A Network Enabled, Centralized DSP, Distributed Speaker System

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Project Overview

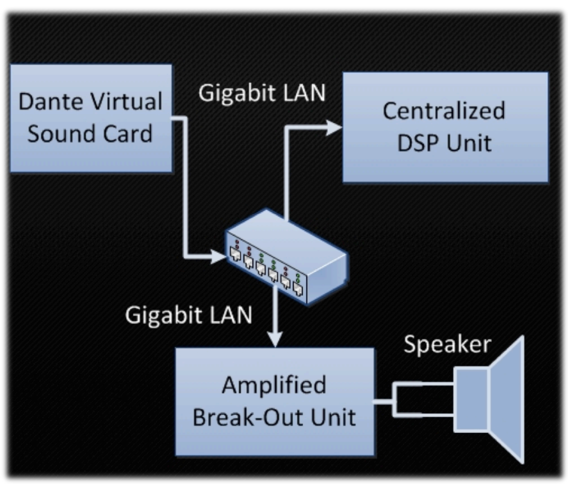
This project began as a dream, the inevitable dream that every audiophile is predestined to have at some point in their life. The dream: to experience reproduced sound just as it was when it was recorded; to replicate the experience the band had when they played their 30^{th} take of the song and called it finished.

The project initially began as a tube amplifier, preceded in the signal chain by digital signal processing to handle advanced filtering and dynamics processing. If a tube amplifier were not enough to bring the project into the audiophile category, the project would feature 192 kHz sampling rates and 24-bit word lengths. This would ensure for the end user that the analog signal entering the device would be faithfully reproduced at the input of the amplifier.

A couple of weeks into Senior Design 1, Matt Webb approached Herb Gringold after class and inquired about his knowledge of audio industry sponsors around Orlando. Mr. Gringold pointed us towards Alcorn McBride Inc. (www.alcorn.com). Matt Webb with a large amount of luck and a short message managed to reach the Director of Engineering at Alcorn McBride. Jim Carstensen recommended the use of an audio-over-Ethernet standard called Dante by Audinate. It was then that the current project proposal was born.

The goal of the project is simple in theory:

> To create a system that is capable of processing many channels of audio and distributing them over standard Ethernet networks to break-out boxes providing audio channel selection, signal level audio outputs, and a Class-D amplified output.



The simple system diagram at right decribes the goal stated above. As depicted, a pre-existing ethernet network is central to the system. This is key because ethernet networks are pervasive in today's ever advancing world. The existance of installed ethernet networks lowers the difficulty and cost of a new installation. There are three distinct devices that will interface with the network. The first device, shown in the top left, introduces the audio tracks into the network. The device in the top right is the centralized digital signal processing unit we are proposing. It will intercept eight to sixteen channels from ethernet, apply filtering and dynamics processing, and reintroduce the processed audio into the network. The device depicted at the bottom of the graphic is a break-out box that connects to ethernet, contains a class-D stereo amplifier, and outputs stereo audio via digital and analog formats. The number of break-out boxes that can be run on the system at any one time is only limited by the amount of bandwidth available in the network.

The described system should be reliable, configurable over the network, easily scalable, require zero maintainance after installation, and be very flexible. Our sponsor company, Alcorn McBride, specializes in embedded systems designed to run without fail 24/7. Therefore, our system must ensure longterm reliability through copious and diverse testing scenarios. In order to increase flexibility and decrease cost of system changes, the system must be network configurable. A web interface will be able to control filtering on the centralized DSP unit in addition to monitoring all break-out boxes. Flexiblity is a major factor in audio industry adoption rates. In order to design a successful system, we must ensure that the product caters to more than one application. For instance, the ability to change the channel a break-out box plays back greatly increases the flexibility of the entire system.

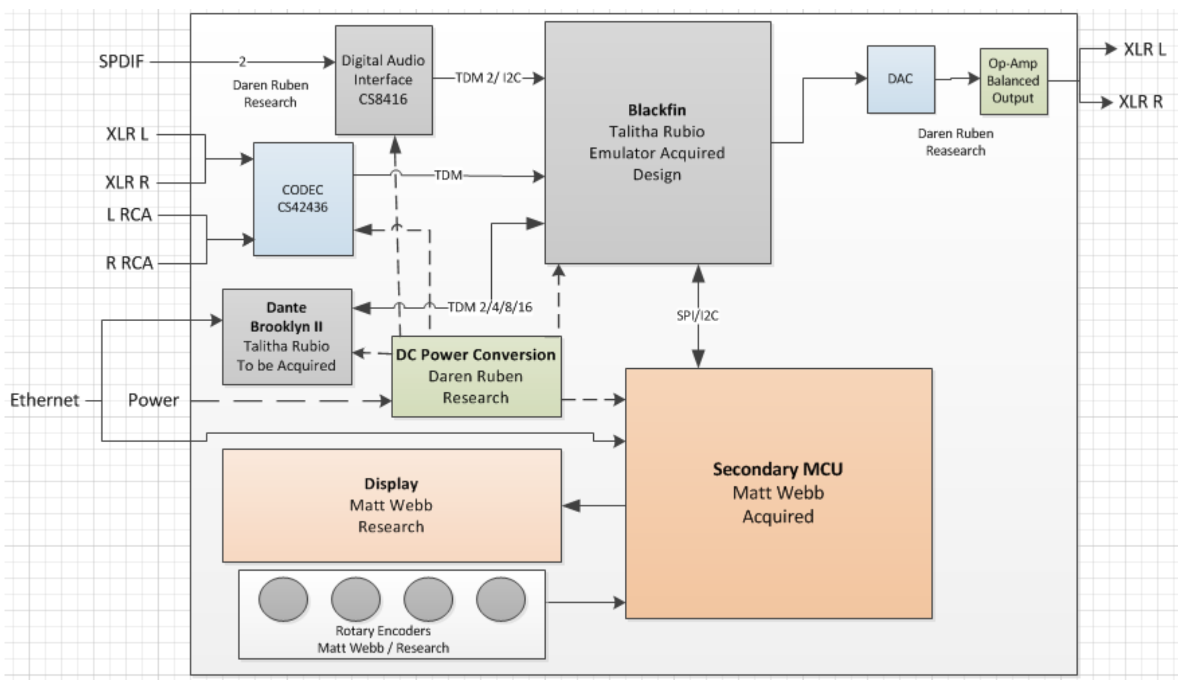
The applications of a system like this are limitless in the audio world. One great application is an event like Halloween Horror Nights by Universal Studios. Universal sets up brand new enviroments once a year that only exist for one month. One month is far too little time to invest in a costly permanent installation. The proposed system would enable Universal to centralize audio processing, utilize pre-existing ethernet networks instead of running new wire, and easily place speakers wherever they need to go with very little trouble. Another application is the expansion of a ride at a theme park. For example, a speaker may be required 100 yards away from the amplifier rack. One-hundred yards is too far to run speaker wire because of resistive losses and may even be impossible due to the lack of wall or attic access. In this case, the solution would be to plug a break-out box into a pre-existing ethernet network, select your audio channel, and place the speaker.

Preliminary Design Specifications

- Centralized Audio DSP
    - 8/16 Processed Channels (Equalization, Dynamics, Reverb)
    - Dante Audio I/O
    - Network Control & Monitoring
    - 96 KHz+ Sampling Rate
    - 24-bit Audio Word
    - Front Panel Controls
    - 1U or 2U Size
- Amplified Break-Out Box
    - Mono Class-D Amplifier
    - Output any one/two channels from Dante
    - Stereo signal output (Analog, AES-3, S/PDIF)
    - Compact Size (mount on rear of small speaker)

DSP Block Diagram

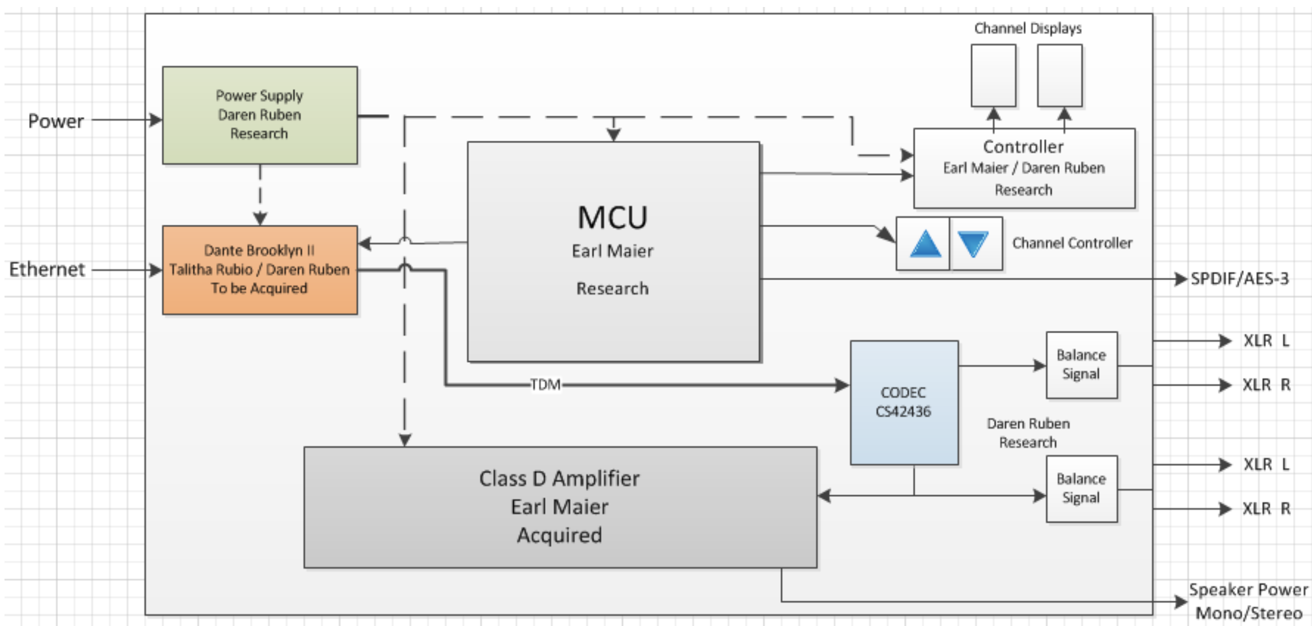
The centralized box block diagram is depicted below. After much deliberation we have decided to use the Blackfin processor for a few important reasons. One is that our sponsor has provided our group with an emulator that we could start writing code on. Also they offer their experience with this particular processor, which happens to cater to all of our specifications. One of the unique sections of this block diagram is the Ethernet input/output. With Dante we will be able to sample at 192 kHz with a 24-bit audio word which will provide high fidelity digital audio. We also have other inputs such as RCA's and XLR's that can be used to connect to an iPod or television for residential use. The XLR outputs will be mainly used for testing purposes to make sure the parametric equalizer is working and audio is departing the Blackfin processor. Although the Blackfin can handle the control of peripherals, a second processor will be used for this in order to provide the division of labor appropriate for this course. In this screen the user will have the ability to increase/decrease the volume using rotary knobs and change the parametric equalizer.



Acronym	Name	Description
ADC	Analog-t-Digital	Converts a analog signal to digital code
MUX	Multiplexer	Selects one signal and forwards the selected input.
DAC	Digital-to-Analog Converter	Converts a digital code to an anlog signal
MCU	Micro Controller	A small computer containing a processor core, memory and programmable input/output peripherals.
TDM	Time-Division Multiplexing	A type of digital multplexing in which two or more bit streams or signals are transferred simultaneously.
S/PDIF	Sony/Phillips Digital Interface	A digital audio interconnection

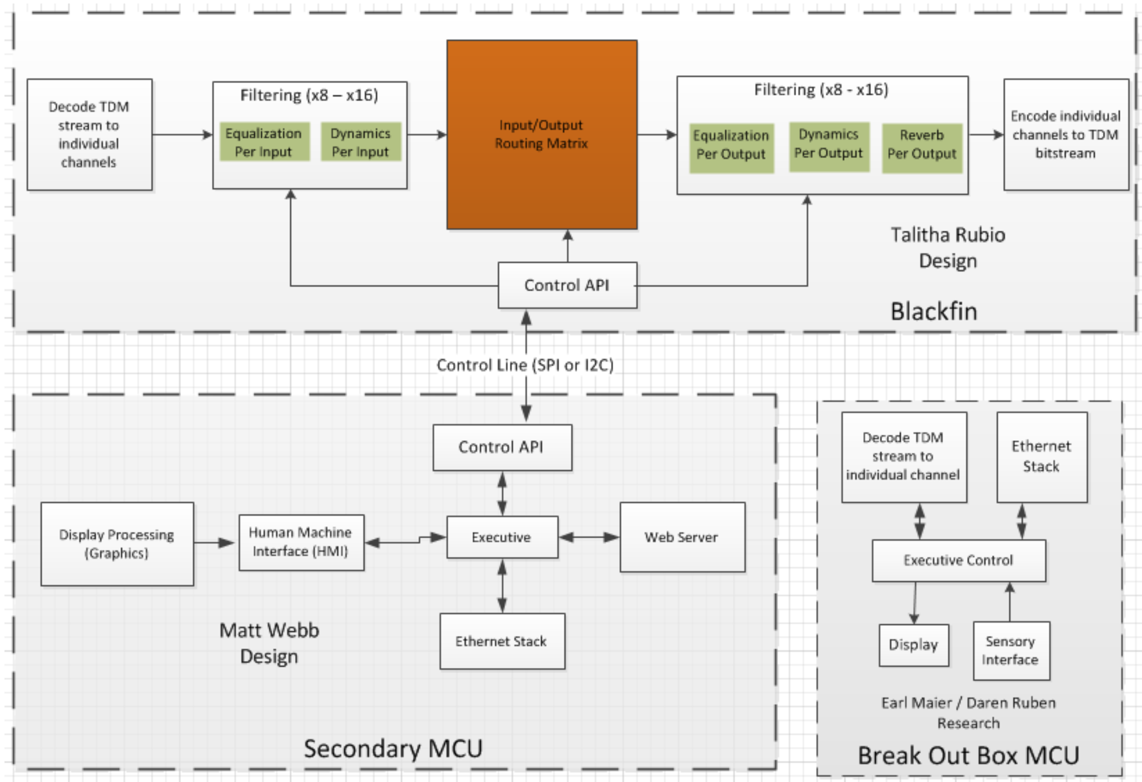
Break-Out Box Block Diagram

In our breakout box we plan to accomplish a single channel/two channel output, depending on the scale of the project. The channel signal will be received over a Dante network. With Dante we should be able choose the channel desired and receive the signal and the channel name. From the Dante device we should be able to feed into a DAC and straight in to our class D amplifier. The microcontroller will run our user interface which will consist of some kind of display screen to display the channel and a device to choose which channel will be played. It will also be in control of temperature using a sensor to monitor safe conditions for operation and to take necessary actions if otherwise. The outputs from the breakout box consist of a SPDIF, XLR cables, and sound. The SPDIF and XLR cables will be used for testing and the speaker is intended for the user.



Acronym	Name	Description
MCU	Micro Controller	memory and programmable input/output peripherals.
DIX	Digital Audio Transceiver	Transmits and Receives Digital Audio
DAC	Digital-to-Analog Converter	Converts a digital code to an anlog signal
XLR	Ground, Left, Right	An audio/electrical connector
S/PDIF	Sony/Phillips Digital Interface	A digital audio interconnection
AES-3	Audio Engineering Society 3	A standard used to transport digital audio
TDM	Time-Division Multiplexing	A type of digital multplexing in which two or more bit streams or signals are transferred

Software Block Diagram



The diagram above illustrates the various components of the project that will need software control. The Blackfin microprocessor will be performing all of the DSP on the audio signals which will involve coding of filtering processes such as parametric equalization and dynamics equations. Reverb convolution equations will also be programmed at the output of the routing matrix. Signal encoding and decoding will also be integrated at the output and input of the processor. There will also be control signals being fed to the processor from the Secondary MCU.

The Secondary MCU will process the peripherals associated with display and user interface. This MCU will interface with the Ethernet port and also upload device stats to a web server for monitoring.

Each break out box will have an MCU for dealing with peripherals that include display and sensor interfacing. The sensors can be power and temperature monitoring and these can be fed back through Ethernet to the Secondary MCU for appropriate adjustments. A TDM decode stack will also be needed to process the incoming signal and place it into temporary memory.

Division of Labor

The above box diagram depicts in greater detail the division of labor. Below is a simplified breakdown:

Matt Webb –
- Secondary MCU
- User interface design
- Human Interface / rotary knobs

Earl Maier –
- Break-out box MCU
- Class-D amplifier
- Sensor Interface

Talitha Rubio –
- Blackfin
- ADCs/Digital Inputs/MUX
- Equalization/Filtering
- Dante Interfacing

Daren Ruben –
- Power supplies
- Dante output
- DAC analog out
- Sensor interface

Milestones

Fall
- Schematics first draft – November 7th
- Senior Design 1 term paper – Dec 1st
- Basic algorithms implemented on Blackfin – Dec 5th
- Power supplies prototyped – Dec 5th

Spring
- Schematics finalized – January 16th
- PCB design complete – February 6th
- Parts on PCB – February 27th
- Begin system testing – March 26th
- Functioning product delivery – April 16th
- Paper complete – April 30th

Project Budget and Financing

Financing will be provided by Workforce Central Florida. This qualifies for the Workforce Central Florida grant under the category of digital media. This senior design project will be able to process and route audio digitally on the blackfin processor. Then send the processed audio over Ethernet to separate breakout boxes and were the audio will be amplified and played. The aspect of processing and sending is done digitally and the information being processed and sent is audio falls in the category of digital media. This financing will be in form of reimbursement up to $5,000. We received 2 evm boards for the Blackfin processor and a class D amplifier from our mentor. These parts were taken into account in our budget. An initial project budget projection is below. This is an estimate for 1 DSP box and 3 breakout boxes. The need for three breakout boxes is to demonstrate the Ethernet network capabilities.

Initial Project Budget

Parts	Number of Parts	Parts Price	Comments
Blackfin processor	2	$50.00	Dupilcates of each processor are for testing and redundancy purposes.
Stellaris processor	2	$40.00	
MCU (breakout box controller)	3	$100.00	For each breakout box there needs to be one microcontroller. The need for multiple breakout boxes is to show that a network of boxes can operate together.
Rotatary knob interface	1	$60.00	
ADC/DAC/MUX		$100.00	
I/O jack(spdif,XLR,RCA)		$60.00	
Dante Brooklyn II	4	$1,000.00	We were quoted $500 plus shipping for two devices.
Class D Amp	2	$250.00	One class D amp has already been acquired. Two more still need to be purchased for remaining breakout boxes.
LCD Displays	3	$60.00	
op-amp/extra circuitry		$75.00	
Software for schematic capture		$350.00	Our mentor advised that a special software may be needed to do schematic capture with the blackfin processor.
PCB		$800.00	The Blackfin processor needs to be developed on a 6 layer PCB board. The more layers the more $$. Also each breakout box will be developed onto PCB increasing the cost of PCB.
GitHub Membership	1	$65.00	Code sharing website. The free version is open sourced. For closed code sharing there is a monthly fee.
Power Supplies	4	$500.00	Each breakout box and the DSP box need there separate power supply.
Speakers	3	$300.00	For high quality audio high quality speakers are needed.
Bread boards	2	$50.00	Bread boards will be need to be purchased so for intail project design.
Container/box	4	$400.00	The DSP box and each breakout box will each need there separate containers.
Misc.		$500.00	This accounts for any unforseen expenditures.
Total Budget		$4,760.00	