

Embedded Modems Enable Appliances to Communicate with Distant Hosts via the Internet

by Rick Blessington
Software & Systems Technology Division*

INTRODUCTION

Today's smart appliances do much more than shut off the dryer when the clothes are dry or display a new photograph when one has been shot. For example: they provide status information indicating when a vending machine needs to be filled or a drop box emptied; they run remote diagnostics when needed, and automatically upgrade their settings and download software upgrades to stay current; they schedule and request maintenance to avoid malfunctions; they add intelligence to the appliances that harbor them.

Any equipment that does not require an embedded PC, but relies on data or fax to communicate with a remote host, is likely to require an embedded modem. Internet appliances designed solely to provide information via email or the Web need embedded modems to provide the communications link to the Internet. Set-top boxes for interactive cable and satellite television require embedded modems to communicate billing information, interactive programming, pay-per-view, and home shopping orders. Appliances and handheld computers (or PDAs) become much more useful when they can link to remote hosts.

The Handspring Visor™, for example, can maintain schedules and calendars, contact lists and telephone directories, expense logs and time sheets, stock portfolios, and sports team statistics. To be completely useful, however, the information must be both current and identical to the information in the user's computer, company database, and administrative assistant's office tools and paper files. With its Springboard modem, from card access, which uses an Analog Devices embedded modem chipset, the Visor can be connected to a telephone line and automatically update both itself and its user's host computer. In this way, the Visor becomes the accurate, timely, and functional information appliance its users need. Its embedded modem makes all of these capabilities possible by linking it to a remote host without loading the PDA, because of the Analog Devices DSP used in the embedded modem.

The Visor required its modem to have low power, small size, high reliability, standalone form factor, and ease of Internet interfacing. The resulting Springboard modem fits entirely inside the Visor package, operates from the Visor's existing batteries without significantly shortening their life, and automatically connects to

the Internet when connected to a telephone line. It makes the Visor an extension of its user's computer network.

Embedded Modem Components

Embedded modems contain a data pump, DAA (data access arrangement), and modem code. They may or may not include a controller, Internet protocol stack, and SDRAM. The number of chips depends on the application requirements, including the need for any additional functions. They connect to telephone lines, and include all the necessary hardware and software.

A *data pump* includes a processor (DSP) that translates data to a standard protocol (fax or Internet), at a specific bit rate, such as V.32, V.34, V.90, employing *modem code*. A *DAA* provides the physical and software interface to a POTS (plain old telephone service) line. A *silicon DAA* performs this function without external codecs, relays, optocouplers, and transformers. An *Internet protocol (IP) stack* implements the Internet protocols (such as PPP, TCP, HTTP, POP3, FTP, etc.) on the modem's DSP. This permits file downloads, standard Web-page hosting, and email capability for the device to which the modem is *connected without the use of a PC, microcontroller, or other processor*. Thus the DSP executes both the modem code and the IP stack.

Modem Architecture Trade-Offs

Embedded modems may be either controller-based (parallel) or operate without a controller. In both cases they need a fixed-point DSP data pump and DAA. The modem code can either run on the DSP data pump, or on a Pentium® or RISC processor (for host-based or software modems), or on a multifunction programmable DSP (such as an ADSP-218x). For comparison, modem architectures may be divided into two host-based classes (with and without on-board processing), and two standalone classes (microcontroller- and DSP-based). Their characteristics and advantages/disadvantages are compared in Table I.

The *controller-based designs* work without hosts, so they don't care about operating systems or whether the host has crashed. This standalone approach assures greater redundancy, since the modem operates independently of the host computer and its operating system. Their downside is they need a microcontroller and its memory, as well as DSP memory, to run the supervisory code. This entails additional parts count, real estate and power, and consequently added cost and risk. Also, their modem software is usually hard-coded and consequently not upgradeable.

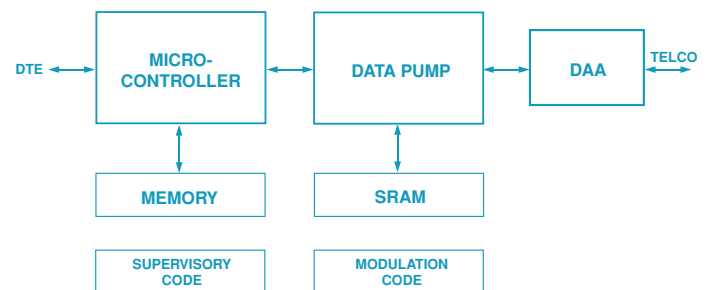


Figure 1. Controller-based modem.

*For more details, contact willie.waldmann@analog.com or
ajai.gambhir@analog.com.

Table I. Modem Architecture Overview

Type Trade-Offs (+ and -)	Controller-Based— Parallel	Controllerless—Serial (or Winmodem)	Software—Host-Based	Multifunction Programmable—DSP-Based
Requires Host	No	Yes	Yes	No
Redundancy	Best. Stays alive when host crashes.	None. Relies on host.	None. Relies on host.	Best. Stays alive when host crashes.
Upgradeability	None	Depends on host.	Least	Best
Cost	Most	Moderate	Lowest	Moderate
Downside(s)	Needs microcontroller with memory to run supervisory code.	Needs host to run supervisory code. Data pump still needs memory.	Requires more power. Limited to Pentium and Windows applications.	Ongoing price competition with host-PC pricing erosion.
Uniqueness	Operating-system neutral	Memory resides on host.	Software only. Supervisory code and DSP runs on host.	No host or operating system dependencies. Integrated controller and data pump.

Controllerless (software-controlled, or win-) modems, offer lower cost, real estate, and power since the memory resides on the PC and no microcontroller (nor memory for it) is needed. However, they require a PC to run the supervisory code, so these winmodems are heavily dependent on the PC operating system. Consequently, uptime of the PC host is important to their operation, and they are affected by the typical PC install/support issues. Their performance suffers when the host is heavily loaded with other jobs. They still require a data pump with memory. Code upgrades and diagnostics are dependent on the reliability of the PC host, with no redundancy. Software upgrades are limited by the modem's fixed amount of memory.

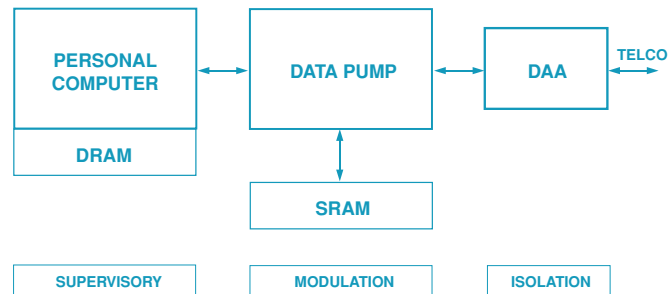


Figure 2. Controllerless modem (ISA and PCI).

Software, host-based or soft-modems operate without a DSP or microcontroller, since their supervisory and data pump code runs on the PC host. This approach has been promoted by PC processor manufacturers to take advantage of the “free” unused MIPS of the increasingly more powerful host processors, since the modems do not significantly load the host, but at the same time they help justify the need to upgrade to it. These modems are very low cost because they use the existing host. On the other hand, if the cost of upgrading to a sufficiently fast host to handle the modem functions is taken into consideration, the result will far surpass the cost of either a controller-based or controllerless design. Host-based modems are also heavily dependent on their host's reliability, as well as concurrency issues encountered when running many operations simultaneously. In addition, this approach typically limits the modem to communicating only Windows and Pentium applications, limiting the “free” MIPS (millions of instructions per second) on the host to particular functions. The power drain

and cost-per-MIPS for a Pentium is much higher than for a DSP-based design, so the power used by the board must be taken into account, even if the cost is not. The cost of modem IP must still be paid, so the concept of “free” is not accurate.

A multifunction DSP-based embedded modem incorporates a programmable DSP, such as an ADSP-218x. By integrating the controller, memory, and data pump on a single chip, real estate (board space), cost, and power are reduced. No separate microcontroller or associated memory is required. A software-based UART is used, further reducing the hardware cost, real estate, and power. The standalone design operates independently of the host and operating system, offering redundancy and remote software upgradeability via the included FLASH memory. The codec adds international capabilities, accommodating country-specific parameters. Three modulation speeds are possible, each using the same components but a different Internet protocol (IP): up to 14.4 kbps, up to 33.6 kbps and up to 56 kbps.

The Analog Devices programmable DSP-based embedded modems capture the advantages of all the above approaches with few of their disadvantages. Even as PC prices fall while host PC performance increases, embedded DSP MIPS will always remain less expensive, more reliable, and independent of host processing.

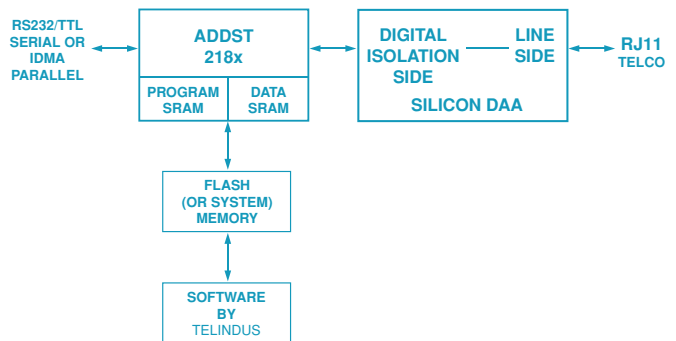


Figure 3. Multifunction DSP-based modem.

All of the alternatives, except the host-based design, have the disadvantage of facing competition with continuing PC host price erosion. As the PC host price decreases relative to that of the standalone modem, host-based modems become more cost effective. The trade-off between redundancy and cost, however, will continue.

DAA Approaches

The DAA (data access arrangement) supports country-specific Call Progress and Caller ID, which must be specified for each country. Different DAA components are available to support worldwide operation of a subset of countries. The DAA handles TIP and RING telephone connections—and includes a second codec for nonpowered lines, such as leased lines and wireless. Multiple DAAs can be supported by a single DSP for use in multi-line applications.

The state-of-the-art international silicon DAA with integral codec eliminates the cost and real estate of transformers, optoisolators, relays, and hybrids. All of this is replaced with two small TSSOP packages that directly connect to the DSP, improving reliability and manufacturing ease while decreasing real estate and cost. The design improves performance, since the signals are digitally transmitted over the isolation barrier. The silicon DAA includes international support in a single design and supports both U.S. and international caller ID without relays, via software programmability, for different countries. No hardware modification is required. Advanced power management, caller ID, and *sleep* mode save power and offer green compliance, enabling a smaller power supply and longer battery life. Monitor output and microphone input support voice and handset applications.

Each modem design also supports legacy DAAs used for unpowered telephone line applications, such as wireless and leased lines.

Software Development

Analog Devices' embedded modems include modem code supplied by Telindus. Product-specific software can be obtained from modem partners of Analog Devices. For example, one can automatically link the Handspring Visor to the Internet by adding a Springboard modem from Card Access. One can enable a Lavazza e-esspresso coffee machine to send and receive emails (to trigger maintenance checks and restocking visits, and display weather or traffic reports) by adding an Internet modem from Analog Devices that executes a TCP/IP stack from eDevice.

Modem Reference Designs

The Analog Devices embedded modem development platform includes an ADSP-218x programmable DSP and a silicon DAA. It consumes under 200 mW maximum power at 3.3 V. No customer

code is required. The development platform includes modem software from ISO 9001-certified Analog Devices' technology partner Telindus. The board comes with connectors for EZ-ICE, JTAG, and RS-232 I/O for modification and testing of the AT command set and S registers.


Embedded Modem Applications

The products that use embedded modems for communication include vending machines (which can communicate levels of inventory and when they need to be filled), kiosks, POS terminals, security and surveillance systems, games, and drop boxes that can communicate when they have shipments to be picked up. The ways in which the basic product communicates via these standalone modems are established by programming in relevant web content and communication data. The results for designers are products with such characteristics as built-in investment protection, appliances that "know" and communicate when they need to be serviced, fixed, filled, emptied, updated, or picked up. Products that use the Internet to provide customer information and communications can be located wherever needed. Industrial equipment can indicate when it needs to be serviced. Refrigerators can display recipes containing only the ingredients on their shelves.

Standalone embedded modems can reduce operating costs at the same time that they make possible new product categories with features to spur new sales. With new Internet-enabled power, these products can create new opportunities for e-commerce, e-service, and e-information vendors.

Standalone embedded modems offer complete and flexible design alternatives for worldwide communications in a variety of approaches. Each approach can be configured on as few as three chips, offers a choice of speeds, and can be implemented inexpensively with low power and real estate requirements. Embedded modems can bring the power of Internet information and communications to both new and installed devices and can add automatic software upgrades and remote diagnostics at the same time.

For Further Information

For additional help, contact systems.solutions@analog.com, or visit Analog Devices Software & Systems Technologies on the Web. Or contact Analog Devices' modem partners: Card Access and eDevice. 

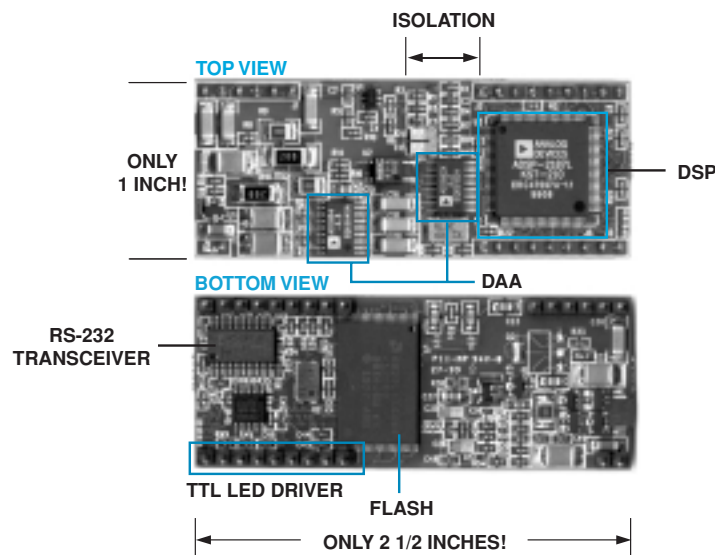


Figure 4. V.90 standalone embedded modem reference design.