The KFC 225's Internal GPSS

by Dan Herr, TTCF Member

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The KFC 225 was designed after the advent of aviation GPS, but before WAAS and before GPS approaches had a glideslope. Unlike VOR navigation, GPS navigation is able to provide the ground track of the aircraft. Ground track and other pertinent data could be packaged in 429 data and could enable autopilots to fly much more precisely – no longer would the autopilot need to hunt for the wind correction based upon only the old VOR information (desired course and CDI deflection).

The 225 was one of the first light GA autopilots that could take 429 data from a GPS to achieve wonderfully precise and stable nav performance. Back at this time, remember that GPS navigators were standalone boxes. There were no GPS/Coms nor GPS/Nav/Coms (like the G530). In airplanes with dual VORs, there was a switch to change the VOR source for the HSI (with the HSI connected to the autopilot) or a switch to select the nav source to be used by the autopilot. That old style of VOR switch architecture would work for a non-429 GPS (tracking would be done based upon the CDI just like a VOR source), but would not work for a 429 GPS.

In designing the interface between the KFC 225 and a standalone GPS capable of 429 outputs, there needed to be a way to tell the 225 when it should use 429 GPS data rather than the analog CDI data from the GPS. In order to tell the 225 when to use 429 data, the engineers gave the 225 the 429 enable pin (aka GPSS enable pin), 2252-34 (aka pin 34). The logic for pin 34 is as follows: <u>grounded</u> means to use 429 data; <u>open</u> means to use analog CDI data.

There is one installer-configuration note on the KFC 225 to keep in mind. In order for the grounding of pin 34 to result in the use of 429 data, there is an internal 225 configuration called "ARINC 429 (GPS) Steering". A config setting of "1" allows the KFC 225 to receive nav information via the ARINC 429 bus from a GPS sensor. A config setting of "0" limits the KFC 225 to receiving nav information via an analog NAV sensor or CDI.

When GPS navigators were standalone boxes, the architecture for pin 34 was simple. When connecting a 429 GPS to the 225, the switch that would change the nav source for the autopilot (from VOR to GPS), would incorporate connecting pin 34 to ground. That way, whenever the nav source was GPS, the 225 would know to use the 429 data rather than the CDI data.

For some reason that is probably lost to the dustbin of history, the designers of the KFC 225 were worried about pilots switching between GPS and VOR nav sources. The designers had no worry about switching between VOR1 and VOR2, but switching to or from this new fangled 429 mode must have been a peril in their minds. Accordingly, the designers caused the 225 to kick out of

NAV and APR modes whenever the 225 switched from 429 GPS (pin 34 grounded) to VOR (pin 34 open). Note that the kickout also occurs when switching from VOR to 429 GPS, i.e. the direction of change does not matter. I view this kickout into ROL (wings level) mode as more dangerous than whatever demons the designers envisioned. But I concede that the designers were on the cusp of this unproven GPS thing - and I can understand their caution.

From a pilot's perspective, the operation of the 225, back in the era of standalone GPS boxes, created just one minor complication. Whenever the pilot switched the nav source between GPS and VOR (in either direction), pin 34 would change state and the designers' caution would cause the 225 to kick out of NAV and APR modes. So for every change between VOR and GPS, the pilot would have to know that he would need to re-engage the NAV mode or APR mode in order to compensate for the kickout. This was not a huge gotcha because the VOR/GPS change was always initiated by the pilot. The 225 re-engagement became just another button push as part of the process of the VOR/GPS switch.

Slightly later in time, things began to get complicated when we had nav boxes combining VOR and GPS: the Garmin 530 in other words. If you wanted to use the 429 GPS provided by the 530, the 530 could not be connected to the 225 as would a VOR box. When the 530 is connected to the 225, sometimes the 225 needs to use the CDI (VOR), and sometimes the 225 needs to use the 429 data (GPS). There needed to be a way for the 530 to tell the 225 whether to use analog (CDI) or 429 (GPS). Garmin, in order to accommodate the 225, created a discrete on the 530 called "GPS" (I will use quotes when referring to this discrete). In this original iteration of "GPS", the logic was eminently simple: the discrete would provide a ground when the 530 was in GPS mode and the discrete would be open when the 530 was in VLOC (VOR) mode. The "GPS" discrete was designed to be connected to pin 34 of the 225. This arrangement made things slightly more complicated for the avionics shops installing 530s with the 225, but it did not create any further complications for pilots. For pilots, switching the 530 between GPS and VOR caused the 225 to kickout, and the pilots would need to re-engage the autopilot (comparable to the operation of switching between a VOR box and a GPS box).

The only wrinkle in this scheme was the 530's ability to automatically switch from GPS to VLOC on an ILS approach. This feature on the 530 had to be disabled with a 225 because the automatic switch would cause the 225 to kickout to ROL mode (wings level). Kickouts occur with no aural annunciation: just a flashing "ROL" on the KFC 225 display. This is not a high visibility warning. The 530's auto-switch from GPS to ILS would cause a kickout for 2 reasons: 1) pin 34 would change state from ground to open; and 2) the ILS energize pin would change state on the 225. If the auto-switch to ILS was mistakenly enabled, the pilot, at the switch to VLOC, would be put adrift into ROL mode. With the 530's auto- switch to ILS disabled, pilots would manually switch to VLOC. If the KFC 225 had been in NAV mode, the 225 would kickout with the switch, and pilots would then hit the APR button so that the 225 could fly the ILS.

Now, let's move ahead to the WAAS era, where suddenly GPS boxes can provide a glideslope on a GPS approach. This was never envisioned (or at least not provided for) in the design of the KFC 225, so this is where the major complications arise. Before we delve into this, let's make a foray into how the 225's internal GPSS capability handles 429 GPS navigation (GPS source and pin 34 grounded). When the 225 is in NAV or APR mode and pin 34 (GPSS enable) is grounded, the 225 will navigate based upon the nav data coming from the 429 connection. This use of 429 nav data is sometimes referred to as "roll steering" – because it essentially gives the autopilot the same type of information as the autopilot would receive from a heading bug, i.e. whether the airplane is on heading, or how far it is off of heading (thereby enabling the autopilot to know how much bank/roll to use to get back on heading). When the 225 uses 429 GPS data for its internal GPSS capability, the 225 is actually in HDG mode (despite NAV or APR being annunciated). In other words, the 225 uses the same type of circuitry to process the 429 GPS data as the 225 uses in HDG mode to process data from the heading bug. The best term I have for describing this came from someone at Honeywell. He told me than when pin 34 is grounded (429 GPS enabled), the 225 is in "PHANTOM HDG" mode, not NAV, and not APR – despite the actual annunciation of NAV or APR.

The "PHANTOM HDG" aspect of 429 GPS operation becomes critical with the introduction of a glideslope for GPS approaches. With the advent of GPS WAAS approaches with a glideslope, most KFC 225 pilots would have naturally expected that their 225 could easily fly those GPS glideslope approaches. Since the KFC 225 can track a glideslope in APR mode, and since the 225 can perform 429 GPS in APR mode, it would seem a simple matter for the 225 to track a glideslope on a GPS approach (perhaps as simple as providing a glideslope energize signal to the 225). Alas, it is not possible for the 225 to track a glideslope while performing 429 GPS in APR, because even though APR is annunciated when the 225 is performing 429 GPS in APR mode, the 225 is really in "PHANTOM HDG" mode whenever pin 34 (429 GPS enable) is grounded. Since the 225 is not truly in APR mode (the annunciation is lying to the pilot) when pin 34 is grounded, the 225 cannot track a glideslope (just as the 225 cannot track a glideslope in HDG mode). I repeat: the 225 cannot track a glideslope while performing 429 GPS because the 225 thinks it is not in APR mode for 429 GPS - the 225 thinks it is in HDG mode. Remember, 429 NAV and 429 APR are both really a "PHANTOM HDG" mode.

This "PHANTOM HDG" mode of the KFC 225 was a huge curveball for GPS approaches with a glideslope. The 225 can track a glideslope using analog (CDI) lateral navigation, but cannot track a glideslope using 429 navigation. Despite all the wonderful benefits and smoothness of 429 navigation, the 225 would have to fly GPS glideslope approaches with lateral nav based upon old-fashioned CDI analog nav. This meant that the old "GPS" discrete provided by the 530 (grounded when in GPS mode and open when in VLOC) was no longer adequate. For the 530W, there needed to be a more sophisticated discrete to connect to pin 34. The new discrete would need to tell the 225 to use 429 when there is a GPS nav source, except when a GPS approach is underway, in which case the discrete would need to be open (despite there being a GPS nav

source and not a VOR source). Garmin's solution to this was a new discrete called "GPS SELECT".

In the 530W Install Manual (rev G), GPS SELECT is described as follows:
"The GPS Select Output is driven low [grounded] when GPS data is being displayed on the CDI/HSI and the ILS/GPS Approach Output is not active. It is intended for use with autopilots having a GPS Select input (such as the Bendix/King KAP 140 and KFC 225)[referring to pin 34], so that the autopilot can capture vertical guidance while GPS data is being displayed on the CDI/HSI."

Garmin's GPS SELECT ungrounds pin 34 for GPS approaches (even those without a glideslope), thereby putting the 225 back into analog mode (and out of PHANTOM HDG) so that a glideslope can be tracked in APR mode for a GPS GS approach. Although GPS SELECT was a practical solution for the glideslope tracking problem, GPS SELECT caused side effects. Somewhere in the transition from enroute GPS navigation (GPS SELECT grounded for 429 nav) to approach GPS (GPS SELECT open for analog nav and glideslope tracking), GPS SELECT has to change from ground to open. As we know all too well, that change on pin 34 will cause the KFC 225 to kick out of NAV and APR and into ROL mode – an especially dangerous trap as the airplane is turning onto the final approach course. In order to prevent some airplane from hitting a mountain as the 225 flies along in ROL mode, Garmin needed a way to warn pilots before GPS SELECT changes state (ground to open) prior to the GPS approach. Garmin's solution was the PROMPT to enable autopilot outputs.

This is from the 530W (note that this is from the 530W and is not in the 530 version) Pilot's Guide:
"To enable autopilot outputs
1. Load and activate approach information as usual.
2. When you are turned on course to the FAF (Track and Desired Track are within 10°), a message will prompt you to enable the autopilot outputs before using your autopilot for an approach.
3. Press PROC. Highlight "Enable A/P APR Outputs?" with the large right knob, if necessary, and press ENT. [This allows GPS SELECT to open and will kick the autopilot out of NAV and APR and into ROL.]
4. Press the Approach button on the autopilot [since it is now in ROL mode] to switch it to Approach mode. Your autopilot will now use guidance from the 500W-series unit for the approach."

A more complete description of PROMPT is that it is a warning to the pilot that if the PROMPT is acknowledged, then the navigator will disable GPSS navigation (pin 34 will go to open) and will allow the glideslope to energize (if the approach has a glideslope). Accordingly, the pilot should be prepared for the KFC 225, if it is engaged in NAV or APR modes, to kickout to ROL

mode, and the pilot will have to push a button on the 225 to select an operating mode other than ROL.

Another issue to discuss is the logic of GPS SELECT. Technically, GPS SELECT could remain grounded for GPS approaches that do not have a glideslope – since there is no need to put the 225 into analog mode when there is no need to track a glideslope. Despite that opportunity for improved nav tracking on GPS approaches without a glideslope, GPS SELECT goes open for all approaches. So with the 225 in NAV or APR modes, all GPS approaches are flown using analog (CDI) data.

KFC 225 kickouts: I do not have the exhaustive list, but there are many things that will cause the 225 to kick out of NAV and APR modes:

1. Change on pin 34 (GPSS enable)
2. Change in ILS energize pin (this applies to both NAV and APR modes).
3. CDI flag (this will cause a kickout even if the 225 is using 429 GPSS and is not using the CDI).
4. Note that kickouts do not occur when switching the nav source between analog GPS (pin 34 open) and VLOC, as long as the ILS energize is in the same state for both sources.

An interesting question is whether to utilize the 225's internal GPSS, or simply to rely upon external GPSS with the 225 in HDG mode (with an external switch to select between the heading bug or roll steering). When I first installed my 225, my inclination was to be a purist: HDG mode on the 225 should be for the heading bug only; GPSS should be performed in NAV and APR in order to take advantage of the 225's internal capabilities. Given the dangers associated with unexpected kickouts (which are not aurally annunciated), my view has changed. The 225's NAV and APR modes should be reserved for analog operations only (no 429 GPS). All GPSS operations should be conducted with the use of an external GPSS source with the 225 in HDG mode (this configuration requires an external switch to select between the heading bug or the external GPSS source).

Despite Garmin's best efforts with GPS SELECT and with the PROMPT for approach outputs, I have experienced kickouts using the 225's internal GPSS (225 in NAV mode and connected to a GTN750). The most specific example is while on a STAR that ended in a heading leg. The STAR involved flying to various waypoints, with the instruction to fly heading 270 when leaving the final waypoint (in anticipation of further vectors to final). Although the 750 outputs the 429 data that the 225 needs to fly heading legs, the 750 may flag the CDI on heading legs. A CDI flag causes the 225 to kickout (despite the 225 not using the CDI when conducting 429 nav).

On the other hand, if a STAR with a heading leg is flown using external GPSS (225 in HDG mode), the STAR and heading leg can be flown in its entirety by the 225. Likewise, SIDS with heading legs can be flown by the 225 using external GPSS. Using external GPSS rather than the 225's internal GPSS simplifies the 225's interface to Garmin boxes: GPS SELECT is not needed since there is no connection to pin 34. Further, external GPSS allows a GPS approach without glideslope to be flown using GPSS with the 225 in HDG mode.

Although this overview of GPSS with the KFC 225 contains complaints on Garmin's interface to the 225, I hope it is clear that the emphasis on Garmin is due to the fact that Honeywell has not modernized the 225 to adapt it to WAAS. If Honeywell would upgrade the 225, it would greatly reduce the burden upon Garmin. Bear in mind that if Garmin had not developed methods (GPS SELECT and PROMPT) to mitigate the dangers of the 225's kickouts, the FAA might not have approved the 530, 530W, 750, etc. to be connected to the 225. So despite all the confusion and the complication, at least we are not in the boat of being prohibited from using our KFC 225s with these modern boxes.

If Honeywell were to update the 225's software so that changes in pin 34 would no longer cause kickouts, and so that glideslope energizing would not cause kickouts, it would greatly modernize and simplify the operation of the 225. Other modernization possibilities include: 1) enhanced communication between the 225 and G600 so that a selected altitude in one box crossfills to the other box; 2) enabling the 225 to use GPSS while tracking a glideslope for improved performance on LPV approaches; 3) stability protection (autopilot engages if certain bank or pitch limits are exceeded); and 4) enabling the 225 to remain engaged when a missed approach is commanded. These upgrades would further spur sales of the 225 – and could also generate considerable revenue from existing 225 owners purchasing the upgrades.