Physics 116A Notes

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Draft v.0.95

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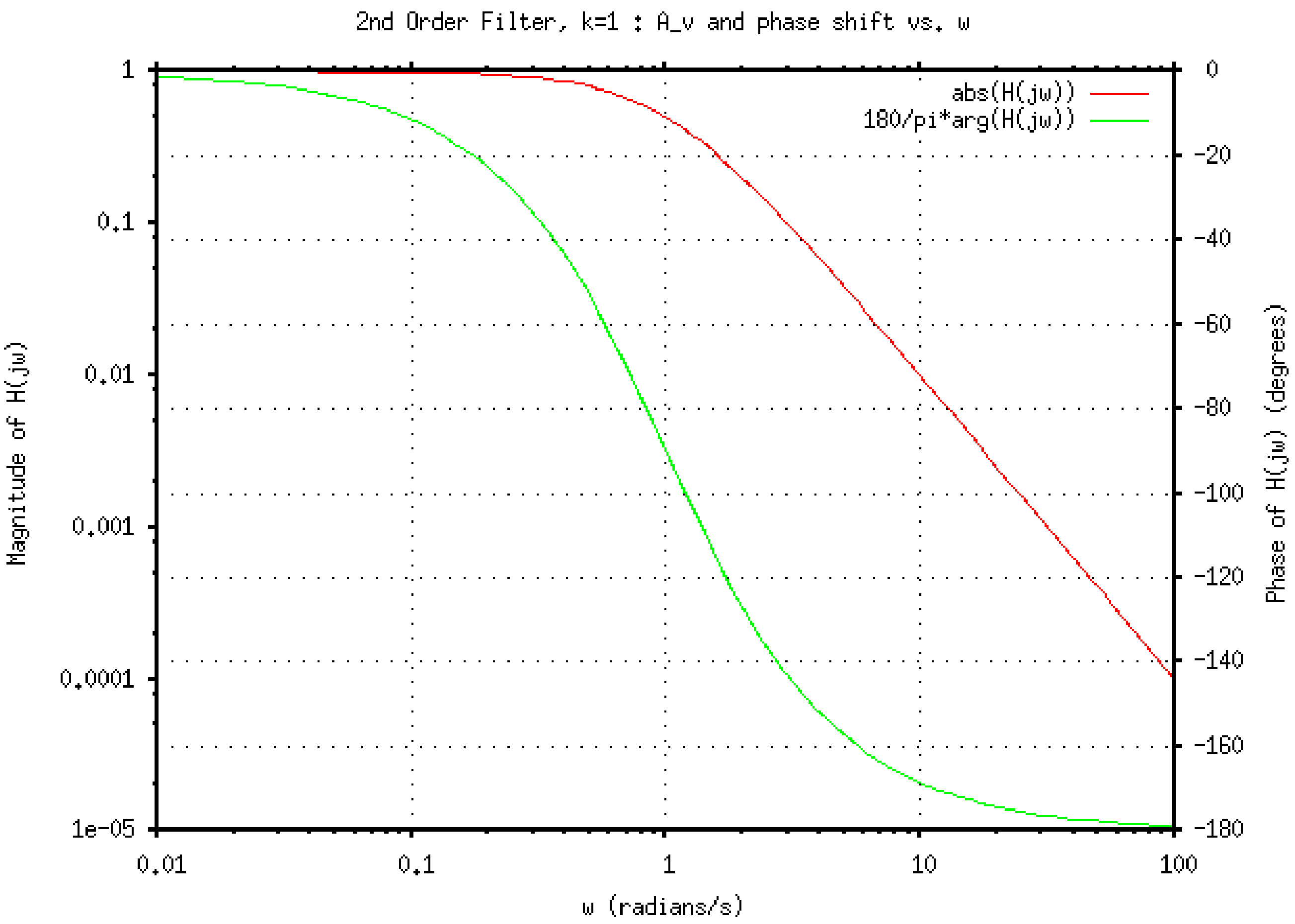
- References:
  - Text for course:
    Fundamentals of Electrical Engineering, second edition, by Leonard S. Bobrow, published by Oxford University Press (1996)
  - Others as noted

Outline

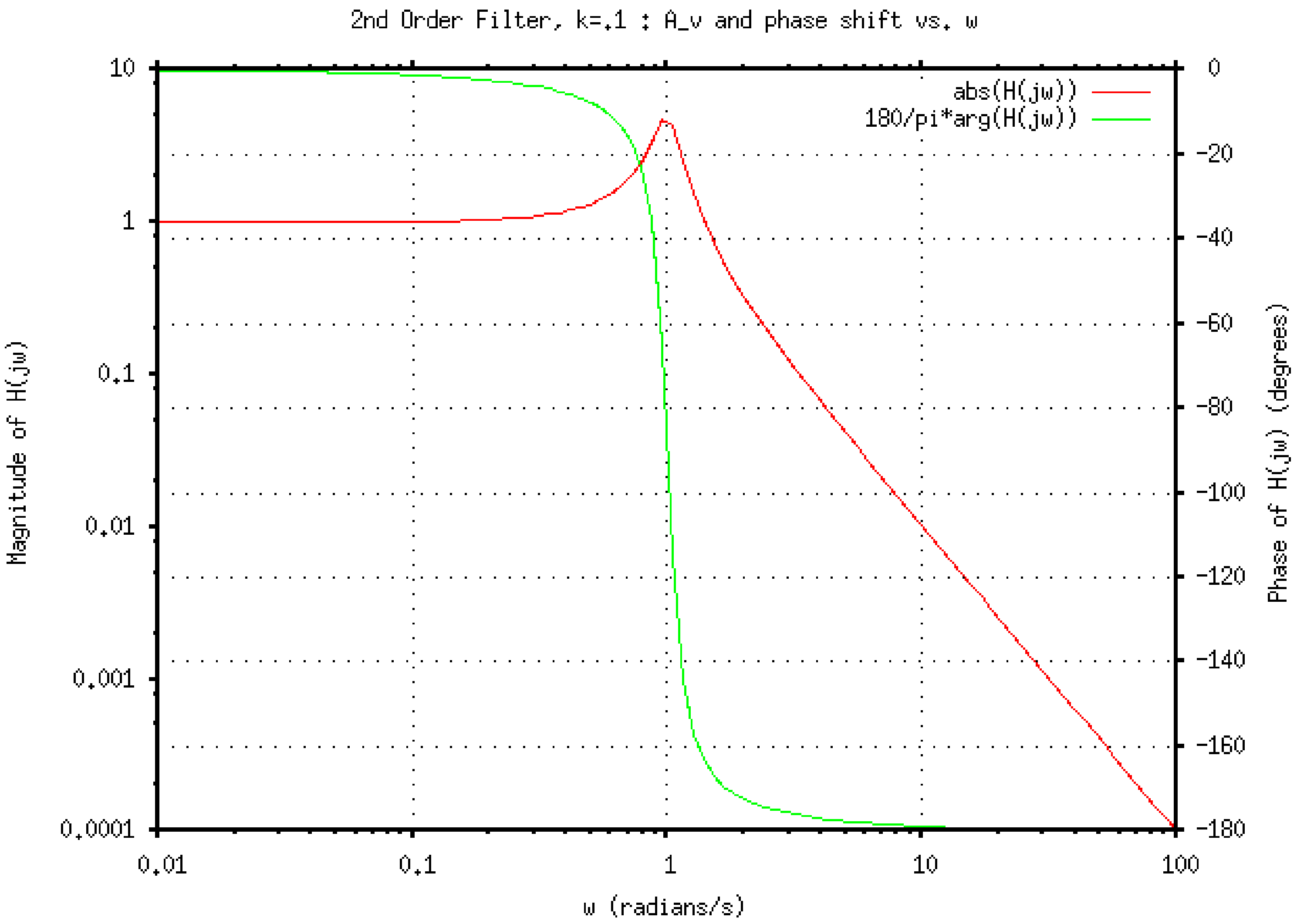
- Primitive radio transmitters based on LC circuits
  - early instant messaging ;-)
- **H(s)** and Bode plots again
- Active filters: Butterworth and friends
  - At audio frequencies, can be implemented with Op-Amps
- Connection of **H(s)** with Laplace transforms

2nd Order k=1 LP Filter Bode Plot



Damping factor k: 2k=(coefficient of s) in quadratic expression

2nd Order k=.1 LP Filter Bode Plot



Butterworth Polynomials

In general, $H(s) = \frac{A(s)}{B(s)}$. For Butterworth filters, $B(s)$ is given below:

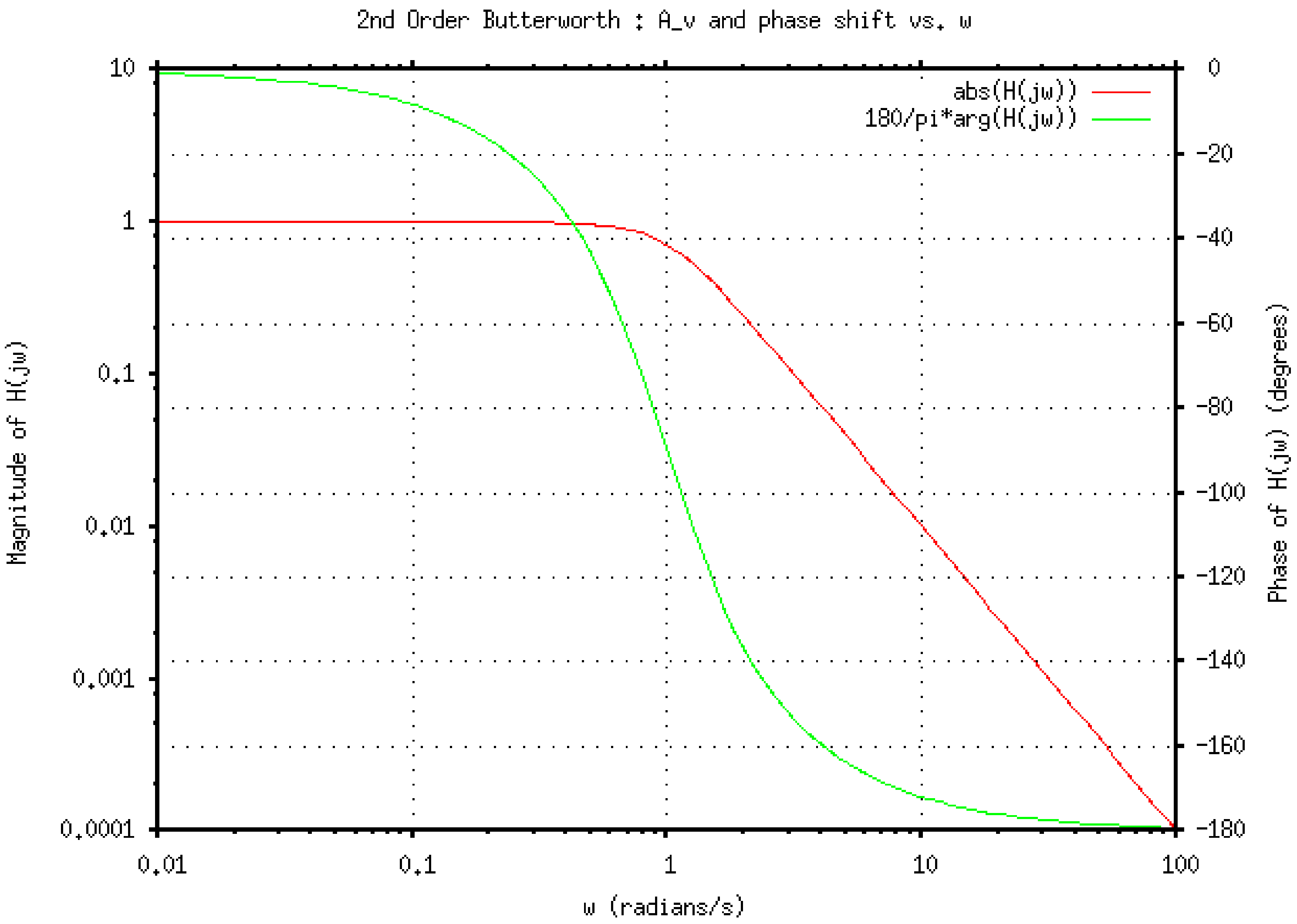
Table 16-1 Normalized Butterworth polynomials

n	Factors of polynomial $B_n(s)$
1	$(s + 1)$
2	$(s^2 + 1.414s + 1)$
3	$(s + 1)(s^2 + s + 1)$
4	$(s^2 + 0.765s + 1)(s^2 + 1.848s + 1)$
5	$(s + 1)(s^2 + 0.618s + 1)(s^2 + 1.618s + 1)$
6	$(s^2 + 0.518s + 1)(s^2 + 1.414s + 1)(s^2 + 1.932s + 1)$
7	$(s + 1)(s^2 + 0.445s + 1)(s^2 + 1.247s + 1)(s^2 + 1.802s + 1)$
8	$(s^2 + 0.390s + 1)(s^2 + 1.111s + 1)(s^2 + 1.663s + 1)(s^2 + 1.962s + 1)$

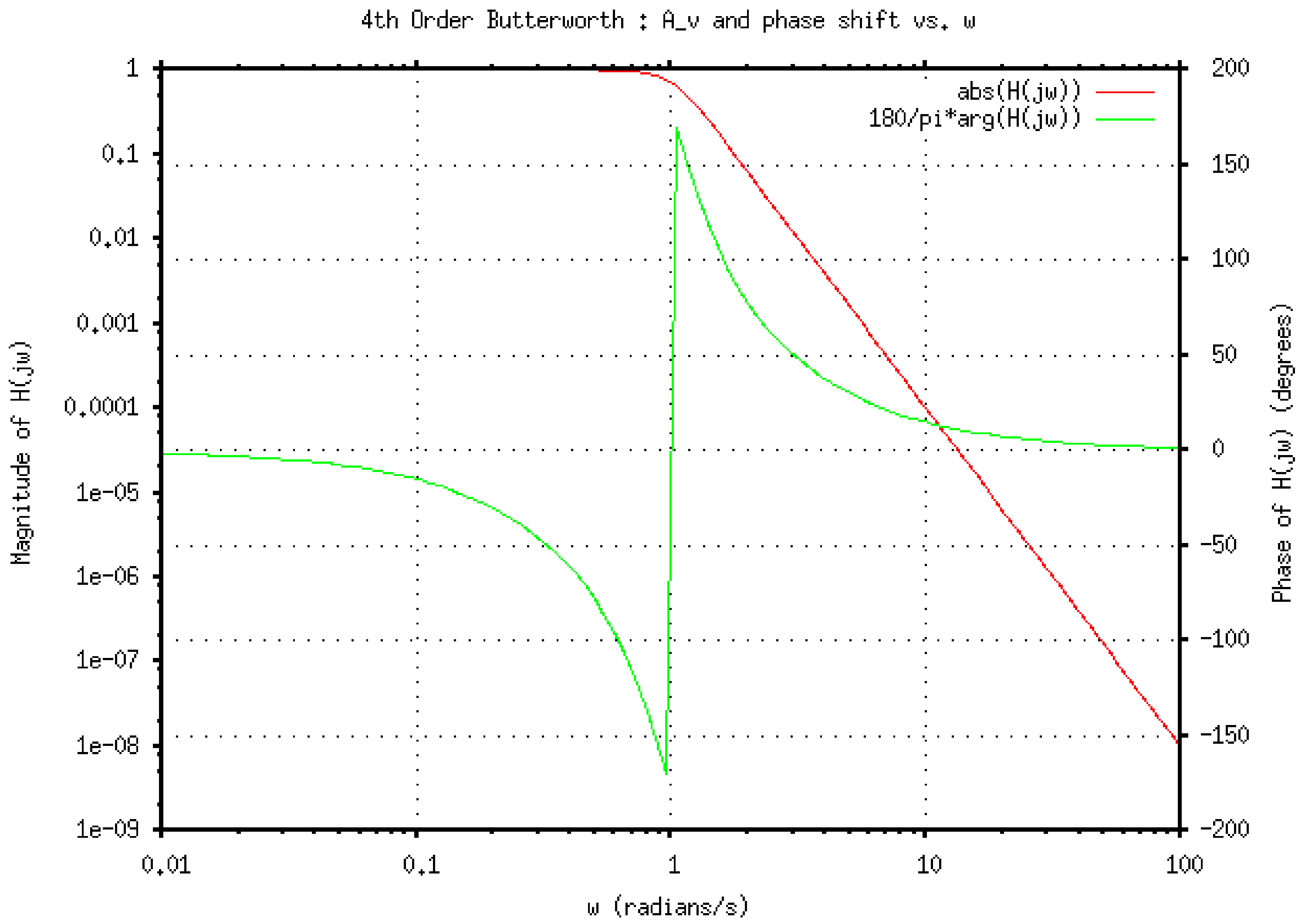
For a low-pass filter, $A(s) =$ constant. Butterworth polynomials maximize the flatness of the response in the pass band.

Other possibilities: Chebychev (more ripple but faster cutoff in knee region) or Bessel (more linear phase shift performance)

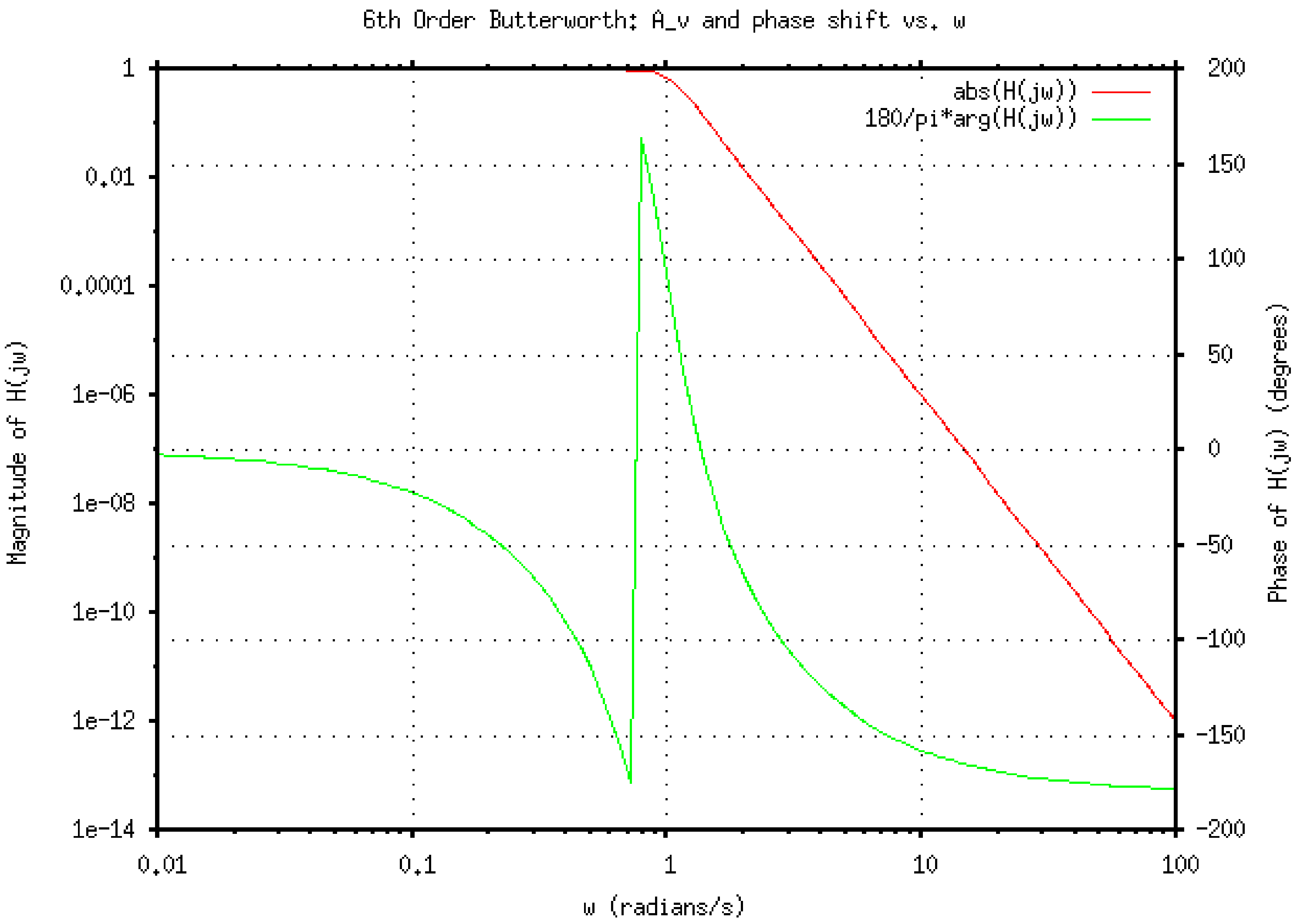
2nd Order Butterworth LP Filter Bode Plot



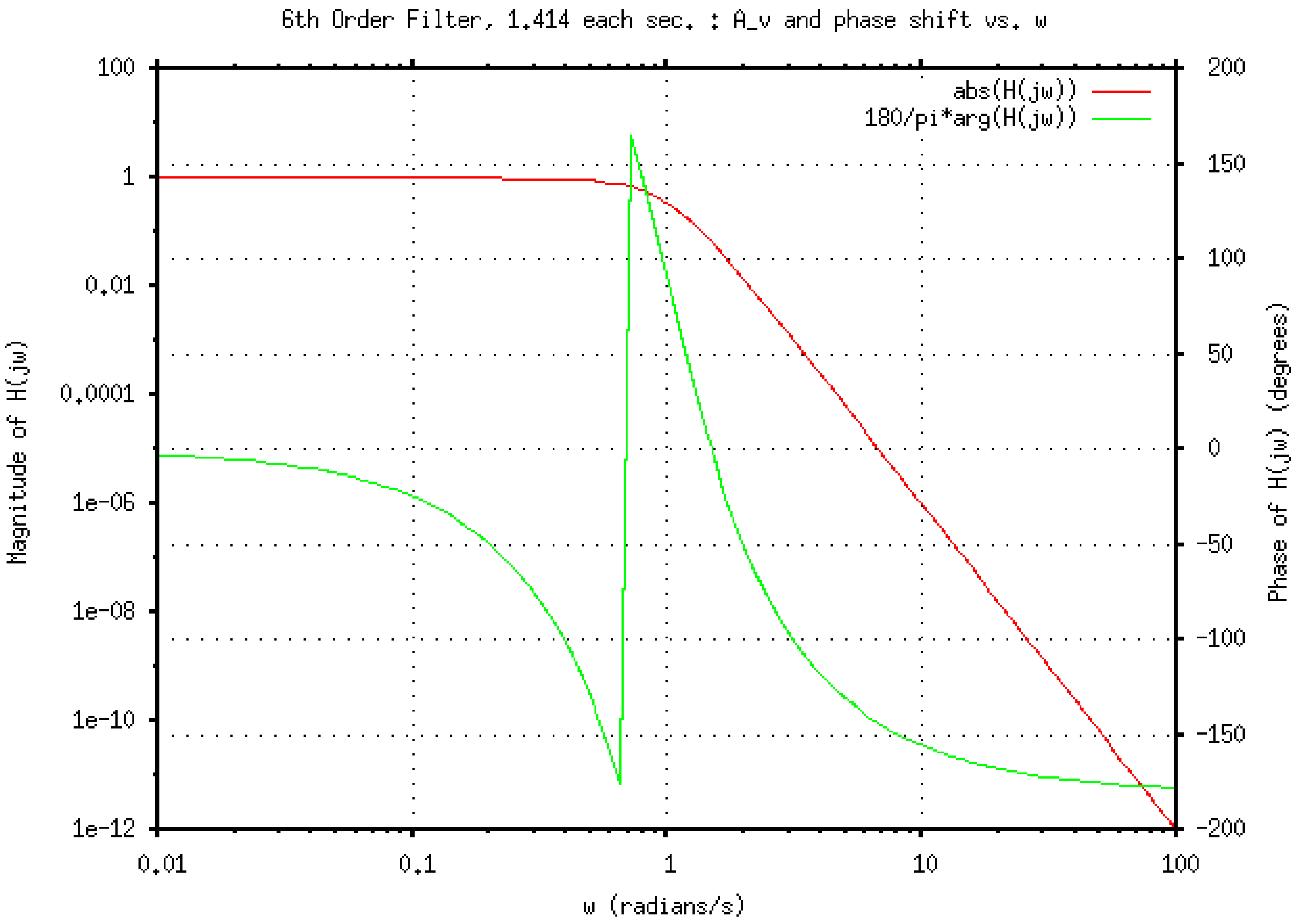
4th Order Butterworth LP Filter Bode Plot



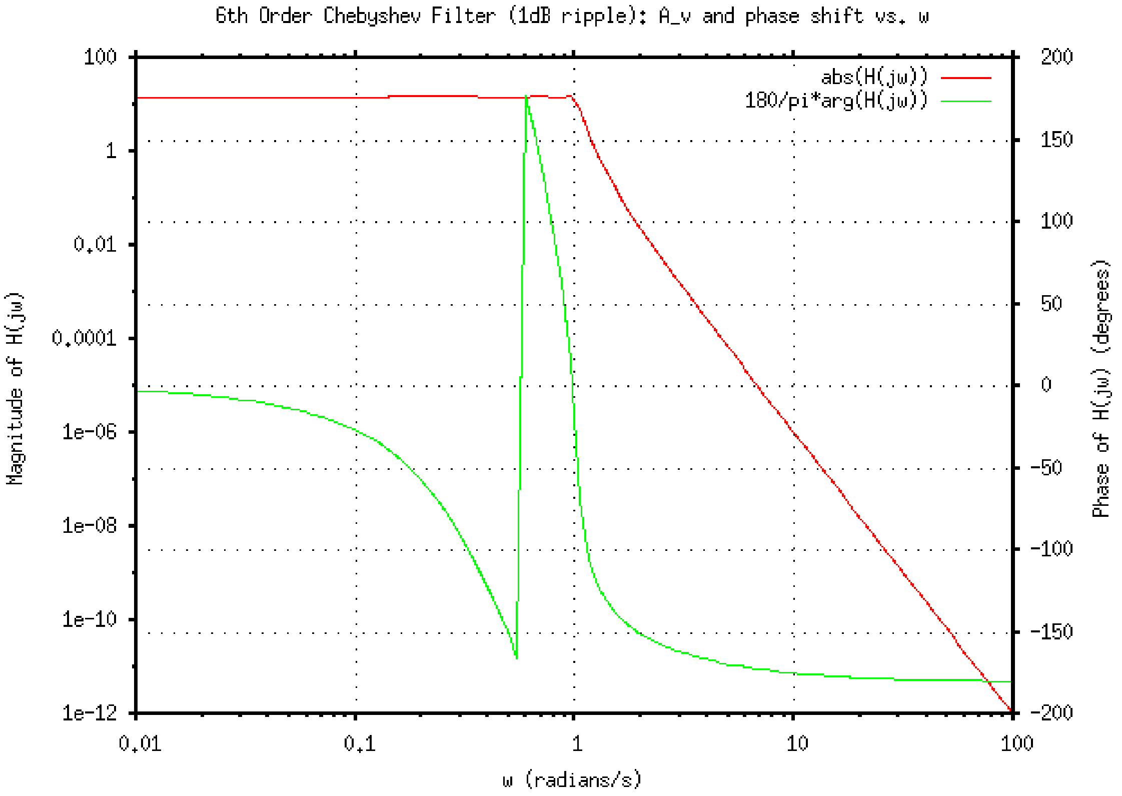
6th Order Butterworth LP Filter Bode Plot



6th Order Non-Optimum Filter Bode Plot



6th Order Chebychev LP Filter Bode Plot



$$B(s) = (s^2 + 0.1244s + 0.9907)(s^2 + 0.3398s + 0.5577)(s^2 + 0.4642s + 0.1247)$$

This design allows 1 dB of pass band ripple but gives a sharp cutoff in the neighborhood of ω_c. Eventually, $|H(j\omega)|$ falls as $1/\omega^6$.