Human Temperature Detection Solution by Bosch

en Operation Manual

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1 Safety

Read, follow, and retain for future reference all of the following safety instructions. Follow all warnings before operating the device.

Disclaimer

Bosch is not liable for any damage, injuries, financial loss, or other negative consequences that result from intentional or unintentional misuse of the system. Any person who is responsible for the operation of the system must understand the used operational mode, the related workflow, and the system's performance, specifications, and restrictions. The required details are available in the provided documentation and, on demand, by the Bosch support organization.

The list that follows identifies situations that Bosch considers to be intentional misuses of the system:

- Operating the system with a lack of understanding.
- Allowing untrained or otherwise unqualified personnel to operate the system.
- Any workflow shortcuts or other spoofing attempts by operators are considered intentional misuse.
- Operating the system outside its documented specifications.
- Using the system as the final decision point for the classification of a person's health status.
- Using the system in non-cooperative scenarios.
- For automatic person processing, allowing a situation where two or more persons cannot be separated by the camera's IVA algorithm.

To prevent unintentional misuse, configure the appropriate permissions and provide adequate trainings for the operators.

The precision of 0.1°C of the displayed temperature reflects the internal temperature resolution, and must not be confused with the actual temperature accuracy. The basic input value for any person temperature estimation is the measured maximum skin temperature, either for a specific, manually selected skin segment, or for all exposed skin segments in the face area of a person. The estimated person temperature is derived in most operational modes from the measured maximum skin temperature of a tracked person by correcting an (optionally drift-compensated) temperature offset. The user must interpret what the estimated person temperature actually indicates, depending on the choice of the working point temperature's value (which is the basis for offset correction) and meaning. Potential choices for the working point temperature's meaning are:

- the assumed or measured average body core temperature of healthy persons,
- the measured average forehead temperature of a group of reference persons, or
- any other kind of average temperature related to a group of persons.

Singular estimated person temperature values may deviate to an unspecified degree from the actual person's temperature because of various distorting effects, both person-specific and scene-specific. The scenario-specific quantification of the accuracy of the estimated person temperature is only possible in a statistical sense. For this, a large number of persons must be processed to collect both actual (using a medical thermometer) person temperatures and estimated person temperatures. Assuming that the histogram of estimated person temperatures is a convolution of the histogram of actual person temperatures with a Gaussian function that approximates the various measurement uncertainties and distorting effects, the statistical error (or standard deviation) for a singular estimated person temperature can be derived. For the described scenarios, statistical errors in the range x to y are typical, but not guaranteed.

Interpreting the estimated person temperatures as accurate values with the displayed precision of 0.1°C is considered intentional misuse.

2 Introduction

This document describes the operational modes of the Human Temperature Detection (HTD) Solution from Bosch.

The minimum components of the human temperature detection (HTD) system from Bosch are:

- one DINION IP thermal camera with calibrated DRS thermal module (part number NBT-9000-F19QSM)
- one VIDEOJET decoder (part number VJD-7513)
- one full HD monitor (part number UML-245-90)
- one PTZ keyboard (part number KBD-UXF)
- one extended blackbody reference device (part number IBB-5000-35)

2.1 Abbreviations

Abbreviation	Description
AbsP	Absolute alarm threshold profile
AFT	Active face track
AT	Alarm threshold
AutoP	Automatic alarm threshold profile
CFTH	Closed face tracks history
FC	Face candidate
FDH	Face detection history
HTD	Human temperature detection
HTDH	Human temperature detection histogram
IVA	Intelligent Video Analytics
RelP	Relative alarm threshold profile
WP	Working point

2.2 Subscripts

Abbreviation	Description
AT	Alarm threshold
BB	reference device (extended area blackbody)
co	Calibrated once (that is, a fixed offset correction is applied to all measured values)
cc	Continuously calibrated (that is, stabilized with reference device, thus dynamic offset correction)
conf	Configured
est	Estimated
FN	False negative
FP	False positive
meas	Measured

Abbreviation	Description
P	Person
S	Skin
WP	Working point

2.3 Variables and constants

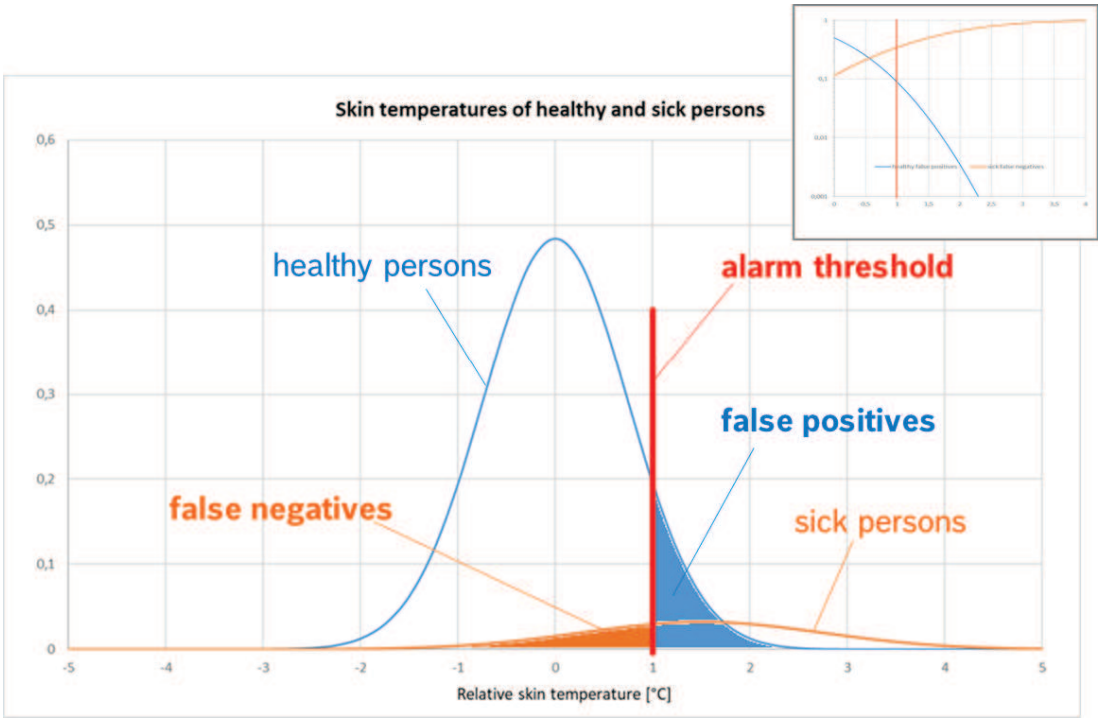
Abbreviation	Description
$r_{FP,target}$	Target false positive ratio
r_{FN}	False negative ratio
ΔT	Relative temperature
$\Delta T_{AT,conf}$	Configured relative alarm temperature
$T_{AT,conf}$	Configured absolute alarm threshold
T_{BB}	Controlled target temperature of calibrated extended area blackbody device
$T_{BB,conf}$	Configured extended area blackbody device temperature, equals TBB
$T_{BB,meas}$	Camera temperature readout for blackbody surface
$T_{P,est}$	Estimated person temperature (for example, body core temperature or forehead temperature)
$T_{P,conf}$	Configured average person temperature for all observed persons (for example, measured average body core temperature or measured average forehead temperature)
$T_{S,meas}$	Camera temperature readout for hottest face skin segment, uncorrected
$\bar{T}_{S,meas}$	Average camera temperature readout for hottest face skin segments of multiple persons
T_{WP}	Working point temperature
$T_{WP,conf}$	Working point temperature, calibrated upfront, for fixed offset correction
$T_{WP,meas}$	Measured working point temperature

3 Fundamentals

This chapter provides the basics that are assumed to be required for understanding the scope and applicability of the human temperature detection (HTD) solution from Bosch.

3.1 Detecting persons with elevated core body temperature

The spreading of contagious diseases can be slowed down or stopped only with a variety of measures. One of those measures is the detection of persons with elevated body core temperatures in public areas. An elevated body core temperature is a typical symptom for infected persons at a certain stage (fever), leading to an elevated skin temperature. There are various other reasons that are not related to any illness. Also, not every infected contagious person shows an elevated body core temperature.
The body core temperature is typically derived from the temperature of a skin segment whose temperature has a well-known, low-variance offset to the body core temperature (for example, the auditory canal or the oral cavity). Even in an ideal-world scenario, measured skin temperatures vary from person to person to a certain degree.
The graphic that follows illustrates the problem caused by overlapping distributions of healthy persons and ill persons. A clear separation is not possible. To select the position of the alarm threshold for detecting persons with elevated body core temperatures, system users must consider the use case, the scenario, and the customer's preferences. There is no one-size-fits-all alarm threshold.



Simulated illustration of basic terms (not based on actual data!). The distributions of healthy and sick persons are assumed to be Gaussian in the simulation, the percentage of sick persons (10%) is highly exaggerated for improved discriminability of the displayed curves. After an operator identifies a potentially infected person, further medical examinations are typically performed.

When evaluating temperature data of a large group of persons, it is safe to assume that the number of ill persons is much lower than the number of healthy persons. If that would not be the case, it would make sense to examine every person directly. This implies that the temperature distribution of all persons (healthy and ill) is almost identical to the distribution of healthy persons.

3.2 Capturing and processing thermal data

The DINION IP thermal 9000 RM camera (part number NBT-9000-F19QSM), with a calibrated thermal module, supports the readout of temperature maps. Drift correction for the thermal sensor is required, and can be achieved with an extended area blackbody device as reference. The temperature maps have calibrated absolute temperatures and IVA metadata for object tracking, with object outlines, from the metadata from the Intelligent Video Analytics.
The VIDEOJET decoder (part number VJD-7513) provides the user interface and processes the thermal data and the metadata from the Intelligent Video Analytics.

3.3 Visual feedback

The screen of the decoder shows the captured thermal data and the derived metadata. Side-by-side usage of thermal and optical cameras is possible with the IP matrix feature set in the decoder. One decoder may process and visualize the input from multiple thermal cameras in parallel.
The visual feedback features an adaptive false color scheme for the thermal images to support easy and intuitive discriminability of persons with elevated temperatures from average persons. The visual feedback also emphasizes important aspects with brighter colors. The colors range from dark blue for low temperatures to red for the average human temperature to bright yellow for high temperatures. For better discriminability of details at lower temperatures, a periodic brightness modulation is applied.

3.4 Color scheme

The temperature map, when displayed directly, is a grayscale image. Thermal cameras typically have contrast enhancements and false color images to enhance the discriminability of image sections with slightly different temperatures. Typically, contrast enhancement and the application of a false color scheme are non-invertible operations. It is not possible to retrieve the actual temperature value from a pixel color.
The Bosch HTD solution uses an adaptive, false color scheme for rendering thermal images. The color scheme was designed to allow easy visual detection of hotspots in the thermal image. The color range is dark blue (low temperatures) to red around the working point (refer to the section that follows) to bright yellow (high temperatures).
The current state of the adaptive false color scheme shows across the right side of the thermal image.

3.5 Basic working principle

Thermal cameras, with their non-invasive, contactless measurement principle, can only measure the temperature of exposed skin and of visible skin segments. Several biological, physical, and scenario-specific effects cause various significant deviations in the measured temperatures. Thus, the accuracy of any camera type and model is inferior to the accuracy of certified medical thermometers.

The simplest approach to measure a person's skin temperature is to measure at the hottest visible spot and see if the temperature exceeds the alarm threshold. This is possible in real-world scenarios, but only at the cost of certain restrictions for the use cases (such as well-defined ambient conditions, cooperative scenarios).
Some of those restrictions can be improved by adding to the observed scene a reference device with a controlled surface temperature (for example, an extended area blackbody device). This approach allows more accurate absolute temperature measurements and compensation for drift.
More advanced approaches are based on relative measurements. Here, the setup is calibrated on a regular basis by acquiring the mean value of measured skin temperatures either once (or on demand from time to time)) for a small set of healthy persons. Again, certain restrictions on the use cases exist.
The Bosch solution for human temperature detection (HTD) covers all of the above-mentioned working principles. The solution may run in a fully automatic way when the object tracking of the camera's built-in Intelligent Video Analytics is working well, or it may be used in a 100% manually controlled way. In addition, the Bosch solution offers an automatic alarm threshold mode, where the alarm threshold is derived continuously from the histogram of all observed persons.
The following subchapters define and describe the used terms, items, components, and methods.

3.5.1 Hotspot areas

There are two pre-configured hotspot areas: one for the definition of the reference device's position in the thermal image, and one for the definition of the mask for face detections. The former must not include the image center, while the latter needs to enclose the image center, and the two areas must not overlap. The system detects and corrects misalignments.
The operator can manipulate the position, size, and aspect ratio of each hotspot area on the decoder screen. Each hotspot area shows as a green rectangle on the thermal images. The moving average of the temperature of the hottest pixel inside the hotspot area shows in the upper right corner.

3.5.2 Face candidates

Face candidates are rectangular areas on the thermal image that may contain a face. Proposals for face candidates are derived in one of two ways:
– The system can create a proposal automatically from object outlines from Intelligent Video Analytics (one face candidate per detected object).
– The operator can provide one user-defined face candidate from the mask for face detections.

START HERE The operator can select the face candidate (FC) mode with the PTZ keyboard. By default, face candidates are derived from tracked IVA objects.

Manual mode

The decoder operates in manual face candidate mode (FC mode manual) when the operator:
– adds at least one hotspot area that encloses the center of the thermal image
– increases the minimum detection size to a value that exceeds the size of the configured hotspot areas

The largest of those hotspot areas will then be used as one and only face candidate. All other hotspot areas continue to work as before.

Automatic mode

The decoder runs in automatic face candidate mode (FC mode automatic) when:
– the operator adds one or more hotspot areas that enclose the center of the image

– the minimum detection size does not exceed the size of the hotspot areas

Then, face candidates are only derived when they are inside the hotspot areas. The configured hotspot areas can then be interpreted as masks for face detections.

In automatic mode, the bounding boxes of IVA objects show as dark green rectangles on the thermal images. Face candidates have the same color as hotspot areas, and show as green rectangles on the screen.

3.5.3 Face detections

Face detections are only supported inside the rectangular image areas that are marked as face candidates (one in manual mode, zero or more in automatic mode). To address issues with detecting a face, the operator may adapt two detection thresholds:

– a threshold that defines a lower limit for the minimum hotspot temperature that is required for a proper face detection
– a threshold that defines a lower limit for the face width on the thermal image

Face detections show as light green rectangles on the thermal images, with small squares indicating the hotspot locations on the face.

The current frame-specific maximum hotspot temperature of the detected face is displayed in the upper right corner. The temperature in the lower right corner represents the overall (filtered) face track maximum hotspot temperature. The current value may exceed the overall maximum value due to the applied filtering mechanism. In case that the overall maximum value exceeds the current alarm threshold, an alarm icon shows in the lower left corner, always in conjunction with the global alarm icon in the lower left corner of the video panel. The upper left corner provides a pseudo ID (capital roman letter) to link the face detection to other user interface elements such as temperature markers.

In manual face candidate mode, the operator may use the PTZ keyboard to override and adapt the predefined face detection rectangle within the boundaries of the rectangle that identifies the face candidate. This allows the fast manual selection of a specific face segment (for example, forehead or eyes) for each processed person in use-cases where that is specifically required.

Whenever one or more faces have been detected in a thermal image, the thermal image is kept for a certain time in the face detections history (FDH). The FDH shows across the top of the thermal image. The operator can navigate in the FDH with the PTZ keyboard (instant rewind feature). The FDH is only visible when there is at least one face detection in the history.

3.5.4 Face tracks

A sequence of face detections for the same person is called a face track. A face track keeps a limited number of the hottest thermal images for closer inspection. A face track is “active” when it collects further data, and is “closed” when no further data is appended. A limited number of the most recent closed face tracks is stored in the closed face tracks history (CFTH). Closed face tracks erode the set of attached thermal frames on a regular basis after a certain number of face tracks area closed (shrink interval).

Automatic mode

In automatic mode, face candidates are derived from IVA object outlines. Those IVA objects are tracked by the camera’s IVA module, and can be identified by their object ID. A sequence of face detections for the same IVA object is called an automatic face track. An automatic face track is “active” while the IVA still tracks the respective object, with a timeout of a few seconds. Whenever an active automatic face track times out after the object has disappeared, the automatic face track is closed automatically

Manual mode

In manual mode, whenever the hotspot area that defines the one and only face candidate exceeds the detection threshold for the minimum hotspot temperature, the face detection is stored in the one and only active face track, called manual face track. This active manual face track keeps a limited number of the most recent hottest face detections, and times out only in the sense that older face detections are discarded, which means that there is no mechanism available that automatically closes the active manual face track in manual face detection mode. The operator can either close this active manual face track with the PTZ keyboard, or discard the active manual face track and start a new active manual face track. Closed manual face tracks are again stored in the CFTH.

All active face tracks show side by side on the thermal image below the FDH. Pseudo IDs (capital Roman letters) as the headline for the active face tracks support the operator by the identification of the according face detection rectangles (a fake ID shows as reference in the upper left corner) and temperature markers. Closed face tracks are displayed in the CFTH across the left side on the thermal image. The CFTH is only visible when at least one closed face track is stored in the history.

Closed face tracks with an insufficient number of face detections will not be added to the CFTH.

3.5.5 Human temperature detections histogram

Human temperature detections are derived from closed face tracks. The maximum skin hotspot temperatures across all face detections in a face track are used to derive the observed person’s temperature. Depending on the operational mode, this human temperature represents either the stabilized measured skin hotspot temperature or the stabilized estimated person temperature for the observed person.

The Bosch HTD solution features a human temperature detections histogram (HTDH). The histogram shows across the bottom of the thermal image. The HTDH is derived from the CFTH on a regular basis, such as every time that a certain number of face tracks are closed. The default interval for the HTDH update is 10. The HTDH shows only after the first update, and is stored on the decoder’s SSD at every update. On decoder startup, the previous HTDH is restored from the SSD. The operator can clear the HTDH with the PTZ keyboard. Clearing the HTDH also clears the active face tracks, the FDH, and the CFTH.

The distribution of human temperatures is assumed to follow a Gaussian distribution. The parameters for the Gaussian distribution fit curve are derived from the history of observed human temperature detections. In order to stabilize the resulting fit curves, a certain fraction of outliers is neglected. A simple filtering of outliers would lead to an underestimation of the standard deviation (fit curve becomes too narrow). To compensate, the system assumes a Gaussian distribution for the filtered outliers.

The derived Gaussian fit curve for the HTDs shows two times in the background of the HTDH, one time normally and one mirrored on the x-axis. In the foreground of the HTDH, the list of newly closed active face tracks shows above the x-axis, and the HTDs for all closed face tracks before the last update show below the x-axis. Every time that the HTDH update interval elapses, the HTDs below the x-axis assimilate the HTDs that show above the x-axis.

The HTDH stores a limited high number of HTDs. The default limit is 100. During the update process, the system deletes the oldest HTDs that exceed this limit number.

3.5.6 Reference device

The extended area blackbody device acts as the reference device. An active control loop keeps the reference device's surface temperature at a certain configured value. The system detects when the reference device is missing or seems to be turned off, and notifies the user accordingly.

3.5.7 Reference device area

The operator can configure a hotspot area with a maximum temperature value that the operator can use as a stable reference. This hotspot area must not enclose the center of the thermal image. If more than one hotspot area is configured that fulfills this criteria, the largest of them is used as reference device area when this operational mode is active. If active, the corresponding hotspot area shows on the screen with a red rectangular border.

3.5.8 Usage profiles

The following usage profiles are supported:

– Absolute alarm threshold (AbsP)
– Relative alarm threshold (RelP)
– Automatic alarm threshold (AutoP)

The absolute alarm threshold profile is suitable for scenarios where the system shall provide an alarm whenever the temperature of the hottest observed skin segment exceeds a configurable absolute temperature threshold. Depending on the configured working point temperature, the system applies a certain temperature offset correction.
The relative alarm threshold profile is suitable for scenarios where the system shall provide an alarm whenever the temperature of the hottest observed skin segment exceeds the captured average temperature of a group of healthy reference persons to a certain configurable degree (relative alarm threshold). This average observed reference person temperature is derived by the system once with the first HTDH update, i.e. whenever the HTDH is cleared and a configurable number of healthy reference persons (HTDH update interval, by default 10) got processed manually or automatically. Depending on the configured average person temperature, the system applies a certain temperature offset correction by setting a suitable working point temperature automatically. The offset correction ensures that the displayed value of the average measured skin temperature of the group of healthy reference persons reflects the configured known actual average person temperature of that group.
The automatic alarm threshold profile is suitable for scenarios where the system shall provide an alarm whenever the temperature of the hottest observed skin segment is within a configurable fraction (alarm ratio) of the hottest previously observed values. Depending on the configured average person temperature, the system applies a certain temperature offset correction by setting a suitable working point temperature automatically. The offset correction ensures that the displayed value of the average measured skin temperature of all previously observed persons reflects the configured assumed average person temperature in the scenario. The offset correction is adapted with each HTDH update.
The value for the thermal sensor drift-compensation is derived continuously for all usage profiles from the observed reference device surface temperature.

3.5.9 Working point

The Bosch HTD solution centers around a working point (WP). The operator can set a constant value for the WP (WP mode fixed). The operator can combine this value with the observed surface temperature of a reference device in the scene (WP mode reference), or the HTD

system can derive the value automatically from the HTDH (WP mode automatic). The WP has different meanings in different operational modes. The WP is the anchor of the color scheme, and has the color red.
The operator can configure a WP temperature, or calibrate the WP, by assigning a working point temperature T_{WP} to the WP. This temperature has a different meaning in each WP mode. If the operator sets T_{WP}, then the WP temperature configuration becomes active. If configured, both values T_{WP} and $T_{WP,meas}$ show on the screen. The configured value T_{WP} is then printed as the primary WP temperature before the square brackets, and the measured value $T_{WP,meas}$ is printed as the secondary WP temperature inside the square brackets. Whenever the WP temperature is configured, the configuration can be cleared with an attempt to change the WP mode.
The tables that follow explain the meanings for the different WP modes:

WP mode	WP temperature	Meaning of WP
Fixed	Not configured	Color scheme anchored at the average observed skin temperature of a group of reference persons
Fixed	Configured	Color scheme anchored as some user-defined average temperature of a group of reference persons (for example, an average estimated body core temperature or an average measured forehead temperature)
Reference	Not configured	Color scheme anchored at preference
Reference	Configured	Color scheme anchored at preference
Automatic	Not configured	Color scheme anchored at average observed skin temperature of all persons
Automatic	Configured	Color scheme anchored at some user-defined average temperature of all persons (for example, an average estimated body core temperature or an average measured forehead temperature)

WP mode	WP temperature	Meaning of primary WP temperature
Fixed	Not configured	The averaged measured temperature derived one time from the first HTDH update
Fixed	Configured	The configured temperature (for example, an average estimated body core temperature or an average measured forehead temperature)
Reference	Not configured	The measured maximum surface temperature of the reference device
Reference	Configured	The configured or measured surface temperature of the reference device, with an optional intentional offset so that the actual area of interest (for example, a person’s forehead) shows accurate on-screen values
Automatic	Not configured	The average measured skin temperature derived from HTDH

Automatic	Configured	The configured temperature (for example, the assumed average human body core temperature or an average measured forehead temperature)

WP mode	WP temperature	Meaning of secondary WP temperature
Fixed	Not configured	N/A
Fixed	Configured	The averaged measured temperature derived one time from the first HTDH update
Reference	Not configured	N/A
Reference	Configured	The measured maximum surface temperature of the reference device
Automatic	Not configured	N/A
Automatic	Configured	The average measured skin temperature derived from HTDH

The operator can select the active WP mode with the PTZ keyboard. The WP mode does not affect the data collection mechanism for the HTDH.

Fixed mode
If the WP mode is set to fixed, then the system, at the first histogram update, sets the WP one time (that is, initially and after each clear-history event) to the center of the HTDH. The first update of the HTDH occurs after the default interval for the HTDH update occurs. This mode must be active when the operator uses a group of known healthy persons as reference for all other persons that the system observes.

Automatic mode
If the WP mode is set to automatic, the WP follows the center of the HTDH, and is updated whenever the HTDH is updated. The WP can then be interpreted as a moving average for all cached HTDs.

3.5.10 Average Person Temperature

The average person temperature needs to be set to the known actual average temperature of a group of healthy reference persons (the actual measurement location or principle does not matter) when the relative alarm threshold profile is used, or to the assumed average temperature of all persons in the scene when the automatic alarm threshold profile is used. The average person temperature is not required in the absolute alarm threshold profile.

3.5.11 Alarm threshold

Beside the working point, the alarm threshold (AT) is the second essential element of the Bosch HTD solution. Every time when the maximum hotspot temperature of a face detection exceeds the AT, an alarm is generated. Alarms show on the screen as alarm icon in the upper left corner of face detections, as global alarm icon in the lower left corner of the video panel, and as alarm markers in the active face tracks in the FDH and in the CFTH. Changing the AT causes a re-evaluation of all cached face detections, and will thus adapt the amount of alarm markers displayed on the screen. Changing the AT does not affect any previously recorded alarm events, and does not create new alarm events for cached closed face tracks that exceed the current AT after a change.

The AT can be set to an absolute temperature (AT mode absolute), set to a temperature relative to the WP temperature (AT mode relative), or derived automatically from the HTDH to achieve a certain configurable false positive ratio (AT mode automatic).
The meaning of the alarm threshold is different for each AT mode, and depends also on the configured WP mode.
The table that follows is a list of the different combinations of WP and AT modes:

ID	WP mode	WP temperature	AT mode	AT working principle	AT meaning
1	Fixed	Not configured	Absolute	T_S,meas > T_AT,conf	Measured skin temperature exceeds a configured absolute threshold (default operational mode)
2	Fixed	Not configured	Relative	T_S,meas > T_WP,meas + dT_AT,conf	Works similarly to 1, but is suited better for repeated manual calibrations with group of reference persons
3	Fixed	Not configured	Automatic	T_S,meas in hottest x percent of histogram	Find the hottest x percent with fixed color scheme
4	Fixed	Not configured	Absolute	T_S,co > T_AT,conf	Corrected measured skin temperature exceeds a configured absolute threshold
5	Fixed	Configured	Relative	T_S,co > T_WP,conf + dT_AT,conf	Works similarly to 4, but is suited better for repeated manual calibrations with group of reference persons
6	Fixed	Configured	Automatic	T_S,co in hottest x percent of histogram	Works very similarly to 3
7	Reference	Not configured	Absolute	T_S,meas > T_AT,conf	Mode combination makes no sense, reference device has no benefit
8	Reference	Not configured	Relative	T_S,meas > T_WP,meas + dT_AT,conf	Mode combination makes no sense, reference device has no benefit
9	Reference	Not configured	Automatic	T_S,meas in hottest x percent of histogram	Mode combination makes no sense, reference device has no benefit
10	Reference	Configured	Absolute	T_S,cc > T_AT,conf	Drift-compensated corrected skin temperatures exceeds a configured absolute threshold

ID	WP mode	WP temperature	AT mode	AT working principle	AT meaning
11	Reference	Configured	Relative	T_S,cc > T_BB,conf + dT_AT,conf	Works very similarly to 10
12	Reference	Configured	Automatic	T_S,cc in hottest x percent of histogram	Find hottest x percent while displaying drift-compensated corrected skin temperatures
13	Automatic	Not configured	Absolute	T_S,meas > T_AT,conf	Mode does not really make sense
14	Automatic	Not configured	Relative	T_S,meas > meanT_S,meas + dT_AT,conf	Measured skin temperature exceeds the average measured skin temperature by a configured relative threshold
15	Automatic	Not configured	Automatic	T_S,meas in hottest x percent of histogram	Find hottest x percent with adaptive color scheme
16	Automatic	Configured	Absolute	T_P,est > T_AT,conf	Estimated person temperature exceeds a configured absolute threshold
17	Automatic	Configured	Relative	T_P,est > meanT_P,conf + dT_AT,conf	Estimated person temperature exceeds the configured assumed average person temperature to a certain configured degree
18	Automatic	Configured	Automatic	T_P,est in hottest x percent of histogram	Find hottest x percent with adaptive color scheme, present estimated person temperature values on screen

The table that follows is a list of terms related to alarm threshold.

Abbreviation	Description
BB	Reference device (extended area blackbody)
co	Calibrated once (that is, a fixed offset correction is applied to all measured values)
cc	Continuously calibrated (that is, stabilized with reference device, thus dynamic offset correction)
conf	Configured
est	Estimated
meas	Measured

Abbreviation	Description
P	Person
S	Skin

The table that follows is a list of the abbreviations of the configured and measured values related to alarm threshold:

Abbreviation	Description
$\Delta T_{AT,conf}$	Configured relative alarm temperature (dT_AT)
$T_{AT,conf}$	Configured absolute alarm threshold
T_{BB}	Controlled target temperature of calibrated extended area blackbody device
$T_{BB,conf}$	Configured extended area blackbody device temperature, equals T_{BB}
$T_{BB,meas}$	Camera temperature readout for blackbody surface
$T_{P,est}$	Estimated person temperature (for example, body core temperature or forehead temperature)
$T_{P,conf}$	Configured average person temperature for all observed persons (for example, measured average body core temperature or measured average forehead temperature)
$T_{S,cc}$	Camera temperature readout for hottest face skin segment, stabilized with reference device
$T_{S,co}$	Camera temperature readout for hottest face skin segment, with fixed offset correction
$T_{S,meas}$	Camera temperature readout for hottest face skin segment, uncorrected
$-T-_{S,meas}$	Average camera temperature readout for hottest face skin segments of multiple persons
$T_{WP,conf}$	Working point temperature, calibrated upfront, for fixed offset correction
$T_{WP,meas}$	Measured working point temperature

The target ratio for false positive (FP) detections becomes active whenever the AT mode is set to automatic. The target FP ratio is configurable with the PTZ keyboard, and is shown as marker on the HTDH. The label of the target FP ratio marker in the HTDH depicts the percentage of persons with a HTD below the given threshold, that is (1 – ratio (r)$_{FP,target}$) x 100% with ratio (r)$_{FP,target}$ as the target FP ratio. As an example, the default target FP ratio is 0.1, which leads to a target FP ratio marker label of “90.0%”. This means that the hottest 10% of all observed persons will cause an alarm. If the AT mode automatic is active, the AT value is updated whenever the HTDH is updated. The AT is then set to the threshold that correlates with the point on the histogram’s x-axis where the area underneath the HTD fit curve accumulates to the configured target FP ratio.
Note that the operational mode ID of the current combination of WP mode, WP temperature configuration state and AT mode is displayed in the label of the AT marker at the color scheme (ID range 1 - 18, see the table above) when the AT control is active. Together with this ID the FC mode is depicted (“a” for automatic, “m” for manual), and an exclamation mark indicates a potential misconfiguration. If the exclamation mark is visible, check if the selected

combination of modes is really as desired. If this is actually the case, the exclamation mark may be safely ignored, the system will work as configured even if the configuration is assumed to make no sense for practical use cases. Whenever a second operational mode is displayed in square brackets, then there is a difference between the active operational mode (before the square brackets) and the target operational mode (in the square brackets). The on-screen help texts offer details on what to do for each control to enter the target operational mode.

3.5.12 Target alarm ratio

The target alarm ratio is configurable with the PTZ keyboard, and is shown as marker on the HTDH. The label of the target alarm ratio marker in the HTDH depicts the percentage of persons with a HTD below the given threshold, i.e. (1- r_"A,target")·100%, with r_"A,target" as target alarm ratio. As an example, the default target alarm ratio is 0.1, which leads to a target alarm ratio marker label of “90.0%”. This means that the hottest 10% of all observed persons will cause an alarm. The AT value is updated whenever the HTDH is updated. The AT is then set to the threshold that correlates best (resolution 0.1°C) with the point on the histogram’s x-axis where the area underneath the HTD fit curve accumulates to the configured target alarm ratio.

3.6 Restrictions

The Bosch HTD system has the following restrictions:

- Setup layout and workflow must allow stable IVA person tracking to support automatic person processing
- Processed persons need to act in a cooperative way
- Distance between camera and observed persons needs to be the same (+-0.5m) for each person
- Actual alarm ratio may deviate from target alarm ratio, especially at the beginning with few processed persons in the histogram
- If the automatic alarm threshold profile is active, then the system does not mark any persons (beside random alarms, if configured) until the histogram appears on the screen
- The background temperature needs to be cooler than the lowest person temperature, and cooler than the reference device surface temperature
- Camera and reference device must run in a thermal steady state, i.e. must be turned on at least 30 minutes before any HTD live operations
- The HTD histogram may need to be cleared manually with the PTZ keyboard before starting HTD live operations to remove any undesired early detections
- The reference device needs to visible in the thermal image at any point in time, without intermediate occlusions by persons or objects like doors
- The only moving object in the camera’s field of view shall be the person which steps in front the camera
- The system’s internal temperature resolution is 0.1°C for single measurements
- The system’s displayed temperature resolution is 0.1°C or 0.2°F

4 Installation

NBT-8000-F19QSM

See Quick Installation Guide.

VJD-7513

See Installation Manual.

KBD-UXF

See Installation Manual.

5 Connection

NBT-8000-F19QSM

See Quick Installation Guide.

VJD-7513

See Installation Manual.

KBD-UXF

See Installation Manual.

6 System Configuration

6.1 Camera configuration

Using Configuration Manager 7.10 or higher, complete the steps that follow to configure the camera:

1. Upgrade the camera firmware to 7.70.0089 or higher.
2. Set passwords for the service account, the user account, and the live account on the camera.
3. Configure the static IP address of the camera.
4. Set video authentication to SHA-256.
   In the camera, the path is General > Display stamping > Video authentication.
   In Configuration Manager, the path is Camera > Video Input > Display stamping > Video authentication.
5. Set the signature interval to 1 second.
   In the camera, the path is General > Display Stamping > Signature interval [s].
   In Configuration Manager, the path is Camera > Video Input > Display stamping > Signature interval [s].

6.2 VIDEOJET decoder configuration

Using Configuration Manager 7.10 or higher, complete the steps that follow to configure the decoder:

1. Upgrade to firmware 10.21.0003 or higher.
2. Set passwords for the service account and for the user account.
3. Install the HTD license.
4. Configure a static IP address.
5. Set the general password of the decoder to the user password of the camera (Advanced > Advanced > Destination > General password.)
6. If you use a UHD monitor, make sure that the actual resolution is restricted to 1920x1080 (Advanced > Display > Display resolution> Best at 1080p60).
7. Use this device as the master in IP matrix.
8. Add the thermal camera(s) to the IP matrix, with key values that are less than or equal to the number of licensed HTD channels.
9. Set (or clear) the passcode for the IP matrix keyboard.
10. Select the auto-lock mode for the IP matrix keyboard.

7 Mode Configuration

Absolute temperature mode

1. Select absolute temperature mode. Pause mode starts automatically.
2. Configure the reference area. Using the keyboard joystick, pan the camera to the temperature reference device. When you see the selection rectangle, press the toggle button on the keyboard to record the temperature of the device. Press the ESC key to exit pause mode.
3. Adjust the FD settings for automatic mode automatically.
4. Enter the temperature of the reference device. The default is 35 °C. Press OK.
5. Enter the temperature that will trigger the on-screen alarm. The default is 35 °C. After the AT is set, the message, "System setup completed" appears.
6. Press OK.
7. Press the ESC key.

Relative temperature mode

1. Select relative temperature mode. Pause mode starts automatically.
2. Configure the target area. Rotate the joystick. Using the keyboard joystick, pan the camera to the target area. Do not include the area of the temperature reference device. When you see the selection rectangle, press the toggle button on the keyboard to record the temperature of the target area. Press the ESC key to exit pause mode.
3. Adjust the FD settings for automatic mode automatically.
4. Enter the temperature of the reference device. The default is 35 °C. Press OK. Press the ESC key.
5. Record the temperature, sequentially, of 10 healthy people (without elevated skin temperature). After the system has each sample, the message, “OK, please proceed” appears. After the tenth person, the message, “System calibration completed” appears.
6. Press OK.
7. Press the ESC key.

Auto mode

1. Select relative temperature mode. Pause mode starts automatically.
2. Configure the target area. Rotate the joystick. Using the keyboard joystick, pan the camera to the target area. Do not include the area of the temperature reference device. When you see the selection rectangle, press the toggle button on the keyboard to record the temperature of the target area. Press the ESC key to exit pause mode.
3. Adjust the FD settings for automatic mode automatically.
4. Enter the temperature of the reference device. The default is 35 °C. Press OK. Press the ESC key.
5. Enter the alarm percentage. The default is 10%.
6. Enter the random alarm percentage. The default is 0%.
7. After the AT is set, the message, “System calibration completed” appears.
8. Press OK.
9. Press the ESC key.

8 User interface

The user interface of the Bosch HTD solution is an extension of the Bosch Videojet decoder IP matrix user interface. The only supported human interface device is the KBD UXF keyboard (PTZ keyboard), which needs to be attached to one of the decoder's USB ports.

8.1 IP matrix command extensions

Almost all documented IP matrix keyboard commands are also supported for HTD panels. Some formerly unused buttons are now functional in an HTD context and some other buttons now have an extended functionality. The PTZ control with the joystick is not available for digital zoom on HTD panels; it is used for user interactions with HTD controls.
The graphic that follows shows the user input controls of the analog keyboard (KBD-UXF). The shuttle ring and the PTZ joystick are used for HTD control. The jog dial has no additional functionality in an HTD context.

Figure 8.1: User input controls for KBD-UXF

1	Shuttle ring
2	Jog dial
3	PTZ joystick

The following user controls are available in an HTD context:
- alarm threshold (AbsP and RelP(
- working point (AbsP and RelP)
- detection thresholds
- target alarm ratio (AutoP)
- face detections history (available if FDH is visible)
- closed face tracks history (available if CFTH is visible)

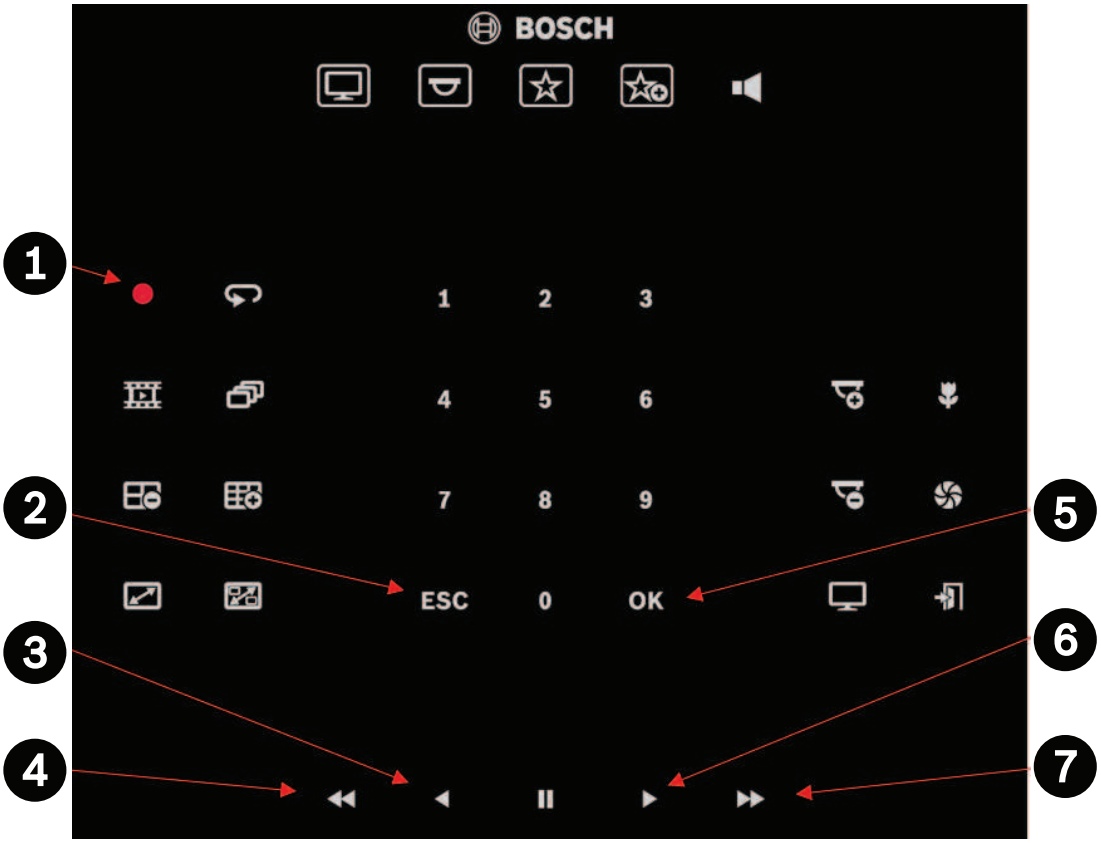


Figure 8.2: KBD-UXF_keyboard-buttons

1	Toggle	2	Clear
3	Previous	4	Previous control
5	Accept	6	Next
7	Next control		

The operator can navigate through the available HTD controls with the PTZ keyboard. The order in which the controls can be activated with the next control / previous control (fast forward / fast reverse) buttons is given by the list above. The next control after the last control is “no control”, and the next control after “no control” is the first control (vice versa for previous control).
After the operator activates a control, one or more control markers related to that control indicate graphically that they are now active. The operator can configure one or two values for the controls, called primary control value and secondary control value. The amount of a control’s values is independent of the number of markers per control on the screen. The operator can change the primary control value with the next / previous (forward / reverse) buttons or with the PTZ joystick’s pan or tilt, the secondary control value can only be changed with the PTZ joystick’s zoom.
Some HTD controls have multiple modes. The active mode of the selected HTD control can be changed with the toggle (record) button. The current mode of an HTD control can be derived from the control marker’s graphical representation.

Please note that all HTD panels enter the pause state when the operator uses the PTZ keyboard to switch any video panel to full-screen or picture-in-picture mode (without changing the actual video panel layout). If an HTD panel shall be displayed in full-screen mode, the according layout (1x1) needs to be chosen for that decoder screen.

8.2 Usage profile selection

The usage profile can be selected once by the operator after each reset-to-defaults operation. All primary and secondary HTD control values will then be reset to profile-specific defaults. The following commands allow an usage profile selection:

- Reset to defaults [Press (ESC) button six times in close succession].
- Select the usage profile [Press button 1, 2, or 3, and press accept (OK) button].

8.3 Live operations mode

Live operations are all those actions that an operator performs while the system is processing live thermal captures. While the system can be configured to run unattended and fully automatic in some use cases, various other use cases require operator interactions on a regular basis.

8.3.1 Global commands

The following commands are always available in live operations mode:

- enter pause mode [press pause button]
- select active HTD control [press next control / previous control (fast forward / fast reverse) buttons]
- unselect HTD controls [press accept (OK) or clear (ESC) button when a HTD control is selected]
- toggle mode of active HTD control [press toggle (record) button]
- close active tracks [press accept (OK) button when no HTD control is selected]
- clear active tracks [press clear (ESC) button when no HTD control is selected]
- clear all [press clear (ESC) button three times in close succession]
- reset to defaults [press clear (ESC) button six times in close succession]
- inspect FDH (instant rewind feature) [rotate shuttle ring, this activates the FDH control automatically]

8.3.2 Detection thresholds control

The detection threshold control has a primary value and a secondary value. The primary value is the minimum temperature that a hotspot must exceed in a face candidate area before a face is detected. The secondary value is the minimum width for face candidates derived from the IVA metadata. Whenever the secondary value exceeds the size of the configured face candidate area(s), the manual face processing mode becomes active. The following commands are available in live operations mode:

- Change primary value [PTZ joystick’s pan and tilt]
- Change secondary value [PTZ joystick’s zoom, next (forward) and previous (reverse) buttons]
- Toggle mode between absolute and relative to WP [press toggle (record) button]

8.3.3 Working point control

The working point control has a primary and a secondary value. The primary value defines the location of the working point (WP always has the same color) in the color scheme. The secondary value defines the WP temperature. The following commands are available in live operations mode:

– Change primary value [PTZ joystick’s pan and tilt]
– Change secondary value [PTZ joystick’s zoom, press next (forward) and previous (reverse) buttons]
– Toggle mode to either clear the WP temperature configuration (if configured), or to switch between fixed and reference/automatic [press toggle (record) button]

If the WP is not in mode fixed, the actual WP mode is defined by the existence of a reference area. If a reference area is configured, WP mode reference is used, else WP mode automatic is active.

8.3.4 Average person temperature control

The average person temperature control has only the secondary value, the primary value is always fixed to average observed person temperature (gray 50% marker in HTDH). The following commands are available in live operations mode:

– change secondary value [PTZ joystick’s zoom, press next (forward) and previous (reverse) buttons]

The average person temperature control is only available for RelP and AutoP.

8.3.5 Alarm threshold control

The alarm threshold control has a primary value, which defines the AT temperature. The secondary control value determines the target operational mode. The following commands are available in live operations mode:

– Change primary value [PTZ joystick’s pan and tilt]
– Change secondary value [PTZ joystick’s zoom, next (forward) and previous (reverse) buttons]
– Toggle mode between absolute, relative, and automatic [press toggle (record) button]

8.3.6 Target alarm ratio control

The target false positive (FP) ratio control has only a primary value, which can be changed via the PTZ joystick’s pan and tilt.

8.3.7 Automatic person processing

The operator can run the system with automatic person processing. To enable that mode, the detection thresholds need to allow an automatic face detection, that is, the configured minimum required face size needs to be smaller than the width of the configured mask for the face candidates.

In the graphics that follow, the average person temperature is configured as 37°C.

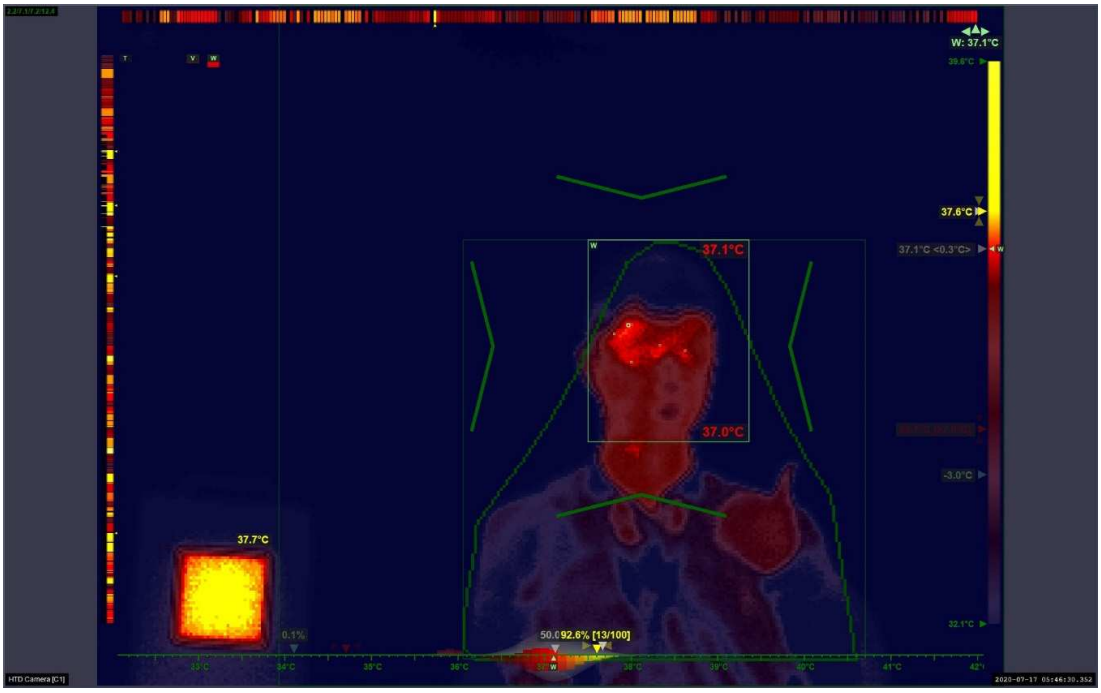


Figure 8.3: Automatic person processing (normal temperature)

Preview of final user interface representation for automatic alarm threshold profile and automatic person processing.

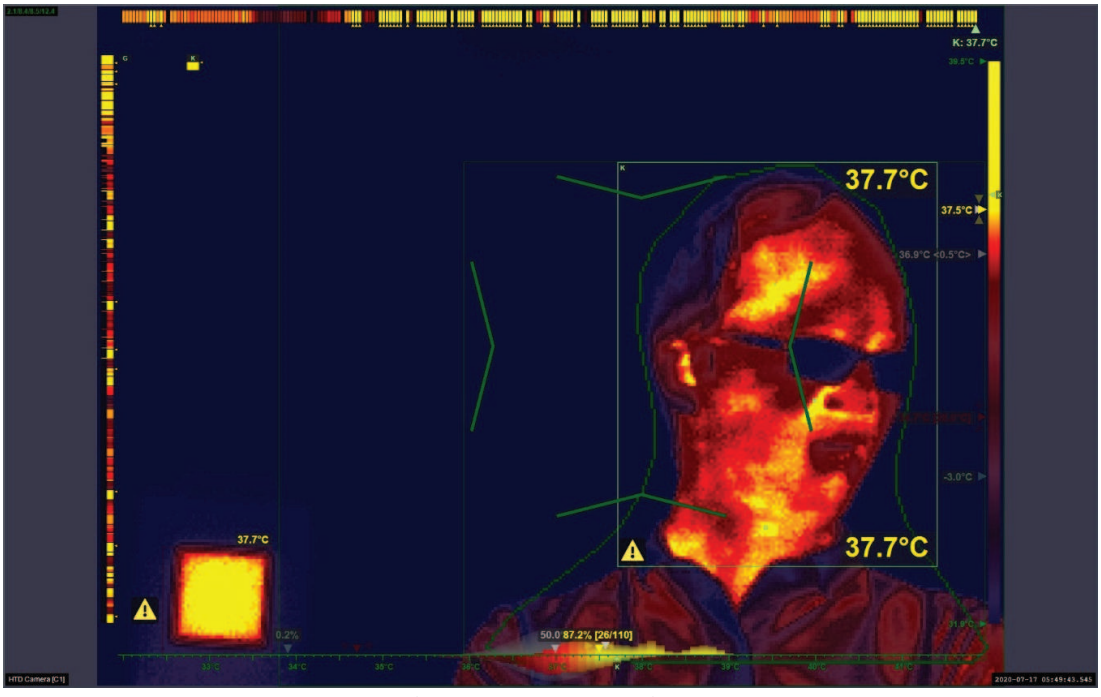


Figure 8.4: Automatic person processing (high temp trigger alarm)

Preview of final user interface representation for automatic alarm threshold profile and automatic person processing in case of an alarm.

8.3.8 Manual person processing

The operator can run the system with manual person processing. To enable that mode, the detection thresholds need to forbid an automatic face detection, that is, the configured minimum required face size needs to be larger than the width of the configured mask for the face candidates. The system cannot resolve that contradiction and enter the manual person processing mode.

By default, one face detection with the size of the configured mask for face candidates is presented on the screen. Alternatively, the operator my adapt the manual face detection rectangle individually within the mask for face candidates to focus on certain face segments, for example, the forehead of each person.

The according one and only manual face track captures the hottest readings within the manual face detection area for a certain period of time. In order to process a person, this face track needs to be manually closed by the operator.

The following commands allow manual person processing:

- adapt face detection rectangle [PTZ joystick, adapt aspect ratio by moving against the borders]
- close active track [press accept (OK) button when no HTD control is selected]
- clear active track [press clear (ESC) button when no HTD control is selected]

In the graphics that follow, the average person temperature is configured as 37°C.

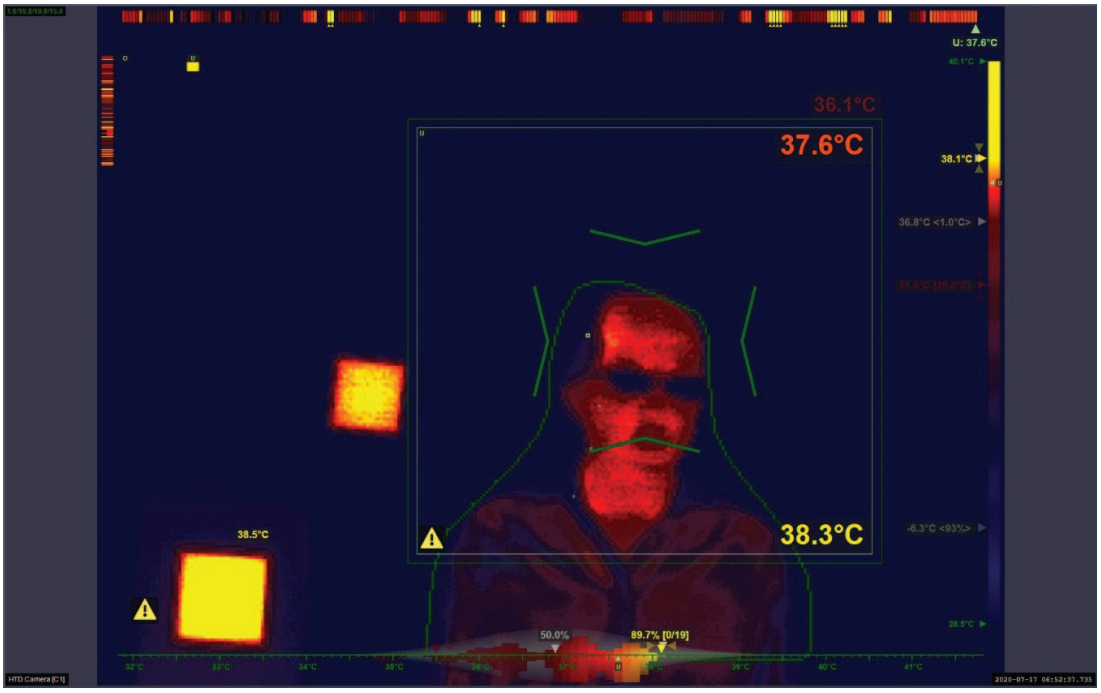


Figure 8.5: Manual person processing (alarm)

Preview of final user interface representation for automatic alarm threshold profile and manual person processing in case of an alarm. The face detection (light green rectangle) fills up the face candidate area (green rectangle).

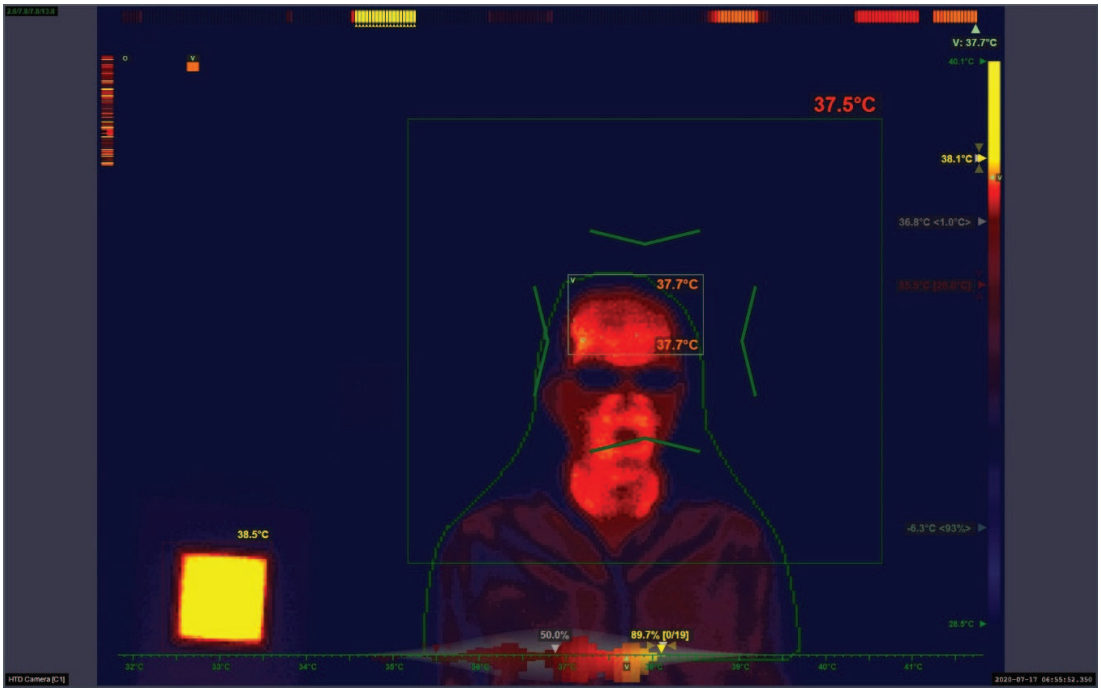


Figure 8.6: Manual person processing (face detection on forehead)

Preview of final user interface representation for automatic alarm threshold profile and manual person processing. The face detection (small light green rectangle) has been adapted individually with the PTZ joystick to focus on the forehead of the persons.

8.3.9 Face detections history inspection mode

The FDH can be inspected to re-visit the most recent face detections. The following commands allow FDH inspection:

- short-cut to inspect FDH (instant rewind feature) [rotate shuttle ring, this activates the FDH control automatically]
- navigate in FDH [PTZ joystick's pan and tilt, rotate shuttle ring]
- leave FDH inspection immediately [press accept (OK) or clear (ESC) button]

In the graphic that follows, the average person temperature is configured as 37°C.

Figure 8.7: Preview of final user interface representation for history inspection (face detection history)

8.3.10 Closed face tracks history inspection mode

8.4 Paused mode

The following commands are always available in pause mode:

– leave pause mode [press pause button]

8.4.1 Hotspot area configuration

The following commands are supported during hotspot area configuration:

– Adapt selection rectangle [PTZ joystick, shuttle ring for aspect ratio control]
– Add snapshot area with size of selected area [press toggle (record) button]
– Remove all snapshot areas inside the selection area [press toggle (record) button]

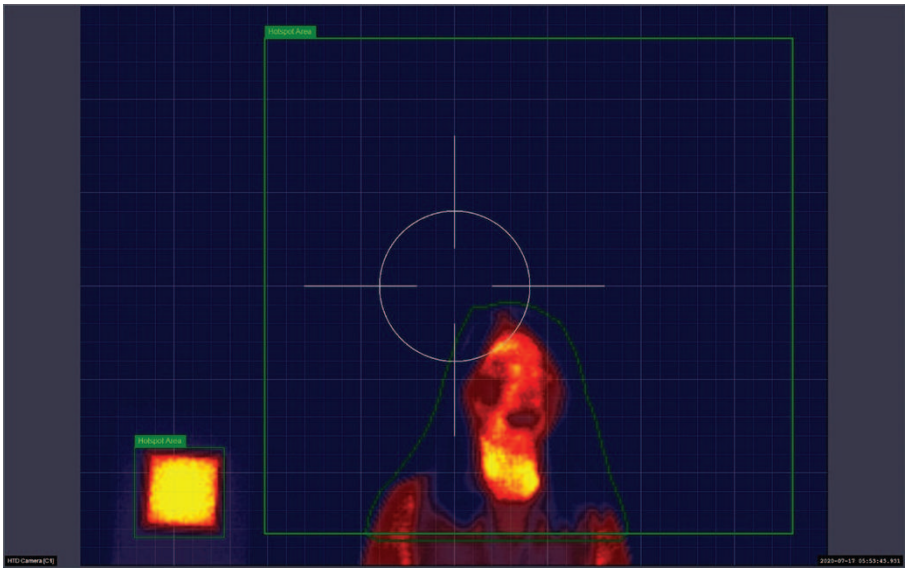


Figure 8.8: Preview of final user interface representation for hotspot area configuration (pause mode)

8.5 Playback mode

The playback mode can be selected, but since no thermal data is stored in the camera's recordings, the HTD overlay and all HTD features are then turned off.

8.6 Self-service mode

The following aspects are important for a high level of acceptance for a HTD system in several societies worldwide:

- Voluntary
- Privacy-respecting
- No central data storage, no traceability
- Disclosed working principle
- Self-determination

The Bosch HTD solution can address all listed aspects with its self-service mode.

Operators can activate self-service mode by locking the PTZ keyboard. In self-service mode, the visual output of the system is meant for the person who is in the camera's field of view, so the decoder's monitor needs then to face towards that person. In self-service mode, the visual output is anonymized and mirrored. The mirroring assists with one's self-alignment, and the anonymization addresses legal obligations regarding the privacy of personal data. The system will mark a certain fraction of all observed persons with a yellow square. Those persons will be asked to check themselves for elevated temperatures with a medical thermometer at a nearby self-service checkpoint.

Privacy issues

In several countries, marking a person in a public area because of a too hot-skin temperature is already a violation of that person's privacy, and thus not always allowed. Depending on the applicable laws and obligations for the system owner, this point may be addressable by adding a certain ratio of random alarms. Any bystander could then no longer distinguish between an alarm caused by a too-hot skin temperature and a random alarm. All other persons get marked with a light green circle, and may proceed on their way.

The process of gathering data is indicated by a shrinking green circle inside the light green circle. In case that no person is found in the camera's field of view, the system indicates its activity by a scanning animation. The scanning animation itself is unrelated to the internal working principle.

The Bosch HTD system can be configured to discard any privacy-related data. No thermal images are then stored in the history, and even all internal timestamps have a granularity that does not allow any correlation between a person and a stored temperature value in the system's history.

In order to optimize the acceptance of the HTD system's self-service mode and discourage spoofing attempts, it is proposed to choose a workflow for marked persons that respects privacy and dignity. All yellow-marked persons should be allowed to determine for themselves what they do with their private temperature reading from the medical thermometer at the self-service checkpoint, with a full trust that they will act reasonably and responsibly.

8.6.1 Setup example

- At the entrance (for example, to a factory), have a setup with one camera (or more), one decoder, one monitor, one PTZ keyboard, one IR thermometer (secured with a Kensington lock), and one blackbody reference device.
- Configure the system to run with automatic alarm threshold profile so that it continuously marks the hottest x percent of all observed persons.

- The monitor faces towards the person under test.
- Ensure that all persons can only enter the camera's field of view in a sequential way.
- All data storage and recording options of the system need to be turned off.
- Revoke the permission to inspect the face detection history. This will turn off any caching of thermal images on the decoder itself.
- Lock the PTZ keyboard to activate self-service mode.

8.6.2 Example of Workflow

Considerations

- No operator required; the system runs unattended 24/7.
- The PTZ keyboard is only required for initial fine-tuning of hotspot areas and detection thresholds, and is locked at any other point in time.
- Marking a person as member of the hottest x percent of all observed persons on a monitor in a public or semi-public area is already a violation of that person's privacy. In several countries, the body temperature value is considered sensitive private data. The system can circumvent a direct correlation by adding a certain configurable ratio of random alarms that cannot be distinguished from an elevated-temperature alarm, so nobody knows why the system marked a person. It could always have been a random marking.
- With a (secured) IR thermometer, an accurate check of one's body temperature provides reliable feedback.

Steps

1. A person steps in front of the camera and looks at the monitor screen.
2. The monitor shows mirrored thermography (for easier alignment of one's position in the image) without any readable temperature values.
   - For all persons that are rated as ok, the face will be replaced with a light-green filled circle.
   - For all persons that are rated as not ok, the face will be replaced with a yellow filled square.
   - Any person who gets marked on the screen with a yellow square is asked to advance to the voluntary self-service temperature measurement station. (All other persons are of course allowed to use that station, too).
3. The person asked to take his or her temperature does so with the IR medical thermometer. This person does not need to share the thermometer readout with any other colleagues, managers, or authorities. What the person does with the result is up to him/her. There is no traceability. There are no consequences of ignoring the data (beside a bad conscience caused by knowing that one might infect dear colleagues). Trust people to act responsibly and reasonably when the medical thermometer says 38 °C or more.

9 Troubleshooting

10 Maintenance

10.1 Updates

Firmware and software updates are carried out via the Configuration Manager application or other management systems in use. Please refer to the relevant documentation.

10.2 Service

- Never open the housing of the unit. The unit does not contain any user-serviceable parts.
- Never open the housing of the power supply unit. The power supply unit does not contain any user-serviceable parts.
- Ensure that all maintenance or repair work is carried out only by qualified personnel (electrical engineers or network technology specialists). In case of doubt, contact your dealer's technical service center.

11 Disposal

	**Disposal** Your Bosch product has been developed and manufactured using high-quality materials and components that can be reused. This symbol means that electronic and electrical devices that have reached the end of their working life must be disposed of separately from household waste. In the EU, separate collecting systems are already in place for used electrical and electronic products. Please dispose of these devices at your local communal waste collection point or at a recycling center.

12 Technical data

For product specifications, see the datasheet for your camera, available on the appropriate product pages of the Online Product Catalog at www.boschsecurity.com.

13 Support

Support

Access our **support services** at https://www.boschsecurity.com/xc/en/support/.

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- Apps & Tools
- Building Information Modeling
- Commissioning
- Warranty
- Troubleshooting
- Repair & Exchange
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