TECH TIME

Helpful tips for the Avionics Technician

BY AL INGLE

This month we continue our series on autopilot theory and operation. In previous articles we have explored the pioneering work of Elmer Sperry, the advances in closed loop technology, basic aircraft aerodynamics, the position based (Gyro Stabilized) autopilot, the rate based (Turn Coordinator/Accelerometer Stabilized) autopilot, electrical pickoffs in gyroscopes (with reactance errors) and the basic modes of operation of an autopilot. We now turn our attention to the servos.

The purpose of an autopilot is to smoothly control an aircraft and in doing so to relieve the pilot of this tedious chore. To perform properly, the autopilot system must operate as a closed loop between the attitude/pressure sensors, the computer and the servos. For the smoothest operation, the computer must know in real time how far and how fast the control surfaces are being moved or more specifically, how much pressure is being placed on the control surfaces. If you look at the ailerons on an airline transport aircraft on a typical flight, if any movement is visible at all, at cruise altitude they are not moving more than an inch or two. The ailerons are simply placing a slightly greater positive or negative pressure on the wing surface's airflow and this has sufficient effect to control an aircraft. In other words, to fly an aircraft straight and level, you do not have to move the control surfaces as much as apply a slight pressure against the slip stream.

So how does the computer measure this "pressure" when driving the servos? Should it drive the servo until the error condition is nullified as sensed by the gyroscope or air data sensor? Some autopilots do exactly this, such as the Century I ,II, III and IV series of autopilots, along with the Meggitt S-Tec line up through their 65 Series autopilots. Others, however, anticipate the required control surface movement by sensing how much energy has been expended by the servo's motor and compensates accordingly.

In our industry there are two primary methods by which this is done. The 21, 31, 41, 2000 and Triden models of digital autopilots manufactured by Century Flight Systems and the APS 65 autopilot manufactured by Rockwell Collins all utilize the method of measuring the back **E**lectro**M**otive **F**orce (EMF) principle. The electric motor in a servo consists of a coil of wire wound around a magnetic core, surrounded by magnets (or some variation thereof). To drive the servo, the autopilot amplifier energizes the motor's coil and a magnetic field is created by the flow of current in the coil. When the drive current from the amplifier is removed, the magnetic field in the coil collapses and current is induced into the coil in the opposite direction. In other words, the coil becomes a generator of voltage which quickly decays to zero. But this voltage or back EMF, is directly proportional to the amount of work the servo was performing and a good indicator of how much the aircraft control surface was moving. By driving the servo with a square wave of varying duty cycle, the aircraft may be smoothly controlled. Figure 1 below demonstrates the back EMF principle.

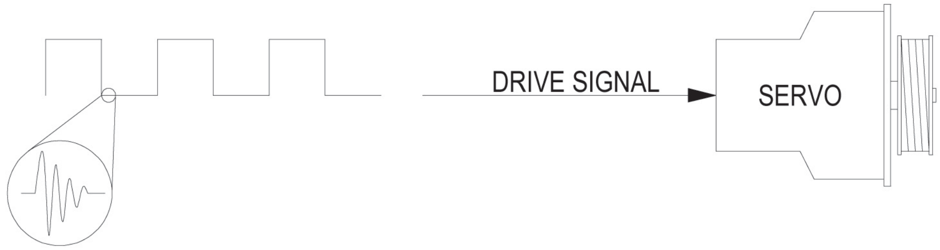

Figure 1. Using back EMF to provide feedback.

The second method by which an aircraft control surface movement is anticipated is by directly sensing the servo motor's rotation. This is done by mechanically connecting a second DC motor to the servo's drive motor and using it as a voltage generator. The faster the servo motor is driven the higher the output voltage from the second "generator" motor. Bendix/King and Rockwell Collins use this method in most of their product lines.

The evolution of exactly how you make such a system reliable is a study in persistence and determination. Since the autopilot amplifier is looking for a feedback voltage in order to know how hard to drive the servo, any failure or intermittency in the generator motor will cause an underperforming or malfunctioning autopilot. And where you have mechanical, moving parts, there is a potential for wear and subsequent failures. The generator motor's slip rings or brush/armature contacts ultimately determine the reliability of the feedback loop.

Rockwell Collins over the years has refined the slip ring or brush/armature contact technology by constantly addressing the deficiencies as they became apparent. Their early autopilots had the closed loop smoothness enabled by the motor generator being coupled to the drive motor. But after years of operation, it became apparent that intermittent generator motors could cause the autopilot amplifier to drive servos too hard. The solution in the next generation was to place *two* motor generators mechanically coupled to the drive motor and compare the two outputs. If they differed, then that channel was disabled. This prevented the possibility of overdriving a servo but in the event that either motor generator became intermittent, the autopilot was disabled. In effect, the chance of failure doubled and the nuisance disconnects increased. Rockwell Collins' solution in the next (and current) generation has been to place *double* sets of brushes in *two* motor generators. You now have four times the source of failure of the original autopilots, but it takes two simultaneous failures in a limited combination in order for the autopilot performance to be affected. The result is a smooth, safe, reliable autopilot. Figure 2 below demonstrates this method.

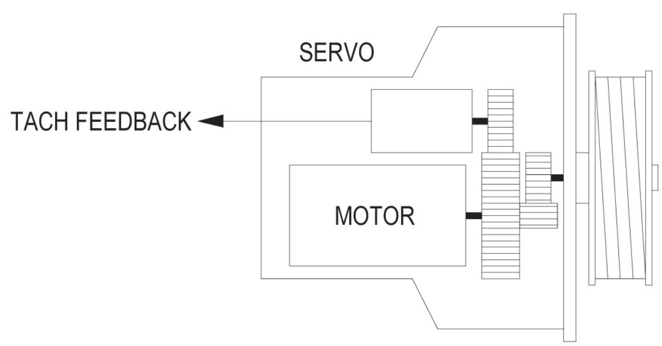

Figure 2. Using tach feedback.

One last universal consideration of autopilot servos is that due to their being directly connected to the aircraft control surfaces, the failure of a servo and/or its associated hardware could result in the loss of the aircraft. Every autopilot therefore, without exception, has an electrical interlock which can be broken by the pilot through multiple means. This should disengage the servos due to their being spring loaded in the disengaged position and only coupled to the aircraft control surface by electrically activated solenoids. Should this primary means of disengagement fail, again without exception, there is a secondary mechanical clutch that can be overridden by the pilot without damage to the aircraft. The caveat is that these systems must be properly maintained, which is your job.

Next Month: More autopilots