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Evaluation of SMD 20µ period encoder with VC America Electronics scales

Contents

Overview

Introduction:

SMD-01B and SMD-04B encoders are essential building blocks for achieving high resolution and accuracy. Designers seeking high resolutions add differential OpAmps to drive a 12-16-bit ADC (usually SAR type). Low noise design improves repeatability and enables error correction algorithms achieving 10–12-bit accuracies with 12–16-bit interpolation.

A rotary scale with 4096 periods (CPR) equals 12-bit resolution per revolution. Analog Interpolation of each period using 12-16-bit ADC totals resolution per revolution of 24-28-bits. 22–24-bit accuracies are achievable. Need more bits? Increase scale to 8192, 16384, or 32,768 CPR.

Medium to High accuracy circuit design approaches are shown on pages 15-18 or contact us at sales@vcamericaelectronics.com for more assistance.

Evaluation

Included are the PCB with mounted SMD-04B encoder, FFC cable, and breakout board to connect power and signals for testing.

A 20µm (micron) period precision linear or rotary scale rotary glass scale matching the encoder is included.

SMD-0xx evaluation board

FFC Cable connecting encoder board and breakout board.

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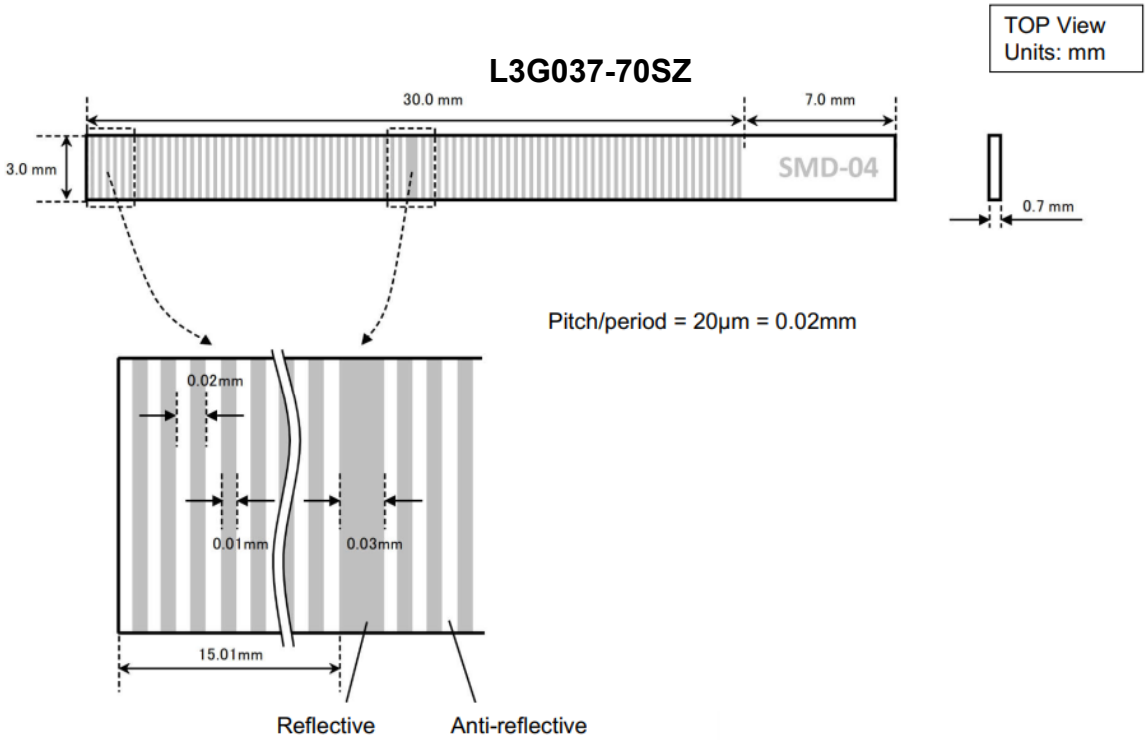
SMD-04 Evaluation Parts List (BOM)

SMD-04B-L37-KIT Linear scale

Item Name	Part number	BOM Qty	Description
Precision Scale	L3G037-70SZ	1	37mm x 3mm x 0.7mm thick. 20µm scale and track length=30mm, with 30µm mid-point index.
Encoder PCB assembled		1	Mounted SMD-04B with Bypass Capacitors 0.01µF and 1µF, FFC connector. (APC setting default)
Breakout board assembled		1	
FFC Connector		1	FFC right angle 0.5mm pitch 10 pins



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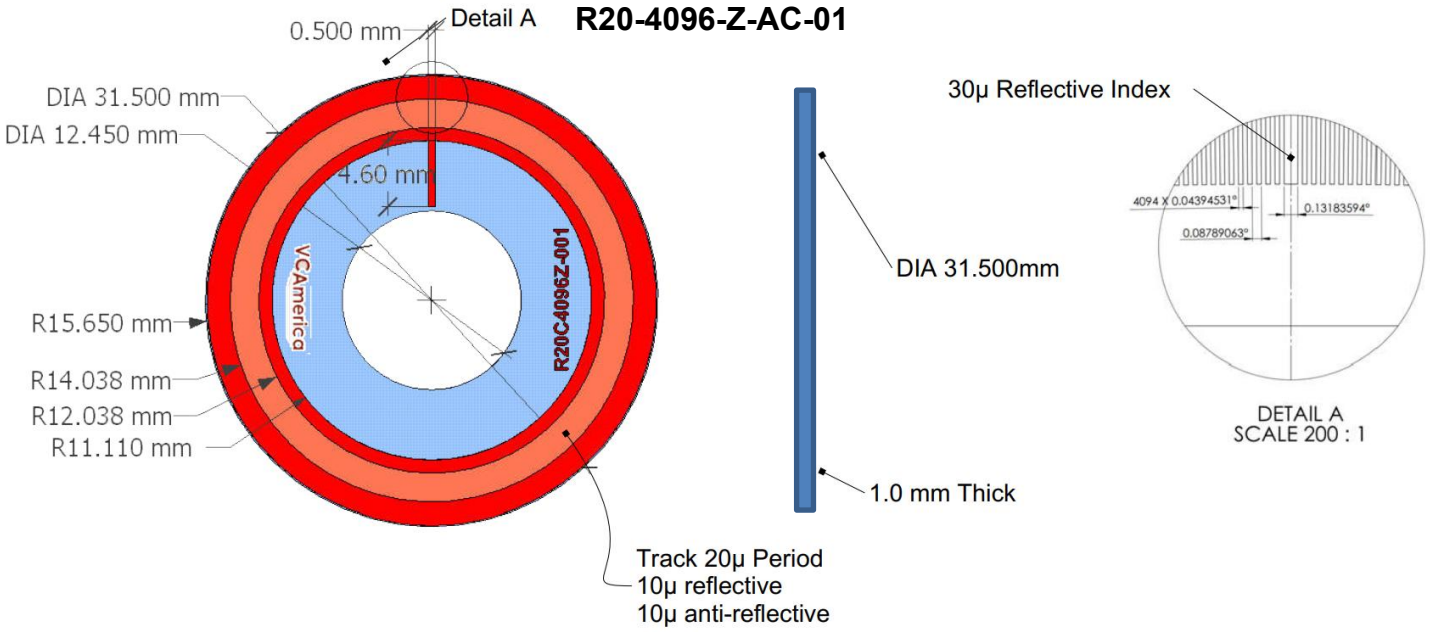
SMD-04B-R4096-KIT Rotary 4096 period scale

Item Name	Part number	BOM Qty	Description
Precision Scale	R20-4096-Z-AC-01	1	Scale 31.50mm OD 12.45mm ID 4096 period track w/ 30µ Index; reflective chrome & AR coatings; clear center zone; 1.0mm thick soda-lime glass; Marking= R20C4096Z-001
Encoder Module PCB and Break out		1	Mounted SMD-04B with Bypass Capacitors 0.01µF and 1µF. (APC setting default)
FFC Connector		1	FFC right angle 0.5mm pitch 10 pins



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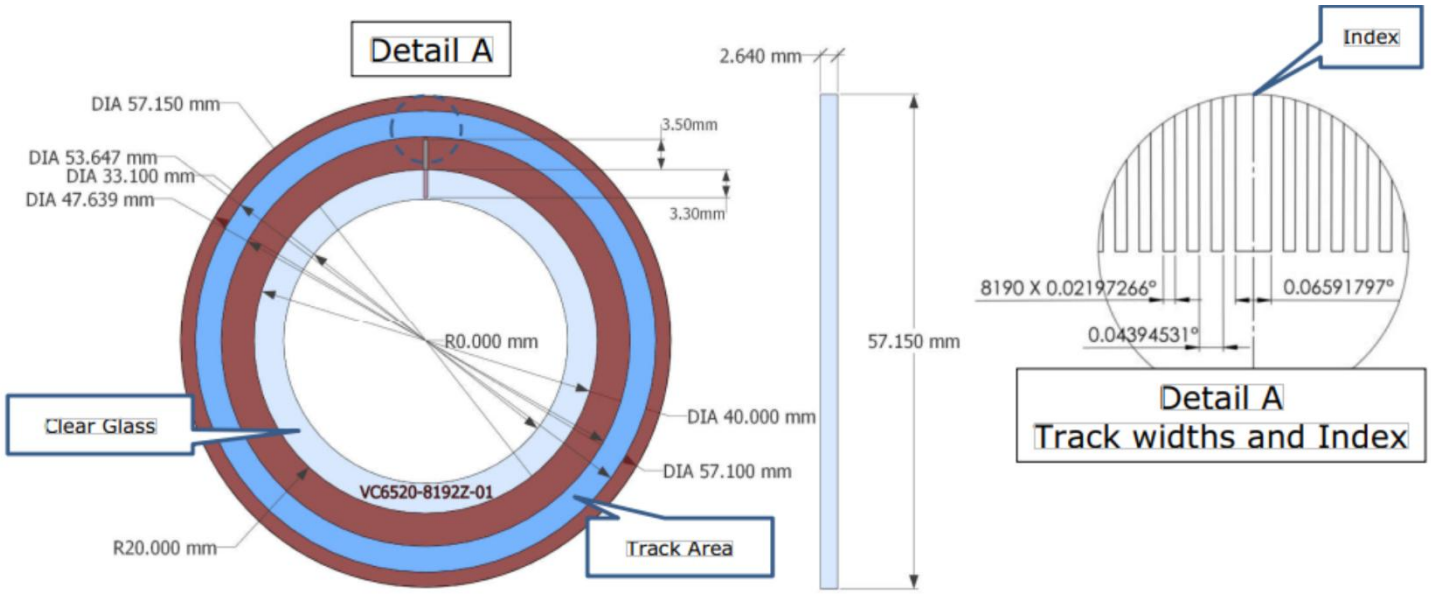
Item Name	Part number	BOM Qty	Description
Precision Scale	R20-8192-Z-AC-01	1	Scale 57.15mm OD 33.10mm ID 8192 period track with 30µ index; reflective chrome and AR coatings & clear center zone; soda-lime glass; Marking=VC6520-8192Z-01
Encoder Module	SMD-04B	1	Optical Read Head 20µm period with index function (APC setting)
Connection/ breakout PCB	SMD-ABZ-PCB	1	Connection board with encoder board via FFC cable. Dimensions = 35mm x15mm x1.6mm
Encoder board	SMD-0xx_PCB	1	Dimensions= 25mm x 9mm x 1.6mm
Capacitor, ceramic	Multiple	1	0.01µF 50V, 0603 (1608 metric) capacitor
Capacitor, ceramic	Multiple	1	1 µF ≥16V, 0603 (1608 metric) capacitor
FFC Connector	Multiple	2	FFC right angle 0.5mm pitch 10 pins
Ribbon Cable	Multiple	1	0.5mm pitch Ribbon Cable 200mm (7.87”), contacts same side

R20-8192-Z-AC-01



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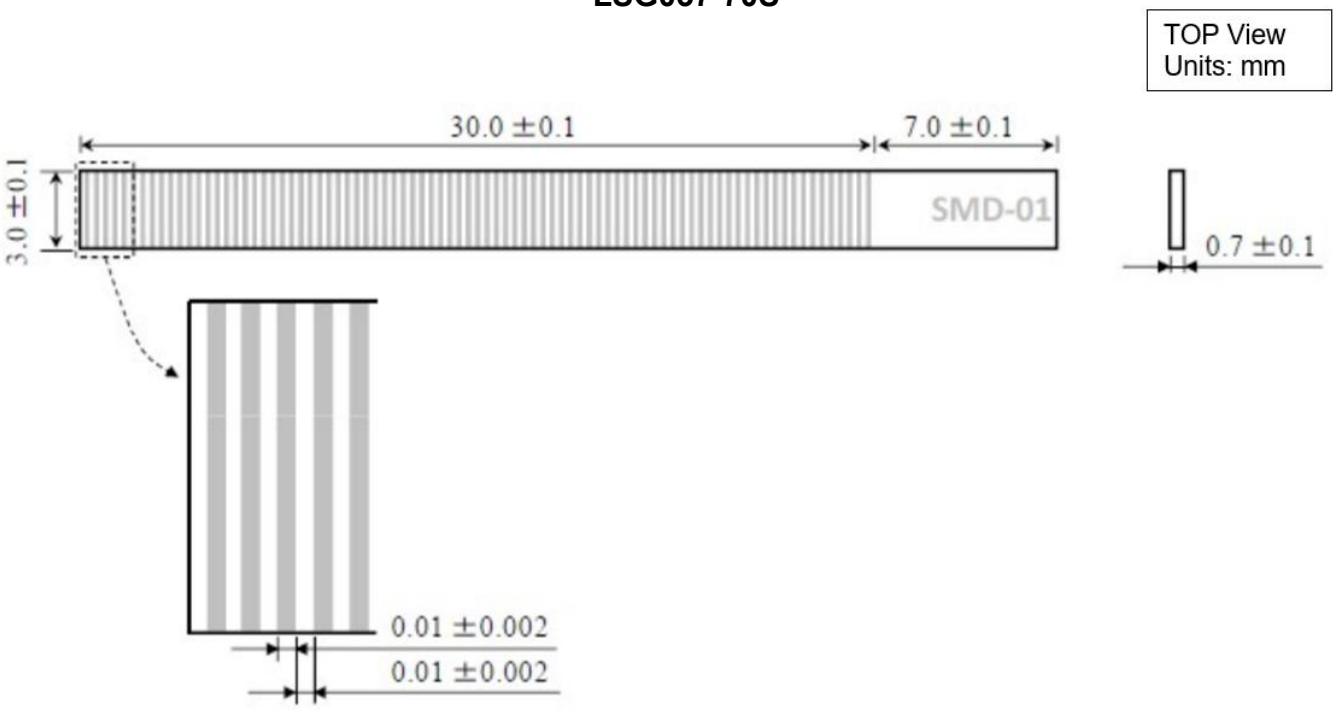
Item Name	Part number	BOM Qty	Description
Precision Scale	L3G037-70S	1	37mm x 3mm x 0.7mm thick 20µm scale track
Encoder Module	SMD-01B	1	Optical Read Head 20µm period, no index function
Evaluation connection/ breakout PCB	SMD-AB-PCB*	1	Connection board with encoder board via FFC cable. Dimensions = 35mm x15mm x 1.6mm
Encoder board	SMD-0xx_PCB	1	Dimensions= 25mm x 9mm x 1.6mm
Capacitor, ceramic	Multiple	1	0.01µF 50V, 0603 (1608 metric) capacitor
Capacitor, ceramic	Multiple	1	1 µF ≥16V, 0603 (1608 metric) capacitor
FFC Connector	Multiple	2	FFC right angle 0.5mm pitch 10 pins
Ribbon Cable	Multiple	1	0.5mm pitch Ribbon Cable 200mm (7.87”), contacts same side

*SMD-ABZ-PCB may be used as substitute

LSG037-70S



Pitch/period = 20µm (0.02mm)

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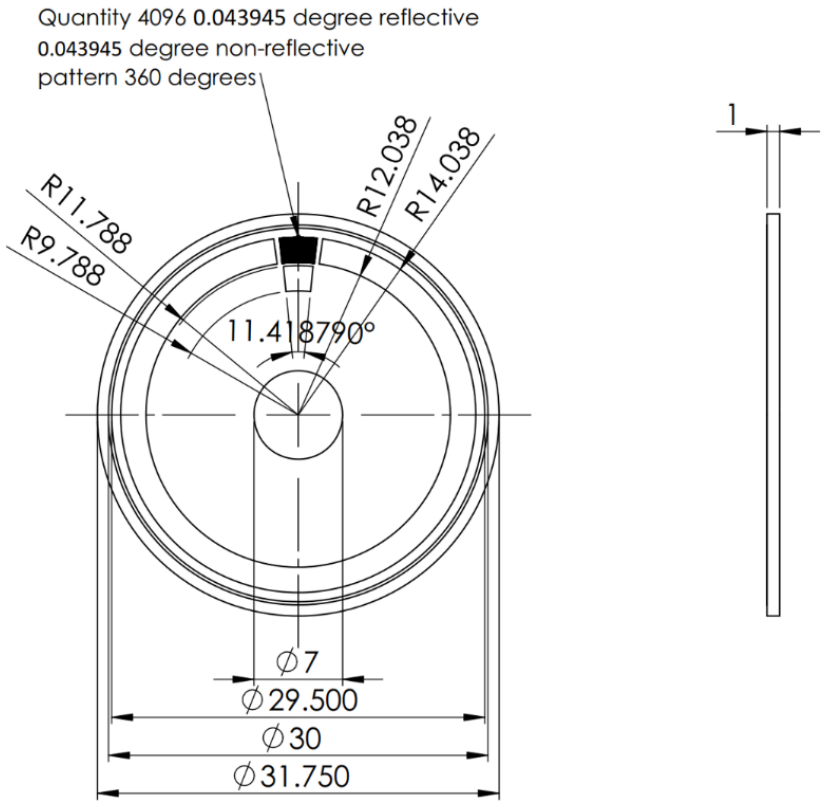
SMD-01B-R4096-KIT Rotary 4096 period scale

Item Name	Part number	BOM Qty	Description
Precision Scale	R20-4096-T-AC-01	1	Scale 31.50 OD 12.45 ID 4096 period track w/ 30µ Index; reflective chrome & AR coatings; clear center zone;1.0mm thick soda-lime glass; Marking= R20C4096Z-001
Encoder Module	SMD-04B	1	Optical Read Head 20µm period, no index function
Evaluation connection/ breakout PCB	SMD-AB-PCB*	1	Connection board with encoder board via FFC cable. Dimensions = 35mm x15mm x 1.6mm
Encoder board	SMD-0xx_PCB	1	Dimensions= 25mm x 9mm x 1.6mm
Capacitor, ceramic	Multiple	1	0.01µF 50V, 0603 (1608 metric) capacitor
Capacitor, ceramic	Multiple	1	1 µF ≥16V, 0603 (1608 metric) capacitor
FFC Connector	Multiple	2	FFC right angle 0.5mm pitch 10 pins
Ribbon Cable	Multiple	1	0.5mm pitch Ribbon Cable 200mm (7.87”), contacts same side

*SMD-ABZ-PCB may be used as substitute

R20-4096-T-AR-01



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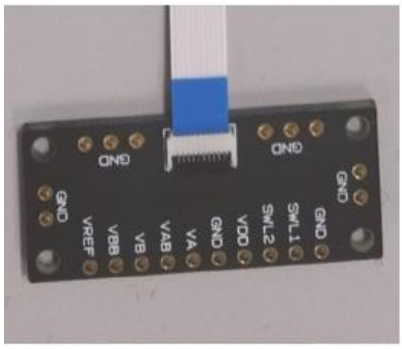
Appendix 1 BOM for assembled Evaluation boards with ribbon cable

BOM for SMD-ABZ-PCB breakout board

Item Name	Part number	BOM Qty	Description
Encoder IC	SMD-04B	1	
Encoder board	SMD-0xx_PCB	1	
Capacitor, ceramic	Multiple	1	0.01F 50V, 0603 (1608 metric) capacitor
Capacitor, ceramic	Multiple	1	1 µF ≥16V, 0603 (1608 metric) capacitor
FFC Connector	Multiple	1	FFC right angle 0.5mm pitch 10 pins
Ribbon Cable	Multiple	1	0.5mm pitch 10pin FFC Ribbon Cable



Breakout board for SMD-04B

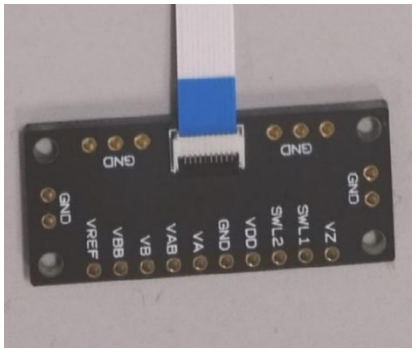
Item Name	Part number	BOM Qty	Description
Breakout PCB	SMD-ABZ-PCB	1	
FFC Connector	Multiple	1	FFC right angle 0.5mm pitch 10 pins
Ribbon Cable	Multiple	1	0.5mm pitch 10pin FFC Ribbon Cable

BOM for SMD-01B PCB

Item Name	Part number	BOM Qty	Description
Encoder IC	SMD-01B	1	
Encoder board	SMD-0xx_PCB	1	
Capacitor, ceramic	Multiple	1	0.01F 50V, 0603 (1608 metric) capacitor
Capacitor, ceramic	Multiple	1	1 µF ≥16V, 0603 (1608 metric) capacitor

Breakout board for SMD-01B

Item Name	Part number	BOM Qty	Description
Breakout PCB	SMD-AB-PCB	1	SMD-ABZ-PCB also may be used
FFC Connector	Multiple	1	FFC right angle 0.5mm pitch 10 pins
Ribbon Cable	Multiple	1	0.5mm pitch 10pin FFC Ribbon Cable



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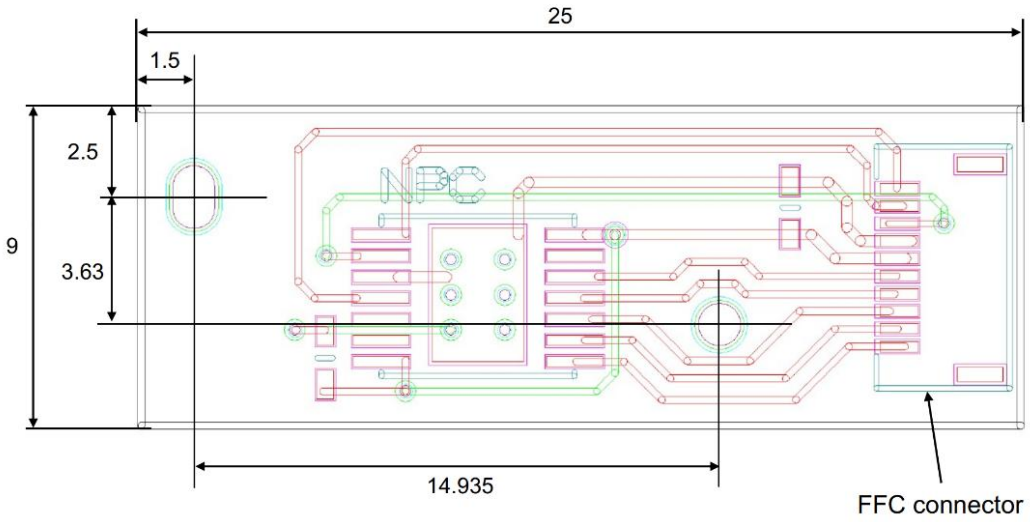
Appendix 2: SMD-AB(Z)-PCB Encoder board

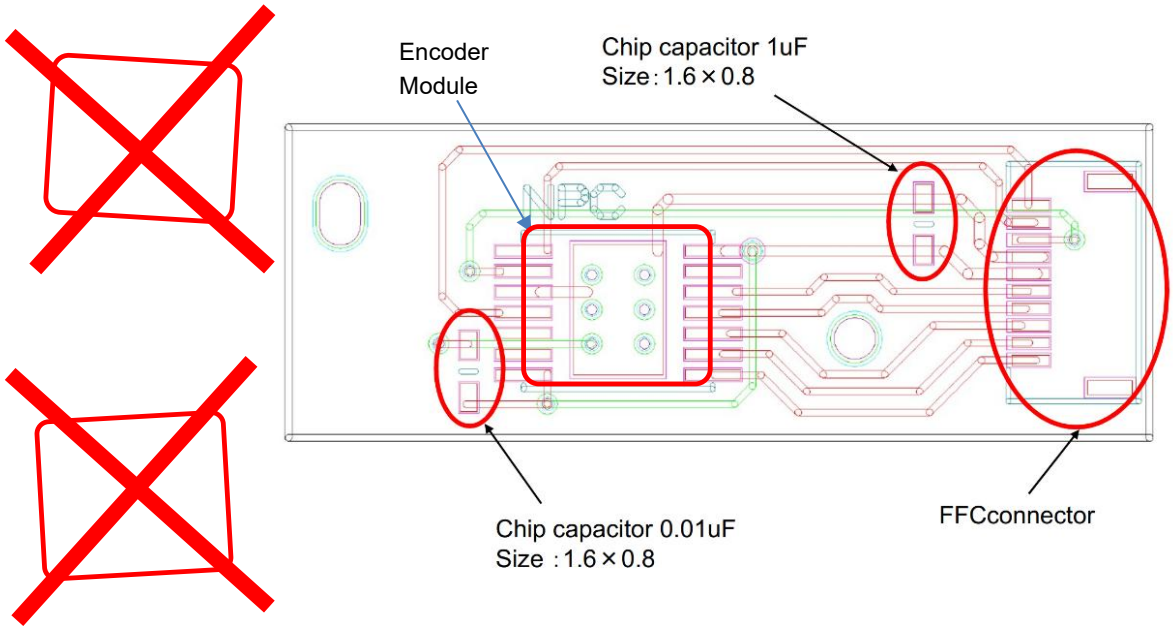
SMD-0xx_PCB Encoder Module Diagram



SMD-0xx_PCB component placement

In addition to encoder module, solder / mount the FFC connector plus four capacitors are shown.

Best performance is attained with module positioned <u>in-line</u> with PCB (no YAW, pitch, roll).



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SMD-0xx_PCB VREF Settings

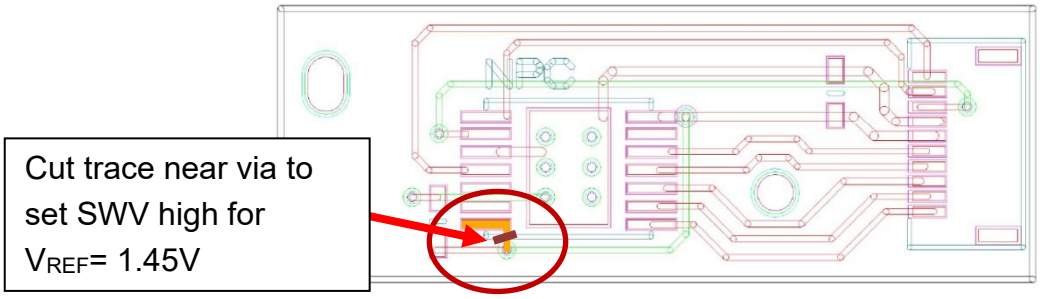
SWV, SWL1, SWL2 have internal pull-up resistors. No connect (NC) = Logic H

Operating at 3.3V require SWV = Logic High so V_{REF} operate at 1.45V nominal

Operating at 5V, set SWV, V_{REF} setting may be High or Low

The SMD-0xx_PCB as designed is for 5V operation with V_{REF} = 2.25V.

To set V_{REF} low and/or test SMD-01B at 3.3V, the trace from SWV to ground need be severed / cut.



o

Encoder	SMD-01B		SMD-01B SMD-04B	
V_{DD}	3.3V		5V	
SWV (V_{REF} setting)	H	L	**H**	**L**
V_{REF} output	1.45V	Do not use	1.45V	2.25V

LED Brightness Settings

Analog output amplitude can be adjusted by setting LED power for brightness..

SMD-01B LED settings

SWL1	SWL2	A/B amplitude
H	H	X1.0
H	L	X1.8
L	H	X2.6
L	L	Off

SMD-04B LED Settings

SWL1	SWL2	A/B amplitude	Index
H	H	X1.0	No
H	L	X1.8	No
L	H	APC*	Yes
L	L	Off	No

***APC** = Auto Power Control

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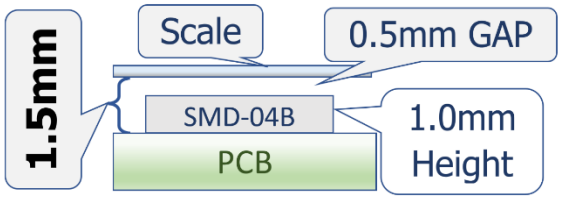
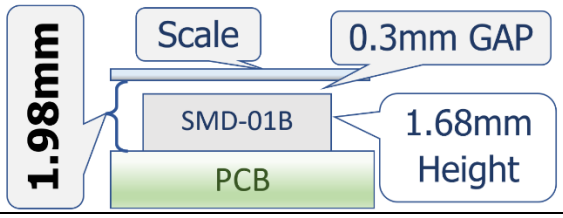
Appendix 3: GAP between Encoder and Scale

SMD-04B	SMD-01B
	

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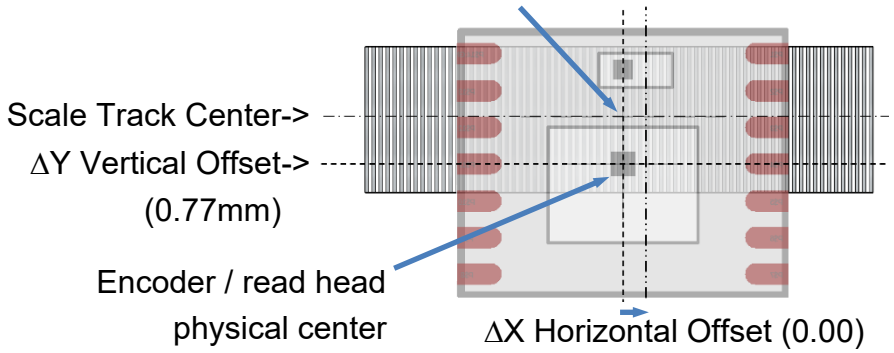
Optical Center of Encoder

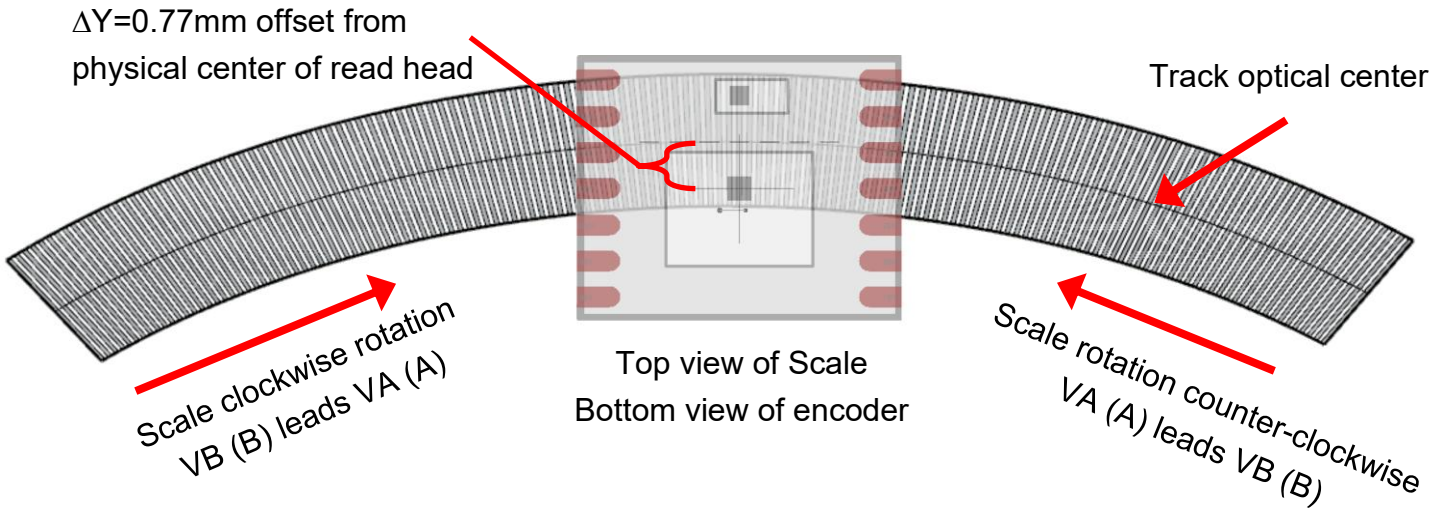
Align linear scale to encoder Optical Center



ΔY offset from center is 0.77mm for SMD-01A, SMD-01B and SMD-04B

The scale (track) can be as narrow as 0.5mm with encoder optical center properly aligned. A 2-3mm wide scale provide for ample ΔY tolerance for placement.

For rotary scales, aligning to optical center of encoder to the track optical center line is required for proper operation and achieve best encoder performance.



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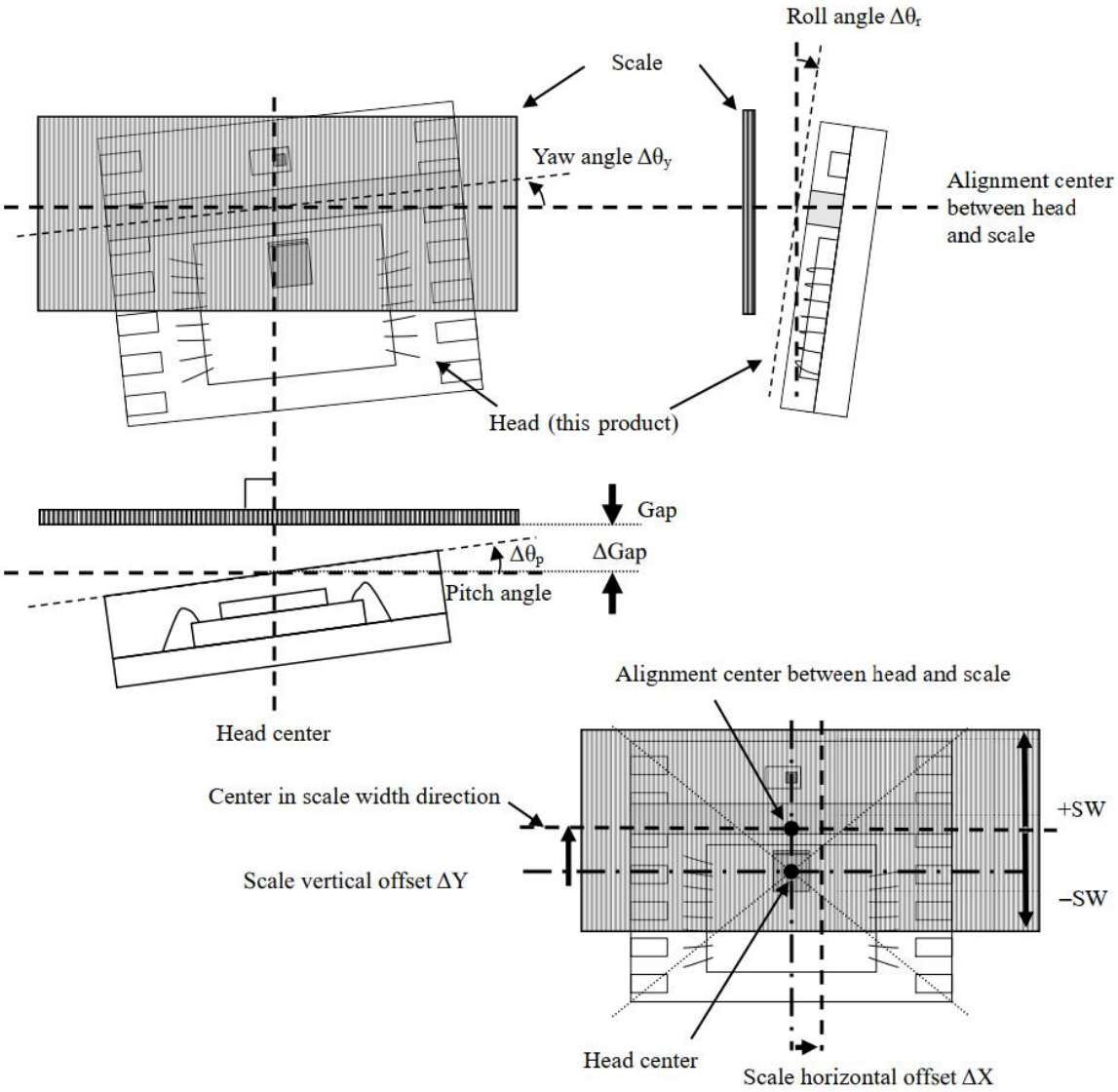
Encoder alignment to scale variation

The optical center of the encoder head is offset from physical center by 0.77mm in the vertical direction (ΔY) and 0.00mm for horizontal (ΔX). For linear scale, position encoder so optical center is over the track; at center line is ideal but within 0.5mm of scale edge is acceptable. Mount with 0° Yaw, 0°pitch, 0° roll, and specified gap.

For rotary scale, the ΔY and ΔX position need be accurately placed over the track optical center for optimum performance. Mount with 0° Yaw, 0°pitch, 0° roll, and specified gap.

See datasheet final pages for plots on output effects of misalignment. Mounting placement effects on amplitude and phase difference are greater for small diameter rotary scales than linear scales.



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Link to Scales for encoder applications

Scales for encoder applications

The best encoder accuracies are achieved using both Seiko NPC encoders and VC America Electronics precision glass scales which optimally maintain encoder low distortion and phase outputs. This is noticeable when seeking low error / highest accuracies.

VC America Electronics photolithographic processes are same used in semiconductor low sub-micron feature size to provide exceptional accuracy. Close examination of scales and specifications confirm the best interpolation require the least distortion; high definition scales and lower defects improve repeatability. And with error correction, best accuracies result.

Soda-lime glass and chrome coatings for reflective and anti-reflective patterns support most uses, And as needed we manufacture with specialized glasses and/or chrome coatings to meet specific customer requirements, (low CTE, specific spectral responses, etc)

Stainless Steel up to 135mm diameter or length offer alternative for thin scale 0.2mm.

Rotary

- Scales manufactured to specifications to 700mm diameter.
- Reflectivity coatings;
  - 50% minimum optimized for 650nm (Seiko SMD series 20µ period)
  - 60% minimum optimized for 850nm (Seiko SME series 80µ period)
- Anti-reflective:
  - None (Clear <5%)
  - Anti-reflective, optimized for 650nm or 850nm (Glass appears near black)
  - Other coatings for Blue, Infrared, and others
- Rotary scales edge
  - Straight cut
  - Laser cut and saw cut [where required.
  - Beveled with flat or round chamfer
  - Outside Diameter and/or inner core may be beveled.

Linear

Glass scales for up to 700mm in length, using same process outlined for rotary scales above; most common is chrome top-side pattern with bottom side Anti-Reflective coating (AR).

Less stringent applications supplied in stainless steel up to 135mm in length.

More detailed information about scale at sales@vcamericaelectronics.com and web site https://www.vcamericaelectronics.com

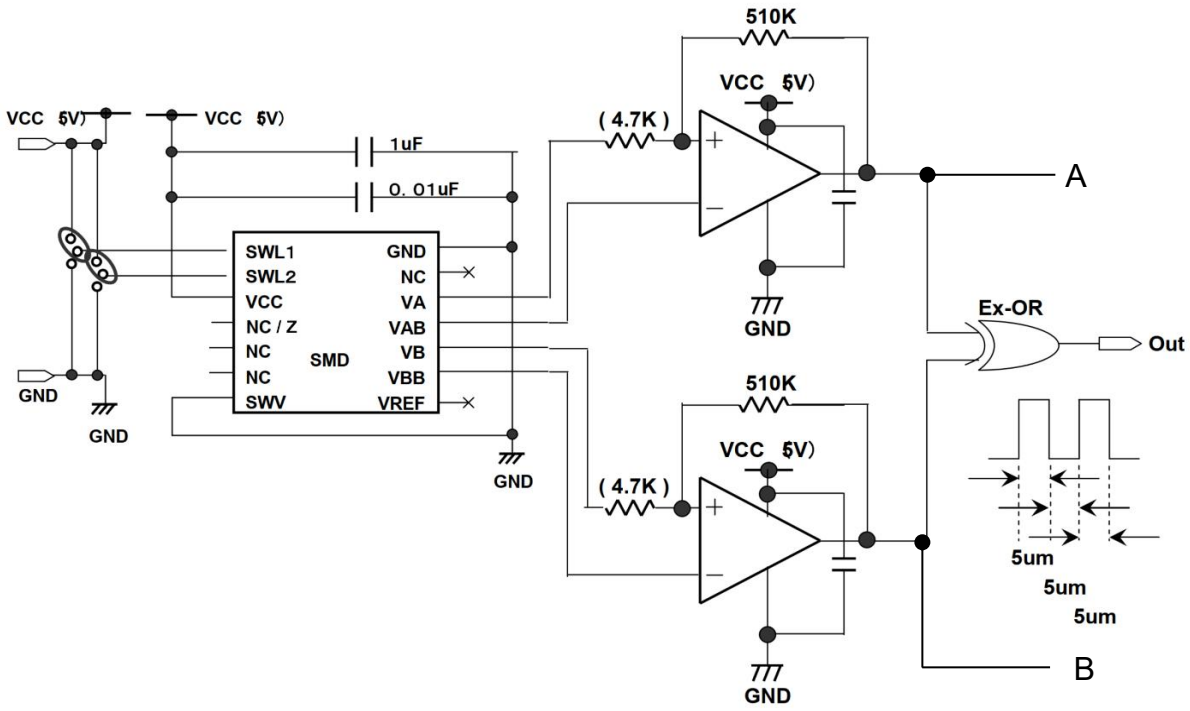
Link to Application Examples

How much resolution and accuracy are needed for an application?

How might those requirements influence design approach?

Three approaches for higher than native 20µm (micron) pitch/period are outlined here.

Medium resolution (5µm) application circuit



For 5-micron resolution and accuracy within ±1/2 count, this circuit output 4x quadrature digital outputs without ADC interpolation; Two comparators and Ex-OR gate generate the 5-micron digital output. A and B channels outputs are used to determine direction.

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Better resolution to ~1µm application circuit.

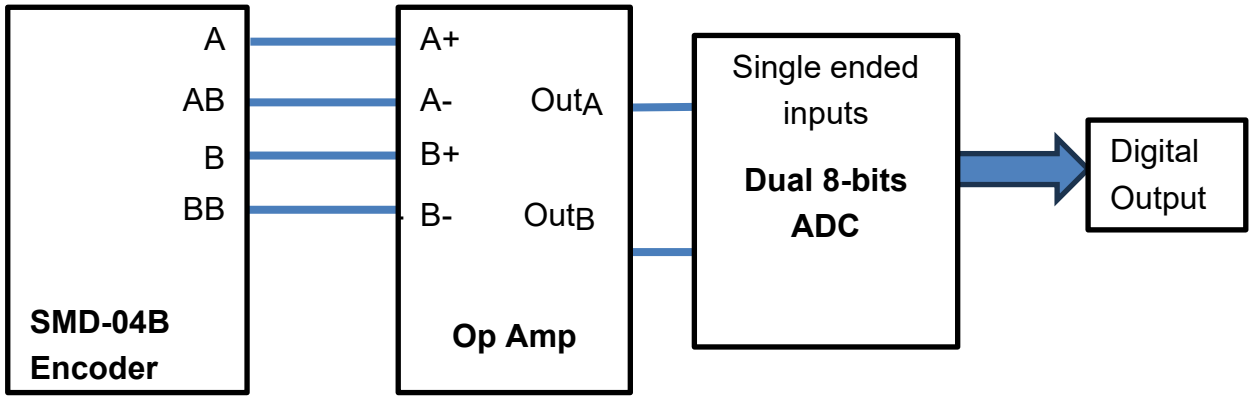
For applications requiring better than 5µm resolution and accuracy, Opamp buffers between the encoder and ADC are required. Where cost is particularly sensitive, a low cost opamp and single ended inputs to an 8-Bit ADC may work well provided attention to lowering ground and power supply is made. Adding an LDO (low dropout) voltage regulator with low noise, and some filtering may be sufficient.

This circuit buffers SMD-04B for low distortion outputs and the OpAmp outputs drive the inputs of ADC. We recommend multi-layer PCB to lower ground noise, good layout as recommended by the ADC maker, lowering power supply noise with added low noise LDO voltage regulator and filtering.

Circuit can achieve acceptable accuracies with interpolation factors of 8x and 16x (3-bit-4-bit) and better when circuit noise is low and highest voltage reference range is used.

Advantages: Lower production costs having selected low cost components.

Drawbacks: Higher voltage offsets and errors from OpAmp, ground noise added into ADC inputs which increase ADC conversion errors.



OpAmp buffers between Encoder and ADC

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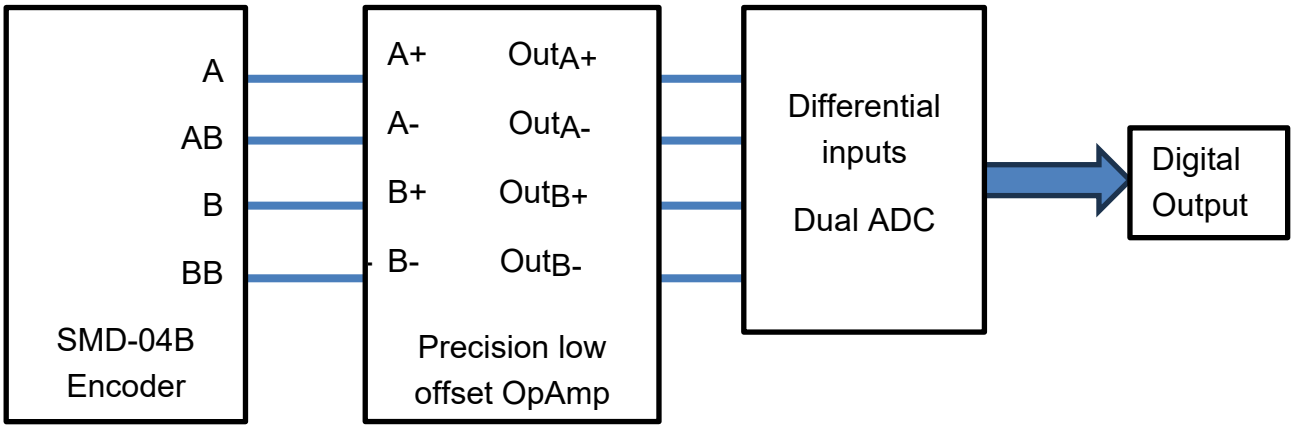
Higher to high resolution to <1nm application circuit

These circuits require good analog design and layout, separate analog grounds, power supply from a low noise LDO +filtering to achieve high SNR (signal to noise ratio) needed to convert the encoder output with acceptable accuracy.



Encoder with differential input and output OpAmps connecting to ADC

Circuit Noise. The two main sources of noise are power supply noise and ground noise, which can couple into the ADC's analog input and reference voltage, affecting the conversion process and impact Analog-to-Digital Converter (ADC) accuracy. The third is low noise voltage reference.

Using a 4.096V reference

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Lissajous curve

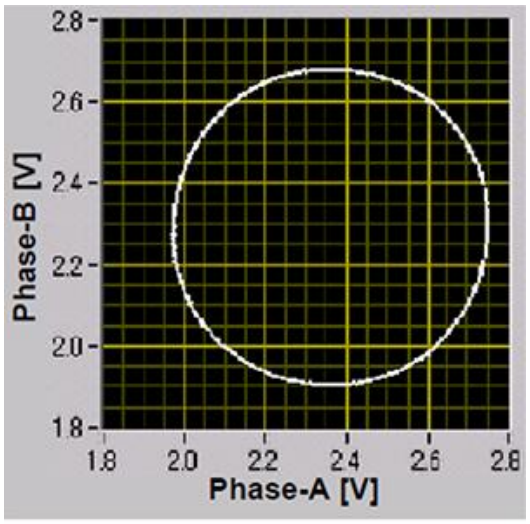
A good measure of linearity can be observed by generating a Lissajous curve/pattern.

This requires an oscilloscope which support XY display mode.

Set-up require 2-channel input: one input= X axis and the second=Y axis.

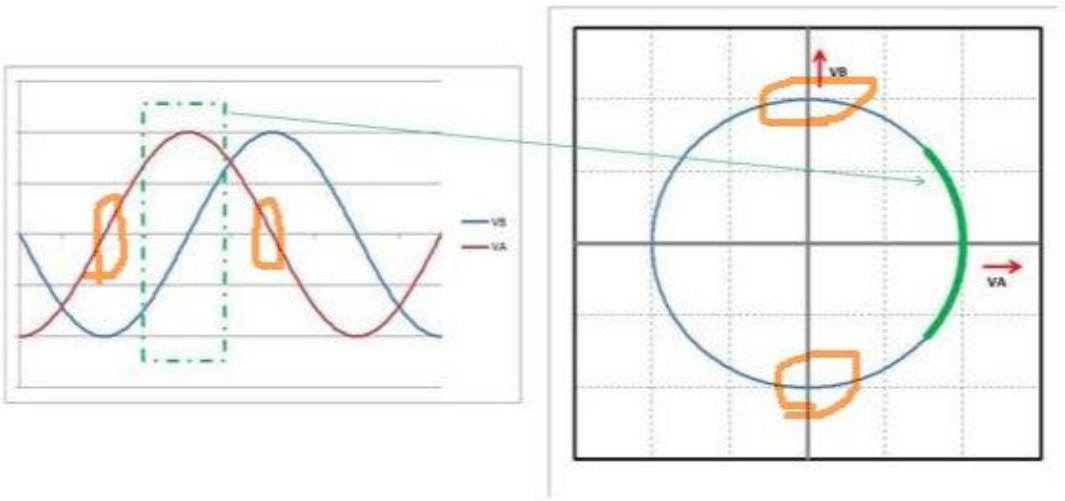
Graph at left show low distortion response of SMD-04B.

Use high impedance input for the probes as 50Ω termination will attenuate and distort signal



Measurement waveform

The graphic below shows the relationship and orientation of resulting circle relative to A and B signals. SMD-04B exhibits low distortion output with near perfect Lissajous circle pattern.



Support

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