The Virgil Project – Audio Management System

Michael Cole (ECE), Tyler Hill (EE), Walker Legrand (ECE),
Brody Taylor (EE), Tanner White (EE)

Problem Statement

Modern recording studios need a way to control which speakers are being referenced at a given time and accurately meter the level of audio input signals. Additionally, there is no monitor management solution currently on the market which integrates an audio amplifier, despite the normal use of passive speakers in many recording studios. An additional problem is that digital audio may be in a variety of incompatible formats which need to be bridged for interoperability. In particular, AVB and Dante are two networked audio formats which need to be bridged. To devise an intuitive way of controlling this system, it is necessary to provide a set of simple user controls including switching and preset storage, eliminating noisy and unrecallable analog potentiometers and buttons.

Objective

To be able to create a system that allows multiple inputs to output to multiple devices in the forms of AVB, I2S (simulating a Dante device) and analog signals.

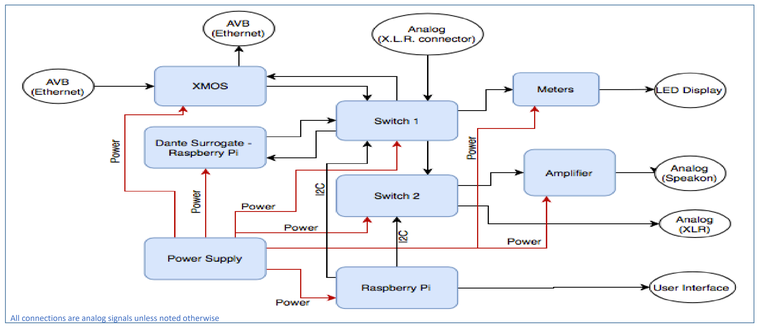
Requirements

Engineering Requirements	Justification
1.) Must fit in standard 19" studio rack	19" studio racks are industry standard
2.) System should operate using 120V/60Hz input voltage	Powered by standard wall outlet
3.) ≥4 AVB and Dante in/outs as well as at least 2 stereo analog in/outs	Smallest Dante PDK has 4 in/outs, multiple analog outs for passive and active speakers
4.) Converts AVB and Dante inputs to analog	Converting to analog allows us to convert to Dante, AVB or keep it as analog
5.) Routes internal analog to AVB/Dante/analog outputs	Satisfies client requirement of bridging AVB and Dante with an option for analog
6.) Internal Class D amplifier >60W continuous, 120W peak output power to 8-ohm nominal load	Class D is most efficient amplifier; Wattage ratings determined for Yamaha NS-10M
7.) Frequency response <3dB from 20Hz-20kHz	Consistent with human auditory range
8.) Input meter range –48dB to +18dB	Covers usable signal range for audio; same range used by most PreSonus equipment
9.) Total harmonic distortion of <0.1%	Low distortion desired because unit will be used for reference
10.) Unit will have recallable digital encoders to store/recall/edit up to 99 user presets	Analog potentiometers introduce noise and make settings impossible to restore

Inputs/Outputs

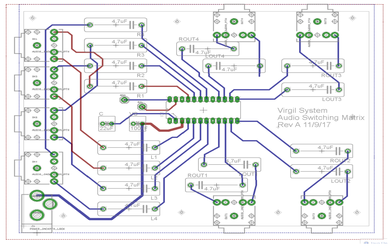
Inputs	Outputs
2 channels of AVB audio over Ethernet via an XMOS multichannel audio platform microcontroller.	2 channels of AVB audio over Ethernet via an XMOS multichannel audio platform microcontroller.
2 Channels of I2S audio via Dante Surrogate Device (Raspberry Pi)	2 Channels of I2S audio via Dante Surrogate Device (Raspberry Pi)
2 channels of analog audio via XLR connector	2 channels of analog audio to passive XLR connector or built in class D amplifier over Speakon connector

Test setup featuring AVB recording, passive, and active speakers with Virgil System mounted in standard 19"rack



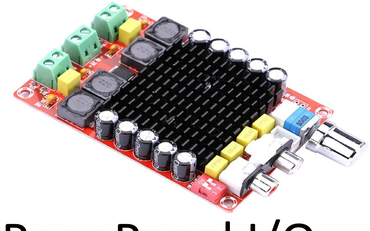
System signal flow diagram

Switching



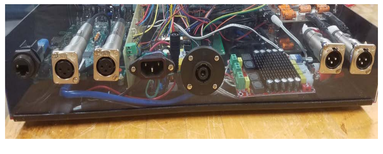
The goal of the switching subsystem is to route any of the system's inputs to any of the system's outputs, as well as provide gain control to the signals. The subsystem consists of two custom PCB designs centered around the TEA6420 audio matrix IC which provides 5 stereo analog audio inputs, four stereo analog outputs, output muting, and is controlled via I2C bus from a Raspberry Pi. All inputs and outputs are routed through these PCBs except for AVB after being converted into analog signals by their respective source devices.

Amplification



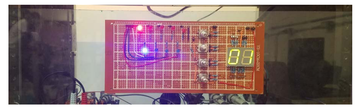
The amplifier subsystem is a 2 channel class D design capable of 60 watts of continuous output at 1kHz. Additionally, the power THD of the amplifier output was less than 1% when powering an 8 ohm nominal load.

Rear Panel I/O



- 2x XLRF analog inputs
- 2x XLRM analog outputs for active speakers
- NL4 Speakon connector for stereo passive speakers
- Ethernet connection for AVB recording. playback
- IEC power connector

User Interface

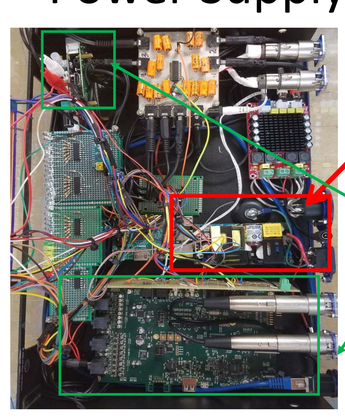


The user interface consists of 4 digital encoders, several LEDs, and a two digit seven segment display. The digital encoders are used to control the input, output, selected preset, and volume. There are two rows of LEDs, one row of red and one row of blue, that indicate which input and output have been selected, respectively. The seven segment display indicates which preset is currently selected. This subsystem is controlled by a Raspberry Pi.

Meters

The meters give a 30-segment LED display with a range from -48dB to +18dB for a total range of 66 decibels for both the left and right inputs. The meters utilize a 12-bit analog-to-digital converter which communicates with an Arduino Nano to apply the proper conversion to be output to the LED display.

Power Supply

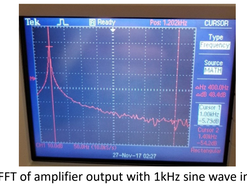


The switching power supply consists of a 200W switch mode power supply set to an output voltage of 48V. Using a 120VAC input the voltage is filtered twice and rectified before passing through the power switcher and stepped down to 48V DC. After a second stage of filtering the voltage is split between three voltage dividing circuits before being distributed to the system.

AVB/ Dante I/O

An XMOS multichannel audio platform receives analog signals from the switching circuit and converts the signals to I2S format, which is then communicated bidirectionally over Ethernet in the AVB protocol to a computer for recording and playback. Likewise, a raspberry pi accepts analog signals, converting them to I2S and passing analog signal back to the switcher as a proof of concept for communication with Dante Devices.

Results



FFT of amplifier output with 1kHz sine wave input

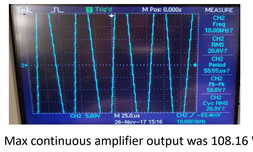
1k = -05.79dB → 0.263633W
2k = -53.40dB → 4.57E-06W
3k = -52.20dB → 6.03E-06W
4k = -52.60dB → 5.5E-06W
5k = -51.40dB → 7.24E-06W
6k = -61.00dB → 7.94E-07W
7k = -59.00dB → 1.26E-06W

dB to power conversions of harmonics of 1kHz

$$THD = 100 * \sqrt{\frac{P_2+P_3+P_4+P_5+P_6+P_7}{P_1}} \rightarrow THD = 0.981357\%$$

THD of amplifier output with 1kHz sine wave input

Successful recording over Ethernet via AVB



Max continuous amplifier output was 108.16 Watts @ 18kHz

Routing/ Conversion Success:
All inputs were successfully routed and reproduced by every device type: AVB, Analog, and I2S (Dante surrogate).