

## Pac to PacHP transition application note

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## Introduction

The XtrapulsPacHP™ servo drive is an upgrade of the current XtrapulsPac™ servo drive range. This servo drive upgrade concerns the mechanical housing, a technical improvement and an increased servo performances level.

The new XtrapulsPacHP™ servo drive is fully compatible with the current XtrapulsPac™ servo drive for product replacements: same dimensions, same connector pinouts. Furthermore, the current XtrapulsPac™ servo drive parameter file is also compatible with the XtrapulsPacHP™ servo drive.

A new parameter set allows activating the new functionalities and increasing the servo performances level with the new XtrapulsPacHP™ servo drive. The Gem Drive Studio release version greater than or equal to 5.30 is required for accessing these new features.

This document provides only information about technical changes and new functionalities of the XtrapulsPacHP™ drive with regard to the current XtrapulsPac™ servo drive range. Please refer to the general product manuals for complete information about the XtrapulsPac™ servo drive range:

- XtrapulsPac™ Installation Guide
- XtrapulsPac™ User Guide
- XtrapulsPac™ Safe Torque Off manual
- Gem Drive Studio software Quick Start manual.
- EtherCAT® fieldbus interface.
- XtrapulsGDPS™ Power Supply Unit manual.

### 1) XtrapulsPacHP™ product identification

The XtrapulsPacHP™ servo drive housing differs from the current XtrapulsPac™ servo drive. The XtrapulsPacHP™ version can be easily identified by the blue front panel.

**Current XtrapulsPac™ servo drive**



**New XtrapulsPacHP™ servo drive**



## 2) XtrapulsPacHP™ hardware change

The main differences between the current XtrapulsPac™ and the XtrapulsPacHP™ versions concern the fieldbus and the communication ports location. Other connectors are fully compatible for product replacements.

### 2-1) RS232 port and USB port

The RS232 communication port available on the current XtrapulsPac™ servo drive for the parameter setting via the Gem Drive Studio PC software has been moved from the front panel to the top of the drive as shown below.

#### Current XtrapulsPac™ servo drive

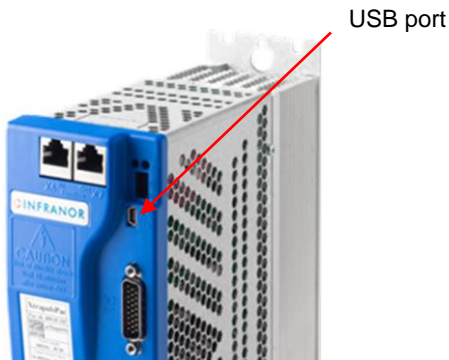


#### New XtrapulsPacHP™ servo drive



A new USB communication port is available on the front panel of the XtrapulsPacHP™ servo drive for the parameter setting via the Gem Drive Studio PC software.

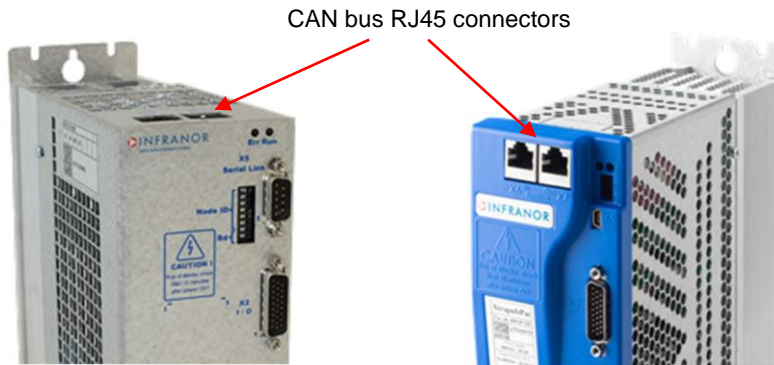
#### New XtrapulsPacHP™ servo drive



### 2-2) Fieldbus connectors on the XtrapulsPacHP-ak™ version

The CAN bus RJ45 connectors have been moved from the top of the drive to the front panel.

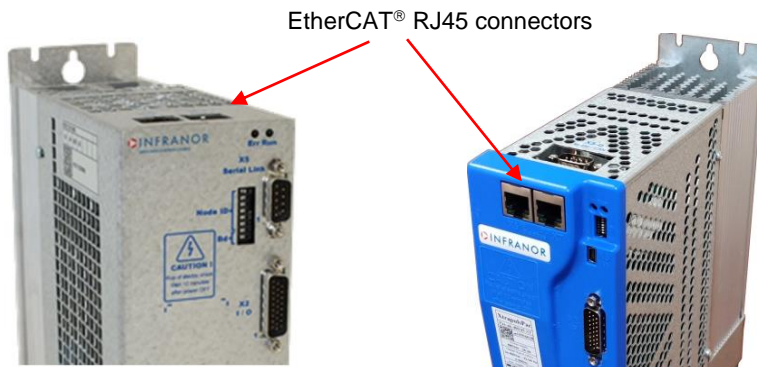
**Current XtrapulsPac-ak™ servo drive**      **New XtrapulsPacHP-ak™ servo drive**



### 2-3) Fieldbus connectors on the XtrapulsPacHP-et™ version

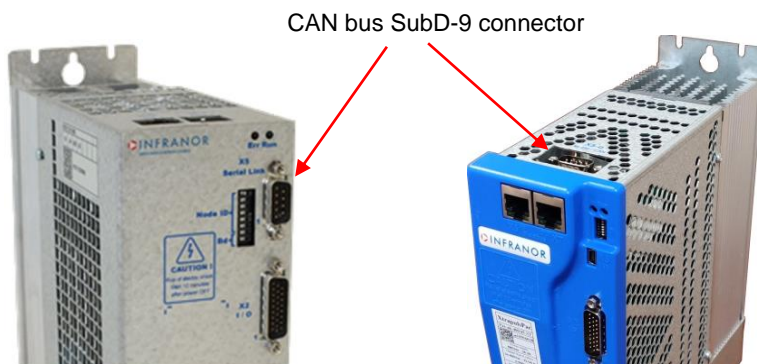
The EtherCAT® bus RJ45 connectors have been moved from the top of the drive to the front panel.

**Current XtrapulsPac-et™ servo drive**      **New XtrapulsPacHP-et™ servo drive**



The CAN bus SubD 9 connector has been moved from the front panel to the top of the drive.

**Current XtrapulsPac-et™ servo drive**      **New XtrapulsPacHP-et™ servo drive**



### 3) XtrapulsPacHP™ technical improvements

Hardware upgrade	<b>Servo drive</b>	<b>XtrapulsPac™</b>	<b>XtrapulsPacHP™</b>
	Current measurement resolution	12 bit	16 bit
	Resolver conversion resolution	12 bit	16 bit
	Analog inputs resolution	12 bit	16 bit
	Analog output resolution	8 bit	12 bit
PWM frequency	<b>Servo drive</b>	<b>XtrapulsPac™</b>	<b>XtrapulsPacHP™</b>
	Switching frequency	8kHz	Selectable: 4kHz, 8kHz, 16kHz
Speed and position controller	<b>Servo drive</b>	<b>XtrapulsPac</b>	<b>XtrapulsPacHP</b>
	Sampling rate	2kHz	Selectable: 2kHz, 4kHz, 8kHz

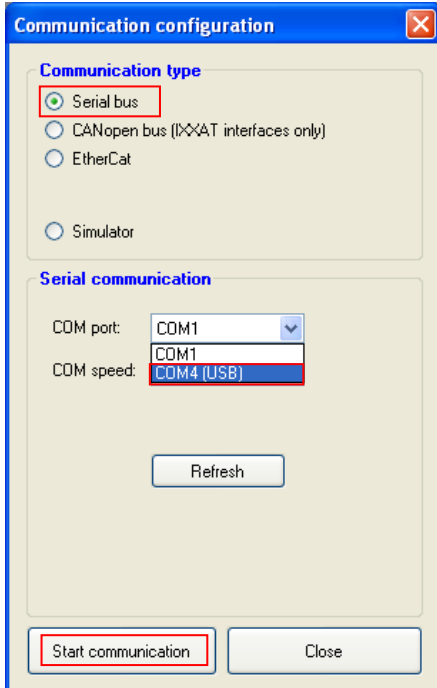
### 4) XtrapulsPacHP™ specifications evolution

Current loop bandwidth	<b>PWM frequency</b>	<b>Current sampling rate</b>	<b>Max current loop BW (-3db)</b>
	4kHz	8kHz	1000Hz
	8kHz	16kHz	2000Hz
	16kHz	32kHz	3000Hz
Speed and position loop bandwidth	<b>Sampling rate select</b>	<b>Max speed loop BW (-3db)</b>	<b>Max position loop BW (-3db)</b>
	2kHz	200Hz*	75Hz*
	4kHz	400Hz*	150Hz*
	8kHz	800Hz*	300Hz*
* with high resolution encoder feedback			

## 5) XtrapulsPacHP™ setup and commissioning

### 5-1) USB port communication

The USB communication is started in the Gem Drive Studio PC software (from release 5.30) as shown below.



Select the “Serial bus” communication type.

The detected USB communication ports are displayed in the “COM port” list.

When the drive USB port has been selected, start the communication



In a noisy environment, a USB to USB isolator may be required for a better PC-drive communication. An example of such devices is shown below.



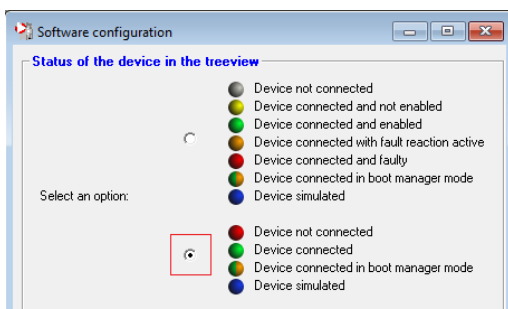
UHR 401 model



UH401 model

For more information, please see B&B website: [www.bb-elec.com/](http://www.bb-elec.com/)

**Remark:** If the following Gem Drive Studio PC software configuration is selected, the cyclic drive status display with a refreshing period of 1 second is disabled. In this case, the USB communication traffic is reduced, and operation in a noisy environment is more robust.





## 5-2) Drive PWM frequency

### 5-2-1) Influence of the drive PWM frequency

The XtrapulsPacHP™ PWM frequency default configuration is 8kHz. This is the optimum value for the XtrapulsPac™ servo drive range, regarding dynamic performances and power losses at rated current. Other PWM frequency settings must be used only for very specific application requirements.

PWM frequency at 4kHz is required only when the drive power losses must be reduced for specific applications. The origin of this requirement could be a reduction of the drive external heatsink when the cold-plate cooling version is used. The drive power losses reduction could also be required when the machine efficiency must be increased (less electrical power consumption). However, when the PWM is operating at 4kHz, the drive and motor switching frequency noise remains within the human audible range. Furthermore, the motor current ripple and the motor heating can be increased when using low-inductance motors.

PWM frequency at 16kHz is required only when the drive and motor switching frequency noise must be dropped out of the human audible range or when the drive current loop bandwidth must be increased for a specific motor (high speed with high number of poles). However, when the PWM is operating at 16kHz, the drive power losses are increased. Consequently, the drive rated current must be reduced by 30% with regard to the rated output current value given in the drive specifications (see XtrapulsPac™ Installation guide).

### 5.2.2) PWM frequency changing

The drive PWM frequency can be changed by using parameter 0x31F6-1 as described below.

Index	0x31F6
Name	Power stage parameters
Object Code	ARRAY
Number of Elements	1

#### Value Description

Sub Index	1
Description	PWM frequency value
Data Type	Unsigned16
Access	rw
PDO Mapping	No
Unit	Hz
Value	4000 or 8000 or 16000
Remark	<p>The new PWM frequency value is only effective at the drive 24V power up.</p> <p>PWM frequency changing Procedure:                      -change the object value with disabled drive                      -store parameters into the drive                      -switch off and switch on again the drive 24V logic supply</p> <p>The current loop gains are automatically adapted inside the drive regarding the PWM frequency value.</p>



### 5-3) Speed and position controller sampling rate selection

#### 5-3-1) Influence of the controller sampling rate

The controller sampling rate introduces a delay into the servo loop. This delay can be modeled by a 1<sup>st</sup> order low-pass filter with a time constant equal to approximately half of the sampling period value (reverse of the sampling rate). So, the choice of the servo loop sampling rate influences both servo loop stability and max. allowable bandwidth.

According to the servo systems theory, the max. value for the servo loop bandwidth is bounded by the controller sampling rate. The sampling rate value must be 5 to 10 times higher than the required servo loop bandwidth.

However, in the real world, for a servo drive, there are also other factors which limit the max. possible servo loop bandwidth. The most common bandwidth limiting factors are listed below:

- The position sensor delay (limits the servo loop stability especially with resolver feedback),
- The position sensor resolution (limits the servo loop gain value because of the quantization noise),
- The load mechanical coupling elasticity, backlashes and frictions (mechanical resonances).

In practice, the highest servo loop bandwidth can only be reached when the following conditions are met for the servo system:

- High resolution motor position sensor (for example 20-bit encoder for a rotating motor),
- Less than 1 for the load inertia to motor inertia ratio,
- Stiff motor-load mechanical coupling without backlashes,
- Sampling rate greater than 5 to 10 times the required servo loop bandwidth.

For a given servo loop gain setting, the influence of the sampling rate changing is discussed below.

- When the sampling rate is decreased, the internal servo loop delay is increased. In this case, the system phase margin is reduced, and the loop stability is also reduced (increased step response overshoot, reduced damping, possible oscillations).
- On the other hand, when the sampling rate is increased, the servo loop stability is increased. But the servo loop filtering is modified because of the reduced internal delay. So, in case of high frequency mechanical resonance due to the mechanical coupling, the servo loop may become unstable.

In conclusion:

- An higher sampling rate allows reaching higher servo loop bandwidth, but other bandwidth limiting factors must also be considered (motor position sensor resolution, motor-load mechanical coupling design).
- For a given application (servo drive + motor + load), changing the sampling rate will modify the servo loop filtering behavior. The consequences of this change are not fully predictable and the servo loop may become unstable.

#### 5-3-2) Changing the drive controller sampling rate

The XtrapulsPacHP™ default controller sampling rate value is 2kHz (factory-set). This value ensures the compatibility with the current XtrapulsPac™ servo drive range in case of product replacement.

For changing the XtrapulsPacHP™ controller sampling rate value, a Gem Drive Studio release version greater than or equal to 5.30 is required. Please, see our website [www.infranor.com](http://www.infranor.com) for downloading the “Gem Drive Studio” software.

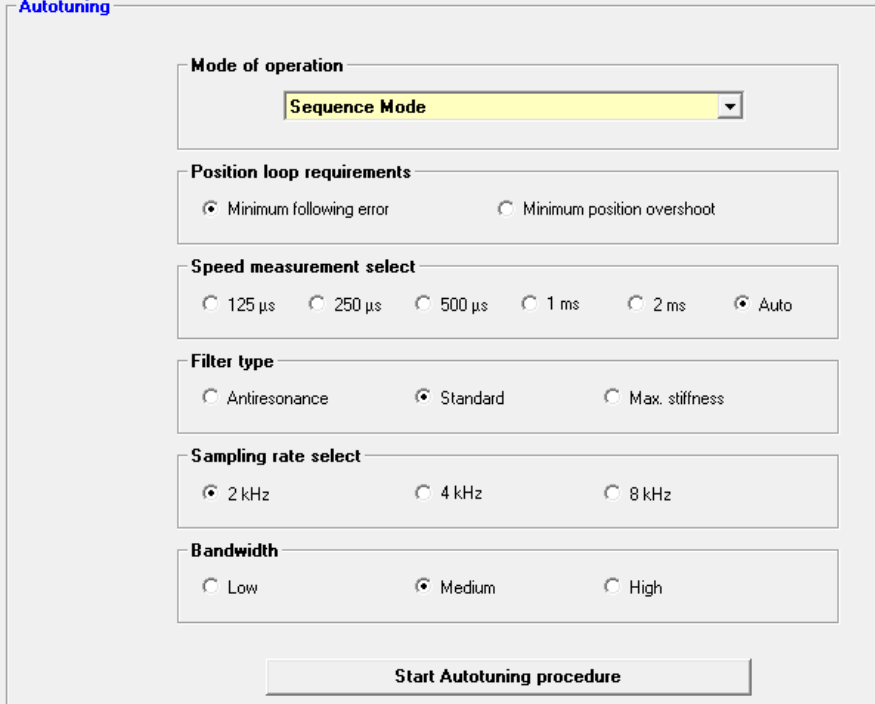


The sampling rate value can only be changed, with disabled drive.

## 5-4) Servo loop adjustment by using the Auto-tuning procedure

### 5-4-1) Auto-tuning configuration

The XtrapulsPacHP™ configuration window for the drive Auto-tuning procedure is shown below.



The drive operating mode is selected first according to the application:

- In Velocity mode, only the speed loop gains are calculated by the Auto-tuning procedure.
- In Position mode, all gains of both speed and position regulators are calculated.

The position loop requirement is concerned only if the position mode was selected before:

- The choice Minimum following error allows getting an accurate following of the position reference value during the whole motor displacement. In this case, all feedforward gain values are calculated.
- The choice Minimum position overshoot allows getting a motor positioning without any overshoot of the target position. In this case, all feedforward gain values are set at 0, and the motor position is lagging with regard to the position reference value during the whole motor displacement.

The Speed measurement filter time constant is set according to the motor position sensor resolution and the acceptable noise level in the speed measurement.

- The shortest speed measurement filter time constant allows getting the highest servo controller gain value and, consequently, the highest servo loop bandwidth. However, in case of low position sensor resolution, the quantization noise will result in a high level of audible motor noise. This motor noise is due to the position measurement LSB flickering.
- The larger the speed measurement filter time constant, the better the position sensor quantization noise filtering. But, in this case, because of the increased speed measurement delay, the servo controller gain value is reduced and so the servo loop bandwidth.



The speed measurement filter time constant value cannot be lower than the servo loop sampling period value (reverse of the sampling rate).

-When « Auto » is selected, the speed measurement filter time constant value is calculated by the Auto-tuning procedure. The choice of the time constant value is made according to the position sensor resolution and the motor + mechanical load specifications in order to get the lowest audible motor noise level. So, this automatic selection may lead to a low servo loop gain value and a reduced servo loop bandwidth in case of poor position sensor resolution or heavy mechanical load.

The servo loop Filter type is selected according to the drive application.

- The Standard filter type is suitable for most applications with a stiff enough mechanical coupling between the servo motor and the load and no mechanical resonance on the mechanical load.

- The Anti-resonance filter type is using a 3<sup>rd</sup> order low pass filter on the current command in order to filter servo loop oscillations dues to the axis mechanical resonances (loud noise in the motor). In this case, the resulting servo loop bandwidth is lower than the mechanical resonance frequency value.

- The Maximum stiffness filter type is used when minimum position and velocity deviation is required regarding the set point value and the load disturbances. A very high integral gain value is set and the controller damping gain allows reducing the servo loop overshoot. In this case, the resulting servo loop bandwidth is the highest regarding the other filter type selection.

The sampling rate and the servo loop bandwidth are both directly related as shown on the following chart.

Sampling rate value	2kHz			4kHz			8kHz		
Bandwidth select	Low	Med	High	Low	Med	High	Low	Med	High
Max speed loop BW (-3db)	50Hz	100Hz	200Hz	300Hz	350Hz	400Hz	500Hz	650Hz	800Hz
Max position loop BW (-3db)	18Hz	37Hz	75Hz	100Hz	130Hz	150Hz	180Hz	240Hz	300Hz

Remark: in this chart the bandwidth values are given for the maximum stiffness adjustment

For a given sampling rate value there are 3 selectable Bandwidth.

- The High bandwidth choice result in the highest gain values with minimum servo loop filtering.
- The Medium bandwidth choice result in a better servo loop filtering with reduced gain values.
- The Low bandwidth choice set an increased servo loop filtering with lower gain values.

The most suitable bandwidth selection for a given application depends mainly on the following points:

- the position sensor type (resolver, TTL encoder, SinCos encoder, digital encoder),
- the position resolution for an encoder sensor type,
- the motor-load mechanical coupling (backlash, coupling elasticity),
- the load mechanical structure (frictions, mechanical resonance).

So, the Auto-tuning procedure must be generally executed with different settings in order to found the most suitable sampling rate and bandwidth selection.

### 5-4-2) Auto-tuning procedure execution

When the Auto-tuning configuration has been set, the Auto-tuning procedure can be started.



It is recommended to start the Auto-tuning with the drive disabled. A wrong Auto-tuning configuration regarding the application can result in the servo loop instability.

The Auto-tuning procedure identifies first the motor and mechanical load specifications by using a small load displacement. Then, the appropriate gain values are calculated according to the user's Auto-tuning configuration.



It is recommended to reduce the drive current capability and set the I2t protection in the Fusing mode before enabling the drive after the Auto-tuning has been performed. A wrong Auto-tuning configuration regarding the application can result in the servo loop instability when the drive is enabled.

When the drive is enabled after the Auto-tuning, in case of loud noise in the motor at standstill or when running, start a new Auto-tuning procedure by selecting a lower Bandwidth.

### 5-4-3) Iterative Auto-tuning process

For a given application, the most suitable Auto-tuning configuration depends on the following points:

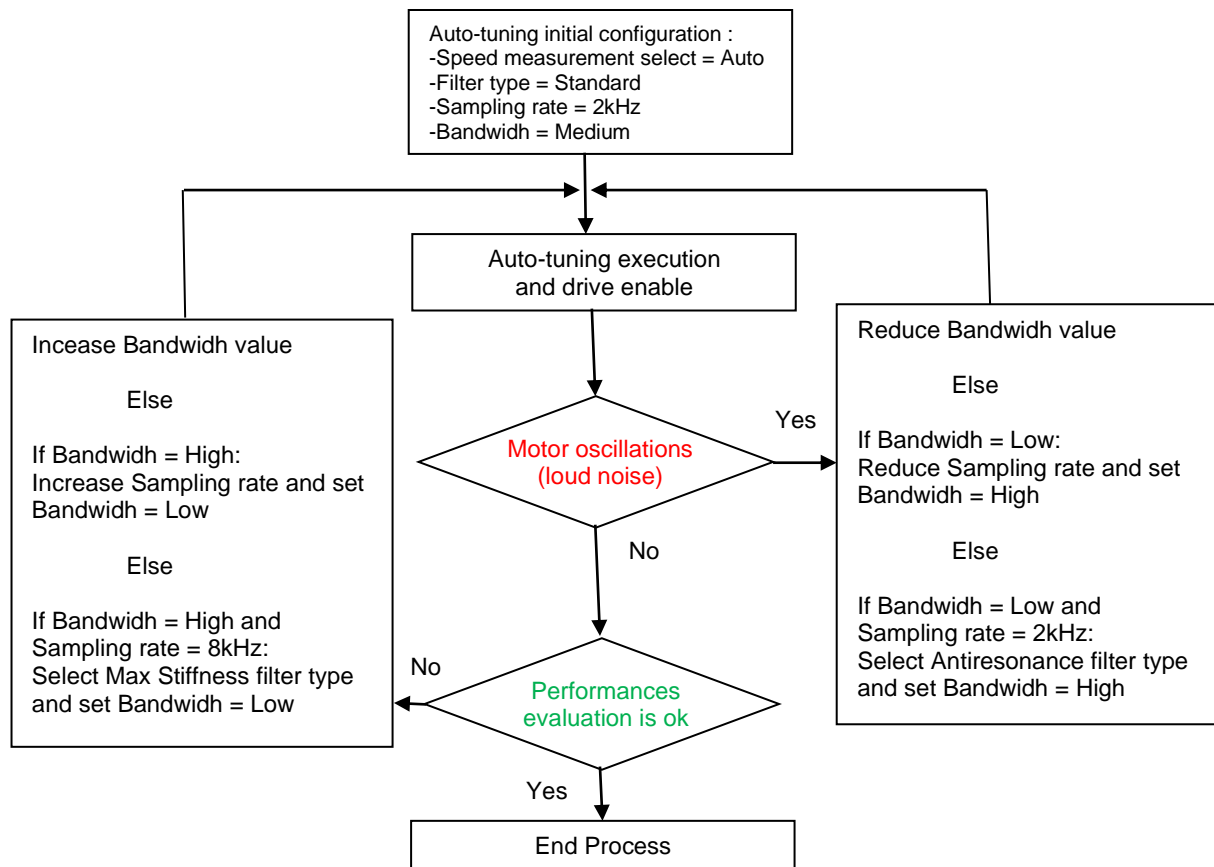
- the position sensor type (resolver, TTL encoder, SinCos encoder, digital encoder),
- the position resolution for an encoder sensor type,
- the motor-load mechanical coupling (backlash, coupling elasticity),
- the load mechanical structure (frictions, mechanical resonance).

The first Auto-tuning can be started with Standard filter type, 2kHz sampling rate and medium bandwidth.

-If the servo loop behaviour is stable, then the bandwidth selection and the sampling rate value can be increased up to the stability limit of the application in order to improve the dynamic performances.

-If the servo motor is oscillating, then the bandwidth selection and the sampling rate value must be decreased up to get the correct stability of the servo loop.

This process is described on the following diagram.



#### 5-4-4) Mechanical resonance filtering

When the Anti-resonance filter type is selected, the sampling rate, the bandwidth selects and the cut off frequency of the 3<sup>rd</sup> order low pass filter are related as shown on the following chart.

Sampling rate value	2kHz			4kHz			8kHz		
Bandwidth select	Low	Med	High	Low	Med	High	Low	Med	High
3 <sup>rd</sup> order low pass filter cut off frequency	50Hz	100Hz	200Hz	300Hz	450Hz	600Hz	700Hz	850Hz	1000Hz

Remark: this chart is only valid when the Anti-resonance filter type is selected

If the mechanical structure of the application is well specified in terms of resonances analysis, choose the low pass filter cut off frequency value just below the mechanical resonance frequency value. Set the corresponding sampling rate and bandwidth selection and execute the Auto-tuning procedure.

If the mechanical structure of the application is not specified in terms of resonances analysis, proceed as follow: Start with 100Hz cut off frequency value (sampling rate 2kHz and bandwidth medium selection). If the servo loop is stable after the Auto-tuning procedure execution, increase progressively the bandwidth selection and the sampling rate selection up to the stability limit (loud noise in the motor at standstill or when moving). Then go back to the previously stable cut off frequency value, or reduce manually the 3<sup>rd</sup> order low pass filter cut off frequency.

When the suitable cut off frequency value has been found, the controller gains can then be increased manually in order to get the best possible servo loop response.

#### 6) XtrapulsPacHP™ drive firmware update

The XtrapulsPacHP™ servo drive firmware update can be performed either via the CAN or the USB communication port. The RS232 communication port is not suitable for the drive firmware update operation.

## Appendix

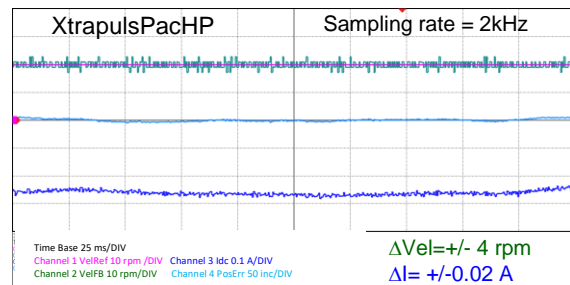
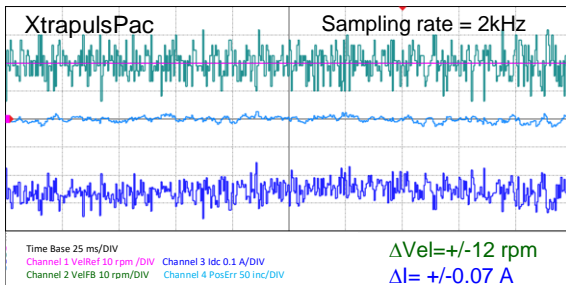
### Comparative tests between XtrapulsPac™ and XtrapulsPacHP™ servo drives

- Test material:
- XtrapulsPac-ak™ 230/17 and XtrapulsPacHP-ak™ 230/17 servo drives
  - BLS72-A motor with SinCos encoder feedback (2048 periods/rev)
  - BLS72-A motor with resolver feedback



### Speed regulation improvement with the same parameter setting

The speed regulation at 10rpm with resolver feedback is evaluated with the same parameter file for both drives.

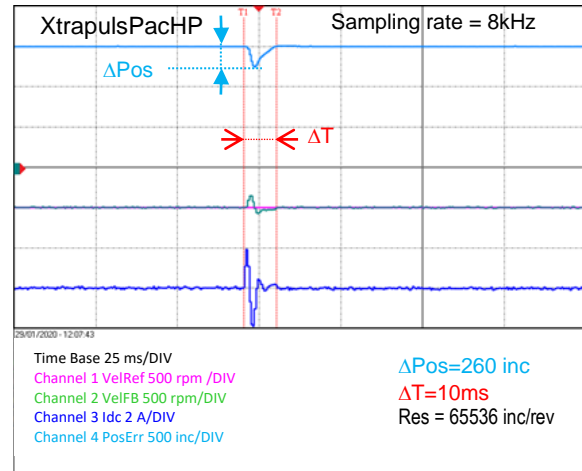
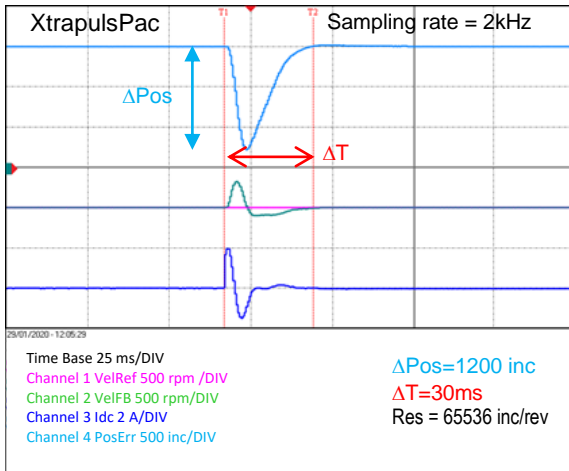


**With the XtrapulsPacHP servo drive, the speed regulation accuracy at low speed is increased by a factor of 3 with regard to the XtrapulsPac results. Furthermore, the audible motor noise level is also dramatically reduced.**



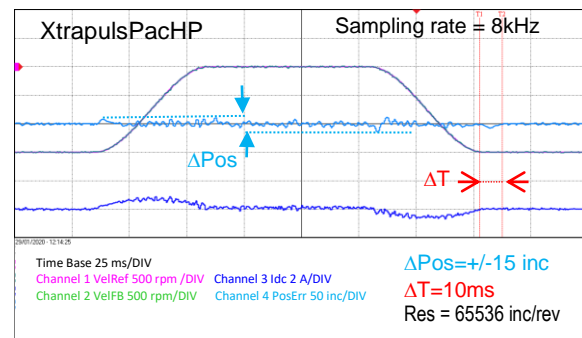
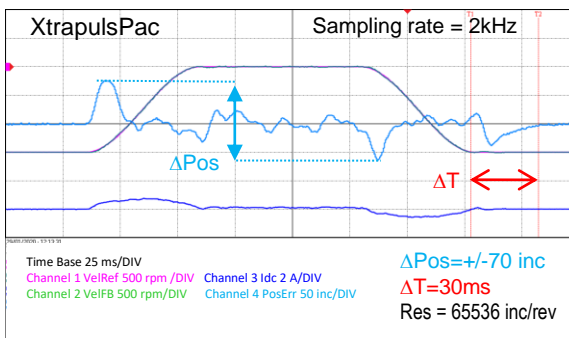
### Servo performances improvement with resolver feedback

The position deviation for a step-like torque disturbance applied to the motor shaft (stiffness) is evaluated.



With the XtrapulsPacHP™ servo drive, the position deviation is divided by 4 and the drive reaction time is divided by 3 with regard to the XtrapulsPac™ results. The servo loop stiffness has been dramatically improved.

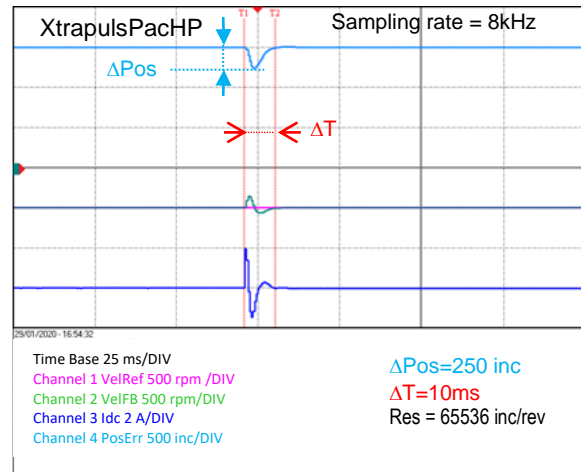
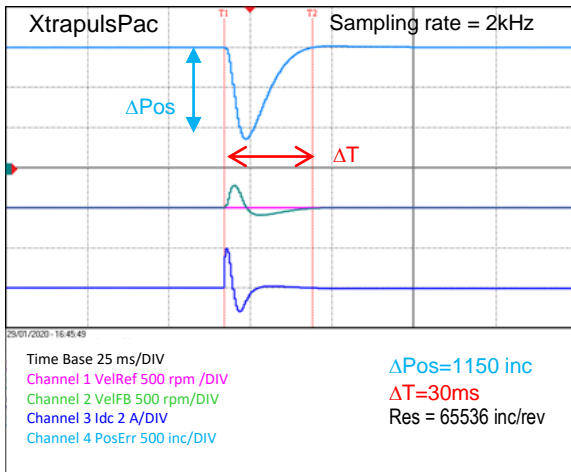
The position following error in profile position mode with a S-curve trajectory shape is evaluated.



With the XtrapulsPacHP™ servo drive, the position following error value is divided by 4 and the drive reaction time by 3 with regard to the XtrapulsPac™ results. The servo loop tracking performances are greatly improved.

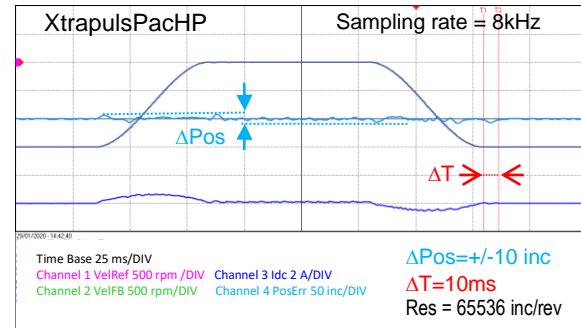
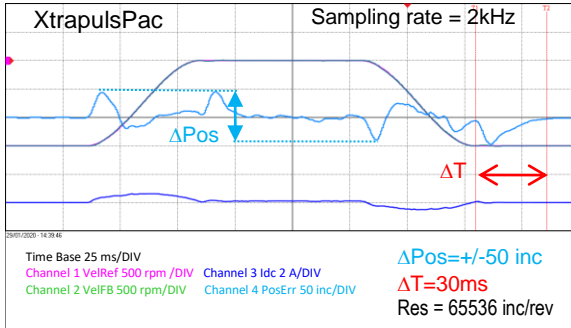
### Servo performances improvement with SinCos encoder feedback

The position deviation for a step-like torque disturbance applied to the motor shaft (stiffness) is evaluated.



With the XtrapulsPacHP™ servo drive, the position deviation is divided by 4 and the drive reaction time by 3 with regard to the XtrapulsPac™ results. The servo loop stiffness has been dramatically improved. Furthermore, because of the SinCos encoder feedback and the drive internal interpolation (x256), there is no audible noise in the motor at standstill when the controller is adjusted for the highest servo loop bandwidth with sampling rate = 8kHz.

The position following error in profile position mode with a S-curve trajectory shape is evaluated.



With the XtrapulsPacHP™ servo drive, the position following error value is divided by 5 and the drive reaction time by 4 with regard to the XtrapulsPac™ results. The servo loop tracking performances are greatly improved. Furthermore, because of the SinCos encoder feedback and the drive internal interpolation (x256), there is no vibration during the motor displacement when the controller is adjusted for the highest servo loop bandwidth with sampling rate = 8kHz.