The University of Texas Rio Grande Valley
College of Engineering and Computer Science
Department of Electrical & Computer Engineering

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Lab Report 2
Filters and Transfer Functions

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Contents

I. ABSTRACT

In this laboratory experiment, two active filters were designed, built, and tested in accordance with **Project K** specifications. The first filter, designated as Filter #1, was a **fifth-order (n=5) 1 dB Chebyshev high-pass filter (HPF)** with a cutoff frequency of **403 Hz** and a passband gain of **22 V/V**. The second filter, designated as Filter #2, was a **second-order resonant bandpass filter** with a center frequency of **480 Hz**, a quality factor (Q) of **18**, and a peak gain of **15 V/V**. Both filters were designed based on standard transfer functions, including Chebyshev polynomials for the HPF and a resonant second-order equation for the bandpass filter.

Following standard active filter design practices, resistor and capacitor values were calculated by comparing theoretical transfer functions to canonical op amp topologies (first-order, second-order, etc.). SPICE simulations (AC sweep and transient) confirmed that each filter's frequency response and step response aligned with theoretical predictions. Physical prototypes were constructed on a breadboard using operational amplifiers such as the LM741 (or equivalents), and the frequency response was measured over a 10 Hz–100 kHz sweep to verify critical specifications. Step responses were recorded with an oscilloscope, using a low-frequency square wave to approximate a unit step.

Measurements demonstrated that the **Chebyshev HPF** achieved the desired higher-order roll-off at approximately 403 Hz with a small (1 dB) ripple in the passband, while the **bandpass filter** exhibited a resonant peak at approximately 480 Hz with a gain near 15 V/V. Minor discrepancies (on the order of a few percent) were observed, primarily due to resistor/capacitor tolerance and nonideal op amp limitations. The results confirmed that both the theoretical and simulated designs transferred effectively to real-world circuits, demonstrating the viability of active filters for precise frequency-selective applications.

II. BODY

FILTER TESTING

PART A Bandpass Filter

Before constructing any filter circuits, a project letter was assigned which specifies what type of filter will be constructed, the order of the circuit, cut off frequency, passband gain, center frequency, Q, and peak Gain. In our case, project letter K was assigned which the filter specifications say that two separate filters will be made and tested as "Filter #1" and "Filter #2". Where Filter #1 is a Chebychev 1 dB High Pass Filter (HPF) and Filter #2 is a Bandpass filter of 2^{nd} order Resonant. Since the Bandpass filter is easier to construct compared to the HPF, the Bandpass filter was constructed/tested first.

To construct the Bandpass filter, the following specifications must be noted down for the given project letter filter specifications table which are the following:

Filter #2				
Type	Characteristic	Center (f)	Q	Peak Gain (Ao)
Bandpass	2^{nd} order Resonant	480 Hz	18	15 v/v

Table 1 - Filter Specifications for Bandpass Filter#2

After noting down the required filter specifications for the Bandpass filter, the next step would be to find the resistor values and capacitor values for the given circuit schematic of how a Resonant Bandpass filter should be structured by using the 2^{nd} order transfer function equation of that specific Resonant Bandpass filter, compare coefficients to the vout/vin transfer function of that circuit, and solve for the resistor values. To begin, the angular frequency w0 was pre-calculated to incorporate it into the 2^{nd} order resonant transfer function as it is a missing variable that can be calculated using the given values from the filter specification Table 1 giving us an angular frequency of w0 = 2*pi*frequency = 2*pi*480Hz = 3015 rad/s. Having found all the necessary missing variables for our transfer function, the following calculations were performed to find the missing resistor values R1, R2, and R3 by making all capacitors equal to 0.1 uF:

<u>Given 2^{nd} Order Transfer Function</u>

$$H(s) = \frac{Ao * s\left(\frac{w0}{Q}\right)}{s^2 + s\left(\frac{w0}{Q}\right) + w0^2}$$

$$H(s) = \frac{(15) * s\left(\frac{3015}{18}\right)}{s^2 + \left(\frac{3015}{18}\right)s + (3015)^2}$$

$$H(s) = \frac{\left(\frac{5025}{2}\right)s}{s^2 + \left(\frac{335}{2}\right)s + (3015)^2}$$

<u>Resonant Bandpass Filter Transfer Function</u>

$$H(s) = \frac{-s\left(\frac{1}{R1 * C1}\right)}{s^2 + (\frac{C1 + C2}{R3 * C1 * C2})s + \left(\frac{1}{(R1||R2)R3 * C1 * C2}\right)}$$

<u>Compare Coefficients that are Highlighted</u>

$$\frac{1}{R1 * C1} = \frac{5025}{2}$$

$$\frac{1}{R1 * (0.1\,uF)} = \frac{5025}{2}$$

R1 = 3980 Ω, C1 = 0.1 uF

$$\frac{C1 + C2}{R3 * C1 * C2} = \frac{335}{2}$$

$$\frac{(0.1uF + 0.1uF)}{R3 * 0.1uF * 0.1uF} = \frac{335}{2}$$

R3 = 119,402 Ω, C2 = 0.1 uF

$$\frac{1}{(R1||R2) * R3 * C1 * C2} = (3015)^2$$

$$\frac{1}{Req * R3 * C1 * C2} = (3015)^2$$

$$\frac{1}{Req * (119{,}402\ \Omega) * 0.1uF * 0.1uF} = (3015)^2$$

Req = 92 Ω

$$Req = R1||R2 = 92\ \Omega$$

$$\frac{3980 * R2}{3980 + R2} = 92$$

R2 = 94 Ω

After finding the resistance values for R1, R2, R3, and capacitor values, the circuit was implemented by finding resistor values that are close to our calculated resistance values and the circuit schematic used to build the Bandpass filter will be displayed below using one LM741 op amp.

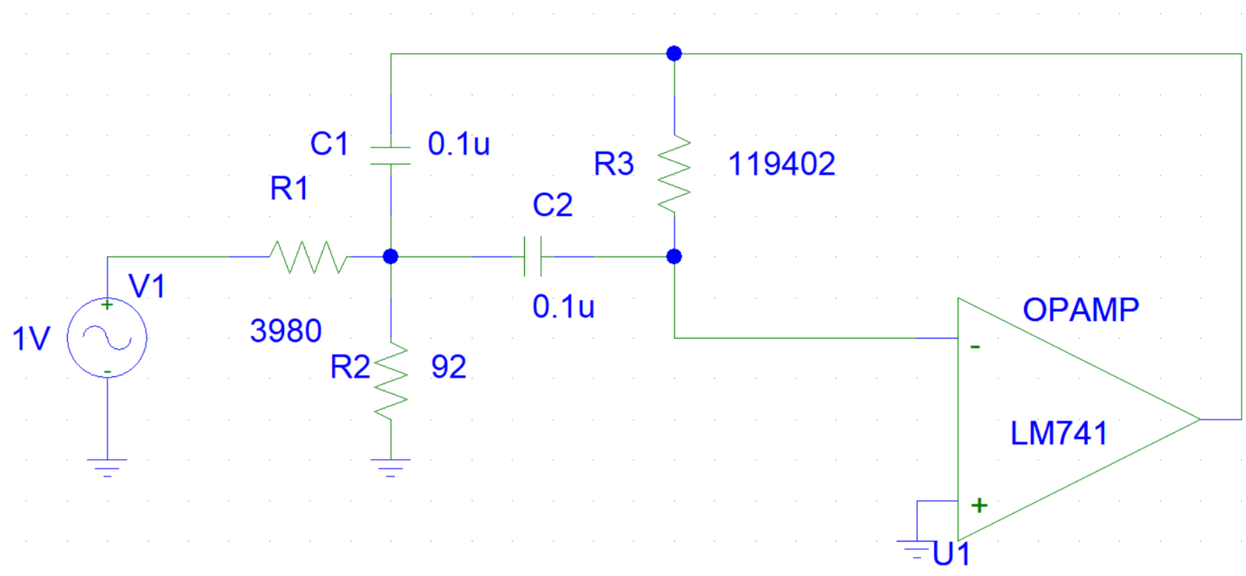
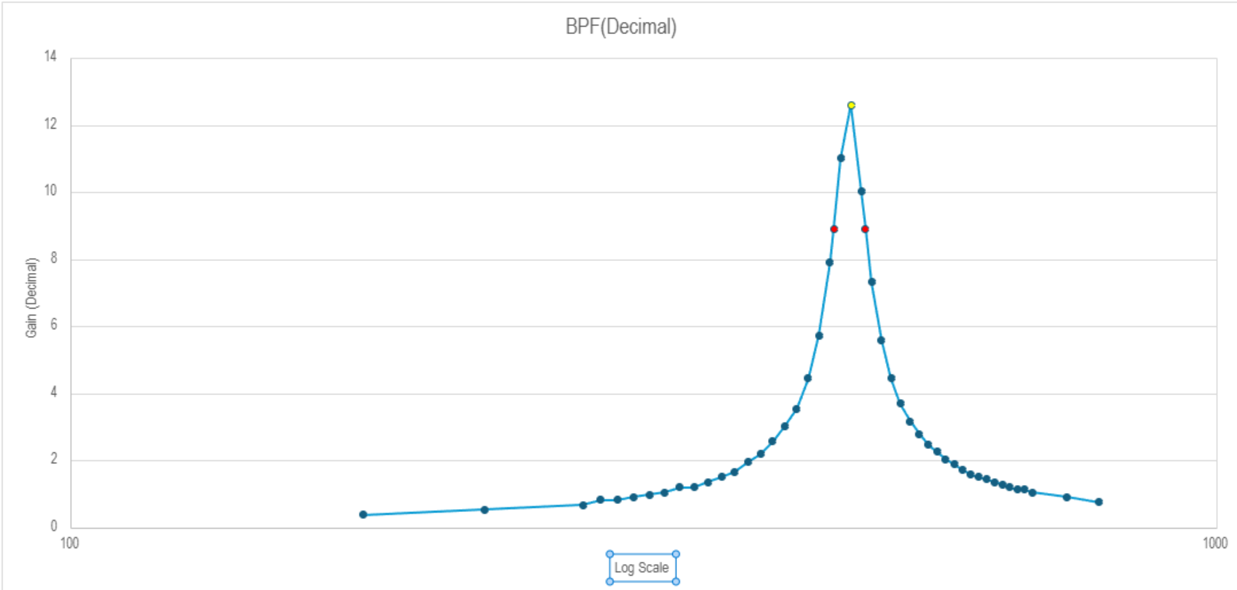


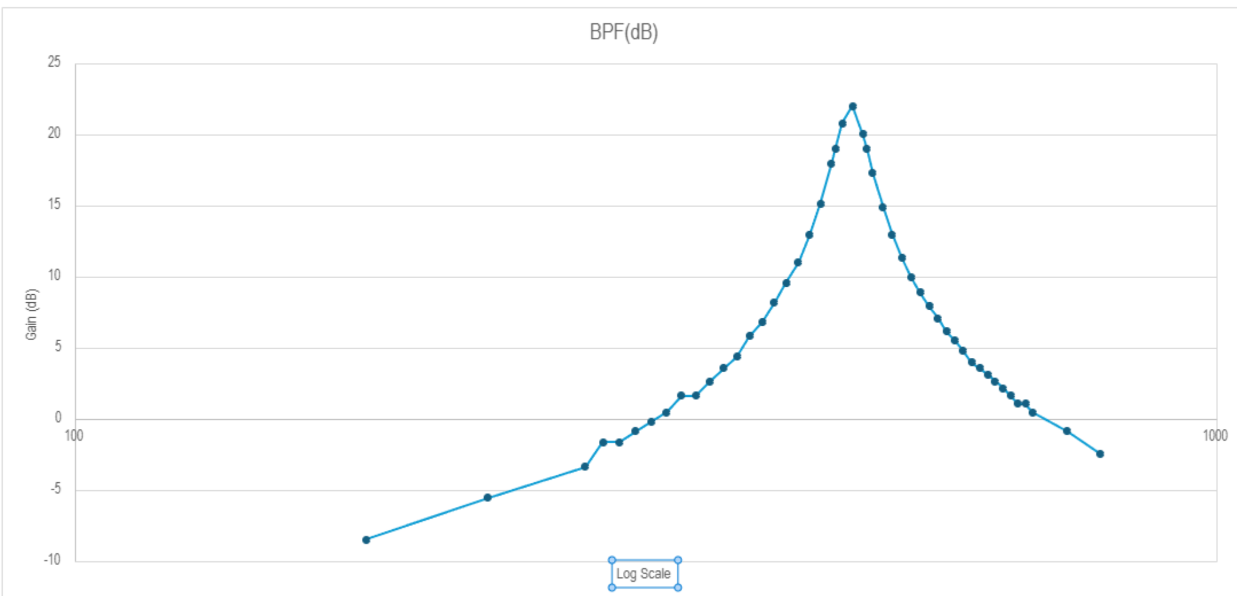
Figure 1 - Resonant Bandpass Filter Circuit Schematic

PART B Bandpass Filter

After successfully building the Resonant Bandpass filter circuit, the next step would be to test it, the way to check if the circuit is working as per the given filter specifications from Table 1 would be to compare the Q, Bandwidth (BW), and Peak Gain (Ao) from our circuit Bode plot to the filter specifications from Table 1 by making a Bode plot and taking multiple test points with our y-axis being the gain of the filter (Vout/Vin) and x-axis being the frequency at that specific point (Hz). By making multiple points, the Bode plot should look like the expected Bode plot for that Resonant Bandpass filter which looks like an upside-down parabola.

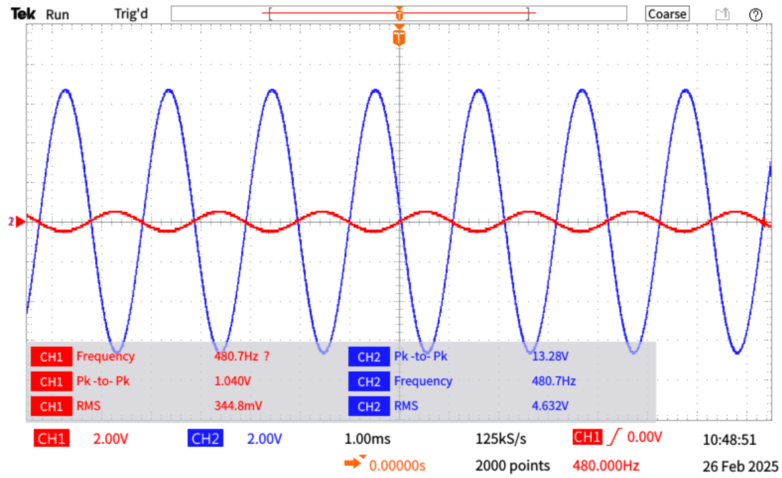


Bode Plot 1 - Bandpass Filter Bode Plot (Decimal)

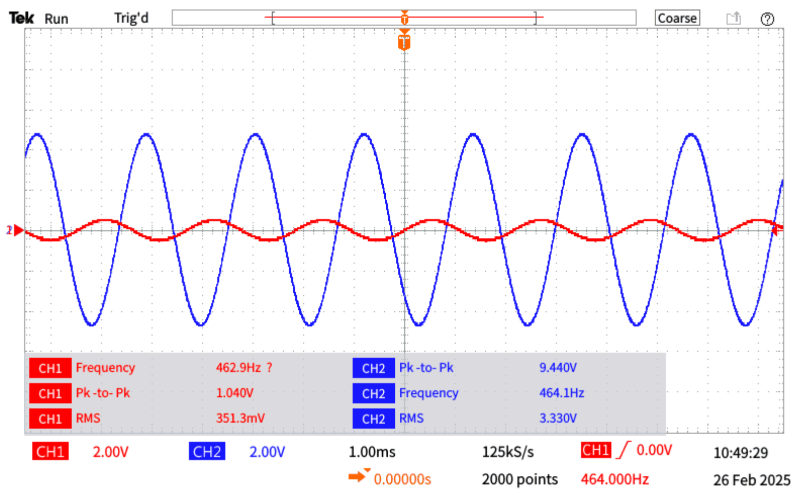


Bode Plot 2 - Bandpass Filter Bode Plot (Decibels)

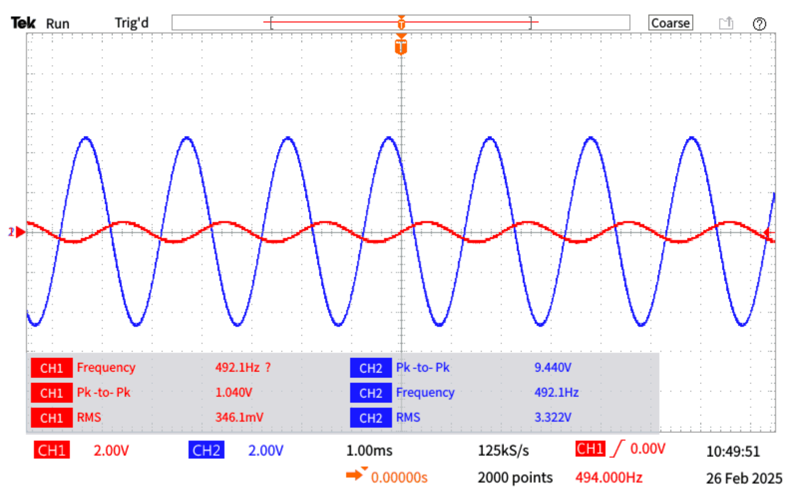
The main points to consider from our Bandpass filter Bode plot to verify that it's working correctly would be to check the center frequency which should be the frequency at which the peak gain is located, Q, and bandwidth (BW) by taking note of the 3 dB down point. Our center frequency from our created Bode plot would be 480 Hz which matches the Table 1 filter specifications center frequency of 480 Hz. The peak gain at that center frequency point of 480 Hz would be 12.6 V/V (Decimal) and 22 dB gain, which the 12.6 V/V is close to our required 15 V/V which was accepted by our instructor. For the bandwidth (BW) it can be calculated by getting the 3 dB down point from the peak gain (Ao) but since its in decimal not in decibels then the “3 dB down point” would be the peak gain divided by square root of 2 (Ao/sqrt(2)) which gives us a “3 dB down point” of 8.9 V/V; with that down point, two frequency points can be noted, one called fL and the other called fR with the right frequency being 494 and left frequency being 467. With fR and fL, the bandwidth (BW) can be calculated by getting the angular frequency of those two points and subtracting them, BW(Bode plot) = wR – wL = 494*2*pi – 467*2*pi = 169.64 rad/s and when comparing it to our actual bandwidth from the given specifications by doing the following BW(theoretical) = w0/Q = (3015 rad/s)/(18) = 167.5 rad/s and comparing the Bode plot bandwidth with the theoretical bandwidth we can see that it is very close with a percent error of 1.27 %. For the Q, it can be calculated from the Bode plot by using the following formula, Q = fc/(fR – fL) where fc is the center frequency, since we have all the values for fc, fR, and fL we can simply plug them in and find Q like so: Q = 480/(494 – 467) = 17.77 which comparing it to our given Q value of 18 we can observe that it’s really close with a percent error of 1.28 %. The following scope shots display the peak frequency fc, fL, and fR with each input voltage and output voltage at the ”3dB down point” for fL and fR:



Scope Shot 1 - fc Peak Frequency of Bandpass Filter



Scope Shot 2 - fL Left Frequency of Bandpass Filter



Scope Shot 3 - fR Right Frequency of Bandpass Filter

PART A Chebychev High Pass Filter

After building the Bandpass filter it was decided to build and test filter #1 which would be the Chebychev High Pass Filter (HPF). Just like the Bandpass filter, there are certain filter specifications that were given to us for the design process of the HPF; for project letter K, the filter specifications will be shown in the table below:

Filter #1				
Type	Characteristic (Ripple)	Order (n)	Cutoff (fo)	Passband Gain (Ap)
HPF	Chebychev 1 dB	5	403 Hz	22 V/V

Table 2 - Filter Specifications for Chebychev High Pass Filter (HPF) Filter#1

To design the Chebychev HPF, the given specs must be noted like the ripple = 1 dB, order (n) of the filter = 5, cutoff frequency (fo) = 403 Hz, passband gain (Ap) = 22 V/V, and angular frequency which is w0 = fo*2*pi = (403 Hz) *2*pi = 2532 rad/s. After noting down the important specs, the next step would be to note down what Chebychev polynomial is needed by going to the lab handout and looking for a 1 dB Ripple 5th order Chebychev polynomial Q equation which is the following: $Q_5(s) = s^5 + 0.937s^4 + 1.689s^3 + 0.974s^2 + 0.581s + 0.123 = (s + 0.289)(s^2 + 0.179s + 0.988)(s^2 + 0.468s + 0.429)$. To get the transfer function, finding K was needed to complete the transfer function; to solve for K, the following equation was used:

$$K = Ap * Q(s = 0)$$

$$K = (22)(0 + 0.289)(0^2 + 0.179(0) + 0.988)(0^2 + 0.468(0) + 0.429)$$

$$K = 2.69485$$

After successfully finding K, the general transfer function can be put together as H(s) = K/Q(s), after assembling the general transfer function the variable s will be replaced with s = w0/s = 2532/s for HPF only. Then after simplifying the general transfer function so that the coefficient of the highest order term in each factor is 1 then, similarly to the process of finding the resistances for the Bandpass filter, we'll compare coefficients of the general transfer function to the 1st or 2nd order transfer equations pertaining to those specific circuits. Since our Chebychev is in the 5th order, that means we'll need two 2nd order HPFs and one 1st order HPF and connect them together in series to achieve our desired 5th order Chebychev HPF. The equation and process to simplify the general transfer function and comparing coefficients to find appropriate resistances will be shown step by step below (NOTE: All capacitors are going to be 0.1 uF):

SIMPLIFY GENERAL TRANSFER EQUATION

$$H(s) = \frac{K}{Q(s)}$$

$$H(s) = \frac{2.69485}{(s + 0.289)(s^2 + 0.179s + 0.988)(s^2 + 0.468s + 0.429)}$$

$$H(s) = \frac{2.69485}{\left(\frac{2532}{s}+0.289\right)\left((\frac{2532}{s})^2+0.179\left(\frac{2532}{s}\right)+0.988\right)\left((\frac{2532}{s})^2+0.468(\frac{2532}{s})+0.429\right)}$$, Replace s = w0/s

$$H(s) = \frac{2.69485}{\left(\frac{2532}{s}+0.289\right)\left((\frac{2532}{s})^2+0.179\left(\frac{2532}{s}\right)+0.988\right)\left((\frac{2532}{s})^2+0.468(\frac{2532}{s})+0.429\right)} * \frac{s^5}{s*s^2*s^2}$$

$$H(s) = \frac{2.69485}{(0.289s+2532)(0.988s^2+453.228s+2532^2)(0.429s^2+1184.976s+2532^2)} * \frac{(\frac{1}{0.289}*\frac{1}{0.988}*\frac{1}{0.429})}{(\frac{1}{0.289}*\frac{1}{0.988}*\frac{1}{0.429})}$$

$$H(s) = \frac{21.99s^5}{(s + \frac{2532}{0.289})(s^2 + \frac{453.228}{0.988}s + \frac{2532^2}{0.988})(s^2 + \frac{1184.976}{0.429}s + \frac{2532^2}{0.429})}$$

SOLVE FOR ONE 2nd ORDER HPF RESISTANCES BY COMPARING COEFFICIENTS

$$H(s) = \frac{Ao * s^2}{s^2 + \frac{3 - Ao}{RC}s + \left(\frac{1}{RC}\right)^2}$$

$$\left(\frac{1}{RC}\right)^2 = \frac{2532^2}{0.429}$$

$$\left(\frac{1}{R(0.1\ uF)}\right)^2 = \frac{2532^2}{0.429}$$

R = 2587 Ω

$$\frac{3 - Ao1}{RC} = \frac{1184.976}{0.429}$$

$$\frac{3 - Ao1}{(2587)(0.1\ uF)} = \frac{11.84.978}{0.429}$$

$$Ao1 = 2.28542 \frac{V}{V}$$

FIND R1 & R2 USING GAIN EQUATION (Ao1)

$$Ao1 = 1 + \frac{R2}{R1}$$

$$2.28542 = 1 + \frac{R2}{R1}$$

Pick R1 = 10k Ω

$$R2 = 12850\ \Omega$$

SOLVE FOR THE OTHER 2nd ORDER HPF RESISTANCES BY COMPARING COEFFICIENTS

$$\left(\frac{1}{RC}\right)^2 = \frac{2532^2}{0.988}$$

$$\left(\frac{1}{R(0.1\,uF)}\right)^2 = \frac{2532^2}{0.988}$$

R = 3925

$$\frac{3 - Ao2}{RC} = \frac{453.228}{0.988}$$

$$\frac{3 - Ao2}{(3925)(0.1\,uF)} = \frac{453.228}{0.988}$$

$$Ao2 = 2.819947\frac{V}{V}$$

FIND R1 & R2 USING GAIN EQUATION (Ao2)

$$Ao2 = 1 + \frac{R2}{R1}$$

$$2.819947 = 1 + \frac{R2}{R1}$$

Pick R1 = 10k Ω

R2 = 18200 Ω

SOLVE FOR ONE 1st ORDER HPF RESISTANCES BY COMPARING COEFFICIENTS

$$H(s) = Ao * \frac{s}{s + \frac{1}{RC}}$$

$$\frac{1}{RC} = \frac{2532}{0.289}$$

$$\frac{1}{R(0.1\,uF)} = \frac{2532}{0.289}$$

R = 1141 Ω

FIND R1 & R2 USING GAIN EQUATION (Ao3)

$$Ao1 * Ao2 * Ao3 = 22\frac{V}{V}$$

$$(2.28542) * (3.41362) * Ao3 = 22\frac{V}{V}$$

$$Ao3 = 3.41362\frac{V}{V}$$

$$Ao = 1 + \frac{R2}{R1}$$

$$3.41362 = 1 + \frac{R2}{R1}$$

Pick R1 = 10k Ω

R2 = 24136 Ω

After successfully finding all the resistances, to implement it on the circuit, resistances had to be rounded to the nearest whole tenth, hundredth, etc. to grab resistor values close to the calculated ones and add some in series if necessary (no more than two resistors in series). There's no particular order but it was decided to put the 1st order HPF first then the other two 2nd order HPFs in series. The following circuit schematic displays how the circuit was implemented with the approximated resistor values for each HPF using the LM741 op amps:

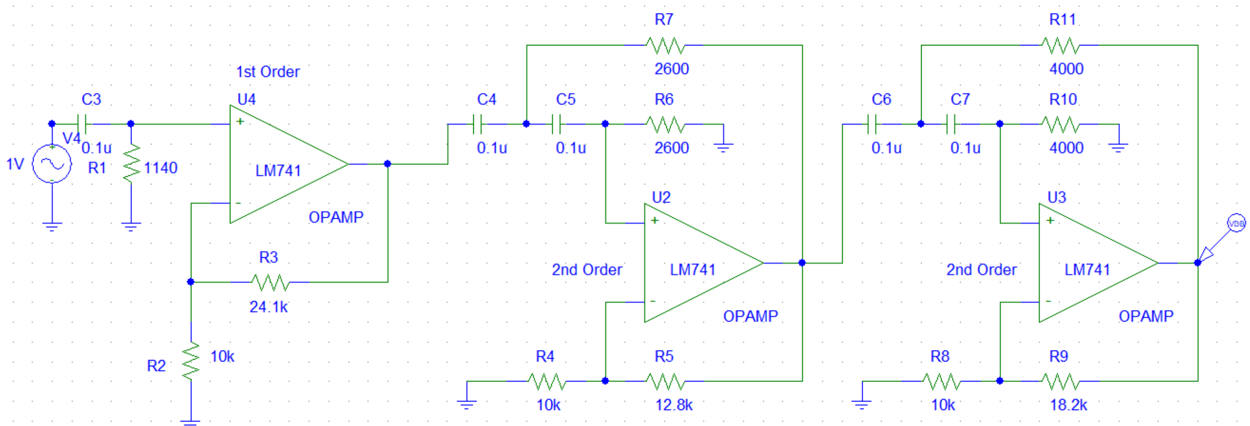
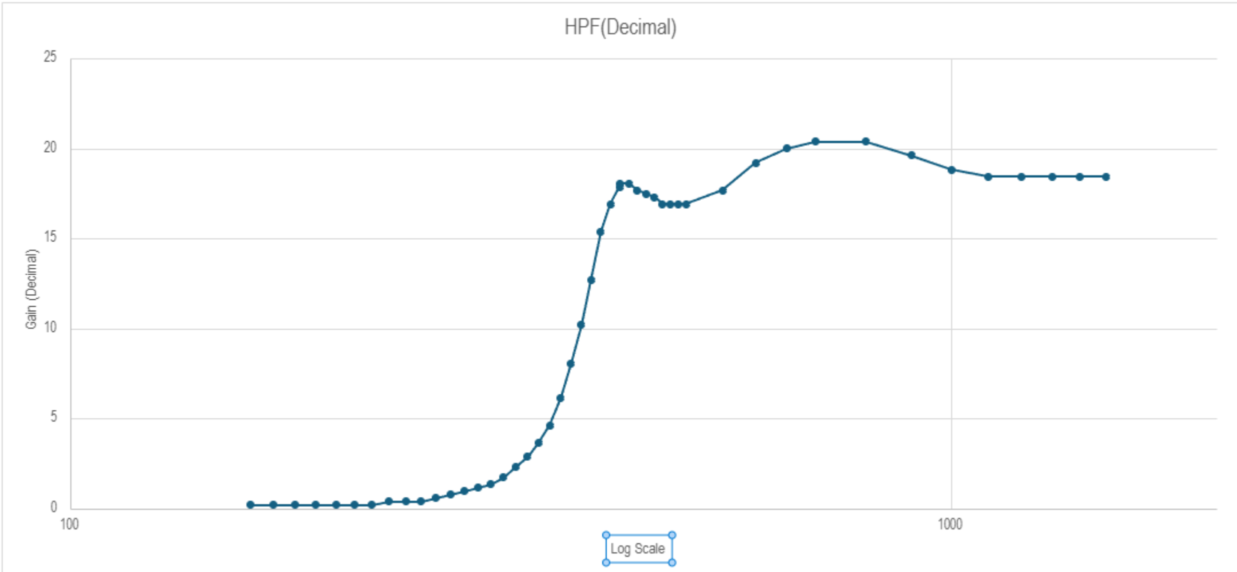


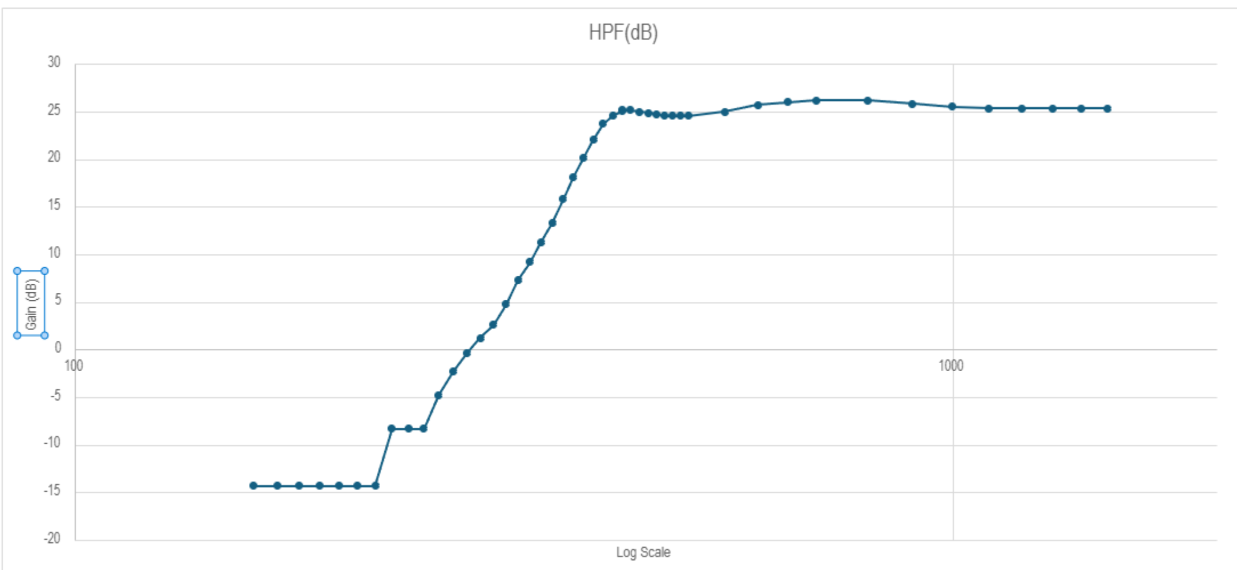
Figure 2 - Chebychev High Pass Filter Circuit Schematic

PART B Chebychev High Pass Filter

After successfully building the Chebychev HPF, the next step would be to test it thoroughly and to do that, the cutoff frequency as well as the passband gain had to be observed by creating a Bode plot and compare observed data to the given cutoff frequency and passband gain. To create the Bode plot, a plethora of test points had to be taken with our y-axis being the gain of the filter (Vout/Vin) and x-axis being the frequency at that specific point (Hz). The final Bode plot graph should look like the expected one with no gain at low frequencies and gain at higher frequencies with a 1 dB ripple after it reaches max gain. The following Bode plot displays how the Chebychev 1 dB Ripple 5th order HPF behaves from low frequencies to higher frequencies:



Bode Plot 3 – Chebychev HPF Bode Plot (Decimal)



Bode Plot 4 - Chebychev HPF Bode Plot (dB)

The main points of interest when verifying that the Chebychev HPF is working would be by verifying that there is indeed a 1 dB Ripple, the specified cutoff frequency, and the passband gain. To check for the ripple, the following equation must be used:

$$Ripple = Peak\ gain\ in\ dB - lowest\ peak\ of\ the\ ripple\ in\ dB$$

Or

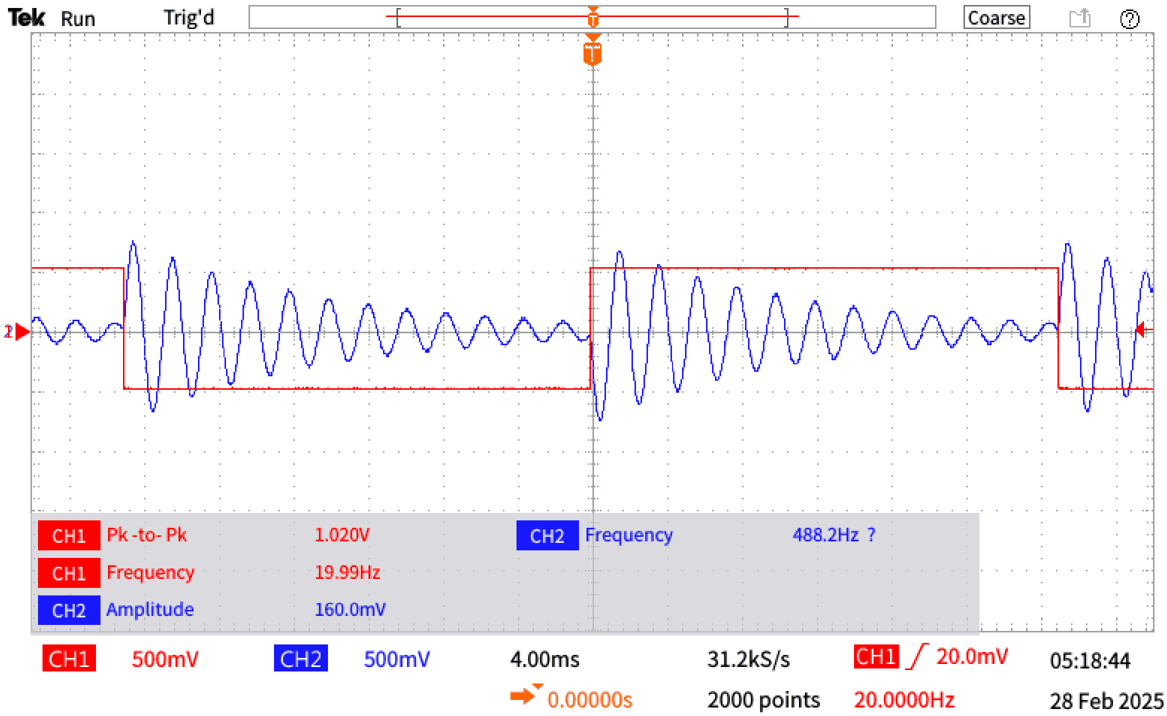
$$Ripple = 20\log(peak\ gain\ decimal) - 20\log\ (lowest\ peak\ of\ ripple\ gain\ in\ decimal)$$

$$Ripple = 20\log(18.07) - 20\log(16.92) = 1.31\ dB$$

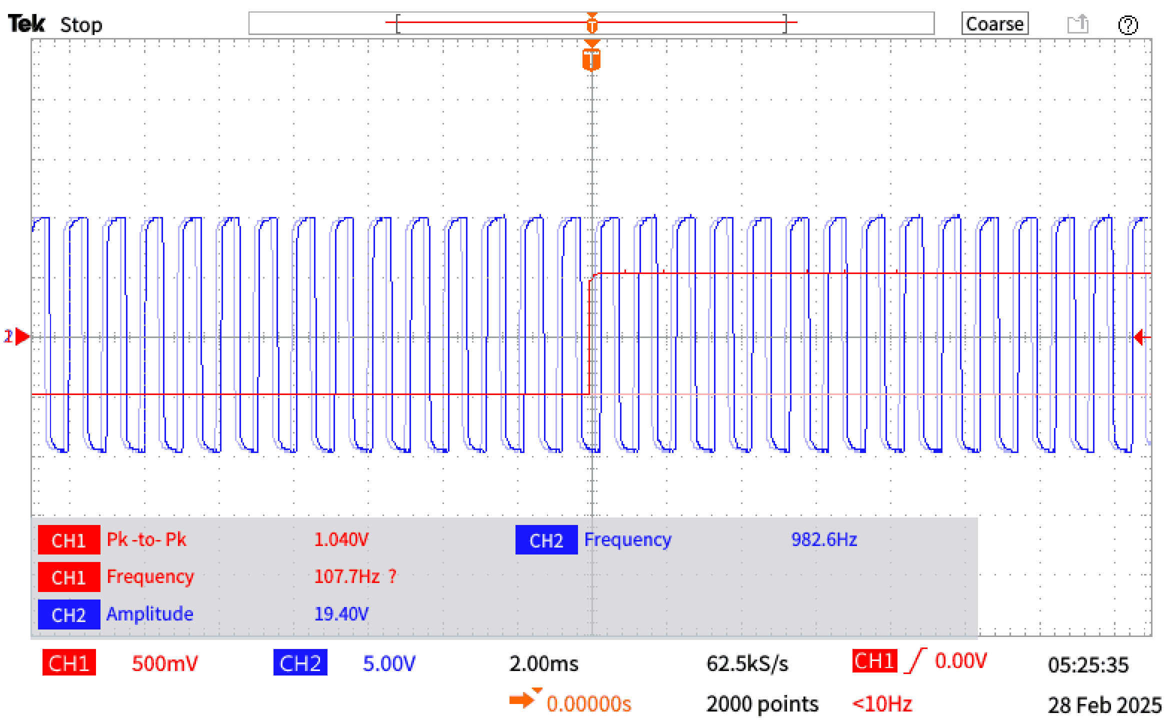
As seen above, the calculated ripple from the Bode plot is 1.31 dB when the specified ripple is of 1 dB which is close with a percent error of 31 %. For the cutoff frequency, the way to check for that would be to first check what constant gain you get at really high frequencies which was noted to be 19.2 V/V, then the frequency will be swept from high to low until the gain reaches around the 19.2 V/V stable gain again before it dies down from the low frequencies which was noted to be around 421 Hz when the gain reached around 18.8 V/V. When comparing the observed cutoff frequency of 421 Hz to the given cutoff frequency of 403 Hz, it can be said that it is close with a percentage error of 4.46 %. To check for the passband gain, the constant gain at higher frequencies must be noted and compared to the given passband gain, the observed constant gain at higher frequencies was 19.2V/V and compared to the given passband gain of 22 V/V there's an error of 12.7 % which was accepted by the instructor.

STEP RESPONSES

To display and record the step response for each circuit on the oscilloscope would be by using a square wave as the input frequency with the function generator to approximate the unit step. The following recorded step responses for the Bandpass and Chebychev HPF will be displayed below (NOTE: There were some technical difficulties on checking the step response for the HPF but was still approved by the instructor):



Scope Shot 4 - Recorded Step Response for Bandpass Filter



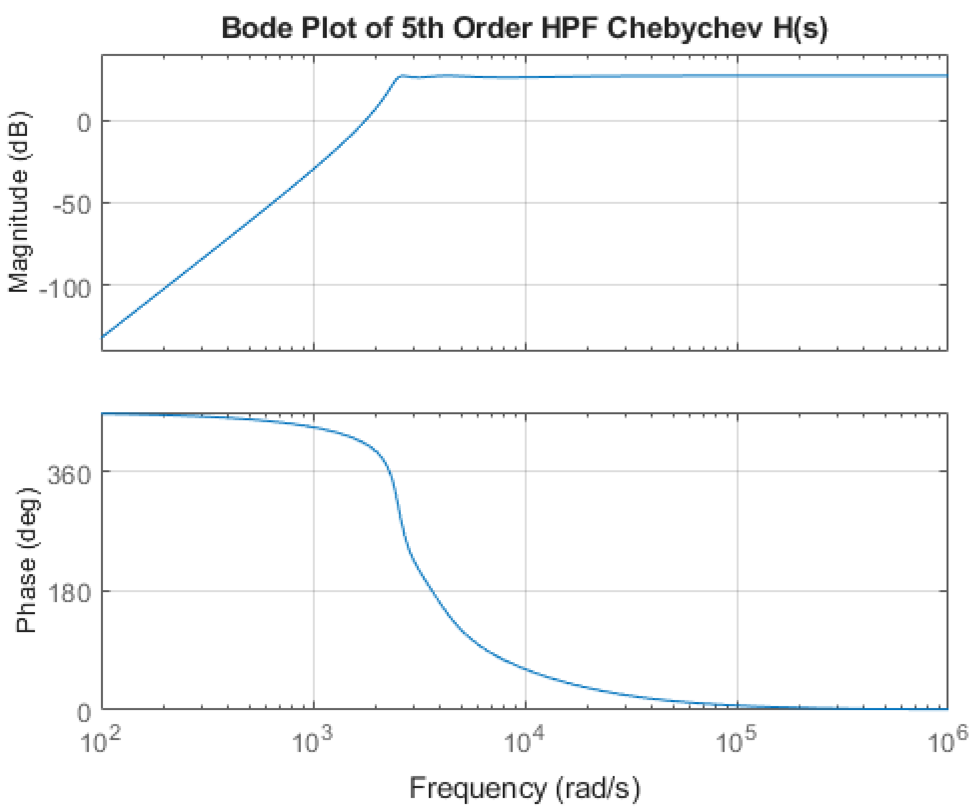
Scope Shot 5 - Recorded Step Response for Chebychev High Pass Filter

AFTER THE LAB

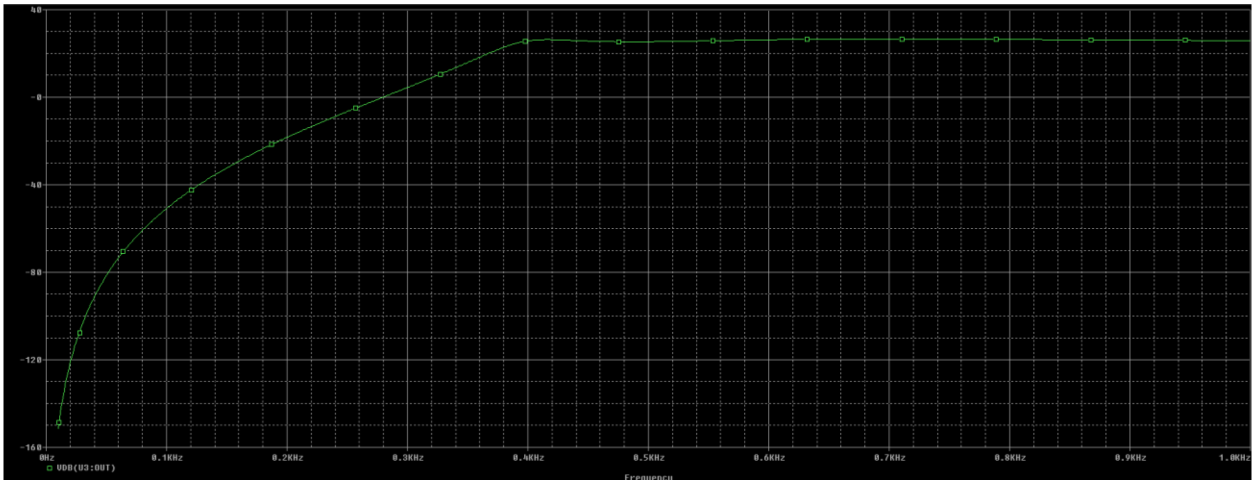
CHEBYCHEV COMPARISON OF FREQUENCY RESPONSE

The following figures will display the bode plots for the 5th Order Chebychev HPF and the Bandpass Filter separately which will be compared to the created bode plot as well as the PSPICE simulation.

First, we'll compare all three Chebychev bode plots, the Chebychev bode plots will be displayed for the PSPICE simulation, MATLAB simulation, and created bode plot in excel which was already displayed above as "Bode Plot 4" since all three are in decibel.



Bode Plot 5 – MATLAB Bode Plot for 5th Order Chebychev HPF in Decibel

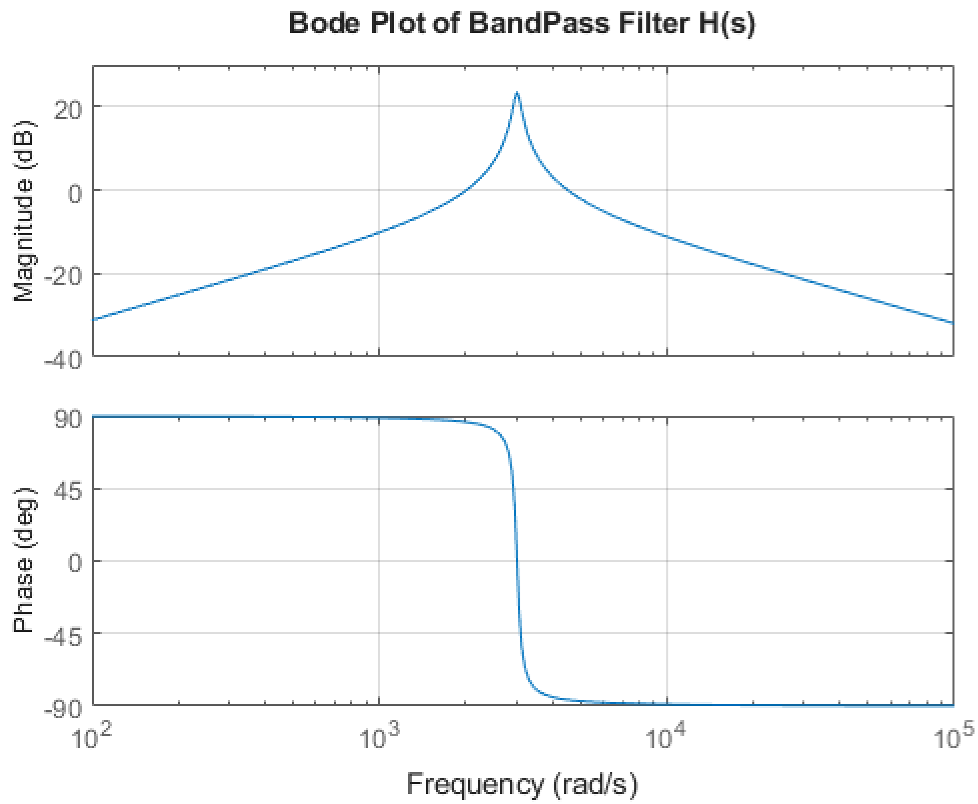


Bode Plot 6 - PSPICE Bode Plot for 5th Order Chebychev HPF in Decibel

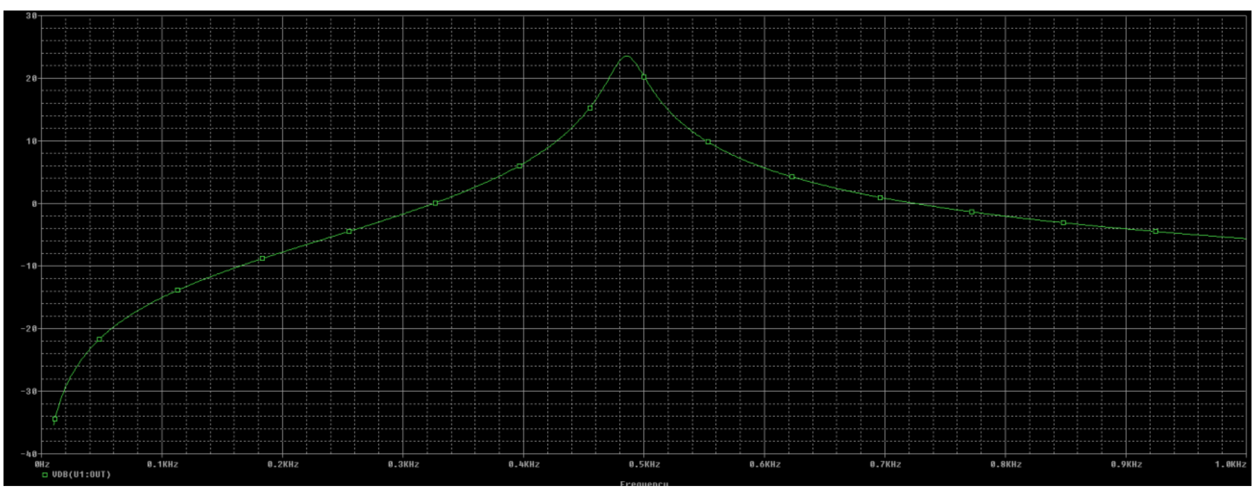
By comparing Bode Plot 4, 5, and 6 it can be observed that they all match what they are supposed to look like. More specifically, the excel created Bode Plot 4 in decibel matches the expected bode plots from the MATLAB Bode Plot 5 and the PSPICE Bode Plot 6 which means that it's correct. Also, the reason why the MATLAB Bode Plot 5 doesn't curve as it increases to its steady output but instead is a straight line as it reaches its higher frequency steady output would be because MATLAB doesn't take component values into consideration like capacitors, resistances, or MOSFET specifications.

BANDPASS COMPARISON OF FREQUENCY RESPONSE

After comparing the bode plots for the Chebychev HPF, the next step would be to compare the bode plots for the Bandpass filter. Similarly to how the comparison process was performed previously for the Chebychev HPF, the same comparison process will be performed on the Bandpass filter by comparing the following three bode plots: created excel bandpass bode plot, MATLAB bandpass bode plot, and PSPICE bandpass bode plot.



Bode Plot 7 - MATLAB Bode Plot for Bandpass Filter in Decibel



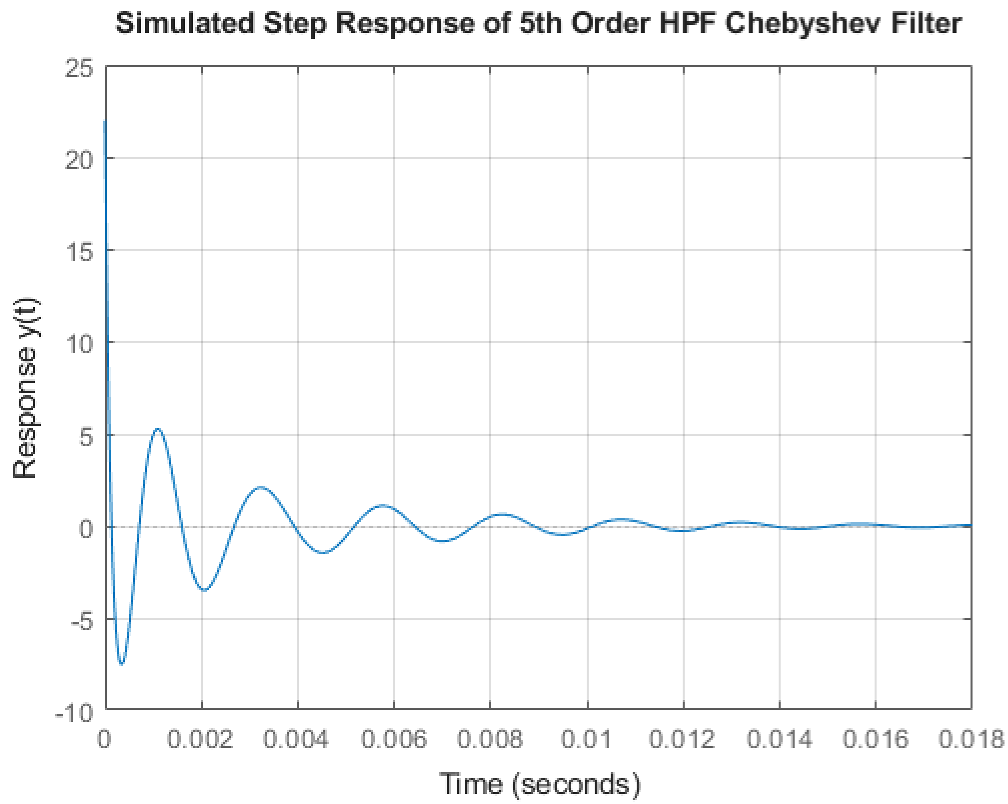
Bode Plot 8 - PSPICE Bode Plot for Bandpass Filter in Decibel

By comparing all three Bode plots, the created excel Bode Plot from the implemented circuit named Bode Plot 2, the MATLAB Bode Plot 7, and PSPICE Bode Plot 8, it can be observed that they all match on how they’re supposed to look like. To be more specific, the excel created Bode Plot 2 matches the simulated and expected bode plots displayed on the PSPICE simulation and MATLAB simulation confirming that the circuit was implemented/designed correctly.

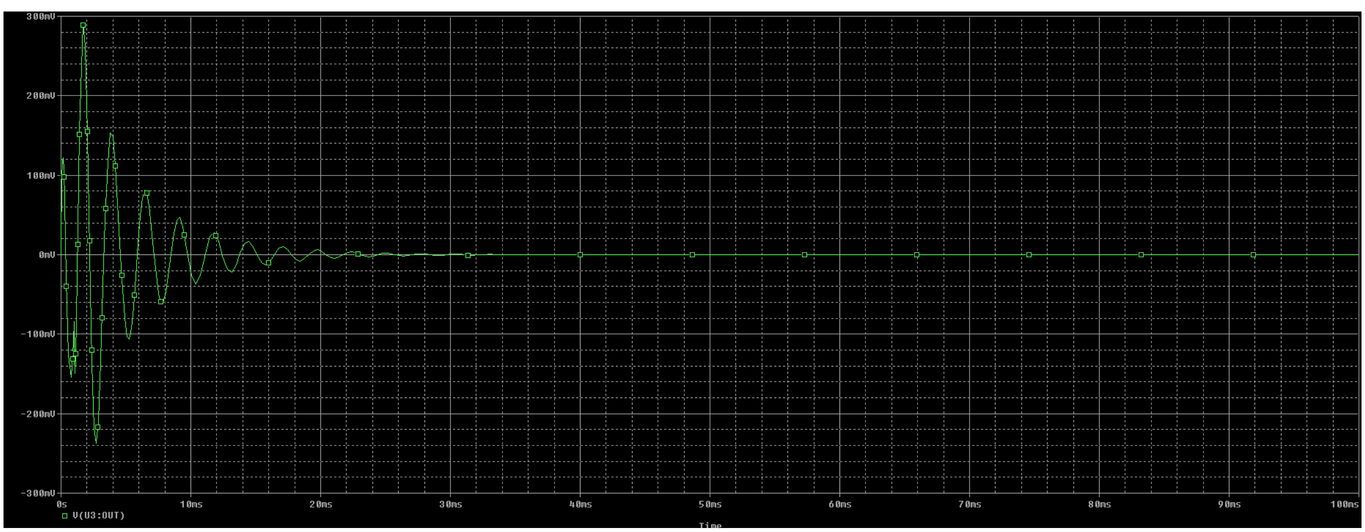
CHEBYCHEV COMPARISON OF STEP RESPONSE

For this portion of the AFTER THE LAB, the oscilloscope, MATLAB, and PSPICE step response plots will be compared for accuracy and to check if the design process was correct for both Chebychev and Bandpass.

First, the implemented circuit step response using the oscilloscope to take a scope shot will be compared with the MATLAB and PSPICE step responses which the MATLAB/PSPICE step response plots will be displayed below since the scope shot is already shown "IN THE LAB" as Scope Shot 5.



Scope Shot 6 - MATLAB Step Response for 5th Order Chebychev HPF

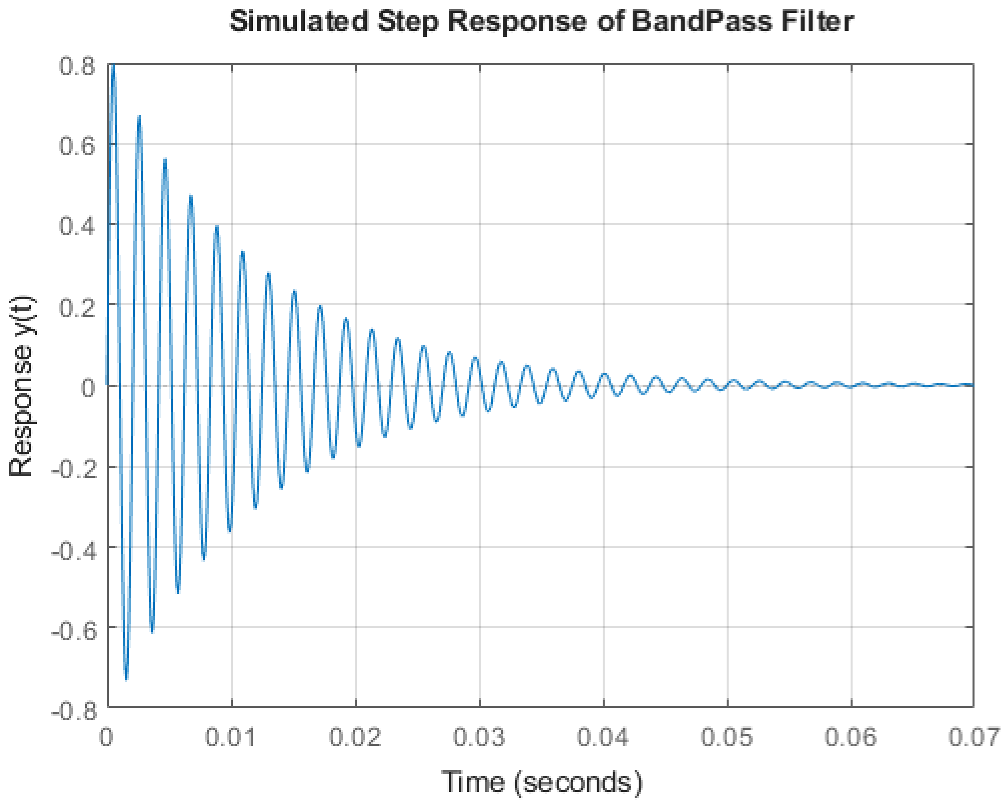


Scope Shot 7 - PSPICE Step Response for 5th Order Chebychev HPF

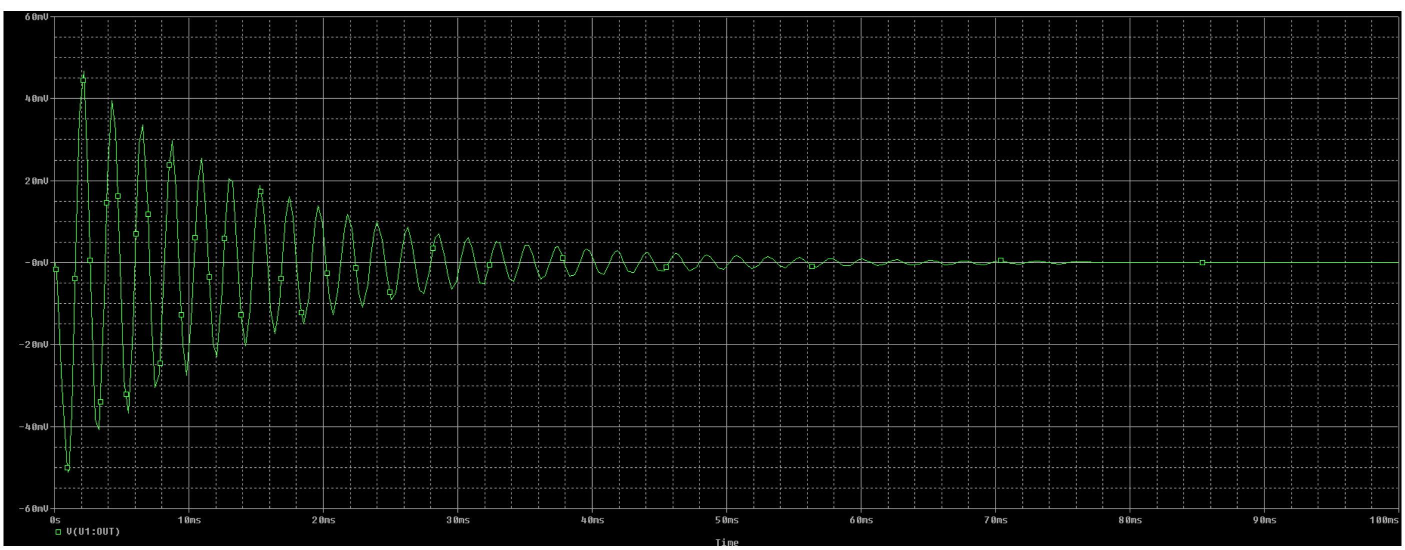
Comparing all three Step responses, it can be observed that the MATLAB step response and PSPICE step response match but not the scope shot of the implemented circuit. The reason why that might be is that in order to get a good step response scope shot of a high order circuit like the chebychev, the function generator square wave input frequency has to be extremely low for it to be displayed on the oscilloscope; as a result, it never displayed for us correctly most likely due to either the extremely low frequency or wiring/components. The implemented circuit worked as expected and got approved by the instructor so the process of achieving the step response on the oscilloscope using the function generator was probably wrong.

BANDPASS COMPARISON OF STEP RESPONSE

Similarly to how the comparison process was performed previously with the Chebychev HPF, the same process will be performed to verify that the Bandpass filter circuit was designed/implemented correctly by comparing the step response scope shot taken of the implemented circuit displayed "IN THE LAB" as Scope Shot 4, the MATLAB simulated Bandpass step response, and the PSPICE simulated Bandpass step response.



Scope Shot 8 - MATLAB Step Response for Bandpass Filter



Scope Shot 9 - PSPICE Step Response for Bandpass Filter

By comparing all three step response plots, it can be observed that all three plots match what the step response should look like. To be more specific, the scope shot step response matches the expected MATLAB/PSPICE simulated step responses meaning that the design/implemented process was performed correctly. The reason why the MATLAB step response has a greater amplitude at the beginning and stabilizes smoothly would be because the MATLAB program doesn't take into consideration component values, function generator frequency/amplitude, resistances, etc. therefore making it look slightly different but still correct in the end.

III. SUMMARY OF RESULTS

The table below summarizes the key measurements collected for **Project K**, specifically for the two filters (Filter #1: 5th-order Chebyshev HPF; Filter #2: 2nd-order resonant bandpass).

Filter	Specification	Measured Result
Bandpass	Center Frequency: 480 Hz	480 Hz
	Quality Factor: 18	17.77
	Peak Gain: 15 V/V	12.6 V/V
Chebyshev High-Pass	Cutoff Frequency: 403 Hz	421 Hz
	Passband Gain: 22 V/V	19.2 V/V
	Passband Ripple: ~1 dB	1.31 dB

IV. CONCLUSION

Both filters outlined in **Project K** were successfully implemented following standard design procedures for active op amp circuits. As detailed in the lab body:

1. **Resonant Bandpass Filter**
   The second-order bandpass filter was built first due to its simpler structure, relying on a resonant transfer function. From the theoretical standpoint, key parameters included the center frequency of 480 Hz, a quality factor of 18 (indicating a relatively narrow bandwidth), and a peak gain of 15 V/V. By choosing $\omega_0 = 2\pi \times 480$ rad/s and fixing the capacitors to 0.1 µF, the appropriate resistor values were derived by comparing coefficients in the standard second-order resonant bandpass equation. Laboratory measurements verified that the filter gain indeed peaked near 480 Hz, with a measured bandwidth consistent with the expected $\frac{\omega_0}{Q}$. The step response further revealed a characteristic damped sinusoidal behavior at the center frequency, validating the design's resonant nature.

2. **Chebyshev High-Pass Filter**
   The fifth-order, 1 dB ripple Chebyshev HPF, specified at 403 Hz with a passband gain of 22 V/V, required cascading three stages: two second-order high-pass sections plus one first-order high-pass section. The Chebyshev polynomial (order 5, ripple 1 dB) dictated the necessary pole locations, and each stage's component values were determined by matching the polynomial's coefficients to the canonical high-pass filter forms. Laboratory tests showed negligible gain at low frequencies, rapid attenuation near and below 403 Hz, and a well-defined passband region above 403 Hz where the filter's gain approached 22 V/V. Small discrepancies in ripple magnitude were attributed to resistor and capacitor tolerance, as well as op amp bandwidth limitations.

Interpreting the results confirmed that the theoretical transfer functions provided an excellent blueprint for constructing real-world filters. Simulations closely mirrored actual performance, and final measured outcomes—in both the frequency domain (Bode plots) and time domain (step response)—largely matched the projected targets. Key lessons learned included:

- **Hierarchy of Filter Stages**: Higher-order filter requirements are typically met by cascading lower-order building blocks.

- **Polynomial Selection**: Employing a Chebyshev approach provides a faster roll-off at the expense of passband ripple; resonant designs yield narrowband or peaked responses.

- **Practical Tolerances**: Real components and op amps impose minor deviations, underlining the value of iterative testing and minor design adjustments.

- **Verification Techniques**: Frequency sweeps highlight exact passband, cutoff, and center frequency data, while step response measurements emphasize transient and damping characteristics.

Overall, the experiment demonstrated the utility of theoretical design formulas, polynomial approximations, and systematic laboratory verification. By applying these methods, it was possible to realize two distinctly different active filters—one resonant and one Chebyshev—both of which satisfied the specified frequency-domain and gain requirements. Such experiences reinforce the importance of combining theory, simulation, and hands-on testing in developing reliable analog filter solutions.

University of Texas – Rio Grande Valley
EECE 3225 / EECE 3230
LAB DEMONSTRATION CERTIFICATION

++

This section to be filled in by project team

Course EECE 3230 Project Filters & Transfer Function

Team Members :

1. Emilio Chavez
2. Jordan
3.

Describe what is being demonstrated:

Bandpass Project K

++

This section to be filled in by instructor

Signature: Date: Time:

Comments:

$f_c = 480Hz$

$f_L = 463$

$f_H = 493$

$$Q = \frac{480}{493 - 463} = \frac{480}{30} = 16$$

If an instructor is not available at demo time, this form can be signed by an EE faculty, teaching assistant, or lab technician. Tape or paste this certification in the lab notebook.

NOTE: The reason why Q,Gain, f0 values are slightly different is because the demo was performed using another station with not so good oscilloscope/function generator.

University of Texas – Rio Grande Valley

EECE 3225 / EECE 3230

LAB DEMONSTRATION CERTIFICATION

++

This section to be filled in by project team

Course EECE 3230 Project Filters & Transfer Functions

Team Members :

1. Emilio Chavez
2. Jordan
3.

Describe what is being demonstrated:

HPF Project K Bode Plot + circuit

CC

++

This section to be filled in by instructor

Signature: Date: Time:

Comments:

Gain = 18 V/V

f_0 = 410Hz

If an instructor is not available at demo time, this form can be signed by an EE faculty, teaching assistant, or lab technician. Tape or paste this certification in the lab notebook.