University of California, Davis

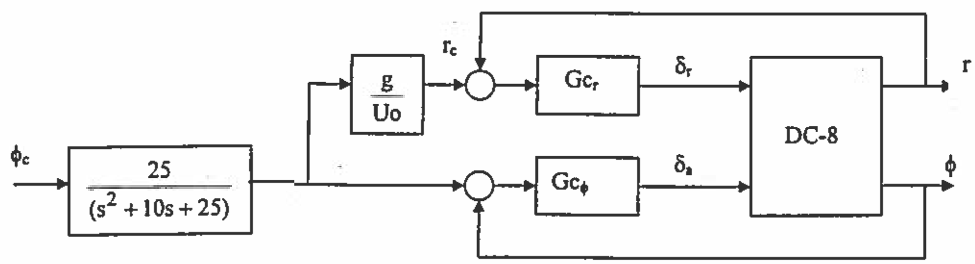
Dept. of Mechanical and Aerospace Engineering

MAE 275

Homework Assignment 5

Due: Thursday, May 14

This problem will involve designing an attitude-command/attitude hold stability augmentation system for the DC-8 aircraft in flight condition 8002. In addition, you are to implement a turn-coordination auto-pilot as part of the design. The block diagram for the system is shown below. Use sequential-loop closure and loop-shaping to do this.



The design requirements are:

Roll-attitude bandwidth (ϕ/ϕ_c) of 3.0 rad/sec (approximate). Minimum overshoot in step ϕ step response

Separation between r-loop and ϕ-loop bandwidths of approximately a factor of three (r-loop bandwidth lower).

Gain and phase margins of at least 12 dB and 45 deg in each loop

Strictly proper compensators, i.e., each with more poles that zeros.

Demonstration of turn-coordination in a Simulink simulation, i.e. using a $\phi_c = 20$ deg, show that a nearly circular flight path results. To do this you will have to solve the "navigation equations" describing dX/dt and dY/dt in Simulink. Use the non-linear versions of these equations for this part. The necessary sin and cos functions can be found in the math menu in Simulink.

1.) Show all your design work, i.e., Bode diagrams, and Simulink diagrams. Your design should also include sketches of the Nyquist diagrams for each loop closure.

2.) Show plots of the control inputs, δ_r and δ_a, and the response variables yaw-rate r, roll attitude ϕ, and sideslip β in the maneuver, i.e. for $0 \le t \le 50$ sec. Plot using units of deg and deg/sec.

3.) Using the Bandwidth/Phase-Delay boundaries explained on the following pages, estimate the Handling Qualities Level of your design.

Phase Delay:

$$\tau_p = \frac{\Delta\Phi 2\omega_{180}}{57.3\,(2\omega_{180})}$$

Note: if phase is nonlinear between ω_{180} and $2\omega_{180}$, τ_p shall be determined from a linear least squares fit to phase curve between ω_{180} and $2\omega_{180}$

Rate Response-Types:

ω_{BW} is lesser of $\omega_{BW_{gain}}$ and $\omega_{BW_{phase}}$

Attitude Response-Types:

$\omega_{BW} \equiv \omega_{BW_{phase}}$

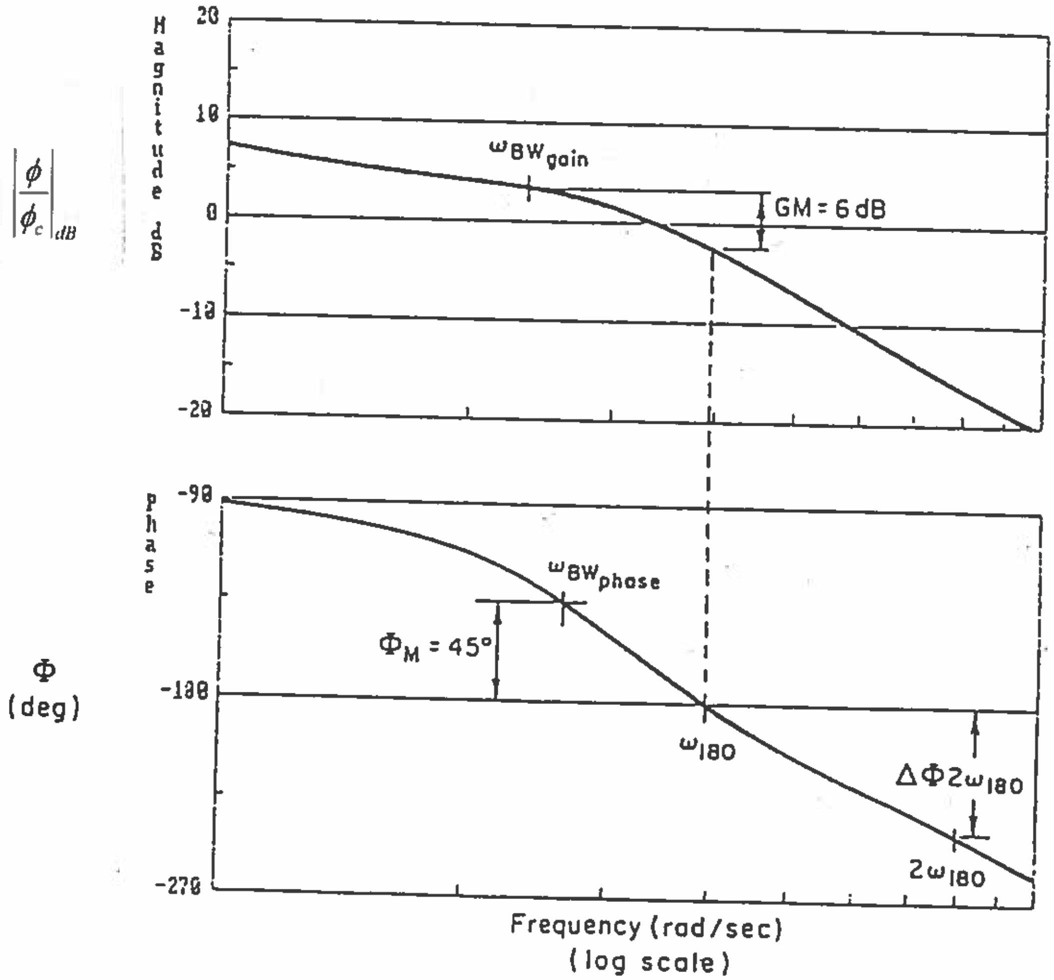
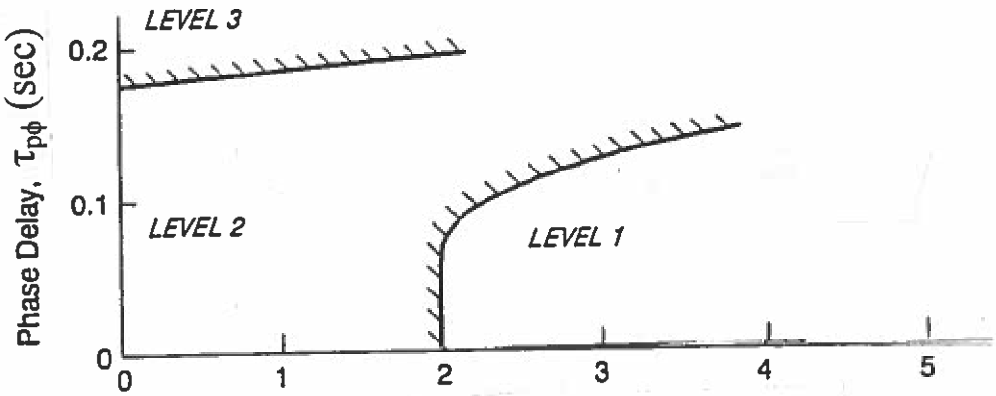


Figure 2(4.2.1.2). Definitions of Bandwidth and Phase Delay



Roll Attitude Bandwidth $\omega_{BW\phi}$ (rad/sec)