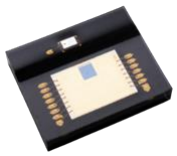
SMD-04B Reflective type Optical Encoder IC



Smallest in its class: Can be mounted in tiny spaces
High accuracy: <1μm high resolution with external interpolation circuit
Origin signal: The origin detection pattern can be placed in the scale pattern of the incremental signals.

1. SMD-04B Overview

The SMD-04B is the world's smallest encoder IC in its class, incorporating a LED light source and a OEIC (Opto-Electric Integrated Circuit) in a single surface-mounted-device package. 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 characteristics.

[Features]

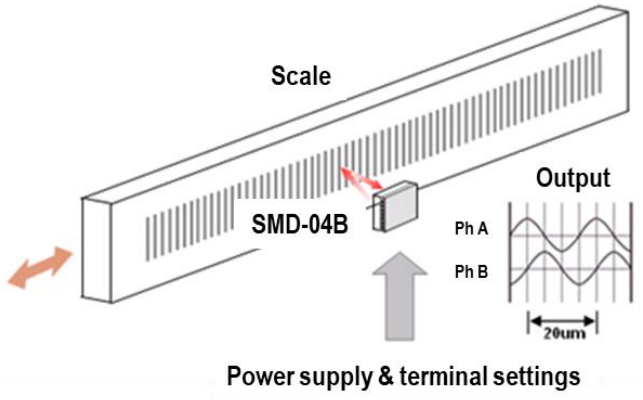
- Miniature clear molded package — 5.3mm (W) × 4.3mm (L) × 1.68mm (H)
- High-accuracy two-phase differential analog output — A-phase/B-phase analog, sine wave outputs. Also, inverted differential outputs for noise cancellation
- 20μm output signal period (fixed) — High S/N ratio and superior Lissajous characteristic for better than sub-micron resolution, in combination with external interpolation circuit
- Origin detection signal — A origin detection signal (Z-phase signal) can be output by providing a scale pattern for origin detection in the scale pattern for incremental signals
- Built-in LED light source — 2-step adjustment and automatic adjustment light intensity
- Supply voltage range — 4.5 to 5.25 V
- Low current consumption — 2.2mA (typ)
- Easy positioning/installation
- Reflow mounting (*confirm suitability of reflow conditions)

[Typical Applications]

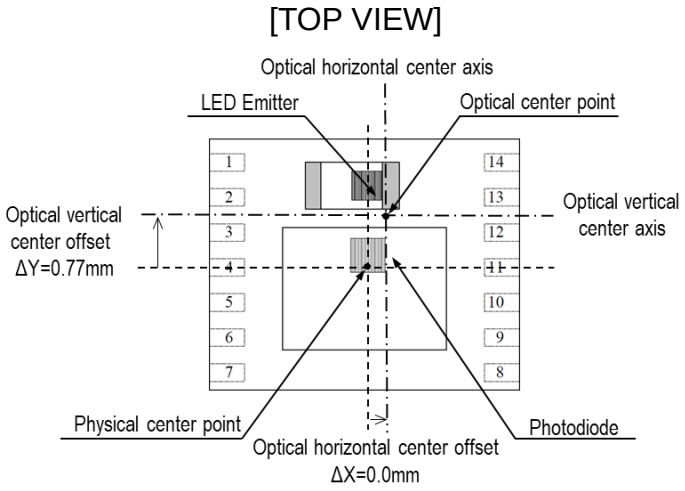
- Miniature actuators, piezo-actuators
- Precision stages
- Distance measurement equipment, angle measurement equipment, linear gauges
- Galvanometers
- Optical axis control of laser light
- Chip mounters, PCB/FPC substrate processing, IC handlers & FA mounting/processing
- Motion control of industrial robots and consumer robots
- Position/speed control in applications requiring miniaturization and high accuracy

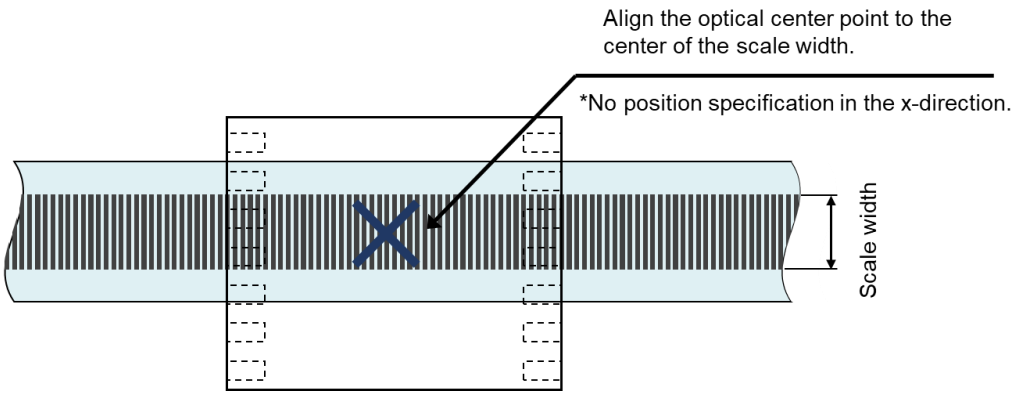
2. Typical SMD-04B Encoder Configurations

2.1. Linear Encoder Configuration and Alignment

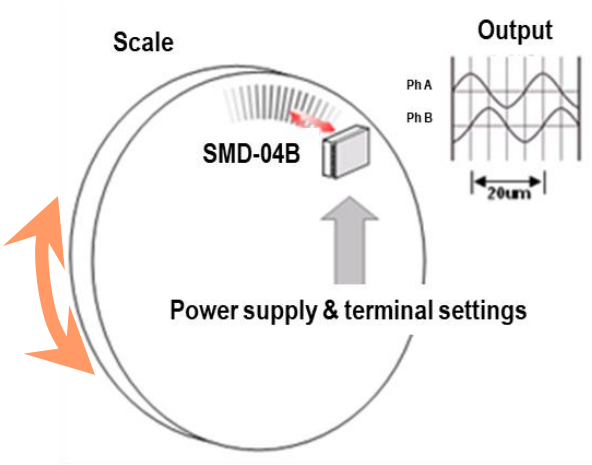


A linear encoder can be constructed using the SMD-04B and a linear scale.
The linear scale pattern width can be made as narrow as ±0.5mm when the linear scale pattern width center correctly matches the SMD-04B optical center (Y orientation in the following figure). The pattern width should be chosen after careful evaluation.
The optical center point is a point midway between the SMD-04B built-in LED source optical center and the light sensor photodiode center.

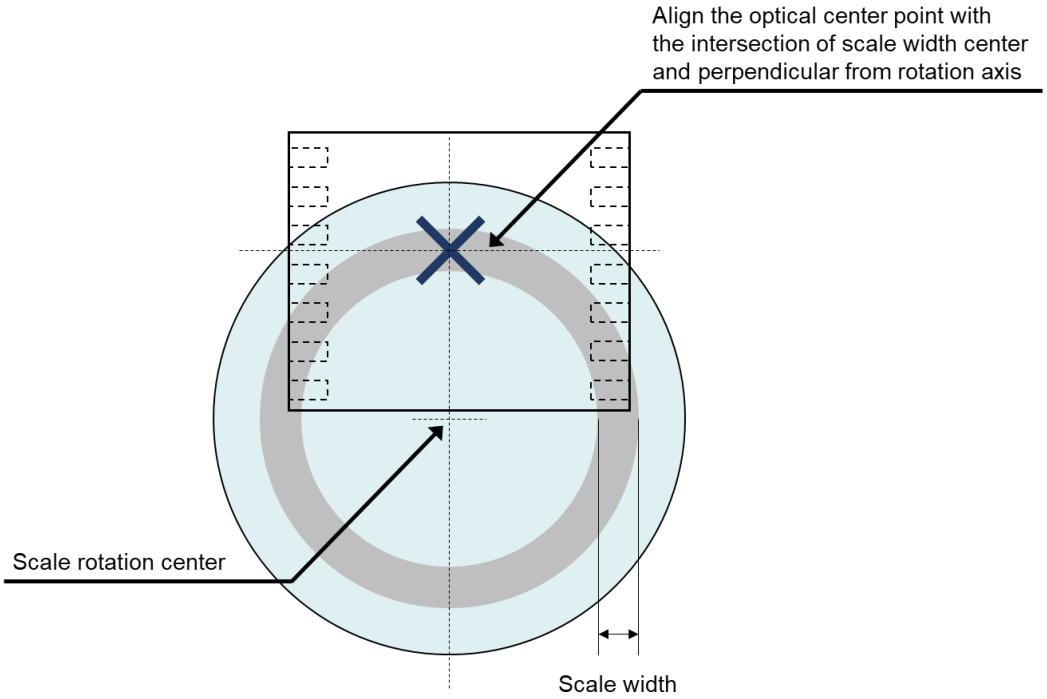




2.2. Rotary Encoder Configuration and Alignment

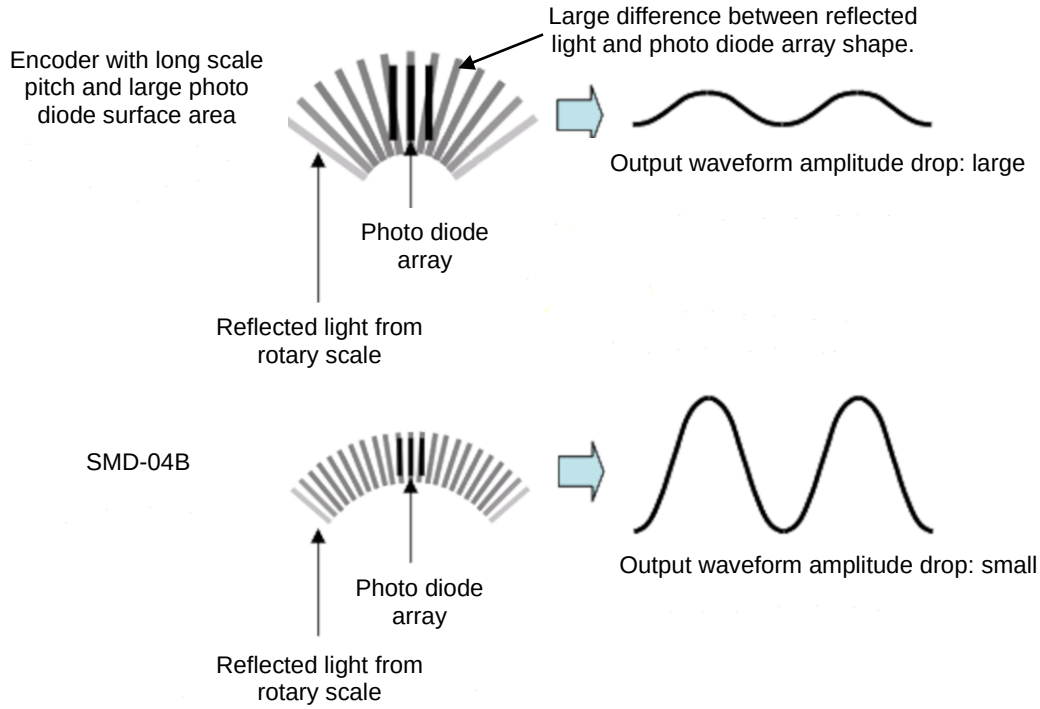


A rotary encoder can be constructed using the SMD-04B and a disk-shaped rotary scale.
For a rotary encoder, the SMD-04B optical center point must be correctly positioned in the center of the rotary scale horizontally and vertically, as shown in the following figure.



2.3. Advantages of Small Diameter Rotary Encoders

When a general-purpose encoder IC is used for a rotary encoder, the output amplitude tends to decrease because the encoder IC is designed to receive parallel reflected light of the correct period whereas the reflected light is fan-shaped due to the scale pattern. As the output amplitude decreases, operation at high interpolation factors becomes difficult and high resolution increasingly difficult to obtain.
The SMD-04B, however, has a miniature light receiver with a short scale pitch that reduces the effects of reflected light from fan-shaped rotary scales. Consequently, it can be employed in miniature, lightweight rotary encoders. It also helps to reduce the rotational inertia of parts with attached encoder or scale for better system miniaturization and weight reduction.



The following table shows typical signal amplitudes for a small-diameter rotary encoder configuration using the SMD-04B.

SMD-04B output amplitude using small-diameter rotary scale (reference data)

Scale diameter (mm)	Scale pattern width (mm)	CPR (pulse count / revolution)	SMD-04B output amplitude (%) [linear scale representing 100% amplitude][*2]
9.5	0.5	≒1500[*1]	95
6.4	0.5	≒1000[*1]	80
5.1	0.4	≒800[*1]	60

*1: These values are achieved by converting A/B phase analog signals to a binary code with a comparator circuit. The CPR values are calculated using the following equation.

$$CPR = \frac{Scale\ diameter\ (mm) \times \pi}{0.02\ (mm)}$$

Resolution equivalent to 4 times as much as CPR above is obtained by counting rising/falling of A/B phases respectively. Higher resolution according to interpolation factors is realized by using an external interpolation circuit.

*2: Rotary scale mounting position is individually adjusted to obtain largest signal amplitude. Values in the table are example.
When using a small-diameter rotary scale, effect of mounting conditions on amplitude, phase difference and Z-phase signal is greater than a linear scale. Individualized alignment is recommended to obtain better product characteristics.

2.4. Scales for SMD-04B

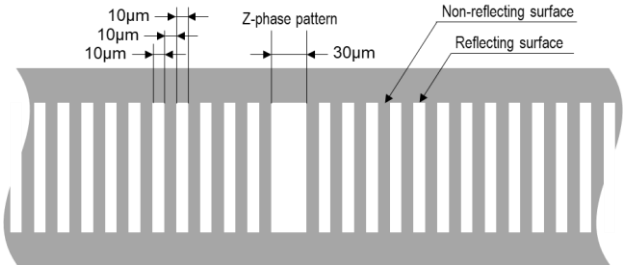
As described, a linear/rotary encoder can be constructed in combination with a linear scale or rotary scale.
Scales are not provided with the SMD-04B; they must be acquired separately. The following manufacturers can supply scales that can be used with the SMD-04B.

2.4.1. Glass scale

Generally, glass scales using a glass substrate are most suitable.
The following manufacturer can supply both linear and rotary scales.

[Glass scale manufacturer]
- Koshibu Precision Co.,Ltd.
- 2-20-11 Hayamiya, Nerima-ku, Tokyo 179-0085, Japan
- TEL: (03) 3934-2670
- URL: https://www.koshibu.co.jp
- E-mail: kakizawa@koshibu.co.jp (Attn: YUTAKA KAKIZAWA)

Note that the SMD-04B output signal is designed for a detection period of 20μm so the scale should be 20μm pitch (reflective surface 10μm / non-reflective surface 10μm). Detection period cannot be changed even if the scale pitch is changed.
However, the SMD-04B high-accuracy analog output signals can be configured to work with arbitrary resolution using external interpolation circuits and counters. With a glass scale, it is possible to achieve resolutions of 0.1μm or better with careful design.
The pattern for origin detection (Z-phase pattern) should be provided with a 30 μm wide reflective surface at one location on a 20 μm pitch pattern. The origin detection signal (phase-Z signal: VZ) can be output by providing an origin detection pattern. The origin detection signal is issued during the high section of phase A (VA>Vref1 (or Vref2)). For details, see the data sheet.



For rotary scales, the pattern width at the center of the scale width should be 10 μm or 30 μm.

3. Operating Principles and SMD-04B Characteristics

The SMD-04B optical encoder IC operates using the diffraction image projection method. The main structural components are the SMD-04B built-in LED and OEIC, and an external scale.
The light emitted from the LED is reflected and diffracted by the scale, and the diffracted light is designed to focus on the OEIC, which detects the periodic shading of the diffracted light and outputs two phase signals.
The periodic patterns of shade and light are detected in order to determine the position on the scale. OEIC contains an array of light sensors (photodiodes) precisely aligned at 1/4 pitch of the diffracted light to observe the shading pattern of the diffracted light. The photodetector array is configured to simultaneously observe several periods of diffracted light from the scale and output the average of the photodetectors at the same position in different periods.
The SMD-04B is designed in a manner that, even if the position of the SMD-04B and the scale deviate slightly from perfect parallelism, the effects of the deviation are cancelled out by the A and B phases, and a stable output is obtained.

These abilities provide the SMD-04B with the following features:

1) Reduces susceptibility to output signal effects caused by localized defects or dirt on the surfaces of the SMD-04B and scale.

2) Reduces susceptibility to SMD-04B output amplitude variation due to positioning errors.

Reference data for the output amplitude variation due to positioning errors are provided in the device datasheet. However, conditions of optimum optics of this product may vary due to mounting tolerance of optical elements, so thorough evaluation is needed to set the conditions. It is recommended to check the output signals while positioning the encoder particularly when using a small-diameter rotary scale, which effect of alignment conditions on signal amplitude and phase difference is greater than a linear scale, or an external interpolation circuit to achieve resolutions of 1μm or better.

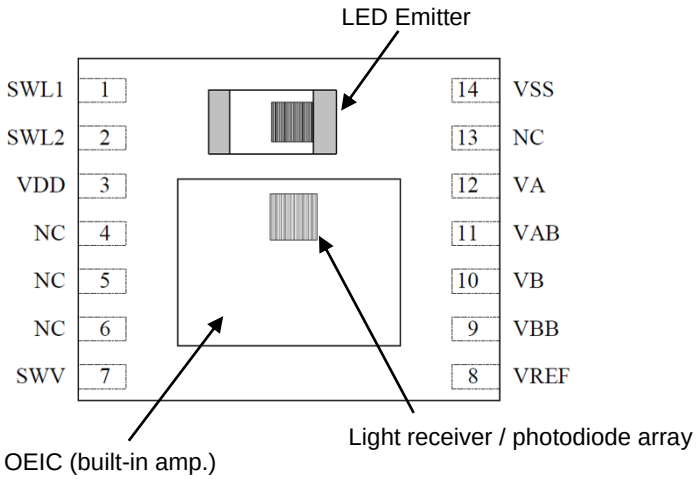
4. Reference Information about SMD-04B Specifications

4.1. Reference Information about Package

4.1.1. Layout of SMD-04B Internal Components

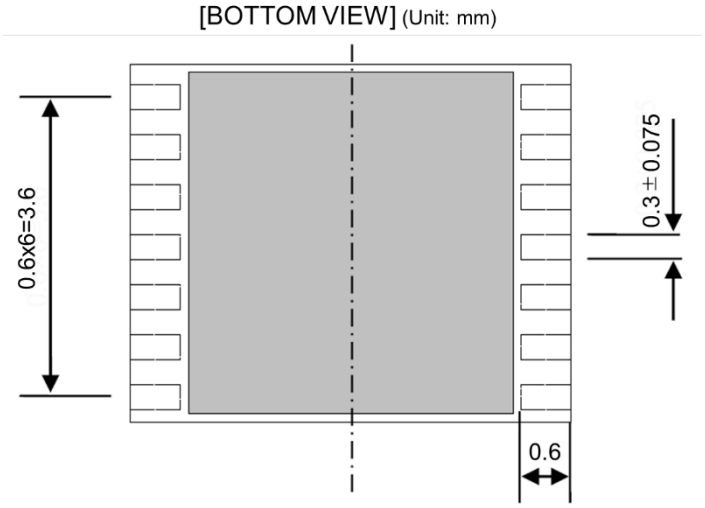
The LED and OEIC are arranged as shown below.
The optical center is the point midway between the LED emitter and light receiver. See sections 2-1 and 2-2 for examples.

[TOP VIEW]



4.1.2. Bottom Surface External View

The gray rectangular portion in the following diagram from the datasheet indicates the bottom surface insulation resin portion, and is not an electrical terminal.



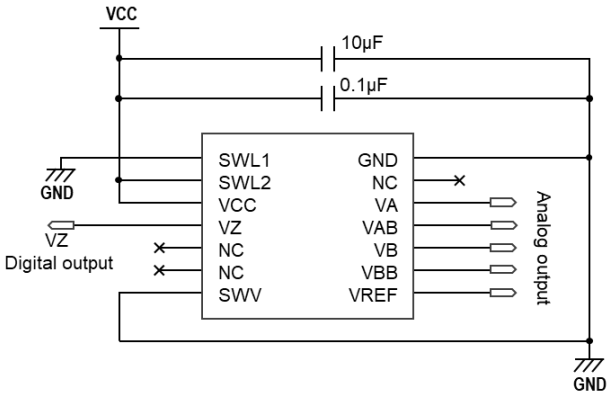
4.1.3. Environmental Data

The SMD-04B is a lead-free, PVC-free (polyvinyl chloride), Halogen-free, and RoHS compliant product.

4.2. Electrical Specifications Reference Information

4.2.1. Basic Connection

The SMD-04B operates with just power supply and setting terminal connections. However, bypass capacitors should also be connected as shown below to counter environmental noise and in applications that require high accuracy. The 0.1μF capacitor should be positioned as close as possible to the SMD-04B. Ceramic bypass capacitors with excellent frequency response are most suitable.



[Typical connection (VCC=5V supply, minimum LED current)]

4.2.2. Output Amplitude Adjustment

[SMD-04B Electrical Characteristics Excerpt]

Parameter	Symbol	Conditions	Min	Typ	Max	Unit	Terminal
A-phase output signal amplitude	VAP-P	Vp-p SWL1=L SWL2=H *Reference scale	0.8	1.2	1.92	V	VA
AB-phase output signal amplitude	VABP-P						VAB
B-phase output signal amplitude	VBP-P						VB
BB-phase output signal amplitude	VBBP-P						VBB

The SMD-04B output signal specifications are outlined above.
If the output amplitude must be guaranteed to be above a certain value (for example, 0.9V), the LED luminosity for each device can be adjusted to increase/decrease the output amplitude using the following trimming settings.

[Output Amplitude Multiplication Settings]

SWL1 terminal	H	H	L	L
SWL2 terminal	H	L	H	L
A,B-phase output amplitude multiplication	×1.0	×1.8	APC	×0

*H = VCC level, L = GND level, APC: Auto Power Control

Returning to the example, the SWL1 and SWL2 logic levels can be adjusted to ensure the output amplitude is set to 0.9V or higher.
Note that changing the LED current will also greatly affect the SMD-04B current consumption. Check the electrical characteristics to determine the current consumption under the desired operating conditions.
In practice, the output amplitude rarely approaches the maximum or minimum values published in the electrical specifications. In almost all applications, the LED current can be set to the minimum value without problem.

[Auto Power Control Function]

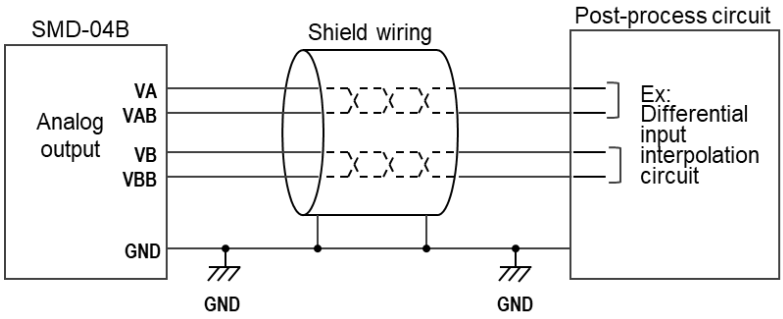
When the Auto Power Control function is enabled, the light reflected from the scale is detected by a dedicated photodiode and the LED current is automatically adjusted. This function reduces output signal variations caused by individual variations in LED luminance and compensates for variations in LED luminance caused by temperature.

[Reference voltage switching function]
The reference voltage (Vref) of the SMD-04B can be switched by setting the SWV terminal. Set SWV terminal according to the input conditions of the post-process circuit.
Note that when SWV = H, the origin detection signal (VZ) is an open drain output, so an external pull-up is required.

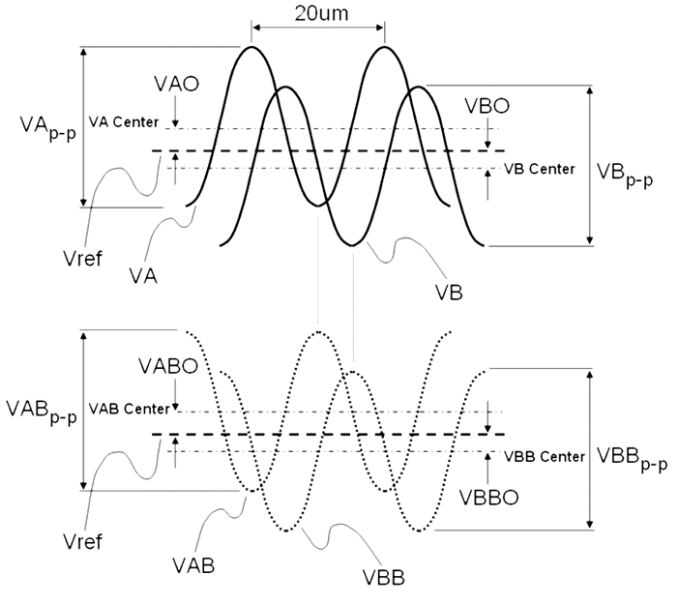
4.2.3. Output Noise Measures: Differential Outputs

The SMD-04B outputs two sine wave signals (VA and VB) with a period of 20μm, and two inverted forms of these signals (VAB and VBB). There is a 90° phase difference between VA and VB, and between VAB and VBB.
The differential output of non-inverted and inverted signals for both A-phase and B-phase waveforms can be used to prevent external electric field interference that can cause common-mode noise.

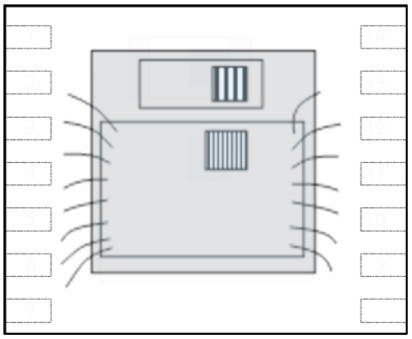
A typical differential output connection is shown in the following figure.



The four analog signals have an offset from the Vref reference voltage output. Any external circuit connected to the outputs must calibrate for these offsets.



5. 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 SMD-04B and scale when handling, installing, or adjusting.
- Ensure that the operating temperature of any unit or housing containing the SMD-04B will not exceed the temperature specifications of the device.
- The SMD-04B is designed to prevent external light interference. However, note that there is the potential that strong localized light sources may affect the encoder output.
- The light intensity of the SMD-04B built-in LED does not exceed the value for Class 1 standard visible LED eye safety as prescribed by IEC60825-1.

6. 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.
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