Motorola Unveils First Magic Cap Device

$1,500 Envoy Is First PDA with Built-In Wireless Communications

by Michael Slater

Motorola has jumped into the personal communicator market with the first device based on General Magic's Magic Cap operating system. At $1,500, the device—called Envoy—is too expensive for the mass market, but it is the smallest and least expensive device to offer built-in, two-way wireless data communications. First shipments are promised for this summer.

Sony plans to offer a similar device at roughly the same time, probably without a built-in wireless interface. Sony has not yet disclosed any details of its offering. Philips, Matsushita, Toshiba, and Fujitsu also have licensed the Magic Cap software but are not expected to ship devices until next year.

Envoy, which is 7.5" wide ×5.75" high ×1.2" thick and weighs 1.6 pounds, is too big for most pockets but fits easily in a briefcase and is easy to hold. In addition to the built-in wireless modem, it also includes a regular fax/data modem, infrared communications, and two PCMCIA slots, making it a potent bundle.

The hardware design uses an ASIC, called Astro, that provides most of the system logic. Astro was designed by General Magic and is made by Motorola, and it will be offered only to Magic Cap licensees.

The built-in wireless modem connects to the Ardis packet-switched network owned by IBM and Motorola. The Ardis network has been in operation since 1990 and has been used largely for field-service organizations and other vertical-market applications. With 1,300 base stations, Ardis claims to cover 80% of the U.S. population in more than 400 metropolitan areas and 10,700 cities and towns. Communication speed is 4,800 bps, but the sustained bandwidth is lower due to protocol overhead.

The Magic Cap software *(see **080102.PDF**)* presents a cartoon-like user interface, with desk, hallway, and downtown metaphors. Figure 1 shows the desk, through which most of the built-in functions are accessed. Touching the card file, for example, activates the address book. Despite the apparent simplicity of the interface, the software is quite rich in its capabilities and is full of nice touches. For example, any time an e-mail message is received, the sender's information is automatically added to the address book. Magic Cap also supports the Telescript language, which allows messages to include programs as well as data and will enable an entirely new class of communicating applications.

In addition to the standard Magic Cap software, Motorola has bundled a few additional applications: PenWare's PenCell spreadsheet, Intuit's Pocket Quicken SmartWallet, and interface software for four on-line services: AT&T's PersonaLink, RadioMail, America Online, and Official Airline Guides. America Online can be accessed only via a wire-line connection; PersonaLink and RadioMail are available through the built-in Ardis wireless connection.

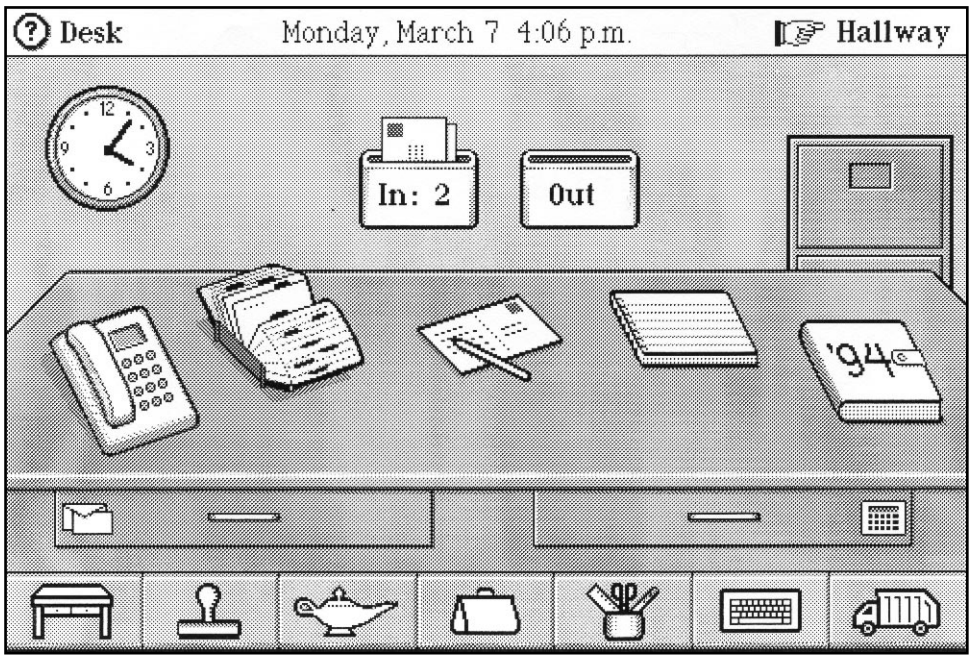

Figure 1. The built-in functions of Magic Cap are accessed by touching the appropriate item on the desk: the phone accesses the autodialer and the postcard activates e-mail, for example.

Users can send wireless mail to nearly any other e-mail service or to a fax machine or pager, with either RadioMail or PersonaLink serving as the gateway. All the access information is built into simple "stamps," making the message routing transparent to the user. RadioMail is currently primarily an e-mail service, but the company expects to add information services. One key difference between the RadioMail and PersonaLink mail services is that RadioMail operates like a pager: messages arrive on the device automatically. PersonaLink, on the other hand, requires that the user specifically connect to the service and check for messages.

The on-line services, including AT&T's Telescript-based PersonaLink, are supposed to be available when the first communicators ship this summer, along with at least 15 third-party applications. Pricing for these services has not been disclosed. (RadioMail currently offers wireless e-mail service for PCs and Macs for $89 per month.) The Ardis charges will be bundled with the on-line service costs.

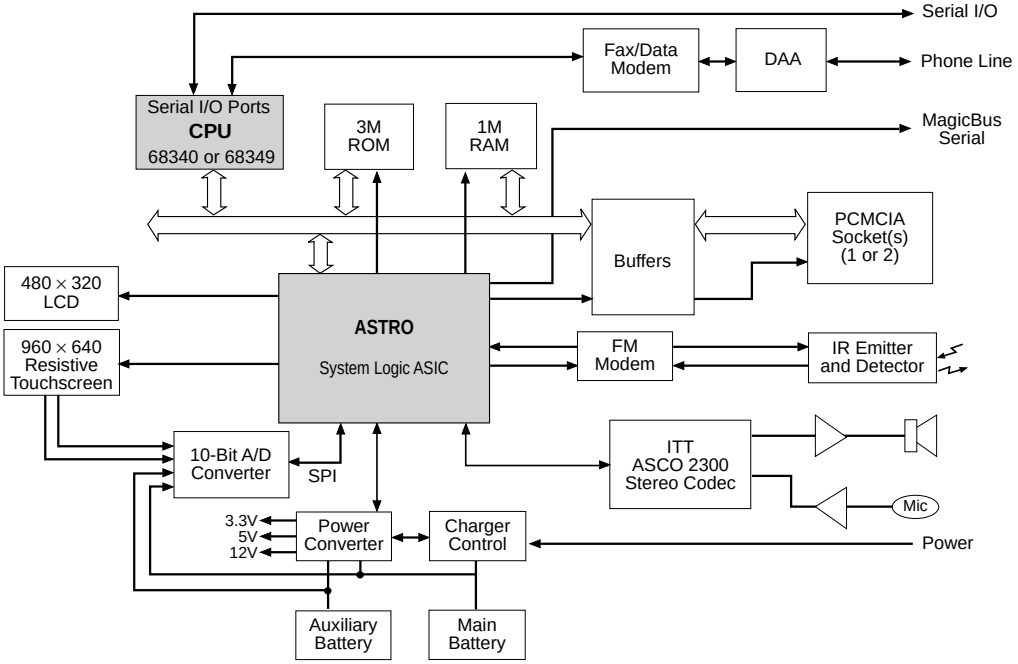

Figure 2. The Astro ASIC provides most of the support logic for the minimum Magic Cap system shown here. Envoy adds an RF modem and increases the ROM size to 4M.

Reference Design

Motorola's communicator is based on the reference design developed by General Magic. Figure 2 shows the block diagram for a basic Magic Cap communicator. This diagram represents what General Magic calls the minimal functional specification; many implementations will include additional features (such as the RF modem in Envoy), but all devices must include this basic set of capabilities, which includes a 2,400-baud data and 9,600-baud fax modem with a direct phone-line connection.

The microprocessor can be either a 68340 or a 68349, both from Motorola. The latter device, code-named Dragon I *(see **070803.PDF**)*, has been widely associated with General Magic but is not required. (Motorola's communicator uses the 68349.) It includes a 1K instruction cache and a 4K data RAM on-chip, and it has a 32-bit data bus, whereas the 68340 has no on-chip memory and a 16-bit bus, so the '349 provides a much-needed performance increase.

The Magic Cap software uses the on-chip SRAM in the '349 for fast access to its program stacks. It can also be used, under program control, to store a copy of data from a flash card for faster access, and especially for faster write cycles.

Both the '340 and '349 include two serial ports and a DMA controller on chip. The on-chip DMA controller is used for the MagicBus interface and for sound input; a separate DMA controller in the Astro ASIC transfers data for the display and audio output.

The Magic Cap software uses the 6834x's LPSTOP instruction to put the processor into a low-power state whenever no processing is needed—which is most of the time. The Astro ASIC refreshes the display and memory independently of the processor. Power to the modem and sound circuits is switched off when these functions are not in use. Most of the power management is implemented in software.

Although an all-5-V implementation is possible for highest performance, the desire for maximum battery life has driven existing Magic Cap designs to use a 3.3-V processor, memory, and ASIC. Some of the analog circuits still are not available at this voltage, so they run at 5 V, as do the optional PCMCIA cards. At 3.3 V, the 68340 and 68349 have a maximum clock rate of 16.7 MHz, at which Envoy operates. The bus protocol requires at least one wait state for external memory; depending on the type of memory used and the cost tradeoffs chosen, memory systems will vary from one to four wait states.

The Astro ASIC is a 208-pin, 35,000-gate CMOS device that provides most of the system logic and draws about 20 mA at 3.3 V. The chip costs approximately $20, bringing the cost of the CPU and ASIC set to about $40 in volume.

Power consumption for the complete system is approximately 520 mW when running (but with the modem and sound off). In doze mode, the processor is in its low-power stop state and power drops to about 330 mW. In sleep mode, with only the Astro chip and the memory powered, it falls to less than 2 mW with DRAM, or as low as a few microwatts with SRAM. Motorola claims that Envoy's NiCd battery will last 8 hours of active use with the radio on, or up to 24 hours with the radio off.

In addition to the interfaces that are apparent in the figure, the Astro chip includes a real-time clock and a 16 ×16 multiplier with a 40-bit accumulator. The mul-

tiplier was included to support compression and signal-processing algorithms, but it is not used in the current version of Magic Cap. Even supplemented by the multiplier, the 68349 lacks the performance needed to implement a data or fax modem in software.

Flexible Memory Support

The Magic Cap software is stored in ROM and requires about 2.6 Mbytes, of which about half is the core system software and half is software objects (which include both code and data), such as sounds, stamps, animations, and the built-in applications. A minimal Magic Cap system therefore requires a 3M ROM and leaves about 400K available for other software; Motorola's Envoy uses a 4M ROM to support its additional built-in applications.

Astro provides control logic for up to three banks of read/write memory. Most designs will use two memory banks. Bank 1, which must be 16 bits wide, is considered transient; the system uses this memory for working storage and does not assume that it remains intact after power is turned off. The Magic Cap software requires about 300K of working memory, including the display frame buffer; typical designs will provide 512K, leaving about 200K available for application scratchpad memory. Bank 2 is the persistent (nonvolatile) memory for user data and applications, so it must be battery-backed. This bank can be 16 or 32 bits wide and must be at least 512K; the ASIC supports as much as 16M.

The memory controller is programmable to support nearly any kind of RAM—including SRAM, pseudo-static RAM, self-refreshing DRAM, or standard DRAM—without external logic. Although Magic Cap does not require a traditional MMU, the memory controller provides basic memory protection functions. Access to each of 10 separate regions of programmable size and location can be enabled separately for reads and writes and for user and supervisor (operating-system) accesses. This protection logic enables Magic Cap to prevent application programs from crashing the operating system, increasing the system's reliability. Most other PDA operating systems, including Newton, PenPoint, and WinPad, require a full MMU. (GeoWorks' Geos is one operating system that does not require an MMU.)

Additional storage, such as flash memory, typically will be provided in a PCMCIA card. Astro generates the control signals for the PCMCIA interface; external buffers on the processor's address and data lines provide the rest of the PCMCIA signals. The ASIC supports two external PCMCIA slots and a third, internal PCMCIA interface that can be used for a built-in device such as a wireless modem. General Magic's software supports hot insertion of PCMCIA cards, even in a two-slot system with a single set of buffers.

Astro directly drives the LCD panel. The minimum resolution required is 480 ×320 (and this is what Envoy uses), but Astro's LCD controller is programmable to support a range of displays. The frame buffer for the LCD is stored in the Bank 1 memory. Most devices are expected to use two bits per pixel to provide four gray levels.

The touch-screen interface consists of control outputs from Astro to enable sensing of either axis, and an A/D converter for position sensing. The A/D also provides battery-level sensing. Astro implements the standard Serial Peripheral Interface (SPI) for connecting to a 10-bit, multichannel A/D (such as a Motorola MC370605). The digitizer must provide a resolution at least twice that of the LCD display in each direction, that is, there must be four resolvable points for each pixel.

A 16-bit stereo codec provides audio I/O. The standard sample rate for input and output is 11,025 sample/s; a lower rate of 7,350 samples/s can be selected for input (by holding down the option key) if the user is willing to sacrifice some quality to decrease the memory required for the stored sounds.

Magic Cap uses ADPCM (adaptive pulse-code modulation) compression to cut the storage requirements to about half of the raw data rate, resulting in a storage requirement of about 11K bytes per second of speech. Without much more memory than required by the base configuration, voice messages must be kept short; a single one-minute message would use all the available memory in the basic device. Motorola's Envoy limits voice messages to 20 seconds. For audio output, mono or stereo can be selected by software; although the built-in speaker typically will support mono only, some devices may include a stereo headphone jack.

Communications Interfaces

The infrared communications interface requires an external chip set (for example, Sony's CXA1781 and CXA1111) to modulate and demodulate the data on a 1.25-MHz center frequency. The IR interface is not compatible with the Newton, Zoomer, or HP devices, each of which uses a different format, but it is compatible with consumer electronics products; a Magic Cap communicator with the right software could be the ultimate universal remote control. The IR data rate is 38.4 kbps; the range is 3 meters. General Magic plans to support the emerging Irda standard in future devices.

One of the CPU's built-in serial ports connects to the fax and data modem, which is required in all Magic Cap devices. Any modem chip can be used; only 2,400-baud data is required, although high-end devices may choose to provide a faster modem. The device must also include the DAA (data access arrangement) that connects the modem directly to the phone line.

All electrical connections for a basic Magic Cap device are combined into a pair of connectors: a two-pin connector for the telephone line and a 14-pin connector

that carries the power input, MagicBus serial I/O, and standard serial I/O. The standard serial I/O interface connects to the CPU's second serial port; it can be used for an external modem or other serial peripheral. This port also could be used to connect to a desktop computer, but external level shifters would be required; the serial signals are at 3.3-V CMOS levels, and RS-232 or RS-422 drivers are not included.

The MagicBus serial port is separate from the standard serial I/O port. MagicBus uses a synchronous serial protocol running at 14.7 Mbps. MagicBus supports "hot plugging" (devices can be connected while the system is running) and allows up to six external devices. It supports isochronous communication, in which a device is guaranteed a minimum sustained bandwidth. The MagicBus signals are data and clock, both bidirectional; an interrupt input; and power and ground.

A MagicBus device typically will implement the communication protocol in an 8-bit microcontroller, which can also provide other control functions for the peripheral. General Magic will provide peripheral developers with MagicBus interface source code for either the 6502 or the 6805.

Mitsubishi has worked with General Magic to offer a single-chip microcontroller for MagicBus peripherals. This device, the M37690, runs at 20 MHz with a 3.3-V supply and has a 6502-compatible CPU core, 16K ROM, and 512 bytes of RAM. The mask-ROM version will sell for $4.70 in 25,000-unit quantities. An emulation version of this chip that works with external memory will be available in April; EPROM, OTP, and mask-ROM versions are promised for July. The M37690 integrates the MagicBus interface circuitry, providing a single-chip solution. A 6805 microcontroller can also be used, but it requires a simple ASIC for the MagicBus interface.

Integration Trends

The Magic Cap hardware design is, in many respects, very similar to Apple's Newton MessagePad *(see **071303.PDF**)*. While it uses a 68000-family processor instead of an ARM, both devices depend on an ASIC to provide most of the digital system logic and peripheral interfaces. Both designs use external chips for analog functions. Apple's design uses a dual UART chip, whereas General Magic was able to use the two UARTs that Motorola had already integrated into its 68300-family CPUs; otherwise, the system partitioning is remarkably similar.

Intel/VLSI's Polar chip set, which will be used in WinPad devices, uses a somewhat different partitioning, moving the display and memory control onto the processor chip. Tandy/Casio's Zoomer uses a partitioning similar to Polar, with the display controller integrated on the same chip as the CPU core.

For Apple and General Magic, using standard microprocessors was the quickest path to market. The next generation of PDA designs, however, is likely to offer a higher level of integration. One partitioning that seems natural is one digital chip, combining the processor with all the functions that Newton and Magic Cap devices put in a supporting ASIC, and one analog chip, sweeping up the functions that require discrete devices today.

For Magic Cap, the big question for the next generation is what the CPU will be. The 68349's modest performance makes the device sluggish, and as General Magic moves forward, a shift to a RISC architecture seems inevitable. The strongest contender may be MIPS, which Sony plans to use throughout its consumer electronics products and which already has inexpensive, low-power implementations *(see **071506.PDF**)*. Motorola would surely like the successor to be PowerPC, but this architecture is inherently more complex to implement than MIPS and there are not yet any very low power, low-cost implementations. Motorola and IBM are rumored to be developing such devices, however.

Unfortunately, future versions of Magic Cap running on different processors would require most application developers to port their software; unlike Newton applications, most Magic Cap applications are not distributed in a processor-independent form. (Some Magic Cap applications use only the MagicScript scripting language, and these are portable.)

Businesspeople Today, Consumers Tomorrow

Motorola has chosen to leverage its wireless communication strengths by making the wireless modem standard, and in fact has coined yet another name—the personal wireless communicator. For many users, however, a Magic Cap device with only a land-line modem would still be compelling, and such a device should come closer to the cost of a Newton with a modem; the manufacturing cost of a basic Magic Cap device should be similar to that for a Newton. Such products presumably will emerge from General Magic's other licensees.

One factor that may limit Envoy's success is the mismatch between Magic Cap's style and Envoy's $1,500 price tag; while the price will limit it to business users, the style of the user interface is better matched to a consumer market. In addition, General Magic's vision is focused on a device that connects to an on-line service, and it remains to be seen how good the PC connectivity will be. The lack of handwriting recognition also limits the device's flexibility, especially for note-taking.

Despite today's high price, Envoy gives a glimpse of how handheld computing devices will move into the mainstream. The slick software and painless communications go well beyond what previous devices have offered, and as prices fall—which they inevitably will—a device such as this could have broad appeal. ♦

