



**THE DATASHEET OF
MLX90640ESF-BAA-000-TU**

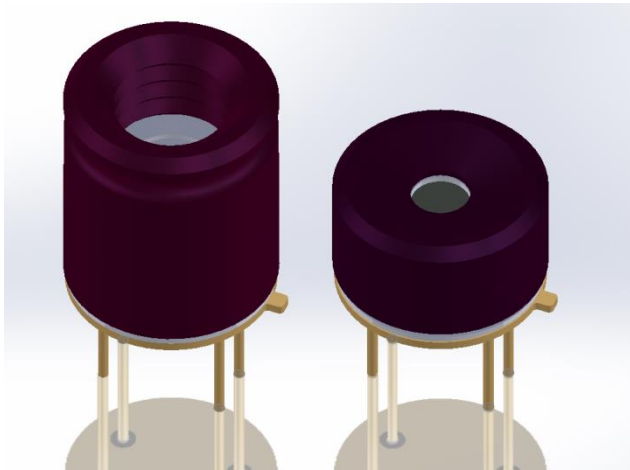


MLX90640 32x24 IR array

Datasheet

1. Features and Benefits

- Small size, low cost 32x24 pixels IR array
- Easy to integrate
- Industry standard four lead TO39 package
- Factory calibrated
- Noise Equivalent Temperature Difference (NETD) 0.1K RMS @1Hz refresh rate
- I²C compatible digital interface
- Programmable refresh rate 0.5Hz...64Hz
- 3.3V supply voltage
- Current consumption less than 23mA
- 2 FOV options – 55°x35° and 110°x75°
- Operating temperature -40°C ÷ 85°C
- Target temperature -40°C ÷ 300°C
- Complies with RoHS regulations



2. Application Examples

- High precision non-contact temperature measurements
- Intrusion / Movement detection
- Presence detection / Person localization
- Temperature sensing element for intelligent building air conditioning
- Thermal Comfort sensor in automotive Air Conditioning control system
- Microwave ovens
- Industrial temperature control of moving parts
- Visual IR thermometers
- Driver software for MCU available at: <https://github.com/melexis/mlx90640-library.git>

3. Description

The MLX90640 is a fully calibrated 32x24 pixels thermal IR array in an industry standard 4-lead TO39 package with digital interface.

The MLX90640 contains 768 FIR pixels. An ambient sensor is integrated to measure the ambient temperature of the chip and supply sensor to measure the VDD. The outputs of all sensors IR, Ta and VDD are stored in internal RAM and are accessible through I²C.

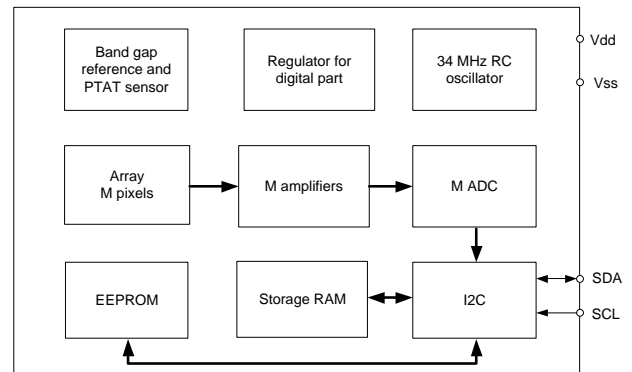


Figure 1 Block diagram

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4. Ordering Information

| Product | Temperature | Package | Option Code | Custom Configuration | Packing Form | Definition |
|----------|-------------|---------|-------------|----------------------|--------------|----------------|
| MLX90640 | E | SF | BAA | 000 | TU | 32x24 IR array |
| MLX90640 | E | SF | BAB | 000 | TU | 32x24 IR array |

Legend:

| | |
|----------------------|--|
| Temperature Code: | E: -40°C to 85°C |
| Package Code: | “SF” for TO39 package |
| Option Code: | xAx – TGC is disabled and may not be changed |
| Option Code: | xxA – FOV = 110°x75° xxB – FOV = 55°x35° |
| Custom configuration | 000 – standard product |
| Packing Form: | “TU” - Tubes |
| Ordering Example: | “MLX90640ESF-BAA-000-TU” |

Table 1 Ordering information

5. Glossary of Terms

| | |
|------------------|--|
| TC | Temperature Coefficient (in ppm/°C) |
| POR | Power On Reset |
| IR | Infra-Red |
| Ta | Ambient Temperature – the temperature of the TO39 package |
| IR data | Infrared data (raw data from ADC proportional to IR energy received by the sensor) |
| ADC | Analog To Digital Converter |
| TGC | Temperature Gradient Coefficient |
| FOV | Field Of View |
| nFOV | Field Of View of the N-th pixel |
| I ² C | Inter-Integrated Circuit communication protocol |
| SDA | Serial Data |
| SCL | Serial Clock |
| LSB | Least Significant Bit |
| MSB | Most Significant Bit |
| Fps | Frames per Second – data refresh rate |
| MD | Master Device |
| SD | Slave Device |
| ASP | Analog Signal Processing |
| DSP | Digital Signal Processing |
| ESD | Electro Static Discharge |
| EMC | Electro Magnetic Compatibility |
| CP | Compensation Pixel |
| NC | Not Connected |
| NA | Not Applicable |
| TBD | To Be Defined |

Table 2 Glossary of terms

6. Pin Definitions and Descriptions

| Pin # | Name | Description |
|-------|------|---|
| 1 | SDA | I ² C serial data (input / output) |
| 2 | VDD | Positive supply |
| 3 | GND | Negative supply (Ground) |
| 4 | SCL | I ² C serial clock (input only) |

Table 3 Pin definition

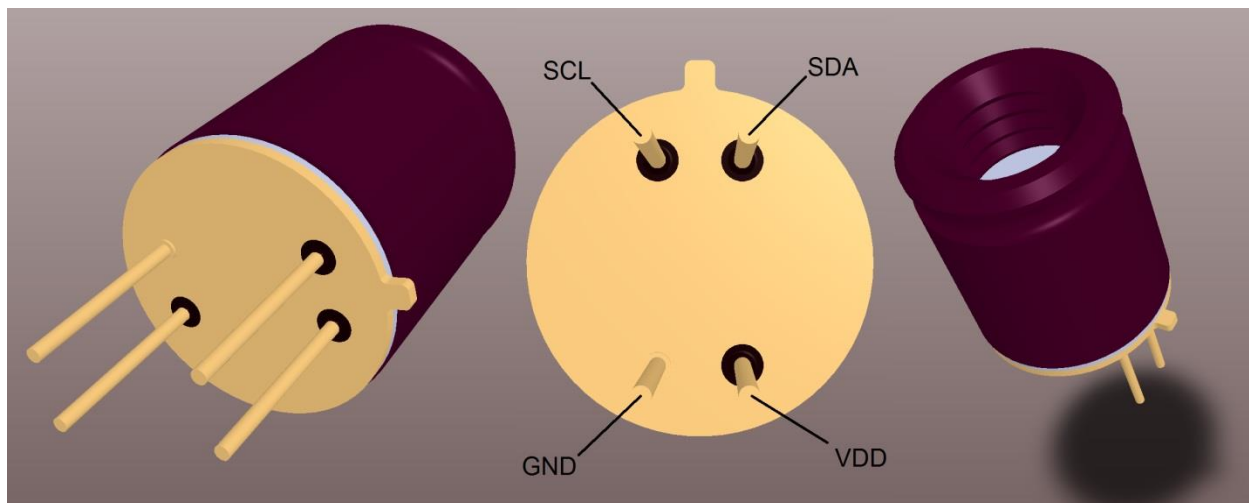


Figure 2 MLX90640 Overview and pin description

7. Absolute Maximum Ratings

| Parameter | Symbol | Min. | Typ. | Max. | Unit | Remark |
|--|------------------|------|------|------|------|----------------------|
| Supply Voltage (over voltage) | V _{DD} | | | 5 | V | |
| Supply Voltage (operating max voltage) | V _{DD} | | | 3.6 | | |
| Reverse Voltage (each pin) | | | | -0.3 | V | |
| Operating Temperature | T _{AMB} | -40 | | +85 | °C | |
| Storage Temperature | T _{ST} | -40 | | +85 | °C | Not in plastic tubes |
| ESD sensitivity (AEC Q100 002) | | 4 | | | kV | |
| SDA DC sink current | | | | 40 | mA | |

Table 4 Absolute maximum ratings

Exceeding the absolute maximum ratings may cause permanent damage. Exposure to absolute maximum-rated conditions for extended periods may affect device reliability.

8. General Electrical Specifications

| Electrical Parameter | Symbol | Min. | Typ. | Max. | Unit | Condition |
|--|-----------------------|---------------------|---------------|---------------------|-------|---|
| Supply Voltage | V _{DD} | 3 | 3.3 | 3.6 | V | |
| Supply Current | I _{DD} | 15 | 20 | 25 | mA | |
| POR level up analog | V _{POR_UP} | 2.2 | | 2.6 | V | VDD rising |
| POR level down analog | V _{POR_DOWN} | | | 2.55 | V | VDD falling |
| POR hysteresis | V _{POR_hys} | | 50 | | mV | |
| I ² C address ^(NOTE 3) | | 0x01 | 0x33(default) | 0xFF | | |
| Input high voltage (SDA, SCL) | V _{IH} | 0.7*V _{DD} | | | V | Over Ta and V _{DD} |
| Input low voltage (SDA, SCL) | V _{LOW} | | | 0.3*V _{DD} | V | Over Ta and V _{DD} |
| SDA output low voltage | V _{OL} | | | 0.4 | V | Over Ta and V _{DD} I _{SINK} =3mA |
| SDA leakage | I _{SDA_leak} | | | ± 10 | µA | V _{SDA} =3.6V, Ta=85°C |
| SCL leakage | I _{SCL_leak} | | | ± 10 | µA | V _{SCL} =3.6V, Ta=85°C |
| SDA capacitance | C _{SDA} | | | 10 | pF | |
| SCL capacitance | C _{SCL} | | | 10 | pF | |
| Acknowledge setup time | T _{SUAC(MD)} | | | 0.45 | µs | |
| Acknowledge hold time | T _{DUAC(MD)} | | | 0.45 | µs | |
| Acknowledge setup time | T _{SUAC(SD)} | | | 0.45 | µs | |
| Acknowledge hold time | T _{DUAC(SD)} | | | 0.45 | µs | |
| I ² C clock frequency | F _{I2C} | | 0.4 | 1 | MHz | |
| EEPROM erase/write cycles | | | | 10 | times | |
| Write cell time | T _{WRITE} | 5 | | | ms | |

Table 5 Electrical specification

NOTE 1: For best performance it is recommended to keep the supply voltage as accurate and stable as possible to 3.3V ± 0.05V

NOTE 2: When a data in EEPROM cell to be changed an erase (write 0x0000) must be done prior to writing the new value. After each write at least 5ms delay is needed in order to writing process to take place.

NOTE 3: Slave address 0x00 must be avoided.

NOTE 4: According to I²C standard the max sink current is specified to be 20mA, however due to the thermal considerations (the dissipated power into the driver) the max current is limited to 10mA. This is the only parameter which does not comply with the FM+ specification.

NOTE 5: Max EEPROM I²C speed operations to be done at 400kHz

9. False pixel correction

The imager can have up to 4 defective pixels, with either no output or out of specification temperature reading. These pixels are identified in the EEPROM table of the sensor and can be read out through the I²C. The defective pixel result can be replaced by an interpolation of its neighboring pixels.

10. Detailed General Description

10.1. Pixel position

The array consists of 768 IR sensors (also called pixels). Each pixel is identified with its row and column position as Pix(*i,j*) where *i* is its row number (from 1 to 24) and *j* is its column number (from 1 to 32)

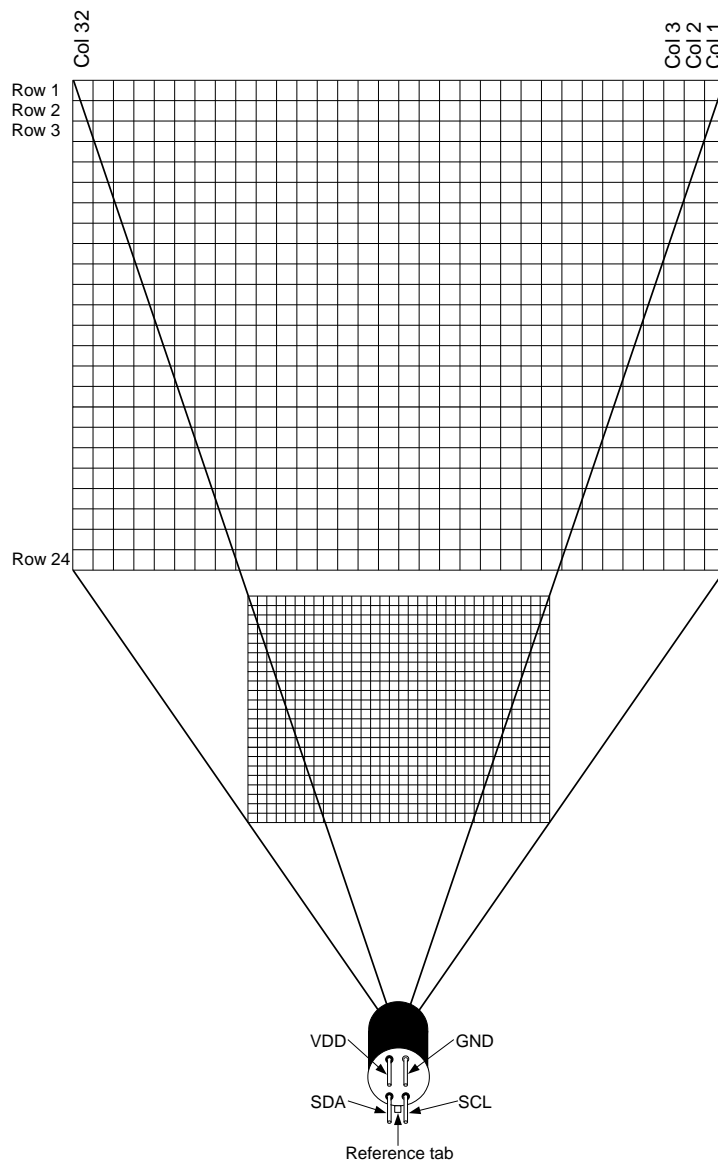


Figure 3 Pixel in the whole FOV

10.2. Communication protocol

The device use I²C protocol with support of FM+ mode (up to 1MHz clock frequency) and can be only slave on the bus. The SDA and SCL ports are 5V tolerant and the sensor can be directly connected to a 5V I²C network. The slave address is programmable and can have up to 127 different slave addresses.

10.2.1. Low level

10.2.1.1. Start / Stop conditions

Each communication session is initiated by a START condition and ends with a STOP condition. A START condition is initiated by a HIGH to LOW transition of the SDA while a STOP is generated by a LOW to HIGH transition. Both changes must be done while the SCL is HIGH.

10.2.1.2. Device addressing

The master is addressing the slave device by sending a 7-bit slave address after the START condition. The first seven bits are dedicated for the address and the 8th is Read/Write (R/W) bit. This bit indicates the direction of the transfer:

- Read (HIGH) means that the master will read the data from the slave
- Write (LOW) means that the master will send data to the slave

10.2.1.3. Acknowledge

During the 9th clock following every byte transfer the transmitter releases the SDA line. The receiver acknowledges (ACK) receiving the byte by pulling SDA line to low or does not acknowledge (NoACK) by letting the SDA 'HIGH'.

10.2.1.4. I²C command format

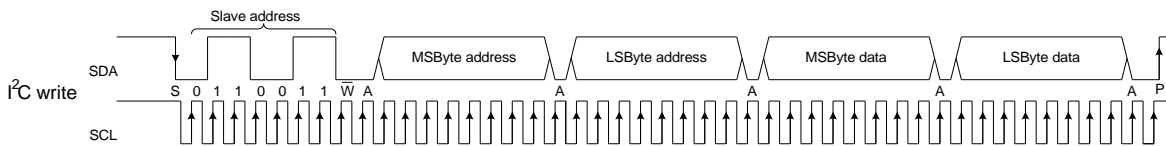


Figure 4 I²C write command format (default SA=0x33 is used)

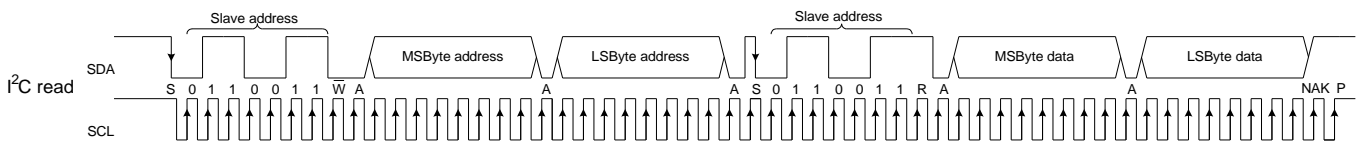


Figure 5 I²C read command format (default SA=0x33 is used)

10.3. Measurement mode

In this mode the measurements are constantly running. Depending on the selected frame rate F_{ps} in the control register, the data for IR pixels and T_a will be updated in the RAM each $\frac{1}{F_{ps}}$ second. In this mode the external microcontroller has full access to the internal registers and memories of the device.

10.4. Refresh rate

The refresh rate is configured by “Control register 1” (0x800D) i.e. if “Refresh rate control” = 011 → 4Hz this would mean that each 250ms a new subpage data is available in the RAM.

NOTE: It is possible to program the desired refresh rate into device EEPROM eliminating the necessity to reconfigure the device every time it is powered on. The corresponding EEPROM cell is at address 0x240C (see Table 8)

Which subpage is updated is indicated by the “Last measured subpage” field.

It is important to read both subpages as the necessary information for the T_a calculations is only available by combining the data from both subpages i.e. the T_a is refreshed with an update speed twice as low as the one set in “Refresh rate control”.

When a complete new data set (subpage) is available, a dedicated bit is set to indicate this – bit 3 “New data available in RAM” in “Status register” (0x8000). It is up to the customer to reset the bit once the data has been read.

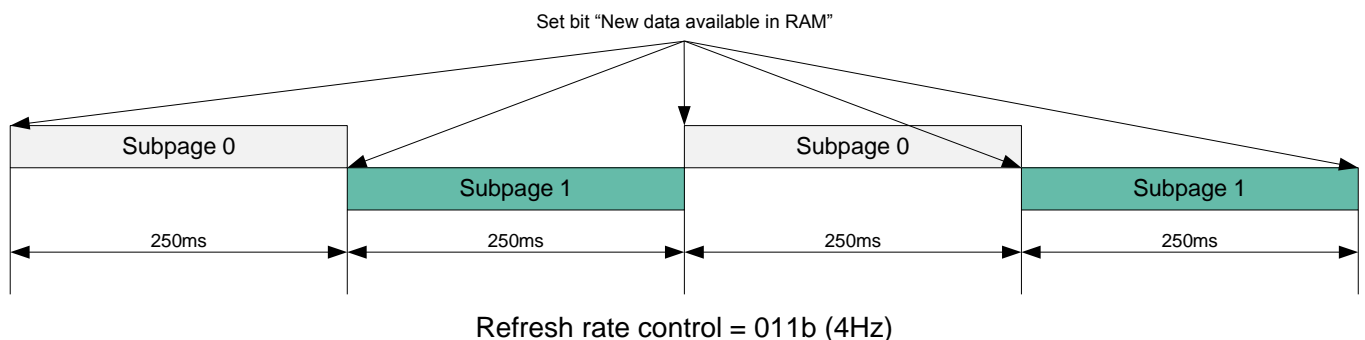


Figure 6 Refresh rate timing

10.5. Measurement flow

Following measurement flow is recommended:

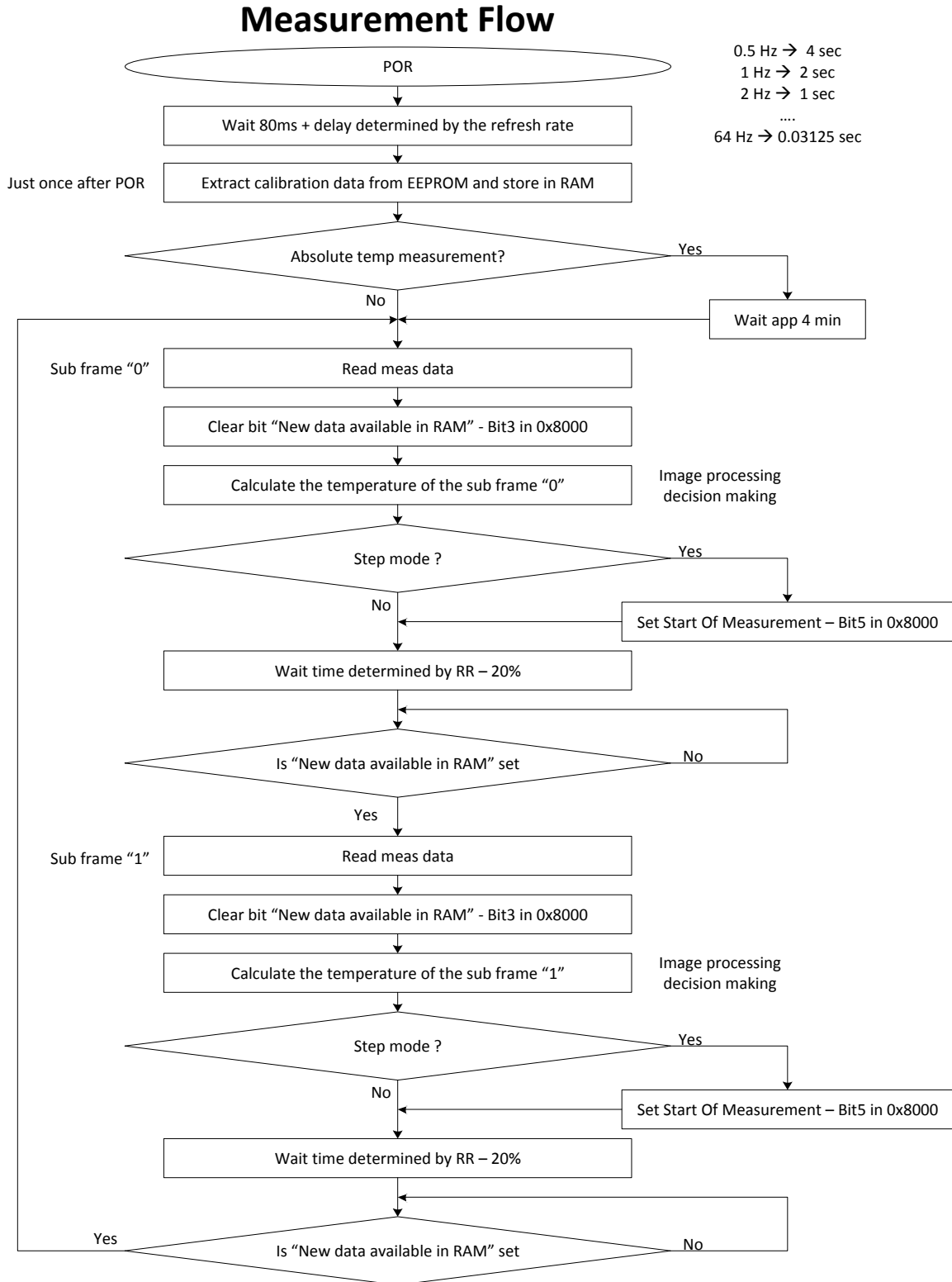


Figure 7 Recommended measurement flow

10.6. Reading patterns

The array frame is divided in two subpages and depending of bit 12 in “Control register 1” (0x800D) – “Reading pattern” there are two modes of the pixel arrangement:

- Chess pattern mode (factory default)
- TV interleave mode

NOTE1: As a standard the MLX90640 is calibrated in Chess pattern mode, this results in better fixed pattern noise behaviour of the sensor when in chess pattern mode. For best results Melexis advises to use chess pattern mode.

NOTE2: Please make sure a proper configuration of the subpage control bit is done. See: [Table 6 Priorities of subpage controls](#)

Subpage 0 --> 0x8000 = 0xXXX8

| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|--------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| 0x0400 | 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 |
| 0x0420 | 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 |
| 0x0440 | 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 |
| 0x0460 | 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 |
| 0x0480 | 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 |
| 0x04A0 | 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 |
| 0x04C0 | 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 |
| 0x04E0 | 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 |
| 0x0500 | 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 |
| 0x0520 | 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 |
| 0x0540 | 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 |
| 0x0560 | 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 |
| 0x0580 | 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 |
| 0x05C0 | 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 |
| 0x05E0 | 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 |
| 0x0600 | 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 |
| 0x0620 | 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 |
| 0x0640 | 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 |
| 0x0660 | 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 |
| 0x0680 | 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 |
| 0x06A0 | 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 |
| 0x06C0 | 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 |
| 0x06E0 | 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 |

Subpage 1 --> 0x8000 = 0xXXX9

| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|--------|-----|-------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| 0x0400 | 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 |
| 0x0420 | 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 |
| 0x0440 | 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 |
| 0x0460 | 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 |
| 0x0480 | 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 |
| 0x04A0 | 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 |
| 0x04C0 | 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 |
| 0x04E0 | 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 |
| 0x0500 | 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 |
| 0x0520 | 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 |
| 0x0540 | 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 |
| 0x0560 | 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 |
| 0x0580 | 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 |
| 0x05A0 | 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 |
| 0x05C0 | 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 |
| 0x05E0 | 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 |
| 0x0600 | 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 |
| 0x0620 | 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 |
| 0x0640 | 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 |
| 0x0660 | 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 |
| 0x0680 | 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 |
| 0x06A0 | 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 |
| 0x06C0 | 705 | 706</ | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |

10.7. Address map

| | |
|--------|-----------------------------|
| 0x0000 | ROM |
| 0x03FF | |
| 0x0400 | RAM |
| 0x07FF | |
| 0x2400 | EEPROM |
| 0x273F | |
| 0x8000 | Registers (MLX reserved) |
| 0x800C | |
| 0x800D | Registers |
| 0x8010 | |
| 0x8011 | Registers (MLX reserved) |
| 0x8016 | |

Figure 10 MXL90640 memory map

10.7.1. Internal registers

There are a few internal registers that are customer accessible through which the device performance can be customized:

| B15 | B14 | B13 | B12 | B11 | B10 | B9 | B8 | B7 | B6 | B5 | B4 | B3 | B2 | B1 | B0 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|------------------|-----|-----|-----|-----|-----|----|----|----|----|----|------------------|---------------------------|--|----|----|--------------------------|--|---|---|--|---|---|---|------------------|--|---|---|---|------------------|--|--|---|---|---|------------------|--|--|---|---|---|------------------|--|--|---|---|---|------------------|--|--|---|---|---|------------------|--|--|--|---|---|--|--|--|--|--|---|--------------------------------|--|--|--|--|---|-----------------------------------|--|--|--|---|
| Melexis reserved | | | | | | | | | | | Enable overwrite | New data available in RAM | Last measured subpage controlled by MLX90641 | | | Status register - 0x8000 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | 0 | 0 | 0 | | Measurement of subpage 0 has been measured | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | 0 | 0 | 1 | Measurement of subpage 1 has been measured | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | | 0 | 1 | 0 | Melexis reserved | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | | | | | | | 0 | 1 | 1 | Melexis reserved | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 1 | 0 | 0 | Melexis reserved | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 1 | 0 | 1 | Melexis reserved | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 1 | 1 | 0 | Melexis reserved | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 1 | 1 | 1 | Melexis reserved | | | | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 0 | No new data is available in RAM (must be reset by the customer) | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 1 | A new data is available in RAM | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 0 | Data in RAM overwrite is disabled | | | | |
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 1 |
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |

Figure 11 Status register (0x8000) bits meaning

| B15 | B14 | B13 | B12 | B11 | B10 | B9 | B8 | B7 | B6 | B5 | B4 | B3 | B2 | B1 | B0 | | |
|------------------|-----|-----------------|--------------------|-----|----------------------|----|----|----------------|----|----|------------------------|------------------|------------------|--|------------------------------------|--|--|
| Melexis reserved | | Reading pattern | Resolution control | | Refresh rate control | | | Select subpage | | | Enable subpages repeat | Enable data hold | Melexis reserved | Enable subpages mode | Control register 1 - 0x800D | | |
| | | | | | | | | | | | | | | 0 No subpages, only one page will be measured | | | |
| | | | | | | | | | | | | | | 1 Subpage mode is activated (default) | | | |
| | | | | | | | | | | | | | | 0 Keep this bit = "0" (default) | | | |
| | | | | | | | | | | | | | | 0 Transfer the data into storage RAM at each measured frame (default) | | | |
| | | | | | | | | | | | | | | 1 Transfer the data into storage RAM only if en_overwrite = 1 (check 0x8000) | | | |
| | | | | | | | | | | | | | | 0 Toggles between subpage "0" and subpage "1" if Enable subpages mode = "1" (default) | | | |
| | | | | | | | | | | | | | | 1 Select subpage determines which subpage to be measured if Enable subpages mode = "1" | | | |
| | | | | | | | | | | | | | | 0 0 0 Subpage 0 is selected (default) | | | |
| | | | | | | | | | | | | | | 0 0 1 Subpage 1 is selected | | | |
| | | | | | | | | | | | | | | 0 1 0 Not Applicable | | | |
| | | | | | | | | | | | | | | 0 1 1 Not Applicable | | | |
| | | | | | | | | | | | | | | 1 0 0 Not Applicable | | | |
| | | | | | | | | | | | | | | 1 0 1 Not Applicable | | | |
| | | | | | | | | | | | | | | 1 1 0 Not Applicable | | | |
| | | | | | | | | | | | | | | 1 1 1 Not Applicable | | | |
| | | | | | | | | | | | | | | 0 0 0 IR refresh rate = 0.5Hz | | | |
| | | | | | | | | | | | | | | 0 0 1 IR refresh rate = 1Hz | | | |
| | | | | | | | | | | | | | | 0 1 0 IR refresh rate = 2Hz (default) | | | |
| | | | | | | | | | | | | | | 0 1 1 IR refresh rate = 4Hz | | | |
| | | | | | | | | | | | | | | 1 0 0 IR refresh rate = 8Hz | | | |
| | | | | | | | | | | | | | | 1 0 1 IR refresh rate = 16Hz | | | |
| | | | | | | | | | | | | | | 1 1 0 IR refresh rate = 32Hz | | | |
| | | | | | | | | | | | | | | 1 1 1 IR refresh rate = 64Hz | | | |
| | | | | | | | | | | | | | | 0 0 ADC set to 16 bit resolution | | | |
| | | | | | | | | | | | | | | 0 1 ADC set to 17 bit resolution | | | |
| | | | | | | | | | | | | | | 1 0 ADC set to 18 bit resolution (default) | | | |
| | | | | | | | | | | | | | | 1 1 ADC set to 19 bit resolution | | | |
| | | | | | | | | | | | | | | 0 Interleaved (TV) mode | | | |
| | | | | | | | | | | | | | | 1 Chess pattern (default) | | | |
| | | | | | | | | | | | | | | - - - Melexis reserved | | | |

Figure 12 Control register1 (0x800D) bits meaning

| Enable subpage mode (Bit 0) | Enable subpage repeat (Bit 3) | Select subpage (Bit 4) | Working mode |
|-----------------------------|-------------------------------|------------------------|------------------------|
| 0 | 0 | - | measure subpage 0 only |
| 0 | 1 | - | measure subpage 0 only |
| 1 | 0 | - | 0 → 1 → 0 → 1 ... |
| 1 | 1 | 0 | measure subpage 0 only |
| 1 | 1 | 1 | measure subpage 1 only |

Table 6 Priorities of subpage controls (0x800D)

| B7 | B6 | B5 | B4 | B3 | B2 | B1 | B0 | B7 | B6 | B5 | B4 | B3 | B2 | B1 | B0 | | | | | | | | | | |
|------------------|----|----|----|----|----|----|----|----|----|----|----|------------------|----------------------------------|--|-------------|-------------------------------------|--|--|--|--|--|--|--|--|--|
| Melexis reserved | | | | | | | | | | | | Melexis reserved | SDA driver current limit control | I2C threshold levels | FM+ disable | I2C configuration register - 0x800F | | | | | | | | | |
| | | | | | | | | | | | | | 0 | FM+ mode enabled (default) | | | | | | | | | | | |
| | | | | | | | | | | | | | 1 | FM+ mode disabled | | | | | | | | | | | |
| | | | | | | | | | | | | | 0 | VDD referred threshold (normal mode) (default) | | | | | | | | | | | |
| | | | | | | | | | | | | | 1 | 1.8V referred threshold (1.8V mode) | | | | | | | | | | | |
| | | | | | | | | | | | | | 0 | SDA driver current limit is ON (default) | | | | | | | | | | | |
| | | | | | | | | | | | | | 1 | SDA driver current limit is OFF | | | | | | | | | | | |
| | | | | | | | | | | | | 0 | Melexis reserved | | | | | | | | | | | | |
| | | | | | | | | | | | | Melexis reserved | | | | | | | | | | | | | |

Figure 13 I²C configuration register (0x800F) bits meaning

10.7.2. RAM

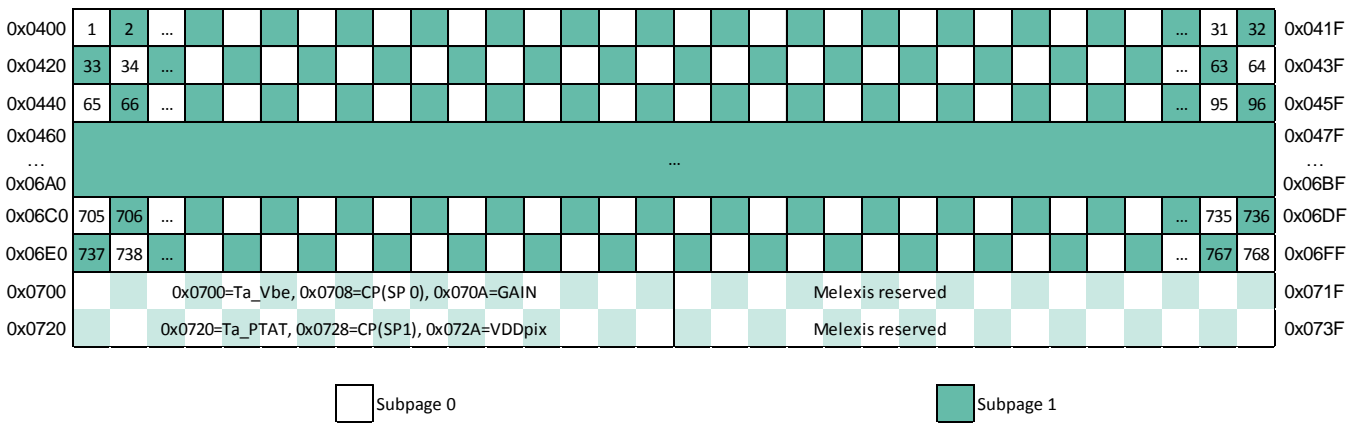


Figure 14 RAM memory map (Chess pattern mode) – factory default mode

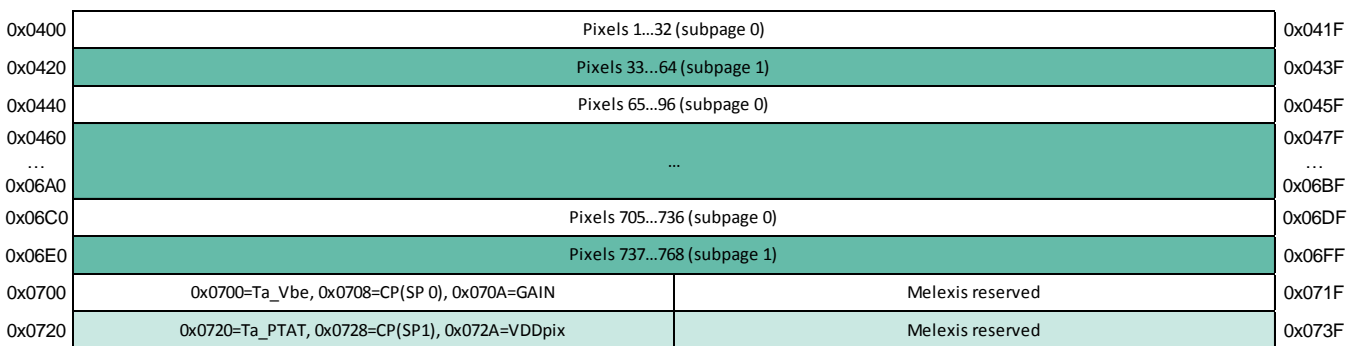


Figure 15 RAM memory map (Interleaved mode)

10.7.3. EEPROM

The EEPROM is used to store the calibration constants and the configuration parameters of the device

| EEPROM address | Access | Meaning |
|----------------|----------|--------------------------------|
| 0x2400 | Melexis | Melexis reserved |
| 0x2401 | Melexis | Melexis reserved |
| 0x2402 | Melexis | Melexis reserved |
| 0x2403 | Melexis | Configuration register |
| 0x2404 | Melexis | Melexis reserved |
| 0x2405 | Melexis | Melexis reserved |
| 0x2406 | Melexis | Melexis reserved |
| 0x2407 | Melexis | Device ID1 |
| 0x2408 | Melexis | Device ID2 |
| 0x2409 | Melexis | Device ID3 |
| 0x240A | Melexis | Device Options |
| 0x240B | Melexis | Melexis reserved |
| 0x240C | Customer | Control register_1 |
| 0x240D | Customer | Control register_2 |
| 0x240E | Customer | I2CConfReg |
| 0x240F | Customer | Melexis reserved / I2C_Address |

Table 7 Configuration parameters memory

After POR the device read dedicated EEPROM cells and transfers their content to into the control and configuration register of the device. This way the device is configured and prepared for operation. The relation between EEPROM and register address is shown here after (explanation of the bit meaning can be found in section 10.7.1 Internal registers:

| EEPROM address | Register address | Access | Name | Data [hex] |
|----------------|------------------|----------|--|------------|
| 0x240C | 0x800D | Customer | Control_register_1 | 1901 |
| 0x240D | 0x800E | Customer | Control_register_2 | 0000 |
| 0x240E | 0x800F | Customer | I2CConfReg | 0000 |
| 0x240F | 0x8010 | Customer | Melexis internal use (8 bit) I2C_Address (8bit) | BE33 |

Table 8 EEPROM to registers mapping

| Address | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | A | B | C | D | E | F | |
|---------|-----------|------------|-------------------------------------|-----------|--------|-----|---------|-------------|--|-------------|------------|-----------|------------|------------|----------|---------|--|
| 0x2400 | Osc Trim | Ana Trim | MLX | Conf reg | MLX | MLX | MLX | ID 1 | ID 2 | ID 3 | MLX | MLX | Cont reg 1 | Cont reg 2 | I2C conf | I2C add | |
| 0x2410 | Scale OCC | Pix os avg | OCC_row_01...24 (6 x 4 x 3bit+sign) | | | | | | OCC_column_01...32 (8 x 4 x 3bit+sign) | | | | | | | | |
| 0x2420 | Scale ACC | Pix α avg | ACC_row_01...24 (6 x 4 x 3bit+sign) | | | | | | ACC_column_01...32 (8 x 4 x 3bit+sign) | | | | | | | | |
| 0x2430 | GAIN | PTAT_25 | Kv, Kt ptat | Kv Vdd_25 | Kv_avg | MLX | Kta_avg | Kv, Kta Sca | ACP 1,2 | Off - CP1,2 | Kv, Kta Cp | KsTa, TGC | KsTo 4, 3 | KsTo 2, 1 | CT 4, 3 | | |
| 0x2440 | | | | | | | | | | | | | | | | | |
| 0x2450 | | | | | | | | | | | | | | | | | |
| 0x2460 | | | | | | | | | | | | | | | | | |
| 0x2470 | | | | | | | | | | | | | | | | | |
| 0x2480 | | | | | | | | | | | | | | | | | |
| 0x2490 | | | | | | | | | | | | | | | | | |
| 0x24A0 | | | | | | | | | | | | | | | | | |
| 0x24B0 | | | | | | | | | | | | | | | | | |
| 0x24C0 | | | | | | | | | | | | | | | | | |
| 0x24D0 | | | | | | | | | | | | | | | | | |
| 0x24E0 | | | | | | | | | | | | | | | | | |
| 0x24F0 | | | | | | | | | | | | | | | | | |
| 0x2500 | | | | | | | | | | | | | | | | | |
| 0x2510 | | | | | | | | | | | | | | | | | |
| 0x2520 | | | | | | | | | | | | | | | | | |
| 0x2530 | | | | | | | | | | | | | | | | | |
| 0x2540 | | | | | | | | | | | | | | | | | |
| 0x2550 | | | | | | | | | | | | | | | | | |
| 0x2560 | | | | | | | | | | | | | | | | | |
| 0x2570 | | | | | | | | | | | | | | | | | |
| 0x2580 | | | | | | | | | | | | | | | | | |
| 0x2590 | | | | | | | | | | | | | | | | | |
| 0x25A0 | | | | | | | | | | | | | | | | | |
| 0x25B0 | | | | | | | | | | | | | | | | | |
| 0x25C0 | | | | | | | | | | | | | | | | | |
| 0x25D0 | | | | | | | | | | | | | | | | | |
| 0x25E0 | | | | | | | | | | | | | | | | | |
| 0x25F0 | | | | | | | | | | | | | | | | | |
| 0x2600 | | | | | | | | | | | | | | | | | |
| 0x2610 | | | | | | | | | | | | | | | | | |
| 0x2620 | | | | | | | | | | | | | | | | | |
| 0x2630 | | | | | | | | | | | | | | | | | |
| 0x2640 | | | | | | | | | | | | | | | | | |
| 0x2650 | | | | | | | | | | | | | | | | | |
| 0x2660 | | | | | | | | | | | | | | | | | |
| 0x2670 | | | | | | | | | | | | | | | | | |
| 0x2680 | | | | | | | | | | | | | | | | | |
| 0x2690 | | | | | | | | | | | | | | | | | |
| 0x26A0 | | | | | | | | | | | | | | | | | |
| 0x26B0 | | | | | | | | | | | | | | | | | |
| 0x26C0 | | | | | | | | | | | | | | | | | |
| 0x26D0 | | | | | | | | | | | | | | | | | |
| 0x26E0 | | | | | | | | | | | | | | | | | |
| 0x26F0 | | | | | | | | | | | | | | | | | |
| 0x2700 | | | | | | | | | | | | | | | | | |
| 0x2710 | | | | | | | | | | | | | | | | | |
| 0x2720 | | | | | | | | | | | | | | | | | |
| 0x2730 | | | | | | | | | | | | | | | | | |

768 x Offset, α, Kta, Outlier

Table 9 EEPROM overview (words)

| Address \ bit | 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|---------------|---|----|----|----|------------------------------|----|---|---|------------------------------|---|---|---|--------------------------------|---|---|---|
| 0x2410 | (Alpha PTAT - 8)*4 | | | | scale_Occ_row | | | | scale_Occ_col | | | | scale_Occ_rem | | | |
| 0x2411 | ± Pix_os_average | | | | | | | | | | | | | | | |
| 0x2412 | ± OCC row 4 | | | | ± OCC row 3 | | | | ± OCC row 2 | | | | ± OCC row 1 | | | |
| 0x2413 | ± OCC row 8 | | | | ± OCC row 7 | | | | ± OCC row 6 | | | | ± OCC row 5 | | | |
| 0x2414 | ± OCC row 12 | | | | ± OCC row 11 | | | | ± OCC row 10 | | | | ± OCC row 9 | | | |
| 0x2415 | ± OCC row 16 | | | | ± OCC row 15 | | | | ± OCC row 14 | | | | ± OCC row 13 | | | |
| 0x2416 | ± OCC row 20 | | | | ± OCC row 19 | | | | ± OCC row 18 | | | | ± OCC row 17 | | | |
| 0x2417 | ± OCC row 24 | | | | ± OCC row 23 | | | | ± OCC row 22 | | | | ± OCC row 21 | | | |
| 0x2418 | ± OCC column 4 | | | | ± OCC column 3 | | | | ± OCC column 2 | | | | ± OCC column 1 | | | |
| 0x2419 | ± OCC column 8 | | | | ± OCC column 7 | | | | ± OCC column 6 | | | | ± OCC column 5 | | | |
| 0x241A | ± OCC column 12 | | | | ± OCC column 11 | | | | ± OCC column 10 | | | | ± OCC column 9 | | | |
| 0x241B | ± OCC column 16 | | | | ± OCC column 15 | | | | ± OCC column 14 | | | | ± OCC column 13 | | | |
| 0x241C | ± OCC column 20 | | | | ± OCC column 19 | | | | ± OCC column 18 | | | | ± OCC column 17 | | | |
| 0x241D | ± OCC column 24 | | | | ± OCC column 23 | | | | ± OCC column 22 | | | | ± OCC column 21 | | | |
| 0x241E | ± OCC column 28 | | | | ± OCC column 27 | | | | ± OCC column 26 | | | | ± OCC column 25 | | | |
| 0x241F | ± OCC column 32 | | | | ± OCC column 31 | | | | ± OCC column 30 | | | | ± OCC column 29 | | | |
| 0x2420 | Alpha scale - 30 | | | | Scale_ACC_row | | | | Scale_ACC_column | | | | Scale_ACC_remand | | | |
| 0x2421 | ± Pix_sensitivity_average | | | | | | | | | | | | | | | |
| 0x2422 | ± ACC row 4 | | | | ± ACC row 3 | | | | ± ACC row 2 | | | | ± ACC row 1 | | | |
| 0x2423 | ± ACC row 8 | | | | ± ACC row 7 | | | | ± ACC row 6 | | | | ± ACC row 5 | | | |
| 0x2424 | ± ACC row 12 | | | | ± ACC row 11 | | | | ± ACC row 10 | | | | ± ACC row 9 | | | |
| 0x2425 | ± ACC row 16 | | | | ± ACC row 15 | | | | ± ACC row 14 | | | | ± ACC row 13 | | | |
| 0x2426 | ± ACC row 20 | | | | ± ACC row 19 | | | | ± ACC row 18 | | | | ± ACC row 17 | | | |
| 0x2427 | ± ACC row 24 | | | | ± ACC row 23 | | | | ± ACC row 22 | | | | ± ACC row 21 | | | |
| 0x2428 | ± ACC column 4 | | | | ± ACC column 3 | | | | ± ACC column 2 | | | | ± ACC column 1 | | | |
| 0x2429 | ± ACC column 8 | | | | ± ACC column 7 | | | | ± ACC column 6 | | | | ± ACC column 5 | | | |
| 0x242A | ± ACC column 12 | | | | ± ACC column 11 | | | | ± ACC column 10 | | | | ± ACC column 9 | | | |
| 0x242B | ± ACC column 16 | | | | ± ACC column 15 | | | | ± ACC column 14 | | | | ± ACC column 13 | | | |
| 0x242C | ± ACC column 20 | | | | ± ACC column 19 | | | | ± ACC column 18 | | | | ± ACC column 17 | | | |
| 0x242D | ± ACC column 24 | | | | ± ACC column 23 | | | | ± ACC column 22 | | | | ± ACC column 21 | | | |
| 0x242E | ± ACC column 28 | | | | ± ACC column 27 | | | | ± ACC column 26 | | | | ± ACC column 25 | | | |
| 0x242F | ± ACC column 32 | | | | ± ACC column 31 | | | | ± ACC column 30 | | | | ± ACC column 29 | | | |
| 0x2430 | ± GAIN | | | | | | | | | | | | | | | |
| 0x2431 | ± PTAT_25 | | | | | | | | | | | | | | | |
| 0x2432 | ± Kv_PTAT | | | | ± Kv_Vdd | | | | ± Kt_PTAT | | | | ± Vdd_25 | | | |
| 0x2433 | ± Kv_avg_RowOdd-ColumnOdd | | | | ± Kv_avg_RowEven-ColumnOdd | | | | ± Kv_avg_RowOdd-ColumnEven | | | | ± Kv_avg_RowEven-ColumnEven | | | |
| 0x2434 | ± IL_CHESS_C3 - 5 bits | | | | ± IL_CHESS_C2 - 5 bits | | | | ± IL_CHESS_C1 - 6 bits | | | | | | | |
| 0x2435 | ± Kta_avg_RowOdd-ColumnOdd | | | | ± Kta_avg_RowEven-ColumnOdd | | | | ± Kta_avg_RowOdd-ColumnEven | | | | ± Kta_avg_RowEven-ColumnEven | | | |
| 0x2436 | ± Kta_avg_RowOdd-ColumnEven | | | | ± Kta_avg_RowEven-ColumnEven | | | | ± Kta_avg_RowOdd-ColumnOdd | | | | ± Kta_avg_RowEven-ColumnOdd | | | |
| 0x2437 | MLX | | | | Res control calib | | | | Kv scale | | | | Kta scale_1 | | | |
| 0x2438 | MLX | | | | temp step x 10 | | | | CT4 | | | | CT3 | | | |
| 0x2439 | ± Alpha (CP subpage_1 / CP subpage_0 - 1)*2^7 | | | | Alpha CP subpage_0 | | | | KsTo range 2 (0°C...CT1°C) | | | | KsTo range 1 (<0°C) | | | |
| 0x243A | ± Offset (CP subpage_1 - CP subpage_0) | | | | ± Offset CP subpage_0 | | | | ± KsTo range 4 (CT2°C...) | | | | ± KsTo range 3 (CT1°C...CT2°C) | | | |
| 0x243B | ± Kv_CP | | | | ± KsTo range 1 (<0°C) | | | | KsTo range 2 (0°C...CT1°C) | | | | KsTo range 3 (CT1°C...CT2°C) | | | |
| 0x243C | ± KsTo range 1 (<0°C) | | | | KsTo range 2 (0°C...CT1°C) | | | | KsTo range 3 (CT1°C...CT2°C) | | | | KsTo range 4 (CT2°C...) | | | |
| 0x243D | ± KsTo range 1 (<0°C) | | | | KsTo range 2 (0°C...CT1°C) | | | | KsTo range 3 (CT1°C...CT2°C) | | | | KsTo range 4 (CT2°C...) | | | |
| 0x243E | ± KsTo range 1 (<0°C) | | | | KsTo range 2 (0°C...CT1°C) | | | | KsTo range 3 (CT1°C...CT2°C) | | | | KsTo range 4 (CT2°C...) | | | |
| 0x243F | MLX | | | | temp step x 10 | | | | CT4 | | | | CT3 | | | |
| 0x2440 | ± Offset pixel (1, 1) | | | | α pixel (1, 1) | | | | ± Kta (1, 1) | | | | Outlier | | | |
| 0x2441 | ± Offset pixel (1, 2) | | | | α pixel (1, 2) | | | | ± Kta (1, 2) | | | | Outlier | | | |
| ... | ... | | | | ... | | | | ... | | | | ... | | | |
| 0x245E | ± Offset pixel (1, 31) | | | | α pixel (1, 31) | | | | ± Kta (1, 31) | | | | Outlier | | | |
| 0x245F | ± Offset pixel (1, 32) | | | | α pixel (1, 32) | | | | ± Kta (1, 32) | | | | Outlier | | | |
| 0x2460 | ± Offset pixel (2, 1) | | | | α pixel (2, 1) | | | | ± Kta (2, 1) | | | | Outlier | | | |
| 0x2461 | ± Offset pixel (2, 2) | | | | α pixel (2, 2) | | | | ± Kta (2, 2) | | | | Outlier | | | |
| ... | ... | | | | ... | | | | ... | | | | ... | | | |
| 0x273E | ± Offset pixel (24, 31) | | | | α pixel (24, 31) | | | | ± Kta (24, 31) | | | | Outlier | | | |
| 0x273F | ± Offset pixel (24, 32) | | | | α pixel (24, 32) | | | | ± Kta (24, 32) | | | | Outlier | | | |

Table 10 Calibration parameters memory (EEPROM - bits)

NOTE 1: EEPROM addresses from 0x2440...0x273F contain the individual pixel calibration information and may not be equal to 0x0000. In case any pixel data is equal to 0x0000 this means that this particular pixels has failed and the calculation for To should not be trusted and avoided. Depending on the application, the To value for such pixels can be replaced with a default value such as -273.15°C, can be equal to Ta or one calculate an average value from the adjacent pixels.

NOTE 2: The LSB for EEPROM addresses from 0x2440...0x273F indicate if all pixel parameters are within the calibration specification. If this bit is set i.e. = "1" this would mean that at least one of the calibration parameters for this particular pixel is outside the calibration specifications and the pixel is considered as Outlier i.e. the sensor accuracy is not guaranteed by the calibration.

NOTE 3: Pixels identified during calibration process as potentially long term deviating pixels are marked in the same manner. Long term deviating pixels are identified in zone 1 and zone 2 only, zone 3 is excluded (for zone information please refer to paragraph 12.1.1 Figure 18). An unidentified long term deviating pixel may be still present.

NOTE 4: The maximum number of deviating pixels is 4 (please check False pixel correction), none of the deviating pixels are adjacent to each other. Depending on the application one may have to choose to replace the measurement results of such pixel by an average of the temperature indicated by the adjacent pixels.

11. Calculating Object Temperature

11.1. Restoring calibration data from EERPOM

NOTE: All data in the EEPROM is coded as two's complement (unless otherwise noted)

In the example we are restoring the calibration data for pixel (12, 16)

11.1.1. Restoring the VDD sensor parameters

Following formula is used to calculate the VDD of the sensor:

$$K_{Vdd} = \frac{EE[0x2433] \& 0xFF00}{2^8}$$

$$\text{If } K_{Vdd} > 127 \rightarrow K_{Vdd} = K_{Vdd} - 256$$

$$K_{Vdd} = K_{Vdd} * 2^5$$

$$VDD_{25} = EE[0x2433] \& 0x00FF$$

$$VDD_{25} = (VDD_{25} - 256) * 2^5 - 2^{13}$$

11.1.2. Restoring the Ta sensor parameters

Following formula is used to calculate the Ta of the sensor:

$$T_a = \frac{\left(\frac{V_{PTAT_{art}} - V_{PTAT_{25}}}{1 + K_{V_{PTAT}} \cdot \Delta V} \right)}{K_{T_{PTAT}}} + 25, \text{ } ^\circ\text{C}$$

Where:

$$K_{V_{PTAT}} = \frac{EE[0x2432] \& 0xFC00}{2^{10}}$$

$$\text{If } K_{V_{PTAT}} > 31 \rightarrow K_{V_{PTAT}} = K_{V_{PTAT}} - 64$$

$$K_{V_{PTAT}} = \frac{K_{V_{PTAT}}}{2^{12}}$$

$$K_{T_{PTAT}} = EE[0x2432] \& 0x03FF$$

$$\text{If } K_{T_{PTAT}} > 511 \rightarrow K_{T_{PTAT}} = K_{T_{PTAT}} - 1024$$

$$K_{T_{PTAT}} = \frac{K_{T_{PTAT}}}{2^3}$$

$$\Delta V = \frac{RAM[0x072A] - VDD_{25}}{K_V}$$

$$V_{PTAT_{25}} = EE[0x2431]$$

$$\text{If } V_{PTAT_{25}} > 32767 \rightarrow V_{PTAT_{25}} = V_{PTAT_{25}} - 65536$$

$$V_{PTAT_{art}} = \left(\frac{V_{PTAT}}{V_{PTAT} * \text{Alpha}_{PTAT} + V_{BE}} \right) * 2^{18}$$

Where:

$$V_{PTAT} = \text{RAM}[0x0720]$$

$$\text{If } V_{PTAT} > 32767 \rightarrow V_{PTAT} = V_{PTAT} - 65536$$

$$V_{BE} = \text{RAM}[0x0700]$$

$$\text{If } V_{BE} > 32767 \rightarrow V_{BE} = V_{BE} - 65536$$

$$\text{Alpha}_{PTAT_EE} = \frac{EE[0x2410] \& 0xF000}{2^{12}}$$

$$\text{Alpha}_{PTAT} = \frac{\text{Alpha}_{PTAT_EE}}{2^2} + 8$$

11.1.3. Restoring the offset

$$\text{pix}_{OS_{ref}}(i,j) = \text{Offset}_{average} + OCC_{row_i} * 2^{OCC_{scale_{row}}} + OCC_{column_j} * 2^{OCC_{scale_{column}}} + \text{offset}(i,j) * 2^{OCC_{scale_{remnant}}}$$

$$\text{Offset}_{average} = EE[0x2411]$$

$$\text{If } \text{Offset}_{average} > 32767 \rightarrow \text{Offset}_{average} = \text{Offset}_{average} - 65536$$

$$OCC_{row_{12}} = \frac{EE[0x2414] \& 0xF000}{2^{12}} \text{ (i.e. the four most significant bits, signed)}$$

$$\text{If } OCC_{row_{12}} > 7 \rightarrow OCC_{row_{12}} = OCC_{row_{12}} - 16$$

$$OCC_{scale_{row}} = \frac{EE[0x2410] \& 0x0F00}{2^8} \text{ (unsigned)}$$

$$OCC_{column_{16}} = \frac{EE[0x241B] \& 0xF000}{2^{12}} \text{ (i.e. the four most significant bits, signed)}$$

$$\text{If } OCC_{column_{16}} > 7 \rightarrow OCC_{column_{16}} = OCC_{column_{16}} - 16$$

$$OCC_{scale_{column}} = \frac{EE[0x2410] \& 0x00F0}{2^4} \text{ (unsigned)}$$

$$\text{offset}(12,16) = \frac{EE[0x25AF] \& 0xFC00}{2^{10}} \text{ (i.e. the six most significant bits, signed)}$$

$$\text{If } \text{offset}(12,16) > 31 \rightarrow \text{offset}(12,16) = \text{offset}(12,16) - 64$$

$$OCC_{scale_{remnant}} = EE[0x2410] \& 0x000F \text{ (unsigned)}$$

11.1.3.1. Restoring the offset in case of Interleaved reading pattern

To compensate the IR data for interleaved reading pattern following formula is used:

$$\text{pix}_{OS}(i,j) = \text{pix}_{gain}(i,j) + I_{CHESS_{c3}} * (2 * I_{PATTERN} - 1) - I_{CHESS_{c2}} * \text{Conversion}_{pattern} - \text{pix}_{OS_{ref}} * \left(1 + K_{Ta(i,j)} * (T_a - T_{a0}) \right) * \left(1 + K_{V(i,j)} * (V_{dd} - V_{dd0}) \right)$$

Highlighted in yellow parameters are extracted hereafter.

As a default the device is factory calibrated in Chess pattern mode thus the best performance will be when a Chess pattern is used. However some customers may choose to use the device in interleaved mode which will degrade the device performance. In this case a correction can be applied to restore to some extent the performance. Once the IR data is compensated the calculation for To is done using default flow. The goal of this correction is to equalize the offset of the pixels due to the different pattern reading modes. We can achieve this by using several correction coefficients stored into the device EEPROM extracted and decoded as follows:

$$IL_{CHESS_{C1EE}} = EE[0x2435] \& 0x003F$$

$$\text{If } IL_{CHESS_{C1EE}} > 31 \rightarrow IL_{CHESS_{C1EE}} = IL_{CHESS_{C1EE}} - 64$$

$$IL_{CHESS_{C1}} = \frac{IL_{CHESS_{C1EE}}}{2^4}$$

$$IL_{CHESS_{C2EE}} = \frac{EE[0x2435] \& 0x07C0}{2^6}$$

$$\text{If } IL_{CHESS_{C2EE}} > 15 \rightarrow IL_{CHESS_{C2EE}} = IL_{CHESS_{C2EE}} - 32$$

$$L_{CHESS_{C2}} = \frac{IL_{CHESS_{C2EE}}}{2}$$

$$IL_{CHESS_{C3EE}} = \frac{EE[0x2435] \& 0xF800}{2^{11}}$$

$$\text{If } IL_{CHESS_{C3EE}} > 15 \rightarrow IL_{CHESS_{C3EE}} = IL_{CHESS_{C3EE}} - 32$$

$$IL_{CHESS_{C3}} = \frac{IL_{CHESS_{C3EE}}}{2^3}$$

The above calculated parameters have to be applied as a correction for the offset of each individual pixel. We do need additional patterns in order to make these calculations and the formula to calculate those patterns are as shown below depending on the pixels number:

$$IL_{PATTERN} = \text{int} \left(\frac{\text{pixel}_{number}-1}{32} \right) - \text{int} \left(\frac{\text{int} \left(\frac{\text{pixel}_{number}-1}{32} \right)}{2} \right) * 2$$

$$\text{Conversion}_{pattern} = \left(\text{int} \left(\frac{\text{pixel}_{number}-3}{4} \right) - \text{int} \left(\frac{\text{pixel}_{number}-2}{4} \right) + \text{int} \left(\frac{\text{pixel}_{number}}{4} \right) - \text{int} \left(\frac{\text{pixel}_{number}-1}{4} \right) \right) * (1 - 2 * IL_{PATTERN})$$

11.1.4. Restoring the Sensitivity $\alpha_{(i,j)}$

$$\alpha_{(i,j)} = \frac{\alpha_{reference} + ACC_{row_i} * 2^{ACC_{scale_{row}}} + ACC_{column_j} * 2^{ACC_{scale_{column}}} + \alpha_{pixel(i,j)} * 2^{ACC_{scale_{remnant}}}}{2^{\alpha_{scale}}}$$

Where (calculating for pixel (12,16)) :

$$\alpha_{reference} = EE[0x2421]$$

$$\alpha_{scale} = \frac{EE[0x2420] \& 0xF000}{2^{12}} + 30$$

$$ACC_{row_{12}} = \frac{EE[0x2424] \& 0xF000}{2^{12}} \text{ (i.e. the four most significant bits, signed)}$$

$$\text{If } ACC_{row_{12}} > 7 \rightarrow ACC_{row_{12}} = ACC_{row_{12}} - 16$$

$$ACC_{scale_{row}} = \frac{EE[0x2420] \& 0x0F00}{2^8} \text{ (unsigned)}$$

$$ACC_{column_{16}} = \frac{EE[0x242B] \& 0xF000}{2^{12}} \text{ (i.e. the four most significant bits, signed)}$$

$$\text{If } ACC_{column_{16}} > 7 \rightarrow ACC_{column_{16}} = ACC_{column_{16}} - 16$$

$$ACC_{scale_{column}} = \frac{EE[0x2420] \& 0x00F0}{2^4} \text{ (unsigned)}$$

$$\alpha_{pixel}(12,16) = \frac{EE[0x258F] \& 0x03F0}{2^4}$$

$$\text{If } \alpha_{pixel}(12,16) > 31 \rightarrow \alpha_{pixel}(12,16) = \alpha_{pixel}(12,16) - 64$$

$$ACC_{scale_{remnant}} = EE[0x2420] \& 0x000F \text{ (unsigned)}$$

11.1.5. Restoring the $K_V(i,j)$ coefficient

$K_{V(i,j)}$ depend on the pixel position in the array i.e. if the pixel row and column is odd or even

$$\text{If row number is **ODD** (1, 3, 5...23) and column number is **ODD** (1, 3, 5...31) then } K_{V(i,j)} = \frac{EE[0x2434] \& 0xF000}{2^{12}}$$

$$\text{If row number is **EVEN** (2, 4, 6...24) and column number is **ODD** (1, 3, 5...31) then } K_{V(i,j)} = \frac{EE[0x2434] \& 0x0F00}{2^8}$$

$$\text{If row number is **ODD** (1, 3, 5...23) and column number is **EVEN** (2, 4, 6...32) then } K_{V(i,j)} = \frac{EE[0x2434] \& 0x00F0}{2^4}$$

$$\text{If row number is **EVEN** (2, 4, 6...24) and column number is **EVEN** (2, 4, 6...32) then } K_{V(i,j)} = EE[0x2434] \& 0x000F$$

$$\text{If } K_{V(i,j)} > 7 \rightarrow K_{V(i,j)} = K_{V(i,j)} - 16$$

$$K_{V(12,16)} = \frac{K_{V(i,j)}}{2^{K_{V_{scale}}}} \text{ (signed)}$$

Where:

$$K_{V_{scale}} = \frac{EE[0x2438] \& 0x0F00}{2^8} \text{ (unsigned)}$$

11.1.6. Restoring the $K_{Ta}(i,j)$ coefficient

$$K_{Ta(12,16)} = \frac{K_{Ta_{RC_EE}} + K_{Ta(12,16)_EE} * 2^{K_{Ta_{scale_2}}}}{2^{K_{Ta_{scale_1}}}}$$

Where:

$$K_{Ta(12,16)_EE} = \frac{EE[0x25AF] \& 0x000E}{2} \text{ (signed)}$$

$$\text{If } K_{Ta(12,16)_EE} > 3 \rightarrow K_{Ta(12,16)_EE} = K_{Ta(12,16)_EE} - 8$$

$K_{Ta_RC_EE}$ depends on the pixel position in the array i.e. if the pixel row and column is odd or even

If row number is **ODD** (1, 3, 5...23) and column number is **ODD** (1, 3, 5...31) then $K_{Ta_RC_EE} = \frac{EE[0x2436] \& 0xFF00}{2^8}$

If row number is **EVEN** (2, 4, 6...24) and column number is **ODD** (1, 3, 5...31) then $K_{Ta_RC_EE} = EE[0x2436] \& 0x00FF$

If row number is **ODD** (1, 3, 5...23) and column number is **EVEN** (2, 4, 6...32) then $K_{Ta_RC_EE} = \frac{EE[0x2437] \& 0xFF00}{2^8}$

If row number is **EVEN** (2, 4, 6...24) and column number is **EVEN** (2, 4, 6...32) then $K_{Ta_RC_EE} = EE[0x2437] \& 0x00FF$

If $K_{Ta_RC_EE} > 127 \rightarrow K_{Ta_RC_EE} = K_{Ta_RC_EE} - 256$

$K_{Ta_scale_1} = \frac{EE[0x2438] \& 0x00F0}{2^4} + 8$ (unsigned)

$K_{Ta_scale_2} = EE[0x2438] \& 0x000F$ (unsigned)

11.1.7. Restoring the GAIN coefficient (common for all pixels)

GAIN = $EE[0x2430]$ (signed)

If GAIN > 32767 \rightarrow GAIN = GAIN – 65536

11.1.8. Restoring the KsTa coefficient (common for all pixels)

$K_{STa} = \frac{K_{STa_EE}}{2^{13}}$

Where:

$K_{STa_EE} = \frac{EE[0x243C] \& 0xFF00}{2^8}$ (signed)

If $K_{STa_EE} > 127 \rightarrow K_{STa_EE} = K_{STa_EE} - 256$

11.1.9. Restoring corner temperatures (common for all pixel)

The information regarding corner temperatures is stored into device EEPROM and is restored as follows:

$Step = \frac{EE[0x243F] \& 0x3000}{2^{12}} * 10$

$CT3 = \frac{EE[0x243F] \& 0x00F0}{2^4} * Step$

$CT4 = \frac{EE[0x243F] \& 0x0F00}{2^8} * Step + CT3$

Or we can construct the temperatures for the ranges as follows:

CT1=-40°C (hard coded) < **Range 1** > CT2=0°C (hard coded) < **Range 2** > CT3 < **Range 3** > CT4 < **Range 4**

11.1.10. Restoring the KsTo coefficient (common for all pixels)

$$K_{STo1} = \frac{K_{STo1_EE}}{2^{K_{STo_scale}}}$$

Where:

$$K_{STo_scale} = EE[0x243F] \& 0x000F + 8 \text{ (unsigned)}$$

Where:

$$K_{STo1_EE} = EE[0x243D] \& 0x00FF \text{ (signed)}$$

$$\text{If } K_{STo1_EE} > 127 \rightarrow K_{STo1_EE} = K_{STo1_EE} - 256$$

$$K_{STo2} = \frac{K_{STo2_EE}}{2^{K_{STo_scale}}}$$

Where:

$$K_{STo2_EE} = \frac{EE[0x243D] \& 0xFF00}{2^8} \text{ (signed)}$$

$$\text{If } K_{STo2_EE} > 127 \rightarrow K_{STo2_EE} = K_{STo2_EE} - 256$$

$$K_{STo3} = \frac{K_{STo3_EE}}{2^{K_{STo_scale}}}$$

Where:

$$K_{STo3_EE} = EE[0x243E] \& 0x00FF \text{ (signed)}$$

$$\text{If } K_{STo3_EE} > 127 \rightarrow K_{STo3_EE} = K_{STo3_EE} - 256$$

$$K_{STo4} = \frac{K_{STo4_EE}}{2^{K_{STo_scale}}}$$

Where:

$$K_{STo4_EE} = \frac{EE[0x243E] \& 0x00FF}{2^8} \text{ (signed)}$$

$$\text{If } K_{STo4_EE} > 127 \rightarrow K_{STo4_EE} = K_{STo4_EE} - 256$$

11.1.11. Restoring sensitivity correction coefficients for each temperature range

$$Alpha_{corr_{range1}} = \frac{1}{(1 + K_{STo1} * (0 - (-40)))}$$

$$Alpha_{corr_{range2}} = 1$$

$$Alpha_{corr_{range3}} = 1 + K_{STo2} * (CT3 - 0)$$

$$Alpha_{corr_{range4}} = (1 + K_{STo2} * (CT3 - 0)) * (1 + K_{STo3} * (CT4 - CT3))$$

11.1.12. Restoring the Sensitivity α_{CP}

Please note that there are two sensitivities for the compensation pixel – one for each subpage

$$\alpha_{CP_subpage_0} = \frac{EE[0x2439] \& 0x03FF}{2^{\alpha_{scale_CP}}}$$

$$\alpha_{CP_subpage_1} = \alpha_{CP_subpage_0} * \left(1 + \frac{CP_P1_P0_ratio}{2^7}\right)$$

Where:

$$\alpha_{scale_CP} = \frac{EE[0x2420] \& 0xF000}{2^{12}} + 27$$

$$CP_P1/P0_ratio = \frac{EE[0x2439] \& 0xFC00}{2^{10}} \text{ (signed)}$$

$$\text{If } CP_P1/P0_ratio > 31 \rightarrow CP_P1/P0_ratio = CP_P1/P0_ratio - 64$$

11.1.13. Restoring the offset of the Compensation Pixel (CP)

Please note that there are two offsets for the compensation pixel – one for each subpage

$$Off_CP_subpage_0 = EE[0x243A] \& 0x03FF \text{ (signed)}$$

$$\text{If } Off_CP_subpage_0 > 511 \rightarrow Off_CP_subpage_0 = Off_CP_subpage_0 - 1024$$

$$Off_CP_subpage_1 = Off_CP_subpage_0 + Off_CP_subpage_1_delta$$

Where:

$$Off_CP_subpage_1_delta = \frac{EE[0x243A] \& 0xFC00}{2^{10}} \text{ (signed)}$$

$$\text{If } Off_CP_subpage_1_delta > 31 \rightarrow Off_CP_subpage_1_delta = Off_CP_subpage_1_delta - 64$$

11.1.14. Restoring the Kv CP coefficient

$$K_{VCP} = \frac{K_{VCP_EE}}{2^{K_{Vscale}}}$$

$$K_{Vscale} = \frac{EE[0x2438] \& 0x0F00}{2^8} \text{ (unsigned) (the same one as for the } K_{V(i,j)} \text{ coefficients)}$$

Where:

$$K_{VCP_EE} = \frac{EE[0x243B] \& 0xFF00}{2^8} \text{ (signed)}$$

$$\text{If } K_{VCP_EE} > 127 \rightarrow K_{VCP_EE} = K_{VCP_EE} - 256$$

11.1.15. Restoring the Kta CP coefficient

$$K_{TaCP} = \frac{K_{TaCP_EE}}{2^{K_{Ta_scale_1}}}$$

$$K_{Ta_{scale_1}} = \frac{EE[0x2438] \& 0x00F0}{2^4} + 8 \text{ (unsigned) (the same one as for the } K_{Ta(i,j)} \text{ coefficients)}$$

Where:

$$K_{Ta_{CP_EE}} = EE[0x243B] \& 0x00FF \text{ (signed)}$$

$$\text{If } K_{Ta_{CP_EE}} > 127 \rightarrow K_{Ta_{CP_EE}} = K_{Ta_{CP_EE}} - 256$$

11.1.16. Restoring the TGC coefficient

$$TGC = \frac{TGC_{EE}}{2^5}$$

Where:

$$TGC_{EE} = EE[0x243C] \& 0x00FF \text{ (signed)}$$

$$\text{If } TGC_{EE} > 127 \rightarrow TGC_{EE} = TGC_{EE} - 256$$

NOTE 1: In a MLX90640ESF-BAx-000-TU device, the TGC coefficient is set to 0 and must not be changed.

NOTE 2: In a MLX90640ESF-BCx-000-TU device, the EEPROM contains a typical value for the TGC coefficient but the user may choose to adjust the value such to best fit for a specific application. Using the TGC increases noise in the temperature calculations which can be reduced by external filtering (averaging) of the CP sensor data. By making the TGC coefficient "0" the gradients compensation is bypassed.

11.1.17. Restoring the resolution control coefficient

$$Resolution_{EE} = \frac{EE[0x2438] \& 0x3000}{2^{12}} \text{ (unsigned)}$$

11.2. Temperature Calculation

11.2.1. Example Input Data

11.2.1.1. Example Measurement Data

| Input data name | Input data value |
|---|--------------------|
| Object temperature | 80°C |
| Emissivity (ϵ) | 1 |
| Control register 1 (Res _{ctrl}) | 0x0901 (2 decimal) |
| RAM[0x056F] (pix(12,16) data) | 0x0261 (609) |
| Vbe - RAM[0x0700] | 0x4BF2 (19442) |
| CP subpage 0 – RAM[0x0708] | 0xFFCA (-54) |
| CP subpage 1 – RAM[0x0728] | 0xFFC8 (-56) |
| GAIN - RAM[0x070A] | 0x1881 (6273) |
| PTAT - RAM[0x0720] | 0x06AF (1711) |
| VDD - RAM[0x072A] | 0xCCC5 (-13115) |

Table 11 Calculation example input data

11.2.1.2. Example Calibration Data

| EEPROM address | Calibration parameter name | Parameter value | Decoded value |
|----------------|--|-----------------|--|
| 0x2410 | K_PTAT – 4 bits Scale_OCC_row – 4 bits Scale_OCC_column – 4 bits Scale_OCC_remnand – 4 bits | 0x4210 | K_PTAT = 9 Scale_OCC_row = 2 Scale_OCC_column = 1 Scale_OCC_remnand = 0 |
| 0x2411 | Pix_os_average – 16 bits | 0xFFBB | Pix_os_average = -69 |
| 0x2412 | OCC_rows_04 – 4 bits OCC_rows_03 – 4 bits OCC_rows_02 – 4 bits OCC_rows_01 – 4 bits | 0x0202 | OCC_rows_04 = 0 OCC_rows_03 = 2 OCC_rows_02 = 0 OCC_rows_01 = 2 |
| 0x2413 | OCC_rows_08 – 4 bits OCC_rows_07 – 4 bits OCC_rows_06 – 4 bits OCC_rows_05 – 4 bits | 0xF202 | OCC_rows_08 = -1 OCC_rows_07 = 2 OCC_rows_06 = 0 OCC_rows_05 = 2 |
| 0x2414 | OCC_rows_12 – 4 bits OCC_rows_11 – 4 bits | 0xF2F2 | OCC_rows_12 = -1 OCC_rows_11 = 2 |

| | | | |
|--------|--|--------|---|
| | OCC_rows_10 – 4 bits OCC_rows_09 – 4 bits | | OCC_rows_10 = -1 OCC_rows_09 = 2 |
| 0x2415 | OCC_rows_16 – 4 bits OCC_rows_15 – 4 bits OCC_rows_14 – 4 bits OCC_rows_13 – 4 bits | 0xE2E2 | OCC_rows_16 = -2 OCC_rows_15 = 2 OCC_rows_14 = -2 OCC_rows_13 = 2 |
| 0x2416 | OCC_rows_20 – 4 bits OCC_rows_19 – 4 bits OCC_rows_18 – 4 bits OCC_rows_17 – 4 bits | 0xD1E1 | OCC_rows_20 = -3 OCC_rows_19 = 1 OCC_rows_18 = -2 OCC_rows_17 = 1 |
| 0x2417 | OCC_rows_24 – 4 bits OCC_rows_23 – 4 bits OCC_rows_22 – 4 bits OCC_rows_21 – 4 bits | 0xB1D1 | OCC_rows_24 = -5 OCC_rows_23 = 1 OCC_rows_22 = -3 OCC_rows_21 = 1 |
| 0x2418 | OCC_column_04 – 4 bits OCC_column_03 – 4 bits OCC_column_02 – 4 bits OCC_column_01 – 4 bits | 0xF10F | OCC_column_04 = -1 OCC_column_03 = 1 OCC_column_02 = 0 OCC_column_01 = -1 |
| 0x2419 | OCC_column_08 – 4 bits OCC_column_07 – 4 bits OCC_column_06 – 4 bits OCC_column_05 – 4 bits | 0xF00F | OCC_column_08 = -1 OCC_column_07 = 0 OCC_column_06 = 0 OCC_column_05 = -1 |
| 0x241A | OCC_column_12 – 4 bits OCC_column_11 – 4 bits OCC_column_10 – 4 bits OCC_column_09 – 4 bits | 0xE0EF | OCC_column_12 = -2 OCC_column_11 = 0 OCC_column_10 = -2 OCC_column_09 = -1 |
| 0x241B | OCC_column_16 – 4 bits OCC_column_15 – 4 bits OCC_column_14 – 4 bits OCC_column_13 – 4 bits | 0xE0EF | OCC_column_16 = -2 OCC_column_15 = 0 OCC_column_14 = -2 OCC_column_13 = -1 |
| 0x241C | OCC_column_20 – 4 bits OCC_column_19 – 4 bits OCC_column_18 – 4 bits OCC_column_17 – 4 bits | 0xE1E1 | OCC_column_20 = -2 OCC_column_19 = 1 OCC_column_18 = -2 OCC_column_17 = 1 |
| 0x241D | OCC_column_24 – 4 bits OCC_column_23 – 4 bits OCC_column_22 – 4 bits OCC_column_21 – 4 bits | 0xF3F2 | OCC_column_24 = -1 OCC_column_23 = 3 OCC_column_22 = -1 OCC_column_21 = 2 |
| 0x241E | OCC_column_28 – 4 bits OCC_column_27 – 4 bits OCC_column_26 – 4 bits OCC_column_25 – 4 bits | 0xF404 | OCC_column_28 = -1 OCC_column_27 = 4 OCC_column_26 = 0 OCC_column_25 = 4 |
| 0x241F | OCC_column_32 – 4 bits OCC_column_31 – 4 bits | 0xE504 | OCC_column_32 = -2 OCC_column_31 = 5 |

| | | | |
|--------|---|--------|---|
| | OCC_column_30 – 4 bits OCC_column_29 – 4 bits | | OCC_column_30 = 0 OCC_column_29 = 4 |
| 0x2420 | Alpha scale – 4 bits Scale_ACC_row – 4 bits Scale_ACC_column – 4 bits Scale_ACC_remnand – 4 bits | 0x79A6 | Alpha scale = 37 Scale_ACC_row = 9 Scale_ACC_column = 10 Scale_ACC_remnand = 6 |
| 0x2421 | Pix_sensitivity_average - 16 bits | 0x2F44 | Pix_sensitivity_average = 8.80391E-08 |
| 0x2422 | ACC_rows_04 – 4 bits ACC_rows_03 – 4 bits ACC_rows_02 – 4 bits ACC_rows_01 – 4 bits | 0xFFDD | ACC_rows_04 = -1 ACC_rows_03 = -1 ACC_rows_02 = -3 ACC_rows_01 = -3 |
| 0x2423 | ACC_rows_08 – 4 bits ACC_rows_07 – 4 bits ACC_rows_06 – 4 bits ACC_rows_05 – 4 bits | 0x2210 | ACC_rows_08 = 2 ACC_rows_07 = 2 ACC_rows_06 = 1 ACC_rows_05 = 0 |
| 0x2424 | ACC_rows_12 – 4 bits ACC_rows_11 – 4 bits ACC_rows_10 – 4 bits ACC_rows_09 – 4 bits | 0x3333 | ACC_rows_12 = 3 ACC_rows_11 = 3 ACC_rows_10 = 3 ACC_rows_09 = 3 |
| 0x2425 | ACC_rows_16 – 4 bits ACC_rows_15 – 4 bits ACC_rows_14 – 4 bits ACC_rows_13 – 4 bits | 0x2233 | ACC_rows_16 = 2 ACC_rows_15 = 2 ACC_rows_14 = 3 ACC_rows_13 = 3 |
| 0x2426 | ACC_rows_20 – 4 bits ACC_rows_19 – 4 bits ACC_rows_18 – 4 bits ACC_rows_17 – 4 bits | 0xEF01 | ACC_rows_20 = -2 ACC_rows_19 = -1 ACC_rows_18 = 0 ACC_rows_17 = 1 |
| 0x2427 | ACC_rows_24 – 4 bits ACC_rows_23 – 4 bits ACC_rows_22 – 4 bits ACC_rows_21 – 4 bits | 0x9ACC | ACC_rows_24 = -7 ACC_rows_23 = -6 ACC_rows_22 = -4 ACC_rows_21 = -4 |
| 0x2428 | ACC_column_04 – 4 bits ACC_column_03 – 4 bits ACC_column_02 – 4 bits ACC_column_01 – 4 bits | 0xEEDC | ACC_column_04 = -1 ACC_column_03 = -1 ACC_column_02 = -2 ACC_column_01 = -3 |
| 0x2429 | ACC_column_08 – 4 bits ACC_column_07 – 4 bits ACC_column_06 – 4 bits ACC_column_05 – 4 bits | 0x10FF | ACC_column_08 = 1 ACC_column_07 = 0 ACC_column_06 = -1 ACC_column_05 = -1 |
| 0x242A | ACC_column_12 – 4 bits ACC_column_11 – 4 bits ACC_column_10 – 4 bits ACC_column_09 – 4 bits | 0x2221 | ACC_column_12 = 2 ACC_column_11 = 2 ACC_column_10 = 2 ACC_column_09 = 1 |

| | | | |
|--------|--|--------|--|
| 0x242B | ACC_column_16 – 4 bits ACC_column_15 – 4 bits ACC_column_14 – 4 bits ACC_column_13 – 4 bits | 0x3333 | ACC_column_16 = 3 ACC_column_15 = 3 ACC_column_14 = 3 ACC_column_13 = 3 |
| 0x242C | ACC_column_20 – 4 bits ACC_column_19 – 4 bits ACC_column_18 – 4 bits ACC_column_17 – 4 bits | 0x2333 | ACC_column_20 = 2 ACC_column_19 = 3 ACC_column_18 = 3 ACC_column_17 = 3 |
| 0x242D | ACC_column_24 – 4 bits ACC_column_23 – 4 bits ACC_column_22 – 4 bits ACC_column_21 – 4 bits | 0x0112 | ACC_column_24 = 0 ACC_column_23 = 1 ACC_column_22 = 1 ACC_column_21 = 2 |
| 0x242E | ACC_column_28 – 4 bits ACC_column_27 – 4 bits ACC_column_26 – 4 bits ACC_column_25 – 4 bits | 0xEEFF | ACC_column_28 = -2 ACC_column_27 = -2 ACC_column_26 = -1 ACC_column_25 = -1 |
| 0x242F | ACC_column_32 – 4 bits ACC_column_31 – 4 bits ACC_column_30 – 4 bits ACC_column_29 – 4 bits | 0xBBDD | ACC_column_32 = -5 ACC_column_31 = -5 ACC_column_30 = -3 ACC_column_29 = -3 |
| 0x2430 | GAIN | 0x18EF | GAIN = 6383 |
| 0x2431 | PTAT_25 | 0x2FF1 | PTAT_25 = 12273 |
| 0x2432 | Kv_PTAT - 6 bits Kt_PTAT - 10 bits | 0x5952 | Kv_PTAT = 0.005371094 Kt_PTAT = 42.25 |
| 0x2433 | K_Vdd - 8 bits Vdd_25 - 8 bits | 0x9D68 | K_Vdd = -3168 Vdd_25 = -13056 |
| 0x2434 | Kv_avg_RO_CO – 4 bits Kv_avg_RE_CO – 4 bits Kv_avg_RO_CE – 4 bits Kv_avg_RE_CE – 4 bits | 0x5454 | Kv_avg_RO_CO = 5 Kv_avg_RE_CO = 4 Kv_avg_RO_CE = 5 Kv_avg_RE_CE = 4 |
| 0x2435 | IL_CHESS_C3 – 5 bits IL_CHESS_C2 – 5 bits IL_CHESS_C1 – 6 bits | 0x0994 | IL_CHESS_C3 = 0.125 IL_CHESS_C2 = 3 IL_CHESS_C1 = 1.25 |
| 0x2436 | Kta_avg_RO_CO – 8 bits Kta_avg_RE_CO – 8 bits | 0x6956 | Kta_avg_RO_CO = 105 Kta_avg_RE_CO = 86 |
| 0x2437 | Kta_avg_RO_CE – 8 bits Kta_avg_RE_CE – 8 bits | 0x5354 | Kta_avg_RO_CE = 83 Kta_avg_RE_CE = 84 |
| 0x2438 | Resolution_control_cal – 2 bits Kv_scale – 4 bits Kta_scale_1 – 4 bits Kta_scale_1 – 4 bits | 0x2363 | Resolution_control_cal = 2 Kv_scale = 3 Kta_scale_1 = 14 Kta_scale_1 = 3 |
| 0x2439 | CP_SP_1/SP_0_ratio – 6 bits | 0xE446 | CP_SP_1/SP_0_ratio = -0.0546875 |

| Alpha_CP_SP_0 – 10 bits | | Alpha_CP_SP_0 = 4.0745362639427E-09 | |
|-------------------------|--|-------------------------------------|---|
| 0x243A | CP_off_delta (SP_1 - SP_0) – 6 bits Offset_CP_SP_0 – 10 bits | 0xFBB5 | CP_off_delta (SP_1 - SP_0) = -2 Offset_CP_SP_0 = -75 |
| 0x243B | Kv_CP – 8 bits Kta_CP – 8 bits | 0x044B | Kv_CP = 0.5 Kta_CP = 0.00457763671875 |
| 0x243C | KsTa – 8 bits TGC – 8 bits | 0xF020 | KsTa = -0.001953125 TGC = 1 |
| 0x243D | KsTo2 (0°C...CT3°C) – 8 bits KsTo1 (<0°C) – 8 bits | 0x9797 | KsTo2 (0°C...CT3°C) = -0.0008010864 KsTo1 (<0°C) = -0.0008010864 |
| 0x243E | KsTo4 (CT4°C...) – 8 bits KsTo3 (CT3°C...CT4°C) – 8 bits | 0x9797 | KsTo4 (CT4°C...) = -0.0008010864 KsTo3 (CT3°C...CT4°C) = -0.0008010864 |
| 0x243F | Step – 2 bits CT4 – 4 bits CT3 – 4 bits KsTo_scale – 4 bits | 0x2889 | Step = 20°C CT4 = 320°C CT3 = 160°C KsTo_scale = 17 |

Table 12 Calculation example calibration data

11.2.2. Temperature calculation

After the parameters restore the temperature calculation is done using following calculation flow (assuming that the EEPROM data are already extracted):

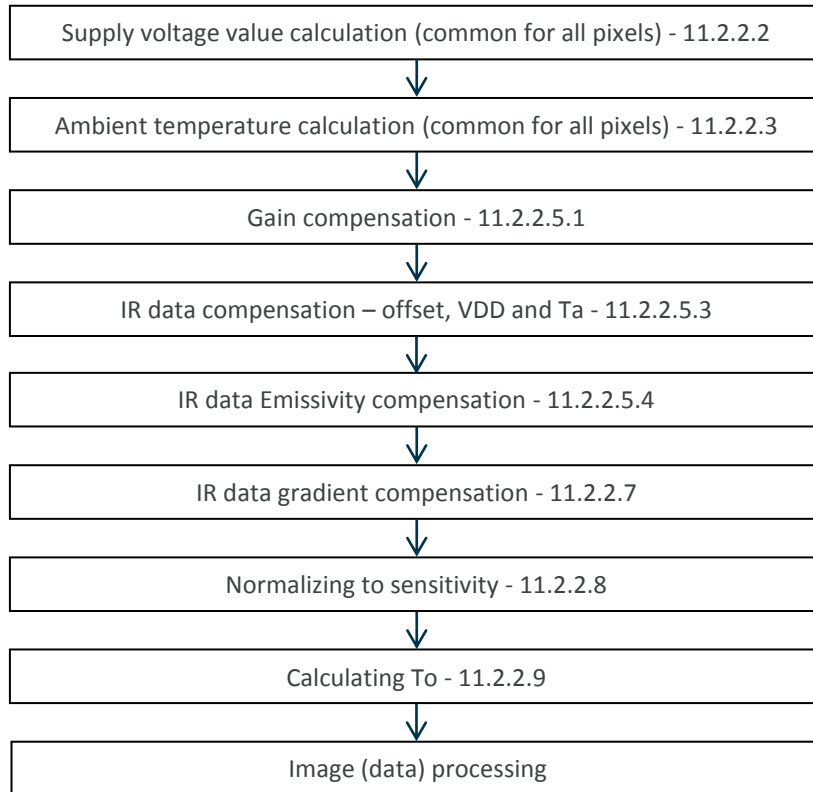


Figure 16 To calculation flow

For this example we calculate the temperature of pixel (12, 16) i.e. row=12 and the column=16.

Values marked with green are extracted from device EEPROM

Values marked with grey are final parameter values or are values to be used for next calculations

11.2.2.1. Resolution restore

The device is calibrated with default resolution setting = 2 (corresponding to ADC resolution set to 18bit see Fig 11) i.e. if the one choose to change the ADC resolution setting to a different one a correction of the data must be done. First we must restore the resolution at which the device has been calibrated which is stored at EEPROM 0x2438.

$$Resolution_{corr} = \frac{2^{Resolution_{EE}}}{2^{Resolution_{REG}}}$$

Where:

$$Resolution_{EE} = \frac{EF10x2438 \& 0x3000}{2^{12}} = \frac{0x236x \& 0x3000}{2^{12}} = 0x0002 = 2 \text{ (unsigned)}$$

$$Resolution_{REG} = \frac{RAM[0x800D] \& 0x0C00}{2^{10}} = \frac{0x1901 \& 0x0C00}{2^{10}} = 0x0002 = 2 \text{ (unsigned)}$$

$$Resolution_{corr} = \frac{2^{Resolution_{EE}}}{2^{Resolution_{REG}}} = \frac{2^2}{2^2} = 1$$

In case the ADC resolution is changed the one must multiply the $Resolution_{corr}$ coefficient with the RAM data for VDD only. Please note that the data for Vbe, PTAT and IR pixels (including CP) **must** not be changed.

11.2.2.2. Supply voltage value calculation (common for all pixels)

$$V_{dd} = \frac{Resolution_{corr} * RAM[0x072A] - V_{dd25}}{K_{Vdd}} + V_{dd0}$$

Where: Constants calculation of the EEPROM stored values (can be done just once after POR)

$$K_{Vdd} = \frac{EE[0x2433] \& 0xFF00}{2^8} = \frac{0x9D68 \& 0xFF00}{2^8} = 0x009D = 157$$

$$\text{If } 157 > 127 \rightarrow K_{Vdd} = 157 - 256 = -99$$

$$K_{Vdd} = K_{Vdd} * 2^5 = -99 * 32 = -3168$$

$$V_{dd25} = EE[0x2433] \& 0x00FF = 0x9D68 \& 0x00FF = 0x0068 = 104$$

$$V_{dd25} = (V_{dd25} - 256) * 2^5 - 2^{13} = -152 * 32 - 8192 = -13056$$

VDD calculations:

$$RAM[0x072A] = 0xCCC5 = 52421$$

$$\text{If } 52883 > 32767 \rightarrow RAM[0x072A] = 52421 - 65536 = -13115 \text{ LSB}$$

$$V_{dd} = \frac{1 * -13115 - (-13056)}{-3168} + 3.3 = \frac{-59}{-3168} + 3.3 \approx 0.0186 + 3.3 \approx 3.319V$$

11.2.2.3. Ambient temperature calculation (common for all pixels)

$$T_a = \frac{\left(\frac{V_{PTAT_{art}}}{1 + K_{V_{PTAT}} * \Delta V} - V_{PTAT_{25}} \right)}{K_{T_{PTAT}}} + 25, \text{ } ^\circ\text{C}$$

Where:

$$K_{V_{PTAT}} = \frac{EE[0x2432] \& 0xFC00}{2^{10}} = \frac{0x5952 \& 0xFC00}{2^{10}} = 0x0016 = 22$$

$$\text{If } 22 < 31 \rightarrow K_{V_{PTAT}} = 22$$

$$K_{V_{PTAT}} = \frac{K_{V_{PTAT}}}{2^{12}} = \frac{22}{4096} = 0.005371094$$

$$K_{T_{PTAT}} = EE[0x2432] \& 0x03FF = 0x5952 \& 0x03FF = 0x0152 = 338$$

$$\text{If } 338 < 511 \rightarrow K_{T_{PTAT}} = 338$$

$$K_{T_{PTAT}} = \frac{K_{T_{PTAT}}}{2^3} = \frac{338}{8} = 42.25$$

$$\Delta V = \frac{RAM[0x072A] - V_{dd25}}{K_{Vdd}}$$

$$RAM[0x072A] = 0xCCC5 = 52421$$

$$\text{If } 52421 > 32767 \rightarrow RAM[0x072A] = 52421 - 65536 = -13115 \text{ LSB}$$

$$\Delta V = \frac{-13115 - (-13056)}{-3168} = \frac{-59}{-3168} \approx 0.018623737$$

$$V_{PTAT_{25}} = 55[0x2431] = 0x2FF1 = 12273$$

$$\text{If } 12273 < 32767 \rightarrow V_{PTAT_{25}} = 12273$$

$$V_{PTAT_{art}} = \left(\frac{V_{PTAT}}{V_{PTAT} * Alpha_{PTAT} + V_{BE}} \right) * 2^{18}$$

Where:

$$V_{PTAT} = RAM[0x0720] = 0x06AF = 1711$$

$$\text{If } 1711 < 32767 \rightarrow V_{PTAT} = 1711$$

$$V_{BE} = RAM[0x0700] = 0x4BF2 = 19442$$

$$\text{If } 19442 < 32767 \rightarrow V_{BE} = 19442$$

$$Alpha_{PTAT_{EE}} = \frac{55[0x2410] \& 0xF000}{2^{12}} = \frac{0x2410 \& 0xF000}{2^{12}} = \frac{0x4000}{2^{12}} = \frac{16384}{4096} = 4$$

$$Alpha_{PTAT} = \frac{Alpha_{PTAT_{EE}}}{2^2} + 8 = \frac{4}{4} + 8 = 9$$

$$V_{PTAT_{art}} = \left(\frac{V_{PTAT}}{V_{PTAT} * Alpha_{PTAT} + V_{BE}} \right) * 2^{18} = \left(\frac{1711}{1711 * 9 + 19442} \right) * 2^{18} = 12873.57952$$

$$T_a = \frac{\left(\frac{V_{PTAT_{art}}}{1 + KV_{PTAT} * \Delta V} - V_{PTAT_{25}} \right)}{K_{T_{PTAT}}} + 25 \text{ , } ^\circ\text{C}$$

$$T_a = \frac{\left(\frac{12873.57952}{1 + 0.005371094 * 0.018623737} - 12273 \right)}{42.25} + 25 = 14.18440152 + 25 \approx 39.184 \text{ } ^\circ\text{C}$$

11.2.2.4. Gain parameter calculation (common for all pixels)

$$K_{gain} = \frac{GAIN}{RAM[0x070A]}$$

$$RAM[0x070A] = 0x1881 = 6273$$

$$\text{If } 6273 < 32767 \rightarrow RAM[0x070A] = 6273$$

$$GAIN = 55[0x2430] = 0x1881 = 6383$$

$$\text{If } 6383 < 32767 \rightarrow GAIN = 6383$$

$$K_{gain} = \frac{6383}{6273} = 1.01753546947234$$

Please note that this value is updated every frame and it is the same for all pixels including CP regardless the subpage number

11.2.2.5. Pixel data calculations

The pixel addressing is following the pattern as described in Reading pattern shown in Fig 5:

11.2.2.5.1. Gain compensation

The first step of the data processing on raw IR data is always the gain compensation, regardless of pixel or subpage number.

$$pix_{gain}(12, 16) = RAM[pixel\ data] * K_{gain} = RAM[0x056F] * K_{gain}$$

$$RAM[0x056F] = 0x0261 = 609$$

$$\text{If } 609 < 32767 \rightarrow RAM[0x056F] = 609$$

$$pix_{gain}(12, 16) = 609 * 1.01753546947234 = 619.679100908656$$

11.2.2.5.2. Offset calculation

$$pix_{OS_{ref}}(12,16) = Offset_{average} + OCC_{row_{12}} * 2^{OCC_{scale_{row}}} + OCC_{column_{16}} * 2^{OCC_{scale_{column}}} + offset(12,16) * 2^{OCC_{scale_{remnant}}}$$

$$Offset_{average} = EE[0x2411] = 0xFFBB = 65467$$

$$\text{If } 65467 > 32767 \rightarrow Offset_{average} = 65467 - 65536 = -69$$

As the row=12, we select EEPROM cell 0x2414 ($\pm OCC_{rows_{12}} \dots 08$ (4 x 4bit)) and extract the four most significant bits corresponding to parameter $OCC_{rows_{12}}$. If another row number is selected, the corresponding OCC parameter must be selected.

$$OCC_{row_{12}} = \frac{EE[0x2414] \& 0xF000}{2^{12}} = \frac{0xF000 \& 0xF000}{2^{12}} = 0x000F = 15$$

$$\text{If } 15 > 7 \rightarrow OCC_{row_{12}} = 15 - 16 = -1$$

$$OCC_{scale_{row}} = \frac{EE[0x2410] \& 0x0F00}{2^8} = \frac{0x0F00 \& 0x0F00}{2^8} = 0x0002 = 2$$

Please note that $OCC_{scale_{row}}$ is a common parameter for all OCC_{row_i} calculation

As the column=16, we select EEPROM cell 0x2425 ($\pm OCC_{column_{16}} \dots 13$ (4 x 4bit)) and extract the four most significant bits corresponding to parameter $OCC_{column_{16}}$. If another column number is selected, the corresponding OCC parameter must be selected.

$$OCC_{column_{16}} = \frac{EE[0x2425] \& 0xF000}{2^{12}} = \frac{0xF000 \& 0xF000}{2^{12}} = 0x000E = 14$$

$$\text{If } 14 > 7 \rightarrow OCC_{column_{16}} = 14 - 16 = -2$$

$$OCC_{scale_{column}} = \frac{EE[0x2410] \& 0x00F0}{2^4} = \frac{0x00F0 \& 0x00F0}{2^4} = 0x0001 = 1$$

Please note that $OCC_{scale_{column}}$ is a common parameter for all OCC_{column_j} calculation

$$offset(12,16) = \frac{EE[0x254F] \& 0xFC00}{2^{10}} = \frac{0x0070 \& 0xFC00}{2^{10}} = 0x0002$$

$$\text{If } 2 < 31 \rightarrow offset(12,16) = 2$$

$$OCC_{scale_remnant} = EE[0x2410] \& 0x000F = 0x4210 \& 0x000F = 0x0000 = 0$$

$$pix_{OS_ref}(12,16) = -69 + (-1) * 2^2 + (-2) * 2^1 + 2 * 2^0 = -69 - 4 - 4 + 2 = -75$$

11.2.2.5.3. IR data compensation – offset, VDD and Ta

$$pix_{OS}(12,16) = pix_{gain}(12,16) - pix_{OS_ref} * \left(1 + K_{Ta(12,16)} * (T_a - T_{a0})\right) * \left(1 + K_{V(12,16)} * (V_{dd} - V_{ddV0})\right)$$

$$K_{Ta(12,16)} = \frac{K_{Ta_RC_EE} + \frac{K_{Ta(12,16)} - EE \& 0x000E}{2} * 2 * K_{Ta_scale_2}}{2^{K_{Ta_scale_1}}}$$

Where:

$$K_{Ta(12,16)_EE} = \frac{EE[0x254F] \& 0x000E}{2} = \frac{0x0070 \& 0x000E}{2} = 0x0000 = 0$$

$$\text{If } 0 < 3 \rightarrow K_{Ta(12,16)_EE} = 0$$

As row and column numbers are even then

$$K_{Ta_RC_EE} = EE[0x2437] \& 0x00FF = 0x5354 \& 0x00FF = 0x0054 = 84$$

$$\text{If } 84 < 127 \rightarrow K_{Ta_RC_EE} = 84$$

$$K_{Ta_scale_1} = \frac{EE[0x2438] \& 0x00F0}{2^4} + 8 = \frac{0x2363 \& 0x00F0}{2^4} + 8 = 0x0006 + 8 = 6 + 8 = 14$$

$$K_{Ta_scale_2} = EE[0x2438] \& 0x000F = 0x2363 \& 0x000F = 0x0003 = 3$$

$$K_{Ta(12,16)} = \frac{84 + 0 * 2^3}{2^{14}} = \frac{84}{16384} = 0.005126953125$$

As row and column numbers are even:

$$K_{V(i,j)} = EE[0x2434] \& 0x000F = 0x5454 \& 0x000F = 0x0004 = 4$$

$$\text{If } K_{V(i,j)} < 7 \rightarrow K_{V(i,j)} = 4$$

$$K_{V(12,16)} = \frac{K_{V(i,j)}}{2^{K_{V_scale}}} \text{ (signed)}$$

Where:

$$K_{V_scale} = \frac{EE[0x2438] \& 0x0F00}{2^8} = \frac{0x2363 \& 0x0F00}{2^8} = 0x0003 = 3$$

$$K_{V(12,16)} = \frac{K_{V(i,j)}}{2^{K_{V_scale}}} = \frac{4}{2^3} = \frac{4}{8} = 0.5$$

$$pix_{OS}(12,16) = 619.679100908656 - (-75) * \left(1 + 0.005126953125 * (39.184 - 25)\right) * \left(1 + 0.5 * (3.319 - 3.3)\right)$$

$$pix_{OS}(12,16) = 700.882495690877$$

11.2.2.5.4. IR data Emissivity compensation

Emissivity compensation: For the example we assume Emissivity = 1. Note that the Emissivity coefficient is user defined and it is not stored in the device EEPROM)

$$V_{IR(12,16)_{Emissivity_COMPENSATED}} = \frac{pix_{OS(12,16)}}{\epsilon} = \frac{700.882495690877}{1} = 700.882495690877$$

11.2.2.6. CP data calculations

11.2.2.6.1. Compensating the GAIN of CP pixel

$$pix_{gain_CP_SP0} = RAM[0x0708] * K_{gain}$$

$$RAM[0x0708] = 0xFFCA = 65482$$

$$\text{If } 65482 > 32767 \rightarrow RAM[0x0708] = 65482 - 65536 = -54$$

$$pix_{gain_CP_SP0} = -54 * 1.001753546947234 = -54.9469153515065$$

$$pix_{gain_CP_SP1} = RAM[0x0728] * K_{gain}$$

$$RAM[0x0728] = 0xFFC8 = 65480$$

$$\text{If } 65480 > 32767 \rightarrow RAM[0x0728] = 65480 - 65536 = -56$$

$$pix_{gain_CP_SP1} = -56 * 1.001753546947234 = -56.9819862904511$$

NOTE: In order to limit the noise in the final T_o calculation it is advisable to filter the CP readings at this point of calculation. A good practice would be to apply a Moving Average Filter with length of 16 or higher.

11.2.2.6.2. Compensating offset, T_a and VDD of CP pixel

$$pix_{OS_CP_SP0} = pix_{gain_CP_SP0} - Off_CP_{subpage_0} * (1 + K_{Ta_CP} * (T_a - T_{a0})) * (1 + K_{V_CP} * (V_{dd} - V_{ddV0}))$$

The value of the offset for compensating pixel for the subpage 1 depends on the reading pattern. In case the chess reading pattern mode is used following formula is to be applied:

$$pix_{OS_CP_SP1} = pix_{gain_CP_SP1} - Off_CP_{subpage_1} * (1 + K_{Ta_CP} * (T_a - T_{a0})) * (1 + K_{V_CP} * (V_{dd} - V_{ddV0}))$$

In case of interleaved mode is used following formula is to be applied:

$$pix_{OS_CP_SP1} = pix_{gain_CP_SP1} - Off_CP_{subpage_1} + IL_{CHESS_C1} * (1 + K_{Ta_CP} * (T_a - T_{a0})) * (1 + K_{V_CP} * (V_{dd} - V_{ddV0}))$$

The correction parameter (highlighted in yellow) is extracted in 11.1.3.1

Where:

$$Off_CP_{subpage_0} = EE[0x243A] \& 0x03FF = 0xFBB5 \& 0x03FF = 0x03B5 = 949$$

$$\text{If } 949 > 511 \rightarrow Off_CP_{subpage_0} = 949 - 1024 = -75$$

$$Off_CP_{subpage_1} = Off_CP_{subpage_0} + Off_CP_{subpage_1_delta}$$

Where:

$$Off_CP_{subpage_1_delta} = \frac{EE[0x243B] \& 0xFC00}{2^{10}} = \frac{0x243B \& 0xFC00}{2^{10}} = 0x003E = 62$$

$$\text{If } 62 > 31 \rightarrow Off_CP_{subpage_1_delta} = 62 - 64 = -2$$

$$Off_CP_{subpage_1} = -75 + (-2) = -77$$

$$K_{T_{a_{CP}}} = \frac{K_{T_{a_{CP_EE}}}}{2^{K_{T_{a_{scale_1}}}}} = \frac{75}{2^{14}} = 0.00457763671875$$

Where:

$$K_{T_{a_{scale_1}}} = \frac{EE[0x243B] \& 0x00F0}{2^4} + 8 = 14 \text{ (unsigned) (the same one as for the } K_{T_{a(i,j)}} \text{ coefficients)}$$

$$K_{T_{a_{CP_EE}}} = EE[0x243B] \& 0x00FF = 0x044B \& 0x00FF = 0x004B = 75$$

$$\text{If } 75 < 127 \rightarrow K_{T_{a_{CP_EE}}} = 75$$

$$K_{V_{CP}} = \frac{K_{V_{CP_EE}}}{2^{K_{V_{scale}}}} = \frac{4}{2^3} = 0.5$$

$$K_{V_{scale}} = \frac{EE[0x243B] \& 0x0F00}{2^8} = \frac{0x243B \& 0x0F00}{2^8} = 0x0003 = 3 \text{ (unsigned) (the same one as for the } K_{V(i,j)} \text{ coefficients)}$$

Where:

$$K_{V_{CP_EE}} = \frac{EE[0x243B] \& 0xFF00}{2^8} = \frac{0x044B \& 0xFF00}{2^8} = 0x0004 = 4$$

$$\text{If } 4 < 127 \rightarrow K_{V_{CP_EE}} = 4$$

$$pix_{OS_CP_SP0} = -54.9469153515065 - (-75) * (1 + 0.00457763671875 * (39.184 - 25)) * (1 + 0.5 * (3.319 - 3.3))$$

$$pix_{OS_CP_SP0} = 25.6666575059956$$

$$pix_{OS_CP_SP1} = -56.9819862904511 - (-77) * (1 + 0.00457763671875 * (39.184 - 25)) * (1 + 0.5 * (3.319 - 3.3))$$

$$pix_{OS_CP_SP1} = 21.6315865670509$$

11.2.2.7. IR data gradient compensation

As stated in “Reading patterns” the device can work in two different readings modes (Chess pattern – the default one and IL (Interleave mode)).

Depending on the device measurement mode and $pixel_{number} = 1 \dots 768$ we can define a pattern which will help us to automatically switch between both subpages.

- In case of **Chess pattern** is selected please use following expression:

$$Pattern = \left(\text{int} \left(\frac{pixel_{number} - 1}{32} \right) - \text{int} \left(\frac{\text{int} \left(\frac{pixel_{number} - 1}{32} \right)}{2} \right) * 2 \right) \text{ xor} \left((pixel_{number} - 1) - \text{int} \left(\frac{pixel_{number} - 1}{2} \right) * 2 \right)$$

- In case of **Interleaved pattern** please use following expression:

$$Pattern = \left(\text{int} \left(\frac{pixel_{number} - 1}{32} \right) - \text{int} \left(\frac{\text{int} \left(\frac{pixel_{number} - 1}{32} \right)}{2} \right) * 2 \right)$$

Where the *int* function is giving the truncated whole number without fractional component of the result.

Where *xor* is *exclusive or* or *exclusive disjunction* is a logical operation that outputs true only when inputs differ. The truth table is as follows:

| Input 1 | Input 2 | Output |
|---------|---------|--------|
| 0 | 0 | 0 |
| 0 | 1 | 1 |
| 1 | 0 | 1 |
| 1 | 1 | 0 |

Table 13 XOR truth table

Example: Let's assume that the $pixel_{number} = 368$ (12x16)

If we are in chess mode:

$$Pattern = \left(\text{int} \left(\frac{368 - 1}{32} \right) - \text{int} \left(\frac{\text{int} \left(\frac{368 - 1}{32} \right)}{2} \right) * 2 \right) \text{xor} \left((368 - 1) - \text{int} \left(\frac{368 - 1}{2} \right) * 2 \right)$$

$$Pattern = \left(\text{int}(11.46875) - \text{int} \left(\frac{\text{int}(11.46875)}{2} \right) * 2 \right) \text{xor} (367 - \text{int}(183.5) * 2)$$

$$Pattern = \left(11 - \text{int} \left(\frac{11}{2} \right) * 2 \right) \text{xor} (367 - 183 * 2) = (11 - 5 * 2) \text{xor} (1) = (1) \text{xor} (1) = 0$$

If we are in IL mode:

$$Pattern = \left(\text{int} \left(\frac{368 - 1}{32} \right) - \text{int} \left(\frac{\text{int} \left(\frac{368 - 1}{32} \right)}{2} \right) * 2 \right) = \left(\text{int}(11.46875) - \text{int} \left(\frac{\text{int}(11.46875)}{2} \right) * 2 \right)$$

$$Pattern = \left(11 - \text{int} \left(\frac{11}{2} \right) * 2 \right) = (11 - 5 * 2) = 1$$

$$V_{IR(12,16)COMPENSATED} = V_{IR(12,16)Emissivity_COMPENSATED} - TGC * \left((1 - Pattern) * pix_{OS_CP_SP0} + Pattern * pix_{OS_CP_SP1} \right)$$

$$TGC = \frac{TGC_{EE}}{2^5} = \frac{32}{32} = 1$$

Where:

$$TGC_{EE} = EE[0x243C] \& 0x00FF = 0x7020 \& 0x00FF = 0x0020 = 32$$

$$\text{If } 32 < 127 \rightarrow TGC_{EE} = 32$$

$$V_{IR(12,16)COMPENSATED} = 700.882495690877 - 1 * 21.6315865670509 = 679.250909123826$$

11.2.2.8. Normalizing to sensitivity

$$\alpha_{comp(12,16)} = \left(\alpha_{(12,16)} - TGC * \left((1 - Pattern) * \alpha_{CP_subpage_0} + Pattern * \alpha_{CP_subpage_1} \right) \right) * (1 + K_{STa} * (T_a - T_{a0}))$$

$$\alpha_{CP_subpage_0} = \frac{EE[0x2439] \& 0x03FF}{2^{\alpha_{scale_CP}}} = \frac{0x2446 \& 0x03FF}{2^{\alpha_{scale_CP}}} = \frac{0x2446 \& 0x03FF}{2^{34}} = \frac{0x0046}{2^{34}} = 4.07453626394272E - 09$$

$$\alpha_{CP_subpage_1} = \alpha_{CP_subpage_0} * \left(1 + \frac{CP_P1_P0_ratio}{2^7} \right) = 4.07453626394272E - 09 * \left(1 + \frac{-7}{2^7} \right)$$

$$\alpha_{CP_subpage_1} = 3.85171006200835E - 09$$

Where:

$$\alpha_{scale_CP} = \frac{EE[0x2420] \& 0xF000}{2^{12}} + 27 = \frac{0x79A6 \& 0xF000}{2^{12}} + 27 = 0x0007 + 27 = 34$$

$$CP_P1_P0_ratio = \frac{EE[0x2439] \& 0xFC00}{2^{10}} = \frac{0x2446 \& 0xFC00}{2^{10}} = 0x0039 = 57$$

$$\text{If } 57 > 31 \rightarrow CP_P1_P0_ratio = 57 - 64 = -7$$

$$K_{STa} = \frac{K_{STa_EE}}{2^{13}} = \frac{-16}{2^{13}} = -0.001953125$$

Where:

$$K_{STa_EE} = \frac{EE[0x2439] \& 0xFF00}{2^8} = \frac{0x79A6 \& 0xFF00}{2^8} = 0x00F0 = 240 \text{ (common for all pixels)}$$

$$\text{If } 240 > 127 \rightarrow K_{STa_EE} = 240 - 256 = -16$$

$$\alpha_{(12,16)} = \frac{\alpha_{reference} + ACC_{row_{12}} * 2^{ACC_{scale_row}} + ACC_{column_{16}} * 2^{ACC_{scale_column}} + \alpha_{pixel(12,16)} * 2^{ACC_{scale_remnant}}}{2^{\alpha_{scale}}}$$

Where:

$$\alpha_{reference} = EE[0x2421] = 0x2F44 = 12100$$

$$\alpha_{scale} = \frac{EE[0x2420] \& 0xF000}{2^{12}} + 30 = \frac{0x79A6 \& 0xF000}{2^{12}} + 30 = 0x0007 + 30 = 37$$

$$ACC_{row_{12}} = \frac{EE[0x242A] \& 0xF000}{2^{12}} = \frac{0x3333 \& 0xF000}{2^{12}} = 0x0003 = 3$$

$$\text{If } 3 < 7 \rightarrow ACC_{row_{12}} = 3$$

$$ACC_{scale_row} = \frac{EE[0x2420] \& 0xF00}{2^8} = \frac{0x79A6 \& 0xF00}{2^8} = 0x0009 = 9$$

$$ACC_{column_{16}} = \frac{EE[0x242B] \& 0xF000}{2^{12}} = \frac{0x3333 \& 0xF000}{2^{12}} = 0x0003 = 3$$

$$\text{If } 3 > 7 \rightarrow ACC_{column_{16}} = 3$$

$$ACC_{scale_column} = \frac{EE[0x2420] \& 0x00F0}{2^4} = \frac{0x79A6 \& 0x00F0}{2^4} = 0x000A = 10$$

$$\alpha_{pixel(12,16)} = \frac{EE[0x258F] \& 0x03F0}{2^4} = \frac{0x0840 \& 0x03F0}{2^4} = 0x000A = 10$$

$$\text{If } 10 < 31 \rightarrow \alpha_{pixel(12,16)} = 10$$

$$ACC_{scale_remnant} = EE[0x2420] \& 0x000F = 0x79A6 \& 0x000F = 0x0006 = 6$$

$$\alpha_{(12,16)} = \frac{12100+3*2^9+3*2^{10}+10*2^6}{2^{37}} = 1.26223312690854E - 07$$

$$\alpha_{comp(12,16)} = \left(\alpha_{(12,16)} - TGC * \left((1 - Pattern) * \alpha_{CP_subpage_0} + Pattern * \alpha_{CP_subpage_1} \right) \right) * (1 + K_{sTa} * (T_a - T_{a0}))$$

$$\alpha_{comp(12,16)} = (1.26223312690854E - 07 - 1 * ((1 - 0) * 4.07453626394272E - 09 + 0 * 3.85171006200835E - 09)) * (1 + -0.001953125 * (39.184 - 25))$$

$$\alpha_{comp(12,16)} = 1.1876487360496E - 07$$

11.2.2.9. Calculating To for basic temperature range (0°C...CT3 °C)

$$K_{sTo2} = \frac{K_{sTo2_EE}}{2^{K_{sTo2_scale}}} = \frac{-105}{2^{17}} = -0.00080108642578125$$

Where:

$$K_{sTo2_EE} = \frac{EE[0x2430] \& 0xFF00}{2^8} = \frac{0x2430 \& 0xFF00}{2^8} = 0x0097 = 151$$

$$\text{If } 151 > 127 \rightarrow K_{sTo2_EE} = 151 - 256 = -105$$

$$K_{sTo2_scale} = EE[0x243F] \& 0x000F + 8 = 0x2889 \& 0x000F + 8 = 0x0009 + 8 = 17$$

As the IR signal received by the sensor has two components:

1. IR signal emitted by the object
2. IR signal reflected from the object (the source of this signal is surrounding environment of the sensor)

In order to compensate correctly for the emissivity and achieve best accuracy we need to know the surrounding temperature which is responsible for the second component of the IR signal namely the reflected part - T_r . In case this T_r temperature is not available and cannot be provided it might be replaced by $T_r \approx T_a - 8$.

Let's assume $T_r = 31^\circ\text{C}$.

$$T_{aK4} = (T_a + 273.15)^4 = (39.184 + 273.15)^4 = 312.334^4 = 9516495632.56$$

$$T_{rK4} = (T_r + 273.15)^4 = (31 + 273.15)^4 = 304.15^4 = 8557586214.66$$

$$T_{a-r} = T_{rK4} - \frac{T_{rK4} - T_{aK4}}{\varepsilon} = 8557586214.66 - \frac{8557586214.66 - 9516495632.56}{1} = 9516495632.56$$

$$S_{x(12,16)} = K_{sTo2} * \sqrt[4]{\alpha_{comp(12,16)}^3 * V_{IR(12,16)COMPENSATED} + \alpha_{comp(12,16)}^4 * T_{a-r}}$$

$$S_{x(12,16)} = -0.00080108642578125 * \sqrt[4]{(1.1876487360496E - 07)^3 * 679.250909123826 + (1.1876487360496E - 07)^4 * 9516495632.56}$$

$$S_{x(12,16)} = -3.34259382357449E - 08$$

$$T_{O(12,16)} = \sqrt[4]{\frac{V_{IR(12,16)COMPENSATED}}{\alpha_{comp(12,16)} * (1 - K_{sTo2} * 273.15)} + T_{a-r} - 273.15}$$

$$T_{O(12,16)} = \sqrt[4]{\frac{679.250909123826}{1.1876487360496E - 07 * (1 - (-0.00080108642578125) * 273.15)} + 9516495632.56 - 273.15}$$

$$T_{O(12,16)} = 80.363312506592 \approx 80.36, ^\circ\text{C}$$

11.2.2.9.1. Calculations for extended temperature ranges

In order to extend the object temperature range and get the best possible accuracy an additional calculation cycle is needed. We can identify 4 object temperature ranges (each temperature range has its own so called Corner Temperature – CT which is the temperature at which the range starts):

- Object temperature range 1 = -40°C ... 0°C (Corner temperature for this range is -40°C and cannot be changed)
- Object temperature range 2 = 0°C ... CT3°C (Corner temperature for this range is 0°C and cannot be changed)
- Object temperature range 3 = CT3°C ... CT4°C
- Object temperature range 4 = CT4°C ...

In order to be able to carry out temperature calculation for the ranges outside of temperature range 2 (To = 0°C...CT3) an additional parameters are needed and must be extracted from the device EEPROM. Those parameters are:

- So called corner temperature (CTx) i.e. the value of temperature at the beginning of the range. Please note that the corner temperatures for range 1 is fixed to -40°C and corner temperatures for range 2 is fixed to 0°C while CT3 and CT4 are adjustable
- Sensitivity slope for each range – K_{STo_x}
- $T_{O(x,y)}$ calculated in 11.2.2.9

11.2.2.9.1.1. Restoring corner temperatures

The information regarding corner temperatures is stored into device EEPROM and is restored as follows:

$$Step = \frac{EE[0x243F] \& 0x3000}{2^{12}} * 10 = \frac{0x2889 \& 0x3000}{2^{12}} * 10 = 0x0002 * 10 = 2 * 10 = 20^{\circ}C$$

$$CT3 = \frac{EE[0x243F] \& 0x00F0}{2^4} * Step = \frac{0x2889 \& 0x00F0}{2^4} * 20 = 0x0008 * 20 = 8 * 20 = 160^{\circ}C$$

$$CT4 = \frac{EE[0x243F] \& 0x0F00}{2^8} * Step + CT3 = \frac{0x2889 \& 0x0F00}{2^8} * 20 + 160 = 0x0008 * 20 + 160 = 8 * 20 + 160 = 320^{\circ}C$$

Or we can construct the temperatures for the ranges as follows:

$$CT1 = -40^{\circ}C < \text{Range 1} > CT2 = 0^{\circ}C < \text{Range 2} > CT3 = 160^{\circ}C < \text{Range 3} > CT4 = 320^{\circ}C < \text{Range 4}$$

11.2.2.9.1.2. Restoring the sensitivity slope for each range

$K_{STo_{scale}} = 17$ has been extracted in 11.1.10

$$K_{STo1} = \frac{K_{STo1_{EE}}}{2^{K_{STo_{scale}}}} = \frac{-105}{2^{17}} = -0.00080108642578125$$

Where:

$$K_{STo1_{EE}} = EE[0x243D] \& 0x00FF = 0x9797 \& 0x00FF = 0x0097 = 151 \text{ (signed)}$$

$$\text{If } K_{STo1_{EE}} > 127 \rightarrow K_{STo1_{EE}} = K_{STo1_{EE}} - 256 = 151 - 256 = -105$$

$$K_{STo3} = \frac{K_{STo3_{EE}}}{2^{K_{STo_{scale}}}} = \frac{-105}{2^{17}} = -0.00080108642578125$$

Where:

$$K_{STo3_{EE}} = EE[0x243E] \& 0x00FF = 0x9797 \& 0x00FF = 0x0097 = 151 \text{ (signed)}$$

$$\text{If } K_{S_{T_{03_EE}}} > 127 \rightarrow K_{S_{T_{03_EE}}} = K_{S_{T_{03_EE}}} - 256 = 151 - 256 = -105$$

$$K_{S_{T_{04}}} = \frac{K_{S_{T_{04_EE}}}}{2^{K_{S_{T_{04_scale}}}}} = \frac{-105}{2^{17}} = -0.00080108642578125$$

Where:

$$K_{S_{T_{04_EE}}} = \frac{EE[0x243E] \& 0x00FF}{2^8} = \frac{0x0097 \& 0xFF00}{2^8} = 0x0097 = 151 \text{ (signed)}$$

$$\text{If } K_{S_{T_{04_EE}}} > 127 \rightarrow K_{S_{T_{04_EE}}} = K_{S_{T_{04_EE}}} - 256 = 151 - 256 = -105$$

Now we can calculate sensitivity correction coefficients for each temperature range:

$$Alpha_{corr_{range1}} = \frac{1}{(1 + K_{S_{T_{01}}} * (0 - (-40)))} = \frac{1}{(1 - 0.00080108642578125 * (0 - (-40)))} = 1.033104231$$

$$Alpha_{corr_{range2}} = 1$$

$$Alpha_{corr_{range3}} = 1 + K_{S_{T_{02}}} * (CT3 - 0) = 1 - 0.00080108642578125 * (160 - 0) = 0.871826172$$

$$Alpha_{corr_{range4}} = (1 + K_{S_{T_{02}}} * (CT3 - 0)) * (1 + K_{S_{T_{03}}} * (CT4 - CT3))$$

$$Alpha_{corr_{range4}} = (1 - 0.00080108642578125 * (160 - 0)) * (1 - 0.00080108642578125 * (320 - 160))$$

$$Alpha_{corr_{range4}} = 0.76008087418$$

11.2.2.9.1.3. Extended To range calculation

The input parameter for this calculation is the object temperature calculated in 11.2.2.9

If $T_{O(12,16)} < 0^{\circ}\text{C}$ we are in range 1 and we will use the parameters ($K_{S_{T_{01}}}$, $Alpha_{corr_{range1}}$ and $CT1 = -40^{\circ}\text{C}$)

If $0^{\circ}\text{C} < T_{O(12,16)} < CT3^{\circ}\text{C}$ we are in range 2 and we will use the parameters ($K_{S_{T_{02}}}$, $Alpha_{corr_{range2}}$ and $CT2 = 0^{\circ}\text{C}$)

If $CT3^{\circ}\text{C} < T_{O(12,16)} < CT4^{\circ}\text{C}$ we are in range 3 and we will use the parameters ($K_{S_{T_{03}}}$, $Alpha_{corr_{range3}}$ and $CT3 = 160^{\circ}\text{C}$)

If $CT4^{\circ}\text{C} < T_{O(12,16)}$ we are in range 4 and we will use the parameters ($K_{S_{T_{04}}}$, $Alpha_{corr_{range4}}$ and $CT4 = 320^{\circ}\text{C}$)

$$T_{O_{extra_range(12,16)}} = \sqrt[4]{\frac{V_{IR(12,16)COMPENSATED}}{\alpha_{comp(12,16)} * Alpha_{corr_{rangeX}} * (1 + K_{S_{T_{0X}}} * (T_{O(12,16)} - CT_X))}} + T_{a-r} - 273.15$$

12. Performance graphs

12.1. Accuracy

12.1.1. Pixel accuracy

All accuracy specifications apply under settled isothermal conditions only.

Furthermore, the accuracy is only valid if the object fills the FOV of the sensor completely.

Parameter definitions:

Frame accuracy is defined as average value of the all (768) pixels in the frame or for frame n can be expressed as:

$$\overline{T_{o_frame(n)}} = \frac{1}{768} \sum_{m=1}^{768} T_o(m, n)$$

$$Frame\ accuracy = \overline{T_{o_frame(n)}} - T_{target}$$

Non-uniformity is defined as the maximum deviation of each individual pixel reading vs. the absolute accuracy.

$$Non\ Uniformity = MAX(|T_o(m) - \overline{T_{o_frame(n)}}|)$$

Pixel absolute accuracy is defined as:

$$T_{O_accuracy(n)} = Frame\ accuracy + Non\ Uniformity$$

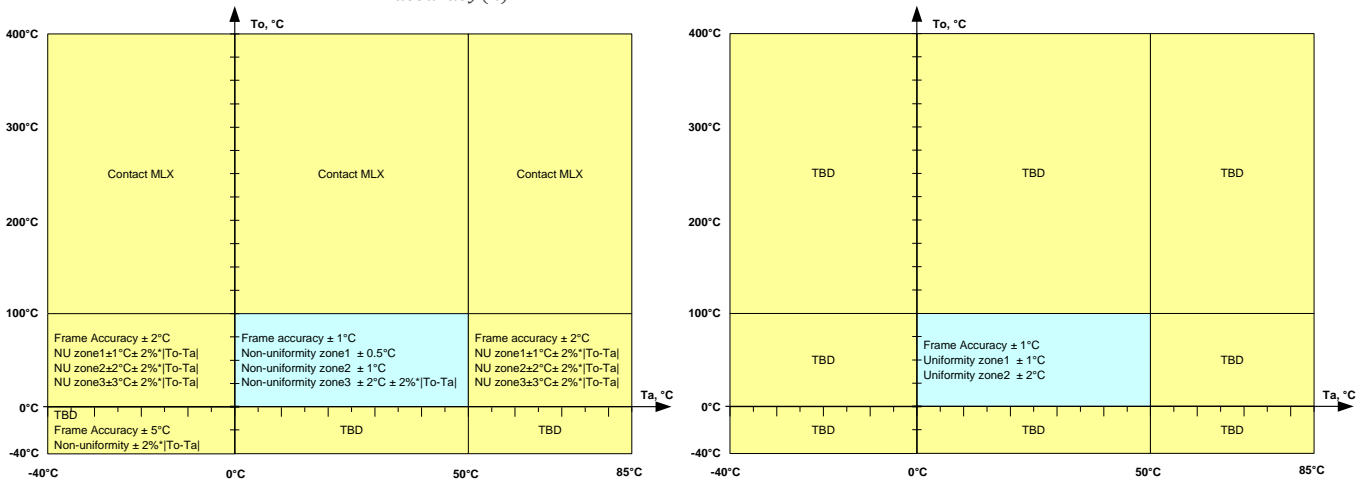


Figure 17 Absolute temperature accuracy – MLX90640BAA (left) and MLX90640BAB (right)

Example: If we assume that the sensor (BAA type, zone 1) is measuring a target at 80°C that would mean that there should be no pixel with error bigger than:

$$T_{O_accuracy(n)} = Frame\ accuracy + Non\ Uniformity = \pm 1 \pm 0.5 = \pm 1.5^\circ C$$

NOTES:

- 1) For best performance it is recommended to keep the supply voltage as accurate and stable as possible to 3.3V ± 0.05V
- 2) As a result of long term (years) drift there can be an additional measurement deviation of ± 3°C for object temperatures around room temperature.

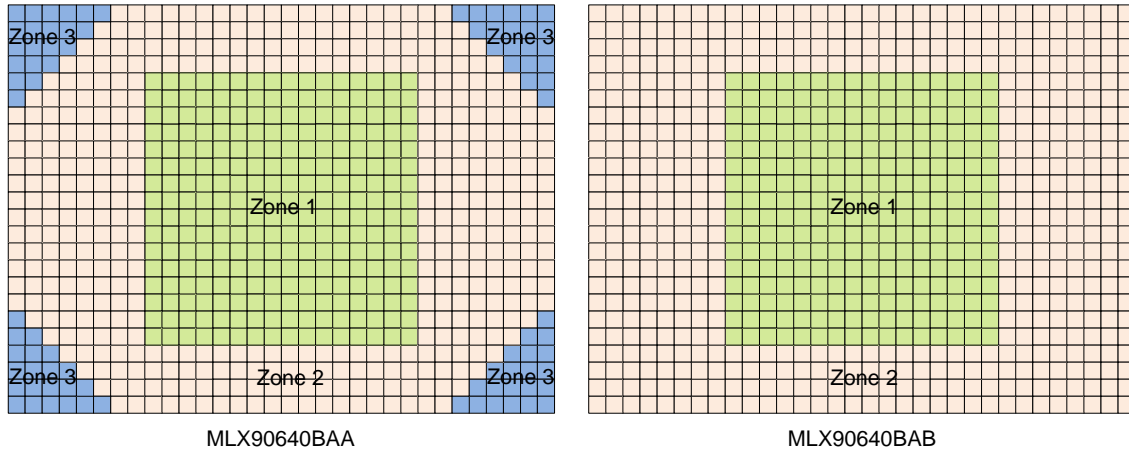


Figure 18 Different accuracy zones depending on device type (BAA on the left and BAB on the right)

12.1.2. Ta accuracy

Absolute accuracy for the Ta channel (die temperature):

$$T_{Accuracy} = \pm 0.5^{\circ}C$$

NOTE: Actual sensor surrounding temperature would be approximately 8°C lower

12.2. Startup time

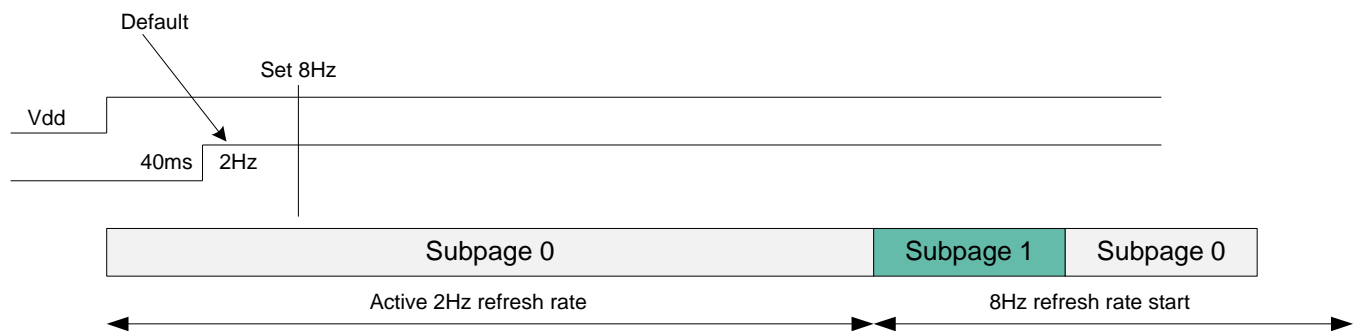
12.2.1. First valid data

After POR the first valid data is available after (depending on the selected refresh rate) T_{valid_data} which is calculated as:

$$T_{valid_data} = 40 + 500, \text{ ms} \quad (\text{Example refresh rate is 2Hz – the default value})$$

It is always subpage 0 to be measured first after POR then subpage 1 and so on alternating.

NOTE: In case one changes the refresh rate on the fly (by writing new values into device register (0x800D)) the settings will take place only after the subpage under measurement is finished.



12.2.2. Thermal behavior

Although electrically the device is set and running there is thermal stabilization time necessary before the device can reach the specified accuracy – up to 4 min.

12.3. Noise performance and resolution

There are two bits in the configuration register that allow changing the resolution of the MLX90640 measurements. Increasing the resolution decreases the quantization noise and improves the overall noise performance. Measurement conditions for the noise are: $T_o = T_a = 25^\circ\text{C}$

NOTE: Due to the nature of the thermal infrared radiation, it is normal that the noise will decrease for high temperature and increase for lower temperatures

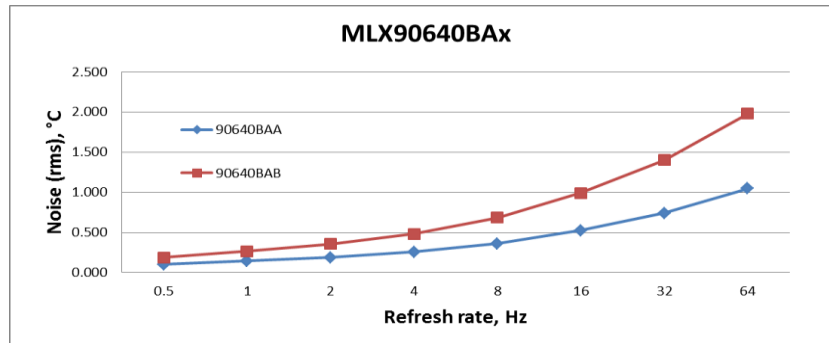


Figure 19 MLX90640BAx noise vs refresh rate for different device types

Not all pixels have the same noise performance. Because of the optical performance of the integrated lens, it is normal that the pixels in the corner of the frame are noisier in comparison with the sensors in the middle. The graphs below show the distribution of the noise density versus the pixel position in the frame (pixel number)

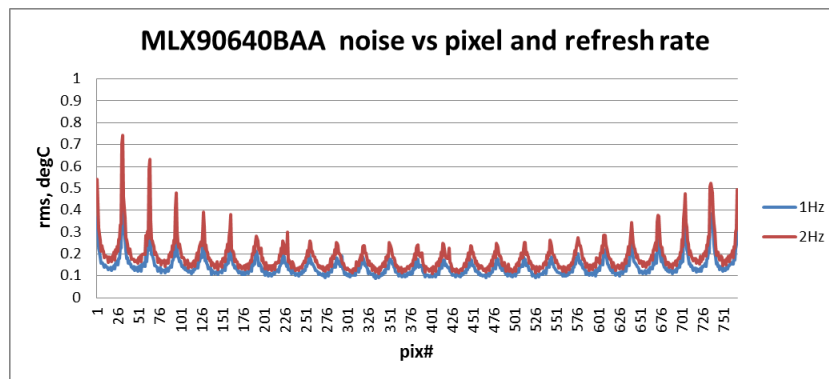


Figure 20 MLX90640BAA noise vs pixel and refresh rate at 1Hz and 2Hz

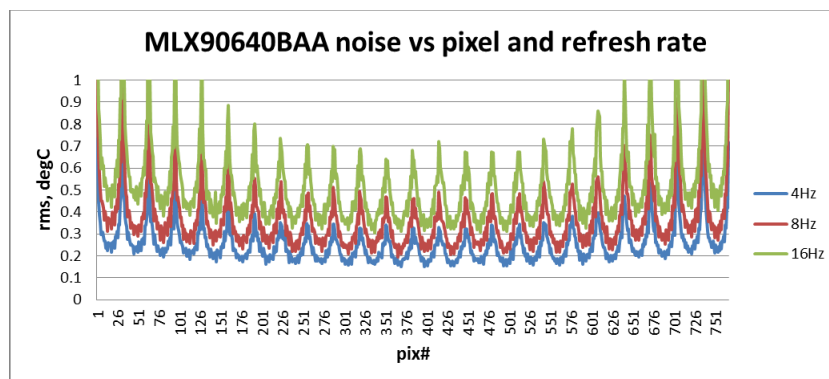


Figure 21 MLX90640BAA noise vs pixel and refresh rate at 4Hz, 8Hz and 16Hz

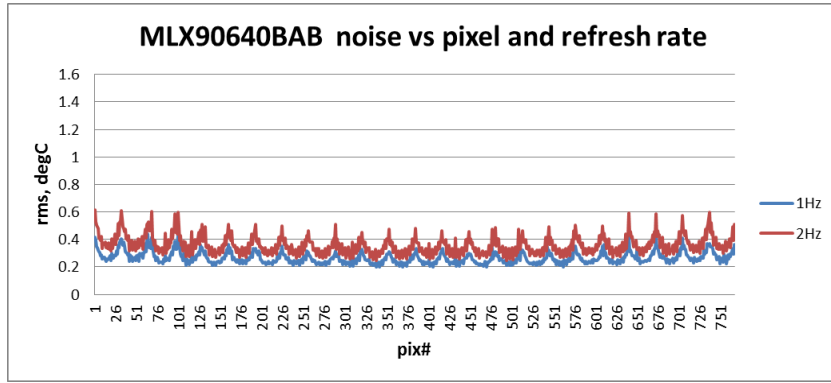


Figure 22 MLX90640BAB noise vs pixel and refresh rate at 1Hz and 2Hz

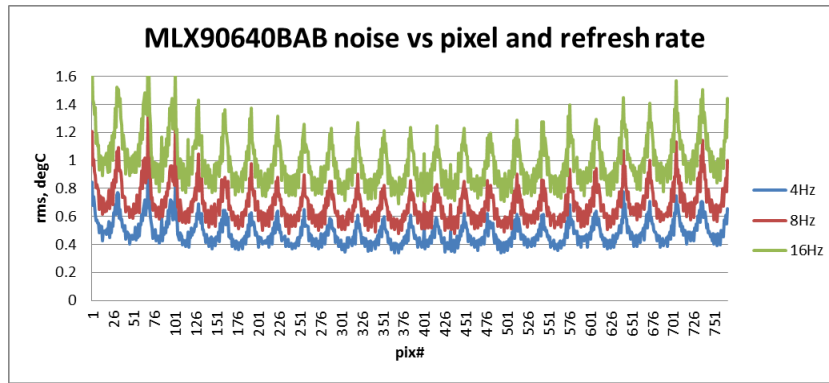


Figure 23 MLX90640BAB noise vs pixel and refresh rate at 4Hz, 8Hz and 16Hz

| NETD (K) | 1Hz RMS noise (temperature equivalent), all pixels | | |
|----------|--|-----|--------------------|
| MLX90640 | Average | Min | Standard deviation |
| BAA | 0.14 | 0.1 | 0.05 |
| BAB | 0.25 | 0.2 | 0.05 |

Table 14 Noise performance

12.4. Field of view (FOV)

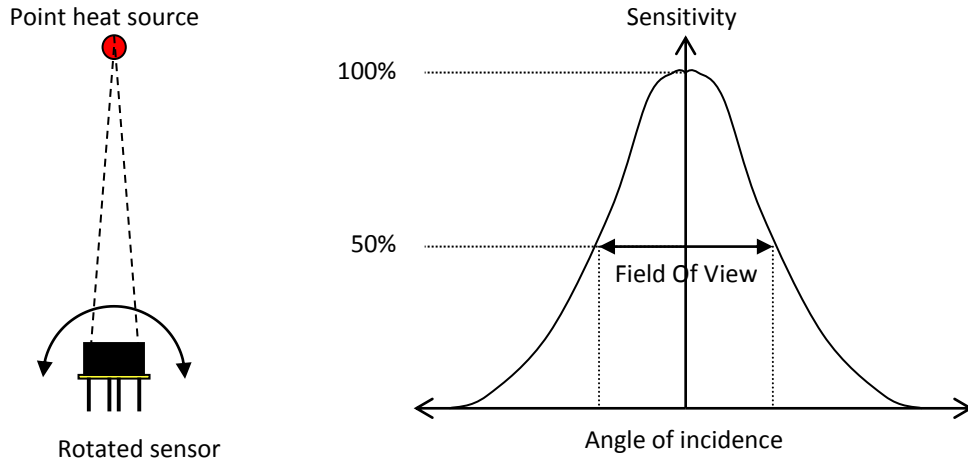


Figure 24 Field Of View measurement

The specified FOV is calculated for the wider direction, in this case for the 32 pixels.

| FOV | X direction | Y direction | Central pointing from normal (X & Y direction) |
|------------------|-------------|-------------|--|
| | Typ | Typ | Max |
| MLX90640-ESF-BAA | 110° | 75° | 5° |
| MLX90640-ESF-BAB | 55° | 35° | 3° |

Table 15 Available FOV options

13. Application information

13.1. Optical considerations

As this is an optical device a care must be taking such that the device performs according to the specification. One such parameter is FOV obstruction. It is paramount that the FOV in the optical path is kept clear. The external aperture is designed such to shape the FOV of the device and is installed prior calibration process thus can be considered as part of the device which does not impact the performance but may be used as a reference for the so called “Optical free zone” – see Figure 27 hereafter.

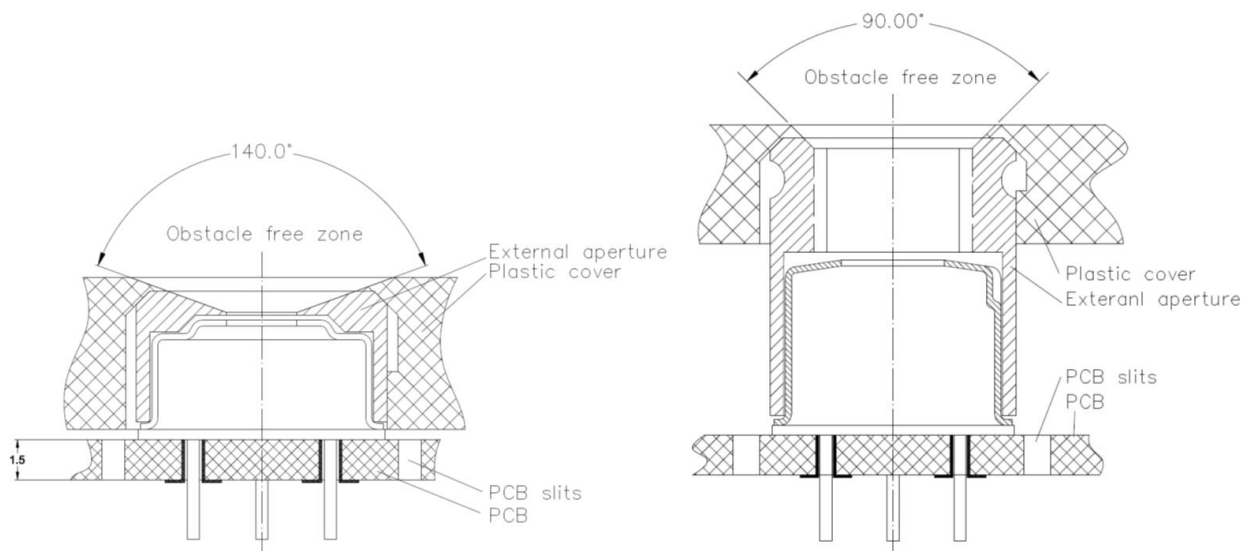


Figure 25 Application examples concerning the optical consideration

13.2. Electrical considerations

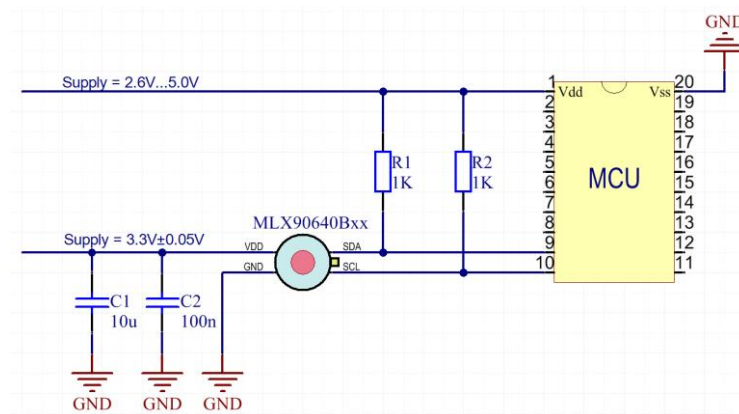


Figure 26 MLX90640 electrical connections

As the MLX90640Bxx is fully I2C compatible it allows to have a system in which the MCU may be supplied with VDD=2.6V...5V while the sensor it's self is supplied from separate supply VDD1=3.3V (or even left with no supply i.e. VDD=0V), **with the I2C connection running at supply voltage of the MCU.**

13.3. Using the device in “image mode”

In some applications may not be necessary to calculate the temperature but rather to have just an image (for instance in machine vision systems). In this case it is not necessary to carry out all calculations which would save computation time or allow the one to use weaker CPU.

In order to get thermal image only following computation flow is to be used:

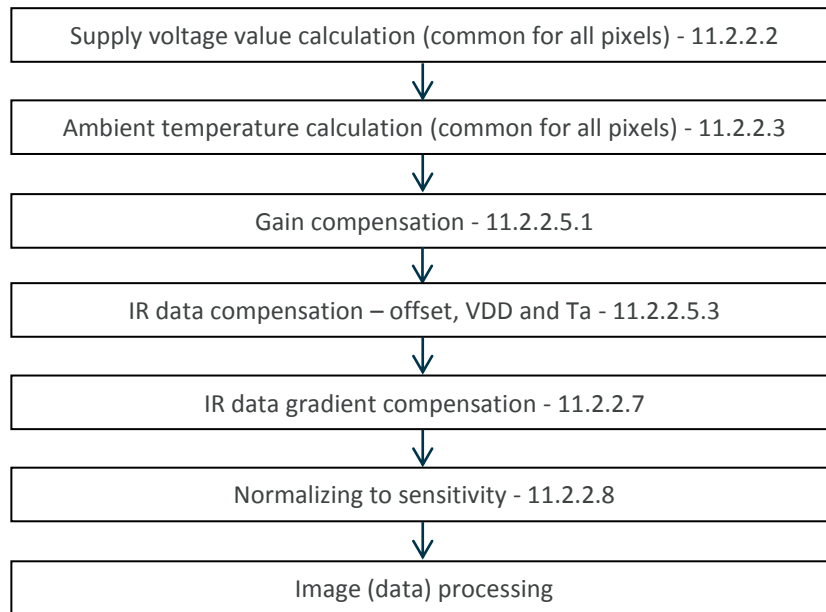


Figure 27 Calculation flow in thermal image mode

14. Application Comments

Significant **contamination** at the optical input side (sensor filter) might cause unknown additional filtering/distortion of the optical signal and therefore result in unspecified errors.

IR sensors are inherently susceptible to errors caused by **thermal gradients**. There are physical reasons for these phenomena and, in spite of the careful design of the MLX90640Bxx, it is recommended not to subject the MLX90640Bxx to heat transfer and especially transient conditions.

The MLX90640Bxx is designed and calibrated to operate as a non-contact thermometer in **settled conditions**. Using the thermometer in a very different way will result in unknown results.

Capacitive loading on an I²C can degrade the communication. Some improvement is possible with use of current sources compared to resistors in pull-up circuitry. Further improvement is possible with specialized commercially available bus accelerators. With the MLX90640Bxx additional improvement is possible by increasing the pull-up current (decreasing the pull-up resistor values). Input levels for I²C compatible mode have higher overall tolerance than the I²C specification, but the output low level is rather low even with the high-power I²C specification for pull-up currents. Another option might be to go for a slower communication (clock speed), as the MLX90640Bxx implements Schmidt triggers on its inputs in I²C compatible mode and is therefore not really sensitive to rise time of the bus (it is more likely the rise time to be an issue than the fall time, as far as the I²C systems are open drain with pull-up).

Power dissipation within the package may affect performance in two ways: by heating the “ambient” sensitive element significantly beyond the actual ambient temperature, as well as by causing gradients over the package that will inherently cause thermal gradient over the cap

Power supply decoupling capacitor is needed as with most integrated circuits. MLX90640Bxx is a mixed-signal device with sensors, small signal analog part, digital part and I/O circuitry. In order to keep the noise low power supply switching noise needs to be decoupled. High noise from external circuitry can also affect noise performance of the device. In many applications a 100nF SMD plus 10μF ceramic capacitors close to the Vdd and Vss pins would be a good choice. It should be noted that not only the trace to the Vdd pin needs to be short, but also the one to the Vss pin. Using MLX90640Bxx with short pins improves the effect of the power supply decoupling.

Check www.melexis.com for most recent application notes about MLX90640Bxx.

15. Mechanical drawings

15.1. FOV 55°

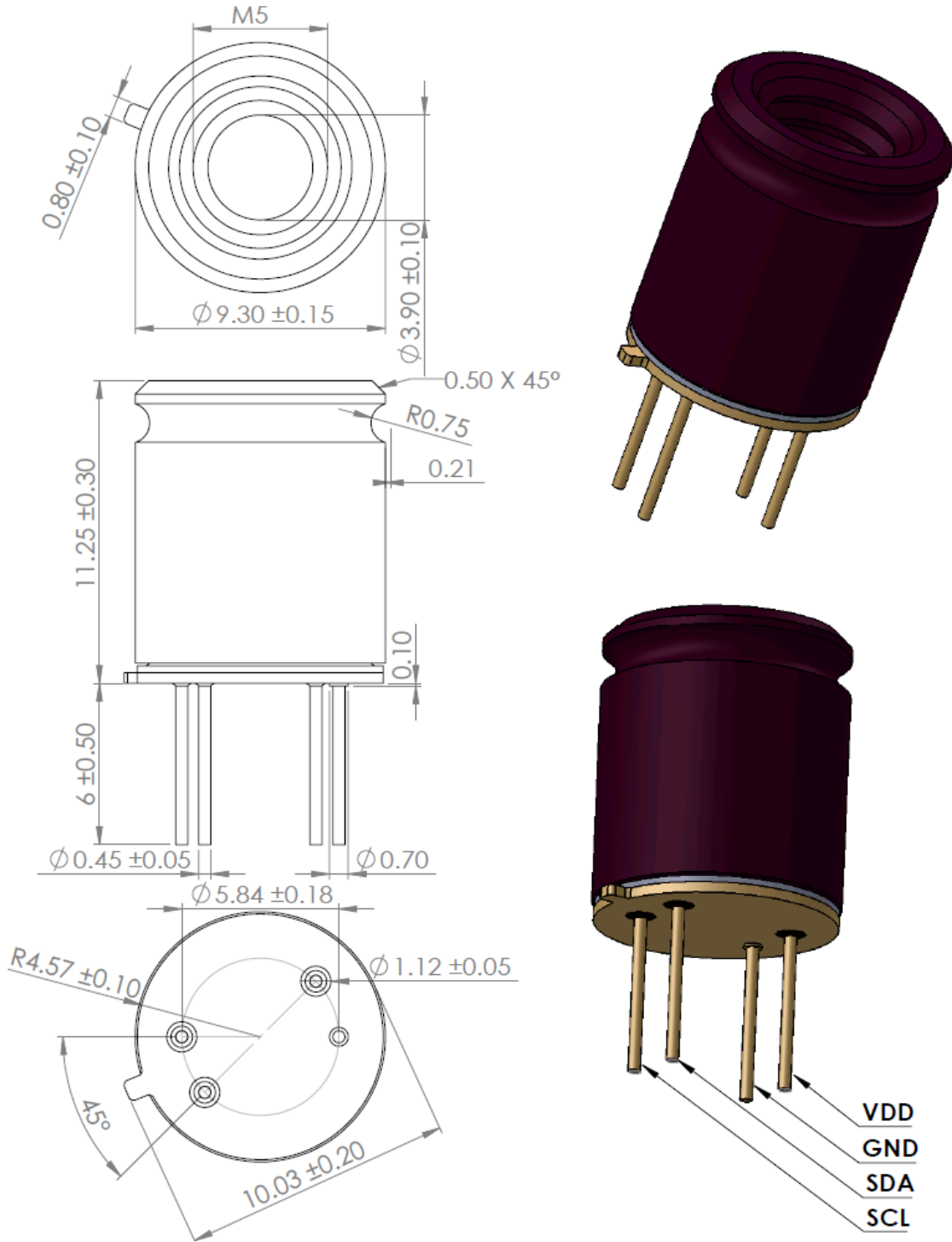


Figure 28 Mechanical drawing of 55° FOV device

15.2. FOV 110°

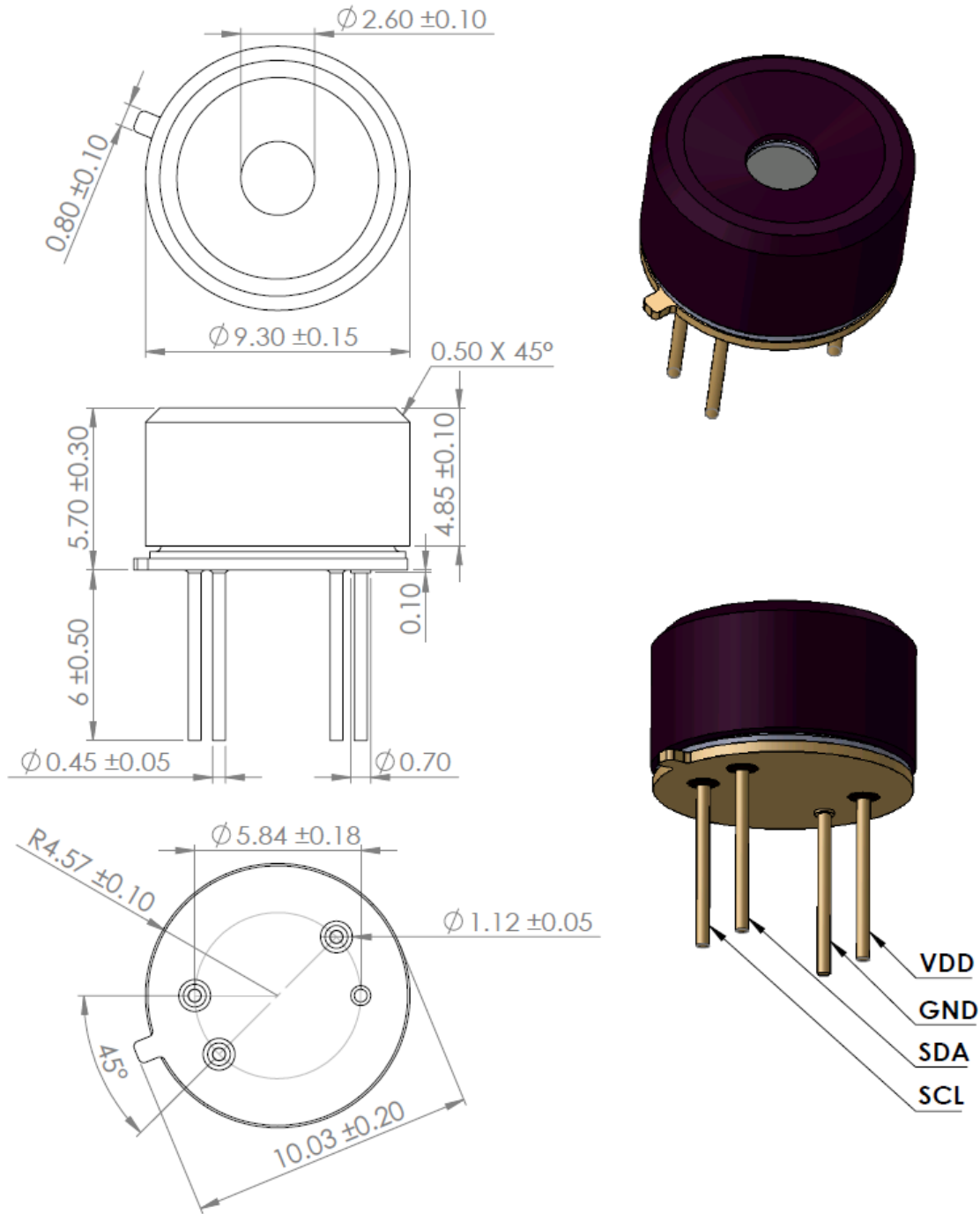


Figure 29 Mechanical drawing of 110° FOV device

15.3. Device marking

The MLX90640 is laser marked with 10 symbols as follows.

| 0 | A | A | xxxxx | xx | Laser marking |
|---|----------|---|-------|----|---|
| | | | | | 2 digits Split number |
| | | | | | 5 digits LOT number |
| | | A | | | FOV = 110° |
| | | B | | | FOV = 55° |
| | A | | | | Device without thermal gradient compensation (TGC = 0 and may not be changed) |
| | C | | | | Device with thermal gradient compensation (TGC = -4...+3.98) |
| 0 | MLX90640 | | | | |

- Example: “OCA1010218” – Device type MLX90640BAA from lot 10102, sub LOT split 18 and Thermal Gradient Compensation activated.

16. Standard Information

Our products are classified and qualified regarding soldering technology, solderability and moisture sensitivity level according to standards in place in Semiconductor industry.

For further details about test method references and for compliance verification of selected soldering method for product integration, Melexis recommends reviewing on our web site the General Guidelines [soldering recommendation](#). For all soldering technologies deviating from the one mentioned in above document (regarding peak temperature, temperature gradient, temperature profile etc.), additional classification and qualification tests have to be agreed upon with Melexis.

For package technology embedding trim and form post-delivery capability, Melexis recommends consulting the dedicated trim & forming recommendation application note: [lead trimming and forming recommendations](#)

Melexis is contributing to global environmental conservation by promoting **lead free** solutions. For more information on qualifications of **RoHS** compliant products (RoHS = European directive on the Restriction Of the use of certain Hazardous Substances) please visit the quality page on our website: <http://www.melexis.com/en/quality-environment>

17. ESD Precautions

Electronic semiconductor products are sensitive to Electro Static Discharge (ESD).

Always observe Electro Static Discharge control procedures whenever handling semiconductor products.

18. Revision history table

| | |
|------------|---|
| 25/07/2016 | Initial release |
| 15/12/2016 | Calibration data stored into EEPROM, pixel reading modes explained |
| 17/01/2017 | Some errors fixed |
| 07/02/2017 | Some calculations errors fixed |
| 24/02/2017 | Noise, FOV and accuracy graphs added, some inaccuracies fixed |
| 02/03/2017 | Overall rearranged , some typo and grammar mistakes fixed |
| 18/05/2017 | Two's complement for IR data from RAM and CP, added outlier identification in EEPROM , added application information |
| 07/07/2017 | Slave address changed to 0x240F, default mode is chess, CP RAM address changed 0x0709 -> 0x0708 and 0x0729 -> 0x0728, resolution control included in calculations, PCB under TO can removed |
| 30/08/2017 | Laser marking added, Max number of fail pixels added, Measurement flow (continuous and step mode) added, FOV definitions updated |
| 10/10/2017 | Added a note regarding CP averaging. Add dimension tolerances in mechanical drawings. Spelling errors corrected |

| | |
|------------|---|
| 11/04/2018 | Updated accuracy table including BAB version, CP for different subpages, compensation for different reading patterns, extended temperature ranges calculations. |
| 03/08/2018 | Added: github driver link, ESD changed from 2kV to 4kV, Step mode removed, Internal register tables updated |
| 03/12/2019 | Rev 12: Max storage temp changed: 125°C to 85°C, added long term accuracy note, Ta accuracy added, added optical considerations, electrical consideration diagram updated with 10µF, added chamfer info, Doc server № added in the footer |

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| | |
|----------------|----------------------------------|
| Europe, Africa | Telephone: +32 13 67 04 95 |
| | Email : sales_europe@melexis.com |
| Americas | Telephone: +1 603 223 2362 |
| | Email : sales_usa@melexis.com |
| Asia | Email : sales_asia@melexis.com |

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