A 22.5dBm 2.4GHz Linear Power Amplifier for 802.11b WLAN Applications

History of WLAN traced from 801.11 adoption in 1997. WLAN market projected to be over $2B in 2003. Two WLAN techniques at 2450MHz: DSSS and FHSS. MAX2242 power amplifier (PA) is designed for 802.11b operation. Typical RF front end is shown. ACPR of -33dBc is measured with +22.5dBm output power. PA bias is set with resistor or DAC. UCSP of 1.5mm x 2.0mm uses ball pitch of 0.5mm.

Wireless local area networks (WLANs) have come a long way since the IEEE 802.11 standard was adopted officially in 1997. Since then, we have seen the data rate rise from 1Mb/s to 2Mb/s to the current 11Mb/s; in the near future, it is expected to climb to 22Mb/s and even up to 54Mb/s at 5GHz. Meanwhile, the price of a 2.4GHz 802.11 WLAN PC card went from an astronomical $600 to $800 to the current $129 price offered conveniently on the Internet. With multiple vendors offering Wi-Fi certified (802.11b-compliant) WLAN cards and with interoperability established among these vendors, the price of a WLAN card is projected to drop below $100 by the end of 2001 and head toward $50 to $60 by 2002.

The WLAN market is forecast to exceed $2B in annual revenue by 2003 by several market-research firms. These forecasts will likely be revised upward, as WLANs continue to expand rapidly in offices, homes, and public places such as airports, hotels, and convention centers. Home networking is expected to play a major role in driving up demand for WLAN cards. Simultaneously sharing a broadband Internet connection (via DSL or a cable modem), printing to a common printer, and sharing files among family members are truly compelling applications for an in-home WLAN.

As WLAN applications continue to expand into portable devices, the size requirement also becomes smaller. Next-generation WLAN radios will fit on a PC board in the size of a compact flash card (measuring 1.7in x 1.4in). The small size makes it possible to integrate WLAN functionality in portable devices such as PDAs, digital cameras, MP3 players, web pads, and IP cordless phones.

There are two major WLAN technologies operating on the 2.4GHz ISM band today. One is direct-sequence spread spectrum (DSSS), and the other is frequency-hopping spread spectrum (FHSS). To ensure high security and rejection of interference, DSSS radios generate a redundant bit pattern for each bit to be transmitted. This bit pattern is called a chip (or chipping code). The longer the chip, the greater the probability that the original data can be recovered, but at the cost of more bandwidth. FHSS radios use a narrowband carrier that changes frequency or hops in a pattern known to both transmitter and receiver.

The widespread acceptance of WLANs depends on industry standardization to ensure product compatibility and reliability among the various manufacturers. The IEEE recently ratified the

802.11b standard (also known as 802.11 High Rate) that extends the raw-data rate to 11Mb/s using the 2.4GHz DSSS system. According to the 802.11b standard and Federal Communications Committee (FCC) rules, the maximum transmitted power must be 1000mW or less for the United States, 100mW or less for Europe, and 10mW/MHz or less for Japan. The 802.11b standard also requires the transmission mask to meet the following conditions: The transmitted spectral products should be less than -30dBr (dB relative to the SIN(x)/(x) peak) in the first side lobes (fc - 22MHz < f < fc - 11MHz and fc + 11MHz < f < fc +22MHz, where fc is the channel center frequency) and -50dBr in the second side lobes (f < fc - 22MHz and f > fc + 22MHz).

The MAX2242 is a low-cost silicon linear PA designed specifically for 802.11b WLAN applications. It delivers +22.5dBm of linear output power with an adjacent-channel power rejection (ACPR) of <-33dBc in the first side lobe and <-56dBc in the second side lobe, providing a margin of 3dB and 6dB, respectively, compared to the 802.11b standard. The +22.5dBm output power overcomes the insertion loss of the T/R switch and bandpass filter, which typically totals 2.5dB, allowing an output of +20dBm at the antenna. Figure 1 is a typical WLAN transceiver front-end block diagram.

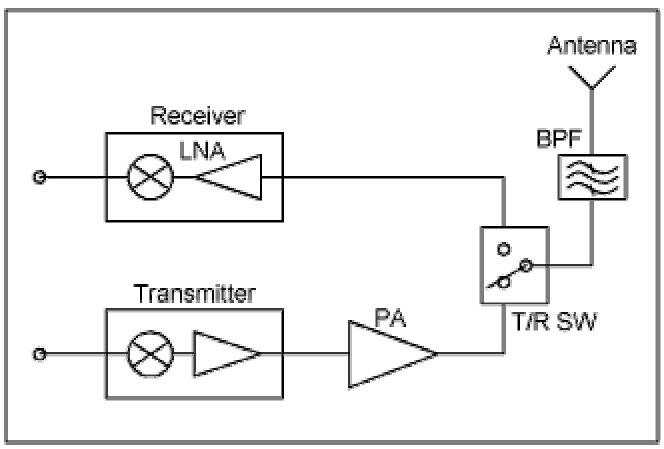

Figure 1. Typical RF front end

To demonstrate the performance of the PA, an evaluation (EV) board has been created and tested. This EV board is made from low-cost FR4 material, consisting of four layers stacked with dielectric thickness of 6mils, 44mils, and 6mils. To ensure simplicity of the board design, no micro-vias are used. The photo in Figure 2 shows the EV board on which the PA device with all the necessary passive components has been installed. Figure 3 depicts the typical application circuit used on the EV board.

Figure 2. Photo of MAX2242 EV board

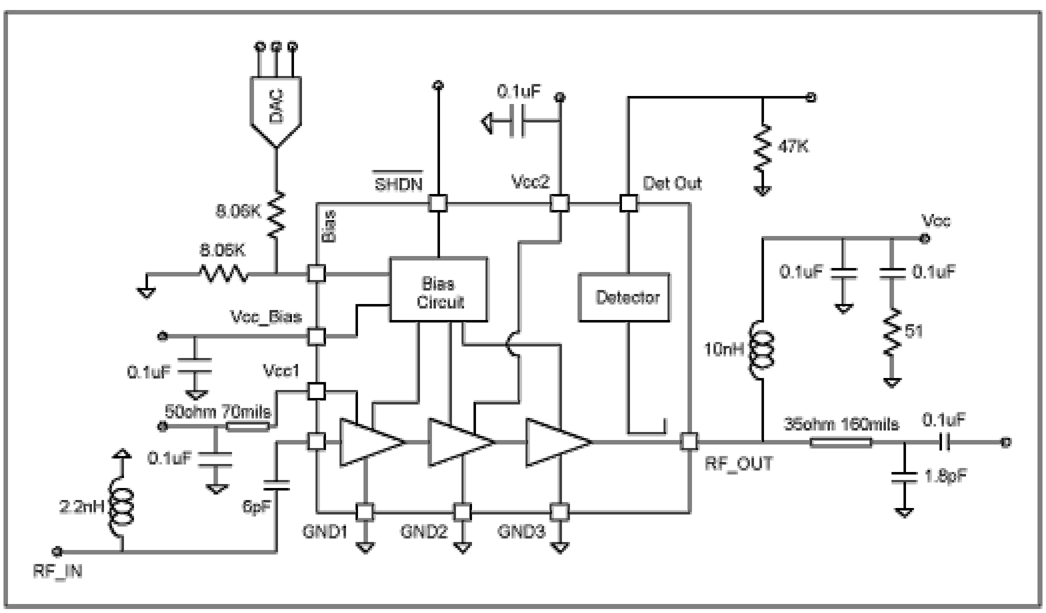

Figure 3. Typical application circuit

Figure 4 shows a spectral plot of ACPR at +22.5dBm output. This plot is taken at 2.45GHz by using an IEEE802.11b-compatible signal source with CCK modulation and a data rate at 11Mb/s. The PA consumes about 310mA DC current at its maximum linear output power. Most

PA drivers available today can provide only about -4dBm output power, requiring a high-gain power amplifier to follow. The MAX2242 cascades three amplifier stages to provide at least 26.5dB gain and ensure an output of +22.5dBm. Figure 5 is a plot of gain versus frequency. The PA provides a flat gain response over the entire 2.4GHz to 2.5GHz ISM band.

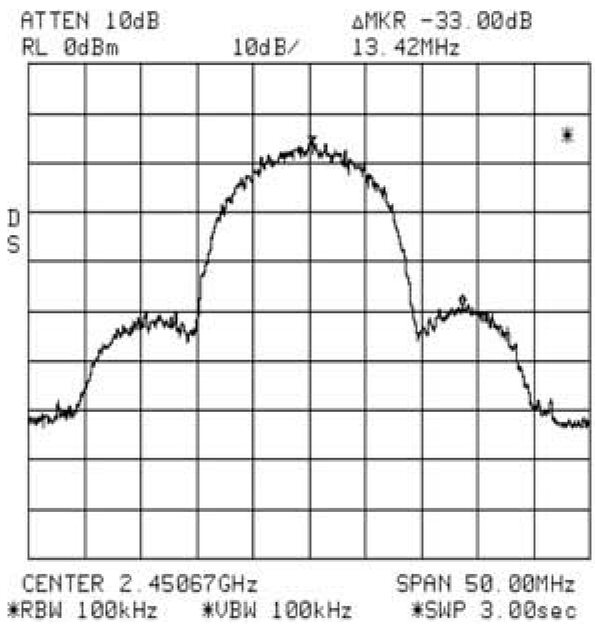

Figure 4. Output spectrum of the MAX2242 at 2.45GHz

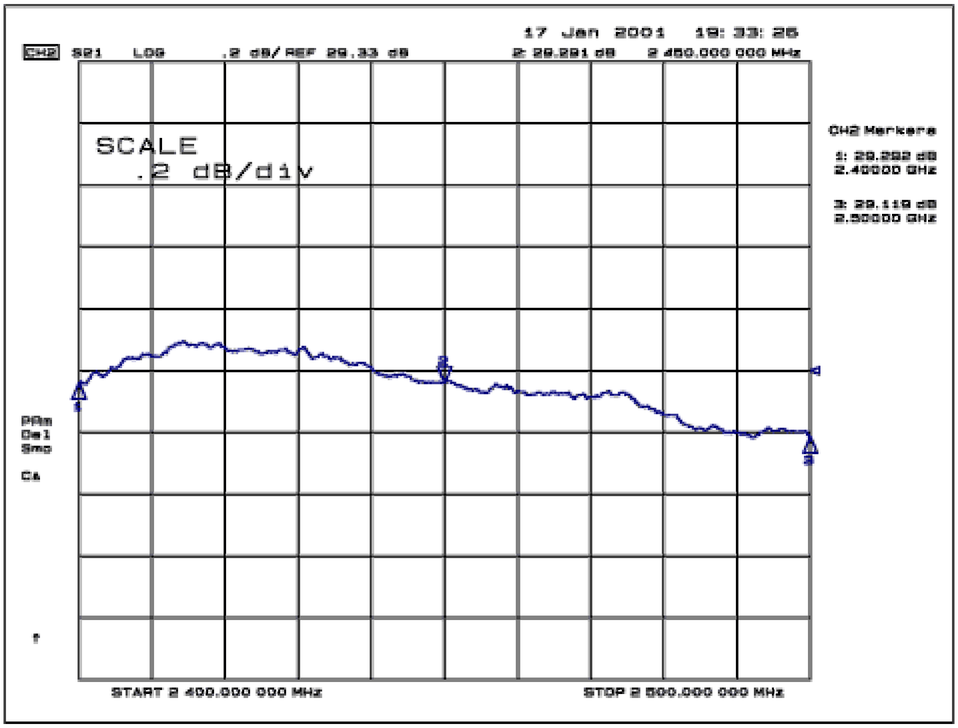

Figure 5. Frequency response of the MAX2242

The PA has a power detector coupled to the output port, providing at least 20dB of dynamic range with ±0.8dB accuracy at the maximum linear output-power level. An accurate automatic level control (ALC) function can be implemented easily using the detector circuit. With this detector integrated, the traditional directional coupler and discrete detector are eliminated, greatly reducing the overall PC-board area.

The PA also features an external bias control pin. Through the use of an external DAC, the current can be throttled back at lower output-power levels while maintaining sufficient ACPR performance. As a result, the highest-possible efficiency is maintained at all output-power levels. Table 1 shows the linear output power versus idle current and supply current (IDC) with -33dBc ACPR (unchanged). (Note that the supply current is the current drawn by the MAX2242 when an RF signal is present; idle current is the current drawn when an RF signal is *not* present.) This table shows that supply current can be reduced significantly by using the external DAC. Also, power efficiency is essentially maintained when the output power is adjusted to lower levels using the external DAC.

Table 1. Bias Current Control through DAC

Linear Output Power (dBm)	I_{Idle} (mA)	IDC (mA)
22	279	303
20	180	213
18	134	165
16	94	128
14	81	105
12	61	83
10	41	63
6	21	40
0	18	27

Only a series capacitor and a shunt inductor are needed for the PA input match, and two capacitors are required for the output match. This further minimizes the PC-board size.

Most PCMCIA and PC cards provide only a 3.3V power supply. The PA circuit has been designed to operate from a single +2.7V to +3.6V supply.

Time-division duplex (TDD) is commonly used in WLAN applications. This requires that the PA device be shut off separately to maximize battery life during receive mode. An on-chip shutdown feature has been created for just this reason. In shutdown, the operating current reduces to 0.5uA without the need for an external supply switch.

The PA is packaged in an ultra-small 3x4 ultra-chip-scale-package (UCSP™) measuring only 1.5mm x 2.0mm, virtually the same size as a 0805 resistor. The small size makes it ideal for WLAN radios built in small PC-card and compact-flash-card form factors. Figure 6 shows the detailed dimensions of the UCSP package. The UCSP packaging technology allows the integrated circuit to be attached to the PC board facedown, with the chip's pads connecting to the PC board's pads through individual balls of solder. This technology differs from other ball grid array, leaded, and chip-scale packages, because there are no bond wires or interstitial laminates. The main advantage of the UCSP is that the IC-to-PC-board inductance is minimized so that RF performance is improved. Secondary benefits are reduction in package size and enhanced thermal conduction characteristics.

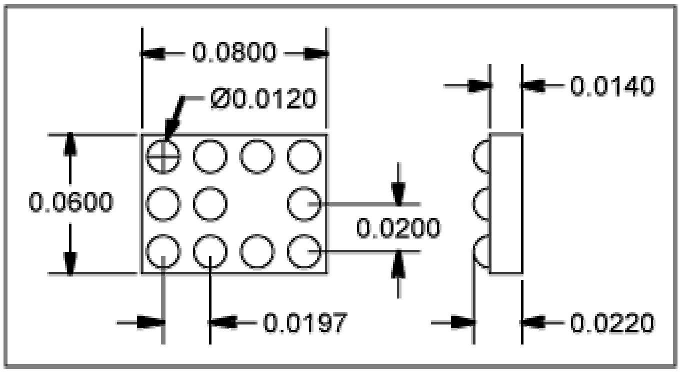

Figure 6. Dimensions of 3x4 UCSP package (in inches)

The MAX2242 PA combines the benefits of low-cost silicon technology, high output power, an on-chip detector, and external bias control, all in one tiny UCSP package. It is available for volume production.

A similar version of this article appeared in the March 2001 issue of *Microwaves and RF* magazine.

MORE INFORMATION

MAX2242: QuickView -- Full (PDF) Data Sheet (200k) -- Free Sample