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# **360-degree Rotation Angle Sensor Consisting of MRE Sensors with a Membrane Coil**

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**NIPPON SOKEN INC,**

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**DENSO corp.**

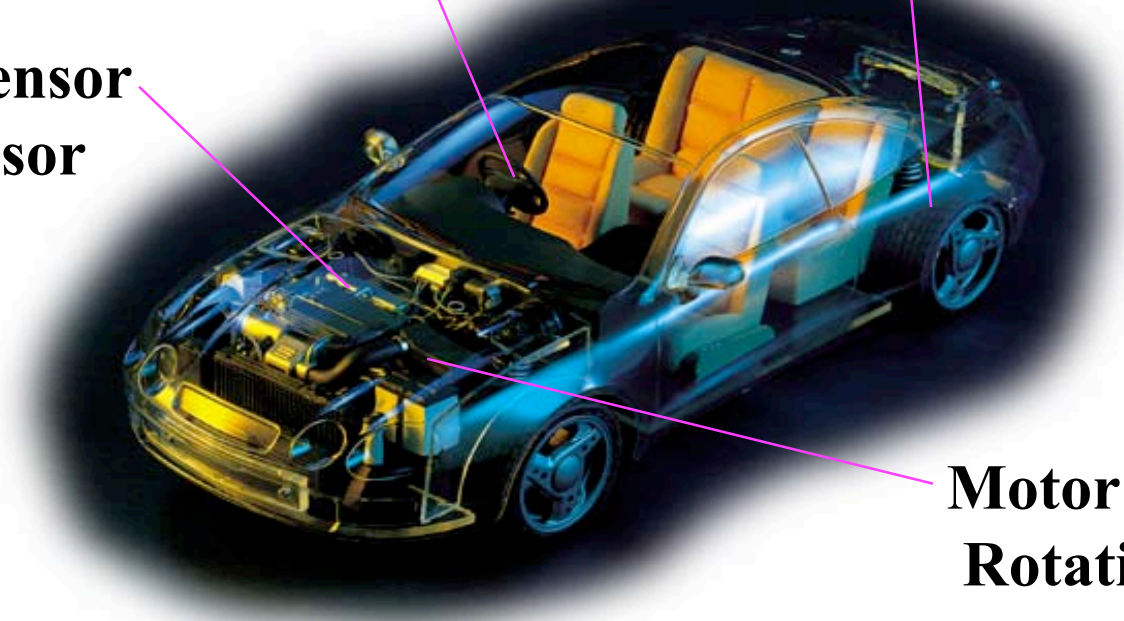
## Progress in electronic vehicle control system

**Steering Wheel Angle Sensor**

**Wheel Rotation Sensor**

**Crank Angle Sensor**

**Cam Angle Sensor**

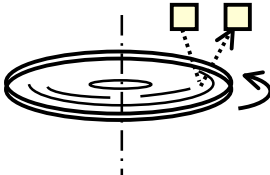
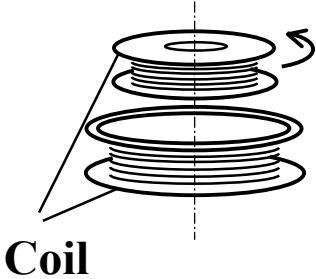
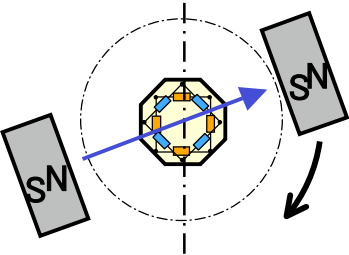


**Motor Generator  
Rotation Sensor**

Progress in electronic vehicle control system has created the need for contactless detection of rotation angles up to 360 degree

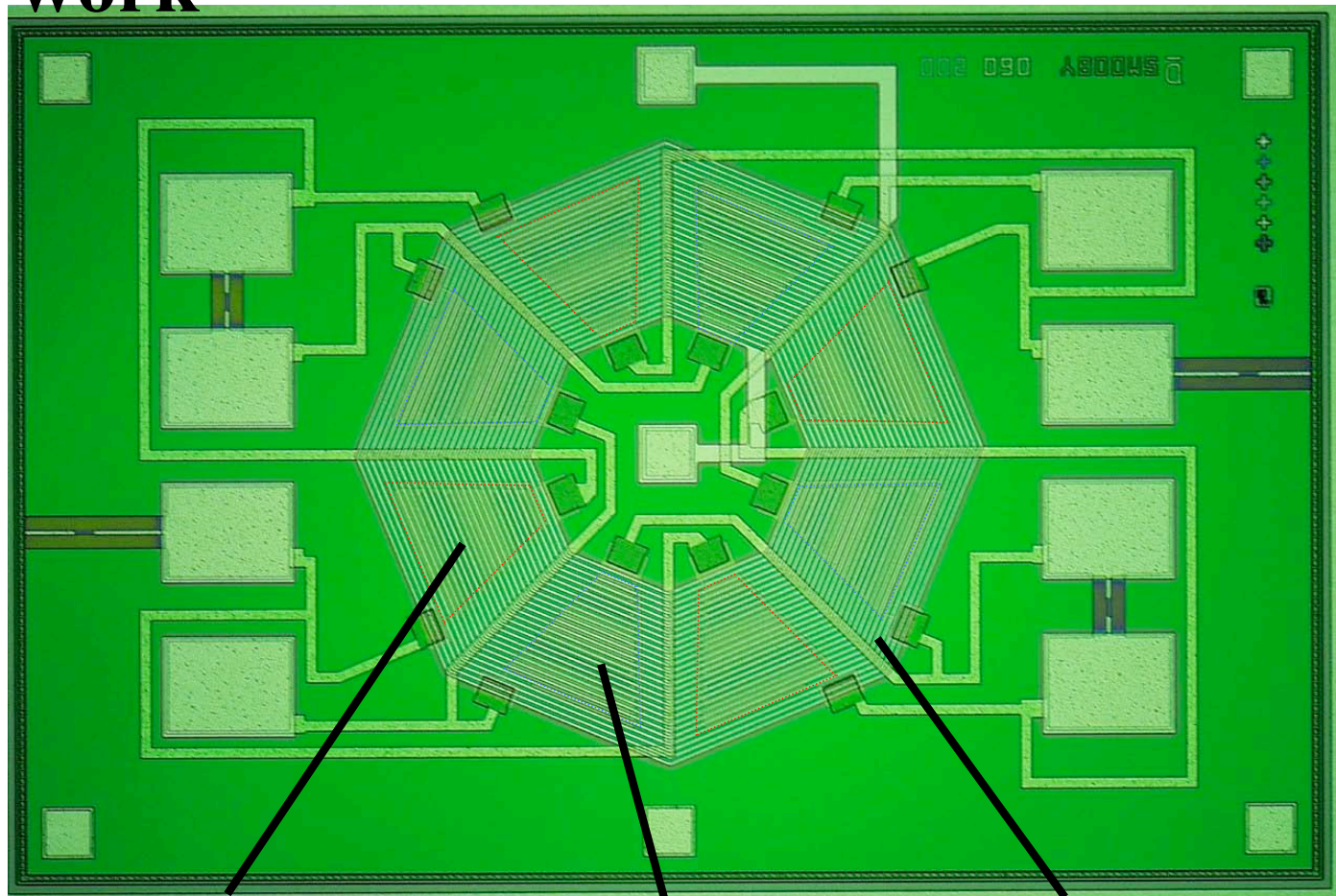
# Principle and Disadvantage of Rotation Angle Sensors

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	Optical sensor	Resolver	2-phase type MRE
<b>Principle</b>	 <ul style="list-style-type: none"> <li>* Barcode pattern reading</li> </ul>	 <ul style="list-style-type: none"> <li>* Induced voltage</li> <li>* Two-phase detection</li> </ul>	 <ul style="list-style-type: none"> <li>* Magnetic field rotation angle</li> <li>* Two-phase detection</li> </ul>
<b>Disadvantage</b>	<ul style="list-style-type: none"> <li>* Sensitive to high temperatures</li> <li>* Axis dislocation</li> <li>* Sensitive to staining</li> <li>* Expensive</li> </ul>	<ul style="list-style-type: none"> <li>* Large size</li> <li>* Expensive</li> </ul>	<p>Impossible to detect 180 to 360 degree rotation angles</p>

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# Sensor Chip developed in our present work

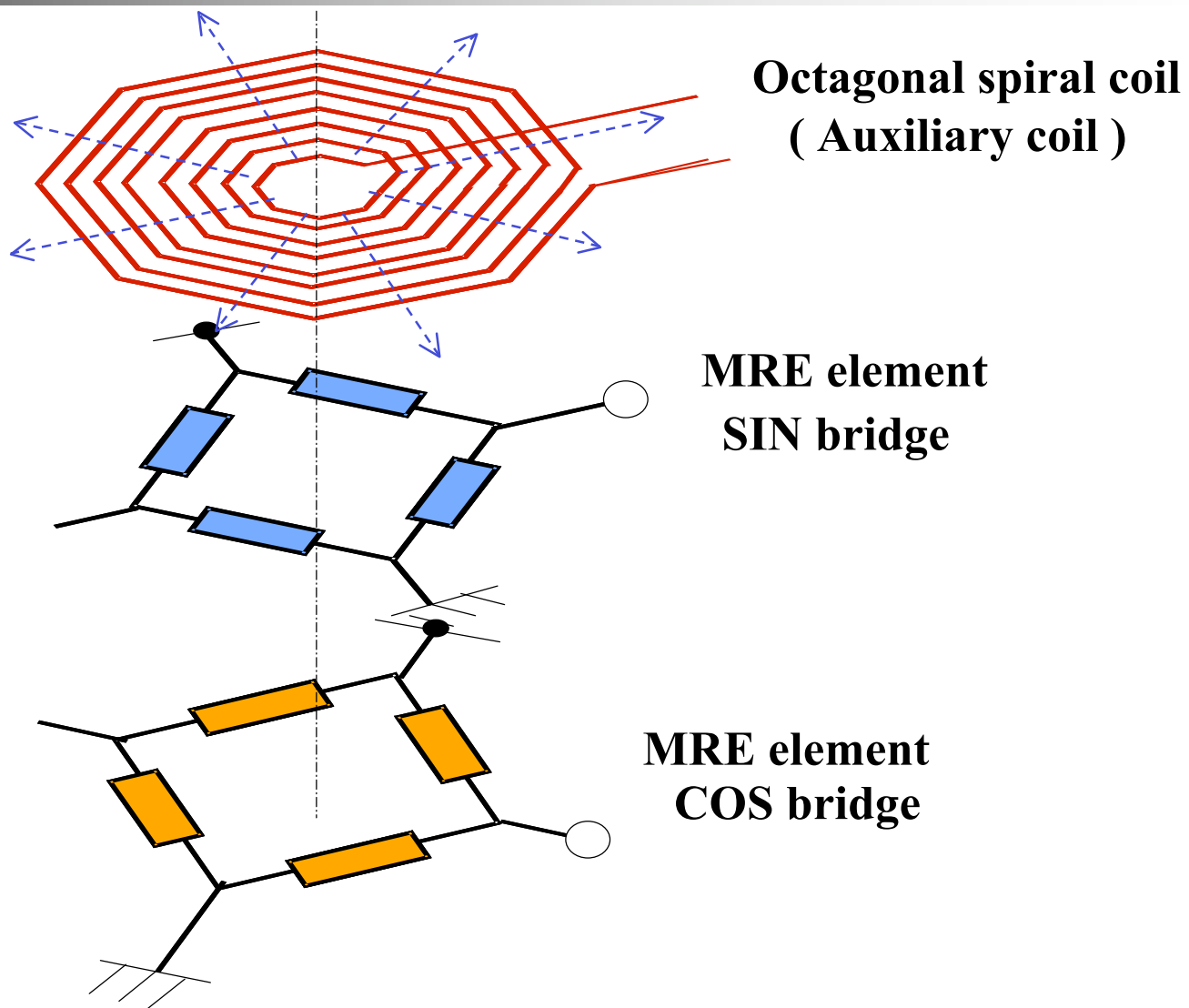


**MRE element  
( COS Bridge )**

**MRE element  
( SIN Bridge )**

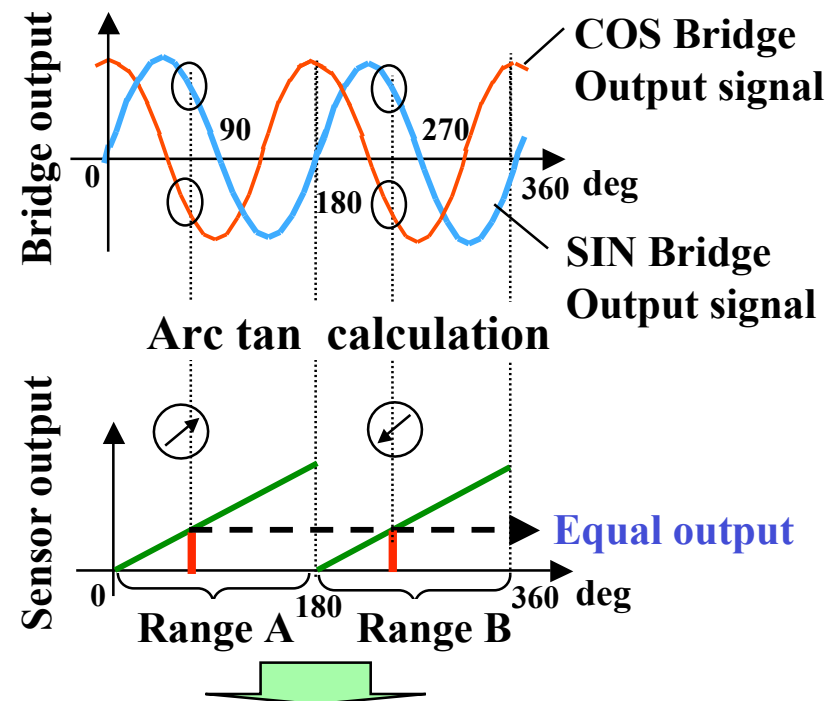
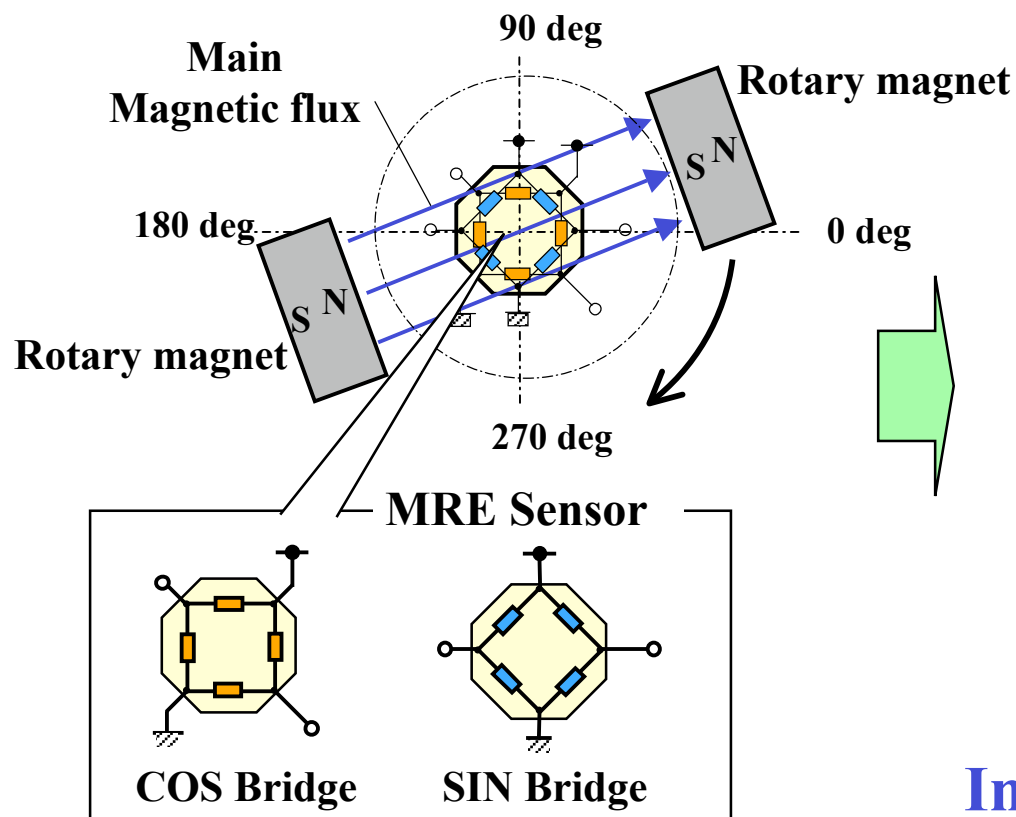
**Auxiliary coil**

# Construction of Our Sensor Chip



# Angle Detection Principle of Conventional MRE Sensor

## 2-phase detection method

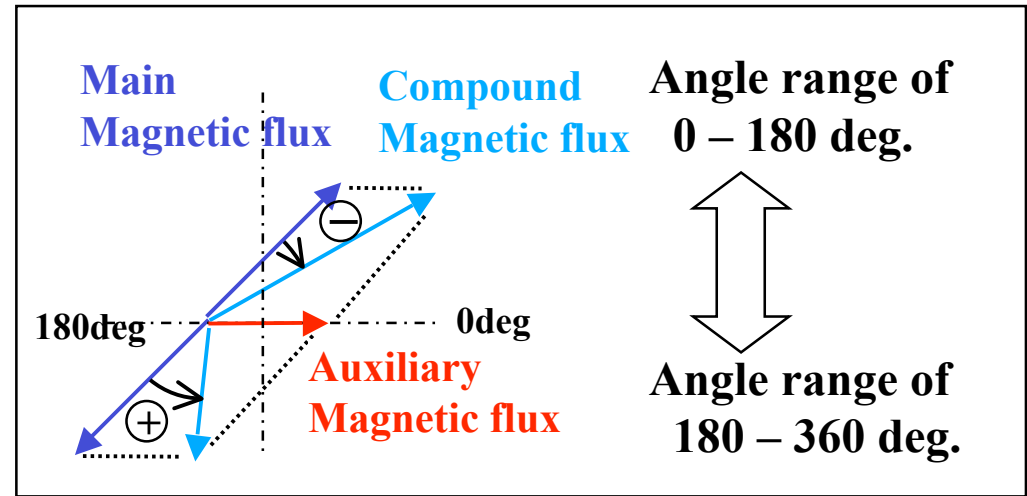
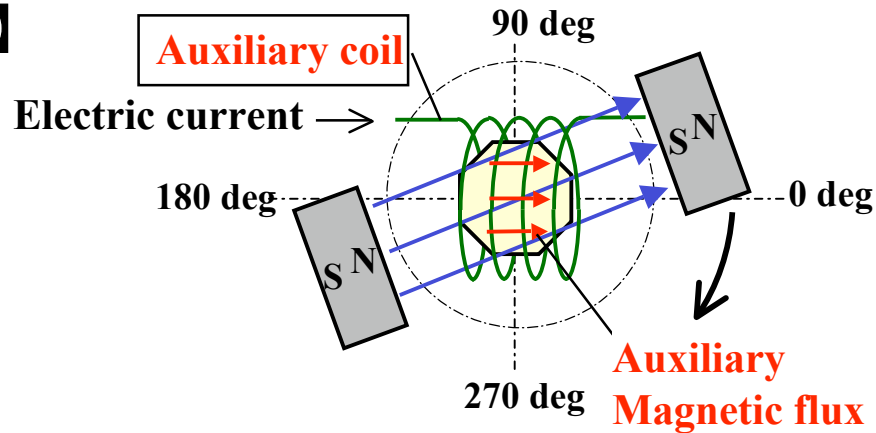


**Impossible to distinguish  
Range A and Range B  
Because of 180-deg. detection cycle**

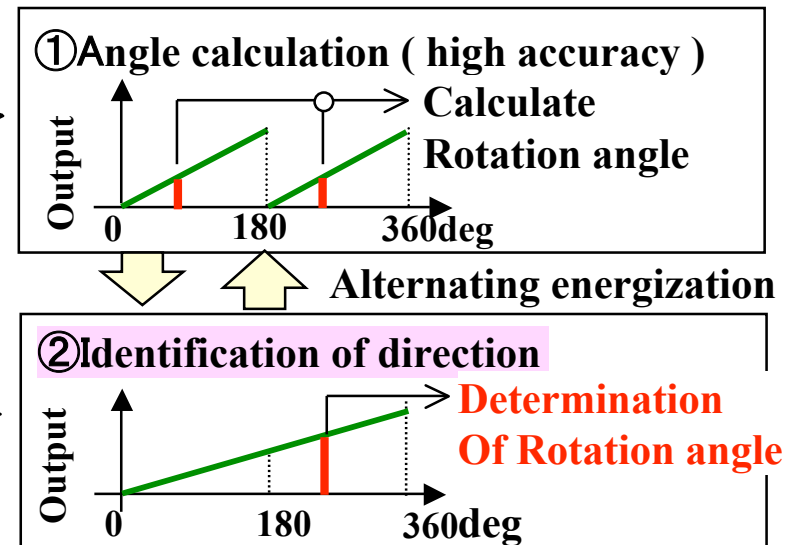
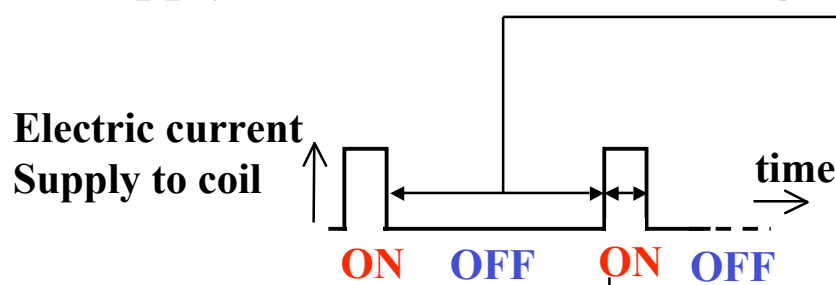
# Principle of Rotation Angle Detection to 360 Degrees

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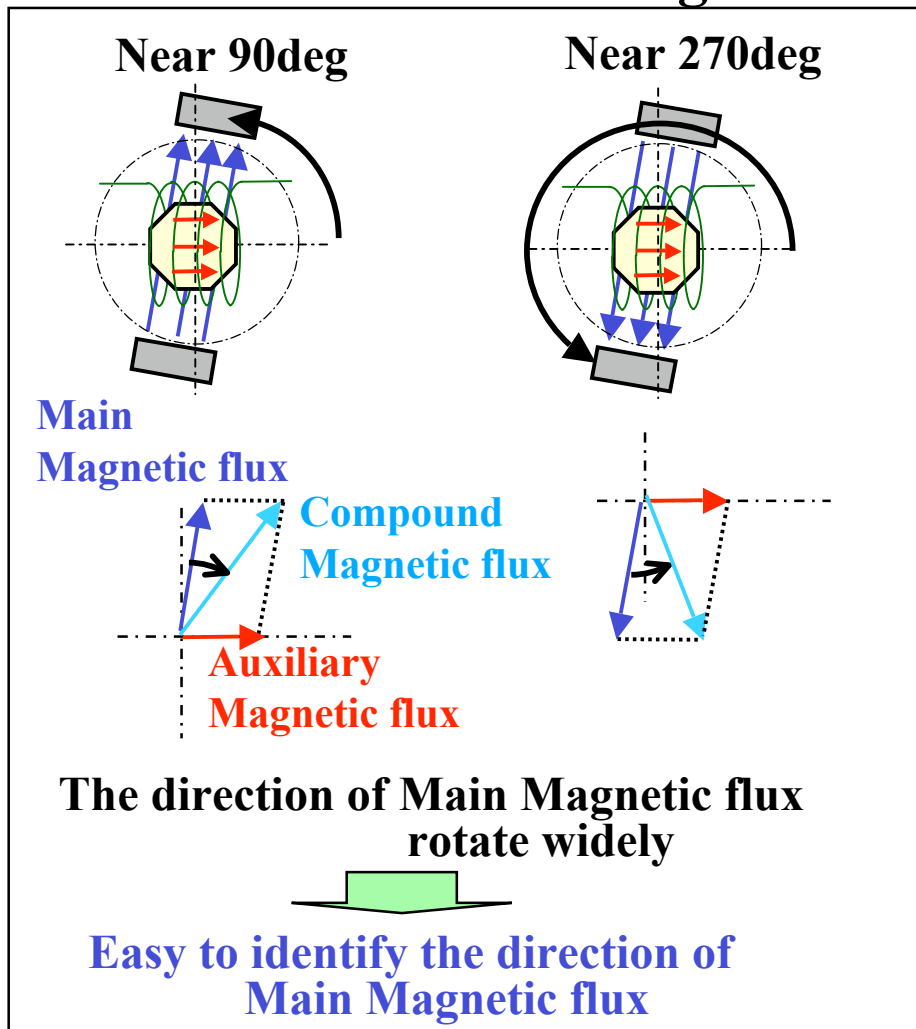
**【Identification of direction by additional installation of Auxiliary coil】**



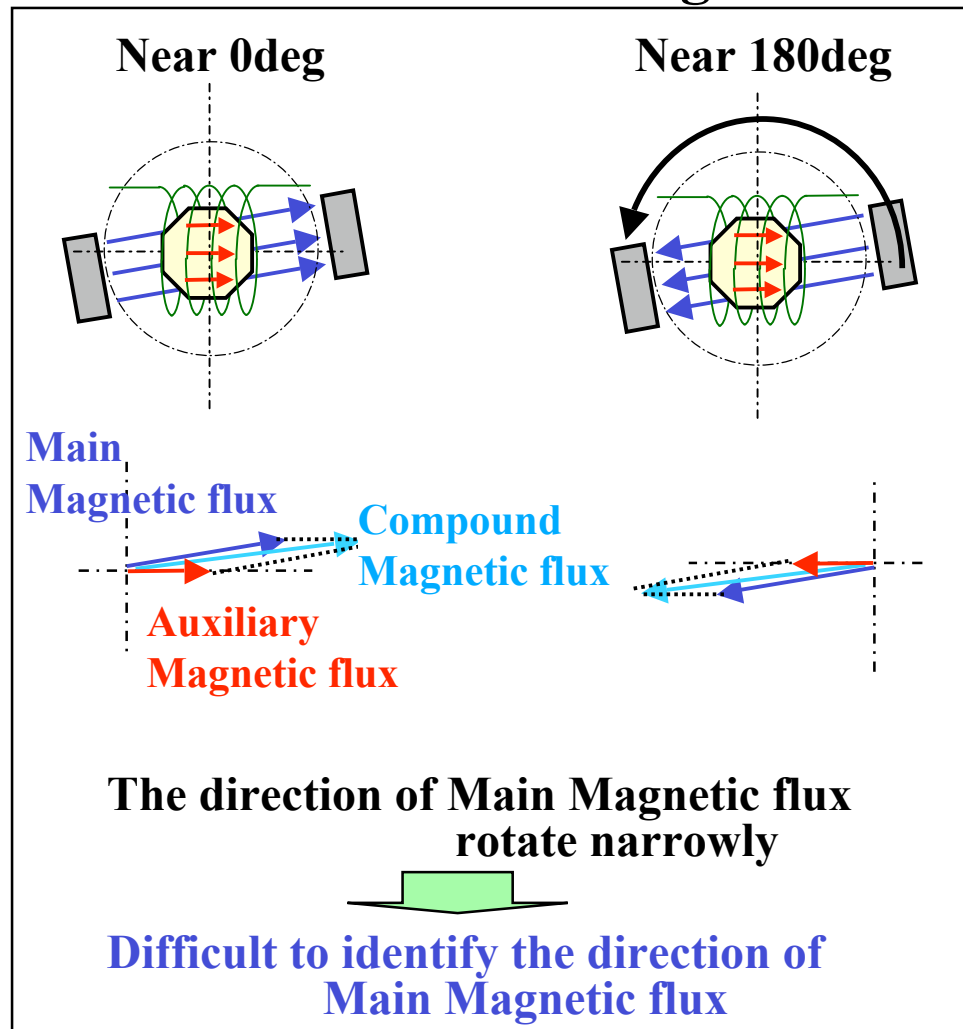
**【Coil supply current ON/OFF timing】**



## Near 90 & 270 deg

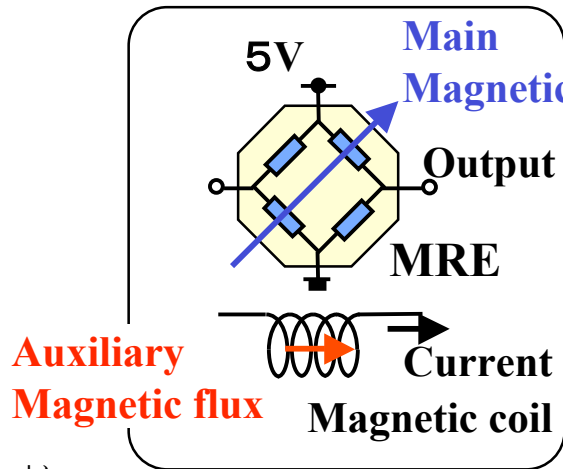


## Near 0 & 180 deg

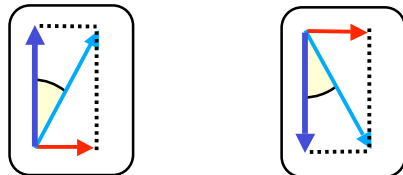
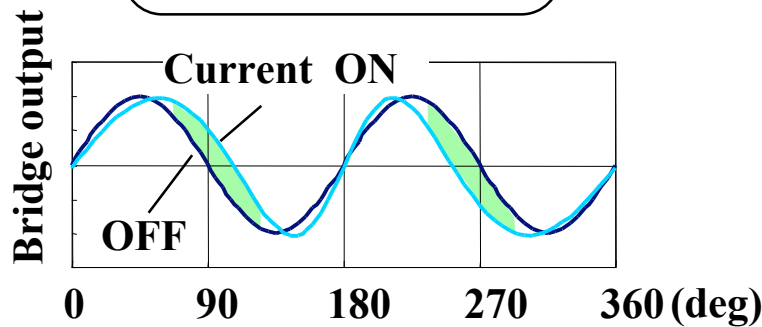
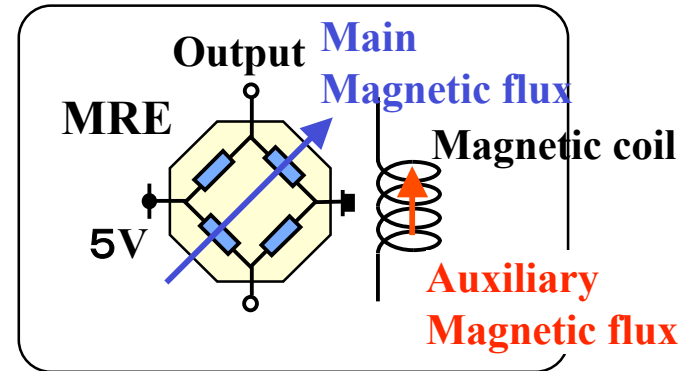
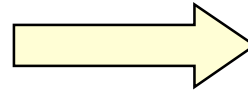


# Method of Improving Identification

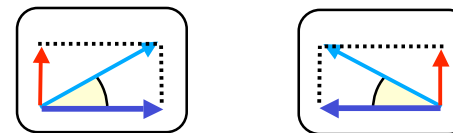
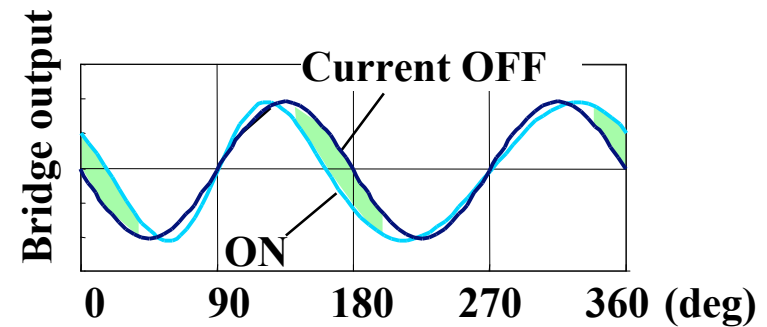
*SOKEN* Performance in Angle Range near 0 & 180 deg. 9/15



Shifting characteristics by 90 deg.



Easy to identify the direction of Main Magnetic flux



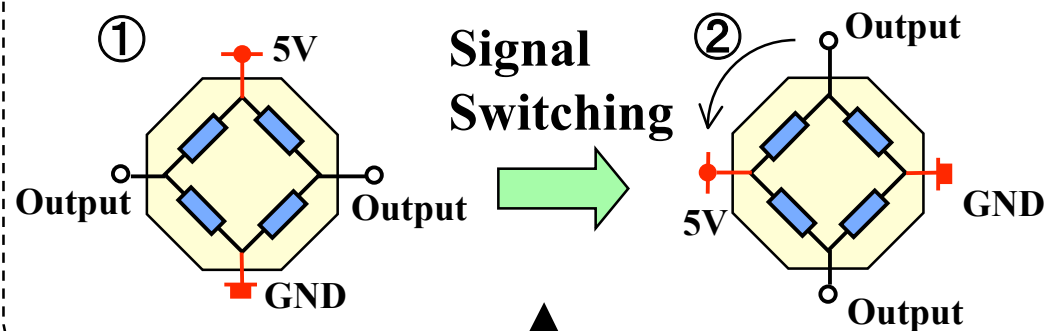
← Shifting 90 deg.

Easy to identify the direction of Main Magnetic flux

# Signal Switching in Bridge Circuit for Shifting Characteristics by 90 deg.

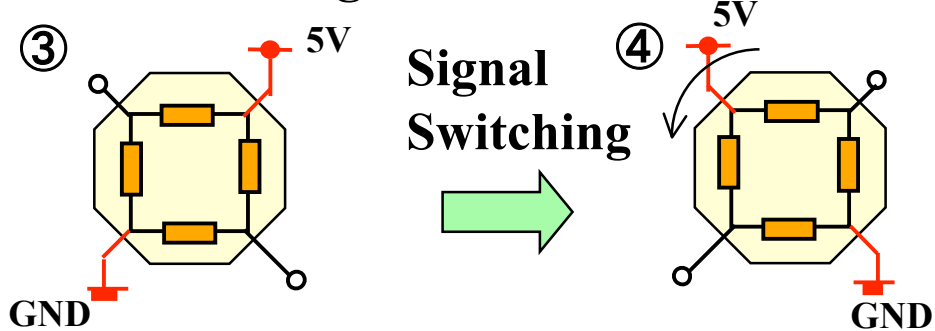
## 【Signal Switching in Bridge Circuit】

### SINE Bridge Circuit

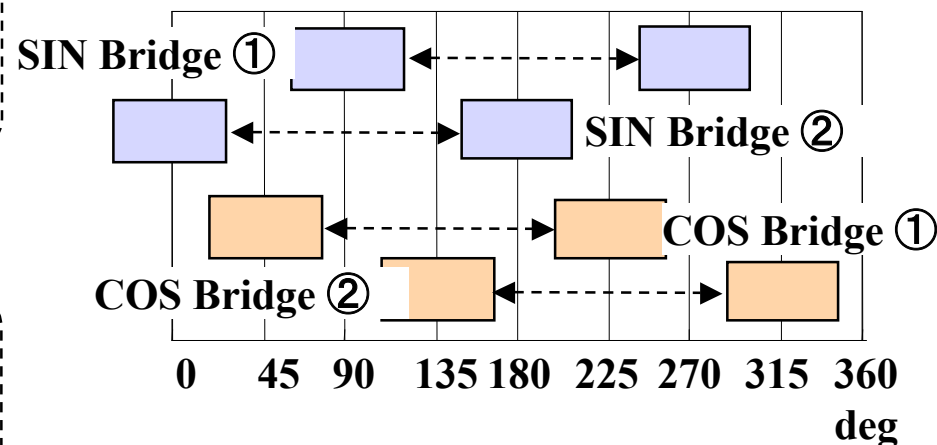


Phase difference by 45 deg.

### COSINE Bridge Circuit



## 【Detectable Angle Range of Bridge Circuit】



Easy to identify the direction of Main Magnetic flux in 0 – 360 Angle Range

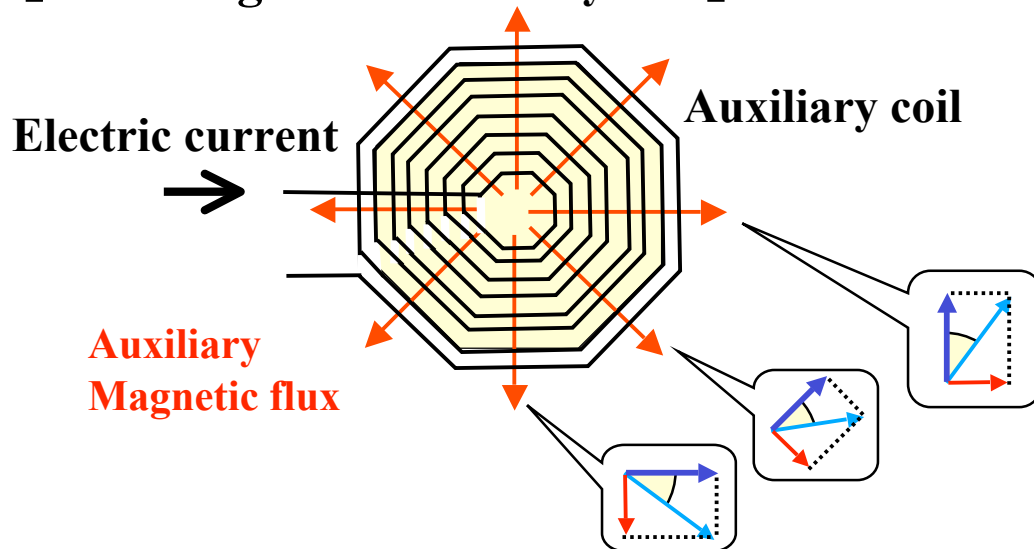
# Producing Symmetric Magnetic Field by Spiral Coil

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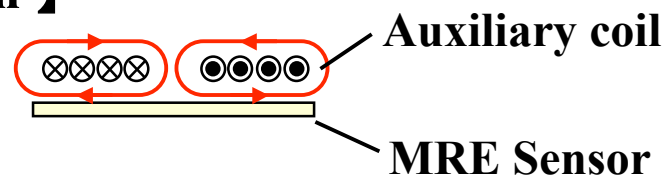
## Octagonal Spiral Coil

## MRE Sensor Bridge Circuit

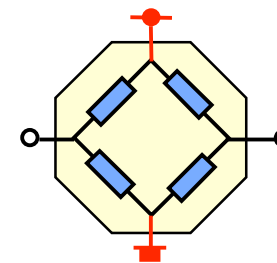
【 Plane figure of Auxiliary coil 】



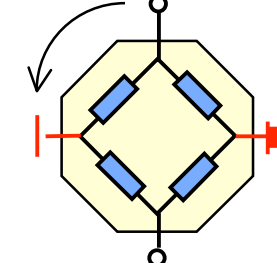
【 Cross section 】



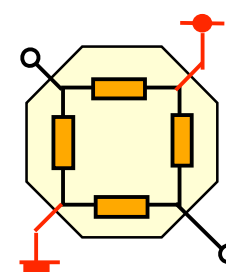
SIN Bridge ①



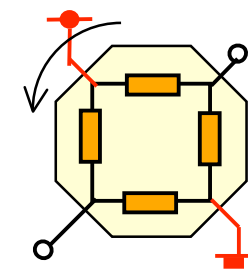
SIN Bridge ②



COS Bridge ①

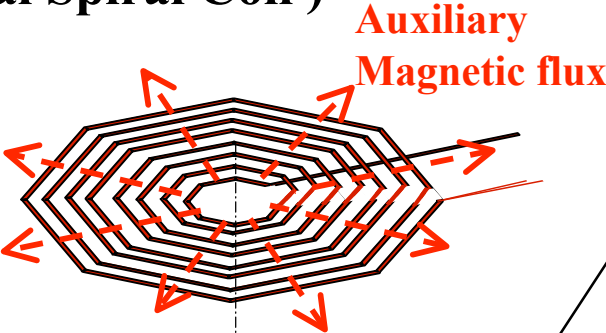


COS Bridge ②



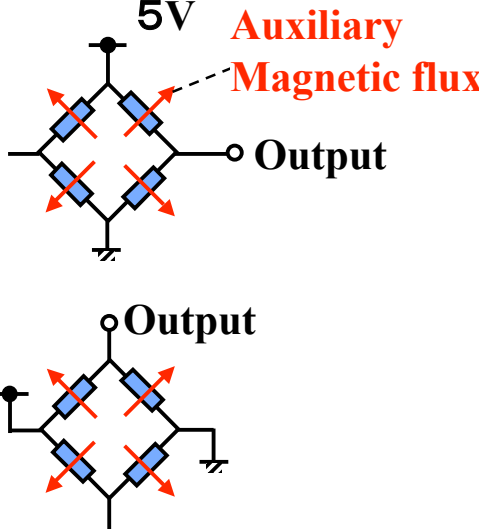
# Construction of the Our Sensor

## Auxiliary Coil ( Octagonal Spiral Coil )

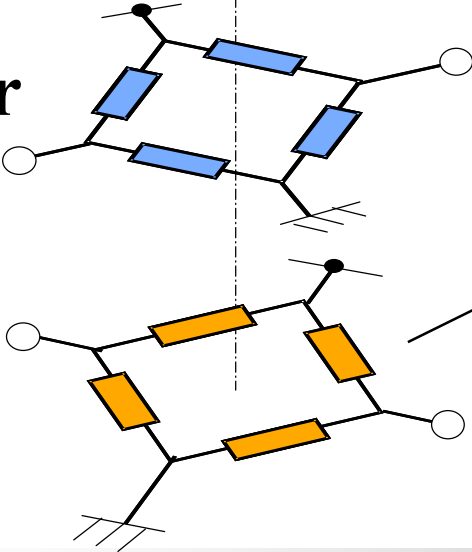


SIN Bridge Circuit

Signal Switching

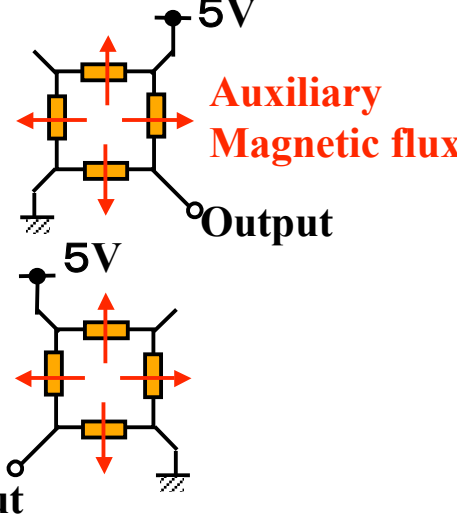


## MRE Sensor



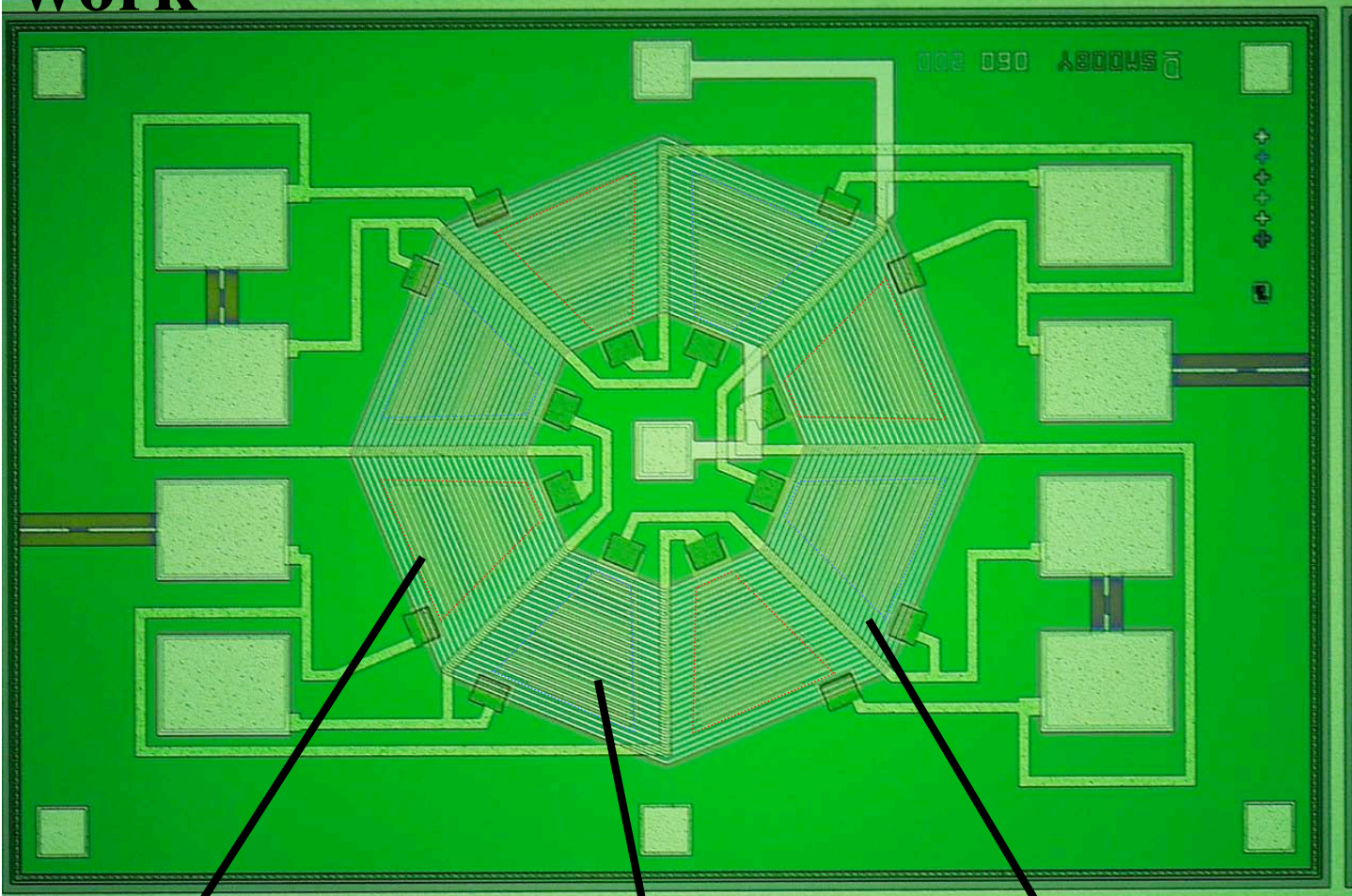
COS Bridge Circuit

Signal Switching



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# Sensor Chip developed in our present work



MRE element  
( COS Bridge )

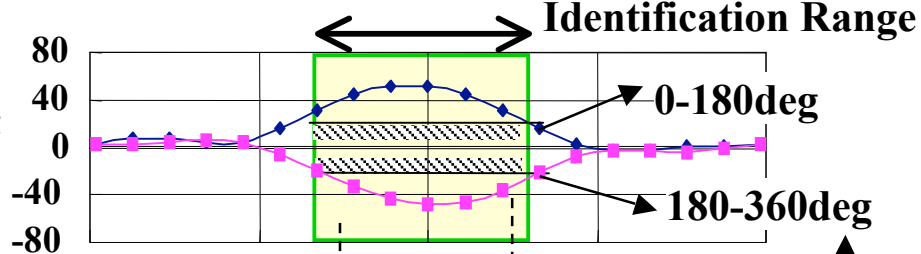
MRE element  
( SIN Bridge )

Auxiliary coil

# Characteristics

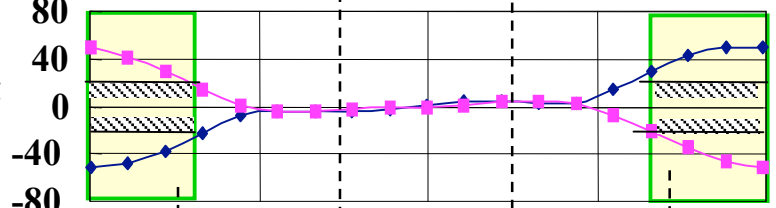
## SIN Bridge ①

Sensor output (mV)



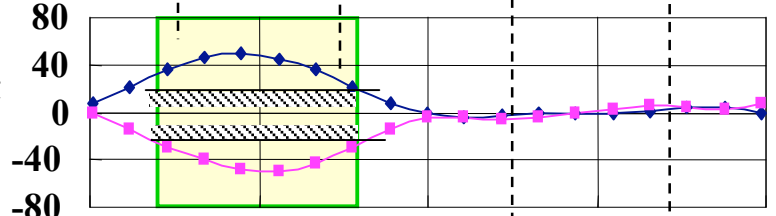
## SIN Bridge ②

Sensor output (mV)



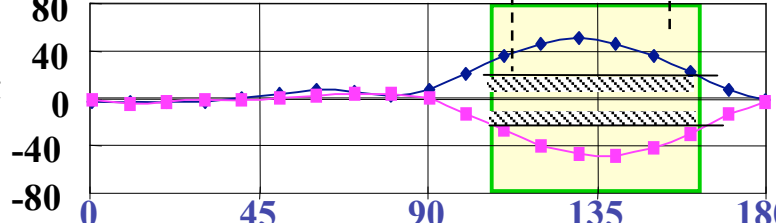
## COS Bridge ①

Sensor output (mV)



## COS Bridge ②

Sensor output (mV)



0 45 90 135 180  
180 225 270 315 360

Rotation Angle [deg]

Select the  
Bridge Circuit  
By Rotation Angle

# CONCLUSION

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- 1. We devised a unique MRE Sensor . This Sensor is very small size and can detect absolute angle from 0 to 360 degrees.**
- 2. Our Sensor is constructed by octagonal shaped auxiliary spiral coil and MRE sensor bridge that are energized alternately.**