PAT9136E1-TXQT/ PAA5160E1-Q: Marker Detection Application Note (AN07)

General Description

This application note provides a method to detect marker using PAT9136E1/ PAA5160E1.

Ordering Information

Part Number	Description
PAT9136E1-TXQT	Optical Tracking Chip
PAA5160E1-Q	Optical Tracking Chip

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1.0 Introduction

1.1 Overview

This application note provides a method to detect marker using PAT9136E1/ PAA5160E1. As the chip detects motion, the shutter value changes according to the reflectiveness of tracking surface. When the tracking surface changes, the shutter value will change accordingly. By optimizing the surface selection and marker design, the host can leverage the shutter value change to obtain the marker information at a constant polling rate.

Note: Throughout this application note, the PAT9136E1 and PAA5160E1 are referred to as the "chip".

1.2 Relevant Information

Table 1. Related Document

No.	Item	Version
1	PAA5160E1-Q Product Datasheet	0.83
2	PAA5160E1-Q Sensor Resolution Normalization Application Note (AN00)	1.0
3	PAA5160E1-Q Chip Orientation Determining and Re-mapping Application Note (AN03)	1.0
4	PAT9136E1-TXQT Product Datasheet	0.83
5	PAT9136E1-TXQT and PAA5160E1-Q: Chip Cover Glass and Protective Cover Cleaning Procedure (AN04)	1.0
6	PAT9136E1-TXQT and PAA5160E1-Q: Module Test Recommendation (AN05)	1.0
7	PAT9136E1-TXQT and PAA5160E1-Q: CPI Calibration and Adjustment (AN06)	1.0

1.3 Terminology

Term	Description
CPI	Count per Inch
VCSEL	Vertical Cavity Surface Emitting LASER
AOI	Area of Interest

2.0 Marker Detection

Generally, the chip tracks on trackable surfaces at consistent and low resolution variation, as stated in the respective datasheets. However, over a longer distance of repeated tracking, error will accumulate. To reset the error, a marker or multiple markers can be applied at known locations along the tracking path of the chip. With this, the host can detect the presence of the marker and reset the error. The marker can also be used to provide positional information.

The following steps are the considerations of the marker detection application.

1. Marker material selection (refer to Section 2.1)
2. Calculate marker width (refer to Section 2.2)
3. Determine maximum speed in the target application
4. Calculate maximum polling interval/minimum polling rate (refer to Section 2.3)
5. Setting a shutter threshold for marker detection (refer to Section 2.4)

2.1 Tracking Surface Requirement

When the chip is tracking on markers, the shutter value needs to be changed significantly from the tracking surface, in order to be detected. The shutter control is a mechanism of the chip to regulate the amount of light reflected back into the chip from the VSCEL illumination and keep the average raw data values within a target range.

On surface with higher reflectivity, the shutter value will be smaller; and vice versa for surface with lower reflectivity (higher absorbance of light), the shutter will extend wider to receive more reflected light.

For example, on metal surfaces such as Aluminum and Stainless Steel, which are higher in reflectivity, the marker needs to be less reflective to achieve large difference in shutter values. The same applies for less reflective tracking surface, where the marker needs to be more reflective. It is recommended to have a minimum shutter difference of 400 counts between tracking surface and marker.

Figure 1. Example of Marker on a Stainless-Steel Surface

The marker surface can be fabricated by:

1. Laser marking on steel or any other metal surfaces, or
2. Using different type of material that overlays or sits in between the tracking surfaces, such as tape material.

Regardless of the marker options, the marker surface needs to be a trackable surface for the chip.

2.2 Marker Design Requirement

The minimum marker size is dependent on three parameters:

1. Tracking height
2. Polling interval
3. Maximum tracking speed

The effective angle of the chip towards the tracking surface is 21 degrees. An example of tracking height at 30mm is as shown below.

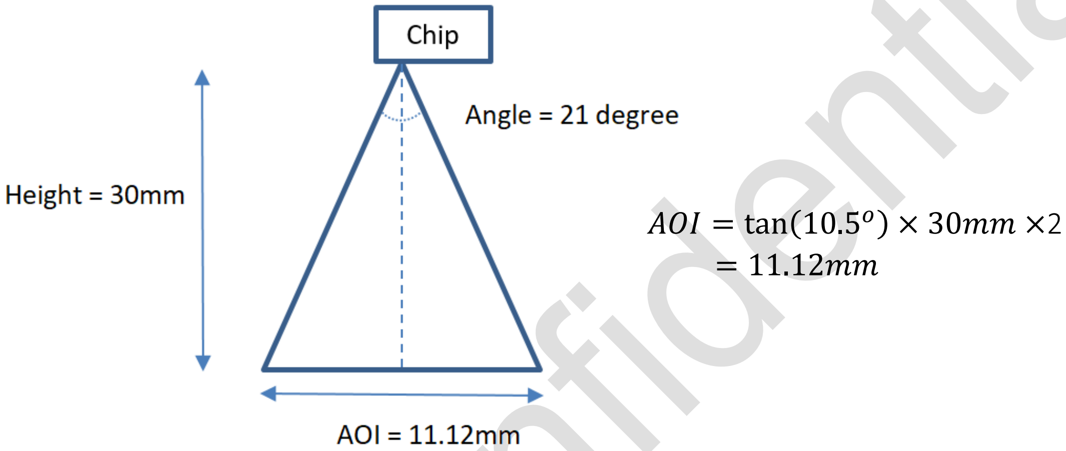

Figure 2. Area of Interest (AOI) at 30mm

The AOI is roughly 11.12mm in diameter, calculated using Theorem Pythagoras. Thus, the minimum marker size needs to be 11.12mm x 11.12mm.

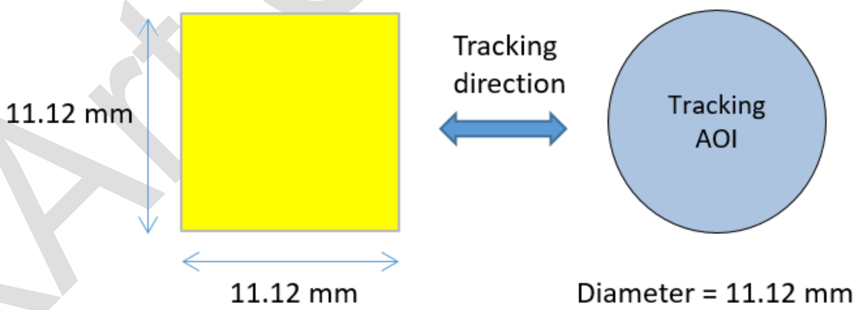

Figure 3. Minimum Marker Size in Tracking Direction

For application where the height is varied, the marker size should base on the AOI at the highest height.

It is recommended to add 20% margin to the calculated AOI, where in this example is 11.12 with 20% buffer and round up to 13.50mm.

$$Marker\ width = 11.12mm \times 1.2 = 13.34mm$$

2.3 Marker Detection Tolerance

The accuracy of the marker detection depends on the host motion polling interval and the tracking speed. For example, if the application's maximum tracking speed is 2.5m/s and the host polls the chip's motion data at 1ms, the distance travelled for each polling interval will be 2.5mm (2.5m/s divided by 1000).

To trigger a significant change of shutter value, the minimum area of marker size needs to be at least 60% of the calculated AOI. For illustration, the first possible marker detected size is 60% of the chip's AOI, which triggers sufficient change of shutter value to be detected as marker. Otherwise, if the first polling is just slightly off (eg. at 59%), the changes in shutter value may not meet the threshold setting. It needs to rely on the second polling to be detected and confirmed as marker. By then, the chip has already travelled additional 2.5mm.

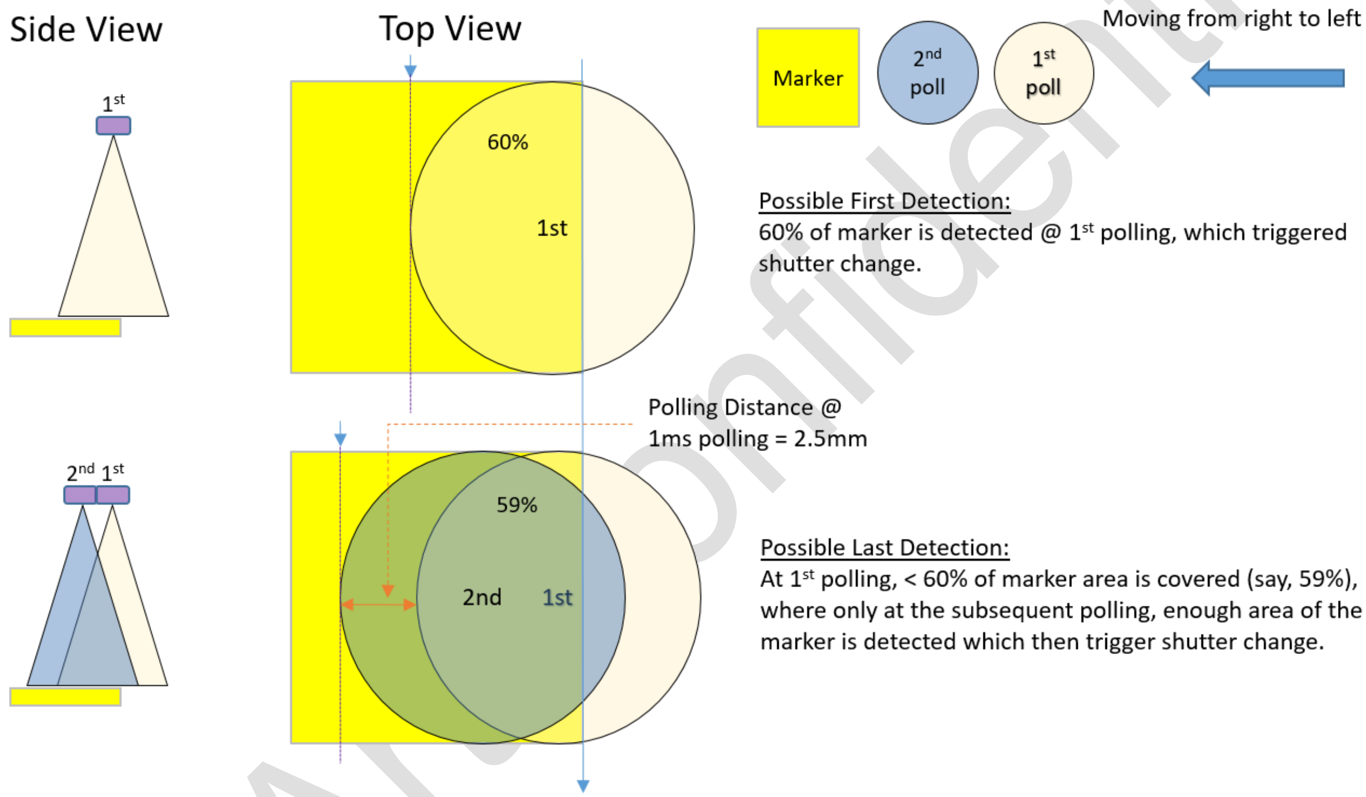

Figure 4. Marker Detection Tolerance

Therefore, for a more accurate detection of the marker, host to sensor polling interval needs to be considered. A shorter interval time (or higher polling rate) enables the host to sample the shutter more often in order to detect the marker based on the change in shutter values.
The worst-case scenario where marker detection miss could happen is when the chip is moving at high speed with long polling interval (or low polling rate). Having a long polling interval means the two continuously polled shutter values may miss the marker's shutter value, and the chip is unable to detect the marker.

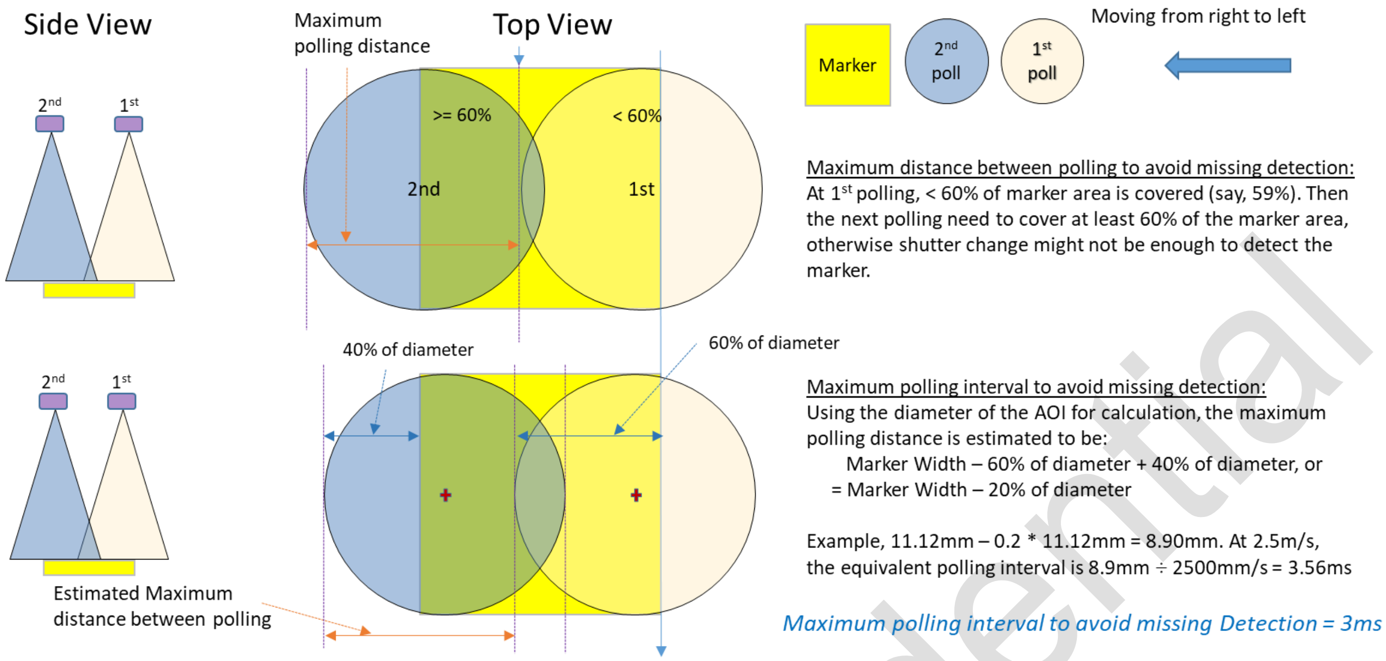

Figure 5. Maximum Polling Interval

Using the height of 30mm as example, the AOI's diameter is 11.12mm and if the marker width is also the same, the maximum distance between polling would be roughly 8.9mm (11.12mm x 80% = 8.9mm), refer to Figure 5. Thus, the equivalent polling interval is 3.56ms. If the polling time needs to be a round number, then the maximum polling interval is 3ms, at the speed of 2.5m/s.

2.4 Detection Threshold for Shutter

The shutter's threshold needs to be determined by collecting the shutter values from multiple iterations of tracking on the surface with marker. The shutter values need to be stable and repeatable over multiple iterations on both tracking surface and markers. Then, identify the shutter value threshold to distinguish the tracking surface and marker.

Below is the example of shutter changes for the stainless-steel bar with marker as shown in Figure 1. The moving speed is 20ips or about 0.5m/s. The polling interval is 2ms.

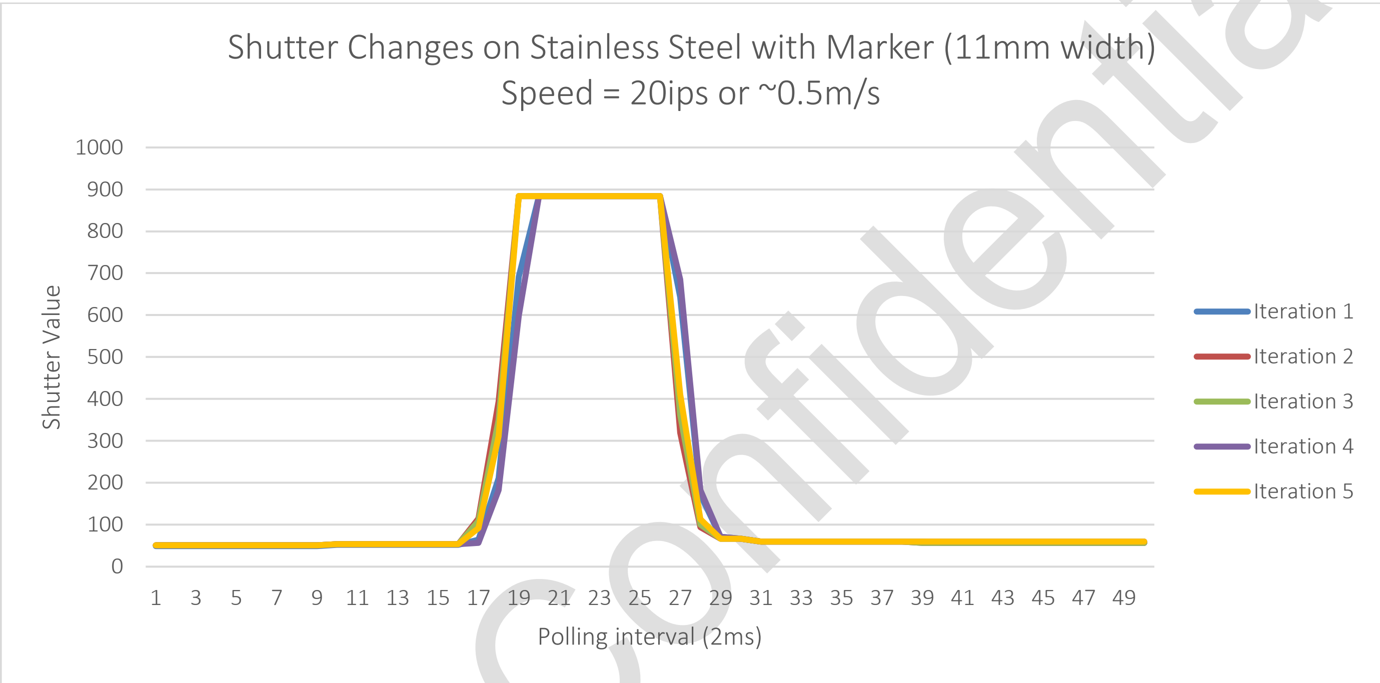

Figure 6. Shutter Changes when Travelled Over Markers

The plot shows that on the tracking surface, the shutter value is around 50 and when travelling over the marker, it changes to the maximum value of 884. For this example, the shutter's threshold can be set to midpoint between 50 and 884. It is recommended that to have at least 400 counts of difference between tracking surface and marker's shutter value. The data collection needs to include the application's highest speed to cater for the least changes of the shutter value to determine the final threshold.

Applying the shutter's threshold is dependent on the movement's direction. As illustrated in the figure below, when moving from left to right, it is deemed as entering the marker. But when moving from right to left, it is deemed as exiting the marker. If the objective is to reset accumulated error on one side of the marker, it will then depend on whether is entering or exiting the marker.

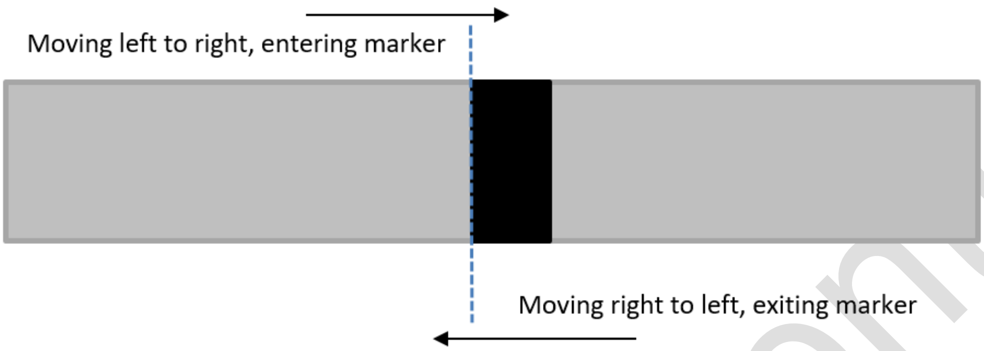

Figure 7. Entering or Exiting the Marker

For example, if the final threshold is determined to be 450, the marker detection's logic will be:

1. If last polled shutter value is < 450 and current shutter is ≥ 450, the chip is entering the marker.
2. If last polled shutter is ≥ 450 and current shutter is < 450, the chip is exiting the marker.

2.5 Related Register

Usage	Name	Bank	Address
For Marker detection	*Shutter_Lower*	0	0x0B
	Shutter_Upper	0	0x0C

<table>
<tr><th>Register Name</th><th colspan="4">Shutter_Lower</th></tr>
<tr><td>Bank</td><td>0</td><td colspan="2">Address</td><td>0x0B</td></tr>
<tr><td>Access</td><td>R</td><td colspan="2">Default Value</td><td>0x00</td></tr>
<tr><th>Register Name</th><th colspan="4">Shutter_Upper</th></tr>
<tr><td>Bank</td><td>0</td><td colspan="2">Address</td><td>0x0C</td></tr>
<tr><td>Access</td><td>R</td><td colspan="2">Default Value</td><td>0x01</td></tr>
<tr><td>Bit Field</td><td>Name</td><td>Default Value</td><td colspan="2">Description</td></tr>
<tr><td>3:0</td><td>S[11:8]</td><td>0</td><td colspan="2">Upper 4-bit of the 12-bit Shutter register.</td></tr>
<tr><td>Description</td><td colspan="4">12-bit Shutter register. Unit is clock cycles of the internal oscillator.
Read Shutter_Upper first, then Shutter_Lower. They should be read consecutively. The shutter is adjusted to keep the average raw data values within normal operating range. The shutter value is checked and automatically adjusted to a new value if needed on every frame.</td></tr>
</table>

Revision History

Revision Number	Date	Description
1.0	8 June 2024	Initial release