

24GHz Microwave Intelligent Distance Measurement Sensor Module for Middle Distance (20 meter) with Low-profile

The NJR4234BW is a sensor module that can measure the distance to a moving object and/or stationary object more than 20 m ahead and incorporates a 24 GHz band microwave circuit, antenna, and signal processing circuit in a low profile package of 38 x 38 x 4.2 mm.

As a sensor capable of distance measurement using microwave, it is possible to detect moving objects by innovative proprietary signal processing, even to detect stationary objects, and also has the function to calculate and output the distance to the objects in indoor and outdoor environments. In addition, it has the unique algorithm to prevent radio interference, possible to use multiple sensors under the same location.

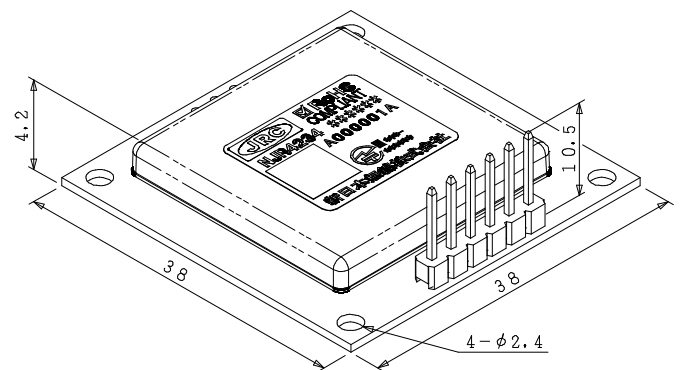
It can be used as a sensor front end with built-in primary signal processing for distance measurement. In addition, since it can be easily connected to other equipment via the UART interface, it can be used in a wide range of applications.

Features:

- Distance measurement sensor using the 24GHz microwave
- Measurement distance of 20 m for a pedestrian.
*Note1
- Antenna, Microwave RF circuit, Base-band IF circuit, MCU and also signal processing are integrated in a low-profile package
- Low-power-consumption
37 mA @ 3.3 V power supply*Note2
- Unique Signal Processing / Algorithm Installation
 - High sensitivity mobile object detection (Patented Technology)
 - Distance measurement signal processing
 - Automatic calibration and gain control
 - Radio interference prevention
- Adopted UART and digital CMOS output for interface
- Possible to be installed in indoor and outdoor locations

Applications:

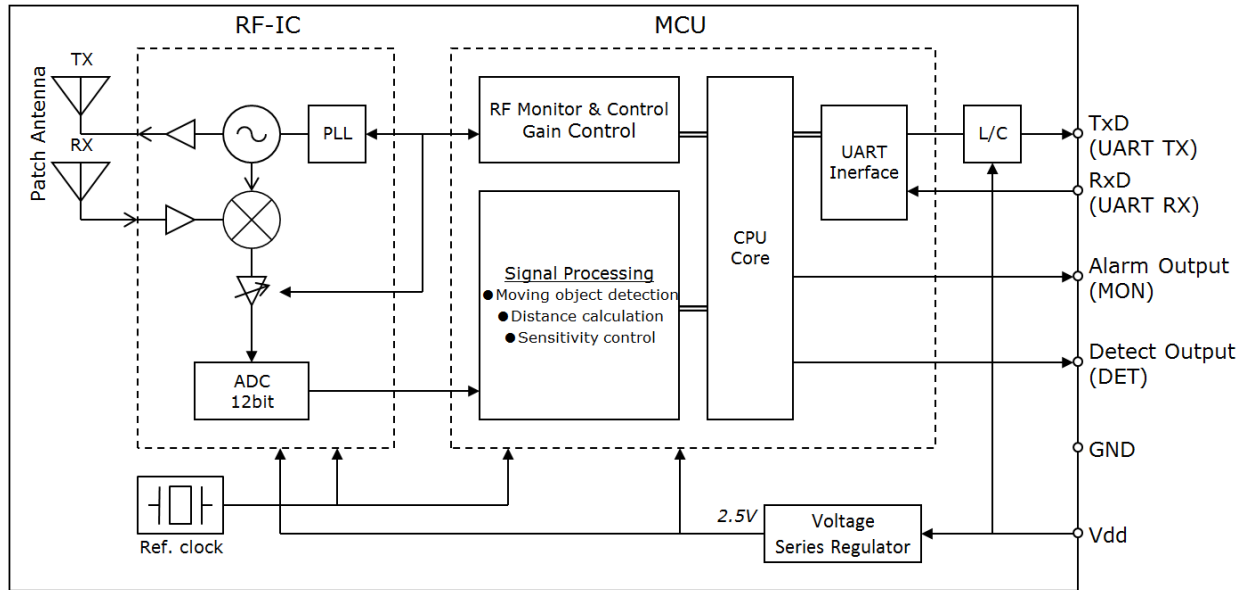
- Various equipment control by moving objects detection and measurement
 - Security equipment
 - Traffic control system
 - FA robot
 - Industrial drone
 - Parking management system



*Note1) Distance measurement 20 m is based on evaluation results. It varies depending on the reflection intensity of the moving object.

*Note2) It is realized by intermittent operation and measurement repetition time. Please use the power supply circuit for the peak current.

Functional Block diagram:



Products Line-up:

N J R 4 2 3 4 B W F 1 C 1

Identity Number & Interface Type:

C1: Standard Model / 2.54 mme Pin-header (L:10.5mm)

RF Frequency: *Note3

F1: 24.05 to 24.25 GHz / Japan

F2: 24.15 to 24.25 GHz / All of EU resions

F3: 24.075 to 24.175 GHz / United States

Measurement Operation Mode:

V: Distance Measurement for Moving Objects

W: Distance Measurement for Moving and Stationary Objects

Detection Distance Range

B: 20 m range (Detection Angle: 42°/28°) / Dimensions: 38 x 38 x 4.2 mm

Product Series Number

Model Number List:

Model No.	RF Frequency	Measurement Operation Mode	Detection Distance Range	Region / Regulations
NJR4234BWF1C1	24.05~24.25 GHz (F1 type)	Distance Measurement for Moving Objects	20 m range (Angle: 42°/28°)	JAPAN / Technical Conformity ARIB STD-T73
NJR4234BWF2C1	24.15~24.25 GHz (F2 type) ^{*Note3}			All of EU regions / RED 2014/53/EU (CE Marking)
NJR4234BWF3C1	24.075~24.175 GHz (F3 type) ^{*Note3}			US / FCC Part 15.245

*Note3) Please contact NJR for compliance status of RED and FCC.

1. Absolute Maximum Rating

ITEM	MIN.	TYP.	MAX.	UNITS	REMARKS
Supply Voltage	0	—	6.5	V	
Source / Sink Current of MON port	-5	—	5	mA	
Source / Sink Current of DET port	-5	—	5	mA	
Source / Sink Current of UART TX port	-5	—	5	mA	
UART RX	0	—	3.6	V	Do NOT exceed supply voltage
Operating Temperature	-40	—	+85	°C	
Storage Temperature	-40	—	+85	°C	

2. Electrical Characteristics

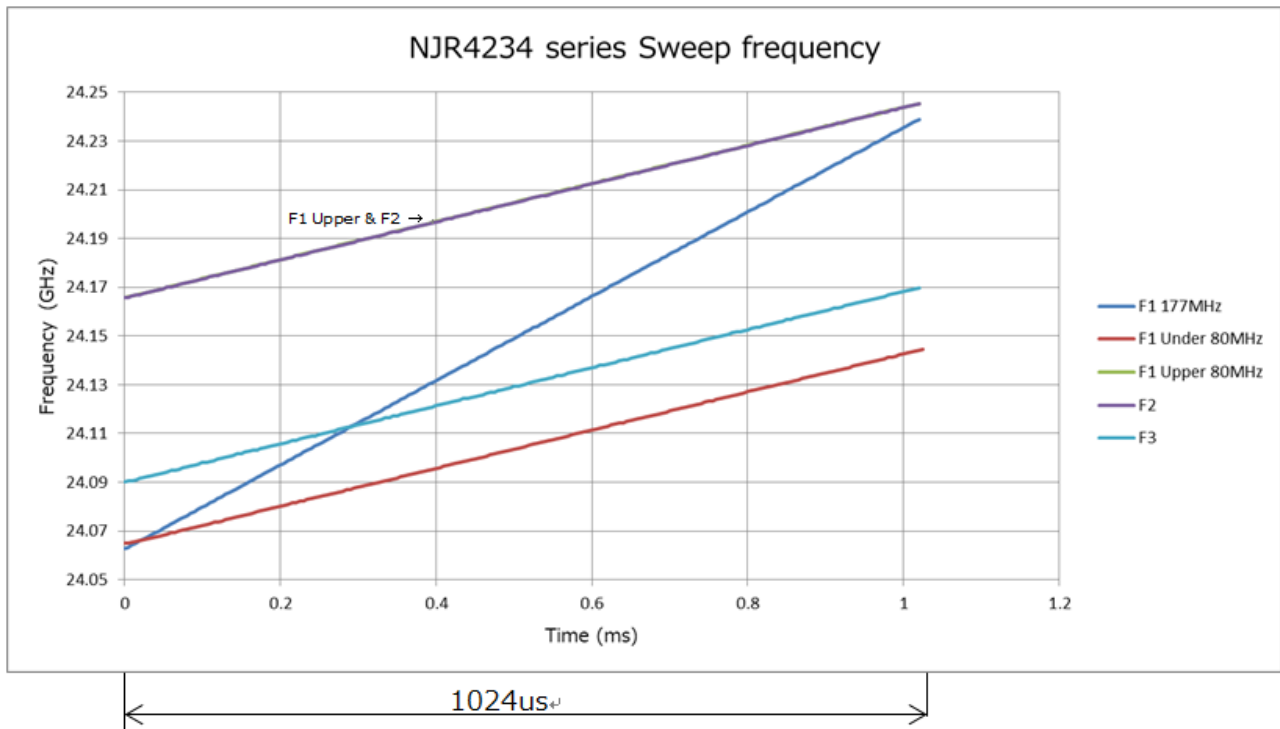
Common measure condition Ta= +25 °C

ITEM	PARAMETER			UNITS	REMARKS
	MIN.	TYP.	MAX.		
2.1. Power Supply					
Supply Voltage	2.9	3.3	3.6	V	Vdd
Operating Current					
i) Distance Measurement mode					
Peak current	—	—	250	mA	Refer to figure 1.
Average current	—	37	50	mA	
ii) Initialization and Calibration mode					
Peak current	—	—	250	mA	Refer to figure 2.
Average current	—	—	75	mA	
iii) Sleep mode	—	—	15	mA	
2.2. Characteristic of Input and Output Ports					
Input Voltage of UART RX Port					
Range of High Level	0.8*Vdd	—	Vdd	V	
Range of Low Level	0	—	0.2*Vdd	V	
Output Voltage of UART TX Port					
Range of High Level	Vdd-0.6	—	Vdd	V	
Range of Low Level	0	—	0.6	V	
Source Current of UART TX port	—	—	5	mA	
Sink Current of UART TX port	—	—	5	mA	
Output Voltage of MON Port					
Range of High Level	1.9	—	2.5	V	
Range of Low Level	0	—	0.6	V	
Source Current of MON port	—	—	4	mA	
Sink Current of MON port	—	—	4	mA	
Output Voltage of DET Port					
Range of High Level	1.9	—	2.5	V	
Range of Low Level	0	—	0.6	V	
Source Current of DET port	—	—	4	mA	
Sink Current of DET port	—	—	4	mA	

NJR4234BW series

ITEM	PARAMETER			UNITS	REMARKS
	MIN.	TYP.	MAX.		
2.3. Sensor RF					
Conformity Standard	● MIC Technical Conformity (Japan): ARIB STD-T73 ● EU Regulation: Radio Equipment Directive 2014/53/EU *Note1 ● FCC Regulation: Part 15.245 *Note1				
Operating Frequency					
F1 type	24.05	—	24.25	GHz	Technical Conformity
F2 type	24.15	—	24.25	GHz	EU Regulation *Note1
F3 type	24.075	—	24.175	GHz	FCC Regulation *Note1
Output Power (E.I.R.P.)	9	12	13.8	dBm	
Spurious Emission (E.I.R.P.)	—	—	-30	dBm	Wide-band including 2 nd harmonics
Maximum modulation band width					
F1 type	—	—	177	MHz	
F2 & F3 type	—	—	80	MHz	
Modulation Sweep Time	—	1024	—	us	
Antenna: 2 x 4 planar antenna type					
Antenna Gain	—	13.5	—	dBi	
-3dB beam width / Horizontal	—	42	—	deg.	Refer to figure 3.
-3dB beam width / Vertical	—	28	—	deg.	
Side-lobe suppression / Horizontal	—	—	—	dB	No Side lobe
Side-lobe suppression / Vertical	—	—	—	dB	No Side lobe

Operation Frequency Modulation Band Width (Reference)



*Note1) Please contact NJRC for compliance status of RED and FCC.

Actual Operating Current (Reference)

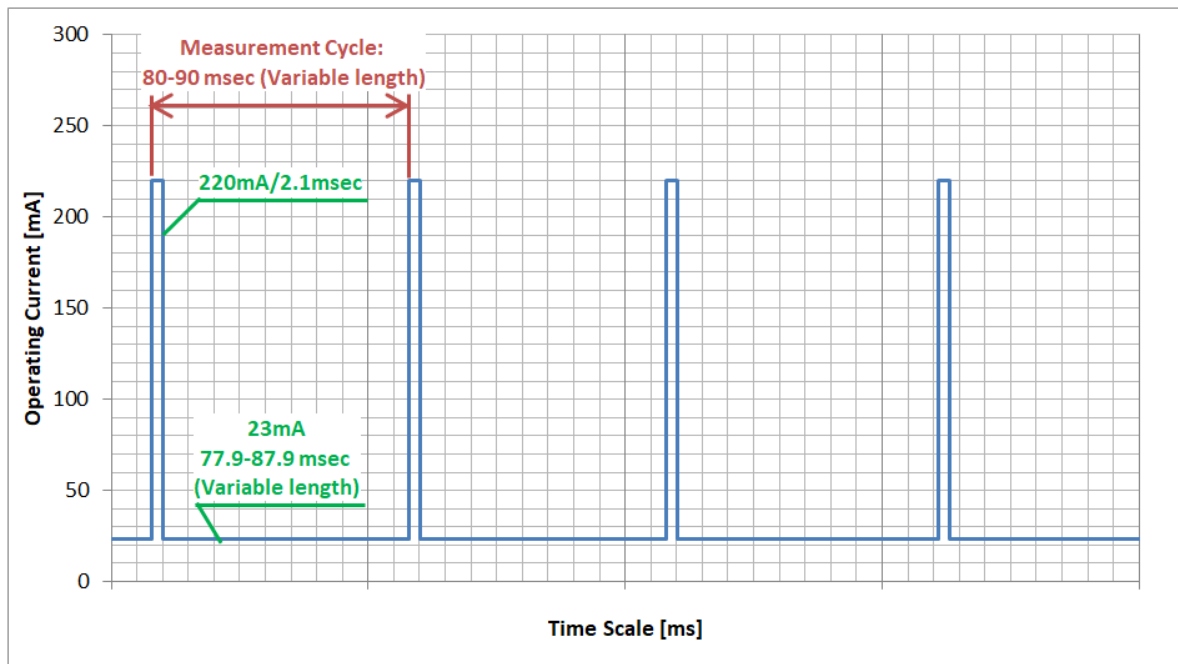


Fig. 1 Variation of Operating Current at Distance Measurement Mode

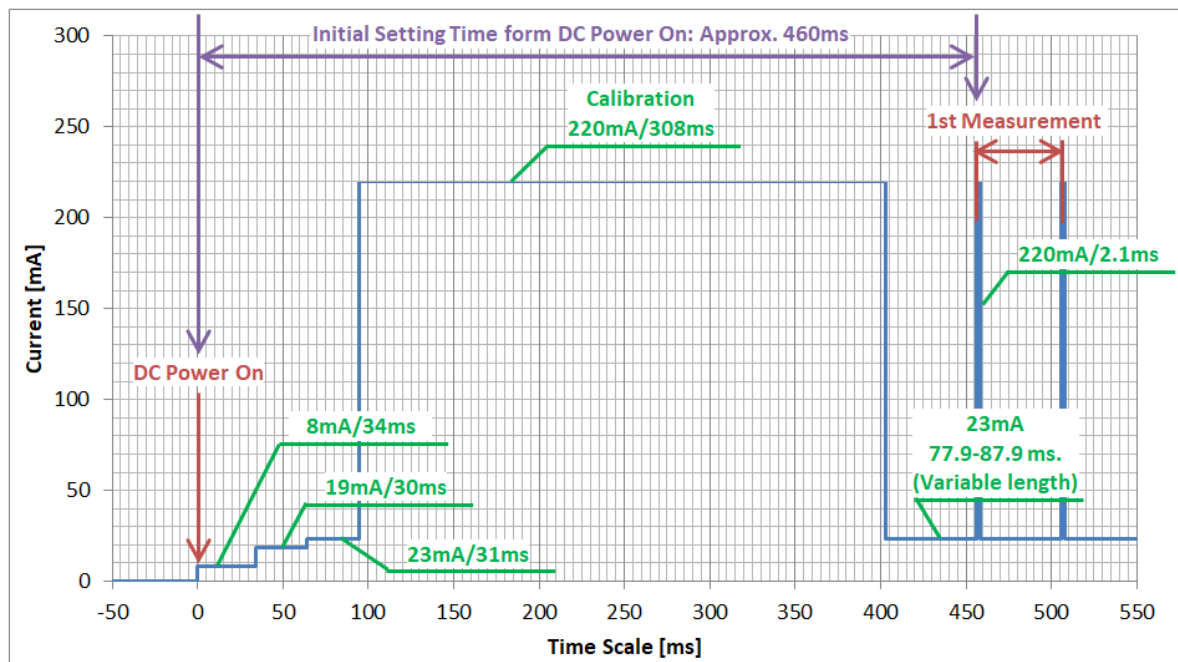


Fig. 2 Variation of Operating Current at Initialization Mode

Antenna Pattern

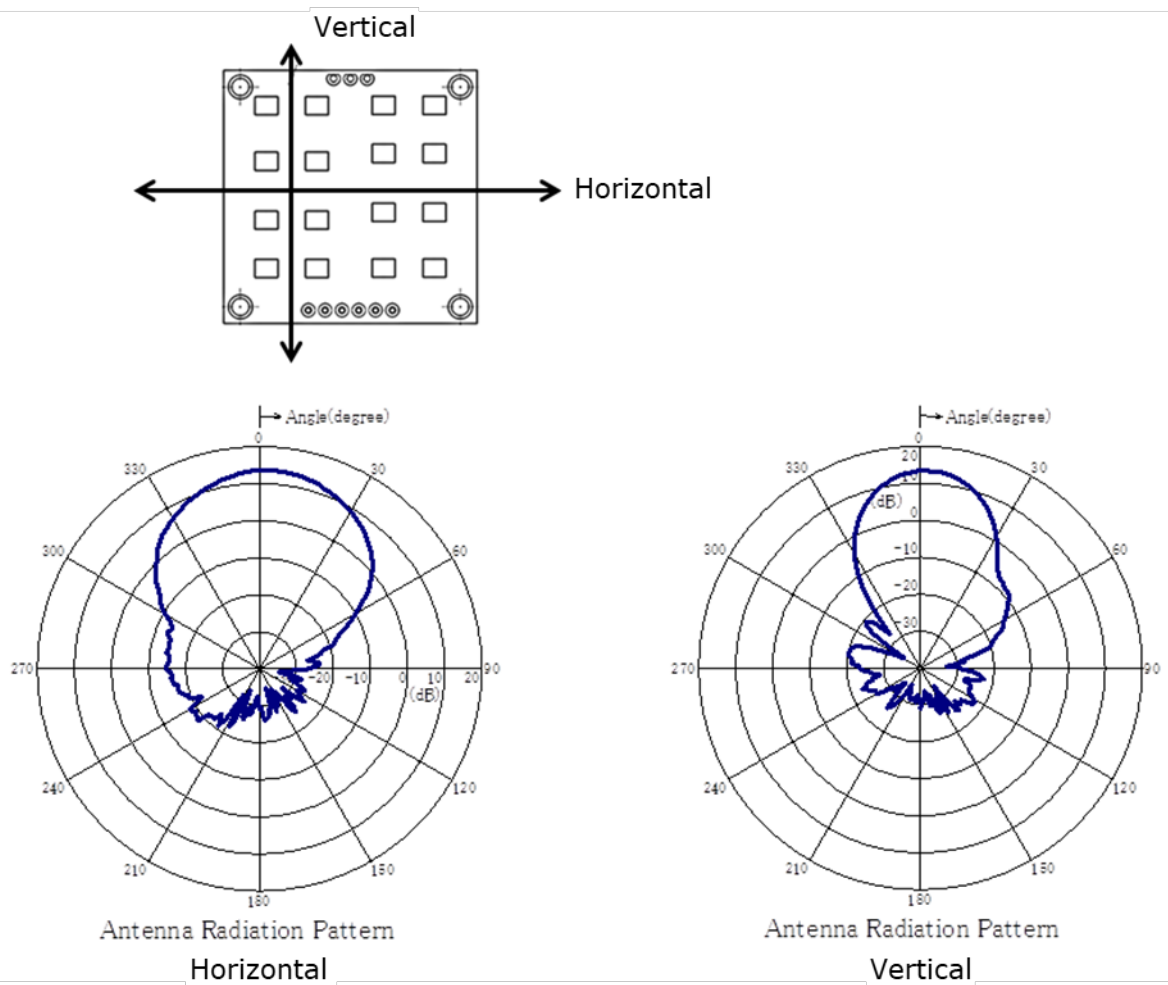


Fig. 3 Antenna Radiation Pattern

Attention point on antenna characteristics in installation

- To avoid the influence on the antenna pattern, please do not put any objects of radio reflections within 30 cm in front of the antenna surface of this sensor.
 - When storing this sensor in a cover, design it appropriately to reduce the influence on the antenna pattern, and check with a demonstration experiment etc.
- Refer to Section 14 for the design of the cover.

3. Sensing Specifications

3.1. Sensing Performance

Common measure condition Ta= +25 °C

ITEM	PERFORMANCE	UNITS	REMARKS
Maximum Detection Distance	20	m	Depends on RCS
Maximum Detection Distance by Nyquist			
F1 type	86	m	177MHz Band Width
F2 & F3 type	170	m	80MHz Band Width
Minimum Detection Distance			
F1 type	0.85	m	177MHz Band Width
F2 & F3 type	1.9	m	80MHz Band Width
Detectable Angle			
Horizontal	42	deg.	Depends on -3dB beam width of antenna
Vertical	28	deg.	
Distance Resolution			
F1 type	1	cm	177MHz Band Width
F2 & F3 type	2	cm	80MHz Band Width
Separation Resolution			
F1 type	1.7	m	177MHz Band Width
F2 & F3 type	3.8	m	80MHz Band Width
Measurement Time Interval	80 to 90	ms	Variable length *Note1

*Note1) When the radio interference prevention function is enabled, the measurement time interval is variable between 80 and 90 ms. It is fixed at 80 ms when it is disable.

3.1.1. Maximum Detection Distance

The detection distance is the value measured by the standard target (adult) moving towards the sensor in an open space without obstacles. The details are mentioned in below. The performance of the detection distance varies depending on installation conditions, the shape and size of the object, the angle of penetration of radio waves, and other conditions. The detection distance is not guaranteed parameter but the performance of this product is specified by electrical characteristics.

Measurement condition of detection performance

- * Temperature:
Ta = +25 °C
- * Target of Measurement:
An adult of 170 cm / 70 kg is walking toward sensor.
(Refer to figure 4 and figure 5)
- * Installation of the Sensor:
The sensor is installed as the antennas horizontal horizontally in a height of 1 m from the ground. (Refer to figure 4)

With respect to the accuracy of the detection distance, when measuring the object moving with high-speed, the Doppler frequency of the moving object is overlapped (Doppler shift), so an error occurs. In the case of the 80 MHz band, an error of about 1 m will result at a speed of 11 km / h.

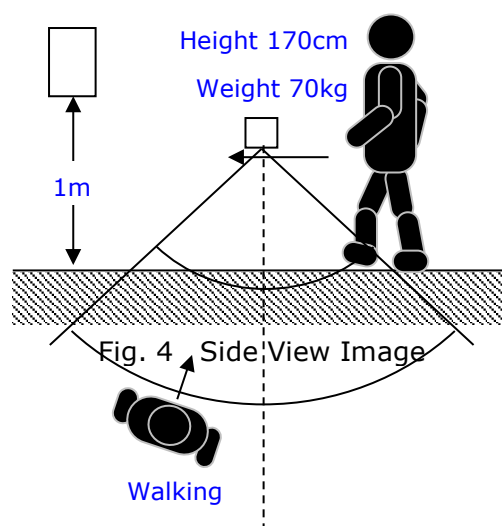


Fig. 5 Top View Image

3.1.2. Maximum Detection Distance by Nyquist

The maximum detection distance is limited by the Nyquist frequency of the AD sampling frequency inside the sensor. Depending on the reflection intensity of radio waves it may be subject to limitations on this distance.

3.1.3. Minimum Detection Distance

The minimum detection distance is determined by the value of $1/2$ that is divided the speed of light by the modulation band of the frequency. Although the distance closer than the minimum detection distance is output, accuracy and stability of measurement are significantly reduced. When detecting targets that are nearer than the minimum detection distance it shall be used after sufficient evaluation.

3.1.4. Distance Resolution and Separation Resolution

The distance resolution is determined by the size of FFT analysis in signal processing of distance calculation. The size of FFT analysis is 11th power of 2.

The separation resolution is limited by the value that is divided the speed of light by the modulation band of the frequency, but if objects are moving at different speeds, the separation resolution will be equal to the distance resolution.

3.2. Measurement Time and Radio Interference Prevention Function

The measurement time is approx. 80 ms. The time which the RF circuit transmits radio waves during measurement is approx. 2 ms. The operating current is reduced by intermittently operating radio wave transmission. The measurement time is fixed length and unchangeable.

When the radio interference prevention function is enabled, the measurement time is random variable length between 80 to 90 ms.

The details of the measurement time are shown in figure 6.

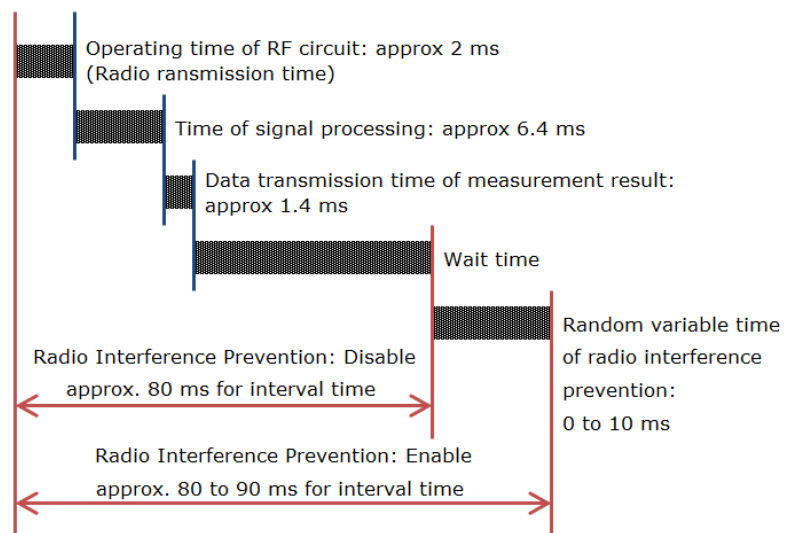


Fig. 6 Measurement Time

3.2.1. Radio Interference Prevention Function

If the same frequency at the same time is used, the radio wave sensor will become inoperable due to radio interference. This sensor has a function to probabilistically prevent radio interference. It can be enabled / disabled by command control.

It is recommended that this function is enabled when using multiple in a small area.

A random variable time (10 ms / 256 steps) is added by the radio interference prevention function after 50 ms of normal measurement time. The random variable time changes for each measurement.

3.3. Detectable Area

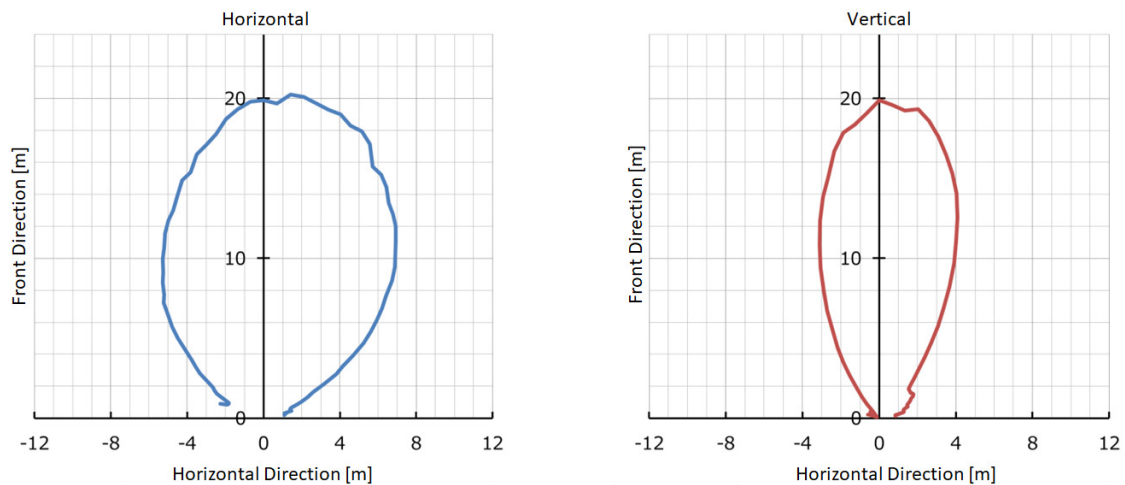


Fig. 7 Detectable Area (Reference Data form Antenna Radiation Pattern)

3.4. Signal Processing and Software

It is designed to do signal processing with the MCU inside the sensor. The details of signal processing are referred to Section 4.

Software may be upgraded due to performance improvement etc.

4. Signal Processing and Function

This sensor has the function to detect the moving and stationary objects and calculate the distance to them by our internal signal processing.

Distance information for up to seven stationary objects and up to three moving objects are output in ascending order of the distance from the sensor or in descending order of the signal. In the default value, when there are stationary objects, up to seven are output, and the moving body outputs only peak 1.

The following signal processing and functions are loaded in order to improve the detection accuracy of moving objects and the sensitivity of distance measurement.

List of signal processing and functions

- | | |
|---------------------------------|--|
| 1) Calibration | 5) Peak Emphasis Function |
| 2) Gain Control Function | 6) Moving Average Function |
| 3) Measurement Distance Range | 7) Zoom FFT Function |
| 4) Sensitivity Setting Function | 8) Frequency Band Switching Function(F1 type only) |

4.1. Calibration

Calibration is loaded for the purpose of reducing unexpected reflection of radio waves and multipath influence. It is executed automatically when power is turned on and reset, or arbitrarily by command.

Calibration is a function to cancel DC offset and trend of internal circuit. DC offsets and trends are generated by the reflection of radio waves from short range reflectors on the front of the antenna. Also if it is put in a case and/covers it will also occur in radio wave reflection by the case. Moreover, these signals may fluctuate due to temperature fluctuation and time continuation.

It shall be performed when changing the sensor installation environment. And also it is recommended that it is performed with periodical time (about once a day).

4.2. Gain Control Function

The gain configuration can be set in two steps to detect a moving object in the range from a short distance to a long distance. There is also a configuration to control these gains automatically, and a configuration to select fixed low gain and high gain. The default configuration is automatic control.

If there is an object near the sensor or there is a target with a large reflection area, the amplifier inside the sensor may be saturated with the received power. The gain control function is used to avoid this saturation.

The basic gain at automatic control configuration is high gain. The sensor checks the saturation of the signal once every 2.4 seconds and changes it to low gain when saturated. If saturation does not exist, it returns to high gain. When using this sensor in a narrow area such as indoor room, it is recommended to set a fixed low gain.

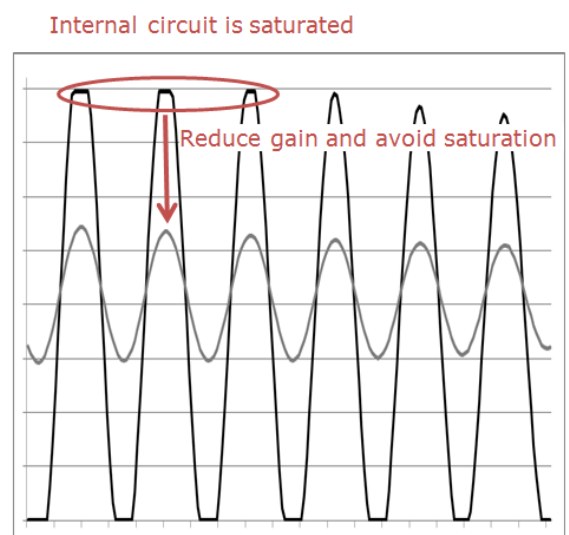


Fig. 8 Image of Gain Control

4.3. Measurement Distance Range

The measurement distance range is a function that can specify the range of distance to be measured, and use it when there is a range that is wanted to detect. The configurable range is between 0 m and the maximum detection distance by Nyquist. The maximum detection distance by Nyquist is 86 m for F 1 type and 170 m for F 2 and F 3 Type.

When measurement distance range is configured, up to three distance information within this range is output. The distance of the peak outside this range is not output. Also, if there is no peak within this range, non-detection (0xFFFF) is output. It can be set for each stationary object and mobile object.

4.4. Sensitivity Setting Function

The sensitivity setting is a function to reduce the possibility of erroneous detection and failure. This function is used to distinguish between signal and noise.

4.4.1. Sensitivity Setting Function of the stationary objects

The sensitivity setting is a function not to recognize peaks that are lower than setting sensitivity. In particular the distance information of peaks that are lower than setting sensitivity will be not output (note that the power information of all peaks including lower than setting sensitivity will be output).

4.4.2. Sensitivity Setting Function of the moving objects

The larger the configuration value, the lower the sensitivity. Also, this function affects the maximum detectable distance.

This sensitivity setting is not a threshold value for a specific peak value but by the integration power in the whole band of the received signal. When the integration power exceeds the sensitivity setting configuration, the distance information of peaks is output. If it does not exceed it, it outputs non-detection (0xFFFF). The integration power is output together with the distance information as the signal level regardless of the state of sensitivity setting. The sensitivity setting also combines with setting of the DET terminal. When integration power exceeds the sensitivity setting, the output of the DET terminal changes "H", and when it does not exceed "L".

The figure 9 is the measured value of the signal level (integration power) indicated by the standard target shown in Section 4.1.1 in an environment with very little reflection. Based on the target detection distance, it can be used as a reference value for sensitivity setting configuration.

The recommendation value of sensitivity setting is shown in following chart. The default configuration is 100.

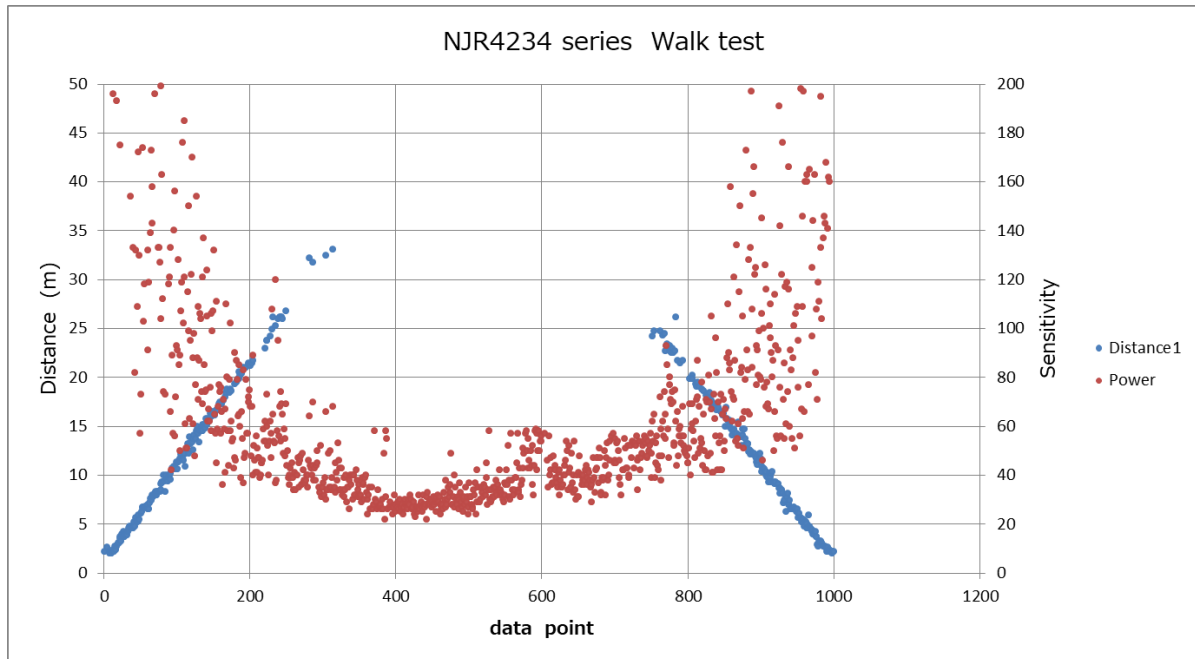


Fig. 9 Actual Evaluation Data of Signal Level

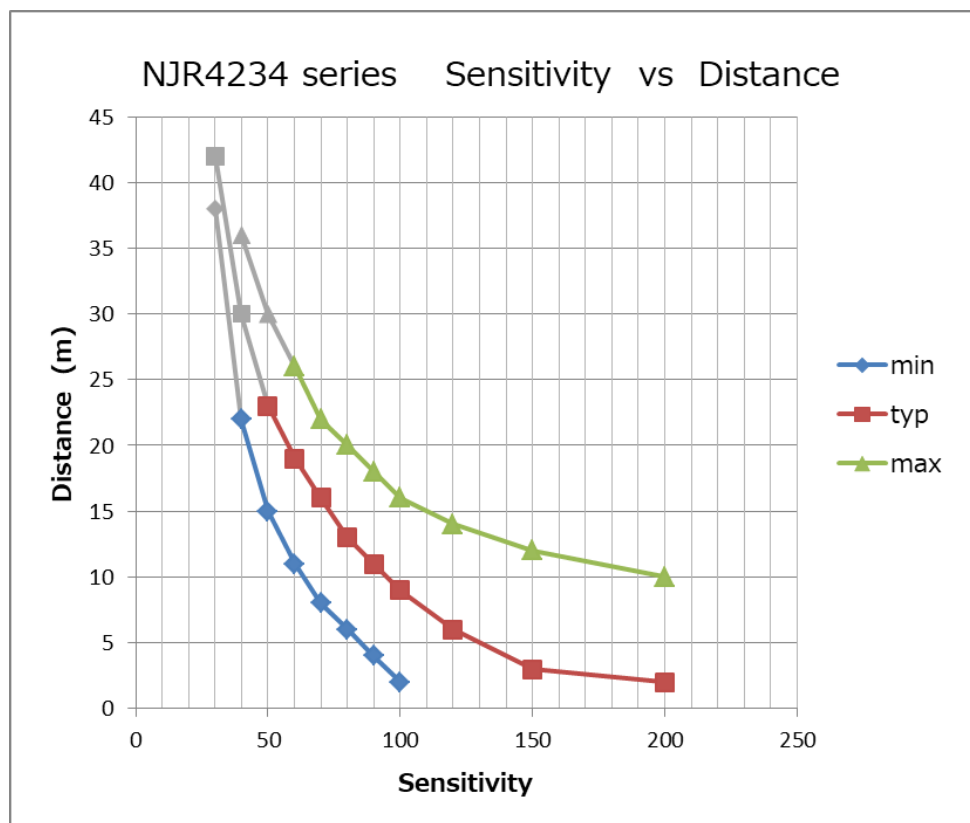


Fig. 10 Sensitivity vs Distance

4.5. Peak Emphasis Function

The sensor outputs up to three distance information which means Peak 1, Peak 2 and Peak 3 in order of closer to the sensor. The peak emphasis is a function not to select peaks smaller than the configuration value in order to emphasize the largest peak among these three peak values. The default configuration is valid.

In a generic peak search, very small peaks may be selected as compared with the largest peak. In order to avoid this phenomenon, the small peaks are not intentionally selected by setting the ratio with the largest peak value. The peak selection range is set between the largest peak and the value which the largest peak is divided by the configuration value. For example, if the configuration is 4, the peak selection range will be from 25 % to 100%. The explanation of this function is shown in figure 10.

Even when the measurement distance range is configured, peak outside the range is also selected for the largest peak. The image of this description is shown in figure 11.

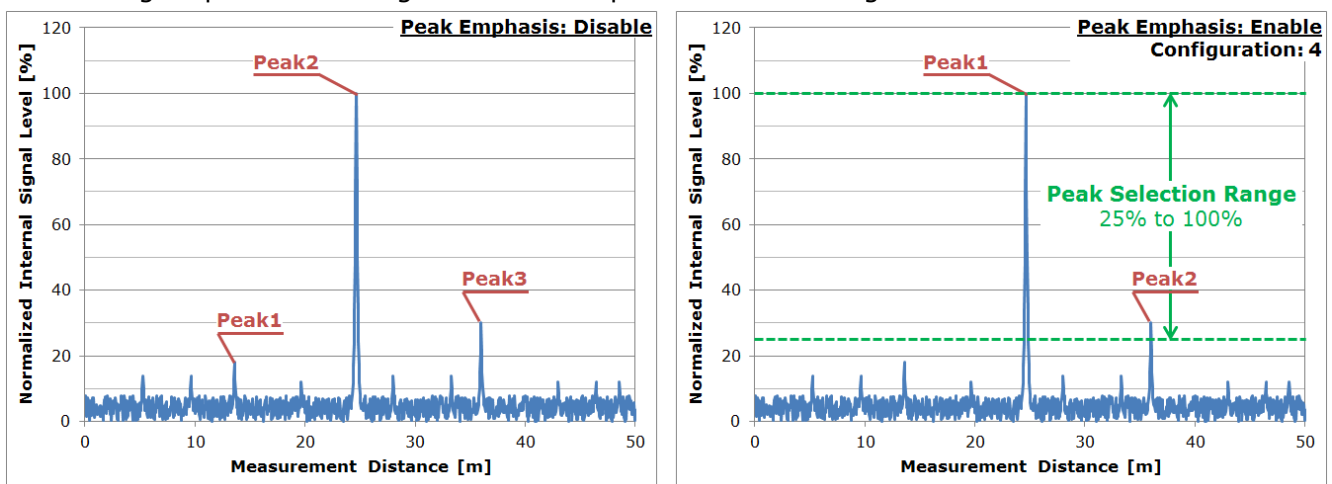


Fig. 11 Explanation of Peak Emphasis Function

4.6. Moving Average Function

The moving average is a function that performs moving average processing on distance measurement results and can be used to reduce false detection. The default configuration is valid and 4 times of moving average. The configurable is disable of this function, 2 times and 4 times. If the detection target moves at high speed (10 km/h and more), it is recommended to configure 2 times of the moving average.

4.7. Frequency Band Switching Function (F1 type only)

This sensor adopts a PLL (Phase Lock Loop) type oscillator and controls the frequency.

In this function, it is possible to set it to 80 MHz on the lower side, 80 MHz on the upper side and the 177 MHz band. The default configuration is 177 MHz band.

The band is managed by the frequency plan of Fig. 12 and it is not available to be changed from outside.

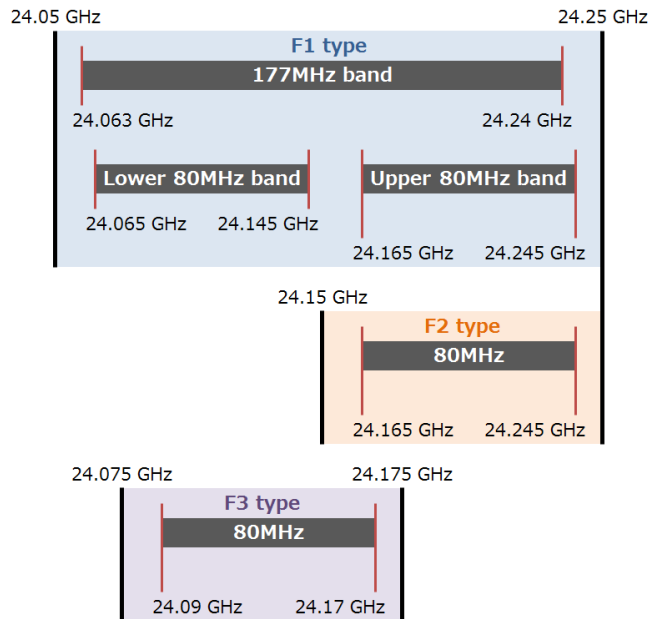


Fig. 12 Frequency Plan

4.8. Zoom FFT Function

This function improves accuracy of distance resolution by zooming the measurement distance. The magnification of the zoom FFT can be selected from 2 times / 4 times / 8 times, and the distance resolution is improved instead of narrowing the detection distance range.

For the F1 type (177 MHz band), the maximum detection distance is 86 m and the distance resolution is about 8.3 cm for the standard (1 time). But when the zoom FFT is set to 2 times the distance range will be 38 m and the distance resolution will be about 4.2 cm. When the zoom FFT is set to 4 times, the distance range becomes 19 m and the distance resolution is about 2.1 cm. When the zoom FFT is set to 8 times, the distance range becomes 9 m and the distance resolution becomes about 1 cm.

For the F2 and F3 type (80 MHz band), the maximum detection distance is 170 m and the distance resolution is about 18.75 cm for the standard (1 time). But when the zoom FFT is set to 2 times the distance range will be 76 m and the distance resolution will be about 9.4 cm. When the zoom FFT is set to 4 times, the distance range becomes 38 m and the distance resolution is about 4.7 cm. When the zoom FFT is set to 8 times, the distance range becomes 19 m and the distance resolution becomes about 2.4 cm.

Since the detection distance range is narrowed, when using the zoom FFT function, it is necessary to set the lower limit distance of the measurement range after setting the magnification. If not set, the lower limit value is 0 m

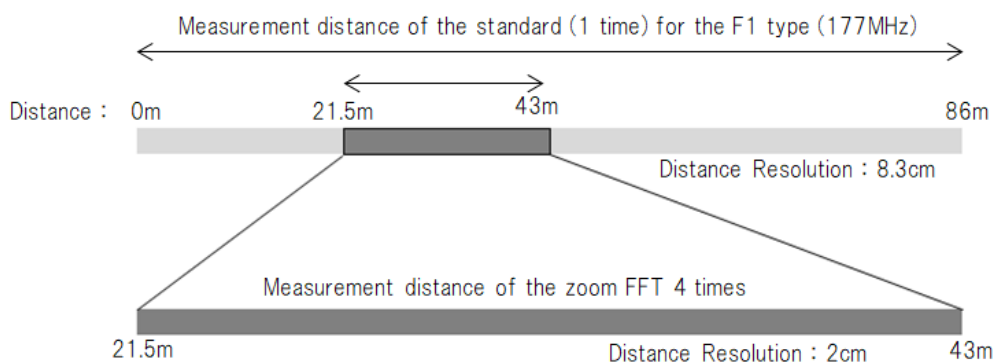


Fig. 13 Explanation of Zoom FFT Function

5. Interface

5.1. Pin Assignment

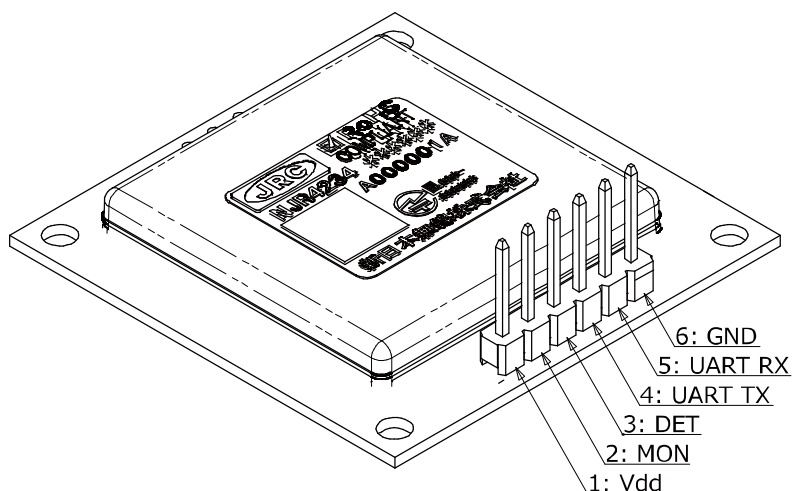


Fig. 14 Pin Diagram

#	NAME	I/O	DESCRIPTION
1	Vdd	I	Power Supply: 2.9 to 5.25 V *Note1
2	MON	O	Notice of abnormal condition (alarm) *Note2 The alarm is output when the internal PLL circuit is unlocked. The state is checked every measurement. H: Normal / L: Alarm Output current < +/-4 mA max.
3	DET	O	Digital output of CMOS level for detection result *Note2 Detection result is output when the signal level exceeds the sensitivity setting. The details are referred to Section 4.4. H: Detect / L: No detect Output current < +/-4 mA max.
4	UART TX	O	UART TX *Note3
5	UART RX	I	UART RX *Note4
6	GND	—	GND Pin

Connector: Pin-header of 2.54mm pitch

*Note1) Applied voltage must be paid attention because there is no reverse connection protection circuit at the Vdd pin.

The applied voltage should be the same voltage as the power supply of the connected equipment.

*Note2) The logic voltage of those pin is 0 V low level and 2.5 V high level. The voltage for the receiving circuit of the connected equipment should be the same voltage as this logic

*Note3) This pin (UART TX) outputs using the internal level conversion IC. High level voltage is same as Vdd voltage.

*Note4) The input voltage of high level input for this pin (UART RX) must not exceed the voltage of Vdd.

5.2. UART Communication Interface

This sensor has a built-in MCU, it is possible to control various configurations and to acquire distance information from external MCU by UART.

ITEM	FORMAT	UNITS	REMARKS
Signal Level	CMOS	—	Refer to Section 5.1.
Communication Parameters			
Baud Rates	115200	bps	
Data Bits	8	bits	
Stop Bits	1	bits	
Parity	no	—	
Handshake	no	—	
Byte Order	LBS	—	

6. Operational Mode

6.1. MODE

MODE	DESCRIPTION
Power ON / Reset	CPU Reset.
Initialization Mode	Initialization and default configuration for RF-IC. (approx. 70 ms)
Calibration Mode	Performing calibration. The details are referred to Section 4.1 (approx. 340 ms)
Distance Measurement Mode	Measure the distance of the moving and stationary objects periodically (80 to 90 ms) and output the distance measurement result. The following items can be set. Configurations settings are accepted in this mode and sleep mode. • Radio Interference Prevention Function: Default – Enable (Refereed to Section 3.2.1) • Number of Distance Measurement Output Data: Default – 7 peaks for stationary object and peak 1 for moving object • Gain Control: Default – Automatic Control (Refereed to Section 4.2) • Measurement Distance Range: Default - 0 m and Maximum Measurement Distance by Nyquist (Refereed to Section 4.3) • Sensitivity Setting Function: Default – 100 (Refereed to Section 4.4) • Peak Emphasis Function: Default – 4 (Refereed to Section 4.5.) • Moving Average Function: Default – 4 times (Refereed to Section 4.6) • Zoom FFT Function: Default – 1 time (Refereed to Section 4.7) • Frequency Band Switching Function (only F1 type): Default – 177 MHz band (Refereed to Section 4.8) An example other than the default configurations is referred to Configurations Example of Control Command of Section 7.1.3.
Sleep Mode	Stop the distance measurement and put the built-in RF-IC and MCU to sleep state. Resume with the command of sleep mode OFF and move to distance measurement mode. It accepts the setting command even in sleep mode. When receiving the execution command of calibration during sleep mode, it transits to calibration mode when returning to sleep mode OFF.

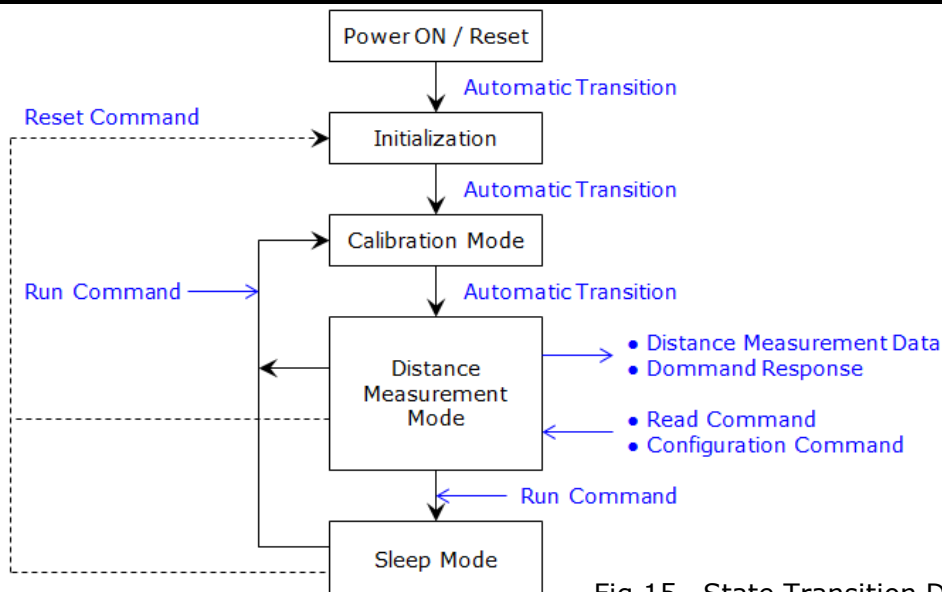
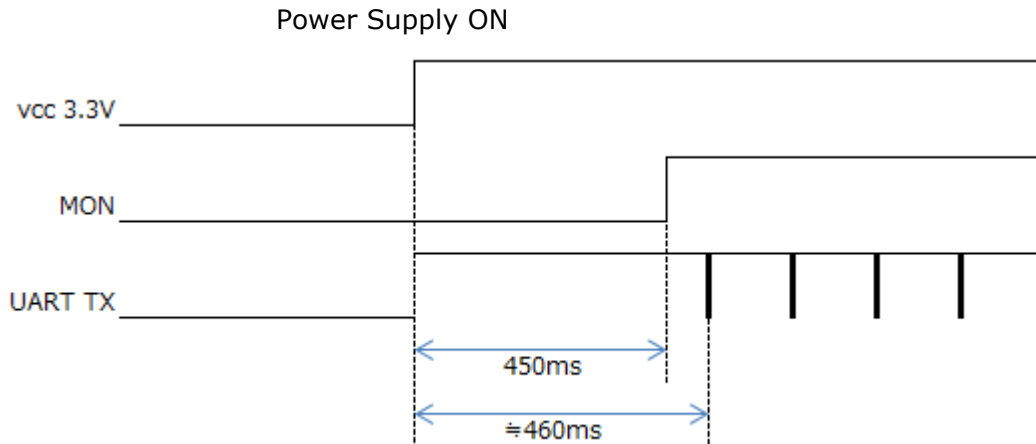


Fig.15 State Transition Diagram

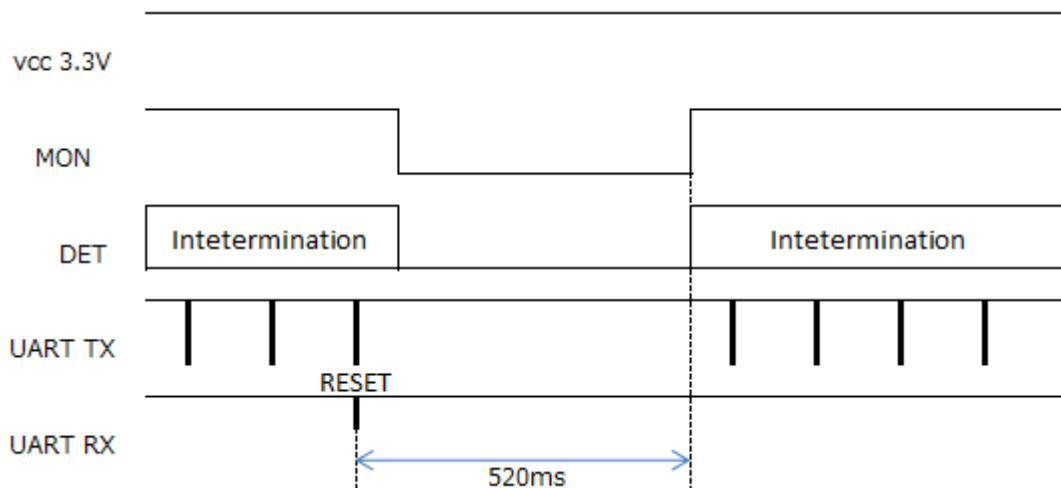
6.2. Time Chart

6.2.1. Start Up



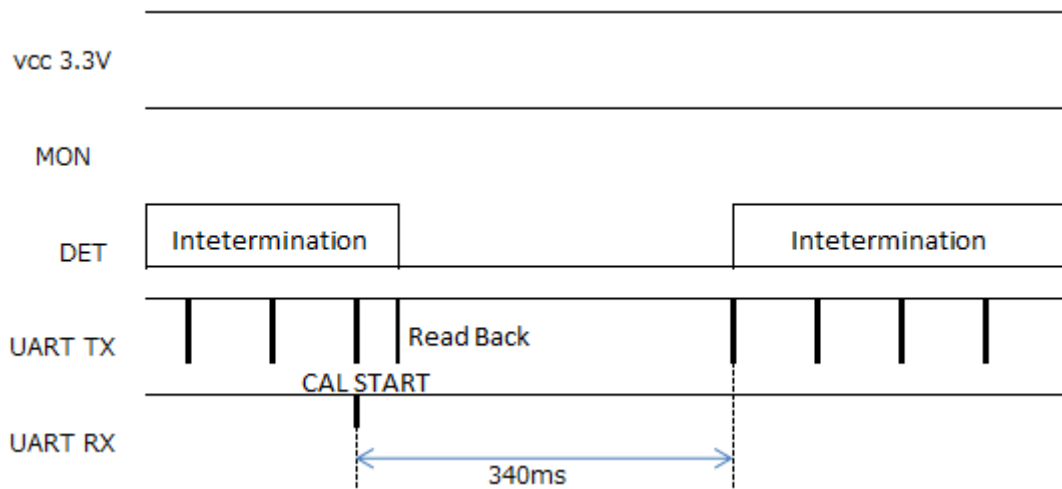
MON becomes "H: Normal" between 450ms and 500ms later after Vcc is applied to the sensor. And then after about 20ms the distance data output from UART TX starts.

6.2.2. Reset Command



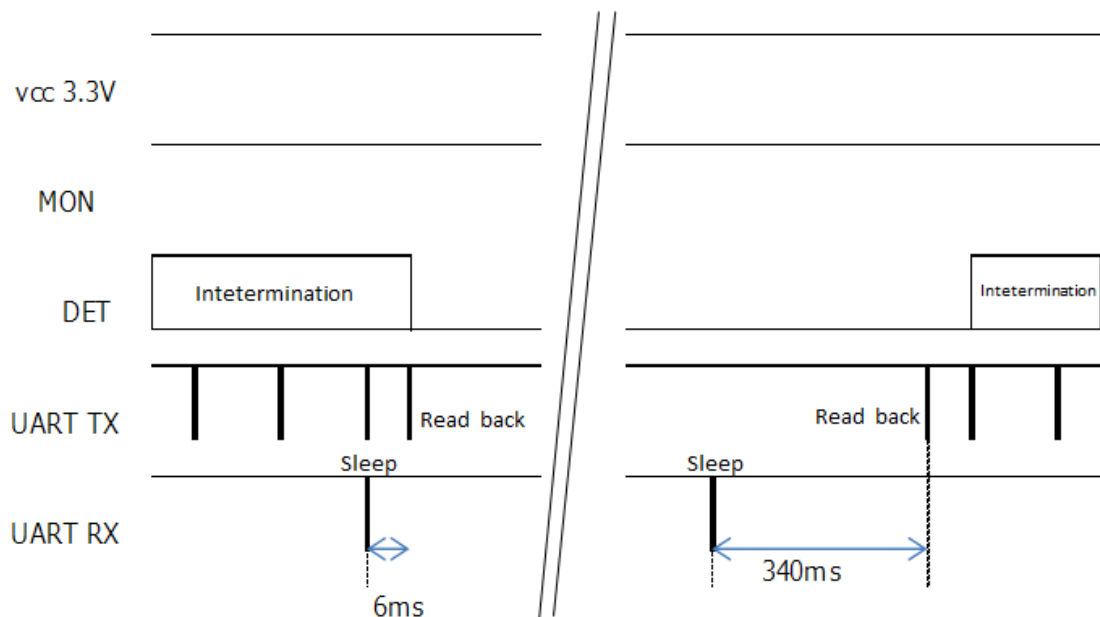
When the command of software reset is received, the reset process starts at the timing of UART TX internal processing. Distance Measurement Mode is restarted about 520ms later after the start of the reset process. During reset processing MON becomes "L: Alarm". After returning normal operation, MON becomes "H: Normal". And DET becomes H or L that depends on detection result.

6.2.3. Calibration Mode



When the command of calibration is received, the calibration process starts at the timing of UART TX internal processing. Distance Measurement Mode is stopped during calibration and MON keeps "H: Normal", besides UART TX doesn't come out. Distance Measurement Mode is restarted about 340ms later after the start of the calibration process, and measurement data is output at UART TX and at this DET become effective.

6.2.4. Sleep Mode



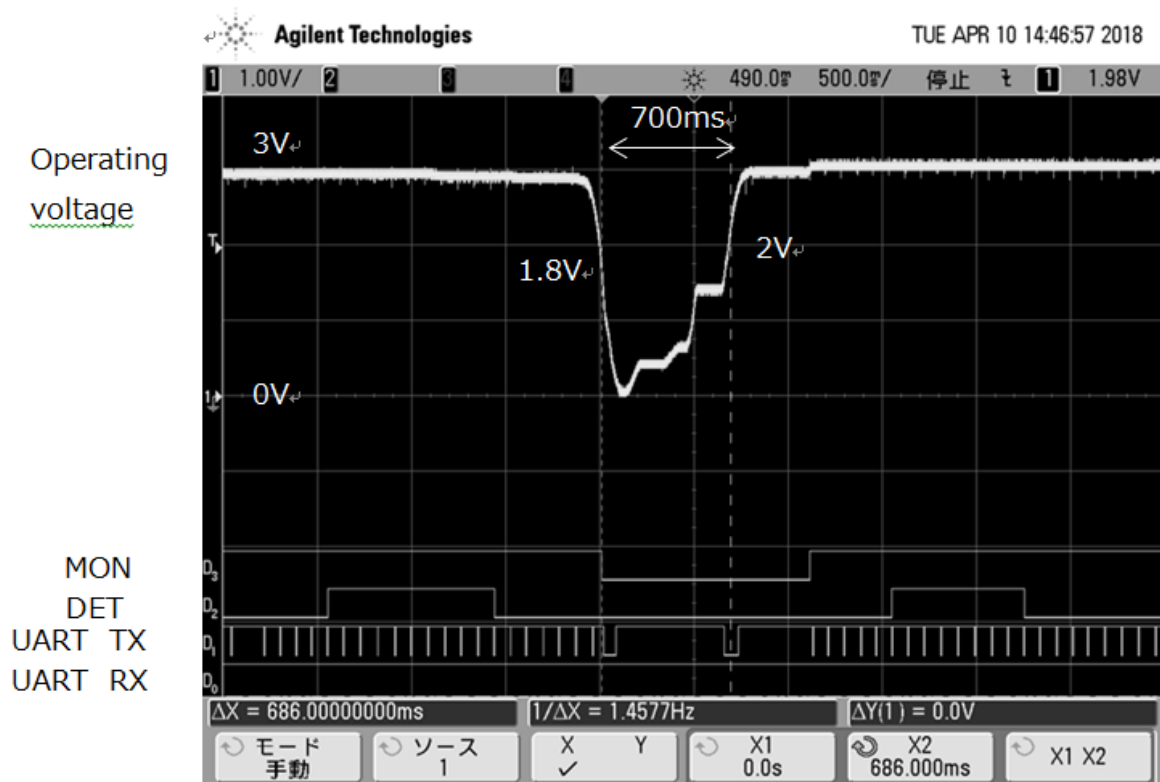
When the command of Sleep Mode ON is received, Sleep Mode starts after 6ms read back comes out. During Sleep Mode the command can be received.

The sensor keeps stopping measurement during Sleep Mode. When the command of Sleep Mode OFF is received, Initialization is executed and measurement is restarted with status before Sleep Mode condition. During Sleep Mode if the command is received, it becomes effective. Measurement is started without calibration. After 340ms from the command of Sleep Mode OFF, and then read back comes out and Distance Measurement Mode is started. After that DET become effective. During

Sleep Mode, MON keeps same the condition. (Normally MON is "H: Normal".)

6.2.5. Momentary operating voltage interruption

The sensor automatically executes Reset according to input voltage monitoring of internal MCU, when operating voltage momentary interrupt or drop.



In case that input voltage drop, the operation is stopped when the power supply voltage is about 1.8 V or less. And the operation is restarted in Initialization mode when the power supply voltage is about 2 V or more. This function becomes effective until 700ms maximum of momentary voltage interruption.

7. Communication Command

7.1. Control Command

The saved parameters are used for the setting at startup of distance measurement mode. When the parameter save command is not used, the default value is used.

It is possible to control and change the configurations by UART when using other than the default configurations or changing the mode. It is recommended to change the configurations setting according to the conditions to be used. If restart of the power supply or reset, it must be set again. The format of the control command is as follows.

- Byte Length: 3 bytes (fixed)
- Command Interval: minimum 120 ms
- Command Code: binary

Configuration change and mode change are executed within 120 ms after receiving the control command.

7.1.1. Control Command List

Command	1 st Byte	2 nd Byte	3 rd Byte
Run Command			
Run of Software Reset	0 0 0 0 0 0 0 0	0 0 0 0 0 0 0 0	0 0 0 0 0 0 0 0
Run of Calibration	0 0 1 0 1 0 0 0	0 0 0 0 0 0 0 0	0 0 0 0 0 0 0 0
Change to Sleep Mode ON	0 0 0 0 0 1 0 1	0 0 0 0 0 0 0 1	0 0 0 0 0 0 0 0
Change to Sleep Mode OFF	0 0 0 0 0 1 0 1	0 0 0 0 0 0 0 0	0 0 0 0 0 0 0 0
Save of Parameters	0 0 0 1 0 0 0 1	0 0 0 0 0 0 0 0	0 0 0 0 0 0 0 0
Read Command			
Read of Software Version	0 0 0 0 0 0 0 1	0 0 0 0 0 0 0 0	0 0 0 0 0 0 0 0
Read of Default Parameters	0 0 0 1 0 0 1 0	0 0 0 0 0 0 0 0	0 0 0 0 0 0 0 0
Read All Parameters	0 0 1 1 1 0 0 0	0 0 0 0 0 0 0 0	0 0 0 0 0 0 0 0
Read Individual Parameter (Group 1)	1 0 1 X X X X X	0 0 0 0 0 0 0 0	0 0 0 0 0 0 0 0
Read Individual Parameter (Group 2)	1 1 1 X X X X X	0 0 0 0 0 0 0 0	0 0 0 0 0 0 0 0
Configuration Command			
Configuration of Gain Control	0 0 0 0 0 0 1 0	0 0 0 0 0 0 X X	0 0 0 0 0 0 0 X
Configuration for Measurement Output Data	0 0 1 0 0 0 0 0	X 0 0 0 0 X X X	0 0 0 0 0 0 0 0
Configuration of Threshold for Stationary Objects	0 0 1 0 0 0 0 1	X X X X X X X X	X X X X X X X X
Configuration of Moving Average	0 0 1 0 0 1 0 1	0 0 0 0 X X X X	0 0 0 0 0 0 0 0
Configuration of Frequency Band Switching (only F1 type)	0 0 1 0 1 0 0 1	0 0 0 0 0 0 X X	0 0 0 0 0 0 0 0
Configuration of Measurement Distance Range for Stationary Objects	0 0 1 0 1 0 1 0	X X X X X X X X	X X X X X X X X
Configuration of Measurement Distance Range for Moving Objects	0 0 1 0 1 0 1 1	X X X X X X X X	X X X X X X X X
Configuration of Radio Interference Prevention	0 0 1 0 1 1 0 0	0 0 0 0 0 0 0 X	0 0 0 0 0 0 0 0
Configuration of Sensitivity Setting for Moving Objects	0 0 1 0 1 1 0 1	X X X X X X X X	X X X X X X X X
Configuration of Peak Emphasis for Moving Objects	0 0 1 0 1 1 1 0	0 0 0 0 X X X X	0 0 0 0 0 0 0 0
Sort Setting	0 0 1 1 0 1 0 0	0 0 0 0 0 0 0 X	0 0 0 0 0 0 0 X
Configuration of Zoom FFT	0 0 1 1 0 1 0 1	0 0 0 0 0 0 X X	X X X X X X X X

7.1.2. Description of Control Command

7.1.2.1. Run of Software Reset

This is a command to reset by software. After reset, calibration is performed and all configurations return to the default. There is no response to this command.

- Run Command:

1 st Byte	2 nd Byte	3 rd Byte
0 0 0 0 0 0 0 0	0 0 0 0 0 0 0 0	0 0 0 0 0 0 0 0
(0x00)	(0x00)	(0x00)

7.1.2.2. Run of Calibration

This is a command to perform calibration. It is recommended to perform periodically. The details are referred to Section 4.1.

- Run Command:

1 st Byte	2 nd Byte	3 rd Byte
0 0 1 0 1 0 0 0	0 0 0 0 0 0 0 0	0 0 0 0 0 0 0 0
(0x28)	(0x00)	(0x00)

7.1.2.3. Change to Sleep Mode ON

This is a command to change from distance measurement mode to sleep mode.

In sleep mode, all commands anytime are accepted without 120 ms of command interval. After receiving the command, the command response is returned. The configuration parameters will be effective when the sleep mode is OFF.

- Run Command:

1 st Byte	2 nd Byte	3 rd Byte
0 0 0 0 0 1 0 1	0 0 0 0 0 0 0 1	0 0 0 0 0 0 0 0
(0x05)	(0x01)	(0x00)

7.1.2.4. Change to Sleep Mode OFF

This is a command to change from sleep mode to distance measurement mode. Before transmitting distance measurement mode, calibration is performed.

- Run Command:

1 st Byte	2 nd Byte	3 rd Byte
0 0 0 0 0 1 0 1	0 0 0 0 0 0 0 0	0 0 0 0 0 0 0 0
(0x05)	(0x00)	(0x00)

7.1.2.5. Save of Parameters

This is a command to save all parameters in flash memory. Next Power On and/ or software rest, it will operate with the saved parameters.

- Run Command:

1 st Byte	2 nd Byte	3 rd Byte
0 0 0 1 0 0 0 1	0 0 0 0 0 0 0 0	0 0 0 0 0 0 0 0
(0x11)	(0x00)	(0x00)

7.1.2.6. Read of Software Version

This is a command to check the current software version. The command response is referred to Section 7.2.2.4.

- Read Command:

1 st Byte	2 nd Byte	3 rd Byte
0 0 0 0 0 0 0 1	0 0 0 0 0 0 0 0	0 0 0 0 0 0 0 0
(0x01)	(0x00)	(0x00)

7.1.2.7. Read of Default Parameters

This is a command to check all parameters to factory shipped default configuration. The command response is referred to Section 7.2.2.2.2.

- Run Command:

1 st Byte	2 nd Byte	3 rd Byte
0 0 0 1 0 0 1 0	0 0 0 0 0 0 0 0	0 0 0 0 0 0 0 0
(0x12)	(0x00)	(0x00)

7.1.2.8. Read of All Parameters

This is a command to check all current parameters. The command response is referred to Section 7.2.2.2.2.

- Read Command:

1 st Byte	2 nd Byte	3 rd Byte
0 0 1 1 1 0 0 0	0 0 0 0 0 0 0 0	0 0 0 0 0 0 0 0
(0x38)	(0x00)	(0x00)

7.1.2.9. Read of Individual Parameter (Group 1)

This is a command to check individually the current parameter for group 1. Group 1 is defined as all of configuration commands except "Configuration of Gain Control". If not set configuration parameter, the default parameter is read. The command response is referred to Section 7.2.2.2.3.

- Read Command:

1 st Byte	2 nd Byte	3 rd Byte
1 0 1 X X X X X	0 0 0 0 0 0 0 0	0 0 0 0 0 0 0 0
(0xXX)	(0x00)	(0x00)

1st Byte [4:0] – The same value as 1st Byte [4:0] of configuration command.

7.1.2.10. Read of Individual Parameter (Group 2)

This is a command to check individually the current parameter for group 2. Group 2 is defined as Configuration of Gain Control. If not set configuration parameter, the default parameter is read. The command response is referred to Section 7.2.2.2.3.

- Read Command:

1 st Byte	2 nd Byte	3 rd Byte
1 1 1 X X X X X	0 0 0 0 0 0 0 0	0 0 0 0 0 0 0 0
(0xXX)	(0x00)	(0x00)

1st Byte [4:0] – The same value as 1st Byte [4:0] of configuration command.

7.1.2.11. Configuration of Gain Control

This is a command to configure the gain control function. The default configuration is "Automatic Control". The details are referred to Section 4.2.

1 st Byte	2 nd Byte	3 rd Byte
0 0 0 0 0 0 1 0	0 0 0 0 0 0 0 X X	0 0 0 0 0 0 0 0 X

2nd Byte [1:0] - Configuration between high and low gain,

10: high gain / 00: low gain

3rd Byte [0] - Configuration between automatic and fixed control,

1: automatic control / 0: fixed control

- Command for Automatic Control (Default):

0 0 0 0 0 0 1 0	0 0 0 0 0 0 0 N N	0 0 0 0 0 0 0 0 1
(0x02)	(0x0N)	(0x01)

- Command for High Gain of Fixed Control:

0 0 0 0 0 0 1 0	0 0 0 0 0 0 0 1 0	0 0 0 0 0 0 0 0 0
(0x02)	(0x02)	(0x00)

- Command for Low Gain of Fixed Control:

0 0 0 0 0 0 1 0	0 0 0 0 0 0 0 0 0	0 0 0 0 0 0 0 0 0
(0x02)	(0x00)	(0x00)

7.1.2.12. Configuration for Measurement Output Data

This is a command to configure type of output data. The configurable contents are whether distance measurement output data for each of moving and stationary objects are output or not, and number of distance measurement output data for moving object. The default configuration is output of both moving and stationary objects and "Peak 1 of moving object". Only the closest peak 1 is output with default against the three peaks (Peak1 / Peak2 / Peak3) for moving objects.

1 st Byte	2 nd Byte	3 rd Byte
0 0 1 0 0 0 0 0	X 0 0 0 0 0 X X X X	0 0 0 0 0 0 0 0 0

2nd Byte [7] - Configuration for output data of moving objects, 1: enable / 0: disable

2nd Byte [2] - Configuration for "Peak 3" of output data, 1: enable / 0: disable

2nd Byte [1] - Configuration for "Peak 2" of output data, 1: enable / 0: disable

2nd Byte [0] - Configuration for "Peak 1" of output data, 1: enable / 0: disable

3rd Byte [7] - Configuration for output data of stationary objects, 1: enable / 0: disable

- Command to output both moving of Peak1 and stationary objects (Default):

0 0 1 0 0 0 0 0	1 0 0 0 0 0 0 0 1	1 0 0 0 0 0 0 0 0
(0x20)	(0x81)	(0x80)

- Command to output moving objects of Peak1 / Peak2:

0 0 1 0 0 0 0 0	1 0 0 0 0 0 0 0 1	0 0 0 0 0 0 0 0 0
(0x20)	(0x83)	(0x00)

- Command only to output stationary objects:

0 0 1 0 0 0 0 0	0 0 0 0 0 0 0 0 0	1 0 0 0 0 0 0 0 0
(0x20)	(0x00)	(0x80)

- Command to output both moving objects of Peak1 / Peak2 / Peak3 and stationary objects:

0 0 1 0 0 0 0 0	1 0 0 0 0 0 0 1 1	1 0 0 0 0 0 0 0 0
(0x20)	(0x87)	(0x80)

7.1.2.13. Configuration of Threshold for Stationary Objects

This is a command to configure threshold value for stationary objects. Only peaks exceeding this threshold are output. The distance of the peak not exceeding the threshold is 0xFFFF, but

power value is output as it is.

The configuration range is 0 to 65535, and the default value is 0.

1 st Byte	2 nd Byte	3 rd Byte
0 0 1 0 0 0 0 1	X X X X X X X X	X X X X X X X X

2nd Byte [7:0] : 3rd Byte [7:0] – Configuration of threshold, Range: 0 to 65535

- Command for configuration of "0" threshold (Default):

0 0 1 0 0 0 0 1	0 0 0 0 0 0 0 0	0 0 0 0 0 0 0 0
(0x21)	(0x00)	(0x00)

- Command for configuration of "4,096" threshold:

0 0 1 0 0 0 0 1	0 0 0 1 0 0 0 0	0 0 0 0 0 0 0 0
(0x21)	(0x10)	(0x00)

7.1.2.14. Configuration of Moving Average

This is a command to configure moving average for each of moving objects and stationary objects. The details are referred to Section 4.6.

1 st Byte	2 nd Byte	3 rd Byte
0 0 1 0 0 1 0 1	0 0 0 0 X X X X	0 0 0 0 0 0 0 0

2nd Byte [3:2] – Configuration of moving average for stationary objects

Default: disable

2nd Byte [1:0] – Configuration of moving average for moving objects

Default: average of 4 times

10: average of 4 times / 01: average of 2 times / 00: disable

- Command for Default Configuration:

0 0 1 0 0 1 0 1	0 0 0 0 0 0 1 0	0 0 0 0 0 0 0 0
(0x25)	(0x02)	(0x00)

- Command for Configuration of "Average of 4times" for both moving objects and stationary objects:

0 0 1 0 0 1 0 1	0 0 0 0 0 0 0 1	0 0 0 0 0 0 0 0
(0x25)	(0x01)	(0x00)

- Command for Disable for both moving objects and stationary objects:

0 0 1 0 0 1 0 1	0 0 0 0 0 0 0 0	0 0 0 0 0 0 0 0
(0x25)	(0x00)	(0x00)

7.1.2.15. Configuration of Frequency Band Switching (only F1 type)

This is a command to configure band of the frequency band switching function. The default configuration is "177 MHz Band". Since this function is not implemented in F2 type and F3 type, this command is not accepted. The details are referred to Section 4.7.

1 st Byte	2 nd Byte	3 rd Byte
0 0 1 0 1 0 0 1	0 0 0 0 0 0 X X	0 0 0 0 0 0 0 0

2nd Byte [1:0] – Configuration of frequency band,

11: 177 MHz band / 01: lower 80 MHz band / 10: upper 80 MHz band

- Command for Configuration of 177 MHz Band (Default):

0 0 1 0 1 0 0 1	0 0 0 0 0 0 1 1	0 0 0 0 0 0 0 0
(0x29)	(0x03)	(0x00)

- Command for Configuration of Lower 80 MHz Band:

0 0 1 0 1 0 0 1	0 0 0 0 0 0 0 1	0 0 0 0 0 0 0 0
(0x29)	(0x01)	(0x00)

- Command for Configuration of Upper 80 MHz Band:

0 0 1 0 1 0 0 1	0 0 0 0 0 0 1 0	0 0 0 0 0 0 0 0
(0x29)	(0x02)	(0x00)

7.1.2.16. Configuration of Distance Range for Stationary Objects

This is a command to configure the distance range of output measurement data for stationary objects. The default configuration is 0 m as minimum distance and maximum distance measurement by Nyquist as maximum distance. The details are referred to Section 4.3.

1 st Byte	2 nd Byte	3 rd Byte
0 0 1 0 1 0 0 1	X X X X X X X X	X X X X X X X X

2nd Byte [7:0] - Configuration for minimum distance of output measurement data

3rd Byte [7:0] - Configuration for maximum distance of output measurement data

The configuration range is 0 to 86 for F1 type and 0 to 170 for F2 type and F3 type.

- Command for Configuration of 0 to 86 m (Default for F1 type):

0 0 1 0 1 0 0 1	0 0 0 0 0 0 0 0	0 1 0 1 0 1 1 0
(0x2A)	(0x00)	(0x56)

- Command for Configuration of 0 to 170 m (Default for F2 type and F3 type):

0 0 1 0 1 0 0 1	0 0 0 0 0 0 0 0	1 0 1 0 1 0 1 0
(0x2A)	(0x00)	(0xAA)

- Command for Configuration of 5 to 25 m (Example):

0 0 1 0 1 0 0 1	0 0 0 0 0 1 0 1	0 0 0 1 1 0 0 1
(0x2A)	(0x05)	(0x19)

- Command for Configuration of 15 to 50 m (Example):

0 0 1 0 1 0 0 1	0 0 0 0 1 1 1 1	0 0 1 1 0 0 1 0
(0x2A)	(0x0F)	(0x32)

7.1.2.17. Configuration of Distance Range for Moving Objects

This is a command to configure the distance range of output measurement data for moving objects. The default configuration is 0 m as minimum distance and maximum distance measurement by Nyquist as maximum distance. The details are referred to Section 4.3.

1 st Byte	2 nd Byte	3 rd Byte
0 0 1 0 1 0 1 1	X X X X X X X X	X X X X X X X X

2nd Byte [7:0] - Configuration for minimum distance of output measurement data

3rd Byte [7:0] - Configuration for maximum distance of output measurement data

The configuration range is 0 to 86 for F1 type and 0 to 170 for F2 type and F3 type.

- Command for Configuration of 0 to 86 m (Default for F1 type):

0 0 1 0 1 0 1 1	0 0 0 0 0 0 0 0	0 1 0 1 0 1 1 0
(0x2B)	(0x00)	(0x56)

- Command for Configuration of 0 to 170 m (Default for F2 type and F3 type):

0 0 1 0 1 0 1 1	0 0 0 0 0 0 0 0	1 0 1 0 1 0 1 0
(0x2B)	(0x00)	(0xAA)

- Command for Configuration of 5 to 25 m (Example):

0 0 1 0 1 0 1 1	0 0 0 0 0 1 0 1	0 0 0 1 1 0 0 1
(0x2B)	(0x05)	(0x19)

- Command for Configuration of 15 to 50 m (Example):

0 0 1 0 1 0 1 1	0 0 0 0 1 1 1 1	0 0 1 1 0 0 1 0
(0x2B)	(0x0F)	(0x32)

7.1.2.18. Configuration of Radio Interference Prevention

This is a command to configure the radio interference prevention function. The default configuration is "enable". The details are referred to Section 3.2.1.

1 st Byte	2 nd Byte	3 rd Byte
0 0 1 0 1 1 0 0	0 0 0 0 0 0 0 X	0 0 0 0 0 0 0 0

2nd Byte [0] - Configuration of radio interference prevention, 1: enable / 0: disable

- Command for Enable (Default):

0 0 1 0 1 1 0 0	0 0 0 0 0 0 0 1	0 0 0 0 0 0 0 0
(0x2C)	(0x01)	(0x00)

- Command for Disable:

0 0 1 0 1 1 0 0	0 0 0 0 0 0 0 0	0 0 0 0 0 0 0 0
(0x2C)	(0x00)	(0x00)

7.1.2.19. Configuration of Sensitivity Setting for Moving Objects

This is a command to configure the sensitivity of the sensitivity setting function. This function is applicable for measurement of moving objects. The default configuration is "100". The details are referred to Section 4.4.

0 0 1 0 1 1 0 1	X X X X X X X X	X X X X X X X X
-----------------	-----------------	-----------------

2nd Byte [7:0] : 3rd Byte [7:0] - Configuration of sensitivity, Range: 1 to 65535

- Command for Configuration of 100 (Default):

0 0 1 0 1 1 0 1	0 0 0 0 0 0 0 0	0 1 1 0 0 1 0 0
(0x2D)	(0x00)	(0x64)

- Command for Configuration of 50:

0 0 1 0 1 1 0 1	0 0 0 0 0 0 0 0	0 0 1 1 0 0 1 0
(0x2D)	(0x00)	(0x32)

- Command for Configuration of 300:

0 0 1 0 1 1 0 1	0 0 0 0 0 0 0 1	0 0 1 0 1 1 0 0
(0x2D)	(0x01)	(0x2C)

7.1.2.20. Configuration of Peak Emphasis

This is a command to configure the peak selection range of the peak emphasis function. This function is applicable for measurement of moving objects. The default configuration is "4". The details are referred to Section 4.5.

1 st Byte	2 nd Byte	3 rd Byte
0 0 1 0 1 1 1 0	0 0 0 0 X X X X	0 0 0 0 0 0 0 0

2nd Byte [3:0] - Configuration of peak selection range,
Range: 0 to 15 / 0: disable

- Command for Configuration of 4 (Default):

0 0 1 0 1 1 1 0	0 0 0 0 0 1 0 0	0 0 0 0 0 0 0 0
(0x2E)	(0x04)	(0x00)

- | | | | | | | | | | | | | | | | | | | | | | | | |
|--------|---|---|---|---|---|---|---|--------|---|---|---|---|---|---|---|--------|---|---|---|---|---|---|---|
| 0 | 0 | 1 | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| (0x2E) | | | | | | | | (0x0F) | | | | | | | | (0x00) | | | | | | | |

- | | | | | | | | | | | | | | | | | | | | | | | | |
|--------|---|---|---|---|---|---|---|--------|---|---|---|---|---|---|---|--------|---|---|---|---|---|---|---|
| 0 | 0 | 1 | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| (0x2E) | | | | | | | | (0x00) | | | | | | | | (0x00) | | | | | | | |

134	135	136
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1 st Byte								2 nd Byte								3 rd Byte							
0	0	1	1	0	1	0	0	0	0	0	0	0	0	0	X	0	0	0	0	0	0	0	X

figuration (Default):

- | | | | | | | | | | | | | | | | | | | | | | | | |
|--------|---|---|---|---|---|---|---|--------|---|---|---|---|---|---|---|--------|---|---|---|---|---|---|---|
| 0 | 0 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| (0x34) | | | | | | | | (0x00) | | | | | | | | (0x00) | | | | | | | |

1. 2. 3. 4. 5. 6. 7. 8. 9. 10. 11. 12. 13. 14. 15. 16. 17. 18. 19. 20. 21. 22. 23. 24. 25. 26. 27. 28. 29. 30. 31. 32. 33. 34. 35. 36. 37. 38. 39. 40. 41. 42. 43. 44. 45. 46. 47. 48. 49. 50. 51. 52. 53. 54. 55. 56. 57. 58. 59. 60. 61. 62. 63. 64. 65. 66. 67. 68. 69. 70. 71. 72. 73. 74. 75. 76. 77. 78. 79. 80. 81. 82. 83. 84. 85. 86. 87. 88. 89. 90. 91. 92. 93. 94. 95. 96. 97. 98. 99. 100. 101. 102. 103. 104. 105. 106. 107. 108. 109. 110. 111. 112. 113. 114. 115. 116. 117. 118. 119. 120. 121. 122. 123. 124. 125. 126. 127. 128. 129. 130. 131. 132. 133. 134. 135. 136. 137. 138. 139. 140. 141. 142. 143. 144. 145. 146. 147. 148. 149. 150. 151. 152. 153. 154. 155. 156. 157. 158. 159. 160. 161. 162. 163. 164. 165. 166. 167. 168. 169. 170. 171. 172. 173. 174. 175. 176. 177. 178. 179. 180. 181. 182. 183. 184. 185. 186. 187. 188. 189. 190. 191. 192. 193. 194. 195. 196. 197. 198. 199. 200. 201. 202. 203. 204. 205. 206. 207. 208. 209. 210. 211. 212. 213. 214. 215. 216. 217. 218. 219. 220. 221. 222. 223. 224. 225. 226. 227. 228. 229. 230. 231. 232. 233. 234. 235. 236. 237. 238. 239. 240. 241. 242. 243. 244. 245. 246. 247. 248. 249. 250. 251. 252. 253. 254. 255. 256. 257. 258. 259. 260. 261. 262. 263. 264. 265. 266. 267. 268. 269. 270. 271. 272. 273. 274. 275. 276. 277. 278. 279. 280. 281. 282. 283. 284. 285. 286. 287. 288. 289. 290. 291. 292. 293. 294. 295. 296. 297. 298. 299. 300. 301. 302. 303. 304. 305. 306. 307. 308. 309. 310. 311. 312. 313. 314. 315. 316. 317. 318. 319. 320. 321. 322. 323. 324. 325. 326. 327. 328. 329. 330. 331. 332. 333. 334. 335. 336. 337. 338. 339. 340. 341. 342. 343. 344. 345. 346. 347. 348. 349. 350. 351. 352. 353. 354. 355. 356. 357. 358. 359. 360. 361. 362. 363. 364. 365. 366. 367. 368. 369. 370. 371. 372. 373. 374. 375. 376. 377. 378. 379. 380. 381. 382. 383. 384. 385. 386. 387. 388. 389. 390. 391. 392. 393. 394. 395. 396. 397. 398. 399. 400. 401. 402. 403. 404. 405. 406. 407. 408. 409. 410. 411. 412. 413. 414. 415. 416. 417. 418. 419. 420. 421. 422. 423. 424. 425. 426. 427. 428. 429. 430. 431. 432. 433. 434. 435. 436. 437. 438. 439. 440. 441. 442. 443. 444. 445. 446. 447. 448. 449. 450. 451. 452. 453. 454. 455. 456. 457. 458. 459. 460. 461. 462. 463. 464. 465. 466. 467. 468. 469. 470. 471. 472. 473. 474. 475. 476. 477. 478. 479. 480. 481. 482. 483. 484. 485. 486. 487. 488. 489. 490. 491. 492. 493. 494. 495. 496. 497. 498. 499. 500. 501. 502. 503. 504. 505. 506. 507. 508. 509. 510. 511. 512. 513. 514. 515. 516. 517. 518. 519. 520. 521. 522. 523. 524. 525. 526. 527. 528. 529. 530. 531. 532. 533. 534. 535. 536. 537. 538. 539. 540. 541. 542. 543. 544. 545. 546. 547. 548. 549. 550. 551. 552. 553. 554. 555. 556. 557. 558. 559. 560. 561. 562. 563. 564. 565. 566. 567. 568. 569. 570. 571. 572. 573. 574. 575. 576. 577. 578. 579. 580. 581. 582. 583. 584. 585. 586. 587. 588. 589. 590. 591. 592. 593. 594. 595. 596. 597. 598. 599. 600. 601. 602. 603. 604. 605. 606. 607. 608. 609. 610. 611. 612. 613. 614. 615. 616. 617. 618. 619. 620. 621. 622. 623. 624. 625. 626. 627. 628. 629. 630. 631. 632. 633. 634. 635. 636. 637. 638. 639. 640. 641. 642. 643. 644. 645. 646. 647. 648. 649. 650. 651. 652. 653. 654. 655. 656. 657. 658. 659. 660. 661. 662. 663. 664. 665. 666. 667. 668. 669. 670. 671. 672. 673. 674. 675. 676. 677. 678. 679. 680. 681. 682. 683. 684. 685. 686. 687. 688. 689. 690. 691. 692. 693. 694. 695. 696. 697. 698. 699. 700. 701. 702. 703. 704. 705. 706. 707. 708. 709. 710. 711. 712. 713. 714. 715. 716. 717. 718. 719. 720. 721. 722. 723. 724. 725. 726. 727. 728. 729. 730. 731. 732. 733. 734. 735. 736. 737. 738. 739. 740. 741. 742. 743. 744. 745. 746. 747. 748. 749. 750. 751. 752. 753. 754. 755. 756. 757. 758. 759. 760. 761. 762. 763. 764. 765. 766. 767. 768. 769. 770. 771. 772. 773. 774. 775. 776. 777. 778. 779. 780. 781. 782. 783. 784. 785. 786. 787. 788. 789. 790. 791. 792. 793. 794. 795. 796. 797. 798. 799. 800. 801. 802. 803. 804. 805. 806. 807. 808. 809. 810. 811. 812. 813. 814. 815. 816. 817. 818. 819. 820. 821. 822. 823. 824. 825. 826. 827. 828. 829. 830. 831. 832. 833. 834. 835. 836. 837. 838. 839. 840. 84

$$\text{Hyperion Linerite Zone Start Position} = (\text{Maximum Measurement Distance} / \text{Magnification}) \times 0.9$$

* Upper limit will be up to the maximum measurement distance when it is bigger than

| 1 st Byte | | | | | | | | 2 nd Byte | | | | 3 rd Byte | | | | | | | | | | |
|----------------------|---|---|---|---|---|---|---|----------------------|---|---|---|----------------------|---|---|---|---|---|---|---|---|---|---|
| 0 | 0 | 1 | 1 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | X | X | X | X | X | X | X | X | X |

The configuration range is 0 to 86 for F1 type and 0 to 170 for F2 type and F3 type.

- | | | | | | | | | | | | | | | | | | | | | | | | |
|--------|---|---|---|---|---|---|---|--------|---|---|---|---|---|--------|---|---|---|---|---|---|---|---|---|
| 0 | 0 | 1 | 1 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| (0x35) | | | | | | | | (0x00) | | | | | | (0x00) | | | | | | | | | |

- | | | | | | | | | | | | | | | | | | | | | | | | | |
|--------|---|---|---|---|---|---|---|--------|---|---|---|---|---|---|---|--------|---|---|---|---|---|---|---|---|
| 0 | 0 | 1 | 1 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 |
| (0x35) | | | | | | | | (0x02) | | | | | | | | (0x14) | | | | | | | | |

In case of F1 and F3 type, the measurement range is 20 to 58 m.

7.1.3. Configurations Example of Control Command

| Configuration Item | Default | Outdoor
Few Obstacles |
|---|--------------------|--------------------------|
| Radio Interference Prevention | Enable | Enable |
| Number of Distance
Measurement Output Data | 1 | 1 to 3 |
| Gain Control Function | Automatic
Cont. | Automatic
Cont. |
| Sensitivity Setting Function | 100 | 60 |
| Peak Emphasis Function | 4 | 4 |
| Moving Average Function | 4 times | 4 times |
| Detection Target | Pedestrian | Pedestrian |

7.2. Notification Response

There are only three notification responses as follows

1) Output Data of Measurement Distance

Stationary Objects (36 bytes):

Preamble (4 bytes) + Header (4 bytes) + Distance data (28 bytes)

Moving Objects(16 bytes):

Preamble (4 bytes) + Header (4 bytes) + Distance data (8 bytes)

2) Command Response (8 bytes): Preamble (4 bytes) + Header (4 bytes)

3) Response of All Parameters(31 bytes):

Preamble (4 bytes) + Header (4 bytes) + Parameters (23 bytes)

The format of the notification command is as follows.

- Byte Length: 8 to 36 bytes (variable by notification response)
- Command Code: binary

7.2.1. Output Data of Measurement Distance

This output data is automatically sent for each measurement.

When outputting both Stationary Objects and Moving Objects, Output Data of Measurement Distance is output in the order of Stationary Objects and Moving Objects

7.2.1.1. Output Data of Measurement Distance for Stationary Objects

The format of the output data to be sent is as follows.

| Preamble
(4 bytes) | Header
(4 bytes) | | | | Distance Data 1
(4 bytes) | | Distance Data 2
(4 bytes) | |
|-----------------------|---------------------|--------------------|--------------------|--------------------|------------------------------|--------------------|------------------------------|--------------------|
| 0xCCCC5555 | H1 [7:0]
(0x21) | H2 [7:0]
(0xX2) | H3 [7:0]
(0x0X) | H4 [7:0]
(0xXX) | Dist.1
(0XXXXX) | Power1
(0XXXXX) | Dist.2
(0XXXXX) | Power2
(0XXXXX) |

| Distance Data 3
(4 bytes) | | Distance Data 4
(4 bytes) | | Distance Data 5
(4 bytes) | | Distance Data 6
(4 bytes) | | Distance Data 7
(4 bytes) | |
|------------------------------|--------------------|------------------------------|--------------------|------------------------------|--------------------|------------------------------|--------------------|------------------------------|--------------------|
| Dist.3
(0XXXXX) | Power3
(0XXXXX) | Dist.4
(0XXXXX) | Power4
(0XXXXX) | Dist.5
(0XXXXX) | Power5
(0XXXXX) | Dist.6
(0XXXXX) | Power6
(0XXXXX) | Dist.7
(0XXXXX) | Power7
(0XXXXX) |

H1 [7:0] - Fixed value: 0010 0001 (0x21)

H2 [7:4] - Gain control information / 0000: low gain, 0010: high gain

[3:0] - Fixed value: 0000 (Data Notice of Stationary Objects)

H3 [7:4] - Fixed value: 0000

[3:0] - Fixed value: 0000

H4 [7:0] - Information for the random variable time of the measurement cycle

0 to 256: 0 corresponds to 80 ms and 256 corresponds to 90 ms

Distance Data - Notify the value of distance and individual power information of Peak #1 to #7 for stationary objects. Distance Data 1 is Peak #1 of stationary object and closeness or biggest signal level object

Dist. (2 bytes) - Notify the value of 100 times the distance information of stationary object.
Range: 0 to 17000 (170 m).

The distance of the peak not exceeding the threshold is 0xFFFF.

Power (2 bytes) - Notify the value of individual power information of stationary object.
Range: 0 to 65535

7.2.1.2. Output Data of Measurement Distance for Moving Objects

The format of the output data to be sent is as follows.

| Preamble
(4 bytes) | Header
(4 bytes) | | | | Distance Data
(8 bytes) | | | |
|-----------------------|---------------------|--------------------|--------------------|--------------------|----------------------------|-------------------|-------------------|-------------------|
| 0xCCCC5555 | H1 [7:0]
(0x21) | H2 [7:0]
(0xX2) | H3 [7:0]
(0x0X) | H4 [7:0]
(0xXX) | Data1
(0xXXXX) | Data2
(0xXXXX) | Data3
(0xXXXX) | Data4
(0xXXXX) |

H1 [7:0] - Fixed value: 0010 0001 (0x21)

H2 [7:4] - Gain control information / 0000: low gain, 0010: high gain

[3:0] - Fixed value: 0010 (Data Notice of Moving Objects)

H3 [7:4] - Fixed value: 0000

[3:0] - Fixed value: 0000

H4 [7:0] - Information for the random variable time of the measurement cycle

0 to 256: 0 corresponds to 80 ms and 256 corresponds to 90 ms

Data 1 (2 bytes) - Notify the value of 100 times the distance information of Peak 1.

Range: 0 to 17000 (170 m).

When no peak that is configured, 0xFFFF is outputs as distance information.

Data 2 (2 bytes) - Notify the value of 100 times the distance information of Peak 2.

Range: 0 to 17000 (170 m).

When no peak that is configured, 0xFFFF is outputs as distance information.

Data 3 (2 bytes) - Notify the value of 100 times the distance information of Peak 3, Range: 0 to 17000 (170 m).

When no peak that is configured, 0xFFFF is outputs as distance information.

Data 4 (2 bytes) - Notifies the integrated power in the whole band of the received signal as the signal level. It is a value used for sensitivity setting function. The details are referred to Section 4.4.

Range: 0 to 65535

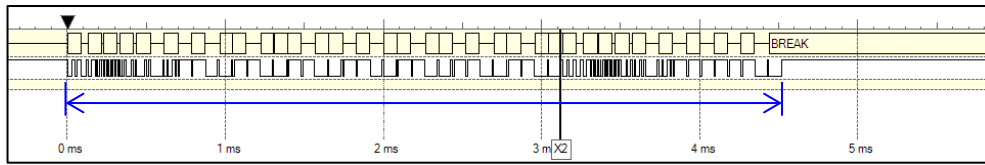
7.2.1.3. Example for Output Data of Measurement Distance

a) Binary Data – Example of text characteristic for both Stationary Objects and Moving Objects

```
CC CC 55 55 21 20 00 6A 00 26 02 F0 00 43 02 A0 00 70 00 0C 00 89 00 00 00 9E 00 02 00 B8 00 00 00 FA 00 00
CC CC 55 55 21 22 00 6A FF FF FF FF FF FF 00 46
CC CC 55 55 21 20 00 0D 00 26 02 F0 00 43 02 A1 00 70 00 0C 00 89 00 00 00 9F 00 02 00 B8 00 00 00 F7 00 00
CC CC 55 55 21 22 00 0D FF FF FF FF FF FF 00 47
CC CC 55 55 21 20 00 A2 00 26 02 EF 00 43 02 9A 00 70 00 0C 00 8A 00 00 00 A0 00 02 00 B8 00 00 00 F5 00 00
CC CC 55 55 21 22 00 A2 FF FF FF FF FF FF 00 47
CC CC 55 55 21 20 00 73 00 26 02 EC 00 43 02 96 00 70 00 0C 00 8A 00 00 00 A0 00 02 00 B8 00 00 00 F5 00 00
CC CC 55 55 21 22 00 73 FF FF FF FF FF FF 00 48
CC CC 55 55 21 20 00 15 00 26 02 EC 00 43 02 8D 00 70 00 0D 00 8A 00 00 00 A0 00 02 00 B8 00 00 00 F4 00 00
CC CC 55 55 21 22 00 15 FF FF FF FF FF FF 00 49
```

b) Waveform of Logic Analyzer

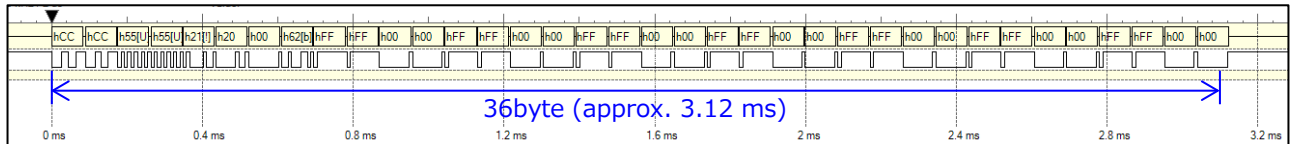
- Output waveform of both Stationary Objects and Moving Objects (1 time)



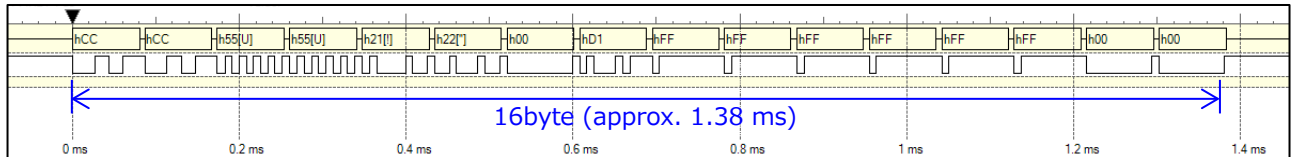
Stationary Objects
36byte (approx.3.12 ms)

Moving Objects 16byte
(approx.1.38 ms)

- Output waveform of only Stationary Objects (1 time)

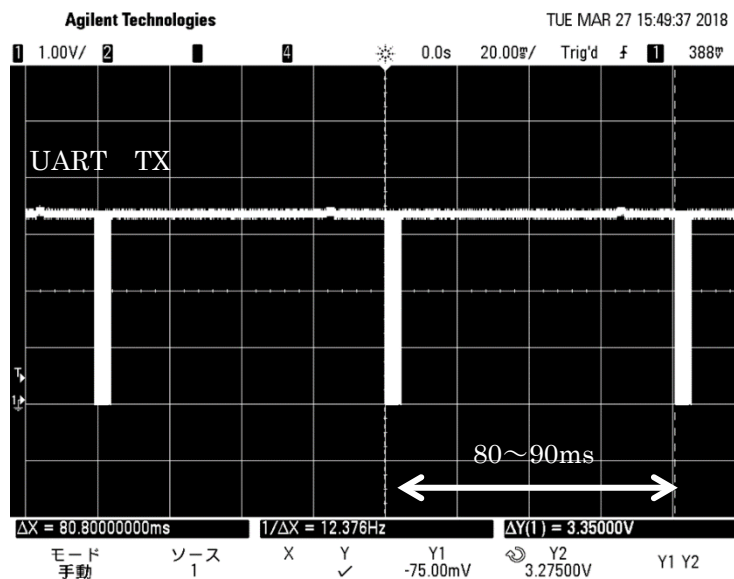


- Output waveform of only Moving Objects (1 time)

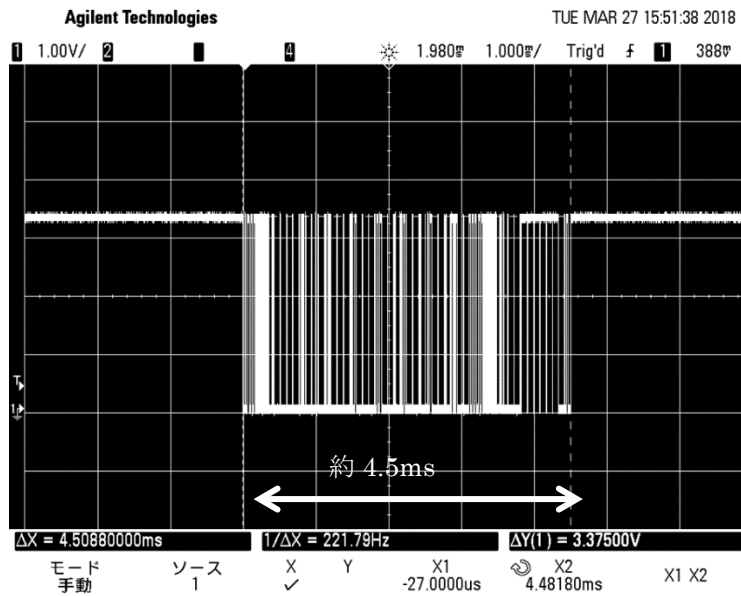


c) UART TX Waveform for both Stationary Objects and Moving Objects

- Waveform of Output UART TX signal Timing



- Waveform of Output UART TX signal of single Output Data
(Stationary Objects(36 bytes) & Moving Objects(16 bytes), total 52 bytes)



7.2.2. Command Response

The command response is sent after the sensor receives the control command. If incorrect control commands or no configuration range exists, an error response is sent.

7.2.2.1. Response for Run Command

This response is sent after receiving a correct run command in the control command. There is no response to run command of software reset.

The format of this response to be sent is as follows.

| Preamble
(4 bytes) | Header
(4 bytes) | | | |
|-----------------------|---------------------|--------------------|--------------------|--------------------|
| 0xCCCC5555 | H1 [7:0]
(0xE0) | H2 [7:0]
(0xFF) | H3 [7:0]
(0xFF) | H4 [7:0]
(0xFF) |

H1 [7:0] - Fixed value: 1110 0000 (0xE0)

H2 [7:0] - Same as 1st byte of the control command

H3 [7:0] - Same as 2nd byte of the control command

H4 [7:0] - Same as 3rd byte of the control command

7.2.2.2. Response for Read Command

This response is sent including response data after receiving a correct read command in the control command.

7.2.2.2.1. Response for "Read of Software Version"

The format of this response to be sent is as follows.

| Preamble
(4 bytes) | Header
(4 bytes) | | | |
|-----------------------|---------------------|--------------------|--------------------|--------------------|
| 0xCCCC5555 | H1 [7:0]
(0xE0) | H2 [7:0]
(0xFF) | H3 [7:0]
(0xFF) | H4 [7:0]
(0xFF) |

H1 [7:0] - Fixed value: 1110 0000 (0xE0)

H2 [7:0] - Same as 1st byte of the control command

H3 [7:0] : H4 [7:0] - Software Version

7.2.2.2.2. Response for "Read of Default Parameters" and "Read All Parameters"

The command response is sent after the sensor receives "Read of Default Parameters" and "Read All Parameters".

The format of this response to be sent is as follows.

| Preamble
(4 bytes) | Header
(4 bytes) | | | | Parameters
(23 byte) |
|-----------------------|---------------------|--------------------|--------------------|--------------------|--------------------------|
| 0xCCCC5555 | H1 [7:0]
(0x23) | H2 [7:0]
(0x17) | H3 [7:0]
(0x00) | H4 [7:0]
(0x00) | Refer to following table |

H1 [7:0] - Fixed value: 0010 0011 (0x23)

H2 [7:0] - Fixed value: 0001 0111 (0x17)

H3 [7:0] - Fixed value: 0000 0000 (0xFF)

H4 [7:0] - Fixed value: 0000 0000 (0x00)

Parameters - It outputs in the order of items shown in the table below. The number of bytes to be output varies depending on the item.

| # | Parameter Item | Bytes | Description |
|----|---|-------|---|
| 1 | Software Version | 2 | |
| 2 | Gain Control | 2 | Same parameter configuration as 2 nd and 3 rd byte of configuration command |
| 3 | Sleep Mode | 1 | Same parameter configuration as 2 nd byte of configuration command |
| 4 | Measurement Output Data | 2 | Same parameter configuration as 2 nd and 3 rd byte of configuration command |
| 5 | Threshold for Stationary Objects | 2 | Same parameter configuration as 2 nd and 3 rd byte of configuration command |
| 6 | Moving Average | 1 | Same parameter configuration as 2 nd byte of configuration command |
| 7 | Frequency Band Switching | 1 | Same parameter configuration as 2 nd byte of configuration command |
| 8 | Measurement Distance Range for Stationary Objects | 2 | Same parameter configuration as 2 nd and 3 rd byte of configuration command |
| 9 | Measurement Distance Range for Moving Objects | 2 | Same parameter configuration as 2 nd and 3 rd byte of configuration command |
| 10 | Radio Interference Prevention | 1 | Same parameter configuration as 2 nd byte of configuration command |
| 11 | Sensitivity Setting for Moving Objects | 2 | Same parameter configuration as 2 nd and 3 rd byte of configuration command |
| 12 | Peak Emphasis for Moving Objects | 1 | Same parameter configuration as 2 nd byte of configuration command |
| 13 | Sort Setting | 2 | Same parameter configuration as 2 nd and 3 rd byte of configuration command |
| 14 | Zoom FFT | 2 | Same parameter configuration as 2 nd and 3 rd byte of configuration command |

7.2.2.2.3. Response for "Read of Individual Parameters"

The command response is sent after the sensor receives "Read Individual Parameter (Group 1)" or "Read Individual Parameter (Group 2)".

The format of this response to be sent is as follows.

| Preamble
(4 bytes) | Header
(4 bytes) | | | |
|-----------------------|---------------------|-------------------|-------------------|-------------------|
| 0xCCCC5555 | H1 [7:0]
(0xE0) | H2 [7:0]
(0XX) | H3 [7:0]
(0XX) | H4 [7:0]
(0XX) |

H1 [7:0] - Fixed value: 1110 0000 (0xE0)

H2 [7:0] - Same as 1st byte [7:0] of specified configuration command

H3 [7:0] - Same parameter configuration as 2nd byte [7:0] of specified configuration command

H4 [7:0] - Same parameter configuration as 3rd byte [7:0] of specified configuration command

7.2.2.3. Response for Configuration Command

This response is sent after changed configuration at receiving a correct configuration command in the control command.

The format of this response to be sent is as follows.

| Preamble
(4 bytes) | Header
(4 bytes) | | | |
|-----------------------|---------------------|--------------------|--------------------|--------------------|
| 0xCCCC5555 | H1 [7:0]
(0xE0) | H2 [7:0]
(0xFF) | H3 [7:0]
(0xFF) | H4 [7:0]
(0xFF) |

H1 [7:0] - Fixed value: 1110 0000 (0xE0)

H2 [7:0] - Same as 1st byte of the control command

H3 [7:0] - Same as 2nd byte of the control command

H4 [7:0] - Same as 3rd byte of the control command

7.2.2.4. Error of Control Command

This response is sent when receiving an incorrect control command.

The format of this response to be sent is as follows.

| Preamble
(4 bytes) | Header
(4 bytes) | | | |
|-----------------------|---------------------|--------------------|--------------------|--------------------|
| 0xCCCC5555 | H1 [7:0]
(0xE0) | H2 [7:0]
(0xFF) | H3 [7:0]
(0xFF) | H4 [7:0]
(0x00) |

H1 [7:0] - Fixed value: 1110 0000 (0xE0)

H2 [7:0] - Fixed value: 1111 1111 (0xFF)

H3 [7:0] - Fixed value: 1111 1111 (0xFF)

H4 [7:0] - Fixed value: 0000 0000 (0x00)

7.2.2.5. Error of Control Command

This response is sent when receiving an invalid configuration range of correct control command.

The format of this response to be sent is as follows.

| Preamble
(4 bytes) | Header
(4 bytes) | | | |
|-----------------------|---------------------|--------------------|--------------------|--------------------|
| 0xCCCC5555 | H1 [7:0]
(0xE0) | H2 [7:0]
(0xFF) | H3 [7:0]
(0xFF) | H4 [7:0]
(0x00) |

H1 [7:0] - Fixed value: 1110 0000 (0xE0)

H2 [7:0] - Same as 1st byte of the control command

H3 [7:0] - Fixed value: 1111 1111 (0xFF)

H4 [7:0] - Fixed value: 0000 0000 (0x00)

7.2.3. Alarm Notice

This notice is sent when the sensor becomes abnormal. The abnormal means the internal PLL circuit is unlocked. The state is checked every measurement. There is a possibility of sensor failure.

The format of this notice to be sent is as follows.

| Preamble
(4 bytes) | Header
(4 bytes) | | | |
|-----------------------|---------------------|--------------------|--------------------|--------------------|
| 0xCCCC5555 | H1 [7:0]
(0x00) | H2 [7:0]
(0x01) | H3 [7:0]
(0x00) | H4 [7:0]
(0x00) |

H1 [7:0] - Fixed value: 0000 0000 (0x00)

H2 [7:0] - Fixed value: 0000 0001 (0x01)

H3 [7:0] - Fixed value: 0000 0000 (0x00)

H4 [7:0] - Fixed value: 0000 0000 (0x00)

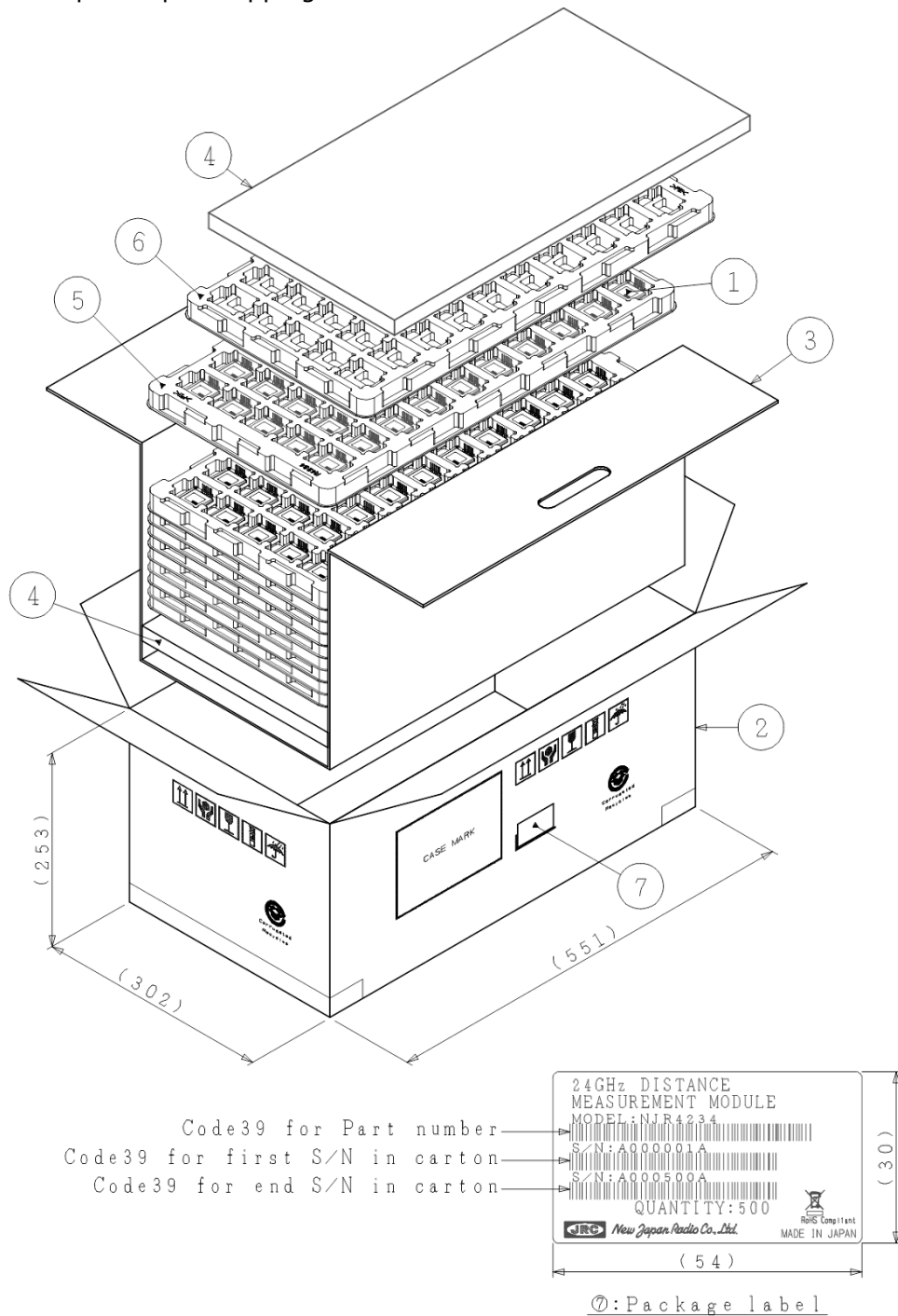
9. Environmental Characteristics

| ITEM | SPECIFICATION |
|-----------------------|--|
| Operation Temperature | -20 to +60 °C |
| Storage Temperature | -40 to +80 °C |
| Humidity | 0 to 95 %RH @+30 °C |
| Vibration | 49.03 m/s ² (5 G), 30 to 50 Hz, 10 minutes, XYZ direction |
| Shock | 196.13 m/s ² (20 G), Half sine, 11 msec, XYZ direction, 3 times |

10. Package

Standard Package

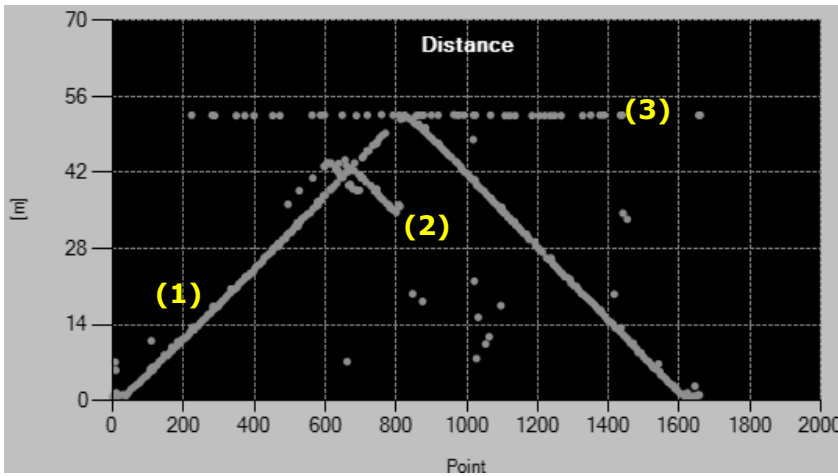
Packing Quantity: 500 pieces per shipping box



- ①NJR4234 24GHz Distance Measurement module
- ②Outer packaging:double wall corrugated fiberboard
- ③Inner packaging:single wall corrugated fiberboard
- ④Package cushioning:polyethylene foam
- ⑤Tray for modules (50 pcs×10 trays):conductive polystyrene
- ⑥Dummy tray:conductive polystyrene
- ⑦Package label

11. Actual Measurement Result (Reference)

11.1. Measurement of person walking in corridor



Measurement Result

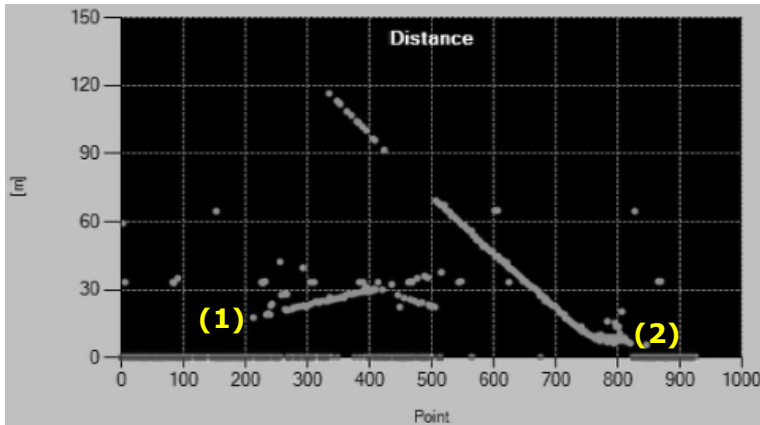


Measurement Condition

Measurement Objects:

- (1) Person walking from the front of the sensor to the wall at the end after that walking toward the sensor again.
- (2) Person different from (1) coming out of the door and walking toward the sensor
- (3) The wall at the end

11.2. Measurement of people walking and moving vehicle outdoors



Measurement Result

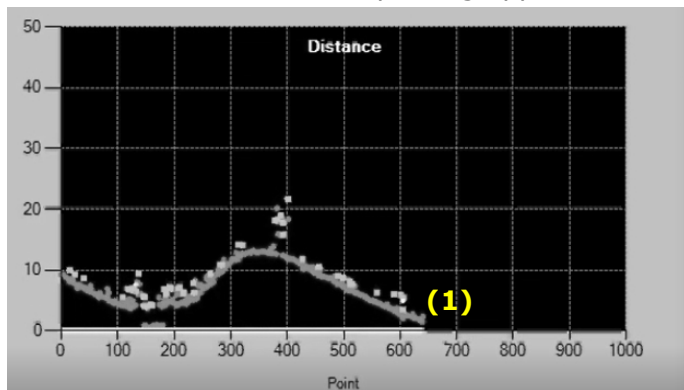


Measurement Condition

Measurement Objects:

- (1) People walking away from the front of the sensor
- (2) Vehicle approaching the sensor from a distance

11.3. Measurement of vehicle repeating approach and leave



Measurement Result



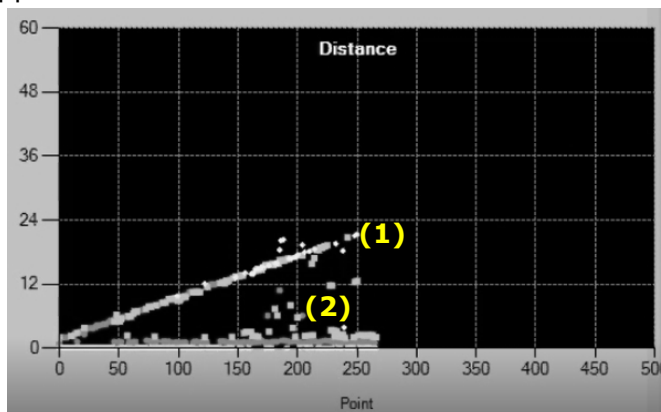
Measurement Condition

Measurement Object:

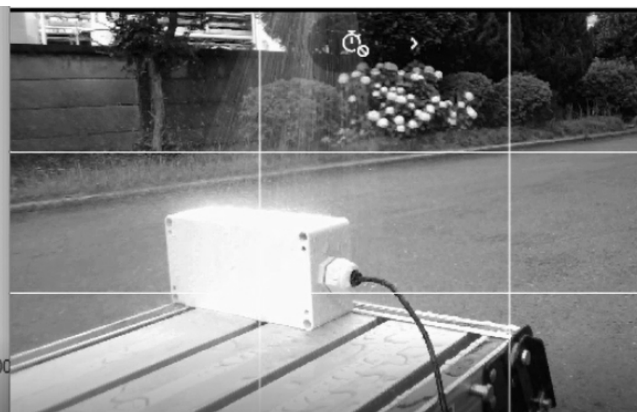
- (1) Vehicle repeatedly approaching and leaving from the sensor

11.4. Effect of rainfall

After mounting the sensor on the case, the pedestrian measurement is tested with water shower applied to the case.



Measurement Result



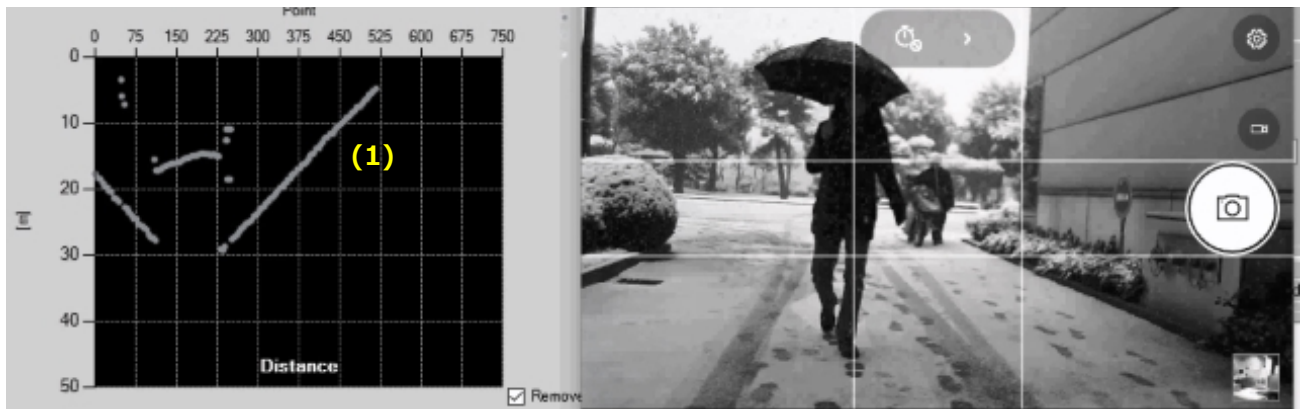
Measurement Condition

Measurement Objects:

- (1) People walking away from the front of the sensor
- (2) The effect of rainfall on the distance measurement of pedestrian is small, but the raindrop on the front of the case has a slight influence.

11.5. Effect of snowfall

After mounting the sensor on the case, the pedestrian measurement is tested with snowfall condition.



Measurement Result

Measurement Condition

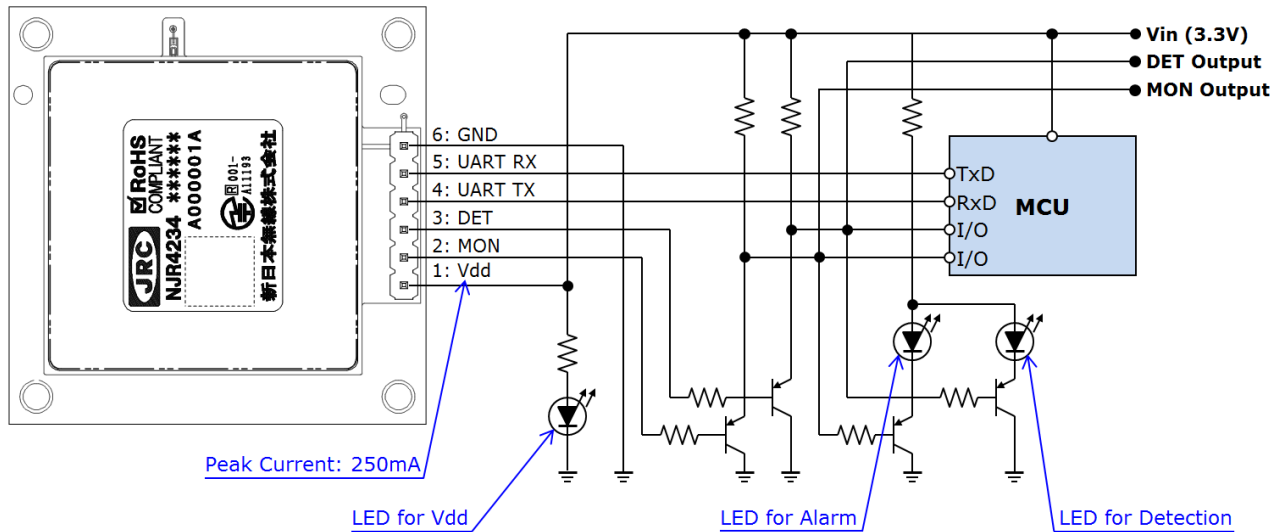
Measurement Objects:

- (1) People walking away from the front of the sensor

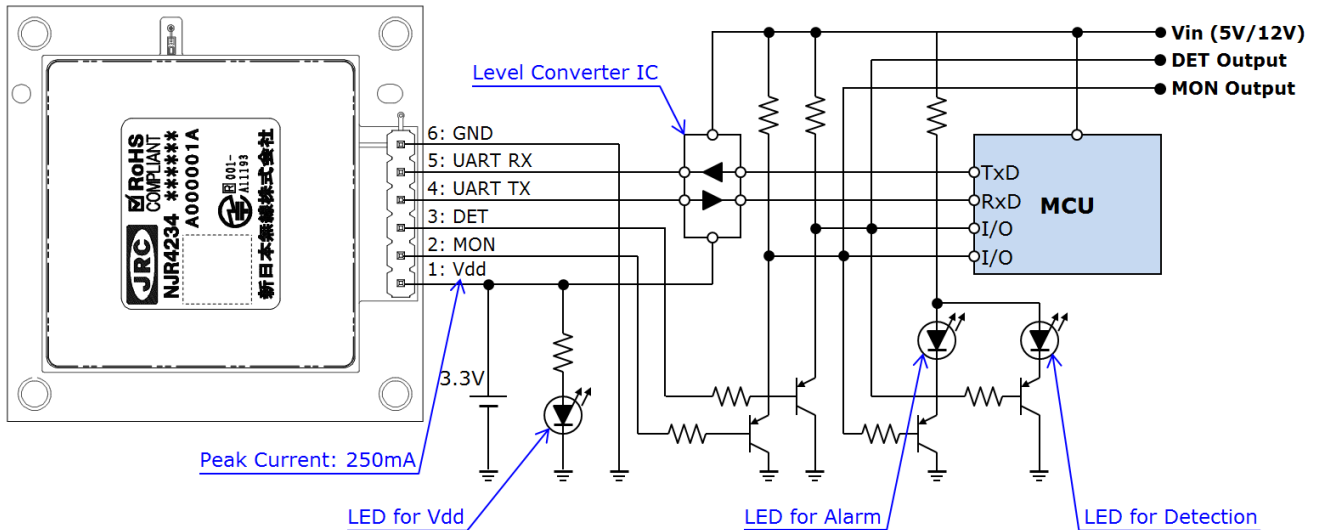
12. Reference Circuit

12.1. Control Circuit / Secondary Circuit

1) When the power supply voltage between the sensor and connection circuit are the same



2) When the power supply voltage between the sensor and connection circuit are different

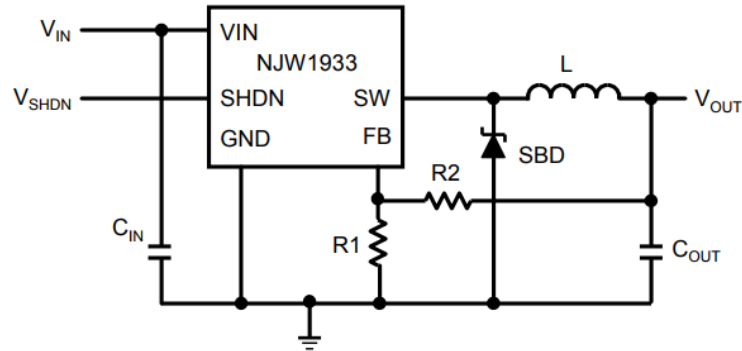


The sensor outputs distance information, but it is recommended to use the signal processing on the user's connected device based on the distance information.

Since the DET output will be high level when the signal level exceeds the sensitivity setting, it can be used only for primary processing such as returning to sleep mode on the user's connected device side.

12.2. Recommendation Power Supply Circuit

IC : NJW1933F1-AT
 Input Voltage : $V_{IN}=12V$
 Output Voltage : $V_{OUT}=3.3V$
 Output Current : $I_{OUT}=0.6A$
 Oscillation Frequency : $f_{osc}=500kHz$

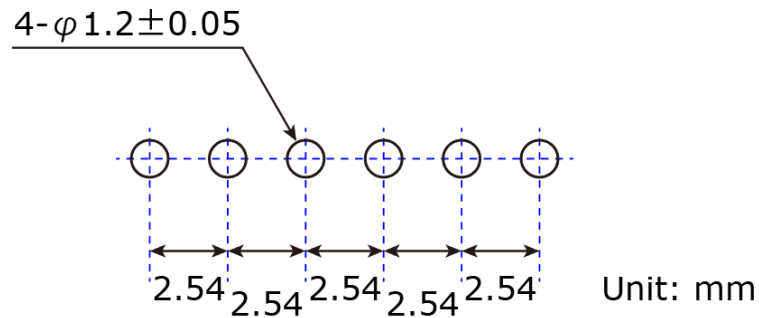


| SYMBOL | QTY. | PART NUMBER | DESCRIPTION | MFR. |
|------------------|------|-------------------|--|------------------|
| IC | 1 | NJW1933F1-AT | 0.6A MOSFET built-in SW.REG. IC | New JRC |
| L | 1 | CDRH6D28NP-220NC | Inductor 22 μ H, 1.2A | Sumida |
| SBD | 1 | MBRM140T3G | Schottky Diode 40V, 1A | ON Semiconductor |
| C _{IN1} | 1 | GRM31CB31H225KA87 | Ceramic Capacitor 3216 2.2 μ F, 50V, B | Murata |
| C _{OUT} | 1 | GRM32EB31C476ME15 | Ceramic Capacitor 3225 47 μ F, 16V, B | Murata |
| R1 | 1 | 3.3k Ω | Resistor 1608 3.3k Ω , $\pm 1\%$, 0.1W | Std. |
| R2 | 1 | 5.6k Ω | Resistor 1608 5.6k Ω , $\pm 1\%$, 0.1W | Std. |

(*) The details of power supply circuit is referred to datasheet of NJW1933.

13. Recommendation Mounting Conditions

13.1. Footprint dimensions *Note1



13.2. Soldering conditions

- Soldering way: Solder iron *Note2
- Solder iron temperature: 350 °C or less
- Soldering time: in below

| Pin # | Soldering time |
|---------|------------------|
| 1 to 5 | 3 second or less |
| 6 (GND) | 6 second or less |

*Note1) In actual design, please optimize in accordance with the situation of your board design and soldering condition.

*Note2) The soldering iron to be used must be grounded via a resistance of about 1 MΩ.

14. Recommendation Condition for Cover Design

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Microwave sensor is possible to detect by passing through glass or plastic, pottery, etc. Therefore, there are advantages such as hiding properties and a high degree of freedom in the cover design when it incorporated into a product. However, the cover is the reflecting object which is located in closest to the sensor. If it is not made by a suitable material and a suitable shape, it will adversely affect the sensor characteristics. It will be helpful to prevent trouble such that the performance of the sensor can not be obtained, by understanding about the important parameters for designing the cover.

Role of Cover

Protecting the sensor from rain and dust is important object of cover. Therefore, the appropriate material for your use should be selected as the cover material. On the other hand, since the cover is located in closest position to the sensor, the reflection by the cover affect to the sensor performance. Therefore, the cover should be designed to reduce the reflection by it as much as possible.

Key Points in Cover Design

- The cover shall be selected the material with the low dielectric constant and low insertion loss, such as polycarbonate.
- Do not select the material of the cover including some of the conductive such as metal or carbon.
- Do not coat with paint that contains some of the conductive such as metal or carbon.
- The thickness of cover is approx. 3 to 4 mm generally for plastic materials in 24 GHz microwave. However, it varies depending on the dielectric constant of the material.
- The distance between cover and antenna of the sensor is approx. 6.2 mm or more generally in 24 GHz microwave. However, it is recommended to test the sensor performance by changing the distance to the sensor with a plate material to use.
- The design against vibration of both cover and sensor must be paid careful attention.

14.1. Material of Cover

In regards to the cover materials, the cover shall be selected the material as follows.

- Electrically non-conductive material
- Low dielectric constant (ϵ_r) and low dielectric loss ($\tan\delta$) at transmit frequency.
- Shape must be stable in used temperature range and pressure range.
- No water absorption and no hygroscopic. Water-repellent is desirable.
Water is a material that has high dielectric loss and large dielectric constant. Therefore, the dry cloth and wood are pass the microwaves well but when those absorb moisture, those attenuation is greatly increase.
- Other environmental performance, that is, light resistance, chemical resistance, flame retardant may be required by the situation of the product.

Table: Example of Material used for the Cover *Note1

| Material | Dielectric Constant (ϵ_r) | Dielectric Loss ($\tan\delta$) | Feature |
|----------------|--------------------------------------|----------------------------------|---|
| Polycarbonate | 2.9 | 0.012 | Shock Resistance / Heat Resistance / Flame Retardant |
| ABS Resin | 2.5 – 3.5 | 0.001 – 0.02 | Excellent moldability
Characteristics may be different due to the composition *Note2 |
| PTFE (Teflon®) | 2.0 | 0.0002 | Electrical Characteristics at High frequency is excellent. |

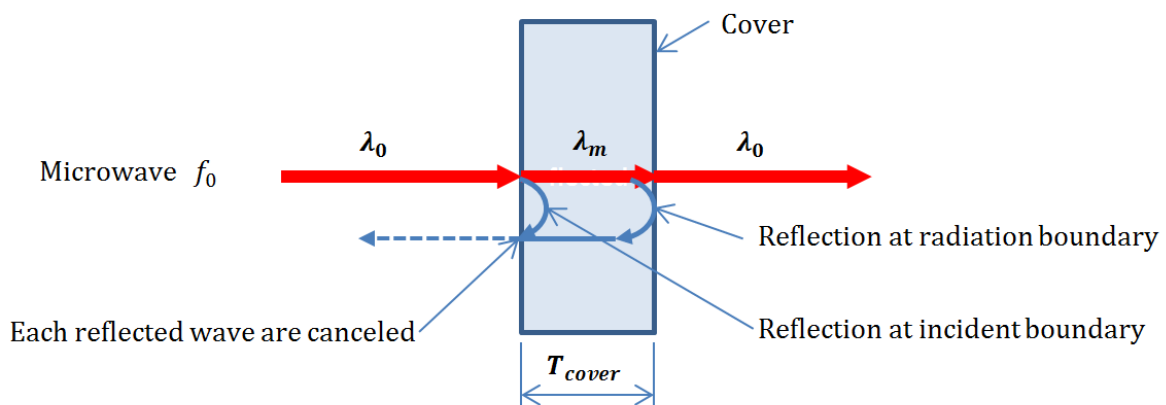
*Note1) Characteristic values showing in the table are typical values that are published on the web or documents. When you actually design a cover, it is better to ask the manufacturer about the characteristics of material. However, please take care about the measured frequency of dielectric constant / dielectric loss of manufacturer data.

To design a microwave cover, It is necessary the value of the frequency (10 / 24GHz) to be used, but in many cases data of manufacturer is the data measured at 1MHz or at lower than 1GHz.

*Note2) Engineering plastics such as ABS resin requires a separate confirmation because there are many kinds of changing the composition and additives. Also, please avoid coating with paint containing the metal or carbon.

14.2. Thickness of Cover

Cover is designed to minimize microwave reflection in order to reduce the influence to the sensor performance. Some part of microwaves incident into the cover is reflected at the boundary between the air and the cover. Further, some part of the microwaves that was inserted into the cover will be reflected again at the boundary of the cover and the air. When the thickness of the cover is about half of the wavelength in the cover material, the reflected wave of the incident boundary and the radiation boundary is canceled and it will become the minimum loss.



Reflection of microwave at the Cover

Ex.) Polycarbonate ($\epsilon_r=2.9$) | Frequency(f_0) = 24.15 GHz

Wavelength in the air (λ_0) = $c_0/f_0 \approx 12.4$ mm

Wavelength in Cover material (λ_m) = $\lambda_0/\sqrt{\epsilon_r} \approx 7.3$ mm

Thickness of Cover for minimum loss (T_{cover}) = $\lambda_m/2 \approx 3.6$ mm

c_0 : Speed of light (3×10^8 m/s)

ϵ_r : Dielectric Constant of Cover material

14.3. Distance between Cover and Antenna

The distance between the antenna of the sensor and the cover is also important parameter to reduce the effect of the cover.

Reflected wave by the cover will affect the receiving noise characteristics by the phase of incident into the receiving antenna as following figure is an example of actually measured in our sensor.

Dashed line is the noise level without cover

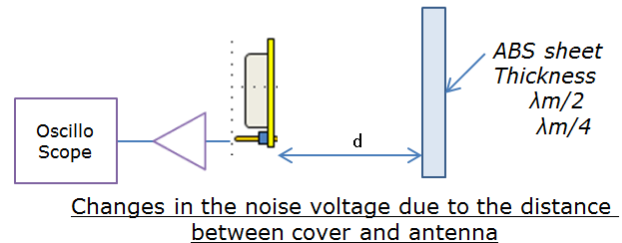
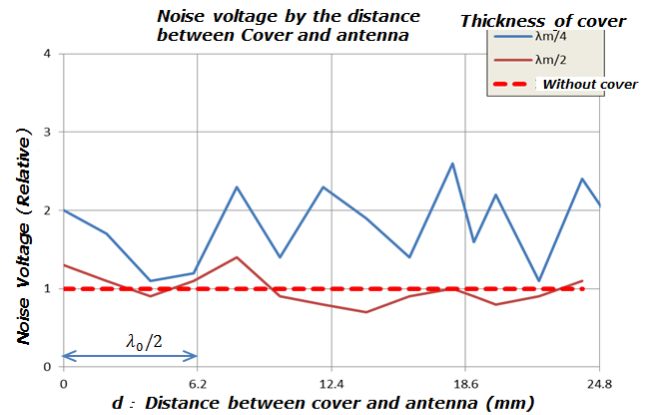
- In case thickness $\lambda_m/2$ (red): reflection at the cover is small, not much change in the noise in the distance.
- In case thickness $\lambda_m/4$ (blue): reflection at the cover is large, the noise has changed significantly in the distance.
- In either case, noise at the distance about $\lambda_0/2$ is low.
- Noise becomes worse in excessively close distance ($<\lambda_0/4$)

Ex.) Frequency(f_0) = 24.15 GHz

$$\text{Wavelength in the air } (\lambda_0) = c_0/f_0 \approx 12.4 \text{ mm}$$

$$\text{Distance between cover and antenna } (d) = \lambda_0/2 \approx 6.2 \text{ mm}$$

c_0 : Speed of light (3×10^8 m/s)

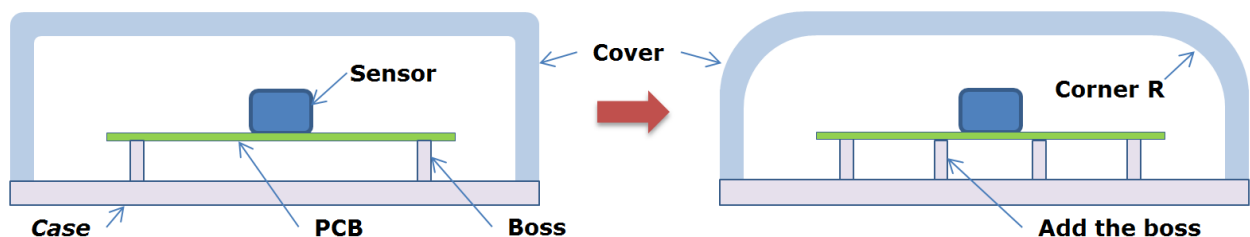


Actually distance for the minimum noise might be shifted from $\lambda_0/2$. It is recommended to confirm the optimal value of the thickness and the distance using the cover material to be actually used by this measurement.

14.4. Consideration to the vibration

It would appear as increase of noise when the distance of the cover and the sensor is relatively changed by the vibration. Therefore, cover needs a mechanically sufficient strength to avoid the moving by vibration. Mounting of the sensor also need to be careful to the motion by vibration.

The following figure is example of weak structure to vibration and the example of counter measure to the vibration. If using the sensor in locations there is a vibration, it is strongly recommended that the natural vibration of the structure and consider the adoption of the damper to reduce the vibration.



In case of the cover is flat and wide, it is a possibility to sway the cover by vibration.
If the PCB is supported only around of large Board, it is also a possibility to swaying by the vibration.

By increasing the corner R, sway of the cover will be able to reduce.
By supporting the PCB in the vicinity of the sensor, sway of the sensor will be able to reduce.

Example of mechanical vibration measures



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