Designing motion detection systems with PIR and ultrasonic sensors

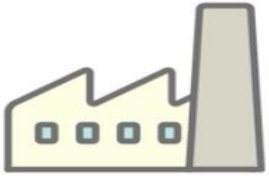
Internet of Things Application

Digitalised and connected

Metering

Transportation

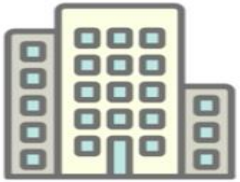
Factory / M2M



Agriculture

IoT

Everywhere you look today



Building

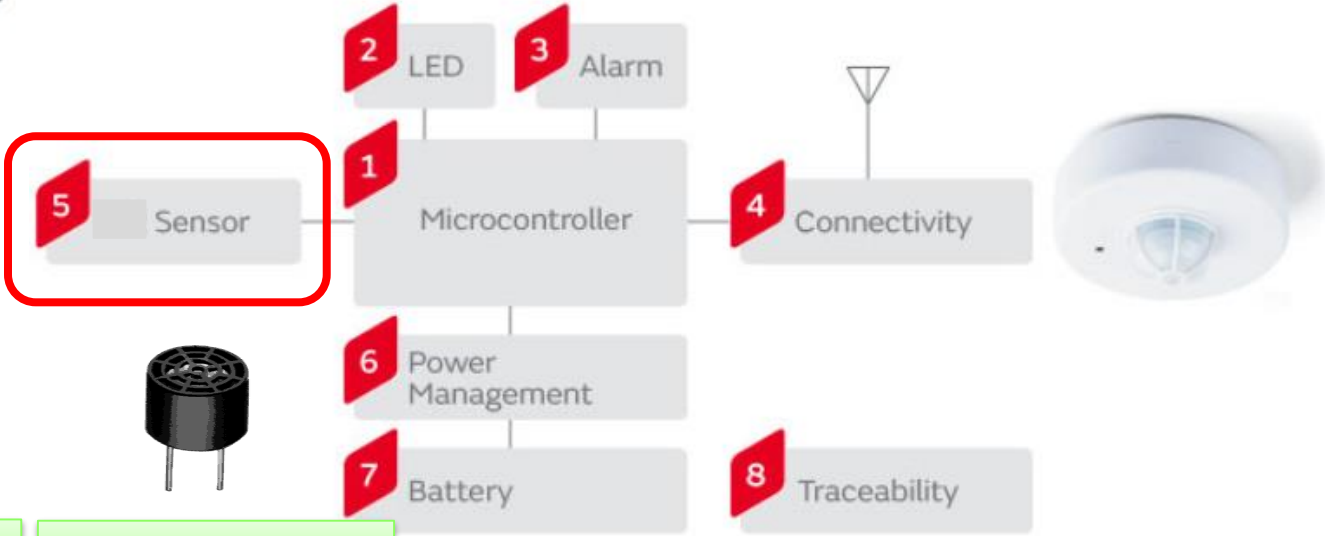
Environment

Healthcare

Home

Smart Home / Office Applications

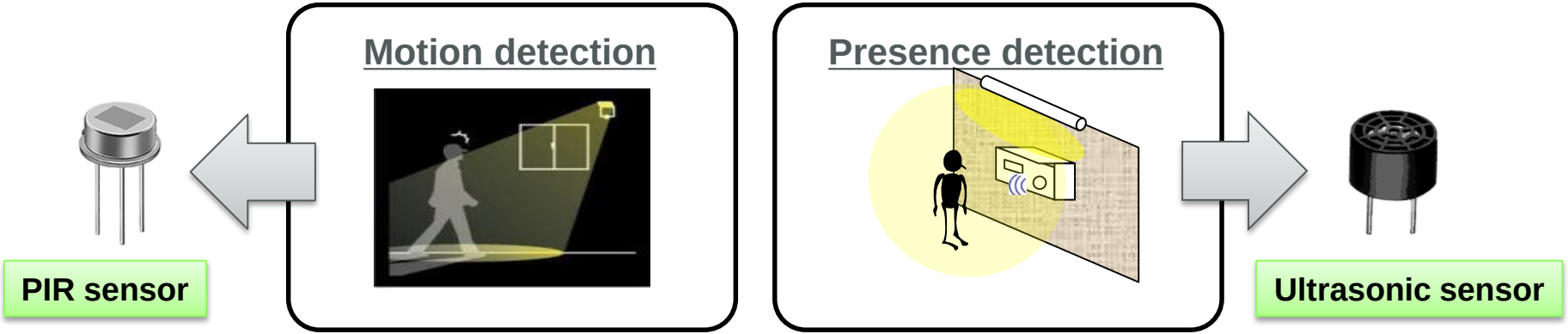
Providing high level of automation



PIR sensor **Ultrasonic sensor**

Presence Detection

● Motion detection ≠ Presence detection



- PIR sensors have very high sensitivity to changes of temperature (coming/going of human)
- Ultrasonic sensors have a sensitivity to detect objects (human) and can measure a distance

Topics

1. What is a PIR sensor ?

2. Tips: Motion detector design using PIR sensors

3. What is an Ultrasonic sensor?

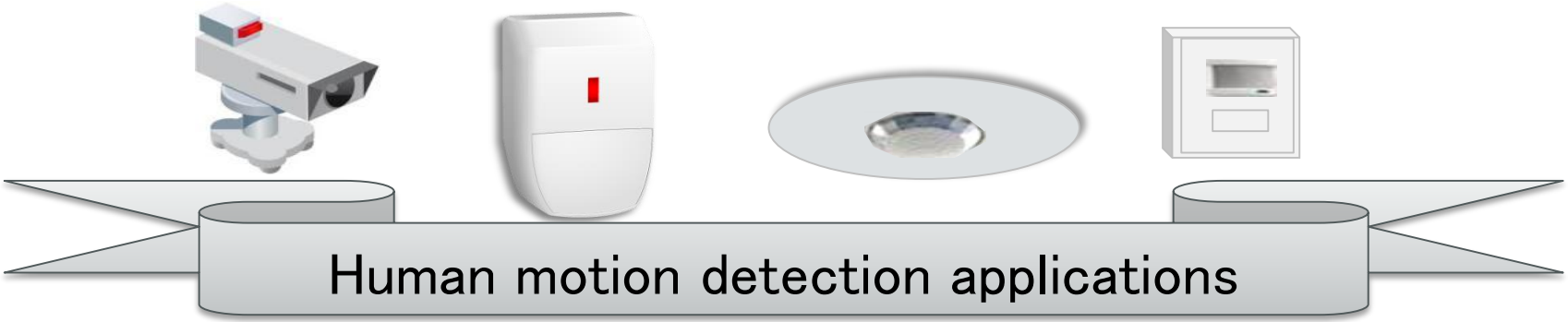
4. Tips: Presence detector design using Ultrasonic sensors

What is a PIR sensor?

● PIR sensor = Pyroelectric Infrared sensor

It detects **the temperature change** caused by infrared rays from humans using the pyroelectric effect (ceramic's material property)

utilised for...



→ What is the human 'motion' detection ?

Pyro-electric effect

output = behavior electric charge

Infrared energy input OFF O N OFF

Temperature change (increase)

Temperature change (decrease)

Stabled/ balanced

Temp. change of PIR element

Stabled/ balanced

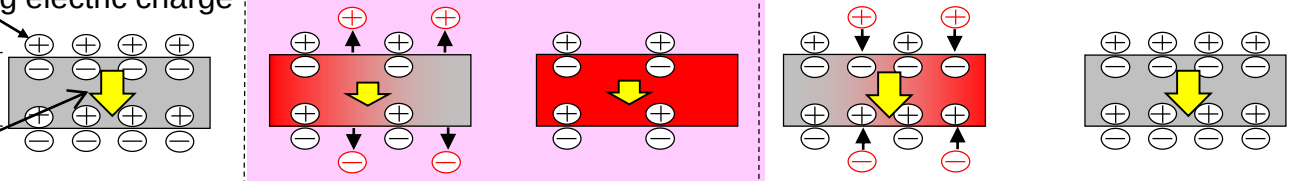
Stabled/ balanced

Condition of electric charge

Floating electric charge

polarisation

Dipole moment
(amount of polarisation)



Output signal is generated
at the time of temperature change
of pyro-electric element.

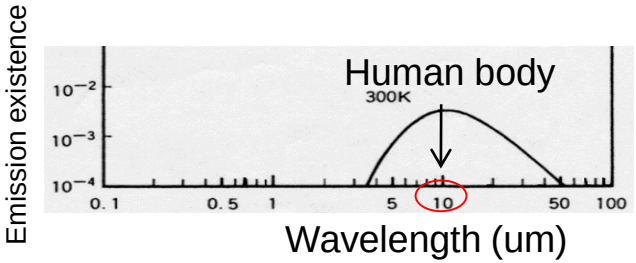
Sensor output (Voltage)

Why do PIR sensors only detect human motion?

What are infrared rays?

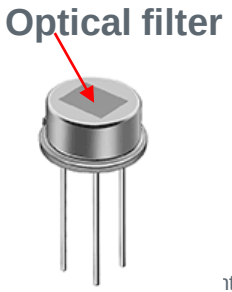
All objects in nature radiate infrared rays corresponding to the temperature of the object, and the peak wavelength of infrared ray corresponds to the surface temperature. (This is Wien's law).

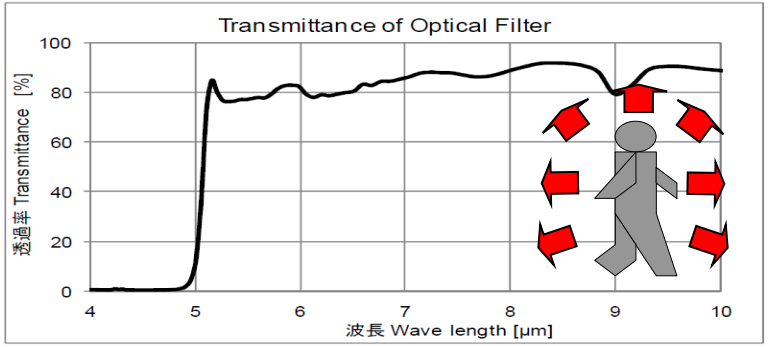
Characteristics of the human emission



Function of 'Optical Filter'

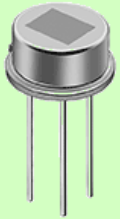
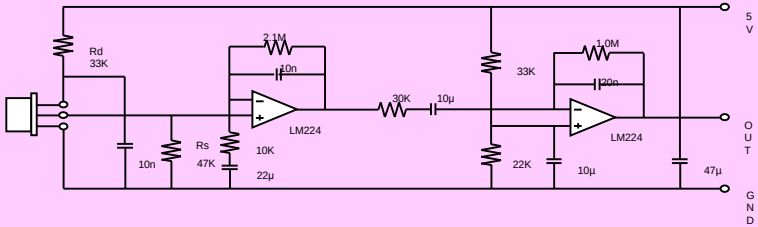
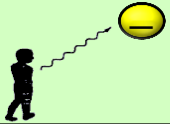
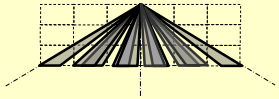
The pyro-electric ceramic itself doesn't have wavelength dependence, so we have to use optical filters which have suitable transmittance to detect a target object (human). Generally, we use a 5um cut-on long pass filter as an optical filter for the application of human body detection, because the peak wavelength of infrared ray emitted from a human body is around 10um and a 5um cut-on filter has high transmittance around this wavelength.





Design flow of a motion detector with a PIR sensor

- **Lens and amplifier circuit is needed**

	Sensor	Optical system ex). Lens/Mirror	Circuit (Typical Application Circuit)
Products			
Function	Heat => Electricity 	Area design Angle, Range 	Sensor Signal amplification Signal filtering

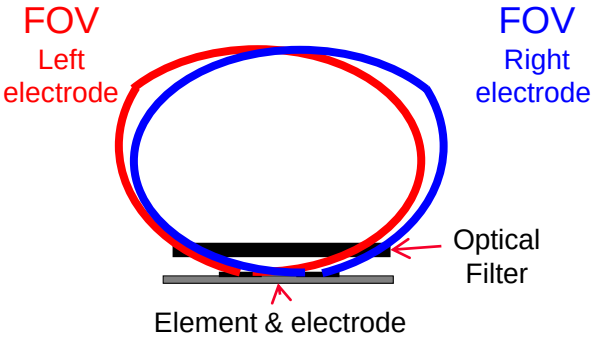
Murata supply

Customer/ Partner (lens maker etc..) design

→ Why optical system (lens) is necessary?

Design flow of a motion detector with a PIR sensor

● Why is an optical system (lens) necessary ?

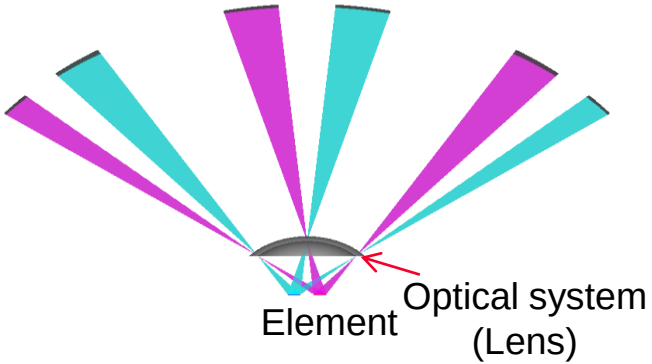


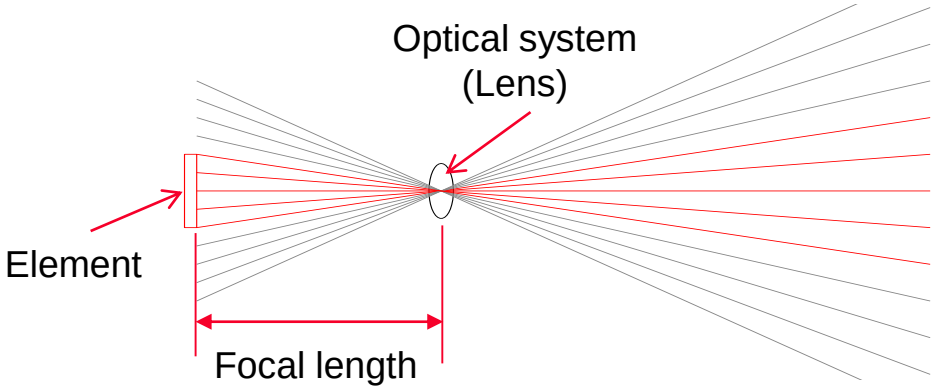
Output signal in the area overlaps red and blue circle is canceled

If an optical system is not used in front of sensor, directivity of the sensor is as shown in the left figure and the detection area is not formed.

An optical system is used to condense the infrared-ray to the element.

Detection area is designed by the optical system.

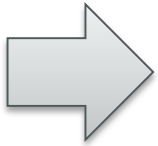




Design flow of a motion detector with a PIR sensor

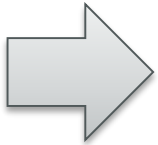
● Check point in the design

1. Usage condition of the application
   - Indoor use / Outdoor use
   - Wall mount use / Ceiling mount use



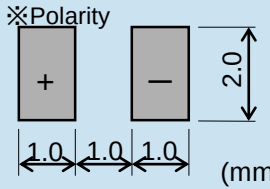
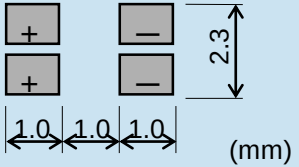
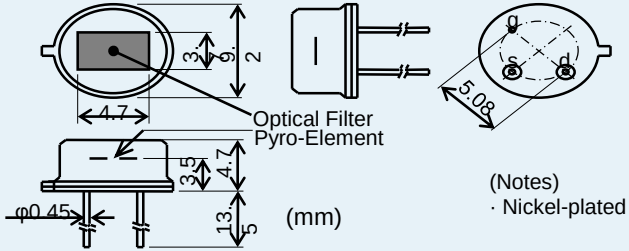
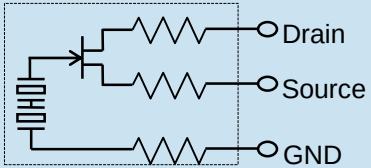
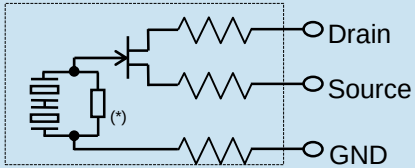
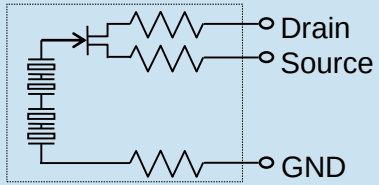
PIR sensor selection

2. Requirement about detection area
   - Angle
   - Distance



Lens selection

Product Lineup - Wall type

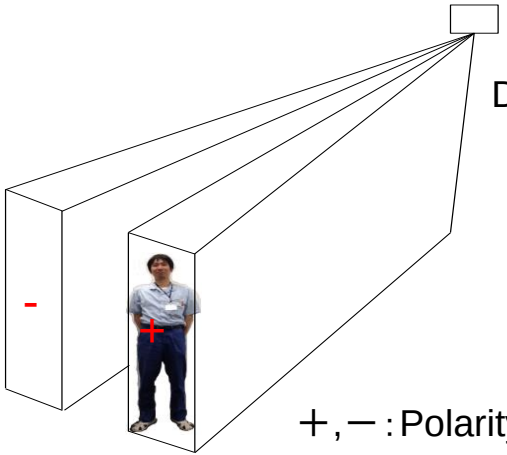
	Standard		High Sensitivity
	IRA-S200ST01A01	IRA-S220ST01A01	IRA-S400ST01A01
Pyro-electric Element	 ※The meaning of Polarity When the target intrude the detection area with below condition, "Electrode of polarity +" show + output signal. 「Target Heat Temp. > Background Temp.」		
Outline Drawing	 (Notes) · Nickel-plated on the lead		
Equivalent Circuit		 (*) Gate Resistor	

Rg (gate resistor) makes the temperature characteristics stable.
It means that the part which has Rg is suitable for the application uses in rapid temperature change situation like outdoor

Product Lineup - Wall type

Item	Unit	IRA-S200ST01A01	IRA-S220ST01A01	IRA-S400ST01A01
Sensitivity (500K, 1Hz)	mV	4.6	4.6	7.0
White noise	mV	150	180	200
Source voltage (5V, 47KΩ)	V	0.2～1.5	0.2～1.5	0.2～1.5
F.O.V (Ver./Hor)	deg.	±45/±45	±45/±45	±38/±45
Transmittance of optical filter	-	5μmLPF	5μmLPF	5μmLPF
Supply voltage range	V	2～15	2～15	2～15
Dimension of electrode	mm	2 x 1 Dual	2 x 1 Dual	2.3 x 1.0 Serial Quad
Element height	mm	3.5	3.5	3.5
Gate resistor (Rg)	-	—	○	—
Dimension	mm	Φ9.2 x 4.7	Φ9.2 x 4.7	Φ9.2 x 4.7

Signal output of a dual element



Detector

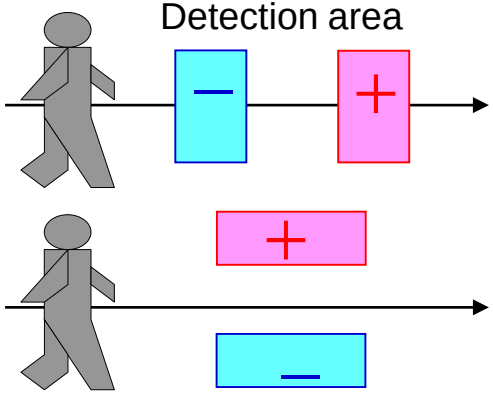
Dual element has the advantage in detection of motion across the detection area.

＋,－：Polarity of element

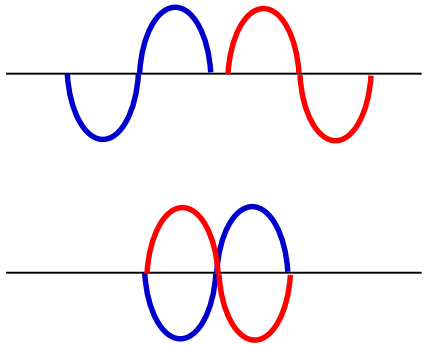
Dual element

Place the element in horizontal direction in series

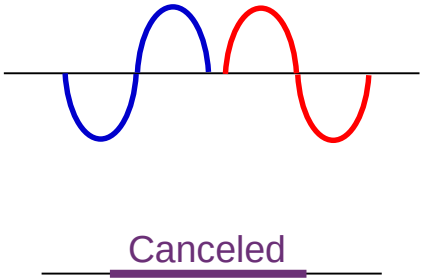
Place the element In vertical direction



Signal output image (from each element)

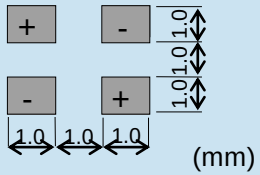
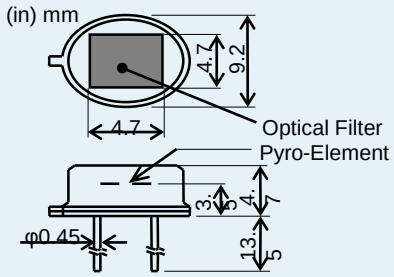
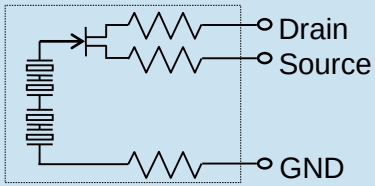


Signal output



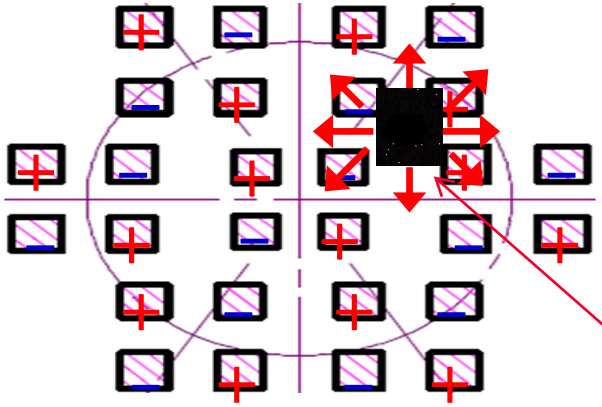
Canceled

Product Lineup - Ceiling type

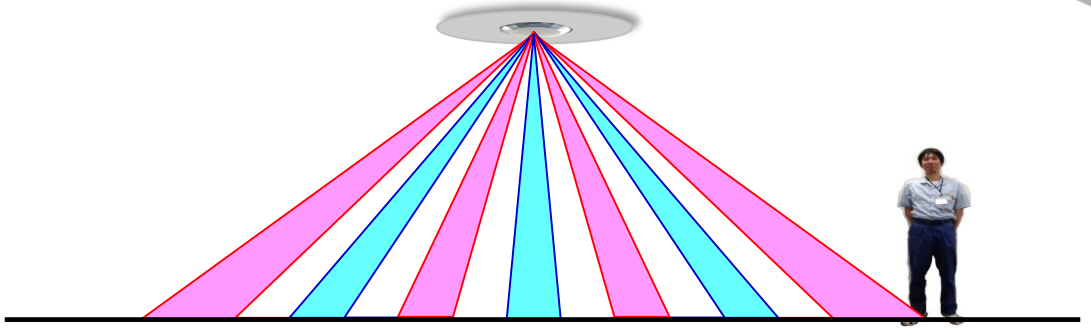
	IRA-S500ST01A01
Pyro-electric Element	
Outline Drawing	
Internal circuit diagram	

Item	Unit	IRA-S500ST01A01
Sensitivity (500K, 1Hz)	mV	3.3
White noise	mV	250
Source voltage (5V, 47KΩ)	V	0.2～1.5
F.O.V (Ver./Hor)	deg.	±44/±44
Transmittance of optical filter	-	5μmLPF
Supply voltage range	V	2～15
Dimension of electrode	mm	1.0 x 1.0, gap1.0 Serial Quad
Element height	mm	3.5
Gate resistor (Rg)	-	—
Dimension	mm	Φ9.2 x 4.7

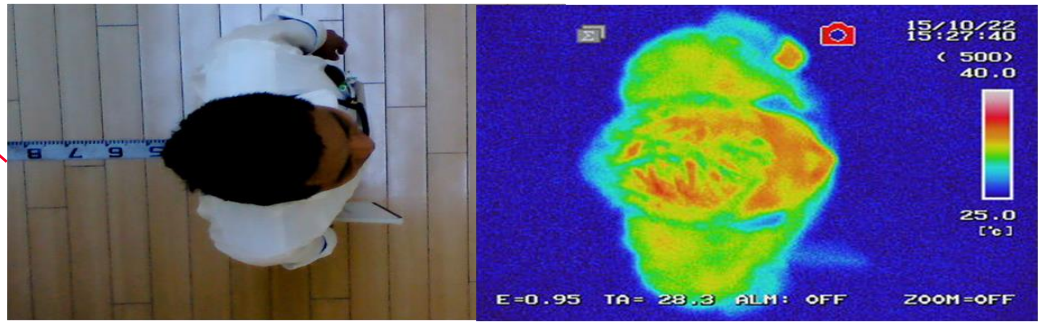
The advantage of a quad element



Detection area image
(on the floor)

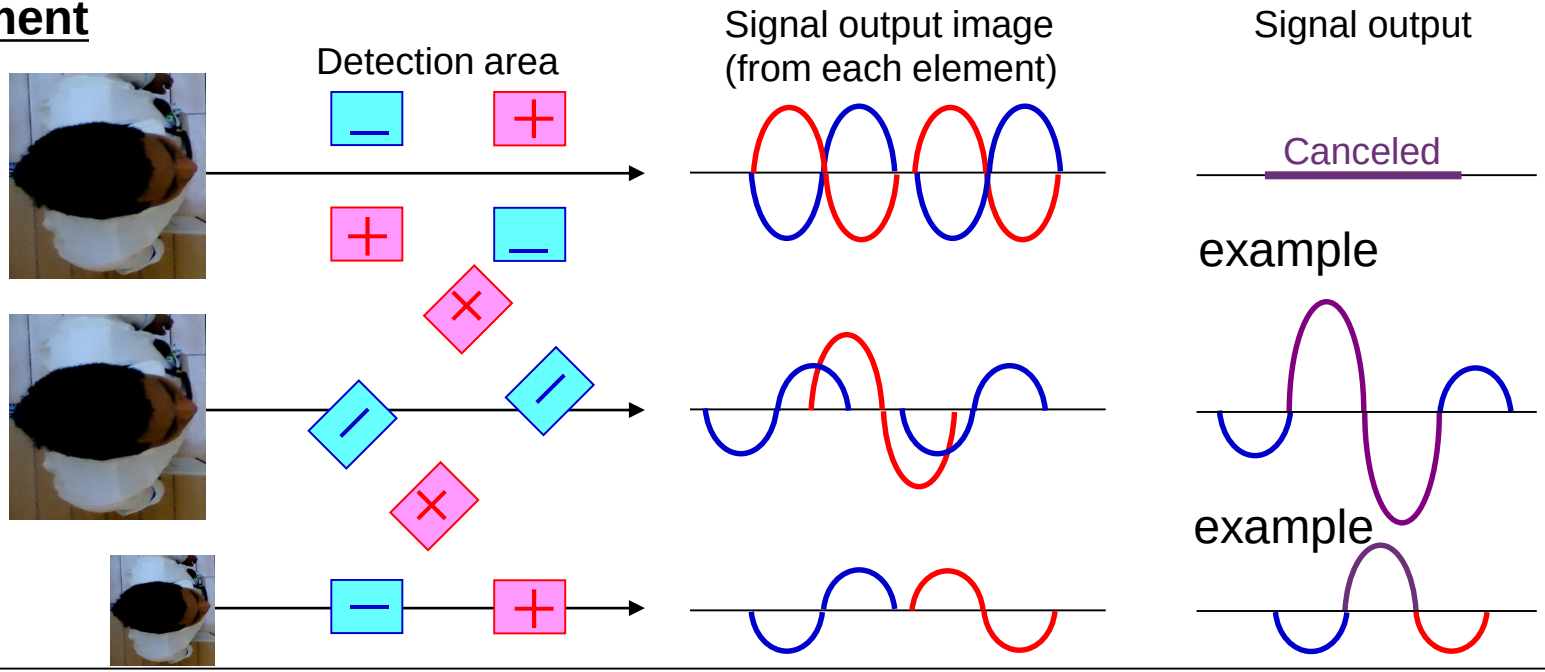


Detection area image (cross-sectional image)



Signal output of a quad element

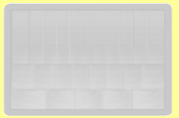
Quad element



Quad element has the advantage in **the fine motion detection** when it is used in a ceiling mount detector. This performance comes from the arrangement of element polarity and number of detection area.

⚠ This performance is realised by the combination of sensor and optical design.

Fresnel Lens Line-up for Lead type

Type	Part Number	Feature, Application	Detection Angle (deg.)		
			Horizontal	Vertical	
Cap on sensor Type	**IML-0635/0685**	• Smaller size • General purpose	95	20	
	IML-0636/0686		65	60	
	IML-0637/0687		30	20	
	IML-0638/0688		90	80	
PCB mount Type	**PPGI0626**	• Wide area detection • For ceiling attached equipment • General purpose	110	120	
	IML-0663	• Wide area detection • General purpose	118	46	
Case mount Type	**PPGI0902**	• Long range detection • For wall attached equipment • Security system	75	20	

Valued points of muRata PIR sensors

Features of muRata PIR sensor

- Excellent S/N ratio
- High stability against ambient temperature change
- Excellent immunity characteristic to electromagnetic waves

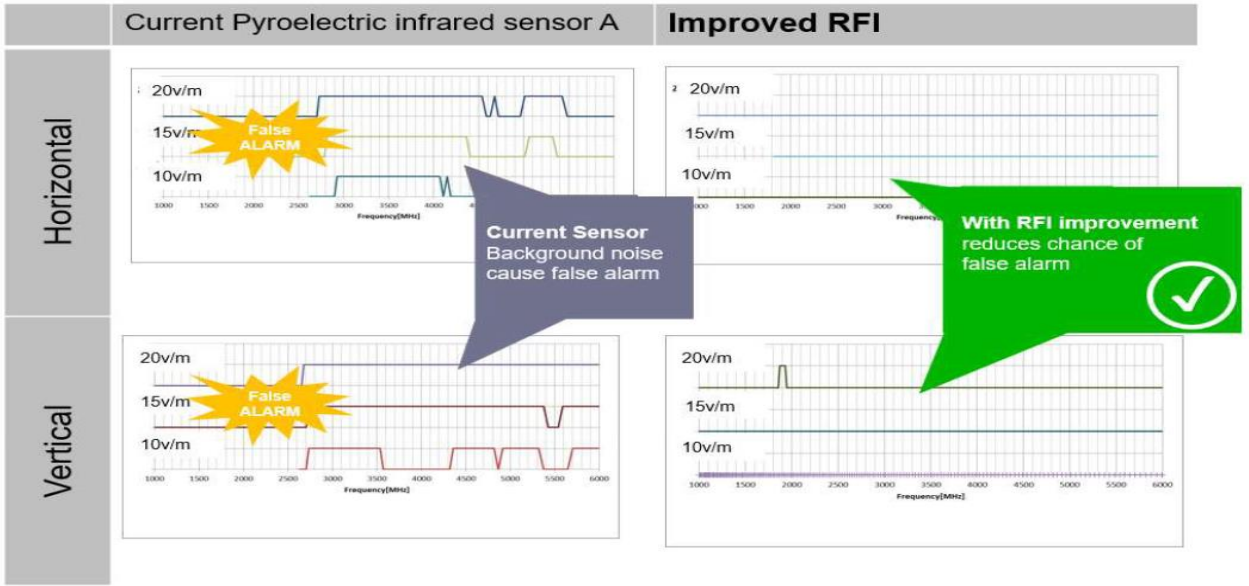
IRA-S*** series

～2017	2018	2019	2020	2021
Dual(IRA-S200 series), Quad(IRA-S400 series) : Standard, Narrow Gap, Short Lead terminal etc				
Ceiling Quad (IRA-S500 series)				
	- RFI Improvement type			
		- 2 out-put type (IRA-S900 series)		

Due to the market situation change, high performance PIR sensors must be needed. Especially, RFI performance.

Valued points of muRata PIR sensors

● Why is the RFI improved type effective ?



【Test condition】

- ・Reference : IEC61000-4-3
- ・Direction : Horizontal and Vertical
- ・Field Strength : 20V/m, 15V/m, 10V/m
- ・RFI test room : Murata's test site condition (J2 room)
- ・Frequency : 1GHz to 6 GHz
- ・Aggressor type : Pulse Modulation

RFI performance can be improved by only replacing PIR sensor to our product !!

Caution in use

1. **In the case of outdoor use, suitable optical filter and water and humidity proof structure should be applied.**
2. **To prevent failure or malfunction, please use a stabilised power supply.**
3. **Please avoid using the sensor in the following conditions because it may cause failure or malfunction ;**

a. In a fluid such as water, alcohol etc. corrosive gas (SO2, Cl2, NOX etc.) or sea breeze
b. In high humidity
c. In a place exposed directly to sunlight or headlight of automobile
d. In a place exposed to rapid ambient temperature change
e. In a place exposed directly to blow from air-conditioner or heater
f. In a place exposed to strong vibration
g. In a place exposed to strong electromagnetic field
h. In such a place where infrared ray is shaded
i. In such a place where there is a charge field or static electricity field
j. In any other place similar to the above (a) through (i)

Topics

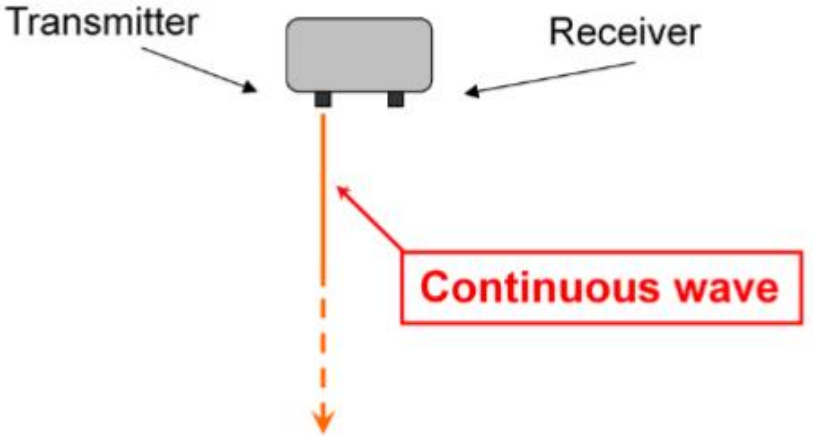
1. What is PIR sensor ?

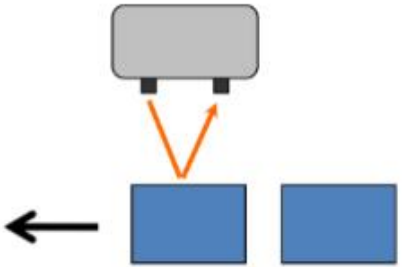
2. Tips: Motion detector design using PIR sensor

3. What is an Ultrasonic sensor?

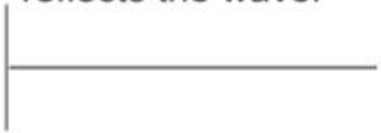
4. Tips: Presence detector design using Ultrasonic sensors

Object detection using Ultrasonic sensors

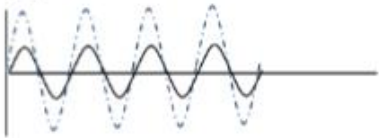




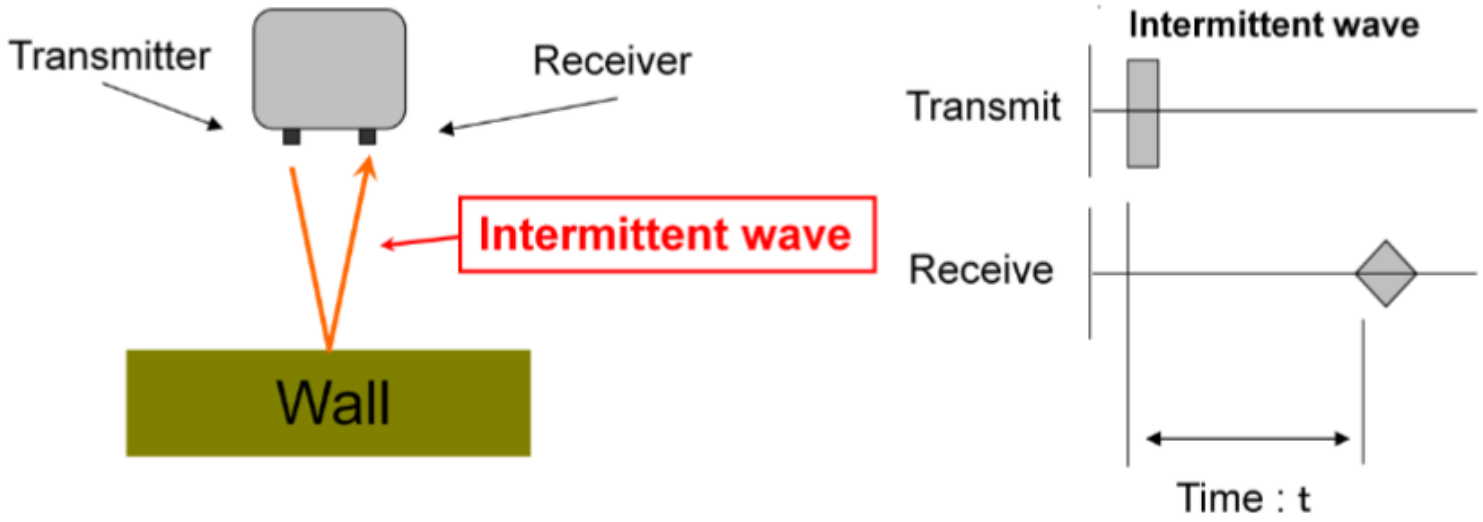
Received signal will not appear in the case that no object reflects the wave.



Smaller distance between sensor and object make signal bigger.



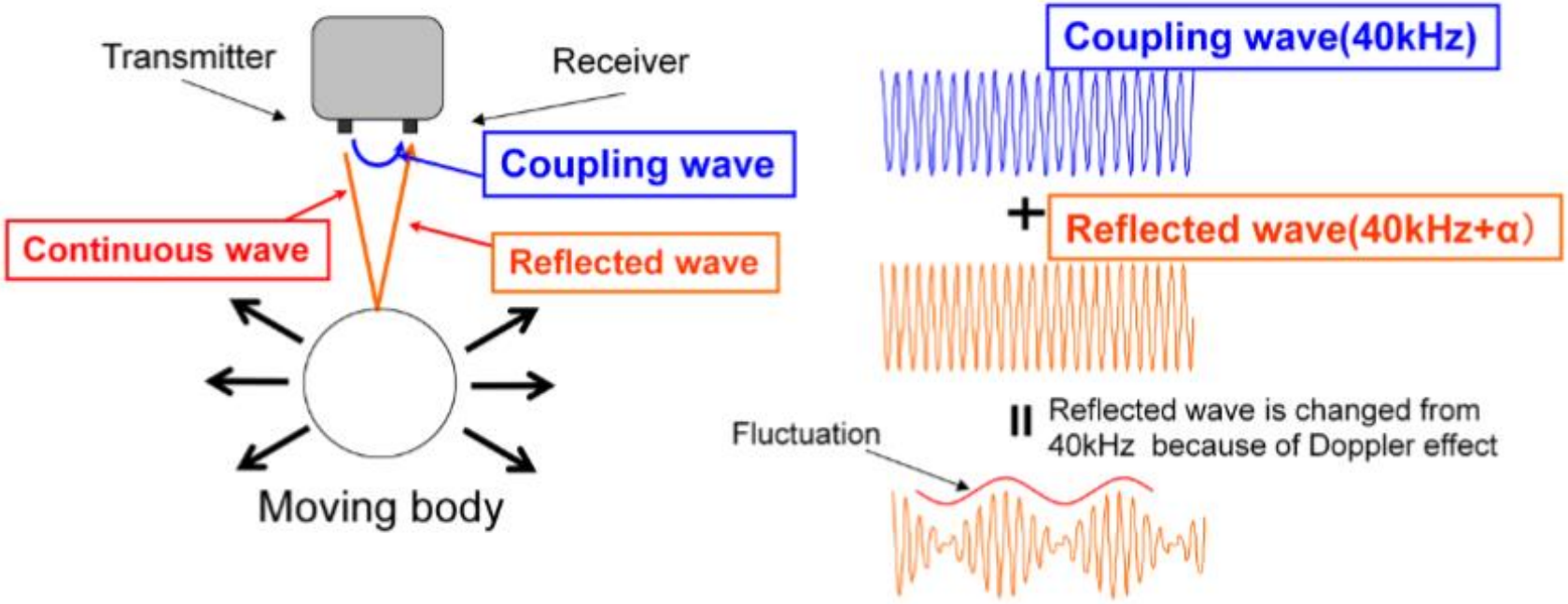
Measuring distance using Ultrasonic sensors



Measuring the time from transmitting to receiving (using clock)

Time x Sonic speed(340m/s) ＝ Distance to the object

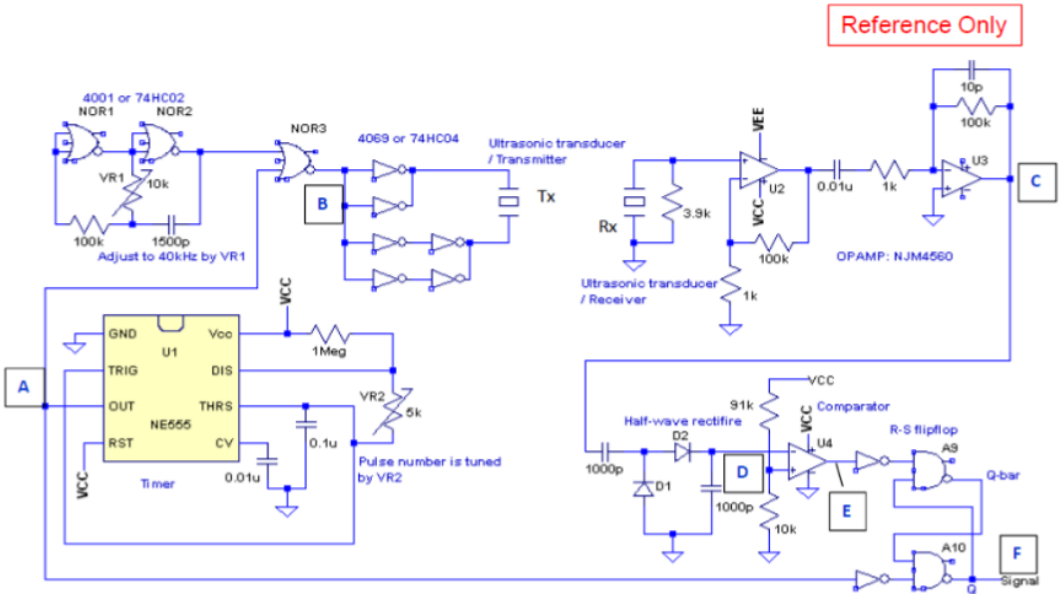
Dynamic body detection using Ultrasonic sensors

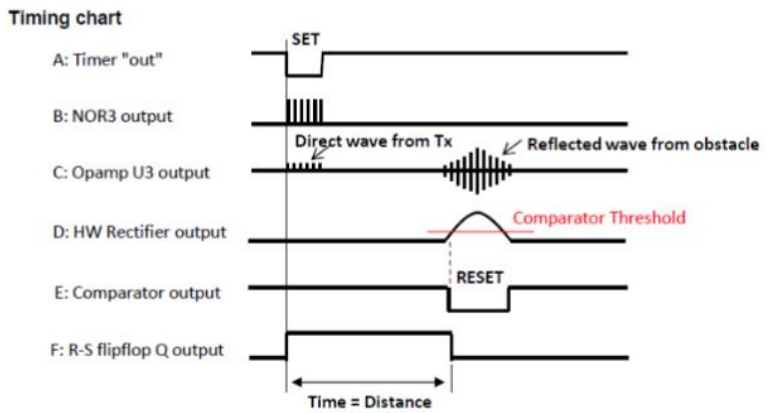


The movement is detected by fluctuations of mixed signal.

Reference circuit for ultrasonic sensor

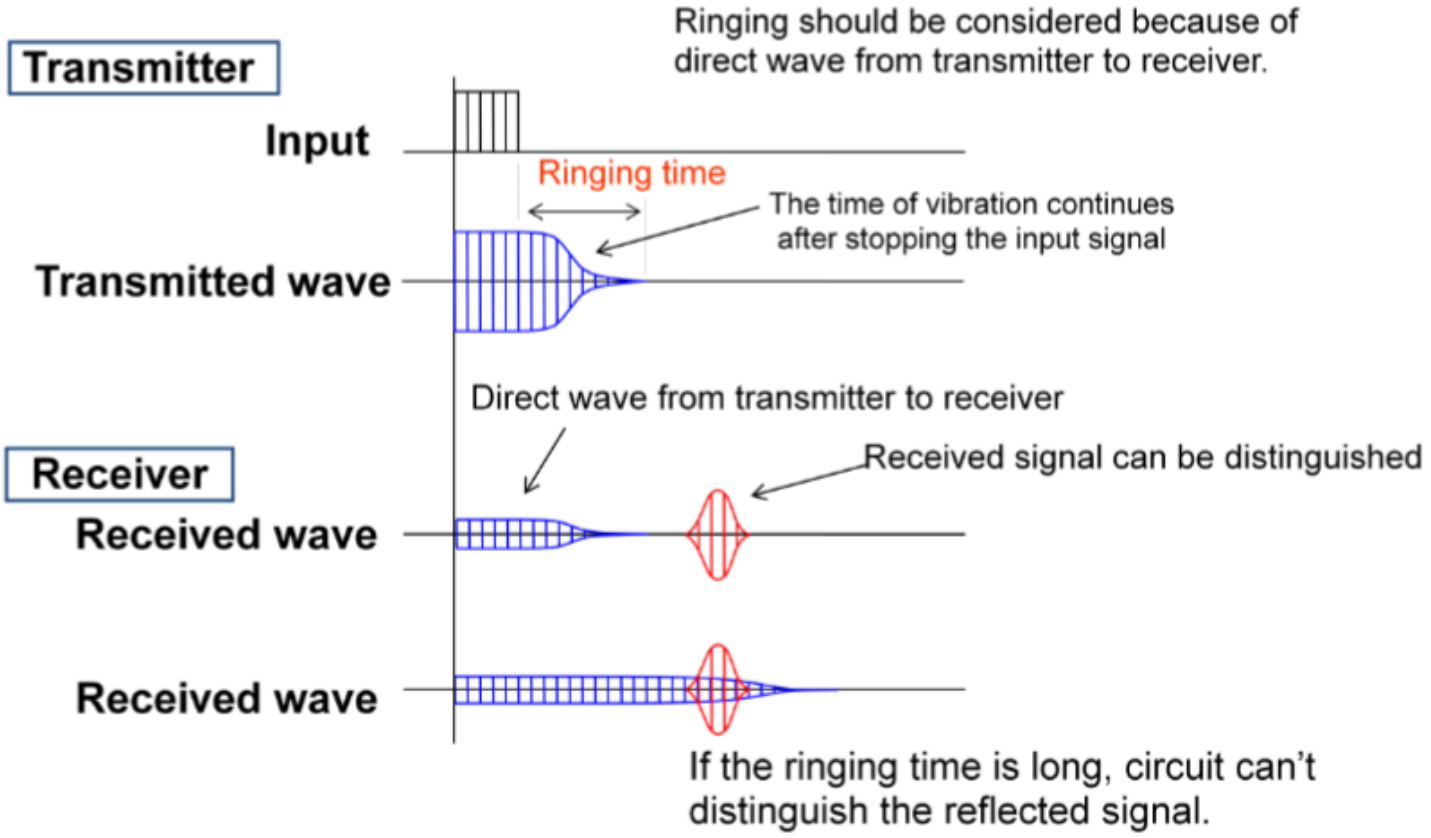
Measuring distance





Measuring Method
Set the R-S flipflop at the rise of timer output
Detect the received signal by comparator fallen down and make reset
The time between R-S flipflop is highly equal to distance
Distance= time x 346m/s at 25°C

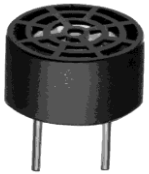
Ringing time / important to consider



Features of Lead type ultrasonic sensors

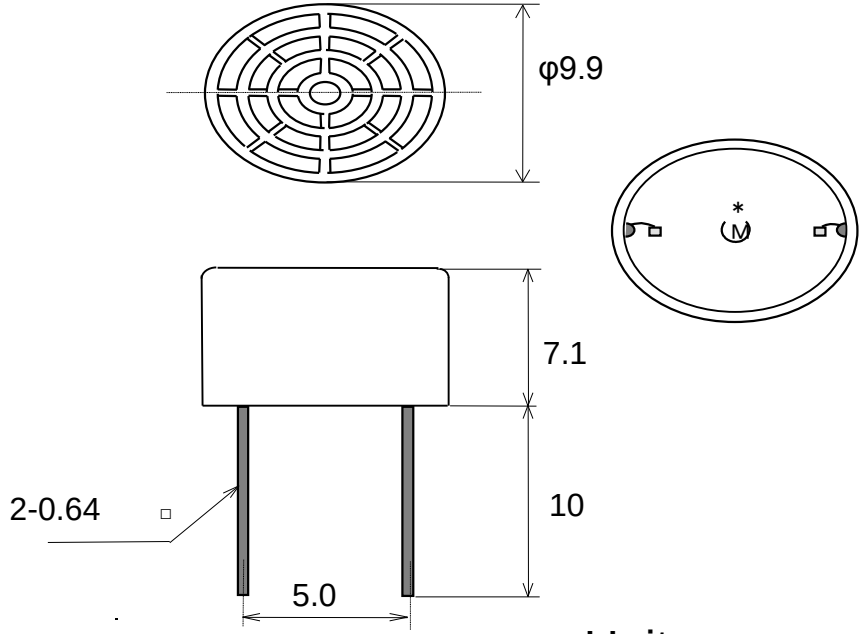
P/N:

MA40S4S
（For Transmitter）



MA40S4R
（For Receiver）

Dimension:



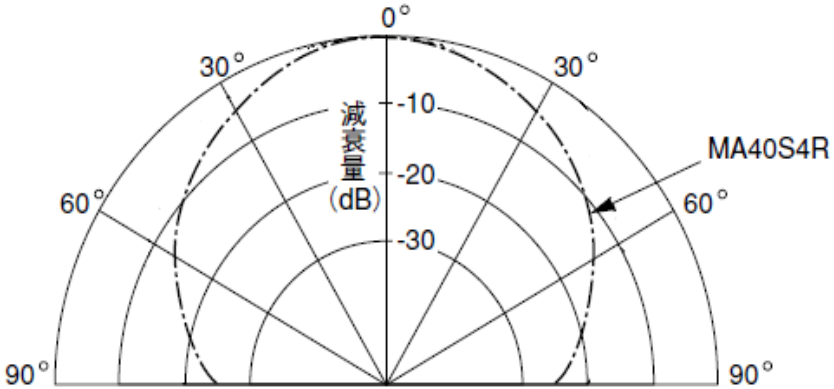
Unit: mm

Feature

- ✓ **High sensitivity and SPL**
- ✓ **For indoor applications**
- ✓ **Non waterproof**

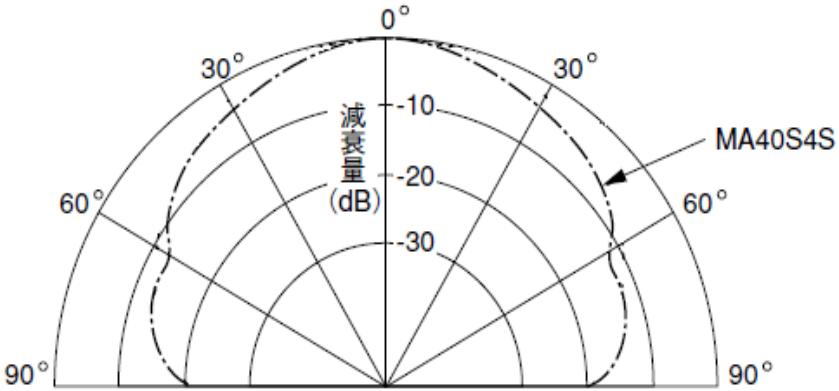
Directivity data（MA40S4R,MA40S4S）

Frequency 40kHz
Distance 30cm



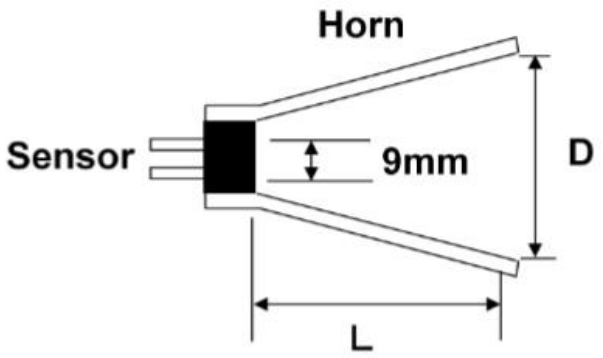
MA40S4R (Sensitivity)

Frequency 40kHz
Input Sine wave 10Vrms
Distance 30cm



MA40S4S (Pressure)

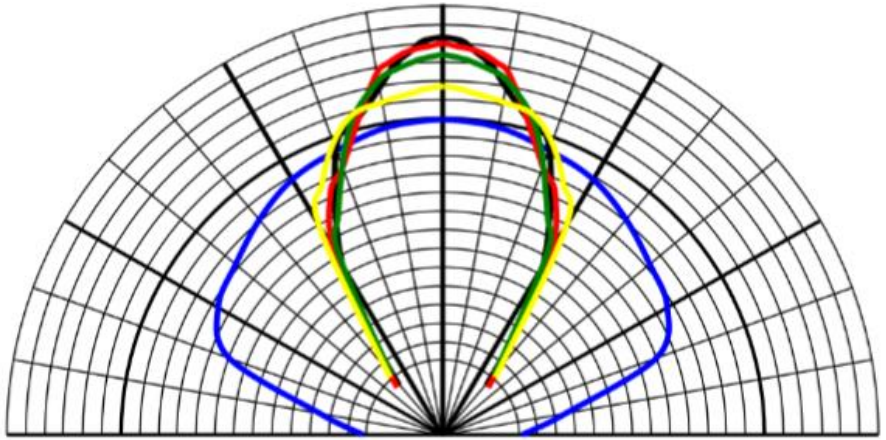
Directivity adjustment (reference)



Horn Size

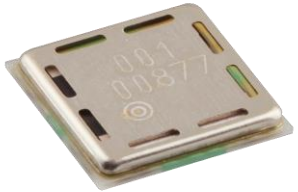
Line Color	L	D
Blue	none	none
Black	43	40
Red	33	33
Green	22	25
Yellow	11	17

(mm)



Features of SMD type ultrasonic sensors

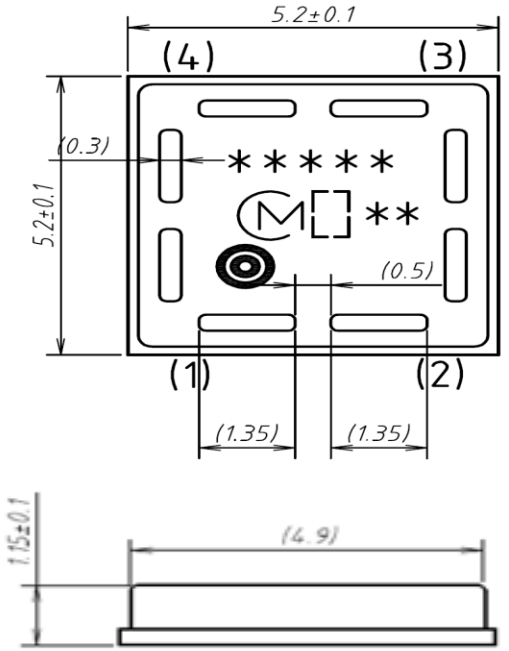
P/N:
MA40H1S-R



Feature

- ✓ **Small (5.2mm x 5.2mm)**
- ✓ **Thin (t1.15mm)**
- ✓ **SMD**
- ✓ **For indoor applications**
- ✓ **Non waterproof**
- ✓ **Not for automotive**

Dimension



Unit: mm

Application example: Distance detection
Detection range and measurement resolution

Detection range

Object	Type	Min	Max
Wall	LEAD	20cm	600cm
	SMD	20cm	400cm
Human	LEAD	20cm	300cm
	SMD	20cm	200cm

※ measurement in the front and optimised condition using horn.

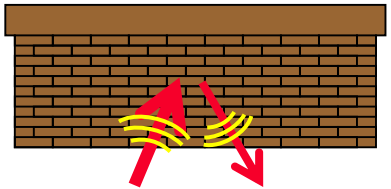
・While the receiver is receiving the direct wave, it can not measure the reflected wave
→ Short range measurement limit
・Reflected waves from distant objects have low intensity and can not be measured.
→ Long distance measurement limit

Measurement resolution

about 1cm

Effect on reflection intensity by object status

	Easy to detect （Reflection intensity is high）	Difficult to detect （Reflection intensity is low）
Size	Large	Small
Shape	Flat	Round
Surface	Hard and smooth (easy to reflect sound)	Soft (easy to absorb sound wave)



Smart Home / Office Application

Murata can contribute to your design by different type of components

CAPs, THMs

2 LED

3 Alarm

Buzzers

1 Microcontroller

5 PIR Sensor

4 Connectivity

CSPs, Crystal, DC/DC

Sensors

WiFi modules, inductors

6 Power Management

CAPs, Coils, THM, resonators

7 Battery

8 Traceability

Batteries, THMs

RFID

Thank you very much for your attention!