"VOCO-LOCO" Model

Mic Preamp and Effects Loop

Modeled as Originally Designed by: Radial Engineering Ltd.

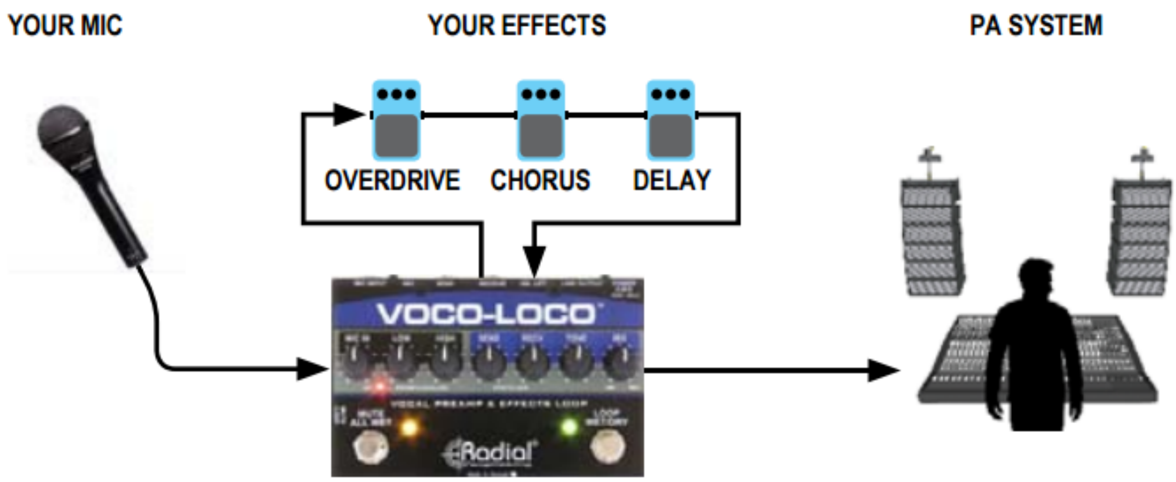
Modeled by: Jullian Rives

Final Project for MMI-401: Audio Electronics

December 10th, 2015

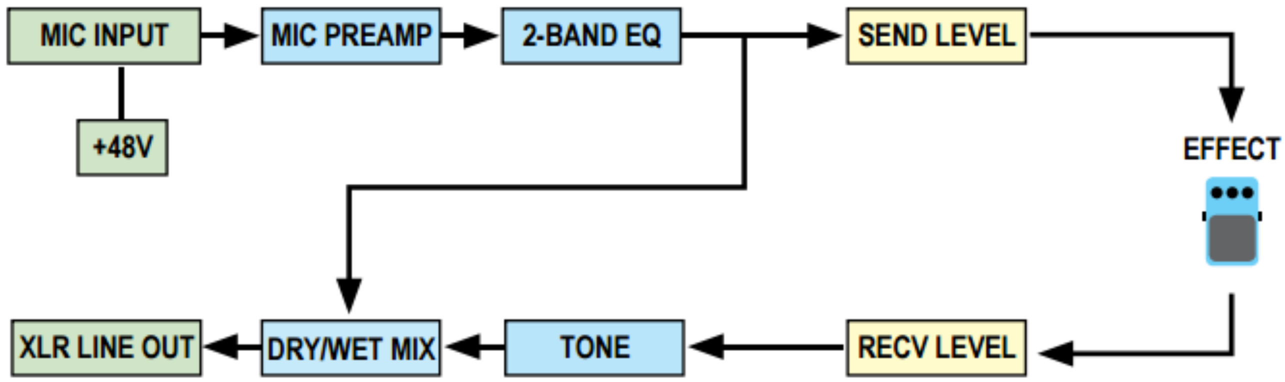
Contents

Introductory Synopsis



The Voco-Loco is by design, a "mic-to-effects" interface that grants the user the ability to use effects pedals on virtually any type of instrumentation the same way a guitar or bass player would. The Voco-Loco functions by taking the connected microphone's signal and converting it into a usable signal that can be mixed with guitar effects. At this point, the blended signal is then routed to the Voco-Loco's output to be sent to a PA system where it may be amplified and processed as desired.

Signal Flow Chart



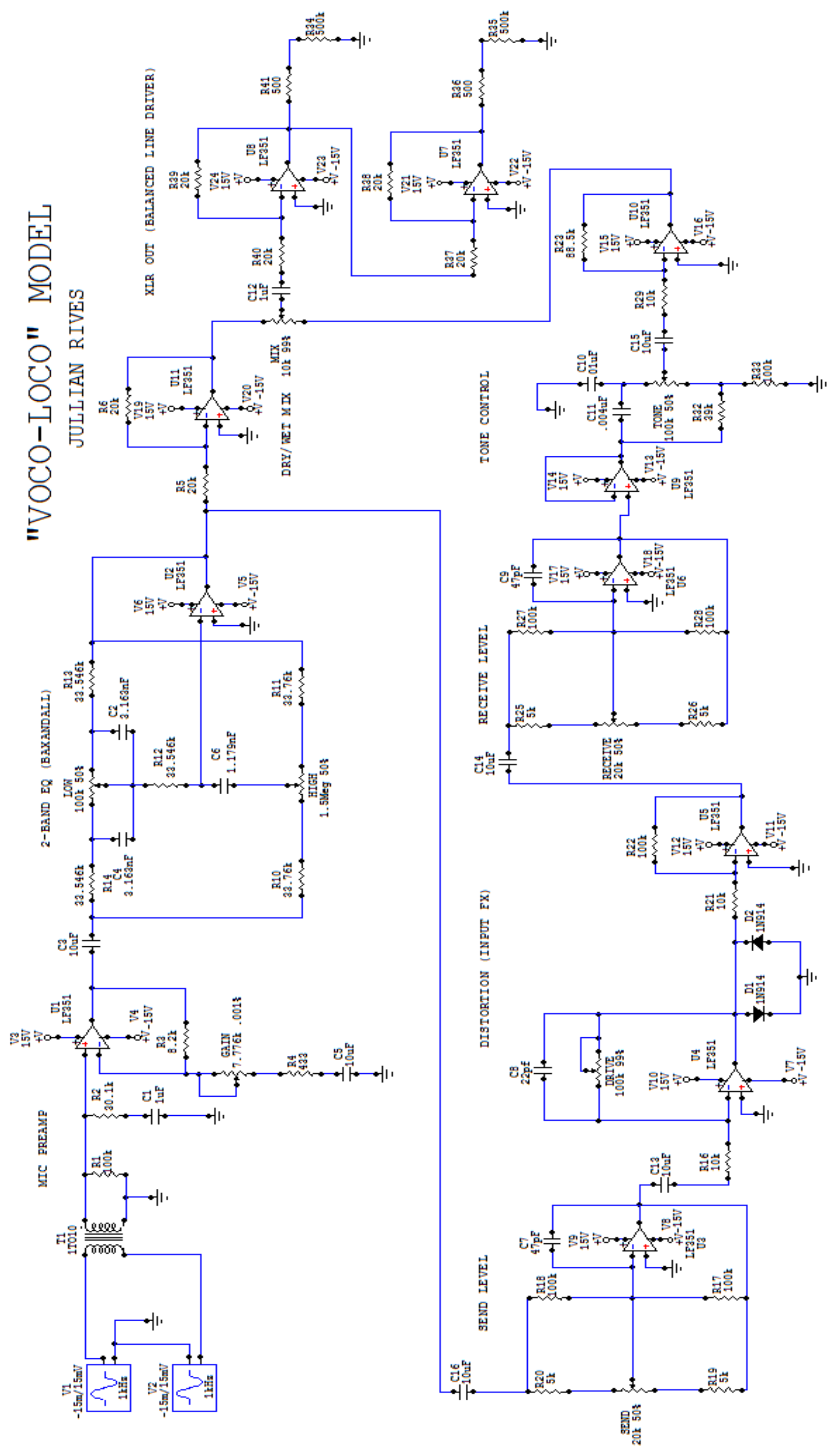
The signal flow that occurs within the Voco-Loco originates from the input microphone's signal and is fed directly into the Mic Preamp. The Mic Preamp is used to amplify or attenuate the input signal using an adjustable gain knob that can be raised up to +52dB across the entire circuit. After the Mic Preamp, the signal enters a 2-Band Baxandall EQ that contains two adjustable high and low EQ knobs. Each knob, depending on placement, will boost or cut the high and low bands up to 12dB.

After the 2-Band EQ, the signal is split into two directions to create the "dry" (unaffected signal) and "wet" (signal mixed with effect pedal) mixes that will be blended at the output. In one direction, the dry signal bypasses all potential effects and is sent straight to the "Dry/Wet Mix" knob to be blended for output. The wet signal path takes the same unaffected signal and sends it to an adjustable plus or minus 12dB send level knob that controls the amount of dry signal sent into the effects chain.

The signal is then fed into the desired effects pedal(s), returned to the Voco-Loco, and sent to an identical plus or minus 12dB knob that controls the amount of signal received from the effects pedal(s). Next, the specified receive signal is sent to an adjustable tone control knob. In this model, the tone control knob (modeled after the Electro-Harmonix "Big Muff" Tone Control) will boost the treble response and cut the bass response when rotated clockwise, and conversely boost the bass response and cut the treble response when rotated counter-clockwise.

Finally, the wet signal then reaches a crossroad with the dry signal in an adjustable wet/dry mix control knob that simply controls that ratio between the wet and dry mix that is then sent to the balanced line driver (XLR Line Out) that converts the mixed wet/dry signal into a usable balanced XLR output, producing a "hot" (in phase) signal and a "cold" (180 degrees out of phase) signal at the final output.

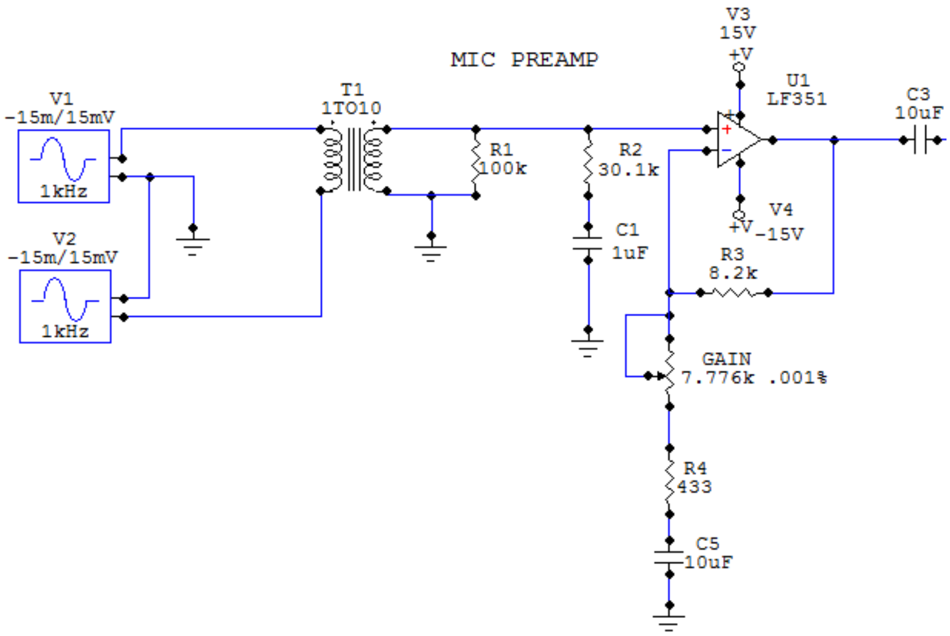
Full Schematic



***NOTE: Bypass capacitors on OpAmp rails have been omitted from this model to prevent Circuit Maker simulation errors ONLY, but are necessary for real world functionality

***NOTE: All component values ARE NOT real world values, but calculated values used for simulation and modeling purposes only

Mic Preamp Stage Design



$$1.)\ Av = 1 + \frac{Rf}{Ri}\ ; \qquad 2.)\ Av = (2 * 10)\left(1 + \left(\frac{Rf}{Ri}\right)\right);$$

$$3.)\ Av = 10^{\frac{dB}{20}}\ ; \qquad 4.)\ Av = 1 + \frac{Rf}{(Ri + Rp)}$$

This mic pre-amp is designed to receive a balanced input (XLR), and is capable of producing up to 52dB gain across a circuit using a 1:10 ratio step up transformer in tandem with gain achieved with a Non-Inverting OpAmp. To design this circuit, I used a modified version of the original (#1 above) gain equation for a Non-Inverting Negative Feedback OpAmp that incorporates the transformers effect on the circuit, with respect to achieving 52dB gain across the entire circuit and not just the OpAmp. Approaching the fabrication of the modified equation, it must be acknowledged that although the transformer has a 1:10 ratio, a balanced XLR input enters the circuit that sums to twice its original signal (I.E: A-(-A)=2A), yielding equation #2 above.

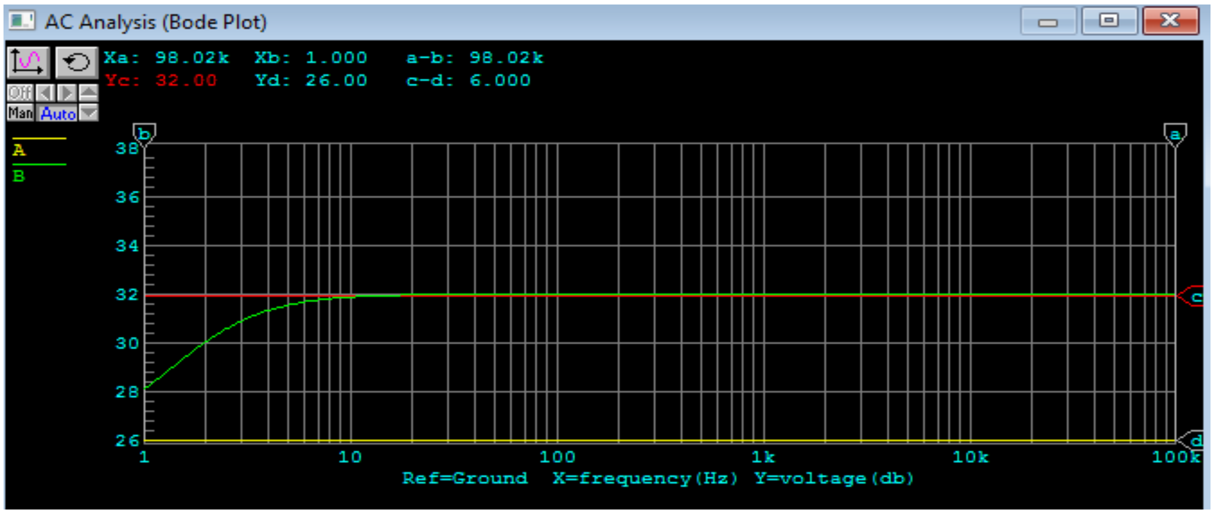
To solve for Ri, I first used equation #3 above to convert my desired overall max gain of 52dB into its correlative multiplier/scalar ratio, yielding an approximate Av of 398.107. By subbing that value (398.107) into equation #2 in place of "Av", and setting Rf at a fixed value of my choice (8.2k ohms), I was then able to solve for Ri at approximately 433 ohms. In addition, while modeling this specific design I eventually settled on adding another modification that would essentially establish a "gain floor" when the specified gain knob was set to max impedence (or max attenuation).

Mic Preamp Stage Design (Cont.)

To achieve this, I replaced the design's originally set potentiometer, Ri, with a new potentiometer, Rp, that would take its place as the variable gain knob while allowing Ri to retain its calculated value as a set resistor (this changes equation #1 to equation #4). I then set the new potentiometer (Rp) at a value equivalent to the difference between Rf and Ri (approx. 7.7k), so that when Rp is at maximum impedance (max attenuation), the equation (#4) would create unity between Rf and the summation of Ri and Rp (I.E: 1/1), thus, equating to a Av of 2 (1+1/1). This Av of 2 would establish a fixed "gain floor", where the minimum observable gain over the OpAmp (not including transformer) would be set to 6dB (when converted back to dB using equation #3).

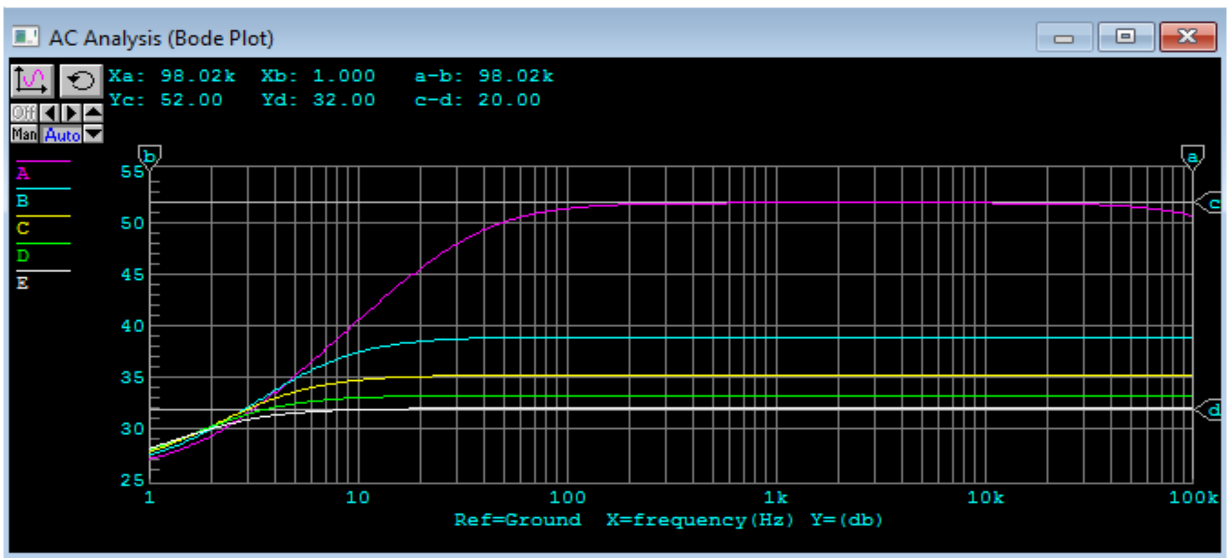
Mic Preamp Stage Analysis

“Gain Floor” Analysis



-The above circuit shows the calculated 6dB gain at the max impedance of Rp, outlined by the gap between sliders “c” and “d”.

Variable Gain Analysis (dB)

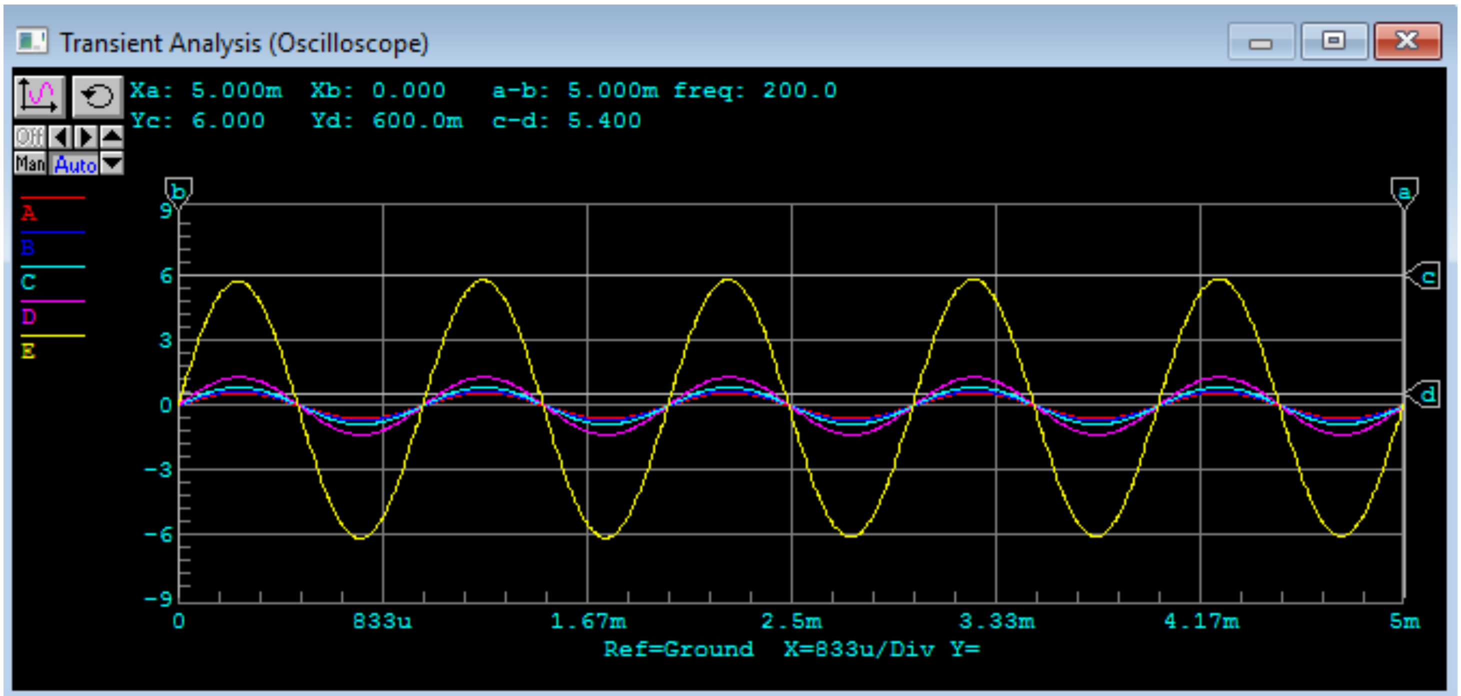


Potentiometer Settings (Bode Analysis in dB)

White= 99.99% (Gain Knob at Max Cut)
Green= 75%
Yellow= 50% (Gain Knob at Unity)
Cyan= 25%
Magenta= .001% (Gain Knob at Max Boost)

Mic Preamp Stage Analysis (cont.)

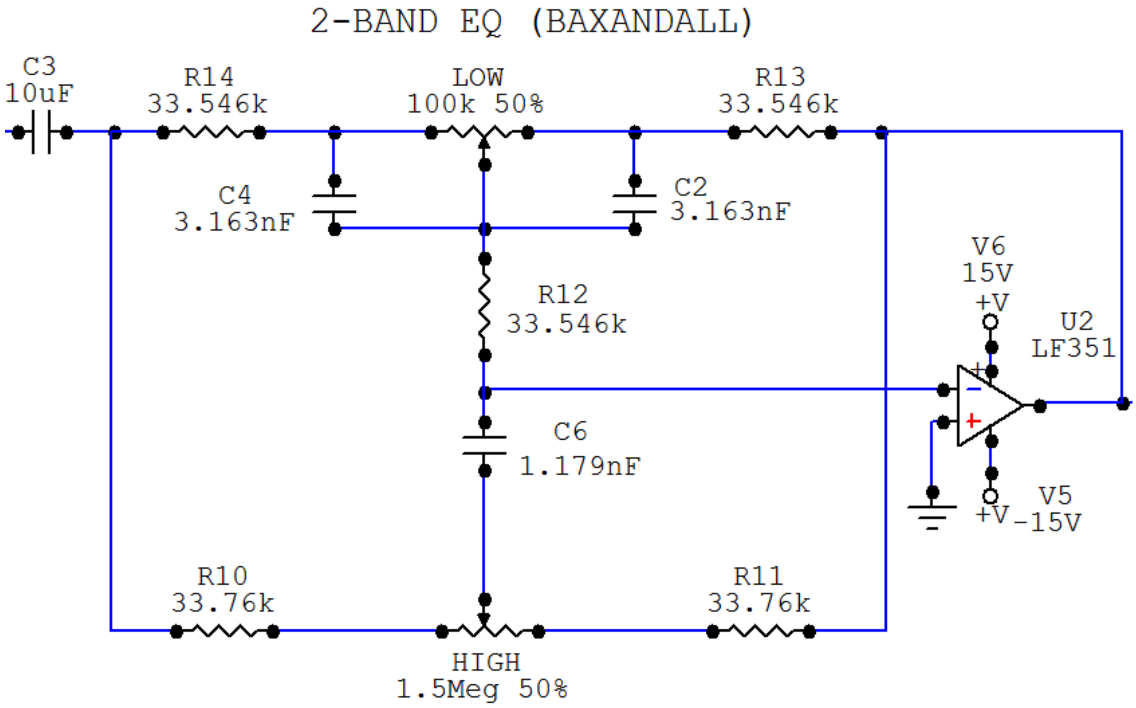
Variable Gain Analysis (Voltage)



Potentiometer Settings (Transient Analysis in Volts)

Green= Input Voltage @ 15mV
Red= 99.99% (Gain Knob at Max Cut)
Blue= 75%
Cyan= 50% (Gain Knob at Unity)
Magenta= 25%
Yellow= .001% (Gain Knob at Max Boost)

2-Band EQ Stage Design



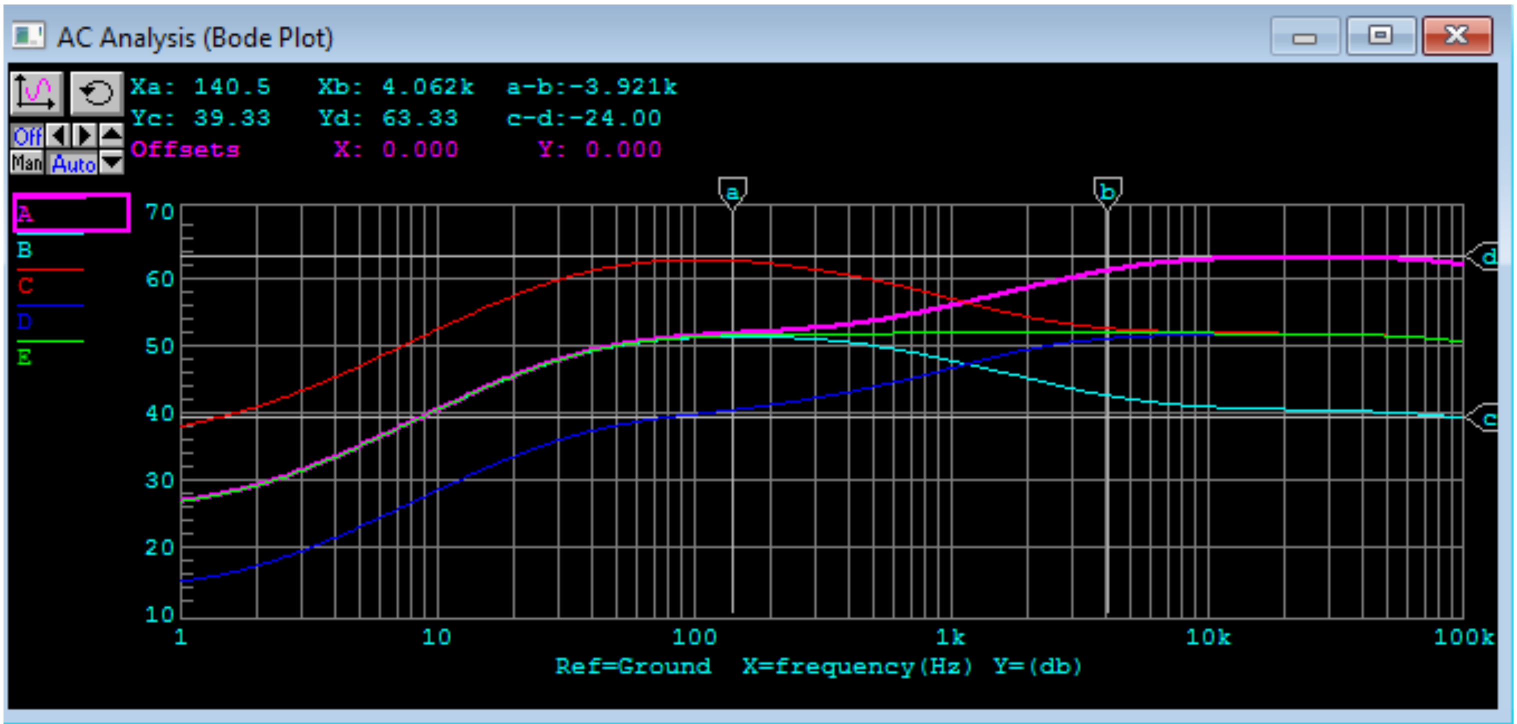
$$\textbf{\textit{Bass Design}}: R1 = \frac{R2}{Avb - 1};\ fLB = 10fL;\ C1 = \frac{1}{2\pi * fLB * R1}$$

$$\textbf{\textit{Treble Design}}: R5 = R1; R3 = \frac{R1 + 2R5}{Avt - 1}; C3 = \frac{1}{2\pi * fH * R3}; R4 \geq 10(R3 + R1 + 2R5)$$

This circuit functions as a variable two band EQ and is designed to boost or cut the low and high spectrums of a specified frequency band by plus or minus 12dB. The circuit design is based using the Americanized Baxandall Filter, and functions via two adjustable potentiometers that act to control the boost and cut of the high and low bands. In my design, I selected a low shelving frequency (*fl*) of 140Hz, and a high shelving frequency (*fh*) of 4kHz; these specific set frequencies dictate the 2-Band EQ's specified operational spectrum, and thus, the specific frequency ranges of the high and low bands at which plus or minus 12 dB boost or gain can be observed.

By setting my R2 potentiometer value at 100k and solving for all other values by using the above equations with respect to the circuits specified operational frequency range (140-4kHz), I was able to successfully replicate and simulate the adjustable Low and High frequency spectrum EQ's up to a 12 dB boost or cut. One important factor to note in the design is that Avb and Avt are expressed as multipliers, and not dB (same as preamp design for Av).

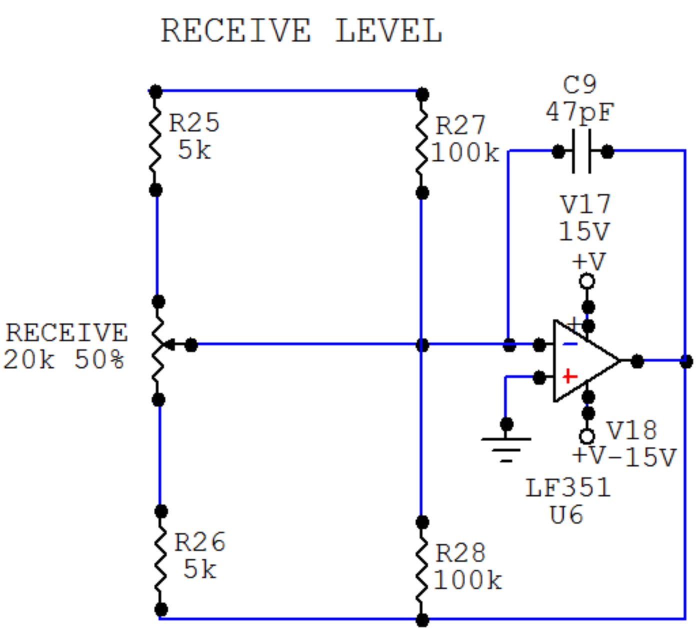
2-Band EQ Stage Analysis

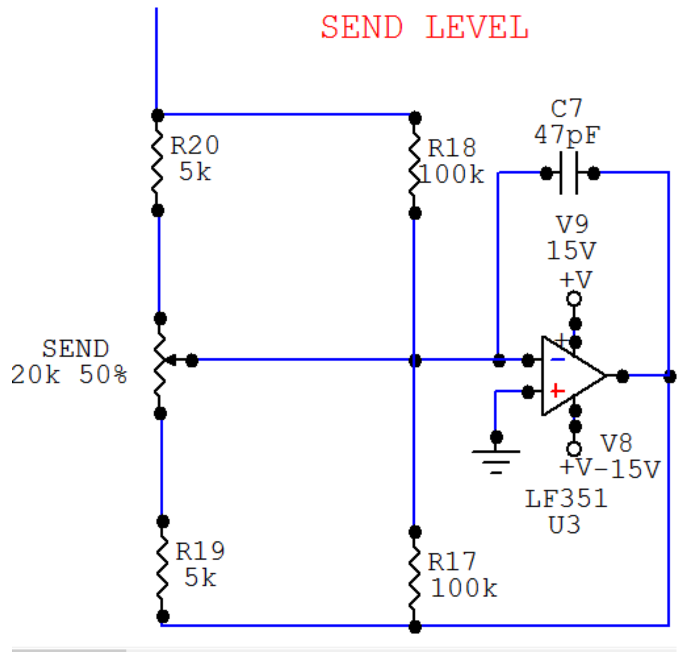


Potentiometer Settings (Bode Analysis in dB)

	LOW	HIGH
Red=	99.99%	50% (Max Bass Boost +12dB)
Blue=	.001%	50% (Max Bass Cut -12dB)
Green=	50%	50% (Flat Response)
Cyan=	50%	99.99% (Max Treble Cut -12dB)
Magenta=	50%	.001% (Max Treble Boost +12dB)

Send/Receive Level Stage Design

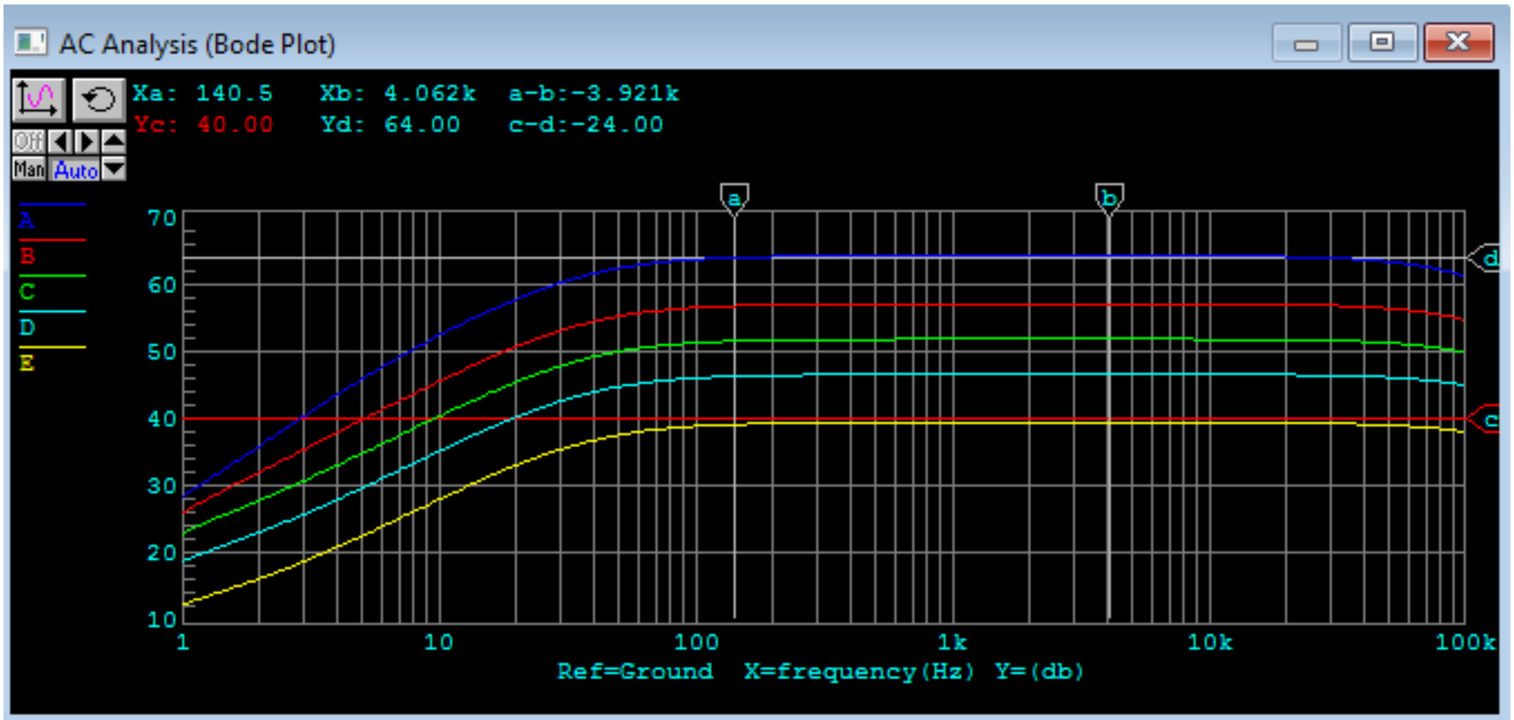




The Send and Receive Level Controls are identical circuits, with the exact component values modeled straight from a common Rane Variable Gain circuit. These circuits simply boost or attenuate the incoming signal within a plus or minus 12dB range and send the boost, cut, or unaffected (leveled) signal to the next stage in the equipment string. These circuits are specifically unique, being that the two top left resistor values combine in parallel with the set proportioned value of the closest half of the potentiometer to create the Rf value, while the bottom two left resistors combine in parallel with the lower half of the potentiometers available set impedance to create an Ri value (dependent on potentiometer percentage of distribution to top and lower half of circuit).

This Rane circuit is a great choice in terms of variable gain potentiometer quality, as it was originally designed in order to mitigate issues with previous configurations that would distort or generate noise due to dirt and other small particles that would gather under the adjustable arm over time.

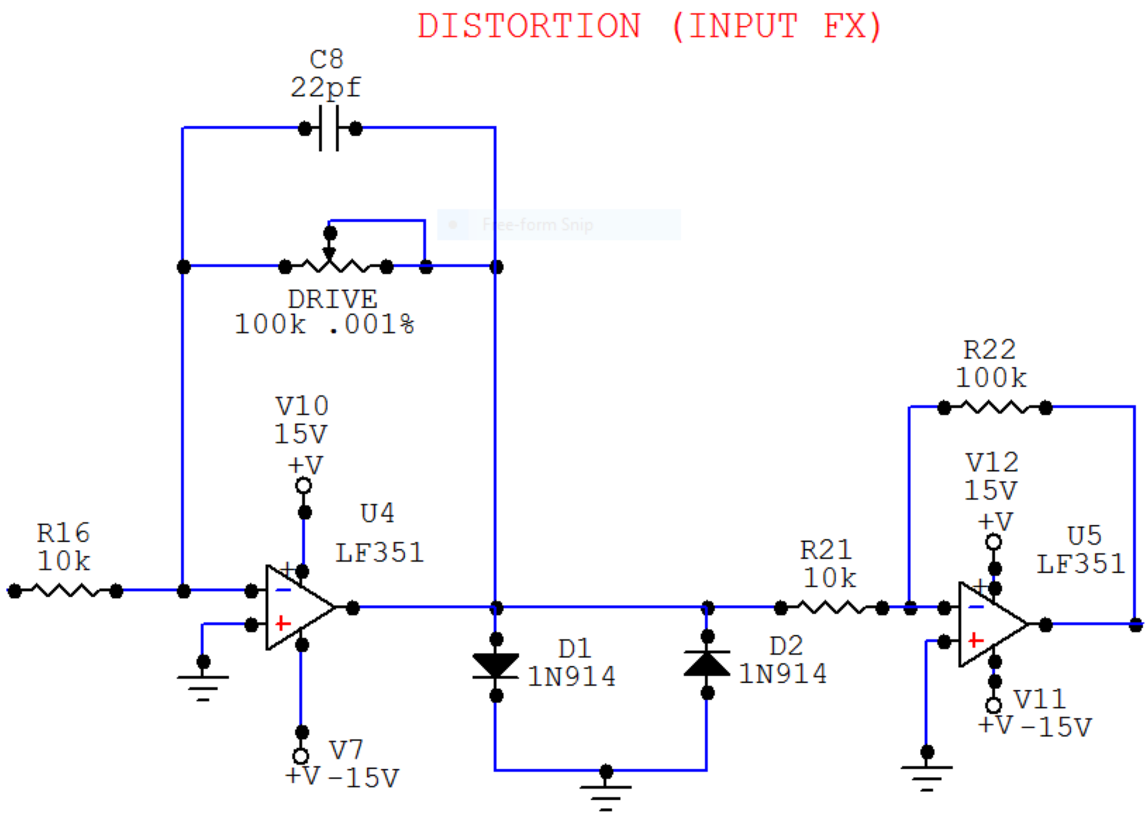
Send/Receive Level Stage Analysis



Potentiometer Settings (Bode Analysis in dB)

Yellow= 99.99% (Max Cut in Gain -12dB)
Cyan= 75%
Green= 50% (Unity: No Boost or Cut)
Red= 25%
Blue= .001% (Max Boost in Gain +12dB)

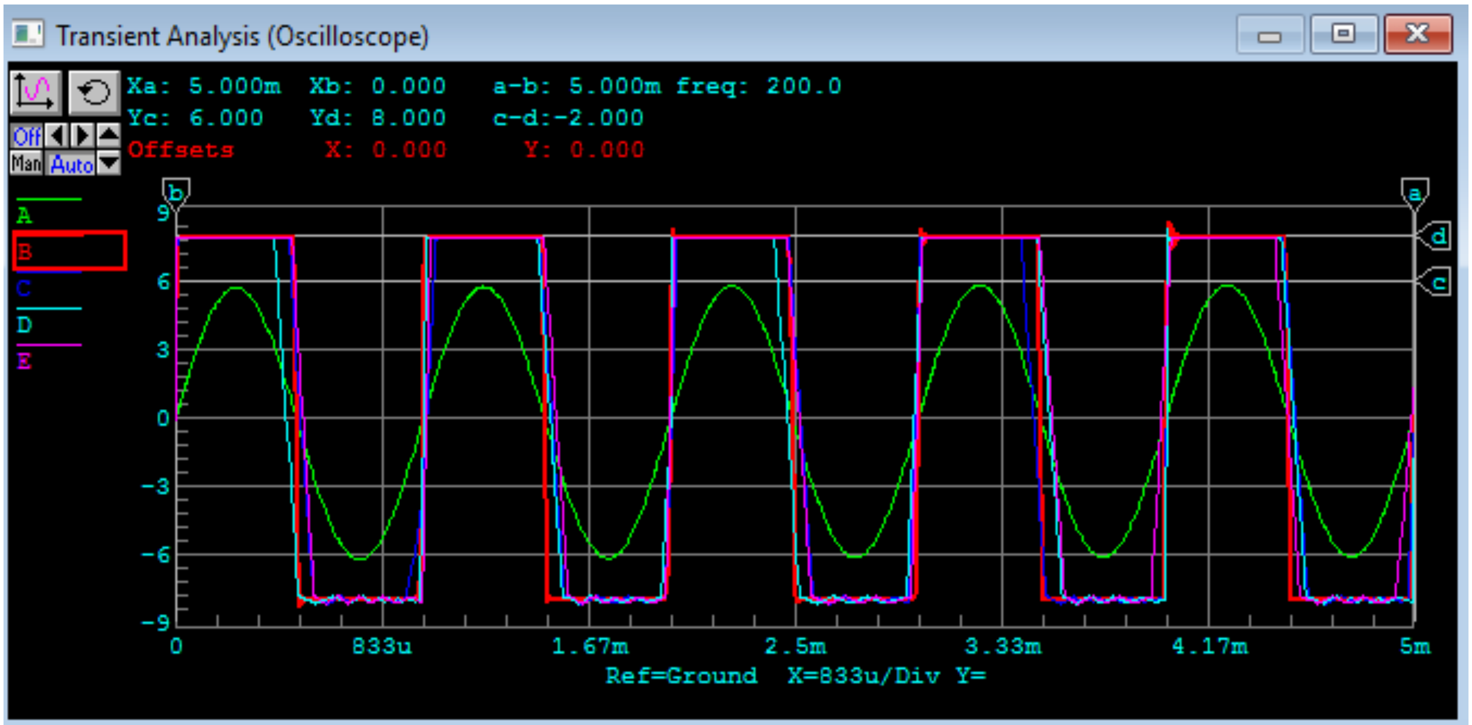
Effects Stage (Distortion) Design



This distortion effect is simply a "place holder" effect inserted for simulation purposes only. It is modeled after the MXR Distortion+ guitar effects pedal using the same values from the original design. The pedal also includes and adjustable "Drive" that is controlled by a potentiometer. Simply put, the lower the potentiometer percentage value, the lower the distortion effect introduced into the signal. After integrating this distortion into my design, I would discover a serious issue that needed to be addressed: an unusual amount of signal attenuation.

Most distortion designs include a variable makeup stage after their distortion circuit to correct this, but this specific pedal did not. In order to correct signal loss after the distortion and maintain voltage integrity across the entire circuit, I designed the make-up gain stage after the distortion (far right OpAmp) using the distortions output voltage set seen at the lowest possible drive value (Vout= -Vin (Rf/Ri)) and solving for Rf by setting an Ri value and plugging in the desired output voltage into the equation.

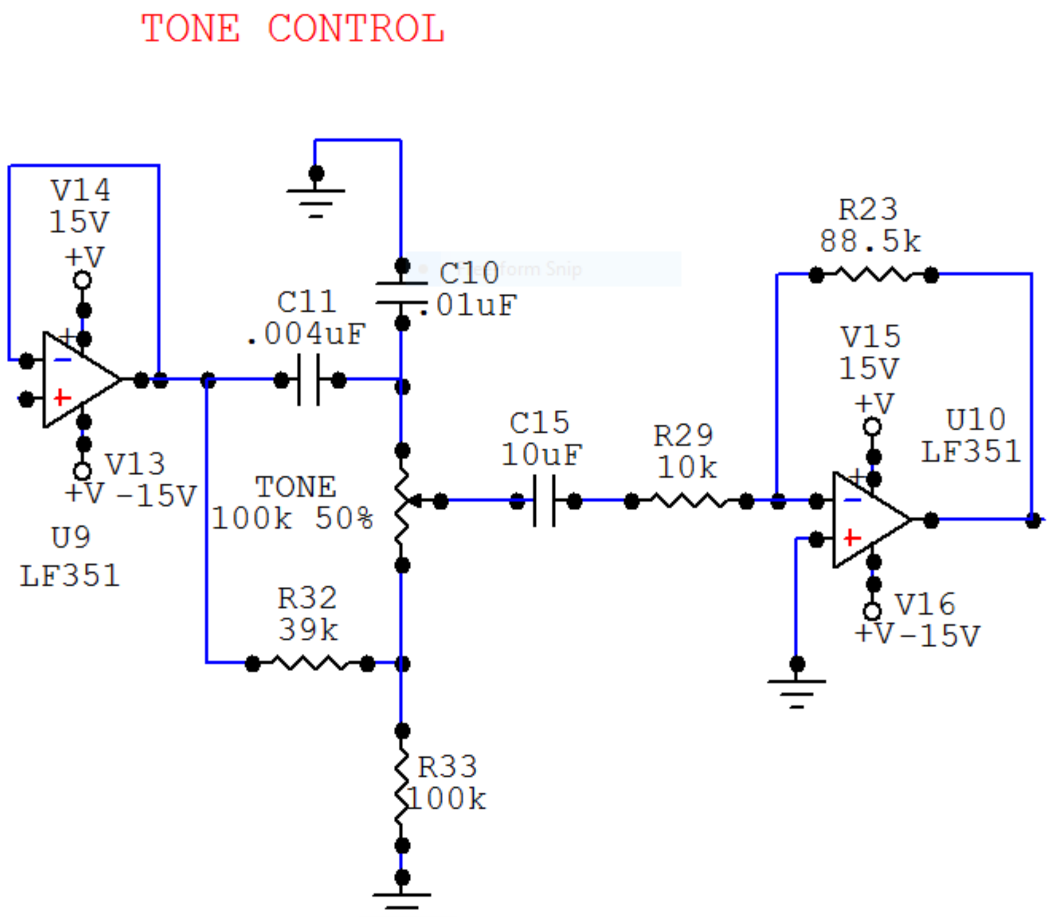
Effects Stage (Distortion) Analysis



Drive Potentiometer Settings (Transient Analysis in Volts)

Green= 1% (Lowest Drive Level; Virtually No Distortion)
Red= 25%
Blue= 50%
Cyan= 75%
Magenta= 99% (Highest Drive Level; Max Distortion)

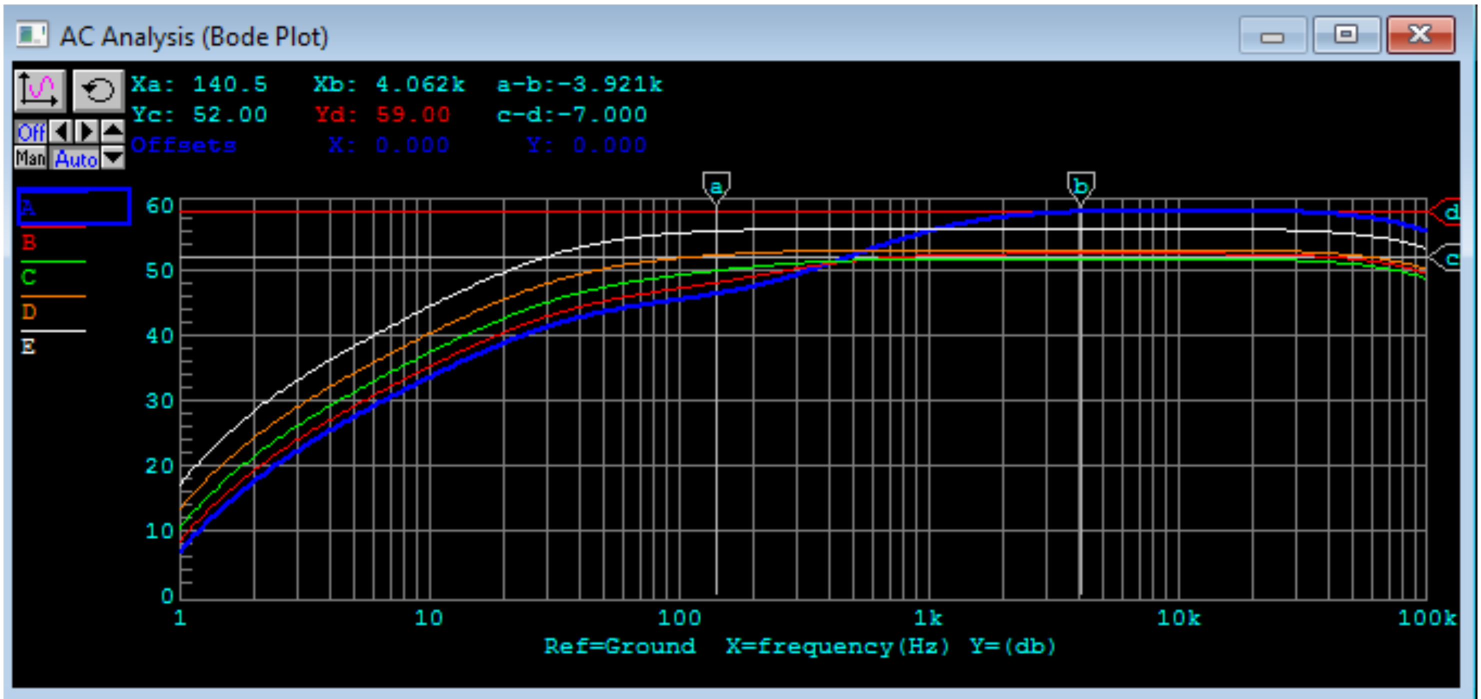
Tone Control Stage Design



The tone control stage schematic is modeled after the Electro-Harmonix “Big Muff” Tone Control design, and functions as an adjustable high/low-shelving filter that is controlled by a single potentiometer. In theory, as the knob is rotated in a clockwise direction, the treble is boosted and the bass cut. Conversely, counter clockwise rotation will boost the bass and cut the treble.

Similar to the distortion design, a makeup gain stage was integrated into the design to correct signal loss/voltage attenuation as well as a **unity gain buffer** placed at the input stage of the tone control circuit to correct previously occurring mismatched impedance/loading issues.

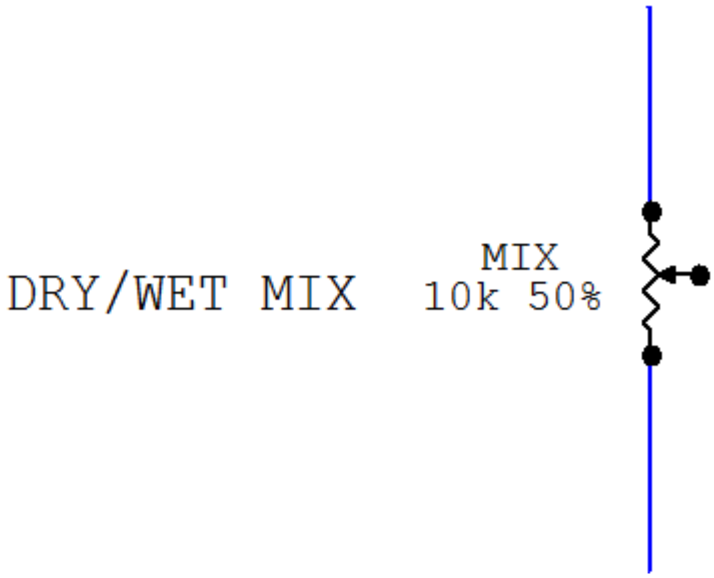
Tone Control Stage Analysis



Potentiometer Settings (Bode Analysis in dB)

White=99% (Bass Boost; Full Counter Clockwise Turn)
Orange=75%
Green= 50% (Knob at Unity)
Red= 25%
Blue= 1% (Treble Shelf Boost; Full Clockwise Turn)

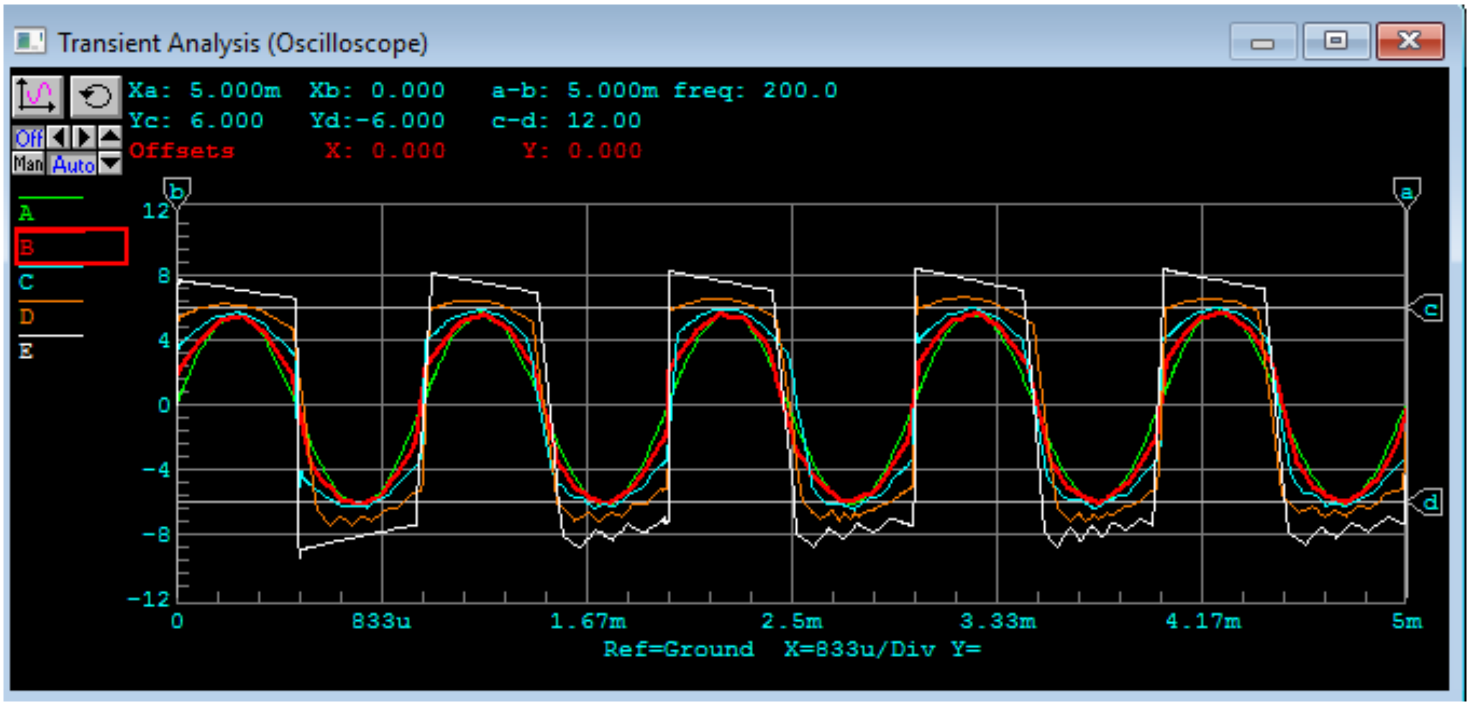
Dry/Wet Mix Stage Design



The Dry/Wet Mix design is as simple as it looks. It's simply a variable resistor that adjusts the ratio of dry signal (unaffected input signal; passes only through Baxandall 2-Band EQ and straight to Dry/Wet Mix) and the wet signal (passes through send, effects path, receive, and tone) blend at the output of the circuit. When the mix is turned completely down (lowest impedance), only the dry signal path is fed to the XLR Out stage. When the mix is turned all the way us (highest impedance), only the wet signal is sent to the XLR Output.

The Dry/Wet mix knob allows the user to simply control how much of the input effect he would like to feed into his output. This allows the user to achieve their desired output blend ratio by turning only one knob instead of many.

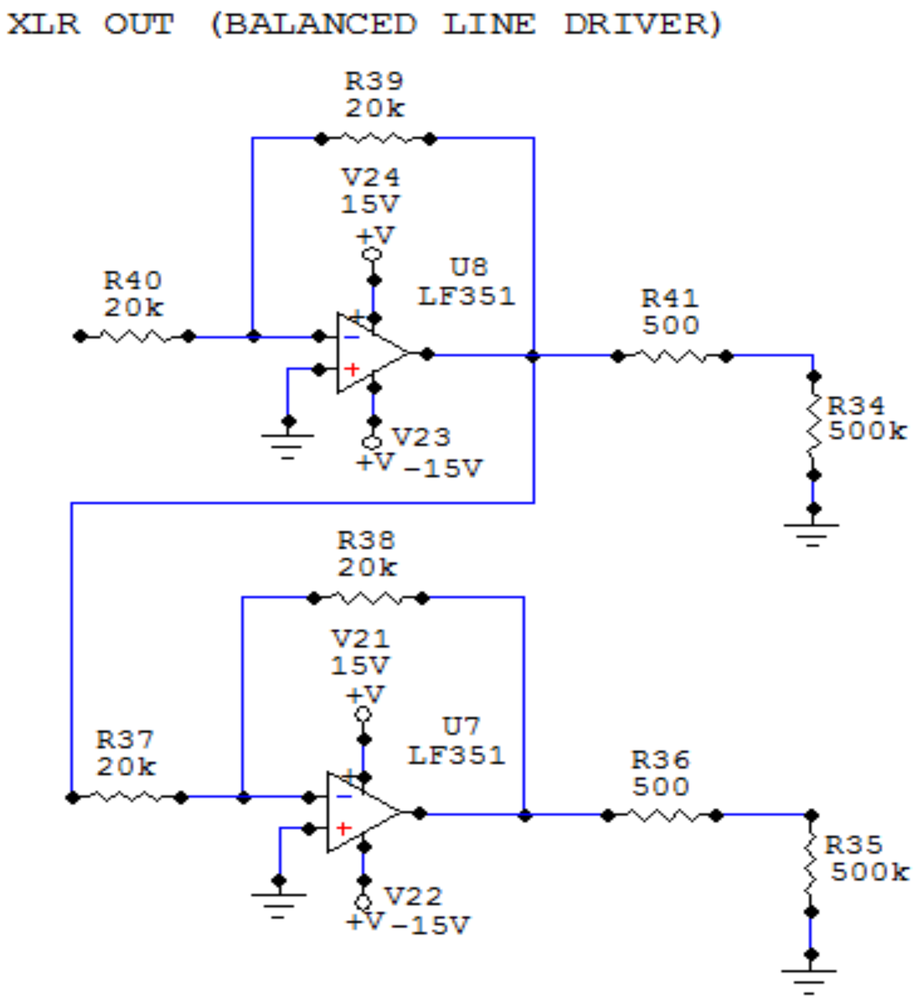
Dry/Wet Mix Stage Analysis



Potentiometer Settings (Transient Analysis in Volts)

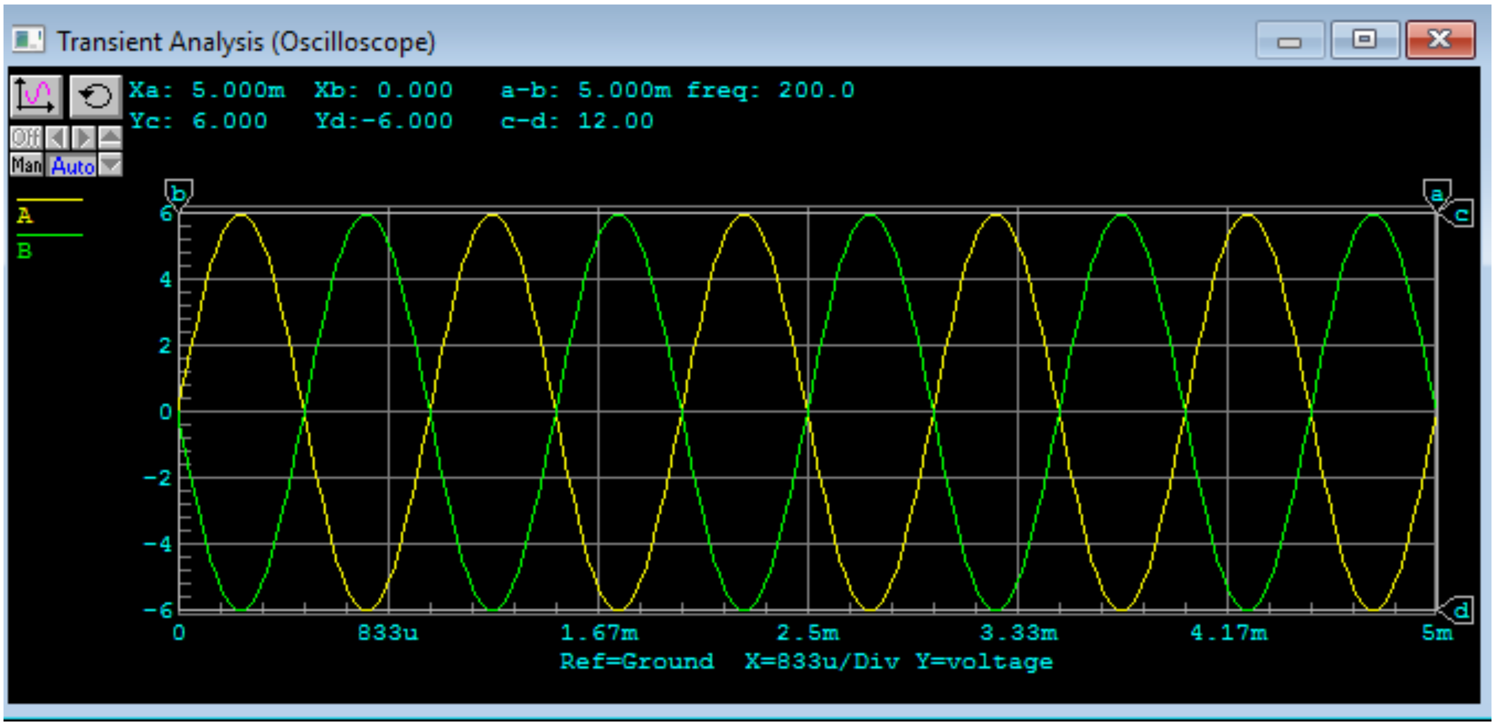
Green= 1% DRY
Red= 25%
Cyan= 50% Even Mix
Orange= 75%
White= 99% WET

XLR Line Out Stage Design



The last sub circuit in the signal path a balanced line driver that's used to convert the signal from unbalanced to balanced. While passing through the first OpAmp in the balanced line driver, the signal is inverted 180% and sent to the cold lead (top output), while half of the signal passes on to the second OpAmp to be inverted once more and sent to the "Hot" lead (in phase). Both inverting OpAmps operate at Unity (meaning Rf=Ri ratio) as to only invert phase and not boost or cut the signal.

XLR Line Out Stage Analysis



Potentiometer Settings (Transient Analysis in Volts)

Green= Cold Output Lead: 180-Degree Phase Shift

Yellow= Hot Output Lead: In Phase

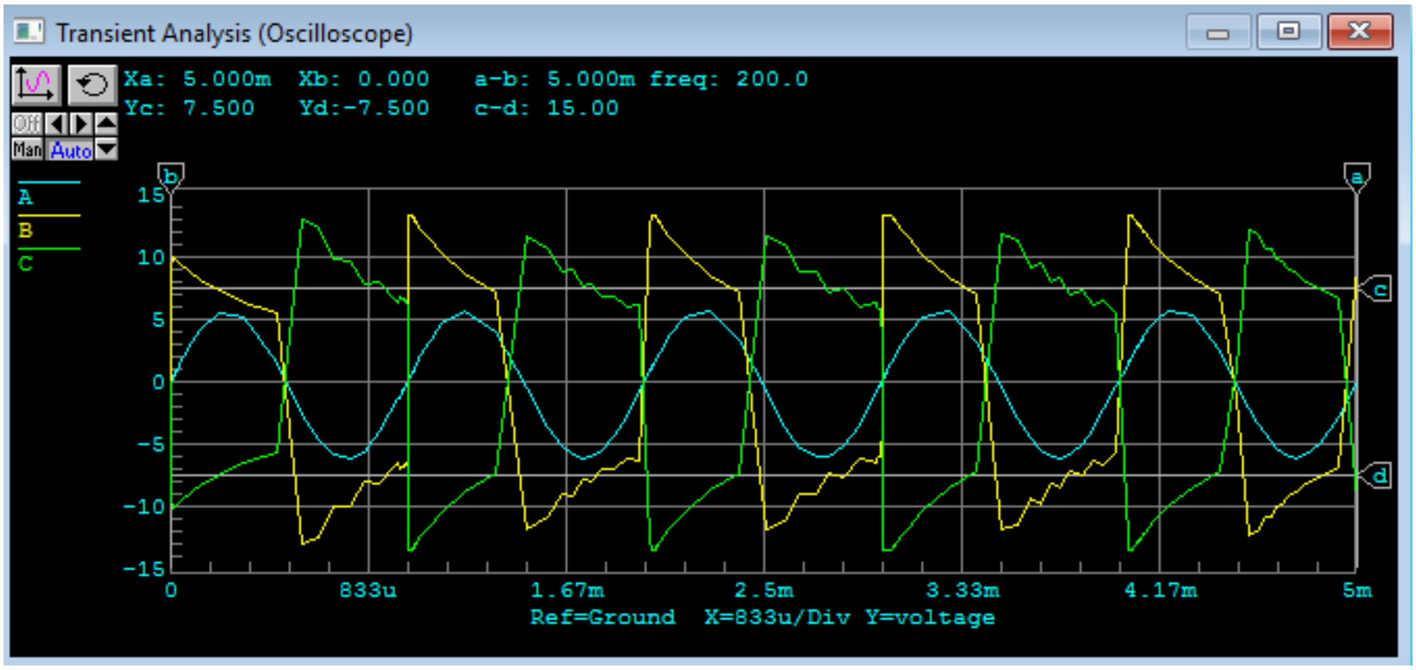
Full Circuit Design Summary

Now that we've covered all of the sub circuits, its important to understand how they all connect and function together to form the "Voco-Loco" Mic PreAmp and Effects Loop. From an operational standpoint, you may have noticed the seemingly random 1μF capacitors placed between each sub circuit. These capacitors are called coupling capacitors, and are used to block DC voltage from bleeding between sub circuits, keeping the signal clean and unbiased.

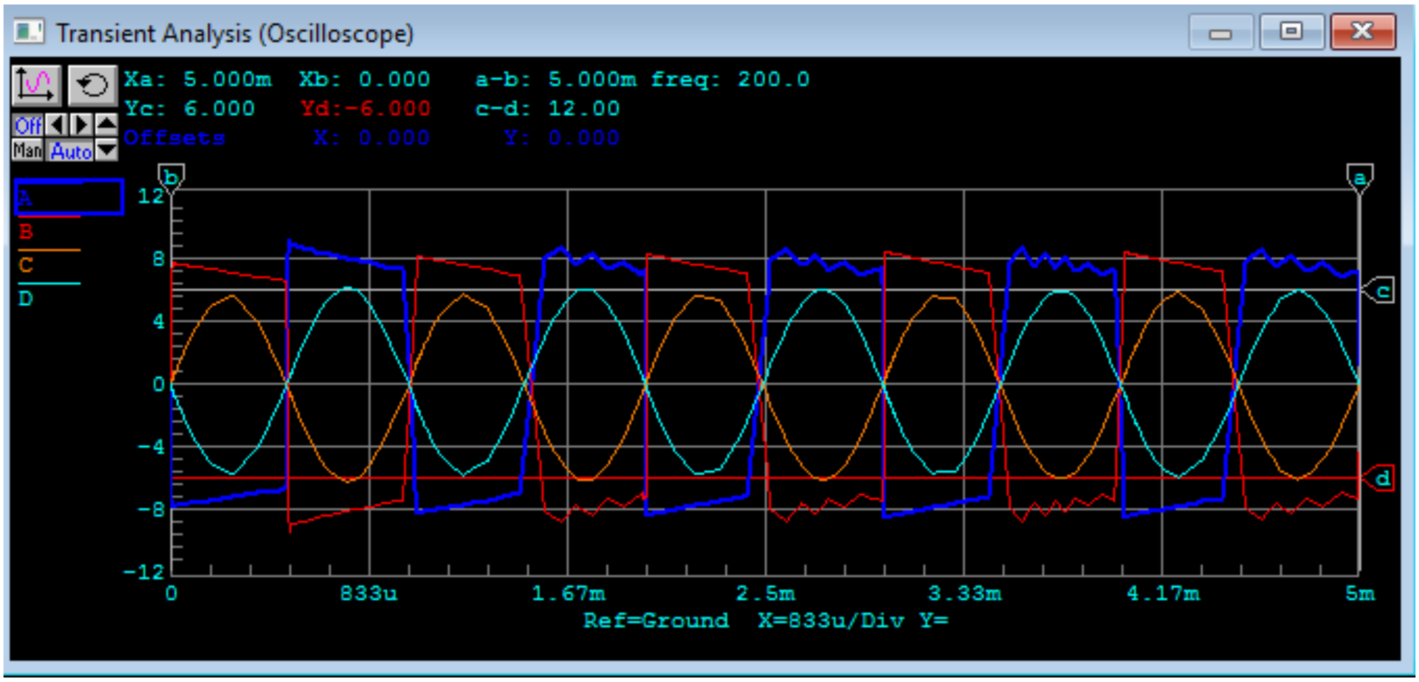
I would also the like to point out the inverting negative feedback opamp placed in the dry signal path just before the dry/wet mix knob. This opamp was placed in order to correct a previously occurring phase issue that was causing phase cancellation and massive signal attenuation when the dry/wet mix level was set to 50%. In designing this circuit, I discovered the importance of troubleshooting a circuit chronologically (in reference to signal flow path) in order to discover the root of issues and to confirm results. Tracing the signal flow path for voltage consistency and confirming results of calculated values against the analysis proved invaluable to the success of this design.

As final analyses, I ran an output simulation of the Mic PreAmp output voltage against a 50/50 dry and wet mix output voltage with distortion (note: distortion does not contain variable makeup gain, resulting in a slightly higher wet output). Last, a full circuit simulation has been conducted showing the balanced line out signal at the hot and cold leads at both extremes of the dry/wet mix against one another (distortion is added to the wet signal).

Full Circuit Design Analysis



Analysis Across Full Circuit (Transient Analysis in Volts)
Cyan: Signal Measure at Mic PreAmp Output
Yellow: 50/50 Mixed Dry/Wet Control with Distorion and Tone Manipulation (Hot)
Green: 50/50 Mixed Dry/Wet Control with Distorion and Tone Manipulation (Cold)



Balanced Output Comparison: Wet Vs. Dry (Transient Analysis in Volts)
Blue: Wet & Cold Lead Distortion
Red: Wet & Hot Lead Distortion
Cyan: Dry & Cold Lead
Orange: Dry & Hot Lead

Future Design Improvements & Ideas

- Variable makeup gain after Effects Stage

- Replace/correct Tone Control Stage: high shelving filter works at max boost, but bass shelving response and unity setting response need correction

- Add on circuitry for stomp switches