DAVID MARSH, CONTRIBUTING TECHNICAL EDITOR,
AND STEPHEN KEMPAINEN, TECHNICAL EDITOR

ADSL trims down with G.lite

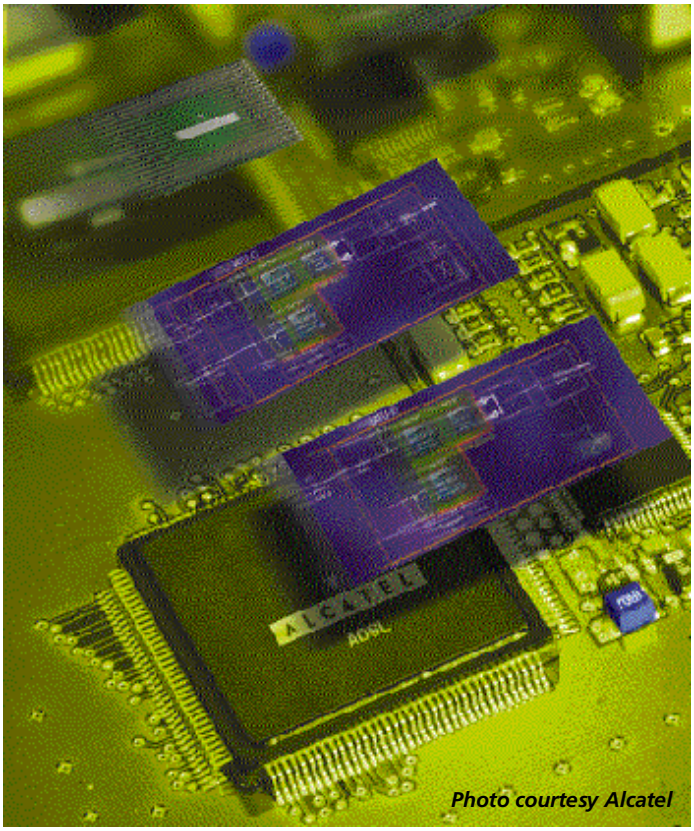
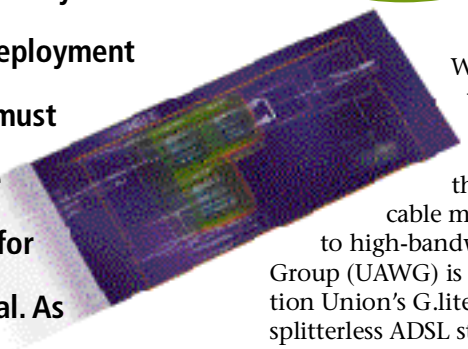


Photo courtesy Alcatel

Slow to satisfy its projected deployment numbers, ADSL must now rely on the G.lite standard for consumer appeal. As computer and telephone companies push G.lite, ADSL chip-set vendors are upgrading their products for consumer-grade modems.



Wide-scale proliferation of ADSL (asymmetrical-digital-subscriber-line) access to the Internet has stalled as a result of confusion over industrywide standards and unexpectedly high implementation costs. In the United States—currently ADSL's prime territory—cable modems have surged ahead in providing home access to high-bandwidth services. Now, the Universal ADSL Working Group (UAWG) is rallying around the International Telecommunication Union's G.lite specification for a lower cost, longer reaching, and splitterless ADSL standard. By solidifying a global standard, IC vendors can optimise their products for consumer-grade modems. But questions still remain over ADSL's widespread deployment.

Back in December 1996, proponents of ADSL deployment predicted 5 million connections by 2000, but recent, more realistic predictions suggest approximately 1.4 million. This significant shortfall is principally due to the lack of standard, end-to-end network protocols coupled with uncertainty over line-coding techniques. Furthermore, ADSL field trials demonstrate that widespread deployment is more expensive than anticipated because of spectrum-compatibility issues and anomalies in twisted-pair cable plant. But discrete-multitone (DMT) line coding now has won the standardisation battle, and consensus holds that asynchronous transfer mode (ATM) will provide networkwide compatibility.

Thus, chip-set designs reflect various levels of ADSL maturity—with new designs featuring integrated ATM access.

Full-rate ADSL slims to G.lite

Full-rate ADSL transmits information to the consumer downstream at up to 8 Mbps, accepting response data "upstream" at up to 800 kbps. These data rates depend heavily on line conditions, including length. Full-rate ADSL needs a filter, or "splitter," to separate the digital data from analogue telephony, permitting both services to run concurrently. But the splitter requirement implies engineer visits to customer premises, adding cost. By contrast, G.lite exchanges data at 1.5 Mbps downstream and 512 kbps upstream (maximum) and needs no splitter. G.lite makes it easy for consumers to install modems and increases ADSL's reach to virtually all households (**Figure 1**).

The UAWG's marketing boost and the emergence of the ADSL Forum's end-to-end architecture restore ADSL's credibility. In the United States, telecomm companies are currently deploying ADSL; trials are occurring throughout Europe, with target deployments by year-end (see **sidebar** "Europe checks out ADSL"). Questions of whether a single worldwide standard is possible revolve around myriad regional telephone systems that need accommodation. ADSL's promoters are rallying around 1.5-Mbps G.lite because they perceive cable-TV operators' broadband-access advantage. But high-bandwidth telephony-based services such as multimedia gaming, videoconferencing, and video-on-demand (VoD) still demand full-rate ADSL.

EUROPE CHECKS OUT ADSL

With all of the media attention that asymmetrical digital-subscriber line (ADSL) is receiving recently, you may be lulled into thinking that your Internet bandwidth problems are just a phone call away. But, realistically, what sort of services should you expect in the near future, and how do Europe's widespread integrated-services digital networks (ISDNs) fit into the picture?

Europe's two largest telecomm operators are Deutsche Telekom (DTAG), having 45 million subscribers, and British Telecom (BT), which has 28 million customers. Both companies have invested heavily in ISDN and have substantial interests in ADSL. BT originally proposed ADSL as the enabling technology for video-on-demand (VoD), so the company ran ADSL-based trials with approximately 2500 test consumers from 1994 to 1995. But on its own, VoD failed as a commercial proposition. ADSL's emerging commercial service model adds Internet access, multimedia, online services, and videoconferencing for business and residential users. The Internet-access requirement is huge and growing fast: DTAG's T-Online, Europe's largest Internet-service provider, currently handles 60 million calls per month and has reported 60% growth over the company's 1996 and 1997 earnings.

ADSL must live with ISDN

Compatibility with ISDN is critical for ADSL's success in Europe (see **sidebar** "ADSL complements ISDN"). ISDN is a huge success in Germany, where DTAG's Hans Gusbeth confirms that the company has 3.3 million basic-rate lines and more than 8.5 million channels in use. In the United Kingdom, BT declines to confirm how many ISDN lines the company leases, but independent 1996 figures suggest 750,000 lines, and BT's current advertising boasts 2000 new installations per week.

ISDN's design doesn't accommodate simultaneous digital and conventional analogue telephony over the same line, but that isn't a problem. Digital phones guarantee the integrity of the voice circuit over ISDN because they can take power from the incoming phone line, ensuring life-line service. But with so many subscribers having only ISDN connections, ADSL must be simultaneously deliverable with ISDN. Because ADSL's original specification conflicted with ISDN, DTAG initially rejected the new technology, but soon the company became a prime mover in redesigning the specification. At the CeBIT '98 show, held in March in Hannover, Germany, DTAG's Gerd Tenzer affirmed his company's commitment to xDSL technologies—and ADSL in particular.

Prepare for ADSL roll-outs

BT's and DTAG's technical trials are now complete, and both companies are busy test-marketing ADSL-based applications. DTAG started pilot projects during April to approximately 100 commercial and 300 business customers, as well as to a university campus. Service-provider partners will assess subscriber acceptance of broadband services—including a business TV channel and an animated multimedia shopping mall—storing source material directly on DTAG's servers. Building on this experience, DTAG expects to roll out xDSL systems in eight major German cities before the end of this year: Berlin, Bonn, Cologne, Dusseldorf, Frankfurt, Hamburg, Munich, and Stuttgart. Furthermore, the company plans to have 40 xDSL networks operating next year—with 70 in place by 2002.

BT plans to provide ADSL links to approximately 2500 business and residential customers in West London this summer. BT's new trials involve approximately 30 independent service providers who will furnish Internet access, online services, and VoD. The downlink will be 2 Mbps with 148 kbps upstream and will be based on standard discrete-multitone (DMT) technology. According to David Orr at BT's press office, the organisation is fully committed to ADSL and will roll out full-blown services in "suitable locations," provided the West London trials succeed.

Other European trials include Telecom Italia's Milan venture, in conjunction with AMUSE, the European Commission's Advanced Multimedia Services to Residential Users programme. Technical trials began last year with an 8.2-Mbps downlink and 640-kbps uplink that suits VoD delivery using MPEG-2 video streams. Similarly, Belgium's Belgacom, France

Optimising the cost-to-performance trade-off has ADSL-IC vendors offering products that target varying bandwidth requirements (**Table 1**). Vendors base their chip sets either on a general-purpose, high-performance DSP or on a lower performance DSP coupled with coprocessor blocks. The high-performance DSP route is more flexible, but the DSP needs top-end performance to keep up with G.lite's real-time processing requirements or ADSL's full-rate speeds. Alternatively, coprocessors can perform parallel tasks, such as trellis coding and echo cancellation, and can significantly reduce overall system power consumption.

Varied architectures make straightforward comparisons of multiple chip sets difficult. Some vendors, such as Analog Devices, include all of the chips you need for a modem with their chip sets—and for an inclusive price. Other chip sets may include the transceiver and analogue front-end (AFE) in the price, but they exclude a controller and line driver. To make a realistic comparison, ask vendors to supply a bill of materials for completing a modem using various chip sets.

You'll notice that ADSL chip sets claim to comply with numerous versions of ADSL standards. Don't assume that chips claiming compliance to the same standard will necessarily work together. The problem is maturity—that is, vendors often claim compliance with standards that are not yet final. The base-line ADSL standard is ANSI T1.413 Issue 1, Category 1. Category 2 is a higher performance option that includes trellis coding and echo cancel-

Telecom, Norway's Telenor, and Kingston Communications (a UK independent) are all offering video-bandwidth services on a trial basis. Operators in Finland, Ireland, the Netherlands, Spain, Sweden, and Switzerland have trials that target ADSL's contemporary mixed-service commercial model.

Where will ADSL reach?

BT's "suitable-locations" phrase masks myriad commercial and technical considerations that vary from country to country. The Scandinavian countries enjoy the largest installed base of PCs in the world, with Sweden boasting the largest number of telephone lines per capita—68.3 lines per 100 people compared with 60.2 lines per 100 residents in the United States. (Note that those are *1994* figures.) In the Netherlands, cable companies have achieved close to 100% penetration, so coaxial solutions might look more attractive than ADSL. But the weak Italian cable infrastructure drives Telecom Italia's aggressive ADSL roll-out plans, which are scheduled to begin next year. Other operators with major ISDN investments want to protect their interests but may come under separate attack from the European Union's 1998 telecomm deregulation activity.

What's more quantifiable is the number of households that ADSL can potentially reach. Italy has the shortest average local-loop lengths anywhere, with almost all subscribers within a 3.7-km carrier-serving-area (CSA) range and 6.1-Mbps delivery. In the United Kingdom, more than 85% of subscribers are within CSA range, and in Germany that figure reaches 80%. Virtually all European subscribers fall within 5.5-km and 1.5-Mbps delivery range, which is also the specified reach for basic-rate-interface (BRI) ISDN lines.

Moreover, wiring practices differ from nation to nation. Some countries, such as Italy, use "bridge taps," which are unterminated spare pairs on the line that can resonate unpredictably. In some regions—including the United Kingdom—not all lines are copper. Aluminium-based connections are approximately 50% more resistive than copper per unit length, reducing reach. What's worse, the impedance change where copper meets aluminium creates reflections. Wire gauge is also significant, and, again, impedance changes between different connections affect performance. Although more of a problem in the United States, very long lines may have inductive load coils that maintain high-frequency voice response but kill ADSL-frequency signals. These considerations mean that operators must survey their lines to ensure that full-speed ADSL links are viable.

BT is considering test-marketing G.lite, which can theoretically reach almost every UK household. Implementation is a challenge, however, because the company has no control over the end user's intended location and therefore has no qualification of local-loop quality. But in February, BT became the first European telecomm operator to join the Universal ADSL Working Group and is now working to solve practical implementation issues. Because this process is so new, the company has no timetable for G.lite roll-outs.

What about the backbone?

You might wonder where the backbone bandwidth will come from to support the mass of new, potentially multi-Mbps subscribers. According to Robert Bury, marketing manager at Alcatel Microelectronics in Belgium, "ATM is emerging as the clear transport winner for ADSL applications. ATM's bit-rate flexibility matches the ADSL/DMT rate-adaptive model extremely well. Alcatel promoted this model from the start, initially with better acceptance in Europe than in the US where the frame-relay model was more prevalent. But in the last year, ATM has become the main model in the US, too." Bury's statement explains why you're beginning to see ADSL chip sets with integrated ATM ports.

Meanwhile, the backbone grows stronger with techniques such as ultradense wave-division multiplexing from Lucent Technologies. Lucent's WaveStar OLS 400G is a regenerative system for optical fibre that can transmit 3.2 Tbps using eight 400-Gbps parallel connections. Lucent estimates that WaveStar will work with approximately 90% of all installed fibre, which would provide 80 times more bandwidth than you currently enjoy.

lation for higher bit rates over longer distances. The follow-on specification, T1.413 Issue 2, is now complete and awaits final ratification. Issue 2 resolves ambiguities in Issue 1, and it adds a rate-adaptive operating mode and an optional ATM interworking layer.

Vendors compete for territory

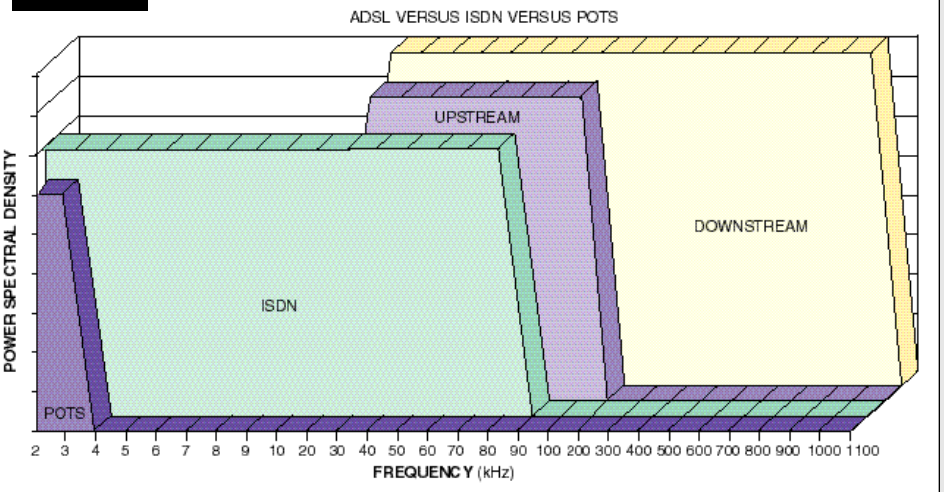
Currently, the only Issue 1, Category 2-compliant chip set available is Motorola's CopperGold transceiver that centres on the company's MC145650 DMT transceiver IC. This device integrates a general-purpose DSP, a T1.413-compliant data interface, and the AFE. The embedded 563xx-series 24-bit DSP core processes 20-bit precision DMT algorithms; coprocessors handle error-correction and echo-cancellation algorithms. Dedicated hardware allows the DSP to work at lower clock speeds and saves power. (CopperGold's transceiver typically dissipates less than 1W.) Motorola also offers the line driver, ATM cell processor, and a choice of host-controller options to complete an ADSL modem. Developers can also purchase an evaluation board, complete with application programming interface and system analyser software.

Texas Instruments' ADSL chip sets provide three configurations—one for network-side modems and two for client-side modems. TI's chip sets comply with ANSI T1.413 Issue 2, Category 2 and support 8-Mbps downstream and 800-kbps upstream data rates. The TNETD2000C chip set suits exchange

ADSL COMPLEMENTS ISDN

To understand integrated-services digital-network (ISDN) and asymmetrical-digital-subscriber-line (ADSL) interoperability issues, consider the basic technologies. ISDN's designers fitted it seamlessly within the increasingly digital n364-kbps telephone system, and there's little difference between a normal analogue phone line and an ISDN connection. For ISDN you need different wall-socket components to terminate and split the digital transmission line, but the underlying communications infrastructure is essentially the same. The big change for ISDN is that the codecs that translate between voice and the phone system's native PCM format move from your local exchange into your phone. If you're just transmitting data, you can benefit from an all-digital connection into your local trunk.

FIGURE A



The original ADSL specification conflicts with ISDN's spectrum starting at 25.8 kHz (courtesy Texas Instruments).

An ISDN basic-rate interface (BRI) provides two 64-kbps voice/data channels and one 16-kbps signalling/control channel, respectively termed "2B+D." If your equipment permits, you can concatenate both data channels for a 128-kbps data connection. Germany uses the "4B/3T" pulse-amplitude-modulation (PAM) line-coding technique to encode the data; the rest of Europe (and the United States) use "2B/1Q" coding. Either coding system relies on combining two or more bits into one symbol. "2B/1Q" means two-binary, one-quaternary, signifying coding 2 bits into one four-level element called a "quat." An ISDN signal's frequency spectrum depends on the line-coding technique but contains energy up to 110 to 120 kHz for the higher bandwidth 4B/3T code.

Most current ADSL implementations in the United States use carrier-amplitude-phase (CAP) modulation, a more complex version of an analogue modem's quadrature-amplitude-modulation system. CAP's competitor is discrete multitone (DMT), which communicates using a number of discrete frequencies, or "bins." DMT has won the standardisation battle that's now embodied within the baseline ANSI specification T1.413, and CAP is not part of any standard. But this move did nothing to ensure that ADSL could coexist with ISDN.

In the original specification, the DMT upstream spectrum comprised 32 tones spaced 4.3125 kHz apart, with tones one to five and 32 remaining unused. Low-frequency usage extended from approximately 25 kHz, which was well above

equipment, with two-line support from one transceiver. Two full-rate ADSL lines suit an exchange's DSL access multiplexer (DSLAM) as well as ADSL line cards; both lines are programmable for upgrades as standards evolve or subscriber bandwidth requirements change (**Figure 2**). TI's client-side modem ICs comprise the TNETD2000R chip set that suits external- and network-termination modems and the TNETD2000P chip set for PCI-card modems. The 2000P includes an ATM host interface controller and Microsoft Windows drivers. A reference design will be available by third quarter.

Alcatel, which pioneered ATM as the transport protocol for ADSL, offers silicon that includes the Issue 2 option for ATM interworking. DynaMiTe is the company's third-generation ADSL chip set in which the DMT modem IC integrates the ATM framing function. The chip set doesn't include ATM's segmentation and reassembly (SAR) because this function takes only approximately 2% of a host Pentium's bandwidth. But to remove any real-time constraints from the host processor, DynaMiTe includes a dedicated controller. Alcatel also provides a reference design for its chip set.

Polite local loop meets ATM

To promote rapid ADSL take-up, Alcatel licenced the DMT/ATM transceiver and AFE designs to AMD, ST-Microelectronics (formerly, SGS-Thomson), and Integrated Telecom Express,

analogue phones at 4 kHz but well within ISDN bandwidth (**Figure A**). For ADSL to coexist with ISDN, the ADSL data link must use higher frequencies than originally envisaged. Solutions include shifting tones up using a mixer, as well as extending the FFT algorithm to accommodate higher frequencies (**Figure B**). Consensus recommends shifting the base ADSL spectrum up from ISDN, with a corner frequency around 130 kHz to separate both systems. The newly extended ADSL upstream spectrum comprises 64 tones with the same 4.3125-kHz frequency spacing, but with tones one to 32 and 64 remaining unused (**Figure C**).

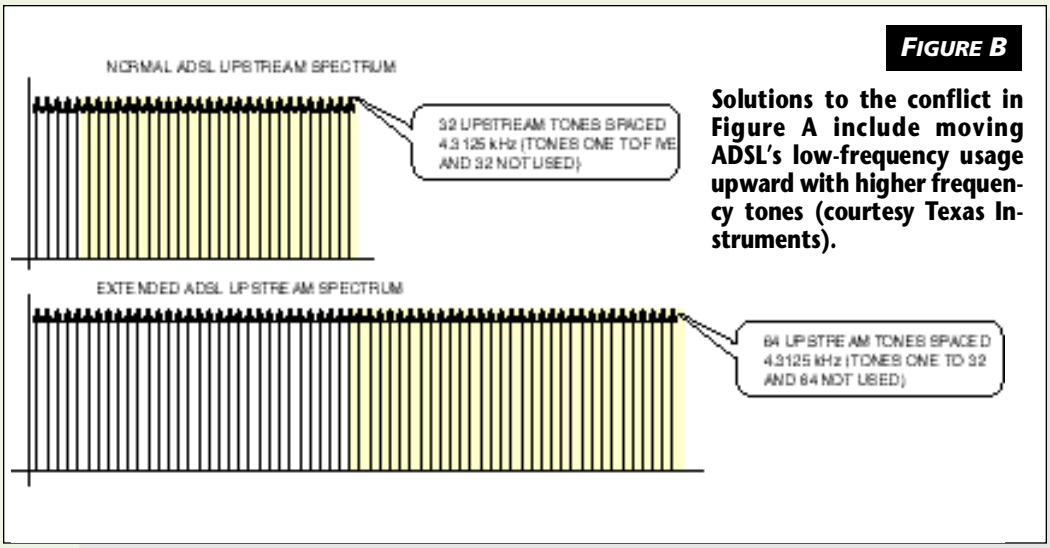


FIGURE B

Solutions to the conflict in Figure A include moving ADSL's low-frequency usage upward with higher frequency tones (courtesy Texas Instruments).

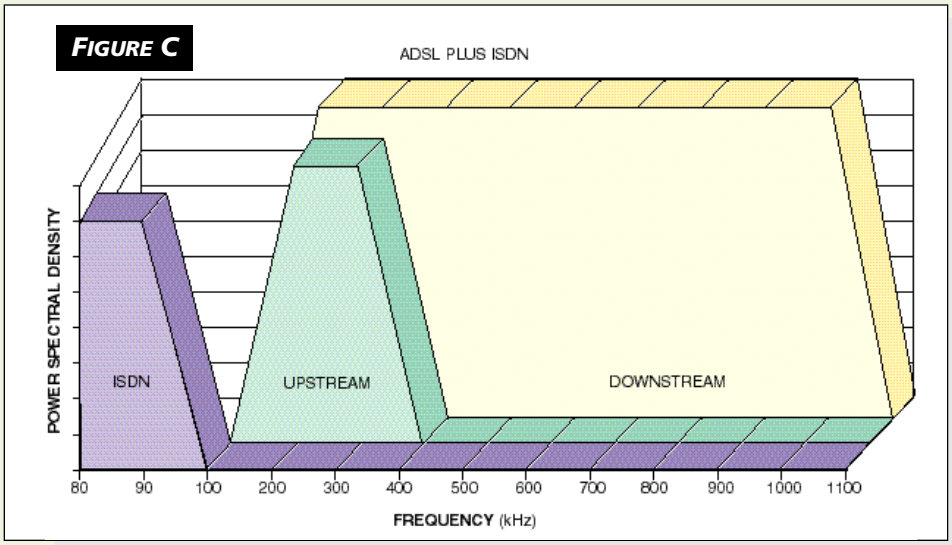


FIGURE C

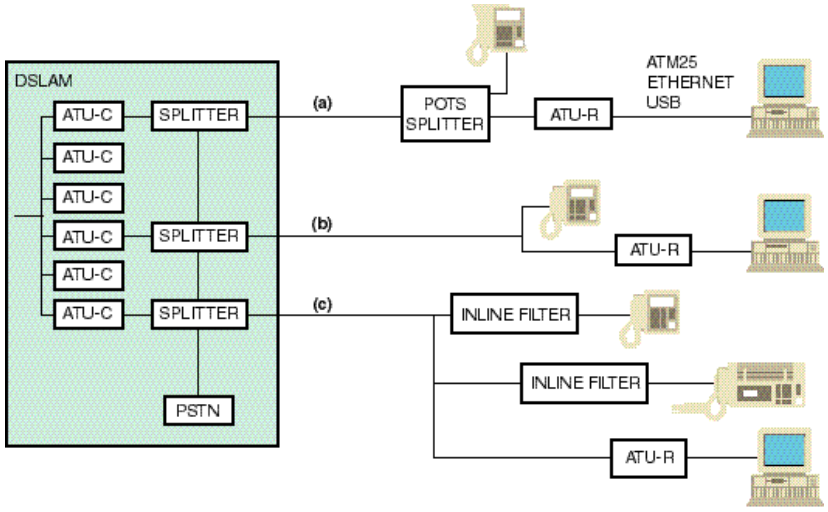
The modified spectrum separates ISDN and ADSL services with a corner frequency above 130 kHz (courtesy Texas Instruments).

G.LITE FOR ADSL

but licensees must develop their own controller ICs. STMicroelectronics' Tosca chip set is the first option to offer integrated ATM transport and framing functions. The Utopia level-2 interface connects directly to ATM systems. Using the vendor's mC code, the chip set can operate as a remote ADSL terminal unit (ATU-R) or central-office (exchange) device (ATU-C). A transmission "politeness" feature attenuates signal levels to reduce crosstalk in short local loops. In the downstream direction, an external multiplexer selects appropriate attenuation for reliable reception.

The customer-end ADSL termination has three possible splitter variations: full-rate ADSL, with a splitter where the local loop enters the premises (a); G.lite, with no splitter termination (b); and a nonstandard proprietary solution, with a filter at each terminal device (c) (courtesy Texas Instruments).

FIGURE 1



REPRESENTATIVE xDSL-MODEM CHIP-SET VENDORS AND STANDARDS ORGANISATIONS

For more information on the products and standards discussed in this feature, circle the appropriate numbers on the Information Retrieval Service card, or use *EDN Europe*'s Express Request service. When you contact any of the following manufacturers directly, please let them know that you read about their products in *EDN Europe*.

xDSL STANDARDS AND TRADE ORGANISATIONS:

ADSL Forum
Fremont, CA, USA
+1-510-608-5905
fax +1-510-608-5917
www.adsl.com
Circle No. 324

European Telecommunications Standards Institute (ETSI)
Sophia Antipolis, France
+33 4 92 94 43 95
fax +33 4 93 65 47 16
www.etsi.fr/
Circle No. 325

International Telecommunication Union
Geneva, Switzerland
www.itu.ch
Circle No. 326

Universal ADSL Working Group
www.uawg.org
Circle No. 327

xDSL MODEM IC VENDORS:

Alcatel
Brussels, Belgium
+32 2 72 81 83 76
www.alcatel.com/mietec
Circle No. 328

AMD
Woking, UK
+44 1276 803100
fax +44 1276 803102
www.amd.com
Circle No. 329

Analog Devices
Walton-on-Thames, UK
+44 1932 266000
www.analog.com
Circle No. 330

Fujitsu Microelectronics
Frankfurt, Germany
+44 1959 562772
fax +44 1959 562800
www.fujitsu-ede.com
Circle No. 331

Integrated Telecom Express (ITeX)
Santa Clara, CA, USA
+1-408-980-8689
fax +1-408-980-8831
www.itexinc.com
Circle No. 332

Lucent Technologies
Bracknell, UK
+44 118 932 4299
fax +44 118 932 8148
www.lucent.com
Circle No. 333

Motorola
March, UK
fax +44 1354 688248
www.motorola.com/adsl
Circle No. 334

Orckit Communications
Tel Aviv, Israel
+972 3 696 2121
www.orckit.com
Circle No. 335

Rockwell Semiconductor
Sophia Antipolis, France
+33 4 93 00 33 35
fax +33 4 93 00 33 03
www.rss.rockwell.com
Circle No. 336

STMicroelectronics
St Genis Pouilly, France
+33 4 50 40 25 00
fax +33 4 50 40 28 60
www.st.com
Circle No. 337

Texas Instruments
Velizy-Vellacoublay, France
+33 1 30 70 11 67
fax +33 1 30 70 10 32
www.ti.com
Circle No. 338

VOTE . . .
Please also use the Information Retrieval Service card to rate this article (circle one):
High Interest 590
Medium Interest 591
Low Interest 592

Super Circle Number
For more information on the products available from all of the vendors listed in this box, circle one number on the reader service card. **Circle No. 339**

G.LITE FOR ADSL

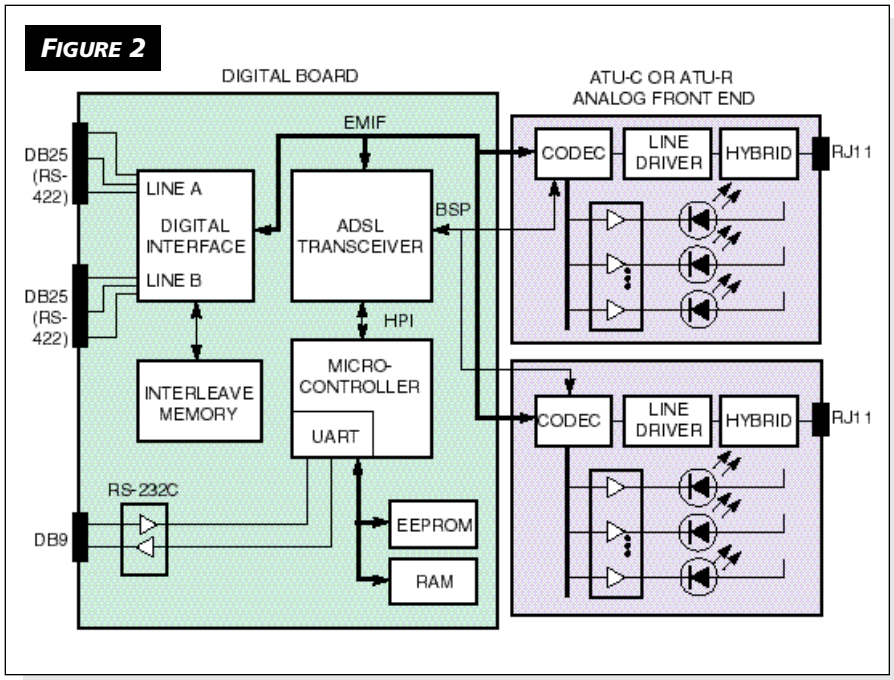
Analog Devices' second-generation AD20msp918 IC also adds Issue 2's ATM framing options, complying with Issue 2 Category 1, as well as higher performance trellis coding. The company's designers chose to omit Category 2 echo cancellation, believing that reach is more important than data rate. Crosstalk increases when using echo cancellation for higher data rates, reducing effective reach. With trellis coding, the bit-error rate (BER) remains acceptably low over longer distances. Suiting applications in which ISDN (integrated-services digital network) shares the same twisted-pair line, the IC features programmable frequency division between upstream and downstream spectra.

The latest ADSL chip set introductions from Lucent and Rockwell sidestep ANSI standards, bidding for consumer acceptance with a combination analogue-and-ADSL modem. Lucent's WildWire chip set evolves from its ITU V.90 (56-kbps) offering by adding G.lite capability (**Figure 3**). The DSP1690 IC couples two DSP1600 cores in one chip to provide 200-MIPS processing capability, typically consuming 1.5W. The chip set includes an autodetect feature that determines if the loop provides a DSL connection, allowing the user's modem to exchange data at the highest available rate. Software upgrades to G.lite compliance will become available when the standard is complete. Details for Rockwell's chip set were just emerging at press time, so check with the company (www.rss.rockwell.com) for full details.

Testing ensures success

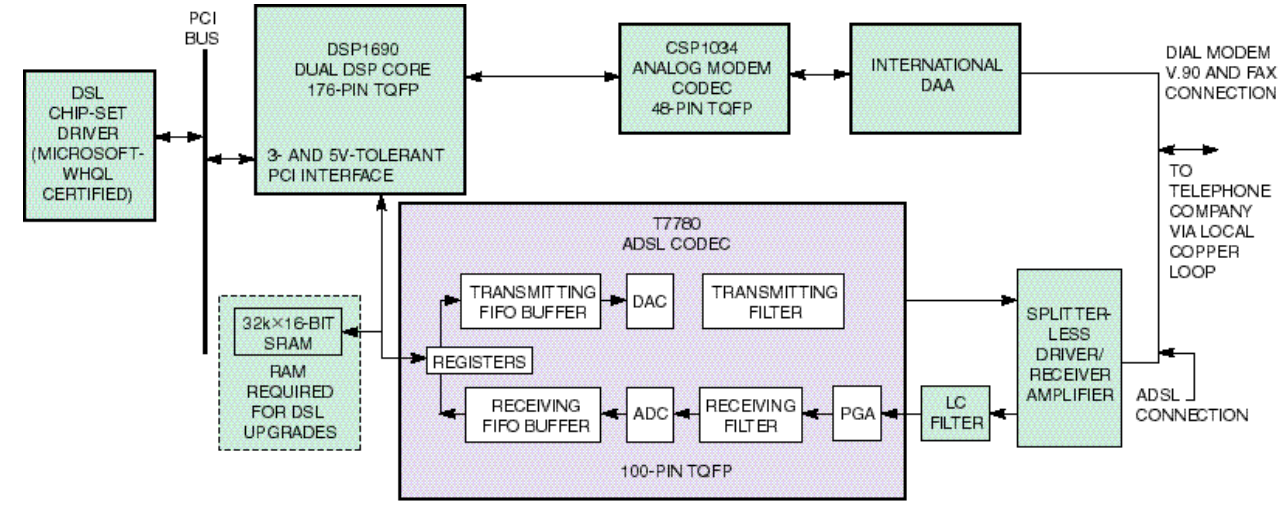
With the diverse array of ADSL chip sets available, interoperability testing is

FIGURE 2



An evaluation board for an exchange application shows the dual-line capability of the ADSL transceiver using the TMS320C6x DSP core (courtesy Texas Instruments).

FIGURE 3



Lucent's WildWire modem reference design builds on Windows plug-and-play V.90 (56-kbps) modem designs.

critical to success. Chip vendors must track evolving standards and cooperate with one another to guarantee physical-layer compatibility, while modem vendors need to cooperate at the network-protocol level. The ADSL Forum steers these issues, contracting independent test labs to develop compliance test specifications for ITU and ANSI standards. Individual companies are also taking action. For example, Alcatel produces an open implementation guide that describes the choices for the company's chip set in the standards context, notably with respect to ATM layer choices. And Alcatel, Analog Devices, and Texas Instruments have jointly announced intentions to perform mutual interoperability testing.

Universal interoperability testing should complete the UAWG's consumer-grade modem goal and restore ADSL to the forefront of the race for the home information superhighway. Because IC vendors are newly confident that ADSL will fulfil its initial promise, you can expect more highly integrated and application-specific chip sets to appear soon. EDN

Acknowledgments

Thanks to Rupert Baines at Analog Devices and Jean-Claude Baumer at Texas Instruments for assistance in preparing this article.

You can reach Contributing Technical Editor David Marsh at forncett@compuserve.com, or contact Technical Editor Stephen Kempainen at ednkempainen@worldnet.att.net.

VOTE

Please use the Information Retrieval Service card to rate this article (circle one):

High Interest	Medium Interest	Low Interest
590	591	592

TABLE 1—REPRESENTATIVE SAMPLING OF ADSL CHIP SETS

Vendor	Product	Functions and features	Standards	Price (qty)
Alcatel Circle No. 328	MTK-20131 DynaMiTe	Three chips include AFE, integrated DMT modem/ATM framer IC, and real-time transceiver controller; less than 2W power dissipation; direct ATM Utopia interface; complete reference design	T1.413 Issue 2, Category 1, G.lite	$60 (50,000)
Analog Devices Circle No. 330	AD20msp910	Five-device chip set for complete ADSL modem; includes controller, AFE, DMT coprocessor, framer/interface, and line driver/receiver; includes object code software for modem and management; chip set handles all real-time functions	T1.413 Issue 2, Category 1	$50 (50,000)
	AD20msp918	Second generation of msp910; adds trellis coding, ATM Utopia-2 interface, and new framing modes for improved performance at long reach; flexible frequency bin assignments	T1.413 Issue 2, Category 1+	$50 (50,000)
Fujitsu Circle No. 331	ADSL modem device	Single fully integrated chip with ATM framer and Utopia-2 interface; digital bit pump, AFE including filters; developed with Orckit	T1.413 Issue 2, Category 2, G.lite	$45 (50,000) (ships Q1 '99)
Integrated Telecom Express Circle No. 332	SAM (scalable ADSL modem)	Two chips–DSP modem and codec–designed for PC use; limits channel range to 4 to 500 kHz to accommodate 128 of possible 255 DMT channels; software allows host processor to perform some modulation tasks	G.lite	$40 (100,000) (ships Q4 '98)
	Full Rate chip set	Based on Alcatel chip set	T1.413 Issue 2, Category 1	$70 (100,000) (ships Q4 '98)
Lucent Circle No. 333	WildWire chip set	Three chips and software; V.90 functionality; upgrades for G.lite; includes DSP1690 dual DSP core, ADSL codec, and analogue modem codec; targeted for ATU-R, compatible with Lucent's Switching and Access Group's central-office (exchange) products	G.lite, V.90	$69 (10,000) (ships Q3 '98)
Motorola Circle No. 334	CopperGold	Two chips–line driver and transceiver–that integrate the digital bit pump, data interface, and AFE; less than 1W typical power dissipation; embedded DSP56300 with coprocessors	T1.413 Issue 2, Category 2, G.lite	$50 (100,000)
Rockwell Circle No. 336	V.90/ADSL combo chip set	Three chips, client-side target based on PairGain's single-chip 8-Mbps Falcon technology; V.90 dual-mode capability, programmable for G.lite	T1.413 Issue 2, G.lite, V.90	$67.50 (10,000) (ships Q1 '99)
STMicro-electronics Circle No. 337	Tosca ADSL modem chip set	Two chips and software, DMT transceiver, and AFE; transceiver integrates ATM transport with Utopia interface; 1.3W typical power dissipation; industrial operating temperature range; ATU-C and ATU-R applications	T1.413 Issue 2, Category 1, G.lite	$50 (10,000)
Texas Instruments Circle No. 338	TNETD2000P TNETD2000R TNETD2000C	P chip set for PCI card modems, R for external modems, and C for central-office (exchange) equipment; includes TMS320C6x DSP-based transceiver, digital interface IC, codec, and line driver; C chip set supports multiple lines from single transceiver	T1.413 Issue 2, Category 2, G.lite	C, $95; P, $76; R, $65 (25,000)