Trigger Synchronization using a Newport XPS Series Motion Controller

In electro-optical experiments or automated test and measurement systems, configuration of multiple instruments is often required to perform a series of synchronized tasks. A common challenge of integrating multiple instruments into a setup is the difficulty of controlling each of the instruments at a precise timing, either simultaneously or in a specific sequence. When a setup requires high accuracy and throughput motions, an ability to synchronize tasks of the motion controller with other instruments becomes of a key importance. This technical note describes trigger synchronization methods of multiple instruments using a Newport XPS universal motion controller and provides examples of specific configurations.

Overview:

Figure 1: Setup Configuration for Optical Quality Testing with Gimbal

Input and output trigger controls are common features for test, measurement and motion control instruments including Newport XPS, ESP301 and SMC series controllers as well as Newport optical power meters, laser diode drivers and tunable laser controllers. In a schematic of typical setup shown in Figure 1, an input trigger signals an XPS controller to start a specific task, and the controller sends out an output trigger to other instruments at a programmed event.

Below is a list of key questions to consider when determining overall hardware and software configurations for trigger synchronizations.

- What types of signals (digital or analog) are available to use as trigger in and trigger out?
- What are the program logics that need to be defined for the trigger events and actions?
- For digital TTL trigger, do the input/output pins require pull-up resistors or are they pulled up internally?
- What is the acceptable time delay between events and actions when synchronizing multiple instruments?

Digital and Analog Trigger

The XPS controller provides number of digital TTL inputs and outputs from GPIO (General Purpose Inputs and Outputs) as well as from Trigger In, used as External Trigger Input for Data Gathering, and PCO (Position Compare Output) connectors. TTL is the most widely used form of trigger signal in various instrumentations. TTL logic gate circuits are designed to input and output only two distinct states of signals – “high” (1) and “low” (0). Ideally, the two states are represented by voltage values, 5 volts for “high” and 0 volt for “low” in positive logic. However, due to the stray voltage drop, the input and output voltages are not exact values of 5 or 0 volts, and manufacturers specify acceptable ranges for voltage and current values. The input and output specifications of the TTL digital signal for the Newport XPS series controllers are shown in Figure 2 and Figure 3 below.

Parameter	Symbol	Min.	Max.	Units
Low Level Input Voltage	V_{IL}	0	0.8	V
High Level Input Voltage	V_{IH}	1.6	5	V
Input Current LOW	I_{IL}	–	-2.5	mA
Input Current HIGH	I_{IH}	–	0.4	mA

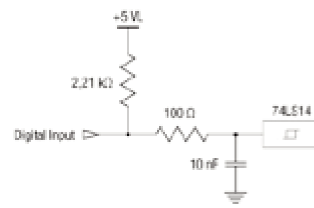

Figure 2: XPS Digital TTL Input

Parameter	Symbol	Min.	Max.	Units
Low Level Output Voltage	V_{OL}	0	1	V
High Level Output Voltage	V_{OH}	2.4	30	V
Input Current LOW	I_{OL}	–	-40	mA
Input Current HIGH	I_{OH}	–	0.2	mA

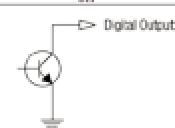

Figure 3: XPS Digital Output

The digital TTL input and output of the XPS controller are in negative logic, producing maximum 5 volts for “low” (0) state and minimum 0 volt for “high” (1) state. As shown in Figure 2, the digital TTL input is internally powered by 5 volts supply. Hence, when connecting an output of an external device to the digital TTL input of the XPS controller, no external pull-up resistor is required. The digital TTL output, however, is an open-collector type as shown in Figure 3, and it requires an external +5V power supply and a pull-up resistor. The GPIO1, GPIO3, GPIO4 and PCO connectors of the XPS controller provide outputs of +5V supply, that can be used to pull up the output signals.

The XPS also allows defining the trigger actions based on the analog input signal values. In the GPIO connectors, there are 4 analog inputs and 4 analog outputs that use voltage signals in range of ± 10 V.

Programming of GPIO Trigger Logics

A total of 30 TTL inputs and 30 TTL outputs are available in GPIO connectors of the XPS controller. This allows synchronization of specific task executions

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based on multiple events. For example, during a single trajectory of motion, the XPS allows sending TTL trigger outputs at the motion start, constant velocity start, constant velocity end and the motion end as well as at any trajectory elements defined for specific position and velocity values.

Implementation of TTL input and output in the XPS controller can be done similar to IF/THEN statements in programming. “If” the event occurs, “then” the action is triggered. Some of the available events and actions are shown in Figure 4.

Possible Events	Possible Actions
• Always • Immediate • Motion start • Motion end • Motion state • Constant velocity start • Constant velocity end • Constant velocity state ... • Trajectory element start • Trajectory element state ...	• Toggle digital output • Generate pulse on digital output • Set digital output • Copy setpoint position to analog output • Copy setpoint velocity to analog output • Copy setpoint acceleration to analog output • Start TCL script • Start data gathering ...

Figure 4: Possible Events and Actions from XPS controller

When the XPS is triggered by other instruments, a trigger signal from other instruments is always defined as the event. Number of actions can be triggered such as executing specific motion commands, gathering data, sending modulated analog output signals or starting a programmed trajectory.

When the XPS triggers other instruments, the triggering events can be defined based on time, specific motion parameters (velocity, acceleration, deceleration, start or stop), state of motion or a trajectory. In this case, the action is always the triggering signal to other instruments.

Synchronization Time Delay and Position Error

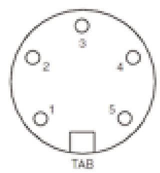
Typical delay of sending out the trigger signal from the XPS controller is 100 µs, coming from a servo cycle of the controller electronics. While a ‘time’ based event triggers an action immediately every servo cycle of 100 µs, an event related to ‘motion’ triggers an action based on the motion profiler, which runs on every 400 µs.

For applications demanding high accuracy and fast synchronization to external devices, the XPS controller features ‘Position Compare Output’ (PCO), providing 50 ns delay between the moment of crossing specific positions and sending out the trigger signal. Similarly, the ‘Trig In’ connector of the XPS enables 50 ns delay between a trigger input signal and an acquisition of position data.

A minimum latency in the trigger delay is critical in high speed, high throughput motion where the trigger output signal is sent on the fly during a move. With 50 ns latency of the trigger pulse from PCO, the scanning speed of 200 mm/s from a motorized stage produces minimal uncertainty of 10 nm in position, which is much smaller compared to uncertainty of 20 µm resulting from 100 µs latency of trigger pulse from the GPIO.

Example #1: Digital TTL Output to Trigger a Mechanical Shutter

In the following example, a Newport 845HP digital shutter system is triggered by digital TTL outputs from the GPIO3 connector of an XPS-Q4 universal controller.



J1 Pin #	Function
1	Signal Ground
2	Start (input) – opens shutter
3	Reset (input) – closes shutter
4	+5VDC (output)
5	Busy (output)

Figure 5: Description of 845HP shutter interface control 5-PIN DIN connector

The digital TTL outputs from GPIO3 connector are pulled up to +5V supply with resistors, as shown in Figure 6.

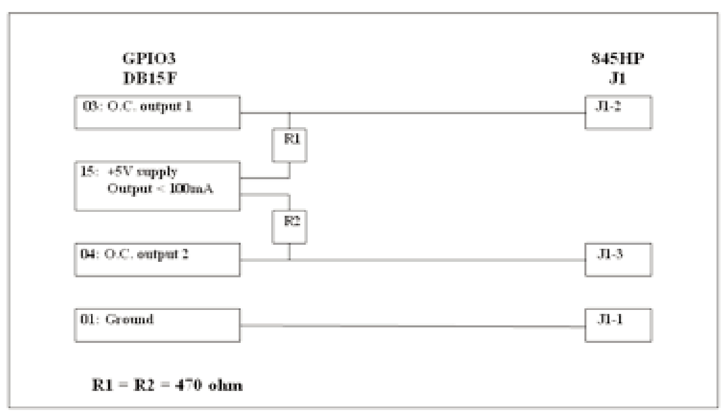


Figure 6: Wiring diagram of GPIO3 to 845HP J2 interface connector

Please note that the inputs of 845HP interface connector are “active high” and the digital outputs of the GPIO are in negative logic. This means that the shutter will open with high-to-low transition of the trigger pulse to J1-2 pin, and close with the high-to-low transition of the trigger pulse to J1-3 pin.

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The following conditions define the open, the close of the shutter and the ready mode by changing the state of bit number to #0 or #1.

```
# Ready mode (DO1 = 1, DO2 = 1)
set ErrorCode [catch "GPIODigitalSet $SocketID GPIO3.DO  3 3"]
if {$tcl_argv(0) != 0}  {close_socket ; return $tcl_argv(0)}

# Open the Shutter (Switch DO1 from 1 to 0)
set ErrorCode [catch "GPIODigitalSet $SocketID GPIO3.DO  3 2"]
if {$tcl_argv(0) != 0}  {close_socket ; return $tcl_argv(0)}

# Close the Shutter (Switch DO2 from 1 to 0)
set ErrorCode [catch "GPIODigitalSet $SocketID GPIO3.DO  3 1"]
if {$tcl_argv(0) != 0}  {close_socket ; return $tcl_argv(0)}
```

In the following example of a TCL script, when positioner G1.P1 reaches a constant velocity, it opens the shutter. When the constant velocity is over, the shutter is closed.

```
EventExtendedConfigurationTriggerSet (Always, 0, 0, 0, 0,
G1.P1.SGamma.ConstantVelocityStart, 0, 0, 0, 0)
EventExtendedConfigurationActionSet (GPIO3.DO.DOSet, 3, 2, 0, 0)
EventExtendedStart()
EventExtendedConfigurationTriggerSet (Always, 0, 0, 0, 0,
G1.P1.SGamma.ConstantVelocityEnd, 0, 0, 0, 0)
EventExtendedConfigurationActionSet (GPIO3.DO.DOSet, 3, 1, 0, 0)
EventExtendedStart()
GroupMoveAbsolute (G1.P1, 50)
GroupMoveAbsolute (G1.P1, -50)}
```

Example #2: Position Compare Output (PCO) to Trigger a High Speed Camera

In the second example, the Position Compare Output is used with an XML350 Linear Stage and an XPS controller. The pulse output triggers an image capture of a high speed camera system in Automated Optical Inspection (AOI) application.

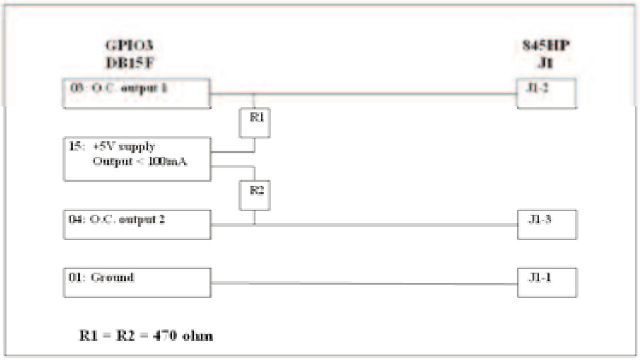

Figure 7: Wiring Diagram of XPS PCO to External Camera

The Axis 1 pulse output from PCO connector is pulled up to +5V output with a resistor as shown in Figure 7. Once the wiring is properly configured, the following TCL commands can be used.

```
PositionerPositionComparePulseParameterSet()
PositionerPositionCompareSet()
PositionerPositionCompareGet()
PositionerPositionCompareEnable()
PositionerPositionCompareDisable()
```

In the TCL script below, one trigger pulse is generated every 5 µm between the minimum position of 10 mm and the maximum position of 50 mm. The first trigger pulse will be at 10 mm and the last trigger pulse will be at 50 mm with duration of 200 nanoseconds per each pulse.

```
GroupInitialize(GROUP1)
GroupHomeSearch(GROUP1)
PositionerPositionCompareSet(GROUP1.POSITIONER,10, 50, 0.005)
PositonerPositionCompareEnable(GROUP1.POSITIONER)
PositionerPositionCompareGet(GROUP1.POSITIONER, double *, double *,
double *, bool *)
PositionerPositionComparePulseParametersGet(GROUP1.POSITIONER,
double *, double *)
GroupMoveAbsolute(GROUP1.POSITIONER, 150)
PositionerPositionCompareDisable(GROUP1.POSITIONER)
```

For additional information about the Newport XPS controller and its advanced features for trigger synchronizations, please contact Newport sales and application engineers at tech@newport.com.

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