



Quark™

Product Specification

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1 Document

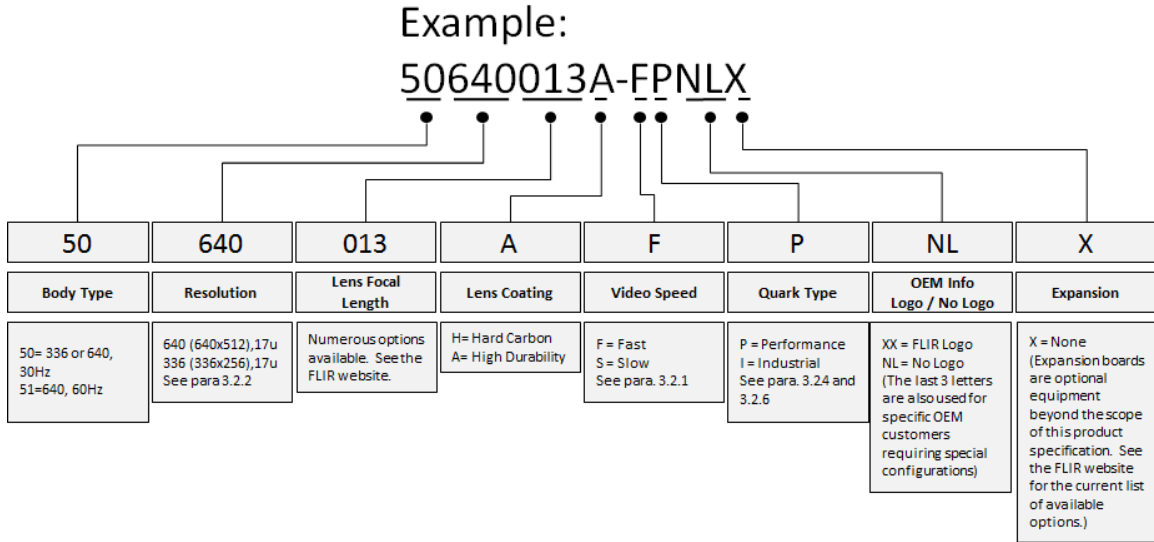
1.1 Revision History

Version	Date	Comments
Rev 100	11/07/2011	Initial Release.
Rev 101	11/21/2012	3.4.1: Added operating-temperature-range requirement for commercial-grade configuration.
Rev 102	09/20/2013	Removed WEEE and REACH compliance information 3.3.2.1.1 Removed FFC status flag requirement
Rev 103	10/22/2013	3.2.1 Updated PAL analog resolution to 640x480 3.2.1 Added Note 1 for digital video recommendation and Note 2 for BT.656 resolution clarification 3.2.1 Added Table 2 for Quark field of views and lens options
Rev 110	06/09/2014	Updated for Quark 2.0 Release. Specific changes include: 1.2 Added Release History for Quark 3.1.2.4 Updated digital modes for new options 3.1.2.6 Added new discrete I/O options 3.1.2.7 Added 60Hz external sync capability 3.2.1 Added to output resolution for eZoom enabled digital output 3.2.2 Updated frame rates for 1002 and eZoom enabled digital output 3.3.1.1 Removed the two splash screen option (only 1 available in Quark 2). Added splash/symbol capability in digital output option 3.3.1.5 Added Note2 for Quark 1 to Quark 2 upgrade 3.3.2.1 Added variable FFC frames feature 3.3.2.2 Added Gain Modes for low gain support. Defined shutterless gain switching feature. 3.3.2.4 Overhauled zoom section with new features 3.3.2.5 Updates to DDE algorithm 3.3.2.6 Added new Plateau equalization features ACE, SSO, and Tail Rejection 3.3.2.6.1 Updated IIR filter parameter meaning for current release and past releases and renamed to AGC filter for alignment with SW IDD 3.3.2.6.2 Added new Information-based algorithm descriptions 3.3.2.6.2 Updated Linear Histogram for tail rejection and overhauled AGC ROI section 3.3.2.7.1/2 Added Bayer Encoding and YCbCr sections 3.3.2.8 Symbology updates for variable resolution, user-selectable, and digital output with symbology 3.3.2.9 Added 8BMP snapshot capability 3.3.2.10 Added SSN feature description 3.3.3 Added Radiometry section with Isotherm, Spotmeter, and Advanced Radiometry sub-sections 3.3.4.4 Added Overtemp status feature 3.3.4.5 Added Status flag feature



1.2 Scope

Quark is a highly miniaturized infrared imaging core from FLIR Systems®, offered in various configurations. The part numbering scheme is defined below:



Quark 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 Quark core. In most cases, these expansion cards modify or augment the standard core functionality. This specification only applies to the standalone core.

**Table 1: Quark Release Summary**

Release Version	Release Date	New Features
1.0	Oct. 2011	Initial Release of Quark 1.0
2.0	July 2014	<p>New features or changes shown below are relative to Quark 1.0. (Each of these items are shown in blue font for emphasis in the current revision of this document.):</p> <ul style="list-style-type: none"> • 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) • 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) • Low gain available for 336 configuration (see 3.3.2.2) • 640 resolution, 60Hz configuration offered (3.2.2) • Improved AGC/DDE with new features and additional Information-based algorithms (3.3.2.6) • YCbCr colorization SW selectable in 8-bit and 16-bit CMOS digital output (3.1.2.4, 3.3.2.7) • SSN (silent shutterless NUC) feature, allows for shutterless operation and reduces noise with or without shutter (3.3.2.12) • Variable frames for FFC feature (3.3.2.1) • Shutterless gain mode switch features (3.3.2.5) • Isotherm update for saturation threshold (3.3.1) • Four additional discrete I/O and status flags offered (3.1.2.6, 3.3.4.5) • External sync available in 60Hz/50Hz modes (3.1.2.7)

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 Quark 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/quark/

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-ApplicationsEng@flir.com.



2.2 FLIR Systems Documents

102-PS241-01	Quark 2 Quick-Start Guide
102-PS241-41	Quark 2 Electrical Interface Description Document (IDD)
102-PS241-43	Tau2.0/Quark Software IDD
Various	Mechanical Interface Description Drawing (varies by part number)

2.3 External Documents

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 a large number of lens options for Quark, as denoted in the part number. Weight of the product varies as a function of lens type. Because new lens types are being added to the product list on a regular basis, this product specification does not list weight requirements for all configurations. Instead these requirements are specified in separate Mechanical Interface Description Drawings (IDDs) unique to each configuration. The cross section of Quark is 22.0 mm x 22.0 mm. The length is a function of lens type and is specified in the Mechanical IDD for the configuration.

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

3.1.1.2 Mounting

The Quark provides a number of options for mounting. The preferred approach is via four threaded holes (M1.6x0.35) on the rear surface of the core. See the relevant Mechanical IDD for more detailed information. Zinc-plated steel screws are recommended with a thread penetration of 2.4mm to 2.6mm.

3.1.2 Electrical Interface

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

3.1.2.1 Connector

The electrical interface to the Quark is a single high-density 60-pin connector: Samtec #ST4-30-1.50-L-D-P-TR. The recommended mating connector is Samtec #SS4-30-XXX-L-D-K-TR where XXX is either 3.00 or 3.50 for a mated stack height of 4.5mm or 5mm. See the Quark Electrical IDD for pin-out.

3.1.2.2 Input Power

The input-voltage range for the Quark is $3.3V \pm 0.1V$. Nominal power dissipation is approximately equal to 1.0W at room temperature. See the Quark Electrical IDD for detailed requirements regarding the power interface.



3.1.2.3 Analog Channel

The Quark 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)

The analog output is interlaced for all configurations and frame rates. See the Quark 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 Quark 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))
2. CMOS 8-bit (post-AGC)
3. CMOS 8-bit (post-AGC, Bayer colorization, user selectable eZoom/symbol overlay)
4. CMOS 8-bit (post-AGC, double-clocked YCbCr colorization, user selectable eZoom/symbol overlay)
5. CMOS 14-bit (pre-AGC)
6. CMOS 16-bit (post-AGC, YCbCr colorization, user selectable eZoom/symbol overlay)
7. Disabled (saves approximately 10 mW)

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)
3. LVDS 8-bit (post-AGC, Bayer colorization, user selectable eZoom/symbol overlay)
4. Disabled (saves approximately 10 mW)



See the Quark 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 Quark provides an RS-232 channel for command / control. See the Quark Electrical IDD for detailed requirements regarding the physical interface and the Tau 2 / Quark 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 Quark website (see 2.1).

3.1.2.6 Discrete I/O

The Quark 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 Quark 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		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 (if applicable) whenever the discrete pin changes from the float state to the ground state



Function	Input or Output	Detail
FFC Desired	Output	This output signal is normally in low state and will transition to high state when an FFC is desired in Manual/External FFC modes. The FFC_PERIOD and FFC_TEMP_DELTA commands control the timing of when a FFC is desired.
Gain-State Change Desired	Output	This output signal is normally in low state and will transition to high state when a gain state transition is desired in Manual/External FFC mode and Auto gain mode. The GAIN_SWITCH_PARAMS command controls gain switching thresholds.
Table Change Desired	Output	This output signal is normally in low state and will transition to high state when a calibration table switch is desired in Manual FFC mode and High/Auto gain mode. The calibration data specific to each camera controls the camera temperatures defining the table boundaries.
FFC In Progress	Output	This output signal is normally in low state and will transition to high state when an FFC is in progress.

3.1.2.7 External Sync

The Quark provides an external sync channel that can be used to synchronize frame start between two Quark cores, one configured as master and the other configured as slave. It can also be used to synchronize the frame start of a Quark with that of another product. The Quark 2.0 release introduces the external sync capability in both 60Hz/50Hz averager disabled and 30Hz/25Hz averager enabled modes for applicable configurations. See the Quark Electrical IDD for more detailed requirements regarding the interface. Each Quark can be configured into one of three external-sync modes:

- **Disabled:** In “disabled” external-sync mode, the core relies on internal timing, and the external-sync channel is used as neither input nor output.
- **Master:** 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.
- **Slave:** 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 Quark, and correct operation is not guaranteed. See the Quark 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	Output Resolution, analog & BT.656 ₂	Output Resolution, LVDS & CMOS
640	NTSC	640x480	640x512 ₁
640	PAL	640x480	640x512 ₁
336	NTSC	320x240	336x256
336	PAL	320x256	336x256

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

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

Note 1: Due to manufacturing tolerances, FLIR only guarantees the center 640x480 region for Quark 640 cameras. Customers utilizing digital data are recommended to crop the top and bottom rows to achieve this resolution.

Note 2: 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	006 6.3 mm (f/1.4)	009 9 mm (f/1.4)	013 13 mm (f/1.25)	014 14 mm (f/1.25)	017 17 mm (f/1.25)	019 19 mm (f/1.25)	025 25 mm (f/1.2)	W35 35 mm (f/1.5)	035 35 mm (f/1.2)
640 (17u)	n/a	69° x 56°	45° x 37°	43° x 35°	36° x 29°	32° x 26°	25° x 20°	18° x 14°	18° x 14°
336 (17u)	50° x 40°	35° x 27°	25° x 19°	23° x 18°	19° x 15°	17° x 13°	13° x 10°	9.3° x 7.1°	9.3° x 7.1°

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 Quark performs automatic “smart” averaging of pairs of frames from the detector array.

Note 1: 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.



Note2: For Quark 2.0 and later releases, the optional “Digital eZoom Mode” affects the frame rate for 8-bit CMOS and LVDS digital output when enabled for the 336 and 640, 30Hz configurations – the frame rate will be 25/50Hz or 29.97/59.94Hz 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 & Settings

Configuration, Video Speed	Configuration, Resolution	Video Setting	Averager Mode	Frame Rate (Hz)	Frame Rate (Hz) 8-bit Digital eZoom Enabled Mode
Fast	336	NTSC	Disabled	59.94 Hz	29.97 Hz
Fast	336	PAL	Disabled	50.00 Hz	25.00 Hz
Fast	336	NTSC	Enabled	29.97 Hz	29.97 Hz
Fast	336	PAL	Enabled	25.00 Hz	25.00 Hz
Fast	640, 30Hz	NTSC	not applicable	29.97 Hz	29.97 Hz
Fast	640, 30Hz	PAL	not applicable	25.00 Hz	25.00 Hz
Fast	640, 60Hz	NTSC	Disabled	59.94 Hz	59.94 Hz
Fast	640, 60Hz	PAL	Disabled	50.00 Hz	50.00 Hz
Fast	640, 60Hz	NTSC	Enabled	29.97 Hz	29.97 Hz
Fast	640, 60Hz	PAL	Enabled	25.00 Hz	25.00 Hz
Slow	336	NTSC	Disabled	8.56 Hz	29.97 Hz
Slow	336	PAL	Disabled	8.33 Hz	25.00 Hz
Slow	336	NTSC	Enabled	7.49 Hz	29.97 Hz
Slow	336	PAL	Enabled	8.33 Hz	25.00 Hz
Slow	640, 30Hz	NTSC	not applicable	7.49 Hz	29.97 Hz
Slow	640, 30Hz	PAL	not applicable	8.33 Hz	25.00 Hz

3.2.3 Optical Performance

Field of view (FOV) varies by lens. 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 IDD's unique to each configuration.

Note: Current lens offerings are shown on FLIR's Quark 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 Quark presents a splash screen in the analog and 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 Quark website for an Application note describing this capability.) The timing of the splash screen (i.e., how long the splash screen is displayed) can also be adjusted via serial command.

For Quark 2.0 and later releases, the splash screen is also presented in the colorized/eZoom enabled digital channels. Similar to the analog channels, digital symbols are user selectable and must be enabled if a splash screen is desired in the digital channel; the default mode is digital symbols disabled. For Quark 2.0 and later releases, analog symbols are user selectable and must be enabled if a splash screen is desired; the default mode is analog symbols enabled.

3.3.1.2 Readiness Time

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

3.3.1.3 Power-On Defaults

The Quark 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 336 configuration of Quark 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. The 640 configurations provide fault-tolerant software upgrade but not fault-tolerant firmware upgrade.

Note: The 336 configuration of Quark 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. The 640 configurations do not provide an upgrade block. Caution should be exercised when upgrading firmware.

3.3.1.5 *Backward Compatibility*

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

Note1: Not all feature improvements planned for later releases will necessarily work when a fielded Quark 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.

Note2: For Quark 1.0 cores that are upgraded to Quark 2.0 or later:

- *Radiometric features (e.g., spotmeter, isotherms, and/or image metric) require factory calibration, and the Quark cannot be upgraded to enable these features in the field.*
- *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 (see 3.3.2.2).*
- *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 Quark 2.0. A Quark 1.0 core that is field-upgraded to Quark 2.0 will default to having the AGC ROI subtend 100% of the displayed image.*



3.3.2 Image Processing Features

3.3.2.1 FFC

All configurations of the Quark are delivered with factory-calibrated correction terms that provide uniform pixel response. Flat-field correction (FFC) is a process whereby one of the correction terms, referred to as the FFC map, is updated periodically in the field to improve image quality. Recalibrating the FFC map corrects for temporal pixel drift.

While it is possible for the Quark to operate over long periods of time without FFC, performance can be maintained at the highest possible level by performing FFC often, for example:

- At power-up
 - When the ambient temperature has changed by several degrees since the last FFC
- Note: An internal temperature sensor is readable by command. See 3.3.4.3.*
- When several minutes have elapsed since the last FFC

It is not essential to repeat the FFC process as often as recommended above, but superior image quality will be maintained as a result of doing so.

Recalibration of the FFC map is typically executed by subtending the entire field of view by a uniform source (such as by closing a shutter mechanism over the lens or by pointing the core to a uniform scene) and then initiating the FFC process via command. The Quark does not include a shutter or other internally-controlled mechanism that presents a uniform temperature required to complete the FFC process. Therefore, it is assumed that one of the following conditions is true:

- The Quark is integrated with an external shutter assembly capable of being controlled by means of control signals SHUTTER0 and SHUTTER1 from the Quark. (See 3.3.2.1.2.)
- External logic commands the Quark to perform FFC at appropriate opportunities (such as when the external logic has driven an external shutter closed or when the Quark is known to be imaging a uniform source such as a lens cap).
- The Quark is operated in stable temperature conditions such that the small degradation in image quality resulting from not performing periodic FFC is acceptable. *Note: Even when the Quark is operated in stable conditions, it is highly recommended that FFC be performed whenever possible. Even if the application does not support the possibility of performing FFC at each power cycle, it should be performed whenever possible and saved to the non-volatile memory, as further described below.*

The FFC process takes nominally 0.4 seconds to complete, depending upon the user-specified parameters, Shutter Close Time and Shutter Open Time (see 3.3.2.1.2). The digital output data (CMOS and LVDS) is frozen throughout, and a warning symbol consisting of a square in the upper-right corner is displayed in the analog and BT.656 video. The FFC process can be initiated via command at any time.



It is possible to save the currently-applied FFC map to non-volatile memory. The saved map, referred to as the non-volatile FFC (NVFFC) map, will be applied at the next power-up. (Note that recalibrating the FFC map and storing it as the NVFFC map are two separate operations, each initiated by command.) Every Quark is delivered with a factory-calibrated NVFFC map that is applied at start-up. After each commanded FFC recalibration, the newly-generated map is applied in lieu of the NVFFC map. However, the new map is lost after power cycling *unless* it is saved as the NVFFC map (in which case, it overwrites the previous NVFFC map). If possible, a new NVFFC map should be stored at each power cycle. (The older the stored NVFFC map, the less effective it is because of temporal pixel drift).

Note: It is not recommended to erase the NVFFC map without replacing it. If there is no NVFFC map to apply, image quality at start-up may be severely degraded.

The Quark provides three user-selectable FFC modes:

- **Automatic:** In automatic FFC mode, the stored NVFFC map is applied at start-up. 5 seconds after start-up, the core automatically initiates the FFC recalibration process. Thereafter, the core autonomously initiates periodic FFC recalibration events as triggered by elapsed time or temperature change or both. (The elapsed time period and the amount of temperature change that trigger a new FFC event are both parameters that can be specified by the user. In automatic mode, the user can also command an FFC event at any time rather than waiting for the automatic event.) Automatic FFC mode is not recommended unless the Quark is interfaced to a shutter assembly that it signals to open / close automatically via the logic signals SHUTTER0 and SHUTTER1. (See 3.3.2.1.2).
- **Manual:** In manual mode, the stored NVFFC map is applied at start-up. However, the FFC process is only initiated via command, never automatically / autonomously by the core. (See the one exception in the note below.) In manual mode, the core signals shutter close / open via the signals SHUTTER0 and SHUTTER1 (see 3.3.2.1.2).
- **External:** External mode is essentially identical to manual mode except that the signals SHUTTER0 and SHUTTER1 are not used. That is, even if the Quark is interfaced to a shutter assembly that responds to logic signals from SHUTTER0 and SHUTTER1, the core will not exercise it when NVFFC is commanded. The assumption in external mode is that the core is imaging an external uniform source when FFC is initiated.

Note: If the NVFFC map is erased and not replaced (which is not recommended, as described in a previous note), Quark initiates an automatic FFC immediately after start-up when in automatic or manual mode (but not in external mode).

The option to specify the number of frames averaged for an FFC correction is available in the Quark 2.0 release and later releases. Increasing the number of frames can aid in reducing spatial noise. FLIR recommends a setting of 4 with the averager enabled (if applicable) and 8 with the averager disabled. See the Tau 2/Quark Software IDD for further details.



3.3.2.1.1 Long FFC

When the Quark is heated or cooled across its full operating temperature range, it may occasionally require a “long” FFC process depending upon the FFC mode. 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, the long FFC process takes place automatically. When operating in external FFC mode, calibration terms are loaded automatically without requiring an FFC process. (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.

Note: Nominally long FFC is required whenever the Quark core is heated / cooled through approximately 0C, 40C, and 65C. For example, if the core temperature is 35C when first powered on and then heated to 45C, it will normally require long FFC. If the core is then cooled back down to 35C, a second long FFC will again be signaled.

3.3.2.1.2 Shutter Control

Quark provides two logic signals, SHUTTER0 and SHUTTER1, intended to signal an external shutter-drive circuit when to open / close an external shutter device during the FFC process. (These signals are logic signals only and are not intended to directly drive a shutter assembly.) Table 7 depicts a truth table to be implemented by the shutter-drive circuit.

Table 7: Shutter-Signals and Intended Shutter Response

SHUTTER0	SHUTTER1	Intended Shutter-Circuit Action
Low	Low	Idle
High	Low	Drive shutter closed
Low	High	Drive shutter open
High	High	(Quark never signals this state.)

The shutter-drive profile can be programmed to match the characteristics of the external shutter. For example, a shutter with a return spring will typically need to be driven closed constantly for it to remain closed whereas a bistable shutter will typically remain in its current state (open or closed) when the drive circuit is idle. Both the close profile and the open profile are specified via a 32-entry look-up table (LUT), where each 4-bit entry represents one video field (1/60th of a second in NTSC mode, 1/50th in PAL mode). The upper two bits of each entry are not used; bit 1 represents the intended state of SHUTTER0, and bit 0 represents the intended state of SHUTTER1. The last entry in the table represents the “repeat” state, which is repeated until a specified timeout period. (The timeout period is from 0 to 7000 fields and is included to mitigate against burnout of the shutter motor in the event that the repeat state is “drive shutter closed” and the shutter is left in the closed position.) Figure 1 provides an example of a shutter close profile for a shutter with a return spring and another for a bi-stable shutter.

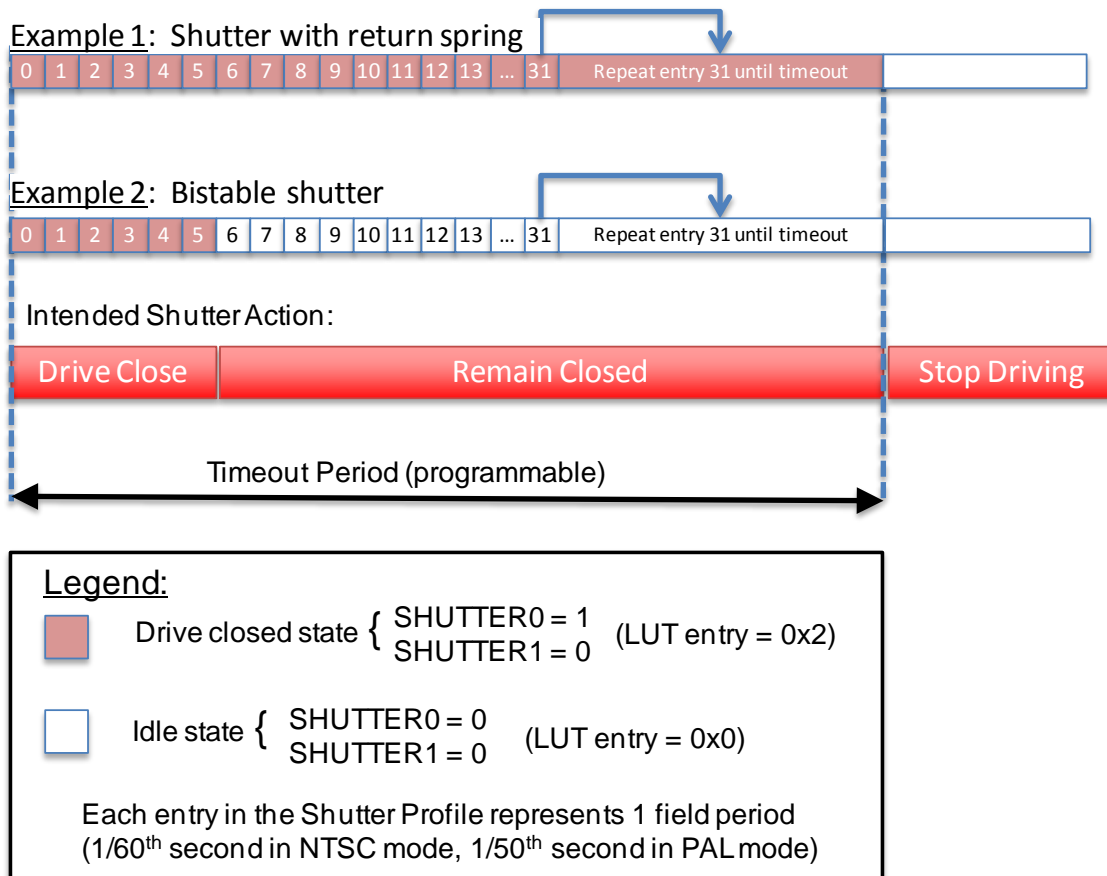


Figure 1: Two Examples of a Shutter Close Profile

Figure 2 shows the timeline for the FFC process, which consists of three distinct periods:

- **The FFC Close Period** is programmable in units of video frames. The FFC Close Period should be set to a value which represents the time required to completely close the shutter once the Shutter Close Profile is initiated plus a minimum of 3 frames. (The extra 3 frame periods represent the time for the pixel elements to fully respond to a change in incident radiation. The time constant of the Quark detector array is approximately 12 msec, so 3 frames represents approximately 8 time constants. If the FFC Close Period is set too low, the resulting FFC map may include some residual influence from whatever scene the Quark was imaging at the time the FFC was initiated, particularly if there are very hot or very cold items in the scene.)
- **The FFC Acquire Period** is not adjustable. It represents the time during which the core is integrating frames used to update the correction map and is always 4 frame periods.
- **The FFC Open Period** is programmable and should be set to a value equal to the time required for the shutter to fully open plus 2 frames.

Note that in automatic and manual FFC mode, SHUTTER0 and SHUTTER1 are signaled according to the specified close and open profiles described above.

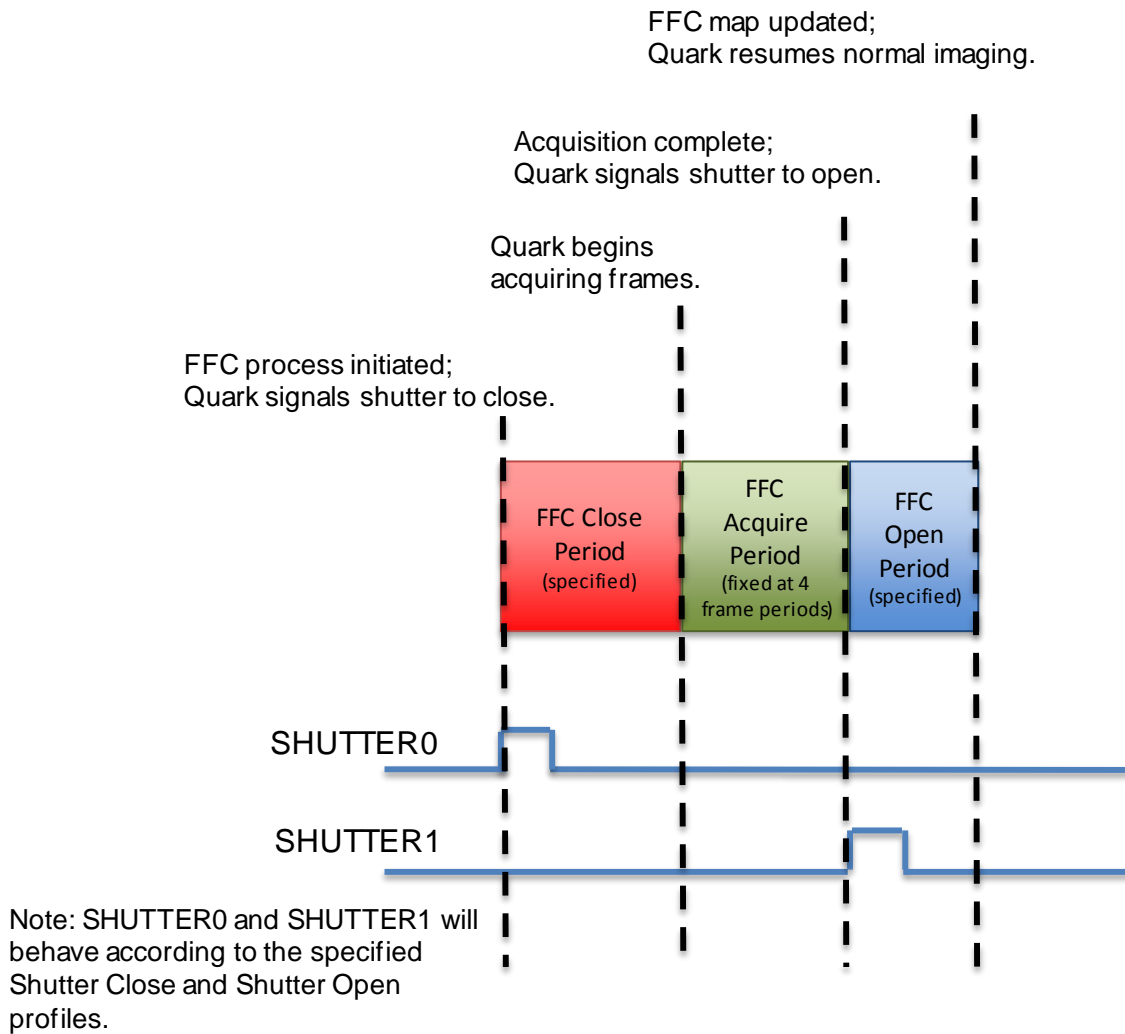


Figure 2: Illustration of FFC Timeline

3.3.2.2 Gain State

Note: The Quark 1.0 release supported a high-gain state only.

The Quark 2.0 release and later versions provide a high-gain state (lower NEDT, lower intrascene range), and the 336 configuration also provides 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 (see 3.3.2.1.1). See the Tau 2 /Quark Software IDD for more information regarding the status flag indicating a gain mode switch is desired.

Shutterless gain mode switching in external FFC mode is supported, but requires a user calibration procedure. Accurate radiometry or temperature measurement is required for proper automatic gain mode switching behaviour; therefore a relatively accurate FFC is required for both the high gain mode and the low gain mode states. The capability to calibrate and store two NVFFC maps, one for each gain mode, is included to accomplish this. With the feature enabled and the NVFFC maps calibrated, it is possible to operate in Auto gain mode and external FFC mode without the requirement of a run-time FFC.

Note: The “Shutterless Gain Switch Calibration” is defined in the Advanced Radiometry Application Note and provided in the FLIR Camera Controller GUI. See the FLIR website for each of these resources.

3.3.2.3 Image Orientation

The Quark provides four image-orientation modes, described below and illustrated in Figure 3:

- 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.

Invert and revert settings apply to all data channels (LVDS, CMOS, BT.656, and analog video).

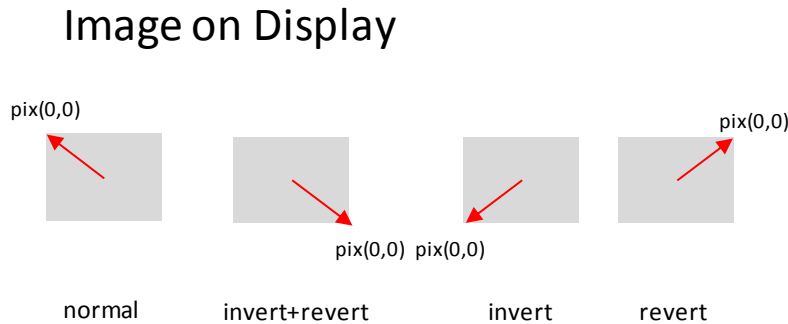


Figure 3: Illustration of Image-Orientation Modes

3.3.2.4 Zoom

The Quark provides an optional zoom capability. The maximum zoom factor varies depending upon configuration (4x for the 336 configuration and 8x for 640 configurations). For Quark 1.0, the zoom algorithm applied to the analog and BT.656 output data (not to the CMOS or LVDS output data). For Quark 2.0 and later releases, the zoom algorithm is also user selectable to be applied to the 8-bit CMOS and LVDS output data (excludes application to the 14-bit CMOS and LVDS data).

For the Quark 1.0 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 Quark 1.0, zoom is always relative to the center of the field of view.

The Quark 2.0 release and later 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 Quark 1.0 command VIDEO_MODE for selecting discrete zoom states (2X, 4X, and 8X) remains valid in Quark 2.0 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 12c 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 4 illustrates ROI for the following coordinates:
 - Left: -40%
 - Top: 0%
 - Right: +40%
 - Bottom: +50%

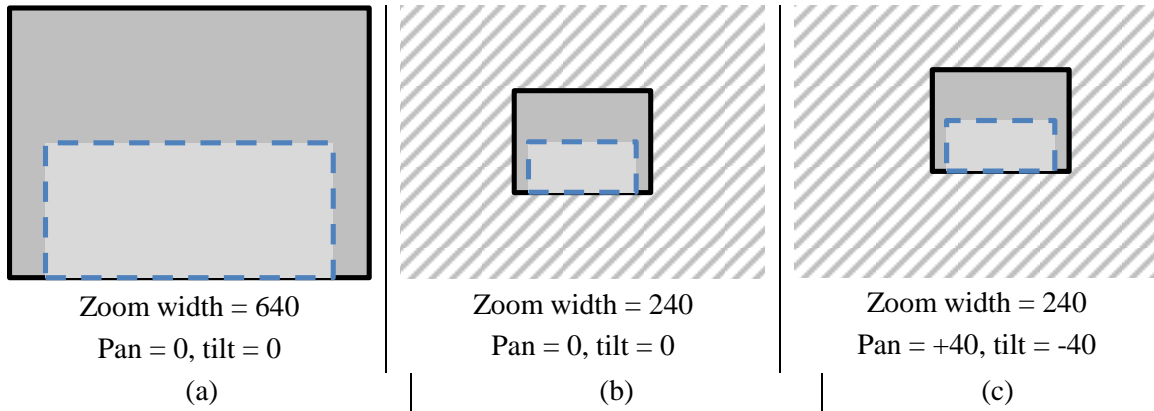


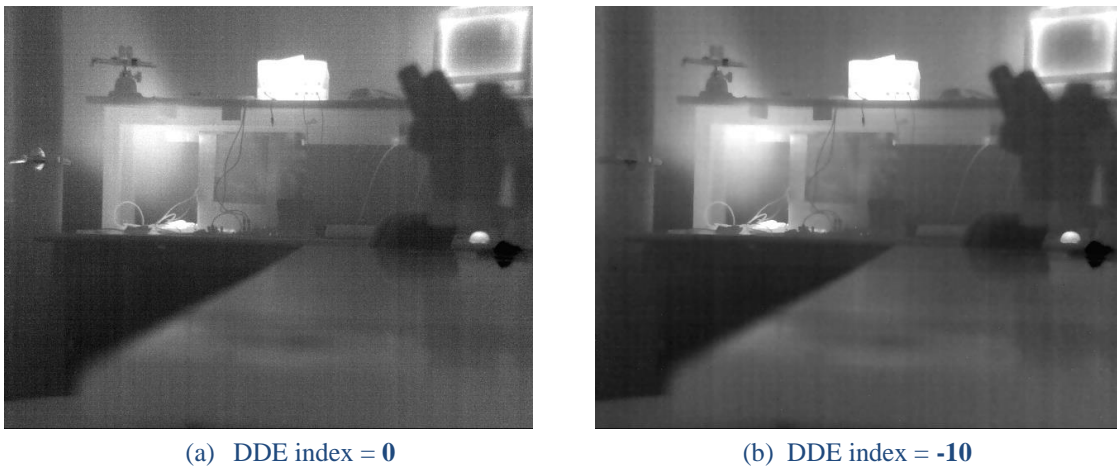
Figure 4: Illustration of ROI for Quark 2.0

(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 Quark 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:

- **Dynamic mode:** 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 -20 to 100 for Quark 2.0 and later releases, 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, as exemplified in Figure 5. Values greater than 0 sharpen the details in the image, as shown in Figure 6. For Quark 1.0, the DDE index ranged from 0 to 63, where 0 to 16 softened the image, 17 was neutral, and 18 to 63 sharpened detail.



(a) DDE index = 0

(b) DDE index = -10

Figure 5: Illustration of Noise Suppression with DDE
(Notice fixed pattern noise is reduced in the image on the right.)

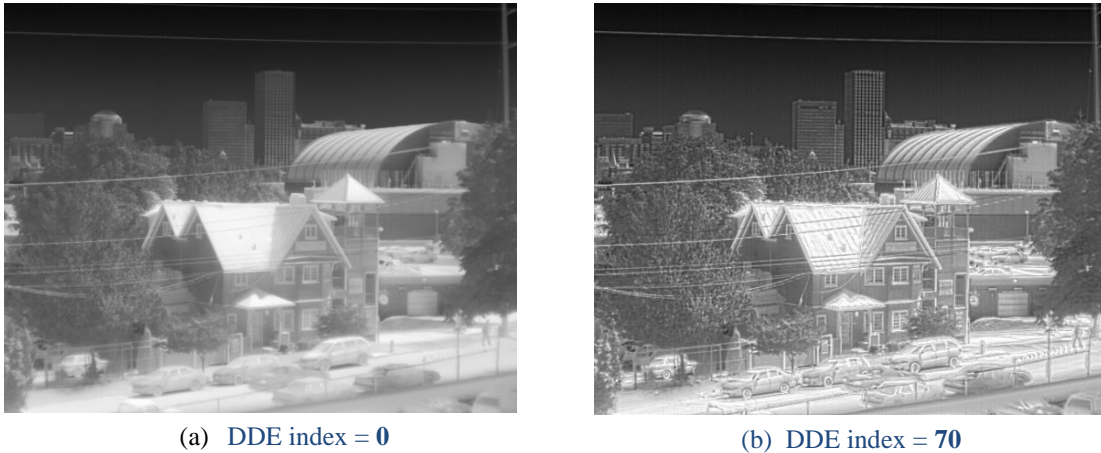


Figure 6: Illustration of Detail Enhancement with DDE

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 65535 for Quark 2.0 and later releases and represents the magnitude of high-frequency boost
 - For gain = 0, DDE is disabled
 - For gain > 0, details are enhanced by gain/2048. In other words, a value of 1 represents a 1/2048 attenuation of details whereas a value of 8192 represents a 4X enhancement of details. Note that gain is also applied globally and locally to the low frequency portion of the image, and therefore the DDE gain is relative (as a result, users are strongly discouraged from using manual DDE mode).
 - DDE threshold: ranges from 0 to 255 and represents the maximum detail magnitude that is boosted. Details with variance exceeding the threshold are not enhanced. Details with variance less than the thresholds are 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 Quark 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
 - ACE threshold
 - SSO value
 - Tail rejection
 - Region of Interest (ROI)
 - IIR filter
- Information-based and Information-based equalization (see 3.3.2.6.1)
 - Information-based Threshold
- Linear histogram (see 3.3.2.6.3)
 - ITT midpoint
 - ROI
 - IIR filter
- Manual (see 3.3.2.6.4)
 - Brightness
 - Contrast
 - IIR filter
- Auto-bright (see 3.3.2.6.5)
 - Brightness
 - Contrast
 - IIR filter
- Once-bright (see 3.3.2.6.6)
 - 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 the 8-bit image to be specified. Quark 2.0 and later releases includes the ability to allot a linear portion to the histogram (via Smart Scene Optimization), include an irradiance dependent contrast adjustment (via Active Contrast Enhancement), and specify outlier rejection (via Tail Rejection). The description below provides explanation of each of these 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 7 illustrates both of the cases.

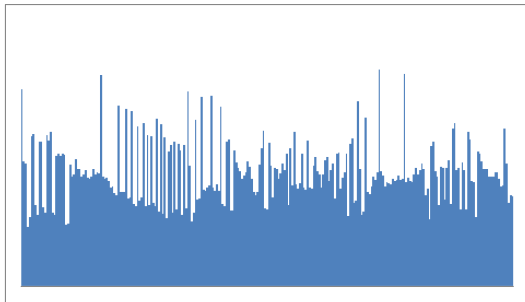
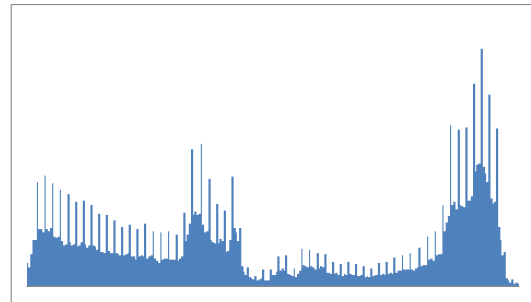
(a) Plateau Value = **1000**(b) Plateau Value = **10**(c) 8bit Histogram for Plateau Value = **1000**(d) 8-bit Histogram for Plateau Value = **10**

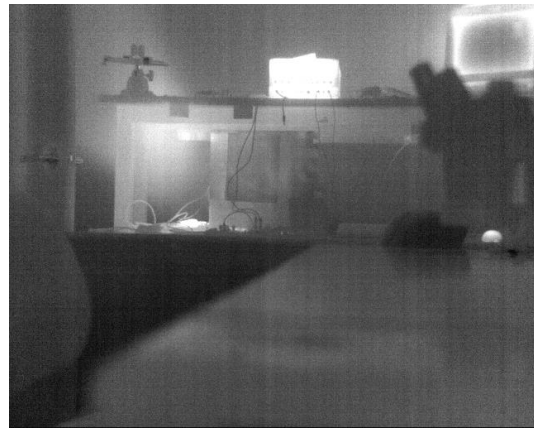
Figure 7: Illustration of Plateau Value

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

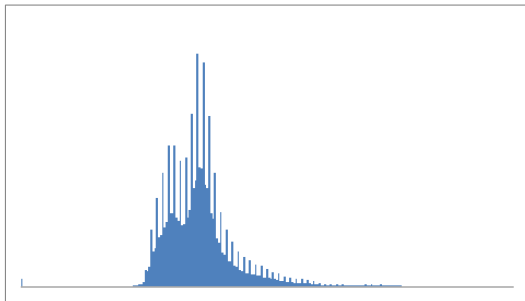
Maximum Gain. For scenes with high dynamic range (that is, wide 14-bit histogram), the maximum gain parameter has little effect. For a very bland scene, on the other hand, it can significantly affect the contrast of the resulting image. Figure 8 provides an example.



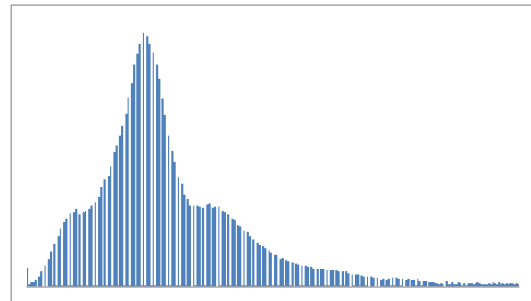
(a) Maximum Gain = 6



(b) Maximum Gain = 24



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



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

Figure 8: Illustration of Maximum Gain in a Bland Image
(Notice more details but also greater fixed-pattern noise in the right image.)

ITT Midpoint. 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 9. 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 9d.

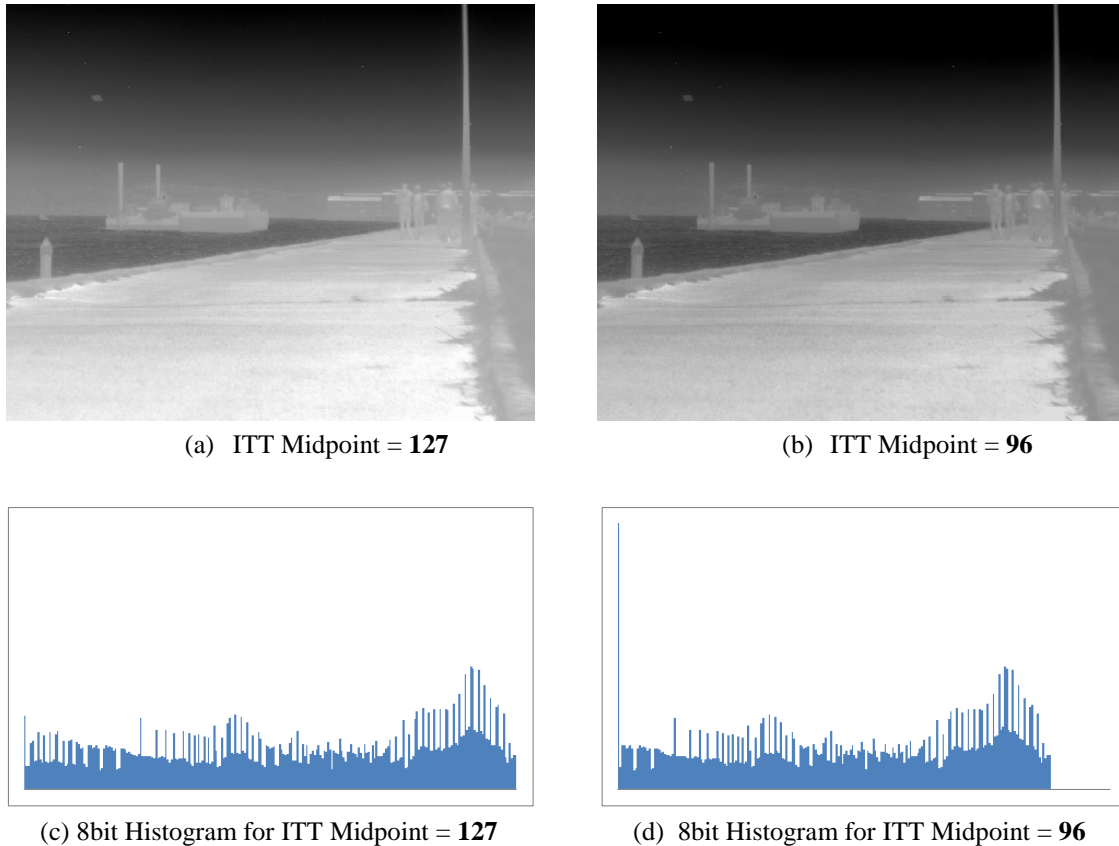


Figure 9: Illustration of ITT Midpoint

(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.)

ACE Threshold. The Active Contrast Enhancement (ACE) feature provides a contrast adjustment dependent on the relative scene temperature. ACE thresholds greater than 0 impart more contrast to hotter scene content and decrease contrast for colder scene content (e.g. sky or ocean). ACE threshold less than 0 do the opposite by decreasing contrast for hotter scene content and leaving more of the gray-scale shades to represent the colder scene content. Figure 10 illustrates the effects of ACE. FLIR recommends a conservative setting of 3 for generic use-case scenarios.



(a) ACE threshold = -4 (b) ACE threshold = 0 (**neutral**) (c) ACE threshold = 8

Figure 10: Illustration of Active Contrast Enhancement (ACE)

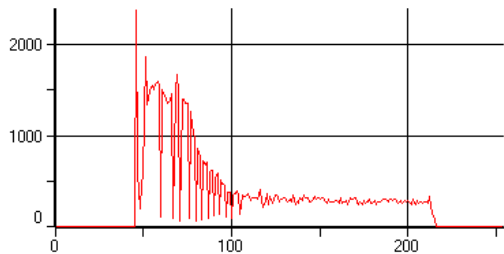
SSO Value. The Smart Scene Optimization (SSO) value defines the percentage of the histogram that will be allotted a linear mapping. Enabling this feature facilitates the avoidance of irradiance level compression, which is specifically important for bi-modal scenes. With SSO enabled, the radiometric aspects of an image are better preserved (i.e. the difference in gray shades between two objects is more representative of the difference in temperature). While radiometry is better preserved with this feature, the compromise is the optimization in local contrast. Figure 11 illustrates the effects of SSO. In the left image, SSO is disabled and the hot object and person get mapped to two shades of gray next to one another causing a “washed out” effect and making it appear as though the person and fire are similar in temperature. In the right image, SSO is enabled, and the hot object and person are decompressed with gray shades separating them.



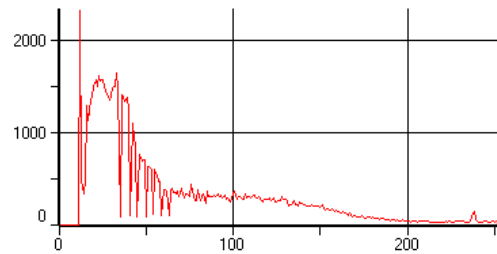
(a) SSO = 0% (**disabled**)



(b) SSO = 30%



(c) 8bit Histogram of SSO = 0% (**disabled**)



(d) 8bit Histogram of SSO = 30%

Figure 11: Illustration of Smart Scene Optimization (SSO)

Tail Rejection. The tail rejection 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.

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 Quark 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 12. 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 Quark 1.0, 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 Quark 2.0 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%).

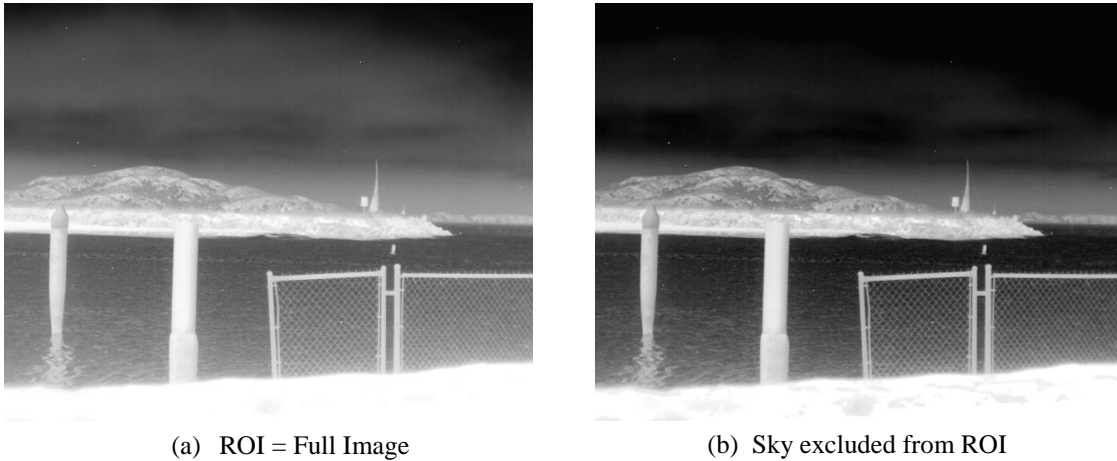


Figure 12: Illustration of ROI

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

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 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. For Quark 2.0 and later releases, 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. For Quark 1.0, a filter coefficient of 0 was a special case for immediate updates, a value of 1 was the most filtering or slowest refresh rate, and the case for no further AGC updates was unavailable.

3.3.2.6.2 Information-based and Information-based equalization

The Quark 2.0 release and subsequent releases include the Information-based algorithms which reserve more shades of gray for areas with more information or scene content by assigning areas with less information or scene content lesser gray shades. By assigning lesser gray shades to areas with less information (e.g. sky, sea, roads) the fixed pattern noise is reduced in these areas also allowing for more detail to be given to the more interesting portions of the image. Both Information-based algorithms undergo the plateau equalization process described in the previous section, and therefore all parameters described also apply.

The differences between the Information-based and Information-based Equalization algorithms are noteworthy as both have advantages. The Information-based algorithm completely excludes pixels from histogram equalization if they are below the information threshold (described later in this section). This is advantageous in that noise is completely removed from areas of the image determined by the algorithm to not contain information, but scenarios in which the user is attempting to detect small temperature or emissivity variations are not ideal for this mode because desired information may be lost depending on the threshold. The Information-based Equalization algorithm includes every pixel independent of scene information in the histogram equalization process, but simply weights each pixel based on the information threshold. This mode shows more moderate improvements in scenes with large areas void of information, but the advantage over the Information-based mode is that scene content will never be removed. Figure 13 shows the Plateau Equalization algorithm on the left for reference and the Information-based and Information-based Equalization algorithms center and right respectively with information threshold set to 40.



(a) Plateau Equalization

(b) Information-based

(c) Information-based
Equalization

Figure 13: Illustration of the difference between Plateau Equalization, Information-based, and Information-based Equalization algorithms

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 included in the Information-based algorithm and 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. Figure 14 illustrates the effects of the Information Threshold setting while operating in Information-based mode.

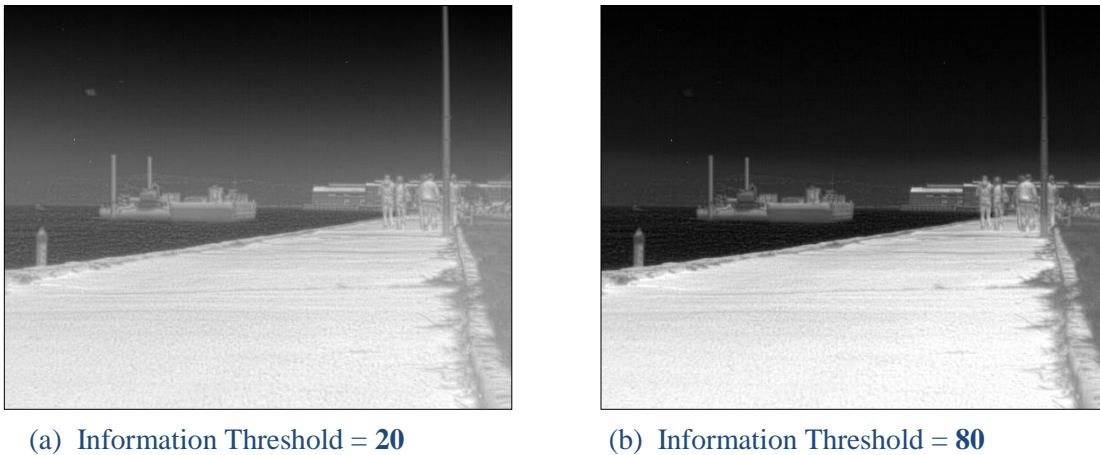


Figure 14: Illustration of Information Threshold

3.3.2.6.3 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:

$$m = 255 / (14bit_{(100 - Tail\ Rejection)\%} - 14bit_{(Tail\ Rejection)\%}),$$

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

The offset is then computed as

$$b = ITT\ midpoint - avg(14bit_{(100 - Tail\ Rejection)\%}, 14bit_{(Tail\ Rejection)\%}), * m$$

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, as shown in Figure 15 for the case in which the tail rejection parameter selected is 5%. The 8-bit values resulting from the above equations are clipped to a minimum value of 0 and a maximum value of 255.

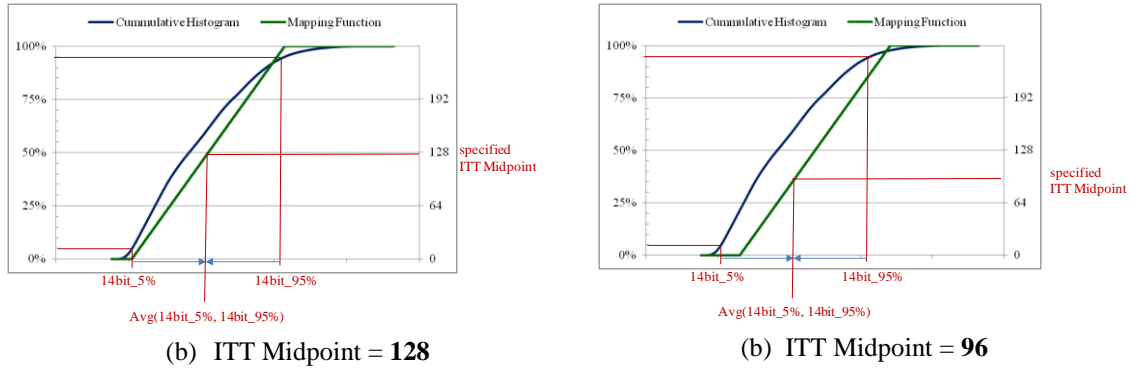


Figure 15: Illustration of the Linear-Histogram Mapping Function

3.3.2.6.4 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:

$$m = \text{specified contrast} / 64$$

$$b = 127 - (\text{brightness}) * m.$$

3.3.2.6.5 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.

3.3.2.6.6 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

$$b = 127 - (\text{frame mean} - \text{brightness bias}) * m,$$

where brightness bias is a user-specified parameter.

3.3.2.7 Palette

The Quark provides up to 15 user-selectable palettes (also referred to as look-up tables or LUTs). For Quark 1.0, the palette selection applies to the analog and BT.656 output data. For Quark 2.0 and later releases, the palette selection applies to the analog and BT.656 output data and in addition, is user selectable in the colorized digital output modes. The palettes are available in the 8-bit Bayer encoded CMOS or LVDS digital output channels and in the 8-bit or 16-bit YCbCr CMOS digital output channels.

3.3.2.7.1 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 both CMOS and LVDS 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 16 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 16 is an example of the ‘GB’ option.

Green	Blue
Red	Green

Figure 16: Illustration of Bayer pattern

3.3.2.7.2 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 8 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.

Configuration	Col0	Col1	Col2	Col3	Col4	Col5	Col6	Col7	Col8	Col9
4:2:2 Centered YCbYCr	Y0	$(C_{i0}+C_{i1})/2$	Y1	$(C_{i0}+C_{i1})/2$	Y2	$(C_{i2}+C_{i3})/2$	Y3	$(C_{i2}+C_{i3})/2$	Y4	$(C_{i4}+C_{i5})/2$
4:2:2 Centered CbYCrY	$(C_{i0}+C_{i1})/2$	Y0	$(C_{i0}+C_{i1})/2$	Y1	$(C_{i2}+C_{i3})/2$	Y2	$(C_{i2}+C_{i3})/2$	Y3	$(C_{i4}+C_{i5})/2$	Y4
4:2:2 Cosited YCbYCr	Y0	C_{i0}	Y1	C_{i0}	Y2	C_{i2}	Y3	C_{i2}	Y4	C_{i4}
4:2:2 Cosited CbYCrY	C_{i0}	Y0	C_{i0}	Y1	C_{i2}	Y2	C_{i2}	Y3	C_{i4}	Y4

Table 8: 8-bit Double-Clocked YCbCr output based on configuration

3.3.2.8 Symbol Overlay

The Quark 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 Quark 1.0, symbol resolution was 640x512 for all configurations. For Quark 2.0 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 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 ability to enable/disable symbology in the analog and BT.656 data is user selectable in Quark 2.0 and later releases. The 14-bit and normal 8-bit LVDS and CMOS channels do not include symbol overlay data. For Quark 2.0 and later releases, the colorized/eZoom LVDS and CMOS digital data channels provide a user selectable option for enabling symbology. Latency between transmitting a symbol-draw command and the actual update on the BT.656/analog output channels in approximately 0.5 sec.

Note: Variable symbol resolution is only available for analog and BT.656 channels. The digital channels that include symbology only support the 640x512 symbol resolution.



3.3.2.9 Snapshot

The 336 configuration of Quark provides snapshot capability in which 14-bit frames of data can be stored in non-volatile memory and downloaded via the serial-com. interface. Quark 2.0 and later releases provides the additional capability to store 8-bit frames of data with playback capability for the 336 configuration. The 8-bit snapshots are stored in BMP format and include colorization. The available capacity is reported upon command, and also all stored snapshots can be erased upon command. The 640 configurations does not provide capability to store a snapshot to non-volatile memory. (To support the calibration routines accessible via the GUI, snapshots can be stored temporarily to volatile memory.)

3.3.2.10 Silent Shutterless NUC (SSN)™

The silent shutterless non-uniformity correction (SSN)™ feature introduced in Quark 2.0 allows for noise reduction without the conventional FFC, specifically intended for cameras without a shutter in applications with continuous motion. The algorithm can also be useful in reducing noise in cameras with a shutter. See the SSN Application Note for details regarding the algorithm and associated parameters. A variety of presets based on level of motion for a particular application are available in the Camera Controller GUI.

3.3.3 Radiometric Features

Quark 2.0 provides radiometry features defined in the following sub-paragraphs. Quark 1.0 did not provide any of the following radiometric capabilities, and furthermore these features are not field-upgradeable.



3.3.3.1 Isotherm

The Quark 2.0 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 gray shades 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, with the option for a fourth threshold. If the four isotherm mode is enabled, the fourth value represents the saturation threshold (specified in either degrees Celsius or in percentage of full-scale of the temperature symbol bar) above which pixels will be mapped to the top shade of the palette (255). The third is the upper threshold 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 first 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 $\pm 20\text{ C}^\circ$ in high-gain state (see 3.3.2.2) and the greater of $\pm 20\%$ or $\pm 20\text{ C}^\circ$ in low-gain state. (Typical performance is on the order of $\pm 10\text{ C}^\circ$ 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

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

- Improved accuracy: typical performance on the order of $\pm 5\text{ C}^\circ$ 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

3.3.4 Diagnostic / Status Features

3.3.4.1 Scratch Pad

The 336 configuration of Quark 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 Quark 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 Quark provides capability to report internal core temperature. Accuracy of the measurement is $\pm 5^{\circ}\text{C}$.

3.3.4.4 Overtemp Indicator

The Quark 2.0 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.

3.3.4.5 Status Indicators

The Quark 2.0 core provides the capability to signal the user that certain camera operations are in progress or need to occur for more user control over background operations that normally take place in the camera. The “FFC in progress” status flag indicates that an FFC is currently in progress; further commands should not be sent until the FFC operation is complete. The “Table change desired” status flag indicates to the user operating in Manual FFC mode that a calibration table switch needs to take place due to the camera’s change in temperature; the user can perform a long FFC to initiate the table switch. The “FFC desired” status flag indicates to the user operating in Manual FFC mode that an FFC needs to take place based on the user-selectable time and temperature change intervals. The “Gain-State Change Desired” status flag indicates to the user operating in Auto gain mode and Manual FFC mode that the current scene requires a switch between high and low gain states based on the user-selectable gain switch parameters. The status flags are available via serial command and discrete I/Os. See the Tau 2/Quark Software IDD for further information.

3.4 Environmental Requirements

3.4.1 Operating Temperature

The Quark meets all requirements of this specification and exhibits no damage or permanent degradation when operated in conditions in which the core frame is within the range shown below.

Configuration, Tau Type	Operating Temperature Range
Commercial Grade	-20°C to +60°C
Performance Grade	-40°C to +80°C
Industrial Grade	-40°C to +80°C

3.4.2 Storage Temperature

The Quark 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 Quark 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 Quark 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 Quark meets all requirements of this specification and exhibits no damage or permanent degradation after exposure to shock pulses of 250 g (1.5msec half-sine) and 500g (0.8msec half-sine) along any axis.

3.4.6 Vibration

The Quark 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 9 (also shown graphically in Figure 17).

Table 9: 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

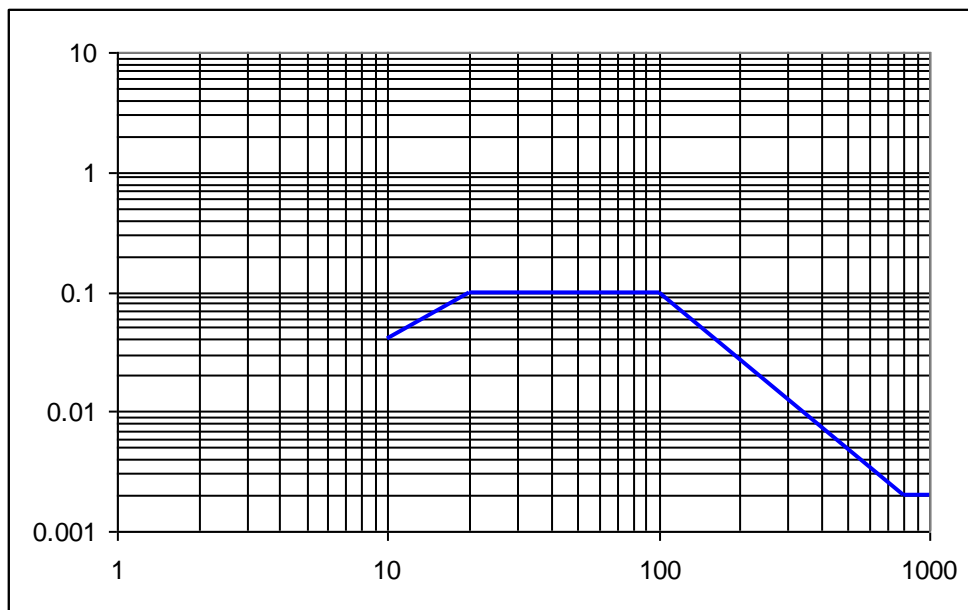


Figure 17: Random Vibration Profile

3.4.7 Altitude

The Quark 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) and IP Rating (3.4.9) requirements that follow each assume the Quark lens barrel is sealed to a bulkhead via an o-ring. Neither requirement applies to the portion of the core behind the o-ring seal, only to the protruding lens barrel. Exposure of the rearward portion of the core to these environmental conditions will cause permanent damage.



3.4.8 Blowing Sand

After bulkhead mounting via an o-ring seal to the lens barrel, the protruding portion of the Quark 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 Quark with hard-carbon coating (as denoted in the part number – see 1.2).

3.4.9 IP Rating

After bulkhead mounting via an o-ring seal to the lens barrel, the protruding portion of the Quark provides ingress protection rating no less than IP67.

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 EMC

To be specified in a later release, pending formal qualification.



3.5 Design and Assembly requirements

3.5.1 Reliability / Design Life

The Quark 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.

3.5.2 ROHS

The Quark complies with the following directives / regulations:

- Directive 2002/95/EC, "Restriction of the use of certain Hazardous Substances in electrical and electronic equipment (RoHS)"



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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.

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