Signals Systems and Transforms
EEET-332
Lab 6

A quiz will be given at the beginning (first 10 minutes) of the lab, covering the content of the prelab. One quiz will be dropped. NO make-up quizzes.

Prelab:

1. Find the order “n” of a Butterworth low-pass filter whose gain ($|H|^2$) is down by 10 dB (-10 dB) at f=1.5f_{co} (also ω=1.5ω_{co} since $\omega = 2\pi f$). Hint: using the equation for $|H|^2$ below, solve for n showing it must be at least three (when rounded up).

$$|H|^2 = \frac{1}{1 + (\frac{\omega}{\omega_{CO}})^{2n}}$$

2. Find the value (dB) of the gain ($|H|^2$) at f=2f_{co} for the above third-order Butterworth low-pass filter.

Signals Systems and Transforms
EEET-332
Lab 6

Section 1: Filter Design (building a 3rd order Chebyshev filter)

Compared to a Butterworth filter, a Chebyshev type 1 filter trades off flatness in the passband for a higher initial rate of attenuation in the stopband. Both a 3rd order Butterworth and 3rd order Chebyshev will meet the design requirement from the prelab section. We will use the 3rd order Chebyshev.

1) In the MATLAB Command Window, type [B,A] = cheby1(3,0.5,1,'s') to request the coefficients of a 3rd order type 1 Chebyshev filter with 0.5dB ripple in the passband.
2) Finish the table and equation below and **get a sign-off.**

	s^3 coefficient	s^2 coefficient	s coefficient	constant coefficient
B	0	0	0	0.7157
A		1.2529		0.7157

$$H = \frac{V_0}{V_G} = \left(\frac{0.7157}{s^3 + 1.2529s^2 + \_\_\_\_\_\_\_\_ s + 0.7157}\right)$$

Section 2: Verify the design (Bode Plot)

1) Create a Lab6.mlx live script
2) Create a Bode Plot for the following transfer function by modifying the example script below. Set proper x and y limits, or you can initially remove them to get a plot with defaults limits.

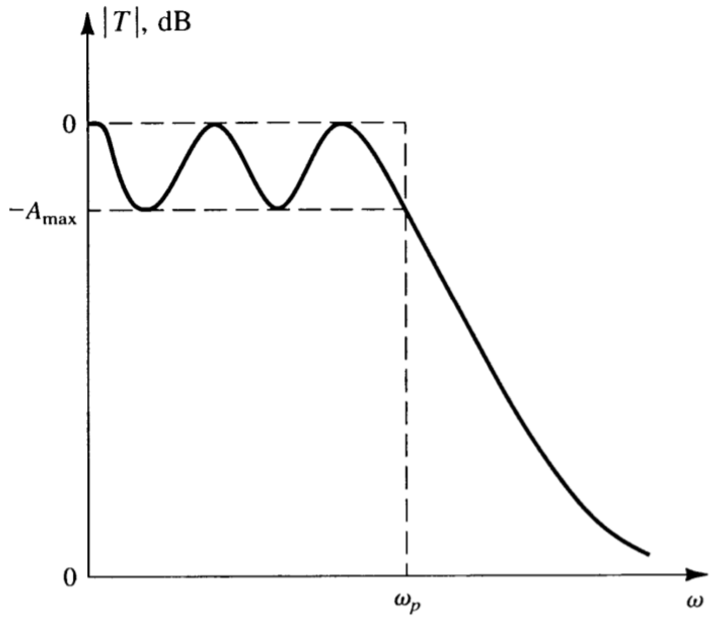
$$H = \frac{V_0}{V_G} = \left(\frac{1.1424}{s^2 + 0.6265s + 1.1424}\right)\left(\frac{0.6265}{s + 0.6265}\right)$$

This Chebyshev filter is slightly better in the stopband than the third order Butterworth. The gain of the filter will easily go under 10 dB at $\omega = 1.5\omega_{co}$.

Bode plot example

```
syms s
H = simplifyFraction(4*(s+0.5)/s);
[symNum,symDen] = numden(H);
opts = bodeoptions; opts.Grid = 'on';
opts.PhaseVisible = 'off';
% opts.FreqUnits ='Hz'
opts.xlim = [0.01 100]; opts.ylim = {[0 50], [-90 0]};
bode(sym2poly(symNum),sym2poly(symDen),opts);
```

Signals Systems and Transforms
EEET-332
Lab 6



Shown for reference is a fifth-order Chebyshev low pass filter with |T| instead of |H|. **It is not the third-order** filter used in this section.

Starting at zero, a 5th-order Chebyshev alternates between the maximum ripple ($-A_{MAX}$) and zero five times - low-high-low-high-low. Our third order does it three times.

The break is at $-A_{MAX}$.

3) Identify the value of the filter at the break ω_{co} and $1.5\omega_{co}$. Verify that is 10dB below the passband at $1.5\omega_{co}$. Remember the plot is in rad/s, not Hz. Click the “Data Cursor” button on the magnitude plot and then click the curve to add data values.

Show the Bode plot with ω_{co} and $1.5\omega_{co}$ identified for a sign-off.

Signals Systems and Transforms
EEET-332
Lab 6

Section 3: Make it real – shift the break frequency from 1 rad/sec to 10KHz.

1) Change H for the third-order Chebyshev low-pass filter to have a cutoff frequency of 10 kHz. The transfer function below uses the prototype variable "p" just like in the book. To shift the break frequency, substitute p with s/(2π10*10^3) and then use algebra to put H in the standard form by filling in the blanks below.

$$H = \frac{V_0}{V_G} = \left(\frac{1.1424}{p^2 + 0.6265p + 1.1424}\right)\left(\frac{0.6265}{p + 0.6265}\right)$$

$$at\ 10KHz$$

$$H_{10K\_LP} = \left(\frac{4.51x10^9}{s^2 + \_\_\_\_\_\_\_\_\_ s + \_\_\_\_\_\_\_\_\_}\right)\left(\frac{39.364x10^3}{s + \_\_\_\_\_\_\_\_\_}\right)$$

2) Make a Bode plot of the new filter with the 10 kHz break frequency. You have to change the xlim and ylim ranges. You can use the commented bode command to remove the bodeoptions allowing plotting to use default values to help you find xlim and ylim. Set the frequency units to 'Hz'.

3) Identify the value on the plot where f = 15 kHz and verify that is 10dB below the passband.

Show the Bode plot with 15 kHz identified for a sign-off.

Signals Systems and Transforms
EEET-332
Lab 6

Section 4: Create a high pass filter with a break frequency at 10KHz.

1) Change H for the third-order Chebyshev (0.5dB ripple) low-pass filter to a high pass with a cutoff frequency of 10 kHz. The transfer function below uses the prototype variable “p” just like in the book. To shift the break frequency and create a high pass filter, substitute p with (2π10*10^3)/s and then use algebra to put H in the standard form by filling in the blanks below.

$$H = \frac{V_0}{V_G} = \left(\frac{1.1424}{p^2 + 0.6265p + 1.1424}\right)\left(\frac{0.6265}{p + 0.6265}\right)$$

$$at\ 10KHz$$

$$H_{10K\_HP} = \left(\frac{s^2}{s^2 + \_\_\_\_\_\_\_\_\_\_ s + \_\_\_\_\_\_\_\_\_\_}\right)\left(\frac{s}{s + \_\_\_\_\_\_\_\_\_\_}\right)$$

2) Make a Bode plot of the new filter with the 10 kHz break frequency. The break for a Chebyshev filter is on the rising edge at the ripple value. In this case, 0.5 dB down.

Submit a screenshot of the code, and the Bode plot, with the break frequency identified, in your report.

Signals Systems and Transforms
EEET-332
Lab 6

Report:
Create your cover page.
Submit your cover page, the requested screenshots from section 4, and this sign-off sheet.

Sign-offs

Name ______________________

Section 1: Filter design

	/ /
Signature	Date

Section 2: ω_{co} and $1.5\omega_{co}$

	/ /
Signature	Date

Section 3: 15 kHz

	/ /
Signature	Date