Chapter: **AFX_Abstract_**

"Abstract" for the "AFX" project :

Title: **"Analog Phase-Filtering in OpAmp Active-Band-Pass Circuits"**

This project presents an experimental study of original Analog Phase-Filters and Parallel-Channel-Filters which provide near DSP narrow filtering characteristics, with-out computer processing.

This project circuit utilizes

- **(a) Pre-Amp**
- **(b) Triad-Roofing-Differential Filters, BW = 350 Hz, f(700).**
- **(c) Active Log-Limiter**
- **(d) Main Filter of Quad Multiple-FeedBack band-pass stages which are adjustable 600 - 700 - 800 Hz by user.**
- **(e) Phase-Filtered Non-Resonant Dual-Notch stage**
  producing notches at 560 Hz and 860 Hz,
  very Deep (aprox. -80 dB)
  Octave Stop-Band very low (aprox. -110 dB).
  These Notches are Not Quadrature in concept.
- **(f) Variable Narrow Q=20 final band-pass filter, user variable.**
- **(g) Audio Amp.**

This project has applications that include in-lab analog instrument filters
(proto-boarded and no PC computer required)

****

****

Chapter: **AFX_Introduction_**

Title: "Analog Phase-Filtering in OpAmp Active-Band-Pass Circuits"

PreRequisite for Reading this Paper:

This is not an academic Algebra / Calculus based tutorial.
This is not a tutorial in Linear I.C. Design Applications.
It is expected that the reader will have
...(1) a good understanding of Linear I.C. Design Applications.
(2) a good understanding of Active BandPass Filter Concepts
(3) an open mind to new ideas.

[The Multi-Feed-Back Band-Pass Filter is the basic filter used
[because it is very versatile, tunable, and stable.
[This website & project does not contain an in-depth presentation
[of this basic Delyanis-Friend Multi-Feed-Back Filter (MFB) .
[The primary I.C. is the LM-324 as it is 10x viable for audio.

MFB schematic and equations:

R(2) is the Resonant Loading resistor
used for minor tuning of f(0) .

Fundamental Transfer Function

$$\frac{vo}{vi} = \frac{-\frac{1}{R1C1}s}{s^2 + s\left(\frac{1}{R3C2} + \frac{1}{R3C1}\right) + \frac{1}{R3C1C2}\left(\frac{1}{R1} + \frac{1}{R2}\right)}$$

All concepts presented herein are common to Active BandPass Filters
as presented in tutorials and academic course-work
presented for Electronic Engineering Technology students.
Concepts presented here are ONLY the SYNTHESIS of common ideas
into radically new approaches.

Your Imagination is more important than prior academic learning.

Design choices:

***** Simple repetitive application of**
Modified *Deliyannis-Friend*-Multple-FeedBack design.

***** MFB topology was chosen because :**

***** (1) input vs output impedances match well,**
loading is naturally controlled, stage to stage.

***** (2) one single resistor frequency control each stage.**

***** (3) frequency adjustments alters gain**
by only the square-root of the f(change) .

***** (4) the Roof-Triad-Differential design**
provides superior side-band suppression.
and is wide enough to be very tolerant
of component variations for central channel f(0) signal.

Just for reference:
Delyannis-Friend Multiple-Feed-Back design

MULTIPLE FEEDBACK BAND-PASS DESIGN EQUATIONS

$$\frac{-H\ \omega_0 s}{s^2+\alpha\ \omega_0 s+\omega_0{}^2}$$

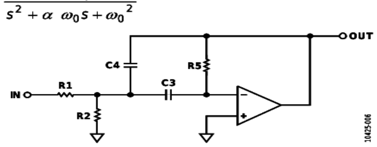


Figure 6.

$$\frac{V_O}{V_{IN}}=\frac{-s\frac{1}{R1C4}}{s^2+s\frac{C3+C4}{C3C4R5}+\frac{1}{R5C3C4}\left(\frac{1}{R1}+\frac{1}{R2}\right)}$$

To design the filter, choose C3.

Then

$$k=2\pi F_0 C3$$

$$C4=C3$$

$$R1=\frac{1}{H\ k}$$

$$R2=\frac{1}{(2Q-H)k}$$

$$R5=\frac{2Q}{k}$$

Your Imagination is more important than prior academic learning.

>>   First, please read through the "Intro" chapter !

>>   Second,
read the sub-chapters for greater basic details
about each of the modules comprising the AFX project.

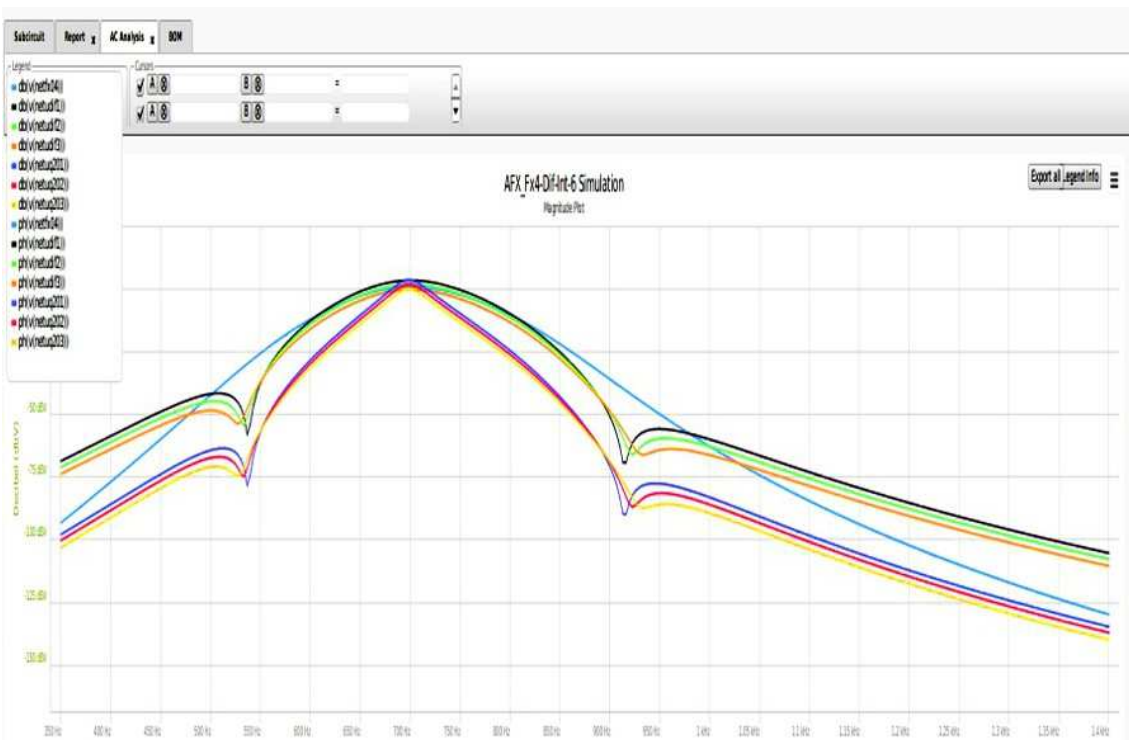
>>> several additional chapters have been added
which expand greatly on the applications of "AFX"
.
The extra chapters are about
Phase-Filter Non-Resonant Filter Applications:
(1) AF'V'   variable AFX version with Dual-Notches.
(2) AF'T'   Simple No-Notch circuit.
(3) AP'C'   All-Pass Band-Pass with Dual-Notches.

The AFX designs include these features :

*** BandPass 90Hz @ -3dB and 340Hz @ -60dB,
*** SideBand Spread = 5Hz per dB attenuation (“variance”).
*** Dual-Notch BandPass = -90 dB @ 350Hz bandpass
*** Variable-Frequency PassBand ability (f(0) = 600-700-800)

Note:
AFX Dual Notch PassBands are not Gaussian shaped.
and are not I/Q Quadrature generated.

Magnitude Plot: **Phase-Filter Dual-Notch Band-Pass**



Above:
the 1... blue trace is the Quad-Filter BandPass
the 2,3,4 three traces are Notched BandPass.
the 5,6,7 three traces are High ‘Q’ BandPass.

About this project :

This project was begun before 2014 in my personal lab,
using radio equipment at my Amateur Radio Station “K4KKQ”
and was presented to the ResearchGate.Net forum thereafter,
where it received critical review.

This project is our Current research in Analog I.C. Applications,
as applied to CW (morse code) Radio Operations
... posted at www.GeoCities.WS/glene77is
... posted at www.ResearchGate.net
... posted at Yahoo HW8 Group (in years past)

Our Analog Project shows the evolution of filter design from common Resonant Active BandPass circuits into Active Phased-Filtered Non-Resonant circuits. Presented in circuits “AFX’V’”, “AFX’T’”, “AFX’C’”.

About The “AFX” project :
(1) “AFX” is about Analog Electronic Technology
applied to Amateur Radio CW operations.

(2) “AFX” applies concepts to Narrow Band-Pass Morse Code CW operations.

(3) “AFX” has produced a Series of Analog Filters
approaching DSP quality in narrow band-pass CW operations.

(4) “AFX” emphasizes Parallel-Channel-Filtering and Phase-Filtering
to generate Narrow Band-Pass Dual-Notched effects.

(5) “AFX” emphasizes a radical Phase-Filtered Non-Resonant design
in the final stage.

(6) “AFX” is not a digital project requiring a PC computer to function.

Applications include
in-lab analog instrument filters
where the circuit is proto-boarded as a stand-alone device.

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,
interferring with the 700 Hz signal.
These ‘other’ interferring signals are presented here
as 600 Hz and 800 Hz.

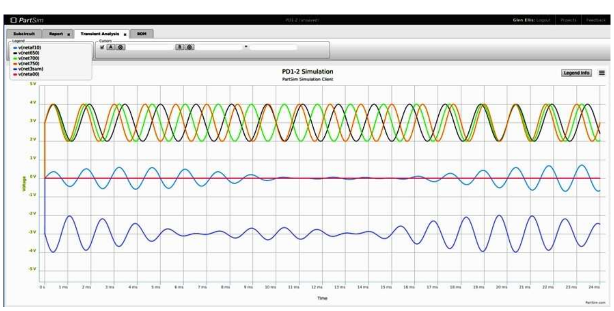
Below:
Transient Plot shows Phase Delays and inter-actions based on
triple-signals (600Hz , 700Hz , 800Hz) injected simultaneously.
Triple-Signals are shown as they phase-shift across time.

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 center signal,
while attenuating the other two.

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

* (blue trace on bottom)
Filter forces phase shifting on input signal
and produces a symetrical 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 .



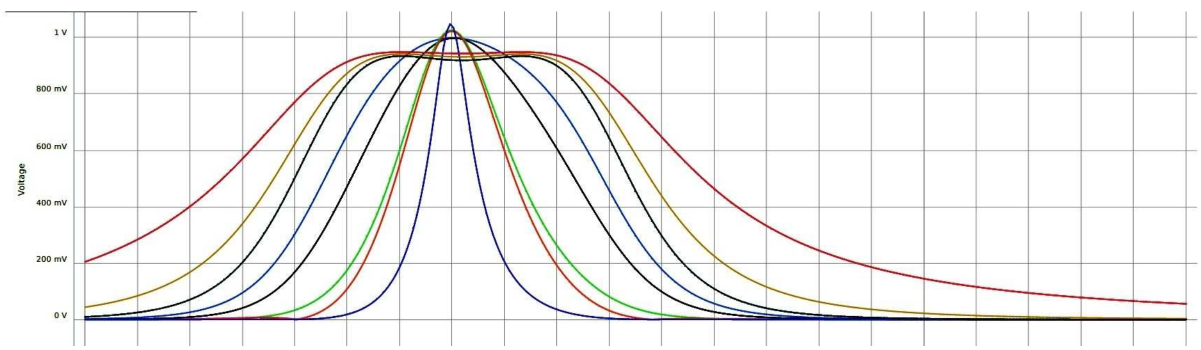
Note about the Non-Gaussian Band-Pass shape :

"Variance" is used to describe the "BW" vs "Q" relation.

"v" = slope of best fit for the non-Gaussian sideband shape]
[(BW@-12dB) - (BW@-3dB) / 9dB

Therefore,

v=25 is very wide sidebands (similar to low "Q')
v=5   is a very steep sideband (similar to high "Q")



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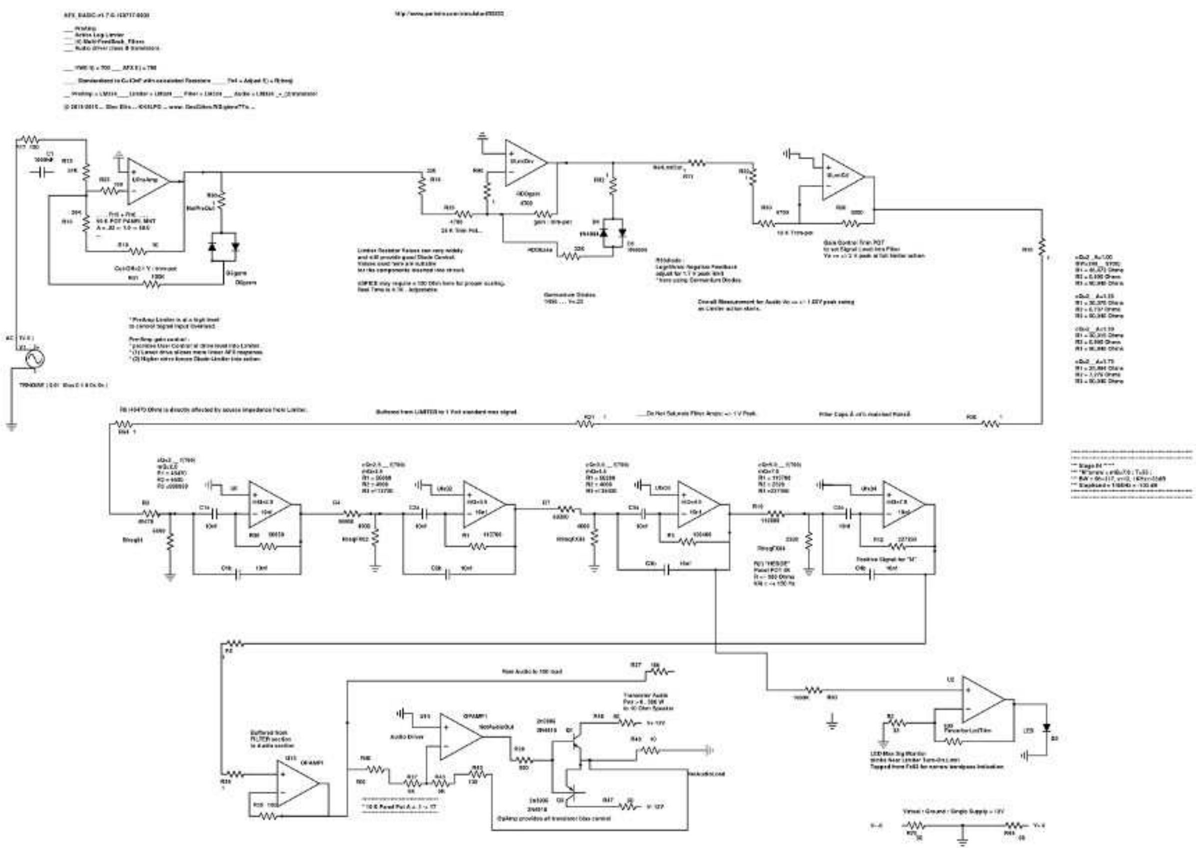
the **"AFX" B.A.S.I.C.** Simple Schematic

where it all started simply.



Examine the modular function blocks:

(1) PreAmp

(2) Active Log-Limiter

(3) Quad MFB resonant Active Band-Pass Filters.

(4) Audio amp

(5) Level Indicator for signal in center of band-pass..

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Chapter: AFX_Main_0

"Analog Active Band-Pass Phase Filtering"

The initial Problem for the "AFX" Research Project :

**This project is about designing
a very selective CW Audio Filter.**

**In C.W. (morse-code) radio operations
we may have three signals within a 300Hz audio passband.
Typical signals may be 650Hz, 700Hz , 750Hz.
Commonly we listen for a 700Hz target signal tone,
but we may also hear signals +/- 50 Hz, +/- 150 Hz, +/- 250 Hz,
which can make accurate copy of the target signal difficult.**

**Therefore we design Narrow CW Audio Band-Pass Filters,
to pass only the 700Hz target tone +/- 50 Hz** (BW=100Hz)**.**

**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 signal in the pass-band.**

**Our "AFX" analog passband 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 many signals passing through the circuit.**

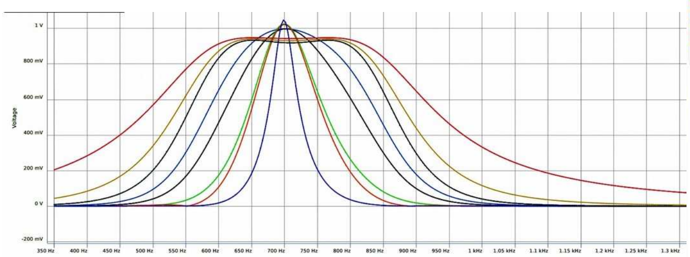
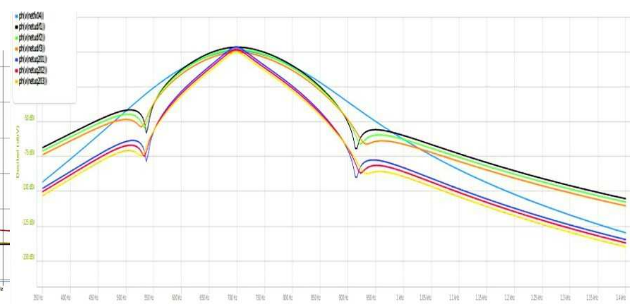
**Our "AFX" analog design is comprised of modular sub-sections
which could be utilized as stand-alone stages in other applications.**

Our "AFX" analog design functions with out computer processing.

Chapter: **AFX_Main_0**

Radical Analog Designs
for ‘CW’ narrow filtering circuits


****

all about Analog Active Filters
and Electronic_Technology and Ham Radio
circuits for Receiving CW Morse-Code

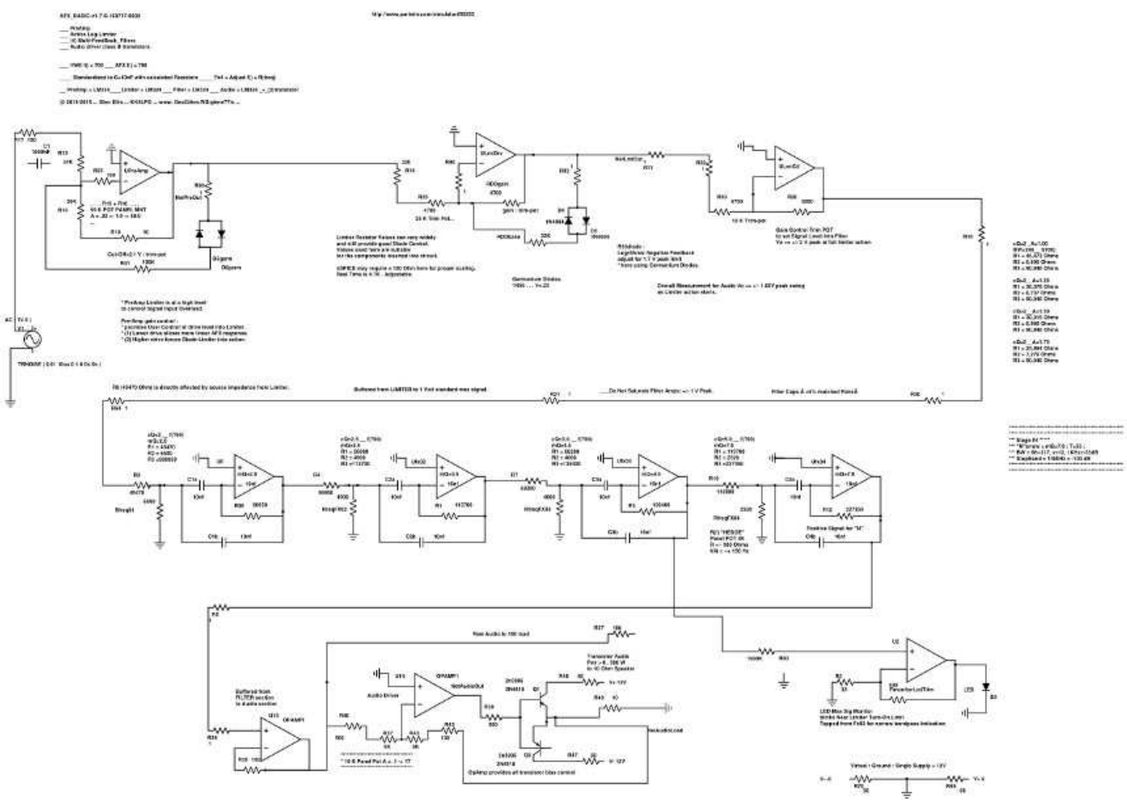
Modules in the “AFX” Analog Signal Procesor

1. Pre-Amp-driver with Over-Load-Limiter
   Roofing Dual-Channel+Differential Filter
2. Active-Log_limiter
3. Quad-MFB Band Pass audio filter (Resonant)
   Differential-Phase Filter (Double-Notch = Non-Resonant)
6. Audio out 0.5 W class-B

****

Circuit-1: the **"AFX" B.A.S.I.C.** Simple Schematic

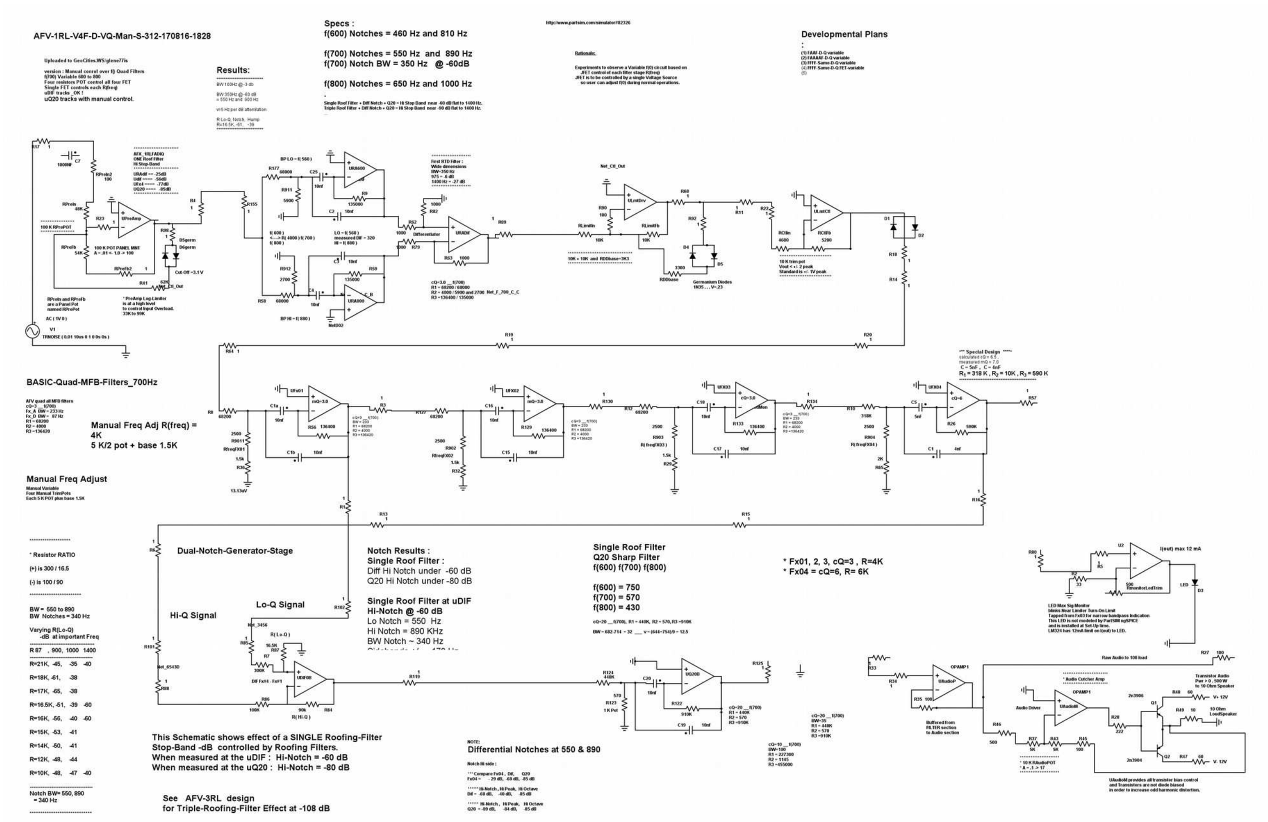
where it all started simply
without Roof-Filters,
without Phase-Filtering.



Examine the modular function blocks:
(1) PreAmp
(2) Active Log-Limiter
(3) Quad MFB resonant Active Band-Pass Filters.
(4) Audio amp
(5) Level Indicator .

****

Circuit-2: the **"AFX" 'Variable' Advanced Schematic**



plus Roof-Triad-Differential stages
plus Phase-Filter Non-Resonant Dual-Notch module.

Examine the modular function blocks:

(1) PreAmp
plus Roofing-Filter
(2) Active Log-Limiter
(3) Quad MFB resonant Active Band-Pass Filters.
plus Differential Dual-Notch Generator.
(4) Audio amp
(5) Level Indicator.

****

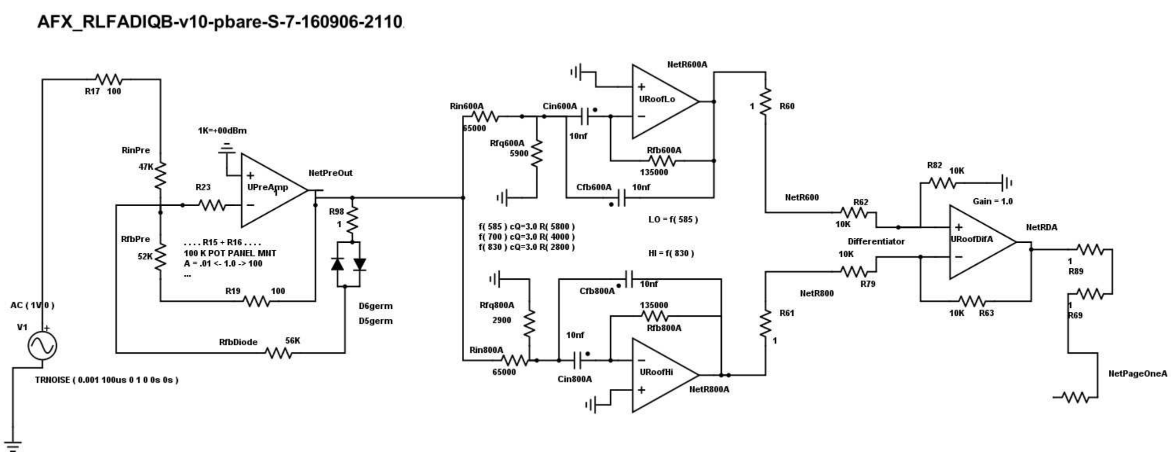
****

Below are the **Functional Blocks**
of the General AFX circuit development

*** The following pages are an Index
into the **Modular Stages that Build the AFX**

_______the **Pre-Amp and AFX Roofing-Triad-Differential Filter**

(see page: AFX_Main_1_Roof_)

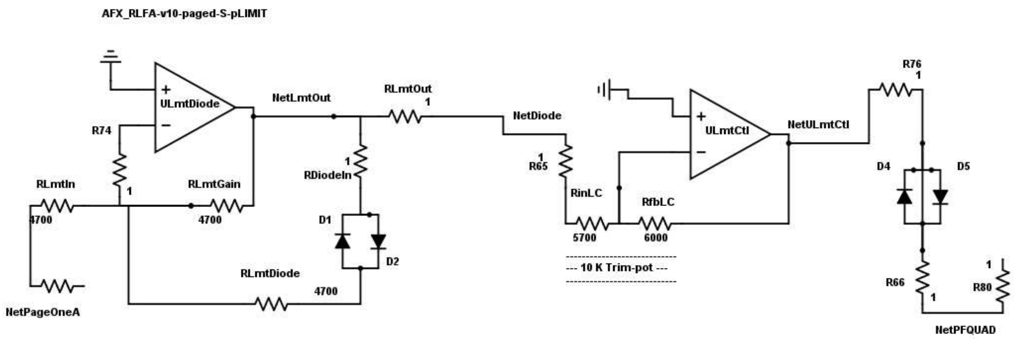


***** Pre-Amp with Over-Load Limiter.**
***** Dual Channels 600Hz and 800Hz**
driving the Differentiatial Final stage
to produce a 700Hz Roof Signal Output.

---

the **AFX Active-Log-Limiter :**

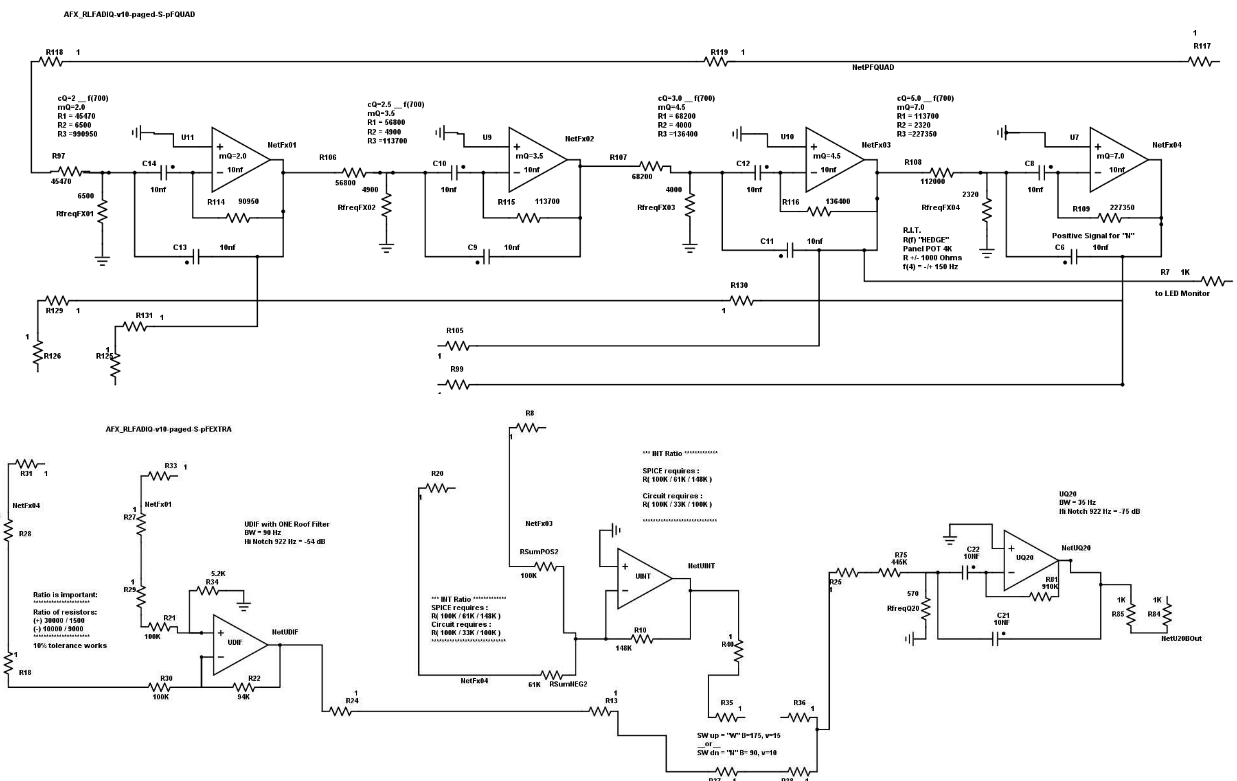
(see page: AFX_Main_2_Limiter_)



The Negative FeedBack has an additional R(series).
The R(series) adds to the combined “Diode-Internal-Resistance” and “Diode-Dynamic-Impedance”.

______the __AFX Quad-MFB Filter
with the Non-Resonant Phase-Filter Dual-Notch module

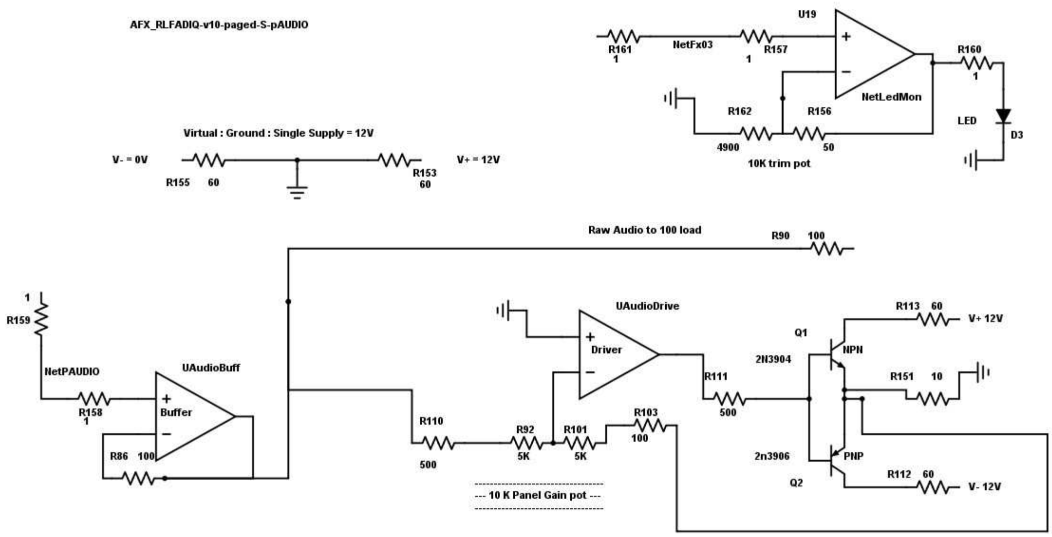
(see chapter: AFX_Main_3_Filter_)



When the Roof-Triad-Differential-Filters,
and the Quad-MFG-Band-Pass Filters,
and a final High ‘Q’ filter
are all combined, then
this Differential-Phase-Filter can produce Dual-Notches at -98 dB
Variance = 7 Hz sideband spread per dB attenuation .

________ AFX Audio Driver

(see page: AFX_Main_4_Audio_)



Simply a raw Cutcher Audio Amp (without the base-bias)

V(audio) output has increased third harmonics.

****

Above :

Functional Blocks of the General AFX circuit development

****

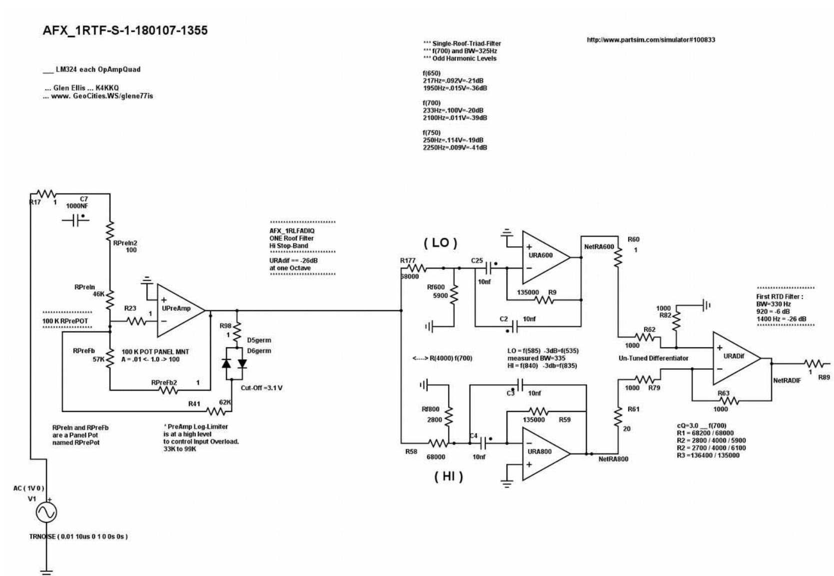
****

****

Chapter: PreAmp + Roof-Triad-Differential Filter

***** Triad of Dual Channels and Differential Final**

***** test signal is V(signal)=TR(noise) signal from ngSPICE**
***** Differentiated Signal Output is 330Hz wide at -3dB**
***** and f(center)=700Hz**
***** SideBand FallOff is -27 dB per octave**
cumulative for each triplet-stage ;
ie, 350 Hz = -27 dB; 700 Hz = 0 dB ; 1400 Hz = -27 dB
for each triplet-stage.



The preliminary OPA stage is basically gain control with limiter.
Low Impedance Out.

First Roof Stage:
High Impedance Input
Normal V(input) is from a Transceiver's audio output .
Since the signal is well above noise level at this point,
we wanted to prevent pop-corn radio band noise
from shocking the Roofing-Filter and Active-Limiter stage.

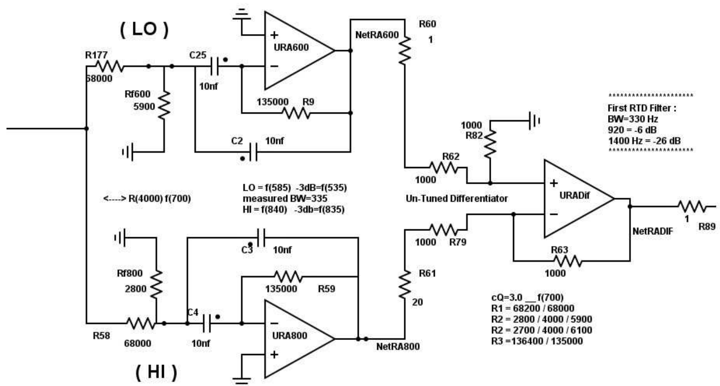
We included a PreAmp with Log-Negative-FeedBack function,
Purpose of Gain Control is to deliver enough V(out) through
the Roof-Triad-Filter on into the Active-Limiter stage
so that the Active-Limiter module can be forced into Limiting Level.

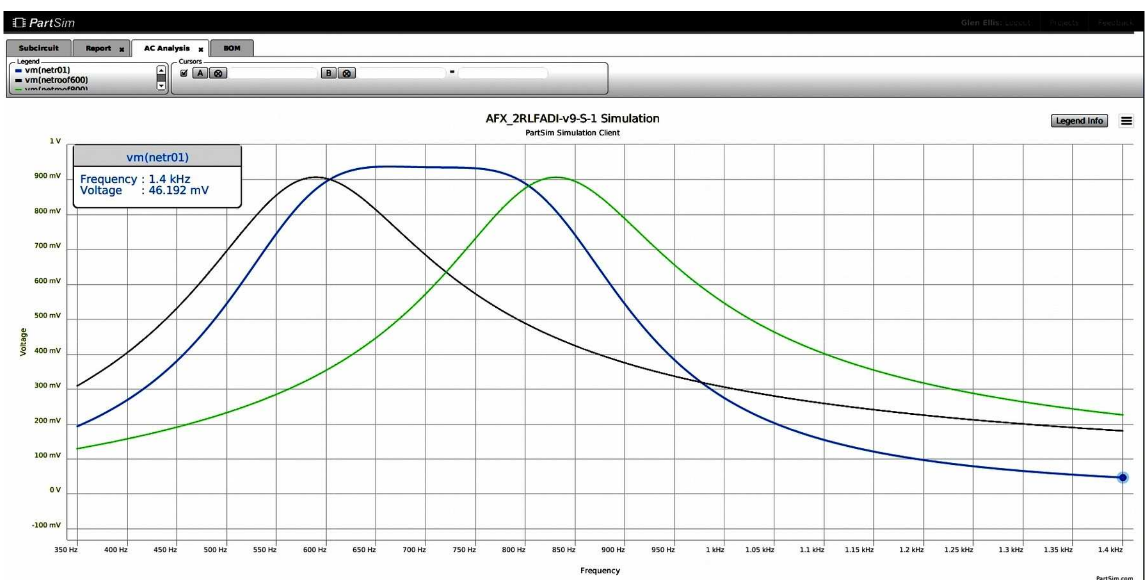
Functional Process of the “Roof-Triad-Filter”:

We split the V(input) into two paths:
*** The “High” Filter is tuned to 800 Hz aprox. See schematic.**
*** The “Low” Filter is tuned to 600 Hz aprox. See schematic.**
*** These two signals are Subtracted by the Differential Amp.**

(1) This Single Roofing Triad-Filter circuit produces f(700)
a flat-topped (BW = 330 Hz @ -3dB) signal
with sideband attenuation of -27 dB per Octave .

(2) The Roofing Signal output has “symetrical” waveform This reduces intermodulation distortion within the following “Active Limiter” module.

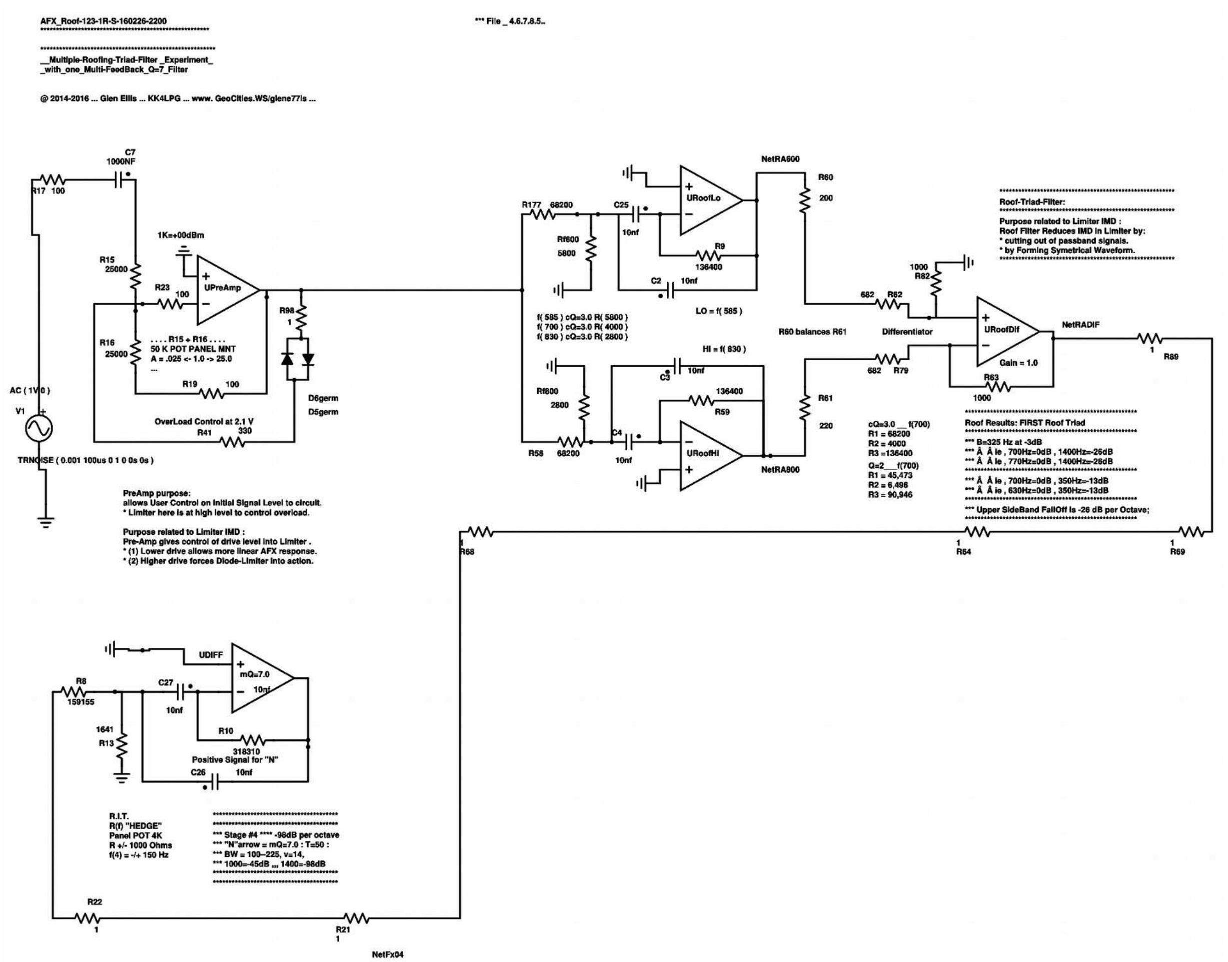




*** Roofing Filter BW=300Hz, with Wide, Flat Top.
ie, 350 Hz = -27 dB; 700 Hz = 0 dB ; 1400 Hz = -27 dB
for each triplet-stage.
*** Low Impedance Output.

Description : **Single Roofing-Triad Filter circuit** :
*** Roofing Filter BW=300Hz, with Wide, Flat Top.
*** Sideband FallOff is -27 dB per octave;
"v" = 32 Hz band-width expansion per dB attenuation.

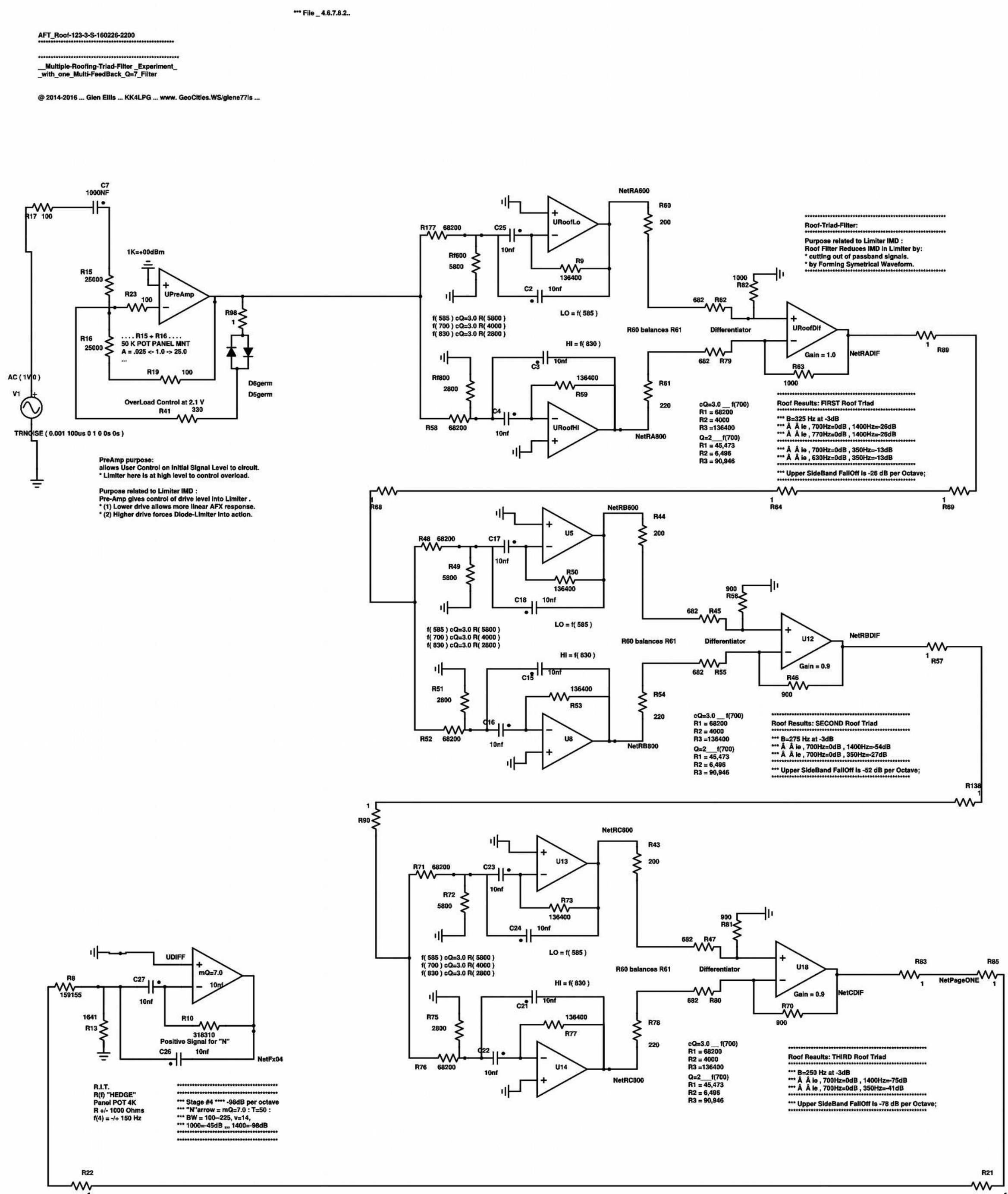
"v"ariance = sideband slope of best fit is calculated by :
((BW@-12dB) - (BW@-3dB) / (9dB))



Simply run this Single Roofing-Triad-Filter circuit
before any standard CW audio filter circuitry.
The Single Roofing-Triad filter
can be sequenced (1, 2, 3 stages)
for a summing effect.

Triple Roof-Triad Filter circuit :

**** V(signal)=TR(noise) from ngSPICE and f(center)=700Hz*

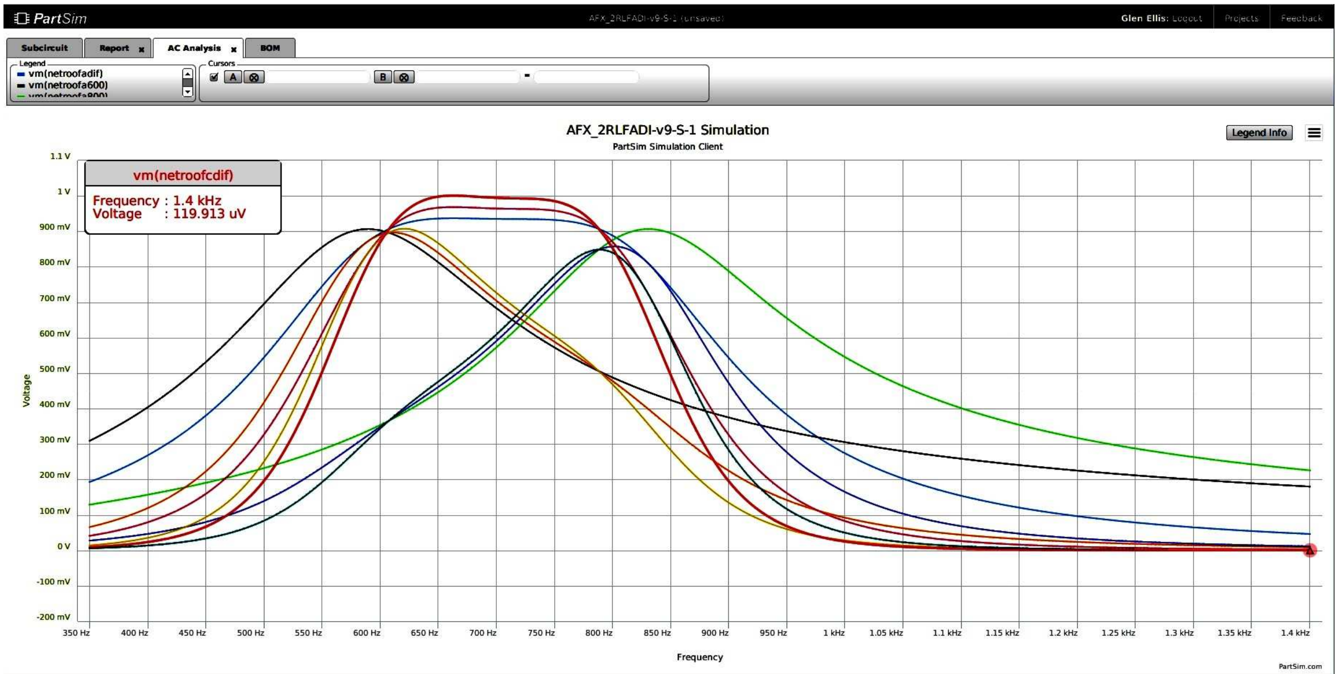


**** Stacked Triad-Roof-Filter*

= Differentiated Signal is about 250Hz wide at -3dB

Triple Roof-Triad Filter *bode plot :*

*** Sideband FallOff is -78 dB per octave
ie, 350 Hz = -78 dB and 1400 Hz = -78 dB (red trace)
*** Stop-Band = -78 dB to the limits .



Results of **Stacked** Roof Triad Filters

****
Roof Results: FIRST Roof Triad
****

design BW=325 Hz at -3dB
***** ie , 700Hz=0dB , 1400Hz=-26dB**
***** ie , 700Hz=0dB , 350Hz=-13dB**
***** SideBand FallOff is -26 dB per Octave;**

****
Roof Results: SECOND Roof Triad
****

design BW=325 Hz at -3dB
***** ie , 700Hz=0dB , 1400Hz=-54dB**
***** ie , 700Hz=0dB , 350Hz=-15dB**
***** SideBand FallOff is -54 dB per Octave;**

****
Roof Results: THIRD Roof Triad
****

design BW=325 Hz at -3dB
***** ie , 700Hz=0dB , 1400Hz=-75dB**
***** ie , 700Hz=0dB , 350Hz=-18dB**
***** SideBand FallOff is -75 dB per Octave;**

****
***** Cumulative Results after the Sharp Filter**
***** cumulative measured results : Q=7**
***** cumulative measured -98dB per octave**
***** BW = 35 @ -3dB , range 35---126, v= 10,**
***** 1000 Hz=-75dB ,,, 1400 Hz = -110 dB**
****

****

Preliminary Info about 'WHY' to use a Roofing Filter :

*** ***Transient Analysis showing Time Domain Phase data.***
*** ***The 'black/blue' is the signal noise injected for testing.***
*** ***The Noise signal has random frequencies,***
very little 700 Hz C.W. signal.
*** ***The Roof filtering action is the 'green' smooth trace.***

*** ***This is a most basic idea behind***
a Roof-Triad Filter.
*** ***Roof-Triad Filter controls Common Mode noise from the radio band***
and minimizes IMD in signal sent to the Active-Limiter stage
by producing a "Symetrical Waveform Signal".

*** *Center band 300 Hz wide*
is free from narrow-band phase-shift/phase-delay.
*** *Only Sidebands outside of the 300 Hz center band are supressed*
to minimize Limiter InterModulation-Distortion (IMD).

****

*** a ***First Reason for using a Roof Filter*** **:**

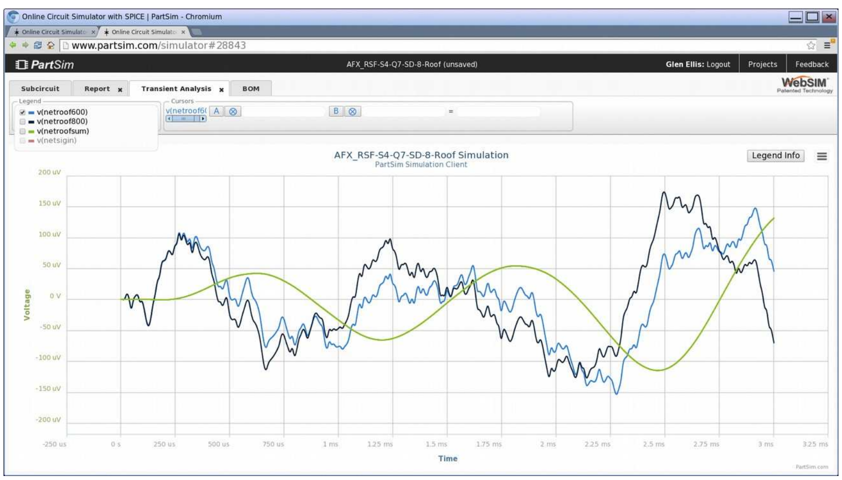
*** *The Vinput "aSymetrical" Noise signal*
is converted into a Voutput "Symetrical Signal."

****** Symetrical signals produce far less InterModulation Distortion during Hard Limiter Action (in the Active Limiter stage).***

****** The Noise Signal Common Mode energy is canceled by the Differentiator.***

****** See the full "AFX" circuit for the context of this Roofing Function.***

*** *Black and Blue trace is Random noise signal injecting common-mode signals.*
*** *These have been filtered by the 600Hz and 800Hz filters.*
*** *The **Green** trace is the Differentiated C.W. signal Vout without any Common Mode Noise.*
*** *The **Green** trace shows the combined 600Hz and 800Hz signals centering on 700Hz.*



*** **Notice** that the Vinput "aSymetrical" Noise signal
is converted into the "Symetrical" Voutput Signal,
balanced on 0V line and phase-aligned.

*** This is the same action that occurs in an All-Pass Filter;

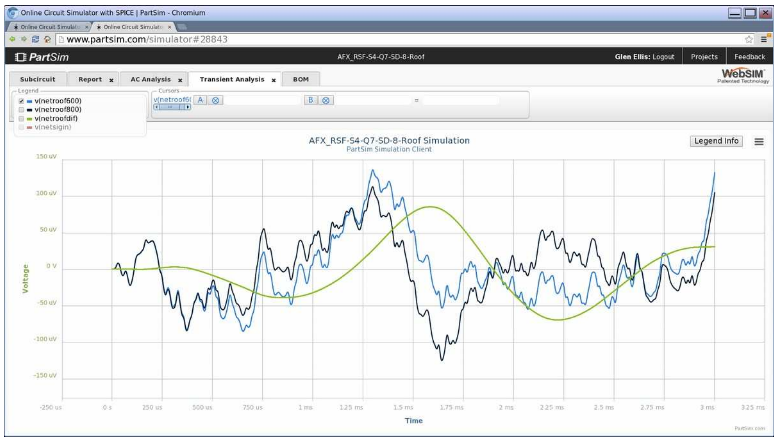
*** "Symetrical" signals produce far less InterModulation Distortion
during Hard Limiter Action in the "Active-Limiter" stage.

*** See the full "AFX" circuit for the context of
this Roofing Function and the Active-Limiter.

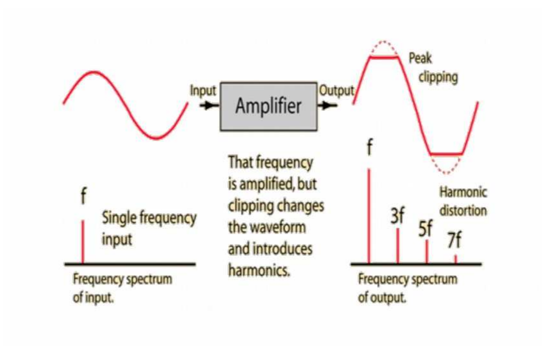
****

A Second Reason for using a Roof Filter :

***** Differentiated Signal is about 300Hz wide at -3dB**
***** which attentuates much Out-Of-BandPass signal,**
and possible overload IMD in the Active-Limiter stage.
***** The wide BandPass has little affect on the Phase Relations**
of the ‘target’ center-of-passband information signals.



Example of Noise Signals passing through stages of Roof-Triad-Filters.



(fig source unknown)
Example of
Inter-Modulation Distortion Effects
at saturation in a Limiter circuit.

***Do "Exotic" amplifiers even exist? - ResearchGate*.**
Available from:
https://www.researchgate.net/post/Do_Exotic_amplifiers_even_exist
[accessed Dec 17, 2015].

(Regarding a query about final purpose of the Roofing Triad Filter)

First off, the preliminary stage is only gain control.

The Higher Filter is tuned to 800 Hz. See schematic.
The Lower Filter is tuned to 600 Hz. See schematic.
These two different signals are Subtracted by the Differential Amp.

(1) This Roofing Filter circuit produces a flat-topped
(300 Hz @ -3dB) signal
with sideband attenuation of -27 dB per Octave.
(2) The Roofing Signal out has symetrical waveform.
That is the most obvious function, for this one triad stage.

This Roofing and the total of the AFX project functions
within the context of Amateur Radio C.W. (morse-code) operations,
to produce narrow pass-band filtering, making use of analog phase-sensitive filters.

Looking at the whole AFX circuit,
I am working with phase relations amongst signals that are surrounding 700Hz,
feeding an Active Log-Limiter, and four MFB bandpass filters, and a final Differential untuned-filter.
The overall AFX circuit object is
to produce a Double-Notched Narrow-passband Audio Signal,
centered on 700Hz.

The Roofing Filter is for clarity in CW operations,
where in I need to reduce the wide sideband signals,
and form symetrical waveforms for the Limiter.

The quad filter and Differential are used to produce a Narrow bandpass,
We need to subtract two particular phase related signals
to produce double -48dB notches at plus/minus 230 Hz
around 700 Hz.

The above numbers are aprox. to simplify the description.

I hope the two attached plots will assist directly.

I use the larger AFX circuit daily 'on the air',
and there is a simpler version we put on the market.
The whole project is at my website linked below.
We found this to be an interesting and effective analog project,
with clarifying suggestions by Dr. Barrie Gilbert, Analog Devices, Inc.
and much commentary by engineer/professors on ResearchGate.Net.

Glen Ellis

added: attached a schematic with more readable detail.

I should note that i did run a series of experiments
using analog sequential circuits
comprised basically of the same high and low filters,
and also using a simple Summing stage, and also a simple MFB Q=2 passband at 700Hz
... but found much better results using current parallel + differential 'triad' filter.
Much of this information is on my website.

The use of the differential stage and the phase-sensitive approach
has intrigued me and caused me to stop
and 'put on the robes of the electron' as Barrie describes the intuitive analysis.
The concepts involved were not immediately apparent to me,
and I had little descriptive math from my readings,
and no models to guide.
The project as part of a long term interest,
with many approaches designed, Spiced, and prototyped,
and tested with real-time C.W. on-the-air contacts
and analyzed via critical O'scope monitored listening.
Eventually, all designs were passed through ngSPICE
and re-developed to these published stages.

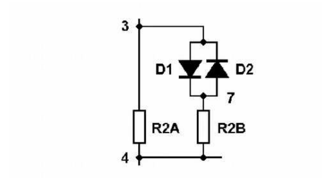
quote taken from :
Do "Exotic" amplifiers even exist? - ResearchGate.
Available from: https://www.researchgate.net/post/Do_Exotic_amplifiers_even_exist
[accessed Dec 17, 2015].

****

****

Chapter: **Active-Log-Limiter**

Intro:
AGC : uses feedback to ensure that the output signal always has a certain amplitude, whereas a
LIMITER : merely ensures that the output doesn't *exceed* a certain amplitude.

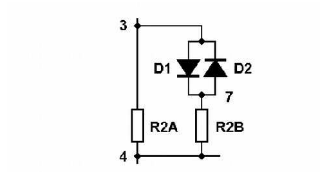


Log-Limiter circuits based on personal designs from 1975, from consult with Dr. Joseph Laughter, Bio-Med-Instrumentation, University of TN, Medical Units, Memphis, TN.

Ref: http://en.wikipedia.org/wiki/Diode_modeling

Note: Basic Log Diode Limiter is a single stage , Negative-Feedback , Germanium Diode , nearly instant response design.
R(series with diodes) adjusts limiting level in combination with R(feedback gain).
Germanium Diodes are 'matched'.

***** (!) We apply this "Anti-Parallel Diode" in order to obtain a full-wave audio effect.**
One Volt Input can be adjusted to One Volt Output at onset of Limiting, or as needed throughout the following circuitry.
Standard "normalized" Working Signal Voltage is 1 Volt, for 'testing' all stages of AFX circuit at one time.
The V(out) Limiter stages varies from 1.7V up to 2.24V.



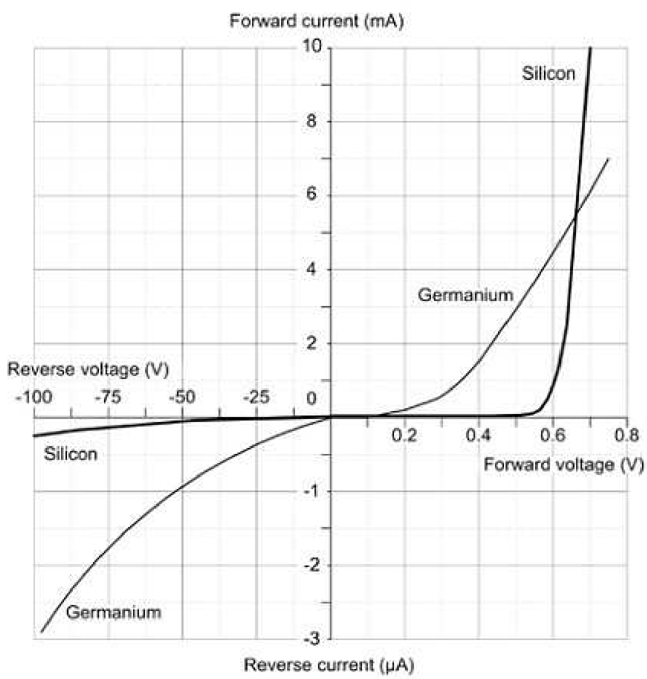
Resistors in series will push the Diode Turn-On Curve up the scale, to the greater than 1V range, which is the author's choice for Standard Operating Voltage.

R(limitdiode) 777 Ohms can be varied up towards 3333 Ohms for higher turn-on curves within this circuit.
Logging Diodes are Germanium and measure 0.23 V , 'matched' by comparison , using the diode measuring circuit on the author's VOM (Amprobe AM-270).

Below:

Graph of the “Advantage of Germanium over Silicon” diodes.

***** Softer Knee produces**
much less InterModulation Distortion during Limiting Action.
***** This a dynamic affect**
is produced by diode forward current conduction,
and varies widely with the particular diode internal impedance,
and varies widely with the particular circuit impedance.



(((Germanium provides Lower Slope on load curve than silicon)))

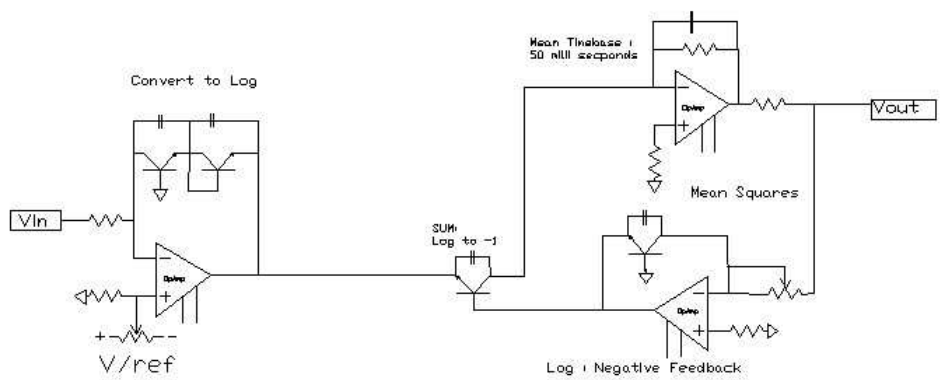
(((Germanium produces Less InterModation-Distortion during limiter action.)))

(((Germanium diodes produces Less Odd-Harmonic Distortion during limiter action.)))

(source of fig unknown)

Below:
Note that Diode Conduction (limiting) occurs at all levels of current flow.
The author has observed (measured) this
from 1 micro-Volt upward to 3 V in test circuits.
(below: author's Log-Amp circuits presented on
chapter for " Notes from University of Tennessee .

True R.M.S. Calculating Amplifier, Glen Ellis, UT/STIM, June82.



ET_True_RMS_Calculating_Amp_Drawing2a.dwg

In common Limiter circuits,
this effect is used from the 0.5V forward to 0.7V forward range
for Silicon diodes, at aprox. 10 milli-Amp current.

In author’s Active-Limiter circuits,
this effect is used from the 10 micro-Amp to 10 milli-Amp
for matched Germanium diodes.

This circuit was just one of six advanced circuits
prototyped/tested/submitted/approved for graduation, 1982.

Background on the author's Active Limiter circuit :

There are two stages in the AFX version.
(1) The First stage is the actual "Limiter".

In General, the Negative FeedBack has an additional R(series).
The R(series) adds to the Diode-Internal-Resistance
and Diode-Dynamic-Impedance,
...
Stated this way :
Vf = VK log (If/Is(T))
where "If" is I(forward)
real world current "I"
always = V / (R+Dynamic-Impedance)
and we are adding to the "R" .

(2) The Second stage is a simple Post-Amp
with a wide-range gain control,
which allows adjusting the "actively limited" signal
to a standard 1 Volt for the following circuitry.

In tests, the resulting combination works well , just as described :
(1) R(series) linear resistance.
(2) Diode-Internal-Resistance , dynamic and Logrithmic.
(3) Diode-Dynamic-Impedance from the PN junction,
dynamic and Logrithmic.
All function together to lengthen the initial slope
(which 'softens' the limiters 'attack')
but will still produce abrupt "Roll-Over-the-Log"
at some upper level.

1 V signal works well into the Roof-Triad-Filter
and also matches the Roll-Over in the Limiter.
More than 1.7V pushes the Signal into the Limiter
enough to begin activating Limiter action.
1 V standard max signal makes run time measurements
much easier between stages/modules.
O'scope Visual Comparision is much faster.
Same idea applies later in the dedicated Limiter Stage
with the log-Negative-Feed-Back diodes.
Similar idea of using ~ 1 V standard max signal
applies in filter stages.

We did Transient plots to compare various combinations,
of diode bias and added-resistance,
and did real circuit adjustments with O'scope to check.

For some people,
it helps to verbalize this
“Resistor-in-Series-with-Diodes FeedBack” as :

(1) normal Resistive Negative-FeedBack R(fb)

(2) with the Diodes limiting any signal
going above the R(fb) gain setting.

The ‘soft-limiter’ effect is desired :
(Germanium is ‘softer’ than Silicon)
1) as it generates lower harmonic distortion.
2) as a human criteria for what the ear/brain system
can hear/read more clearly.

The Roof-Triad-Filter produces a very “symetrical” signal output.
This reduces the Inter-Modulation-Distortion (IMD)
created when the Limiter section is active doing 'hard' limiting ;
ie, "Hard" limiting of an “Asymetrical” signal will produce
more IMD and odd-harmonic distortion.

The stage for Monitoring the Limiter Action (LED (D3))
is not traced through SPICE since it does not transfer a signal.
In practice, the LM324 has about 50 Ohms Z(out)
and the voltage swing is limited to 4.5 V up or down
by the chip itself (+/- 6 V supply) and is thusly ‘current-controlled’. .
The monitoring LED runs OK as-is because
the Front to Back Voltage ratings on the single LED
are tolerant of this level of push/pull voltage.

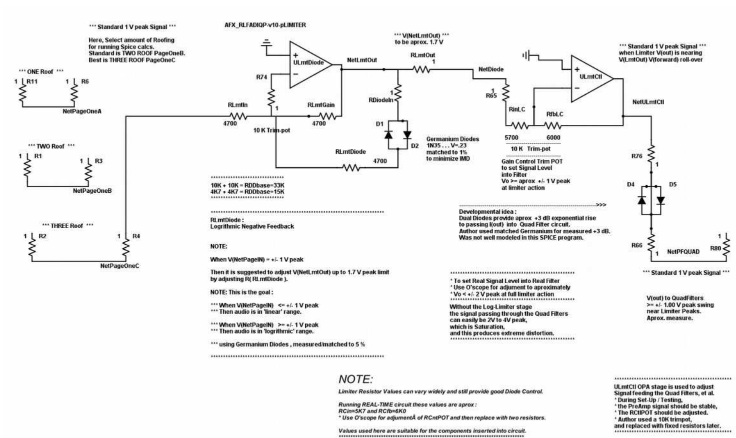
***

These ideas were introduced to peer discussion
in the below listed article.

What is the secret of diode clippers?
Can we build these diode circuits in a logical manner
rather than giving them as ready-made circuit solutions?
***- ResearchGate*. Available from:**
https://www.researchgate.net/post/What_is_the_secret_of_diode_clippers_Can_we_build_these_diode_circuits_in_a_logical_manner_rather_than_giving_them_as_ready-made_circuit_solutions#view=56ff9c6693553b2e143e5750
[accessed Apr 2, 2016].
***

We did an earlier Limiter
which was Pre-Processed with All-Pass Phase-Rotating stages
to shift Asymetrical signals to be Symetrical, at F(700) Hz,
in order to reduce odd harmonic distortion
as created by the instant acting diode limiters.

We observed that
Inter-Modulation-Distortion can occur during heavy limiting action,
when signals are close together in frequency and/or "Asymetrical".
Through experiment, it was observed that multiple All-Pass stages
were not equal to the Roofing-Triad-Filter.

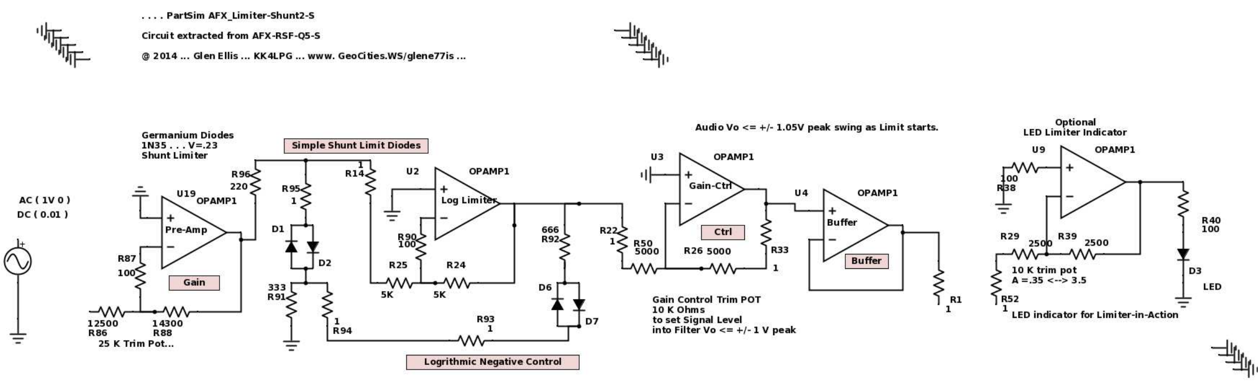


The All-Pass Filters method was discarded
because the Roofing-Filter
had measurably better results

in aligning the phases and
producing Symetrical
waveforms .

R(Limiter Diode) = 4700 Ohms can be varied up towards 33000 Ohms
for longer linear shaped attack curves, with good diode curve at very top.
Diode current flow is from aprox. 10 microAmps to 10 milliAmps.

Below:
***** Negative-FeedBack <u>Diode-Base-Biasing</u>**
applied at the grounding of the Shunt Diodes :
This experiment produced dual levels
of Diode Conduction (turn-on) at V(out).
This shows the Negative Feedback signal
being used to control
the base-bias of the shunt-diode matrix.
There was a difference to this more complex design,
as it has two distinct turn-on curves.
Higher level pulse noise would receive tighter (quicker) diode limiting.

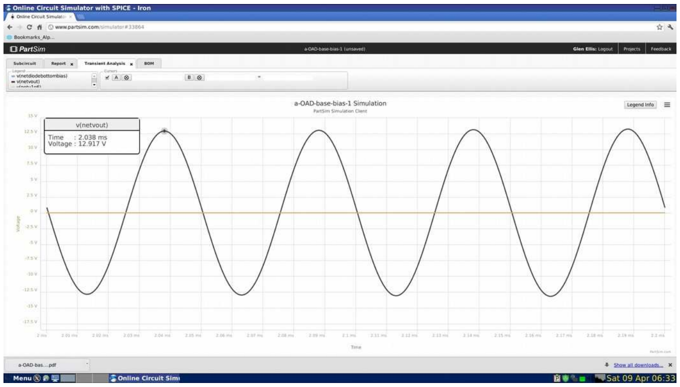


It was discarded in favor of a simpler circuit:
the simple Resistor+Diode Negative-FeedBack method.

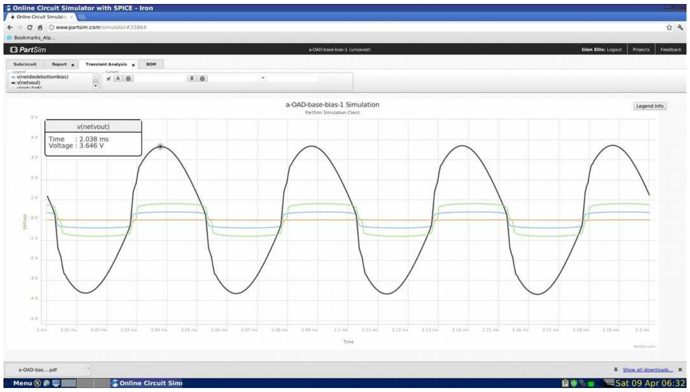
****

***** Transient analysis**
for various combinations of Shut vs Negative-FeedBack methods.
***** These Transient plots are from above Test Circuit with**
(1) Shunt-Limiting
(2) combined with Negative-FeedBack Diode Base Bias.

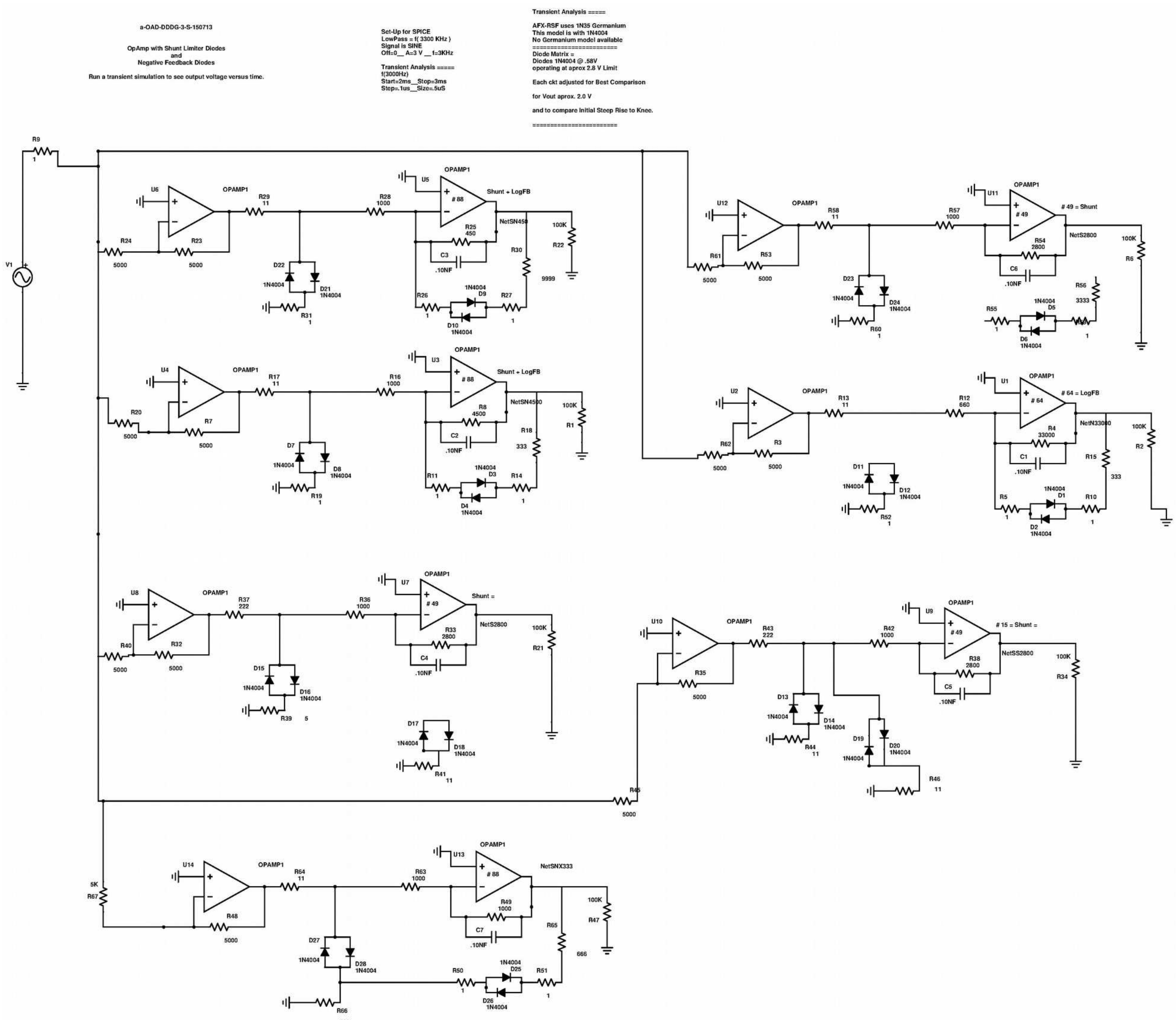
***** First No Shunt Limit and No Negative-FeedBack**
***** Vout max = 12.9V**



***** Second, Transient for Shut Limit combined**
***** with Negative-FeedBack base-biasing the Shunt Diodes.**
***** Vout max = 3.6V**



*** Test Schematic for various combinations of the Linearized-Log Negative-FeedBack Method.

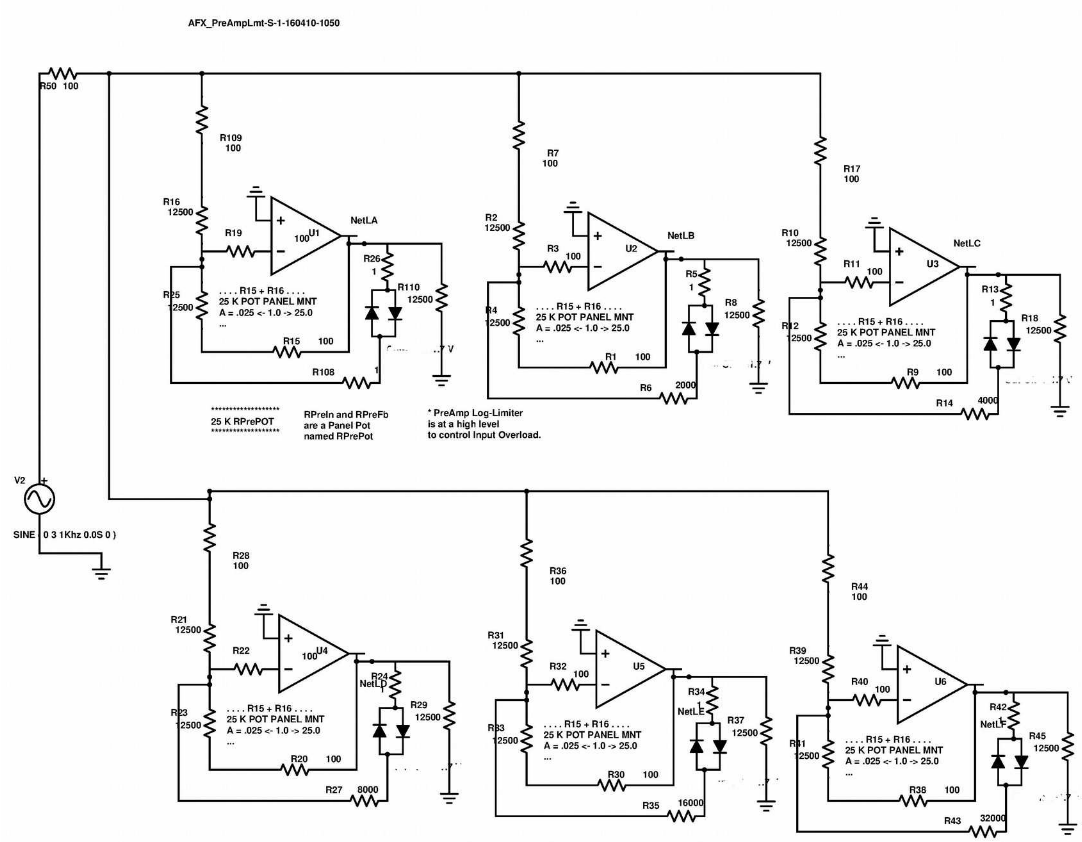


***** Below**
The Author's Pre-Amp includes an Active Log-Limiter,
whose Limit Level is based on the Gain of the OPA stage.
Gain is calculated by R(in) / R(feedback).
As the stage gain is adjusted, in normal usage,
the V(Limit-out) also changes.
The Non-Linear Limiter is altered by a Linear relation with Gain.
As Gain is increased, so the V(limit-log-out) also increases,
providing more head room for the possibly larger V(out) signal.
(Any pro/con to this method is up for discussion.)

The attached Bode demonstrates
the results of a full swing of gain from minimum to maximum.
Blue signal is V(in), and rainbow signals
are various logs of the V(in) signal.

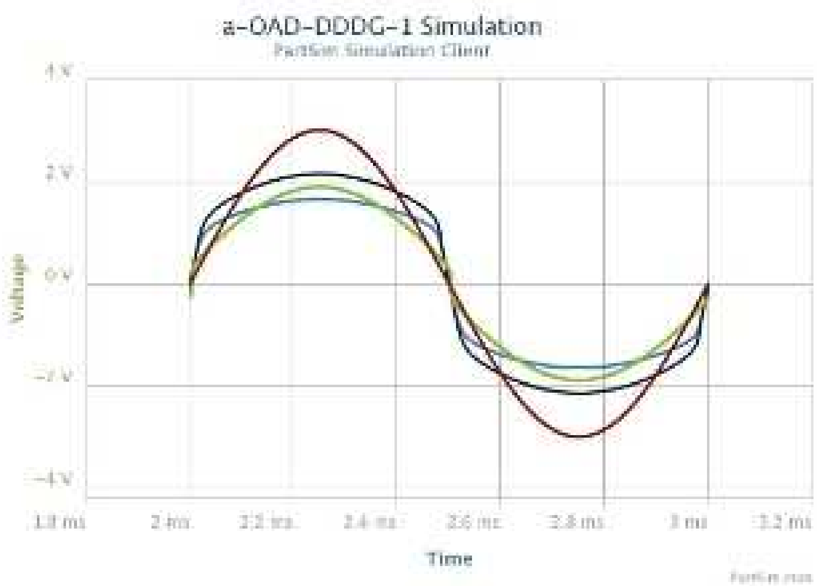
We Published this in the thread "*What is the secret of diode clippers?*" - *ResearchGate*.
Available from: https://www.researchgate.net

Another test schematic to demonstrate variations of the Linearized-Log Negative-FeedBack method.



Below:
***** Given V(in) = 3V (blue sine trace),**
the V(out)Limiter varies from 1.7V up to 2.124V. (rainbow traces)

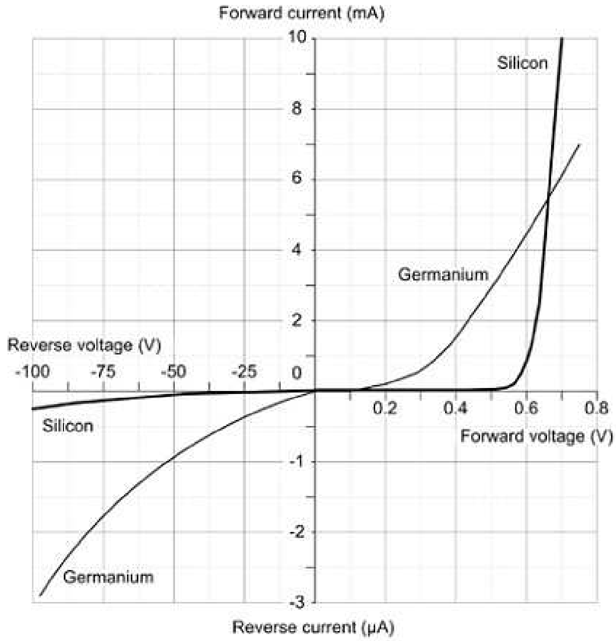
Below:
These Bodes show the various types of diode limiting signals
and their natural shape.
Normalized to about 1V for display, as in actual use,
which also aids in visualizing their effects.
Vsignal is the dark-red trace at 3V,
Vdiodes are rainbow traces taken at V(out) and are in the 1V range.
Vdiodes are actually in the .23V to .60V range
(Schottky , Germanium , Silicon)
and the circuit is adjusted to a standard 1V V(out)
in the selected circuit as prototyped.



Author's Spice traces :
optimized/normalized to normal 1V standard
so that the curve shape can be visually compared.

Silicon has as a sharper cut-off and Schottky has a more sloping cut-off.
The author selected the Germanium soft curve
for use in AFX Limiter stage
because the characteristic curve could be measured
and thus ‘matched’ diodes were selected in pairs.
Another research associate selected silicon (KC9ON)
for our commercial production model.
The dark-red sine wave is the applied test signal.

Comparison of Germanium vs Silicon diodes from Data Sheets.



(graphicsource unknown)

****** Summary**

Sharper Knee produces
more InterModulation Distortion during Limiting Action.

More IMD means more
odd Harmonic Distortion.

More Harmonic Distortion
means more distorted
message signal,
ie, loss of information.

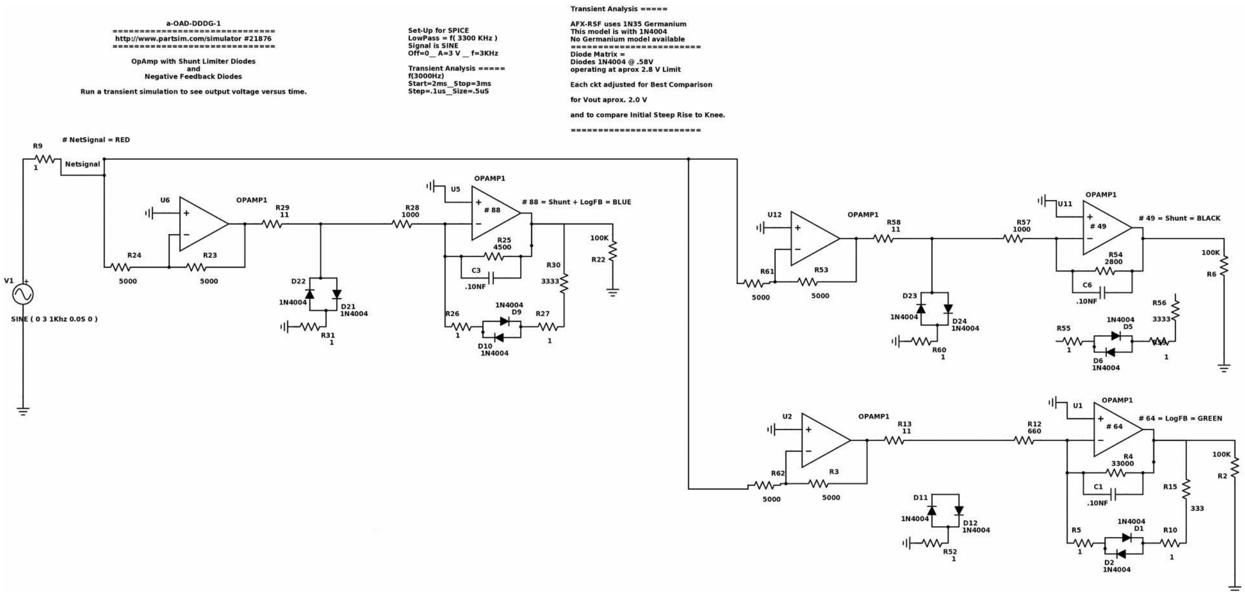
****

Author's set-up for Studying and Comparing

(1) the Simple-Shunt

vs.

(2) the Negative-FeedBack Limiters



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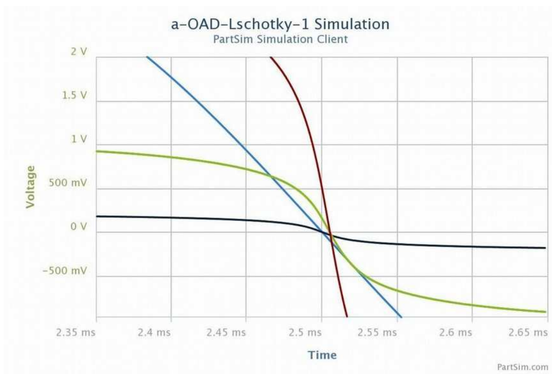
***** Below : Normalized to the standard 1 V.**
Vsignal is 3V, and Vdiodes is actually in the .23 to .60 range.
***** In a real circuit the Vout is always normalized to some standard, such as 1V out Peak, by the user.**
***** Each type of Diode has a different Vout curve, and here they are Normalized for easier visual comparison.**



Left plot shows the 'corner curve'. **Right plot shows over-all curve. .**

Blue is Sine Sig at 3 V input, for reference.
Red is Germanium Diode gain controlled to compare with the Sine Sig.
Green is Germanium Diode at the standard 1 V .
Black is Germanium Diode at real turn-on level.of 0.189 V in this circuit.

Real world Turn-On curves are relative to the actual current flowing through the 'circuit' and through 'diode'.
Thus, a diode's impedance is dynamic.
(The authors have designed working circuits,
using negative-feedback,
which work in the 10 microA through 6 milliA range,
using Germanium diodes in circuits including extra "R" .)

****

Note: The Author did a study of Simple-Shunt Limiting using Schotty Diode array, for "softer" log curves.
Various modules were inserted / disconnected.
Schotty show a very soft curve but were difficult to match which is important in using "Anti-Parallel Diode" configuration.

****

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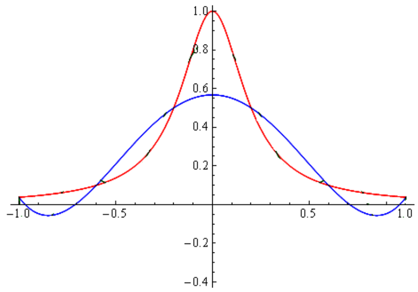
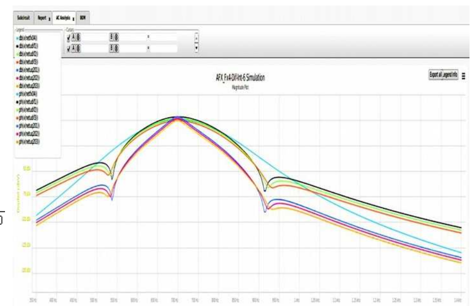
Chapter: **Main-Filter**





"AFX" filter circuit

This Page is about the author's AFX core filter circuit
with Non-Resonant Double-Notch Phase-Filter module

Design choices in concept :

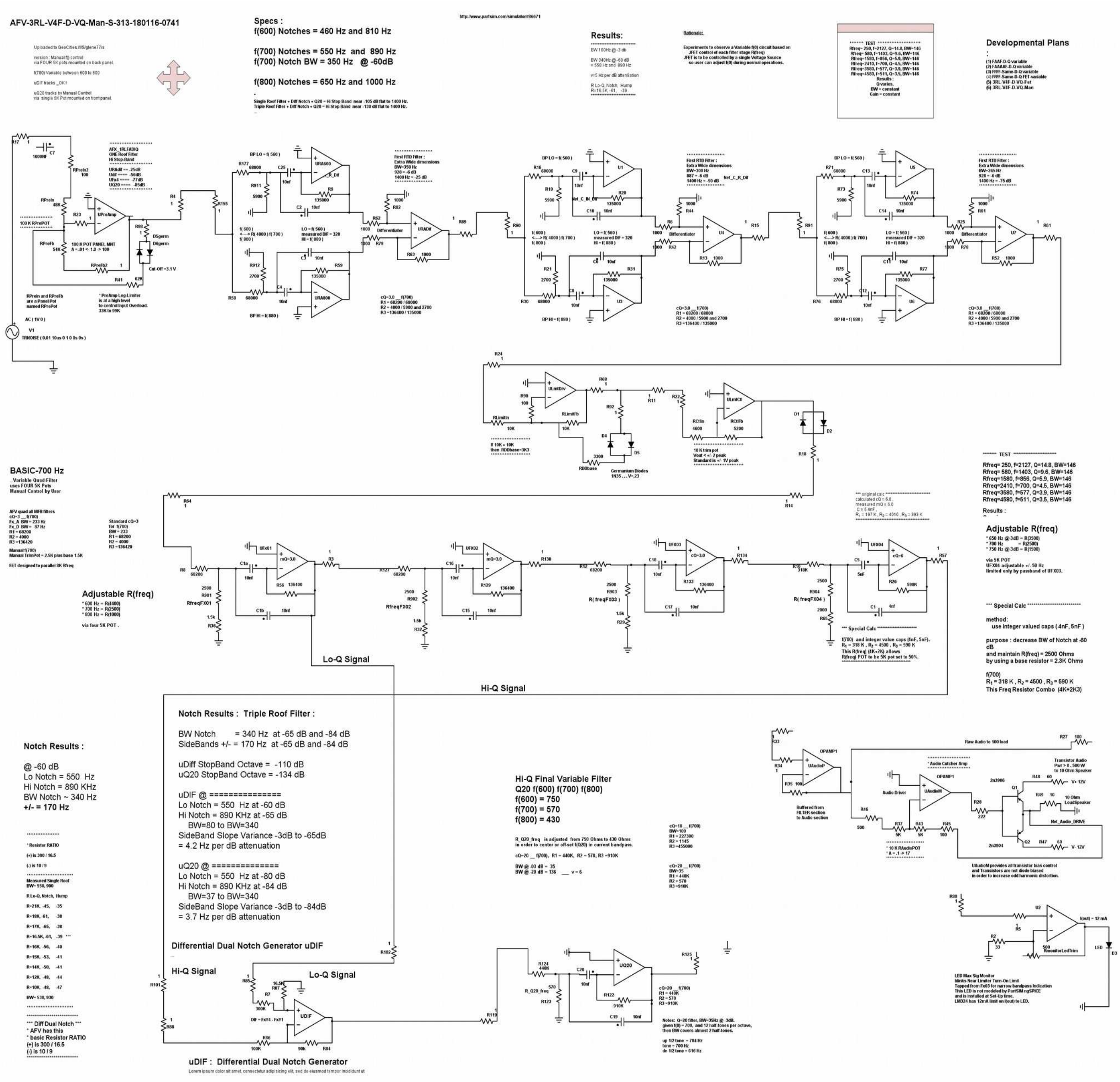
***** Simple repetitive application of**
Modified *Deliyannis-Friend*-Multi-FeedBack topology.

***** Multi-FeedBack design was chosen because :**
(1) input vs output stage impedances match well,
(2) single resistor frequency control each stage.
(3) frequency adjustments alters gain
by only the square-root of the f(change) .

***** Phase-Filter stage for generating**
a Dual-Notch Band-Pass.

Circuit : AFX ‘V’

which has the Double-Notch Phase-Filter module



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Note: circuit dox.
in the following diagrams for the Operational Amplifiers,
Filter resistor R2 is the R(freq) for adjusting f(center) .
R2 adjusts the primary current source into the tuned circuit.

Note:
The -1dB level is equivalent to 900 mV level .

Note:
The -3dB level is equivalent to 700 mV level
which is the usual BandWidth point.

Note: about the Non-Gaussian Band-Pass shape :
“Variance” is used to describe the “BW” vs “Q” relation.
"v" = slope of best fit for the non-Gaussian sideband shape]
[(BW@-12dB) - (BW@-3dB) / 9dB
Therefore,
v=25 is very wide sidebands (similar to low “Q’)
v=5 is a very steep sideband (similar to high “Q”)

Note:
All Filter stages are set to run at aprox standard 1V peak
for easy O’scope tracing.

Note:
Power Supply ByPass caps are not shown.
OpAmp Null trim pots were not necessary
in this development
with LM-324 quad OpAmp chips.

Note: Non-Resonant modules

(1) “u-Differential” stage is the Phase-Filter stage
which produces "N"arrow Double-Notch passband.
Stage “u-DIF” will DIFFerentiate Fx01 with Fx04
to produce a "N"arrow Double-Notched Phase-Filtered signal.

(2) “u-Integration” produces "W"ide Flat-Topped Steep Skirt passband.
Stage “u-INT” will INTEgrate #3 negative and #4 positive signals.

Note:
These plots and specs are from PartSIM.com , ngSPICE.

Note:
Author did the build-up on ProtoBoards.
Author used this AFX daily in the radio operations, several years.
Active in-use measurements with o’scope
compare favorably with ngSPICE plots.

Schematic specs show both
(1) the "cQ" calculated "Q" , specific to each stage,
(2) the "mQ" measured "Q", accumulated progressively.

Below is the section about the Quad Filter
the reader should note these filter characteristics :

(1) the Quad Filters have Gausian Curves, normal to band-pass filter.

(2) The u-DIFFerential and u-INTEgration Filter Stages
have passband curves that ARE NOT GAUSIAN CURVES.
The DIFF stage is used to create the Dual-Notch effects, et al .
The "Q" of the passband, based on BandWidth at -3dB down to -12dB
does **not** compare with regular band-pass circuits.
A modified **slope-of-best-fit** is used to better describe these curves.
This is the ‘variance’ calculation :
‘v’ = **[(BW@-12dB) - (BW@-3dB)] / 9dB = v**
where ‘variance’ is a special **slope-of-best-fit .**

(3) The **Non-Resonant DIFFerential Phase-Filter stage**
produces a "N"arrow signal,
via a Subtraction Operation,
which is useful for singling out one precise signal in a group.
This module (alone) produces two -48dB notches with BW=100 Hz
at aprox. 150 Hz from f(700).
This is further narrowed by the Final High ‘Q’ Resonant filters.

(4) The **Non-Resonant INTEgration stage**
produces a "W"ide top-band signal,
via a simple Summing Operation,
producing a flat top, and steep side-bands
which is useful for tuning/searching in a radio band.

****

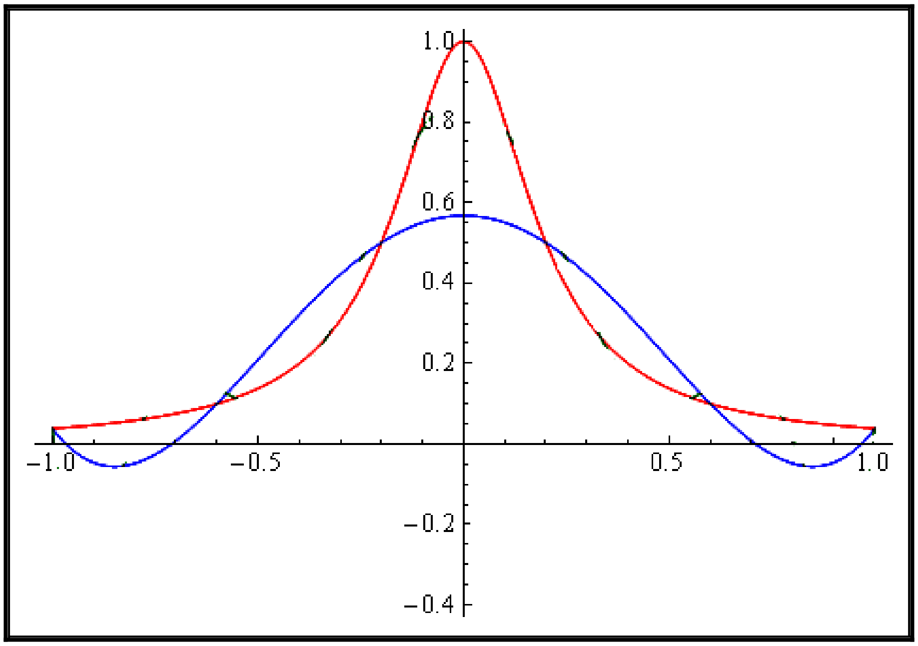
Note :

Non-Resonant Differentiated Phase-Filtered Narrow Output

*****_ Dual Notch= 535 Hz & 920 Hz ,**
which is loosely aprox. +/- 90 degrees from f(700) by design.

*****_ Dual Notch concept IS NOT the same as "I/Q" Quadrature.**

***** Below: Graphical Concept for the Dual-Notches**



Dual Notch is developed via
a Phase-Differentiation at the Cross-Over Points.
which, in this example, are aproximately
where Y=+0.5
where X=-0.2 and X=+0.2 .
Other cross-over points are buried near ground level.

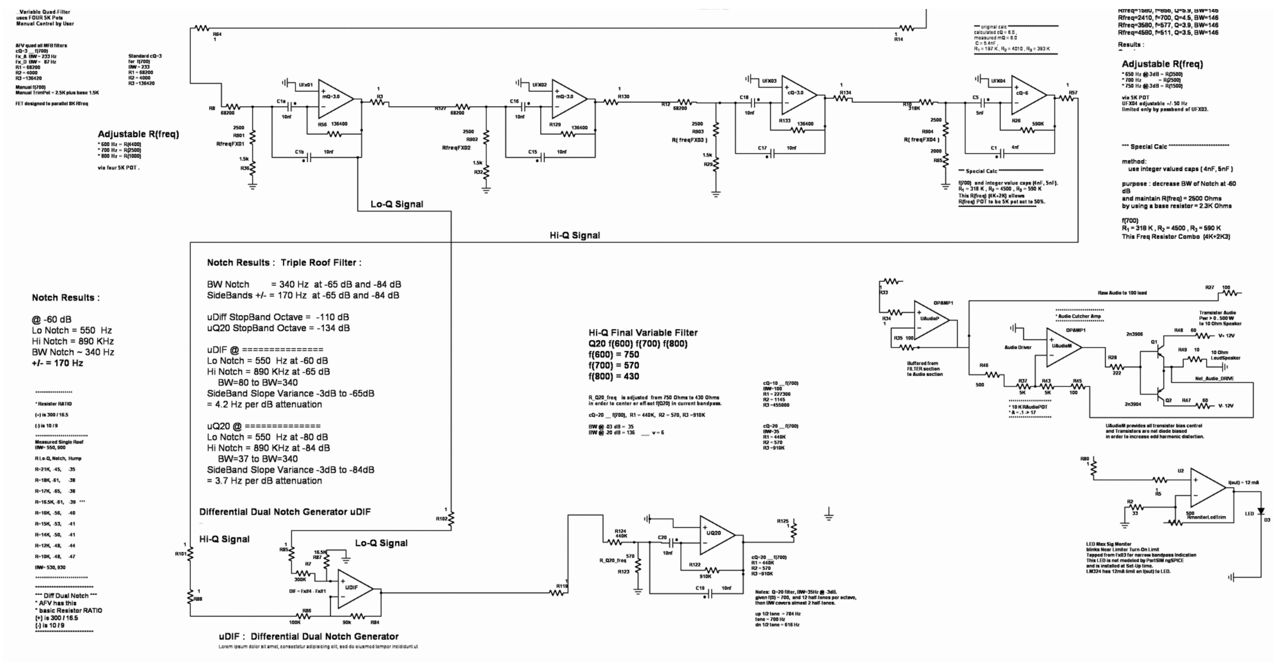
circuit: Quad-Filter and Phase-Filter module

****** below is the basic QUAD FILTER module including**

(1) Differential Phase-Filter Dual-Notch-Generator

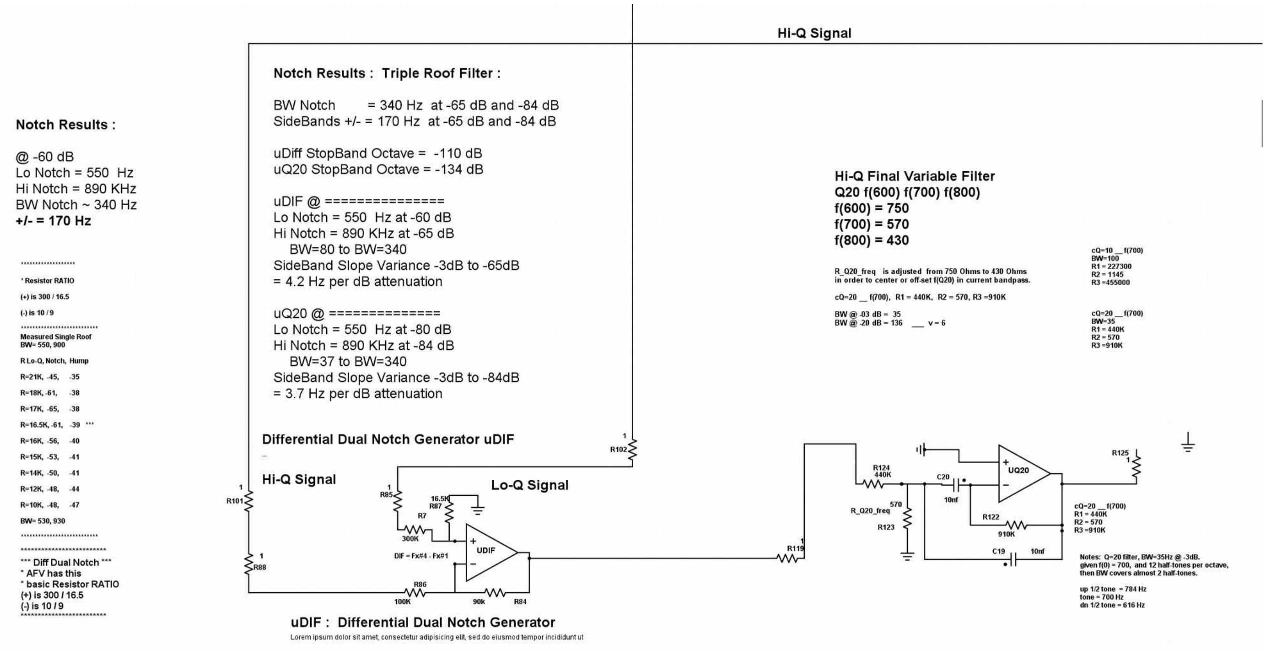
(2) Integrated Wide-Flat-Topped Generator.

(3) High 'Q' final stage



circuit detail:

Phase-Filter Differential Notch-Generator



(1) BandPass shape is NOT gaussian.
(2) Sideband falloff is -48 dB per octave .
(3) BW @ -3dB = 90Hz
(4) BW @ -12dB = 185Hz
(5) BW @ -48dB (Notch-to-Notch) =385Hz
(6) Notches at : 535Hz = Low Notch and 920Hz = High Notch.
(7) NOT a Quadrature Filter by design
and NOT Conceptually related to a "I/Q" Quadrature Filter.
(8) 920Hz is 27 dB under Fx04 band-pass curve.
920Hz is 48 dB down from 1V standard "0 dB" signal.
(9) Variance=12 Hz via BW measured from 89Hz to 196Hz
(V = Hz passband spread per dB attenuation)
(10) When Differential output is followed by a Q=20 filter
then then Narrow results are much enhanced.

Only the single u-Differential stage has critical components.

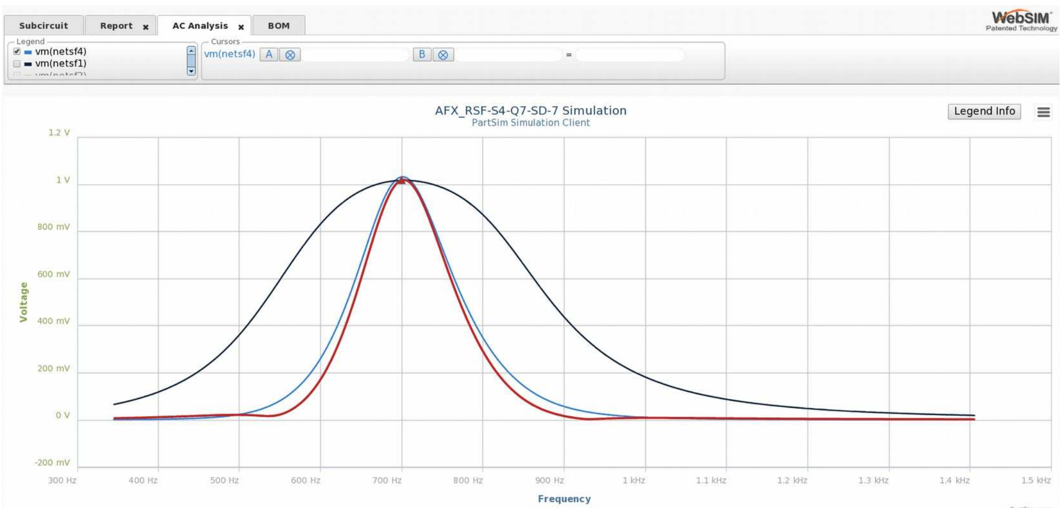
Band-Width Notch-Depth Measurements vary according to the number of Roof-Filters used in the actual circuit.

Bode Plot : Basic Wave-forms

Single-Roof (black)

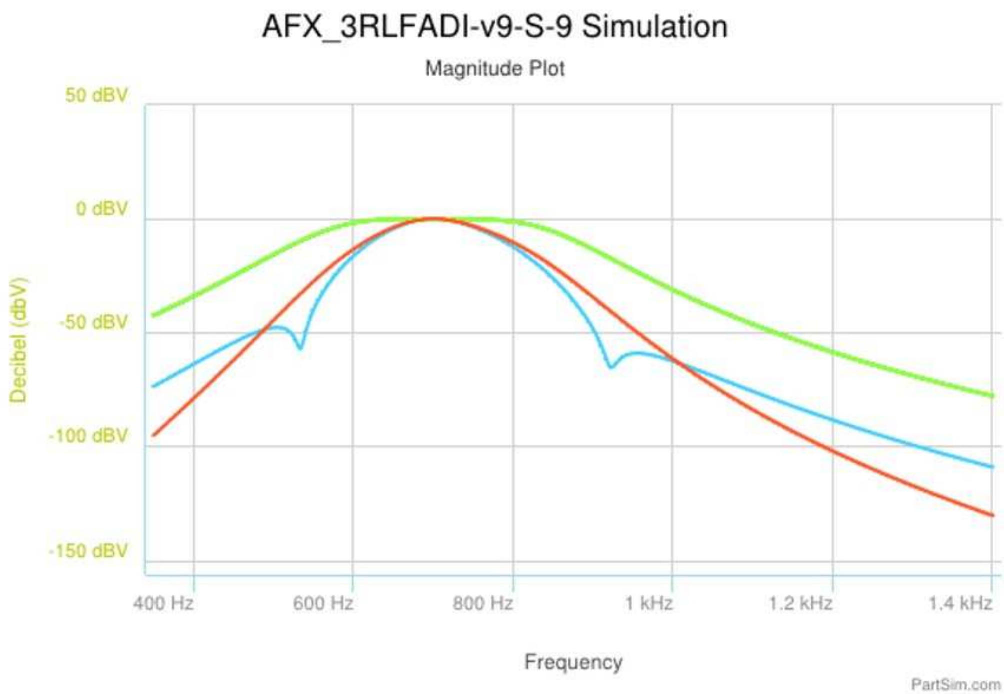
Quad-Filter sharp band-pass (blue)

Differential-Dual-Notch Generator (red).



Magnitude Plot : Basic Wave-forms

from a Single-Roof plus Differential-Dual-Notch Generator.



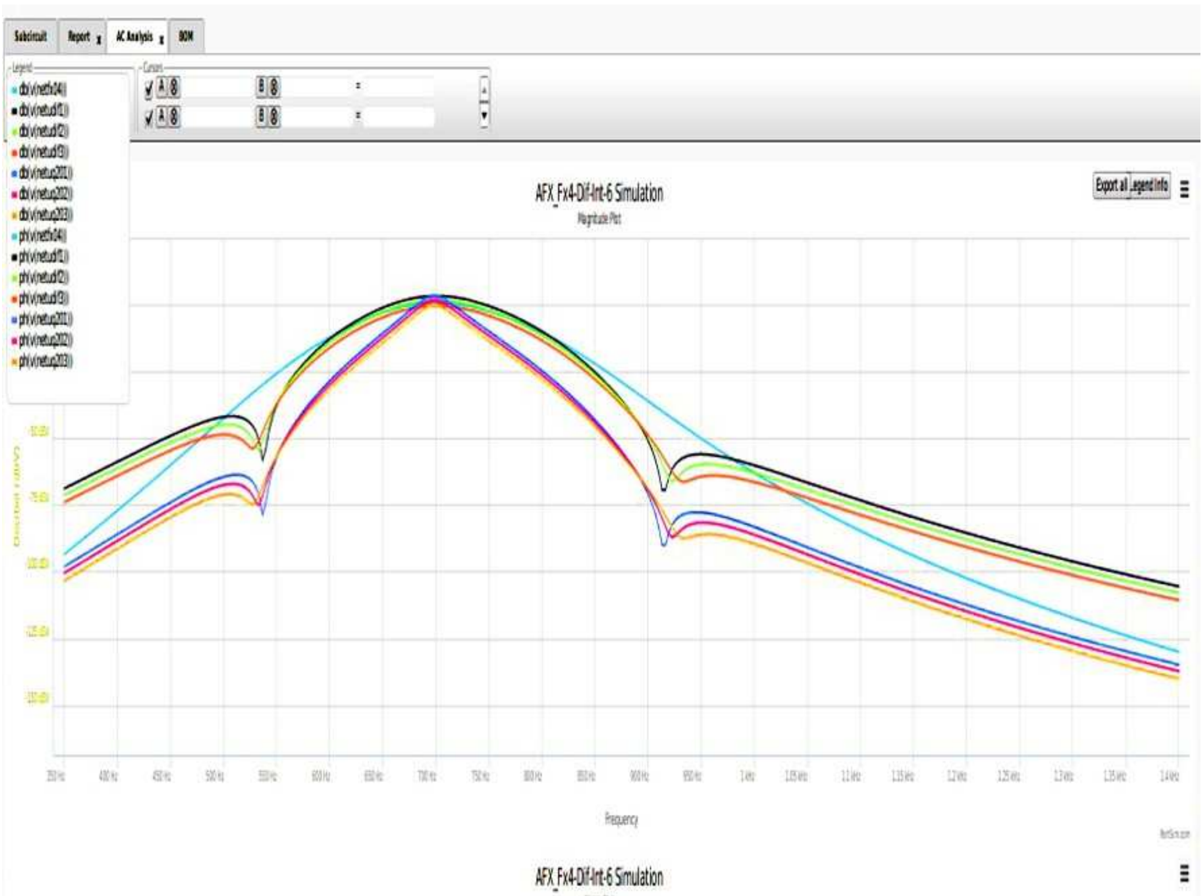
Basic Roof-Filter (green)

QuadFilters (red)

—**Basic Dual-Notches dip at 48 dB. (blue)**

—**=== as much as -96dB Notches.**

Magnitude Plot: **Main Waveforms**



Here: Initial Signal (blue) and three adjusted Notch settings.
Top (1) : blue trace is V(output) from Filter #4.
Upper (2) : Basic Dual-Notch, -58dB notch depth.
Lower (3) : signal has been passed through a Q=20 Filter at -78dB notch depth..

Plots are from PartSIM.com and ngSPICE .
O'scope observations follow this pattern.

***** Special Note for Plots : *********************

***** F1-F4+DIF = Notches are -25dB below Fx04**

***** DIF :**

***** BW=86--190___v=12**

***** Notch at 533 @ -50dB**

***** Notch at 920 @ -50dB**

***** StopBand= -48dB to limits**

****

***** F3+F4+INT**

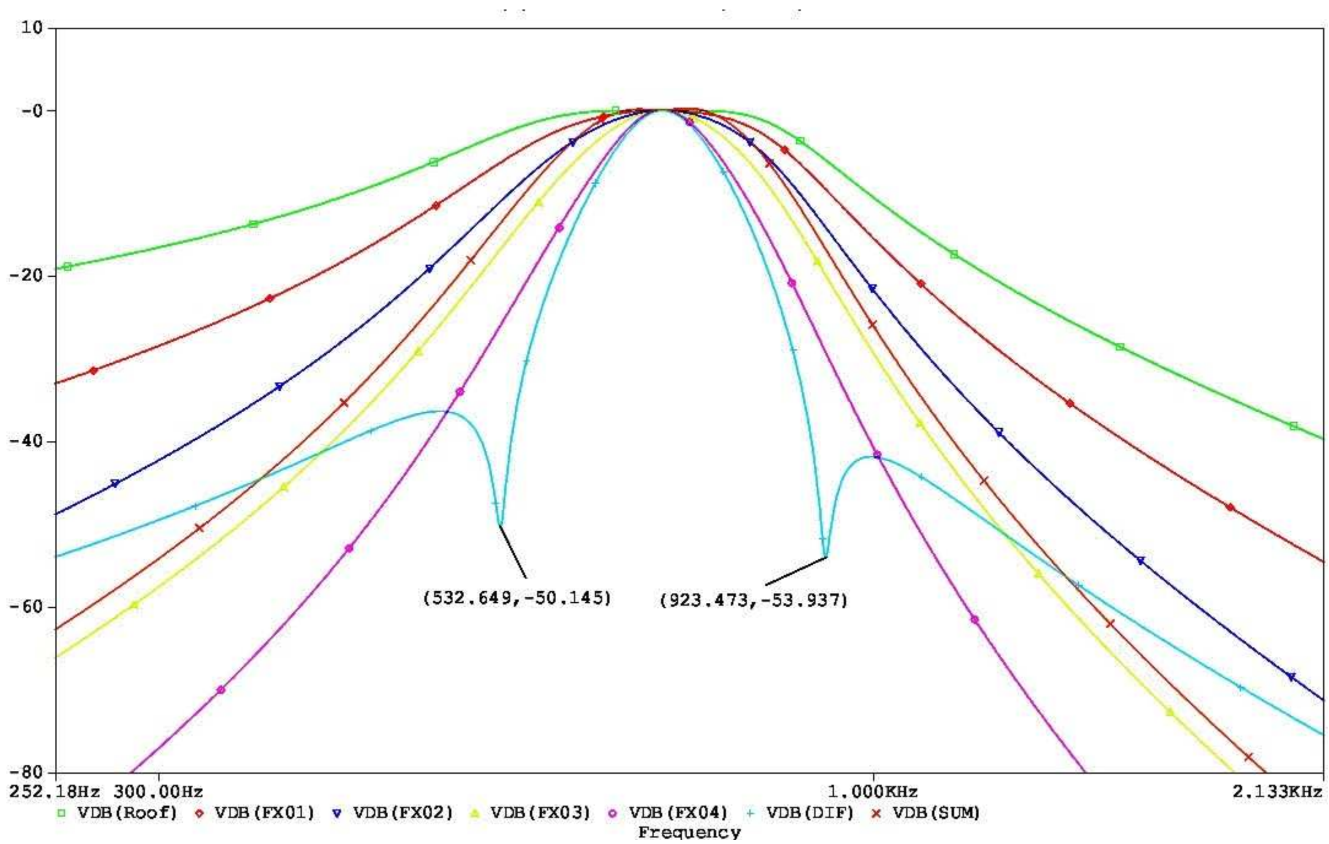
***** BW taken from 176-and-369___v=-22**

***** StopBand = -19dB to -42dB**

****

Excellent Digital Model has been provided by professor Dobromir Dobrev ... Ph.D ... Bulgarian Academy of Sciences

This digital documentation was developed following discussion on ResearchGate.Net .
Developed using an entirely Digital Analysis of the AFX circuit concept.
It is remarkably close to the Analog Spice Results that the author obtained.
At the -48dB level, the digital results are the same as the author's analog development.



More Discussion: about the Standard "AFX" Circuit

Summary:

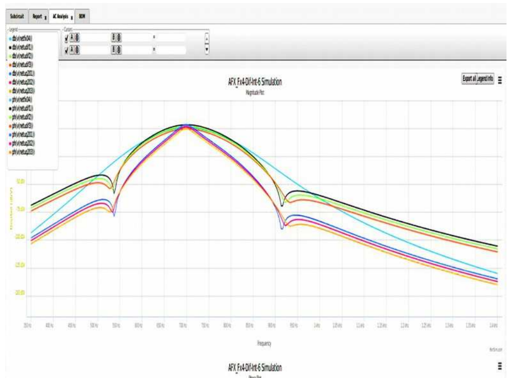
1) Bullet-Proof Construction and Easy to tune
just using a VOM and ordinary signal source off the (radio) air.
2) Very steep side-band skirts .
3) very low passband signal level at 1000 Hz.

*** Initial PreAmp has wide gain in order to drive the Limiter into action.
*** Roofing Filter is very wide Band-Pass => 300 Hz t -3dB.
*** Log Diode Limiter is a single stage, instant response,
Actively Driven by user control in Initial Pre-Amp stage.
*** LED indicator shows “Diode-Limiter-in-Action”
(if tapped from Fx04, then indicates the Center-of-Passband).

*** Filtering stage BandWidth Ranges :
"W"ide calculated Q=2.5 BW=250, measured "Q" = 3.5
"N"arrow calculated Q=5 BW=100. ... measured “Q” = 6.5

*** Quad Filter has Variable f(0) in Stage #4
which acts like an RIT tuner for +/- 100 Hz
within the overall band-pass..
*** Hedge f(0) by shifting the Stage #4 f(0) within the source passband,
to better capture a slightly QSY signal.
*** Standard Design options :
* a Stage **UDI**F (DIFferentiating Fx01 with Fx04)
to produce a "N"arrow Double-Notched signal.
*** Optional :
* a Stage **UINT** (INTegrating #3 negative and #4 positive signals)
to produce a "W"ide flat-top steep sided signal.

* Note: the Calculated "cQ" and Measured "mQ" are shown.
* Because circuit measurements show the cumulative effect of several stages.
* the Measured "mQ" is always much higher than the Calculated "cQ"
of the sequence of four filters. .
* The **Cumulative Measured "mQ" is the Real-Time Signal out of this filter**.



****
::: Some Circuit specs:
::: 12V split supply. So, +/- 6V supply
::: LM741 & LM308 Vout max = +/- 4.2V. (only tested)
::: LM324 Vout max = +/- 5.2V (actually used in the AFX)

General Setup :
::: Set Diode Limiting at 1.25 V as aprox. Limit Function roll-over.

::: Set Limiter V(out) = +/- 1.0V peak into audio filters ,
as approximate Standard 'max' Signal Level.

::: Filters run at +/- 1V peak aprox. at max. signal level.
analogous to the Log-Limiter Peak range.

::: Filter Stage #4,
calculated cQ=5, ,measured mQ=7 cumulative,
measured BW=100.

****

This Chapter has been about the author's AFX core filter circuit

The project is for use with Vintage and Analog QRP rigs,
such as the Heathkit HW-8

It also provides excellent results attached to a Kenwood 830-S.

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Chapter: **Audio Stage**

***** Cutcher style Audio Circuit & LED drivers**

**At this point, the previous filter stages
have produced a 'soft' sine-shaped CW audio pulse .
All sub-harmonics and supra-harmoncs have been filtered out,
leaving principally a narrow filtered passband of 650 to 750 Hz.**

**What is needed is a "crisp" CW signal
for better ear/brain function in reading the CW message.
High fidelity music audio is NOT desired.
"Crisp" CW pulse , extra treble, is required.**

**This stage is an OpAmp-Driven Two-Transistor Push-Pull Class "B".
OpAmp directly drives all Transistor Biasing,
which produces cross-over distortion.**

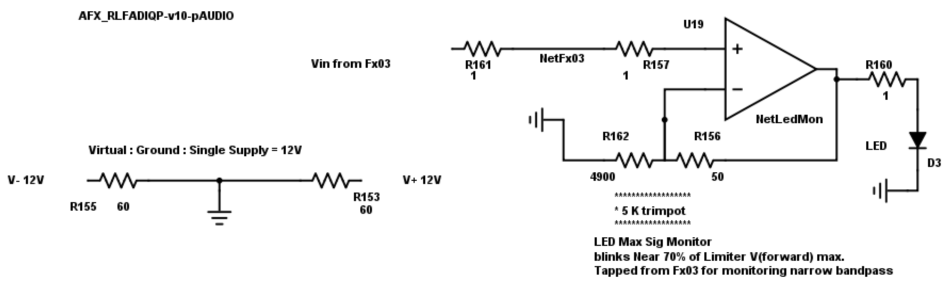
**Our Design introduces third-harmonic distortion ,
without saturating the amplifier,
without compressing the signal amplitude,
without loosing amplitude variations between
the possible multiple signals in the passband.**

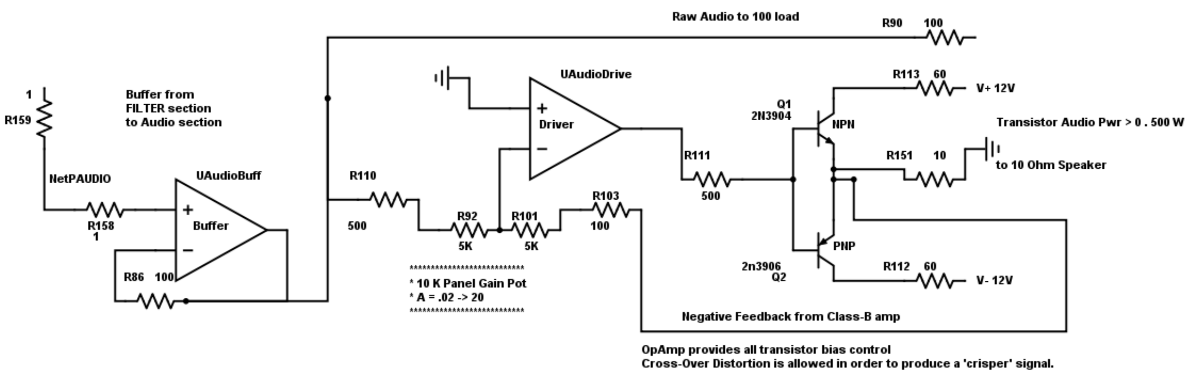
**In radio operations with CW at f(700) Hz ,
signals closer than 50Hz can occur
and enter the passband to be discerned by the ear.**

**Our goal is to produce a "crisper" CW audio
for better ear/brain copy.**

***** Below: the Standard Audio Circuit schematic**
(with simple LED monitor on top right)

OpAmp directly drives the Class-B audio stage,
without diode-offset base-bias
thus producing obvious cross-over distortion
and thus producing a 'crisp' CW audio signal.



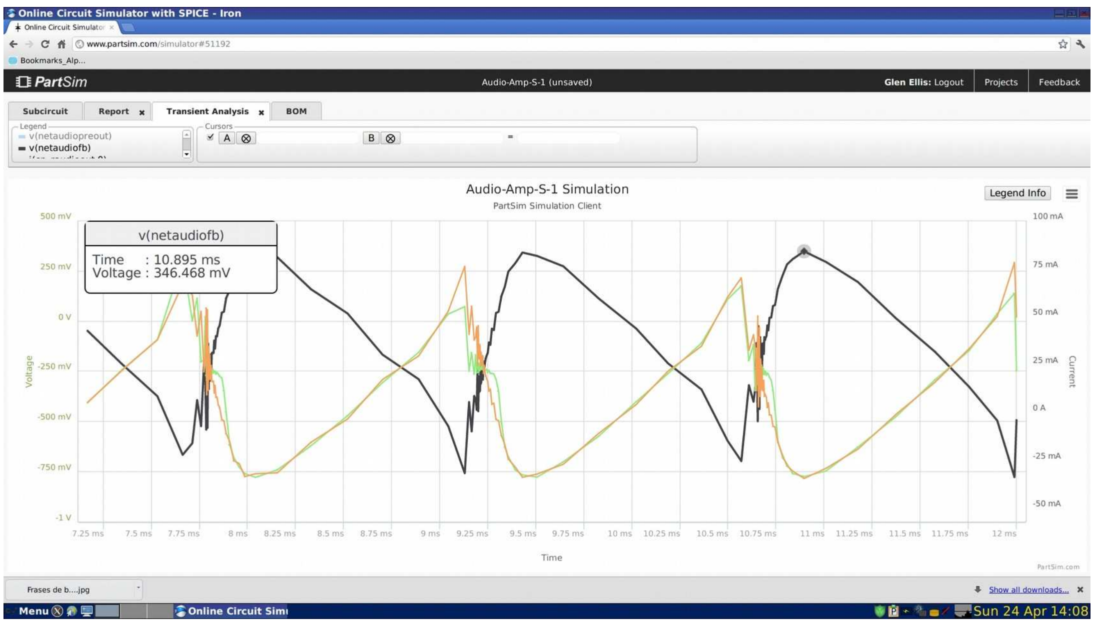


In this AFX circuit,
the OpAmp Drives Two Transistor Push-Pull Class "B"
produces a Saw-Tooth signal.
This is a common Cutcher Amp, un-biased.

**Received signal is a 'soft' sine-shaped CW audio pulse.
This stage produces a distorted Audio to the loud-speaker
which is a sawtooth.**

**Design Goal of this un-biased class-B amp
is to introduces third-harmonic distortion
to produce a "crisper" CW audio for better ear/brain copy.**

The circuit produces an Audio V(out) shown in the below Transient Plot.



**This Transient Plot shows the Distorted Audio Output
which has more third harmonic
which is a "crisper" signal to the ear.**

****


CQ

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