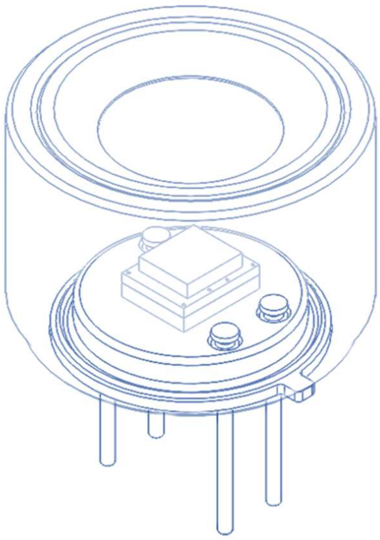

HTPA16x16dR3L5.0/1.0F7.7

Datasheet for Thermopile Array Sensor with Lens Optic

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Revision 7
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Content

Changelog

2024-03-15	Initial release
2024-07-12	Pixel orientation is mirrored on the x-axis
2024-12-18	Updated graphic for optical orientation
2025-01-31	Updated order code, added order code chart w/ available options
2025-04-28	Updated operating conditions for IDD running, idle and standby
2025-08-18	Corrected graphic for pixel orientation
2025-10-16	Added max. measurable temperature
2025-11-18	Corrected accuracy specification
2025-03-02	Added calculation formula for CLK_Trim Register

1 Cleaning and Handling of Sensors with Optical Elements

Cleaning of Filter with Isopropyl Alcohol or Acetone

This is the method most universally used for cleaning optical elements with or without coatings. Filters or lenses mounted in our sensors may be cleaned rubbing the surfaces lightly with a clean, soft, all-cotton cloth or cotton swab during immersion in solvent or simply moistened with the solvent. The parts are then immediately wiped dry with another clean, soft, all-cotton cloth or cotton swab.

Cleaning with Detergent and Water

A very mild, non-abrasive detergent (one which does not contain additives) and water may also be used for cleaning optical elements. In general, a detergent and water mixture is an excellent method for removing fingerprints and other smudges. The liquid detergent is first mixed with deionized water (proportions recommended by the manufacturer should be followed). The element is then washed, rinsed, and immediately wiped dry. Use a clean, soft cloth when cleaning and drying. If the part is allowed to dry in air, a permanent stain may result.

Please note:

- Do not use isopropyl alcohol or acetone or detergent if the elements will be mounted in an assembly with a finish which may be soluble by these solvents.
- Please avoid glass isolation being moistened by solvent.
- If the part is allowed to dry in air, a permanent stain may result.

Handling Advice

Sensors with optical elements deserve special consideration in their handling and care. Ordinarily, filters or lenses are cleaned and inspected prior to shipment. If proper care is exercised during handling cleaning should not be necessary prior to use.

- Wear gloves when handling a sensor or optical element. Lightweight nylon or cotton gloves, which are relatively lint-free are recommended.
- Avoid touching the surface of filters and lenses.
- Protect devices from static discharge and static fields.
- Thermopile sensors are electrostatic sensitive devices. Sensors should be handled over an electrostatic protected work area.
- Precautions should be taken to avoid reverse polarity of power supply for sensors with integrated signal processing. Reversed polarity of power supply results in a destroyed unit.
- Sensors should rest preferably in a partitioned container where the mounted filters or lenses will be not coming into contact with other material.
- During storage optical surfaces should be covered to avoid contamination from the surrounding environment.

- A covered container can eliminate damage during transportation and storage.
- Sensors or optical elements should be stored in a restricted access area to eliminate handling.
- Do not expose the sensors to aggressive detergents such as freon, trichlorethylen, etc.
- Avoid rotating the sensors when they are soldered into a PCB or something similar.
- Shortening of the pins is not suggested. This may cause cracks in the glass of the pins and result in a leakage.
- If this is necessary, a tool for this is recommended. Please contact Heimann Sensor for further information.

Soldering Recommendations

Attention: For all of our array sensors we give no guarantee on the calibration and its performance if the pins are shortened by the customer. Additionally, **we strongly recommend to not solder the sensor with its backplate directly to a PCB.** This will cause different thermal conductivity compared to air and the measurement results could get worse. **Use a minimum gap between PCB and backplate of 2 mm or more**. The glass of the pins to the back plate can get damage by applying high temperatures (during soldering), which will lead into a lower temperature reading what cannot be repaired afterwards.

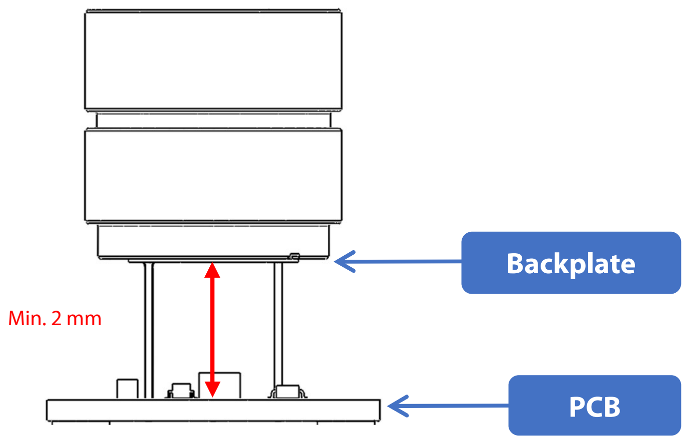


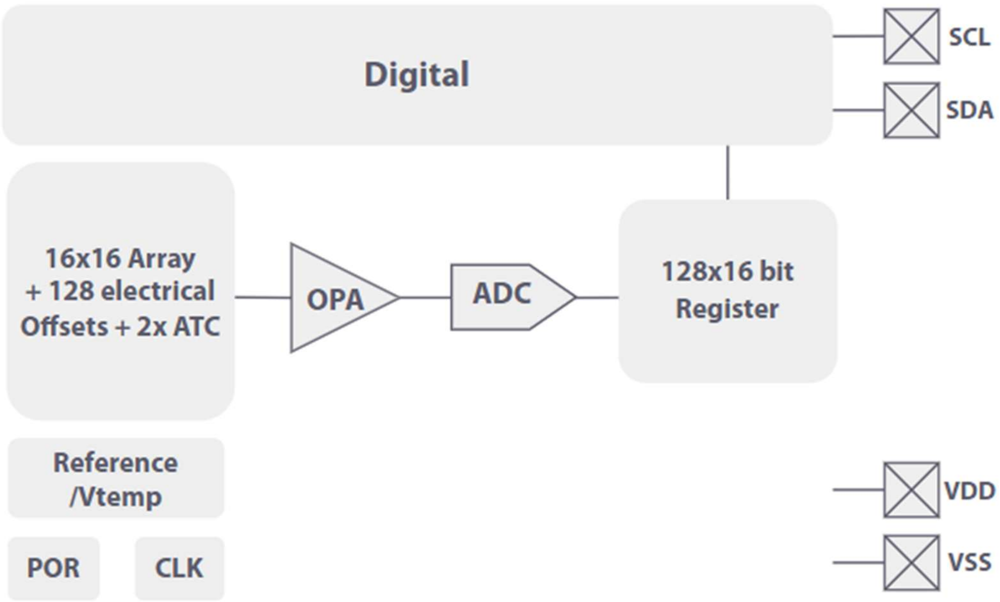
Figure 1: Soldering height

Manual Iron Soldering and Automatic Point-to-Point Iron Soldering

Manual Iron Soldering and Automatic Point-to-Point Iron Soldering methods are allowed for TO packages. It is recommended for through hole applications to shield the package body from soldering heat by PCB or similar.

The soldering iron temperature should be set as low as possible (maximum 350 °C) and should not exceed recommended soldering time (maximum 3 seconds). The minimum distance between the housing body and the liquid solder should be at least 1.5 mm for 350 °C. Reflow soldering is not recommended.

2 Principal Schematic for HTPA16x16d



3 Pin Assignment– Bottom View

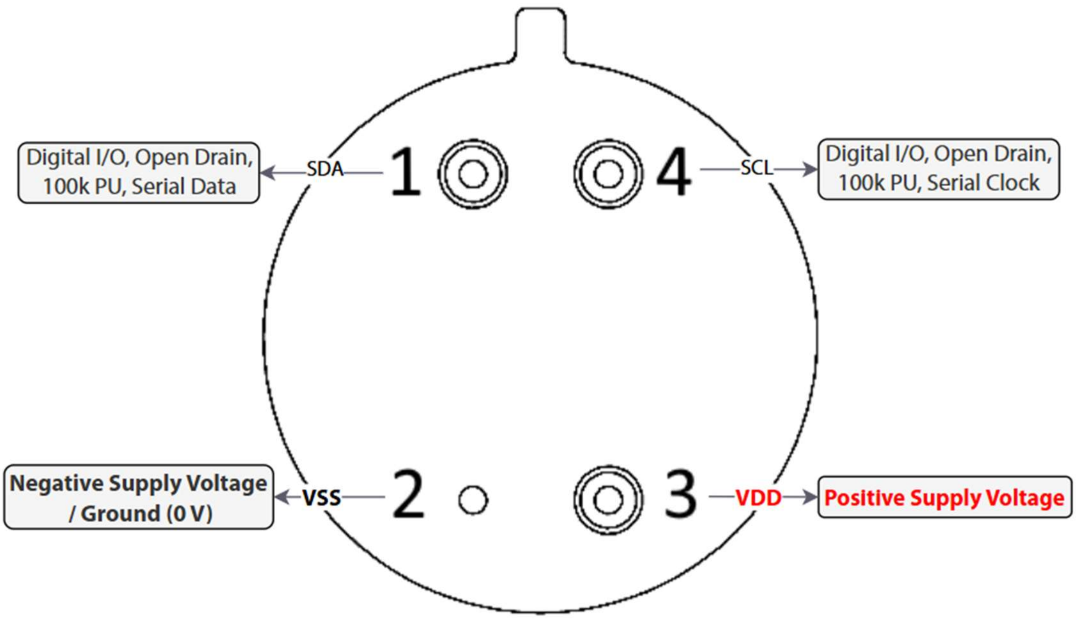
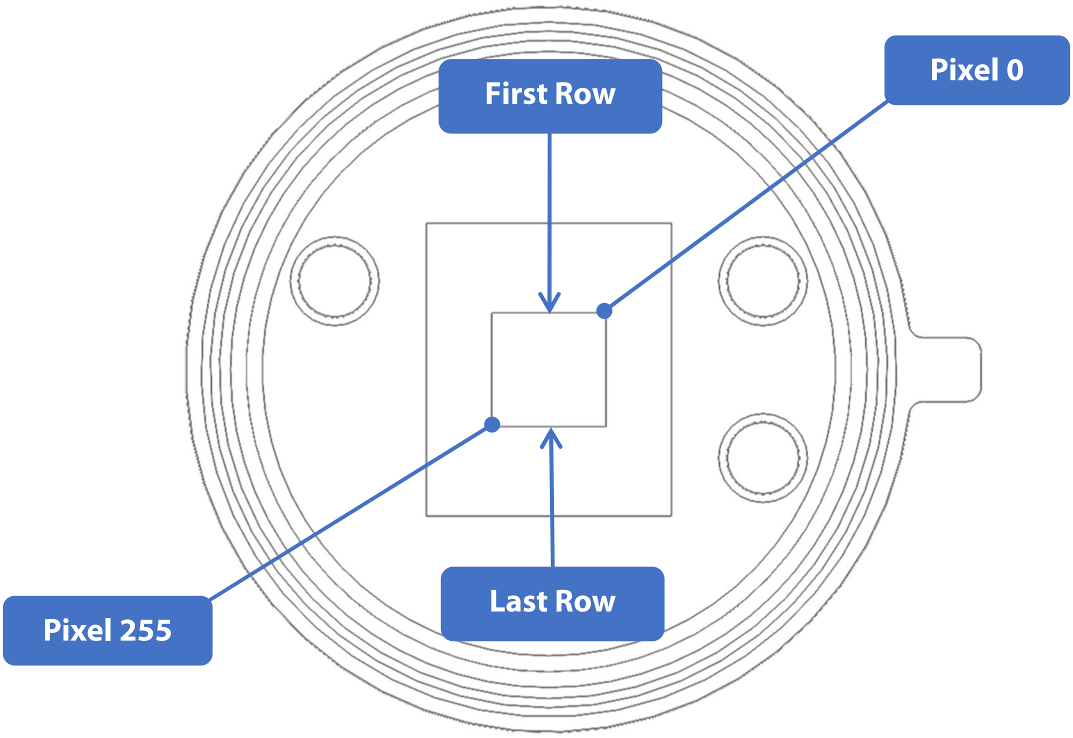
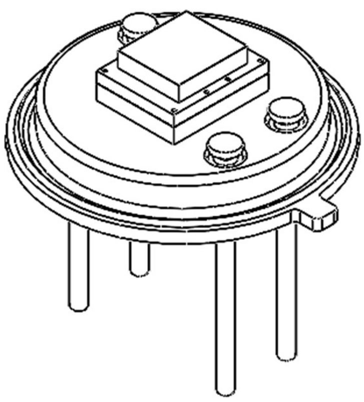


Figure 2: Pin-allocation

4 Optical Orientation



This illustration shows the pixel orientation after mirroring through the lens.



5 Order Code Example

HTPA32x32d	R2	L5.0/0.8	F7.7	e	Hi	M	(UDP)
1	2	3	4	5	6	7	8

		Description
1	Sensortype	TP Array with 32x32 Pixel For all available HTPA and module combinations contact our support
2	Revision	Silicon revision 2
3	Optics	Focal length/F-Number Focal length: L5.0 = 5.0 mm F-Number: 0.8
4	Filter	F: Filter characteristics Not declared: Broadband AR Coating
5	External Aperture	Not declared: without external aperture e: with external aperture
6	Sensitivity	UHi: increased sensitivity Hi: default sensitivity Not declared: lower sensitivity (greater measurement range)
7	Version	A: Application Set: comes with GUI, housing, power supply C: Calibrated sensor M: Modul: HTPA sensor soldered to PCB, calibrated stream
8	Interface	UDP: Ethernet connection, CAT5 PoE: Power over Ethernet, CAT5* i^2C: 4 Pin Connector* USB: Power and data via USB 2.0** * Interface option is only available for modules (HiM) ** Interface option is only available for Application Set (HiA) *** Interface option is only available for calibrated sensors (HiC)

6 Application Note

A pull-up resistor of 4.7 kΩ for the I²C pins (SDA and SCL) is recommended. In addition, adding 100 nF and 47 µF are improving the stability of the supply voltage.

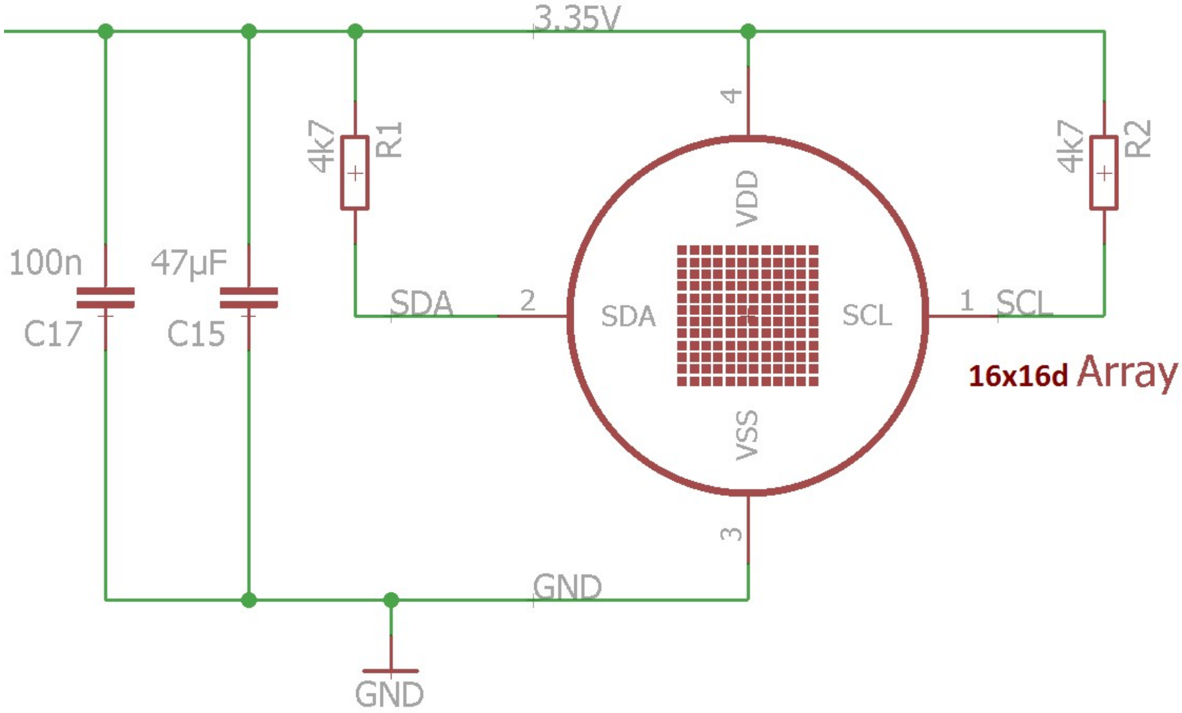


Figure 3: Recommended circuit for operation

The sensor can be powered directly via 3.35 V if the supply voltage is stable enough, this has to be measured before and tested with the sensor. It is important to not insert any inductor or otherwise the noise will increase.

7 Serial Order of Frame

The sensor is divided into two parts (top and bottom half), which are again separated into 2 blocks. The readout order is shown below for the different blocks.

Block 0 (top)
Block 1 (top)
Block 1 (bottom)
Block 0 (bottom)

Figure 4: Division of blocks

Whenever a conversion is started the Block x of the top and bottom half are measured at the same time. Each block consists of 64 Pixel that are sampled fully parallel. The readout order on the bottom half is mirrored compared to the top half so that the central lines are always read last.

0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47
48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63
64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79
80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95
96	97	98	99	100	101	102	103	104	105	106	107	108	109	110	111
112	113	114	115	116	117	118	119	120	121	122	123	124	125	126	127
128	129	130	131	132	133	134	135	136	137	138	139	140	141	142	143
144	145	146	147	148	149	150	151	152	153	154	155	156	157	158	159
160	161	162	163	164	165	166	167	168	169	170	171	172	173	174	175
176	177	178	179	180	181	182	183	184	185	186	187	188	189	190	191
192	193	194	195	196	197	198	199	200	201	202	203	204	205	206	207
208	209	210	211	212	213	214	215	216	217	218	219	220	221	222	223
224	225	226	227	228	229	230	231	232	233	234	235	236	237	238	239
240	241	242	243	244	245	246	247	248	249	250	251	252	253	254	255

readout order top

readout order bottom

Figure 5: 16x16d readout order for active pixel

The electrical offsets are sampled in parallel for the top and bottom half. The matching rows for the corresponding electrical offsets and active Pixel are marked with the same color. The conversion of the electrical offsets is started by sending the command for the BLIND bit during the start command.

0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47
48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63
64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79
80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95
96	97	98	99	100	101	102	103	104	105	106	107	108	109	110	111
112	113	114	115	116	117	118	119	120	121	122	123	124	125	126	127

Figure 6: 16x16d readout order for electrical offset

8 Characteristics

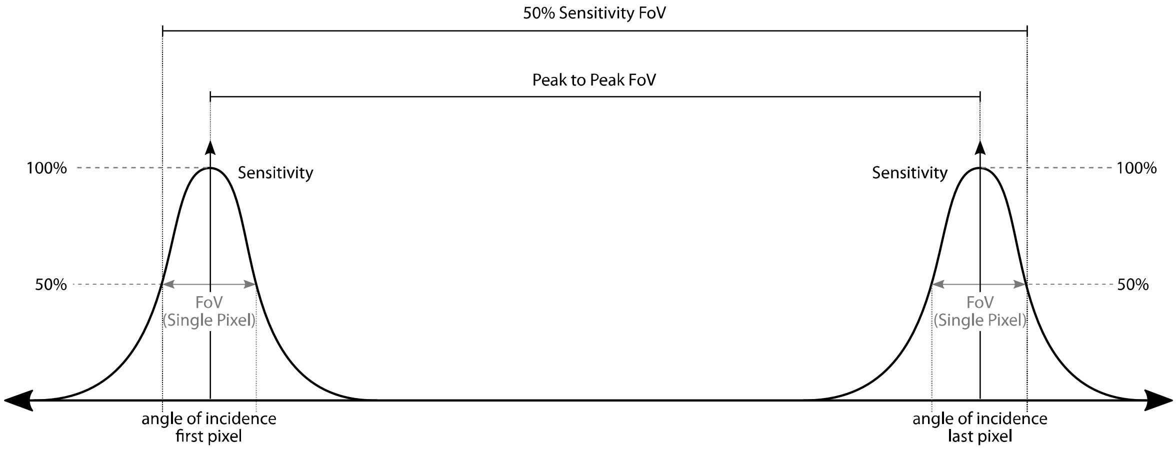
8.1 Common Specifications

Technology:	n-poly/p-poly Si
Element Resistance:	approx. 300 kOhms
Thermal pixel time constant:	<4 ms
Digital Interface:	I^2C
EEPROM size:	1024 x 16 Bit
Pitch:	90 µm
Absorber size:	44 µm
Max. Framerate:	120 Hz
Max. measurable temperature:	300°C with default settings
	600°C with RefCal0

(complete frame with maximum I^2C and sensor clock speed and reduced ADC resolution)
256 sensitive elements

8.2 Optical Characteristics

Focal length:	5.0 mm ("L" equals the focal length of the lens)
F-Number:	0.8
Field of view:	16 x 16 deg. (50 % sensitivity FoV)



Lens coating:	LWP-Coating 5.0 Cut On (Tr. 5 %): 5.0 µm
Accuracy:	±3 % or ±3 K (whatever is larger) in the working ambient temperature range of 5° to 50 °C and object temperatures ≤ to 300 °C

9 Electric Specifications

Table 1: Absolute Maximum Ratings

Parameter	Symbol	Condition	MIN.	TYP.	MAX.	Unit
Supply Voltage	VDD		-0.3		3.6	V
Voltage at all inputs and outputs	VIO		-0.3		VDD+0.3	V
Storage Temperature	TSTG		-40		85	Deg. C

Table 2: Operating Conditions

Parameter	Symbol	Condition	MIN.	TYP.	MAX.	Unit
Supply Voltage	V_{DD}		3.3	3.35	3.6	V
Supply Current (sensor running)	I_{DD}		3.7	4.0	4.3	mA
Supply Current (sensor in idle state)	I_{SBY}		3.5	3.7	3.9	mA
Standby Current (sensor in sleep state)	I_{SBY}		8.4	8.6	8.8	µA
Operation Temperature	T_A		-20		65	Deg. C
ESD-Protection		Human body model 100pF + 1k5Ohm	2			kV

Table 3: Electrical Characteristics

Parameter	Symbol	Condition	MIN.	TYP.	MAX.	Unit
Digital Input						
Internal Clock frequency	F_{CLK}		1	5	13	MHz
Internal I²C Pull up	R_{PU}		1	100	100	kOhm
BIAS current	I_{BIAS}		1	3	13	µA
BPA current	I_{BPA}		0.2	1.5	4.0	µA
Input voltage high	V_{IH}		$0.7xV_{DD}$			V
Input voltage low	V_{IL}				$0.3xV_{DD}$	V
PTAT						
Temperature range			TBD		TBD	Deg. C
PTAT gradient				TBD		K/V

Table 4: Preamplifier / ADC

Parameter	Symbol	Condition	MIN.	TYP.	MAX.	Unit
Chopper frequency	F_{CHP}			20		kHz
Preamplifier Noise	N_{PA}	at 20 kHz		72		nV/HZ$^{1/2}$
Frame rate (Full Array)	FR1			18		Hz
Frame rate (Half Array)	FR4			36		Hz
ADC pos. Reference	V_{REFP}			1.6		V
ADC pos. Reference	V_{REFP}			0.9		V
ADC resolution	ADC_{LSB}	at 16-Bit		21		µV

10 I²C Timings HTPA16x16d

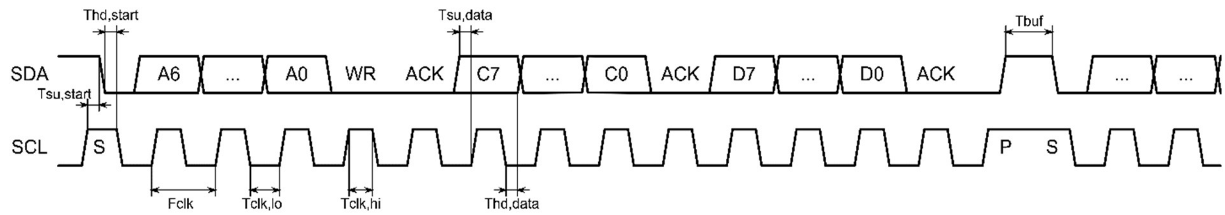


Figure 7: I²C Timings of HTPA16x16d

Table 5: I²C Timings

Parameter	Symbol	Condition	MIN.	TYP.	MAX.	Unit
I²C clock frequency	F_{CLK}			400	1000	kHz
low pulse duration	$T_{CLK,lo}$		0.50			µs
high pulse duration	$T_{CLK,hi}$		0.26			µs
data set up time	$T_{SU,data}$		0.05			µs
data hold time	$T_{hd,data}$		0.00			µs
start setup time	$T_{SU,start}$		0.26			µs
start hold time	$T_{hd,start}$		0.26			µs
stop setup time	$T_{SU,stop}$		0.26			µs
stop hold time	$T_{hd,stop}$		0.26			µs
time between STOP / START	T_{buf}		0.50			µs
Time startup (after Power-on Reset)	$T_{startup}$				100	µs
Time wakeup (after sending WAKEUP)	T_{wakeup}				80	µs

11 I²C Communication

The chip uses the 7-bit I²C address 0x1A for configuration and sensor data and the address 0x1B to access the internal EEPROM followed by 1-bit of read/write command. The address byte is followed by an 8-bit command.

11.1 Write Command

In case of a write access to an internal register the command is followed by the data byte. The chip acknowledges each byte with a low active ACK bit.

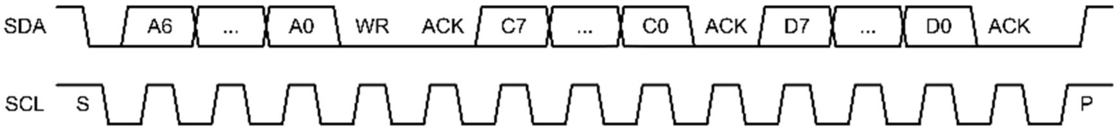


Figure 8: Write Command

11.2 Read Command

To read data from the chip first the address and command must be sent. After the last ACK a new start-bit (repeated start) and the address with a set read-flag initiates the read sequence. There can be bytes read as many as required. The last byte must be denoted by a not-acknowledge. The shown example below can be used e.g. to get the status register.

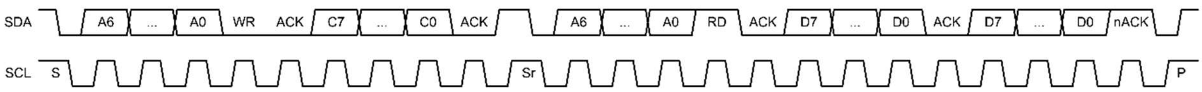


Figure 9: Read Command

11.3 Sensor Commands

The sensor has several registers that can be written and read, they are listed below.

Table 6: Configuration Register (write only)

Addr / CMD	**0x1A (7-bit!)/ 0x01**							
Config Reg	7	6	5	4	3	2	1	0
Name	RFU				START	VDD_MEAS	BLIND	WAKEUP
Default	0	0	0	0	0	0	0	0

The WAKEUP bit is used to switch on / off the chip and must be set prior all other operations. After the START bit is set the chip starts a conversion of the array or blind elements and enters the idle state (not sleep!), when finished.

If the BLIND bit is set the electrical offsets are sampled instead of the active pixel.

If VDD_MEAS bit is set the VDD voltage is measured instead of the PTAT value.

RFU means reserved for future use and can be subject to change.

Table 7: Status Register (read only)

Addr / CMD	0x1A (7-bit!)/ 0x02							
Status Reg	7	6	5	4	3	2	1	0
Name	RFU				Block	VDD_MEAS		EOC
Default	0	0	0	0	0	0	0	0

If the EOC flag is set a previous started conversion has been finished.

Trim Register 1 (write only)

Addr / CMD	0x1A (7-bit!)/ 0x03							
Trim Reg 1	7	6	5	4	3	2	1	0
Name	RFU				MBIT TRIM			

REF_CAL: selectable amplification

MBIT_TRIM: m = 4 to 12 ⟹ (m+4) bit as ADC resolution

Trim Register 2 (write only)

Addr / CMD	0x1A (7-bit!)/ 0x04							
Trim Reg 2	7	6	5	4	3	2	1	0
Name	RFU			BIAS TRIM TOP				

BIAS_TRIM_TOP: 0 to 31 ⟹ 1 µA to 13 µA

This setting is used to adjust the BIAS current of the ADC. A faster clock frequency requires a higher BIAS current setting.

Trim Register 3 (write only)

Addr / CMD	0x1A (7-bit!)/ 0x05							
Trim Reg 3	7	6	5	4	3	2	1	0
Name	RFU			BIAS TRIM BOT				

BIAS_TRIM_BOT: 0 to 31 ⟹ 1 µA to 13 µA

This setting is used to adjust the BIAS current of the ADC. A faster clock frequency requires a higher BIAS current setting.

Trim Register 4 (write only)

Addr / CMD	0x1A (7-bit!)/ 0x06							
Trim Reg 4	7	6	5	4	3	2	1	0
Name	RFU		CLK TRIM					

CLK_TRIM ranges from 0 to 63 and corresponds the clock frequency F_{CLK} which can be determined via the following formula:

$$F_{CLK} = \left(F_{CLK,\min} + \frac{F_{CLK,\max} - F_{CLK,\min}}{63} \cdot \text{CLK\_TRIM}\right) \text{MHz}$$

with

$$F_{CLK,\min} = 1 \text{ MHz}$$
$$F_{CLK,\max} = 13 \text{ MHz}$$

The measure time depends on the clock frequency settings. One quarter frame takes about:

$$t_{fr4} = \frac{32 \cdot (2^{MBIT} + 4)}{F_{CLK}} \approx 27ms@5MHz$$

$MBIT$ is equal to MBIT TRIM In Trim Register 1.

Trim Register 5 (write only)

Addr / CMD	0x1A (7-bit!)/ 0x07							
Trim Reg 5	7	6	5	4	3	2	1	0
Name	RFU			BIAS TRIM TOP				

BPA_TRIM_TOP: 0 to 31 ⇒ 0.2 µA to 4.0 µA

This setting is used to adjust the common mode voltage of the preamplifier.

Trim Register 6 (write only)

Addr / CMD	0x1A (7-bit!)/ 0x08							
Trim Reg 6	7	6	5	4	3	2	1	0
Name	RFU			BIAS TRIM BOT				

BPA_TRIM_BOT: 0 to 31 ⇒ 0.2 µA to 4.0 µA

This setting is used to adjust the common mode voltage of the preamplifier.

Trim Register 7 (write only)

Addr / CMD	0x1A (7-bit!)/ 0x09							
Trim Reg 7	7	6	5	4	3	2	1	0
Name	PU SDA TRIM				PU SCL TRIM			

PU_SDA_TRIM: select internal pull up resistor on SDA (Default: 100 kOhm)
PU_SCL_TRIM: select internal pull up resistor on SCL (Default: 100 kOhm)

"1000" = 100 kOhm; "0100" = 50 kOhm; "0010" = 10 kOhm; "0001" = 1 kOhm

Table 8: Read Data 1 Command (Top Half of Array)

Addr / CMD	**0x1A (7 Bit!) / 0x0A**							
Read Data	7	6	5	4	3	2	1	0
1. Byte / 2. Byte	PTAT 1 MSB / LSB or VDD 1 MSB / LSB							
3. Byte / 4. Byte	ATC 1 MSB / LSB							
5. Byte / 6. Byte	Pixel (0+BLOCK*64) MSB / LSB							
7. Byte / 8. Byte	Pixel (1+BLOCK*64) MSB / LSB							
…	…							
129. Byte / 130. Byte	Pixel (63+BLOCK*64) MSB / LSB							

Table 9: Read Data 2 Command (Bottom Half of Array)

Addr / CMD	**0x1A (7 Bit!) / 0x0B**							
Read Data	7	6	5	4	3	2	1	0
1. Byte / 2. Byte	PTAT 2 MSB / LSB or VDD 2 MSB / LSB							
3. Byte / 4. Byte	ATC 2 MSB / LSB							
5. Byte / 6. Byte	Pixel (240-BLOCK*64) MSB / LSB							
7. Byte / 8. Byte	Pixel (241-BLOCK*64) MSB / LSB							
…								
35. Byte / 36. Byte	Pixel (255-BLOCK*64) MSB / LSB							
37. Byte / 38. Byte	Pixel (224-BLOCK*64) MSB / LSB							
39. Byte / 40. Byte	Pixel (225-BLOCK*64) MSB / LSB							
…								
67. Byte / 68. Byte	Pixel (239-BLOCK*64) MSB / LSB							
69. Byte / 70. Byte	Pixel (192-BLOCK*64) MSB / LSB							
…								
131. Byte / 132. Byte	Pixel (207-BLOCK*64) MSB / LSB							

The complete sensor data must be read at once. If the communication fails somewhere in between, all successive data will be corrupted. The readout can be stopped anywhere by pausing the clock. A new initialized readout proceeds at this stopped byte by continuing the clock, but the index is reset when a new conversion has been started.

If the bit for the electrical offsets (Bit 1 in Config 0x01) is set the electrical offsets are sampled and can be read similar to the active pixel:

Read Data Electrical Offsets (Top Half of Array)

Addr / CMD	**0x1A (7-bit!)/ 0x0A**							
Read Data	7	6	5	4	3	2	1	0
1. Byte / 2. Byte	PTAT 1 MSB / LSB or VDD 1 MSB / LSB							
3. Byte / 4. Byte	ATC 1 MSB / LSB							
5. Byte / 6. Byte	electrical offset (0) MSB / LSB							
7. Byte / 8. Byte	electrical offset (1) MSB / LSB							
…	…							
131. Byte / 132. Byte	electrical offset (63) MSB / LSB							

Read Data Electrical Offsets (Bottom Half of Array)

Addr / CMD	**0x1A (7 Bit!) / 0x0B**							
Read Data	7	6	5	4	3	2	1	0
1. Byte / 2. Byte	PTAT 2 MSB / LSB or VDD 2 MSB / LSB							
3. Byte / 4. Byte	ATC 2 MSB /LSB							
5. Byte / 6. Byte	electrical offset (112) MSB / LSB							
7. Byte / 8. Byte	electrical offset (113) MSB / LSB							

...	...
35. Byte / 36. Byte	electrical offset (127) MSB / LSB
37. Byte / 38. Byte	electrical offset (96) MSB / LSB
...	...
131. Byte / 132. Byte	electrical offset (79) MSB / LSB

The complete sensor data must be read at once. If the communication fails somewhere in between, all successive data will be corrupted. The readout can be stopped anywhere by pausing the clock. A new initialized readout proceeds at this stopped byte by continuing the clock, but the index is reset when a new conversion has been started.

11.4 EEPROM Commands

To read/write data from/to the internal EEPROM the I²C address 0x1B is used.

EEPROM Commands

Name	CMD	Read / Write	Comment
Standby	0x00	W	
Active	0x01	W	releases all signals to default state wait for 15µs when wake up from standby
Normal Erase	0x02	W	program pulse width 5ms
Normal Write	0x03	W	program pulse width 5ms
Block Erase	0x04	W	program pulse width 5ms
Block Write	0x05	W	program pulse width 5ms
Normal Read	0x06	W	program pulse width 5ms
Set Address	0x09	W	program pulse width 5ms
Set Data	0x0A	W	16 bit data, MSB first
Get Data	0x0B	R	16 bit data, MSB first

Note:

The EEPROM must be activated (wake up from standby) prior being used. The active command also initializes the EEPROM to its default state.

Note:

Each word must be erased before it can be written, a write command stores only a "1" to the EEPROM cell. Note: The commands "SET_DATA" / "GET_DATA" will increment the address pointer, except for the first execution after "SET_ADDR".

11.5 I²C Example Sequences – EEPROM Wakeup / Standby

	ADDR	W/R	EEPROM_ACTIVE	
S	0x1B	0	0x01	P

	ADDR	W/R	EEPROM_STANDBY	
S	0x1B	0	0x00	P

11.6 I²C Example Sequences – EEPROM Block Erase / Block Write

	ADDR	W/R	EEPROM_ACTIVE	
S	0x1B	0	0x01	P

wait 1 ms

	ADDR	W/R	BLOCK_ERASE	
S	0x1B	0	0x04	P

wait 5 ms

	ADDR	W/R	SET_DATA	DATA_MSB	DATA_LSB	
S	0x1B	0	0x0A	DATA	DATA	P

	ADDR	W/R	BLOCK_WRITE	
S	0x1B	0	0x05	P

wait 5 ms

	ADDR	W/R	STANDBY	
S	0x1B	0	0x00	P

11.7 I²C Example Sequences – EEPROM Sequential Erase / Write

	ADDR	W/R	EEPROM_ACTIVE	
S	0x1B	0	0x01	P

wait 1 ms

	ADDR	W/R	SET_ADDR	EEP_ADDR	
S	0x1B	0	0x09	ADDR	P

	ADDR	W/R	NORMAL_ERASE	
S	0x1B	0	0x02	P

wait 5 ms

	ADDR	W/R	SET_DATA	DATA_MSB	DATA_LSB	
S	0x1B	0	0x0A	DATA	DATA	P

	ADDR	W/R	NORMAL_WRITE	
S	0x1B	0	0x03	P

wait 5 ms

	ADDR	W/R	SET_ADDR	EEP_ADDR	
S	0x1B	0	0x09	ADDR	P

	ADDR	W/R	NORMAL_ERASE	
S	0x1B	0	0x02	P

wait 5 ms

	ADDR	W/R	SET_DATA	DATA_MSB	DATA_LSB	
S	0x1B	0	0x0A	DATA	DATA	P

	ADDR	W/R	NORMAL_WRITE	
S	0x1B	0	0x03	P

wait 5 ms

	ADDR	W/R	SET_ADDR	EEP_ADDR	
S	0x1B	0	0x09	ADDR	P

	ADDR	W/R	NORMAL_ERASE	
S	0x1B	0	0x02	P

wait 5 ms

	ADDR	W/R	SET_DATA	DATA_MSB	DATA_LSB	
S	0x1B	0	0x0A	DATA	DATA	P

	ADDR	W/R	NORMAL_WRITE	
S	0x1B	0	0x03	P

wait 5 ms

	ADDR	W/R	SET_ADDR	EEP_ADDR	
S	0x1B	0	0x09	ADDR	P

	ADDR	W/R	NORMAL_ERASE	
S	0x1B	0	0x02	P

wait 5 ms

	ADDR	W/R	STANDBY	
S	0x1B	0	0x00	P

11.8 I²C Example Sequence – EEPROM Continuous Erase

	ADDR	W/R	EEPROM_ACTIVE	
S	0x1B	0	0x01	P

wait 1 ms

	ADDR	W/R	SET_ADDR	EEP_ADDR	
S	0x1B	0	0x09	ADDR	P

	ADDR	W/R	NORMAL_ERASE	
S	0x1B	0	0x02	P

wait 5 ms

	ADDR	W/R	SET_ADDR	EEP_ADDR	
S	0x1B	0	0x09	ADDR	P

	ADDR	W/R	NORMAL_ERASE	
S	0x1B	0	0x02	P

wait 5 ms

	ADDR	W/R	STANDBY	
S	0x1B	0	0x00	P

11.9 I²C Example Sequence – EEPROM Continuous Write

	ADDR	W/R	EEPROM_ACTIVE	
S	0x1B	0	0x01	P

wait 1 ms

	ADDR	W/R	SET_ADDR	EEP_ADDR	
S	0x1B	0	0x09	ADDR	P

	ADDR	W/R	SET_DATA	DATA_MSB	DATA_LSB	
S	0x1B	0	0x0A	DATA	DATA	P

	ADDR	W/R	NORMAL_WRITE	
S	0x1B	0	0x03	P

wait 5 ms

	ADDR	W/R	SET_DATA	DATA_MSB	DATA_LSB	
S	0x1B	0	0x0A	DATA	DATA	P

	ADDR	W/R	NORMAL_WRITE	
S	0x1B	0	0x03	P

wait 5 ms

	ADDR	W/R	STANDBY	
S	0x1B	0	0x00	P

11.10 I²C Example Sequence – EEPROM Sequential Read

	ADDR	W/R	EEPROM_ACTIVE	
S	0x1B	0	0x01	P

wait 1 ms

	ADDR	W/R	SET_ADDR	EEP_ADDR	
S	0x1B	0	0x09	ADDR	P

	ADDR	W/R	NORMAL_READ	
S	0x1B	0	0x06	P

	ADDR	W/R	GET_DATA		ADDR	W/R	DATA_MSB	DATA_LSB	
S	0x1B	0	0x0B	Sr	0x1B	1	??	??	P

	ADDR	W/R	SET_ADDR	EEP_ADDR	
S	0x1B	0	0x09	ADDR	P

	ADDR	W/R	NORMAL_READ	
S	0x1B	0	0x06	P

	ADDR	W/R	GET_DATA		ADDR	W/R	DATA_MSB	DATA_LSB	
S	0x1B	0	0x0B	Sr	0x1B	1	??	??	P

	ADDR	W/R	STANDBY	
S	0x1B	0	0x00	P

11.11 I²C Example Sequence – EEPROM Continuous Read

	ADDR	W/R	EEPROM_ACTIVE	
S	0x1B	0	0x01	P

wait 1 ms

	ADDR	W/R	SET_ADDR	EEP_ADDR	
S	0x1B	0	0x09	ADDR	P

	ADDR	W/R	NORMAL_READ	
S	0x1B	0	0x06	P

	ADDR	W/R	GET_DATA		ADDR	W/R	DATA_MSB	DATA_LSB	
S	0x1B	0	0x0B	Sr	0x1B	1	??	??	P

	ADDR	W/R	GET_DATA		ADDR	W/R	DATA_MSB	DATA_LSB	
S	0x1B	0	0x0B	Sr	0x1B	1	??	??	P

	ADDR	W/R	GET_DATA		ADDR	W/R	DATA_MSB	DATA_LSB	
S	0x1B	0	0x0B	Sr	0x1B	1	??	??	P

	ADDR	W/R	GET_DATA		ADDR	W/R	DATA_MSB	DATA_LSB	
S	0x1B	0	0x0B	Sr	0x1B	1	??	??	P

	ADDR	W/R	STANDBY	
S	0x1B	0	0x00	P

11.12 I²C Example Sequence – Init and Read Thermopile Array

	ADDR	R/W	CONFIG_REG	WAKEUP	
S	0x1A	0	0x01	0x01	P

	ADDR	R/W	TRIM_REG1	MBIT_TRIM	
S	0x1A	0	0x03	0x0C	P

	ADDR	R/W	TRIM_REG2	BIAS_TRIML	
S	0x1A	0	0x04	0x0C	P

	ADDR	R/W	TRIM_REG3	BIAS_TRIMR	
S	0x1A	0	0x05	0x0C	P

	ADDR	R/W	TRIM_REG4	CLK_TRIM	
S	0x1A	0	0x06	0x14	P

	ADDR	R/W	TRIM_REG5	BPA_TRIML	
S	0x1A	0	0x07	0x0C	P

	ADDR	R/W	TRIM_REG6	BPA_TRIMR	
S	0x1A	0	0x08	0x0C	P

	ADDR	R/W	TRIM_REG7	PU_TRIM	
S	0x1A	0	0x09	0x88	P

	ADDR	R/W	CONFIG_REG	START / WAKEUP	
S	0x1A	0	0x01	0x09	P

	ADDR	R/W	STATUS_REG		ADDR	R/W	STATUS	
S	0x1A	0	0x02	Sr	0x1A	1	??	P

WAIT 30ms

	ADDR	R/W	STATUS_REG		ADDR	R/W	STATUS	
S	0x1A	0	0x02	Sr	0x1A	1	??	P

	ADDR	R/W	READ_DATA1		ADDR	R/W	PTAT1 MSB	PTAT1 LSB	P0,0 MSB	P0,0 LSB	...	Px,y MSB	Px,y LSB	
S	0x1A	0	0x0A	Sr	0x1A	1	??	??						P

	ADDR	R/W	READ_DATA2		ADDR	R/W	PTAT1 MSB	PTAT1 LSB	P0,0 MSB	P0,0 LSB	...	Px,y MSB	Px,y LSB	
S	0x1A	0	0x0B	Sr	0x1A	1	??	??						P

	ADDR	R/W	CONFIG_REG	SLEEP	
S	0x1A	0	0x01	0x00	P

12 Temperature Calculation

The object and ambient temperature can be calculated from the sensor output and the stored calibration data. The table below is showing an overview of the EEPROM.

16x16d	0x00	0x01	0x02	0x03	0x04	0x05	0x06	0x07	0x08	0x09	0x0A	0x0B	0x0C	0x0D	0x0E	0x0F
0	PixCmin [float]		PixCmax [float]						gradScale	GlobalGain			TN	epsilon	NrOfDefPix/Mask	DeadPixAdr
10											MBIT(calib)	BIAS(calib)	CLK(calib)	BPA(calib)	PU(calib)	
20	MBIT(user)	BIAS(user)	CLK(user)	BPA(user)	PU(user)	VddMeas(Th1)	VddMeas(Th2)						PTAT (Th1) [unsig	PTAT (Th2) [un		
30					PTAT-gradient (float)		PTAT-offset (float)				Device ID				VddScGrad	VddScOff
40 … 90	VddCompGrad stored as 12 bit sigend values															
A0 … F0	VddCompOff stored as 12 bit sigend values															
100 … 1F0	$Th1_{ij}$ / $Grad_{ij}$ stored as 16 bit signed values															
200 … 2F0	$Th2_{ij}$ /$Offset_{ij}$ stored as 16 bit signed values															
300 … 3F0	P_{ij} stored as 16 bit unsigned values															

All values are stored as unsigned 16 bit values in the little endian format unless they are specified otherwise. Grey marked areas are used during calibration or for future use and are Heimann Sensor reserved.

MBIT(calib), BIAS(calib), CLK(calib), BPA(calib) and PU(calib) are the settings for the registers that have been used during calibration. MBIT(user), BIAS(user), CLK(user), BPA(user) and PU(user) are free to be set by the user. The temperature calculation is only valid, if the same settings are used, that have been set during calibration!

TN is the table number and has to match the given table number in the sample code.

GlobalGain, VDDTh1, VDDTh2, PTATTh1 and PTATTh2 are stored as 16 bit unsigned values.

VDDTH1 and VDDTH2 is the used supply voltage during calibration measured by the sensor itself and stored in Digits.

The corresponding order of $ThGrad_{ij}$, $ThOffset_{ij}$ and P_{ij} to the Pixel number is given by the following overview:

16x16d

$ThGrad_{0,0}$ → Pixel 0	$ThGrad_{0,1}$ → Pixel 1	…	$ThGrad_{0,31}$ → Pixel 15
$ThGrad_{1,0}$ → Pixel 16	$ThGrad_{1,1}$ → Pixel 17	…	$ThGrad_{1,31}$ → Pixel 31
.			
.			
.			
$ThGrad_{7,0}$ → Pixel 112	$ThGrad_{7,1}$ → Pixel 113	…	$ThGrad_{7,15}$ → Pixel 127
$ThGrad_{8,0}$ → Pixel 240	$ThGrad_{8,1}$ → Pixel 241	…	$ThGrad_{8,15}$ → Pixel 255
$ThGrad_{9,0}$ → Pixel 224	$ThGrad_{9,1}$ → Pixel 225	…	$ThGrad_{9,15}$ → Pixel 239
.			
.			
.			
$ThGrad_{15,0}$ → Pixel 128	$ThGrad_{15,1}$ → Pixel 129	…	$ThGrad_{15,15}$ → Pixel 143

Figure 10: Readout Order 16x16d

The order of $VddCompGrad_{ij}$ and $VddCompOff_{ij}$ is similar to the electrical Offsets and have to be used block by block. $VddCompGrad_{ij}$ and $VddCompOff_{ij}$ are stored as 12 bit signed values with an offset of 0x800. Please check the sample code for a more detailed readout of the 12 bit values.

16x16d

$VddCompGrad_{0,0}$	→	Pixel 0	$VddCompGrad_{0,1}$	→	Pixel 1	…	$VddCompGrad_{0,15}$	→	Pixel 15	top half
$VddCompGrad_{1,0}$	→	Pixel 15	$VddCompGrad_{1,1}$	→	Pixel 16	…	$VddCompGrad_{1,15}$	→	Pixel 31	
$VddCompGrad_{2,0}$	→	Pixel 32	$VddCompGrad_{2,1}$	→	Pixel 33	…	$VddCompGrad_{2,15}$	→	Pixel 47	
$VddCompGrad_{3,0}$	→	Pixel 48	$VddCompGrad_{3,1}$	→	Pixel 49	…	$VddCompGrad_{3,15}$	→	Pixel 63	
$VddCompGrad_{0,0}$	→	Pixel 64	$VddCompGrad_{0,1}$	→	Pixel 65	…	$VddCompGrad_{0,15}$	→	Pixel 79	
.										
.										
.										
$VddCompGrad_{3,0}$	→	Pixel 112	$VddCompGrad_{3,1}$	→	Pixel 113	…	$VddCompGrad_{3,15}$	→	Pixel 127	
$VddCompGrad_{4,0}$	→	Pixel 240	$VddCompGrad_{4,1}$	→	Pixel 241	…	$VddCompGrad_{4,15}$	→	Pixel 255	bottom half
$VddCompGrad_{5,0}$	→	Pixel 224	$VddCompGrad_{5,1}$	→	Pixel 225	…	$VddCompGrad_{5,15}$	→	Pixel 239	
$VddCompGrad_{6,0}$	→	Pixel 208	$VddCompGrad_{6,1}$	→	Pixel 209	…	$VddCompGrad_{6,15}$	→	Pixel 223	
$VddCompGrad_{7,0}$	→	Pixel 192	$VddCompGrad_{7,1}$	→	Pixel 193	…	$VddCompGrad_{7,15}$	→	Pixel 207	
$VddCompGrad_{4,0}$	→	Pixel 176	$VddCompGrad_{4,1}$	→	Pixel 177	…	$VddCompGrad_{4,15}$	→	Pixel 191	
.										
.										
.										
$VddCompGrad_{7,0}$	→	Pixel 128	$VddCompGrad_{7,1}$	→	Pixel 129	…	$VddCompGrad_{7,15}$	→	Pixel 143	

Figure 11: Readout of VDDCompGrad 16x16d

12.1 Ambient Temperature

The ambient temperature (Ta) is calculated from the average measured PTAT value, the $PTAT_{gradient}$ and the $PTAT_{offset}$. It is recommended to use a stack buffer for the PTAT values in order to get a more stable ambient temperature result.

$$Ta = PTAT_{av} \cdot PTAT_{gradient} + PTAT_{offset}$$ (Value is given back in dK)

where:

$PTAT_{gradient}$	is the gradient of the PTAT stored in the EEPROM as a float value
$PTAT_{offset}$	is the offset of the PTAT stored in the EEPROM as a float value
$PTAT_{av} = \frac{\sum_{i=0}^{3} PTAT_i}{4}$	is the average measured PTAT value

12.2 Thermal Offset

The thermal offset of the sensor needs to be subtracted for each pixel to compensate for any thermal drifts.

$$V_{ij\_Comp} = V_{ij} - \frac{ThGrad_{ij} \cdot Ta}{2^{gradScale}} - ThOffset_{ij}$$

where:

ij	represents the row (i) and column (j) of the pixel
V_{ij_Comp}	is the thermal offset compensated voltage
V_{ij}	is the raw pixel data (digital), readout from the RAM
$ThGrad_{ij}$	is the thermal gradient, stored in the EEPROM from 0x40 to 0x7F
$ThOffset_{ij}$	is the thermal offset, stored in the EEPROM from 0x80 to 0xBF
$gradScale$	is the scaling coefficient for the thermal gradient stored in the EEPROM

12.3 Electrical Offset

The electrical offset is used to compensate changes in the supply voltage. This compensation is only a subtraction, so it can be done before or after the thermal offset compensation (here done afterwards). It is recommended
to use an electrical offset stack in order to get a more stable electrical offset result and a more stable temperature result at the end. The electrical offsets should be sampled every 8th to 10th frame.

The compensation for the top half is done by using the following formula:

$$V_{ij\_Comp} *= V_{ij\_Comp} - elOffset[(j + i \cdot 16)\%64]$$

and the bottom half analogue with this formula:

$$V_{ij\_Comp} *= V_{ij\_Comp} - elOffset[(j + i \cdot 16)\%64 + 64]$$

where:

ij	represents the row (i) and column (j) of the pixel and electrical offset
$V_{ij\_Comp} *$	is the thermal and electrical offset compensated voltage
V_{ij_Comp}	is the thermal offset compensated voltage
$elOffset_{ij}$	is the electrical offset belonging to Pixel ij
$i\%64$	is the rest of the integer division of i by 64 (e.g. 68%64=2) (“modulo”)

12.4 VDD Compensation

A supply voltage compensation called VddComp is used to take care of supply voltage changes. In order to use this compensation the supply voltage of the sensor (Vdd) has to be measured by the sensor from time to time by setting the configuration register and the average of Vdd 1 and Vdd 2 is resulting in Vdd (similar like $PTAT_{av}$). It is recommended to use a VDD stack buffer in order to get a more stable VDD value. The stack should be similar to the PTAT stack.

The compensation for the top half is done by using the following formula:

$$VDD_{av} = \frac{\sum_{i=0}^{3} VDD_i}{4}$$

$$V_{ij_{VDDComp}} = V_{ij_{Comp*}} - \frac{\left(\frac{VddCompGrad[(j + i \cdot 16)\%64] \cdot PTAT_{av}}{2^{VDDScGrad}} + VddCompOff[(j + i \cdot 16)\%64]\right)}{2^{VDDScOff}} \cdot \left(VDD_{av} - VDD_{TH1} - \left(\frac{VDD_{TH2} - VDD_{TH1}}{PTAT_{TH2} - PTAT_{TH}}\right) \cdot (PTAT_{av} - PTAT_{TH1})\right)$$

And the bottom half analogue with this formula:

$$V_{ij_{VDDComp}} = V_{ij_{Comp*}} - \frac{\left(\frac{VddCompGrad[(j + i \cdot 16)\%64 + 64] \cdot PTAT_{av}}{2^{VDDScGrad}} + VddCompOff[(j + i \cdot 16)\%64 + 64]\right)}{2^{VDDScOff}} \cdot \left(VDD_{av} - VDD_{TH} - \left(\frac{VDD_{TH} - VDD_{TH}}{PTAT_{TH} - PTAT_{TH1}}\right) \cdot (PTAT_{av} - PTAT_{TH})\right)$$

where:

ij	represents the row (i) and column (j) of the pixel
$V_{ij\_VDDComp}$	is the Vdd compensated voltage
$V_{ij\_Comp}*$	is the thermal and electrical offset compensated voltage
$VddComGrad[ij]$	is the VddComp gradient belonging to Pixel ij
$VddComOff[ij]$	is the VddComp offset belonging to Pixel ij
$i\%64$	is the rest of the integer division of i by 64 (e.g. 66%64=2) (“modulo”)
VDD_{av}	is the average measured supply voltage of the sensor in Digits
$VddScGrad$	is a scaling coefficient and stored in the EEPROM 0x3E
$VddScOff$	is a scaling coefficient and stored in the EEPROM 0x3F
VDD_{TH1}	is the supply voltage during calibration 1 stored in the EEPROM 0x25

VDD_{TH2}	is the supply voltage during calibration 2 stored in the EEPROM 0x26
$PTAT_{TH1}$	is the PTAT value of calibration 1 stored in the EEPROM 0x2C
$PTAT_{TH2}$	is the PTAT value of calibration 2 stored in the EEPROM 0x2D

12.5 Object Temperature

The calculation of the object temperature is done by using a look-up table and doing a bi-linear interpolation, the matching table is given by the table number (TN). The table is supplied in a separate file named "Table.c". If you do not have the file, please ask Heimann Sensor for support.

The sensitivity coefficients ($PixC_{ij}$) are calculated in the following way:

$$PixC_{ij} = \left(\frac{P_{ij} \cdot (PixC_{max} - PixC_{min})}{65535} + PixC_{min}\right) \cdot \frac{epsilon}{100} \cdot \frac{GlobalGain}{10000}$$

where:

$PixC_{ij}$	is the sensitivity coefficient for each pixel
P_{ij}	is the stored sensitivity coefficient scaled to 16 bit
$PixC_{min}$	is the minimum sensitivity coefficient, used for scaling
$PixC_{max}$	is the maximum sensitivity coefficient, used for scaling
$epsilon$	is the emissivity factor
$GlobalGain$	is a factor for fine tuning of the sensitivity for all Pixel

Leading to a compensation of the pixel voltage

$$V_{ij\_PixC} = \frac{V_{ij\_VDDComp} \cdot PCSCALEVAL}{PixC_{ij}}$$

where:

V_{ij_PixC} is the sensitivity compensated IR voltage

$PCSCALEVAL$ is a defined scaling coefficient, typically set to $1 \cdot 10^8$

13 Example Calculation

Example values:

$$PTAT_{av} = \frac{\sum_{i=0}^{3} PTAT_i}{4} = 38152 Digits$$

$$PTAT_{gradient} = 0.0211\ dK/Digit$$

$$PTAT_{offset} = 2195.0\ dK$$

$$V_{00} = 34435\ Digits$$

$$elOffset[0] = 34240$$

$$gradScale = 17$$

$$THGrad_{00} = 87 \rightarrow signcheck\ 87$$

$$THOffset_{00} = 65506 \rightarrow signcheck - 30$$

$$VDD_{av} = 35000$$

$$VDD_{TH1} = 33942$$

$$VDD_{TH2} = 36942$$

$$PTAT_{TH1} = 30000$$

$$PTAT_{TH2} = 42000$$

$$VddCompGrad[0] = 10356 \rightarrow signcheck\ 10356$$

$$VddCompOff[0] = 51390 \rightarrow signcheck - 14146$$

$$VddScGrad = 16$$

$$VddScOff = 23$$

$$PixC_{00} = 1 \cdot 10^8$$

$$PCSCALEVAL = 1 \cdot 10^8$$

Calculation of ambient temperature:

$$Ta = PTAT \cdot PTAT_{gradient} + PTAT_{offset} = 32357 \cdot 0.046 + 1511.6\ dK = 3000\ dK$$

Compensation of thermal offset:

$$V_{00\_Comp} = V_{00} - \frac{ThGrad_{00} \cdot Ta}{2^{gradscale}} - ThOffset_{00} = -\frac{-8842 \cdot 3000}{2^{15}} - 44 = 35200$$

Compensation of electrical offset:

$$V_{00\_Comp} *= V_{00\_Comp} - elOffset_{00} = 35200 - 35000 = 200$$

13.1 Example Look-up Table

Look-up table, TO values are given in dK				
TA[dK]/dig	2882	3032	3182	3332
-64	1494	2128	2491	2775
-32	2466	2692	2898	3091
0	2882	3032	3182	3332
32	3170	3285	3406	3530
64	3396	3491	3592	3699
96	3584	3665	3754	3848
128	3746	3818	3897	3981
160	3890	3954	4025	4102
192	4019	4078	4143	4214
224	4137	4191	4251	4317
256	4246	4296	4351	4413
288	4347	4393	4445	4503
320	4441	4485	4534	4588

$$V_{00\_Comp} = \frac{200 \cdot 1 \cdot 10^8}{1.1 \cdot 10^8}$$

Ta was calculated before to 3000 dK.

The matching region in the look-up table is already marked yellow, the bi-linear interpolation is leading to an object temperature of 4026 dK = (4026dK-2732dK)/10 = 129.4 °C.

The matching look-up table has to be taken from the “Table.c” file. Here is just shown an exemplary data for one optic.

To in dK

dig \ Ta[dK]	2782	2882	2982	3082	3182	3282	3382
-512	0	0	0	[illegible]	1742	2005	2202
-448	[illegible]	[illegible]	[illegible]	[illegible]	2094	2284	2442
-384	[illegible]	[illegible]	[illegible]	[illegible]	2340	2496	2634
-320	[illegible]	[illegible]	[illegible]	[illegible]	2534	2671	2797
-256	[illegible]	[illegible]	[illegible]	[illegible]	2697	2822	2938
-192	2287	2445	2587	2717	2839	2954	3065
-128	2481	2612	2735	2852	2964	3073	3180
-64	2642	2755	2865	2972	3078	3182	3285
0	2782	2882	2982	3082	3182	3282	3382
64	2906	2996	3089	3183	3278	3375	3473
128	3019	3101	3187	3276	3368	3462	3558
192	3121	3197	3278	3363	3452	3544	3638
256	3216	3286	3363	3445	3531	3621	3715
320	3305	3370	3443	3522	3606	3695	3787
384	3387	3449	3519	3595	3677	3764	3856
448	3465	3524	3590	3664	3745	3831	3922
512	3539	3595	3659	3731	3810	3895	3986
576	3609	3662	3724	3794	3872	3957	4047
640	3676	3727	3787	3855	3932	4016	4106
704	3740	3788	3847	3914	3990	4073	4163
768	3802	3848	3904	3971	4046	4128	4218
832	3861	3905	3960	4025	4100	4182	4271
896	3918	3960	4014	4078	4152	4233	4322
960	3973	4014	4066	4129	4202	4284	4372
1024	4026	4065	4117	4179	4251	4332	4421
1088	4077	4115	4166	4227	4299	4380	4469
1152	4127	4164	4213	4274	4345	4426	4515
1216	4175	4211	4260	4320	4391	4471	4560
1280	4222	4257	4305	4364	4435	4515	4604
1344	4268	4302	4349	4408	4478	4558	4647
1408	4312	4345	4391	4450	4520	4600	4689
1472	4355	4388	4433	4491	4561	4641	4730
1536	4398	4429	4474	4532	4601	4681	4770
1600	4439	4470	4514	4571	4640	4720	4809
1664	4480	4509	4553	4610	4679	4758	4848
1728	4519	4548	4591	4648	4716	4796	4885
1792	4558	4586	4629	4685	4753	4833	4922
1856	4595	4623	4666	4721	4790	4869	4959
1920	4633	4660	4702	4757	4825	4905	4995
1984	4669	4696	4737	4792	4860	4940	5030
2048	4705	4731	4772	4826	4894	4974	5064
2112	4740	4765	4806	4860	4928	5008	5098
2176	4774	4799	4839	4894	4961	5041	5131
2240	4808	4832	4872	4926	4994	5074	5164
2304	4841	4865	4904	4958	5026	5106	5197
2368	4873	4897	4936	4990	5058	5137	5228
2432	4906	4929	4968	5021	5089	5169	5260
2496	4937	4960	4998	5052	5119	5199	5291
2560	4968	4991	5029	5082	5149	5230	5321
2624	4999	5021	5059	5112	5179	5259	5351
2688	5029	5050	5088	5141	5208	5289	5381
2752	5059	5080	5117	5170	5237	5318	5410
2816	5088	5109	5146	5199	5266	5346	5439
2880	5117	5137	5174	5227	5294	5375	5467
2944	5145	5165	5202	5255	5322	5402	5495
3008	5173	5193	5230	5282	5349	5430	5523
3072	5201	5220	5257	5309	5376	5457	5550
3136	5228	5247	5284	5336	5403	5484	5577
3200	5255	5274	5310	5362	5429	5510	5604
3264	5282	5300	5336	5388	5455	5537	5630
3328	5308	5326	5362	5414	5481	5563	5656
3392	5334	5352	5388	5439	5507	5588	5682
3456	5360	5377	5413	5465	5532	5613	5708
3520	5385	5403	5438	5489	5557	5638	5733
3584	5410	5427	5462	5514	5581	5663	5758
3648	5435	5452	5487	5538	5606	5688	5783
3712	5459	5476	5511	5562	5630	5712	5807
3776	5483	5500	5535	5586	5654	5736	5831
3840	5507	5524	5558	5610	5677	5760	5855
3904	5531	5547	5582	5633	5701	5783	5879
3968	5554	5571	5605	5656	5724	5806	5902
4032	5578	5594	5628	5679	5747	5829	5925
4096	5601	5616	5650	5702	5769	5852	5948
4160	5623	5639	5673	5724	5792	5875	5971
4224	5646	5661	5695	5746	5814	5897	5994
4288	5668	5683	5717	5768	5836	5919	6016
4352	5690	5705	5739	5790	5858	5941	6038
4416	5712	5727	5760	5811	5879	5963	6060
4480	5734	5748	5782	5833	5901	5984	6082
4544	5755	5770	5803	5854	5922	6006	6103
4608	5776	5791	5824	5875	5943	6027	6125
4672	5797	5811	5844	5896	5964	6048	6146
4736	5818	5832	5865	5916	5984	6069	6167
4800	5839	5853	5886	5937	6005	6089	6188
4864	5859	5873	5906	5957	6025	6110	6208
4928	5880	5893	5926	5977	6045	6130	6229
4992	5900	5913	5946	5997	6065	6150	6249
5056	5920	5933	5965	6017	6085	6170	6269
5120	5940	5953	5985	6036	6105	6190	6289
5184	5959	5972	6005	6056	6124	6209	6309
5248	5979	5991	6024	6075	6144	6229	6329
5312	5998	6011	6043	6094	6163	6248	6348
5376	6017	6030	6062	6113	6182	6267	6368
5440	6036	6049	6081	6132	6201	6286	6387
5504	6055	6067	6099	6150	6220	6305	6406
5568	6074	6086	6118	6169	6238	6324	6425
5632	6092	6104	6136	6187	6257	6343	6444
5696	6111	6123	6155	6206	6275	6361	6462
5760	6129	6141	6173	6224	6293	6379	6481
5824	6147	6159	6191	6242	6311	6398	6499
5888	6165	6177	6209	6260	6329	6416	6517
5952	6183	6195	6226	6277	6347	6434	6536
6016	6201	6212	6244	6295	6365	6451	6554
6080	6219	6230	6261	6313	6382	6469	6571
6144	6236	6247	6279	6330	6400	6487	6589
6208	6253	6264	6296	6347	6417	6504	6607
6272	6271	6282	6313	6364	6434	6522	6624
6336	6288	6299	6330	6381	6451	6539	6642
6400	6305	6316	6347	6398	6468	6556	6659
6464	6322	6332	6364	6415	6485	6573	6676
6528	6339	6349	6380	6432	6502	6590	6693
6592	6355	6366	6397	6448	6519	6607	6710
6656	6372	6382	6413	6465	6535	6623	6727
6720	6388	6399	6430	6481	6552	6640	6744
6784	6405	6415	6446	6497	6568	6656	6761
6848	6421	6431	6462	6514	6584	6673	6777
6912	6437	6447	6478	6530	6600	6689	6794
6976	6453	6463	6494	6546	6616	6705	6810
7040	6469	6479	6510	6562	6632	6721	6826
7104	6485	6495	6526	6577	6648	6737	6842
7168	6501	6511	6542	6593	6664	6753	6858
7232	6517	6526	6557	6609	6680	6769	6874
7296	6532	6542	6573	6624	6695	6785	6890
7360	6548	6557	6588	6640	6711	6800	6906
7424	6563	6572	6603	6655	6726	6816	6922
7488	6578	6588	6618	6670	6742	6831	6937
7552	6594	6603	6634	6685	6757	6847	6953
7616	6609	6618	6649	6700	6772	6862	6968
7680	6624	6633	6664	6715	6787	6877	6984
7744	6639	6648	6678	6730	6802	6892	6999
7808	6654	6663	6693	6745	6817	6907	7014
7872	6669	6677	6708	6760	6832	6922	7029
7936	6683	6692	6723	6774	6846	6937	7044
8000	6698	6707	6737	6789	6861	6952	7059
8064	6712	6721	6752	6803	6876	6966	7074
8128	6727	6735	6766	6818	6890	6981	7089
8192	6741	6750	6780	6832	6905	6996	7104
8256	6756	6764	6795	6847	6919	7010	7118
8320	6770	6778	6809	6861	6933	7024	7133
8384	6784	6792	6823	6875	6947	7039	7147
8448	6798	6806	6837	6889	6961	7053	7162
8512	6812	6820	6851	6903	6976	7067	7176
8576	6826	6834	6865	6917	6990	7081	7190
8640	6840	6848	6878	6931	7003	7095	7205
8704	6854	6862	6892	6944	7017	7109	7219
8768	6868	6875	6906	6958	7031	7123	7233
8832	6881	6889	6919	6972	7045	7137	7247
8896	6895	6903	6933	6985	7058	7151	7261
8960	6908	6916	6946	6999	7072	7164	7275
9024	6922	6930	6960	7012	7086	7178	7288
9088	6935	6943	6973	7026	7099	7192	7302
9152	6949	6956	6987	7039	7112	7205	7316
9216	6962	6969	7000	7052	7126	7219	7329
9280	6975	6983	7013	7065	7139	7232	7343
9344	6988	6996	7026	7079	7152	7245	7356
9408	7001	7009	7039	7092	7165	7259	7370
9472	7015	7022	7052	7105	7178	7272	7383
9536	7028	7035	7065	7118	7191	7285	7396
9600	7040	7048	7078	7130	7204	7298	7410
9664	7053	7060	7091	7143	7217	7311	7423
9728	7066	7073	7103	7156	7230	7324	7436
9792	7079	7086	7116	7169	7243	7337	7449
9856	7092	7098	7129	7181	7256	7350	7462
9920	7104	7111	7141	7194	7268	7363	7475
9984	7117	7123	7154	7207	7281	7375	7488
10048	7129	7136	7166	7219	7294	7388	7501
10112	7142	7148	7179	7231	7306	7401	7513
10176	7154	7161	7191	7244	7318	7413	7526
10240	7166	7173	7203	7256	7331	7426	7539
10304	7179	7185	7215	7268	7343	7438	7551
10368	7191	7197	7228	7281	7356	7451	7564
10432	7203	7210	7240	7293	7368	7463	7576
10496	7215	7222	7252	7305	7380	7475	7589
10560	7227	7234	7264	7317	7392	7488	7601
10624	7239	7246	7276	7329	7404	7500	7614
10688	7251	7258	7288	7341	7416	7512	7626
10752	7263	7270	7300	7353	7428	7524	7638
10816	7275	7281	7312	7365	7440	7536	7651
10880	7287	7293	7323	7377	7452	7548	7663
10944	7299	7305	7335	7389	7464	7560	7675
11008	7311	7317	7347	7400	7476	7572	7687
11072	7322	7328	7358	7412	7488	7584	7699
11136	7334	7340	7370	7424	7499	7596	7711
11200	7346	7352	7382	7435	7511	7608	7723
11264	7357	7363	7393	7447	7523	7619	7735
11328	7369	7375	7405	7458	7534	7631	7747
11392	7380	7386	7416	7470	7546	7643	7758
11456	7392	7397	7427	7481	7557	7654	7770
11520	7403	7409	7439	7493	7569	7666	7782
11584	7414	7420	7450	7504	7580	7677	7793
11648	7426	7431	7461	7515	7592	7689	7805
11712	7437	7443	7473	7526	7603	7700	7817
11776	7448	7454	7484	7538	7614	7712	7828
11840	7459	7465	7495	7549	7625	7723	7840
11904	7471	7476	7506	7560	7637	7734	7851
11968	7482	7487	7517	7571	7648	7746	7862
12032	7493	7498	7528	7582	7659	7757	7874
12096	7504	7509	7539	7593	7670	7768	7885
12160	7515	7520	7550	7604	7681	7779	7896
12224	7526	7531	7561	7615	7692	7790	7908
12288	7536	7542	7572	7626	7703	7801	7919
12352	7547	7552	7583	7637	7714	7812	7930
12416	7558	7563	7593	7648	7725	7823	7941
12480	7569	7574	7604	7658	7736	7834	7952
12544	7580	7585	7615	7669	7746	7845	7963
12608	7590	7595	7625	7680	7757	7856	7974
12672	7601	7606	7636	7690	7768	7867	7985
12736	7612	7617	7647	7701	7779	7878	7996
12800	7622	7627	7657	7712	7789	7888	8007
12864	7633	7638	7668	7722	7800	7899	8018
12928	7643	7648	7678	7733	7810	7910	8029
12992	7654	7659	7689	7743	7821	7920	8040
13056	7664	7669	7699	7754	7832	7931	8050
13120	7675	7679	7709	7764	7842	7942	8061
13184	7685	7690	7720	7774	7852	7952	8072
13248	7695	7700	7730	7785	7863	7963	8082
13312	7706	7710	7740	7795	7873	7973	8093
13376	7716	7720	7751	7805	7884	7984	8104
13440	7726	7731	7761	7816	7894	7994	8114
13504	7736	7741	7771	7826	7904	8004	8125
13568	7746	7751	7781	7836	7914	8015	8135
13632	7757	7761	7791	7846	7925	8025	8145
13696	7767	7771	7801	7856	7935	8035	8156
13760	7777	7781	7811	7866	7945	8046	8166
13824	7787	7791	7821	7876	7955	8056	8177
13888	7797	7801	7831	7886	7965	8066	8187
13952	7807	7811	7841	7896	7975	8076	8197
14016	7817	7821	7851	7906	7985	8086	8207
14080	7827	7831	7861	7916	7995	8096	8218
14144	7836	7841	7871	7926	8005	8106	8228
14208	7846	7851	7881	7936	8015	8116	8238

13.2 Pixel Masking

A maximum of 1 defect Pixel is allowed on the complete array, this means that at least 99.5 % of the Pixels are working correctly. The amount of defect Pixels is given in the EEPROM at address 0x0E (LSB) and is named $NrOfDefPix$. $DeadPixAdr$ (EEPROM 0x0F) is the address of the defect Pixel and $DeadPixMask$ (EEPROM 0x0E, MSB) determines the neighbours, that should be used for masking the pixel. A simple averaging of all selected nearest neighbours is done to overwrite the temperature value of these Pixel.

The values for $NrOfDefPix$ and $DeadPixMask$ are stored as 8 bit unsigned values, the $DeadPixAdr$ is saved as an 16 bit unsigned value.

The order of the top and bottom half is the same as the readout order that is stated in Serial Order of Frame.

The value stored in $DeadPixAdr$ is equal to the pixel number if $DeadPixAdr$ is <0x80. If the value is greater, that means between 0d128 and 0d255, the actual read-out pixel has to be calculated first. For example: If you have a pixel number of 199 stored to the EEPROM, this is actually 183. The pixel number, that is store in the EEPROM corresponds to the number of the read-out pixel. So the bottom half is mirrored.

Example calculation:

$$adaptedAdr[i] = 256 + 128 - DeadPixAdr[i] + k[i] \cdot 2 - 16$$

$where:$

$adaptedAdr[i]$ is the adapted dead pixel address

$k[i]$ is the column of the corresponsive pixel (for pixel number 199 this would be 7)

$$adaptedAdr[i] = 256 + 128 - 199 + 14 - 16 = 183$$

The neighbours to use is given in a binary format and the order is shown in the overview below in decimal and binary values for the top and bottom half.

top half

128	1	2
64	DeadPix	4
32	16	8

0b1000 0000	0b0000 0001	0b0000 0010
0b0100 0000	DeadPix	0b0000 0100
0b0010 0000	0b0001 0000	0b0000 1000

bottom half

32	16	8
64	DeadPix	4
128	1	2

0b0010 0000	0b0001 0000	0b0000 1000
0b0100 0000	DeadPix	0b0000 0100
0b1000 0000	0b0000 0001	0b0000 0010

Example 1 for the masking:

$NrOfDefPix$ = 0x01
$DeadPixAdr[0]$ = 0x000A → Pixel 10
$DeadPixMask[0]$ = 0x7C → 0b0111 1100 (top)

The readout order is the same as shown in Serial Order of Frames, Figure 4.

According to the sample values 1 Pixel is defect and need to be interpolated. The Pixels is on the top half. Assuming that the neighbouring Pixels are having the temperature data stated below and the green marked cells are used for averaging (according to DeadPixMask), then the interpolated temperature will be the following:

$$\text{Pixel 10} = \frac{3007 + 3008 + 3008 + 3011 + 3009}{5} dK = \frac{15043}{5} dK \approx 3009 dK$$

All values are given in dK

3007	Pixel 10	3008
3008	3011	3009

Pixel 9	Pixel 10	Pixel 11
Pixel 25	Pixel 26	Pixel 27

Example 2 for the masking:

$NrOfDefPix$ = 0x01
$DeadPixAdr[0]$ = 0x00C7 → Pixel 199 (read-out pixel) actual pixel number is 183
$DeadPixMask[0]$ = 0xFE → 0b1111 1110 (bot)

$$\text{Pixel 183} = \frac{3010 + 3012 + 3005 + 3007 + 3008 + 3008 + 3009}{7} dK = \frac{21059}{7} dK \approx 3008 dK$$

3010	3012	3005
3007	Pixel 183	3008
3008	3011	3009

Pixel 166	Pixel 167	Pixel 168
Pixel 182	Pixel 183	Pixel 184
Pixel 198	Pixel 199	Pixel 200

14 Order Code Chart

HTPA16x16d	R3	**L1.0/0.8**	F5.0	UHi	**A**	**(USB)**
HTPA16x16d	R3	**L1.0/0.8**	F5.0	UHi	**A**	**(UDP)**
HTPA16x16d	R3	**L1.0/0.8**	F5.0	UHi	**M**	**(UDP)**
HTPA16x16d	R3	**L1.0/0.8**	F5.0	UHi	**C**	
HTPA16x16d	R3	**L1.6/0.8**	F5.0	UHi	**A**	**(USB)**
HTPA16x16d	R3	**L1.6/0.8**	F5.0	UHi	**A**	**(UDP)**
HTPA16x16d	R3	**L1.6/0.8**	F5.0	UHi	**M**	**(UDP)**
HTPA16x16d	R3	**L1.6/0.8**	F5.0	UHi	**C**	
HTPA16x16d	R3	**L2.1/0.8**	F5.0	UHi	**A**	**(USB)**
HTPA16x16d	R3	**L2.1/0.8**	F5.0	UHi	**A**	**(UDP)**
HTPA16x16d	R3	**L2.1/0.8**	F5.0	UHi	**M**	**(UDP)**
HTPA16x16d	R3	**L2.1/0.8**	F5.0	UHi	**C**	
HTPA16x16d	R3	**L5.0/1.0**	F7.7	UHi	**A**	**(USB)**
HTPA16x16d	R3	**L5.0/1.0**	F7.7	UHi	**A**	**(UDP)**
HTPA16x16d	R3	**L5.0/1.0**	F7.7	UHi	**M**	**(UDP)**
HTPA16x16d	R3	**L5.0/1.0**	F7.7	UHi	**C**	

Bold: Selectable options
Regular: Fixed/Not selectable

15 Outer Dimension