ELECTRONOTES

WEBNOTE 59 10/17/2019

ENWN-59

More on Cascading Identical Bandpass

-by Bernie Hutchins

Since the posting of the finding (previous Webnote – ENWN-58) pointing out that the cascading of identical bandpass only enhances Q by a modest factor of 1.5537 a number of items have occurred.

First, I was unable to find any writing concerning my belief* that I did a calculation years ago (at least an experiment, perhaps) to the same general result.

Secondly, I did continue to look for any confirming results on the web. I found a tiny bit at:

https://electronics.stackexchange.com/questions/245552/four-order-filter-bandwidth-and-the-two-order-fileter-bandwidth-is-same

(Incorrect spelling is part of correct title/URL !) The relevant result is seen in the material delineated by the lines of stars on page 2 below. It appears to be a simple question/answer offering, and does indicate the enhancement of 1.55 for two cascaded filters. Good. It does not, however, provide a theoretical derivation of the result (1.55) or offer a reference to any related information. Bad. Back to the positives, it offers MORE than the requested result, a table giving the enhancements for cascades of from 1 to 5. If the method offered in ENWN-58 is valid, and we apply it to more multiple cascaded, do we duplicate not just the 1.55 value, but the other ones in the new table?

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I have a two-order bandpass filter, the fc = 10k, bandwidth = 2k. Is the bandwidth changed, if I use this to make a four-order bandpass filter ? if No, why the image

Table 5. Cascading Identical Bandpass Filter Sections

TOTAL SECTIONS	TOTAL BW	TOTAL Q	Q
1	1.000 B	1.00 Q	1.0000
2	0.644 B	1.55 Q	1.5538
3	0.510 B	1.96 Q	1.9615
4	0.435 B	2.30 Q	2.2990
5	0.386 B	2.60 Q	2.5933
6			2.8576
7			3.0995
8			3.3240
9			3.5342
10			3.7327
50			8.4638

filter

share improve this question

asked Jul 12 '16 at 3:04

tommy

26 ● 1 ● 2

closed as unclear what you're asking by uint128_t, Bence Kaulics, Daniel Grillo, Sparky256, Voltage Spike Jul 13 '16 at 17:31

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Added to the table are the numbers in red which are my own added calculations. Note that my values agree with the ones from the link for n = 1 to 5. I have added my calculations for n = 6 to 10 beyond those in the table, and for kicks, for n=50. The modest progress when viewed in terms of Q-enhancement remains evident. A bit more on this later.

It was no chore to calculate the enhancements noted here – a few lines of Matlab code which do little except set up and solve a quadratic equation (as in ENWN-58). The program that did this is below. In fact, only the last 10 lines are used in this note – the bulk of the program produced the figures of ENWN-58.

```
omega=0:.001:3  ;
omega0=1
Q=3
QE=3*1.5537

T2=(omega0^2 - omega.^2).^2;
T2=T2 + (omega0/Q)^2.*omega.^2;
T2=omega0^2*omega.^2 ./ T2;
T2=T2/(Q^2);
T3=(omega0^2 - omega.^2).^2;
T3=T3 + (omega0/QE)^2.*omega.^2;
T3=omega0^2*omega.^2 ./ T3;
T3=T3/(QE^2);
T3=T3.^(1/2);
T=T2.^(1/2);
plot(omega,T2,'k')
hold on
plot(omega,T,'r')
plot(omega,T3,'c:')
plot([0  3],[.7071 .7071],'b')
hold off
grid



%  choose n =  number of stages
          n=5
n=n/2
n=1/n
 C=1/(sqrt(2)^n)
 C=1/C
P=[1, -(1+C), 1]
R=roots(P)
SR=sqrt(R)
B=SR(1)-SR(2)
QENHANCED=1/B
```

All the above suggests that cascading is not an effective method of sharpening (increasing – in the conventional sense of Q). Is something different apparent if we consider how very effective the cascade was in reducing the "skirts" rather than sharpening in the immediate vicinity of the center frequency. Perhaps the "Q" is not the most appropriate performance parameter for all bandpass instances. In fact, we may face a situation of having a bandpass that is so sharp it is largely invisible to a usual steady-state frequency response measurement (like Q=1000, although it "rings" like crazy in the time domain of course). That is, the sharper the response the harder the filter is to tune at all.

A SynthDIY member (Guy McCusker in a personal email to me on 9/11/2019) made a similar point. He noticed that when we speak of "Q" we may well need to recognize that it applies strictly only to second-order. We CAN always talk about a center frequency divided by a half-power-bandwidth as a meaningful measure. But to insist that it be called "Q" (except in 2^{nd}-order where, by strict mathematical relationships, it DEFINES Q) is nebulous. Good point.

We do get by with speaking generally of a "high-Q filter" as whatever we have that is seen as being "sharp".

Further, we may speak of an INDIVIDUAL pole is being high-Q (regardless of how that pole participates in an overall frequency response. In so characterizing an individual pole, we often speak of a Q and of a corresponding "damping" D=1/Q, where D is minus the real part of the pole divided by the pole radius. Hence a pole that is RELATIVELY closes to the jω-axis (having more influence on the filter's response) is considered lightly damped and high in Q.

* HERE IS MY ORIGINAL SynyhDIY Post:

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Wed Sep 11 04:58:33 CEST 2019

- Previous message (by thread): [sdiy] LC delay lines and scanner chorus/vibrato taps
- Next message (by thread): [sdiy] Roland's cross mod and metal sync
- **Messages sorted by:** [date] [thread] [subject] [author]

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A week ago (Vocoder thread), I said, based on my memory of examining the notion many
years ago, that the idea of cascading two identical BP filters to sharpen Q was
distressingly slow.

If I wrote this up in the distant past, I can't find it.   Anyone?

I did it again:

http://electronotes.netfirms.com/ENWN58.pdf

and found cascading multiplies the original Q by 1.5537, for all Q.   Did I make a
mistake?

Nice-looking bandpass - just not much sharper Q-wise.

Bernie
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