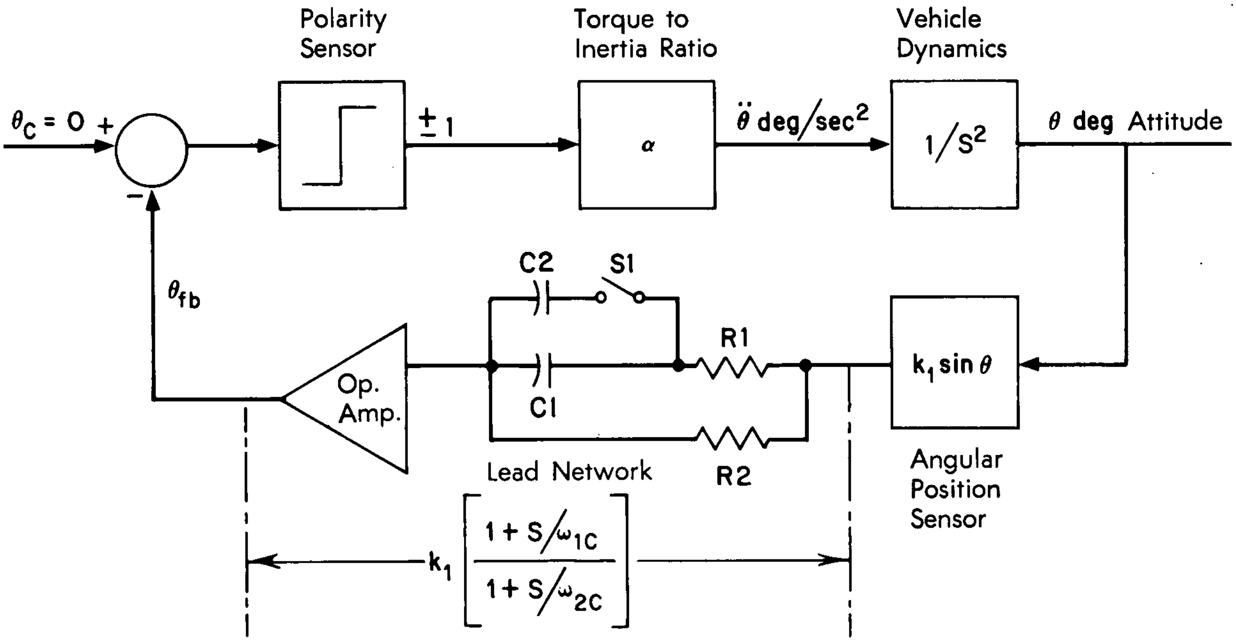
NASA TECH BRIEF

Ames Research Center

Adaptive Position Control Loop

The problem:

Design an attitude control system for a sounding rocket which minimizes the time required to achieve coarse pointing over a wide range of initial error angles up to 90° and consumes a minimum amount of cold gas for the maneuver. Thrusters will operate in the bang-bang mode and push-pull configuration to supply a control torque that is plus or minus a saturation value and never zero. Gas pressure is unregulated, hence thrust will decay exponentially during acquisition. The only sensor on board produces a signal proportional to the sine of the angle of error.



The solution:

Establish a control loop which incorporates a lead network to convert the position output into a feedback signal that is approximately proportional to position, plus a constant times rate. Either of two different values of ratio of position to rate feedback is selected depending on the magnitude of the position error signal. The direction of thrust is determined by the sign of the feedback signal, with sense selected to cause vehicle response to trend toward the desired position to rate ratio.

The optimum ratio in any given case is a function

(continued overleaf)

of the initial error. A ratio that will minimize overshoot at large angles will cause the system to "creep" in the vicinity of small errors. This difficulty is resolved by switching to a faster rate when the error draws within a preset value.

The result is a simple adaptive control system that conserves gas by minimizing the overall time of function.

How it's done:

The essential elements of the control loop are as shown in the diagram. One practical design for a lead network with two alternate position to rate values is illustrated.

The feedback signal, Θ_{fb}, is compared with the desired signal, Θ_c, of zero angle at zero rate. The sign of the difference is detected by the polarity sensor, which then determines the direction of the torque. The resulting angular acceleration $\ddot{\Theta}$ of the vehicle is proportional to α, the ratio of torque to inertia, and acts in the direction that will reduce Θ_{fb}.

The feedback loop starts with the attitude sensor whose output is proportional to the sine of the angle Θ. The lead network develops a rate signal through the action of resistor R_1 and capacitors C_1 and C_2. This is added to the position signal at resistor R_2. Electronic switch S1 is opened at smaller angles of error, removing C_2 from the circuit, and reducing the rate component. Operation of S1 is not dependent on angular velocity $\dot{\Theta}$, but is governed by Θ only, as the vehicle response is constrained by Θ.

This is expressed in the transfer characteristic shown, wherein the ratio of position to rate feedback is governed by the lead-break frequency ω_{1c}. The lag corner frequency ω_{2c} is kept sufficiently larger than ω_{1c} to insure that the network output is approximately proportional to position plus a constant times rate. A typical ratio of ω_{2c}/ω_{1c} is 100. A typical ratio of ω_{1c} at small angles to ω_{1c} at large angles is 4 or 5 to 1.

Notes:

1. This approach avoids the difficulty of establishing a fixed slew rate, where it is difficult to compute Θ electronically from sin Θ, especially in the vicinity of 90°.
2. Digital computer simulations strongly supported the use of two lead-break frequencies over a single one as a technique for achieving substantial reduction in time required for coarse acquisition.
3. The following documentation may be obtained from:

   National Technical Information Service
   Springfield, Virginia 22151
   Single document price $3.00
   (or microfiche $0.95)
   Reference: NASA CR-73304 (N69-29306),
   Fluidic Proportional Thruster System.

4. Requests for additional information may be directed to:

   Technology Utilization Officer
   Ames Research Center
   Moffett Field, California 94035
   Reference: TSP72-10052

Patent status:

No patent action is contemplated by NASA.

Source: W. L. Keltz of
General Electric Company,
Specialty Fluids Operation
under contract to
Ames Research Center
(ARC-10255)