RENKUS-HEINZ AUDIO OPERATIONS NETWORK

DIGITAL AUDIO NETWORKING AND REMOTE SYSTEM MANAGEMENT

A Renkus-Heinz Engineering White Paper

By Ralph Heinz, Vice President, Renkus-Heinz, Inc.

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RHAON
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RHAON ("rayon"), the Renkus-Heinz Audio Operations Network, is engineered to integrate powered loudspeakers into digital audio networks. Network technology can give sound system designers and operators greater control over powered loudspeakers: this means more flexibility in using loudspeakers. RHAON extends the network to its endpoints: the loudspeakers that deliver sound to the audience. It does not replace digital consoles, DSP engines or other commonly used components of those networks –RHAON supplements these devices with a unique combination of digital audio distribution plus remote system management (control and supervision).

Audio Operations? What Are Those?

For the purpose of this white paper, Audio Operations are the essential functions of a functional sound system for large-scale events and/or public buildings. They fall into three main areas:

- **Signal Distribution**

  Typically, acoustic signals (sound) and audio signals are collected from a number of inputs such as microphones, CD or DVD players, and electronic instruments. These input signals are collected and processed at a central point such as a mixing console or automixer. The mixed and processed signals must then be amplified, distributed and turned back into sound by loudspeakers located throughout the facility.

  Self-Powered loudspeakers reversed the order of distribution and amplification. With passive loudspeakers, the power amplifiers are located in a central "amp closet" and the amplified signals are distributed to the loudspeakers via heavy-gauge copper wire. With self-powered loudspeakers, the distribution network carries low-level signals in analog or digital format. Digitization, if required, can be performed at the origination point or at the central collection point. In this white paper we will be discussing the use of digital networks to handle signal distribution requirements for sound reinforcement, i.e. from the central mixing or collection point to self-powered loudspeakers.

- **Signal Processing**

  Audio signals can be and often are processed at multiple points along the signal distribution path. Processing is applied for both "creative" and "technical" purposes: creative signal processing includes effects such as reverb, chorusing, and compression. It is used by the mix engineer to enhance the signal for the audience. Technical signal processing aims at either improving the signal itself, or the linearity of the transfer function of the sound system as it converts sound into analog or digital audio and back into sound.

  RHAON is not designed for the "creative input processing" that mix engineers do. It is designed for "technical output processing," with the goal of making sure that everyone in the audience hears what the mix engineer intends them to hear. In this white paper we will be discussing the technical aspects of signal processing when used to compensate for non-linearities in the acoustics of the venue.

- **System Management**

  System management tasks include control, monitoring and maintenance. Control can be as simple as turning the system on and off, or as complex as re-configuring the entire system to accommodate different building functions.

Critical monitoring tasks involve the signal distribution network, the amplifiers and the loudspeakers. When problems arise, they can be dealt with by adjusting controls such as gain levels. In extreme cases some form of maintenance might be required. RHAON can't perform the maintenance, but it can make it much easier to monitor every amplifier module and every transducer in the system in order to make sure that the system is fully functional whenever it is needed. It is important, vitally important in life-safety systems, to be sure that the entire sound system is functioning properly, and to correct any problems at the earliest opportunity.

CobraNet: RHAON's Signal Distribution Technology

CobraNet is licensed by Cirrus Logic. The standard is maintained by the CobraNet Manufacturers Consortium (CobraMC). The technology – a communications protocol, firmware and hardware – allows reliable transmission of uncompressed PCM digital audio over standard Ethernet networks. CobraNet devices are based on a common hardware reference design from Cirrus Logic. Cirrus also supplies the firmware that implements the communications protocol. Audio can be delivered between CobraNet devices from different manufacturers.
CobraNet was first used in the background music system of Disney's Animal Kingdom in 1997. Today, CobraNet is installed in thousands of government hearing rooms, stadiums, convention centers, houses of worship and touring shows.

Ethernet

CobraNet devices are networked using standard Ethernet hardware and Cat 5 copper and/or fiber optic cables. Computers or other system controllers can also be connected to the network for setup, but are not required for digital audio distribution.

Invented in 1973 by Robert Metcalfe at the now-legendary Xerox PARC t, Ethernet was patented in 1976 and became the Institute of Electrical & Electronics Engineers standard IEEE 802.3a-z in 1985. Ethernet is easily the most widely available data networking technology in use today. Ethernet speeds continue to increase from the original version's 2.94 megabytes per second. The nearly universal (over 50 million nodes installed) 100 MB Ethernet standard is already being replaced by Gigabit Ethernet in many applications.

The first PHY (physical layer) hardware that is compliant with the 10 Gigabit Ethernet standard is already available commercially. Ethernet data can typically travel 100 meters over CAT-5 copper cable or 2 kilometers over multimode fiber without the use of a switch or repeater.

The CobraNet Interface

The CobraNet interface augments the standard Ethernet interface with dedicated DSP chips and clock circuitry. The DSP transmits and receives CobraNet audio data using the proprietary protocol. The clock circuitry is used to accurately decode the system master clock timing needed for high-quality real-time audio delivery.

CobraNet: The Numbers

CobraNet networks operate at a fixed sample rate of either 48 or 96 kHz with a bit depth of 16, 20 or 24. 20 bit CobraNet audio has 122 dB dynamic range and 146 dB at a bit depth of 24. Frequency response is ±0dB from 0 to 24k Hz. For reliable operation, each CobraNet device must implement transmit and receive buffering. The buffer's size can be fixed at 256, 128 or 64 samples, resulting in a minimum network latency of 5.33 milliseconds (256 samples at 48kHz), 2.66 milliseconds (128 samples) or 1.33 milliseconds (64 samples). Since 96 kHz audio uses two CobraNet channels, these latency figures remain the same at the higher sample rate.

CobraNet Data Packets

CobraNet data packets are standard Ethernet packets. These link layer packets pass easily through hubs, media converters, bridges and switches. CobraNet uses a registered logical link layer protocol (protocol identifier 0x8819). Due to performance considerations, CobraNet does not use TCP/IP addressing.

The CobraNet protocol includes three basic packet types. The beat packet is transmitted with a multicast address (01:60:2B:FF:FF:00) from the conductor at a rate of 750 packets per second. Audio data packets from other CobraNet devices on the network follow the beat packet. Reservation packets are transmitted with a multicast address (01:60:2B:FF:FF:01) approximately once per second. Reservation packets control bundle allocation (see below) and allow the status of CobraNet devices to be monitored.

Bundles and Audio Channels

CobraNet transmits and receives audio data in multi-channel bundles. A bundle is a 1500-byte Ethernet data packet that contains multiple channels of digital audio. Each CobraNet device can transmit and receive up to four bundles of up to 8 audio channels, for a maximum transmit/receive capacity of up to 32 audio channels.

The total amount of data in each bundle cannot exceed the 1500 byte Ethernet payload limit. 8 audio channels/bundle x 64 samples/isochronous cycle x 20 bits/sample = 10,240 bits = 1280 bytes. When you go to 24 bits/sample you get 12,288 bits or 1536 bytes, which is in violation of the 1500 byte limit.

Each CobraNet bundle has a unique number and only one CobraNet transmitter can be assigned this number. Bundles numbered from 1 – 255 are multicast, while bundles between 256 - 65,279 are unicast: multicasting sends the same data to all devices on the network, while unicast data is sent to one and only one device.
32 channels may not sound like much, but keep in mind that this is per-device, not per-network. Since each device can send and receive four Bundles, CobraNet audio routing is very flexible. Up to 8 multicast bundles (64 audio channels) can be transmitted on a simple repeater-based Ethernet network. Up to 4 multicast bundles (32 audio channels) can be transmitted simultaneously with up to 421 unicast bundles (3368 audio channels) on a full-duplex switch-based Ethernet network.

The Conductor

The entire CobraNet network is synchronized to a single CobraNet device on the network, designated as the Conductor. The Conductor either generates a timebase from a crystal oscillator or receives it from an external clock source. Based on this timebase, the Conductor regularly broadcasts beat packets onto the network. Other devices on the network lock onto the arrival time of this packet and regenerate the clock locally.

CobraNet is unable to deliver audio data in the absence of a Conductor, but the good news is that any CobraNet can serve as the Conductor for the entire network. If the designated Conductor fails, another CobraNet device will assume the duties of the conductor. The changeover is accomplished within milliseconds.

The error or “wander” in clock delivery is ±1/4 sample period (about 5 microseconds at the 48KHz sample rate). Due to careful control of the clock corrections, cycle-to-cycle clock variation (jitter) is maintained at less than 1 nanosecond.

CobraNet audio data is completely synchronous for channels coming from the same CobraNet connection and within 10 microseconds for channels coming from different connections to the same switch. Devices connected to different switches may be experiencing different forwarding delays and will have a clock skew proportionate to that.

The Conductor’s ability to represent permission for many active transmitters in a maximum length 1500 byte beat packet limits the number of active transmitters available on a CobraNet network. If each device is transmitting one bundle, there can be up to 184 transmitters active simultaneously, producing a total of 184 active bundles. If each device is transmitting a full four bundles, only 105 transmitters can be active, though these would be producing a total of 421 active bundles.

Primary and Secondary Network Ports

(Dualink) CobraNet devices can implement two network connections. This provides for added reliability in the event of problems with network hardware or cabling. If the primary connection is lost, the secondary connection can immediately be enabled using an entirely separate network hardware path.

Repeater Networks

CobraNet can operate on both simple repeater-based networks and more complex switch-based networks. Repeater networks use Ethernet hubs. On a repeater-based network, all packets are broadcast to all connected nodes. CobraNet multi-cast and unicast Bundles can be assigned, but because of the simpler repeater-type hubs, even unicast transmissions are broadcast to all nodes. Therefore, a maximum of 64 audio channels (8 fully loaded bundles) are allowed on a repeater-based network. More bundles may be allowed if they are loaded with less than the full eight audio channels. There is no limit to the number of active receivers on a repeater network. Generally, a repeater-based CobraNet network must be dedicated to CobraNet traffic to guarantee reliable transmission of audio packets.

Switched Networks

As hardware prices have come down, simple repeaters have been replaced on most Ethernet networks by switches. Ethernet switches do not simply broadcast each and every packet to all nodes. Instead, they examine the destination address of each packet received on each port, and then "switch" that data to the identified recipient. CobraNet unicast Bundles exploit this feature to allow more overall network traffic. Cirrus recommends that not more than four multicast bundles be used on a switched CobraNet network.

Another enhancement available with most Ethernet switches is "full-duplex" links. A full-duplex link allows simultaneous send and receive over the same Ethernet connection. This enables a CobraNet device to send and receive up to 64 channels per node simultaneously, for a total of 128 channels.

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The combination of switching and full-duplex technologies in switched CobraNet networks allows up to 128 channels and 3368 individual audio channels per 100 MB Ethernet link. There is no limit to the number of active receivers on a switched CobraNet network.

Switched networks also eliminate the potential for Ethernet collisions. This allows general PC network traffic such control and monitoring data to coexist with CobraNet traffic on the same network.

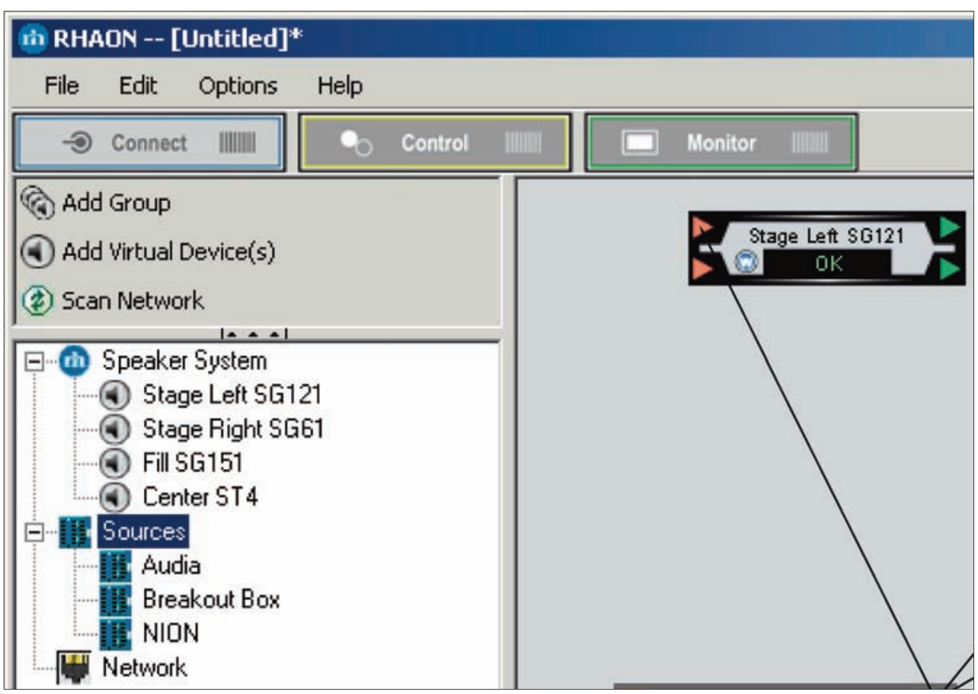
Both managed and unmanaged Ethernet switches are commonly available. While unmanaged switches are less expensive, basic managed switches are available for under $100. They allow you to implement advanced features of Ethernet networks such as multicast filtering, VLANs (Virtual Local Area Networks) that create separate “logical” networks using the same cable infrastructure, fully redundant network infrastructure, trunking, etc.

Control via CobraNet

CobraNet provides a common transport for control protocols. Because CobraNet is Ethernet, multiple protocols may be carried on the medium without seeing or interfering with one another. Any bandwidth not consumed by audio data is available for control messaging.

RHAON Setup

The RHAON GUI is designed to simplify the process of connecting RHAON-Empowered loudspeakers to a CobraNet network or other Ethernet network (in some applications, RHAON is used for system management and analog audio is distributed via conventional copper wire).



RHAON Modules identify themselves to the network.

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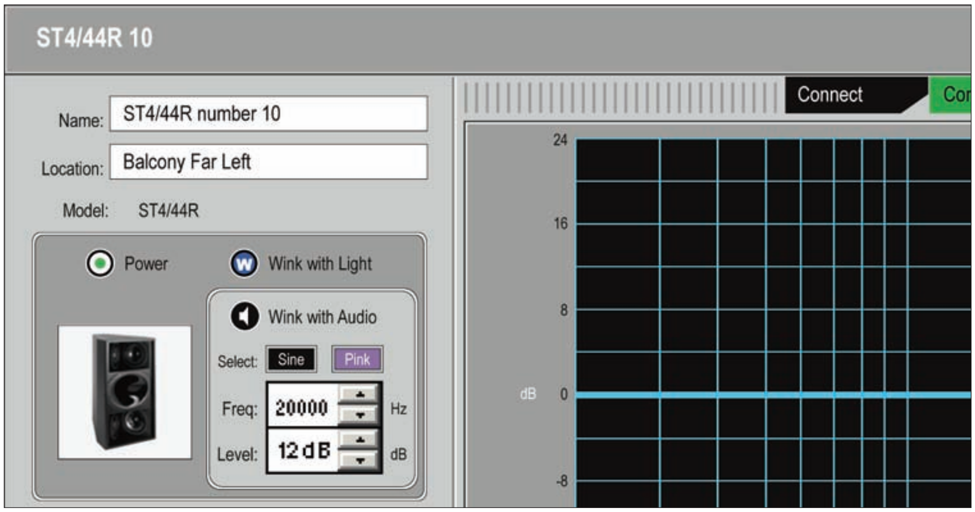
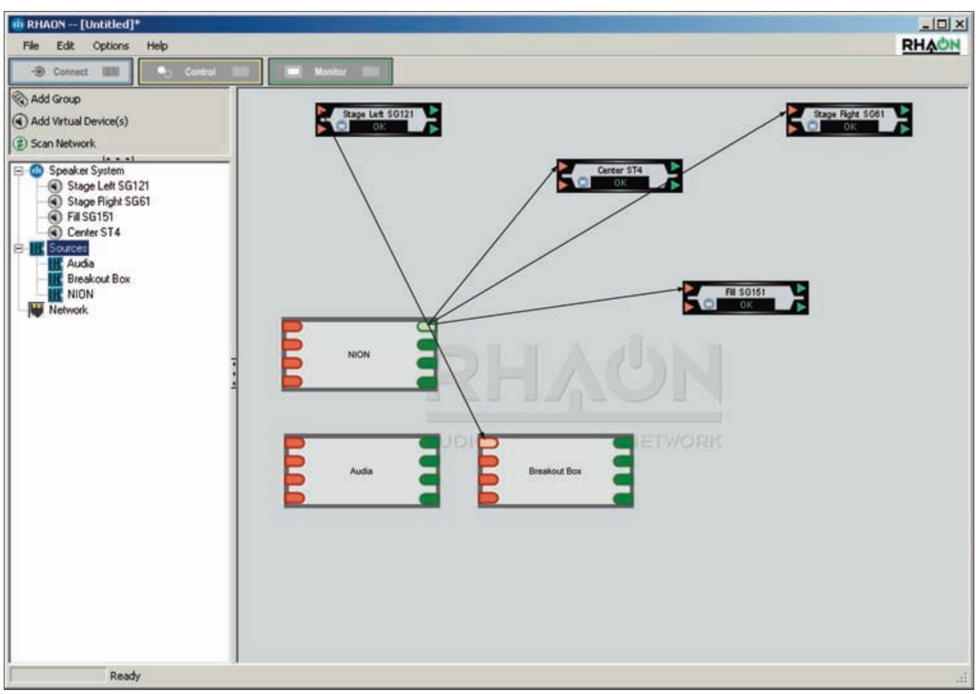
Test signals and a Wink function that lights up the front grille LED make it easy to confirm the location of loud-speakers.



Wink with Light and/or Wink with Audio (Sine Tone or Pink Noise)

Transmit/Receive Bundle IDs can be set remotely from the central computer, without a physical visit to the loud-speaker.



RHAON System Screen

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The First Generation of Renkus-Heinz PN-1 Amplifier Module

Signal Processing: From “Black Box” to “Smart Box”

The RHAON Module is an option for all Renkus-Heinz self-powered loudspeakers. All models in the CF Series, Sygma SG Series, PN Series and ST Series can be RHAON-Empowered. So can powered Iconyx Digitally Steerable Arrays. A few of our self-powered systems are only available in RHAON-Empowered versions. These include bi-amplified two-way systems, tri-amped three-way systems and the VerSys Networked Line Array System.
This is the input panel of our first-generation PN-1 amplifier module:

A loudspeaker powered by this type of amplifier is a “black box.” All the signal processing applied by the manufacturer (crossover filters, frequency response equalization, driver alignment delay, protection limiting, etc.) is out of the sound system operator’s sight, out of mind and out of control. Any processing required to adapt this powered loudspeaker to its specific function or application within the system would have to be done upstream, which would require that a separate audio channel be assigned to this speaker.

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The RHAON Module replaces analog input modules that look somewhat similar to the one pictured above. It includes the following rear panel connections, controls and indicators:

- **Primary & Secondary Ethernet inputs   RJ-45 female**
- **Primary & Looping Analog Audio input/outputs   XLR female/male**
- **Secondary Analog input   Phoenix**
- **Serial Digital Audio input (AES 3d = AES/EBU)   Phoenix**
- **Fault Detect and Fault Relay outputsPhoenix**
- **IEC Power input**
- **On/Off Switch**
- **Push-to-Reset Circuit Breaker**
- **Input Pad Button**
- **Volume ± Buttons**
- **Mute Button**
- **Signal, Power and Overdrive LED indicators**

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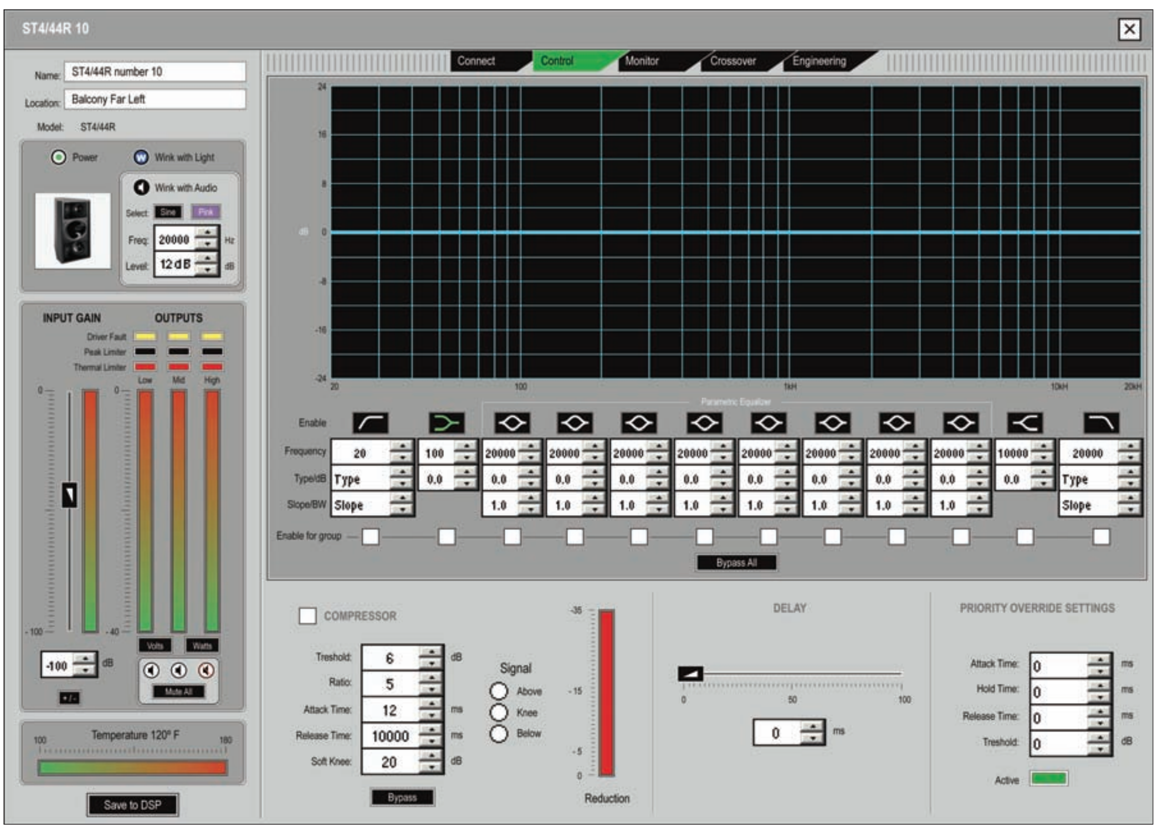
The RHAON Input Module uses Ethernet to communicate with a control computer running RHAON software. This Windows GUI (Graphical User Interface) allows the operator to adjust eight bands of parametric EQ, high and low cut and shelving filters, up to 18 milliseconds of delay and a compressor/limiter. In addition, the RHAON Module enables the amplifier to report on its status via the network. Voltage, current and temperature levels, input clip and output load impedance are all monitored – load impedance monitoring enables the RHAON Module to alert the operator if a driver fails.

With bi-directional communication and operator control of the RHAON Module's onboard DSP, the self-powered loudspeaker becomes a "smart box" that is able to respond to user input. This gives the system operator the ability to optimize each loudspeaker's transfer function for its specific location and application.

For example, a front fill loudspeaker typically requires a small amount of delay to time align its output to the main array, plus some equalization and perhaps level adjustment. With RHAON, all of these can be performed at the loudspeaker using the same audio channel that is sent to the rest of the system. Delays could be adjusted precisely to the location of each loudspeaker instead of using an approximation that averages the distances of several loudspeakers.

Similarly, the top and bottom rows of a RHAON-Empowered line array can have different EQ settings applied within the loudspeaker. Top rows typically require some HF boost to compensate for air absorption. Bottom rows normally need the opposite because they are so close to the audience. With RHAON, both of these adjustments can be made inside the loudspeaker without sending a separate audio channel to the array.



The RHAON Module's DSP is designed for "technical" or "corrective" functions. 8 bands of parametric equalization are available, along with high and low cut filters and high and low shelving filters.

As stated earlier, the DSP functions available through RHAON are “technical.” They are not designed to alter the audience experience as shaped by the mix engineer. Their purpose is to make sure that everyone in the audience hears what the mix engineer intends them to hear.

Control & Monitoring with RHAON

At the most basic level, monitoring and control of a sound system consists of the end user (such as a DJ, club band or church deacon) turning the system on, listening to its performance and either attempting to deal with problems or calling a professional for help. As systems become larger and more complex, this kind of monitoring and control becomes impossible. In large facilities, no single person can hear all of the system at the same time. Inspection of every component becomes time-consuming and labor-intensive if it requires a physical presence at the device in question, whether it is an amplifier, a signal routing/processing device or a loudspeaker.

Networks make it possible to keep close contact with every element of a large system using a centrally located computer. Of course, driver failures and other problems require physical remediation and repair, but many other problems can be dealt with via the network.

More importantly, any problem with the sound system, no matter how small or large, can be detected via the network. Early warning can make the difference between a minor annoyance and a catastrophic failure.

The RHAON Module provides several reporting and alert methods that can be enabled and used at the discretion of the system designer and operator. RHAON can be used for monitoring and control purposes whether the audio input is analog, serial digital (i.e. not networked) or CobraNet digital. It monitors the following parameters for each networked loudspeaker:

Network Status
- unassigned, offline (loudspeaker is in “standby” mode or has lost power)
- online (loudspeaker is connected to the network and making sound).

Amplifier Status
- Hot (amplifier has shut down due to overtemperature)
- Overload (amplifier is being driven into clipping)
- Carrier Loss (amplifier has lost input signal)

Driver Status
- Failure (one of the drivers in the loudspeaker has failed)

Alarm Status
- Voltage (the alarm voltage line connected to the amplifier has been disconnected or has dropped below its normal operating level – for more on this see Life Safety below).

The PM3 tri-amplifier RHAON Module used in the VerSys Line Array also monitors the protection circuits for the LF and mid/hi amplifiers, and notifies the operator if any of the amplifiers has been put in Protect mode (i.e. shut down to prevent damage to the loudspeaker).

RHAON monitors these operating parameters continuously and reports to the operator via the loudspeaker icon’s Status Bar. The Meters screen provides a more detailed look at the source of any warnings that may appear on the status bar. RHAON can also save a .log file to the control computer for review at a later time.

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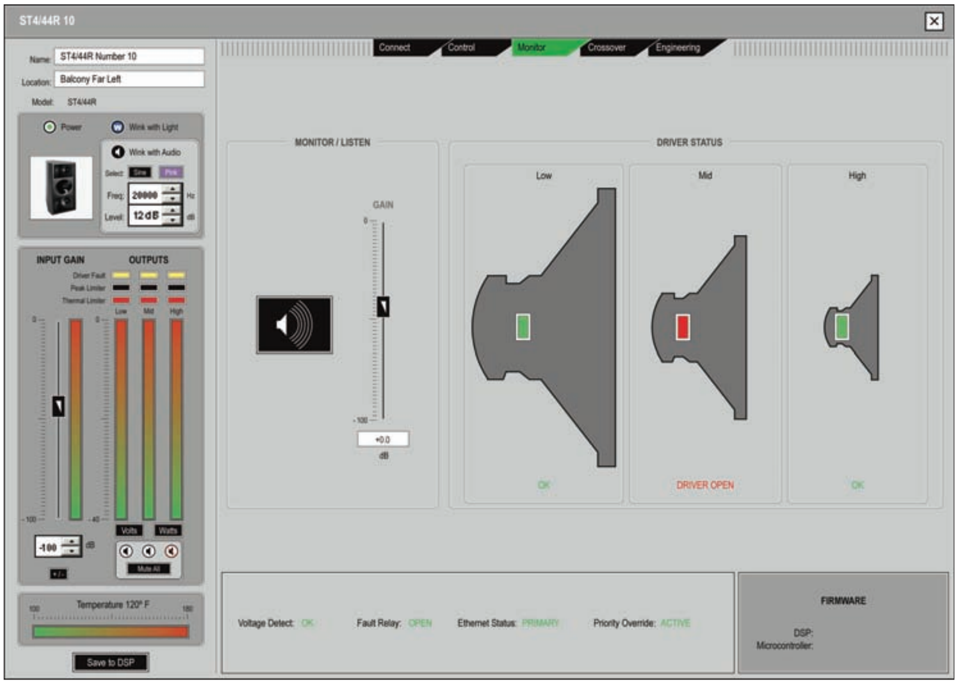
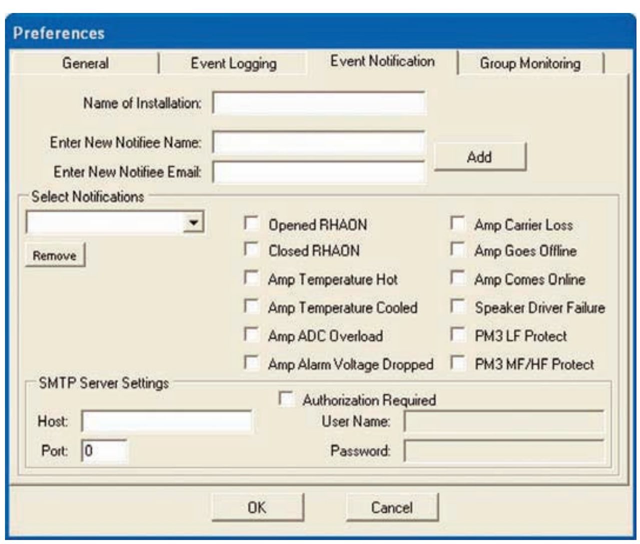


RHAON Monitor Screen

RHAON can also email events to a remote location, provided that an Internet connection is available on the control computer (the connection to the Internet will be separate from the RHAON network, which does not use TCP/IP addressing).



RHAON Preferences Screen

Audio Evacuation / Life Safety Operations

Requirements for certification as a “Life Safety” system vary widely from one locality to another. However, most Life Safety systems have certain features in common, and RHAON has been designed to provide these. They include:

- Redundant Ethernet Connections with automatic changeover if the primary connection to the network fails.
- Priority Overide Paging via the designated input, which can be any of RHAON’s digital or analog inputs.
- Continous Fault Monitoring as outlined above.
- Event Logging and Notification, as described above.
- Fault Monitoring of an external wiring loop via an opto-isolated input that reports the absence of a “sense” voltage via the Ethernet network.
- An isolated Fault Relay that sends a signal to associated equipment via external wiring: this relay will close if the Ethernet carrier is lost.

Software / Hardware Integration via RHAON

RHAON integrates computer technology into the sound system and each individual loudspeaker system that is on the network. This opens the possibility to communicate with other kinds of computer software. Specifically, simulation or modeling programs and measurement programs can be used to provide an objective component to decisions about EQ, delay and other control inputs. With integration of RHAON with modeling and measurement software, the tuning and optimization steps of system commissioning can be started before the hardware is physically installed.

The process would work like this: a sound system would be modeled and designed in EASE using a venue model that is either created in EASE, or (if the building is standing already) incorporates measurements taken with EASERA or Systune. As of EASE 4.0, RHAON DSP settings can be part of the object-oriented Generic Loudspeaker Library (GLL) loudspeaker model. EASE can predict system performance and store the DSP settings that optimize it. When the system is actually installed, those settings can be uploaded via the network to the loudspeakers. The system can then be measured in the actual room with EASERA or Systune and final corrections or optimizations can be performed, using the measurement data to confirm and refine subjective listening impressions.

Evolution or Revolution?

RHAON does not change the way sound systems operate, but an Audio Operations Network does create many opportunities to use digital technology as an enhancement to human system designers and operators. At the design stage, RHAON simplifies audio signal distribution – because RHAON puts user-configurable DSP at every “output node” (i.e. every loudspeaker) on the network, location-specific and/or application-specific signal processing can be applied without dedicating an audio channel to the zone or loudspeaker. One important exception is delay zones that require more than 18 milliseconds of delay.

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When RHAON is integrated with modeling software, preliminary DSP settings can be created within the sound system model, stored, and uploaded to the system once it is installed.

At the installation or load-in/setup phase, RHAON saves time and money. Digital audio networks have proven themselves to be less expensive than conventional analog signal distribution using heavy-gauge copper wiring and either electrical conduit or multi-core snakes. RHAON extends the network to the loudspeaker, maximizing cost effectiveness. RHAON also saves time when connecting the audio network – multiple audio channels can be connected at once by inserting an RJ-45 jack into the RHAON Module's Ethernet input.

RHAON combines distributed DSP with centralized computer control and management, making many audio operations more efficient. As mentioned above, DSP settings can be uploaded to the loudspeakers from modeling software. Measurement software such as EASERA or EASERA SysTune can be used to help system technicians optimize performance. EASERA SysTune is a "source-independent" measurement system that allows both system response and room characteristics such as RT60 and intelligibility to be measured in real time while the venue is in use with an audience present listening to the planned program material.

In sum, RHAON provides a number of powerful options that audio professionals can use to optimize sound system performance and customize it to a specific venue, audience and program. The efficiencies of digitally networked operations give designers, installers and operators the time to exercise those options and produce a satisfying aural experience.

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Renkus-Heinz, Inc.
19201 Cook Street, Foothill Ranch, CA 92610, USA
Tel: +1 949 588 9997 • Fax: +1 949 588 9514
sales@renkus-heinz.com • www.renkus-heinz.com

Renkus-Heinz International
Ellakrogsvägen 187 33 Täby, Sweden
Tel: +46 8 544 725 88 • Fax: +46 8 544 725 89
info@renkus-heinz.net • www.renkus-heinz.com