

HTPA16x16dR3L1.0/0.8F5.0

Datasheet for Thermopile Array Sensor with Lens Optic

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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.

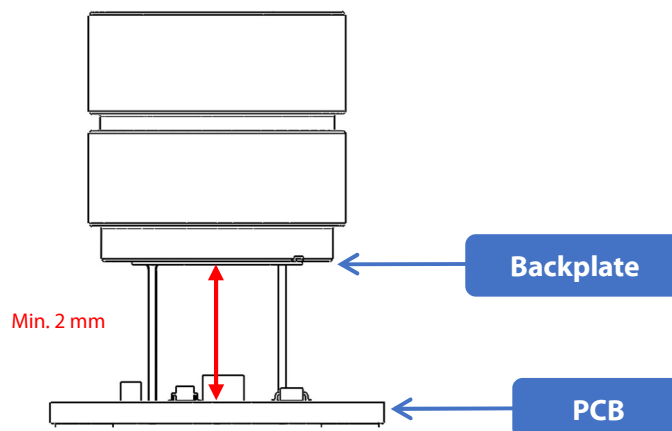


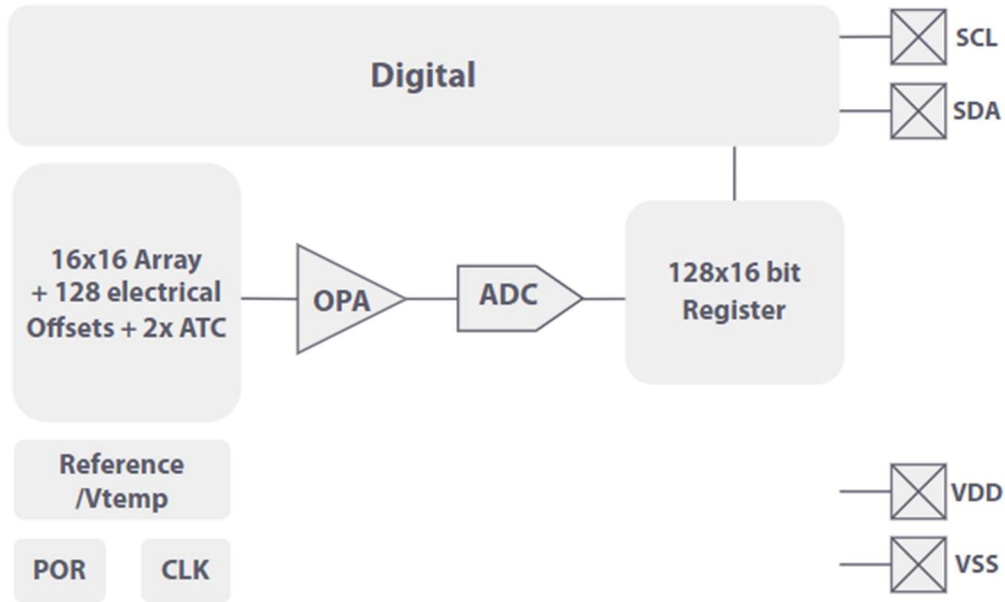
Figure 1: Soldering height

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

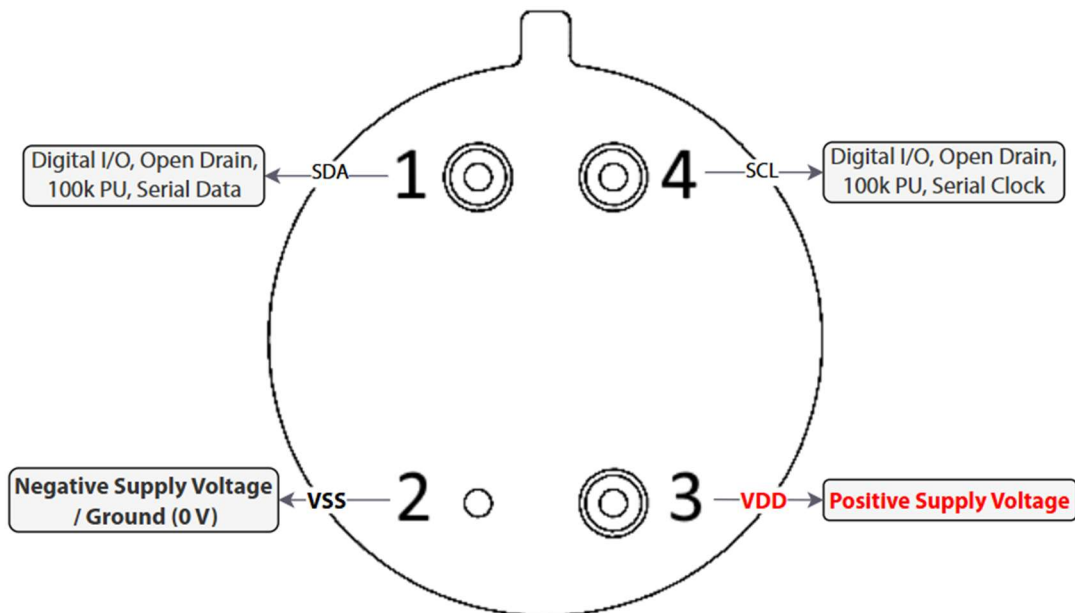
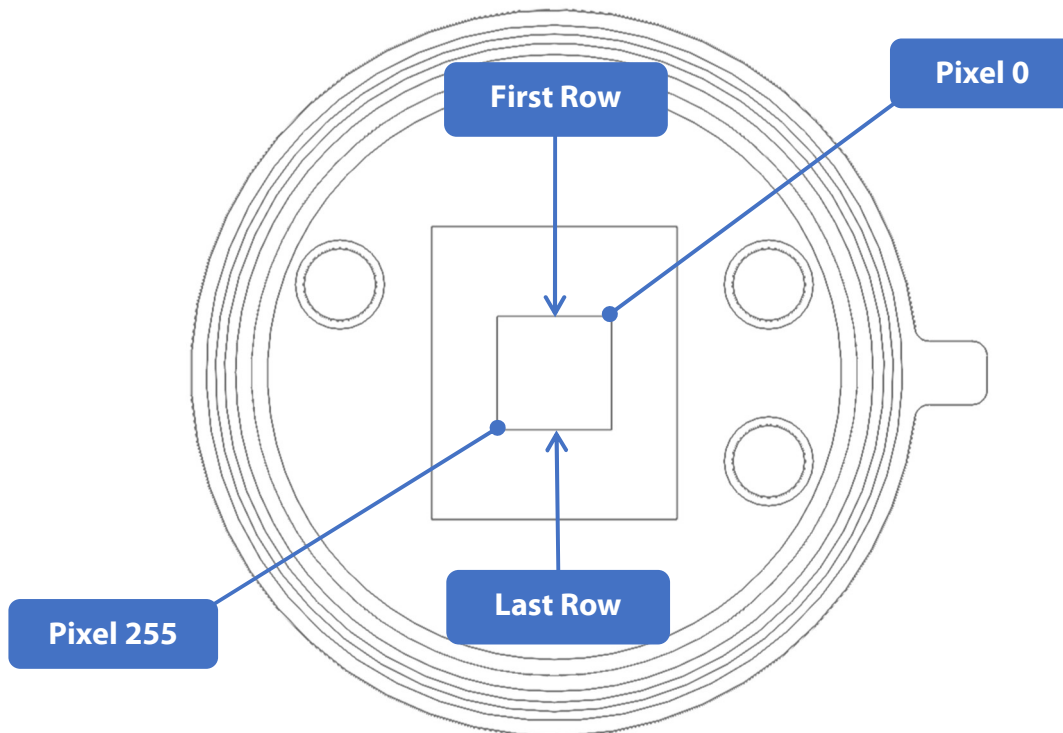
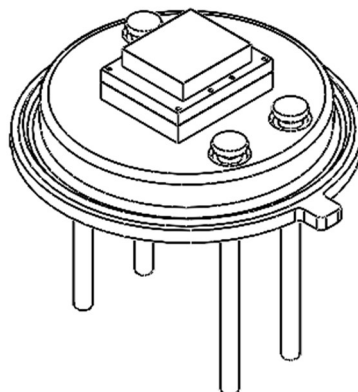


Figure 2: Pin-allocation

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 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) *** 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.

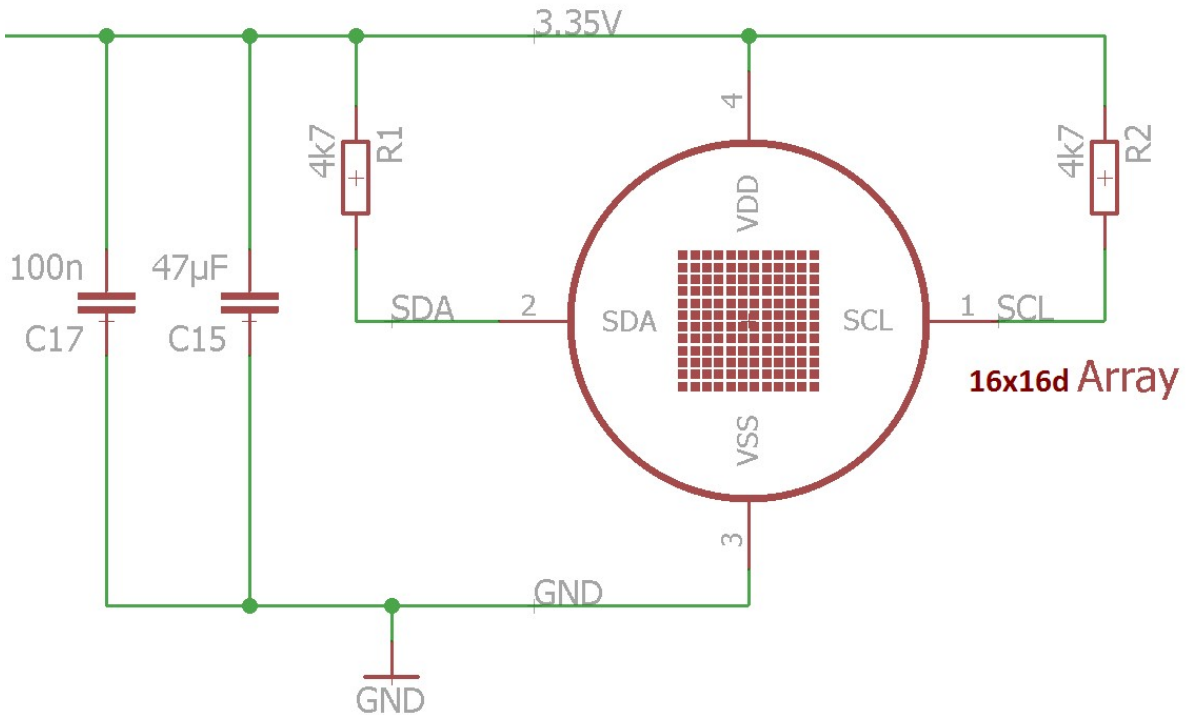


Figure 3: Recommended circuit for operation

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

readout order top

readout order bottom

Figure 6: 16x16d readout order for electrical offset

8 Characteristics

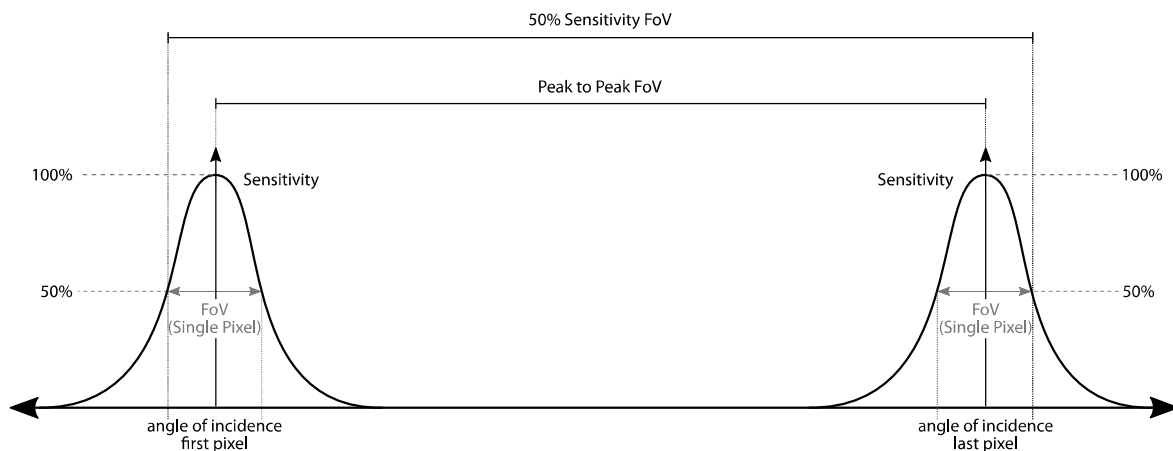
8.1 Common Specifications

Technology:	n-poly/p-poly Si
Element Resistance:	approx. 300 kOhms
Thermal pixel time constant:	<4 ms
Digital Interface:	I ² C
EEPROM size:	1024x 16 Bit
Pitch:	90 µm
Absorber size:	44 µm
Max. Framerate:	120 Hz
Max. measurable temperature:	200°C with default settings 400°C with RefCal0

(complete frame with maximum I²C and sensor clock speed and reduced ADC resolution)
256 sensitive elements

8.2 Optical Characteristics

Focal length:	1.0 mm ("L" equals the focal length of the lens)
F-Number:	0.8
Field of view:	≥90 x 90 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
-----------	-------------------------------------------------------------------------------------------------------------------------------

The radiometric radius is specified for pixels listed below with a "1". All pixels outside this area can have a higher tolerance and less accuracy.

0	0	0	0	1	1	1	1	1	1	1	1	1	0	0	0	0
0	0	0	1	1	1	1	1	1	1	1	1	1	1	0	0	0
0	0	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0
0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0
1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0
0	0	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0
0	0	0	1	1	1	1	1	1	1	1	1	1	0	0	0	0
0	0	0	0	1	1	1	1	1	1	1	1	1	0	0	0	0

Figure 7: Radiometric radius in a matrix of 16x16 pixels

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	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

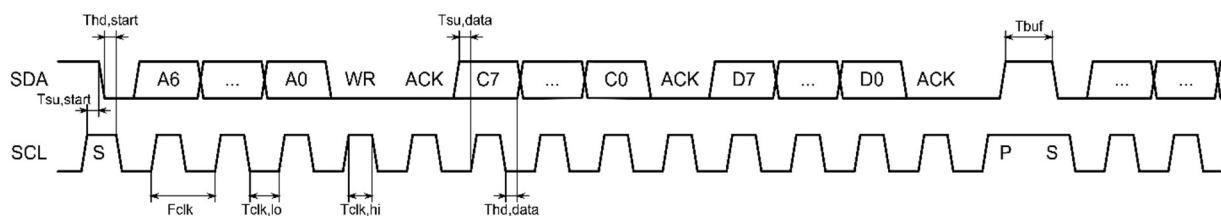


Figure 8: I²C Timings of HTPA16x16d

Table 5: I²C Timings

Parameter	Symbol	Condition	MIN.	TYP.	MAX.	Unit
I ² C 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.

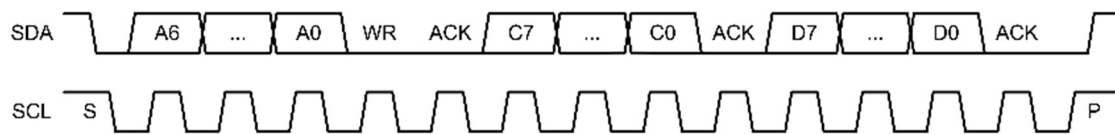


Figure 9: Write Command

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.

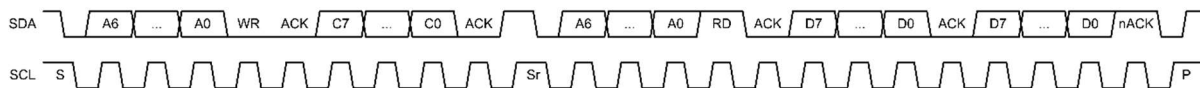


Figure 10: Read Command

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:

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

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:

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

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	PixCmp (float)		PixCmp (float)						gradScale	GlobalGain			TN	epsilon	nrOfsePix/Max	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) [unsg]	PTAT (Th2) [unsg]		
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															
100	Th1j / Gradj stored as 16 bit signed values															
1F0	Th2j / Offsetj stored as 16 bit signed values															
200	Th2j / Offsetj stored as 16 bit signed values															
2F0	Pj stored as 16 bit unsigned values															
300	Pj stored as 16 bit unsigned values															
3F0	Pj 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:

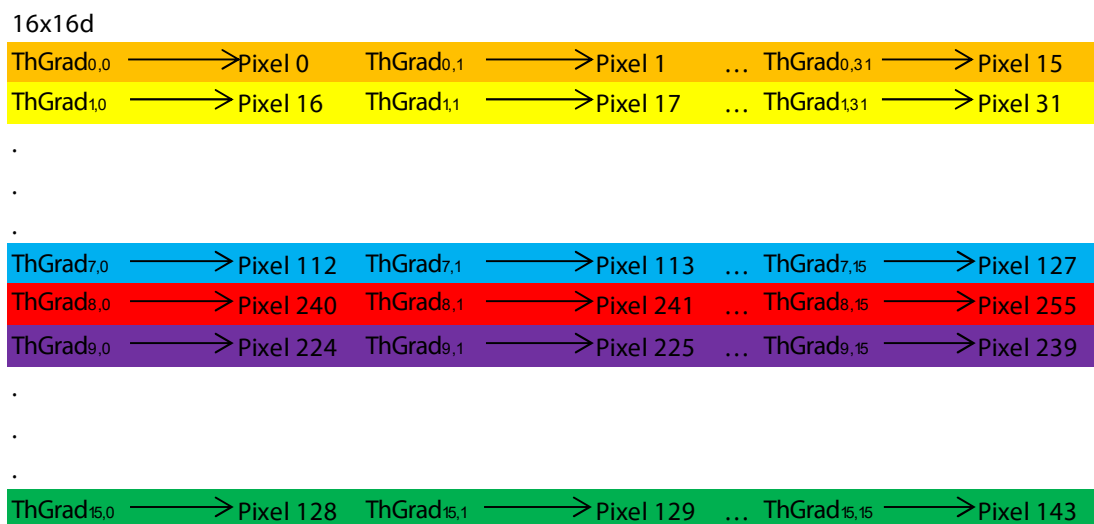


Figure 11: Readout Order 16x16d

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.



Figure 12: 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:

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

$$V_{ijVDDComp} = V_{ijComp}^*$$

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

And the bottom half analogue with this formula:

$$V_{ijVDDComp} = V_{ijComp}^*$$

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

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
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

Example values:

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

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

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

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

$$elOffset[0] = 34240$$

$$gradScale = 17$$

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

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

$$VDD_{av} = 35000$$

$$VDD_{TH} = 33942$$

$$VDD_{TH} = 36942$$

$$PTAT_{TH1} = 30000$$

$$PTAT_{TH2} = 42000$$

$$VddCompGrad[0] = 10356 \rightarrow \text{signcheck } 10356$$

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

$$VddScGrad = 16$$

$$VddScOff = 23$$

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

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

Calculation of ambient temperature:

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

Compensation of thermal offset:

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

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.

HTPA16x16dR3L1.0/0.8F5.0

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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					2324	2482	2634
-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	2754	2865	2972	3078	3182	3285
0	2762	2862	2962	3062	3162	3262	3372
64	2936	2996	3096	3196	3276	3373	3473
128	3016	3101	3187	3276	3368	3465	3568
192	3121	3197	3276	3363	3452	3544	3638
256	3216	3286	3363	3445	3531	3621	3715
320	3305	3370	3443	3522	3606	3695	3777
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	4222	4257	4306	4365	4435	4514	4603
1344	4268	4302	4350	4409	4478	4557	4647
1408	4312	4345	4391	4450	4520	4600	4689
1472	4355	4388	4433	4492	4561	4641	4730
1536	4396	4429	4474	4532	4601	4681	4770
1600	4436	4470	4514	4571	4640	4720	4809
1664	4474	4507	4551	4607	4676	4756	4845
1728	4510	4542	4585	4641	4710	4790	4876
1792	4545	4576	4619	4675	4744	4824	4905
1856	4579	4609	4651	4707	4776	4856	4937
1920	4612	4641	4682	4738	4807	4887	4969
1984	4644	4672	4713	4769	4838	4918	5000
2048	4675	4702	4742	4798	4867	4947	5029
2112	4704	4731	4771	4827	4896	4976	5058
2176	4732	4758	4798	4854	4923	5003	5085
2240	4759	4784	4824	4880	4949	5029	5111
2304	4784	4809	4849	4905	4974	5054	5136
2368	4808	4832	4872	4928	4997	5077	5159
2432	4831	4855	4895	4951	5020	5100	5182
2496	4853	4877	4917	4973	5042	5122	5204
2560	4874	4898	4938	4994	5063	5143	5225
2624	4895	4919	4959	5015	5084	5164	5246
2688	4915	4939	4979	5035	5104	5184	5267
2752	4934	4958	4998	5054	5123	5203	5288
2816	4952	4976	5016	5072	5141	5221	5302
2880	4969	4993	5033	5089	5158	5238	5319
2944	4985	5009	5049	5105	5174	5254	5336
3008	5000	5024	5064	5120	5189	5269	5353
3072	5014	5038	5078	5134	5203	5283	5370
3136	5027	5051	5091	5147	5216	5296	5387
3200	5039	5063	5103	5159	5228	5308	5395
3264	5050	5074	5114	5170	5239	5319	5406
3328	5060	5084	5124	5180	5249	5329	5413
3392	5069	5093	5133	5189	5258	5338	5420
3456	5077	5101	5141	5197	5267	5347	5427
3520	5085	5109	5149	5205	5274	5354	5434
3584	5092	5116	5156	5212	5281	5361	5441
3648	5098	5122	5162	5218	5287	5367	5448
3712	5103	5127	5167	5223	5292	5372	5455
3776	5107	5131	5171	5227	5296	5376	5462
3840	5111	5135	5175	5231	5300	5380	5469
3904	5114	5138	5178	5234	5303	5383	5476
3968	5117	5141	5181	5237	5306	5386	5483
4032	5119	5143	5183	5239	5308	5388	5490
4096	5121	5145	5185	5241	5310	5390	5497
4160	5122	5146	5186	5242	5311	5391	5504
4224	5123	5147	5187	5243	5312	5392	5511
4288	5124	5148	5188	5244	5313	5393	5518
4352	5124	5148	5188	5244	5313	5393	5525
4416	5124	5148	5188	5244	5313	5393	5532
4480	5124	5148	5188	5244	5313	5393	5539
4544	5124	5148	5188	5244	5313	5393	5546
4608	5124	5148	5188	5244	5313	5393	5553
4672	5124	5148	5188	5244	5313	5393	5560
4736	5124	5148	5188	5244	5313	5393	5567
4800	5124	5148	5188	5244	5313	5393	5574
4864	5124	5148	5188	5244	5313	5393	5581
4928	5124	5148	5188	5244	5313	5393	5588
4992	5124	5148	5188	5244	5313	5393	5595
5056	5124	5148	5188	5244	5313	5393	5602
5120	5124	5148	5188	5244	5313	5393	5609
5184	5124	5148	5188	5244	5313	5393	5616
5248	5124	5148	5188	5244	5313	5393	5623
5312	5124	5148	5188	5244	5313	5393	5630
5376	5124	5148	5188	5244	5313	5393	5637
5440	5124	5148	5188	5244	5313	5393	5644
5504	5124	5148	5188	5244	5313	5393	5651
5568	5124	5148	5188	5244	5313	5393	5658
5632	5124	5148	5188	5244	5313	5393	5665
5696	5124	5148	5188	5244	5313	5393	5672
5760	5124	5148	5188	5244	5313	5393	5679
5824	5124	5148	5188	5244	5313	5393	5686
5888	5124	5148	5188	5244	5313	5393	5693
5952	5124	5148	5188	5244	5313	5393	5700
6016	5124	5148	5188	5244	5313	5393	5707
6080	5124	5148	5188	5244	5313	5393	5714
6144	5124	5148	5188	5244	5313	5393	5721
6208	5124	5148	5188	5244	5313	5393	5728
6272	5124	5148	5188	5244	5313	5393	5735
6336	5124	5148	5188	5244	5313	5393	5742
6400	5124	5148	5188	5244	5313	5393	5749
6464	5124	5148	5188	5244	5313	5393	5756
6528	5124	5148	5188	5244	5313	5393	5763
6592	5124	5148	5188	5244	5313	5393	5770
6656	5124	5148	5188	5244	5313	5393	5777
6720	5124	5148	5188	5244	5313	5393	5784
6784	5124	5148	5188	5244	5313	5393	5791

6848	5421	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	6874
7296	6532	6542	6573	6624	6694	6783	6888
7360	6548	6557	6588	6640	6710	6800	6905
7424	6563	6572	6603	6655	6725	6814	6920
7488	6578	6588	6619	6670	6740	6830	6935
7552	6593	6603	6634	6685	6755	6845	6950
7616	6609	6618	6649	6700	6770	6860	6965
7680	6624	6633	6664	6715	6785	6875	6980
7744	6639	6648	6679	6730	6800	6890	6995
7808	6654	6663	6694	6745	6815	6905	7010
7872	6669	6677	6708	6759	6829	6919	7025
7936	6683	6692	6723	6774	6844	6934	7040
8000	6698	6707	6737	6788	6858	6948	7055
8064	6712	6721	6752	6803	6873	6963	7070
8128	6727	6735	6766	6817	6887	6977	7085
8192	6741	6750	6781	6832	6902	6992	7095
8256	6756	6764	6795	6846	6916	7006	7105
8320	6770	6778	6809	6860	6930	7020	7110
8384	6784	6792	6823	6874	6944	7034	7115
8448	6798	6806	6837	6888	6958	7048	7120
8512	6812	6820	6851	6902	6972	7062	7125
8576	6826	6834	6865	6916	6986	7076	7130
8640	6840	6848	6879	6930	7000	7090	7135
8704	6854	6862	6893	6944	7014	7104	7140
8768	6868	6876	6907	6958	7028	7118	7145
8832	6881	6889	6920	6971	7041	7131	7150
8896	6895	6903	6934	6985	7055	7145	7155
8960	6908	6916	6947	7000	7070	7160	7160
9024	6922	6930	6961	7012	7082	7172	7165
9088	6935	6943	6974	7025	7095	7185	7170
9152	6949	6957	6988	7039	7110	7200	7175
9216	6962	6970	7001	7052	7122	7212	7180
9280	6975	6983	7014	7065	7135	7225	7185
9344	6988	6996	7027	7078	7148	7238	7190
9408	7001	7009	7040	7091	7161	7251	7195
9472	7015	7022	7053	7104	7174	726	

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:

$NrOfDefPix = 0x01$
 $DeadPixAdr[0] = 0x000A \rightarrow$ Pixel 10
 $DeadPixMask[0] = 0x7C \rightarrow 0b0111\ 1100$ (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:

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

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:

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

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

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

