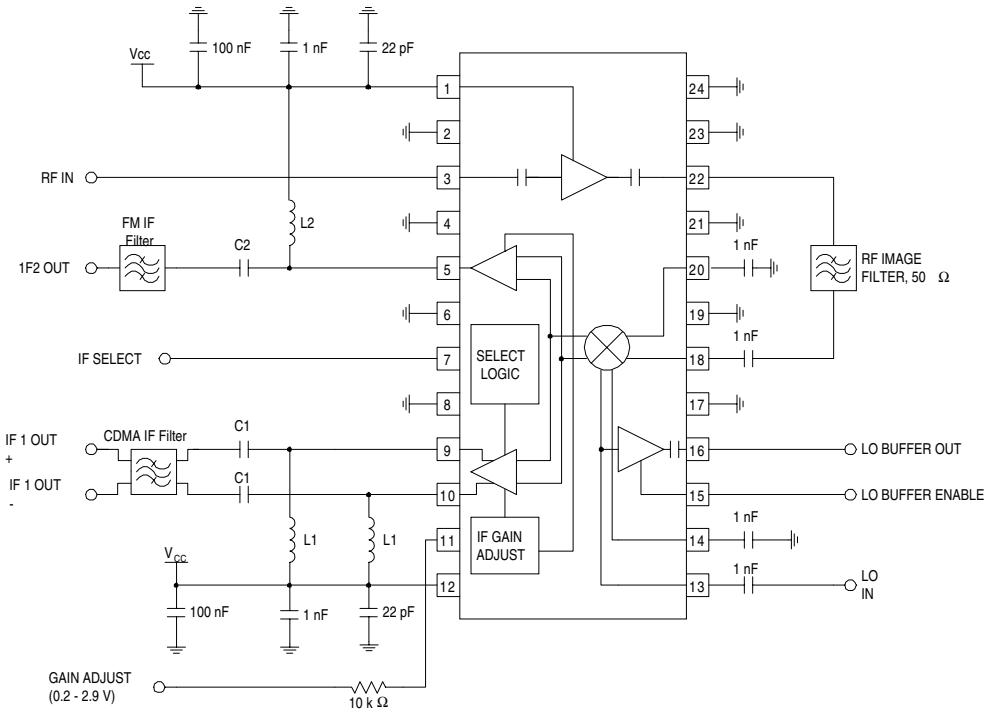

Figure 2: The RF9906 integrates an LNA, mixer, two switched variable-gain IF amplifiers, and a switched local-oscillator (LO) output buffer.

The RF9906's double-balanced mixer is a series-connected differential RF amplifier with a cross-coupled active LO switch (Gilbert cell). Series feedback sets the third-order intercept point. The mixer draws 9 mA and features measured double-sideband noise figure of 9 dB and an input third-order intercept point of +6 dBm. The 50 Ω device can achieve an input third-order intercept point of +10 dBm at +4.8 V_{DC} with no increase in noise figure. The mixer's gain is reduced by only 0.4 dB when the LO power is reduced to -9 dBm.

Two variable-gain IF amplifiers follow the mixer, selected by logic-level signals. The gain-control circuit uses a phase-cancellation technique. The mixer noise figure and input third-order intercept point are affected by less than 1 dB by the IF output selection at the nominal gain setting. The mixer's gain at the IF1 port is 13.5 ± 4.5 dB while gain at the IF2 port is 3.5 ± 4.5 dB. Current drains for the IF1 and IF2 selections, including bias and logic circuits, are 14 and 6 mA, respectively.

The switched LO output buffer provides 0-dB gain into a 50 Ω load over the LO input-power range of -6 to -3 dBm. The isolation to the LO port is 20 dB. The on/off output ratio is also 20 dB. The buffer, with an AC-coupled output port, is switched on with greater than 3.1 V on pin 15. DC current drain is dependent upon the LO drive, being 2.7 mA with -6-dBm LO power and 4.3 mA with 0 dBm LO power.

The RF9908 upconverter IC is housed in an eight-pin SOIC package. It contains a Gilbert-cell mixer with differential IF inputs and differential LO ports (for single-ended LO operation, one port is connected to an AC ground). The mixer is followed by a Class B push-pull output buffer amplifier. The IC operates at +3.6 VDC with 0 dB conversion gain and +13 dBm output third-order intercept point. The gain and intercept-point performances are not affected by changing the LO level.

The mixer is made of a differential pair amplifier and a four-quadrant multiplier. The lower differential part of the mixer pair is the IF amplifier, which has emitter-degeneration resistors to reduce the IF gain. By keeping the IF level small and well below the LO level, mixer linearity improves. The upper portion of the mixer incorporates switching transistors. Large LO signals (ideally square waves) are applied to the bases of the two cross-coupled transistors to alternately turn the

paired transistors on and off with minimal distortion.

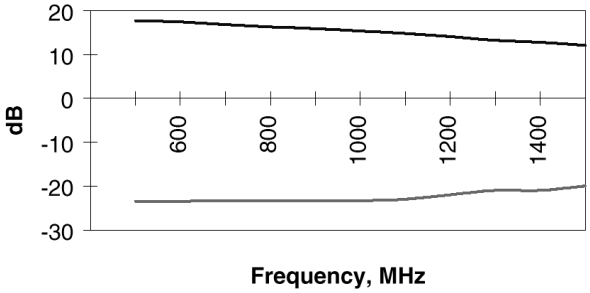

Figure 3. The LNA in the RF9906 provides gain of better than 12dB at 1.1 GHz, with more than 22 dB isolation at that same frequency.

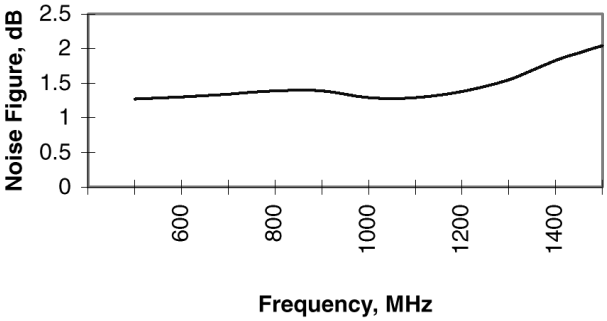

Figure 4. The LNA in the RF9906 has better than 1.5 dB noise figure to about 1200 MHz.

Because of the balanced nature of the mixer, the unit has excellent port-to-port isolation and low LO feedthrough at the output port. The spurious content within a 20 MHz bandwidth of the desired output range is typically better than -70 dBc and better than -50 dBc in a 60 MHz bandwidth. The LO leakage to the RF output port is -30 dBm, with at least 30 dB IF-to-RF-port isolation. In the output stage, the current for each transistor flows for approximately one-half of the input cycle, with each transistor providing a different half of the output waveform, resulting in considerable current conservation compared to Class A (always on) designs.

The RF9908 operates with LO drive levels of -6 to 0 dBm, with better than 1.50:1 VSWR and no external matching. The self-contained IC works to 2 GHz. The only external components needed are supply bypass capacitors and DC blocking capacitors on the IF and LO ports.

To complement the two frequency-translation ICs, the RF9909 and RF9907 AGC amplifiers provide gain-control functions for the CDMA transmitter and receiver sections, respectively. The AGC circuits are critical in maintaining consistent power levels with changing distances between handsets and base stations in a cellular network. Similar to the frequency converter ICs, the AGC ICs both operate from a single +3.6 VDC supply with low power consumption.

In a dual-mode system, the transmit AGC amplifier will typically handle a constant-level narrowband input signal. This AGC amplifier must provide linear amplification when needed or attenuation when signal levels are too high (close to the base station). To do this, the RF9909 offers an 84 dB gain range stretching from -45 to +39 dB. The gain control characteristic is monotonic and linear over the 84 dB range.

At the maximum gain setting of 39 dB, the output third-order intercept point is +16 dBm referenced to 1000 Ω. The noise figure is better than 20 dB for gain settings of 0 to 39 dB. The IC typically draws only 20 mA power-supply current from a single +3.6 VDC supply and handles signals from DC to 200 MHz.

The RF9907 receiver AGC amplifier must handle a wide range of input-signal levels, but must do so with consistently-low noise figure. The RF9907 features a 90 dB gain range (-45 to +45 dB), with analog gain control tuned by means of a DC voltage. The monotonic gain-control characteristic is extremely linear over the 90 dB gain range. Under maximum gain conditions, the RF9907's noise figure remains under 6 dB in either analog (FM) or digital (CDMA) modes. Under minimum gain conditions, the input third-order intercept point is better than -5 dBm (referenced to a 500 Ω load). The RF9907 typically draws only 13 mA from a single +3.6 VDC supply and features a 3 dB frequency range of 10 to 175 MHz.

This article was originally presented in **Microwaves & RF**, December 1994.

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