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SPI Interface:

SCK-Frequencies:

HTPA8x8: 5 MHz HTPA32x31: 10 MHz

Protocol Specifications:

Data format: 8 data bits
Frame Sync: None
Module-Selection: \$\overline{SS}\$-Pin

Clock Edge Select: Serial output data changes on transition from idle

to active clock state

SPI Data Input Sample Phase: Data sampled on transition from active to idle

clock state

Clock Polarity: Idle State is low level, active is high level.

Electrical Specifications:

VDD: Supply (+3.3V DC)

SPI Transmit/Receive: TTL VSS GND

Power Supply: 3.3 VDC +/- 5%, 300mA

IDD (Idle mode) 75 mA IDD (Operating mode) 135 mA

Pinout:

No.	Function	Туре
1	VDD	Power
2	VDD	Power
3	VSS	Power
4	VSS	Power
5	SS#	Input
6	UTX/SDO **	Output
7	URX/SDI **	Input
8	SCK	Input
9	CTX*	Output
10	CRX*	Input

* Pins planned for CAN Bus.

** URX/UTX is used for the UART Module

SDI/SDO/SS#/SCK pins support the Module with SPI Interface.

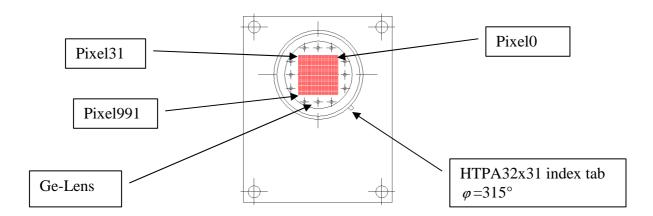
Connector layout: see drawings.

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HTPA32x31 SPI[HP] Module Optical Orientation of Pixels:

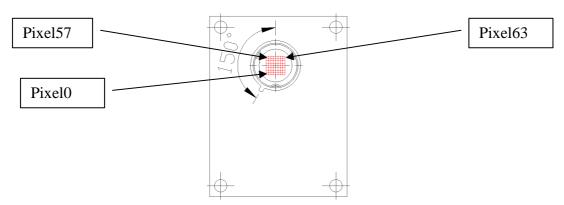
(Physical, lens system may mirror the image)



Top View

HTPA8x8 SPI[HP] Module Optical Orientation of Pixels:

(Physical, lens system may mirror the image)

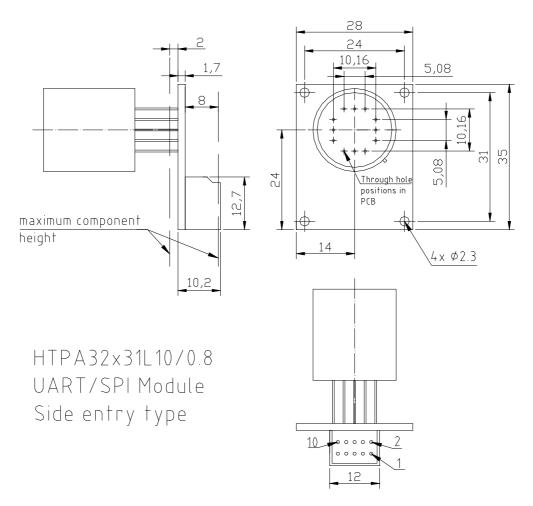


Top View

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Module dimensions:

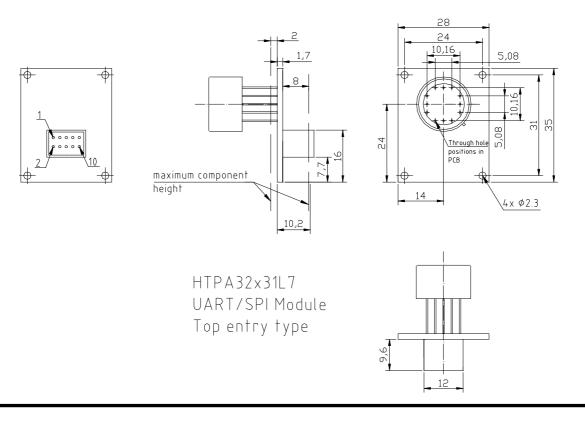


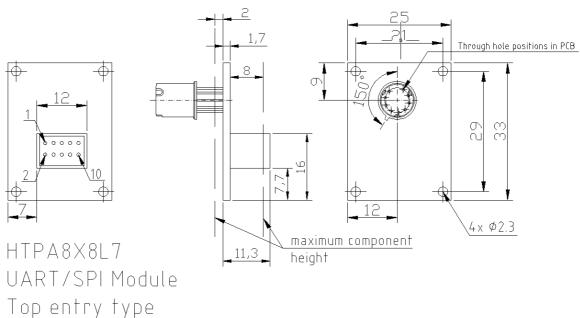
In these drawings always only one optic option is shown for each HTPA type. If another optic is built in, refer to the datasheet of the HTPA sensor. PCB size, pin length of the HTPA and positions on the PCB remain the same, only the cap of the HTPA changes.

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Module dimensions (continued):





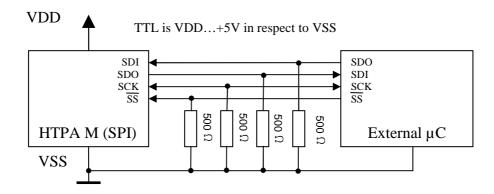
In these drawings always only one optic option is shown for each HTPA type. If another optic is built in, refer to the datasheet of the HTPA sensor. PCB size, pin length of the HTPA and positions on the PCB remain the same, only the cap of the HTPA changes.

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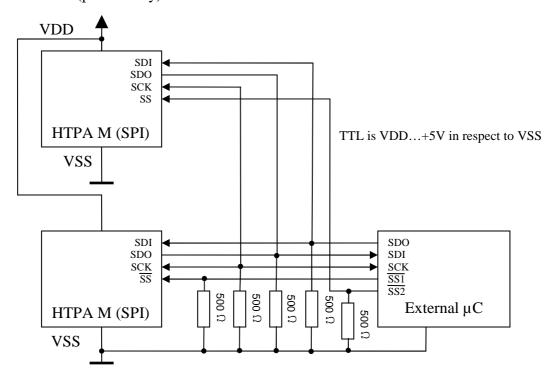


Electrical Connections:

Single Module:



Multiple Modules (preliminary):



SCK is bidirectional because HTPA M (SPI) becomes Master if streaming is in progress. Streaming can be aborted any time by sending any command (preferable 'x') or by toggling \overline{SS} line.

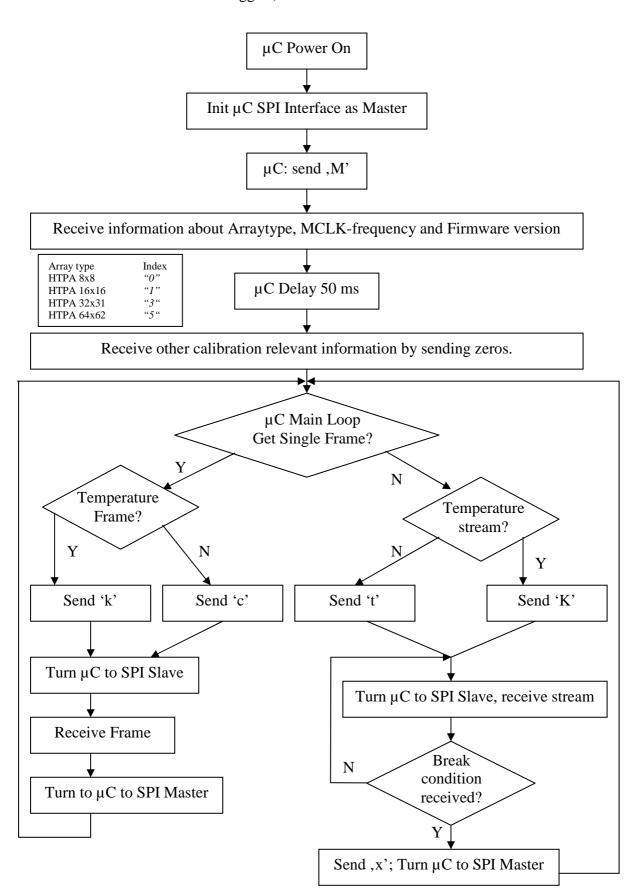
In case of multiple devices only one slave must be selected. Selection of multiple slaves will result in collisions on SPI bus and maybe in damage of the devices.

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Communication and Timings:

Proposed flow chart of communication. (External controller is referred as μ C, HTPA module as HTPA since Master direction toggles)



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Communication and Timings (continuation):

SPI data transfer. For SCK frequencies see page 1.

Receive of command:

SS	
SCK	
SDI	
SDO	
SS	Sending Answer:
SCK	
SDI	
sdo	—{MSB/ / / / LSB /MSB/ / / / LSB /

If the module sends an ASCII answer, each line is closed with the sequence of CR and LF (carriage return [0x0D]; line feed [0x0A]).

A single line answer is sent at the receive of following commands:

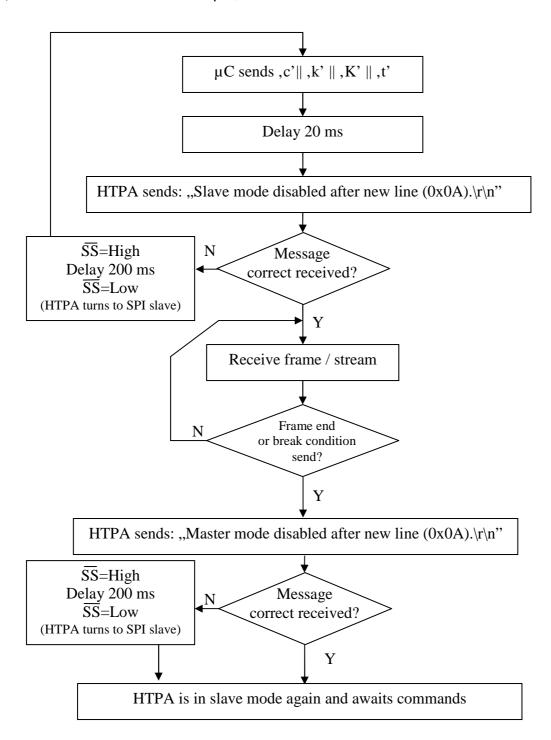
'a'/'A'/'b'/'B'/'f'/'F'/'g'/'G'/'J'/'l'/'m'/'o'/'O'/'q'/'Q'/'\$'/'y'/'Y'/'z'/'Z'

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Communication and Timings (continuation):

Gathering of Frames and streams. Module toggling to SPI Master and back to Slave: (External controller is referred as μ C, HTPA module as HTPA since Master direction toggles)





Communication commands:

						Ca	omm uni cati o	n via Termin	ial / UDP				
Sent Char	HT PA8x8	HTPA16x16	HTPA32x31	Result/Received message									
'a'	X	X	X	Decreases th	ne operating f	requency of t	he array						
'A'	X	X	_		e operating fr								
'b'	X	X	X		DD (reference								
'C'	X	X		Capture sing	gle voltage fra	ame. Use AD	C of ASIC. C	Output via AS	SCII if sent via	a UART, bin	ary if sent	via UDP.	
'c'	X	X	X	Capture sing	gle voltage fra	ame. Use AD	C of µC. Out	put via ASC	II if sent via U	JART, binary	if sent via	UDP.	
'd'/'D'	X	X		Toggle POF									
'f'	X	X	X	Toggle Rese									
'F	X	X							nals convertab		. 11		
'G'	X	X	_					_	nd negative sig		able		
'g'	X	X	37				<i>)</i> -range, only	negative sigi	nals convertab	ole			
'h' 'i'	X	X	_		ry EEDATA		A CCII 6 4	C:-11	D:14-4-[IZ:	*101 -1 Off-		Т	·
T'	H								: Pixeldata[K ² order: Pixelda				
Т 'J'	X	X		Toggle Am		name. Outpu	t III ASCII IOI	mat. serial (nuer. Pixeida	ы[к 10], el.	Offsets, A	morent rem	perature
'k'	X	-	_		temperature	frame Outro	t in hinary for	mat					
'K'	X		_		ous binary ter								
IX	21	71	71		complete cyc	-	-	ibe)[it 10]					
				Output of a	complete cyc	ic ili ulis oruc							
				HTF	PA 8x8 and H	TPA 16x 16 · P	Pixel0 Pixel1	PixelX el	.Offset0, el.Of	fsetl el (Offset Y PTA	ATO PTAT1	PTATZ
					11 000 000 11	111110011011	brero,r brerr,		1: see Table2.		,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,	,	,
						Fe	or a detailed i		of the serial o		le2.		
						- '			.,				
				16x16 Array	y:	8x8	Array:						
				16x16 Array X=255; Y=	-		Array: 3; Y=4; Z=4						
					-		•						
				X=255; Y=	7; Z =7	X=6	3; Y=4; Z=4	s send, then t	the high-byte.	Each Datase	t contains	the measure	d Temperature i
				X=255; Y=2 One dataset Kelvin*10.	7; Z=7 has exactly 2 The first 4 da	X=6 bytes: first tl	3; Y=4; Z=4 he low-Byte is		the high-byte. ast Pixel volta				-
				X=255; Y='	7; Z=7 has exactly 2 The first 4 da	X=6 bytes: first tl	3; Y=4; Z=4 he low-Byte is						-
				X=255; Y=2 One dataset Kelvin*10.	7; Z=7 has exactly 2 The first 4 da	X=6 bytes: first tl	33; Y=4; Z=4 the low-Byte is et0el.Offset	3 after the la	ast Pixel volta	ge <i>PixelX</i> tra	ansmit addi		l Temperature i urrent VDD
				X=255; Y=2 One dataset Kelvin*10. in the MSB2	7; Z=7 has exactly 2 The first 4 da 's:	X=6 bytes: first tl tasets el.Offso	3; Y=4; Z=4 the low-Byte is tet0el.Offset VDD and T	3 after the la	Ast Pixel volta	ge <i>PixelX</i> tra	ansmit addi	itional the cu	nrrent VDD
				X=255; Y=2 One dataset Kelvin*10. in the MSB	7; Z=7 has exactly 2 The first 4 da 's:	X=6 bytes: first tl	33; Y=4; Z=4 the low-Byte is et0el.Offset	Amb for H	EPA8x8 and	ge <i>PixelX</i> tra	ansmit addi	Bit1	Bit0
				X=255; Y=2 One dataset Kelvin*10. in the MSB	has exactly 2 The first 4 da 's: Bit15 MSB VDD	X=6 bytes: first tl tasets el.Offso	3; Y=4; Z=4 the low-Byte is tet0el.Offset VDD and T	Amb for H	EPA8x8 and D Bit11 MSB elOff0	ge <i>PixelX</i> tra	ansmit addi	itional the cu	Bit0 LSB elOff0
				X=255; Y=2 One dataset Kelvin*10. in the MSB2 Dataset elOff0 elOff1	has exactly 2 The first 4 da 's: Bitts MSB VDD Bittt VDD	X=6 bytes: first the tasets el. Offset Bit 14	3; Y=4; Z=4 the low-Byte is tet0el.Offset VDD and T	Amb for HT Bit12 Bit12 VDD Bit8 VDD	FPA8x8 and D Bit11 MSB elOff0 MSB elOff1	ge <i>PixelX</i> tra HTPA16x16 Bit 10	ansmit addi	Bit1	BitO LSB elOff0 LSB elOff1
				X=255; Y=2 One dataset Kelvin*10. in the MSB2 Dataset elOff0 elOff1 elOff2	has exactly 2 The first 4 da 's: Bit15 MSB VDD Bit11 VDD Bit7 VDD	X=6 bytes: first tl tasets el.Offso	3; Y=4; Z=4 the low-Byte is tet0el.Offset VDD and T	Amb for HT Bit12 Bit12 VDD Bit8 VDD Bit4 VDD	FPA8x8 and D Bit11 MSB elOff0 MSB elOff1 MSB elOff2	ge <i>PixelX</i> tra	ansmit addi	Bit1	Bit0 LSB elOff0 LSB elOff1 LSB elOff2
				X=255; Y=2 One dataset Kelvin*10. in the MSB2 Dataset elOff0 elOff1	has exactly 2 The first 4 da 's: Bitts MSB VDD Bittt VDD	X=6 bytes: first the tasets el. Offset Bit 14	3; Y=4; Z=4 the low-Byte is tet0el.Offset VDD and T	Amb for HT Bit12 Bit12 VDD Bit8 VDD	FPA8x8 and D Bit11 MSB elOff0 MSB elOff1	ge <i>PixelX</i> tra HTPA16x16 Bit 10	ansmit addi	Bit1	BitO LSB elOff0 LSB elOff1
				X=255; Y=' One dataset Kelvin*10.' in the MSB' Dataset elOff0 elOff1 elOff2 elOff3	has exactly 2 The first 4 da 's: Bit15 MSB VDD Bit11 VDD Bit7 VDD Bit3 VDD	X=6 bytes: first tl tasets el.Offso Bit 14	VDD and T Bit13	Amb for H7 Bit12 Bit12 VDD Bit8 VDD Bit4 VDD LSB VDD	FPA8x8 and I Bit11 MSB elOff0 MSB elOff1 MSB elOff2 MSB elOff3	ge <i>PixelX</i> tra HTPA16x16 Bit 10	ansmit addi	Bit1	BitO LSB elOff0 LSB elOff1 LSB elOff2
				X=255; Y=' One dataset Kelvin*10.' in the MSB' Dataset elOff0 elOff1 elOff2 elOff3 The Sensor	has exactly 2 The first 4 da 's: Bit15 MSB VDD Bit1 VDD Bit3 VDD temperature i	X=6 bytes: first that tasets el. Offso Bit 14 s a vailable in	VDD and T Bit13 the datasets	Amb for H7 Bit12 Bit12 VDD Bit8 VDD Bit4 VDD LSB VDD after el. Offse	FPA8x8 and D Bitl 1 MSB elOff0 MSB elOff1 MSB elOff3 MSB elOff3	ge PixelX tra HTPA16x16 Bit10	ansmit addi	Bitl	Bit0 LSB dOff0 LSB dOff1 LSB dOff2 LSB dOff3
				X=255; Y=' One dataset Kelvin*10.' in the MSB' Dataset elOff0 elOff1 elOff2 elOff3 The Sensor	has exactly 2 The first 4 da 's: Bit15 MSB VDD Bit1 VDD Bit3 VDD temperature i Bit15	X=6 bytes: first tl tasets el.Offso Bit 14	VDD and T Bit13	Amb for H7 Bit12 Bit12 VDD Bit8 VDD Bit4 VDD LSB VDD after el. Offse Bit12	FPA8x8 and D Bitl 1 MSB elOff0 MSB elOff1 MSB elOff2 MSB elOff3 ### Bitl 1 Bitl 1	ge <i>PixelX</i> tra HTPA16x16 Bit 10	ansmit addi	Bit1	BitO LSB dOff0 LSB dOff1 LSB dOff2 LSB dOff3
				X=255; Y=' One dataset Kelvin*10.' in the MSB Dataset elOff0 elOff1 elOff2 elOff3 The Sensor Dataset elOff3+1	has exactly 2 The first 4 da 's: Bit15 MSB VDD Bit1 VDD Bit3 VDD temperature i Bit15 MSB TAmb	X=6 bytes: first that tasets el. Offso Bit 14 s a vailable in	VDD and T Bit13 the datasets	Amb for H7 Bit12 Bit12 VDD Bit8 VDD Bit4 VDD LSB VDD after el. Offse Bit12 Bit12 TAmb	FPA8x8 and I Bitl1 MSB elOff0 MSB elOff1 MSB elOff2 MSB elOff2 Bitl1 MSB elOff5+1	ge PixelX tra HTPA16x16 Bit10	ansmit addi	Bitl	Bit0 LSB elOff0 LSB elOff1 LSB elOff2 LSB elOff3
				X=255; Y=' One dataset Kelvin*10.' in the MSB' Dataset elOff0 elOff1 elOff2 elOff3 The Sensor	has exactly 2 The first 4 da 's: Bit15 MSB VDD Bit1 VDD Bit7 VDD Bit3 VDD temperature i Bit15 MSB TAmb Bit11 TAmb	X=6 bytes: first that tasets el. Offso Bit 14 s a vailable in	VDD and T Bit13 the datasets	Amb for HT Bit12 Bit12 VDD Bit8 VDD Bit4 VDD LSB VDD after el. Offse Bit12 Bit12 TAmb Bit8 TAmb	FPA8x8 and 1 Bit11 MSB elOff0 MSB elOff1 MSB elOff2 MSB elOff2 MSB elOff3 t3: Bit11 MSB elOff3+1 MSB elOff3+2	ge PixelX tra HTPA16x16 Bit10	ansmit addi	Bitl	BitO LSB dOff0 LSB dOff1 LSB dOff2 LSB dOff3
				X=255; Y=2 One dataset Kelvin*10. 'in the MSB' Dataset elOff0 elOff1 elOff2 elOff3 The Sensor Dataset elOff3+1 elOff3+2 elOff3+2 elOff3+3	has exactly 2 The first 4 da 's: Bit15 MSB VDD Bit1 VDD Bit7 VDD Bit3 VDD temperature i Bit15 MSB TAmb Bit11 TAmb Bit7 TAmb	X=6 bytes: first that tasets el. Offso Bit 14 s a vailable in	VDD and T Bit13 the datasets	Amb for H' Bit12 Bit12 VDD Bit8 VDD Bit4 VDD LSB VDD after el. Offse Bit12 Bit12 TAmb Bit8 TAmb Bit4 TAmb	FPA8x8 and 1 Bit11 MSB elOff0 MSB elOff1 MSB elOff2 MSB elOff3 ### Bit11 MSB elOff5 ### Bit11 MSB elOff5+1 MSB elOff5+2 MSB elOff5+3	ge PixelX tra HTPA16x16 Bit10	ansmit addi	Bitl	Bit0 LSB el Off1 LSB el Off2 LSB el Off3 LSB el Off3 LSB el Off3+1 LSB el Off3+2 LSB el Off3+2 LSB el Off3+3
				X=255; Y=' One dataset Kelvin*10.' in the MSB Dataset elOff0 elOff2 elOff3 The Sensor Dataset elOff3+1 elOff3+2	has exactly 2 The first 4 da 's: Bit15 MSB VDD Bit1 VDD Bit7 VDD Bit3 VDD temperature i Bit15 MSB TAmb Bit11 TAmb	X=6 bytes: first that tasets el. Offso Bit 14 s a vailable in	VDD and T Bit13 the datasets	Amb for H' Bit12 Bit12 VDD Bit8 VDD Bit4 VDD LSB VDD after el. Off se Bit12 Bit12 TAmb Bit8 TAmb LSB TAmb	FPA8x8 and 1 Bit11 MSB elOff0 MSB elOff1 MSB elOff2 MSB elOff2 MSB elOff3 t3: Bit11 MSB elOff3+1 MSB elOff3+2	ge PixelX tra HTPA16x16 Bit10	ansmit addi	Bitl	BitO LSB dOff0 LSB dOff1 LSB dOff3 LSB dOff3 LSB dOff3+1 LSB dOff3+2
T	X	X	X	X=255; Y= One dataset Kelvin*10. in the MSB Dataset elOff0 elOff1 elOff2 elOff3 The Sensor Dataset elOff3+1 elOff3+2 elOff3+3 elOff3+4 elOff3+5	has exactly 2 The first 4 da 's: Bit15 MSB VDD Bit11 VDD Bit7 VDD Bit3 VDD temperature i Bit15 MSB TAmb Bit1 TAmb Bit3 TAmb	X=6 bytes: first that tasets el.Offs Bit 14 s available in Bit 14	### Company of the content of the co	Amb for H' Bit12 Bit12 VDD Bit8 VDD Bit4 VDD LSB VDD after el. Off se Bit12 Bit12 TAmb Bit8 TAmb Bit8 TAmb	FPA8x8 and 1 Bit11 MSB elOff0 MSB elOff1 MSB elOff2 MSB elOff3 ### Bit11 MSB elOff3 ### Bit11 MSB elOff3 ### Bit11 MSB elOff3+1 MSB elOff3+2 MSB elOff3+3 MSB elOff3+3 MSB elOff3+4	Bit 10 Bit 10 Bit 10	ansmit addi	Bitl	Bit0 LSB dOff0 LSB dOff1 LSB dOff2 LSB dOff3 Bit0 LSB dOff3+1 LSB dOff3+2 LSB dOff3+2 LSB dOff3+3 LSB dOff3+3
<u>'T</u> 'm'	X	XXX	_	X=255; Y= One dataset Kelvin*10. in the MSB Dataset eloff0 eloff1 eloff2 eloff3 The Sensor Dataset eloff3+1 eloff3+2 eloff3+2 eloff3+4 eloff3+5 Get Ambier	has exactly 2 The first 4 da 's: Bit15 MSB VDD Bit11 VDD Bit7 VDD Bit3 VDD Bit8 VDD Bit8 VDD Bit9 VDD	X=6 bytes: first that tasets el.Offs Bit 14 s available in Bit 14 ce (Calculates	### Company of the Ambient Company of the Company	Amb for H' Bit12 Bit12 VDD Bit8 VDD Bit8 VDD LSB VDD after el. Offse Bit12 Bit12 TAmb Bit8 TAmb LSB TAmb LSB TAmb Temperature	FPA8x8 and 1 Bit1 MSB elOff0 MSB elOff2 MSB elOff3 f3: Bit11 MSB elOff3+1 MSB elOff3+2 MSB elOff3+2 MSB elOff3+2 MSB elOff3+3 MSB elOff3+4 0 MSB elOff3+5 e from the last	Bit10 Bi	ansmit addi	Bitl Bitl Bitl	BiO LSB dOff0 LSB dOff1 LSB dOff2 LSB dOff3 BiO LSB dOff3+1 LSB dOff3+4 LSB dOff3+5
		_	X	X=255; Y= One dataset Kelvin*10. in the MSB Dataset elOff0 elOff1 elOff2 elOff3 The Sensor Dataset elOff3+1 elOff3+2 elOff3+3 elOff3+4 elOff3+5 Get Ambier Toggle usag	has exactly 2 The first 4 da 's: Bit15 MSB VDD Bit11 VDD Bit7 VDD Bit3 VDD Bit8 VDD Bit8 VDD Bit9 VDD	Bit 14 s a vailable in Bit 14 be (Calculates	### Company of the Ambient Sets (Stack de Face) 13	Amb for HT Bit12 Bit12 VDD Bit8 VDD Bit8 VDD LSB VDD after el. Offse Bit12 TAmb Bit4 TAmb LSB TAmb Temperature pth = 64 for	Bitl1 MSB elOff3 Bitl1 MSB elOff3 MSB elOff3 MSB elOff3 MSB elOff3 MSB elOff3+1 MSB elOff3+2 MSB elOff3+3 MSB elOff3+4 0 MSB elOff3+5 el from the last	Bit10 Bi	ansmit addi	Bitl Bitl Bitl	Bit0 LSB dOff0 LSB dOff1 LSB dOff2 LSB dOff3 Bit0 LSB dOff3+1 LSB dOff3+2 LSB dOff3+2 LSB dOff3+3 LSB dOff3+3
ʻm'	X	X	X	X=255; Y= One dataset Kelvin*10. in the MSB Dataset elOff0 elOff1 elOff2 elOff3 The Sensor Dataset elOff3+1 elOff3+2 elOff3+3 elOff3+4 elOff3+5 Get Ambier Toggle usag Shows curre	has exactly 2 The first 4 da s: Bit15 MSB VDD Bit11 VDD Bit7 VDD Bit3 VDD temperature i Bit15 MSB TAmb Bit1 TAmb Bit1 TAmb Bit3 TAmb Cut Temperature te of µC-Buff ent and calibr	Bit 14 s available in Bit 14 ce (Calculates	web low-Byte is et al. (1984) and T leads to the datasets is leads (1984) and T leads to the datasets is leads (1984) and the Ambient leads (Stack de Device print)	Amb for HT Bit12 Bit12 VDD Bit8 VDD Bit8 VDD LSB VDD after el. Offse Bit12 TAmb Bit4 TAmb LSB TAmb Temperature pth = 64 for steep of the following st	Bitl1 MSB elOff3 Bitl1 MSB elOff3 MSB elOff3 MSB elOff3 MSB elOff3 MSB elOff3+1 MSB elOff3+2 MSB elOff3+3 MSB elOff3+4 0 MSB elOff3+5 el from the last	Bit10	i:	Bit1	Bit0 LSB dOff0 LSB dOff1 LSB dOff3 LSB dOff3+1 LSB dOff3+1 LSB dOff3+4 LSB dOff3+5 - HTPA32x31)
ʻm'	X	X	X	X=255; Y= One dataset Kelvin*10. in the MSB Dataset eloff0 eloff1 eloff2 eloff3 The Sensor Dataset eloff3+1 eloff3+2 eloff3+2 eloff3+4 eloff3+4 eloff3+5 Get Ambier Toggle usag Shows curre "HTPA ser"	has exactly 2 The first 4 da 's: Bit15 MSB VDD Bit11 VDD Bit7 VDD Bit3 VDD temperature i Bit15 MSB TAmb Bit1 TAmb Bit3 TAmb Control of the first Amb Bit4 TAmb Bit5 TAmb Bit4 TAmb Bit5 TAmb Bit5 TAmb Bit6 TAmb Bit7 T	Bit 14 S a vailable in Bit 14 Bit 14 C c (Calculates et Coffs ation settings dt I am Arra	vDD and T Bit13 the datasets is Bit13 the Ambient sets (Stack de . Device print wytype X'' Po	Amb for HT Bit12 Bit12 VDD Bit8 VDD Bit8 VDD LSB VDD after el. Offse Bit12 Bit12 TAmb Bit12 TAmb Bit4 TAmb LSB TAmb LSB TAmb Temperature pth = 64 for is the following sible values	Bitl1 MSB elOff3 Bitl1 MSB elOff3 MSB elOff3 MSB elOff3 MSB elOff3 MSB elOff3 MSB elOff3+1 MSB elOff3+2 MSB elOff3+2 MSB elOff3+3 MSB elOff3+4 0 MSB elOff3+5 E from the last HTPA8x8 and ng stream:	Bit 10 Bi	i:	Bit	Bit0 LSB elOff0 LSB elOff1 LSB elOff3 LSB elOff3+1 LSB elOff3+2 LSB elOff3+2 LSB elOff3+4 LSB elOff3+5
ʻm'	X	X	X	X=255; Y= One dataset Kelvin*10. in the MSB Dataset eloff0 eloff1 eloff2 eloff3 The Sensor Dataset eloff3+1 eloff3+2 eloff3+2 eloff3+4	has exactly 2 The first 4 da 's: Bit15 MSB VDD Bit11 VDD Bit7 VDD Bit3 VDD temperature i Bit15 MSB TAmb Bit1 TAmb Bit3 TAmb Control of the first Amb Bit4 TAmb Bit5 TAmb Bit4 TAmb Bit5 TAmb Bit5 TAmb Bit6 TAmb Bit7 T	Bit 14 S a vailable in Bit 14 Bit 14 C c (Calculates et Coffs atton settings dt I am Arratten by B.Fo	WDD and T Bit13 the datasets is Bit13 the Ambient sets (Stack de Device print ytype X'' Porg; Heimann	Amb for HT Bit12 Bit12 VDD Bit8 VDD Bit8 VDD LSB VDD after el. Offse Bit12 TAmb Bit12 TAmb Bit4 TAmb LSB TAmb Temperature pth = 64 for is the following sible values Sensor Gmi	Bitl1 MSB elOff3 Bitl1 MSB elOff3 MSB elOff3 MSB elOff3 MSB elOff3 MSB elOff3+1 MSB elOff3+2 MSB elOff3+2 MSB elOff3+2 MSB elOff3+2 MSB elOff3+5 E from the last HTPA8x8 and ng stream: s for X: "0"=H bH; YYYY-M	Bit 10 Bi	i:	Bit	Bit0 LSB elOff0 LSB elOff1 LSB elOff3 LSB elOff3+1 LSB elOff3+2 LSB elOff3+2 LSB elOff3+4 LSB elOff3+5
ʻm'	X	X	X	X=255; Y= One dataset Kelvin*10.' in the MSB Dataset elOff0 elOff1 elOff2 elOff3 The Sensor Dataset elOff3+1 elOff3+2 elOff3+4	has exactly 2 The first 4 da 's: Bit15 MSB VDD Bit1 VDD Bit3 VDD Bit3 VDD temperature i Bit15 MSB TAmb Bit1 TAmb Bit3 TAmb Control of the co	Bit 14 S available in Bit 14 Bit 14	web low-Byte is et al. (1984) and T leads to the datasets is leads (1984) and the datasets is leads (1984) and the Ambient leads (Stack de Device print lytype X" Porg; Heimann ctual MCLK-	Amb for HT Bit12 Bit12 VDD Bit8 VDD Bit8 VDD Bit4 VDD LSB VDD after el. Offse Bit12 Bit12 TAmb Bit8 TAmb Bit8 TAmb LSB TAmb CSB TAmb Temperature pth = 64 for st the followingssible values Sensor Gmisetting in kH	Bitl1 MSB elOff3 Bitl1 MSB elOff3 MSB elOff3 MSB elOff3 MSB elOff3 MSB elOff3+1 MSB elOff3+2 MSB elOff3+2 MSB elOff3+2 MSB elOff3+2 MSB elOff3+5 E from the last HTPA8x8 and ng stream: s for X: "0"=H bH; YYYY-M	Bit 10 Bit 10	i:	Bit	Bit0 LSB elOff0 LSB elOff1 LSB elOff3 LSB elOff3+1 LSB elOff3+2 LSB elOff3+2 LSB elOff3+4 LSB elOff3+5
ʻm'	X	X	X	X=255; Y= One dataset Kelvin*10.' in the MSB Dataset elOff0 elOff1 elOff2 elOff3 The Sensor Dataset elOff3+1 elOff3+2 elOff3+2 elOff3+4 elOff3+5 Get Ambier Toggle usag Shows curre "HTPA ser "Firmware "I am runn "Amplifica	has exactly 2 The first 4 da 's: Bit15 MSB VDD Bit1 VDD Bit3 VDD temperature i Bit15 MSB TAmb Bit1 TAmb Bit3 TAmb Control of the control of	Bit 14 S available in Bit 14 Bit 14 C te (Calculates for for el. Offs atton settings d! I am Arra tten by B.Fot X.X kHz" Actual set amp	web low-Byte is et al. (1984)el. (1984)ell (1984)	Amb for HT Bit12 Bit12 VDD Bit8 VDD Bit8 VDD Bit8 VDD Strip VDD After el. Offse Bit12 Bit12 TAmb Bit12 TAmb Bit8 TAmb Bit8 TAmb LSB TAmb Temperature pth = 64 for st the following string in kH cossible string	Bitl1 MSB elOff3 Bitl1 MSB elOff3 MSB elOff3 MSB elOff3 MSB elOff3 MSB elOff3+1 MSB elOff3+2 MSB elOff3+3 MSB elOff3+3 MSB elOff3+3 MSB elOff3+5 E from the last HTPA8x8 and ng stream: s for X: "0"=H bH; YYYY-N [z	Bit 10 Bit 10	ansmit addi	Bit1	Bit0 LSB dOff0 LSB dOff1 LSB dOff3 LSB dOff3+1 LSB dOff3+1 LSB dOff3+4 LSB dOff3+5 - HTPA32x31)
ʻm'	X	X	X	X=255; Y= One dataset Kelvin*10.' in the MSB Dataset elloff0 elloff1 elloff3 The Sensor Dataset elloff3+1 elloff3+2 elloff3+3 elloff3+4 elloff3+5 Get Ambier Toggle usag Shows curre "HTPA ser "Firmware "I am runn "Amplifica "MAC-ID:	has exactly 2 The first 4 da 's: Bit15 MSB VDD Bit1 VDD Bit3 VDD temperature i Bit15 MSB TAmb Bit1 TAmb Bit3 TAmb Control of the control of	Bit 14 s a vailable in Bit 14 c (Calculates er for el. Offs atton settings d! I am Arra tten by B.Fot X.X kHz" Ac ctual set amp ID: Z\r\n" (c	wype X'' Por Conly Etherne	Amb for HT Bit12 Bit12 VDD Bit8 VDD Bit8 VDD Bit8 VDD String Bit12 TAmb Bit12 TAmb Bit12 TAmb Bit14 TAmb LSB TAmb LSB TAmb Temperature pth = 64 for is the following sible values Sensor Gm setting in kH ossible string at devices shot	Bitl1 MSB elOff3 MSB elOff3 MSB elOff3 MSB elOff3 MSB elOff3 MSB elOff3+1 MSB elOff3+2 MSB elOff3+3 MSB elOff3+3 MSB elOff3+3 MSB elOff3+5 E from the last HTPA8x8 and ng stream: s for X: "0"=H bH; YYYY-M [z s for X: "low"	Bit10 Bi	ansmit addi	Bit1	Bit0 LSB el Off0 LSB el Off1 LSB el Off3 LSB el Off3+1 LSB el Off3+2 LSB el Off3+2 LSB el Off3+3 LSB el Off3+4 LSB el Off3+5 THTPA32x31)

Table1: Control Characters



Table1, continuation:

Sent 🕱		Communication via Terminal / UDP											
Char	HIPA8x8	HTPA16x16	HTPA32x31		Result/Received message								
'o'		X	X	Use extern	nal reference v	oltages							
'O'		X	X	Use intern	al reference v	oltages							
	X	X			anges (require								
't' 2	X	X	X	Continuou	ıs binary volta	ge data o	f the μC-ADC	is transmitted.					
				Output of	a complete cy	cle in this	order:						
				НТ	TPA 8x8 and F	HTPA16x.		ell,PixelX, e HTPA32x3 iled Description	1: see Table 2	2.		TATO,PTAT1,.	,PTATZ
				16x16 Arr X=255; Y			8x8 Array: X=63; Y=4; Z	Z=4					
							Offset3 after	yte is send, then the last Pixel vo	ltage PixelX	transmit add			
				Datas et	Bit15	Bit 14	Bit13	Bit12	Bit11	Bit 10		Bit1	Bit0
				elOff0	MSB VDD			Bit12 VDD	MSB elOff0				LSB el Off0
				elOff1	Bit11 VDD			Bit8 VDD	MSB elOffl				LSB el Off1
				elOff2	Bit7 VDD			B it4 VDD	MSB elOff2				LSB el Off2
				elOff3	Bit3 VDD			LSB VDD	MSB elOff3				LSB el Off3
'T' 2	X	X			is binary data		IC-ADC is tra	ansmitted.					
					der is equal to		TG 1 D G 1						
'u' 🛛 🗵	X	X			is binary data der is equal to		IC-ADC is tra	nsmitted. PTAT	-voltages are	sampled w	ith the uC-A	ADC.	
'U' 2	X	X					f A CIC Outo	ut via ASCII. P	AT Waltaga	oro compla	d with the v	C ADC	
	X	X	Y		IP (Only Ethe			ut viä ASCII. P	A 1 - v on ages	are sample	u with the t	ic-ADC.	
	X	X			aits control m		-/	met devices)					
	X	X	X		ibration-const	<u> </u>	my non-edite	net de vices)					
	Х	X	X		n. ATTENTIC		ataset cannot	he restored!					
	X	X			am without pr		anasor cumor	ee restored:					
	X	X			am by sending	_	\r\n''						
	X	X			ASIC-Supply		1- 1						
_	X				ASIC-Supply	. ,							

Table1 (continuation): Control Characters

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Serial order in Frame:

	HTPA8x8 Temperature Mode
Dataset	Value
C	Temperature of Pixel0 in K*10
1	Temperature of Pixel1 in K*10
2	Temperature of Pixel2 in K*10
3	Temperature of Pixel3 in K*10
63	Temperature of Pixel63 in K*10
64	4 bits of VDD and elOff0 in digits (refer to Table1)
65	4 bits of VDD and elOff1 in digits (refer to Table1)
66	4 bits of VDD and elOff2 in digits (refer to Table1)
67	4 bits of VDD and elOff4 in digits (refer to Table1)
68	4 bits of TAmb and PTAT0 in digits (refer to Table1)
68	4 bits of TAmb and PTAT1 in digits (refer to Table1)
68	4 bits of TAmb and PTAT2 in digits (refer to Table1)
68	4 bits of TAmb and PTAT3 in digits (refer to Table1)

	HTPA16x16 Temperature Mode
Dataset	Value
(Temperature of Pixel0 in K*10
1	1 Temperature of Pixel1 in K*10
2	Temperature of Pixel2 in K*10
	Temperature of Pixel3 in K*10
254	 Temperature of Pixel255 in K*10
	6 4 bits of VDD and elOff0 in digits (refer to Table1)
	7 4 bits of VDD and elOff1 in digits (refer to Table1)
	3 4 bits of VDD and elOff2 in digits (refer to Table1)
	9 4 bits of VDD and elOff3 in digits (refer to Table1)
	elOff4 in digits
	l elOff5 in digits
262	elOff6 in digits
263	B elOff7 in digits
264	4 bits of TAmb and PTAT0 in digits (refer to Table1)
265	4 bits of TAmb and PTAT1 in digits (refer to Table1)
266	6 4 bits of TAmb and PTAT2 in digits (refer to Table1)
267	7 4 bits of TAmb and PTAT3 in digits (refer to Table1)
268	B PTAT4 in digits
27	PTAT7 in digits

	HTPA32x31 Temperature Mode
Dataset	Value
0	Temperature of Pixel0 in K*10
1	Temperature of Pixel16 in K*10
2	Temperature of Pixel1 in K*10
3	Temperature of Pixel17 in K*10
	Town arcture of Divol45 in V*10
	Temperature of Pixel15 in K*10
	Temperature of Pixel31 in K*10
	Temperature of Pixel32 in K*10
33	Temperature of Pixel48 in K*10
	Temperature of Pixel991 in K*10
	elOff0 in digits
	elOff16 in digits
	elOff1 in digits
995	elOff17 in digits
1022	elOff15 in digits
	elOff31 in digits
	least significant 12 bits of VDD
	most significant 4 bits of VDD
	least significant 12 bits of TAmb
	most significant 4 bits of TAmb
1028	no value, ignore
1029	no value, ignore
1039	no value, ignore
1040	PTAT0 in digits
1041	no value, ignore
1042	PTAT1 in digits
	no value, ignore
	PTAT7 in digits
1055	no value, ignore

		HTPA8x8 Voltage Mode
Dataset		Value
	0	absolute Voltage of Pixel0 in in digits
	1	absolute Voltage of Pixel1 in in digits
	2	absolute Voltage of Pixel2 in in digits
	3	absolute Voltage of Pixel3 in in digits
	63	absolute Voltage of Pixel63 in in digits
	64	4 bits of VDD and elOff0 in digits (refer to Table1)
	65	4 bits of VDD and elOff1 in digits (refer to Table1)
	66	4 bits of VDD and elOff2 in digits (refer to Table1)
	67	4 bits of VDD and elOff4 in digits (refer to Table1)
	68	4 bits of TAmb and PTAT0 in digits (refer to Table1)
	68	4 bits of TAmb and PTAT1 in digits (refer to Table1)
	68	4 bits of TAmb and PTAT2 in digits (refer to Table1)
	68	4 bits of TAmb and PTAT3 in digits (refer to Table 1)

	HTPA16x16 Voltage Mode
Dataset	Value
C	absolute Voltage of Pixel0 in in digits
1	absolute Voltage of Pixel1 in in digits
2	absolute Voltage of Pixel2 in in digits
3	absolute Voltage of Pixel3 in in digits
255	absolute Voltage of Pixel255 in in digits
256	4 bits of VDD and elOff0 in digits (refer to Table1)
257	4 bits of VDD and elOff1 in digits (refer to Table1)
258	4 bits of VDD and elOff2 in digits (refer to Table1)
259	4 bits of VDD and elOff3 in digits (refer to Table1)
260	elOff4 in digits
261	elOff5 in digits
262	elOff6 in digits
263	elOff7 in digits
264	4 bits of TAmb and PTAT0 in digits (refer to Table1)
265	4 bits of TAmb and PTAT1 in digits (refer to Table1)
266	4 bits of TAmb and PTAT2 in digits (refer to Table1)
267	4 bits of TAmb and PTAT3 in digits (refer to Table1)
268	PTAT4 in digits
271	PTAT7 in digits

	HTPA32x31 Voltage Mode
Dataset	Value
0	absolute Voltage of Pixel0 in in digits
1	absolute Voltage of Pixel16 in in digits
2	absolute Voltage of Pixel1 in in digits
3	absolute Voltage of Pixel17 in in digits
	absolute Voltage of Pixel15 in in digits
	absolute Voltage of Pixel31 in in digits
	absolute Voltage of Pixel32 in in digits
33	absolute Voltage of Pixel48 in in digits
	 absolute Voltage of Pixel991 in in digits
	elOff0 in digits
	elOff16 in digits
	elOff1 in digits
	elOff17 in digits
000	oron in argue
1022	elOff15 in digits
1023	elOff31 in digits
1024	least significant 12 bits of VDD
1025	most significant 4 bits of VDD
1026	least significant 12 bits of TAmb
1027	most significant 4 bits of TAmb
1028	no value, ignore
1029	no value, ignore
	no value, ignore
	PTAT0 in digits
	no value, ignore
1042	PTAT1 in digits
1053	
	no value, ignore PTAT7 in digits
	no value, ignore

Table2: Serial order

Each dataset consists of a 16 bit value. If a frame consists out of more than one packet, packets are appended. For UART and SPI devices the 16 bit values are transmitted with LSB first.

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Control Messages:

In the set of control messages, expressions in angled braces have to be substituted by following strings:

[DEVID] insert 5 digit device ID in ASCII format, i.e. "00197" Range: 00000... 65535

Set of control messages:

Message5: "Set EEPROM data"

Conditions: **ATTENTION!** Calibration data is overwritten!!!

Result: Writes the next received packets into EEPROM. Device writes to EEPROM,

until EEPROM is completely filled. EEPROM size depends on Device type:

HTPA8x8 16384 byte; HTPA32x31 and HTPA64x62: 65536 byte.

Answer: "Write was successful.\n\r"

Message6: "Set DeviceID to [**DEVID**]"

Result: The given Device ID [**DEVID**] is written to EEPROM. This ID is shown on

receive of 'M'. The Device ID can be used for customer specific purposes.

Answer: "DeviceID changed to [**DEVID**]\r\n"

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Temperature calculation:

To get the calibration settings for your device, request a single temperature frame, by sending 'k'. Now the device automatically loaded the settings which were used during calibration. After the receive of the temperature frame request the actual configuration of the device by sending 'M'. Store the information in the line:

"PIXCvsTA *X*, BFL3 *X*, F8_14 *X*, THvsTA *X* IGNORE_ELOFF *X* ELOFF32 *X* SBY *Y* FC *X* EXP *Z*". All cursive letters are device dependent constants. Possible strings: *X*="true" or "false", *Y*="1" or "0", *Z* is the string of a 2 digit decimal value, i. e. "3.47". Store those constants, the calculation algorithm is depending on those.

Now load the calibration constants by sending 'w'. The module will send the calibration information, according to Table 3. Store the coloured constants. All stored constants will be labelled according to the value in "Name of constant". If there is no coloured mark in the example string and no insertion in "Name of constant", it is not necessary to store it.

Header of calibration data					
Example String	Name of constant	Unit(s)			
"ASIC-Register @ Calib was 0x402\r\n"					
"Written back 0x402 to ASIC.\r\n"					
"PTAT-gradient 0.569000 dK/dig PTAT-Offset@0V 1973.000000\r\n"	$\overline{PTAT_G}$, $\overline{PTAT_O}$	[dK/dig], [dig]			
"Ambient 1: 285.2, Ambient 2: 295.2 Ambient 3: 310.2 Ambient 4: 324.3 at Calibration\r\n"	T_{cT1} , T_{cT2} , T_{cT3} , T_{cT4}	[K]			
"TObj1: 373.2, TObj2: 373.2 TObj3: 373.2 TObj4: 373.2 at Calibration\r\n"					
"TObjcal1: 285.9, TObjcal2: 297.2 TObjcal3: 311.2 TObjcal4: 323.3 at Calibration\r\n"	$T_{cO1}, T_{cO2}, T_{cO3}, T_{cO4}$	[K]			
"Arraytype is 3\r\n"					
"Nr. Thermaloff(1) PixC(1) Thermaloff(2) PixC(2) Thermaloff(3) PixC(3) Thermaloff(4) PixC(4) ThGrad ThOff\r\n"					

Table3: Header of calibration data

Constant:	Meaning:
$PTAT_G$	Gradient of the PTAT circuit in tenths of Kelvin per digits.
$PTAT_O$	Offset of the PTAT circuit in digits.
T_{cT1}	Absolute ambient temperature during calibration of the thermal offsets in calibration point 1.
T_{cT2}	Absolute ambient temperature during calibration of the thermal offsets in calibration point 2.
T_{cT3}	Absolute ambient temperature during calibration of the thermal offsets in calibration point 3.
T_{cT4}	Absolute ambient temperature during calibration of the thermal offsets in calibration point 4.
T_{cO1}	Absolute ambient temperature during calibration of the pixel constants in calibration point 1.
T_{cO2}	Absolute ambient temperature during calibration of the pixel constants in calibration point 2.
T_{cO3}	Absolute ambient temperature during calibration of the pixel constants in calibration point 3.
T_{cO4}	Absolute ambient temperature during calibration of the pixel constants in calibration point 4.

Table4: Meaning of constants (1)

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After the header the pixel dependent constants are immediately transmitted. The number of packets (UDP) or lines (UART) depends on the device type and is equal to the number of sensitive pixels. Each packet / line consists of:

Pixelnumber, Thermal1(X), Pixelconstant1(X), Thermal2(X), Pixelconstant2(X), Thermal3(X), Pixelconstant3(X), Thermal4(X), Pixelconstant4(X).

X represents in the above line the corresponding pixel number.

Store all the pixel dependent constants.

Pixel dependent calibration data			
No.	Example String	Name of constant	Comments
0	"0 127 1316732 112 1182251 98 1126390 72 849857" "1 137 1396731 132 1482251 128 1516391 127 1549867"	$Th_1(0)$, $P_1(0)$, $Th_2(0)$, $P_2(0)$, $Th_3(0)$, $P_3(0)$, $Th_4(0)$, $P_4(0)$, $Th_2(1)$, $Th_2(1)$, $Th_3(1)$, $Th_3(1)$, $Th_3(1)$, $Th_4(1)$,	Number of dataset grey marked Number of dataset grey marked
N	"N 127 1516732 112 1182251 98 1126390 72 849857"	$Th_1(N)$, $P_1(N)$, $Th_2(N)$, $P_2(N)$, $Th_3(N)$, $P_3(N)$, $Th_4(N)$, $P_4(N)$,	N equals the number of pixels-1. HTPA8x8→N=63 HTPA16x16→N=255 HTPA32x31→N=991

Table5: Pixel dependent calibration data

Constant:	Meaning:	
$Th_1(X)$	Thermal offset of Pixel X in digits at the thermal calibration point $1 \rightarrow T_{cT1}$	
$Th_2(X)$	Thermal offset of Pixel X in digits at the thermal calibration point $2 \rightarrow T_{cT2}$.	
$Th_3(X)$	Thermal offset of Pixel X in digits at the thermal calibration point $3 \rightarrow T_{cT3}$	
$Th_4(X)$	Thermal offset of Pixel X in digits at the thermal calibration point $4 \rightarrow T_{cT4}$	
$P_1(X)$	Pixel constant of Pixel X at the object calibration point $1 \rightarrow T_{cO1}$	
$P_2(X)$	Pixel constant of Pixel X at the object calibration point $2 \rightarrow T_{cO2}$	
$P_3(X)$	Pixel constant of Pixel X at the object calibration point $3 \rightarrow T_{cO3}$	
$P_4(X)$	Pixel constant of Pixel X at the object calibration point $4 \rightarrow T_{cO4}$	

Table6: Meaning of constants (2)

The calibration is done with four different ambient temperature calibration points for Thermals and pixel constants, each.

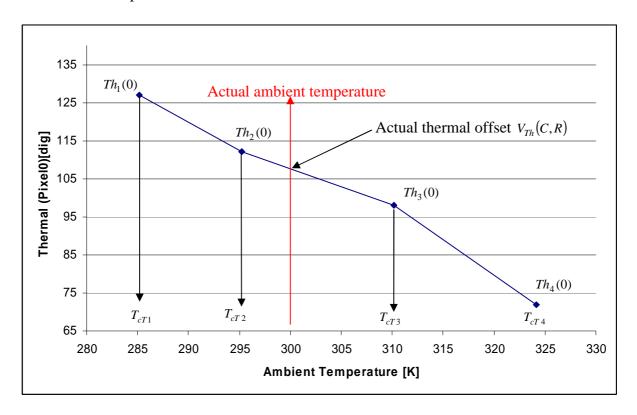
Therefore, it is useful to calculate a gradient and an offset (each for thermal offsets and pixel constants) between two calibration points and to do a linear interpolation between the two calibration points, which are the closest to the actual ambient temperature. This will provide the highest accuracy.

For the following example we took the data of Pixel0, provided in Table 3 and Table 5. The linear interpolation is shown at the example of the thermal offset. Assume an actual ambient temperature of 300 K. Refer to chapter "Ambient temperature" for ambient temperature calculation.

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Calculation example for actual thermal offset of Pixel 0 at 300 Kelvin:



To calculate the actual thermal offset $V_{Th}(C,R)$ a linear interpolation is sufficient. (C,R) represents the column and row dependency of the value. The same proceeding for the pixel constants is recommended.

Ambient Temperature:

Calculate the ambient temperature by following equation:

$$T_{Amb} = \frac{\sum_{i=0}^{N} PTAT_{i}}{N+1} \cdot PTAT_{G} + PTAT_{O} \text{ [dK]}$$

 T_{Amb} is the actual ambient temperature in tenths of Kelvin.

PTAT_i represents the N current PTAT-values, refer to Table 2. N is device dependent.

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Object Temperature:

In the followings dependency of the column is displayed as variable-name (C). Dependency of row and column (pixel dependent) is displayed as variable-name (C,R).

The transmitted absolute pixel voltage consist of the electrical offset of the amplifier $V_{eloff}(C)$, the thermal offset of the pixel $V_{Th}(C,R)$ and the amplified pixel voltage $V_{Pix}(C,R)$:

$$V_{Abs}(C,R) = V_{Pix}(C,R) + V_{Th}(C,R) + V_{elOff}(C)$$

For the HTPA8x8 and the HTPA16x16 the corresponding electrical offset to a pixel voltage can be determined by the modulo-n-check. Divide the pixel number by the number of amplifiers (refer to the datasheet of the sensor), the residue is the corresponding electrical offset. For the HTPA32x31 the column address of the pixel is equal to the number of the electrical offset value.

If your device has a calibration setting of "IGNORE_ELOFF false" it is necessary to subtract the corresponding electrical offset of the amplifier $V_{elOff}(C)$ from the transmitted absolute Voltage of the pixel, else the electrical offset can be set to zero.

IGNORE_ELOFF false
$$\rightarrow V_{Abs}(C,R) - V_{elOff}(C) = V_{Pix}(C,R) + V_{Th}(C,R)$$

IGNORE_ELOFF true $\rightarrow V_{Abs}(C,R) = V_{Pix}(C,R) + V_{Th}(C,R)$

The next step is to subtract the corresponding thermal offset to get the amplified pixel voltage: IGNORE_ELOFF false $\rightarrow V_{Pix}(C,R) = V_{Abs}(C,R) - V_{elOff}(C) - V_{Th}(C,R)$ IGNORE_ELOFF true $\rightarrow V_{Pix}(C,R) = V_{Abs}(C,R) - V_{Th}(C,R)$

As described before, the value of $V_{Th}(C,R)$ should be determined by a linear interpolation between the two thermal offset values out of $Th_1(C,R)$, $Th_2(C,R)$, $Th_3(C,R)$, $Th_4(C,R)$, which are as closest to the actual ambient temperature.

Next step is the linear interpolation to get the actual pixel constant PixC(C,R), in dependency of the current ambient temperature T_{Amb} .

Now the object temperature T_0 in tenths of Kelvin can be calculated by:

$$T_{O} = \sqrt[X]{\frac{V_{Pix}(C,R) \cdot PixC(C,R) \cdot VDM}{\varepsilon} + T_{Amb}^{X}}$$
 [dK]

 ε is the emission coefficient of the surface the pixel is receiving the radiation from. VDM is a multiplier, which is equal to the VDM constant.

X is an exponent, which is equal to the EXP constant. VDM and EXP can be both obtained with the control character 'M'.