SPECIFICATION

Specificatin No.
DATE: 2021. 08. 23

To

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CUSTOMER'S PRODUCT NAME	TDK'S PRODUCT NAME
	HHS-TAB4140BAAB-0010 TMR Angle Sensor TAB4140-BAAB

RECEIPT CONFIRMATION

DATE: YEAR MONTH DAY

TDK Corporation
Sales

APPROVED	Person in Charge

APPROVED	CHECKED	Person in Charge
T. Kagami	S. Koide	H. Naganuma

Contents

1 Product Description

1.1 Product Overview

- The TAB4140-BAAB is an angle sensor with TMR (Tunnel Magnet Resistance) technology for Automotive.
- This sensor detects applied magnetic field direction, and provides Sine and Cosine analog voltage output. The phase difference between Sine and Cosine is 90 degrees, and it can detect 360 degree in one rotation.
- This sensor contains two set of an angle sensor and an Amplifier ASIC in one package to support redundancy. It can be supported ISO26262.

1.2 Features

- High output and high precision sensor for magnetic field angle measurement based on TMR technology
- 360° contactless angle measurement
- High accuracy 0.6° overall angle error
- Integrate two sets of an angle sensor and an amplifier ASIC to support redundancy
- Single-ended analog voltage output Sine and Cosine
- 3V to 5.5V operating supply voltage
- Operating Temperature range (ambient): -40 to 150℃
- AEC-Q100 Automotive qualified

1.3 Target Applications

- EPS Motor-shaft Angle Sensor
- Steering Wheel Angle Sensor
- Pedal Position Sensor
- Throttle Position Sensor

2 Functional Description

2.1 Pin Assignment

Pin No	Name	Description
1	VREF1	Reference Voltage terminal for CH1
2	Cos1+	Cos1+ Analog Output
3	GND1	Ground for CH1
4	Cos1-	Cos1- Analog Output
5	Sin1-	Sin1- Analog Output
6	Vcc1	Power Source (Vcc) for CH1
7	Sin1+	Sin1+ Analog Output
8	TEST1	Test Mode setting terminal for CH1
9	VREF2	Reference Voltage terminal for CH2
10	Sin2+	Sin2+ Analog Output
11	GND2	Ground for CH2
12	Sin2-	Sin2+ Analog Output
13	Cos2-	Cos2- Analog Output
14	Vcc2	Power Source (Vcc) for CH2
15	Cos2+	Cos2+ Analog Output
16	TEST2	Test Mode setting terminal for CH2

Table 1: List of Pin Assign

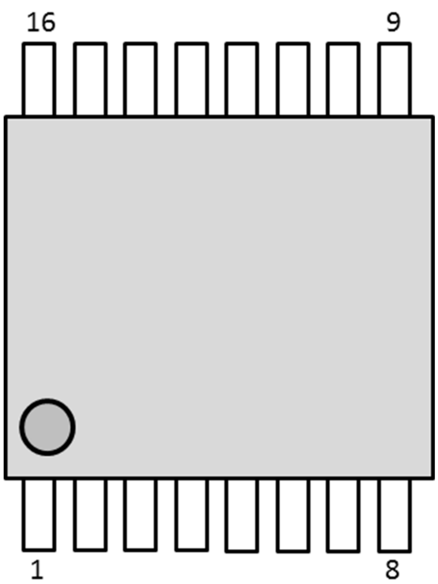


Figure 1: Pin No. Definition

2.2 Block Diagram

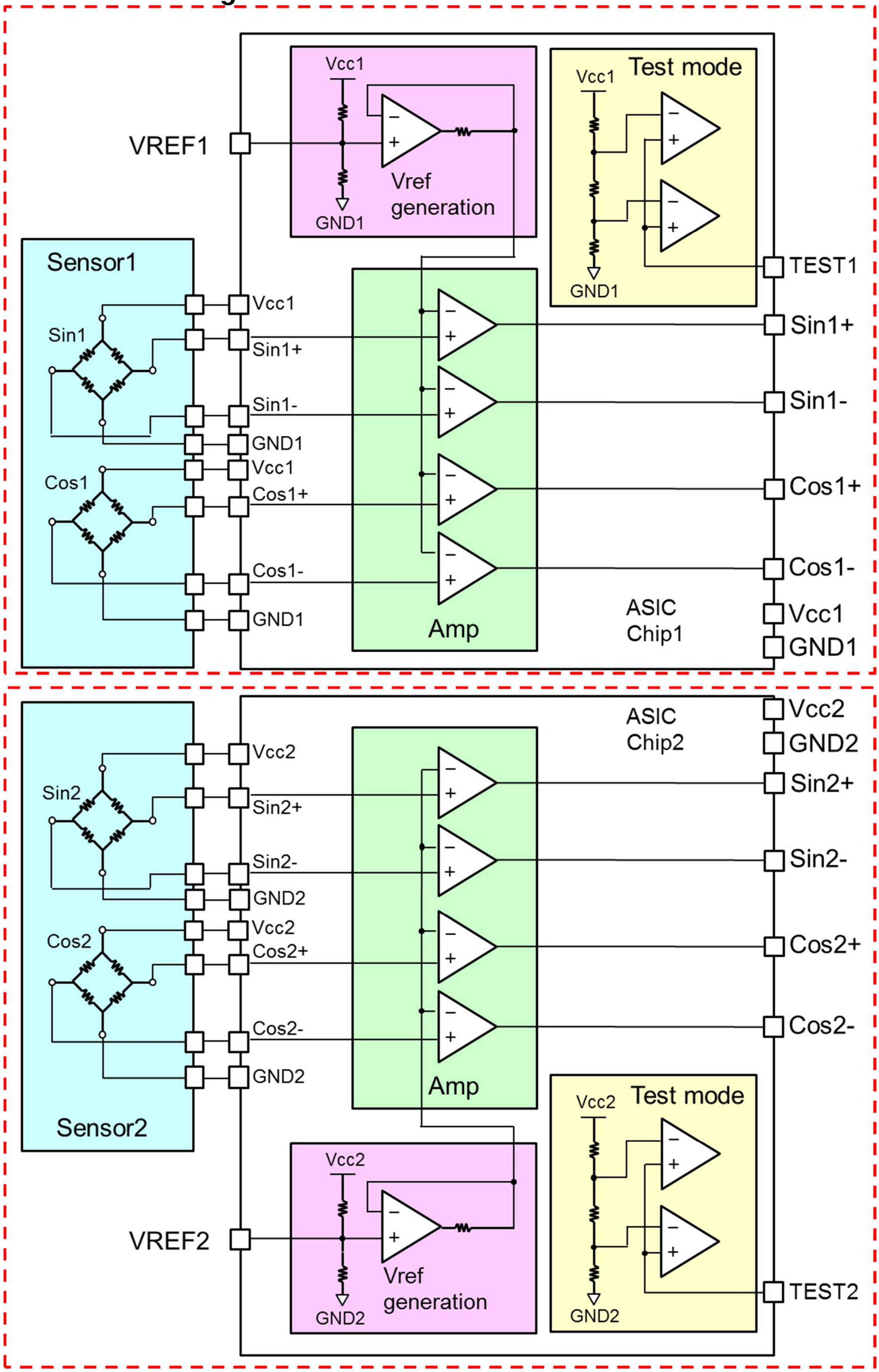


Figure 2: Block Diagram

2.3 Definition of Magnetic field direction

Definition of Magnetic field direction is as below.

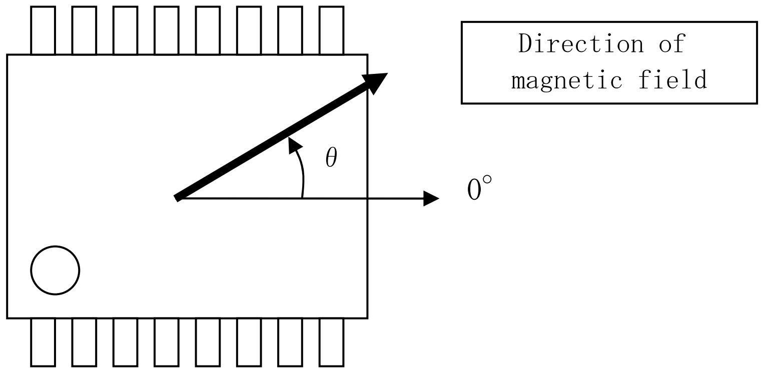
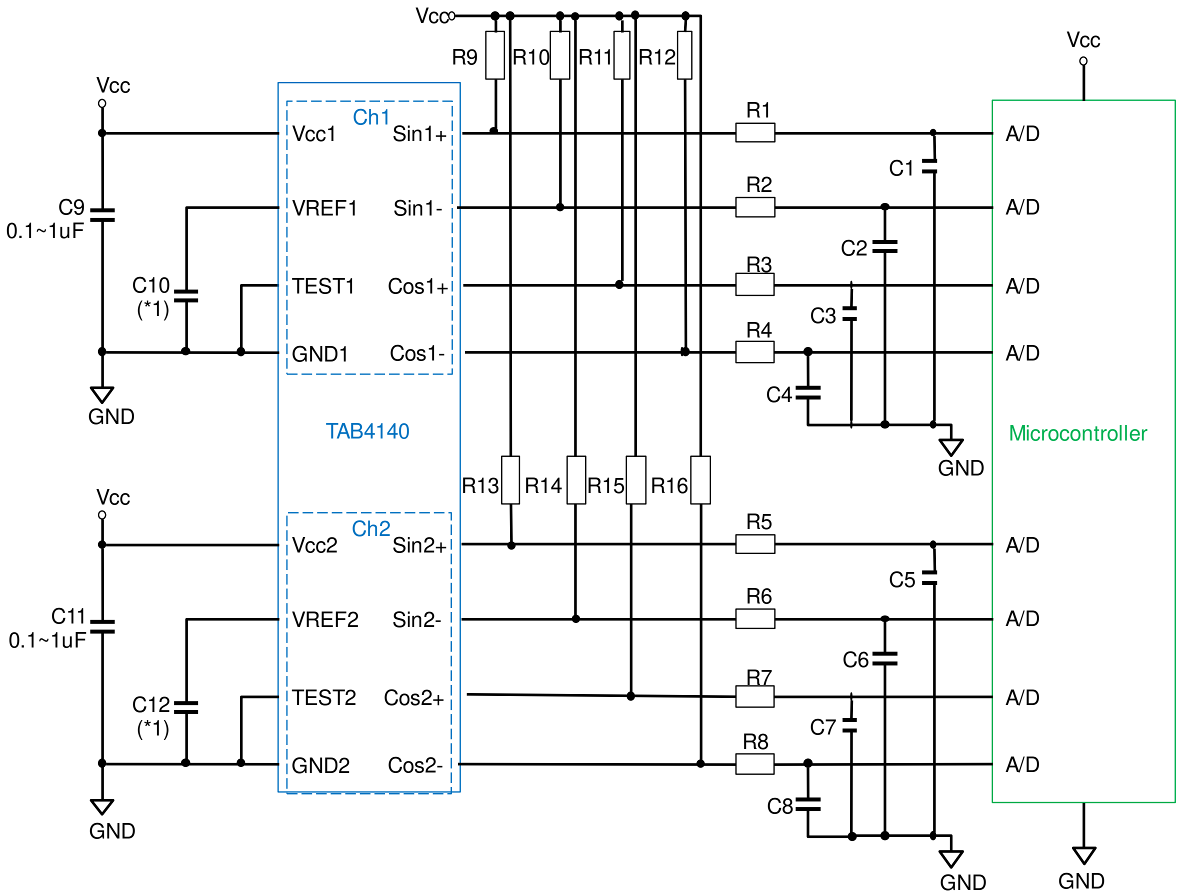


Figure 3: Definition of Magnetic field direction

2.4 Application Circuit



R1, R2, R3, R4, R5, R6, R7, R8: 470Ω*
C1, C2, C3, C4. C5, C6, C7, C8: 3.3nF*
R9, R10, R11, R12, R13, R14, R15, R16: ≧10kΩ
* The resistance value and the capacitance value are example.
  Depend on AAF (Anti Aliasing Filter) of ADC.
*1 C10 and C12 value is affected to the Start-up time.

Figure 4: Application Circuit

3 Specification

3.1 Absolute Maximum Ratings

Item	Symbol	Min.	Typ.	Max.	Unit	Remark
Supply Voltage	Vcc	-0.3		6.5	V	Maximum 1hour in case of more than 5.5V
Input Voltage	Vin	-0.3		Vcc	V	Any pin
Operating Temperature	Ta	-40		150	℃	
Junction Temperature	Tj	-40		170	℃	Tj = Ta + θja x Pd θja = 200℃/W Pd = Vcc x Icc
Storage Temperature	Tstg	-50		150	℃	
External Magnetic Field	Hext			|200|	mT	Less than 5 minutes

Table 2: Absolute Maximum Ratings

3.2 Operating Range

Item	Symbol	Min.	Typ.	Max.	Unit	Remark
Supply Voltage	Vcc	3.0	5.0	5.5	V	
Power Consumption	Icc		9	15.3	mA	Vcc=6.0V, two set total
Operating Temperature	Ta	-40		150	℃	
Junction Temperature	Tj	-40		170	℃	Tj = Ta + θja x Pd θja = 200℃/W Pd = Vcc x Icc
External Magnetic Field	Hext	20		80	mT	
Rotation Speed	θspd			10000	rpm	
Detectable Angle	θrng	0		360	degree	

Table 3: Operating Range

3.3 Electrical Characteristics

Ta=-40 to 150℃, Hext=20～80nmT, unless otherwise noticed.

Item	Symbol	Min.	Typ.	Max.	Unit	Remark
Output voltage amplitude	V_{out}	530	600	670	mV/V	Ta=25℃, 0hours
Temperature Coefficient of Output Voltage Amplitude	TC_{output}	-0.145	-0.125	-0.105	%/℃	
Output voltage offset	V_{offset_nor}	-20		20	mV/V	Ta=25℃, 0hours
Temperature drift of output voltage offset	V_{off_td}	-2.6		2.6	mV/V	Change value from Ta=25℃
Amplitude synchronism ratio	AR	95	100	105	%	Ta=25℃
Temperature drift of amplitude synchronism	$AR_{\_td}$	-1		1	%	Change value from Ta=25℃
Orthogonality Sin and Cos	Orth	87	90	93	degree	Ta=25℃
Orthogonality Sin+&sin-, Cos+&Cos-	Φ_{diff}	177	180	183	degree	Ta=25℃, 0hours
Temperature drift of orthogonality	$Orth_{\_td}$	-1		1	degree	Change value from Ta=25℃
Angle error	AE_OA			0.6	degree	Accordance chapter 5 Absolute value
Output cutoff(-3dB) frequency	f_{-3dB}	100			kHz	R_{LPF} ≧ 470ohm C_{LPF} ≦ 3.3nF
Startup time	T_{strup}			30	us	After Vcc>3V VREF1,2: Open Vcc rise-up time≦5us
				300	us	After Vcc>3V VREF1,2: 1nF Vcc rise-up time≦50us

Table 4: Electrical Characteristics

・Output voltage amplitude and output voltage offset

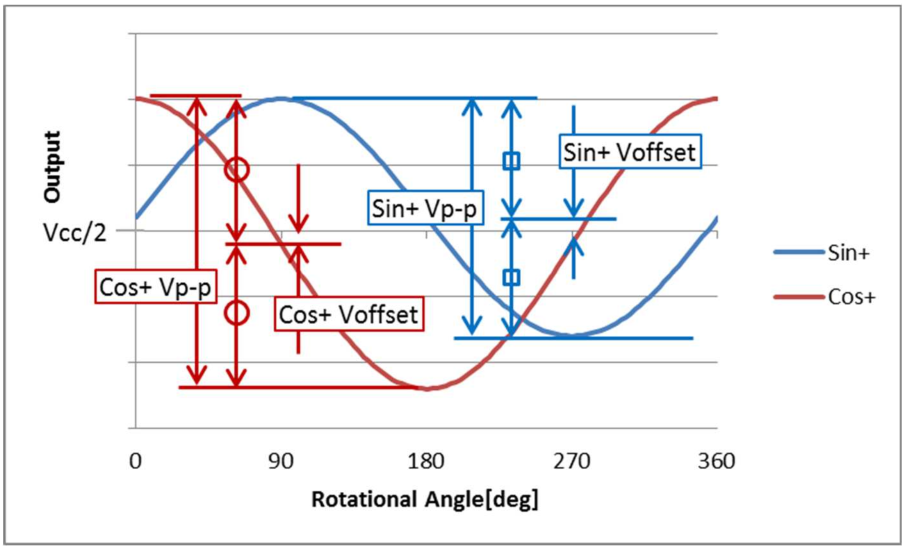


Figure 5: Definition of output voltage amplitude and output voltage offset

$$\mathrm{Vout} = \frac{V_{p-p}}{Vcc}$$

$$\mathrm{Voffset\_nor} = \frac{V_{offset}}{Vcc}$$

・Temperature coefficient of output voltage amplitude

$$\mathrm{TCoutput} = \frac{\left(V_{p-p@150℃} - V_{p-p@-40℃}\right)}{\left(V_{p-p@25℃} \times (150℃ - (-40℃)\right)} \times 100$$

・Temperature drift of output voltage offset

$$\mathrm{Voff_{td}} = \frac{V_{offset@150℃} - V_{offset@25℃}}{Vcc}, \quad \frac{V_{offset@-40℃} - V_{offset@25℃}}{Vcc}$$

・Amplitude synchronism ratio

$$\mathrm{AR} = \frac{\mathrm{Cos}V_{p-p}}{\mathrm{Sin}V_{p-p}} \times 100$$

・Temperature drift of Amplitude synchronism ratio

$$\mathrm{AR_{td}} = \frac{\text{AR@150℃-AR@25℃}}{\text{AR@25℃}} \times 100, \quad \frac{\text{AR@-40℃-AR@25℃}}{\text{AR@25℃}} \times 100$$

3.4 ESD Protection

Item	Symbol	Min.	Typ.	Max.	Unit	Remark
Human Body Model	V_{HBM}			±4	kV	Pin combination: 1 to 8pin or 9 to 16pin
				±2	kV	Pin combination: either of 1-8pin and either of 9-16pin
Charged Device Model	V_{CDM}			500	V	
Latch-up	I_{lat}			±100	mA	

Table 5: ESD Protection

3.5 Diagnostics

3.5.1 Self-Diagnosis

The TAB4140 performs the following self-diagnostic for sensor. The output of Amp becomes Hi or Lo as following Table 6.

Sensor Output	Amplifier Output *4
Hi *1	Hi *1
Lo *2	Lo *2
HiZ *3	Hi *1

Table 6: Self-Diagnosis

(*1) Hi: Digital high > VCC-0.23V
(*2) Lo: Digital low < 0.23V
(*3) HiZ: Resistor of sensor to ground > 100MOhm
(*4) Amplifier output will react after 200us worst case

3.5.2 Test mode Description

The TAB4140 has built-in test circuit as shown Table 7 and Table 8. The test mode is determinate by the selection of three levels from the voltage of TEST1 and TEST2.

Mode	TEST1 Supply Voltage	Sin1+ Output	Sin1- Output	Cos1+ Output	Cos1- Output
Normal	0	Normal Operation			
Sensor Output Test	Vcc1/2	Sin1+ Output of sensor	Sin1- Output of sensor	Cos1+ Output of sensor	Cos1- Output of sensor
Amp Offset test	Vcc1	Amplifier output when the input of each amplifier is short-circuited			

Table 7: Mode select table TEST1

Mode	TEST2 Supply Voltage	Sin2+ Output	Sin2- Output	Cos2+ Output	Cos2- Output
Normal	0	Normal Operation			
Sensor Output Test	Vcc2/2	Sin2+ Output of sensor	Sin2- Output of sensor	Cos2+ Output of sensor	Cos2- Output of sensor
Amp Offset test	Vcc2	Amplifier output when the input of each amplifier is short-circuited			

Table 8: Mode select table TEST2

TEST1 and TEST2 are independent. For example, even if the voltage is added to TEST1, the outputs (Sin2+, Sin2-, Cos2+ and Cos2-) are not changed.

4 Package Information

4.1 Package Parameter

Item	Min.	Typ.	Max.	Unit	Remark
Thermal Resistance (θ_{ja})		200		℃ /W	4 layers substrate
Moisture Sensitivity Level	MSL 1				IPC/JEDEC J-STD-020E
Leadframe Material	Cu				EFTEC-64T
Plating Material	Sn 100%				

Table 9: Package Parameter

4.2 Package Outline

TSSOP16

Unit : mm

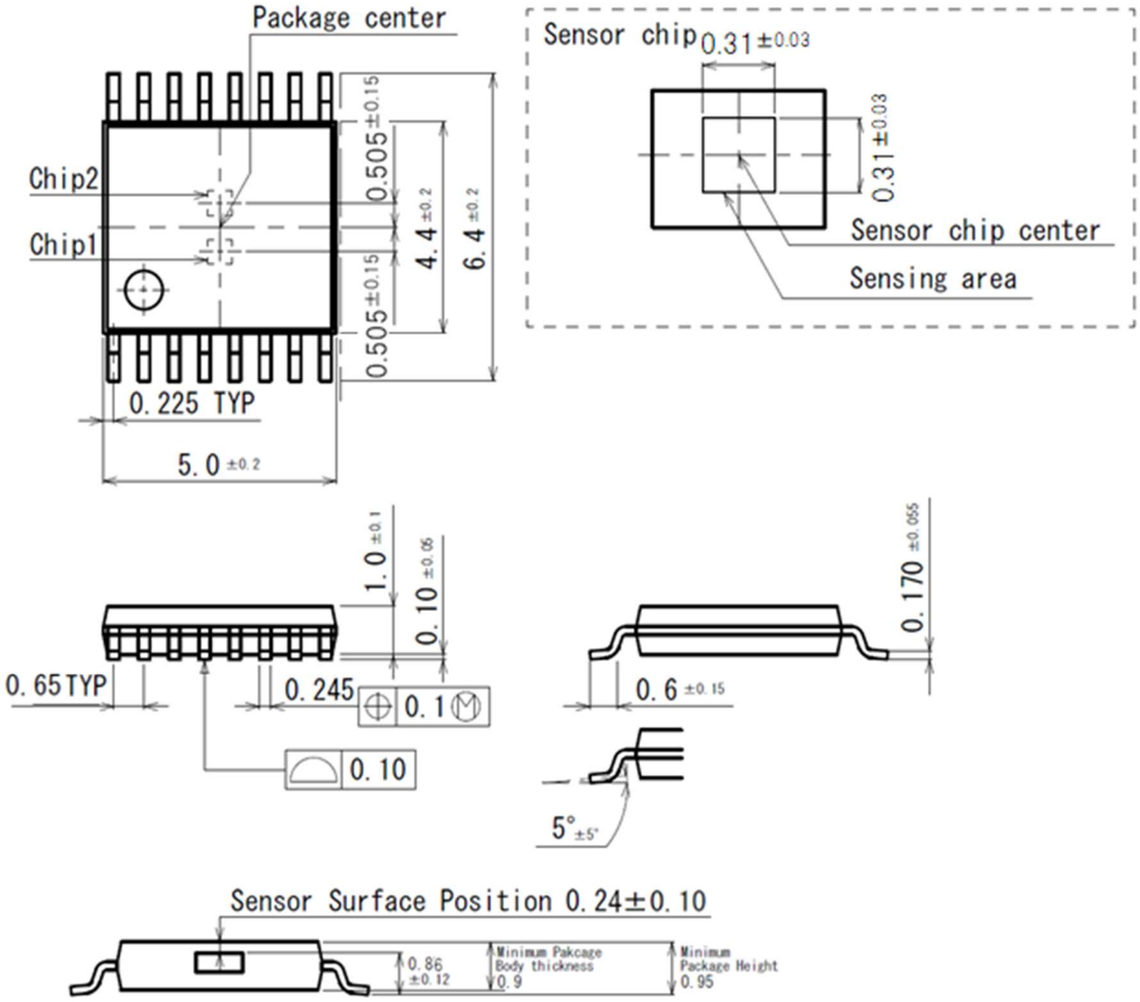


Figure 6: Package dimensions of TSSOP-16

4.3 Device marking

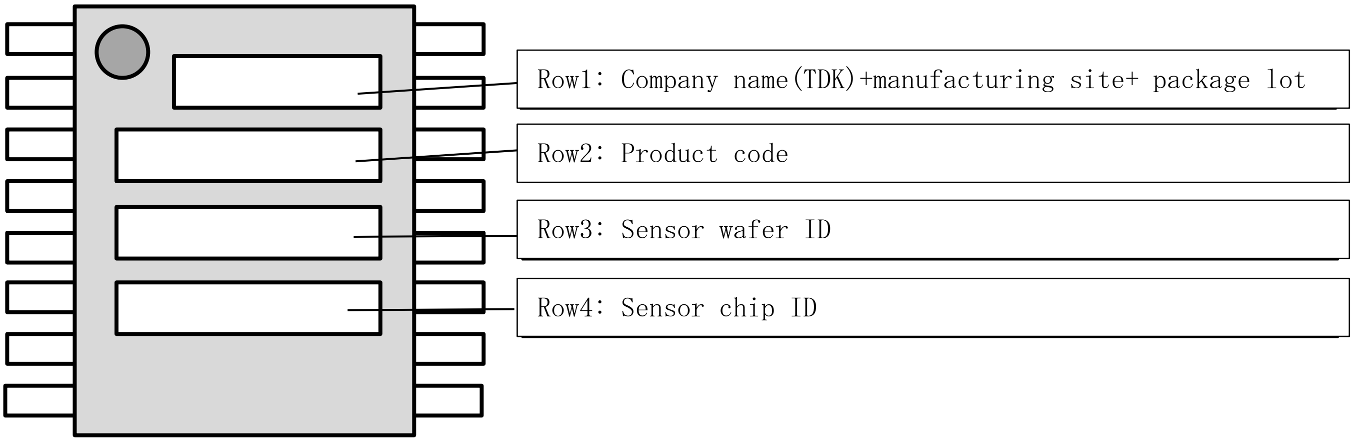


Figure 7: Marking Description

4.4 Footprint

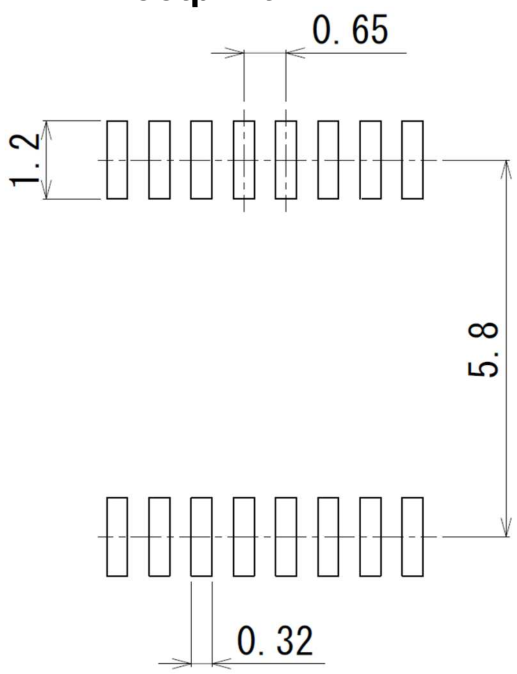
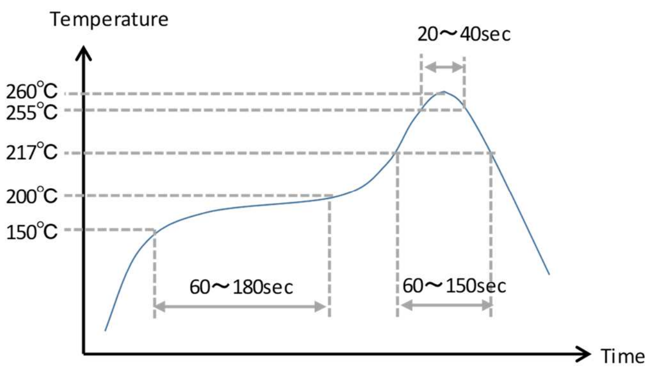


Figure 8: Footprint

4.5 Reflow profile (Reference)

Peak temperature should not exceed 260degC.
Reflow Profile: JEDEC IPC/JEDEC J-STD-020D

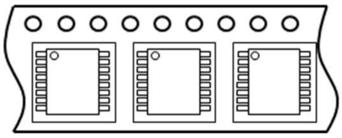


Item	Contents
Peak temperature	260℃
Peak temperature time	20～40sec, 255～260℃
Reflow time	60～150sec, 217℃ or more
Residual heat condition	60～180sec, 150～200℃
Heating rate	3℃/sec Max, 217～255℃
Cooling rate	6℃/sec Max
Total heating time	8min or less
Number of reflows	3times Max

4.6 Packing Specifications

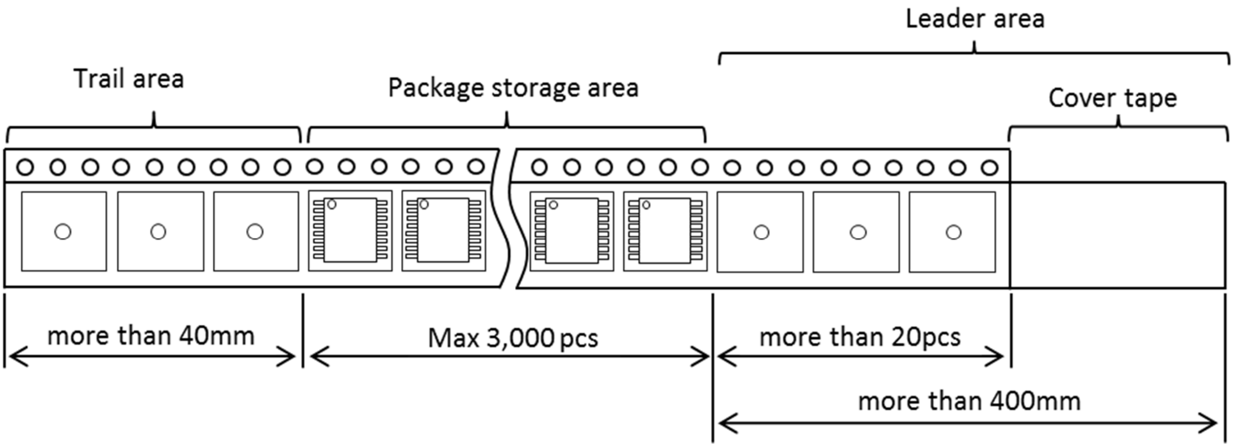
1. Taping Specification

E2 Type



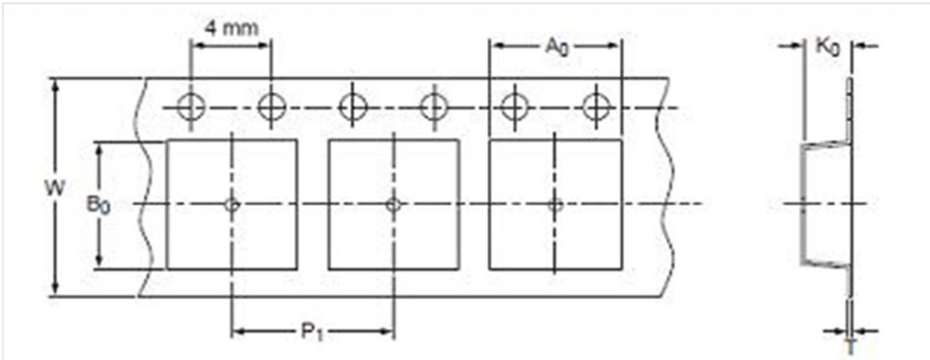
Pulling Direction→

2. Package storage method



3. Carrier Tape

Material: Polystrene + Carbon
Surface resistance: 1×10^7Ω/10cm
Color: Black

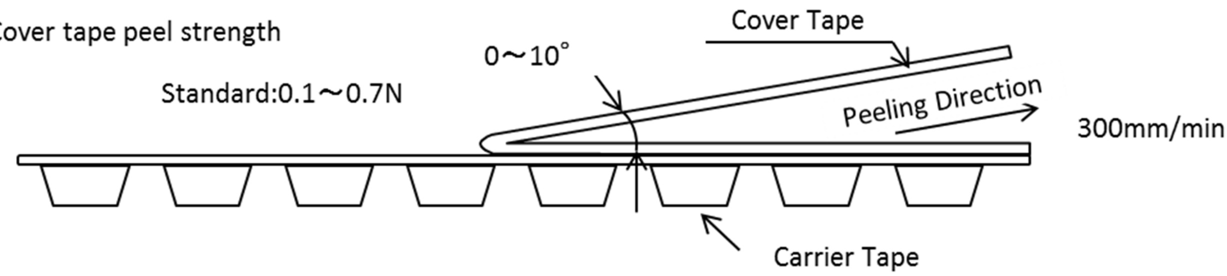


unit : mm

A_0	B_0	K_0	T	P_1	W
6.95	5.60	1.60	0.30	8.00	12.00

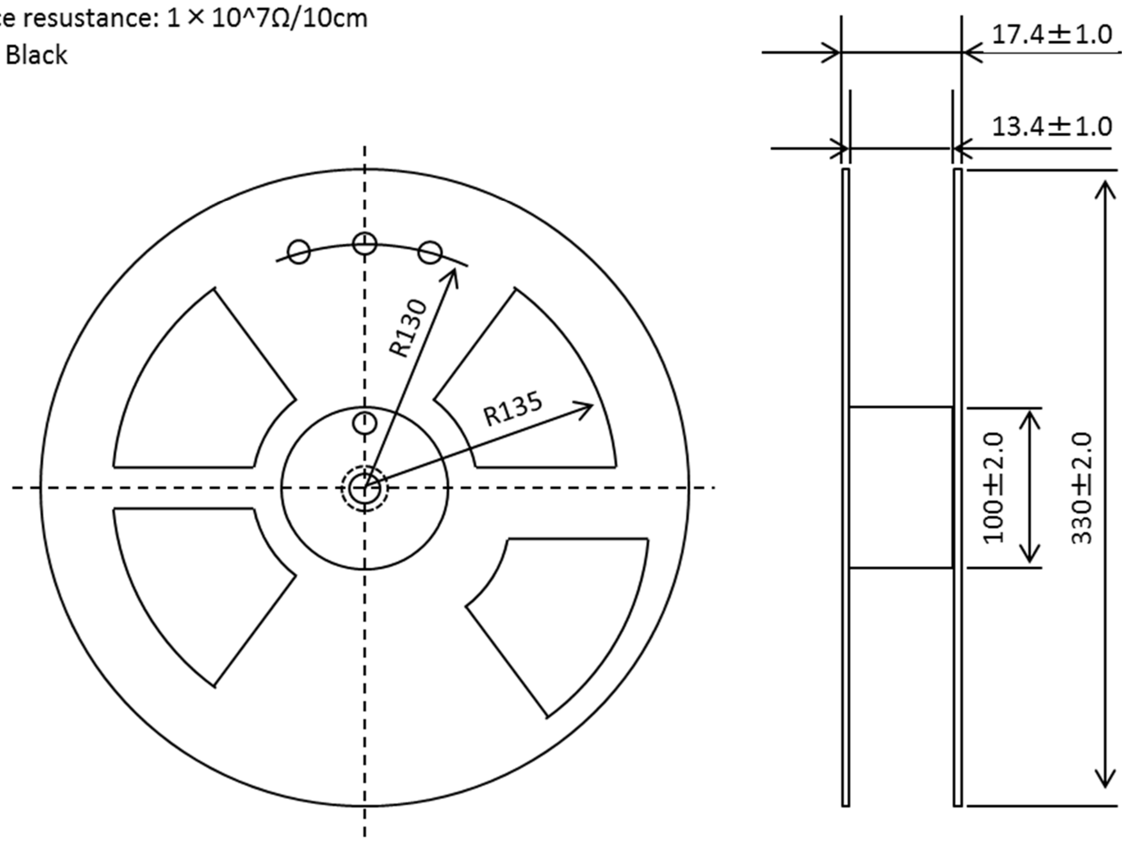
4. Cover tape peel strength

Standard:0.1～0.7N



5. Reel Specification

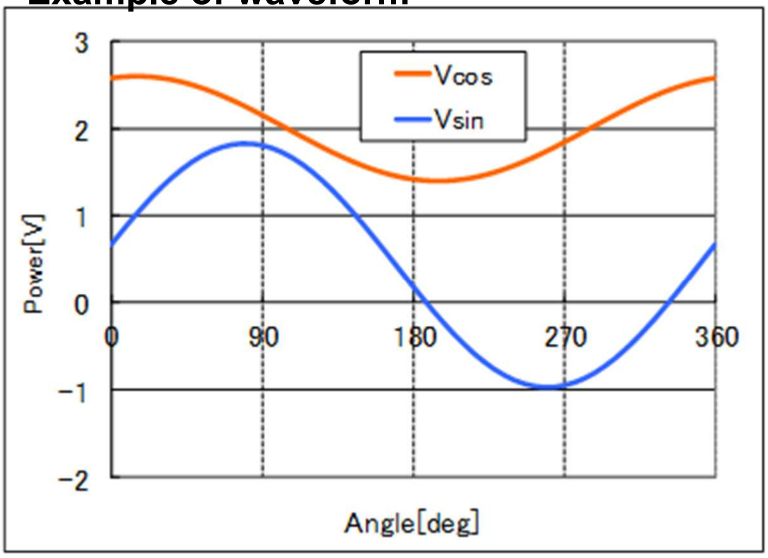
Material: Polystyrene
Surface resustance: 1×10^7Ω/10cm
Color: Black



5 Angle calculation and compensation

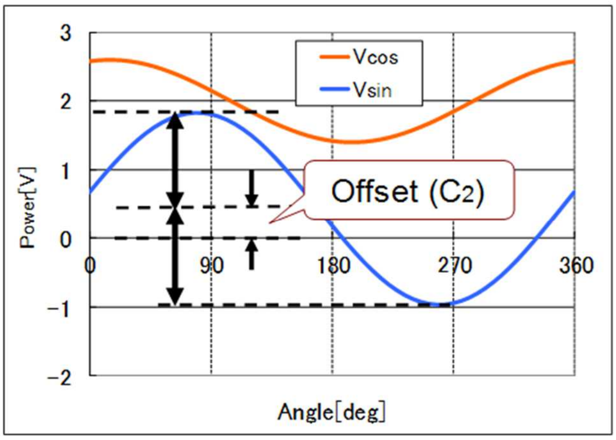
No.	Compensation	Description
1	Offset compensa-tion	The output offset would be 0
2	Gain compensation	The output gain would be normalized
3	Phase Compensation	The phase offset between Sine and Cosine would be 90deg by "Cos+Sin" & "Cos - Sin".
4		Angle & Angle Error calculation
5		Offset compensation of Angle Error

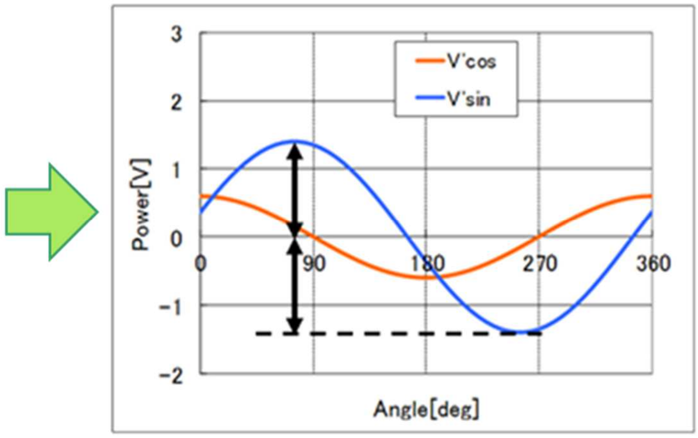
Example of waveform



5.1 Output voltage offset compensation

The output voltage offset value is calculated by Output Maximum value and Output Minimum value.





1. Calculate the output offset value

$$C_1 = \frac{\mathrm{Max}[V_{\cos}(\theta)] + \mathrm{Min}[V_{\cos}(\theta)]}{2}$$

$$C_2 = \frac{\mathrm{Max}[V_{\sin}(\theta)] + \mathrm{Min}[V_{\sin}(\theta)]}{2}$$

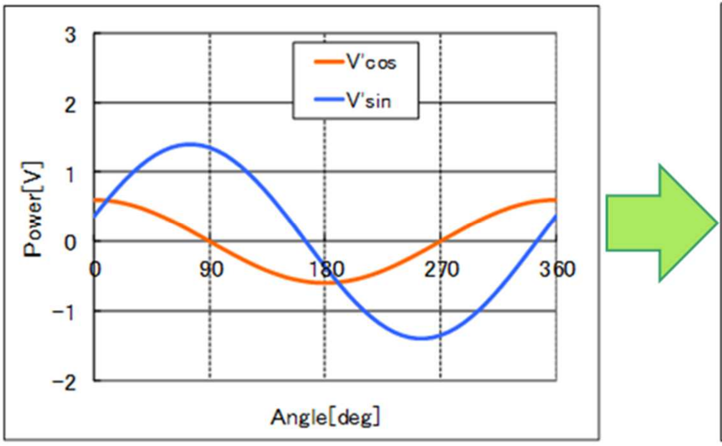
2. Subtract the output offset value

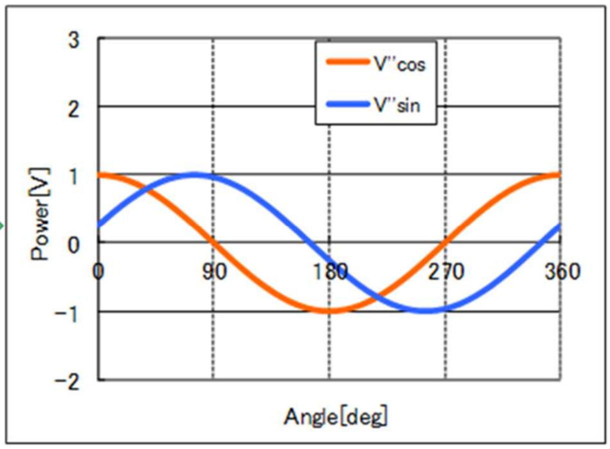
$$V'_{\cos}(\theta) = V_{\cos}(\theta) - C_1$$

$$V'_{\sin}(\theta) = V_{\sin}(\theta) - C_2$$

5.2 Gain compensation

The Compensation value of output gain is calculated by Output maximum value and Output minimum value for normalizing to 1.





1. Calculate the output amplitude

$$A_1 = \frac{\mathrm{Max}[V_{\cos}(\theta)] - \mathrm{Min}[V_{\cos}(\theta)]}{2}$$

$$A_2 = \frac{\mathrm{Max}[V_{\sin}(\theta)] - \mathrm{Min}[V_{\sin}(\theta)]}{2}$$

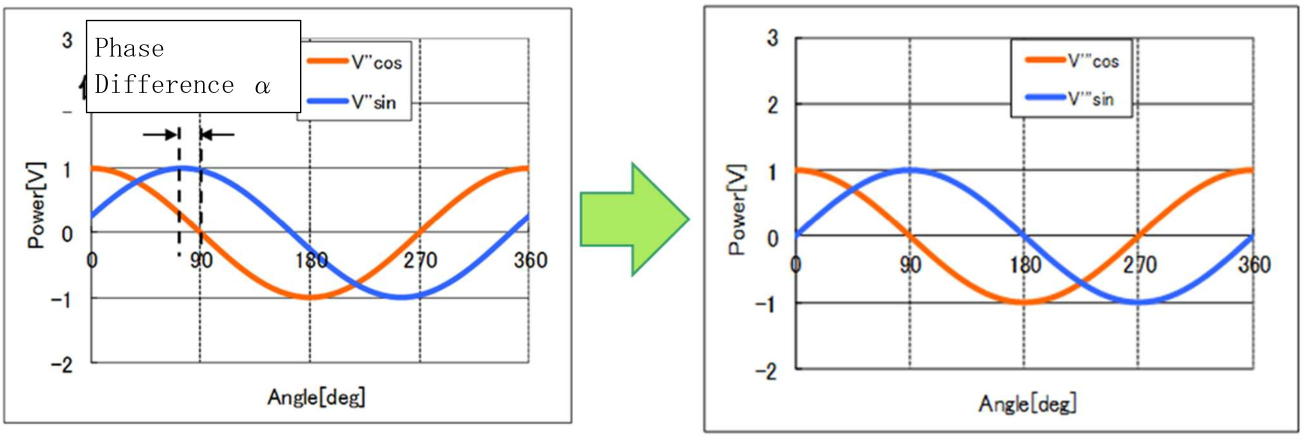
2. Normalize the output to 1.

$$V''_{\cos}(\theta) = \frac{1}{A_1} V'_{\cos}(\theta)$$

$$V''_{\sin}(\theta) = \frac{1}{A_2} V'_{\sin}(\theta)$$

5.3 Phase compensation

Using Sine Output value and Cosine Output value, the orthogonality between Sine and Cosine would be compensated.



When the phase difference between Sine and Cosine would be 90deg, it becomes to decrease the Angle Error.

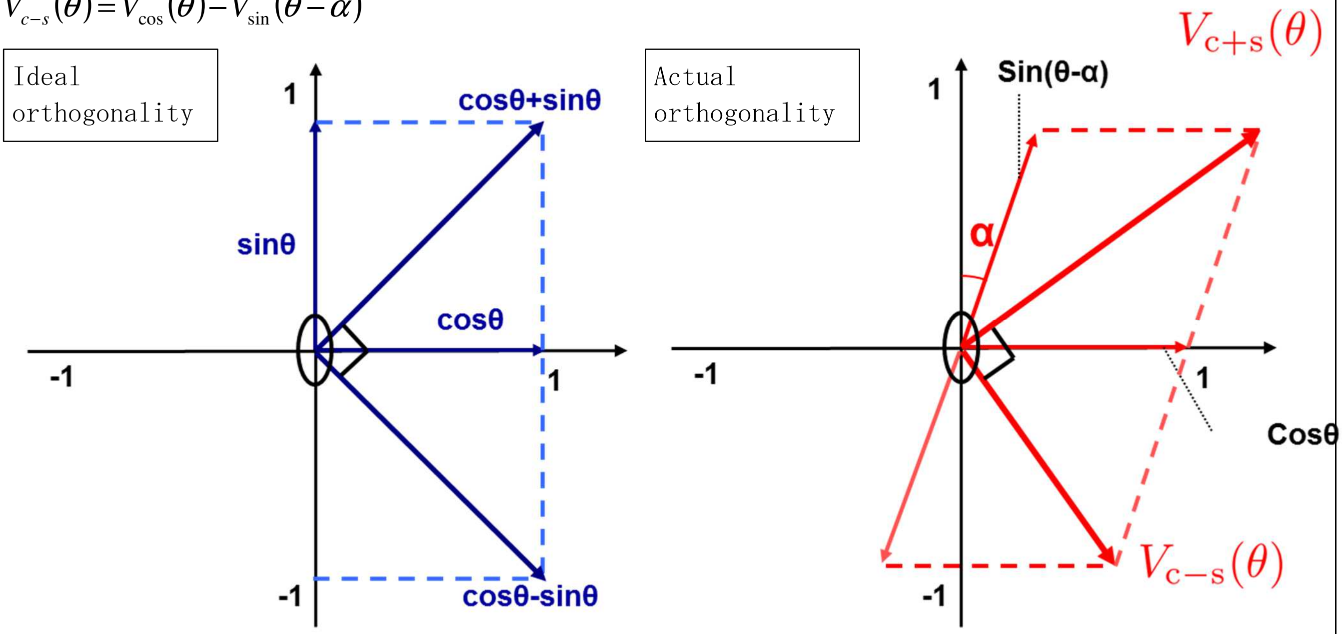
It is possible to compensate without measuring the value of phase difference α.

The detail of phase compensation method is as below.

1. To calculate Vc+s and Vc-s, which define that V" cos(θ) should be ideal phase and the phase difference between ideal Sinθ and V" sin(θ) should be α,

$$V_{c+s}(\theta)=V_{\cos}^{"}(\theta)+V_{\sin}^{"}(\theta-\alpha)$$

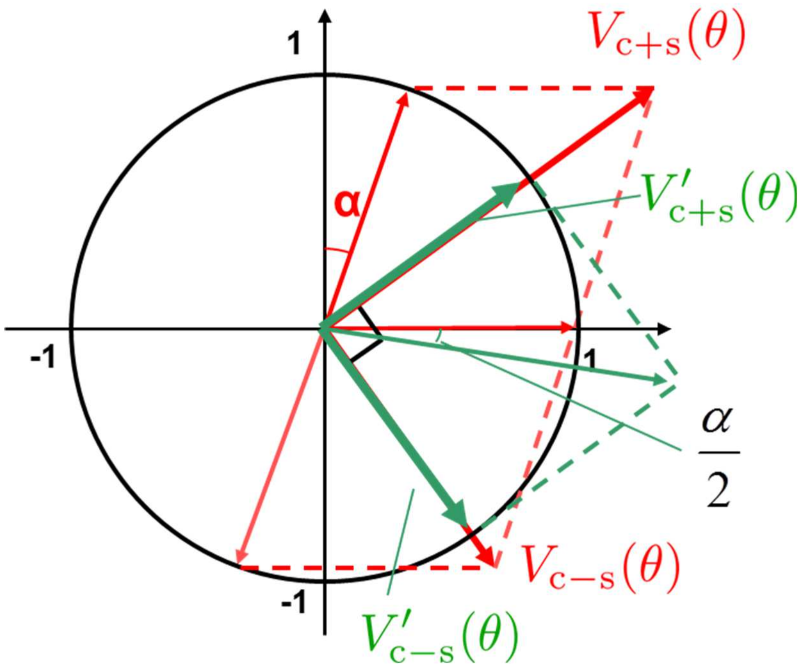
$$V_{c-s}(\theta)=V_{\cos}^{"}(\theta)-V_{\sin}^{"}(\theta-\alpha)$$



2. When calculate the amplitude value of Vc+s and Vc-s, those amplitude value should be normalized to 1.

$$B_1 = \frac{\mathrm{Max}[V_{c+s}(\theta)] - \mathrm{Min}[V_{c+s}(\theta)]}{2} \qquad V'_{c+s}(\theta) = \frac{1}{B_1} V_{c+s}(\theta)$$

$$B_2 = \frac{\mathrm{Max}[V_{c-s}(\theta)] - \mathrm{Min}[V_{c-s}(\theta)]}{2} \qquad V'_{c-s}(\theta) = \frac{1}{B_2} V_{c-s}(\theta)$$



3. Calculate phase compensation value form the amplitude of Vc+s and Vc-s

$$\phi = \tan^{-1}\left(\frac{B_2}{B_1}\right) = 45 - \frac{\alpha}{2}$$

5.4 Angle and Angle error calculation

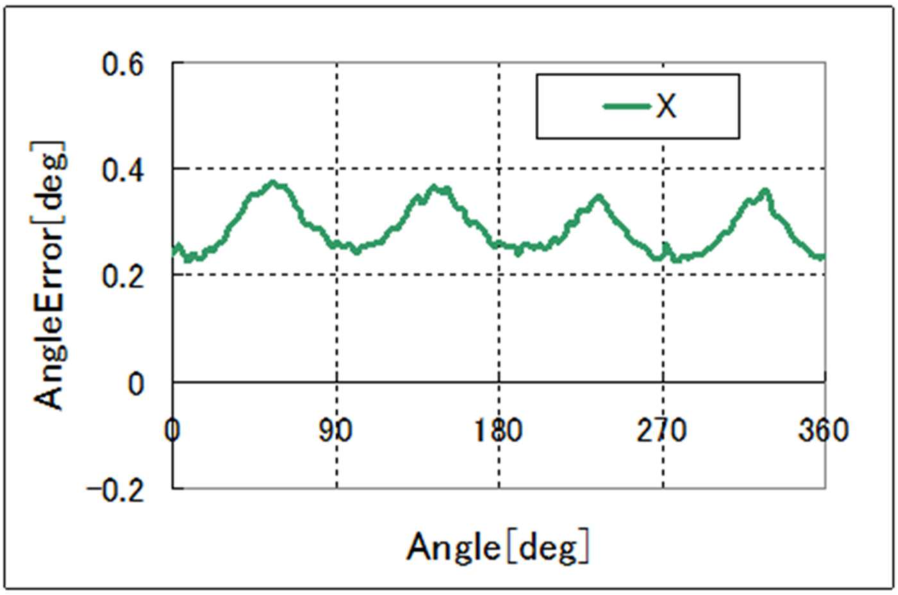
1. The Angle & Angle Error would be calculated with phase compensation.

$$\theta_{sens} = \tan^{-1}\left(\frac{V'_{c+s}(\theta)}{V'_{c-s}(\theta)}\right) - \phi \qquad \phi = 45 - \frac{\alpha}{2}$$

2. Calculate Angle Error X(θ)

$$X(\theta) = \theta_{\text{sens}} - \theta_{\text{std}}$$

Angle value θstd is coming from the Encoder value.



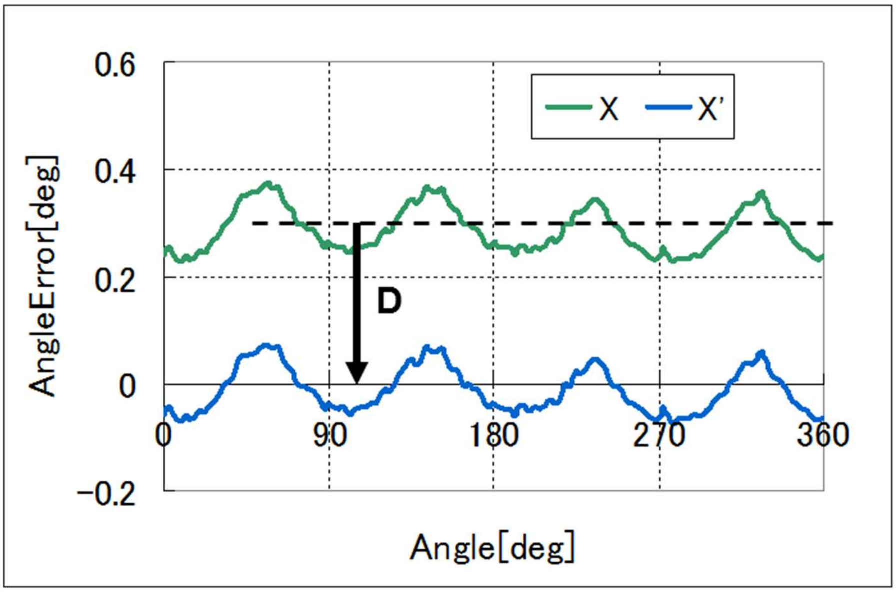
5.5 Compensation of angle error offset

1. Calculate the offset value D of Angle Error X(θ)

$$\mathrm{D} = \frac{\mathrm{Max}[X(\theta)] + \mathrm{Min}[X(\theta)]}{2}$$

2. Calculate compensated Angle Error X' (θ)

$$X'(\theta) = X(\theta) - \mathrm{D}$$



3. Angle Error AE is defined as below

$$AE = Max(X'(\theta))$$

6 Instruction for use

A) Instruction for Use

① Before using of this product, please read this specification.

B) Instruction for Safety

① Please pay attention to each notice when designs safety application.

C) Notice :

① The recommended storage period should be:
   1. Less than 12 months with packing condition in Tape and Reel.
   2. Less than 30 days without packing condition.
   3. Less than 12 months by combined with and without packing condition.

② Please be careful of storage conditions:
   1. The temperature should be from 5degC to 40degC.
   2. The humidity should be less than 75%RH in a packing state.
   3. Prevent the formation of any condensation by sudden temperature change.

③ If exceed the recommended storage period, there is a possibility that solderability of the terminal may deteriorate.

④ The storage for a long time in a magnetic field may affect the sensor characteristics, so please keep it in a weak magnetic field condition less than 0.3mT or no magnetic field condition without any generating a magnetic field nearby.

⑤ The starting date of the storage period should be the date of displayed in the label attached to the reel.

⑥ The storage to affect some stress to package is dangerous. Do not apply a load of 5 N or more to the product top side (printed side). Please prevent the load to package under storage because there are some risk like the deformation of package pin and the change of sensor characteristics.

⑦ Please do not store or use in the environment (salt, acid, alkali, etc.) accompanied by gas corrosion (chlorine, acid, alkali, etc.)

⑧ When do re-soldering after mounting on PCB, there is a possibility of a short circuit, performance deterioration, and a decrease of lifetime by excessively heating.

⑨ When incorporate the PCB with sensor package to the set module, do not apply residual stress of this process to the sensor package.

⑩ Avoid to use the adhesion due to protection material. It may affect to the sensor performance by residual stress.

⑪ Please pay attention layout of sensor package on PCB or the placement in set module. There is some risk of malfunction by magnetic interference, which may come from the neighbor magnetic materials (Fe, Ni, etc.).

⑫ The induced electromotive force may interfere with the sensor performance. Please measure against the induced electromotive force at circuit design.

⑬ Please do not use to exceed the absolute maximum ratings. If placed the sensor package at the exceeded magnetic field environment, please do not use it and scrap the sensor package.

⑭ Please do not use the dropped products.

D) Remarks

① Products described in this specification are mounted on automobiles or automotive products and are used in standard applications in automobiles according to the scope and conditions stated in this specification and are also used for automobiles or automotive products including this product it is intended to be used in normal operation and usage. In addition to automobiles, a high degree of safety or reliability is required, or failure, malfunction, or malfunction of the equipment may cause damage to life, body, property, etc. to people, or cause serious social impacts It does not guarantee compatibility, performance demonstration and quality to the following applications (hereinafter referred to as "specific applications") that may be given.
We are not responsible for the damage, etc. caused by exceeding the scope and condition of this specification, or being used for specific purposes. If you exceed the scope and conditions of this specification, or if you are planning to use it for a specific purpose, please contact us beforehand. We will discuss about specifications different from those specified in this specification according to customer's application.
① Aviation, Space Equipment
② Transportation equipment (train, ship, etc.)
③ medical equipment
④ Equipment for power generation control
⑤ Nuclear related equipment
⑥ submarine equipment
⑦ Transportation control equipment
⑧ Information processing equipment with high public nature
⑨ Military equipment
⑩ Electrical heating equipment, combustion equipment
⑪ Disaster prevention and crime prevention equipment
⑫ Various safety devices
⑬ Other use recognized as specific use
Before designing the equipment that uses this product, please secure the protection circuit / equipment and backup circuit according to the intended use and mode of the equipment.

② We assume no responsibility that the infringement of third party rights caused by the information in this document.

③ Please note. We assume no responsibility If you have damage from its use without our agreement.

④ Our warranty for this product is limited to conformity with the value and description expressly stated in this document. Please note we cannot warrant suitability and fitness for your particular intended purpose.

Changes

Date	Rev	Charge	Changes
2015/01/30	0	H.Naganuma	Initial Release
2015/02/25	1	H.Naganuma	Change Pin Layout Change TSSOP16 dimension
2015/07/27	2	H.Naganuma	Fixed typo on Figure5
2015/08/07	3	H.Naganuma	Change the typical application circuit (Figure4) Change the value and condition of Start-up time
2018/10/29	4	H.Naganuma	Change product name from ATAS4001 to TAB4140-BAAB Update absolute maximum voltage Change Operating voltage range Update rotational speed Update angle error Remove ESD protection spec of Machine model Update Moisture sensitivity model Fix a typo in device marking
2020/05/19	5	H.Naganuma	Update Temperature drift of output voltage offset spec Update sensor surface position
2020/10/21	6	H.Naganuma	Update 2.4 application circuit (add pull-up resistor)
2021/08/23	7a	S. Koide	Update 2.4 Application circuit (R1~R8, C1~C8 value) Update 6 Instruction for use D) Remarks