

DID YOU KNOW THAT EVERY room in your home already has three or four network ports? That's the message the HomePlug Powerline Alliance is trying to get out. Since announcing the first release of their ac-line networking

HomePlug: EVERY **O**UTLET A NET**W**ORK **P**ORT?

**IF POWER-LINE-NETWORKING VENDORS DO IT
RIGHT, CONNECTING YOUR PC, PRINTER, OR
STEREO TOGETHER WILL JUST "HAPPEN" WHEN
YOU PLUG THE POWER CORD IN THE WALL.**

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specification in June, member companies, such as Netgear and Phonex, have been busy building products that allow you to use the ac-power lines in your home not only to power your networked PCs but also to interconnect them (**Reference 1, Figure 1**). The idea of using your home's ac-power lines to exchange data between computers has been around for a while. The difference this time is that technology has caught up to the task. HomePlug is promising data rates as fast as 14 Mbps over your home's power lines. Moore's Law, faster silicon, and sophisticated algorithms are allowing engineers to overcome the technical obstacles that plagued earlier efforts.

HOME NETWORKING

The rate at which customers subscribe to broadband services is not as fast as broadband providers would like, but it's these

consumers who are most interested in home networking. There are several ways to connect two or more computers together in a home. One of the cheapest and easiest ways is to install a couple of inexpensive Ethernet cards into your PCs (if they don't have them) and string some cable between them. This method may be OK for the average *EDN* reader, but most homeowners want a more sophisticated and unobtrusive option. People building their own homes will probably spend the extra money to install low-voltage or structured wiring consisting of Category 5 cable. But that leaves millions of homeowners with two options: tear up walls to install cable or use the "No New Wires" approach.

Because so few homes have structured wiring in their walls, vendors of home-networking equipment are fond of the "No New Wires" slogan. But not having to install new wiring to gain network access throughout a home or building is a real advantage. Wi-Fi (Wireless-Fidelity) owes a great deal of its success to peoples' reluctance to string new wires throughout their homes or office buildings (**Reference 2**). In fact, Netgear's Home Networking Product Line Manager, Debashis Pramanik, says that retail wireless-networking sales are growing 50% per quarter, and 50% of those products are going into homes. On the other side of that coin is the fact that retail prices for those products have dropped significantly from only a year ago. HomeRF is the other home-wireless-networking alternative, but its market share is dropping. Cahners InStat/MDR reports that HomeRF shipments made up 45% of all wireless nodes shipped in 2000. But in 2001 that figure dropped to 30%, with Wi-Fi nodes making up nearly the entire remainder.

So why not just set up a Wi-Fi network in your home instead of bothering with power-line networking? Good question. You'll be hard pressed to find a home-networking vendor willing to say bad things about Wi-Fi. One reason is that many of them sell Wi-Fi products. Another reason is that Wi-Fi technology works and is popular with users. And a third reason is that vendors feel it's important to first sell the idea of home networking, then fight over who gets the biggest piece of the pie. Most vendors pushing alternative home-networking technology say that Wi-Fi and their "No



New Wires" products are complementary and both have their strengths. Their hope is that you will use a combination of the two technologies—Wi-Fi for untethered network access and HomePlug everywhere else.

Because home-networking vendors know they can't compete with the mobility Wi-Fi offers, they point out that Wi-Fi networks rarely achieve 100% coverage in a home. Due to obstructions such as metal laths in walls or interference from 2.4-GHz cordless phones, you will experience diminished or nonexistent throughput between your PC and your access point as you roam about your house. You can always add another access point, but that option adds significant cost to your home network. Wireless networking has another disadvantage, at least potentially. The technology requires an RF section, which adds to the cost of the chip set. You don't see this difference in cost today, though, because

802.11 chips have been shipping for more than four years, and their volumes are much greater than for HomePlug chip sets. If HomePlug unit sales catch up to wireless sales, HomePlug technology should cost less.

HomePlug advocates also claim that HomePlug networks outperform Wi-Fi networks at greater distances. Also, 802.11b uses an optional 40-bit encryption key, whereas HomePlug always uses a 56-bit key. Plus, you have to be physically connected to the HomePlug network to intercept transmissions. Another point is that HomePlug was designed for the home market and is easier for users to set up.

QOS (quality of service) is another issue. A lot of people will use their home networks for more than sharing an Internet connection or printer. More and more people are using their PCs to store and play digital music. Some of these users will want to stream digital content

Illustration by Mike O'Leary



to other rooms of their homes. To do that task well, a home-network protocol must support QOS, so that priority is given to streaming audio or video data over other data. The current 802.11 standard does not support QOS, but the IEEE 802.11 Task Group E recently adopted QOS-enhancement proposals made by the 1394 Trade Association's Wireless Working Group. In fact, some see the IEEE 1394 standard as an alternative for multimedia home networks. The 1394a standard has a cable-length limitation, but the next-generation 1394b standard has greater flexibility (**Reference 3**). HomePlug and most other home-networking protocols support QOS.

One such protocol is HomePNA (Home Phoneline Networking Alliance), which uses the phone wiring in your home rather than the power lines (see **sidebar** "HomePNA is on the line"). The biggest drawback to HomePNA is that the average house in the United States has fewer than five phone jacks. On the other hand, most homes have 10 times as many ac outlets. In Europe, the average number of phone jacks per house is less than two. Another obstacle to HomePNA is lack of consumer education. It's not intuitive to a lot of consumers that you can simultaneously use your phone wiring as a computer network and make phone calls. HomePlug may face similar resistance when salespeople try to convince potential customers that it's OK to plug a network card into a 120V wall outlet.

The analysts at Cahners InStat/MDR believe HomePlug will overcome such re-

AT A GLANCE

▶ HomePlug 1.0 offers a way to build 14-Mbps home networks using house ac wiring. Part of its appeal is that the network connection can be the appliance's ac power cord.

▶ Home ac wiring is an extremely harsh environment for networks. Power-line networking is practical today thanks to sophisticated DSP algorithms, faster silicon, and ingenuity.

▶ Other power-line-networking options exist. Inari has proposed its technology to the Consumer Electronic Association as a basis for a new standard that would compete with HomePlug.

▶ Home-networking options also include HomePNA, which uses your house's phone wiring, and wireless technology, such as Wi-Fi.

sistance. The group is predicting that the home-power-line-networking market will grow from less than \$18 million in 2001 to nearly \$190 million in 2002. Hoping to grab a share of that market is HomePlug competitor Inari (see **sidebar** "Outlet competition"). The advantage HomePlug has at the moment is the backing of 90 member companies, multiple silicon suppliers, and the HomePlug logo, promising that networking gear from different vendors will interoperate after you plug it in. The Consumer Electronics Association's R-7.3 is a rival power-line standard that will be based on

technology from Inari, Intran, or nSine. The association plans to complete trials of the three power-line-networking technologies by April.

HOMEPLUG'S HOME

Thirteen companies founded HomePlug as a nonprofit industry association in March 2000. Their goal was to create an open specification for home-power-line networking and create demand for their products. The group created an MRD (marketing-requirements document) describing goals that HomePlug technology should meet before its release to the market. The MRD includes regulatory, interoperability, performance, noninterference, reliability, scalability, diagnostics, and maintenance requirements. Performance requirements include "10BaseT-like rates" for multinode file transfers and QOS support for multiple voice-over-IP calls. The MRD also addresses coexistence with other power-line-networking technologies, such as X-10, CEBus, and LonWorks. HomePlug members also want strong built-in privacy features.

HomePlug reviewed 10 proposals before selecting Intellon's PowerPacket technology as the basis for the HomePlug specification. The group spent more than a year comparing Intellon's proposal against the MRD. After making modifications, the PowerPacket technology evolved into the HomePlug 1.0 specification, which the alliance announced in June 2001. The specification is available to members. Version 1.0.1 is the most re-

HOME PNA IS ON THE LINE

HomePNA (Home Phoneline Networking Alliance) uses your house's phone wiring, instead of ac power lines, for home networking. Several companies interested in home networking created the alliance in 1998, and today it has more than 120 member companies. In the fall of 1998, HomePNA released its 1.0 Specification, which supported a 1-Mbps throughput. In December 1999, HomePNA released the current 10-Mbps 2.0 Specification, which maintains compatibility with the 1-Mbps specification. The alliance

announced at the Fall 2001 Comdex convention in Las Vegas that it has released a marketing-requirements document for a 100-Mbps HomePNA 3.0 Specification. Expect to see the specification released at the end of 2002.

Like HomePlug and Inari power-line technology, HomePNA supports quality of service for streaming-data applications. HomePNA 2.0 data rates can exceed 10 Mbps. Broadcom's iLine32 HomePNA 2.0 chip set can transmit as fast as 32 Mbps. The technology uses

frequency-diverse QAM (quadrature-amplitude modulation) in the 4- to 10-MHz band. Companies such as Ucentric believe that a peak bandwidth of 30 Mbps and \$20 silicon will make multimedia applications in the home practical.

HomePNA may have a head start over HomePlug in terms of certification. HomePNA claims to have so far certified around 100 products. The organization has a rigid certification process in place and requires you to participate in its plugfests, which are held every three months. Upon

successful certification, HomePNA authorizes you to use the official HomePNA seal of approval.

Security may be a weak point for HomePNA. The specification does not require encryption, leaving your privacy at the mercy of Windows' networking software and, of course, good ol' signal attenuation.

HomePNA silicon includes AMD's HomePNA 1.0 Am79C978A controller and Am79C901A HomePNA PHY. Conexant's CX24611 is a HomePNA 2.0-compatible PHY.

cent update and includes errata to clean up the initial release. Before releasing the specification, HomePlug conducted field trials in more than 500 homes in the United States and in Canada. It tested nearly 10,000 outlet-to-outlet paths against the MRD requirements. HomePlug testers hoped to see a throughput of at least 5 Mbps between 80% of all outlet pairs within a home and a minimum of 1.5 Mbps in 98% of outlet pairs. The field trials' results showed 80% of outlet pairs getting at least 4.8 Mbps of

throughput and 1.4 Mbps in 98% of all outlet-to-outlet paths.

With field trials complete and the specification released, HomePlug members are concentrating on getting products out the door and not worrying, for the moment, about HomePlug 2.0. The alliance is satisfied with HomePlug's performance and feels that it compares favorably with Wi-Fi's. Both organizations have several members who hope to create demand for their respective products by offering con-

sumers compatible networking gear.

Sending millions of bits per second over common house wiring requires sophisticated algorithms running on fast silicon. House wiring is a hostile environment for high data rates. Brush motors in hair dryers and kitchen appliances are a significant source of interference. Turning appliances on and off, using dimmer switches, and using halogen lights injects noise spikes into the transmission line. Each branch off the main breaker panel acts as a stub, causing mul-

OUTLET COMPETITION

HomePlug may have an edge in marketing, but it's not the only game in town. Inari is proposing its technology to the Consumer Electronics Association R-73 Committee as the basis for the new Electronics Industries Alliance power-line data-networking specification. Novell spun off its power-line-networking group in 1997, forming Intelogis, the developer of the PassPort Plug-In Network product. In 1999, the spin-off switched its focus to being a fabless silicon provider and changed its name to Inari.

Inari claims its technology better addresses the issues of scalability, affordability, and QOS (quality of service) than HomePlug. Inari offers a family of chips that range from 2 to 12 Mbps with pricing proportional to performance. By offering a chip set that offers midlevel throughput at 2 Mbps, Inari

believes it is making power-line technology more affordable than HomePlug. In effect, you pay only for the bandwidth you need. Inari also claims that its outlet coverage is better than 99%. HomePlug claims 98% coverage.

Inari also stresses that its QOS is superior, calling HomePlug's QOS only a "best-effort" attempt to provide bandwidth to time-sensitive data. Inari uses a two-phase protocol on its networks. When a node wishes to use the network, it senses datagrams and randomly backs off if it detects one using datagram-sensing multiple access. Once a node asserts itself as the Active Powerline Exchange Protocol Manager, the network uses centralized token passing to eliminate collisions and multinode contention. Inari and others in the industry see this protocol as a better approach to addressing QOS than HomePlug's.

Inari uses a multiple-carrier system with phase-shift modulation similar to HomePlug. But to reduce cost, Inari reduces the number of channels a particular transceiver processes based on its rated throughput. For higher throughput applications, Inari

offers transceivers that implement

more channels. Starting with the 2-Mbps IPL0202 Powerline Network Controller, you can add your own front end, comprising a DAC, a power amp, and a

receiver. The IPL0202 chip set has a built-in full-speed USB port, sells for \$12.50 (100,000), and is shipping. Inari plans to offer the \$15 (100,000) IPL0401 4-Mbps network controller in the second quarter of 2002. The IPL0401 will have an MII (media-independent interface) and generic-memory-bus interface and an eight-channel communications processor. Inari plans to offer a 12-Mbps network controller in the third quarter of 2002. The IPL1201 will support 24 channels and rate-adaptive data speeds. Interfaces will include MII, generic memory bus, and PCI. The IPL1201 will cost \$28 (100,000). According to Inari, power-line networking adds \$3 to \$4 worth of components to an entry-level design plus the power-line chip set. So, for example, adding Inari's 2-Mbps chip set to your set-top box costs an additional \$15. Adding 12-Mbps power-line networking capability increases your bill-of-materials costs by about \$35.

Scalability can significantly affect your design's cost. Not only can entry-level designs use a cheaper network controller, they make the other parts in your bill of materials less critical. High-end designs using a full-speed controller need more expensive parts. Keep this fact in mind when you consider your product's requirements. With HomePlug, one size fits all. For example, if you're building a

voice-over-IP product, you probably don't need the full 14-Mbps performance of HomePlug chip sets and their corresponding costs.

Inari also likes to point out that its technology's security is more robust than HomePlug's. Inari uses the recently announced 128-bit AES (Advanced Encryption Standard, <http://csrc.nist.gov/encryption/aes/>) encryption scheme, whereas HomePlug uses the 56-bit DES (Data-Encryption Standard) system. According to Inari, if a computer took one second to break the DES, it would take that same computer about 1.5 trillion years to break the AES.

At January's Consumer Electronics Show in Las Vegas, Inari demonstrated several vendors' Inari-based products inter-operating on a power-line network. Inari also announced its Power Developer Program. Program members will have early access to Inari's development tools and products, access to reference designs and enhanced support, and "fast-track" access to "Inari-enabled" certification.

For help with building networking gear based on Inari and other power-line technology, Lugh Networks offers design and engineering services. Lugh offers a reference design of an Ethernet/USB access point built around the Inari IPL0202 (Figure A).



Figure A

Lugh Networks' Ethernet/USB reference design uses Inari's IPL0202 Powerline Network Controller and a Motorola ColdFire processor.

tipath interference. Plus, the whole network of house wiring acts as an antenna, picking up RF interference from radio transmitters.

Signal attenuation is another problem. Long runs between outlets are one cause, but the common surge-suppressor power strip often contains a filter to block high frequencies—the very ones HomePlug uses to carry data. And most houses in the United States take power from both sides of the neighborhood distribution transformer's secondary windings, creating two 120V phases and one 240V phase. Power-line signals must go through this winding if you use an outlet on one phase and a second outlet on the other phase. The secondary winding acts as a lowpass filter, attenuating the signal. All these factors create a unique, often-complex, time-varying, transfer function for each outlet-to-outlet channel in a home.

PLUGGING AWAY AT THE PROBLEM

HomePlug technology overcomes these obstacles using a combination of approaches. The PHY uses OFDM (orthogonal-frequency-division multiplexing) to transmit on as many as 84 carriers in the 4.5- to 21-MHz band. The PHY also applies concatenated Viterbi and Reed-Solomon FEC (forward error cor-



Figure 1 Netgear demonstrated its XE602 Powerline to Ethernet Bridge at the January 2002 Consumer Electronics Show in Las Vegas.

rection) with interleaving to the payload data to ensure the receiver can recover the data even if parts of the bit stream are lost. Next, the PHY maps the encoded data onto a set of channels that the transmitter and receiver previously agree upon. An inverse FFT processor modulates each bit stream to create each channel's waveform—in effect, converting the signals from the frequency domain to the time domain. HomePlug typically uses DQPSK (differential quadrature-phase-shift-keying) modulation, in which the current symbol is encoded as the difference in phase between it and the previous symbol. Using all carriers, DQPSK delivers a raw bit rate of about 20 Mbps, which yields just less than 14 Mbps to the MAC (media-access controller). To recover the bit stream, the receiving PHY demodulator applies a forward FFT to the received waveform, converting the symbols back into the frequency domain.

The PHY reconstructs the original data payload from the symbols modulated onto the carriers.

Before a transmitter sends data to a receiver, the two nodes agree on what carriers to use based on the characteristics of the channel between them. Deselecting “bad” carriers helps prevent the loss of data that would otherwise be transmitted on those carriers. During transmission, if a few of the carriers encounter interference, the receiver can still recover the lost data thanks to the FEC that the transmitter applies. HomePlug hardware can also adapt to changing channel characteristics by switching between DQPSK and DBPSK (differential binary-phase-shift keying). DQPSK yields the highest throughput at 152 bits per symbol. The more robust DBPSK symbols each carry 76 bits. A third adaptation technique varies the convolutional code rate between $\frac{1}{2}$ and $\frac{3}{4}$. When two nodes communicate for the first time or when the channel between them is especially harsh, the transmitter uses ROBO (robust-OFDM) mode, which uses DBPSK on all available carriers.

The PHY is also responsible for the basic HomePlug frame format (**Figure 2**). A frame consists of a start-of-frame delimiter, a data payload, and an end-of-frame delimiter. The start- and end-of-

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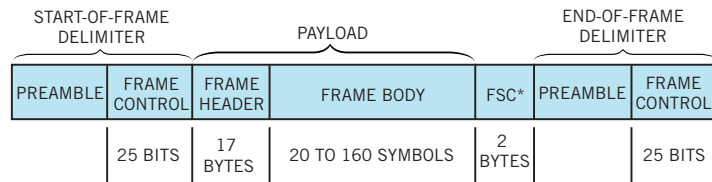
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frame delimiters begin with a preamble followed by a 25-bit frame-control field. The preamble is a pattern of bits chosen so that all receivers can reliably detect it under the most demanding conditions. The PHY encodes the frame-control field using a Turbo Product Code to ensure that receivers can decode the MAC information it contains (for example, packet lengths and status). A destination node acknowledges a unicast transmission by sending a response delimiter. ACK signifies that the destination successfully received the packet. FAIL indicates that the receiver was unable to process the packet. And NACK means that the packet was too corrupted for the receiver to understand. The PHY sends delimiters using all available carriers, whereas the payload uses a predetermined carrier subset.

The HomePlug MAC uses a CSMA/CA (carrier-sense multiple-access-with-collision avoidance) protocol similar to the one that 802.11 uses. The protocol listens to the channel before transmitting. If the node detects no other transmission, it waits a random amount of time before beginning its transmission. HomePlug also uses virtual carrier sense to avoid collisions. When the MAC sees a frame on the channel, it reads the payload-length in the start-of-frame delimiter and determines how long the channel will be in use. The node can postpone transmitting by setting a timer to the length of time it will take the frame to complete. HomePlug also adds other features to the MAC to support priority, provide fairness, and control latency.

HomePlug also adds a priority scheme to its protocol to enhance QoS. At the end of a transmission, the HomePlug



*FCS=FRAME-CHECK SEQUENCE

Figure 2

The HomePlug packet format consists of a start-of-frame delimiter, a data payload, and an end-of-frame delimiter.

network enters a priority-resolution period in which nodes transmit the highest priority level of their queued frames. The priority bits (PRS1 and PRS0) are encoded so that all nodes can determine the level of the highest priority frame requesting access. Nodes with frames having the highest priority randomly select a transmission slot within a contention window and start counting down to their slot number. If a transmission begins before a node has counted down to its slot number, the node stops counting and listens. The node resumes counting after the transmission ends. Because each node chooses its slot number independently of other nodes, two or more nodes may select the first slot, causing a collision.

The PRS bits provide four levels of priority, with the highest priority restricted to time-critical packets, such as streaming audio data. HomePlug also breaks up packets with long transmission times to prevent them from tying up the network. Packet segmentation allows higher priority packets to jump in between the segments of a long packet. A node can transmit all segments of a long packet

back-to-back if no other higher priority packets are queued. A contention-free access scheme can also improve QoS by giving a node uninterrupted access when transmitting a limited number of frames to different destinations.

HomePlug addresses security by creating a logical network in your home based on a password and a 56-bit DES (Data Encryption Standard) key. Although power-line networks don't broadcast their data to the world like a wireless network, data can travel to other homes connected to the same power transformer. In the United States, one transformer usually connects less than six homes, somewhat mitigating the problem. HomePlug has tweaked the transmitter power level so that the signal reaching another residence is low enough to make eavesdropping difficult but strong enough to ensure the nodes in your home network can hear one another.

HomePlug tries to be a good neighbor by avoiding frequencies used by other power-line technologies. The technology also limits its power spectral density around the amateur-radio bands by in-

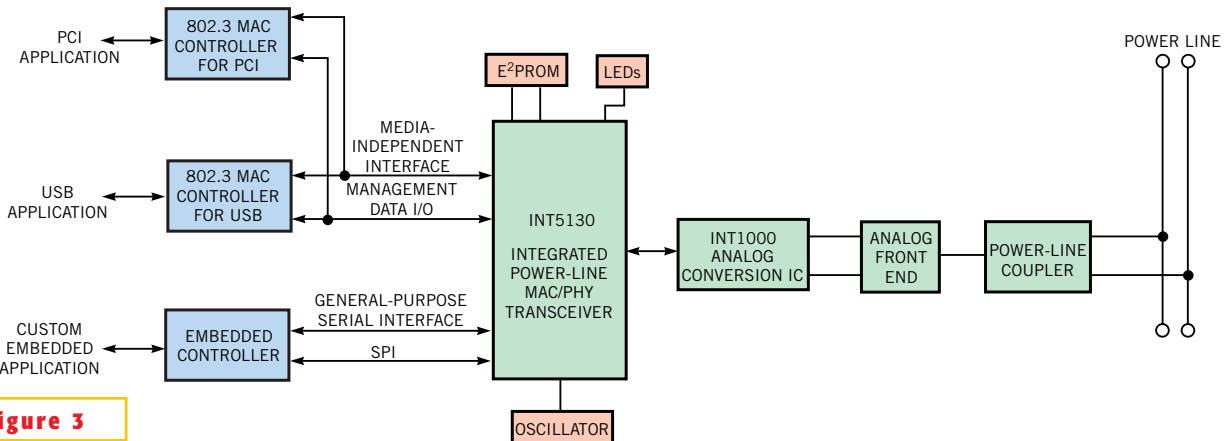


Figure 3

The Intellon INT5130/INT1000 chip set is the first to gain HomePlug 1.0 certification.

serting 30-dB notches in the 4.5- to 21-MHz HomePlug frequency range.

So far, a handful of vendors have announced HomePlug-compatible chip sets. It's not surprising that Intellon's INT5130 is the first chip set to receive HomePlug 1.0 certification, because Intellon's Power-Packet technology forms the basis of the HomePlug specification (**Figure 3**). The 5130 is an integrated MAC/PHY transceiver packaged in a 144-pin LQFP. The part uses 0.25-micron CMOS and 5V-tolerant 3.3V I/O. The 100-MHz core runs off 2.5V. You can configure the transceiver's host interface as either an eight-wire GPSI (general-purpose serial interface) or an IEEE 802.3u MII (media-independent interface). The INT5130 also gives you the option of using an external EEPROM for configuration and control information, allowing you to use standard Ethernet device drivers.

The analog half of the chip set is the 64-pin INT1000 power-line converter available in a LQFP. The INT1000 contains a 10-bit ADC and DAC, which provide 54 and 45 dB of dynamic SNR, respectively. The chip set began shipping last year and costs \$23 (1000). You'll need some discrete components, including filters, a line driver, and an isolation transformer, adding \$3 to \$6 to the bill of materials. Intellon also offers reference designs for Ethernet (RD5130-ETH) and USB 1.1 (RD5130-USB) to shorten development schedules. You can also purchase the EK5130-PCI evaluation kit, which is ready to plug into the wall.

Cogency Semiconductor recently announced a HomePlug chip set (**Reference 4**). The Piranha chip set consists of the CS1100 MAC/PHY and Analog Devices' AD9875 mixed-signal front end (**Figure 4**). The CS1100 has a 1.8V, 150-MHz core fabricated in 0.18-micron CMOS. Its I/Os operate at 3.3V, and the chip comes in a 100-pin LQFP. The CS1100 includes an ARM-based MAC, and you can upgrade its firmware in the field. Interfacing to the Piranha MAC is similar to using Intellon's chip. The CS1100 has an IEEE 802.3u MII interface, which you can configure as an 8-bit general-purpose CPU control bus. You can also connect an optional EEPROM for code storage.

The AD9875 has a 10-bit ADC and DAC and provides -6 to +36 dB of programmable gain control. The chip oper-



Figure 4

Cogency Semiconductor's Piranha HomePlug chip set consists of Cogency's CS1100 integrated MAC/PHY and Analog Devices' AD9875 mixed-signal front end.

ates from 3.3V and comes packaged in a 48-pin LQFP. The Piranha chip set sells for \$23 (25,000) with volume production expected in the first quarter of 2002. Cogency also offers an evaluation kit with two evaluation boards, drivers, and software tools for \$5000.

Conexant offers the CX11647 HomePlug 1.0 PHY that you can connect to an embedded MAC through its IEEE 802.3u MII. The MII is also configurable as a GPSI. The device operates on both 2.5 and 3.3V and comes in a 144-pin LQFP. Conexant expects to ship the CX11647 in the first quarter of 2002 for \$35 (1000). You can use Ubicom's IP2022 Internet processor to control a HomePlug PHY, such as the CX11647, through the processor's GPSI port. The IP2022 has a 120-MIPS RISC processor with a 64-kbyte flash memory, a 16-kbyte program/data RAM, and a 4-kbyte data RAM.

Once your design is working, you need to make sure your device complies with FCC regulations. Part 15 of the FCC's rules classifies a power-line device as an intentional radiator operated as a carrier-current system. Such devices have restrictions on the amount of interference they create for other devices, such as ham radios. The FCC requires that you make measurements at three installation sites before the FCC will certify your device.

To earn the HomePlug logo for your product, you must complete a self-certification process. Part of the process requires you to participate in plugfests, in which you test your equipment with other vendor's products. HomePlug conducted the

first plugfest in February. The second part of the certification process requires you to complete a formal checklist of conformance statements. As of today, HomePlug has no independent lab testing products for compliance. The certification process will improve in phases, progressing from self-certification to establishing an independent certification lab.

Until then, concentrate on testing as many error-handling conditions within your MAC as possible. This process can be difficult when you work with equipment designed to function correctly instead of intentionally creating errors. Spend some time learning how to extract bit settings in frames captured on the network. This effort will pay off when you diagnose bugs. Also, pay attention to your transmitter's signal quality to ensure good performance and reduce interference. Good receiver performance is also important. A sensitive receiver with good immunity to large narrowband interference will go a long way toward improving your product's throughput.

Using home power lines for data networking has been a goal for years. There's a lot of appeal for a product that connects to a network by simply plugging into a wall outlet. Using sophisticated algorithms running on powerful silicon enables engineers to design this type of equipment for the first time. HomePlug offers one approach to building power-line-networking gear. Inari and other companies offer other approaches. It's fair

to say that HomePlug has the marketing edge at the moment. Whether the alliance prevails is anyone's guess—especially when no one yet knows whether power-line networking itself will survive as a product category. □

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