

Concept of the calibration box 1 – FPPN box

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Abstract

This document gives an overview of the concept of the first calibration box (fppn box). This box is intended to perform FPPN, FPN, thermal drift and lens calibration for pmd camera modules.

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1. Functional Description

The first calibration box is intended to perform FPPN, FPN, thermal drift and lens calibration for pmd camera modules. It consists of a frame, a camera tray and a planar target which has a homogeneous matt surface. Underneath this surface, there are tiny drill holes with IR LEDs inside which can be switched on to perform lens calibration (the camera sees a well-defined dot pattern in this case).

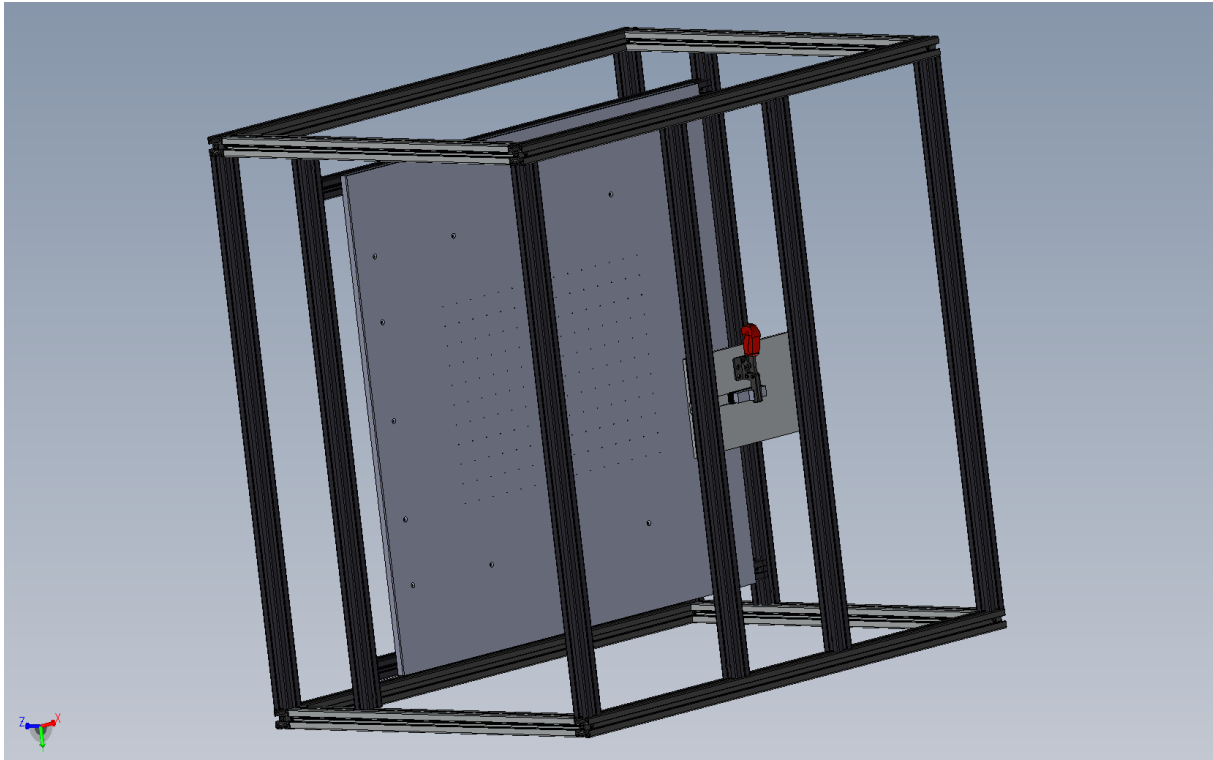


Figure 1: CAD construction drawing

2. Mechanical Construction

This calibration box is an open-frame construction, made from aluminum profiles which can be ordered machined and cut-to-length from the company Bosch-Rexroth¹. The frame is intentionally open for testing and easy access. In a production environment, the sides of the box should be closed to avoid dust.

2.1. Frame

The frame is constructed from 3 types of Strut profiles, quantity is 4 pieces each. The part numbers of the profiles are No. 1 for the blue profile, No. 3 for the red profile, and No. 5 for the green profile. The profiles are connected with 24 pieces of self-tapping central bolts, part No. 6 in the BOM. See Table 1 for the bill of material.

¹ There are other vendors available for these profiles, but the exact dimensions may change slightly, so it is strongly recommended to check the construction when changing the vendor.

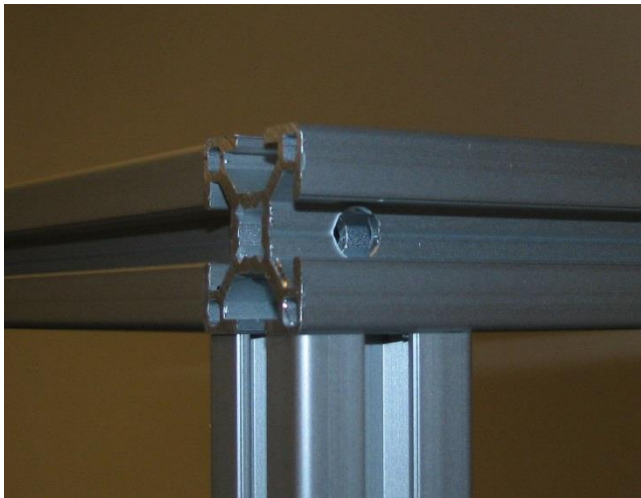


Figure 2: Detail view of strut profile connection



Figure 3: Basic frame construction

2.2. LED Target

The LED target consists of an aluminium plate (BOM item 27) with drill holes to mount the IR LEDs. The drill hole is subdivided into two parts – the upper part has a small diameter of 1mm. This results in spots in the **pmd** intensity image, which are neither too small to be discernible nor too large to impede their centre detection. This is shown in Figure 4.

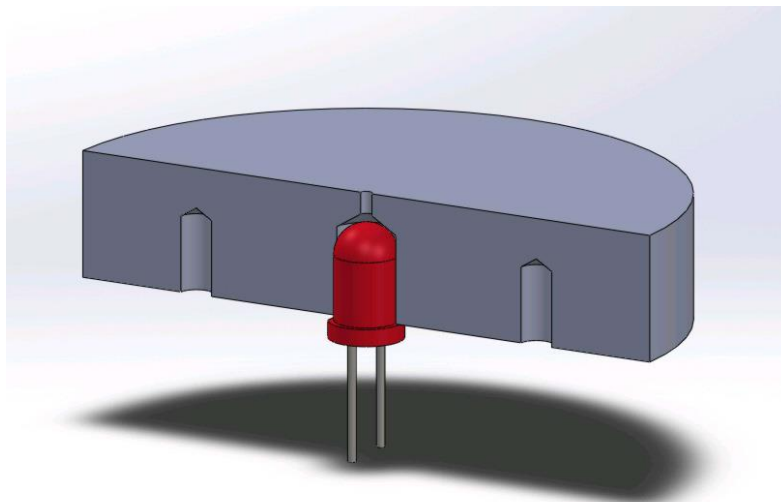


Figure 4: Detail view - drill holes for LED mounting

A special foil (BOM item 14) is glued on top of this plate. This foil needs to have a very homogeneous matte surface, and it needs to be transparent enough so that the LEDs can shine through it. The drill holes are distributed all over the target. The proposed layout is to have a regular grid with a distance of 30mm. However, arbitrary patterns are principally feasible as the crucial point is to have a priori known positions of the drill holes.

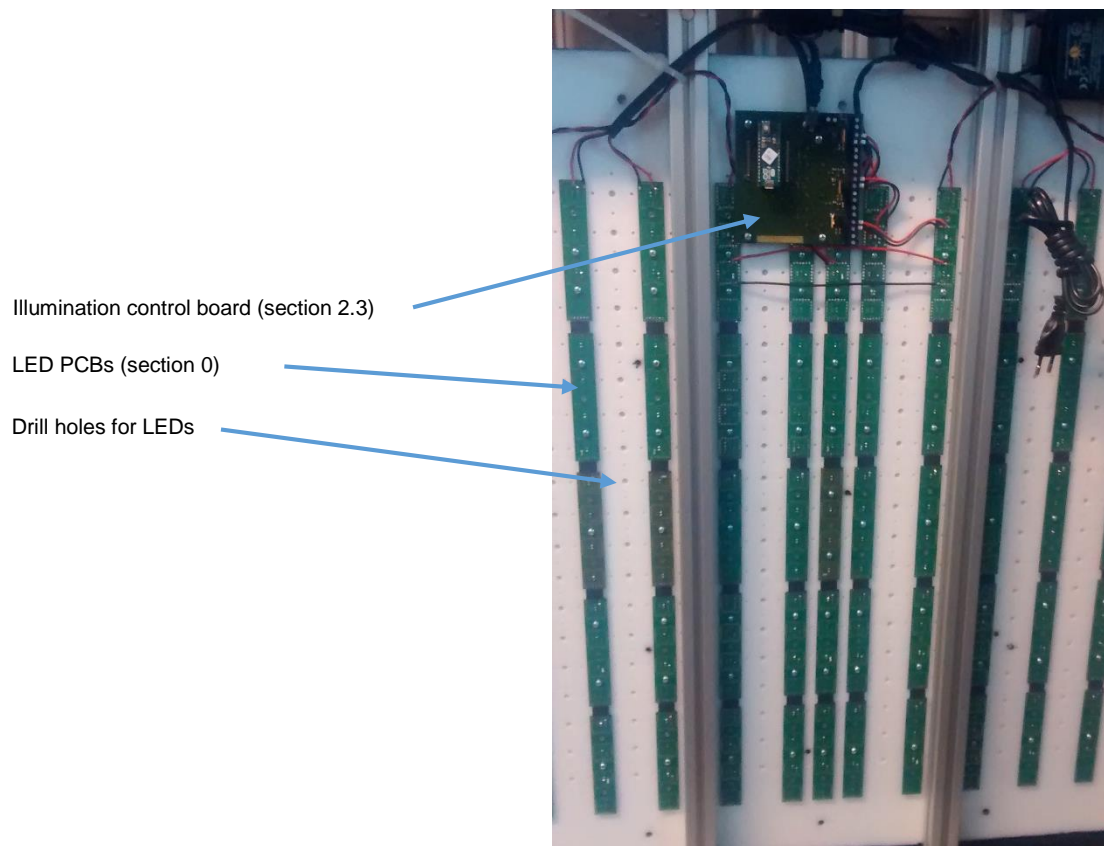


Figure 5: bottom side of LED plate

2.3. Illumination Control Board

The LEDs can be switched off and on by means of a simple illumination control board (BOM item 16) with three independent outputs. Its heart is an Arduino Micro (BOM item 15) which is connected to the PC via USB. The calibration software switches those LEDs on only for the lens calibration so as to have a dot pattern with known world coordinates.

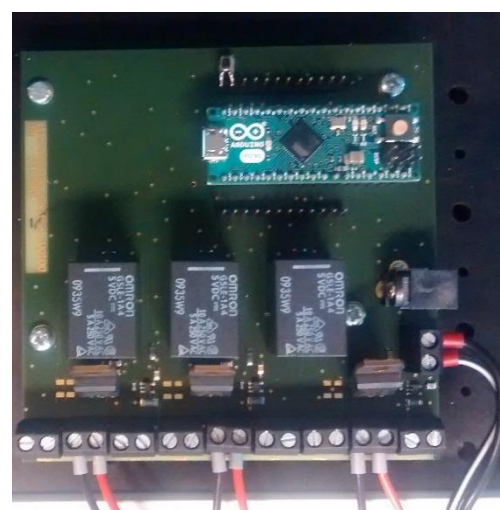


Figure 6: illumination control board

2.3.1. LED PCB Boards

The LEDs are mounted in groups of 4 LEDs to PCBs (BOM item 19). These PCBs can be connected to each other by connectors. See Figure 7 and Figure 8 to get an idea of those PCBs. The layout can be shared by **pmd**.

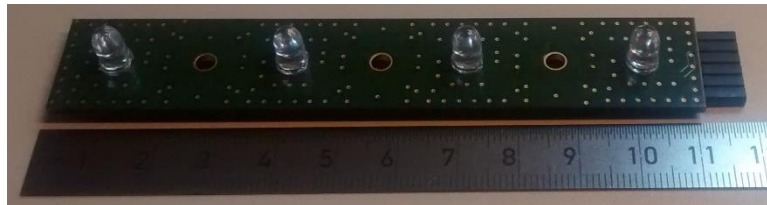


Figure 7: LED PBC Board



Figure 8: LED PBC Board

2.4. Camera Mounting / Coupling

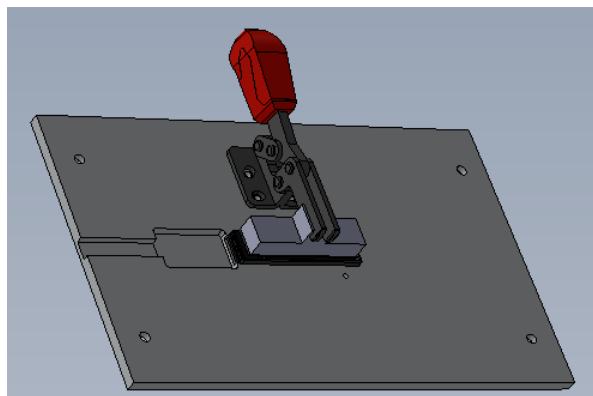


Figure 9: Camera Mounting

The tray for the camera module is specific for any camera module. Figure 9 shows an example for the **pmd** pico flex camera board². The module is inserted into a recess and it is held by a clamping fixture. A smaller recess next to the module recess is used for the USB cable. The positioning tolerance of the tray relates to the position of the optical center (i.e. the lens) and needs to be in the range of $\pm 0,15\text{mm}$.

The tray itself is mounted to two strut profiles (BOM item 2) with four sliding blocks (BOM item 9) and four M6 screws.

² <http://pmdtec.com/picoflexx/>

2.5. Alignment

The calibration is designed to work in a mass-production environment with high throughput. Rather than capturing numerous images from different camera positions, the calibration works with few images taken from only one position. This position, however, needs to be precise. This is why the box needs to be aligned carefully once, when putting the box into operation.

There are two key elements of the alignment (listed by order!): firstly, the lens plate needs to be geometrically levelled, and secondly, the optical center (i.e. usually the center of the module's lens) needs to be aligned normally to the plate.



Figure 10: The precision water level is used to level the lens plate.

1. Lens Plate Levelling: use a high precision water level (BOM item 17) to make sure that the plate is levelled – cf. Figure 10. The threaded levelling feet (BOM item 18) can be used for fine adjustments.³
2. Lateral Alignment Tray ↔ Plate: Use a plumb bob to ensure that the vector from the pattern center (typically a red, visible LED) to the camera's lens center is as short as possible, i.e. the vector is normal to the target plate. For this, it may be required to guide the plumb bob through a mechanical camera dummy with central bore instead of a lens, so that a lateral precision of < 1 mm can be achieved. Use the plumb's cord to measure the exact distance – cf. Figure 11.

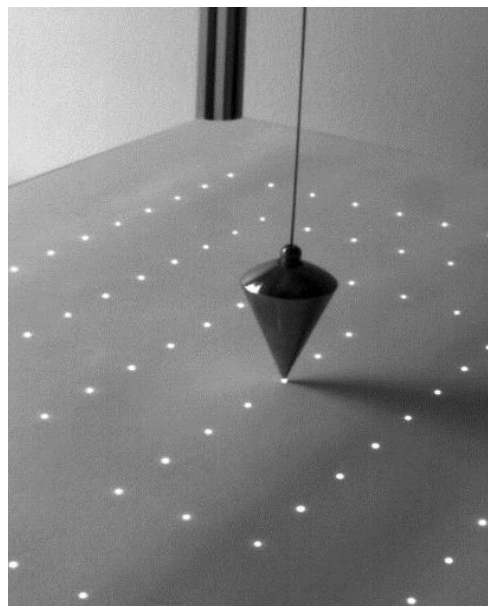


Figure 11: Plumb bob for alignment

2.6. Stray Light Avoidance and Covering

- It is advisable to protect the box against dust, dirt and ambient light. For this purpose, pmd recommends black acrylic glass (BOM item 13), which is mounted onto the outer side of the strut profiles. As this material reflects IR light, however, it is important to glue absorbing material (e.g. cellular rubber, BOM item 12) onto the inner side of these side elements.
- In particular, such an anti-reflection protection must be applied to the part of the camera tray, which is oriented to the inner of the box. The POM material used for our reference tray appears black in the visible spectrum, but it *does* reflect in the IR spectrum!
- The strut profiles need to be covered by cellular rubber as well. Black anodic treatment does not help much in the IR spectrum.
- Light reflections result in wrong offsets during the calibration, i.e. the final device would have an offset to the ground truth distance (e.g. measurement 0.95m vs. 1.0m ground truth).

3. Tables

No.	QTY	Description	Drawing/ Source	pmdtec	Customer
1	4	Strut profile, 30x30x900mm ³	Bosch-Rexroth No. 3 842 990 720/900	-	Order component or define alternative product from local supplier
2	4	Strut profile, 30x30x900mm ³ Machined with 11mm hole	Bosch-Rexroth No. 3 842 990 725/900	-	Order component or define alternative product from local supplier

³ After the last alignment step, the calibration box may be carefully moved or even rotated for better accessibility, but the box must be rigid enough so that it does not change its geometry in any way.

Application Note

Cal-1-2-AN



No.	QTY	Description	Drawing/ Source	pmdtec	Customer
3	4	Strut profile, 30x30x700mm ³ Machined with 2x 8mm blind hole	Bosch-Rexroth 3 842 992 965/700	-	Order component or define alternative product from local supplier
4	2	Strut profile, 30x30x640mm ³ Machined with 11mm Hole	Bosch-Rexroth No. 3 842 990 725/640	-	Order component or define alternative product from local supplier
5	4	Strut profile, 30x30x600 ³	Bosch-Rexroth No. 3 842 990 720/600	-	Order component or define alternative product from local supplier
6	24	Self-tapping central bolt, S8x25-T40	Bosch-Rexroth No. 3 842 527 174	-	Order component or define alternative product from local supplier
7	12	Quick connector, 8/10 mm slot, 90°,	Bosh-Rexroth No. 3 842 535 465	-	Order component or define alternative product from local supplier
9	8	Sliding block, swivel-in, with spring 8mm slot, M6	Bosch-Rexroth No. 3 842 529 296	-	Order component or define alternative product from local supplier
11	1	LED power supply	12V / 5A	-	Order component
12	6m ² 30m	Cellular rubber	http://www.gummiprofile24.de/epages/64048014.sf/de_DE/?ObjectPath=/Shops/64048014/Products/62102-SK and for the struts: http://www.gummiprofile24.de/epages/64048014.sf/de_DE/?ObjectPath=/Shops/64048014/Products/80230	-	Order component or define alternative product from local supplier
13	6m ²	Acrylic glass	Plexi glass 9H01 from http://www.hs-kunststofftechnik.de/index.php?id=2	-	Order component or define alternative product from local supplier
14	1m ²	Special foil: matte highly opaque polypropylene with paper-like touch and a high tensile strength	“HP Everyday Adhesive Matte Polypropylene” * C0F22A for 1524 mm x 22.9 m (60 in x 75 ft) * C0F20A for 1067 mm x 22.9 m (42 in x 75 ft) Alternative German supplier: http://www.rauch-papiere.de/fileadmin/dow	-	Order component or define alternative product from local supplier

No.	QTY	Description	Drawing/ Source	pmdtec	Customer
			nloads/Datenblatt/EN/DB_SynthPapSK_E.pdf		
15	1	Arduino Micro	https://www.arduino.cc/en/Main/ArduinoBoardMicro	-	Order component or define alternative product from local supplier
16	1	Illumination control board	pmdtec Tango_IFM_BOX_Illumination_V0300.zip	Share all relevant design data (Schematic, Layout, BOM)	Find a local PCB manufacturer and SMT assembly
17	1	High-precision water level	Precision: 0.1 mm/m = 0.0057° e.g. http://www.messwerkzeuge24.de/Maschinen-Wasserwaagen/Praezisions-Wasserwaage/Praezisions-Wasserwaage-Genauigkeit-0-02-mm-m::1286.html	-	Order component or define alternative product from local supplier
18	4	Threaded levelling feet	Bosch Rexroth part no 3842502257	-	Order component or define alternative product from local supplier
19	1	LED module	pmdtec Tango_IFM_BOX_Illumination_Control_V0300.zip	Share all relevant design data (Schematic, Layout, BOM)	Find a local PCB manufacturer and SMT assembly
20	150	IR LEDs	Osram SFH 4550	-	Order component or define alternative product from local supplier
21	4	Hexagon Socket Head Screw M6x20	-	-	Order component or define alternative product from local supplier
22	2	Hexagon Socket Head Screw M6x25	-	-	Order component or define alternative product from local supplier
23	1	Camera Mounting Plate	Module specific!	Share all relevant design data	Find a local CNC manufacturer
24	4	Hexagon socket countersunk head screw M6x12	-	-	Order component or define alternative product from local supplier

Application Note

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No.	QTY	Description	Drawing/ Source	pmdtec	Customer
25	4	Hexagon socket countersunk head screw M6x16	-	-	Order component or define alternative product from local supplier
26	-	-	-	-	-
27	1	LED aluminum top plate	Drawing Lens_Calib_Bottom_Plate_V 0102.PDF	Share all relevant design data	Find a local CNC manufacturer

Table 1: Bill of Material

Document History

Document title: Calibration Box 1 – Cal-1-2-AN

Revision	Origin of Change	Submission Date	Description of Change
0	SBe	2016-04-13	New Application Note
1	BAI	2016-04-15	Edit Bill of Material
2	OLo	2016-09-28	Edit Bill of Material

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