

AN1040

Low-Power IC Packs GPS Receivers

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This highly integrated GPS receiver IC improves upon earlier-generation devices by including more components in a smaller package with a reduction in power consumption.

Global Positioning System (GPS) receivers have proven to be tremendous time-saving devices as well as invaluable safety tools when position location is needed in an emergency. And five years ago, California Eastern Laboratories (Santa Clara, CA) and NEC (Tokyo, Japan) made a huge impact on the design of hand-held GPS receivers by means of a highly integrated GPS receiver IC. But with the increased demand for embedded GPS functionality in Personal Digital Assistants (PDAs) and cellular telephones, the firms have redefined the state of GPS integrated circuitry through the development of the model UPB1007K GPS receiver IC, which is smaller and more integrated than previous-generation GPS receiver ICs. The UPB1007K, which is supplied in a 36-pin QFN package, consumes only 75 mW of power when running on a single +3-VDC supply.

The first venture by CEL/NEC into GPS integration—the UPB1004GS receiver IC—found its way into the GPS2000 Satellite Navigator from Magellan Systems Corp.

(Monrovia, CA), helping the compact receiver become the first hand-held GPS unit to sell for less than \$200. Today, these receiver ICs are found in many applications besides GPS handsets. They are installed in dashboard navigation systems, asset tracking systems, satellite dispatch systems, and most recently, in PDAs and cellular handsets.

Regarding cellular systems, recent Federal Communications Commission (FCC) regulations have mandated the introduction of enhanced 911 (E-911) call location functionality. Cellular carriers will be required to provide latitude and longitude data — called Automatic Location Identification (ALI) — to all public service answering organizations that receive emergency calls from cellular users. To comply, carriers are looking at GPS enabled handsets, network-based solutions, or a combination of both. To date, approximately half have announced they'll opt for the GPS-enabled handsets.

Location Based Services (LBS) is another emerging market driving the development of GPS-enabled handsets. An example scenario would have two cellular users determining a meeting point or selecting a restaurant location by means of the LBS capability. LBS services are available now on a limited basis in Europe and Japan — with global revenues expected to grow from \$1.6 billion last year to \$40.7 billion in 2006.

Personal Digital Assistant (PDA) manufacturers are also looking at GPS. With screens that are larger and more colorful than those of their cellular cousins, PDAs seem like the ideal vehicle for displaying GPS-based information. But PDA manufacturers are wary of widespread

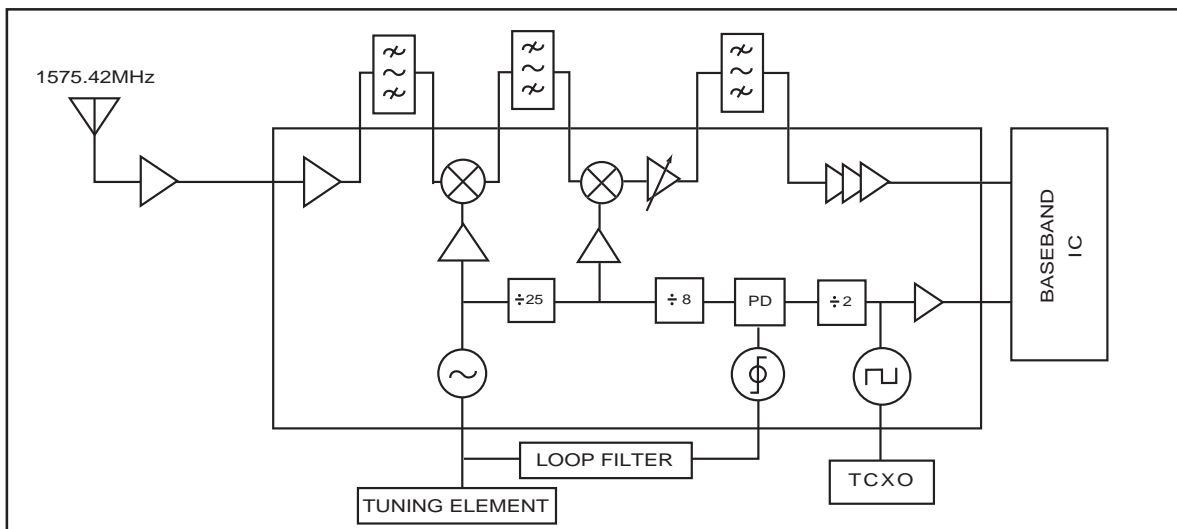


Figure 1

acceptance for GPS. Not yet convinced of the demand for GPS services, their approach is to provide GPS functionality in add-on external modules, rather embedded in their PDA chipsets.

Cellular system designers have issues with embedded GPS as well. The fact is, the two technologies really don't fit well together. With the GPS receiving signals from satellites in space and cellular receiving signals from a mile or so away, the power levels are vastly different. Plus, with two entirely different RF front ends, crosstalk is a major concern.

While companies are working on solutions to the problems of embedded GPS, handset manufacturers, especially those in the cellular market, need solutions now. In the case of E-911, the FCC has mandated that the new ALI-enabled handsets be available on the market by October of this year. By December 2002, all handsets sold in the US must include the technology.

NEC has responded with a new GPS receiver IC. Smaller and more highly integrated than previous NEC receiver ICs, the UPB1007K was developed at the NEC/California Eastern Laboratory Design Center (Santa Clara, CA) and is fabricated at NEC facilities in Japan using NEC's latest

ultra high-speed UHS0 25-GHz transition-frequency bipolar process. The high-cutoff-frequency process results in good gain figures at very low bias, and much lower current consumption than earlier receiver ICs — just 25 mA, currently the lowest on the market for a device offering the UPB1007K's level of integration.

Another benefit of the UHS0 process is that it has both PNP and NPN transistors in a vertical structure. This enables the IC designer to configure high-frequency charge-pump circuits in the device. There are many advantages to using charge-pump circuitry. First, its constant amplitude signal has a duty cycle that's directly related to the phase difference between the local oscillator (LO) and the crystal reference. Therefore, unlike loop amps that are "on" at all times to drive the varactor, the charge pump consumes only as much current as needed to correct the phase error. Once the LO is locked to the crystal reference — barring any major system disruption — very little current is used.

Charge pumps also allow for a simplified loop filter circuits, resulting in fewer components and a more compact system design. In the UPB1007K (**Fig. 1**), the charge pump

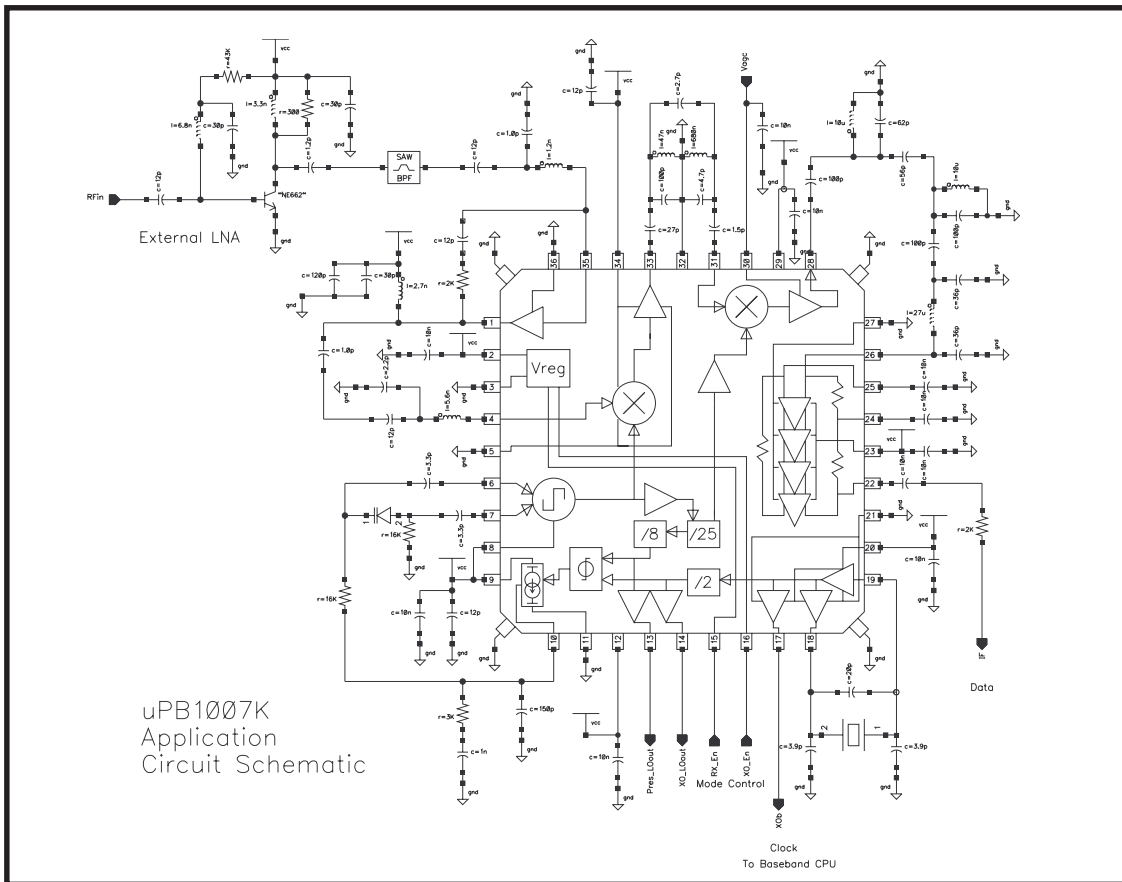


Figure 2

is driven by a flip-flop based digital phase detector, a scheme that was chosen because of its insensitivity to incoming power levels from the LO or crystal oscillator—and its digital output is ideally suited to run the charge pump.

The new UHS0 process also results in improved noise figures, which in turn has enabled NEC to integrate the low-noise amplifier (LNA) on-chip with the remaining GPS receiver circuitry. This means that applications that employ active antennas can now feed signals directly into the UPB1007K. With the addition of one external single-stage LNA such as the NE661M04 from CEL/NEC, excellent sensitivity can also be achieved with passive antennas. The on-chip LNA features cascode architecture for higher gain and lower power consumption than a cascade scheme: 2.5 mA, with a noise figure under 3 dB and associated gain of 15 dB.

In addition to the LNA, the GPS chip includes an integrated mixer, voltage-controlled oscillator (VCO), and crystal oscillator. Besides the obvious savings in real estate, the integration of these last two functions helps improve frequency stability, resulting in less frequency pulling on the phase-lock loop (PLL) and the phase detectors. This crystal oscillator also features a buffered output, which allows it to be used to time the central processing unit (CPU). This eliminates the need for a second crystal oscillator, which simplifies the design, saves space and reduces power consumption. And since the

crystal oscillator and receiver power-down circuitry are separate, the receiver can be turned off when no GPS reception is required, while the crystal oscillator continues to drive the CPU.

The UPB1007K features a superheterodyne dual downconversion receiver architecture. The receiver is designed to process 1575.42-MHz signals from the antenna through either a discrete LNA or the on-board LNA. The signals are downconverted to a first intermediate frequency (IF) of 61.38 MHz by mixing with the 1636.8-MHz signals from the on-board LO. The LO is also used to create a second set of signals at 65.472 MHz for the second downconversion process, which results in a typical second IF of 4.092 MHz.

The on-board crystal oscillator generates a set of 16.3667-MHz reference signals which are sent with the second IF signal to the GPS system's digital signal processor (DSP) for analysis and subsequent display on the system's screen.

The RF downconversion chain features 36 dB typical power conversion gain, delivering a maximum first IF output power of -5 dBm. The LO leakage at the IF or RF point is below $\{-45$ dBm, while the single sideband (SSB) noise figure is typically 3.5 dB for an RF input power level of $\{-40$ dBm.

The IF downconversion chain, with a minimum 40 dB voltage gain control range, features typical second IF output

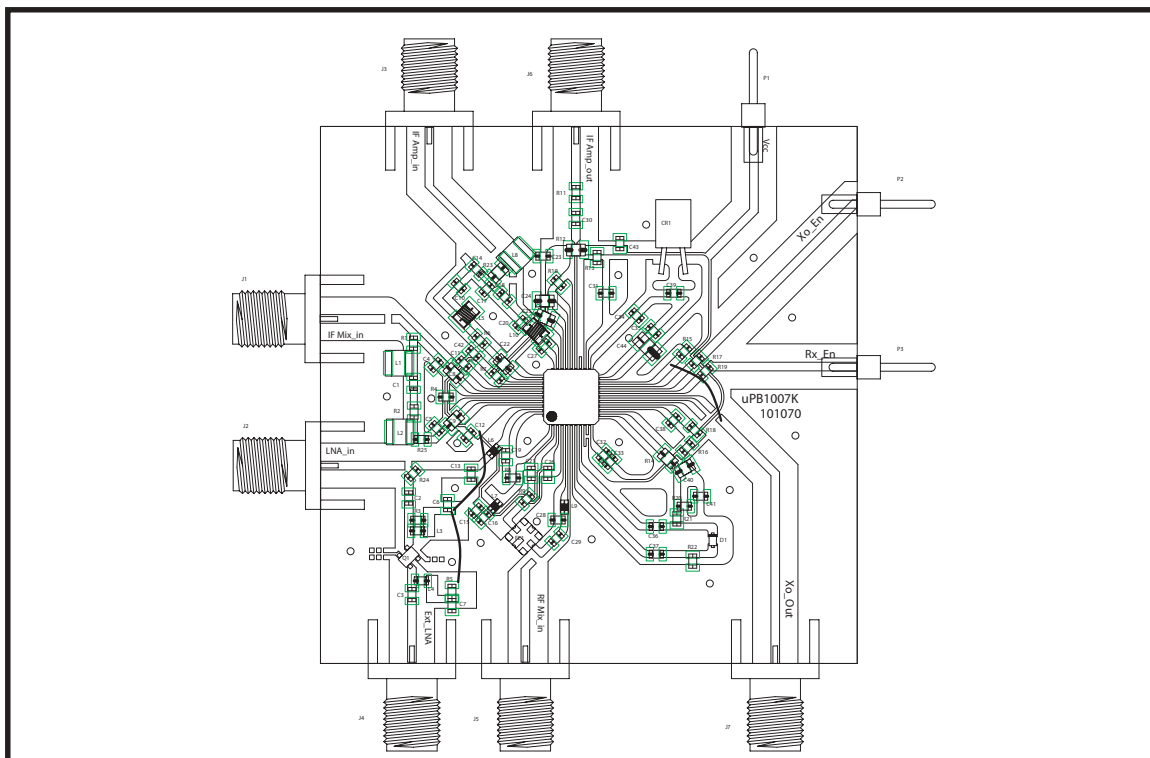


Figure 3

levels of 1.2 VPP into a 2K Ω load. The LO leakage at the first and second IF pin is typically -80 dBm minimum. The second IF amplifier provides an additional 40 dB gain, for total conversion gain through the entire device of 120 dB.

The UPB1007K is supplied in a miniature 36-pin QFN package, which represents a 62-percent reduction in size compared to earlier 30-pin SSOP GPS receiver ICs. It operates on a single +3-VDC supply (about 25 mA typical current draw) and is designed for 1575.42-MHz input signals. It translates input signals into 4-MHz baseband output signals. The IC provides typical peak-to-peak output voltage of 1 V and achieves more than 120-dB on-chip gain with an automatic-gain-control (AGC) range of 40 dB. The phase noise is only {MINUS}88 dBc/Hz offset 10 kHz from the carrier. The on-board LNA achieves a typical noise figure of 2.8 dB at 1575 MHz with 15 dB gain.

The GPS receiver IC is rated for operating temperatures from {MINUS}40 to +85{DEG}C. The maximum LO leakage at the RF input pin is {MINUS}48 dBm. In a typical application (**Fig. 2**), well-distributed ground pins in each corner maintain good RF integrity while an external LNA helps maximize receiver sensitivity. An evaluation board is available for the UPB1007K (**Fig. 3**) that combines the IC with RF and IF filtering and an external LNA to simulate a complete GPS receiver. P&A: \$5.36 each (10,000 qty.); stock.

CAPTIONS

1. The UPB1007K GPS receiver IC features an on-chip frequency synthesizer, low-noise amplifier, and crystal oscillator circuitry for low-power reception of GPS signals.
2. This typical application schematic diagram for the UPB1007K GPS receiver IC shows the connections for power-supply circuitry and other external components.
3. The UPB1007K GPS receiver IC can be used with an evaluation board that contains all the required RF and IF filtering as well as an external LNA.

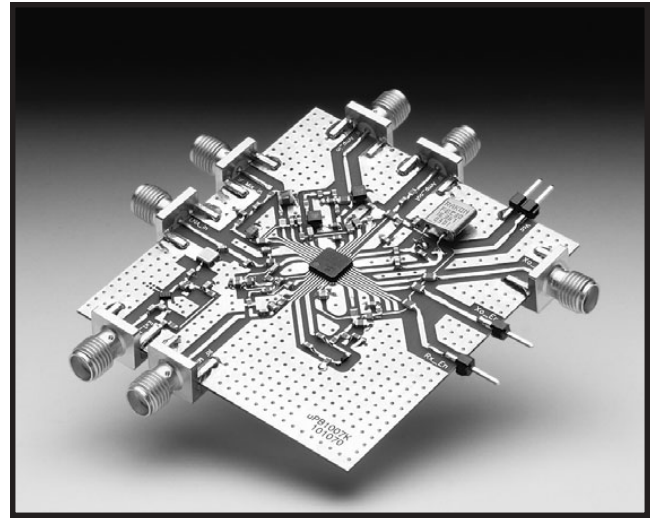


Figure 4

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