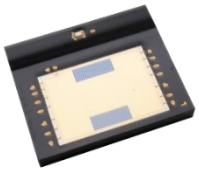
SM3414B Reflective Absolute Optical Encoder IC



Compact package: Can be mounted in tiny spaces
Absolute position data: Outputs 9-bit absolute position at 100 µm resolution
Adjustment function: Built-in adjustment functions configurable via serial interface

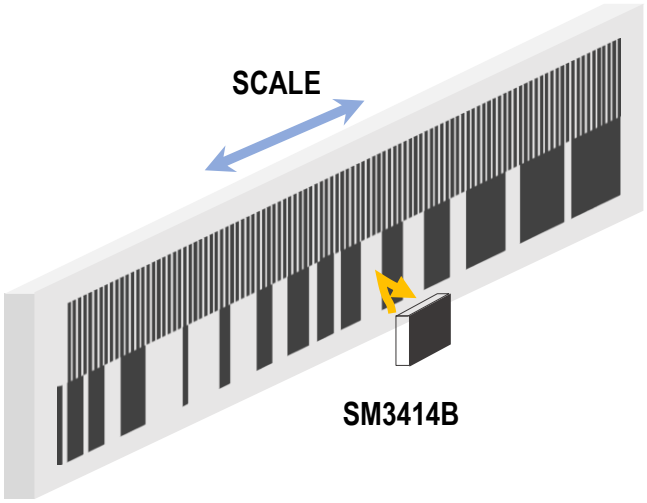
1. SM3414B Overview

The SM3414B is a compact encoder IC that integrates a LED light source and an OEIC (Opto-Electric Integrated Circuit) in a small package for surface mounting and can output two-phase analogue signals and 9-bit absolute position data.
It employs an optical sensor array that greatly reduces signal degradation problems due to variations in mounting position. It delivers high-accuracy position detection even when mounted using reflow methods. It is ideal for various applications that require the following features.

[Features]
- Miniature clear molded package 7.7mm (W) × 6.4mm (L) × 1.0mm (H)
- High-accuracy two-phase differential analog output
  A-phase/B-phase analog, sine wave outputs
- 100µm output signal period (fixed) High S/N ratio and superior Lissajous characteristic for high resolution, in combination with external interpolation circuit
- Capable of outputting 9-bit data with a resolution of 100 µm in a range of up to 51.2 mm
- Built-in terminal function with adjustable LED brightness and independent LED power supply
- Built-in adjustment circuits can be used to adjust gain, binarization threshold, etc.
- A serial interface compatible with SPI Mode 0 and Mode 3 enables adjustment circuit configuration and absolute data readout
- Supply voltage range 2.7 to 3.3V
- Logic input tolerant function. Logic inputs are allowed up to 3.6 V
- Low current consumption 8mA (typ)
- Easy positioning/installation
- Reflow mounting (*confirm suitability of reflow conditions)

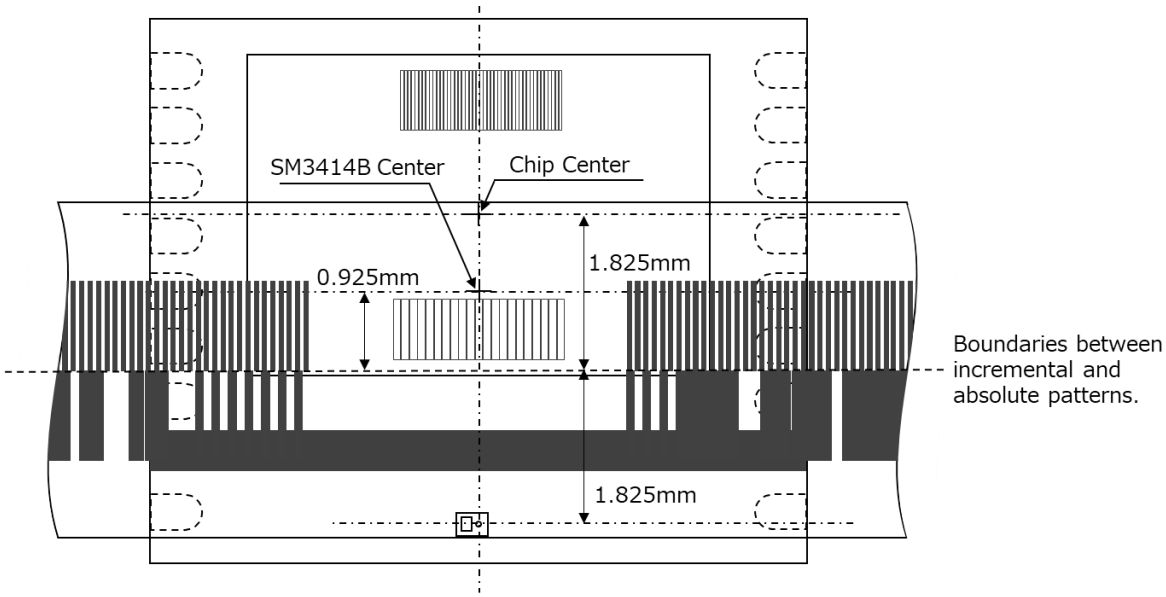
[Typical Applications]
- Miniature actuators, piezo-actuators
- Linear gauges
- Chip mounters, PCB/FPC substrate processing, IC handlers & FA mounting/processing
- Consumer equipment requiring precise position control, such as camera lenses
- Position/speed control in applications requiring miniaturization and high accuracy

2. Typical SM3414B Encoder Configuration and Alignment



A linear encoder can be constructed using the SM3414B and a linear scale.
Position the linear scale with the boundary line between the incremental and absolute patterns on an axis passing through the center of the IC chip center position and the LED center position (1.825 mm from the IC chip center and the LED center).

[TOP VIEW]



3. Scales for SM3414B

As described above, linear encoders using the SM3414B can be configured in combination with linear scales having both incremental and absolute patterns.
Scales are not provided with the SM3414B; they must be acquired separately. The following manufacturers can supply scales that can be used with the SM3414B.

3.1. Flexible PET scale

Flexible scales that use a PET substrate are more suitable. These can be supplied by the following manufacturer.
PET scales, in comparison with glass scales, are typically used for encoders in thin, narrow spaces.

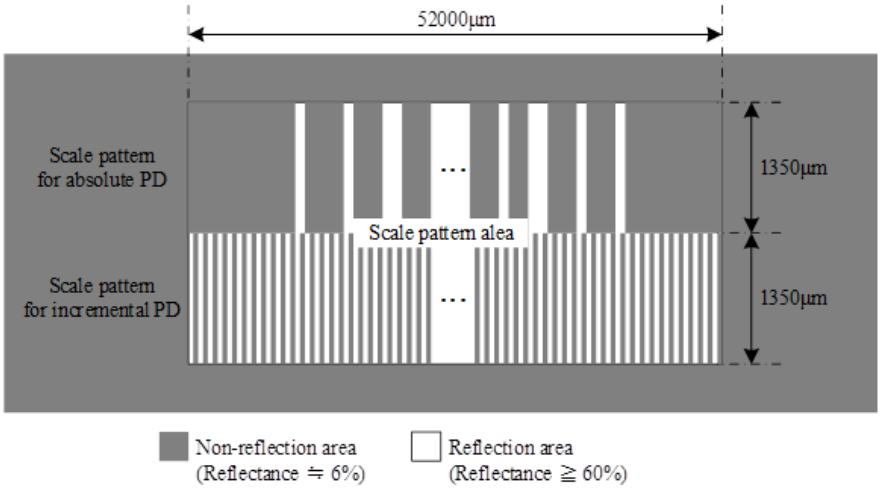
[Flexible (PET) scale manufacturer]

- Meltec Corporation sales Dept.
- 1038 Nagareyama, Nagareyama City, Chiba 270-0164, Japan
- TEL: +81-4-7178-8800
- URL: https://www.e-meltec.jp
- E-mail: info@e-meltec.jp

Note that the SM3414B incremental signal output is designed for a detection period of 100µm so the scale should be 100µm pitch (reflective surface 50µm / non-reflective surface 50µm). Detection period cannot be changed even if the scale pitch is changed.
However, the SM3414B high-accuracy analog output signals can be configured to work with arbitrary resolution using external interpolation circuits and counters.
Similarly, the absolute output of the SM-3414B is designed to operate on a scale with a 1-bit width of 100 µm. Do not change the 1-bit width of the scale for absolute.

The absolute pattern should be a 100 µm wide pattern with 1 bit and a continuous 9-bit pattern indicating the position on the scale. The SM3414B's absolute output photodetector is configured to read a 9-bit pattern, enabling it to output an absolute position data of 512 positions. Our recommended scale pattern uses a method called M-code to encode the position so that 512 positions can be specified on a single track. SM3414B is equipped with a function to convert M-code into 9-bit binary numbers when outputting absolute position data. In addition to outputting the data as it is, the SM3414B can also output binary-converted position data.
For details on the M code conversion function, see data sheet '9.11. M code conversion function'.

[Recommended scale pattern]



4. Operating Principles and SM3414B Characteristics

The main structural components are comprised by the SM3414B built-in LED and OEIC, and an external scale. Light emitted from the LED is reflected with an intensity corresponding to the bright/dark pattern of the scale, and the reflected light creates a bright/dark pattern on the OEIC. The SM3414B realizes the functions of an incremental encoder and an absolute encoder by monitoring this bright/dark pattern on the OEIC.

To monitor the pattern for incremental signals, the photodetectors (photodiodes) are arranged in an array on the surface of the OEIC at a pitch corresponding to 1/4 of the bright/dark cycle of the reflected light. This arrangement of photodetectors enables the output of two-phase sine signals with a phase shift of 90°. The photodetector array for incremental signals monitors several cycles of reflected light from the scale simultaneously and outputs the average value. The SM3414B is designed with A-phase and B-phase outputs used to counterbalance the effects of variations from perfect parallel movement as the photodiode array moves relative to the scale.

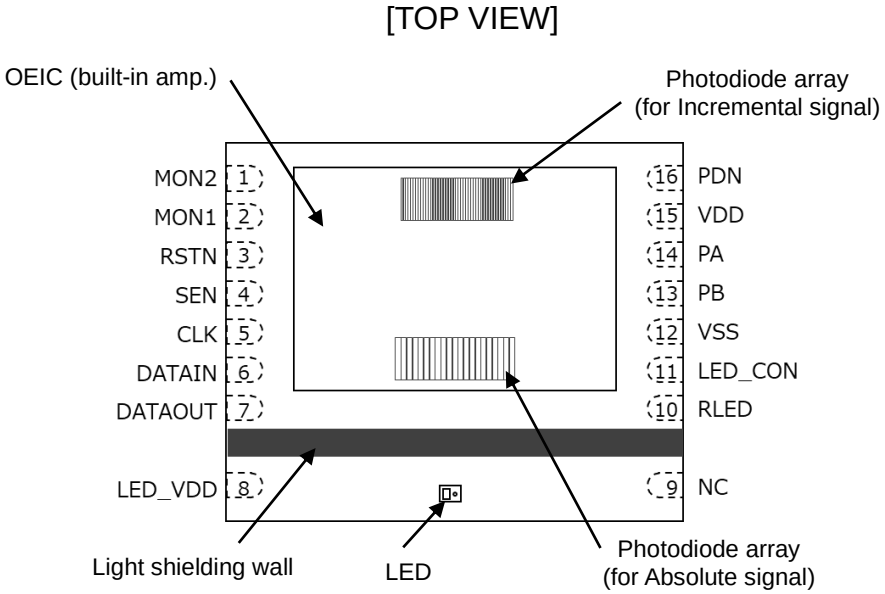
To monitor the bright /dark pattern for absolute data, 18 photodetectors (for 9 bits of the absolute signal) and 2 dummy photodetectors at both ends (1 + 9 x 2 + 1) are arranged in an array at a pitch corresponding to 1/2 of the bright /dark pattern. The pattern for absolute data is monitored by the odd-numbered 9 photodetectors and the even-numbered 9 photodetectors, and is output as a 9-bit signal with a 1/2 cycle shift. Since two sets of 9-bit absolute data are generated at positions that are half a cycle shifted, it is possible to select and read out the one with the more stable signal.

5. Reference Information about SM3414B Specifications

5.1. Reference information on package

5.1.1. Layout of SM3414B Internal Components

LED and OEIC are arranged as shown below.



5.1.2. Environmental Data

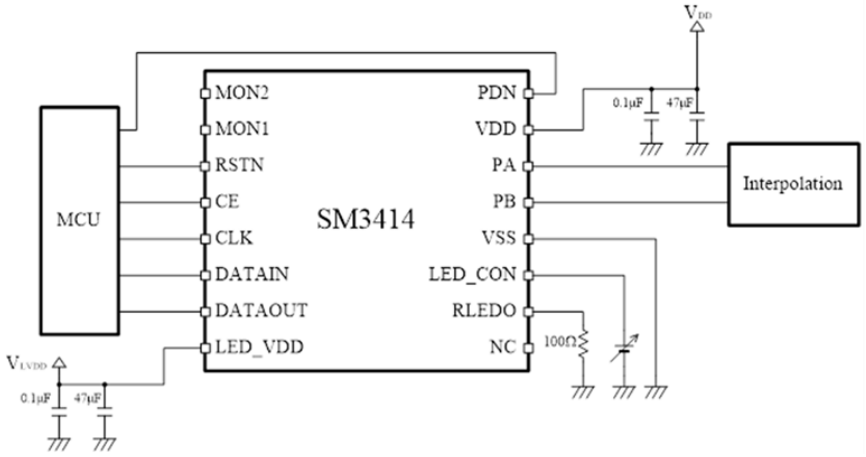
The SM3414B is a lead-free, PVC-free (polyvinyl chloride), Halogen-free, and RoHS compliant product.

5.2. Electrical Specifications Reference Information

5.2.1. Basic Connection

When using the SM3414B for the first time, make the necessary setup using the serial interface in the actual environment in which it will be used.
The SM3414B should be used with bypass capacitors as shown below. Ceramic capacitors with good frequency response are suitable as bypass capacitors. The 0.1 µF capacitor should be placed as close to the SM3414B as possible.

[Typical connection]



5.2.2. Setup and readout from the serial interface

To use the SM3414B, it is necessary to set various functions by writing to the internal registers using the serial interface and to read information by reading the internal registers. The serial interface of the SM3414B supports SPI mode 0 and mode 3. For details on the serial interface, see data sheets '9.12. Serial interface functions' and '10.1. Timing chart Serial interface'.

5.2.3. Adjustment of incremental signal output amplitude

To use the SM3414B, it is necessary to set various functions by writing to the internal registers using the serial interface

[SM3414B Electrical Characteristics Excerpt]

Parameter	Symbol	Conditions	Min	Typ	Max	Unit
Incremental signal output signal amplitude	VAPP	PA, PB pins, 100kΩ load resistance (R), ILED: 5mA (RLED=100Ω, VLED_CON=0.5V) I/V conversion gain: 1 (register GA, GB [2:0]=0h *1) DYAW=0, DPTCH=0, DROL=0, DGAP=0, DCNTR=0	0.18	0.35	0.70	Vp-p

The SM3414B output signal specifications are outlined above.
This signal amplitude is based on an LED current of 5 mA (RLED = 100 Ω, VLED_CON = 0.5 V) on a standard scale and an I/V conversion gain of 1x (GA [2:0] and GB [2:0] set value = 0). After adjustment of the gap, adjust the LED current so that the signal amplitude of PA and PB is approximately 0.3 - 0.4 V. After that, change the GA[2:0] and GB[2:0] settings to obtain the desired amplitude of the PA and PB signals.
The incremental signals (PA and PB) are 2-phase analogue sine signals with a phase difference of 90° and are output with the above signal width centered at 1/2 the voltage of VDD. One cycle of this incremental signal corresponds to a scale movement of 100 µm.

[LED Current Adjustment Function]

The SM3414 has a built-in LED element and LED driver, and the LED current can be adjusted by varying the voltage applied to the LED_CON pin and the resistance value connected to the RLEDO pin.
In addition, the LED_VDD supply voltage is provided separately from the VDD pin. If the LED was driven from only the VDD voltage, the LED current control range is reduced by the forward voltage VF across the LED. However, a voltage higher than VDD can be applied to the LED_VDD pin to alleviate this problem.

$$\text{LED current } [A] = \frac{\text{LED\_CONvoltage } [V]}{\text{RLED } [\Omega]}$$

[I/V Conversion Gain Setting Function]

The gain settings for the I/V conversion, which determines the amplitude of the incremental signals, can be adjusted via the serial interface built into the SM3414B. By setting "001" to address [2:0] of the built-in register, the gain can be set using the values set for phase A gain GA[2:0] and phase B gain GB[2:0].

5.2.4. Configurations about absolute output

[Configuration overview]

To use absolute output, several functions must be configured. This section gives an overview of the whole process. The configuration of the absolute output is carried out in the following order, after the LED current has been adjusted by means of an incremental signal.

Configure the amplitude of the absolute signal.
Configure the threshold voltage for the binarization of the absolute signal.
Verification of the binarized absolute output.

[Configure the amplitude of the absolute signal]

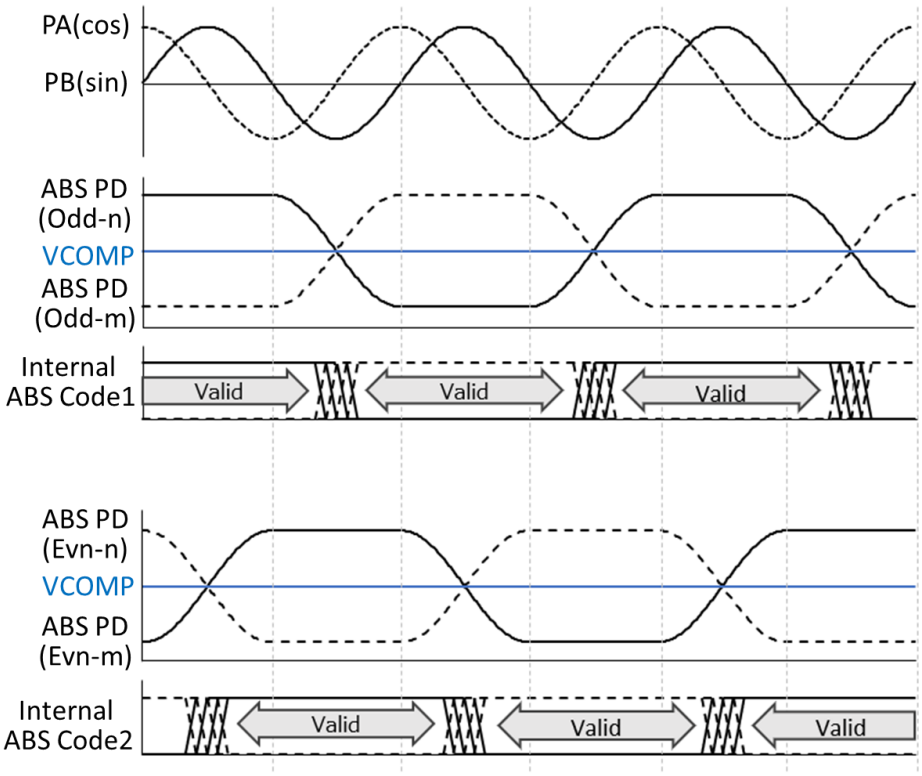
Configures the function to specify internal signals to be monitored to enable monitoring of absolute signals and binarization thresholds. By setting "0110" to the internal register MON_SEL[3:0] and "01001" to OUT_SEL2[4:0], the binarization threshold signal (VCOMP) is output to the MON1 pin, the ninth photodetector output (ABS PD9) signal will be output to the MON2 pin. Confirm that the amplitude of the ABS PD9 signal is about 0.1 Vp-p. The absolute I/V converter resistance adjustment function can be used to set the conversion voltage to 1x or 2x. If necessary, use the absolute I/V converter resistance adjustment function to set the amplitude of the ABS PD9 signal to approximately 0.1 Vp-p.

[Configure the threshold voltage for the binarization of the absolute signal]

After configuring the amplitude of the absolute signal, use the VCOMP signal adjustment function to set the voltage for binarizing the absolute signal. Move the scale in the region where the ABS PD output changes from dark to bright to dark, and set the VCOMP signal so that the width of the voltage higher than the VCOMP signal of the ABS PD signal and the width of the voltage lower than the VCOMP signal are approximately equal in length. By setting VCOMP to such a voltage, the binarized absolute signal can be read out with stable timing.
The voltage of the VCOMP signal can be calculated using the following formula. Refer to the datasheet for details.

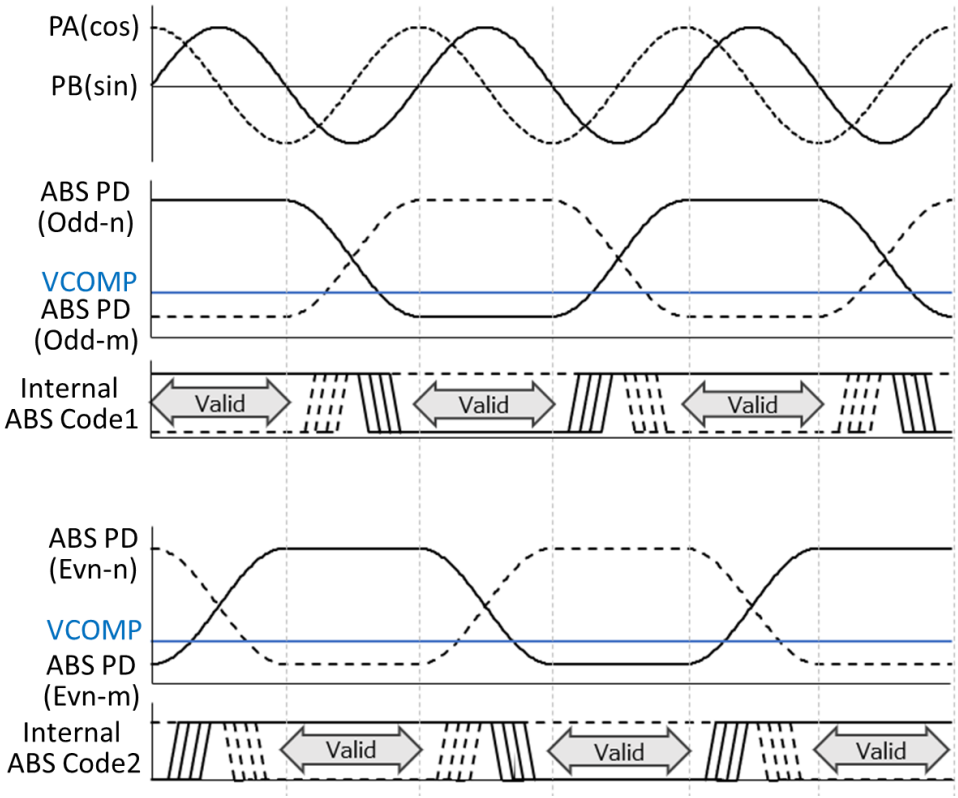
$$\text{VCOMP} = \text{VCOMP}_{\text{DAC}} - \text{GVCOMP} \times (\text{INC\_PD} - \text{VCOMP\_DAC})$$

[Waveforms when VCOMP is properly set]



ABS PD (Odd-n) : Waveform of the first odd PD for a bright → dark → bright pattern.
ABS PD (Odd-m) : Waveform of the second odd PD for the same pattern
ABS PD (Evn-n) : Waveform of the even PD next to the first odd PD for the same pattern
ABS PS (Evn-m) : Waveform of the second even PD for the same pattern

[Waveform at low VCOMP setting]



Due to the low set voltage of VCOMP, the Hi period of ABS PD is longer than the Lo period, resulting in a shorter valid period for the binarized Internal ABS Code.

[Verification of the binarized absolute output]

The internal registers MON_SEL[3:0], OUT_SEL1[4:0] and OUT_SEL2[4:0] are used to set the odd-numbered signal of ABS Co (binarized ABS_PD signal) to the MON1 pin and the even-numbered signal of ABS Co to the MON2 pin. Move the scale in the same way as when setting the VCOMP signal, and confirm that the binarization switching timing of the even-numbered element of ABS Co does not overlap with the binarization switching timing of the odd-numbered element.

Since correct absolute data cannot be read at the timing when the ABS Co signal is switched, if the switching timing of the even-numbered and odd-numbered elements overlap, correct absolute data may not be read.

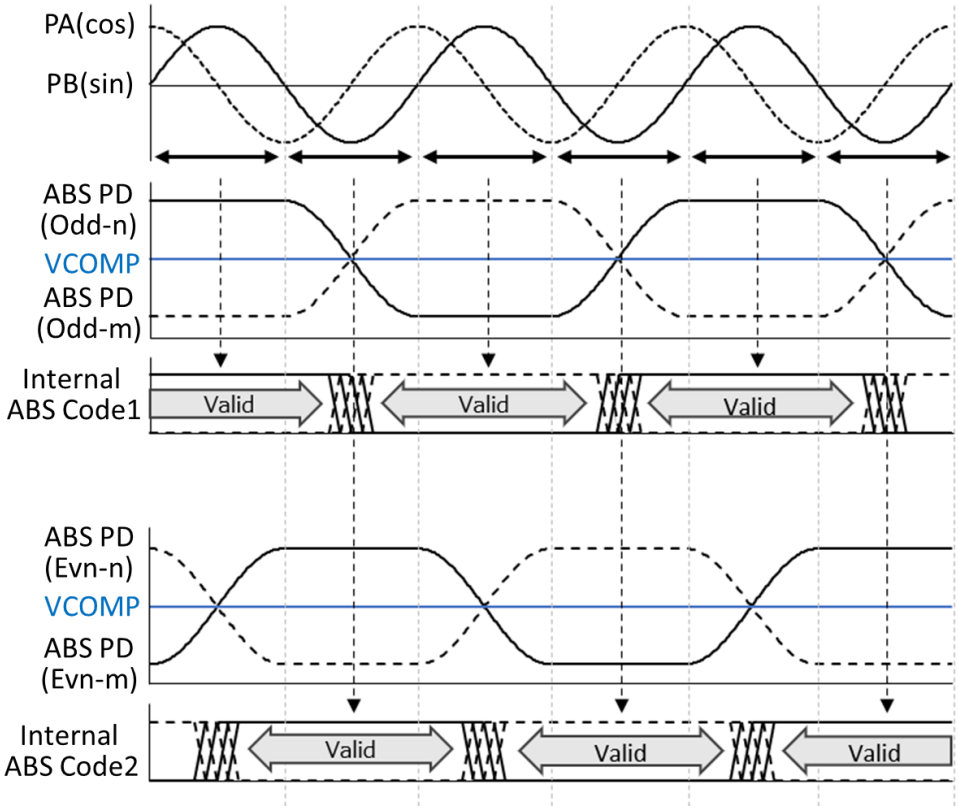
In such a case, set VCOMP again.

5.2.5. Absolute data readout

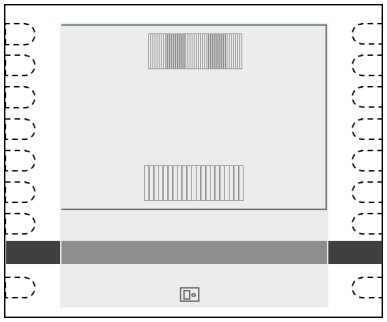
Absolute data is read from the internal register via the serial interface. The internal register stores two sets of 9-bit data: the data of the odd-numbered 9 elements of the ABS PD (Internal ABS Code1) and the data of the even-numbered 9 elements (Internal ABS Code2), which are binarized at VCOMP voltage.
To read the even-numbered side or the odd-numbered side of the absolute data is selected by the level of the incremental signal. If there is no yaw misalignment between the encoder IC and the scale mounting and no phase difference between the incremental and absolute signals, the data of the odd element (Internal ABS Code1) will be read during the period when the PB signal is Hi and the data of the even element (Internal ABS Code2) will be read during the period when the PB signal is Lo. If misalignment exists in Yaw, the scale pattern is projected diagonally to the PD for incremental signals and the PD for absolute signals, resulting in a phase difference between the incremental signals and absolute signals. If there is any misalignment in Yaw, the scale pattern is projected diagonally to the PD for incremental signals and the PD for absolute signals, resulting in a phase difference between the incremental and absolute signals. In this case, it is necessary to select the appropriate PA or PB according to the amount of phase shift, and select readout of even or odd absolute data at Hi or Lo of the PA or PB. For details, please refer to the data sheet.
The data recorded on the NPC standard scale is binary data indicating positions encoded in M-code. The SM3414B has a built-in M-code conversion function, and the data converted from the read M-code data to binary data is also stored in the internal register at the same time, so select and read the data corresponding to the scale to be used. For the address of the register to be read, refer to the data sheet.

When the voltage setting of VCOMP is appropriate, as shown in the figure below, the binarized Hi time and Lo time of the ABS PD output are approximately the same, and stable absolute data can be read by switching the information to be read by the incremental signal level.

[Switching of data to be read out by PB level]



6. Handling Precautions



- Ensure the gray portion containing the LED and OEIC, shown in the diagram, clean and free from dust and other contaminants.
  If it is dirty, gently wipe the surface with a soft clean cloth dipped in methanol or ethanol to remove all contaminants. The use of other liquids or wiping vigorously may cause scratching, clouding, or otherwise damage the surface of the encoder. Exercise caution when cleaning the device surface.
- Avoid direct contact with the SM3414B and scale when handling, installing, or adjusting.
- Ensure that the operating temperature of any unit or housing containing the SM3414B will not exceed the temperature specifications of the device.
- Please note that there is the potential that strong localized light sources may affect the encoder output.
- The light intensity of the SM3414B built-in LED does not exceed the value for Class 1 standard visible LED eye safety as prescribed by IEC60825-1.

7. USAGE AND PRECAUTIONS

This product is designed and manufactured to the generally accepted standards of reliability as expected for use in general electronic and electrical equipment, such as personal equipment, machine tools, and measurement equipment. This product is not designed and manufactured to be used in any other special equipment requiring extremely high level of reliability and safety, such as aerospace equipment, nuclear power control equipment, medical equipment, transportation equipment, disaster prevention equipment, security equipment.
If you wish to use this product in equipment requiring extremely high level of reliability, please contact our sales department or representative in advance.
In the event that this product is used in such equipment, please take scrupulous care and apply fail-safe techniques including redundancy and malfunction prevention in order to prevent damage to life, health, property, or infrastructure etc. in case there is some malfunction in the product.

This Application Note is provided as a reference for product introduction and customer evaluation purposes for this product. Typical characteristics and other values mentioned in this document are provided as reference data only to demonstrate principles and trends; this document does not include manufacturing tolerances and other characteristics data. Devices should only be used after thorough evaluation under actual operating conditions.

Please pay your attention to the following points at time of using the products shown in this document.

1. The products shown in this document (hereinafter ”Products”) are designed and manufactured to the generally accepted standards of reliability as expected for use in general electronic and electrical equipment, such as personal equipment, machine tools and measurement equipment. The Products are not designed and manufactured to be used in any other special equipment requiring extremely high level of reliability and safety, such as aerospace equipment, nuclear power control equipment, medical equipment, transportation equipment, disaster prevention equipment, security equipment. The Products are not designed and manufactured to be used for the apparatus that exerts harmful influence on the human lives due to the defects, failure or malfunction of the Products.
   If you wish to use the Products in that apparatus, please contact our sales section in advance.
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