Tau™ SWIR Product Specification

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1 Document

1.1 Revision History

Version	Date	Comments
105	10/12/2018	Update restrictions, TEC settings
104	8/17/2017	Update bad pixel section to exclude first/last rows and columns
103	8/25/2016	Update to TEC control table
101	8/10/2016	Update to TEC set temps and typographic errors
100	7/26/2016	Initial Release
098	7/22/2016	Pre-Initial release

1.2 Scope

Tau ™ SWIR is a family of miniature Short-Wave Infrared (SWIR) imaging cores from FLIR Systems, offered in various configurations. This product specification specifically applies to the Tau SWIR configurations, utilizing FLIR's ISC1202 InGaAs or VisGaAs sensor. Part numbering is as shown below.

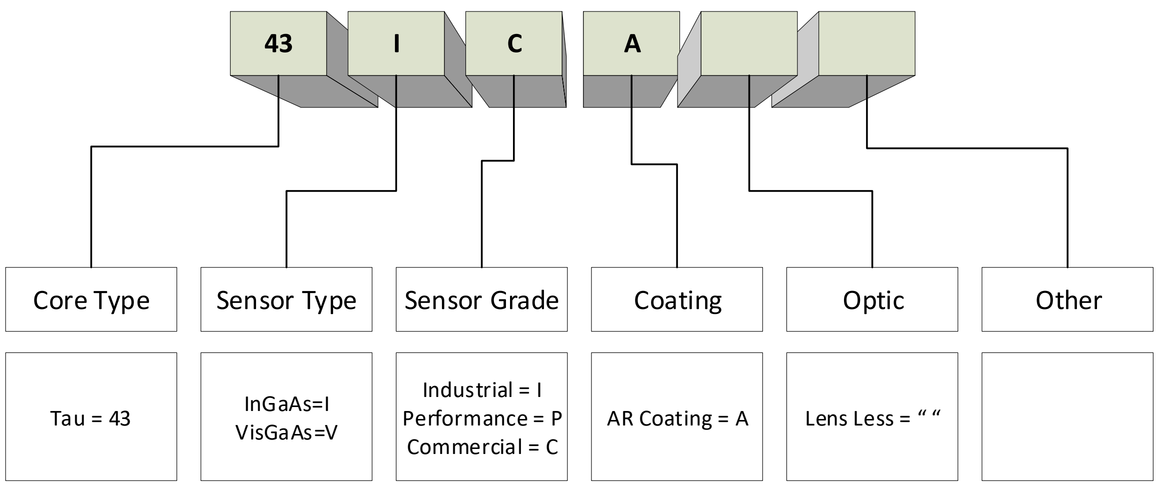


Figure 1, Part Number Explanation

2 References

The following documents form a part of this specification to the extent specified herein.

2.1 FLIR Website / Contact Information

FLIR's Tau SWIR website can be accessed via the following URL:

https://www.flir.com/products/tau-swir/

Additionally, FLIR's Applications Engineering Department is referenced as a resource for obtaining additional help or information. The department can be accessed via the following phone number: +1-805-964-9797 (or toll-free within the United States at 888-747-FLIR (888-747-3547).) Email requests can be addressed to SBA-cores@flir.com.

2.2 FLIR System Documents

102-2009-42	Tau SWIR Software Interface Description Document (IDD)
102-2009-45	Tau SWIR ISC 1202 User's Guide
102-2009-44	Mechanical Interface Description Drawing (Generic for Tau SWIR)

2.3 External Documents

IEC 60529	Degrees of protection provided by enclosures (IP Code)
IEC 61000	Electromagnetic Compatibility (EMC)
Directive 2002/95/EC	Restriction of the use of certain Hazardous Substances in electrical and electronic equipment (RoHS)

2.4 Abbreviations / Acronyms

AGC	Automatic Gain Correction
CDS	Correlated Double Sampling
DDE	Digital Detail Enhancement
FFC	Flat Field Correction (Per Pixel Offset)
FOV	Field of View
GUI	Graphical User Interface
ICD	Interface Control Drawing/Document
IDD	Interface Description Drawing/Document
IIR	Infinite Impulse Response
InGaAs	Indium Gallium Arsenide (Detector Material)
ITR	Integrate Then Read
IWR	Integrate While Read
LUT	Look-Up Table
LVDS	Low-Voltage Differential Signaling
NEI	Noise Equivalent Irradiance
NTSC	National Television System Committee
NUC	Non-Uniformity Correction
PAL	Phase Alternating Line
ROI	Region of Interest
SDK	Software Developers Kit
SWIR	Short-Wave Infrared
TEC	Thermo-Electric Cooler

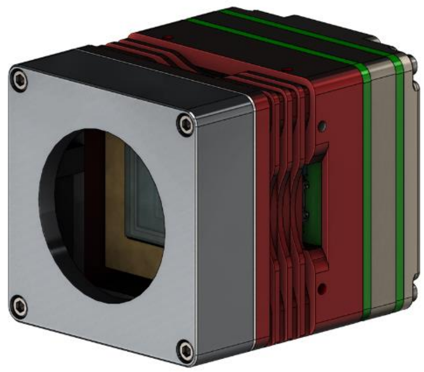


Figure 2 Tau SWIR Camera from FLIR

3 Requirements

3.1 Product Description

Tau ™ SWIR is a miniature, 38mm×38mm×47mm, Short-Wave infrared (SWIR) imaging core from FLIR Systems, built around FLIR's ISC1202 InGaAs SWIR sensor. This sensor provides high sensitivity from 0.9 to 1.7µm, low dark current, temperature stabilization and on chip (in-pixel) correlated double sampling (CDS) for noise reduction, CDS fold-over protection (prevents "black sun effect"), anti-blooming (low gain only), snapshot integration, 640 × 512 resolution with a 15µm pixel pitch running at 60 frames per second. FLIR's proprietary image processing algorithms start with 14-bit digital imagery and result in high-quality, analog video or 8-bit digital imagery in both low light conditions and full daylight.

Frame rates may be adjusted from a minimum of 1fps to a maximum of 60fps for a full frame image. A preset 2X window of the central 320 × 256 pixels may be selected allowing for a frame rate of up to 120fps. (See, Get/Set Window Parameters, for both the frame rate and the window size in the Tau SWIR Software IDD). An external sync mode allows integration with other camera systems, SWIR illuminators or pulsed lasers, synchronizing the integration period of the camera with the external system.

There are three sensitivity modes, Low, Mid or High. Low sensitivity is appropriate for well illuminated, wide dynamic range scenes while each step up in sensitivity allows imaging under lower SWIR illumination levels with an accompanying decrease in the dynamic range that can be imaged.

Within each sensitivity mode, the integration period may be adjusted from as little as 10µs to as high as the frame period minus the readout overhead (overhead ≈75 µs). Response of the 14-bit digital imagery increases linearly with increasing integration period.

FLIR's built in Auto-Exposure algorithm allows automatic, smooth transitions of integration period (t_{int}) based on scene content to maximize image quality and detail without user intervention.

The camera includes FLIR's advanced Non-Uniformity Correction (NUC), in-camera non-responsive pixel replacement and Automatic Gain Control (AGC) algorithms.

The Tau SWIR comes standard with a C-mount lens adapter installed. This may be removed allowing for custom lens mounts.

3.1.1 Accessories

3.1.1.1 Camera Mount

A ¼-20 camera mount accessory allows for mounting on many standard camera tripods.

3.1.1.2 Adaptor Boards

Two Optional adaptor boards are available as accessories.

3.1.1.2.1 Camera Link

The Camera Link adaptor board outputs both analog video, on an MCX connector, and digital video on a mini Camera Link SDR female connector. A USB connector allows for serial communication and control as well as power to the camera.

3.1.1.2.2 VPC

A low profile VPC Module provides a USB connector for both power and serial communications and an MCX connector for analog video.

With either of these two accessory boards a USB cable with a second power input is provided to handle higher than ½ amp current normally supplied through USB from a computer.

Both of these adaptor boards also include a separate connector to the TEC drive board, which can supply power to the TEC from the USB connector.

3.1.2 Applications

- SWIR imaging
- Night-glow imaging
- Haze penetration
- Covert surveillance
- Machine vision applications
- Low light level imaging
- Laser spot tracking

3.1.3 Features

- 60Hz full window frame rate, 120Hz at 2X zoom
- 640 × 512 resolution, 15µm pixel-pitch
- 14-bit digital video output
- SWIR spectral sensitivity
  - 0.9 to 1.7 µm; InGaAs sensors
  - 0.6 to 1.7 µm; VisGaAs sensors
- On-board, in-pixel CDS with fold-over protection and anti-blooming (Anti blooming in low gain mode only)
- On-board AGC and NUC
- Scene-based digital detail enhancement (DDE)
- Automatic exposure control
- Automatic temperature stabilization
- Small size (38×38×47mm)

3.2 Interface

3.2.1 Mechanical Interface

3.2.1.1 Size

Dimensions are nominally 38mm×38mm×47mm with the C-Mount adapter installed, or 38mm×38mm×36mm without the C-Mount adaptor. Detailed dimensions are specified in a separate drawing: 102-2009-44.

3.2.1.2 Weight

The Tau SWIR camera core without a lens has a mass ≤ 95g (<75g without C-mount adaptor).

3.2.1.3 Mounting

The Tau core provides precision mounting features on each of three sides. The mounting holes are 30mm apart M2x0.4 ~4mm deep and compatible with the ¼-20 camera mount accessory.

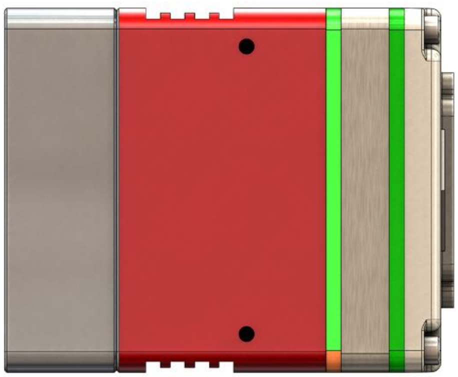


Figure 3 Mounting Holes, Bottom View

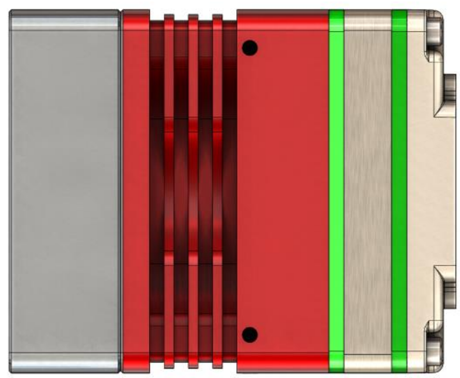


Figure 4 Mounting Holes. Top View

These mounting holes are found on the top, bottom and the opposite side from the TEC power connector.

3.2.2 Electrical Interface

There are two electrical interfaces to the Tau SWIR camera: The TEC power connector and the main camera connector.

3.2.2.1 TEC Power Connector

A Molex connector on the side of the camera requires a 4.9V -5.5V input to power the TEC. Peak power for this connection is limited to 2.5W while actual power consumption will vary with the ambient and mounting environment. Commonly, this connector requires 0.3W at room ambient temperatures with the camera mounted on a tripod.

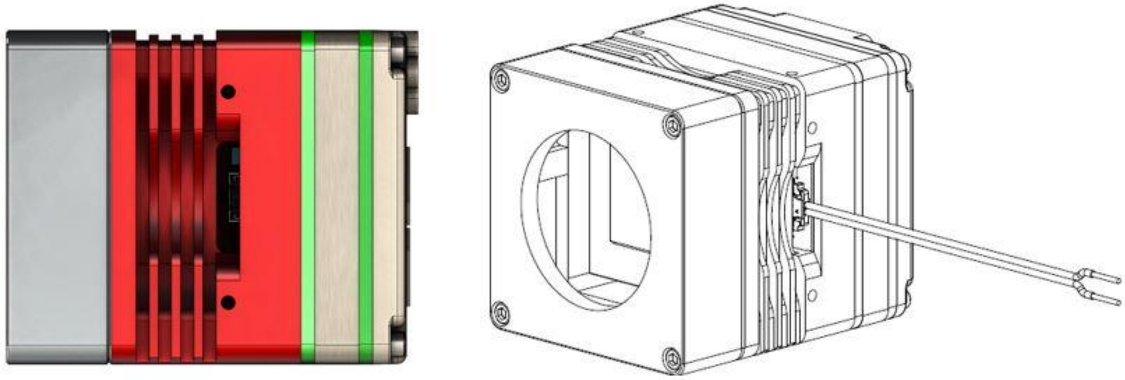


Figure 5 TEC Power connector on one side of the camera body

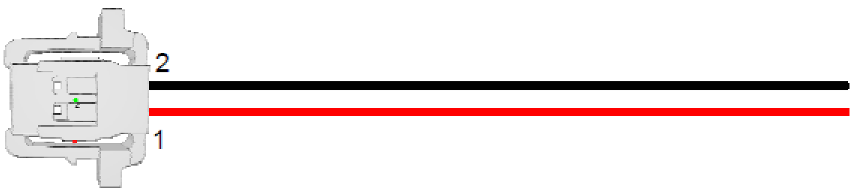


Figure 6 Molex Pigtail Connector for TEC Power

A Molex Pico-Lock connector pigtail comes standard with the Tau SWIR allowing a separate power supply for the TEC.

Connector Pin #	28 AWG	Wire color
1	5V	RED
2	GND	BLACK

Figure 7 TEC Power Connector Pins

3.2.2.1.1 TEC Power Through Accessory Boards

When using the either the VPC or Camera Link Adaptor accessory boards, power may be supplied to this connector via a cable from the accessory board. A cover plate is installed over the cable and TEC power connector port on the side of the camera. In this configuration both camera power and TEC power are supplied through the USB connector on the accessory board.

Figure 8 Tau SWIR with VPC module and cover plate.

3.2.2.2 Main Connector

The main electrical interface to the Tau SWIR camera is a single high-density 50-pin connector: Hirose #DF12-50DS-0.5V(86). The recommended mating connector is Hirose #DF12(5.0)-50DP-0.5V(86) for a mating stack height of 5mm.

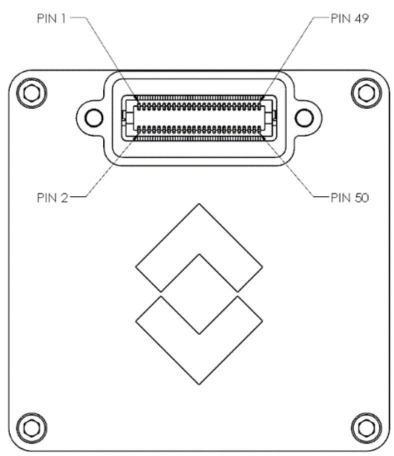


Figure 9 Hirose #DF12-50DS-0.5V(86)

Table 3-1 Pinout Hirose 50-Pin Connector, Default Output Mode (2) CMOS 14-bit

Pin #	Signal Name	Pin #	Signal Name
1	COMM_TX (RS232_TX_OUT)	2	COMM_RX (RS232_RX_IN)
3	CMOS LINE_VALID_OUT	4	CMOS FRAME_VALID_OUT
5	DGND	6	DGND
7	CAMLINK_CLK [P]	8	CAMLINK_CLK [N]
9	CAMLINK_DATA [0P]	10	CAMLINK_DATA [0N]
11	CAMLINK_DATA [1P]	12	CAMLINK_DATA [1N]
13	CAMLINK_DATA [2P]	14	CAMLINK_DATA [2N]
15	CAMLINK_DATA [3P]	16	CAMLINK_DATA [3N]
17	DGND	18	DGND
19	DISCRETE IO REG [0]	20	CMOS DATA_OUT [13]
21	EXTERNAL_SYNC	22	CMOS DATA_OUT [12]
23	CMOS DATA_OUT [11]	24	CMOS DATA_OUT [10]
25	CMOS DATA_OUT [9]	26	CMOS DATA_OUT [8]
27	DGND	28	DGND
29	CMOS DATA_OUT [7]	30	CMOS DATA_OUT [6]
31	CMOS DATA_OUT [5]	32	CMOS DATA_OUT [4]
33	CMOS DATA_OUT [3]	34	CMOS DATA_OUT [2]
35	CMOS DATA_OUT [1]	36	CMOS DATA_OUT [0]
37	DGND	38	DGND
39	CMOS CLOCK_OUT	40	Z
41	DGND	42	DGND
43	VID_OUT_H	44	VID_OUT_L
45	DGND	46	n/c
47	MAIN_PWR_RTN	48	MAIN_PWR
49	MAIN_PWR_RTN	50	MAIN_PWR

See also Table 3-2 (mode 3) and Table 3-3 (mode 1).

3.2.2.3 Input Power

The Tau SWIR core input-voltage range is 4.9V – 5.5V. Core power is **< 3W**. If an adaptor board is used with the power supply to the TEC board, peak total power to this adaptor board may reach 5.5W. (See 3.2.2.1)

3.2.2.4 Analog Channel

Tau SWIR provides either NTSC or PAL compatible composite video output selectable through a software command VIDEO_STANDARD. The analog output frame rate is determined by this selection, 30Hz for NTSC, 25Hz for PAL; however, the digital frame rate is set independently and is not affected by this choice. The analog output is interlaced in all configurations. Additional controls for Analog Video are associated with software commands VIDEO_MODE, VIDEO_PALETTE and VIDEO_ORIENTATION.

3.2.2.5 Digital Channels

Tau SWIR provides two digital transmit channels, one parallel and one serial. Each output can be enabled or disabled. Three options for the parallel data are software selectable DIGITAL_OUTPUT_MODE; 14-Bit CMOS, 8-bit CMOS or 8-bit BT656.

3.2.2.5.1 Parallel Digital Data (CMOS 14-bit)

CMOS parallel digital video consisting of 14 parallel bits of data and three control signals, a clock, line valid and frame valid, all at 3.3V TTL levels is the default configuration for the Tau SWIR camera. This CMOS output is capable of 40M pixels per second while driving 24 inch single ended lines. See Table 3-1 for the pinout associated with this output mode. The 14-bit digital data is fully corrected, however the AGC selections are not applied.

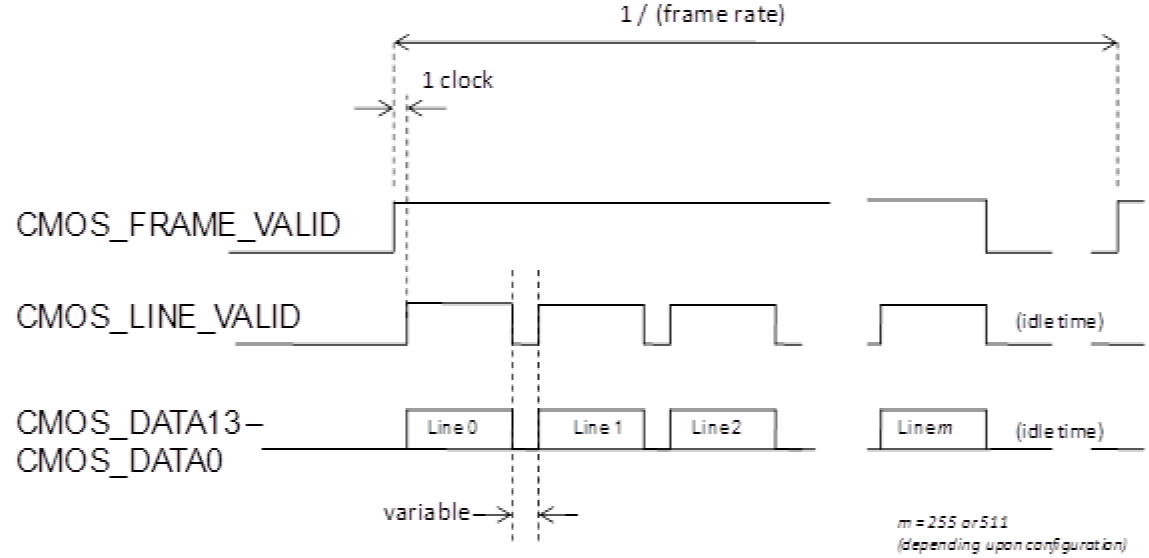


Figure 10 Frame Timing CMOS Protocol

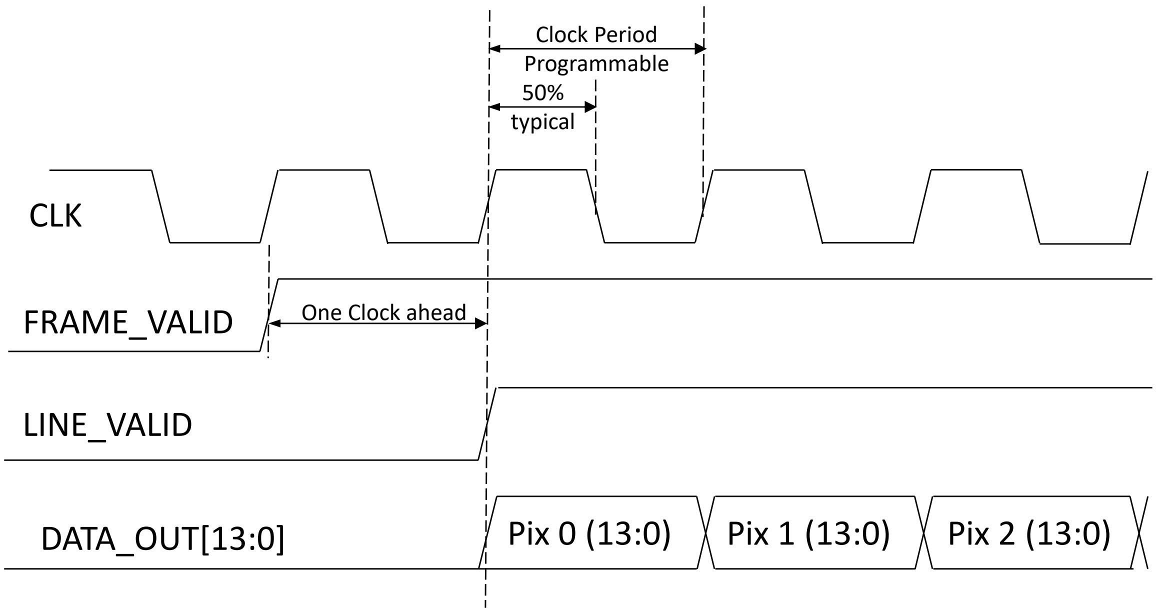


Figure 11 Line Timing

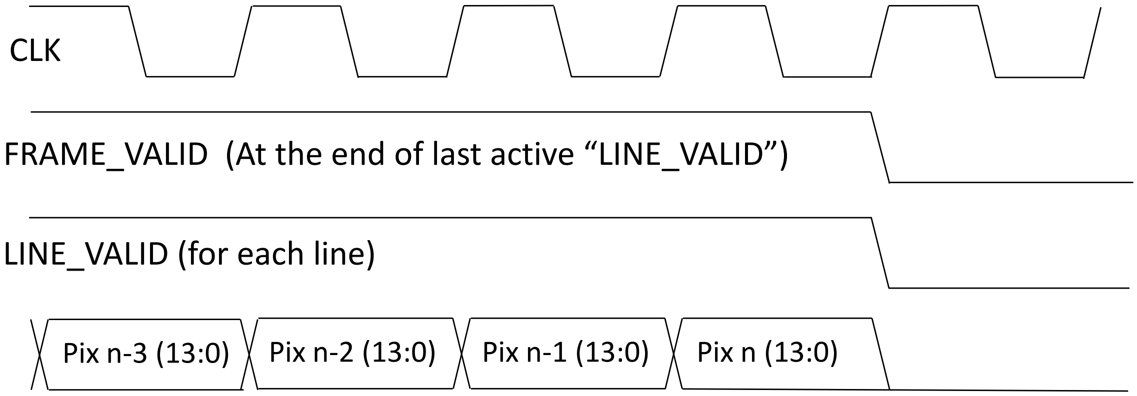


Figure 12 End of Active Frame Timing

3.2.2.5.2 Parallel Digital Data (CMOS 8-bit)

Output mode 3 provides 8-bit CMOS digital data. In this mode, the digital data provided has AGC selections applied as well as being fully corrected.

Table 3-2 Pinout Hirose 50-Pin Connector, Output Mode (3) CMOS 8-bit

Pin #	Signal Name	Pin #	Signal Name
1	COMM_TX (RS232_TX_OUT)	2	COMM_RX (RS232_RX_IN)
3	LINE_VALID_OUT	4	FRAME_VALID_OUT
5	DGND	6	DGND
7	CAMLINK_CLK [P]	8	CAMLINK_CLK [N]
9	CAMLINK_DATA [0P]	10	CAMLINK_DATA [0N]
11	CAMLINK_DATA [1P]	12	CAMLINK_DATA [1N]
13	CAMLINK_DATA [2P]	14	CAMLINK_DATA [2N]
15	CAMLINK_DATA [3P]	16	CAMLINK_DATA [3N]
17	DGND	18	DGND
19	DISCRETE IO REG [0]	20	DISCRETE IO REG [1]
21	EXTERNAL_SYNC	22	(XP 12) Z
23	DISCRETE IO REG [2]	24	DISCRETE IO REG [3]
25	DISCRETE IO REG [4]	26	DISCRETE IO REG [5]
27	DGND	28	DGND
29	CMOS DATA_OUT [7]	30	CMOS DATA_OUT [6]
31	CMOS DATA_OUT [5]	32	CMOS DATA_OUT [4]
33	CMOS DATA_OUT [3]	34	CMOS DATA_OUT [2]
35	CMOS DATA_OUT [1]	36	CMOS DATA_OUT [0]
37	DGND	38	DGND
39	CLOCK_OUT	40	Z
41	DGND	42	DGND
43	VID_OUT_H	44	VID_OUT_L
45	DGND	46	n/c
47	MAIN_PWR_RTN	48	MAIN_PWR
49	MAIN_PWR_RTN	50	MAIN_PWR

3.2.2.5.3 Parallel Digital Data (BT656 8-bit)

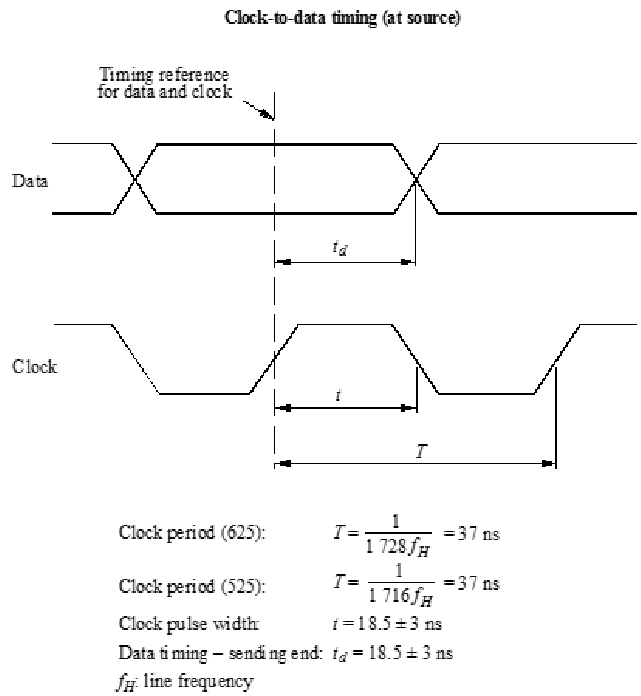


Figure 13 BT.656 Timing

Table 3-3 Pinout Hirose 50-pin Connector, Output Mode (1), BT.656

Pin #	Signal Name	Pin #	Signal Name
1	COMM_TX (RS232_TX_OUT)	2	COMM_RX (RS232_RX_IN)
3	DISCRETE IO REG [6]	4	DISCRETE IO REG [7]
5	DGND	6	DGND
7	CAMLINK_CLK [P]	8	CAMLINK_CLK [N]
9	CAMLINK_DATA [0P]	10	CAMLINK_DATA [0N]
11	CAMLINK_DATA [1P]	12	CAMLINK_DATA [1N]
13	CAMLINK_DATA [2P]	14	CAMLINK_DATA [2N]
15	CAMLINK_DATA [3P]	16	CAMLINK_DATA [3N]
17	DGND	18	DGND
19	DISCRETE IO REG [0]	20	DISCRETE IO REG [1]
21	EXTERNAL_SYNC	22	(XP 12) Z
23	DISCRETE IO REG [2]	24	DISCRETE IO REG [3]
25	DISCRETE IO REG [4]	26	DISCRETE IO REG [5]
27	DGND	28	DGND
29	BT656 DATA_OUT [7]	30	BT656 DATA_OUT [6]
31	BT656 DATA_OUT [5]	32	BT656 DATA_OUT [4]
33	BT656 DATA_OUT [3]	34	BT656 DATA_OUT [2]
35	BT656 DATA_OUT [1]	36	BT656 DATA_OUT [0]
37	DGND	38	DGND
39	CLOCK_OUT BT656 (27Mhz)	40	Z
41	DGND	42	DGND
43	VID_OUT_H	44	VID_OUT_L
45	DGND	46	n/c
47	MAIN_PWR_RTN	48	MAIN_PWR
49	MAIN_PWR_RTN	50	MAIN_PWR

3.2.2.5.4 Camera Link Serial Data

Camera Link serial data is provided on pins 7 through 16 of the as shown in all three pinout tables for the Hirose 50-pin connector.

3.2.2.5.4.1 Camera Link from the Accessory Board

The Tau SWIR can provide Camera Link serial digital data through the Camera Link adaptor board. A Tau Camera Link Accessory Kit (P/N:421-0058-00) includes the Tau Camera Link Accessory (P/N:500-842-00). Output from this accessory board is directly driven by pins 7 through 16 on the Hirose 50 pin connector.

1. Per Camera Link, base configuration.
2. Clock rate > 21MHz.
3. Requires 100Ω differential termination at the receiver.

3.2.3 Command / Control Interface

The Tau SWIR core provides for serial communication conforming to the industry standard RS-232C.

1. Default factory BAUD rate is 921.6K.
2. The auto-baud feature will detect either 57.6K or 921.6K automatically.
3. Baud rate may be configured for any standard baud rate and saved as a configuration parameter. (See BAUD_RATE in the Tau SWIR Software IDD).
4. One start bit, 8-bit data, one stop format. (See BAUD_RATE in the Tau SWIR Software IDD).
5. LVTTL format.
6. Signal levels are from 0V to 3.3V, 5V compatible.

3.2.3.1 Discrete I/O

The Tau SWIR core provides the option of user-configured discrete I/O pins that can be used as either input signals to the core (for example, to signal the core to toggle between white hot and black hot) or as output signals from the core (for example, to signal that a temperature set point has changed). Depending upon the selected digital mode, see 3.2.2.5, there are between 1 and 8 pins available as discrete I/O. The function assigned to each discrete I/O pin is defined by a control file. No file is loaded by factory default. See FLIR's Tau website for an Application note further describing discrete I/O files.

3.2.3.2 SDK

FLIR's software developer's kit (SDK) can provide control and operation of the Tau SWIR camera core. Most commands and operations are compatible with other FLIR Tau (LWIR), Quark and Neutrino products while some commands and operations specific to the Tau SWIR are added and some commands that are inappropriate for the Tau SWIR are not available.

3.2.3.3 GUI

A graphical user interface (GUI), as similar as practical to other FLIR Tau/Quark user interfaces is available to allow access to the features and functions of the Tau SWIR camera core. This GUI uses the same commands and functions as the SDK while also giving the user an intuitive camera operation environment.

3.3 Functional Description

3.3.1 Temperature Stabilized Operation

Tau SWIR is a temperature stabilized camera core. Calibration is performed at the factory for the stabilized temperature setting (~20°C set in software). The TEC must be supplied with a separate 5V (> 0.5 Amp) power supply for normal operation. A thermistor provides temperature readings of the FPA to the camera core and an automatic shut-down of the TEC and camera core will be triggered when the temperature cannot be maintained within operational limits. Practically, this shut down is triggered by the FPA temperature rising above a factory set limit of 71°C. (Note that 80°C is the maximum non-operating temperature).

It is possible to operate the camera core without use of the TEC which may be turned off by a software command, then it is not necessary to supply the external power to the TEC. In that case the image quality will be degraded as a function of how far from the calibration temperature the FPA is being operated. Temperature feedback to the core will trigger a shutdown of the camera if the FPA temperature is above the safe operating range of the FPA (71°C).

3.3.1.1 TEC Settings

TEC power consumption is determined by the set temperature as well as the ambient environment. A nominal **set temperature of 20°C** is applied for ambient temperatures approximately up to 50°C while a **40°C set point** is applied for ambient temperatures from 50°C to 71°C. There is also a lower set temperature of 0°C for ambient temperatures below 0°C. **These ambient temperature ranges are only approximate** since, normally, as long as the TEC is enabled, the Tau SWIR camera automatically chooses the TEC set point beginning with 20°C on startup and will maintain that set temperature unless the combination of ambient temperature and heat sinking of the unit prevent the TEC from maintaining this temperature at the sensor.

Automatic adjustment is controlled by a table of 4 entries (0 through 3) with 5 parameters in each entry. These parameters, for each table entry, determine whether the camera will adjust to the next or previous table entry or stay on the current table entry. The parameters are the maximum and minimum values for the hot side of the TEC (we are referring to the side of the TEC away from the FPA as the “hot side”); the maximum and minimum FPA temperatures; and the set point for each table entry:

Table 3-4, TEC Control Table Showing Default Values

	Hot Side Minimum; Parameter 0	Hot Side Maximum; Parameter 1	FPA Side Minimum; Parameter 2	FPA Side Maximum; Parameter 3	FPA Side Set Point; Parameter 4
Entry 0	-60°C	40°C	-40°C	2°C	0°C
Entry 1	10°C	60°C	18°C	22°C	20°C
Entry 2	15°C	80°C	38°C	42°C	40°C
Entry 3	20°C	95°C	43°C	75°C	45°C

The Tau SWIR software assumes the table entries to be in ascending order such that when the FPA temperature exceeds the FPA Side Maximum, or the Hot Side temperature exceeds the Hot Side Maximum for the current table, the next higher table entry is selected and made active, while an FPA temperature dropping below the FPA Side Minimum or the Hot Side temperature dropping below the Hot Side Minimum triggers the software to select the next lower table entry.

Each NUC table will save the TEC table entry that is active during the save NUC process. So, when a NUC table is selected, it will automatically load and make active the TEC table entry it was saved with.

See COOLED_CORE_COMMANDS> "Get/Set TEC Parameters" in the Tau SWIR Software IDD.

3.3.1.2 Heat Dissipation

To maintain an FPA temperature, heat must be removed from the camera system. The camera body acts as a radiator, however, since it presents a small surface area, it is limited in the amount of heat it can radiate. Additionally, air flow around the camera body can convectively remove some of the heat. By far the most effective heat removal mechanism is conduction through the mounting surface(s). Mounting directly to a metal frame with good contact over the mounting surface of the camera body will provide the best results.

3.3.2 FPA Timing Settings (Frame Rate & Integration Period)

FPA timing is internally configured based on the user's choices of **frame rate** and **integration period**. Any frame rate may be selected between 1fps and 60fps, corresponding to frame periods from ~1s to 16.67ms respectively. Integration periods may be set as short as 10µs or as long as a frame period minus ~70µs. In "Integrate While Read (IWR) mode when the integration period is longer than the frame period minus the frame readout time, (readout time ~16.3ms), embedded software in the camera core adjusts the selected integration time to match a whole number of "line times" effectively limiting the integration period precision to 32µs. This integration period granularity is unrestricted for the "Integrate Then Read" (ITR) mode when integration periods are less than the frame period minus frame readout time. Note that lower frame rates will allow for a wider range of integration periods that meet this ITR criteria. Frame rate control is part of the COOLED_CORE_COMMANDS "Set Window Parameters" described in the Tau SWIR Software IDD, while integration period control is found in the GET_INT_TIME & SET_INT_TIME command described in the Tau SWIR Software IDD.

3.3.3 Free Run Imaging

When operating in normal "Free Run" mode, no external frame sync is required because a frame sync is generated internally at the frame rate set, or the last saved frame rate. Note that selecting a NUC table causes the frame rate to adjust to the one saved for that NUC table. Normally, free run is set to "Readout Priority" which is selectable in the GUI or by software command in which case a frame period begins with a short dead time followed by readout of the previous frame. In this mode integration begins at the set integration period before the end of the frame. The user may also select the "Integration Priority" mode in which a frame period begins with frame integration followed by a required delay before readout of the frame just integrated begins. Integration priority is usually only used for external sync operation. See Figure 14.

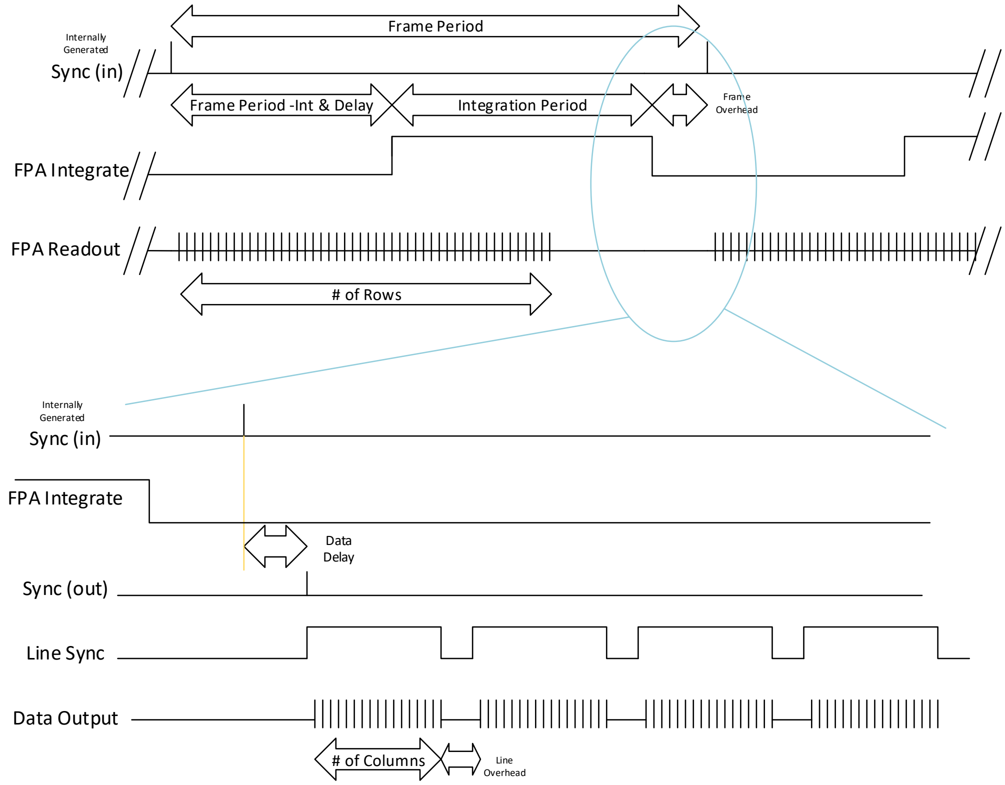


Figure 14 Free Run, Readout Priority

3.3.4 Frame Synchronized (External Sync)

(See EXTERNAL_SYNC in the Tau SWIR Software IDD)

When operating in "Free Run", the first mode of the EXTERNAL_SYNC setting, a synchronization signal is internally generated at the frame rate selected or set by the user, however three External Sync modes are available. The second mode is a "**Slave**" mode. In this case, the synchronization signal is not internally generated, but the camera waits for an externally supplied signal. The third is the "**Master**" mode in which case a second internally generated synchronization signal is output on the external sync pin. Finally, there is a fourth setting which is another "**Slave**" mode. In the Tau SWIR there is no difference between the two slave modes. In either case, Master or Slave, the user has the same two choices between **Integration Priority** or **Readout priority** (default is readout priority). External synchronization may be at any frame rate equal to or less than setup frame rate. Required delays between one input sync signal and the next are based on the frame period set up by the selection of a frame rate. Setup should be at a frame rate slightly higher than the expected external signal. If the input external signal arrives before it can be allowed by the setup timing, that signal will be ignored until the next external signal arrives.

3.3.4.1 Integration Priority

In Integration Priority, integration of the current frame is initiated by the external sync. The delay between external sync and the start of integration is 650ns ±70ns. At the completion of integration, a data delay occurs (approximately 73µs) and then readout of this integrated frame begins. This readout may overlap with the beginning of the next integration. Any signal on the external sync input pin that arrives after the start of integration but before the completion of the frame period is discarded. See Figure 15.

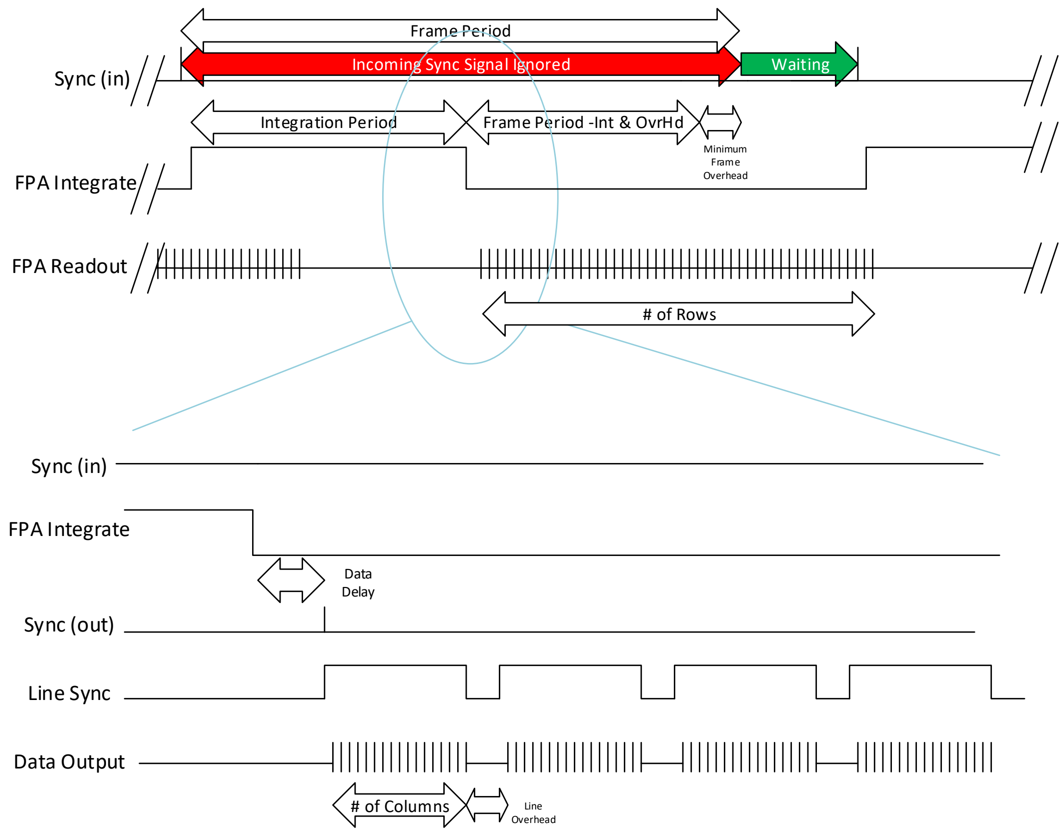


Figure 15 Integration Priority

3.3.4.2 Readout Priority

In Readout Priority, the readout of the previously integrated frame is initiated by the frame sync. A delay, equal to the expected frame period minus the integration time, follows this initiation. The camera will finish integration of the current frame and transfer this data to a sample and hold circuit before it begins waiting for the next frame sync. Any signal on the external sync input pin that arrives after readout begins and before integration is complete is discarded. See Figure 16.

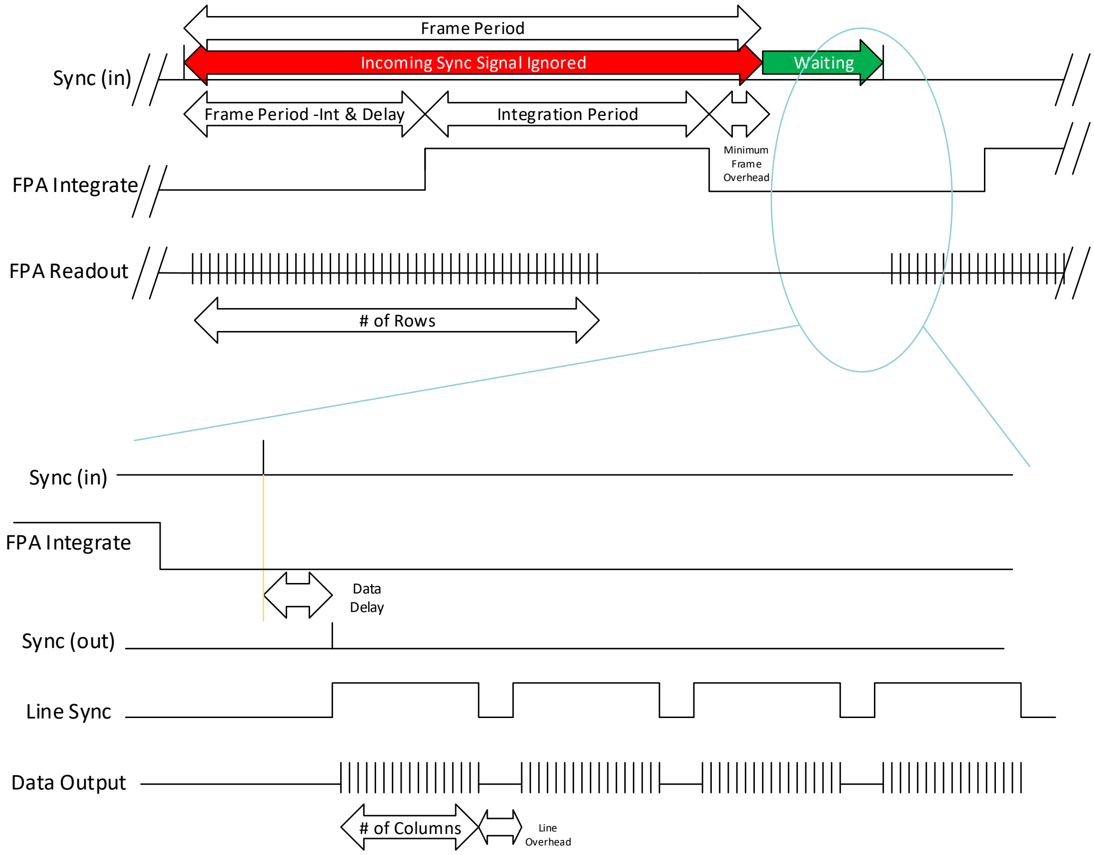


Figure 16 Readout Priority

3.3.4.3 Disable External Sync

When external sync is disabled, the sync input/output pin has no effect on operation of the camera.

3.3.5 Integration Mode

Each NUC table may have a restriction set on the type of integration possible. Unrestricted is the default, however the user may restrict all timing to integrate while read (IWR) or integrate then read (ITR) to maintain consistent non-uniformity correction results, since the offset correction for these two cases will be somewhat different. See Get/Set Integration mode under the COOLED_CORE_COMMANDS in the Tau SWIR Software IDD.

3.3.6 Frame Rate

Digital output frame rate may be set via the GUI or a software command from a minimum of 1fsp to a maximum of 60fps for full frame imaging, or 120fps for a pre-selected windowed frame of 320 × 256 pixels. Getting and setting the window size and frame rate is a combined command. See COOLED_CORE_COMMANDS; Set Window Parameters in the Tau SWIR Software IDD.

3.3.6.1 Legacy Mode

For frame grabber systems that require a longer line period, there is a “Legacy Mode”. This reduces the frame data output to a maximum of 30fps for setup frame rates of 60fps or less. The output digital signal in Non-Legacy mode bursts the frame data out in 16.3ms, or each line in 32µs, as required for 60fps operation, and it maintains this burst speed for all frame rates. This results in “dead time” between frames on the digital output that increases as the frame rate decreases. Legacy mode shifts the dead time to between lines so that the frame data is burst out over 32.6ms such that the time from the beginning of one line to the beginning of the next line is 64µs as required for 30fps operation. With this mode on, any frame rate setup above 30fps results in skipped frames of data reducing the output to approximately half of the setup frame rate, while setup frame rates below 30fps output frames at the setup rate. See AVERAGE_STRETCH_COMMAND in the Tau SWIR Software IDD.

3.3.7 Output Resolution

Digital output is 640 × 512 pixels or the user may select a 320 × 256 centered window which allows a faster frame rate ~120fps. See COOLED_CORE_COMMANDS; Set Window Parameters in the Tau SWIR Software IDD.

3.3.8 Optical Performance

Optical performance will be function of the lens Quality, Field of view (FOV) and f/# as well as the sensitivity set by integration time and gain settings. Whatever the field of view, the sensor is limited to 640 by 512 pixels.

3.3.8.1 Quantum Efficiency and Fill Factor

The average quantum efficiency-fill factor product is greater than 60% over the 1.0µm to 1.6µm spectral band.

3.3.8.2 Uncorrected Uniformity of DC Output

The uncorrected non-uniformity (spatial standard deviation/mean) of the DC output is less than 5% in all gain modes when the sensor is viewing a uniform source at approximately the mid-range illumination.

3.3.8.3 Dark Current Density

Typical median dark current, at 20 °C, is expected to be < 10 nA/cm^2**.**

Camera/FPA Grade	Dark Current Density
Industrial	< 10 nA/cm^2
Performance	< 50 nA/cm^2
Commercial	< 100 nA/cm^2

3.3.8.4 Operability and Bad Pixel Clusters

Operability will be > 98.0% for the center 638 x 510 pixels in the array.

Camera/FPA Grade	Operability
Industrial	> 99.5%
Performance	> 99.0%

Commercial	> 98.0%

A bad pixel is defined by a pixel that meets at least one of the following criteria:

a) DC output is outside of ±50% of the array mean DC output when the DC output is measured in the 25 – 75% full scale range.

OR

b) Responsivity is less than ±50% of the array mean responsivity, where the responsivity is taken as the difference between two frames in the 25% and 75% full scale range.

OR

c) The NEI exceeds 3X the mean NEI for the entire array.

Clusters of bad pixels shall conform to the requirements described in Table 3-5. The number of clusters for each zone is exclusive of the smaller zones. Zones are defined by the following table:

Table 3-5 Inoperable pixel specifications for FPA pixel zones.

Zone	ROI
Zone 1	Central 128x128
Zone 2	Central 320x256 Outside Zone 1
Zone 3	Central 400x400 Outside Zone 2
Zone 4	Central, 638x510 Outside Zone 3

Industrial

	Allowable Bad Pixel Clusters			
Cluster Size (pixels)	**Zone 1**	**Zone 2**	**Zone 3**	**Zone 4**
4 <= x < 10	1	1	2	10
10<= x < 15	0	0	1	2
15<= x < 20	0	0	0	0
20 <= x	0	0	0	0

Performance

	Allowable Bad Pixel Clusters			
Cluster Size (pixels)	**Zone 1**	**Zone 2**	**Zone 3**	**Zone 4**
4 <= x < 10	2	2	4	20
10<= x < 15	1	1	2	10
15<= x < 20	0	0	1	2
20 <= x	0	0	0	0

Commercial

	Allowable Bad Pixel Clusters			
Cluster Size (pixels)	**Zone 1**	**Zone 2**	**Zone 3**	**Zone 4**
4 <= x < 10	4	4	10	40

10<= x < 15	2	2	4	10
15<= x < 20	1	1	2	5
20 <= x	0	0	1	2

3.3.8.5 Pixel replacement

Defective pixels are replaced in the output video by the average value of adjacent non-defective pixels using a proprietary FLIR algorithm. The defective pixel map is stored within the gain map of the camera. The FLIR Camera Controller GUI's advanced tab allows the user to add pixels to this map if required. A default, factory specified, bad pixel map is also stored in the camera memory and can be loaded to any existing gain map or as the starting point when creating a new gain map. (See also 3.3.10.3; 3.3.10.1).

3.3.8.6 Noise Equivalent Irradiance

Array average NEI shall be as indicated at 20 °C and using the conditions shown in Table 3-6

Table 3-6 NEI specifications

	High Gain			Low Gain		
	Industrial	**Performance**	**Commercial**	**Industrial**	**Performance**	**Commercial**
Parameter	**Value**	**Value**	**Value**	**Value**	**Value**	**Value**
Integration Time (ms)	33	5	2	1	1	1
Irradiance (photons cm^{-2} s^{-1})	1.00E+10	1.00E+10	1.00E+10	5.00E+14	5.00E+14	5.00E+14
NEI (photons cm^{-2} s^{-1})	1.78E+09	1.03E+10	2.36E+10	7.12E+11	7.13E+11	7.13E+11

For reference: Conversion between irradiances (W/cm^2) and photon irradiances (photons cm^{-2} s^{-1}) are based on the energy of a photon at the center of the specified spectral band, hc/λ = 1.24E-19 J at 1.6µm.

3.3.9 Start-Up Features

3.3.9.1 Splash Screen

At start-up, the Tau SWIR core presents a splash screen (or optionally 2 splash screens, displayed one after the other) on the analog channel. The Tau SWIR GUI provides a means to download custom splash screens in bitmap format. The display time of each splash screen can also be specified, from the Tau SWIR GUI or see SPLASH_CONTROL in the Tau SWIR Software IDD.

3.3.9.2 Readiness Time

Elapsed time from application of power to output of SWIR video is approximately 5 sec. (This only applies if first splash-screen display time is set below the readiness time.). Startup time will increase by the display time of the second splash screen if loaded. On startup, the Tau SWIR may provide video output before the TEC has stabilized resulting in some temperature dependent non-uniformity in the image until the TEC reaches the set point, usually within only a few seconds.

3.3.9.3 Power-On Defaults

The Tau SWIR core allows the user to specify default settings to be applied at start-up. Additionally, it is possible to reset the core to factory-specified defaults. See SET_DEFAULTS in the Tau SWIR Software IDD.

3.3.9.4 Fault-Tolerant Upgradeability

The Tau SWIR core provides the capability to safely upgrade firmware / software. In the event of power loss or data corruption during the upgrade process, the core will continue to provide at least the minimum functionality required for the upgrade process to be repeated.

3.3.9.5 Backward Compatibility

All future releases of Tau SWIR firmware / software will be backwards compatible with all fielded versions of Tau SWIR. In other words, upgrading the core in the field with an authorized firmware / software release will not result in a loss of function or performance.

3.3.10 Image Processing Features

3.3.10.1 Gain Calibration (Two Point NUC)

The Tau SWIR camera can generate gain and offset non-uniformity correction (NUC) coefficient tables in the field and store them to flash. The camera comes with stored factory NUC tables which can be overwritten. NUC tables are specific to the associated optical system and a new table removes the effect of non-uniform illumination inherent in most optical systems, as well as the slight pixel to pixel response non-uniformity.

Nine different tables can be stored. Saving a NUC update to the flash is a user option which overwrites the existing coefficients for that table. It also saves the settings of frame rate, integration period and the current FFC. To save only the 2pt gain correction, see WRITE_GAIN_TABLE in the Tau SWIR Software IDD, see also CORRECTION_MASK, MIN_PIXEL_GAIN & MAX_PIXEL_GAIN & WRITE_NUC_HEADER in the Tau SWIR Software IDD.

3.3.10.2 Flat Field Correction (FFC)

This is a per pixel offset calculated from a collection of uniformly illuminated frames. This offset can remove pixel to pixel DC non-uniformities inherent in the sensor separate from the pixel to pixel response non-uniformities corrected by the gain correction. See 3.3.10.1. Note that saving this FFC using the GUI will save the current gain calibration as well. To save only an offset correction see the command, repurposed for the Tau SWIR, WRITE_LAGRANGE_TABLE in the Tau SWIR Software IDD, see also CORRECTION_MASK & WRITE_NUC_HEADER in the Tau SWIR Software IDD.

3.3.10.3 Pixel Replacement

In any sensor, some pixels may be too noisy, flashing, non-responsive or excessively responsive. Such pixels are not suitable for imaging and are replaced by a weighted combination of neighbouring, non-defective pixels. This replacement algorithm is applied to pixels on a stored list. An initial list is determined at the factory, however, over time a user may notice pixels that should be added to that list. The Tau SWIR camera core allows the user to supplement the factory bad pixel list with additions. A user may also discard any additions and restore the factory bad pixel list. See PIXEL_GAIN, see also CORRECTION_MASK & WRITE_NUC_HEADER in the Tau SWIR Software IDD.

3.3.10.4 Auto Exposure (Integration Time) & Gain Selection

The Tau SWIR provides three user selectable gain (sensitivity) states: High, Medium, and Low. The Low gain state is appropriate for high illumination scenes and wide ranges of illumination within a scene. Each step up in gain increases the sensitivity of the camera and allows imaging under lower illumination conditions. Each step up in gain also reduces the range of illumination levels within a scene (the dynamic range of the scene) that may be imaged. See COOLED_CORE_COMMAND Get/Set Sensor Gain in the Tau SWIR Software IDD.

Within each gain setting there is a separate adjustment of the integration period. Response of the camera to illumination in the scene increases linearly with this integration period setting.

Tau SWIR default gain selection at start-up is determined by the gain selection associated with the NUC table selected when settings were last saved. The default integration period on start-up is as it was when that NUC table was saved.

Auto-Exposure settings, Enabled or Disabled and Histogram Maximum or Histogram Mean, will be as they were set the last time settings were saved. Auto-exposure automatically adjusts integration time based on the scene content. This auto-exposure feature has two possible modes; one based on the maximum of the scene histogram and one on the mean value of the scene histogram. Direct manual control of integration time to any value within the limits of the frame rate is returned by disabling the auto-exposure feature before setting the integration period.

Operation of the auto-exposure feature is based on the selected region of interest (ROI). Rather than an independent ROI, this is the same ROI as selected for AGC. Auto-adjustment takes some hysteresis into account to avoid rapid “flashing” or oscillating between settings.

Step size for any integration period adjustment is based on actual levels of the histogram, so that adjustments will quickly converge on a setting that places the histogram nicely in the acceptable range of the digital output.

(See COOLED_CORE_COMMAND Get/Set Auto Exposure State & Get/Set Auto Exposure Tail rejection & Get/Set Auto Exposure Mode & Get/Set Auto Exposure Max Percent Change & Get/Set Auto Exposure Target Max in the Tau SWIR Software IDD.)

3.3.10.5 Automatic Gain Correction (AGC)

NOTE: This does not refer to the sensitivity setting as described in the section on auto-exposure and gain control.

The Tau SWIR core provides multiple AGC options applicable to the 8-bit digital and analog outputs but not to the 14-bit output data. An IIR filter is used to adjust how quickly the AGC algorithm reacts to a change in scene or parameter value.

For those algorithms that use the scene histogram as input, the histogram is taken from a user-specified region of interest (ROI). Any scene content located outside of the ROI will not affect the algorithm. Separate ROI are automatically applied for un-zoom and 2X zoom.

The following paragraphs will describe the AGC modes, separated into the Legacy Modes and the more advanced Histogram Equalization Modes. But first, we will look at the AGC parameters that can be set. These parameters will be separated into the Linear Parameters, Automatic Parameters and the Enhancements. In each case we will indicate which AGC modes a given parameter applies to. See AGC_TYPE in the Tau SWIR Software IDD.

3.3.10.5.1 AGC Parameters

3.3.10.5.1.1 Linear Parameters

3.3.10.5.1.1.1 Contrast

In Tau SWIR, this parameter has been expanded to allow extreme values. This parameter applies to "Once Bright", "Manual" and "Auto Bright" Legacy Modes (See 3.3.10.5.2.1.1 & 3.3.10.5.2.1.2 & 3.3.10.5.2.1.3 below). It affects the range of 14-bit input values that may be mapped to the 256 brightness levels of the display (0 to 255). A contrast of "128" will map the entire 14-bit range into 256 brightness levels while a contrast setting of "8192" will properly display only a range of 256 values into the 256 brightness values of the display (unity transfer). For a very low contrast scene with a range of only 64 values in the 14-bit data, a contrast setting of 32640 will expand that over the entire 8-bit output range, maximizing the contrast between displayed values. See CONTRAST in the Tau SWIR Software IDD.

3.3.10.5.1.1.2 Brightness

This setting applies to the "Manual" Legacy Mode. Essentially, this is the 14-bit level that will be mapped to the middle of the 256 brightness levels of the display. See BRIGHTNESS in the Tau SWIR Software IDD.

3.3.10.5.1.1.3 Brightness Bias

Applies to "Auto Bright" and "Once Bright" modes.

In "Auto Bright" Mode the base brightness level is continuously determined as the mean value of the 14-bit histogram so that a pixel with that value maps to the center of the output range (127). The Brightness Bias is then added to the 14-bit input before the mapping takes place so that positive values give a brighter picture while negative values darken the image.

In "Once Bright" Mode the base brightness is determined only at the moment when this mode is selected, again this is the mean value of the 14-bit histogram. Pixels with that value are mapped to 127. However, the Brightness Bias is added to the Brightness setting in this case so that negative values brighten the output image, while positive values reduce the brightness on the display. See BRIGHTNESS_BIAS in the Tau SWIR Software IDD.

3.3.10.5.1.2 Automatic Parameters

3.3.10.5.1.2.1 SSO

<u>Smart Scene Optimization</u>, applies to Histogram Equalization Modes and determines the percent of the image histogram that will be allotted linear mapping. Low settings allow full histogram equalization which assigns no shades of gray to unoccupied regions of the histogram. Higher settings prevent the occupied regions of the histogram from mapping too close to each other such that a very bright region appears only slightly brighter than a much darker region. At 100% you will see no benefit from histogram equalization, the image is 100% linear. See getLinearPercent & setLinearPercent in the AGC_TYPE command in the Tau SWIR Software IDD.

3.3.10.5.1.2.2 Plateau Value

Plateau value applies to Histogram Equalization Modes and clips the number of pixels counted in each histogram bin when calculating the slope of the transfer function. This prevents using too many shades of gray to represent rather uniform areas such as the sky.

The Histogram Equalization Modes are variants of classic histogram equalization, an algorithm that maps 14-bit to 8-bit using the cumulative histogram of the 14-bit image as the mapping function. In classic histogram equalization, an image histogram comprised of 60% sky will devote 60% of the available 8-bit shades to the sky, leaving only 40% for the remainder of the image. Plateau limits reduce the maximum number of gray shades devoted to any particular portion of the scene by clipping the histogram. The maximum gain value is an additional, separate limit to the maximum slope of the mapping function. See 3.3.10.5.1.3.1. See PLATEAU_LEVEL in the Tau SWIR Software IDD.

3.3.10.5.1.3 ITT Mean

This parameter applies to the "Linear" Legacy Mode as well as Histogram Equalization Modes.

The ITT midpoint value allows the mean brightness of the 8-bit image to be specified. The ITT Midpoint can be used to shift the 8-bit histogram darker or brighter. The nominal value is 128. A darker image can help improve the perceived contrast, but it is important to note that more of the displayed image may be "railed" (8-bit value = 0 or 255) by moving the midpoint away from 128. See AGC_MIDPOINT in the Tau SWIR Software IDD.

3.3.10.5.1.3.1 Max Gain

This parameter applies to the "Linear" Legacy Mode as well as the Histogram Equalization Modes. It limits the maximum slope of the 14-bit to 8-bit transfer function.

For scenes with high dynamic range (that is, wide 14-bit histogram), the maximum gain parameter has little effect. For a very bland scene, on the other hand, it can significantly affect the contrast of the resulting image. See MAX_AGC_GAIN in the Tau SWIR Software IDD.

3.3.10.5.1.3.2 AGC Filter

AGC Filter. The AGC filter is an IIR filter used to adjust how quickly the AGC algorithm reacts to a change in scene or parameter value. The filter is of the form

$$n' = n * \alpha/256 + n'-1 * (256-\alpha)/256$$

where:

n' = actual filtered output value for the current frame

n = unfiltered output value for the current frame

n'-1 = actual filtered output value for the previous frame

α = filter coefficient, user-selectable from 0 to 255

If the AGC filter value is set to a low value, then if a bright object enters the field of view, the AGC will adjust more slowly to the bright object, resulting in a more gradual transition. In some applications, this can be more pleasing than a sudden change to background brightness. For the Tau SWIR, a filter coefficient of 255 is a special case for immediate updates, a value of 1 provides the most filtering or slowest refresh rate, and a value of 0 indicates no further updates to AGC. See AGC_FILTER in the Tau SWIR Software IDD.

3.3.10.5.1.3.3 Tail Rejection

The tail rejection parameter applies to all Histogram Equalization Modes. A separate tail rejection parameter applies to the Auto-Exposure feature (see 3.3.10.4). This parameter defines the percentage of the total number of pixels in the array that will be excluded prior to histogram equalization. The user-selected percentage of pixels will be removed from both the bottom and top of the 14-bit histogram prior to AGC. This feature is useful for excluding outliers and the most extreme portions of the scene that may be of less interest. FLIR recommends tail rejection settings less than 1% to avoid the exclusion of important scene content. See TAIL_SIZE in the Tau SWIR Software IDD.

3.3.10.5.1.4 Enhancements

3.3.10.5.1.4.1 Dynamic DDE

Dynamic mode: DDE parameters are computed automatically based on scene contents. The DDE index is the only controlling parameter and ranges from -20 to 100 for Tau SWIR, with higher values representing higher degrees of detail enhancement. If no enhancement is desired, the value should be set to 0. Values less than 0 soften the image and filter fixed pattern noise. Values greater than 0 sharpen the details in the image. There is a complex transformation from this parameter to the DDE_GAIN, DDE_THRESHOLD and SPATIAL_THRESHOLD parameters found in the Tau SWIR Software IDD, all of which are affected by this single choice in the GUI.

3.3.10.5.1.4.2 ACE Threshold

The Active Contrast Enhancement threshold (ACE) feature provides a contrast adjustment dependent on the relative scene brightness. ACE thresholds greater than 0 impart more contrast to brighter scene content and decrease contrast for darker scene content (e.g. sky or ocean). ACE thresholds less than 0 do the opposite by decreasing contrast for brighter scene content and leaving more of the gray-scale shades to represent the darker scene content. See ISCA_CORRECT in the Tau SWIR Software IDD.

3.3.10.5.1.4.3 Information Threshold

Information Threshold. The information threshold parameter defines the difference between neighboring pixels used to determine whether the local area contains “information” or not. Lower thresholds result in the algorithm determining that more of the scene contains information, resulting in more areas given a higher weighting in the Information-based Equalization algorithm. Decreasing the threshold will result in imagery approaching the appearance of the Plateau Equalization algorithm. Increasing the threshold will result in a more information-dependent image, that is the flat portions of the scene (e.g. sky or sea) are given less contrast and the pixels exceeding the information threshold will be given more contrast. See AGC_TYPE in the Tau SWIR Software IDD, get/setEBThreshold.

3.3.10.5.2 AGC Modes

3.3.10.5.2.1 Legacy Modes

All of the Legacy Modes are linear transformations from the 14-bit corrected data.

3.3.10.5.2.1.1 Manual

A linear transformation from 14-bit to 8-bit is generated based entirely on user settings of the contrast and brightness parameters. The transformation is not automatically optimized for scene conditions, however, in the new Tau SWIR camera, when selecting “Manual” the initial contrast and brightness settings are calculated and set based on the current scene. Subsequent adjustments of both contrast and brightness are user inputs that remain as long as “Manual” remains the selection. Re-selecting “Manual” will automatically adjust the contrast and brightness to a new set of initial levels.

$$8\ bit\ pixel\ Value = (14\ bit\ pixel\ Value) \cdot \frac{Contrast}{8192} + 127 - Brightness \cdot \frac{Contrast}{8192}$$

See AGC_TYPE, CONTRAST & BRIGHTNESS in the Tau SWIR Software IDD.

3.3.10.5.2.1.2 Once Bright

The “Once Bright” algorithm is identical to the “Manual” algorithm except that the Brightness value is optimized automatically for the current scene histogram at the time the algorithm is selected, while contrast remains fixed by the user input. However, the Brightness Bias setting at the time the “Once Bright” algorithm is selected will add to or subtract from the Brightness setting.

$$8\ bit\ = (14\ bit\ ) \cdot \frac{Contrast}{8192} + 127 - (frame\ mean - Brightness\ bias) \cdot \frac{Contrast}{8192}$$

See AGC_TYPE, CONTRAST & BRIGHTNESS_BIAS in the Tau SWIR Software IDD.

3.3.10.5.2.1.3 Auto Bright

The “Auto Bright” algorithm is similar to the “Once Bright” algorithm except that brightness value is dynamically, continuously optimized based on the scene histogram. A “Brightness Bias” parameter adds to or subtracts from the dynamically determined Brightness level and allows the optimized value to be made darker (negative bias) or lighter (positive bias). Again, the contrast input by the user remains fixed. See AGC_TYPE, CONTRAST & BRIGHTNESS_BIAS in the Tau SWIR Software IDD.

3.3.10.5.2.1.4 Linear AGC (Linear Histogram)

This is a linear transformation from 14-bit to 8-bit is generated automatically based on the image histogram.

Controls for the gray-scale mid-point (ITT Mean) and maximum gain are user-selectable.

The linear histogram algorithm performs a linear transformation from 14-bit to 8-bit of the form:

$$8\text{-bit}_i = m * 14\text{-bit}_i + b$$

The slope of the transformation is computed automatically based on the ROI histogram:

m = 255 / (14-bit_(100 – Tail Rejection)% - 14-bit_(Tail Rejection)%),

where 14-bit (Tail Rejection)% is the 14-bit value corresponding to the user selectable tail rejection percentage point on the cumulative ROI histogram and 14-bit_(100 – Tail Rejection)% is the value corresponding to the difference between 100% and the user selectable tail rejection percentage point.

The offset is then computed as

b = ITT midpoint - avg(14-bit_(100 – Tail Rejection)%, 14-bit_(Tail Rejection)%),* m

In other words, the algorithm attempts to map the midway point between the top and bottom tail rejection points on the cumulative histogram to the specified ITT midpoint. The 8-bit values resulting from the above equations are clipped to a minimum value of 0 and a maximum value of 255. See AGC_TYPE in the Tau SWIR Software IDD.

3.3.10.5.2.2 Histogram Equalization Modes

3.3.10.5.2.2.1 Auto (Histogram Equalization)

A non-linear transformation from 14-bit to 8-bit is generated automatically based on the image histogram. The plateau is a clipping threshold applied to the histogram. Controls for the gray-scale mid-point (ITT mean), maximum gain (AGC gain), SSO (Smart Scene Optimization), and plateau value are user-selectable. See AGC_TYPE, plateau histogram & PLATEAU_LEVEL in the Tau SWIR Software IDD.

3.3.10.5.2.2.2 LACE

Local Area Contrast Enhancement performs histogram equalization separately over 20 tiled regions of the image. This accentuates the contrast in each local area rather than the entire scene. LACE can greatly enhance the visual quality of imagery where there is a lot of local contrast and detail in a scene with a wide global dynamic range. Dynamic DDE, ACE threshold and ITT mean are all applicable to LACE. This mode is defined for the full 640 × 512 window size. See AGC_TYPE, CLAW, ISCA_CORRECT, AGC_MIDPOINT & DDE_GAIN in the Tau SWIR Software IDD.

3.3.10.5.2.2.3 Auto with Information Based

Information-based algorithms reserve more shades of gray for areas with more information or scene content, assigning fewer shades of gray to areas with less information (e.g. sky, sea, roads). Fixed pattern noise is reduced in these low content areas which allows giving more detail to the more interesting portions of the image. The “Auto with Information-based” algorithm undergoes the plateau and max gain limited equalization process found in “Auto” mode and therefore all parameters described there also apply. The Information Threshold determines the sensitivity to “information” in the scene. In this case, the histogram equalization uses all pixels in the scene and weights them according to their information. See AGC_TYPE, Plateau+entropy, ISCA_CORRECT, AGC_MIDPOINT & DDE_GAIN in the Tau SWIR Software IDD.

3.3.10.5.2.2.4 Information Based

The Information Based Algorithm completely excludes pixels from histogram equalization if they are below the information threshold. The advantage here is that spatial noise is completely removed before histogram equalization is performed. The disadvantage is that subtle scene variations are lost as well. See AGC_TYPE, entropy, ISCA_CORRECT, AGC_MIDPOINT & DDE_GAIN in the Tau SWIR Software IDD.

3.3.10.6 Color Palettes

The Tau SWIR core provides user-selectable palettes (also referred to as look-up tables or LUTs). Twelve standard palettes are provided by factory configuration. The palette selection applies to the analog, and 8bit digital data. 14-Bit data is not affected by the color palette. See VIDEO_PALETTE in the Tau SWIR Software IDD.

3.3.10.6.1 Bayer Encoding

Bayer encoding allows colors to be produced with 8-bit resolution, instead of the traditional 24-bit (RGB) representation. Bayer encoding is available on digital 8-bit outputs. By assigning each pixel a red, green, or blue value and averaging the neighboring pixel values, the color components of the specified pixel can be decoded. Multiple filter arrays can be applied to create the encoding; Figure 17 Illustration of Bayer Encoding, describes one filter array option for the four upper-left corner pixels of the image. The Bayer order is user selectable with the following options: ‘GR’, ‘GB’, ‘BG’, and ‘RG’. The order is defined by the top two pixels from left to right in the pattern, such that is an example of the ‘GB’ option.

Green	Blue
Red	Green

Figure 17 Illustration of Bayer Encoding

See DIGITAL_ OUTPUT_MODE in the Tau SWIR Software IDD.

3.3.10.6.2 YCbCr Encoding

YCbCr is a common method of encoding RGB information for digital outputs. Y represents the luminance component and Cb and Cr represent the blue-difference and red-difference chrominance components.

The Y, Cb, and Cr components are calculated as follows:

$$Y = 16 + \frac{1}{256}(65.738R + 129.057G + 25.064B)$$

$$Cb = 128 - \frac{1}{256}(37.945R - 74.494G + 112.439B)$$

$$Cr = 128 + \frac{1}{256}(112.439R - 94.154G - 18.285B)$$

The YCbCr output allows digital colorization for two different CMOS output options: 16-bit and 8-bit double-clocked. The 16-bit option encodes the YCbCr information in each pixel which contains both the chrominance (upper bits [15:8]) and luminance (lower bits [7:0]) components. The 8-bit double-clocked option doubles the output resolution width, and each pixel either contains the chrominance or the luminance components. Two different sub-sampling options for the chrominance are available: 4:2:2 centered and 4:2:2 cosited. The 4:2:2 centered option uses the average of two neighboring pixels for the chrominance values, while the 4:2:2 cosited option uses every other pixel for the chrominance values. The YCbCr order is also user-selectable with two options for the 8-bit double-clocked mode: YCbYCr and CbYCrY. Table 3-7 illustrates the expected output of the first row and first ten pixels for each sub-sampling and order configuration possible for the 8-bit double-clocked mode.

Table 3-7 8-bit Double-Clocked YCbCr output based on configuration

Configuration	Col0	Col1	Col2	Col3	Col4	Col5	Col6	Col7	Col8	Col9
4:2:2 Centered YCbYCr	Y0	$(C_b0+C_b1)/2$	Y1	$(C_r0+C_r1)/2$	Y2	$(C_b2+C_b3)/2$	Y3	$(C_r2+C_r3)/2$	Y4	$(Cb_4+Cb_5)/2$
4:2:2 Centered CbYCrY	$(C_b0+C_b1)/2$	Y0	$(C_r0+C_r1)/2$	Y1	$(C_b2+C_b3)/2$	Y2	$(C_r2+C_r3)/2$	Y3	$(C_b4+C_b5)/2$	Y4
4:2:2 Cosited YCbYCr	Y0	C_b0	Y1	C_r0	Y2	C_b2	Y3	C_r2	Y4	C_b4
4:2:2 Cosited CbYCrY	C_b0	Y0	C_r0	Y1	C_b2	Y2	C_r2	Y3	C_b4	Y4

See DIGITAL_ OUTPUT_MODE in the Tau SWIR Software IDD.

3.3.10.7 Symbol Overlay

The Tau SWIR core provides symbol-overlay capability in which arbitrary text, rectangles (filled or outline), or bitmaps may be specified via run-time commands for on-screen display. Each symbol may be displayed in 1 of 256 colors / translucency shades (Translucency must be the same for all symbols). The symbol overlay capability, including built-in icons, zoom symbol, and spot-meter graphics apply to the analog video output and the 8-bit digital. Digital data is colorized via Bayer encoding or YCbYCr. See VIDEO_MODE in the Tau SWIR Software IDD.

3.3.10.8 Image Orientation

The Tau SWIR core provides 4 image-orientation modes:

- Normal
- Invert + revert: flips image vertically and horizontally. This is the recommended mode when the core is mounted upside-down.
- Invert: flips image vertically. This is the recommended mode when the core images the scene via a vertical fold mirror.
- Revert: flips image horizontally. This is the recommended mode when the core images the scene via a horizontal fold mirror.

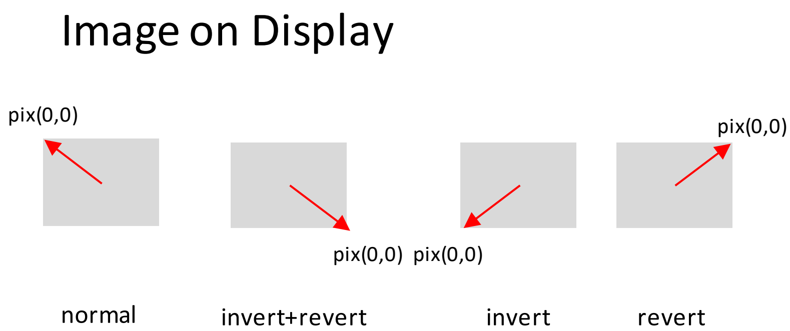


Figure 18 Illustration of Image Orientation Modes

See VIDEO_ORIENTATION in the Tau SWIR Software IDD.

3.3.10.9 ROI

Region of Interest (ROI). In some situations, it is desirable to have the AGC algorithm ignore a portion of the scene when collecting the histogram. For example, if the Tau SWIR core is rigidly mounted such that the sky will always appear in the upper portion of the image, it may be desirable to leave that portion of the scene out of the histogram so that the AGC can better optimize the display of the remainder of the image. Similarly, for a hand-held application, it may be desirable to optimize the display of the central portion of the image. For those applications, it is possible to specify a region of interest (ROI) beyond which data is ignored when collecting the image histogram. Any scene content located outside of the ROI will therefore not affect the AGC algorithm. (Note: this does not mean the portion outside of the ROI is not displayed, just that the portion outside does not factor into the optimization of the image.) See AGC_ROI in the Tau SWIR Software IDD.

3.3.10.10 Dynamic Zoom

The Tau SWIR core provides an optional zoom capability. The zoom algorithm applies to the analog and 8-bit digital output data.

- Zoom factor is continuously variable.
- The zoom window need not be centered with the field of view. It is possible to pan the zoom window horizontally and tilt it vertically up to ±40 columns / rows.
- The coordinates of the AGC region of interest (ROI) are specified as a percentage of the zoom window size (relative to the center of the zoom window), and the ROI is automatically sized / located relative to the zoom window. This feature precludes the user from having to change size and/or location of the ROI as the zoom window size or location is modified.

See VIDEO_MODE and EZOOM_CONTROL in the Tau SWIR Software IDD.

3.3.11 Diagnostic / Status Features

3.3.11.1 Test Patterns

The Tau SWIR core provides capability to display a test pattern. A test pattern is intended primarily to adjust display properties and/or for diagnostic purposes (e.g., to verify the core is providing a valid output). FLIR’s Tau GUI or the SDK can be used to enable test patterns. See TEST_PATTERN in the Tau SWIR Software IDD.

3.4 Environmental Requirements

3.4.1 Operating Temperature

The Tau SWIR camera will exhibit no damage or permanent degradation when operated in ambient conditions in the range -40ºC to +71ºC.

3.4.2 Storage Temperature

The Tau SWIR camera will exhibit no damage or permanent degradation after storage within the range -50ºC to +80ºC.

3.4.3 Relative Humidity

The Tau SWIR camera will exhibit no damage or permanent degradation when operated in non-condensing humidity in the range 5% to 95%.

3.4.4 Thermal Shock

The Tau SWIR camera will exhibit no damage from temperature excursions over the allowed temperature range within one minute (non-operating).

The camera will exhibit no image degradation in operating mode over the temperature range within 3 minutes.

3.4.5 Mechanical Shock

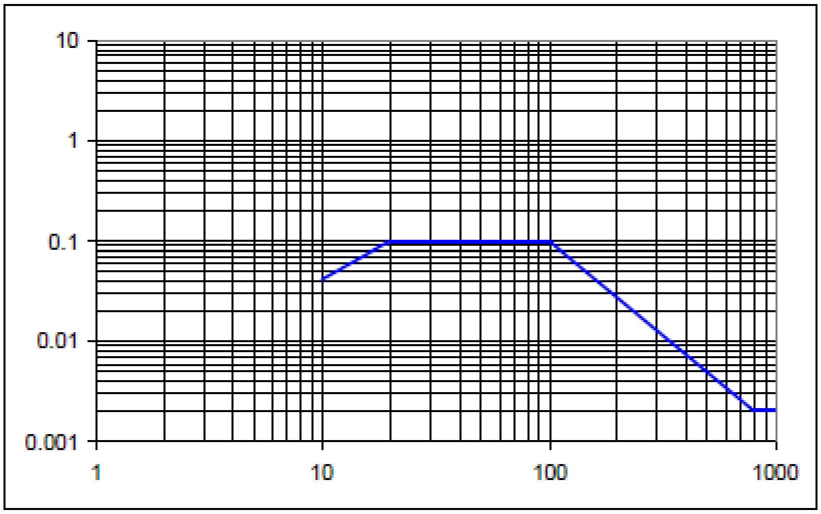
When properly mounted the camera shall survive a 1.5ms half-sine, 250g shock or a half-sine 500g 0.8ms shock along any axis.

3.4.6 Vibration

The Tau SWIR camera will show no damage (non-operational) or degradation (operational) after exposure to random vibration along any axis up to 4.3 grms (one hour each axis) per the profile specified in the following table and profile

Table 3-8 Random Vibration Profile

Frequency (Hz)	Acceleration density (G2/Hz)
10	0.040
20	0.100
100	0.100
800	0.002
1000	0.002



3.4.7 Altitude

The Tau SWIR camera will exhibit no damage or permanent degradation after exposure to pressure equivalent to 12 km above sea level.

3.4.8 EMC / EMI / ESD

The radiated emissions from Tau SWIR are compliant to IEC 61000-6-3, Class A and Class B when a rear cover is installed and proper cabling/line-terminations are provided.
Best design principles were employed to ensure survival of the camera in a cluttered EMI environment.

The Tau SWIR camera will exhibit no functional damage when subjected to electrostatic discharges per IEC 61000-4-2:

- Direct ESD Air Discharge: +2.0kV, +4.0kV, +6kV, +8kV (insulated surfaces)
- Direct ESD, Contact Discharge, +2.0kV, and +4.0kV (conductive surfaces)
- Indirect ESD, +2.0kV and +4.0kV (HCP and VCP)

3.5 Compliance

3.5.1 ROHS / WEEE / REACH

The Tau SWIR camera complies with the following directives / regulations:

- Directive 2002/95/EC, “Restriction of the use of certain Hazardous Substances in electrical and electronic equipment (RoHS)”
- Directive 2002/96/ EC, “Waste Electrical and Electronic Equipment (WEEE)”.
- Regulation (EC) 1907/2006, “Registration, Evaluation, Authorization and Restriction of Chemicals (REACH)”

4 Appendix

ANSI/SMPTE 170M-1994	Composite Analog Video Signal – NTSC for Studio Applications
ANSI/TIA/EIA-644	Electrical Characteristics of Low Voltage Differential Signaling (LVDS) Interface Circuits
ITU-R BT.470-6	PAL Conventional Television Systems
ITU Recommendation BT.656	Interface for digital component video signals in 525-line and 625-line television systems operating at the 4:2:2 level of Recommendation ITU-R BT.601
ANSI/TIA/EIA-232	Interface between Data Terminal Equipment and Data Circuit-Terminating Equipment Employing Serial Binary Data Interchange
IEC 60529	Degrees of protection provided by enclosures (IP Code)
Directive 2002/95/EC	Restriction of the use of certain Hazardous Substances in electrical and electronic equipment (RoHS)
Directive 2002/96/EC	Waste Electrical and Electronic Equipment (WEEE)
Regulation (EC) 1907/2006	Registration, Evaluation, Authorization and Restriction of Chemicals (REACH)