Last month alternating current fundamentals were explored as well as their relevance to a gyroscope's electrical pickoffs. Particular attention was paid to the phase shift that occurs due to transformer action and the methods utilized to minimize the processed errors in the computer. We also showed how an autopilot computer can derive an aircraft's attitude in space from vertical gyroscope outputs. This month we will harness this information and make it work for us.

Let's begin with the roll axis. The most fundamental mode of operation for an autopilot is "wings level" mode. Most, if not all autopilots default to this mode when activated. Simply put, the autopilot attempts to keep the wings level after being upset and the aircraft flies in one general direction but without any other guidance. This basic control is generally used for about as long as it takes the pilot to select another mode.

Heading Hold (HDG) is standard on most autopilots and adds a heading error to the basic wings level mode of operation. The pilot selects the desired heading and the autopilot is commanded to roll in the proper direction to minimize the HDG error. Note that as a rule of thumb, 10º of HDG error equates to 10º of roll attitude with roll bank angles typically limited to 22-25º.

The NAV mode of operation, also found on most autopilots, takes the basic circuitry found in the HDG mode and adds lateral deviation. In other words, in the absence of a lateral deviation error from a VOR, LOC, GPS, etc., (i.e. centered needle), the autopilot will fly the selected course (CRS) which is processed by the autopilot computer in a manner similar to the HDG signal.

The NAV (APR) mode of operation gets more complex when approaches are called for. Here the lateral gain (sensitivity) is increased and, depending upon the system installed, may further vary with altitude above the ground (from a Radar Altimeter) and distance from the runway (from a Marker Beacon receiver). Back course (BC) localizer equipped autopilots reverse the lateral signals before processing because the localizer signals appear backwards to the approaching aircraft. During all NAV modes of operation, crosswind drift must be compensated for by allowing the CRS error to "washout" over time.

Roll Steering (STR) has entered the General Aviation autopilot scene as a result of GPS approaches. The GPS units have the ability to navigate complex approaches with procedure turns and arcs but our standard lateral deviation based autopilots cannot keep up. Roll steering inputs to an autopilot are of the same type found in the HDG mode. They are instantaneous and have great authority.

There are two ways that the lateral information can be conveyed to the pilot and autopilot. One is by the use of a directional gyro (with a HDG bug) and some type of VOR/LOC/ILS indicator. This is common in smaller, less expensive aircraft and is most economical. Note that the HDG bug does double duty - it acts as a HDG reference and also as selected course (CRS), depending upon the autopilot mode selected.

The second method combines the functions of the DG and VOR/LOC/ILS indicator into one instrument called a Horizontal Situation Indicator, or HSI. Avionics manufacturers have given this instrument a different name over the years, however its purpose is to place in front of the pilot all necessary lateral information in a format that is spatially easy to comprehend. Intercepting a radial or executing an approach can often be confusing due to the information overload and speed in which critical decisions must be made. Procedure turns, poor visibility, cockpit communication chores, traffic concerns and other duties may create a high workload environment with reduced positional awareness for the pilot. The HSI provides lateral and vertical deviation information, selected Course (CRS) and Heading (HDG) together in one integrated display. Figure 1 represents a typical Horizontal Situation Indicator, or HSI.

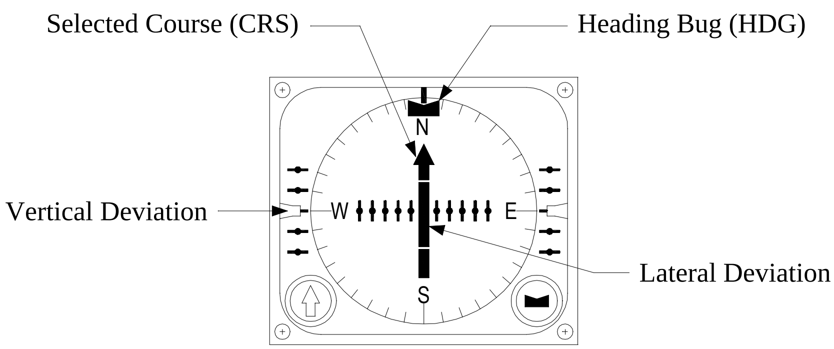

Figure 1 Typical Horizontal Situation Indicator (HSI).

In any given lateral mode of operation, the autopilot must know the aircraft attitude, from the turn coordinator or attitude gyro, and the amount of error present in the summed roll circuits in the computer. In HDG mode, when a pilot selects a new heading by displacing the HDG bug from its 12:00 o'clock position, a voltage proportional to the amount of error from the 12:00 o'clock position is sent to the autopilot computer. The roll attitude signal is summed with the HDG error and the resultant command sent to the roll servo to activate the ailerons. For example: Air Traffic Control requests the pilot to turn 45º right. The HDG bug, which is now at 12:00 o'clock, is displaced 45º to the right. The autopilot computer does not care what heading is actually being flown, only the amount of error left or right that exists. The corresponding HDG error introduced with the wings level will create an output in the computer from the summed lateral circuits to drive the roll servo and move the ailerons. The aircraft rolls right until the turn coordinator/attitude gyro signal effectively equals and cancels the HDG error. The aircraft is now in a standard rate turn. This turn continues until the aircraft is within 25º - 30º of the selected heading and the resultant HDG error voltage is reduced accordingly. The roll gyro signal will now begin to dominate and the summed lateral circuits in the computer will reduce the roll servo drive accordingly to reduce the bank angle. This corresponding reduction in roll attitude and HDG error will continue until the aircraft has settled on its new heading. The same scenario occurs when the HDG bug is selected to the left. The roll attitude is command limited to the specified bank limit and this roll angle is held until closely approaching the selected heading.

The HSI provides independent HDG and CRS outputs to the autopilot computer allowing more freedom for the pilot and crisper performance during approach. In the NAV mode, think of the selected course (CRS) as similar to the heading bug and add lateral deviation. Now the autopilot computer sums attitude (can't let the aircraft exceed 22º-25º roll attitude), selected CRS error (wants to drive ailerons to turn aircraft to that heading), and lateral deviation (must center needle). The result is a compromise where the summed lateral circuits in the computer will typically allow up to 45º of intercept angle between the actual heading of the aircraft and the selected course on the HSI with a full scale (150mV) lateral deviation error in that direction. As the lateral deviation is reduced (the needle approaches the center) the CRS signal dominates and the autopilot computer commands the aileron servo to reduce the intercept angle accordingly.

This is a fundamental lesson in lateral circuit theory, however, when troubleshooting a roll axis problem, a basic understanding will prove invaluable.

Answer to last month's question: The demodulated attitude signals would be lower than normal. The autopilot would think the aircraft has not been driven adequately in that axis and overdrive. Symptoms: roll, pitch, yaw oscillation; excessive bank and pitch angles.

Next Month: More autopilots