Tau™ 2
Product Specification

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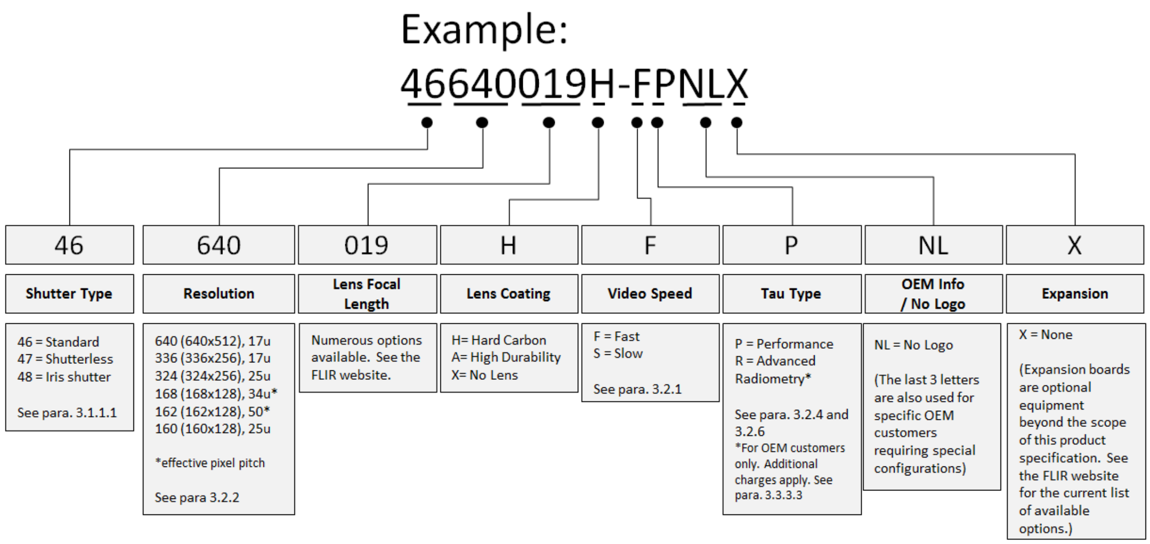
1.1 Revision History

Version	Date	Comments
100	11/07/2011	Initial release.
110	9/13/2012	Updated for Tau 2.1 release. Specific changes include: • 3.2.1: Addition of new resolution options • 3.3.2.4: Description of new continuous ezoom feature • 3.3.2.8: Description of new variable symbol resolution • 3.3.2.6: Reiterated the changes to the ROI between Tau 2.0 and Tau 2.1. • 3.3.2.9: Description of new 8-bit snapshot feature. • 3.3.3.3: New advanced radiometric requirements. • 3.3.4.4: Description of new overtemp feature. • 3.4.9: Added clarification on IP67 typical validation procedure.
111	11/21/2012	3.4.1: Added operating-temperature-range requirement for commercial-grade configuration.
112	02/04/2013	3.3.2.11 Added the supplemental FFC capability for the Tau 2.1.1 release
120	02/04/2013	Updated for Tau 2.2 release. Specific changes include: • 3.1.2.4: Added a note about BT.656 unavailability for Tau 2.2 • 3.2.1: Specified 8-bit CMOS resolution due to eZoom • 3.2.2: Added a note about frame rate for 8-bit CMOS output • 3.3.2.4: Added notes about eZoom in 8-bit CMOS • 3.3.2.7: Added information about Bayer encoding • 3.3.2.11: Updated supplemental FFC information for this release
130	05/20/2013	Updated for Tau 2.4 release. Specific changes include: • 1.2: Updated part number figure to include the advanced radiometry option "R" • 3.1.2.4: Added a note about colorization and eZoom being SW selectable in 8-bit digital output • 3.2.1: Specified 8-bit digital resolution due to Digital eZoom Mode • 3.2.2: Added a note about frame rate for 8-bit digital output with Digital eZoom Mode enabled • 3.3.2.2 Added note about low gain for all configurations • 3.3.2.4: Added notes about eZoom in 8-bit CMOS/LVDS • 3.3.2.7: Added information about Bayer encoding patterns • 3.3.1.5: Added Tau 2.1 to Tau 2.4 upgrade notes • 3.3.3.3: Added TLinear feature • 3.4.1 Adjusted Commercial temp range (max 65C) • 3.5.1 Added vacuum life statement • 3.5.2 Updated ROHS directive number and removed REACH/WEEE
131	10/22/2013	• 3.2.1 Added a note for BT.656 resolution clarification • 3.5.1 Updated reliability specifications • 3.3.3.3 Updated radiometric accuracy to include % also

1.2 Scope

Tau ™ is a family of miniature infrared imaging cores from FLIR Systems®, offered in various configurations. This product specification specifically applies to the Tau 2 configuration, available in multiple array sizes. Part numbering is as shown below.



While Tau 2 resembles the Tau 1.5 (324x256) and Tau 1.7 (640x512) configurations in size and shape, it is a different product providing more capabilities not possible with the older hardware platform. Furthermore it is intended to be field-upgradeable with feature improvements over time. Consequently this product specification will be updated to reflect the new features of each upgrade. These are summarized in Table 1.

Note: A number of expansion cards intended for specific applications are available for the Tau 2 core. In most cases, these expansion cards modify or augment the standard core functionality. This specification only applies to the standalone core.

Table 1: Tau 2 Release Summary

Release Version	Release Date	New Features
2.0	Oct. 2011	New features shown below are relative to Tau 1.X: • New baud rate options are provided (see 3.1.2.5) • 60Hz frame rate is available for array sizes 336x256 and smaller (see 3.2.1) • Splash screen display time is adjustable via command (see 3.3.1.1) • FW / SW upgrade is fault tolerant (see 3.3.1.4) • Revert applies to all digital output channels (see 3.3.2.3) • All configurations, regardless of number of pixels, provide 640x512 symbol resolution (see 3.3.2.8) • Isotherms provide three color ranges rather than two (see 3.3.3.1)
2.1	August 2012	New features shown below are relative to Tau 2.0: • Newly available resolutions (see 3.2.1) • New continuous electronic zoom feature (see 3.3.2.4) • Selectable symbol resolution (see 3.3.2.8) • New 8-bit snapshot / playback feature (see 3.3.2.9) • Advanced radiometric features (see 3.3.3.3) • New overtemp indicator (see 3.3.4.4)
2.2	February 2013	New features or changes shown below are relative to Tau 2.1: • E-zoom in 8-bit CMOS digital output (see 3.2.1, 3.2.2, and 3.3.2.4) • Bayer encoding for colorization in 8-bit CMOS digital output (see 3.3.2.7) • BT.656 output is disabled for Tau 2.2 only (see 3.1.2.4) • Supplemental FFC feature is available in Tau 2.1.1 and later (see 3.3.2.11)
2.4	May 2013	New features or changes shown below are relative to Tau 2.2. (Each of these items are shown in blue font for emphasis in the current revision of this document.): • E-zoom SW selectable in 8-bit CMOS/LVDS digital output (see 3.2.1, 3.2.2, and 3.3.2.4) • Bayer encoding for colorization SW selectable in 8-bit CMOS/LVDS digital output (see 3.3.2.7) • TLinear feature for advanced radiometric customers (see 3.3.3.3) • Low gain available for all configurations (see 3.3.2.2)

2 References

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

2.1 FLIR Website / Contact Information

In multiple locations throughout this document, FLIR's Tau website is referenced as a source of additional information. This website can be accessed via the following URL:

www.flir.com/cvs/cores/uncooled/products/tau/

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 Systems Documents

102-PS242-01	Tau 2 Quick-Start Guide
102-PS242-41	Tau 2 Electrical Interface Description Document (IDD)
102-PS242-43	Tau2.0/Quark Software IDD
Various	Mechanical Interface Description Drawing (varies by part number)

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

CMOS	Complementary Metal-Oxide-Semiconductor
DDE	Digital Detail Enhancement
EMC	Electromagnetic Compatibility
ESD	Electrostatic Damage
FFC	Flat Field Correction
FOV	Field of View
GUI	Graphical User Interface
I/O	Input / Output
ICD	Interface Control Drawing / Document
IDD	Interface Description Drawing / Document
IIR	Infinite Impulse Response
IP	Ingress Protection
LUT	Look-Up Table
LVDS	Low-Voltage Differential Signaling
MTBF	Mean Time Between Failure
NETD	Noise Equivalent Temperature Difference
NFOV	Narrow Field of View
NTSC	National Television System Committee
PAL	Phase Alternating Line
RoHS	Reduction of Hazardous Substances
ROI	Region of Interest
SDK	Software Developers' Kit
TBD	To Be Determined
URL	Uniform Resource Locator
NVFFC	Non-volatile FFC
WFOV	Wide Field of View

3 Requirements

3.1 Interface Requirements

3.1.1 Mechanical Interface

3.1.1.1 Size / Weight

There are three body types for the Tau 2 core denoted by the first two digits of the part number (see 1.2): standard, shutterless, and iris-style shutter. There are a large number of lens options for Tau 2, also denoted in the part number. Size and weight of the product varies by both body type and lens type. Because new lens types are being added to the product list on a regular basis, this product specification does not list size and weight requirements for all configurations. Instead these requirements are specified in separate Mechanical Interface Description Drawings (IDDs) unique to each configuration.

Note: Current lens offerings are shown on FLIR's Tau website under the Optics tab. IDD STEP files and PDF drawings are available for download from the Tau website under the Drawings / Models tab.

3.1.1.2 Mounting

The Tau 2 core provides precision mounting features on both sides and on the bottom surface. Additionally, the WFOV configuration of the core (lens focal length $\leq$ 19mm) can be bulkhead-mounted via a thread (M29X1.0-6h) on the lens barrel. See the relevant Mechanical IDD for more detailed information.

Note: Only a FLIR-specified plastic nut should be used for bulkhead mounting. The WFOV lens flange is made of Magnesium and the protective coatings can be damaged with the use of a metal nut.

3.1.2 Electrical Interface

Note: The paragraphs that follow describe high-level electrical-interface requirements. See the Tau 2 Electrical IDD for detailed requirements.

3.1.2.1 Connector

The primary electrical interface to the Tau 2 core is the same single high-density 50-pin connector used on Tau 1.X configurations, 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. The pin-out is backwards compatible with Tau 1.X configurations. (In other words, a Tau 2.X can be plugged into the same socket as a Tau 1.X core.) Some of the pin assignments are field-configurable as described in detail in the Tau 2 electrical IDD.

3.1.2.2 Input Power

The input-voltage range for the Tau 2 core is 4.0V – 6.0V (same as Tau 1.X configurations). The iris-shutter configurations (i.e., type 48) are an exception, requiring a minimum input voltage of 4.4V.

Nominal power dissipation is approximately equal to 1.0W at room temperature for 336 and lower resolutions and approximately 20% higher for the 640 configuration. See the Tau 2 Electrical IDD for detailed requirements regarding the power interface. Power consumption may be reduced by approximately 75 mW by disabling the analog video channel.

Note: Voltage range can be extended to 6.0V – 28.0V via the "Photon Replicator" expansion board.

3.1.2.3 Analog Channel

The Tau 2 core provides an analog channel that can be field-configured to any of the following options:

1. NTSC
2. PAL
3. NTSC, monochrome
4. PAL, monochrome
5. Disabled (saves approximately 75 mW)

See the Tau 2 Electrical IDD for detailed requirements regarding the analog channel.

Notes:

1. *To comply with the frame-rate requirements of the NTSC and PAL standards, "slow" (export-compliant) configurations duplicate each analog frame multiple times. For example, in PAL mode, the digital output frame rate of a slow configuration is nominally 8.33Hz whereas each analog frame is duplicated (total of 3 copies) to produce a 25Hz rate.*
2. *In the monochrome modes, color encoding is not used and video low-pass filtering is disabled, which results in slightly higher bandwidth data to the display system. This mode can be used to improve image sharpness when color palettes and color symbols are not required. The monochrome option applies only to analog output.*

3.1.2.4 Digital Channels

The Tau 2 core provides two simultaneous digital channels, one parallel and one serial. The parallel channel can be configured to one of the following options:

1. BT.656 (post-AGC with color palettes applied (see 3.3.2.7) and symbols overlaid (see 3.3.2.8)) *Note: Tau 2.2 does not include BT.656 output*
2. CMOS 8-bit (post-AGC) *Note: Color palettes and eZoom are run-time selectable options in Tau 2.4and later releases*
3. CMOS 14-bit (pre-AGC)
4. Disabled

Similarly, the serial channel can be configured to one of the following options:

1. LVDS 14-bit (pre-AGC)
2. LVDS 8-bit (post-AGC) *Note: Color palettes and eZoom are run-time selectable options in Tau 2.4and later releases*
3. Disabled

Note: All configurations of Tau 2 utilize a 4-pair LVDS interface (clock, sync, two data lines). In Tau 1.X, the 320 configuration utilized a 3-pair LVDS interface (clock, sync, single data line).

See the Tau 2 Electrical IDD for detailed requirements regarding each option. Note that it is possible to enable both the parallel and serial digital output as well as the analog channel simultaneously, though it is assumed that unused channels will be disabled for power savings.

3.1.2.5 Command / Control Interface

The Tau 2 core provides an RS-232 channel for command / control. Tau 1.5/1.7 provided an auto-baud-rate selection between 57.6k and 921.6k. Tau 2 supports this auto-baud mode and additionally provides the ability to set several other fixed baud rates as low as 9.6k. See the Tau 2 Electrical IDD for detailed requirements regarding the physical interface and the Tau 2 Software IDD for detailed requirements regarding the protocol and commands associated with the interface.

A graphical user interface (GUI) is provided to facilitate configuration of core settings. This GUI is available for download on FLIR's Tau website (see 2.1).

3.1.2.6 Discrete I/O

The Tau 2 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 imminent FFC). Depending upon the selected digital mode (see 3.1.2.4), 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. Table 2 lists potential signals that can be assigned to discrete I/O pins.

Table 2: Signals Available for Discrete I/O Pin Assignment

Function	Input or Output	Detail
White hot/black hot	Input	The voltage level of this pin controls the palette applied to the analog image (see 3.3.2.7). The pin has a pull-up so that the no-connection state is High (3.3V). When this pin is high (3.3V) the analog image will use the White Hot palette (palette 1 in the standard palette file). When this pin is low (0V) the analog image will use the Black Hot palette (palette 2 in the standard palette file). The camera will power up in the saved default state and switch to the discrete input defined state when the pin state is changed.
Do FFC	Input	The application of Positive going edge to this pin will perform the "Do FFC" function.
FFC imminent	Output	This pin is normally at 0V and changes to 3.3V when the FFC Imminent Icon is present on the analog display. The "FFC Warn Time" command controls both the analog icon and this output signal.
FFC Mode	Input	The voltage level of this pin controls the FFC mode. When the pin is high (also the non-connection state), the core operates in "automatic" FFC mode (see 3.3.2.1). When the signal is pulled low, the core will switch to "manual" mode. The camera will power up in the saved default state and switch to the discrete input defined state when the pin state is changed.
Palette Toggle	Input	This function will change the color palette from the current value to the next palette in the loaded LUT table when the discrete pin transitions from the no-connection state to the low state. No LUT change happens on the transition from low to no-connection. The LUT state after LUT14 will be LUT1.
Zoom (2X)	Input	The voltage level of this pin controls the applied zoom. When high (the no-connection state), 1X zoom is selected. When low, 2X zoom is selected.
Zoom toggle	Input	This function will change the current zoom state from 1X to 2X to 4X to 8X zoom (iff applicable) whenever the discrete pin changes from the float state to the ground state
Zoom Out	Input	This function increments the zoom width (see 3.3.2.4)
Zoom In	Input	This function decrements the zoom width

3.1.2.7 External Sync

The Tau 2 core provides an external sync channel that can be used to synchronize frame start between two Tau cores, one configured as master and the other configured as slave. It can also be used to synchronize the frame start of a Tau 2 core with that of another product. See the Tau 2 Electrical IDD for more detailed requirements regarding the interface. Each Tau can be configured into one of three external-sync modes:

- <u>Disabled</u>: In "disabled" external-sync mode, the core relies on internal timing, and the external-sync channel is used as neither input nor output.
- <u>Master</u>: In "master" mode, the core relies on internal timing to control its own frame start but also outputs a synchronization pulse on the external-sync channel.
- <u>Slave</u>: In "slave" mode, the core synchronizes its frame start to a pulse received on the external-sync channel.

Note: The external-sync feature is not recommended for "slow" configurations of Tau 2, and correct operation is not guaranteed. See the Tau 2 electrical ICD for more information.

3.2 Imaging Requirements

3.2.1 Output Resolution

Output resolution (i.e., number of pixels) varies by configuration as well as user-specified runtime settings, as shown in Table 3 and Table 4. The resolution of the configuration is encoded in the part number (see 1.2). For reference, Table 5 compares field of view of each configuration for a number of available lens options.

Table 3: Output Resolution by Configuration & Video Setting for Normal Mode

Configuration, Resolution	Video Setting (runtime selectable)	Output Resolution, analog and BT.656[1]	Output Resolution, LVDS & CMOS
640	NTSC	640x480	640x512
640	PAL	640x512	640x512
336	NTSC	320x240	336x256
336	PAL	320x256	336x256
324	NTSC	320x240	324x256
324	PAL	320x256	324x256
168	NTSC	160x120	168x128
168	PAL	160x128	168x128
162	NTSC	160x120	162x128
162	PAL	160x128	162x128
160	NTSC	160x120	160x120
160	PAL	160x128	160x128

Table 4: Output Resolution by Configuration & Video Setting for Digital eZoom Enabled Mode

(Tau 2.4 and later releases)

Configuration, Resolution	Video Setting (runtime selectable)	Output Resolution, analog and BT.656[1]	Output Resolution, 14-bit CMOS & LVDS	Output Resolution, 8-bit CMOS & LVDS
640	NTSC	640x480	640x512	640x512
640	PAL	640x512	640x512	640x512
336	NTSC	320x240	336x256	640x512
336	PAL	320x256	336x256	640x512
324	NTSC	320x240	324x256	640x512
324	PAL	320x256	324x256	640x512
168	NTSC	160x120	168x128	640x512
168	PAL	160x128	168x128	640x512
162	NTSC	160x120	162x128	640x512
162	PAL	160x128	162x128	640x512
160	NTSC	160x120	160x120	640x512
160	PAL	160x128	160x128	640x512

Note 1: BT.656 format requires 720 pixels per line; to meet this requirement the 640 and 320 resolution outputs are interpolated (not duplicated) up to 720 via a linear weighted average algorithm.

Table 5: Field of View by Configuration / Lens Focal Length

(values are approximate; see the mechanical IDD for each configuration)

Configuration, Resolution	005 5.0 mm (f/1.25)	007 7.5 mm (f/1.4)	009 9 mm (f/1.4)	013 13 mm (f1/.25)	019 19 mm (f/1.25)	025 25 mm (f/1.1)	W35 35 mm (f/1.5)	035 35 mm (f/1.2)	050 50 mm (f/1.2)	060 60 mm (f/1.25)	100 100 mm (f/1.6)
640 (17u)	n/a	90° x 69°	69° x 56°	45° x 37°	32° x 26°	25° x 20°	18° x 14°	18° x 14°	12° x 9.9°	10° x 8.3°	6.2° x 5.0°
336 (17u)	n/a	45° x 35°	35° x 27°	25° x 19°	17° x 13°	13° x 10°	9.3° x 7.1°	9.3° x 7.1°	6.5° x 5.0°	5.5° x 4.2°	3.3° x 2.5°
324 (25u)	n/a	63° x 50°	48° x 37°	34° x 26°	24° x 18°	18° x 14°	13° x 10°	13° x 10°	9.1° x 6.9°	7.6° x 5.7°	4.6° x 3.4°
168 (34u*)	n/a	45° x 35°	35° x 27°	25° x 19°	17° x 13°	13° x 10°	9.3° x 7.1°	9.3° x 7.1°	6.5° x 5.0°	5.5° x 4.2°	3.3° x 2.5°
162 (50u*)	n/a	63° x 50°	48° x 37°	34° x 26°	24° x 18°	18° x 14°	13° x 10°	13° x 10°	9.1° x 6.9°	7.6° x 5.7°	4.6° x 3.4°
160 (25u)	43° x 35°	30° x 24°	25° x 20°	17° x 14°	12° x 9.6°	9.1° x 7.3°	6.5° x 5.2°	6.5° x 5.2°	4.6° x 3.7°	3.8° x 3.1°	2.3° x 1.8°

* not actual FPA pixel pitch but rather effective pixel pitch obtained by interpolation

Note: The W35 fits inside the WFOV lens flange whereas the 035 lens utilizes the NFOV lens flange.

3.2.2 Frame Rate

Table 6 shows digital frame rate as a function of configuration as well as two user-specified runtime settings: video setting and averager mode. In averager-enabled mode, the Tau 2 core performs automatic "smart" averaging of pairs of frames from the detector array.

Note1: The averager operation is designed to reduce blur by only averaging a given pixel's output if the difference from one frame to the next is small enough to be considered noise. The 640 configuration does not provide an averager option (because the native sensor output is 30Hz).

Note2: For Tau 2.4 and later releases, the optional "Digital eZoom Mode" affects the frame rate for 8-bit CMOS and LVDS digital output when enabled – the frame rate will be 25Hz or 29.97Hz depending on the video setting, but regardless of the averager and video speed. For slow configurations, the 8-bit CMOS and LVDS output is also 25Hz or 29.97Hz, but frames are replicated to give a true data update of only 7.49Hz or 8.33Hz.

Table 6: Frame Rate by Configuration & Video Setting for Tau 2 in Normal Mode

Configuration, Video Speed	Configuration, Resolution	Video Setting	Averager Mode	Frame Rate (Hz)	Frame Rate (Hz) 8-bit Digital eZoom Enabled Mode
Fast	all except 640	NTSC	Disabled	59.94 Hz	29.97 Hz
Fast	all except 640	PAL	Disabled	50.00 Hz	25.00 Hz
Fast	all except 640	NTSC	Enabled	29.97 Hz	29.97 Hz
Fast	all except 640	PAL	Enabled	25.00 Hz	25.00 Hz
Fast	640	NTSC	not applicable	29.97 Hz	29.97 Hz
Fast	640	PAL	not applicable	25.00 Hz	25.00 Hz
Slow	all except 640	NTSC	Disabled	8.56 Hz	29.97 Hz
Slow	all except 640	PAL	Disabled	8.33 Hz	25.00 Hz
Slow	all except 640	NTSC	Enabled	7.49 Hz	29.97 Hz
Slow	all except 640	PAL	Enabled	8.33 Hz	25.00 Hz
Slow	640	NTSC	not applicable	7.49 Hz	29.97 Hz
Slow	640	PAL	not applicable	8.33 Hz	25.00 Hz

3.2.3 Optical Performance

Because new lens types are being added to the product list on a regular basis, this product specification does not list optical requirements for all configurations. Instead the FOV for each configuration are specified in separate Mechanical IDDs unique to each configuration. See Table 5 for approximate FOVs for a number of available configurations.

Note: Current lens offerings are shown on FLIR's Tau website under the Optics tab.

3.2.4 Sensitivity

See Appendix A. (This appendix contains proprietary performance specifications and is available to parties having a Non-Disclosure Agreement (NDA) on file with FLIR Systems. Please contact FLIR Systems to obtain this appendix.)

3.2.5 Intrascene Range

See Appendix A.

3.2.6 Operability

See Appendix A.

3.3 Functional Requirements

3.3.1 Start-Up Features

3.3.1.1 Splash Screen

At start-up, the Tau 2 core presents a splash screen (or optionally 2 splash screens, displayed one after the other) in the analog and BT.656 channel *(Note: Tau 2.2 does not include the BT.656 channel).* The default splash screen is the FLIR Splash screen. It is possible to customize the splash screen in the field. (See FLIR's Tau website for an Application note describing this capability.) The timing of each splash screen (i.e., how long each is displayed) can also be adjusted via serial command.

3.3.1.2 Readiness Time

Elapsed time from application of power to output of IR video is approximately 2 to 3 sec for the 324 / 336 configurations and approximately 4 to 5 sec for the 640 configurations. (This requirement only applies if splash-screen display time is set to "minimum".)

3.3.1.3 Power-On Defaults

The Tau 2 core presents capability to specify default setting to be applied at start-up. Additionally, it is possible to reset the core to factory-specified defaults. See the Tau 2 / Quark Software IDD for a list of applicable settings and factory default values.

3.3.1.4 Fault-Tolerant Upgradeability

The Tau 2 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.

Note: The Tau 2 core reserves a portion of non-volatile memory referred to as the "upgrade" block. FLIR recommends writing only to the upgrade block and not to the "factory" block when upgrading firmware. Fault-tolerant upgrade is not ensured when writing the factory block. When the upgrade block is written, boot-up time increases by approximately 300 msec.

3.3.1.5 Backward Compatibility

All future releases of Tau 2 firmware / software will be backwards compatible with all fielded versions of Tau 2. 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.

Note 1: Tau 2 hardware is different than Tau 1.X and the firmware / software. Attempting to upgrade a Tau 1.X core with Tau 2 code releases will result in part failure.

Note 2: Not all feature improvements planned for later releases will necessarily work when a fielded Tau 2 core is upgraded because some may require factory calibration to function properly. However, in those cases, the new feature will simply not function rather than causing the upgraded core to behave erroneously.

Note 3: For Tau 2.0 cores that are upgraded to 2.1 or later:

- *If radiometric features (e.g., spotmeter and/or isotherms) were active prior to upgrade, they will continue to function after upgrade as they did previously. See 3.3.3.*
- *As described in 3.3.2.4, the coordinates for AGC ROI are no longer specified in pixels but rather as a percentage of the zoom window size. This change precludes the user from having to change the ROI as the zoom window size is varied. As a result of this change, there is no need for separate zoom ROI (for 2X, 4X, and 8X zoom), and the coordinates for these are ignored in Tau 2.1. A Tau 2.0 core that is field-upgraded to Tau 2.1 will default to having the AGC ROI subtend 100% of the displayed image.*

Note 4: For Tau 2.1 cores that are upgraded to Tau 2.4 or later:

- *The TLinear feature will only be available if the Tau 2.1 camera had advanced radiometry features enabled when originally received (see 3.3.3).*
- *The low gain feature will not be made available with a field upgrade alone. Factory calibration must be performed to allow the low gain capability for configurations other than the 324 (see 3.3.2.2).*

3.3.2 Image Processing Features

3.3.2.1 FFC

Flat field correction (FFC) is a process whereby offset terms are updated to improve image quality. Output data is frozen throughout the FFC event (nominally 0.4 sec), and a warning symbol consisting of a square in the upper-right corner is displayed before/during FFC. (The time prior to the FFC event that the warning symbol is displayed is user-selectable.)

All configurations of the Tau 2 core provide three user-selectable FFC modes:

- Automatic: FFC is performed automatically at start-up and periodically thereafter as triggered by elapsed time or temperature change or both. (Both parameters may be modified by the user.) FFC is also performed upon command. For cores with an internal shutter, the shutter is automatically moved in and out of the FOV when FFC takes place. Automatic mode is not recommended for shutterless configurations because there is no assurance that the core will be imaging a uniform source when it initiates an automatic FFC.

- Manual: FFC is performed automatically at start-up and only upon command thereafter. For those configurations that include an internal shutter, the shutter is automatically moved in and out of the FOV when FFC takes place. This mode is recommended when it is desirable that an FFC event not take place at any arbitrary time (for example, when tracking a target). Repeated FFC events are necessary to correct for temperature drift in the camera. For this reason, it may be necessary to command FFC more frequently during startup or when the camera temperature changes quickly.
- External: FFC is performed only upon command. The shutter control signals are not exercised even if the core includes an internal shutter. That is, offset terms are generated based upon whatever the core is imaging at the time FFC is commanded. (It is recommended to subtend the entire FOV with a uniform scene prior to commanding external FFC.) For configurations that contain no internal shutter, external FFC mode is the preferred mode.

After any FFC event, it is possible to store the currently-applied map to non-volatile memory via command, in which case that map will be applied automatically at the next power-up. This feature is particularly useful for shutterless configurations. If a non-volatile FFC (NVFFC) map has been saved, the behavior of the automatic and manual FFC modes differs slightly from that described above:

- Automatic: FFC is *not* automatically performed at start-up. Instead the stored NVFFC map is applied for the first 5 seconds after power-up, after which time an automatic FFC event takes place.
- Manual mode: FFC is *not* automatically performed at start-up. Instead the stored NVFFC map is applied until another FFC operation is commanded.
- External: No change to the behavior of external FFC mode described above. (That is, FFC is only performed upon command regardless of whether or not NVFFC is stored.)

When operating in high-gain state (see 3.3.2.2), the Tau 2 core requires a “long” FFC operation whenever if heats or cools through approximately 0C, 40C or 65C. For example, long FFC is required if the core is powered on at -10C and then is heated to +10C. The long FFC operation takes approximately 0.1 sec longer than the normal “short” FFC operation and allows the core to automatically load calibration terms that are appropriate for the current operating temperature range. When operating in automatic FFC mode, long FFC operations take place automatically. When operating in external FFC mode, calibration terms are loaded automatically without requiring an FFC. (Image quality may appear slightly worse until FFC is commanded.) When operating in manual FFC mode, the core awaits a long FFC command before loading new calibration terms. (A status flag readable via serial command indicates when the core is awaiting a long FFC command. See the Tau 2 software IDD for more information.)

3.3.2.2 Gain State

Note: In the Tau 2.0, Tau 2.1, and Tau 2.2 release, only the 324 configurations provide low-gain state. In the Tau 2.4 and later releases, all configurations provide the low-gain state; this feature is not field-upgradeable.

The Tau 2 core provides a high-gain state (lower NEDT, lower intrascene range), and some configurations also provide a low-gain state (higher NEDT, higher intrascene range). There are three gain-selection modes (of which only the first is applicable for those configurations without the low-gain state):

- High: Core operates in high-gain state only
- Low: Core operates in low-gain state only
- Automatic: Core automatically selects between high and low-gain state based on scene conditions and the following user-selectable parameters:
  - High-to-low temperature / high-to-low population: The core transitions to low gain when a sufficient percentage of the pixel population is imaging sufficiently hot scene temperature
  - Low-to-high temperature / low-to-high population: The core transitions to high gain when a sufficient percentage of the pixel population is imaging sufficiently cold scene temperature

Note: When operating in manual FFC mode (see 3.3.2.1), automatic gain-state switching logic is suspended until long FFC is commanded.

3.3.2.3 Image Orientation

The Tau 2 core provides four image-orientation modes, described below and illustrated in Figure 1:

- 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 or when used in a rear-facing application intended to simulate the view through a rear-view mirror.

Unlike Tau 1.X, both invert and revert settings apply to all channels in Tau 2. (For Tau 1.X, revert only applied to analog and BT.656 output and not to CMOS or LVDS.)

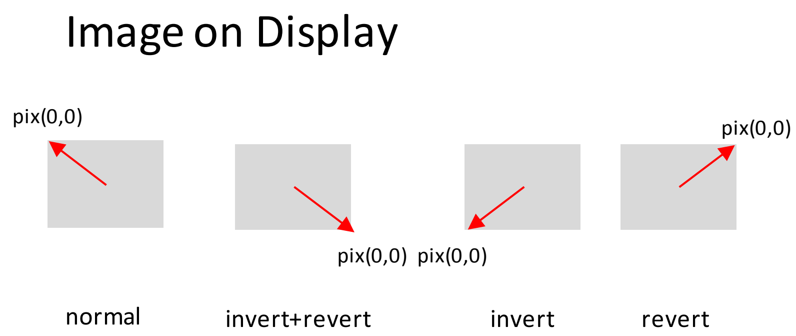


Figure 1: Illustration of Image-Orientation Modes

3.3.2.4 Zoom

The Tau 2 core provides an optional zoom capability. For Tau 2.0 and Tau 2.1, the zoom algorithm applies to the analog and BT.656 output data (not to the CMOS or LVDS output data). For Tau 2.4, the zoom algorithm is also user selectable for application to the 8-bit CMOS and LVDS output data (excludes application to the14-bit CMOS and LVDS data).

For the Tau 2.0 release, zoom is in discrete steps of 2X, or 4X, (or 8X for the 640 config. only). A zoom symbol indicating the zoom factor is displayed (in the analog and BT.656 channels) when in the zoom mode. Note that for Tau 2.0, zoom is always relative to the center of the field of view.

The Tau 2.1 release and later Tau 2 releases provide improved zoom capability as follows:

- Zoom factor is continuously variable. The user specifies the width of the zoom window, ranging from a minimum value of 80 pixels to a maximum value equal to the maximum horizontal dimension shown in the "Analog Video" column of Table 3. For example, for the 640 configuration, it is possible to specify a zoom width of 240, meaning that a 240x192 portion of the array will be stretched to the 640x512 analog video output size in PAL mode (or a 240x180 portion in NTSC mode). This represents a 2.67X zoom.

  Note: Continuous zoom is specified via a new software command, EZOOM_CONTROL. However, the Tau 2.0 command VIDEO_MODE for selecting discrete zoom states (2X, 4X, and 8X) remains valid in Tau 2.1 and later releases. The on-screen zoom symbol is only displayed when zoom is selected via VIDEO_MODE. See the software IDD for more detail.

- 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. Figure 8c illustrates a case in which the zoom window is not centered with the field of view. (In the figure, the full array dimension is illustrated as the cross-hatched rectangle and the zoom window by the thick black outline. The ROI is illustrated by the blue dashed outline.)
- 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. Figure 8 illustrates ROI for the following coordinates:
  - Left: -40%
  - Top: 0%
  - Right: +40%
  - Bottom: +50%

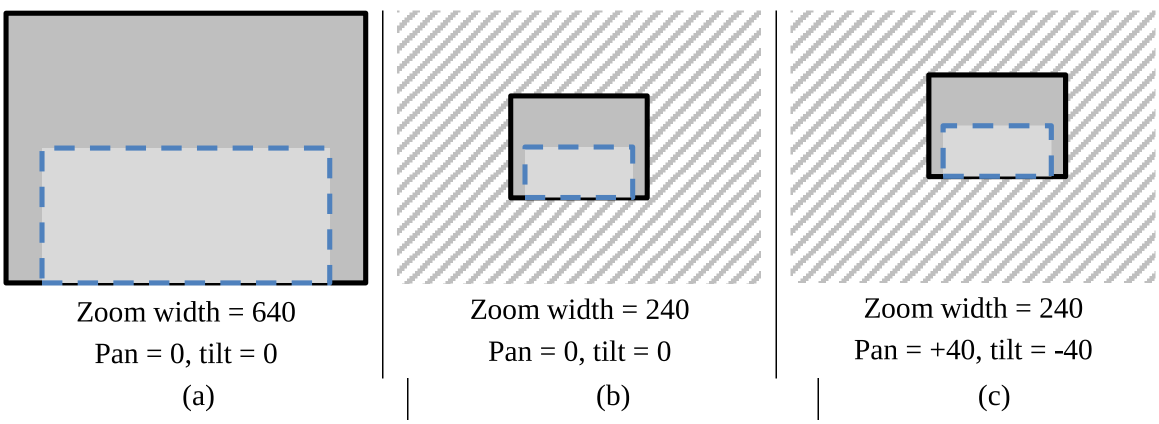


Figure 2: Illustration of ROI for Tau 2.1 and 2.2.

(Dark gray rectangle illustrates the displayed image (i.e., the zoom window) within the total FOV. The light gray rectangle with dash outline illustrates the ROI.)

3.3.2.5 Digital Data Enhancement (DDE)

The Tau 2 core provides an optional “digital-data-enhancement” (DDE) algorithm which can be used to enhance image details and/or suppress fixed pattern noise. Two modes are available, “manual” and “dynamic”. The descriptions of each mode are as follows:

- <u>Dynamic mode</u>: DDE parameters are computed automatically based on scene contents. DDE index (which supplants the spatial-threshold parameter used in the manual algorithm) is the only controlling parameter and ranges from 0 to 63, with higher values representing higher degrees of detail enhancement. If no enhancement is desired, the value should be set to 17. Values less than 17 soften the image and filter fixed pattern noise, as exemplified in Figure 3. Values greater than 17 sharpen the details in the image, as shown in Figure 4.

(a) DDE index = **17**

(b) DDE index = **8**

Figure 3: Illustration of Noise Suppression with DDE

(Notice fixed pattern noise is reduced in the image on the right.)

(a) DDE index = **17**

(b) DDE index = **24**

Figure 4: Illustration of Detail Enhancement with DDE

(Notice details such as the links in the fence are sharper in the image on the right.)

Note: The recommended DDE mode is "dynamic". "Manual" is provided for customers of previous FLIR cores that have familiarly with the manual DDE mode.

- Manual mode: The following three parameters are user-specified:
  - DDE Gain: ranges from 0 to 255 and represents the magnitude of high-frequency boost (scaled by 16)
    - For gain = 0, DDE is disabled
    - For gain > 0, details are enhanced by gain/16. In other words, a value of 1 represents a 1/16 attenuation of details whereas a value of 64 represents a 4X enhancement of details.
  - DDE threshold: ranges from 0 to 255 and represents the maximum detail magnitude that is boosted. Details with magnitude exceeding the threshold are not enhanced. Values greater than 255 will place the camera in Dynamic DDE mode with a DDE index of x-255. In this case, DDE Gain and DDE spatial threshold are adjusted dynamically.
  - DDE spatial threshold: ranges from 0 to 15, and represents the threshold of the pre-filter (smoothing filter) applied to the signal prior to high-frequency boost. The pre-filter prevents low-magnitude fixed-pattern noise from being amplified. Note that the DDE spatial threshold also represents the DDE index when in automatic DDE mode.

3.3.2.6 Automatic Gain Correction (AGC)

The Tau 2 core provides multiple AGC algorithms used to transform 14-bit data to 8-bit. These options include the following, with associated parameters shown below each algorithm:

- Plateau equalization (see 3.3.2.6.1)
  - Plateau value
  - Maximum gain
  - ITT midpoint
  - Region of Interest (ROI)
  - IIR filter
- Linear histogram (see 3.3.2.6.2)
  - ITT midpoint
  - ROI
  - IIR filter
- Manual (see 3.3.2.6.3)
  - Brightness
  - Contrast
  - IIR filter
- Auto-bright (see 3.3.2.6.4)
  - Brightness
  - Contrast
  - IIR filter
- Once-bright (see 3.3.2.6.5)
  - Brightness bias
  - Contrast
  - IIR filter

Note: FLIR highly recommends that each customer optimize AGC settings for each particular application. "Preferred" AGC settings are highly subjective and vary considerably depending upon scene content and user preferences. Generally speaking, FLIR recommends the plateau equalization algorithm, but there are scenarios where each of the other algorithms may be better suited.

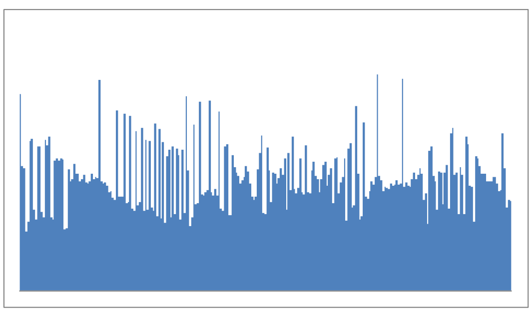
3.3.2.6.1 Plateau Equalization

The plateau equalization algorithm performs a non-linear transformation from 14-bit to 8-bit based on image histogram. It is a variant 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 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 equalization limits the maximum number of grayshades devoted to any particular portion of the scene by clipping the histogram (via the plateau value) and limiting the maximum slope of the mapping function (via the maximum gain value). It also provides an ITT midpoint value that allows mean brightness of the8-bit image to be specified. The description below provides explanation of each of these three parameters.

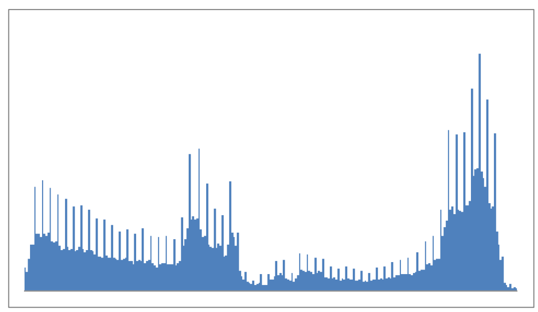
Plateau value. When plateau value is set high, the algorithm approaches the behavior of classic histogram equalization – grayshades are distributed proportionally to the cumulative histogram, and more grayshades will be devoted to large areas of similar temperature in a given scene. On the other hand, when plateau value is set low, the algorithm behaves more like a linear AGC algorithm – there is little "compression" in the resulting 8-bit histogram. Figure 5 illustrates both of the cases.

(a) Plateau Value = **1000**

(b) Plateau Value = **10**



(c) 8bit Histogram for Plateau Value = **1000**



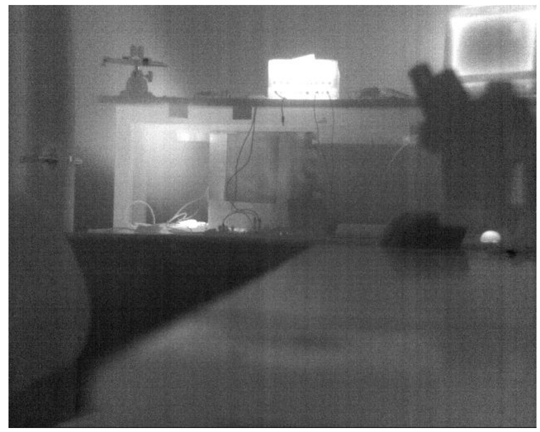
(d) 8-bit Histogram for Plateau Value = **10**

Figure 5: Illustration of Plateau Value

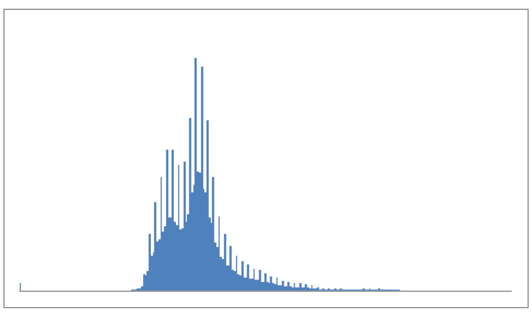
(Notice details in the sidewalk in the left image whereas more grayshades are available for the pedestrians in the right image.)

Maximum Gain. 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. Figure 6 provides an example.

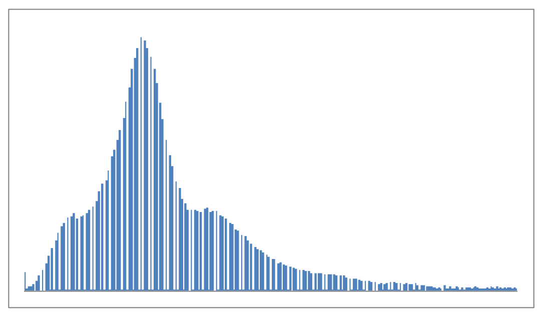
(a) Maximum Gain = **6**



(b) Maximum Gain = **24**



(c) 8bit Histogram for Max. Gain = **6**

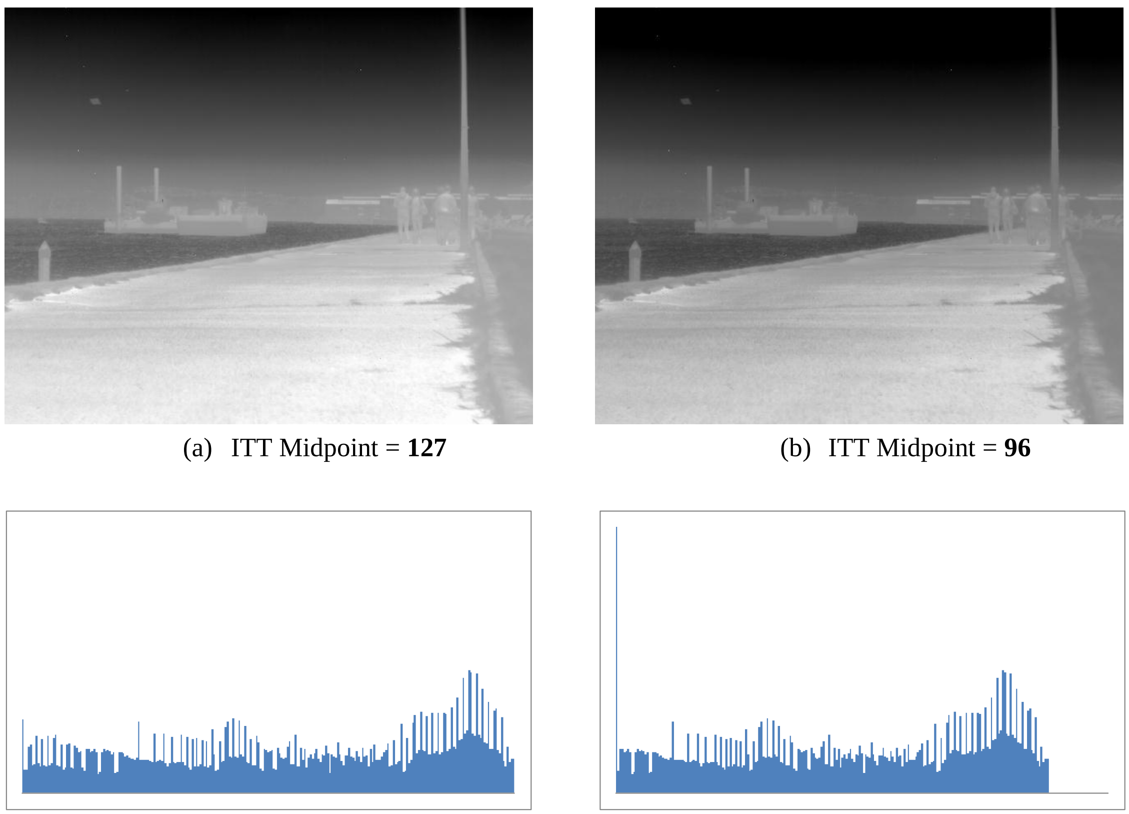


(d) 8bit Histogram for Max. Gain = **24**

Figure 6: Illustration of Maximum Gain in a Bland Image

(Notice more details but also greater fixed-pattern noise in the right image.)

<u>ITT Midpoint</u>. The ITT Midpoint can be used to shift the 8-bit histogram darker or brighter. The nominal value is 128. A lower value causes a darker image, as shown in Figure 7. A darker image can help improve the perceived contrast, but it is important to note that more of the displayed image may be railed (8bit value = 0 or 255) by moving the midpoint away from 128. This can be seen in the histogram of Figure 7d.



(a) ITT Midpoint = **127**

(b) ITT Midpoint = **96**

(c) 8bit Histogram for ITT Midpoint = **127**

(d) 8bit Histogram for ITT Midpoint = **96**

Figure 7: Illustration of ITT Midpoint

(Notice image on the right is darker. Notice in the histogram on the right that far more pixels have a value of 0 and that no pixels have a value between 224 and 255.)

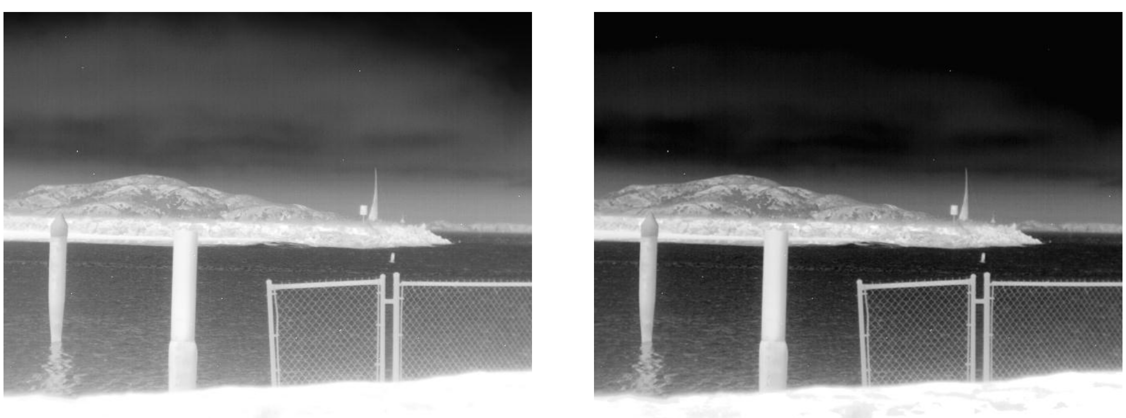
Region of Interest (ROI). In some situations, it is desirable to have the AGC algorithm ignore a portion of the scene when collecting the histogram. For example, if the Tau 2 core is rigidly mounted such that the sky will always appear in the upper portion of the image, it may be desirable to leave that portion of the scene out of the histogram so that the AGC can better optimize the display of the remainder of the image. This is illustrated in Figure 8. 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.)

For Tau 2.0, separate ROI are automatically applied for un-zoom, 2X, 4X, and 8X zoom. Coordinates for the ROI are as follows:

- Top / Bottom: 0 = center of the display, negative values are above center, positive values are below center, units are in pixels
- Left / Right: 0 = center of display, negative values are left of center, positive values are right of center, units are in pixels

For Tau 2.1 and later, a single ROI is specified regardless of zoom (see 3.3.2.4). Coordinates for the ROI are as follows:

- Top / Bottom: 0 = center of the window, negative values are above center, positive values are below center, units are percentage of zoom window size (-512 = -50%, +512 = + 50%).
- Left / Right: 0 = center of display, negative values are left of center, positive values are right of center, units are percentage of zoom window size (-512 = -50%, +512 = + 50%).



(a) ROI = Full Image (b) Sky excluded from ROI

Figure 8: Illustration of ROI

(Notice the image on the right has more contrast in the portion of the image below the sky.)

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

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

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 IIR filter value is set to a low value, then if a hot object enters the field of view, the AGC will adjust more slowly to the hot object, resulting in a more gradual transition. In some applications, this can be more pleasing than a sudden change to background brightness.

3.3.2.6.2 Linear Histogram

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

$$8bit_i = m * 14bit_i + b$$

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

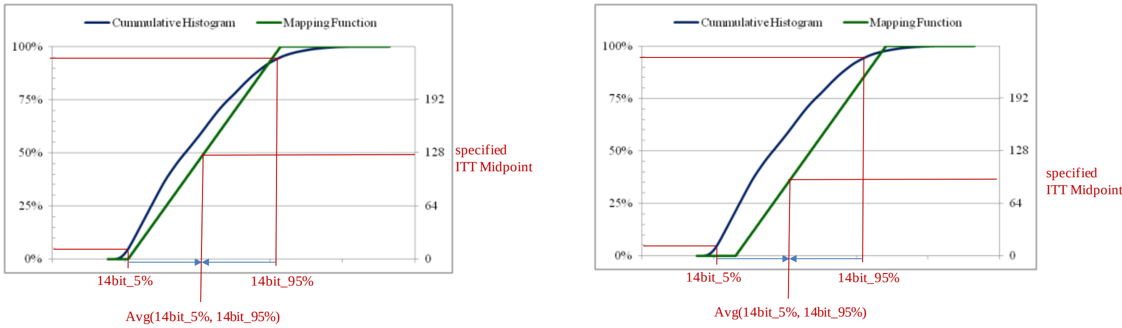
$$m = 255 / (14bit\_95\% - 14bit\_5\%),$$

where 14bit_5% is the 14-bit value corresponding to the 5% point on the cumulative ROI histogram and 14bit_95% is the value corresponding to the 95% point.

The offset is then computed as

$$b = \text{ITT midpoint} - \text{avg}(14bit\_5\%, 14bit\_5\%) * m$$

In other words, the algorithm attempts to map the midway point between the 5% and 95% points on the cumulative histogram to the specified ITT midpoint, as shown in Figure 9. The 8-bit values resulting from the above equations are clipped to a minimum value of 0 and a maximum value of 255.



(b) ITT Midpoint = **128**

(b) ITT Midpoint = **96**

Figure 9: Illustration of the Linear-Histogram Mapping Function

3.3.2.6.3 Manual

The "manual" algorithm performs a linear transformation from 14-bit to 8-bit, with slope based solely on a specified contrast value and offset based solely on a specified brightness value as shown below:

m = specified contrast / 64

b = 127 – (brightness)*m.

3.3.2.6.4 Auto Bright

The auto-bright algorithm is identical to the "manual" algorithm except that brightness value is automatically and dynamically updated to equal array mean. In other words, the array mean is automatically mapped to an 8-bit value of 127.

3.3.2.6.5 Once Bright

The "once bright" algorithm is identical to the "auto-bright" algorithm except that the offset of the linear transformation, b, is computed only at the time the algorithm is selected and is not dynamically updated. It is computed as

b = 127 – (frame mean – brightness bias)*m,

where brightness bias is a user-specified parameter.

3.3.2.7 Palette

The Tau 2 core provides up to 15 user-selectable palettes (also referred to as look-up tables or LUTs). For the Tau 2.0 and 2.1 releases, the palette selection applies to the analog and BT.656 output data. For the Tau 2.4 release, the palette selection applies to the analog and BT.656 output data and in addition, is user selectable in the 8-bit CMOS and LVDS digital output data. With the digital colorization mode enabled, the 8-bit digital data is colorized via Bayer encoding. Bayer encoding allows colors to be produced with 8-bit resolution, instead of the traditional 24-bit (RGB) representation. 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 10 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 Figure 10 is an example of the 'GB' option.

Green	Blue
Red	Green

Figure 10: Illustration of Bayer pattern

3.3.2.8 Symbol Overlay

The Tau 2 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. For Tau 2.0, symbol resolution was 640x512 for all configurations. For Tau 2.1 and later releases, symbol resolution is the same as the splash-screen size, either 640x512 or 320x256. (The primary advantage of lower resolution symbols is the ability to generate larger fonts – see FLIR's Tau website for an Application note showing example fonts for both resolutions.) Each symbol may be displayed in 1 of 256 colors / translucency shades. The symbol overlay capability, including built-in icons such as the FFC warning indicator (3.3.2.1), zoom symbol (see 3.3.2.4), and spot-meter graphics (see 3.3.3.2), apply to the analog and BT.656 output data. The LVDS and CMOS channels do not include symbol overlay data. Latency between transmitting a symbol-draw command and the actual update on the BT.656/analog output channels in approximately 0.5 sec.

3.3.2.9 Snapshot

The Tau 2 core provides snapshot capability in which 14-bit frames of data can be stored in non-volatile memory and downloaded via the serial-com. interface. The available capacity is reported upon command, and also all stored snapshots can be erased upon command.

The Tau 2.1 core provides additional capability to store 8-bit frames of data with playback capability. Note that snapshots do not include symbol overlay. (See FLIR's Tau website for an Application note describing this capability.)

3.3.2.10 Gain Calibration

The Tau 2 core provides capability to field-calibrate gain terms and defective pixels (in case, for example, the lens is replaced or significantly refocused). Terms for up to 2 lenses can be stored / selected.

Note: Use of the gain-calibration feature requires the advanced tab in the Tau 2 GUI. This capability is not typically required unless the lens is changed after delivery from FLIR. This capability is only available for certain configurations (e.g. Tau 160, Tau 324, Tau 336, and Tau 640).

3.3.2.11 Supplemental FFC

The supplemental FFC feature is only supported in the Tau 2.1.1 release and later. A supplemental FFC field-calibration may be applied to compensate for the non-uniformities introduced by out-of-field radiation. Terms for up to 2 lenses can be stored / selected.

Note: Use of the supplemental offset feature requires the advanced tab in the Tau 2 GUI. This capability is not typically required unless the lens is changed after delivery from FLIR to a large lens that does not have desirable thermal contact with the camera core. This capability is only available for certain configurations (e.g. Tau 160, Tau 324, Tau 336, and Tau 640).

3.3.3 Radiometric Features

Note: In the Tau 2.0 release, only the 324 configurations provided the radiometric features defined in the following sub-paragraphs. In the Tau 2.1 release and later releases, all configurations provide this capability.

3.3.3.1 Isotherm

The Tau 2 core performance configuration provides an "isotherm" feature in which portions of the scene exceeding a user-selectable threshold are mapped to different portions of the palette. The isotherm feature is most useful for palettes in which the bottom half is composed of grayshades and the upper half is composed of color shades (for example, yellow to orange to red). Three user-specified thresholds are applicable to the isotherm mode. The first is the upper threshold (specified either in degrees Celsius or in percentage of full-scale) above which pixels will be mapped to the top shades of the palette (224 to 255). The second is the middle threshold; pixels with value between the middle and upper threshold are mapped to shades 176 to 223. The third is the lower threshold; pixels with value between the lower and middle threshold are mapped to shades 128 to 175.

3.3.3.2 Spot Meter

The Tau 2 core performance configuration provides temperature-measurement capability via a spot meter in the central 4x4 area. Accuracy of the spot meter is ±20 C° in high-gain state (see 3.3.2.2) and the greater of ±20% or ±20C in low-gain state. (Typical performance is on the order of ±10 C° in high-gain state.)

The spot meter value is readable via command. Additionally, two user-selectable options for on-screen display of spot-meter data are provided: a numeric value and/or a thermometer-style gauge. The numeric indicator and gauge can be shown in degrees Celsius or Fahrenheit.

3.3.3.3 Advanced Radiometry and TLinear

For high-volume OEM customers, the Tau 2 core provides the option of the following advanced radiometric features:

- Improved accuracy: typical performance on the order of ±5 C° or 5% in high-gain state (varies slightly across the full operating temperature range)
- Moveable / resizable spot-meter: coordinates user-selectable to any arbitrary location on the array
- Additional spot-meter data: spot-meter reports average, standard deviation, minimum, and maximum value
- TLinear: digital data linear in scene temperature, i.e. in real-time operation, the pixel values in the 14-bit digital data correspond to the temperature of the scene.

In normal mode with TLinear disabled, the Tau camera outputs digital data linear in radiometric flux. In TLinear mode, the Tau camera outputs digital data linear in scene temperature. The TLinear feature applies to the 14-bit CMOS and LVDS channels and is user selectable. Two resolution modes are available and user selectable: high resolution (0.04 Kelvin/count) and low resolution (0.4 Kelvin/count).

3.3.4 Diagnostic / Status Features

3.3.4.1 Scratch Pad

The Tau 2 core provides capability to store arbitrary data (up to 128 kbytes) to non-volatile memory upon command. (It is envisioned that this scratch pad can be used to log operational data in the field.)

3.3.4.2 Test Patterns

The Tau 2 core provides capability to display various test patterns. These are intended primarily to adjust display properties and/or for diagnostic purposes (for example, to verify the core is providing a valid output).

3.3.4.3 Temperature Measurement

The Tau 2 core provides capability to report internal core temperature. Accuracy of the measurement is $\pm 5C^{o}$.

3.3.4.4 Overtemp Indicator

The Tau 2 core provides capability to signal when the operating temperature is higher than the specified range of the core. The overtemp status is available via serial command. For some configurations, is also possible for the core to display an overtemp indicator when operating outside the specified temperature range.

3.4 Environmental Requirements

3.4.1 Operating Temperature

The Tau 2 core meets all requirements of this specification when operated in conditions in which the core frame is within the range shown below. Commercial Grade cameras are available 640, 336 and 168 configurations.

Configuration, Tau Type	Operating Temperature Range
Commercial Grade	-20°C to +65°C
Performance Grade	-40°C to +80°C
Industrial Grade	-40°C to +80°C

3.4.2 Storage Temperature

The Tau 2 core meets all requirements of this specification and exhibits no damage or permanent degradation after storage within the range -50°C to +85°C.

3.4.3 Relative Humidity

The Tau 2 core meets all requirements of this specification and exhibits no damage or permanent degradation when operated in non-condensing humidity in the range 5% to 95%.

3.4.4 Thermal Shock

The Tau 2 core meets all requirements of this specification and exhibits no damage or permanent degradation after extreme thermal shock from one extreme of the operating temperature range to the other. *Note: During extreme thermal shock, image quality may be temporarily compromised.*

3.4.5 Mechanical Shock

The Tau 2 core meets all requirements of this specification and exhibits no damage or permanent degradation after exposure to shock pulses along any axis with magnitude / duration as follows:

- 250 g (1.5msec half-sine)
- 500g (0.8msec half-sine)

Note: Movement of the iris-style shutter into the field of view may occur during exposure to harsh shock or vibration. FLIR recommends the shutterless or flag-style shutter for applications that may result in significant shock events.

3.4.6 Vibration

The Tau 2 core meets all requirements of this specification and exhibits no damage or permanent degradation after exposure to random vibration along any axis up to 4.3 grms per the profile specified in Table 7 (also shown graphically in Figure 10).

Table 7: Random Vibration Profile

Frequency (Hz)	Acceleration density (G^2/Hz)
10	0.040
20	0.100
100	0.100
800	0.002
1000	0.002

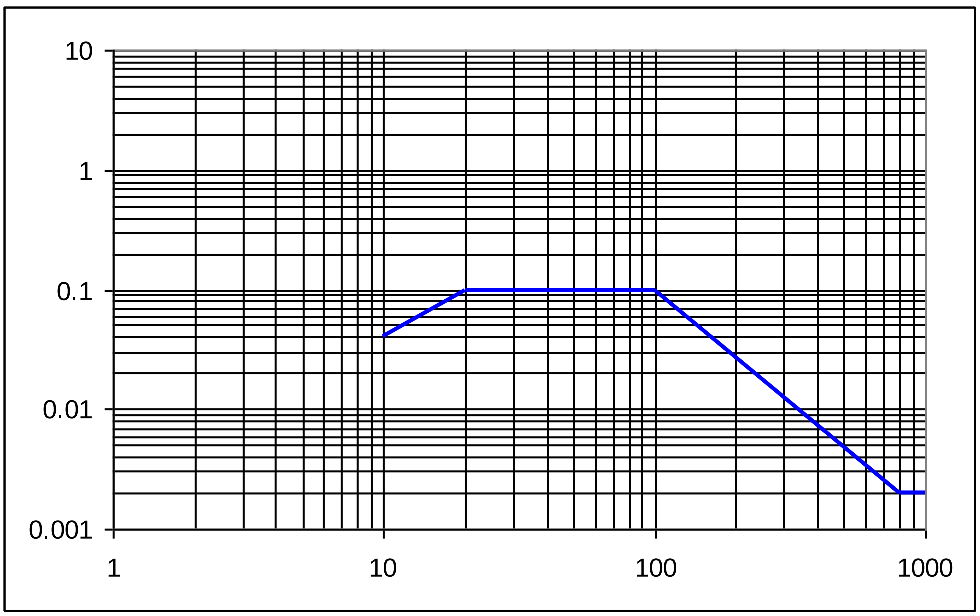


Figure 11: Random Vibration Profile

3.4.7 Altitude

The Tau 2 core meets all requirements of this specification and exhibits no damage or permanent degradation after exposure to pressure equivalent to 12 km above sea level.

Note: The Blowing Sand (3.4.8), IP Rating (3.4.9), and Salt-Fog / Salt Spray (3.4.10) requirements that follow each assume the front face of the Tau 2 core is mounted to a bulkhead via the bulkhead-mounting feature or via an o-ring seal to the lens barrel. None of these requirements apply to the portion of the core behind the bulkhead-mounted seal. Exposure of the rearward portion of the core to these environmental conditions will cause permanent damage.

3.4.8 Blowing Sand

After sealing the front face of the Tau 2 core to a bulkhead via the bulkhead-mounting feature or via an o-ring seal to the lens barrel, the protruding portion withstands up to 90 minutes of blowing sand at normal incidence, rate of 18 m/sec. Following exposure, responsivity of the core will be degraded by no more than 10%.

Note: This requirement applies only to those configurations of the Tau 2 core with hard-carbon coating (as denoted in the part number – see 1.2).

3.4.9 IP Rating

After sealing the front face of the Tau 2 core to a bulkhead via the bulkhead mounting feature, the protruding portion provides ingress protection rating no less than IP 66/67.

Note: IP67 requires a 30 minute dunk under 1 meter of water. FLIR typically validates by subjecting the core to pressure equivalent to 8.6 meters for 2 minutes, which based on previous experience is an excellent indicator that it will withstand IP 66/67 exposure.

3.4.10 Salt Spray / Salt Fog

The WFOV lenses (forward of o-ring grove) and NFOV lenses (sealed to lens barrel) are resistant to at least 200 hours of salt spray / salt fog with minimal corrosion of the metal or degradation of the lens coating. All lens housings are anodized aluminum. The WFOV lens housing is magnesium with environmental coatings to provide resistance against salt fog.

3.4.11 EMC

The radiated emissions from the Tau 2 core are compliant to IEC 61000-6-3 (Class B) when a rear cover is installed and proper cabling / line-termination are provided. Certification has not been formally completed on the core, but testing has confirmed that radiated emission levels were below CE Class B with proper grounding and shielding.

Note: Radiated emissions from Tau 2 are comparable to those from Tau 1.X.

3.5 Design and Assembly requirements

3.5.1 Reliability / Design Life

The Tau 2 core was designed to meet all the requirements of this specification with a mean time between failure (MTBF) $\geq$30,000 hrs operation and a service life (including storage) in excess of 7 years.

FLIR also assesses product reliability with reliability predictions, utilizing industry standard methodology. As shown in Table 8, the predicted MTBF are quite long but are indeed the results of standard electronics reliability predictions combined with accelerated life testing at FLIR. As this is a theoretical prediction it is also interesting to assess actual field reliability. For this FLIR has utilized an on-line calculator found at http://reliabilityanalyticstoolkit.appspot.com/field_mtbf_calculator (method 2). Assuming a usage duty cycle of 80% across all fielded Taus (actually includes many environments and use cases) the MTBF is calculated at 12.1 years (operating hours) with a 90% confidence level.

Table 8: Tau Camera Reliability Prediction

	Tau w/ Flag Shutter		
	Camera MTBF (years)		
Temp, °C	Ground Fixed	Ground Mobile	Airborne Inhabit. Cargo
30	61.7	20.6	12.3

3.5.2 ROHS

The Tau 2 core complies with the following directives / regulations:

- Directive 2011/65/EU, “Restriction of the use of certain Hazardous Substances in electrical and electronic equipment (RoHS)”

If you have questions that are not covered in this manual, or need service, contact FLIR Commercial Systems Customer Support at 805.964.9797 for additional information prior to returning a camera.

This documentation and the requirements specified herein are subject to change without notice.

This equipment must be disposed of as electronic waste.
Contact your nearest FLIR Commercial Systems, Inc. representative for instructions on how to return the product to FLIR for proper disposal.

FCC Notice. This device is a subassembly designed for incorporation into other products in order to provide an infrared camera function. It is not an end-product fit for consumer use. When incorporated into a host device, the end-product will generate, use, and radiate radio frequency energy that may cause radio interference. As such, the end-product incorporating this subassembly must be tested and approved under the rules of the Federal Communications Commission (FCC) before the end-product may be offered for sale or lease, advertised, imported, sold, or leased in the United States. The FCC regulations are designed to provide reasonable protection against interference to radio communications. See 47 C.F.R. §§ 2.803 and 15.1 et seq.

Industry Canada Notice. This device is a subassembly designed for incorporation into other products in order to provide an infrared camera function. It is not an end-product fit for consumer use. When incorporated into a host device, the end-product will generate, use, and radiate radio frequency energy that may cause radio interference. As such, the end-product incorporating this subassembly must be tested for compliance with the Interference-Causing Equipment Standard, Digital Apparatus, ICES-003, of Industry Canada before the product incorporating this device may be: manufactured or offered for sale or lease, imported, distributed, sold, or leased in Canada.

Avis d'Industrie Canada. Cet appareil est un sous-ensemble conçu pour être intégré à un autre produit afin de fournir une fonction de caméra infrarouge. Ce n'est pas un produit final destiné aux consommateurs. Une fois intégré à un dispositif hôte, le produit final va générer, utiliser et émettre de l'énergie radiofréquence qui pourrait provoquer de l'interférence radio. En tant que tel, le produit final intégrant ce sous-ensemble doit être testé pour en vérifier la conformité avec la Norme sur le matériel brouilleur pour les appareils numériques (NMB-003) d'Industrie Canada avant que le produit intégrant ce dispositif puisse être fabriqué, mis en vente ou en location, importé, distribué, vendu ou loué au Canada.

EU Notice. This device is a subassembly or component intended only for product evaluation, development or incorporation into other products in order to provide an infrared camera function. It is not a finished end-product fit for general consumer use. Persons handling this device must have appropriate electronics training and observe good engineering practice standards. As such, this product does not fall within the scope of the European Union (EU) directives regarding electromagnetic compatibility (EMC). Any end-product intended for general consumer use that incorporates this device must be tested in accordance and comply with all applicable EU EMC and other relevant directives.