3 bands of glory

How the Pultec EQP-1A Tube Program Equalizer does its magic

Pultec
eqp-1a

As mentioned on analogvibes.com - if there is a holy grail of vintage tube equalizers, the Pultec EQP-1A introduced by Eugene Shenk and Olli Summerland back in 1951 is certainly it. A true legend of which the magic can be heard on countless records from the golden era of analog recording to the present day. The passive design of amazingly smooth filters paired with a push-pull tube amplifier...

Ok, let's start from the top. I'm sure most of you know what the EQP-1A is, even though most of you - just like myself a couple of years back, have only used it as a plugin until now as it's probably the most emulated equalizer in history. Even tough the controls are not as intuitive as let's say an LA2A, once you got your head around it it's very easy to use.

In the picture on the right you can see that the front panel is actually separated into 3 main sections.
On the left you see the low frequency control section (CPS). With the selector you can choose between 20Hz, 30Hz, 60Hz and 100Hz. The thing is now, that both, the boost AND the attenuation pot work at the frequency selected below. Weird right?
We're talking shelving filter in this band.

And you might think "what gives?!" - like how would it make sense to boost and cut at the exact same frequency?

PROGRAM EQUALIZER

Well, the term "exact" is maybe a little bit exaggerated when speaking of an EQP-1A as it's not like THE exacto knife of EQs. It's more like a knife going through a piece of butter...or actually more like a knife made from a piece of butter? Or cream? Anyway...

What I was trying to explain:
Even though the faceplate tells us we're cutting and boosting the exact the same frequency, both actually miss each other by a hair or two, which leads to a very interesting effect.
This effect, commonly described as "The Pultec Trick" allows us to e.g. boost the low end of a kick drum to add some weight to it while removing some low-midrange muddiness at the same time. If you've tried it once you know exactly what I'm talking about.

Also, even though you can either boost the signal by 18db or cut it by the same rate, if you do both simultaneously, the amount of low end boost will dominate over low end attenuation.

THE SMOOTH OPERATOR

The graph on the right shows what happens if both - boost & cut are gradually turned up the same way. In the beginning the ratio is kind of balanced, but with more extreme settings it's becomming pretty clear who is the boss in the low-end hood.

As a fun fact the original Pultec manual warns not to use both, boost and attenuation simultaneously :D

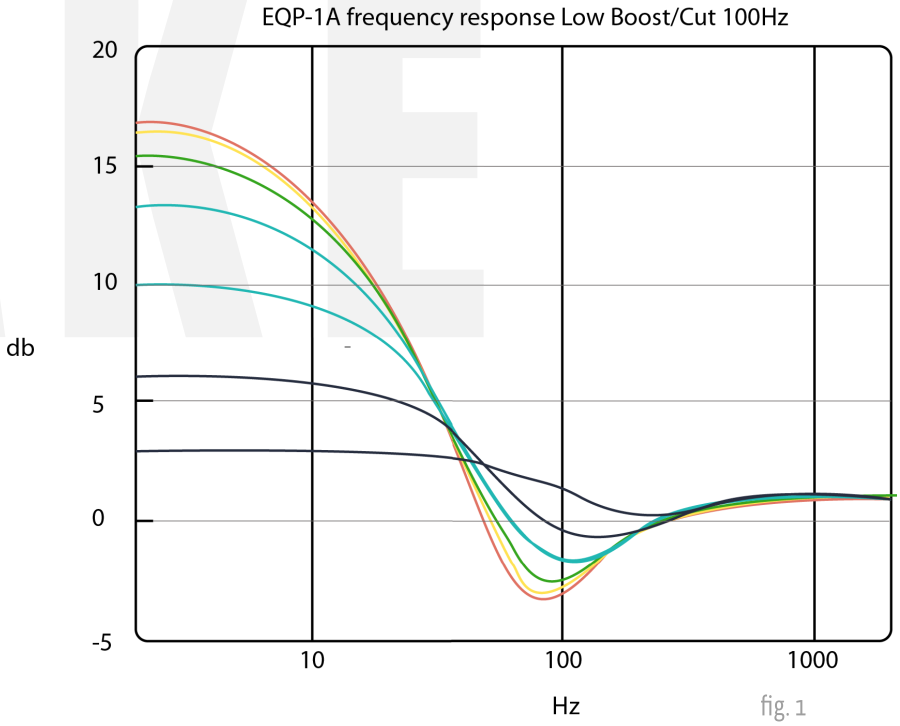


fig. 1

The HFsection of the EQP-1A has a dedicated frequency select switch for each band, boost and cut, even though looking at the front panel for the first time doesn't make it obvious. **The 3 knobs in the center cover the HF boost section of the equalizer.** You can select frequencies from 3Khz up to 16Khz. Other than the low end section here we have a bandwith control that allows us to manipulate the q-factor of the frequency curve from narrow to wide. How this feature works exactly I'll explain a little later. For now the picture on the right shows what it does.
Last but not least we have the HF cut section. While the HF boost section is a bell filter, both the low end as well as the HF cut section are shelving.

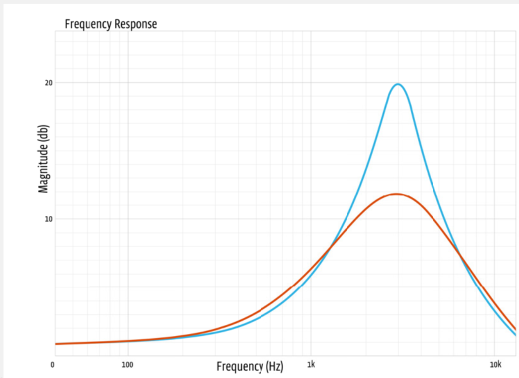


fig. 2

WHAT'S GOING ON INSIDE

Other than that the only thing left on the front panel apart from the power switch is the bypass switch on the far left. Obviously when it's switched to "IN" the filter is active, but that doesn't mean the Pultec is completely out of your signal chain when the filters are "OFF". **The signal is still going through the amp circuit - that means through the tubes and transformers.** And even though measuring the frequency response with filters bypassed shows it's pretty much flat, many engineers around the world are convinced the signal sounds better simply by going through the amp.

I mean the signal hits some heavy iron and tubes, so these things have to do something to the sound, right?
We might look into this a little bit later also in terms of what components might be responsable for that assumption.

But let's take a look at the bigger picture first. What are the main stages the signal passes going through this legendary piece of equipment?
I made kind of a first very simple diagram that sheds should help us to approach the circuit little by little:

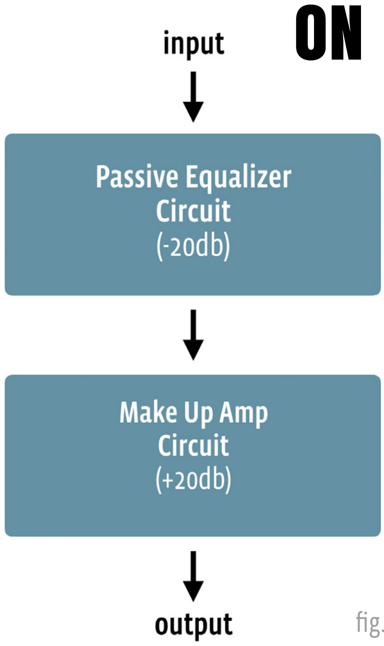


fig. 3

As you can see if we break it down to the two main modules, the signal is going through the filter unit first, where it's attenuated by around 20db, before it moves on to the amp circuit where in turn the signal is boosted by the same amount.
That means first of all the pultec filter is a simple 10:1 or 20db attenuator which is followed by a tube amp with a fixed 20db gain.
This brings us closer to how a passive equalizer works.

Hang on - why is it a passive equalizer when there's a tube amp involved?!
Well, the term »passive« is related to the filter itself being passive as opposed to an active filter where the amplification of certain frequencies is directly happening within the filter section.

TO BOOST OR NOT TO BOOST...

But again let's keep it slow and we'll decipher this circuit one step after another. If we take a closer look at the overall circuit the first part looks like this:

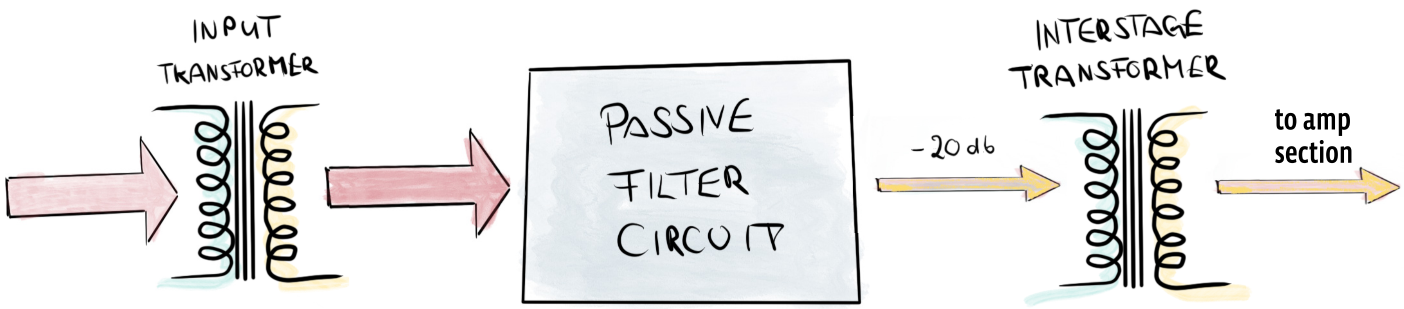


fig. 4

Coming from the input the signal goes directly to the input transformer - on to the filter circuit - and from there on to the interstage transformer, before it hits the amp circuit.
So first thing: the filter circuit sits in between two transformers. One reason for that is the filter expects a certain load/impedance on input and output in order to work properly and sound amazing. And the trannys make sure these conditions are met.

Like some singers do sound amazing too, but also only work properly when loaded...uhm...I mean that's what I heard...you know - I mean I'm not really a singer...but that's a different story anyway...

Another reason is the signal in the filter circuit being unbalanced while the push-pull tube circuit of the make up amp needs a balanced signal. And the interstage transformer is taking care of that.

And finally the interstage transformer is a step-up transformer with a 1:2 ratio. Simply put that means a level increase.
But why is this necessary? Now we already heard those kinda things before *"...the filter is an attenuator", "make-up amp", "step-up converter"*... what the heck is going on here?!

Ok let's take yet another step closer - it's actually pretty simple.

WORKING PRINCIPLE

The working principle of a passive equalizer:
On the way in the signal is attenuated over the entire frequency spectrum by a certain amount (like a PAD).
In order to be able to boost frequencies in a passive design what we actually do is to set the controls in a way **certain frequencies are not affected by the attenuation as much as the rest** - and in turn appear as if they were being boosted.
If we try to use a similar graph to fig. 2 - maybe a little bit exaggerated it would look something like this:

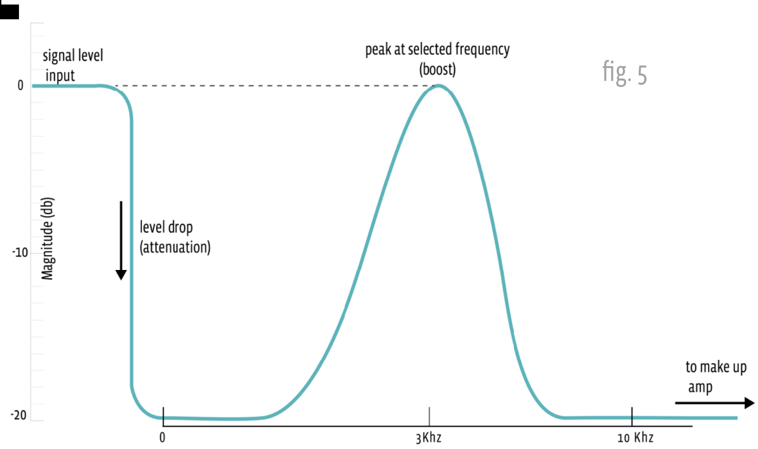


fig. 5

Beyond the myths

Of course if we used a passive filter equalizer like that the overall signal level would be extremely low - except for the boosted frequencies. **That's why we need the make up amp. And in case of the EQP-1A it's a push-pull tube amp that looks something like this:**

MAKE-UP GAIN

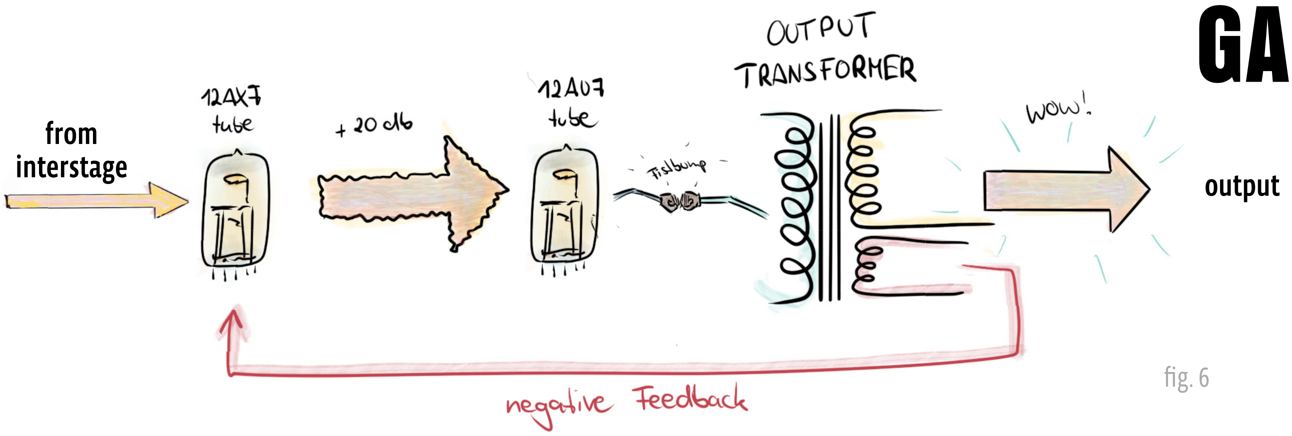


fig. 6

This part of the circuit is a negative feedback amplifier - somewhat similar to the LA2A, but still different.
The first tube stage is built around a 12AX7 tube which finally gives us back the long awaited missing 20db!

But even though we're almost there in terms of signal level, in regards to sound we're still lacking and we need an additional instance to make sure that distortion is at a minimum while the frequency response is awesome!
If you read my LA2A e-papers you know that in an LA2A there's a 12BH7 tube taking care of the negative feedback.

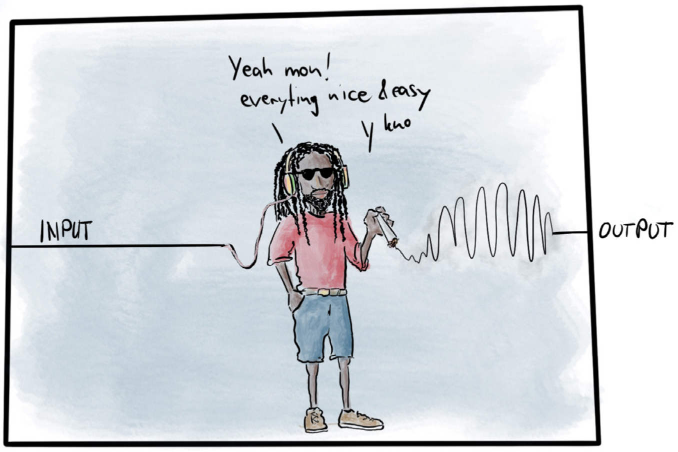
But in the EQP-1A design there's a 12AU7 - and it doesn't have to take care of the situation all by itself.
To prevent the 12AX7 from making a fuss the 12AU7 brought his homie - the big ass Peerless S217-D output transformer!

It's like the Notorious B.I.G. of output transformers and the 12AX7 knows that. But what the 12AX7 didn't expect that this output transformer not only has a primary and a secondary winding - but also a hidden tertiary winding (red) no one else has!
And through that third winding B.I.G. sends negative feedback to the 12AX7.

Of course the 12AX7 has a hell of a lot of respect and does absolutely all it can, to deliver nothing but pristine sound quality. And that's why the EQP-1A amp sounds so great :D

Ok so now we know the basic principle of the Pultec EQP-1A tube program equalizer and how a passive filter generally works.
But how exactly does it do its magic? What makes for that massive low end and these incredibly sweet highs?

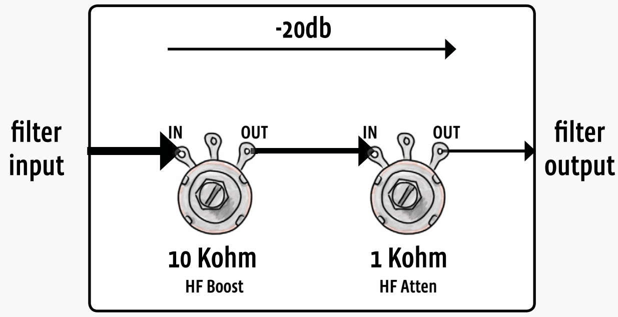
...INSIDE THE FILTER UNIT



...well, yes this guy seems like a plausible explanation for massive low end and sweet highs, but no - it's not him.

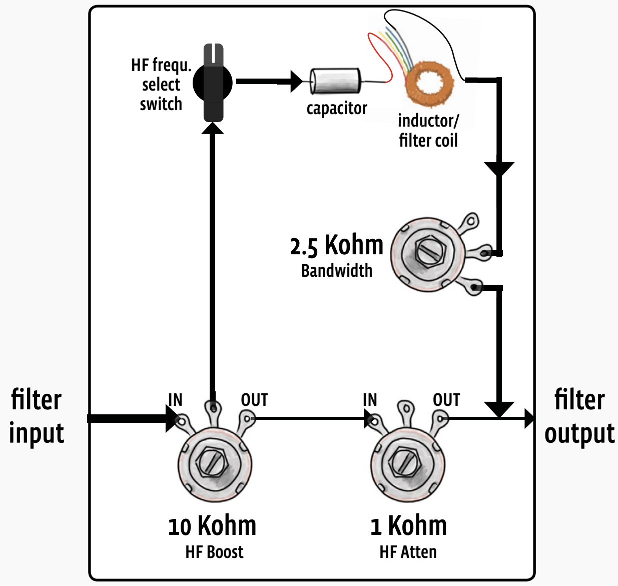
As stated before, the filter is a -20db PAD. Inside the filter box this pad is created by two resistors in series - namely the **10 Kohm HF boost pot and the 1Kohm HF attenuation pot.** And the pad is in the signal chain wether the filters are in bypass or not.

Just to get a better understanding the diagram on the right shows the signal flow through the EQP-1A filter with filters in **BYPASS**: The signal goes through the 10Kohm HF boost pot followed by the 1Kohm HF cut pot. On the way the signal level decreases by around 20db.



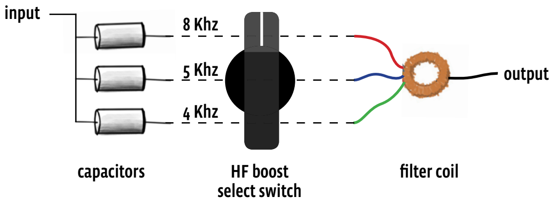
EQ bypass

Now let's activate the filters and go through the controls one by one starting with the HF BOOST:
By gradually turning up the HF boost pot an increasing portion of the input signal is going from the wiper of the 10Kohm pot to an array of **capacitors connected to an inductor (filter coil) through the HF boost select switch** - thus **bypassing the PAD to a certain degree**. (see diagram)



HF BOOST circuit

As we learned at the beginning the HF boost select switch on the frontpanel of the EQP-1a allows to choose from 7 peak frequencies going from 3Khz all the way up to 16Khz - so simply put, **all the switch does is connecting the signal with different capacitors in series with different wires of the filter coil:**

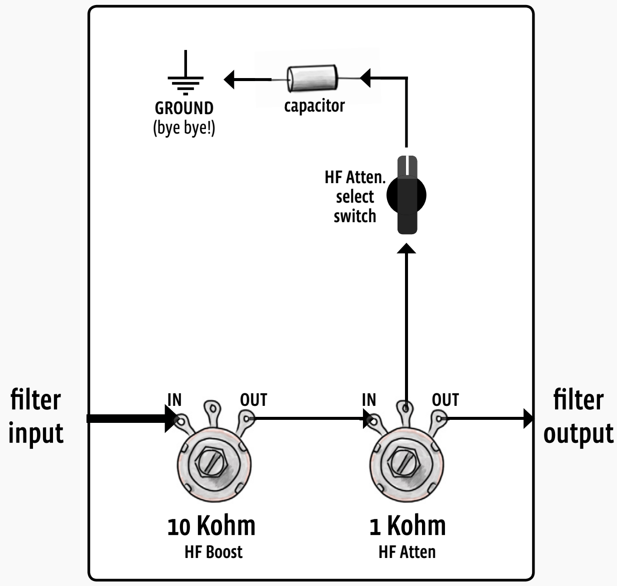


The technical term for that kind of array **is LC-filter** (L=inductor, C=capcitor). But the term is not really as important as **what it does: it has a low impedance at a certain resonating frequency** depending on which capacitor and which tap of the filter coil is in circuit.

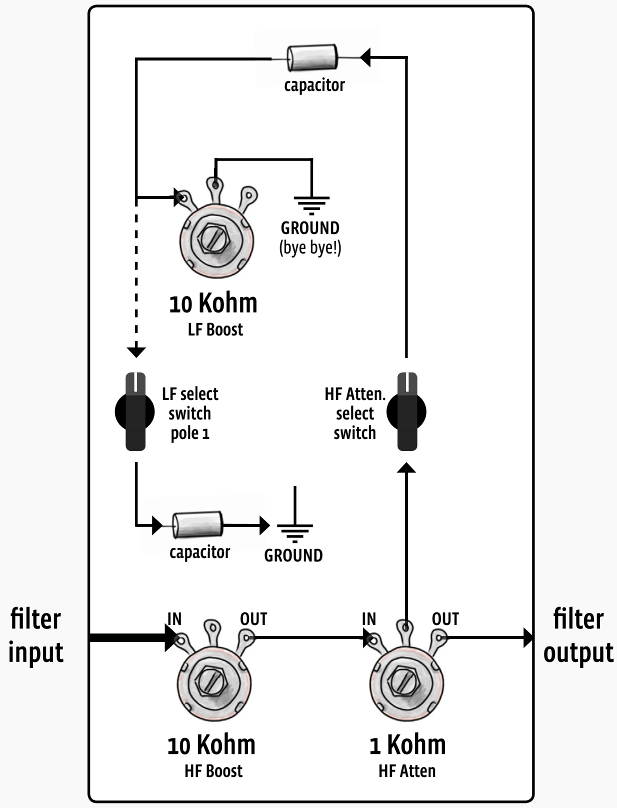
In short: depending on the setting of the switch it let's through certain frequencies easier than others so more of these frequencies make the bypass around our earlier discussed PAD and as a result appear louder -> **boost!**

As mentioned before the bandwith control (2.5Kohm pot) only adds resistance to the LC-filter so we can decide how narrow or how broad we want the boost to be. **Hoorayy!!**

FEEL IT IN THE ONE DROP...



HF CUT circuit



LF BOOST circuit

Let's move right on to the HF CUT circuit:
To some extent it's similar to the HF BOOST, only that the signal is taken from the wiper from the 1Kohm HF Atten pot. From there it's a lot easier: **The signal is sent to the HF Atten. select switch** which is connected to an array of 3 capacitors. Which in turn are going to ground on the other side.

And a signal going to ground means the signal is gone!

Depending on the value (capacitance) of the capacitor it let's everything above a certain frequency (cut-off frequency) pass through.
So only these frequencies go to ground, not the entire signal.

DO I HEAR THE PENNY DROP ALREADY? :D

Now that means the more we turn up the HF Atten. pot, the more of the signal is going to the switch, and depending on it's position the signal is forwarded to one of the 3 caps - respectively everything above 5Khz, 10Khz or 20Khz goes through the according capacitor to ground -> **HF CUT**.

Alright now - I have a confession to make folks.

It's not that I straight out lied to you, but I didn't tell you the whole truth...
...yeah so sorry shame on me!

But I swear I only did it so it's easier for you to understand!
And the truth is, the above mentioned caps are not directly going to ground...well at least not necessarily.

The big bad bass boost circuit has it's foot in the door and as soon as you turn up that LF Boost knob it will squeeze another array of capacitors in combination with the LF Frequency Select switch between the above mentioned HF capacitors and ground. (As long as the LF Boost pot remains at "0" these HF capacitors are directly connected to ground as explained before.)

What this does is gradually introducing a higher impedance to low frequencies (what frequencies exactly depends on the LF Select switch setting) **so these don't get attenuated by the resistance of the 1K pot as the rest does.**

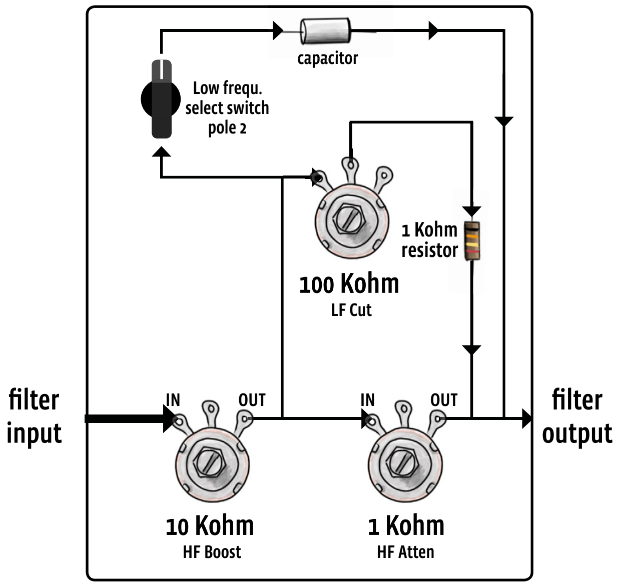
Again in short that means the more you turn up the LF Boost pot, the less of the low frequency content gets cut in comparison to the rest of the frequency spectrum. Following our logic from earlier on: less attenuation **in a passive filter circuit means BOOST!!**

...almost there

LAST CUT AIN'T THE DEEPEST

I hope you could follow me until here? I know it's very technical, but take it easy - you can always come back here and go through it once more. I don't think as a musician or engineer it's not vital to know every single detail down to the last capacitor - but I found it to be extremely helpful to have a solid understanding about how the gear I use actually works. If you're new here - most of that technical know how will come step by step as we proceed.
In regards to the EQP-1A we're almost there now...

To wrap it all up let's take a look at the LF Cut circuit. As explained earlier it shares the frequency select switch with the LF Boost section. To be precise it is a 2 pole rotary switch - the LF Boost section is connected to pole 1 while the Cut section is connected to pole 2.
Other then being controlled simultaneously by the same knob these are otherwise independent circuits.
Now - what do we have here:
If the 100Kohm LF ATTEN pot is turned fully CCW (to "0"), the signal is passed on straight through a 1K ohm resistor to the filter output.
If you look closely (diagram on the right) - that means that part of the signal goes through the exact same 10Kohm and 1Kohm in series as the rest of the signal.
You remember? Even in bypass everything goes through the 10Kohm (HF Boost) and 1Kohm (HF Atten.) pot?



LF CUT circuit

Right, so again in case of the LF Cut knob being turned completely down that portion of the signal is doing pretty much the same - only that the 1Kohm resistance is coming from that resistor pictured above instead of the 1Kohm pot.

By turning up LF Cut, more of the signal goes to the 2nd pole of the frequency select switch, which again is connected to an array of 4 different capacitors and from there it moves on to the output of the filter unit.
As we learned earlier the cap let's pass only frequencies above a certain cut-off frequency (depenending on cap value) so it actually is a **high-pass filter**.
In other words it blocks low end content...tadaa Low-Cut!

And why should the signal walk the extra mile to the switch, cap etc. instead of going straight through the 1Kohm pot to the ouptut? Because like some people I know, the signal is pretty lazy and always follows the path of the least resistance ;)

Ok folks, I hope that helped a little to get an idea of how the circuit works - next time we talk about how it's wired up...