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A Monster System with 23 Tubes



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Vacuum Tube Home Theater System (Part 1)

System Architecture

A “monster” system uses 23 vacuum tubes

By Dr. Gregory L. Charvat

Deployed in my college dorm room, it quickly earned the name, “Frankenstein.” It’s a home theater system built using 23 vacuum tubes, including 10 EL34s, five 12AU7s, seven 12AX7s, and one 5U4G, providing 373 W of root-mean-squared (RMS) average power across five channels (see **Photo 1**). It was a true monster powered by 535 VDC of plate voltage, over 20 A of filament current, protected by a 10-A main circuit breaker and over a dozen 3AG fuses. Power and status indication is provided by light bulbs, not boring LEDs. All of this is mounted in a 7' tall military surplus equipment rack from World War II, enameled in black crinkle paint and emblazoned with chrome accents. Until now, DVD rentals never sounded so good.

Most of the analog signal chain is implemented using vacuum tubes. Consumer electronics provide the audio signals to be amplified and routed appropriately. Vacuum tubes are desirable in a home theater system because they provide that inexplicable smooth and warm tube sound for movie soundtracks. In addition, vacuum tube power amplifiers are capable of producing high-peak power, accurately reproducing the most hair-raising action scenes.

This is the first of a two-part series on how to build a vacuum tube home theater system. In this article, I will describe the system architecture, functionality, and circuit-level details on audio signal routing and power distribution. In the next article, the power amplifier designs that provide relatively high-peak power for movies, with considerable dynamic range, will be discussed.

AUDIO TRANSFER SWITCH AND SURROUND PRE-AMPLIFIER

“Frankenstein” supports two operating modes—high-fidelity stereo and home theater. Complete diagrams are shown in **Figure 1** and **Figure 2**. The audio transfer switch and surround pre-amplifier controls are routed to the power amplifiers (see **Photos 2, 3, 4**). There are five tube power amplifiers. The quad power amplifier is made up of four tube amplifiers built into one chassis providing 80-W RMS each for the front R and L speakers and the rear R and L speakers. The mono-block power amplifier provides 52-W RMS for the sub woofer.

Dolby 5.1 and DTS is decoded by a surround processor providing six channels of analog output, digital volume control, and selection of multiple digital ports. The bitstream output from a DVD player is fed into the surround processor. Of the six analog outputs from the surround processor, five are fed into the audio transfer switch and surround pre-amplifier (see **Figure 3**). These include front R/L, surround R/L, and subwoofer, which are fed into J1–J5 respectively. The center channel is optional and can be fed into a center channel power amplifier but this is not included here because the center channel is mixed into the front R and L channels inside of the surround processor. Connections are provided in the form of a 120-VAC switched bus facilitating the future addition of a center channel that is only powered on when in the system is in surround mode.

Output from the surround processor is too low to drive the power amplifiers directly therefore each channel is amplified by a 12AX7 triode preamplifier (V1–V3).



Photo 1: The Frankenstein, a vacuum tube home theater system

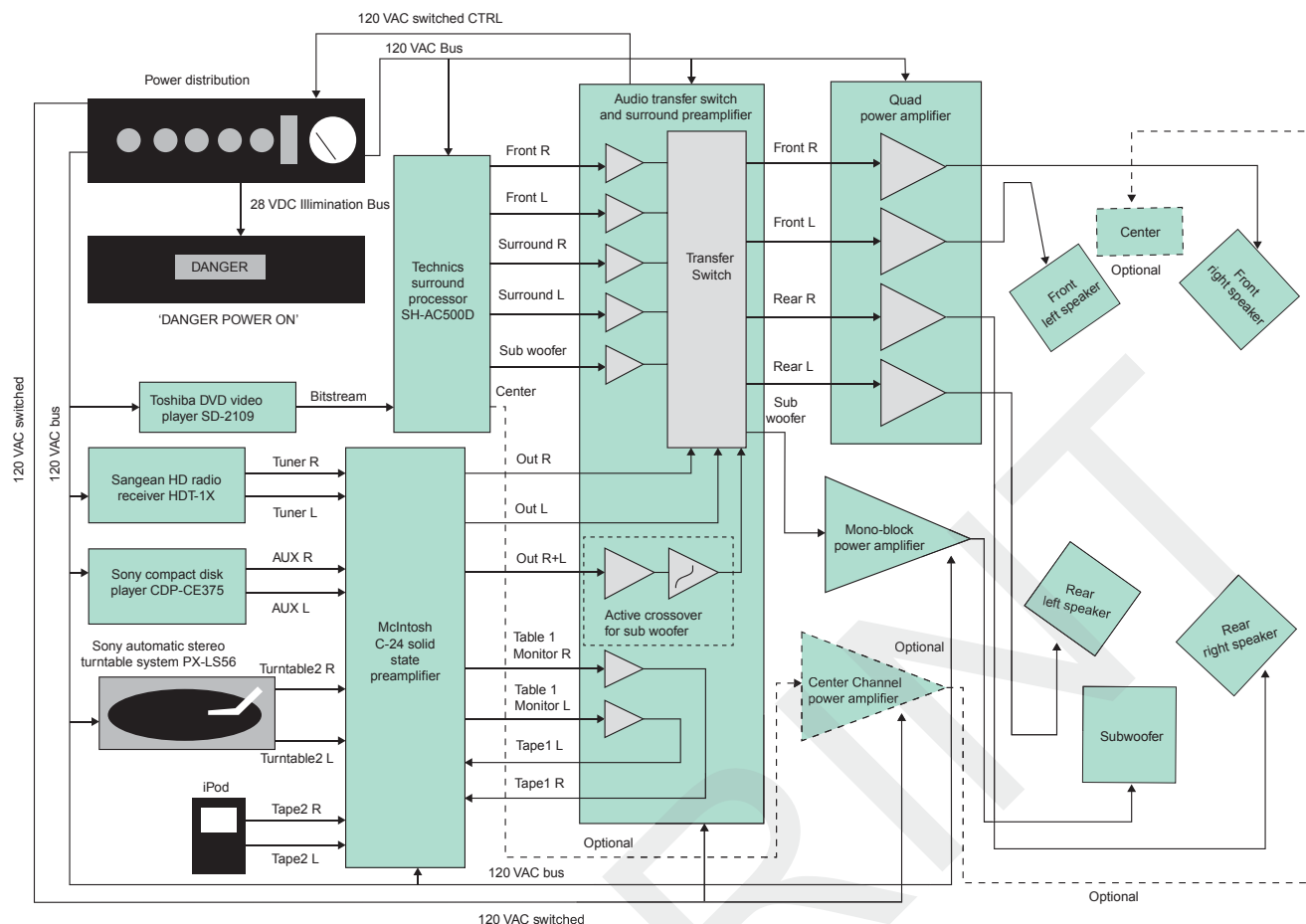


Figure 1: Block diagram

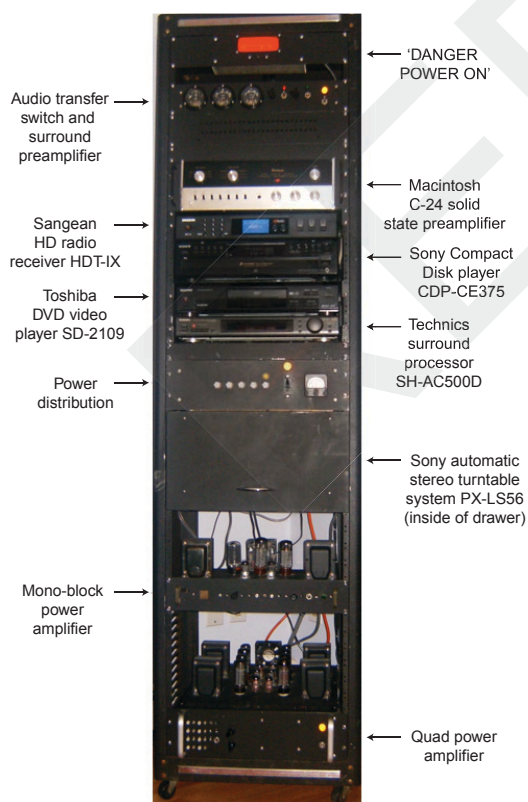


Figure 2: Call-out diagram

Direct bias is used in each preamplifier provided by an op-amp circuit (U1), but, a cathode bias could be utilized similar to that used in.^[1]

The amplified output from the surround processor is fed into a transfer switch matrix made up of U2 and U3, which are analog devices, ADG333A analog switches. It was observed while testing an earlier design that small signal relays used in the transfer switch matrix caused an audible "pop" on the output of the power amplifiers while changing modes. This could not be suppressed sufficiently, which lead to the use of the ADG333As that do not cause any audible switching noise.

High fidelity stereo is sourced by a McIntosh C-24 solid-state pre-amplifier. The C-24 is a convenient pre-amplifier for selecting audio sources, adjusting treble, bass, loudness contour, and adjustment of volume. An HD radio receiver is fed into the tuner R and L input ports, a CD player is fed into the AUX ports, a turntable is fed into the Turntable 2 ports, and an iPod is fed into the Tape 2 ports. The output of Tape 1 monitor ports are fed into J6 and J8 in the audio transfer switch and surround pre-amplifier where they are amplified by two triodes from a 12AX7 (V4) then fed back out through J7 and J9 to the Tape 1 input ports on the C-24. This allows the C-24 to function as a hybrid tube and solid-state preamplifier and provides a signal boost when low-level iPod audio is fed into the C-24.

Out R and Out L from the C-24 is fed directly into the switch matrix through J12 and 13. Out R+L is fed into J17 and through the solid-state switch U3 then into an active crossover circuit consisting of a 12AX7 triode pre-amplifier and a second-order Sallen Key active low-pass filter (U5) where, the cut-off frequency can be adjusted by RV2 located on the rear panel.^[2] This



Photo 2: The transfer switch and surround pre-amplifier

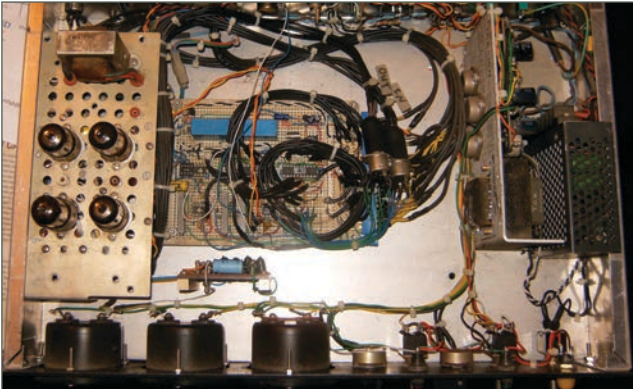


Photo 3: The inside of the transfer switch and surround pre-amplifier



Photo 4: A rear view of the transfer switch and surround pre-amplifier showing rear-panel audio input and output connections

crossover circuit can be placed in-line or bypassed by switch SW3 located on the front panel.

The surround and high-fidelity mode is controlled by SW2 on the front panel. Closing SW2 enables surround sound mode by routing the amplified output of the surround processor to all of the power amplifiers. When SW2 is closed, +5 V is fed out J18 through the 120-VAC switched CTRL line to the power distribution, which then energizes the 120-VAC switched bus to power the optional center channel power amplifier.

Opening SW2 enables high-fidelity mode by routing Out R from the C-24 to the inputs of the Front R and Rear R power amplifiers that reside within the quad power amplifier. Leaving SW2 open routes Out L from the C-24 to the inputs of the Front L and Rear L power amplifiers that reside within the quad power amplifier. In addition, the output of the active crossover circuit is routed to the mono-block power amplifier, which powers the subwoofer.

POWER DISTRIBUTION

Power to all equipment is supplied by 120 VAC line voltage. The power distribution system (see **Photos 5, 6, 7**) filters in-



Photo 5: The power distribution

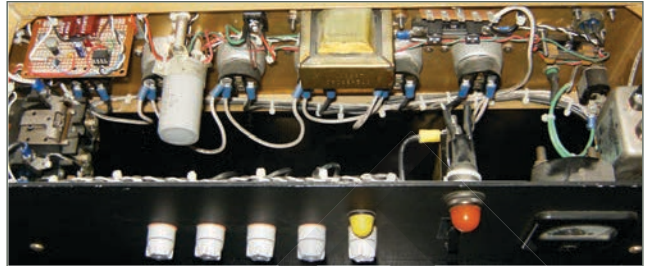


Photo 6: Inside the front of the power distribution, showing 120-VAC outlets and relay driver



Photo 7: An inside view of the rear of the power distribution showing front-panel fuses

coming line voltage from transients, provides a common ground point for all power cords to reduce ground-loop hum, and controls power to the optional center channel power amplifier.

The power distribution schematic is shown in **Figure 4**. Line voltage is fed in through P1. The hot line is fed through a 10-A circuit breaker BRKR1, through AC amp meter MTR1 and through line voltage filter FL1. The neutral line is also fed through FL1. System power is turned on by closing BRKR1. The hot output of FL1 is bussed out to fuses F1-6 and the neutral is bussed out to J1-J4, transformer T1, and relay K1. F1-5 are located on the front panel for trouble-shooting purposes.

The 120 VAC is fed to the quad power amplifier through J1, where J1 is protected by a 10-A fuse, F1. The 120 VAC is fed to the mono-block power amplifier through J2 where, J2 is protected by a 3-A fuse, F2. The surround audio transfer switch and surround pre-amplifier, C-24, the surround processor, and all other audio sources are powered by the 120 VAC from J3, where J3 is protected by a 3-A fuse, F3. One additional outlet is provided by J4, which powers the turntable. J5 is reserved for the optional center channel power amplifier. Power to J5 is controlled by the relay K1. K1 is controlled by an optically isolated relay control circuit, which is enabled by a +5-V signal from the 120 VAC Switched CTRL line fed through J8. Lamp1 indicates that main system power is on. Lamp2 indicates that power to the optional center channel power amplifier is on. A 28 VDC is provided by the relay control circuit to illuminate the "DANGER: POWER ON" sign at the top of the

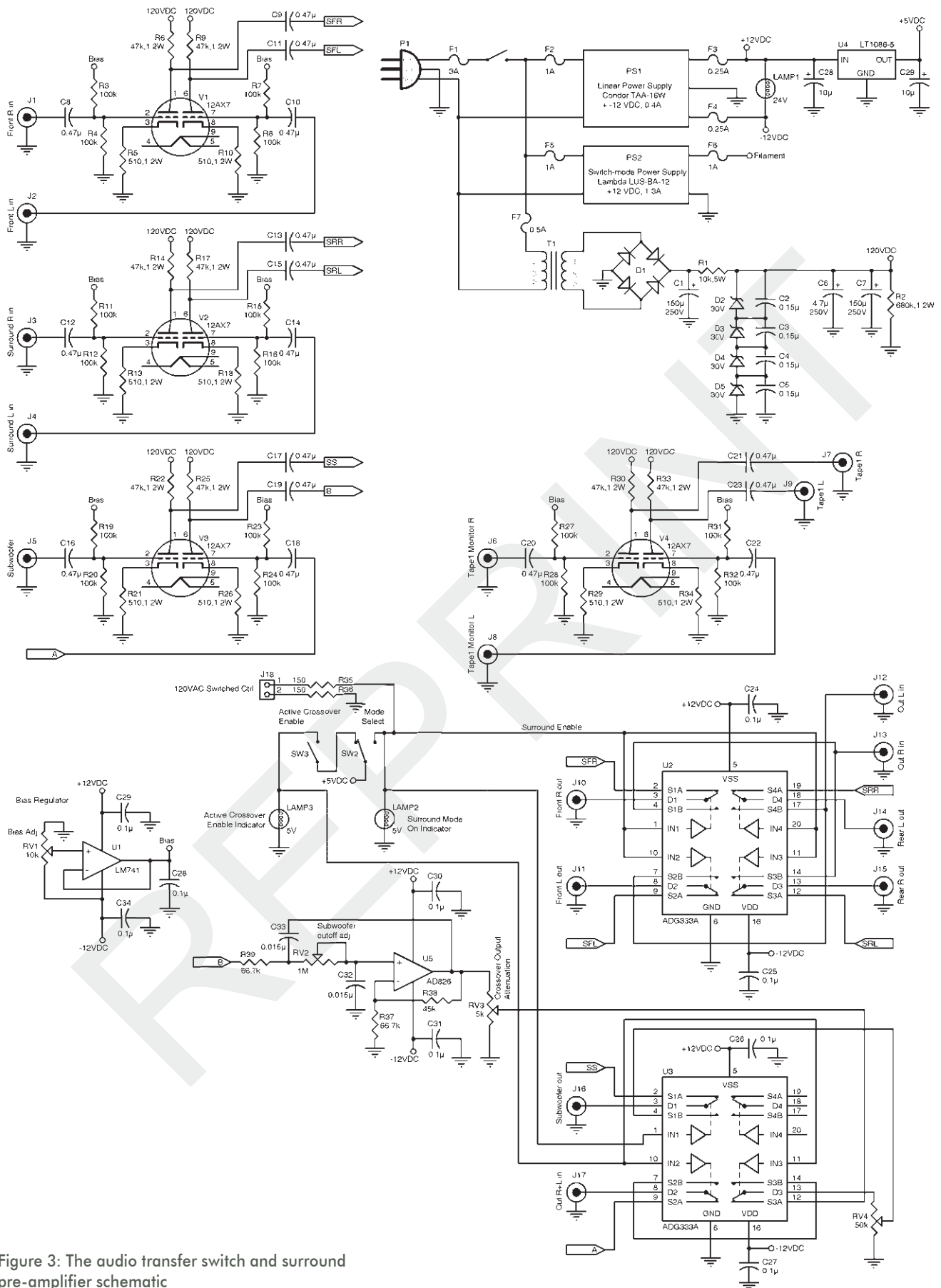


Figure 3: The audio transfer switch and surround pre-amplifier schematic

rack. Additional decorative lighting can be added to the 28-VDC illumination bus.

PLUG IN YOUR AMPLIFIERS

The core of this vacuum tube home theater is the power distribution and the audio transfer switch and surround pre-amplifier. These provide the infrastructure, enabling the use of tube audio amplifiers in a home theater application that supports both high-fidelity and surround sound modes. Consumer audio components are used for the surround processing, DVD player, digital, and analog audio sources. Tubes were used for surround pre-amplification and as part of the active crossover circuit. Using this architecture, you could use your tube amplifiers, substitute a different surround processor, or try other components.

In Part 2 of this series, vacuum tube power amplifiers will be developed specifically for action movies that push the limits of maximum power of the EL34 pentode. The objective is to achieve high peak power for those brief periods of loud action while limiting the design to use readily available vacuum tubes. *aX*

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[1] G. L. Charvat, "Portable Tube Pre-amp," *audioXpress*, March 2010.

[2] D. Lancaster, *Active Filter Cookbook*, 17th edition, Synergetics Press, Thatcher, AZ, 1995.

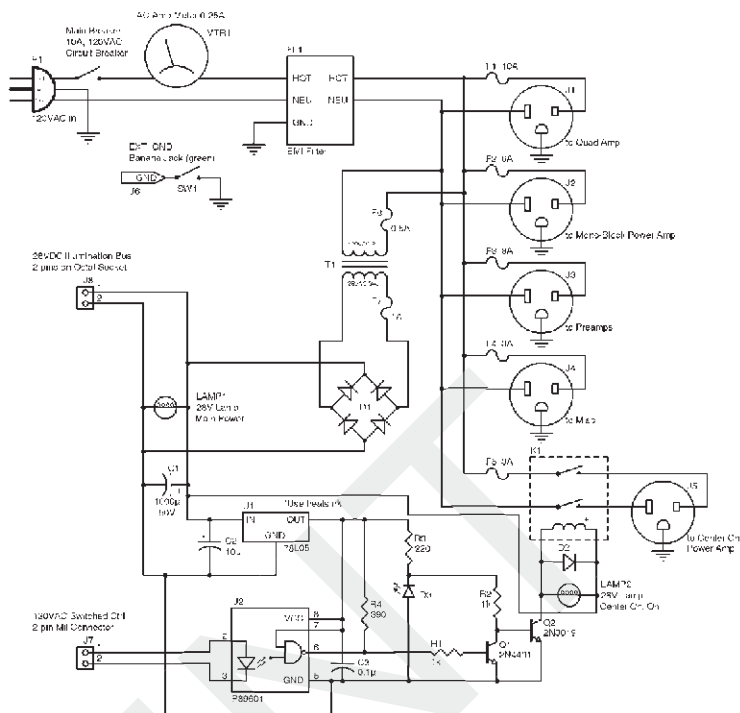


Figure 4: The power distribution schematic

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