

Active Filter Design Made Easy With WEBENCH® Active Filter Designer

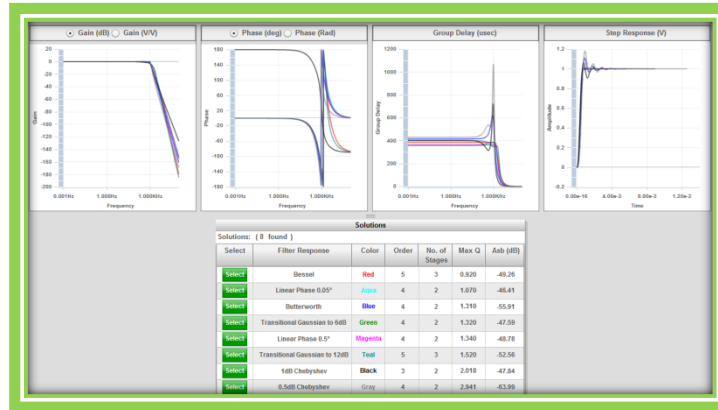
Custom Active Filter Designs Including Spice Simulation

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

1. Select a Filter Type

The screenshot shows the 'Filter Type' selection screen. Under 'Filter Type', 'Lowpass' is selected. The 'Specification' section includes: Gain (A) at 8.00 dB/VV, -3dB Frequency (F3dB) at 1000 Hz, Max Passband Ripple (Rp) at 1 dB, Stopband Frequency (Fs) at 5000 Hz, and Stopband Attenuation (Asb) at -45 dB. A graph on the right shows the magnitude response with a 3dB point and -45dB stopband attenuation. The 'Additional Specs (Optional)' section shows 'Supply Voltage' set to 'Dual Supply' with a ratio of '+1.5'. A 'Start Filter Design' button is visible at the bottom right.

2. Design Frequency response



3. Analyze with SPICE

The screenshot shows the 'FILTER DESIGNER DESIGN SUMMARY' page. It includes a circuit diagram of an active lowpass filter using an LMC6572BIM op-amp, a resistor R1 (10.500kOhm), and a capacitor C1 (10.000nF, 50.000V). The design parameters are: Filter Type: Lowpass, Filter Order: 5, Gain: 1.0 V/V, Stopband Attenuation: -45.0 dB, Passband Frequency: 5000.0 Hz, and Dual Supply: +/-5.0 V. A 'Bill of Materials' table is provided at the bottom.

Part #	Manufacturer	Part Number	Price / Value	Footprint	Top View	Edit
A1	Texas Instruments	LMC6572BIM (Dual ...)	\$0.55 / N/A	N/A	N/A	Select Alternative Part
C1	Kemet	C803C103J50ACTU	\$0.01 / 10.000nF	4.800000"	-	Select Alternative Part
R1	Vishay Dale	CRCW0402105KFKED	\$0.01 / 10.500k	3.0 mm"	-	Select Alternative Part

Accessing Filter Designer

ti.com/webenchfilters

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WEBENCH® Filter Designer

Active Filter Designs Within Minutes!

WEBENCH® Filter Designer

Rapidly Design Active Filters to Meet Your Specifications

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 within 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 cost, pass-band ripple, and stop-band attenuation.

DESIGN your filter using Sallen-Key or Multiple Feedback topologies, select the best operational amplifiers for your design by evaluating gain bandwidth vs. current vs. cost and other parameters. Specify your resistor/capacitor tolerances between ideal, 0.5%, 1%, 2%, 5%, 10% and 20% values (E192, E96, E48, E24, E12, and E6). Experiment with user defined capacitor seed values. Optimize your filter topologies for sensitivity, lowest cost, and smallest footprint.

ANALYZE your design by running SPICE electrical simulation with closed-loop frequency response, step response, and sine-wave Response analysis options.

Step by Step:

WEBENCH® Designer My Designs

PLL Filters Amps

Filter Type

- Lowpass
- Highpass
- Bandpass
- Bandstop

Start Design

WEBENCH Help Page

Select your filter type

Start Design

NEW Filter Designer Requirements page

FILTER DESIGNER REQUIREMENTS

3A/μP HotSwap Simple Switcher **Filters** Clocks Interface Load Switch DDR Power Sequencers Amp

Filter Type

Lowpass Highpass Bandpass Bandstop

Specification

Search Filter ? Specify Filter ?

Gain (A) dB V/V

-3dB Frequency (f3dB) * Hz

* This frequency is used as fp for Chebyshev calculations. ?

Max Passband Ripple (Rp) ? dB

Stopband Frequency (fs) Hz

Stopband Attenuation (Asb) dB

Graph

Magnitude

Frequency f3dB fs

Supply Voltage

Dual Supply Single Supply ▾

Advanced View ?

Changes to specifications

Specification

Search Filter Specify Filter

Gain (A) dB V/V

Gain: 20

-3dB Frequency (f3dB) *: 5000 Hz

* This frequency is used as fp for Chebyshev calculations.

Max Passband Ripple (Rp): 1 dB

Stopband Frequency (fs): 25000 Hz

Stopband Attenuation (Asb): -45 dB

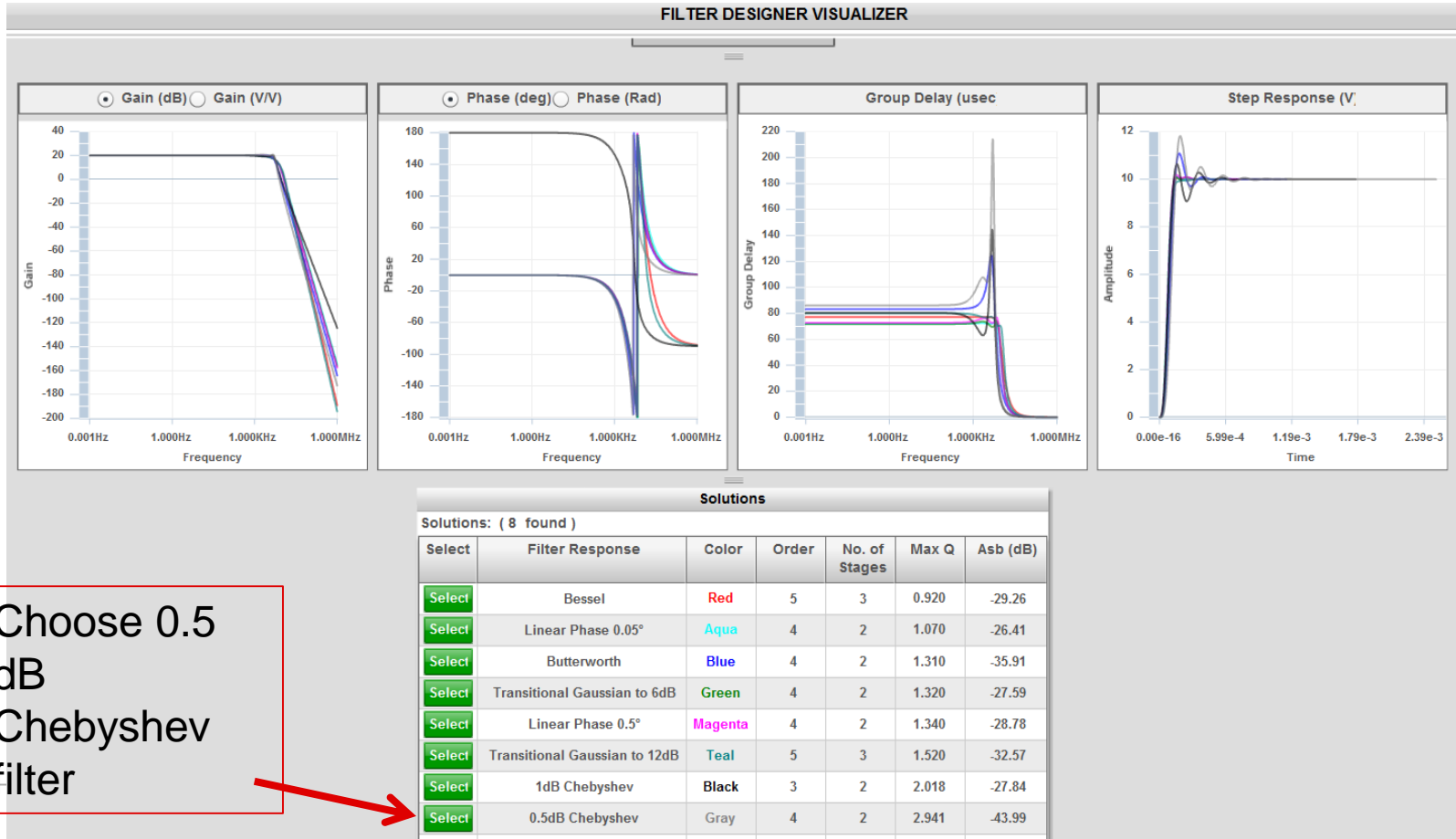
Gain units \rightarrow V/V

Gain = 20 V/V

-3 dB = 5 kHz

fs = 25 kHz

NEW Visualizer page



Choose 0.5 dB Chebyshev filter



Filter Design Summary page

Note Min OpAmp GBWP values

WEBENCH® Optimizer

Lowest BOM Cost / Smallest Footprint / Sensitivity

Op-Amp

TLC081CP Single device
Dual Supply: +/-5V

Filter Topology Specification

Topology: Sallen Key

CapSeedValue: 1e-8

Res Tolerance: E96(1%)

Cap Tolerance: E24(5%)

Update

Current Design: #4337

FilterType	Lowpass
FilterOrder	4
Gain	20.0 V/V
StopbandAttenuation	-45.0 dB
Dual Supply	+/-5.0 V
PassbandFrequency	5000.0 Hz
StopbandFrequency	25000.0 Hz

Name: Lowpass, Sallen Key, Chebyshev 0.5

Notes:

Save Name & Notes

Your Complete Design

Product Folder View My Orders

Share this design

Copy this Design

FILTER DESIGNER DESIGN SUMMARY

Schematic

Stage: 1

Second Order Topology: Sallen Key Gain: 4.472 V/V

Cutoff Frequency: 2.985 KHz Q: 0.705

Min OpAmp GBWP: 944.102 KHz

Update

Stage: 2

Second Order Topology: Sallen Key Gain: 4.472 V/V

Cutoff Frequency: 5.156 KHz Q: 2.941

Min OpAmp GBWP: 6.781 MHz

Update

Note OpAmp Bandwidth – 10MHz

Bill of Materials

Part	Manufacturer	Part Number	Price	Value	Footprint	Top Vi	Edit
A1	Texas Instruments	TLC081CP (Single d...	\$0.45	N/A	N/A	-	Select Alternate Part
C1	Kemet	C0603C103J5RACTU	\$0.01	10.000r	4.680000	-	Select Alternate Part
C2	MuRata	GRM1885C1H272JA...	\$0.02	2.700nF	4.680000	-	Select Alternate Part
R1	Vishay-Dale	CRCW040216K2FKED	\$0.01	16.200Ω	3.0 mm²	-	Select Alternate Part
R2	Vishay-Dale	CRCW04026K49FKED	\$0.01	6.490KΩ	3.0 mm²	-	Select Alternate Part
R3	Vishay-Dale	CRCW04022K49FKED	\$0.01	2.490KΩ	3.0 mm²	-	Select Alternate Part
R4	Vishay-Dale	CRCW04028K66FKED	\$0.01	8.660KΩ	3.0 mm²	-	Select Alternate Part

Filter Design adjust gain values

FILTER DESIGNER DESIGN SUMMARY

Stage: 1

Second Order Topology: Gain: V/V

Cutoff Frequency: 2.985 KHz Q: 0.705

Min OpAmp GBWP: 2.104 MHz

Stage: 2

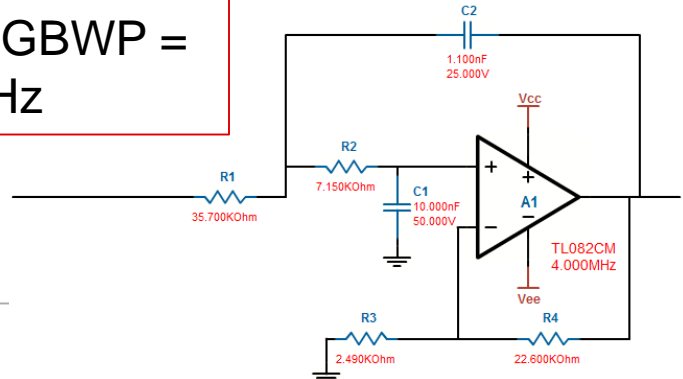
Second Order Topology: Gain: V/V

Cutoff Frequency: 5.156 KHz Q: 2.941

Min OpAmp GBWP: 3.032 MHz

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

The screenshot displays the Filter Designer simulation environment. At the top, a toolbar includes icons for Back, New, Visualizer, Schematic, Sim, Export, Print, and Share Design. Below the toolbar, the 'FILTER DESIGNER SIMULATION' window is active, showing a 'Simulation List' with 'Step 1 Select Simulation Type' and 'Step 2 Start New Simulation'. A dropdown menu for 'Closed Loop Freq Respo' is open, listing 'Closed Loop Freq Response', 'Sine Wave Response', and 'Step Response'. The main workspace shows a circuit diagram of a two-stage active filter with op-amps A1_S1 and A1_S2, resistors R1, R2, and capacitors C1, C2. The simulation results are shown in the 'Interactive Waveform' section, which includes a 'Waveform Controls' panel and a plot of Gain (dB) and Phase (degrees) versus Frequency (Hz) on a log scale. The Gain plot (blue line) shows a roll-off from 0 dB to -140 dB, and the Phase plot (red line) shows a phase shift from 0 degrees to -700 degrees.

Everything old is new

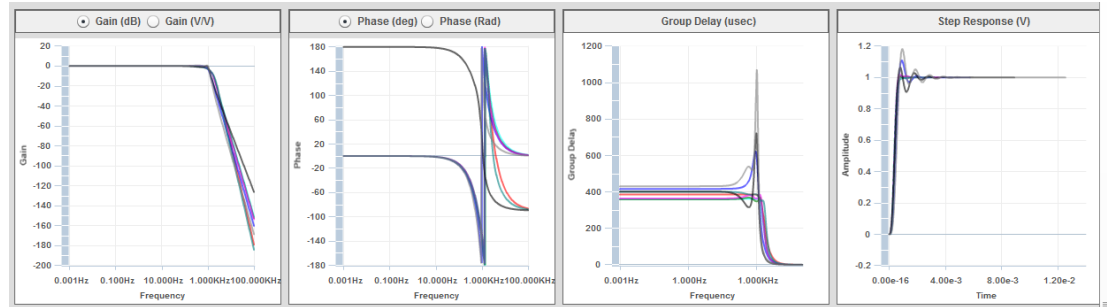
- Is live today
- Big changes in Filter Type (page 1)
- Bigger changes in Visualizer (page 2)

The screenshot shows the 'Filter Designer' interface. At the top, 'Filter Type' is set to 'Lowpass'. The 'Specification' section includes:

- Gain (A): 0.00 (dB/VV)
- 3dB Frequency (f3dB): 1000 Hz
- Max Passband Ripple (Rp): 1 dB
- Stopband Frequency (fs): 5000 Hz
- Stopband Attenuation (Asb): -45 dB

A note states: '* This frequency is used as fp for Chebyshev calculations.' The 'Graph' section shows a magnitude plot with a 3dB point at f3dB and a stopband attenuation of Asb at fs. The 'Supply Voltage' section is set to 'Dual Supply' with a value of '+/-5'. A 'Start Filter Design' button is visible at the bottom right.

- ti.com/filterdesigner



Hands-on Exercise

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

Hands On Problems

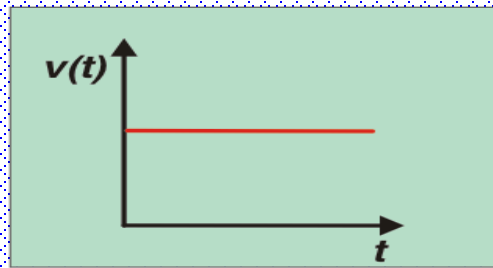
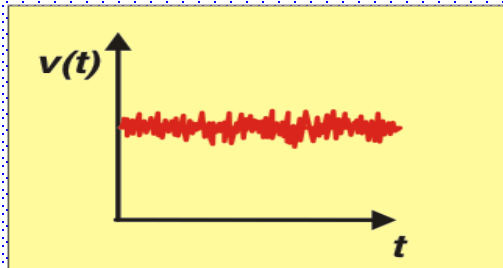
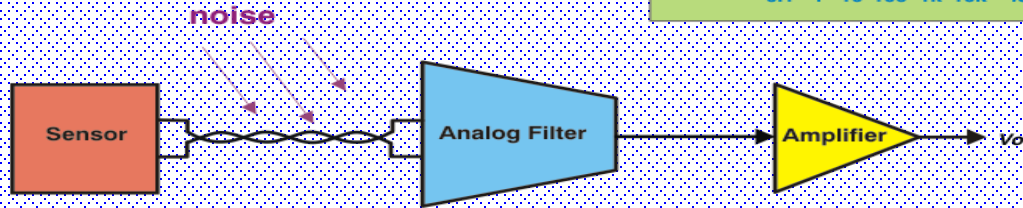
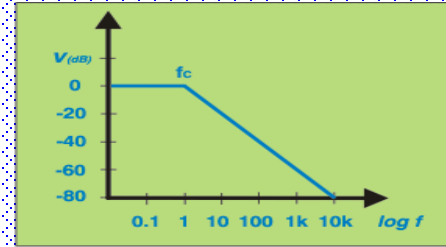
- Go to hands on problem set for Signal Chain
- Work the problems from the following:
- **Active Filter Designer**
 - 10kHz Low Pass Filter
 - Optimize Low Pass Filter
 - Anti-aliasing filter

Active Filter Design Made Easy With WEBENCH[®] Active Filter Designer

Custom Active Filter Designs Including Spice Simulation

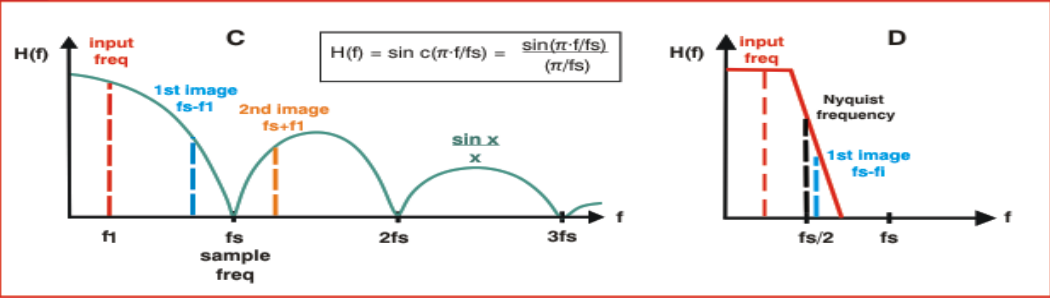
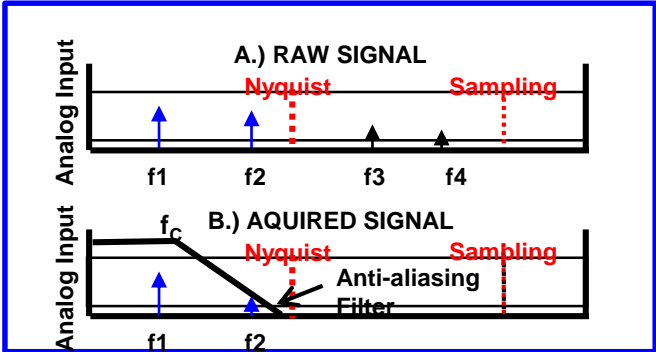
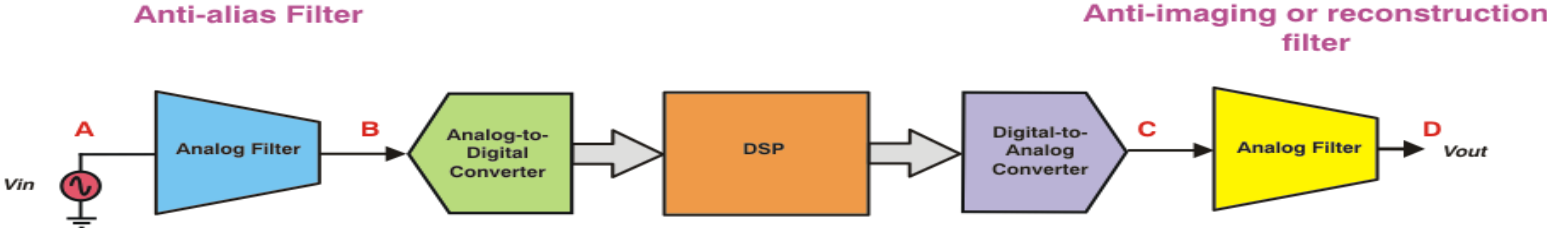
Common Filter Applications

Band limiting filter in a noise reduction application



Common Filter Applications

Mixed-Signal Filter Applications



Filter Types

Lowpass, Highpass, Bandpass, and Bandstop Filters

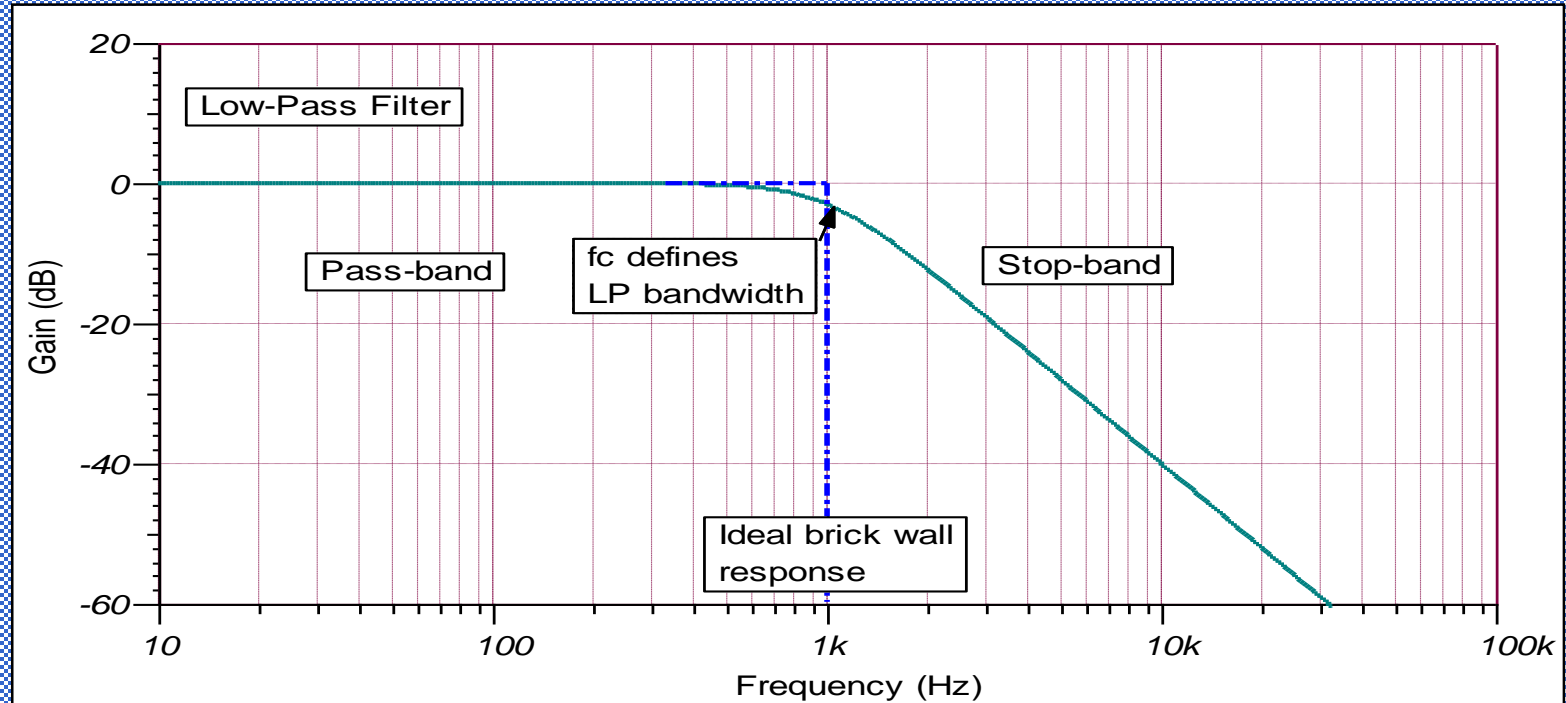
- A lowpass filter the bandwidth is equal to DC to f_c
- A highpass filter has a single stop-band DC to f_c , and pass-band $f > f_c$
- A bandpass filter has one pass-band, between two cutoff frequencies f_L and $f_u > f_L$, and two stop-bands $0 < f < f_L$ and $f > f_u$. The bandwidth = $f_u - f_L$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

16

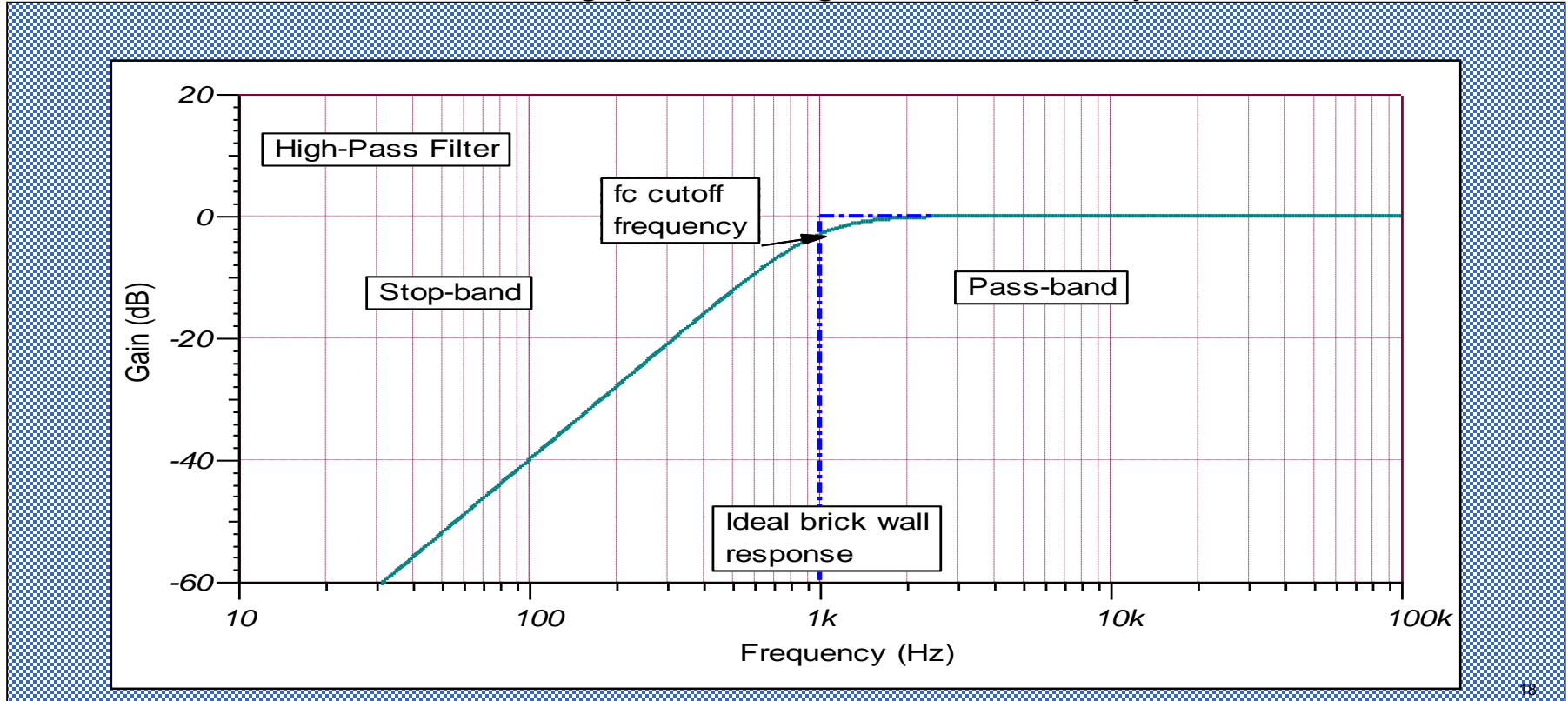
Filter Types

1-kHz Lowpass filter gain vs. frequency



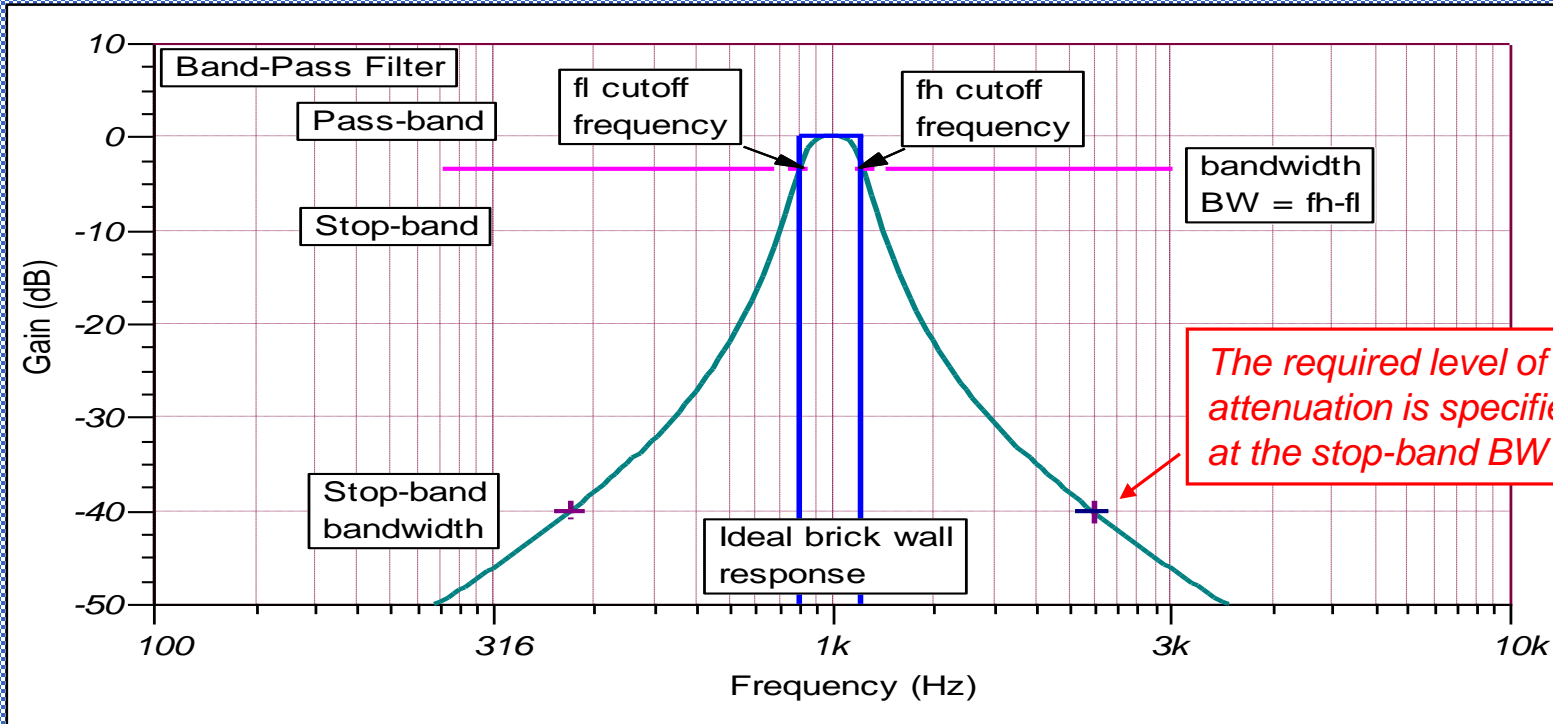
Filter Types

1-kHz highpass filter gain vs. frequency



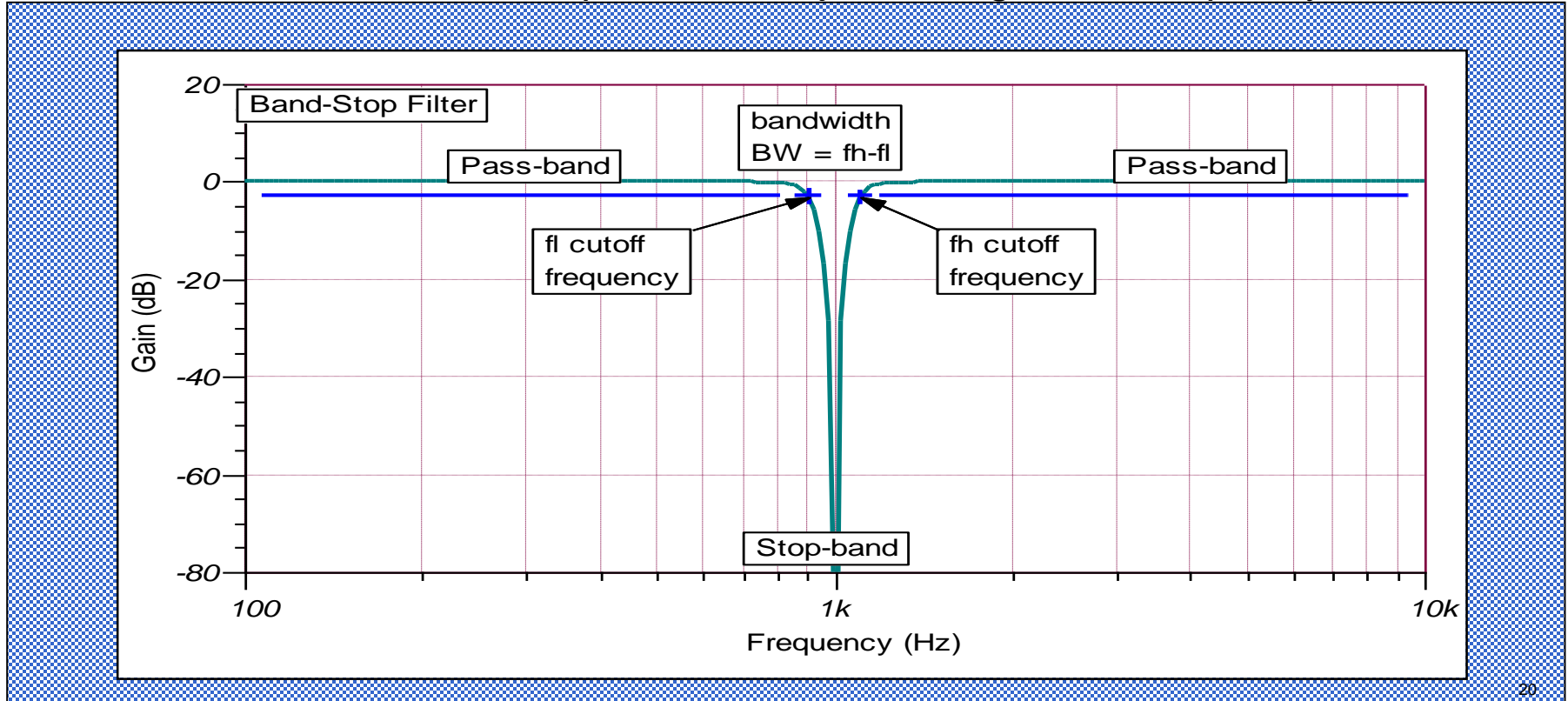
Filter Types

1-kHz bandpass filter gain vs. frequency



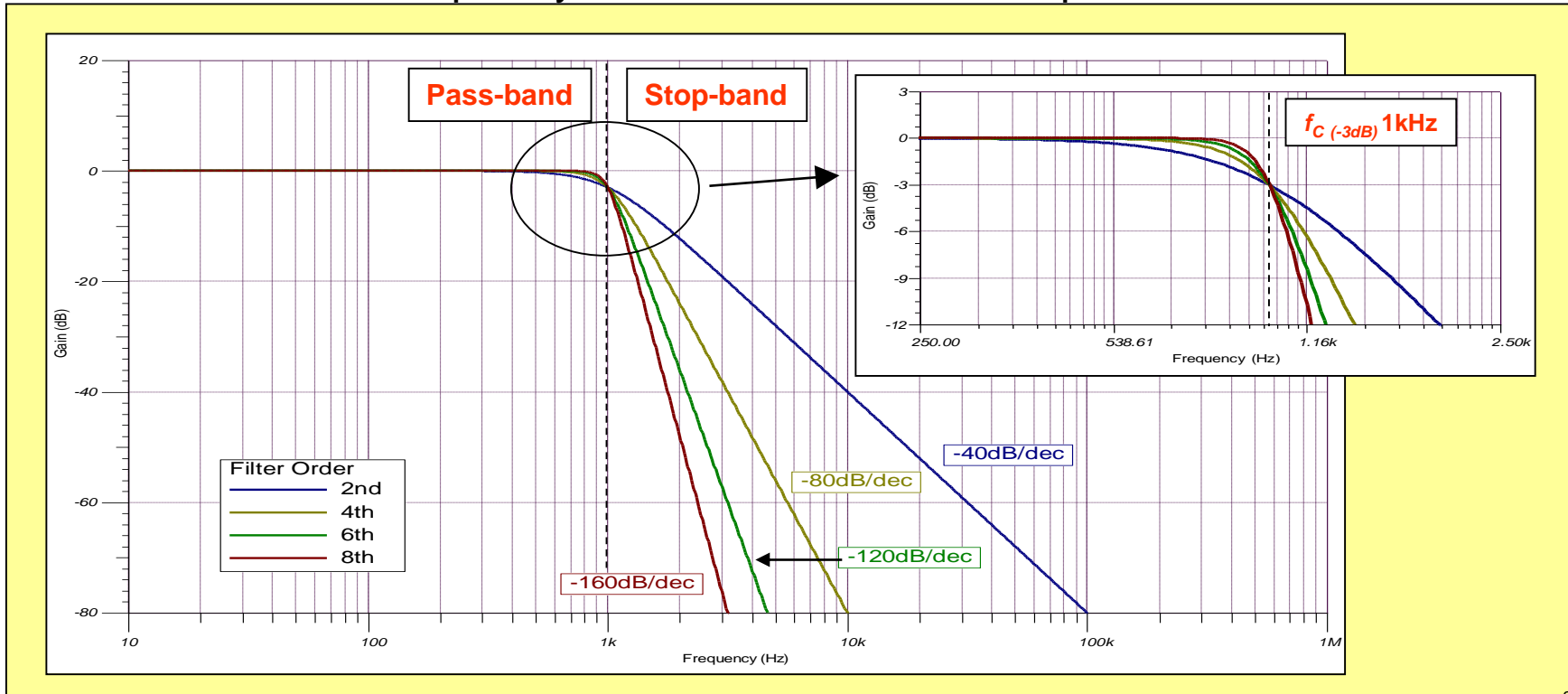
Filter Types

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



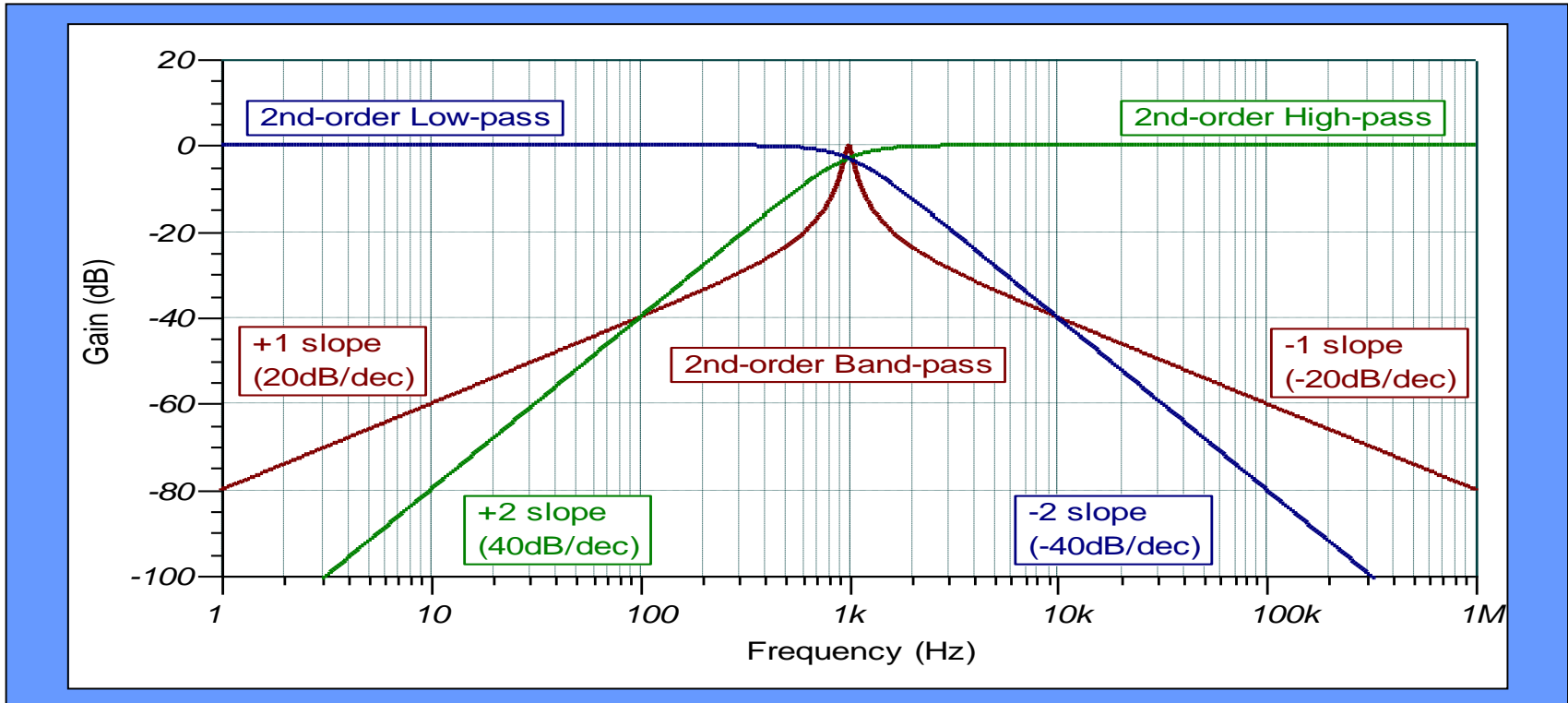
Filter Order

Gain vs. frequency behavior for different lowpass filter orders



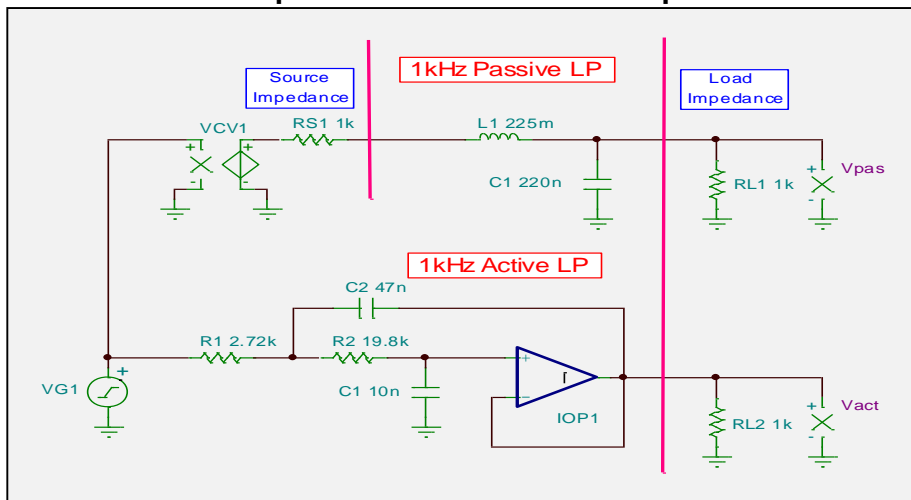
Filter Order

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

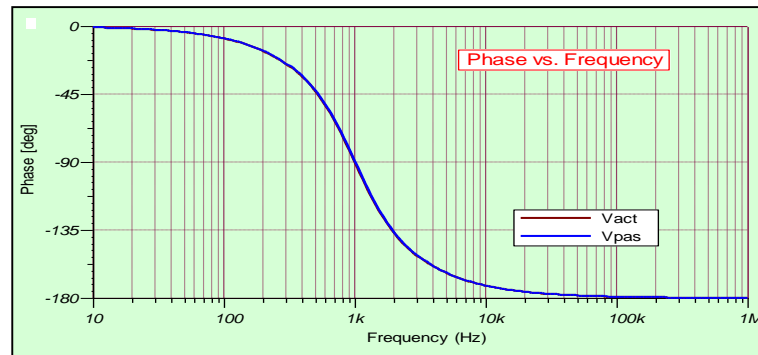
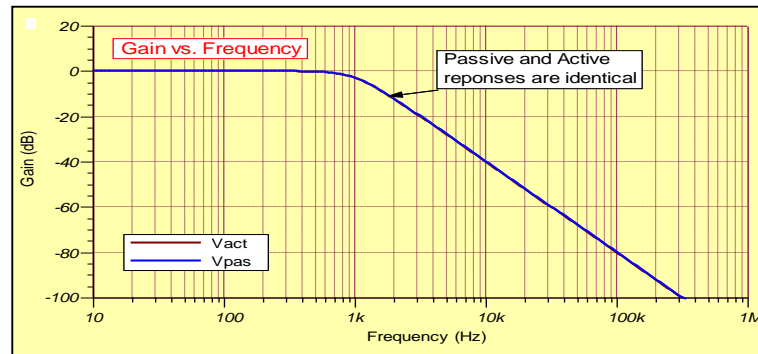


Why Active Filters?

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



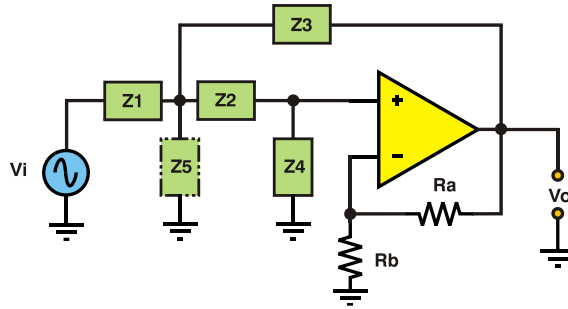
- Inductor size, weight and cost for low frequency filters may be prohibitive
- Inductor magnetic coupling considerations
- Active filter size is small and low in cost
- R and C values are easily scaled in active filters



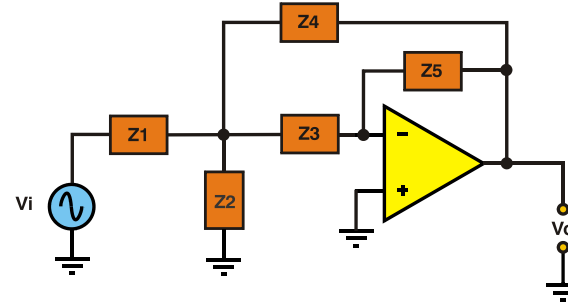
Popular Active Filter Topologies

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

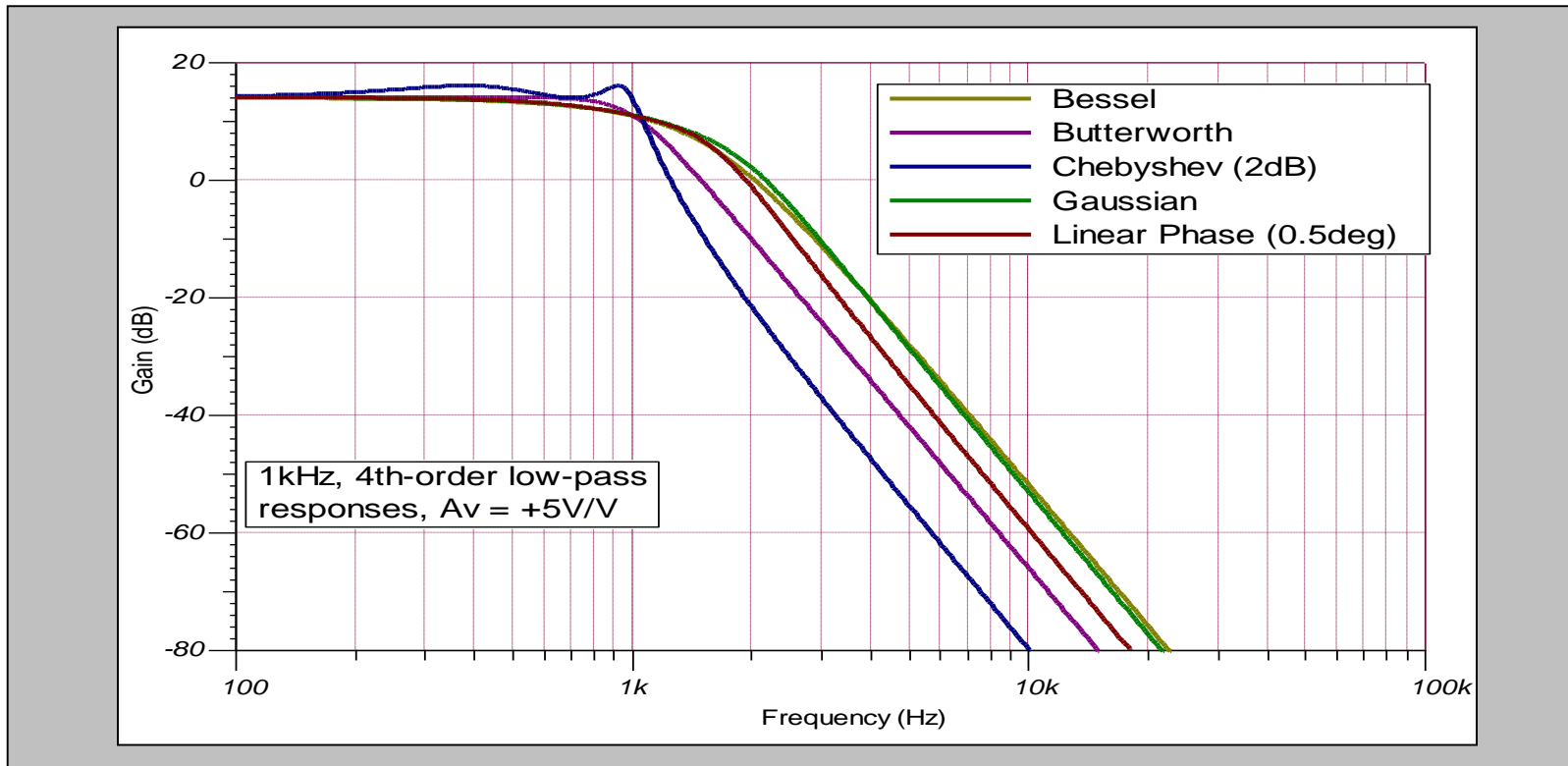
Filter Responses

Response Considerations

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

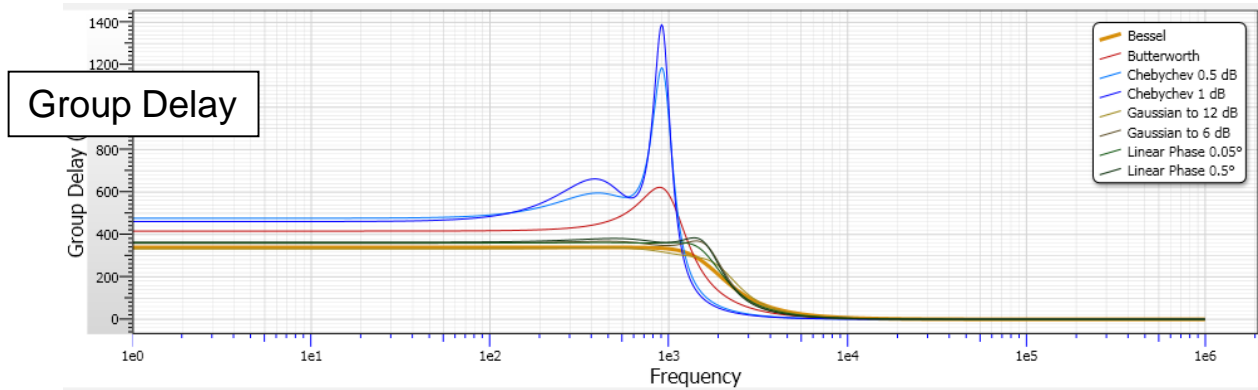
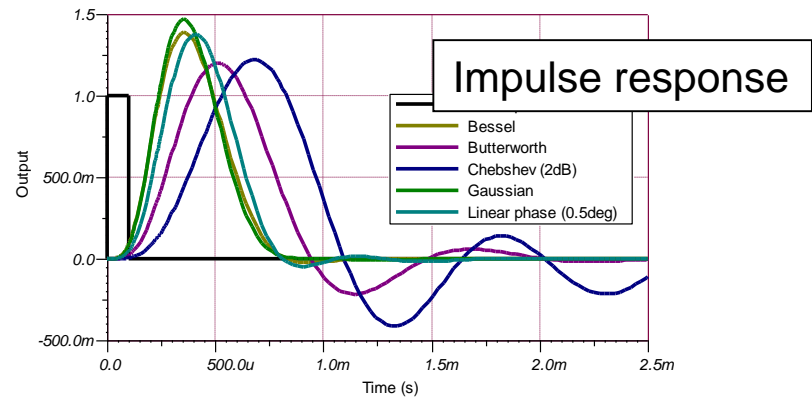
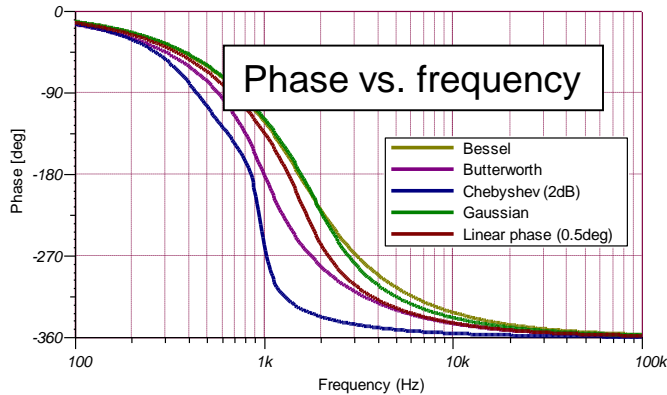
Filter Responses

Common active lowpass filters - amplitude vs. frequency



Filter Responses

Common active lowpass filters – other responses



Specify Filter Requirements

Select Filter

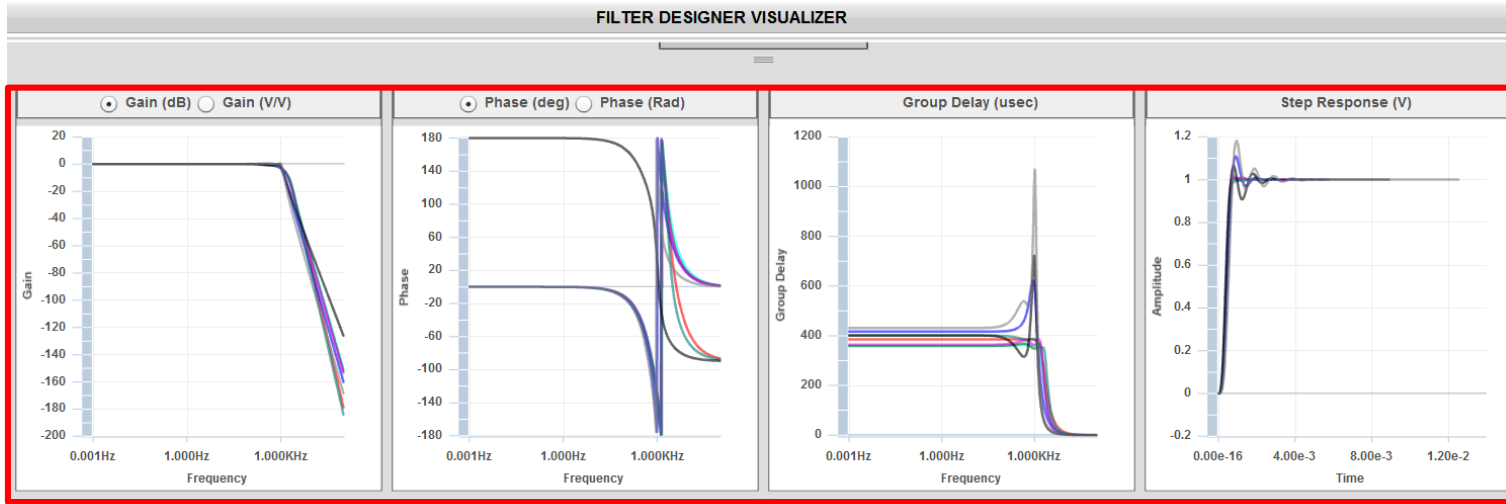
The screenshot shows a software interface for specifying filter requirements. It is divided into several sections:

- Filter Type:** Radio buttons for Lowpass, Highpass, Bandpass (selected), and Bandstop.
- Specification:** Radio buttons for Search Filter (selected) and Specify Filter. Below are input fields for Gain (A) in dB (0.00), Center Frequency (fo) in Hz (1000), -3dB Bandwidth (BW3dB) in Hz (100), Max Passband Ripple (Rp) in dB (1), Stopband Bandwidth (BW_s) in Hz (1000), and Stopband Attenuation (Asb) in dB (-45). A note states: "* This frequency is used as BWp for Chebyshev calculations." There is also an "Additional Specs (Optional)" button.
- Graph:** A magnitude response plot showing a bandpass filter. The y-axis is labeled "Magnitude" and the x-axis is "Frequency". The center frequency is marked as fo. The 3dB bandwidth is labeled BW3dB, and the stopband attenuation is labeled Asb. The stopband bandwidth is labeled BW_s.
- Supply Voltage:** Radio buttons for Dual Supply (selected) and Single Supply, with a dropdown menu showing "+/-5".
- Advanced View:** A checkbox that is currently unchecked.
- Start Filter Design:** A green button at the bottom right, highlighted with a red box and an arrow.

Program Frequencies

Click to Continue

View / Select Filter Response



Performance
Graphs



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

The screenshot displays the WEBENCH Optimizer interface for a filter design. The left sidebar contains the optimizer controls, and the main area shows two circuit diagrams and their corresponding Bill of Materials (BOM) tables.

Optimizer Dial: A dial with a needle pointing to 'Lowest' (1) on a scale from 1 to 5, with 'Smallest' on the left and 'Sensitivity' on the right.

Topology and Component Specifications:

- Op-Amp: LMC6572BIM (Dual device), Dual Supply: +/-5V
- Filter Topology Specification: Topology: Sallen Key, CapSeedValue: 1e-8, Res Tolerance: E96(1%), Cap Tolerance: E24(5%)
- Current Design: #4795, FilterType: Lowpass, FilterOrder: 4, Gain: 1.0 V/V, StopbandAttenuation: -45.0 dB, DualSupply: +/-5.0 V, PassbandFrequency: 1000.0 Hz, StopbandFrequency: 5000.0 Hz
- Name: Lowpass, Sallen Key, Butterworth

Stage 1 Design Summary:

- Second Order Topology: Sallen Key, Gain: 1 V/V, Cutoff Frequency: 1 KHz, Q: 0.540, Min OpAmp GBW/F: 54 KHz
- Components: R1 (12.400KOhm), R2 (16.900KOhm), C1 (10.000nF, 50.000V), C2 (12.000nF, 25.000V)

Stage 2 Design Summary:

- Second Order Topology: Sallen Key, Gain: 1 V/V, Cutoff Frequency: 1 KHz, Q: 1.310, Min OpAmp GBW/F: 131 KHz
- Components: R1 (4.220KOhm), R2 (7.870KOhm), C1 (10.000nF, 50.000V), C2 (82.000nF, 25.000V)

Bill of Materials (BOM) Tables:

Part #	Manufacturer	Part Number	Price	Value	Footprint	Top Vi	Edit
A1	Texas	LMC6572BIM (Dual d...	\$0.55	N/A	N/A	-	Select Alternate Part
C1	Kemet	C0603C103J5RACTU	\$0.01	10.000n	4.680000n	-	Select Alternate Part
C2	AVX	06033C123JAT2A	\$0.06	12.000n	4.680000n	-	Select Alternate Part
R1	Vishay-Dale	CRCW040212K4FKED	\$0.01	12.400K	3.0 mm²	-	Select Alternate Part

Part #	Manufacturer	Part Number	Price	Value	Footprint	Top Vi	Edit
A1	Texas Instruments	LMC6572BIM (Dual ...	\$0.55	N/A	N/A	-	Select Alternate Part
C1	Kemet	C0603C103J5RACTU	\$0.01	10.000n	4.680000n	-	Select Alternate Part
C2	AVX	12063A822JAT2A	\$0.14	82.000n	10.92000n	-	Select Alternate Part
R1	Vishay-Dale	CRCW04024K22FKED	\$0.01	4.220K	3.0 mm²	-	Select Alternate Part

Topology and Component Specifications

Tweak Design

Current Design and Design Notes

Share or Copy Design

Electrical Simulation

Click to Run Sim

Select Sim Type

Closed Loop Frequency Response,
Sine Wave Response,
Step Response

The screenshot displays the TI Simulink software interface. At the top, a toolbar includes icons for Back, New, Visualizer, Schematic, Sim, Export, Print, and Share Design. Below the toolbar, the 'FILTER DESIGNER SIMULATION' window is open, showing a simulation list with 'Closed Loop Freq Respo' selected. A dropdown menu is open, listing 'Closed Loop Freq Response', 'Sine Wave Response', and 'Step Response'. The main workspace shows a circuit diagram of a two-stage op-amp filter. The simulation parameters are set to 0.6. The 'Interactive Waveform' window is open, showing a Bode plot with Gain (dB) on the left y-axis and Phase (degrees) on the right y-axis, both plotted against Frequency (Hz) on a logarithmic x-axis. The Gain plot (blue line) shows a roll-off from 0 dB to -140 dB, and the Phase plot (red line) shows a phase shift from 0 degrees to -700 degrees.

Hands-on Exercise

Design Problem:	Goals:
<p>Design a low pass filter with fast falling after the cut-off frequency.</p> <p>Filter</p> <ul style="list-style-type: none"><li>Low pass<li>Gain = 20 V/V<li>-3db = 5000 Hz<li>Stop band frequency = 25000 <p>Hz</p> <ul style="list-style-type: none"><li>Stop band attenuation = - 45 dB<li>Chebyshev – allowable ripple ≤ 0.5 dB	<p>Optimize the amplifier bandwidths to be as low as possible.</p>

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

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WEBENCH® Filter Designer

Active Filter Designs Within Minutes!

WEBENCH® Filter Designer

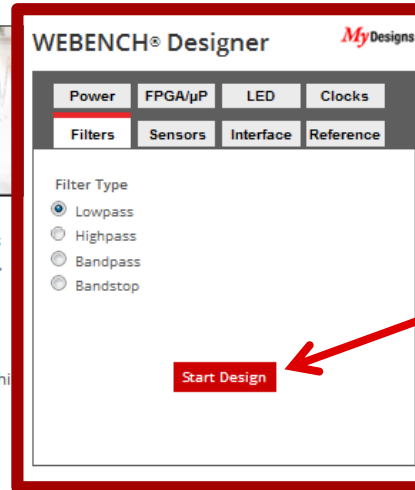
Rapidly Design Active Filters
to Meet Your Specifications



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 within 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

Start Design

Demo

Optimizer Knob

The screenshot displays the WEBENCH Optimizer interface. At the top, it says "WEBENCH® Optimizer" and "Lowest BOM Cost". A central knob is shown with a red pointer pointing to the "1" position. The knob has five positions labeled 1 through 5, each with a corresponding colored arc: 1 (red), 2 (green), 3 (blue), 4 (purple), and 5 (orange). A red callout box on the left contains the text "Use knob to optimize" with a red arrow pointing to the knob. Below the knob are three buttons: "<<", ">>", and a central button. Below these are three input fields: "Group Delay" with the value "10.258", "Filter Order" with the value "4", and "Attenuation" with the value "-59.99". At the bottom, a legend lists five optimization goals corresponding to the knob positions: 1 - Best Pulse Response, 2 - Lowest Settling Time, 3 - Default Setting - Lowest Cost, 4 - Lowest passband ripple, and 5 - Best Stopband Attenuation. A help icon (?) is also present.

WEBENCH® Optimizer

Lowest BOM Cost

Use knob to optimize

Best Pulse Response

Best Stopband Attenuation

1 5

<< >>

Group Delay Filter Order Attenuation

10.258 4 -59.99

1 - Best Pulse Response
2 - Lowest Settling Time
3 - Default Setting - Lowest Cost
4 - Lowest passband ripple
5 - Best Stopband Attenuation

Modify Constraints

Change Inputs

Filter Type: Lowpass Recalculate

Attenuation

Cutoff Frequency(fc): Hz

Gain(Ao): V/V dB

Search Filter Response Pick Filter Response

Stopband

Stopband Attenuation(Asb): dB

Stopband Frequency(fs): Hz

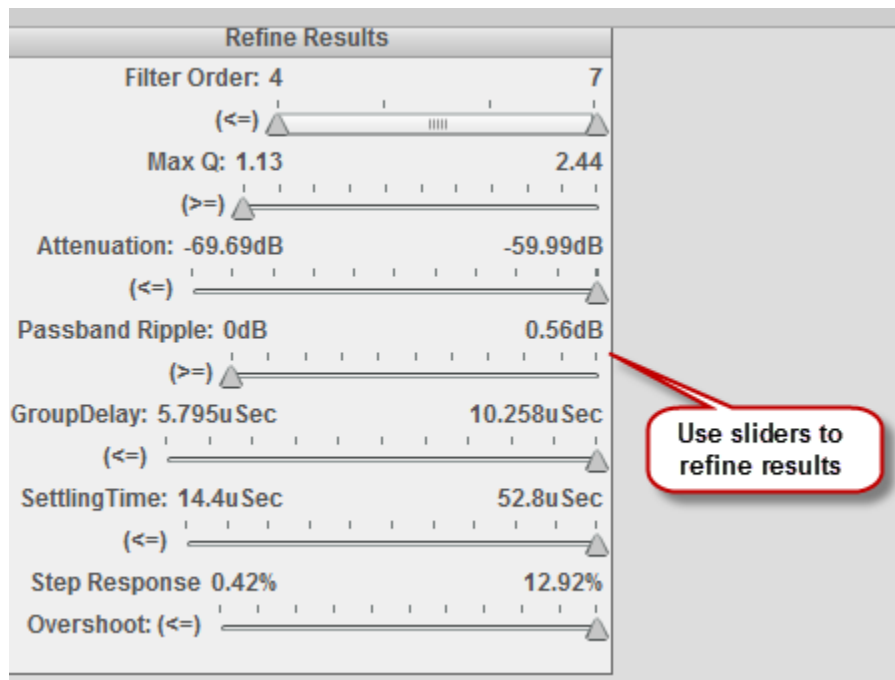
Supply Voltage

Dual Supply Single Supply

Supply Voltage: ▾

**Change inputs
and click
“Recalculate”**

Refine Results



View/Optimize Filter Response Solutions

Filter Optimization Response Chart Solutions

FILTER ARCHITECT VISUALIZER

Change Inputs

Filter Type: Lowpass

Attenuation

Cutoff Frequency(fc): 80000 Hz

Stopband Attenuation(Asb): -60 dB

Stopband Frequency(fs): 400000 Hz

Gain(Ao): 1.00 V/V, 0.00 dB

Enter Flatness Specs

Enter Group Delay Specs

Enter Step Response Specs

Recalculate

Refine Results

Filter Order: 4 (range 4-7)

Max Q: 1.13 (range 1.13-2.44)

Attenuation: -59.69dB (range -59.69dB to -59.99dB)

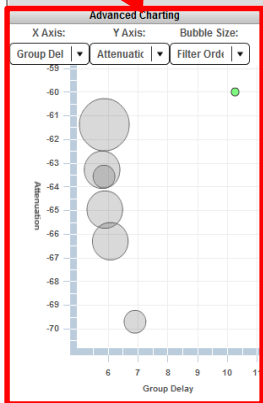
Passband Ripple: 0dB (range 0dB to 0.56dB)

Group Delay: 5.795uSec (range 5.795uSec to 10.250uSec)

Settling Time: 14.4uSec (range 14.4uSec to 52.8uSec)

Step Response 0.42% (range 0.42% to 12.92%)

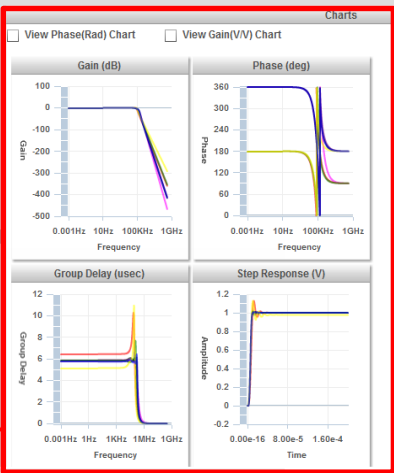
Overshoot: 0% (range 0% to 12.92%)



Solutions (7 found)

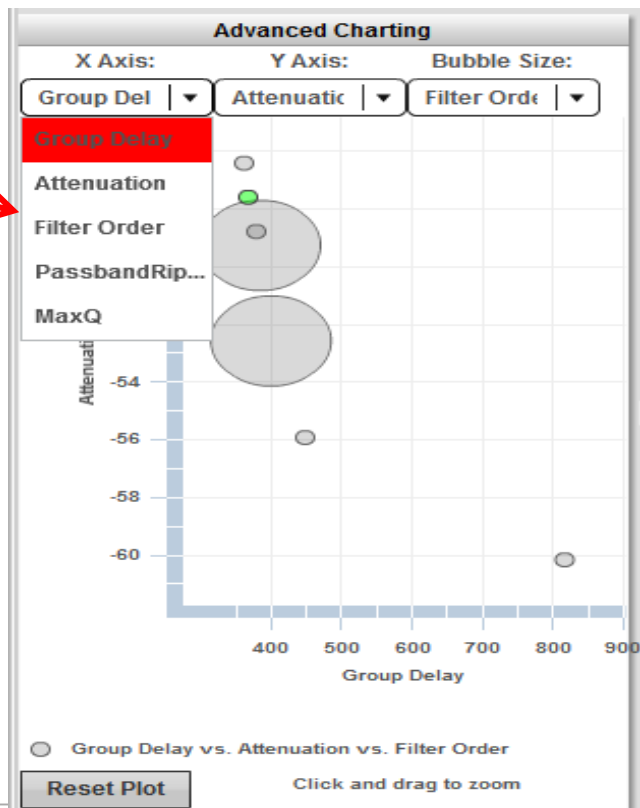
Select	Filter Response	Color	Order	Max Q	Att (dB)	Passband Ripple (dB)	Group Delay (uSec)	Group Delay Flatness (uSec)	Settling Time (uSec)	Step Response Overshoot (%)
Select	Chebyshev	Yellow	4	2.435	-59.99	0.199	10.258	5.119	52.800	12.92
Select	Butterworth	Red	5	1.62	-69.69	3.25e-4	6.895	0.457	41.200	12.77
Select	Gaussian_6dB	Green	5	2.26	-63.56	0.569	5.852	0.168	29.999	1.78
Select	Linear_Phase_005	Purple	6	1.69	-63.27	0.456	5.795	0.027	16.700	0.42
Select	Linear_Phase_05	Black	6	2.2	-66.29	0.327	6.068	0.249	22.399	1.05
Select	Gaussian_12dB	Blue	6	2.44	-64.95	0.387	5.886	0.148	21.899	0.84
Select	Bessel	Magenta	7	1.13	-61.37	0.467	5.909	2.07e-5	14.400	0.49

Performance Graphs

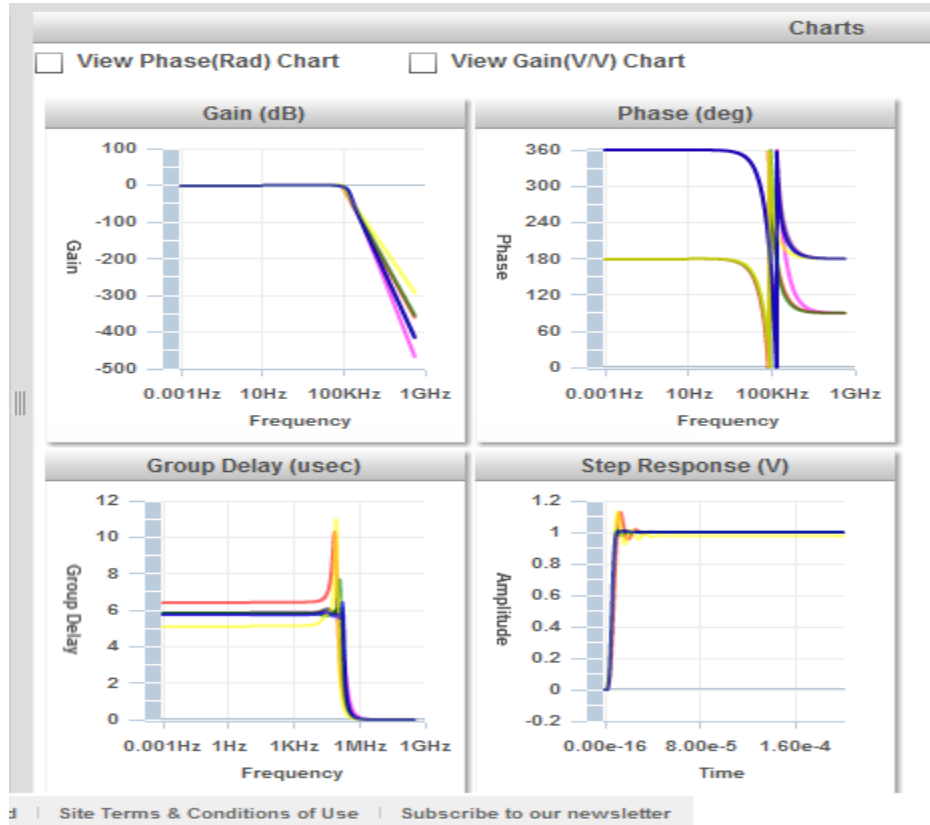


Optimization Graph

Modify
Axis
Parameters



Charts



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	Gaussian_6dB	Green	5	2.26	-63.56	0.569	5.852	0.168	29.999	1.78
Select	Linear_Phase_005	Purple	6	1.69	-63.27	0.456	5.795	0.027	16.700	0.42
Select	Linear_Phase_05	Black	6	2.2	-66.29	0.327	6.068	0.249	22.399	1.05
Select	Gaussian_05		6	2.44	-64.95	0.387	5.886	0.148	21.899	0.84
Select			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 Schematic

BOM

WEBENCH® Optimizer

Lowest BOM Cost
Smallest Footprint
Sensitivity

Op-Amp
OPA177GP Select Alternate
Dual Supply: +1.5V

Filter Topology Specification
Topology: Sallen Key
CapSeedValue: 1e-8
Res Tolerance: E192(0.5%)
Cap Tolerance: E6(20%)
Update

Tweak Design
Response: Transitional Gaussian to 6dB
Order: 4
Update

Current Design: #9583
Name: Lowpass, Sallen Key, Gaussian to 6 dB
Notes:

Save Name & Notes
Your Complete Design
Product Folder View My Orders
Share this design
Copy this Design

FILTER DESIGNER DESIGN SUMMARY

Stage: 1
Second Order Topology: Sallen Key Gain: 1
Cutoff Frequency: 940Hz Q: 0.59
Min OpAmp GBWP: 55.460 KHz
Update

Stage: 2
Second Order Topology: Sallen Key Gain: 1
Cutoff Frequency: 1,665 KHz Q: 1.32
Min OpAmp GBWP: 219.780 KHz
Update

Bill of Materials

Part	Manufacturer	Part Number	Price	Value	Footprint	Top Vie	Edit
A1	Texas Instruments	OPA177GP	\$1.00	N/A	N/A		Select Alternate Part
C1	MuRata	GRM216R71H103KA01D	\$0.01	10.00nF	13.0		Select Alternate Part
C2	Yageo America	CC0805KRX7R9BB153	\$0.01	15.00nF	13.0		Select Alternate Part
R1	Vishay-Dale	CRCW080510K5FKEA	\$0.01	10.50K	13.0		Select Alternate Part
R2	Vishay-Dale	CRCW080517K8FKEA	\$0.01	17.80K	13.0		Select Alternate Part

Part	Manufacturer	Part Number	Price	Value	Footprint	Top Vie	Edit
A1	Texas Instruments	OPA177GP	\$1.00	N/A	N/A		Select Alternate Part
C1	MuRata	GRM216R71H103KA01D	\$0.01	10.00nF	13.0		Select Alternate Part
C2	MuRata	GRM21BR71E104KA01L	\$0.01	0.10uF	13.0		Select Alternate Part
R1	Vishay-Dale	CRCW08051K62FKEA	\$0.01	1.62K	13.0		Select Alternate Part
R2	Vishay-Dale	CRCW08055K92FKEA	\$0.01	5.62K	13.0		Select Alternate Part

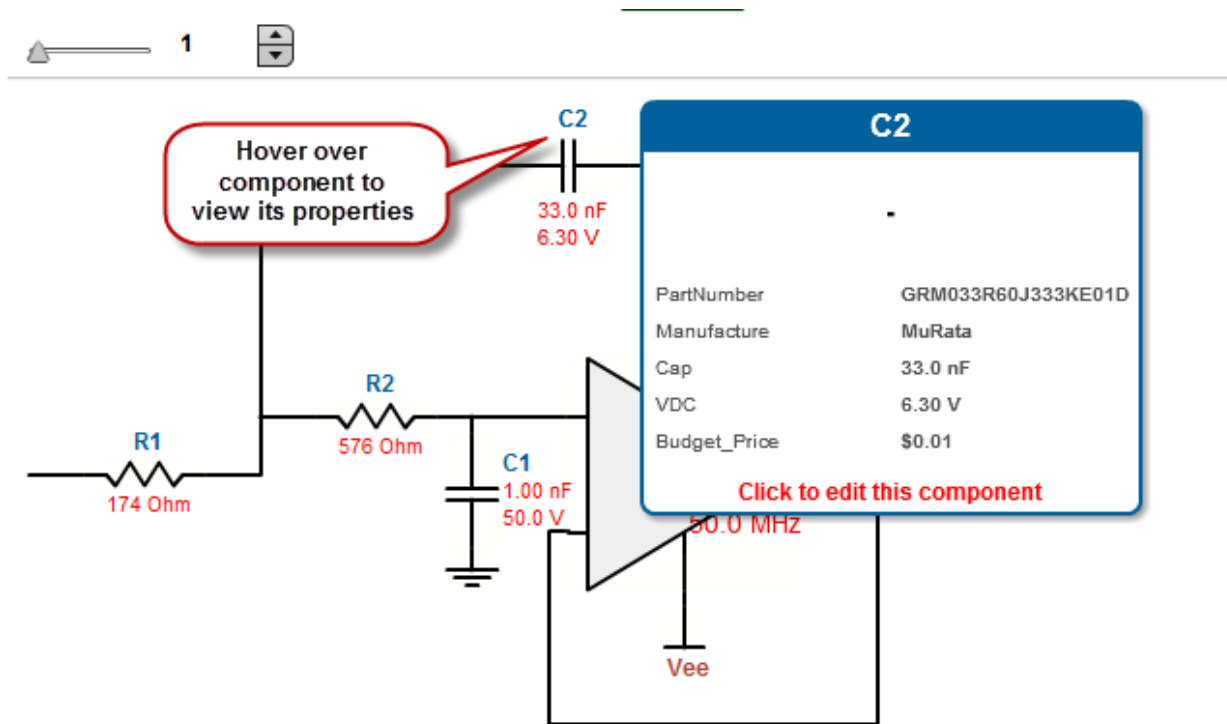
Update Gain/Topology per stage

Click to
update

Stage: 1

Second Order Topology:	<input type="text" value="Sallen Key"/>	Gain:	<input type="text" value="1"/>
Cutoff Frequency:	<input type="text" value="940Hz"/>	Q:	<input type="text" value="0.59"/>
Min OpAmp GBWP:	<input type="text" value="55.460 KHz"/>		

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	<input type="checkbox"/>	Select Alternate Part
C2	Yageo America	CC0805KRX7R9BB222	\$0.01	2.20nF	13.0	<input type="checkbox"/>	Select Alternate Part
R1	Vishay-Dale	CRCW08051K13FKEA	\$0.01	1.13KΩ	13.0	<input type="checkbox"/>	Select Alternate Part
R2	Vishay-Dale	CRCW08053K24FKEA	\$0.01	3.24KΩ	13.0	<input type="checkbox"/>	Select Alternate Part

Select Alternate Part

Select Alternate Part

Alternate Parts - Charts

Filter by Manufacturer: Select All

Update X Axis: Cap | Update Y Axis: Footprint (mm2)

Alternate parts displayed = 66

Reset All Cancel

FILTER ARCHITECT ALTERNATE PARTS

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
Select	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

The screenshot displays the WEBENCH Optimizer interface for a filter design. The top navigation bar includes buttons for Back, New, Visualizer, Sim, Sim Exp, Print, and Share Design. The main area is titled "FILTER DESIGNER DESIGN SUMMARY" and is divided into two stages of design.

Stage 1:
Second Order Topology: Sallen Key | Gain: 1 V/V
Cutoff Frequency: 1 KHz | Q: 0.540
Min OpAmp GBW/F: 54 KHz

Stage 2:
Second Order Topology: Sallen Key | Gain: 1 V/V
Cutoff Frequency: 1 KHz | Q: 1.310
Min OpAmp GBW/F: 131 KHz

The circuit diagrams show an LMC6572BIM op-amp configured as a filter. Stage 1 uses a 16.900KOhm resistor (R2) and a 12.400KOhm resistor (R1). Stage 2 uses a 7.870KOhm resistor (R2) and a 4.220KOhm resistor (R1). Both stages use a 10.000nF capacitor (C1) and a 12.000nF capacitor (C2).

Bill of Materials (Stage 1):

Part #	Manufacturer	Part Number	Price	Value	Footprint	Top Vi	Edit
A1	Texas	LMC6572BIM (Dual d...	\$0.55	N/A	N/A	-	Select Alternate Part
C1	Kemet	C0603C103J5RACTU	\$0.01	10.000n	4.680000n	-	Select Alternate Part
C2	AVX	06033C123JAT2A	\$0.06	12.000n	4.680000n	-	Select Alternate Part
R1	Vishay-Dale	CRCW040212K4FKED	\$0.01	12.400K	3.0 mm²	-	Select Alternate Part

Bill of Materials (Stage 2):

Part #	Manufacturer	Part Number	Price	Value	Footprint	Top Vi	Edit
A1	Texas	LMC6572BIM (Dual ...	\$0.55	N/A	N/A	-	Select Alternate Part
C1	Kemet	C0603C103J5RACTU	\$0.01	10.000n	4.680000n	-	Select Alternate Part
C2	AVX	12063A822JAT2A	\$0.14	82.000n	10.92000n	-	Select Alternate Part
R1	Vishay-Dale	CRCW04024K22FKED	\$0.01	4.220K	3.0 mm²	-	Select Alternate Part

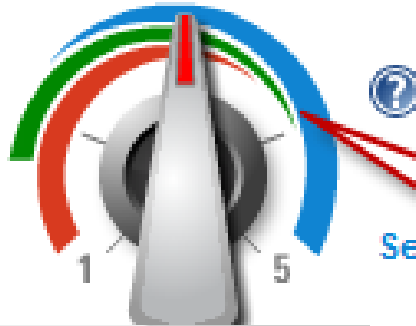
The left sidebar contains the WEBENCH Optimizer controls, including a dial for optimization (Lowest, Smallest, Sensitivity), Op-Amp selection (LMC6572BIM), Filter Topology Specification (Sallen Key, CapSpeedValue: 1e-8, Res Tolerance: E96(1%), Cap Tolerance: E24(5%)), and a table of design parameters for the current design (#4795). At the bottom of the sidebar are buttons for "Save Name & Notes" and "Your Complete Design".

Optimization Knob

WEBENCH® Optimizer

Lowest
BOM Cost

Smallest
Footprint



Sensitivity

Use knob to
optimize -
the design
will be
updated

WEBENCH® Optimizer Help


Philosophy of the WEBENCH Optimizer Dial

- 1 - Smallest Footprint: If gain = 1, select Sallen-Key with R tolerance at E96 and C tolerance at E6; if $G \neq 1$, select MFB with same tolerances.
- 2 - Lowest Cost: If gain = 1, select Sallen-Key with R and C tolerances at E6 (20%); if $G \neq 1$, select MFB with E6 tolerances.
- 3 - Balanced Solution: Select MFB with R tolerance at E96, C tolerance at E6.
- 4 - Best Accuracy: Select Sallen-Key with R and C tolerances at E96.
- 5 - Lowest Sensitivity: Select MFB with R and C tolerances at E96.

Filter Topology Specification

Cap seed
and
tolerances

Op-Amp

LM318MWC  **Select Alternate**

Double Supply: +/-5V

Filter Topology Specification

Topology: Sallen Key ▾

CapSeedValue: 1e-8

Res Tolerance: E192(0.5%) ▾

Cap Tolerance: E6(20%) ▾

Update

Select
Alternative
Amplifier

Select Topology
for all stages

Tweak Design

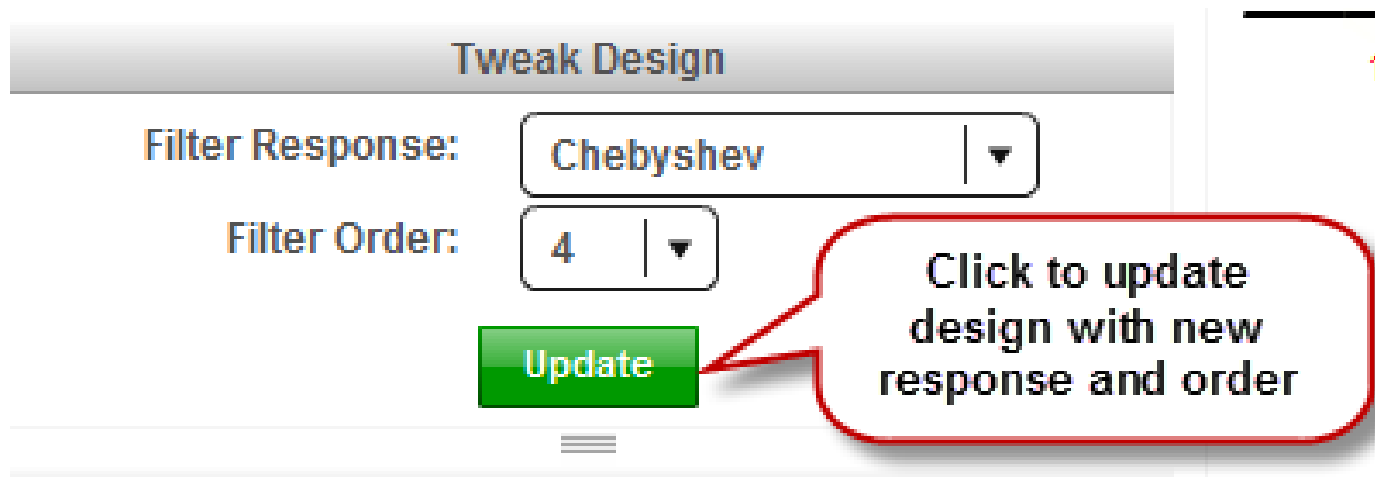
Tweak Design

Filter Response:

Filter Order:

Click to update design with new response and order

1

The image shows a software interface for adjusting filter design parameters. At the top, a grey header bar contains the text "Tweak Design". Below this, there are two rows of controls. The first row is labeled "Filter Response:" and features a dropdown menu with "Chebyshev" selected. The second row is labeled "Filter Order:" and features a dropdown menu with "4" selected. Below these controls is a prominent green button with the word "Update" in white text. A red callout bubble with a white border points to the "Update" button, containing the text "Click to update design with new response and order". To the right of the main interface, there is a vertical line and a small red number "1".

Notate and Share

The screenshot displays a web interface for a design tool. At the top, a grey header bar contains the text "Current Design: #926", which is highlighted with a red box and pointed to by a red arrow labeled "Design ID". Below this, the "Name" field contains "Lowpass, Sallen Key, Chebyshev 0.2 dB" and the "Notes" field is empty. A green button labeled "Save Name & Notes" is positioned below the notes field, along with icons for sharing and copying. A red horizontal bar below the buttons reads "Your Complete Design". Underneath, there are two links: "Product Folder" and "View My Orders". The "Share this design" option is highlighted with a red box and pointed to by a red arrow labeled "Share Design". It features an envelope icon and a person icon. Below it is the "Copy this Design" option with a document and arrow icon.

Electrical Simulation

My Designs/Projects | English | 日本語 | 简体中文 | 繁體中文 | 한국어 | Русский Язык | Português | Deutsch | Welcome | khang.nguyen@ti.com

Back New Visualize **Sim** Print Design

FILTER DESIGNER DESIGN SUMMARY

Stage: 1 Schematic Step: 2

Second Order Topology: Sallen Key Gain: 1 Cutoff Frequency: 940Hz Q: 0.59 Min OpAmp GBWP: 55.460 KHz

Second Order Topology: Sallen Key Cutoff Frequency: 1.665 KHz Q: 1.32 Min OpAmp GBWP: 219.780 KHz

Op-Amp: OPA177GP Select Alternate Dual Supply: +5V

Filter Topology Specification: Topology: Sallen Key CapSeedValue: 1e-8 Res Tolerance: E192(0.5%) Cap Tolerance: E6(20%)

Tweak Design: response: Transitional Gaussian to 6dB Order: 4

Current Design: #9583 Name: Lowpass, Sallen Key, Gaussian to 6 dB

Notes: Save Name & Notes

Your Complete Design Product Folder View My Orders Share this design Copy this design

Bill of Materials

Part	Manufacturer	Part Number	Price	Value	Footprint	Top Vie	Edit
A1	Texas Instruments	OPA177GP	\$1.00	N/A	N/A		Select Alternate Part
C1	MuRata	GRM216R71H103KA01D	\$0.01	10.00nF	13.0		Select Alternate Part
C2	Yageo America	CC0805KRX7R9BB153	\$0.01	15.00nF	13.0		Select Alternate Part
R1	Vishay-Dale	CRCW080510KS5FKEA	\$0.01	10.50KΩ	13.0		Select Alternate Part
R2	Vishay-Dale	CRCW080517K8FKEA	\$0.01	17.80KΩ	13.0		Select Alternate Part

Part	Manufacturer	Part Number	Price	Value	Footprint	Top Vie	Edit
A1	Texas Instruments	OPA177GP	\$1.00	N/A	N/A		Select Alternate Part
C1	MuRata	GRM216R71E104KA01L	\$0.01	0.10uF	13.0		Select Alternate Part
R1	Vishay-Dale	CRCW08051K62FKEA	\$0.01	1.62KΩ	13.0		Select Alternate Part
R2	Vishay-Dale	CRCW08055K62FKEA	\$0.01	5.62KΩ	13.0		Select Alternate Part

Click to Simulate

Electrical Simulation

Click to Run Sim

Select Sim Type

Closed Loop Frequency Response,
Sine Wave Response, Step
Response

The screenshot displays the TI Simulink software interface. At the top, a toolbar includes icons for Back, New, Visualizer, Schematic, Sim, Export, Print, and Share Design. Below the toolbar, the 'FILTER DESIGNER SIMULATION' window is active. The 'Sim Types' tab is selected, showing a dropdown menu with options: Closed Loop Freq Respo, Closed Loop Freq Response, Sine Wave Response, and Step Response. A red box highlights the 'Closed Loop Freq Response' option. The 'Start New Simulation' button is also highlighted with a red box. Below the simulation controls, a circuit diagram is shown, featuring two operational amplifiers (A1_S1 and A1_S2) with various resistors (R1, R2) and capacitors (C1, C2). The circuit is powered by VDD and VEE rails. To the right of the circuit diagram, the 'Interactive Waveform' window is open, displaying a Bode plot. The plot shows the Gain (dB) and Phase (degrees) versus Frequency (Hz) on a logarithmic scale. The Gain plot (blue line) shows a roll-off starting around 1e4 Hz, reaching approximately -140 dB at 1e8 Hz. The Phase plot (red line) shows a phase shift from 0 degrees to approximately -700 degrees over the same frequency range. The plot is titled 'Waveform Controls' and includes zooming instructions.

Electrical Simulation

Waveform List

Simulation Results

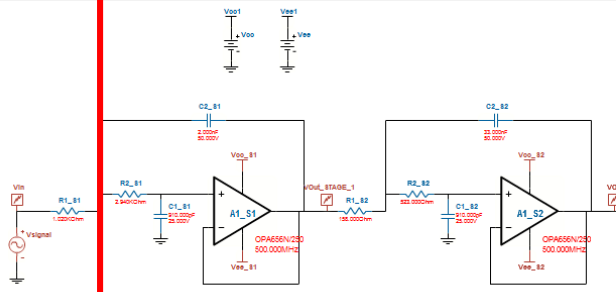
FILTER DESIGNER SIMULATION

5455 | Sim Types | Simulation List | Summary

Step 1 Select Simulation Type: Closed Loop Freq Respo | ▾

Step 2 **Start New Simulation**

0.0 | FIT | Show Pins | EDIT | EXPORT



Design Version: **Show Latest Design Version** Past simulation simId=4

Active eSim | Past Simulations

Start New Simulation

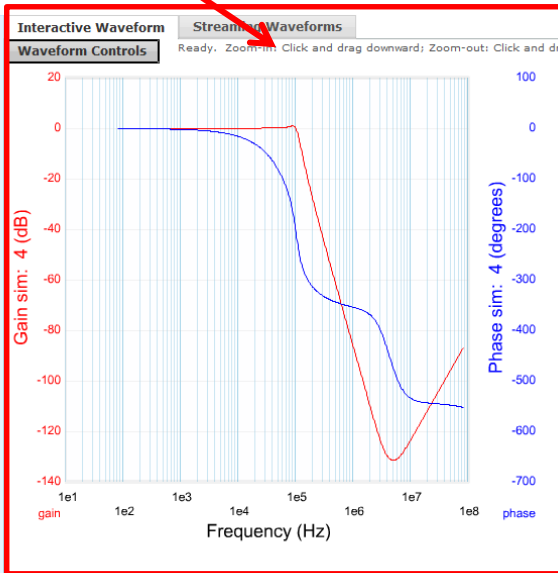
simId= 4 Closed Loop Freq Response : 2014-11-06 23:18 Status = Success

Messages | eSim Report | Download .cir file

STAGE 1 | ALL

Interactive Waveform | Streaming Waveforms

Waveform Controls: Ready. Zoom-in: Click and drag downward; Zoom-out: Click and drag



Frequency (Hz)	Gain (dB)	Phase (degrees)
1e1	0	0
1e2	0	0
1e3	0	0
1e4	0	0
1e5	-20	-90
1e6	-40	-180
1e7	-60	-270
1e8	-80	-360

Electrical Simulation

FILTER DESIGNER SIMULATION

5455 | **Sim Types** | Simulation List | Summary

Step 1 Select Simulation Type | Closed Loop Freq Respo |

Step 2 | **Start New Simulation**

0.6 | FIT | Show Pins | EDIT | EXPORT

Design Version : **Show Latest Design Version** | Past simulation simId=4

Active eSim | Past Simulations | Simulation Quantity : 4 | Help

Closed Loop Freq Response

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

Review Past Simulations

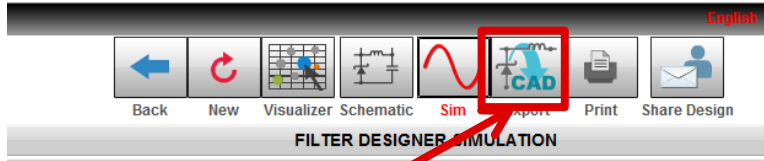
Interactive Waveform | Streaming Waveforms

Waveform Controls | Ready. Zoom-in: Click and drag downward; Zoom-out: Click and drag

Gain sim: 4 (dB) | Phase sim: 4 (degrees)

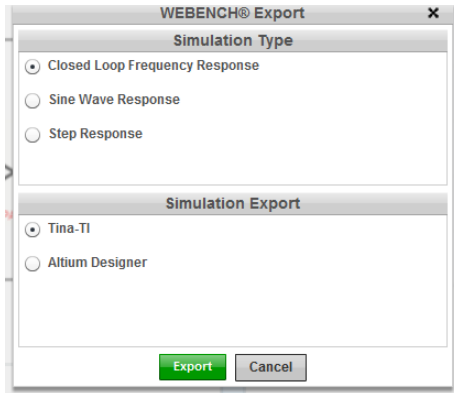
Frequency (Hz)

Export to External Simulator

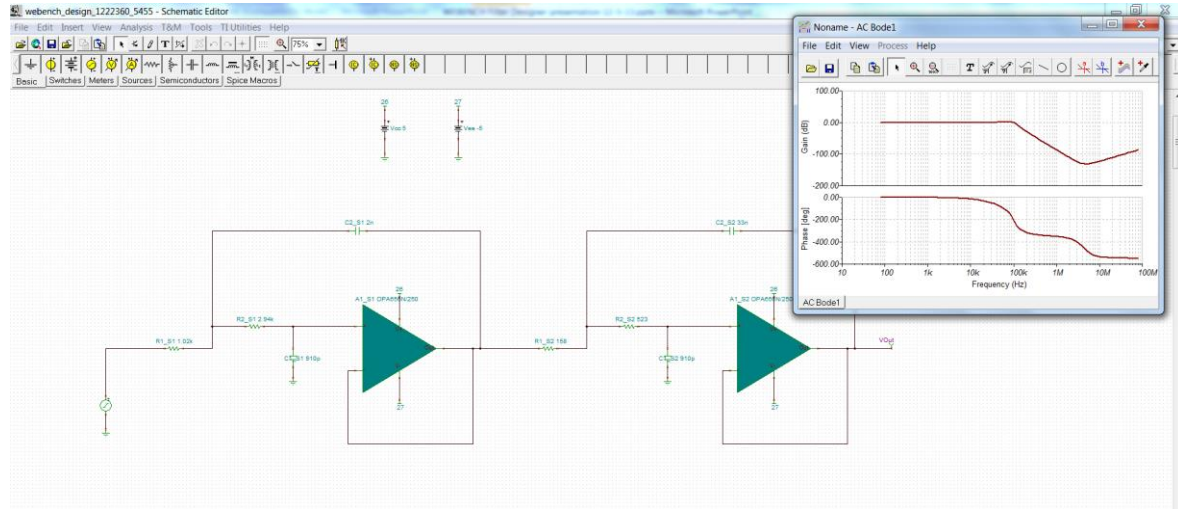


1) Click export

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

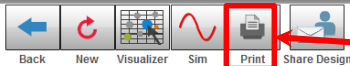


2) Choose sim type and export format



Design Report

My Designs/Projects English | 日本語 | 繁体中文 | 繁體中文 | 한국어 | Русский Язык | Português | Deutsch Welcome khang.nguyen@ti.com



View and Print PDF Report

WEBENCH® Optimizer

Lowest BOM Cost
Smallest Footprint
Sensitivity

Op-Amp
OPA177GP Select Alternate
Dual Supply: +/-5V

Filter Topology Specification
Topology: Sallen Key
CapSeedValue: 1e-8
Res Tolerance: E192(0.5%)
Cap Tolerance: E0(20%)
Update

Tweak Design
Response: Transitional Gaussian to 6dB
Order: 4
Update

Current Design: #9584
Name: Lowpass, Sallen Key, Gaussian to 6 dB
Notes:
Save Name & Notes
Your Complete Design
Product Folder View My Orders

FILTER DESIGNER DESIGN SUMMARY

Stage: 1 Stage: 2
Second Order Topology: Sallen Key Gain: 1 Cutoff Frequency: 9.41kHz Min OpAmp GBWP: 1.54
Second Order Topology: Sallen Key Gain: 1 Cutoff Frequency: 1.665 kHz

webench_design_238809_9583_561095666.pdf - Adobe Reader

File Edit View Window Help
1 (1 of 4) 103% Comment

TEXAS INSTRUMENTS
WEBENCH® Design Report
Design : 238809/9583 OPA177GP
Lowpass, Sallen Key, Gaussian to 6 dB

Type : Lowpass
Response : Gaussian_6dB
Topology : Sallen_Key
Order : 4
Stage Qty : 2

Device = OPA177GP
Topology = Custom LP Filter
Created = 9/4/13 2:52:08 PM

Part #	Manufacturer	Part Number
A1	Texas Instruments	OPA177GP
C1	MuRata	GRM216R71H103
C2	Yageo America	CC0805KRX7R9B
R1	Vishay-Dale	CRCW080510K5F
R2	Vishay-Dale	CRCW080517K8F