Application note "ETEL Fast Trigger feature for external events management"

Keywords:
Fast Trigger, External events, Cost reduction, Accuracy, Robustness, Throughput.

Disclaimer

This note is based on the stated hardware and software as well as the corresponding documentation. This note is therefore only valid for the described installation. New hardware and software versions may need to be handled differently. Additional modifications may occur without notification. Please refer to the detailed description in the specific manuals.

Abstract

In different fields of manufacturing and process industries, the standard processes such as image acquisition for inspection, laser application, printing, glue dispensing or starting any other external procedure, are critically related to the quality of the final product. These operations need to be executed with high position accuracy while running on top of a high dynamic system continuously in motion.

Introduction

This document illustrates the advantages of using ETEL Fast Trigger advanced feature compared to time-based events or less advanced trigger features. Fast Trigger is designed for applications/processes such as image acquisition for inspection, laser application, printing, glue dispensing, etc.

Goals:

- Understand the principles of standard processes using external events.
- Identify time-based events limitations.
- Be introduce to standard ETEL Fast Trigger solution for external events management.

Standard processes using external events

The basic hardware configuration for applications using external events, can be summarized as follows:

- PC → interface with the user,
- Position controllers → control unit that drives the motion system,
- Motion system → stacked or planar system containing the motors and moving parts,
- Workpiece → piece/part that is being moved by the system. The process is executed on its surface,
- Device → device that is executing the process on the workpiece e.g. laser, camera, injector, etc.

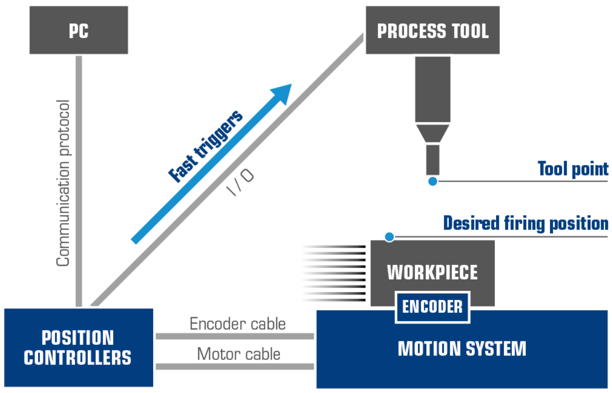

Figure 1: Overview of process using external events.

The basic idea of the above procedure is to drive the 'moving point' below the 'tool point' and execute a pre-defined event. The event management is characterized by the (de)activation of external device in order to execute an action accurately on a specific position of the workpiece.

Some examples of events can be listed:

- Laser application, the events are: on and off of the laser beam.

- Glue dispensing application, the events are: open and close the nozzle of the dispensing system.
- Optical inspection application, the events are: on and off of the camera.

Process challenges

The nowadays industries that are focused in high duty cycle are driven by high throughput, accuracy, repeatability, robustness and low costs of production. These requirements are directly applied to application where the processes occur while the system is in motion.

Therefore, it is mandatory to reduce the time at stand still and/or increase systems dynamics. These actions should not deteriorate accuracy at the tool point and also not increase production costs.

In order to present the benefits of using Fast Trigger for such processes, the basic time-based event management is chosen as reference.

Time-based event

In time-based events, the variable that trigger the events is the time t (controller internal clock). These events are pulses usually generated by a Position Controller (cf. Figure 1) through its digital outputs. Each pulse will be seen as a request of new event from the Device (cf. Figure 1).

Thus, if an event is executed while the system is in motion, the position of the occurred event is function of the theoretical trajectory of the system.

As stated previously, the aim of such technic is to execute an event accurately on a specific position of the workpiece.

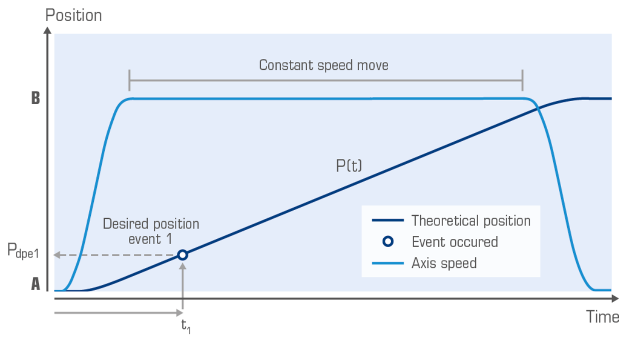

Figure 2: Time-based event for event 1.

Figure 2 represents the execution of a time-based event. The theoretical position P(t) is assumed to be known for the entire motion. The desired position of event 1 is: $P_{dpe1} = P(t_1)$.

However, P(t) function can be very complex, as for example the S-curve trajectories. It becomes difficult to know when to activate the events during acceleration and deceleration phases. Thus, in most of cases, time-based events are performed with the system moving at constant speed or assuming it. The equation of motion for a system moving at constant speed becomes $P_{dpe}(t) = (v_{cst} * t_{trg}) + P_0$, where

- P_{dpe}: desired position of event,
- v_{cst}: theoretical constant speed,
- P_0: the initial position,
- t_{trg}: time of trigger.

It can be seen that for all desired positions, t_{trg} is easily calculated $t_{trg} = (P_{dpe} - P_0) / v_{cst}$

Figure 3 illustrates the execution of an event 2 at constant speed. The theoretical position function P(t) becomes $P_{dpe2} = P(t_2) = v_{cst} * (t_2 - t_1) + P(t_1)$, with $t_2 > t_1$ for all event 2 at constant speed v_{cst}. The time t_2 at which event 2 is triggered is found from $t_2 - t_1 = (P_{dpe2} - P_{dpe1}) / v_{cst}$.

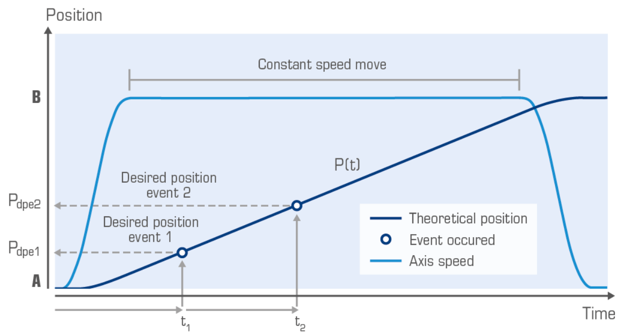

Figure 3: Time-based event at constant speed for event 2.

ETEL Fast Trigger

The ETEL AccurET family products propose position controllers of high performance. ETEL position controllers can handle a variety of external signals. For example, fast position capture or Fast Trigger allows the management of other devices such as laser, camera, etc.

Figure 4: AccurET Family

The aim of ETEL is to propose to user, the full control on the management of accurate external events by using the Fast Triggers functions.

The Fast Triggers feature allows the user to execute an event based on the theoretical trajectory or based on the encoder position. Both possibilities are represented as axis position on Figure 5. This means that the event is no longer time dependent. Figure 5 shows the execution of three desired positions events, while the axis moves from point A to B. Moreover, the uniqueness of the feature also stands in the fact it can use a mapped position to include all mechanical corrections on the encoder position without adding delays in the event firing chain (see Figure 8).

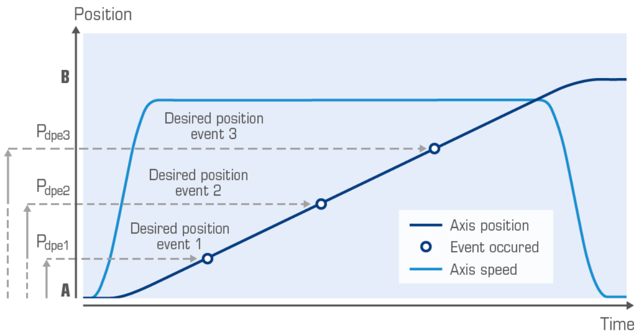

Figure 5: ETEL Fast Trigger based on position.

Using Fast Trigger rather than time-based events brings improvements on:

- Accuracy,
- Robustness,
- Throughput,
- Cost reduction.

Fast Trigger performance

Increase of event accuracy

Events accuracy is of main interest for applications such as laser cutting, glues dispensing or image acquisition.

The goal of these processes is to execute an event at a pre-defined position on the surface of the workpiece. No event can be executed with zero position error. However, ETEL AccurET controllers and their Fast Triggers function brings unique functionalities in order to achieve high accuracy specifications.

The levels of accuracy can be presented in three points:

1. Time-based event or Fast Trigger based theoretical position.
2. Fast Trigger based real (encoder) position.
3. Fast Trigger based real (encoder) position with stage mapping.

Time-based event or Fast Trigger based theoretical position

Figure 6 shows the absolute error at tool point when the event executed. The system moves at constant speed.

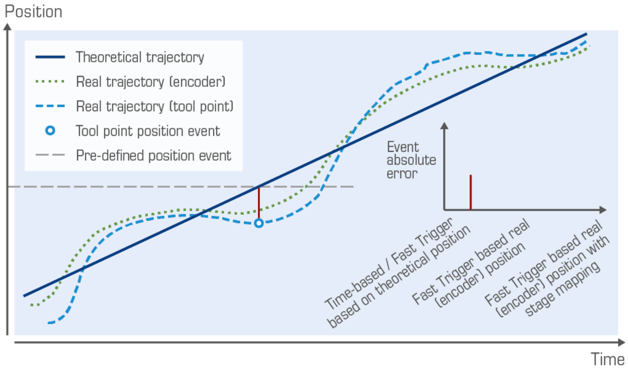

Figure 6: Time-based and Fast Trigger based on theoretical position.

For time-based events, the position where the event will occur is based on the theoretical speed. By knowing the speed and the time, the position of an event can be theoretically calculated.

Therefore, for time-based events, it is assumed that the stage moves perfectly on its theoretical generated trajectory. In addition, it can be concluded that for an event executed at constant speed, time-based event and Fast Trigger based on theoretical position achieves same accuracy.

The main contributors for the absolute position error are:

- System Repeatability,
- Stage Error Mapping (not implemented),
- Tracking Error (during motion),
- Hardware Time Delays (position controller, cables, device).

Fast Trigger based real (encoder) position

In order to easily improve in accuracy, the Fast Trigger function allows the user to select the position read by the encoder as the trigger reference of an event.

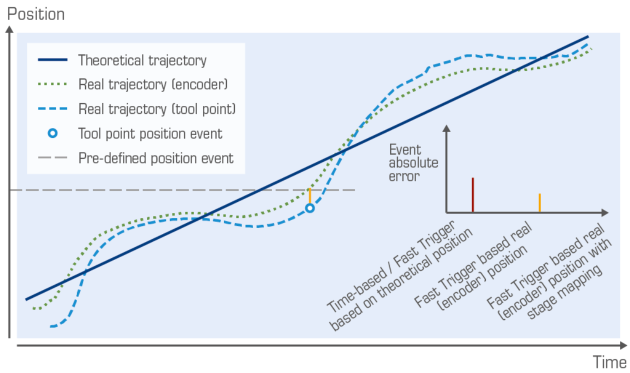

Figure 7: Fast Trigger based on real (encoder) position.

Figure 7 shows that the absolute error at tool point is decreased compared to a process using time-based event. By choosing Fast Trigger based real (encoder) position, the tracking error is removed from the absolute position error contribution.

The main contributors for the absolute position error are:

- System Repeatability,
- Stage Error Mapping (not implemented),
- Hardware Time Delays (position controller, cables, device),
- Encoder Signal to Noise Ratio (SNR),
- Encoder Position Digital Resolution.

Fast Trigger based real (encoder) position with stage mapping

The best performance with respect to accuracy will be reached with the ETEL AccurET stage error mapping functionality. This feature allows the user to map the deviation/error between encoder position and tool point position.

Figure 8 shows the impact of stage mapping on the events' absolute position error.

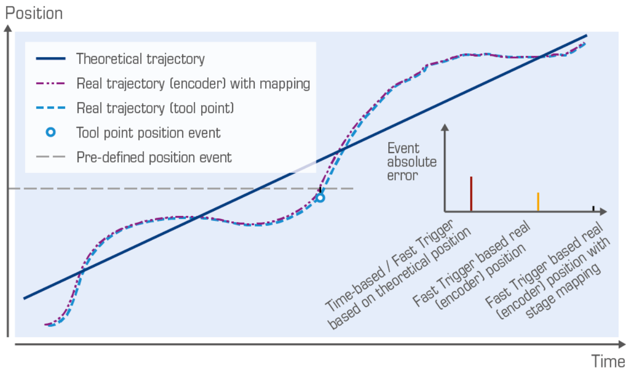

Figure 8: Fast Trigger based on real (encoder) position with AccurET stage error mapping.

The main contributors for the absolute position error are:

- System Repeatability,
- Stage Error Mapping Quality,
- Hardware Time Delays (position controller, cables, device),
- Encoder Signal to Noise Ratio (SNR),
- Encoder Position Digital Resolution.

Improvement of event robustness

In this section, the robustness is characterized by the capability of a disturbed system to execute the events at the pre-defined position. The next paragraphs will present a use case to illustrate, how Fast Trigger handles external disturbances compared to time-based event management.

A user application could be defined to turn on and off a laser throughout the system's axis stroke. Each event has to be equally spaced of Δp. The events are executed with the axis in motion at constant speed (see Figures 9).

In production site, any machine can be subject to external disturbances (e.g. surrounding machines generates vibrations to the system, large amount of grease on system's rails, etc.). It is mandatory to handle such disturbances during processes.

Figure 9 presents the error between theoretical and real trajectories at the moment when disturbance occurred.

If it is assumed that the disturbance comes from a large amount of grease on the axis rails, the system is held back when moving through it. The system cannot follow its theoretical trajectory, resulting in a large tracking error.

The aim of the process is to execute the laser events at the desired positions 1 to 3. The real trajectory is the real position of the stage (encoder or mapped encoder position) during the motion. Therefore, the events should be executed when the real position is at the desired positions 1 to 3.

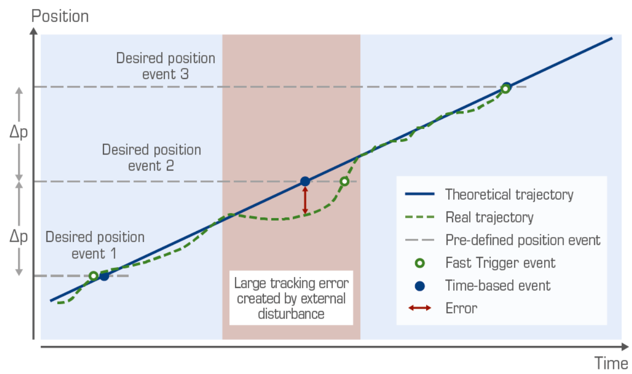

Figure 9: External events management with external disturbance.

As mentioned previously, the triggering of time-based events are based on theoretical trajectory calculation. Thus, the execution of the time-based event are aligned on the theoretical trajectory on Figure 9. The events 1 and 3 are relatively accurate when comparing the real trajectory at the executed time. However, event 2 presents a relatively large error. This error could lead to damage to processed workpiece. The time-based event cannot compensate for external disturbances and cannot be considered as robust.

In comparison, Fast Trigger function is able to execute all events based on real position. The external disturbances will not affect the position accuracy of the laser events.

Gain of throughput and system footprint

Nowadays, in the industry, companies are always seeking technologies that increase production throughput, without degrading its processes or increasing its cost.

For external events management using time-based events, the process is most of the time executed at constant speed. This means that the motion can be separated into three phases:

- Phase 1: acceleration,
- Phase 2: motion at constant speed (event execution),
- Phase 3: deceleration.

The notion of throughput can be characterized by the number of events executed per units of time.

Figure 10 represents a system that performs a point-to-point motion (for a given motion profile: acceleration, speed and jerk time). During its motion, 6 events are executed at pre-defined positions. These events were executed firstly, using time-based events and secondly, using ETEL Fast Trigger.

In the case where time-based event are used, the total distance traveled is from position A to B. The total motion time is calculated as the sum of time taken in phase 1, phase 2 and phase 3 (i.e. acceleration, constant speed and deceleration).

In comparison, Fast Trigger allows to execute the same events within a shorter time and distance. The ability to execute the events based on the positions, makes phase 2 not mandatory. In the presented example, the gain of throughput is characterized by the removal of Phase 2 from the motion. Gain of time = (distance A'-B') / (constant speed).

The Fast Trigger feature also brings the advantage to reduce systems' foot print. The total distance needed to execute the events is reduced from A-B to A'-B'. The distances needed for phase 1 and phase 3 are merged in the process.

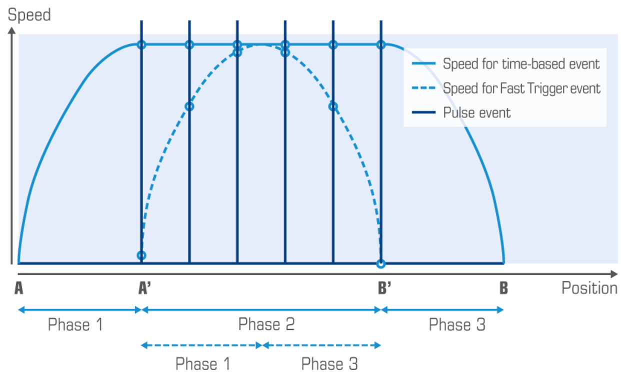

Figure 10: Speed profile with respect to position for time-based and Fast Trigger events.

Cost reduction

Cost is one of key factors when choosing a product technology. Fast Trigger brings the possibility to reduce cost by reducing the power needed from the system.

A simple representation of power reduction can be seen in Figure 11. The plot on the top shows 6 events being executed with time-based event and with Fast Trigger.

The plot in the bottom of Figure 11 shows the electrical current levels needed to move the system for both technologies. By reducing the dynamics, it creates the opportunity to choose smaller and less power consuming motor or system.

The motion profiles (acceleration, speed and jerk time) are chosen differently so that the time to move from A to B (time-based) and A' to B' (Fast Trigger) are equal (see Figure 12). This would ensure same process throughput. Therefore, cost reduction can be achieved without affecting process throughput.

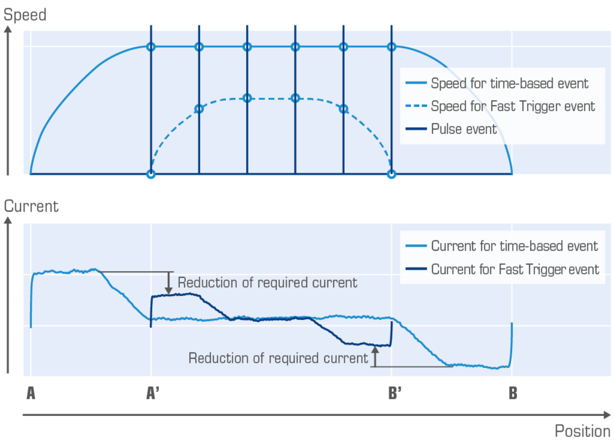

Figure 11: Down-sizing opportunity thanks to Fast Triggers.

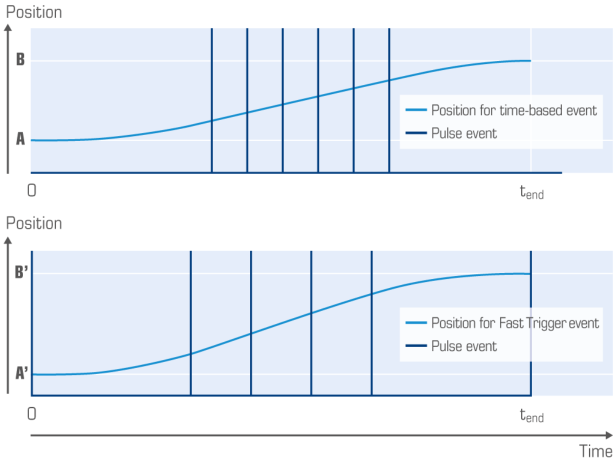

Figure 12: Time representation of process executed with time-based events and Fast Trigger event. The dynamics are set such that the motion time (t_{end}) is equal.

Conclusion

ETEL's AccurET controller and its Fast Trigger feature is the perfect technology for processes such as image acquisition for inspection, laser application, printing, glue dispensing running on top of a high dynamic system continuously in motion.

Fast Trigger brings accuracy, robustness, throughput, reduction of machine footprint and cost reduction on user applications.

End of Note.