1. Introduction

In some applications we recommend the use of our *Sample&Hold* circuit. It ensures that the closed-loop control holds the actuated mirrors in the last stabilized positions during periods without a laser beam and then continues to control them from there. As a result, a stable beam position is ensured even if the laser beam is switched on and off during operation. This is often the case, for example, in laser material processing when different areas on a work piece are successively targeted by the laser. Similarly, lasers with low repetition rates (e.g. below 1 kHz), with single pulses or irregular pulse trains, have times when no laser light hits the detectors.

Another application of the circuit are laser systems with a very large distance between the actuated mirrors and the detectors. Here, it can happen that after the laser has been switched off for a while, the beam no longer hits the detector in the uncontrolled state because the initial alignment has changed due to drifts. That is why it is also good here to hold the actuated mirrors in place before switching off the laser.

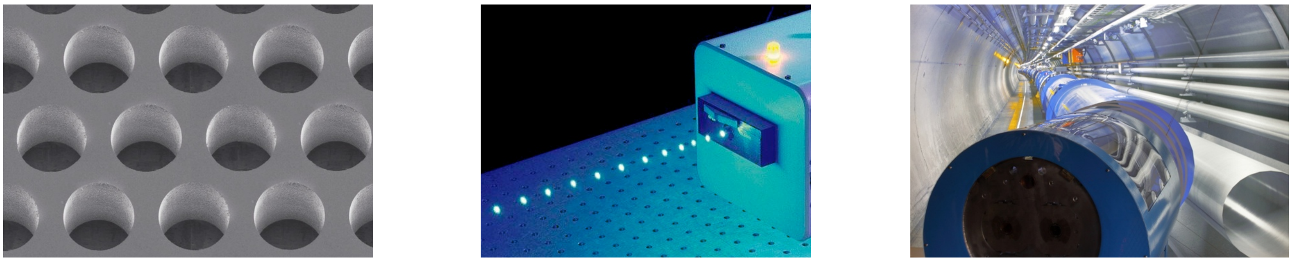

Figure 1: Application fields for the use of the Sample&Hold circuit such as laser micromachining, lasers with low repetition rates or setups with long beam paths

During the periods without a laser beam, the detectors cannot determine any positions, so that the system lacks the control signal during these times. Without the additional *Sample&Hold* circuit, the piezo actuated mirrors then return to their zero positions. These are the mirror positions to which they were manually adjusted before the stabilization was activated. If the laser is switched on again after an interruption, the stabilization starts from these positions. The zero positions can be good starting points, but if the interruptions are short, the laser may oscillate between the zero position and the stabilized position. In the opposite case, if the interruptions are relatively long or if there are moving elements in the setup such as in laser machines, the beam line may have changed in such a way that the zero positions are no longer good enough. For such cases we recommend the use of the *Sample&Hold* circuit.

2. Description

With the *Sample&Hold* circuit ("ADDA"), the piezo actuated mirrors remain in their last stabilized positions during periods without laser power. For this purpose, the stabilized positions are temporarily stored. As soon as laser light hits the detectors again, the closed-loop system continues to stabilize in real time. This ensures the highest position and angular stability of the beam even with lasers at low repetition rates or laser on/off times.

The term "ADDA" is derived from the aspect that the control signals of the actuators are continuously AD-converted and digitally stored. When required, they are DA-converted again and given to the amplifiers of the piezo actuators. This makes it possible for the actuated mirrors to be held for any length of time until the system continues to control from the last stabilized position.

3. Modes of operation

The *Sample&Hold* circuit can be used in two modes: automatic control and control with external triggering. Both are explained below.

3.1. Automatic control

The system has an automatic detection of laser on/off times. For this purpose, it reads the intensities of the detectors. With each reading, the control voltages of the steering mirrors are stored. If a subsequent reading gives a laser off time, the piezo actuators are held in the current position. For automatic control it is necessary that the laser on times or the pulse trains are longer than 100 ms. Then the user does not have to provide any further signals. The system stabilizes automatically according to the on/off times.

3.2. External triggering

For lasers with short pulse trains or single pulses (<100 ms) as well as for lasers with low repetition rates (<1 kHz), the circuit should be synchronized with the laser on/off times by external triggers. In these cases, the automatic control would not update the storage of the control signals fast enough. Via the trigger signals for the on/off times, there is an exact time assignment to the laser intensity, when the system shall hold the actuated mirrors and when it shall start the closed-loop control.

To reach the optimal function, the time specifications for the trigger signal must be met. Figure 2 shows the tolerances.

- duration of the trigger signal: $t_{min} \geq 10$ µs
- time T1 of trigger start: not earlier than 10 µs before and not later than 50 µs after start of pulse
- time of trigger end T2: not later than 1 ms after end of pulse

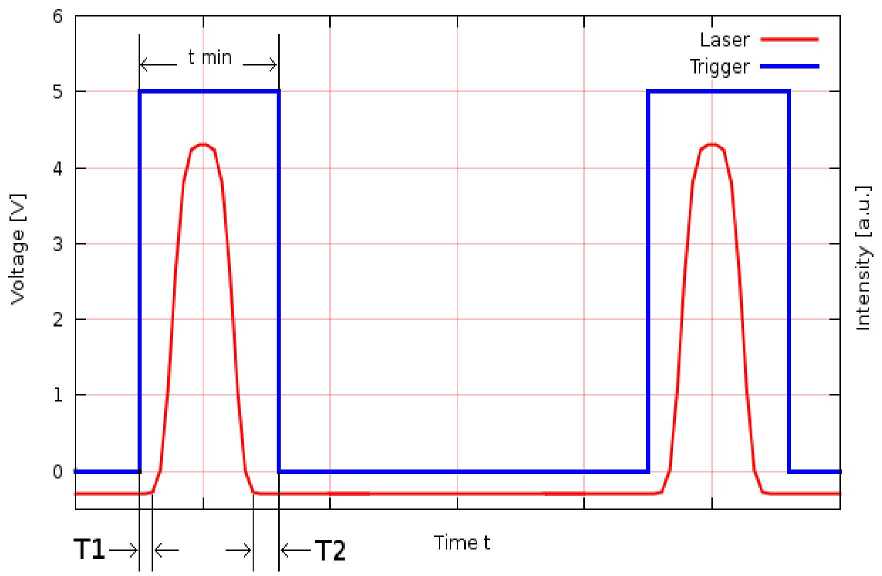

Figure 2: Timing of the trigger signal

The levels are defined as follows:

- TTL level "high" when laser intensity is present and level "low" when intensity is absent

The controller of the *Compact* system is equipped with a trigger input for each of the two control stages. It is also possible to set the trigger signals via the serial interface. Thus, it is possible to stabilize the laser easily.

4. Example of a laser with a repetition rate of 10 Hz

The oscillogram below shows the example of a laser with a repetition rate of 10 Hz. The upper curve shows the position signal of the individual laser pulses and the lower curve the trigger signal. At a voltage of 0 V in the upper curve, the desired target position is reached. The laser is thus initially in a bad position. At the fourth laser pulse seen from the left, the beam stabilization system equipped with *Sample&Hold* is activated. In the subsequent course, it can be clearly seen that the beam gets closer to the target position with each pulse until it finally remains there as a stable beam. In this example, approximately four pulses are required to reach the target position. Depending on the setup, the components used and the set P-factor, the required number of pulses may vary.

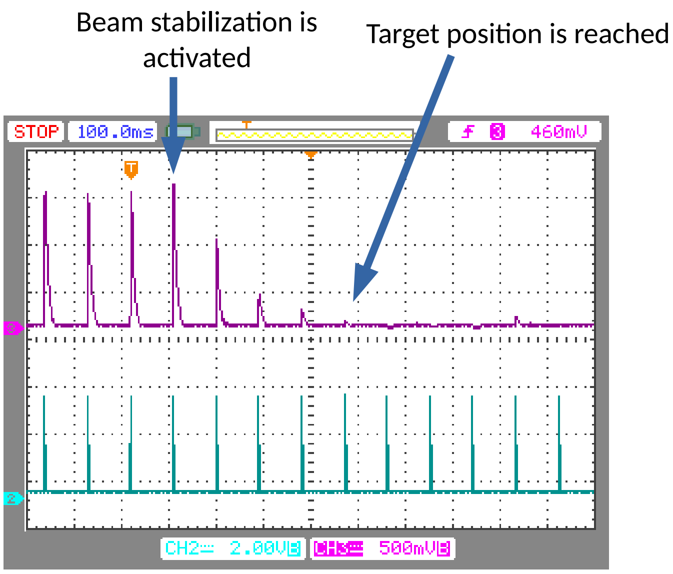

Figure 3: Single laser pulses (10 Hz), explanations see text

5. Example of a laser with pulse trains

If a trigger signal is available for the on/off times of the laser, it is advantageous to use it. Due to the better temporal assignment to the laser intensity, better results are usually obtained with the triggering. Figure 4 shows an example with pulse trains of a laser with a repetition rate of 1 kHz. The pulse trains are approximately 170 ms long and shown in green. Here, the trigger is not set on the individual laser pulses (1 kHz), but on the on/off times of the pulse trains. This is recommended for repetition rates of approximately 300 Hz or higher. The blue curve shows the trigger signal, the violet curve in the middle of the diagram shows the stable position signal.

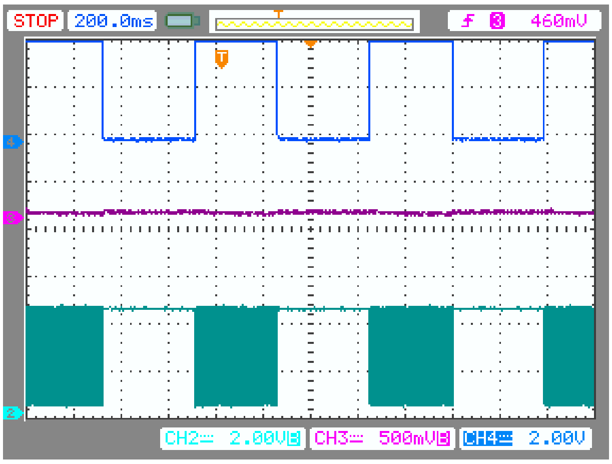

Figure 4: Pulse trains (bottom) stabilized with trigger (top)

6. Note for the use of mechanical shutters

In cases where a mechanical shutter interrupts the laser beam, external triggering should always be used. The trigger signals should then be timed so that the detectors do not detect a partially covered beam during the opening and closing of the shutter. If partially covered beams were detected, the system would not hold the desired positions because the center of the power distribution would shift. Even without a shutter, it should be taken care that the beam is not cut off by apertures.

7. Technical properties

Sample & Hold circuit	
Storage principle	Digital storage of position data
Sampling rate	25 kHz
Freezing interval	Unlimited
Requirement for automatic triggering	Minimal laser on time: > 100 ms
Trigger (analog)	
Signal levels	TTL, „high“ for laser on, „low“ for laser off
Input	One per control stage
Cable (optional)	LEMO 00 → BNC
Minimal length of trigger signal „high“	$t_{min} \geq 10$ µs
Trigger start	10 µs before and up to 50 µs after pulse start
Trigger end	max. 1 ms after pulse end
Trigger (digital)	
Via serial interface	Commands: „SetTriggerFreeze“, „ClearTriggerFreeze“

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Subject to change.