Specification for HTPA32x31L10/0.8HiM(LC)

Rev.2: 2013.02.22 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

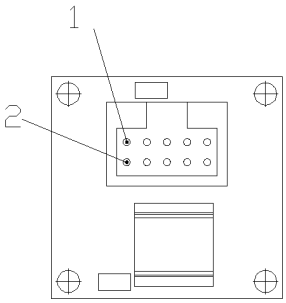
HTPA32x31L10/1.0HiM(SPI)

- 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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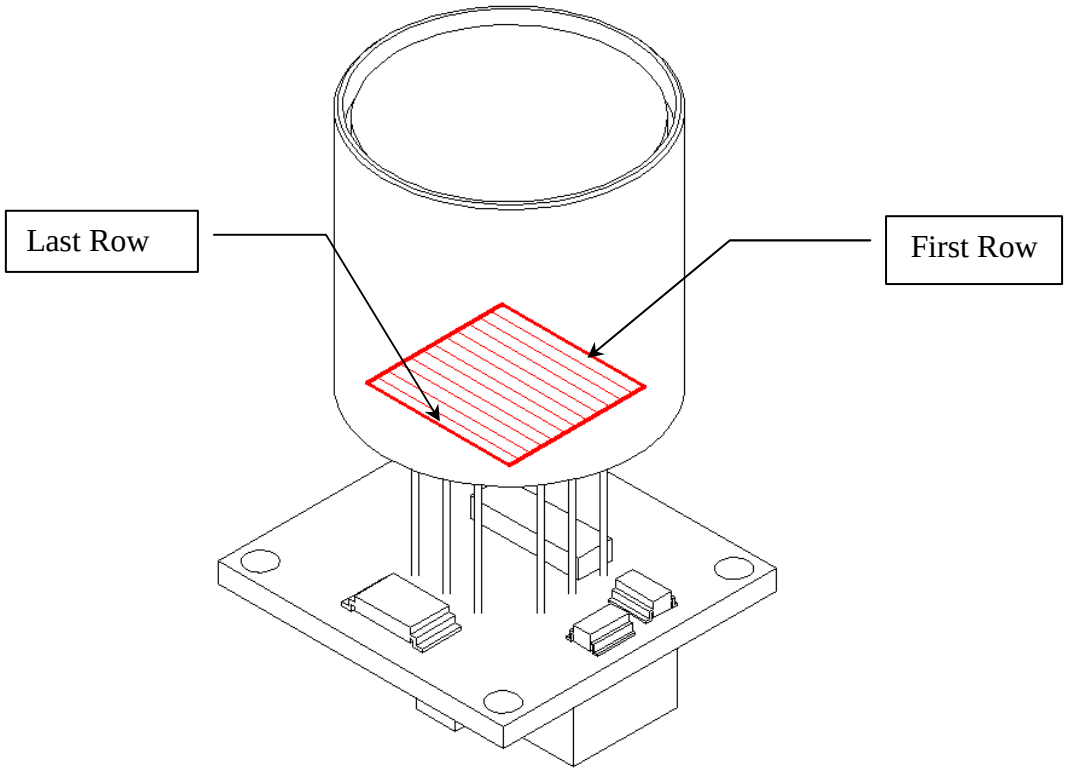
SPI Interface:

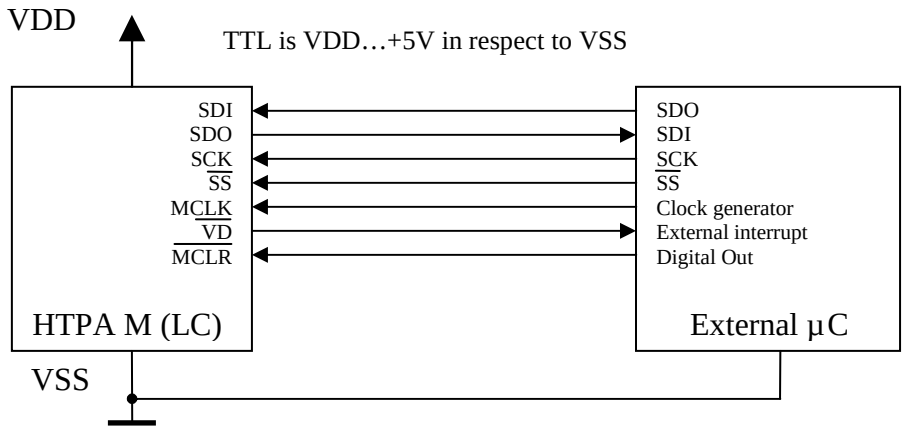
SCK-Frequency:	350 kHz …10 MHz
Protocol Specifications:	
Data format:	16 data bits
Frame Sync:	None
Module-Selection:	$\overline{SS}$-Pin
Clock Edge Select:	Serial output data changes on transition from idle to active clock state
SPI Data Input Sample Phase:	Data sampled on transition from active to 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:

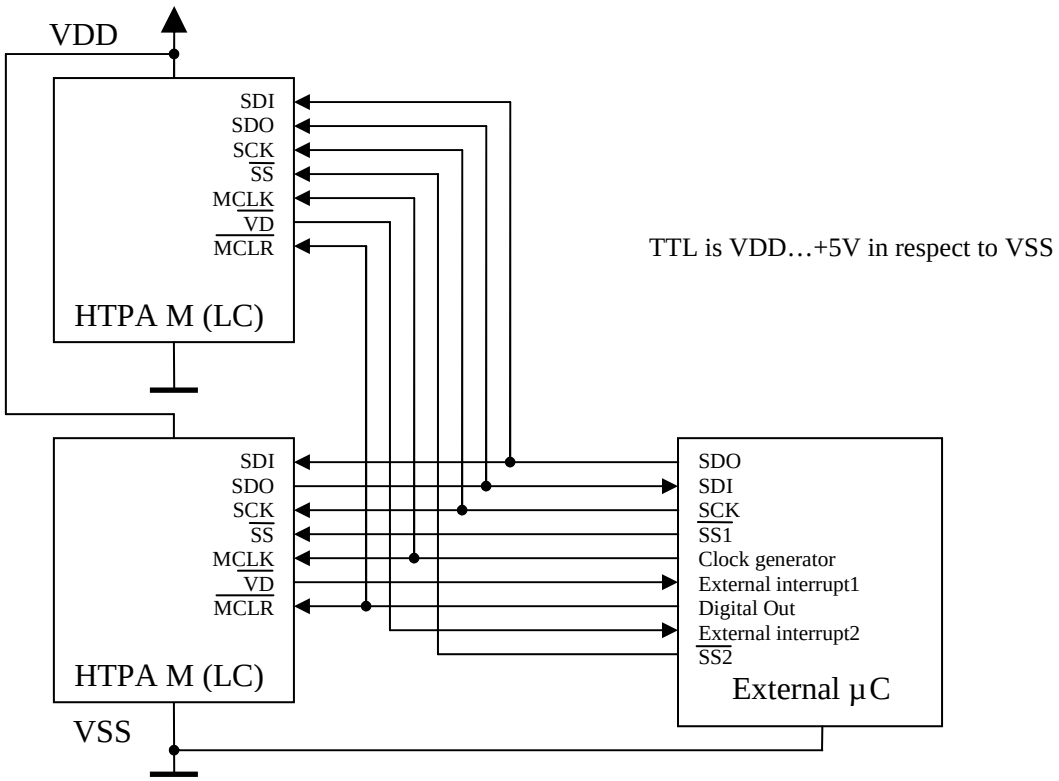


Electrical Connections:

Single Module:

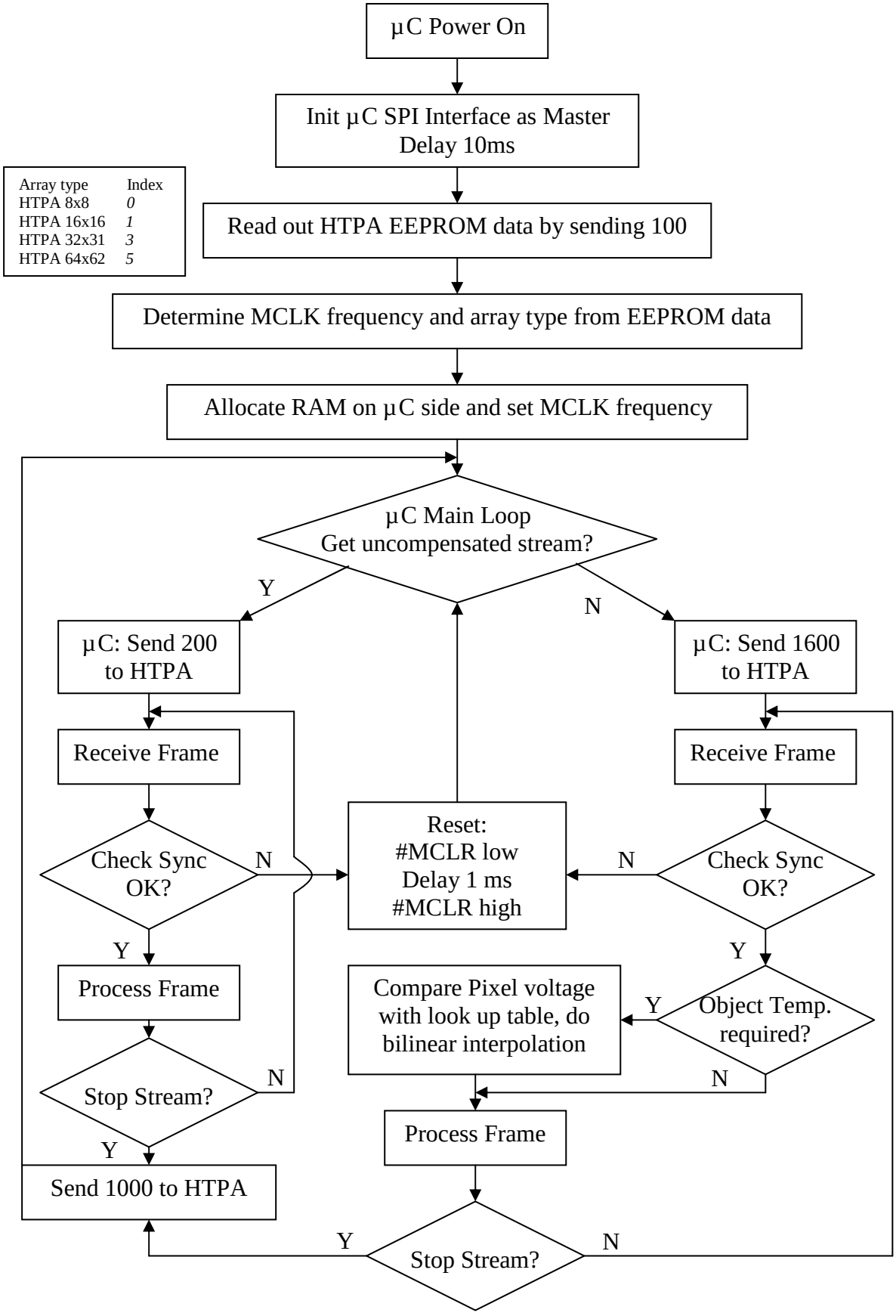


Multiple Modules (preliminary):



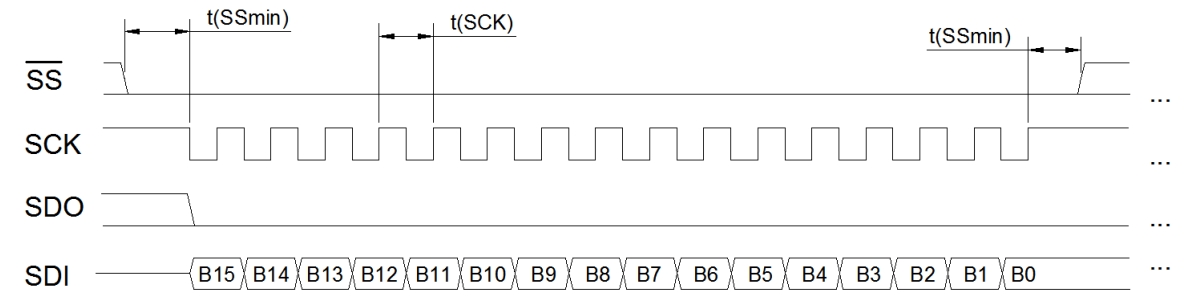
Communication and Timings:

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



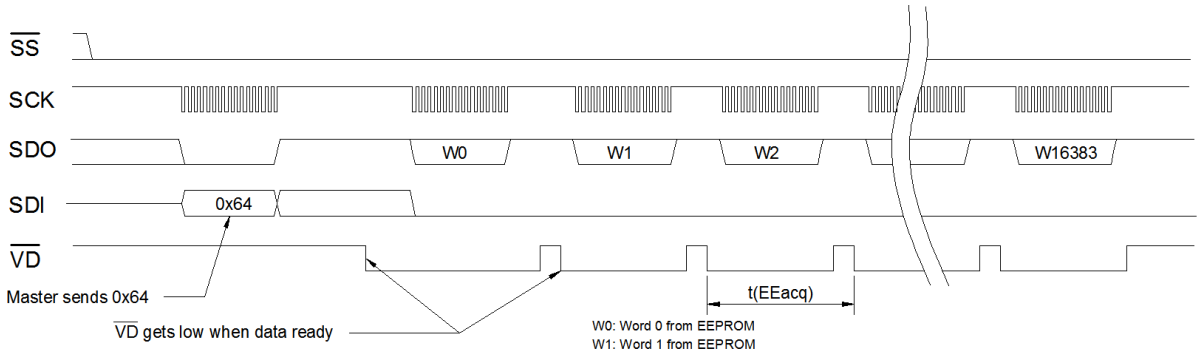
Communication and Timings (continuation):

Receive of command:

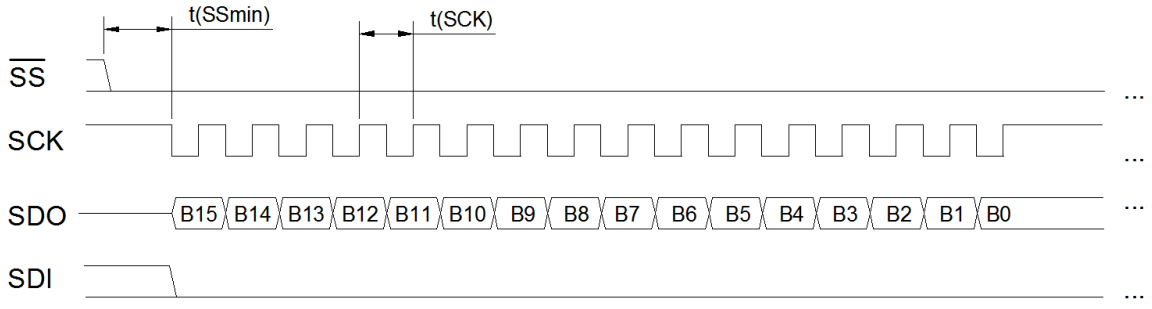


(High state of #SS is not necessary, only for communication with multiple devices)

Send of EEPROM content:

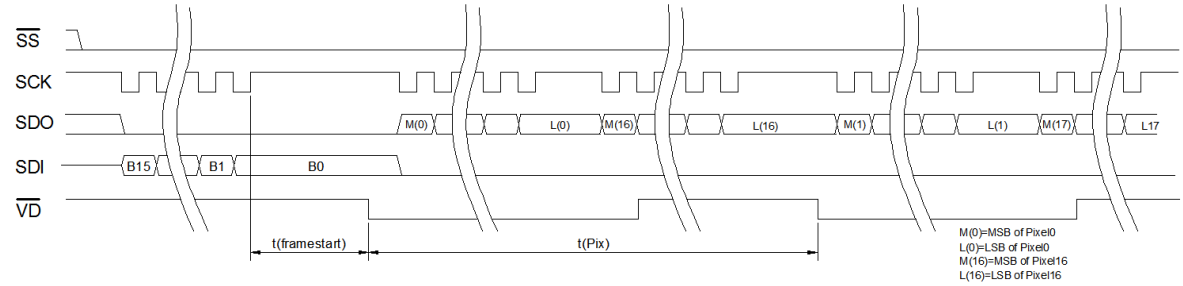


Pixel data:



B15...B0: Raw or compensated ADC reading (depending from streaming mode)

Receive of stream command:



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:

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

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:

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

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

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

```
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;
}
```

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

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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.

Look up table:

	Ambient Temperature [dK]						
Pixel voltage[	2582	2732	2882	3032	3182	3332	3482
-256	2107	2359	2579	2780	2970	3150	3325
-192	2256	2469	2665	2850	3027	3199	3366
-128	2380	2566	2743	2914	3081	3245	3406
-64	2487	2653	2815	2975	3133	3289	3445
0	2582	2732	2882	3032	3182	3332	3482
64	2667	2805	2945	3086	3229	3373	3518
128	2745	2872	3003	3137	3274	3413	3553
192	2817	2936	3059	3186	3317	3451	3587
256	2884	2995	3112	3233	3359	3488	3620
320	2946	3051	3162	3278	3399	3524	3652
384	3005	3104	3209	3321	3438	3559	3684
448	3061	3154	3255	3362	3475	3592	3714
512	3113	3203	3299	3402	3511	3625	3744
576	3163	3249	3341	3441	3546	3657	3773
640	3211	3293	3382	3478	3581	3689	3802
704	3257	3335	3421	3514	3614	3719	3829
768	3301	3376	3459	3550	3646	3749	3857
832	3343	3416	3496	3584	3678	3778	3883
896	3383	3454	3532	3617	3708	3806	3909
960	3423	3491	3566	3649	3738	3834	3935
1024	3461	3527	3600	3680	3768	3861	3960
1088	3497	3561	3633	3711	3796	3888	3985
1152	3533	3595	3665	3741	3824	3914	4009
1216	3567	3628	3696	3770	3851	3939	4033
1280	3601	3660	3726	3799	3878	3964	4056
1344	3634	3691	3755	3827	3904	3989	4079
1408	3666	3721	3784	3854	3930	4013	4102
1472	3697	3751	3812	3881	3955	4037	4124
1536	3727	3780	3840	3907	3980	4060	4146
1600	3756	3808	3867	3932	4005	4083	4167
1664	3785	3836	3894	3958	4028	4105	4189
1728	3813	3863	3919	3982	4052	4128	4210
1792	3841	3890	3945	4007	4075	4149	4230
1856	3868	3916	3970	4030	4098	4171	4250
1920	3894	3941	3994	4054	4120	4192	4270
1984	3920	3966	4018	4077	4142	4213	4290
2048	3946	3991	4042	4100	4163	4233	4310
2112	3971	4015	4065	4122	4185	4254	4329
2176	3995	4039	4088	4144	4206	4274	4348
2240	4019	4062	4110	4165	4226	4293	4366
2304	4043	4085	4133	4187	4247	4313	4385
2368	4066	4107	4154	4207	4267	4332	4403
2432	4089	4129	4176	4228	4286	4351	4421
2496	4111	4151	4197	4248	4306	4369	4439
2560	4133	4173	4218	4268	4325	4388	4456
2624	4155	4194	4238	4288	4344	4406	4474
2688	4176	4215	4258	4308	4363	4424	4491
2752	4197	4235	4278	4327	4381	4442	4508
2816	4218	4255	4298	4346	4400	4459	4525
2880	4239	4275	4317	4364	4418	4477	4541
2944	4259	4295	4336	4383	4435	4494	4558
3008	4279	4314	4355	4401	4453	4511	4574
3072	4298	4333	4374	4419	4471	4527	4590
3136	4318	4352	4392	4437	4488	4544	4606
3200	4337	4371	4410	4455	4505	4560	4622
3264	4356	4389	4428	4472	4522	4577	4637

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

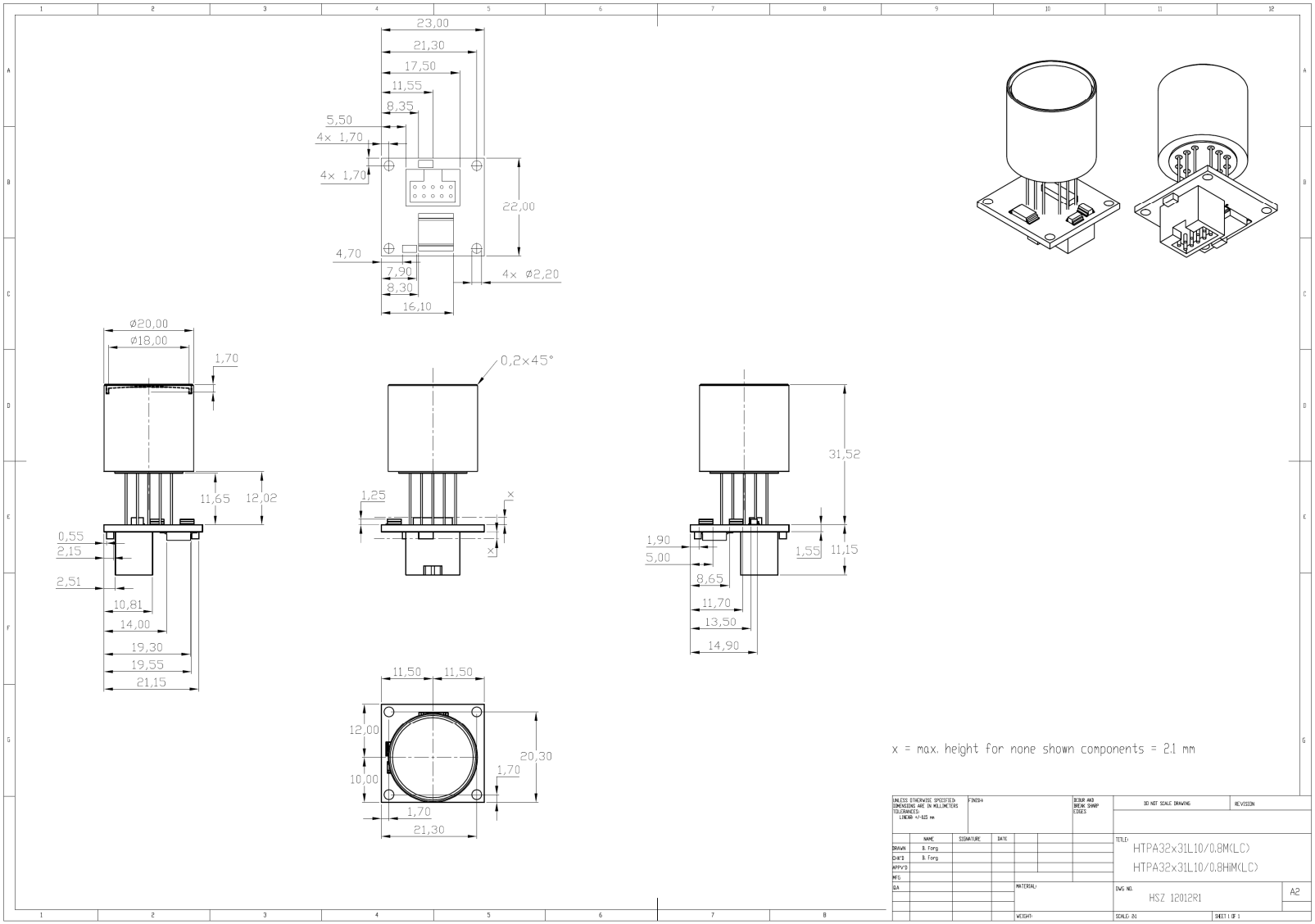
Table Number #6

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

Specification for HTPA32x31L10/0.8HiM(LC)

Rev.2: 2013.02.22 Fg

Dimensions:



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