# THE ERREDE TUBE SCREAMER

# MULTI-DISTORTION PEDAL

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University of Illinois
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*PHYS 498-POM* *Semester Project/Report*

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# Introduction

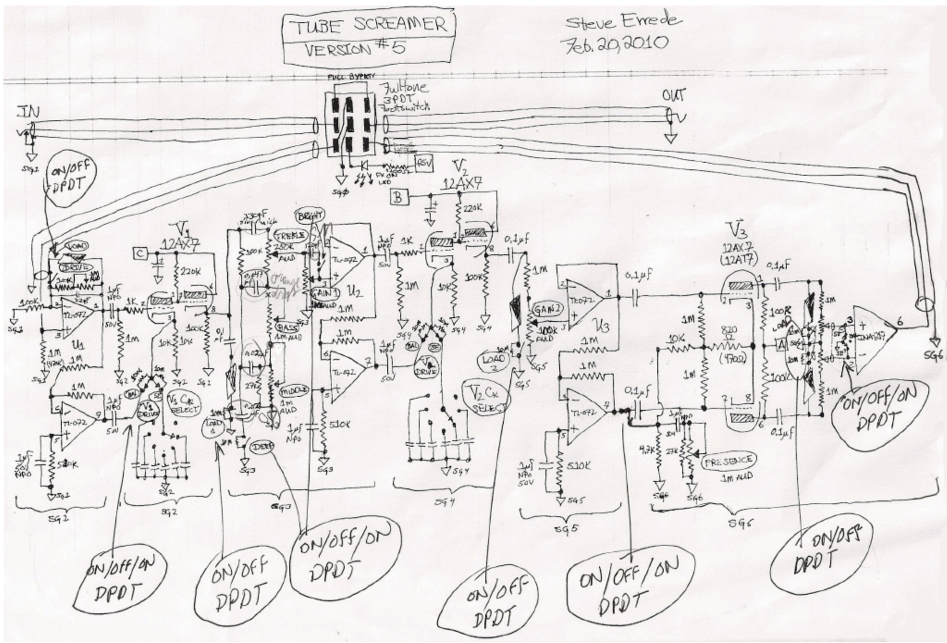
I used to think that tube amplifiers were just a bunch of hype to get people to buy a more expensive product; similar to feel good adjectives like "boutique" and "vintage." My first two years in high school were spent playing through a solid state Fender amplifier. This was a great starting amp and was well suited for learning to play guitar. Once I got into my junior year of high school, I started playing music in bands and began meeting people that owned tube amplifiers and they would let me try them out. Each one had a unique sound, but they all sounded great. After trying out their amps, I would go home and try to mimic the sound on my Fender amp, but I could not recreate it no matter what I tried. It was during those frustrating hours that I developed the desire for a tube driven sound. I saved up my money and finally purchased a Vox AC50CPH after graduating high school. I was pleasantly surprised by the rich distortion that my new amp was able to create and I knew that I was hooked on tubes. Since then I have wanted to learn the "magic" behind vacuum tubes.

*Images from the enclosure building process*

Coming into this project, I knew that I wanted to build something with tubes, but was not sure what to build. My goal was to gather a basic understanding of how vacuum tubes work, how they function in a circuit, and why they produce such a great sounding distortion. I eventually decided to build a tube-based distortion pedal designed by Professor Errede, which he called the "Tube Screamer." Steve had originally designed three versions of the tube screamer, each having a different tube configuration. Steve had yet to build any of the three versions, because he could not decide which one to build. My only concern when starting to build this project was that Steve's pedal would not produce the type of distortion that I was looking for. When Steve first designed his circuits, he had a "blues" tone in mind. In contrast, I was hoping to get a "metal" type distortion from the same circuit. After several modifications to the designs, version five was born, which combined the concepts of the first three versions and featured many more tone shaping knobs and switches, which theoretically would allow for a highly versatile, impressive sounding distortion pedal.

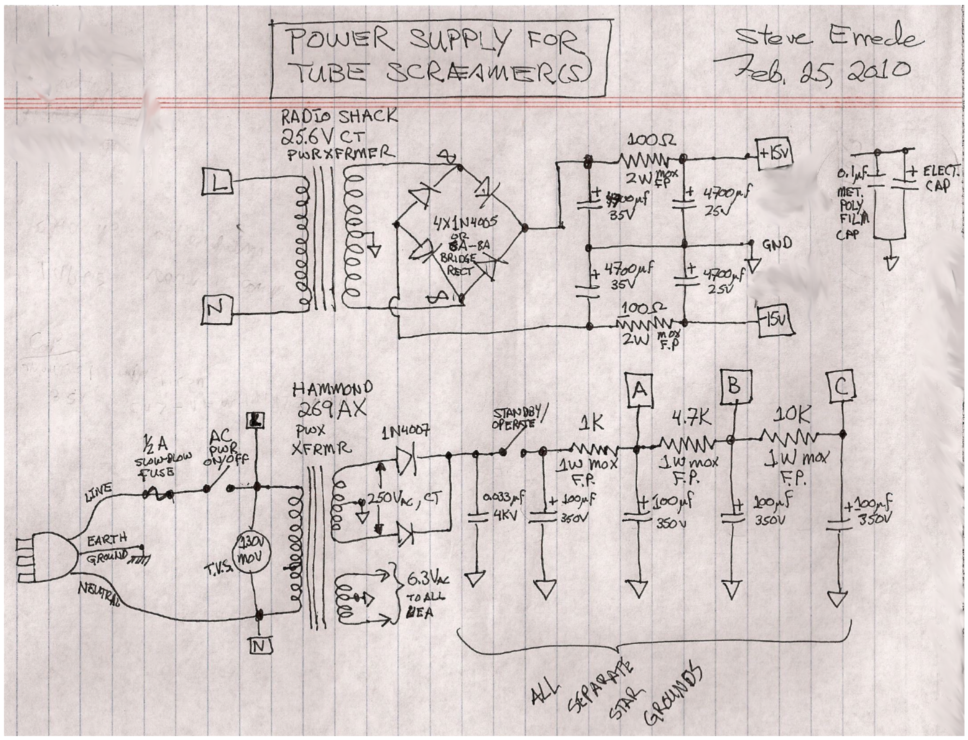
# Schematics

The Tube Screamer version 5 is fairly complex; sporting 8 knobs, 11 switches, and over 150 components.




## Signal Path *(Will include full-sized PDF file)*

The signal path consists of three cascaded stages of pre-amp tube distortion. SG2 contains the first tube stage. It also has a switch that allows the selection of either the capacitor select in SG2 or the inverted TL-072 op-amp from SG1. The capacitor select is a 6 position rotary switch that is connected to six different valued capacitors. These values of the capacitors will a drastic difference in the sound. As the value of the capacitor increases, the frequency response curve at this stage of the circuit is shifted to the right (+ω). A low valued capacitor will have an essentially flat response, because it builds up and levels off before 82.4 Hz (low E string). In contrast, a high valued capacitor will have a drastic response difference, in that higher frequencies have more volume than lower frequencies. When the inverted op-amp is engaged it acts like an overdrive by creating a very large voltage differences between the grid and the cathode of the tube (+ to - 15 V instead of a difference of +15V to 0V). This will drive the tubes hard, creating an overdriven sound. The final op-amp (IN4007) located in SG6 is a instrumentation op-amp. When the audio signal passes through the tubes and becomes distorted from the addition of harmonic content, the signal needs to be preserved by using a true differential op-amp so that tone is not lost. There is also a switch located in SG6 that adds the ability to select between a balanced or single ended signal. This will select the type of distortion produced by the pedal. A balanced signal will produce odd order harmonics which produce a "blues" type distortion. Whereas a single-ended signal will produce even order harmonics which will generate a "metal" type distortion.




## Power Section *(Will include full-sized PDF file)*

The power section consists of a Hammond 269AX power transformer to supply power to the three 12AX7 preamp tubes, and a 25.2V C.T. Radio Shack transformer to supply the op-amps with + and - 15V. The Hammond transformer was a little expensive, but it was chosen for its high-quality. This was necessary because of its effect on the tone of the circuit due to its interaction with the tubes. The Radio Shack transformer was chosen for its price and not for its quality, because its only task is to supply the voltage rails for the op-amp and does not affect the tone.

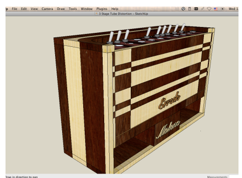
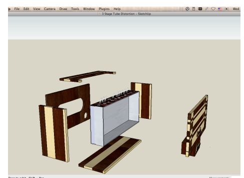
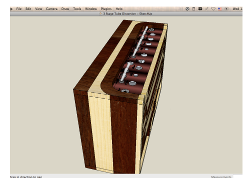
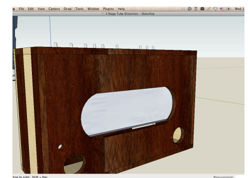
| Qt. | Category | Part | Manufacturer | Value | Description | Part No. | Retailer | Price/per | Price Overall |
|---|---|---|---|---|---|---|---|---|---|
| 1 | Power Section | Transformer | Hammond Manufacturing | 250V C.T. @ 115ma | "Classic" Plate & Filament (263-282 Series) | 269AX | Antique Electronic Supply | $42.20 | $42.20 |
| 1 | Power Section | Transformer | | 25.2V C.T. 2.0A | Heavy-Duty Chassis-Mount Transformer with Lead | 273-1512 | Radio Shack | $10.49 | $10.49 |
| 1 | Power Section | Power Cord | | 16 AWG | 3 CONDUCTOR, BLACK, 8' | S-W125 | Antique Electronic Supply | $4.50 | $4.50 |
| 2 | Power Section | Switch | Sold to KIM!!!!! | SPST | TOGGLE, REPLACEMENT FOR FENDER | P-H495 | Antique Electronic Supply | $3.50 | $7.00 |
| 4 | Power Section | Diode | HVCA | 1 A (MAX.) @ 25C IF | 1.1 V (MAX.) @ 25C; 5 UADC (MAX.) @ 25C IR | 1N4005 | Allied Electronics | $0.04 | $0.16 |
| 2 | Power Section | Diode | HVCA | 1 A (MAX.) @ 25C IF | 1.1 V (MAX.) @ 25C; 5 UADC (MAX.) @ 25C IR | 1N4007 | Allied Electronics | $0.03 | $0.06 |
| 4 | Power Section | Capacitor | Vishay | .1uF | Metal Polypropolene Film | 715P10454LD3 | Allied Electronics | $0.85 | $3.40 |
| 2 | Power Section | Capacitor | Illinois Capacitor | 4700uF, 25V | Aluminum Electrolytic Capacitor | 478CKS025M | Allied Electronics | $1.03 | $2.06 |
| 2 | Power Section | Capacitor | Illinois Capacitor | 4700uF, 35V | Aluminum Electrolytic Capacitor | 478CKE035M | Allied Electronics | $1.36 | $2.72 |
| 1 | Power Section | Capacitor | ASC Capacitors | 0.047uF (NOT .033uF) | Metallized Polyester Axial; 4000VDC; +/-10% | X675-.047-10-4000 | Allied Electronics | $4.13 | $4.13 |
| 1 | Power Section | Resistor | | 1K | 1 Watt Metal Oxide Power Resistors | R-E | Antique Electronic Supply | $1.75 | $1.75 |
| 1 | Power Section | Resistor | | 4.7K 1W | 1 Watt Metal Oxide Power Resistors | R-E | Antique Electronic Supply | $1.75 | $1.75 |
| 1 | Power Section | Resistor | | 10K | 1 Watt Metal Oxide Power Resistors | R-E | Antique Electronic Supply | $1.75 | $1.75 |
| 1 | Power Section | Resistor | | 100 ohm | 2 Watt Metal Oxide Power Resistors | R-F | Antique Electronic Supply | $2.00 | $2.00 |
| 2 | Power Section | Voltage Regulator | | | | | | | $0.00 |
| 1 | Power Section | Varistor | Little Fuse | 130VAC; 340V; 4500A | Circuit Protection; Metal Oxide; 1000pF; Radial | V130LA10AP | Allied Electronics | $0.40 | $0.40 |
| 1 | Power Section | Fuse Holder | Little Fuse | Size 3AG | | 342014 | Allied Electronics | $2.72 | $2.72 |
| 1 | Power Section | Fuse | Little Fuse | 1/2A | Slow Blow Fuse | 0313.500HXP | Allied Electronics | $0.57 | $0.57 |
| 1 | Structural | Chassis | Bud Industries | 17"L x 8"W x 3"H | Aluminum Chassis ("Bud Box") | AC-412 | Allied Electronics | $28.70 | $28.70 |
| | Structural | Wood | | | | | | | $0.00 |
| | Structural | Screws | | | | | | | $0.00 |
| | Aesthetic | Face Plate | | | Bronze | | | | $0.00 |
| | Aesthetic | LED | | | LED for Tube backlighting | | | | $0.00 |
| | Aesthetic | Knob | | | | | | | $0.00 |
| | Aesthetic | Grill Clothe | | | | | | $0.00 | $0.00 |
| | Aesthetic | Handle | | | | | Mojo Tone | | $0.00 |
| 1 | I/O | LED | | | FX/Bypass Indicator | | | | $0.00 |
| 1 | I/O | Resistor | Ohmite | 1200 Ω | Carbon Film (Pwr-Rtg 0.25 W; Tol 5%; Axial; Cer-Core) | OK1225E | Allied Electronics | $0.05 | $0.05 |
| 2 | I/O | 1/4" Mono Jack | Cliff | 4-Terminal (Gold) | Marshall Style Input Jack | S-H502G | Antique Electronic Supply | $2.35 | $4.70 |
| 2 | SG1 | Resistor | Ohmite | 100K | Carbon Film | OK1045E | Allied Electronics | $0.05 | $0.10 |
| 1 | SG1 | Resistor | Ohmite | 510K | Carbon Film | OK5145E | Allied Electronics | $0.05 | $0.05 |
| 3 | SG1 | Resistor | Ohmite | 1M | Carbon Film | OK1055E | Allied Electronics | $0.05 | $0.15 |
| 1 | SG1 | Capacitor | Silver Mica | 22pF @ 500V | | C-SM22 | Antique Electronic Supply | $0.40 | $0.40 |
| 3 | SG1 | Capacitor | Vishay | 1uF (63v) | NPO | BC2076-ND | DigiKey | | $0.00 |
| 1 | SG1 | Potentiometer | Alpha | 1M | Audio Taper, 8mm Bushing | R-VA-8MM-1A | Antique Electronic Supply | $1.40 | $1.40 |
| 1 | SG1 | Switch | Carling | SPST | TOGGLE, 2 POSITION, (ON-OFF) | P-H526 | Antique Electronic Supply | $3.25 | $3.25 |
| 1 | SG1 | Op Amp | | | Dual Channel | TL072CP | Allied Electronics | $0.39 | $0.39 |
| 1 | SG2 | Resistor | Ohmite | 1M | Carbon Comp. | OF105JE | Allied Electronics | $0.54 | $0.54 |
| 2 | SG2 | Resistor | Ohmite | 10M | Carbon Comp. | OF106JE | Allied Electronics | $0.54 | $1.08 |
| 1 | SG2 | Resistor | Ohmite | 1K | Carbon Comp. | OF102JE | Allied Electronics | $0.54 | $0.54 |
| 1 | SG2 | Resistor | Ohmite | 220K | Carbon Comp. | OF224JE | Allied Electronics | $0.54 | $0.54 |
| 1 | SG2 | Resistor | Ohmite | 10K | Carbon Comp. | OF103JE | Allied Electronics | $0.54 | $0.54 |
| 1 | SG2 | Resistor | Ohmite | 100K | Carbon Comp. | OD104JE | Allied Electronics | $0.45 | $0.45 |
| 1 | SG2 | Resistor | Ohmite | 2.7K | Carbon Comp. | OF272JE | Allied Electronics | $0.54 | $0.54 |
| 5 | SG2 | Capacitor | | Various Values | | | | | $0.00 |
| 1 | SG2 | Switch | GrayHill | 6 Position Rotary | | GH5602-ND | DigiKey | $12.61 | $12.61 |
| 1 | SG2 | Knob | GrayHill | 1/8"Diameter | Knob Plastic Black | GH7335-ND | DigiKey | $1.43 | $1.43 |
| 1 | SG2 | Switch | Carling | DPDT | TOGGLE, 2 POSITION, (ON-NONE-ON) | P-H523 | Antique Electronic Supply | $7.65 | $7.65 |
| 1 | SG2 | Vacuum Tube | JJ Electronics | 12AX7 | DUAL TRIODE, SPIRAL FILAMENT, GOLD PINS | T-12AX7-GOLD-JJ | Antique Electronic Supply | $20.00 | $20.00 |
| 1 | SG3 | Resistor | Ohmite | 100K | Carbon Film | OK1045E | Allied Electronics | $0.05 | $0.05 |
| 1 | SG3 | Resistor | Ohmite | 27K | Carbon Film | OK2735E | Allied Electronics | $0.05 | $0.05 |
| 3 | SG3 | Resistor | Ohmite | 10M | Carbon Comp. | OF106JE | Allied Electronics | $0.54 | $1.62 |
| 1 | SG3 | Resistor | Ohmite | 510K | Carbon Film | OK5145E | Allied Electronics | $0.05 | $0.05 |
| 2 | SG3 | Resistor | Ohmite | 1M | Carbon Film | OK1055E | Allied Electronics | $0.05 | $0.10 |
| 1 | SG3 | Capacitor | Silver Mica | 330pF | 300pF (NOT 330pF )@ 500V | C-SM300 | Antique Electronic Supply | $0.50 | $0.50 |
| 1 | SG3 | Capacitor | Orange Drop | 0.047uF | 715P Series | C-RD | Antique Electronic Supply | $0.55 | $0.55 |
| 2 | SG3 | Capacitor | Orange Drop | 0.022uF | 715P Series | C-RD | Antique Electronic Supply | $0.66 | $1.32 |
| 1 | SG3 | Capacitor | Silver Mica | 120pF @500V | | C-SM120 | Antique Electronic Supply | $0.41 | $0.41 |
| 1 | SG3 | Capacitor | Vishay | 1uF (63v) | NPO | BC2076-ND | DigiKey | | $0.00 |
| 5 | SG3 | Capacitor | | Various Values | | | | | $0.00 |
| 1 | SG3 | Capacitor | Orange Drop | 0.1uF | 715P Series | C-RD | Antique Electronic Supply | $1.16 | $1.16 |
| 1 | SG3 | Potentiometer | Alpha | 250K | Audio Taper, 3/8" Bushing | R-V38-A | Antique Electronic Supply | $1.75 | $1.75 |
| 3 | SG3 | Potentiometer | Alpha | 1M | Audio Taper, 8mm Bushing | R-VA-8MM-1A | Antique Electronic Supply | $1.40 | $4.20 |
| 1 | SG3 | Switch | Carling | DPDT, Toggle | TOGGLE, 3 POSITION, (ON-OFF-ON) | P-H522 | Antique Electronic Supply | $6.90 | $6.90 |
| 1 | SG3 | Switch | Carling | SPST | TOGGLE, 2 POSITION, (ON-OFF) | P-H526 | Antique Electronic Supply | $3.25 | $3.25 |
| 1 | SG3 | Op Amp | Texas Instruments | | Dual Channel | TL072CP | Allied Electronics | $0.39 | $0.39 |
| 1 | SG4 | Resistor | Ohmite | 1M | Carbon Comp. | OF105JE | Allied Electronics | $0.54 | $0.54 |
| 1 | SG4 | Resistor | Ohmite | 1K | Carbon Comp. | OF102JE | Allied Electronics | $0.54 | $0.54 |
| 2 | SG4 | Resistor | Ohmite | 10M | Carbon Comp. | OF106JE | Allied Electronics | $0.54 | $1.08 |
| 1 | SG4 | Resistor | Ohmite | 10K | Carbon Comp. | OF103JE | Allied Electronics | $0.54 | $0.54 |
| 1 | SG4 | Resistor | Ohmite | 220K | Carbon Comp. | OF224JE | Allied Electronics | $0.54 | $0.54 |
| 1 | SG4 | Resistor | Ohmite | 100K | Carbon Comp. | OD104JE | Allied Electronics | $0.45 | $0.45 |
| 1 | SG4 | Capacitor | | Various Values | | | | | $0.00 |
| 2 | SG4 | Capacitor | Vishay | 1uF (63v) | NPO | BC2076-ND | DigiKey | | $0.00 |
| 1 | SG4 | Switch | GrayHill | 6 Position Rotary | Buy knob also | GH5602-ND | DigiKey | $12.61 | $12.61 |
| 1 | SG4 | Knob | GrayHill | 1/8"Diameter | Knob Plastic Black | GH7335-ND | DigiKey | $1.43 | $1.43 |
| 1 | SG4 | Switch | Carling | DPDT | TOGGLE, 2 POSITION, (ON-NONE-ON) | P-H523 | Antique Electronic Supply | $7.65 | $7.65 |
| 1 | SG4 | Vacuum Tube | JJ Electronics | 12AX7 | DUAL TRIODE, SPIRAL FILAMENT, GOLD PINS | T-12AX7-GOLD-JJ | Antique Electronic Supply | $20.00 | $20.00 |
| 3 | SG5 | Resistor | Ohmite | 1M | Carbon Film | OK1055E | Allied Electronics | $0.05 | $0.15 |
| 1 | SG5 | Resistor | Ohmite | 10M | Carbon Comp. | OF106JE | Allied Electronics | $0.54 | $0.54 |
| 1 | SG5 | Resistor | Ohmite | 510K | Carbon Film | OK5145E | Allied Electronics | $0.05 | $0.05 |
| 1 | SG5 | Capacitor | Orange Drop | .1uF | 715P Series | C-RD | Antique Electronic Supply | $1.16 | $1.16 |
| 1 | SG5 | Capacitor | Vishay | 1uF (63v) | NPO | BC2076-ND | DigiKey | | $0.00 |
| 1 | SG5 | Potentiometer | Alpha | 100K | Audio Taper, 3/8" Bushing | R-V38-A | Antique Electronic Supply | $1.75 | $1.75 |
| 1 | SG5 | Op Amp | | | Dual Channel | TL072CP | Allied Electronics | $0.39 | $0.39 |
| 1 | SG5 | Switch | Carling | SPST | TOGGLE, 2 POSITION, (ON-OFF) | P-H526 | Antique Electronic Supply | $3.25 | $3.25 |
| 1 | SG6 | Resistor | Ohmite | 4.7K | Carbon Film | OK4725E | Allied Electronics | $0.05 | $0.05 |
| 1 | SG6 | Resistor | Ohmite | 27K | Carbon Film | OK2735E | Allied Electronics | $0.05 | $0.05 |
| 1 | SG6 | Resistor | Ohmite | 10K | Carbon Comp. | OF103JE | Allied Electronics | $0.54 | $0.54 |
| 4 | SG6 | Resistor | Ohmite | 1M | Carbon Comp. | OF105JE | Allied Electronics | $0.54 | $2.16 |
| 1 | SG6 | Resistor | Ohmite | 470ohm | Carbon Comp. | OF471JE | Allied Electronics | $0.54 | $0.54 |
| 2 | SG6 | Resistor | Ohmite | 100K | Carbon Comp. | OD104JE | Allied Electronics | $0.45 | $0.90 |
| 2 | SG6 | Resistor | Ohmite | 10M | Carbon Comp. | OF106JE | Allied Electronics | $0.54 | $1.08 |
| 4 | SG6 | Capacitor | Orange Drop | .1uF | 715P Series | C-RD | Antique Electronic Supply | $1.16 | $4.64 |
| 1 | SG6 | Capacitor | Vishay | 1uF (63v) | NPO | BC2076-ND | DigiKey | | $0.00 |
| 1 | SG6 | Switch | Carling | DPDT | TOGGLE, 2 POSITION, (ON-NONE-ON) | P-H523 | Antique Electronic Supply | $7.65 | $7.65 |
| 1 | SG6 | Switch | Carling | DPDT | TOGGLE, 2 POSITION, (ON-NONE-ON) | P-H523 | Antique Electronic Supply | $7.65 | $7.65 |
| 1 | SG6 | Switch | Carling | DPDT | TOGGLE, 3 POSITION, (ON-OFF-ON) | P-H522 | Antique Electronic Supply | $6.90 | $6.90 |
| 1 | SG6 | Potentiometer | Alpha | 1M | Audio Taper, 8mm Bushing | R-VA-8MM-1A | Antique Electronic Supply | $1.40 | $1.40 |
| 1 | SG6 | Potentiometer | Alpha | 100K | Dual Potentiometers - Linear Taper, 8mm Bushing | R-VA-8MM-2L | Antique Electronic Supply | $2.50 | $2.50 |
| 1 | SG6 | Op Amp | Texas Instruments | | Instrumentation Op Amp | INA217AIP | Digikey | $6.25 | $6.25 |
| 1 | SG6 | Vacuum Tube | JJ Electronics | 12AX7 | DUAL TRIODE, SPIRAL FILAMENT, GOLD PINS | T-12AX7-GOLD-JJ | Antique Electronic Supply | $20.00 | $20.00 |
| 3 | Misc. | Tube Socket | | 9-Pin | Socket w/ Shield Base | P-ST9-213MX | Antique Electronic Supply | $3.95 | $11.85 |
| | | | | | | | Overall Budget | Total Cost | $321.90 |
| | | | | | | | Unused Budget | $300.00 | |
| | | | | | | | | -$21.90 | |

# Parts List & Ordering *(Will include the excel file)*

A parts list had to be generated from the schematic. I decided to section off the circuit into the power section and the signal path. I further broke down the signal path by the circuit's star grounds. I entered the parts into an excel file and included basic information such as the quantity, type of component, and value. Once I had the list made, I began shopping around for parts. I quickly realized that I would not be able to make my purchase from a single retailer. I then set out to allocate my purchases to as few retailers as possible. Once I had the parts ordered, I went back and added columns to the list for the manufacturer, retailer, price, and part number. I also summed up the total cost at the bottom of the spreadsheet to keep track of how much I had spent.

# Chassis *(Will include a PDF file of hole dimensions and locations)*

The chassis that I bought measured 17" x 8" x 3." With so many controls, it was difficult to arrange everything to fit on the face of the chassis, while maintaining a comprehensive layout for intuitive usability. The placement of the preamp tubes and transformers also had to be considered. The transformers need to be far away from the input and beginning stages of the circuit to avoid 60 cycles hum getting into the audio signal path. Holes also need to be made to mount the circuit boards to their standoffs, run the wires from the outside to the inside of the chassis, and for the power cord. Once I finalized the dimensions and locations of these holes, I plotted the points on the chassis with a ruler and a marker. The next step was to use a center punch on the marks to create small dimples in the metal. This allowed the drill bit to rest in the indentions; preventing the drill bit from slipping and putting a hole in the wrong place. All of the holes were made using a hand-drill and reamer except for the three for the tube sockets. These were too large and had to be made using a chassis punch. After the holes were made, the flashing needed to be removed. This was done by using various sized counter sinks on both the inside and outside of the holes. Finally, the holes for running wire from the inside to the outside of the chassis needed to be fitted with grommets to prevent the wires from getting cut on the metal edges and the power cord was fitted with a strain relief.

# Enclosure

Initially this project was supposed to be a pedal, but after considering the mass number of controls and components, it was decided that it would fit better in an amp styled enclosure. The design of the enclosure started out on paper with some rough sketches to get the idea down. I then learned about a free 3D design software made by google called Sketchup. I downloaded this program and, after overcoming the learning curve, I made a 3D design of the enclosure taking into consideration the size of the chassis, transformers, and tubes. I calculated what the dimensions of the boards needed and used Sketchup to make a scaled model. This was helpful because I was later able to reference the dimensions of the boards using the measurement tool in Sketchup. After figuring out how much wood I would need, I purchased 3/4" thick cedar wood boards and 1/2" dowel rods from Home Depot. I then attempted a wood working technique known as marquetry, which connects planks of wood together using dowel rods. Marquetry is used a lot in making cutting boards and table tops, because it provides cross bracing for the wood grain inside of a board, making it stronger than an unaltered board of the same thickness. Part of my reason for using this technique was to add structural strength to the enclosure. However, I also wanted to attempt to create a striped wood enclosure by applying stain to every other piece before assembling. This process turned out to be very difficult, due to the required precision of cuts made and holes drilled so that the boards actually match up. Also, after the boards had been stained and assembled, I began applying the first coat of finish by hand. This turned out to be a bad idea. The stained pieces began to smudge into the unstained pieces creating a mess. I quickly cleaned up the problem areas and had to apply the finish to the stained and unstained boards separately using different rags. I would suggest using a spray-on finish, at least for the first coat, to prevent the stain from being transfered to the natural boards. An even better way would be to purchase two different kinds of wood, one dark and one light, and avoid staining all together. I learned many wood-working lessons the hard way building this enclosure. Although my enclosure turned out fairly well, I plan to make a second enclosure using a slightly modified design and the knowledge I gained from the first enclosure.

## Layout *(Will include the .cap file so student could open up file and see the layout in detail and a PDF version)(Also will include a PDF file listing every connection that needs to be made)*

Before the circuits could be assembled, I needed to create a functional layout of the components on separate Perfboards from the schematic, keeping in mind several key considerations. First, I needed to leave room to screw in the bolts for the standoffs. Second, I needed to arrange the components in such a way as to avoid running jumper wires from component to component. Third, I needed to arrange the components so that the star ground points met at a central location. I first designed the layouts in sections on paper. I later found a free 2D software program online called Cap 1.0. I used this software to create a full layout of the project. I also went through and drew in color coded wired connections between the components.

## Circuit Board *(I will take a picture of the tops of the circuit boards and the bottoms of the circuit boards. I will then invert the bottom pictures and layer them with their tops. I will then set the opacity of the bottom pictures fairly low so the only the solder joints are visible. I will then match up the top and bottom so that you can see the top of the circuits with their actual solder connections. I will include this layered photos in a separate PDF file)*

Once everything was laid out in a functional manner, the Perfboards were ready to be assembled. I started with SG1's circuit, placing the components into the board without soldering the connections. I mounted the 8-pin DIP sockets instead of the actual TL-072 chip so that the op-amp could easily be replaced later if it happened to go bad. Once all of the components had been placed on SG1's board, I soldered the connections that would not need additional wires to or from them. I repeated this process for the remaining star ground boards and for the power circuits.

# Mounting *(Will include photos where everything is mounted)*

Once I finished soldering, I decided to mount the circuit boards to the chassis. I started by mounting the SG boards to the inside of the chassis using short standoffs. Short standoffs were used to keep these circuit close to the ground plane, which leaves them less exposed to interference. When mounting the boards I found that it was not necessary to tighten them down, because I would need to take them out one at a time to wire them up to the controls. After the inside was finished, I moved to the backside of the chassis and mounted the two power section circuits using taller standoffs. This was to keep the high voltages away from the metal chassis.

# Wiring *(Will include the program file and a PDF version)(Also will include a PDF file listing all of the connections that need to be made)*

The next stage was to run wires from the input, output, and controls to the circuit boards. To run the signal wires, I used coax cable, which is a shielded wire typically used as a transmission line for radio frequency signals. The reason for using this type of wire was to help block out unwanted signals from getting into the audio path. This is especially important in the earlier stages of the circuit, where unwanted interference entering the audio signal would be amplified and sent on through the circuit. To wire up the controls, the shield braid going the controls was trimmed off and covered with shrink wrap. The other end of the coax was separated into two parts, the central wire and the braided shield. The braided shield was attached to star ground, sometimes via a jumper wire, and the central wire was attached to the necessary components to carry the audio signal down the circuit. When wiring components on one board to components on a different board, both ends were left as two parts, so that the SGs could be connected by the metal braid. There were also some that ran directly to star ground, which were wired with an unshielded green cable. Throughout the wiring process, it is very beneficial to cut the wires a little longer than needed so that it is not difficult to unmount circuit boards and work on them later.

The next stage would be to wire up the transformers, run heater wires to the tubes, and to wire up the power cord. When doing this wiring, it is important to stick to a color code, such as red = +15V and black = -15V.

# Test Run & Adjustments

Once everything is wired up the "smoke test" must be performed. This test requires the project to be plugged in for the first time. The switch is turned on and is watched closely for smoke, sparks, smells, etc. If everything seems to be operating normally, it is time to carefully take voltage measurements at critical points on the circuit. These measurements are compared with the theoretical predictions to see if the circuit is functioning correctly. If this step is passed, a guitar is plugged into the circuit and the sound is tested while adjusting the knobs and switches up and down to determine if there are any bad connections and if the controls are functioning properly. During this process, you are listening for anything that is not supposed to be in the signal, such as squeals or pops. If there are problems during any of the stages, the circuit will need to be powered down and the problem will need to be addressed. This can range from small quick fixes to devastating issues. After adjustments are made, the circuit is re-tested and the procedure repeats until everything is up and running.

# Measurements *(Will include graphs in a PDF file)*

Once the project is up and running, I would like to take measurements on the tonal characteristics of the pedal. I would like to use these measurements to generate graphs where the data can be visually analyzed. I also would like to take data on the effects of some of the switches and knobs, especially the capacitor select with different valued capacitors.

# Conclusion *(Will include sound files and maybe a video demonstration)*

While I plan to use this pedal through my VOX head for live applications, I am curious to see if this can also be used for recording guitar directly into a mixer or audio-interface. The most common way to record good sounding guitar tones is to mic a cranked up amp. However, I will be living in an apartment next semester, so this is out of the question, yet I would still like to be able to record good sounding guitar tracks. I have tried running my guitar directly into a mixer to record and I just don't think it sounds good at all. I am hoping that by running my guitar through this pedal before the

Because it has so many components, this project has plenty of room for modification and tweaking to dial in one's perfect tone. Future builders could potentially build this project for a lot less money. Once this pedal is up and running, it could be used as a reference to dial in a student's desired tone. The values of some of the controls could be measured at the student's settings and the potentiometers and switches could be replaced with constant valued resistors and capacitors. This would result in less control over the shaping of the tone, but would allow the builder to achieve a custom sounding distortion pedal. Also, with the reduction of parts, the project could fit into a smaller chassis and could be implemented as a pedal.