

## **Abstract: “All-Pass Phase-Filtering in Analog Active Band-Pass Circuits”**

**We present an experimental study  
of original design Analog Phase-Filters  
emphasizing the “ALL-PASS” filter  
and comprised of :**

- (a) Parallel-Channel-Differential Filters**
- (b) All-Pass Filters**
- (c) Differentially derived Dual-Notch filter**

**This project provides near DSP narrow filtering characteristics,  
narrow band-width, without computer processing.**

**This project’s modules include :**

- (a) Pre-Amp with OV limiter**
- (b) Triad-Roofing-Differential Filters**
- (c) Active Log-Limiter**
- (d) All-Pass Filters,**
- (e) Phase-Filtered Non-Resonant Dual-Notch stage**
- (f) Delyannis Narrow band-pass filters,**

**This project has applications which include**

- (a) Narrow Passband Audio Filters for Radio Operations**
- (b) Laboratory Analog Instrument filters “stand-alone”.**

This “AFC” project was developed to explore **All-Pass Filters**  
and is the continuation of the author’s previous project “AFX”  
and produced via the PartSIM.com browser based Simulator.

See “RGN” presentation of “AFX” at :

<https://www.researchgate.net/post/Are-there-any-Analog-Active-Audio-Filters-that-match-any-Digital-Signal-Processing-filters>

This paper presents an experimental project  
produced via the PartSIM.com browser based ngSPICE Simulator,  
in our lab as posted on our website, and as posted on ResearchGate.Net,  
during 2014 thru 2021.

Reference analysis for modules in “AFC” are written in our previous “AFX” project.

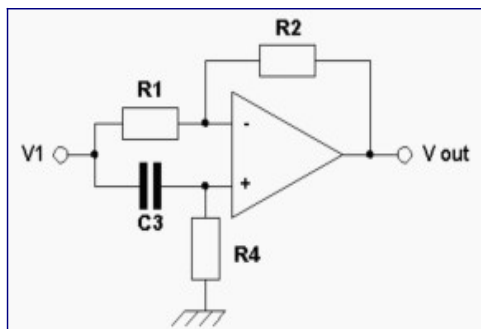
**All concepts presented herein are common to Active BandPass Filters as presented in tutorials and academic course-work presented for Electrical Engineering students.**

**ONLY the SYNTHESIS of common ideas into radically new approaches is different.**

Some All-Pass Filter Theory from common Electrical Engineering textbooks :

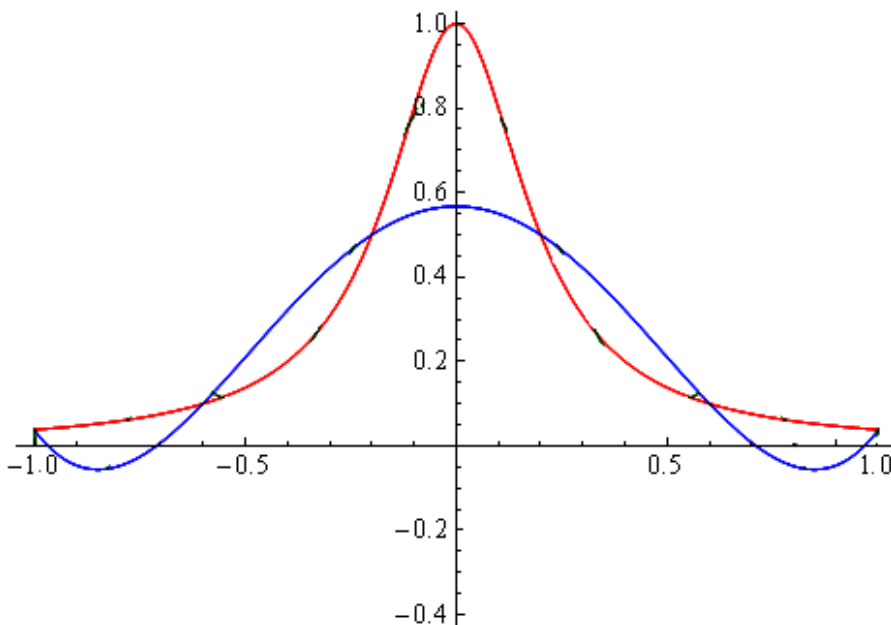
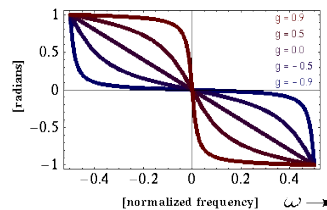
An *all-pass filter* is a signal processing *filter* that *passes all* frequencies equally in gain, but changes the phase relationship among various frequencies. Wiki

All-Pass Filter via LaPlace Transform :  $H(s) = [(n1(s)/d1(s)] + [n2(s)/d2(s)]$



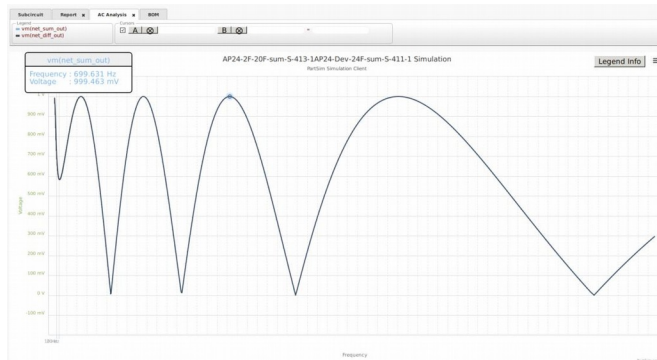
First-Order Allpass Phase Response (let  $g = r e^{j\theta}$ )

$$\Theta(\omega) \triangleq \angle H(e^{j\omega}) = -\omega - 2 \tan^{-1} \left[ \frac{r \sin(\omega - \theta)}{1 - r \cos(\omega - \theta)} \right]$$

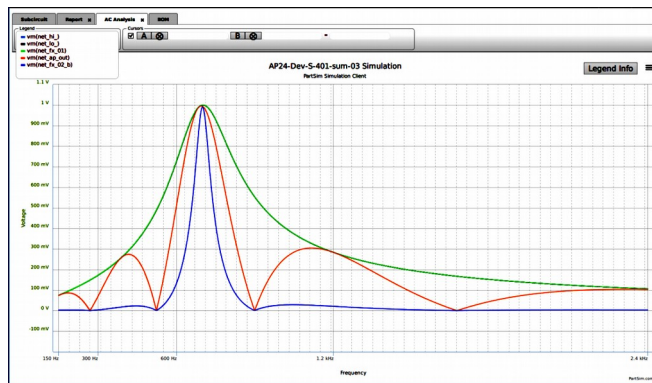


**“The AFC / AFC  
”Differential Dual Notch”  
can be developed  
at the points  
where these  
two waveforms  
cross-over.**

\*\*\* We have developed working **Dual-Notch Band-Pass** circuits which emphasize the **All-Pass Filter** elements in “LoPass and HiPass combined” circuit configurations .



\*\*\* Raw All-Pass Bode\*\*\*  
All-Pass Filters in a lattice network.  
(example of All-Pass Bode as used in the AFC circuits)



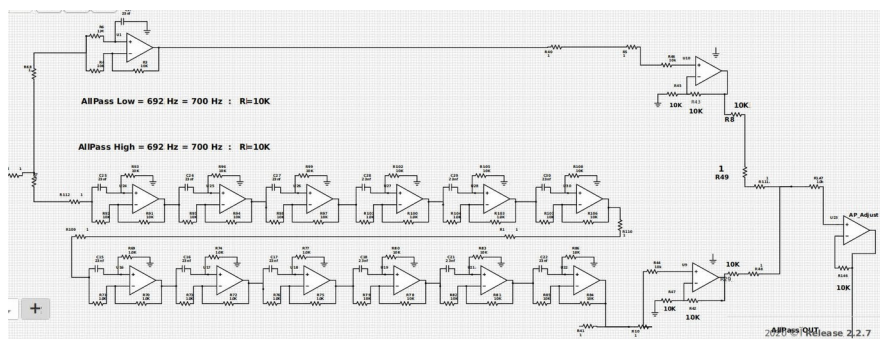
\*\*\* Bode Plot \*\*\*  
All-Pass driven through several stages of Resonant MFB filters.  
(example of “AFC” circuit. Major Vout signals )

\*\*\*\*\*  
\*\*\* **AFC Project Begins** \*\*\*\*\*  
\*\*\*\*\*

## The "All-Pass" Band-Pass Filter

We examine this All-Pass Phase-Filter circuit :

Circuit #1  
AFC lattice core  
1 Lo-Pass  
and  
12 Hi-Pass



The All-Pass filter has **frequency responses** which **must be zero at  $w=0$  and at  $w=\pi$ .** [wiki](#)

All-Pass Filter via LaPlace Transform :  $H(s) = [(n1(s)/d1(s)] + [n2(s)/d2(s)]$

The principle is ... adding signals with the same amplitude and different phase. For a phase shift of  $180^\circ$  ( $+ 360^\circ$ ;  $+ 720^\circ$ ; ... etc.) we obtain a minimum of transmission. (Dr. Josef Puncochar, VŠB-Technical University of Ostrava)

Calcs for the All-Pass components at  $f(0)$  :  $f = 1 / (2 \pi) ( R2 ) ( C3 )$   
Original design was for all  $f()$  to be 700 Hz. :  $R = 10 \text{ K Ohm}$ .  $C = 23 \text{ nF}$  .

Circuit #1: Revised  $f(600)$  in order to align the 'zero' frequencies closer together.  
 $f = 600 \text{ Hz}$   $R = 12.1 \text{ K Ohm}$ .  $C = 22 \text{ nF}$  .

Circuit #2: Revised  $f(677)$  in order to align the 'zero' frequencies closer together.  
 $f = 677 \text{ Hz}$   $R = 11.1 \text{ K Ohm}$ .  $C = 22 \text{ nF}$  .

\*\*\*\*\*

This paper presents the experimental development of two unique original circuits emphasizing All-Pass-Filters .

Presented here are the CURRENTLY PREFERRED versions. Certainly we have developed other topologies but these are two good examples.

**Circuit #1** is a narrow Band-Pass Audio Filter

**AFC\_1R-1A-12A-2F-Sum**

which includes filter designs with these characteristics:

- ... Based on the All-Pass Filter group
- ... Parallel-Channel Differential Filters as a Roof-Filter
- ... All-Pass Filter stages for multiple w/0 signal lobes
- ...  $f(0)$  Revised to  $f(600)$  in order to align the 'zero' frequencies closer together.  
 $f = 600 \text{ Hz}$      $R = 12.1 \text{ K Ohm}$ .     $C = 22 \text{ nF}$  .
- ... Summing **Phase-Filter** for Dual-Notch at +/- 200 Hz of  $f(0)$
- ... driving Final Hi-Q MFB filters  
(Details on schematic #1 )

**Circuit #2** is a narrow Band-Pass Audio Filter

**AFC\_3R-2F-8A-Dif**

which includes filter designs with these characteristics:

- ... Based on the Basic 'AFX' design
- ... Parallel-Channel Differential Filters as a Roof-Filter
- ... All-Pass Filter stages for multiple w/0 signal lobes
- ...  $f(0)$  Revised to  $f(677)$  in order to align the 'zero' frequencies closer together.  
 $f = 677 \text{ Hz}$      $R = 11.1 \text{ K Ohm}$ .     $C = 22 \text{ nF}$  .
- ... Differential **Phase-Filter** for Dual-Notch at +/- 200 Hz of  $f(0)$
- ... driving Final Hi-Q MFB filters  
(Details on schematic #2 )

\*\*\*\*\*

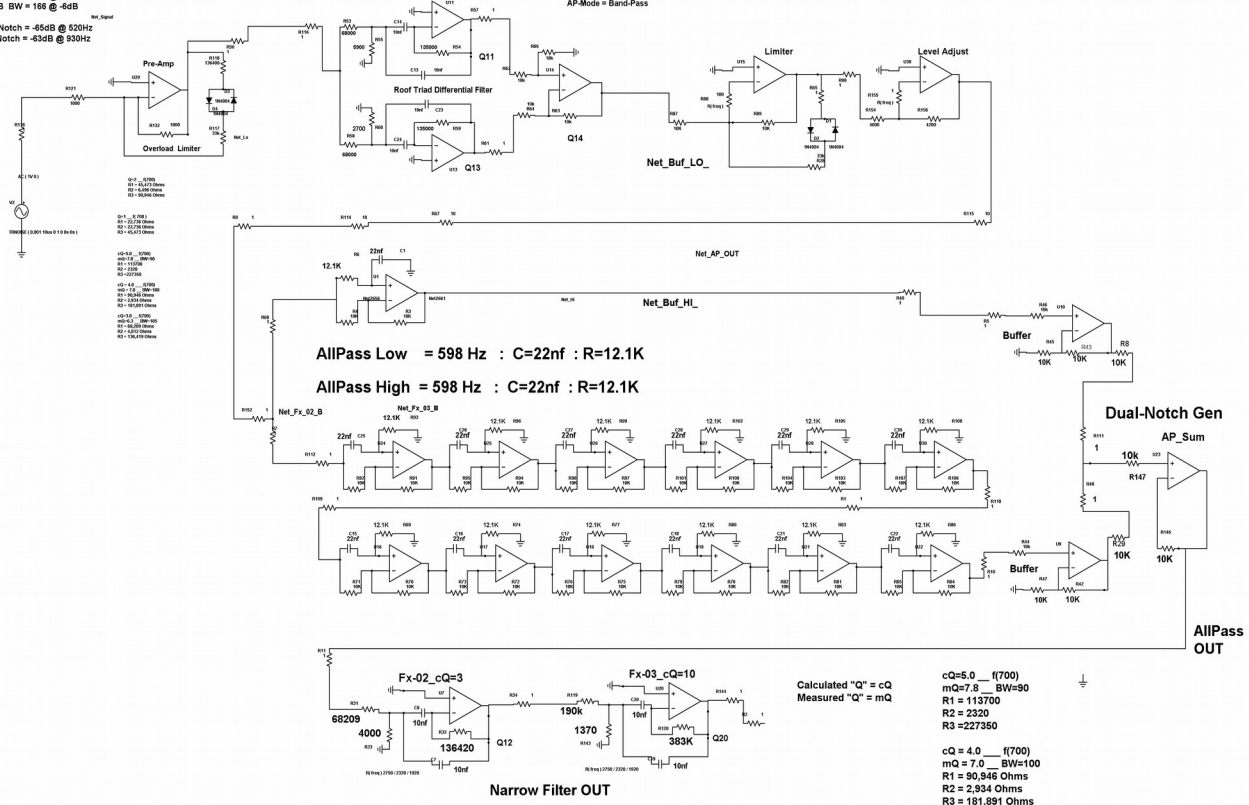
# Circuit #1 : AFC-1RL-1A-12A-2F-Sum

## AFC\_1R-1A-12A-2F-Sum-S-451-1-211003-1930

All-Pass BW = 138 @ -3dB  
 All-Pass BW = 192 @ -6dB  
 AP Lo Notch = -60dB @ 520Hz  
 AP Hi Notch = -58dB @ 530Hz  
 Fx-02-B BW = 118 @ -3dB  
 Fx-02-B BW = 168 @ -6dB  
 Fx Lo Notch = -45dB @ 520Hz  
 Fx Hi Notch = -43dB @ 530Hz

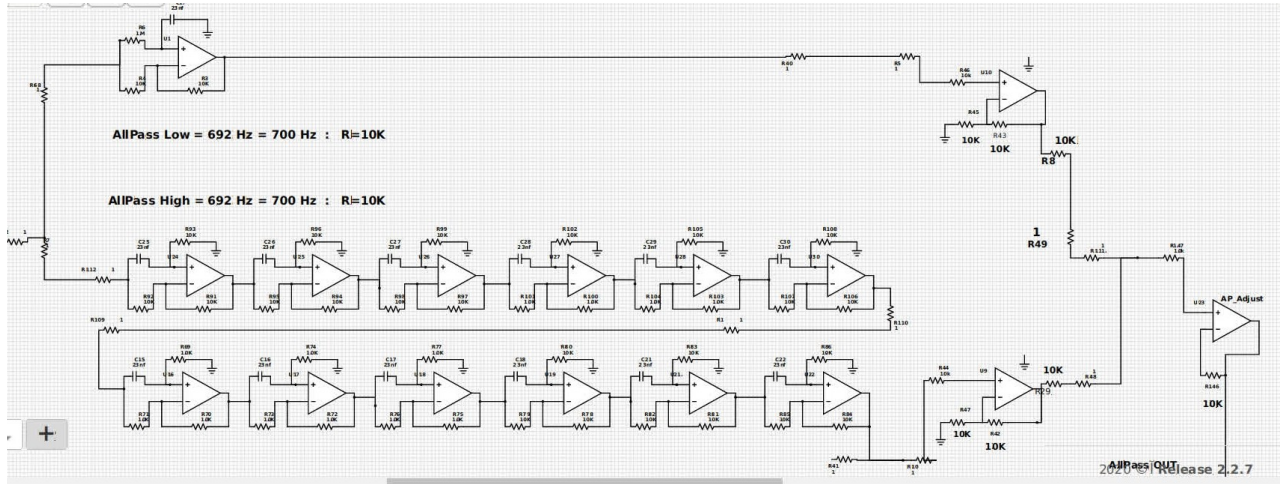
Design Format:  
 PreAmp=1  
 Roof=1  
 Limiter = 1  
 Filter Stages Pre = 0  
 All-Pass = 24 parallel  
 Filter Stages Post = 2  
 AP-Mode = Band-Pass

ResearchGate.Net ,  
 Glen Ellis : Univ Tennessee, Memphis, TN ,  
 Mark Sitkowski, Ph.D. Design Systems Ltd., Australia,  
 Joseph Puncocar, Prof, VSB-Technical University of Ostrava Czech .



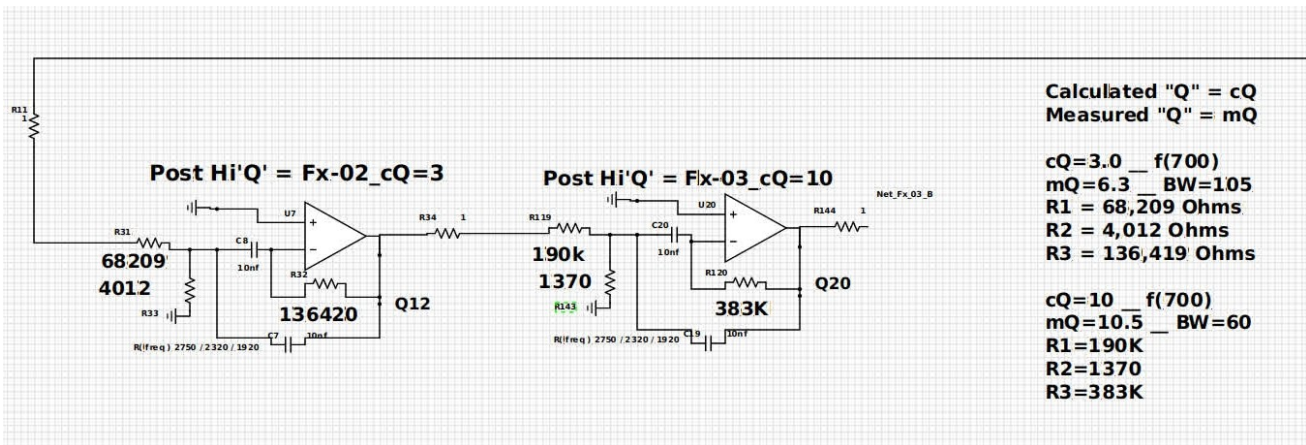
## Detail of Circuit #1 : example : All-Pass general schematic

All-Pass module generates Dual-Notches :  
 The All-Pass-Low and the All-Pass-Hi are Buffered and Summed  
 to generate the Narrow Dual-Notch Pass-Band. .

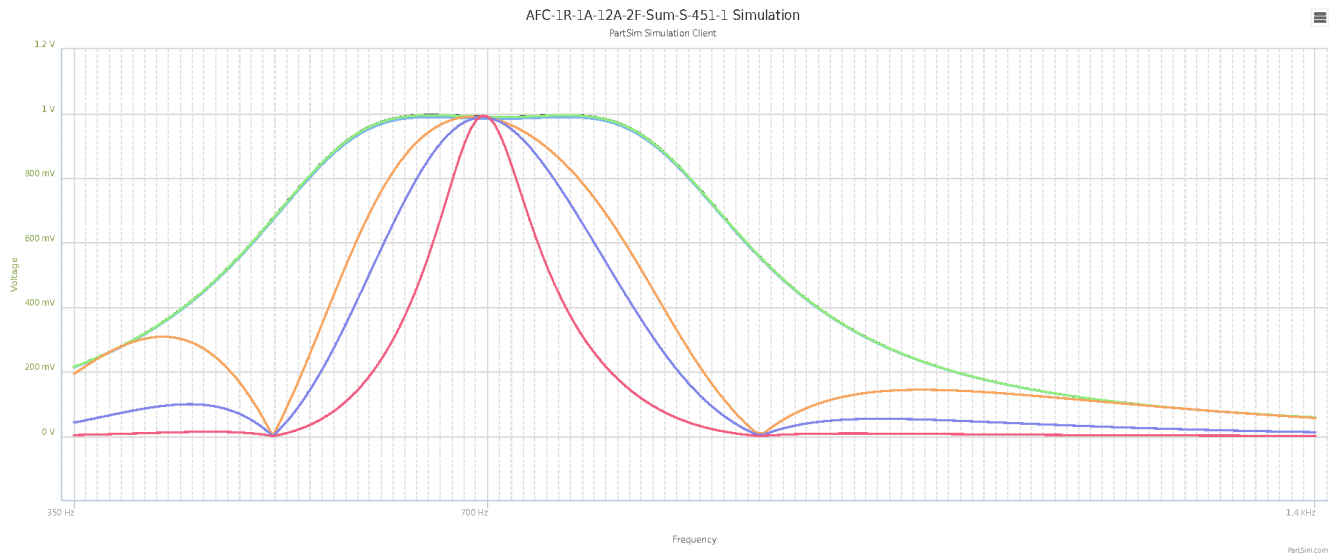


Dual Notch Bode Plot is generated from this Phase-Filter stage.

Below: example Detail:  
 Hi 'Q' Filters sharpen the Band-Pass inside of the Dual-Notches :  
 Resonant MFB Post-Filters  
 are for producing an enhanced Narrow Band-Pass.



## Bode Plot : Circuit #1



### Bode Plot : **f(0) is 700 Hz.** ###

### The flat-topped **GREEN** trace is the "Roofing-Filter" which precedes the Limiter circuit, ( Notice the -27 dB per Octave attenuation of side-band signals, outside of BW=350Hz. )

\*\*\* **ORANGE** trace is the Dual-Notches around f(0)

\*\*\* **BLUE** trace is the first MFB filter, with 150 Hz Band-Pass.

\*\*\* **RED** trace is the final MFB filter, with 35 Hz Band-Pass.

\*\*\* Notice: **Fx-02 Q=3** and **Fx-03 Q=10** are for narrow Band-Pass, inside of Dual-Notches.

\*\*\* **ORANGE** trace is AllPass circuit final V(output)

\*\*\* Scale : 700mV = -3dB ; 500mV = -6dB

\*\*\* Notch High 900 Hz = -53 dB

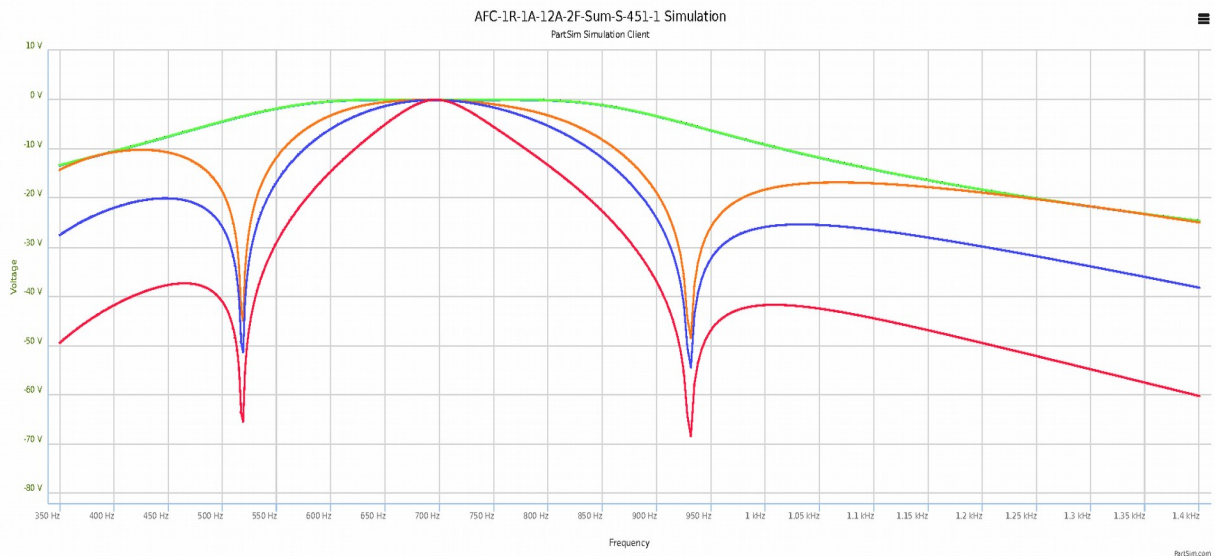
Notch BW = 100 Hz @ -3 dB

Notch BW = 360 Hz @ -53 dB

Variance = 5.2 Hz sideband expansion per -dB attenuation which is analogous to the DSP "brick-wall" effect.



## Magnitude Plot : Circuit #1



**ORANGE** trace is basic AllPass Output plot.

\*\*\* **RED** trace is final Q=20 result

\*\*\* **f(0) Shifts** are confined within the **ORANGE** AllPass Output plot.  
( approx DSP "**Brick-Wall**" )

\*\*\* **Magnitude Scale readings : V = -dB**

\*\*\* Scale : 700mV = -3dB ; 500mV = -6dB

**Notch BW = 100 Hz @ -3 dB**

**Notch BW = 360 Hz @ -53 dB**

**Variance = 5.2 Hz sideband expansion per -dB attenuation**  
**which is analogous to the DSP "**Brick-Wall**" effect.**

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# Circuit #2 : AFC\_3R-2F-8A-Dif

## ### Special Advanced All-Pass Band-Pass circuit combining AFX and AFC concepts.

### AFC-F8AFQ-S-432-1-210917-1113

**Purpose 1:** Develop Narrow Band-Pass Filter (Notch) with Notch at 510 Hz and 890 Hz  
**Overall Design:** to provide simpler Variable (f0) adjustment by user.  
**Design decision:** to use All-Pass was to replace two MFB Band-Pass Filters which would require two more R(freq) for a total of 4 R(freq) pots, not matching each other, and not controlled by a Dual-Pot of 4K center. If only 2 R(freq) are required, then a Dual-Pot of 4K can control (f0) adjustment.  
**Method:** Emphasis on use of All-Pass Filters to replace two MFB Resonant H-Q Band-Pass Stages, in order to have only two R(freq) of same value for variable (f0) user adjustable (f) tuning. In order to use only one Dual-Gang Pot 4K center to control (f0).  
**Format:** Combine AFX and AFC design parameters.  
 Two MFB filter stages are needed with 8 All-Pass Filters of All-Pass to align signal phase as an alternate to a two MFB Filters.

### All-Pass Specs 677 Hz: Notch at 510 Hz and 890 Hz.

Notch Hi Depth: 46 dB and 47 dB and 77 dB  
 Notch Lo Depth: 45 dB and 43 dB and 74 dB  
 Pz01 BW = 210 @ 3 dB  
 Pz02 BW = 150 Hz @ 3 dB ; 220 Hz @ 4 dB ; 300 Hz @ 12 dB  
 CDF Notch at 510 Hz and 890 Hz  
 Final Sharp Filters at Q=10 (BW=165) and Q=20 (BW=85)  
 Main (f0) BW (R(f0)) variable +/- 70 Hz at 3 dB via single Dual-Gang Pot.  
 Q20 (f0) BW (R(f0)) variable +/- 70 Hz via (Single-gang) potentiometer.

http://www.partsim.com/simulator  
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 #405296 #404249 #404084 #404077  
 #404073 #404058 #403960 #400798

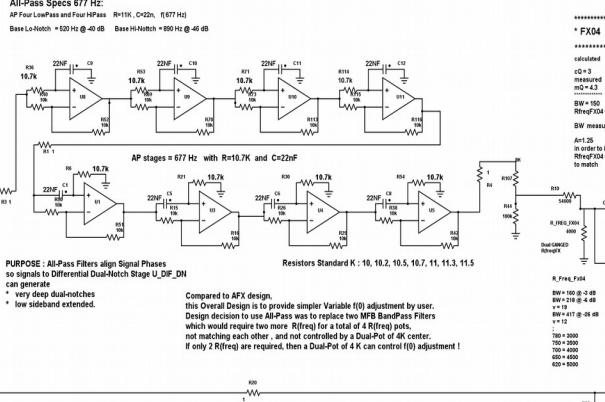
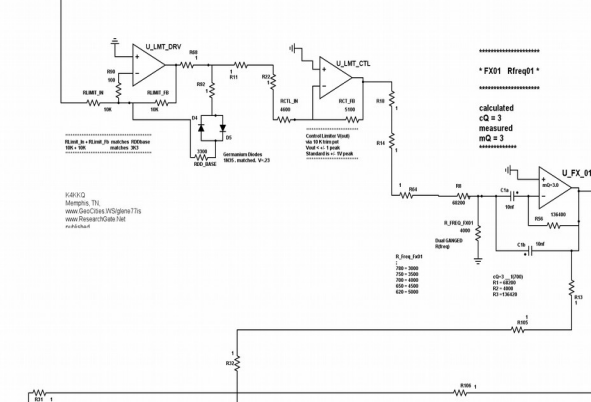
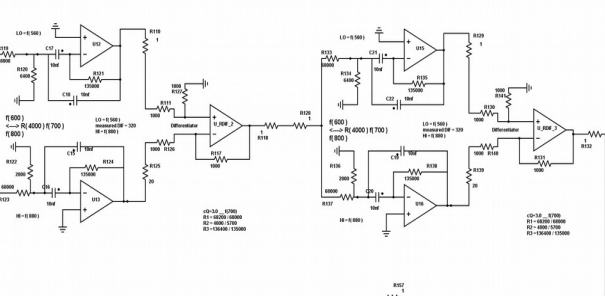
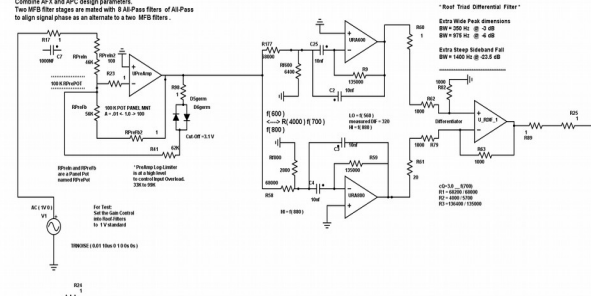
ResearchGate Net  
 Glin Ellis: Univ Tennessee, Memphis, TN,  
 Mark Kitkowski, Ph.D. Design Systems Ltd, Australia,  
 Joseph Puncoch, Prof. VSB-Technical University of Ostrava Czech.

### \*\*\* Diff-Dual-Notch Results \*\*\*

\* Resistor RATIO: (r) is 300 (R) : (r) is 100 (R)  
 \* % variations are close enough  
 Base Lo-Notch = 520 Hz @ 45 dB Base Hi-Notch = 890 Hz @ 45 dB  
 Notch Hi-Depth = 45 dB and 46 dB and 72 dB  
 SideBand at 45 dB and 42 dB and 72 dB  
 SideBand at 45 dB  
 Notch BW = 300 Hz  
 Notch Lo-Depth = 45 dB and 43 dB and 74 dB

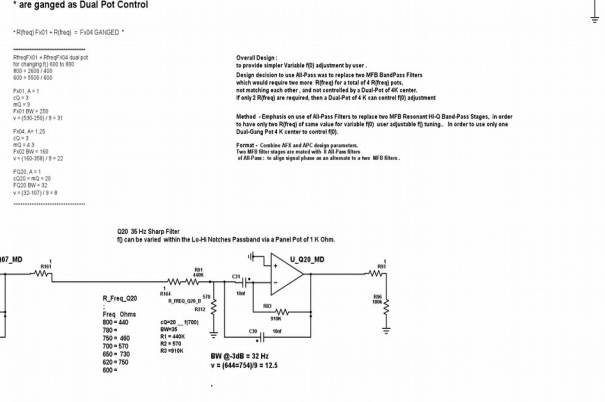
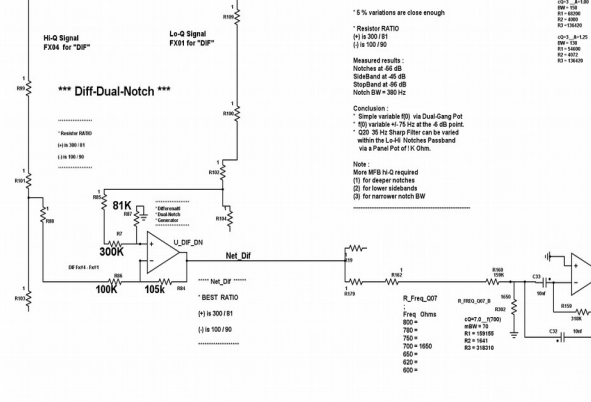
### Conclusion :

- Simple variable (f0) via Dual-Gang Pot
- Simple Band-Pass
- (f0) variable +/- 70 Hz at the 4 dB point
- Q=20: 20 Hz Sharp Filter can be varied within the Differential
- Resistor RATIO: r is 300 (R) : (r) is 100 (R)
- Match 0% MFB values within +/- 70 Hz at +/- 45 dB single Dual-Gang Pot of 4K center.
- Two MFB filters are needed with 8 All-Pass Filters of All-Pass to align signal phase as an alternate to a two MFB Filters.
- Two MFB filter stages are needed with 8 All-Pass Filters of All-Pass to align signal phase as an alternate to a two MFB Filters.



### \* FX04 Rfreq04 \*

calculated  
 C=3  
 measured  
 mC=4.3  
 BW = 150  
 70Hz @ Q=20-4000  
 SW measured at 98-117, +/-12  
 in order to increase R(freq) to 4000 to match  
 A=1.25  
 R1 = 100000  
 R2 = 10000  
 R3 = 2200  
 R4 = 100000  
 R5 = 100000  
 R6 = 100000  
 R7 = 100000  
 R8 = 100000  
 R9 = 100000  
 R10 = 100000  
 R11 = 100000  
 R12 = 100000  
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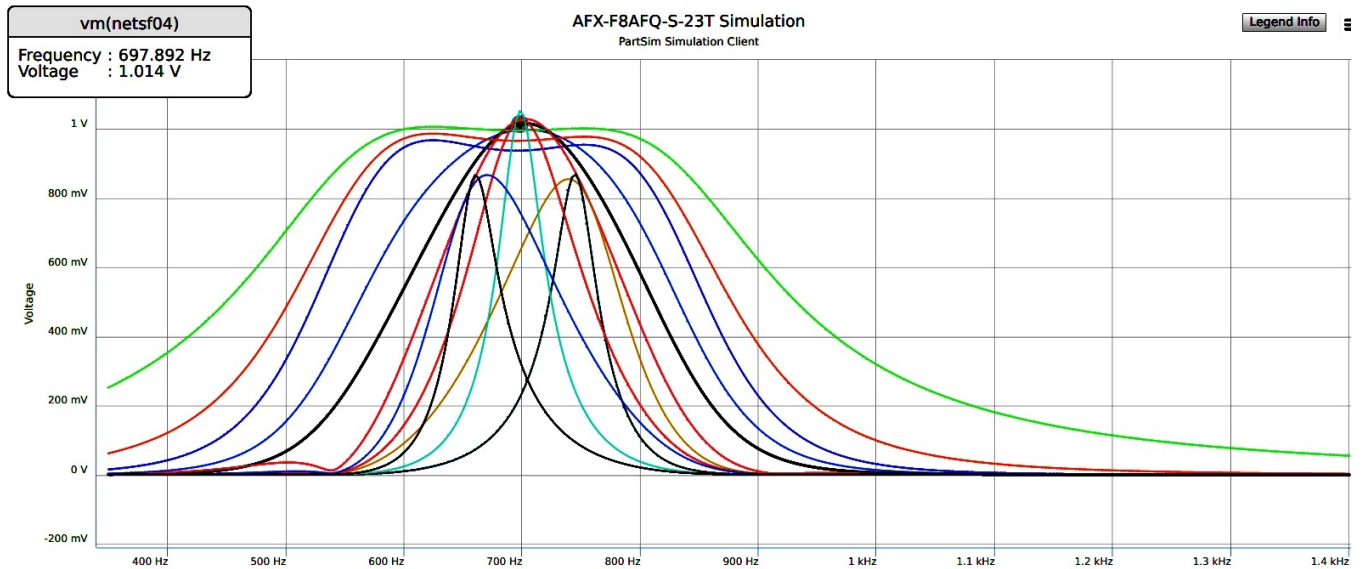


Overall Design:  
 to provide simpler Variable (f0) adjustment by user.  
 Design decision to use All-Pass was to replace two MFB Band-Pass Filters which would require two more R(freq) for a total of 4 R(freq) pots, not matching each other, and not controlled by a Dual-Pot of 4K center. If only 2 R(freq) are required, then a Dual-Pot of 4K can control (f0) adjustment.  
**Method:** Emphasis on use of All-Pass Filters to replace two MFB Resonant H-Q Band-Pass Stages, in order to have only two R(freq) of same value for variable (f0) user adjustable (f) tuning. In order to use only one Dual-Gang Pot 4K center to control (f0).  
**Format:** Combine AFX and AFC design parameters.  
 Two MFB filter stages are needed with 8 All-Pass Filters of All-Pass to align signal phase as an alternate to a two MFB Filters.

\*\*\* Two Variable MFB Filters with 8 All-Pass stages inserted in the middle Result One Dual-Pot can control f(0) +/- 75 Hz, reading at the -3dB level.

\*\*\* ONE f(Lo) ~ 677 Hz and Twelve f(Hi) ~ 677 Hz .  
 \*\*\* 677 Hz freq is based on R=10.7K , C=22nF.

## Bode Plot : Circuit #2 ... from a test circuit



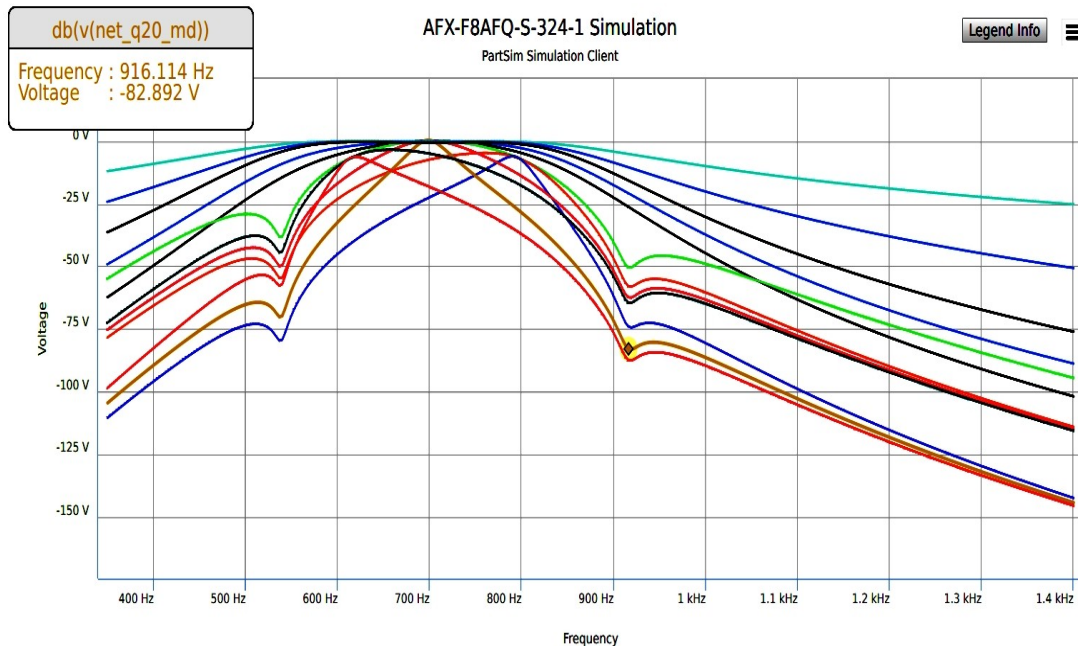
Showing All Bodes while varying Final Sharp Filters,  
( Variable Final Sharp Filters stay within All-Pass ).  
Final variable BandPass drops only to -2dB at +/- 70 Hz..

**Notch BW = 100 Hz @ -3 dB**

**Notch BW = 360 Hz @ -53 dB**

**Variance = 5.2 Hz sideband expansion per -dB attenuation  
which is analogous to the DSP “Brick-Wall” effect.**

### Magnitude Plot : Circuit #2 ... from a test circuit

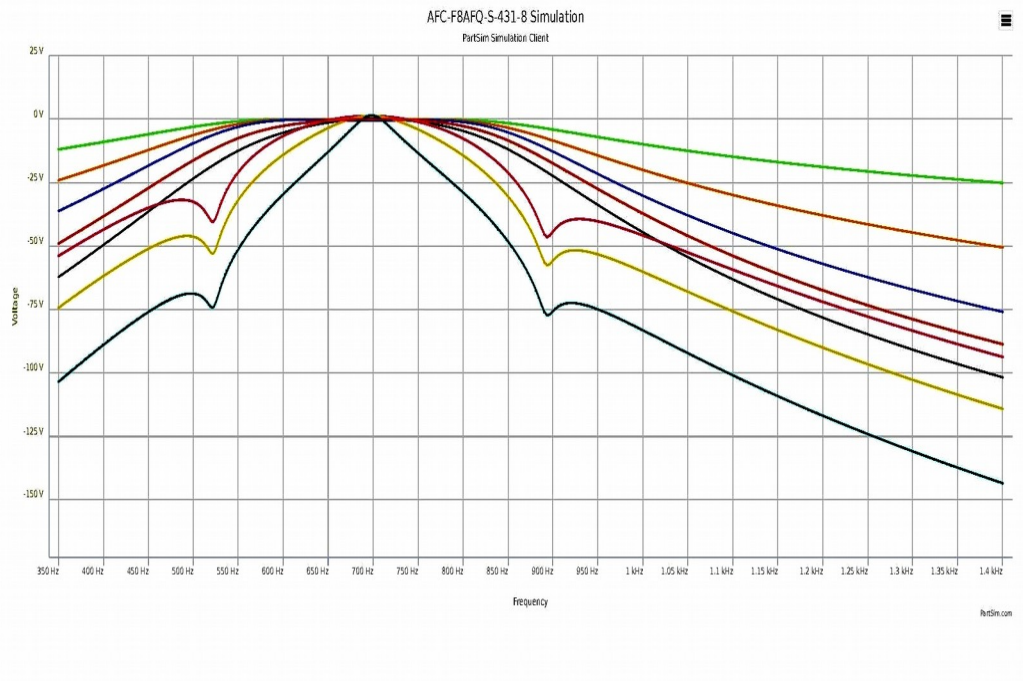


Magnitude Scale : V = -dB ; 700mV = -3dB ; 500mV = -6dB

\*\*\* Notch Generator freq tracks with f(0) band-pass varying.  
\*\*\* at +/- 100 Hz f(0) is 0.5dB down

**Notch BW = 100 Hz @ -3 dB**  
**Notch BW = 360 Hz @ -53 dB**  
**Variance = 5.2 Hz sideband expansion per -dB attenuation**  
**which is analogous to the DSP "Brick-Wall" effect.**

## Magnitude Plot : Circuit #2 ... from a test circuit



Magnitude Scale : V = -dB ; 700mV = -3dB ; 500mV = -6dB

\*\*\* Magnitude plot: At f(700) normal settings

Red trace is Raw AllPass , Yellow is Fx(01) , Green is Fx(02)  
Hi-Notch at 890 Hz, -46 dB and -57 dB and -77 dB .  
Lo-Notch at 510 Hz, -40 dB and -53 dB and -74 dB .

\*\*\* Green trace is Fx(02) (Final Sharp Filter )

Spreads at the rate of 5. Hz per dB attenuation

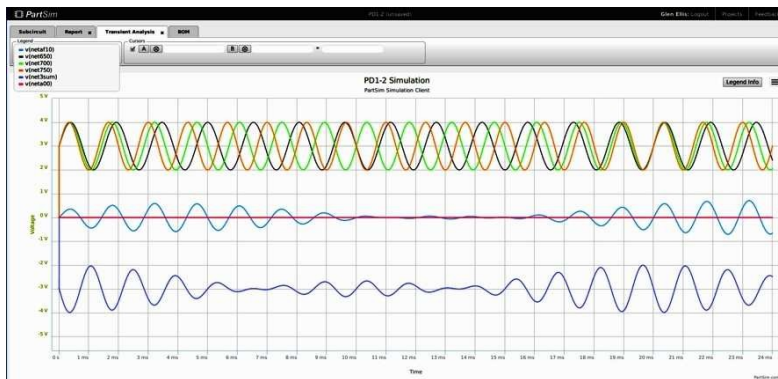
This Phase-Filtered final signal is aprox DSP "Brick-Wall" .

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## Rationale for this project:

In Amateur Radio CW operations, we commonly tune for a 700 Hz audio signal, but other signals may also be present, interfering with the 700 Hz signal. These 'other' interfering signals are presented here as 600 Hz and 800 Hz.



Above:  
Transient Plot shows Phase Delays and inter-actions based on "triple-signals "( 600Hz , 700Hz , 800Hz ) injected simultaneously.

"Triple-Signals" are shown as they phase-shift across time.  
"Triple-Signals" are similar to CW radio signals of differing frequencies as received for processing in the radio receiver and operator ears.

The purpose of the Filter is to select the 700Hz signal, while attenuating the other two.

\* ( red-green-blue trace on top )  
Shows "Triple-Signal" phase differences on input signal .

\* (blue trace on bottom)  
Filter forces phase shifting on input signal and produces a symmetrical output signal. Filter responds to the beat frequencies with peaks and nulls in its output.

\* Without any Filtering,  
we are left with only the bottom Blue trace and information is lost in middle of bottom trace.



\*\*\*\*\*

## **Background Introduction ...**

### **The initial Problem for the “AFC” Research Project :**

**This project began while we were designing a very selective Morse-Code Audio Filter.**

**In Morse-Code Amateur-Radio operations we may receive three signals within a 300Hz audio passband. Typical signals may be 650Hz, 700Hz , 750Hz. Commonly we tune for and listen for a 700Hz target signal tone, but we may also hear signals +/- 50 Hz, +/- 150 Hz, +/- 250 Hz, etc, which can make accurate copy of the target signal difficult.**

**Therefore we design Narrow Audio Band-Pass Filters, to pass primarily the 700Hz target signal +/- 50 Hz .**

**Frequently, adjacent signals are 30 dB louder than the target signal and these strong adjacent signals need to be attenuated for clear hearing of the morse-code message signal.**

**Having several Morse Code signals at nearly the same audio pitch is Very confusing to the ear/brain.**

**Our ear/brain system can only focus on one of them thus, we need to filter for the 700Hz target signal.**

**Our “AFC” filtering method may be described as ‘phasing-out’ the odd signals and ‘phasing-in’ the desired signals ; ie, by controlling / comparing / differentiating the phases of the confluence of signals passing through the circuit.**

**Our “AFC” analog design is comprised of modular sub-sections which could be utilized as stand-alone stages in other applications.**

**Our “AFC” analog design functions with-out computer processing; ie, the “AFC” circuit normally receives the “ear-phone” signal and then processes the signal and is a “Stand-Alone Circuit”.**

\*\*\*\*\*

**Consult : [Robert Arnold Orban](#) (Orban Labs Inc.)  
published on [ResearchGate.Net](#) 2019.**

First, please be aware that the resulting notch filter will be very non-minimum-phase (i.e. many zeros in the Laplace s-plane will have positive real parts), so the filter's step and impulse response are likely to distort waveforms much more than a simpler, minimum-phase realization. So please make sure this is really what you want.

As for analyzing the network, this can be done algebraically in the Laplace Transform domain. If the transmission gain function is

$$H(s) = [(n1(s)/d1(s))] + [n2(s)/d2(s)]$$

where n1 and d1 are the numerator and denominator of the upper allpass chain and n2 and d2 are the numerator and denominator of the lower allpass chain,

then the poles of H are all of the poles of the two branches (11 in total, if the top is one stage and the bottom is 10 stages).

The zeros can be found by a numerical root finder, where the polynomial n3 representing the zeros is

$$n3 = n1 * d2 + n2 * d1$$

That is, we rearrange H to put it in the form n(3)/d(3), where d3 = d1 \* d2 and is the polynomial whose roots are all poles of both branches. The only potential messiness is finding the roots of the high-order polynomial n3.

I would use a computer algebra program like Maple to manipulate the polynomials into the proper form and then to take the roots of n3 numerically.

Once you have the roots of n3 (i.e. the zeros of the notch filter), you should see some complex conjugate roots with a 0 or very small real part (due to numerical accuracy limitations in the rootfinder), putting them on the imaginary axis in the Laplace s-plane. These represent the notch frequencies of the resulting notch filter, and the absolute values of the imaginary parts are the notch frequency in units of radians/second.

As a side note, this differential allpass structure is useful for synthesizing certain classes of lowpass filters, including odd-order Butterworth and odd-order Elliptic Function lowpass filters. However, this technique is mainly popular for making digital filters that have low sensitivity to coefficient quantization.

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## **Consults on ResearchGate.Net**

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