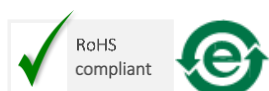# PAA3905E1-Q: External Light Assist Application Note(AN04)

General Description

This Application Note provides the information and guidance for using PAA3905E1-Q in an ultra-low light environment, with the assistance of external lighting.

Ordering Information

Part Number	Description
PAA3905E1-Q	Optical Motion Tracking Chip
L242-ZSZ1	Lens Set

RoHS compliant

For any additional inquiries, please contact us at https://www.pixart.com

Table of Contents

List of Figures

List of Tables

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1.0 Introduction

1.1 Overview

The PAA3905E1-Q is PixArt Imaging's optical motion tracking chip specifically designed for low-light condition operation. The matching lens set provides a 42° effective viewing angle (FOV) and allows motion tracking under low light conditions as low as 5 lux without needing external lighting.

In addition, the chip supports the external lighting assist option in maintaining the chip tracking performance according to the environment's ambient light condition.

The user owns the responsibility to design the external lighting circuitry in the specific use model, as well as the responsibility to perform qualification of the product with the use of external lighting, where the qualification should comprehend the reliability and effectiveness of the product during actual usage and operations.

1.2 Relevant Information

Table 1. Related Document

No.	Item	Version
1	PAA3905E1-Q Datasheet	1.0
2	L242-ZSZ1: Lens Datasheet	1.0

1.3 Terminology

Term	Description
FOV	Field of View
LED	Light-Emitting Diode
IR	Infrared
fps	Frame per second

2.0 Hardware
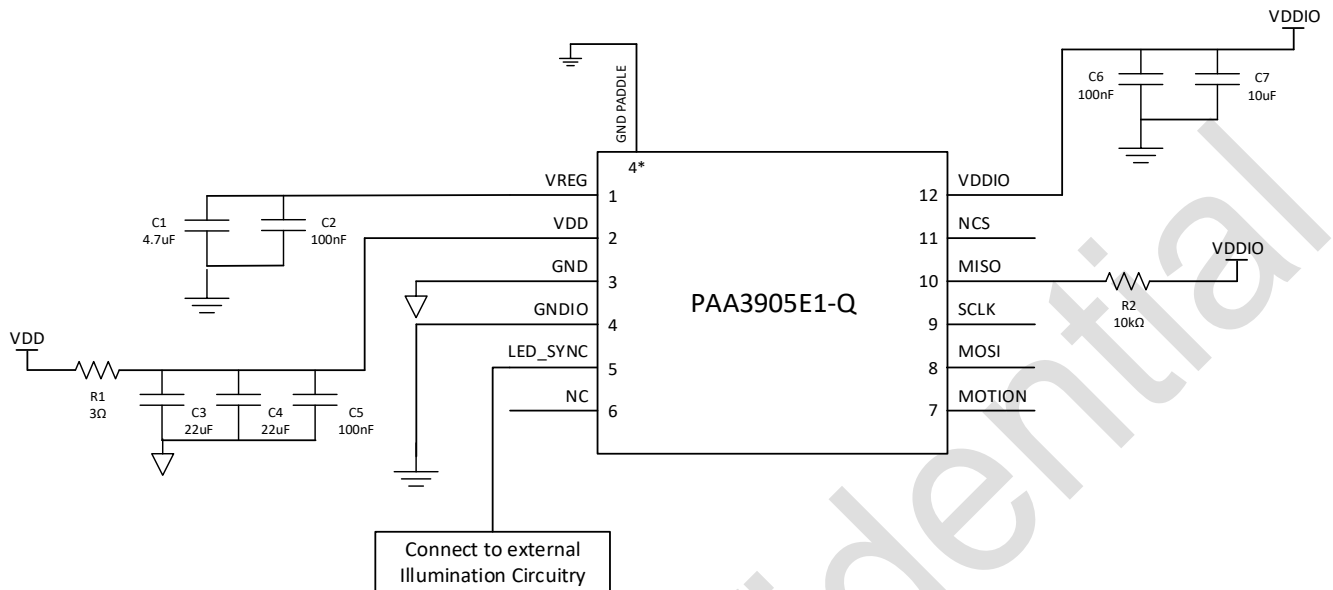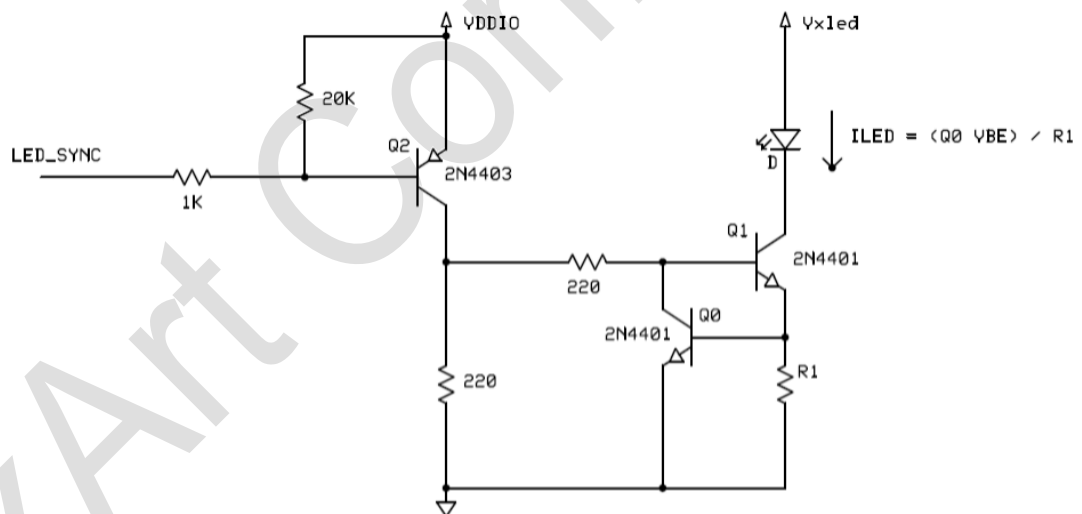
2.1 Reference Schematic

Figure 1. Reference Schematic to Drive External LED Circuitry

Note:
1. The maximum continuous current for 2N4401 is 600mA.
2. For driving more than one LED, connect the extra LED(s) in parallel.
   Adjust R1 accordingly to cater to the total current consumption of all LEDs.

Figure 2. Reference of External LED Circuitry Schematic

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4

2.2 LED Characteristic Requirement

The High-Power IR LED is recommended in this application.

Below is the general IR LED characteristic requirement.

Table 2. Characteristic Requirement of High-Power IR LED at T_A = 25°C

Parameter	Symbol	Min.	Typ.	Max.	Unit	Note
Wavelength	λ		850		nm	
Viewing Angle			60		°	
Radiant Intensity			55		mW/sr	I_F = 100 mA; t_p = 20 ms
Maximum Forward Current	I_F			100	mA	
Power Consumption				180	mW	
Reverse Voltage	V_R			5	V	
Reverse Current	I_R		0.01	10	µA	V_R = 5 V
Forward Voltage	V_F		1.5	1.7	V	I_F = 100 mA

2.3 LED Placement

There are two types of LED placements, being tested with PAA3905E1's Design Kit.

1. One-sided: LEDs are lined up on one side of the chip.
2. Four-sided: LEDs are on four different sides of the chip.

Other LED placements may also be considered to complement specific end product designs. Avoid placing the LEDs within the field of view of PAA3905E1.

2.3.1 One-sided Placement

For this kind of placement, all the LEDs are lined up to one side of the chip, as shown in Figure 3.
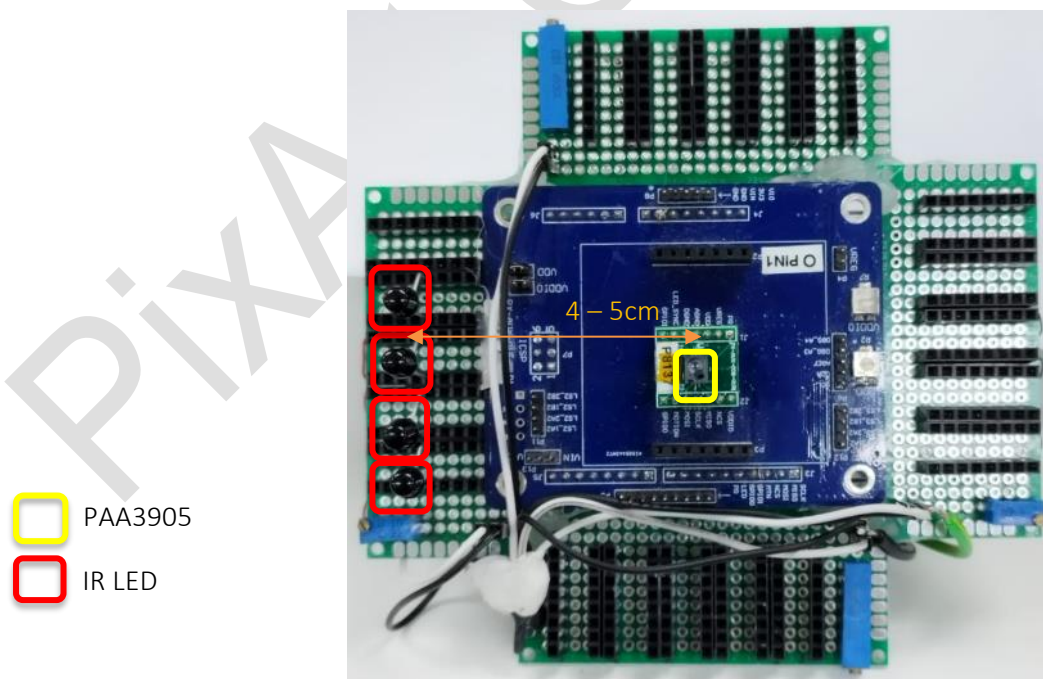

Figure 3. LEDs with One-sided Placement

2.3.2 Four-sided Placement

The LEDs are placed with almost equal number to the four sides of the chip, as shown in Figure 4.
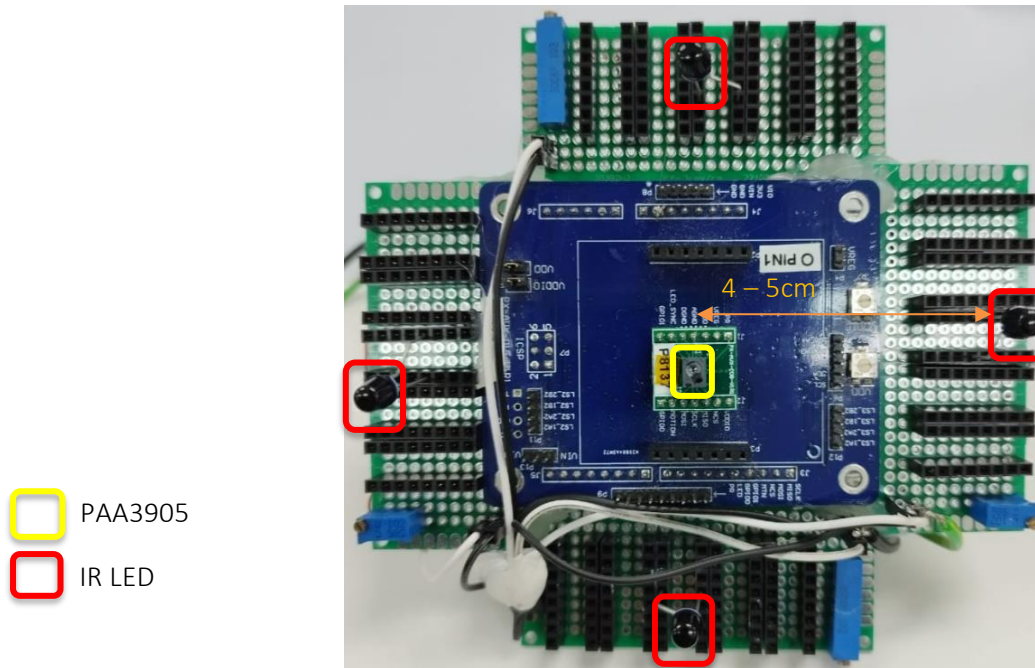

PAA3905

IR LED

Figure 4. LEDs with Four-sided Placement

2.4 Minimum Requirement

The required conditions of light assist for different low light modes are determined by 2 parameters:-

- The minimum number of LED
- The minimum total current consumption, and the average current per LED

Table 3. Light Assist Requirement of Respective Operation Mode

Mode	Description	Minimum LED	Minimum Current (One-sided)	Minimum Current (Four-sided)
1' @126fps	Low-Light Mode with light assist1	7	700mA [100mA/LED]	700mA [100mA/LED]
2' @50fps	Super-Low Light Mode with light assist	4	400mA [100mA/LED]	320mA [80mA/LED]
3' @20fps	Ultra-Low Light Mode with light assist[2]	3	300mA [100mA/LED]	150mA [50mA/LED]

Note:

Optimum performance is achieved up to VDD = 2.0 V as per the table above. Additional 1 to 2 LEDs may be required for VDD > 2.0 V.

1. For Low-Light Mode tracking, additional register setting is required, refer to section 3.1.
2. Ultra-Low Light Mode is an additional operation mode, refer to section 3.1.

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2.5 Verification Condition

The tested surfaces are Crimson Carpet and Glossy Grey Vinyl surfaces, which cover the range of diffused and glossy surfaces, at the working range of up to 1.5m height.

Figure 5. Tested Surfaces

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3.0 Operation Mode

By default, PAA3905E1 automatically switches among three standard operation modes when operating under different brightness conditions. When the ambient light becomes darker, it will switch to the next lower light mode.

Besides the three operating modes, Bright, Low Light and Super Low Light, as stated in PAA3905E1's datasheet, the Ultra-Low Light mode (Mode 3) is an additional mode that cater for even lower brightness after Super-Low Light mode (Mode 2). This mode will set the typical frame rate down to 20 fps and allow the shutter to open longer. However the speed capability when operating at this mode will be much lower compare to Mode 2.

Table 4. Three Operation Modes

Mode	Frame Rate (Typ)	Description
0	126 fps	**Bright Mode** for general motion tracking
1	126 fps	**Low Light Mode** for low light motion tracking
2	50 fps	**Super-Low Light Mode** for super-low light and low-speed motion tracking
3	20fps	**Ultra-Low Light Mode** for ultra-low light and low speed motion tracking

3.1 Ultra-low Light Mode

To allow automatic switching from Mode 0 to Mode 3, perform below register writes:-

1. Write register 0x7F with value 0x08
2. Write register 0x68 with value 0x03
3. Write register 0x7F with value 0x00

To manually switch to Ultra-low Light mode, perform below register writes:-

1. Write register 0x7F with value 0x08
2. Write register 0x68 with value 0x33
3. Write register 0x7F with value 0x00

The above two settings can only be applied after loaded the initialization register setting in Section 7.1.2 of PAA3905E1's Datasheet.

The host can read the *Observation* register to identify the chip's operation mode status.

Speed vs Height (Mode 3)

$$y = 1.2819x$$
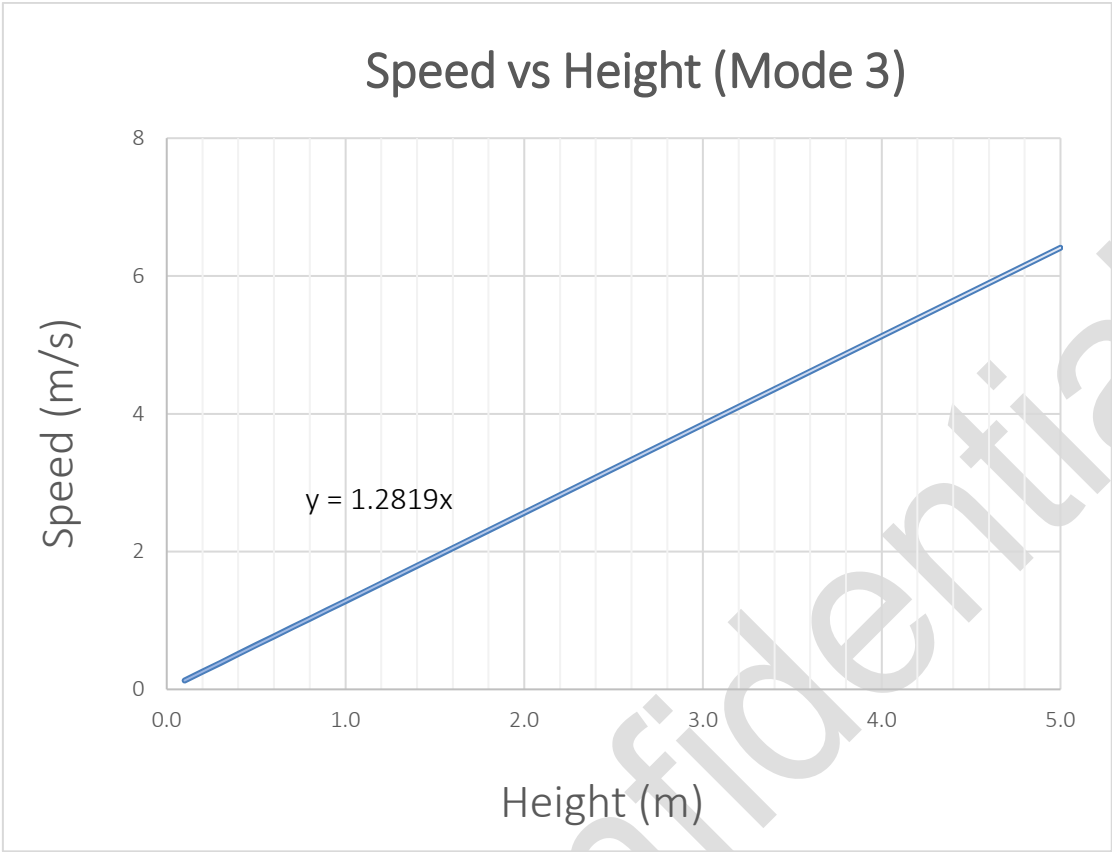
Note: Interpolation is applied beyond 0.5 m.

Figure 6. Speed versus Height Chart (Mode 3)

3.2 Related Registers

Register Name	Observation		
Bank		**Address**	0x15
Access	R/W	**Default Value**	0x00
Description	The user must clear the register by writing 0x00, wait for 30 ms, and read the register. The active processes *OB*[5:0] will have set their corresponding bits. The read-back value for *OB*[5:0] should be 0x3F. *OB*[7:6] indicates the current operation mode of the chip.		

Bit Field	Name	Default Value	Description
7:6	OB[7:6]	0	0: Bright Mode 1: Low Light Mode 2: Super-Low Light Mode 3: Ultra-Low Light Mode
5:0	OB[5:0]	0	0x3F: chip is working correctly Other value: recommend issuing a software reset command to the chip and configuring the register as per section 7.1 in this datasheet.

4.0 Operation Control and Setting

Operation Mode Auto Switching Condition

Under Operation Mode Auto Switching Condition, the chip's operation mode changes automatically based on the environment ambient light condition.

When the chip operates in darker environment, the chip's operation mode will change to a lower light operation mode. The host can read the observation register periodically to activate lighting assist as needed.

Operation Mode Manual Switching Condition

With maintaining the motion tracking performance as requirement, the host can configure the operation mode manually. The host can turn on the lighting assist when the chip operates in a darker environment. The recommended lighting assist requirement is as shown in Section 2.4.

4.1 LED Control

For power-saving purposes, LED control (LED_SYNC) is disabled by default. Below is the step to enable the LED Control (LED_SYNC).

1. Power up the chip and initialize register settings as outlined in Section 7.1.1 Initial Flow of PAA3905E1's datasheet.

2. Perform below register writes in sequence:
   a. Write register 0x7F with value 0x14
   b. Write register 0x6F with value 0x0C
   c. Write register 0x7F with value 0x00

To disable the LED control and back to the default state, perform the below register writes in sequence:
1. Write register 0x7F with value 0x14
2. Write register 0x6F with value 0x2C
3. Write register 0x7F with value 0x00

NOTE: While this section aims to guide in utilizing the LED_SYNC pin, the user owns the responsibility to select the appropriate LED and design its circuitry to meet the desired end application.

4.2   Register Settings for Mode 1: Low Light Mode

Note that when external light assist is activated under Mode 1: Low Light Mode, there are additional register settings that need to be applied on top of the register settings outlined in Section 7.1.2 Initialization Register Setting of the PAA3905E1's datasheet. When exiting Mode 1: Low Light Mode, these additional settings need to be turned off.

Note: Additional register settings for other modes (Mode 2 & 3) are not needed.

Below are the extra registers write after the chip switches into Mode 1: Low Light Mode, either automatically or manually.

1.   Write register 0x7F with value 0x05
2.   Write register 0x4F with value 0x32
3.   Write register 0x7F with value 0x00

To return to the normal setting when exiting Mode 1: Low Light Mode.

1.   Write register 0x7F with value 0x05
2.   Write register 0x4F with value 0x65
3.   Write register 0x7F with value 0x00

Revision History

Revision Number	Date	Description
1.0	26 May 2023	Initial release