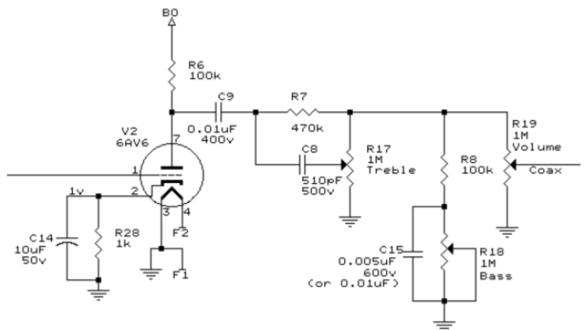
‘Tone Stack’ and Frequency Response

for Regal/Lifco Model 630 and 630 2 Amplifiers

(rev 1 – last updated April 28, 2016)

The noted amplifiers are fitted with two knobs for tone control – labelled Treble and Bass.

These controls appear after the first pre-amp tube, and are illustrated in the schematic excerpt below:

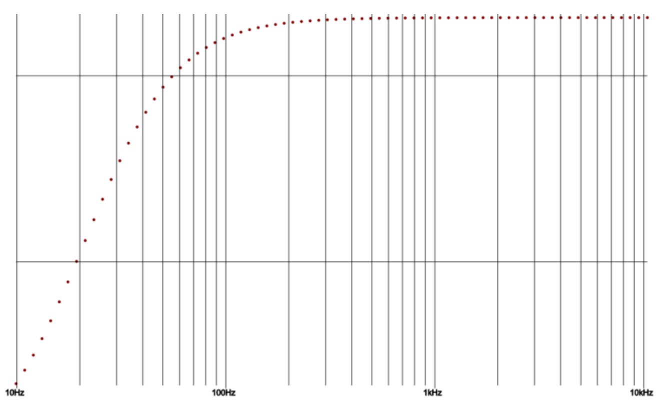


There are three main elements which impact the frequency response in this stage:

1) The cathode bypass of V2
2) The Treble control
3) The Bass control

<u>Cathode Bypass</u>

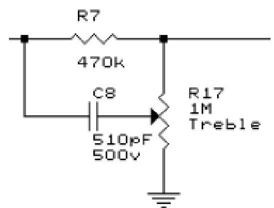
The 10uF capacitor attached to the cathode of V2 acts with the 1k cathode resistor to give a response similar to the following:



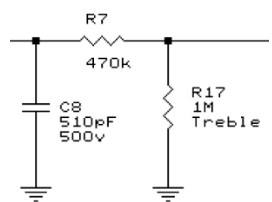
Nearly full gain is achieved for even the lowest standard guitar frequencies, only rolling off below those.

<u>Treble Control</u>

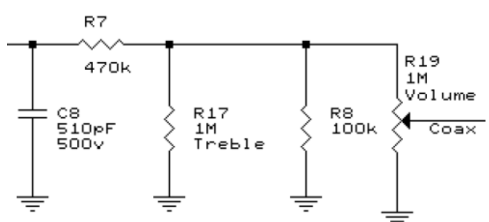
The user-level treble control is as follows:



For a 'minimum' treble setting (full counter-clock-wise on the knob), the potentiometer is such that capacitor C8 is grounded at one end, resulting in an effective circuit of:

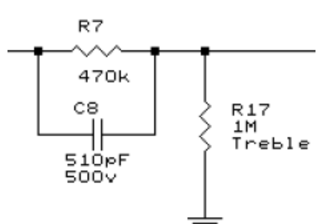


In this configuration, the main signal path is resistive – and so the output level is determined by the voltage divider formed by R7 and the parallel resistance of R17 and the resulting circuit from the 'bass' section. In a "minimum bass, minimum treble" configuration we would have:



As there are only resistors involved, there isn't any expected variation with frequency (e.g., a flat frequency response, with a magnitude set by the resistor network).

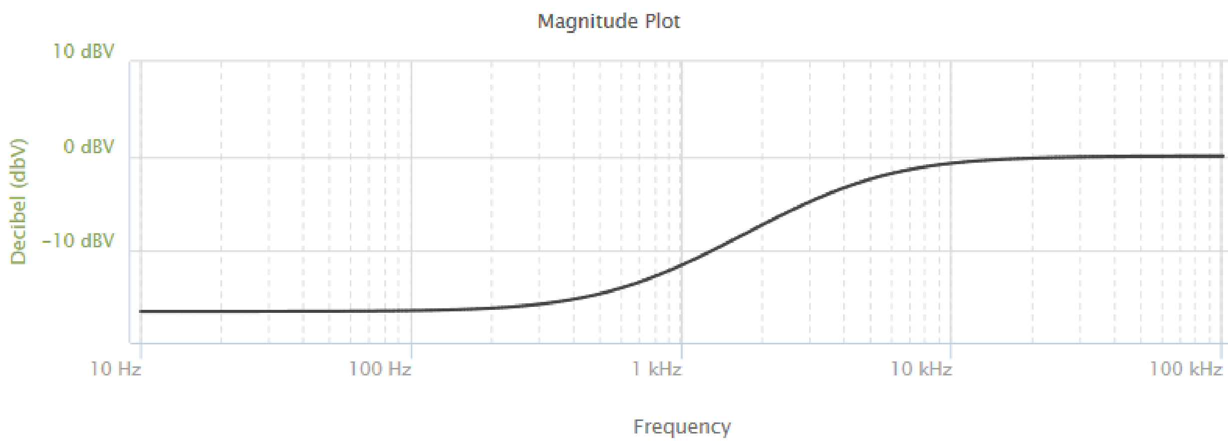
For a 'maximum' treble setting (full clock-wise on the knob), the potentiometer is such that capacitor C8 is fully parallel with R7, and R17 follows this to ground:



When the knob is at maximum treble:

- For low frequencies, the capacitor effectively appears as an 'open' – and so the gain is determined by the resistor divider of R7 and the parallel combination of the other resistors.
- For high frequencies, the capacitor effectively appears as a 'short' – thus removing the impact of R7. As R7 is shorted, there is no further resistor divider, and the full output voltage goes to the next stage (e.g., maximum signal transfer).

The circuitry describes a high-pass shelving filter – with an overall response similar to:



For the response above, the 3dB lower break frequency is:

$$F_{lower} = \frac{1}{2 * \pi * R7 * C8} = 664Hz$$

The upper 3dB break frequency is:

$$F_{upper} = \frac{1}{2 * \pi * C8 * \frac{(R7 * R_{eff})}{(R7 + R_{eff})}}$$

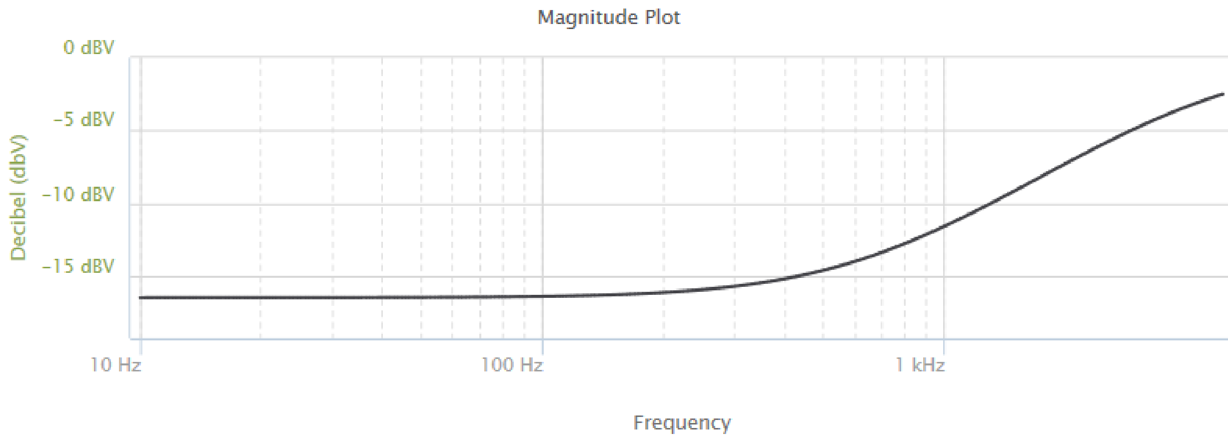
Where Reff is the effective resistance formed with R8, R17 and R19:

$$R_{eff} = \frac{1}{\left(\frac{1}{R8}\right) + \left(\frac{1}{R17}\right) + \left(\frac{1}{R19}\right)}$$

At minimum bass, R8 = 100k, R17 = R19 = 1M so:

$$F_{upper} = 4409Hz$$

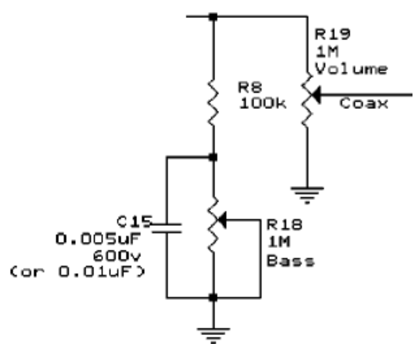
Looking over a more representative frequency range (e.g., up to 5kHz, vs. 100kHz) we have:



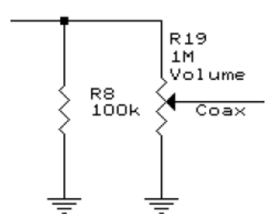
So – while this is generally a shelving high-pass response, over the nominal frequency range, this provides an increasing treble boost, starting to come into effect at 200Hz, at up by 3dB by 664Hz.

<u>Bass Control</u>

The user-level Bass control elements from the schematic are as follows:

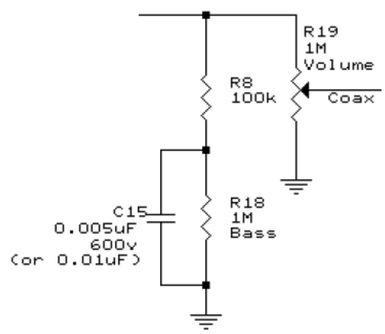


For a 'minimum' bass setting (full counter-clock-wise on the knob), the potentiometer is such that capacitor C15 is shorted to ground, with the effective circuit appearing as:



In this configuration, the main signal path is only resistive – and so the output level is determined by a voltage divider between the earlier treble circuit and R8 and R19 in parallel. For low frequencies, this results in no variation with frequency (e.g., a flat frequency response, with the magnitude set by the resistor network).

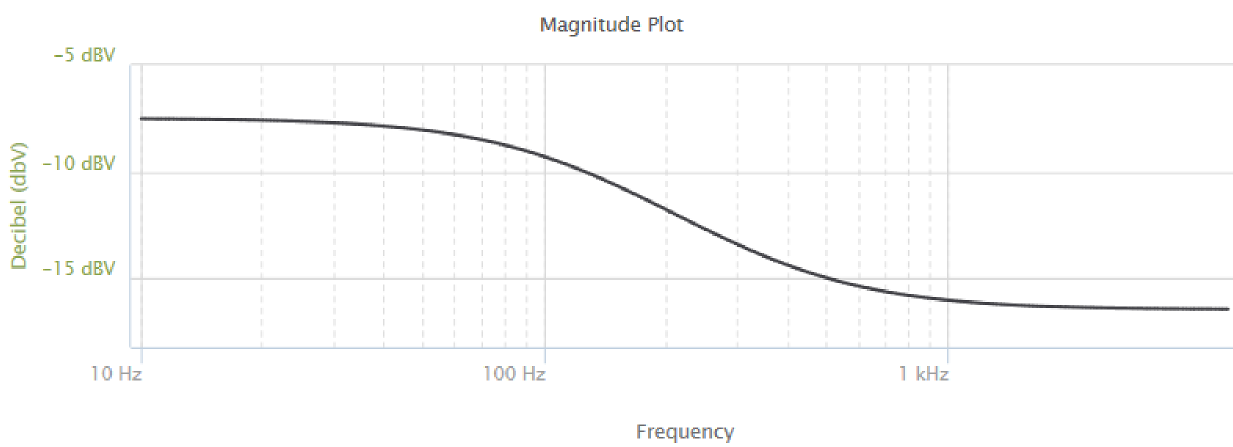
For a ‘maximum’ bass setting (full clock-wise on the knob), the potentiometer is such that capacitor C15 is in parallel with R18:



While the knob is at maximum bass:

- For low frequencies, the capacitor effectively appears as an ‘open’ – and so the gain is determined by the resistors in the circuit only. R8 is in series with R18 – thus increasing the resistance of that branch. This means that the voltage across R19 will be much higher than it would be for the case where R18 is shorted.
- At high frequencies, the cap effectively appears as a ‘short’ – and thus R18 is shorted to ground. This has the effect of removing R18 and C15 – which is exactly the situation for the ‘minimum’ bass setting.

This section will work as a shelving low-pass filter, as illustrated here (for C15 = 0.005uF):



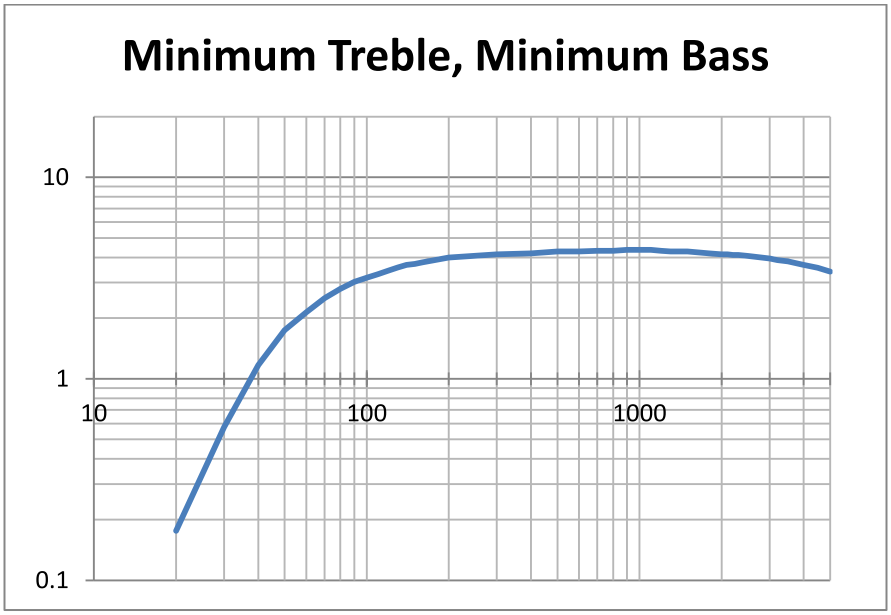
The upper 3dB break frequency is approximately:

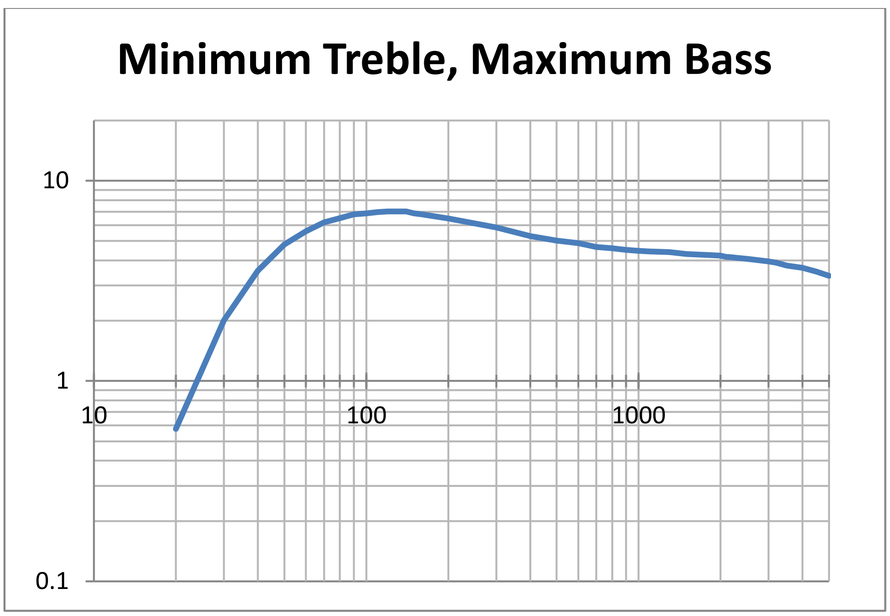
$$F_{upper} = \frac{1}{2 * \pi * R8 * C15} = 318Hz$$

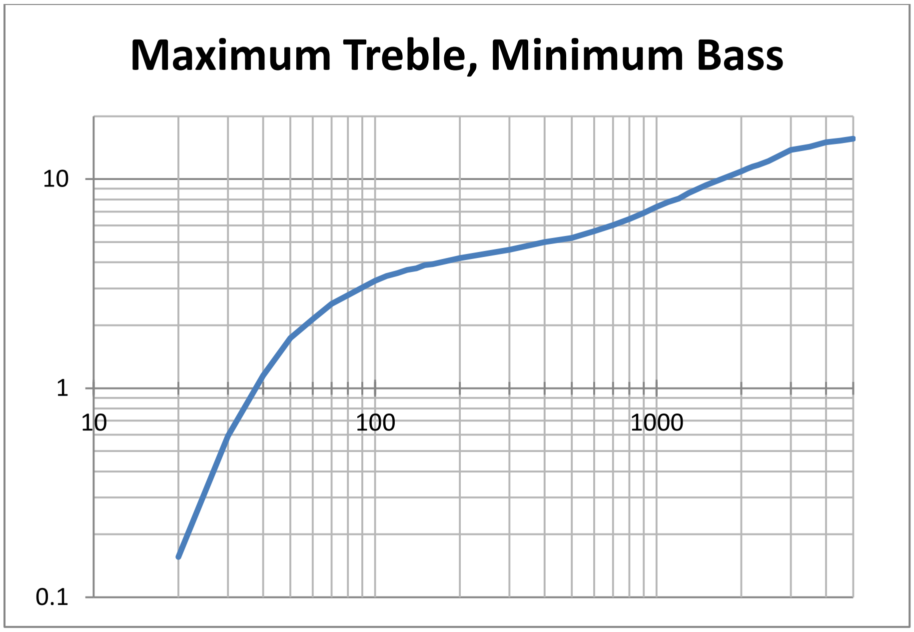
The calculation of the lower break frequency is a bit more complicated – but can be seen graphically above.

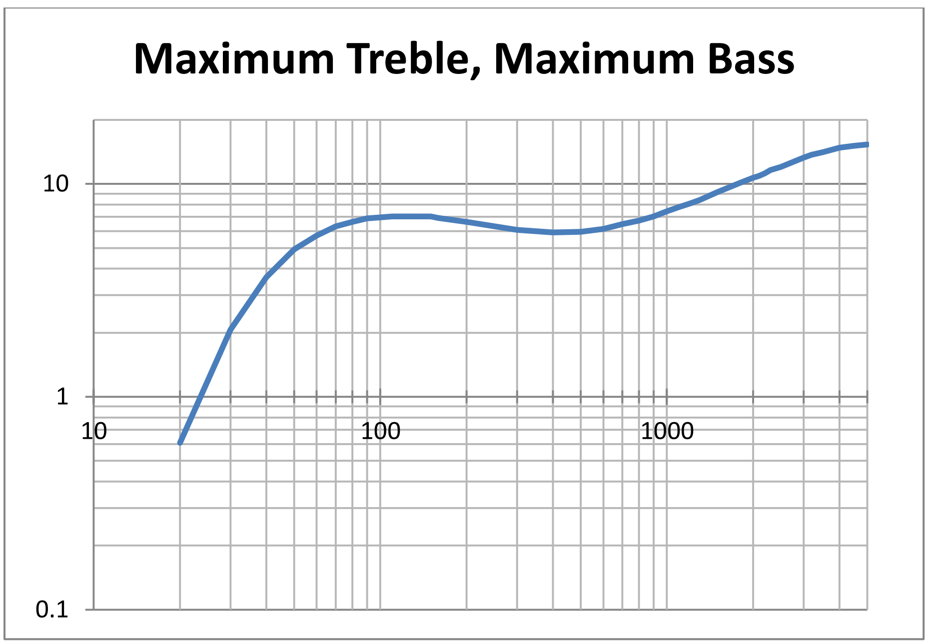
Response Plots

The effect of the Bass and Treble knobs, as measured on an actual unit, are illustrated below. These plots were taken on a representative amplifier –measured across an 8 ohm purely resistive load (where C15 is 0.005uF, and the volume was kept about 1.5 / 10 – to help ensure no clipping of the output).

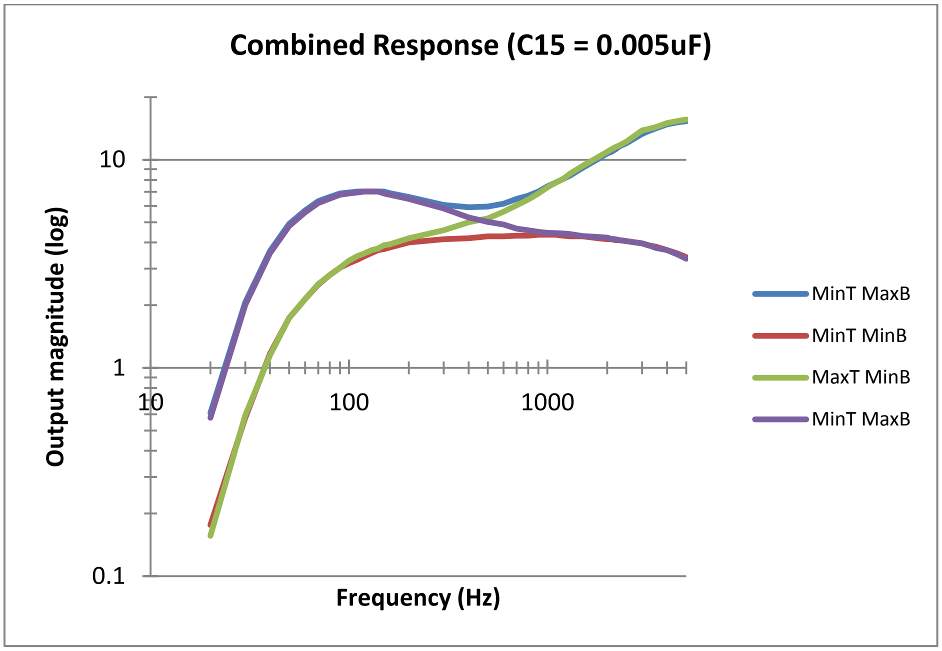





Maximum Treble, Minimum Bass
10
1
0.1
10
100
1000


Maximum Treble, Maximum Bass
10
1
0.1
10
100
1000

To compare these, we can place all the responses in a single plot:



When both knobs are at their minimum value, the response is essentially flat across a guitar range.

When either of the knobs is increased (turning clock-wise), there is a corresponding increase in that parameter (when bass knob is increased, the bass response increases - with generally no impact on treble – and when treble knob is increased, the treble response increases - with generally no impact on bass).

Variability of C15

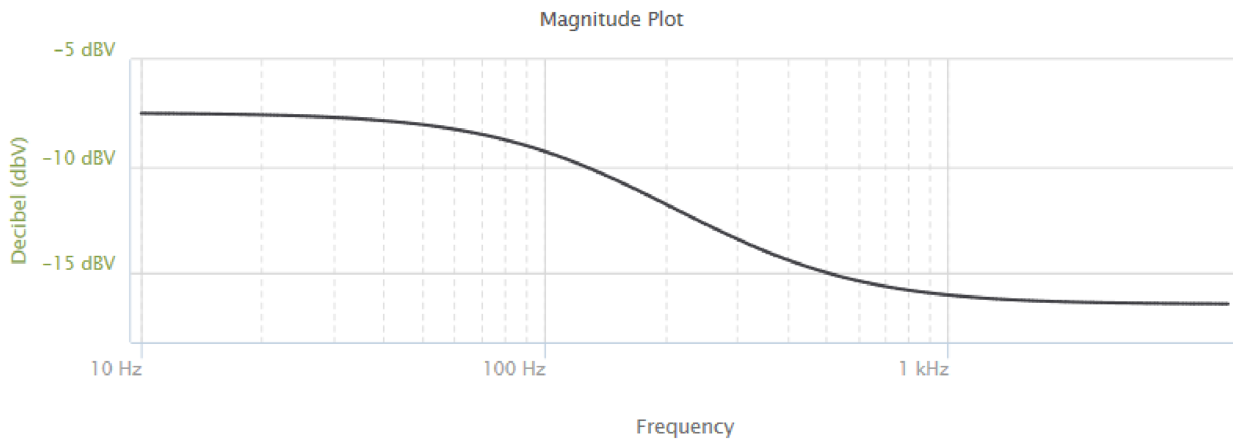
The schematic excerpt at the start of this document showed the bass control capacitor (C15) as being "0.005uF or 0.01uF."

It has been found that some instances of the 'old' Model 630 chassis have a 0.005uF capacitor installed at C15, while others have a 0.01uF capacitor installed. Although not definitively confirmed, there may have been other (lower) values also used in this location.

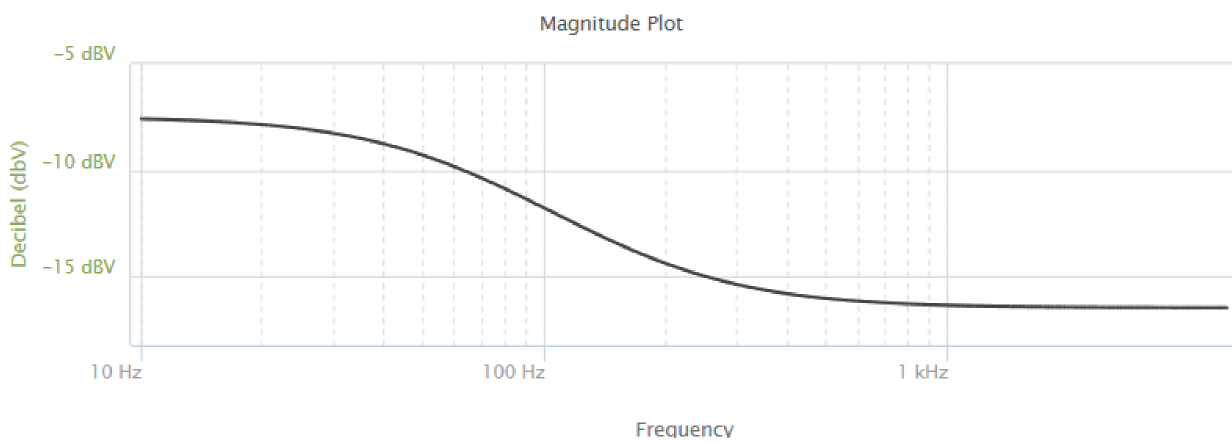
It is unclear if the change from one value to the other was intentional (e.g., perhaps to better match a given combo speaker response, or in a desire to offer more/less bass control) or if there was just variability in the factory builds. In any case, there are different values found in different units – and the different values do impact bass control.

The graphs below illustrate the expected response of the bass control electronics for the observed values of C15. (These assume the Bass knob is at maximum, and the Treble knob is maintained at minimum – and do not take into account the impact of V2's cathode bypass).

C15 = 0.005uF:

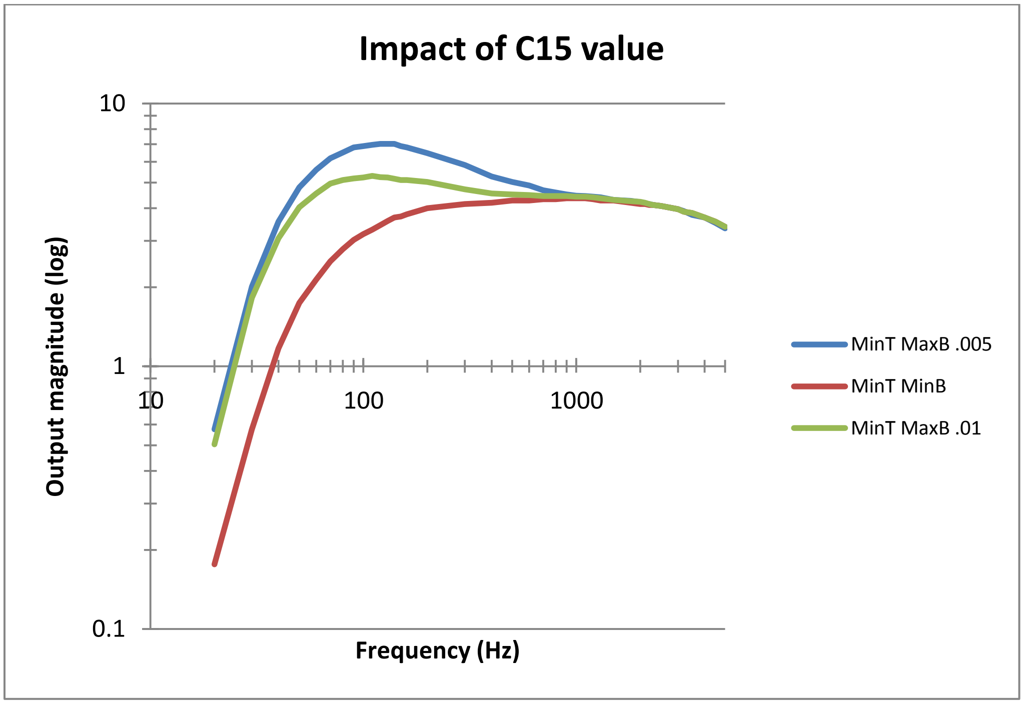


C15 = 0.01uF:



We can see that as the capacitance value increases, the break frequencies go lower.

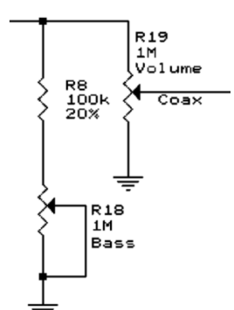
For comparison purposes (and to illustrate the net combination of the cathode bypass with the bass control), the following plot illustrates the bass response with a 0.005uF value capacitor (maximum bass setting), a 0.01uF value capacitor (maximum bass setting) – and the setting where the capacitor doesn't come into play (minimum bass setting):



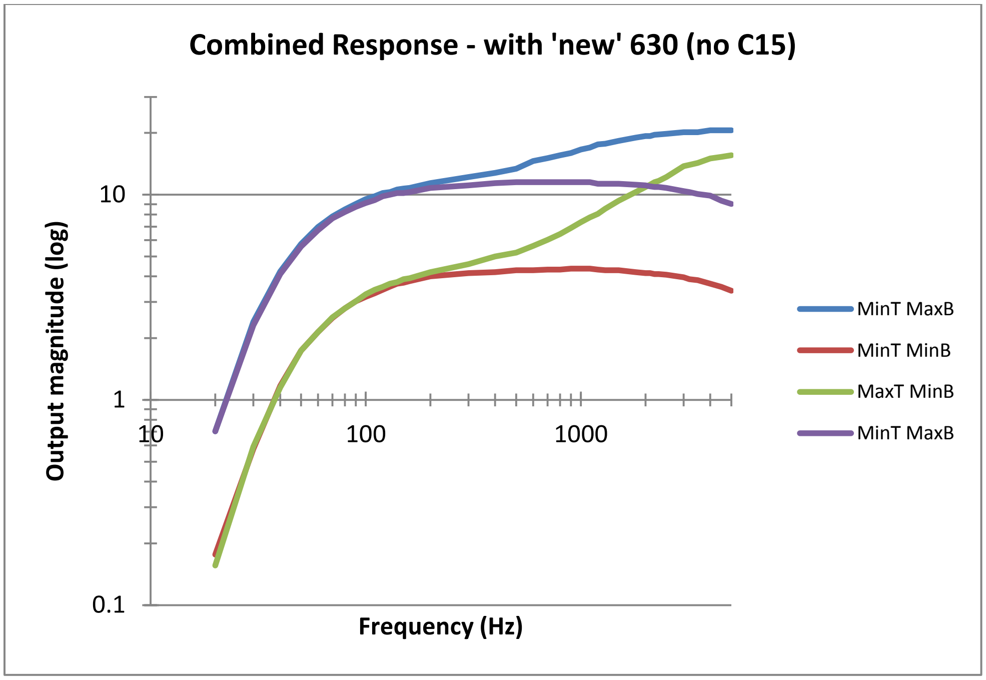
As the capacitance value gets smaller, the peak occurs at a higher frequency, and the the bass response increases.

Absence of C15

As discussed above, there was variability seen in the 'old' Model 630 with regard to the value of C15. That said - the 'new' Model 630 appears to completely omit this capacitor – and instead, R18 is present alone. In that case, the stage effectively becomes:



As there is no capacitor this is no longer a frequency-selective control. Instead, the 'Bass' control only affects the effective resistance of that branch – which in turn will impact how much signal is presented to R19 (and the load into the next tube). To a high degree this means the 'Bass' control acts more like a 'volume' control, as illustrated below:



With C15 missing, the bass control does not selectively impact bass – but it still may be useful for some users in that it would allow the amplifier to overdrive more easily (since the levels are all pushed higher). Whether or not this is desired would depend on a particular user's taste.

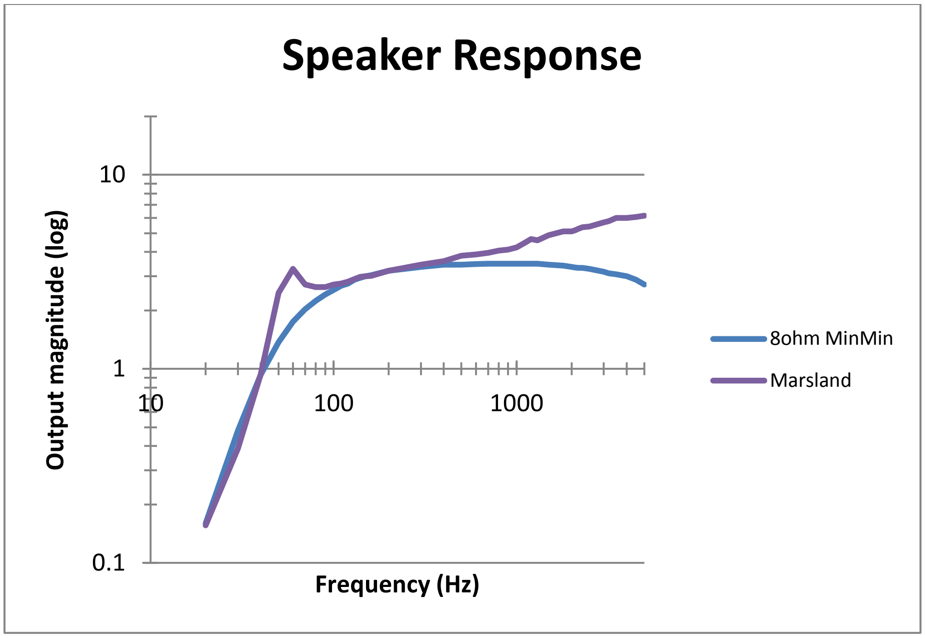
As with the differing C15 values on the 'old' Model 630's, it is uncertain if the missing capacitor on the 'new' Model 630's was absent on purpose (be that for sonic reasons, or perhaps just cost savings) – or if it was a production oversight.

Impact of Attached Speaker

The earlier plots reflect the behaviour of the amplifier when driving a fixed 8 ohm load.

While this provides visibility into the overall control of tone, it doesn't necessarily reflect the end-to-end 'response' of the amplifier when connected to an actual speaker (which isn't consistently 8 ohms across its frequency range.) Speakers themselves will impart their own frequency response – including how the impedance changes with frequency.

By way of an example, the following graph illustrates the response of the amplifier (with both tone knobs set to minimum), first with a fixed 8 ohm load – then with a 15" Marsland speaker (original to the factory configuration of an 'old' Model 630 combo).



The difference in the voltage output represents the influence of the speaker. In this case, we can see that the speaker causes a natural increase in lower frequency response – as well as an increase in upper treble response.