Operational Amplifiers Product Introduction

Aug. 20, 2021
Analog Product Design Dept.
Standard LSI Development. Div.
LSI Business Unit

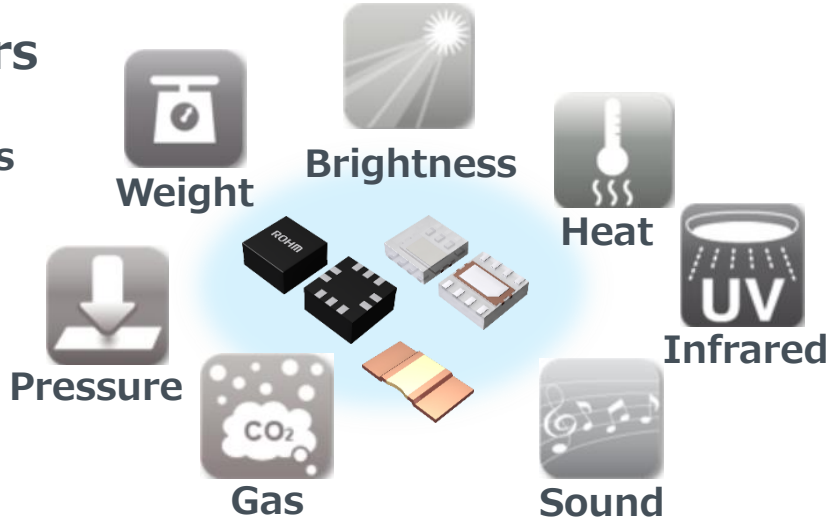
The arrival of a 1 trillion sensor society by IoT

Detect and utilize environmental changes with sensors

Consumer, industrial, medical automotive

Control request becomes higher accuracy

Weak Signal



Sensor

Sensors are included every applications

- 3D goggles
- CD player
- IR remote control
- Ambient light sensor
- Night vision device
- Laser distance measurement
- Rain sensor
- Security equipment
- Low noise mic amp
- Motion sensor
- Handheld testing machine
- HDD
- Industrial equipment
- Light sensor
- Electronic scale
- Magnetic force balance meter
- Gas detector

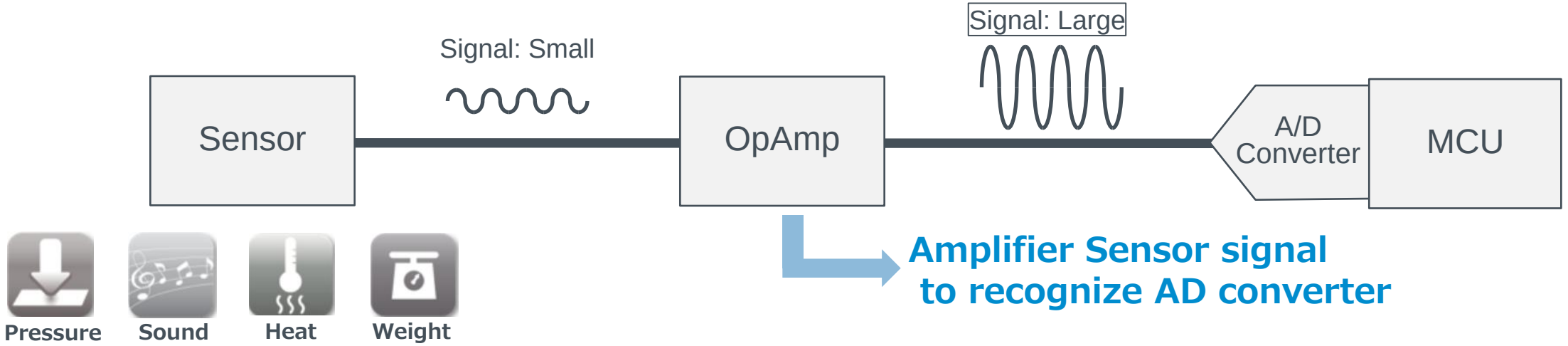
Converting weak environmental changes into electrical signals

- Acceleration sensor
- Pressure sensor
- Photodiode
- Thermocouple / temp. sensor
- Strain sensor
- Current sensor (shunt resistor)

The role of op-amps and comps that detect and amplify sensor signal is becoming more important

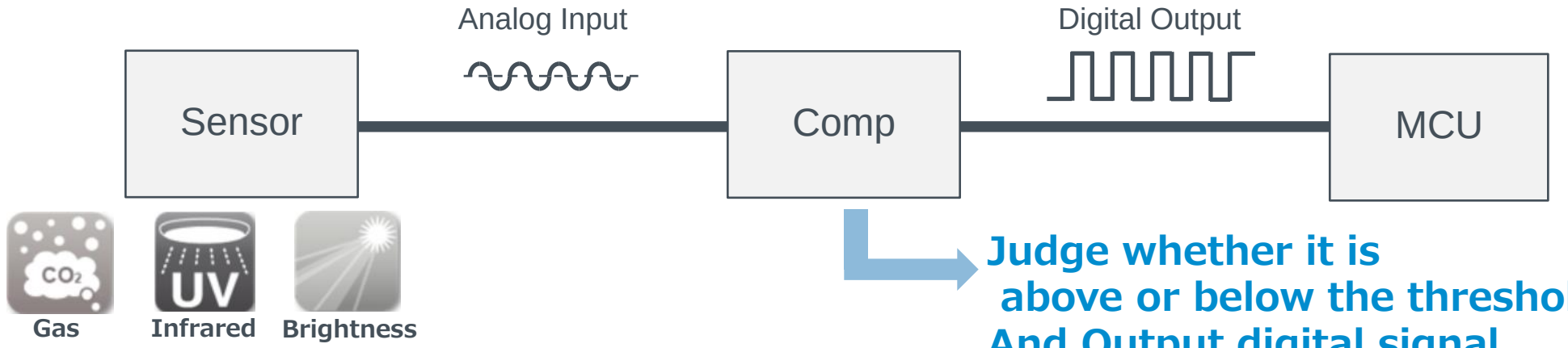
“What is OPAMP / COMP ? ”

Operational Amplifier = Signal amplifier



Amplifier Sensor signal to recognize AD converter

Comparator = Comparison between signal



Judge whether it is above or below the threshold, And Output digital signal.

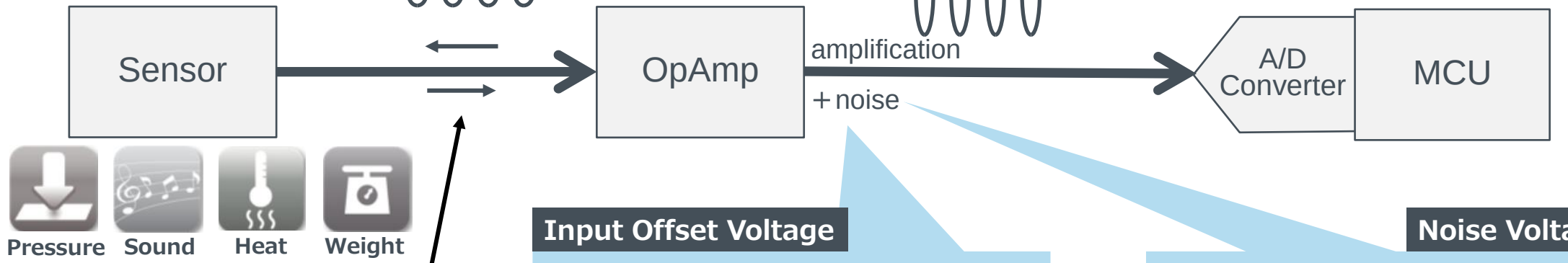
Basic performance required for operational amplifiers

A sensor that converts weak environmental changes into electrical signals

Signal: Small

High Amplification

Noise causes malfunction

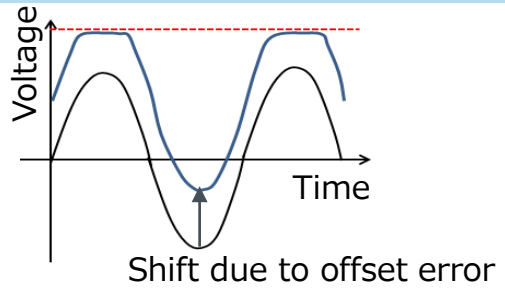


Input Bias Current

Indicates the current that flows into or out of the input terminal.

When the sensor output is high impedance, it affects the sensor output.

Input Offset Voltage

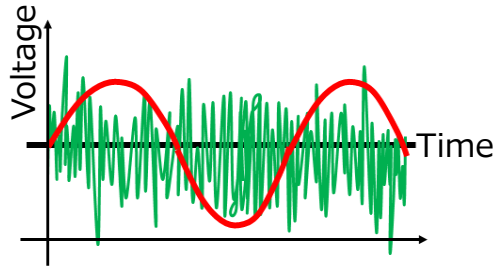


DC Voltage error of OpAmp

Appears as a shift in output DC Voltage

Amplifying at High Gain may cause system malfunction.

Noise Voltage Density



AC Voltage error of OpAmp

Appears as noise in the output.

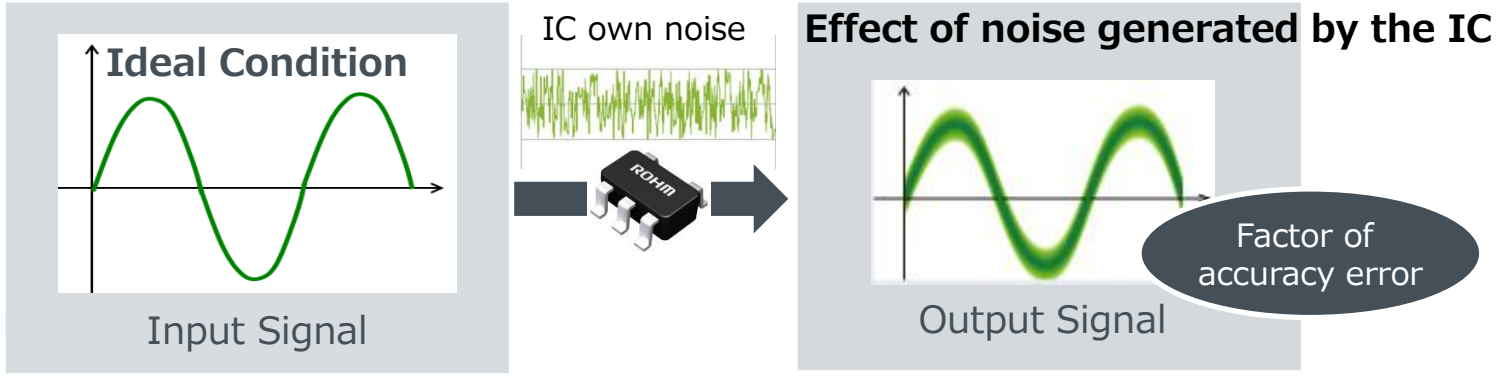
高When amplified at High Gain, the signal component is buried in noise and can't be detected.

The accuracy of the sensor system depends on the OpAmp

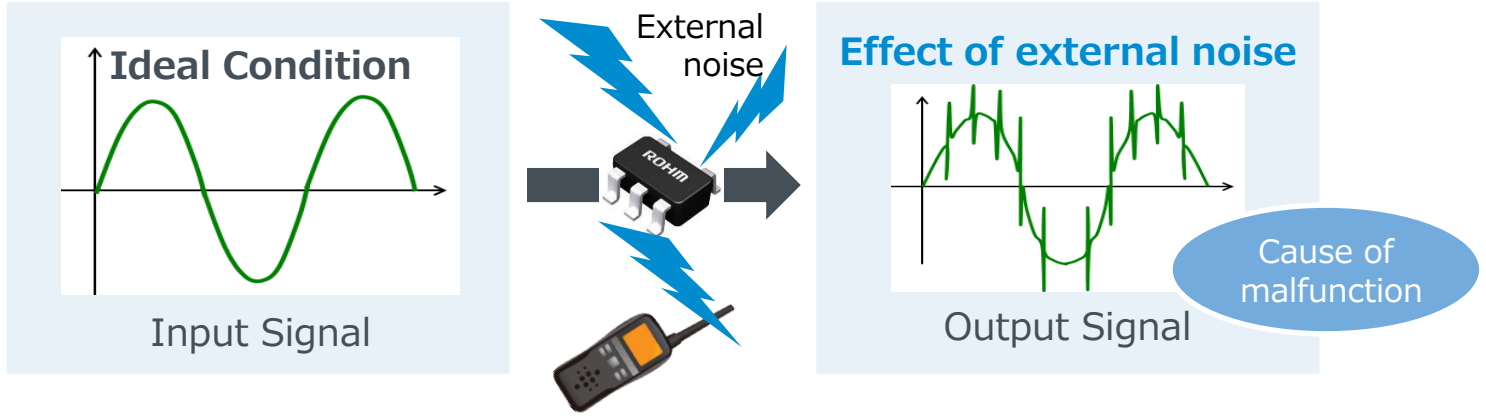
Noise that hinders the high accuracy of the sensor system

EMC
- EMI
- EMS

EMI is the interference caused by one electrical or electronic device to another by the electromagnetic field set up by its operation.



EMS is an indicator of how much noise is affected form outside. If the EMS characteristics are good, the IC will not be affected by external noise.



Low noise and noise immunity of OpAmp are important for sensor applications that require high accuracy.

Noise Definition ～ EMI & EMS ～

EMC = **E**lectro**m**agnetic **C**ompatibility

EMI = **E**lectro**m**agnetic **I**nterference

～ How much noise is generated to the outside～

～ Good EMI characteristics ⇒ IC **dosen't emit** electromagnetic noise～

Op Amps with superior EMI characteristics define Low Noise Op Amps in the sense that they are not output noise.

EMS = **E**lectro**m**agnetic **S**usceptibility

～ How much is it affected by external noise～

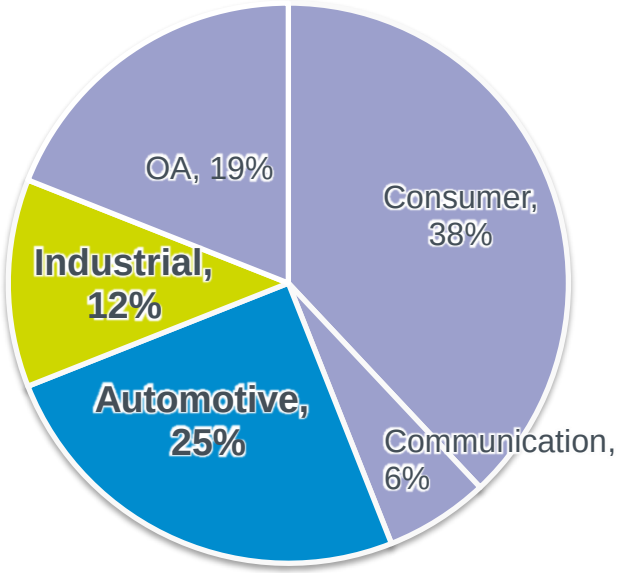
～ Good EMS characteristics ⇒ IC **dosen't receive** external noise～

～ **High EMI immunity** ⇒ Highly resistant to external noise (EMI) ～

Op Amps with superior EMS characteristics define high EMI immunity Op Amps in the sense that they are not affected by external noise.

“ How we see ourselves “

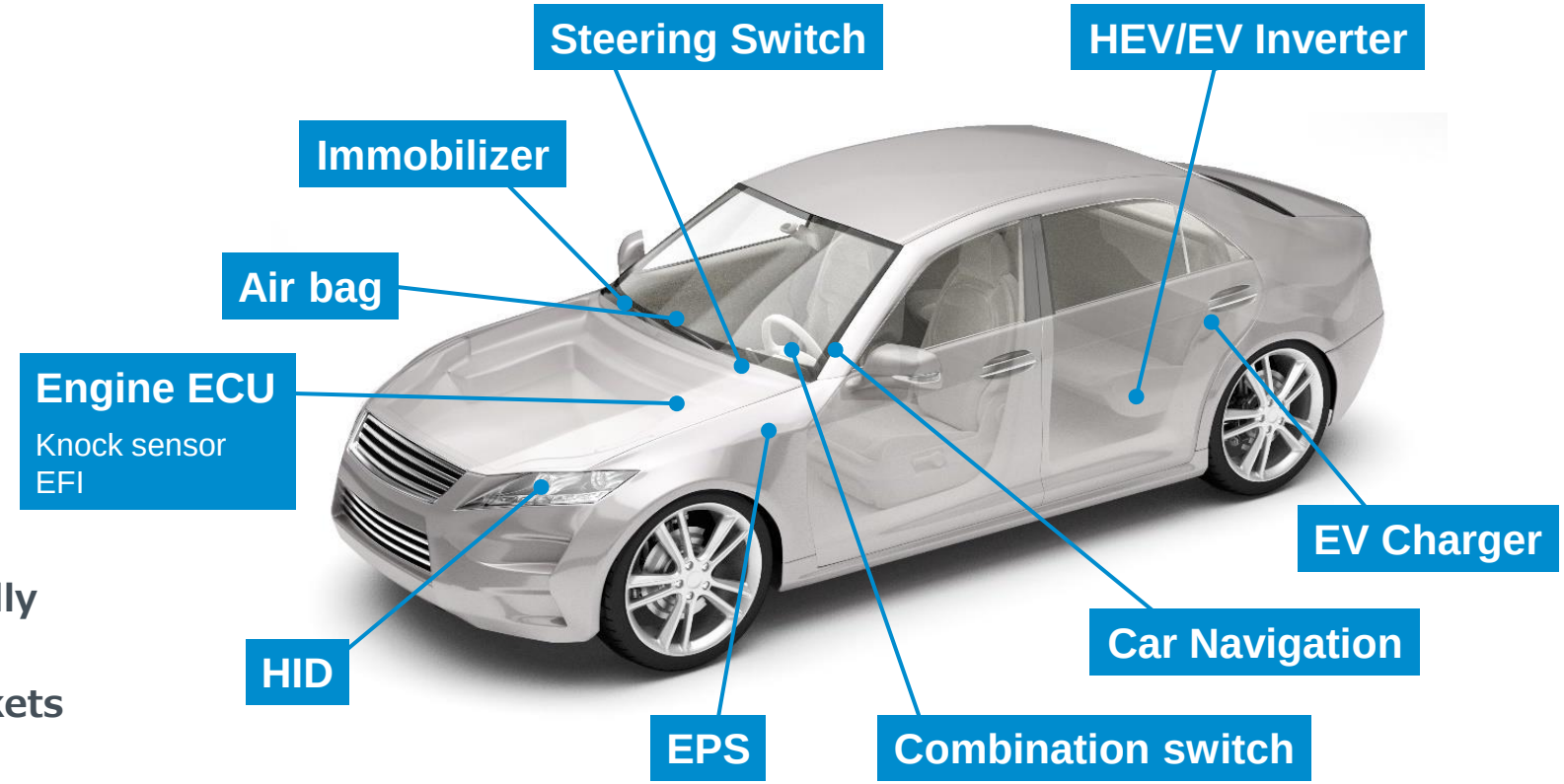
Shipment record ‘2020



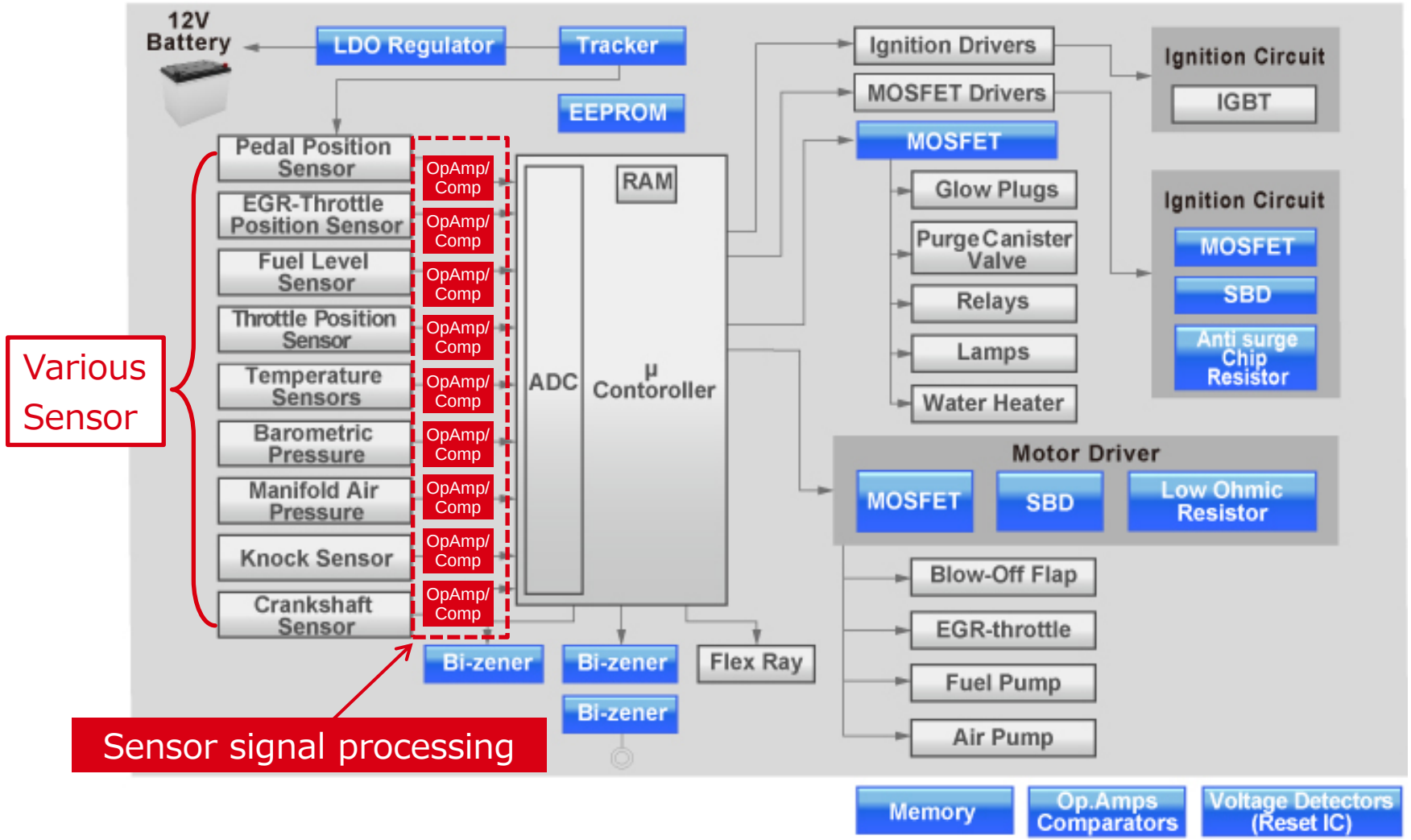
Over 500 million units shipped annually

Focus on Automotive & Industrial markets

Automotive application adoption example.



Supplement : OpAmp Adopt example (Automotive ECU)



Developing Two Op Amps from Accumulated Technologies and an Integrated Production System

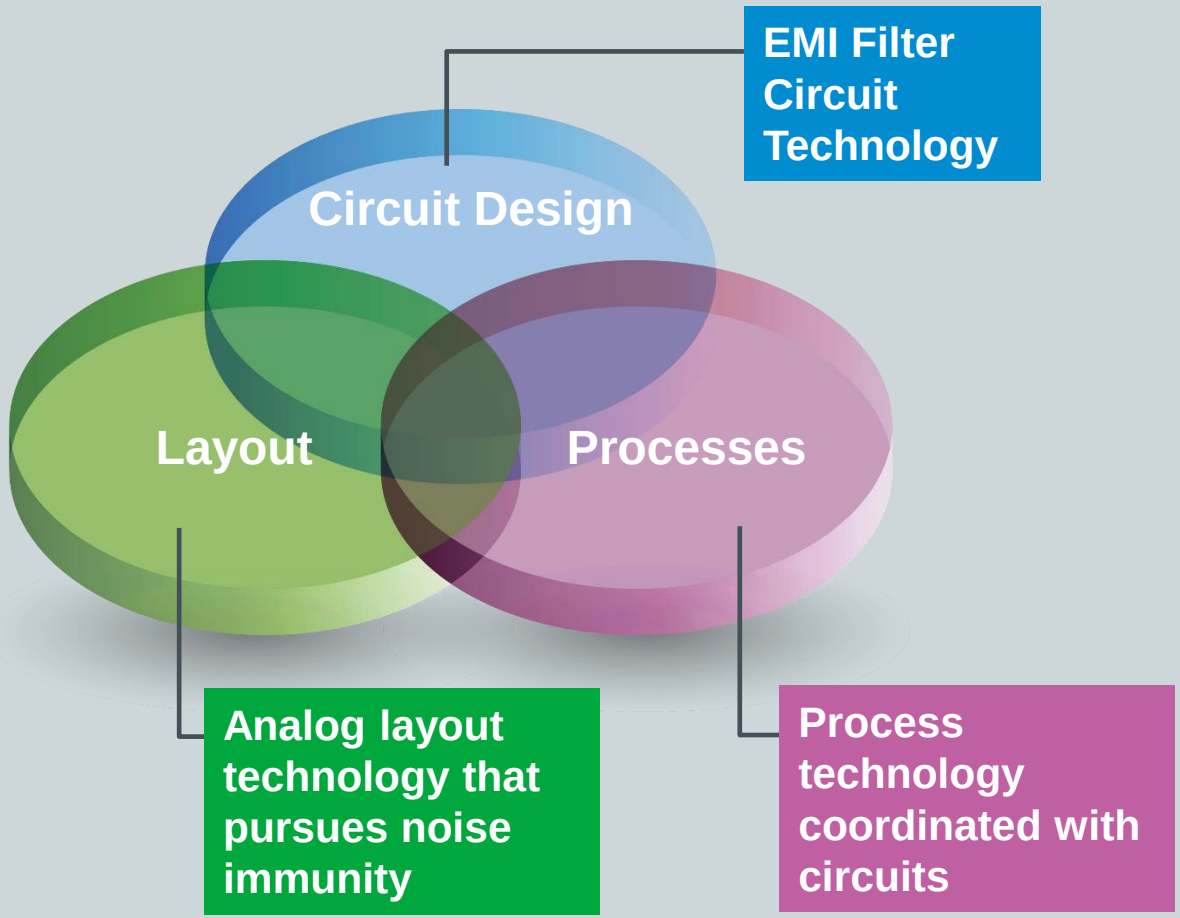
At ROHM, circuit design engineers take the lead in IC development, referring to process and layout rules

Two op amps that pursue superior noise characteristics were also developed using our integrated production system.

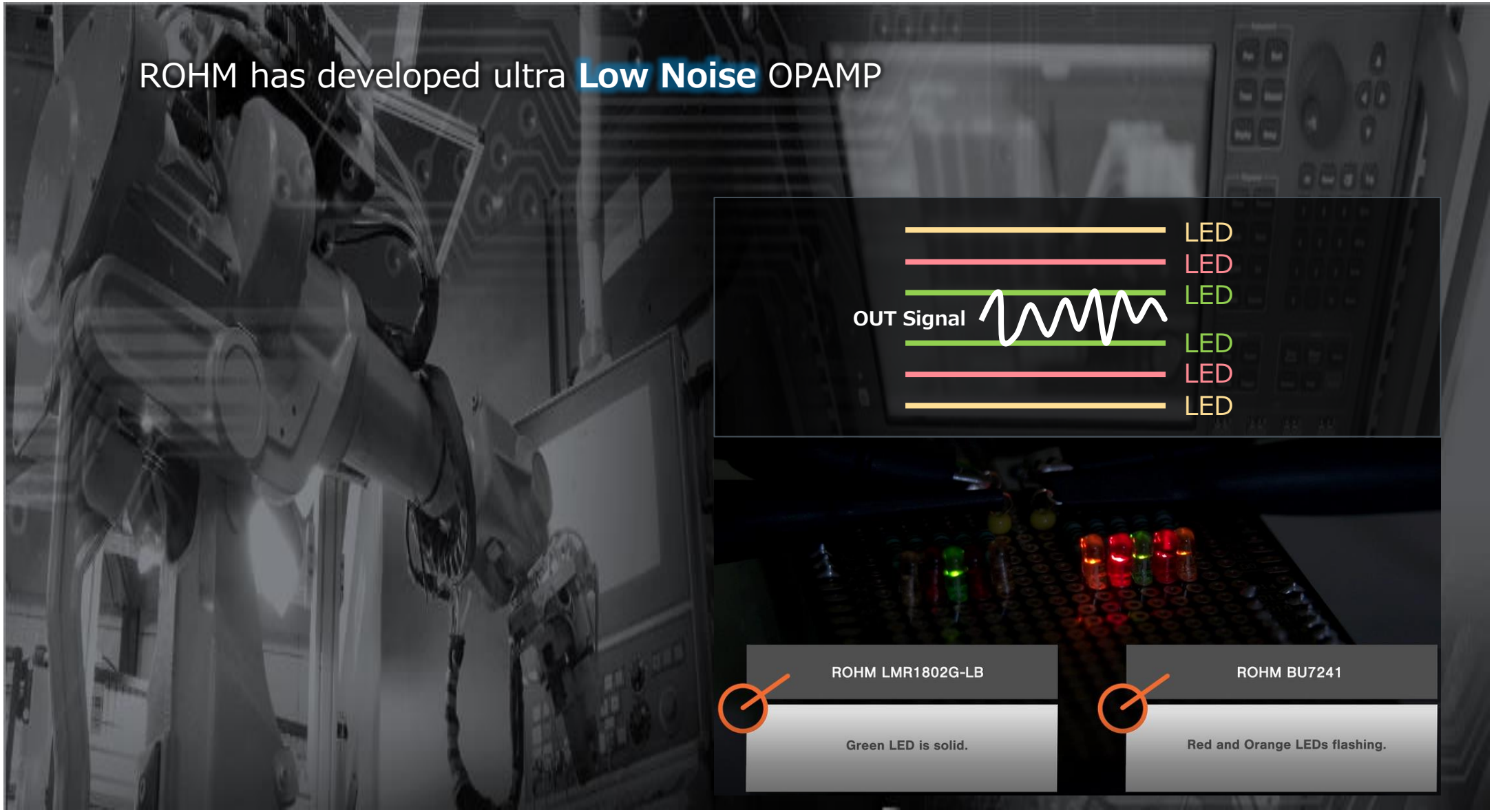
High EMI Immunity Op Amps

Ultra-Low Noise Op Amps

Integrated Technology Development



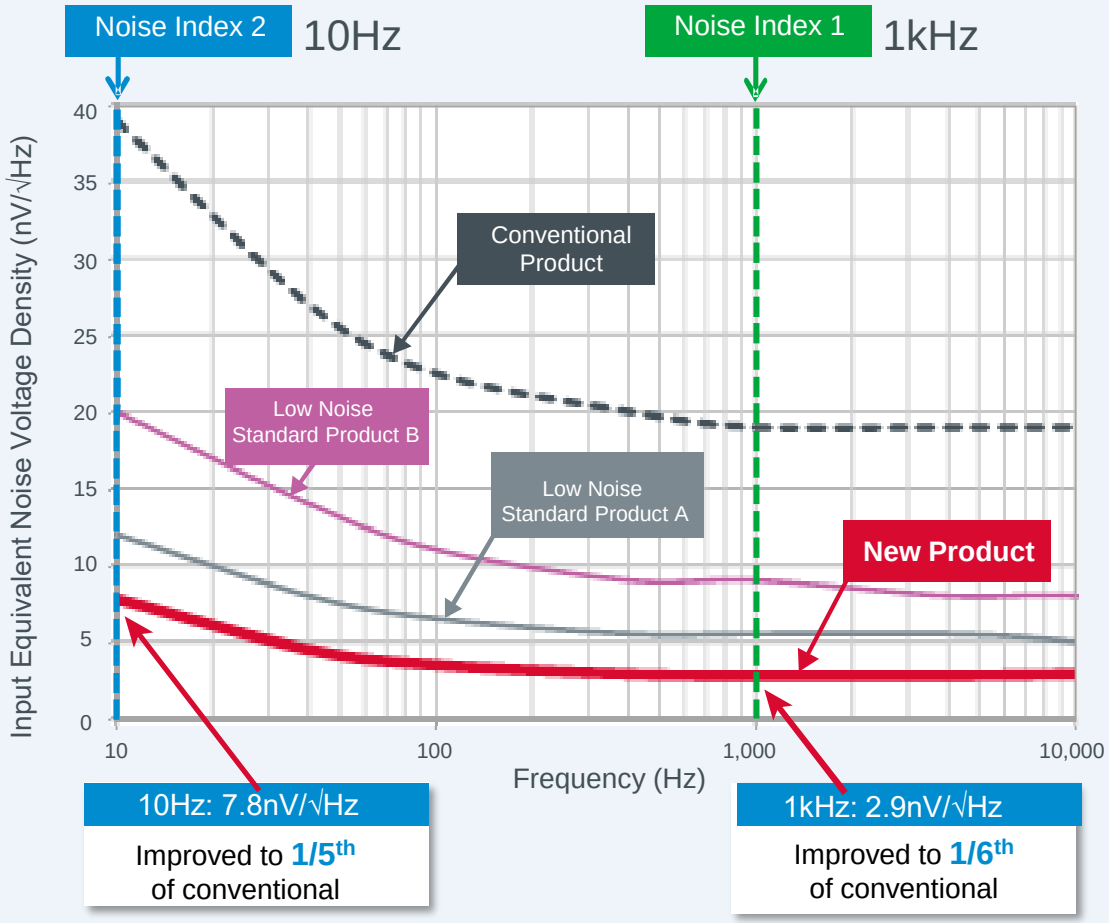
“ Why Rohm’s OPAMP ? ”



Low-Low Noise Ground Sense Op Amps

Achieves even higher accuracy with the industry's lowest* noise

Noise generated within the IC is reviewed from the process level and improved to achieve ultra-low noise in all areas from 10Hz to 1kHz.



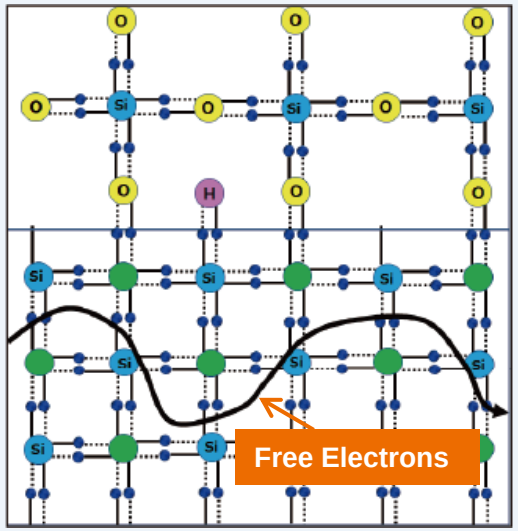
*ROHM May 2021 study

Low Noise Ground Sense Op Amps

Achieves ultra-low noise by thoroughly reviewing processes and circuits

We have improved flicker noise that regularly occurs and reviewed the basic elements to ensure low noise

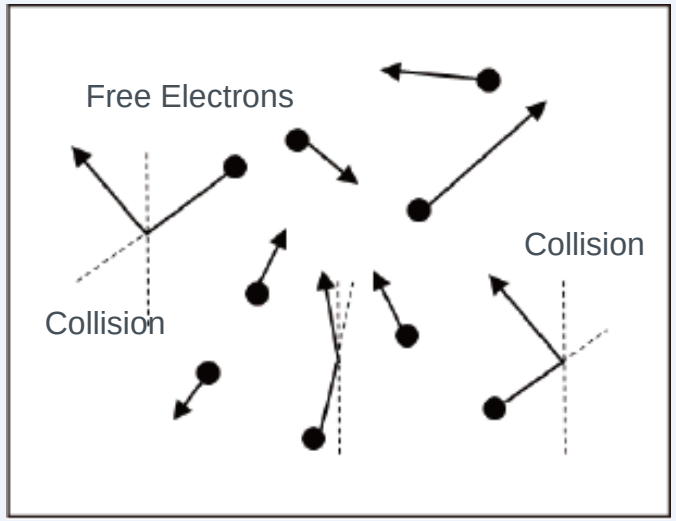
Improvements through the manufacturing process



Flicker noise

Flicker noise is believed to be caused by the scattering (fluctuation) of electrons due to impurities contained within the semiconductor. Therefore, suppressing electron scattering in the semiconductor will cause the electrons to flow more smoothly.

Improvements through circuit design



Thermal noise

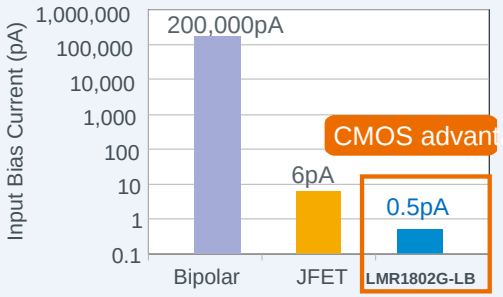
Thermal noise occurs in the internal resistance components, pure resistors, transistors, wiring, and other elements. Improvements are achieved by reducing the resistance value and optimizing the circuit configuration and transistor size.

Further Improving Basic Performance

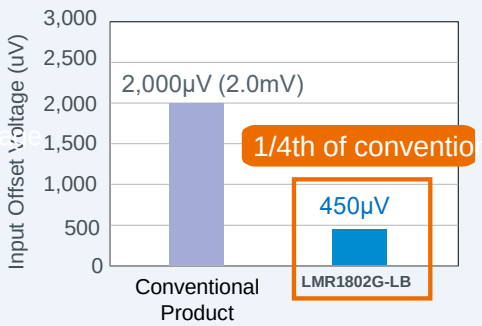
Significantly reduces input bias current and input offset voltage

- Element leakage current
- Suppresses current to just 0.5pA (about half that of conventional products)
- Minimizes the effects of device variations by increasing transistor element size
- Higher voltage gain by reviewing circuit design
- Optimized input offset voltage
- Achieves a low value of 450μV (1:4 vs conventional)

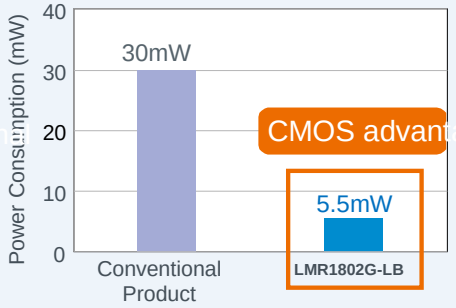
Low Input Bias Current



Input Offset Voltage



Lower Power Consumption (Low Voltage Operation)

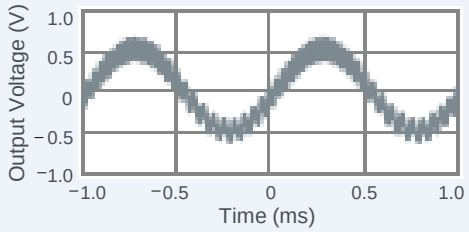


	Conventional Product*	LMR1802G-LB
Input Equivalent Noise Voltage Density	5nV/√Hz	**2.9nV/√Hz**
Circuit Current	6mA	**1.1mA**
Supply Voltage	4V to 32V	**2.5V to 5.5V**

*Comparison with a conventional bipolar low-noise type at 5V

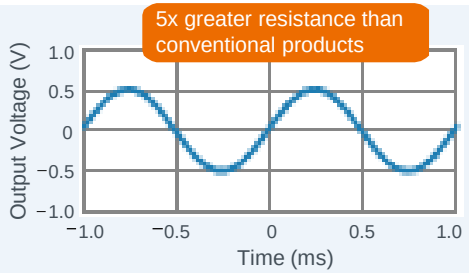
Improved phase margin ensures superior stability

Achieves a high phase margin of 68° by integrating optimized phase compensation into several areas



Oscillation Example

***200pF load capacitance connected**



LMR1802G-LB

***1000pF load capacitance connected**

	Standard Product A	Standard Product B	Conventional Product	LMR1802G-LB
Input Equivalent Noise Voltage Density	5.5nV/√Hz	7.5nV/√Hz	19nV/√Hz	**2.9nV/√Hz**
Phase Margin*	24°	60°	40°	**68°**
Capacitive Load Characteristics	100pF	250pF	100pF	**500pF**

*At no load

Low Offset & Low Noise CMOS OPAMP

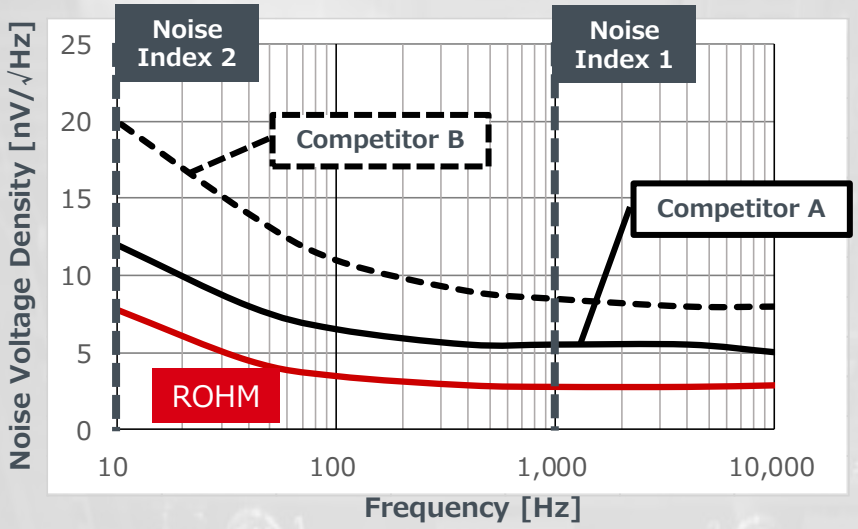
LMR180x Series
TLRx37x Series

ROHM has developed ultra **Low Noise** CMOS OPAMP.

Low Noise characteristic is indicated by the「**Input-Referred Noise Voltage Density**」in the data sheet, and is the minute voltage fluctuation generated by

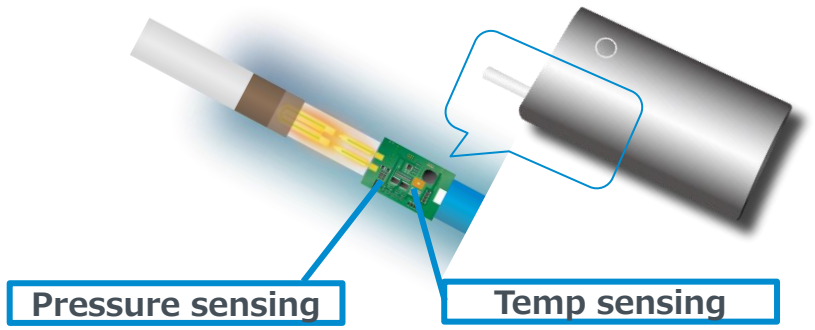
「Low Offset Voltage」
「Low Noise」
High precision operational amplifier

- **Input Offset Voltage** 950uV,450uV,150uV
- **Input Bias Current** 0.5pA (Ta=25℃)
- **Input Referred Noise Voltage Density**
  2.9nV/√Hz(1kHz) 7.8nV/√Hz(10Hz)

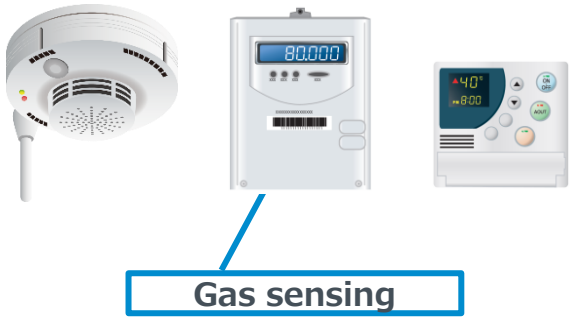


Part No.	Ch	Input Offset Voltage【MAX】	Noise Voltage Density【TYP】	Supply Current【TYP】	DS	CS	Package
LMR1801YG-C (Ground Sense)	1	950uV@25℃ 1200uV@all Temp	5.0nV/√Hz @1KHz	0.95mA	✓	✓	SSOP5
LMR1802YG-C (Ground Sense)	1	**450uV@25℃ 500uV@all Temp**	**2.9nV/√Hz @1KHz**	1.10mA	✓	✓	SSOP5
TLRx377Yxx-C (Rail to Rail)	1,2,4	1200uV@25℃ 1300uV@all Temp	8.0nV/√Hz @1KHz	1.00mA @1ch	✓	✓ 1ch ✓ 2ch '21/4Q 4ch	SSOP5/MSOP8 /SSOP-B14
TLRx376Yxx-C (Rail to Rail)	1,2,4	**150uV@25℃ 550uV@all Temp**	8.0nV/√Hz @1KHz	1.00mA @1ch	✓	✓ 1ch ✓ 2ch '21/4Q 4ch	SSOP5/MSOP8 /SSOP-B14

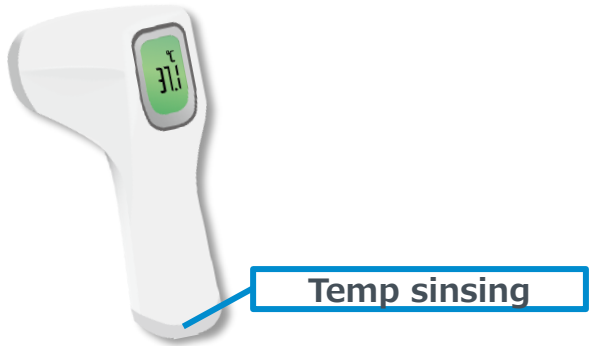
Success stories



Application : Electronic Cigarette



Application : Gas Alarm



Application : Non-contact thermometer

<Customer request>

1, High precision OPAMP

2, Small Package

High precision technology
① Low Offset Voltage
② Low Noise

Package
Small HVSOF5 & SSOP5

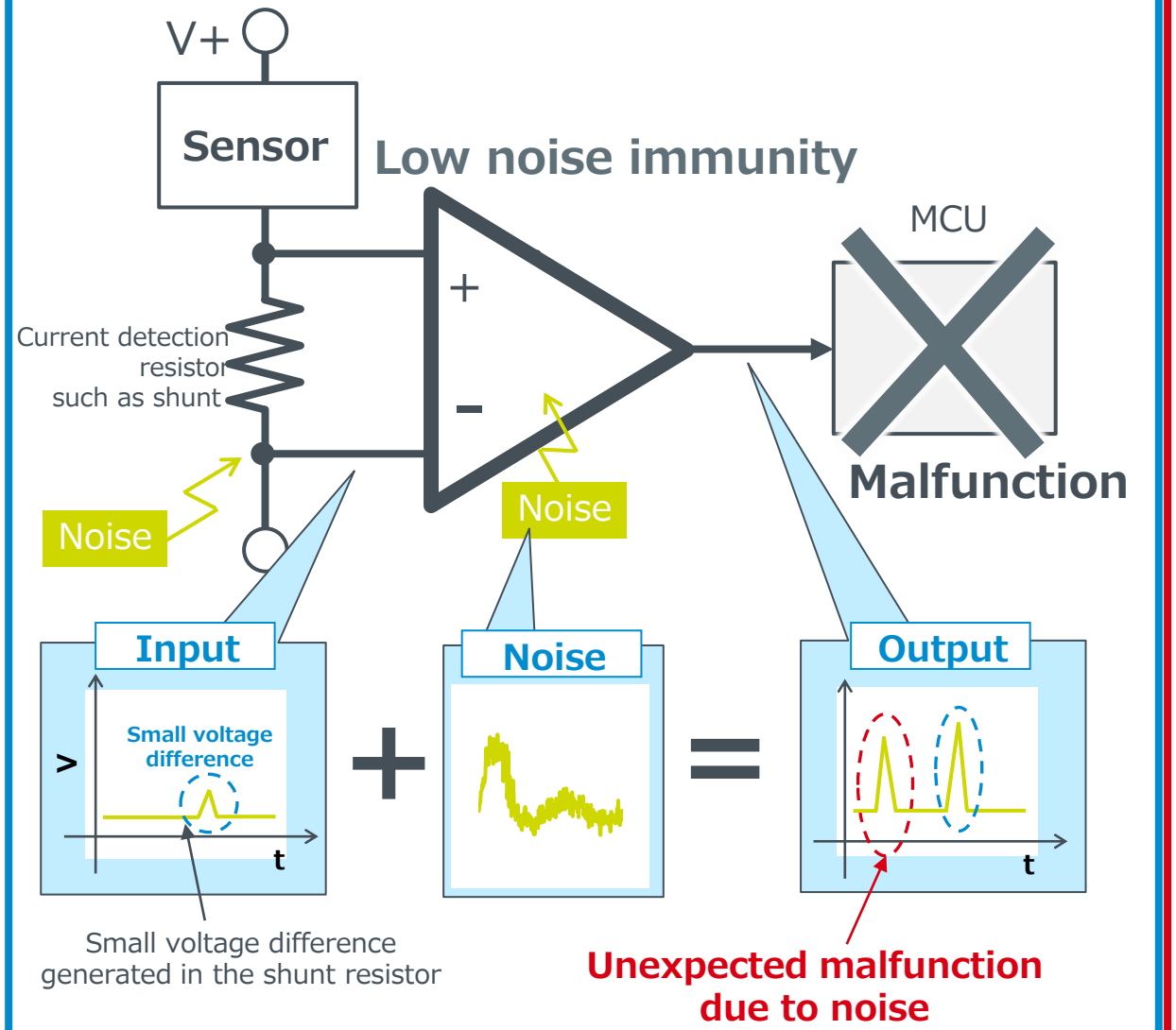
Ultra-High EMI Immunity

“ Why Rohm’s OPAMP ? ”

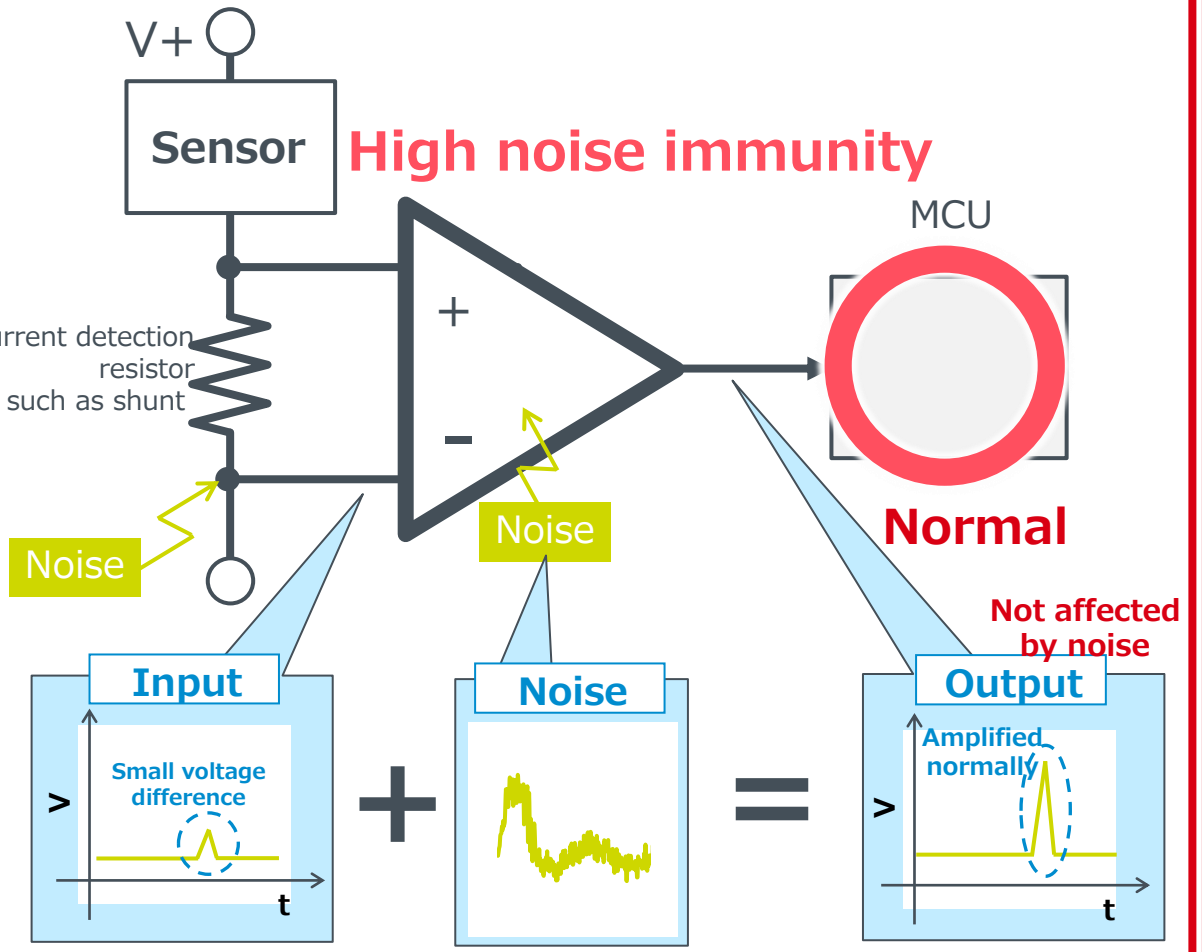
Ultra-High EMI Immunity

Advantage of using Excellent EMI Characteristics OPAMP ①

Conventional Product



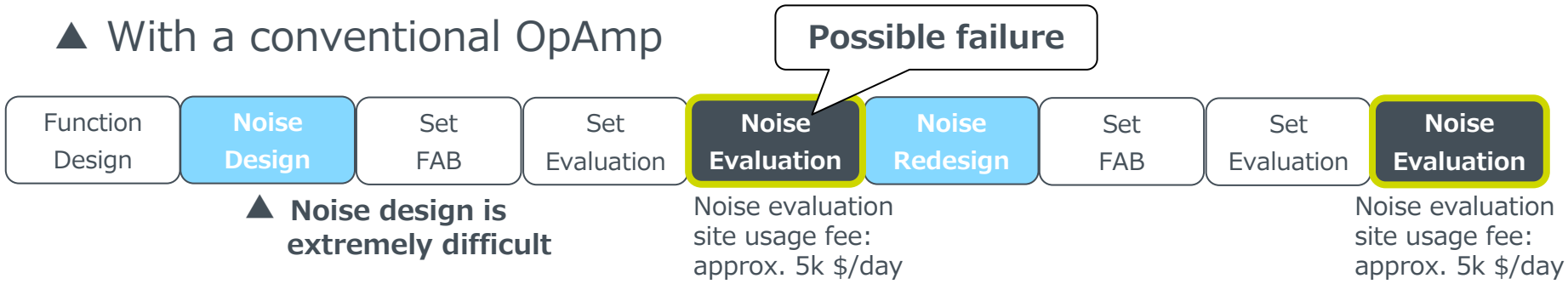
EMARMOUR OPAMP



Advantage of using High EMI Immunity OPAMP

Process flow (each time) when designing a new model (board)

▲ With a conventional OpAmp



○ With ROHM's new OpAmp

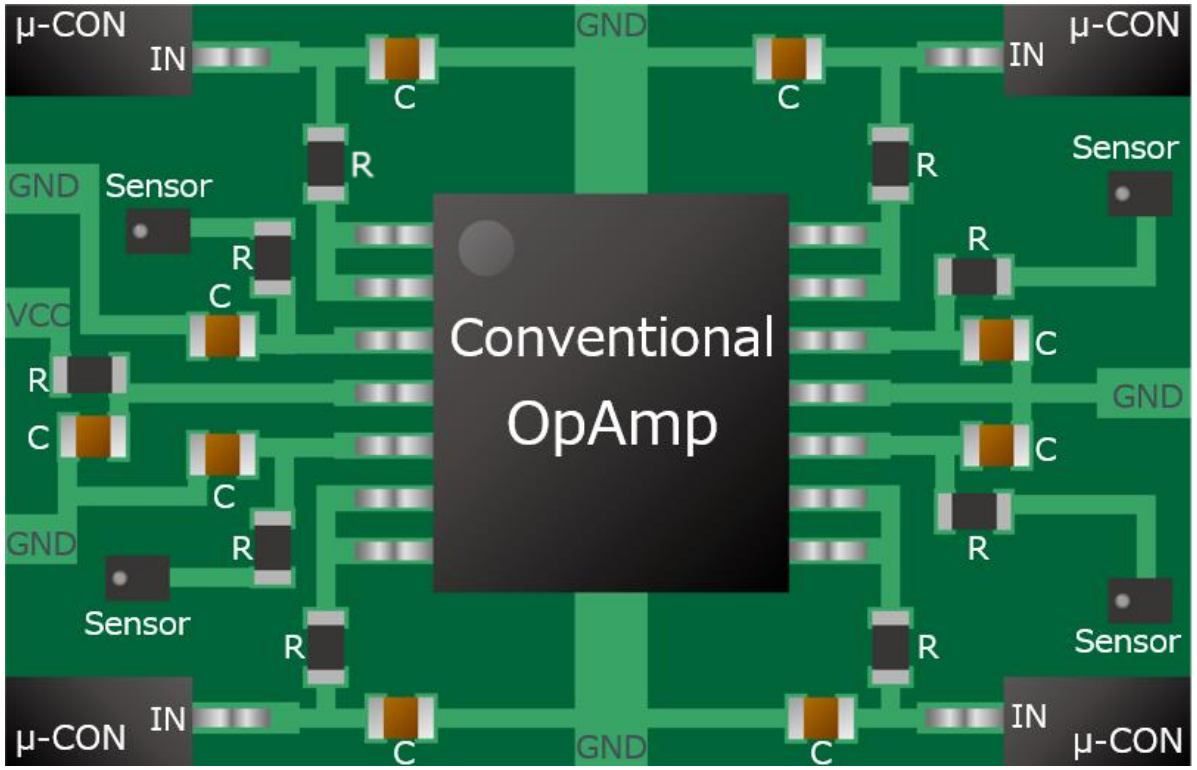
○ **Noise-tolerant design**

Noise-tolerant design reduces design load and cost

→ Enables quick response to meet short delivery times

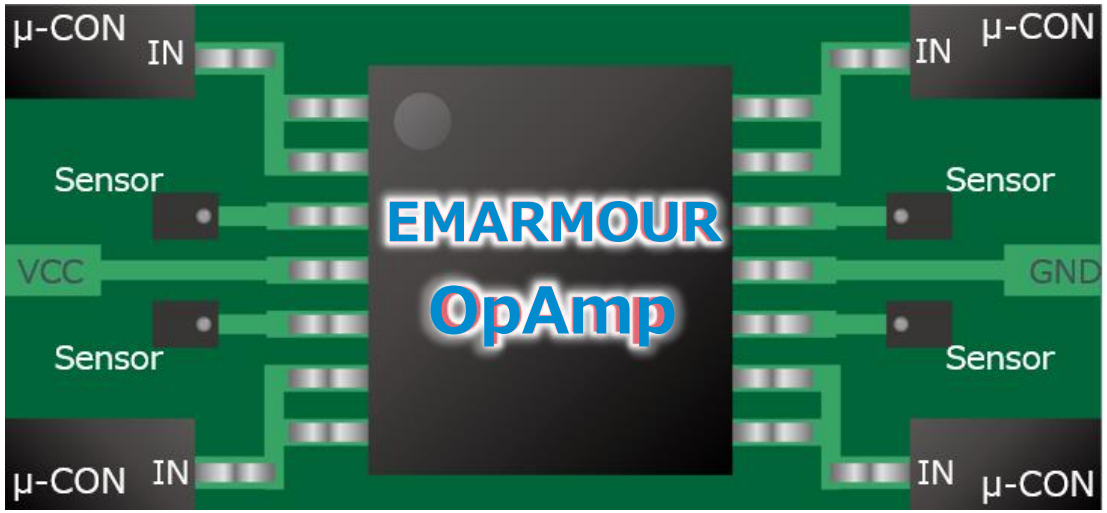
Advantage of using High EMI Immunity OPAMP

Conventional Op Amp



RC filters are added to the input and output to minimize external noise

ROHM's High EMI Immunity Op Amp



Eliminates up to 18 parts

Using a high noise immunity opamp reduces the number of noise suppression components.

※Reduced efficiency depends on the tolerance of the noise effects in the set.

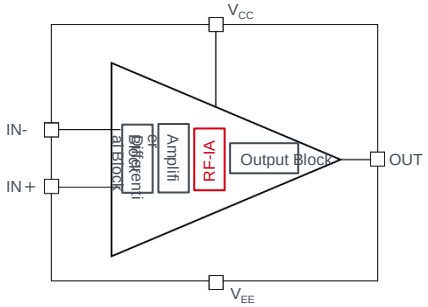
Noise Resistance Achieved Through Integrated Technology Development

Greatly improves noise immunity by conducting a thorough review of circuits, layout, element size, and other factors

Fundamentally analyzing noise immunity from all angles, reviewing noise suppression circuit design and layout, and developing optimal processes allowed ROHM to dramatically improve EMI immunity.

Circuit Review

Noise tolerance is improved by incorporating newly developed noise countermeasure circuits (RF-IA) in specific locations.

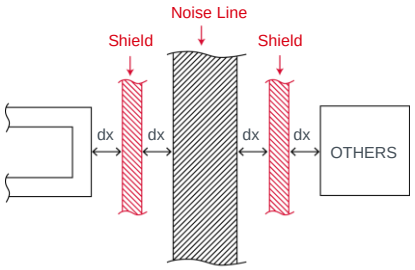


Newly developed noise countermeasure circuits (RF-IA) added

※RF-IA (Radio Frequency Impedance Adjuster)
High Frequency Impedance Adjustment Function

Layout Review

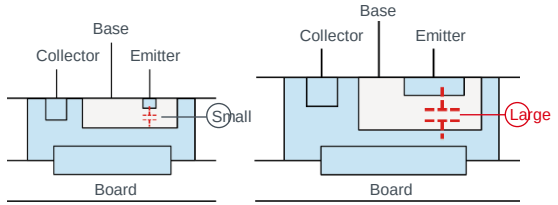
In addition to reviewing wiring interference, shields were placed in the noise line and the impedance of the internal analog core adjusted.



① Noise Line Shield
② Review of Wiring Interference
③ Impedance Adjustment of Internal Analog Core

Utilizing Optimized Processes

Focusing on high noise immunity when the parasitic capacitance is large makes it possible to select the process and element size that will result in the ideal parasitic capacitance.



The parasitic capacitance will differ based on process and element size. Processes that yielded the ideal parasitic capacitance were selected.

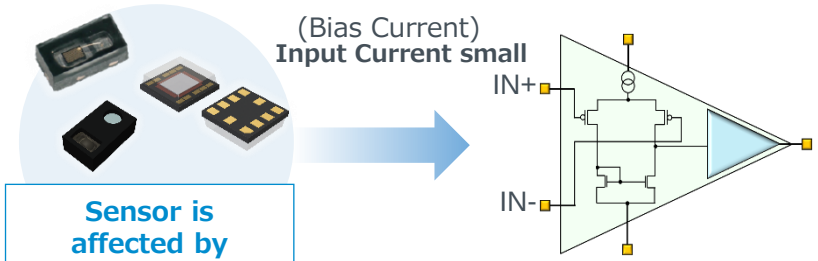
EMC noise immunity improves when the above three are completely aligned.

EMARMOUR™OPAMP/COMP Line Up

Element Structure		Part No	Function	Max Operating Voltage	External Noise Immunity	Bias Current	Slew Rate
Bipolar	MP	BA82904Yx	2ch OPAMP	36V	◎	20nA	0.2V/μs
	MP	BA82902Yx	4ch OPAMP				
	MP	BA82903Yx	2ch COMP				-
	MP	BA82901Yx	4ch COMP				
CMOS	NEW	BD87581YG-C	1ch OPAMP	14V		0.001nA	3.5V/μs
	NEW	BD87582YFVM-C	2ch OPAMP				
	NEW	BD87584YFV-C	4ch OPAMP				

High Speed

In the case of a CMOS structure, the bias current is small and does not affect the sensor.



Bias Current : Current flowing to the input of the operational amplifier.
Slew Rate : Output rise time per unit time.

EMARMOUR™ Op Amp Development Concept

To prevent op amps from malfunctioning due to noise without taking special measures in applications, ROHM not only supports general DPI, but also conducts tests at the device level normally performed by electronic device manufacturers.

Overview of Noise Evaluation Tests

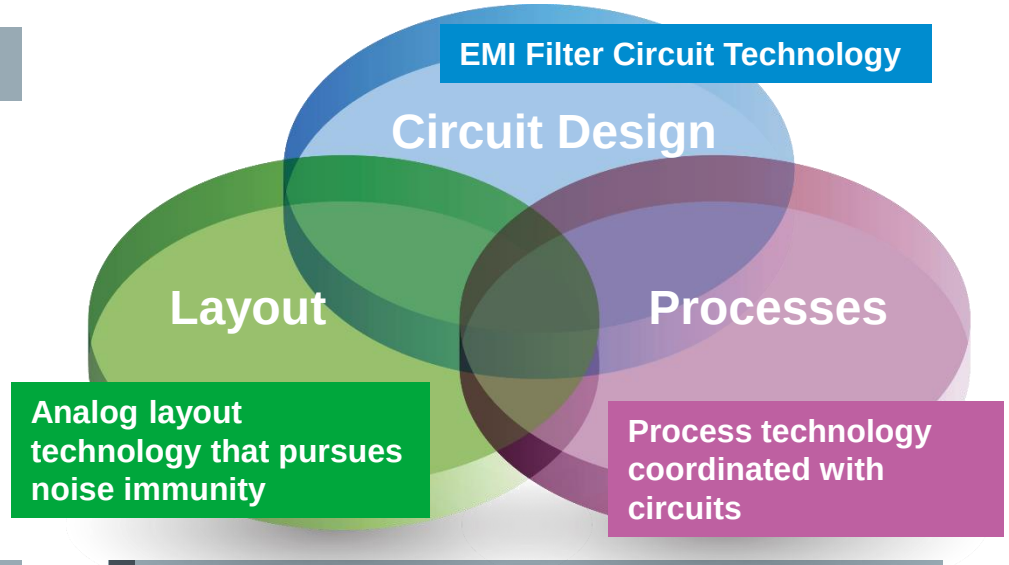
	Standard High EMI Immunity Op Amp	ROHM's EMARMOUR™ High EMI Immunity Op Amp	Overview of Noise Evaluation Tests
Approach to Noise	Noise suppression in applications is handled by electronics manufacturers	**Designed to prevent malfunctions without taking special measures in applications**	—
Radio Emission Test ISO 11452-2	—	○	Testing is commonly carried out by electronics manufacturers. Cannot be prevented by input filters due to electromagnetic radiation from the antenna.
BCI Test ISO 11452-4	—	○	A test in which noise is applied to the wiring harness connected to an electronic device using a current injection probe. The immunity of electronic devices is evaluated when excited by strong magnetic field noise.
Proximity Immunity Test ISO 11452-9	—	○	Testing has increased due to the proliferation of cell phones. Cannot be prevented by input filters due to electromagnetic radiation from the antenna.
DPI Test IEC 62132-4	△ Resistant to noise only in specific frequency bands due to filter measures	○	A test in which noise signals are directly applied to a semiconductor terminal. Countermeasures are relatively easy, such as installing a filter at the input terminal in advance.

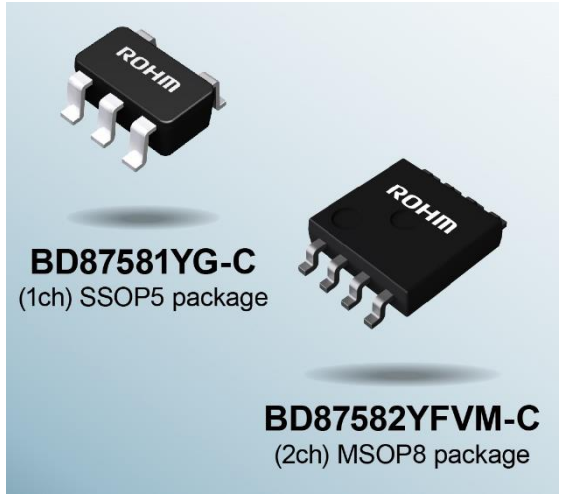
ROHM EMC Site

Rail to Rail Input - Output High Speed CMOS Op Amps「BD8758xYx-C」

Features

- **Ultra high EMI immunity**
- Rail to Rail Input - Output
- CMOS structure
- AEC-Q100 qualified
- Compatible with universal op amp
- **High-precision simulation model**





Key specification

- Supply voltage: 4.0V to 14V

- Rail to Rail Input-Output -

- Input voltage: VSS to VDD
- Output voltage: VSS+0.03 to VDD-0.05

- CMOS structure -

- Input bias current: 0.001nA
- Slew Rate: 3.5V/μs
- Temp: −40°C to +125°C

Line up

Part No.	Channel	Package
BD87581YG-C	1ch	SSOP5
BD87582YFVM-C	2ch	MSOP8

Supply status

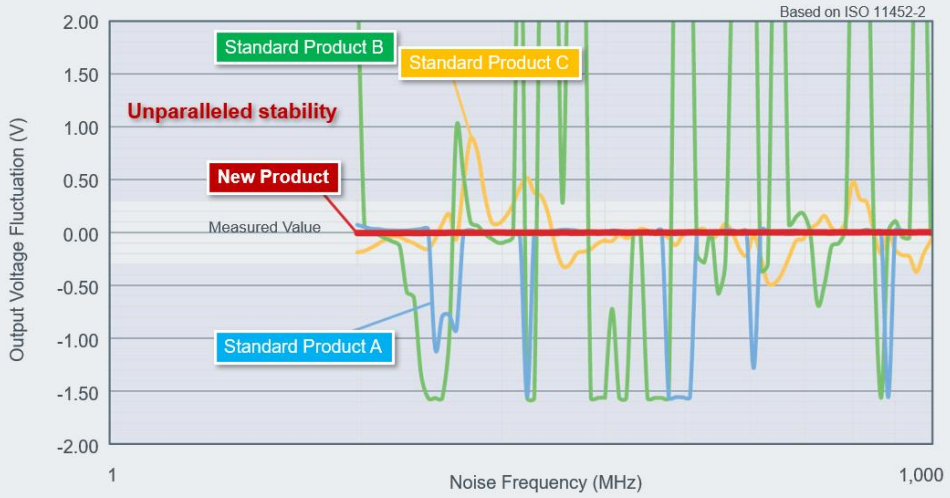
- MP: May 2021 ~
- Price: 300 yen/pcs (Excluding Tax)

Applications

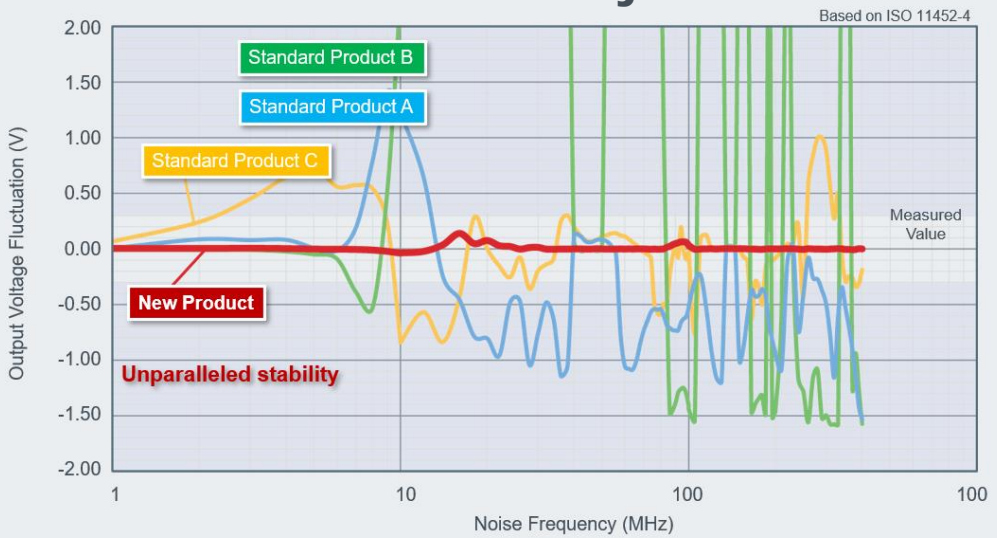
- Automotive: EV / HEV inverter, Engine Control Unit, Car GPS, eCall(emergency-Call system), Car A/C
- Industrial: FA, Measuring equipment, Servo system, Sensor system can be used in all in-vehicle and industrial with electronic circuits that are concerned about noise immunity

Features 1
Overwhelming noise immunity was achieved in four international noise test.

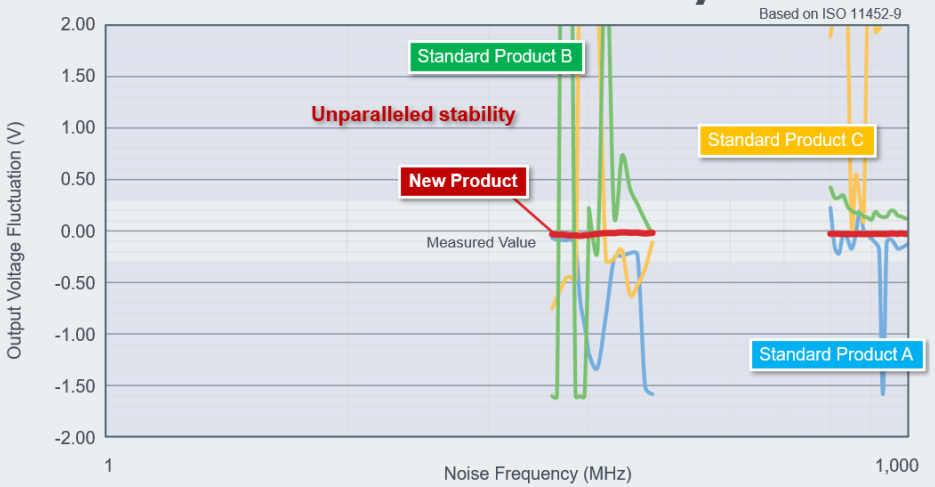
Radio Wave Emission Test



Bulk Current Injection

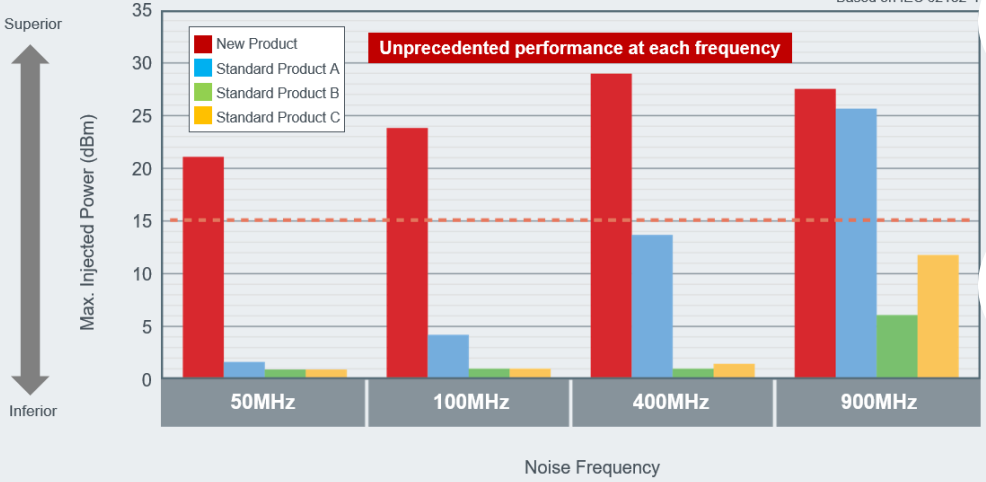


Near Field Immunity Test



DPI Test

*Output voltage fluctuation is less than 300mV
Indicates the max. injected power value
Based on IEC 62132-4

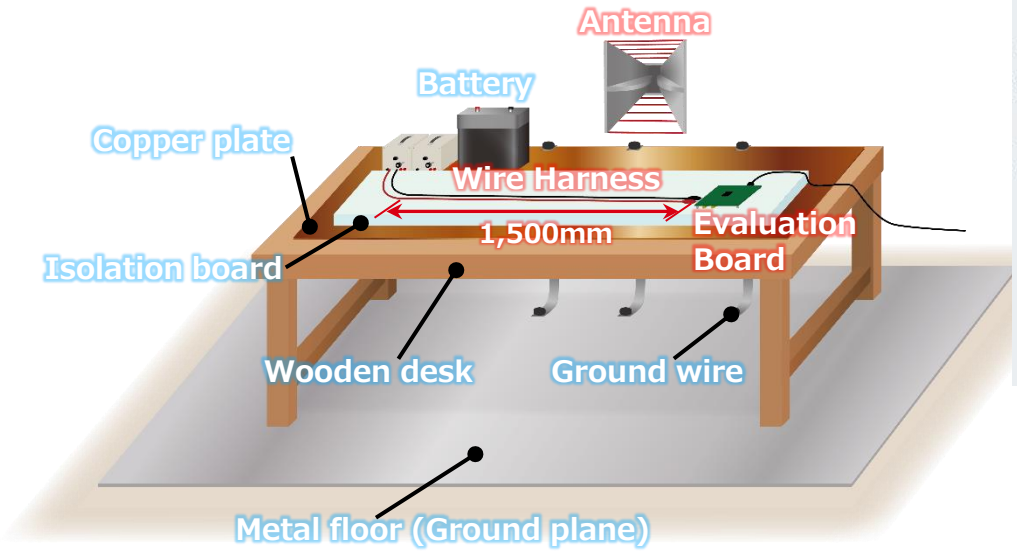


Easy Noise Design

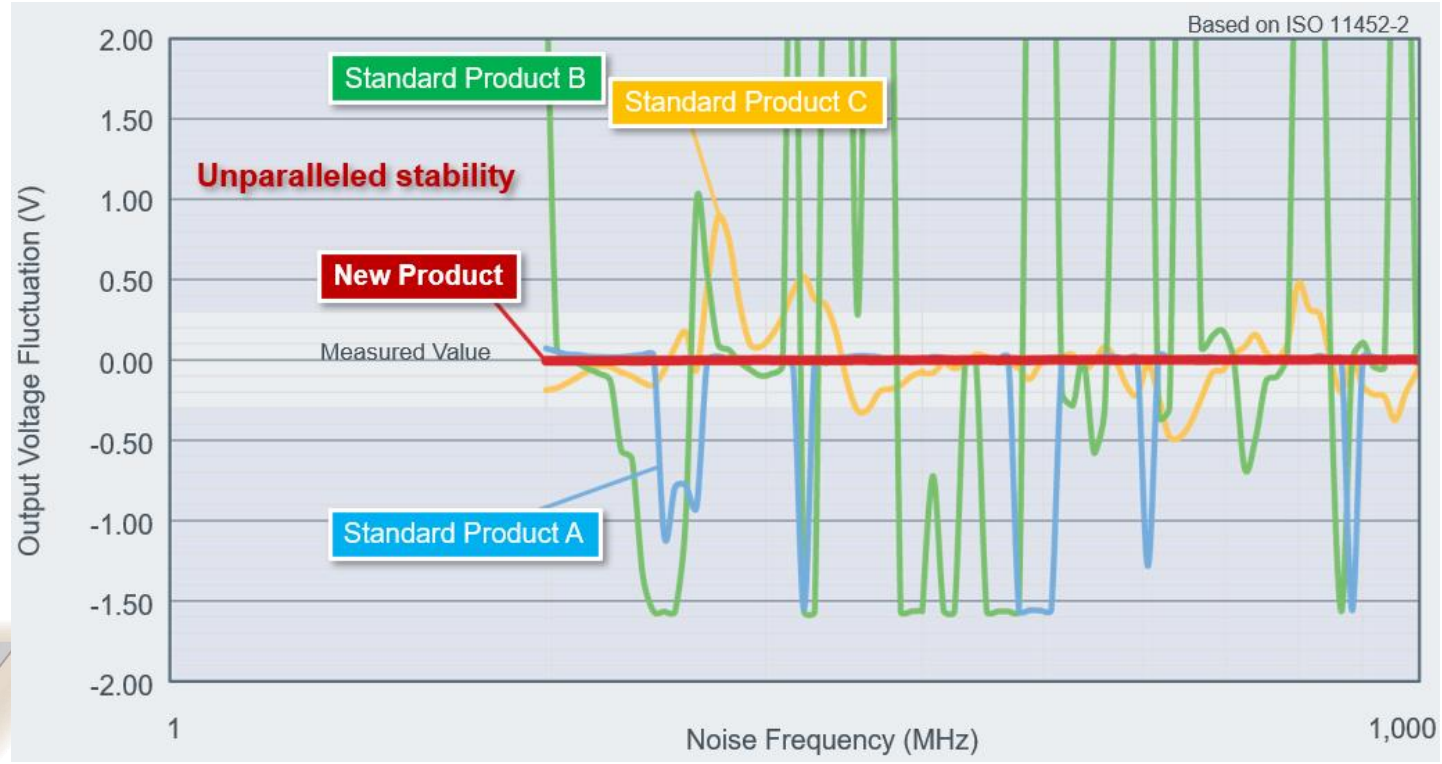
CR parts 10pcs reduction

Features1:
Radio Wave Emission Test

<Test Conditions> ISO 11452-2 Standard
Measurement Circuit: Voltage Follower
Temp: Ambient
Test Method: Replacement (Travelling Wave)
Electric Field Strength: 200V/m
Test Wave: CW (Continuous Wave)
Frequency: 200MHz-1GHz (2%STEP)

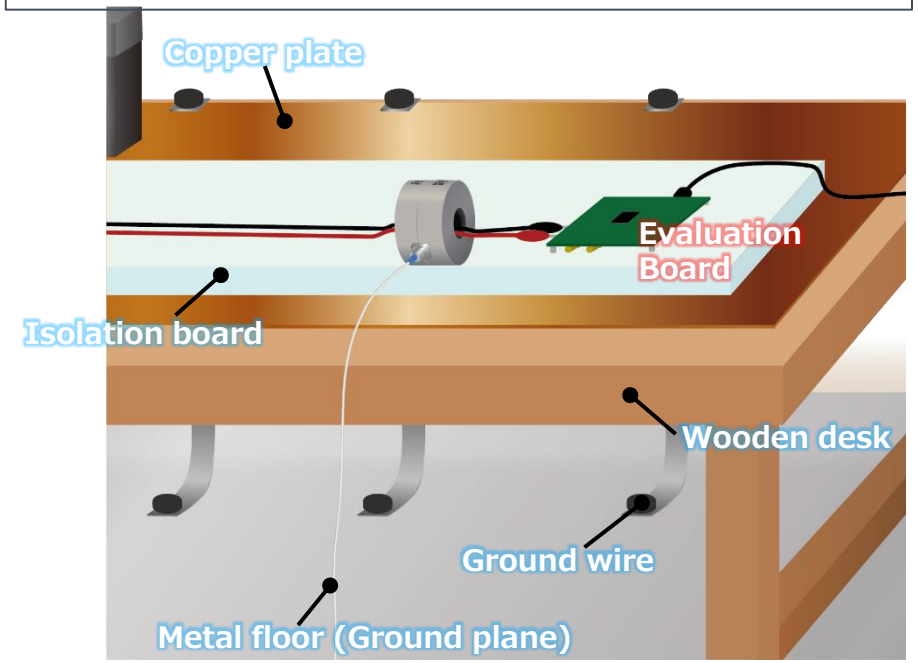


Frequency vs Output Voltage is plotted.

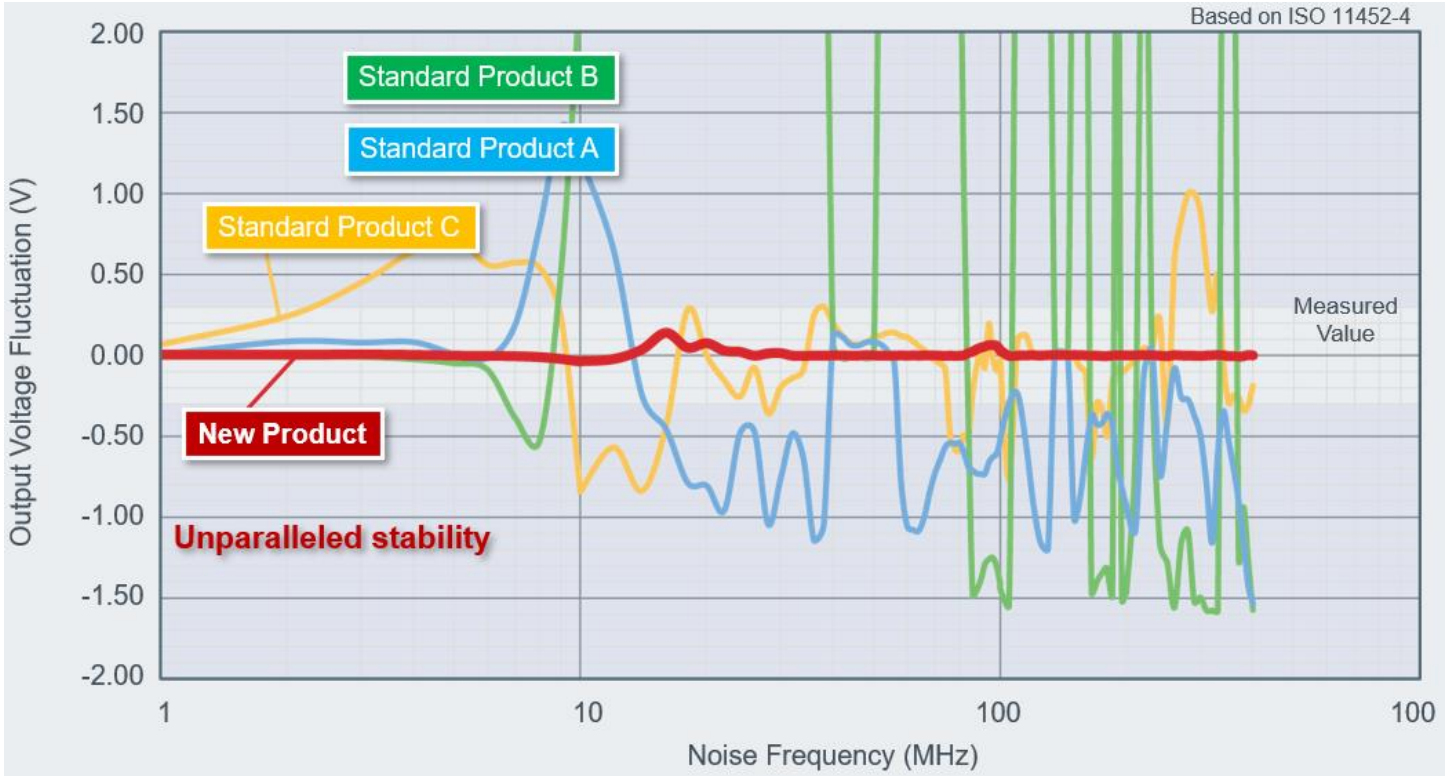


Feature 1
Bulk Current Injection Test

<Test Conditions> ISO 11452-4 Standard
Measurement Circuit: Voltage Follower
Temp: Ambient
Test Wave: CW(Continuous Wave)
Test Power: 200mA
Frequency:1-10MHz(1MHz STEP)
10-100MHz(2MHz STEP)
100-200MHz(5MHz STEP)
200-400MHz(10MHz STEP)

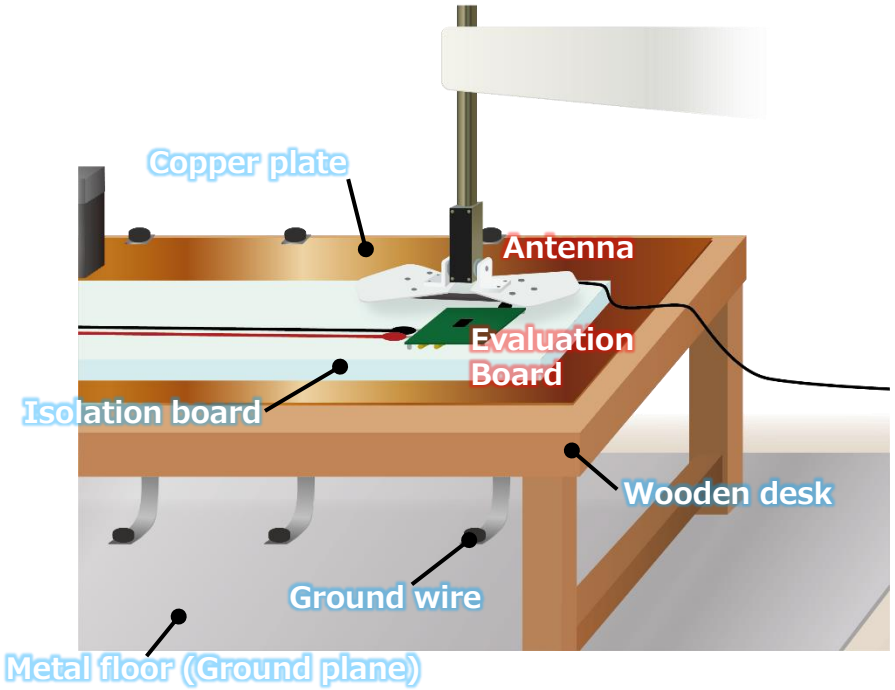


Frequency vs Output Voltage is plotted.

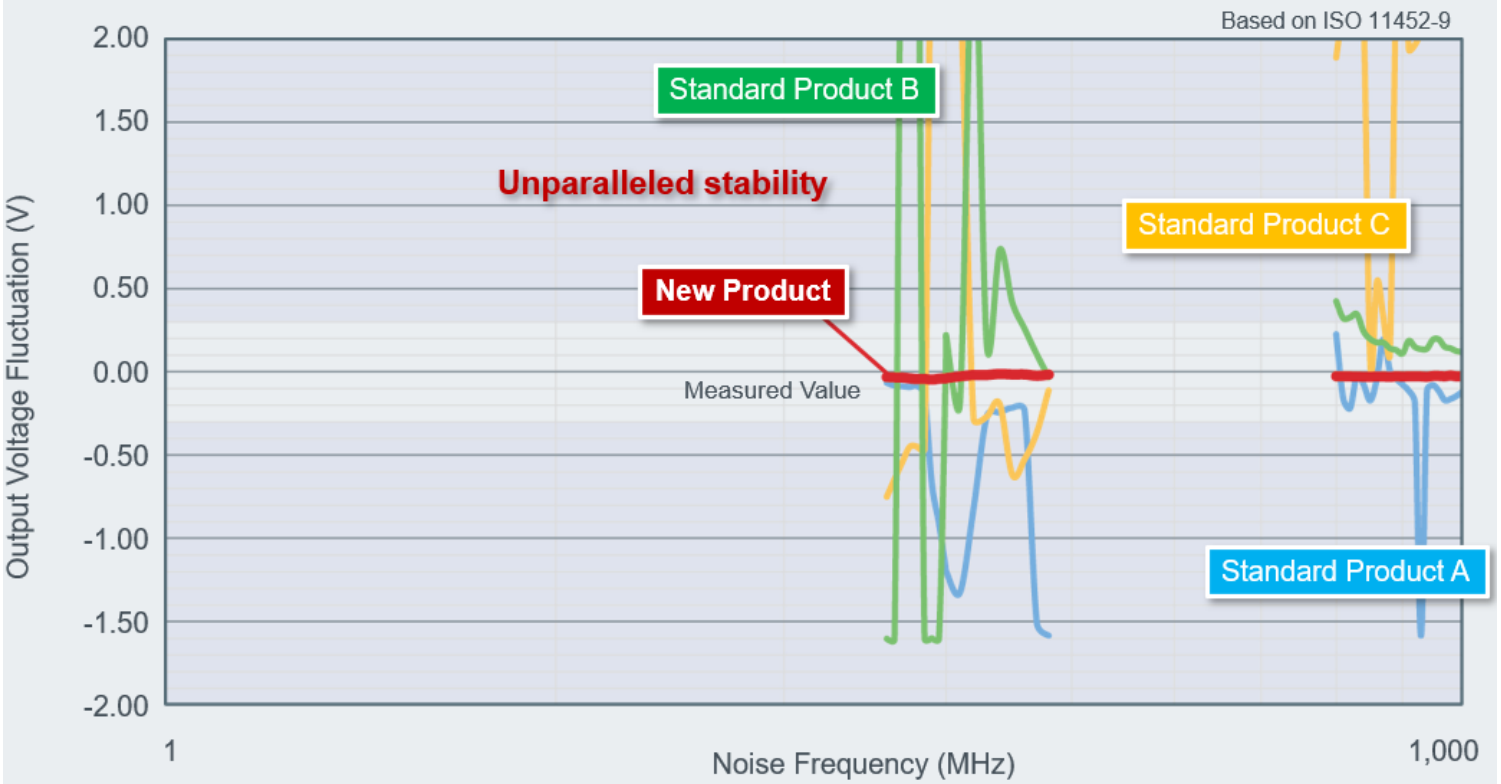


Feature 1
Near Field Immunity Test

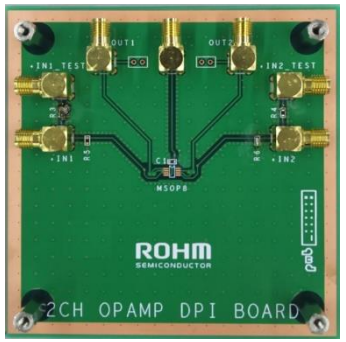
<Test Conditions> ISO 11452-9 Standard
Measurement Circuit: Voltage Follower
Temp: Ambient
Test Power: 9W(360-480MHz)
14W(800-1000MHz)
Test Wave: CW(Continuous Wave)
Frequency: 360-480MHz(5MHz STEP)
800-1000MHz(10MHz STEP)



Frequency vs Output Voltage is plotted.

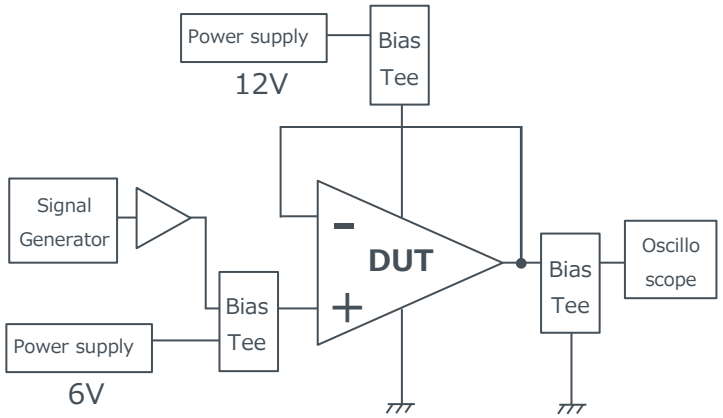


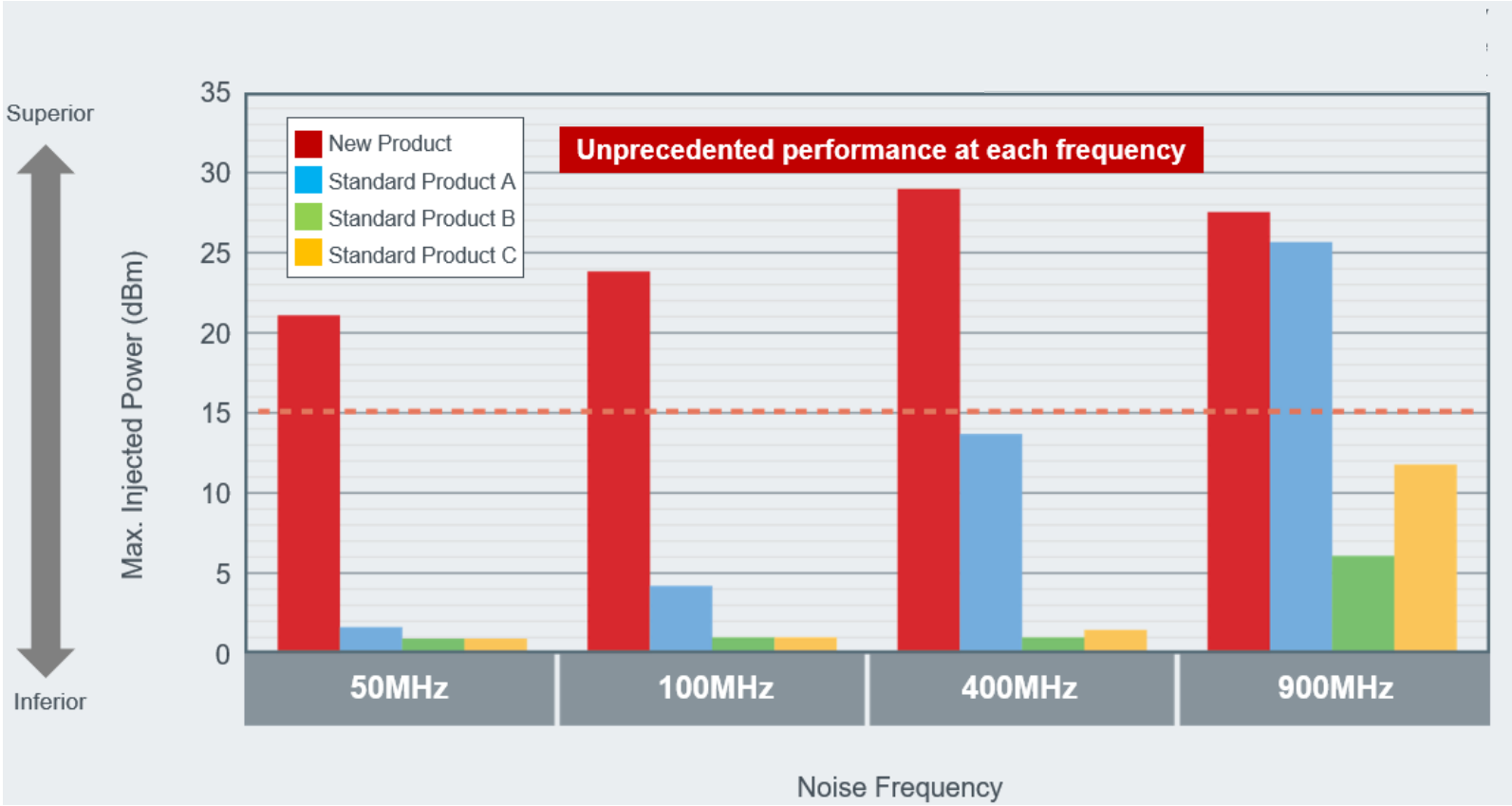
Output voltage fluctuation is less than 300mV Indicates the max. injected power value Based on IEC 62132-4



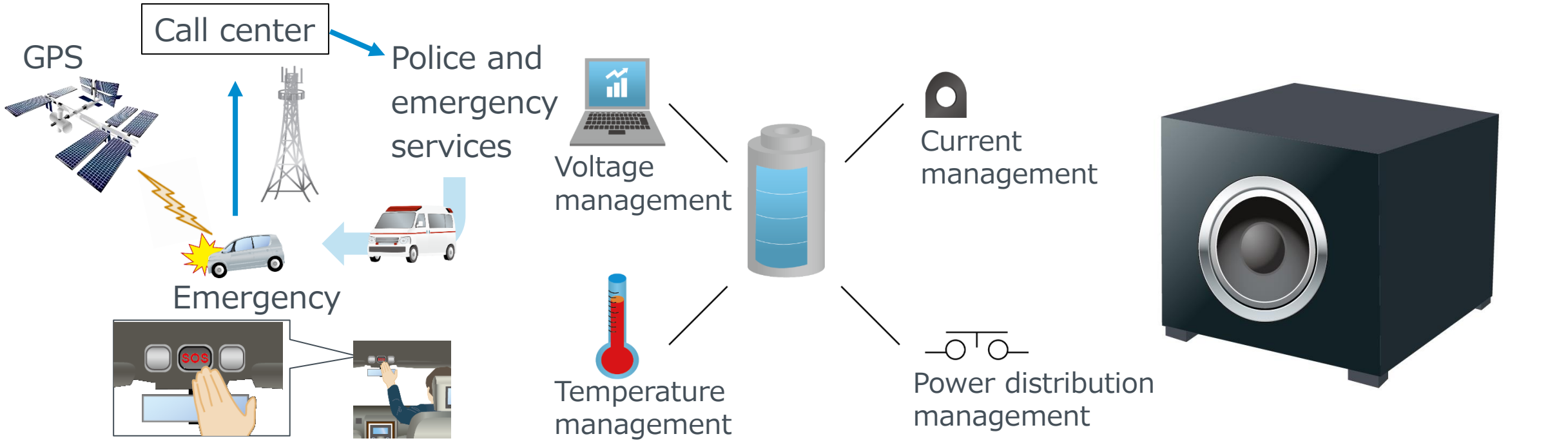
＊VCC, IN wiring : 50Ω Impedance

Measurement Circuit





Success stories



Application : eCall

Application : BMS
(Battery management system)

Application : Subwooder

<Customer request>
OPAMP not affected by external noise

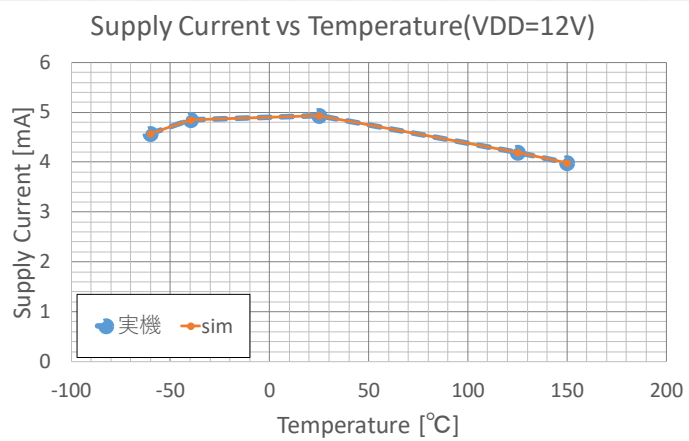
EMARMOUR™ technology
High EMI immunity

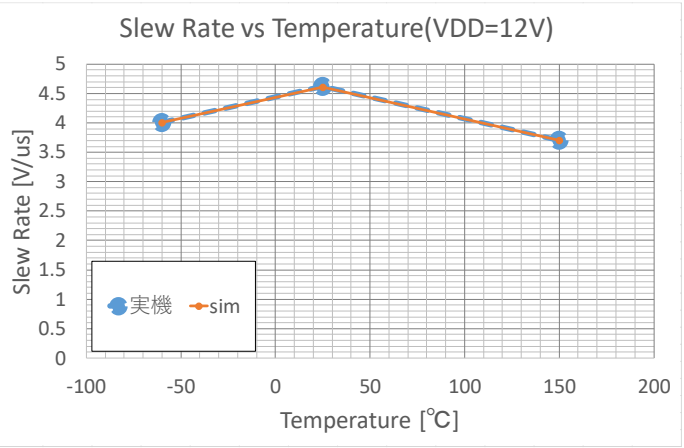
ROHM Real Model Simulations Carry out Realistic Reproduction of All Performance Characteristics (Including Temperature) For model-based design

	Op Amp SPICE Models				
Category	Characteristics	ROHM	Co. A	Co. B	Co. C
DC	Zero Input Current	○	○	○	○
	Circuit Current	○	○	○	○
	Short-Circuit Output Current	○	○	○	○
	Max. and Min. Output Voltage Amplitudes	○	○	○	○
	Input Bias Current	○		○	○
	Common Mode Supply Voltage Removal Ratio	○		○	
	DC Output Resistance	○	○	○	
	Rail-to-Rail	○	○	○	○
	Source/Sink Output Current Limit	○	○	○	○
	Input Offset Voltage	○	○	○	○
	Input Capacitance	○		○	○
	Supply Voltage Dependence	○			
	Temperature Characteristics	○			
AC	Slew Rate	○	○		
	Unity Gain Frequency	○	○	○	○
	1-Pole or 2-Pole Amp Gain/Phase	○	○	○	○
	Common Mode Supply Voltage Removal Ratio	○		○	
	AC Output Resistance	○	○		
	Phase Margin (Oscillation Margin)	○	△	△	△

ROHM high EMI immunity CMOS Rail-to-Rail op amps are offered with original Model-Base designed SPICE models that allow the actual ICs to operate according to user simulation designs.

Reproduce phase margins with high accuracy





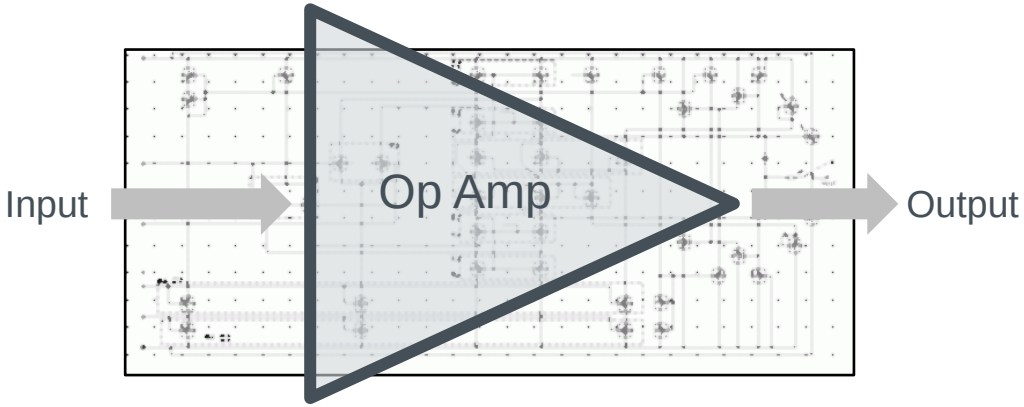
Completely reproduce temperature characteristics

[ROHM Real Model] Modeling Technology

ROHM Real Model is ROHM"s proprietary modeling technology that achieves high characteristics reproducibility by designing and recombining the characteristics of the entire transistor circuit for each function.

Conventional Modeling Technology

Element-Based Modeling

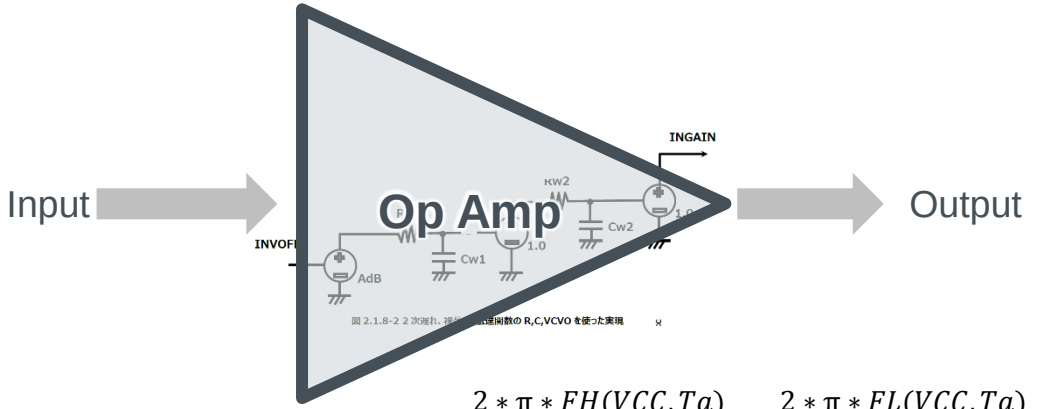


Since the characteristics of each element are modeled and connected together, it is difficult to match all characteristics (including parasitic elements) with the actual device

Simulation results do not match the actual device

ROHM Real Model

Formula-Based Modeling



$$G(s) = AdB(VCC,Ta)\frac{2*\pi*FH(VCC,Ta)}{s+2*\pi*FH(VCC,Ta)}\frac{2*\pi*FL(VCC,Ta)}{s+2*\pi*FL(VCC,Ta)}$$

Relationship between input and output is mathematically formulated (modeled) the based on actual evaluation results

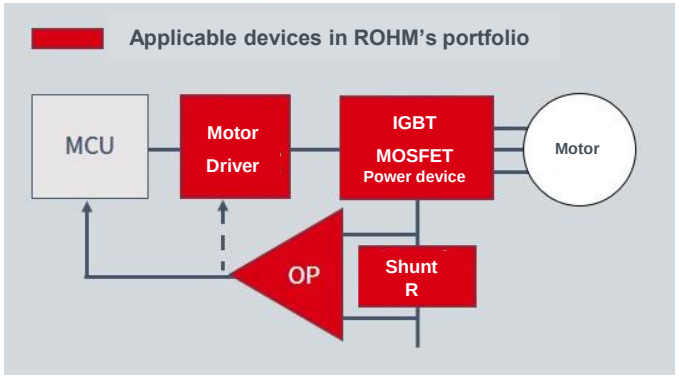
Simulation matches the actual device

High performance Op Amp + Shunt resistor solution

Target applications for GMR, PSR series

- Automotive
  (ECUs, Motors, OBC, e-Comp, Heater, BMS etc.)
- Industrial (Inverter, Pump)
- Energy (PV inverter, Energy storage. Power supply)
- White goods (Air conditioner, Refrigerator etc.)

Total solution example



Proposal examples by application

Detection	Application	Usage	Current range	Op Amps	Shunt resistors	R value (mohm)
High precision	EPS	Motor control	100A	LMR1802 TLRx376Yxxx series	PSR100	0.5 / 1
	Inverter for EV bike	Motor control	50-100A		PSR100 PSR400	0.3
	E-compressor	Motor control	30-50A		PSR100 PMR100	0.5 / 1 / 2
	Engine ECU	Fuel injection	5-10A	BD8758xY series TLRx377Yxxx series	GMR50 GMR100	20 – 30
High Speed	On board charger	Over current protection (PFC)	30-40A	BA8347xYxxx series BD8758xYxxx series	PSR100 PMR100	1 / 2
	Industrial inverter	Over current protection	50-60A		PSR100 PMR100	0.5 / 1 / 2
	White goods	Motor control	20-30A		PMR50 GMR50	1 – 5

Future

ROHM has contributed to high reliability and high accuracy of the system by improving noise performance

- Ultra-high EMI immunity EMARMOUR series line-up expansion
- Low noise OPAMP

Make it easier to use by improving basic performance

- Low current consumption
- Low input offset voltage
- High speed

Amplifies all sensor signals with high reliability and high accuracy