Elliott Sound Products

Project 252

# 6-Band Guitar Equaliser

© May 2024, Rod Elliott (ESP) [1]

## Introduction

There are several guitar EQ circuits on the ESP site, and this adds another option. With six bands, the EQ provided is flexible, and the filters can be re-tuned if you have a particular requirement. The circuit was contributed by TruVAL (his nickname and preferred ID for the project). It's taken me a while to get to it, but hopefully readers will find it interesting.

The filters are multiple feedback (MFB) types, and are set for a gain of 3.33 and a Q of 1.3 (nominally 1.29). There's normally an extra resistor to ground for this type of filter, but it has not been included in this design. This is a perfectly valid (if unusual) configuration, which saves one resistor for each filter section. Saving a resistor doesn't seem like much of a saving, but in this case it means that the available frequencies are set only by selecting the capacitance, and all filters use the same resistance.

Anyone who's built a string of MFB bandpass filters (with close to exact frequencies) will know just how frustrating it is to have (say) eight filters, many with slightly different values. It's very easy to make a mistake! With the resistor values fixed, available frequencies are (roughly) based on the 1/12$^{th}$ root of 10 - that's how the standard E12 series of resistors and capacitors got their values. The ratio is 1.211, so we get the following ...

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Ideal** | 1.0 | 1.21 | 1.47 | 1.78 | 2.15 | 2.61 | 3.16 | 3.83 | 4.64 | 5.62 | 6.81 | 8.25 | 10 |
| **Actual** | 1.0 | 1.2 | 1.5 | 1.8 | 2.2 | 2.7 | 3.3 | 3.9 | 4.7 | 5.6 | 6.8 | 8.2 | 10 |

**Table 1 - E12 Resistor/ Capacitor Sequence**

While resistors are readily available in the E24 series (24 values per decade) capacitors are not. This means that the frequencies that can be used are also limited to 12 frequencies/ decade. In most cases this isn't a limitation, but it does affect this project unless you're willing to use paralleled caps to obtain specific frequencies. Given the intent of this project, there's no need unless you have a particular frequency that demands action.

## Project Description

A 'conventional' MFB filter is shown below, along with the modified version shown here. Normally the gain and Q can be separately selected, but the modified version doesn't allow that. The gain is set to 3.33 and the Q is fixed at just under 1.3. This is in contrast to the standard configuration where everything can be specified, and it will be accurate within the component tolerances used. Note that for the desired characteristics, a conventional MFB bandpass filter designed for a gain of 3.33 and a Q of 1.3 uses 1,383k (1.383MΩ) for R2, which is so high that removing it makes almost no difference. Once the values of R1 and R3 are 'rationalised' to standard values, we get the simplified version. The tuned frequency, Q and gain are almost identical. The gain is increased by 0.09dB with the simplified version, which can be ignored. Since R2 has been removed, R3 is re-numbered to become the 'new' R2.

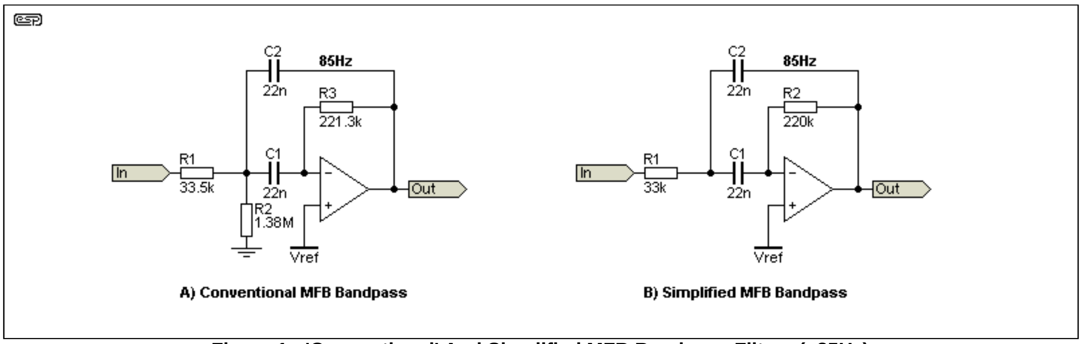


**Figure 1 - 'Conventional' And Simplified MFB Bandpass Filters (~85Hz)**

The circuit was originally published on a Russian guitar forum, but it's been re-drawn to match other ESP circuit diagrams. Project 64 (Musical Instrument [Expandable] Graphic Equaliser) was published in 2000, and it also uses MFB filters, albeit 'conventional'. This was essential for that project because it has 1/3$^{rd}$ octave frequency spacing, and the filters required unity gain.

The calculated (and simulated) frequencies for the filters shown is as follows ...

| Capacitance | Frequency | Capacitance | Frequency | Capacitance | Frequency |
|---|---|---|---|---|---|
| 47nF | 40 Hz | 6.8nF | 275 Hz | 1.0nF | 1,869 Hz |
| 39nF | 48 Hz | 5.6nF | 334 Hz | 820pF | 2,280 Hz |
| 33nF | 56 Hz | 4.7nF | 398 Hz | 680pF | 2,750 Hz |
| 27nF | 69 Hz | 3.9nF | 479 Hz | 560pF | 3,338 Hz |
| 22nF | 85 Hz | 3.3nF | 566 Hz | 470pF | 3,977 Hz |
| 18nF | 104 Hz | 2.7nF | 692 Hz | 390pF | 4,793 Hz |
| 15nF | 125 Hz | 2.2nF | 850 Hz | 330pF | 5,665 Hz |
| 12nF | 156 Hz | 1.8nF | 1,038 Hz | 270pF | 6,923 Hz |
| 10nF | 187 Hz | 1.5nF | 1,246 Hz | 220pF | 8,497 Hz |
| 8.2nF | 228 Hz | 1.2nF | 1,558 Hz | 180pF | 10,345 Hz |

**Table 2 - Capacitance Vs. Frequency**

The frequencies indicated by a yellow background are those used in the original project, but you can use any of those shown in the table. What you *cannot* do is add more frequencies to the circuit, because the opamp (U1A/B) will have difficulty driving any additional pots. Capacitance below 150pF (12,462 Hz) is not recommended, because stray capacitance will play havoc with the tuning. The formula for determining frequency is shown in the Conclusions section if you want to play with other values. You *can* use unequal capacitor values, but that will just make your life miserable. If you enjoy a bit of misery, I leave this as an exercise for the reader, and I'm not even going to try to determine a formula or provide more details. If you want to try that you're on your own.

The simplified filter is harder to tune accurately than the conventional version because we lose one 'degree of freedom' by omitting a resistor. However, as you can see from the table, there are plenty of frequency choices just by changing the two caps (which should *always* be the same value or it gets weird). The limitation is that the gain is fixed, in this case to 3.3 (just over 10dB). Strictly speaking, the gain is -3.3, because the MFB topology is inverting. I admit that I hadn't seen this arrangement before. One thing that I expected is that the tuned frequency changes (a little) depending on the pot position, due to additional resistance at the input of the filter. The frequency shift will be (just) measurable, but not audible. The calculated and simulated frequencies are slightly different, but this is unlikely to cause much grief. For example, the '400Hz' filter calculates to 397Hz, but simulates as 388Hz (a bit over 2% error).

The frequencies available by just changing caps don't align with any of the standard equaliser frequencies. For a 1/3$^{rd}$ octave EQ, the interval is 1.26 (cube root of 2), or 1.414 (square root of 2) for half-octave divisions. To get the frequencies to align with the industry-standard intervals, you have to change resistors and capacitors, or use paralleled caps to get the 'proper' (i.e. industry standard) frequencies. With the values shown, the frequencies are spaced at an interval of between 1.1 to 1.2 octaves. If you wanted 'true' 1 octave spacing you'll need to use paralleled caps, because the standard values don't include 2:1 spacing for any value.

There's no point going above 5kHz with (electric) guitar, as there's very little of any interest beyond that. For bass, you might want to include a 40Hz filter, but you'll probably have to 'lose' a frequency band as more than six filters will be too hard for the opamp (U1) to drive. If U1 is an NE5532 (or OPA2134) you can probably add a couple of extra frequencies, because these opamps can drive lower impedances. A minimum supply voltage of 12V is suggested whatever opamps you use.

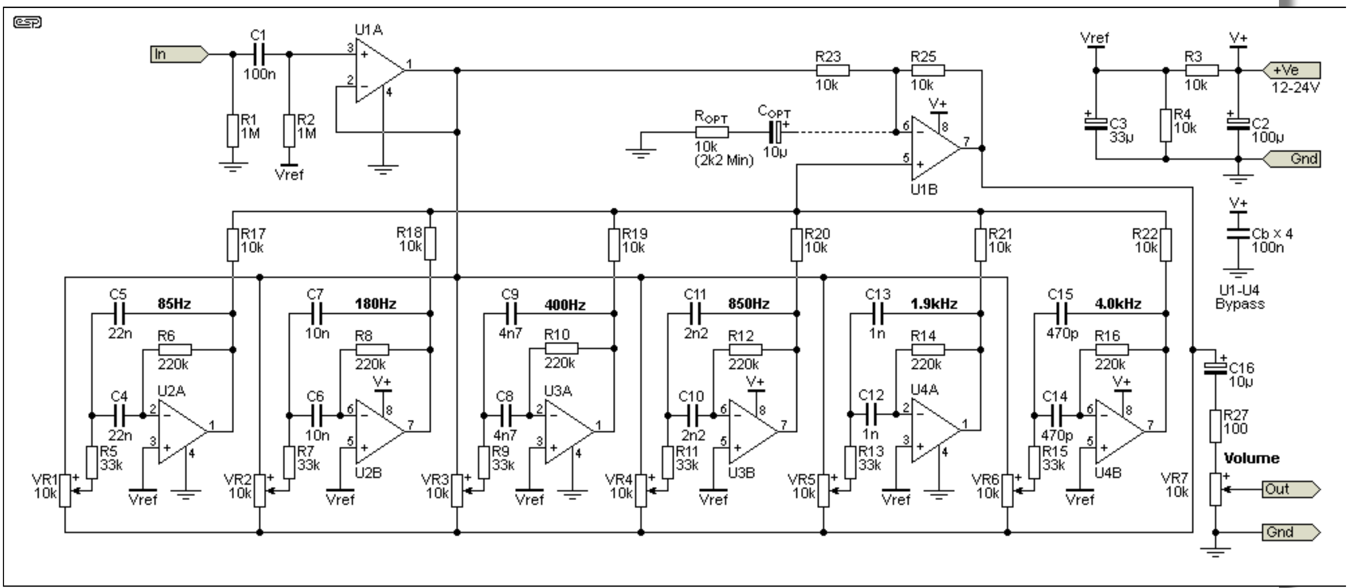

**Figure 2 - Full Schematic Of 6-Band Equaliser**

The circuit has an input buffer (U1A) that drives one end of the tone pots, and an output amplifier that sums the filter outputs and drives the other end of the tone pots. When the pot wiper is at maximum (+ on the pot symbols), the signal at that frequency is boosted and vice versa. If all pots are set for maximum boost, the mid-frequency gain is 8dB, with -3dB at 50Hz and 6.7kHz. If a single frequency is boosted, the peak gain is about 2.2 (7dB). The amount of boost/ cut can be increased to 10dB by adding $R_{OPT}$ and $C_{OPT}$. The lowest value I recommend is 2.2k, and the value of $C_{OPT}$ needs to be around 10µF, which will work for any resistance. If $R_{OPT}$ is 2.2k, the maximum boost and cut is increased to 16dB, or 10dB for a single frequency. $R_{OPT}$ could be made variable, but I doubt there's much point.

The suggested supply is a single 12-24V DC supply, with the network of R3, R4, and C3 forming a ½ voltage reference. If you prefer, you can use a ±12 or ±15 volt supply. That means that Pin 4 of each opamp goes to the negative supply instead of ground, and all connections to '$V_{ref}$' are grounded. While the circuit *can* be operated from a 9V supply, you'll have limited headroom, especially with guitars with 'hot' pickups.

The circuit was originally specified to use TL074 (quad) opamps, but as most readers will be aware I rarely recommend them. The range of suitable dual devices is much greater, and they're easier to wire on Veroboard. Provided the supply is 12V or more, TL072 opamps can be used, or you can use RC4558 opamps if you prefer. The latter will work with a 9V supply. The TL07x series might or might not work with a 9V supply - it's not a guaranteed parameter (the minimum suggested is 10V).

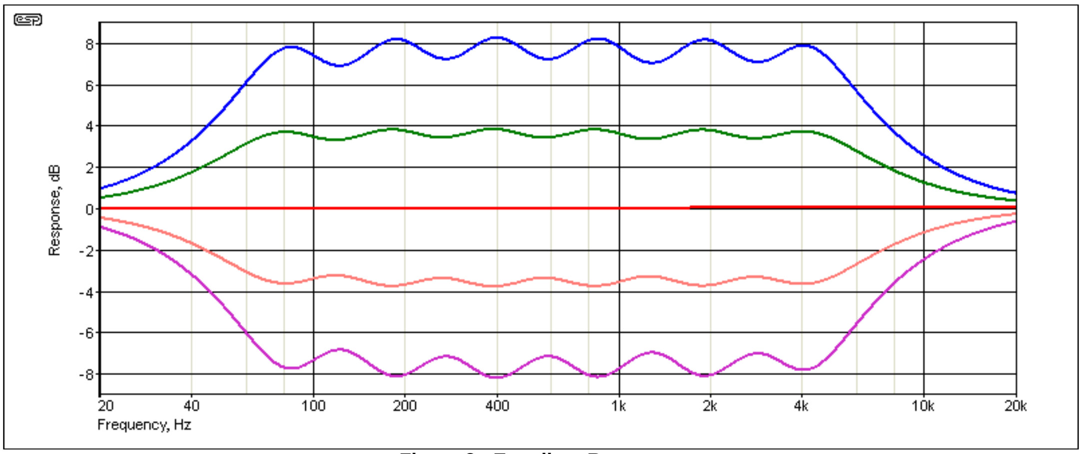


**Figure 3 - Equaliser Response**

The response is shown with all controls advanced/ retarded by the same amount, in 25% steps. $R_{OPT}$ is not installed for the graphs shown. There are far too many possibilities to show every combination, but this gives a reasonable overall impression of what can be achieved. The boost and cut are limited to about 8dB, but this should be more than sufficient, as the circuit will be used along with normal tone controls, providing a very wide range of EQ.

---

### Power Supply Considerations

Be aware that all modern plug-pack ('wall-wart') supplies are switchmode, and many are configured to operate at very low input power when unloaded. This is usually done by using 'skip-cycle' operation, so the supply may only switch at a low frequency (which may be as low as 200Hz or so). This causes a great deal of audible noise that is very difficult to remove with a filter. If you get a lot of noise with a plug-pack supply, this is the reason. There doesn't appear to be any way to defeat this, other than ensuring that the project draws enough current for the supply to operate normally. You may have to draw 100mA or more from a 'typical' 12V, 1A supply (i.e. at least 1.2W) to ensure 'normal' switching. A 120Ω, 5W resistor can be used, mounted well away from heat-sensitive parts (ICs, electrolytic caps, etc.). Some supplies may need you to draw even more current, which becomes a real nuisance.

Of course you can build a linear supply, with a mains-frequency transformer, rectifier, filter bank and regulator. This will be a great deal quieter (electrically), but it will be bigger and cost more. This isn't always a deal-breaker though, and the P05-Mini is ideal for the task. A suitable PSU can easily be assembled on Veroboard, especially if only a single 12V supply is needed.

---

### Conclusions

This is an interesting project, and the minimalistic MFB filter is worth remembering. Unfortunately, devising a formula for it wasn't so straightforward without some lateral thinking. The 'standard' MFB filter is a can of worms to calculate, but the simplified version initially proved resistant to my attempts to devise a sensible formula. It's easy enough if you simply follow the values in the table above, but that only works for a limited number of frequencies.

The formula I worked out is based on the standard MFB bandpass calculation, with the 'missing' resistor (normally R2 to ground) replaced by a high value that has little or no influence on the calculation. If you use the formula, be very careful with brackets, as a misplaced bracket will cause large errors. The default value of 'k' is 10MΩ but it can be increased to 1GΩ if you prefer. The difference is inconsequential. The final accuracy of the calculated frequency depends mostly on the tolerance of the capacitors (resistors should be 1% metal film).

> k = 10MΩ
> f = 1 / ( 2π × C ) × √ (( R1 + k ) / ( R1 × R2 × k ))        For example ...
> f = 1 / ( 2π × C ) × √ (( 33k + k ) / ( 33k × 220k × k )) = 85Hz

The gain and Q of the simplified MFB bandpass filter are set by R1 and R2, and they can't be changed independently as that will affect gain and Q. That leaves only the capacitance as a variable. If R1 and R2 are changed by the same amount (both increased or both decreased using standard values), you get a bit more flexibility for frequency, but the ratios of E12 resistors means that an increase to (say) 39k and 270k with 22nF provides almost identical performance to using 33k and 220k with 27nF. The gain and Q remain the same, but the frequency is reduced to 70Hz (within 2Hz with exact values).

The complete set of formulae for a standard MFB bandpass filter is shown in Project 63, but it's much easier to use the small program I wrote to do the maths for you (mfb-filter.exe). The program actually works with the simplified version, but you must include R2 as being at least 10MΩ (10000 - resistor values are assumed to be in kΩ). If you calculate the resistors (gain of 5 [just to be different], Q of 1.3) R2 will show up as a *negative* resistance. This won't work in the calculator program, but it does work if you use the full formula in a calculator or spreadsheet. Using the above formula, the calculation will be accurate to better than 1%.

As with so many other ESP projects and articles, this is as much about giving people ideas as it is a project in its own right. I'm firmly of the opinion that you can never have too many new (if only to you) ideas to play with. Where the frequencies are not overly critical, the simplified MFB filter works well, and is sufficiently interesting to warrant your time to evaluate it. A simulator will give good results, and lets you play around with different values to see the effects.

---

### References

The only 'real' reference is the original information that 'TrueVAL' sent back in 2021, and copyright on the schematic extends to him as well. (It's taken me a while to get this completed.) The project article Project 64 and the article on Active Filters were also used, along with the MFB bandpass filter calculator that I wrote some time ago.

---

---

**Main Index**

**Projects Index**



Change Log: Page Created and © Rod Elliott May 2024.