The Trinity Amps Amp Theory Guide

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Table of Contents

Version Control

Version	Date	Change
22.1	12Feb21	First issue

Guitar Amplifier Basics

Electric guitarists can be fairly criticized for their reluctance to change to new ideas and technologies; however, there is no doubt that a classic 1950's guitar and tube amplifier in good condition still sounds great in modern recordings. This is a testament to good design from the start. What has improved today is consistency, and the cost benefits of production line manufacturing. This is offset by the rarity of good guitar wood (it makes a huge difference, even on an electric guitar), increased labour costs for both guitars and amplification equipment, and the availability of good and consistent quality tubes.

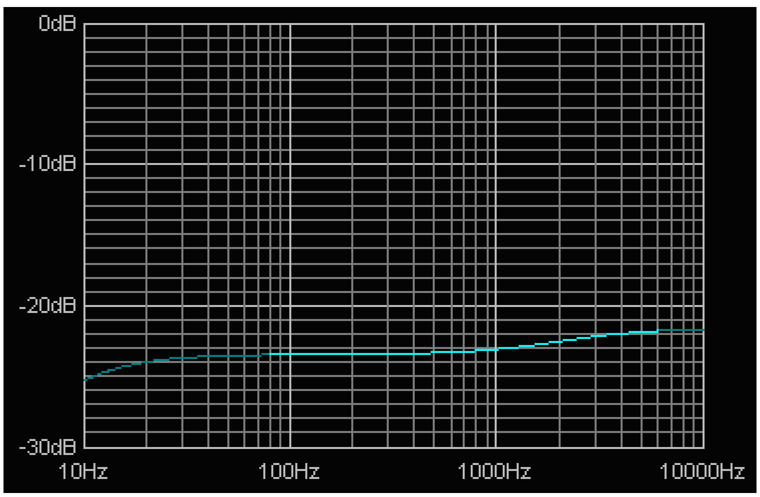
There is also an element of nostalgia, with memories of many of the great players of years gone by, and the desire to use the same types of instruments and equipment to recapture the magic. Vintage instruments and equipment have also become valuable collectors items (some with very inflated prices) which adds further to the desirability of older tools of the trade. There has been a recent trend by many companies to re-market their original instruments and equipment; new guitars can even be bought now 'pre-aged'!

This desire for vintage equipment is also related to guitarists' reluctance to part with tube amplification, and there are many reasons why tube and solid state amplifiers behave differently. Quite simply, if players prefer the sound of tubes, they will continue to buy and use them. Below are some fundamentals.

Input Impedance Typically 1M, 500K minimum (humbucking pickup guitars have volume pots up to 500K, single coil pickup guitars typically of 250K) .

Tone Controls Magnetic guitar pickups are inductive, and require compensation, although this opportunity is also used for tone enhancement, not just correction. Without compensation, they have a strong low middle emphasis and little high frequency response - overall a very muddy and muffled sound. This is why typical hi-fi Baxandall treble & bass controls are unsuitable.

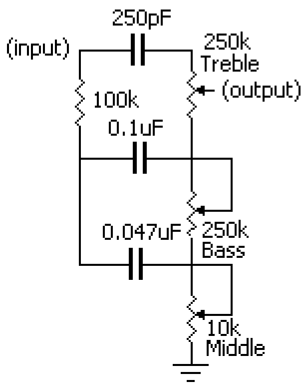
To hear the natural sound of a pickup, use a typical guitar amp with the middle set to full, and bass and treble on 0. This is actually sets a flat response in the amp (see below). Expect to hear a muffled and muddy sound. And that's the whole point of these tone controls providing compensation for the natural sound of a pickup - the middle control simply boosts the pickup's normal 'middley' sound. The treble and bass controls do the opposite - they boost higher and lower frequency levels, leaving a notch in-between for middle cut (see the Fender/Marshall comparison below). So with typical settings of a bit of bass, middle and treble, the overall tone equalization complements the natural pickup sound for a balanced response of lows, mids and highs.



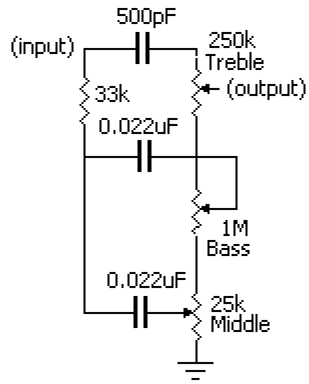
Full middle boost with no bass or treble actually gives a near-flat frequency response, allowing you to hear the natural sound of your pickups.

Fender and Marshall Tone controls

Here are circuit diagrams of typical Fender and Marshall tone controls. They both meet the criteria of compensating for pickups' low-middle emphasis, as well as providing a useful range of tone adjustment.



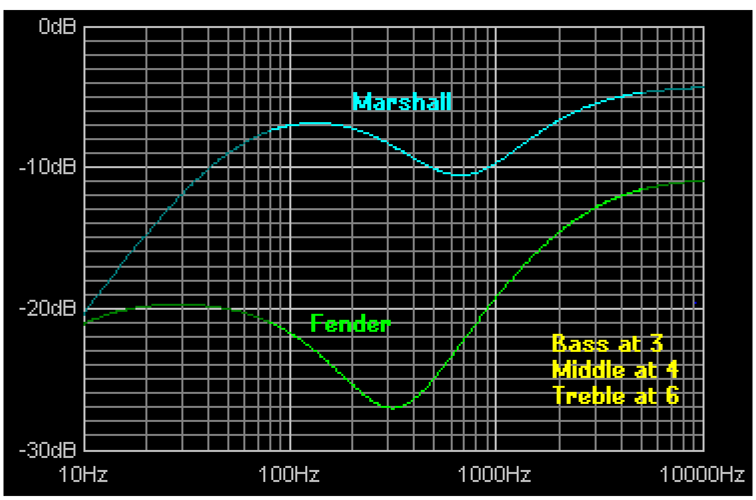
Fender Tone Controls



Marshall Tone Controls

The Fender and Marshall circuits are each tailored to suit their own styles, which are quite different. Although a generalization, Fender's market and consequently the power output stage are geared towards provided clean and chunky tones at clean and early-overdrive levels. Marshall amps are best at low-middley and crunchy rock tones, played at medium to high overdrive levels.

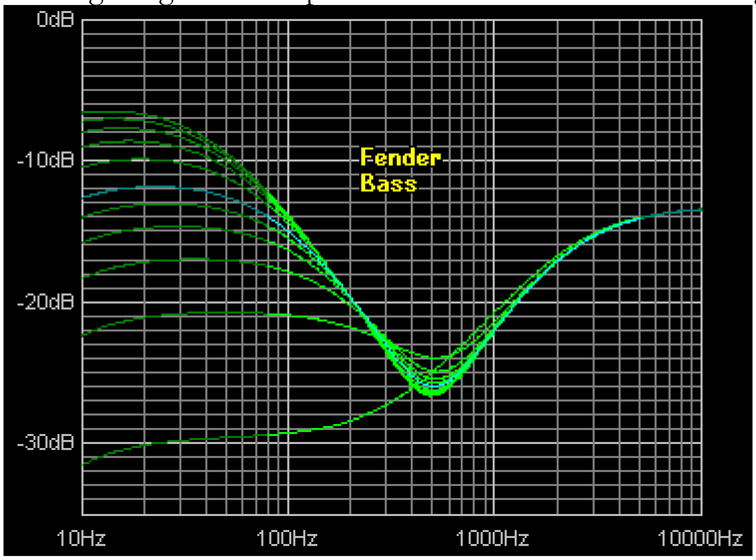
Here is a simple comparison of Marshall and Fender response with what might loosely be called 'typical settings' of Bass on 3, Middle on 4, and Treble on 6. The most obvious difference is that the Marshall lets more level through, and their tone controls have less range of adjustment. The higher level means that by using the same number of preamp tube stages, a Marshall can overdrive the output stage more.

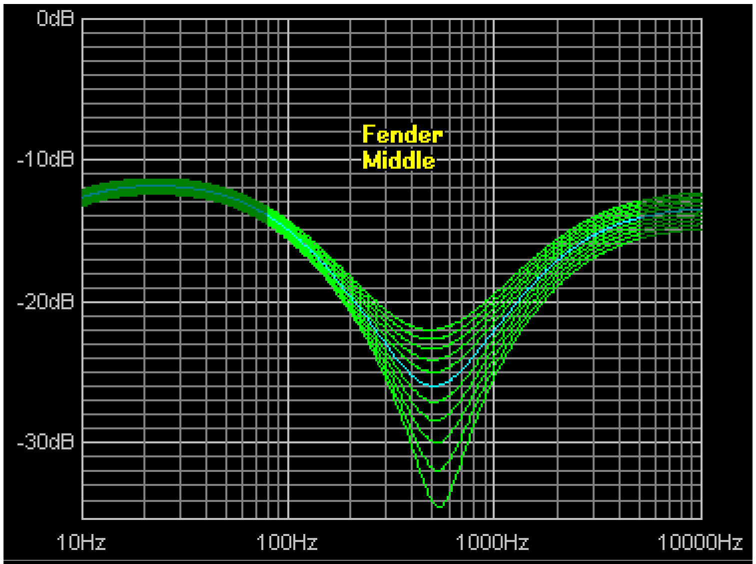


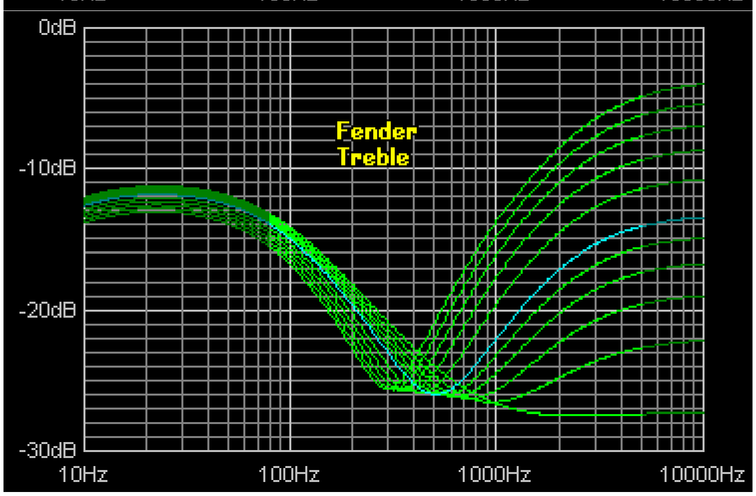
Bearing in mind that typical 6-string guitar notes don't go below 80Hz, and typical guitar speakers cut above about 5KHz, these responses are similar. Both have a middle dip that is primarily compensation for typical pickups' middle emphasis, rather than an obvious dip in middle response. The Marshall circuit has this cut about an octave higher than the Fender, leaving the low mids and bass intact for that full Marshall sound. On the other hand, Fender's tone controls allow high-mids to pass with the treble response, and add little bass boost for the sparkling and tight sounds they're famous for.

Here are charts each of the Fender controls. In all cases, the other two controls are left at 5. For example, the treble chart shows the effect of varying Treble from 0 to 10, with Bass and Middle both at 5. Notice that all controls have a wide range of adjustment, and that the bass control has most effect from 0 to about

3. Anyone's who has used a Fender will know this, and this control could easily be replaced by a control with a stronger logarithmic taper to smooth this out without changing the range of available tones.

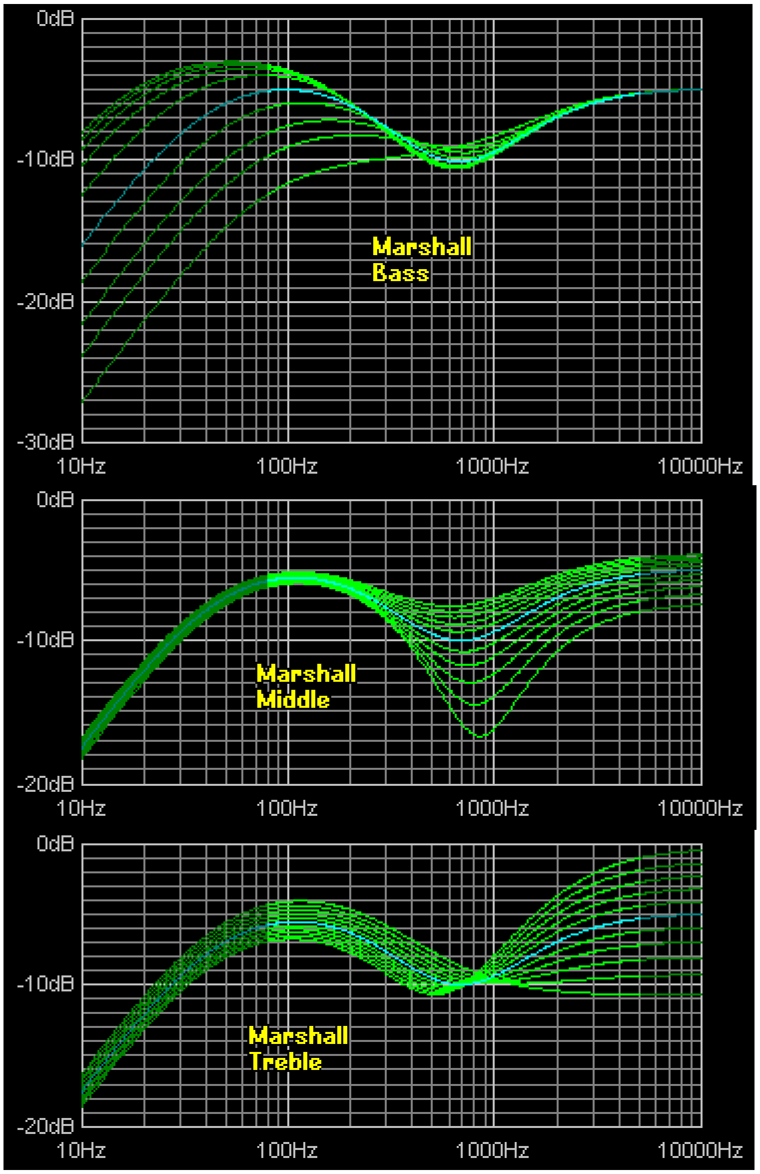






The Fender circuit also has the unusual side effect that if all controls are set to 0, then no sound is produced at all. The Marshall design avoids this, but the tone with all controls set to 0 is not something you'd be likely to use anyway.

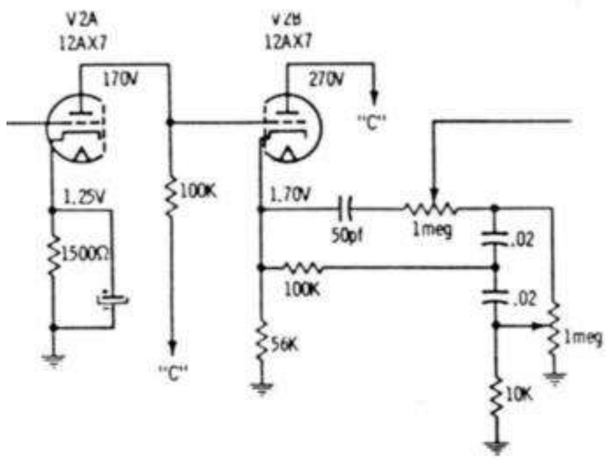
Here are the same charts for Marshall tone controls. As mentioned already, the main points to note are the smaller range of adjustment, the higher frequency for the middle cut control, and the higher overall signal level. The smaller adjustment range and higher level are both caused by the use of the 33K resistor in place of Fender's 100K. The also gives the tone stack a lower input impedance, requiring it to be fed from a lower output impedance (cathode follower) preamp tube stage.



Tube power amplifiers often provide an additional presence control (which reduces negative feedback in the power amplifier section) to provide a small amount of boost at frequencies above the treble control.

VOX Tone controls

The VOX type Top Boost circuit response is used in the TC15. This is well-known for it's interactive nature.



When VOX re-designed their AC30 and removed the EF86, they added a Top Boost circuit to regain some of the high end sparkle the amp had lost. What was used was the high gain circuit from the 1954 Gibson GA-77 "Vanguard" - An Amplifier known for it's 'high gain' channel. The interesting point is that the original Gibson diagrams happen to have an error on the Bass pot, grounding one end that should be left floating.

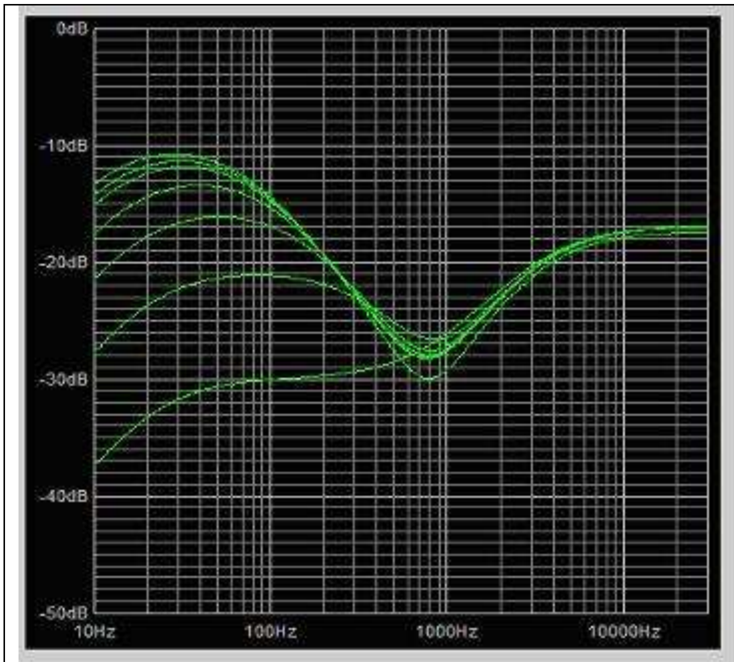
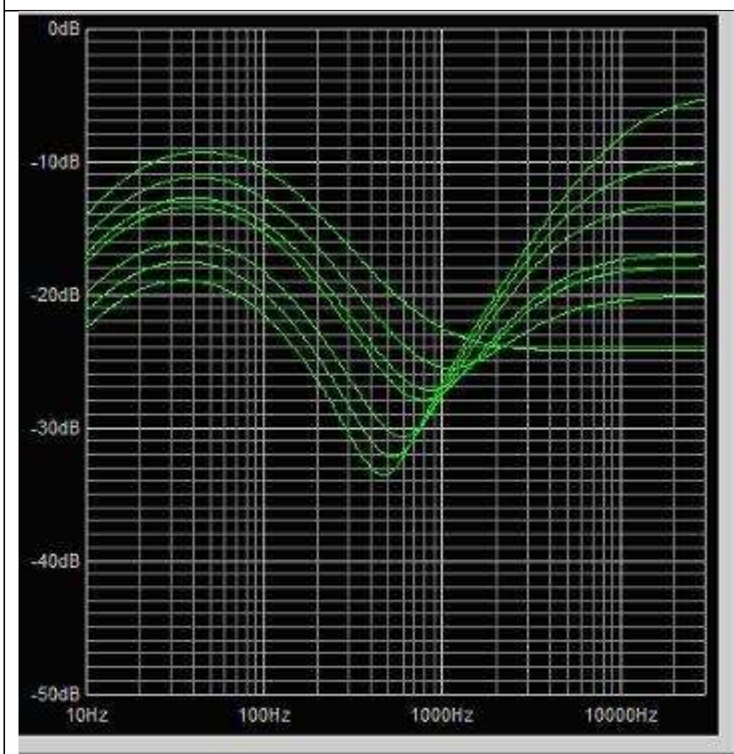
Glen Lambert - 2002. For more information see:

http://www.geocities.com/vintage325/topboost.html

This error was carried across to the VOX JMI 'Brilliance' unit. This affects the way the tone controls interact and the effect of the Bass control on mid band. Normally it would be desirable for the Bass control to effect only the Bass content, but in this case the Bass control will effect the midrange and to some extent the Treble when it is at it's extreme travel. Even in correct form the circuit is not ideal. It's a compromise to keep the component count low, but the error does make it slightly harder to control Treble and Bass separately.

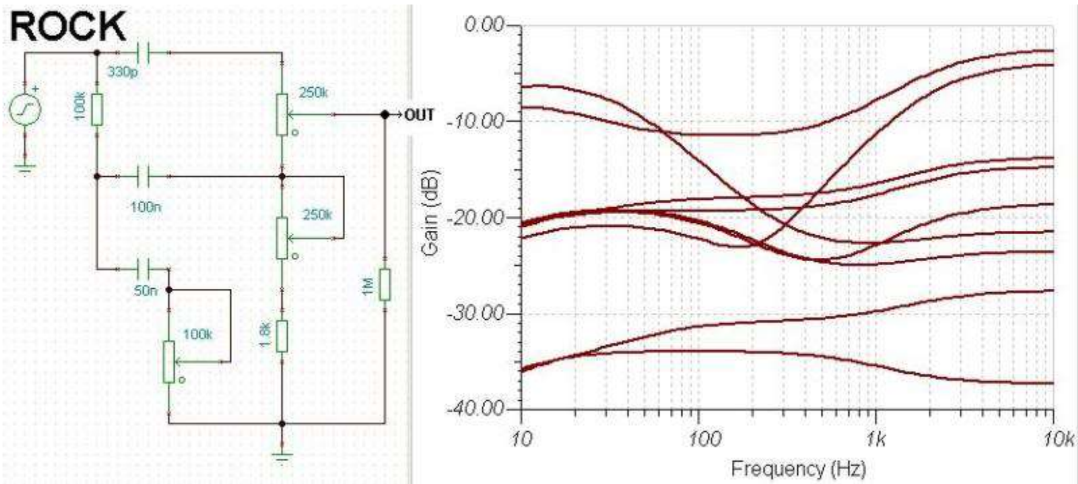
This same circuit will be present on every VOX amp that contains a Top Boost section.

If you're curious to hear how the tone controls were meant to respond it's not a difficult thing to do. Just unsolder the ground connection from the Bass pot. You can leave it floating or join this terminal to the wiper to make it a variable resistor.

	Trinity 15/TC15 Bass Control Frequency Response. Note the interactive effect on Treble control.
	Trinity 15/TC15 Treble Control Frequency Response. Note the interactive effect on Bass control.

Dumble Tone Stack – from Merlin

It may interest people to see the fundamental differences between the Dumble tone stack in Rock and Jazz mode. Frequency response plots correspond to a 40k source resistance. Here it is in rock mode:

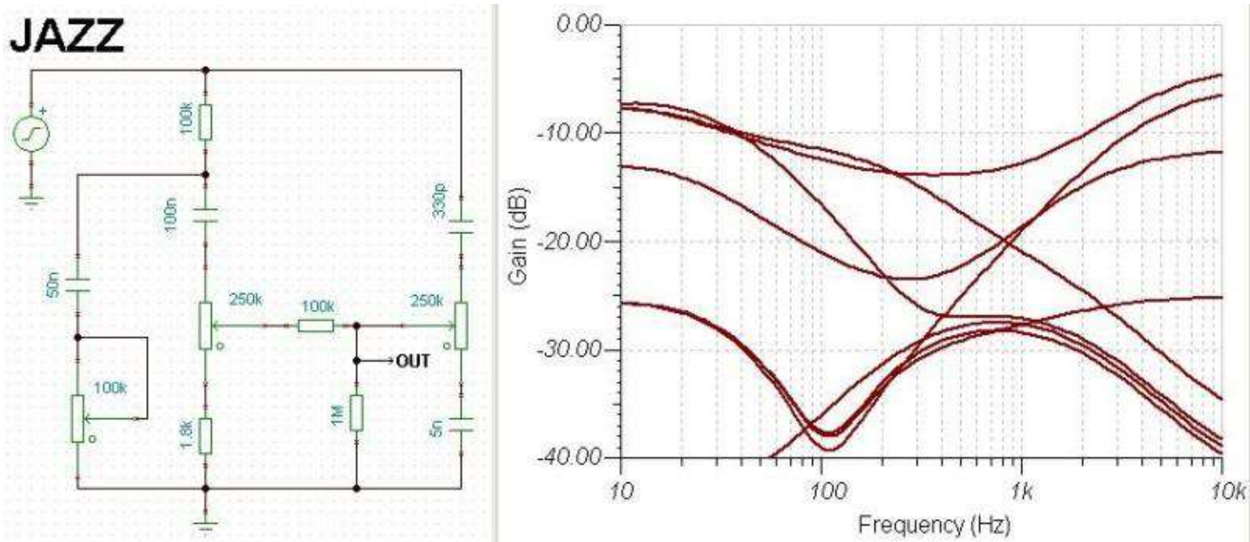


As you can see, it's basically a Fender tone stack, except the Mid control has been separated from the Bass control.

Treble frequencies are fed directly to the Treble pot via the 330pF cap.

All frequencies pass through the 100k slope resistor, and the upper plus midrange frequencies are then bled off via the Midrange pot. This leaves only the lower frequencies which are always fed to the Bass pot. Therefore the Bass pot really controls bass and middle; the Mid pot simply decides how much mid actually gets fed to the Bass pot. Also, the more you turn up the bass, the less you can cut the treble, because the two pots are stacked.

Here it is in jazz mode:



Look vaguely familiar? It should do; it's more-or-less a James tone stack plus mid-shift resistor (that's the 100k resistor between the Treble and Bass pots). The operation of the Mid and Bass are the same as before.

The Treble pot, however, is now pretty much independent of the Bass pot, so that more treble cut is available even with the bass pot set to max.

Lowering the value of the mid-shift resistor to zero ohms will shift the whole response up by about one octave (it actually has very little effect on the separation of the controls), so there is something you can play with.

What about the .001uF cap across the bass pot and the 10K to ground on the CCW?

The 1nF cap scoops the mids a tiny bit. The 10K resistor just sets the limit of the bass pot.

Distortion

The overdriven sound of a tube power amplifier is highly desirable, with many different output stage designs to produce the variety of trademark sounds heard on modern recordings. The only problem is that a tube power amplifier is only capable of producing this sound at one volume (usually, fairly loud!).

There are probably 3 distinctly identifiable types of tube power amplifiers used:

Leo Fender's classic early designs used 6V6 tubes, and later, the higher powered 6L6's. This gave a characteristic full and punchy sound, suitable for many styles of the day, and later. Steel and country players like the chime-like clean sounds, and blues players were quick to discover the classic way it breaks up when pushed hard. At really high overdrive, though, the sound becomes quite dirty, with bass in particular sounding flabby.

Marshall designs started as Fender copies, but soon switched to EL34 output tubes, possibly for local supply reasons. Anyway, the rest is history. These tubes exhibit a softer overdrive transition, and maintain clarity even at high overdrive levels. They also have a limited middle response, giving rise to the famous Marshall crunch sound. The lower powered EL84 tubes have similar characteristics.

Vox AC30 (and the more popular top boost model) uses a Class AB power amplifier design, with the tubes biased 'hot', so while this operates in class A at lower levels, it is a class AB design. There's no negative feedback in the power amp either, so this gives a different sound, often described as a sweeter overdrive. Listen to Brian May's sounds for plenty of good examples.

The Fender and Marshall designs use class AB for their output designs, biased with the tubes almost off with no signal. This is more efficient (more watts per tube), and better for tube life. When you play, tubes take turns handling each half of the signal. This leads to some (unwanted) distortion as the tubes cross over. Class A designs are rare in medium to high power guitar amps, but true class A has the tubes operating at half power, with no signal applied. When you play, the tube fluctuates between full and no power, so there is no switching to add unwanted distortion. This is a very superficial explanation; please read elsewhere on the Internet for more detailed descriptions.

Wide Dynamic Range A plucked guitar string requires a wide dynamic range to handle the initial peak, and then cleanly amplify the decaying string vibrations. Some poor designs do not have this capability in their preamp stages, let alone the power amp to handle this. Pre-amplifier stages need generous power rails, and should not have gain stages which cause the initial plucked part of the string sustain envelope to be clipped.

Instrument Speakers Unlike hi-fi speakers, which are designed to keep the coil entirely within the magnetic field to maximize linearity, instrument speakers are designed to have the coil partially leave the magnetic field at the extremes of cone travel. This is partly to protect the speaker, but also produces a 'soft-clipping' effect which is desirable with guitar amplifiers. It is also therefore important to match speaker power ratings reasonably closely with the power of the amplifier. Popular instrument speakers are available from Tone Tubby, Celestion, Jensen and others.

Note: If you were to use two cabinets hooked directly into the amp, be sure to set the amp at half the impedance of the cabinets. For example, if your cabinets are 8 ohms each, set the impedance selector to 4 ohms.

Durability Most musical styles will require the amplifier to be overdriven for extended periods of time, and the amplifier must be designed to provide this without duress on any components. Common non-guitar design principles assume that circuitry will be designed to avoid overdrive, and technicians working in this field have to 'un-learn' many basic assumptions. Popular circuits have evolved through trial and error, due to a general lack of documented knowledge in the field of non-linear amplification.

Road Worthiness Musical equipment of this type needs both physical and electrical protection. A band often has its equipment transported and set up by a road crew with little guarantee of physical care. Likewise, an assumption should be made that the output stage will at times be inadvertently shorted, so most professional equipment is designed to handle this contingency, preferably electronically, and at the very least without fuses inside the chassis.

General Amplifier Operation

Some DO NOTS

- Never, Never, Never run the amp without a speaker plugged in. This can cause major damage.
- Do not flip the power switch off, and then back on rapidly. This can cause power supply damage.
- Never replace a burned out fuse with a bigger-amperage one. Remember - there was a reason the first one burned out, usually protecting something more expensive. Putting a bigger fuse in will just ratchet

up the power level until something really vital burns out. If the second equal-rating fuse pops, turn it off and get a tech to look at it.

- Never ignore signs of high heat inside - a wisp of smoke or a burning smell is **NOT** normal.
- Your amp produces lots of heat, and will continue to do so even if you block the fresh air vents. Blocking the vents will overheat the amp and you may have to get some very expensive repairs done.
- Never ignore a red glow other than the small orange ends of the filaments. A red glow over a large part of the internal plates of the output tubes means they're about to melt. If you notice this, shut it down and get a tech to help you find out what it wrong.

Some DOs

Add another speaker into the "external speaker" jack; a mismatched speaker load won't kill it, while an open circuit (disconnected speakers) may do so.

Overdrive the stuffing out of it. Tubes are very forgiving of massive overdrives, unlike solid state stuff. As long as they tubes don't overheat or stay overdriven for long periods, it's not fatal.

Introduction to Vacuum Tubes and Common Terms

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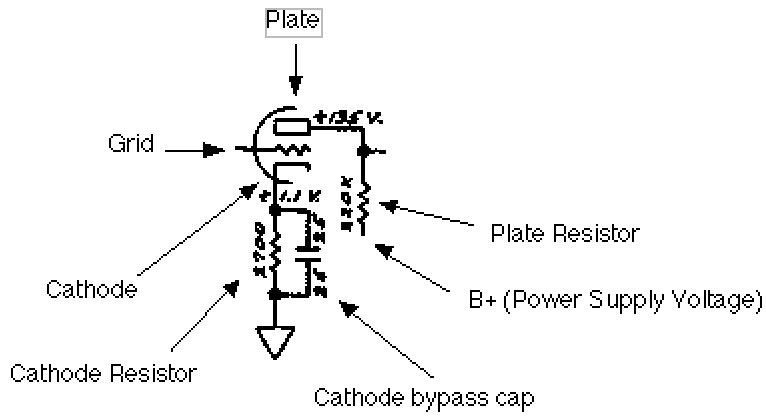
Here are a few terms that you may see online when referencing tube schematics. Like distortion pedals, tube circuits seemingly have their own language! I present this knowledge in the hopes that it may help you decipher the interesting life of tubes! Below, is a picture and a very simplistic view of a tube stage.



As you can see above, in this tiny snippet of a tube schematic, the terms you commonly see are there in this triode stage example.

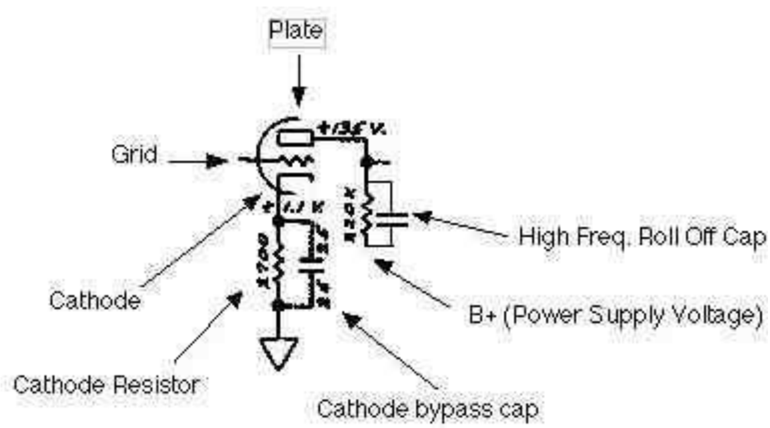
Plate - the plate is usually connected to a plate resistor which is usually connected to the B+ or power supply voltage. Typical Plate Resistor values are 100K, 150K, 220K. Larger values equal more gain.

The Grid is where the signal enters the tube.

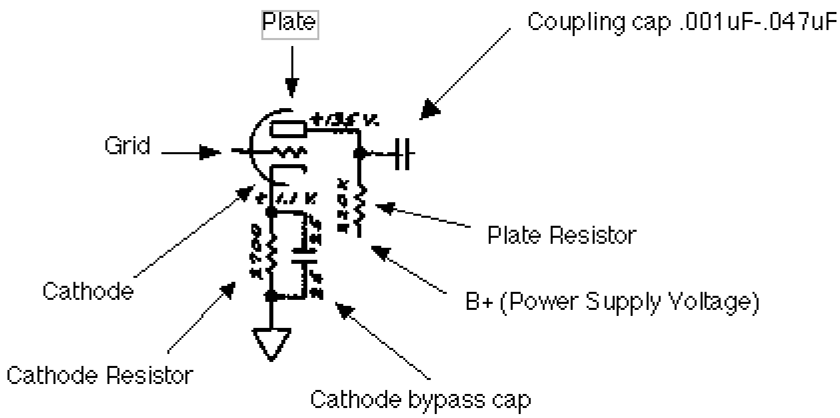
The Cathode is usually connected to a cathode resistor which usually goes to ground. The cathode resistor, along with the Plate resistor, control the gain of the tube stage. Typical values are anywhere from 100 ohms to 10K. Smaller values = more gain.

It is common to see a cathode bypass cap connected in parallel with the cathode resistor. By altering the values of the cathode resistor and cathode bypass cap, it is possible to roll off various degrees of bass with this triode stage. <u>The cathode resistor and plate resistor control the biasing of the tube</u>. The cathode bypass cap also gives the stage more gain.

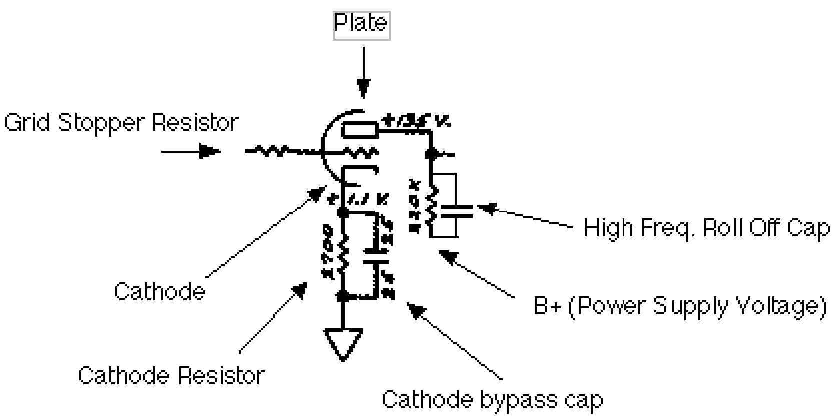
Sometimes you see a capacitor in parallel with the plate resistor, much like the cathode resistor bypass cap. It is usually a small value (i.e. .001uF) and it rolls off highs in the stage. Sometimes you see a high frequency roll off cap going from the plate pin to the cathode pin - 350pf->500pf in value.



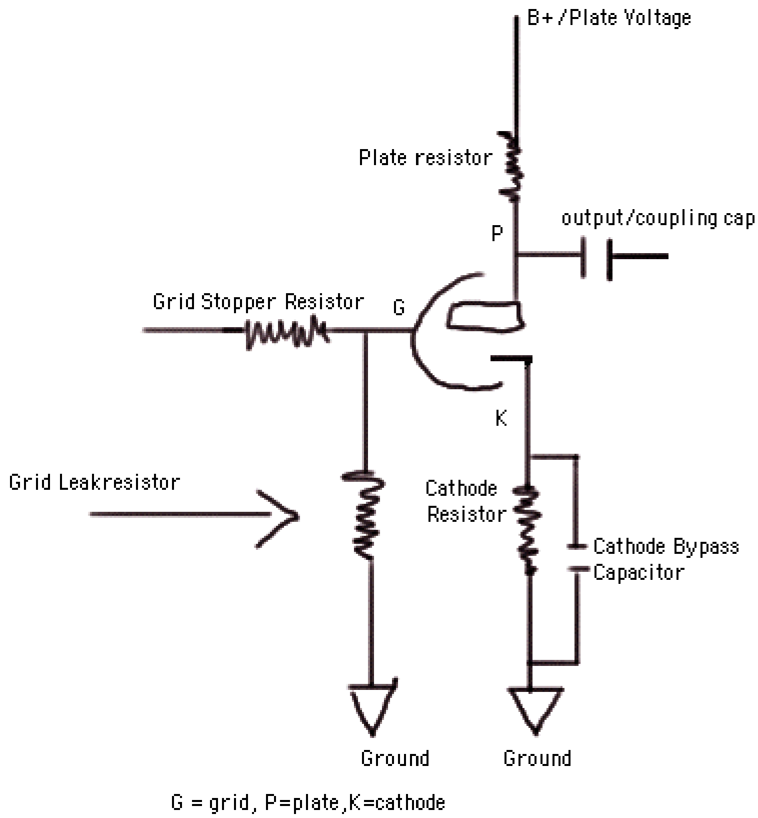
You will also see a coupling cap in between triode stages. The coupling cap controls the bass and rolls off bass between stages and blocks DC from entering the next stage - which could throw off the bias on the next tube stage. As usual, smaller values roll off more bass, larger values retain more bass between stages.



Another modification you may see is a Grid Stopper Resistor, this can also control gain between stages and also interacts with the tube to roll off highs. Values can be 1.5K->100K. Larger values roll off more highs and reduce gain between stages. The Grid Stopper Resistor works best when mounted directly or as close as possible to the grid pin.



"Complete" typical tube preamp stage:



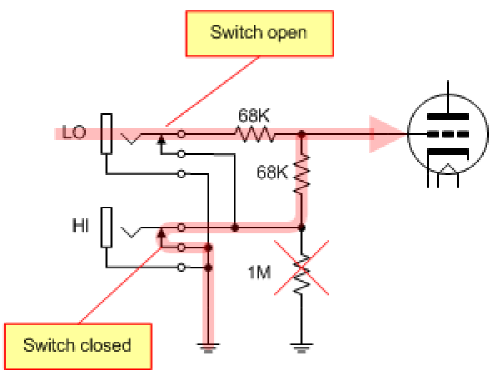
The grid ("leak") resistor, typically sets the impedance of the stage and biasing. It is interesting because it and the previous stage's plate resistor form a voltage divider on the signal. What this means to you is that the grid leak resistor can be used to control the level into the stage. Low grid leak values will attenuate the signal into the tube stage. If you look at different tube amp schematics, you can see where they control the level into the stage by using different values for the grid leak resistor. There is a maximum value that you need to adhere to. Check the datasheet for the tube you are using to see the typical value of the grid leak resistor. This particular circuit is called cathode bias which you can read about here.

In summary, the cathode resistor, plate resistor and grid resistor, determine the biasing of the tube stage. The cathode bypass cap controls the degree of bass reduction - generally 25uF passes all frequencies - commonly used in Fender amps, 1uF an 0.68uF are used in Marshall amps. A capacitor can be placed in parallel with the plate resistor to roll off highs and you see this in bass channels of amps sometimes. The plate receives the voltage from the power supply through a plate resistor, the grid receives the AC signal as input and the cathode is grounded through a cathode resistor.

Input Jack Theory

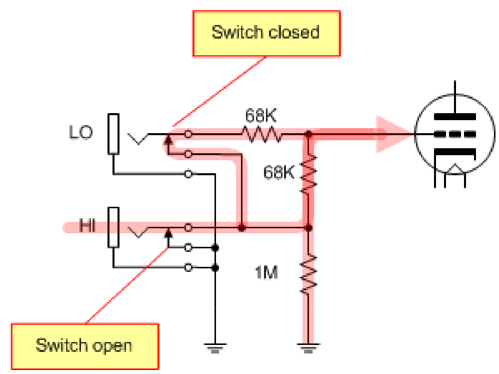
These first two circuits represent the typical Hi/Lo jacks found in most Fender and Marshall amps. Many other amp manufacturers use this circuit as well.

Using the Lo Input



The LO jack delivers the signal to a 2:1 voltage divider made up of the two 68K resistors. The 1meg is shorted out by the switch contacts on the HI jack. The signal taps off the junction of the two 68Ks. Half the signal is dropped across each 68K, therefore only 50% of the signal is applied to the tube.

Using the Hi Input



The HI jack delivers ALL the signal to the tube. The signal enters the HI jack and first sees a 1 Meg resistor to ground. Since the LO jack switch is closed, the two 68Ks are parallel for an effective resistance of 34K and the signal travels through the paralleled 68Ks to the tube. There is no voltage divider so 100% of the signal arrives at the tube.

~ from 18watt.com