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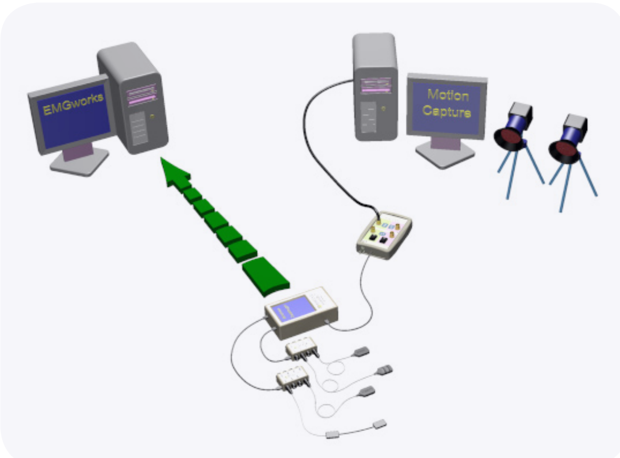
Technical Note 301: Synchronization and Triggering



Purpose

The need to synchronize data from more than one measurement system often arises during physiological studies. This Technical Note focuses on important concepts concerning synchronization and triggering. It focuses on general examples. Please see ***Technical Note 302: Myomonitor Data Synchronization*** for detailed instructions regarding a specific situation.

Synchronization Concepts

- Primary Data Acquisition System
- Secondary Data Acquisition System
- Constant Time Delays
- Variable Time Delays
- Start Trigger Input
- Start Trigger Output
- Stop Triggers

Triggering Scenarios

- Primary/Secondary Triggering
- Independent-Signal Triggering
- Common Signal Synchronization

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The Need for Synchronization

Physiological studies often utilize a variety of specialized measurement systems in experimental designs. The ideal case employs a single data acquisition system that records all necessary data types, inherently time-synchronizing all measurements. In many cases, however, it is necessary to have multiple data acquisition systems that are specifically designed for only one type of measurement. An example that is often encountered in the Biomechanics field is the need to record EMG data from the body's muscles as well as Motion Capture data from the body's movements. It is important to ensure that an EMG event detected by the EMG system is correlated to the corresponding biomechanical event detected by the Motion Capture system at the same point in time. In order to ensure this, the Motion Capture system must start at the same time that the EMG data acquisition system starts, so that no effective delay is observed between the two.

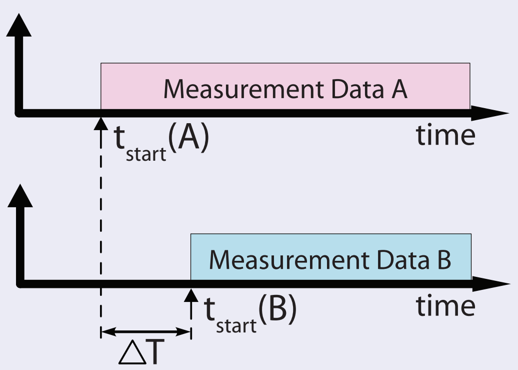

Figure 1: It is important to ensure that the time delay in starting multiple data acquisition system is minimized to an acceptable period.

Acceptable Delays

The ability to discern the time delay between data acquisition systems is determined by the lowest sampling frequency. For example, the typical sampling rate for a surface EMG signal is 1000 samples/second, which constitutes a sampling period of 1 ms. A Motion Capture systems may sample at 100 frames/second, corresponding to a sampling period of 10 ms. In this case, a synchronization delay of 10 ms or less would be virtually undetectable, since the Motion Capture system is not able to resolve a time quantum smaller than this value. From a practical perspective, time delays up to several hundred milliseconds may be acceptable for physiological measurements, depending on the nature of the investigation.

Constant vs. Variable Time Delays

An important distinction between *constant time delays* and *variable time delays* must be understood. In some cases, the delay between data acquisition systems is a known, constant quantity, usually inherent in one of the measurement systems. A constant time delay is a benign inconvenience that can be corrected during data analysis. For example, if it is known that Motion Capture Data is always measured with a 100 ms delay with respect to the EMG data, then the data can be shifted in time by this same amount during analysis so that the information presented is time-synchronized.

Time delays that are variable in measurement systems are usually unknown to the investigator, and thus pose greater difficulty in their management. These types of delays are often introduced by software processes that are intrinsic to computer operation and cannot be controlled by data acquisition systems. In some cases an upper limit can be placed on these delays. These upper limits are usually a statistical average and must be treated as such. If this upper bound is smaller than the largest sampling period, or if it is otherwise an acceptable time period for the experimental design, then it can be effectively ignored. If, however, this upper bound is too large or unknown, then a synchronization strategy must be implemented to manage the delay. Fortunately, most data acquisition systems offer a variety of strategies for minimizing, and, in some cases, completely eliminating time delays.

The Concept of Triggering

The key to implementing a successful triggering strategy is to establish a control signal that is capable of immediately starting data acquisition on one or more systems. The ability for a data acquisition system to start with a digital control signal is usually described as a **Start Trigger Input**. The ability for a data acquisition system to start other systems with a digital control signal is usually described an a **Start Trigger Output**. In most cases, the specifications of these control signals are 5V digital pulses whose polarity and width will vary for different manufacturers.

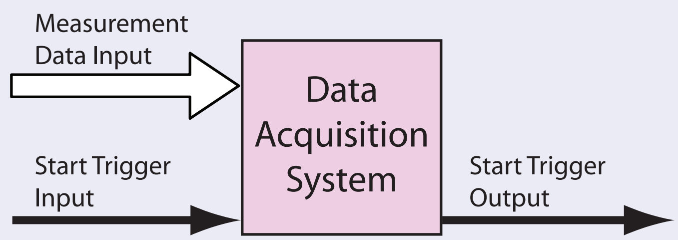

Figure 2: Full flexibility is obtained with systems that can perform Input and Output Triggering Functions.

Primary/Secondary Triggering

A common strategy is to designate one data acquisition system as the primary device that controls all other data acquisition systems, the secondary devices. In this case, the **Primary Data Acquisition System** must have a **Start Trigger Output**, which is asserted the moment data sampling begins. This trigger signal is connected directly to the **Start Trigger Input** of the **Secondary System**, which initiates sampling on the second system. Note that it is possible to control more than one Secondary Data Acquisition System in this way. It may be necessary to condition the Start Trigger Output signal so that it can be interpreted correctly by the Secondary System, as dictated by the manufacturer's specifications.

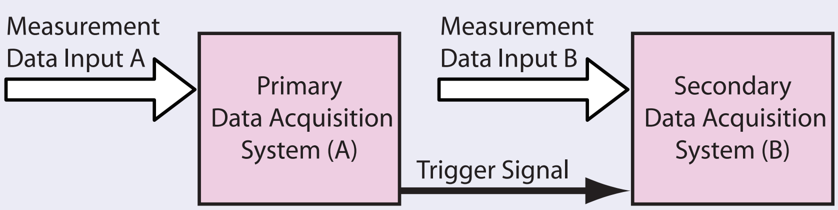

Figure 3: The Primary System issues a Start Trigger Output signal which controls the Secondary System. It may be necessary to condition the signal so that it is interpreted correctly.

Independent-Signal Triggering

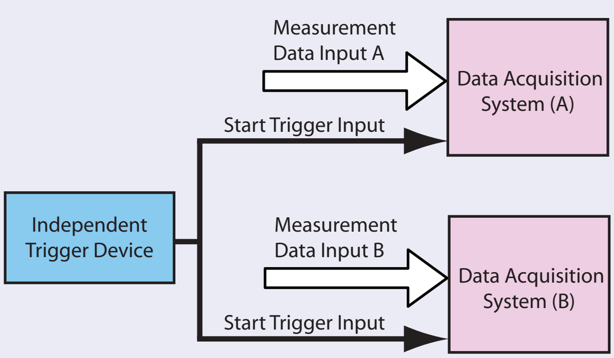

Figure 4: All data acquisition systems are started by an independent device that issues a common Start Trigger Input.

For those systems that are **only** equipped with a **Start Trigger Input** feature, it is necessary to implement a control signal that is independent from the data acquisition systems in order to start them. In this scenario, all of the data acquisition systems are connected as Secondary Systems under the control of this independent device. This device could be a simple push-button switch or a digital control signal coming from a computer or other instrument.

Common Signal Synchronization

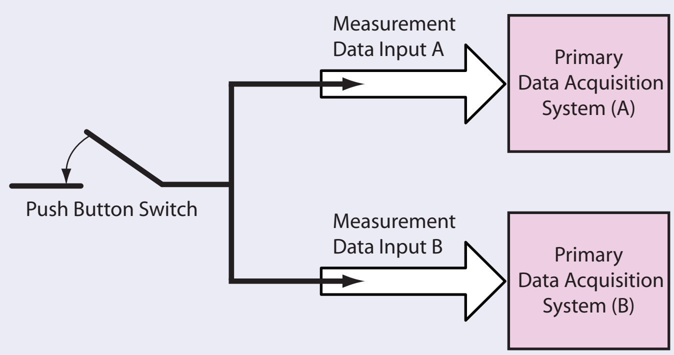

Figure 5: A common signal is sampled by both measurement systems so that the same time marker exists in all data sets. This may require dedicated data channels.

In those cases where data acquisition systems do not support triggering functions, it may be possible to establish time synchronization of data by measuring a signal that is common to all systems. This is usually accomplished by sending an electrical pulse to one channel in each data acquisition system. All systems will record this electrical event on their respective channels, regardless of when the actual data sampling was started. A simple example of this technique might employ a 5V pulse that is activated by a push-button switch, which is sampled by all the active data acquisition systems. The time resolution of this technique is limited by the system which samples at the lowest rate, hence having the largest sampling period. Note that this approach may require each system to have a dedicated channel for observing the synchronization signal.

Stop Triggers

All of the triggering concepts discussed for synchronizing the start of data acquisition systems can be directly extended to situations requiring the synchronous stopping of data acquisition systems. Delays associated with Stop Triggers are not as critical as those affecting Start triggers, since they only dictate the length of the recorded data set and can be truncated as needed. Stop Trigger features can only be implement with those devices that offer Stop Trigger Inputs and Stop Trigger Outputs.