White Paper:

High Quality Analog Interface Cards for Use with Asterisk®

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Digium's Asterisk® software has, since its first release in December of 1999, become the global standard for companies and individuals who want to decrease their cost of ownership of, and improve their control over, telecommunications. With Asterisk users build anything from simple home-based business solutions to complex multi-location enterprise telephone systems. Since 2001 Digium has designed, manufactured, and sold PC-based interface cards for extending the functionality of Asterisk to the Public Switched Telephone Network (PSTN). Besides cards for connecting to digital E1/T1/PRI or BRI, Digium® also manufactures a number of modular analog interface cards for connecting to regular POTS lines and trunks.

Presently, Digium offers five (5) different modular analog interface cards with another, the sixth (6), scheduled to be available in July, 2008. These interface cards are the four port TDM410 and AEX410 (Available in July, 2008), the eight port TDM800 and AEX800, and the twenty-four port TDM2400 and AEX2400. With these cards, users can transport calls from POTS to POTS, POTS to PBX, or POTS to VoIP.

Digium is committed to providing our customers with a high-quality telephony solution. All Digium analog interface cards are manufactured to be RoHS compliant in a ISO 9001:2001 certified manufacturing facility in the United States. Each analog card maintains an MTBF greater than one (1) million hours. Further, each Digium analog interface card is backed by a five (5) year hardware warranty and the Digium Exceptional Satisfaction Program (ESP). In the event that any customer is not satisfied with the performance of their Digium card, they may apply for the ESP, in which case they may be refunded directly by Digium. If Digium refunds the customer directly, the reseller is not penalized and can maintain their margin. Further details about the ESP program are available at the Digium website here:

http://www.digium.com/en/company/view-policy.php?id=Risk-Free-Guarantee

Digium, as a globally minded company, ensures that all Digium analog interface cards maintain telecom, safety and emissions certifications permitting their use in Australia, Canada, the European Union, and the United States. Is your country not on our current list? Talk to your reseller. Have them let us know and we'll see what we can do.

To support our analog interface cards, Digium manufactures loopstart analog modules for both Foreign Exchange Station (FXS) extension-side interfaces and Foreign Exchange Office (FXO) trunk-side interfaces. These modules are built both in single-port, for smaller installations, and quad-port, where density is important.

Having shipped nearly a half-million analog ports for use with Asterisk since 2003, Digium is the leader.

Digium® Hardware

The **TDM410** is a four (4) port half-length, full-height, PCI 2.2+, 3.3/5.0V Universal voltage analog interface card that utilizes our single-port modules to provide an entry-level card for SOHO and distributed applications. The TDM410 provides four two-wire RJ-11 interfaces for connecting regular telephone cables.

The **AEX410**, available in July 2008, is a PCI-Express 1.0 x1 compatible version of the TDM410.

The **TDM800** is an eight (8) port half-length, full-height, PCI 2.2+, 3.3/5.0V Universal voltage analog interface card. It utilizes up to four of our single-port modules or up to two of our quad-port modules to provide a mid-level card for SOHO and SMBs. The TDM800 provides eight two-wire RJ-11 interfaces for connecting regular telephone cables.

The **AEX800** is a PCI-Express 1.0 x1 compatible version of the TDM800.

The TDM2400 is a twenty-four (24) port full-length, full-height PCI2.2+ 3.3/5.0V Universal voltage analog interface card. It utilizes up to six of our quad-port modules to provide a high-end solution for SMBs and SMEs. The TDM2400 provides a 50-pin RJ-21X connector for use with wiring closet blocks or patch panels.

The **AEX2400** is a PCI-Express 1.0 x1 compatible version of the TDM2400.

All of Digium's analog interface cards make use of Digium's patent-pending Voicebus architecture. This architecture allows Digium to take advantage of common interfaces already found in millions of PCs. Because of this widespread use, Digium is able to provide a card with the highest level of system compatibility.

All of Digium's PCI-Express cards – the AEX410, AEX800, and AEX2400 – are compatible with PCI-Express 1.0 x1 connectors. This means that each card may be used in any PCI-Express connector.

All of Digium's PCI cards – the TDM410, TDM800, and TDM2400 – are compatible with 3.3 and 5.0V PCI slots. This means that any card may be used in any PCI or PCI-X connector.

All of Digium's analog interface cards may be used with Digium's low-density hardware echo cancellation module, the VPMADT032. This module provides 128ms (1024 taps) of G.168 compliant AT&T Labs certified carrier-class echo cancellation. It cancels up to three (3) reflections, provides CNG, handles double-talk detection, possesses rapid convergence, and more.

The Digium® Difference

Besides Digium, there are a number of other firms, including Sangoma® Technologies Corporation of Canada and Rhino® Equipment Corporation of Arizona, that manufacture analog interface cards for use with Asterisk.

Digium believes the total of its offerings are superior to those offered by other companies, and would like to demonstrate the reasoning behind this belief.

1) Digium wrote the drivers.

An examination of other companies' drivers will reveal that the majority of their code for interfacing with both analog modules and analog lines was originally written by Digium.

Who better to provide you with support than the company that actually wrote the underlying code?

2) Digium is the author of Asterisk.

Neither Sangoma Technologies nor Rhino Equipment employ staff that is paid to develop Asterisk. Instead, those companies only maintain staff paid to ensure their cards can be used with Asterisk. Digium maintains more than a dozen staffers who work full-time to develop the core of Asterisk and its applications.

Digium is more capable than anyone of supporting the end-to-end solution of interface cards and telephony applications.

3) Digium offers single-port analog modules.

Both Sangoma Technologies and Rhino Equipment manufacture only dual-port modules. Digium four and eight-port analog cards may be populated with Digium single-port modules for better granularity.

Why pay for more ports than you need?

4) Digium offers modular hardware-based echo cancellation.

Sangoma Technologies and Rhino Equipment require that customers wanting hardware-based echo cancellation purchase it up-front. There is no upgrade capability. The hardware-based echo cancellation module for Digium cards may be purchased with the card, or may be purchased later and installed at the user's convenience.

Digium is more flexible.

5) Digium cards outperform the rest.

Sangoma Technologies and Rhino Equipment accuse Digium of a technical deficiency - poor handling of Interrupt Requests (IRQ) and high CPU usage.

Digium will now debunk these myths.

Interrupt Requests

To determine the effectiveness of various vendor cards functioning in servers that maintain poor real-time characteristics, Digium constructed a test that simulates a condition under which a card's driver will not be able to service its interrupt in a timely fashion – an example of poor interrupt handling.
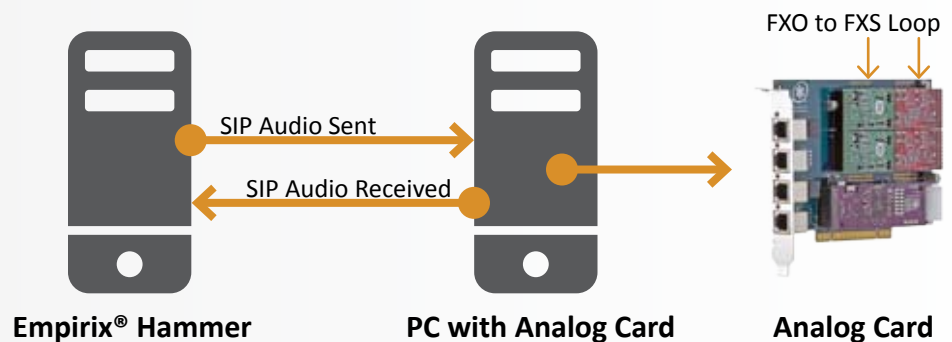
To simulate this condition, Digium wrote an application to export a file in the sysfs file system that allows a user to specify how many microseconds to stop interrupt processing on each CPU of the system. When this file is written, local interrupts are disabled for that specified period of time.

This degraded condition is found in production systems with any combination of high load or devices that hold interrupts for extended periods of time – like Ethernet or RAID controllers. It is very representative of what telephony boards, which want to operate in as near of a real-time environment as possible, face when trying to pass their calls without error.

Test Components:

- Asterisk 1.4.17 tarball
- Zaptel SVN 1.4 r41114
- Dell Dimension 3100
- Debian "Etch" 2.6.18.5-amd64
- Empirix Hammer

This test was configured as follows:

FXO to FXS Loop

SIP Audio Sent

SIP Audio Received

Empirix® Hammer   **PC with Analog Card**   **Analog Card**
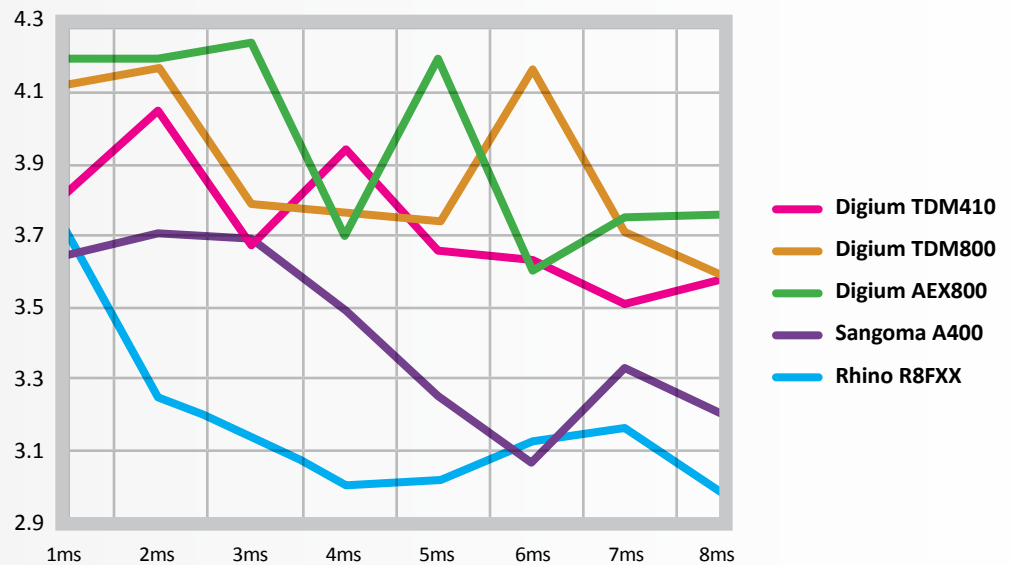
In this test, the Empirix Hammer is used to measure voice quality. It establishes a SIP call to a PC running Asterisk. An analog board with an FXS module looped to an FXO module is installed in the PC. The call is routed, by Asterisk, through the analog modules and then back to Asterisk where it is then passed in SIP to the Hammer.

The Hammer measures Perceptual Evaluation of Speech Quality (PESQ), an objective assessment of the speech quality of a telephony system. A PESQ score below 3.5 is not considered a passing score. Another commonly used measure for speech quality is Mean Opinion Score (MOS). Digium elected PESQ for this test because PESQ is objective, whereas MOS is subjective.

The cards tested were:

- Digium TDM410
- Digium TDM800
- Digium AEX800
- Sangoma A400, Wanpipe 3.2.5 Driver Package
- Rhino R8FXX, Rhino 2.2.4 Driver Package

Results graph of PESQ score maintained for time, in ms, that interrupt processing is blocked:

Digium's TDM410, TDM800, and AEX800 cards can maintain their audio quality when interrupts are blocked up to 8ms. Audio quality is acceptable for all interrupt lengths.

Sangoma's A400 is able to maintain a score above 3.5 for all interrupt blocks under 4ms. Beyond that, the scores are below 3.5 and audio quality is not acceptable.

Rhino's R8FXX is able to maintain a score above 3.5 only for 1ms of interrupt blocking. At 2ms and beyond, the score has dipped to 3.25 and audio quality is not acceptable.

Digium compared to the competition:

- The Digium TDM410 maintains a mean PESQ score that is 9.38% higher than the Sangoma A400 and 18% higher than the Rhino R8FXX.
- The Digium TDM800 maintains a mean PESQ score that is 13.96% higher than the Sangoma A400 and 22.61% higher than the Rhino R8FXX.
- The Digium AEX800 maintains a mean PESQ score that is 15.69% higher than the Sangoma A400 and 24.79% higher than the Rhino R8FXX.

These results demonstrate one point:
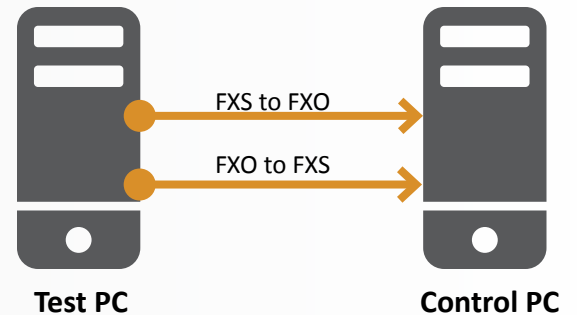Digium analog interface cards have superior interrupt handling.

CPU Usage

Digium conducted a test to determine how analog interface cards effected the CPU utilization of the PC. In this test, calls were constantly run through the system hosting the card under test. Calls were passed out of the system in test to another idle system that simply accepts them and provides termination for thirty (30) seconds each before hanging up.

The CPU utilization figures were captured from the % idle CPU provided by the top program and an average utilization was calculated over a five (5) minute period.

Test Components:

- Asterisk 1.4.17 tarball
- Zaptel 1.4.8 tarball
- Dell Dimension 3100
- Control Digium TDM844B
- Whitebox PC
- Debian "Etch" 2.6.18.5-amd64

FXS to FXO
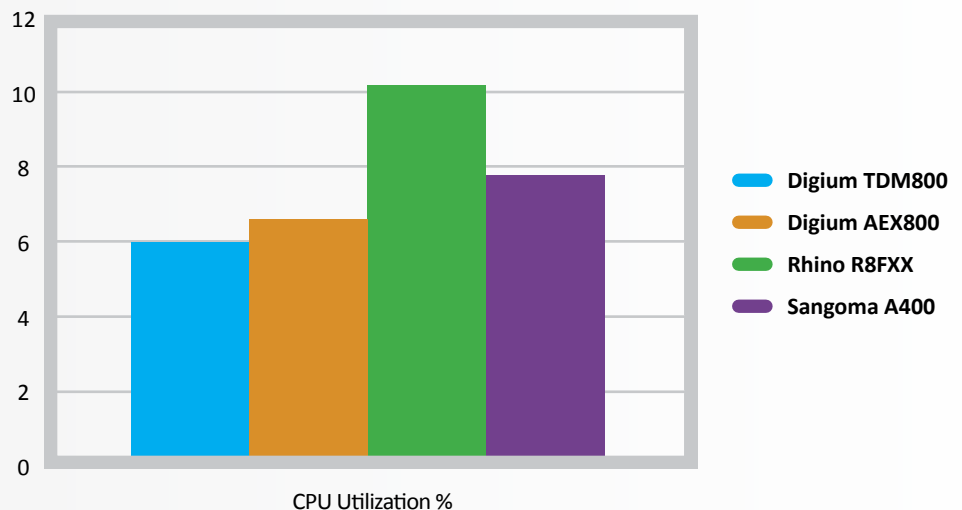
FXO to FXS

Test PC **Control PC**

This test utilized a Dell Dimension 3100 running Asterisk with analog interface card modules installed on tested telephony board interfacing with a Digium TDM844B in Whitebox PC running Asterisk.

The cards tested were:
- Digium TDM844E with Hardware Echo Cancellation and 8 concurrent calls
- Digium AEX844E with Hardware Echo Cancellation and 8 concurrent calls
- Sangoma A400, Wanpipe 3.2.3 Driver Package, with Hardware Echo Cancellation and 6 concurrent calls
- Rhino R8FXX, Rhino 2.2.4 Driver Package, with Hardware Echo Cancellation and 4 concurrent calls

Results graph of CPU utilization %:

CPU Utilization %

- Digium TDM800
- Digium AEX800
- Rhino R8FXX
- Sangoma A400

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Digium compared to the competition:

- The Rhino Equipment R8FXX with 4 active channels utilizes 70% more CPU than the Digium TDM800 with 8 active channels, and 54% more CPU than the Digium AEX800, also with 8 active channels.

- The Sangoma Technologies A400 with 6 active channels utilizes 30% more CPU than the TDM800 with 8 active channels, and 17% more CPU than the Digium AEX800, also with 8 active channels.

These results demonstrate one point:

Digium analog interface cards handle more channels with less CPU.

Glossary of Technical Terms and Acronyms

BRI (Basic Rate Interface) – BRI is a digital communications line utilizing ISDN. BRI is comprised of two bearers (B) and one delta (D) channel to provide up to two channels for voice communications. Digium's B410P is a four port (8 channel) four–wire S/T BRI interface card for use with EuroISDN networks.

CNG (Comfort Noise Generation) – CNG is small amounts of white noise or artifacts inserted into an audio stream to provide the caller with audible feedback that confirms their call is still connected. CNG is supported by Digium's hardware echo cancellation modules.

CPU (Central Processing Unit) – The CPU is the primary system processor. Vendors include Intel and AMD.

E1 – Also known as a DS1, an E1 is comprised of 32 timeslots with 31 channels of data that may be transporting voice or data. An E1 is the international equivalent of a North American T1. Digium manufactures 1, 2, and 4 port E1 interface cards.

ESP (Exceptional Satisfaction Program) – ESP is a program that Digium offers as a part of the warranty for its products. Should a customer not be satisfied with the performance of the product, the customer may contact Digium, allow Digium a period of time to address the issue and, if unsuccessful, then the customer's money for the product may be refunded. The ESP program is mindful of distributors and resellers as it protects their margins – the refunds are processed directly from Digium to the customer.

FXS (Foreign Exchange Station) – FXS devices provide ring–voltage and battery to FXO devices. An FXS device is provided by the telco to the customer's telephones, themselves FXO devices. Digium manufactures FXS modules in single and four port varieties for use with its analog interface cards.

FXO (Foreign Exchange Office) – FXO devices connect to FXS devices. An FXO device acts as a normal telephone. Digium manufactures FXO modules in single and four port varieties for use with its analog interface cards.

G.168 – The ITU standard for measuring the effectiveness of echo cancellation algorithms at quashing line echo. Digium's hardware echo cancellation modules and its commercial HPEC software echo cancellation are G.168 compliant.

IRQ (Interrupt Request) – An IRQ is a request by a computer system to interrupt the ongoing traffic on system buses so that a device may transmit or receive its own data. Digium has been accused by other companies of handling IRQs poorly. These accusations have been proven invalid.

ISO 9001:2001 – A standard by the International Standards Organization that sets forth requirements for quality. All of Digium's products are manufactured under an ISO 9001:2001 certified process.

MOS (Mean Opinion Score) – MOS is a subjective measurement for determining voice quality in a telecommunications system.

MTBF (Mean Time Between Failure) – MTBF is a calculation performed using specific Telcordia guidelines to provide an estimate of the amount of time a device should run before failure. MTBF accounts for the calculated lifetimes of all component parts in a completed device. All of Digium's analog interface cards maintain MTBF times in excess of one (1) million hours.

PBX (Private Branch Exchange) – A PBX is a system for the switching of telephone calls. A PBX typically offers a number of applications such as call conferencing and voicemail and can connect phones between PBXs or the PSTN. Digium's Asterisk is one of the world's leading PBX applications.

PCI (Peripheral Component Interconnect) – PCI is a standard for connecting devices or interface cards to computer devices. Digium's analog interface cards are compatible with PCI specification 2.2 and greater, support both 3.3 and 5.0V interface slots, and may be used in PCI–X slots.

PCI–Express – A standard designed to replace the older PCI standard. PCI–Express operates at 3.3V, provides smaller connectors, and greater bandwidth versus PCI. Digium's analog interface cards are compatible with PCI–Express x1 interface slots. This means that Digium's analog interface cards may be used in any PCI–Express (x1, x4, x8, x16) slot.

PESQ (Perceptual Evaluation of Speech Quality) – PESQ is an objective measurement for determining voice quality in a telecommunications system.

POTS (Plain Old Telepone Service) – POTS generally refer to 2–wire analog telephony. Digium's analog cards are designed to connect Asterisk to POTS.

PRI (Primary Rate Interface) – PRI is a 24–channel digital TDM line that utilizes ISDN for signaling. All of Digium's 1,2, and 4 port E1/T1 interface cards may be used with PRI.

PSTN (Public Switched Telephone Network) – The PSTN is the network of all publically connected telephone systems of the world – much as the Internet is the sum of publically connected computer systems.

RAID (Redundant Array of Inexpensive Disks) – RAID defines a redundant or fault tolerant grouping of data storage for computer systems. RAID controllers, the devices that are used to manage the group of storage, have demonstrated long–blocking of IRQs.

RJ–11 – A two–wire interface for the termination of telephone service. Digium's four and eight–port analog interface cards utilize four and eight RJ–11 jacks respectively for their connection to telephone sets or telephone trunks.

RJ–21X – A fifty–wire telephone interface for the termination of telephone service. Digium's twenty–four–port analog interface cards utilize an RJ–21X connector. RJ–21X connectors are typically found in wiring closets connected to punch blocks, 66 Blocks, 110 Blocks, or patch panels.

RoHS (Restriction of Hazardous Substances directive) – RoHS restricts the use of Lead, Mercury, Cadmium, Hexavalent Chromium, Polybrominated Biphenyls, and Polybrominated Diphenyl Ether in manufactured products. Digium's manufactured products meet RoHS requirements.

SIP (Session Initiation Protocol) – SIP is the world's most commonly used VoIP signaling protocol. Asterisk provides support for SIP.

SMB (Small and Medium Business)

SOHO (Small Office / Home Office)

SVN (Subversion) – SVN is a source code control repository used by development teams to enhance their ability to collaboratively work.

T1 – Also known as a DS1, a T1 is comprised of 24 channels of TDM data that may be transporting voice or data. An E1 is the international equivalent of a North American T1. Digium manufactures 1, 2, and 4 port T1 interface cards.

VoIP (Voice over Internet Protocol) – VoIP is the collective term for the transmission of human speech in packetized format over data networks. Digium's Asterisk is one of the most commonly used VoIP–capable systems in the world.