



Synchronizing modes of allPIXA classic, pro and wave

Whitepaper

Authors
Sebastian Georgi
Timo Eckhard

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Executive Summary:

The aim of this work is to give a general overview as well as to function as a reference for all tasks related to synchronizing allPIXA classic, allPIXA pro and allPIXA wave cameras. Firstly, the camera acquisition needs to be synchronized to the sample motion speed by setting up the encoder. Subsequently, further devices like other cameras (master / slave mode) or flash controllers can be controlled by the camera to match its acquisition rate. Each of these steps is described in its own chapter.

1 Introduction

The image formation in a line scan camera is dependent on a relative movement between the camera and the sample. In most cases either the sample or the camera are mounted to a linear stage or conveyor band. The velocity of the sample movement and the camera acquisition need to be synchronized to each other in such a way that the relative distance covered between the acquisition of two lines stays constant. Otherwise the image quality will decrease significantly and effects like color fringes or stretched or compressed image contents occur.

Therefore, the camera needs to receive information about the current speed of the movement which is usually delivered by an encoder signal. The encoder signal is transmitted to the camera through one of several available input channels which are described in the next chapter. Subsequently the camera must be set up to correctly interpret the encoder signal such that the image is generated with the desired image resolution which is described in chapter 3. For some applications, several cameras need to be synchronized to each other which is achieved through the master/slave configuration described in chapter 4. Chapter 4.4 describes the cascaded master/slave mode where one master camera controls several other cameras that themselves also act as a master for a slave camera. Alternatively, the camera can also be used as a flash controller for scene illumination as described in chapter 5.

There are three different allPIXA models available at the moment (excluding GenICAM models which are not covered here): the allPIXA classic (CP000383), the allPIXA pro (CP000476) and the allPIXA wave (CP000498). In this paper we show screenshots and explanations for the allPIXA pro model. In general, the other models will be configured analogously but the configuration settings might look slightly different to the ones shown here. Chapter 2, 3 and 4 are applicable to each allPIXA model while the flashing chapter is only relevant for the allPIXA pro and the allPIXA wave model.

All settings of the camera described in this paper have to be set using the Chromasens software CST. Please refer to the respective manual of your camera for details about the installation and basic handling of this software. Also make sure that the camera is up to date with the current firmware version, which can be found on our homepage (www.chromasens.de).

2 The allPIXA input/output interface

The allPIXA camera has three different interfaces that can be used for synchronization. The most general one is the digital I/O interface that uses a 15 pole D-Sub connector. There are four pins dedicated for two differential input signals (RS422) as well as six pins for single-ended signals (LVCMOS) for multi-purpose use available at this interface. The second synchronization interface is via the Camera Link cables that connect the camera to the frame grabber / PC. There are 4 dedicated lines available for synchronization via the cable connected to port 1. They are abbreviated with as CC1 to CC4. Both the I/O interface and the Camera Link interface of the camera are visible in the back view of the camera shown in figure 1.

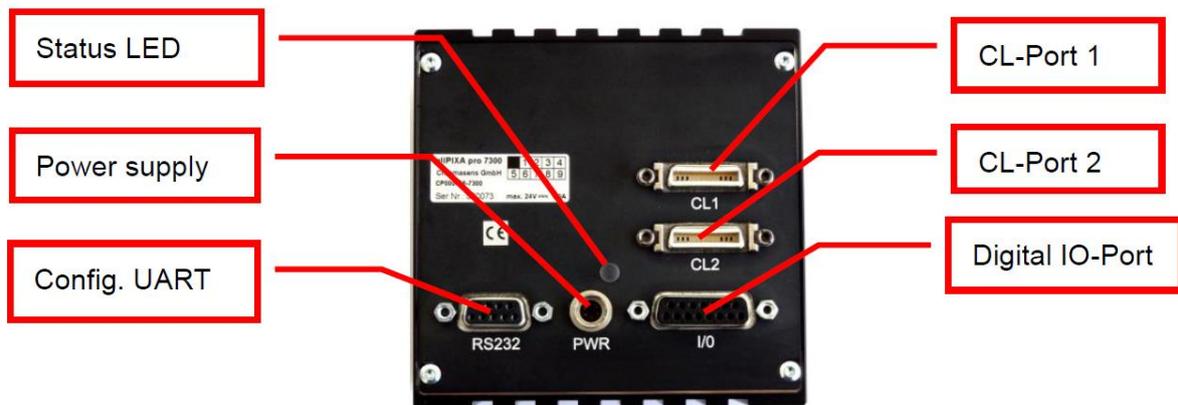


Figure 1: Backside view of an allPIXA pro camera

The third interface is only available for a few special camera models based on the allPIXA pro and allPIXA wave cameras like the dual versions of the 3DPIXA. Here, several single board-level cameras are mounted together in one housing which allows for an additional internal interface available for the master-slave synchronization of the single modules.

Table 1 lists all the available interfaces and which functions can be associated with them. Each of the functions listed is explained in the chapter denoted in the last column of the table. Note that functions not being available for the allPIXA classic camera are marked with an X.

Some functions have the option to be associated with different interfaces and some interfaces have more than one option of which function they are associated with. These different options provide better flexibility for integrating the camera in an existing machine environment. For a valid configuration, however, the assignment between function and interface has to be a one-to-one correspondence.

The association of a functions with an interface can be done in the I/O menu of the CST (icon: ). We will show screenshots of the relevant part of this menu in each chapter.

Table 1: allPIXA interface overview and associated functions. The last column denotes the chapter where the function is explained further. The X marks functions that are not available for the allPIXA classic camera. Functions marked with an A are for advanced users only and are not explained in this paper.

	IO Pin	Functions	Classic	Pro
Differential I/O interface inputs (RS422)	IO-Interface 1&9	Encoder channel 0		3
		Frame trigger		4
	IO-Interface 2&10	Encoder channel 1		3
		Frame trigger		4
		Select scan direction	X	3
Single ended I/O interface in-/outputs (LVCMOS)	IO-Interface 3	Frame trigger		4
		Select master		4
	IO-Interface 4	Encoder channel 0		3
		Flash control channel 1	X	5
		External master/slave/hub synchronization	X	4.4
		FSYNC / FVAL		A
	IO-Interface 6	Flash control channel 3	X	5
		External master/slave(+hub) synchronization	X	4.4
	IO-Interface 8	Flash control channel 4	X	5
		External master/slave(+hub) synchronization	X	4.4
	IO-Interface 12	Encoder channel 1		3
		Flash control channel 2	X	5
		External master/slave/hub synchronization	X	4.4
		HSYNC / LVAL		A
IO-Interface 14	Flash control clock	X	A	
CameraLink signals	CL1-9/22 (CC1)	Encoder channel 0		3
	CL1-10/23 (CC2)	Encoder channel 1		3
		Enable encoder		3
		Select scan direction	X	3
	CL1-11/24 (CC3)	Frame trigger		4
	CL1-12/25 (CC4)	Frame trigger		4
		Enable encoder		3
	Select master		4	
Internal Interface	Internal Interface A	Internal master/slave synchronization	X	4
	Internal Interface B	Internal master/slave synchronization	X	4

3 Operating an allPIXA camera in encoder mode

A line-scan camera needs to be synchronized to the relative movement between target and camera in such a way that the distance covered per line acquisition is kept constant. Otherwise the target geometry will fluctuate along the scan direction and color fringes will occur in the image when using an RGB camera. This synchronization is realized using an encoder that records the current velocity of the movement and sends the information to the camera. The camera will use this signal to adjust its acquisition rate to the movement velocity in real time.

3.1 Connecting the encoder to the camera

There is the possibility to either connect the encoder directly to the camera using the I/O interface of the camera or to connect the encoder to the trigger input of the frame grabber. Connecting the encoder signals indirectly over the frame grabber has the advantage that the I/O interface pins can be used for one of the other functions that they are associated with. But since both camera and grabber have to be set up for this configuration it is more prone to errors. How to set up the frame grabber for this mode is different for each manufacturer so we can only describe the camera setup in this whitepaper. For a setup where the encoder is directly connected to the camera all relevant configurations are described in this document.

The camera can be operated with a one channel or a two channel encoder. Depending on the type of encoder and the interface used different settings are needed in the I/O menu . Figure 2 shows the section of this menu relevant for setting up the encoder connection. If the order of the lines happens to be different in your view you can still find the relevant lines by checking the Internal Function and IO Pin content for a match with the ones shown here. Also note that you need at least “Expert” user level to change any settings in the I/O menu (see manual: “Setting the user level in CST”).

	Name of IO function	Connector	Internal Function	IO Pin	Signal name	IO-Standard	Bit Value	ID	Bit	Register
01	Encoder Ch 0 / line trigger	CL1-CC1	Encoder0/line trigger	CL1-9/22	CL_CC1	LVDS	<input checked="" type="checkbox"/>	f	0	Encoder
02		X5-1/9	Encoder0/line trigger	IO-Interface-1/9	GPIO_P0/N0	RS422	<input type="checkbox"/>	f	2	Encoder
03		X5-4 (Pull-Down)	Encoder0/line trigger	IO-Interface-4	GPIO_P2	LVCNMOS	<input type="checkbox"/>	f	4	Encoder
04		---	Encoder0/line trigger -> static Low	---	static Low	---	<input type="checkbox"/>	f	12	Encoder
05		---	Encoder0/line trigger -> static High	---	static High	---	<input type="checkbox"/>	f	14	Encoder
06	Encoder Ch 1	CL1-CC2	Encoder1	CL1-10/23	CL_CC2	LVDS	<input type="checkbox"/>	g	1	Encoder
07		X5-2/10	Encoder1	IO-Interface-2/10	GPIO_P1/N1	RS422	<input type="checkbox"/>	g	3	Encoder
08		X5-12(Pull-Down)	Encoder1	IO-Interface-12	GPIO_N2	LVCNMOS	<input type="checkbox"/>	g	5	Encoder
09		---	Encoder1 -> static Low	---	static Low	---	<input checked="" type="checkbox"/>	g	13	Encoder
10		---	Encoder1 -> static High	---	static High	---	<input type="checkbox"/>	g	15	Encoder
11	Enable Encoder	---	Enable Encoder -> static Low/inactive	---	static Low	---	<input type="checkbox"/>	f	6	EnableEncoder
12		---	Enable Encoder -> static High/active	---	static High	---	<input checked="" type="checkbox"/>	f	7	EnableEncoder
13		CL1-CC2	Enable Encoder	CL1-10/23	CL_CC2	LVDS	<input type="checkbox"/>	f	8	EnableEncoder
14		CL1-CC4	Enable Encoder	CL1-12/25	CL_CC4	LVDS	<input type="checkbox"/>	f	9	EnableEncoder

Figure 2: Section of the I/O menu used for setting up the encoder connection

You will always need to select exactly one of the three lines with Internal Function “Encoder0/line trigger”. When connecting the encoder to the frame grabber the first CC signal (CC1) needs to be used and consequently the line with the IO Pin “CL1-9/22” needs to be set active. For the direct interface with differential signal use IO Pin “IO-Interface-1/9” and for single ended signals use IO Pin “IO-Interface-4”. For a one channel encoder also activate the “Internal Function” line “Encoder1 -> static Low”. For a two channel encoder choose the correct line for your interface from the three lines with the “Internal Function” line “Encoder1” analogous to channel one.

Also note that you need to set the “Internal Function” called “Enable Encoder -> static High/active” for the encoder interface to be active. If you need to disable the encoder interface temporarily in between scans you can use the “CC2” or “CC4” signal for the “Enable Encoder” function. If one of them is activated the encoder signal will only trigger the camera line acquisition while this signal is high which can usually be set using the API of the frame grabber.

3.2 Configuration of the encoder

After successfully connecting the encoder to the camera the correct interpretation of the signal needs to be configured. This is done in the encoder menu (icon: ) of the CST which is shown in figure 3. Start the configuration by checking the box in front of “Enable encoder” at the top of the page.

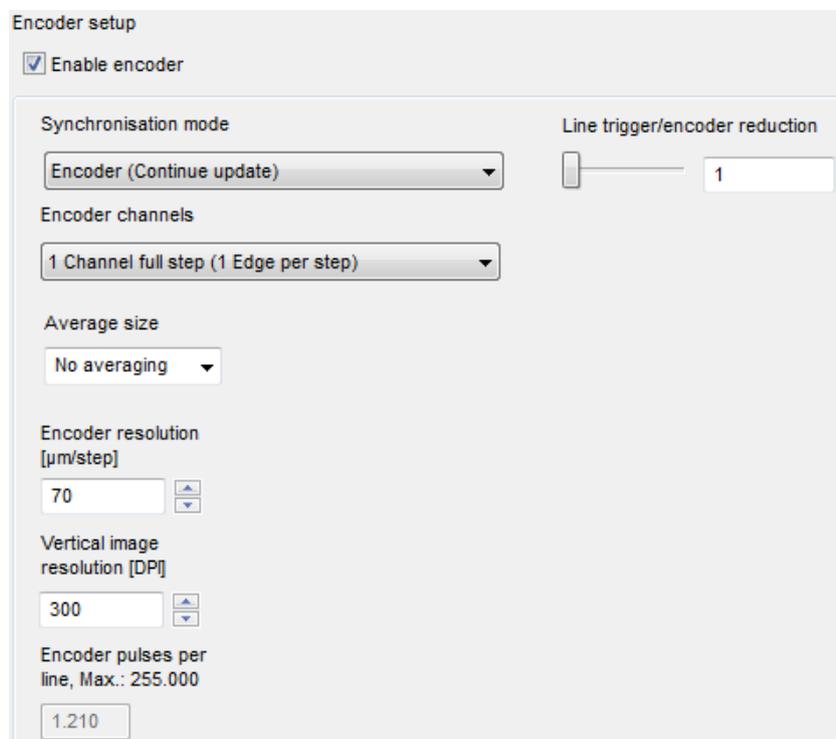


Figure 3: Encoder menu

There are two different synchronization modes available. In line-trigger mode the camera starts capturing a new line whenever there is an impulse on the encoder signal. Unless the encoder signal is digitally post-processed this will most likely lead to an unwanted squeezing or stretching of the image when the encoder and the camera have different resolutions.

This is why in most cases the “Synchronization mode” called “Encoder (Continue Update)” should be used. This mode can interpolate the encoder signal in such a way that the vertical image resolution can be set to any reasonable value. Start setting up this mode by selecting the number of encoder channels in the appropriate dropdown menu. Then the target value for the vertical image resolution (in dots per inch, i.e. DPI) can be set in the lowest input box. For square pixels set the target value to the same value as the optical resolution. The conversion factor from metric units (e.g. μm per pixel) to DPI is 0.0254m/inch or $25400 \mu\text{m/inch}$. For example, to achieve $10\mu\text{m/pixel}$ resolution, the target image resolution is $(25400\mu\text{m/inch}) / (10\mu\text{m/pixel}) = 2540\text{DPI}$.

The last value needed for the interpolation to work correctly is the number of pulses the encoder sends per μm of movement. For a linear stage this can be calculated from the number of pulses per revolution from the encoder and the spindle pitch.

In the example shown in figure 3 the target resolution is 300 DPI which requires the camera to take a line for every $85\mu\text{m}$ of movement from the linear stage. But as the encoder gives a pulse every $70\mu\text{m}$ the camera interpolates the encoder signal and only captures a line for every 1.21 encoder pulses.

For a description of the other functions available in this menu please refer to the manual.

3.3 Scan direction

The advantage of using a two-channel encoder is the additional available information about the current scan direction. This is interesting if your stage also intermittently runs backwards which can be the case e.g. for conveyor belt setups. With the standard configuration this would lead to parts of the images being captured three times and with color fringe artifacts. But with the additional information from a two-channel encoder and the correct setting of the (allPIXA pro) camera the extra image content can be completely omitted allowing for an image that is indistinguishable from one captured in constant forward motion. This concept is illustrated in figure 4.



Figure 4: Concept sketch of the backward motion rejection. All images were taken with the same movement pattern of the linear stage which includes a backward drive. The left image uses no direction information, the middle one corrects the color plane shift and the right one suppresses all repeated image content.

To use the advanced operation modes seen in the middle and right figure above you need to have the camera set up with a two-channel encoder. Then go to the subitem called “Camera arrangement” in the settings menu of the CST. In the dropdown-menu called “Set scan direction” you can choose “set by encoder direction” to only correct the color plane shift. For the suppression function you need to keep the scan direction fixed (“Forward” or “Backward”) and activate the checkbox labelled “Enable suppression of lines/frames”.

4 Using two cameras in master/slave configuration

The master slave mode of the allPIXA camera ensures that two cameras are synchronized in such a way that each line is captured at exactly the same moment in both cameras. This is important for applications such as 3D measurements using a 3DPIXA dual camera or when enlarging the FOV through stitching of two camera images. In this mode one of the cameras is the master which receives the encoder signal and determines the line acquisition timing for both cameras.

4.1 Connecting the cameras

The synchronization of two cameras using the master/slave mode (M/S mode) requires that the cameras are connected via a suitable interface. For a standard allPIXA camera this is realized with a synchronization cable that connects the I/O interfaces of the two cameras. The use of this setup together with an encoder or frame trigger connected to the I/O interface is only possible if the interface pins are split to the two different endings of a suitable breakout cable (see 6Appendix A). It is therefore recommended to build up a setup where the encoder and trigger signals are delivered by the frame grabber via the Camera Link signal where the breakout cable is not needed.

Some older 3DPIXA dual cameras also use the external IO-interface for master-slave synchronization. A suitable synchronization cable is included with the camera but with no breakout cable. This synchronization cable has a bridge from pin 3 to a ground pin (pin 11) on one end which is used to determine which camera acts as master (see also chapter 4.2). In principle, either of the cameras can be configured as master but we recommend using the right one when looking at the back of the camera as seen in figure 1. This camera will capture the “A” image used in the 3D calculation and is always the master in the factory default setting.

Later 3DPIXA dual camera models (product number starting with CP000520-D0X or CP000600-D0X) are instead synchronizing the two cameras through an internal interface. The master camera of such a 3DPIXA has an external I/O interface where all pins are available. The slave camera has no external I/O interface as the acquisition timing of this camera is completely determined by the master camera. The options described so far are also shown schematically in figure 5.

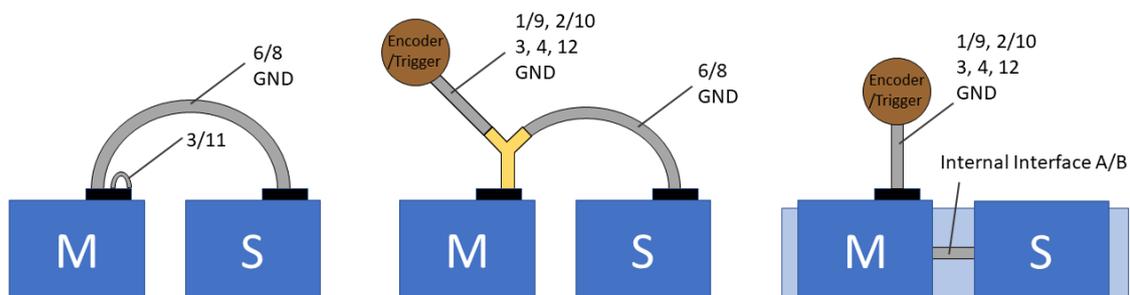


Figure 5: *Left:* M/S mode with an external interface cable.
Middle: M/S mode via interface cable and external triggers via a breakout cable (yellow)
Right: M/S mode via internal interface and external triggers.

The correct interface for your camera model needs to be activated in the I/O configurator for both cameras, figure 6 shows the relevant section. You can open two instances of the CST

and connect to both the master and slave cameras at the same time through the appropriate ports. For models using the external interface for M/S synchronization the line “MS-Interface” / “IO-Interface 6/8” needs to be activated for both cameras. For camera models using the internal interface the correct line is already activated in the default setting. The default setting is always accessible by choosing setting 19 in the CST and can also be rolled back onto the camera in the simple setup mode (icon: 😊).

25	Select master camera	X5-3 (Pull-Up)	nSelMaster	IO-Interface-3	GPIO_P4	LVC MOS	<input type="checkbox"/>	j	0	MasterSlave
26		CL 1-CC4	nSelMaster	CL 1-12/25	CL_CC4	LVDS	<input type="checkbox"/>	j	1	MasterSlave
27	Master / Slave interface	X5-6/8	MS_Interface	IO-Interface-6/8	MS-Interface	LVC MOS	<input type="checkbox"/>	Aa	12	MasterSlave
28		X9-1/8	MS_Interface internal A	Internal Interface-A	MS-Interface	LVC MOS	<input type="checkbox"/>	Aa	13	MasterSlave
29		X12-2/4	MS_Interface internal B	Internal Interface-B	MS-Interface	LVC MOS	<input checked="" type="checkbox"/>	Aa	14	MasterSlave
30		X5-6/8-4/12	MS_Interface + Hub	IO-Interface-6/8 OI	MS-Interface	LVC MOS	<input type="checkbox"/>	Aa	15	MasterSlave

Figure 6: Master-Slave section of the I/O configurator

4.2 Camera setup

In addition to the correct setup of the interface the two cameras also need to be uniquely assigned their respective “roles”, with one camera set to master and the other to slave mode. The camera which receives the frame trigger / encoder signals (either over the external interface or over the Camera Link cables) has to be set as the master camera.

There are several methods to set the role of the cameras: you can statically set the roles using the CST or you can set the cameras to listen to an interface and set their role dynamically depending on the signal level at that interface. Both options can either be set globally for all camera settings or can be set in each setting separately. To choose one of the two possibilities go to the item “Global master/slave config” in the settings menu. Here you can either choose to “get master slave from setting” or globally set the camera to either master, slave or to listen to an input. These three options are also available in the setting specific configuration and can be chosen with the dropdown-menu “Set master-slave mode” in the “Synchronization” menu.

When choosing “auto select by input” the needed signal can either be supplied via the CC4 signal or on pin 3 of the external I/O interface. After configuring this mode (either globally or setting specific) you must also activate the correct interface in the section “Select master camera” of the I/O configurator (see first two lines in figure 6). The 3DPIXA dual models which use the external synchronization cable are configured to use this master select by input through bridging the pin 3 to a ground pin on the master side. Please be aware that the use of the breakout cable described in the appendix does not have this bridge so you can instead use pin 3 to receive a single-ended frame trigger signal. In this case reconfigure your 3DPIXA by statically reassigning the roles of both cameras.

3DPIXA dual cameras with an internal synchronization interface will be correctly configured in the delivery setting. As they are not assigned their roles globally this configuration needs to be repeated in all further settings you create. When setting up your own system in master/slave mode you can choose whether global or setting specific configuration is more convenient for you as long as both cameras are set up consistently. Please note that if any of the settings mentioned here are greyed out in a 3DPIXA camera, you have to change the selected camera type to “allPIXA_pro” in the “System configuration” menu of the CST. For further information please refer to the manual, section “Choosing a different configuration file for the parameter display”.

After setting up the master/slave mode you can parameterize the other settings of each single camera. As the slave camera gets all the needed timing information from the master camera there are several parameters (of the slave camera) that no longer have any influence. For allPIXA pro cameras all parameters available in the categories “Integration time” and “Synchronization” (besides master-slave-mode) from the camera settings menu as well as all encoder setup parameters are ignored in the slave camera. Instead the settings from the master camera are effectively in use as they determine the acquisition of the master camera which is then synchronized onto the slave camera. While this is generally also true for allPIXA wave cameras there is one difference in that they allow for setting the integration time for each camera individually. But in general we recommend setting all cameras to the same integration time. Additionally, please be aware that for any camera model you can independently delay the image starts of each camera using the “Image start delay” value in the “Image sizes” category. For 3DPIXA cameras however, this value needs to be set to the same value in both cameras.

4.3 Setting up the frame grabber

The successful configuration of the M/S mode ensures that the two cameras acquire all image lines synchronized and that the images start at the same time and have the same number of lines. Due to possible delay differences in the camera-internal postprocessing, in the cables and the frame grabbers image reconstruction process the lines might not be received at the same time in the PC. This can result in the two images being shifted relative to each other by a few lines. Depending on the actual setup this shift can even change over time so that a static compensation of the effect will not be possible.

To allow for proper synchronization all allPIXA cameras transmit the so called FVAL signal. This is a dedicated Camera Link signal standard that switches to high for as long as a valid frame is transmitted. As both cameras send this signal for their respective transmitted frames it can be used to synchronize the images even when the lines are not received at the same time. The first line after the FVAL switches to high will be the first line in both images.

To use this signal for camera synchronization the frame grabber needs to be configured to evaluate the FVAL signal. As the FVAL signal is normally a feature of area-scan cameras the frame grabber needs to be set to either area mode or an area applet needs to be used (model dependent). This will require you to set a tap mode in y direction which will always be “1Y” as well as an image height. When distinctive objects with gaps in between are inspected it is recommended for simplicity to set the height of the image to encompass the whole object with some margins. The margin at the end of the image can be easily implemented by slightly longer frames. The start margin however needs a frame trigger that sends its signal before the object actually passes the scan line, e.g. by placing a light barrier upstream of the camera. Please be aware that the maximum image size in area mode might be limited by the internal memory available to the frame grabber.

For a gapless inspection (e.g. of roll material) however, this mode cannot be used. Here the camera needs to be set to frame free run by choosing “Free running” from the dropdown box “Triggered frame scan” in the “Synchronization” category. This will ensure that images will be acquired subsequently with only the “Image start delay [lines]” as pause in between. In an allPIXA pro camera this value can be set to zero allowing for truly gapless acquisition while still evaluating the FVAL for synchronization of the two cameras. The image height in the

cameras and frame grabbers can be set to an arbitrary value that fits best to the needs of the image postprocessing. Please be aware that not all frame grabbers fully support this gapless mode.

The camera can be setup to insert an info block at the beginning of the first line of the image. The content of this info block is described in the “Insert mode” chapter of the manual. But besides the encoded information this info block can also be used to test if your grabbers are configured correctly as the encoded information has to be in the first line in both the master and slave image. To activate the info block go to the “Output format” category of the camera settings and activate the checkbox “First line info block”.

4.4 Using multiple cameras in cascaded master/slave configuration

The master/slave mode is primarily intended for the synchronous operation of two cameras. Optionally, the signal from one master camera can be sent to up to four slave cameras. More receivers are not possible as the signal quality degrades with each extra camera connected. To circumvent this problem there is the cascaded master/slave mode which is not limited to a fixed number of cameras. This mode also allows to synchronize several 3DPIXA dual cameras, which each operate their own internal master/slave interface, to each other.

The general principle of the cascaded M/S mode is that each other camera besides the first (master) and the last (slave) receives the synchronization signal and resends it to the next camera on different pins as shown in figure 7. Therefore there are three different roles in this mode: The conventional master and slave mode as well as the hub mode for the cameras in between. The master and slave camera can be configured as described in the last chapter for using the external interface.

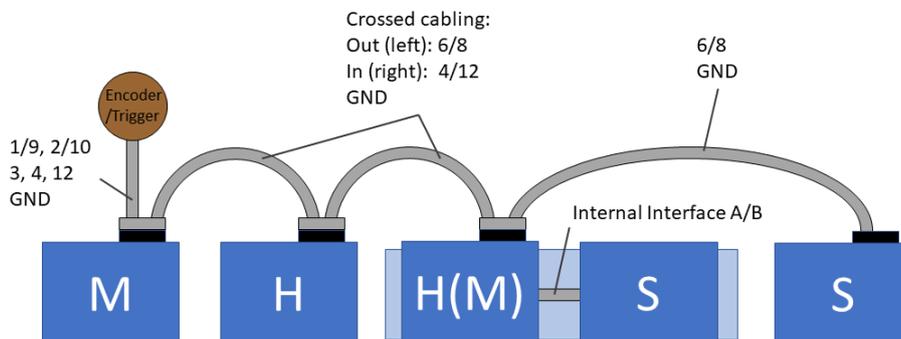


Figure 7: Schematic of the cascaded M/S mode. The numbers in the images describe which pins from the I/O interface are connected.

All hub cameras in the middle have to be set as master camera using one of the available methods described before. Additionally, the hub function is activated in these cameras by checking the line “MS_Interface + Hub” in the I/O configurator (line 30 in figure 6). Even though the camera is configured as master and shown as such in the live values menu of the CST it will wait for a synchronization signal at the external pins before sending lines as soon as the I/O configuration is activated. It will then pass on these signals to the next camera in the chain.

The cascaded master slave mode needs a special cable to function correctly. The pin connection between the different cameras needs to be crossed, as the synchronization signal is sent from the external interface pins 6/8 but is received by the next camera at the

pins 4/12. For a complete specification of the cable including trigger input please refer to the appendix.

5 Flash controller synchronization

The allPIXA pro camera can be used to trigger up to four different flash controller channels synchronized to its line acquisition. This can be used to acquire several images with different illumination geometries or colors simultaneously in only one scan by line-multiplexing. One application where this is useful is in inspection tasks where different some kinds of defects are identified either in images captured with brightfield illumination (e.g. scratches) while other defects require darkfield illumination (e.g. dust particles).

Figure 8 illustrates this concept: The left side shows the raw camera image output for a metal sample with activated flash mode for one brightfield and one darkfield illumination. The size of this image in scan direction is enlarged by a factor of two as each line is captured twice with alternating illumination. The result is an image that is interlaced line by line repeatedly. This image needs to be deinterlaced and a correction for the color plane shift needs to be applied (see below for details) which results in the images shown on the right. The separation of these images is not part of the camera function and needs to be done in a post-processing step.

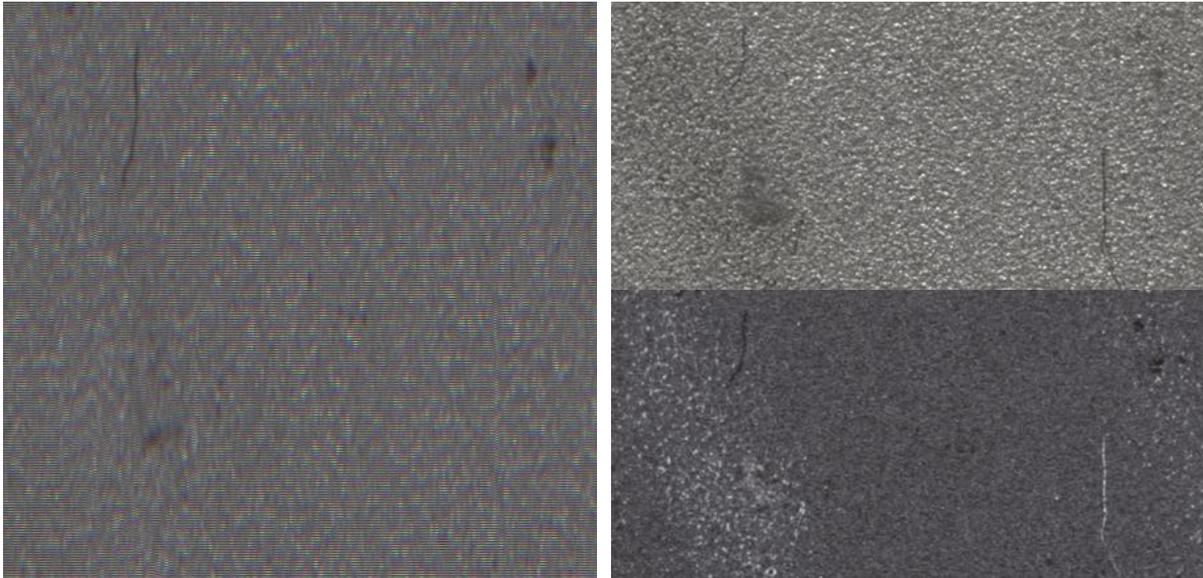


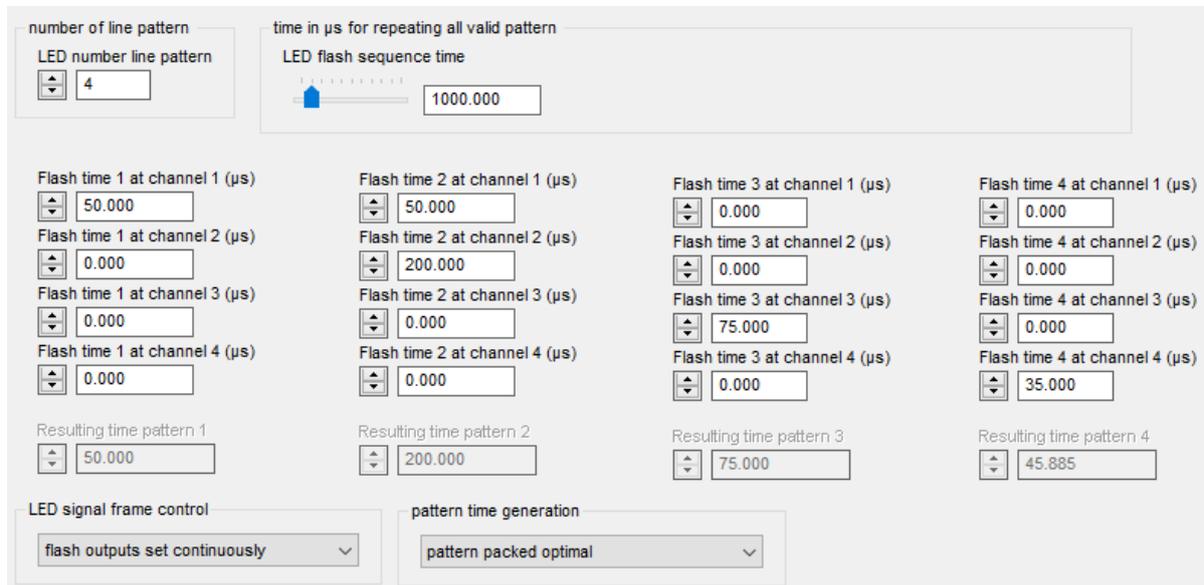
Figure 8: Flash mode acquisition of metal sample with two different illumination geometries. **Left:** raw camera output **Right:** Separated individual images with color plane correction

The flashing can also be done using colored illuminations which would lead to separated images with the maximum intensity concentrated in one of the color channels. Please note that for an RGB camera each of the separated images will nevertheless consist of all three color planes. Extracting the color plane with maximum intensity also needs to be done in post-processing.

5.1 Configuring a flash pattern sequence

The flash control of the camera can trigger not only one but any number of its four outputs for each flash line. The definition of which outputs are active for how long at each line is called a flash pattern. The flash control is set up by two to four patterns which are executed repeatedly one after another. This flash sequence can be parametrized in the CST settings menu subitem “LED flash control”. A screenshot of the relevant part of the page is shown in

figure 9. Not shown is the dropdown menu at the top which enables the flash operation and needs to be set first. Please note that you need to set the user level to “Guru” to access this menu.



Pattern	Channel 1 (μs)	Channel 2 (μs)	Channel 3 (μs)	Channel 4 (μs)	Resulting time (μs)
Pattern 1	50.000	0.000	0.000	0.000	50.000
Pattern 2	50.000	200.000	0.000	0.000	200.000
Pattern 3	0.000	0.000	75.000	0.000	75.000
Pattern 4	0.000	0.000	0.000	35.000	45.885

Figure 9: LED flash control settings page

You can activate up to four different patterns that are executed consecutively during acquisition by entering the number of patterns in the top left number box. The patterns are represented by the four columns of flash time number boxes below. The camera's integration time for a pattern will be automatically set to be equal to the resulting time shown below each pattern column for each pattern individually. In each pattern any number of channels can be set to active for an independently configurable amount of time. For example, in the second pattern the first flash channel is active for 50 μs while the second channel is active for 200 μs with both starting at the same time. Using different active times is needed to adjust the apparent brightness of a flash channel with a constant intensity illumination. The standard minimum active time for a pattern is the bigger time of either the minimum integration time or the minimum time needed for the Camera Link data transfer (for specific times see the manual, chapter “Camera Link interface type and minimum line time”). Setting a shorter flash time will not decrease the resulting pattern time below this minimum (see pattern 4 above) but will decrease the time the flashed illumination is active during that pattern.

The complete sequence time is configured in the top number box. There are two different ways to pack the different pattern times into the full sequence time which are set by the dropdown menu “pattern time generation”. In figure 9 the option “pattern packed optimal” is selected. This will set each pattern time equal to the longest of the flash times from this pattern (or the minimum time). After the last pattern has been executed the camera will remain idle until the specified sequence time has elapsed. The other option available in the dropdown menu is “pattern enlarged to sequence time”. This will enlarge each pattern to be active for the full sequence time divided by the number of patterns in the sequence. With the parameter chosen in figure 9 each pattern would be active for 250 μs. Note that if a flash channel is active for longer than this time the corresponding pattern time is necessarily equal to this flash time. But the other pattern times will still remain equal to their fraction of the sequence time which will effectively prolong the actual sequence time beyond the one set in the CST. When setting up the flash patterns you should keep in mind that there is an

illumination specific on-delay and an off-delay between trigger signal and the actual LED active time. Depending on your used illumination and controller very short flash times (few μs) may not be possible due to the on-delay. The off-delay can lead to crosstalk between patterns if there is no pause between the different patterns. It is advisable to check the illumination behavior with a fast photodiode and an oscilloscope once while integrating the hardware.

In line free run mode a new flashing sequence will start immediately after the previous one has finished completely including idle time from optimal pattern packing. In encoder mode each line trigger (not encoder pulse, see section 3.2) will start the whole sequence off all defined patterns. You need to ensure that the sequence time is always less than the line trigger time through limiting the maximum transport velocity. This ensures that each of the separated flash images has the same transport resolution as a single image captured without flashing.

After setting up the pattern there are some additional settings you will need to adjust. First, switch to the "Image sizes" subitem of the setting menu in the CST and increase the "Number of scanlines per images" by a factor equal to the number of active flash patterns. Additionally, set the "RGB line distance" in the "Camera arrangement" subitem to zero. For correct compensation, this number technically needs to be increased by a factor equal to the number of active flash patterns. This is usually not possible as the maximum allowed value is limited due to the available camera internal memory. Instead the color plane alignment correction needs to be done in a post-processing step which is easiest if the CST compensation is set to zero. After the separation of the flash channels each of the resulting images needs its color planes shifted vertically by the same amount as used for compensation without flash operation. Lastly, the correct I/O ports for flash control are selected automatically when enabling the flash mode. Nevertheless, you should make sure that no other functionality is currently using the flash outputs (pins 4,6,8 and 12 of the external I/O interface).

Flash mode is fully compatible with master / slave operation, though it is strongly recommended to use a dedicated frame trigger (no endless mode). For a 3DPIXA with internal master/slave interface you can send the trigger signals to the camera using the Camera Link signals as this will free up the external interface for flashing. Otherwise the external interface is already in use for the synchronization cable so to access the pins sending the flash signals you need a suitable breakout cable. Just be aware that the pins 4 and 12 are not available for the input of a single-ended encoder in flash mode. Due to conflicting pin usage it is also not possible to use flash mode in cascaded master / slave operation.

5.2 Using flash mode for multi-exposure / HDR imaging

The flash mode of the allPIXA pro and allPIXA wave cameras allows them to capture multi-exposure images during a single scan. This results in several congruent images of the same scene with different integration times. Such a set of images is the prerequisite needed to compose a single high-dynamic-range (HDR) image. The general goal of HDR imaging is to reduce the loss of detail from imaging scenes containing regions with vastly different brightnesses. With a single image one can either use a low integration time which loses information in the dark regions due to camera noise or a higher integration time which leads

to saturation in the bright regions. But if the images from both (or more) exposure times are available it is possible to optimally compress this information into the standard dynamic range of a digital image. This chapter describes how the flash mode can be used to capture these congruent images of different exposure times.

The flash mode of the allPIXA camera is implemented in such a way that the integration time during each pattern is determined by the resulting time of the pattern which is shown below each pattern column(see also Figure 9). So for HDR imaging set up the flash patterns in such a way that the resulting times of the patterns matches the needed different exposure times. But then do not connect the flash outputs of the camera to the illumination controller and keep the illumination constantly switched on instead. This will create an interlaced image like the one shown in Figure 8 but with different exposure times instead of different illumination geometries.

Figure 10 demonstrates it using a ball grid array (BGA) sample. The solder balls are made of highly reflective metal while the base of the sample is usually quite dark. The HDR approach allows to inspect the base for defects (e.g. scratches) without saturating the balls. There exist multiple ways of computing HDR images from multiple low-dynamic range images. For the following example we used the algorithm proposed by Debevec & Malik¹.

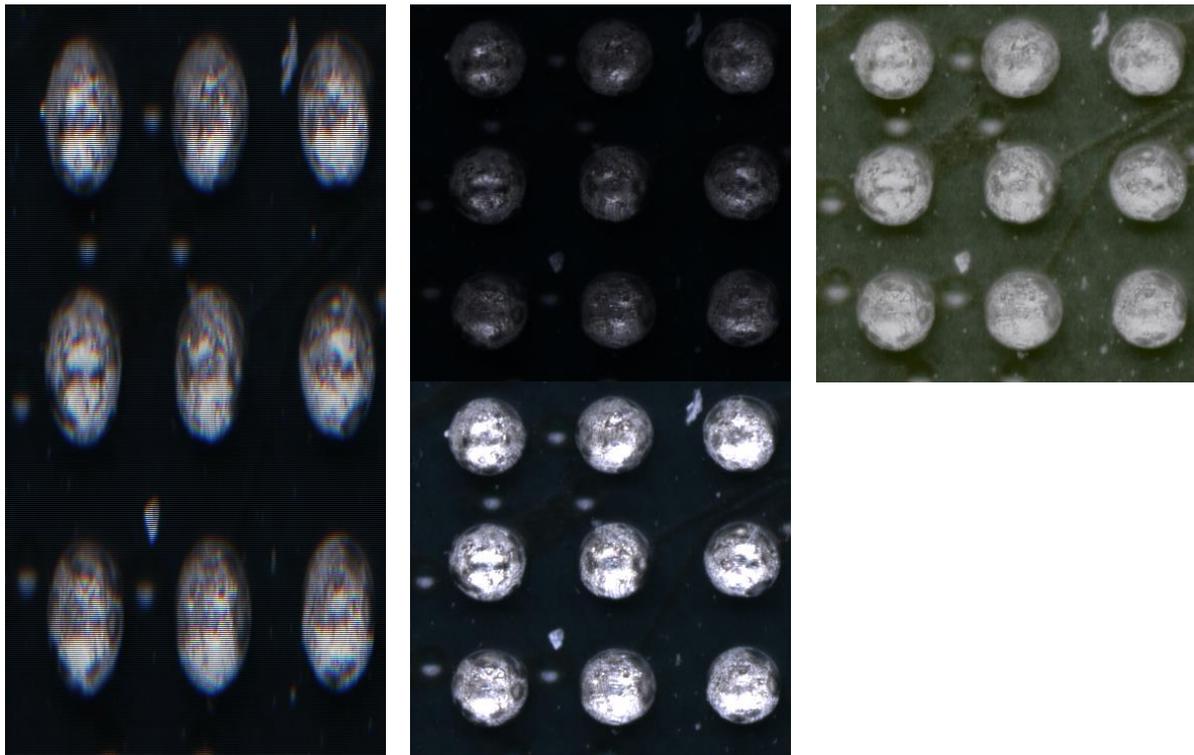


Figure 10: HDR demonstration on ball grid array sample

Left: Interlaced image **Middle:** Separated images with different exposure times **Right:** HDR image

5.3 Flashing an XLC4

Any flash controller that is compatible to the electrical and timing specifications of the camera output interface can be synchronized with an allPIXA pro / allPIXA wave camera. To ensure compatibility it is recommended to use the Chromasens illumination controller XLC4

¹ Debevec, Paul E., and Jitendra Malik. "Recovering high dynamic range radiance maps from photographs." ACM SIGGRAPH 2008 classes. 2008. 1-10.

(CP000411) together with suitable illuminations from the Corona II product line (CP000200...). This chapter describes the setup of an XLC4 controller for flashing with an allPIXA pro.

The first step is correctly cabling the output pins of the external interface to the trigger input of the flash controller. Table 2 lists the assignment of pins to their respective flash channels. For each flash channel in use connect this pin to the controller trigger input and connect one of the three available ground potentials from the camera to the ground of the flash controller.

Table 2: allPIXA flash output pins of the external I/O interface.

Flash channel	I/O pin number	Specification
1	4	Over 680 Ohm + Pull-Down
2	12	Over 10 Ohm + Pull-Down
3	6	Over 10 Ohm + Pull-Down
4	8	Over 10 Ohm + Pull-Down
	14	Flash control clock (optional)
	7,11,13	Ground

There are two versions of the XLC4 controller, the standard version has one trigger input which flashes all illumination channels while the 1A version (CP000411-1A) has four trigger inputs that can flash each illumination channel separately. When triggering all channels at once use the pin 1 off the input port X6 for the signal and the pin 6 at the same port for the ground connection for both models. For individual triggering of the illumination channels use the pins 1, 2,3 and 7 for the different signals instead. Figure 11 shows a detail view of the XLC4 with the correct cabling.

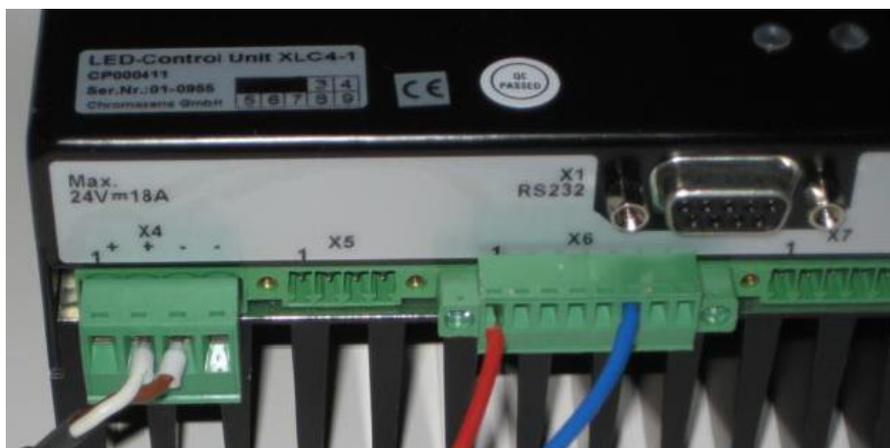


Figure 11: Detail view of the XLC4 controller showing the X6 port with cabling for single signal flash mode

After connecting the XLC4 to the camera you need to activate the flash mode in the controller which in turn will deactivate the manual command for powering the illumination on and off ("LC"). This is done with the "FA" command which expects a hexadecimal input parameter that is a combination of binary flags. The command for flashing all channels at once (with cooling device control activated) for both XLC4 versions is "FA 0x002C" while the single channel flashing operation of the XLC4-1A is activated with "FA 0x022C". To deactivate the flash mode and restore manual control send "FA 0x000C". For detailed information on the FA command please refer to the relevant section in the Corona manual. Please note that any changes to the FA register only take effect after the next power up of the XLC4 controller.

6 Summary

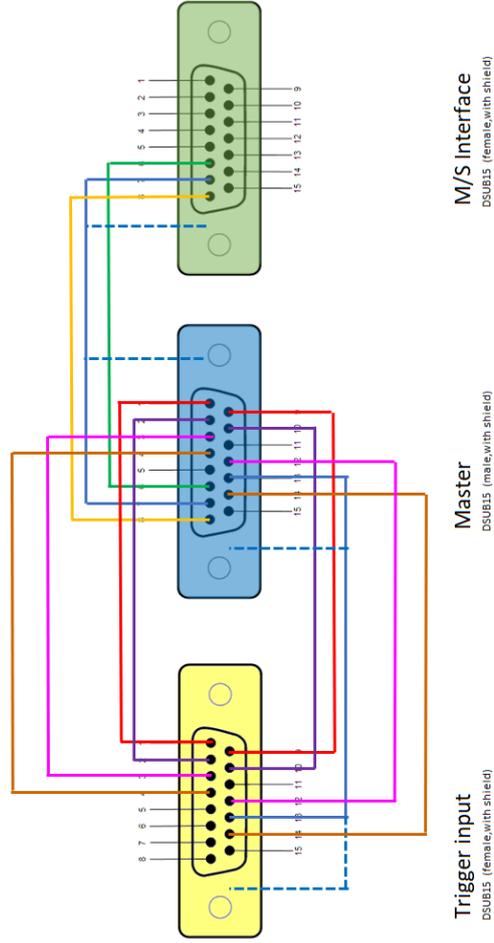
This whitepaper details all setup tasks related to synchronizing an allPIXA camera including the physical cabling as well as the camera configuration. The basics of the available interface useable for synchronizing the camera are covered as well as the setup of an encoder triggered acquisition. This encompasses the advanced functions such as encoder signal interpolation as well as scan direction recognition and suppression of backward motion acquisition.

Section 4 introduces the concept of master / slave operation which is needed for synchronizing the acquisition of two cameras. Besides cabling and camera parameters the importance of the correct frame grabber setup for this mode is also explained. The concept can be extended to include any number of cameras when using the cascaded master / slave operation. The final chapter details the setup of the camera for flash operation, which contains how to define multiple flash patterns, how to use the flash controller for multi-exposure imaging (e.g. high dynamic range (HDR) imaging) and how to use the Chromasens illumination controller XLC4 for flashing a light source.

This paper is intended to accelerate the setup time of the camera for your own application concerning the covered topics. We still recommend reading all relevant chapters in the manual if you are uncertain about the setup. Furthermore you can also contact support@chromasens.de if you have any additional questions after reading these documents.

Appendix A Master / Slave trigger breakout cable

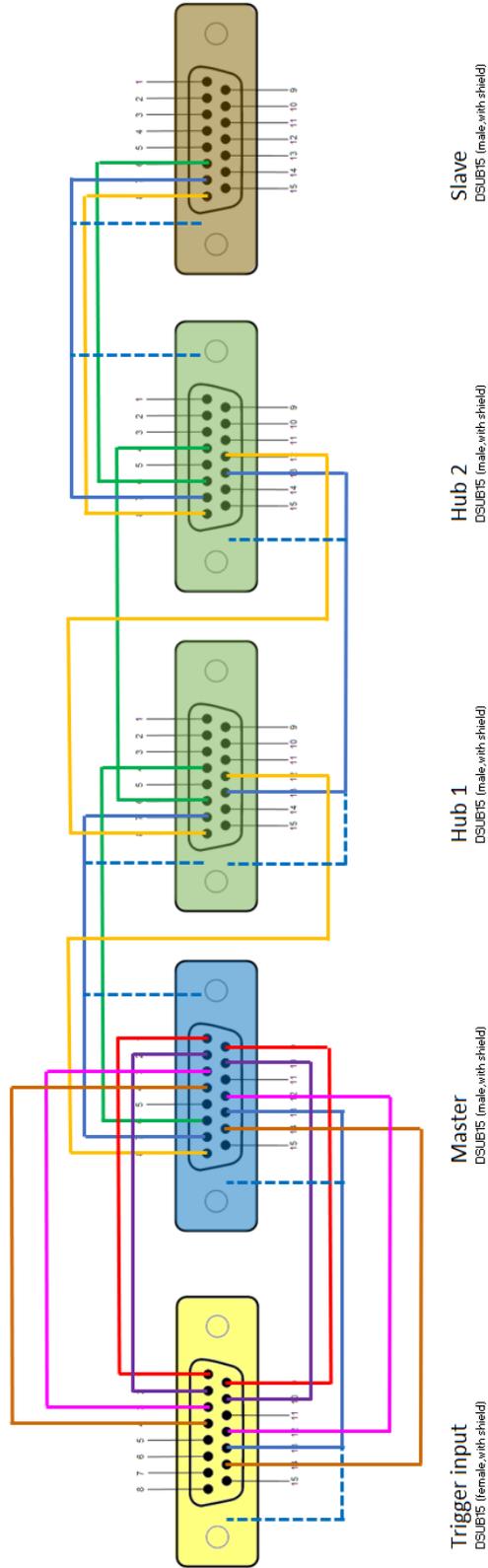
Breakout cable for the trigger interface with external master/slave synchronisation



Notes:
 use shielded cables
 connect GND to shield (dotted lines)

Appendix B Cascaded Master / Slave mode cable

Cascaded Master Slave cable



Notes:
use shielded cables
connect GND to shield (dotted lines)