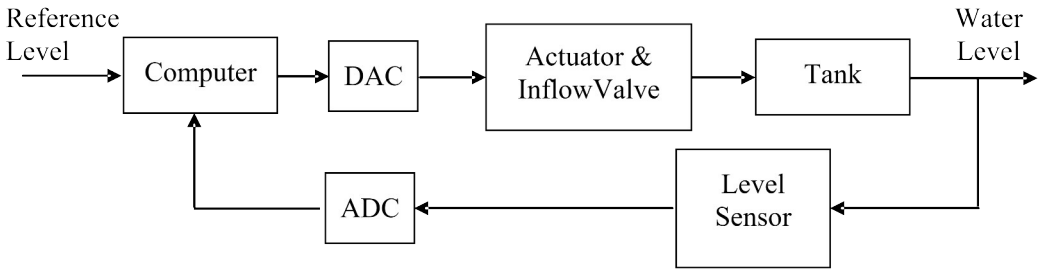
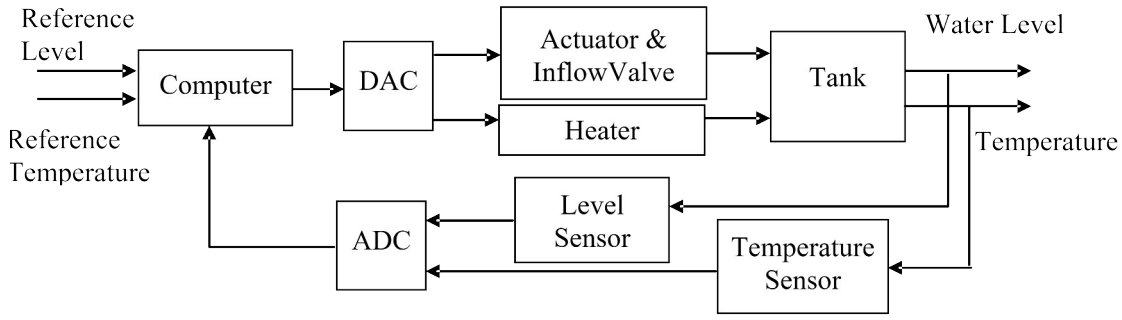
Chapter 1 Solutions

1.1 A fluid level control system includes a tank, a level sensor, a fluid source and an actuator to control fluid inflow. Consult any classical control text[1] to obtain a block diagram of an analog fluid control system. Modify the block diagram to show how the fluid level could be digitally controlled.



Block diagram of water level digital control system.

1.2 If the temperature of the fluid of Problem 1.1 is to be regulated together with its level, modify the analog control system to achieve the additional control (Hint: an additional actuator and sensor are needed). Obtain a block diagram for the two-input-two-output control system with digital control.



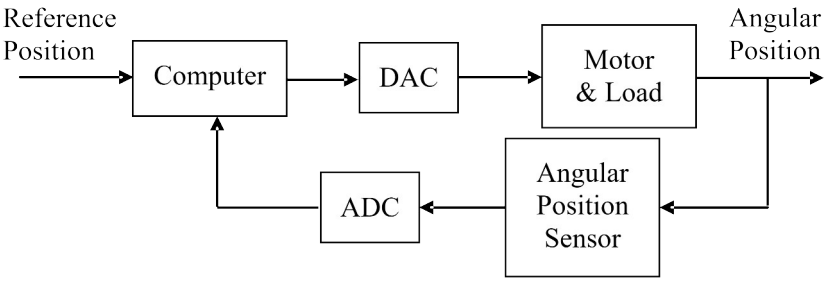
Block diagram of water level and temperature digital control system.

Note that the DAC and ADC can have more than one input and output channel.

1.3 Position control servos are discussed extensively in classical control texts. Draw a block diagram for a DC motor position control system after consulting your classical control text. Modify the block diagram to obtain a digital position control servo.

For the angular position sensor we could use a potentiometer, which is often packaged with an ADC to give a digital output.

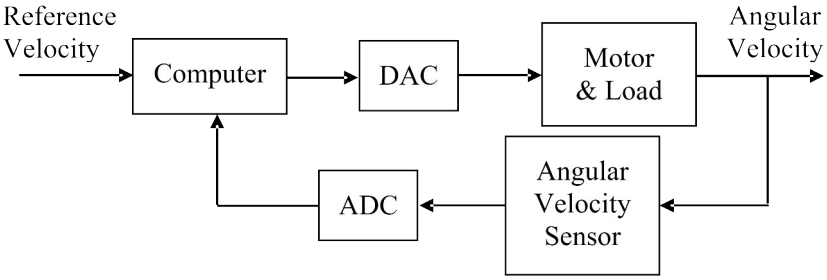
[1] See for example: J. Van deVegte, *Feedback Control Systems*, Prentice Hall, Englewood Cliffs, NJ, 1994.



Block diagram of DC motor digital position control system.

1.4 Repeat Problem 1.3 for a velocity control servo.

For the angular velocity sensor we could use a tachometer, which is often combined with an ADC to give a digital output. Alternatively, we could use an optical encoder , which has a digital output.



Block diagram of DC motor digital velocity control system.

1.5 A ballistic missile is required to follow a predetermined flight path by adjusting its angle of attack α (the angle between its axis and its velocity vector v). The angle of attack is controlled by adjusting the thrust angle δ (angle between the thrust direction and the axis of the missile). Draw a block diagram for a digital control system for the angle of attack including a gyroscope to measure the angle α and a motor to adjust the thrust angle δ.

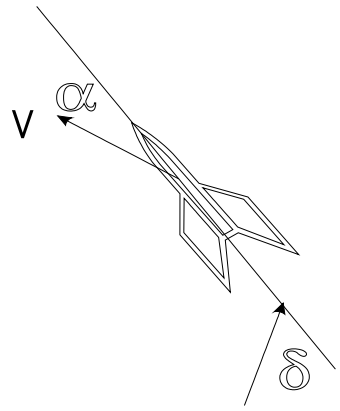
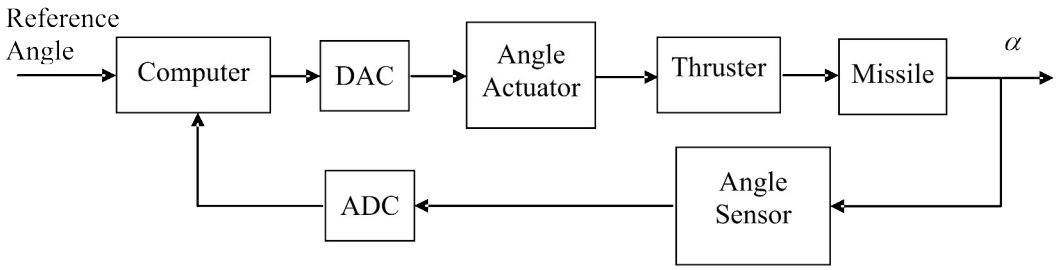


Fig. P1.1 Missile angle of attack control.

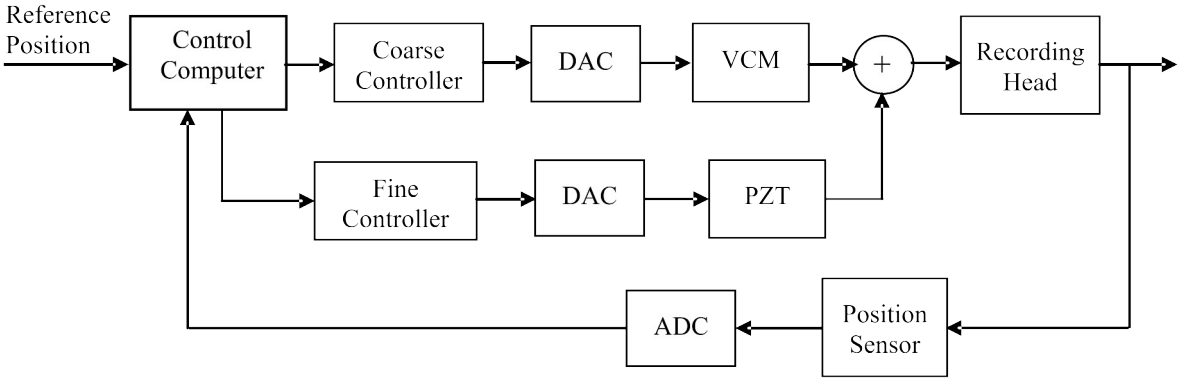


Block diagram of digital missile control system.

1.6 A system is proposed to remotely control a missile from an earth station. Due to cost and technical constraints, the missile coordinates would be measured every 20 seconds for a missile speed of up to 500 m/s. Is such a control scheme feasible? What would the designers need to do to eliminate potential problems?

If the missile is only observed every 20 seconds with speeds of up to 500 m/s, the missile position could change drastically between measurements. This makes the control scheme unrealistic. The missile coordinates need to be measured at a much higher rate.

1.7 The control of the recording head of a dual actuator hard disk drive (HDD) requires two types of actuators to achieve the required high areal density. The first is a coarse voice coil motor (VCM) with large stroke but slow dynamics and the second is a fine piezo-electric transducer (PZT) with a small stroke and fast dynamics. A sensor measures the head position and the position error is fed to a separate controller for each actuator. Draw a block diagram for a dual actuator digital control system for the HDD[2].



[2] J. Ding, F. Marcassa, S.-C. Wu, and M. Tomizuka, "Multirate control for Computational Saving", *IEEE Trans. Control Systems Tech.*, Vol. 14, No. 1, January 2006, pp. 165-169.