

VNAV

This is to explain the practical application of the Honeywell Epic 27.1 Vertical Navigation (VNAV) functions. This does not add any new concepts that are not discussed during ground school rather to emphasize operational concepts used during flight operations.

VNAV Vertical Modes

VNAV provide vertical navigation on a predetermined vertical track. The VNAV button on the Guidance Panel (GP) is a toggle that toggles VNAV ON or OFF. When toggled ON, the FMA (Flight Mode Annunciator) vertical mode is shown in magenta (Figure 1).

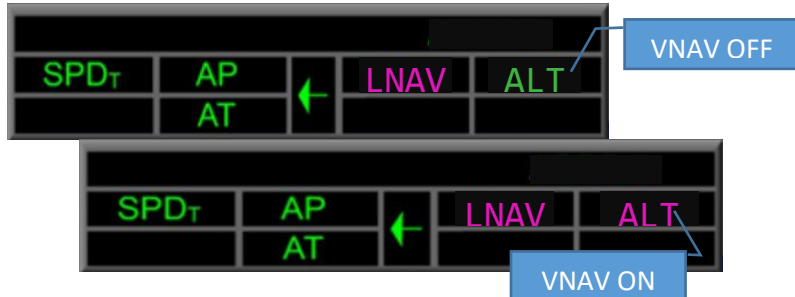


Figure 1

There are only five VNAV modes that are possible and they are ARM, FLCH, PTH, ASEL and ALT. Arm, ASEL and ALT are easy to understand and behavior of which will not be discussed in any detail in this paper. That leaves magenta FLCH and PTH which are the only two practical vertical modes that VNAV will utilize during climbs and descends. It is important to understand that VNAV functions differently in climbs vs descends. **During climbs, magenta FLCH is the only mode that VNAV utilizes for altitude changes while PTH is the default vertical mode in descends.** While PTH is the default descend mode a pilot selected magenta FLCH may be used (more on this later). Obviously there are other vertical modes that can be

utilized during climbs and descends but those are GREEN non-VNAV modes and are not included in this discussion.

Climbs

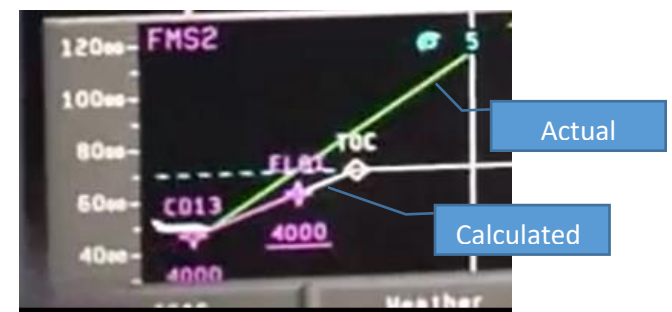
At the gate when TOGA is pressed VNAV is armed. While armed a white VNAV will be displayed in the vertical window of the FMA (Figure 2) and Dual Cue is added to the PFDs. The Vertical track added to profile section of the MFD after populating the PERF DATA pages is based on a calculation that factor in scheduled speeds, entered weights and environmental conditions as well as all the crossing restriction (speeds and altitudes) shown on the FPLN page of the MDCU.



Figure 2. FMA with TOGA pressed at the Gate arming VNAV

Reaching VNAV capture altitude after takeoff the armed VNAV will jump the FMA fence becoming active changing the vertical mode to a magenta FLCH without pilot input. At this point the aircraft is not tracking any specific vertical track. Although the previously

Figure 3. Calculated vertical track is the magenta line between CO13 & ELAI



calculated vertical track line is still shown on the profile section of the MFD it is not been followed. Instead VNAV, through FLCH, is commanding the maximum climb based on actual conditions. The

relationship between the calculated vertical track and actual track can be observed on the MFD by comparing the white and magenta vertical track lines to the airplane trajectory line (Figure 3).

While in magenta FLCH with higher altitude selected by the pilot in the altitude preselect window, VNAV will climb above all “at or above” intermediate crossing restrictions. (Figure 3) shows ELAI with a crossing restriction of “at or above” 4000’. The calculated vertical track line shows ELAI above 6000’ and the trajectory line (what we are actual going to do) is projecting that if we keep current climb rate we will be near the TOC (7000’) when we get to ELAI. If the airplane trajectory is such that a crossing(s) altitude can’t be met a scratch pad message will appear alerting the pilot to take action (increase the rate of climb).

To anticipate the behavior of VNAV It is important to understand the information displayed on the profile section of the MFD during a

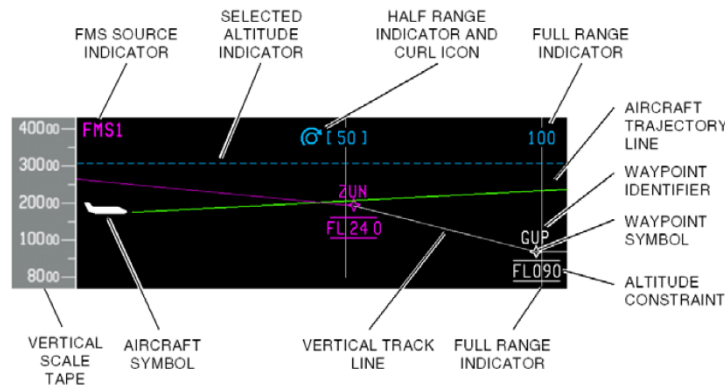


Figure 4. Vertical profile shown on the MFD

climb to ensure that the actual performance is such that all restrictions are going to be met and intervene early if necessary.

Note that even though the ELAI crossing shown on (figure 3) is labeled as “at or above” 4000’ it is drawn at a higher altitude (read fix altitude on the Vertical Scale Tape) and is the previously calculated (at the gate). The vertical track is calculated differently for an “at” or an “at or below” altitude crossing restriction. To understand why we need to understand how VNAV will behave for those type of crossing restrictions. For intermediate “at” or “at or below” crossing restrictions, VNAV will climb in magenta FLCH until the first constraint is reached leveling off at an intermediate latitude temporarily changing the vertical track modes to a magenta ASEL and then ultimately to magenta ALT. Restrictions requiring intermediate level offs are shown on the vertical scale tape at that specific altitudes. It is also important to note that the actual level offs will not occur at geographic location of those fixes. The level off will happen when the altitude is reached independent of corresponding geographic location of the corresponding fixes. The best way to categorize this VNAV behavior is STEP climb (Figure 5).

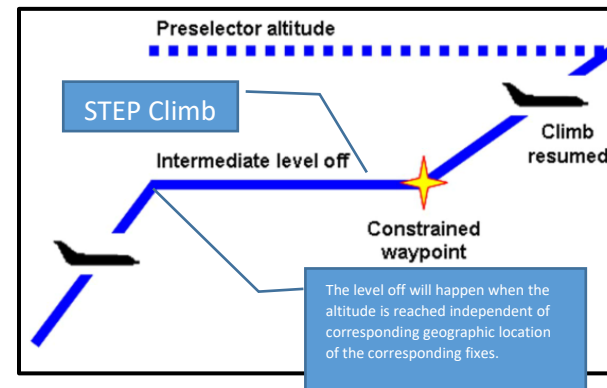


Figure 5. Step climb by VNAV to comply with an “at” or “at or below” altitude crossing restriction.

Passing the fixes, VNAV will auto transition back to magenta FLCH repeating the above described process up to the altitude selected altitude (ATC vertical clearance limit and/or cruise altitude).

Magenta FLCH remains the appropriate VNAV mode in climbs regardless whether you are cleared to “climb Via” or cleared to “Climb and Maintain” a certain altitude. For the latter, however you could use “CLIMB DIR” shown on the FPLN page to delete the intermediate altitudes restrictions (if they exist) between your current altitude and the altitude selected in the altitude preselect (cleared altitude). Deleting each intermediate altitude constraint by dropping a delete on right LSKs from your flight plan or toggling VNAV OFF will also work but are not the preferred methods. FPLN page tools are given to the pilot (such as “CLIMB DIRECT”) to make changes while staying in VNAV and minimize pilot work load.

Normal Descends

The same procedures are used for any VNAV descent including descending on STARs and/or approaches. The VNAV preferred descend mode is PTH. It is important to note unlike FLCH, PTH can only exist in magenta and has no PTH button on the GP. We get PTH when certain criteria is met. That criteria can be grouped in three parts and is as follows:

1 - A lower altitude must be set. Anytime you are cleared to descend whether to “descend via”, “cleared for an approach” or just simply “descend and maintain” the first step is always to set a lower altitude in the altitude per select window. So if you forget to set a lower altitude VNAV will never transition to PTH.

2 - VNAV must be ON with LNAV the active lateral mode (on course). The concept behind vertical navigation between two way points is based on a specific X,Y,Z coordinate for each. The X,Y

coordinates are needed to calculate the lateral distance (RUN). The Z coordinates defines the vertical RISE between the fixes. The angle (RISE over RUN) is calculated and is displayed as a vertical track. So if you are off course (LNAV is not your active lateral mode) an angle can't be calculated due to the inability to calculate a RUN and subsequently an angle to be drawn. **VNAV can be ON without LNAV but in this case VNAV will not transition to PTH.**

3- TOD must be shown ahead. The TOD must be at the same or above the aircraft altitude (TOD can't be behind or below your aircraft).



Figure 7. TOD ahead and same altitude of aircraft

In cruise and one minute prior to TOD and vertical track alert is announced. A magenta VTA is displayed on the PFD and is accompanied with a “C” chord chime. If all above criteria is met VNAV will transition (from ALT) to PTH without pilot intervention. This is the preferred way to descend when you are required to comply with altitude restrictions (such as a STAR) provided that those restrictions are included in your flight plan (displayed on your FPLN page). This is why checking the STAR crossing restrictions shown on the FPLN page in cruise is essential.

Make sure that you are cleared to descend by ATC prior to setting the lower altitude (criteria 1). If a VTA is issued and a descend clearance has not been received quarry ATC. (Figure 6) shows when a VTA is issued. Real world operations may require ATC to give you a late descent. If that should happen tools are provided to help the crew to comply with an early or late clearance and stay in VNAV (VNAV ON).

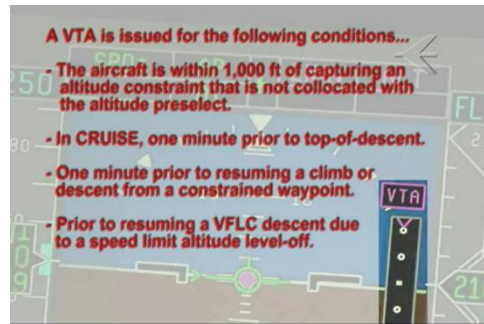


Figure 6

Late Descends

When the descent clearance is received late (TOD is behind you) and the vertical track is more than 500' below you, VNAV will not transition to PTH without pilot intervention. If "DEC NOW" (which appeared 50 NM from TOD) is still displayed on the FPL page it should be elected (Figure 8). This will initiate a descent in PTH mode at a new angle equal to 1.5 degrees more than the angle originally used by the FMS. For example if the initial descend angle used was 3.0 degrees,



Figure 8. DEC NOW

VNAV will initiate a descent at an angle of 4.5 (3.0 + 1.5) degrees. The new descend angle is limited to 6 degrees. Once established in the descent the trajectory line should then be observed to ensure that it will intersect with the original vertical track without violating

any crossing restrictions (Figure 9). If the trajectory line does not intercept with the original vertical track (steeper angle is required) or if a "DEC NOW" is not available (super late descent clearance) magenta FLCH must be selected. Consider adding drag (speed brake) if on a STAR or early landing gear extension if on approach when



Figure 9. PTH descent with a higher angle then originally used by the FMS

speed brake is not available due to flaps). If the angle needed could not be achieved notify ATC. Once the original track is intercepted VNAV will transition back to the original angle used.

Early Descends

While at a cruise altitude of FL320, 70 mile from TOD ATC issue you the following clearance: SKW100 descend now to FL300 then descend via the arrival. The bottom altitude on the arrival is 5000'. There are several ways you can setup the automation to help you comply with that clearance. Set FL300 in the altitude preselect and select magenta FLCH. Pilot intervention (selecting FLCH) to initiate the descent is needed in this situation only because we are trying to descend before TOD. After selecting FLCH, VNAV will initiate the descent and given that the altitude to be lost is less than 4000' FLCH will not schedule an idle descend. If the altitude to be lost is more than 4000' recommend that you select VS or FPA either of which

will knock you out VNAV (VNAV OFF). Reaching FL300 the FMA will transition to green ASEL then to green ALT. Make sure you allow the system to capture the altitude (see ALT in the FMA) before you set the STAR bottom altitude. This is important because if you change the altitude preselect while in ASEL you will continue your descent in FLCH. After FL300 is captured toggle VNAV back to ON and set 5000' in the altitude select. While magenta ALT is the current vertical mode VNAV will track at FL300 until the TOD is reached and will initiate a normal descent.

If you would have received the same clearance but within 50 miles of TOD "DES NOW" would have been available to you. In that instance you would still enter FL300 in your altitude preselect but select "DEC NOW". VNAV in this instance will schedule a PTH descent at a 1000' foot per minute to FL300. Note that "DEC NOW" will behave differently depending on where in relation to the TOD it is selected. If selected early (prior to TOD) it will command a 1000' per minute descent in PTH until intersecting the original vertical track (Figure 10).

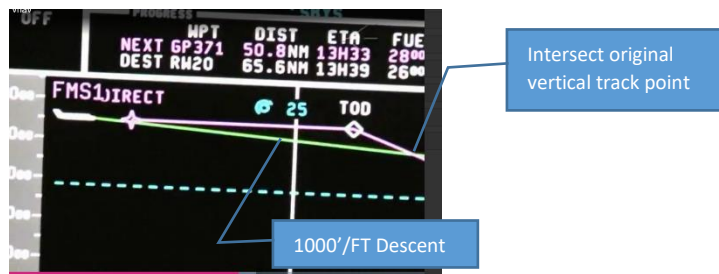


Figure 10. "DEC NOW" selected prior to TOD

After which will capture the original track and will continue the descent in PTH at the original angle. Reference the late descend

discussion above to note how "DEC Now" behaved if selected after TOD.

While in cruise at BURGL (see Figure 11) at FL330 you receive the following clearance: SKW100 cross GRIPR at FL190 then descend via. The "Vertical Direct-to" FMS descend function is the most appropriate for this scenario. Similar to a lateral direct-to in that a direct vertical path to an altitude constraint resident in the flight plan is commanded deleting only the altitudes (not the actual fixes) between your current altitude and the altitude of the fix you select (in this case GRIPR).

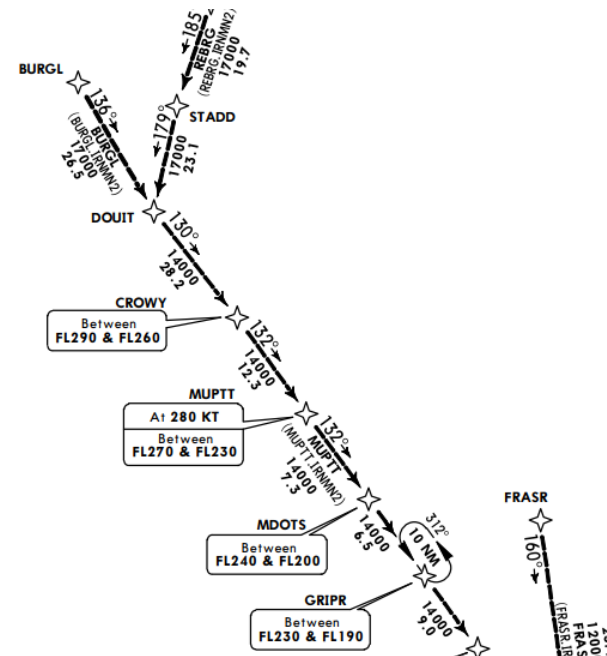


Figure 11

Vertical Direct-To is selected as follows:

- 1- Set bottom STAR altitude in the altitude preselect window (in this example 5000')
- 2- If the current fix has a window crossing constraint (ie below one alt and above another) change the constraint to an "AT" crossing constraint. In this example change the window altitude at GRIPER in the FMS to a hard altitude of FL190 (per the clearance).
- 3- Down-select the altitude constraint from the right side LSKs and reenter it (in this example same FL190 at GRIPR) into the same LSK. All intermediate vertical contaminants between you and GRIPR are removed from the flight plan and VNAV will initial a PTH descent.

Vertical Direct-To may be used (for either a late or early descends) anytime you need to descend directly to an altitude at a specific point without having to delete every intermediate constraint (if they exist) and stay in VNAV.