Optimizing Voice Communication ICs for Voice over Broadband (VoB)

A Legerity White Paper

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Legerity™

The PROVEN Communications IC Company

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Executive Overview

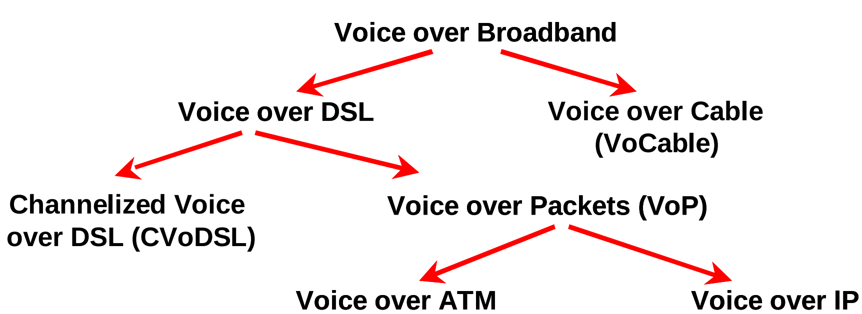
The broadband revolution is underway, driven primarily by the demand for high-speed Internet connections and rapid data transfers. While *data* appears to be the prime mover of broadband communications, many industry observers consider *voice* to be broadband's true "killer app." Although still in its infancy, the emerging "voice over broadband" (VoB) market holds great promise for the communications industry and represents the next incremental step in the ongoing evolution of the global voice/data network from a circuit- to packet-switching architecture. The ability to deliver voice over broadband reliably and efficiently will result in new revenue streams for service providers and provide subscribers with versatile, economical alternatives to "plain old telephone service" (POTS).

What is Voice over Broadband?

Voice over broadband refers to the various ways of delivering "derived voice" services (toll-quality voice, local and long-distance service, caller ID, call waiting, fax and dial-up modem capabilities) over a digital, broadband connection via twisted copper wire, coaxial cable, fiber optics and fixed wireless local loop.

With VoB, packetized voice calls are transmitted over packet-switched data networks, typically as asynchronous transfer mode (ATM) or Internet protocol (IP) packets. These two forms of voice over packet (VoP) are known respectively as VoATM and VoIP.

VoB Technology Variations



Source: Legerity

The two most common forms of VoB transmission technology are voice over digital subscriber line (VoDSL) and cable telephony, sometimes known as "VoCable." VoB can also be deployed through fiber to the home (FTTH) and fixed wireless networks, but these two niche technologies are overshadowed by DSL and cable, which will remain the predominate broadband pipes of choice for several years to come. For example, currently in the U.S., there are approximately seven million cable modem subscribers and 4.5 million DSL lines. Other countries, such as Korea, Germany and Scandinavian nations, have even much higher broadband penetration and are prime markets for VoB.

VoB Subscriber Benefits

VoB enables incumbent and competitive carriers, including cable multi-service operators (MSOs), to “bundle” services, such as voice, high-speed data, and video, to augment their service revenues and offer bundled service packages that will earn greater customer loyalty. Subscribers to these bundled services benefit from a unified, cost-effective service offering—including faster Internet access, video-on-demand, and cheaper second and third telephone lines—with the added convenience of one common billing statement. For the small office/home office (SOHO) and work-at-home market, VoB can enable a “virtual office” environment with such corporate network resources as public branch exchange (PBX) telephony and intranet access. For small-to-mid-size businesses (SMBs), VoB provides unified access to an integrated voice and data network in addition to Web and e-commerce capabilities.

Enabling Technology: Voice Integrated Circuits

Voice communication integrated circuits (ICs), working in concert with digital signal processors (DSPs) and protocol or multi-service processors, provide enabling technology for VoB customer premises equipment (CPE). Examples of CPE systems include integrated access devices (IADs), smart residential gateways (SRGs), network interface units (NIUs), cable modems and set-top boxes. These CPE-based broadband access systems require highly optimized voice connectivity chipsets that handle a variety of critical VoB functions. For examples, the voice chipsets convert digital/analog voice signals, manage the telephone ringing function, detect on-hook/off-hook conditions, and in general provide an interface between the VoB system and the subscriber’s analog telephone handsets and legacy fax/modem devices.

While VoB delivers voice services via new transport channels, a POTS loop is still required to connect voice services to the subscriber. VoB POTS loops differ from traditional POTS loops in several ways: they are much shorter (typically less than two thousand feet, often only a hundred feet inside the premises), have lower power requirements, and generally use simpler linecard circuitry. Historically, this circuitry—namely subscriber line interface circuits (SLICs) and codec/filters ICs—has been designed for such long-loop telephony applications as central office (CO) and digital loop carrier (DLC) linecards. But the advent of broadband access and VoB applications has pushed the local loop much closer to the subscriber, effectively collapsing the so-called “last-mile” into a very short loop or “zero loop” within the subscriber’s premises. The performance requirements of the VoB systems are much less stringent than those for, say, a CO-based Class 5 switch. VoB system designs are therefore much simpler.

Accordingly, voice chipsets can be optimized for the specific market and technical requirements of VoB applications. VoB system developers, too, have begun to question the need for retaining stringent performance requirements common to POTS systems.

This white paper highlights the evolution of POTS voice circuits, from their long-loop beginnings to their use today in short-loop VoB applications. It also explores the voice chipset requirements—such as reduced system costs, shorter loop lengths, fewer discrete components, integrated test features and support for CLASS features—that are unique to VoB.

The Emerging VoB Market—Scope and Growth

Primary users of broadband CPE include residential subscribers, SOHOs, and SMBs. Carriers and equipment makers are making significant investments in developing network and CPE solutions that support all aspects of VoB infrastructure, including the "last mile" reaching these users. While speed has been the dominant reason users have been signing on to broadband for data, value and reliability are also key criteria. Having an "always-on" connection is now considered just as important as performance and data rates. Until recently, such access was only available to large businesses that could afford the more expensive T1/T3 lines and other high-speed connections.

Unprecedented access, speed and flexibility are now available to many broadband subscribers at relatively affordable monthly rates. The value of broadband—the price versus speed tradeoff—is one key aspect to the VoB market's growth potential. In the U.S., individual and small business consumers currently access broadband more through cable (6.45 million as of mid-2001) than through DSL (2.91 million).[1] While only 5 to 8 percent of U.S. households use broadband access today, demand is outstripping supply. In the U.S. alone, 80 percent of all businesses are SMBs, of which 53 percent are home-based.[2] Also, most have fewer than 20 employees.

While worldwide the PSTN market continues to grow by an estimated 100 million voice lines a year—the majority of that growth occurring in China and India—the worldwide rate of national broadband penetration is still quite small even in the most industrialized countries. While the U.S. has a 3 percent broadband penetration rate, it is estimated that 75 percent of all U.S. households are broadband ready—up from 60 percent in 2000.[3] Other nations like Korea, Canada and Sweden all have higher penetration rates but still are in the single digits.

To reach critical mass in this splintered market, using VoB to unify telephony and data services is a compelling proposition. Besides minimizing the number of lines coming into the SMB or residence, life is greatly simplified by having a single, unified bill from one cost-effective service provider. Some industry observers suggest that bundling voice and data services is "a must" for retaining customers and realizing significant revenue potential per bit.[4]

Reasons for the growth of broadband and the emergence of the VoB market include:

- Worldwide deregulation of the telecom market, beginning in the U.S. with the Telecommunications Act of 1996

- The ongoing Internet explosion, with consumer demand for richer content and faster access

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[1] "DSL and Cable Battle for Broadband Supremacy in the Last Mile," Louis E. Frenzel, Electronic Design, July 23, 2001.

[2] U.S. Depart. of Commerce, Bureau of the Census; U.S. Depart. of Labor, Bureau of Labor Statistics; Advocacy-funded study by Joel Popkin & Company; U.S. Depart. of Commerce, International Trade Admin., SBA Office of Government Contracting.

[3] The Yankee Group, Oct 2001.

[4] Telechoice senior analyst Beth Gage, July 18, 2001 presentation to DSL World Forum.

- The need for convenient, unified access to data, voice and multimedia services
- "Copper exhaustion," with the demand for traditional access outpacing supply in developing nations, along with the need for second and third residential lines in developed nations.

Varieties of VoB Customer Premises Equipment

VoB technology addresses the needs of a new kind of customer who demands a new kind of access solution and voice service. A growing number of broadband-savvy residential, SOHO and SMB users are looking for voice services to be delivered over their broadband connection, be it cable or DSL. Broadband access equipment designed to accommodate such derived voice capabilities must be cost-effective, as well as space- and power-efficient. The market for VoB access equipment is highly competitive, and time to market is measured in months.

In traditional telephone service, all the action used to happen at the central office (CO). Evolving from "patch panels" to automated mechanical switches to digital switches, control of the subscriber loop began and ended at the CO. The advent of universal and then integrated digital loop carriers (UDLCs and IDLCs) moved the subscriber loop closer to the subscriber's premises.

With the proliferation of broadband and the deployment of fiber, the subscriber loop is much shorter—and more complex. The last mile to the subscriber must support a variety of broadband transport media (DSL, cable, wireless and fiber) over a network infrastructure installed and maintained by multiple carriers[5]. Depending on the media and the pipe, various broadband access devices have been developed to enable subscriber connectivity.

Broadband Delivery Access Equipment				
Pipe Type	**CPE by VoB Type**			
Wireline	VoIP / VoDSL ▪ IAD ▪ Home gateway & router ▪ SRGs & router	Cable Telephony ▪ Circuit-switched (NIU)* ▪ Packet-switched (NIU)* ▪ Set-top box** ▪ House-side box** ▪ Voice-enabled modem**	Others ▪ ISDN ▪ IP PBX ▪ Routers	
Fiber***	Fiber in the loop (FITL)****	Fiber to the neighborhood (FTTN)**** Hybrid fiber cable (HFC)****	Fiber to the home (FTTH)****	Fiber to the curb (FTTC)****
Wireless	Wireless Local Loop	Cellular	Wireless ▪ LMDS ▪ MMDS	Satellite
*Located outside the building. ** Located inside the building. ***Depending on how close a fiber line comes to the subscriber, fiber can be both wired and wireless. ****NIUs are network interface units used by both cable telephony and fiber.				

[5] Incumbent local exchange carriers (ILECs), competitive local exchange carriers (CLECs), building local exchange carriers (BLECs), Internet service providers (ISPs) as well as cable providers all offer services to homes and small businesses.

VoDSL

VoDSL is a generic term for VoB systems that transmit digitized voice as ATM packets over an xDSL copper loop. Examples of VoDSL access equipment include integrated access devices (IADs), smart residential gateways (SRGs) and multiservice broadband access devices for multi-tenant units (MTUs).

An IAD resides at the customer premises and connects to a local loop that has been converted to a DSL line. An IAD can support from two to 24 analog or T1 digital voice ports, as well as data ports via Ethernet or USB ports over a single DSL line. The IAD's analog voice port can support a conventional analog telephone, fax machine and analog modem.

In very simplistic terms, the IAD has two inputs (one for analog voice and one for digital data) and one output. The IAD converts analog voice signals into digital signals and then converts the digital voice stream and the incoming data stream into packets. These packets are transmitted over the DSL lines. The other end of DSL line connects to a DSLAM where the voice packets are identified and passed on to a voice gateway, which in turn "de-packetizes" them into signals that can be transported over an ILEC's public switched telephone network (PSTN). The data packets from the DSLAM go directly into a public switched data network, such as the Internet.

Cable Telephony

Cable telephony involves telephony functions that are carried over either cable or hybrid cable-fiber (HFC) networks. Cable telephony has a promising future because it supports bundled services that include voice, data and television entertainment. In the past, this market did not grow due to the lack of universal standards and lack of investment that was needed in upgrading cable infrastructure from one-way to two-way communication capabilities. However, over the past couple years, realizing the potential that cable can offer, AT&T, Microsoft and AOL-Time Warner began investing billions of dollars in upgrades and standardization efforts. AT&T is now the largest cable company in North America.

The CPE units to which the cable attaches can be located either inside or outside of a house. If it is outside, the unit is known as a Network Interface Unit (NIU). If it is located inside the house, it can be either a separate box or part of set-top box, a residential gateway or cable modem. The location depends entirely on the user's and service provider's preferences and convenience.

Both circuit-switched and packet-switched voice technologies are being deployed in cable NIUs. These systems transmit digitized voice from the customer premises on the cable to the head-end or central office. Voice is then separated and transmitted over the telecommunications or data communications network.

VoB CPE Types for DSL and Cable		
Device:	IAD	NIU
Purpose:	An access node that simultaneously delivers Class 5 switch voice services, packet voice services, and data services (via LAN ports) over a single WAN link. Converges multiple analog/digital lines to digitized packets transmitted over xDSL. The other end connects to a DSLAM where voice packets are IDed and passed to voice gateways to turn signals back for transport over PSTN. Provides a common platform that enables service providers to deliver voice and data over a single access network, reducing the cost of co-located equipment in the telco's CO. *See Figure 1.*	Enables communication between devices that use different protocols, i.e., cable and telephony, by supplying a common transmission protocol. Both circuit-switched and packet-switched voice are being transmitted by NIUs from cable at the customer premises to the CO where voice is separated for transmission over the telco. Standards are still an issue, especially with QoS. *See Figure 2.*
Supports:	• 2-24 analog or T1 digital voice ports; Ethernet or USB data ports • 2 inputs (analog voice, digital data) • Analog port can support devices such as telephone, fax, modem.	Services may include structured and unstructured T1/E1; T3/E3; 10BaseT; video; POTS; frame relay; ATM 25.6; and integrated services digital network (ISDN) basic-rate interface (BRI), primary-rate interface (PRI). Communicates with the base station through a 2-way transceiver that includes: • variable-bandwidth radio modem • an ATM segmentation-and-reassembly (SAR) processing unit • a subscriber equipment interface
Transmits on	DSL or T1	Cable or hybrid cable-fiber (HFC)

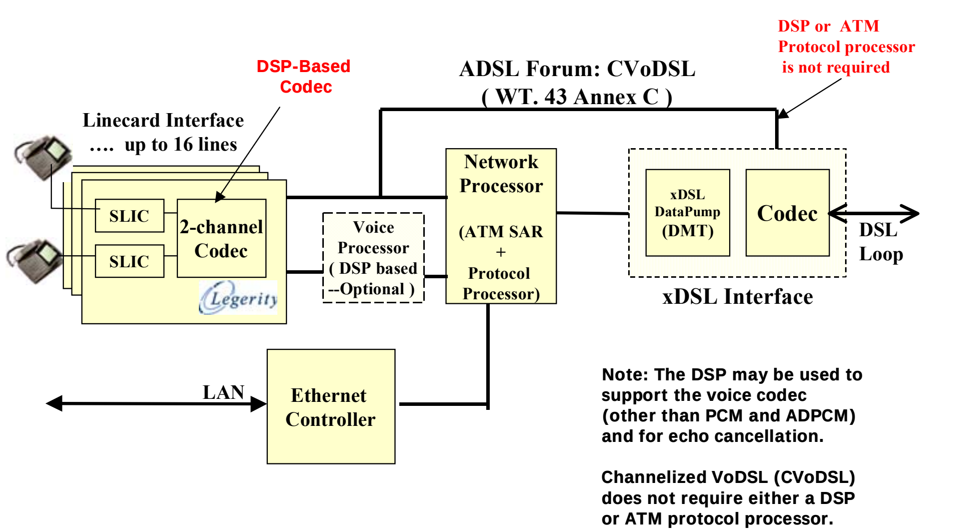

Figure 1.VoB Delivery—IAD block diagram [Source: Legerity]

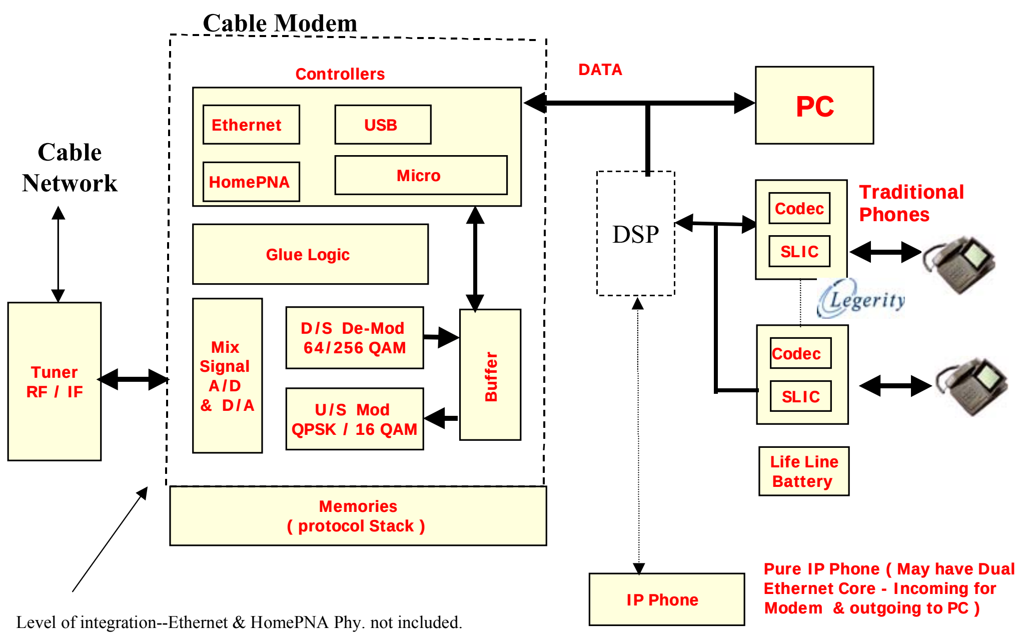

Figure 2. VoB Delivery – Cable Telephony block diagram [Source: Legerity]

The Role of Voice ICs in VoB Access Equipment

The key IC components of a typical broadband CPE system include the network or protocol processor, an optional digital signal processor (for additional voice processing), and line interface ICs, which are known as subscriber line interface circuits (SLICs) and codec/filters. In most designs, SLICs and codecs are paired as voice chipsets that supports standard analog telephones and fax/modem equipment and complement the functions of the network processor and optional DSP.

SLIC Defined

The SLIC—an analog IC that performs the two- to four-wire conversion (known as the "hybrid" function) and DC loop feed—is almost invariably a high-voltage bipolar device. (CMOS-based SLIC-like devices exist, but these require external discretes and power chips that drive up the cost per port.) Most SLICs are single channel, although dual-channel SLICs are preferable for 2-to-4 port VoB applications, enabling higher-density, lower-cost designs. SLICs that operate at 3.3V are preferable for VoB systems where low power dissipation is a must. On-chip features such as ringing, switching regulator and loop testing capabilities are also desirable because a higher level of features integration reduces external component count and system cost.

VoB market requirements for optimized SLICs include:

- *Internal ringer* – On-chip ringing capability reduces system costs by eliminating the need for external ringers and relays. Legerity invented the Ringing SLIC in the mid-1990s.

- *Flexible interface* – The SLIC should be able to interface with codec/filters or combinations of codecs and DSP devices via either a single-ended or differential output.
- *Low power operation* – SLIC devices need two-voltage rails: a high-voltage rail for ringing the phone and a low-voltage rail used during off-hook conversation.
- *Battery switcher* – Internal switch enables "toggling" between high- and low-battery supply.
- *Switching regulator* – This uses a combination of single-supply power rail and pulse width modulated (PWM) switching regulator to drive both the high and low-voltage rail. The regulator can be external or integrated into the SLIC—an innovative approach that reduces component count and system-level cost for the board manufacturer. An internal switcher is desirable for most VoB applications, which are typically 2-4 channel.

Codec Defined

A codec is a highly integrated, CMOS-based mixed-signal device that performs analog-to-digital and digital-to-analog (A/D and D/A) conversion, as well as signal processing such as filtering, line equalization, hybrid balance, supervision, SLIC device control, and critical test routines. Most codecs are multi-channel, with two and four-channel variations being the most prevalent. The majority of codec functionality is based on embedded digital signal processing (DSP) technology. Working in concert with leading communication equipment vendors like Ericsson and Siemens, Legerity pioneered the use of embedded DSP cores in codec/filters. (Legerity codecs are widely known in the communications market as SLAC™ devices.)

Most DSP-based codecs are optimized for long-loop applications and lack additional DSP processing power that may be needed in short-loop VoB systems. As a result, the majority of today's VoB applications use SLICs and codecs in concert with external DSP devices.

A New Flavor of "BORSCHT" for VoB

All POTS line interface circuits, including those used in VoB equipment, must support a handful of the same basic functions, which are described by the industry-standard BORSCHT acronym:

B	O	R	S	C	H	T
Battery feed	Overvoltage protection	Ringing	Supervision	Code/Decode	Hybrid	Test

Beyond these classic BORSCHT functions, VoB system designs must take into account optimal channel density (typically 2-4 lines), performance, power sources and adherence to telecom industry standards to ensure interoperability.

Voice ICs optimized for short-loop VoB applications differ from those designed for the traditional voice market, requiring simplified standards for BORSCHT. [See the **Long-Loop vs. Short-Loop** table for a detailed comparison.] Traditional POTS line circuits can be applied to VoB system designs, but they are not optimized for these short-loop applications. Use of short-loop-optimized voice chipsets in VoB system designs can result in significant savings in cost, power, board space, design complexity and time to market.

Long-Loop vs. Short-Loop Voice Chipset Requirements for BORSCHT Functions		
BORSCHT Function	**Long-Loop Applications**	**Short-Loop Applications**
B attery feed – power supplied to loop for signaling/operation	▪ Typically –48V but can be higher ▪ Life-line support, back-up batteries required	▪ Lower voltage operation desired ▪ No batteries, no life-line support on derived lines
O vervoltage protection – withstand lightning strikes and power line short circuits	▪ Required for safety against lightning and power cross ▪ Supports ITU-20K, UL1950, etc.	▪ Usually no outside wiring ▪ Minimal lightning exposure ▪ Lower voltage levels on power cross
R inging – 40V RMS required at ringing load	▪ Bulk ringers shared among many channels ▪ Loop Z requires high ringing voltages supplied to line	▪ On-chip ringing more cost effective for fewer channels ▪ Lower loop Z, thus lower voltages required to source ring load
S upervision – monitoring loop current to recognize on-hook/off-hook and dialing input	▪ Need to supply larger loop currents (up to 100 mA) ▪ Programmable loop currents, adapt to loop length	▪ Large loop currents not required to avoid unnecessary power dissipation (typically less than 40 mA) ▪ Drive line with lower voltages
C ode/Decode – code and decode voice signals into digital codes for PCM time slots and digital transmission; function handled by a "codec" IC	▪ G.711 A- or μ-Law PCM compliant	▪ Support required for G.711 PCM ▪ Many systems adding G.726 for toll quality and cost effectiveness ▪ Future systems may use G.728 and/or G.729 as these mature
H ybrid – 2-to-4 wire conversion, echo cancellation	▪ Less critical because of line loss	▪ Good performance needed due to transport delay ▪ Benefits from DSP-enabled adaptive balance ▪ Typically achieve 15-30 dB
T est – detect faults and provide maintenance, resulting in higher network reliability and fewer costly "truck rolls"	▪ Required for fault detection and maintenance	▪ Historically ignored in VoB market ▪ Should be on-chip to save cost and board space ▪ Gaining market acceptance

VoB Market Requirements for Voice ICs

VoB equipment manufacturers require highly integrated voice chipsets that enable low-cost, low-power, high-density system designs. These manufacturers also want simplified bills of material (BOMs) and reduced component counts (fewer discrete components), which can contribute to significant board space and system cost savings.

Voice IC products for VoB applications are influenced by the following market requirements:

- Line density
- Power consumption
- Loop length and load
- System-level cost
- Interoperability and standards Support
- Integrated loop testing
- CLASS features support

- Fax/Modem service support
- Application development support for fast time to market.

Line Density

The number of derived voice channels per NIU—or line density—can scale up to 24 lines. However, it is anticipated that 2-4 channels is the sweet spot for the VoB market, especially for the SOHO and residential markets. SMBs may require a few more lines.

The optimal chipset affords the highest density with the fewest number of external components. For example, a two-device voice chipset for two derived voice lines would be considered state of the art in the current communication IC industry.

Power

The total power being consumed by a VoB system is a critical factor that can determine the product's success or failure in the market. One reason why low power operation is essential is that the equipment must be battery-backed. This back-up power capability is required so that subscribers can have "lifeline" service, i.e., assured telephone access to emergency services such as fire, police and medical responders even if there is a main power failure. Lifeline support is obligatory, and often there are laws that require provision of such services.

Lines can be terminated in two ways. One method is to terminate the line inside the customer premises, using equipment such as an IAD, a voice-enabled cable modem, or a set-top box. The other method is to use an environmentally hardened outdoor unit, such as an NIU. Due to various complications associated with access, the status of customer premises wiring, power source, security, warranty, etc, the NIU approach is preferred by most broadband equipment providers. The back-up battery resides in the NIU and is trickled-charged through the loop current.

To minimize total cost of ownership, service providers endeavor to limit the amount of power each NIU draws. Documents obtained from service provider such as AT&T, SBC and British Telecom specify that for four voice line plus data, the average power for the entire unit should be ~4 watts in standby mode and ~6 watts in active mode. Today, the average system power requirement tends to be in the ~7 to 9 watt range. As far as power consumption for line interfaces ICs is concerned, important specifications include on-hook power-standby, on-hook transmission and off-hook active. To be competitive in the market, voice IC power specifications should be as low as possible. Currently, 3.3V voice IC devices are preferred to reduce overall system power and to eliminate the need for multiple voltage rails.

Loop Length and Load

The loop length between the subscriber phones and the line interface card is much shorter for VoB applications than for long-loop POTS applications, which can be measured in terms of miles. The shorter length of VoB applications (2000 feet or less) is a key consideration that affects both power and noise performance. As the current is pushed through the loop, inherent loop resistance leads to a voltage drop that is proportional to loop length. A SLIC is designed to sense this condition, compensate for voltage drops and maintain necessary operating voltage.

Another important factor is "loop load"—how many phones are connected to the loop. This figure is specified as a Ringer Equivalent Number (REN). In a typical non-broadband-equipped household, the REN is five, meaning that the subscriber can connect up to five phones, but each of them will have the same telephone number. However, a VoB system allows users to have multiple phones, each with its own number. As a result, the REN may drop to three, contributing to lower system cost.

System Cost

As the level of voice IC integration increases, the measure of true system-level value should be "dollars per voice port." This value includes the combined cost of all voice ICs and required discrete components. The average total system-level cost per line is ~$ 8.50. Of that, the average per-line cost of the SLIC and codec chipset is about ~$ 4.75.

Current SLIC and codec/filter devices used in VoB systems have evolved from line interface chipsets used in traditional telecom applications, such as CO and DLC linecards. Consequently, traditional voice ICs are optimized for long-loop reach (the distance between the telephone handset and the line termination card), multiple linecards with centralized ringing, high-voltage power rails, and an assortment of remote testing and diagnostic features. VoB systems, however, have distinctly different requirements, such as short loops , multiple codecs, local echo cancellation, caller ID, DTMF generation, lower power, etc. To ensure overall cost-competitiveness, voice chipset features must be optimized for VoB applications.

Interoperability and Standards Support

Interoperability is a key requirement for all broadband systems. The ability to interface with any commercially available analog telephone is imperative for voice ICs used in VoB equipment. Furthermore, to support operations in every country and meet varying telecom standards, the voice ICs must be programmable and be able to handle multiple speech coding standards, such as G.711 (64 Kbits/sec).

Telecom standards vary according to the broadband delivery technology. The DSL Forum (www.adsl.com) is driving VoDSL standards and is considering three separate recommendations: real-time voice under Broadband Loop Emulation System (BLES); non-real-time voice and video under Multi Service Data Network (MSDN); and cost-effective, real-time voice under Channelized VoDSL (CVoDSL). For cable telephony, the Cable Labs industry forum (www.cablelabs.com) is highly influential, and it has adopted a packet-based system known as PacketCable.

Integrated Loop Testing

Remote loop testing is extremely important to service providers because this capability allows them to reduce total cost of ownership by avoiding costly "truck rolls" to the subscriber's premises to troubleshoot line problems. In the early days of VoDSL deployment, integrated test features were ignored, but as the VoB market progresses toward mass-deployment, broadband loop testing is becoming a "must-have" feature that can tip the balance between success and failure of VoB products and services.

The number of test routines integrated into a VoB voice chipset must be weighed against the cost of the test-enabled chipset and the ultimate cost-savings extended to carriers. For these reasons, it is critical that voice ICs offer some level of on-chip testing features. It is also vital that the protocol processor and optional DSP in a VoB design support the voice chipset's integrated test features. The emerging GR-909 standard for optical system testing may be applicable to VoB systems and may define on-chip testing functionality for VoB voice chipsets going forward.

Basic on-chip test features should include checks for integrity of signals on the loop and integrity of connection between the subscriber terminal and the line interface IC. Loop signals that require testing include ringing, voice quality, battery feed and metering. Connectivity test include checking for resistive leakage paths, line capacitance, presence of foreign voltages, noise, excessive ringer loads and open circuits. To enhance on-chip testing, the voice IC must have relay drivers, which can be internal or external to the chip. Internal relays increase chip-level cost but decrease overall system cost.

CLASS Features Support

Custom local area signaling system (CLASS) features have become a mainstay in the POTS world. Subscribers have grown accustomed to having CLASS features, including caller ID, three-way calling, call forwarding, and call waiting. In the past, these functions were performed within the telco's CO or DLC, but increasingly CLASS functions are being performed in VoB equipment in the customer's premises. Therefore, line interface ICs in the CPE systems must have the ability to generate or support CLASS features, such as caller ID.

Fax/Modem Service Support

Many subscribers have invested in fax machines that require a conventional analog dial-up connection. As a result, VoB equipment must provide support for legacy telecommunications equipment, such as fax machines. Upon fax signal detection, the VoB system also must provide automatic switchover capability to PCM. These fax capabilities can be addressed by the on-board voice chipset.

Similarly, a VoB system should support v.90 modem and other legacy analog modem standards, even though a broadband connection effectively renders dial-up modems obsolete. Optimizing the noise performance of linecard ICs will provide the subscriber with the highest possible data rate for an emergency situation, such as a temporary loss of broadband service. On-chip modem support will enable the subscriber to have Internet access under any loss-of-broadband-service scenario. Since a v.90 modem is so inexpensive these days, it's cost-effective to have a modem built into a VoB system to provide a back-up access capability.

Application Development Support for Fast Time to Market

Most broadband equipment developers excel at the data portion of the system but lack essential expertise on the more complex voice side. Offering these data-centric system engineers a voice chipset is not sufficient to guarantee the viability of a VoB system based on that chipset. VoB system designers need a comprehensive application development environment that makes it fast and easy to add voice capabilities to a data system. Key support tools include evaluation boards, demonstration boards and reference designs, as well as associated software developer kits

(SDKs). These application development tools ultimately enable the equipment manufacturer to accelerate the design cycle and speed time to market.

Legerity Voice IC Solutions for VoB

An emerging market like VoB poses both opportunities and risks for service providers and CPE equipment manufacturers. One way to minimize risk is to rely on proven expertise, technologies and solutions that have been fine-tuned to meet the evolving requirements of new markets.

Legerity is a proven supplier of voice ICs for the communications industry. The company has more than 20 years of experience in developing voice chipsets optimized for a wide range of telecommunication applications. Working in concert with leading equipment vendors like Ericsson and Siemens, Legerity pioneered the use of embedded DSP cores in codec/filters, and it invented a line interface product category that has become an industry standard: the Ringing SLIC. As the world's leading supplier of voice ICs for the public network, Legerity has shipped more than 300 million SLAC™ coded/filters and more than 175 million SLIC devices to date. In fact, more than one third of all voice and data calls pass through Legerity ICs.

Legerity has leveraged its long history and deep expertise in POTS chipsets to develop a growing portfolio of voice ICs optimized for short-loop, VoB system designs. Legerity Ringing SLICs are now widely used in VoB applications to generate and drive ringing for telephones connected to VoDSL and VoIP systems. These SLICs are often matched with Legerity's Dual and Quad SLAC codecs to provide a complete voice chipset solution for VoB. Legerity trailblazed the voice IC market for VoB with its Intelligent Access Voice family, the first voice ICs optimized for short-loop applications. Legerity is also a pacesetter in providing on-chip loop testing capabilities in its voice ICs for both traditional POTS and VoB applications.

Legerity's most recent milestone in the VoB market is its introduction of the Voice Access™ Solutions chipset, the industry's first dual-channel, two-device solution for VoB applications. (See the press announcement at http://www.legerity.com/press_room.php?id=37.) Legerity's Voice Access chipset is designed to meet the requirements of customer premises equipment (CPE) manufacturers by reducing system-level cost, decreasing power consumption and increasing board density for a wide range of broadband systems.

The first members of the Voice Access chipset family are the 3.3V, dual-channel VoSLIC™ device and the 3.3V dual-channel VoSLAC™ codec/filter. These initial members of the Voice Access family support a wide range of essential derived voice features, such as on-chip ringing, caller ID, toll-grade voice quality, and integrated loop testing. A key Voice Access chipset innovation is the VoSLIC device's integrated switching regulator, which eliminates the need for external power management chips, increases board density, and ultimately helps reduce total system-level cost.

An evolutionary extension of Legerity's 20 years of POTS voice IC expertise, the new Voice Access chipset is designed to simplify the process of adding toll-grade "derived voice" to VoB applications. When used with Legerity's VoicePath™ software development kit (SDK), the Voice Access chipset can demonstrate compliance with the emerging GR-909 broadband loop testing standard. The SDK meets key North American, European and Asian telecommunications standards. The combination of these development tools, along with Legerity's global applications support, will enable faster design cycles and lower engineering and production expenses for broadband equipment manufacturers around the world.

Voice Access™ Chipset Features	
Le77D11 VoSLIC	**Le78D11 VoSLAC**
• Two channels • 3.3V operation • Constant current feed • Programmable current limit • Low power standby state • On-hook transmission • Optimized on-chip switching regulator • Programmable AC impedance • On-chip 100V ringing (~65Vrms) • Sine or trapezoidal ringing • DC offset ringing • Polarity reversal • Optimized for low power • TQFP Package (44 pin)	• Two Channels • 3.3V operation • µ law, A law or linear • PCM or ADPCM • Programmable gain, impedance and hybrid • Adaptive balance • Constant current design • Several fixed programmable levels • Loop supervision • Ringing/tone generation and control • DTMF detection to Q.24 • Switching regulator support • Caller ID tone generation • Modem tone detection to V.25 • Metering generation • TQFP Package (44 pin)

Future Considerations

The century-old circuit-switched telecom network is in transition, evolving steadily toward a packet architecture. Equipment vendors that provide circuit-switched systems are already beginning to develop packet-based systems. While packet-switching offers greater service flexibility, cost savings and scalability than circuit-switching, quality of service (QoS) parameters and interoperability standards are still being defined for packet. As the QoS issues are resolved and the standards effort solidifies, packet- switching will eventually dominate the telecom market. The overall network transition from circuit- to packet-switching technologies will occur gradually over the remainder of this decade and perhaps well into the next. By the end of the decade, IP telephony and VoP are expected to become more established as the new packet-voice infrastructure builds out.

As packet-switching becomes more prevalent, the need for SLICs in VoB access equipment will diminish. Even today, IP phones, Web phones and most of the feature-rich terminals that connect to either PBX or IP PBX systems do not require SLIC devices. In the future, as the level of silicon integration increases in VoB systems, the functional overlap between the codec and external DSP means that one of these components may eventually become redundant. A codec device with additional DSP horsepower will be useful in VoB applications, and this added cost of integrated DSP capability must be carefully balanced against overall system costs. Over time, the codec function could also become absorbed into the media or network processor.

Meanwhile, SLICs and codecs continue to perform critical functions in VoB access equipment and are essential to system designs that support analog telephones and legacy fax/modem equipment in short-loop environments. Bundling voice and data functions over one line will be ubiquitous over time. But the evolutionary transition to a pure IP network will take a decade, if not longer. In the meantime, service providers and equipment manufactures must make sound investments in intermediate VoB system solutions during the transition from a circuit- to packet-switched architecture.

About Legerity, Inc.

Legerity is the proven communication integrated circuit (IC) company providing system solutions that accelerate the deployment of integrated voice and data networks. Legerity combines IC design expertise and unique process technology with global applications support for leading communication system manufacturers worldwide. Visit Legerity on the Web at www.legerity.com.

Appendix

FREQUENTLY USED ACRONYMS/ABBREVIATIONS

ADM – add drop multiplexer

ATM – asynchronous transfer mode

BLEC – building local exchange carrier

BOM – bill of materials

CLASS – call waiting, caller id, and business (Centrex) services

CLEC – competitive local exchange carrier

CO – central office

Codec – coder/decoder

CPE – customer premises equipment

CSP – communication service provider

DLC – digital loop carrier

DSL – digital subscriber line

DSP – digital signal processor

FTTC – fiber to the curb

FXO – foreign exchange office

IAD – integrated access device

IVD – integrated voice and data

ILEC – incumbent local exchange carrier

IXC – inter-exchange carriers

LCAS – linecard access switch

LMDS – local multipoint distribution service (fixed wireless)

MMDS – multichannel multipoint distribution service (fixed wireless)

MSO – multi-service operator

MTB – multi-tenant broadband

MTU – multi-tenant, multi-dwelling unit

NID – network interface device

NIU – network interface unit

NVI – new voice infrastructure (end-to-end packet network)

PBX – private branch exchange

POTS – plain old telephone service

PSTN – public switched telephone network

REN – ring equivalent number

RT – remote termination

SLIC – subscriber line interface circuit

SLAC™ – subscriber line audio-processing circuit

SMB – small to mid-size business

SRG – smart residential gateway

VoB – voice over broadband

VoDSL – voice over DSL

VoFR – voice over frame relay

VoIP – voice over Internet protocol

VoP – voice over packet