

EXTREME EQUIPMENT SALES & RENTALS

PowerDrive Special Rules & Common Downlink Mistakes Revision 4.0

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 Applicability: PowerDrive, available in multiple sizes
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BACKGROUND INFORMATION

This document is written to promote awareness of the special rules, common downlinking issues, and other common operational issues that Extreme has recognized in failure investigations. The document is meant as a one-time refresher for experienced users.

OVERVIEW

This bulletin will discuss the following in detail:

- Special rules and logic governing the sequence of commands that the tool recognizes:
 - MTF to GTF transition at low inclinations.
 - HIA (hold inclination & azimuth) mode engagement at low inclination.
 - PowerV or Hold Vertical mode versus 180/100% GTF; Engagement & disengagement rules.
 - Exiting HIA or IH (inclination hold) modes.
- Procedures for ensuring optimal downlink transmission and mode performance.
- Common issues observed with downlinking and recommended mitigation.
- Restrictor Setup.

MAGNETIC TOOLFACE TO GRAVITY TOOLFACE TRANSITION

MTF (magnetic tool face) to GTF (gravity tool face) is not possible if $< 1^\circ$ inclination.

If the tool is in a MTF setting with the inclination $< 1^\circ$, a GTF downlink sent will be recognized but ignored. See chart below:

Firmware	"Single/Multi Page" on App	"Tool Mode" on Excel Sheet/App	"Page" on Excel Sheet/App	Currently in MTF/GTF	Inclination	Cmd # Sent	Command Action	Result
3.2	N/A	Manual TF	N/A	MTF	$< 1^\circ$	2-27	Use Gravity Mode	Recognized but ignored b/c $< 1^\circ$. Remain in MTF.
4.1	N/A	Manual TF	Page 0 - Manual	MTF	$< 1^\circ$	2-17	Use Gravity Mode	
4.1	N/A	Manual TF	Page 0 - Manual	MTF	$< 1^\circ$	2-31	Go to Pg 0 w/ GTF neutral: 0/0	
4.6	Single	Manual TF	Single Page Mode	MTF	$< 1^\circ$	2-27	Use Gravity Mode	
4.6	Multi	Manual TF	Page 0 - Manual	MTF	$< 1^\circ$	2-17	Use Gravity Mode	
4.6	Multi	Manual TF	Page 0 - Manual	MTF	$< 1^\circ$	2-31	Go to Pg 0 w/ GTF neutral: 0/0	

If the desire is to maintain vertical, the options are therefore:

- If using firmware 3.2, engage PowerV mode which requires multiple 2-29 D/L's (process is detailed later below).
- If using firmware 4.1, engage Hold Vertical mode which requires a single 2-30 D/L.
- If using firmware 4.6 & currently on "Single Page Mode" tab, engage PowerV mode by sending a single 2-29 D/L.
- If using firmware 4.6 & currently on "Pg 0 - Manual" tab, engage Hold Vertical mode by sending a single 2-30 D/L.
- Move tool to where inclination $> 1^\circ$ and take a survey prior to sending the GTF mode D/L.

Real Event Example

- A PowerDrive tool was used on multiple runs on different wells and left in 180/100 MTF at end of first run.
- On the second run, the inclination was low and D/L's were sent to put tool in 180/100 GTF to maintain vertical.
- The GTF D/L's were received but ignored because inclination $< 1^\circ$.
- As a result, the tool remained in MTF & built angle.
- This was caught quickly & more D/L's sent to put tool in 180/100 GTF. This time the tool swapped over to GTF properly because inclination was greater than 1° .

EXTREME EQUIPMENT SALES & RENTALS

PowerDrive Special Rules & Common Downlink Mistakes
Revision 4.0

RESTRICTIONS TO ENGAGEMENT OF HOLD INCLINATION AND AZIMUTH

HIA mode will not engage if inclination is $< 10^\circ$ or $> 170^\circ$.

A downlink sent to engage HIA mode will be received but ignored if the inclination on the last survey is less than 10° or greater than 170° . The tool will remain in previous setting. An inclination greater than 100° can be caused by a sensor failure.

It is always recommended to use IH mode when operating at lower inclinations.

Real Event Example

- Initially a PowerDrive tool was set in MTF setting & building as desired.
- At $\pm 7^\circ$, an HIA downlink was sent and recognized, but ignored because inclination was less than 10° .
- The tool remained in the previous setting and continued to build.

POWERV MODE VERSUS 180/100% GTF SETTING

PowerV (Hold Vertical) mode and 180/100% GTF are different.

In situations with low angle, being in a 180/100 GTF setting is technically not the same as engaging PowerV/Hold Vertical. While both commands steer at 180/100 GTF trying to maintain vertical, the logic to engage/disengage differs.

When unlocking PowerV in 3.2 firmware 2 D/L's must be sent. First 2-29 is sent to unlock PowerV, then followed by a manual TF cmd. The tool automatically switches from PowerV to MTF mode, but the tool does not exit PowerV until the 2nd command is received.

In contrast, if a MTF D/L is sent while in 180/100 GTF, the tool will immediately be set at whatever direction it happens to be facing in 100% possibly resulting in an unpredictable build.

PowerV helped with historical issues with phantom downlinks (noise interpreted as downlinks), but with improvements over the years these are very rare. While either PowerV or 180/100 GTF can be used to maintain vertical, it's necessary to understand differences in logic to engage/disengage. If using 180/100 GTF (NOT PowerV) and near vertical, it is recommended to send the MTF downlink followed by the desired manual command while off-bottom to avoid unintended deviation while preparing to kickoff.

The figure below details how to properly engage/disengage PowerV mode while using firmware 3.2:

How it Works:

Sending a [2-29] opens a timed window (30 bit periods)

- Following with another [2-29] will engage PowerV
- Following with an absolute setting will disengage PowerV. An absolute setting consists of a Toolface and steer ratio.

The 2nd downlink must finish within 30 bit periods after completing the initial [2-29] downlink. If the DD fails to complete the downlink in the 30 bit period, sends something besides an absolute setting, or makes any other mistake, the tool will continue in its previous setting.

Disengaging PV Lock

- Not necessary to cycle pumps before downlink
- Wait at least 5 bit periods but no more than 10 between downlinks
- 2nd downlink must be fixed steer setting (not inc-hold)
- Tool will automatically switch to MTF
- Look for confirmation in RTSTAT_b if running Real-Time

Disengage Sequence using 18-second bit period

```
00:00 Start [2-29] downlink (PV unlock/lock)
04:57 Wait 90 Sec (5 bit periods)
06:27 Start desired setting downlink [X-XX]
11:24 2nd downlink complete.
      Tool will change settings at the start of the next drill cycle
```

Disengage Sequence using 60-second bit period

```
00:00 Start [2-29] downlink (PV unlock/lock)
16:30 Wait 5 min (5 bit periods)
21:30 Start desired setting downlink [X-XX]
38:00 2nd downlink complete.
      Tool will change settings at start of next drill cycle
```

Engaging PV Lock

- No need to downlink to GTF first
- Not necessary to cycle pumps before downlink
- Wait at least 5 bit periods but no more than 10 between downlinks
- Tool will automatically switch to GTF
- Look for confirmation in RTSTAT_b if running Real-Time

Engage Sequence using 18-second bit period

```
00:00 Start [2-29] downlink (PV unlock/lock)
04:57 Wait 90 Sec (5 bit periods)
06:27 Start 2nd [2-29] downlink
11:24 2nd downlink complete.
      PV will begin at start of the next Drill cycle
```

Engage Sequence using 60-second bit period

```
00:00 Start [2-29] downlink (PV unlock/lock)
16:30 Wait 5 min (5 bit periods)
21:30 Start 2nd [2-29] downlink
38:00 2nd downlink complete.
      PV will begin at start of the next drill cycle
```

EXTREME EQUIPMENT SALES & RENTALS

PowerDrive Special Rules & Common Downlink Mistakes Revision 4.0

When PowerV is engaged in firmware 3.2, the tool only responds to the following downlinks:

Command	Description
2-29	PowerV Unlock/Engage
2-24	Downlink bit period (18 seconds)
2-25	Downlink bit period (36 seconds)

4.1+ DOWNLINK ELIMINATION

In firmware 4.1 and above with multi-page, a downlink step has been eliminated.

In 4.1 or 4.6 firmware from “Pg 0 – Manual”, it is only necessary to send the 2-30 downlink to enter “Pg 1 – Hold Vertical Mode”. To exit “Hold Vertical Mode”, there are multiple MTF downlinks to choose from which will also take you back to “Page 0 – Manual” in one step.

In 4.6 firmware from “Single Page Mode”, it is only necessary to send the 2-29 downlink to enter PowerV mode. To exit, it is only necessary to send a manual TF command. The tool expects to be vertical using PowerV and will automatically swap to MTF upon exiting when a manual TF cmd is sent.

When exiting IH/HIA mode in 3.2 firmware or in “Single Page Mode” using 4.6 firmware to go to a manual mode setting, the tool will remain in GTF. In contrast, using firmware 4.1/above there are 2 D/L options to go to a manual mode setting from either “Pg 2 - IH” or “Pg 3 - HIA. Cmd 1-0 can be sent to “Go to Page 0 w/ a MTF neutral setting” or cmd 2-31 can be sent to “Go to Page 0 w/ a GTF neutral setting”. After it is necessary to send the desired TF/SR cmd if neutral is not the desired setting.

CAUTION: Be careful not to accidentally downlink to MTF mode in the lateral because it will not work properly at higher inclinations.

DOWNLINKING PROCEDURAL BASICS

Several procedural issues have been recognized with downlinking procedures.

- PowerDrive can accept flow & rotary D/L's. The variance for flow is typically 20% between high & low levels. The variance for rotary must be at least 40 RPM.
- There are 3 different bit periods (18 sec, 36 sec, & 60 sec) available when sending D/L's. The RSS may require larger bit periods & greater variations in flow as depth & mud weight increase. The default bit period for flow D/L's is 18 sec and 60 sec is always available. Only 36 & 60 sec are used for rotary D/L's and are available at any given time. **CAUTION: Prior to sending a 36 sec flow D/L, the tool should first be D/L'd to a 36 sec bit period instead of the default 18 sec bit period.**
- The waiting times of stable flow/rotary necessary prior to starting a downlink are shown below:

Table 5-3: Start up downlink command waiting times

Bit Period (seconds)	Waiting Time (seconds)
18	180
36	180
60	240

Table 5-4: Normal drilling waiting times

Bit Period (seconds)	Waiting Time (seconds)
18	60
36	120
60	180

Table 5-5: Waiting times for consecutive downlinks

Bit Period (seconds)	Waiting Time (seconds)
18	90
36	180
60	300

EXTREME EQUIPMENT SALES & RENTALS

PowerDrive Special Rules & Common Downlink Mistakes
Revision 4.0

HIA & IH MODES RECOMMENDATION AND LOGIC

An illustration below details how to swap between modes if using 3.2 firmware or "Single Page Mode" using 4.6 firmware.

From Manual mode:

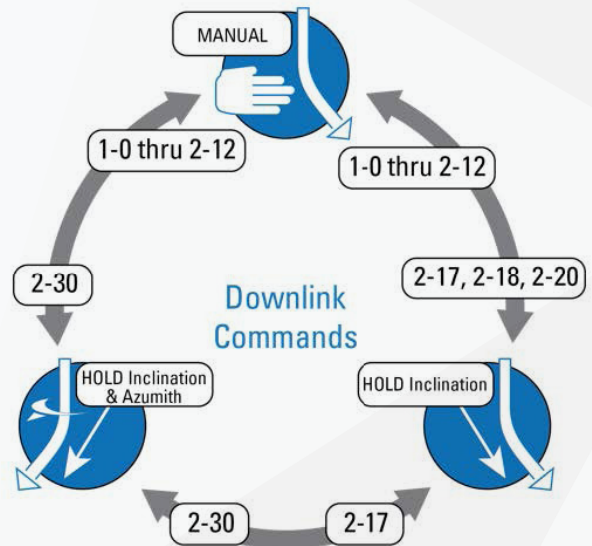
- Send downlink commands 2-17, 2-18 or 2-20 to switch to Inclination Hold mode. The target inclination will be taken from the inclination in the previous static survey. The tool will switch to GTF
- Send downlink command 2-30 to switch to Hold Inclination and Azimuth (HIA) mode. The target inclination and target azimuth will be taken from the inclination and azimuth in the previous static survey. The tool will switch to GTF

From Inclination Hold mode:

- Send any downlink commands from 1-0 thru 2-12 to switch to Manual mode. The tool will remain in GTF.
- Send downlink command 2-30 to switch to Hold Inclination and Azimuth (HIA) mode. **The target inclination and target azimuth will be taken from the inclination and azimuth in the previous static survey**

From Hold Inclination and Azimuth (HIA) mode:

- Send any downlink commands from 1-0 thru 2-12 to switch to Manual mode. The tool will remain in GTF.
- Send downlink command 2-17 to switch to Inclination Hold mode. **The target inclination will be taken from the inclination in the previous static survey**



It is highly recommended to take a survey prior to engaging an automatic mode (IH or HIA). In the past, there have been several instances where the tool was in 100% manual settings and then was D/L'd to IH/HIA mode on the fly without cycling the pumps to get a survey. This can lead to undesired steering correction because the targets for automatic mode are chosen based on the last static survey.

IH mode

PowerDrive steers along a target inclination during tangent & horizontal sections. Only inclination is controlled by algorithm while the azimuth can be manually corrected by the user through left/right turn corrections up to 50%.

Recommended operating range:

Inclination	IH Mode Engage
0-3°	Do Not Use
3-5°	Not Recommended
5-10°	Caution Recommended
10-90°	Normal operating range

HIA mode

Simultaneous closed loop control of inclination & azimuth. Targets captured from the last static survey. Both the inclination & azimuth target can be nudged independently.

Important Notes about HIA:

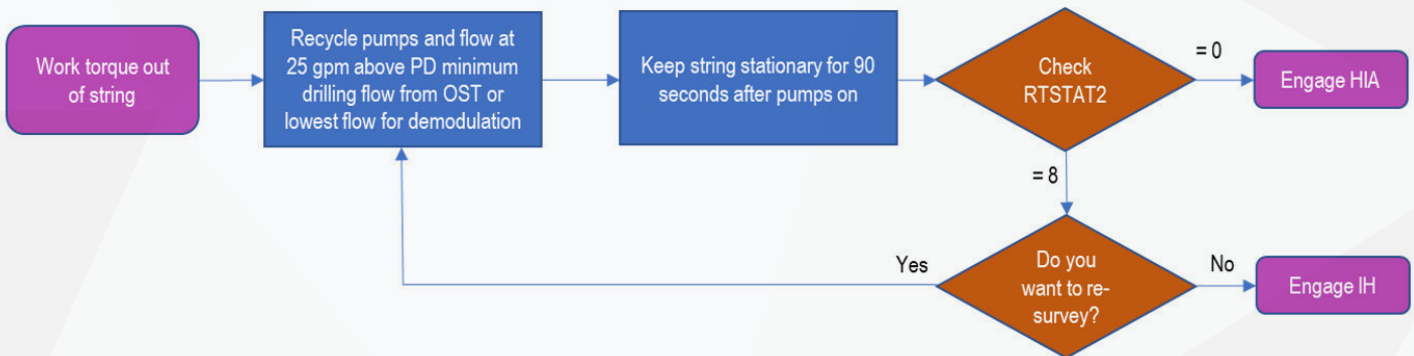
- Will not engage if inclination is <10° or > 170°.
- It is recommended to use HIA at inclinations above 20° where the azimuth is more stable.
- Azimuth nudge size is dependent on current inclination:

Inclination (deg)	Azimuth Nudge Size (deg)
10	11.5
20	5.8
30	4
40	3.1
50	2.6
60	2.3
70	2.1
80	2.0
90	2.0
95	2.0

EXTREME EQUIPMENT SALES & RENTALS

PowerDrive Special Rules & Common Downlink Mistakes Revision 4.0

- High risk scenarios: low angle, high-dip angle, drilling close to the zone of exclusion and near magnetic N/S.
- Ensure RTSTAT2 is included in MWD frames if RT is available to QC the PowerDrive survey quality. A value of '0' means a good survey and a value of '8' means a bad survey based on GTOTAL. Several factors can affect the tool survey accuracy, such as procedure, shock & vibration, or pipe movement. If having difficulties getting a good static survey while clear of casing, attempt the following workflow:



- The tool requires at least one good static survey free from magnetic interference before HIA can be engaged. As stated earlier, the inclination at the PowerDrive also needs to be $> 10^\circ$. Before engaging HIA, compare the continuous azimuth readings to what's expected. There is typically a slight offset in the azimuth readings caused by drill string magnetic issues. If there is a significant discrepancy ($>15^\circ$), be wary of potential azimuth issues.
- If significant turn correction ($>6^\circ$) is required and azimuth is within 25° of magnetic N/S, then consider using IH or manual mode instead of HIA for the turn.
- It is highly recommended to use IH mode first and drill for at least 500' prior to engaging HIA to help ensure getting a good survey and avoid chasing a bad azimuth. Avoid taking surveys on the fly during this period.
- Once HIA has been engaged, it will lock onto certain static survey reference values. Monitor the PowerDrive RT data (Inc/Azi targets, toolface, steer ratio, etc.) if available to confirm close to expected readings. If a poor static survey reference is suspected, it is necessary to exit HIA mode and then re-engage after taking a good static survey to choose new reference values.

COMMON ISSUES OBSERVED WITH DOWNLINKING & RECOMMENDED MITIGATION

There are several common downlinking issues presented below.

Changing from MTF (magnetic tool face) to GTF (gravity tool face) mode or vice versa

When the tool swaps from MTF to GTF, it converts the last MTF setting into a GTF equivalent based on the survey azimuth.

When going from GTF to MTF, it randomly stops at a high side value when the D/L is received.

General Recommendations and Procedures:

- If in a manual setting using firmware 3.2 and you want to swap from MTF to GTF or vice versa, it will take 2 D/L's:
 - First, send either command 2-27 (Use Gravity Mode) or 2-28 (Use Magnetic Mode) depending on what's needed.
 - Second, send the desired manual TF/steering ratio command (e.g., 1-4 for 0/100%).
- If in a manual setting using firmware 4.1/above and on "Page 0 – Manual", it will take 2 D/L's:
 - First, send either command 2-17 (Use Gravity Mode) or 2-18 (Use Magnetic Mode) depending on what's needed. Note, you could also send commands 2-31 (Go to Pg 0 w/ GTF neutral) or 1-0 (Go to Pg 0 w/ MTF neutral).
 - Second, send the desired manual TF/steering ratio command (e.g., 1-4 for 0/100%).
- If in an automatic setting IH/HIA using firmware 3.2 and need to go to a MTF setting, it will take 3 D/L's:
 - First, D/L to a manual setting such as command 1-1 (0/0%). The tool will accept this as a GTF setting.
 - Second, D/L to use MTF with command 2-28.

EXTREME EQUIPMENT SALES & RENTALS

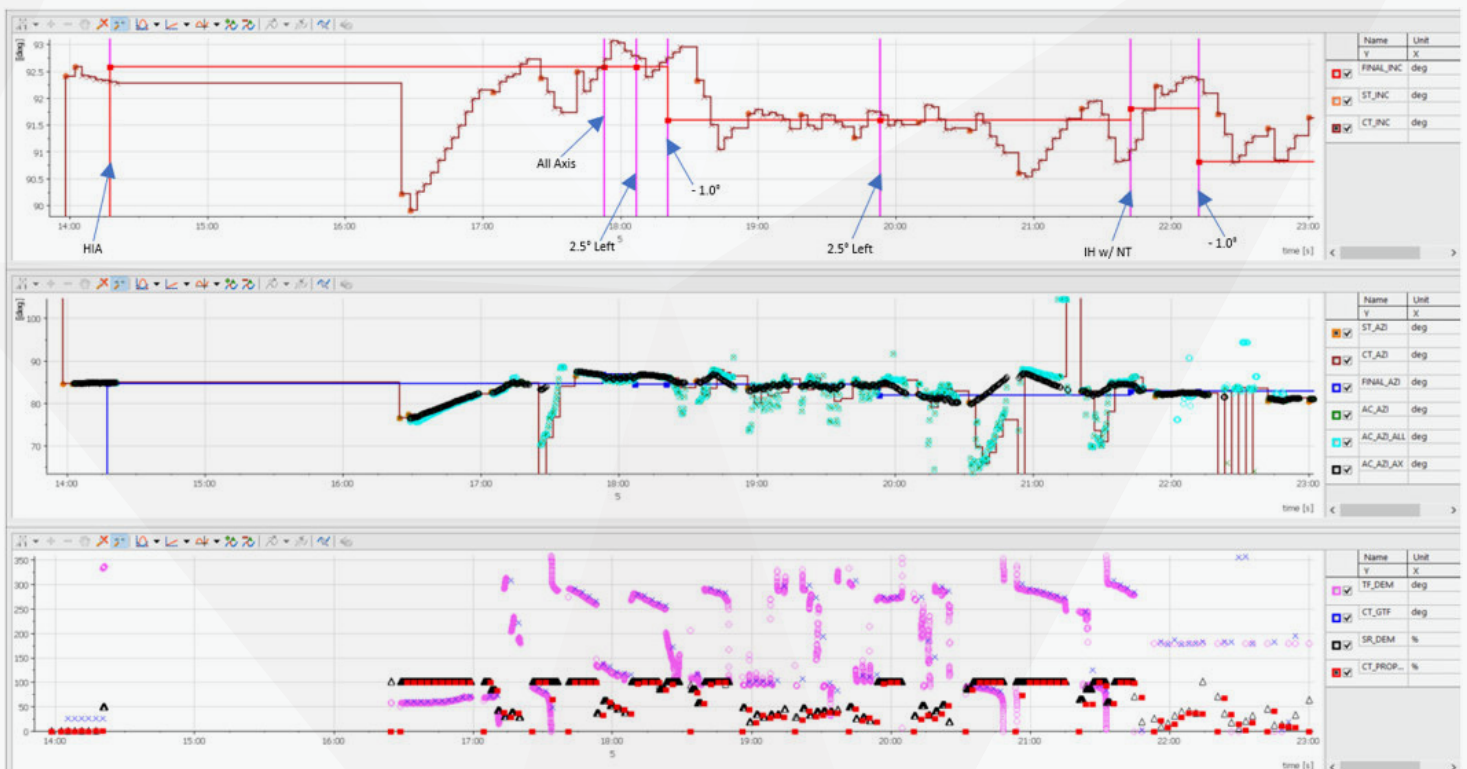
PowerDrive Special Rules & Common Downlink Mistakes Revision 4.0

- Third, send the desired manual TF/steering ratio command (e.g., 1-4 for 0/100%).
- Note, if a MTF D/L (2-28) is sent while in an automatic mode (IH/HIA) prior to going to a manual setting, the D/L will be recognized but ignored.
- If in an automatic setting IH/HIA using firmware 4.1/above and need to go to a MTF steering setting, it will take 2 D/Ls:
 - First, send command 1-0 (Go to Pg 0 w/ MTF neutral).
 - Second, send the desired manual TF/steering ratio command (e.g., 1-4 for 0/100%).
- High Gain (ROP Range 1, 20-100 ft/hr) versus Low Gain (ROP Range 2, 80-400 ft/hr) downlinks
 - All tools are programmed with High Gain as default which can be verified on the OST paperwork.
 - The downlink names are misleading and occasionally get sent based on the current ROP incorrectly.
 - These downlinks pertain to the responsiveness of the tool with High Gain being more responsive and Low Gain being less responsive. In most cases, there is no need to send the Low Gain downlink. However, if the tool is constantly overshooting inclination targets or being overly reactive in an automatic mode, the Low Gain D/L can be sent to try and smooth out the trajectory.
- Engage/disengage DZM (dead zone management) downlink
 - Command 2-31 in firmware 3.2. Not available in 4.1 firmware, but on the Engineering Page in 4.6 firmware.
 - When engaged it changes how the tool manages the torquer distributions where it spends minimal time near zero which theoretically might improve jamming prevention. The downside is that it makes the tool jumpy which could potentially lead to other issues when improperly used. It is NOT recommended to use this downlink.
- Zone of Exclusion (need to consider when planning/drilling a well)
 - Exists in the following situation & need to have both to be affected:
 - +/- 10° if magnetic declination.
 - +/- 10° of 90 – dip (90° minus your magnetic dip).
 - In this situation, you cannot use HIA, MTF or collar RPM downlinks. IH and GTF will still work properly.
- Downlinking to neutral using 4.1/above software using multi-page
 - There are 2 neutral D/L options while using multi-page. They have the same cmd # on each page in case the user gets confused as to what setting the tool is actually in. Command 1-0 is “Go to Page 0 with MTF neutral setting: 0/0%” and command 2-31 being “Go to Page 0 with GTF neutral setting: 0/0%”.
 - When D/L’ing to neutral at higher inclinations or in the lateral, be careful when selecting the command. In the past, there have been several instances where the user accidentally put the tool into MTF mode during the lateral. MTF mode will not work properly in the lateral.
- Drilling near due North/South while in HIA mode
 - At each pump-up event the PowerDrive takes a static 6-axis survey. This static survey becomes the reference value that is locked into memory when HIA is engaged. The tool then relies on single-axis continuous inclination & azimuth measurements to determine desired steering ratio and toolface. Continuous surveys traditionally rely on a single (along-tool) axis while drilling and utilize the previous two axis values from the last static survey to calculate the continuous value. This is to help stabilize the measurement as the two axes perpendicular to the tool axis experience the most fluctuations as the tool rotates and are susceptible to lateral movement or S&V. While drilling away from N/S, PowerDrive uses this single-axis method.
 - When drilling near N/S, holding these two axes steady can cause significant error in azimuth due to the very small magnitude measured by the perpendicular axes. To compensate, PowerDrive will utilize a full 6-axis survey to calculate the continuous readings to improve accuracy. It does this by holding the CU geostationary using the torquers to approximate a static survey.

EXTREME EQUIPMENT SALES & RENTALS

PowerDrive Special Rules & Common Downlink Mistakes Revision 4.0

- Firmware 3.2 summary while drilling in HIA:
 - Tool actively decides whether to use single, blended, or all-axis measurements to calculate the azimuth.
 - It uses single-axis for most situations but when +/- 20° of N/S it will utilize either blended or all-axis.
 - Using blended or all-axis can improve accuracy; however, it is also more susceptible to vibration and when the tool switches automatically between azimuth types this can cause azimuth shifts which affect steering.
- Firmware 4.1/above summary while drilling in HIA:
 - Tool operates similarly with later versions, but a new D/L gives the option to force all-axis azimuth while in HIA. You get the benefits of improved survey accuracy and do not have to worry about azimuth shifts while drilling near due N/S; however, all-axis measurements are still more susceptible to vibration and could be noisy at times.
 - It is not recommended to send the 2-19 D/L (Use Enforced All Axis Azi Measurement) unless +/- 20° from N/S. Below is an example where the all-axis D/L was sent while drilling at +/- 85°. The all-axis readings were more erratic due to severe S&V which affected steering intermittently.



- Once HIA is disengaged, the 2-19 D/L is canceled. If HIA is re-engaged, the 2-19 can be sent again if desired.
- Note, after the 2-19 D/L is sent, it will acquire a new target. The reason behind this is because the all-axis calculated continuous azimuth is most likely going to be different from the single or blended; furthermore, you don't want to steer hard toward a target calculated with different methods.
- Downlinking using the wrong page while using firmware 4.1/above
 - It is recommended to have real-time data, if possible, when using multi-page downlinking options.
 - Once a D/L is sent, look at all the real-time data to make sure steering as expected and not just the D/L confirmation.

EXTREME EQUIPMENT SALES & RENTALS

PowerDrive Special Rules & Common Downlink Mistakes Revision 4.0

- In the past, there have been several instances found when comparing the D/L's (DD reported vs tool accepted) where the user thought he/she was on a different page. Each incident is different and could be due to a missed D/L keeping them on the incorrect page or possible just going to the incorrect page on the excel sheet/app prior to sending the D/L to change the page, etc.
- When there is doubt as to what setting or page the tool is on, there are 2 neutral D/L options while using multi-page which have the same cmd# on each page. Command 1-0 is "Go to Page 0 with MTF neutral setting: 0/0%" and command 2-31 being "Go to Page 0 with GTF neutral setting: 0/0%". Be sure to consider whether MTF or GTF is needed.

RESTRICTOR SETUP

When using a restrictor, it recommended to set up the hydraulics keeping the flow restrictor psi drop less than 50% of the total psi drop to avoid damage/erosion to the restrictor and/or bias unit body.