

EU079

Master Actuator for Automatic Home or Building HVAC System

September 2020



Automatic Home or Building HVAC System Platform

Master Actuator Unit¹

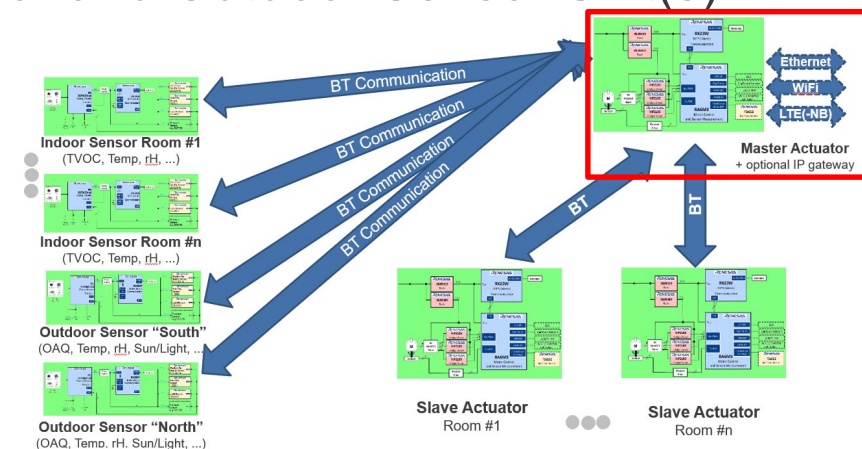
Please see EU076 for problem definition with existing / retrofit buildings, complete solution proposal and benefits.

This is the **Master Actuator Unit** as part of the proposed platform concept:

- determines the optimum time, duration and air flow amount and direction out of the sensor data
- includes HVAC / BLDC fan control
- Bluetooth Mesh communication to Slave Actuator Unit(s), Indoor and Outdoor Sensor Unit(s)
- further improvement by using eAI instead of fixed algorithms

Overall goals:

- achieve optimum air quality in all rooms
- avoid mold
- improve energy efficiency
- improve user experience and comfortability



NOTE ¹: Renesas does not have any plans to provide *end products* to the market; you, our *customers* are the experts in developing and providing such and Renesas does not claim to have the competency to do. Hence, this is just a proposal for a *potential* realization.

EU079



Master Actuator for Automatic Home or Building HVAC System

■ Overview

The master actuator unit(s) is the brain of the system. It fulfils all the functions of a [slave actuator unit](#) and includes other capabilities, such as:

- Collection of all sensors data from indoor sensor unit(s), outdoor sensor unit(s) and slave actuator unit(s)
- Additional weather information may be collected from the internet, if an IP gateway is implemented in the master actuator or separately (see IP Gateway for Automatic Home or Building HVAC System [Automatic Home or Building HVAC System, EU081](#))
- Calculation/Determination of the set points for each slave actuator unit, like flow direction (in/out), temperature, etc., using an algorithm or the latest embedded artificial intelligence (AI) technology
- Provision of the set points for each slave actuator and the master itself
- Local (graphical) GUI of the whole system, which may also be mirrored by a Bluetooth® or web interface
- Real-time clock (RTC) and its distribution to sensor/actuator units for different operation modes, depending on the day, time, holiday, etc.

From a system perspective, the master and slave actuator can have the same hardware and software. In this case, the master is a role rather than a certain device and it would not represent a single-point-of-failure, as another slave actuator could take over the master role in case the original master fails. However, there must be only one master, per system, at a time.

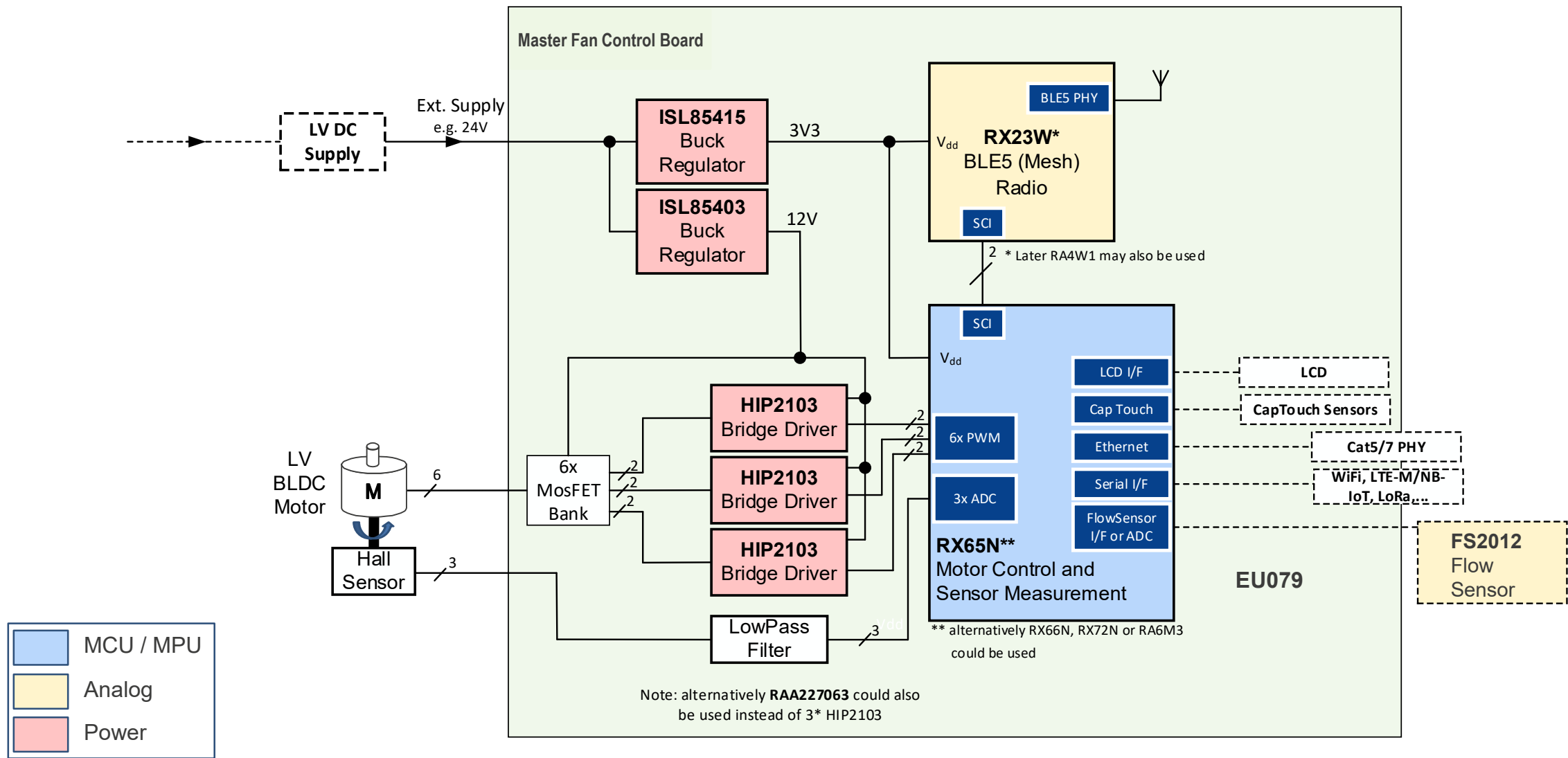
■ System Benefits

- The RX23W MCU enables Bluetooth 5 mesh communication
- The master actuator can (but does not need to) have an integrated gateway to the intranet/internet using a secure communication mechanism like HTTPS or MQTT, if not achieved externally (see IP Gateway for [Automatic Home or Building HVAC System, EU081](#)). For these cases, one or multiple of the following technologies are available:
 - Wi-Fi (based on IEEE 802.11), Thread or Zigbee (based on IEEE 802.15.4), Ethernet (based on IEEE 802.3), LTE-M/-NB (depending on geographical region and available providers), or LoRaWAN

*Note: For the power supply, the mains will usually be needed for the fan/HVAC (e.g. 230V_{ac} or 110V_{ac}; or 24V_{dc} from the building control system).



Master Actuator for Automatic Home or Building HVAC System

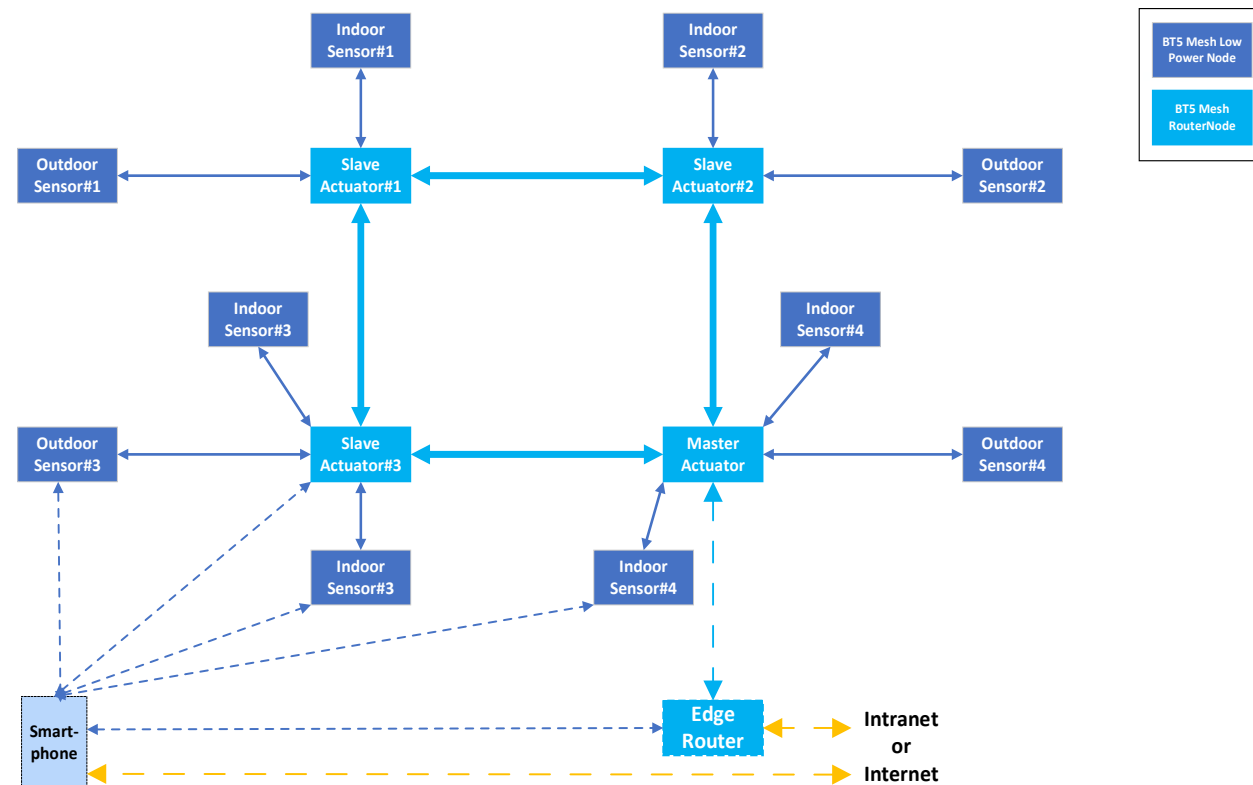




Automatic Home or Building HVAC System Platform

Major advantages of Bluetooth 5 Mesh

- secure communication (Diffie-Hellmann Key Exchange, AES128 etc.)
- bidirectional packet data flow
- low power (can go down to μA average while being connected)
- no need for additional wiring
- automatic routing (with no setup for the routing itself)
- scalability of speed vs. range:
 - for four times range or
 - double speed option depending on location.



EU079



Master Actuator for Automatic Home or Building HVAC System

Device Category	P/N	Key Features
MCU	RX23W	Bluetooth 5.0 MCU w/ RX v2 core and BT Mesh functionality
	RX65N	MCU with RX v2 core for communication
	HIP2103	Half-Bridge Driver 60V, 1A/2A peak
	FS2012	Calibrated Gas Flow Sensor Module
Power	ISL85415	3-36V in, 0.6-34V / 500mA out Buck Regulator
	ISL85403	3-36V in, 0.8-24V / 2.5A out Buck Regulator

RX23W – 32-bit MCU for Bluetooth 5.0 Low Energy

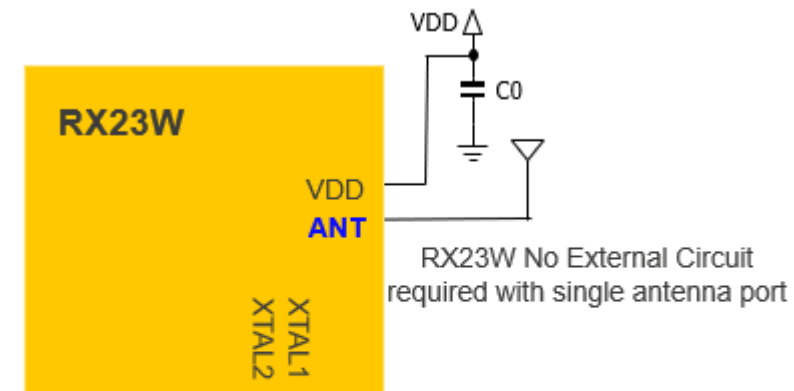
54 MHz RXv2 Core with FPU, Low Power Design, RTC and Encryption Functions

Support for Multiple Communication Functions

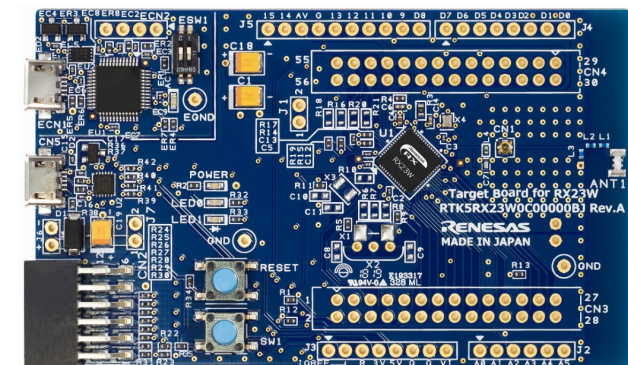
- Bluetooth Low Energy (1Channel)
- An RF transceiver and link layer compliant with the Bluetooth 5.0 Low Energy specification, also supports Bluetooth 4.2
- LE 1M PHY, LE 2M PHY, LE Coded PHY (125 kbps and 500 kbps), and LE Advertising extension support
- On-chip Bluetooth-dedicated AES-CCM (128-bit blocks) encryption circuit
- USB 2.0 host/function/On-The-Go (OTG) (one channel), full-speed = 12 Mbps, low-speed = 1.5 Mbps, isochronous transfer, and Battery Charger supported
- CAN (one channel) compliant to ISO11898-1: Transfer at up to 1 Mbps
- Including many others

High Performance and Low Power Design

- Operation from single 1.8 to 3.6V supply
- Up to 512KB Flash and 64KB RAM
- IEC60730 Compliant
- Capacitive Touch Sensing Unit: 12Keys (Self), 36 Keys (Mutual)
- Max. operating frequency: 54 MHz, Capable of 88.56 DMIPS in operation at 54 MHz
- Enhanced DSP and FPU modules
- RTC capable of operating on the battery backup power supply
- Security: 128- or 256-bit key length of AES for ECB, CBC, GCM, others. TRNG and Safe management of Keys.



Low Cost System Block



Target Board for RX23W – RTK5RX23W0C00000B

Part #	ROM (Kbytes)	RAM (Kbytes)	Security Functions	Package
R5F523W8ADNG#30	512	64	N/A	QFN/56/0.4
R5F523W7ADNG#30	384	64	N/A	QFN/56/0.4
R5F523W8BDNG#30	512	64	Available	QFN/56/0.4
R5F523W7BDNG#30	384	64	Available	QFN/56/0.4

RX65N – 120MHz RXv2 Core MCU

Large ROM/RAM, Enhanced Security, Connectivity and HMI

High Performance and Wide Product Lineup

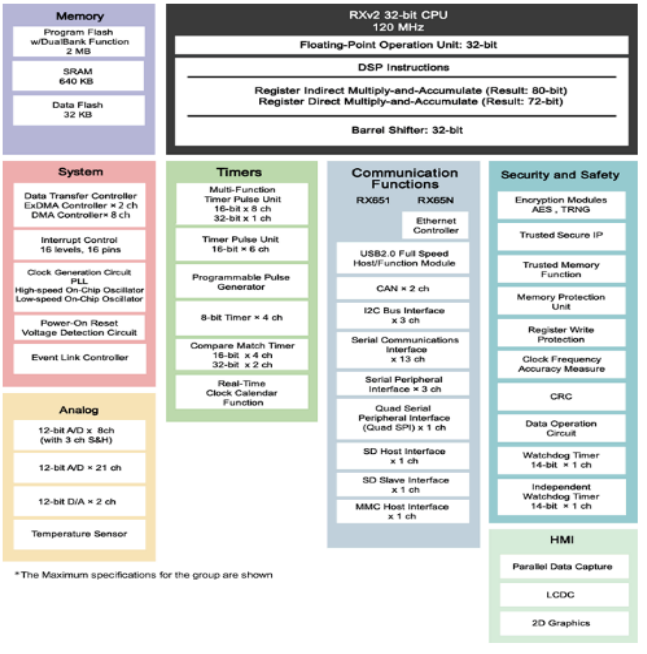
- RXv2 Core 120 MHz operation (34 CoreMark/ma), on-chip FPU
- Up to 2M ROM / 640K RAM, supportive of the dual bank function
- Wide package lineup : 64-pin (4.5mm x 4.5mm, BGA) to 176-pin

Rich Peripheral/Security Functions

- 16-bit TPUa, MTU3a, 8-bit TMRa (4ch), 16-bit CMT(4ch), 32-bit CMTW(2ch)
- 12-bit A/D (8 ch for unit 0, 21ch for unit 1), 12-bit D/A (2ch)
- DMACAa (8ch), DTCb (1ch), EXDMAC(2ch), DMAC for Ethernet controller(1ch)
- Various communication peripheral such as Ethernet, USB, CAN, SD host/slave interface, and quad SPI
- Security: AES, TRNG, TDES, RSA, SHA

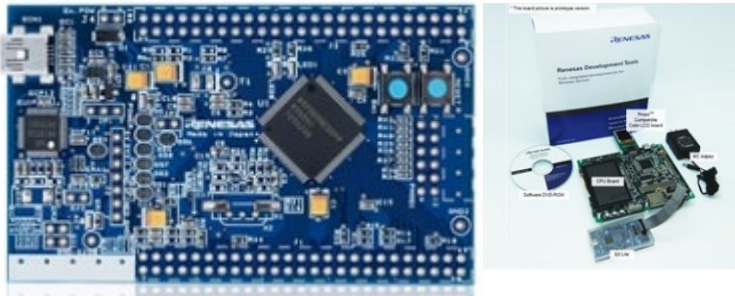
Low Power Design and Architecture

- Operation from a single 2.7- to 3.6-V supply
- Low power consumption: A product that support all peripheral functions draws only 0.19mA/MHz(Typ.)
- RTC is capable of operation from a dedicated power supply
- Four low-power modes



Part #	ROM	RAM	Data Flash	Package
R5F565N4xDxx	512K	256k	None	64-LFQFP,64-LFBGA,100-LFQFP,100-TFLGA, 144-LFQFP, 145-TFLGA
R5F565N7xDxx	768K	256K	None	64-LFQFP,64-LFBGA,100-LFQFP,100-TFLGA, 144-LFQFP, 145-TFLGA
R5F565N9xDxx	1M	256K	None	64-LFQFP,64-LFBGA,100-LFQFP,100-TFLGA, 144-LFQFP, 145-TFLGA
R5F565NCxDxx	1.5M	640K	32K	64-LFQFP,64-LFBGA,100-LFQFP,100-TFLGA, 144-LFQFP, 145-TFLGA,176-LFQFP,176-LPBFA,177-TFLGA
R5F565NExDxx	2M	640K	32K	64-LFQFP,64-LFBGA,100-LFQFP,100-TFLGA, 144-LFQFP, 145-TFLGA,176-LFQFP,176-LPBFA,177-TFLGA

System Block



Renesas Starter Kit for RX65N

HIP2103/4 – 60V, 1A/2A, Half-Bridge Driver

High Voltage Drivers for Industrial Motor Control

Optimized Half-Bridge Drivers

- Supports half bridge, full bridge configurations
- Enables DC and 3 phase BLDC motors

Independent High/Low Inputs

- Reduces connections to MCU and lowers cost
- Supports 3.3V and 5V signals

Sleep Mode

- Low quiescent current (5uA) with unique sleep mode
- Allows direct connection to battery without disconnect switch

Integrated LDO (HIP2104)

- Option with integrated 12V & 3.3V LDO (HIP2104)
- Provides bias to external MCU

Part #	UVLO	VCC Reg	VDD Reg	Package
HIP2103FRTAAZ-T	4.0V	N/A	N/A	8L 3x3 TDF
HIP2104FRTAAZ-T	4.0V	3.3V	12V	12L 4x4 DFN

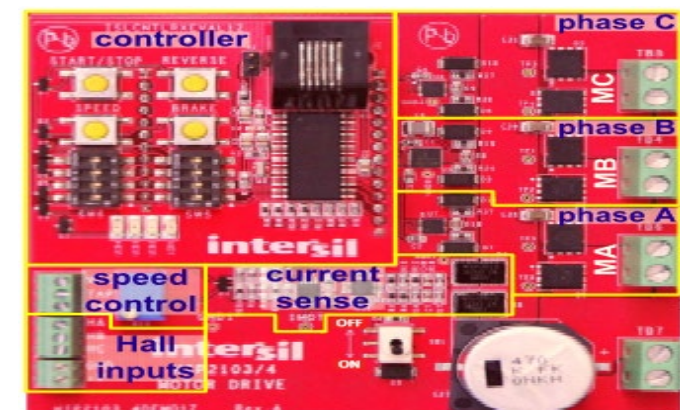
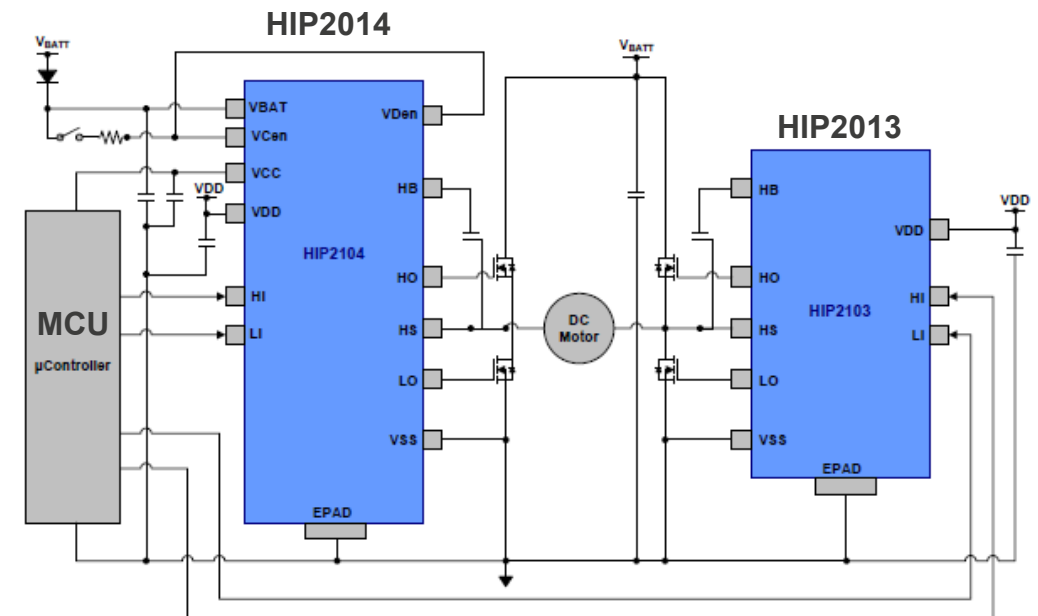


FIGURE 1. HIP2103-4DEMO1Z INPUTS AND OUTPUTS

FS2012 – High Performance Flow Sensor Module

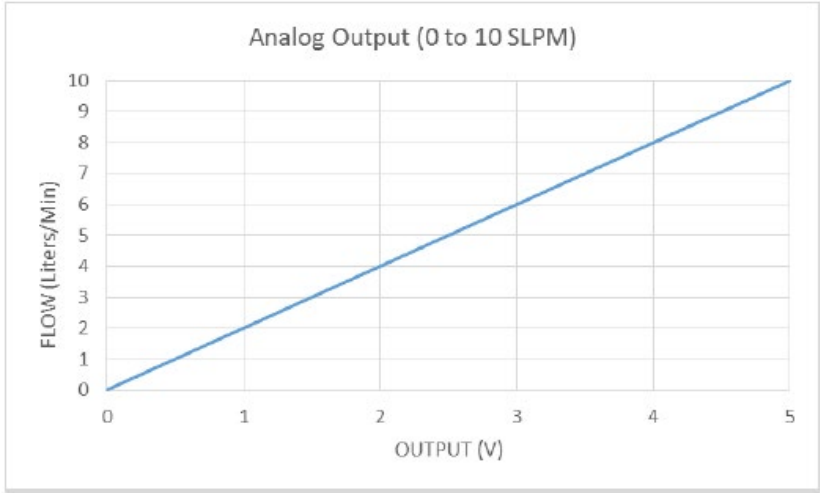
Applications for Process Controls, Oil and Gas Leak Detection, CPAP and Respirator Devices

High Accuracy and Fully Calibrated Output

- Accuracy error down to 2% of reading (typical)
- Full calibrated output

High Performance and Easy to Use

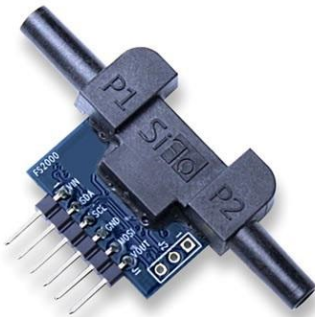
- Robust solid isolation technology
- Resistant to surface contamination
- No cavity to cause clogging
- Resistant to vibration and pressure shock
- Support analog output: 0V to 5V, digital output: I²C
- Supply voltage: 5V(Typ)
- Module operating temperature range: 0°C to +85°C



Analog Output Example

Part #	Parameter	Description
FS2012-1020-NG	Gas Flow	0 to 2 SLPM
FS2012-1100-NG	Gas Flow	0 to 10 SLPM
FS2012-1001-LQ	Liquid Flow	0 to 0.5(500) SLPM(SCCM)
FS2012-1002-LQ	Liquid Flow	0 to 1.0(1000) SLPM(SCCM)

SLPM: Standard liter per minute.
SCCM: Standard cubic centimeter per minute.



FS2012 Module (front)



ISL85415 – 0.5A Regulator with Integrated High Side FET

Support 3V-36V Input Voltage Range for Buck Output

Wide Working Range

- Power input voltage range from 3V to 36V
- The device provides an easy-to-use high-efficiency, low BOM-count solution for a variety of applications.
- Up to 0.5A load over full temperature range

High Efficiency and Performance (Low Board Space)

- Synchronous operation for high efficiency
- No compensation required
- Integrated High-side and Low-side NMOS devices
- Selectable PFM or forced PWM mode at light loads
- Internal fixed (500kHz) or adjustable switching frequency 300kHz to 2MHz

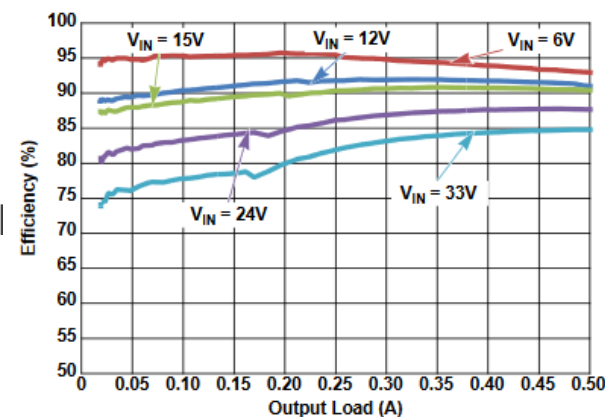
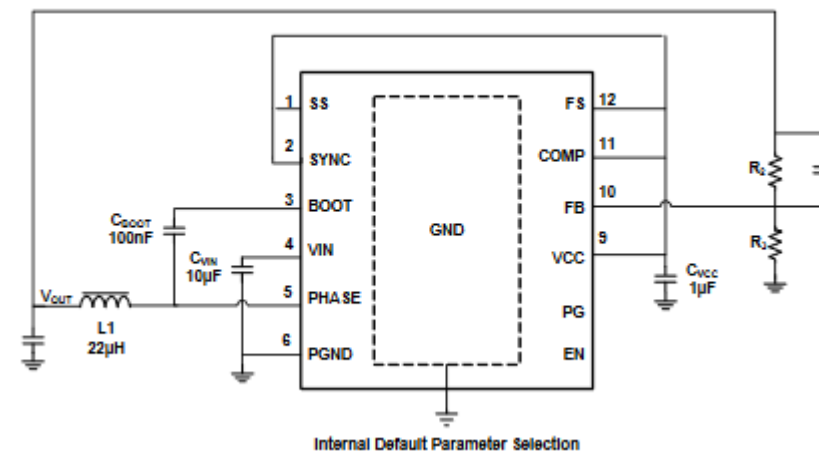


Figure 6. Efficiency vs Load, PFM, $V_{OUT} = 5V$

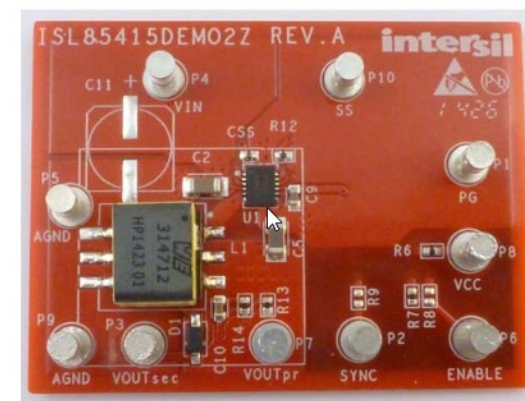


FIGURE 1. FRONT OF EVALUATION BOARD ISL85415DEMO2Z

Part #	V_{IN} Range(V)	Temp.(°C)	Package
ISL85415FRZ	3 to 36	-40 to 125	12 Ld DFN 4x3

ISL85403 – 2.5A Regulator with Integrated High Side FET

Support 3V-40V Input Voltage Range for Buck or Boost-Buck Output

Wide Working Range

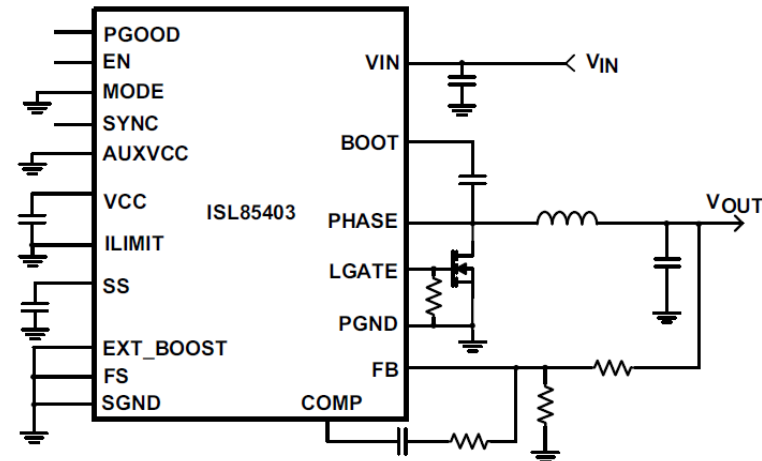
- Power input voltage range from 3V to 40V
- Support both step down (buck) or boost+buck outputs
- Up to 2.5A load over full temperature range

High Efficiency

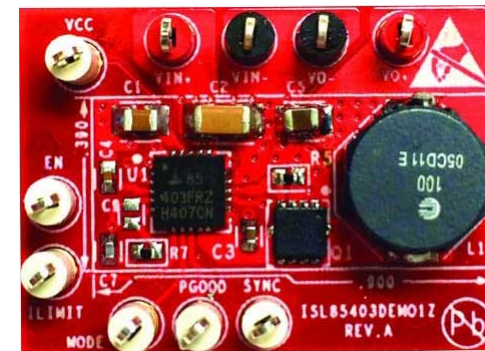
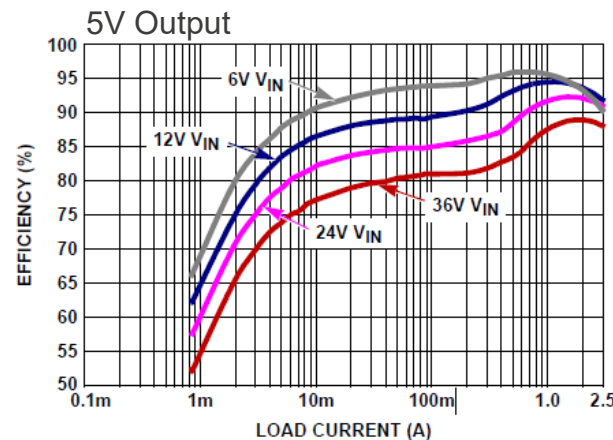
- Optional external low side FET for higher efficiency
- Selectable PWM / PFM modes
- 300uA input quiescent PFM mode current
- Less than 5uA shutdown current

High Performance

- 200KHz to 2.2MHz frequency range
- +/- 1% voltage regulation accuracy



Typical Application Circuit



ISL85403EVAL1Z Evaluation Board

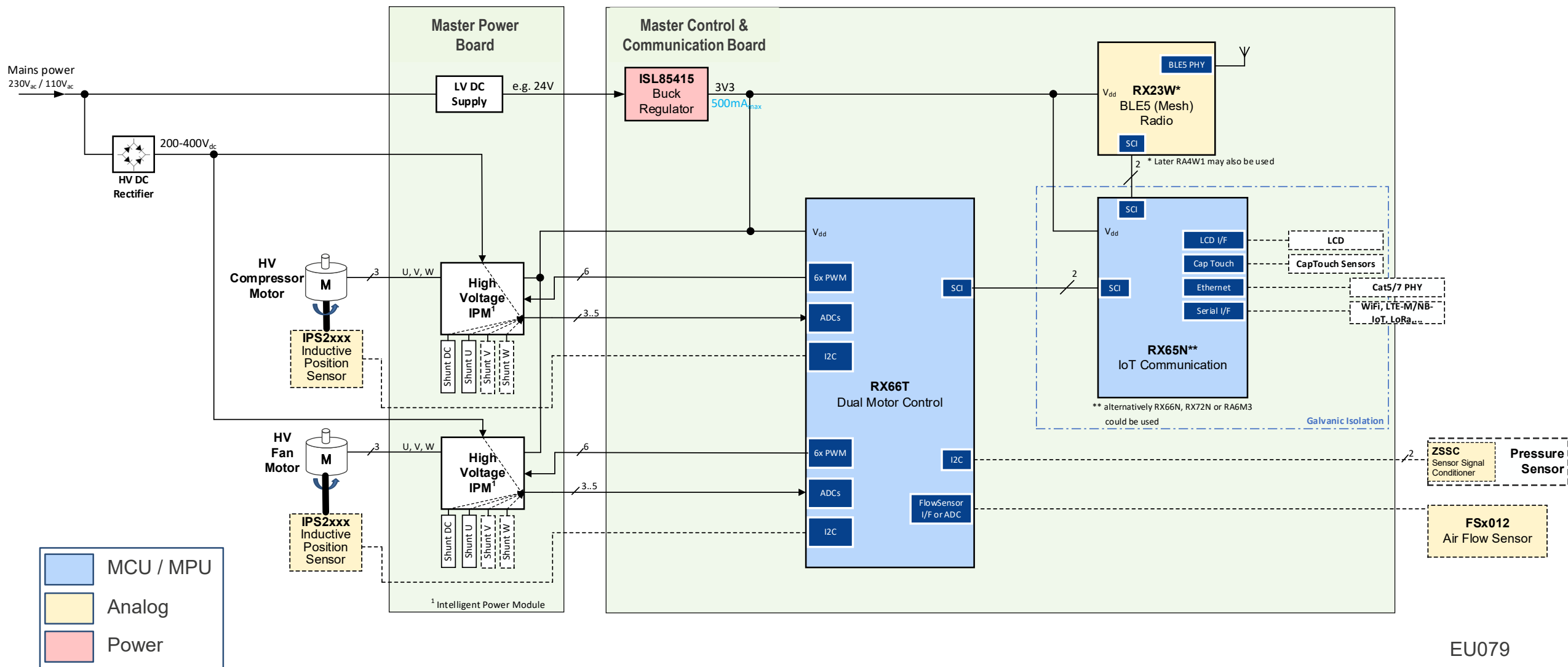
Part #	V _{IN} Range(V)	Temp.(°C)	Package
ISL85403FRZ-T	3 to 40	-40 to 125	20 Ld 4x4 QFN

ALTERNATIVE MASTER ACTUATOR FOR HVAC / COMPRESSOR CONTROL



Smart Home HVAC System

Master Actuator Unit // HVAC / Compressor Control



EU079



Smart Home HVAC System

Master Actuator – HVAC Compressor Control // Major BOM list

Device Category	P/N	Key Features
MCU	RX23W	Bluetooth 5.0 MCU w/ RX v2 core and BT Mesh functionality
	RX65N	MCU with RX v2 core for communication
	RX66T	MCU with RX v3 core for motor control
Analog	FS2012	Calibrated Gas Flow Sensor Module
	IPS2200	Inductive position sensor IC
	ZSSC3224	High End 24-Bit Sensor Signal Conditioner IC
Power	ISL85415	3-36V in, 0.6-34V / 500mA out Buck Regulator

#EU079
Aug 2020

RX23W – 32-bit MCU for Bluetooth 5.0 Low Energy

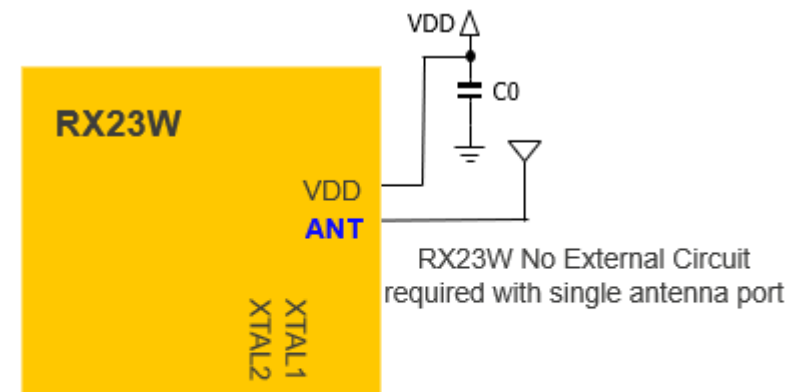
54 MHz RXv2 Core with FPU, Low Power Design, RTC and Encryption functions

Support for Multiple Communication Functions

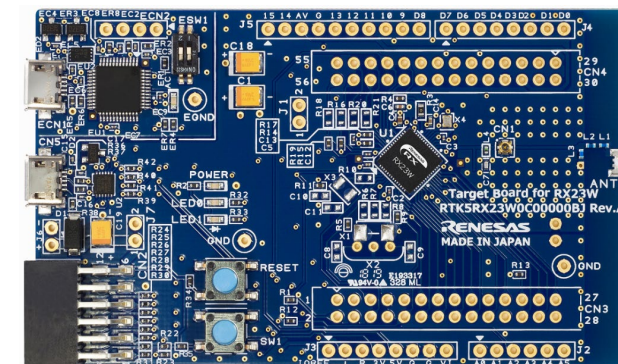
- Bluetooth Low Energy (1Channel)
- An RF transceiver and link layer compliant with the Bluetooth 5.0 Low Energy specification, also supports Bluetooth 4.2
- LE 1M PHY, LE 2M PHY, LE Coded PHY (125 kbps and 500 kbps), and LE Advertising extension support
- On-chip Bluetooth-dedicated AES-CCM (128-bit blocks) encryption circuit
- USB 2.0 host/function/On-The-Go (OTG) (one channel), full-speed = 12 Mbps, low-speed = 1.5 Mbps, isochronous transfer, and Battery Charger supported
- CAN (one channel) compliant to ISO11898-1: Transfer at up to 1 Mbps
- Including many others

High Performance and Low Power Design

- Operation from single 1.8 to 3.6V supply
- Up to 512KB Flash and 64KB RAM
- IEC60730 Compliant
- Capacitive Touch Sensing Unit: 12Keys (Self), 36 Keys (Mutual)
- Max. operating frequency: 54 MHz, Capable of 88.56 DMIPS in operation at 54 MHz
- Enhanced DSP and FPU modules
- RTC capable of operating on the battery backup power supply
- Security: 128- or 256-bit key length of AES for ECB, CBC, GCM, others. TRNG and Safe management of Keys.



Low Cost System Block



Target Board for RX23W – RTK5RX23W0C00000B

Part #	ROM (Kbytes)	RAM (Kbytes)	Security Functions	Package
R5F523W8ADNG#30	512	64	N/A	QFN/56/0.4
R5F523W7ADNG#30	384	64	N/A	QFN/56/0.4
R5F523W8BDNG#30	512	64	Available	QFN/56/0.4
R5F523W7BDNG#30	384	64	Available	QFN/56/0.4

RX65N – 120MHZ RXV2 CORE MCU

LARGE ROM/RAM, ENHANCED SECURITY, CONNECTIVITY AND HMI

High Performance and Wide Product Lineup

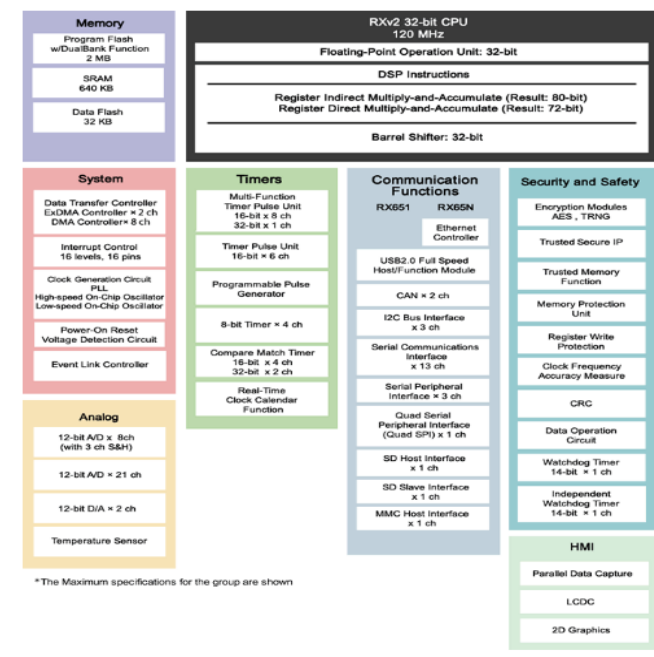
- RXv2 Core 120 MHz operation (34 CoreMark/ma), on-chip FPU
- Up to 2M ROM / 640K RAM, supportive of the dual bank function
- Wide package lineup : 64-pin (4.5mm x 4.5mm, BGA) to 176-pin

Rich Peripheral/Security Functions

- 16-bit TPUa, MTU3a, 8-bit TMRa (4ch), 16-bit CMT(4ch), 32-bit CMTW(2ch)
- 12-bit A/D (8 ch for unit 0, 21ch for unit 1), 12-bit D/A (2ch)
- DMACAa (8ch), DTCb (1ch), EXDMAC(2ch), DMAC for Ethernet controller(1ch)
- Various communication peripheral such as Ethernet, USB, CAN, SD host/slave interface, and quad SPI
- Security: AES, TRNG, TDES, RSA, SHA

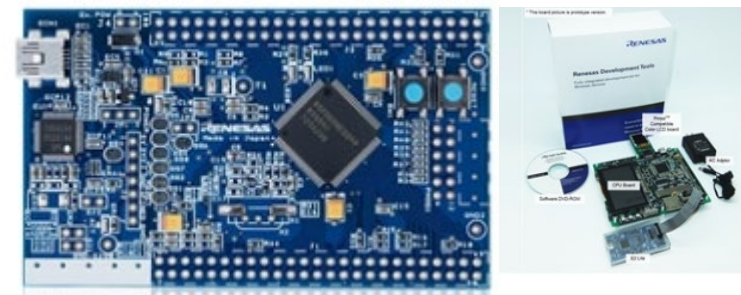
Low Power Design and Architecture

- Operation from a single 2.7- to 3.6-V supply
- Low power consumption: A product that support all peripheral functions draws only 0.19mA/MHz(Typ.)
- RTC is capable of operation from a dedicated power supply
- Four low-power modes



Part #	ROM	RAM	Data Flash	Package
R5F565N4xDxx	512K	256k	None	64-LFQFP, 64-LFBGA, 100-LFQFP, 100-TFLGA, 144-LFQFP, 145-TFLGA
R5F565N7xDxx	768K	256K	None	64-LFQFP, 64-LFBGA, 100-LFQFP, 100-TFLGA, 144-LFQFP, 145-TFLGA
R5F565N9xDxx	1M	256K	None	64-LFQFP, 64-LFBGA, 100-LFQFP, 100-TFLGA, 144-LFQFP, 145-TFLGA
R5F565NCxDxx	1.5M	640K	32K	64-LFQFP, 64-LFBGA, 100-LFQFP, 100-TFLGA, 144-LFQFP, 145-TFLGA, 176-LFQFP, 176-LPBFA, 177-TFLGA
R5F565NExDxx	2M	640K	32K	64-LFQFP, 64-LFBGA, 100-LFQFP, 100-TFLGA, 144-LFQFP, 145-TFLGA, 176-LFQFP, 176-LPBFA, 177-TFLGA

System Block



Renesas Starter Kit for RX65N

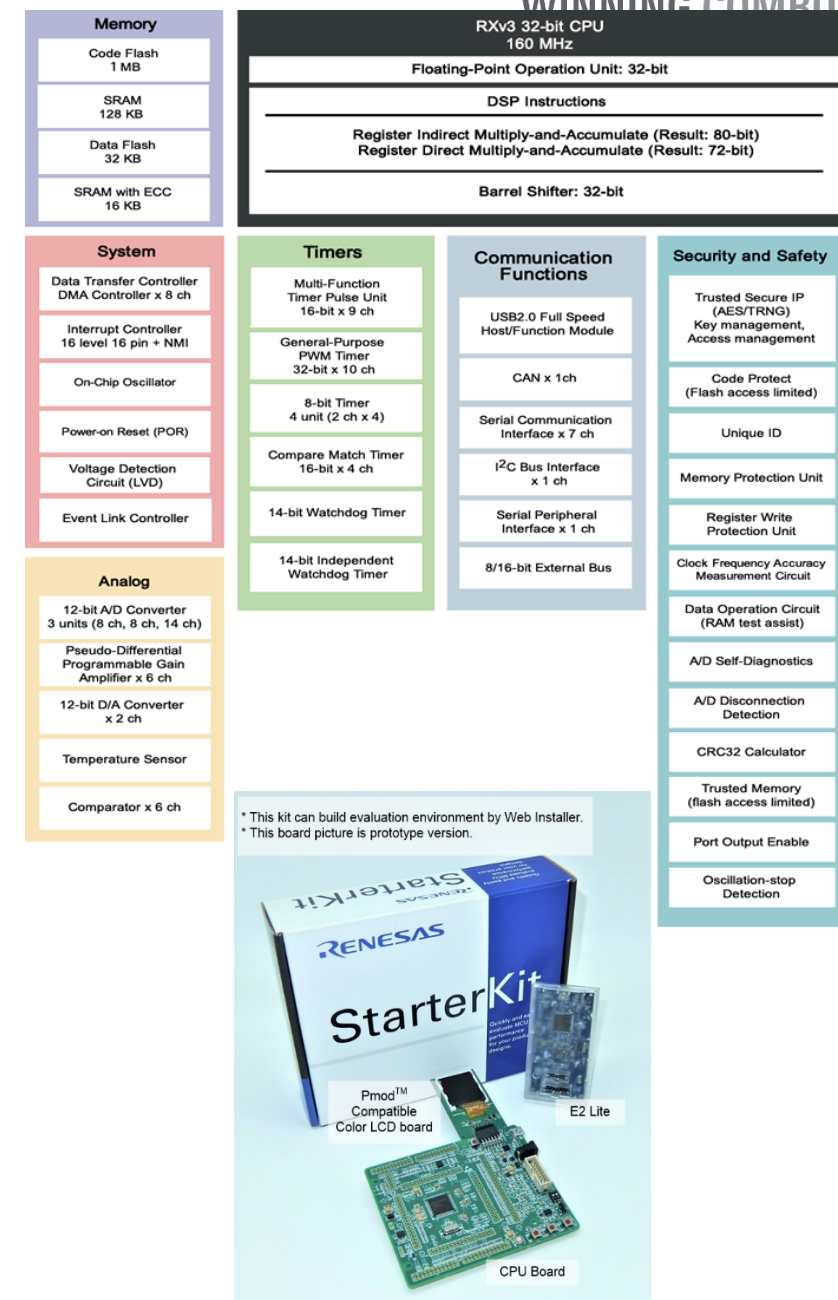
RX66T – 32-bit MCU for Motor Control

160MHz RXv3 Core for Motor Control applications

Key Features

- RXv3 Core 160 MHz operation (5.8 CoreMark/MHz)
- 2.7 to 5.5 V operation
- Operating Temperature -40 to 105 °C
- Program Flash up to 1 MB, SRAM up to 128 KB
- Enhanced Analog:
 - 12-bit A/D Converter x 3 units , 12-bit D/A Converter x 2 channels
 - 6-channel Comparators
 - 6-channel Pseudo-Differential PGA
- 160 MHz PWM
 - 4 channels for 3-phase complementary switching, 2 channels for 5-phase complementary switching, 10 channels for single-phase complementary switching
 - 4-channel high-resolution PWM enables minimum 195 ps timing adjustment
- Trusted Secure IP Lite (AES/TRNG)

Part #	ROM (kB)	RAM (kB)	Data Flash (kB)	Package
R5F566TKADFP	1024	128	32	PLQP0100KB-B
R5F566TEBDFP	512	63	32	PLQP0100KB-B
R5F566TABDFP	256	64	32	PLQP0100KB-B



FS2012 – HIGH PERFORMANCE FLOW SENSOR MODULE

APPLICATIONS FOR PROCESS CONTROLS, OIL AND GAS LEAK DETECTION, CPAP AND RESPIRATOR DEVICES

High accuracy and Fully Calibrated Output:

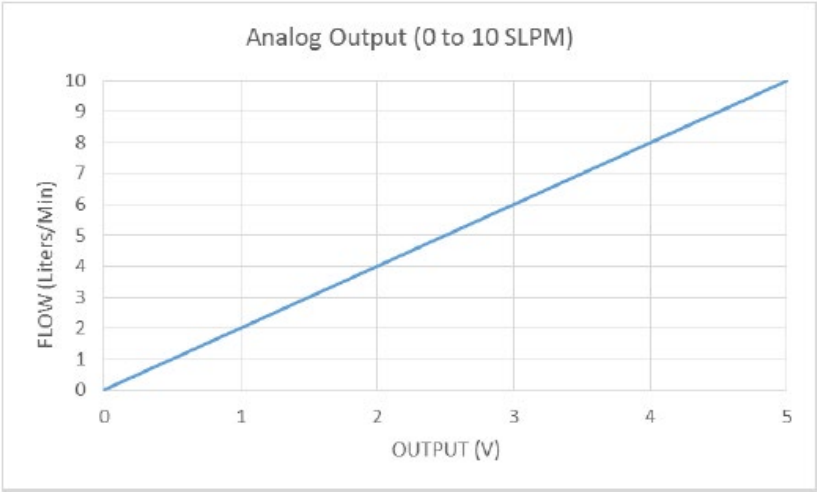
- Accuracy error down to 2% of reading (typical)
- Full calibrated output

High Performance and Easy to Use:

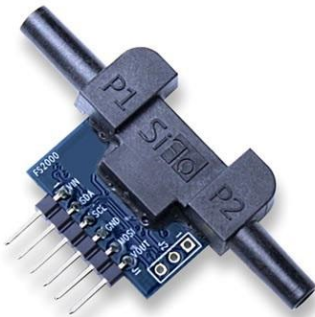
- Robust solid isolation technology
- Resistant to surface contamination
- No cavity to cause clogging
- Resistant to vibration and pressure shock
- Support analog output: 0V to 5V, digital output: I²C
- Supply voltage: 5V(Typ)
- Module operating temperature range: 0°C to +85°C

Part #	Parameter	Description
FS2012-1020-NG	Gas Flow	0 to 2 SLPM
FS2012-1100-NG	Gas Flow	0 to 10 SLPM
FS2012-1001-LQ	Liquid Flow	0 to 0.5(500) SLPM(SCCM)
FS2012-1002-LQ	Liquid Flow	0 to 1.0(1000) SLPM(SCCM)

SLPM: Standard liter per minute.
 SCCM: Standard cubic centimeter per minute.



Analog Output Example



FS2012 Module (front)

IPS2200 – INDUCTIVE POSITIVE SENSOR IC

MAGNET-FREE, INDUCTIVE POSITIVE SENSOR IC FOR HIGH SPEED ABSOLUTE POSITION SENSING

High Performance and Low Cost

- High accuracy : $\leq 0.2\%$ full scale, adaptable to any full-scale angle range
- Rotation sensing up to 360° angle range
- Cost effective, no magnet required, single IC support on-axis and off-axis rotation, liner motion, and arc motion sensing

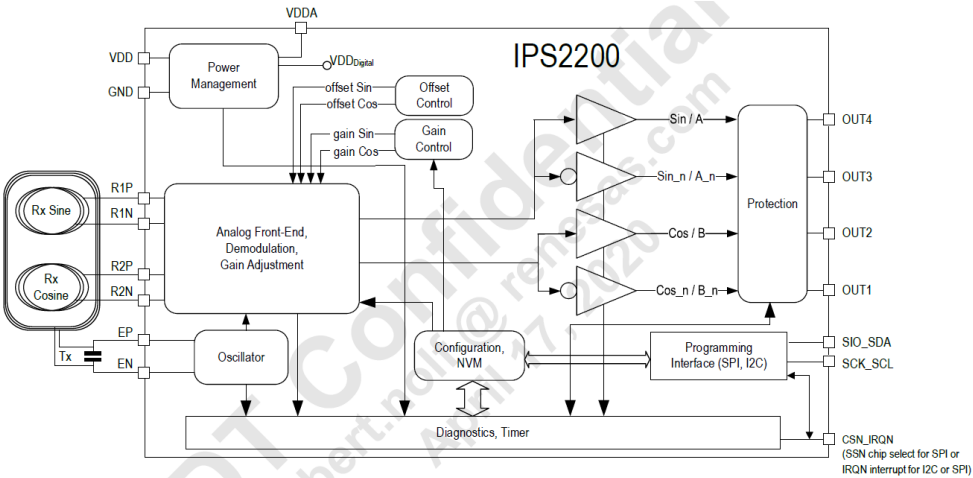
Flexible Usage and Safety Functions

- Differential and single-ended sine and cosine outputs
- Nonvolatile user-configurable memory, programmable via I2C or SPI, Supply voltage programmable for 3.0V to 3.6V or 4.5V to 5.5V
- Fast diagnostic alarm trough interrupt pin, $\pm 18V$ over-voltage and reverse-polarity protection on output pins

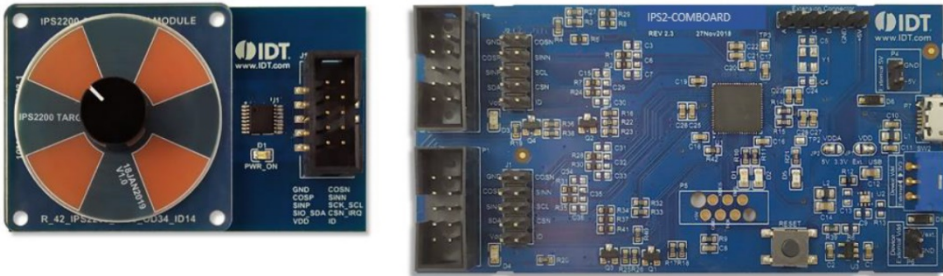
Immunity and Wide Operating Temperature Range

- Immune to magnetic stray fields, no shielding required, suitable for harsh environments and extreme temperature
- Wide operation temperature: -40°C to 125°C

Part #	Carrier Type	Temp Range (°C)	Package
IPC2200BI1W	7" Reel, 500 parts/reel	-40 to +125	16-TSSOP 4.4 x 5.0mm
IPC2200BI1R	13" Reel, 4000 parts/reel	-40 to +125	16-TSSOP 4.4 x 5.0mm



Block Diagram



IPS2-COMBOARD and IPS2200MROT4x90001
Application Module



ISL85415 – 0.5A Regulator with Integrated High Side FET

Support 3V-36V Input Voltage Range for Buck Output

Wide Working Range

- Power input voltage range from 3V to 36V
- The device provides an easy-to-use high-efficiency, low BOM-count solution for a variety of applications.
- Up to 0.5A load over full temperature range

High Efficiency and Performance (low board space)

- Synchronous operation for high efficiency
- No compensation required
- Integrated High-side and Low-side NMOS devices
- Selectable PFM or forced PWM mode at light loads
- Internal fixed (500kHz) or adjustable switching frequency 300kHz to 2MHz

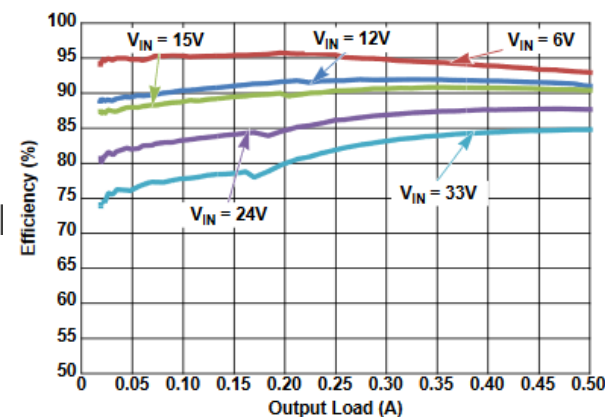
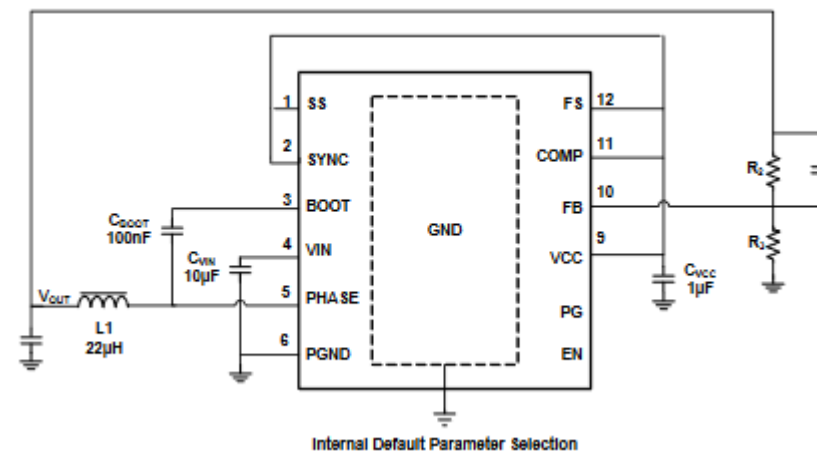


Figure 6. Efficiency vs Load, PFM, $V_{OUT} = 5V$

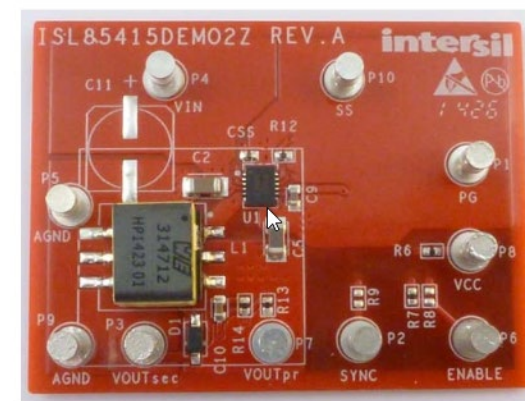


FIGURE 1. FRONT OF EVALUATION BOARD ISL85415DEMO02Z

Part #	V_{IN} Range(V)	Temp.(°C)	Package
ISL85415FRZ	3 to 36	-40 to 125	12 Ld DFN 4x3

ZSSC3224 – SENSOR SIGNAL CONDITIONER

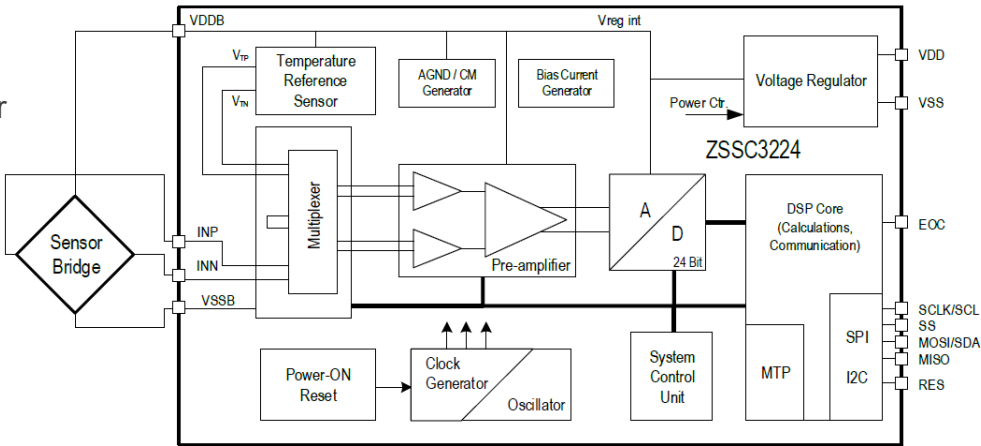
HIGH END 24-BIT SENSOR SIGNAL CONDITIONER IC

Features

- Flexible, programmable analog front-end design; up to 24-bit analog-to-digital converter (ADC)
- Fully programmable gain amplifier for optimizing sensor signals: gain range 6.6 to 216 (linear)
- Internal auto-compensated temperature sensor
- Digital compensation of individual sensor offset; 1st and 2nd order digital compensation of sensor gain as well as 1st and 2nd order temperature gain and offset drift
- Programmable interrupt operation
- High-speed sensing: e.g. 18-bit conditioned sensor signal measurement rate >200s-1
- Typical sensor elements can achieve an accuracy of better than ±0.10% FSO** at -40 to 85°C

Applications

- Barometric altitude measurement for portable navigation or emergency call systems; altitude measurement for car navigation
- Weather forecast
- Fan control
- Industrial, pneumatic, and liquid pressure
- High-resolution temperature measurements
- Object-temperature radiation (via thermopile)



ZSSC3224 Block Diagram

Part #	Operation Condition	MSL Rating	Package
ZSSC3224BI3R	1.68-3.6V -40°C to +85°C	MSL1	24-PQFN
ZSSC3224BI1B	(see above)	Not applicable	die, thickness 304μm
ZSSC3224BI2B	(see above)	Not applicable	die, thickness 725μm (without backlapping)

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