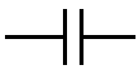
ECE 3510 Final given: Spring 14

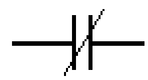
0. (2 pts EXTRA CREDIT) in Homework FC1 you explored ways to use a compensator with a system who's transfer function is unknown. Were would the data come from for the type of calculations you made in FC1?

1. (3 pts) a) What is an "unconventional root-locus plot" (the subject of homework RL8)?

2. (10 pts) a) Ladder logic was originally developed to help design logic circuits based on what type of part?

b) Give the meaning of the following ladder-logic symbols:





c) Show the ladder-logic equivalent of an AND gate where inputs A and B control a light, C.

d) Show the ladder-logic equivalent of an OR gate where inputs A and B (A OR B) control a light, C.

3. (3 pts) An instrumentation amplifier is a good way to implement what function(s) or block(s) in a typical feedback loop?

4. (8 pts) The output of a system is given by:

$$\mathbf{Y}(s) = \frac{b_2 \cdot s^2 + b_1 \cdot s + b_0}{s^2 + a_1 \cdot s + a_0} \cdot X(s) \quad + \quad \frac{s \cdot y(0) + \dot{y}(0) + a_1 \cdot y(0) - b_2 \cdot s \cdot x(0) - b_2 \cdot \dot{x}(0) - b_1 \cdot x(0)}{s^2 + a_1 \cdot s + a_0}$$

a) List the variables which together fully describe the *state* of the system at time $t = 0$ (the initial state).

b) What is $x(0)$ in the expression above. Give me a description.

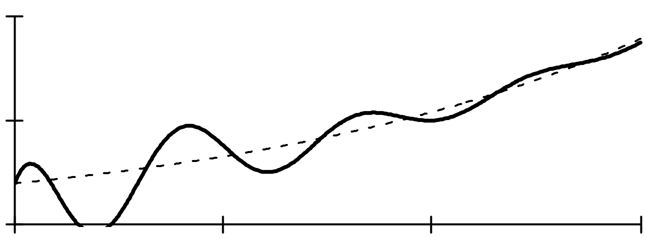
c) What is $\dot{y}(0)$ in the expression above. Give me a description.

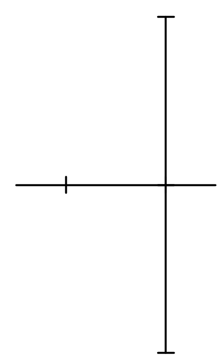
5. (8 pts) a) List Three advantages of state space over classical frequency-domain techniques.

b) Give one advantage of the frequency domain method we are using in this class over the state-space method.

6. (12 pts) For each of the time-domain signals shown, draw the poles of the signal's Laplace transform on the axes provided. All time scales are the same. The axes below all have the same scaling. Your answers should make sense relative to one another. Clearly indicate double poles if there are any.

a)





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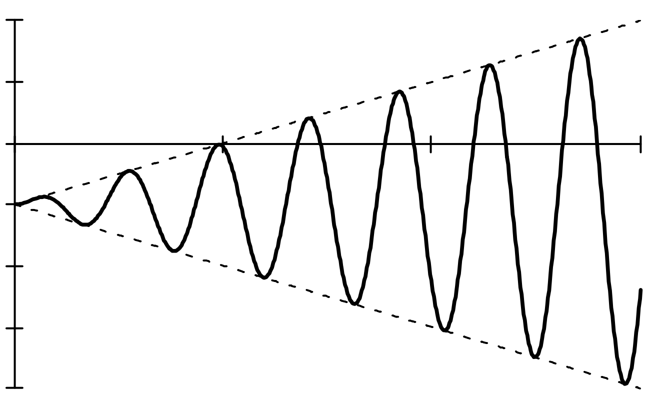
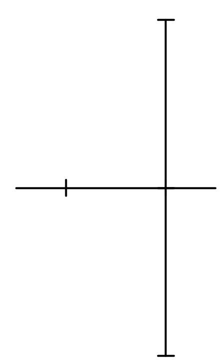
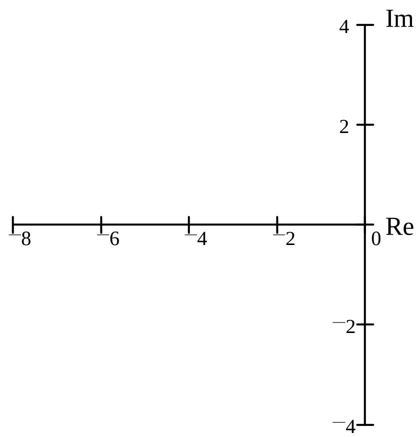


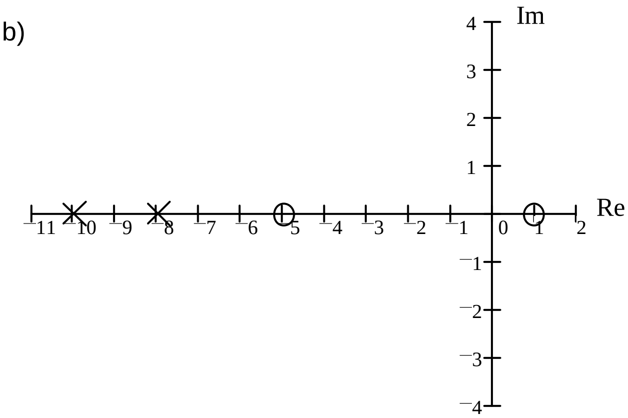


7. (20 pts) Sketch the root-locus plots for the following open-loop transfer function and pole-zero plot. Use only the rules you were told to memorize, that is, you may estimate details like breakaway points and departure angles from complex poles. Show your work where needed (like calculation of the centroid). Draw things like the asymptote angles carefully.

   a) $\mathbf{G}(s) = \dfrac{(s+2)\cdot(s+3)}{s\cdot(s+1)\cdot(s+5)\cdot(s+7)}$



   b)



   c) Find the range of gain (k) for which the system in b) is closed-loop stable. Assume $k > 0$.

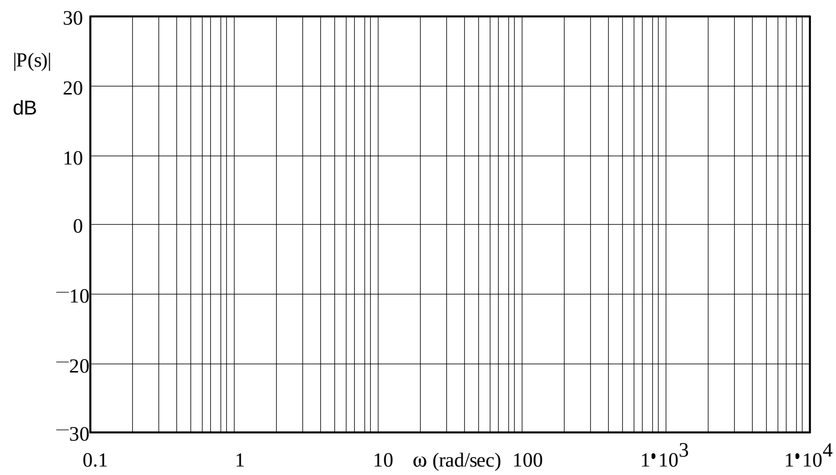
8. (11 pts) You have designed a compensator with the following:

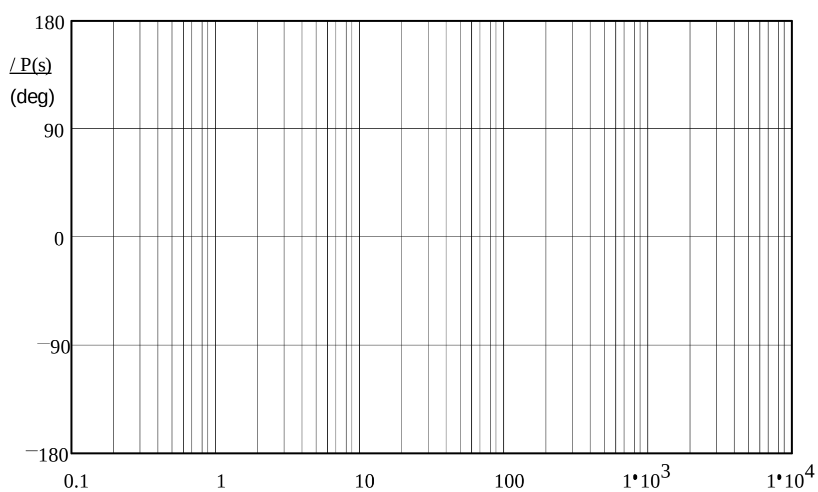
   A pole at the origin A zero at -2 A zero at -30 Gain of 12

   a) Draw the block diagram of a compensator that could give these. Use the factors k_P, k_i, and k_d in the normal way.

   b) Find the k_p, k_i, & k_d of this compensator.

9. (11 pts) Sketch the Bode plot for the following transfer function. Accurately draw the magnitudes and slopes. Also accurately draw the "smooth" lines. Include dB values at important points

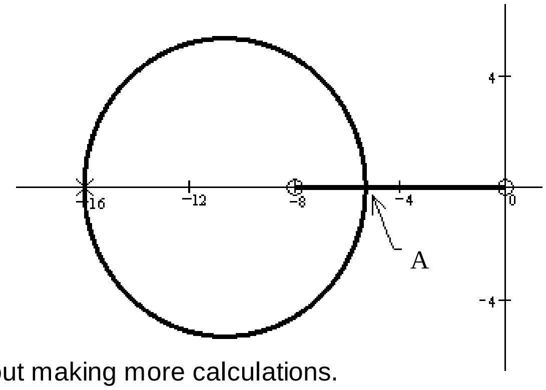




Note:

$2 = 6\cdot dB$ $\frac{1}{2} = -6\cdot dB$ $\frac{1}{4} = -12\cdot dB$ $5 = 14\cdot dB$ $10 = 20\cdot dB$

$4 = 12\cdot dB$ Add dB to multiply numbers $20 = 26\cdot dB$



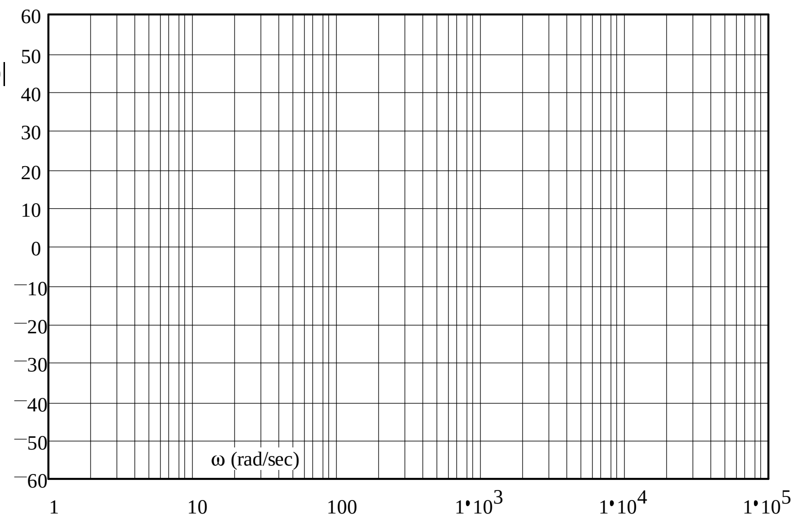
1. (12 pts) a) Point "A" is a special point on the root locus plot. What is it called?

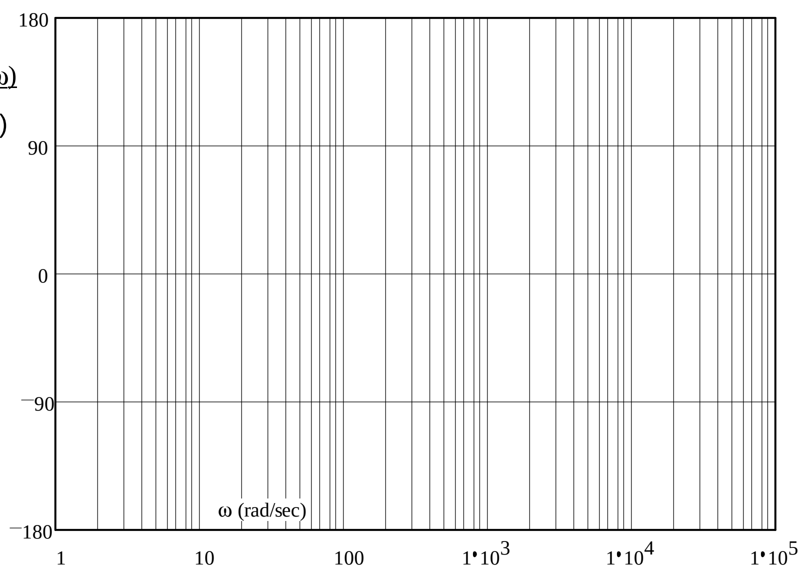
   b) Determine if point "A" is at -5.5. Show your evidence. I want to see specific calculations and numbers to justify your answer.

   c) The gain required to place a closed loop pole at - 4 is: Answer without making more calculations.
   A) LESS than the gain required to place the closed loop poles at point "A".
   B) THE SAME as the gain required to place the closed loop poles at point "A".
   C) GREATER than the gain required to place the closed loop poles at point "A".
   D) It isn't possible to answer this without more calculations.

2. (20 pts) Sketch the Bode plot for the following transfer function. Make sure to label the graphs as necessary to show the magnitudes and slopes. Also accurately draw the "smooth" lines. Include dB values at important points

$$\mathbf{P}(s) = \frac{(s+5000)\cdot 900\cdot s}{(s+20)\cdot\left(s^2+120\cdot s+90000\right)}$$



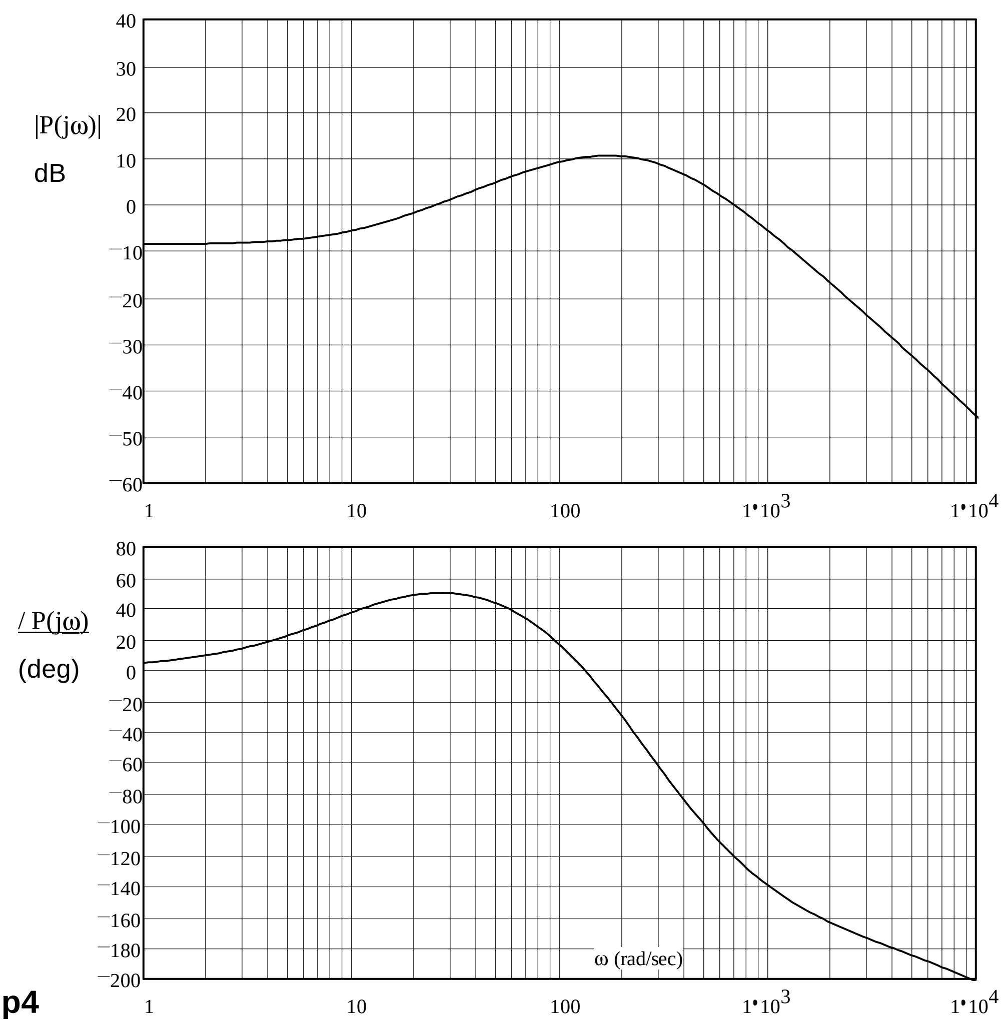


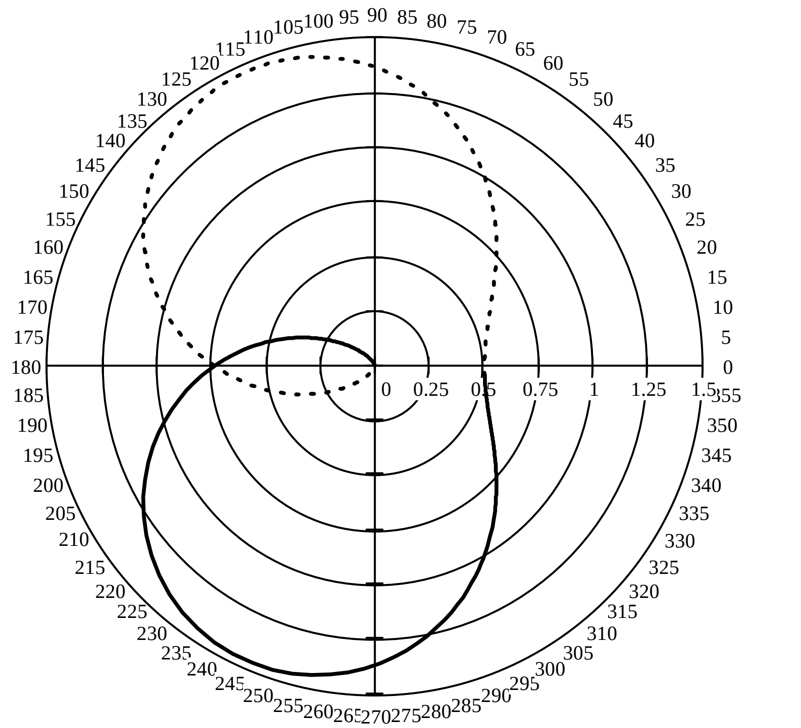
3. (20 pts) Given the magnitude Bode plot of a system, estimate the transfer function of the system.
   Assume there are no negative signs in the transfer function (all poles and zeros are in the left-half plane).
   Use a straight edge and show your work (how you made your estimate).

4. (12 pts) The open-loop Bode plots of a system are given at right.

   a) Find the gain margin and phase margin of the closed-loop system. Show your work on the drawings.

   b) Find the delay margin.





5. (11 pts) For the given Nyquist plot, find the following for the open-loop system:
   a) the DC gain

   b) $n - m$ (number of poles - number of zeros)

   Find the following for the closed-loop system, assuming it is stable:

   e) Gain margin. Show your work on the drawing. Be sure to indicate ALL the regions that would be stable.

   f) Phase margin. Show your work on the drawing.

6. (9 pts) An open-loop system has:

   1 unstable pole

   A DC gain of -3

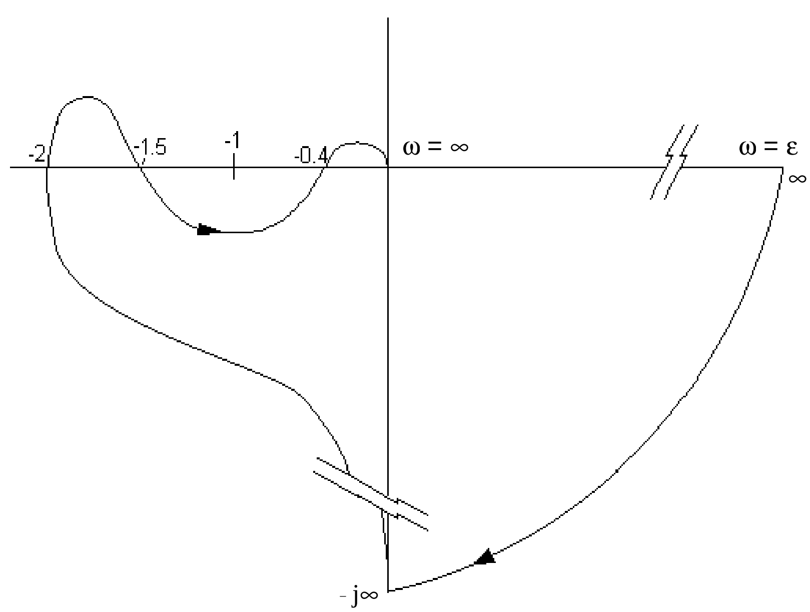
   2 more poles than zeros

   The closed-loop gain margin is

   $$GM = \begin{bmatrix} 0.5 \ , \ 4 \end{bmatrix}$$

   Draw a possible Nyquist plot for this system so that $Z = 0$.

7. (10 pts) Refer to the Nyquist curve at right (only the portion for $\omega > 0$ is plotted).



   a) The closed-loop system is stable. How many unstable poles can the open-loop system have? Show why.

   b) Does the open-loop system have any poles at the origin?

   How do you know?

   If yes, how many?

   c) What is (are) the gain margin(s)?

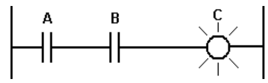
   d) Does the open-loop system have more poles than zeros? If yes, how many?

0. Experimental measurements

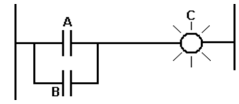
1. Like a regular root locus plot except that the gain is held constant and the plot shows how the closed-loop poles move as the result of changing some variable other than gain.

2. a) Electromechanical relays (and simple switches).
   b) Normally-open switch or contact
   Normally-closed switch or contact

c)



d)



3. The summer with + and - , and the gain block

4. a) $y(0)$ $\quad \frac{d}{dt}y(0)$ $\quad x(0)$ $\quad \frac{d}{dt}x(0)$
   b) The **initial value** of the **input** variable
   c) The **initial slope** of the **output** variable

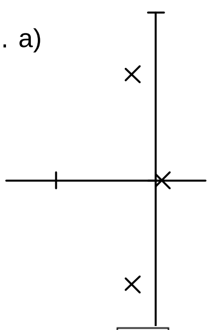
5. a) 1. Easily handles multiple inputs, multiple outputs and initial conditions
   2. Can be used with nonlinear systems 3. Can be used with time-varying systems
   4. Reveals unstable systems that have stable transfer functions (pole-zero cancellations). You can determine:
   Controllability: State variables can all be affected by the input
   Observability: State variables are all "observable" from the output
   5. Basis of Optimal control and adaptive control methods
   6. Good computer modeling packages

   3 of these

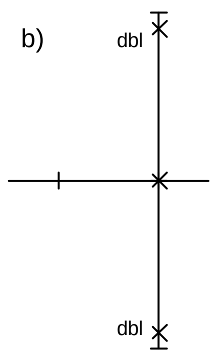
   b) Easy to set up analysis and find transfer functions Rapid, easy and intuitive design
   Transfer functions and poles provide lots of information without a complete analysis

   1 of these

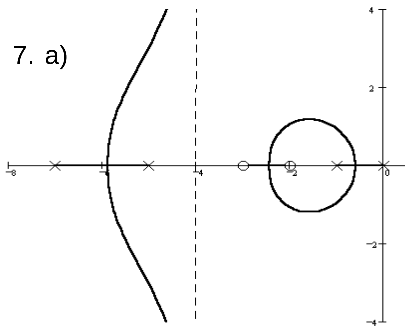
6. a)



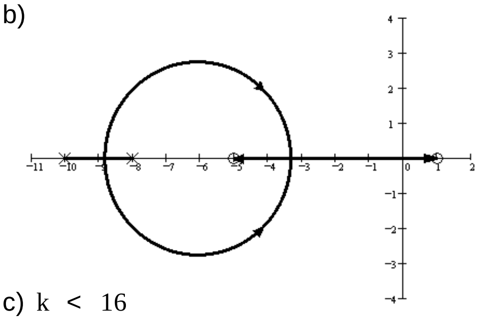
b)



7. a)

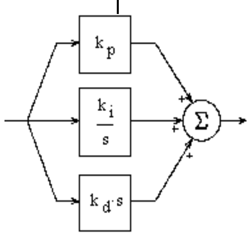


b)



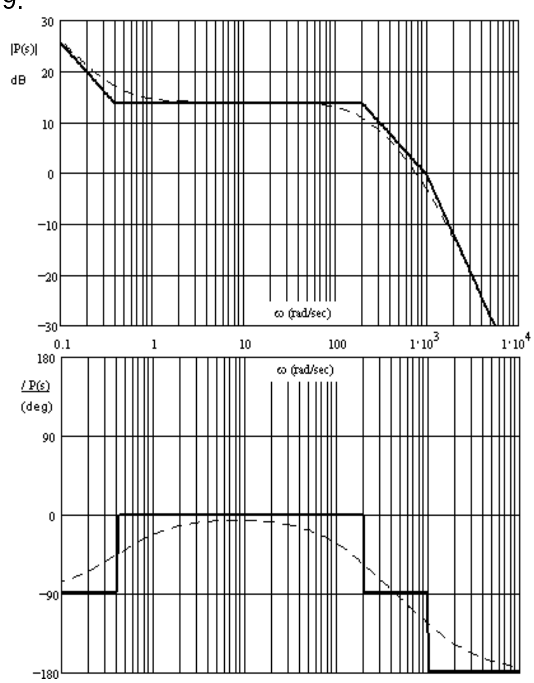
c) $k < 16$

8.



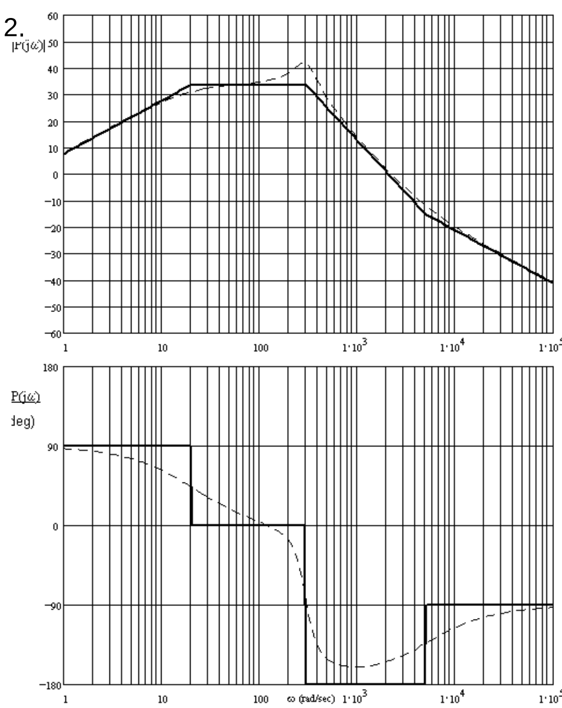
12 720 384

9.



1. b) Break-in point b) NO c) C)

2.



3. $\frac{10000\cdot s\cdot(s+4000)}{(s^2+40\cdot s+40000)\cdot(s+10^5)}$

4. a) $GM := 29\cdot dB$
   $PM := 58\cdot deg$
   $DM := 1.5\cdot ms$

5. a) ~0.5 b) 3
   e) 1.33 f) 15°

6. see below

7. a) $P = 0$
   b) yes
   90° arc at ∞ 1
   c) $[\,0.67\ ,\ 2.5\,]$
   OR gain < 0.5
   d) yes, 3

6.