By Graham Prophet, Editor

Zero in

GPS OPTIONS EXPAND WITH APPLICATIONS

YOU'LL FIND AN EXTRAORDINARY AND DIVERSE range of GPS applications as it becomes both simpler and cheaper to add satellite-based locations. Applications include asset-tracking systems that are following trucks, trailers, railroad cars, shipping containers, and the like as they roam around the country; you can track children via GPS electronics in their backpacks, and you can even track pets. Special beacons can locate key participants in televised sporting events to ensure that the cameras are pointing the right way at the right time, perhaps to guarantee sponsorship. Add-ons, such as PDAs and laptop computers, also play a role.

Designing these GPS systems are teams whose expertise with tricky RF systems varies from comprehensive, such as cell-phone makers, to nonexistent. Even if you are in an inexperienced group, don't feel bad about it; as Geoff Haynes marketing manager at chip vendor SiGe, says, "Few [potential users] have all the expertise needed to get a GPS system up and running."

If you are contemplating adding or embedding the GPS function, you have an increasing range of options in chip sets, modules, and their accompanying software. You probably opt for a module-based approach if your application is low- or medium-volume up to tens of thousands of units. You might also tend to opt for a module to avoid the problem of laying out and verifying the operation of critical RF circuitry. For higher volume designs, the chip-set approach becomes an option. It uses an RF chip and a baseband chip as a pair from a single source or from two specialized suppliers.

Integration is another dimension of your decision. If you need to add a GPS function to your product but face severe space constraints, you may opt to use a chip set. Once you evaluate a highly integrated chip set, you have a range of options

THE REINFORCING CYCLE OF SMALLER, LOWER COST, LOWER POWER GPS ELECTRONICS IS FEEDING, AND FED BY, AN EXPANSION OF DIVERSE APPLICATIONS.

Illustration by Mike O'Leary

for partitioning your system. And don't forget testing, because you'll need to have confidence in both the RF and the algorithm performance of your design (see **sidebar** "Testing GPS is a specialized market").

ARCHITECTURES VARY CONSIDERABLY

Although today's chip sets usually come as pairs, GPS chip sets must incorporate three main functions: the RF-signal chain of the receiver itself, which downconverts the GPS signal from 1575 MHz to baseband; the correlators and associated signal-search management; and the microprocessor, which performs the geometric and timing calculations to turn raw GPS data into a position fix. Some GPS chip sets incorporate the microprocessor core; some do not. If you are marrying GPS to a product that already includes a microprocessor, you have the option of a host-based approach, if your host has sufficient spare computational capacity.

Even if your host does not have the room, it may be power-efficient to upgrade your host microprocessor rather than run a separate core for the GPS subsystem. Depending on your MIPS definition, most vendors quote 4 to 15 MIPS as the resource your system will need to perform the GPS calculations. The real-time dimension of this setup is that the GPS correlator engine presents you with live, new data on the 1-msec timing cycle that the GPS signal dictates, and you must be able to interrupt whatever the host processor is doing to fetch that data in the appropriate window.

As with many other aspects of integrating GPS, you will probably buy a comprehensive software package along with the hardware and thus will not need to develop detail software for this task, but your headroom analysis for the host processor must include both raw capacity and timing. One approach to consider is to have the system perform the math, which is not in itself time-critical, on the host processor, and to provide a small auxiliary processor, such as a state machine and some memory, to handle and buffer the data on demand.

Conversely, if the GPS baseband chip contains a microprocessor core that has more than enough headroom for those GPS computations, you can use that excess capacity to run application code; you can find familiar cores, such as the ARM 7, in baseband chips.

AT A GLANCE

- ▷ Options for integrating GPS functions into your product span modules, chip sets, and silicon-ready intellectual property.
- ▷ New component-level GPS products leverage the development effort targeting E-911 cellular phones.
- ▷ Vendors are improving high-sensitivity and low-power implementations on a quarter-by-quarter basis.
- ▷ Buy comprehensive software packages to accompany chips or modules to perform all low-level GPS calculations.
- ▷ Design problems you will face will include RF-design considerations, system integration, and managing power trade-offs.

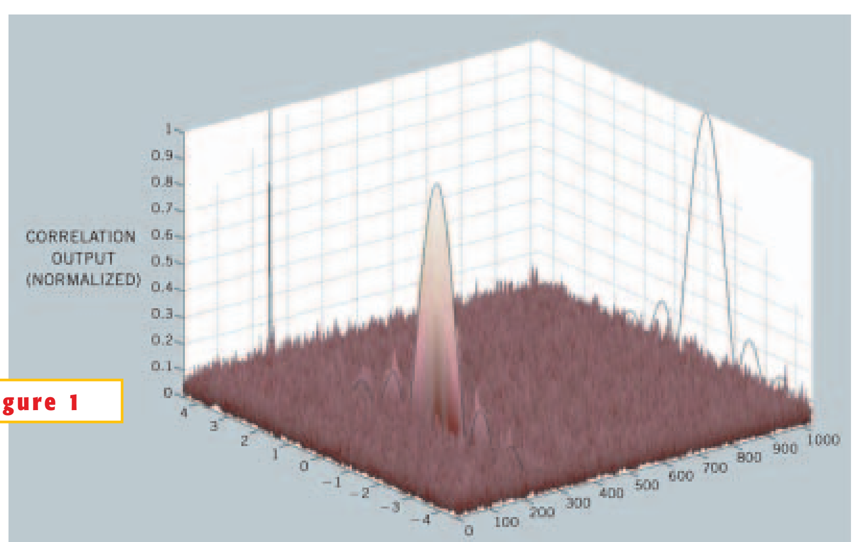
BEING SENSITIVE IN THE 21ST CENTURY

Vendors are focusing on the E-911 locating mandate for cellular phones, which requires that cell-system operators be able to identify with high confidence and accuracy the location of a phone. Thus, improving the basic sensitivity of GPS is perhaps the single biggest story in emerging chip sets. But it does not come without a cost in complexity and bill of materials. Before embarking on that path, you need to consider whether your application needs it, because for many purposes, the basic, outdoor GPS function is insufficient.

Recall how the GPS signal is structured and how a receiver acquires and tracks a number of satellites. Most applications that will in the near future embed the GPS function will use only the 1.575-GHz L1 signal. GPS satellites also transmit the L2 signal in a lower band and with future upgrades will transmit other signals with new coding schemes. All of the satellites transmit on the same frequency with a spread-spectrum signal that each satellite implements by transmitting a 1023-bit, repeating, PRBS (pseudorandom-bit-sequence) code.

The jobs of a GPS receiver are to identify as many GPS signals as possible from the separate satellites and to obtain a precise time of arrival for the start of the code sequence for each one. This code-sequence time is measured relative to the receiver's internal clock. The microwave signal strength itself, as you would expect of a direct-from-satellite signal received on a miniature with little control over antenna location or orientation, is at best very low. With a typical received signal of approximately −130 to −140 dBm, the GPS receiver identifies the signal in the noise by comparing it with the expected PRBS in a correlator. To find an arbitrary signal, the receiver must search by trying all possible codes against the off-air signal. It must also search in a frequency band on either side of the transmitted

Figure 1



A GPS receiver must search for a signal throughout a space defined by code variations on one axis, and Doppler shift on the other (courtesy Global Locate).

frequency (**Figure 1**), because each satellite's signal exhibits a Doppler shift, depending on its orbital position relative to the receiver. Fortunately, in many circumstances, a receiver knows not only what it is looking for, but also roughly where to find it, which greatly speeds the process. Once located, the receiver knows which codes to return to for timing fixes from each visible satellite; you can track them in frequency on successive samples until the satellite is no longer visible.

The correlation and signal-search processes are critical to GPS sensitivity. If you choose to search for a given code in many frequency slots or bins, then each bin can be narrower, exposing the system to a lower noise bandwidth and effectively improving SNR. But you must perform more of these correlations, increasing search time. Alternatively, you can increase sensitivity by using wider bins but performing more correlations at each point and dwelling longer on a given point. In doing so, you integrate the signal over more repetitions, so the noise tends to average out, and the signal accumulates, but search time again increases.

Improving the outcome of this process is at the heart of many of the efforts to produce higher sensitivity GPS systems with the ultimate goal of being able to yield a position fix deep inside a building. The immediate driver for this performance is the E-911 requirement and, network assistance plays a role in this area. A conventional GPS receiver operates in "cold," "warm," or "hot" regimes. In the cold regime, the receiver doesn't

TESTING GPS IS A SPECIALIZED MARKET

At first glance, evaluating and testing GPS functions could not be simpler; a readily available, realistic signal source is present all the time. You need only to place an antenna outside the lab window, and, when you need to evaluate the performance of your design in a mobile environment or in different reception conditions, just head for the car and take your system for ride!

Although this approach tells you whether you have a working GPS-receiver system, it has serious limitations for test and measurement. You can add some degree of rigor to the process by using a receiver of known performance as a so-called golden reference unit and by constantly comparing results against that receiver, but for a more organized approach, you need to consider the available dedicated instrumentation.

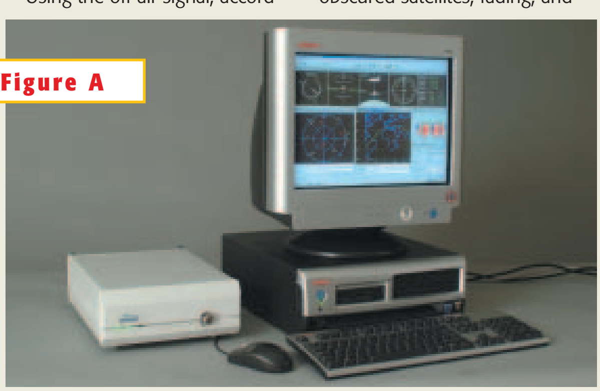
Using the off-air signal, according to Spirent sales manager Mark Wilson, gives you no control over the satellite configuration that your product sees or any other aspect of the signal environment. "All you learn is that product works there and then with those satellites, in that location, at that instant," he says. Spirent produces simulators that you can set up to represent any theoretical or real satellite configuration—using captured almanac data if required for any location, at any past or future time. "It's not unknown, for example, for a software bug to slip through that gives wrong position calculations when the product is taken south of the equator. Without a simulator, unless you go there, you would never know," says Wilson. You can also model satellite failures and errors to evaluate how your product reacts; you can model signal impairments, such as obscured satellites, fading, and multipath; and you can simulate movement of the vehicle in which you will mount the product.

As with any measurement system, Wilson adds, you get consistency and repeatability. In the case of a mobile or airborne system, you can model the mobile environment before building the vehicle or aircraft. Other challenges to your system can include simulation of the effects of jamming or interfering signals. Using an off-air signal is a false economy, Wilson says, because a consistent test environment can greatly reduce development time. You can feed signals to your product in development via a coax feed, giving a known signal level, or as a radiated signal. Prices vary from approximately $16,000 for a single-channel simulator, such as the 4100, to $50,000 for the 12-channel 4500, which also supports the satellite-based accuracy-augmentation systems WAAS (Wide Area Augmentation Service), EGNOS (European Geostationary Navigation Overlay Service), and MSAS (MTSAT Satellite-based Augmentation System) (**Figure A**). Software to configure the instruments runs on an attached PC. Spirent's most recent introduction is the 6560, a multichannel instrument with built-in full scenario generation.

You also have the option of instrumentation from suppliers such as IFR, which offers the single-channel, stand-alone GPS-101 satellite simulator that offers full control over satellite-vehicle and navigation data, Doppler control of signal frequency, and over-air or direct-connect signal interfacing. For more complex scenarios, you can use a digital-signal generator, such as the company's 2029, according to IFR's corporate account manager in Europe, Barry Hack. It lets you generate composite waveforms that represent the complete data a GPS set sees for a full satellite configuration, using software running under standard packages, such as those from MathCad, MatLab, and SystemView.

Alternatively, you can write routines in high-level language to simulate just the effects you want your system to see, or IFR generates waveforms on a custom basis if the library of configurations lacks the required setup. The limitation of this technique is the configuration memory of the signal generator, because you can send as much as 1.5 seconds of GPS data to a receiver, which can repeat. You can also model, albeit for shorter intervals, two signals, such as one GPS and one cellular, to evaluate the performance of multimode products. The mathematical-modeling packages also have numerous third-party GPS features that you can use at baseband frequencies to test and develop correlation and position-computation algorithms.

Figure A



In simulators such as Spirent's STR 4500LT, you can create any configuration of GPS satellites and produce a composite signal for any location.

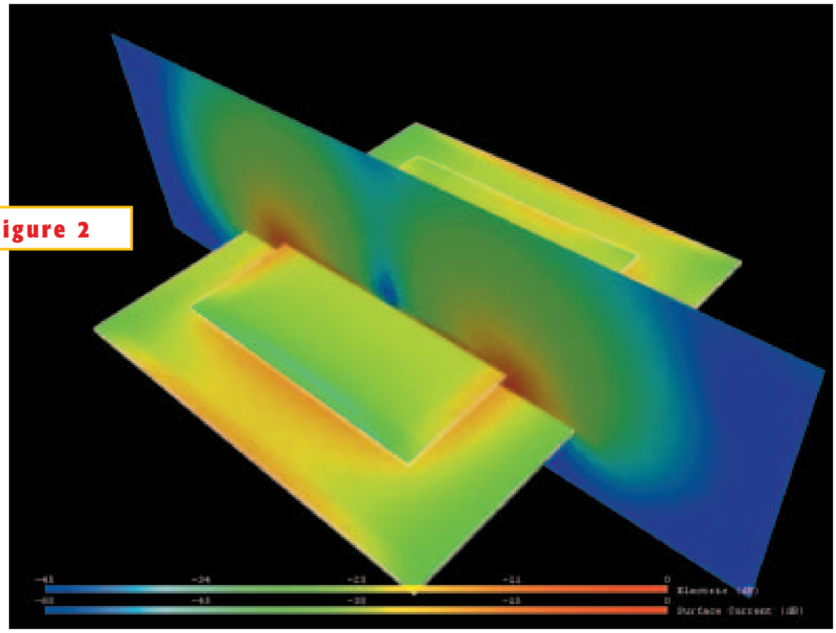


Figure 2

In EDA packages such as Flomerics' MicroStripes, you can model the field patterns around the common GPS patch antenna.

know which satellite data to expect. In the warm one, it has rough almanac data on the satellites it can expect to see in the sky. In the hot regime, it captures ephemeris data, which is transmitted cyclically superimposed on the GPS PRBS code, within the previous two hours, allowing it to precisely predict the signals it sees.

The requisite time a GPS system needs to establish a valid position fix varies accordingly. Within a given cell-phone area, the network can provide satellite ephemeris data, and your receiver always knows where the signal should be, correspondingly reducing your time to fix a position. Or, you can spend longer integrating each bin and still stay within an acceptable overall time to fix location; this approach provides the basis for increased sensitivity in difficult signal conditions. For applications lacking a cell-phone link, you can use the network-broadcast data. You simply have to embed the systems to receive the data as part of the overall system.

The geometrical calculations you must perform to compute position are well-documented, but if your last brush with trigonometry was in high school, they are tough going. To grossly oversimplify, they involve solving time-of-flight measurements from three satellites with known positions for a 2-D fix and four or more satellites for a 3-D fix to yield a position for the receiver, once you convert the time-to-flight data to distance. The math yields a correct fix only if your locating timebase is the same as that on the satellites, which, in general, it is not. Note that the calculation converges to a single-point solution only when it meets that condition, so the algorithm applies a correction factor to the receiver's clock until the system obtains a solution, which locks the local timebase and provides a fix in the same process.

Fortunately, for almost any situation in which you are embedding the GPS function, you can regard all of the software to control the acquisition process and calculate a geometric position as a black box: You buy it along with your choice of chip, module, or IP (intellectual property).

GPS sensitivity is a complex subject. A tendency exists to associate the term "sensitivity" with the front-end performance of the receiver's RF section, and this section is indeed a key element of the overall sensitivity. The most important single parameter in the front-end specification is the noise figure. You try to receive and selectively amplify a signal that at best is buried in the ambient noise, so the less noise the receiver's low-noise amplifier adds, the better.

But you also need to consider how factors such as interfering signals that are close in spectral separation, harmonic relationship, or physical separation affect the performance of the RF section. Many GPS receiver designs use a SAW filter, which you cannot integrate, at or near the ICs' front ends to reject out-of-band signals. Some receiver designs dispense with the SAW filter to reduce parts count, cost, and board area. You need to decide whether this omission compromises the performance in any circumstances that your product design might encounter.

In a GPS system with increased sensitivity, designers can do little to further improve the RF sensitivity, so the improvement in inside-building operation comes from extra processing gain; vendors quote figures of 20, 25, or even 30 dB. As SiRF's technical architect, Greg Turetsky, observes, every 3 dB of increased sensitivity translates to a twofold increase in the time domain, yet constraining that integration time is a designer's challenge. As a product designer importing a GPS function that is to some extent ready-made, you cannot improve many aspects of GPS sensitivity, because other designers have already improved them. You can easily throw away your available GPS sensitivity, however. Poorly matched connections at any point in the signal chain, introducing noise at any point, or simply providing less than the best possible "view of the sky" to your GPS system's antenna can easily lose many decibels of sensitivity.

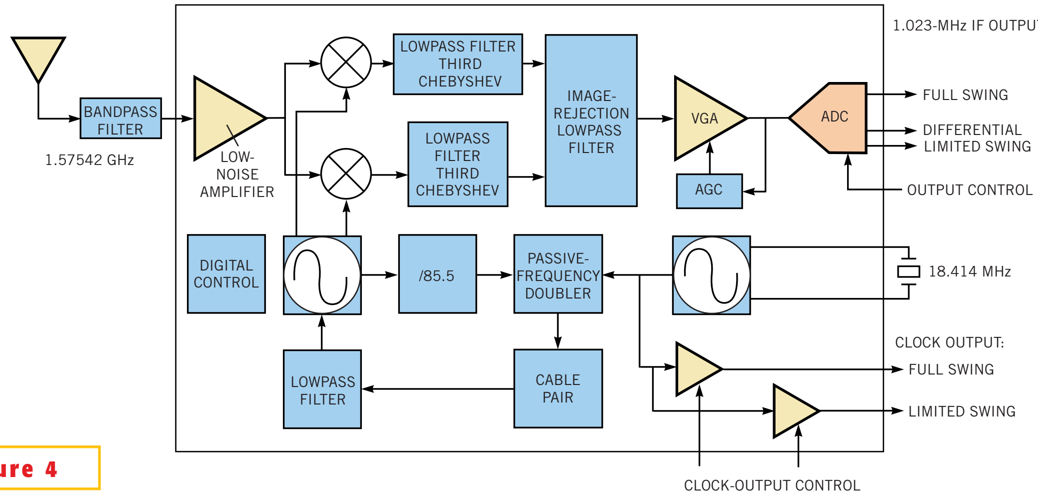
Take, for example, the receiver module manufactured by Finnish company Fastrax. Its module measures 26×26×4.7 mm and consumes 130 mW of power for one-fix/sec operation or 115 mW with the GPS search engine in sleep mode. It requires two independent 2.7V supplies—one for its RF ICs and one for the base-

Figure 3

Garmin's GPS12XL demonstrates the ergonomics of giving the antenna the best possible view of the sky.

band/DSP chips. Its data sheet specifies that you must make the antenna connection to the front-end circuitry with a stripline track and gives detailed track geometry. The company specifies that you can use a passive antenna with its module, but only if the cabling loss between antenna and module is less than 1 dB. Maintaining that loss figure could be a demanding requirement in a volume production run.

Figure 4



Vendors are employing novel receiver architectures for GPS as alternatives to the traditional double-superhet designs; Valence Semiconductor uses this configuration to eliminate external IF and SAW filters.

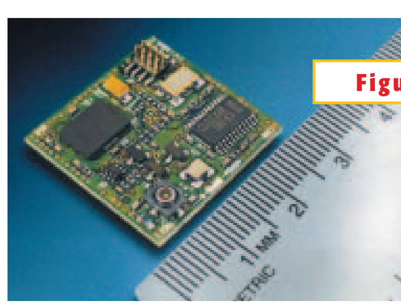
Addressing the many issues that can degrade sensitivity begins with the antenna and goes all the way through the signal path. To preserve your hard-won sensitivity, you need to use high-quality, well-matched connections and best practices in pc-board-track routing. In an application such as automotive navigation or vehicle tracking, it may be relatively simple for you to place an antenna—most likely, a patch configuration—in an advantageous position from which it has a good view of the sky. But in a handheld and often-multifunction product, the less obtrusive you can make the antenna, the greater the consumer appeal. A compact antenna, possibly serving more than one band, becomes attractive in these applications.

EDA vendor Flomerics' published results of antenna-modeling work it performed on typical Bluetooth devices offers some parallels and lessons. The company modeled a proven Bluetooth antenna in free space and in a typical plastic case close to the case material. With the dielectric material of the case in contact with the antenna, the antenna shifted its tuned frequency and degraded the match to the RF circuitry by 6 dB. Flomerics' head of electromagnetic modeling, Rachid Aitmehdi, confirms that it is reasonable to expect that you would see similar effects at 1.6 GHz for GPS compared with 2.4 GHz for Bluetooth.

You cannot place such an antenna within a plastic case and assume that the engineering plastic has no effect; if your design requires such compact designs, you might need to model the effects before committing to a case molding. **Figure 2** shows a typical GPS patch antenna modeled in Flomerics' MicroStripes software. In the case of a handheld product, the effects of a user's hand can be even more important, potentially both shielding the antenna and interfering with its field patterns.

As an illustration, look at the products of companies that have for many years been building GPS devices, such as Garmin's 12XL handheld receiver (**Figure 3**). The internal antenna is under the angled section at the top of the case. The ergonomic design is such that the most natural way to hold the product—in the palm of the hand with the screen uppermost—keeps the top section of the case out of the user's grip and facing the sky. You can demonstrate this point with a simple empirical test, because the Garmin unit can display an arbitrary scale of received-signal strength for each satellite in view. Just laying a finger lightly across the top section of the case almost halves the received-signal-strength indication.

Figure 5



Trimble's Lassen SQ is typical of the physical format of a new generation of modular GPS receiver systems.

HARDWARE AND EMBEDDED APPROACHES

If you ask developers who use GPS for their list of desirable developments, several items appear: lower cost, lower power, greater sensitivity, and reduced physical profile. A smaller profile is well on its way to becoming a nonissue, even if you are using complete modules; numerous companies have recently announced modules that occupy a small physical outline.

Meanwhile, power requirements are also falling. It is customary for vendors to quote power consumption for continuous component operation when producing position fixes once per second, but all of the current-generation products, whether chip sets or modules, offer extensive user control of frequency of operation, plus a range of power-down modes. If your application does not involve measuring rapidly changing positions, then waking the system at infrequent intervals significantly reduces the average power demand. The ephemeris data that the GPS signal acquires, however, is valid for about two hours. Thus, if your system wakes within that interval, it performs a "hot" start and acquires a position within seconds. If you set the interval to be longer, however, you use power less often, but you use more of it because you can do only a "warm" fix, and the system has to run for a longer period.

STMicroelectronics' GPS specialist,

Philip Mattos, points out that you can employ more subtle tricks. The orbital data superimposed on the GPS signal repeats on a cycle of about 30 seconds. The almanac data is good for days or even weeks; once you have it and the correct time, you can ensure that your system wakes just at the right moment to capture a complete cycle of data. It need not wait in switched-on mode for the beginning of the next cycle.

Those in the market for the ultimate integration, which is one of the significant trends in embedded GPS functions, have an IP-based option. For it to be viable, you need total volumes much greater than 100,000 and, more likely, millions, according to Parthus' director of product marketing, Clive de la Fuente. The company's NavStream GPS platform is available both for integration into system-level silicon in host systems or into GPS chip sets by silicon vendors. NavStream products for the cell-phone market offer enhanced sensitivity. Other variants target automotive use and telecommunications-timing sources. For cell phones, it comes as a design for an RF-receiver chip, for fabrication in SiGe (silicon-germanium) BiCMOS, and as a baseband design. The RF front end achieves a noise figure of 2 dB, and the company expects to build the RF function as a separate IC and integrate the baseband structures elsewhere. De la Fuente confirms that the cell-phone manufacturers are looking for an incremental bill-of-materials cost of approximately $5 per terminal to add GPS and that this cost should eventually approach $3.

Cadence-Tality has an agreement with ARC Cores to use a customized ARC microprocessor core as a GPS engine in IP, which Cadence-Tality has yet to make into a product. Neil Hannah, business manager of Cadence Design Foundry, confirms that the company has investigated building GPS systems with off-the-shelf IP. He says the GPS aspect of such designs poses no problems—only the typical issues in IP-based design: importing complex IP, adapting it to a task, and getting to a working chip layout.

TOWARD SINGLE-CHIP GPS

That $5 target figure sounds like the figure numerous design groups cited for a "compete" Bluetooth standard function, which had the same objective of using one silicon die to carry both RF and baseband functional blocks. The market dynamics differ somewhat, however. Bluetooth began as a cable replacement with the underlying assumption that, unless and until vendors reached that low price point, the market would not take off; this goal implied a single-chip design. GPS, on the other hand, is an established function that is migrating downward in cost of implementation, but it is not seeking to compete with or supplant any alternative.

Figure 6

Sarantel combines its Powerhelix ceramic dielectric, helical element antenna with a Sychip GPS receiver module in the antenna base to provide position-output data.

At Cambridge Silicon Radio, a company with the objective of single-chip integration and a resultant low price for Bluetooth, technical director James Collier has no doubt about GPS' ability to fit on one chip. "Once high-volume applications get under way, the market dynamics will become the same as for Bluetooth, and a single-chip solution at a few-dollars price point will inevitably come along," he says. Although the company has no current plans for a GPS chip, Collier has considered that option. It is, Collier says, "perfectly feasible. In fact, in some ways, it should be easier than a Bluetooth design; there is no transmitter section to design." Despite the low-RF-signal levels, Collier also thinks it is feasible to build such a chip in CMOS, although "you would have to use more current to the receiver front end to get the best available noise level than is desirable." In this area, the performance of CMOS is marginal, and an off-chip low-noise transistor amplifier would greatly simplify that task. From his experience with Bluetooth, Collier cautions that, once a market becomes fixated on the single-chip concept, it can become resistant to even a few external components, despite that their cost might be only a few cents.

You can use pure CMOS to build a GPS front end, according to Valence Semiconductor, which recently launched the VS7001 (**Figure 4**). This design incorporates the low-noise amplifier and eliminates all IF and external SAW filters; it achieves a noise figure of 4.5 dB with a power demand of 27 mW at 2.3V. The receiver architecture downconverts directly to a quadrature-differential IF of 1.023 MHz in a quadrature mixer.

A single-chip GPS offering will probably soon emerge. Such a product might also emphasize a division in the embedded-GPS market: Applications such as E-911 cell phones require enhanced sensitivity—either with increased complexity or with network assistance—and other applications require only the basic GPS functions but will be on a separate downward pricing curve.

Do other options for integration exist? If you are building GPS into a product that has another RF channel, vendors may be able to integrate the RF chains of the separate sections of your design into a single section, thereby reducing to one the number of chips to build in more expensive processes, such as BiCMOS or SiGe. For example, a recent introduction from Ashvattha Semiconductor combines GPS, GSM (Global System for Mobile Communications)/GPRS (General Packet Radio Service) and Bluetooth-receiver front-end circuitry on a single chip, using IBM's 0.25-micron SiGe process. The company expects samples to become available this year. Semiconductor vendors are well into producing supporting products for such mixed-function designs. For example, Consumer Microcircuits' CMX882 audio and signaling processor for portable-radio formats also supports the GPS-location-data type, anticipating that low-cost products such as point-to-point, unlicensed, two-way radios will soon include GPS-location functions.

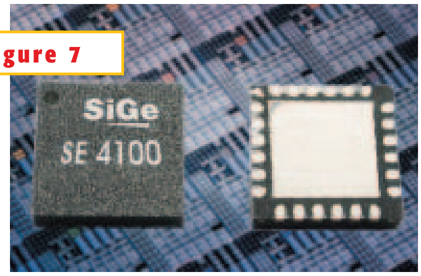
STMicroelectronics plans to soon introduce a chip-set upgrade of its ST20-core-based baseband chips, the GP6 and GP7. Their new baseband part will offer more integration between the DSP engine on the chip and the GPS timebase, reducing the time it takes to fix a location and providing more detailed power control during the GPS-acquisition cycle. ST matches its baseband processors with its STP5610 RF chip. ST's Mattos states that overall power demand greatly depends on memory configuration, and the best way to approach this problem is to run the code from on-chip, masked ROM.

GPS silicon also comes from European silicon vendors Infineon and Xemics, both of which license IP from Trimble; Trimble has recently introduced its Lassen SQ module, which measures 26×26×6 mm and uses 100 mW from 3.3V (**Figure 5**). Trimble also notes that many of its customers do not want to design their own RF device and, therefore, opt for a module-based approach. The company offers such options, ranging from a full module through a host-based modular approach, to a chip set and IP. Xemics manufactures Trimble's FirstGPS architecture as the XE1610 two-chip set, which consumes 25 mW at 2.7V in a host-based system; the chips are a double-conversion receiver and an eight-channel correlator. At Infineon, the Trimble IP becomes the PMB 2500 and 3330 chip set. Other currently available small-format modules include Tyco's A1025 board, which the company built with ST's RF chip and ST20GP7 silicon, and a new introduction from RF Micro Devices, RF8000. This module comes as a 38×38-mm pc board and targets markets such as auto navigation and asset tracking. It requires an active antenna with 30-dB gain.

Start-up Nemerix is also due to announce a chip set with current usage of 7.5 mA for the complete RF chip and less than 1 mA at 2.5V for a baseband processor with 64 correlators. Nemerix has acquired much of the IP and personnel of T-Chip, a company that failed some months ago, and whose front-end RF chips and designs were parts of a number of GPS systems. With a suitable choice of low-power microprocessor, Nemerix anticipates offering a complete PVT (position/velocity/time) system in 2003 with a current requirement of less than 20 mA. Another vendor, u-Blox, offers a range of board- and module-level products, the smallest of which is its TIM "macrocomponent," a 1×1-in. (2.5×2.5-cm) module for fully automatic placement in high-volume manufacturing, using the SiRFstar II chip set.

SiRF is one of the major sources of chip sets; many module vendors' products, such as those of Sychip, Falcom, Leadtek, and Royaltek, use SiRF's products. The company's baseband chips include an ARM7 core and provide sufficient headroom to support additional applications; a port to Nucleus and other RTOSs address real-time issues. Sequoia Technology, SiRF's agent in the United Kingdom, reports that a primary factor pushing users to a chip set rather than a module, apart from the volume and pricing arguments, is the need for OEMs to customize the software. In other words, Sequoia states, "If you want only standard PVT data, the most likely route is a module." Sequoia confirms that the biggest areas of difficulty are integration, system design, and RF design in the face of interactions with other system functions. If you are using a reference design, the company says, you must exactly follow it, using the exact components it specifies, because the type of component substitutions that are often acceptable in other situations can seriously degrade performance with such low signal levels.

Figure 7



Low-profile leadless packages with good RF performance, such as SiGe Semiconductor's PointCharger SE4100 receiver chip, are becoming the norm in GPS-chip introductions.

Vendors confirmed that, in practice, the selection and correct use of the antenna and front-end lies at the heart of achieving good GPS performance (**references 1** and **2**). Special-purpose antennas are available from multiple sources; companies such as Sarantel and Centurion offer novel approaches (**Figure 6**). From the point of view of an antenna designer, the performance of systems with nominally similar specifications can vary considerably. Sarantel's marketing director, Todd Urquhart, observes that big differences exist among systems in acquisition and tracking performance. Some designs quickly acquire and track low-level signals, whereas others need a strong signal to acquire lock but then maintain lock as the signal degrades down many decibels. He states that you must evaluate the actual performance characteristics of the complete system—from antenna to processor output—against your product's needs.

SiGe Semiconductor is marketing a radio chip that uses its SiGe CMOS process to provide low power with low noise factor; the company claims that the noise factor of its internal low-noise amplifier, which integrates IF filtering, is as low as 1.3 dB (**Figure 7**). This approach allows you to use a passive antenna, and the chip uses 10 mA of supply current. Geoff Haynes, marketing manager at SiGe, says that the chip is easy to use because it shares its heritage with the ST product line and it readily interfaces to the ST product, although it can work with any baseband chip. You can also integrate more logic functions because the process is basically CMOS, and the company is considering putting the correlation circuitry onto a radio chip to make a single-chip device for host-based designs.

NEC Compound Semiconductor Devices uses a 30-GHz bipolar process to build the recently introduced microprocessorB1007K, combining a low-noise amplifier, a double-conversion downconverter, an oscillator, and a synthesizer PLL on one chip. The amplifier's noise figure is less than 3 dB, and total power consumption is 25 mA from a 3V supply. Together with NEC's uPD77533, which it developed with SnapTrack, this chip forms an offering that is compatible with SnapTrack's wireless assisted-GPS system for cell-phone location, which aims for −152-dBm sensitivity for in-building location, along with a time to fix location of 3 to 6 seconds. The SnapTrack system employs yet another variation that E-911 developments introduced to the enhanced-sensitivity scene. It touts central-server-based location calculations, meaning that when someone makes an emergency call, the terminal sends unprocessed GPS data over the cellular link. This technique reduces the burden on the cell-phone host processor; allows you to use a suite of sophisticated algorithms in calculating location; and allows you to use cell-geography data in fixing a location, which the network then adds to the emergency-call information. The Web contains a vast amount of information about E-911 and location-based services in general. For examples, visit the Location Forum (www.locationforum.org) or the Institute of Navigation (www.ion.org).

You can also call on the benefits of deep-submicron technology as a route to increased system sensitivity, and Global Locate's products are the prime example of this approach. The company employs many more correlators in its designs than a conventional scheme uses. With an architecture that allows it to build a correlator block in a very small area on an advanced-CMOS process, the company designs as many as 16,000 correlators onto one chip. With these correlators as a resource, the architecture can search small frequency intervals, limit noise, and allocate banks of correlators to a search; this approach effectively compresses long integrations to practical limits. The company claims to have demonstrated acquiring satellites and calculating locations in extreme situations, such as within the trunk of a car or inside metal enclosures within buildings. Such an architecture has power implications. For example, does running all those correlators imply a much more power-hungry chip set? Global Locate says it does not, asserting that, although you have to power all the correlators, they are on for less time before you fix a location, and the overall power consumption is comparable with that of other approaches.

Other architectures use the same approach but to a smaller extent. The Parthus IP, for example, uses a scalable system in which each receiver channel uses 16, 32, or 64 correlators. An FFT-based technique searches in frequency; you can allocate 8-, 16-, 32-, or 64-point FFTs to this task, thus using more resources to effectively shorten acquisition times or increasing integration or dwelling time on each signal location.

In interpreting published power figures, you must also determine whether the figures are describing a host-based or a stand-alone system; whether the power figure assumes the use of host-system memory and, if it does not, whether a working system would require any external memory; and whether the milliamp total includes that memory's power demand.□

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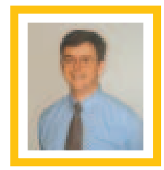

You can reach EDN Europe *Editor Graham Prophet at +44 118 935 1650, fax +44 118 935 1670, e-mail gprophet@reedbusiness.com.*

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