Timing a Two-Pulse Experiment

In the "Laser Control with the LC880" application note, we designed a laser control system using the LabSmith LC880 Programmable Logic Controller. In this application note, we'll discuss two designs for a two-pulse experiment, in which two laser pulses illuminate a fluid to visualize its flow.

Two-Pulse Experiments

Two-pulse techniques such as Particle Imaging Velocimetry (PIV) and variants of Planar Laser Induced Fluorescence (PLIF) have been developed to study fluid or gas flows – from mm/s to supersonic speeds. In these experiments, two laser pulses are produced in rapid succession, typically 10 µs to 10 ms apart, but as close as 200 ns apart. Both techniques have traditionally required two synchronized lasers, though more recently single, special-purpose lasers have been employed. We will focus on the more common two-laser setup here.

In a PIV setup, two lasers, following a common optical path, are formed into sheets to illuminate a plane of the liquid/gas, exposing the location of particles within the flow. A specialized camera records two successive frames, from which the flow can be studied with high precision by measuring particle displacements.

The laser flash lamps, Q-switches, and camera shutter must be synchronized for the experiment. The LC880 has proven particularly effective in this task. Because it provides 8 channels of timing, the LC880 also lets you approach the timing design in several ways.

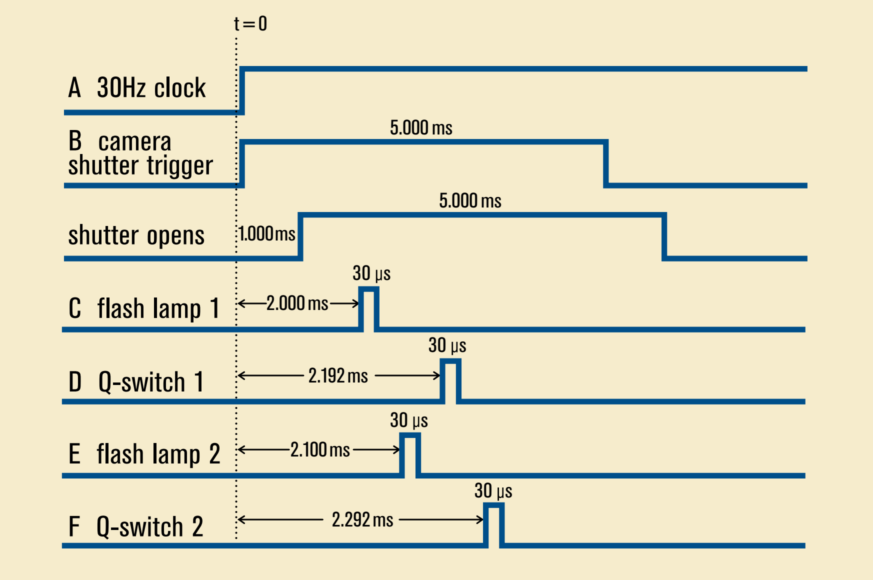

Figure 1a: Timing diagram for a PIV experiment with all timing based on a clock pulse.

```
QSwitchEnable = not in1;//Switch open = warm the lasers; switch closed=run experiment
LaserClock = outA;
Channel A:
   Free-running clock: High duration: 16.666667 ms; low duration: 16.666667 ms.
Channel B:
   Triggering options: Trigger on rising edge. Unlimited retriggering.
   Trigger Input Logic:
   inB = LaserClock and QSwitchEnable; //Clock A triggers the camera only if Q-Enable
   //switch is closed. Shutter stays open for 5 ms.
Channel C:
   Delayed pulse: Delay after trigger 2.000000 ms then pulse output 30.000 µs.
   Triggering options: Trigger on rising edge. Unlimited retriggering.
   Trigger Input Logic:
   inC = LaserClock; //Clock A triggers Flash lamp 1 to warm it up.
Channel D:
   Delayed pulse: Delay after trigger 2.192000 ms then pulse output 30.000 µs.
   Delay/duration notes:
   Triggering options: Trigger on rising edge. Unlimited retriggering.
   Trigger Input Logic:
   inD = LaserClock and QSwitchEnable;//Q-switch fires if Q-Enable switch closed.
Channel E:
   Delayed pulse: Delay after trigger 2.100000 ms then pulse output 30.000 µs.
   Triggering options: Trigger on rising edge. Unlimited retriggering.
   Trigger Input Logic:
   inE = LaserClock; //Clock A triggers Flash lamp 2 to warm it up.
Channel F:
   Delayed pulse: Delay after trigger 2.292000 ms then pulse output 30.000 µs.
   Delay/duration notes:
   Triggering options: Trigger on rising edge. Unlimited retriggering.
   Trigger Input Logic:
   inF = LaserClock and QSwitchEnable;// Q-switch 2 triggered 100 µs after Q-switch 1.
```

Figure 1b: Programming for a PIV experiment with timing based on clock pulse.

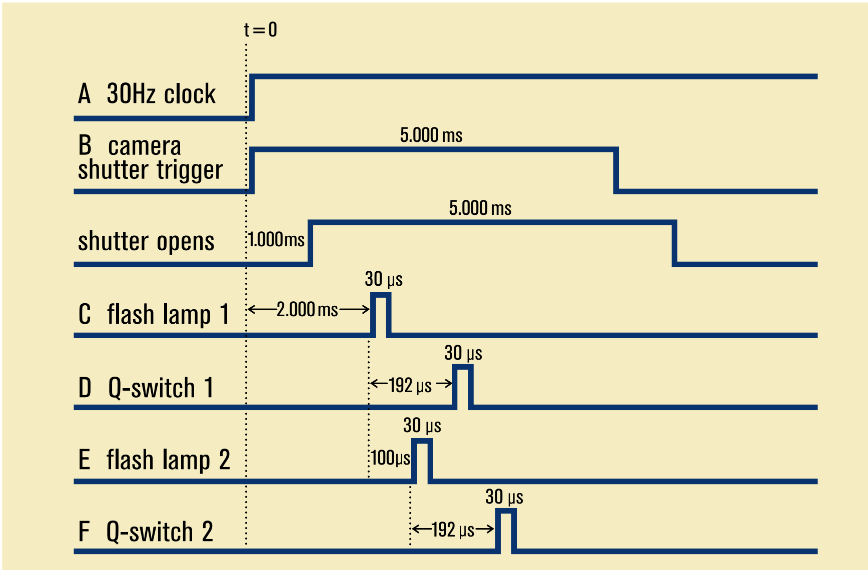

Figure 2a: Timing diagram for a PIV experiment with coupled channels.

```
Channel D:
    Delayed pulse: Delay after trigger 192.000 μs then pulse output 30.000 μs.
    Delay/duration notes:
    Triggering options: Trigger on rising edge. Unlimited retriggering.
    Trigger Input Logic:
    inD = LaserClock and outC;// Flash Lamp 1 triggers Q-Switch 1, only if Q-Enable switch
    closed.
Channel E:
    Triggering options: Trigger on rising edge. Unlimited retriggering.
    Trigger Input Logic:
    inE = outC; //Flash Lamp 1 triggers Flash Lamp 2.
Channel F:
    Delayed pulse: Delay after trigger 192.000 μs then pulse output 30.000 μs.
    Delay/duration notes:
    Triggering options: Trigger on rising edge. Unlimited retriggering.
    Trigger Input Logic:
    inF = QSwitchEnable and outE;// Flash Lamp 2 triggers Q-Switch 2, only if Q-Enable Switch
    is closed.
```

Figure 2b: Programming changes for PIV experiment with coupled channels.

All Timing Based on a Clock Pulse

Figure 1a shows a timing diagram for a PIV experiment with a pulse separation of 100 μs. In this example, the lasers and camera are triggered by the same clock pulse. Per the manufacturer's specs, the lasers reach maximum population inversion 193 μs after the flash lamps fire, and the Q-switches require 1 μs to respond. The camera shutter requires 1 ms to respond. We'll designate Channel A to provide a 30 Hz clock (16.667 ms high, 16.667 ms low).

To warm the flash lamps to thermal equilibrium, Channels C and E will send 30 μs pulses to the two flash lamps during each clock cycle. We'll employ a "Q-Enable Switch" at Input 2 (in2) to prevent the lasers from emitting light until the experimenter is ready. When Q-Enable is closed, the LC880 will first trigger the camera shutter via Channel B. The shutter will open 1 ms later and stay open for 5 ms. We'll begin triggering the flash lamps and Q-switches at t = 2 ms, well within the period that the shutter is open. Channels D and F trigger the Q-switches after the appropriate delays. The LC880 program appears in **Figure 1b**.

Coupling Channels Makes Changes Easier

The first timing design is fairly easy to understand at a glance, since all timing is based off the clock signal at A. **Figure 2a** shows a slightly different approach, in which the Q-switches and Flash Lamp 2 are triggered by Flash Lamp 1, rather than the clock itself.

As in the first design, Channel A supplies a 30 Hz pulse stream, the camera opens 1 ms after receiving a clock trigger, and Flash Lamp 1 fires at t = 2 ms. Here, however, the delay for Q-switch 1 begins when Flash Lamp 1 triggers. The Flash Lamp 2 delay also begins here. Lastly, the delay for Q-switch 2 will begin when Flash Lamp 2 triggers. **Figure 2b** shows the changes in logic and timing for Channels D, E and F.

With this approach, you can now alter the pulse delay by changing a single variable: the delay on Channel E. Coupling channels in this way helps to simplify complex experiments. Note that the timing accuracy remains the same in either case.

Conclusion

The LC880's combinatorial programmable logic and precision timing allow for easy control of lasers and other lab equipment. it's easy to organize and run complex experiments, making the LC880 an indispensable tool for fast, reliable laser-based experiments.

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