Product Document

Published by
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Application note for CMV

Temperature Sensor Calibration

Change record

Issue	Date	Modification
v01	29/06/2015	Origination

Table of Contents

1 INTRODUCTION

This document applies to the following sensors:

- CMV300
- CMV2000
- CMV4000
- CMV8000
- CMV12000
- CMV20000
- CHR70M

This document describes the working of the built-in temperature sensor in the different image sensors.

2 TEMPERATURE REGISTER

For all above sensors, there is a temperature register containing a number which can be translated to a device temperature after calibration.

Device	Registers	Remark
CMV300	78[7:0]: LSB's 79[7:0]: MSB's	Combine for a 16b value
CMV2000/CMV4000	126[7:0]: LSB's 127[7:0]: MSB's	Combine for a 16b value
CMV8000	88[7:0]: LSB's 89[7:0]: MSB's	Combine for a 16b value
CMV12000	127[15:0]	
CMV20000	101[7:0]: LSB's 102[7:0]: MSB's	Combine for a 16b value
CHR70M	125: latch 126[7:0]: LSB's 127[7:0]: MSB's	Set latch 0 → 1 to update the temperature value to reg 126/127 Combine for a 16b value

3 FORMULAS

The value in the temperature sensor registers is dependent on the CMOS input clock (CLK_IN or MCLK) frequency. The value has an offset (at 0°C the value in this register is not 0) and a slope (DN/°C). Both are input clock dependent. So, for example, if you read out a value of 1000DN at 40MHz, you will read a value of 500DN at 20MHz at the same temperature. Below you can find the typical slopes and offsets of the sensors. The CLK_IN frequency is f in MHz.

Device	Typical slope [DN/°C]	Typical offset
CMV300	15.5 * f / 25	5100 * f / 25
CMV2000/CMV4000	3.33 * f / 40	1000 * f / 40
CMV8000	5.13 * f / 60	1600 * f / 60
CMV12000	3.5 * f / 30	825 * f / 30
CMV20000	3 * f / 40	1000 * f / 40
CHR70M	77 * f / 30	23500 * f / 30

Between devices of the same type there can be a large variation in offsets, the slopes will variate much less. The values above are typical and can therefor vary per device. For example if you have 2 CMV300 sensors at 30°C, one could read 5467 while the other reads 5801 (while typical would be 5100 + 15.5 * 30 = 5565).

4 CALIBRATION

Because of the varying offsets (and slopes), you will need to calibrate the temperature register if you want to use it in a meaningful way. A calibration is reading out the register value at one or more known device or camera temperatures.

Knowing that the slopes between the same sensors are quite similar (much less variation than the offsets), you could suffice with one calibration point.

If you want to also calibrate the slope, you will have to choose two calibration temperature points, preferably far away from each other.

If you want a more accurate use of the built-in temperature sensor, you can use multiple calibration temperatures. This will also calibrate any non-linearities in the slopes.

5 EXAMPLE

Below is the calibration data of 2 CMV300 sensors running at 40MHz. You can see the difference in offset (~200) and in the slope (~0.6).

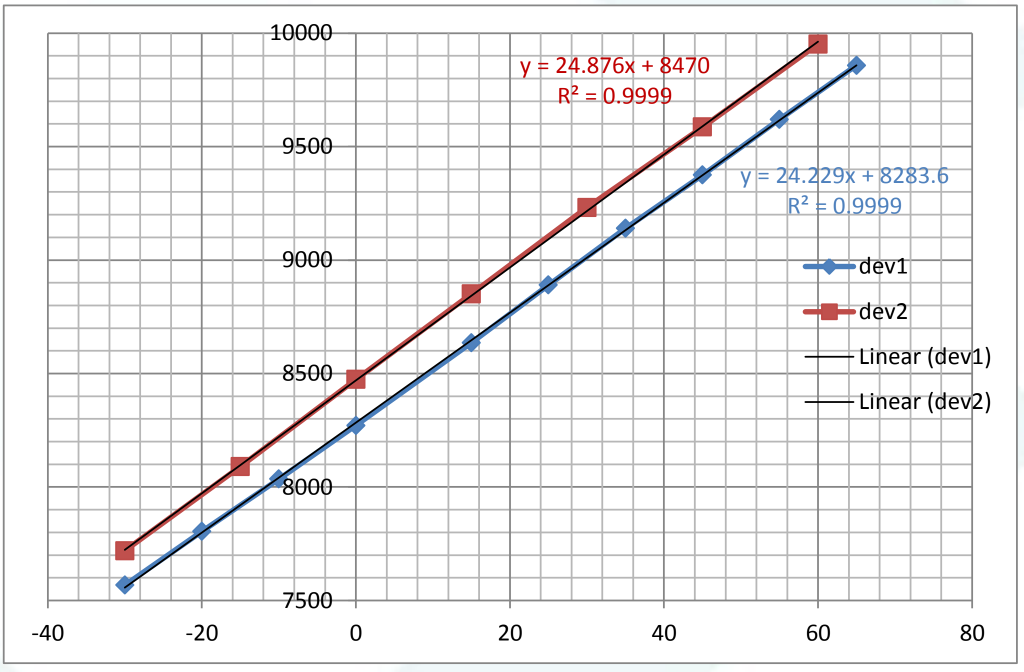

FIGURE 1: TEMPERATURE REGISTER DATA

Temperature dev1	Reg value dev1		Temperature dev2	Reg value dev2
-30	7568		-30	7719
-20	7804		-15	8090
-10	8035		0	8474
0	8271		15	8851
15	8636		30	9231
25	8890		45	9586
35	9140		60	9951
45	9375			
55	9620			
65	9858			

5.1 1-POINT CALIBRATION

So for this, you only do an offset calibration. You let the device settle to a known temperature and read out the register. For example, here we will take device 1 at 25°C. The register value is 8890. The typical slope is 15.5 * f/25 DN/°C, so here that would be 15.5 * 40/25 = 24.8 DN/°C. The offset value (at 0°C) is thus 8890 - (24.8 * 25) = 8270. That would lead to the following results.

Temperature [°C]	Measured data	Calibrated data	Error	Error [°C]
-30	7568	7526	-42	-1.7
-20	7804	7774	-30	-1.2
-10	8035	8022	-13	-0.5
0	8271	8270	-1	0
15	8636	8642	6	0.2
25	**8890**	**8890**	**0**	**0**
35	9140	9138	-2	-0.1
45	9375	9386	11	0.4
55	9620	9634	14	0.6
65	9858	9882	24	1

The 2nd column contains the actual measured register value at each temperature. The 3rd column contains the calculated data using the temperature in the first column, T * 24.8 + 8270. The first Error column contains the error between the calculated data and the actual measured data, while the 2nd one is the error converted back to °C with Error[DN] / 24.8. You can see that even with only a 1-point calibration, the error is < 2°C.

So if you now read out the temperature register of the sensor in a camera and it is (for example) 9488, then the sensor temperature will be (9488 – 8270) /24.8 = 49.1°C

$$Temperature\ [°C] = \frac{Register\ value\ [DN] - Offset[DN]}{Slope\ [\frac{DN}{°C}]}$$

5.2 2-POINT CALIBRATION

So for this, you do an offset and slope calibration. Best is to choose two temperatures not to close to each other.

For example, here we will take device 1 at 25°C and 55°C. The register values are 8890 and 9634. Doing a linear regression yields a slope of 24.33 DN/°C and an offset of 8282DN. With these 2 values we can calculate the data below:

Temperature [°C]	Measured data	Calibrated data	Error	Error [°C]
-30	7568	7552.1	-15.9	-0.7
-20	7804	7795.4	-8.6	-0.4
-10	8035	8038.7	3.7	0.2
0	8271	8282	11	0.5
15	8636	8646.95	10.95	0.5
25	**8890**	**8890.25**	**0.25**	**0**
35	9140	9133.55	-6.45	-0.3
45	9375	9376.85	1.85	0.1
55	**9620**	**9620.15**	**0.15**	**0**
65	9858	9863.45	5.45	0.2

Now the error is <1°C. So if you now read out the temperature register of the sensor in a camera and it is (for example) 9488, then the sensor temperature will be (9488 – 8282) /24.33 = 49.6°C.

5.3 JITTER

Sometimes the values in the temperature registers can jitter a bit, so it is better to read out the register a few times, remove the outliers and average it to get a more correct value.