PAT9125EL: Optical Tracking Miniature Chip

General Description

The PAT9125EL is PixArt Imaging's low power optical tracking miniature chip using PixArt's LASER-based optical navigation technology enabling digital surface tracking. It integrates an optical chip with a LASER light source in a single miniature package, providing wide depth of field (DOF) range on glossy surfaces, and design flexibility into highly space constraint devices. This tracking system also does not require code wheel, code strip and any special marking on tracking surface for motion control or tracking purposes. It is recommended for use in hermetic or enclosed mechanical system design and applications. LASER power calibration process is NOT required in the complete system; it was pre-calibrated at chip level which helps to facilitate high volume assembly.

Key Features

- Miniature reflowable SMT package with built-in VCSEL LASER light source in a single package
- Wide DOF range on glossy surfaces, e.g. stainless steel (STS)
- No lens is needed
- Compliance to IEC/EN 60825-1 Eye Safety
  - Class 1 LASER power output level
  - On-chip LASER fault detection circuitry
- Support I^2C or 3-wire SPI or interface
- Programmable resolution up to 1,275cpi (on flat STS)
- Motion detection interrupt output
- Efficient low power management with programmable sleep modes & downshift time
- Internal oscillator – no external clock input needed

Applications

- Suitable for space-constraint and battery-powered wireless devices
- Devices that requires tracking on surfaces with wide DOF working range
- Devices that require tracking on small diameter of shaft and suitable for wearable and portable devices

Key Parameters

Parameter	Value
Supply Voltage	VDD : 2 connection types type1 2.1 ~ 3.6V type2 1.7 ~ 1.9V
	VLD : 2.7 ~ 3.6V
Control Interface	I^2C or 3-wire SPI
Distance to tracking surface (DOF)	1 ~ 30mm (on STS surface)
Max. tracking speed	On flat STS ▪ 30 ips @ distance ≧ 3mm ▪ 10 ips @ distance 1~3mm On 1.0mm diameter STS shaft ▪ 900 rpm @ distance ≧ 3mm ▪ 300 rpm @ distance 1~3mm
Max Resolution	~1,275 cpi (on flat STS) or ~630 counts/rev (on 1.0mm diameter STS shaft at 1.0mm distance)
Operating current (Average @ VDD = VLD = 3.3V)	Run : 0.7mA Sleep1/2 : 25µA / 10uA Power down : 5µA
Light Source	VCSEL LASER 850 nm
Package Size LWH	3.5 x 3.2 x 1.0 mm

Ordering Information

Part Number	Interface	Package Type
PAT9125EL-TKIT	I^2C	LGA 8-pin
PAT9125EL-TKMT	SPI	LGA 8-pin

RoHS compliant

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PAT9125EL：光学跟踪微型芯片

一般描述

PAT9125EL 是 PixArt 成像公司低功耗光学跟踪微型芯片，采用 PixArt 的基于激光的光学导航技术，实现数字表面跟踪。它将光学芯片与激光光源集成在一个微型封装中，在光滑表面上提供广泛的景深（DOF）范围，并为高度空间受限的设备提供设计灵活性。该跟踪系统也不需要编码轮、编码条和任何特殊标记在跟踪表面上进行运动控制或跟踪。建议在密封或封闭的机械系统设计和应用中使用。

完整系统中不需要激光功率校准过程；它在芯片级别进行了预校准，有助于促进大规模组装。

主要特点

- 带内置 VCSEL 激光光源的微型可回流 SMT 封装，集成在一个封装中
- 在光滑表面上的广泛景深范围，例如不锈钢（STS）
- 无需镜头
- 符合IEC/EN 60825-1眼安全标准
  - 激光功率输出等级为1类
  - 片上激光故障检测电路
- 支持I^2C或3线SPI接口
- 可编程分辨率高达1,275cpi（在平坦的STS上）
- 运动检测中断输出
- 高效低功耗管理，具有可编程睡眠模式和降频时间
- 内部振荡器–无需外部时钟输入

应用

- 适用于空间受限和电池供电的无线设备
- 需要在具有广泛景深工作范围的表面上进行跟踪的设备
- 需要在小直径轴上进行跟踪的设备
  并适合可穿戴和便携式设备

关键参数

参数	值
供电电压	VDD：2种连接类型 type1 2.1 ~ 3.6V type2 1.7 ~ 1.9V
	电压范围 : 2.7 ~ 3.6V
控制接口	I^2C 或 3线 SPI
到跟踪表面的距离 (DOF)	1 ~ 30mm (在 STS 表面上)
最大跟踪速度	在平坦的 STS 上 ▪ 30 ips @ 距离 ≧ 3mm ▪ 10 ips @ 距离 1~3mm 在 1.0mm 直径的 STS 轴上 ▪ 900 rpm @ 距离 ≧ 3mm ▪ 300 rpm @ 距离 1~3mm
最大分辨率	~1,275 cpi (在平坦的 STS 上) 或 ~630 counts/rev (在 1.0mm 直径的 STS 轴上，距离为 1.0mm)
工作电流 (平均 @ VDD = VLD = 3.3V)	运行 : 0.7mA 睡眠1/2 : 25µA / 10µA 关机 : 5µA
光源	VCSEL 激光 850 nm
封装尺寸 LWH	3.5 x 3.2 x 1.0 mm

订购信息

部件编号	接口	封装类型
PAT9125EL-TKIT	I^2C	LGA 8 针
PAT9125EL-TKMT	SPI	LGA 8 针

RoHS compliant

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1.0 Introduction

1.1 Overview

PAT9125EL is a high performance and an ultralow power CMOS-processed optical navigation chip with the integrated digital image process algorithm/circuits and a VCSEL LASER as the light source. It is based on PixArt's optical navigation technology of LASER which measures changes in position by optically acquiring sequential surface images (frames) and mathematically determining the speed, the direction and the magnitude of motion. The displacement X and Y information are available in registers. A host controller can read and translate the displacement X and Y information from the SPI or I^2C serial interface.
Note: Throughout this document PAT9125EL is referred to as the chip.

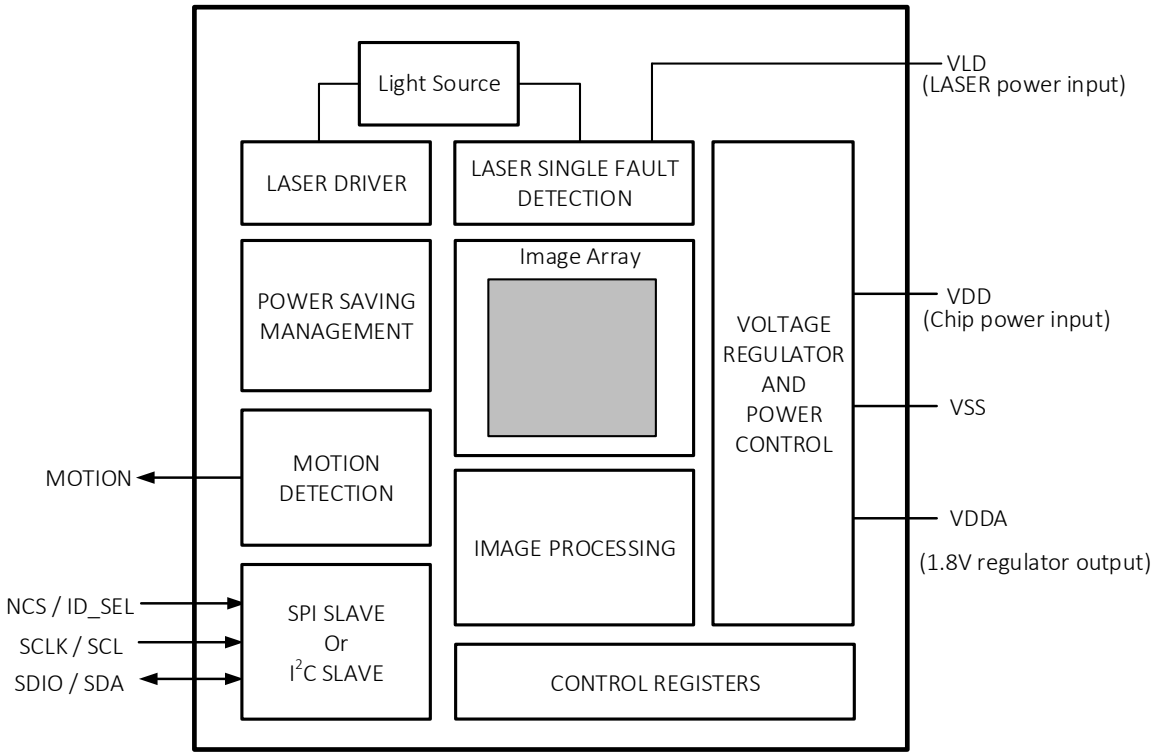


Figure 1. Functional Block Diagram

1.0 介绍

1.1 概述

PAT9125EL 是一款高性能且超低功耗的 CMOS 处理光学导航芯片，集成了数字图像处理算法/电路，并以 VCSEL 激光作为光源。它基于 PixArt 的激光光学导航技术，通过光学获取连续的表面图像（帧）并数学上确定位置变化、速度、方向和运动幅度。位移 X 和 Y 信息可在寄存器中获得。主控制器可以通过 SPI 或 I^2C 串行接口读取并转换位移 X 和 Y 信息。

注意：在本文档中，PAT9125EL 被称为芯片。

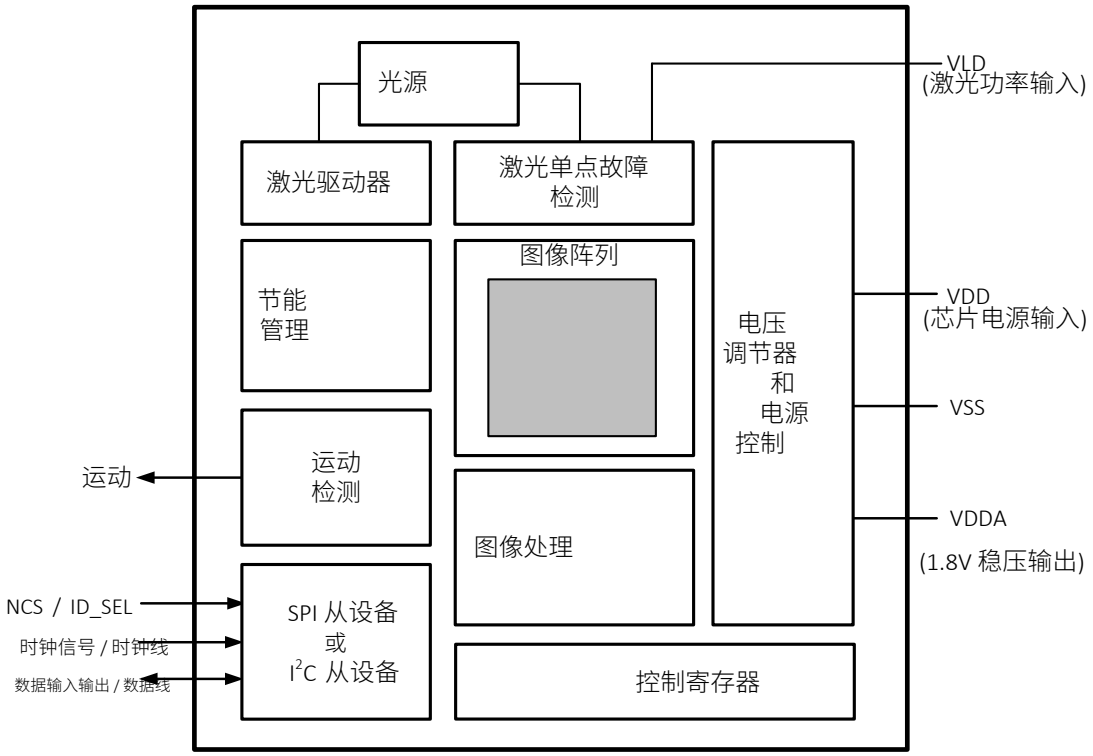
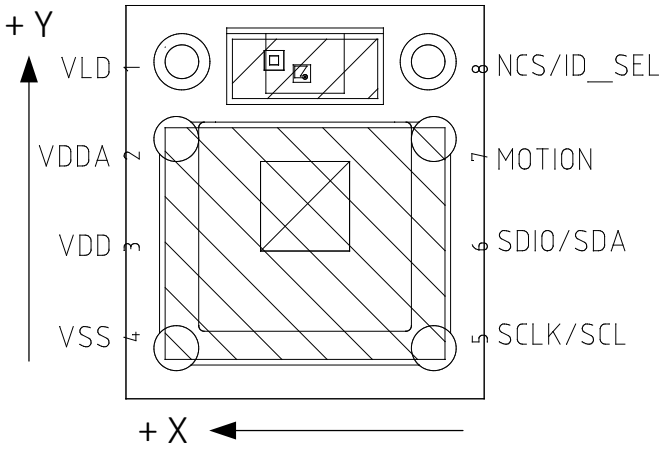


图1. 功能框图

1.2 Signal Description



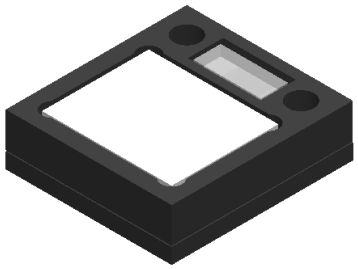
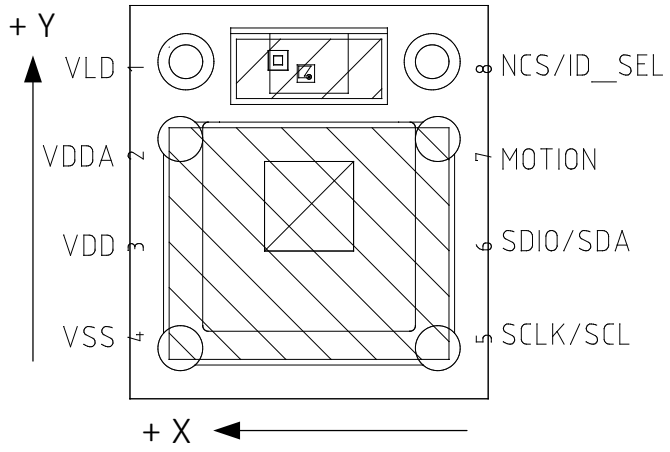


Figure 2. Pin Configuration

Table 1. Signal Pins Description

Pin No.	Signal Name		Type	Description
	SPI	I^2C		
1	VLD	VLD	PWR	Anode of the VCSEL LASER, voltage range: 2.7V ~ 3.3V
2	VDDA	VDDA	PWR	VDD is the main power supply for IC circuits High voltage Segment (VDD: 2.1V ~ 3.6V): VDDA is 1.8V regulator output and should connect a 4.7uF capacitor to ground Low Voltage Segment (VDD: 1.7V ~ 2.1V): VDDA should connect to VDD directly
3	VDD	VDD	PWR	
4	VSS	VSS	GND	Chip ground
5	SCLK	SCL	IN	SCLK : Clock input for SPI interface SCL : Clock input for I^2C interface
6	SDIO	SDA	I/O	SDIO : Bi-directional I/O for SPI interface SDA : Bi-directional I/O for I^2C interface
7	MOTION	MOTION	OUT	Motion detection output (active low)
8	NCS	ID_SEL	IN	NCS : Chip select for 3-wire SPI interface (active low) ID_SEL : Slave ID (7-bit) Selection for I^2C interface High = 0x73, Low=0x75, NC = 0x79
9	TEST	TEST	NC	This pin is located on the back of the chip and is for PixArt testing purpose. Please do NOT connect it to any part of the PCB. Please refer to Figure 9.

1.2 信号描述



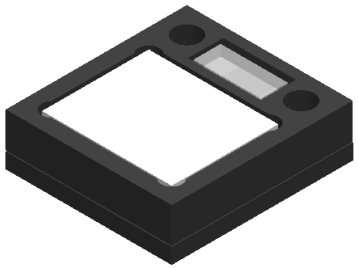


图2. 引脚配置

表1. 信号引脚描述

引脚编号	信号名称		类型	描述
	SPI	I^2C		
1	VLD	VLD	电源	VCSEL 激光的阳极，电压范围：2.7V ~ 3.3V
2	VDDA	VDDA	电源	VDD 是 IC 电路的主要电源 高电压段 (VDD: 2.1V ~ 3.6V)：VDDA 是 1.8V 稳压器输出，应连接一个 4.7uF 电容到地 低电压段 (VDD: 1.7V ~ 2.1V)：VDDA 应直接连接到 VDD
3	VDD	VDD	电源	
4	VSS	VSS	接地	芯片接地
5	SCLK	SCL	输入	SCLK : SPI 接口的时钟输入 SCL : I^2C 接口的时钟输入
6	SDIO	SDA	I/O	SDIO : SPI 接口的双向 I/O SDA : I^2C 接口的双向 I/O
7	运动	运动	输出	运动检测输出（低电平有效）
8	NCS	ID_SEL	输入	NCS : 3线SPI接口的芯片选择（低电平有效） ID_SEL : I^2C接口的从设备ID（7位）选择 高 = 0x73，低 = 0x75，NC = 0x79
9	测试	测试	无连接	此引脚位于芯片的背面，用于PixArt测试目的。 请不要将其连接到PCB的任何部分。请参阅图9。

1.3 Potential Tracking Mechanisms

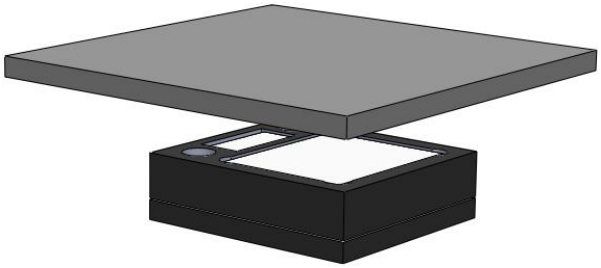


Figure 3. Tracking on a Moving Surface

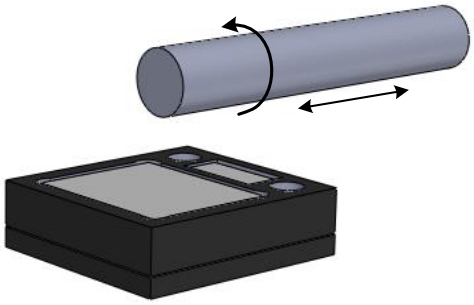


Figure 4. Tracking on the Side of a Rotational Shaft

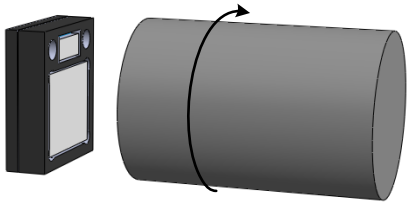


Figure 5. Tracking on the end of a Rotational Shaft

Figure 6. Tracking on a Disk Edge

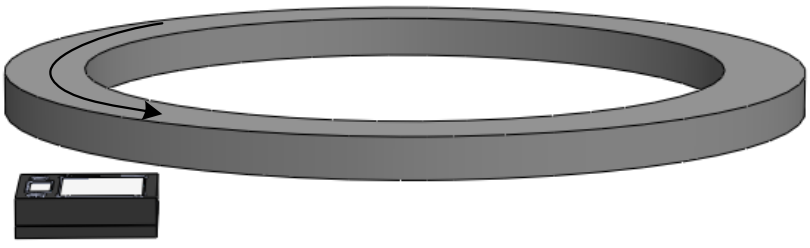


Figure 7. Tracking on a Rotational Bezel

1.3 潜在跟踪机制

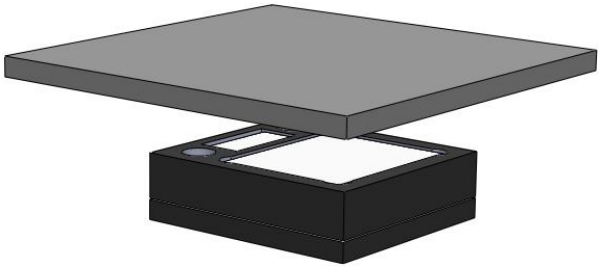


图3。在移动表面上的跟踪

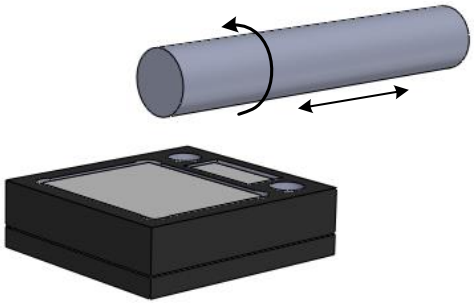


图 4.在旋转轴侧面的跟踪

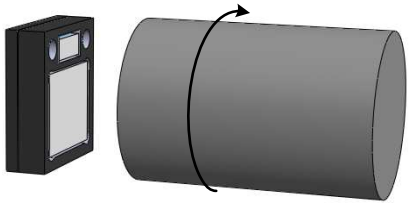


图 5.在旋转轴末端的跟踪

图 6. 在盘边的跟踪

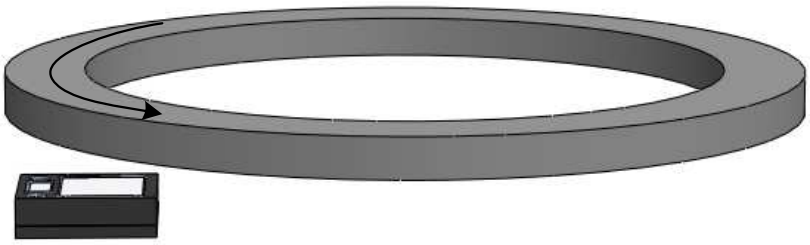


图 7.在旋转表圈上的跟踪

1.4 Terminologies

Term	Description
ACK	Acknowledge bit of I^2C bus
CPI	Counts per Inch
DOF	Depth of Field
FPS	Frames per Second
I^2C	Inter-Integrated Circuit
IPS	Inches per Second
LD	LASER Diode
LGA	Land Grid Array
LOP	LASER output power, unit: uW (micro-watt)
NA	Not-acknowledge bit of I^2C bus
RPM	Revolutions per Minute
SPI	Serial Peripheral Interface
STS	Stainless Steel
VCSEL	Vertical-Cavity Surface-Emitting LASER

1.4 术语

术语	描述
ACK	I^2C 总线的确认位
CPI	每英寸计数
DOF	景深
FPS	每秒帧数
I^2C	内部集成电路
IPS	每秒英寸
LD	激光二极管
LGA	土地栅格阵列
LOP	激光输出功率，单位：uW（微瓦）
NA	I^2C总线的非确认位
RPM	每分钟转数
SPI	串行外设接口
STS	不锈钢
VCSEL	垂直腔面发射激光器

2.0 Operating Specifications

2.1 Absolute Maximum Ratings

Table 2. Absolute Maximum Ratings

Parameters	Symbol	Min.	Max.	Unit	Notes
Storage Temperature	T_{STG}	-40	85	°C	
Power Supply Voltage	V_{DC}	-0.3	3.9	V	
Signal Input Voltage	V_{IN}	-0.3	V_{DC}	V	For all input I/O
Lead Solder Temp	T_{SOL}	-	260	°C	Non-condensing, Non-biased
ESD	V_{HBM}	-	2	kV	All pins, Human Body Model MIL 883 Method 3015

Notes:

1. At room temperature.
2. Maximum Ratings are those values beyond which damage to the device may occur.
3. Exposure to these conditions or conditions beyond those indicated may adversely affect device reliability. Functional operation under absolute maximum-rated conditions is not implied.
4. Functional operation should be restricted to the Recommended Operating Conditions.

2.2 Recommended Operating Conditions

Table 3. Recommended Operating Conditions

Description	Symbol	Min.	Typ.	Max.	Unit	Notes
Operating Temperature	T_A	-20	-	60	°C	
Power Supply Voltage	VDD	2.1	-	3.6	V	For chip operated in High Voltage Segment
		1.7	1.8	1.9	V	For chip operated in Low Voltage Segment
	VLD	2.7	3.0	3.6	V	For LASER Power
Supply Noise	V_{NPP}	-	-	100	mV	Peak to peak voltage within 10kHz – 80 MHz
Distance to Tracking Surface (DOF)	Z	1		30	mm	On STS surface (refer to Notes below)
Tracking Speed	V_{SP}	-	-	30	ips	Based on flat STS with distance ≧ 3mm
				10	ips	Based on flat STS with distance 1~3mm
				900	rpm	Based on 1.0mm diameter STS shaft with distance ≧ 3mm
				300	rpm	Based on 1.0mm diameter STS shaft with distance 1~3mm

Notes:

1. PixArt does not guarantee the performance if the operating temperature is beyond the specified limit.
2. When the distance to tracking surface is < 3mm, the reported CPI resolution could be lower than the CPI value at ≧ 3mm. Please refer to Figure 8 below.

2.0 操作规格

2.1 绝对最大额定值

表2. 绝对最大额定值

参数	符号	最小值	最大值	单位	备注
存储温度	T_{STG}	-40	85	°C	
电源电压	V_{DC}	-0.3	3.9	V	
信号输入电压	V_{IN}	-0.3	V_{DC}	V	适用于所有输入 I/O
焊接温度	T_{SOL}	-	260	°C	非冷凝，无偏置
静电放电	V_{HBM}	-	2	千伏	所有引脚，人体模型MIL 883方法3015

注意事项：
1. 在室温下。
2.最大额定值是超出这些值可能导致设备损坏的值。
3.暴露于这些条件或超出所示条件可能会对设备的可靠性产生不利影响。在绝对最大额定条件下的功能操作并不意味着可以保证。
4.功能操作应限制在推荐工作条件内。

2.2 推荐工作条件

表3. 推荐工作条件

描述	符号	最小值	典型值	最大值	单位	备注
工作温度	T_A	-20	-	60	°C	
电源电压	VDD	2.1	-	3.6	V	对于在高压段操作的芯片
		1.7	1.8	1.9	V	对于在低压段操作的芯片
	VLD	2.7	3.0	3.6	V	对于激光功率
供电噪声	V_{NPP}	-	-	100	毫伏	峰值到峰值电压在10kHz–80 MHz范围内
到跟踪表面的距离（DOF）	Z	1		30	毫米	在STS表面上（请参阅下面的注释）
跟踪速度	V_{SP}	-	-	30	ips	基于平坦的STS，距离 ≥ 3毫米
				10	ips	基于平坦的STS，距离1~3毫米
				900	rpm	基于1.0毫米直径的STS轴，距离 ≥ 3毫米
				300	rpm	基于1.0毫米直径的STS轴，距离1~3毫米

注意事项：
1.如果操作温度超出规定限制，PixArt不保证性能。
2.当到跟踪表面的距离小于3毫米时，报告的CPI分辨率可能低于在 ≥ 3毫米时的CPI值。请参阅下面的图8。

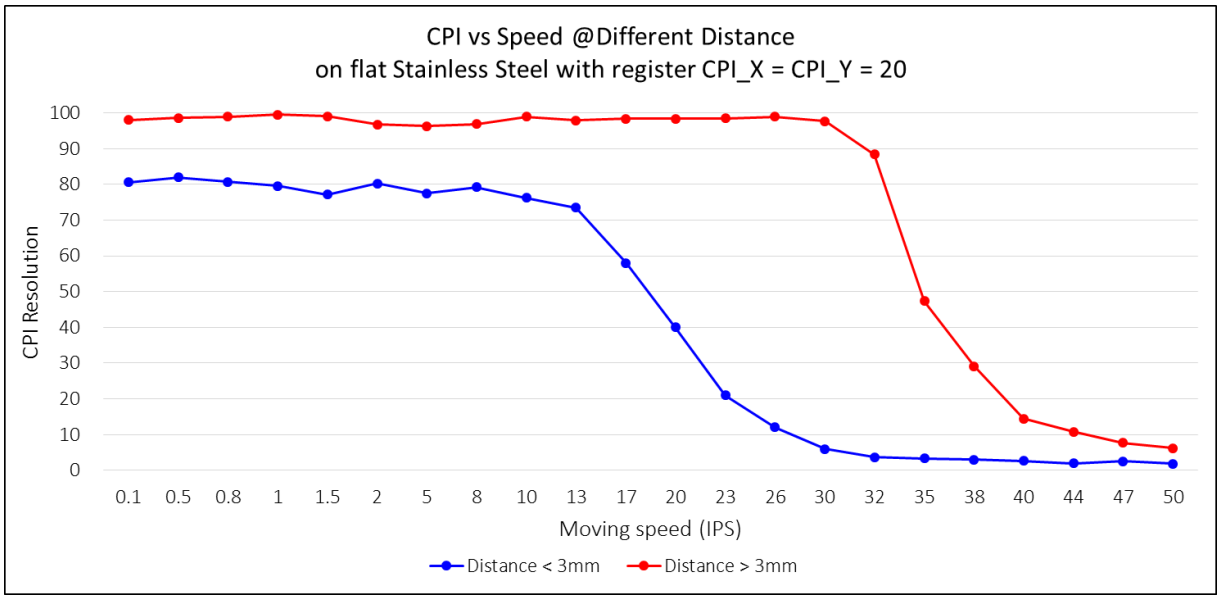


Figure 8. CPI vs Speed @Different Distance

2.3 DC Characteristics

Table 4. DC Electrical Specifications

Parameters	Symbol	Min.	Typ.	Max.	Unit	Conditions
Run mode current	I_{RUN}	-	0.7	-	mA	Tracking speed dependent @VDD=VLD=3.3V on STS
Sleep 1 mode current	I_{SLP1}	-	25	-	µA	Based on 32ms sampling period @VDD=VLD=3.3V on STS
Sleep 2 mode current	I_{SLP2}	-	10		µA	Based on 128ms sampling period @VDD=VLD=3.3V on STS
Power Down current	I_{PD}	-	5	10	µA	@VDD=VLD=3.3V
Input Voltage High	V_{IH}	VDD*0.7	-	-	V	For NCS, SCLK, SDIO, MOTION pins
Input Voltage Low	V_{IL}	-	-	VDD*0.3	V	
Output Voltage High	V_{OH}	VDD-0.4	-	-	V	
Output Voltage Low	V_{OL}	-	-	0.4	V	

Notes: All the parameters are tested under operating conditions: T_A = 25°C

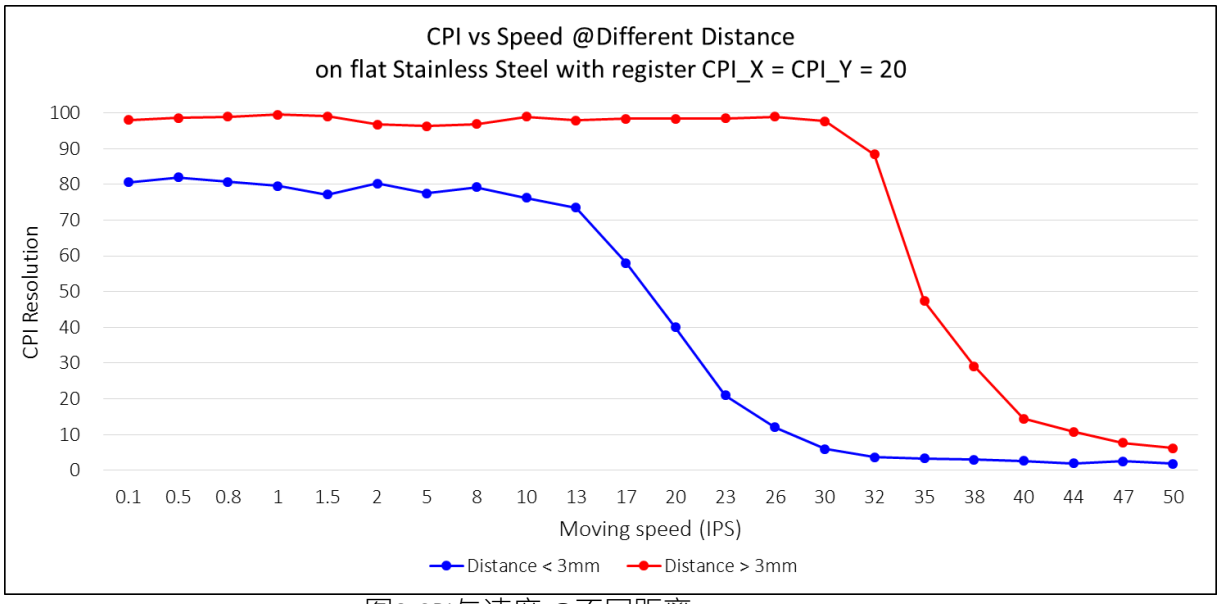


图8.CPI与速度 @不同距离

2.3 直流特性

表4. 直流电气规格

参数	符号	最小值	典型值	最大值	单位	条件
运行模式电流	I_{RUN}	-	0.7	-	毫安	跟踪速度依赖 @VDD=VLD=3.3V在STS上
睡眠1模式电流	I_{SLP1}	-	25	-	微安	基于32毫秒采样周期 @VDD=VLD=3.3V在STS上
睡眠2模式电流	I_{SLP2}	-	10		微安	基于128毫秒采样周期 @VDD=VLD=3.3V在STS上
关机电流	I_{PD}	-	5	10	微安	@VDD=VLD=3.3V
输入电压高	V_{IH}	VDD*0.7	-	-	V	对于NCS、SCLK、SDIO、MOTION引脚
输入电压低	V_{IL}	-	-	VDD*0.3	V	
输出电压高	V_{OH}	VDD-0.4	-	-	V	
输出电压低	V_{OL}	-	-	0.4	V	

注意：所有参数均在工作条件下测试：T_A= 25°C

3.0 Mechanical Specifications

3.1 Mechanical Dimension

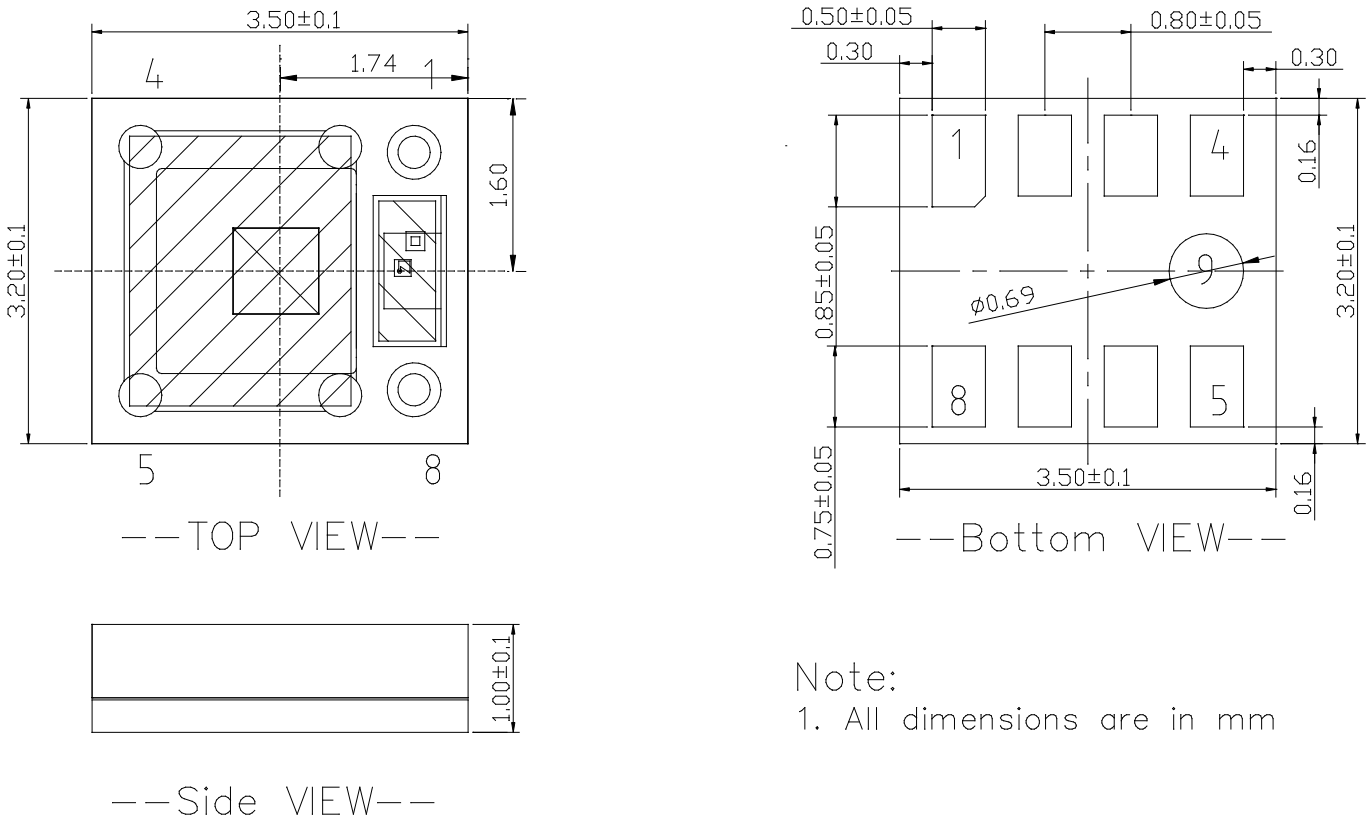


Figure 9. Package Outline Diagram

3.0 机械规格

3.1 机械尺寸

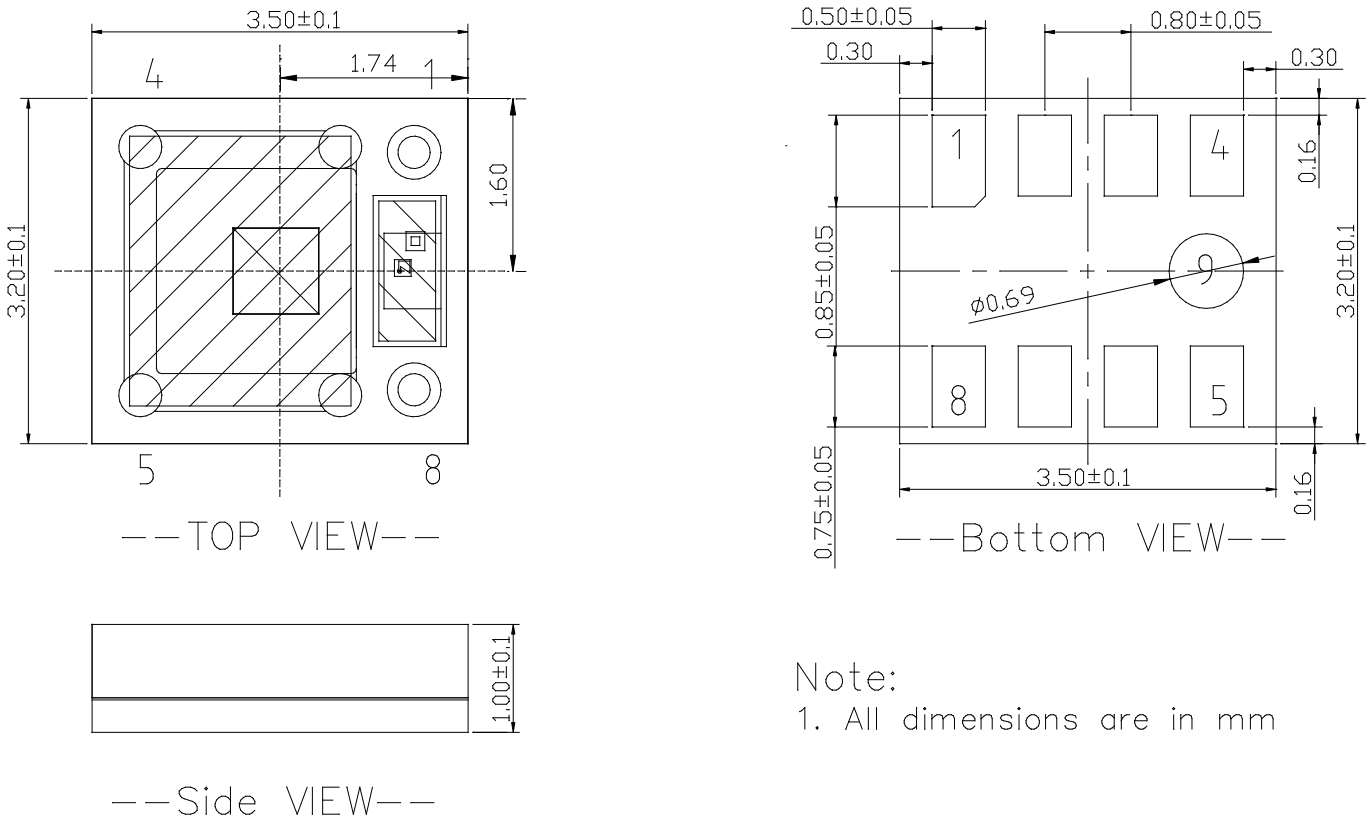


图9. 封装轮廓图

4.0 Reference Schematics

4.1 Schematics for I²C Interface (PAT9125EL-TKIT)

The chip supports standard I²C interface and the SCL clock speed is up to 1MHz. Three different Slave IDs can be selected from the ID_SEL pin (High = 0x73, Low=0x75, NC = 0x79). Notice that 5KΩ of R1 and R2 (SCL/SDA bus pull-high resistors) is just for reference and the resistance might have to be adjusted according to the overall I²C bus loading of user's whole system.

4.1.1 High Voltage Segment (VDD : 2.1V ~ 3.6V)

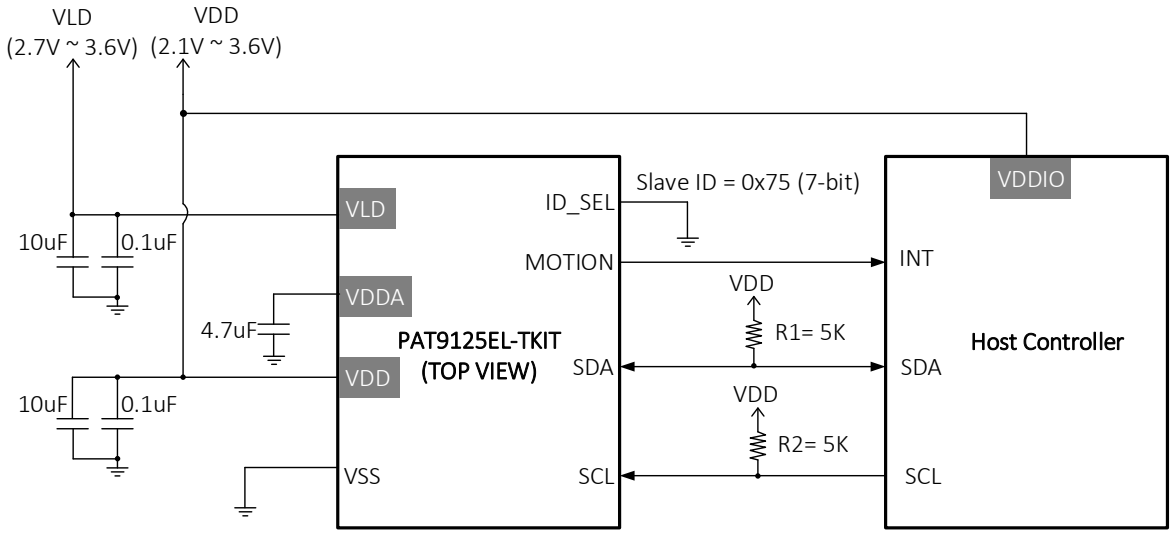


Figure 10. Schematics for High Voltage Segment (I²C Interface)

4.1.2 Low Voltage Segment (VDD : 1.7V ~ 1.9V)

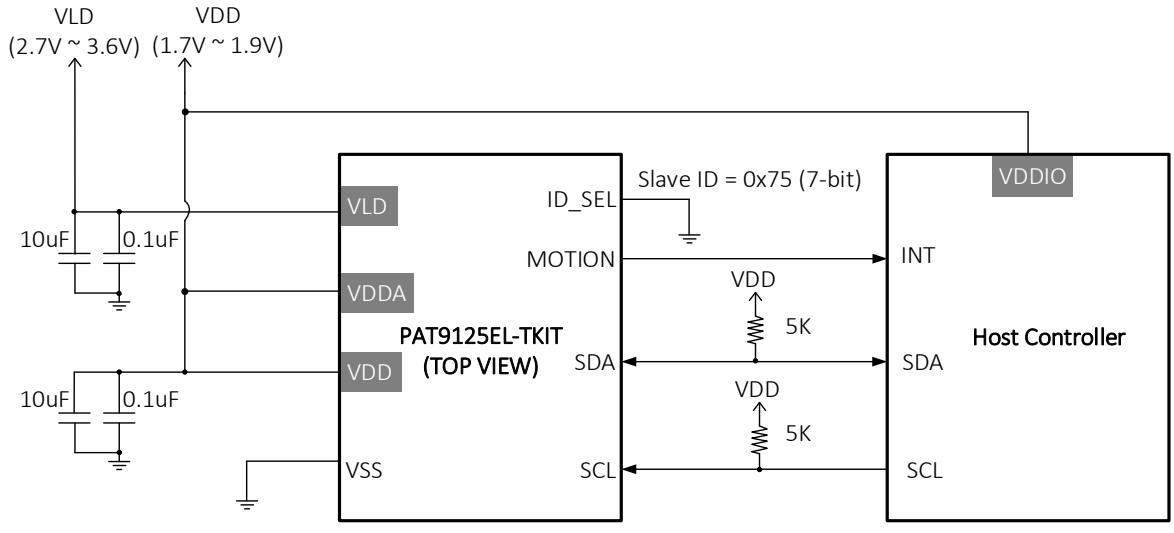


Figure 11. Schematics for Low Voltage Segment (I²C Interface)

4.0 参考原理图

4.1 I²C接口的原理图（PAT9125EL-TKIT）

该芯片支持标准I²C接口，SCL时钟速度高达1MHz。可以从ID_SEL引脚选择三个不同的从设备ID（高=0x73，低=0x75，NC=0x79）。请注意，5KΩof R1和R2（SCL/SDA总线上拉电阻）仅供参考，电阻可能需要根据用户整个系统的I²C总线负载进行调整。

4.1.1 高压段 (VDD : 2.1V ~ 3.6V)

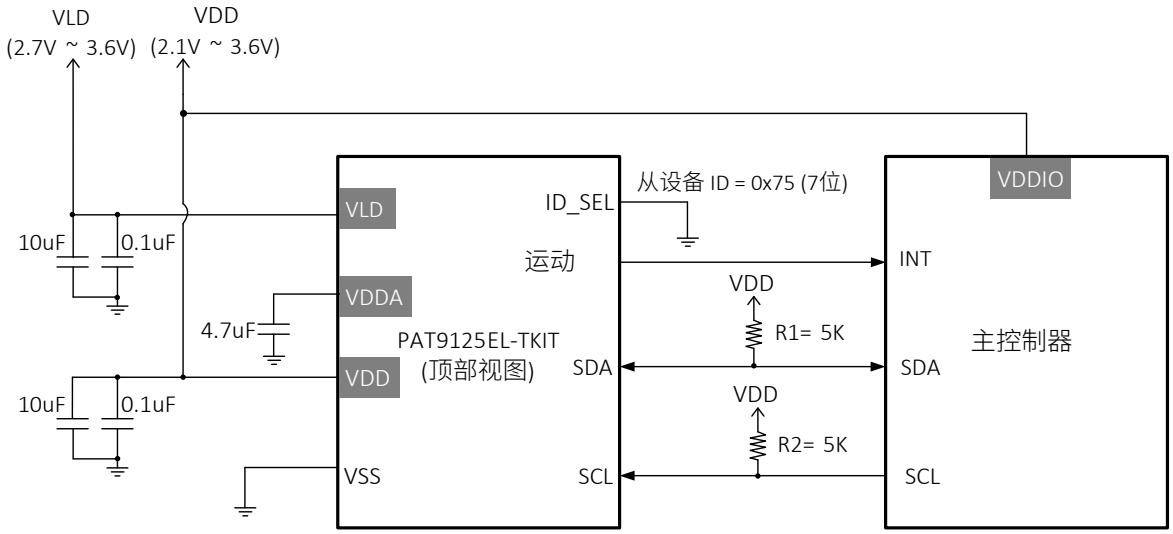


图 10.高压段的原理图 (I²C 接口)

4.1.2 低电压段 (VDD : 1.7V ~ 1.9V)

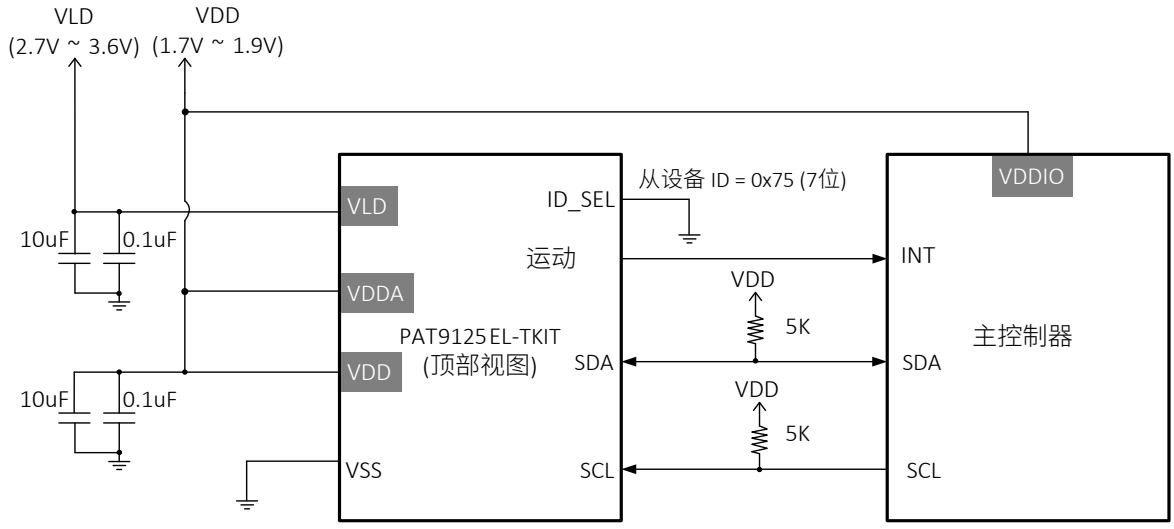


图 11.低压段的原理图 (I²C接口)

4.2 Schematics for SPI Interface (PAT9125EL-TKMT)

The chip only supports simplified 3-wire SPI slave mode, while some host controllers only support standard 4-wire SPI master mode. In this case, users can connect the host controller to the chip using the method shown below to communicate each other. Notice that 3.3KΩ for R1 is just for reference and the resistance might have to be modified according to different I/O capability of different host controllers.

4.2.1 High Voltage Segment (VDD : 2.1V ~ 3.6V)

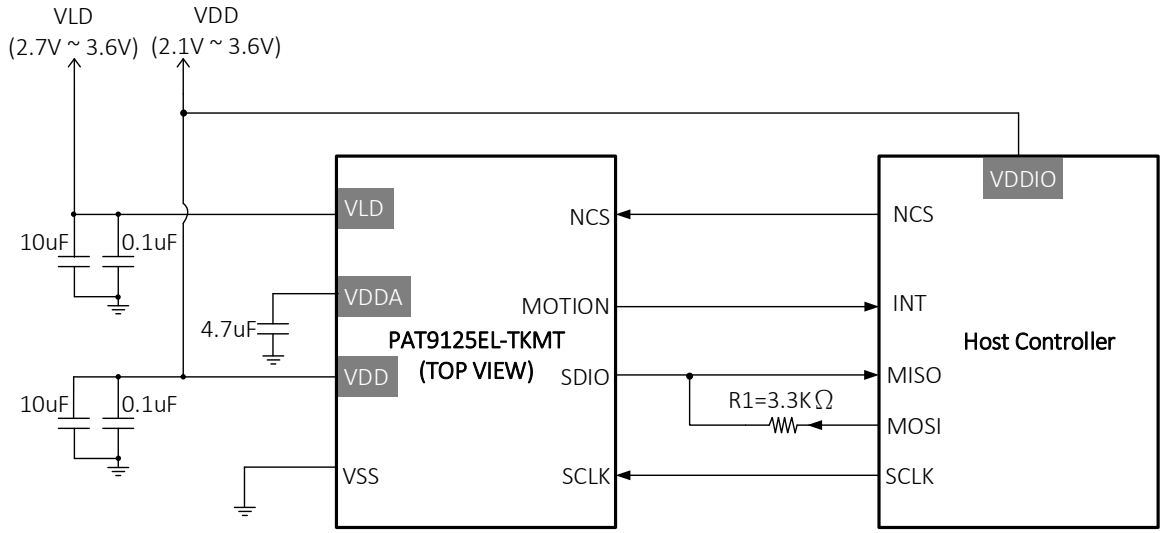


Figure 12. Schematics for High Voltage Segment (SPI Interface)

4.2.2 Low Voltage Segment (VDD : 1.7V ~ 1.9V)

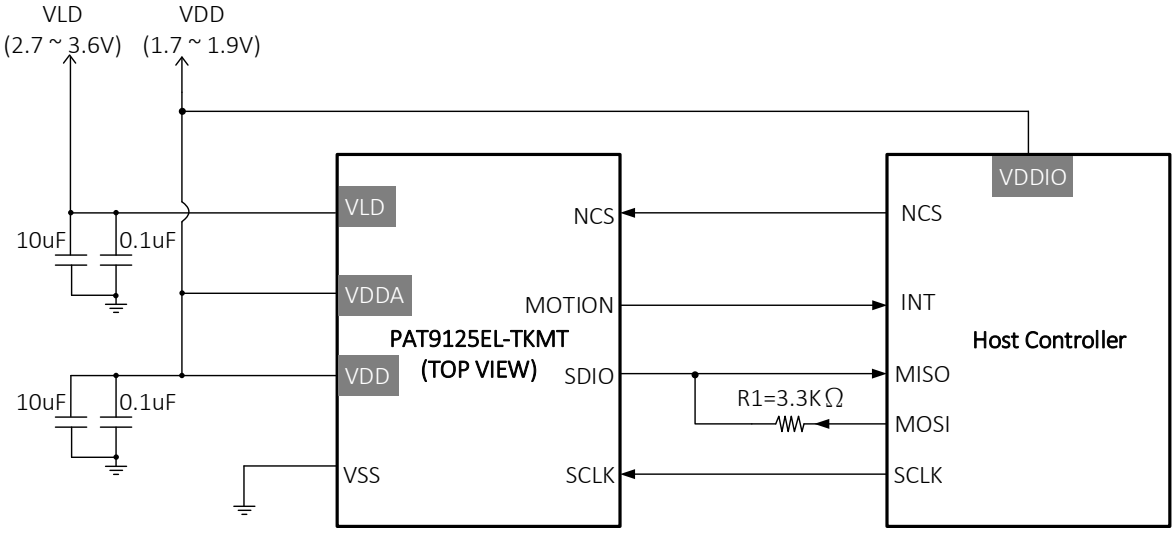


Figure 13. Schematics for Low Voltage Segment (SPI Interface)

4.2 SPI接口的原理图 (PAT9125EL-TKMT)

该芯片仅支持简化的3线SPI从模式，而某些主控制器仅支持标准的4线SPI主模式。在这种情况下，用户可以使用下面所示的方法将主控制器连接到芯片，以便相互通信。请注意，R1的3.3KΩ仅供参考，电阻可能需要根据不同主控制器的不同I/O能力进行修改。

4.2.1 高压段 (VDD : 2.1V ~ 3.6V)

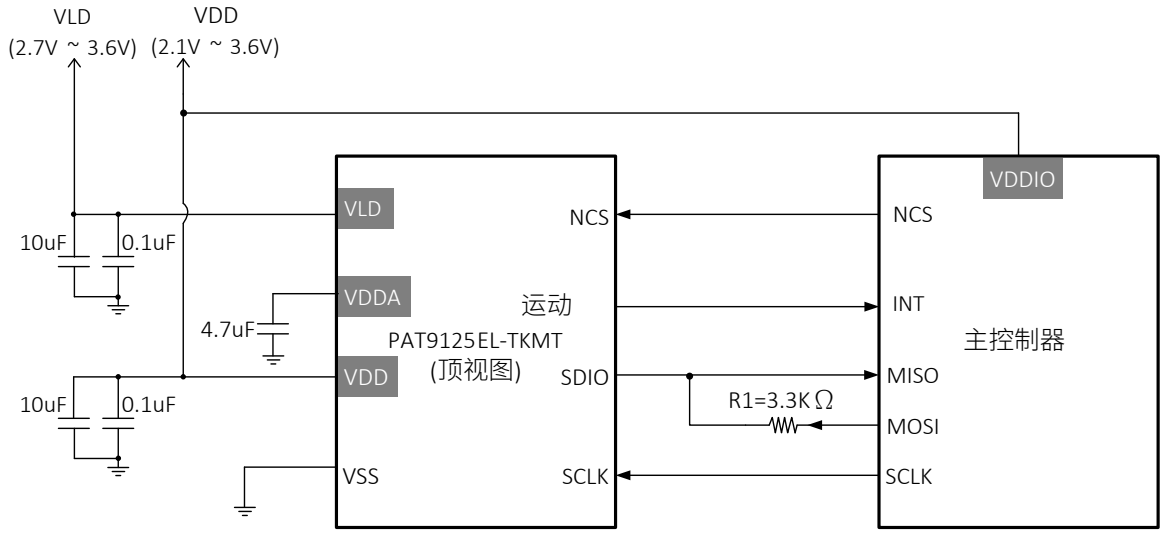


图12。高压段的原理图 (SPI接口)

4.2.2 低电压段 (VDD : 1.7V ~ 1.9V)

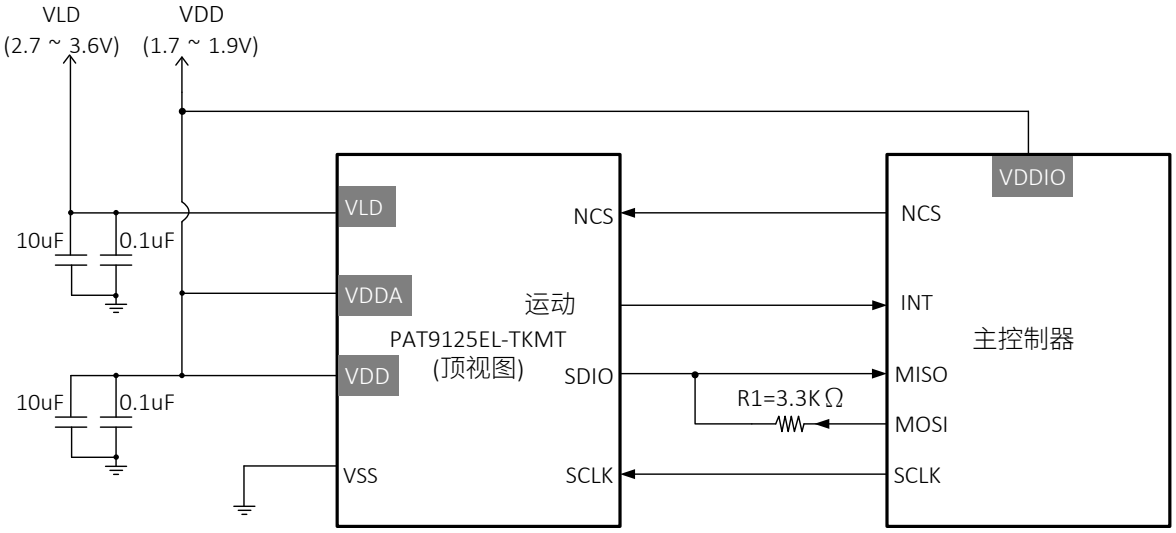


图13。低压段（SPI接口）的原理图

5.0 Registers List

Address	Register Name	Access	Reset	Brief Description
0x00	Product_ID1	RO	0x31	Product Identifier [11:4]
0x01	Product_ID2	RO	0x91	Upper 4 bits for Product Identifier, PID [3:0] Lower 4 bits for Product Version, VID [3:0]
0x02	Motion_Status	RO	-	Motion Status information
0x03	Delta_X_Lo	RO	-	8-bit 2's complement number for X-movement data in 8-bit movement data format X-movement = Delta_X_Lo[7:0]
0x04	Delta_Y_Lo	RO	-	8-bit 2's complement number for Y-movement data in 8-bit movement data format Y-movement = Delta_Y_Lo[7:0]
0x05	Operation_Mode	R/W	0xA0	Operation mode selection
0x06	Configuration	R/W	0x17	Software power down and reset
0x09	Write_Protect	R/W	0x00	Write Protect to avoid missed-writing registers
0x0A	Sleep1	R/W	0x77	Sleep1 configuration
0x0B	Sleep2	R/W	0x10	Sleep2 configuration
0x0D	RES_X	R/W	0x14	CPI resolution setting for X axis
0x0E	RES_Y	R/W	0x14	CPI resolution setting for Y axis
0x12	Delta_XY_Hi	RO	-	High nibble of X-movement and Y-movement for 12-bit 2's complement data format. X-movement = {Delta_XY_Hi[7:4], Delta_X_Lo[7:0]} Y-movement = {Delta_XY_Hi[3:0], Delta_Y_Lo[7:0]}
0x14	Shutter	RO	-	Index of LASER shutter time
0x17	Frame_Avg	RO	-	Average brightness of a frame
0x19	Orientation	R/W	0x04	Chip orientation selection

5.0 寄存器列表

地址	寄存器名称	访问	复位	简要描述
0x00	产品_ID1	只读	0x31	产品标识符 [11:4]
0x01	产品_ID2	只读	0x91	产品标识符的高4位，PID [3:0] 产品版本的低4位，VID [3:0]
0x02	运动状态	只读	-	运动状态信息
0x03	Delta_X_Lo	只读	-	8位2的补码数表示X轴运动数据，采用8位 运动数据格式 X轴运动 = Delta_X_Lo[7:0]
0x04	Delta_Y_Lo	只读	-	8位2的补码数表示Y轴运动数据，采用8位 运动数据格式 Y轴运动 = Delta_Y_Lo[7:0]
0x05	操作模式	读/写	0xA0	操作模式选择
0x06	配置	读/写	0x17	软件电源关闭和重置
0x09	写保护	读/写	0x00	启用写保护以避免错写寄存器
0x0A	睡眠1	读/写	0x77	睡眠1 配置
0x0B	睡眠2	读/写	0x10	睡眠2 配置
0x0D	RES_X	读/写	0x14	X轴的CPI分辨率设置
0x0E	RES_Y	读/写	0x14	Y轴的CPI分辨率设置
0x12	Delta_XY_Hi	只读	-	12位2的补码数据格式的X运动和Y运动的高位部分。 X运动={Delta_XY_Hi[7:4], Delta_X_Lo[7:0]} Y运动={Delta_XY_Hi[3:0], Delta_Y_Lo[7:0]}
0x14	快门	只读	-	激光快门时间的索引
0x17	帧平均	只读	-	一帧的平均亮度
0x19	方向	读/写	0x04	芯片方向选择

Document Revision History

Revision Number	Date	Description
1.1	05 Apr 2017	Based on DS v1.1
1.2	31 May 2017	Based on DS v1.1 1. Widened the spec. of VDD from 2.1V~3.3V to 2.1V~3.6V 2. Widened the spec. of VLD from 2.7V~3.3V to 2.7V~3.6V 3. Added LASER Class 1 Product logo

文档修订历史

修订号	日期	描述
1.1	2017年4月5日	基于DS v1.1
1.2	2017年5月31日	基于DS v1.1 1. 扩大了规格。VDD的范围从2.1V~3.3V扩展到2.1V~3.6V 2. 扩大了规格。VLD的范围从2.7V~3.3V扩展到2.7V~3.6V 3. 添加了激光1类产品标志