TELEDYNE FLIR BOSON®+ THERMAL IMAGING CORE PRODUCT DATASHEET

Doc. # 102-2013-45
Release 114

Official Publication Date: 05-SEP-2025

General Description

With over 60 models, the Boson®+ family represents the most dynamic, highest-performing, uncooled thermal imaging technology in the Teledyne FLIR portfolio. The small, lightweight, low-power OEM package features multiple configurations and onboard image processing for qualitative and quantitative thermal imaging applications.

Features

- Multiple hardware configurations:
  - Quarter Video Graphics Array (QVGA) at 320×256 and Video Graphics Array (VGA) at 640×512
  - Multiple field-of-view (FOV) options: nine QVGA FOVs and nine VGA FOVs
  - Integral shutter and shutterless configurations
- Low size, weight, and power (SWAP); capability to trade feature set for power
- Radiometric output for select configurations
- User-configurable I/O with multiple video and command/control channels
- State-of-the-art signal processing includes advanced noise filters for superior sensitivity, EZoom, and colorization
- External-sync capability
- Power-safe field upgrade
- Quick start-up; approx. 2.5 to 3 seconds, depending upon configuration and settings
- Designed for industrial/military environments
- RoHS-compliant

Applications

- Firefighting
- Security
- Industrial Inspection
- Surveillance
- Unmanned Systems
- Fixed-Asset Monitoring
- Automotive

Key Specifications

Unless otherwise stated, all specifications apply to all Boson+ configurations.

IMAGING	
Sensor technology	Uncooled microbolometer
Array format	320×256 or 640×512
Maximum effective frame rate	60Hz
Thermal sensitivity	Industrial: ≤ 20 mK Professional: ≤ 30 mK
Total Pixel Operability	Industrial: ≥ 99.0% Professional: ≥ 98.5%
NUC	Factory calibrated
Field of view	4° to 95° HFOV
ELECTRICAL	
Input voltage	3.3V
Power dissipation	As low as 600 mW
Video channels	CMOS, MIPI, BT.656-like, or USB3
Control channels	UART, USB, or I2C
MECHANICAL	
Size	As small as 21 x 21 x 11 mm
Weight	As light as 7.5 g
ENVIRONMENTAL	
Operating temp.	-40°C to 80°C
Shock	1500 g @ 0.4 ms

NOTE: All specifications are subject to change without notice.

WARNING: EAR99 Technology Subject to Restrictions Contained on the Cover Page.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

1 DOCUMENT

1.1 Revision History

VERSION	DATE	COMMENTS
Rev 100	06/22/2023	Initial release
Rev 110	08/19/2023	Updated for the Boson+ 4.0 Software Release
Rev 113	07/10/2024	Updated for the Boson+ 4.1 Software Release
Rev 114	09/05/2025	Updates for intrascene dynamic range performance

1.2 Product Upgrade History

The list below lists each Boson+ software release and summarizes the incremental features/improvements each provides.

SOFTWARE REV #	RELEASE DATE	COMMENTS
3.0.26605	June 2022	Initial Boson+ product release (640 configurations only)
4.0.27141	March 2023	Release 4.0 Key new features include: • Support for QVGA (320) configurations • MIPI and I2C • Symbology
4.1.27660	July 2024	Release 4.1 Key new features include: • Improved spatial noise filters (SRNR, SCNR, and SSN) • Updated AGC with DDE+ for more contrast and less noise • Radiometry (select 640 and 320 configurations) • Persistent symbology • Two new color palettes • Optional automatic gain switching for cold scenes

1.3 Contact Us

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

https://www.flir.com/products/boson-plus/

The website also contains Frequently Asked Questions and a knowledge base:

https://www.flir.com/support/products/boson-plus

Teledyne FLIR's Applications Engineering Department is periodically referenced as a resource for obtaining additional help or information. Requests can be submitted through https://flir.custhelp.com/ or the appropriate sales channel.

1.4 Document Conventions

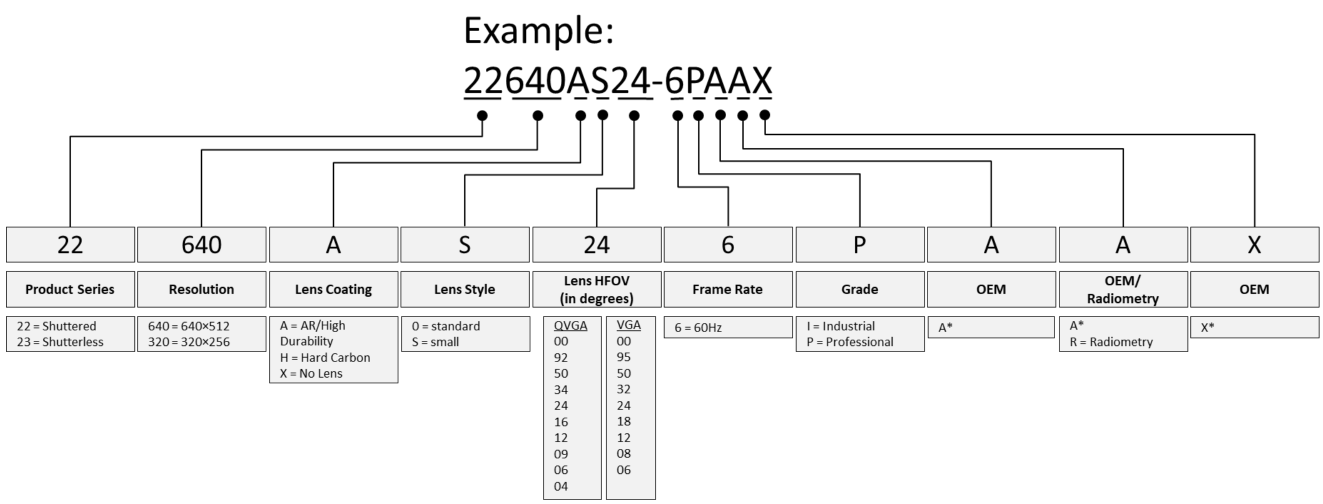
This document shows modes and parameters that are user-configurable via the command-and-control interface (CCI) in **bold font**. Status variables that can be read via the CCI (and via the telemetry line in some cases) but not directly altered are shown in *italic font*.

1.5 Scope

Boson+ is a highly configurable thermal imaging core comprised of the following three major components:

- Lens assembly: Multiple fields of view are available. A lensless configuration is also available with no lens flange. The various lens options are delineated in Section 10.
- Shutter assembly: An integral shutter assembly provides the greatest uniformity by allowing the camera to automatically perform a periodic correction (called a flat-field correction) as required. Shutterless configurations are also available.
- Sensor engine: Boson+ provides both a QVGA (320×256/12 μm) configuration and a VGA (640×512/12 μm) configuration. In either case, the focal plane array (FPA) is integrated with common signal-processing electronics, providing state-of-the-art noise filtering, image enhancement, operational logic, and camera functions as described in Sections 5, 0, and 7. The Boson+ sensor engine also provides all electrical I/O on a single connector, detailed in Section 4.

Figure 1 indicates the part-numbering schema for Boson+. The example part number shown represents a shuttered, professional grade, full frame rate (60Hz) 640×512 Boson+ configured with a small format 24° FOV lens.



* The last three digits (A, A, X) are available for customized OEM configurations.

FIGURE 1: PART-NUMBERING SCHEMA

NOTE: Only those part numbers with "R" in the second-to-last digit support radiometric output. Not all lens types provide this option. See Table 11 for radiometric-capable lens configurations.

Figure 2, Figure 3, and Figure 4 show the available hardware configurations featuring various combinations of lens assembly, shutter assembly, and sensor assemblies.

FIGURE 2: 320 SHUTTERED CONFIGURATIONS

FIGURE 3: 640 SHUTTERED CONFIGURATIONS

FIGURE 4: 640 SHUTTERLESS CONFIGURATIONS

NOTE: All 320 configurations and 640 configurations with large lenses (focal length ≥ 36 mm) include an integrated shutter. Removing the shutters would not provide a size reduction to these models. See Section 10 for more information on available lens configurations.

2 KEY SPECIFICATIONS

Unless otherwise stated, specifications apply to all Boson+ configurations.

TABLE 1: BOSON+ KEY SPECIFICATIONS

SPECIFICATION	DESCRIPTION
Overview	
Sensor technology	Uncooled microbolometer
Pixel size	12 µm
Spectral range	Longwave infrared, nominally 8 µm to 14 µm
Array format	QVGA (320x256) or VGA (640x512)
Effective frame rate	User selectable from 60, 30, 20, 15, 12, 10, 8.6, and 4.3 Hz
Thermal time constant	Nominally 8 ms
Thermal sensitivity (Section 11.1)	Industrial: ≤ 20 mK Professional: ≤ 30 mK
Radiometric Accuracy (Section 11.5)	Radiometric cameras only: ±5°C accuracy
Operability (Section 11.3)	Industrial: ≥ 99% Professional: ≥ 98.5%
Non-uniformity corrections (NUC) (Section 6.6)	Shuttered only: Option of automatic flat-field correction (FFC) All: Teledyne FLIR's Silent Shutterless NUC™ (SSN) suite of scene-based NUC algorithms
Electronic zoom (Section 0)	1X to 8X zoom
Symbol overlay (Section 6.11)	Alpha blending for translucent overlay
Bootup Time (see note 1)	~2.5 seconds for the 320 configurations ~3.0 seconds for the 640 configurations

Note 1: Bootup times are approximate and can be lowered for high-volume OEM configurations by removing support for symbol overlays. Please contact support through your sales channel for more information.

SPECIFICATION	DESCRIPTION
Electrical	
Video output channel (Section 8.2)	• CMOS • USB • MIPI
Video output format (Sections 7.12, 0, and 0)	Three runtime-selectable options: • Data before AGC (16b, output resolution = sensor resolution) • Data after AGC (8b, output resolution = sensor resolution) • Data after electronic zoom and colorization (various bit-width, output resolution = 640x512 regardless of sensor resolution)
Input clock	None required
Frame sync (Section 7.20)	Three runtime-selectable options: • Free running: Frame timing internally synchronized • External sync, slave: Frame timing slaved to an external pulse train • External sync, master: External pulse train generated by frame capture
Command & Control Interface (CCI) (Section 8.1)	• UART • USB • I2C
Command & Control API	See Boson Software Interface Description Document (IDD)
Input supply voltage (Section 12.1)	3.3 V
Power dissipation (Section 12.2)	Between 600 mW and 1550 mW, configuration and temperature dependent
Mechanical	
Package dimensions, lensless, and shutterless configuration	320 and 640 sensor engines: 21 mm x 21 mm x 11 mm (w x h x d) Note: dimensioned drawings and STEP files for each configuration are not included here but are available on the Teledyne FLIR website (Section 1.3).
Weight (Table 12)	Varies by configuration, as low as 7.5g (for lensless)
Environmental (Section 13)	
Operating temperature range	-40°C to +80°C
Storage temperature range	-50°C to +85°C
Shock	1500 g @ 0.4 ms
ESD	EN 61000-4-2 Level 4

3 SYSTEM ARCHITECTURE

A simplified architectural diagram of the thermal imaging core is shown in Figure 5.

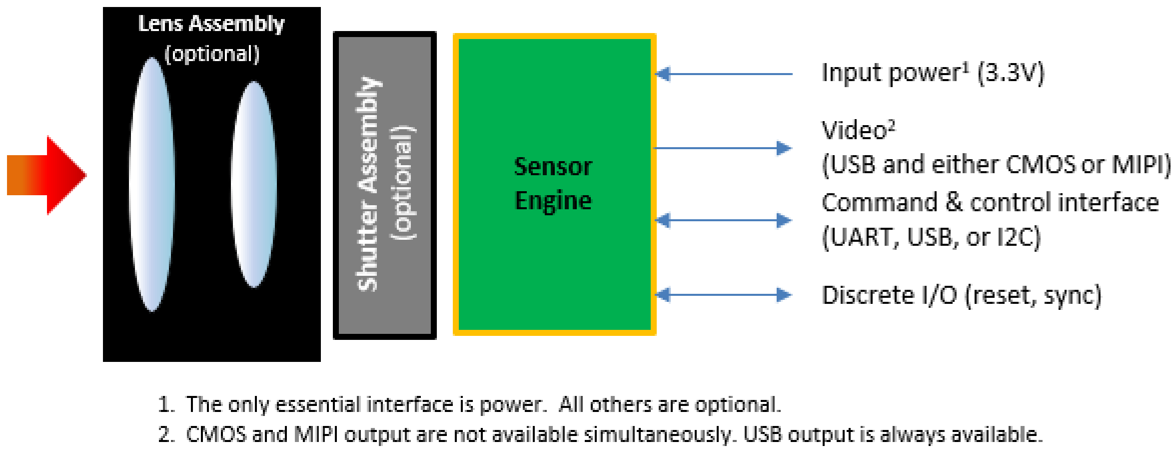


FIGURE 5: SIMPLIFIED ARCHITECTURE

The lens assembly focuses infrared radiation from the scene through the shutter aperture and onto the sensor engine. The shutter assembly periodically blocks radiation from the scene to present a uniform thermal signal to the sensor array. This uniform input signal updates internal correction terms to improve image quality. The shutter assembly is highly recommended for applications with no movement of the Boson+ core relative to the scene (for example, fixed-mount security applications). The shutter is less essential for applications with ample scene movement (for example, handheld applications) due to Teledyne FLIR's Silent Shutterless NUC (SSN) technology described in Section 0. However, the shutter can improve image quality in all applications and is always recommended, especially at start-up.

The sensor engine consists of a focal plane array (FPA) integrated with a System on a Chip (SoC). The FPA is a two-dimensional array of microbolometers with a 12-micron pitch. The QVGA configuration provides 320×256 pixels, while the VGA configuration provides 640×512. The temperature of each microbolometer varies in response to incident flux. The temperature change causes a proportional change in the detector's resistance. The bolometer utilizes a high-temperature coefficient of resistance (TCR) and low 1/f noise material resulting in excellent thermal sensitivity and highly stable uniformity. The microbolometer array is grown monolithically on top of a readout integrated circuit (ROIC). Once per frame, the ROIC senses the resistance of each detector by applying a bias, one row at a time. The SoC digitizes and processes the resulting signal, which provides signal conditioning and output formatting. The SoC is responsible for all camera logic and the Command and Control Interface (CCI). The signal pipeline is fully defined in Section 5, and the output interfaces are defined in Section 8.2.

4 ELECTRICAL PINOUT

Figure 6 shows the electrical interface to the Boson+ core, provided by a single 80-pin Hirose DF40C-80DP-0.4V(51) connector. The recommended mating connector is the Hirose 80-pin board-to-board receptacle (socket) DF40HC-(4.0)-80DS-0.4V(51), for a mating stack height of 4.0 mm. The correct orientation of the camera is as depicted, with the connector above the centerline. Rotating the camera 180 degrees so that the connector is below the centerline rather than above it will result in an upside-down image.

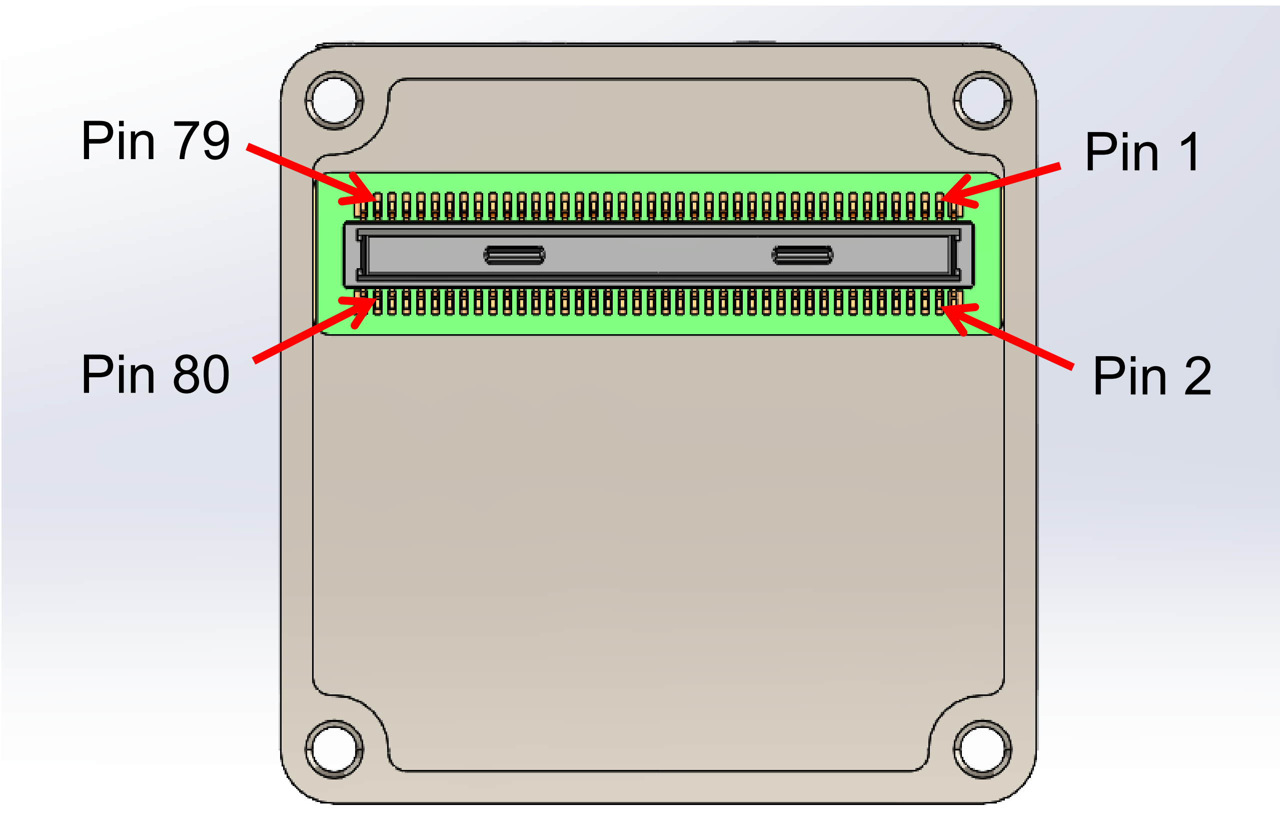


FIGURE 6: CONNECTOR PIN NUMBERING

4.1 Pin Assignments

Pin assignments and descriptions for the main connector are shown in Table 2 and Table 3. Unused channels or signals should be left floating.

TABLE 2: BOSON+ PIN ASSIGNMENTS AND PIN DESCRIPTION

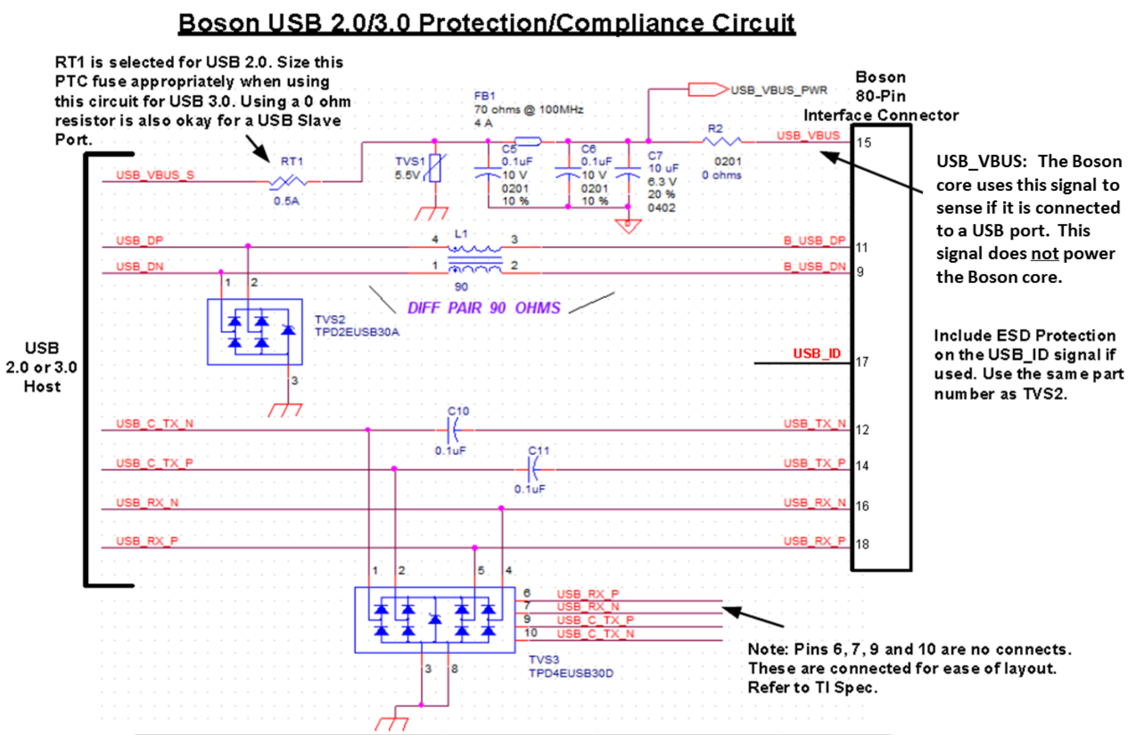
PIN #	PIN NAME	SIGNAL TYPE	SIGNAL LEVEL	DESCRIPTION
1, 3, 5, 7, 10, 13, 19, 20, 29, 30, 39, 40, 49, 50, 59, 60, 69, 70, 79	DGND	Power	GND	Digital Ground
2, 4, 6, 8	3V3	Power	3.3V	Input Power
11	USB_D_P	Diff Pair	USB spec compliant	USB2 data+
9	USB_D_N	Diff Pair	USB spec compliant	USB2 data-
15	USB_VBUS	Power	USB spec compliant	USB VBus (sense line only, not used to power the Boson+ core)
17	USB_ID	I/O	USB spec compliant	USB ID
14	USB_TX_P	Diff Pair	USB spec compliant	USB3 transmit+
12	USB_TX_N	Diff Pair	USB spec compliant	USB3 transmit-
18	USB_RX_P	Diff Pair	USB spec compliant	USB3 receive+
16	USB_RX_N	Diff Pair	USB spec compliant	USB3 receive-
21, 22, 23, 25, 26, 27, 28, 31, 32, 33, 34, 35, 36, 37, 38, 41, 42, 43, 44, 45, 46, 47, 48, 51, 53, 55, 56, 57, 58, 61, 62, 63, 64, 65, 66, 67, 68, 71, 73, 74, 75, 76, 77, 78	GPIO	I/O	1.8V	See Table 3
34, 35, 36, 37, 42, 44, 52, 54, 74, 76	MIPI	Diff Pairs	MIPI spec compliant	MIPI clock and transmit pairs See Table 3
24	RESET	I/O	1.8V (asserted low)	See Section 7.1
72	EXT_SYNC	I/O	1.8V	See Section 0
80	No Connect		N/A	

TABLE 3: ASSIGNMENT OF GPIO PINS.

Connector pin	Signal Name	Signal Description
22	**Unused**	Unused
26	**Unused**	Unused
28	**cmos_data_5**	CMOS bit5
32	**cmos_data_6**	CMOS bit6
34	**mipi_data_P11**	MIPI lane 1
36	**mipi_data_N11**	MIPI lane 1
38	**cmos_data_15**	CMOS bit15
42	**mipi_clock_CP5**	MIPI clock
44	**mipi_clock_CN5**	MIPI clock
46	**cmos_data_9**	CMOS bit9
48	**cmos_data_11**	CMOS bit11
52	**Unused**	Unused
54	**Unused**	Unused
56	**cmos_data_3**	CMOS bit3
58	**SYS_USE**	See section 4.2
62	**cmos_data_1**	CMOS bit1
64	**Unused**	Unused
66	**Unused**	Unused
68	**Unused**	Unused
72	**EXT_FSYNC**	Frame sync
74	**Unused**	Unused
76	**Unused**	Unused
78	**cmos_data_valid**	CMOS data valid
21	**cmos_data_14**	CMOS bit14
23	**Unused**	Unused
25	**cmos_data_8**	CMOS bit8
27	**cmos_data_4**	CMOS bit4
31	**cmos_data_7**	CMOS bit7
33	**uart_apb_sin**	UART input
35	**mipi_data_P10**	MIPI lane 0
37	**mipi_data_N10**	MIPI lane 0
41	**cmos_data_13**	CMOS bit13
43	**uart_apb_sout**	UART output
45	**cmos_data_10**	CMOS bit10
47	**cmos_data_12**	CMOS bit12
51	**cmos_data_2**	CMOS bit2
53	**cmos_vsync**	CMOS vsync
55	**cmos_pclk**	CMOS pixel clk
57	**Unused**	Unused
61	**Unused**	Unused
63	**i2c_scl**	I2C Clk
65	**Unused**	Unused
67	**i2c_sda**	I2C Data
71	**Unused**	Unused
73	**cmos_hsync**	CMOS hsync
75	**Unused**	Unused
77	**cmos_data_0**	CMOS bit0

4.2 External Circuitry

- Teledyne FLIR highly recommends implementing the protection circuit for the USB channel shown in Figure 7 if the USB channel is utilized.
- External pull-up resistors (2.2 kΩ) are recommended on I2C signals if the channel is utilized.
- A pull-up resistor (4.7 kΩ to 10 kΩ) is recommended on the uart_apb_sin signal if the UART is utilized.
- A pull-up resistor (4.7 kΩ to 10 kΩ) is recommended on connector pin 58 Discrete I/O pin 2.
- The Mg frame of the camera should be tied to chassis ground to ensure proper EMI shielding.



Part Description	Vendor	Part Number	Ref Des
RES SMD 0.0 OHM JUMPER 1/20W	Venkel	CR0201-20W-000T	R2
CAP CER 0.1uF 10V X5R 0201	Murata	GRM033R61A104KE15D	C5,C6,C10,C11
CAP - CER 10UF 6.3V 20% X5R 0402	TDK	C1005X5R0J106M050BC	C7
PTC Resettable Fuse 6V 1.5A, SMT 0805	Littelfuse Inc.	0805L150SL	RT1
VARISTOR 7.1V 20A 0402	Littelfuse Inc.	V5.5MLA0402NR	TVS1
TVS DIODE 3.6VWM 8VC SOT3	Texas Instruments	TPD2EUSB30ADRTR	TVS2
TVS DIODE 5.5VWM 8VC 10SON	Texas Instruments	TPD4EUSB30DQAR	TVS3
CHOKE COMMON MODE USB2.0 0805	Coilcraft	0805USB-901MLC	L1
FERRITE CHIP 120 OHM 3000MA 0603	Murata Electronics	BLM18SG700TN1D	FB1

FIGURE 7: RECOMMENDED USB PROTECTION CIRCUITRY TO BE IMPLEMENTED ON INTERFACING ELECTRONICS

5 SIGNAL PIPELINE

A high-level block diagram of the signal pipeline is depicted in

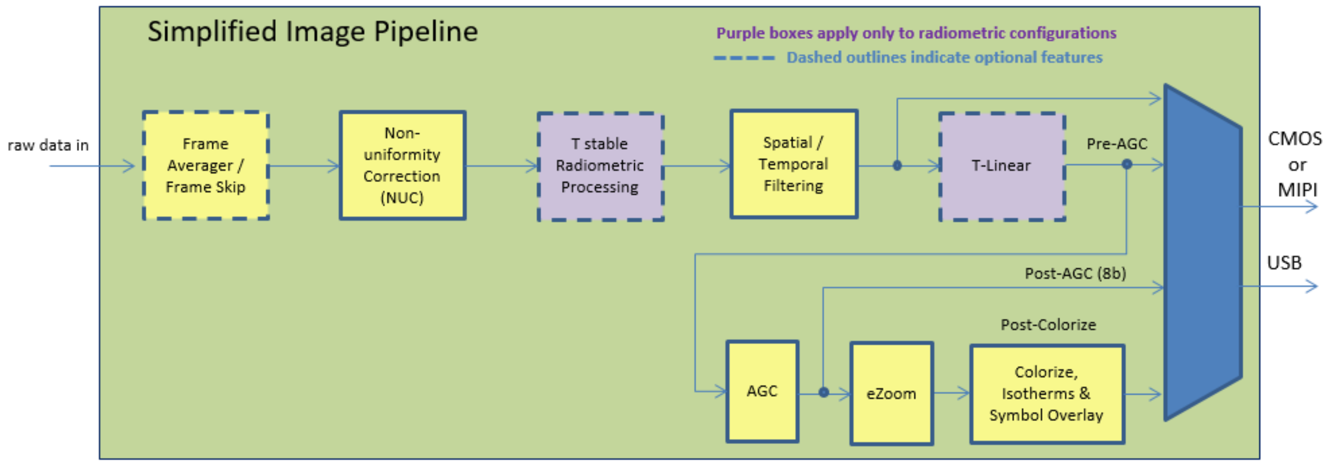


Figure 8. The pipeline includes optional frame averager and frame-skip features, NUC and defect replacement, spatial and temporal filtering, optional radiometric processing and temperature-conversion (select configurations only), automatic gain correction (AGC), electronic zoom, colorization, and symbol overlay. All processing blocks are described in more detail in the sections to follow. Video can be tapped at various locations within this pipeline. See Sections 7.12 (CMOS), 0 (MIPI), and 0 (USB) for a complete description of the video output properties at each tap.

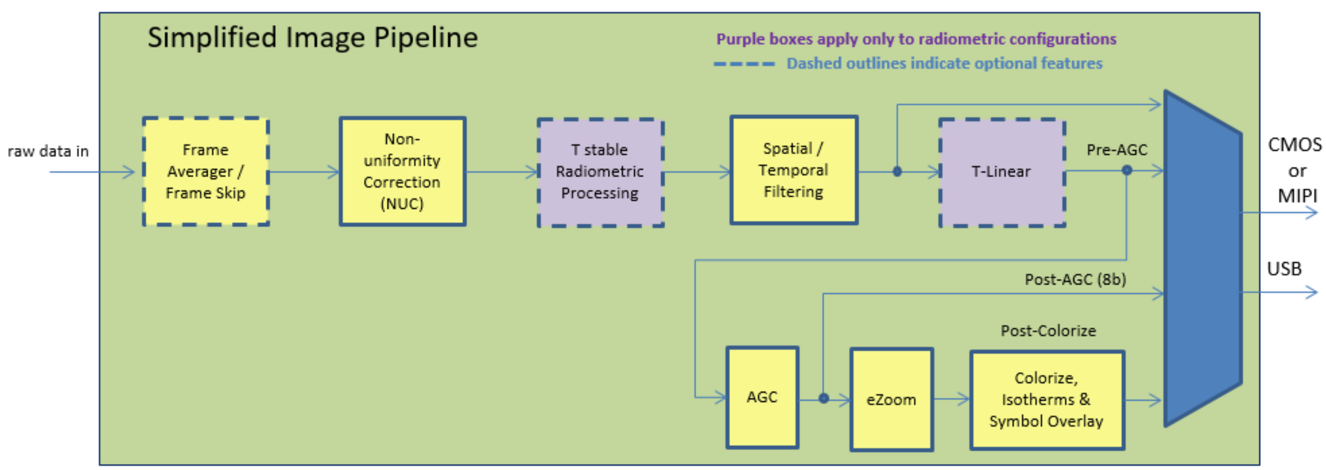


FIGURE 8: BOSON+ SIGNAL PIPELINE

5.1 Frame Averager

At the beginning of the signal pipeline, Boson+ provides an optional frame-averager block (disabled by factory default). The remainder of the signal pipeline operates at a 60Hz frame rate when the averager is disabled and at 30Hz when enabled. The primary benefits of enabling the averager are power reduction and NEDT improvement. Depending upon configuration, power savings approaching 100 mW can be realized, as shown in Section 12.2. NEDT improvement is on the order of 20%. Boson+ utilizes a “smart averager” that minimizes blur during scene motion. When there is motion between the two input frames, the frame data received later in time is provided as output without averaging. A comparison between a simple averager and the Boson+ smart averager is shown in Figure 9.

(a) Simple averager

(a) Boson “smart averager”

FIGURE 9: BOSON+ SMART AVERAGER PREVENTS BLUR IN MOVING SCENES

NOTE: Intended use case is that the averager mode is specified and saved as a power-on default (Section 6.1). A change to the averager mode will not affect the frame rate on the current power cycle. To change the frame rate, the change to the averager mode must be saved as a power-on default and then the camera reset or power cycled. If the change to averager mode is not saved as a power-on default, the selection is inconsequential since it does not affect the current power cycle.

5.2 Frame Skip

Following the optional averager function is an optional frame-skip feature that can further reduce frame rate and power dissipation. The frame skip value *fs* can be set to any integer value between 0 and 6, with the resulting output frame rate calculated as FR / (*fs* + 1) where FR = 60Hz if the averager function is disabled and 30Hz otherwise. The factory default value is fs = 0 for an output frame rate of 60Hz. Setting *fs* = 0xFFFF is a special lowest-power standby case resulting in *all* frames being skipped (e.g., 0Hz output). In this state, all functions of the CCI are still intact.

5.3 Non-Uniformity Correction (NUC)

The NUC block applies correction terms to ensure uniform output from each pixel when the camera is imaging a uniform thermal scene such as a blackbody (BB) plate. Factory-calibrated NUC terms are applied to compensate for temperature effects, pixel response variations, lens-illumination roll-off, and out-of-field irradiance. These terms are enabled by factory default and most users will have no reason to disable them except as noted below.

- FFC: Unlike all other corrections applied by the NUC block, FFC is not one-time calibrated. Instead, it is updated periodically at runtime via a process called flat-field correction (FFC). The FFC process is further described in Section 6.6.
- Temperature-correction: A correction term that compensates for pixel-to-pixel offset variation over the operating temperature.
- Gain: A correction term that compensates for pixel-to-pixel responsivity variation. This term is the product of two components. One compensates for variations stemming from the sensor assembly and the other for variations stemming from the lens assembly. On lensless camera configurations or when the Boson+ camera is installed behind another optical component, the latter component of the gain term (referred to as the lens-gain map) should be field calibrated by the user as described in Section 6.13.
- SFFC: A correction term compensating for out-of-field irradiance (i.e., the heat radiating from surfaces inside the camera assembly). If the Boson+ is installed in an enclosure or environment that significantly increases or reduces camera self-heating, it is recommended that SFFC be field calibrated by the user as described in Section 6.13.
- Bad pixel replacement (BPR): A correction process whereby pixels identified as defective are replaced by a value generated from its nearest neighbors.

All the above corrections are arranged into three separate constructs:

- NUC Tables: Contain the temperature-compensation terms and the portion of the gain term that compensates for variations stemming from the sensor assembly. All NUC tables are factory calibrated. There are 4 NUC tables stored within the camera:
  - NUC Table 0: NUC Table 0 is calibrated for low-gain and spans the entire operating temperature range of -40°C to 80°C.

- NUC Tables 1-3: NUC Tables 1 through 3 are calibrated for high-gain, each spanning a portion of the total operating temperature range. NUC Table 1 is calibrated from approximately -40°C to -20°C, NUC Table 2 is calibrated from approximately -20°C to 60°C, and NUC Table 3 is calibrated from approximately 60°C to 80°C. With the default automatic gain mode, Boson+ automatically loads and applies the proper table at start-up. If during operation the camera heats or cools down such that a different table is optimal, the camera switches tables automatically (if in automatic FFC mode) or signals a *Table Switch Desired* status if in manual or external FFC mode. The camera may also be configured to stay in a specific NUC Table if desired. See Section 7.9 for a description of FFC modes. See Section 6.14.3 for a description of the *Table Switch Desired Status.*

- Lens Tables: The lens tables are comprised of the portion of the gain term stemming from the lens assembly, the SFFC correction, and (for shutterless or field-calibrated cameras) the NVFFC. At start-up, Boson+ automatically loads whichever lens table is stored as the power-on default (Lens 0 or Lens 1). The switch from one lens table to another is only via user command. Boson+ configurations that include a lens are shipped with factory-calibrated lens gain and SFFC correction terms in Lens 0, while Lens 1 is empty. As described in Section 6.13, replacing the factory calibration with a field calibration may be beneficial depending upon installation conditions. Lensless configurations are shipped with both Lens 0 and Lens 1 empty and it is necessary to perform a field calibration once a lens is installed. The decision to calibrate the NVFFC map is application-dependent, as described in Section 7.9.1.

- Defect Map: there is a single defective-pixel map, which is applied independently of NUC-table or Lens-table selection. The map is factory calibrated, but the user has the option of adding pixels. This operation occurs automatically as part of the lens-calibration process described in Section 6.13. The user also has the option to restore the factory-calibrated map if non-defective pixels are inadvertently added during operation.

5.4 Spatial / Temporal Filtering

The signal pipeline includes several image filters designed to enhance the signal-to-noise ratio (SNR) by reducing temporal noise and residual non-uniformity. The filtering suite includes Teledyne FLIR's Silent Shutterless NUC (SSN)™ technology, an advanced set of scene-based NUC algorithms. SSN isolates fixed pattern noise (FPN), which is then removed dynamically. The filtering suite also contains algorithms optimized for reduction of row and column noise. Like the NUC block, the filtering steps performed in this block are transparent to the user and require no external intervention or support.

Below is a brief description of the various filters enabled by factory default. Factory default filters will work for most applications. Disabling filters may result in degraded noise and/or uniformity.

- Spatial Column Noise Reduction (SCNR): A filter to minimize column noise.
- Spatial Row Noise Reduction (SRNR): A filter to minimize row noise.
- Silent Shutterless NUC (SSN): A filter to minimize random spatial noise.
- Low-Frequency Shading Reduction (LFSR): A filter to reduce image side-to-side gradients and circularly symmetric gradients caused by suboptimal environmental conditions. This is enabled by default on shutterless cameras only.
- Temporal Filter (TF): A filter to minimize temporal noise. The TF must be enabled when LFSR or SSN are enabled. If the application of temporal filtering is not desired, set the Delta NF parameter to 255 to allow LFSR and SSN to continue to operate without temporal filtering applied.

NOTE: Teledyne FLIR recommends using either the Boson+ internal shutter or an external shutter periodically for best image quality.

5.5 Radiometry

Configurations of Boson+, which are radiometric capable, feature the ability to output a "temperature stable" output or a "temperature linear" output. For the former, the 16b output is intended to be linear with input flux (i.e., target irradiance) and independent of the camera's temperature. In the latter, the input flux is translated to absolute temperature (Kelvin) such that the output is linear with scene temperature. For temperature linear output, parameters such as target emissivity and atmospheric transmission can be adjusted to reflect current imaging conditions. See Section 6.2 for a more complete description.

5.6 AGC

Boson+ provides a highly configurable contrast enhancement algorithm for converting 16-bit data to an 8-bit output suitable for display. Unlike the NUC block and Spatial/Temporal Filtering block, the AGC block includes several user-selectable parameters which allow the image enhancement to be tailored for application, scene conditions, and subjective taste. See Section 6.8 for a complete description of the algorithm and all associated parameters.

(a) Linear AGC example.

(b) Histogram-based AGC example

FIGURE 10: EXAMPLE IMAGERY WITH LINEAR AND HISTOGRAM-BASED CONTRAST ENHANCEMENT

5.7 eZoom

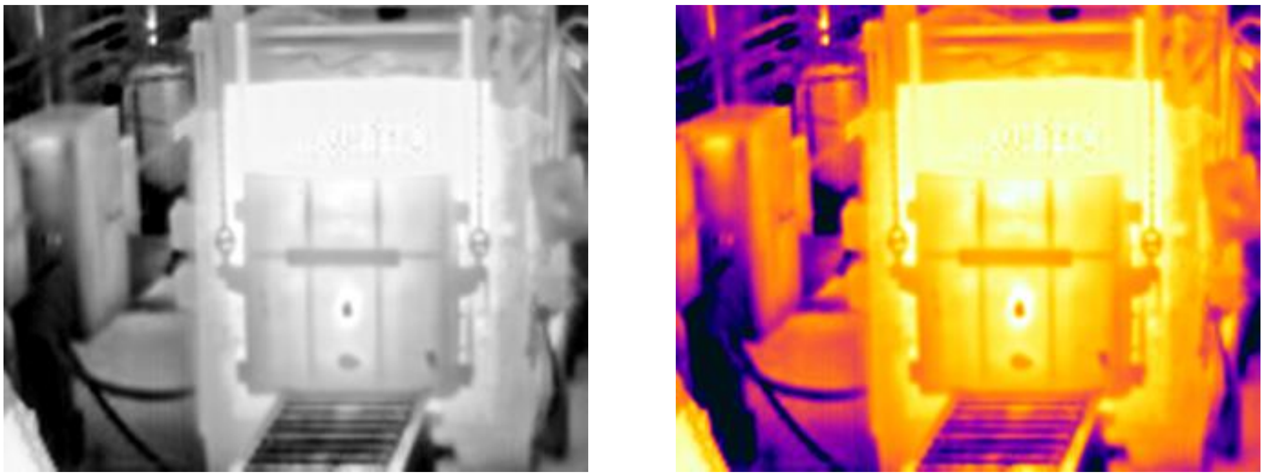
The electronic zoom block provides an optional interpolation of a subset of the field of view to the 640x512 resolution of the output stream. For example, it is possible to select the central 50% of the pixel area and stretch it to the full output resolution, resulting in a 2X zoom. See Section 0 for a complete description of the feature and its associated parameters.

(a) 1X zoom (full FOV displayed) (b) 2X zoom (half FOV displayed)

FIGURE 11: EXAMPLE IMAGERY SHOWING EZOOM

5.8 Colorize

The colorize block takes the contrast-enhanced, post-eZoom thermal image as input and generates an output in which a color palette is applied. Boson+ provides several built-in color palettes, as described in Section 0.



(a) Monochrome Image (b) Colorized Image

FIGURE 12: EXAMPLE IMAGERY SHOWING COLORIZATION

5.9 Symbol Overlay

The symbol-overlay block overlays symbol patterns over the infrared image. In addition to several automatic symbols described in Section 6.11, the symbol overlay block also allows the display of user-specified symbols, as exemplified in Figure 13. A full description of custom-symbol capabilities is provided in Section 6.12.

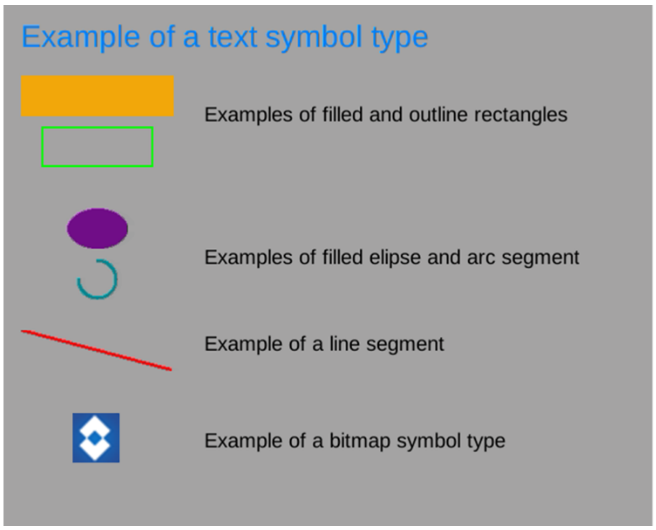


FIGURE 13: EXAMPLES OF BOSON+ SYMBOL TYPES

5.10 Latency

Latency of the signal pipeline is defined as the time difference between when the signal level of a given pixel is read from the sensor and when that signal is available as output from the camera. Referring back to Figure 8, latency is the time for “raw data in” to be fully processed to “data out” at the selected video channel. Teledyne FLIR measures latency as the time difference between an external sync signal and the *cmos_vsync* output.

The latency value varies depending upon where in the signal chain the output is tapped, as follows:

- Pre-AGC: ~6 ms
- Post-AGC: ~7 ms (1 ms greater than the pre-AGC tap)
- Post-zoom: ~25 ms (18 ms greater than the post-AGC tap)

NOTE: The averager function combines two frames of the data from the sensor. The latency numbers shown above apply to the second of the two frames (the later frame) when the averager is enabled.

NOTE: The nominal thermal time constant, 8 ms, is not included in the pipeline latency definition.

6 CAMERA FEATURES

Boson+ provides several operating features, more thoroughly defined in the following sections.

6.1 Power-On Defaults (User Selectable)

Boson+ provides a "save defaults" capability which allows all current mode and parameter settings to be stored as power-on defaults. Boson+ also provides the ability to restore the original factory default settings that can be re-saved as power-on defaults. See Section 8.1 for a list of affected modes and parameters and the factory-default value for each setting.

6.2 Radiometry

NOTE: Only part numbers that have an "R" as their second-to-last digit support radiometric output. The option to support radiometry requires additional factory calibration and not all lens types provide the option. Please contact your Teledyne FLIR sales representative or certified Teledyne FLIR distributor for more information on which lens types currently support radiometry.

Some configurations of Boson+ provide the option of radiometric output. For such configurations, the 16b output (14b output with MIPI) can be configured to "temperature stable" or "temperature linear" as described below and depicted in Figure 14.

- Temperature-stable output: 16b output (14b output with MIPI) value is intended to be proportional to scene-flux only and independent of camera temperature. When imaging a given scene, the output image is stable even if the camera's temperature varies, as shown in the middle graph of Figure 14. By comparison, output varies significantly with camera temperature when radiometry is disabled, as illustrated in the left-most graph.
- Temperature-linear output: 16b output (14b output with MIPI) value is intended to be directly proportional to scene temperature. In high-gain state, the value corresponds to scene-temperature in Kelvin multiplied by 100 (25 with MIPI output), and in low-gain state corresponds to Kelvin multiplied by 50 (12 with MIPI output). For example, expected output in high-gain state when imaging a 20°C BB is (20°C + 273.15) * 100 = 29,315, as depicted in the right-most graph of Figure 14. In practice, radiometric error prevents an output that corresponds perfectly with scene temperature. See Section 11.5 for a discussion of radiometric accuracy.

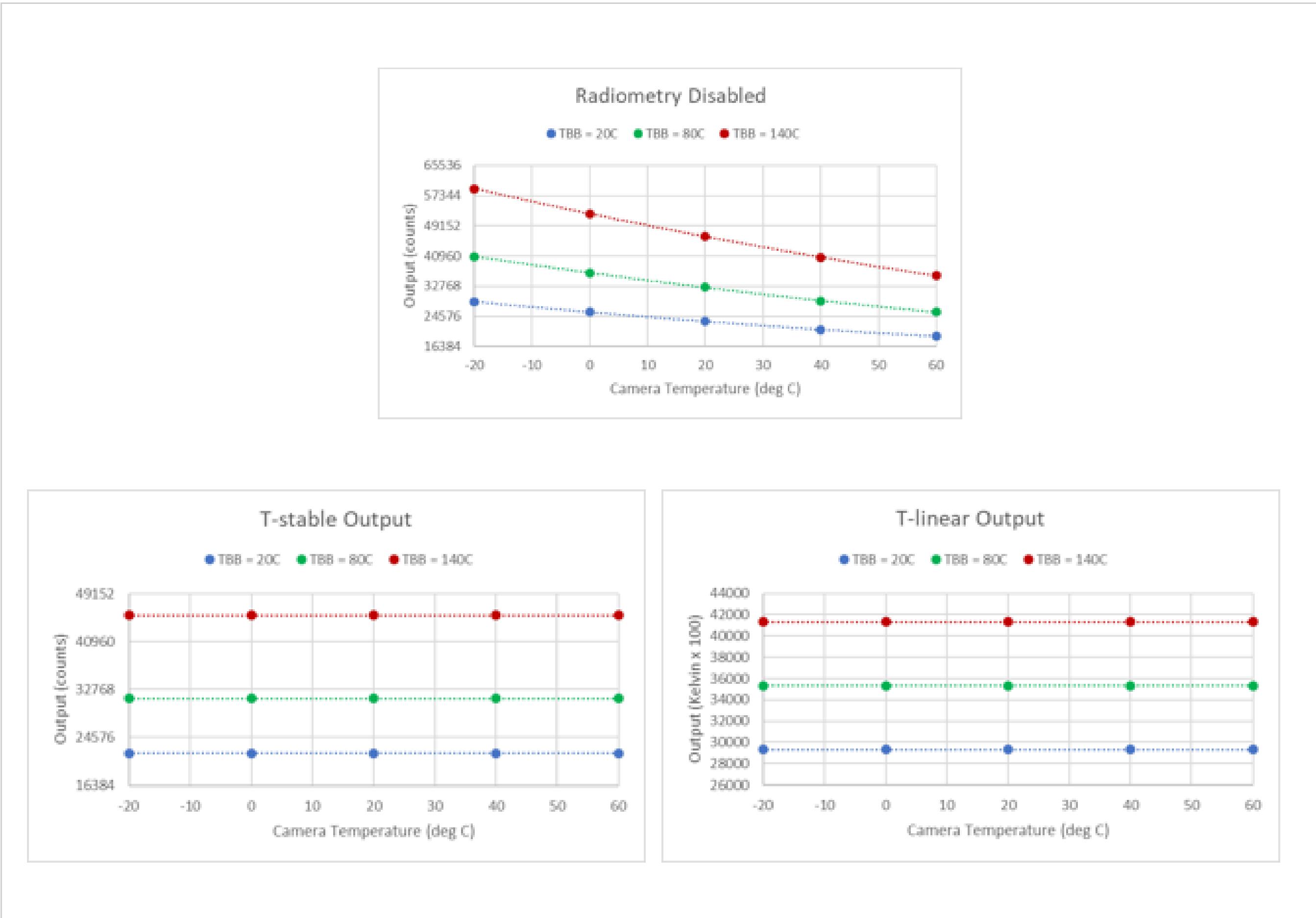


FIGURE 14: OUTPUT VS. CAMERA TEMPERATURE COMPARISON: RADIOMETRY DISABLED, T-STABLE, AND T-LINEAR

From an image-quality standpoint, both radiometry modes produce nearly identical performance (no significant effect on NEDT) and either mode is appropriate for strict imaging applications. For applications in which temperature measurement is required, radiometry must be enabled.

6.2.1 Environmental Factors

Environmental factors must be properly set to achieve optimal radiometric accuracy. In the Boson+ App, they are available in the Radiometry tab.

- **Window Temperature:** The temperature of the IR transmissive window in the optical path of the camera
- **Window Transmission:** The transmission of the IR transmissive window in the optical path of the camera
- **Window Reflection:** The reflection of the IR transmissive window in the optical path of the camera
- **Window Reflection Temperature:** The reflection of the internal temperature on the camera side of the IR transmissive window in the optical path of the camera
- **Atmospheric Transmission:** Transmission of the atmosphere in the optical path between the camera and the target
- **Atmospheric Temperature:** Temperature of the atmosphere (air) between the camera and the target
- **Emissivity Target:** Emissivity of the target
- **Background Temperature:** Temperature of the scene background being imaged (typically near ambient)

FIGURE 15: DEFAULT ENVIRONMENTAL FACTORS AS SHOWN IN THE BOSON+ APP

6.2.2 Spot Meter Accuracy

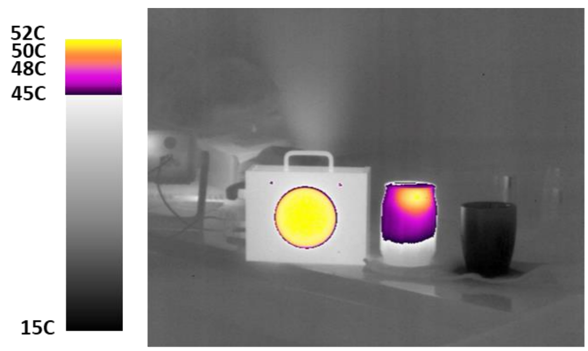
Spot Meter Accuracy represents a measure of the expected radiometric performance by reporting an integer value based on a comparison between the as-calibrated environment and the current camera conditions. A low value indicates more optimal camera conditions and therefore will occur when camera conditions are such that the camera is able to generate a more accurate temperature measurement.

TABLE 4: SPOT METER ACCURACY LOOKUP TABLE

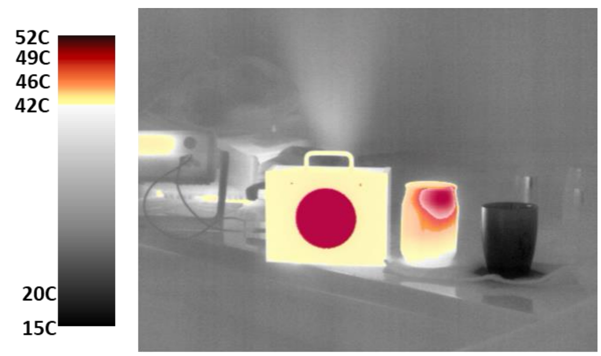
SPOT METER ACCURACY	UNCERTAINTY FACTOR	DESCRIPTION
Best	Scenario 1	Best-case conditions stated in Section 11.5.1
Good	Scenario 2	Steady-state conditions at ambient temperatures within the valid operating temperature range but outside those of Scenario 1
Stable	Scenario 3	Thermally dynamic conditions within the valid operating temperature range with some allowance for a slow rate of temperature change
Unstable	Scenario 4	Any condition outside of Scenario 3
Disabled	Scenario 5	Radiometric data not relevant, either radiometry or spot meter is disabled

6.3 Isotherms

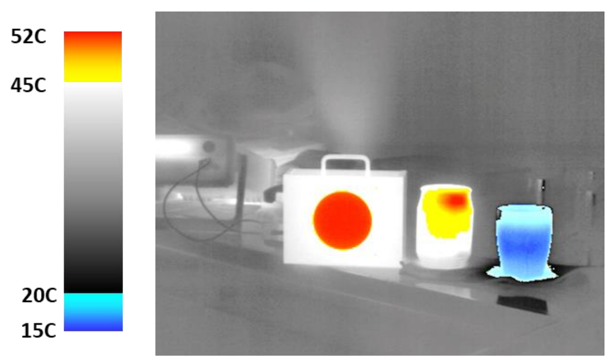
Boson+ provides an optional Isotherm feature for colorizing pixels at the post-colorization video tap. Figure 16 illustrates some of the potential uses of the Isotherms feature.



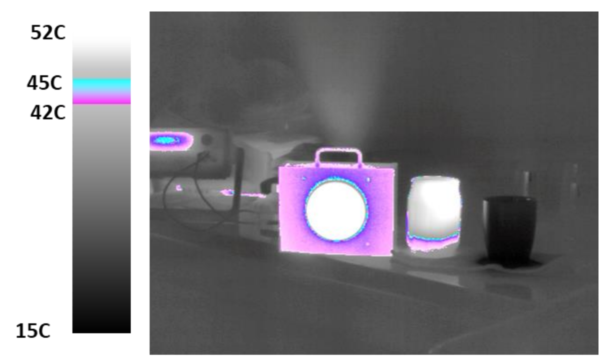
(a) Colorize hot objects



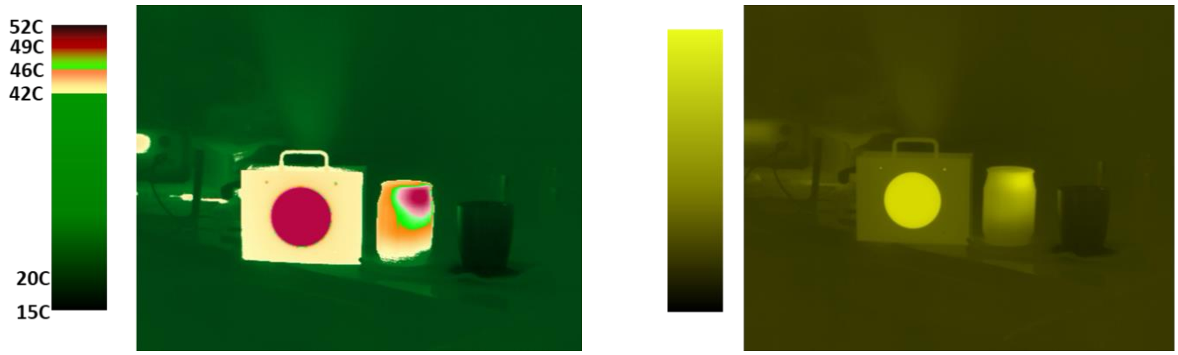
(b) Colorize hot objects



(c) Colorize hot and cold objects



(d) Colorize mid-range objects



(e) Colorize hot objects, green-hot for all else

(f) Yellow-hot (monochrome) palette

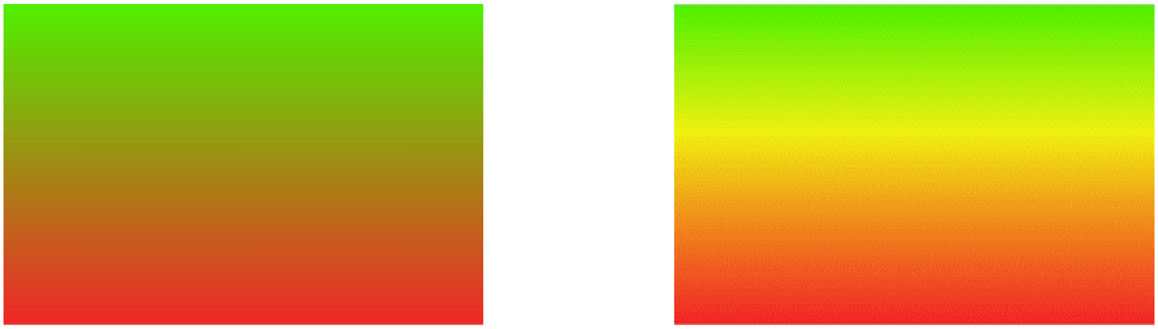
FIGURE 16: EXAMPLE IMAGERY WITH VARIOUS ISOTHERM SETTINGS

The Isotherm feature allows the full 16b range of the camera to be divided into five regions. Different colorization schemes can be applied to each region. The boundaries between regions are specified as a percentage of the 16b range (e.g., 0% = 0 counts, 100% = 65535). For those configurations that support radiometry, boundaries can alternatively be specified in temperature units (Figure 16).

While using isotherms, Teledyne FLIR recommends using AGC linear Percent (Section 6.8.5) at or above 90% or 0.90. This will avoid regions of the isotherm bands being disrupted by non-linear grey bands that are using a histogram equalization set to grey levels (and subsequently to colors).

The Colorization mode of each Isotherm region can be independently selected from one of the following five options, all of which are shown in Figure 18:

- **Linear-RGB mode**: post-colorization output of pixels in a region with mode set to **Linear RGB** mode is linearly interpolated from two specified endpoint colors. For example, if the lower boundary is set to 30°C and assigned an RGB color value of (240,240,0) and the upper boundary is set to 40°C and assigned a color value of (240,0,40), a pixel imaging a 35°C object will have an output color value of (240,120,20).
- **Linear-HSV mode**: identical to **Linear-RGB** mode except that interpolation is performed in Hue Saturation Value (HSV) color space rather than in RGB color space. Use of this color space provides some color mappings that are not possible in RGB. An example is shown in Figure 17. Notice that the colors at the top and bottom are identical, but the interpolated colors in between are not.

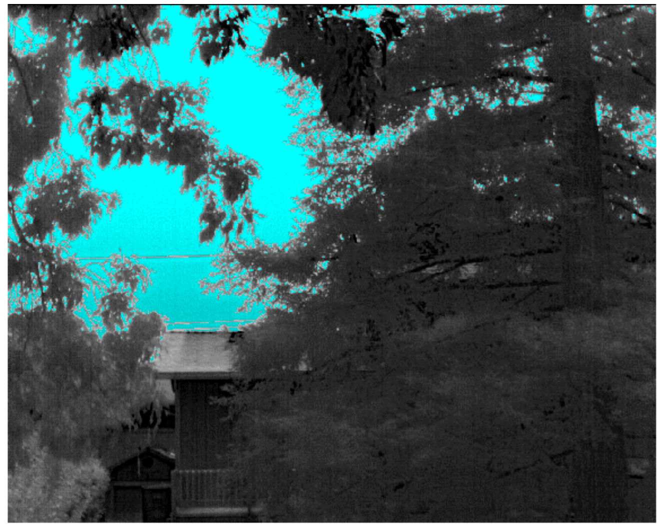


(a) RGB interpolation (b) HSV interpolation

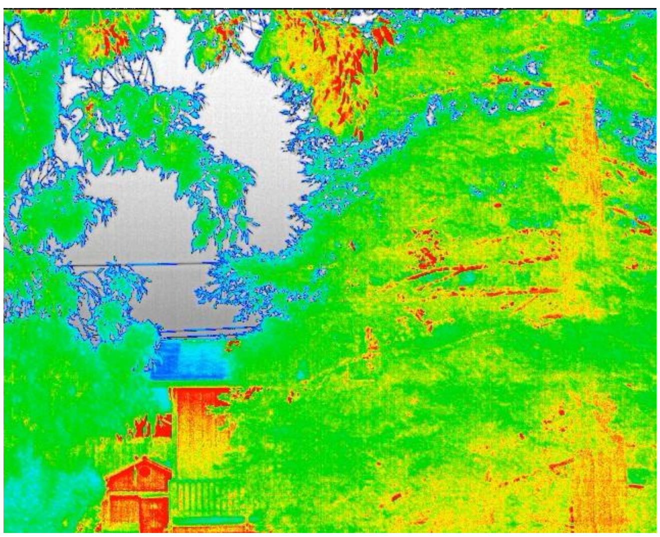
FIGURE 17: EXAMPLE OF RGB VS. HSV INTERPOLATION

- **Standard mode**: post-colorization output of pixels in a region set to **Standard** mode appear the same with isotherms enabled as they do with isotherms disabled if the same colorization LUT is chosen for each mode. The output value of each pixel in a **Standard** region is based strictly on the AGC algorithm and colorization LUT chosen.
- **Non-Linear mode**: post-colorization output of pixels in all such regions are mapped non-linearly between colors, independent of the palette setting and the colorization mode of other regions. This mode attempts to mimic the non-linear AGC algorithm. A potential advantage of **Non-Linear** mode over **Standard** mode is better utilization of available colors. When much of an image is in one or more regions set to **Linear RGB** mode or **Linear HSV** mode, regions set to **Standard** mode may use only a small fraction of the gray shades, as illustrated in Figure 18c. Conversely, regions set to **Non-Linear Gray** mode use the full spectrum of gray shades, as illustrated in Figure 18d.
- **Single-Color mode**: post-colorization output of pixels in a region set to **Single-Color** mode have the same luminance value as with isotherms disabled. However, chrominance values are based on a single specified color. This mode readily supports monochrome color palettes (e.g., red hot).

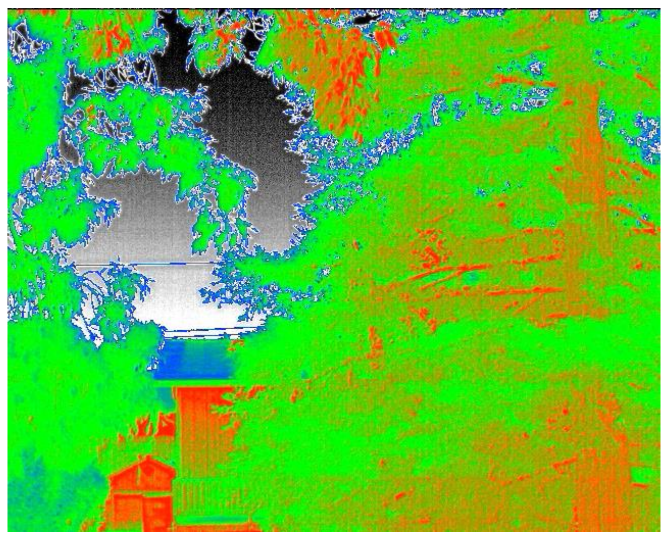
(a) Isotherms disabled, black-hot palette



(b) **Standard** mode (hotter foreground) and **Single-Color** modes (cooler background)



(c) **Linear-HSV** mode (hotter foreground) and **Standard** mode (cooler background)



(d) **Linear-RGB** mode (hotter foreground) and **Non-Linear Gray** mode (cooler background)

FIGURE 18: EXAMPLES OF EACH ISOTHERM MODE

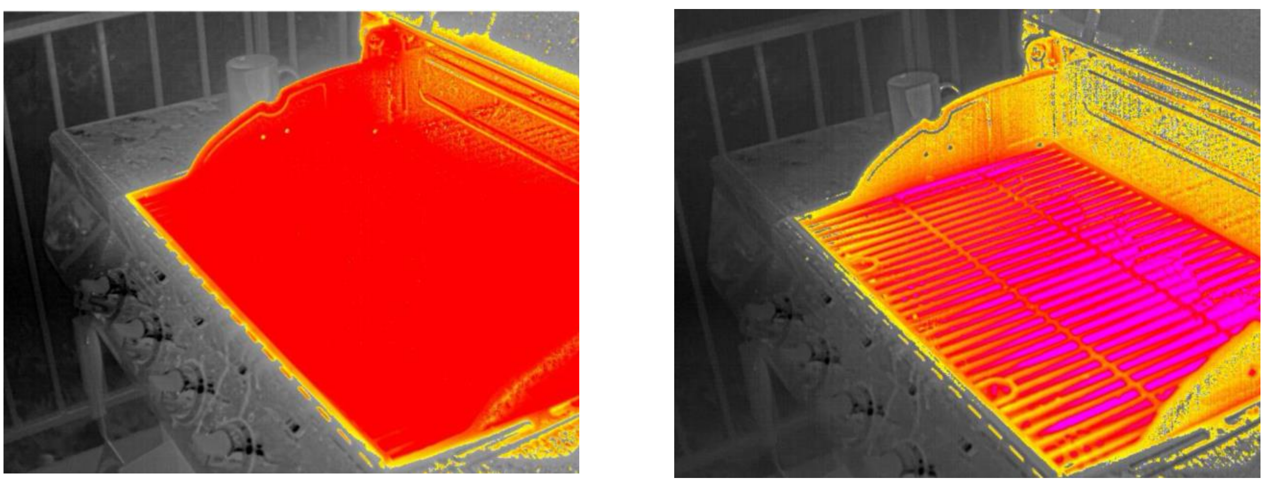
6.4 Spot Meter and Image Statistics

Boson+ provides an Image Statistics feature that reports average pixel value, minimum pixel value, maximum pixel value, and standard deviation within a specified region of interest (ROI). In addition, Boson+ provides a separate Spot Meter feature. Key differences between the Image Statistics feature and the Spot Meter feature are as follows:

- Both features report mean, standard deviation, minimum value, and maximum value upon command and via the telemetry line. The Spot Meter also reports the location (i.e., x,y coordinates within the sensor) of the pixel with minimum value and the pixel with maximum value.
- The Image Statistics feature collects its statistics after the NUC block in the signal pipeline (Figure 8). The Spot Meter feature collects its statistics at the end of the 16b pipeline. Consequently, for configurations which provide radiometric capability, the Spot Meter is for the temperature-stable signal (if Radiometry is enabled and T-linear conversion is disabled) or the temperature-linear signal (if Radiometry and T-linear conversion are both enabled). Units are reported in temperature units (Kelvin x 100) if the 16b tap is configured for temperature-linear output.
- The Spot Meter mean value can be displayed on-screen as a numeric value or thermometer-style gauge. See Section 6.11 for more information on symbol overlays.
- The ROI for the Image Statistics and Spot Meter features are independently configurable. For example, the Image Statistics feature can be configured to collect statistics from the full array, while the Spot Meter feature is configured to collect statistics from a 16x16 pixel area in the center of the array. The maximum Spot Meter ROI is 128×128 pixels.
- The Image Statistics mean value is the basis for gain-state switching, as described in Section 0.

6.5 Dynamic-Range Control

To support a wide range of scene temperatures while providing optimum sensitivity, Boson+ provides two gain states: high-gain and low-gain. In high-gain state, the thermal sensitivity is highest (i.e., NEDT is lowest), but hot objects in the scene are prone to saturation. Similarly, very cold objects are prone to starvation when imaging with a very warm camera. In low-gain state, the thermal sensitivity is reduced but the scene range is significantly higher. See Sections 11.1 and 0, respectively, for NEDT and intrascene range in both gain states. Figure 19 depicts example imagery for both states. In the high-gain example, it is easier to see subtle temperature differences (e.g., smoke rising from the grill), but the entire surface of the grill is saturated. In the low-gain example, it is possible to resolve thermal details within the hot grill because the pixels are not saturated, but the subtler temperature differences are harder to discern.



(a) High-gain state
(higher sensitivity, lower scene range)

(b) Low-gain state
(lower sensitivity, higher scene range)

FIGURE 19: EXAMPLE IMAGES, HIGH-GAIN STATE AND LOW-GAIN STATE

Boson+ provides an automatic gain-switch mode by which the camera automatically selects the optimum gain state based on scene content and several user-specified parameters. The Boson+ 4.1 SW release adds two additional optional gain-switch modes to address starvation when imaging very cold scenes with a warm camera. Starvation describes the behavior of a warm camera imaging a cold scene where the signal output by the camera does not continue to decrease as the scene gets colder. This new cold scene switching is referred to as Cold Automatic Table Switch (CATS) below while the standard hot scene switching is referred to as Standard Automatic Table Switch (SATS). If SATS is not enabled, there is no change in how the automatic gain-switch behaves compared to previous releases. The logic for automatic gain-state switching is shown in Figure 20. The associated parameters are described in the following paragraphs.

- **Gain Mode** (high-gain, low-gain, or automatic): determines whether Boson+ automatically determines the optimum gain state based on current scene conditions. See Section 7.8 for a detailed description of these modes. The default value is high-gain. None of the remaining parameters listed below have any effect except when in automatic gain mode. Note: for shutterless operation, automatic gain mode is not recommended because several noise filters described in Section 5.4 are reset at each gain switch. This can result in poor image quality when toggling frequently between the two gain states.
- **Switch Conditions** (hot, cold, or hot_or_cold): when **Gain Mode** is set to automatic, this determines which switch conditions trigger an automatic gain switch. The default value is hot which implements SATS mode. SATS mode matches the behavior of previous releases. Setting this value to cold implements CATS mode and setting this value to hot_or_cold implements both SATS and CATS.
- **Gain Switch Hysteresis (Frames):** Denotes the number of consecutive frames for which a desired gain switch must be signaled before an automatic gain switch takes place.
- **Gain Switch Hysteresis (Seconds):** Denotes the time interval which must lapse before an automatic gain switch takes place.

In addition to the user-selectable parameters associated with the dynamic-range control feature, Boson+ provides three status variables reported via the telemetry line (Section 6.7) or by status request on the CCI (Section 8.1):

- *Current NUC Table*: The *Current NUC Table* variable has a value of 0 when operating in low-gain state and a value 1, 2, or 3 when operating in high-gain state. For an explanation of NUC Tables, see Section 5.3.
- *Desired NUC Table*: The *Desired NUC Table* variable is automatically set based on ambient temperature, scene conditions and the selectable parameters described previously. When in automatic gain mode, an automatic NUC table switch takes place whenever *the Desired NUC Table* value does not match the value indicated via *Current NUC Table.* In manual or external FFC mode, a table switch only occurs in response to “Table Switch” command. If *Current NUC Table* = 0 and *Desired NUC Table* > 0, a NUC table switch (automatic or commanded) causes the camera to switch from low-gain state to high-gain state. Conversely, if *Current NUC Table* > 0 and *Desired NUC Table* = 0, a table switch causes the camera to switch from high-gain state to low-gain state. The “Table Switch” command has no effect when *Current NUC Table* = *Desired NUC Table:* no table switch occurs under that condition.
- *Table Switch Desired*: The *Table Switch Desired* flag is set whenever *Desired NUC Table* is not equal to *Current NUC Table*. The flag is never set in automatic FFC mode: instead, an automatic table switch takes place. When in manual or external FFC mode, commanding a table switch when the flag is set will cause the switch to take place. Commanding a table switch when the flag is not set has no effect. By factory default, a red circle will appear in a location that circumscribes the *FFC Desired* symbol whenever the *Table Switch Desired* flag is set (Section 6.11).

6.5.1 Standard Automatic Table Switch (SATS)

SATS gain switching is enabled when **Gain Mode** is set to automatic and **Switch Conditions** is set to hot. The logic and parameters used for SATS are described below and are set independently of the parameters used for CATS.

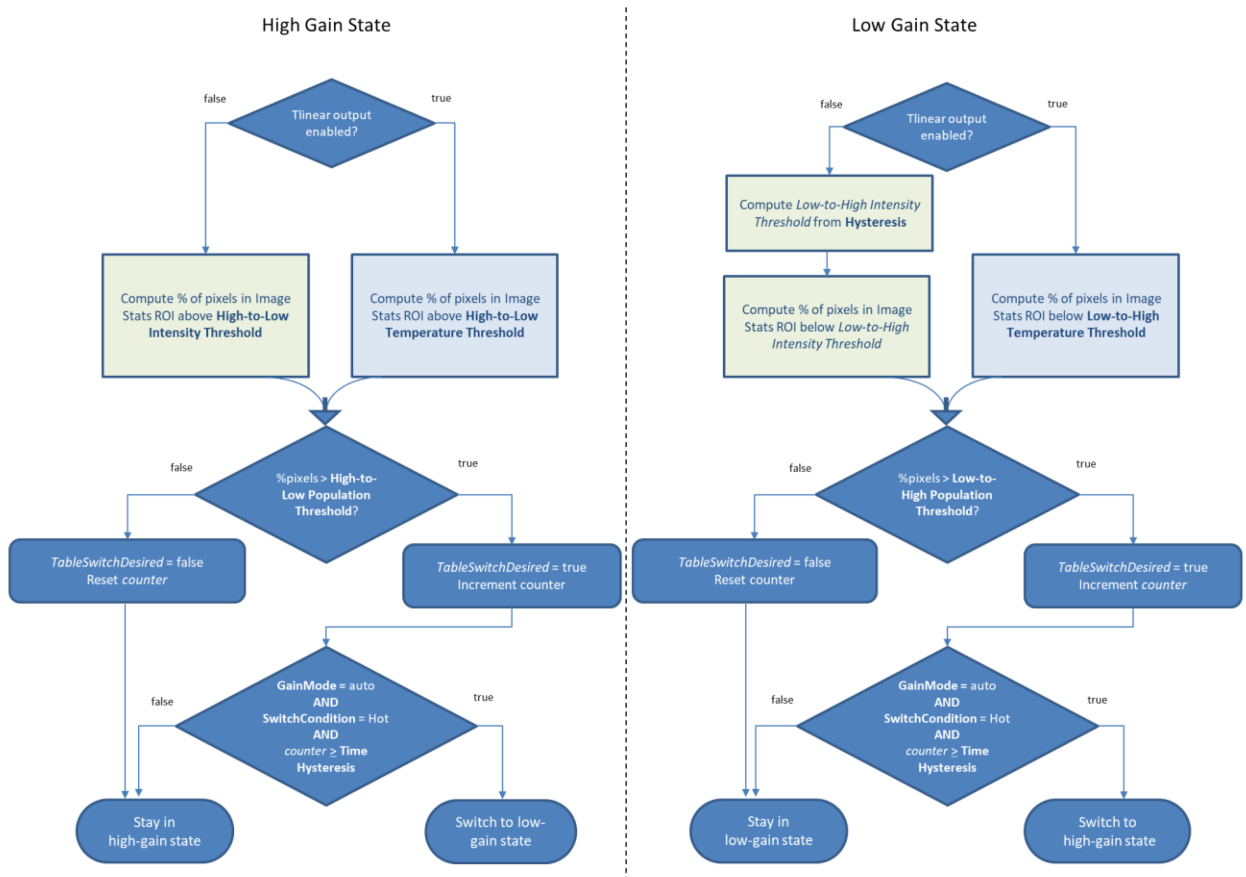


FIGURE 20: SATS AUTOMATIC GAIN-SWITCH LOGIC

- **High-to-Low Intensity or High-to-Low Temperature Threshold:** In conjunction with the parameter **High-to-Low Population** described below, either the **High-to-Low Intensity** or **High-to-Low Temperature Threshold** parameter defines the scene conditions which result in the camera determining that a switch from high-gain state to low-gain state is desired. **High-to-Low Temperature Threshold** only applies in configurations that support radiometry, and only if temperature-linear output is enabled. Otherwise, **High-to-Low Intensity Threshold** is used. The thresholds represent the flux level, expressed as the percentage required to achieve maximum output value, or as scene temperature (in Celsius) above which a pixel is scored as one that would benefit from transition to low-gain state. It is typically set to a value near high-gain saturation. The factory-default value of **High-to-Low Intensity Threshold** is 90%, representing 90% of the maximum output value. It is recommended under most operating conditions. For configurations that support radiometry, the factory-default value of **High-to-Low Temperature Threshold** is 200°C.

- **High-to-Low Population Threshold:** In conjunction with **High-to-Low Intensity Threshold** or **High-to-Low Temperature Threshold** described above, the **High-to-Low Population** defines the scene conditions that result in a desired change from high-gain state to low-gain state. This represents the percentage of the pixel population that must exceed the intensity or temperature threshold needed to signal a desired switch to low-gain state. The factory-default value is 20%. A larger value requires a larger percentage of pixels to be imaging hot objects to produce that result.
- **Low-to-High Population Threshold:** In conjunction with the **Hysteresis** or **High-to-Low Temperature Threshold** parameters described below, **Low-to-High Population Threshold** defines the scene conditions that result in the camera determining that a switch from low-gain state to high-gain state is desired. The **Low-to-High Population Threshold** represents the percentage of the pixel population that must fall below the intensity or temperature threshold to signal a desired switch to high-gain state. The factory-default value is 95%. To avoid scene conditions that might result in oscillation between gain states, the **Low-to-High Population Threshold** value cannot be set to less than 100% minus the **High-to-Low Population Threshold**.
- **Hysteresis** or **Low-to-High Temperature Threshold:** In conjunction with the **Low-to-High Population Threshold** parameter described above, either the **Hysteresis** or **Low-to-High Temperature Threshold** parameter defines scene conditions that result in the camera determining that a switch from low-gain state to high-gain state is desired. **Low-to-High Temperature Threshold** only applies in configurations that support radiometry and only if temperature-linear output is enabled. Otherwise, **Hysteresis** is used to calculate the internal variable *Low-to-High Intensity Threshold*. The resulting thresholds represent the signal level expressed as a percentage of maximum flux level in high-gain state or scene temperature (expressed in Celsius) below which a pixel is scored as being one that would benefit from transition to high-gain state. Whether using **Hysteresis** or **Low-to-High Temperature Threshold,** the lower the value, the cooler the scene must be to result in a switch to high-gain state. The factory-default value of **Hysteresis**, 90%.

6.5.2 Cold Automatic Table Switch (CATS)

CATS gain switching is enabled when **Gain Mode** is set to automatic and **Switch Conditions** is set to cold. The logic and parameters used for CATS are described below and are set independently of the parameters used for SATS.

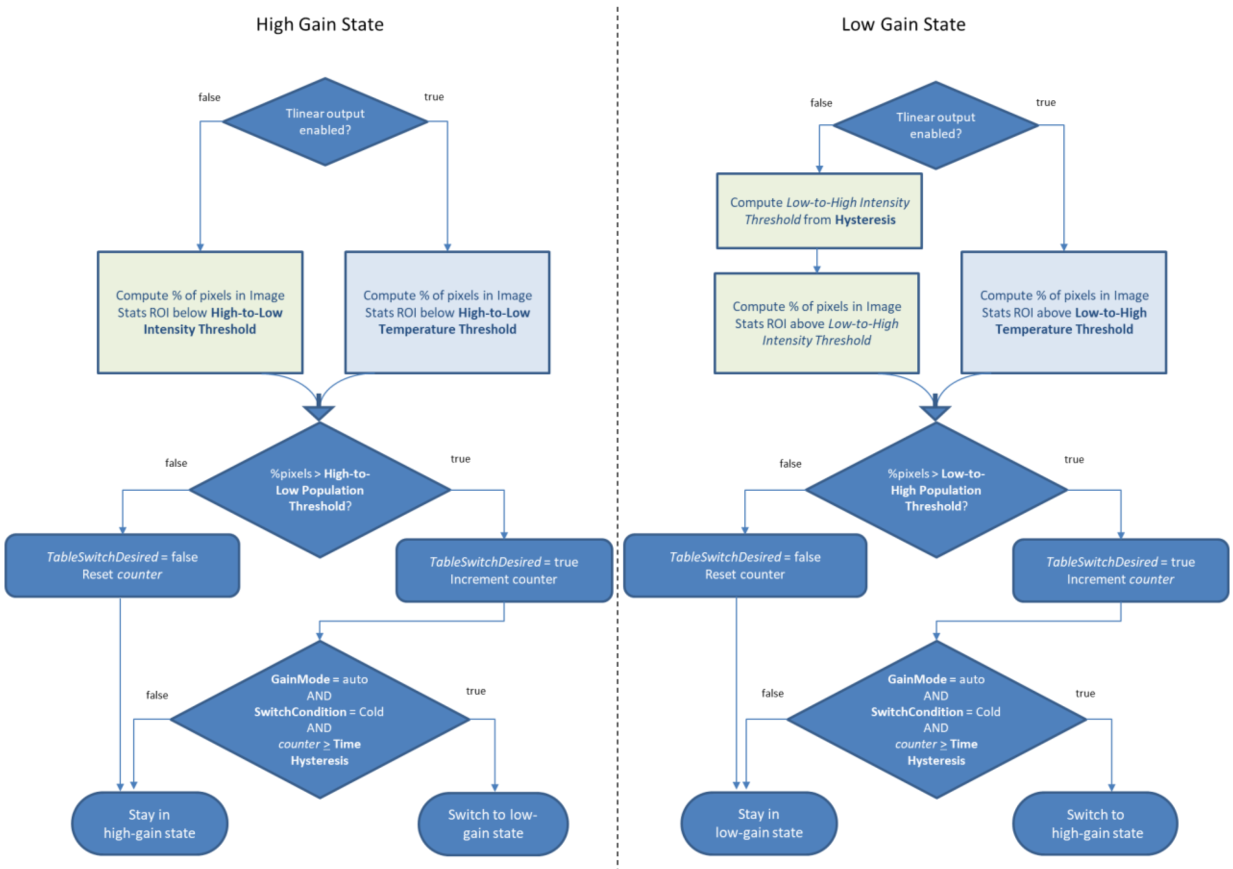


FIGURE 21: CATS AUTOMATIC GAIN-SWITCH LOGIC

- **High-to-Low Intensity or High-to-Low Temperature Threshold:** In conjunction with the parameter **High-to-Low Population** described below, either the **High-to-Low Intensity** or **High-to-Low Temperature Threshold** parameter defines the scene conditions which result in the camera determining that a switch from high-gain state to low-gain state is desired. **High-to-Low Temperature Threshold** only applies in configurations that support radiometry, and only if temperature-linear output is enabled. Otherwise, **High-to-Low Intensity Threshold** is used. The thresholds represent the flux level, expressed as the percentage required to achieve maximum output value, or as scene temperature (in Celsius) below which a pixel is scored as one that would benefit from transition to low-gain state. It is typically set to a value near high-gain cold saturation. The factory-default value of **High-to-Low Intensity Threshold** is 15%, representing 15% of the maximum output value. For configurations that support radiometry, the factory-default value of **High-to-Low Temperature Threshold** is 0°C.
- **High-to-Low Population Threshold:** In conjunction with **High-to-Low Intensity Threshold** or **High-to-Low Temperature Threshold** described above, the **High-to-Low Population** defines the scene conditions that result in a desired change from high-gain state to low-gain state. This represents the percentage of the pixel population that must be below the intensity or temperature threshold needed to

signal a desired switch to low-gain state. The factory-default value is 15%. A larger value requires a larger percentage of pixels to be imaging cold objects to produce that result.

- **Low-to-High Population Threshold:** In conjunction with the **Hysteresis** or **High-to-Low Temperature Threshold** parameters described below, **Low-to-High Population Threshold** defines the scene conditions that result in the camera determining that a switch from low-gain state to high-gain state is desired. The **Low-to-High Population Threshold** represents the percentage of the pixel population that must fall above the intensity or temperature threshold to signal a desired switch to high-gain state. The factory-default value is 90%. To avoid scene conditions that might result in oscillation between gain states, the **Low-to-High Population Threshold** value cannot be set to less than 100% minus the **High-to-Low Population Threshold**.
- **Hysteresis** or **Low-to-High Temperature Threshold:** In conjunction with the **Low-to-High Population Threshold** parameter described above, either the **Hysteresis** or **Low-to-High Temperature Threshold** parameter defines scene conditions that result in the camera determining that a switch from low-gain state to high-gain state is desired. **Low-to-High Temperature Threshold** only applies in configurations that support radiometry and only if temperature-linear output is enabled. Otherwise, **Hysteresis** is used to calculate the internal variable *Low-to-High Intensity Threshold*. The resulting thresholds represent the signal level expressed as a percentage of maximum flux level in high-gain state or scene temperature (expressed in Celsius) above which a pixel is scored as being one that would benefit from transition to high-gain state. Whether using **Hysteresis** or **Low-to-High Temperature Threshold,** the lower the value, the warmer the scene must be to result in a switch to high-gain state. The factory-default value of **Hysteresis**, 90%.

6.5.3 Both SATS and CATS

Both SATS and CATS gain switching is enabled when **Gain Mode** is set to automatic and **Switch Conditions** is set to hot_or_cold. The combined SATS and CATS mode uses the parameters described above for both SATS and CATS. The logic for the combined SATS and CATS mode is described below.

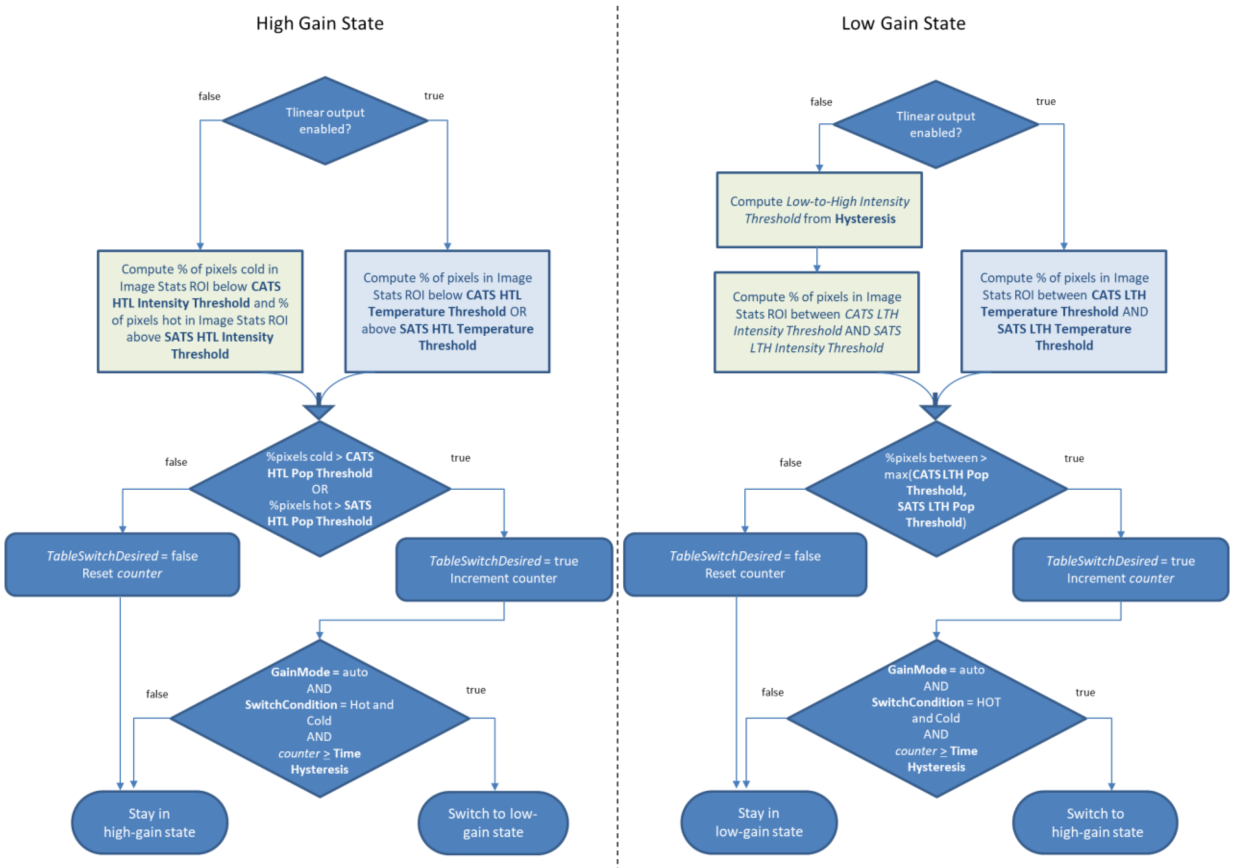
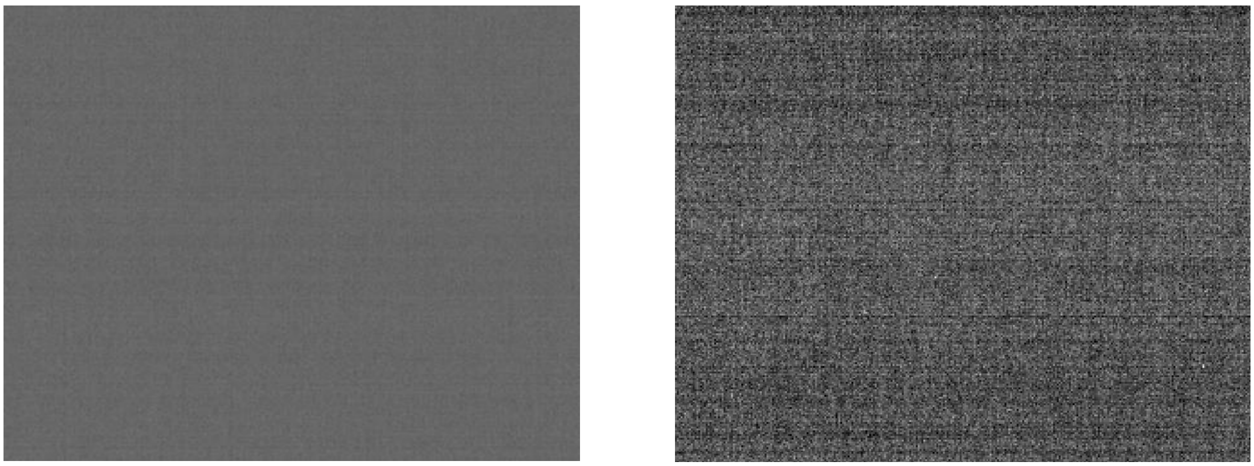


FIGURE 22: SATS AND CATS AUTOMATIC GAIN-SWITCH LOGIC

- **High-to-Low (HTL) Gain Switch:** A HTL gain switch is performed when either SATS or CATS indicates a HTL gain switch is desired (i.e., a HTL gain switch occurs if a HTL gain switch would occur when only SATS or only CATS is enabled.)
- **Low-to-High (LTH) Population Threshold:** The **LTH Population Threshold** is the larger of the SATS LTH Population Threshold and the CATS LTH Population Threshold described in the previous sections. The **LTH Population Threshold** represents the percentage of the pixel population that must fall between the SATS intensity or temperature threshold and the CATS intensity or temperature threshold to signal a desired switch to high-gain state. Note: A scene that causes a LTH gain switch if only SATS or CATS is enabled may not cause a LTH gain switch if both SATS and CATS is enabled.

6.6 Flat-Field Correction

Boson+ is factory calibrated to produce output imagery that is highly uniform when viewing a uniform-temperature scene, as shown in Figure 23a, but drift over long periods of time can degrade uniformity, resulting in grainier imagery as shown in Figure 23b. Operation over a very wide temperature range (e.g., powering on at -20°C and heating to 60°C) can also lead to a grainier image.



(a) Uniform image

(b) Grainy image

FIGURE 23: EXAMPLES OF UNIFORM AND GRAINY IMAGES

For scenarios with ample scene movement (such as most handheld applications), Teledyne FLIR's Silent Shutterless NUC (SSN) suite of algorithms allows Boson+ to automatically compensate for drift effects. For use cases in which the scene is essentially stationary (such as fixed-mount applications), SSN is less effective. In those scenarios, periodically performing a flat-field correction (FFC) is recommended. FFC is a process whereby the NUC terms applied by the camera's signal processing engine are recalibrated to produce optimal image quality. The entire process takes less than a second, during which a sensor is briefly exposed to a uniform thermal scene and the camera updates the NUC terms to ensure uniform output. As described in Section 7.9, Boson+ can be configured to perform FFC automatically or only upon command via the CCI. Boson+ can also be configured to use either its internal shutter or an external scene as the uniform source. In the latter case, the camera must be viewing the uniform scene before FFC is commanded.

NOTE: If FFC is performed in "External" FFC mode while imaging a non-uniform scene, the scene will be "burned in" to the correction map, resulting in severe image artifacts.

There are several user-selectable parameters associated with the FFC process which control when FFC events occur. Each is described below.

- **FFC Mode** (automatic, manual, or external) determines whether Boson+ performs FFC automatically and whether it uses the internal shutter during an FFC event. See Section 7.9 for a detailed description of these modes. Factory-default is "automatic" for configurations that include a shutter, and FFC events are triggered by:
    - Start-up
    - Expiration of internal timer with period specified by **FFC Period** (see below)
    - Temperature change beyond **FFC Temp Delta** (see below)
    - Change in NUC table (Section 5.3)
    - Explicit command

For configurations that do not include a shutter, factory default is "external" and no automatic FFC ever takes place.

- **FFC Integration Period**: During each FFC event, the camera automatically integrates *n* frames of sensor data to generate the resulting correction term. **FFC Integration Period** specifies the value of *n*, either 2, 4, 8, or 16. Utilizing fewer frames decreases the FFC period (with diminishing returns due to overhead). Utilizing more frames provides greater reduction of spatial noise (with diminishing returns due to 1/f noise). Figure 24 quantifies the benefit. The factory-default value is 8 frames for cameras that include a shutter and 16 frames for shutterless. Note that with averager enabled (i.e., 30Hz output rather than 60Hz output), a value of *n* frames represents twice as much time as with averager disabled, since frame period is twice as long.
- **FFC Period:** When the camera is in automatic FFC mode, **FFC Period** defines the maximum elapsed time between automatic FFC events. When the camera is in manual or external FFC mode, this parameter defines the maximum elapsed time before the *FFC Desired* flag is enabled (See below). **FFC Period** is specified in seconds (e.g., the factory-default value of 300 represents a 300 second (5 minute) maximum time between successive FFC events). A specified value of 0 is an exception and disables the time-based trigger. The factory-default value is recommended under most operating conditions. This can be independently controlled for high-gain and low-gain modes.
- **FFC Temp Delta:** When the camera is in automatic FFC mode, **FFC Temp Delta** defines the maximum temperature change of the FPA between automatic FFC events. When the camera is in manual or external FFC mode, this parameter defines the temperature change that triggers the *FFC Desired* flag being set. **FFC Temp Delta** is specified in tenths of a degree Celsius (e.g., the factory-default value of 10 represents a 1-degree Celsius temperature change between successive FFC events). A specified value of 0 is an exception and disables the temp-based trigger. The factory-default value is recommended under most operating conditions. This can be independently controlled for high- and low-gain modes.
- **FFC Start-up Period**: When Boson+ is powered on, it experiences rapid self-heating and benefits from more frequent FFC events than required during steady-state operation. **FFC Start-up Period** specifies a period (in seconds) after power-up during which the camera triggers FFC in response to temperature change equal to one-third of the value of **FFC Temp Delta**. For example, if **FFC Temp Delta** is set to its factory-default value, resulting in an FFC event for every degree when at steady-state, an FFC event

occurs every 1/3rd degree from start-up through the end of the **FFC Start-up Period**. The value of **FFC Start-up Period** is user-selectable but changing the factory-default value of 90 seconds is not recommended.

- **FFC Warn Time**: Prior to any automatic FFC event, Boson+ enters an FFC Imminent state signaled via the telemetry line and an on-screen warning. See Section 7.9 for more detail regarding the "FFC Imminent" state. The length of time that the camera remains in "FFC Imminent" state is user-selectable via the **FFC Warn Time** parameter. The factory-default value is two seconds.

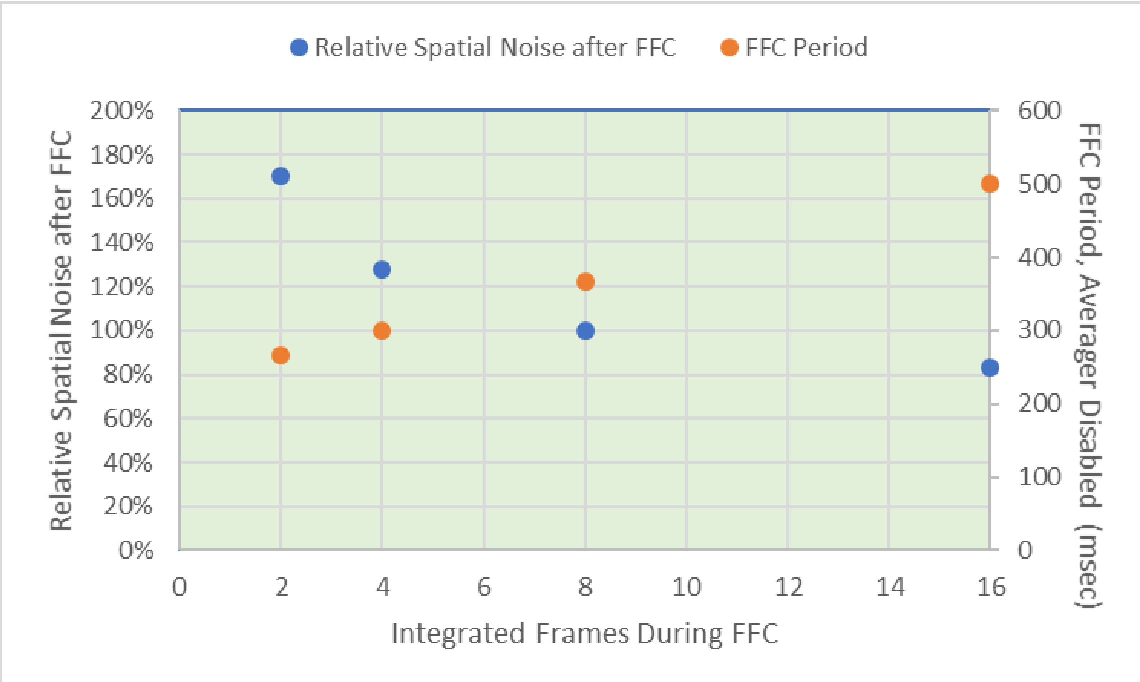


FIGURE 24: RELATIVE SPATIAL NOISE AFTER FFC VS. NUMBER OF INTEGRATED FRAMES (FACTORY DEFAULT = 8)

In addition to the user-selectable parameters associated with the FFC process, Boson+ provides two status variables reported via the telemetry line (Section 6.7).

- *FFC State*: Provides information about the FFC event (e.g., whether it has been initiated since start-up, is imminent, is in progress, is complete). Section 7.9 defines each of the FFC states.
- *FFC Desired*: In manual and external FFC modes, the *FFC Desired* flag signals the user to command FFC at the next possible opportunity. In automatic FFC mode, this flag is never set. See Section 7.9 for a detailed description of these conditions.

NOTE: For shutterless configurations, performing an external FFC whenever the *FFC Desired* flag is set is recommended.

6.7 Telemetry

Boson+ provides the option to enable a single line of telemetry as either the first or last line in each frame. The telemetry line contains metadata describing the image stream and the camera. A complete list of the telemetry-line contents is provided in Table 5.

TABLE 5: TELEMETRY LINE ENCODING

WORD START (16B MODE)	BYTE START (8B MODE)	NUMBER OF BYTES	NAME	NOTES
0	0	2	Telemetry Revision	0001 for Release 1 0002 for Release 2 0003 for Release 3
1	2	4	Camera serial number	
3	6	4	Sensor serial number	
5	10	20	Camera part number	ASCII encoded
15	30	14	Reserved	
22	44	12	Camera software revision	Bytes 44-47: SW major revision # Bytes 48-51: SW minor revision # Bytes 52-55: SW patch revision #
28	56	2	Frame rate	This is the actual data rate of the video output channel (frames per second) when in continuous mode. For some configurations, frames are duplicated to generate an *effective* frame rate that is less than the value shown in this field. Similarly, when external sync is used to affect the frame rate of the readout integrated circuit, the resulting value is not represented by this field.

WORD START (16B MODE)	BYTE START (8B MODE)	NUMBER OF BYTES	NAME	NOTES
29	58	8	Image Stats ROI	
33	66	2	meanInROI	
34	68	2	minInROI	
35	70	2	maxInROI	
36	72	2	Reserved	
37	74	2	Units for ROI stats	
38	76	8	Status bits	Bits 0-1: FFC state 00 = never started 01 = imminent 10 = in progress 11 = complete) Bits 2-4: Gain mode 000 = high-gain 001 = low-gain 010 = automatic 011 – 111 = reserved) Bit 5: FFC Desired Bit 6: Table Switch Desired Bit 7: Low-power state Bit 8: Overtemp state All other bits reserved.
42	84	4	Frame Counter	Rolling counter of output frames since start-up.
44	88	4	Frame Counter at last FFC	Value of the frame counter at the last FFC event
46	92	2	Tfpa (counts)	FPA temperature in counts
47	94	2	Camera temperature	In Kelvin x 10 (e.g., 3001 = 300.1K)
48	96	2	Camera temperature at last FFC	In Kelvin x 10 (e.g., 3001 = 300.1K)
49	98	12	Reserved	

WORD START (16B MODE)	BYTE START (8B MODE)	NUMBER OF BYTES	NAME	NOTES
55	110	4	Pipeline enable bits	Bit 0 = FFC offset enable/disable Bit 1 = Gain enable/disable Bit 2 = Temp compensation en/dis Bit 3 = Averager enable/disable Bit 4 = Temporal filter en/dis Bit 5 = SCNR enable/disable Bit 6 = SSN (SPNR) enable/disable Bit 7 = BPR enable/disable Bit 9 = SFFC enable/disable Bit 13 = SRNR enable / disable Bit 17 = LFSR enable / disable All other bits reserved
57	114	2	Number of frames to integrate at next FFC	
58	116	42	Reserved	
79	158	2	Current NUC Table	See note 2 of Table 8
80	160	2	Desired NUC Table	See note 2 of Table 8
81	162	4	Core Temp	In Celsius x 1000 (e.g., 30021 = 30.021°C)
83	166	4	Overtemp event counter	
85	170	4	ROI Population Below Low-to-High Threshold	
87	174	4	ROI Population Above High-to-Low Threshold	
89	178	6	Toggling pattern (intended as check of stuck CMOS signals)	Bytes 178-179: 0x5A5A Bytes 180-181: 0xA55A Bytes 182-183: 0xA5A5
92	184	4	Zoom factor	
94	188	4	Zoom X-center	Row number

WORD START (16B MODE)	BYTE START (8B MODE)	NUMBER OF BYTES	NAME	NOTES
96	192	4	Zoom Y-center	Column number
98	196	84	Reserved	
140	280	4	Time stamp in ms	
142	284	28	Reserved	
156	312	2	External sync mode	0 = free running, 1 = slave
157	314	62	Reserved	
188	376	4	agcBrightnessBias	
190	380	2	agcBrightness	
191	382	2	Valid Image	
192	384	2	Reserved	
193	386	2	radiometryUncertiantyFactor	
194	388	92	Reserved	
240	480	2	gainSwitchFrameCount	Frames since last gain mode switch
241	482	4	gainSwitchTimestampMs	Timestamp of last gain mode Switch
243	486	2	spotmeterMeanCounts	
244	488	2	spotmeterDeviation	Standard deviation of spot meter
245	490	2	spotmeterMinCount	
246	492	2	spotmeterMinRow	
247	494	2	spotmeterMinColumn	
248	496	2	spotmeterMaxCounts	
249	498	2	spotmeterMaxRow	

WORD START (16B MODE)	BYTE START (8B MODE)	NUMBER OF BYTES	NAME	NOTES
250	500	2	spotmeterMaxColumn	

6.8 AGC

Automatic gain correction (AGC) is the process whereby the 16-bit resolution of the signal pipeline is converted to an 8-bit signal suitable for a display system. The highly customizable Boson+ AGC is a variant of classic histogram equalization (HEQ). It uses the cumulative histogram as the transfer function. For a detailed explanation of histograms and AGC, refer to Teledyne FLIR's Camera Adjustments Application Note available from the Boson+ website linked in Section 1.3. In classic HEQ, an image with 60% sky will devote 60% of the available 8-bit values (referred to as gray shades here forward) to the sky and leave only 40% for the remainder of the image. The algorithm has several parameters intended to optimally allocate gray shades based on user preference. A detailed explanation of each of the ten AGC parameters is provided.

6.8.1 AGC Mode

AGC Mode includes user enabled Information-Based Equalization that determines the weighting of pixels when the histogram is generated. Many scenes are comprised of small number of objects superimposed against uniform backgrounds such as sky and ground. In classic HEQ, the background dominates the histogram for such scenes and therefore allocates a large percentage of the 8-bit gray shades, leaving few for the foreground details.

In Information-Based Equalization Enabled mode, the scene data is segregated into details and background using a High-Pass (HP) and Low-Pass (LP) filter. Pixel values in the HP image are weighted more heavily during the histogram-generation process, resulting in detail being allocated more 8-bit gray shades, thus benefiting from higher contrast in the output image. When Information-Based Equalization is disabled, every pixel is weighted equally. The factory-default value of **AGC Mode** is "Information-Based Equalization enabled (Figure 25: Example Images Showing Both AGC Modes) shows example images for both modes. With Information-Based Equalization disabled, the sky and pavement are assigned more gray shades, while when enabled, the ship and people receive greater emphasis.


(a) Information-Based Equalization Disabled


(b) Information-Based Equalization Enabled

FIGURE 25: EXAMPLE IMAGES SHOWING BOTH AGC MODES

6.8.2 Plateau Value

A characteristic of classic HEQ is that it will devote gray shades proportionally to histogram population, meaning that large, mostly uniform portions of a scene will receive a large percentage of the gray shades. This characteristic can lead to those portions of the scene receiving excessive contrast (i.e., appearing noisy), while small objects are washed out due to getting a small allocation of gray shades. The **Plateau Value** parameter can reduce this effect by clipping the maximum value of any histogram bin. The factory-default value is 10%. Because the parameter value is expressed as a percentage, it is not required to modify the value if the Region of Interest (Section 6.8.9) is modified.

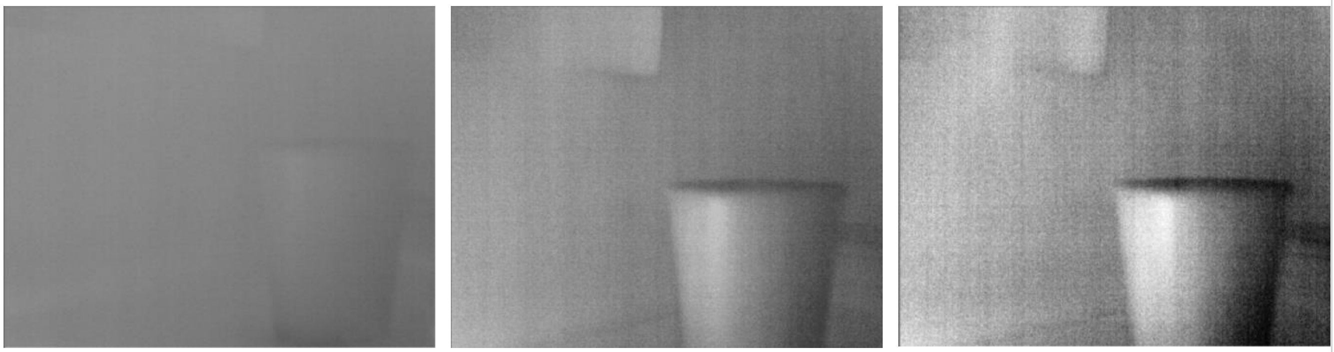
6.8.3 Tail Rejection

Tail Rejection determines the percentage of histogram outliers to ignore when generating the transfer function between 16b and 8b. For example, if the value is set to 2%, the mapping function ignores the bottom 2% of the histogram as well as the top 2%. This optimizes the mapping function for the central 96%. Any pixels in the lower rejected tail are mapped to minimum gray value, and any in the upper rejected tail are mapped to maximum gray value. The factory-default value of **Tail Rejection** is 0%. Tail rejection can be modified by using **Outlier Cut Balance,** which shifts ignored outliers to one side of the histogram. The default for this setting is 1, which designates an even distribution between low and high values cut off as outliers.

WARNING: Information contained herein is classified as EAR99 under the U.S. Export Administration Regulations. Export, reexport or diversion contrary to U.S. law is prohibited.

6.8.4 Max Gain

Max Gain determines the maximum slope of the transfer function between 16b and 8b. In scenes with very little thermal contrast (i.e., narrow histograms), an unconstrained transfer function can allocate essentially all 256 gray shades to a small number of 16b values. While this enhances the displayed contrast, it also makes image noise more obvious. Limiting the maximum slope of the transfer function can result in images that appear less grainy and are more pleasing to the eye. Figure 26 shows an example image with three values of **Max Gain**, illustrating the pros and cons of low and high values. The factory-default value is 1.65 but, perhaps more than any other AGC parameter, the optimal value varies with application and personal preference.

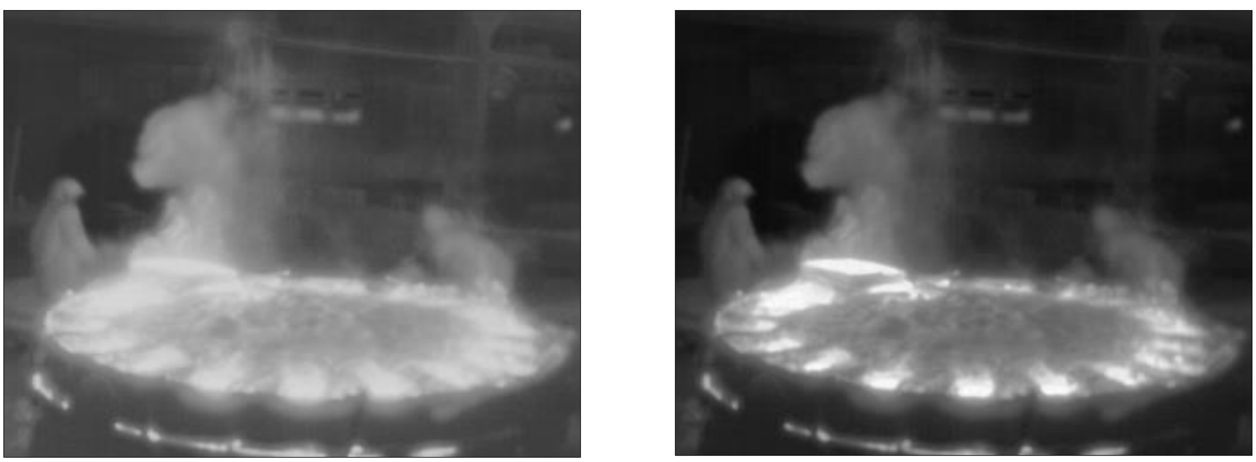


(a) Low value of **Max Gain** (b) Mid value of **Max Gain** (c) High value of **Max Gain**

FIGURE 26: EXAMPLE IMAGES SHOWING THREE DIFFERENT MAX GAIN VALUES

6.8.5 Linear Percent

One of the benefits of non-linear AGC algorithms is efficient mapping of gray shades. Consider a scene containing a single hot object against a cold background. The resulting histogram is bimodal, with a large unpopulated region separating the two modes. A linear mapping function causes one of those modes to be mapped to very dark shades and the other to very bright shades; all the mid-level shades are wasted since the unpopulated bins between the two modes map to them. A non-linear transfer function solves this problem by essentially collapsing the two modes of the input histogram together, preventing any empty bins between them in the resulting output histogram. This can also be non-ideal: consider a scene featuring a person standing in front of a wall. Even if the person is significantly warmer than the wall, the contrast in the displayed image between the two objects might collapse to nearly zero as the result of non-linear mapping. **Linear Percent** provides a compromise between true linear AGC and a non-linear AGC by defining the percentage of the histogram that will be allotted to linear mapping. As shown in Figure 27, a higher value leads to more "separation" in gray shades between the person and the hot furnace in the image. The default value of **Linear Percent** is 20%, but like **Max Gain**, the optimal value varies with application and personal preference.



(a) **Linear Percent** = 0% (b) **Linear Percent** = 30%

FIGURE 27: EXAMPLE IMAGES SHOWING DIFFERENT VALUES OF LINEAR PERCENT

6.8.6 Adaptive Contrast Enhancement (ACE)

ACE provides contrast adjustment dependent on relative scene temperature. The scale of values ranges from 0.5-4.0. In white-hot polarity, an **ACE** value less than 1 darkens the image, increasing the contrast in hotter scene content, while an **ACE** value greater than 1 will do the opposite. Figure 28 shows the effect of **ACE** on the transfer function, and Figure 29 shows an example image with three different values. The factory-default is 0.97.

NOTE: When toggling between white-hot and black-hot, toggling the **ACE** value between 1-X and 1+X is suggested. For example, if a value of 0.90 is utilized in white-hot mode, a value of 1.10 is suggested in black-hot mode.

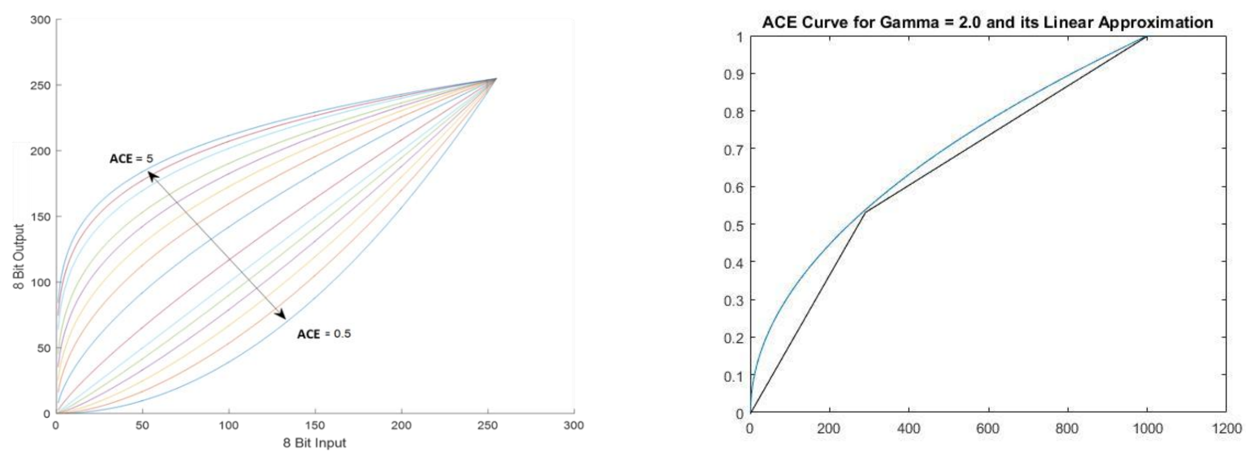


FIGURE 28: GRAPHICAL ILLUSTRATION OF ACE AND THE PIECE-WISE APPROXIMATION OF THE ACE CURVE

(a) **ACE** = 0.9 (b) **ACE** = 1.0 (c) **ACE** = 1.3

FIGURE 29: EXAMPLE IMAGES SHOWING DIFFERENT VALUES OF ACE

6.8.7 Digital Detail Enhancement+ (DDE+)

Boson+ release 4.1 includes an improve detail enhancement algorithm called DDE+. The new algorithm introduces three new parameters: **DDE+ Intensity**, **DDE+ Suppression**, and **DDE+ Boldness**.

6.8.7.1 DDE+ Intensity

The DDE+ Intensity parameter increases or decreases the contrast of edges in the scene. Larger values increase the edge contrast and lower values decrease the edge contrast. The factory-default value is 6.

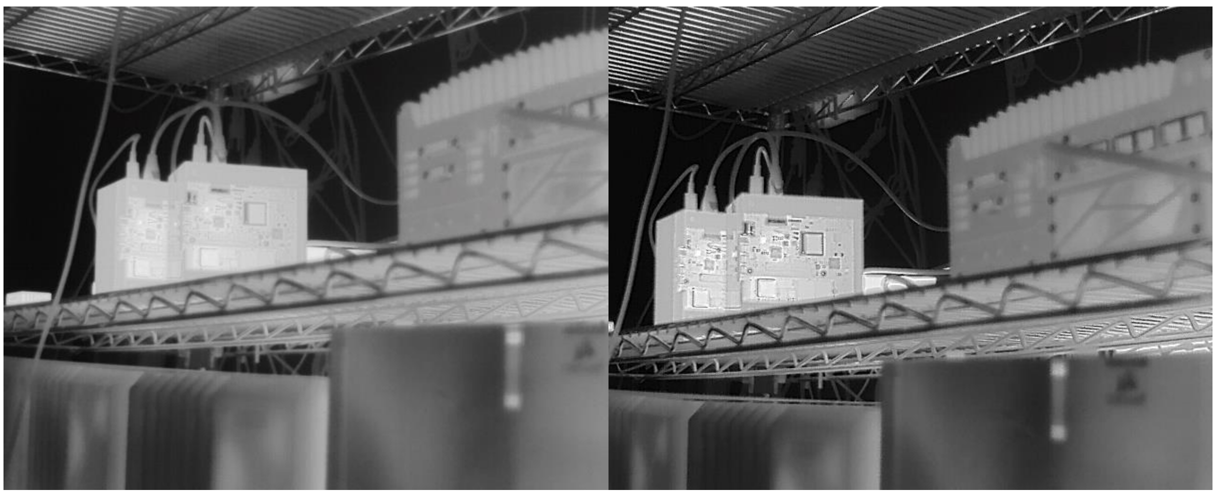


FIGURE 30: EXAMPLE IMAGES SHOWING VALUES OF DDE+ INTENSITY (0.0 LEFT AND 9.0 RIGHT)

6.8.7.2 DDE+ Suppression

The **DDE+ Suppression** parameter suppresses (lower values) the appearance of high frequency noise in the image. Low values **of DDE+ Suppression** risk reducing fine image textures that may appear like noise. Examples are shown in Figure 31. The factory-default value is 0.8.

FIGURE 31: EXAMPLE IMAGES SHOWING VALUES OF DDE+ SUPPRESSION (0.1 LEFT AND 1.2 RIGHT)

6.8.7.3 DDE+ Boldness

The **DDE+ Boldness** parameter adjusts the spatial size of scene content modified by the **DDE+ Intensity** and **DDE+ Suppression** parameters. Fine provides maximum enhancement of fine detail (e.g., leaves of a distant tree), Coarse suppresses some fine detail to enhance larger surface textures (e.g., the temperature variation of human faces), and Medium provides a balance between Fine and Coarse. The factory default value is Fine.

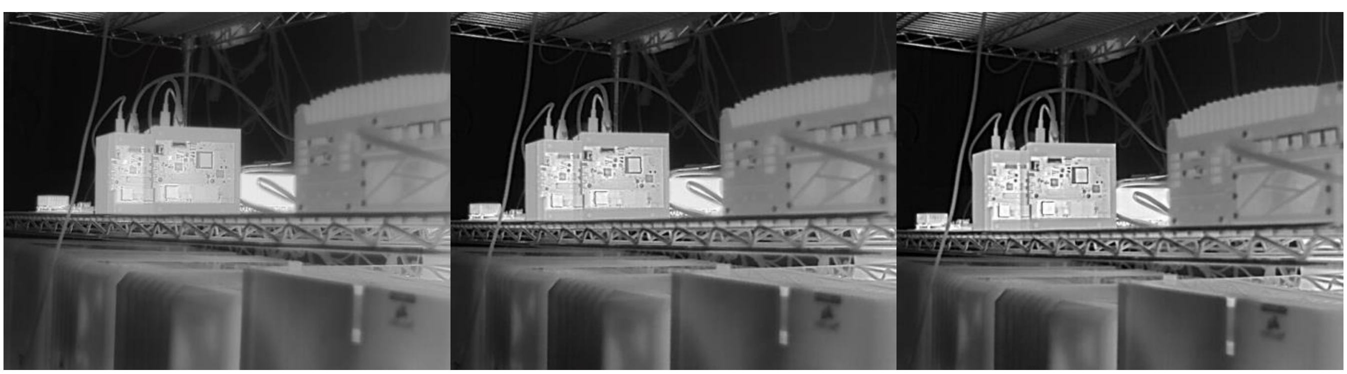


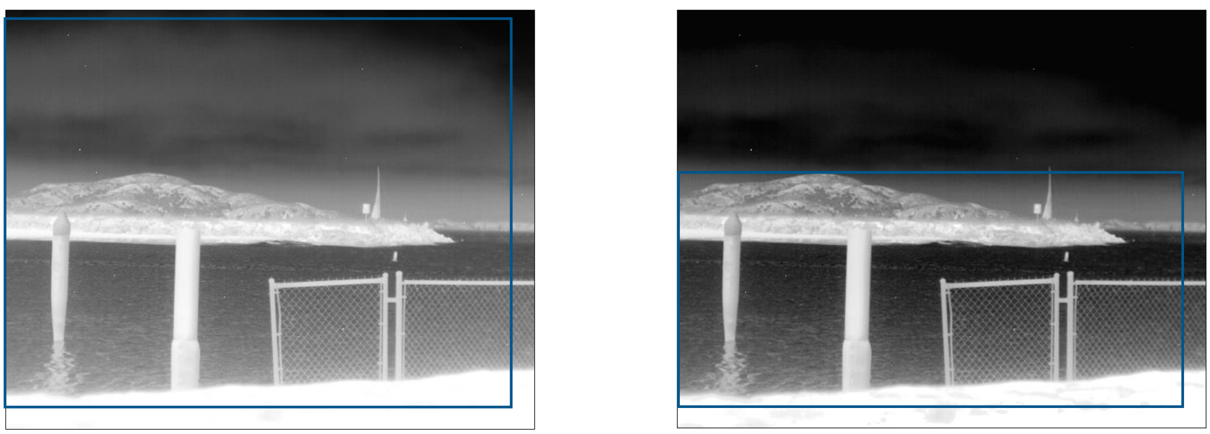
FIGURE 32: EXAMPLE IMAGES SHOWING VALUES FOR DDE+ BOLDNESS (FROM LEFT TO RIGHT: FINE, MEDIUM, AND COARSE)

6.8.8 Smoothing Factor

The **Smoothing Factor** parameter defines which spatial frequencies are included in the HP image and which are in the LP image, both of which are relevant to the Information-Based-Equalization Enabled mode of operation and to the DDE algorithm. A higher value results in more frequencies being included in the HP portion of the image. The factory-default value of **Smoothing Factor** is 10,000. Teledyne FLIR recommends using this value for almost every use case.

6.8.9 Region of Interest (ROI)

In some scenarios, it may be desirable to optimize the AGC for some subset of the total field of view, such as the central portion of the scene. For a fixed-mount application, it may be beneficial to exclude some portion of the scene, as illustrated in Figure 33. The ROI provides this capability and is comprised of four parameters (**Start Column**, **Start Row**, **End Column**, **End Row**): together these define the corners of a rectangle. The default ROI is the full sensor array (i.e., **Start Column** = 0; **Start Row** = 0; **End Column** = 319 for the 320 configuration or 639 for the 640 configuration; **End Row** = 255 for the 320 configuration or 511 for the 640 configuration).



(a) ROI = Full Image

(b) Sky excluded from ROI

FIGURE 33: EXAMPLE IMAGE FOR TWO DIFFERENT ROI

6.8.10 Damping Factor

The AGC algorithm computes the optimum transfer function for each new frame of incoming data, but it is not always beneficial to allow the applied transfer function to change rapidly. Consider a mid-sized hot object entering an otherwise uniform scene. The new object will be allocated brighter grays shades, resulting in the background migrating towards darker shades. If this transition happens suddenly from one frame to the next, it can appear as an image flash and be disconcerting to a viewer. Boson+ provides a temporal filter that can mitigate against a sudden flash by limiting how quickly the AGC can react to a change in scene conditions. A lower value of the **Damping Factor** parameter allows the algorithm to react more quickly. A value of 0% results in no filtering at all, and a value of 100% causes the AGC transfer function to stop updating altogether. The factory-default value is 85%.

6.8.11 Brightness

The AGC algorithm allows for directly shifting the AGC histogram up or down in 8-bit space using the Brightness command. Using this feature does not adjust the AGC transfer function resulting in reduced dynamic range as low or high values are shifted out of the 0-255 range. This feature can be useful to globally brighten or darken the video when maximum dynamic range and sensitivity are not required. As an example, if the system is limited in the ability to darken a display in dark environments, the Brightness value may be adjusted to dim the input to the display.

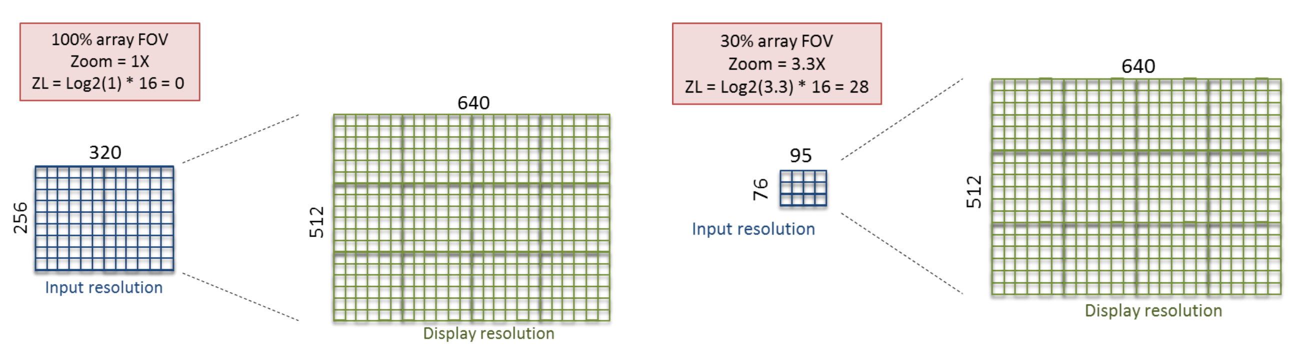
6.9 EZoom

Boson+ provides a digital zoom capability in which a zoom window (either the full sensor-array data or some cropped subset) is interpolated to the 640x512 resolution of the post-zoom output stream (Figure 34). For the 320 configuration, the maximum size of the zoom window is 320x256, which means the minimum interpolation factor is 2:1 (640x512 output from 320x256 input). Using the classical definition of digital zoom (sensor FOV divided by displayed FOV), the minimum zoom is 1X, and that is what is used here. The zoom function provides 49 discrete zoom levels (0 – 48). The transfer function between zoom and specified **Zoom Level** (ZL) is depicted graphically in Figure 35. Note that the maximum zoom is 2^3 = 8X.

Zoom = 2 ^ (ZL/16)

By factory default, the cropped “zoom window” is concentric with the center of the array, but using a feature of the zoom window known as “pan and tilt,” it is possible to specify the center of the zoom window as any valid row/column in the sensor array. This feature is illustrated in Figure 36 for a 2X zoom window (ZL=16). The left pane of the figure shows the default location of the zoom window relative to the full sensor array, while the right pane shows the zoom window panned and tilted to the upper left.

The camera automatically range-checks the specified center row and column of the zoom window and will disallow an invalid value (i.e., one that would cause the zoom window to extend beyond the edge of the sensor array). For example, if **Zoom Level** is set to 16, the column used for the center of the zoom window is automatically constrained to values between 80 and 240. **Zoom Level** does not affect the on-screen position of symbols.



(a) 1X zoom (Displayed FOV = 100% of Camera FOV)

(b) .3X zoom (Displayed FOV = 30% of Camera FOV)

FIGURE 34: VISUALIZATION OF ZOOM FUNCTION

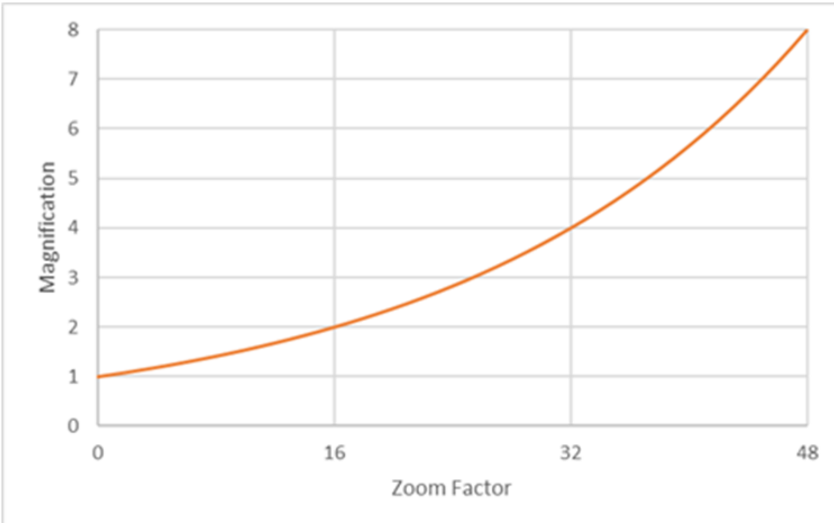
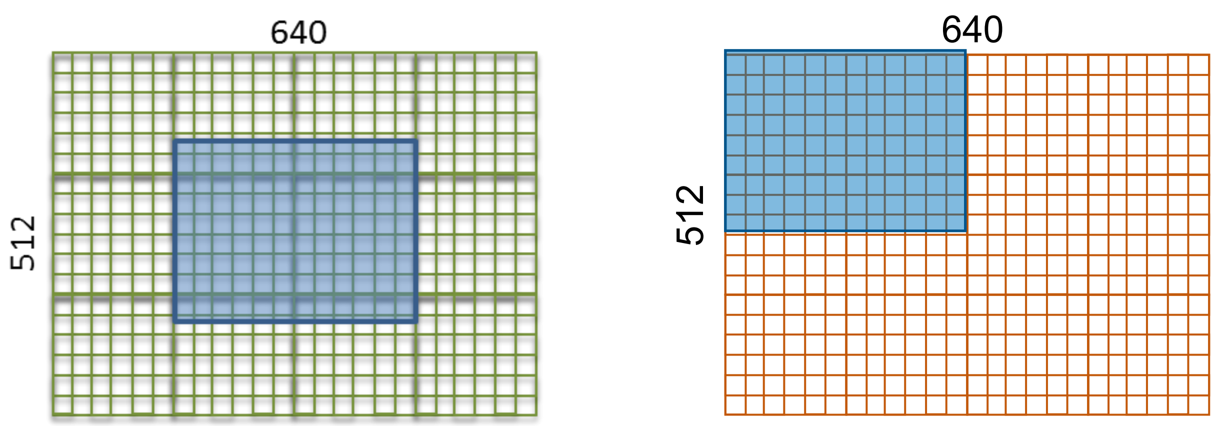


FIGURE 35: ZOOM (RELATIVE MAGNIFICATION) AS A FUNCTION OF SPECIFIED ZOOM LEVEL



(a) Centered Zoom Window
- Center row = 128
- Center column = 160

(b) Panned and Tilted Zoom Window
- Center row = 64
- Center column = 80

FIGURE 36: ILLUSTRATION OF "PAN AND TILT"

The following parameters provide full control of the zoom function:

- **Zoom Level** is a variable between 0 and 48 which determines the applied zoom according to the equation:

Zoom = 2 ^ (ZL/16)

The factory-default value of **Zoom Level** is 0.

- **Zoom Center Column** is the x-coordinate of the sensor array at which the zoom window is centered. For maximum zoom (width of zoom window = 40 rows), valid values range between 20 and 300. However, the valid range automatically shrinks as the zoom window grows to prevent it from spilling outside the sensor array. For example, for minimum zoom (width of zoom window = 320 columns), the only valid value for **Zoom Center Column** is 160. The factory-default value is 160.

Zoom Center Row is the y-coordinate of the sensor array at which the zoom window is centered. For maximum zoom (height of zoom window = 32 rows), valid values range between 16 and 240. However, the valid range automatically shrinks as the zoom window grows to prevent it from spilling outside the sensor array. For example, for minimum zoom (height of zoom window = 256 rows), the only valid value for **Zoom Center Row** is 128. The factory-default value is 128.

NOTE: None of the zoom parameters (**Zoom Level**, **Zoom Center Column**, or **Zoom Center Row**) have any effect on the video signal if it is tapped prior to zoom. See Sections 7.12, 0, and 0 for more information.

6.10 Colorization

As shown in Figure 37, Boson+ provides several factory-installed palettes, referred to as color look-up tables or LUTs. In these illustrations of the palettes, the upper left corner represents the color associated with an 8-bit input value of 0, and the lower-right represents the color associated with a value of 255. Figure 38 shows sample images with each palette applied. Changing the parameter Color Palette causes the applied palette to change. The factory-default value is “white hot.”

NOTE: The selected **Color Palette** has no effect on the video signal if it is tapped prior to colorization. See Sections 7.12, 0, and 0.

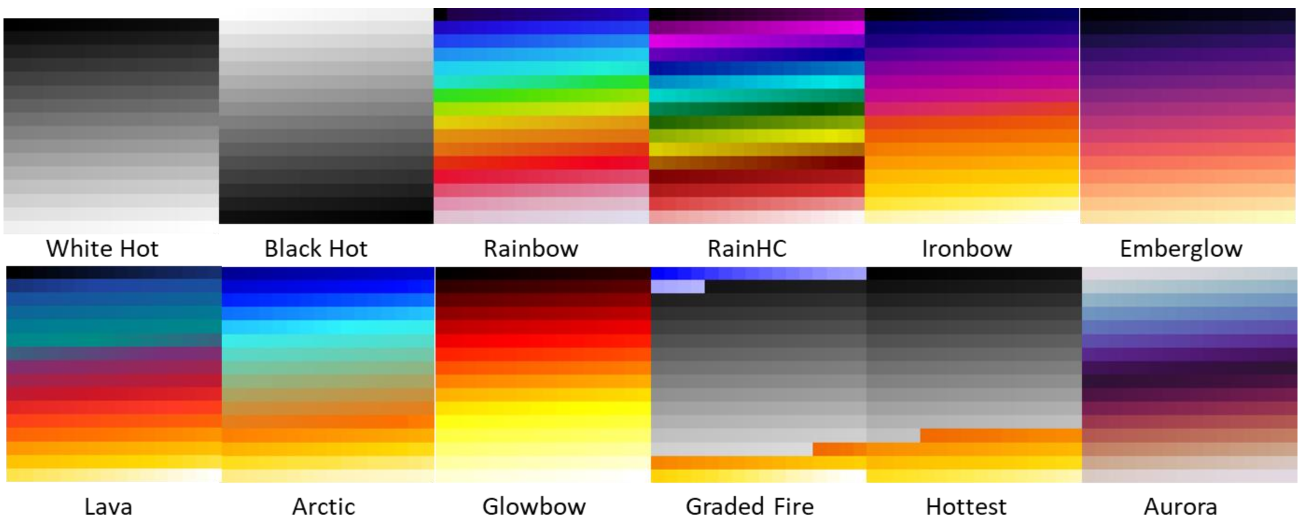


FIGURE 37: BOSON+ FACTORY-LOADED COLOR PALETTES

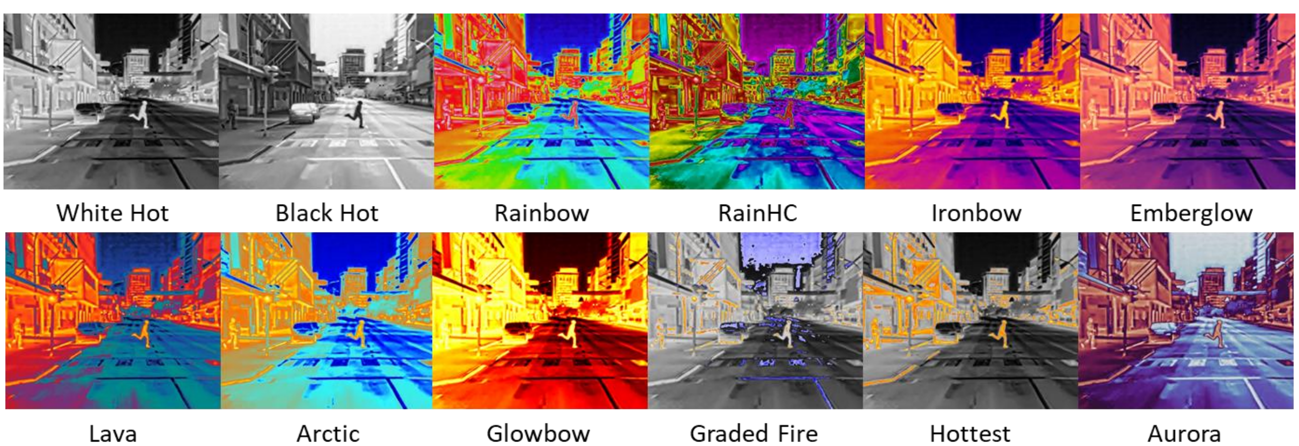


FIGURE 38: SAMPLE IMAGE WITH BOSON+ COLOR PALETTES

6.11 Automatic Symbols

Boson+ has seven symbol overlays which are automatically enabled or disabled in response to various system states and conditions as described below. An override is provided for each. For example, it is possible to override automatic display of the overtemp symbol while leaving all other symbols unaffected. Additionally, it is possible to globally disable the display of all symbol overlays, including the automatic symbols described in this section as well as any custom symbols described in the next section.

- FFC In Progress: By factory default, the symbol shown in Figure 39 is displayed whenever the FFC State = "FFC Imminent" or "FFC in Progress." See Section 7.9 for a full description of the FFC states.
- FFC Desired: By factory default, the symbol shown in Figure 40 is displayed whenever the "FFC Desired" flag is set (Section 6.14.3 and Section 7.9).
- Table-Switch Desired: By factory default, the symbol shown in Figure 41 is displayed whenever the "Table-Switch Desired" flag is set (Section 6.14.3 and Section 7.9).
- Low-Gain State: By factory default, the symbol shown in Figure 42 is displayed whenever the camera is operating in low-gain state. See Section 0 for a full description of this state.
- Overtemp State: By factory default, the symbol shown in Figure 43 is displayed whenever the camera is in the overtemp state. See Section 7.2 for full description of this state.
- Isotherm Bar: By factory default, the symbol shown in Figure 44 is displayed whenever the camera has isotherms enabled. It displays the current color LUT. See Section 7.5 for full description of this feature.
- Spot Meter: By factory default, the symbol shown in Figure 45 is displayed whenever the camera has spot meter enabled. See Section 6.4 for full description of this feature. Four components make up this automatic symbol:
- Spot Meter ROI: 25x25 square grouping bounded by a purple box
  - Spot Meter ROI statistics: Display the min, max, and mean value for the spot meter ROI
  - Mean Value Bar: Graphical display of the mean ROI value in relation to the temperature markers with radiometry enabled and a relative value with radiometry disabled
  - Temperature Markers: Display the designated reference temperature values. Only available with radiometry-enabled cameras.

FIGURE 39: “FFC IMMINENT/IN PROGRESS” SYMBOL (FACTORY-DEFAULT); UPPER RIGHT CORNER

FIGURE 40: “FFC DESIRED” SYMBOL (FACTORY-DEFAULT); UPPER RIGHT CORNER

FIGURE 41: “TABLE-SWITCH DESIRED” SYMBOL (FACTORY-DEFAULT); UPPER RIGHT CORNER

FIGURE 42: “LOW-GAIN” SYMBOL (FACTORY-DEFAULT); LOWER LEFT CORNER

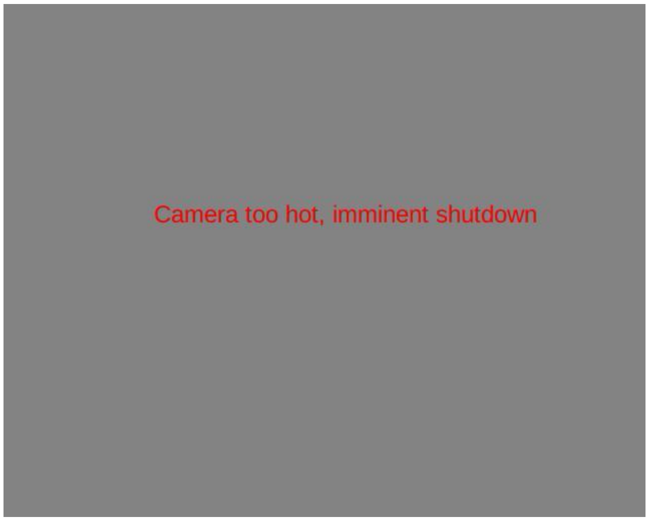


FIGURE 43: “OVERTEMP” SYMBOL (FACTORY-DEFAULT)

FIGURE 44: "ISOTHERM" SYMBOL

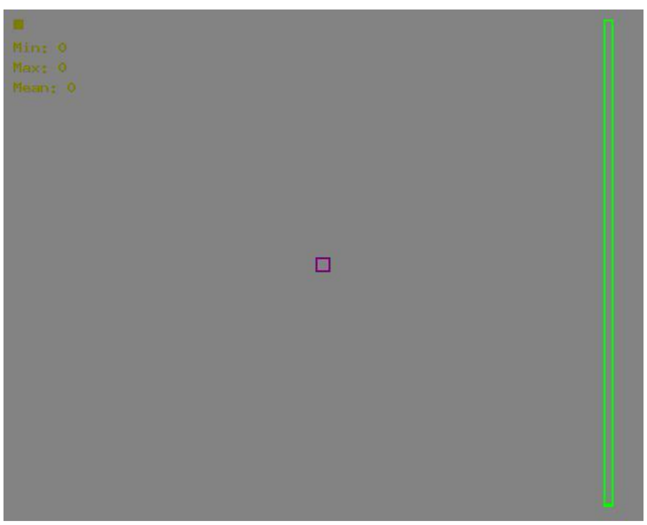


FIGURE 45: "SPOT METER" SYMBOL (RADIOMETRY DISABLED)

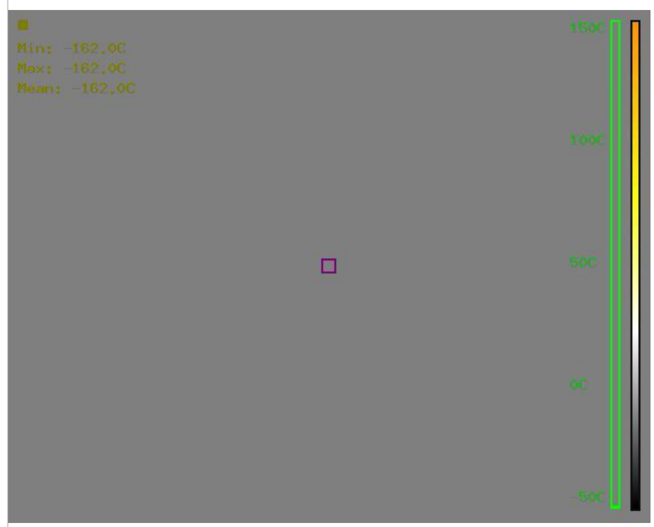


FIGURE 46: "ISOTHERMS AND SPOT METER" SYMBOL (RADIOMETRY ENABLED)

The factory-default attributes of all five automatic symbols are shown in Table 6 below. See Section 6.12 for descriptions of the various attributes. A separate Boson+ Symbols Application Note, available from the Boson+ website linked in Section 1.3, provides more information on modification of automatic symbols. The Isotherm and Spot meter symbols should not be modified and require the explanation in the symbology application note.

TABLE 6: FACTORY-DEFAULT ATTRIBUTES OF THE AUTOMATIC SYMBOLS

	FFC IMMINENT	FFC DESIRED	TABLE-SWITCH DESIRED	LOW-GAIN	OVERTEMP
ID#	10	11	12	13	14
Element Type	Filled Rectangle	Outlined Rectangle	Arc	Text	Text
X Position	620	620	614	10	150
Y Position	50	50	45	470	200
Width	10	10	22	20	400
Height	10	10	22	20	25
Color	0000FF00	0000FF00	00FF0000	00762710	00FF0000
Z-position	0	0	0	0	0
Start Angle			0		
End Angle			0		
Font				1	1
Size				24	24
Alignment				TOP LEFT	TOP LEFT
ASCII Text				L	Camera too hot, imminent shutdown

6.12 Customized Symbols

Boson+ provides the option to specify custom symbol overlays. The camera supports several built-in symbol types, including rectangles, elliptical arcs, text, and lines as exemplified in Figure 47. In addition to built-in symbol types, the camera allows bitmaps to be uploaded for display. The width of the bitmap must be an integer multiple of 8.

NOTE: The Boson+ Graphical User Interface (GUI) is capable of opening PNG, BMP, and JPEG files and converting them into the correct bitmap format.

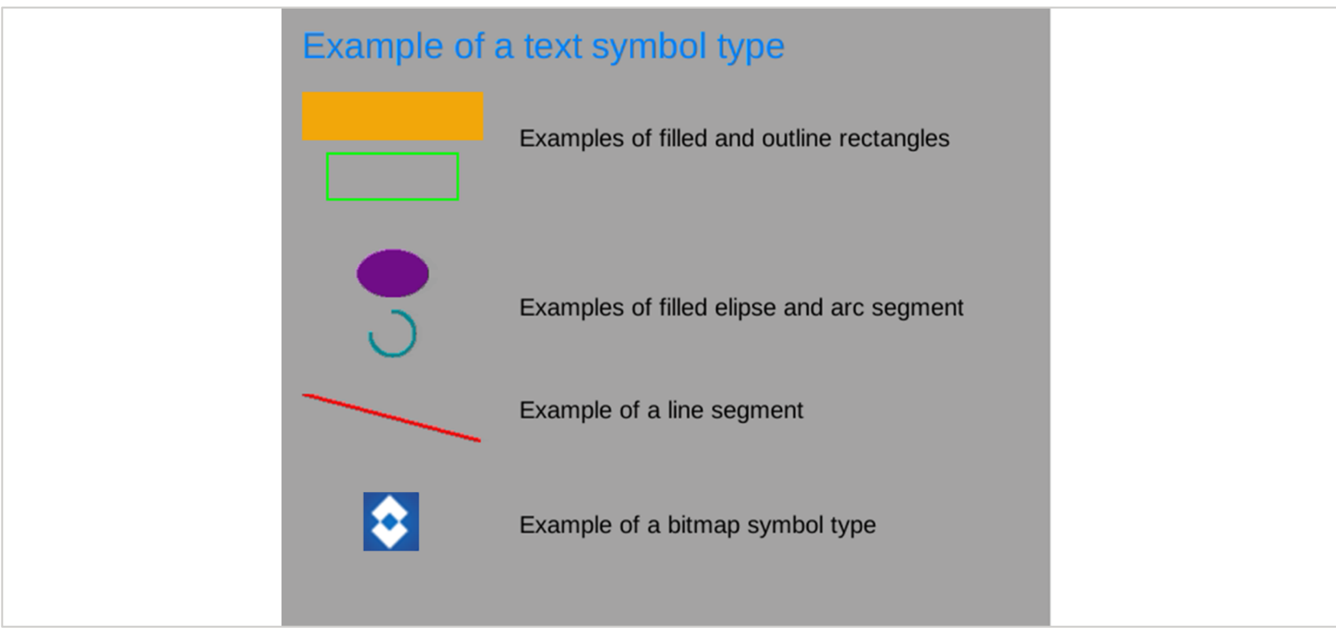


FIGURE 47: EXAMPLES OF BOSON+ SYMBOL TYPES

Each symbol type has a variety of user-specified attributes, as listed below.

Symbol attributes common to every symbol type are:

- Symbol ID# (0 to 254): A handle for addressing the symbol when changing its attributes. Note that ID numbers 10 to 14 are pre-allocated for automatic symbols such as the FFC imminent icon (Section 6.11). Changing the attributes of any symbol ID will alter the appearance of its associated built-in symbol. See Table 6 for the ID# and other attributes of each automatic symbol.
- Symbol enable: 0 = not currently drawn, 1 = currently drawn

- X and Y coordinates, where x=0, y=0 is the upper left of the image and x=639, y=511 is the lower right. The upper-left corner of the symbol is placed at the specified coordinates. Note that the symbol map/canvas is always 640x512 because symbol overlay occurs at the post-colorization tap in the pipeline, and that tap is 640x512 regardless of sensor resolution. Attempting to specify a location such that a portion of a symbol is outside the 640x512 canvas will result in an error.
- Transparency, where a value of 0 represents an opaque symbol and a value of 127 represents a completely transparent symbol. Transparency values of 127-255 are invalid and have undefined behavior. Setting a transparency value greater than 0 allows a symbol to be shown without completely hiding the infrared imagery or other symbols behind it, as illustrated in Figure 48.
- Z-position, indicating a background (z=0) or foreground plane (z=1-255) used to determine precedence in the event of overlapping symbols. For example, a symbol with 0% transparency on the n^{th} plane will completely hide a symbol located on the n-1 plane, as illustrated in Figure 48. If two overlapping symbols have the same z-position, the behavior is undefined.
- Group number, from 1 to 19. It is possible to place multiple symbol ID#s into a common group. This allows the entire group to be enabled/disabled and/or moved simultaneously. Moving a group causes the X/Y location of each symbol within the group to update automatically.

Other attributes for built-in symbol types:

- Color, specified as an RGBA index. This is a required attribute for all symbol types except bitmaps.
- Height / Width, specified in number of rows (1 to 512) / number of columns (1 to 640). This is a required attribute for filled rectangles, outline rectangles, elliptical arc segments, filled ellipses, and text symbol types. For text symbols, the height and width refer to the bounding box for the text. If actual text width exceeds the specified width, wrapping will be applied (potentially exceeding specified height).
- Start radius / end radius, from 0 to 360. This attribute applies to the arc segment symbol type only. It specifies the starting and ending angles where angle = 0 is to the right and angle = 180 is to the left. The arc between the starting angle and ending angle is drawn clockwise. For example, the arc segment shown in Figure 47 has starting radius = 270 and ending radius = 180.
- Start point / end point, each specified as an x/y coordinate. This attribute applies to line segment symbol type only.
- Font type. 1 = built in font (Chrome Croscore Arimo font, used under authority of the Apache License, Version 2.0), 2 = user replaceable font file. This attribute applies to text symbol type only. All the text shown in Figure 47 was generated with the built-in font.
- Font size. This attribute applies to text symbol type only and controls the nominal height of each character of text, in rows. For example, a font size of 32 results in a character height which consumes ~1/8th of the total image height.
- Justification. This attribute applies to text symbol type only, and the valid options are:

- LEFT_TOP
- CENTER_TOP
- RIGHT_TOP
- LEFT_MIDDLE
- CENTER_MIDDLE
- RIGHT_MIDDLE
- LEFT_BOTTOM
- CENTER_BOTTOM
- RIGHT_BOTTOM

- Text, in UTF-8 characters. The text string is a fixed-width, null-terminated buffer containing exactly 128 bytes. This attribute applies to text symbol type only.

Both squares have transparency = 0%.
The z-position of both squares = 2.
Both circles have transparency = 50%.
The z-position of the upper circle is 1, the lower circle = 3

FIGURE 48: EXAMPLES OF OVERLAPPING SYMBOLS, ILLUSTRATING TRANSPARENCY AND Z-LOCATION

A separate Boson Symbols Application Note, available from the Boson+ website linked in Section 1.3, provides many more examples and more detailed treatment of the custom-symbols feature. As of release 4.1, custom symbols, including bitmaps, may be stored in the camera's flash memory.

6.13 Field Calibration

Most configurations of Boson+ include a set of factory-calibrated NUC terms which compensate for temperature effects, pixel response variations, lens-illumination roll-off, and out-of-field irradiance. For such configurations, the generation and application of NUC terms is transparent to the user and requires no external intervention or support. There are three notable exceptions, each of which benefit from a one-time calibration process performed by the user:

(a) The Boson+ lensless configuration

(b) A Boson+ installed behind a window or other optical assembly resulting in a change to the illumination pattern on the focal plane array.

(c) A Boson+ installed in an environment which significantly affects self-heating, for example in an insulative enclosure or in a convective air flow. Re-calibration is recommended if the installation of the camera in the operating environment causes its steady state temperature to be more than one Celsius degree hotter or cooler than it would otherwise be when operated in the same ambient temperature in still-air with no enclosure.

NOTE: Exposing any thermal camera to rapid thermal transients will reduce the effectiveness of the calibration and the quality of the image. For best results, the Boson+ camera should be isolated from the thermal effects of window heaters, variable fans, power circuits, electric motors, or similar intermittent thermal sources, as noted in Section 9.4.

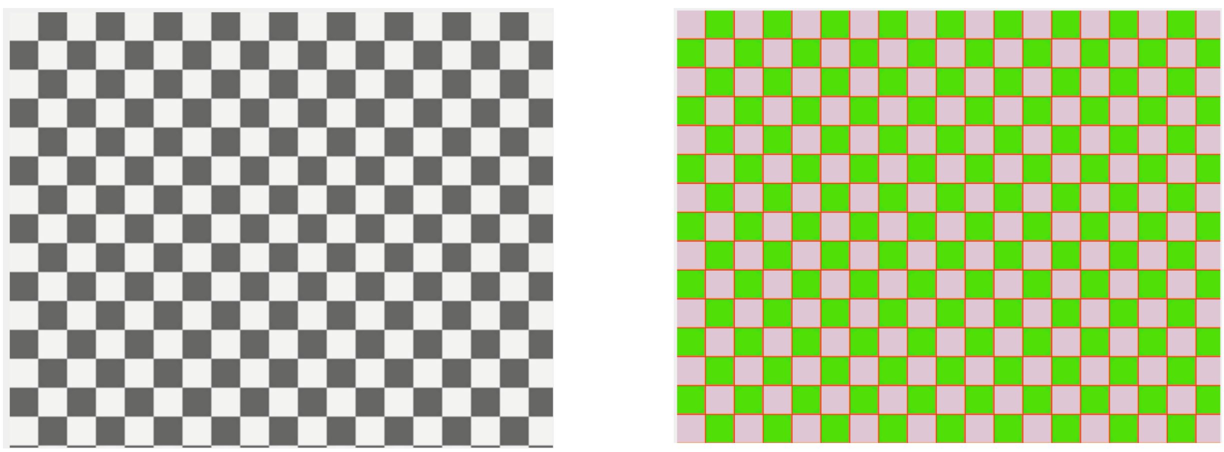
The calibration process requires exposing the camera in its final installation condition (e.g., in enclosure behind a window if applicable) to two different BB temperatures (e.g., room temperature and 20°C above room temperature). The Boson+ Graphical User Interface (GUI) sequences all steps required to complete the calibration process. For a detailed tutorial on using the GUI, refer to Teledyne FLIR's Lens Calibration Application Note, available from the Boson+ website linked in Section 1.3.

6.14 Diagnostic Features

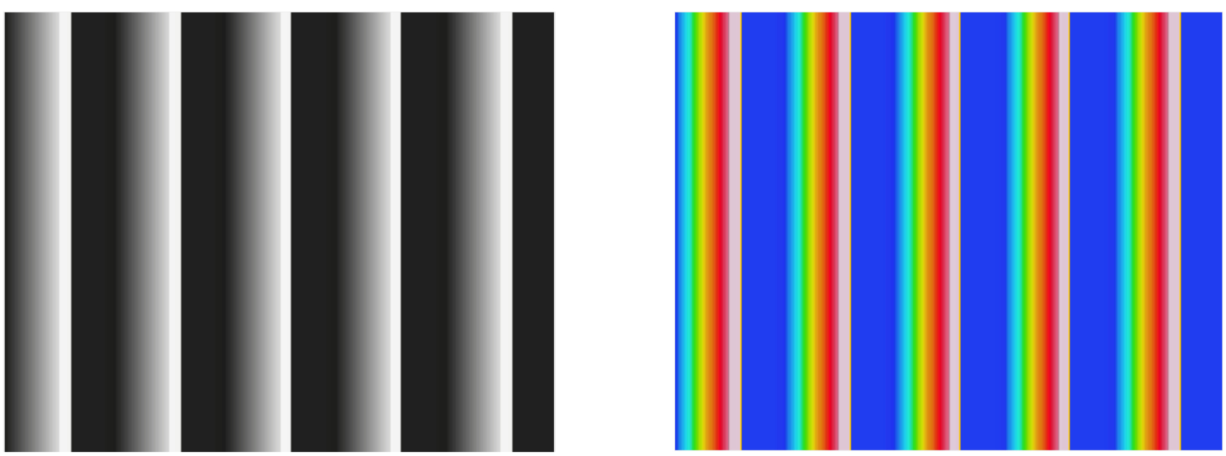
Boson+ provides several diagnostic features, more completely defined in the sections that follow.

6.14.1 Test Patterns

Boson+ provides capability to display test patterns, two of which are illustrated in Figure 49. The test patterns are intended primarily to adjust display properties and/or for diagnostic purposes (e.g., to verify that the core is providing a valid output). Only a select few test patterns are available via the Boson+ GUI and most must be accessed via the SDK.



(a) Checkerboard test pattern



(b) Vertical-shade test pattern

FIGURE 49: TWO OF THE BOSON+ TEST PATTERNS (SHOWN IN BOTH WHITE-HOT AND RAINBOW PALETTES)

Because the test pattern replaces the sensor data at the beginning of the pipeline, its appearance is affected by filters and AGC settings. The Boson+ App automatically disables the pipeline features below. For reproduceable test patterns which appear as intended, the following configuration changes are required:

- Set external FFC to prevent an automatic FFC event from taking place while the test pattern is enabled: bosonSetFFCMode(FLR_BOSON_FFCMODE_E.FLR_BOSON_EXTERNAL_FFC)
- Disable application of NUC terms and pipeline filters:
  - FFC: gaoSetFfcState(FLR_ENABLE_E.FLR_DISABLE)
  - Gain: gaoSetGainState(FLR_ENABLE_E.FLR_DISABLE)
  - Temperature Correction: gaoSetTempCorrectionState(FLR_ENABLE_E.FLR_DISABLE)
  - SFFC: gaoSetSffcState(FLR_ENABLE_E.FLR_DISABLE)
  - Bad Pixel Replacement: bprSetState(FLR_ENABLE_E.FLR_DISABLE)
  - Row filter, SRNR: srnrSetEnableState(FLR_ENABLE_E.FLR_DISABLE)
  - Column filter, SCNR: scnrSetEnableState(FLR_ENABLE_E.FLR_DISABLE)
  - Silent Shutterless NUC: spnrSetEnableState(FLR_ENABLE_E.FLR_DISABLE)
  - Temporal Filter: tfSetEnableState(FLR_ENABLE_E.FLR_DISABLE)
  - Low-Frequency Shading Reduction: lfsrSetApplyOffsetEnableState(FLR_ENABLE_E.FLR_DISABLE)
  - Radiometric cameras only:
    - T-linear TLinearSetControl(FLR_ENABLE_E.FLR_DISABLE)
    - radiometrySetTempStableEnable(FLR_ENABLE_E.FLR_DISABLE)

For post-AGC output (e.g., 8bit), the following AGC settings are additionally recommended:

- AGC Mode = Information-Based Equalization Disabled: agcSetUseEntropy(FLR_ENABLE_E.FLR_DISABLE)
- Plateau Level = 100% agcSetPercentPerBin(100)
- Tail Rejection = 0: agcSetDetailHeadroom(0)
- Max Gain = 8: agcSetMaxGain(8)
- Linear Percent = 100%: agcSetLinearPercent(100)
- Adaptive Contrast Enhancement (ACE) = 1: agcSetGamma(1.0)
- DDE = 0: agcSetd2br(0)
- Smoothing Factor = 0: agcSetSigmaR(0)
- Damping Factor = 0%: agcSetdf(0)
- Brightness = 127: agcSetBrightness(127)

NOTE: AGC settings and other filters disabled above should be returned to their previous state to resume standard operation of the Boson+ core. This is done automatically in the Boson+ App GUI.

6.14.2 Camera Temperature

Boson+ can report its temperature via the *Camera Temperature* status variable. Accuracy of the measurement is ±5°C. This temperature represents that of the sensor and is the value used to determine the proper NUC table (Section 5.3) and to trigger FFC (Section 6.6).

Boson+ can also report the temperature of its internal signal-processing engine via the *Core Temperature* status variable. This temperature is the value used by the overtemp logic described in Section 7.2.

6.14.3 Status Indicators

Boson+ provides several status indicators. These are reported via the telemetry line (Section 6.7), via the CCI, and in some cases as optional symbol overlays on the video signal. These indicators are listed below. See the referenced sections for context and/or more detailed information.

NOTE: The text below describes the factory-default location and appearance of each symbol overlay, but it is possible to change any attribute of these status-indicating symbols. For example, rather than a solid green rectangle appearing in the upper right of the video signal during FFC, it is possible to configure Boson+ to display text or any other symbol (including an uploaded bitmap file) at any location. It is also possible to disable any or all the status-indicating symbols so that they do not appear.

- *FFC State*: The *FFC State* variable provides information about the FFC event (i.e., has it been initiated since start-up, is it imminent, is it in progress, is it complete). Section 7.9 defines each of the FFC states. By factory default, a small solid green square will appear in the upper right of the post-colorization video signal when FFC state = "FFC imminent" or "FFC In Progress" (Figure 39).
- *FFC Desired*: When operating in manual or external FFC mode, the *FFC Desired* flag is used to signal the user to command FFC at the next possible opportunity. In automatic FFC mode, the flag is never set because an automatic FFC takes place instead. See Section 7.9 for detailed description of the conditions that cause the flag to be set. By factory default, a small unfilled square (green border) will appear in the upper right of the post-colorization video signal whenever the *FFC Desired* flag is set (Figure 40).
- *Table Switch Desired*: When operating in manual or external FFC mode, the *Table Switch Desired* flag is set when the camera is operating outside the range of the current NUC table (Section 5.3). This flag is never set in automatic FFC mode: instead, an automatic table switch takes place. By factory default, a red circle will appear in a location which circumscribes the *FFC Desired* symbol whenever the *Table Switch Desired* flag is set (Figure 41).
- *Current NUC Table*: The *Current NUC Table* variable indicates the current NUC table in which the camera is operating. As described in Section 5.3, a value of 0 indicates Boson+ is in low-gain state while a value of 1, 2, or 3 indicates Boson+ is in high-gain state. There is no symbol overlay symbol to indicate this

status directly. However, when Boson+ is operating in low-gain state, a purple “L” will appear by factory-default in the lower-left of the post-colorization video signal (Figure 42).

- *Desired NUC Table*: The *Desired NUC Table* variable indicates the NUC table the camera will switch to upon receipt of the Table Switch command. See Section 0 and Section 7.9 for more information regarding the Table Switch command. There is no symbol overlay symbol to indicate this status. When *Desired NUC Table* differs from *Current NUC Table*, the *Table Switch Desired* flag described above is set.

- *Overtemp*: The *Overtemp* flag indicates that the camera has exceeded its maximum operating temperature and will automatically enter Low-Power state. See Section 7.2 for more information regarding the Overtemp feature and Low-Power state. By factory default, a text warning will appear in the center of the display whenever the *Overtemp* flag is set (Figure 43).

- *Low-Power State*: The *Low-Power* flag indicates the camera is in Low-Power state, typically the result of an Overtemp event. See Section 7.2 for more information regarding the Overtemp feature and Low-Power state. There is no symbol overlay associated with Low-Power State because the video signal is disabled when in this state. The telemetry line will enable the Low-Power flag one frame before Boson+ enters the Low-Power state.

6.14.4 Scratchpad (Jffs2 storage location)

Boson+ allows up to 2.5 MB of file storage in the jffs2 MEM location within the camera’s non-volatile memory. Almost any file type can be loaded into this space if written and read according to the guidelines specified in Boson+ Software IDD. The time-consuming write process (e.g., >90 seconds to write a 2.5MB file) is not recommended for routine use.

6.15 Upgradeability/Backward Compatibility

Fielded Boson+ cameras can be updated with new software releases via the CCI, but because radiometric capability requires a factory-calibration process, it is not possible to upgrade a fielded camera to be radiometrically capable via a software upgrade.

Boson+ provides fault-tolerant software upgradeability, meaning that if power to the camera is disrupted during an upgrade event, the core is capable of rebooting with the functionality required to repeat the upgrade process. All future releases of Boson+ software will be compatible with all previous production versions. Upgrading a production core with an authorized software release will not result in loss of function or performance.

NOTE: Not all feature improvements planned for later releases will necessarily work when a fielded camera is upgraded: some may require factory calibration to function properly. In all cases, a new feature will at worst simply not function rather than causing an upgraded core to behave erroneously.

NOTE: While upgrading a core to a newer release is always guaranteed, downgrading a core to an older release (even to a version used prior to a field upgrade) is not.

6.16 External Synchronization

Boson+ provides capability to either:

- Slave its frame rate to a pulse train received on the EXT_SYNC pin (Sync Mode = Slave)
- Generate its own frame timing, nominally 60.0Hz (Sync Mode = Master or Disabled)
- Optionally transmit a pulse train on the EXT_SYNC pin intended to facilitate synchronizing frame rate of another camera (Sync Mode = Master)

By factory-default, Boson+ operates in “Disabled” Sync mode, in which case it neither responds to an input signal nor generates an output signal on EXT_SYNC.

Figure 50 illustrates the relationship between EXT_SYNC and the camera input and output timing when in Master mode or Slave mode. In Master mode, the camera generates the EXT_SYNC pulse, while in Slave mode the camera responds to an externally generated EXT_SYNC pulse. In both cases, the start of readout from the sensor occurs 0.5 ms after the rising edge of EXT_SYNC. Readout from the sensor is the input to signal-processing pipeline. The lag between the readout and the output from the pipeline is referred to as latency and is described in Section 5.10.

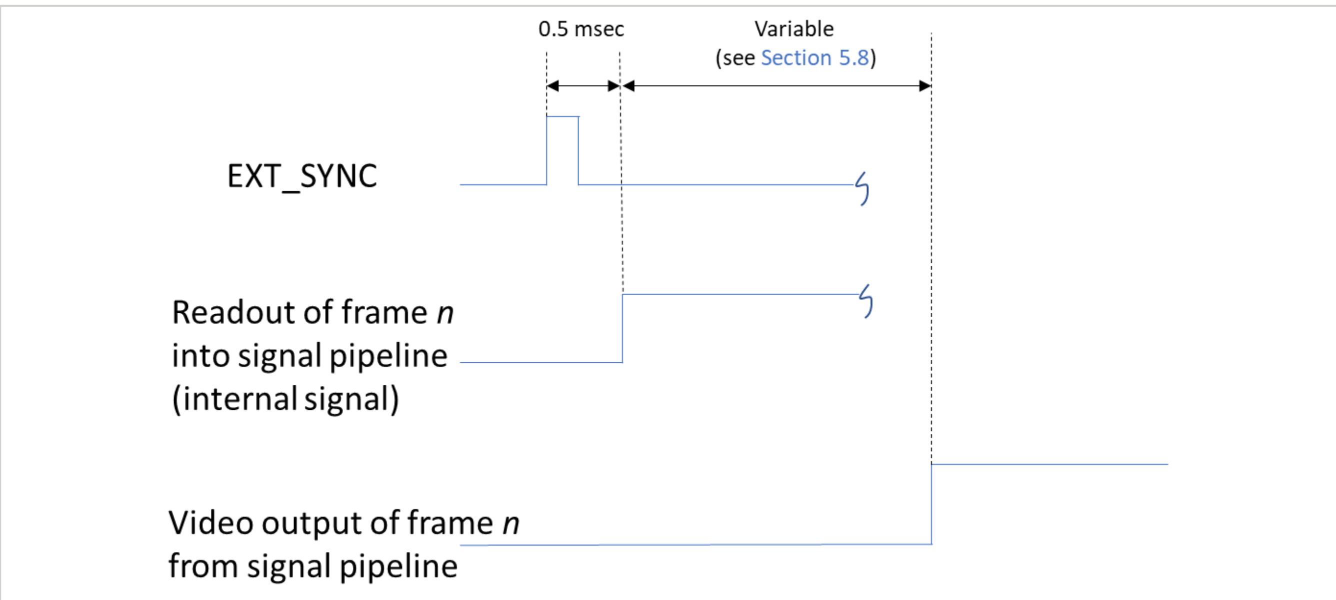


FIGURE 50: TIMING RELATIONSHIP BETWEEN EXT_SYNC AND VIDEO OUTPUT

There are several noteworthy caveats regarding Sync mode:

- In Slave mode, Boson+ responds to the rising edge of an externally generated EXT_SYNC pulse. Recommended pulse width is ≥90 ns. In master mode, the output pulse width is nominally four row periods.
- The sensor assembly is factory-calibrated in free-running mode at a frequency of 60.0Hz. As is generally the case for most thermal cameras, operating Boson+ sensor in Slave mode at a frequency vastly different than that used for calibration can result in degraded image quality. Teledyne FLIR has validated image quality to be comparable to that in free-running mode for frequency in the range 60.0 ±0.25Hz.
    - Much lower external-sync frequencies are possible, but as frame rate is reduced outside the recommended range, performance is expected to be significantly compromised, and particularly where non-uniformity of camera temperature is varied. More frequent FFC is recommended when operating in this manner. It is also worth noting that if EXT_SYNC is provided in "bursts" (e.g., a nominal frequency near 60Hz but with occasional long gaps between pulses), image quality may be compromised for several seconds after the pulse train resumes while the sensor returns to its steady-state temperature.
    - The highest supported sync frequency is 60.4Hz. Any EXT_SYNC pulse sent ≤16.56 ms after a previous pulse will be ignored. For example, if a pulse train is sent at a rate of 60.5Hz (16.53 ms between pulses), every other pulse will be ignored, resulting in readout rate of 30.25Hz (33.06 ms between output frames).
- When operating in Averager-enabled mode (Section 5.1 and Section 7.3), EXT_SYNC rate in Master mode will continue to be 60.0Hz even though output frame rate is 30.0 Hz. Similarly, in Slave mode, EXT_SYNC must be provided at twice the expected output rate. For example, if an output frame rate of 30.0Hz is expected, EXT_SYNC pulses should be provided at a rate of 60.0Hz. This is because the Boson+ sensor must generate two input frames for each output frame from the Averager function when it is enabled.
- In either Master mode or Slave mode, CMOS Output mode should be set to "one-shot" (Section 7.17) if it is intended for the CMOS frame rate to match the frequency of the EXT_SYNC pulse train. In "continuous" CMOS-Output mode, CMOS frame rate is locked at 60.00Hz (even if sensor frame rate is not 60.00Hz) by duplicating or dropping frames as necessary.

7 OPERATING STATES AND MODES

Boson+ provides several operating states and modes, more completely defined in the sections which follow. Modes of operation are user-selectable (i.e., the camera operates this way or that way depending upon user selections) whereas states are camera behaviors or operating conditions which take place automatically.

7.1 Start-Up States

Boson+ provides four start-up states. In most cases, the transitions between states are the result of explicit action from the user, indicated by **bold text** in Figure 51. The transition from "booting" to "fully booted" is automatic, requiring no user intervention. The four states and the transitions between them are described in more detail below.

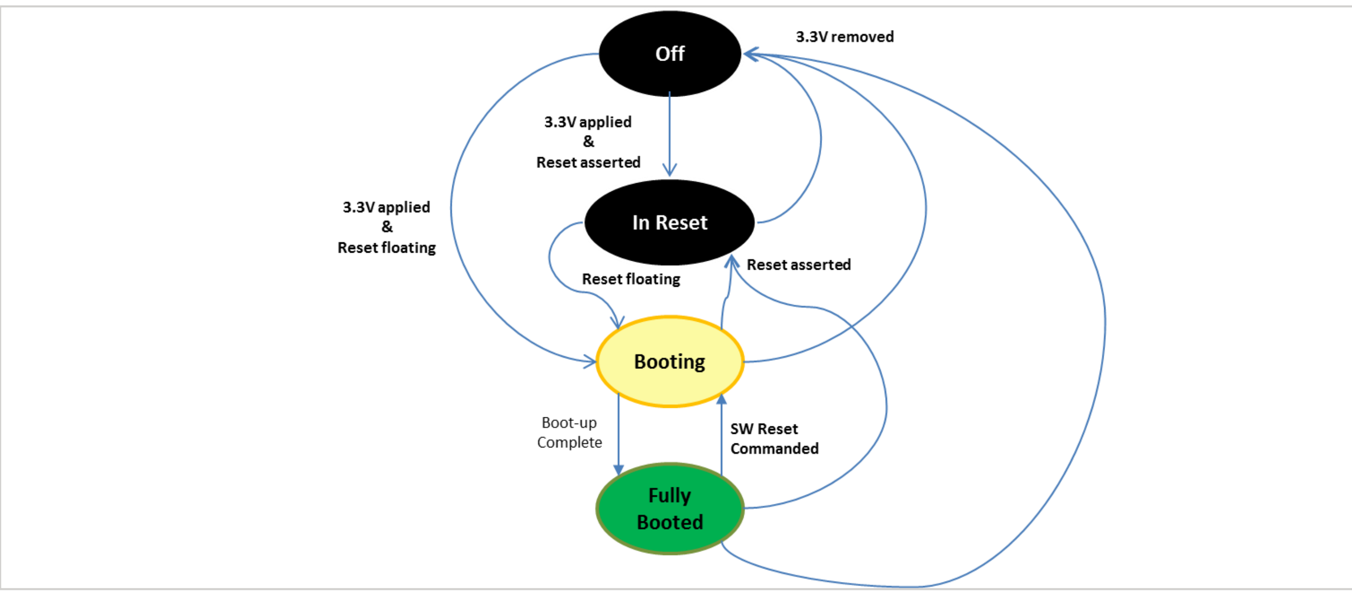


FIGURE 51: BOSON+ START-UP STATES

- **Off**: When no voltage is applied, Boson+ is in the Off state. In the off state, no camera functions are available and the camera consumes no power.
- **In Reset**: When voltage is applied but the reset pin is asserted, Boson+ is in the "In Reset" state. In the "In Reset" state, no camera functions are available and the camera consumes minimal power (~65mW). Note that the Reset pin is asserted low.
- **Booting**: In the "Booting" state, Boson+ is loading its program and initializing itself for full operation. Note that the reset pin must be floating for Boson+ to exit from the "Booting" state to the "Fully-booted" state.

- **Fully Booted**: In the "Fully-booted" state, Boson+ is fully functional, producing imagery and capable of responding to commands via the CCI.

NOTE: It is not necessary to connect the reset pin to power on the Boson+ camera, but it must be floating when the camera is in the "Booting" state, not tied to 1.8V or ground.

NOTE: Avoid sending commands via the CCI while the camera is in any state other than when fully booted. This is indicated by output of imagery on the CMOS or MIPI and/or USB channels.

NOTE: Avoid using the reboot command in the CCI to trigger a Boson reset. Using the reset pin or a full power cycle is advised.

7.2 Overtemp Modes and States

Boson+ provides two overtemp shutdown modes:

- **Enabled (factory default):** The camera automatically transitions to a low-power state when the internal core temperature exceeds the maximum safe value. The camera can respond to commands in the low-power state, but the image pipeline is deliberately disabled to reduce power dissipation, thereby reducing core temperature. As illustrated in Figure 52, the transition between the normal imaging state and the low-power state is via a temporary "overtemp" state, as described below.
- **Disabled:** The camera transitions to the overtemp state but not to the low-power state in response to core temperature exceeding the maximum safe value. This mode is provided strictly for mission-critical applications (such as firefighting), in which it is essential to extend mission life as much as possible, even at the risk of permanent damage to the core. Because of the high risk of damage resulting from extended operation in the overtemp state, operation in the "Overtemp Shutdown Disabled" mode voids the camera warranty.

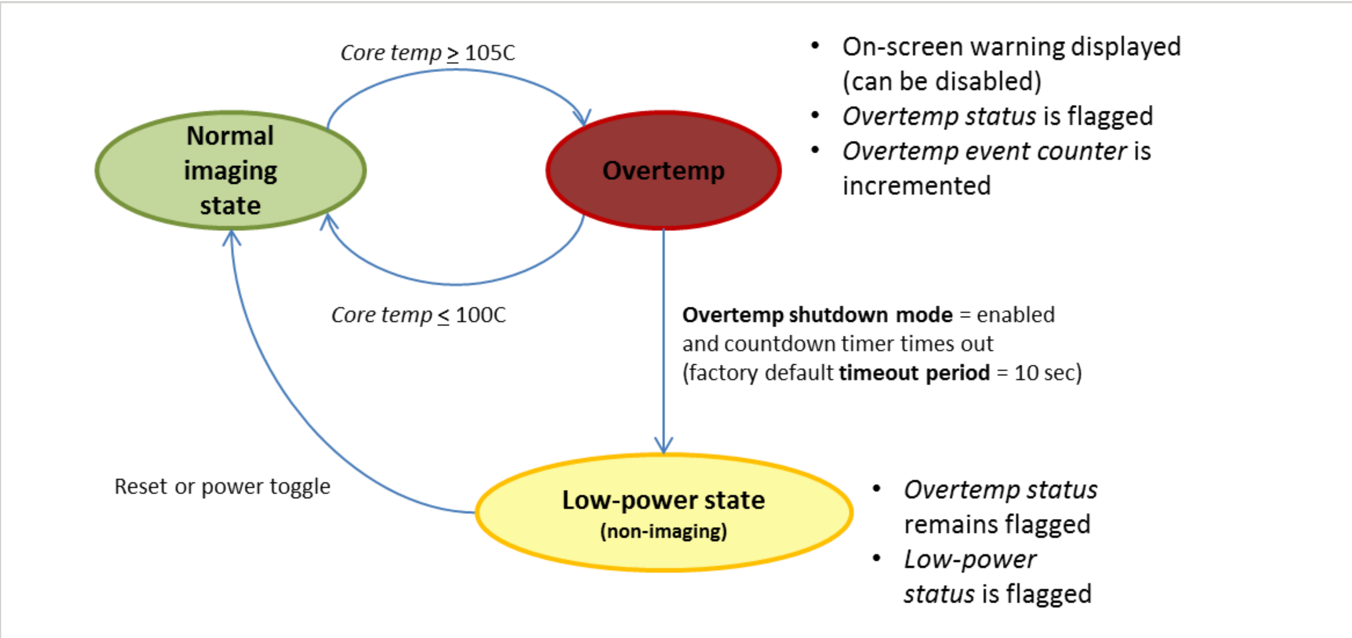


FIGURE 52: BOSON+ OVERTEMP AND LOW-POWER STATES

Normal Imaging State to Overtemp State: When the camera's internal core temperature exceeds its maximum safe value of 105°C, the camera automatically transitions to the overtemp state. In this state, an overtemp status flag is set (Bit 8 of the status bits provided in columns 38 – 41 of the telemetry line, see Section 52), an overtemp event counter is incremented (columns 83 and 84 of the telemetry line), and the on-screen warning shown in Figure 43 is provided on the post-colorize/symbol overlay video tap. It is possible to disable the on-screen warning display (Section 6.11). A countdown timer starts when the camera first enters the overtemp state. The factory-default **timeout period** of the countdown timer is ten seconds.

- **Overtemp State to Normal-Imaging State**: If core temperature falls into a safe operating range (< 100°C) while the camera is still in overtemp state, a transition back to normal-imaging state occurs. The *overtemp status fl*ag is cleared, the on-screen warning is removed, and the countdown timer is stopped and restored to its starting value.
- **Overtemp State to Low-Power State**: Unless **overtemp shutdown mode** has been set to "disabled" (as described above), the camera automatically transitions from overtemp to the low-power state when the overtemp countdown timer times out. In low-power state, the camera continues responding to commands sent over the CCI, but the image-processing pipeline is disabled, causing no further output frames to be provided at the video channels. The camera low-power state can be ascertained via a low-power status flag readable via the CCI. The same status is also provided in the telemetry line (Bit 7 of the status bits provided in columns 38 – 41 of the telemetry line) on the very last frame before the camera transitions from overtemp state to low-power state. The camera core temperature value can also be read via the CCI while in the low-power state.

- **Low-Power State to Normal Imaging State**. The only exit from the low-power state is toggling camera power or resetting (by asserting the reset signal or via a reset command). Note that if the camera's core temperature is still above maximum safe value after reset, the entire process will start over again and the camera will immediately transition back into the overtemp state.

The factory default value of the **timeout period** of the overtemp countdown timer is ten seconds, but it can be varied between 0 and 20 seconds. A value of 0 is treated as an exception. Instead of causing the camera to immediately transition from overtemp to non-imaging state (i.e., a zero-second stay in the overtemp state), a value of 0 causes the camera to never transition to the low-power state. That is, a value of 0 is effectively treated as infinity and is therefore an alternative means of preventing automatic transition to low-power state.

NOTE: Leaving the overtemp shutdown mode at "enabled" and setting the timeout period of the overtemp countdown timer to a value between 1 and 20 seconds is highly recommended. Setting overtemp shutdown mode to "disabled" and/or setting the timeout period to 0 seconds (which is treated as an exception, as described above) voids the camera warranty.

NOTE: Section 6.14.2 explains the distinction between Camera Temperature and Core Temperature. The latter is the relevant variable for triggering overtemp and low-power states.

NOTE: Section 9.1 explains recommended heatsinking practices for avoiding an overtemp condition.

7.3 Averager Modes

Boson+ provides two averager modes affecting the video output signal:

- **Averager disabled (factory default)**
- **Averager enabled**

The mode is selected using the **Averager Enable** command. As described in Section 5.1, the primary benefit of enabling the averager is power reduction for those applications which do not require a high frame rate.

NOTE: Intended use case is that the averager mode is specified and saved as a power-on default (Section 6.1). A change to averager mode will not affect frame rate on the current power cycle. To change frame rate, the change to the averager mode must be saved as a power-on default and then the camera reset or power cycled. If the change to averager mode is not saved as a power-on default, the selection is inconsequential since it has no effect on the current power cycle.

7.4 Frame-Skip Modes

Boson+ provides 7 Frame-Skip settings affecting the output frame rate:

TABLE 7: FRAME-SKIP MODES

FS VALUE	OUTPUT FRAME RATE (FPS) (ASSUMING AVERAGER DISABLED)
0 (factory default)	60
1	30
2	20
3	15
4	12
5	10
6	~8.6

As described in Section 5.2, the primary benefit of frame skipping is power reduction for applications which do not require a high frame rate. Relative power savings are shown in Figure 73.

NOTE: The frame-skip feature is not available in MIPI capable cameras configured for MIPI output.

7.5 Isotherms Modes

Boson+ provides two Isotherms modes:

- **Isotherms Disabled (factory default)**
- **Isotherms enabled**

For the Isotherms feature to provide the desired post-colorization output, each Isotherm region for each gain state (high-gain and low-gain) must be properly configured by specifying up to 39 parameters:

- Boundary Units: Percentage, Kelvin, Celsius, and Fahrenheit
- 8 Boundary Values: Lower-Boundary for Regions 1-4 in high-gain state and in low-gain state.
  - The lower boundary of Region 0 is always min value
  - The upper boundary of Regions 0 – 3 are the lower boundaries of Regions 1 – 4
  - The upper boundary of Region 4 is always max value
- 10 Colorization Modes: Mode for Regions 0-4 in high-gain state and in low-gain state. See Section 6.3 for a description of the Colorization Modes.
- Up to 20 Color Values: Color 1 and Color 2 for Regions 0 - 4 in high-gain state and low-gain state. Note that some Colorization modes require less than 2 colors, and some require none. For those modes, the unused Color Values can be left at factory-default values or set to any value.

7.6 Telemetry Modes

Boson+ provides three telemetry modes affecting the CMOS, MIPI, and USB output signal:

- **Telemetry enable** is either true or false. Factory-default value is true.
- **Telemetry location** determines whether the telemetry line is provided on the first row (as a header) or on the last row (as a footer) of each video frame. Factory-default value is header. For MIPI output modes utilizing pixel-embedded telemetry, the telemetry data is only available on the first row.
- **Telemetry encoding** determines how the telemetry line is provided. For CMOS output:
    - **16b mode**: In this mode, the factory-default, each telemetry datum is provided as a 16b word on cmos_data[0-15].
    - **8b mode**: In this mode, each telemetry datum is provided as two consecutive bytes (big-endian order) on cmos_data[0-7]. Consequently, twice as many clock periods are required to transmit the data, so each datum takes up twice as many "pixels" compared to 16b mode.
    - **8b-swapped mode ("Y" mode)**: This mode is identical to 8b mode except that bytes are provided in little-endian order (least-significant byte provided first).

NOTE: For MIPI camera models, Telemetry is available as an additional top row of the digital output image (513 x 640), containing the same information and in the same formatting as used for CMOS video. Telemetry is also available as an independent meta-data stream. Telemetry can be either enabled or disabled.

7.7 Radiometry Modes

For radiometrically capable configurations, Boson+ provides three radiometric output modes:

- **Radiometry Disabled (T-linear Enable/Disable has no effect on output)**: 16b output varies with both scene flux and camera temperature
- **Radiometry Enabled, T-linear Disabled**: 16b output value is intended to be proportional to scene-flux only, and independent of camera temperature
- **Radiometry Enabled, T-linear Enabled**: 16b output value is intended to be proportional to scene-temperature

See Section 6.2 for a more detailed description of each radiometry mode.

NOTE 1: For non-radiometric configurations, it is not possible to enable radiometry.

NOTE 2: Radiometry is available for CMOS, USB, and MIPI output if the camera part number has the 'R' designation in the second position from the right.

7.8 Gain Modes and States

As described in Section 6.5, Boson+ provides two gain states: high and low. There are 3 gain *modes* which determine in which gain state it operates:

- **High-gain mode (factory default)**: Boson+ operates in high-gain state only and does not signal *Table Switch Desired* in response to scene conditions
- **Low-gain mode**: Boson+ operates in low-gain state only and does not signal *Table Switch Desired* in response to scene conditions.
- **Automatic gain mode**: In automatic FFC mode (Section 7.9), Boson+ automatically transitions between high-gain state and low-gain state based on scene conditions and user-specified parameters. In manual and external FFC mode, *Table Switch* Desired is set based on scene conditions and user-specified parameters. See Section 6.5 for a detailed description of the parameters.

7.9 FFC Modes and States

Boson+ provides four different FFC modes:

- **Automatic (factory default for configurations with a shutter)**: The camera periodically performs automatic FFC in response to a number of conditions, as described in more detail in
- Table 8. See Section 6.6 for a general description of the FFC feature.
- **Manual**: The camera may perform automatic FFC at start-up, depending upon whether a valid non-volatile FFC map is stored (Section 7.9.1). Thereafter, it only performs FFC upon command. The camera sets an *FFC Desired* flag under conditions described in Table 8.
- **External (factory default for shutterless configurations)**: The camera *never* performs FFC except upon receipt of the "Do FFC" command and does not utilize the internal shutter for FFC. Instead, it must be imaging a uniform external source before FFC is commanded. The uniform source must be held in place until the FFC State changes from *FFC In Progress to FFC Complete*, as described below. The camera sets an *FFC Desired* flag under conditions described in Table 8.
- **External with Auto Table Switch**: The FFC behavior is the same as External, but the camera will switch temperature tables automatically when desired. Boson+ does not automatically perform an FFC when the new table is loaded and does not signal *Table Switch Desired* in response to scene conditions.

TABLE 8: CAMERA BEHAVIOR IN EACH FFC MODE IN RESPONSE TO VARIOUS OPERATING CONDITIONS

CONDITION	BEHAVIOR IN AUTO FFC MODE	BEHAVIOR IN MANUAL FFC MODE	BEHAVIOR IN EXTERNAL FFC MODE	BEHAVIOR IN EXTERNAL WITH AUTO TABLE SWITCH
Start-up	Automatic FFC take place	If a valid NVFFC map is stored (Section 7.9.1), it is loaded. Otherwise, automatic FFC takes place.	If a valid NVFFC map is stored (Section 7.9.1), it is loaded. Otherwise *FFC Desired* flag is set.	
Commanded FFC (**Do FFC**)	FFC takes place	FFC takes place; *FFC Desired* is cleared		
Frame Counter – Frame Counter at Last FFC ≥ **FFC Period** (see note 1)	Automatic FFC takes place	FFC Desired is set		
|*Camera Temp* – Camera *Temp at Last FFC*| ≥ **FFC Delta Temp** (see note 1 and note 2)	Automatic FFC take place	FFC Desired is set		

CONDITION	BEHAVIOR IN AUTO FFC MODE	BEHAVIOR IN MANUAL FFC MODE	BEHAVIOR IN EXTERNAL FFC MODE	BEHAVIOR IN EXTERNAL WITH AUTO TABLE SWITCH
Camera is outside the temp span of the current high-gain NUC Table while in high-gain state	Automatic NUC Table switch takes place, followed by automatic FFC	*Table Switch Desired* is set. *Desired NUC Table* is set to the optimal NUC-table value (which will differ from *Current NUC Table)*. See note 4.		Automatic NUC Table switch takes place; *FFC Desired* is set
While in automatic gain mode, scene conditions are sufficient to trigger a gain-state change (i.e., from high to low or vice versa). See Section 6.5.	Automatic gain switch takes place, possibly followed by automatic FFC as described in note 3.	*Table Switch Desired* is set. *Desired NUC Table* set to the optimal NUC-table value (which will differ from *Current NUC Table*).		Automatic gain switch takes place, possibly followed by *FFC Desired* flag being set as described in note 3.
Table Switch Commanded while *Table Switch Desired* is set.	n/a (*Table Switch Desired* is never set)	NUC table switch takes place and *Table Switch Desired* is cleared, possibly followed by automatic FFC as described in note 3.	NUC table switch takes place and *Table Switch Desired* is cleared, possibly followed by *FFC Desired* being set as described in note 3.	
Commanded switch to low-gain mode while in high-gain state or commanded switch to high-gain mode while in low-gain state.	Gain switch takes place, possibly followed by automatic FFC as described in note 3.		Gain switch takes place, possibly followed by *FFC Desired* flag being set as described in note 3.	

Note 1: Frame Counter, Frame Counter at Last FFC, Camera Temp, Camera Temp at Last FFC are all status variables which are provided via the telemetry line (Section 6.7) or via command on the CCI. ***FFC Period*** *and* ***FFC Delta Temp*** *are both user-selectable parameters which can be specified via the CCI, as further described in Section 6.6.*

Note 2: From start-up until a time specified by ***FFC Start-up Period****, the condition is instead |Camera Temp – Camera Temp at Last FFC| ≥* ***FFC Delta Temp*** */ 3, as described in Section 6.6.*

Note 3: Boson+ is capable of transitioning between high-gain and low-gain state without an intervening FFC operation. Separate FFC maps are maintained for high-gain and low-gain states, as well as separate values of Frame Counter at Last FFC and Camera Temp at Last FFC. When transitioning between gain states, whether the result of an automatic switch or commanded switch, automatic FFC or a set of the FFC Desired flag only occurs if elapsed time since FFC in that state and/or temperature change since the last FFC in that state dictate that an FFC take place. See the example below.

Examples of FFC behavior when transitioning between gain states:

- With the camera in automatic FFC mode and high-gain mode, FFC is commanded while *Camera Temperature* has a value of 3000 (300.0K). Following FFC, *Camera Temperature at Last FFC* = 3000 (300.0K). **FFC Temp Delta** is at its factory-default value, 30 (3.0°C).
- When *Camera Temperature* = 301.0K, the camera is commanded into low-gain mode for the first time. Gain switch takes place, and now *Camera Temperature at Last FFC* = 0 since FFC has never been performed in low-gain state. Consequently, automatic FFC takes place, and now *Camera Temperature at Last FFC* = 3010 (301.0K).
- When the camera is at 302.0K, the camera is commanded into high-gain mode. *Camera Temperature at Last FFC* = 3000 again. No FFC takes place and *FFC Desired* is not set since |*Camera Temperature – Camera Temperature at Last FFC*| < **FFC Temp Delta**.
- When the camera is at 303.0K, it is commanded back to low-gain state. Gain switch takes place, and *Camera Temperature at Last FFC* = 3010 again. No FFC takes place and *FFC Desired* is not set since |*Camera Temperature – Camera Temperature at Last FFC*| < **FFC Temp Delta**.
- The camera continues to heat while in low-gain state until it reaches 304.0K. Now an automatic FFC takes place because |*Camera Temperature – Camera Temperature at Last FFC*| ≥ **FFC Temp Delta**. Following FFC, *Camera Temperature at Last FFC* = 3040 (304.0K) and *FFC Desired* is cleared.
- With temperature still at 304.0K, the camera is commanded to high-gain mode. Now *Camera Temperature at Last FFC* = 3000 and another automatic FFC takes place because |*Camera Temperature – Camera Temperature at Last FFC*| ≥ **FFC Temp Delta**.

While the FFC mode defines when and how Boson+ performs FFC, the FFC state pertains to the FFC event itself. There are four FFC states, as illustrated in Figure 53.

1. *FFC not initiated* (power-on default): In this state, Boson+ applies no FFC terms. In automatic FFC mode, this state is never seen because Boson+ always performs automatic FFC at start-up.
2. *FFC imminent*: The camera only enters this state when it is operating in automatic FFC mode. The camera enters “FFC imminent” state at a user-specified period prior to initiating an automatic FFC (factory default = 2 sec). This status warns the user that an FFC is about to occur. Note: the FFC imminent state is not entered prior to an automatic FFC after an automatic table switch.
3. *FFC in progress*: Boson+ enters this state when FFC is commanded from the CCI or when an automatic FFC event is initiated. During each FFC event, the shutter is closed (if in automatic or manual FFC mode), frames of sensor data are collected to generate the correction map, the shutter is opened, and the new FFC map is applied.
4. Boson+ video output is “frozen” throughout the “FFC in progress” state. That is, the last valid frame prior to entering “FFC in progress” is repeated throughout the event. The telemetry line is not frozen; only the thermal image is.
5. *FFC complete*: Boson+ automatically enters this state whenever a commanded or automatic FFC is completed.

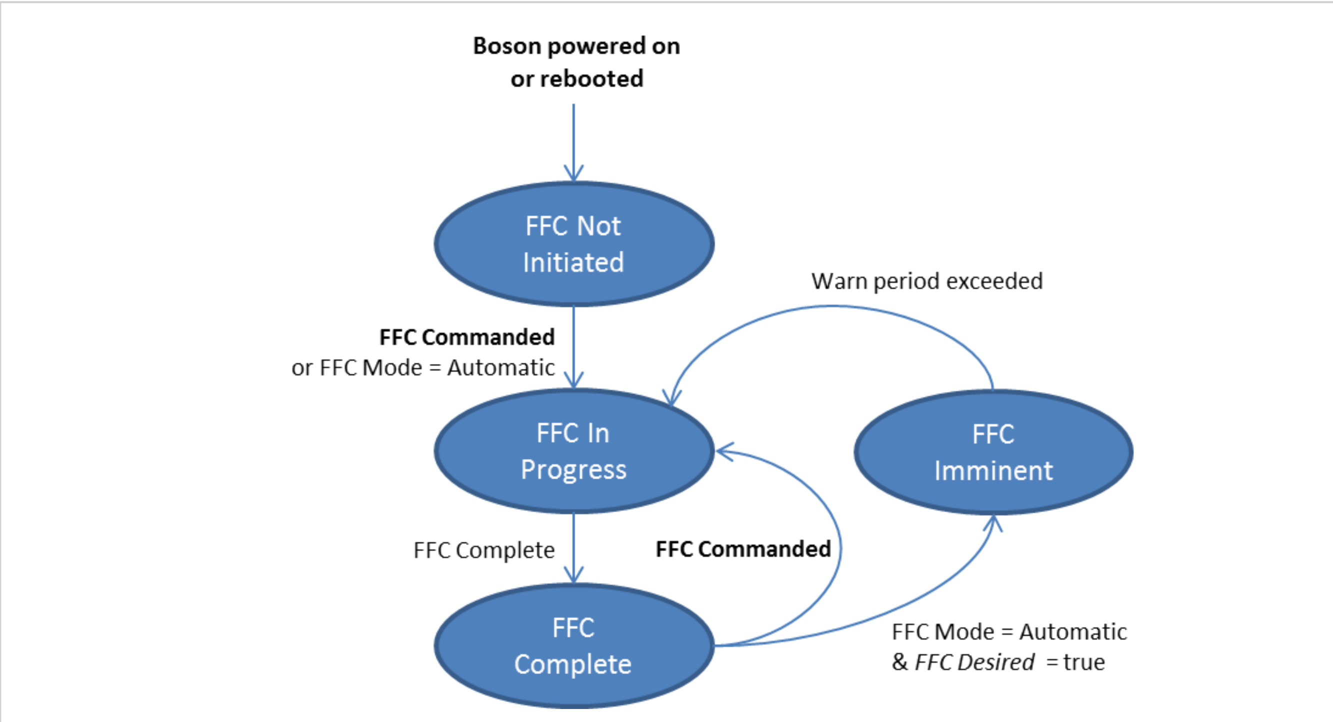


FIGURE 53: BOSON+ FFC STATES

7.9.1 Non-volatile FFC

Boson+ provides the option to store the current FFC map to non-volatile memory. The intent of this feature is to support a faster transition from start-up to useable imagery, particularly when the camera has only been powered down briefly since the last FFC.

When the camera receives a command to store the current FFC map, it also stores the value of "Camera temperature at last FFC" (the same value reported in the telemetry line, as shown in Table 5) as well as the current NUC table. See note 2 of

Table 8 for a description of NUC tables. The next time the camera powers up, the decision to utilize the stored NVFFC map depends upon FFC mode, as described below.

- Automatic FFC: The camera does not load the stored NVFFC map but instead performs automatic FFC. If the option of a faster start-up is desired, the power-on default FFC mode should be set to manual mode.
- Manual FFC: If the stored NVFFC map was generated in the same NUC table as the start-up NUC table, it is loaded and applied. Otherwise, an automatic FFC takes place under the assumption that the stored map is invalid for the current conditions (i.e., will result in sub-optimal image quality). If the map is loaded, the value of "Camera temperature at last FFC" will be set to the value stored with the NVFFC map and the value of "Frame counter at last FFC" will be set to 0. Note that the *FFC Desired* flag may be set

immediately after the NVFFC map is loaded, assuming the difference between current camera temperature and "Camera temperature at last FFC" exceeds the value of **FFC Delta Temp**, as depicted in Table 8.

- External FFC: If the stored NVFFC map was generated in the same gain state as the start-up gain state (Sections 6.2 and 0), it is loaded and applied. Otherwise, no FFC offset is applied and the *FFC Desired* flag will be set under the assumption that the stored map is invalid for the current conditions. If the map is loaded, the value of "Camera temperature at last FFC" will be set to the value stored with the NVFFC map and the value of "Frame counter at last FFC" will be set to 0. Note that the *FFC Desired* flag may be set immediately after the NVFFC map is loaded, assuming the difference between current camera temperature and "Camera temperature at last FFC" exceeds the value of **FFC Delta Temp**, as depicted in Table 8.

NOTE: It is always preferred to generate a fresh FFC map at start-up rather than relying on a stored, potentially stale NVFFC map. The NVFFC feature is intended primarily for when a camera has only been powered down briefly since the previous FFC. Use of the NVFFC feature does not replace the recommendation to perform FFC at start-up, even for shutterless configurations.

7.10 Lens Mode

Boson+ provides two lens modes:

- **Lens 0 (factory default)**
- **Lens 1**

The primary intent of multiple lens modes is to support a dual-FOV lens assembly. For such a lens, the illumination pattern and the out-of-field irradiance may differ between the two FOVs, in which case better image quality can be obtained by switching the applied correction terms when switching the FOV. This can be accomplished by toggling the lens mode, which causes the following terms to be swapped:

- Lens-gain map. (Section 5.3)
- SFFC map. (Section 5.3)
- NVFFC map. (Section 7.9.1) The NVFFC map is only loaded at start-up, and the power-on default selection of lens mode determines which of the two will be loaded. Switching lens mode after start-up will *not* cause the other NVFFC map to load. Instead, the current FFC map will continue to be applied.

NOTE: For any Boson+ configuration which includes a factory-installed lens, Lens 0 is factory-calibrated, and Lens 1 is empty. For lensless configurations, both Lens 0 and Lens 1 are empty, as it is intended that a lens-calibration procedure will be performed by the user after installing a lens assembly.

7.11 AGC Modes

As described in Section 6.8, Boson+ provides two AGC modes:

- **Information-Based Equalization Mode Enabled (factory default)**: AGC transfer function is based on the amount of information in the scene. Portions of the scene which contain variations (e.g., foliage) are weighted more heavily than portions which only vary gradually (e.g., sky).
- **Information-Based Equalization Mode Disabled**: AGC transfer function weights all pixels equally.

7.12 CMOS Video-Tap Modes

As described in Section 5 and shown in Figure 54, there are multiple locations in the signal pipeline where video can be tapped for output on the CMOS channel. Boson+ provides the following CMOS video-tap modes:

- **Pre-AGC (16-bit) (factory default)**: The output is linearly proportional to incident irradiance; output resolution is the same as FPA resolution (e.g., 320x256 or 640x512). Data is provided on CMOS Data[0:15]. Note that AGC settings, zoom settings, and color-encoding settings have no effect on the output signal at this tap point. Note that the Radiometry Modes described in Section 7.7 affect the Pre-AGC output tap.
- **Radiometry Enabled Pre-AGC (16-bit) (factory default with Radiometry enabled)**: On Radiometry enabled cameras the T-stable or T-linear tap point is available. See Figure 54, as well as Section 7.7.
- **Post-AGC / Pre-Zoom (8-bit)**: The output is contrast enhanced via the AGC algorithm; output resolution is the same as FPA resolution. Data is provided on CMOS_Data[0:7]. Note that zoom settings and color-encoding settings have no effect on the output signal at this tap point.
- **Post-Zoom, Post-Colorize (various bit-width options depending upon color-encoding mode)**: The output is stretched to 640x512 resolution regardless of array format, and the displayed field of view is a function of the user-specified zoom parameters. The output is transformed to color space using the specified color palette (Section 6.10) and specified color encoding mode (Section 7.15).

NOTE: USB and the digital output modes, CMOS video or MIPI video, can access different tap points simultaneously. This is especially useful when Radiometric and Post-AGC data are required.

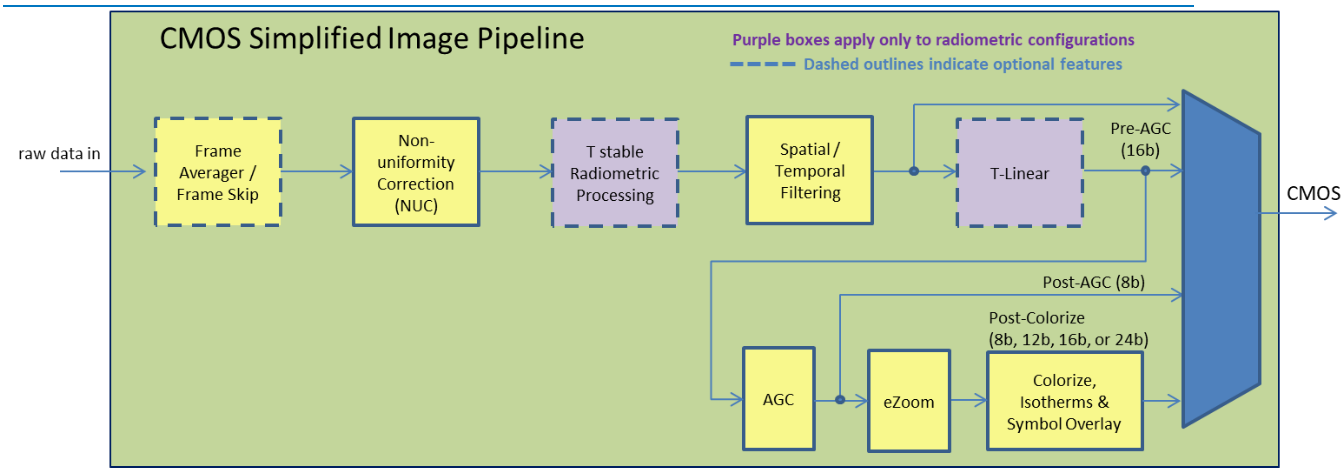


FIGURE 54: BOSON+ SIGNAL PIPELINE – CMOS OUTPUT ENABLED

WARNING: EAR99 Technology Subject to Restrictions Contained on the Cover Page

7.13 MIPI Video-Tap Modes

As described in Section 5 and shown again in Figure 55, there are multiple locations in the signal pipeline where video can be tapped for output on the MIPI channel. MIPI specific details can be found in the Boson MIPI application note 102-2013-106. Boson+ provides the following MIPI video-tap modes:

- **Pre-AGC (14-bit)**: The output is linearly proportional to incident irradiance; output resolution is the same as FPA resolution (e.g., 320x256 or 640x512). Note that AGC settings, zoom settings, and color-encoding settings have no effect on the output signal at this tap point. Note that the Radiometry Modes described in Section 7.7 affect the pre-AGC output tap.
- **Radiometry Enabled Pre-AGC (14-bit) (factory default with Radiometry enabled)**: On Radiometry enabled cameras, the T-stable or T-linear tap point is available. See Figure 55, as well as Section 7.7.
- **Post-AGC / Pre-Zoom (8-bit) (factory default)**: The output is contrast enhanced via the AGC algorithm; output resolution is the same as FPA resolution. Note that zoom settings and color-encoding settings have no effect on the output signal at this tap point.
- **Post-Zoom, Post-Colorize (various bit-width options depending upon color-encoding mode)**: The output is stretched to 640x512 resolution regardless of array format, and the displayed field of view is a function of the user-specified zoom parameters. The output is transformed to color space using the specified color palette (Section 6.10) and specified color encoding mode (Section 7.16).

NOTE: USB and the digital output modes CMOS video or MIPI video can access different tap points simultaneously. This is especially useful when Radiometric and Post-AGC data are required.

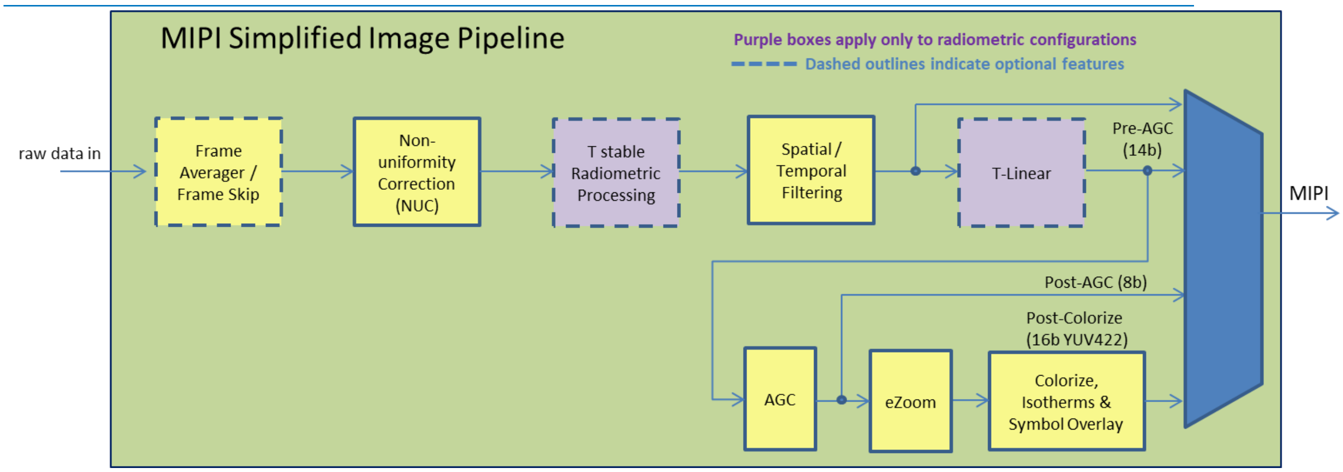


FIGURE 55: BOSON+ SIGNAL PIPELINE – MIPI OUTPUT ENABLED

7.14 USB Video-Tap Modes

As described in Section 5 and shown in Figure 56, there are multiple locations in the signal pipeline where video can be tapped for output on the CMOS channel. Boson+ provides the following CMOS video-tap modes:

- **Pre-AGC (16-bit) (factory default)**: The output is linearly proportional to incident irradiance; output resolution is the same as FPA resolution (e.g., 320x256 or 640x512). Note that AGC settings, zoom settings, and color-encoding settings have no effect on the output signal at this tap point. Note that the Radiometry Modes described in Section 7.7 affect the pre-AGC output tap.
- **Radiometry Enabled Pre-AGC (16-bit) (factory default with Radiometry enabled)**: On Radiometry enabled cameras, the T-stable or T-linear tap point is available. See Figure 56, as well as Section 7.7.
- **Post-AGC / Pre-Zoom (8-bit)**: The output is contrast enhanced via the AGC algorithm; output resolution is the same as FPA resolution. Note that zoom settings and color-encoding settings have no effect on the output signal at this tap point.
- **Post-Zoom, Post-Colorize (various bit-width options depending upon color-encoding mode)**: The output is stretched to 640x512 resolution regardless of array format, and the displayed field of view is a function of the user-specified zoom parameters. The output is transformed to color space using the specified color palette (Section 6.100).

NOTE: USB and the digital output modes, CMOS video or MIPI video, can access different tap points simultaneously. This is especially useful when Radiometric and Post-AGC data are required.

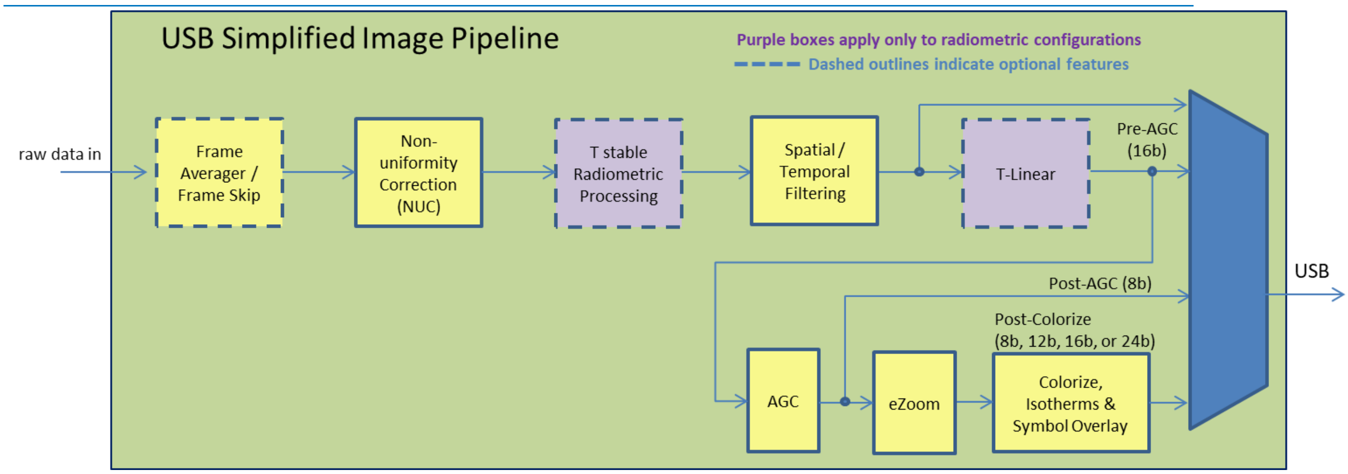


FIGURE 56: BOSON+ SIGNAL PIPELINE – USB OUTPUT ENABLED

7.15 CMOS Color-Encoding Modes

Boson+ provides the following color-encoding modes which affect formatting of the output video signal when the post-colorize tap is selected:

- **YCbCr 4:2:2 (16-bit per pixel) (factory-default)**: The signal consists of a luminance channel (8 bits per clock on CMOS_Data[0:7]), a blue chrominance channel (8 bits on each even clock cycle on CMOS_Data[8-15]), and a red chrominance channel (8 bits on each odd clock cycle on CMOS_Data[8-15]).
- **YCrCb 4:2:2 (16-bit per pixel)**: The signal is identical to YCbCr, except the red and blue chrominance channels are swapped. That is, the red chrominance channel is provided on the even clock cycle and the blue chrominance channel on the odd clock cycle.

NOTE: Only YCbCr 4:2:2 and YCrCb 4:2:2 are validated in the current software release. All remaining options shown below are capable of being selected but are not currently validated. Teledyne FLIR does not recommend relying on any of these without thoroughly testing in the end application.

- **CrCbY 4:2:2 (16-bit per pixel)**: The signal is identical to YCrCb, but the CMOS_Data channels are swapped.
- **CbCrY 4:2:2 (16-bit per pixel)**: The signal is identical to YCbCr, but the CMOS_Data channels are swapped.
- **YCbCr 4:2:2 muxed (16-bit per pixel, 2 clocks per pixel):** The luminance and chrominance channels are time-multiplexed on CMOS_Data[0:7]. Specifically, the luminance is provided on clock cycles *n* and *n*+2, the blue chrominance channel on clock cycle *n*+1, and the red chrominance channel on clock cycle *n*+3, for *n* = 0, 4, 8, etc. The CMOS pixel clock rate is doubled when in this mode.
- **YCrCb 4:2:2 muxed (16-bit per pixel, 2 clocks per pixel):** The signal is identical to YCbCr 4:2:2 muxed except the order of the red and blue chrominance channels are swapped. That is, the red chrominance channel is provided on clock cycles *n*+1 and the blue chrominance channel on cycles *n*+3. The CMOS pixel clock rate is doubled when in this mode.

For reference, the color encoding of each mode is depicted graphically in Figure 57.

Color Mode	Clk	CMOS_Data																							
		23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0

YCbCr 4:2:2	0	Unused	Cb[7:0]	Y0[7:0]
	1	Unused	Cr[7:0]	Y1[7:0]
YCrCb 4:2:2	0	Unused	Cr[7:0]	Y0[7:0]
	1	Unused	Cb[7:0]	Y1[7:0]
CbCrY 4:2:2	0	Unused	Y0[7:0]	Cb[7:0]
	1	Unused	Y1[7:0]	Cr[7:0]
CrCbY 4:2:2	0	Unused	Y0[7:0]	Cr[7:0]
	1	Unused	Y1[7:0]	Cb[7:0]
YCbCr 4:2:2 muxed	0	unused		Y0[7:0]
	1	unused		Cb[7:0]
	2	unused		Y1[7:0]
	3	unused		Cr[7:0]
YCrCb 4:2:2 muxed	0	unused		Y0[7:0]
	1	unused		Cb[7:0]
	2	unused		Y1[7:0]
	3	unused		Cr[7:0]
RBG 8:8:8Muxed	0		G[3:0]	R[7:0]
	1		B[7:0]	G[7:4]
RGB 5:6:5 Muxed	0		G[2:0]	R[4:0]
	1		B[4:0]	G[5:3]

Modes which are highlighted in gray are implemented but have not been validated in the current product release. Use is discouraged without thorough testing.

FIGURE 57: BOSON+ VARIOUS COLOR-ENCODING MODES

7.16 MIPI Color-Encoding Modes

Boson+ provides the following color-encoding modes which affect formatting of the output video signal when the post-colorize tap is selected:

- **YCbCr 4:2:2 (16-bit per pixel) (factory-default)**: The signal consists of a luminance channel (8 bits per clock), a blue chrominance channel (8 bits on each even clock cycle), and a red chrominance channel (8 bits on each odd clock cycle).

The MIPI color-encoding mode has no effect on the video signal unless MIPI video-tap mode is "post colorize."

7.17 CMOS Output Modes

The final stage in the Boson+ signal pipeline is a multi-frame buffer. The CMOS output channel reads the front buffer while the signal pipeline writes a background buffer. Boson+ provides two CMOS output modes which affect the behavior of the CMOS channel in relation to the multi-frame buffer:

- **One-shot:** In this mode, the CMOS channel inserts idle time between successive frames in those instances where there is not a back buffer ready for readout and the front buffer has been completely read. Consequently, the number of clocks per frame period is not a constant, but can instead vary slightly. In this mode of operation, every frame is unique: the output frame rate is equal to the effective frame rate. This mode of operation for interfacing is preferred to a frame grabber which can tolerate slight frame-rate jitter. It is also the preferred mode when in external-sync (slave) mode.

NOTE: The CMOS Output mode has no effect on the USB video channel. The USB video channel always operates in one-shot mode.

- **Continuous (factory-default):** In this mode, the CMOS channel provides data at a regular cadence (i.e., exact same clocks per frame period without exception). If the background buffer is still being written when the front buffer has been fully read out, the front buffer is read out again, resulting in a duplicated frame. This mode of operation is preferred for interfacing to a display system which requires frame data at a regular interval.

NOTE: Since the effective frame rate and the output frame rate are nominally identical in free-running mode, it is very uncommon to find duplicated frames in continuous mode. The presence of a duplicated frame can be detected via the frame counter in the telemetry line since the frame counter does not increment for a duplicated frame.

7.18 MIPI Output Modes

The final stage in a Boson+ non-MIPI signal pipeline is a multi-frame buffer, while for MIPI Boson+ cameras adhering to the MIPI CSI standard there is no multi-frame buffer and no continuous mode option as described for CMOS output (Section 7.17). Instead, MIPI always operates in the equivalent of a low latency (< 4.8 ms) one-shot mode with the video pipeline serving as the software trigger. Consequently, the number of clocks per frame period is not a constant and can vary slightly. In this mode of operation, every frame is unique. For interfacing, this behavior is preferred to a frame grabber able to tolerate slight frame-rate jitter or when in external-sync (slave) mode. The output frame rate is equal to the effective frame rate. Details can be found in the Boson MIPI application note; 102-2013-106.

NOTE: The MIPI Output mode has no effect on the USB video channel. The USB video channel always operates in one-shot mode.

7.19 Analog Modes

Boson+ provides the option of outputting a BT.656 signal using the pins normally used to provide the CMOS video channel. This ability is utilized by the Teledyne FLIR USB / Analog VPC Accessory (Section 15.20) to obtain analog video output. There are three "analog modes":

- **Analog Disabled (factory default)**: The CMOS channel is configured to output video according to the timing and logic described in Section 8.2.1
- **NTSC**: The CMOS channel is configured for BT.656 output at 60Hz frame rate, outputting 525 lines per frame (525/60)
- **PAL**: The CMOS channel is configured for BT.656 output at 50Hz frame rate, outputting 625 lines per frame (626/50)

When the CMOS channel is configured for BT.656 output, cmos_vsync, cmos_hsync, and cmos_data_valid are unused. That is, only cmos_pclk and cmos_data[0-7] are utilized, with the most-significant bit provided on cmos_data7 and the least significant bit provided on cmos_data0. Clock rate remains 27 MHz when the channel is configured for BT.656 output.

There are several noteworthy caveats regarding Boson+ BT.656 output signal:

- The output is single ended, not differential
- Digital line alignment does not follow the BT.656 standard exactly. In a compliant implementation, each video line begins with an EAV code, then blanking, then SAV code, then Video Data. In Boson+, digital alignment is achieved by observing EAV/SAV pairs only when only the "H' bit is changing, making it a non-standard implementation. Teledyne FLIR has not seen any problems from this.

- No scaling of BT.656 output
- Teledyne FLIR has observed some image pulsing on older CRT monitors. LCD monitors are recommended for optimal analog display.
- BT.656 limits output to values within the range 16 to 235. Because the BT.656 channel and the USB channel both receive data from a common output buffer, the post-AGC USB video format will also be limited to values within the range 16 to 235 when Analog mode is set to NTSC or PAL.

When Boson+ is mated with the Teledyne FLIR USB / Analog VPC Accessory, it automatically detects a video encoder on the accessory and will not normally allow the NTSC or PAL modes to be selected unless this video encoder is detected. It is possible (and necessary) to override this automatic detection feature for applications which intend to utilize the BT.656 output without installing the Teledyne FLIR USB / Analog VPC Accessory. This override is accomplished via command over the CCI.

NOTE: The I2C CCI is not available when the camera is configured to output Analog video. Switching from CMOS video to analog video requires a camera reboot.

NOTE: When analog mode is set to NTSC or PAL, Boson+ automatically sets the CMOS Video-Tap Mode to Post Colorization (Section 7.12), the CMOS Color-Encoding Mode to YCbCr 4:2:2 only (Section 7.150), and the CMOS Output Mode to Continuous (Section 7.17). These are required settings, and changing any of them will prevent the BT.656 channel from functioning properly. Operating in External Sync (slave) mode is not recommended (Section 7.20) when analog mode is set to NTSC or PAL.

NOTE: When the averager mode is set to enabled, the BT.656 output channel continues to provide data at either 60Hz (NTSC mode) or 50Hz (PAL mode) by duplicating every frame at the output.

7.20 Sync Modes

Boson+ provides 3 different Sync modes:

- **Disabled Mode (factory default)**: The camera generates its own timing and ignores any externally generated sync signal provided on EXT_SYNC. No output signal is provided on EXT_SYNC.
- **Master Mode**: The camera generates its own timing and ignores any externally generated sync signal provided on EXT_SYNC. It outputs a pulse on EXT_SYNC corresponding to the start of readout from the sensor of each new frame.

- **Slave Mode**: The camera only generates new frames in response to a sync pulse provided on EXT_SYNC.

See Section 0 for a more complete description and associated requirements of each Sync Mode.

8 INTERFACE DESCRIPTIONS

This section describes the primary electrical interfaces to the camera.

8.1 Command and Control Interface

Boson+ provides multiple options for a command-and-control interface (CCI):

- UART (for asynchronous serial interfaces such as RS232), 921600/8-N-1 (921.6kBaud, 8 data bits, no parity bit, 1 stop bit)
- USB virtual serial port
- I2C interface (See 102-2013-106)

Each interface is described in the Boson Software Interface Description Document (IDD), Teledyne FLIR document #102-2013-42. For all CCI channels, the Boson+ core is a “slave” device that never transmits a message without first receiving one, and always transmits a reply to a received message. All commands issued through the CCI take the form of a “get” (reading data), a “set” (writing data), or a “run” command that executes a function. A graphical user interface (GUI) that provides full command and control is available for download on Teledyne FLIR’s Boson+ website. (Section 1.3).

8.2 Video Interfaces

Boson+ provides two separate channels for output video:

1. CMOS or MIPI
2. USB

NOTE: It is possible to provide simultaneous output on both channels. CMOS can be configured to provide 16-bit data prior to AGC, while USB provides the post-colorization video tap. For MIPI capable cameras, the MIPI video output can be configured to provide up to 14-bit data prior to AGC as well as post-colorization video tap simultaneously in addition to the USB output. This is recommended for customers who require a visually pleasing image and radiometric data in parallel.

8.2.1 CMOS

Boson+ provides the option of a digital data protocol resembling that of a typical CMOS camera. Specifically:

1. The CMOS video channel is comprised of a pixel clock, up to 16 parallel bits of data, a vertical sync, a horizontal sync, and a data-valid signal. The channel utilizes 1.8V logic levels. See Table 3 in Section 4.1 for pin assignments. The vertical sync and horizontal sync are asserted low. The data-valid and all data lines are asserted high.
2. Each frame period consists of three distinct sections as illustrated in Figure 58:
    a. The vertical sync period, during which the vertical sync, *cmos_vsync*, is asserted. The width of the vertical sync pulse, *vsw*, varies depending upon whether telemetry is enabled, as depicted in Table 9. The value can be requested via command over the CCI. Note: in one-shot mode, it is possible that the width of *vsw* can vary slightly from the values shown in Table 9.
    b. A period when successive rows of data are provided. The total number of rows during each frame, *nr*, varies depending upon settings, as shown in Table 9. Note that the number of *cmos_hsync* pulses during a frame will typically exceed *nr* because, as illustrated in Figure 58, *cmos_hsync* continues to be output at a regular interval, even during the vertical sync and the blanking periods (i.e., even when cmos_data_valid is not being asserted).
    c. A variable blank period between the end of the last row period and the next vertical sync. This variable blank period is only present in “one shot” CMOS output mode. See Section 7.17. In “continuous” CMOS output mode, this period is always 0 clocks.
3. Each row period consists of four distinct sections, as depicted in Figure 59:
    a. The horizontal sync period, during which the horizontal sync *cmos_hsync* is asserted. The width of the horizontal sync pulse *hsw* is 8 clocks, as depicted in Table 9. The value can be requested via command over the CCI.
    b. A variable blanking period between the horizontal sync and the start of valid data referred to as the front porch. The width of the front porch, *fp*, is not guaranteed, but its value can be requested via command over the CCI.
    c. The period during which valid data is provided on *cmos_data[0:23]* and during which *cmos_data_valid* is asserted. The number of pixels (i.e., number of clocks) in the data valid period, *ppr*, varies depending upon the CMOS tap point, as shown in Table 9.
    d. A variable blanking period between the end of valid data and the end of the row period, referred to as the back porch. Like the front porch, the width of the back porch, *bp*, is not guaranteed, but its value can be requested via command over the CCI. Given that *fp* and *bp* can vary, it is imperative that receiving electronics monitor *cmos_data_valid* to ascertain the start of valid pixel data on a row.
4. All signals in the CMOS channel are latched on the rising edge of the pixel clock *cmos_pclk* as illustrated in Figure 60. As shown in

5. Table 10, the period of the pixel clock is either 27.000 MHz or 13.500 MHz depending upon whether or not the averager feature is enabled (Section 7.2).
6. As shown in

7. Table 10, the output frame rate is dependent upon CMOS Output mode (continuous or one-shot) and Averager mode (enabled or disabled). For Fast cameras, this equates to a framerate of 30Hz or 60Hz respectively.
8. As described in Section 0, the number of valid data bits piped out the CMOS channel is either 8 or 16 depending upon the CMOS video-tap mode, and possibly on the colorization mode (if and only if video-tap mode = post-colorization).

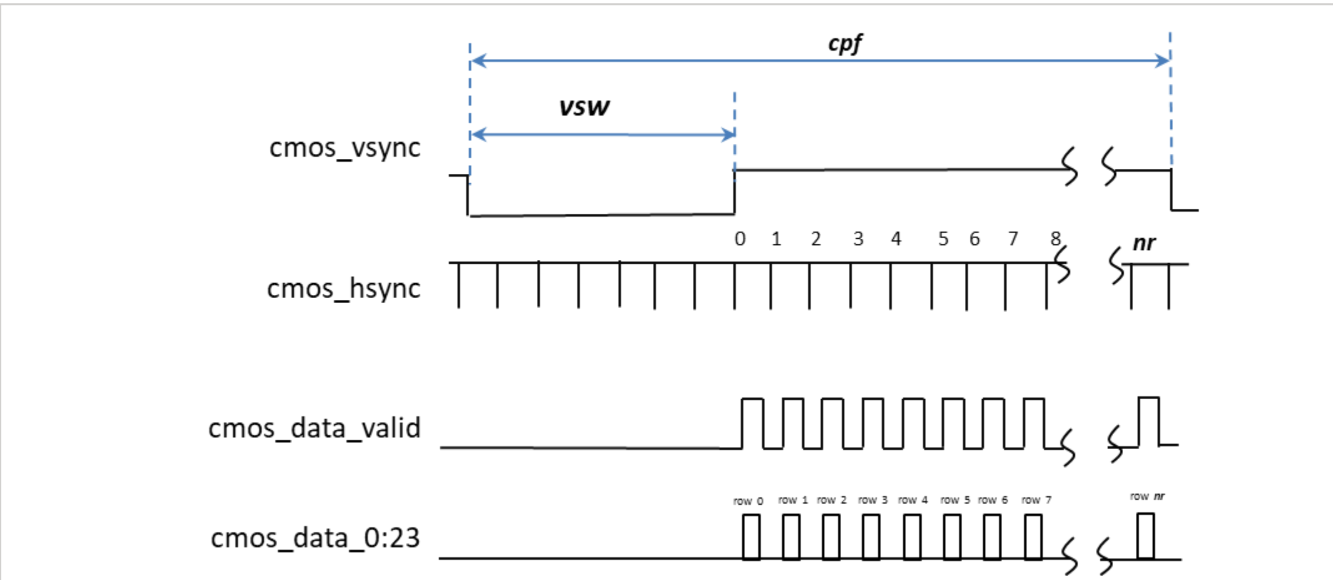


FIGURE 58: FRAME TIMING OF THE CMOS OUTPUT CHANNEL

See Table 9 for the values of *vsw* and *nr.* See

Table 10 for the value of *cpf*.

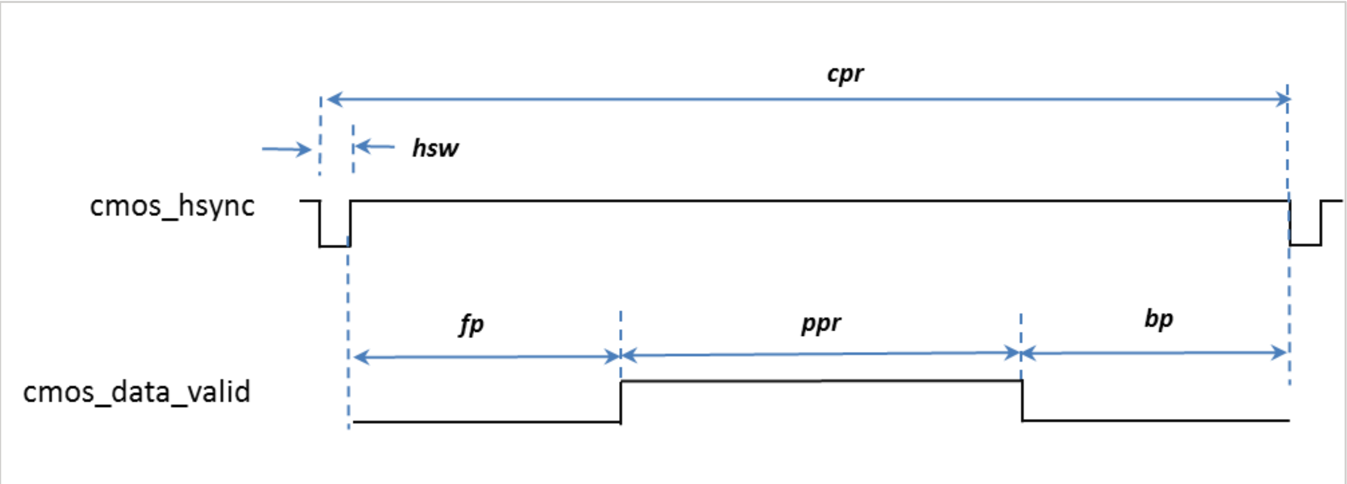


FIGURE 59: LINE TIMING OF THE CMOS OUTPUT CHANNEL

See Table 9 for the values of *hsw*, *cpr*, and *ppr*. *Fp* and *bp* are configuration dependent.

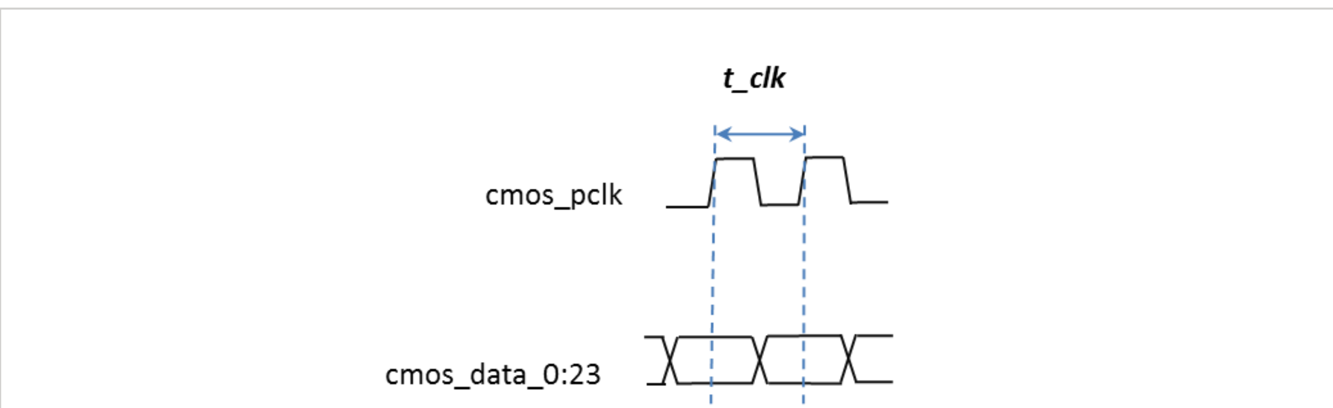


FIGURE 60: PHASE OF PIXEL CLOCK RELATIVE TO CMOS DATA

See

Table 10 for the value of *t_clk*.

TABLE 9: TIMING OF THE CMOS CHANNEL, VALUES COMMON TO CONTINUOUS AND ONE-SHOT MODES

CMOS Tap Point	**320 Configuration: Pre-AGC and Post-AGC taps**		**320 Configuration: Post-Zoom / Post-Colorization tap 640 Configuration: All CMOS Tap Modes**	
Telemetry	Disabled	Enabled	Disabled	Enabled
Vertical sync width, *vsw* (in row periods)	44	43	88	87
Vertical sync width, *vsw* (in clock periods)	66,000 [1]	64,500 [1]	66,000 [1]	65,250 [1]
Valid rows per frame, *nr*	256	258	512	514
Row periods per frame (*vsw + nr*)	300		600	
Horz sync width, *hsw* (in clocks)	8			
Pixels per row, *ppr*	320		640	
Clocks per row period, *cpr* (*hsw + fp + ppr+ bp*)	1500		750	

Note 1: Numbers are exact in Continuous mode. In One-Shot mode, the vertical sync width may be longer than shown due to idle time.

TABLE 10: TIMING OF THE CMOS, VALUES DIFFER BETWEEN CONTINUOUS AND ONE-SHOT MODES

(a) Continuous mode settings

CMOS Tap Point	**320 Configuration: Pre-AGC and Post-AGC taps**		**320 Configuration: Post-Zoom / Post-Colorization tap 640 Configuration: All CMOS Tap Modes**	
Averager	Disabled	Enabled	Disabled	Enabled
Clocks per frame, cpf (*cpr* x (*vsw* + *nr*))	450,000			
Clock rate, (1/*t_clk*) (in MHz)	27.000	13.5	27.000	13.5
Frame rate = 1/(*cpf* x *t_clk*)	60.000	30.000	60.000	30.000

(b) One-shot mode settings

CMOS Tap Point	**320 Configuration: Pre-AGC and Post-AGC taps**		**320 Configuration: Post-Zoom / Post-Colorization tap 640 Configuration: All CMOS Tap Modes**	
Averager	Disabled	Enabled	Disabled	Enabled
Clocks per frame, cpf (*cpr* x (*vsw* + *nr*)) See note 1	Varies, $\geq$450,000		Varies, $\geq$450,000	
Clock rate, (1/*t_clk*) (in MHz)	27.000	13.5	27.000	13.5
Frame rate = 1/(*cpf* x *t_clk*)	$\leq$60.000	$\leq$30.000	$\leq$60.000	$\leq$30.000

Note 1: Additional clock periods of blanking are inserted as necessary at the end of the last row of valid data.

8.2.2 MIPI

Boson+ provides the option of a digital data protocol typical of a MIPI CSI v1.1 and DPHY 1.0 camera. MIPI-specific details can be found in the Boson MIPI application note; 102-2013-106.

1. The MIPI video channel consists of three differential pairs (D-PHY); a clock lane and two data lanes supporting one or two virtual channels of up to 14 parallel bits of data. The channel utilizes 1.2V logic levels. See Table 3 for pin assignments.

2. The MIPI clock rate is 246 MHz, either continuous or discontinuous

3. Frame sync input requires 1.8V 10usec width pixel minimum (rising edge)

4. Latency < 4.8 ms

5. Pixel formats are: RAW8 (monochrome, post-AGC), UYVY (color, post-AGC), and RAW14 (pre-AGC)

6. A single virtual channel can operate at 60Hz frame rate transmitting either:

    - Monochrome 8 bit
    - Monochrome 14 bit
    - Post-AGC 8 bit monochrome
    - Post-AGC 16-bit color YUV422 (UYVY)

7. In a dual virtual channel configuration, the maximum frame rate is limited to 30Hz transmitting either:

    - Monochrome 8 bit & Monochrome 14 bit
    - Post-AGC 16-bit color YUV422(UYVY) & Monochrome 8 bit
    - Post-AGC 16-bit color YUV422(UYVY) & Monochrome 14 bit

8.2.3 USB

Boson+ can provide digital data as a USB Video Class (UVC) compliant device. Two output options are provided. Note: The options are *not* selected via the CCI but rather by the video capture or viewing software selected by the user. The options are:

- **Pre-AGC (16-bit)**: The output is linearly proportional to the flux incident on each pixel in the array; output resolution is 320x256 or 320x258 (if telemetry is desired) for the 320 configurations or 640x512 for the 640 configuration or 640x514 with telemetry. Telemetry is enabled by requesting two extra rows. Note that AGC settings, zoom settings, and color-encoding settings have no effect on the output signal at this tap point. Telemetry location can be altered to the top or bottom of the frame via the CCI. This option is identified with a UVC video format 4CC code of "Y16 " (16-bit uncompressed greyscale image). Three different output formats can be streamed from the Pre-AGC tap point, which are configurable via the CCI:
    - IR16: Standard 16-bit Pre-AGC tap point, default for non-radiometric cameras
    - T-Stable: T-stable tap point
    - T-Linear: T-linear tap point, only available on radiometric cores. This is the default for radiometric cameras. (Section 6.2)
- Post-Colorize, YCbCr: The output is transformed to YCbCr color space using the specified color palette (Section 6.10). Resolution is 640x512 for both the 320 and 640 configurations. As described above, telemetry can be viewed by requesting a frame size two rows larger, 640x514. Three options are provided, identified via the UVC video format 4CC code:
    - I420: 8-bit Y plane followed by 8-bit 2x2 subsampled U and V planes
    - NV12: 8-bit Y plane followed by an interleaved U/V plane with 2x2 subsampling
    - NV21: same as NV12 except reverse order of U and V planes

9 MECHANICAL CONSIDERATIONS

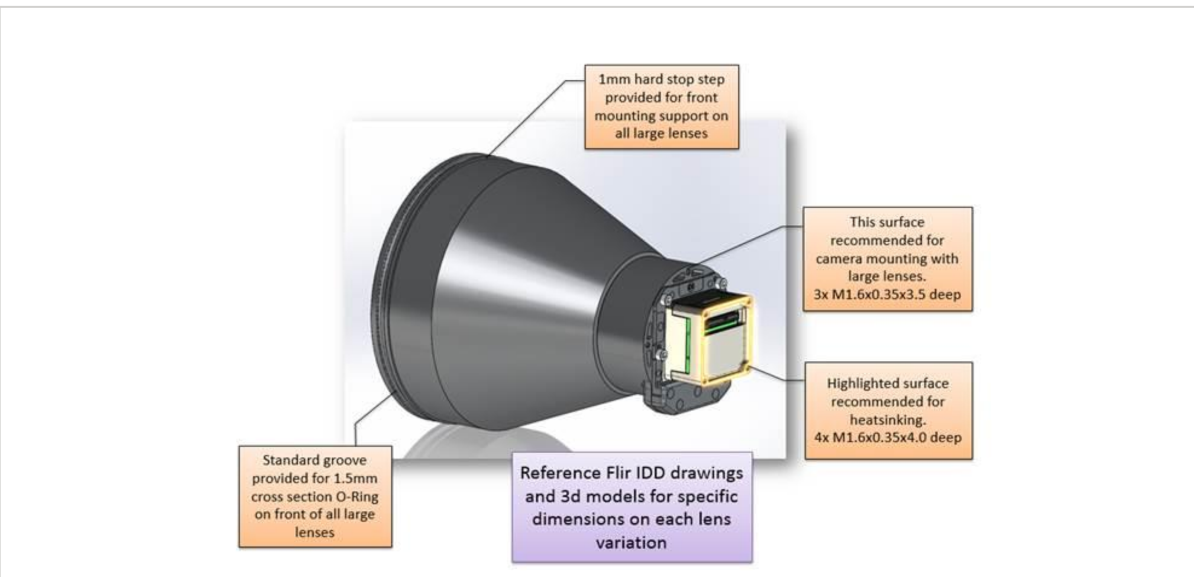
9.1 Mounting

Boson+ provides two primary mounting options:

- **Rear Mounting**: The rear cover of the Boson+ assembly provides four threaded holes (M1.6x0.35). See the relevant Mechanical IDD for more detailed information. Zinc-plated screws with thread penetration of 2.5 to 3.5mm are recommended. This is the preferred mounting for radiometric capable cameras. Heatsinking from the rear of the camera should contact the entire surface highlighted in Figure 61 to promote thermal uniformity similar to the Boson tripod-mount accessory in Figure 78.
- **Lens Mounting**: Boson+ should be supported at its lens for all Boson+ configurations for which the mass of the lens assembly is greater than the mass of the sensor engine. This condition is true for every lens that uses the M24 or M34 flange (Table 12). Each of those lens assemblies provides suitable features for mounting and sealing, as summarized in Figure 61. Even configurations mounted via the lens features require heatsinking via the rear surface. Correct orientation of the camera is with the connector located above centerline, as shown in Figure 6. Rotating the camera 180 degrees so that the connector is below centerline, rather than above, will result in an upside-down image.

NOTE: Consistent external force in the optical axis towards the sensor assembly can result in loss of focus.

Figure 61: Mounting Guidance for Large-Lens Configurations



9.2 Sealing

Two options exist for environmentally sealing the camera: Protruding the lens assembly through the enclosure (Figure 62a) and encapsulating the entire camera behind an LWIR-transparent window (Figure 62b). To facilitate the option shown in Figure 62a, all Boson+ lens assemblies are rated to IP67 using the appropriate sealing interface. The larger lens configurations include an O-ring groove on the lens barrel. The smaller lens configurations without this groove are intended to be sealed by inserting the camera through an O-ring groove in the enclosure. Refer to the lens variant specific mechanical IDD for details on this O-ring seal interface. This assembly process should not leave residual force compressing the lens towards the camera body, as doing so could degrade the camera focus.

For use in an abrasive or marine environment, the fully enclosed sealing option (Figure 62b) is highly recommended because almost all Boson+ lens assemblies provide a high-durability anti-reflection (HAR) coating qualified against mild abrasion (MIL-C-675C section 4.5.11, Moderate Abrasion) but not intended to withstand harsh abrasion (e.g., blowing sand) or salt fog. The exception is the Boson+ 320 configuration with 92 deg HFOV. which provides a diamond-like coating (DLC) qualified against harsh abrasion and ≥ 240 hours exposure to salt-fog. The fully enclosed option is also recommended in applications subject to highly dynamic temperature conditions (e.g., thermal shock, solar loading, convection currents, and other forms of non-symmetrical heat-loading / heatsinking). The fully enclosed option is also preferred when system de-icing is required because heating a window is less likely to produce thermal gradients within the camera than heating the camera's lens assembly would. See Teledyne FLIR's INU Application Note, available from the Boson+ website linked in Section 1.3, for more guidance on integrating the Boson+ camera into an end system.

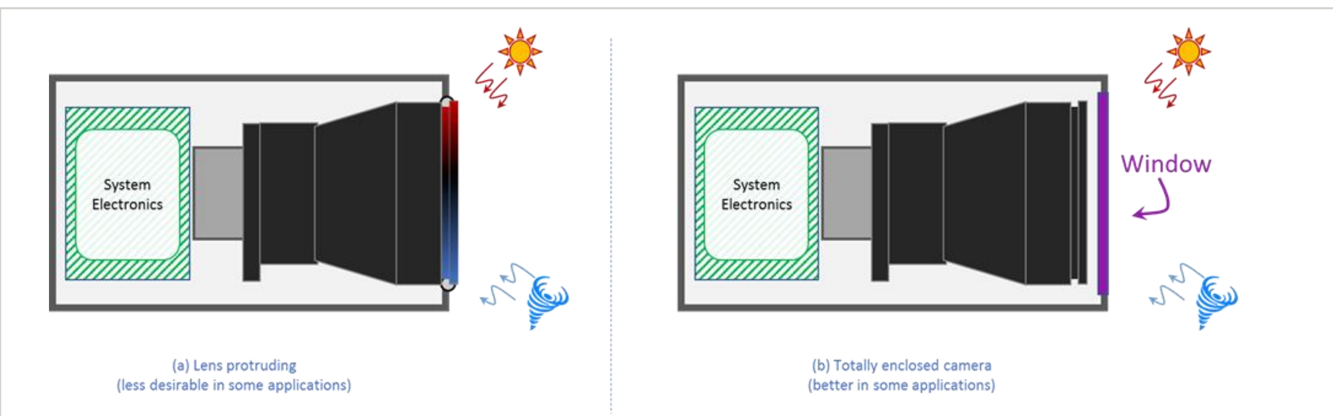


FIGURE 62: TWO CAMERA-ENCLOSURE OPTIONS

A sealed enclosure is not essential in dry, benign environments, though the Boson+ core's magnesium-alloy housing and rear cover are both susceptible to corrosion when exposed to humidity. Also, the edge of a circuit-card assembly (CCA) is exposed on the Boson+ core and is susceptible to failure and permanent damage when exposed to moisture.

NOTE: The camera focus may degrade if the mounting or sealing method places force perpendicular to the focal plane during operation.

9.3 Disassembly

Removal of the lens assembly is not recommended except for the purpose of swapping out an alternative lens. Removing the lens (or removing the protective cap factory-installed on lensless configurations) should *only* be performed in a certified clean room (Class 1000 / ISO 6 or cleaner). When the lens is removed, extreme care must be exercised to avoid exposing the interior of the core to contamination or damage from foreign objects. Even microscopic debris is problematic and prone to causing image blemishes. Exposing the interior of the camera to forced air and/or any cleaning agents is likely to damage or further contaminate the unit and will void the warranty. Debris removal should not be attempted. In the event of contamination, contact Teledyne FLIR Section 1.3 to arrange a Return Merchandise Authorization (RMA).

NOTE: Disassembly of the Boson+ core for any purpose other than swapping out a lens will void the warranty.

9.4 Thermal Considerations

Adequate heatsinking is necessary to prevent the Boson+ core from overheating, particularly when operated in temperatures approaching the device upper range. The rear camera cover (highlighted surface in Figure 61) must always be maintained at a temperature at or below 80°C. If the camera's internal core temperature exceeds its maximum safe temperature, Boson+ signals an overtemp condition and by factory-default enters a low-power non-imaging state 10 seconds later. See Section 7.2 for a detailed description of this feature.

Boson+ should be insulated from rapid thermal transients. Extreme thermal shock will reduce the effectiveness of calibration and degrade image quality. The camera should be isolated from the thermal effects of window heaters, variable fans, and other intermittent thermal loads. Temperature gradients should be minimized, especially in the axes perpendicular to the optical line of sight. Avoid mounting conditions that expose the camera to asymmetric heating from heaters, high-powered devices, and other thermal loads. If convective cooling is required, airflow should be constant and as symmetric as possible across the optical line of sight.

9.5 Radiometric Implications

The thermal characteristics of the camera and its environment influence out-of-field irradiance from the lens assembly, shutter assembly, and other internal components of the camera. Out-of-field irradiance is a spurious signal not representative of the scene being imaged. Radiometric configurations of Boson+ undergo a factory calibration process that includes compensation for out-of-field irradiance. Operating the camera in a way that is substantially different from the configuration during calibration will degrade the quality of the compensation. All thermal considerations described in Section 9.4 are important, not just for good image quality, but also for good radiometric accuracy. Consider the following for best radiometric results:

1. Provide adequate heatsinking to keep camera temperatures well under the operational maximum, preferably from the rear surface of the camera only
2. Minimize conduction from any camera surface other than the rear
3. Minimize airflow across the camera assembly. If possible, utilize a non-insulative enclosure.
4. Avoid embedding the camera in insulative materials (e.g., foam), as doing so affects the self-heating and relative temperature of internal camera components.
5. If using an enclosure with a window, specify its parameters such that attenuation effects and unwanted radiation reflected/emitted from it can be compensated for by using the camera's environmental factors correction feature (Section 6.2.1).

10 OPTICAL CHARACTERISTICS

As fully described in Table 11 and Table 12, numerous lens options are provided for both QVGA and VGA, ranging from very wide field of view (FOV) to very narrow. All lens assemblies are athermalized for stable focus quality across the full operating temperature range. In some cases there are two VGA configurations providing identical or nearly identical field of view. This is due to the introduction of several newer lens designs smaller than the originals, usually resulting in higher cost and/or slightly reduced performance as summarized in Table 11 and Table 12. For example, the smaller version of the 24-deg lens has slightly slower f/#. All smaller lens configurations are denoted with an S preceding the FOV in the part number (e.g., 23640AS32 instead of 23640A032).

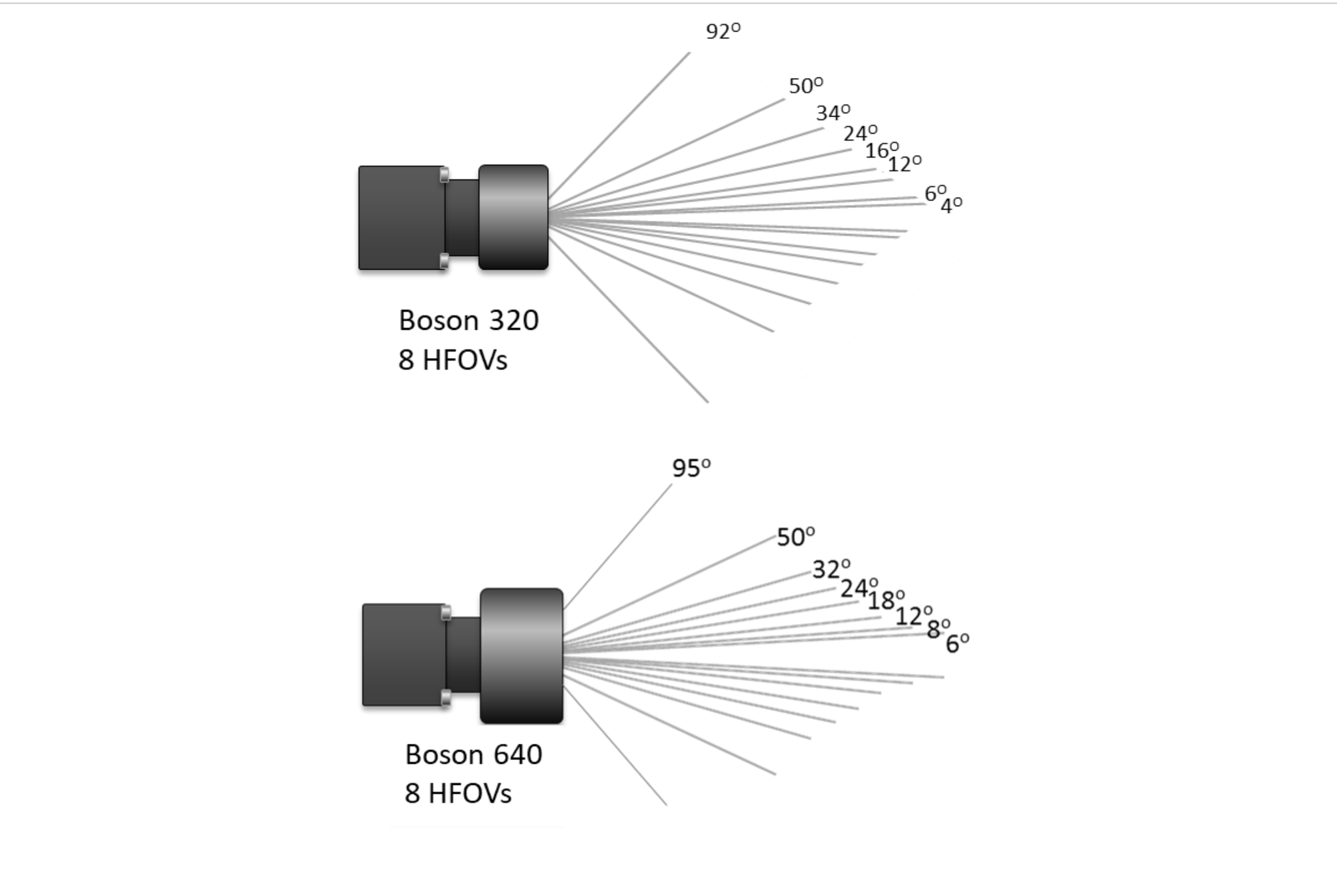


FIGURE 63: SUPPORTED HORIZONTAL FIELDS OF VIEW

WARNING: EAR99 Technology Subject to Restrictions Contained on the Cover Page

TABLE 11: LENS OPTICAL SPECIFICATIONS

CONFIG. SEE NOTE 1	FOV (H×V) (DEG)	FOV (DIAG) (DEG)	F/#	FOCAL LENGTH (MM)	NEAR-FOCUS DISTANCE W/OUT REFOCUS & WITH REFOCUS (M) SEE NOTE 3	AVG. TRANSMISSION, τ	MTF (NOMINAL AT NYQUIST, ON-AXIS, 20°C)	DISTORTION (%)
22320 H092	91.9 x 74.0	124.8	1.00	2.3	0.55 / 0.03	87%	42%	< 43%
22320 A050	50.0x40.0	65.9	1.00	4.3	1.9 / 0.10	93%	42%	< 12%
22320 AS50	50.0x40.0	65.0	1.10	4.5	1.0 / 0.10	93%	31%	< 14%
22320 A034	34.1x27.3	43.6	1.01	6.3	4.0 / 0.20	94%	43%	< 1%
22320 A024	24.1x19.2	30.6	1.02	9.1	8.5 / 0.30	82%	42%	< 1%
22320 A016	16.0x12.8	20.4	1.01	13.8	19 / 0.50	84%	46%	< 3%
22320 A012	12.2x9.7	15.7	1.04	18.0	33 / 1.0	90%	43%	< 1%
22320 A006	6.1x4.9	7.9	1.00	36.0	130 / 4.0	90%	40%	< 1%
22320 A004	4.0x3.2	5.2	1.01	55.0	300 / 10	86%	40%	< 1%
22640 AS95	95.0x77.0	130.5	1.10	4.9	2.5 / 0.10	90%	34%	< 56%
22640 AS50	49.9x39.3	65.9	1.01	9.2	7.5 / 0.3	90%	42%	< 18%
22640 A032	32.0x25.6	40.8	1.00	14.0	20 / 0.50	92%	42%	< 3%
22640 AS32	32.0x25.7	40.9	1.01	13.6	20 / 0.50	90%	42%	< 3%
22640 A024	24.3x19.5	31.3	1.04	18.0	33 / 1.0	90%	43%	< 2%
22640 AS24	24.3x19.2	31.3	1.09	18.0	33 / 1.0	90%	42%	< 2%
22640 A018	18.0x14.4	23.1	1.00	24.0	58 / 1.5	89%	41%	< 2%
22640 A012	12.2x9.8	15.7	1.00	36.0	130 / 4.0	90%	40%	< 1%
22640 A008	8.0x6.4	10.3	1.01	55.0	300 / 10	89%	40%	< 2%
22640 A006	6.0x4.8	7.7	1.05	72.8	550 / 17	89%	38%	< 1%

Note 1: Please contact your Teledyne FLIR sales representative or certified Teledyne FLIR distributor for more information on which lens types currently support radiometry.
Note 2: Shutterless configurations (IE, 23640A032) have the same optical specification as their shuttered counterparts.
Note 3: The first value in the column represents the closest distance at which objects will be in good focus on new cameras. This distance is slightly further away than the typically calculated hyperfocal distance. The second value represents the closest distance at which objects will be in good focus if the user adjusts the focus. Note that a focus tool is required to adjust focus of the smaller lenses (focal length ≤ 18.0mm). (Section 15.6)

TABLE 12: LENS MECHANICAL SPECIFICATIONS

CONFIG.	THREAD PITCH	LENS MAX. DIAM. (MM)	CAMERA LENGTH (MM)	CAMERA WEIGHT (GRAMS)
22320 H092	M18x0.5	21.0	33	24
22320 A050	M18x0.5	21.0	27	18
22320 AS50	M18x0.5	21.0	27	16
22320 A034	M18x0.5	21.0	27	17
22320 A024	M18x0.5	21.0	27	16
22320 A016	M24x0.5	26.0	28	24
22320 A012	M24x0.5	27.6	38	38
22320 A006	M34x0.5	51.0	64	129
22320 A004	M34x0.5	68.4	75	192
22640 AS95	M18x0.5	20.0	28	20
22640 AS50	M18x0.5	20.0	40	36
23640 AS50	“	“	“	31
22640 A032	M24x0.5	26.0	35	39
23640 A032	“	“	“	36
22640 AS32	M18x0.5	21.0	33	28
23640 AS32	“	“	“	23
22640 A024	M24x0.5	27.6	38	41
23640 A024	“	“	“	37
22640 AS24	M18x0.5	21.0	37	31
23640 AS24	“	“	“	27
22640 A018	M24x0.5	37.0	45	52
23640 A018	“	“	“	49
22640 A012	M34x0.5	51.0	64	132
22640 A008	M34x0.5	68.4	75	193
22640 A006	M34x0.5	82.0	100	398

Note 1: Please contact your Teledyne FLIR sales representative or certified Teledyne FLIR distributor for more information on which lens types currently support radiometry.

All configurations above have a standard high-durability AR coating on the outermost lens surface except for the 320 92-degree configuration, which has a diamond-like coating (DLC) on its outermost surface.

11 IMAGE CHARACTERISTICS

11.1 Sensitivity

Table 13 shows sensitivity as a function of configuration, normalized to f/1.0. The specified requirements are for operating in the high-gain state at 20°C, with the averager disabled, in free-running mode, imaging a 30°C background. See Section 5.1 for a description of the averager. NEDT values with averager enabled are approximately 20% lower than shown in the table.

TABLE 13: TEMPORAL NEDT IN HIGH-GAIN STATE

CAMERA GRADE	RANDOM TEMPORAL NOISE (σ_{TVH})
Industrial	≤ 20 mK
Professional	≤ 30 mK

NEDT values shown are acceptance-test limits representing the lensless configuration with an f/1.0 aperture installed. With a lens installed, test limits are scaled by $(f/\#)^2 / \tau$, where f/# and τ are as shown in Table 11.

For reference, Figure 64 illustrates the expected variation in sensitivity as a function of camera temperature. Two curves are shown in the figure: One in which scene temperature is assumed to be 20°C regardless of camera temperature and one in which scene temperature is equal to camera temperature. When scene temperature is constant, noise and responsivity of the camera vary at different rates over temperature (i.e., $\delta\sigma / \delta T \neq \delta\mathcal{R} / \delta T$), causing NEDT variation over temperature. When scene temperature also changes with camera temperature, a greater NEDT variation is seen because of differential radiance versus temperature (i.e., $\delta W / \delta T$) increases with temperature. The difference in infrared energy is significantly higher for an 80°C target relative to a 79°C background than that of a -39°C target relative to a -40°C background.

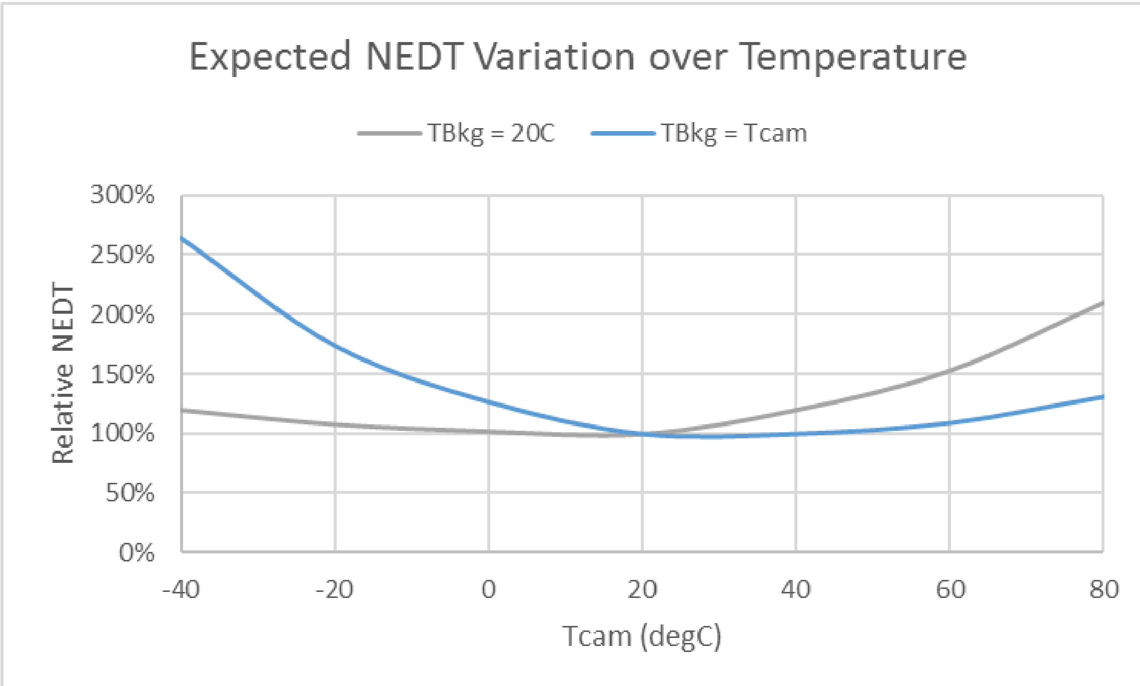


FIGURE 64: EXPECTED NEDT VARIATION OVER TEMPERATURE

11.2 Intrascene Temperature

Intrascene temperature refers to the span of scene temperatures that map to the camera's 16-bit output range (i.e., temperatures that can be imaged without railing the output).

Figure 65 shows the expected maximum scene temperature of the 320 configuration as a function of camera temperature when in high-gain state. The maximum scene temperature in low-gain state is shown for the 320 configuration in Figure 66. Both figures depict typical values as well as the estimated worst-case value expected of every camera. The expected minimum scene temperature of the 320 configuration in high-gain state is unspecified while the expected minimum scene temperature of the 320 configuration in low-gain state is estimated at -40 °C or colder.

Figure 67 shows the maximum and minimum scene temperature of the 640 configuration as a function of camera temperature when in high-gain state. All grades of the 640 configuration camera share the same maximum scene temperature. Industrial grade (I-Grade) cameras have a minimum scene temperature of -30 °C or colder for all supported camera temperatures. Professional grade (P-Grade) cameras have a relaxed minimum scene temperature that varies with camera temperature. The maximum scene temperature in low-gain state is shown for the 320 configuration in Figure 68. The expected minimum scene temperature of the 640 configuration in low-gain state is estimated at -40 °C or colder.

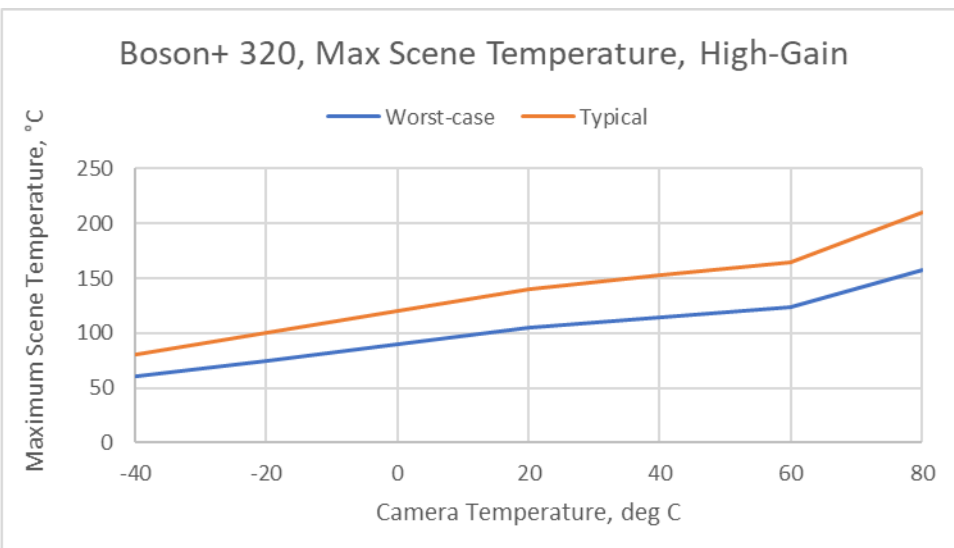


FIGURE 65: EXPECTED MAXIMUM SCENE TEMPERATURE VS. CAMERA TEMPERATURE, HIGH-GAIN STATE, 320

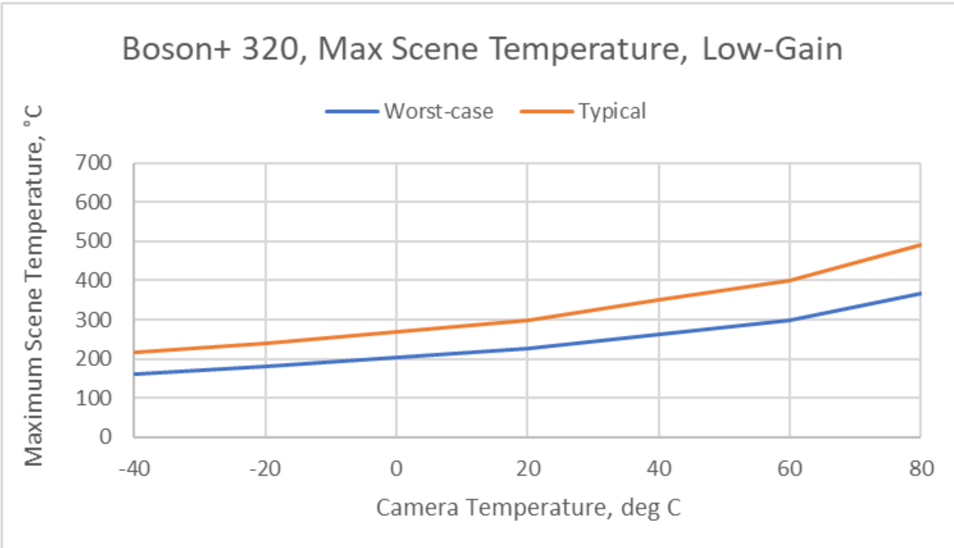


FIGURE 66: EXPECTED MAXIMUM SCENE TEMPERATURE VS. CAMERA TEMPERATURE, LOW-GAIN STATE, 320

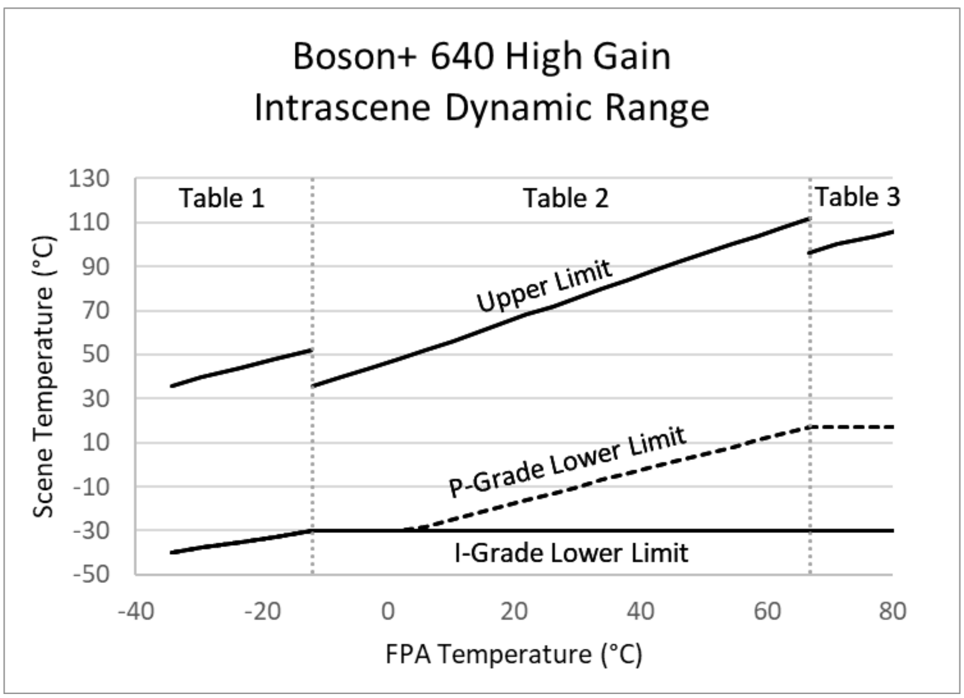


FIGURE 67: EXPECTED MAXIMUM SCENE TEMPERATURE VS. CAMERA TEMPERATURE, HIGH-GAIN STATE, 640

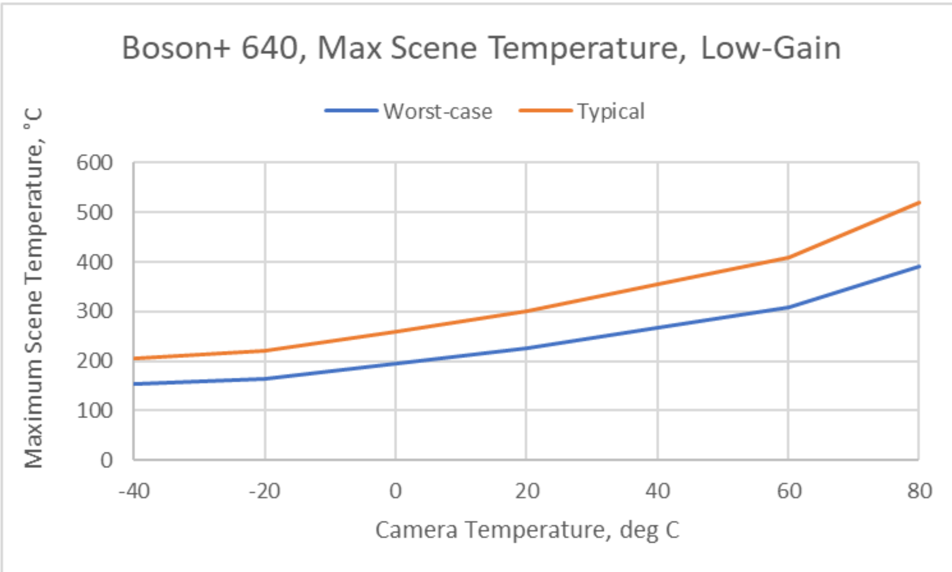


FIGURE 68: EXPECTED MAXIMUM SCENE TEMPERATURE VS. CAMERA TEMPERATURE, LOW-GAIN STATE, 640

11.3 Operability

Operability refers to requirements pertaining to the number and location/grouping of non-operable pixels. Table 14 defines the operability requirements for the 320 configuration as a function of camera grade and Table 15 provides the same for the 640 configuration. By factory-default, all defective pixels are replaced in the output-video stream by data from adjacent non-defective pixels.

TABLE 14: OPERABILITY REQUIREMENTS BY CAMERA GRADE, 320 CONFIGURATION, HIGH GAIN

CAMERA GRADE	TOTAL DEFECTS
Industrial	≤ 1%
Professional	≤ 1.5%

TABLE 15: OPERABILITY REQUIREMENTS BY CAMERA GRADE, 640 CONFIGURATION, HIGH GAIN

CAMERA GRADE	TOTAL DEFECTS
Industrial	≤ 1%
Professional	≤ 1.5%

11.4 Image Uniformity

Image uniformity is a metric of variation in the output image when the camera is imaging a uniform scene, such as a BB. An image non-uniformity (INU) is defined as a group of pixels prone to varying slightly from their local neighbors under certain imaging conditions, as shown in Figure 69 and Figure 70. For more examples, as well as a detailed explanation of INUs and the conditions where they are most observable, see Teledyne FLIR's INU Application Note, available from the Boson+ website linked in Section 1.3.

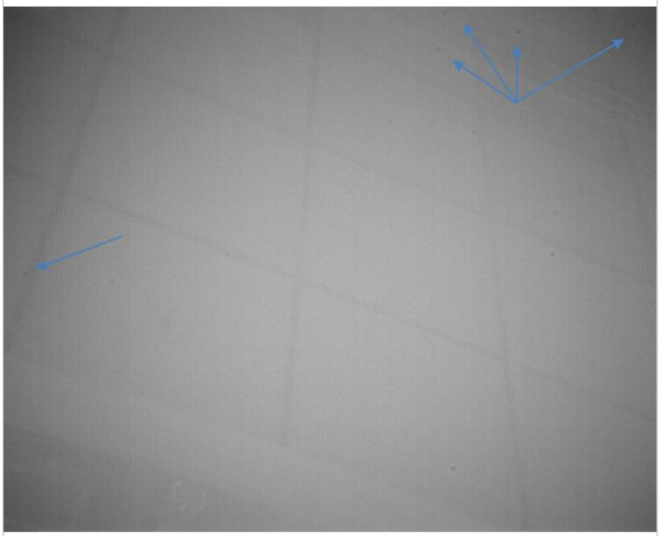


FIGURE 69: EXAMPLE OF TYPE A INUS

FIGURE 70: EXAMPLES OF A TYPE-B INU

Table 16 defines the allowed number of INUs for each camera grade. Type A INU has a radius ≤ 10 pixels while a Type B INU has a radius >10 pixels.

TABLE 16: ALLOWED NUMBER OF INUS BY CAMERA GRADE, 320 CONFIGURATION

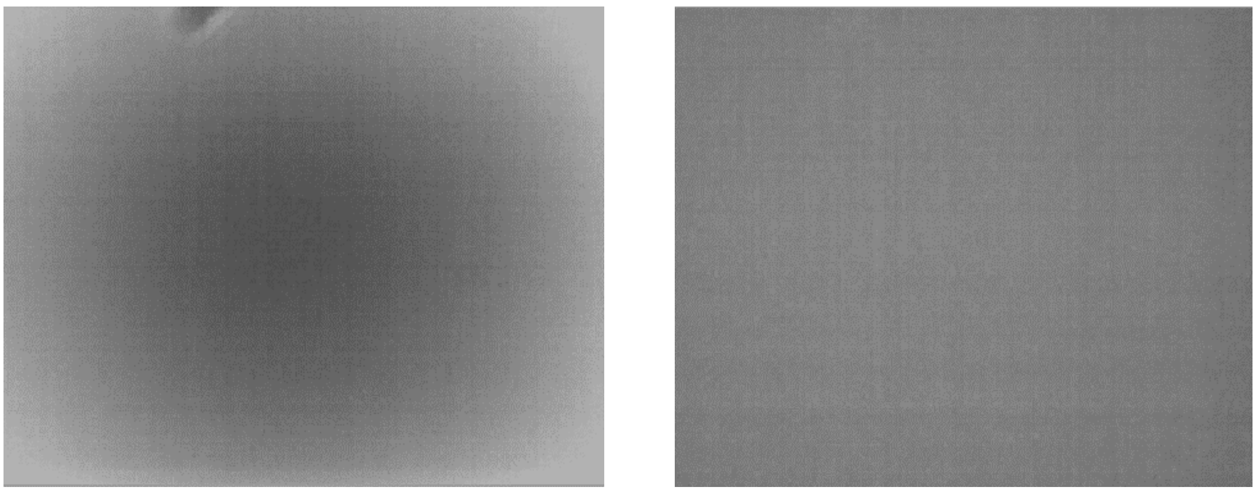
CAMERA GRADE	IN CENTRAL 160X120	OUTSIDE CENTRAL 160X120
Industrial	0	≤1 Type A ≤1 Type B
Professional	0	≤1 Type A ≤1 Type B

TABLE 17: ALLOWED NUMBER OF INUS BY CAMERA GRADE, 640 CONFIGURATION

CAMERA GRADE	IN CENTRAL 320X240	OUTSIDE CENTRAL 320X240

Industrial	0	≤2 Type A ≤2 Type B
Professional	0	≤2 Type A ≤2 Type B

The SFFC feature of Boson+ helps to reduce the appearance of INUs in most imaging conditions. Figure 71 compares images with and without SFFC. The INU shown is considered objectionable and not representative of one that would be seen on a delivered camera. It is provided to highlight the ability of SFFC to improve the appearance of INUs.



(a) Without SFFC

(b) With SFFC

FIGURE 71: EXAMPLE IMAGERY WITH AND WITHOUT SUPPLEMENTAL FFC (SFFC)

11.5 Radiometric Accuracy

Radiometric accuracy is dependent upon many variables, including:

- Target temperature
- Target emissivity and factors in the optical path affecting signal, such as atmospheric absorption.
- Target location in the field of view
- Target distance/subtense
- Camera temperature and temperature stability
- Change in temperature since previous FFC
- FFC type (internal vs. external)
- Mounting/installation considerations (Section 9.5)

Accuracy requirements vary depending on test conditions. Additional radiometric optimization may be necessary to achieve peak accuracy in different system level assemblies.

11.5.1 Test Conditions

For the test conditions defined below, radiometric accuracy should be:

- Steady-state operation (δTfpa/δt < 0.1C / min)
- Target within the Central ROI of the FOV
- Tscene between 5°C and 120°C (high-gain state), 5°C and 500°C (low-gain state)
- TfpaK within 0.2°C of value at previous FFC
- Camera heatsunk from the rear only (no other thermally conductive contacts to camera)
- No window, aperture, or other attenuating material (except air) between camera and target, >99% atmospheric transmission in 8-14 micron spectral band.
- BB emissivity > 98%

TABLE 18: HIGH-GAIN RADIOMETRIC ACCURACY

HIGH-GAIN		T Ambient [C]			
		-20	0	25	50
T Scene [C]	10	+/- 5 C	+/- 5 C	+/- 5 C	+/- 5 C
	50	+/- 5 C	+/- 5 C	+/- 5 C	+/- 5 C
	100	+/- 5 C	+/- 5 C	+/- 5 C	+/- 5 C

TABLE 19: LOW-GAIN RADIOMETRIC ACCURACY

LOW-GAIN		T Ambient [C]			
		-20	0	25	50
T Scene [C]	30	+/- 5 C	+/- 5 C	+/- 5 C	+/- 5 C
	50	+/- 5 C	+/- 5 C	+/- 5 C	+/- 5 C
	100	+/- 5 C	+/- 5 C	+/- 5 C	+/- 5 C

TABLE 20: LOW-GAIN, HIGH SCENE TEMPERATURE RADIOMETRIC ACCURACY

LOW-GAIN		T Ambient [C]			
		-20	0	25	50
T Scene [C]	250	--	--	+/- 5 C	--
	500	--	--	+/- 10 C	--

12 ELECTRICAL SPECIFICATIONS

12.1 DC and Logic Level Specifications

TABLE 21: DC AND LOGIC LEVELS

PARAMETER	DESCRIPTION	MIN	TYP	MAX	RIPPLE, P-P MAX	UNITS
3V3	Core Voltage (primary power for the Boson+ core)	3.14 See note 1	3.30	3.46	0.060	Volts
USB_VBUS	USB Power	4.40	5.00	5.25	--	Volts
I_3V3	Primary supply current for Boson+ core	--	See note 2	560 / 1030 See note 3	n/a	mA
I_VBUS	Supply current for USB	--	--	0.130	n/a	mA

Note(s)

1. *3V3 rise time from 0V to minimum voltage shall not exceed 1 msec.*
2. *Typical current varies with settings. (Section 12.2)*
3. *The first number shown is for the 320 configurations and the second is for the 640 configurations. In both cases, the value shown is during shutter actuation.*

12.2 Power Consumption

Boson+ power consumption is dependent upon five primary variables:

- Camera operating temperature
- Whether the frame averager function is enabled (Section 5.1)
- Whether the frame skip function is enabled; disabled for measurements below (Figure 73)
- Whether the USB channel is streaming video (Section 7)
- Which filters are enabled/disabled (Section 0)

Figure 72 shows typical power consumption of Boson+ cameras over the full operating temperature range, with and without the frame averager enabled while the USB channel is streaming video. All curves assume all filters are enabled.

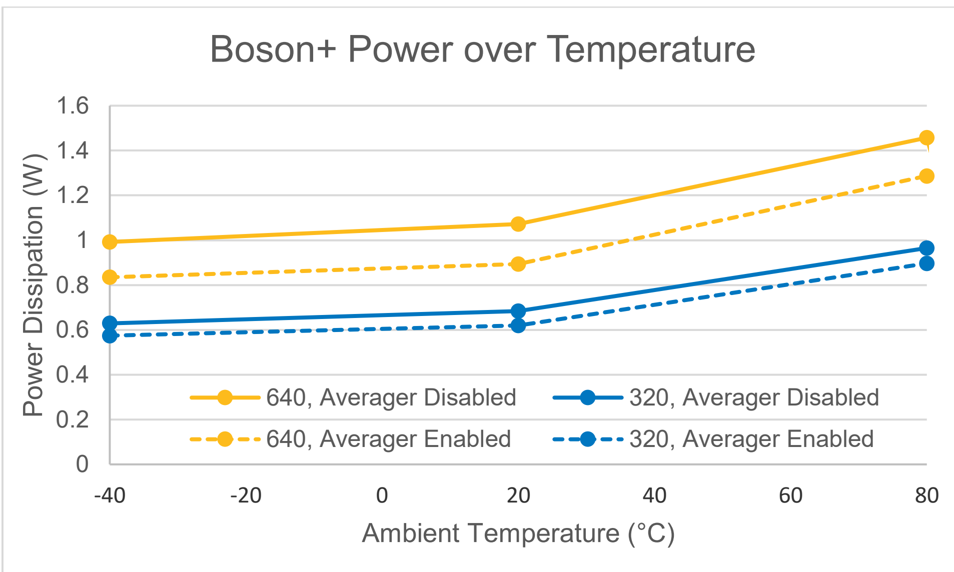


FIGURE 72: TYPICAL POWER VARIATION OF BOSON+ CAMERAS OVER TEMPERATURE

The power curves shown in the figure above are average values. The instantaneous power when the camera's internal shutter is actuated will be higher. The current draw increases by as much as 315 mA during a shutter event for the 320 configuration and as much as 550 mA for the 640 configurations. These values are included in the maximum current supply values listed in Table 21.

In power constrained applications, temporarily or permanently disabling image processing filters to reduce power consumption may be desired. Table 22 shows expected power savings at room temperature resulting from various filter settings. Power savings will vary slightly with temperature and are slightly lower than shown at temperatures below room temperature and slightly higher than shown at temperatures above room temperature. Features should be considered additive in power savings and more helpful when combined over temperature, since the steady state system temperature will ultimately be lower with less overall power consumption.

TABLE 22: POWER IMPLICATIONS OF DISABLING VARIOUS FILTERS AND USB VIDEO

FILTER CONFIGURATIONS	POWER DELTA, 320 CONFIG. (mW)	POWER DELTA, 640 CONFIG., (mW)
All off (SCNR, SRNR, SSN, LFSR, TF, T-linear, USB video)	-115	-150
LFSR & Radiometry disabled	-55	-80
USB video disabled	-50	-70
All on (SCNR, SRNR, SSN, LFSR, TF, T-linear, USB video)	baseline	baseline

The relative power draw from the camera with the frame-skip feature enabled is shown below. Averager is disabled in this case but can be enabled for further power savings with an additional reduction in frame rate.

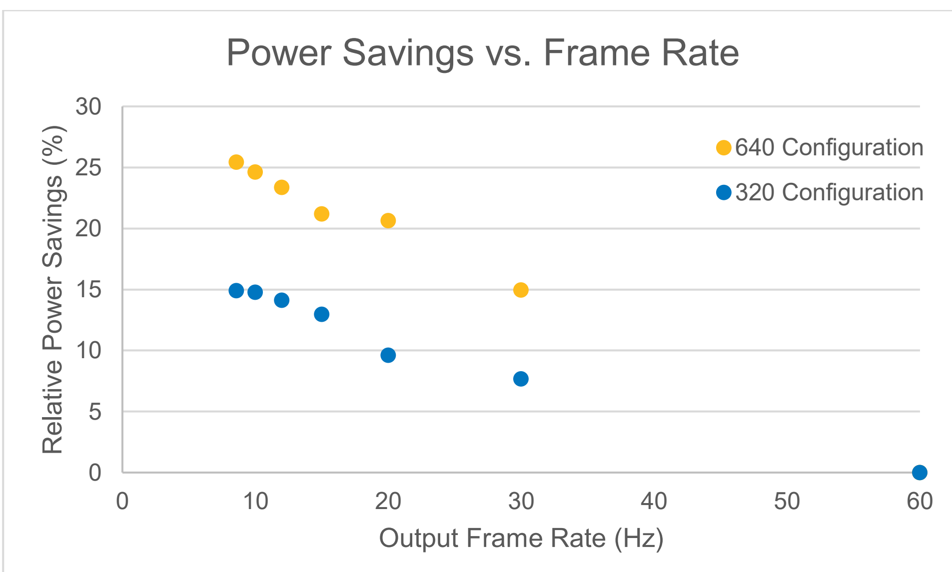


FIGURE 73: POWER SAVINGS AS A FUNCTION OF FRAME RATE

12.3 Absolute Maximum Ratings

Electrical stresses beyond those listed in Table 23 may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated under the recommended operating conditions listed in Table 21 is not implied. Exposure to absolute-maximum-rated conditions for extended periods of time may affect device reliability.

TABLE 23: ABSOLUTE MAXIMUM RATINGS

PARAMETER	ABSOLUTE MAXIMUM RATING
Core Voltage (3V3)	3.63V
USB VBUS	5.25V
Voltage on any GPIO pin	1.98V
Voltage on any USB signal pin	5.25V
Core temperature during operation	105°C

13 ENVIRONMENTAL SPECIFICATIONS

Environmental stresses beyond those listed in Table 24 may cause permanent damage to the device. Exposure to absolute-maximum-rated conditions for extended periods of time may affect device reliability.

TABLE 24: ENVIRONMENTAL SPECIFICATIONS

STRESS	MAXIMUM RATING
Operating Temperature Range[1]	-40° C to 80° C
Storage Temperature	-50° C to 85° C
Altitude (pressure)	12 km altitude equivalent
Relative Humidity	93% non-condensing
Thermal Shock	Air-to-air, between 20°C and storage temp. extremes (i.e., 20°C to -50°C, -50°C to 20°C, 20°C to 85°C, 85°C to 20°C))
Mechanical Shock	250 g, 1.5 ms 500 g, 0.8 ms 1500 g, 0.5 ms Half-sine, all 6 axes
Vibration	Transportation profile, 4.3 grms
Salt Fog[2,3]	HAR configs: unspecified DLC configs: 240 hours per MIL-STD-810G Method 509.4
IP Rating[2]	IP67 per IEC 60529
Abrasion[3]	HAR configs: MIL-C-675C (section 4.5.11) moderate abrasion DLC configs: RSRE TS1888 Windscreen Wiper Test
ESD[4]	EN 61000-4-2 Level 4 8 kV direct discharge 15 kV air-gap discharge

Note(s)

1. *Temperature refers to that at the rear mounting surface of the camera.*
2. *Salt fog and IP rating only applies to the portion of the lens assembly in front of the sealing surface (e.g., the O-ring groove on large lens configurations, the cylindrical portion of the lens flange for smaller-lens configurations).*
3. *Most Boson+ lens assemblies have a high-durability AR (HAR) coating. The 92 deg (2.3mm) lens configuration has a Diamond-Like Coating (DLC).*
4. *Proper ESD packaging and handling procedures are required to protect the Boson+ Core from ESD Damage. Additionally, it is highly recommended for host electronics to incorporate the protection circuitry shown in Section 0.*

14 COMPLIANCE WITH ENVIRONMENTAL DIRECTIVES

Boson+ complies with the following directives and regulations:

- Directive 2011/65/EC, “Restriction of the use of certain Hazardous Substances in electrical and electronic equipment (RoHS)”
- Directive 2002/96/ EC, “Waste Electrical and Electronic Equipment (WEEE)”
- Regulation (EC) 1907/2006, “Registration, Evaluation, Authorization and Restriction of Chemicals (REACH)

15 ACCESSORIES

Several accessories have been designed for use with Boson+. These are listed below and described in more detail in the sections to follow.

15.1 USB VPC Kit (421-0061-00)
15.2 USB/Analog VPC Kit (421-0062-00)
15.3 Camera Link Accessory (250-0609-00)
15.4 Boson Dev Board (250-0593-00)
15.5 Tripod-Mount Accessory (261-2608-00)
15.6 Focus-Tool Accessory (421-2609-00)
15.7 MIPI Development Accessory Board (250-0853-00)

15.1 USB VPC Kit

The USB VPC kit shown in Figure 74 facilitates full interface to the camera via a single USB2 connection providing power, digital video, and comm. The kit includes a 3-foot USB-A to USB-C cable.

Figure 74: Boson VPC Kit (shown in conjunction with the Boson Tripod Accessory)

As of this writing, the USB VPC kit only supports USB2.

15.2 USB/Analog VPC Kit

The USB/Analog VPC kit depicted in Figure 75 is identical to the USB VPC kit except that it includes a custom 6-foot cable with a BNC pigtail, providing an additional analog video signal (NTSC-compliant).

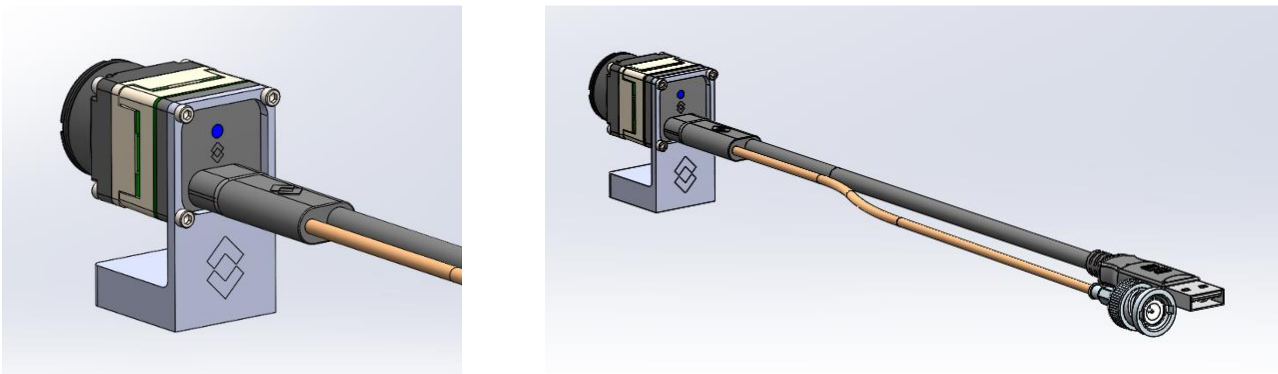


FIGURE 75: BOSON VPC / ANALOG KIT (SHOWN IN CONJUNCTION WITH THE BOSON TRIPOD ACCESSORY)

Cable lengths shown in Figure 74 and Figure 75 are not to scale. Actual length is 0.9m (3.0ft) for the VPC kit and 1.8m (6.0 ft) for the VPC / Analog kit.

15.3 Camera Link Accessory

The Camera Link accessory depicted in Figure 76 converts Boson+ CMOS video signal into a Camera-Link-compliant output, with physical interface via a standard SDR-26 receptacle. Communication and power to the Boson+ is provided via a standard USB-3 micro-B (SuperSpeed) receptacle. A USB-2 micro-B cable is an acceptable alternative to a USB-3 micro-B cable for communication and power but will not support USB3 video.

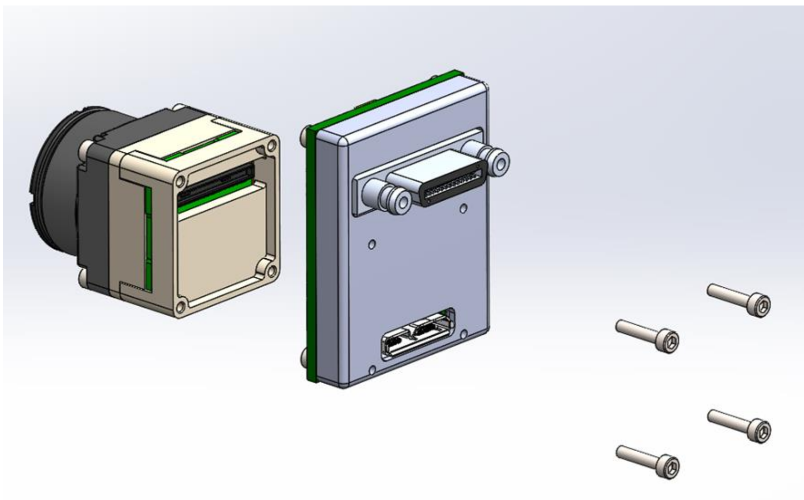


FIGURE 76: BOSON CAMERA LINK ACCESSORY

15.4 Boson Dev Board

The Boson Development Board shown in Figure 77 is intended to support the electronics developer integrating the Boson+ into an end system. It provides full access to the Boson+ 80-pin connector with several fan-out connectors:

- Standard USB-3 micro-B (SuperSpeed) receptacle
- Standard SDR-26 receptacle with Camera-Link compliant output
- SDIO card slot
- UART header
- I2C header
- SPI header
- Power jacks

The SDIO card slot, the I2C header, and the SPI header are to support future Boson+ features not currently offered in the latest Boson+ software release.

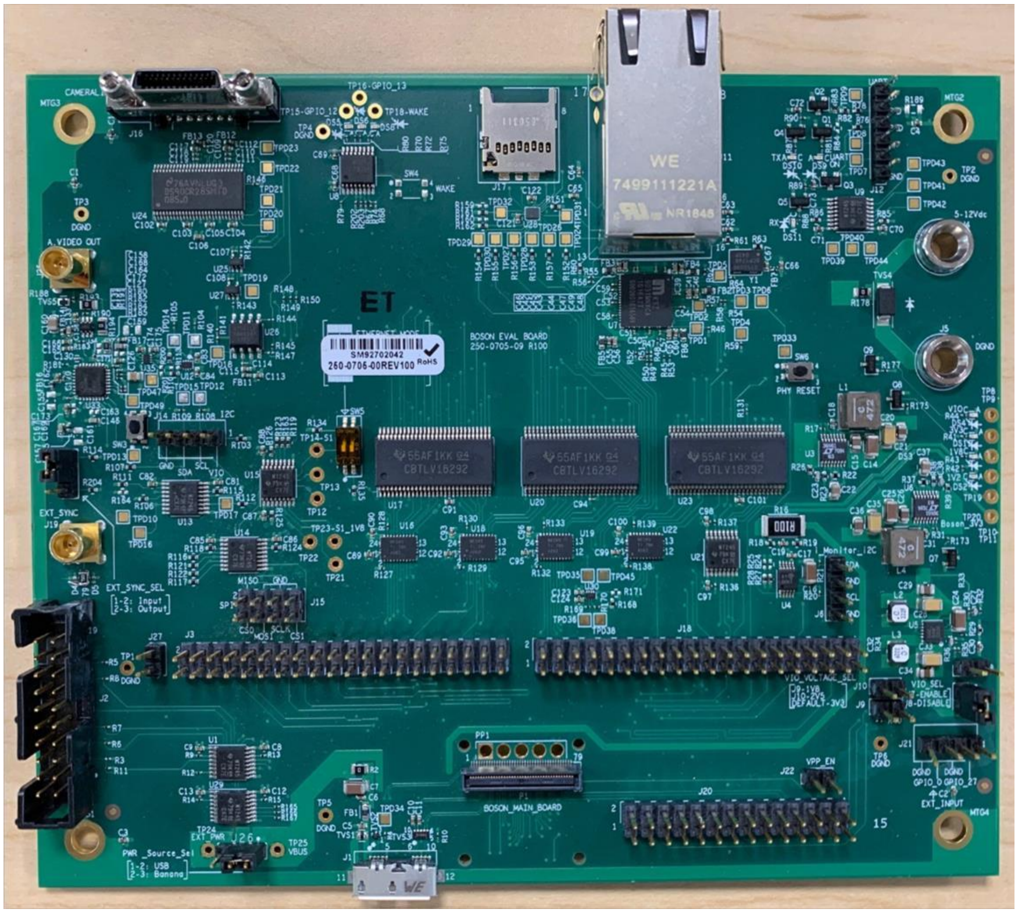


FIGURE 77: BOSON DEV BOARD

15.5 Tripod-Mount Accessory

The Tripod-mount accessory, previously shown in Figure 75 and also shown in Figure 78, provides a way to mount a Boson+ assembly (or a Boson+ configured with either the VPC Accessory or the Camera Link Accessory) to a tripod via a standard 1/4-20 thread. It is designed to interface to the rear of the Boson+ via 4xM1.6 screws.

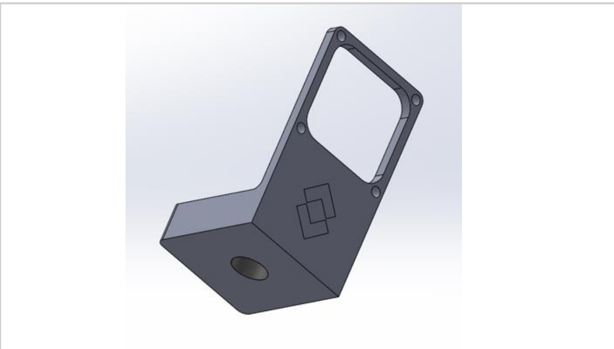


FIGURE 78: BOSON TRIPOD-MOUNT ACCESSORY

15.6 Focus-Tool Accessory

The focus-tool accessory shown in Figure 79 allows any Teledyne FLIR Boson+ lens that cannot be focused by hand to be focused by engaging the appropriate slots on the lens barrel and rotating it inside the lens flange. The focus tool has been properly sized so that no vignetting results when it engages the slots on the lens barrel. Lens configurations with focal lengths $\geq$25mm and 4.9mm do not require a focus tool since focus is achieved by simply turning the outer barrel of the lens assembly by hand.

FIGURE 79: BOSON FOCUS-TOOL ACCESSORY

15.7 MIPI Development Accessory

A test board is available for development purposes to fan out several of the interfaces provided on the primary I/O connector. It is not intended to be integrated into final end-use products. Design and fabrication of an additional interface board is recommended for non-development use cases.

16 REFERENCES

16.1 Teledyne FLIR Documents

DOCUMENT NUMBER	DOCUMENT TITLE
102-2013-01	Boson Quick-Start Guide
102-2013-42	Boson Software IDD
Various	Mechanical Interface Description Drawing (varies by part number)
102-2013-10X-XX	Various Boson Application Notes

Please visit flir.custhelp.com for all Boson+ related documentation, including Application Notes and Mechanical IDDs

16.2 External Documents

DOCUMENT NUMBER	DOCUMENT TITLE
Directive 2011/65/EC	Restriction of the use of certain Hazardous Substances in electrical and electronic equipment (RoHS)
IEC 61000-4-2	Electromagnetic Compatibility (EMC) Testing and Measurement Techniques, ESD Immunity Test
IEC 60529	Degrees of protection provided by enclosures (IP Code)
JESD22-A115C	Electrostatic Discharge Sensitivity Testing, Machine Model (MM)
JESD22-C101E	Field-Induced Charged-Device Model Test Method for Electrostatic Discharge Withstand Thresholds of Microelectronic Components

JEDEC JS-001-2012	Electrostatic Discharge Sensitivity Testing, Human Body Model (HBM) -- Component Testing
MIL-C-675C	Coating of Glass Optical Elements (Anti-reflection)
MIL-STD-810G	DoD Test Method Standard: Environmental Engineering Considerations and Laboratory Tests

16.3 Abbreviations and Acronyms

ABBREVIATION/ ACRONYM	COMPONENTS
4CC	Four Character Code
ACE	Adaptive Contrast Enhancement
AGC	Automatic Gain Control
API	Application Program Interface
AR	Anti-Reflection
CCI	Command and Control Interface
CDM	Charged-Device Model
CMOS	Complementary Metal-Oxide-Semiconductor
CRC	Cyclical Redundancy Check
DDE	Digital Detail Enhancement
DVE	Driver's Vision Enhancer
EMC	Electromagnetic Compatibility
ESD	Electrostatic Damage
FFC	Flat Field Correction
FOV	Field of View
FPA	Focal Plane Array
FPN	Fixed Pattern Noise
GPIO	General Purpose Input/Output

ABBREVIATION/ ACRONYM	COMPONENTS
GUI	Graphical User Interface
HBM	Human Body Model
HEQ	Histogram Equalization
HFOV	Horizontal Field of View
HTL	High-to-Low
I2C	Inter-Integrated Circuit
IDD	Interface Description Drawing/Document
IIR	Infinite Impulse Response
IP	Ingress Protection (also Intellectual Property)
LFSR	Low-Frequency Shading Reduction
LTH	Low-to-High
LUT	Lookup Table
LWIR	Long Wave Infrared
MISO	Master In/Slave Out
MM	Machine Model
MOSI	Master-Out/Slave In
MTBF	Mean Time Between Failure
MTF	Modulation Transfer Function
NETD	Noise Equivalent Temperature Difference
NFOV	Narrow Field of View
NUC	Non-Uniformity Correction
NVFFC	Nonvolatile FFC
QVGA	Quarter VGA, Quarter Video Graphic Array
REACH	Registration, Evaluation, Authorization, and Restriction of Chemicals
RGB	Red, Green, Blue (color space used to represent digital video)

ABBREVIATION/ ACRONYM	COMPONENTS
RoHS	Reduction of Hazardous Substances
ROI	Region of Interest
ROIC	Readout Integrated Circuit
SBNUC	Scene-Based Non-Uniformity Correction
SDIO	Secure Digital Input Output
SDK	Software Developers' Kit
SFFC	Supplemental FFC
SNR	Signal-to-Noise Ratio
SoC	System on a Chip
SSN	Silent Shutterless NUC (also called Spatial Pattern Noise Reduction, SPNR)
SWAP	Size, Weight, and Power
TBD	To Be Determined
TCR	Temperature Coefficient of Resistance
UART	Universal Asynchronous Receiver / Transmitter
UAV	Unmanned Aerial Vehicle
USB	Universal Serial Bus
UVC	USB Video-Device Class
VGA	Video Graphic Array
WEEE	Waste Electrical and Electronic Equipment
WFOV	Wide Field of View
YCrCb	Luma, Red Chrominance, Blue Chrominance (color space used to represent digital video)

This product is protected by patents, design patents, patents pending, or design patents pending.

If you have questions that are not covered in this manual contact Teledyne FLIR Customer Support at flir.custhelp.com for additional information. Contact Customer Support for questions related to the use of open-source software in this product. And contact Customer Support prior to returning a camera which is in need of service.

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 Teledyne FLIR representative for instructions on how to return the product to Teledyne 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.