Active Filter Design Made Easy With WEBENCH® Active Filter Designer

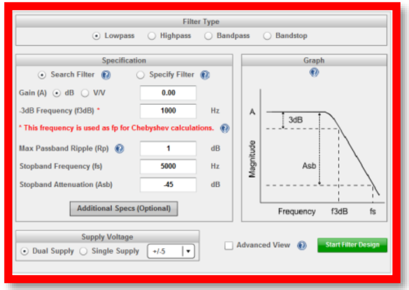
Custom Active Filter Designs Including Spice Simulation

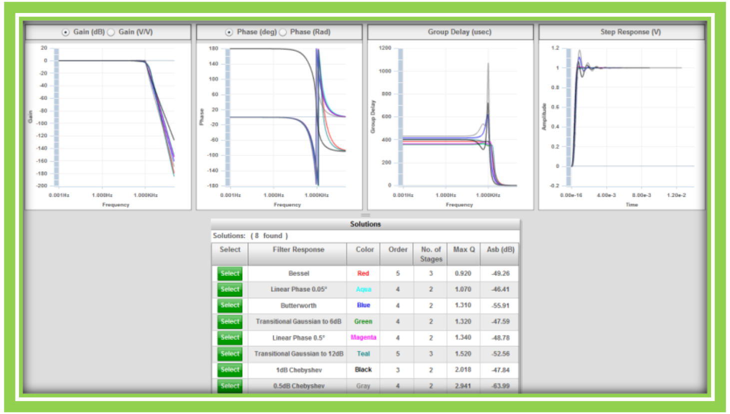
WEBENCH® Active Filter Designer: Active Filter Designs Within Minutes!

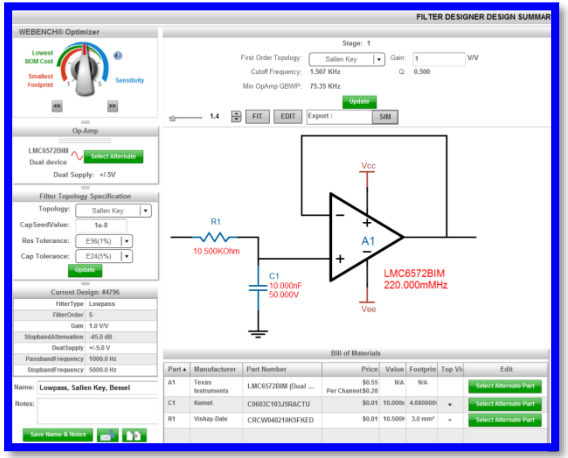
1. Select a Filter Type

2. Design Frequency response

3. Analyze with SPICE

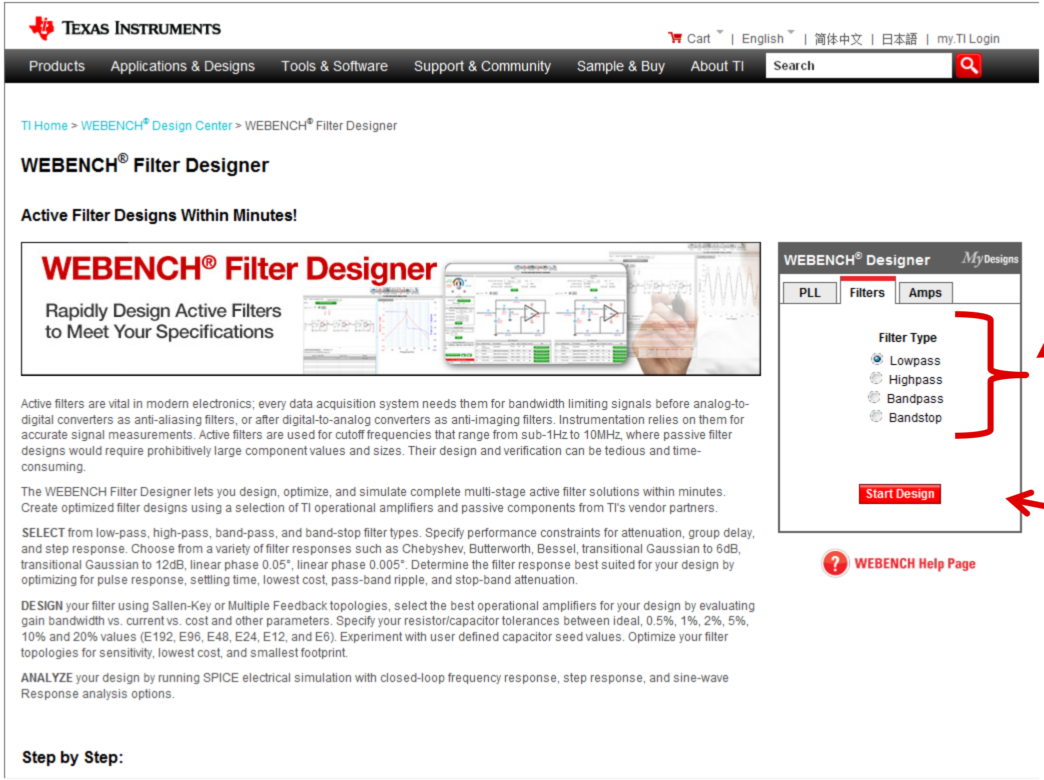






Accessing Filter Designer

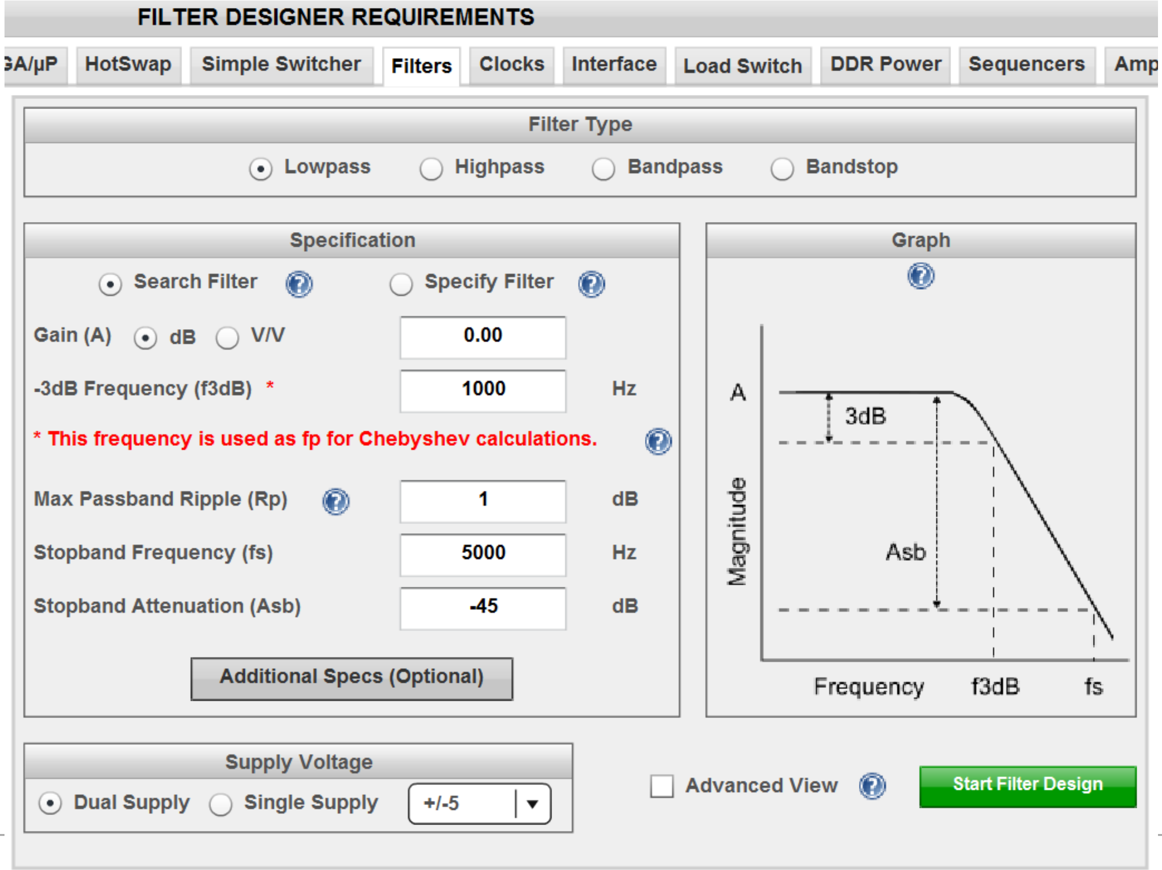
ti.com/webenchfilters



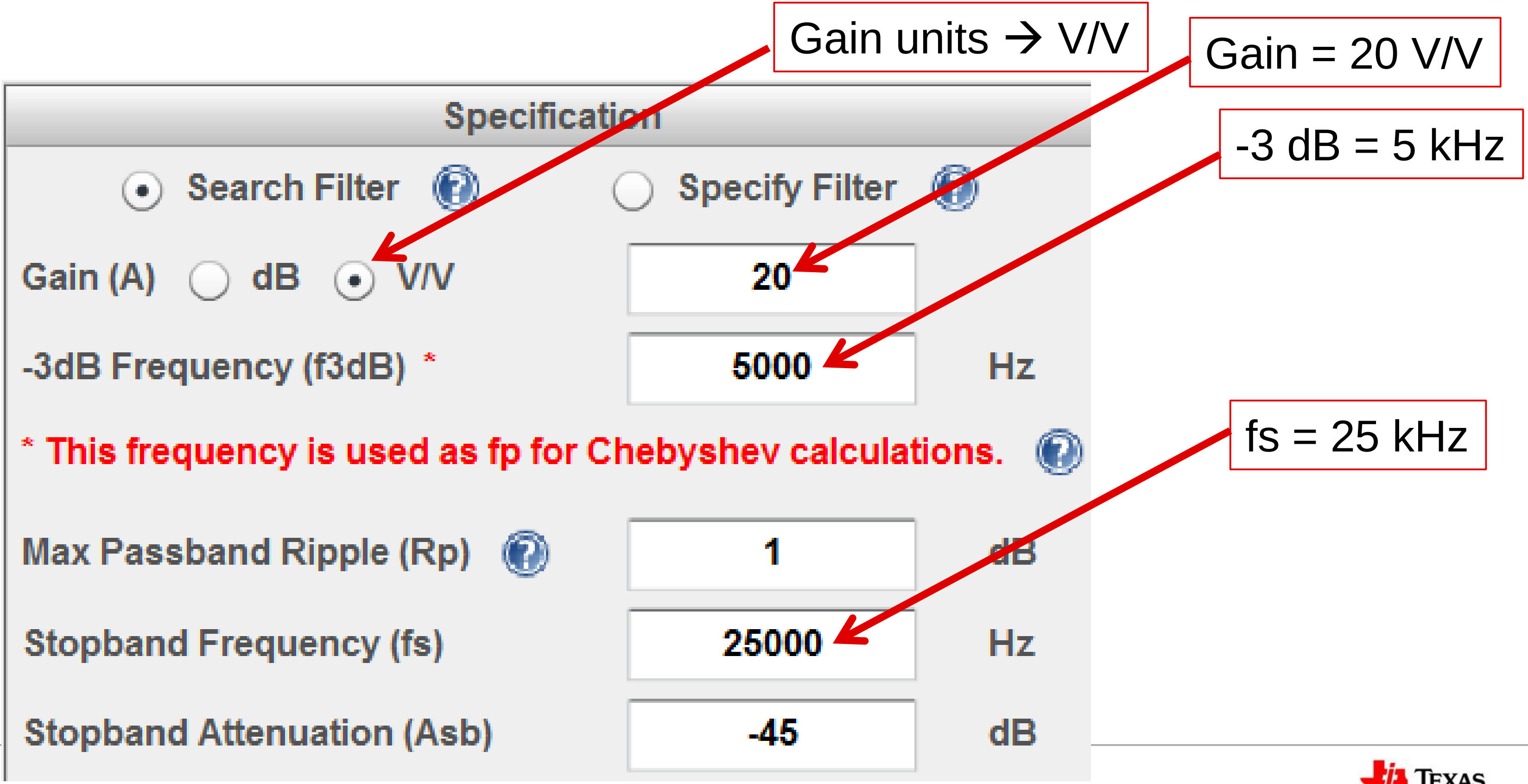
Select your filter type

Start Design

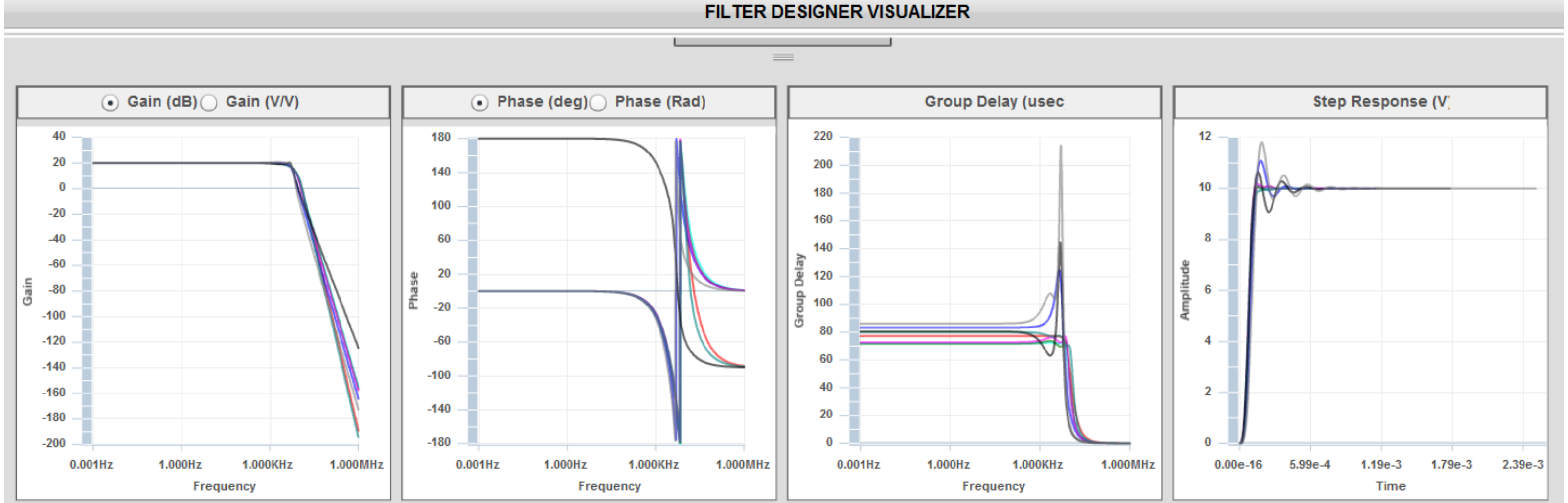
NEW Filter Designer Requirements page



Changes to specifications



NEW Visualizer page



Solutions

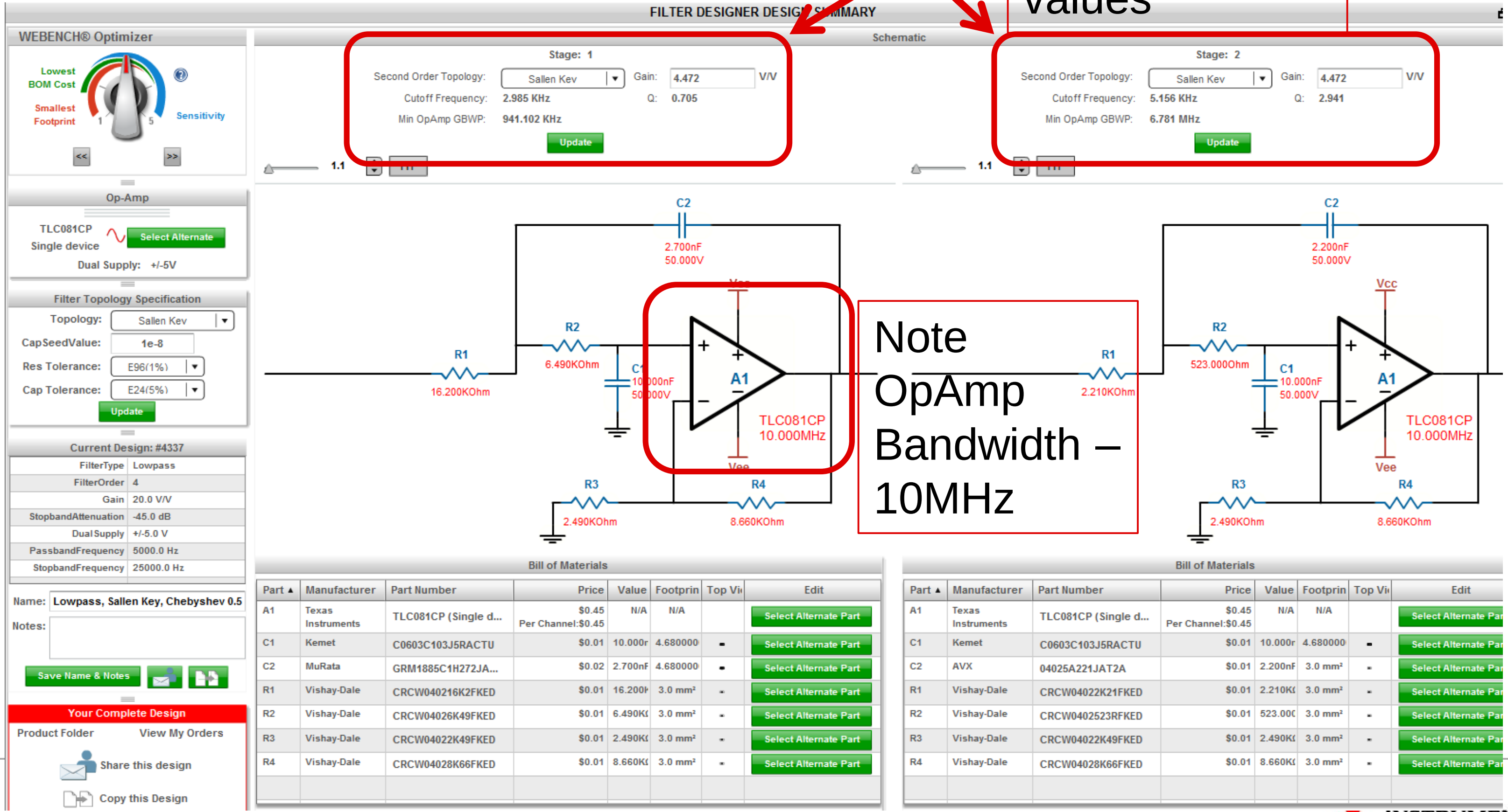
Solutions: (8 found)

Select	Filter Response	Color	Order	No. of Stages	Max Q	Asb (dB)
Select	Bessel	Red	5	3	0.920	-29.26
Select	Linear Phase 0.05°	Aqua	4	2	1.070	-26.41
Select	Butterworth	Blue	4	2	1.310	-35.91
Select	Transitional Gaussian to 6dB	Green	4	2	1.320	-27.59
Select	Linear Phase 0.5°	Magenta	4	2	1.340	-28.78
Select	Transitional Gaussian to 12dB	Teal	5	3	1.520	-32.57
Select	1dB Chebyshev	Black	3	2	2.018	-27.84
Select	0.5dB Chebyshev	Gray	4	2	2.941	-43.99

Choose 0.5 dB Chebyshev filter

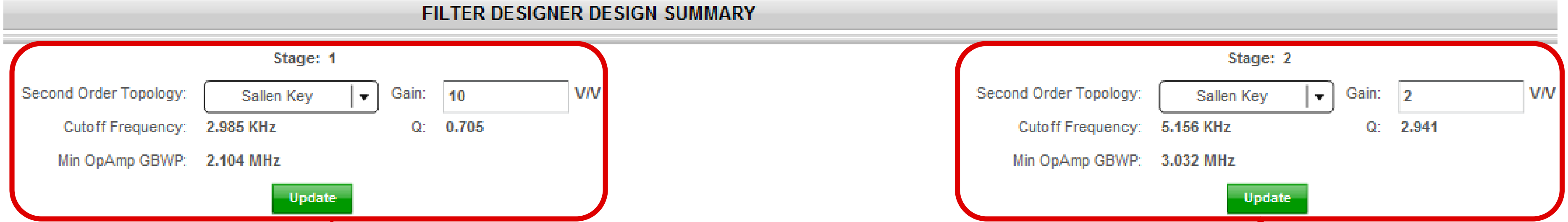
Filter Design Summary page

Note Min OpAmp GBWP values



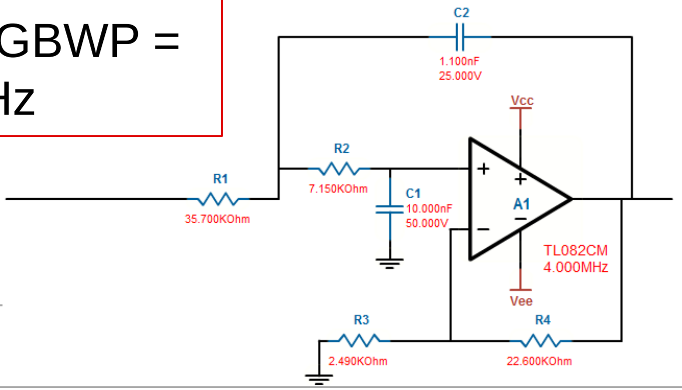
Note OpAmp Bandwidth – 10MHz

Filter Design adjust gain values



Change
Gain = 10
Update
Note Min OpAmp GBWP = 2.104 MHz

Change
Gain = 2
Update
Note Min OpAmp GBWP = 3.032 MHz



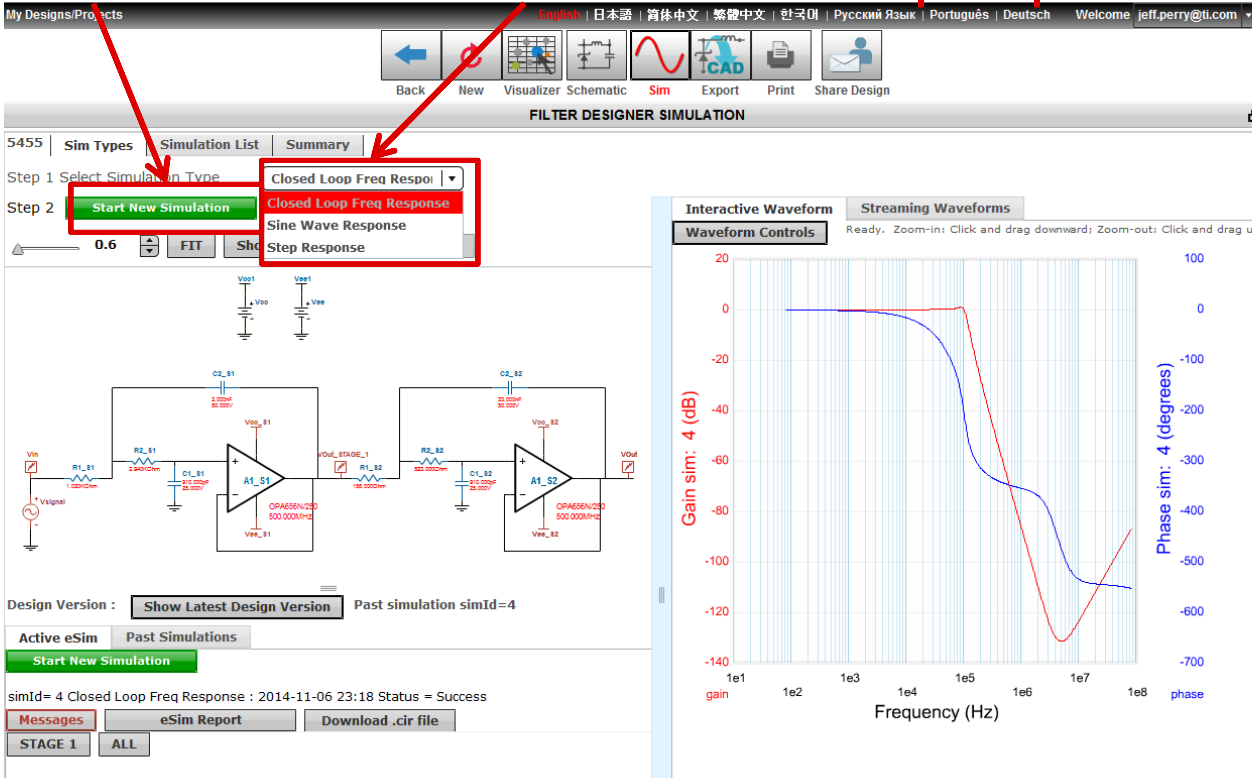
Note OpAmp GBWP = 4.0 MHz

Electrical Simulation

Click to Run Sim

Select Sim Type

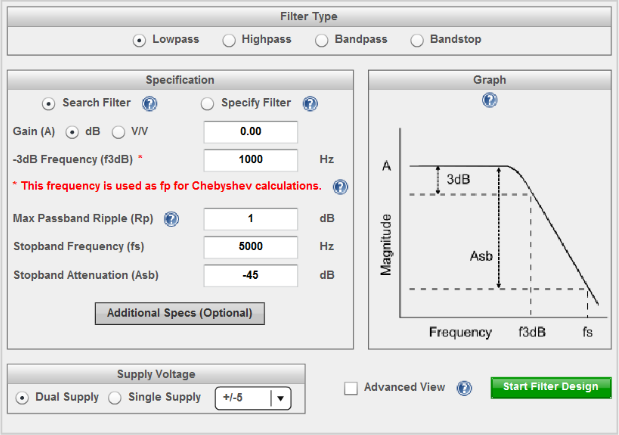
**Closed Loop Frequency Response,
Sine Wave Response,
Step Response**



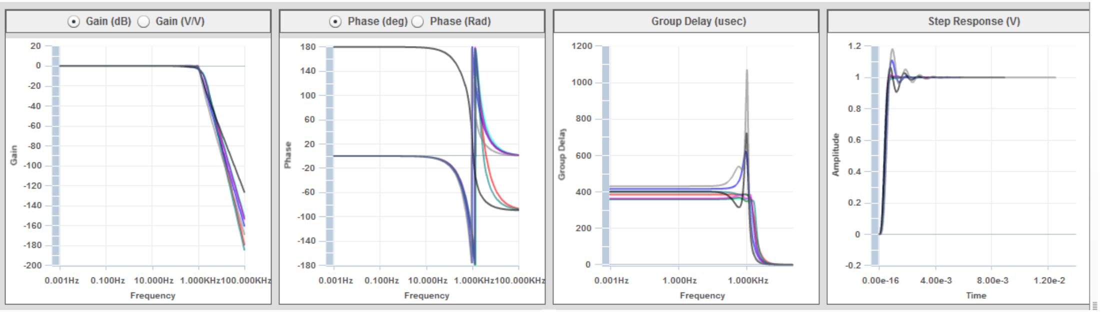
Everything old is new

- **Is live today**

- Big changes in Filter Type (page 1)
- Bigger changes in Visualizer (page 2)



- ti.com/filterdesigner



Texas Instruments

Hands-on Exercise

Design Problem:	Goals:
Customer would like a bandstop filter at 1000kHz with the following constraints: Type: Bandstop Center Frequency: 1kHz Gain: 1 Passband Bandwith: 1kHz Stopband Attenuation: -45 dB Stopband Bandwidth: 100Hz Dual Supply: +/- 5V Filter transfer function: Linear phase .05deg, 6th order	Generate a filter What is the output ripple of a 1V input sine wave at 1kHz? How can this be improved?

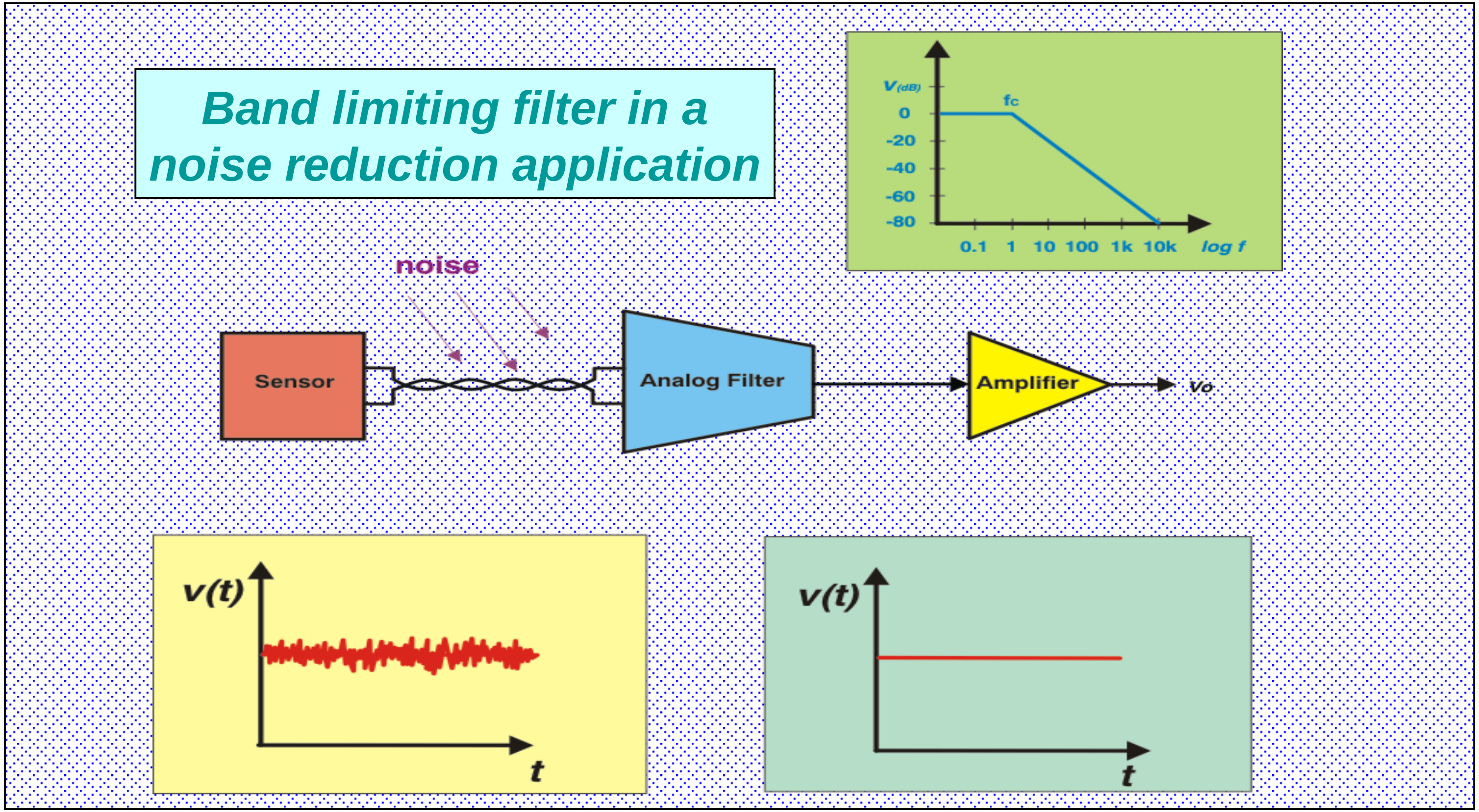
Hands On Problems

- Go to hands on problem set for Signal Chain
- Work the problems from the following:
- **Active Filter Designer**
  - 10kHz Low Pass Filter
  - Optimize Low Pass Filter
  - Anti-aliasing filter

Active Filter Design Made Easy With WEBENCH® Active Filter Designer

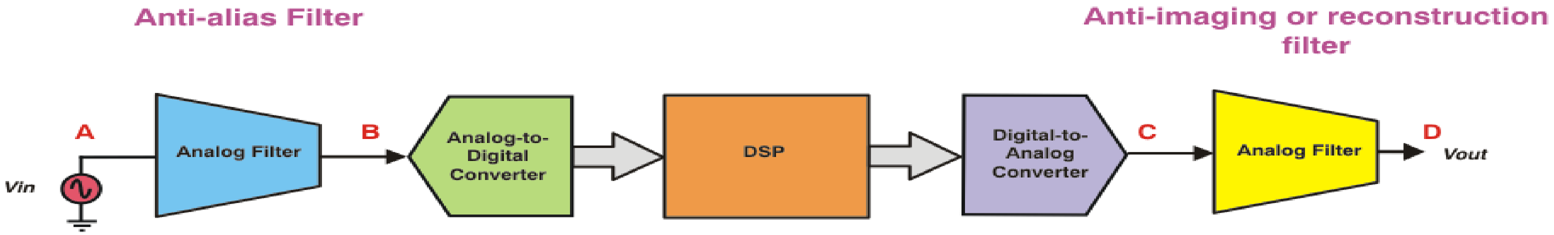
Custom Active Filter Designs Including Spice Simulation

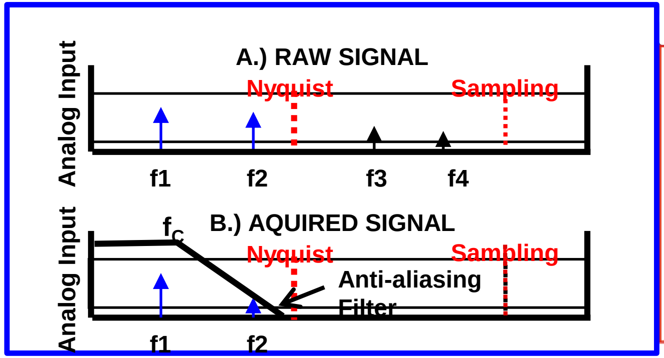
Common Filter Applications

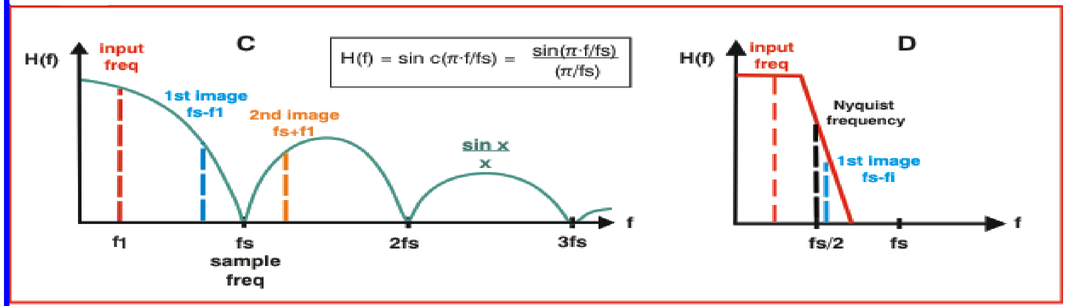


Common Filter Applications

Mixed-Signal Filter Applications







Filter Types

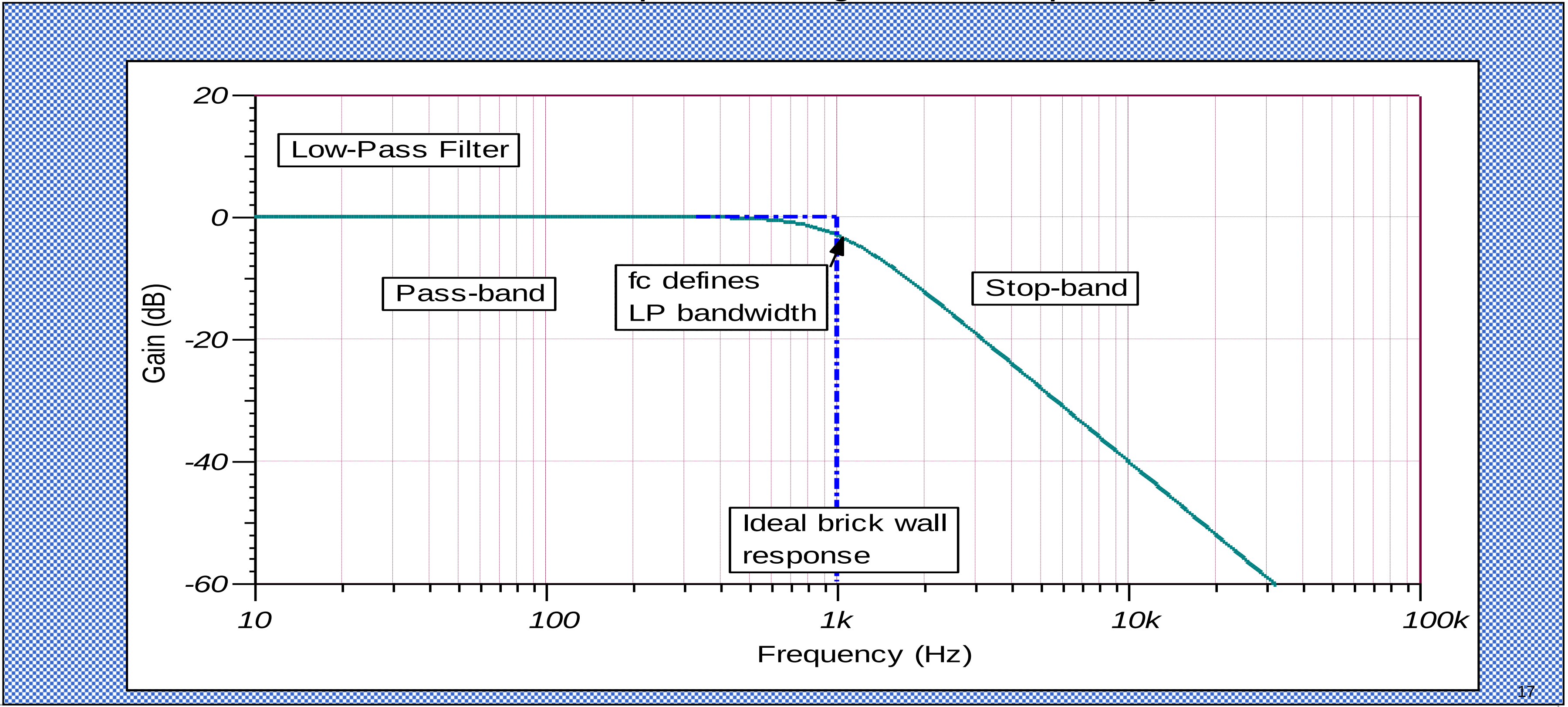
Lowpass, Highpass, Bandpass, and Bandstop Filters

- A lowpass filter the bandwidth is equal to DC to f_c
- A highpass filter has a single stop-band DC to f_c, and pass-band $f > f_c$
- A bandpass filter has one pass-band, between two cutoff frequencies f_L and $f_u > f_L$, and two stop-bands $0 < f < f_L$ and $f > f_u$. The bandwidth = $f_u - f_L$
- A bandstop (band-reject) filter is one with a stop-band $f_L < f < f_u$ and two pass-bands $0 < f < f_L$ and $f > f_u$

Adopted from: *Introduction to Filter Theory* – by David E. Johnson

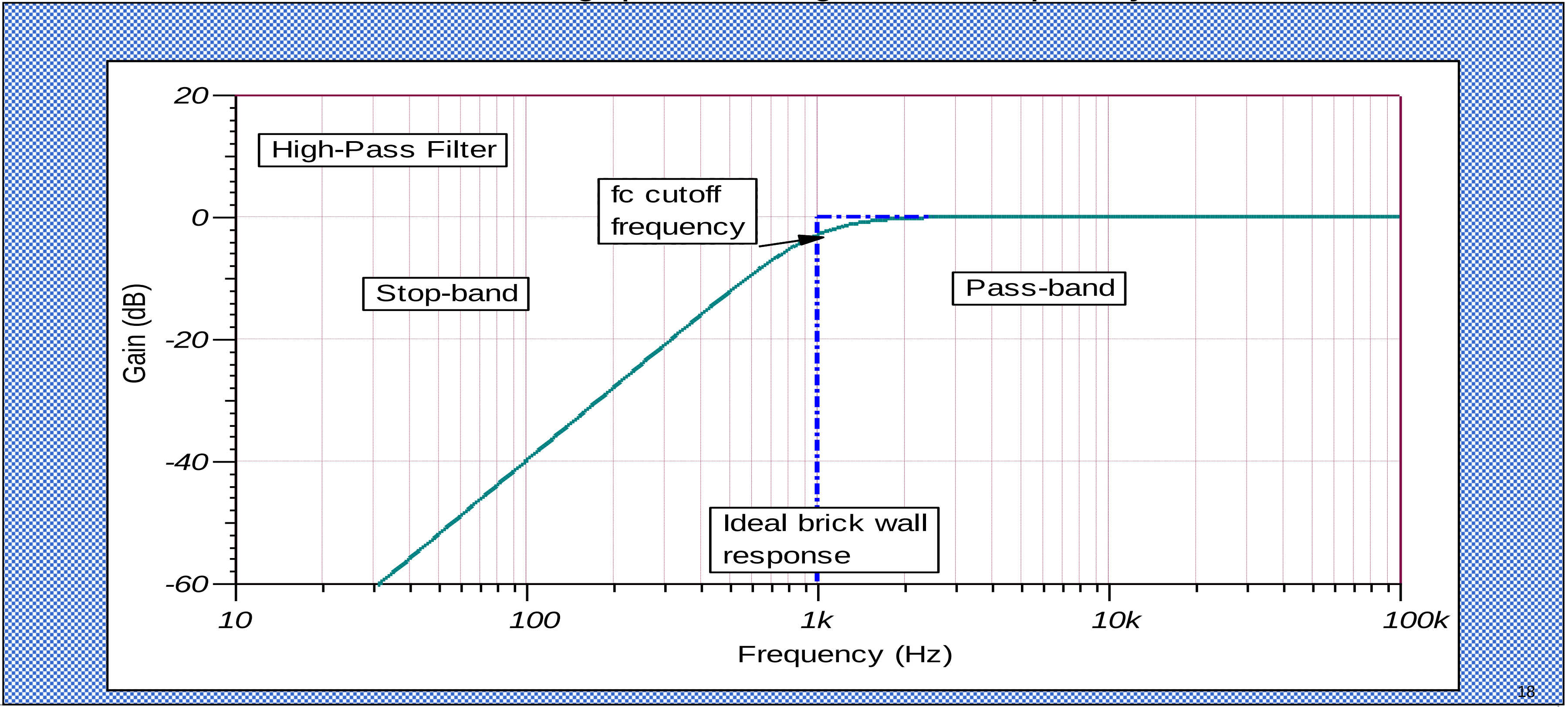
Filter Types

1-kHz Lowpass filter gain vs. frequency



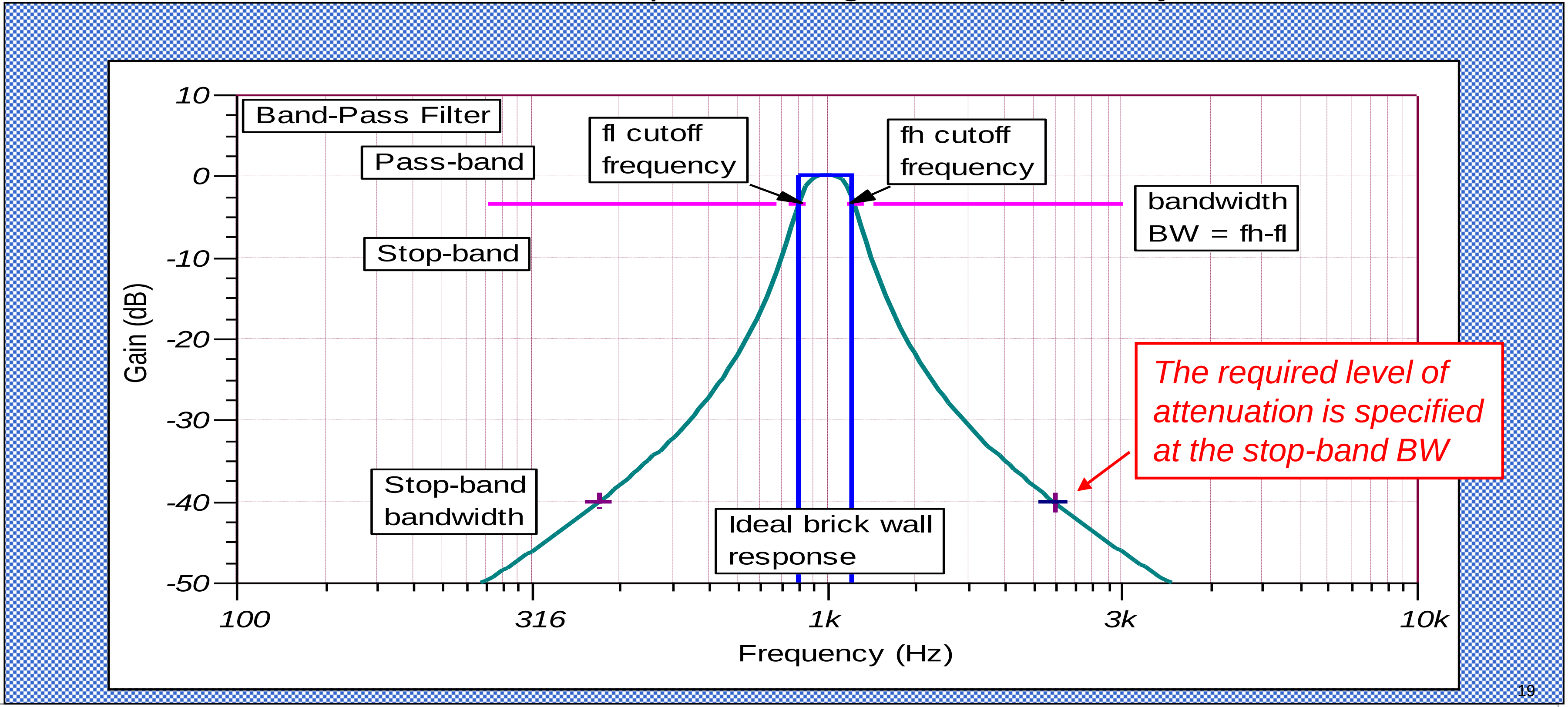
Filter Types

1-kHz highpass filter gain vs. frequency



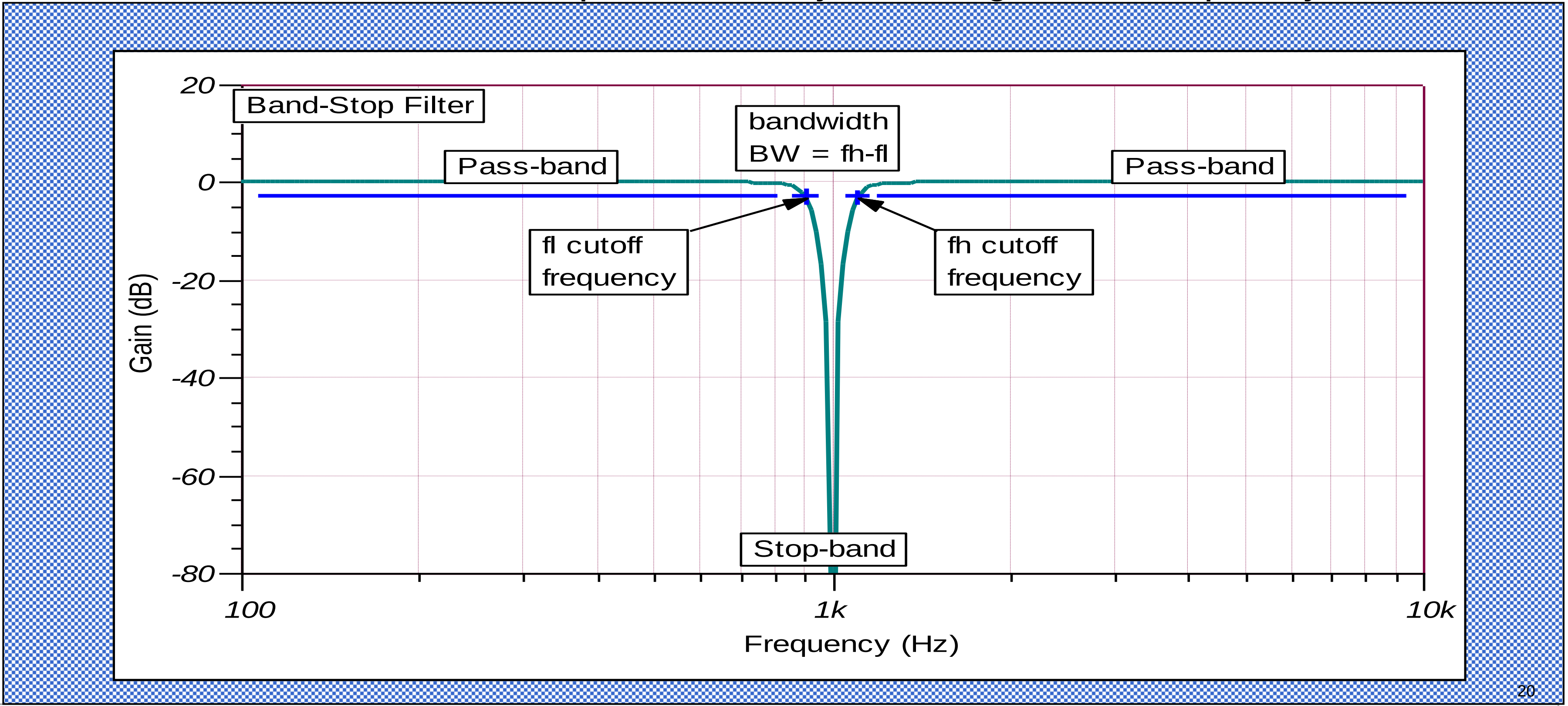
Filter Types

1-kHz bandpass filter gain vs. frequency



Filter Types

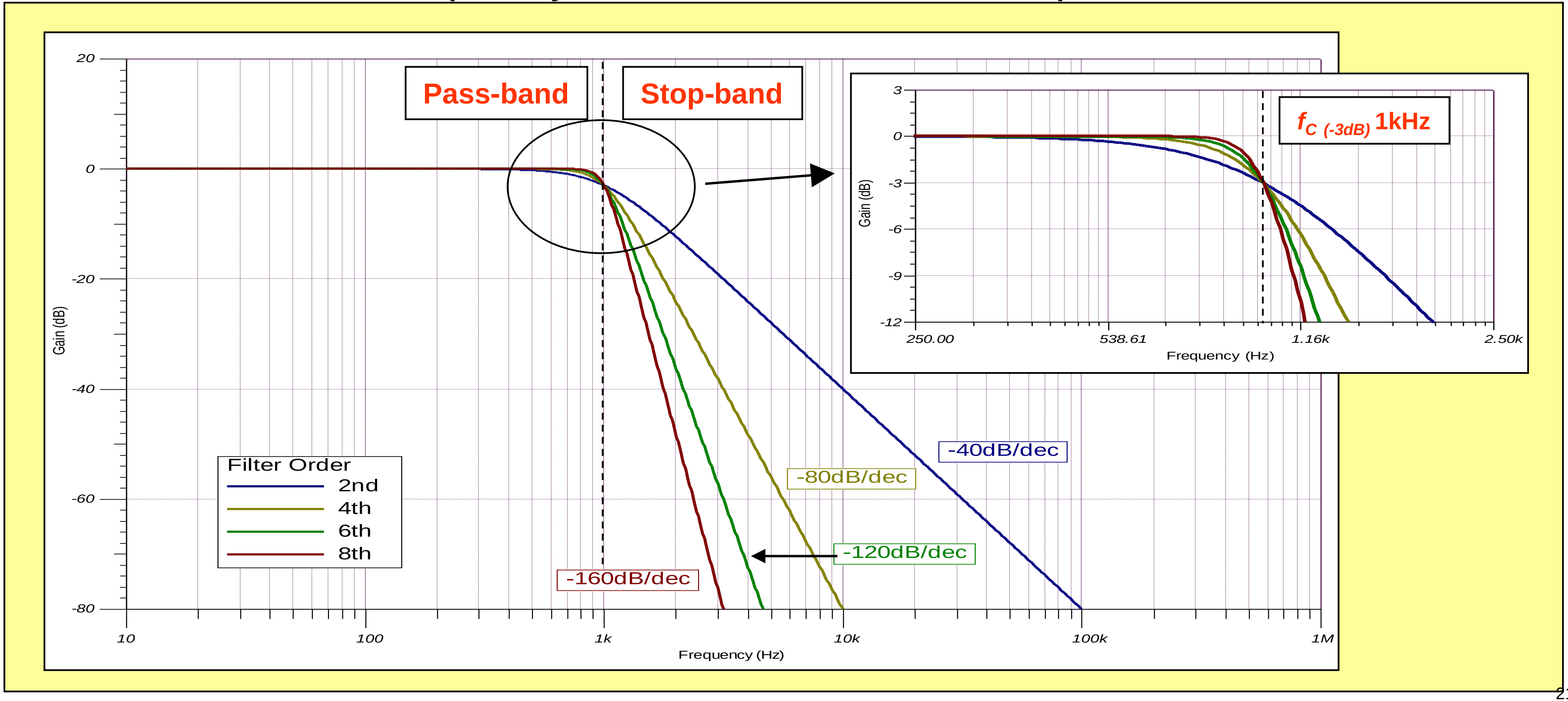
1-kHz bandstop, or band-reject filter gain vs. frequency



TEXAS INSTRUMENTS

Filter Order

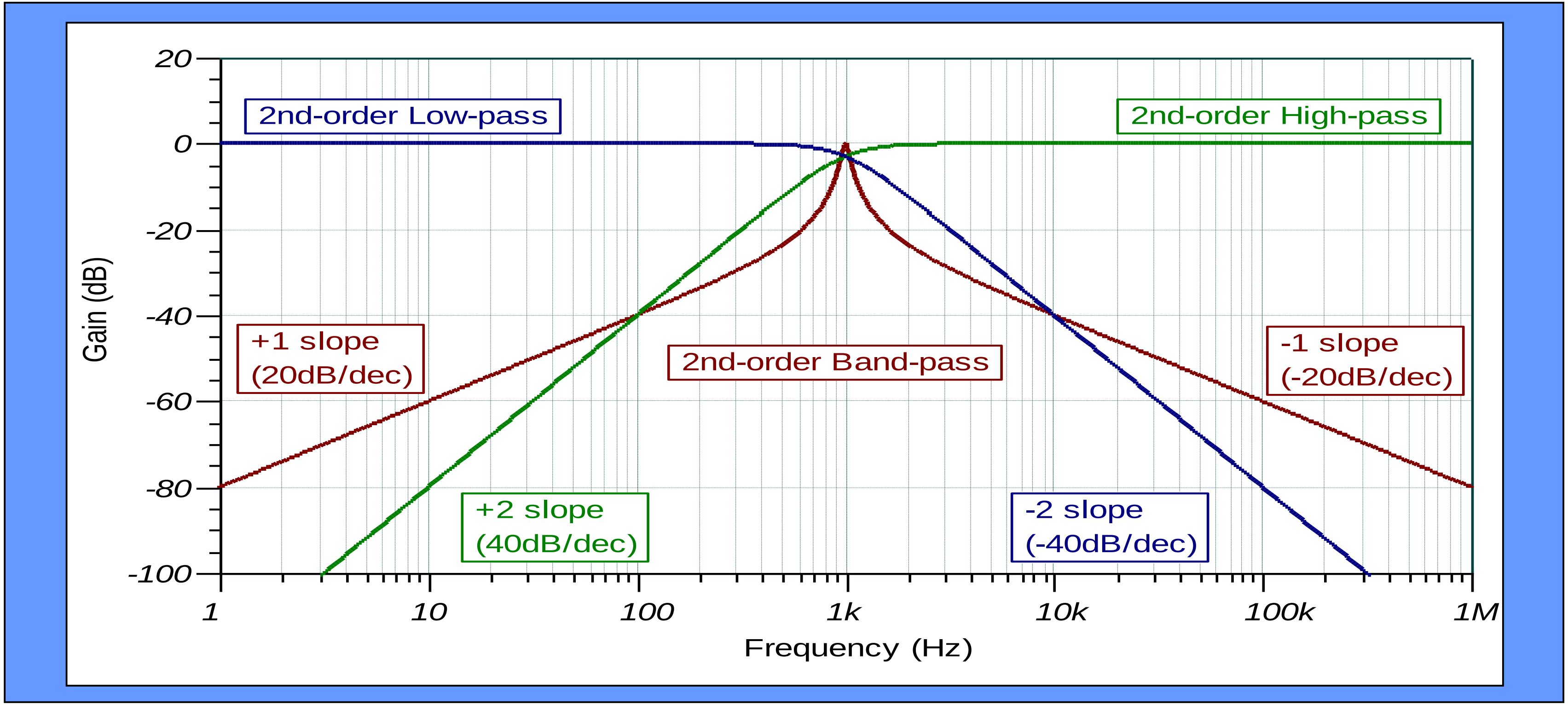
Gain vs. frequency behavior for different lowpass filter orders



Texas Instruments

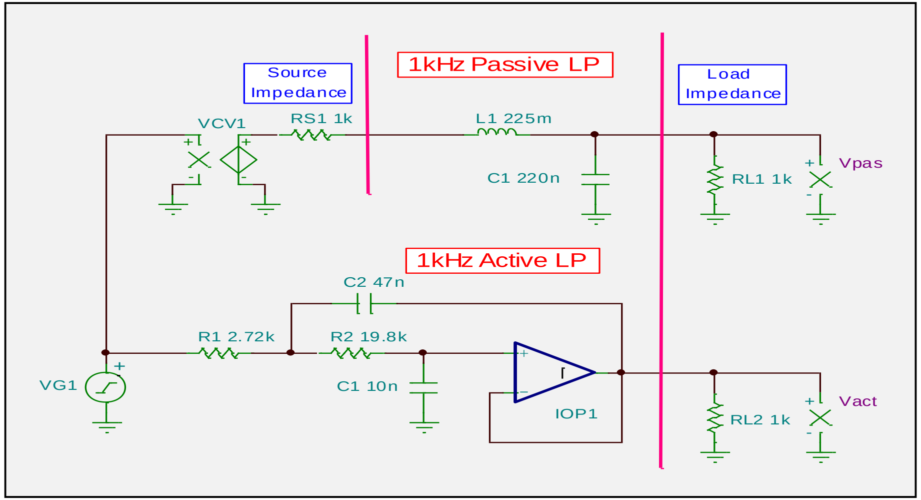
Filter Order

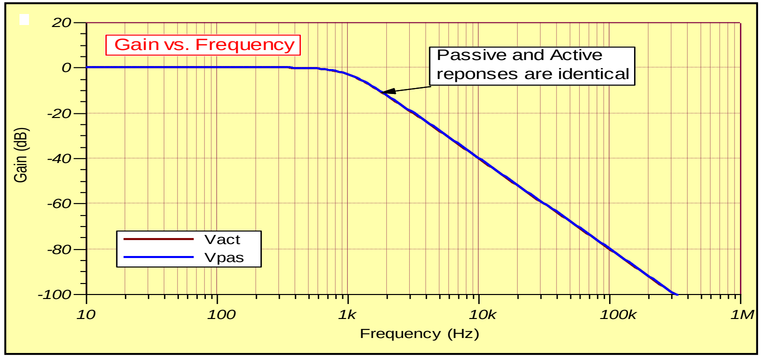
2nd-order lowpass, highpass and bandpass gain vs. frequency slopes

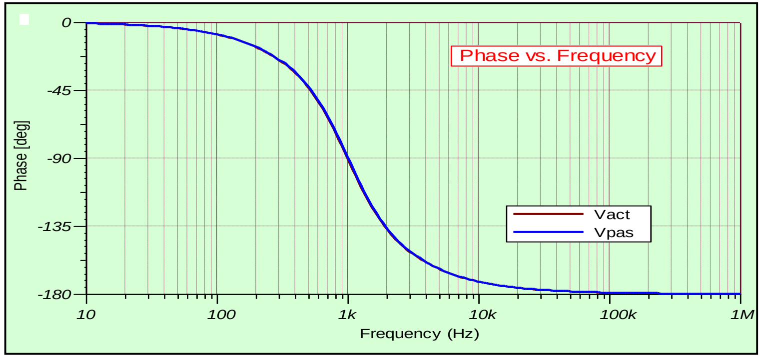


Why Active Filters?

A comparison of a 1kHz passive and active 2nd-order, lowpass filter





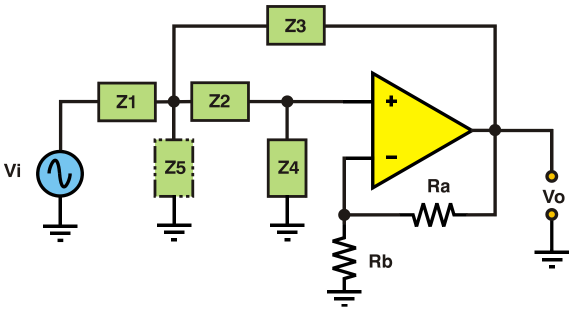


- Inductor size, weight and cost for low frequency filters may be prohibitive
- Inductor magnetic coupling considerations
- Active filter size is small and low in cost
- R and C values are easily scaled in active filters

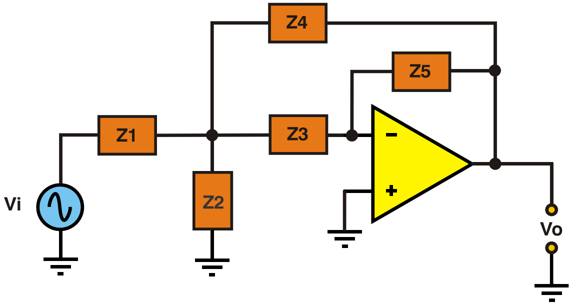
Popular Active Filter Topologies

2nd-order Active filter topologies used by WEBENCH Active Filter Designer

Sallen-Key, VCVS
Non-inverting amplifier topology



Infinite Gain, Multiple-Feedback
Inverting amplifier topology



Component type for each filter topology

Pass	*Z1*	*Z2*	*Z3*	*Z4*	*Z5*
Low	R1	R2	C3	C4	na
High	C1	C2	R3	R4	na

Pass	*Z1*	*Z2*	*Z3*	*Z4*	*Z5*
Low	R1	C2	R3	R4	C5
High	C1	R2	C3	C4	R5
Band	R1	R2	C3	C4	R5

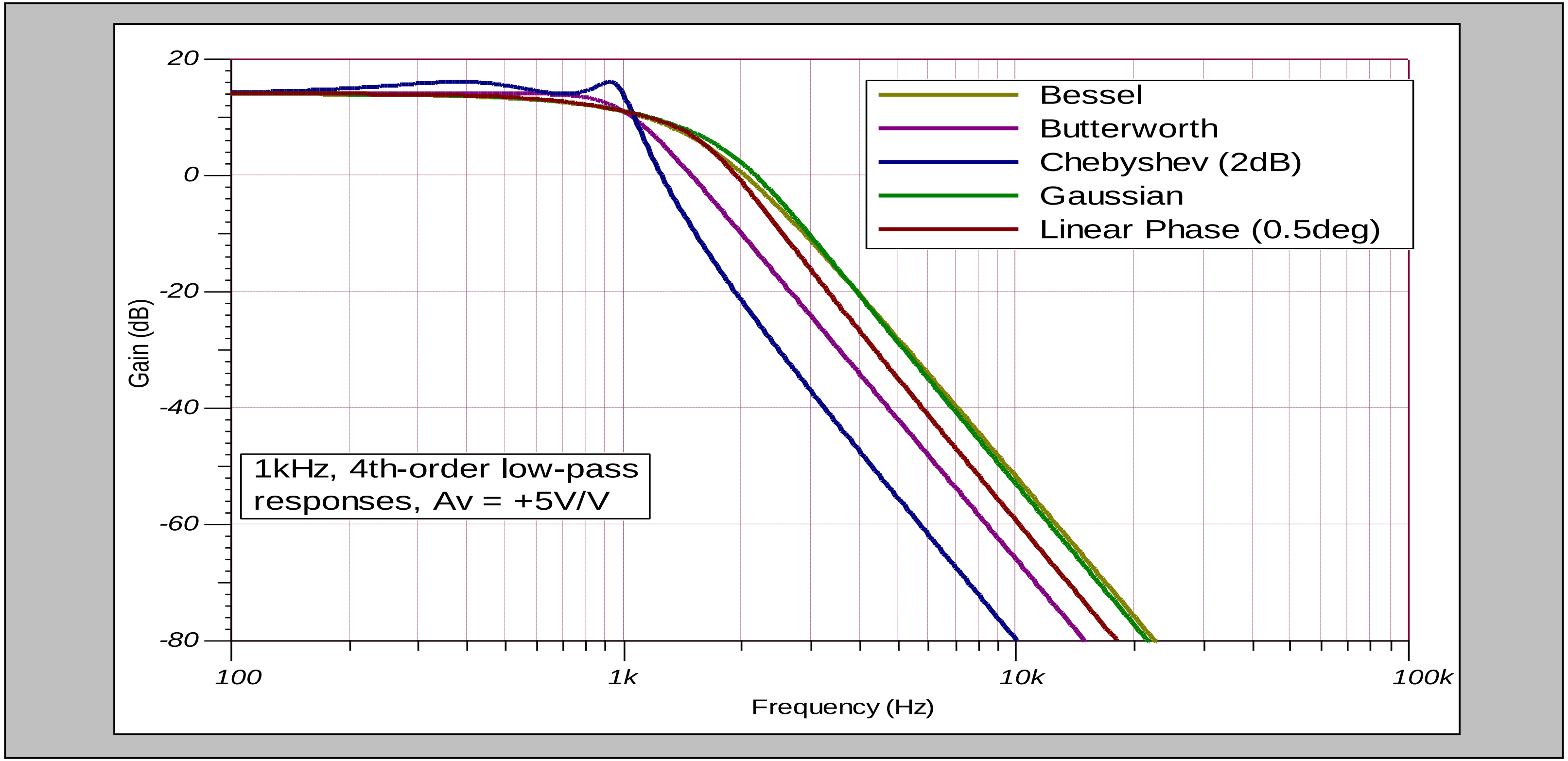
Filter Responses

Response Considerations

- Amplitude vs. frequency
- Phase vs. frequency
- Step and impulse response characteristics

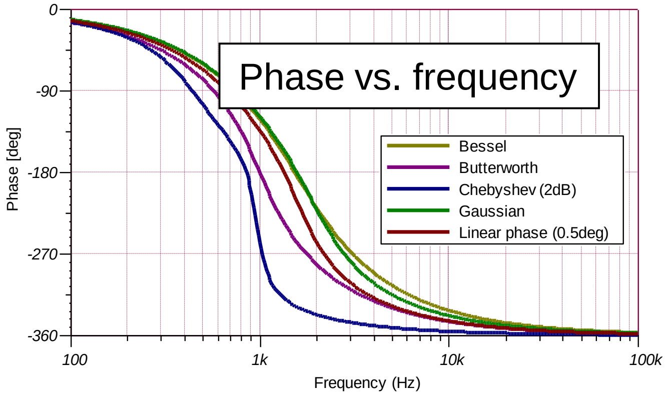
Filter Reponses

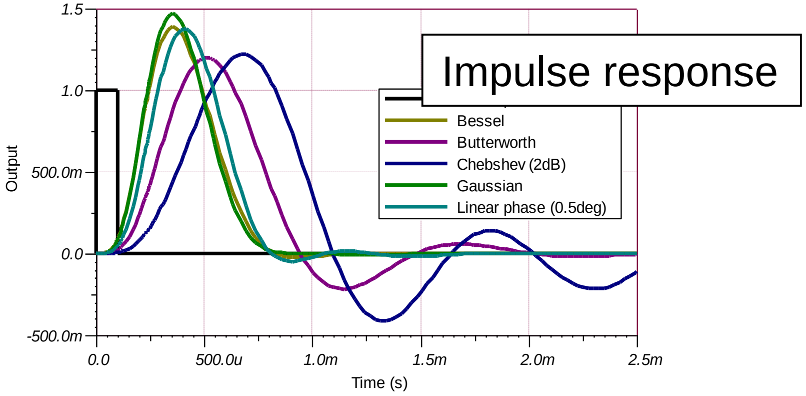
Common active lowpass filters - amplitude vs. frequency

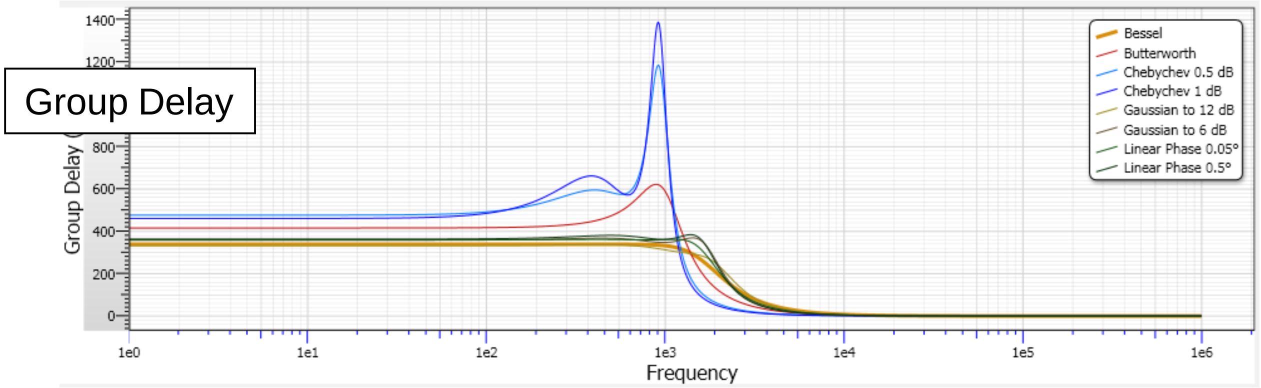


Filter Reponses

Common active lowpass filters – other responses



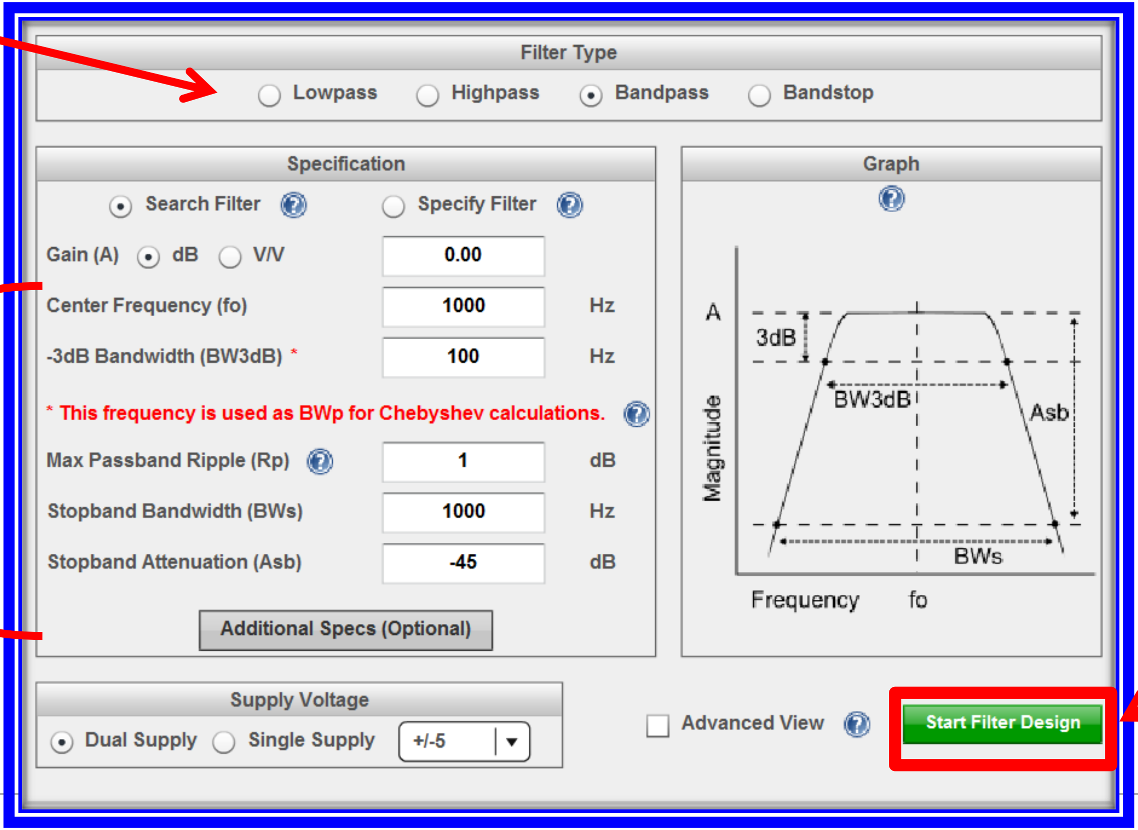




Specify Filter Requirements

Select Filter

Program Frequencies

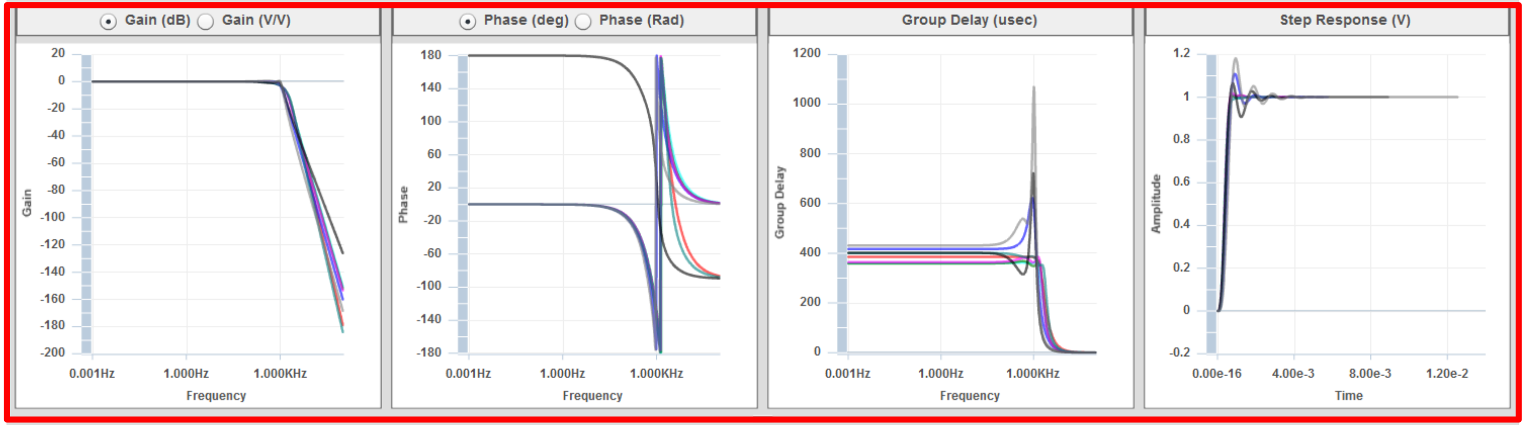


Click to Continue

View / Select Filter Response

FILTER DESIGNER VISUALIZER

Performance Graphs



Solutions

Solutions: (8 found)

Select	Filter Response	Color	Order	No. of Stages	Max Q	Asb (dB)
Select	Bessel	Red	5	3	0.920	-49.26
Select	Linear Phase 0.05°	Aqua	4	2	1.070	-46.41
Select	Butterworth	Blue	4	2	1.310	-55.91
Select	Transitional Gaussian to 6dB	Green	4	2	1.320	-47.59
Select	Linear Phase 0.5°	Magenta	4	2	1.340	-48.78
Select	Transitional Gaussian to 12dB	Teal	5	3	1.520	-52.56
Select	1dB Chebyshev	Black	3	2	2.018	-47.84
Select	0.5dB Chebyshev	Gray	4	2	2.941	-63.99

Select Filter Approximation

Design Summary: Modify your Design

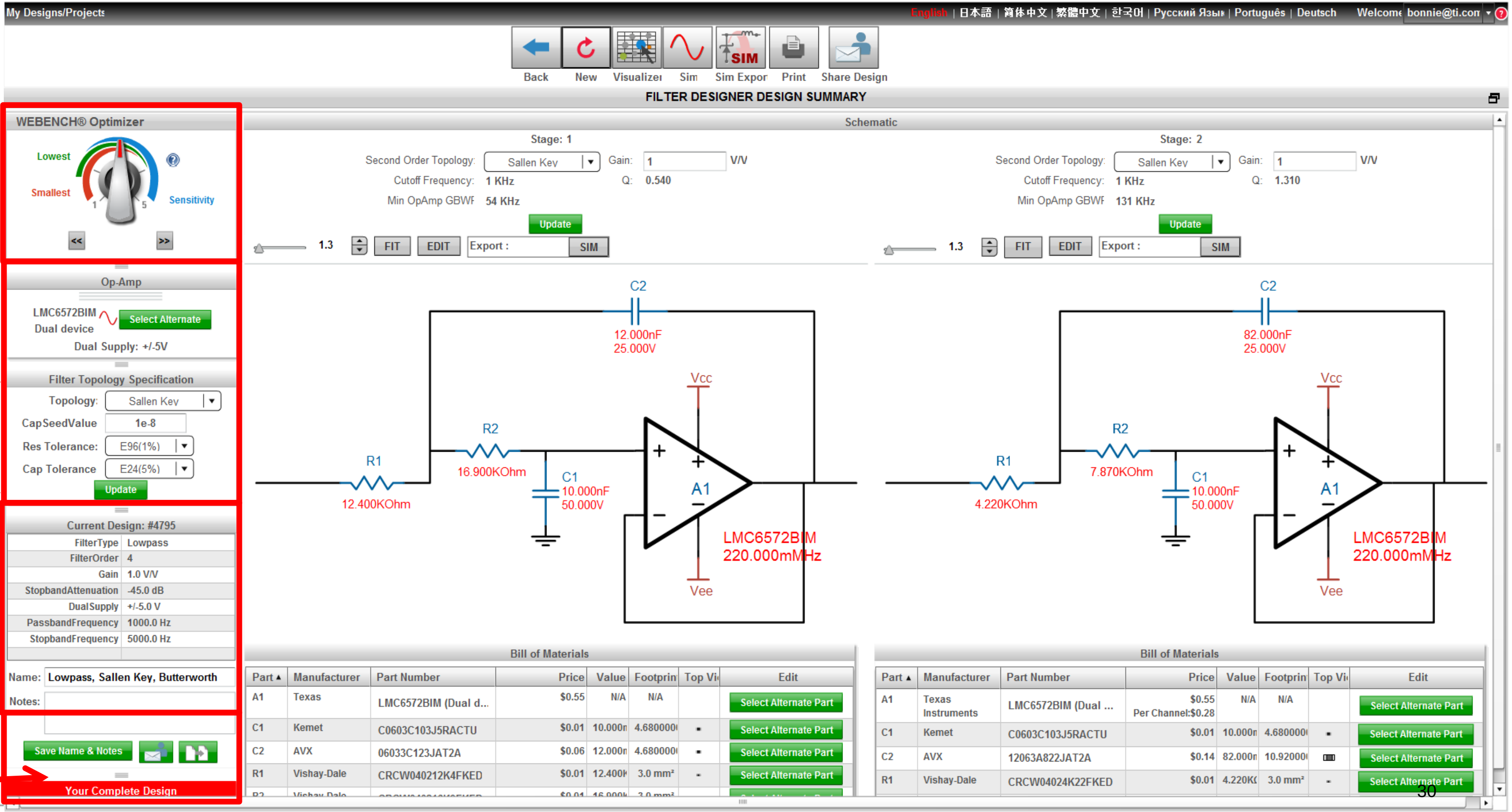
Optimizer Dial

Topology and Component Specifications

Tweak Design

Current Design and Design Notes

Share or Copy Design

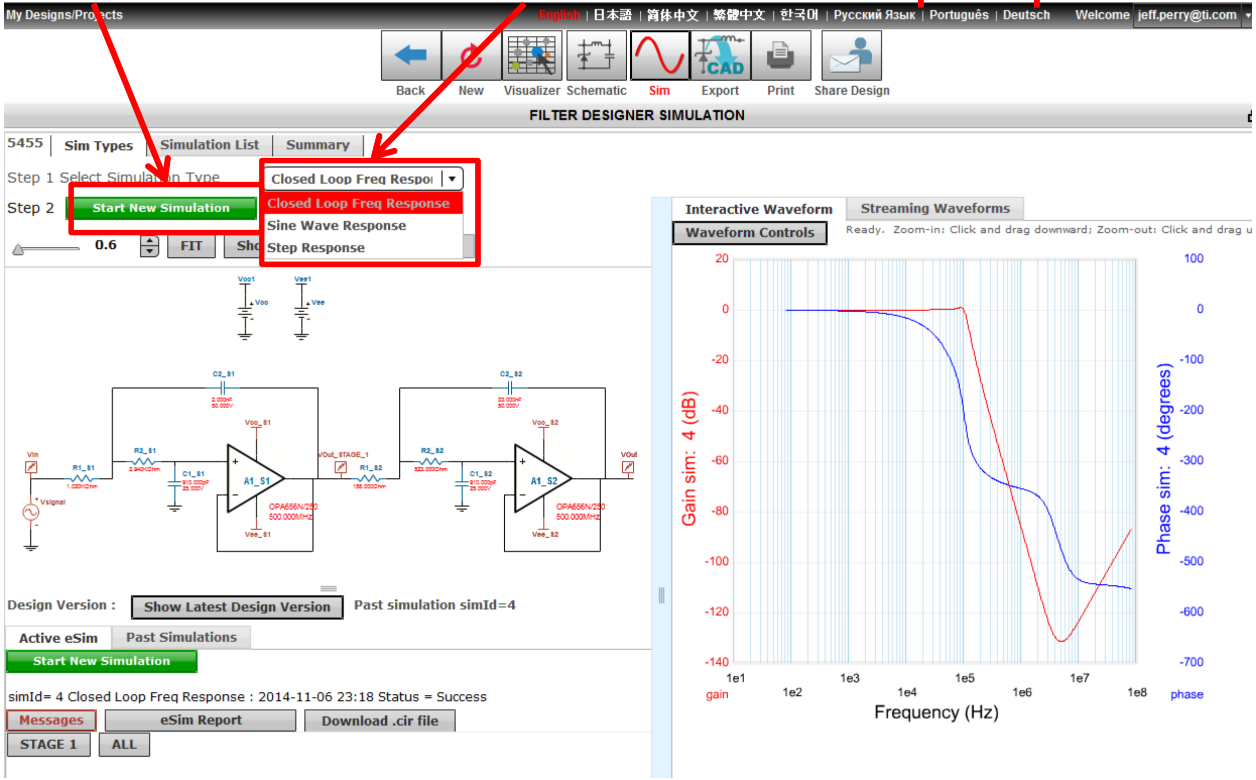


Electrical Simulation

Closed Loop Frequency Response,
Sine Wave Response,
Step Response

Click to Run Sim

Select Sim Type



Hands-on Exercise

Design Problem:	Goals:
Design a low pass filter with fast falling after the cut-off frequency. Filter Low pass Gain = 20 V/V -3db = 5000 Hz Stop band frequency = 25000 Hz Stop band attenuation = - 45 dB Chebyshev – allowable ripple <= 0.5 dB	Optimize the amplifier bandwidths to be as low as possible.

Filter Designer Landing Page (http://ti.com/filterdesigner)

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WEBENCH® Filter Designer

Active Filter Designs Within Minutes!

Active filters are vital in modern electronics; every data acquisition system needs them for bandwidth limiting signals before analog-to-digital converters as anti-aliasing filters, or after digital-to-analog converters as anti-imaging filters. Instrumentation relies on them for accurate signal measurements. Active filters are used for cutoff frequencies that range from sub-1Hz to 10MHz, where passive filter designs would require prohibitively large component values and sizes. Their design and verification can be tedious and time-consuming.

The WEBENCH Filter Designer lets you design, optimize, and simulate complete multi-stage active filter solutions withi minutes. Create optimized filter designs using a selection of TI operational amplifiers and passive components from TI's vendor partners.

SELECT from low-pass, high-pass, band-pass, and band-stop filter types. Specify performance constraints for attenuation, group delay, and step response. Choose from a variety of filter responses such as Chebyshev, Butterworth, Bessel, transitional Gaussian to 6dB, transitional Gaussian to 12dB, linear phase 0.05°, linear phase 0.005°. Determine the filter response best suited for your design by optimizing for pulse response, settling time, lowest

WEBENCH® Designer — *My* Designs

Power | FPGA/µP | LED | Clocks
Filters | Sensors | Interface | Reference

Filter Type

- (•) Lowpass
- ( ) Highpass
- ( ) Bandpass
- ( ) Bandstop

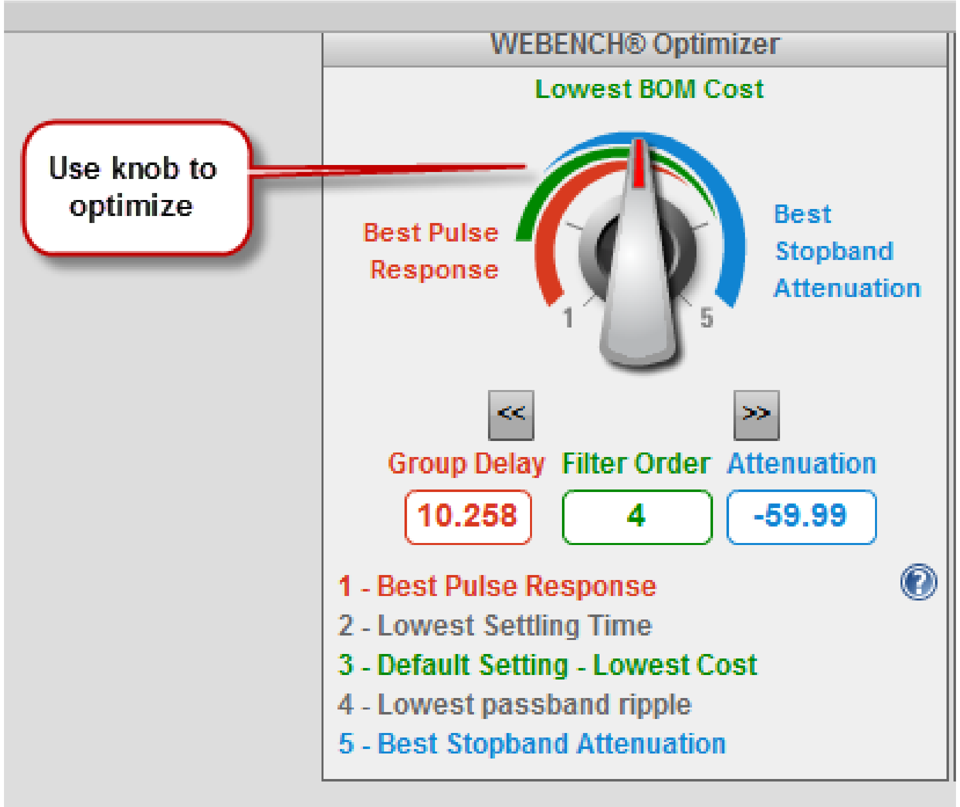
Start Design

WEBENCH Help Page

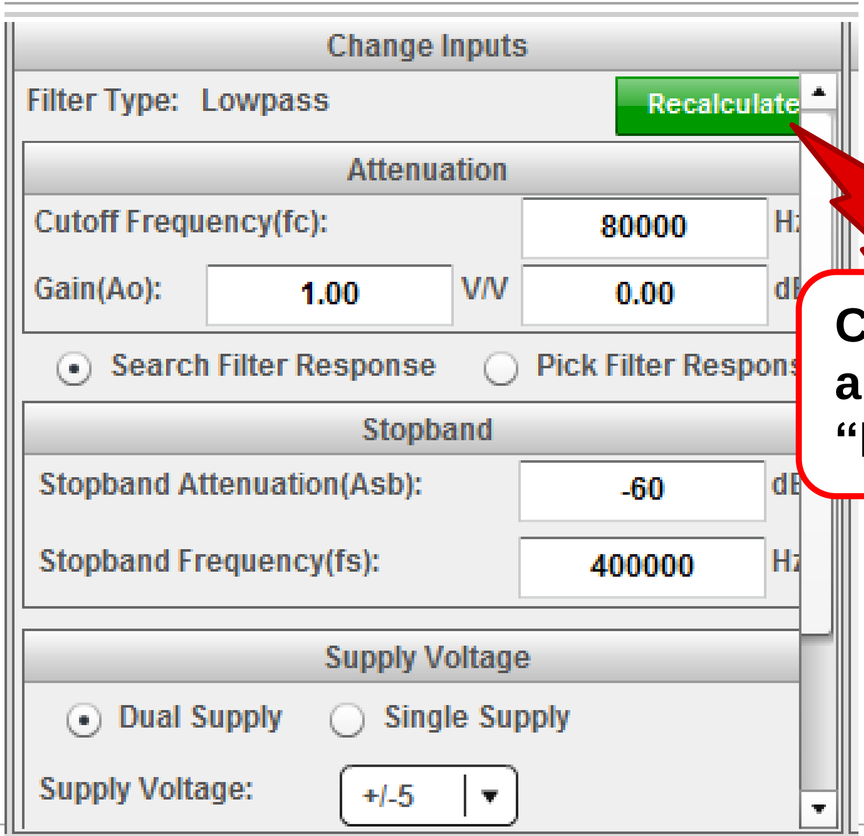
Start Design

Demo

Optimizer Knob

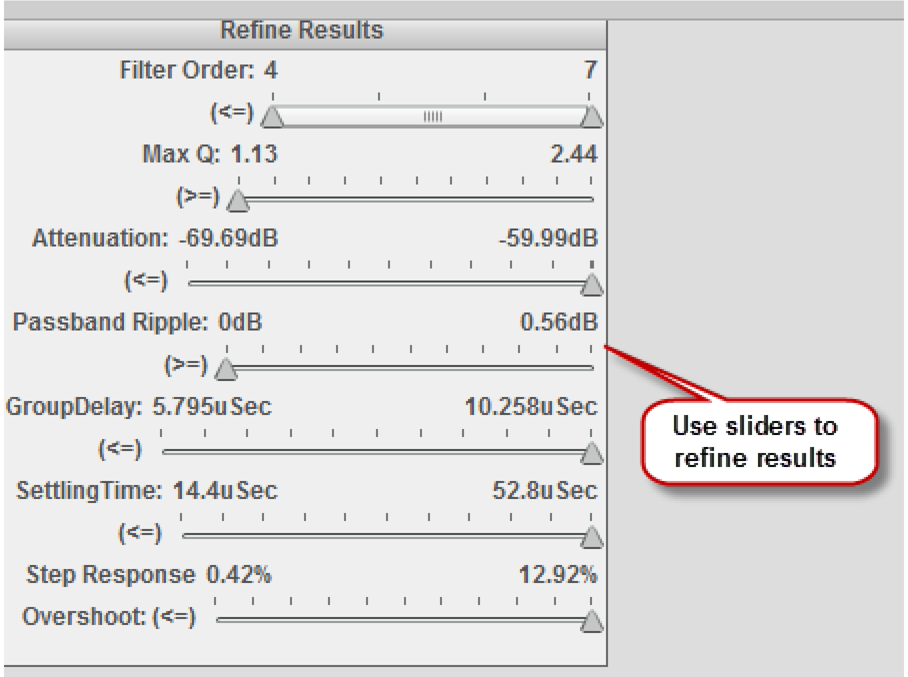


Modify Constraints

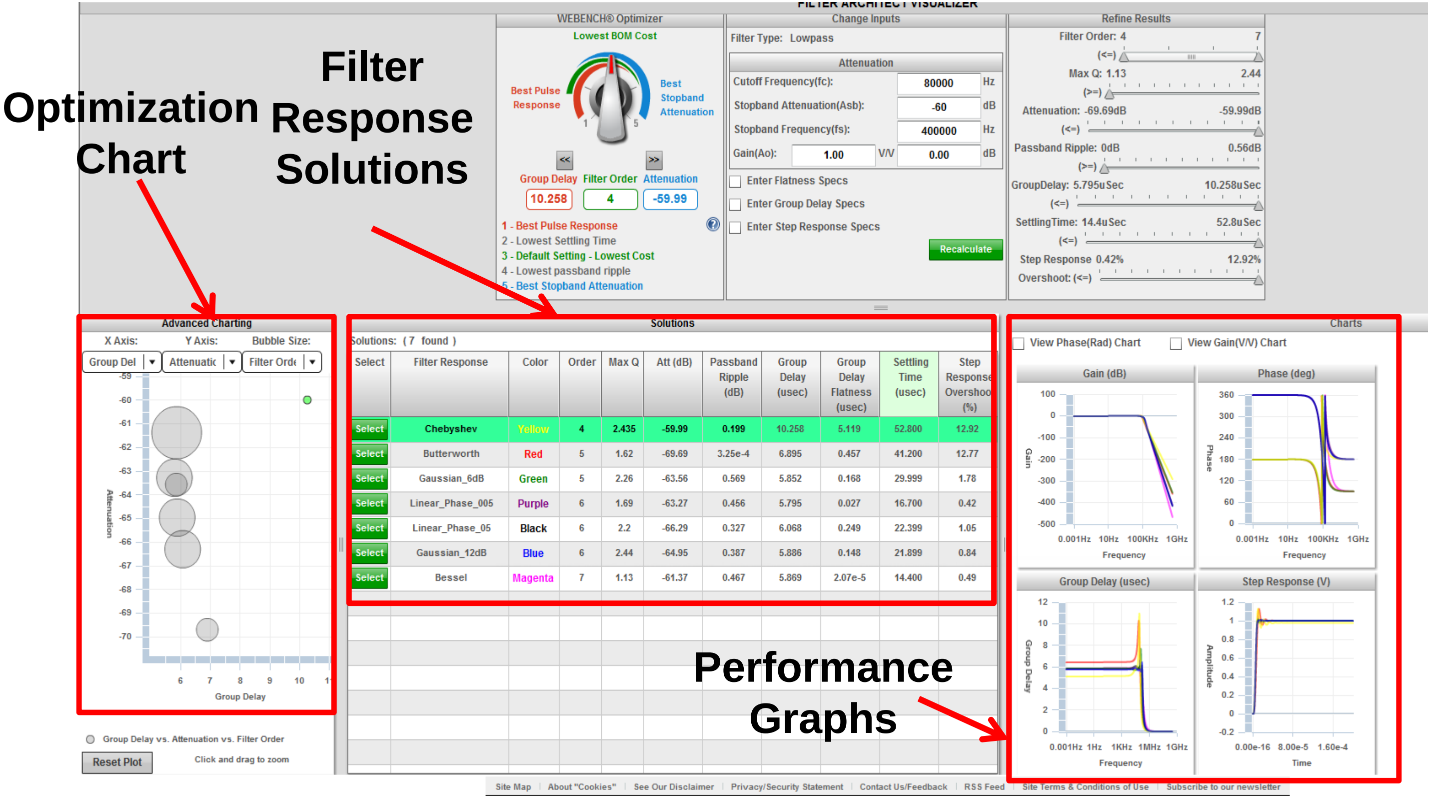


Change inputs and click "Recalculate"

Refine Results

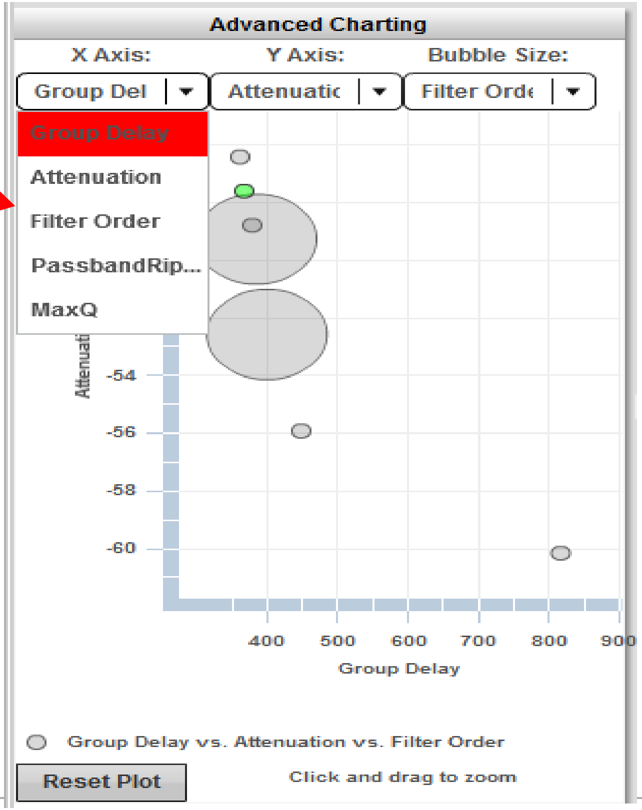


View/Optimize Filter Response Solutions

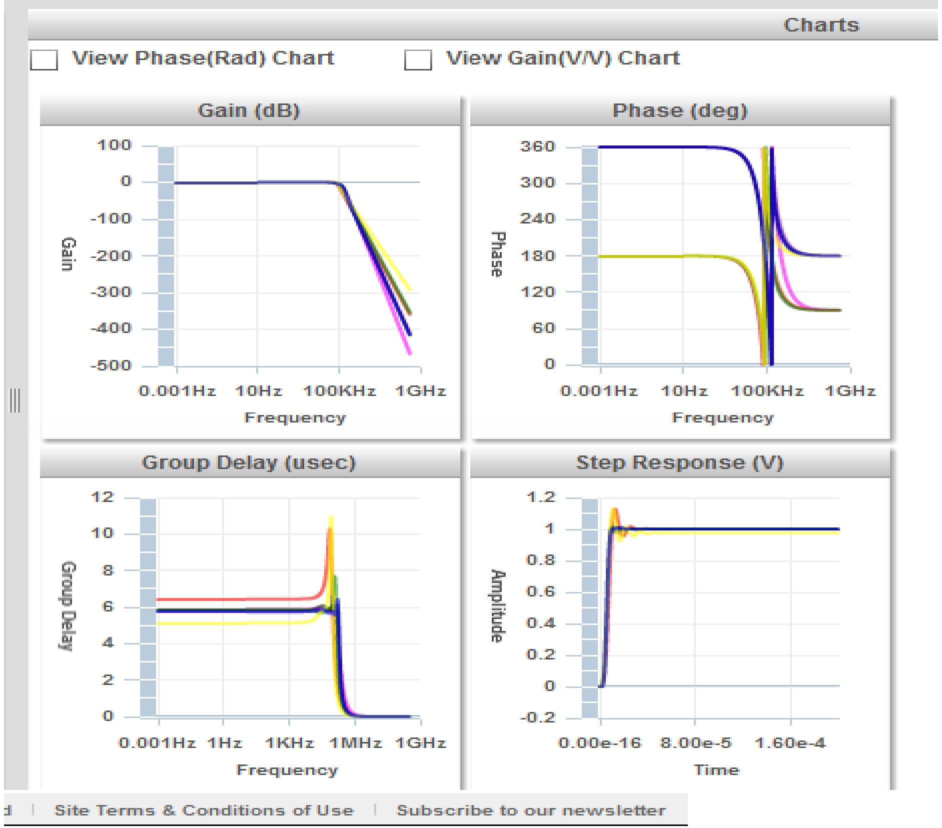


Optimization Graph

Modify Axis Parameters



Charts


Charts
View Phase(Rad) Chart
View Gain(V/V) Chart
Gain (dB)
100
0
-100
-200
-300
-400
-500
Gain
0.001Hz
10Hz
100KHz
1GHz
Frequency
Phase (deg)
360
300
240
180
120
60
0
Phase
0.001Hz
10Hz
100KHz
1GHz
Frequency
Group Delay (usec)
12
10
8
6
4
2
0
Group Delay
0.001Hz
1Hz
1KHz
1MHz
1GHz
Frequency
Step Response (V)
1.2
1
0.8
0.6
0.4
0.2
0
-0.2
Amplitude
0.00e-16
8.00e-5
1.60e-4
Time
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Select a Filter Response

Solutions

Solutions: (7 found)

Select	Filter Response	Color	Order	Max Q	Att (dB)	Passband Ripple (dB)	Group Delay (usec)	Group Delay Flatness (usec)	Settling Time (usec)	Step Response Overshoot (%)
Select	Chebyshev	Yellow	4	2.435	-59.99	0.199	10.258	5.119	52.800	12.92
Select	Butterworth	Red	5	1.62	-69.69	3.25e-4	6.895	0.457	41.200	12.77
Select	G[illegible]ssian_6dB	Green	5	2.26	-63.56	0.569	5.852	0.168	29.999	1.78
Select	Linear_[illegible]ase_005	Purple	6	1.69	-63.27	0.456	5.795	0.027	16.700	0.42
Select	Linear_Pha[illegible]05	Black	6	2.2	-66.29	0.327	6.068	0.249	22.399	1.05
Select	Ga[illegible]	[illegible]	6	2.44	-64.95	0.387	5.886	0.148	21.899	0.84
Select	[illegible]	[illegible]	7	1.13	-61.37	0.467	5.869	2.07e-5	14.400	0.49

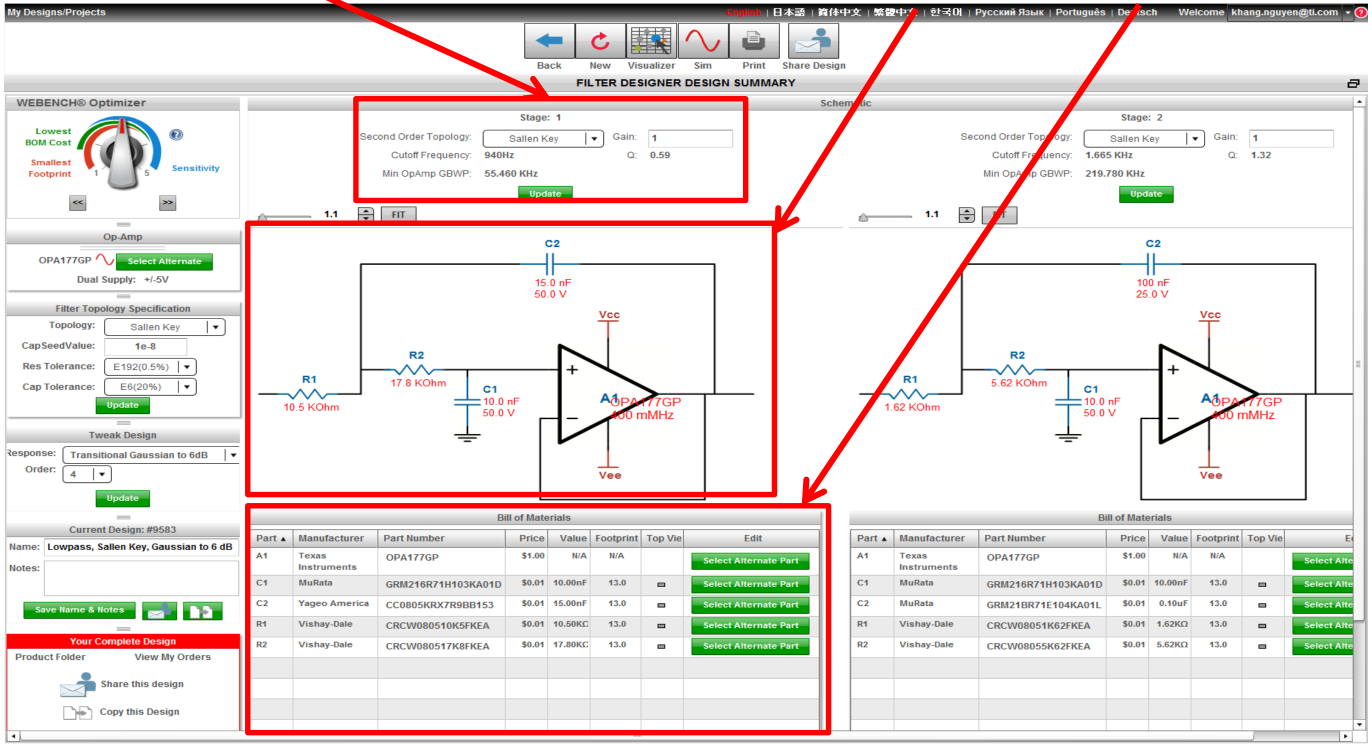
Click 'Select' to start design with the filter response and order in that row

Design Summary: Filter Topology Configuration

Update per stage

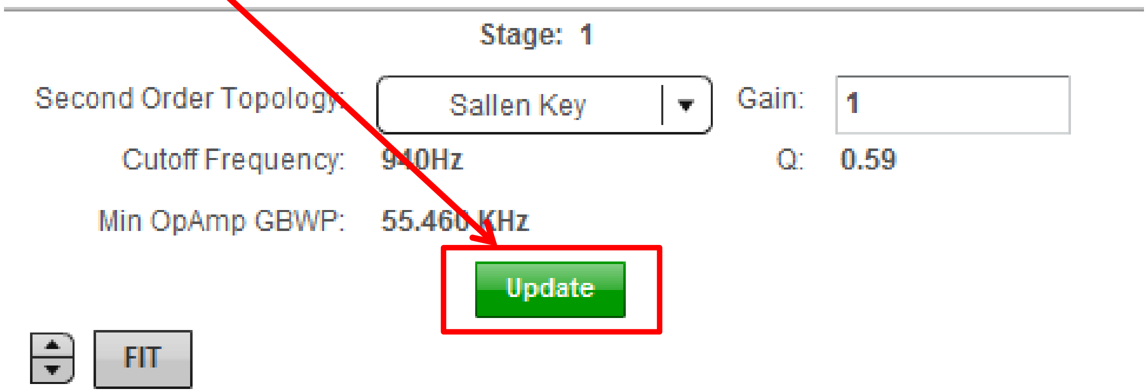
Filter Stage Schematic

Filter Stage BOM

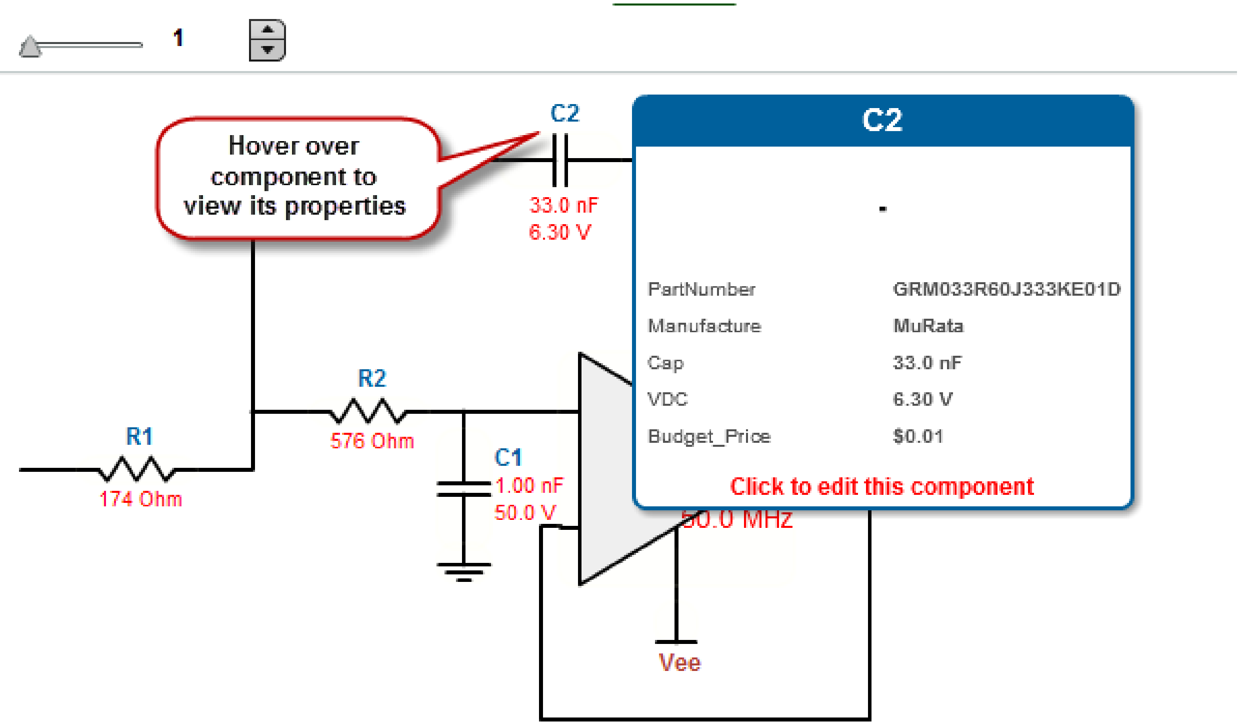


Update Gain/Topology per stage

Click to update



Filter Stage Schematic: View Component Values



Filter Stage: Bill of Materials

Select Alternate Part

Part ▲	Manufacturer	Part Number	Price	Value	Footprint	Top Vie	Edit
A1	Texas Instrument	OPA827AID	$4.50	N/A	N/A		Select Alternate Part
C1	Yageo America	CC0805KRX7R9BB102	$0.01	1.00nF	13.0		Select Alternate Part
C2	Yageo America	CC0805KRX7R9BB222	$0.01	2.20nF	13.0		Select Alternate Part
R1	Vishay-Dale	CRCW08051K13FKEA	$0.01	1.13KΩ	13.0		Select Alternate Part
R2	Vishay-Dale	CRCW08053K24FKEA	$0.01	3.24KΩ	13.0		Select Alternate Part

Select Alternate Part

Select Alternate Part

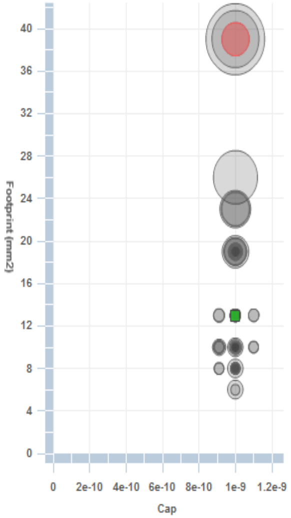
FILTER ARCHITECT ALTERNATE PARTS

Alternate Parts - Charts

Filter by Manufacturer: Select All

Update X Axis: Cap

Update Y Axis: Footprint (mm2)



Alternate parts displayed = 66

Reset All Cancel

Summary information for selected Component C1:

Manuf	Part Number	Cap (F)	ESR (Ohm)	VDC (V)	Price	Qty Avail	Foot Print
Yageo America	CC0805KRX7R9BB102	1n	0	50	$0.01	> 10	13

LIMITS	C (F)
Upperbound	1.1n
Lowerbound	900p
Target	1n

Select an alternate part for Component C1:

Edit	Manuf	Part Number	Cap (F)	ESR (Ohm)	VDC (V)	Price	Qty Avail	Foot Print	Height	Power Dis
Sel	Yageo America	CC0805KRX7R9BB102	1n	0	50	$0.01	> 10	13	2.1	0
Select	MuRata	GRM216R71E102KA01D	1n	0	25	$0.01	0	13	2.1	0
Select	MuRata	GRM1555C1H102JA01D	1n	0	50	$0.01	> 10	8	0.45	0
Select	MuRata	GRM033R71C102KA01D	1n	0	16	$0.01	0	6	0.3	0
Select	Kemet	C0603C102J5GACTU	1n	0	50	$0.01	> 10	10	0.45	0
Select	Kemet	C0603C102J5RACTU	1n	0	50	$0.01	> 10	10	0.45	0
Select	MuRata	GRM1885C1H102JA01D	1n	0	50	$0.01	> 10	10	0.45	0
Select	MuRata	GRM188R72A102KA01D	1n	0	100	$0.01	> 10	10	0.45	0
Select	MuRata	GRM155R60J102KA01D	1n	0	6.3	$0.01	0	8	0.45	0
Select	MuRata	GRM155R61A102KA01D	1n	0	10	$0.01	0	8	0.45	0

Cancel Reset All

Design Summary: Modify your Design

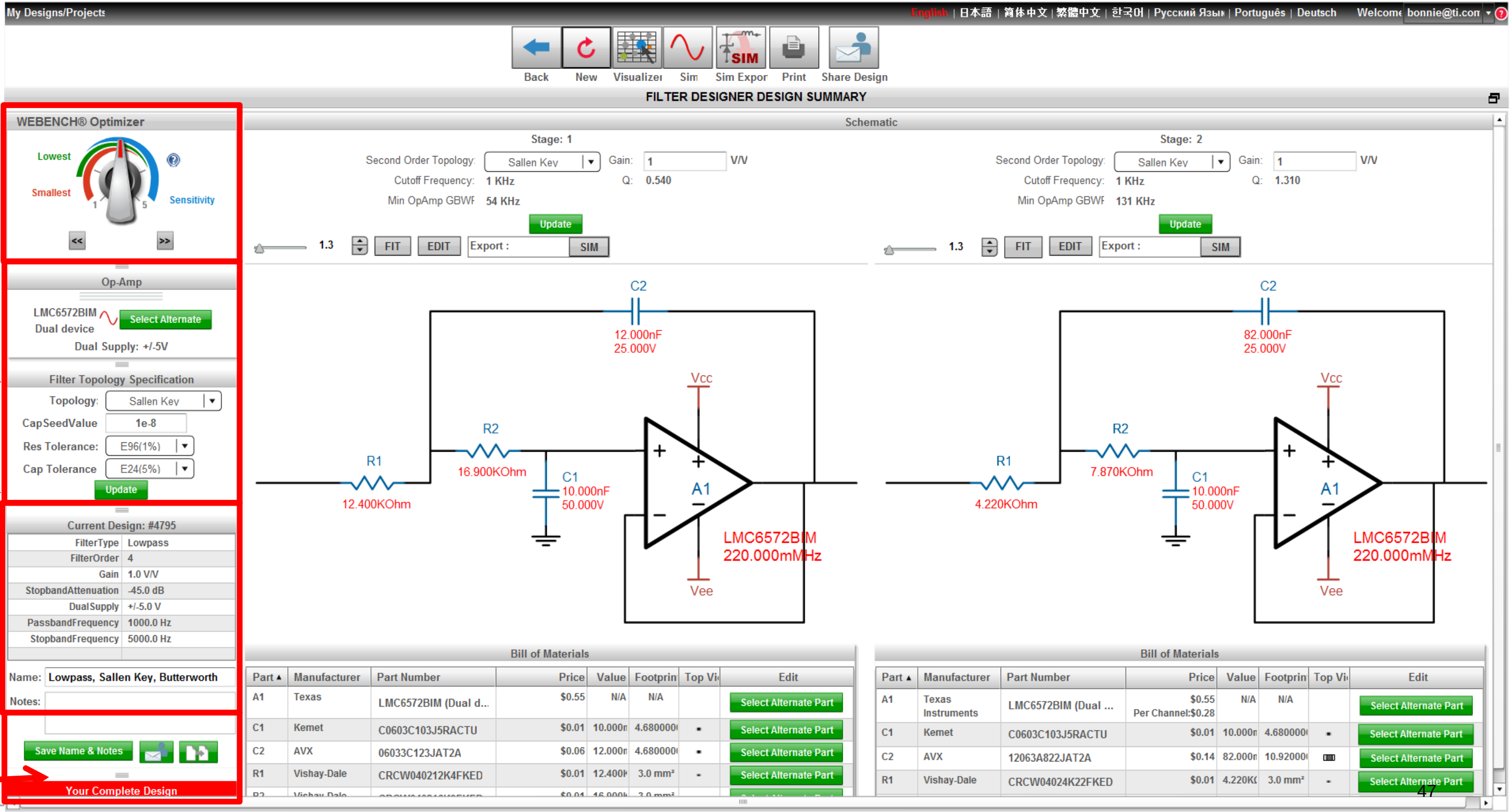
Optimizer Dial

Topology and Component Specifications

Tweak Design

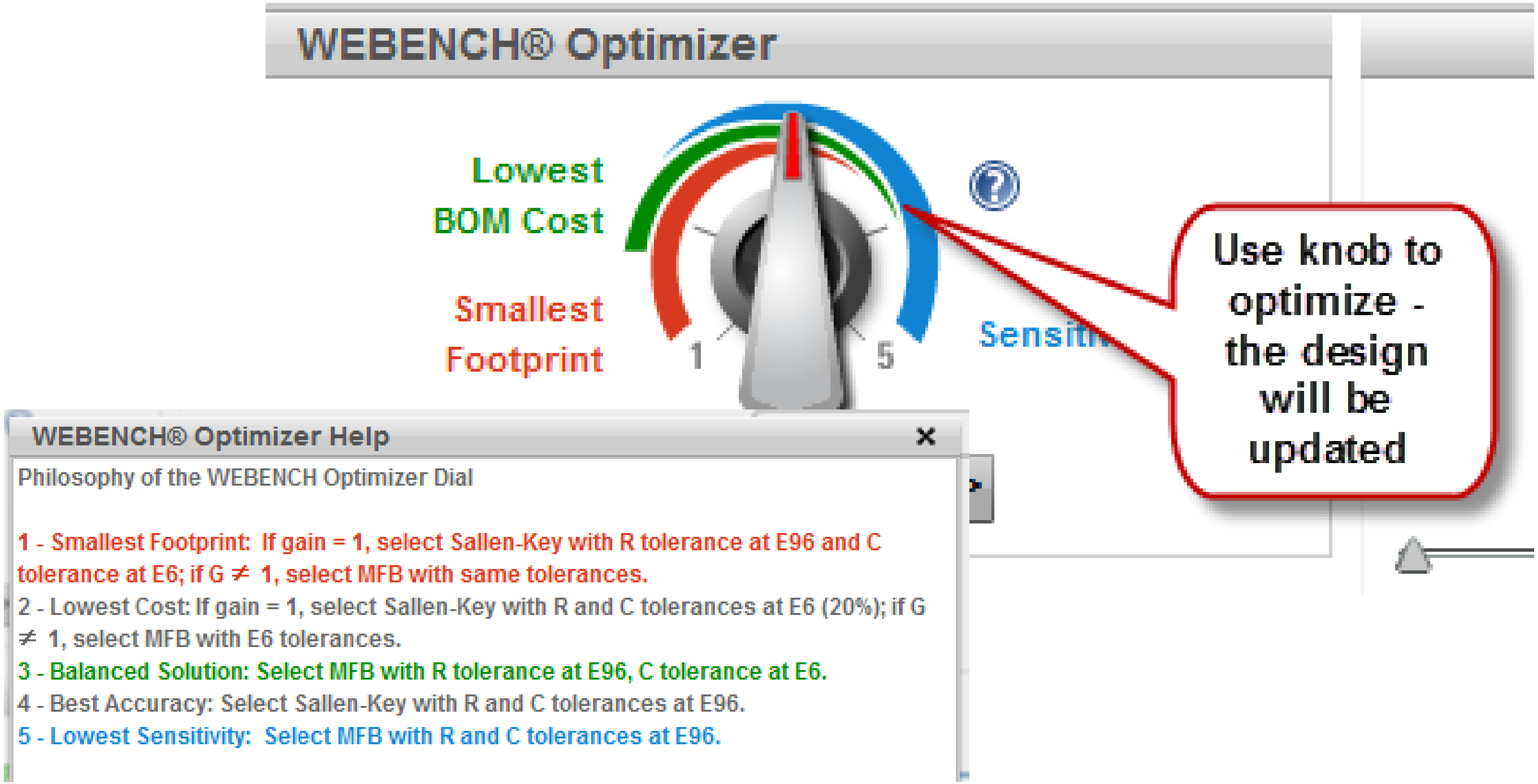
Current Design and Design Notes

Share or Copy Design

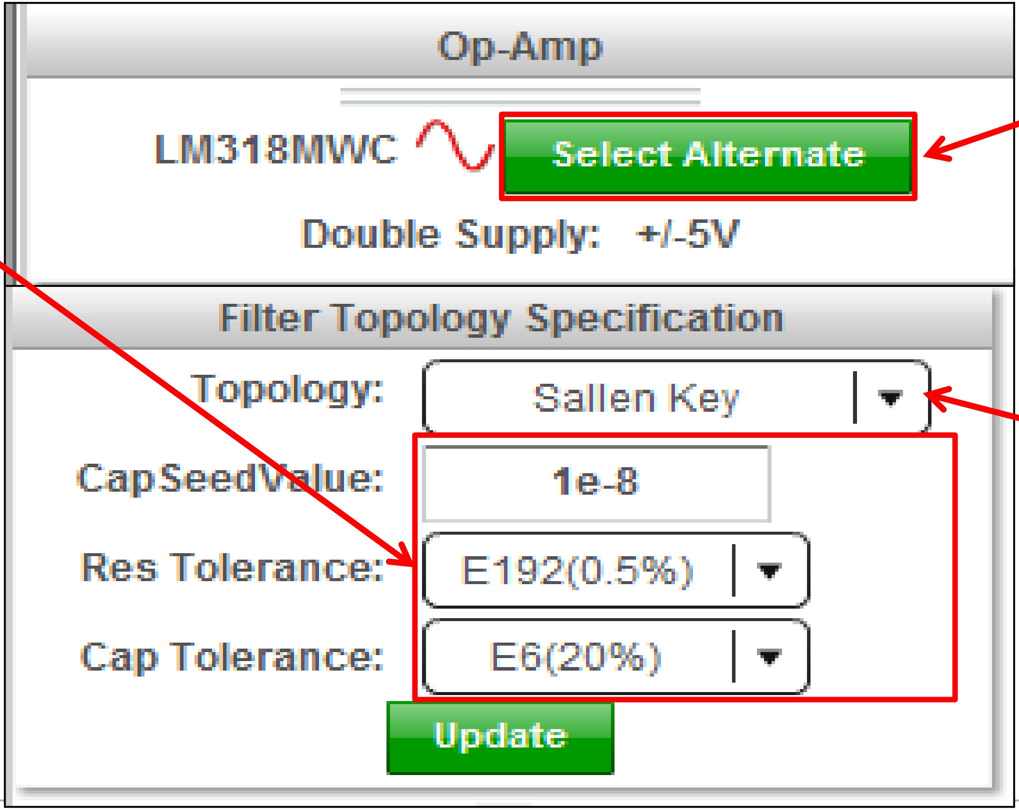


Texas Instruments

Optimization Knob



Filter Topology Specification



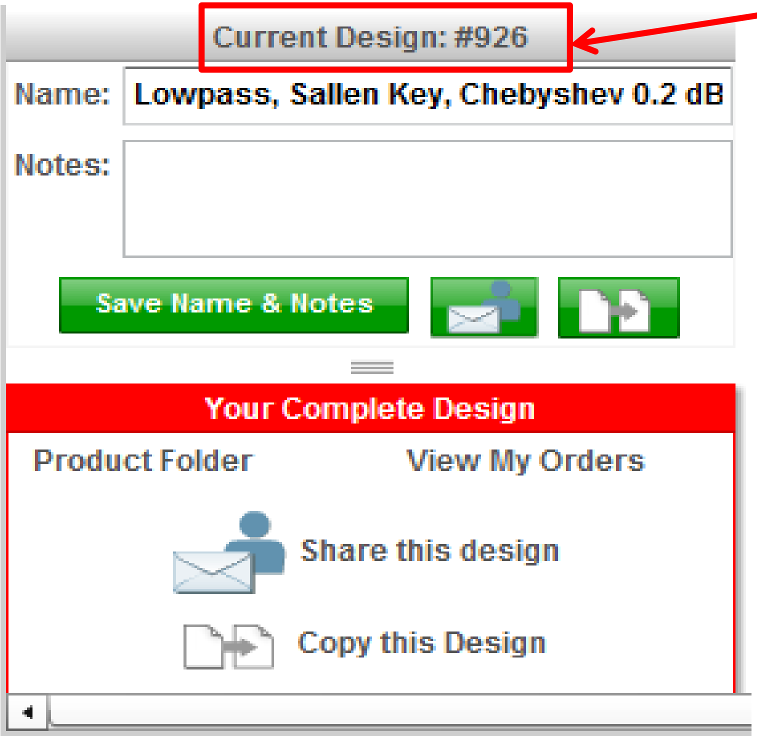
Cap seed and tolerances

Select Alternative Amplifier

Select Topology for all stages

Tweak Design

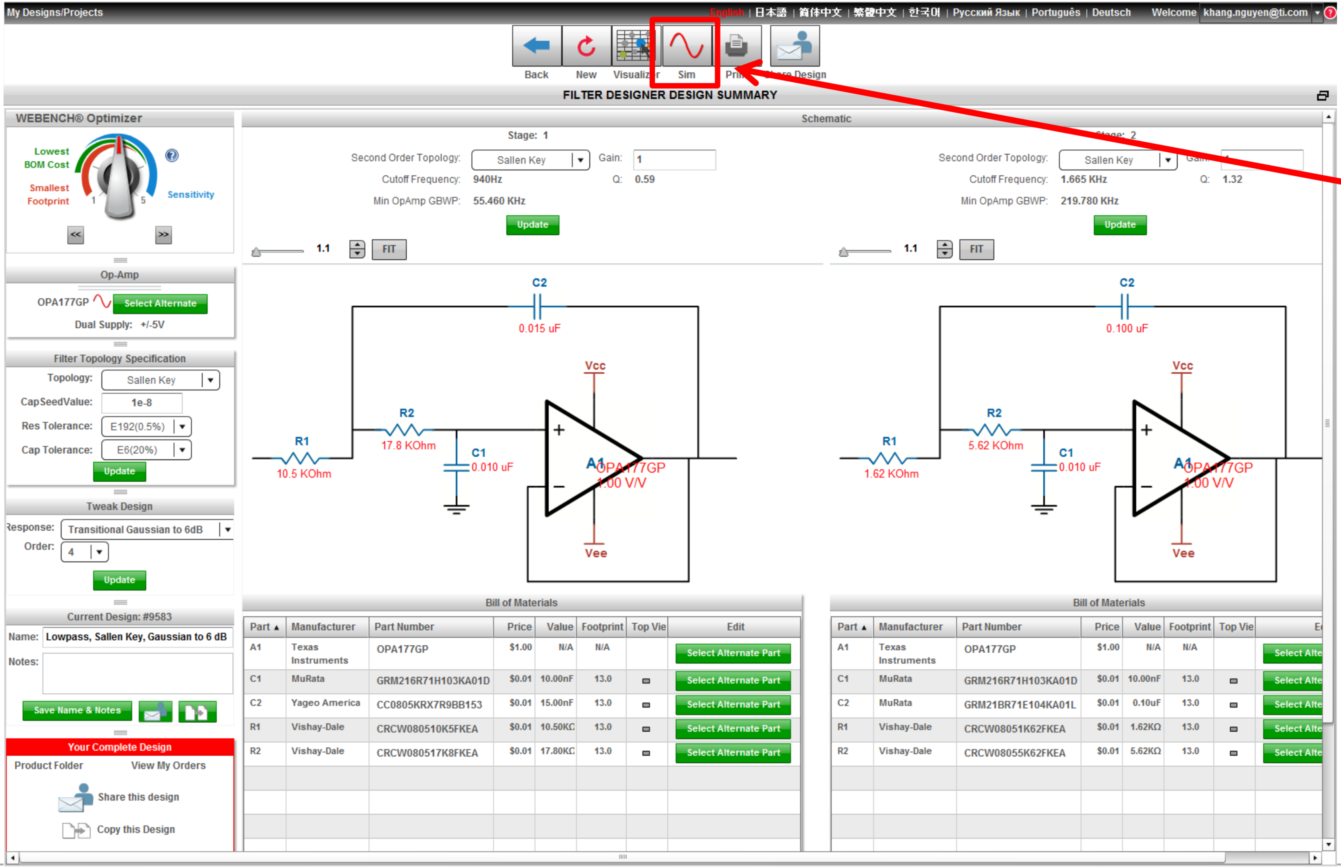
Notate and Share



Design ID

Share Design

Electrical Simulation



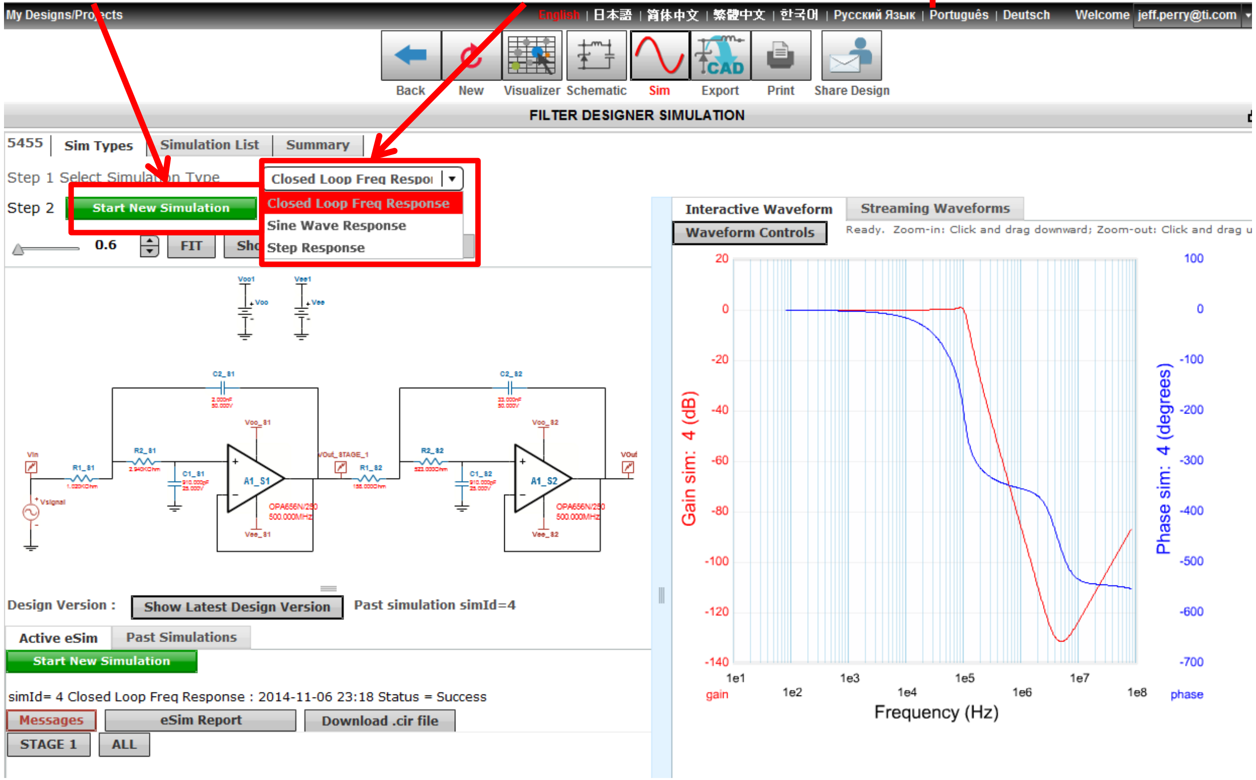
Click to Simulate

Electrical Simulation

Closed Loop Frequency Response, Sine Wave Response, Step Response

Click to Run Sim

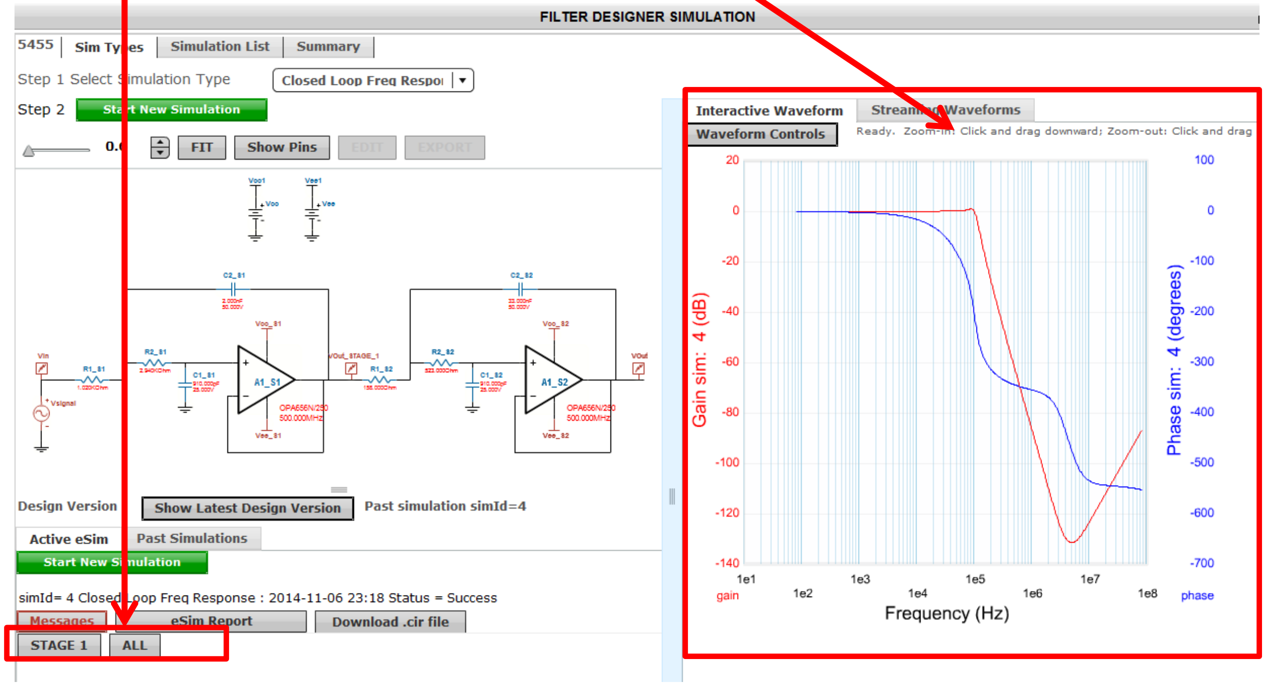
Select Sim Type



Electrical Simulation

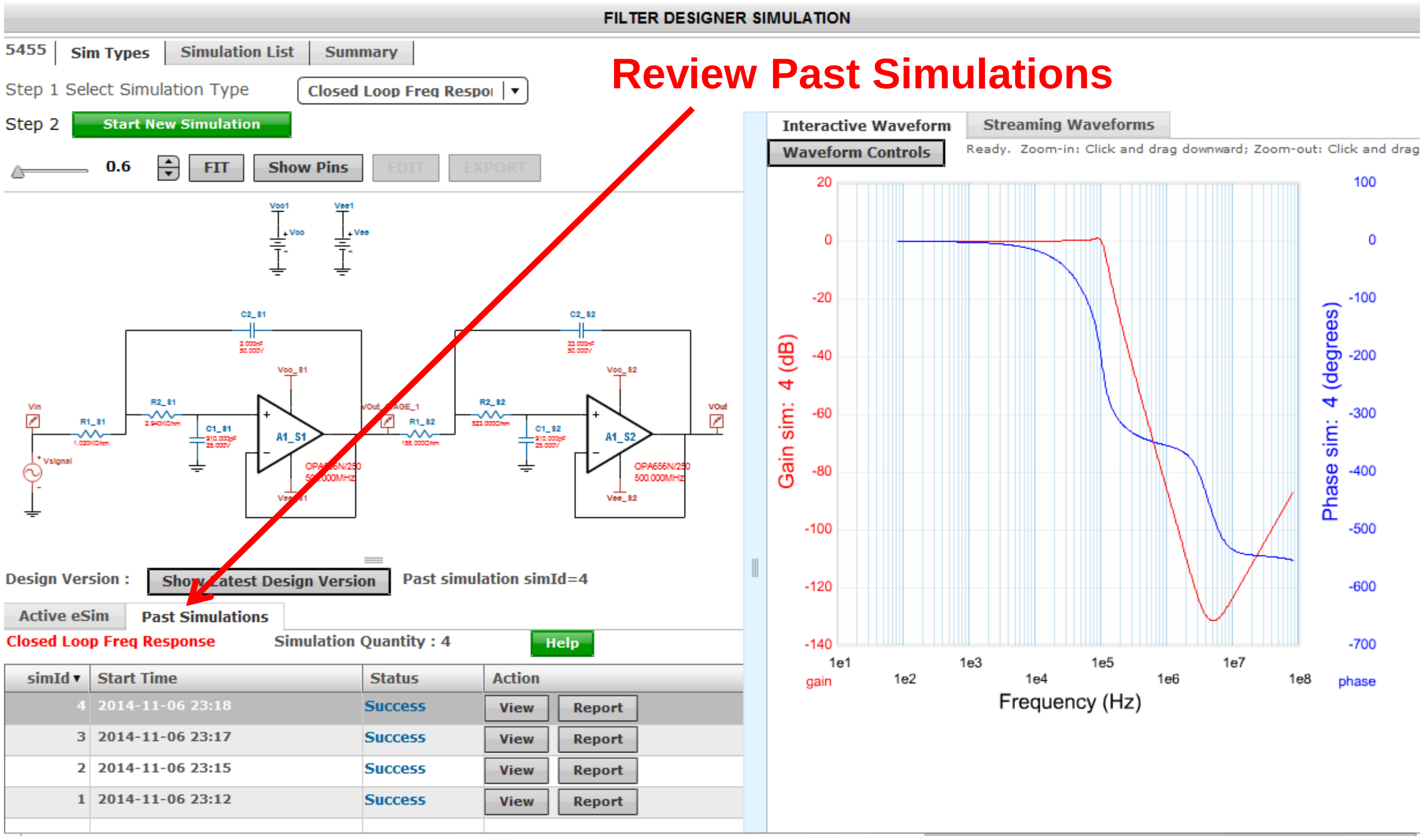
Waveform List

Simulation Results



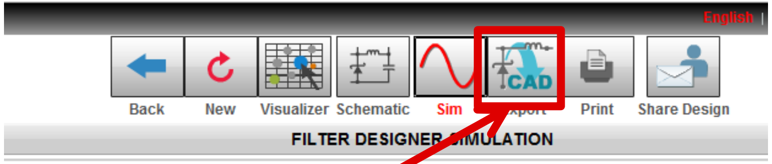
Texas Instruments

Electrical Simulation

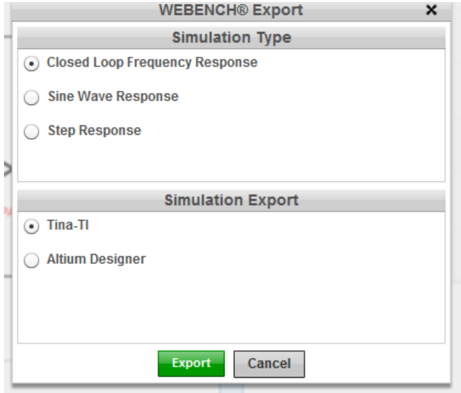


simId	Start Time	Status	Action
4	2014-11-06 23:18	Success	View Report
3	2014-11-06 23:17	Success	View Report
2	2014-11-06 23:15	Success	View Report
1	2014-11-06 23:12	Success	View Report

Export to External Simulator

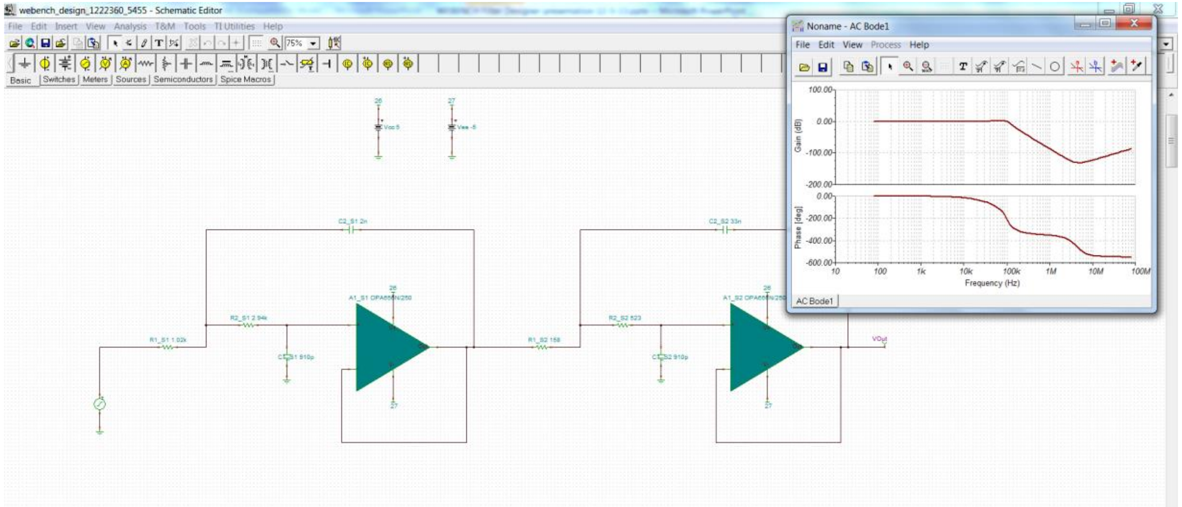


1) Click export

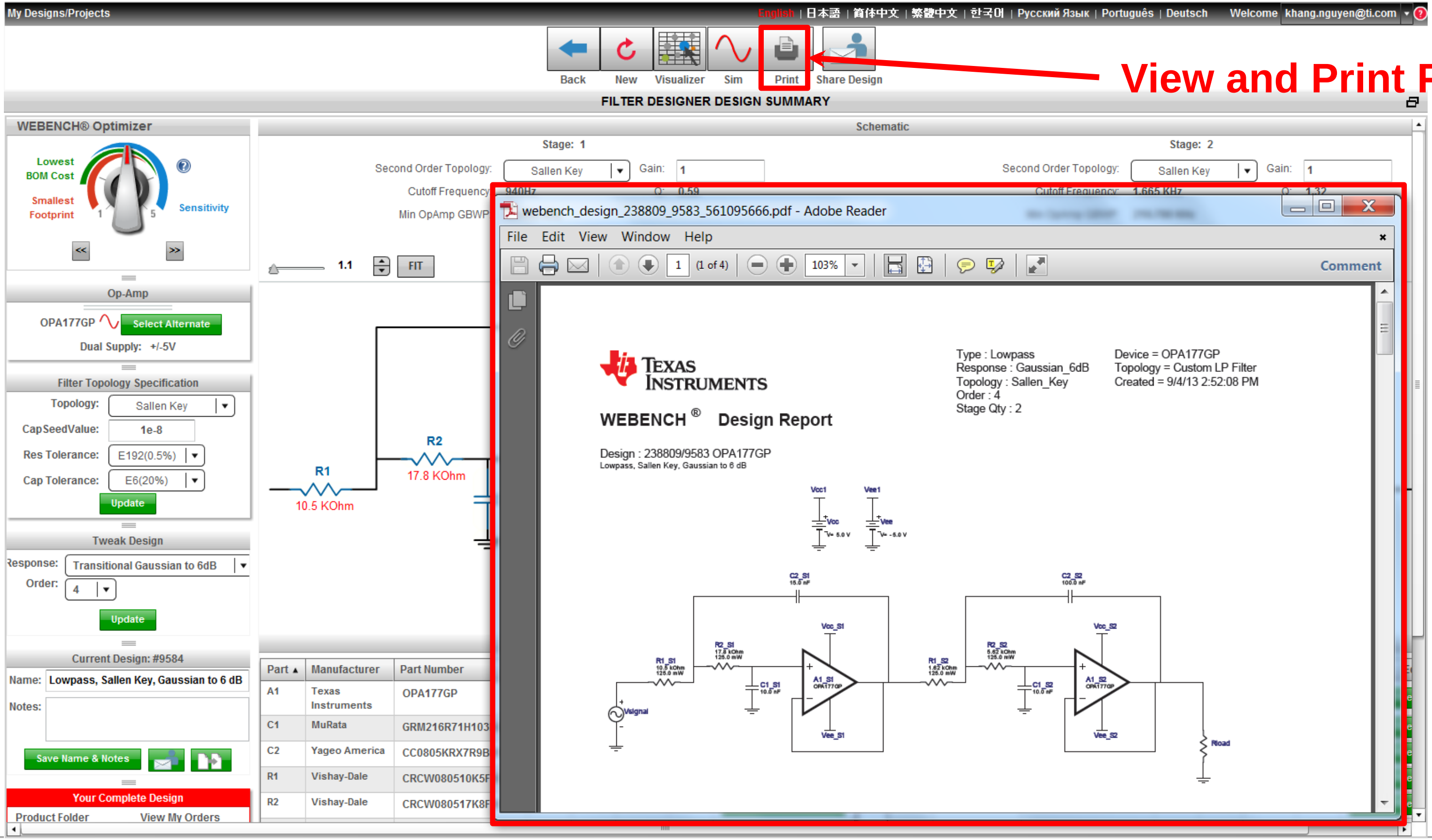


2) Choose sim type and export format

3) Schematic opens in Tina or Altium (Altium requires v14 and TI plug in)



Design Report



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