The 1967/68 Gretsch Jet Firebird and Rally “Sonic Boom” Treble boost amplifier. **Dr. H. Holden Sept. 2015.**

The photo below shows my 1968 Gretsch Jet Firebird that has recently undergone some repairs with the plastic binding replaced.

The photo below shows my Gretsch Rally. Both these guitars had the “Sonic Boom” treble boost amplifier.

The issue arose about the original treble boost amplifier used in these guitars.

Gretsch introduced what they called a “Sonic Boom” treble boost amplifier to this guitar and to the Rally models in the 1967/68 era. Many of these electronic modules have been discarded. Sometimes the germanium transistor becomes noisy, but not always. In two original modules I have currently they are both still perfect with very low noise.

It could well be argued that the battery powered treble boost amplifier placed inside an electric guitar in the 1960's era was the world's first example of "active on board electronic special effects" to be applied to the electric guitar.

Why Have a Treble Boost Amplifier?

The treble boost amplifier has a rising high frequency response. What this means is that its output level increases in *amplitude* as the *frequency* of the input signal increases. This emphasizes high frequency notes while attenuating lower frequency notes.

The overall effect of this type of combined "filtering and amplification" gives the guitar a clear clean cutting bright bell like sound (especially good for guitar solos) and reducing the lower tones and "muddy" sounds from the lower frequency (lower note) strings.

For any note played, it is not just the note or fundamental frequency of that note itself that is generated by the resonating guitar string. There are higher frequency harmonics along with the note that give the characteristic "tone" of the instrument. As result of the "active treble boost effect" these harmonics are amplified, changing the whole tone of the guitar.

World famous electric guitarists such as Eric Clapton, and Marc Bolan (T-Rex) and others used treble boost amplifiers such as the Rangemaster in the mid 1960's. The Rangemaster is essentially a very similar circuit to the module used inside the Gretsch guitar. This gave them a sort of "Secret Weapon" and a characteristic sound on their recordings. There is quite a bit of information on this historic topic on the internet.

In addition there are other possible sound effects added by the treble boost amplifier. Due to the additional signal level output of the treble boost amplifier it is more readily able to drive the guitar amplifier itself to clipping or distortion, especially for higher notes, thereby altering the tone.

Also, depending on the particular guitar and the signal voltage level from its pickups, the transistor in the treble boost amplifier can be driven into clipping itself, meaning the transistor's peak to peak voltage swing on the transistor's collector (output) exceeds the battery's supply voltage and the signal peaks become flattened off or rounded off altering the harmonic content of the sound. This event happens when the peak input voltage to the treble boost module from the pickups is over about 700mV.

It has been said that the germanium transistor introduces some characteristic distortion in this clipping mode compared to a silicon transistors. So some latter day manufacturers of Fuzz boxes or pedals use germanium transistors for this reason where the transistors are deliberately biased to operate in clipping mode.

However, most of the time, the transistor in this treble boost amplifier application is operating in a fairly linear mode and it is the high frequency boost effect that dominates and gives the characteristic tone or sound, not added distortion from the boost module itself.

I have discovered some very interesting information which contradicts remarks made on some discussions forums about the original Gretsch treble boost amplifiers and about treble boost amplifiers in general:

Firstly, despite some negative remarks that the Gretsch treble boost unit didn't work well, I have found that it works spectacularly well. The reason for this is that Gretsch provided a higher spectral range treble boost for their module (compared to the Rangemaster) but then used an output control system to downshift the spectrum of the treble boost. This gave the user a large range of boost control from the guitar. The Rangemaster's output control was merely a level control with little effect on the frequency spectrum of the boost. I think some people must have had faulty Gretsch boost units to have judged them so harshly.

Secondly, some remarks that germanium transistors were always noisy in this application are not in fact correct. Gretsch used low noise transistors I have discovered. The Rangemaster on the other hand used transistors like the OC44 (actually intended for AM radio use as the local oscillator) and the OC72(intended for audio output stage use in transistor radios) These are a little noisy in low level audio applications when the signal if fed on to a high gain amplifier, like a guitar amplifier.

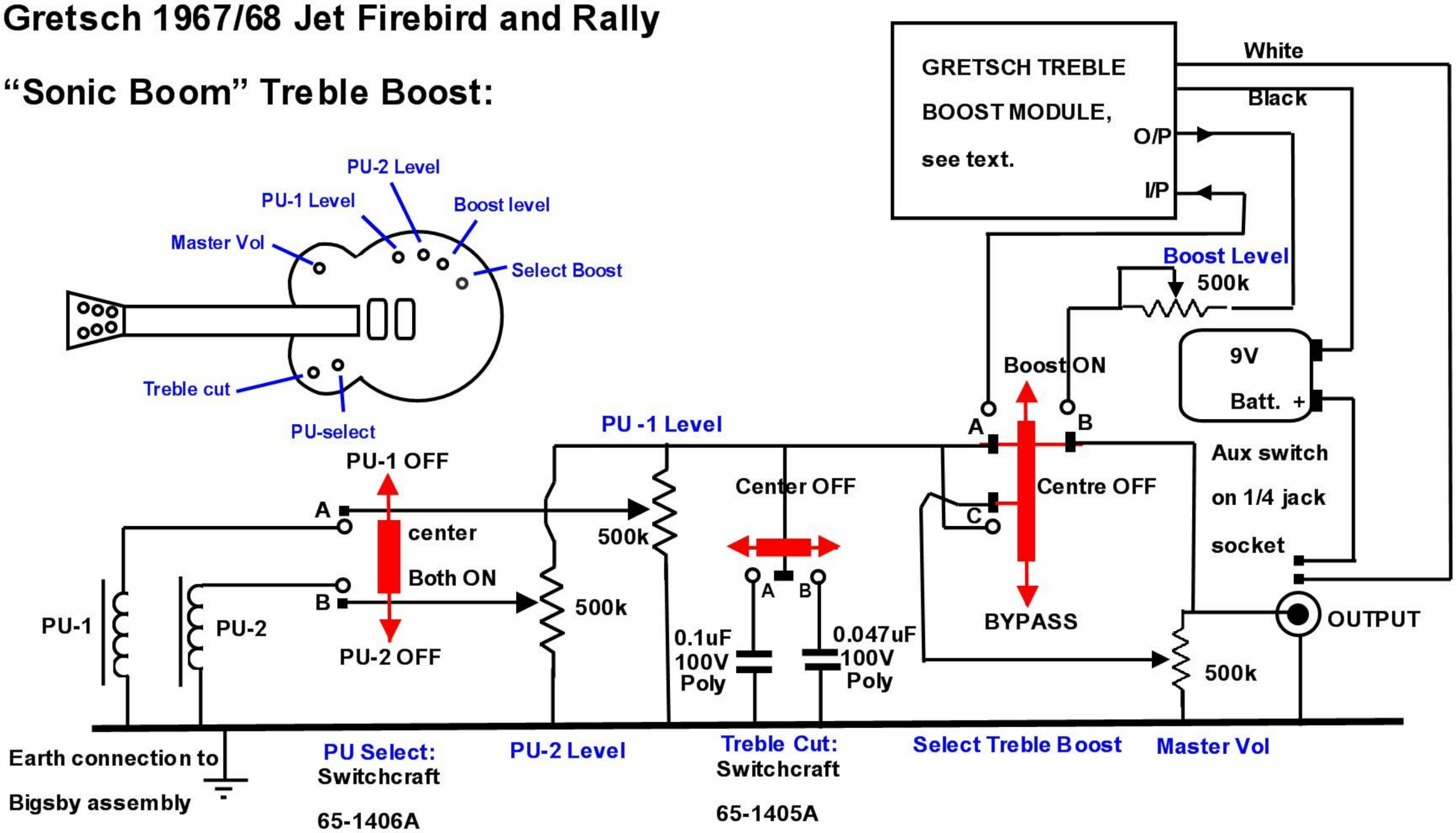
The ideal germanium transistor of the 1960's era from England & Europe, was the low noise AC107. It should probably have been the transistor used the Rangemaster. Perhaps it was the expense of this transistor at the time that prevented the designers from using it. So germanium transistors got a bad reputation unfairly perhaps on the noise issue. However one cannot deny that silicon transistors that followed in the decades later have lower noise than even the best germanium device.

Gretsch Rally Schematic:

The schematic diagram below shows the basic wiring diagram transcribed from a 1967 Gretsch Rally wiring harness which uses the same Sonic Boom Treble boost amplifier.

Gretsch 1967/68 Jet Firebird and Rally

"Sonic Boom" Treble Boost:



All switch, potentiometer and pickup connections done with coaxial cable, braid connected to the pickup bodies, the potentiometer and switch bodies. The Coax earth from the module to the input connection near switch contact "A" is not connected, but the coax earth from this input coax is connected at module end to the modules positive battery connection. The Module gains its earth connection with the coax shield on the output connection from the module to the 500k boost potentiomer body and then from the coax braid from there to the select switch body which is connected to all the other coax earths/braids.

Function of switches:

The pickup select switch switches off either one pickup or the other. In the center position both pickups are connected. The Treble Cut switch can select two filter capacitors (these roll off or cut the high frequency response). In the centre position neither capacitor is selected.

(note: the physical positions of the PU select switch and the treble cut switch might be reversed in some guitars)

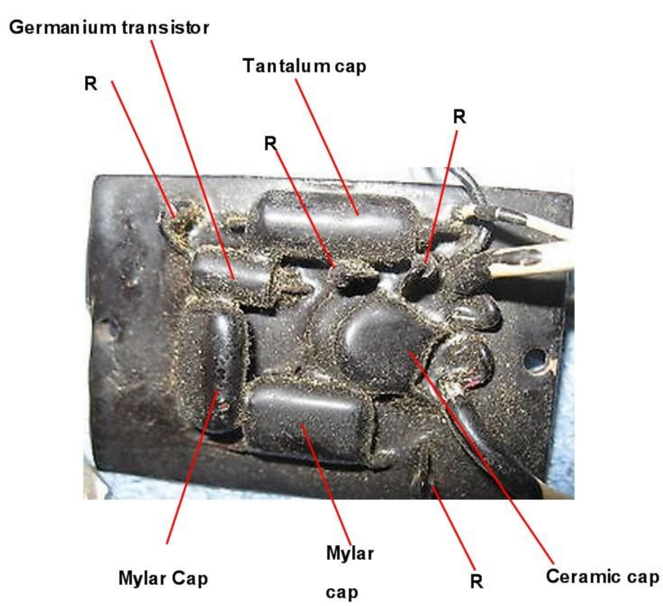
TheTreble boost select switch is off in the the center postion (none of the contact pairs A, B or C are connected and there is no output from the guitar). When the switch is in the bypass mode contact C is closed (contacts A and B open) and the mixed signal from the two pickup level controls is passed to the center leg(slider) of the master volume control and the guitar output taken from the master volume contol's top leg. (Normally a master volume control would not be wired like this and the output would be derived from the slider, not the top leg) Gretsch appears to have wired it this way so that when the Treble Boost is selected, the master volume control is effectively disabled and the contol of both the high frequency boost *and* the output level together to *some extent* is taken over by the series boost control(see below).

In the treble boost mode contact C is open and contact A & B are closed. This feeds the mixed pickup signals into the input of the Treble Boost amplifier module.The output of the module passes via the boost level control and is routed directly to the guitar's output socket. The resistance of the volume control pot shunts this to ground forming a voltage divider with the boost level control.

The consequence of this connection is interesting. Since the the cable leading from the guitar to the guitar amplifer has significant electrical capacitance (about 500pF to 700pF) the 500k series boost control not only affects the overall output level as it feeds into a shunt resistance(the volume control and resistance at the guitar amps input) it also forms a high cut or treble cut filter, opposite to the effect of the treble boost module. The larger the resistance of the boost control, the more treble cut, opposing the action of the treble boost amplifier itself. This gives the player a way of controlling the overall boost result or tone balance.

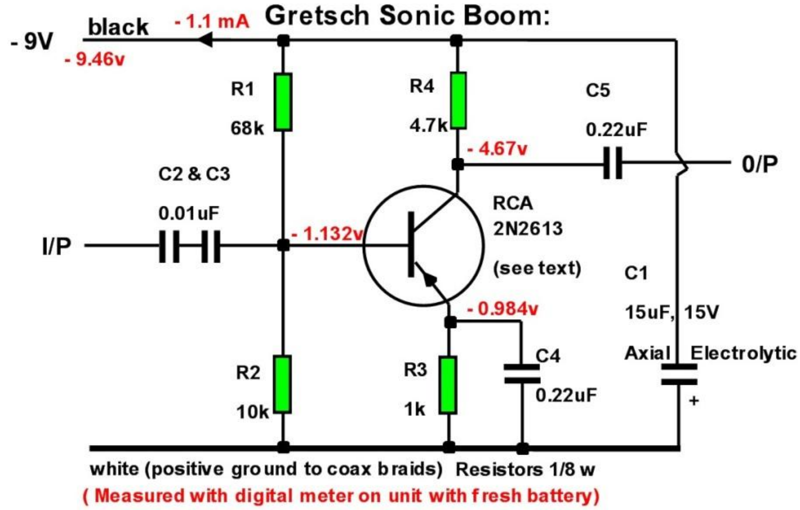
On top of this, as explained later below, the settings of the two pickup controls alter the source resistance of the signal feeding the treble boost amplifier's input.This also to some extent alters the tone too.

The original Sonic Boom module:

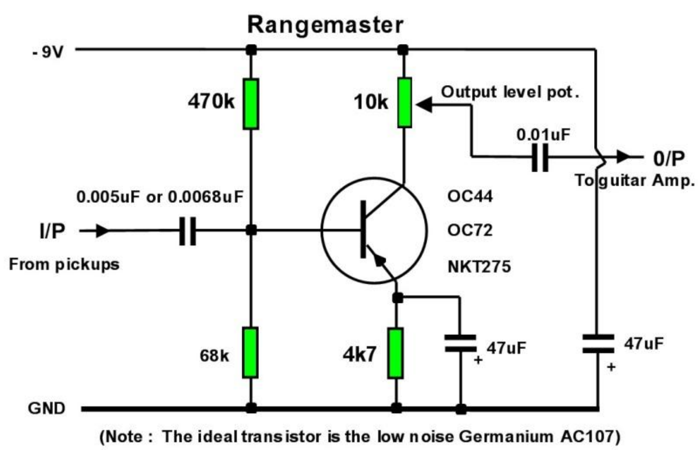


After this module was received it was found that there were in fact two ceramic capacitors, the other one can be seen through the black resin hiding under the one on top of it. Also the axial capacitor turned out to be an Italian made Ducati 15uF 15V, not a Tantalum, but Tantalum is better as it has lower leakage.

The circuit was transcribed from this board. It was possible to gain connections to the pcb side and test the components without damaging it. It is a single transistor amplifier stage with component values chosen for a high pass filter effect, similar to a Rangemaster:



Comparison with Rangemaster:



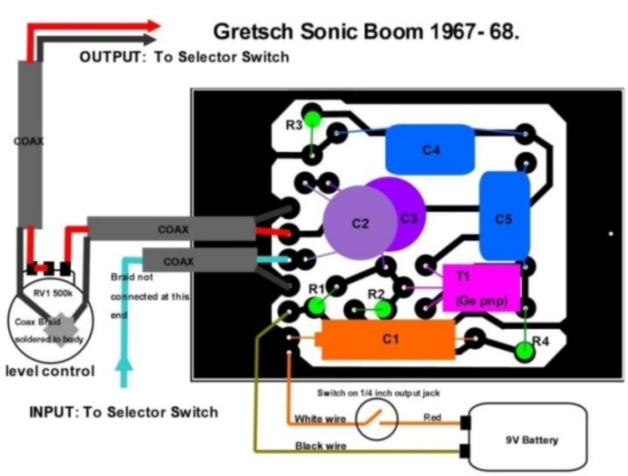
Referring to both circuits above, primarily it is the low value of the input coupling capacitance (total = 0.005uF) which creates the high pass (or low cut) filter effect in conjunction with the low input resistance at the transistor base, which is in the order of 1000 Ohms, much lower than the base bias resistor values. However the value of the 0.22uF emitter resistor bypass capacitor also contributes to the high frequency boost response in the Gretsch circuit because it has a high impedance in the low audio register, much higher than the 1k emitter resistor it bypasses. On the other hand the larger value of 47uF emitter resistior bypass capacitor in the Rangemaster does not affect the overall frequency response because the capacitor has a very low impedance, compared to the 4k7 emitter resistor, at all audio frequencies.

Some DC test voltages are shown in red with respect to ground on the Gretsch module. Being a pnp transistor it is a positive ground circuit.

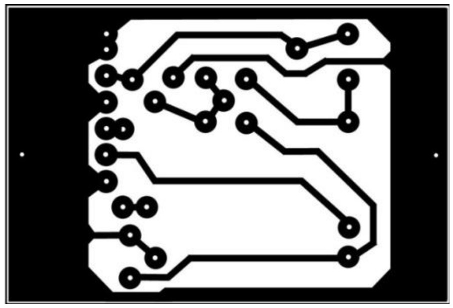
Gretsch used two series 0.01uF ceramic input capacitors (both capacitors measure close to 0.01uF although one could be a 0.0082uF and the other a 0.012uF, the net value of the series combination is 0.005uF) I'm not sure why they did this, perhaps they planned to alter one or both to "tune" the system to their liking, or perhaps different values if the module was used in different guitars, or perhaps they linked one out in some models to down-shift the range of frequencies boosted.

So Gretsch's circuit (unlike the Rangemaster) has two high pass filter elements; one a "passive filter" formed by the low value of input coupling capacitance (0.005uF) and transtor's input resistance and the other an "active filter" affecting the gain of the transistor stage at different frequencies, formed by the 0.22uF capacitor and 1k resistor in the transistor's emitter circuit. On top of this the output boost control in conjunction with the cable capacitance (leading from the guitar to the main amplifier) creates a high cut filter opposing the treble boost.

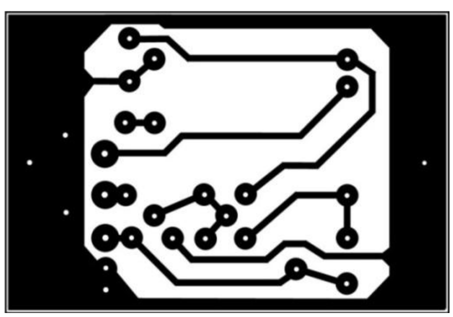
Returning to the original module, it was possible to find the pcb track connections by testing the leads projecting from the bottom pcb surface. A replica pcb was made.The track layout may not be exactly identical but it is very close. The image below shows a view looking through the top:



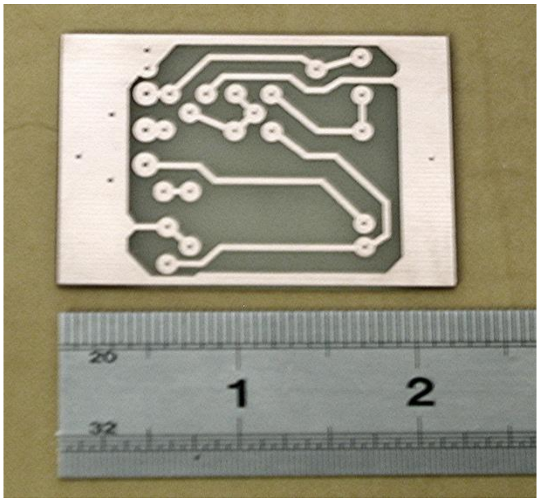
The pcb itself is 1.5 inch by 2.25 inch in size. The diagrams below also show the pcb track arrangement, bottom or track side view:

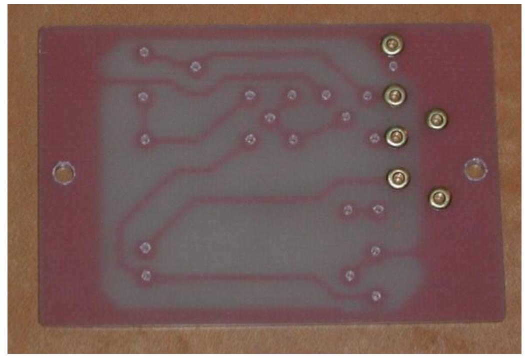


The image below shows the pcb as viewed from the top again and after a modification to space its connections a little wider apart. The original connections were a little crowded and spacing them a little allowed some small eyelets to be used on the replica pcb to make the wire connections a bit more solid and help protect the pcb track.



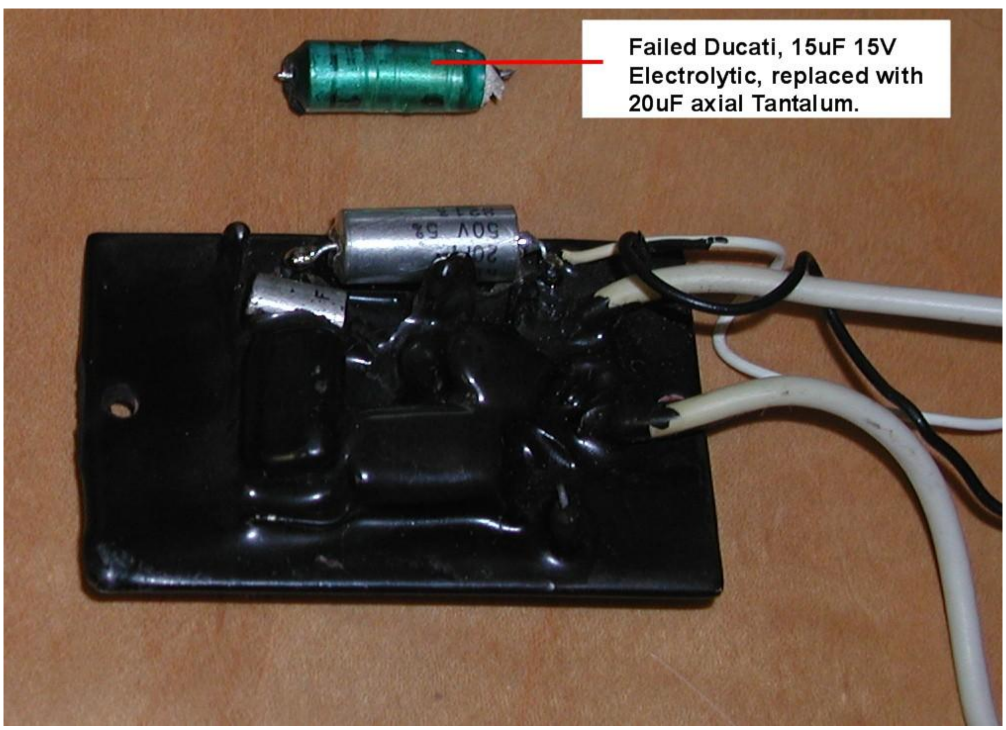
A replica pcb was made by printing the above images to iron on pcb film and then etching with ferric chloride. As noted small (1.6mm diameter) brass eyelets were fitted where the wires connect to make a stonger connection.





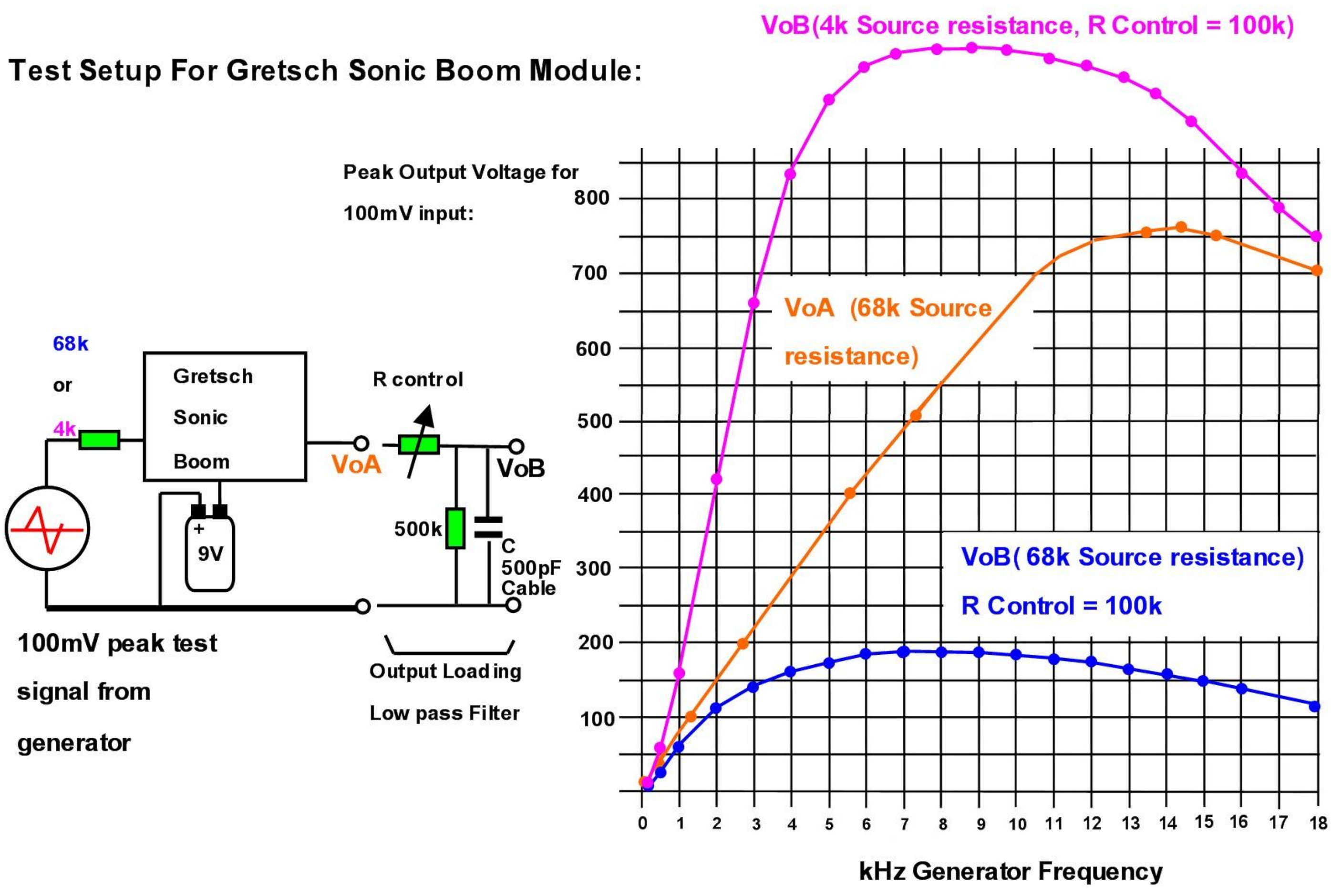
The unit was then assembled with closely matching components to the original module, tested and verified to work identically to the original module:

One of my original modules had a failed electrolytic capacitor, which had burst open leaking out its electrolyte. It was removed from the black resin and found to be a 15uF, 15V value, even though the capacitor tested in my other module measured about 20uF. Since this is the battery bypass capacitor which simply helps mask over a noisy battery connection its value is not very critical and any value of 10 to 25uF is fine. The original capacitor surprisingly was a Ducati brand which is Italian. It was replaced by cutting off its lead wires and soldering another capacitor in place. The black resin is very hard so it is difficult to un-solder the circuit board terminal side. A thin coat of resin was removed from the transistor which is a RCA "2N" type with the numbers after the 2N not visible (see below).



Bench testing the Gretsch module to verify its function:

A test was performed on the module using a 100mV audio test signal (this is well below the signal level that can drive the module's transistor into clipping) and a series resistor of 68k, to represent a situation where the pickup level controls were not quite at 100%. Then the frequency response swept and recording the level from the output VoA of the module) *prior* to the boost level control. This is shown on the orange graph below:



Under this test circumstance (orange graph) the boost unit acts like an attenuator for frequencies under 1000Hz and an amplifier with a gain of about +6 dB per octave with an input frequency above that. The attenuation is fairly heavy at around 100Hz. For example an open low E string is 82Hz.

The output boost level control in conjunction with the cable capacitance has a huge effect, shown on the blue graph. The boost level control (R control) causes ***high frequency cut*** as shown from the blue graph of the signal voltage at VoB as the frequencies increase, even with the boost control's setting equivalent to about 100k of its total 500k range. The output at VoB is the signal presented to the guitar amplifier input. As the boost level control is rotated to a higher resistance the graph is even flatter significantly opposing the effects of the treble boost amplifier. The boost control affects both the average volume to an extent and the high frequency boost at the same time.

In addition, the source resistance from the pickups and pickup level controls have an effect on the boost performance. If, for example, the source resistance is lower, such as 4k, even with the boost control value still being 100k and not at a minimum resistance (maximum boost) value, there is substantial high frequency boost as the overall signal level is generally increased for rising frequencies resulting in the steep slope as shown on the pink graph.

So it is obvious with this Gretsch Sonic Boom system that the maximum high frequency boost is obtained when:

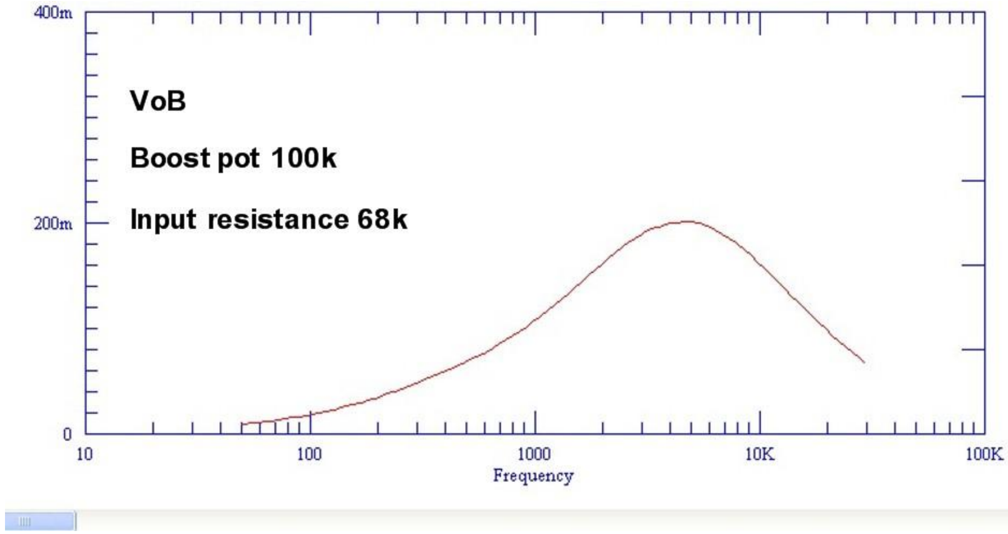
1) The pickup level controls are at full volume.

2) The boost level control is set to full (low resistance end of control range).

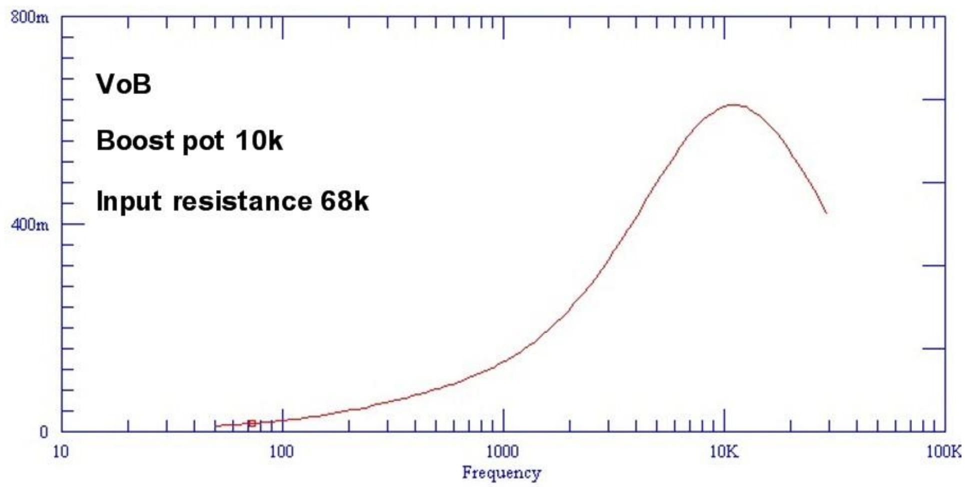
However, since the guitar's master volume control is bypassed in treble boost mode, then the only way to control the overall level, from the guitar, is with the pickup level controls. If the boost control is rotated for lower boost, which also reduces the average volume, the pickup level control/s can be adjusted upward for more average volume to compensate. So there is a balance of factors the guitarist can choose to get the tone and volume right for them in the treble boost mode.

Since the circuit is very simple it is easy to run in a Spice simulation on the Getsch unit, to plot the output voltage VoB. This was done with a simulated with a test 100mV signal swept across a wide frequency range and a 700pF simulated cable capacity. Again, with different values for the input resistance in series with the pickups and for different values of the boost control when looking at the output VoB: (These graphs have output voltage on the Y axis).

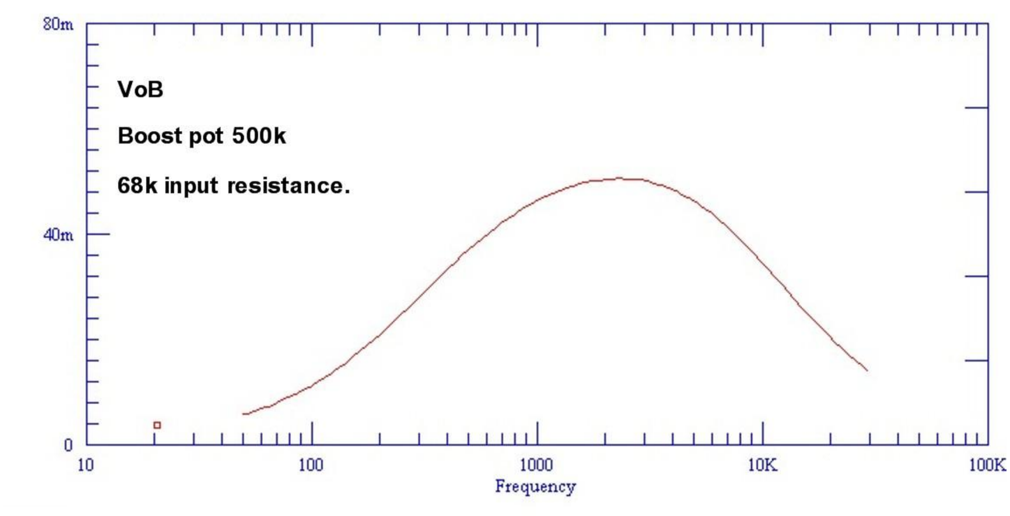
The trace below shows how the output peaks up to about 200mV at around 5kHz when the 500k boost pot is about 100k resistance and the input resistance (the effective series resistance to the pickups from the pickup level controls) is about 68k:



As can be seen below when the boost pot resistance is lowered to 10k the gain of the gain peaks upwards to 700mV output (for 100mV input), so the gain peaks with this scenario at a factor of 7 and the peak shift up to 10kHz. So the Gretsch boost control pot affects both the frequency peak and the overall gain (unlike a Rangemaster where just the gain is altered):

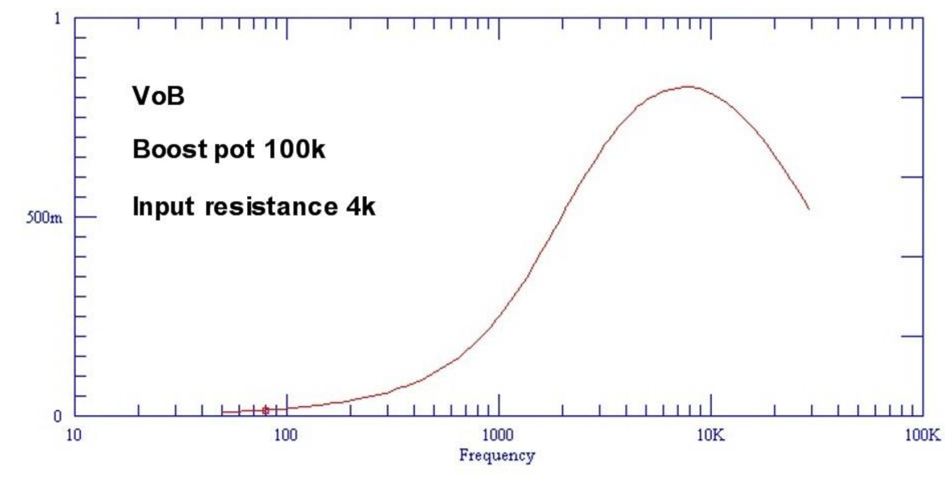


Increasing the boost pot resistance to its max value of 500k drastically lowers the gain and down shifts the overall frequency response:

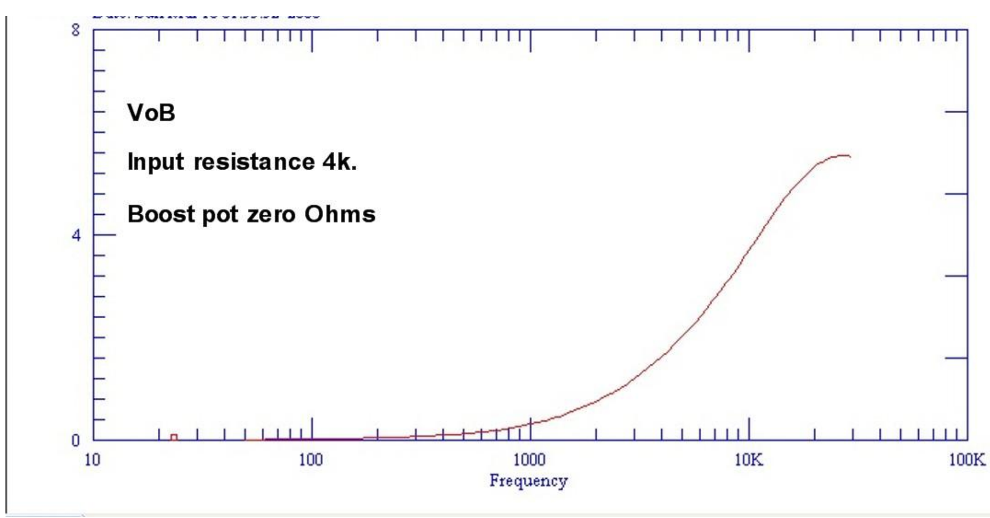


As can be seen from the above this setting of the maximum 500k for the boost control rolls off the very high frequencies and lowers the output level to a peak of only around 50mV or half the level of the input signal to the module, when that signal is sourced from around 68k, ie the pickup volume controls not quite at maximum. Also the frequency range of the response is down shifted.

On the other hand when the pickup volume controls are set to maximum and the source resistance of the signal presented to the boost module is only around 4k (roughly the pickup resistance) the response peaks up again:



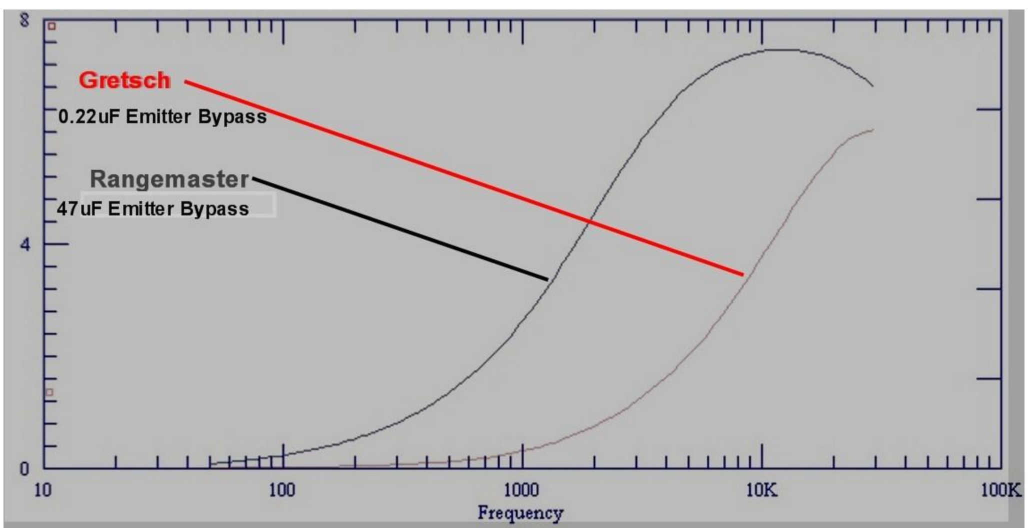
If everything is set to maximum, with the pickup controls at maximum and the boost level at maximum (minimum pot resistance) the following occurs. This up-shifted frequency response gives the Rally guitar an amazingly sharp cutting sound:



So, in summary, it can be seen from the above when using the Gretsch treble boost module, that combinations of the pickup level controls and the boost level control affect not only the overall gain but the frequency range over which the boost operates. Lowering the pickup volume controls and increasing the value of the boost control resistance both lowers the gain via the module system and down shifts the frequency range over which the module boosts the signal. On the other hand when the pickup volume controls are set for maximum volume (minium resistance) and the boost control is set for maximum boost (minimum resistance) then the gain via the module is very high and the frequency range it boosts over is up shifted too and rises significantly over the 1kHz to 10kHz range.

Gretsch's Module Compared to the Rangemaster:

One final simulation for a comparison shows what happens, again in this case with the boost control at maximum (min resistance) and the pickup controls at maximum (min resistance). In this case the module output drives the guitar's cable capacitance directly with negligible series resistance. Also the Rangemaster unit output drives a similar cable to the main amplifier. However manipulation of the Gretsch boost control will down shift the boost to a similar range to the Rangemaster making the Gretsch system more versatile.



As can be seen due to the large value of emitter bypass capacitor (47uF) in the Rangemaster the frequency spectrum over which it boosts the signal is lower than the Gretsch module all other things equal. Since all of a guitar's fundamental notes lie in the range of 82Hz (low E string) to about 1.3kHz (24^{th} fret high E string on a 24 fret guitar example), the Gretsch module amplifies more of the high frequency harmonics proportionally than the Rangemaster which is interesting. This gives the Gretsch a brighter sound with more attenuation of the lower frequencies, especially with the pickup volume controls and boost controls at full.

Gretsch's module might not have been aptly named "Sonic Boom" the **boom** implies some bass or low notes but the module is particularly good as attenuating low notes. It might have been better called "Sonic Ring" or "Sonic Bright" or "Sonic Clean" or "Sonic Blast" or, something like that maybe, with some risk it might sound like a laundry detergent.

What Transistor was originally used in this Gretsch module ?

The original transistor type is largely obscured by the black resin. However transistor noise was a big consideration since the transistor is dealing with low level signals right at the input of a high gain guitar amplifier.

The original transistor is American, and has a visible RCA logo and a 2N prefix. The logical and really only RCA part the designers would have available suited to this task in 1967 would have been the 2N2613, a low noise RCA type in the TO-1 case. This was cited as a current part in the 1966 RCA transistor manual and in fact it was the *only* common pnp **low noise** audio transistor of its type in the TO-1 case at that time made by RCA. So it is almost an inescapable conclusion that the 2N2613 is the original transistor. Tests confirm it has a very low noise level consistent with being one of these transistors. On the other hand Gretsch might have used a common garden device like a 2N217 and just selected them for low noise, though I think this is less likely.

In the European camp the low noise germanium transistor of choice was the AC107. This is a glass cased transistor painted black. However the AC107N is a TO-1 metal case version. It would make a good device for the application and as noted would have been the ideal choice for the Rangemaster in my opinion, but Rangemaster selected slightly more noisy transistors such as the OC44, OC72, however these had low gain so perhaps the noise was not too noticeable.

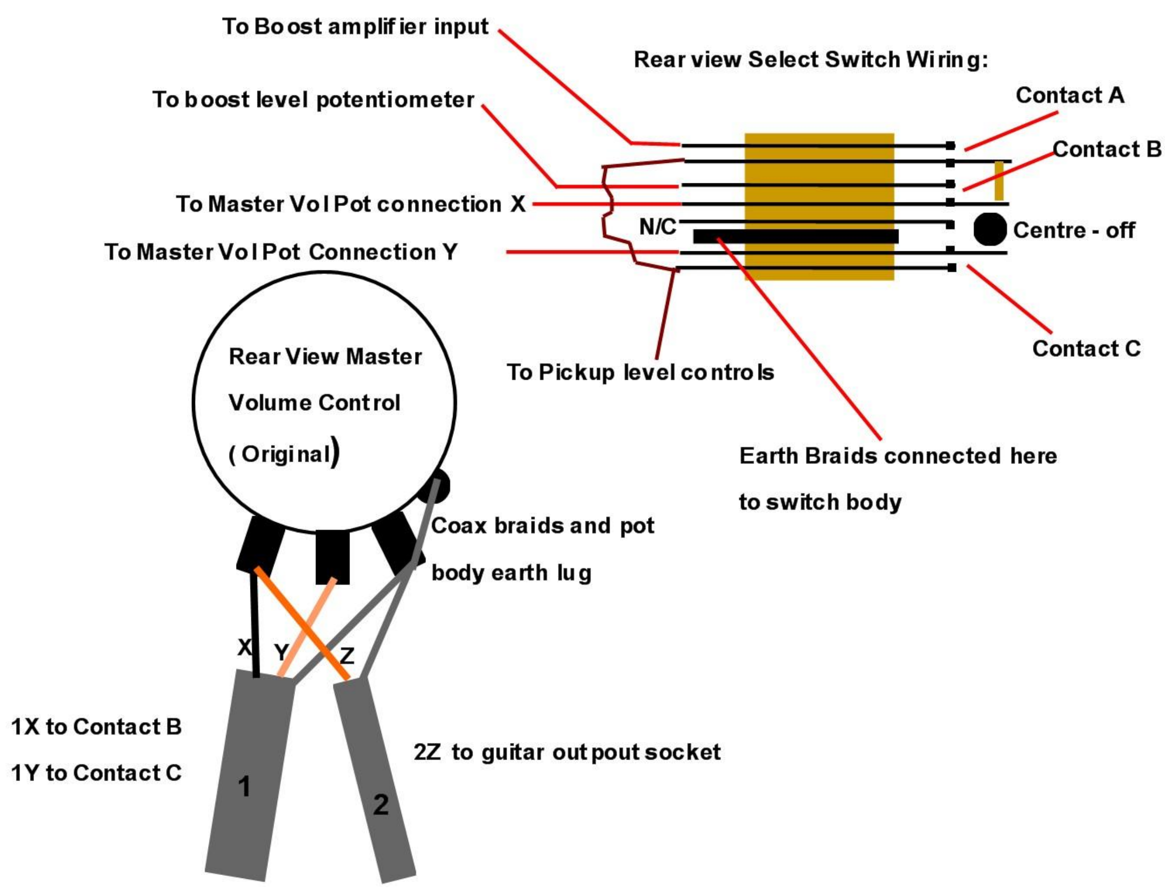
Better Volume Control: (added Oct 2015)

After tracing out the wiring from a Gretsch Rally harness I was surprised at the way they had configured the treble boost system to disable the master volume control when the boost was selected. Could it be that this was not original ? I received a second wiring harness and they are both identical. This system I think is a bit inconvenient as it is still better to have the master volume control operating normally at all times, even with the treble boost selected. And when it is operational there is much better control over the guitar's output level without having to adjust the individual pickup level controls or walk over to the main guitar amps volume control.

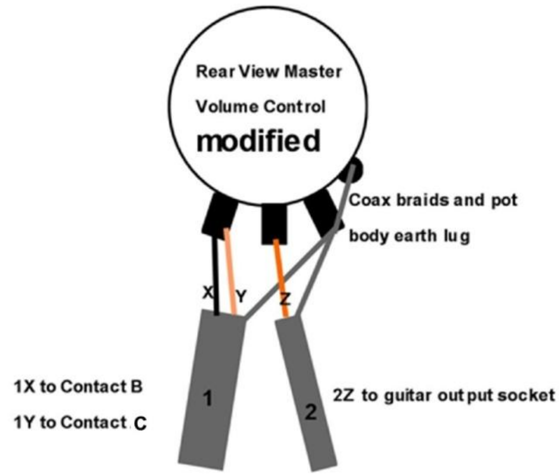
So the wiring was changed to allow this and it gives a superior result actually playing/using the guitar with the treble boost selected. I would recommend that all Rally guitars with the sonic boom are modified this way. It is only a matter of changing the connections on the volume potentiometer.

For clarity firstly the original master volume potentiometer wiring and also the details of the rear view of the *treble boost select switch* (this does not need alteration, just the volume control connections):

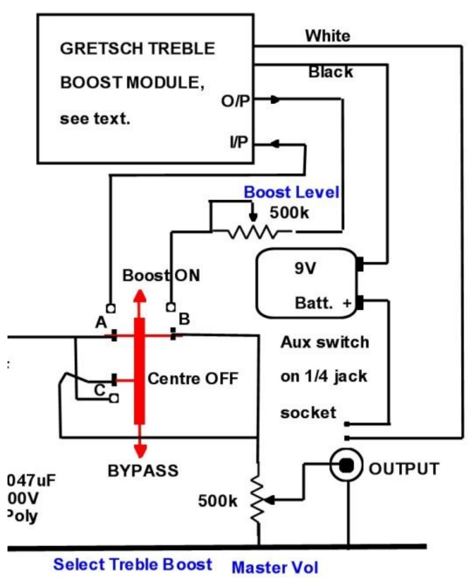
Original Wiring of Gretsch Rally Master volume Control and Treble Boost Select Switch:



Modified Master Volume Gretsch Rally: to allow Master Volume Control to operate in Treble Boost Mode.



This results in the modified partial schematic:



Which has the master volume control wired in a manner that one would expect. Another consequence of the original wiring is that a low volume setting, the resistance presented to the guitar amplifier’s input is high, allowing more stray noise pickup. The way shown immediately above is better in this respect too.