Specification for HTPA32x31L10/1.0HiM(LC)[Si]

Rev.1: 2013.04.25 Fg

The HTPA32x31L_/_M(LC) is a fully calibrated, low cost thermopile array module, with fully digital SPI interface. The module delivers an electrical offset and ambient temperature compensated output stream, which can be already used for image processing, pattern recognition and presence detection purposes. Object temperatures can be easily obtained by this data stream, a look up table and the calibrated sensitivity constants, which can be found in the EEPROM of the module.

Order Code Example

HTPA32x31L10/1.0HiM(SPI)[Si]

Lens material: Si→Silicon, if not declared Germanium

Interface: SPI→ SPI device (14bit ADC)

LC→SPI, 12bit ADC, low speed, external processing required

UDP→Ethernet, CAT5 cable connection

UART→RS232-like, Level: 3.3V

Type: A→Application set: comes with GUI, housing, power supply

M→Module: HTPA sensor soldered to PCB, calibrated stream

S→Sensor: HTPA sensor only. Analogous output.

Sensitivity: Hi→Increased sensitivity

Without "Hi"→ Standard sensitivity

Optics:L→focal length: In example L10 = 10 mm focal length.

/→ F-Number: In example /0.8

For optics see also "HTPA standard optics"

Type: HTPA32x31 (Please contact support for all available HTPA and module combinations.

For modules, the recommended type is M(SPI). The advantages are the better ADC resolution, wider input voltage range, wider measurement range.

Pinout

Pin Assignment HTPA32x31M(LC)			
Pin	Name	Description	Type
1	#MCLR	Master clear, negotiated	Digital Input
2	VDD	Positive supply voltage	Power
3	VSS	Negative supply voltage	Power
4	VSS	Negative supply voltage	Power
5	#SS	Slave select, negotiated	Digital Input
6	SDO	Serial data out of module	Digital Output
7	SDI	Serial data in of module	Digital Input
8	SCK	Serial clock	Digital Input
9	MCLK	Master clock, drives HTPA sensor	Digital Input
10	#VD	Valid Data, negotiated.	Digital Output
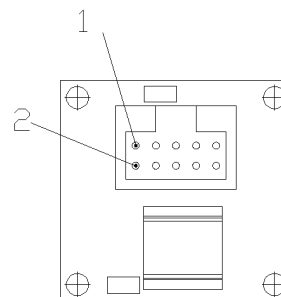
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SPI Interface:
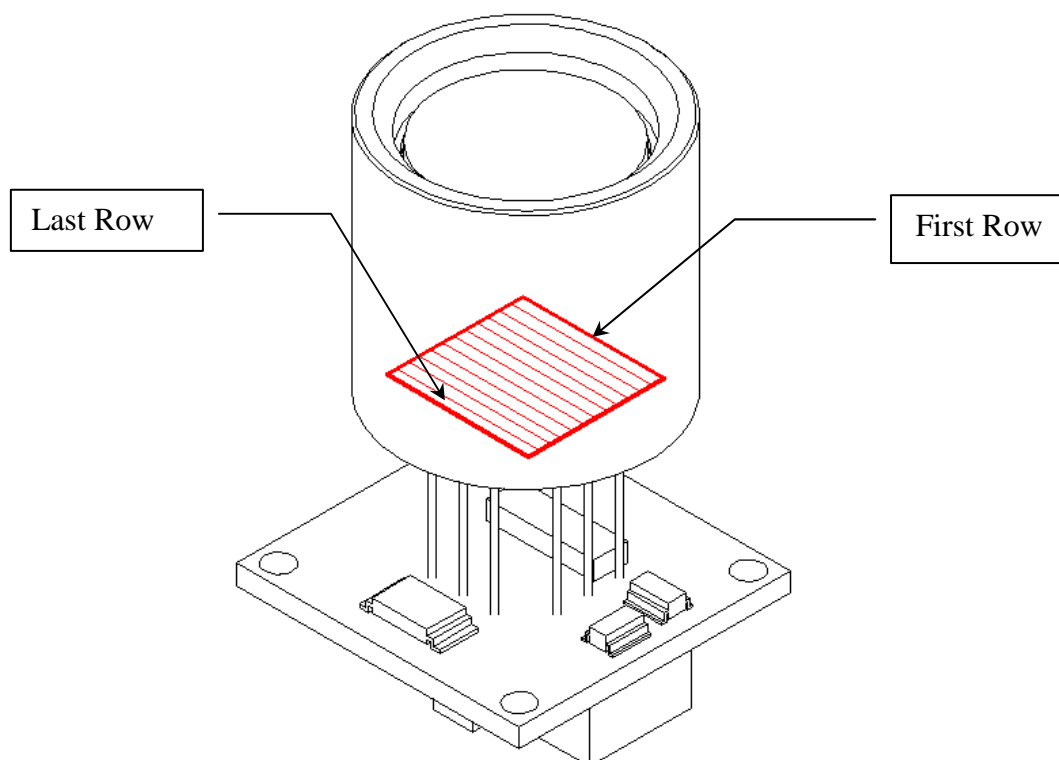
SCK-Frequency: 350 kHz …10 MHz

Protocol Specifications:

Data format: 16 data bits
Frame Sync: None
Module-Selection: $\overline{\text{SS}}$-Pin
Clock Edge Select: Serial output data changes on transition from idle to active clock state
SPI Data Input Sample Phase: Data sampled on transition from active to idle clock state
Clock Polarity: Idle State is high level, active is low level.
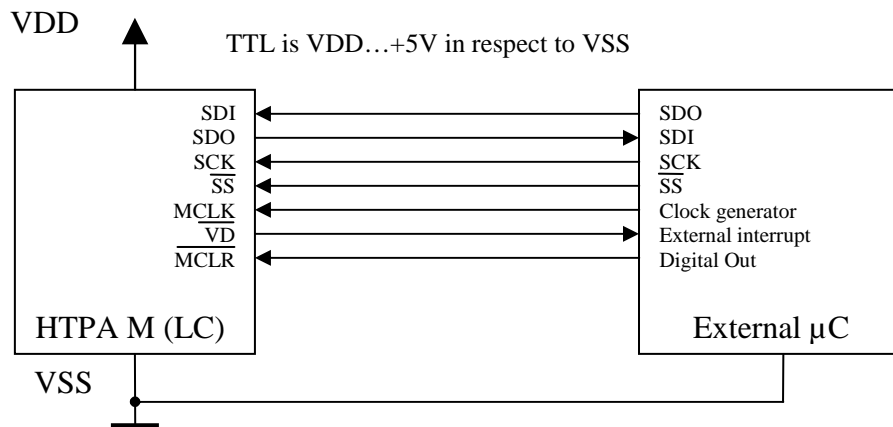
Electrical Specifications:

VDD: Supply (+5.0V DC)
SPI Transmit/Receive: TTL
VSS GND
Power Supply: **5.0** VDC +/- 2%, 300mA
IDD (Idle mode) 20 mA
IDD (Operating mode) 45 mA

HTPA32x31L10/1.0M(LC) Optical Orientation of Pixels:

Electrical Connections:

Single Module:

VDD

TTL is VDD…+5V in respect to VSS

HTPA M (LC)		External µC
SDI	←	SDO
SDO	→	SDI
SCK	←	SCK
SS	←	SS
MCLK	←	Clock generator
VD	→	External interrupt
MCLR	←	Digital Out

VSS

Multiple Modules (preliminary):

VDD

HTPA M (LC)

SDI
SDO
SCK
SS
MCLK
VD
MCLR

TTL is VDD…+5V in respect to VSS

HTPA M (LC)		External µC
SDI	←	SDO
SDO	→	SDI
SCK	←	SCK
SS	←	SS1
MCLK	←	Clock generator
VD	→	External interrupt1
MCLR	←	Digital Out
		External interrupt2
		SS2

VSS

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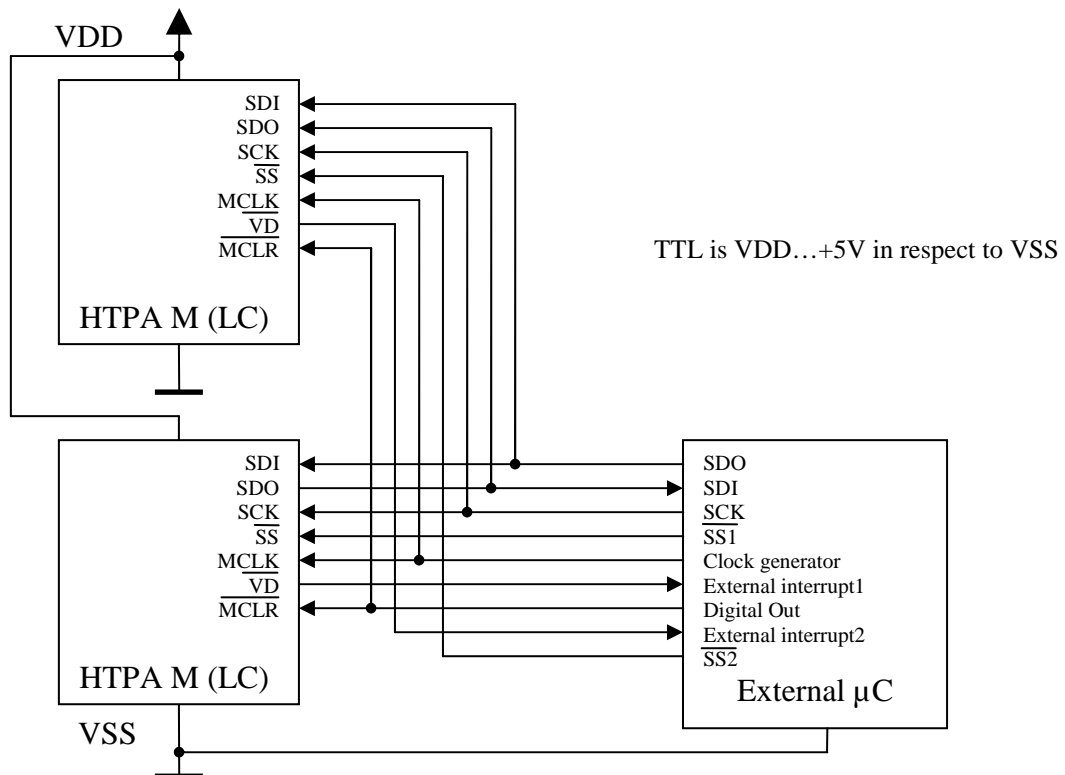
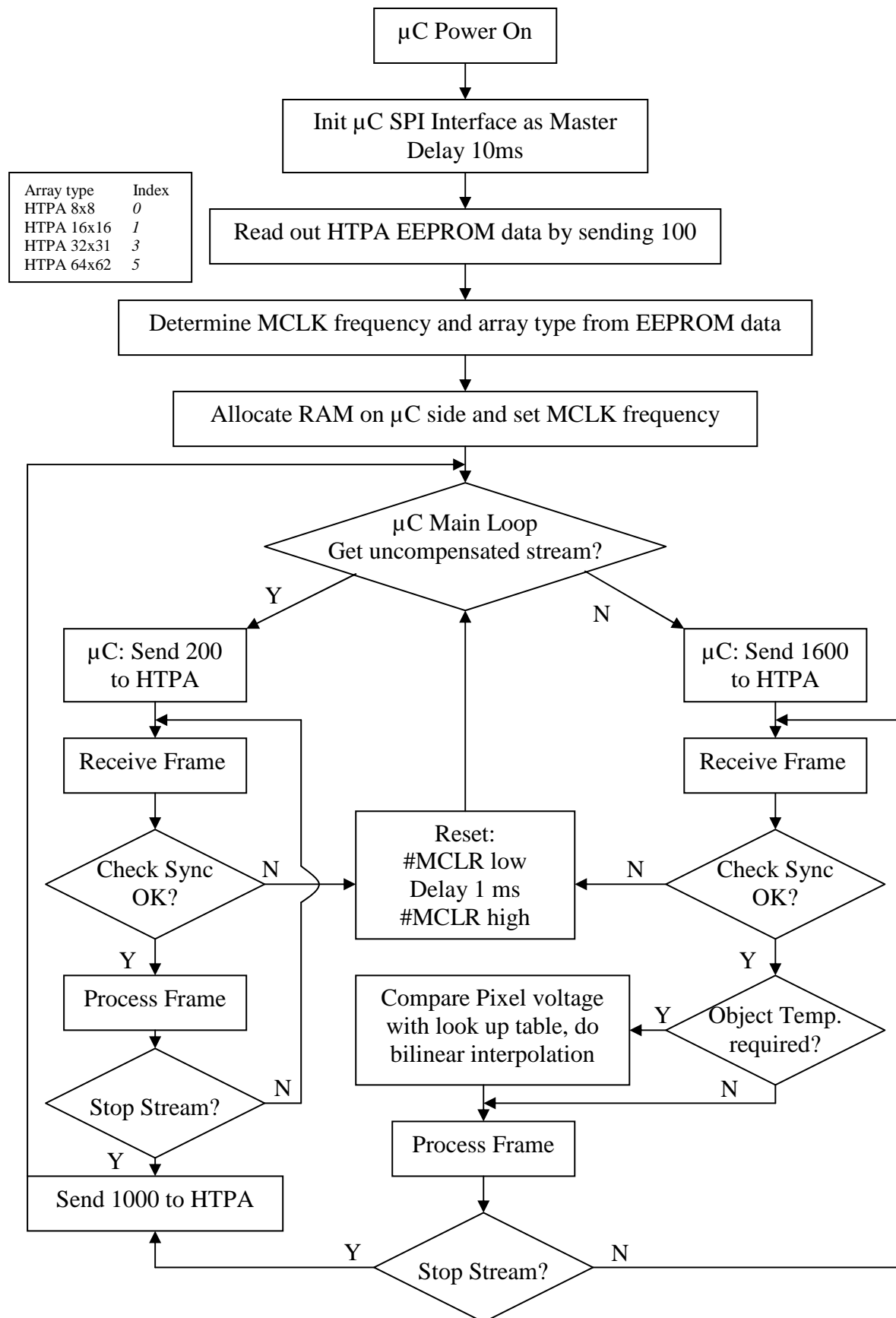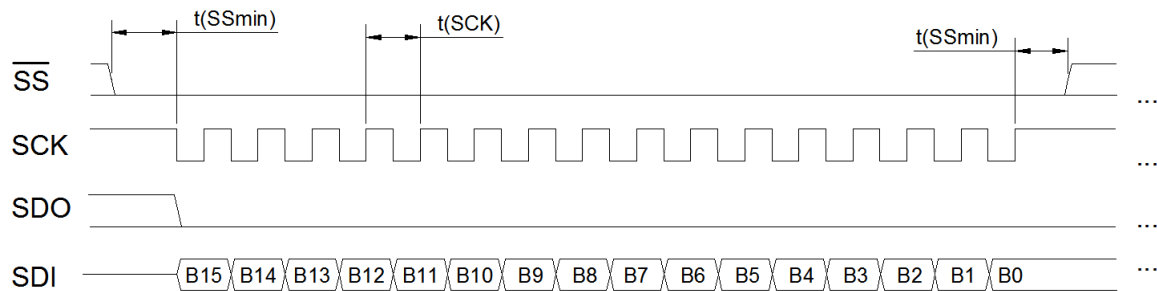## Communication and Timings:

Proposed flow chart of communication. (Master is referred as µC, Slave as HTPA module)

Array type	Index
HTPA 8x8	0
HTPA 16x16	1
HTPA 32x31	3
HTPA 64x62	5

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Communication and Timings (continuation):

Receive of command:

(High state of #SS is not necessary, only for communication with multiple devices)

Send of EEPROM content:

Master sends 0x64

$\overline{VD}$ gets low when data ready

W0: Word 0 from EEPROM
W1: Word 1 from EEPROM
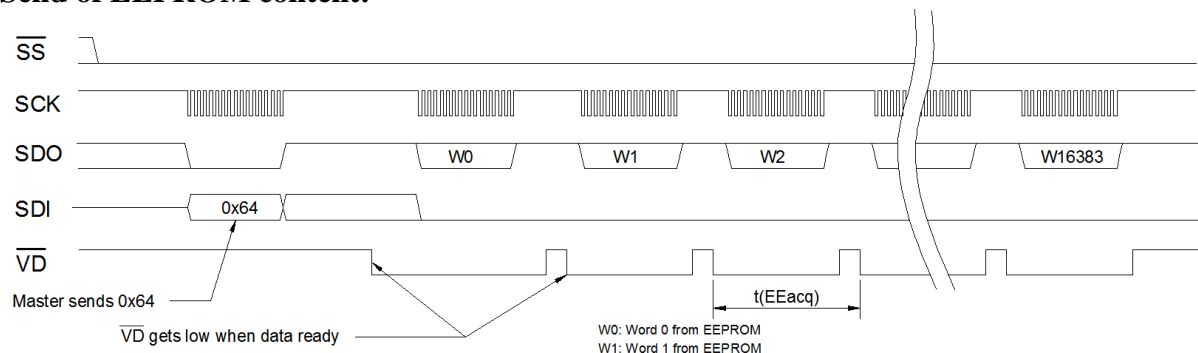
Pixel data:
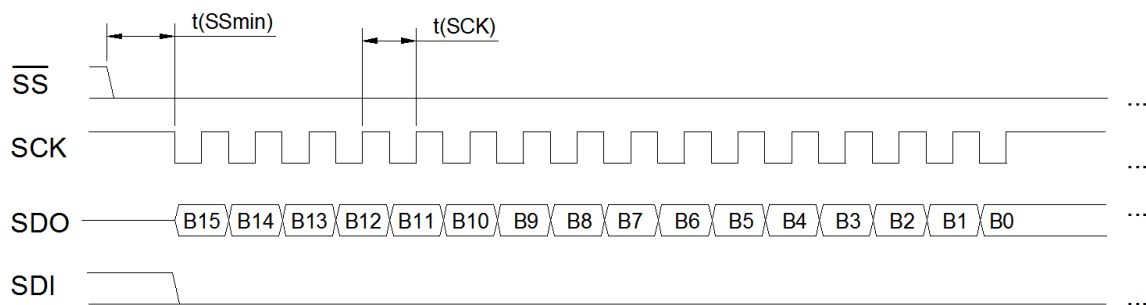
B15...B0: Raw or compensated ADC reading (depending from streaming mode)

Receive of stream command:

M(0)=MSB of Pixel0
L(0)=LSB of Pixel0
M(16)=MSB of Pixel16
L(16)=LSB of Pixel16
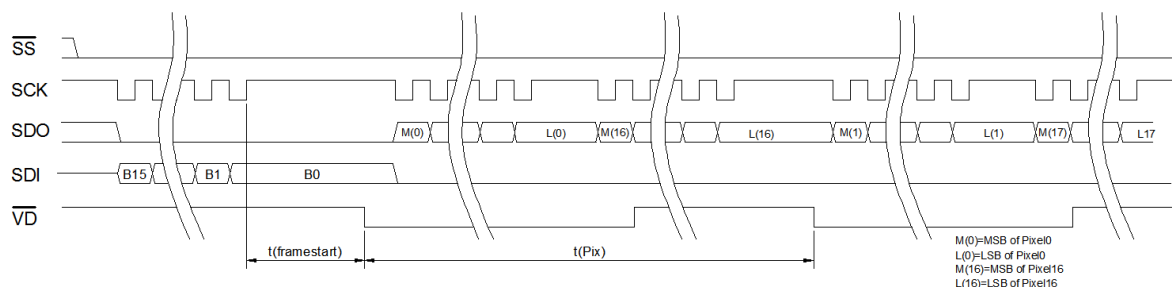
For streaming the adequate frequency needs to be applied to the MCLK pin of the module.

Communication and Timings (continuation):

Absolute values:

	MIN	NOM	MAX	Unit	Remarks
MCLR pulse width (low)	2			µs	
t(SSmin)	150			ns	
t(SCK)	0.1	1	2.86	µs	
t(EEacq)	185			µs	
t(framestart)		120		ms	f(MCLK)=1 MHz
t(Pix)		200		µs	f(MCLK)=1 MHz

t(Pix) and t(framestart) depend on the given MCLK frequency of the master. In example: MCLK frequency is 1003 kHz, then t(Pix) and t(framestart) is calculated via

$$t(Pix) = \frac{200}{f(MCLK)} = \frac{200}{1003000} = 199,4 \mu s \qquad t(framestart) = \frac{t(Pix) \cdot 32 \cdot 33}{2} + 14\text{ms} = 119,3\text{ms}$$

Important:
The SCK frequency needs to be at least that large, that the 32 bits can be submitted within tPix. Therefore, the following condition must be always true:

$$32 \cdot t(SCK) < t(Pix)$$

EEPROM Mapping:

Overview:

Start address	End address	Data type	Value
0x0	0x3	float	Minimum value of PixC's for scaling
0x4	0x7	float	Maximum value of PixC's for scaling
0x8	0x9		Heimann Sensor reserved
0xA	0xA	char	Table number
0xB	0x33		Heimann Sensor reserved
0x34	0x37	float	PTATgrad
0x38	0x3B	float	PTAToff
0x3C	0x58		Heimann Sensor reserved
0x59	0x5A	unsigned int	MCLK Frequency in kHz
0x5B	0x79		Heimann Sensor reserved
0x80	0x83F	unsigned int	scaled down values of PixC's
0x840	0x3FFF		Heimann Sensor reserved

Important Note:

unsigned int: 2 byte; float: 4 byte; char: 1 byte
All the values are stored (if larger than one byte) in little endian, the so called „Intel-Format". Example for the MCLK-Frequency:

$$MCLK_{LB} = EEPROM[0x59] \quad MCLK_{HB} = EEPROM[0x5A]$$
$$MCLK = 256 \cdot MCLK_{HB} + MCLK_{LB}$$

EEPROM Mapping (continuation):

Details for PixC's:

Start address	End address	Data type	Value
0x80	0x81	unsigned int	scaled PixC value of Pixel 0
0x82	0x83	unsigned int	scaled PixC value of Pixel 16
0x84	0x85	unsigned int	scaled PixC value of Pixel 1
0x86	0x87	unsigned int	scaled PixC value of Pixel 17
0x88	0x89	unsigned int	scaled PixC value of Pixel 2
0x8A	0x8B	unsigned int	scaled PixC value of Pixel 18
…	…	…	…
0xBC	0xBD	unsigned int	scaled PixC value of Pixel 15
0xBE	0xBF	unsigned int	scaled PixC value of Pixel 31
0xC0	0xC1	unsigned int	scaled PixC value of Pixel 32
0xC2	0xC3	unsigned int	scaled PixC value of Pixel 48
0xC4	0xC5	unsigned int	scaled PixC value of Pixel 33
0xC6	0xC7	unsigned int	scaled PixC value of Pixel 49
…	…	…	…
0x83C	0x83D	unsigned int	scaled PixC value of Pixel 975
0x83E	0x83F	unsigned int	scaled PixC value of Pixel 991

Calculation of the PixC's:

1. Determine minimum and maximum value of the PixC's out of the EEPROM data by reading associated EEPROM value into a float constant. Pseudocode in C, see function "getPixC(void);"
2. Now scale all scaled down PixC's out of the EEPROM content back to their original value and store them in RAM of your system.

Formulas:

$$PixC_{MAX} = \text{EEPROM}[0x0 \text{-} 0x3] \qquad \text{(4 byte float value in little endian)}$$
$$PixC_{MIN} = \text{EEPROM}[0x4 \text{-} 0x7] \qquad \text{(4 byte float value in little endian)}$$

$$PixC(PixelX) = \frac{\text{EEPROM}[0x80 + (X \cdot 2)] \cdot (PixC_{MAX} - PixC_{MIN})}{65535} + PixC_{MIN}$$

```
unsigned int PixC[992];    //The scaled back PixC's. Most likely, this should be global.

void getPixC(void)         //this function detemines the pixel constants. Precondition: EEPROM content is stored in the char array "EEPROM"
{
        float common[2],min,max;
        unsigned int addr=0x80,i;   //the start address for the scaled pixel constants
        unsigned int pcl;           //this stores the two bytes from the scaled down PixC out of EEPROM.

        memcpy((char*)&common,(unsigned char*)&EEPROM[0],sizeof(float)*2);        //the address of the scaling values for the pixc's
        min=common[0];
        max=common[1];
        for(i=0;i<PIXEL;i++){
        memcpy((char*)&pcl,(unsigned char*)&EEPROM[addr],2);        //include string.h for memcpy
        addr+=2;
        PixC[i]=(unsigned int)(((float)pcl/65535.0)*(max-min)+min+0.5);
        }

        return;
}
```

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Serial order of data in stream:

Compensated Voltage Mode	
Dataset	Value
0	offset corrected Voltage of Pixel0 in in digits
1	offset corrected Voltage of Pixel16 in in digits
2	offset corrected Voltage of Pixel1 in in digits
3	offset corrected Voltage of Pixel17 in in digits
…	…
30	offset corrected Voltage of Pixel15 in in digits
31	offset corrected Voltage of Pixel31 in in digits
32	offset corrected Voltage of Pixel32 in in digits
33	offset corrected Voltage of Pixel48 in in digits
…	…
991	offset corrected Voltage of Pixel991 in in digits
992	elOff0 in digits
993	elOff16 in digits
994	elOff1 in digits
995	elOff17 in digits
…	…
1022	elOff15 in digits
1023	elOff31 in digits
1024	Module transmitts 0x789A (use for sync)
1025	Module transmitts 0xBCDE (use for sync)
1026	least significant 12 bits of TAmb
1027	most significant 4 bits of TAmb
1028	no value, ignore
1029	no value, ignore
…	…
1039	no value, ignore
1040	PTAT0 in digits
1041	no value, ignore
1042	PTAT1 in digits
…	…
1053	no value, ignore
1054	PTAT7 in digits
1055	no value, ignore

Raw Voltage Mode	
Dataset	Value
0	absolute Voltage of Pixel0 in in digits
1	absolute Voltage of Pixel16 in in digits
2	absolute Voltage of Pixel1 in in digits
3	absolute Voltage of Pixel17 in in digits
…	…
30	absolute Voltage of Pixel15 in in digits
31	absolute Voltage of Pixel31 in in digits
32	absolute Voltage of Pixel32 in in digits
33	absolute Voltage of Pixel48 in in digits
…	…
991	absolute Voltage of Pixel991 in in digits
992	elOff0 in digits
993	elOff16 in digits
994	elOff1 in digits
995	elOff17 in digits
…	…
1022	elOff15 in digits
1023	elOff31 in digits
1024	Module transmitts 0x789A (use for sync)
1025	Module transmitts 0xBCDE (use for sync)
1026	no value, ignore
1027	no value, ignore
1028	no value, ignore
1029	no value, ignore
…	…
1039	no value, ignore
1040	PTAT0 in digits
1041	no value, ignore
1042	PTAT1 in digits
…	…
1053	no value, ignore
1054	PTAT7 in digits
1055	no value, ignore

Each dataset consists of a 16 bit value. The 16 bit values are transmitted with LSB first. In case of compensated voltage mode a signed 16 bit value is transmitted, in case of raw voltage mode an unsigned 16 bit value. Signed values are always in 2's complement.

Pixel Map:

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
256	257	258	259	260	261	262	263	264	265	266	267	268	269	270	271	272	273	274	275	276	277	278	279	280	281	282	283	284	285	286	287
288	289	290	291	292	293	294	295	296	297	298	299	300	301	302	303	304	305	306	307	308	309	310	311	312	313	314	315	316	317	318	319
320	321	322	323	324	325	326	327	328	329	330	331	332	333	334	335	336	337	338	339	340	341	342	343	344	345	346	347	348	349	350	351
352	353	354	355	356	357	358	359	360	361	362	363	364	365	366	367	368	369	370	371	372	373	374	375	376	377	378	379	380	381	382	383
384	385	386	387	388	389	390	391	392	393	394	395	396	397	398	399	400	401	402	403	404	405	406	407	408	409	410	411	412	413	414	415
416	417	418	419	420	421	422	423	424	425	426	427	428	429	430	431	432	433	434	435	436	437	438	439	440	441	442	443	444	445	446	447
448	449	450	451	452	453	454	455	456	457	458	459	460	461	462	463	464	465	466	467	468	469	470	471	472	473	474	475	476	477	478	479
480	481	482	483	484	485	486	487	488	489	490	491	492	493	494	495	496	497	498	499	500	501	502	503	504	505	506	507	508	509	510	511
512	513	514	515	516	517	518	519	520	521	522	523	524	525	526	527	528	529	530	531	532	533	534	535	536	537	538	539	540	541	542	543
544	545	546	547	548	549	550	551	552	553	554	555	556	557	558	559	560	561	562	563	564	565	566	567	568	569	570	571	572	573	574	575
576	577	578	579	580	581	582	583	584	585	586	587	588	589	590	591	592	593	594	595	596	597	598	599	600	601	602	603	604	605	606	607
608	609	610	611	612	613	614	615	616	617	618	619	620	621	622	623	624	625	626	627	628	629	630	631	632	633	634	635	636	637	638	639
640	641	642	643	644	645	646	647	648	649	650	651	652	653	654	655	656	657	658	659	660	661	662	663	664	665	666	667	668	669	670	671
672	673	674	675	676	677	678	679	680	681	682	683	684	685	686	687	688	689	690	691	692	693	694	695	696	697	698	699	700	701	702	703
704	705	706	707	708	709	710	711	712	713	714	715	716	717	718	719	720	721	722	723	724	725	726	727	728	729	730	731	732	733	734	735
736	737	738	739	740	741	742	743	744	745	746	747	748	749	750	751	752	753	754	755	756	757	758	759	760	761	762	763	764	765	766	767
768	769	770	771	772	773	774	775	776	777	778	779	780	781	782	783	784	785	786	787	788	789	790	791	792	793	794	795	796	797	798	799
800	801	802	803	804	805	806	807	808	809	810	811	812	813	814	815	816	817	818	819	820	821	822	823	824	825	826	827	828	829	830	831
832	833	834	835	836	837	838	839	840	841	842	843	844	845	846	847	848	849	850	851	852	853	854	855	856	857	858	859	860	861	862	863
864	865	866	867	868	869	870	871	872	873	874	875	876	877	878	879	880	881	882	883	884	885	886	887	888	889	890	891	892	893	894	895
896	897	898	899	900	901	902	903	904	905	906	907	908	909	910	911	912	913	914	915	916	917	918	919	920	921	922	923	924	925	926	927
928	929	930	931	932	933	934	935	936	937	938	939	940	941	942	943	944	945	946	947	948	949	950	951	952	953	954	955	956	957	958	959
960	961	962	963	964	965	966	967	968	969	970	971	972	973	974	975	976	977	978	979	980	981	982	983	984	985	986	987	988	989	990	991

Communication commands:

Sent Command	Answer / Result
100	Output of EEPROM content. Data ready of each 2 bytes is signified by #VD pin.
200	Module streams out uncompensated, raw data stream. Data ready of each 4 bytes is signified by #VD pin.
1000	Stops streaming mode of module.
1600	Module streams offset corrected stream (electrical and thermal). Data ready of each 4 bytes is signified by #VD pin.

Precondition for all streaming modes:

MCLK signal is generated and frequency is in limits shown by the section "Absolute Maximum Ratings"

Preconditions for compensated streams
MCLK signal is generated and frequency matches EEPROM content. Failure of MCLK should be $< \pm 3\%$
VDD must be in the given limits (5V +/-2%). False values for these two may affect calculated absolute object temperatures. False values for the MCLK frequency also may result in pattern formation in frame.

Absolute Maximum Ratings:

Value	MIN	NOM	MAX	Unit	Remarks
TTL Frequency on pin MCLK	MCLK-3%	MCLK	MCLK+3%	Hz	in compensated streaming mode
TTL Frequency on pin MCLK	0.1		1.7	MHz	in raw voltage streaming mode
VDD in respect to VSS	-0.3	5	6.5	V	
VDD in streaming mode	4.9	5	5.1	V	False VDD values affect compensation
Voltage on digital pin with respect to VSS	-0.3		VDD+0.3	V	
Current consumption	37	45	50	mA	In streaming
Current consumption	18	20	25	mA	Idle

Temperature Calculation:

1. Init SPI Interface
2. Read out EEPROM data
3. Determine MCLK frequency, apply to MCLK pin (Refer to EEPROM Mapping)
4. Determine pixel constant PixC for each sensitive pixel, keep them in RAM (Refer also to EEPROM mapping)
5. Enable ISR connected to the #VD pin of the module
6. Write 1600 via the SPI interface to the module
7. Module starts to run and signifies valid data with pull down of #VD
8. In the ISR get 32 bit (2 times 16 bit read) within the given timings from the module
9. These two words represent the compensated pixel voltage of the two corresponding pixels. For serial order of the pixels in frame refer to "Serial order of data in stream"
10. Scale the pixel sensitivity according to the following formula, using the PixC's:

$$V_S(X) = \frac{1E8 \cdot V_C(X)}{PixC(X) \cdot \varepsilon}$$

Where ε is the emissivity of the object, $V_S(X)$ is the sensitivity corrected voltage of pixel X, $V_C(X)$ is the offset compensated voltage of pixel X (submitted by the module).

11. Compare the $V_S(X)$ value with the pixel voltages in the look up table (vertical axis)

12. Calculate the ambient temperature of the sensor out of the given values from the module (see "Serial order of data in stream"). This formula may be used for ambient temperature calculation:

$$T_{AMB} = 4096 \cdot V_C(1027) + V_C(1026)$$

13. Compare the T_{AMB} value with the horizontal axis of the look up table.
14. Do a bilinear interpolation of the 4 neighbour supporting points, where T_{AMB} and $V_S(X)$ intersect.
15. The result is the object temperature in deci-Kelvin [dK].

C-Code for all these calculations can be found in our SDK (**S**oftware **D**evelopment **K**it). Furthermore, the SDK is able to fetch the data from the module and sends it to our GUI (**G**raphical **U**ser **I**nterface) which can visualize the data, records videos and text files and has many additional features. For more information see www.heimannsensor.com.

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Look up table:

Pixel voltage	Ambient Temperature [dK]						
	2582	2732	2882	3032	3182	3332	3482
-320	0x000	0x000	0x000	0x000	1877	2445	2799
-256	0x000	0x000	0x000	1841	2372	2710	2981
-192	0x000	0x000	1925	2356	2659	2910	3133
-128	1574	2079	2395	2648	2870	3073	3263
-64	2256	2476	2675	2861	3039	3211	3378
0	2582	2732	2882	3032	3182	3332	3482
64	2811	2927	3049	3176	3306	3440	3576
128	2991	3087	3191	3301	3417	3538	3663
192	3141	3223	3314	3412	3517	3628	3743
256	3270	3343	3424	3513	3608	3711	3819
320	3385	3450	3523	3604	3693	3788	3889
384	3488	3547	3614	3689	3771	3860	3956
448	3581	3636	3698	3768	3845	3928	4019
512	3668	3718	3776	3841	3914	3993	4079
576	3748	3795	3849	3911	3979	4054	4136
640	3823	3867	3918	3976	4041	4112	4190
704	3893	3935	3983	4038	4100	4168	4243
768	3959	3999	4045	4097	4156	4221	4293
832	4022	4060	4103	4153	4210	4272	4342
896	4082	4118	4159	4207	4261	4322	4388
960	4139	4173	4213	4259	4311	4369	4434
1024	4193	4226	4265	4309	4359	4415	4477
1088	4246	4277	4314	4357	4405	4459	4520
1152	4296	4326	4362	4403	4450	4502	4561
1216	4344	4374	4408	4448	4493	4544	4601
1280	4391	4419	4452	4491	4535	4584	4639
1344	4436	4463	4496	4533	4575	4623	4677
1408	4480	4506	4537	4573	4615	4661	4714
1472	4522	4548	4578	4613	4653	4699	4750
1536	4563	4588	4617	4651	4690	4735	4785
1600	4603	4627	4656	4689	4727	4770	4819
1664	4641	4665	4693	4725	4762	4805	4852
1728	4679	4702	4729	4761	4797	4838	4885
1792	4716	4738	4765	4795	4831	4871	4917
1856	4752	4774	4799	4829	4864	4903	4948
1920	4787	4808	4833	4863	4896	4935	4978
1984	4821	4842	4866	4895	4928	4966	5008
2048	4854	4874	4898	4927	4959	4996	5038
2112	4887	4907	4930	4958	4989	5026	5067
2176	4918	4938	4961	4988	5019	5055	5095
2240	4950	4969	4991	5018	5048	5083	5123
2304	4980	4999	5021	5047	5077	5111	5150
2368	5010	5029	5050	5076	5105	5139	5177
2432	5040	5058	5079	5104	5133	5166	5204
2496	5068	5086	5107	5132	5160	5193	5229
2560	5097	5114	5135	5159	5187	5219	5255
2624	5124	5142	5162	5185	5213	5244	5280
2688	5152	5169	5188	5212	5239	5270	5305
2752	5179	5195	5215	5238	5264	5295	5329
2816	5205	5221	5240	5263	5289	5319	5353
2880	5231	5247	5266	5288	5314	5343	5377
2944	5256	5272	5291	5313	5338	5367	5400
3008	5282	5297	5315	5337	5362	5391	5423
3072	5306	5322	5340	5361	5385	5414	5446
3136	5331	5346	5364	5384	5409	5437	5468
3200	5355	5369	5387	5408	5432	5459	5490
3264	5378	5393	5410	5431	5454	5481	5512
3328	5402	5416	5433	5453	5476	5503	5534
3392	5425	5439	5456	5475	5498	5525	5555
3456	5447	5461	5478	5497	5520	5546	5576
3520	5470	5483	5500	5519	5541	5567	5597
3584	5492	5505	5522	5541	5563	5588	5617
3648	5513	5527	5543	5562	5584	5609	5637
3712	5535	5548	5564	5583	5604	5629	5657

Object and Ambient temperatures in deci-Kelvin [dK]. Pixel voltage in digits [dig]. Insert sensitivity (and emissivity) corrected voltage.
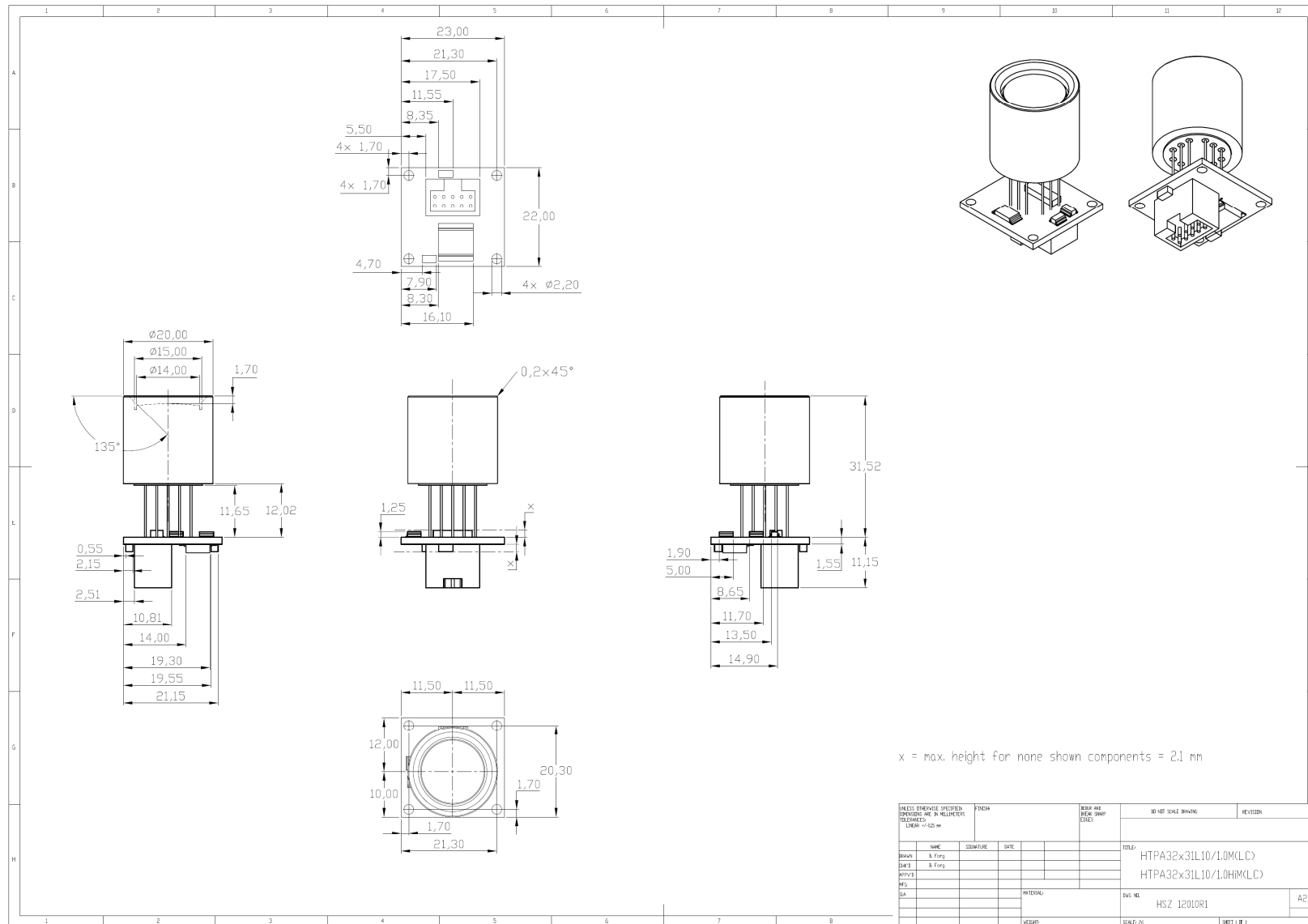
Table Number #13

You can find the matching table number to your device in the EEPROM, refer to "EEPROM Mapping"

Specification for HTPA32x31L10/1.0HiM(LC)[Si]

Rev.1: 2013.04.25 Fg

Dimensions:

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