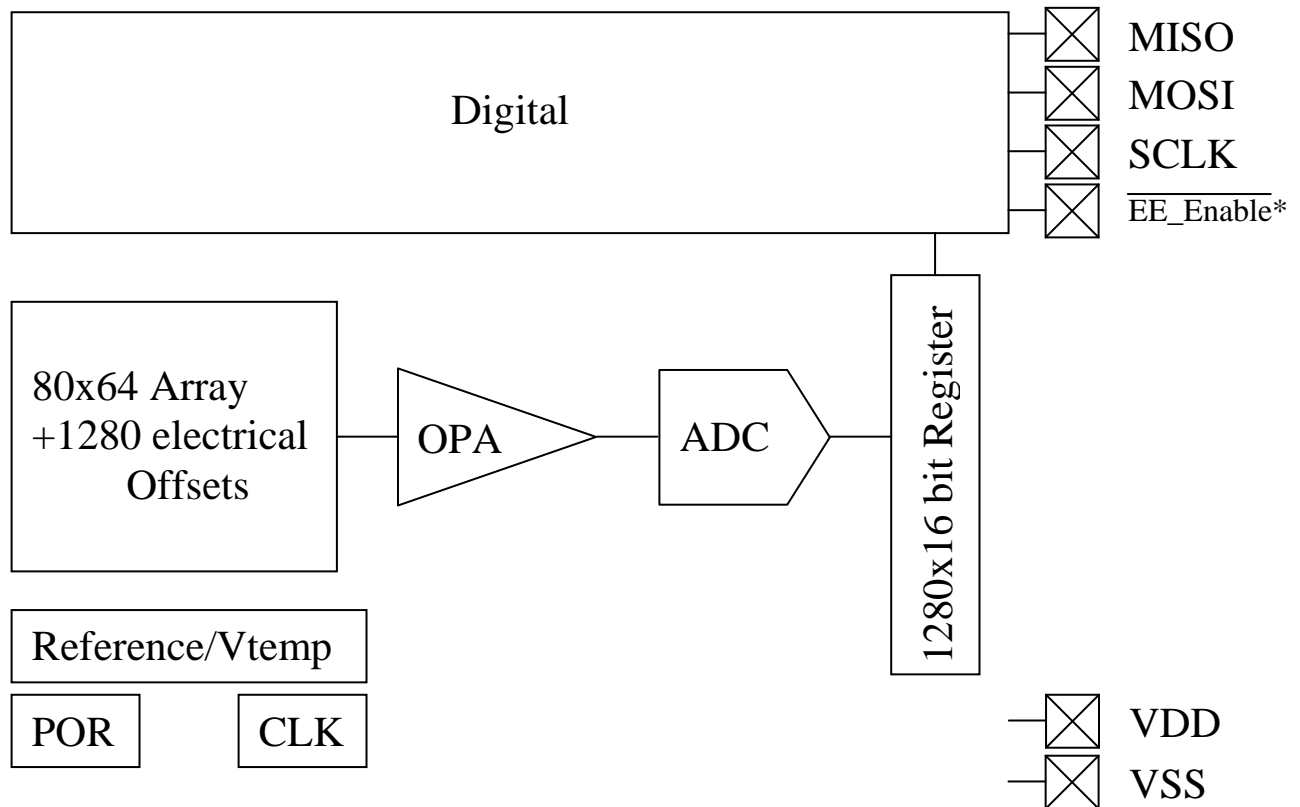
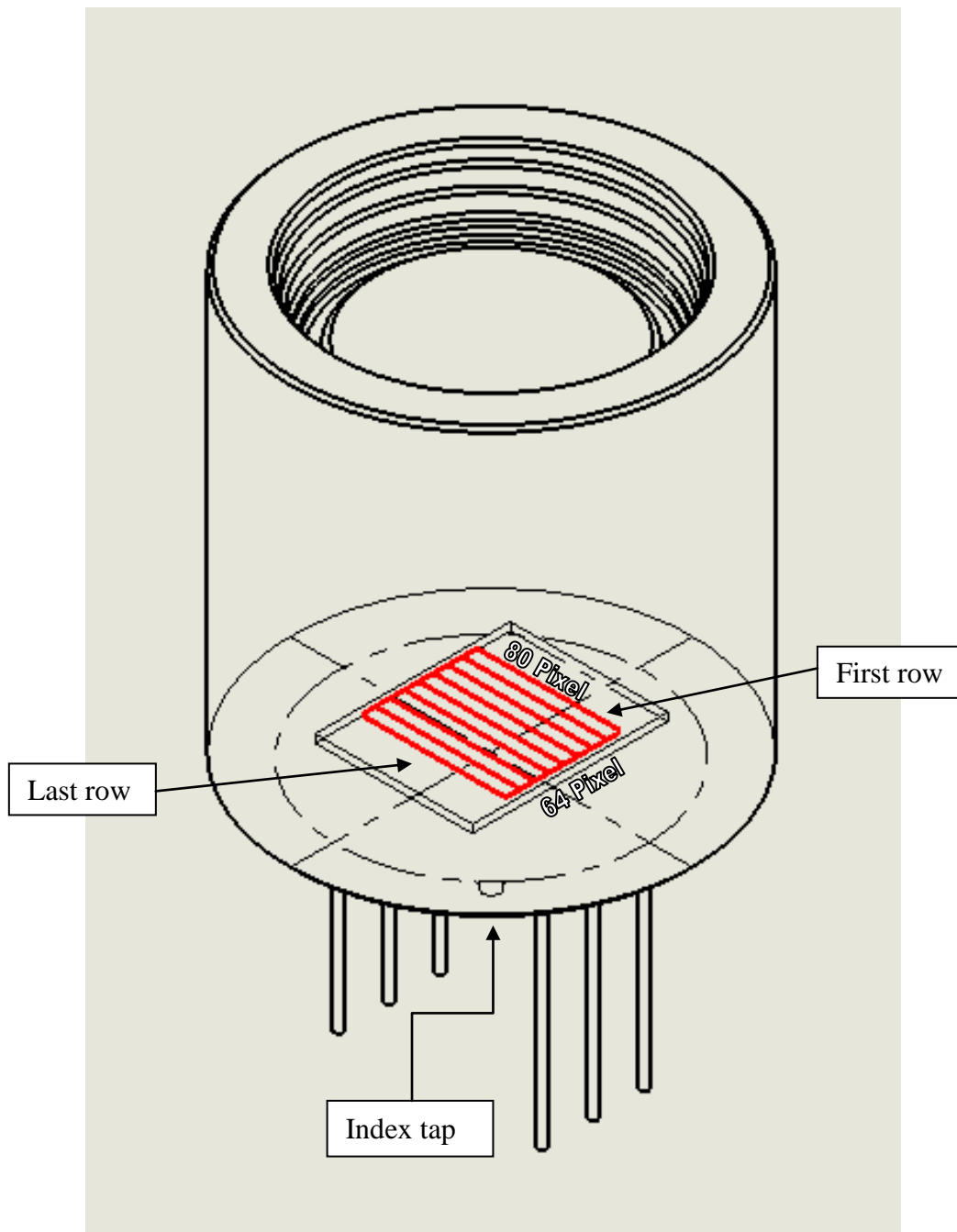


1 Principal Schematic for HTPA80x64d:



* EE_Enable : The slave select is used to switch communication between sensor and EEPROM.

2 Optical Orientation:

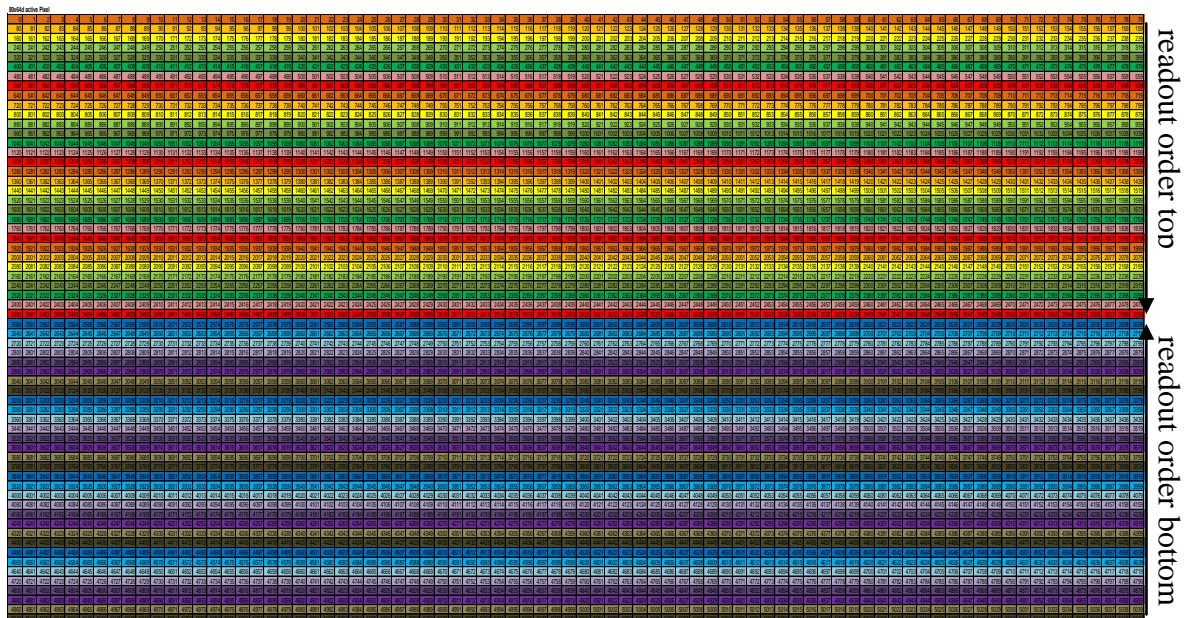


4 Serial Order of Frame

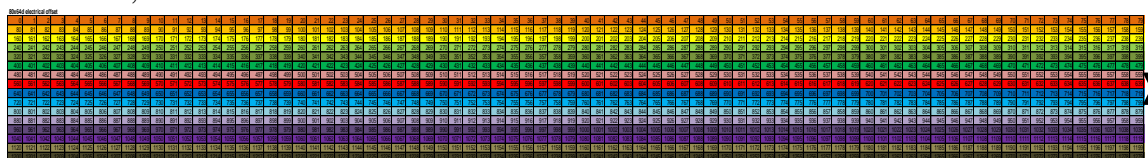
The sensor is divided into two parts (top and bottom half) which are again separated into 4 blocks. The readout order is shown below for the different blocks.

Block 0 (top)
Block 1 (top)
Block 2 (top)
Block 3 (top)
Block 3 (bottom)
Block 2 (bottom)
Block 1 (bottom)
Block 0 (bottom)

Whenever a conversion is started the block x of the top and bottom half are measured at the same time. Each block consists of 640 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.



The electrical offsets are sampled according to 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 setting the BLIND bit during the start command, see 7.3.



5 Characteristics:

5.1 Common Specifications:

Technology	n-poly/p-poly Si
Element Resistance	approx. 300 kOhms
Sensitivity	approx. 450 V/W without optics and filter
Thermal pixel time constant	<4 ms
Digital Interface	SPI
Analog Output	No
selectable Clock	1 to 13 MHz
EEPROM size	256 kBit

Pitch 90 µm

Absorber size 44 µm

Max. Framerate 200 Hz

(complete frame with maximum SPI and sensor clock speed and reduced ADC resolution)

5120 sensitive elements

5.2 Optical characteristics:

Focal length: 10.5 mm ("L" equals the focal length of the lens)

F-Number: 0.95

Field of view: 39 x 31 deg

Lens coating: LWP-Coating 7.7

Cut On (Tr. 5%): 7.7 µm ± 0.3 µm

5.3 Electric Specifications:

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

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}		20	25	30	mA
Supply Current (sensor in idle state)	I _{DD}		tbd	tbd	tbd	mA
Standby Current (sensor in sleep state)	I _{SBY}		tbd	tbd	10	μA
Operation Temperature	T _A		-20		65	Deg. C
ESD-Protection		Human body model	2.0			kV
		100pF + 1k50hm				

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	174	tbd	K/V

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Thermopile Array With Lens Optics

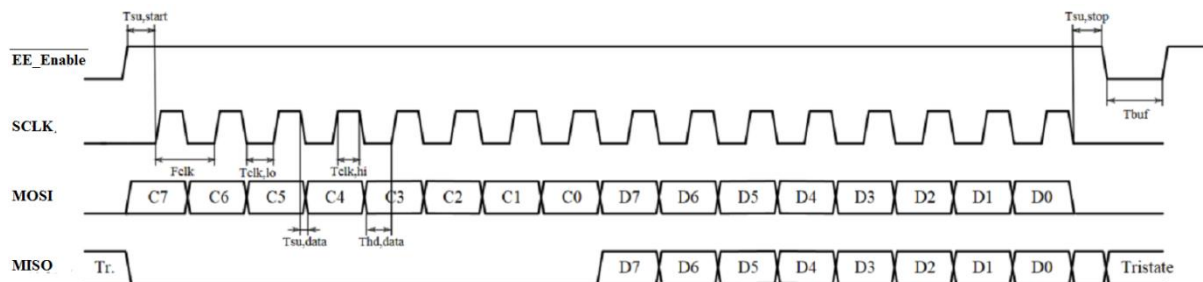
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Preamplifier / ADC

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		1.8	8.9	21.9	Hz
Frame rate (Quarter Array)	FR4		7.2	35.6	87.6	HZ
ADC pos. Reference	V_{REFP}	REF_CAL 00		1.529		V
		REF_CAL 01		1.442		
		REF_CAL 10		1.355		
		REF_CAL 11		1.268		
ADC neg. Reference	V_{REFN}	REF_CAL 00		0.850		V
		REF_CAL 01		0.901		
		REF_CAL 10		0.968		
		REF_CAL 11		1.056		
ADC resolution	ADC_{LSB}	at 16 Bit	6.5		20.7	μV

6 SPI Timings HTPA80x64d:



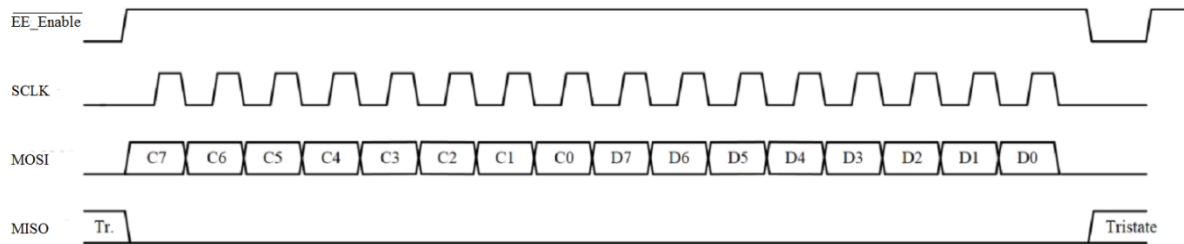
Parameter	Symbol	MIN.	TYP.	MAX.	Unit
SPI clock frequency	F_{CLK}		10		MHz
low pulse duration	$T_{\text{CLK,lo}}$	30			ns
high pulse duration	$T_{\text{CLK,hi}}$	40			ns
data set up time	$T_{\text{SU,data}}$	30			ns
data hold time	$T_{\text{hd,data}}$	10			ns
start setup time	$T_{\text{SU,start}}$	50			ns
stop setup time	$T_{\text{SU,stop}}$	50			ns
Time between STOP/ START	T_{buf}	200			ns

7 SPI Communication:

The chip uses the 8-bit command for accessing configuration and sensor data.

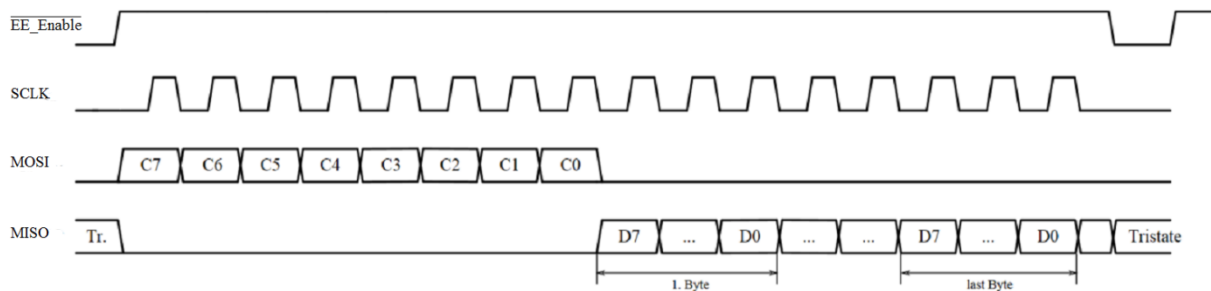
7.1 Write Command:

In case of a write access to an internal register the command is followed by the data byte.



7.2 Read Command:

To read data from the chip first the read command must be sent. The command initiates the read sequence and the first bit of read bytes will be set on MISO with falling edge of SCLK after last command bit. There can be as many byte reads as required.



7.3 Sensor Commands:

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

Configuration register (write only)

Addr / CMD	0x1A (7 Bit!) / 0x01							
Config Reg	7	6	5	4	3	2	1	0
Name	RFU		BLOCK		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. The BLOCK selects one of the four multiplexed array blocks.

If the BLIND bit is set the electrical offsets are sampled instead of the active pixel and the setting of the BLOCK is ignored.

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.

Status Register (read only)

Addr / CMD	0x1A (7 Bit!) / 0x02							
Status Reg	7	6	5	4	3	2	1	0
Name	RFU		BLOCK		RFU	VDD_MEAS	BLIND	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		REF_CAL		MBIT TRIM			
Default	0	0	0	1	1	1	0	0

REF_CAL: selectable amplification, see **Fehler! Verweisquelle konnte nicht gefunden werden.** for more detail

MBIT_TRIM: $m = 4$ to $12 \Rightarrow (m+4)$ bit as ADC resolution (Default: $m=12$)

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				
Default	0	0	0	0	0	1	0	1

BIAS_TRIM_TOP: 0 to 31 $\Rightarrow 1\mu\text{A}$ to $13\mu\text{A}$ (Default: $3\mu\text{A}$)

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				
Default	0	0	0	0	0	1	0	1

BIAS_TRIM_BOT: 0 to 31 $\Rightarrow 1\mu\text{A}$ to $13\mu\text{A}$ (Default: $3\mu\text{A}$)

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				
Default	0	0	0	1	0	1	0	1

CLK_TRIM: 0 to 63 $\Rightarrow 1\text{MHz}$ to 13MHz (Default: 5MHz)

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

$$t_{FR4} = \frac{32 \cdot (2^{MBIT} + 4)}{F_{CLK}} \approx 27\text{ms} @ 5\text{MHz}$$

Trim Register 5 (write only)

Addr / CMD	0x1A (7 Bit!) / 0x07							
Trim Reg 5	7	6	5	4	3	2	1	0
Name	RFU			BPA TRIM TOP				
Default	0	0	0	0	1	1	0	0

BPA_TRIM_TOP: 0 to 31 $\Rightarrow 0.2\mu\text{A}$ to $4.0\mu\text{A}$ (Default: $1.5\mu\text{A}$)

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				BPA TRIM BOT			
Default	0	0	0	0	1	1	0	0

BPA_TRIM_BOT: 0 to 31 \Rightarrow 0.2 μ A to 4.0 μ A (Default: 1.5 μ A)

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			
Default	1	0	0	0	1	0	0	0

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

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

“1000” = 100 kOhm; “0100” = 50 kOhm; “0010” = 10 kOhm; “0001” = 1 kOhm

Read Data 1 Command (Top Half of Array)

CMD	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*640) MSB / LSB							
5. Byte / 6. Byte	Pixel (1+BLOCK*640) MSB / LSB							
...	...							
1281. Byte / 1282. Byte	Pixel (127+BLOCK*640) MSB / LSB							

Read Data 2 Command (Bottom Half of Array)

CMD	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 (5040-BLOCK*640) MSB / LSB							
5. Byte / 6. Byte	Pixel (5041-BLOCK*640) MSB / LSB							
...								
161. Byte / 162. Byte	Pixel (5119-BLOCK*640) MSB / LSB							
163. Byte / 164. Byte	Pixel (4960-BLOCK*640) MSB / LSB							
165. Byte / 166. Byte	Pixel (4961-BLOCK*640) MSB / LSB							
...								
321. Byte / 322. Byte	Pixel (5039-BLOCK*640) MSB / LSB							
323. Byte / 324. Byte	Pixel (4880-BLOCK*640) MSB / LSB							
...								
1281. Byte / 1282. Byte	Pixel (4559-BLOCK*640) 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. A new initialized readout proceeds at this stopped byte, but the index is reset when a new conversion has been started.

If the VDD_MEAS bit (Bit 2 in Config 0x01) is set then the Vdd is sampled instead of the PTAT.

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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)

CMD	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	electrical offset (0) MSB / LSB							
5. Byte / 6. Byte	electrical offset (1) MSB / LSB							
...	...							
1281. Byte / 1282. Byte	electrical offset (639) MSB / LSB							

Read Data electrical offsets (Bottom Half of Array)

CMD	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 (640) MSB / LSB							
5. Byte / 6. Byte	electrical offset (641) MSB / LSB							
...	...							
1281. Byte / 1282. Byte	electrical offset (1279) 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. A new initialized readout proceeds at this stopped byte, but the index is reset when a new conversion has been started.

7.4 EEPROM communication

The built-in EEPROM (25AA256 from Microchip) consists of 32 blocks of 1K x 8-bit. The chip select of the EEPROM is set to 000 (A2 to A0). For further information please see the corresponding datasheet:

<http://ww1.microchip.com/downloads/en/DeviceDoc/21822D.pdf>

7.5 SPI Example Sequences – Init and Read Thermopile Array

CONFIG_REG	WAKEUP
0x01	0x01

TRIM_REG1	MBIT_TRIM
0x03	0x0C

TRIM_REG2	BIAS_TRIML
0x04	0x0C

TRIM_REG3	BIAS_TRIMR
0x05	0x0C

TRIM_REG4	CLK_TRIM
0x06	0x14

TRIM_REG5	BPA_TRIML
0x07	0x0C

TRIM_REG6	BPA_TRIMR
0x08	0x0C

CONFIG_REG	START WAKEUP
0x01	0x09

STATUS_REG	STATUS
0x02	??

WAIT 30ms

STATUS_REG	STATUS
0x02	??

READ_DATA 1	PTAT1 MSB	PTAT1 LSB	P0,0 MSB	P0,0 LSB	...	Px,y MSB	Px,y LSB
0x0A	??	??	??	??	...	??	??

READ_DATA 2	PTAT2 MSB	PTAT2 LSB	P0,0 MSB	P0,0 LSB	...	Px,y MSB	Px,y LSB
0x0B	??	??	??	??	...	??	??

CONFIG_REG	SLEEP
0x01	0x00

8 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.

0x064d	0x00	0x01	0x02	0x03	0x04	0x05	0x06	0x07	0x08	0x09	0x0A	0x0B	0x0C	0x0D	0x0E	0x0F
0x0000	PixCmin (float)				PixCmax (float)				gradScale			TN as 16 bit unsigned	epsilon			
0x0010											MBIT(calib)	BIAS(calib)	CLK(calib)	BPA(calib)	PU(calib)	
0x0020			Arraytype				VddCalib									
0x0030					PTAT-gradient (float)				PTAT-offset (float)							
0x0040															VddScGrad	VddScOff
0x0050					GlobalOff	GlobalGain										
0x0060	MBIT(user)	BIAS(user)	CLK(user)	BPA(user)	PU(user)											
0x0070					DeviceID											NrOfDefPix
0x0080	DeadPixAdr as 16 bit unsigned values															
0x0090																
0x00A0																
0x00B0	DeadPixMask															
0x00C0	DeadPixMask								free to use							
...	free to use															
...																
0x0800	VddCompGrad stored as 16 bit sigend values															
...																
0x11F0																
0x1200	VddCompOff stored as 16 bit sigend values															
...																
0x1BF0																
0x1C00	ThGrad _{ij} stored as 8 bit signed values															
...																
0x2FF0																
0x3000	ThOffset _{ij} stored as 16 bit signed values															
...																
0x57F0																
0x5800	P _i stored as 16 bit unsigned values															
...																
0x7FF0																

All values are stored as unsigned 8 bit values unless they are specified otherwise. The little endian format is used for larger values. 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 7.3 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 tablenumber and has to match the given tablenumber in the sample code.

GlobalOff is stored as an 8 bit signed value, GlobalGain and VddCalib are both stored as 16 bit unsigned.

VddCalib 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 Pixelnumber is given by the following overview:

ThGrad _{0,0} → Pixel 0	ThGrad _{0,1} → Pixel 1	...	ThGrad _{0,79} → Pixel 79
ThGrad _{1,0} → Pixel 80	ThGrad _{1,1} → Pixel 81	...	ThGrad _{1,79} → Pixel 179
...			
...			
...			
ThGrad _{31,0} → Pixel 2480	ThGrad _{31,1} → Pixel 2481	...	ThGrad _{31,79} → Pixel 2559
ThGrad _{32,0} → Pixel 5040	ThGrad _{32,1} → Pixel 5041	...	ThGrad _{32,79} → Pixel 5119
ThGrad _{33,0} → Pixel 4960	ThGrad _{33,1} → Pixel 4961	...	ThGrad _{33,79} → Pixel 5039
...			
...			
...			
ThGrad _{63,0} → Pixel 2560	ThGrad _{63,1} → Pixel 2561	...	ThGrad _{63,79} → Pixel 2639

The order of $VddCompGrad_{ij}$ and $VddCompOff_{ij}$ is similar to the electrical Offsets and have to be used block by block.

VddCompGrad _{0,0} → Pixel 0	VddCompGrad _{0,1} → Pixel 1	...	VddCompGrad _{0,79} → Pixel 79
VddCompGrad _{1,0} → Pixel 80	VddCompGrad _{1,1} → Pixel 81	...	VddCompGrad _{1,79} → Pixel 159
...			
VddCompGrad _{0,0} → Pixel 640	VddCompGrad _{0,1} → Pixel 641	...	VddCompGrad _{0,79} → Pixel 719
...			
...			
VddCompGrad _{7,0} → Pixel 2480	VddCompGrad _{7,1} → Pixel 2481	...	VddCompGrad _{7,79} → Pixel 2559
VddCompGrad _{8,0} → Pixel 5040	VddCompGrad _{8,1} → Pixel 5041	...	VddCompGrad _{8,79} → Pixel 5119
VddCompGrad _{9,0} → Pixel 4960	VddCompGrad _{9,1} → Pixel 4961	...	VddCompGrad _{9,79} → Pixel 5039
...			
...			
VddCompGrad _{8,0} → Pixel 4400	VddCompGrad _{8,1} → Pixel 4401	...	VddCompGrad _{8,79} → Pixel 4479
...			
...			
VddCompGrad _{15,0} → Pixel 2560	VddCompGrad _{15,1} → Pixel 2561	...	VddCompGrad _{15,79} → Pixel 2639

top half

bottom half

8.1 Ambient Temperature:

The ambient temperature (T_a) is calculated from the average measured PTAT value, the $PTAT_{gradient}$ and the $PTAT_{offset}$.

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

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

$$PTAT_{av} = \frac{\sum_{i=0}^7 PTAT_i}{8} \quad \text{is the average measured PTAT value}$$

8.2 Thermal Offset:

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

$$V_{ij_Comp} = V_{ij} - \frac{ThGrad_{ij} \cdot PTAT_{av}}{2^{gradScale}} - ThOffset_{ij}$$

where:

- ij represents the row (i) and column (j) of the pixel
- V_{ij_Comp} is the thermal offset compensated voltage
- V_{ij} is the raw pixel data (digital), readout from the RAM
- $ThGrad_{ij}$ is the thermal gradient, stored in the EEPROM from 0x740 to 0xF3F
- $ThOffset_{ij}$ is the thermal offset, stored in the EEPROM from 0xF40 to 0x173F
- $gradScale$ is the scaling coefficient for the thermal gradient stored in the EEPROM

8.3 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).

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

$$V_{ij_Comp}^* = V_{ij_Comp} - elOffset[(j + i \cdot 32):128]$$

and the bottom half analogue with this formula:

$$V_{ij_Comp}^* = V_{ij_Comp} - elOffset[(j + i \cdot 32):128+128]$$

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
- $i:128$ is the rest of the integer division of i by 128 (e.g. 130:128=2)

Please see chapter 4 for the serial order.

8.4 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 $PTAT_{av}$).

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

$$V_{ij_VDDComp} = V_{ij_Comp}^* \cdot \frac{\left(\frac{VddCompGrad[(j+i \cdot 32):128] \cdot PTAT_{av}}{2^{VddScGrad}} + VddCompOff[(j+i \cdot 32):128] \right) \cdot (Vdd - VddCalib)}{2^{VddScOff}}$$

and the bottom half analogue with this formula:

$$V_{ij_VDDComp} = V_{ij_Comp}^* \cdot \frac{\left(\frac{VddCompGrad[(j+i \cdot 32):128+128] \cdot PTAT_{av}}{2^{VddScGrad}} + VddCompOff[(j+i \cdot 32):128+128] \right) \cdot (Vdd - VddCalib)}{2^{VddScOff}}$$

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
$VddCompGrad[ij]$	is the VddComp gradient belonging to Pixel ij
$VddCompOff[ij]$	is the VddComp offset belonging to Pixel ij
$i:128$	is the rest of the integer division of i by 128 (e.g. 130:128=2)
Vdd	is the average measured supply voltage of the sensor in Digits
$VddCalib$	is the supply voltage during calibration stored in the EEPROM 0x26 & 0x27
$VddScGrad$	is a scaling coefficient and stored in the EEPROM
$VddScOff$	is a scaling coefficient and stored in the EEPROM

8.5 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 tablenumber (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 $1 \cdot 10^8$

8.6 Example calculation:

Example values:

$$PTAT_{av} = \frac{\sum_{i=0}^7 PTAT_i}{8} = 38152 \text{ Digits}$$

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

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

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

$$elOffset[0] = 34240$$

$$gradScale = 24$$

$$ThGrad_{00} = 11137 \xrightarrow{\text{signcheck}} 11137$$

$$ThOffset_{00} = 65506 \xrightarrow{\text{signcheck}} -30$$

$$Vdd = 35000$$

$$VddCalib = 33942$$

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

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

$$VddScGrad = 16$$

$$VddScOff = 23$$

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

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

Calculation of ambient temperature:

$$Ta = PTAT_{av} \cdot PTAT_{gradient} + PTAT_{offset} = 38152 \cdot 0.0211 + 2195.0 \text{ dK} = 3000 \text{ dK}$$

Compensation of thermal offset:

$$V_{00_Comp} = V_{00} - \frac{ThGrad_{00} \cdot PTAT_{av}}{2^{gradScale}} - ThOffset_{00} = 34435 - \frac{11137 \cdot 38152}{2^{15}} - (-30) = 34439$$

Compensation of electrical offset:

$$V_{00_Comp}^* = V_{00_Comp} - elOffset[0] = 34439 - 34240 = 199$$

Compensation of supply voltage:

$$V_{ij_VDDComp} = V_{ij_Comp}^* - \frac{\left(\frac{VddCompGrad[0] \cdot PTAT_{av}}{2^{VddScGrad}} + VddCompOff[0] \right) \cdot (Vdd - VddCalib)}{2^{VddScOff}}$$

$$= 199 - \frac{\left(\frac{10356 \cdot 38152}{2^{16}} - 14146 \right) \cdot (35000 - 33942)}{2^{23}} = 199 - (-1) = 200$$

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Example look-up table:

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

$$V_{00_PixC} = \frac{200 \cdot 1 \cdot 10^8}{1.1 \cdot 10^8} = 182$$

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 3941 dK = 120.9 °C.

A global Offset (GlobalOff) is used for fine tuning of the measured object temperature and has to be added to the object temperature. This value is stored in the EEPROM.

8.7 Pixel Masking

A maximum of 24 defect Pixels are 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 0x007F and is named *NrOfDefPix*. *DeadPixAdr* is the address of the defect Pixels and *DeadPixMask* 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 order of the top and bottom half is the same as the readout order that is stated in 4. 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 values for the masking:

NrOfDefPix = 0x03

DeadPixAdr[0] = 0x002D → Pixel 45

DeadPixAdr[1] = 0x031F → Pixel 799

DeadPixAdr[2] = 0x1054 → Pixel 3461

DeadPixMask[0] = 0x7C → 0b01111100 (top)

DeadPixMask[1] = 0x8F → 0b10001111 (top)

DeadPixMask[2] = 0xFE → 0b11111110 (bot)

According to the sample values 3 Pixels are defect and need to be interpolated. 2 Pixels are on the top and 1 Pixel on the bottom 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:

$$\text{Pixel 45} = \frac{3007 + 3008 + 3008 + 3011 + 3009}{5} dK = \frac{15043}{5} dK \approx 3009 dK$$

$$\text{Pixel 799} = \frac{3010 + 3012 + 3005 + 3008 + 3009}{5} dK = \frac{15044}{5} dK \approx 3009 dK$$

$$\text{Pixel 3461} = \frac{3010 + 3012 + 3005 + 3007 + 3008 + 3008 + 3009}{7} dK = \frac{21059}{7} dK \approx 3008 dK$$

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All values are given in dK

3007	Pixel 45	3008
3008	3011	3009

Pixel 44	Pixel 45	Pixel 46
Pixel 124	Pixel 125	Pixel 126

3010	3012	3005
3007	Pixel 799	3008
3008	3011	3009

Pixel 718	Pixel 719	Pixel 720
Pixel 798	Pixel 799	Pixel 800
Pixel 878	Pixel 879	Pixel 880

3010	3012	3005
3007	Pixel 3461	3008
3008	3011	3009

Pixel 3380	Pixel 3381	Pixel 3382
Pixel 3460	Pixel 3461	Pixel 3462
Pixel 3540	Pixel 3541	Pixel 3542

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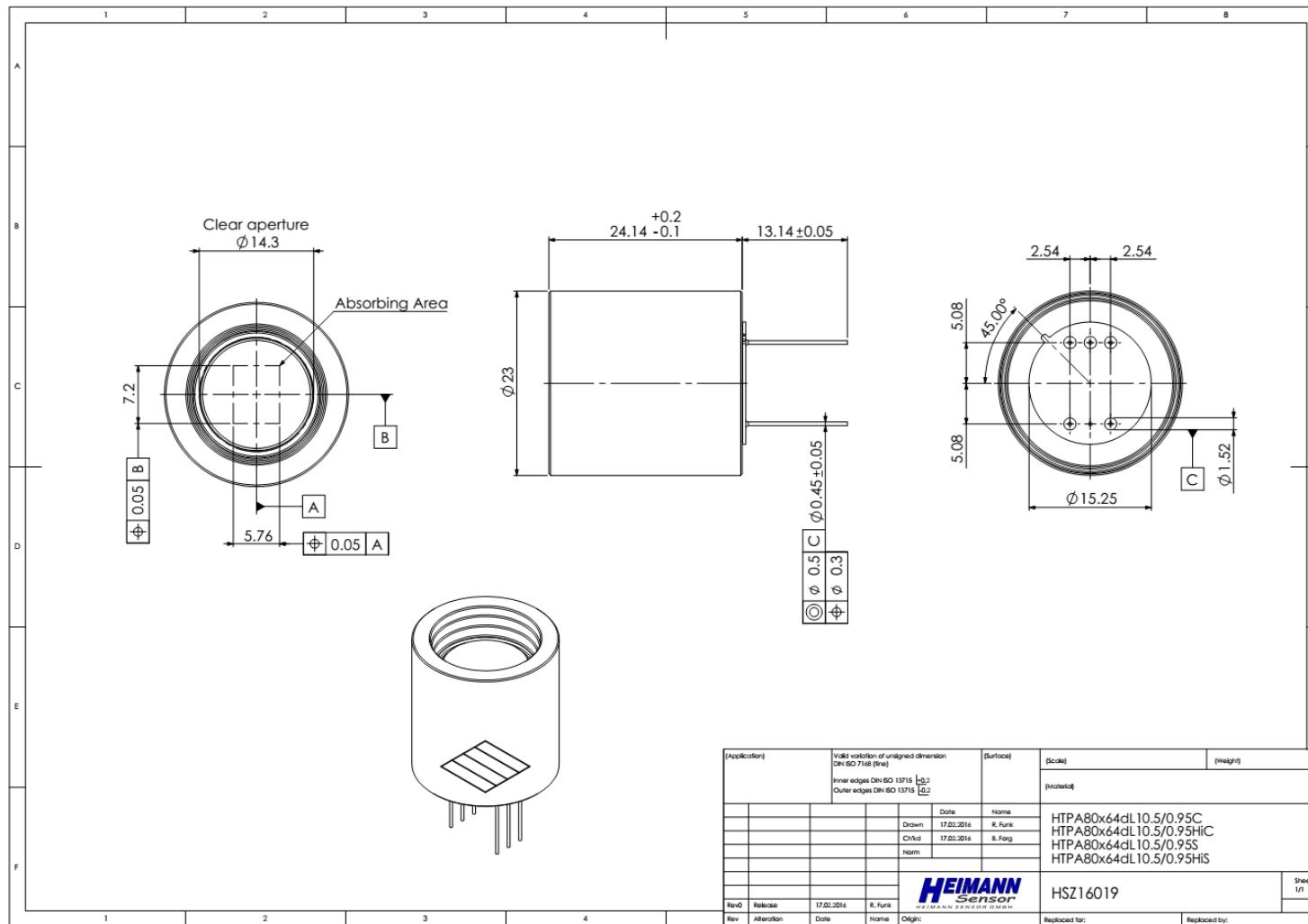


Look-up Table

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

dig \ Ta[dK]	2782	2882	2982	3082	3182	3282	3382	6848	6877	6920	6974	7039	7114	7198	7290
-256	0	0	0	0	1159	1804	2115	2343	6912	6892	6936	6990	7055	7130	7214
-192					2211	2407	2576	2727	6976	6908	6951	7006	7071	7146	7230
-128					2605	2742	2872	2995	7040	6923	6966	7021	7086	7162	7246
-64					2873	2986	3097	3206	7104	6959	6997	7052	7102	7177	7262
0					3082	3182	3282	3382	7168	6984	6987	7036	7102	7193	7277
64	2993	3078	3166	3256	3347	3440	3534	7232	6969	7012	7067	7133	7208	7293	7386
128	3167	3243	3322	3405	3491	3579	3669	7296	6984	7027	7082	7148	7223	7308	7401
192	3316	3385	3459	3537	3619	3703	3790	7360	6999	7042	7097	7163	7239	7324	7417
256	3448	3512	3582	3656	3734	3816	3901	7424	7014	7057	7112	7178	7254	7339	7432
320	3565	3626	3693	3764	3840	3920	4003	7488	7028	7072	7127	7193	7269	7354	7447
384	3673	3731	3794	3864	3938	4016	4097	7552	7043	7086	7141	7207	7284	7369	7462
448	3771	3827	3889	3956	4029	4105	4186	7616	7057	7101	7156	7222	7298	7384	7478
512	3863	3916	3977	4043	4114	4189	4269	7680	7072	7115	7171	7237	7313	7399	7493
576	3948	4000	4059	4124	4194	4269	4348	7744	7086	7130	7185	7251	7328	7414	7507
640	4028	4079	4137	4200	4270	4344	4423	7808	7100	7144	7199	7266	7342	7428	7522
704	4104	4154	4210	4273	4342	4415	4494	7872	7114	7158	7214	7280	7357	7443	7537
768	4176	4224	4280	4342	4410	4484	4561	7936	7128	7172	7228	7294	7371	7457	7552
832	4244	4292	4346	4408	4476	4549	4626	8000	7143	7186	7242	7308	7385	7472	7566
896	4309	4356	4410	4471	4538	4611	4689	8064	7156	7200	7256	7323	7400	7486	7581
960	4371	4417	4471	4532	4599	4671	4748	8128	7170	7214	7270	7337	7414	7500	7595
1024	4431	4476	4530	4590	4657	4729	4806	8192	7184	7228	7284	7351	7428	7515	7609
1088	4488	4533	4586	4646	4713	4785	4862	8256	7198	7242	7298	7365	7442	7529	7624
1152	4543	4588	4641	4700	4767	4839	4916	8320	7211	7255	7311	7378	7456	7543	7638
1216	4597	4641	4693	4753	4819	4891	4968	8384	7225	7269	7325	7392	7470	7557	7652
1280	4648	4692	4744	4803	4869	4941	5018	8448	7238	7282	7338	7406	7483	7570	7666
1344	4698	4742	4793	4852	4918	4990	5068	8512	7252	7296	7352	7419	7497	7584	7680
1408	4746	4790	4841	4900	4966	5038	5115	8576	7265	7309	7365	7433	7511	7598	7694
1472	4793	4836	4888	4946	5012	5084	5162	8640	7278	7322	7379	7446	7524	7612	7708
1536	4839	4881	4933	4991	5057	5129	5207	8704	7291	7336	7392	7460	7538	7625	7721
1600	4883	4924	4977	5035	5101	5173	5251	8768	7304	7349	7405	7473	7551	7639	7735
1664	4926	4968	5019	5078	5144	5216	5294	8832	7317	7362	7418	7486	7564	7652	7748
1728	4968	5010	5061	5120	5185	5258	5336	8896	7330	7375	7431	7499	7578	7665	7762
1792	5009	5051	5102	5160	5226	5299	5377	8960	7343	7388	7444	7512	7591	7679	7775
1856	5049	5091	5142	5200	5266	5338	5417	9024	7356	7401	7457	7525	7604	7692	7789
1920	5088	5130	5180	5239	5305	5377	5456	9088	7369	7413	7470	7538	7617	7705	7802
1984	5126	5168	5218	5277	5343	5416	5494	9152	7382	7426	7483	7551	7630	7718	7815
2048	5164	5205	5255	5314	5380	5453	5532	9216	7394	7439	7496	7564	7643	7731	7828
2112	5200	5242	5292	5351	5417	5490	5569	9280	7407	7451	7508	7577	7656	7744	7841
2176	5236	5277	5328	5386	5453	5526	5605	9344	7419	7464	7521	7589	7668	7757	7854
2240	5271	5312	5363	5421	5488	5561	5640	9408	7432	7476	7533	7602	7681	7770	7867
2304	5305	5347	5397	5456	5522	5595	5675	9472	7444	7489	7546	7614	7694	7783	7880
2368	5338	5380	5431	5490	5556	5629	5708	9536	7456	7501	7558	7627	7706	7795	7893
2432	5372	5413	5464	5523	5589	5663	5742	9600	7468	7513	7570	7639	7718	7807	7904
2496	5405	5446	5496	5555	5622	5695	5775	9664	7481	7526	7583	7652	7731	7821	7919
2560	5437	5478	5528	5587	5654	5728	5808	9728	7493	7538	7595	7664	7744	7833	7931
2624	5468	5509	5560	5619	5685	5759	5840	9792	7505	7550	7607	7676	7756	7846	7944
2688	5499	5540	5590	5649	5716	5790	5871	9856	7517	7562	7619	7688	7768	7858	7956
2752	5529	5570	5621	5680	5747	5821	5902	9920	7529	7574	7631	7701	7781	7870	7969
2816	5558	5600	5651	5710	5777	5851	5932	9984	7541	7586	7643	7713	7793	7883	7981
2880	5588	5629	5680	5739	5806	5881	5962	10048	7553	7598	7655	7725	7805	7895	7994
2944	5617	5658	5709	5768	5836	5910	5992	10112	7564	7610	7667	7737	7817	7907	8006
3008	5646	5687	5737	5797	5864	5939	6021	10176	7576	7621	7679	7749	7829	7919	8018
3072	5674	5715	5765	5825	5893	5968	6049	10240	7588	7633	7691	7760	7841	7931	8030
3136	5701	5742	5793	5853	5920	5996	6078	10304	7599	7645	7703	7772	7853	7943	8042
3200	5728	5769	5820	5880	5948	6024	6106	10368	7611	7656	7714	7784	7865	7955	8054
3264	5756	5797	5847	5907	5975	6051	6133	10432	7622	7668	7726	7796	7876	7967	8067
3328	5782	5823	5874	5934	6002	6078	6160	10496	7634	7679	7737	7807	7888	7979	8078
3392	5808	5849	5900	5960	6028	6104	6187	10560	7645	7691	7749	7819	7900	7991	8090
3456	5834	5875	5926	5986	6054	6130	6213	10624	7657	7702	7760	7830	7911	8002	8102
3520	5859	5900	5951	6012	6080	6156	6239	10688	7668	7713	7772	7842	7923	8014	8114
3584	5885	5926	5977	6037	6105	6182	6265	10752	7679	7725	7783	7853	7935	8026	8126
3648	5909	5950	6001	6062	6131	6207	6290	10816	7690	7736	7794	7865	7946	8037	8138
3712	5934	5975	6026	6086	6155	6232	6315	10880	7702	7747	7806	7876	7957	8048	8149
3776	5958	5999	6050	6111	6180	6257	6340	10944	7713	7758	7817	7887	7969	8060	8161
3840	5982	6023	6074	6135	6204	6281	6365	11008	7724	7769	7828	7899	7980	8072	8172
3904	6006	6047	6098	6159	6228	6305	6389	11072	7735	7781	7839	7910	7991	8083	8184
3968	6029	6070	6121	6182	6252	6329	6413	11136	7746	7792	7850	7921	8003	8094	8195
4032	6052	6093	6145	6205	6275	6352	6437	11200	7757	7803	7861	7932	8014	8105	8207
4096	6075	6116	6167	6228	6298	6376	6460	11264	7767	7813	7872	7943	8025	8117	8218
4160	6097	6139	6190	6251	6321	6399	6484	11328	7778	7824	7883	7954	8036	8128	8229
4224	6120	6161	6213	6274	6344	6421	6507	11392	7789	7835	7894	7965	8047	8139	8241
4288	6142	6183	6235	6296	6366	6444	6529	11456	7800	7846	7905	7976	8058	8150	8252
4352	6164	6205	6257	6318	6388	6466	6552	11520	7811	7857					

9 Outer Dimensions:



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