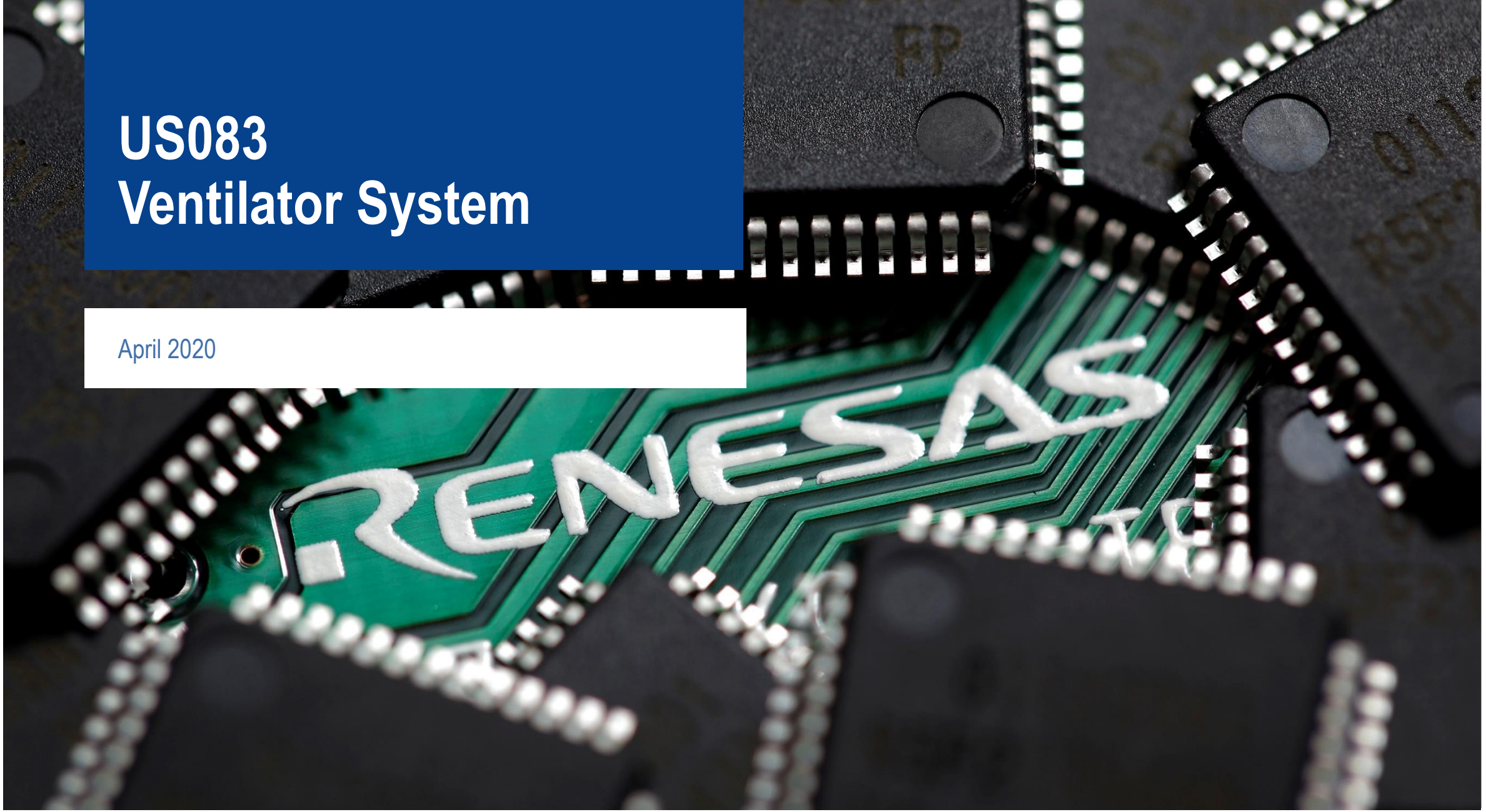
US083
Ventilator System

April 2020



Ventilator System: Overview

The COVID-19 pandemic has created havoc globally, putting more and more people in hospitals. The demand for ventilators is so high that doctors are creating makeshift ventilators to meet the demand. Many companies are contributing to the cause in various ways, including opening up their IPs. Renesas is also helping this global cause by designing ready-to-assemble electronic boards for ventilators.

This is a ventilator system reference design to provide a portable ventilator used in hallway or non-ICU use cases. This machine can provide high pressure oxygen to patients in assist control and pressure control modes. The assist control mode provides a certain tidal volume of gas to a patient with each inhale. The flow sensor (FS1023) would monitor the gas flow rate at the inhale tube and the tidal volume would be calculated by the MCU using the rate integrated with time. The oxygen valve would be controlled by the MCU and manage the oxygen ratio. The pressure control mode provides a certain pressure to the patient with each inhale. There is one proximal air pressure sensor connected to the mask to monitor the inhale pressure and send that information to the RX23W MCU. The blower, which provides pressure and blows air into the system, is driven by a motor control board that is controlled by the RX23T MCU. It uses I^2C communication with the RX23W. A humidifier is added to the system to provide moist gas to the patient.

The system is using two MCUs for higher safety, so these devices can monitor and reset each other.

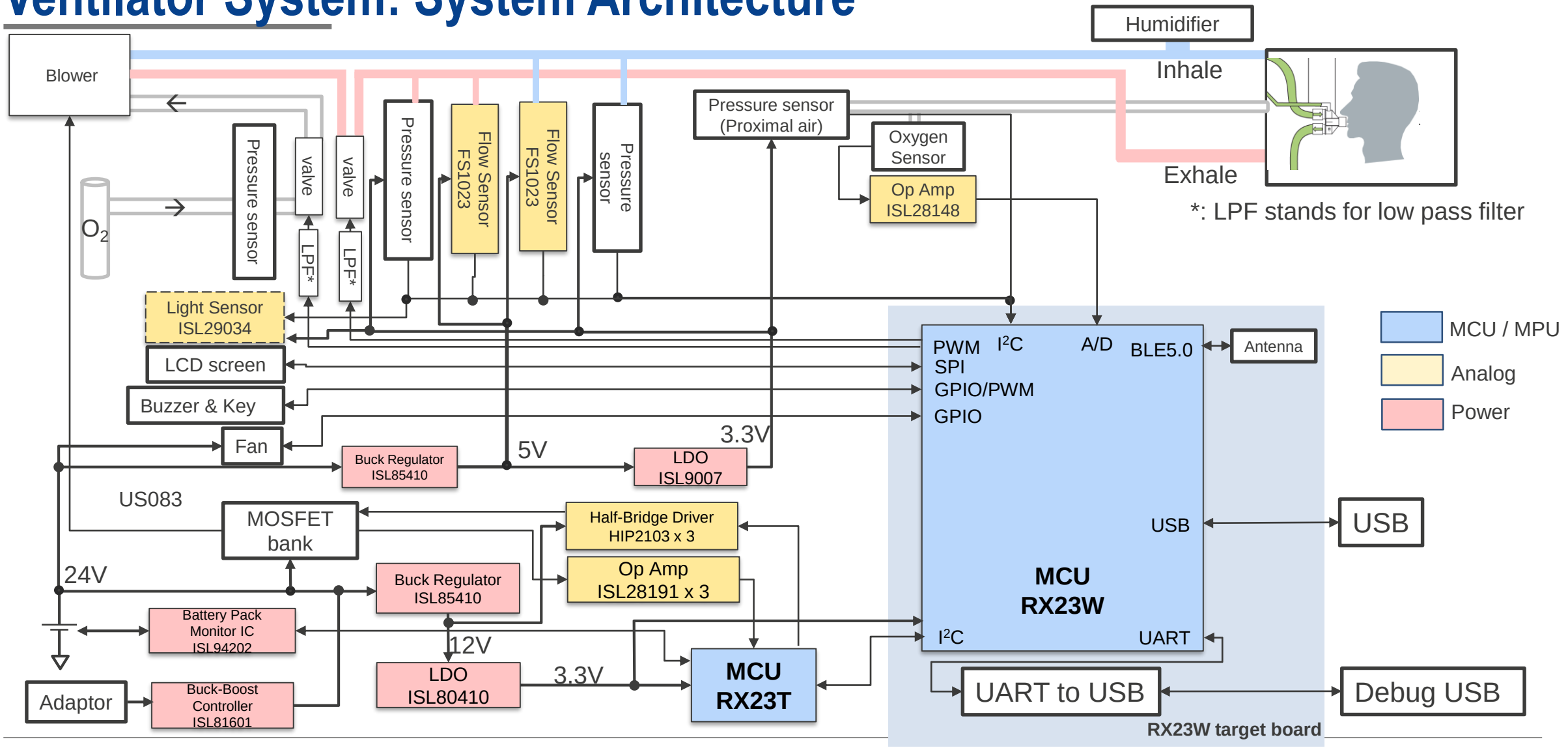
US083

Ventilator System: System Benefits

- Secure system using two MCUs to monitor each other
- System available for assist control mode and pressure control mode
- Hardware is capable of providing low tidal volume, peak pressure, disconnect, and apnea alarms
- Both gas volume and flow rate are monitored by the FS1023
- The oxygen ratio is controlled by the valve, which is controlled by the MCU, and monitored by the flow sensor
- The exhale pressure is controlled by MCU through the exhale valve
- The oxygen sensor is used to test FiO2 (fraction of inspired oxygen)
- The blower is controlled via pressure/flow sensor feedback
- The LCD brightness is controlled by the light sensor monitoring ambient light
- Features a battery balance monitor to extend battery lifetime

US083

Ventilator System: System Architecture



Ventilator System

Device Category	P/N	Key Features
MCU	RX23W	32-bit microcontrollers with Bluetooth® 5 for IoT endpoint devices, system control and wireless communication.
	RX23T	Microcontroller incorporating a floating point unit (FPU), best suited for controlling a single inverter.
Power	ISL9007	300mA high performance LDO, very low quiescent current: 50µA. Low output noise.
	ISL85410	Wide V_{IN} 1A synchronous buck regulator
	ISL80410	40V, low quiescent current, 150mA linear regulator
	ISL94202	Stand-alone 3 to 8 cell Li-Ion battery pack monitor
	ISL81601	60V bi-directional 4-switch synchronous buck-boost controller with current sensing and input/output monitoring
Analog	FS1023	Liquid/gas flow sensor module
	ISL29034	Integrated digital light sensor
	HIP2103	60V, 1A/2A peak, half-bridge driver with 4V UVLO
	ISL28148	4.5MHz, single precision rail-to-rail input-output (RRIO) op amps with very low input bias current
	ISL28191	Single supply ultra-low noise, low distortion rail-to-rail output, op amp

US083

RX23T – 32-bit FPU MCU for Controlling a Single Inverter

40 MHz RX v2 Core with FPU, 5V Power Supply and Highly Accurate 12-Bit ADC

High Performance and Low Power Design

- Max. operating frequency: 40MHz
- Enhanced DSP: 32-bit multiply-accumulate and 16-bit multiply-subtract instructions
- Built-in FPU: 32-bit single-precision floating point (compliant to IEEE754)
- Divider, fast interrupt, CISC Harvard architecture with 5-stage pipeline
- Variable-length instructions, ultra-compact code
- 3 low power consumption modes, software standby mode (with RAM retention) < 0.45 µA

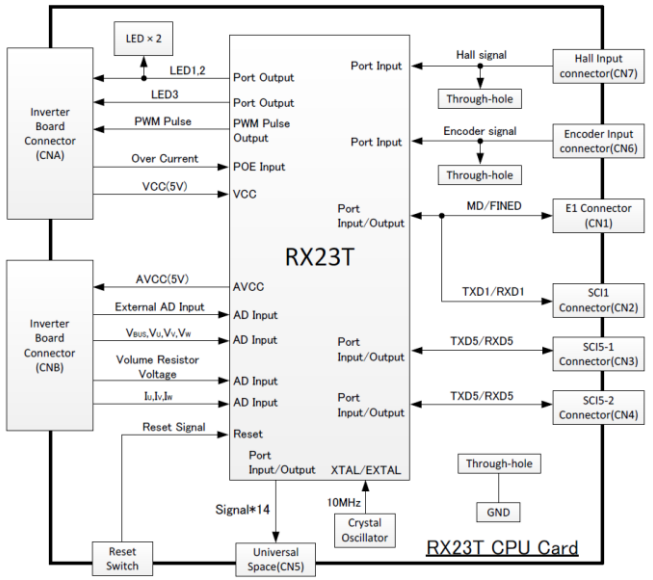
Suitable for Inverter Control

- Enhanced DSP and FPU modules
- 40MHz PWM (three-phase complementary output x 2ch)

Rich Peripheral Functions

- Up to 4 communications channels
- Up to 12 extended-function timers
- 12-bit ADC: 10ch
- Useful functions for IEC60730 compliance

Part #	ROM (Kbytes)	RAM (Kbytes)	Temp.(°C)	Package
R5F523T5ADFM	128	12	-40 to 85	LFQFP64/0.50
R5F523T3ADFD	64	12	-40 to 85	LQFP52/0.65
R5F523T5AGFM	128	12	-40 to 105	LFQFP64/0.50
R5F523T3AGFL	64	12	-40 to 105	LFQFP48/0.50



System Block

Evaluation Kits

RX23W – 32-bit MCU for Bluetooth® 5.0 Low Energy

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

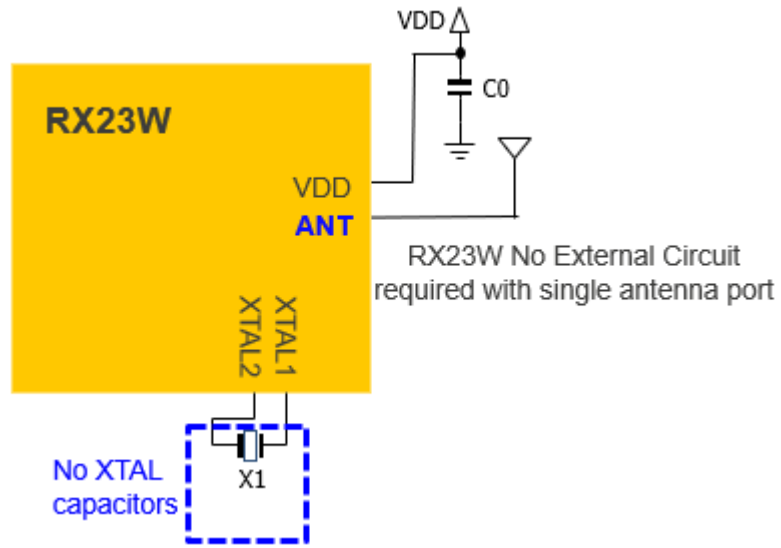
Support for Multiple Communication Functions

- Bluetooth® Low Energy (1 Channel)
- 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

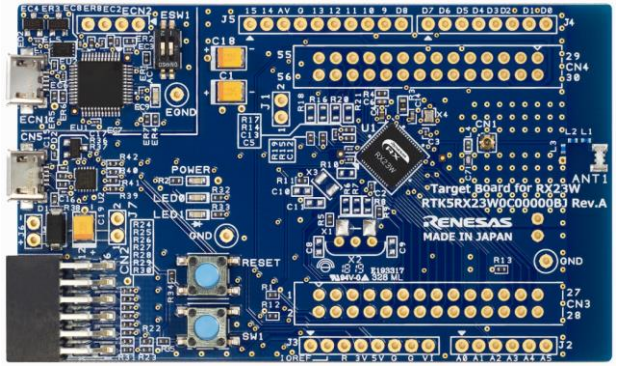
High Performance and Low Power Design

- 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.

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



Low Cost System Block



Target Board for RX23W – RTK5RX23W0C00000B

ISL9007 – V_{IN} 2.3V to 6.5V/400mA LDO

High Current LDO with Low I_Q and High PSSR

High Performance

- Excellent load regulation: <0.1% voltage change across full range of load current
- Very high PSRR: 75dB @ 1kHz

Wide Input Voltage and Stable Output Voltage

- ±1.8% V_{OUT} accuracy over all operating conditions
- Wide input voltage capability: 2.3V to 6.5V
- Low output noise: typically 30µVRMS @ 100µA (2.5V)

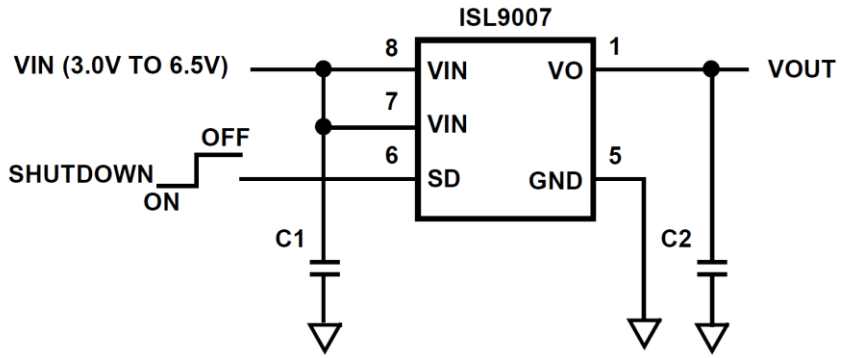
High Efficiency

- Very low quiescent current: 50µA
- Low dropout voltage: typically 200mV @ 300mA
- Low output noise: typically 30µVRMS @ 100µA (2.5V)
- Shutdown pin turns off LDO for 1µA (max) standby current

Excellent Safety

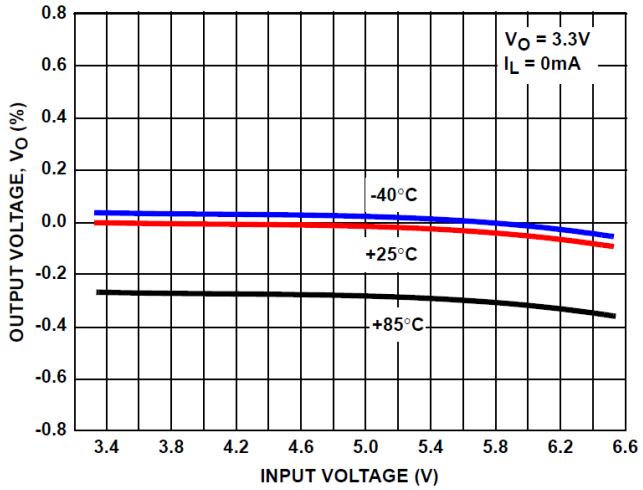
- Current limit and overheat protection
- Soft-start to limit input current surge during enable

Part #	Vout (V)	Temp.(℃)	Package
ISL9007IUNZ	3.3	-40 to +85	8Ld MSOP
ISL9007IUKZ	2.85	-40 to +85	8Ld MSOP
ISL9007IUJZ	2.8	-40 to +85	8Ld MSOP
ISL9007IUFZ	2.5	-40 to +85	8Ld MSOP
ISL9007IUCZ	1.8	-40 to +85	8Ld MSOP



C_1, C_2: 1µF X5R CERAMIC CAPACITOR

Typical Application Circuit



Output Voltage vs Input Voltage(3.3V Output)

ISL85410 – 1A Synchronous Buck with Integrated FETs

Supports 3V-40V Input Voltage Range for Buck Output

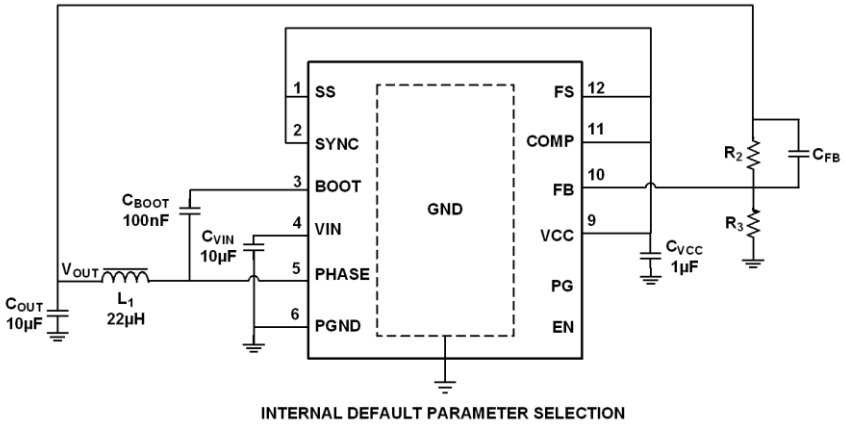
Wide Working Range and Space-Limited Applications

- Power input voltage range from 3V to 40V
- Up to 1A load over full temperature range
- 4mm x 3mm DFN package
- Minimal external components required

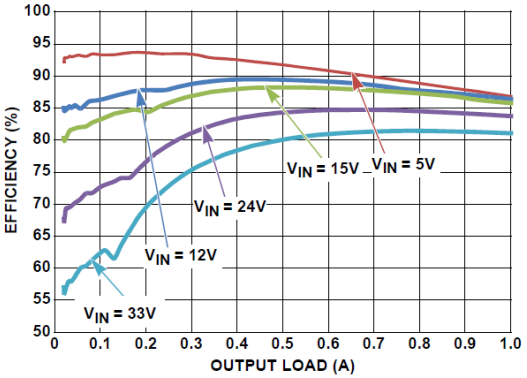
High Efficiency and Performance

- 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

Part #	V_{IN} Range(V)	Temp.(℃)	Package
ISL85410FRZ	3 to 40	-40 to 125	12 Ld DFN 4x3



Typical Application Circuit



Efficiency vs Load, PFM, V_{OUT} = 3.3V

ISL8541xDEMO1Z Evaluation Board

ISL80410 – High Voltage Adjustable V_{OUT} LDO

Low Quiescent Current and 40V/150mA Output

High Performance and Wide Input Range

- Wide V_{IN} range of 6V to 40V
- Adjustable output voltage from 2.5V to 12V
- Ensured 150mA output current
- ±1% accurate voltage reference (over temperature, load)

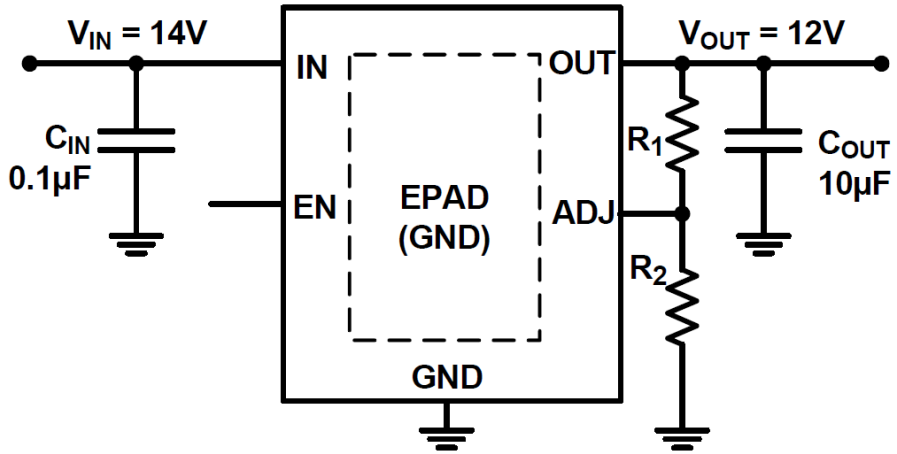
High Efficiency

- Ultra low 18µA typical quiescent current
- Low 2µA of typical shutdown current
- Low dropout voltage of 295mV at 150mA
- Low 26µVRMS noise

Excellent Safety

- 40V tolerant logic level (TTL/CMOS) enable input
- 5kV ESD HBM rated
- Thermal shutdown and current limit protection

Part #	V_{IN} Range(V)	V_{OUT} Range(V)	Enable Pin	Package
ISL80410IBEZ	6 to 40	ADJ	Yes	8 Ld EPSOIC
ISL80410IBEZ-T	6 to 40	ADJ	Yes	8 Ld EPSOIC
ISL80410IBEZ-T7A	6 to 40	ADJ	Yes	8 Ld EPSOIC



Typical Application Circuit

ISL80410EVAL1Z Evaluation Board

ISL81601 – High Voltage Buck Boost Controller

60V Bi-Directional 4-Switch Synchronous Buck-Boost Controller

Bi-directional Buck-Boost

- Peak & average current sensing and monitoring at input & output
- 4 independent controls for input/output voltages and currents
- 4-switch design with smooth transition between buck & boost mode

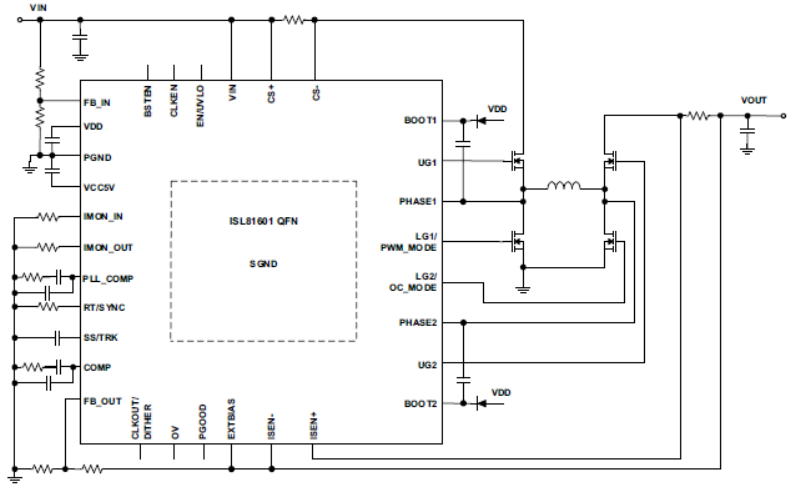
Wide Working Range

- Input voltage range: 4.5V to 60V
- Output voltage range: 0.8V to 60V
- Adjustable switching frequency from 100 to 600 kHz
- Ability to sync to external clock

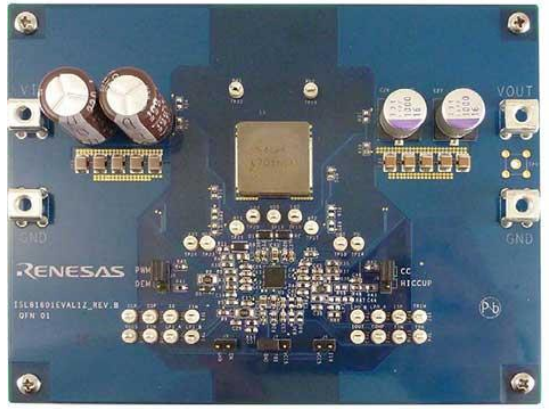
Complete Application Protection

- Multiple protection features: OVP, UVP, OTP, SCP
- Current limits on both input & output
- Adaptive shoot-through protection

Part #	Vin Range (V)	Vout Range (V)	Package
ISL81601FRZ-T	4.5-60	0.8-60	32Ld 5x5 DFN
ISL81601FVEZ-T	4.5-60	0.8-60	38Ld HTSSOP



Typical Operation Circuits



ISL81601EVAL1Z Evaluation Board

ISL94202 – Stand-alone Multi-Cell Li-Ion Battery Manager

Complete Charger for Li-Ion CoO_2, Li-ion Mn_2O_4, and Li-ion FePO4 Batteries

Single IC Solution for Charging

- Supervises 3 to 8 series connected cells
- Highly configurable as a stand-alone unit, optional external MCU communication via I^2C interface
- Cell voltage measurement accuracy ±10mV

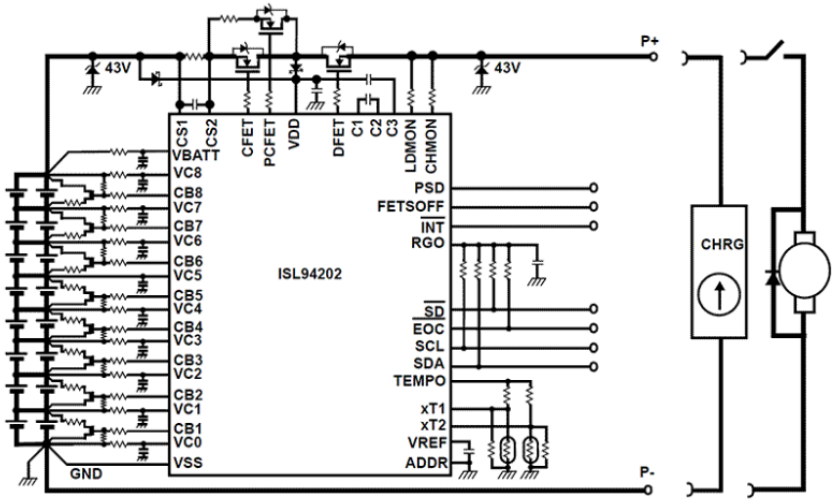
Charging Features

- Multiple voltage protection options (each programmable to 4.8V; 12-bit digital value) and selectable overcurrent protection levels
- Cell balancing uses external FETs (internal drivers) with internal state machine or an optional external MCU

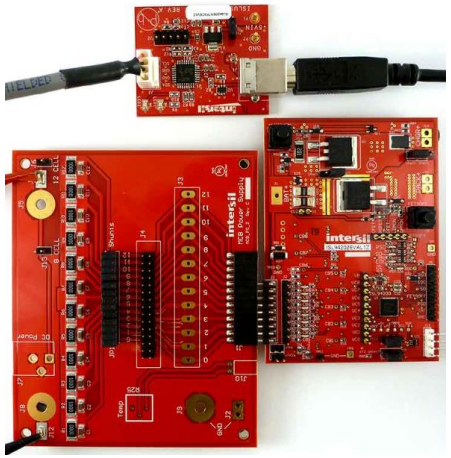
Protection Features

- Programmable detection/recovery times for overvoltage, undervoltage, overcurrent, and short-circuit conditions
- Integrated system diagnostics for all key internal functions

Part #	MOQ	Temp Range	Package
ISL94202IRTZ	1000	-40 to 85°C	48Ld 6x6 TQFN
ISL94202IRTZ-T	4000	-40 to 85°C	48Ld 6x6 TQFN



Typical Application Circuit



ISL94202EVKIT1Z Evaluation Board

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

High Voltage Drivers for Industrial Motor Control

Flexible Half-Bridge Drivers

- Supports half bridge, full bridge, and 3-phase 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

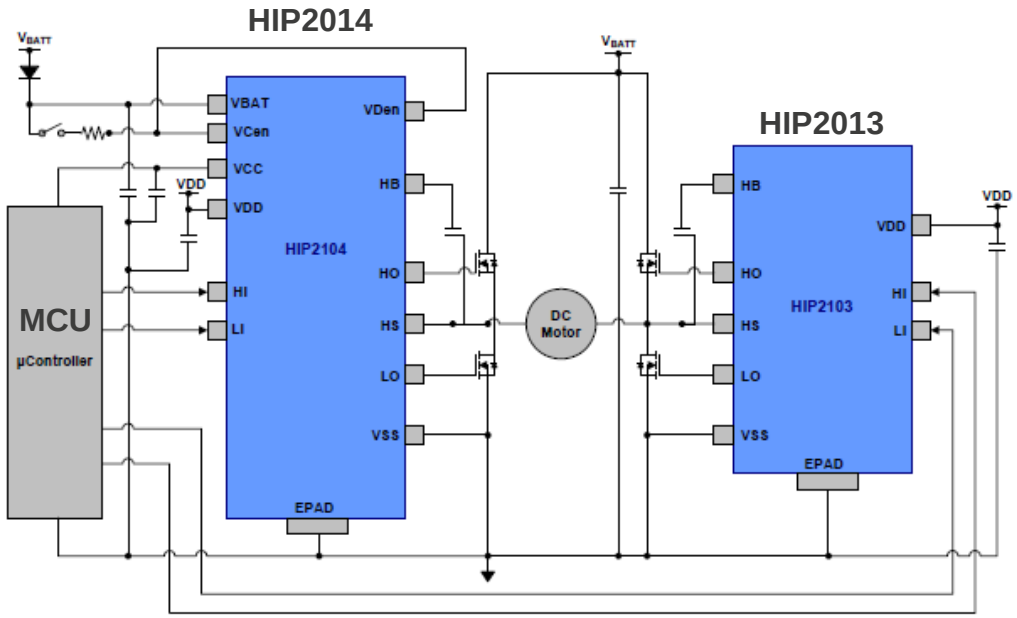
Sleep Mode

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

Integrated LDO (HIP2104)

- HIP2104 includes integrated 12V & 3.3V LDOs
- Provides bias to external MCU plus HIP2103 & HIP2104 drivers

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



Typical Application Circuit

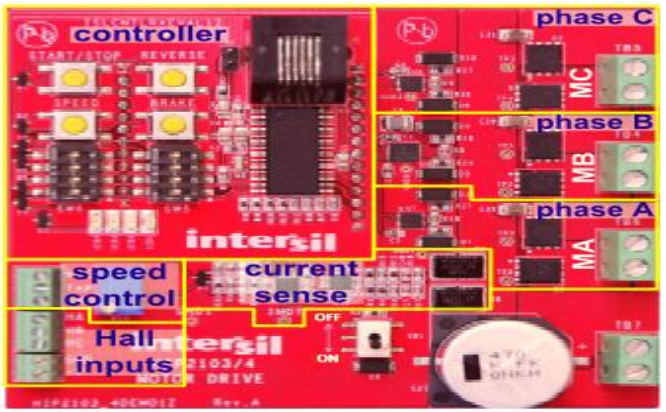


FIGURE 1. HIP2103-4DEMO1Z INPUTS AND OUTPUTS

ISL29034/5 – Integrated Digital Light Sensor with Interrupt

Ambient and Infrared Light-to-digital Converter with I²C (SMBus Compatible) Interface

Integrated Functions and Small Package

- 6 pin 1.5mmx1.3mm ODFN
- On-chip 16-bit ADC
- I²C (SMBus compatible) interface
- Integrated noise reduction 50/60Hz

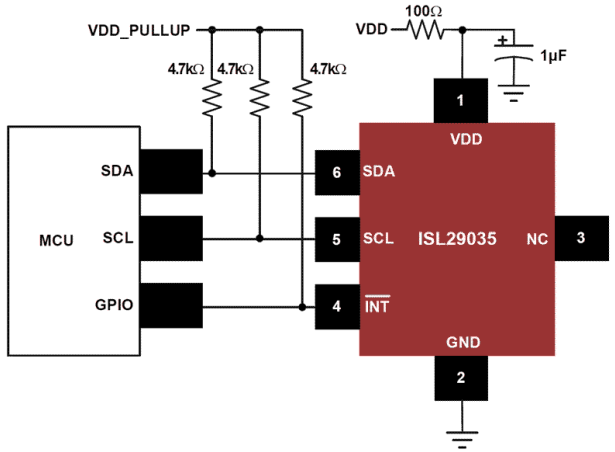
High Performance

- Dynamic Range 1: 4,200,000
- Close to human eye response with excellent IR/UV rejection
- Operation across -40 to +85°C

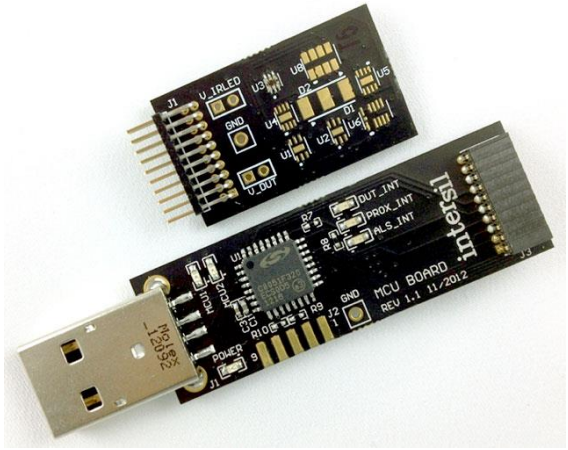
Low Power Design

- Normal operation 57uA
- 2 power down mode support shutdown current < 0.51uA

Part #	ALS Sensing	Interrupt Pin	Package
ISL29034IROZ	Yes	No	4 Ld 1.5x1.3 ODFN
ISL29035IROZ	Yes	Yes	6 Ld 1.5x1.6 ODFN



Typical Operating Circuits



ISL29035EVAL1Z Evaluation Board

ISL28x48 – 4.5MHz Single/Dual RRIO Op Amps

Very Low Input Bias Current for Medical Devices, Low-end Audio and Sensor Amplifiers

Good Dynamic Performance

- Rail-to-rail input and output
- Gain-bandwidth: 4.5MHz
- Enable pin (ISL28148 SOT-23 package only)

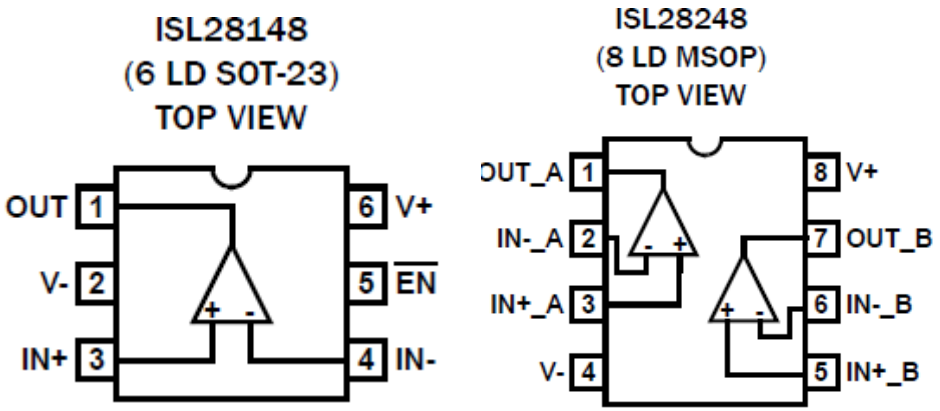
Low Power and Wide Supply Range

- 900µA supply current (per amplifier)
- 1.8mV maximum offset voltage (ISL28248)
- Input bias current: 1pA, typical
- Down to 2.4V single supply operation, allowing operation from one lithium cell or two Ni-Cd batteries

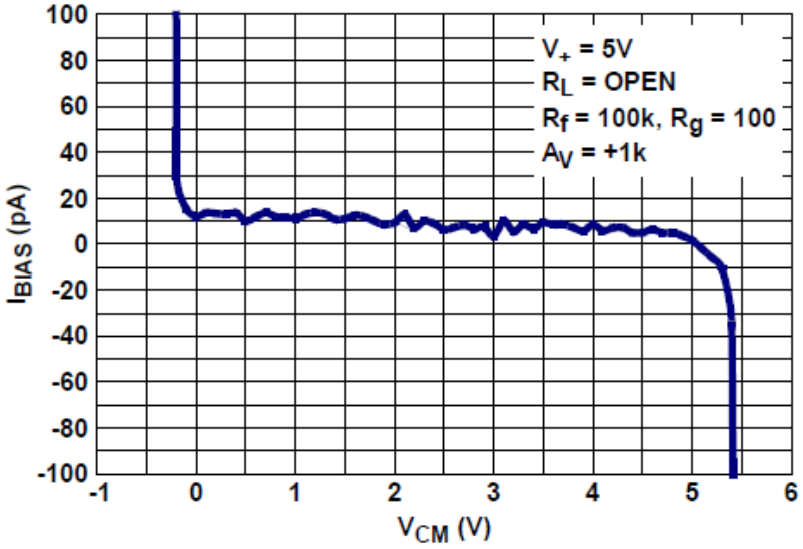
Wide Operating Temperature Range

- All devices operate across the extended temperature range of -40°C to 125°C

Part #	Channel	Enable Pin	Package
ISL28148FHZ-T7	Single	Yes	6 Ld SOT-23
ISL28148FHZ-T7A	Single	Yes	6 Ld SOT-23
ISL28248FBZ	Dual	No	8 Ld SOIC
ISL28248FBZ-T7	Dual	No	8 Ld SOIC
ISL28248FUZ	Dual	No	8 Ld MSOP
ISL28248FUZ-T7	Dual	No	8 Ld MSOP



Pin Configuration



Input Bias Current vs Common-mode Input Voltage

FS1023 – Liquid Flow Sensor Module

Highly Sensitive/Fast Response at Low Flow Rates for Low Power Industry Application

Capable of Measuring Medium

- Gas or liquid medium
- Liquid Flow: 0 to 3 liters/min

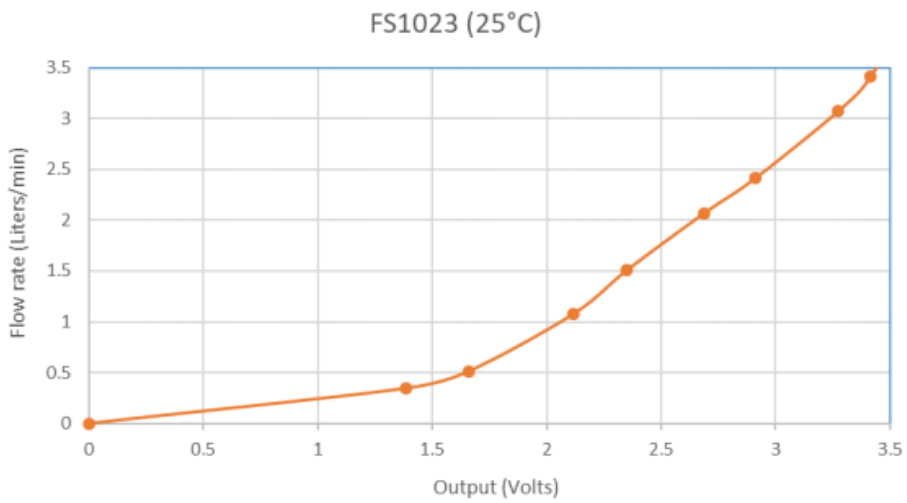
Fast Response and Low Power

- Fast response: <5ms
- Low power consumption

High Performance, Robust in Use

- Robust “solid” isolation technology
- Resistant to surface contamination
- No cavity to cause clogging
- Resistant to vibration and pressure shock
- Sensitive at low flow rates and differential pressure levels
- Supply voltage: 5V
- Module operating temperature range: 0°C to +85°C

Part #	Flow Rate (L/min)	Maximum
FS1023	3	6 Ld Board



FS1023 Flow Curve

FS1023 Module (front)

ISL28x91 – Single/Dual Ultra-Low Noise RRIO Op Amps

Applications for Low Noise Signal Processing, Low Noise Microphones, ADC Buffers, etc.

Ultra-Low Noise and Ultra-Low Distortion

- 1.7nV/√Hz input voltage noise at 1kHz
- 1kHz THD+N typical 0.00018% at $2V_{P-P}$ V_{OUT}
- Harmonic Distortion -76dBc, -70dBc, fo = 1MHz

Good Dynamic Performance

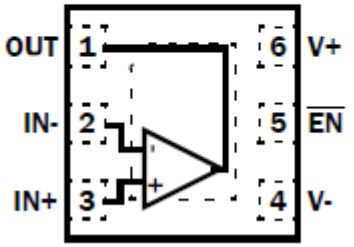
- Rail-to-rail input and output
- Gain-bandwidth: 5MHz
- 61MHz -3dB bandwidth

High Performance and Space-Saving Package

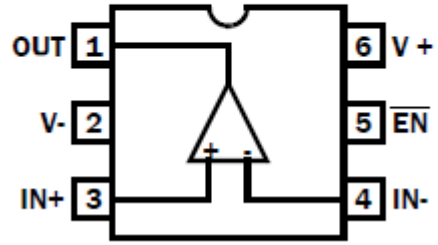
- 630µV maximum offset voltage
- 3µA input bias current
- 100dB typical CMRR
- Ground Sensing and enable pin
- 6 Ld UTDFN(1.6mmx1.6mm) and 6 Ld SOT-23 packages are available in ISL28191

Part #	Channel	Supply Voltage(V)	Package
ISL28191FHZ-T7	Single	3 to 5.5	6 Ld SOT-23
ISL28191FRUZ-T7	Single	3 to 5.5	6 Ld UTDFN
ISL28291FUZ	Dual	3 to 5.5	10 Ld MSOP
ISL28291FBZ	Dual	3 to 5.5	8 Ld SOIC
ISL28291FRUZ-T7	Dual	3 to 5.5	10 Ld UTQFN

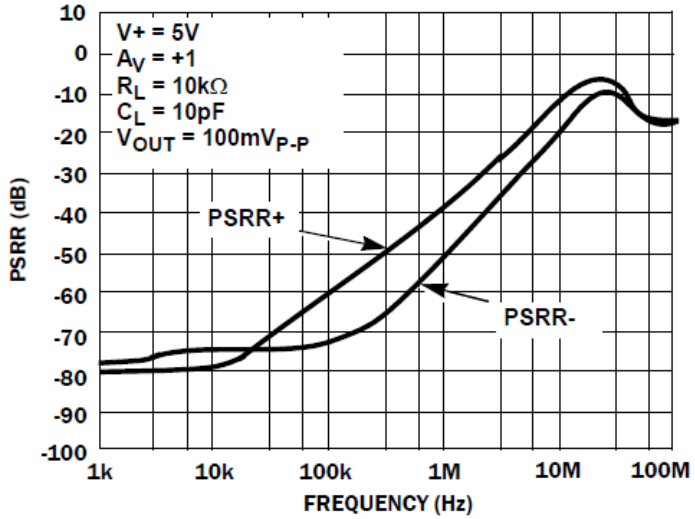
ISL28191
(6 LD 1.6X1.6X0.5 UTDFN)
TOP VIEW



ISL28191
(6 LD SOT-23)
TOP VIEW



Pin Configuration



PSRR vs Frequency

www.renesas.com