WITH ITS ACCUSTOMED FACILITY FOR, ALMOST IMPERCEPTIBLY, TRANSFORMING THE MIRACULOUS INTO THE COMMONPLACE, OUR INDUSTRY HAS MADE SATELLITE NAVIGATION PART OF THE CURRENCY OF EVERYDAY LIFE. WITH A RANGE OF OPTIONS FOR BOARDS, MODULES OR CHIPS, YOU'LL BE ABLE TO DROP-IN A LOCATION FUNCTION TO ALMOST ANY PRODUCT YOU CAN IMAGINE NEEDING IT.

Where in the world?

Embedded GPS heads for high volume

HIGH STREET GADGET SHOPS stock hand-held units that will locate the backpacker or hiker to within a few metres, and we barely pause to consider how remarkable it is that a unit that will decode precision timing signals from a network of orbiting satellites, and receive those signals on a thumb-sized antenna, can be ours for prices that start around 100 euro. Applications are proliferating for embedded GPS systems, many having little to do with the underlying navigation function.

Many of the suggested applications fall into the generic category of "position-aware" devices or services, and to some extent the evaluation by the market awaits the widespread deployment of the (thus far, elusive) multifunction computing-and-communicating device. The all-purpose, cellular-phone-equipped PDA may still be just over the horizon, but it would be a natural platform to host services such as position-aware guidance to restaurants, cash dispensers, shops and to fetch taxis, and the like. More straightforward combinations of cellphone and GPS are already in development. In the USA, the impe-

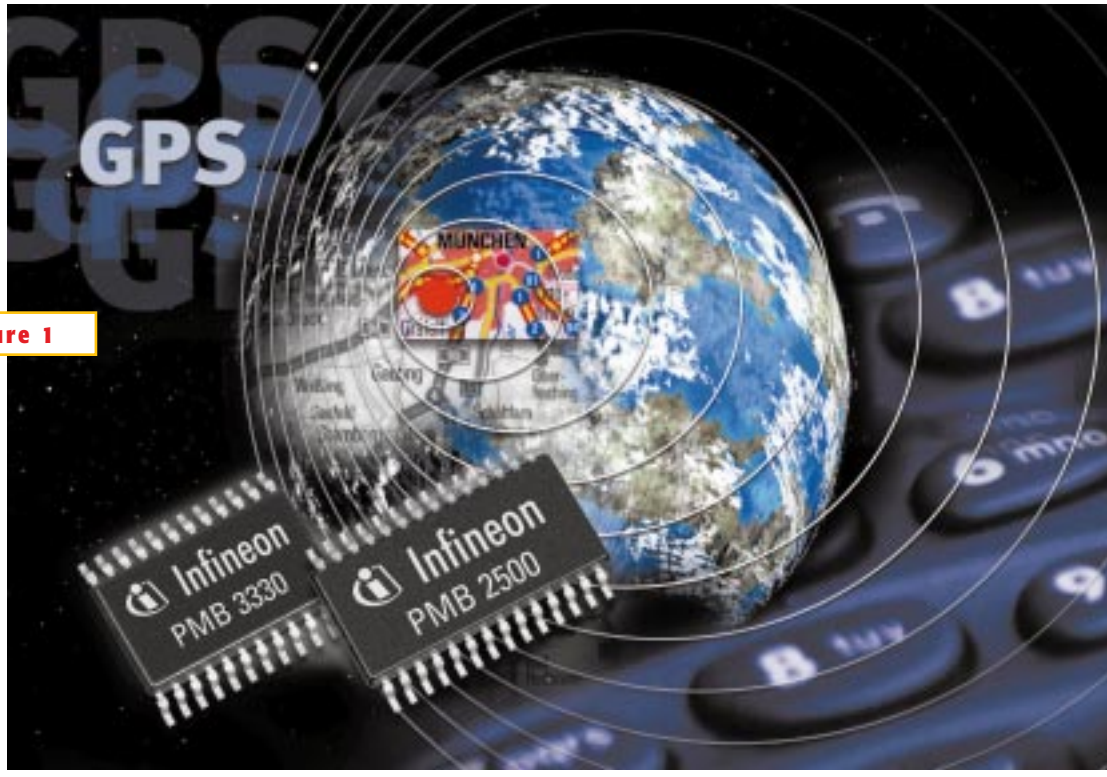


Figure 1

Infineon's 2-chip set has very low power levels in continuous operation and incorporates IP from Trimble

tus is being provided by the E(Enhanced)-911 requirement by the Federal Communications Commission, that by October this year network operators must have in place a viable system by which an emergency call placed from a cellphone must report the location of that cellphone, to within a specified accuracy and with a specified reliability.

The USA, as owner of the most frequently-used constellation of satellites, also gave a significant boost to the proliferation of embedded GPS when, in the Spring of 2000, the feature known as Selective Availability was turned off. This added an error component to the GPS signal and held back, in effect a reserve of accuracy back to be made available at the discretion of the US Government. On May 1st 2000, it was permanently turned off, instantly making an unaugmented civil receiver, not using differential techniques, about an order of magnitude more accurate, typically providing fixes to under 10m. From 2003, new satellites are planned to start transmitting two further frequencies. One is to provide a similar service to the current signal and allow a measure of frequency diversity to be used to consolidate reception. The second new frequency is intended to be used for aeronautical navigation.

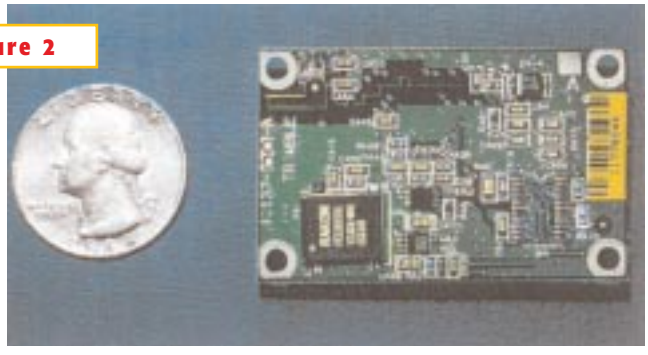
TRACKING ASSETS - OF ALL TYPES

Lacking that explicit motivation of E-911(there is a broadly comparable proposal to the European Commission, but the time scale is about two years behind the US schedule), there are nevertheless proposals in the European market to evaluate the GPS/GSM pairing. Parents who have issued their children with cellphones for safety reasons may appreciate a proposal by Siemens. Immediately tagged the "kid locator", but officially known as the Leonie Project, the suggestion is for a GSM phone that reports its position to a call centre, which will then forward that position information to a parents who have suitably identified themselves. Siemens is to evaluate the concept in a trial with a group of German families, and in collaboration with Gap AG, a company that specialises in embedding location-determining functions, such as fleet and asset tracking.

With many of the newer ideas still poised for growth, the automotive market, and car navigation systems in particular, is today's area of real growth, as OEM navigation systems steadily migrate down the car model hierarchy, away from being a luxury-class-only option. ST Microelectronics has an established presence in this market and for some time has sold a two-chip set of the STB 5600 receiver and the 12-channel ST20GP6 baseband chip. ST Marketing Manager Steve Sutton acknowledges that the chip set, being designed for the car navigation market and dating from 1998, is no longer among the lowest in power demand, but that it remains competitive in performance and integration. ST is preparing a major revision of its chip set for later in 2001, no details being available at present: in the interim, an upgrade is being introduced replacing the GP6 baseband chip with the GP7. This, Sutton says, incorporates some minor changes to the DSP hardware. For example, the GP6 could not read the master timebase register and could not be used in a low-power, infrequent-fix mode due to the need to re-establish real time - this is being changed so that the GP7 will be able to operate at, say, one fix/minute for an average current draw of 8 mA. The new chip set will, "take a new approach", he adds. When might GPS become an item of IP to be routinely added to system-on-chip designs? Sutton guesses at two to three years hence.

If you are contemplating embedding the GPS function within some other system, you are faced with a considerable array of options. There are circuit modules from board level down to multi-chip modules; in general, with these it is intended that you embedded them as complete functioning units that output processed data (position, velocity, time etc.), although there are variants. There are chip-level solutions, in the form of complete and highly-integrated chip sets, and of standard DSP and microprocessor architectures provided with suitable algorithms. There are also, just beginning to emerge (for example, from Motorola, see below), single-chip solutions.

Figure 2



Trimble's embeddable module employs its First Architecture to simplify host-processor operation

INTEGRATION PARTITIONING

In the emergence of single-chip solutions there is something of a parallel with the work being carried out to develop Bluetooth devices: not in a parametric sense, because the problem is significantly different. The GPS signal, although lower in frequency (L-band as opposed to 2.4 GHz) is at a very low level, demanding receiver sensitivities in the -170 dBW range. The similarity exists in the sense that producing a one-chip solution involves combining extensive logic on the same substrate as very sensitive RF circuitry (difficult to design), with possible compromises in the specification of the process used (e.g. a BiCMOS process may be required for the RF sec-

AT A GLANCE

- You can embed GPS functionality at board, module, chipset or IP level
- High volume applications with tightly embedded GPS are just emerging
- Novel concepts for 'position-aware' devices abound; few are yet proven
- The ideal partitioning of RF, DSP and µP for your system may not be obvious
- GPS functional block conveniently return usable ASCII data
- Watch for more highly integrated offerings in the near future

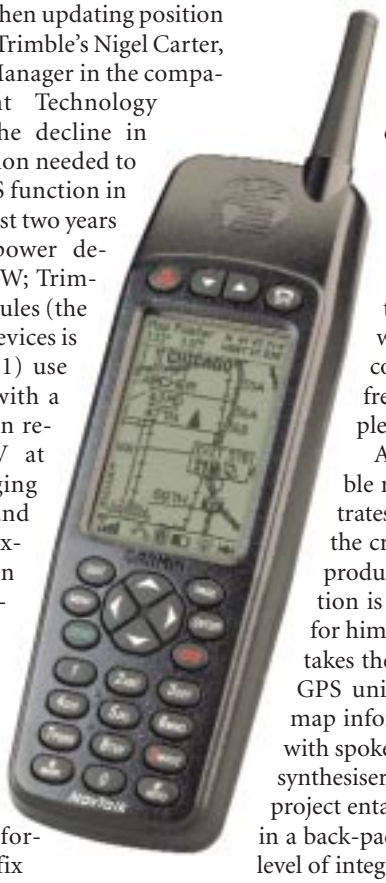
tions, which will not be as economic for the logic portion of the device). Just as with Bluetooth, and depending very much on the projected volumes of the product you propose to build, you may face a complex trade-off analysis between board area, chipset cost, development cost (and time), in the light of partitioning decisions you'll make that will in turn depend on the other resources available within your product.

Deriving usable information from the GPS signal is a three stage process; an RF front end to recover the signal, usually to some IF, from which it is digitised; digital signal processing to extract the raw data (time, almanac, and ephemeris, etc.); and the arithmetic processing to compute position and derive other parameters such as velocity. The latter is effectively an extensive exercise in spherical trigonometry. In passing, you can note that a benefit of the relative maturity of the GPS system itself is that the expected form of the output data is highly usable; often more than one format is presented, but invariably the NMEA (National Marine Electronics Association) format is included. Data is output as a straightforward ASCII character stream that you can use without further processing.

The arithmetic burden is variously estimated at somewhere between 2 and 10 MIPS, depending on the MIPS in question. Not long ago, that was a significant amount of processing power to find, but in the context of a design for, say, the baseband processing of a third-generation mobile handset it is not particularly demanding. Therefore, a host-based solution for the computation is an option. More of a concern is the real-time nature of the task; frequent interrupts are generated that must be serviced within a tight time window; if the CPU and its RTOS does not respond to the interrupts in time, the chip set will lose track of the satellites it is following. It was to deal with this issue that Trimble designed its First-GPS architecture; First stands for "flexible integration of real-time tasks", and permits a delay of up to 5 sec on servicing an interrupt by the host µP, easing the problem of handing off computation to the host.

Trimble is a supplier of GPS devices at all levels from large-scale high accuracy systems, through hand-held and in-vehicle units, modules and chips - and IP (Intellectual Property). In the First architecture, it will supply the 12-channel module with RF section and DSP, and a library of software routines that run on the host processor. Currently supported as hosts are the ARM 7 and 9 cores, and the Hitachi SH 3 and 4; operating systems supported are VxWorks and Windows CE. The 3.3V module measures 30 × 60 mm and will use 30 - 50 mW when updating position once per second. Trimble's Nigel Carter, European Sales Manager in the company's Component Technology Group, charts the decline in power consumption needed to carry out the GPS function in recent months. Just two years ago, a typical power demand was 900 mW; Trimble's current modules (the first of the First devices is due in April 2001) use 600 mW at 5V, with a low power version requiring 183 mV at 3.3V. In managing power demand and looking to maximise battery life in hand-held products, Carter notes that critical metrics become total energy measurements, such as the "energy to a (position) fix". Performance to reach a fix is more often quoted in terms of time; for example, for the forthcoming modules, 90 to 120 sec from a "cold" (no stored data) start, to 8 - 10 sec for a "hot" start where the chip set retains timing, almanac and ephemeris data for the satellites in view. The more usual "warm" start, where satellite almanac data, time and a rough position is known, takes under 40 sec. However, if your critical resource is battery power, you may need to translate specifications into energy - especially if your product will be operating in "fix-on-demand" mode.

Figure 3



Garmin has recently introduced a combined navigation platform and GSM phone for the European market; this is the AMPS version of the US market

Trimble is often associated with hand-held and portable GPS systems, as are suppliers such as Garmin and Magellan, both of which also sell at the embedded level. Garmin's latest OEM engine is the Garmin 25, a board-level design measuring 1.83 × 2.75 × 0.45 in. Garmin has also combined the cellphone with GPS, although in a quite different sense to the embedded function described above, as it is a full navigation instrument and a cellphone; the Navtalk has just been released in a GSM version for the European market. The websites of these companies contain good primer and refresher reading on the principles of GPS navigation.

A customer's tale that Trimble relates on its web site illustrates that there is great scope for the creation of useful integrated products; the gentleman in question is blind, and has engineered for himself a portable package that takes the output from a hand-held GPS unit, correlates it with street map information and provides him with spoken output through a speech synthesiser. To achieve this as a one-of project entails carrying a notebook PC in a back-pack: a clear case for a higher level of integration!

Trimble has worked closely with Infineon to develop its silicon, and its IP is incorporated in the new chip set available from Infineon as the 12-channel PMB 2500 and PMB 3300, Figure A (sampling now). The baseband chip is in standard CMOS and consumes 8 mW in full operation; the RF chip is a bipolar part and uses 20 mW. Product Marketing Manager Christian Joas notes that there are further power-saving modes available, and with wireless-assisted GPS architectures, the option to reduce start up power still further. Joas also anticipates the emergence of novel applications through integration of GPS with cellphones: for instance, location sensitive billing, when the mobile service provider makes it attractive to use the mo-

bile as a home phone, at a fixed-line tariff, when the phone detects that it is in the vicinity of the home address.

Wireless assistance to GPS

In the USA, the E-911 directive does not specify how the location information is to be determined: the options reduce to an embedded GPS receiver in the handset, or some form of measurement based on the location and geometry of the cell sites local to the origin of the distress call. In practice, most proposals involve a combination of techniques, and to a certain extent they are complementary. GPS signals are unlikely to be available within buildings, but in built-up areas there will be a greater concentration of cell sites from which to perform triangulation measurements. Away from urban areas, the cell sites will be more dispersed, but incidents are more likely to be outdoors and the GPS signal available for a normal fix to be obtained. Also left open is the question of where the detail calculation should be done. If location information is not a feature of the mobile unit, but is only required in an emergency, then one approach is to route unprocessed data along with the emergency call, and leave the processing burden to a central facility. Although driven by the emergency location function, the techniques developed seem set to be employed far beyond. San Diego-based SnapTrack is one vendor that has been active in developing these strategies and has licensed its Wireless Assisted GPS techniques to a number of semiconductor and systems house, including Motorola and Texas Instruments.

AWAY FROM URBAN AREAS, THE CELL SITES WILL BE MORE DISPERSED, BUT INCIDENTS ARE MORE LIKELY TO BE OUTDOORS AND THE GPS SIGNAL AVAILABLE FOR A NORMAL FIX TO BE OBTAINED.

SnapTrack has just announced its SnapCore GPS baseband processing product, offering three distinct modes of location, that are designed to enhance GPS operation in difficult environments such as city centres and even within buildings. SnapCore combines algorithms to reduce the effects of multipath propagation in the GPS signals, with hardware such as a massively parallel GPS processing engine, and can be used in three modes. The first is server-based, with calculations being carried out on a fixed server using data gathered by a GPS receiver in the mobile unit. The second is a "thin server" mode, with the calculations carried out in the handset with assistance from the fixed server; and the third is a standard autonomous GPS mode. Using its algorithms, even in the autonomous mode, will still improve the effective signal sensitivity by 10 - 20 dB over conventional GPS, Snaptrack says, with faster time-to-first-fix; cold start times in the 3 - 5 sec range are claimed when the server mode is employed to give the maximum processing assistance. The hardware part of SnapCore can be supplied as IP for integration into ASIC solutions.

INTEGRATED RF AND CORRELATION

One company that has opted for the single-chip option is Motorola, with its

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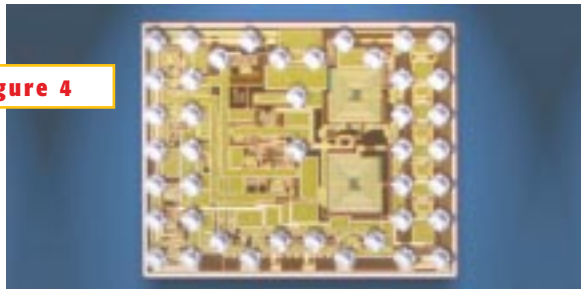
recent introduction of the Oncore MG2000. Once again, this is a host-based approach, with the single chip integrating a dual-down-conversion RF section and a 12-channel correlator. Power consumption in continuous one fix/sec operation is 65 mW, and the dual-conversion architecture is also said to give good immunity to jamming and interference. The RF section integrates the main VCO and multi-mode synthesiser to further reduce component count. The chip is packaged in an 8 × 8 mm BGA and is built in a BiCMOS process.

48-CHANNEL BOARD

The majority of the devices in the market, as might be judged from the foregoing, are 12-channel chip sets: that is, they can track the data streams from that number of satellites, if visible to them. An exception is Septentrio: this Belgian company was formed as a spin-off from the IMEC research organisation in Leuven, Belgium in 1999, and focuses on GPS silicon specifically for high-performance navigation. Its first chip, the GPS-Glonass Receiver Core GReCo 1, was indeed a 12-channel part, but one with a dual-frequency capability to allow it to track both GPS and the Russian Glonass satellite constellations. One difference was that GReCo 1 had the facility to cascade two parts to make a 24-channel set; the company's first chip intended for production, the GReCo 1A, is a 48-channel device, again with the dual frequency capability. GReCo is a baseband processor, and requires a third-party RF front end (or front-ends). Due in prototype form before mid-year, with production in the third quarter, is a full 48-channel receiver board. The dual frequency facility also enables a single board to make use of broadcast GPS augmentation signals in the EGNOS (European Geostationary Navigation Overlay System) and WAAS (Wide-Area Augmentation System) programs - these are, in effect, broadcast correction factors (on a separate frequency) that allow the GPS fix to be further refined for high-end applications. In this design all baseband processing is done on-chip; there is a 486-class core to do the arithmetic calculations, so the output is the standard NMEA data in all its variations.

Figure 4



The Silicon-Germanium RF chip used in IBM 's 12-channel GPS module that measures 66 × 40 × 4.5 mm, features rapid time-to-first-fix and runs on a 3.3V supply

Septentrio has recently published a note (on the company's web site, see **For More Information**) describing how the accuracy of its chip set allowed it to identify a systematic error in the data transmitted from one of the WAAS satellites; two particular symbols at the end of a data frame were always transmitted as zeros. Septentrio's note comments that the error was particularly hard to see because the Viterbi coding of the data meant that the receiver invariably recovered the real data; the problem only manifested itself as an anomalous repeating bit-error-rate feature.

A further newcomer to the GPS market is Lucent spin-off SyChip. SyChip's GPS2020 is a complete GPS engine in a module 11 × 14 × 3.5 mm, based on SiRF's SiRFStarII technology with a DSP and an ARM core on-board. A 3V module, it is specified to use 154 mA in tracking state and has been specifically designed for integration into cellphones for embedded location functions such as the FCC E-911.

In general, all of the major silicon suppliers that have DSP capability have more-or-less active efforts to provide chipset-level GPS solutions. Those that also have mixed signal and RF capability can be expected to be at least investigating routes to the "single-chip solution" - whatever partitioning of major functions that happens to represent in any given case. In the conversations that led up to this article, there were hints of work-in-progress at Texas Instruments, Philips and Toshiba, amongst others. □

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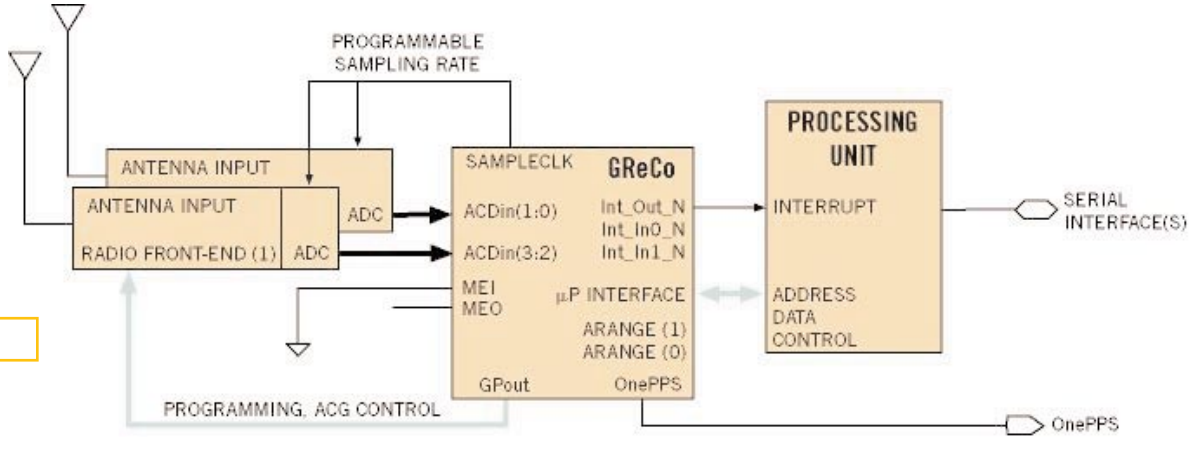
Figure 5



With the dual-frequency capability of the GreCo chip, you need twin RF front-end blocks