Lesson 8
Synchronization

TOPICS

A. Synchronizing Measurements
B. Single Device Synchronization
C. Multiple Device Synchronization
D. Counters and Synchronization

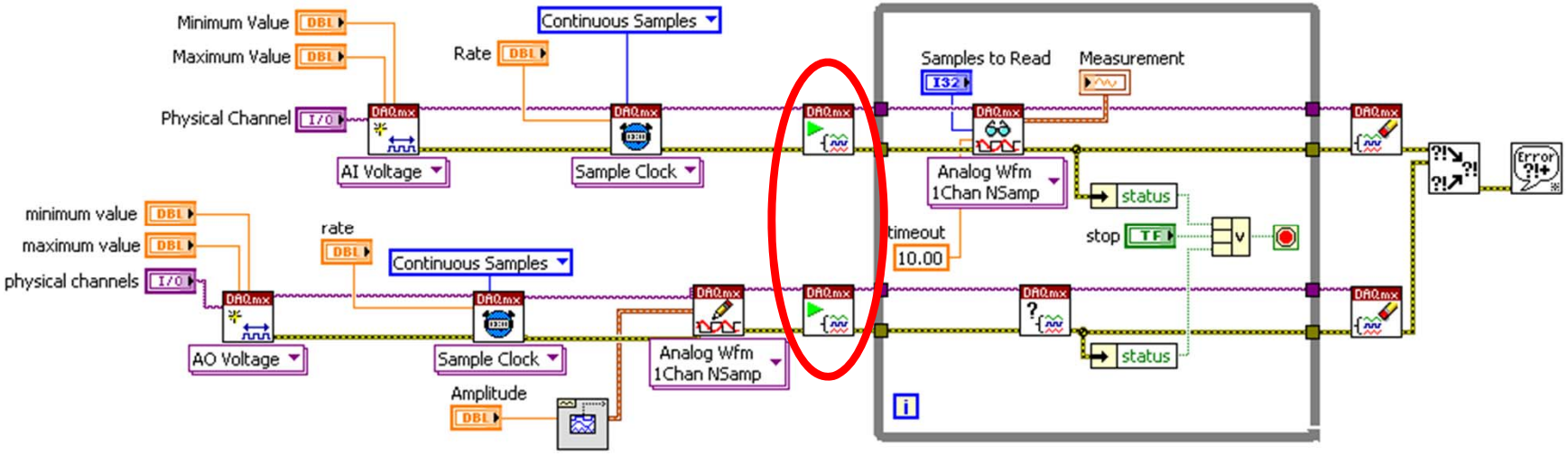
A. Synchronizing Measurements

Many applications require more than one type of measurement at a time

- Simultaneous Measurements
  - Operations are happening at the same time but are not necessarily synchronized
  - Cannot prove that measurements occurred at the same instant
- Synchronous Measurements
  - Measurements are correlated

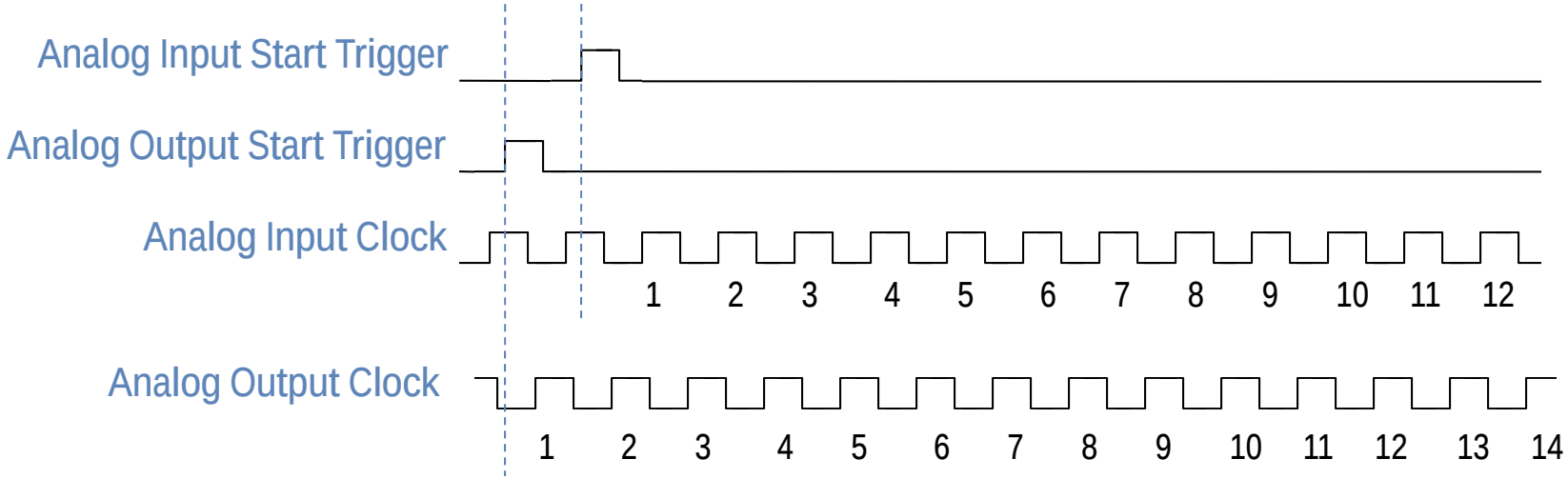
Example: Simultaneous Analog Input/Output

Problem: Simultaneous measurements, but not synchronous



Example: Simultaneous Analog Input/Output

Timing diagram for simultaneous measurements



- AI and AO clocks are based on different timebases
  - Because the timebases are different, the clock signals are out of phase
- Start Triggers for this VI come from the DAQmx Start Task VIs
  - Due to software timing, start triggers can be 100s of milliseconds off from one another

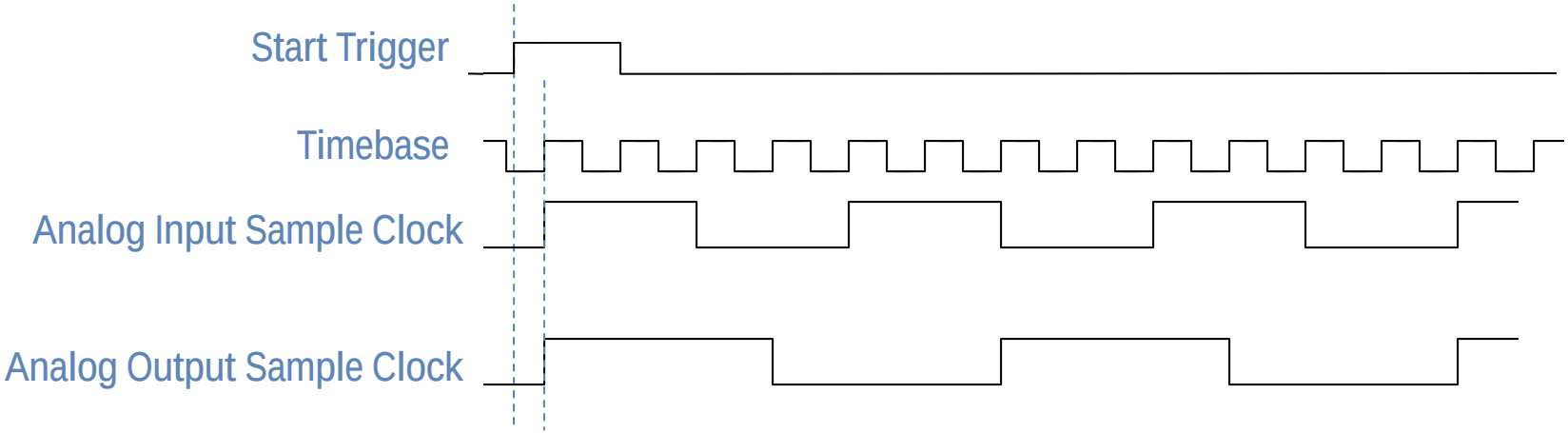
Synchronization Rules

1. Share a Master Timebase* and a Start Trigger
   - Sharing a Master Timebase
     - Prevents phase discrepancies
     - Allows for different rates derived from the timebase
   - Sharing a Start Trigger
     - Verifies that tasks start synchronously
2. Share a Sample Clock
   - Clocked analog and digital measurements only update on a new rising edge from a sample clock
   - Sample Clock derived from master timebase or externally sourced

*Also known as a Reference Clock

Synchronization Rules

Share a Master Timebase and Trigger



- Both sample clocks are derived from the same timebase
  - For a single board, the timebase is always assumed to be the same
  - For multiple boards, must share the timebase to avoid phase errors
- Different sample clocks can be set to different rates
- All tasks have start triggers
  - If not explicitly created, comes from when the software starts the task.

Synchronization Rules within DAQmx

1. Create one master task
   - Configure master task, but do not start immediately
   - Only start master task after all slave tasks have started

2. Create as many slave tasks as necessary
   - Start slave tasks before starting master task

Sources of Error

There are several sources of error when synchronizing measurements:

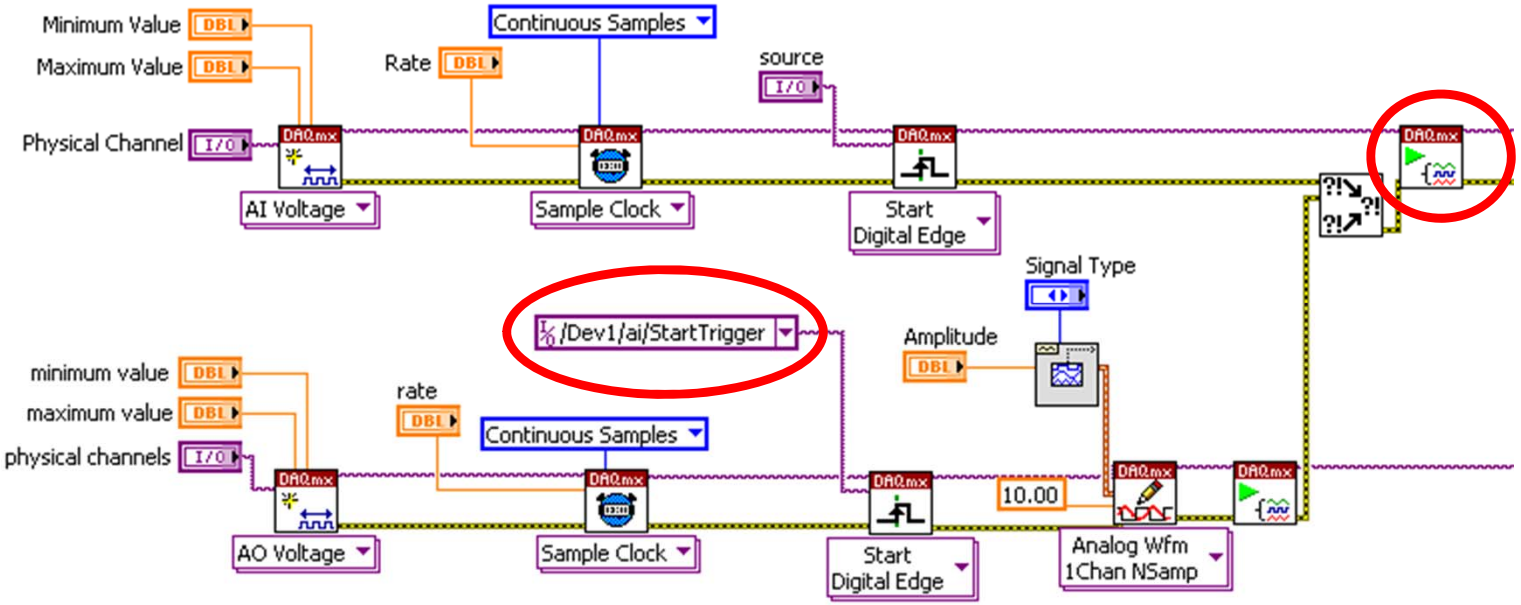
- Jitter
  - Small variations in the period of the clock (from sample to sample)
  - Each component added to the clock's path adds additional jitter
- Stability
  - Can be subject to variations due to temperature, aging, etc.
- Accuracy
  - An oscillator never generates a perfect frequency
  - Error expressed in parts per million (ppm) and parts per billion (ppb)
- Skew
  - Propagation delay that is caused when a signal arrives at two places at different times
  - Affected by distance and impedance of signal paths

B. Single Device Synchronization

- All tasks require a start trigger of some sort
  - But not all measurements require an external hardware trigger
- If a trigger is not explicitly configured for a task, the software creates an implicitly called start trigger.
  - The internal start trigger is called *<Device>/<Type>/StartTrigger*
    - For example: *Dev1/ai/StartTrigger*
- Can use the internal trigger to guarantee that one task does not start before the other

Example: Simultaneous Analog Input/Output

Solution: Trigger slave task start on the start of the master task



*The analog output task starts, but must wait for the analog input task to receive a trigger

Exercise 8-1: Simultaneously Started Analog Input and Output

To become familiar with the two different ways to simultaneously start an analog input and analog output operation.

GOAL

Exercise 8-1: Simultaneously Started Analog Input and Output

- After the analog input and output are simultaneously started, is the acquisition and generation synchronized?

GOAL

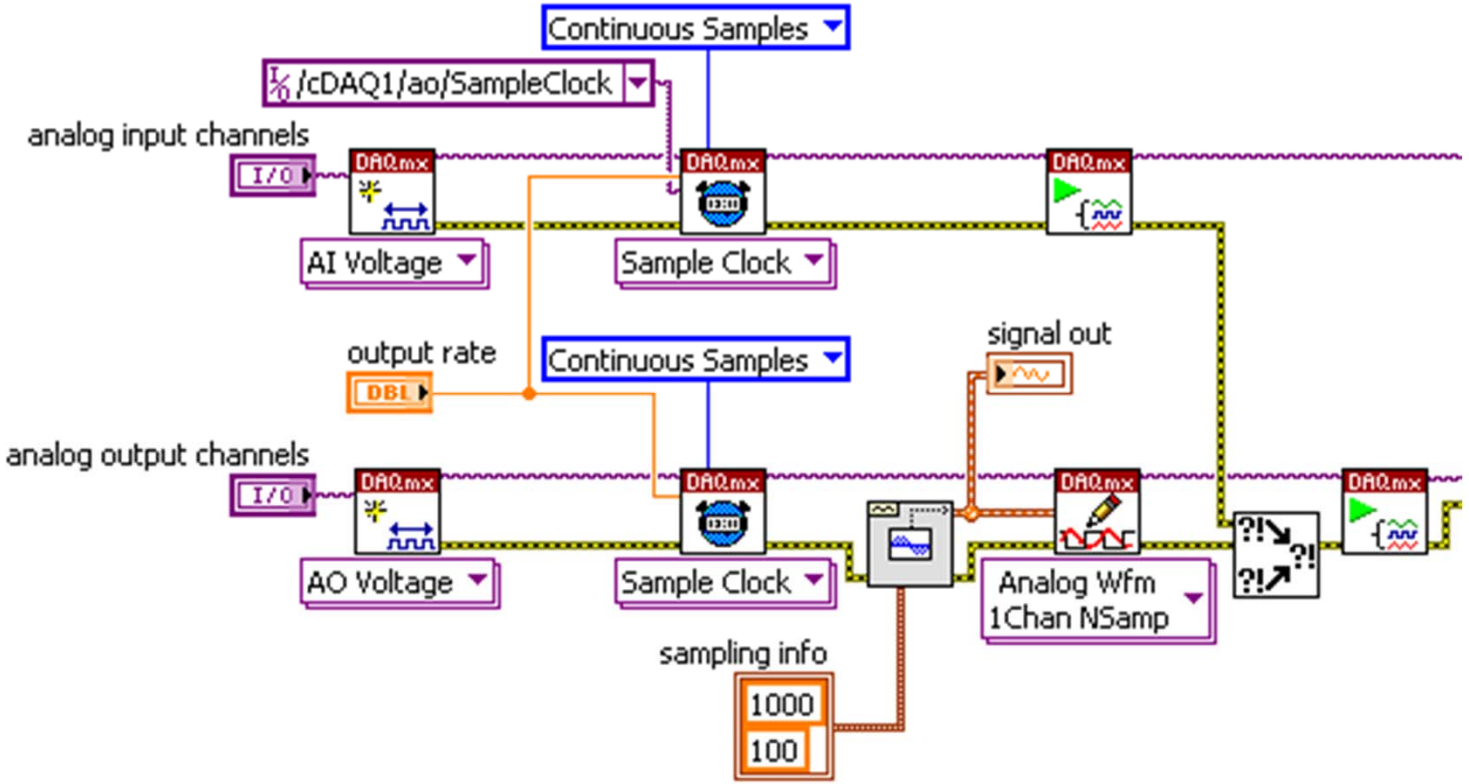
Synchronous Measurements

Share a Sample Clock

- Synchronous Measurements always run at the same rate
- Create synchronous measurements by sharing a sample clock between different tasks
  - Input tasks latch the value on a clock edge
  - Output tasks update a value on a clock edge
- If no clock edges are seen, no values are updated or latched

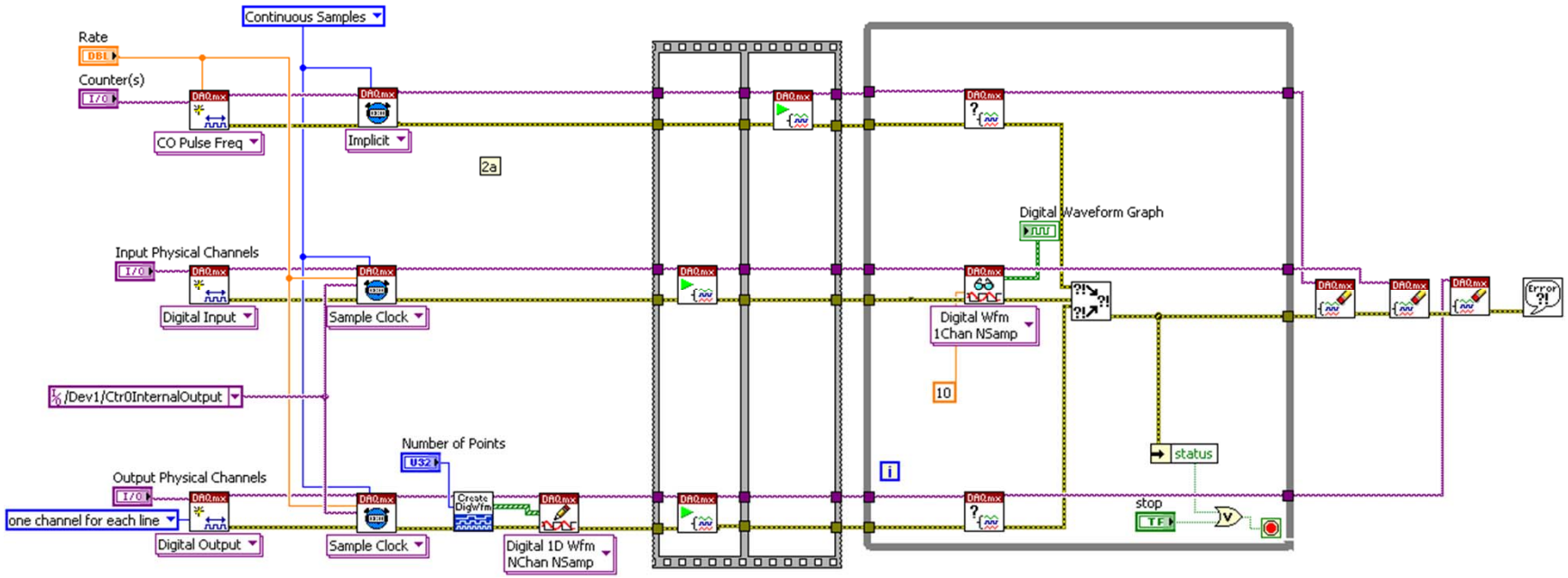
Example: Synchronous Measurements

Synchronous Analog Input and Output



Example: Synchronize Multiple Tasks

Use the counter's internal output to synchronize multiple tasks



Note: This VI can only work on a device that supports clocked digital I/O

C. Multiple Device Synchronization

Same rules apply for multiple devices as apply for a single device:

1. Share a Master Timebase and a Start Trigger
2. Share a Sample Clock

NI-DAQmx Rules

1. Create one master task
   - Configure master task, but do not start immediately
   - Only start master task after all slave tasks have started
2. Create as many slave tasks as necessary
   - Start slave tasks before starting master task

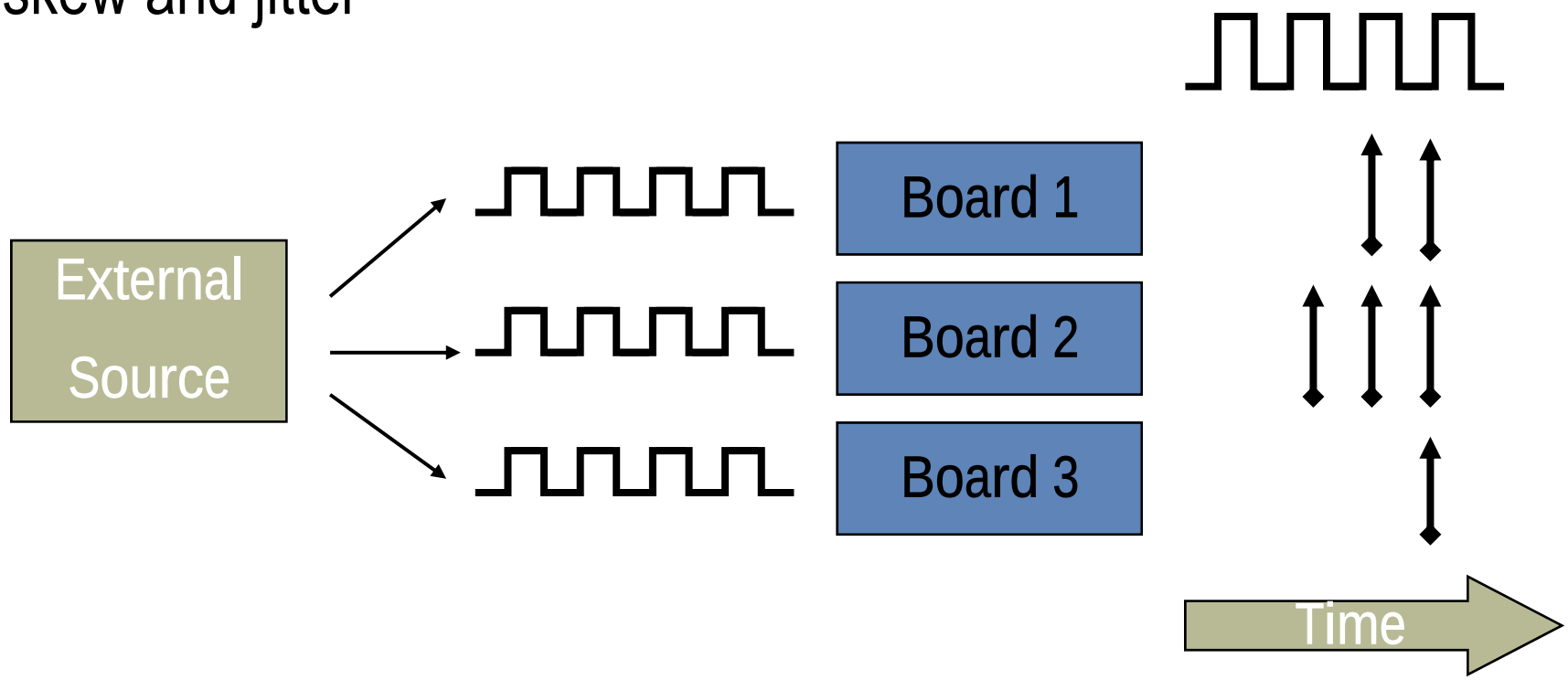
Multi-Device Synchronization

Synchronization Bus

- Data Transfer Bus cannot pass timing and synchronization signals
- If sharing internal signals between devices, must setup a synchronization bus
  - Must physically connect all boards to be synchronized with a synchronization bus cable
- USB Devices have no synchronization bus
  - Must synchronize USB devices with external sample clock

External Signal Connections

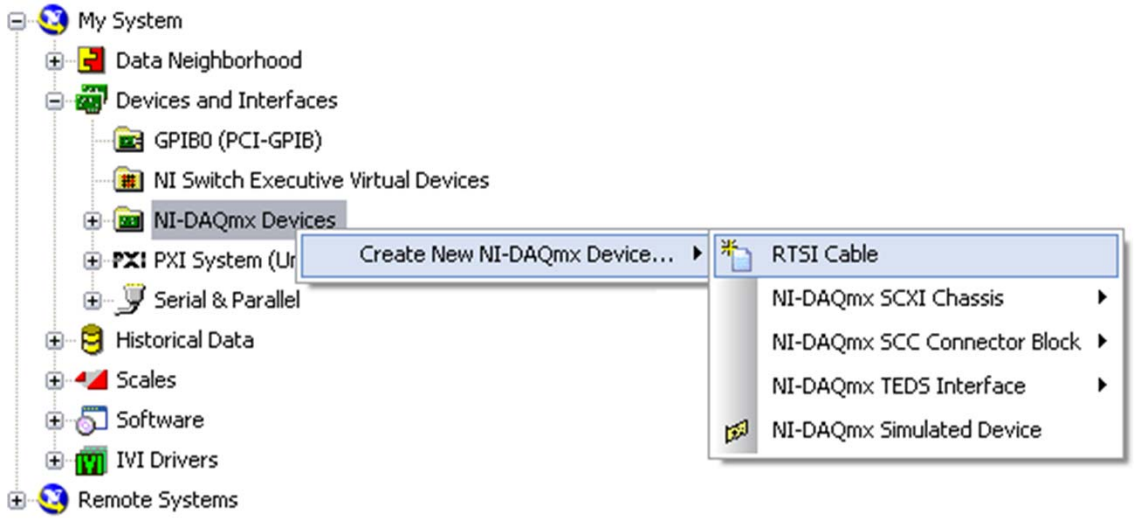
Different boards may start at different clock edges due to skew and jitter



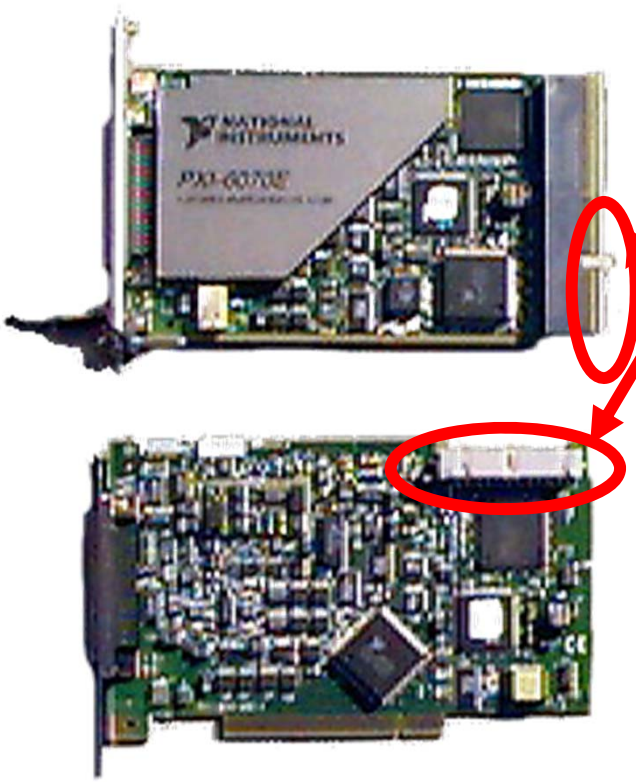
Multi-Device Routing in DAQmx

Real-Time System Integration (RTSI) Bus

- RTSI Cables are used for sharing timing and synchronization lines with other devices
- Setup RTSI Cable in MAX
- Must physically connect the RTSI Cable to all boards to be synchronized
  - Connector is on top back of board
- Once configured DAQmx automatically handles routing across RTSI bus



RTSI Bus



- RSTI Connector
- System Integration
  - Allows you to share timing signals between multiple devices

RTSI

- Most NI DAQ Devices support RTSI
  - PCI Devices: need a RTSI cable
  - PXI Devices: built in to the PXI chassis, referred to as the PXI Trigger Bus
    - Distinguishes PXI devices from CPCI devices
- Can pass timing signals up to 20 MHz
- As with other signal connections, trigger latencies and transmission line effects become pronounced at high frequencies

Programming with RTSI

- Management of the RSTI bus is hidden from user
- PCI Systems: Must register RTSI cable in MAX
- PXI Systems: Must register PXI system in MAX
- USB Systems: Must explicitly route lines to a PFI and physically connect PFI lines between multiple devices
- Use Export Signal.vi to explicitly route signals to RTSI

Multiple Device Simultaneous Operations

Much like with single devices, the common use cases for multiple device simultaneous operations are:

- Start multiple board operations simultaneously
  - Can use a hardware start trigger
- Synchronize multiple board operations
  - Can synchronize inputs and outputs on multiple devices
- Synchronize multiple board operations and start simultaneously

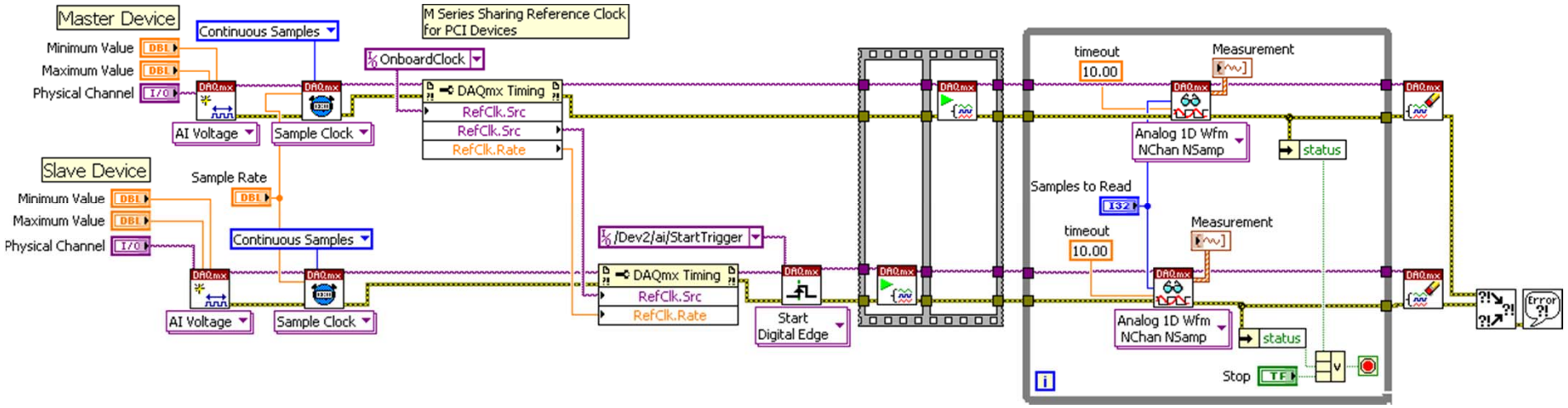
Create a RTSI Cable in MAX

Create a RTSI Cable in MAX for the synchronization of multiple devices

DEMONSTRATION

Example: Multiple Device Analog Input

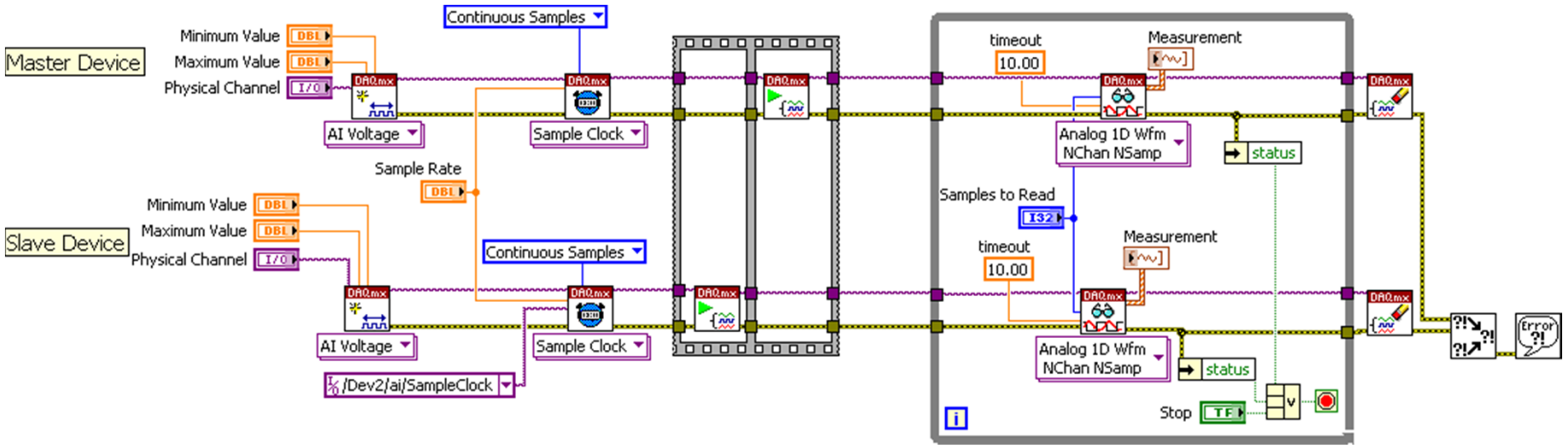
Share a Timebase and a Start Trigger – M Series (PCI)



Note: For CompactDAQ the Reference Clock and Start Trigger must be routed out of a PFI line on the master device and into a PFI line on the slave device(s).

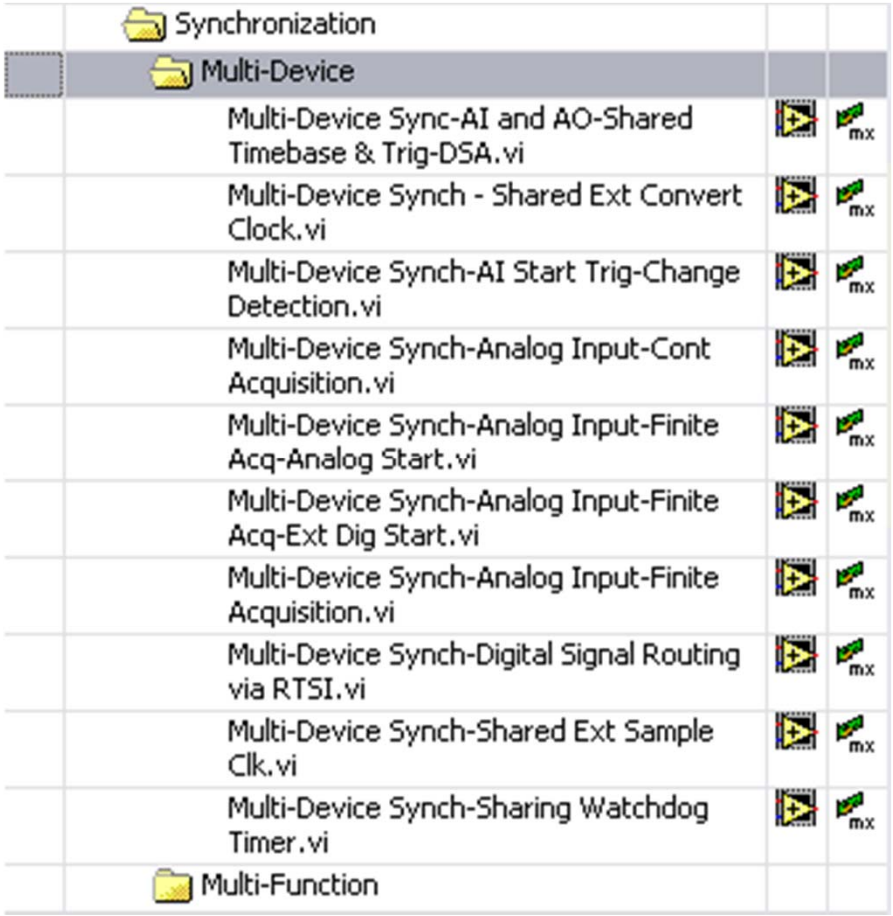
Example: Multiple Device Analog Input

Share a Sample Clock



Multi-Device Synchronization Resources

- *Find Examples > Hardware Input and Output > DAQmx > Synchronization > Multi-Device*
- Examples help to show caveats of using different devices with one another



Exercise 8-2: Synchronous Analog Input and Output

To perform a synchronized analog input and output operation by sharing the AO Sample Clock.

GOAL

Exercise 8-2: Synchronous Analog Input and Output

- How would you modify the VI to add a digital output task to generate data at the same time as the thermocouple and analog output tasks?

DISCUSSION

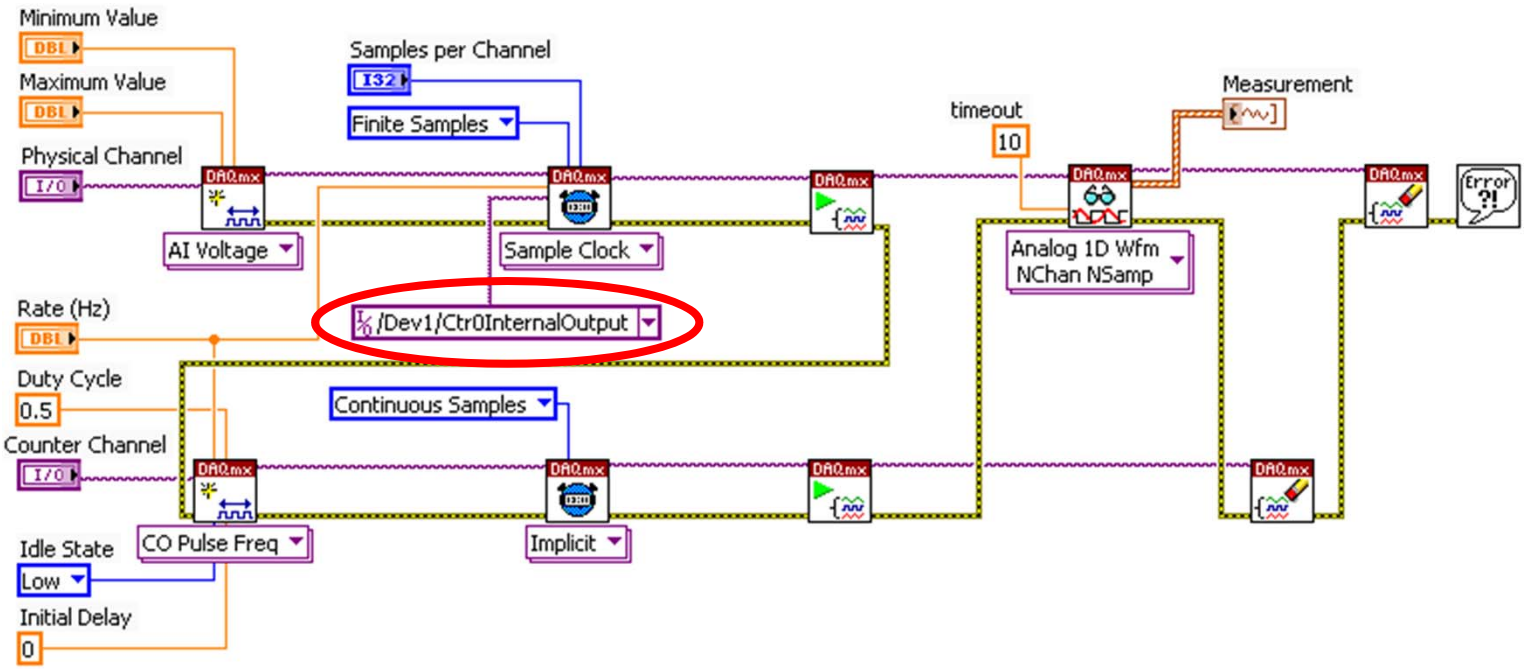
D. Counters and Synchronization

Counters have better flexibility than the clocks for analog or digital inputs and outputs

- Use the counters as clock sources for analog & digital tasks
  - Allows for the creation of
    - Retriggerable input tasks (Retriggerable Finite Pulse Train)
    - Variable rate input/output (Continuous Pulse Train)
    - Trigger after N pulses (Single Pulse with Initial Delay)
- Use AI/AO Sample Clock as the gate for counter measurements
  - Synchronize counter measurements with analog measurements

Example: Counters and Analog Tasks

Internal Output of counter pulse train used for analog input clock

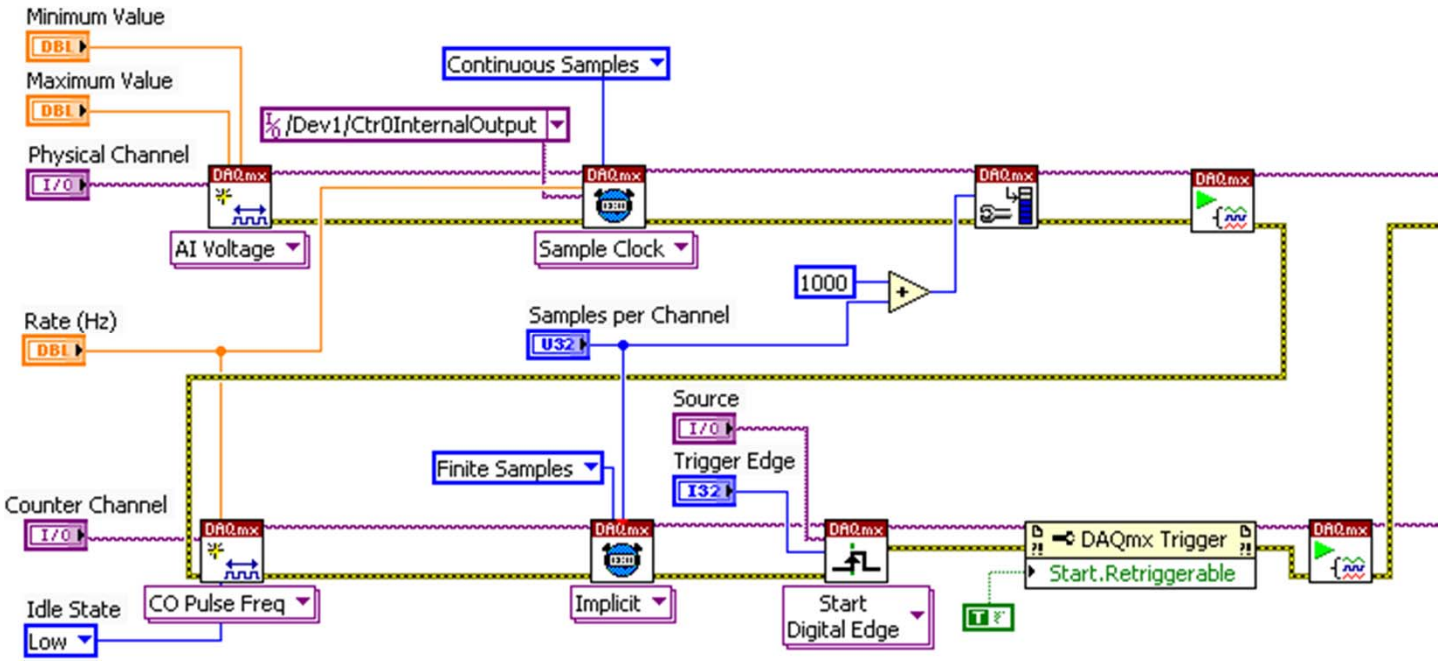


Retriggerable AI/AO

- For STC2-based devices, AI/AO operations are not retriggerable but counters are
  - Use counters to create retriggerable finite pulse train
  - AI/AO performs continuous operation using the retriggerable finite counter output as the sample clock
- Note: Certain STC3-based devices such as X Series can use the Start.Retriggerable property in the DAQmx Trigger property node for AI/AO tasks instead of using counters

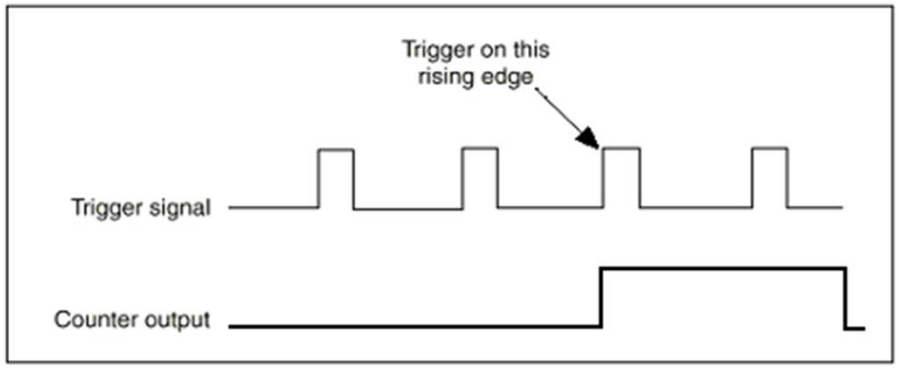
Retriggerable Analog Input Example (STC2-based Devices)

Use a retriggerable counter as the clock source for a continuous analog input.

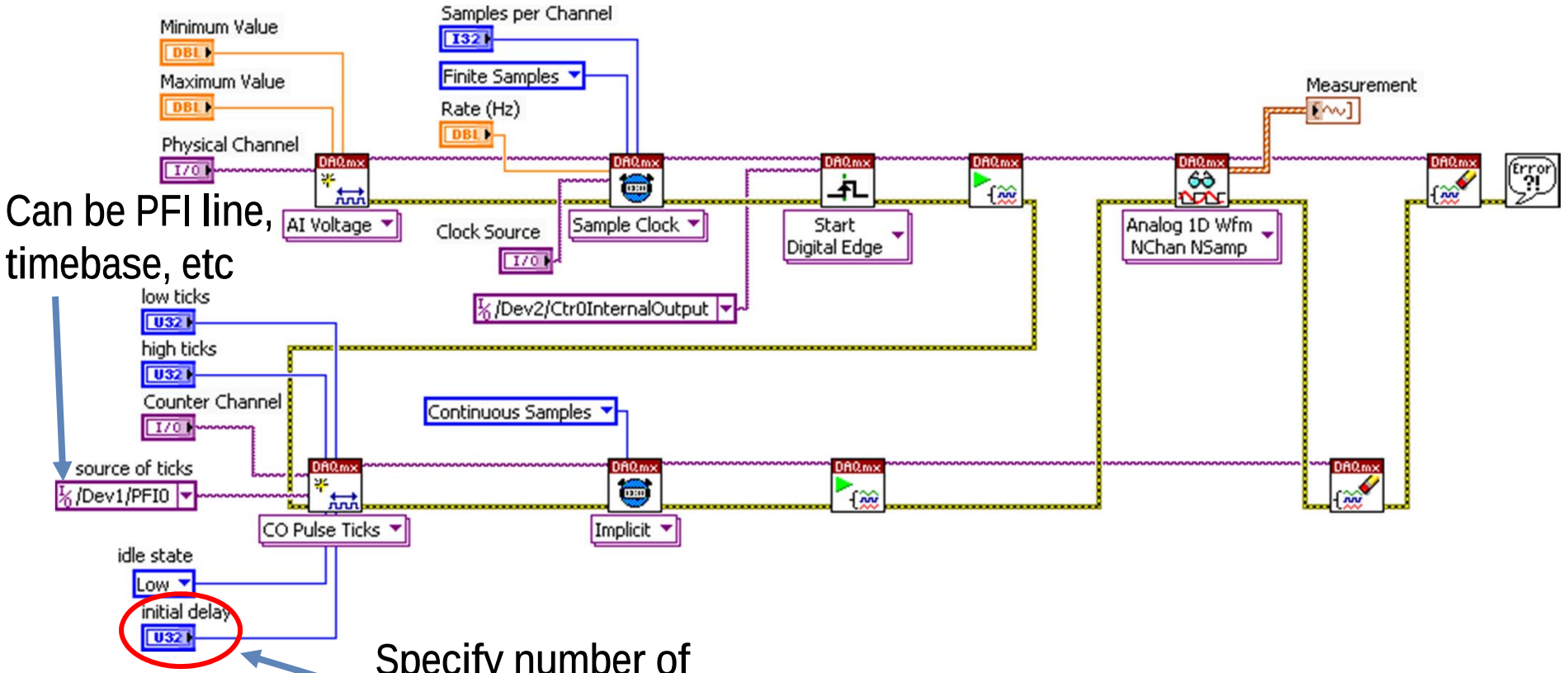


Event Triggering

- Allows you to trigger on the Nth trigger
- Uses a counter to monitor the pulses of your signal
- Actual trigger is generated on counter's output pin



Event Triggering



Use Sample Clocks with Counters

Counter Input:

- Can use an analog sample clock as the gate for a buffered counter measurement.
- Allows for counter measurements to be correlated to analog/digital measurements

Counter Output:

- Generate a pulse for every N ticks of the sample clock
  - For Example: Want to use counter as a trigger for a frame grabber.
    - Grab 1 frame for every 1000 analog input samples
    - Counter outputs a pulse every 1000th tick of the sample clock

Summary—Quiz

1. To simultaneously start and synchronize multiple tasks, you must share which of the following?
   a) Master Timebase
   b) Physical Channel
   c) Sample Clock
   d) Indicator
   e) Trigger

Summary—Quiz Answer

1. To simultaneously start and synchronize multiple tasks, you must share which of the following?

   a) Master Timebase

   b) Physical Channel

   c) Sample Clock

   d) Indicator

   e) Trigger

Summary—Quiz

2. To synchronize multiple boards, which of the following could be used?

   a) GPS

   b) RTSI Bus

   c) External Clock

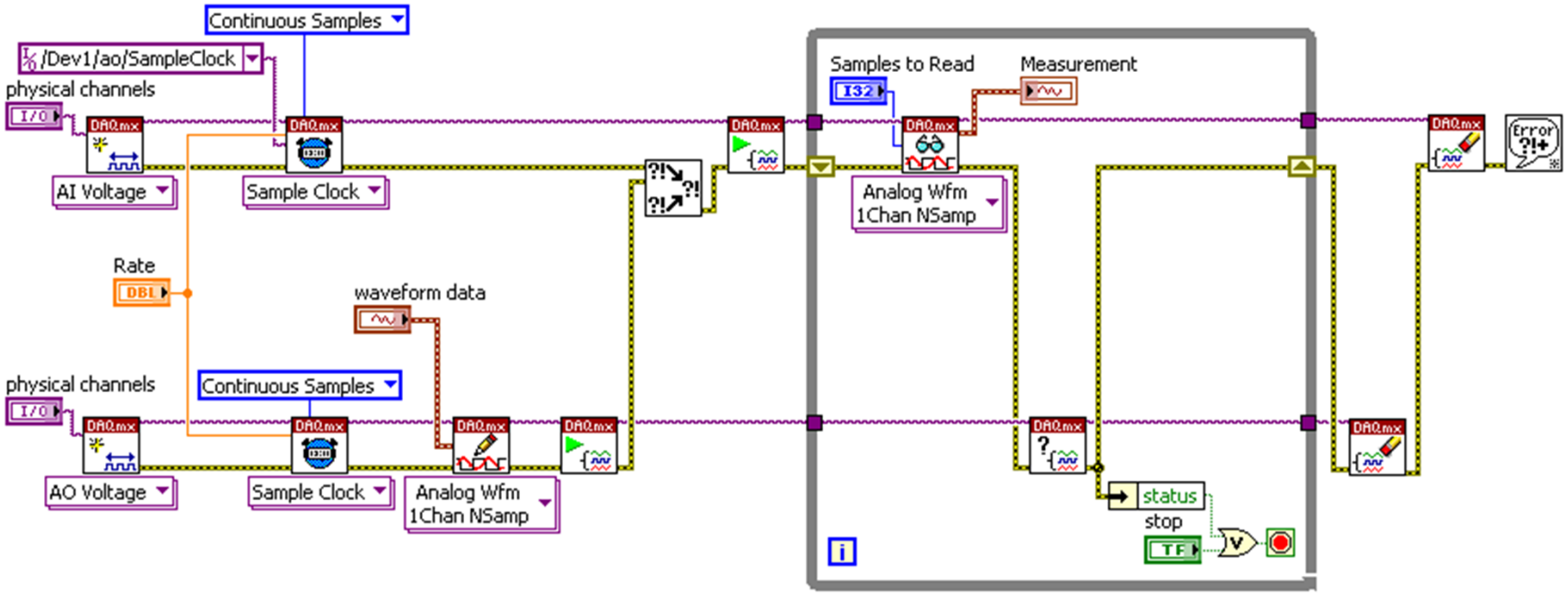
   d) PXI Trigger Bus

Summary—Quiz Answer

2. To synchronize multiple boards, which of the following could be used?
   a) GPS
   b) RTSI Bus
   c) External Clock
   d) PXI Trigger Bus

Summary—Quiz

3. Is this measurement synchronized? If so, why? If not, what prevents it from being synchronized?



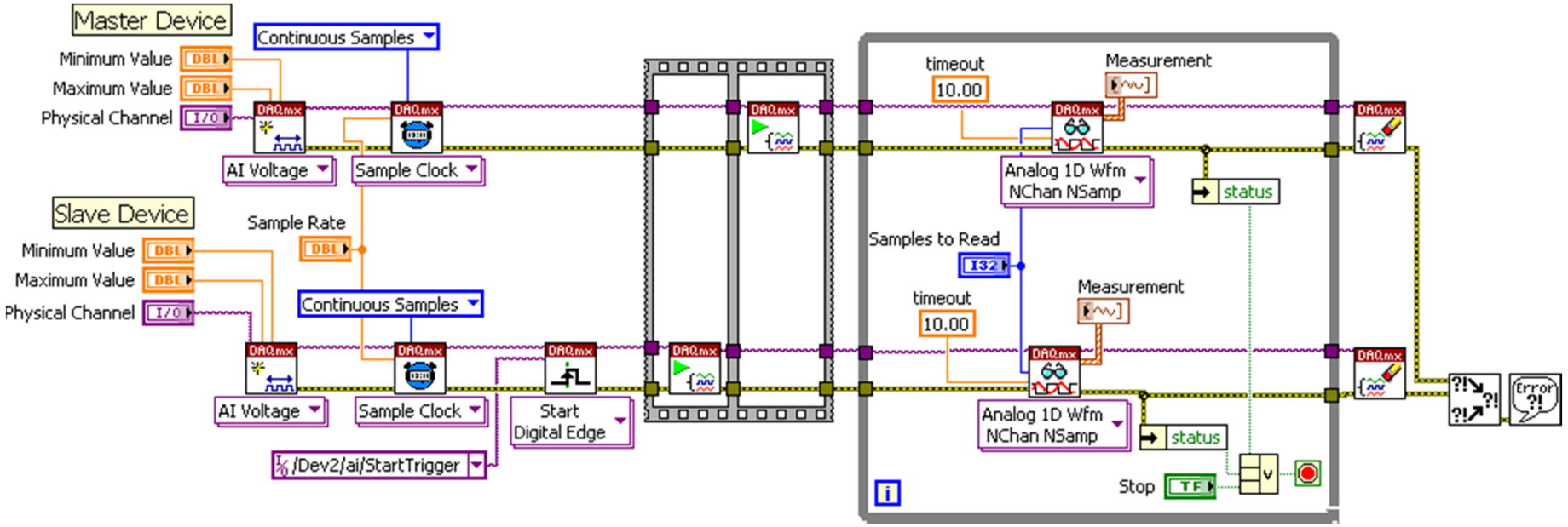
Summary—Quiz Answer

3. Is this measurement synchronized? If so, why? If not, what prevents it from being synchronized?

   No, this measurement is not synchronized. The analog output begins creating a sample clock before the analog input task has started.

Summary—Quiz

4. Is this measurement synchronized? If so, why? If not, what prevents it from being synchronized?



Summary—Quiz Answer

4. Is this measurement synchronized? If so, why? If not, what prevents it from being synchronized?

   No. The measurements share a start trigger, but not a master timebase; therefore, the measurements will be out of phase.

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