

Tutorial: Triggering & Synchronizing Multiple Chronos Cameras

This application document describes how to trigger and synchronize two Chronos high-speed cameras. The procedures can be extended to trigger or synchronize more than two cameras regardless of their model.

Table 1 is a quick reference of the different techniques available. The user can then go to a specific section in this document and get more details about the technique(s) of interest.

Method	Advantages	Disadvantages	Applications	Accuracy
Trigger switch cable	Frame rate, exposure time, and record times set independently for each camera	Output is not synchronized footage	When footage synchronization is not relevant, i.e., multiple views of devices running steadily	Low
Trigger switch cable, transmitter/receiver camera setup	The recorded video is synchronized Recording start time uncertainty is $\pm 50\%$ of the interframe time Captured footage synchronized within 500 ns	The transmitter camera's frame rate defines the receiver's frame rate There can be only one transmitter camera but multiple receiver cameras	This strategy can be applied to Digital Image Correlation, PIV, steady or transient fluid flow and 3D reconstruction, among others	Medium
External signal source, transmitter/receiver setup	Most accurate synchronization method Recording starts within 500 ns of the signal sent to the transmitter camera Video footage synchronized within 500 ns	Function generator, microcontroller, Data Acquisition System (DAQ), or Programmable Logic Controller (PLC) drive the transmitter camera User needs to manually set camera's start/end recording via the touchscreen or camera web interface	Applications that require synchronization of the footage with a particular event. High-precision video footage of R&D projects Academic research projects	High

Table 1. Quick reference describing the different triggering/synchronization schemes

Table of Contents

1. Trigger Multiple Cameras using Trigger Switch Cable	3
1.1 Parts Needed:	3
1.2 How to Set Up:	4
1.3 Trigger/IO Settings:	5
1.3.1 Record End Trigger. Trigger I/O Settings for Stop Recording	5
1.3.2 Toggle Trigger. Trigger I/O Settings for Start and Stop Recording	6
1.3.3 Trigger Delays	6
2. Trigger and Synchronize Multiple Cameras Simultaneously using Transmitter/Receiver Camera	7
2.1 Parts Needed:	8
2.2 How to Set Up:	8
2.2.1 Transmitter Camera	8
2.2.2 Receiver Camera	8
2.3 Trigger/IO Settings:	10
2.3.1 Record End Trigger	10
2.3.1.a Cameras settings	10
2.3.2 Toggle Trigger	11
2.3.2.a Cameras Settings	11
3. Synchronize Shutters on Multiple Cameras Using External Signal Source	12
3.1 Parts Needed:	12
3.2 How to Set Up:	13
3.3 Trigger/IO Settings:	14
3.3.1 Cameras settings:	14
4. Sample footage of the different triggering and synchronization schemes	15
4.1 Cameras triggered by the trigger switch cable	15
4.2 Cameras synchronized using the transmitter/receiver setup	17
4.2.1 Record End Trigger	17
4.2.2 Toggle Trigger	18
4.3 Cameras synchronized using an external signal source	19
Additional Notes	20

1. Trigger Multiple Cameras using Trigger Switch Cable

This setup allows users to trigger multiple Chronos cameras to start and end recording from an external switch, but will not output synchronized footage. Different resolutions, frame rates, and/or record times can be configured for each camera since footage synchronization is not critical for this setup.

1.1 Parts Needed:

Item/Component	Reference/Vendor
1x Trigger Switch Cable	Trigger Switch cable Kron Technologies
1x BNC Tee	BNC-Tee Kron Technologies
1x BNC male-to-male cable (long enough to connect between transmitter and receiver camera).	30m (100') BNC extension cable Kron Technologies
Or use a BNC coupler to connect two or more BNC cables.	7.5m (25') BNC Extension Cable Kron Technologies BNC Coupler Kron Technologies

Table 2. List of components to trigger two* Chronos high-speed cameras

* The parts list is for triggering 2X Chronos cameras. If you are triggering more than two cameras, add an additional BNC Tee and BNC cable for each additional camera.

1.2 How to Set Up:

In this configuration, the cameras are recording independently, however, for consistency, we refer to the cameras as transmitter or driving camera and receiver or driven camera.

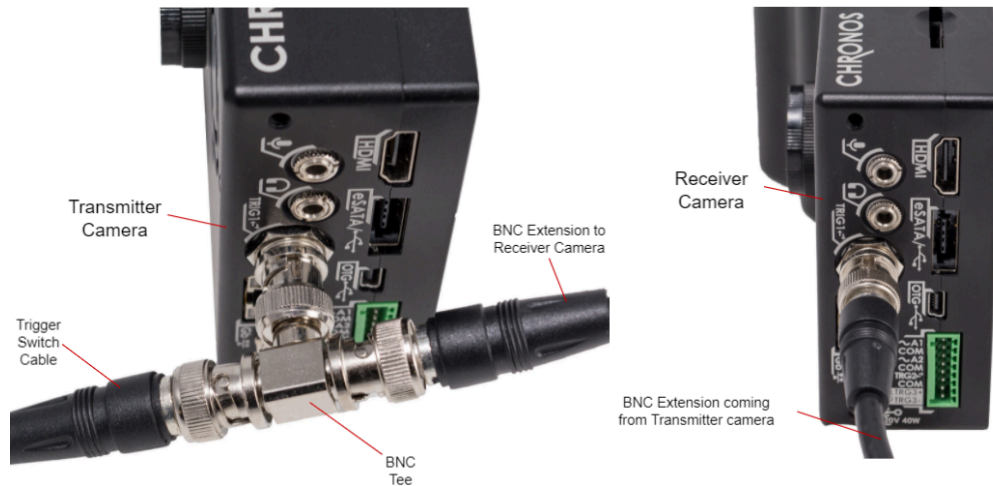


Figure 1.1 Left, trigger switch cable, T-connector and BNC extension to the receiver camera connected to the transmitter camera. Right, BNC extension is connected to the receiver camera.

- Connect the trigger switch cable to the BNC Tee and connect the BNC Tee to the I/O1 BNC connector to the transmitter camera. Then connect the BNC extension to the other end of the Tee connector, as depicted in **Figure 1.1**.
- Connect the other end of the BNC extension cable to the receiver camera's I/O1 BNC connector.

1.3 Trigger/I/O Settings:

The Chronos cameras provide two triggering options with a trigger switch cable: **Record End Trigger and Toggle trigger.**

Record End trigger. The cameras are set to record in a continuous buffer. The user starts the recording manually. The recording ends with the press of the trigger switch button.

Toggle trigger The recording starts and stops with the press of the trigger switch button.

1.3.1 Record End Trigger. Trigger I/O Settings for Stop Recording

This configuration allows users to simultaneously apply a single trigger button press to end recording on multiple cameras. Note that you would still have to start each camera recording manually.

- Set up the transmitter and receiver camera trigger settings as portrayed in **Figure 1.2**. You can use the receiver camera’s settings on any additional receiver cameras.

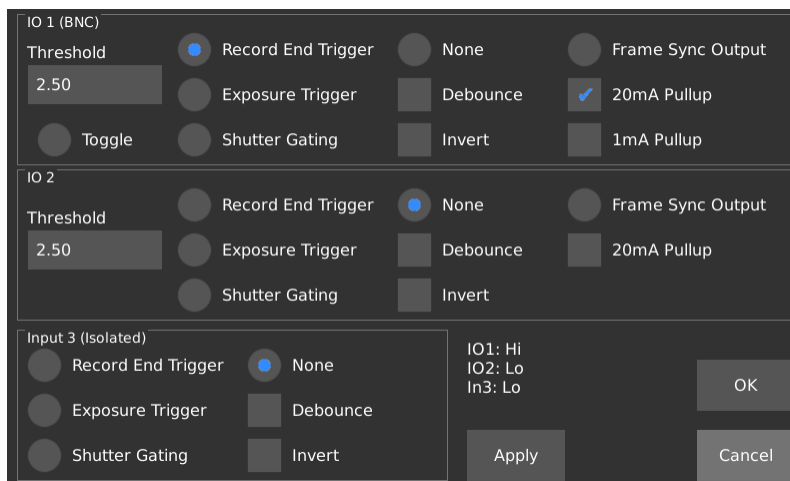


Figure 1.2 Settings for the driving and driven cameras when using the record end option

To capture video

Press the record button of each camera in the main menu, then press the trigger switch button to end the recording.

1.3.2 Toggle Trigger. Trigger I/O Settings for Start and Stop Recording

Warning:

TOGGLE TRIGGER SETTING - Starting a new recording overwrites any existing footage in the camera's memory buffer. Accidentally starting a new recording may result in the loss of valuable footage. To avoid this, users can enable the **“Auto Save”** feature on the **Util > Main page**. The Auto Save feature automatically saves the recorded footage with preset save settings to the selected storage location.

This configuration allows users to start or stop a recording on every connected camera by pressing the trigger switch button.

- In the TRIGGER/IO 1 window, set up both camera's trigger settings as depicted in **Figure 1.3**

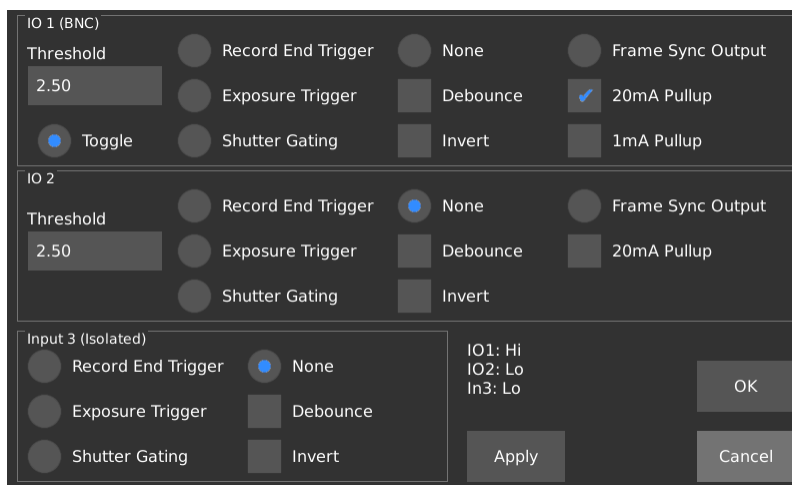


Figure 1.3 Settings for cameras 1 and 2 when using the toggle option

1.3.3 Trigger Delays

- Confirm Post-trigger Delay settings (**Record Settings > Trigger Delay**) are set at the same values. To prevent any delays, press **“Reset to Defaults”** and **“OK”** on both cameras to set post-trigger values to 0.

To capture video

Press the trigger switch button to start and end the recording.

2. Trigger and Synchronize Multiple Cameras Simultaneously using Transmitter/Receiver Camera

A more precise method to synchronize multiple cameras is described next. This may be a suitable option for many users since it does not require an external device.

The camera model, resolution, and record length can vary on each camera. However, keep in mind that the frame rate (fps) set on the receiver camera(s) has to be equal to or greater than the transmitter camera. It is the transmitter camera's frame rate that defines the receiver camera's frame rate and the time of the event, the time stamp of the driving camera.

For instance, a Chronos 2.1-HD camera (transmitter) set to 1920 x 1080p @ 1000 fps with 11 seconds record length can be synchronized with a Chronos 1.4 (receiver) 1280x 1024 @ 1069 fps with 8 seconds record length. The recorded footage on each camera will be 1000fps. Since the record lengths differ, the recorded footage can be synchronized from the end of the recording by using the last frame from each footage as a reference.

As an alternative to this, the user can set the maximum number of frames to record. From the main menu, press **Record Settings > Record Modes**. Next, select Normal under Record Mode and input the desired number of frames under Record Length (frames).

IMPORTANT NOTE REGARDING THE TIMESTAMP OF THE EVENT(S) RECORDED

When two cameras are set to operate in the driving-driven setup the driven camera is set to operate at the frame rate established by the driving camera. Due to this, the recording time is established by the driving camera's time stamp. The timestamp of the driven camera is not disabled and may display a different time from that of the driving camera. This is a feature that will be addressed in future updates of our software.

These synchronization methods hereafter described apply to different combinations, i.e., synchronizing two 1.4 Chronos cameras or one 1.4 Chronos camera and one 2.1-HD Chronos camera.

2.1 Parts Needed:

Item/Component	Reference/Vendor
1x Trigger Switch Cable	Trigger-Switch-cable Kron Technologies
1x BNC Tee	BNC-Tee Kron Technologies
1x BNC male to male cable (long enough to connect between transmitter and receiver camera)	30m-100-bnc-extension-cable Kron Technologies 7.5m (25') BNC Extension Cable Kron Technologies BNC Coupler Kron Technologies
Connecting cable	Sync Cable for Chronos 1.4 and 2.1-HD
Note: Chronos model info is found at the bottom of the cameras.	

**The parts list is for triggering 2X Chronos cameras. If you are triggering more than two cameras, allow for additional parts for the additional cameras.*

2.2 How to Set Up:

2.2.1 Transmitter Camera

- Connect the trigger switch cable to the BNC Tee and connect the BNC Tee to the I/O1 BNC port of the transmitter camera.
- Connect an I/O1 BNC extension cable to the other end of the BNC Tee.
- [Connecting cable](#). Connect one end of the cable to the transmitter camera, see **Figure 1**.

2.2.2 Receiver Camera

- Connect the other end of the BNC extension cable to the receiver camera's I/O1 BNC connector.
- [Connecting cable](#). Connect the other end of the connecting to the receiver camera, see **Figure 2.1**

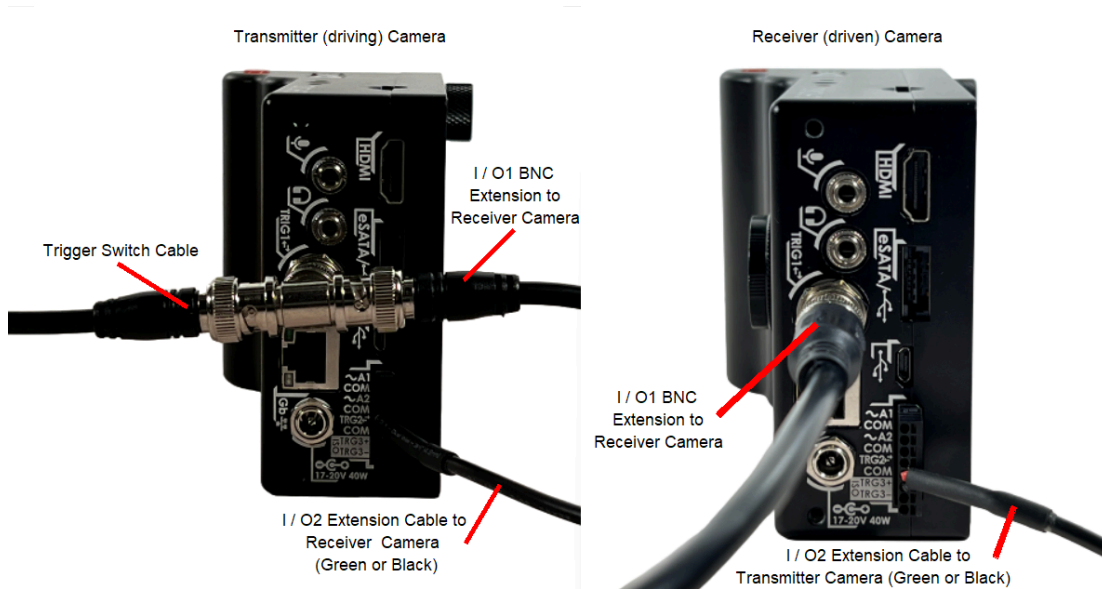


Figure 2.1 Left, connections of the transmitter camera when using the Record End or Toggle option. Right, Connections of the receiver camera when using the Record End or Toggle option

- The final camera setup should appear as depicted in the diagram below.

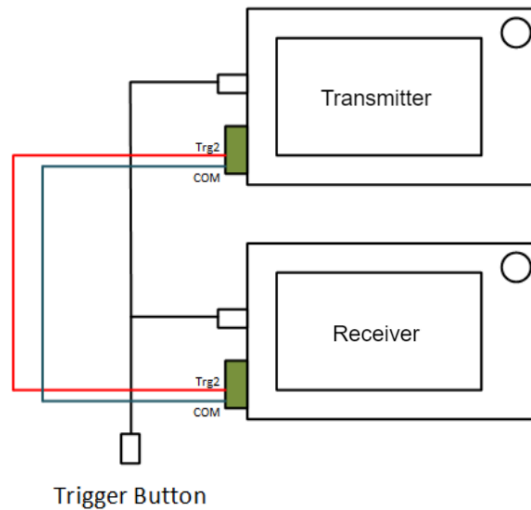


Figure 2.2 Schematic representation of the wiring to synchronize two Chronos cameras using the trigger switch button

2.3 Trigger/IO Settings:

There are two options for synchronizing the cameras:

- Follow [2.3.1 Record End Trigger](#) to end the recording with a button press.
- Follow [2.3.2 Toggle Trigger](#) to start and stop recording.

Note: From the time the trigger switch button is pressed to the time the camera starts/stops the recording an average uncertainty of 50% of the inter-frame time is expected, see [image 4.4](#). This uncertainty applies to both the Record End and the Toggle trigger methods.

2.3.1 Record End Trigger

The following setting enables users to synchronize the footage of multiple cameras. The recording ends with the press of the trigger switch button. You still need to start each camera recording manually.

2.3.1.a Cameras settings

- Set up the transmitter and receiver cameras' trigger settings as seen in [Figure 2.4](#), then press **“Apply”** and **“OK”**.

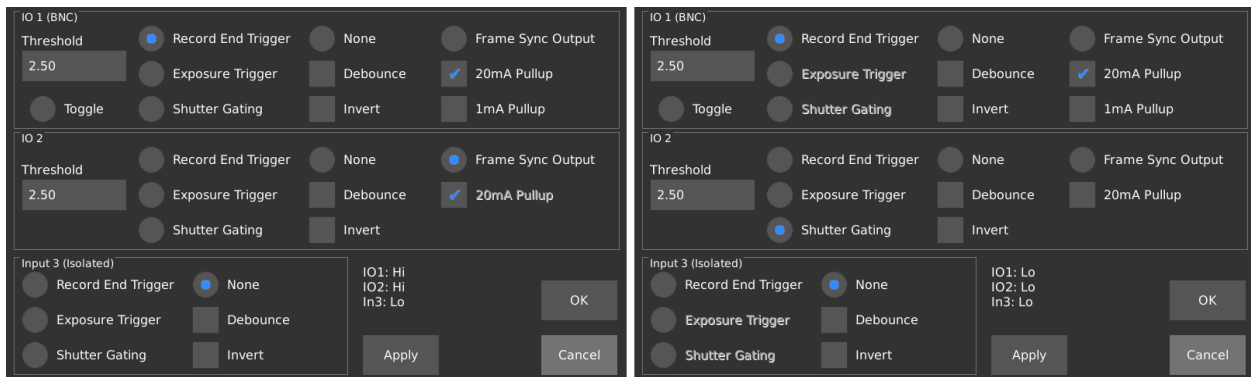


Figure 2.3 Record end option. Left, transmitter camera settings. Right, receiver camera settings

In case the cameras have a different memory size the number of frames recorded is different. To prevent this, the user can set the same number of frames to be saved. In the main menu, go to [Record Settings > Record Modes](#), select Normal, and input the number of frames desired to record.

2.3.2 Toggle Trigger

This configuration allows users to synchronize frames and start or stop a recording on every connected camera by pressing a single trigger button.

Warning: As mentioned in section [1.3.2](#), when using the toggle trigger setting, starting a new recording overwrites the footage in the memory buffer of the camera. Starting a new recording may lead to the loss of valuable footage. Avoid this by enabling the **“Auto**

Save” feature on the **Util > Main** page. This property automatically saves the recorded footage with preset save settings to a predefined storage location.

2.3.2.a Cameras Settings

- In the Trigger settings window, set up the transmitter and receiver cameras’ trigger settings as follows, press **“Apply”** and **“OK”**

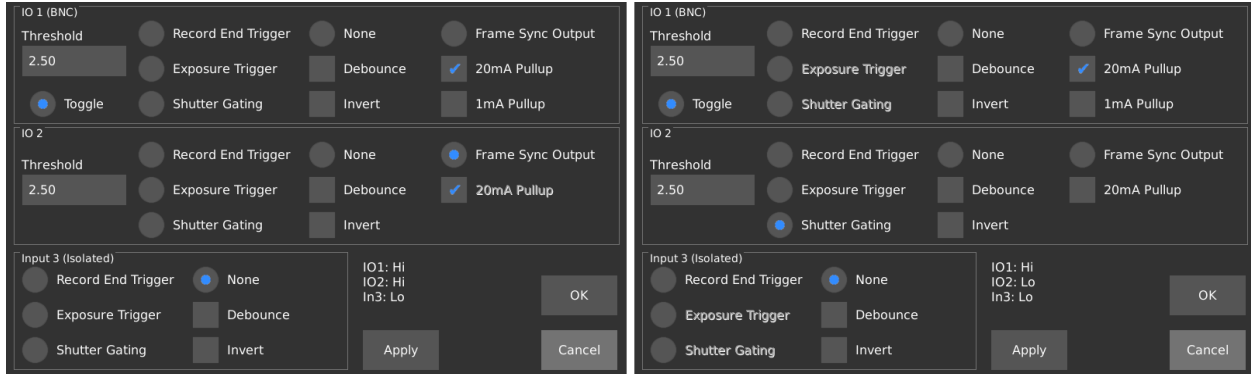


Figure 2.4 Toggle option. Left, transmitter camera settings. Right, receiver camera settings

3. Synchronize Shutters on Multiple Cameras Using External Signal Source

This setup lets users to exactly synchronize the frames on multiple cameras using an external signal source. The signal source can be a signal generator, microcontroller, Data Acquisition System (DAQ), or Programmable Logic Controller (PLC). Also, this method permits users to synchronize multiple camera shutters using the shutter gating feature. A secondary trigger port can be added to the setup (similar to [Trigger Multiple Cameras using the Trigger Switch Cable](#) section) to trigger the camera to start/end recording. The setup described in this section requires the user to manually set cameras to start/end recording using the touchscreen or using the camera web interface.

Users can set the resolution, frame rate, and record lengths on each camera. The signal frequency and duty cycle will define the actual frame rate and exposure time of each camera respectively. However, the maximum achievable frame rate set by the signal source has to be equal to or less than the framerate set by each camera. Like in previous sections, both Chronos 1.4/2.1-HD cameras can be used in a setup simultaneously.

3.1 Parts Needed:

Item/Component	Reference/Vendor
1x Signal/ Function Generator	
2 x BNC male to male cable, long enough to connect the cameras	30m-100-bnc-extension-cable Kron Technologies OR 7.5m (25') BNC Extension Cable Kron Technologies

* The parts list is for triggering 2X Chronos cameras. If you are triggering more than two cameras, allow for additional parts for the additional cameras.

3.2 How to Set Up:

- Connect the Signal Generator output channel port to a BNC extension cable.
- Connect the other end of the BNC extension cable to the driving camera's I/O 1 BNC port. This type of connection is more common with signal generators.
- Set up a square signal to control the driving camera. An example setting is provided below:
 - Waveform: Square Wave Signal.
 - Frequency: 1000 Hz. This sets the frame rate of the cameras. The frequency values must be lower than the set frame rate in record settings.
 - Duty Cycle: 5 %. This value defines the exposure time. For this example the period is 1,000 μ s, thus the exposure time is $1,000 \times 0.05 = 50 \mu$ s
 - Amplitude: 5V. As a rule of thumb, this value should be 2 times the I/O Threshold.
 - Offset: 2.5V.

NOTE: With this setting the driven camera runs with the clock of the driving camera. Hence, the recording time of the event is established by the driving camera's time stamp. The timestamp of the driven camera is not disabled and may display a different time from that of the driving camera. This is a feature that will be addressed in future updates of our software.

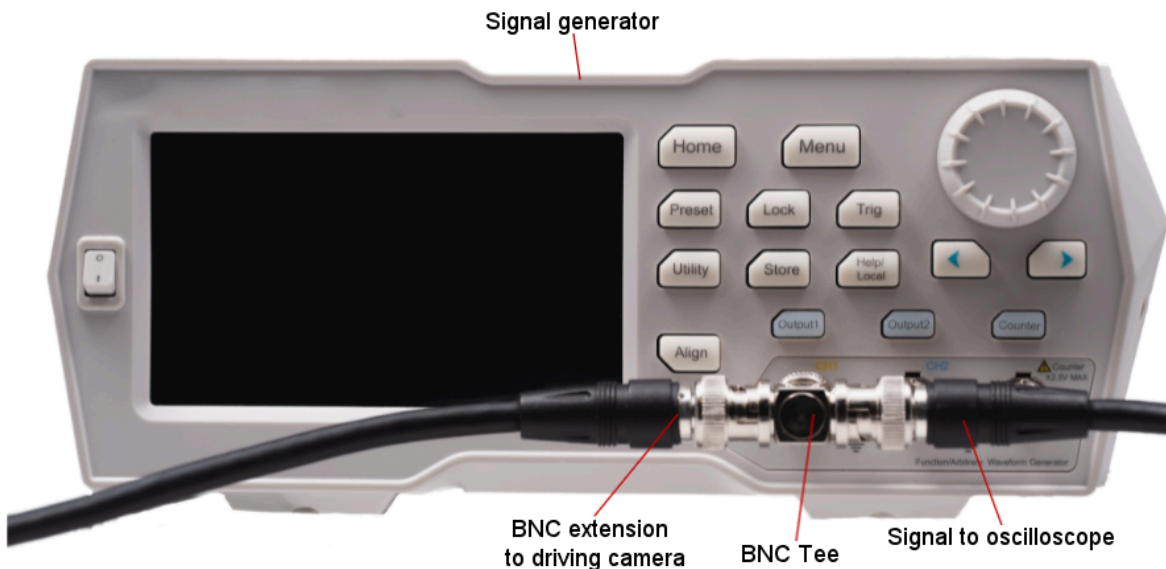


Figure 3.1 Signal generator used to drive the cameras. The signal to the oscilloscope cable is not needed for this tutorial, it is only for reference to check the signal provided by the function generator.

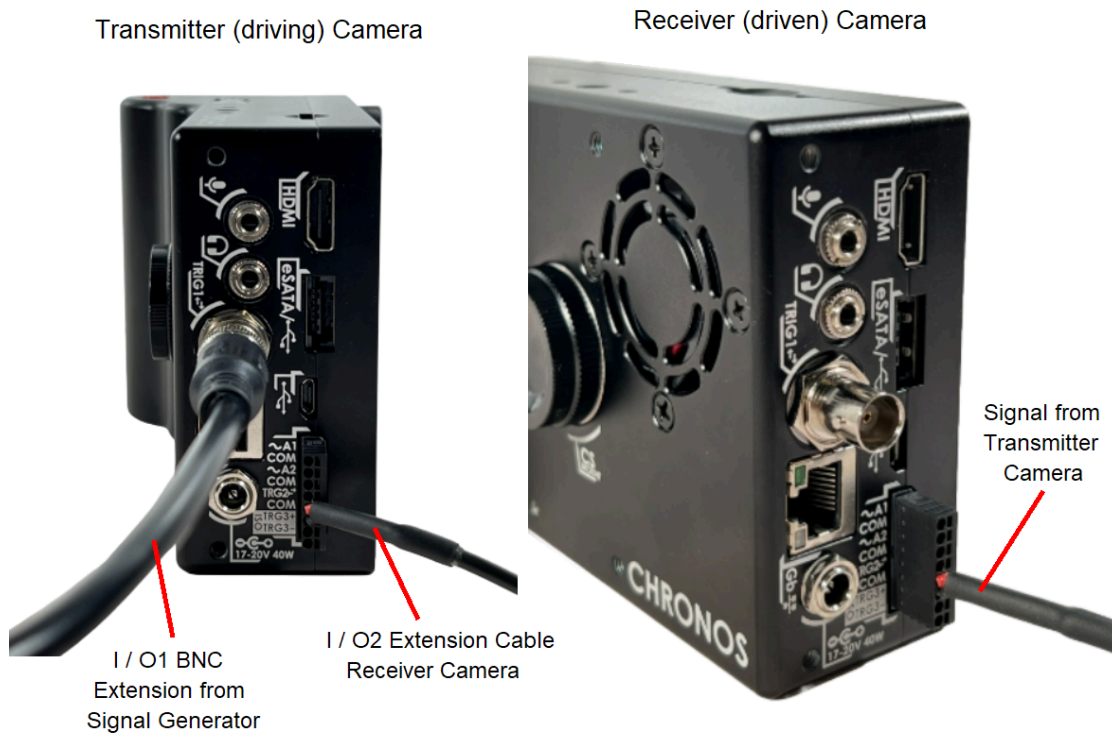


Figure 3.2 Left, connections to and from the driving camera. Right, connection to the driven camera.

- Next, attach the connecting cable to the transmitter and receiver cameras in the I/O2 section of each camera, as seen in **Figure 3.2**. This type of connection is more common with microcontrollers, PLCs, and DAQs.

3.3 Trigger/IO Settings:

With this setup, both cameras have to be manually set to start/end recording. The frequency output of the function generator defines the frame rate. The duty cycle determines the exposure time of both cameras.

3.3.1 Cameras settings:

- In the Trigger settings window, set up the driving and driven cameras' trigger settings as seen in **Figure 3.3**, then press **“Apply”** and **“OK”**

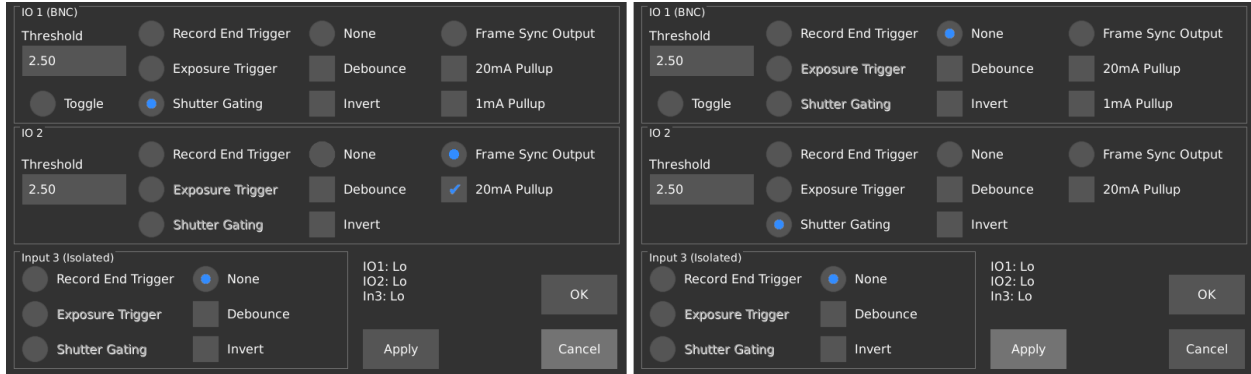


Figure 3.3 External input trigger settings. Left, driving camera. Right, driven camera

4. Sample footage of the different triggering and synchronization schemes

4.1 Cameras triggered by the trigger switch cable

In this section we evaluate the different triggering schemes available. A simple test of a droplet impacting a flat surface is presented. This event was selected due to its reproducibility and simplicity of performance. The position of the droplet to the flat surface can be analyzed, thus the capability of the technique to produce synchronized footage can be inspected.

The tests were performed by placing a metallic column whose height can be varied. At the top of the column, a syringe was attached to it. From the syringe, droplets of ~ 4 to 5 mm in diameter were dispensed. The impact velocity of the droplet was 5.0 m/s.

In front of the camera, two 1.4 Chronos cameras were installed. They are placed 32 cm from the droplet impact location. Hereafter the camera on the left-hand side in **Figure 4.1** is called Camera 1 (driving camera) and the camera on the right-hand is called Camera 2 (driven camera). To provide a reasonable comparison between images we kept approximately the same resolution for each camera. Camera 1 has a resolution of 50 $\mu\text{m}/\text{pixel}$ and Camera 2's resolution is 49 $\mu\text{m}/\text{pixel}$. Two Godox (200W) illumination sources are placed behind the impacting surface. The light is diffused by diffusion paper to get a uniformly illuminated scene. There is also a Godox (300III) illumination source that provides front illumination of the scene.

The signal fed to the camera by either a trigger switch or a function generator was analyzed in a digital oscilloscope (Rigol MSO5074).

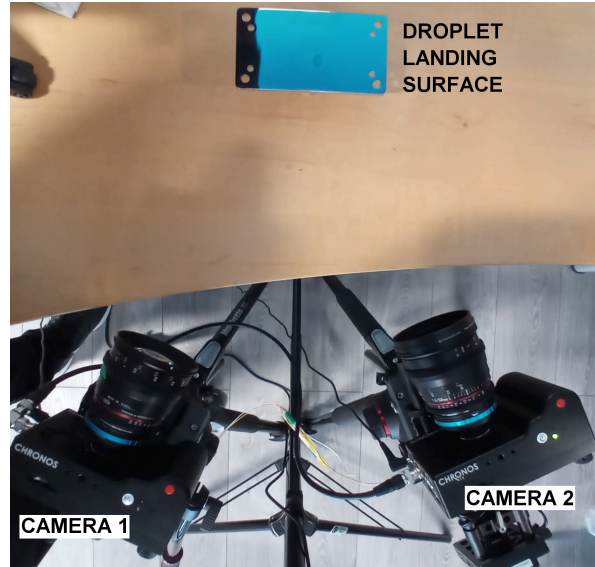


Figure 4.1. The setup used for the camera's synchronization tests

An example of two cameras triggered using Record End to trigger the cameras is presented in **Figure 1.7**. A very similar output is obtained with the Toggle option. The images exhibit a droplet impacting a solid surface. Although the same event was recorded by the cameras, there are several differences in these sequences.

The frame number and the timestamp are not the same, since the cameras are running independently, that is, each camera is operating with its own clock.

The sequence on the left shows the droplet already spreading at $T = -0.31502100$ s, whereas in the sequence on the right the droplet is about to make contact with the solid wall, at $T = -0.31402093$.



Figure 4.2 Images from two cameras triggered using the Record End option

4.2 Cameras synchronized using the transmitter/receiver setup

4.2.1 Record End Trigger

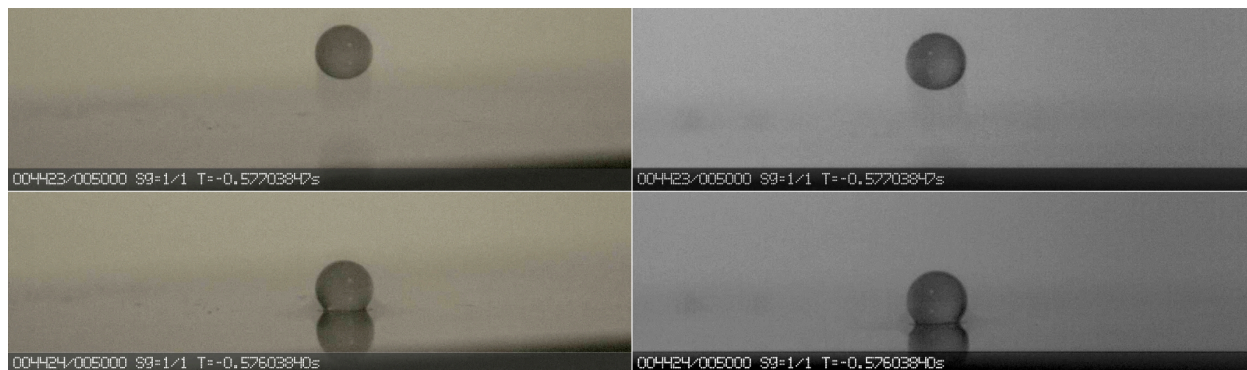


Figure 4.3 Sample images capture with the Record End option

The image captured by Cameras 1 and 2 can be seen in the left and right columns of **Figure 4.3**, respectively. Notice that this time the frame number and the timestamp are the same for both cameras, however, it is Camera 1's time stamp that defines the time of the event recorded. As mentioned before the timestamps may not agree as Camera 2's timestamp is not disabled. This will be addressed in the future. The upper row portrays the droplet just before impact. In the lower row, the droplet just impacted the plate and its bottom part appears flat in the images. You can have a look at the high-speed video that corresponds to **Figure 4.3** [here](#).

Although the video footage is well synchronized we need to inspect the time delay between the trigger switch cable signal and the video signal. To do that, the trigger switch signal was sent to an oscilloscope as well as the video signal from both cameras.

Figure 4.4 depicts the delay between the trigger switch signal and the cameras. The cameras cannot start recording immediately. Instead, they record when the next frame to be exposed is available. Due to this, the uncertainty in the recording start time is $\frac{1}{2}$ of the inter-frame time. The time delay between signals from Camera 1 and Camera 2 seems to be shorter. The left side of **Figure 4.4**, the close-up of the region in the red square of **Figure 4.4**, portrays the time delay between Camera 1 and Camera 2, which is less than 200 ns.

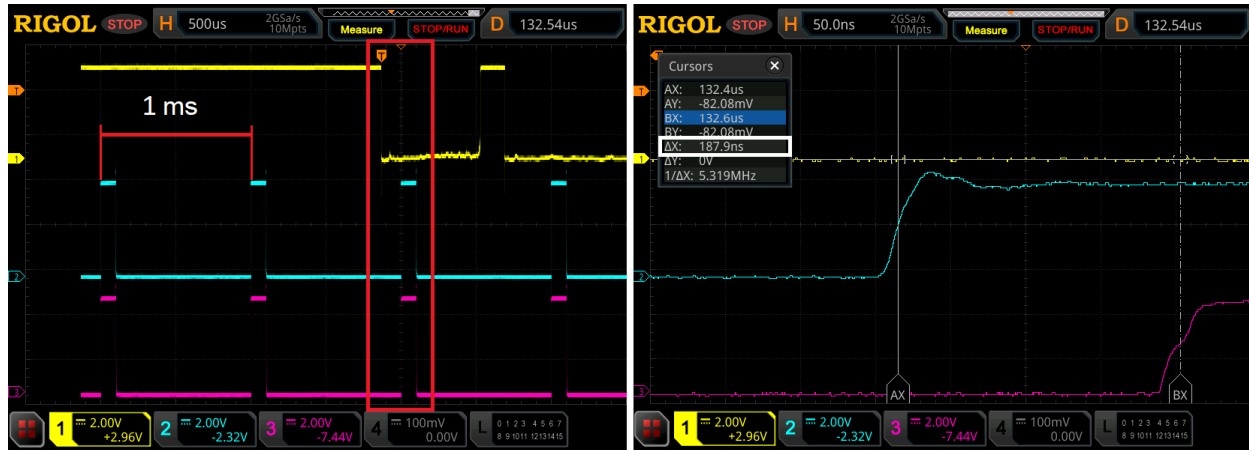


Figure 4.4 Record end test signals. a) Left. Trigger switch, Camera 1 and Camera 2 signals. Right. Zoom of the signals from Camera 1 and Camera 2. Trigger Switch yellow trace, Camera 1 blue trace, Camera 2 magenta trace.

4.2.2 Toggle Trigger

The following image shows an example of a droplet impact on a solid surface. In the pictures of the upper row, the droplet is about to impact the surface at $T=-0.70504700s$. In the pictures of the lower row, 1 frame later, the droplet has just contacted the surface.

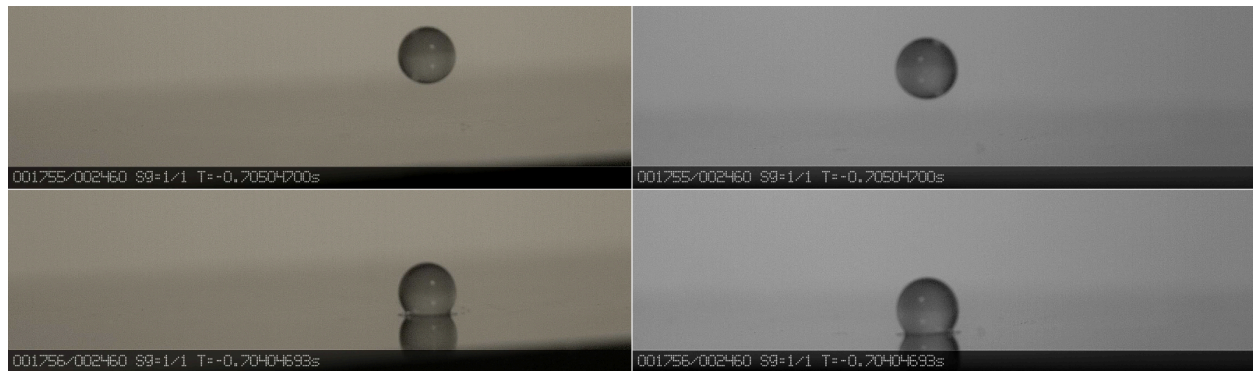


Figure 4.5 Synchronized video output using the toggle option to record the footage.

Notice the frame number is the same in each sequence. The sequence was captured at 1,000 frames per second, exposure time is 1 μs . It is a quick event, thus only 2460 frames were captured after the recording started. The video of the footage depicted above can be seen [here](#).

In summary, the trigger switch can synchronize two cameras with a simple setup. If the application does not demand great accuracy and the user accepts the initial time delay between the trigger switch signal and the cameras' recording start time, this is a convenient option.

4.3 Cameras synchronized using an external signal source

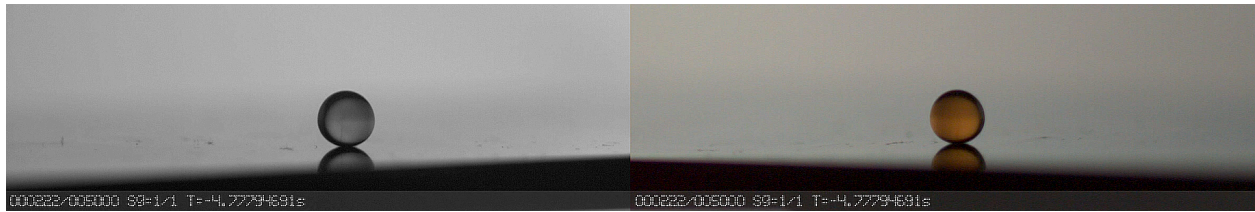


Figure 4.6 Synchronized video output using an external signal source

Figure 4.6 depicts a coffee droplet reaching the solid plate. The function generator triggers the driving camera and provides a signal of 1,000 Hz. The frequency output of the function generator defines the frame rate of the driving camera. The duty cycle is 2%, which determines the exposure time of the camera, 20 μ s. The driven camera runs at the frame rate and exposure time of the driving camera. Both cameras display the same frame number, 000222, and time stamp, $t = -4.77794691$ s. However, as noted in section 3.2, it is the driving camera's time stamp that sets the time of the events. For synchronization tests of this type you can disable the driven camera's timestamp. From the main menu press **Play > Settings**, deselect **Time Overlay**. The sample video can be seen [here](#).

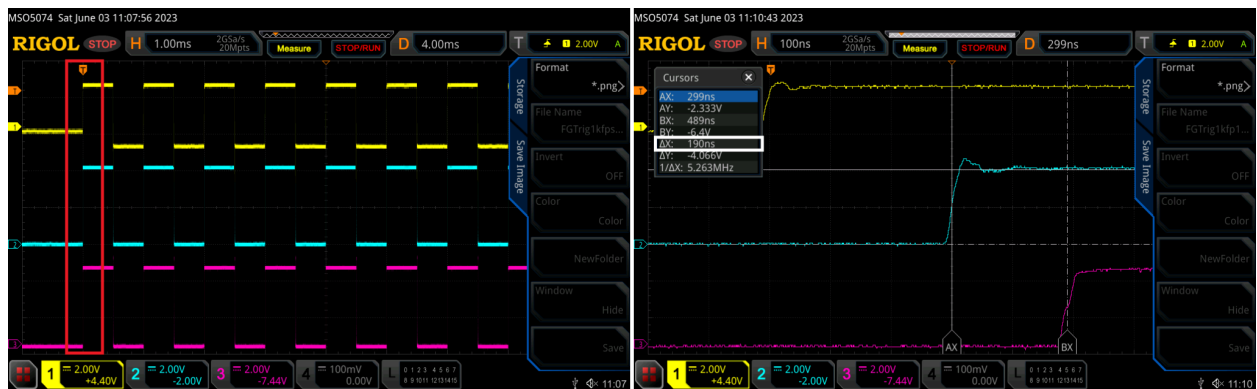


Figure 4.7 External signal source test. Left. Trigger switch, Camera 1 and Camera 2 signals. Right. Zoom of the signals close to the time of the triggering signal. Trigger Switch yellow trace, Camera 1 blue trace, Camera 2 magenta trace.

Figure 4.7 depicts the time delay between the signal from the function generator and the cameras. The three signals seem to be very close to each other, as seen in the red rectangle. The close-up of this region, **Figure 4.7** right side, reveals that Camera 1 starts recording 300 ns after the event starts. The time delay between Camera 1 and Camera 2 is 190 ns.

Additional Notes

These are some notes that might be useful to the user's setup:

- Enable timestamps using **“Text Overlay (H.264/TIFF)”** in the save settings of each Chronos camera. Timestamps will help facilitate cross-referencing synchronized frames. This feature can only be displayed for H.264 and TIFF files.
 - Set saving format to H.264, if interested in saving video footage.
 - Set saving format to TIFF, if interested in saving individual footage files.
 - Set saving format to cinemaDNG, if interested in saving raw footage files. However, a timestamp is not available for this format.
- Save footage using SMB and NFS network shares to avoid transferring footage files from multiple SD cards, SSDs, and USBs.
- Enable **“Auto Save”** in the Util menu to save footage immediately after ending the recording.
- Chronos 1.4 and 2.1-HD cameras can be synchronized if the frame rates are set to the same value or the receiver cameras have a greater frame rate than the transmitter camera. The camera resolution and record lengths will not directly impact the synchronization. Note: The transmitter camera's frame rate will define the receiver's frame rate.
- Change the **“Record length”** value in the **Record Settings > Record Mode**, to reduce maximum footage time.
- Confirm Post-trigger values in the **Record Settings > Trigger Delay** values are set to zero to prevent delays when stopping a recording. In case the triggers do not work as expected, confirm trigger delays are correctly configured.

Checklist:

1. Setup camera trigger Connections
2. Configure camera record settings: Resolution, gains, frame rates
3. Configure Trigger Settings
4. Configure Record length in Record Settings > Record Mode (optional)
5. Configure Post-Trigger in Record Settings > Trigger Delay (**“Reset to Default”** and press **“OK”** for no delays)
6. Perform [Black Calibration](#) based on the instructions in the user manual
7. Start recording!

For more Chronos 1.4 and 2.1-HD resources, visit our website: www.krontech.ca

Please contact us at support@krontech.ca if you need any more information or require further assistance.

Date: (2023-09-06)