

HTPA16x16dR2L5.0/1.0F7.7

Datasheet for Thermopile Array Sensor with Lens Optic

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Changelog

2019-01-10	Added accuracy; erase of default values for TRIM registers
2019-02-28	Added handling advice
2019-03-20	Added allowed pixelmask
2019-09-30	Initial implementation of 16x16dR2L1.6 sensor
2019-11-22	Small corrections for L1.6 datasheet
2019-12-05	Small corrections for L1.6 datasheet
2020-05-11	Revised soldering recommendation to non-SMD
2020-09-05	Stack buffer recommendation; how to dK in °C
2021-01-30	Order code; change note implementation; correction VDD formula
2021-08-12	New order code
2021-12-14	Initial implementation of 16x16dR2L1.0 and L5.0 in Hi and UHi variant
2022-12-12	Updated drawing for 16x16R2L5.0UHiS
2023-02-08	EEPROM communication flow corrected
2023-02-13	Added radiometric radius for 16x16dR2L1.0
2024-12-18	Updated graphic for optical orientation
2025-01-31	Updated order code, added order code chart w/ available options
2025-03-17	Corrected Field of View for L1.6
2025-04-08	Corrected pin allocations
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.

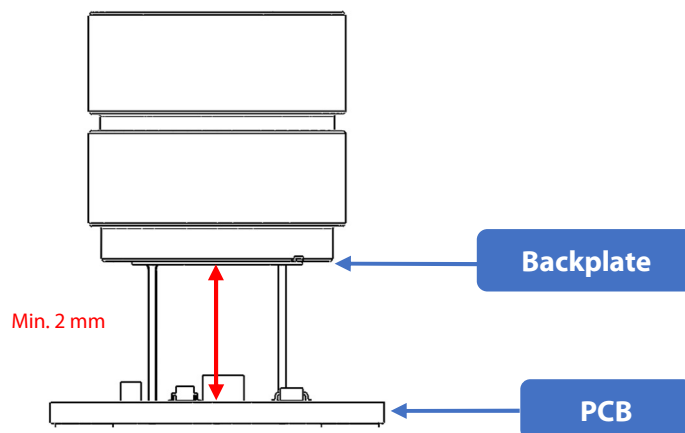


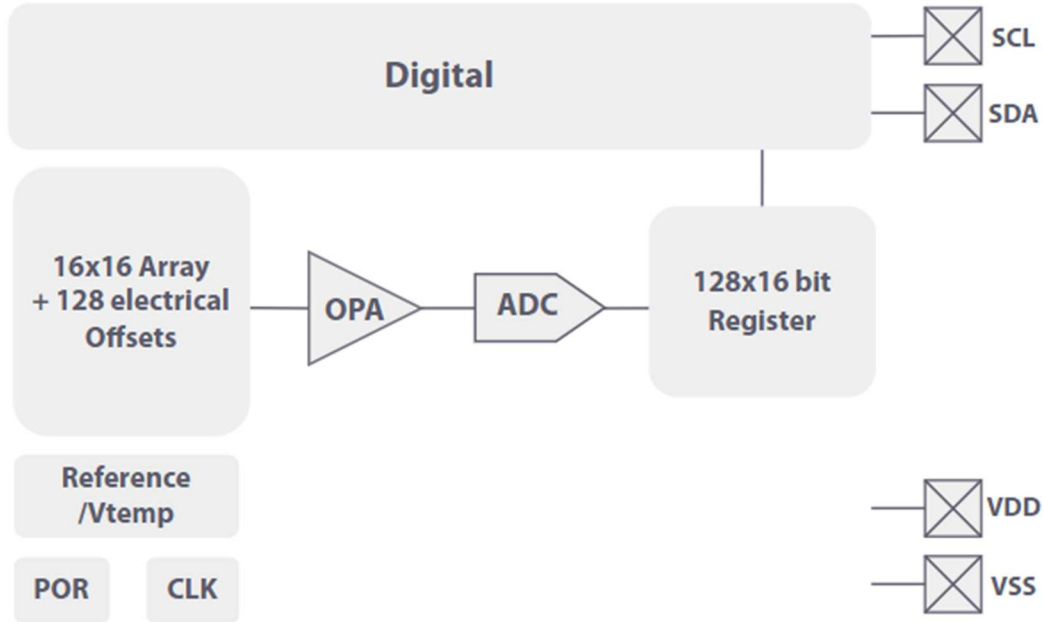
Figure 1: Soldering height

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

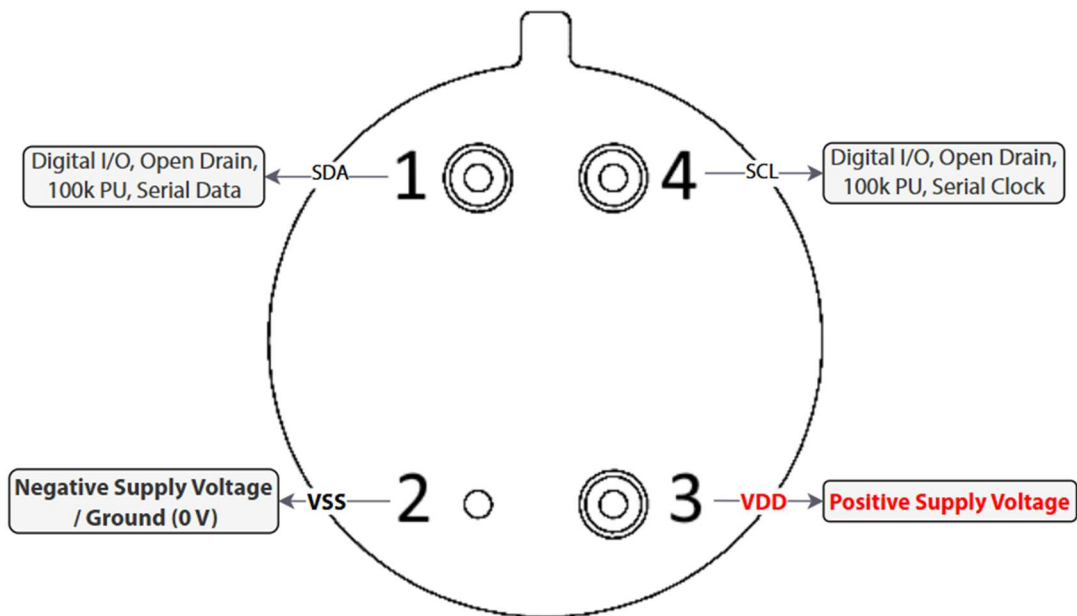
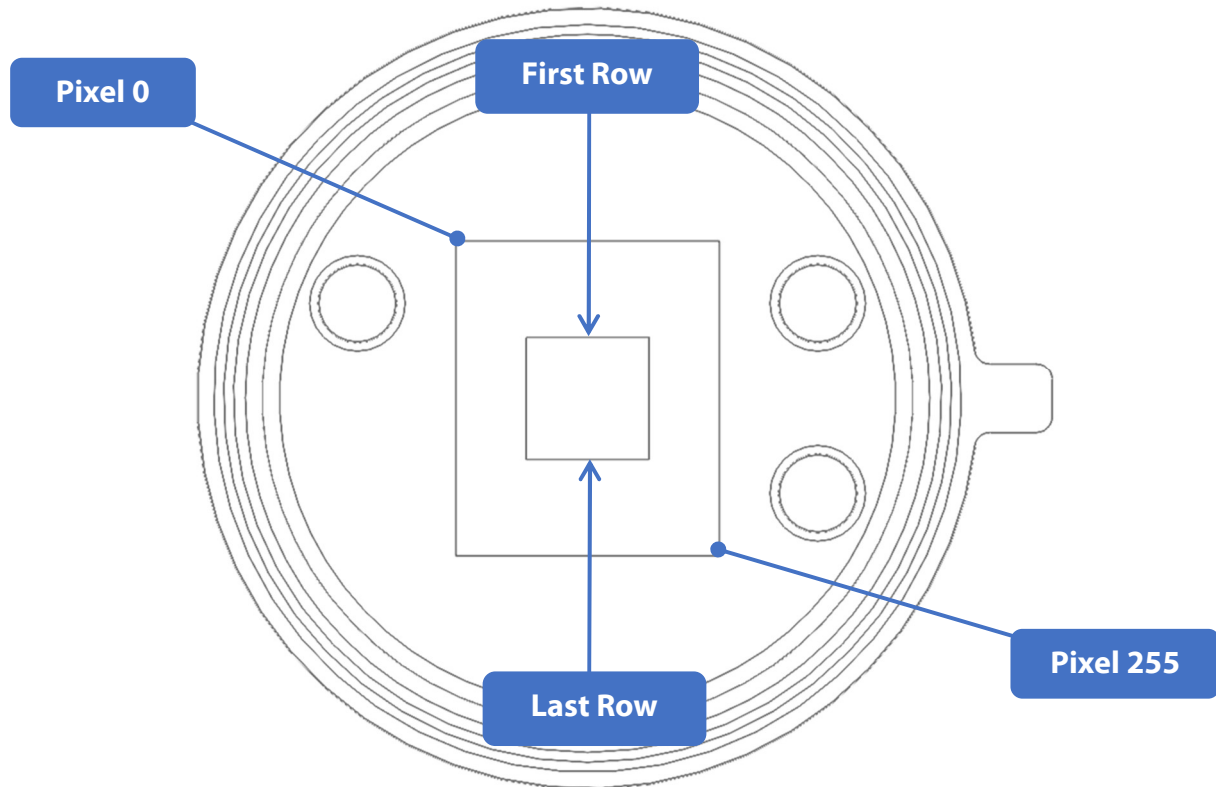
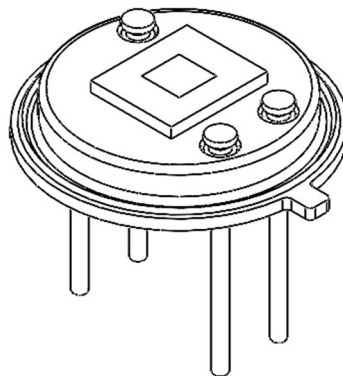


Figure 2: Pin-allocation

4 Optical Orientation



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



5 Order Code Example

HTPA32x32d	R2	L5.0/0.85	F7.7	e	Hi	M	(UDP)
1	2	3	4	5	6	7	8

		Description
1	Sensor Type	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: 0.85
4	Filter	F: Filter characteristics Not declared: Broadband AR Coating
5	External Aperture	Not declared: without external aperture e: with external aperture
6	Sensitivity	UH: 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 ² C: 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)

6 Application Note

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

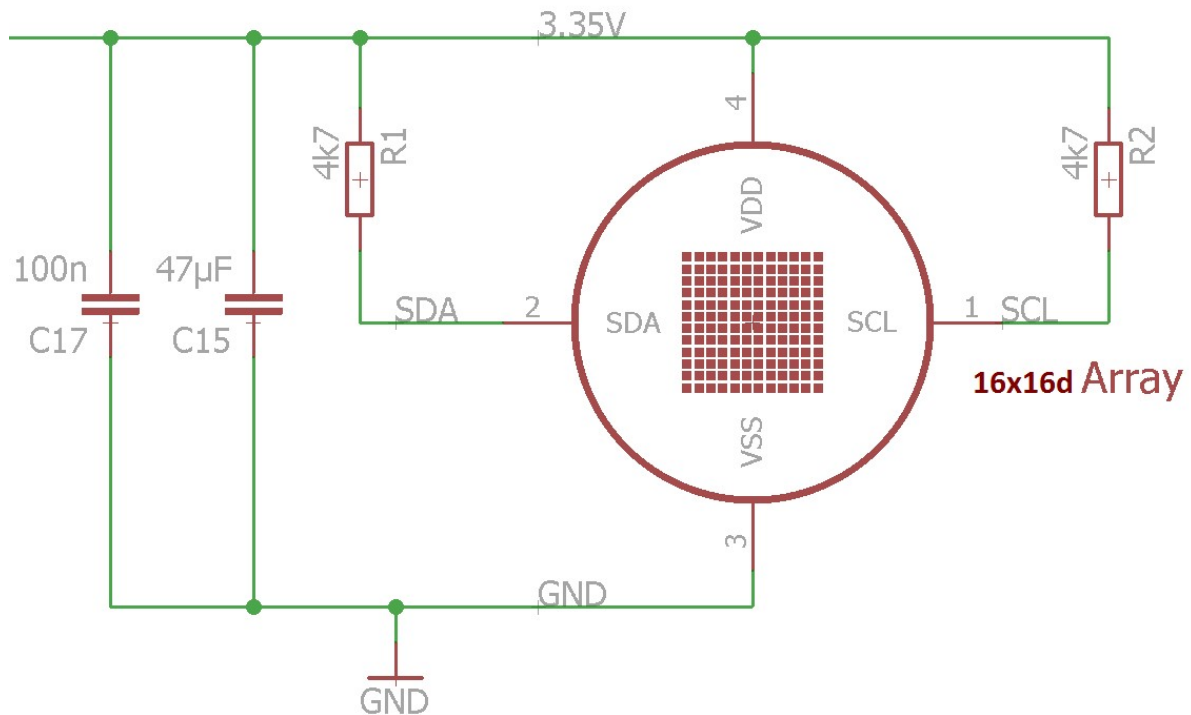


Figure 3: Recommended circuit for operation

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

readout order top

readout order bottom

Figure 6: 16x16d readout order for electrical offset

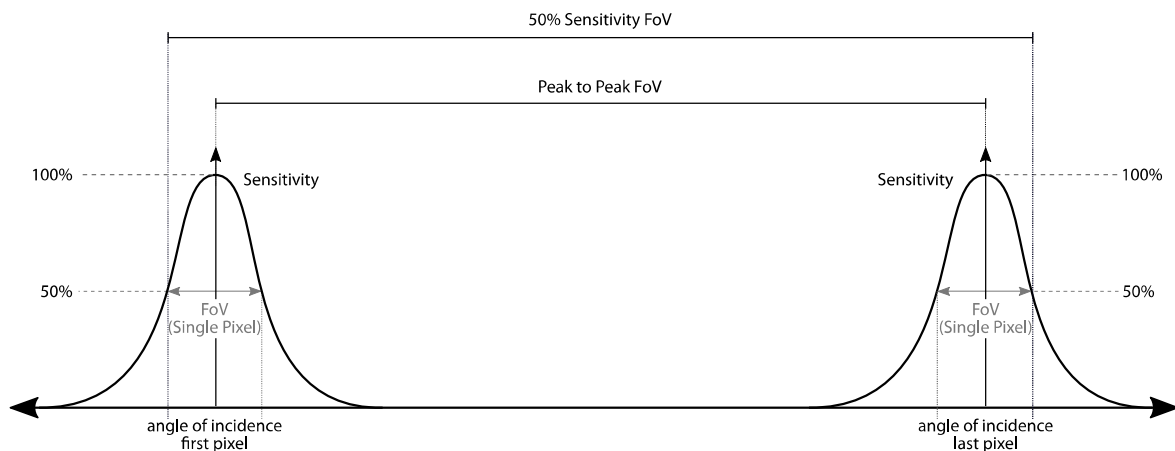
8 Characteristics

8.1 Common Specifications

Technology:	n-poly/p-poly Si
Element Resistance:	approx. 300 kOhms
Thermal pixel time constant:	<4 ms
Digital Interface:	I ² C
EEPROM size:	1024 x 16 Bit
Pitch:	90 µm
Absorber size:	44 µm
Max. Framerate:	120 Hz
Max. measurable temperature:	1100°C with default settings
(complete frame with maximum I ² C 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
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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
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9 Electric Specifications

Table 1: Absolute Maximum Ratings

Parameter	Symbol	Condition	MIN.	TYP.	MAX.	Unit
Supply Voltage	V _{DD}		-0.3		3.6	V
Voltage at all inputs and outputs	V _{IO}		-0.3		V _{DD} +0.3	V
Storage Temperature	T _{STG}		-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	3.9	4.8	mA
Supply Current (sensor in idle state)	I _{SBY}		2.8	3.7	4.5	mA
Standby Current (sensor in sleep state)	I _{SBY}		7	9	11	μA
Operation Temperature	T _A		-20		65	Deg. C
ESD-Protection		Human body model	2			kV
		100pF + 1k50hm				

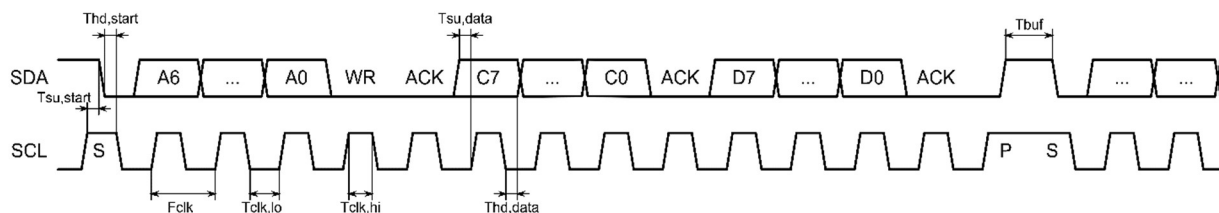
Table 3: Electrical Characteristics

Parameter	Symbol	Condition	MIN.	TYP.	MAX.	Unit
Digital Input						
Internal Clock frequency	F _{CLK}		1	5	13	MHz
Internal I ² C 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 HTPA16x16dTable 5: I²C Timings

Parameter	Symbol	Condition	MIN.	TYP.	MAX.	Unit
I ² C clock frequency	F_{CLK}			400	1000	kHz
low pulse duration	$T_{\text{CLK,lo}}$		0.50			μs
high pulse duration	$T_{\text{CLK,hi}}$		0.26			μs
data set up time	$T_{\text{SU,data}}$		0.05			μs
data hold time	$T_{\text{hd,data}}$		0.00			μs
start setup time	$T_{\text{SU,start}}$		0.26			μs
start hold time	$T_{\text{hd,start}}$		0.26			μs
stop setup time	$T_{\text{SU,stop}}$		0.26			μs
Parameter	Symbol	Condition	MIN.	TYP.	MAX.	Unit
stop hold time	$T_{\text{hd,stop}}$		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.

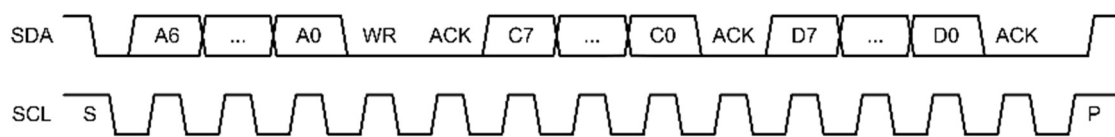


Figure 8: Write Command

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.

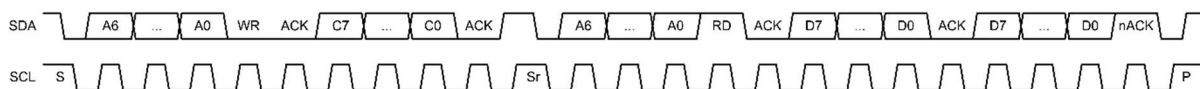


Figure 9: Read Command

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							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 $12 \Rightarrow (m+4)$ 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 $\Rightarrow 1 \mu\text{A}$ to $13 \mu\text{A}$

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 $\Rightarrow 1 \mu\text{A}$ to $13 \mu\text{A}$

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:

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

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	Pixel (0+BLOCK*64) MSB / LSB							
5. Byte / 6. 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	Pixel (240-BLOCK*64) MSB / LSB							
5. Byte / 6. Byte	Pixel (241-BLOCK*64) MSB / LSB							
...	...							

33. Byte / 34. Byte	Pixel (255-BLOCK*64) MSB / LSB
35. Byte / 36. Byte	Pixel (224-BLOCK*64) MSB / LSB
37. Byte / 38. Byte	Pixel (225-BLOCK*64) MSB / LSB
...	
65. Byte / 66. Byte	Pixel (239-BLOCK*64) MSB / LSB
67. Byte / 68. Byte	Pixel (192-BLOCK*64) MSB / LSB
...	
129. Byte / 130. 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 2 MSB / LSB or VDD 2 MSB / LSB							
3. Byte / 4. Byte	electrical offset (0) MSB / LSB							
5. Byte / 6. Byte	electrical offset (1) MSB / LSB							
...	...							
129. Byte / 130. 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	electrical offset (112) MSB / LSB							
5. Byte / 6. Byte	electrical offset (113) MSB / LSB							
...	...							
33. Byte / 34. Byte	electrical offset (127) MSB / LSB							
35. Byte / 36. Byte	electrical offset (96) MSB / LSB							
...	...							
129. Byte / 130. 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	PixCmax (float)		PixCmax (float)						gradScale	GlobalGain			TN	epsilon	NrOfBpiv/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)									
30					PTAT-gradient (float)	PTAT-offset (float)					Device ID				VddScGrad	VddScOff
40	VddCompGrad stored as 12 bit sigend values															
90	VddCompOff stored as 12 bit sigend values															
A0	Th1 _j / Grad _j stored as 16 bit signed values															
F0	Th2 _j / Offset _j stored as 16 bit signed values															
2F0	P _i stored as 16 bit unsigned values															
3F0																

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 (see chapter 11.3 on how to set them). 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:

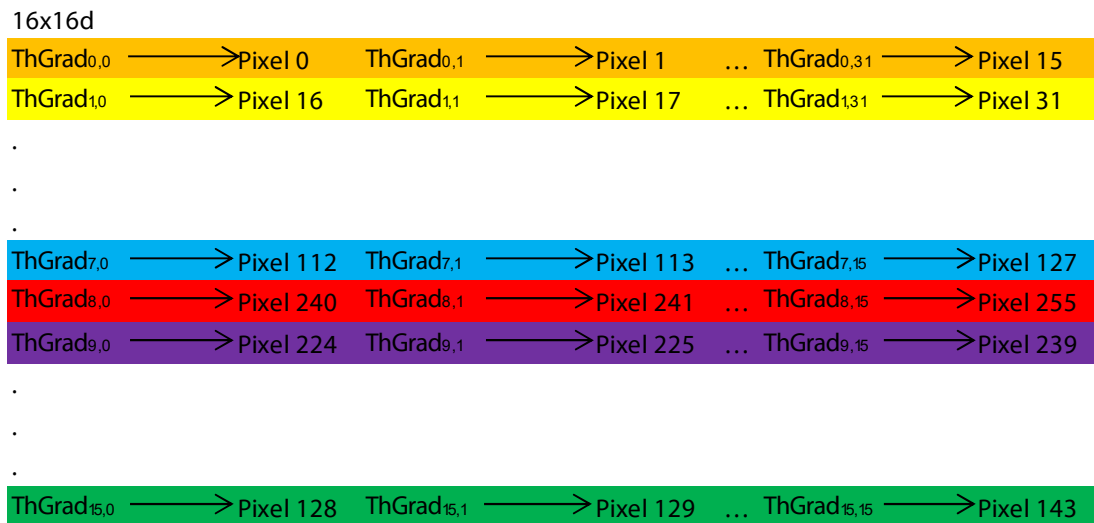


Figure 11: Readout Order 16x16d

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	bottom half
VddCompGrad _{4,0} →	Pixel 240	VddCompGrad _{4,1} →	Pixel 241	...	VddCompGrad _{4,15} →	Pixel 255	
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 10: Readout of VDDCompGrad 16x16d

12.1 Ambient Temperature

The ambient temperature (T_a) 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.

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

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.

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

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:

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

$$V_{ijVDDComp} = V_{ijComp} * \frac{\left(\frac{VddCompGrad[(j + i \cdot 16)\%64] \cdot PTAT_{av} + VddCompOff[(j + i \cdot 16)\%64]}{2^{VDDScGrad}} \right)}{2^{VDDScOff}}$$

$$\cdot \left(VDD_{av} - VDD_{TH} - \left(\frac{VDD_{TH} - VDD_{TH1}}{PTAT_{TH2} - PTAT_{TH1}} \right) \cdot (PTAT_{av} - PTAT_{TH}) \right)$$

And the bottom half analogue with this formula:

$$V_{ijVDDComp} = V_{ijComp} * \frac{\left(\frac{VddCompGrad[(j + i \cdot 16)\%64 + 64] \cdot PTAT_{av} + VddCompOff[(j + i \cdot 16)\%64 + 64]}{2^{VDDScGrad}} \right)}{2^{VDDScOff}}$$

$$\cdot \left(VDD_{av} - VDD_{TH} - \left(\frac{VDD_{TH} - VDD_{TH1}}{PTAT_{TH} - PTAT_{TH1}} \right) \cdot (PTAT_{av} - PTAT_{TH}) \right)$$

where:

ij	represents the row (i) and column (j) of the pixel
$V_{ijVDDComp}$	is the Vdd compensated voltage
$V_{ijComp} *$	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
ϵ	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

$$PTAT = 32357 \text{ Digits}$$

$$PTAT_{gradient} = 0.046 \text{ dK/Digit}$$

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

$$gradScale = 15$$

$$ThGrad_{00} = 56693 \xrightarrow{\text{sign check}} -8842$$

$$ThOffset_{00} = 44$$

$$elOffset_{00} = 35000$$

$$PixC_{00} = 1.1 \cdot 10^8$$

$$PCSCALEVAL = 1.1 \cdot 10^8$$

Calculation of ambient temperature:

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

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.

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

dig 1 Tab(dK)	2782	2882	2982	3082	3182	3282	3382
-512					1742	2002	2202
-448					2094	2284	2442
-384					2310	2420	2534
-320					2534	2671	2797
-256					2697	2822	2938
-192	2287	2444	2587	2717	2839	2954	3065
-128	2481	2612	2734	2852	2964	3073	3180
-64	2642	2755	2865	2972	3078	3182	3285
0	2782	2882	2982	3082	3182	3282	3382
64	2936	2998	3069	3140	3216	3293	3373
128	3016	3101	3187	3273	3360	3445	3530
192	3121	3197	3276	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	3538	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	3849	3904	3971	4046	4128	4216
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	4221	4257	4304	4363	4434	4514	4604
1344	4268	4302	4349	4408	4478	4558	4647
1408	4312	4345	4391	4450	4520	4600	4689
1472	4355	4386	4433	4492	4561	4641	4730
1536	4396	4426	4474	4532	4601	4681	4770
1600	4436	4465	4514	4571	4640	4720	4809
1664	4474	4502	4551	4608	4677	4756	4845
1728	4510	4538	4587	4644	4713	4792	4881
1792	4545	4572	4621	4678	4747	4826	4915
1856	4579	4605	4654	4711	4780	4859	4948
1920	4612	4637	4686	4743	4812	4891	4980
1984	4644	4668	4717	4774	4843	4922	5011
2048	4675	4700	4749	4806	4875	4954	5043
2112	4704	4728	4777	4834	4903	4982	5071
2176	4732	4755	4804	4861	4930	5009	5098
2240	4759	4781	4830	4887	4956	5035	5124
2304	4784	4805	4854	4911	4980	5059	5148
2368	4807	4827	4876	4933	5002	5081	5170
2432	4828	4847	4896	4953	5022	5101	5190
2496	4847	4865	4914	4971	5040	5119	5208
2560	4864	4881	4930	4987	5056	5135	5224
2624	4879	4895	4944	5001	5070	5149	5238
2688	4892	4907	4956	5013	5082	5161	5250
2752	4904	4918	4967	5024	5093	5172	5261
2816	4914	4927	4976	5033	5102	5181	5270
2880	4922	4934	4983	5040	5109	5188	5277
2944	4928	4939	4988	5045	5114	5193	5282
3008	4932	4942	4991	5049	5118	5197	5286
3072	4935	4944	4993	5052	5121	5200	5289
3136	4937	4945	4994	5055	5124	5203	5292
3200	4938	4945	4994	5056	5125	5204	5293
3264	4938	4944	4993	5055	5124	5203	5292
3328	4937	4942	4991	5054	5123	5202	5291
3392	4935	4939	4988	5046	5115	5194	5283
3456	4931	4934	4983	5042	5111	5190	5279
3520	4925	4927	4976	5037	5106	5185	5274
3584	4917	4918	4967	5028	5097	5176	5265
3648	4907	4907	4956	5018	5087	5166	5255
3712	4895	4894	4943	5007	5076	5155	5244
3776	4881	4879	4928	4994	5063	5142	5231
3840	4865	4862	4911	4978	5047	5126	5215
3904	4847	4843	4892	4961	5030	5109	5198
3968	4827	4822	4871	4940	5009	5088	5177
4032	4805	4800	4849	4918	4987	5066	5155
4096	4781	4775	4824	4893	4962	5041	5130
4160	4755	4748	4797	4866	4935	5014	5103
4224	4727	4719	4768	4837	4906	4985	5074
4288	4698	4689	4738	4807	4876	4955	5044
4352	4667	4657	4706	4775	4844	4923	5012
4416	4634	4623	4672	4741	4810	4889	4978
4480	4599	4587	4636	4705	4774	4853	4942
4544	4562	4549	4598	4667	4736	4815	4904
4608	4523	4510	4559	4628	4697	4776	4865
4672	4482	4468	4517	4586	4655	4734	4823
4736	4439	4424	4473	4542	4611	4690	4779
4800	4393	4377	4426	4495	4564	4643	4732
4864	4345	4328	4377	4446	4515	4594	4683
4928	4295	4277	4326	4395	4464	4543	4632
4992	4243	4224	4273	4342	4411	4490	4579
5056	4189	4169	4218	4287	4356	4435	4524
5120	4132	4111	4160	4229	4298	4377	4466
5184	4073	4051	4100	4169	4238	4317	4406
5248	4011	3988	4037	4106	4175	4254	4343
5312	3947	3923	3972	4041	4110	4189	4278
5376	3881	3856	3905	3974	4043	4122	4211
5440	3813	3787	3836	3905	3974	4053	4142
5504	3743	3716	3765	3834	3903	3982	4071
5568	3671	3643	3692	3761	3830	3909	3998
5632	3597	3568	3617	3686	3755	3834	3923
5696	3521	3491	3540	3609	3678	3757	3846
5760	3443	3412	3461	3530	3600	3679	3768
5824	3363	3331	3380	3449	3518	3597	3686
5888	3281	3248	3297	3366	3435	3514	3603
5952	3197	3163	3212	3281	3350	3429	3518
6016	3111	3076	3125	3194	3263	3342	3431
6080	3023	2987	3036	3105	3174	3253	3342
6144	2933	2896	2945	3014	3083	3162	3251
6208	2841	2803	2852	2921	2990	3069	3158
6272	2747	2708	2757	2826	2895	2974	3063
6336	2651	2611	2660	2729	2798	2877	2966
6400	2553	2512	2561	2630	2700	2779	2868
6464	2453	2411	2460	2529	2598	2677	2766
6528	2351	2308	2357	2426	2495	2574	2663
6592	2247	2203	2252	2321	2390	2469	2558
6656	2141	2096	2145	2214	2283	2362	2451
6720	2033	1987	2036	2105	2174	2253	2342
6784	1923	1876	1925	1994	2063	2142	2231

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	6468	6479	6510	6562	6632	6721	6826
7104	6485	6495	6526	6578	6648	6737	6842
7168	6501	6511	6542	6594	6664	6753	6858
7232	6517	6526	6557	6609	6679	6768	6873
7296	6532	6542	6573	6624	6694	6783	6888
7360	6548	6557	6588	6640	6710	6800	6905
7424	6563	6572	6603	6655	6725	6814	6919
7488	6578	6588	6619	6671	6741	6830	6935
7552	6593	6603	6634	6686	6756	6845	6950
7616	6609	6618	6649	6701	6771	6860	6965
7680	6624	6633	6664	6716	6786	6875	6980
7744	6639	6648	6679	6731	6801	6890	6995
7808	6654	6663	6694	6746	6816	6905	7010
7872	6669	6677	6708	6760	6830	6919	7024
7936	6683	6692	6723	6775	6845	6934	7039
8000	6698	6707	6737	6789	6859	6948	7053
8064	6712	6721	6752	6804	6874	6963	7068
8128	6727	6735	6766	6818	6888	6977	7082
8192	6741	6750	6781	6833	6903	6992	7097
8256	6756	6764	6795	6847	6917	7006	7111
8320	6770	6778	6809	6861	6931	70	

14 Order Code Chart

HTPA16x16d	R2	L1.0/0.8	F5.0	Hi	A	(USB)
HTPA16x16d	R2	L1.0/0.8	F5.0	Hi	A	(UDP)
HTPA16x16d	R2	L1.0/0.8	F5.0	Hi	M	(UDP)
HTPA16x16d	R2	L1.0/0.8	F5.0	Hi	C	
HTPA16x16d	R2	L1.6/0.8	F5.0	Hi	A	(USB)
HTPA16x16d	R2	L1.6/0.8	F5.0	Hi	A	(UDP)
HTPA16x16d	R2	L1.6/0.8	F5.0	Hi	M	(UDP)
HTPA16x16d	R2	L1.6/0.8	F5.0	Hi	C	
HTPA16x16d	R2	L2.1/0.8	F5.0	Hi	A	(USB)
HTPA16x16d	R2	L2.1/0.8	F5.0	Hi	A	(UDP)
HTPA16x16d	R2	L2.1/0.8	F5.0	Hi	M	(UDP)
HTPA16x16d	R2	L2.1/0.8	F5.0	Hi	C	
HTPA16x16d	R2	L5.0/1.0	F7.7	Hi	A	(USB)
HTPA16x16d	R2	L5.0/1.0	F7.7	Hi	A	(UDP)
HTPA16x16d	R2	L5.0/1.0	F7.7	Hi	M	(UDP)
HTPA16x16d	R2	L5.0/1.0	F7.7	Hi	C	

Bold: Selectable options

Regular: Fixed/Not selectable

15 Outer Dimension

