
RX, SH, V850ES, RL78 and 78K0R families

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Medical Application Guide

Introduction

This guide provides comprehensive system level solutions for design and development of medical device applications using Renesas microcontrollers, standard integrated circuits and discrete devices. This guide provides solutions in general block diagrams and Renesas FAE can help you to get the optimum solutions, reference designs, reference software, and other technical support.

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1. Consumer Medical Instruments

Products targeted to consumer medical instruments market consists of everything from digital thermometers, blood glucose, digital blood pressure and blood cholesterol meters to health and fitness monitors such as digital pulse/heart rate monitors. Renesas' low power microcontrollers are suitable for all these portable products that operate mostly using batteries with very simple user interface. Some of these products are very cost sensitive and several highly integrated Renesas microcontrollers with rich analog integration address this issue well. On the other hand, some advanced designs aim to improve diagnosis by simultaneously measuring noninvasive blood pressure, oxygen saturation and body temperature. Renesas Electronics simplify these designs with high performance microcontrollers with DSP capability and large memory that support computation of signals from more sophisticated discrete analog signal chain. Moreover, many of these medical devices can implement Continua™ standard, enabling patient data to be transferred to electronic patient storage.

Here are some of the Consumer medical devices

- Digital Thermometer
- Digital Blood Pressure Monitor
- Digital Blood Sugar Monitor
- Pulse Oximeter
- Portable Digital Pulse / Heart Rate monitor

All the above devices have some similar embedded requirements like user interface, display, battery power management, sensor interface and processing engine. Renesas low power microcontrollers provide many integrated hardware blocks such as low voltage indicator, internal oscillator, ADC, DAC and various serial interfaces to reduce system cost. In addition Renesas offers a line of microcontroller products with integrated LCD driver. Many of the microcontrollers have RAM/Flash check, clock monitor and other safety functions to simplify implementation of detection and recovery from system anomalies. Some of microcontrollers have on-chip hardware multiplier and accumulator (MAC) and provide floating point library support required for signal processing tasks. While other families have a hardware floating point unit to simplify implementation, maintenance and upgrade of more sophisticated algorithm.

Table 1 Consumer Medical Instruments

Instrument	Key Requirements	Renesas Microcontroller	Key Features
Low cost Digital Thermometer	<ul style="list-style-type: none"> • 12-bit ADC • LCD display • Low power and low cost 	78K0R/Lx3	<ul style="list-style-type: none"> • 16-bit processor core with 19 DMIPS @ 20 MHz • Integrated 12-bit ADC and LCD driver • On-chip Op Amps for low cost analog front end implementation • Low power
Clinical Digital Thermometer	<ul style="list-style-type: none"> • Support for 14 – 16 bit ADC • Continuous temperature monitoring required in anesthesia, surgery and intensive care • Storage for calibration tables and measurement data • Support for wireless communication 	RL78/G13	<ul style="list-style-type: none"> • 16-bit processor core with 41 DMIPS @ 32 MHz • On-chip Data Flash • Hardware MAC • Special Snooze power mode where ADC and serial interface can operate when the MCU is stopped.
Over the counter Pulse Oximeter	<ul style="list-style-type: none"> • LCD Display • Simple User interface 	78K0R/Lx3	<ul style="list-style-type: none"> • 16-bit processor core with 19 DMIPS @ 20 MHz

	<ul style="list-style-type: none"> Low power and low cost 		<ul style="list-style-type: none"> Integrated 12-bit ADC and LCD driver On-chip Op Amps for low cost analog front end implementation Low power
Clinical Pulse Oximeter	<ul style="list-style-type: none"> Support for more sophisticated analog front end DSP features like hardware MAC to enable fast processing from multiple vital sign signals Storage for calibration tables and archive measurement data. 	RL78/G13	<ul style="list-style-type: none"> 16-bit processor core with 41 DMIPS @ 32 MHz On-chip Data Flash Hardware MAC Special Snooze power mode where ADC and serial interface can operate when the MCU is stopped.
Low cost Digital Blood Pressure Monitor	<ul style="list-style-type: none"> Simple User interface LCD display Low power and low cost 	78K0R/Lx3	<ul style="list-style-type: none"> 16-bit processor core with 19 DMIPS @ 20 MHz Integrated 12-bit ADC and LCD driver On-chip Op Amps for low cost analog front end implementation Low power
Advanced Digital Blood Pressure Monitor	<ul style="list-style-type: none"> Support for more sophisticated analog front end and sensors Multi-lingual and fonts Storage for measurement data Communication port 	V850ES/JG3-L with USB	<ul style="list-style-type: none"> 32-bit processor core with 38 DMIPS @ 20 MHz Up to 1MB Flash Integrated USB function
Low cost Consumer Digital Blood Glucose Monitor	<ul style="list-style-type: none"> Integrated analog LCD display Low power and low cost 	78K0R/Lx3	<ul style="list-style-type: none"> 16-bit processor core with 19 DMIPS @ 20 MHz Integrated 12-bit ADC, 12-bit DAC, and LCD driver On-chip Op Amps for low cost analog front end implementation Low power
Sophisticated Digital Blood Glucose Monitor	<ul style="list-style-type: none"> Support for more sophisticated analog front end Multi-lingual and fonts Processing power required for additional features such as Continua Storage for measurement data Communication port 	V850ES/JG3-L with USB	<ul style="list-style-type: none"> 32-bit processor core with 38 DMIPS @ 20 MHz Up to 1MB Flash Integrated USB function
Portable Pulse and Heart Rate Monitor	<ul style="list-style-type: none"> Simple User interface LCD display Low power and low cost 	78K0R/Lx3	<ul style="list-style-type: none"> 16-bit processor core with 19 DMIPS @ 20 MHz Integrated 12-bit ADC and LCD driver On-chip Op Amps for low cost analog front end implementation Low power

Portable Pulse and Heart Rate Monitor for clinical use	<ul style="list-style-type: none"> • Support for more sophisticated analog front end • DSP features like hardware MAC to enable multiple vital sign derivation from the measured signal • Storage for calibration tables and archive measurement data. 	RL78/G13	<ul style="list-style-type: none"> • 16-bit processor core with 41 DMIPS @ 32 MHz • On-chip Data Flash • Hardware MAC • Special Snooze power mode where ADC and serial interface can operate when the MCU is stopped.
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1.1 Digital Thermometer

A patient's body temperature is important information for the physician to know about the physiological state of the individual. Digital thermometer need to be a low power device operating on a coin cell battery. The user interface should be very simple with few buttons and a LCD display. The analog to digital converter can be a 8-, 10- or 12 bit depending on the sensor and its accuracy requirement. There should be a provision for audio alarm when the reading is abnormal. Advanced models, such as the ones for hospitals, can have USB or wireless (Bluetooth or Zigbee) for transferring the data to an electronic patient record on a computer.

The temperature probe can be a thermistor, thermocouple, thermopile or an infrared radiation sensor depending on the application. Infrared thermometers are used for fast measurement. The amplifier is usually a current to voltage type with a bandwidth 0 – 5 Hz.

The basic block diagram of a digital thermometer is shown in Figure 1.

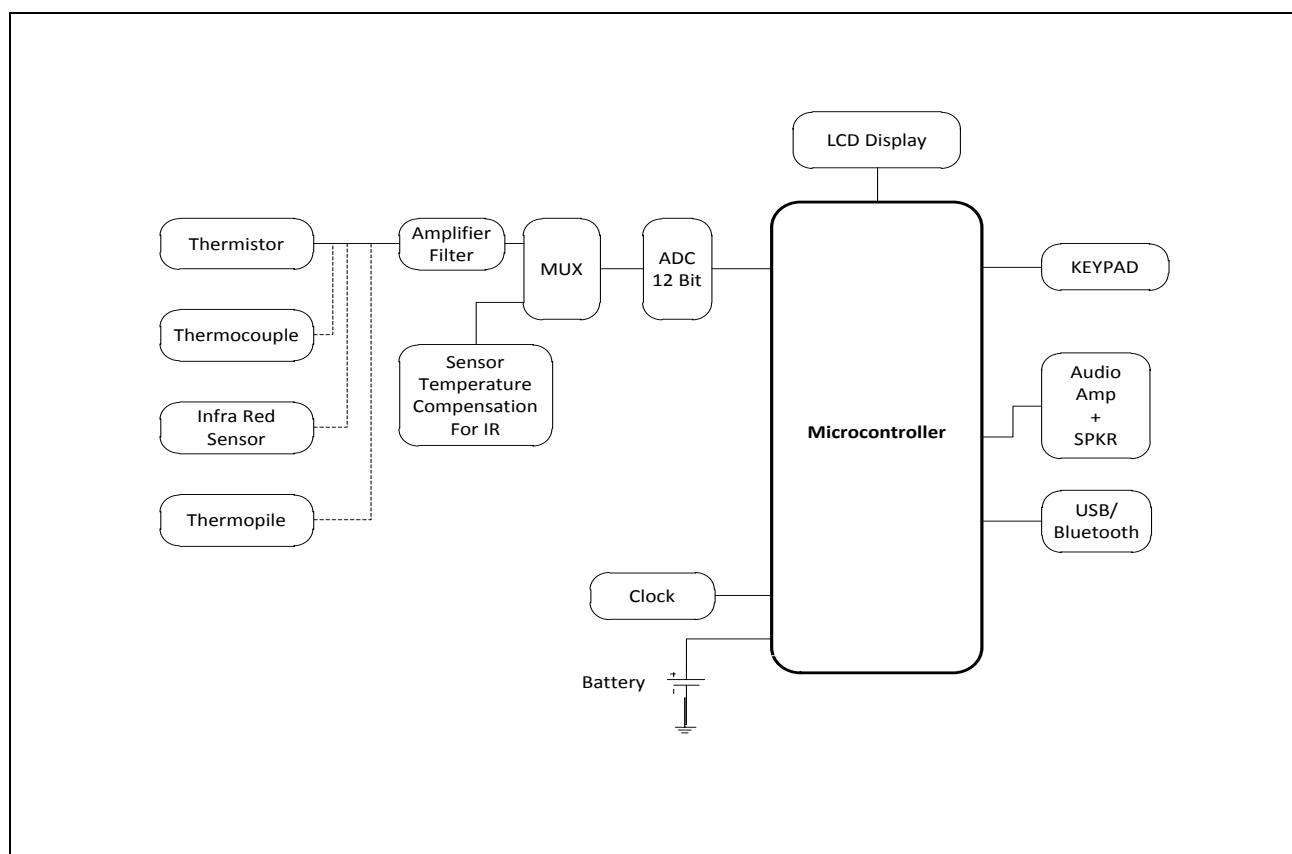


Figure 1 Block Diagram of Digital Thermometer

Low end thermometers will have LCD display with few keys for user interface. The analog filtering and amplification can be part of the SOC solution. An integrated buzzer circuit is enough for generating audio

alarms. Since these low end thermometers are standalone unit, and there is no need for a communication port to transfer the data. These devices should be powered by battery and should have very low power consumption.

A reference solution using Renesas 78K0R/Lx3 series microcontroller for a low end thermometer is shown in Figure 2. 78K0R/Lx3 with integrated 12-bit ADC and operational amplifier provides a cost effective, integrated solution.

Key features of 78K0R/Lx3 are

- 16-bit processor core with maximum frequency at 20MHz
- No need for external reset and voltage-detection
- Supports 3 different LCD drive options, to optimize LCD panel appearance, and to save standby current
- 78K0R/Lx3 Flash memory has security protection
- Flexible clocking scheme and multiple clocking sources for CPU and peripherals for low power
- Integrated operational amplifiers lower system cost and facilitate signal conditioning
- Integrated 12-bit ADC
- Low power consumption : 3.7 μA @ 32KHz, 190 μA @ 1 MHz, 5 mA @ 20 MHz
- Performance is at 19 DMIPS @ 20 MHz

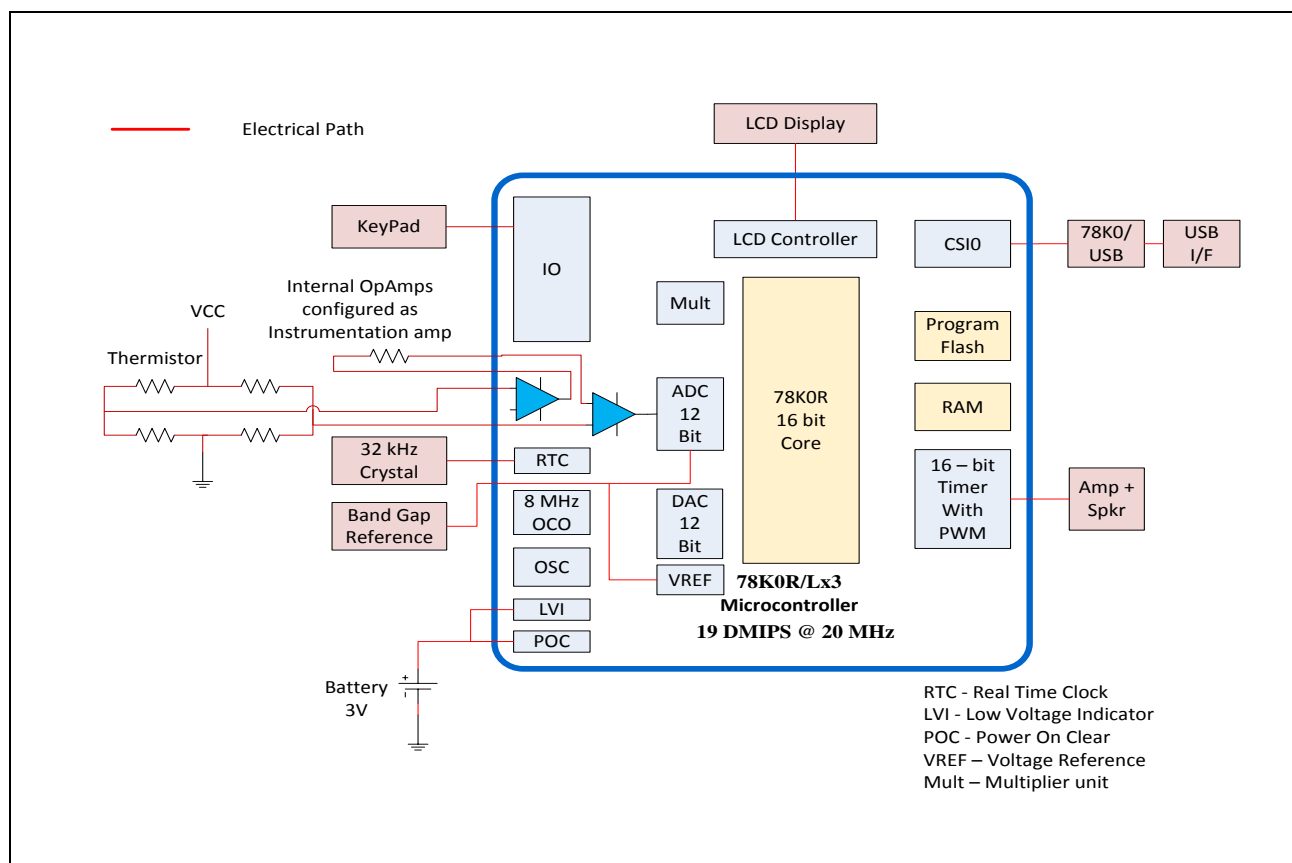


Figure 2 Reference implementation of Low cost Digital Thermometer

In hospitals, temperature measurement on patient is a routine care task and can lead to important decisions regarding investigations and treatments. High end thermometers are targeted for hospital environment especially intensive care units where they are used to continuously measure, record, and transfer temperature

data of the patient to an electronic patient record on a central computer or on a patient monitor. Temperature needs to be monitored continuously during surgery and anesthesia procedures. In these situations, temperature is measured continuously by utilizing contact type probes that use thermocouple or thermistor. These thermometers require storage for measurement data and a communication port to transfer it. This communication port can be USB or wireless like Bluetooth.

For intermittent measurement of patient temperature, hospitals utilize infra-red thermometers also. A reference design for intermittent temperature measurement thermometer utilizing infra-red sensor is shown in Figure 3. This design uses RL78/G13 with an external 20 MHz resonator to improve the clock accuracy better than on chip oscillator to improve the long term stability of measurements. With a stable clock, signal processing like oversampling and averaging can be applied to get better accuracy of the measurement. RL78/G13 with on-chip MAC function can provide capability to implement signal processing algorithms. It has a special Snooze Mode where ADC and serial interface can be left operational when the MCU is stopped. In many wireless networking, the radio is on to maintain the network with not actual data to be processed by the MCU. At this time, the MCU should be in Stop Mode to save power. However, when an actual payload arrives, the radio has to send the data to the MCU via the serial interface for immediate processing. A typical MCU requires an interrupt to wake up the MCU. The delay to process the interrupt could delay the processing of the data. In some cases, the delay would cause the data to be missed and require retransmission. The Snooze Mode enables the serial interface (or ADC) to be operational while the MCU is in Stop Mode to capture the data, reduce delay from the interrupt processing and to avoid unnecessary current consumption from any retransmission.

Key features of RL78/G13 are

- 16-bit processor core with 1.27DMIPS/MHz with maximum frequency at 32MHz
- On-chip hardware multiplier and accumulator
- On-chip oscillator with +/- 1% over temperature and voltage range
- Data flash for storing calibration data, and archival of measured data
- Very low power consumption: operational at 66μA/MHz (executing NOPs) and 0.57μA with only RTC and LVD on
- Special Snooze Mode where ADC and serial interface can operate when the MCU is stopped.
- Operating voltage is down to 1.6V to extend battery life

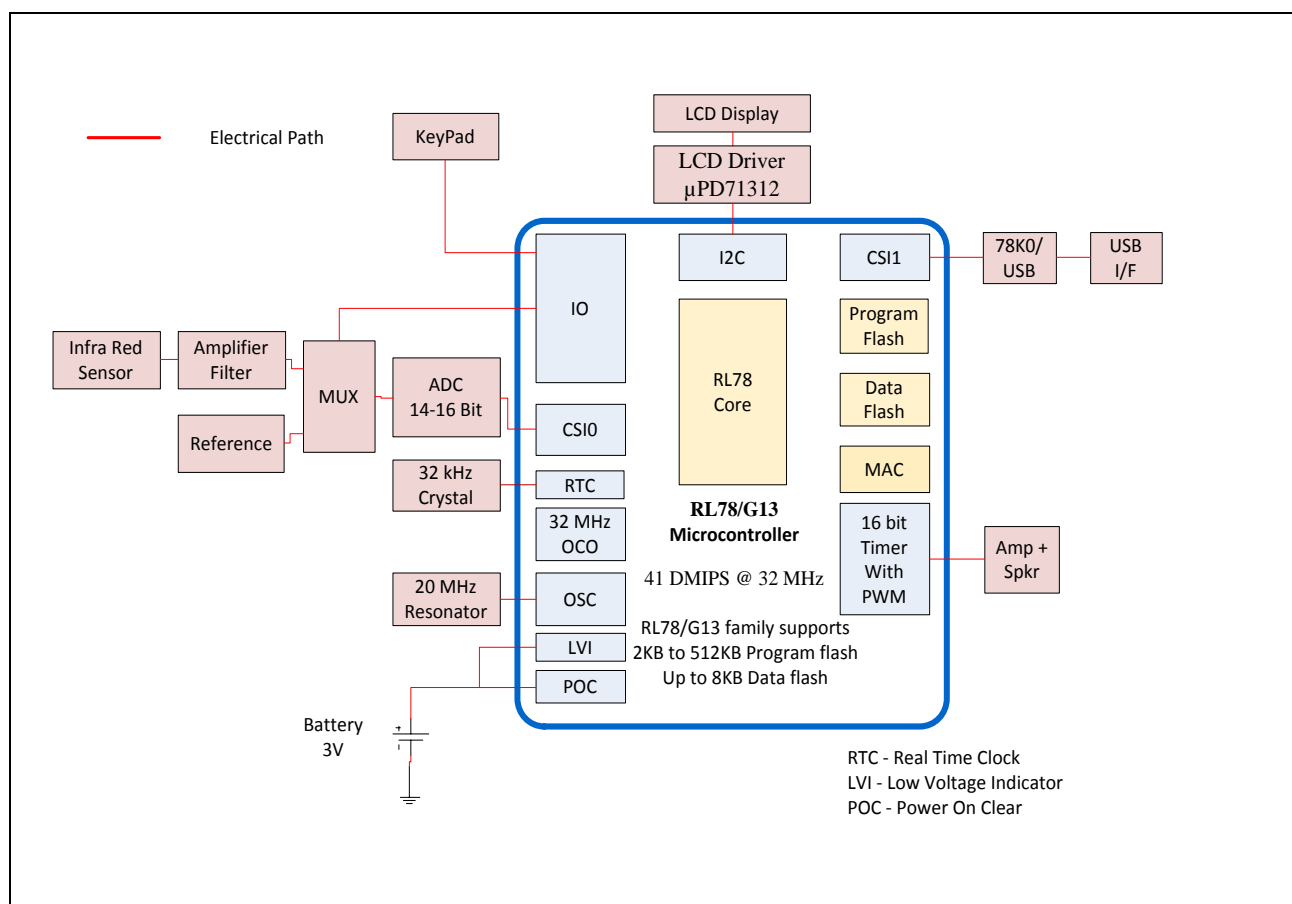


Figure 3 Reference implementation of Infrared Digital Thermometer

Table 2 Digital Thermometer Applicable Renesas Devices

Microcontroller	78K0R/Lx3	RL78/G13
Analog Components	On chip Op Amp	Op-amp (CMOS) HA1630xxx Series
Power Management	Zener Diodes RD series Backflow prevention HRV103A, HRV103B, HRV104B	
Protection	ESD protection diodes NNCD and NSAD Series	
LCD Controller	on-chip LCD driver	μ PD71312

Table 3 Digital Thermometer related Micro controller family

Feature	78K0R/Lx3	RL78/G13
Processor core	16-bit	16-bit
Performance	0.95DMIPS/MHz 19 DMIPS @ 20 MHz	1.27DMIPS/MHz 41 DMIPS @ 32 MHz
Flash	64KB to 128KB	2KB to 512KB
Data Flash	None	Up to 8KB
RAM	4KB to 7KB	2KB to 32KB
Operating Voltage	1.8V to 5.5V	1.6V to 5.5V
Power consumption	190uA @ 1MHz 5mA @ 20MHz 0.37uA stop mode	66 uA @ 1MHz ¹ 2.1mA @ 32MHz 0.2 uA stop mode

¹ MCU is executing NOPs

Table 4 Digital Thermometer related tools and technologies

	Low End Solution	High End Solution
Microcontroller	78K0R/Lx3	RL78/G13
Evaluation Boards	QB-78K0RLH3-TB	QB-R5F100LE-TB
Software Libraries	<ul style="list-style-type: none"> ADPCM-SP Self-Programming EEPROM Emulation Library 	<ul style="list-style-type: none"> ADPCM-SP Self-Programming EEPROM Emulation library Data flash access library
Software Development Tools	Cube suite , PM+, Applilet code generator	IAR, Cube suite+, Applilet code generator
Hardware Debugger	Minicube2	E1
Application Notes	ADPCM-SP Voice Compression/Expansion Software Package	Portable to RL78 as it uses 78K0R core
	78K0R/Kx3-L Low Power Consumption Operation	RL78 Low Power MCU Application Note
	Flash Protection and security setting guide	Flash Protection and security setting guide

1.2 Pulse Oximeter

In modern medical practice, the blood oxygen level is considered one of the important vital signs of the body along with the more traditional ones, such as blood pressure, heart rate, body temperature, and breathing rate. Pulse oximeters provide early information on problems in the respiratory and circulatory systems.

Pulse oximetry combines the principles of photoplethysmography and spectrophotometry to measure noninvasively the oxygen saturation of arterial blood. This is an important tool to assess the status of patient oxygenation. A pulse oximeter is connected to the patient using a finger probe to detect the actual level of oxygen in the patient's blood stream. This is the one of the most advanced patient monitoring technology. It provides safe, continuous and cost effective monitoring of blood oxygenation noninvasively at the patient bedside. Pulse oximeters are widely used in clinical practice. Recently, these devices are also used in physical exercise training and sleep studies.

The main principle of pulse oximetry is based on Lambert Beer's law with differential light absorption of two wavelengths. Oxygen saturation is determined by monitoring pulsations at two wave lengths and then comparing the absorption spectra of oxyhemoglobin and deoxygenated hemoglobin. Pulse oximetry uses the measurement technique, which includes arterial pulsation to differentiate the light absorption in the measuring site due to skin, tissue and venous blood from that of arterial blood.

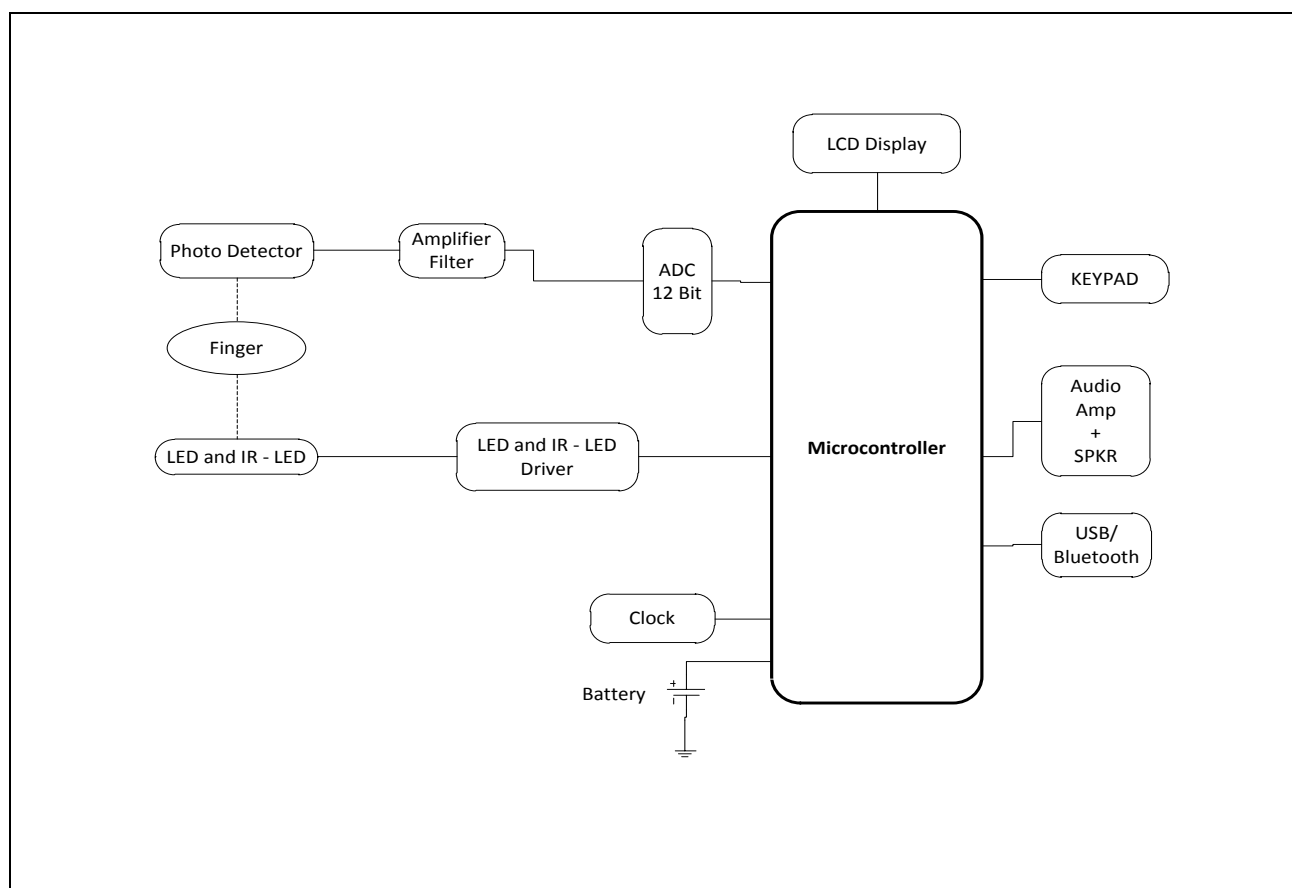


Figure 4 Block Diagram of a Pulse Oximeter

A low cost solution can be implemented using 78K0R/Lx3 family of microcontroller. This has on-chip operational amplifiers which can be used for the analog signal processing like current to voltage conversion and voltage amplification. A reference solution using Renesas 78K0R/Lx3 series micro controller for a low end pulse oximeter is presented in Figure 5. 78K0R/Lx3 with integrated 12 bit ADC and operational amplifier provides a cost effective solution.

Key features of 78K0R/Lx3 are

- 16-bit processor core with maximum frequency at 20MHz
- No need for external reset and voltage-detection
- Supports 3 different LCD drive options, to optimize LCD panel appearance, and to save standby current
- 78K0R/Lx3 Flash Memory has security protection
- Flexible clocking scheme and multiple clocking sources for CPU and peripherals for low power
- Integrated operational amplifiers lower system cost and facilitate signal conditioning
- Integrated 12-bit ADC and 12-bit DAC
- Low power consumption : 3.7 μ A @ 32KHz, 190 μ A @ 1 MHz, 5 mA @ 20 MHz
- Performance is at 19 DMIPS @ 20 MHz

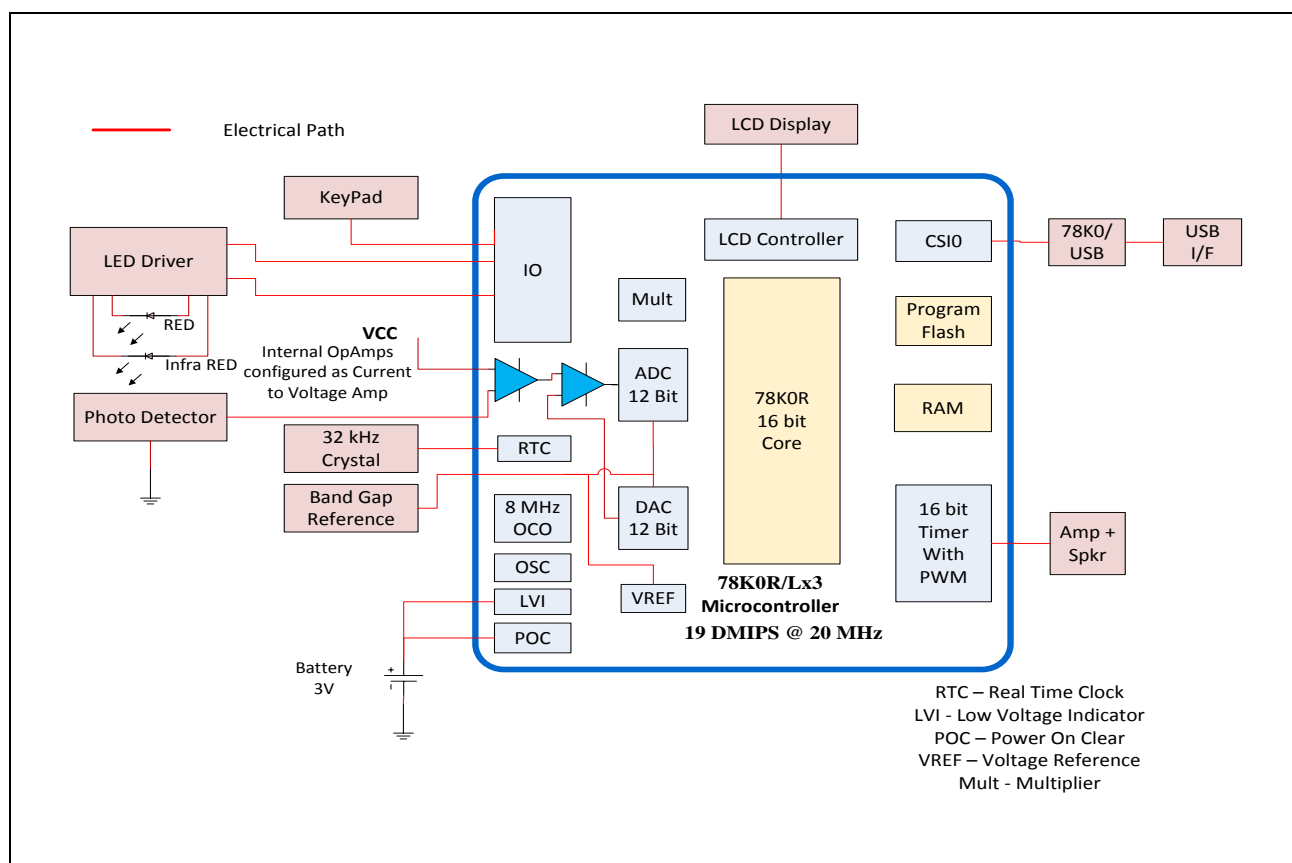


Figure 5 Reference implementation of low cost Pulse Oximeter

A high end design, where a dedicated analog front end is required for better accuracy, can be implemented using RL78/G13. The more sophisticated analog front end can be paired with enhanced DSP features like hardware MAC to improve the diagnostics. Data flash can be used to store calibration tables and archive measurement data. Gain settings for programmable gain amplifier in the analog front end can be altered using digital IO pins. A more advanced system could measure pulse rate from the same signal, and the RL78 can operate up to 32MHz to handle the increased computation. An external 20 MHz resonator is used to improve the stability and accuracy of the clock required for high accuracy system. With a stable clock, signal processing like oversampling and averaging can be applied to get better accuracy of the measurement.

Key features of RL78/G13 are

- 16-bit processor core with 1.27DMIPS/MHz with maximum frequency at 32MHz
- On-chip hardware multiplier and accumulator
- Data flash for storing calibration data, and archival of measured data
- Very low power consumption: operational at 66 μ A/MHz (executing NOPs) and 0.57 μ A with only RTC and LVD on
- Special Snooze Mode where ADC and serial interface can operate when the MCU is stopped.
- Safety features such as clock monitoring, Flash and RAM check

A reference implementation of multipurpose pulse oximeter using RL78/G13 is shown in Figure 6.

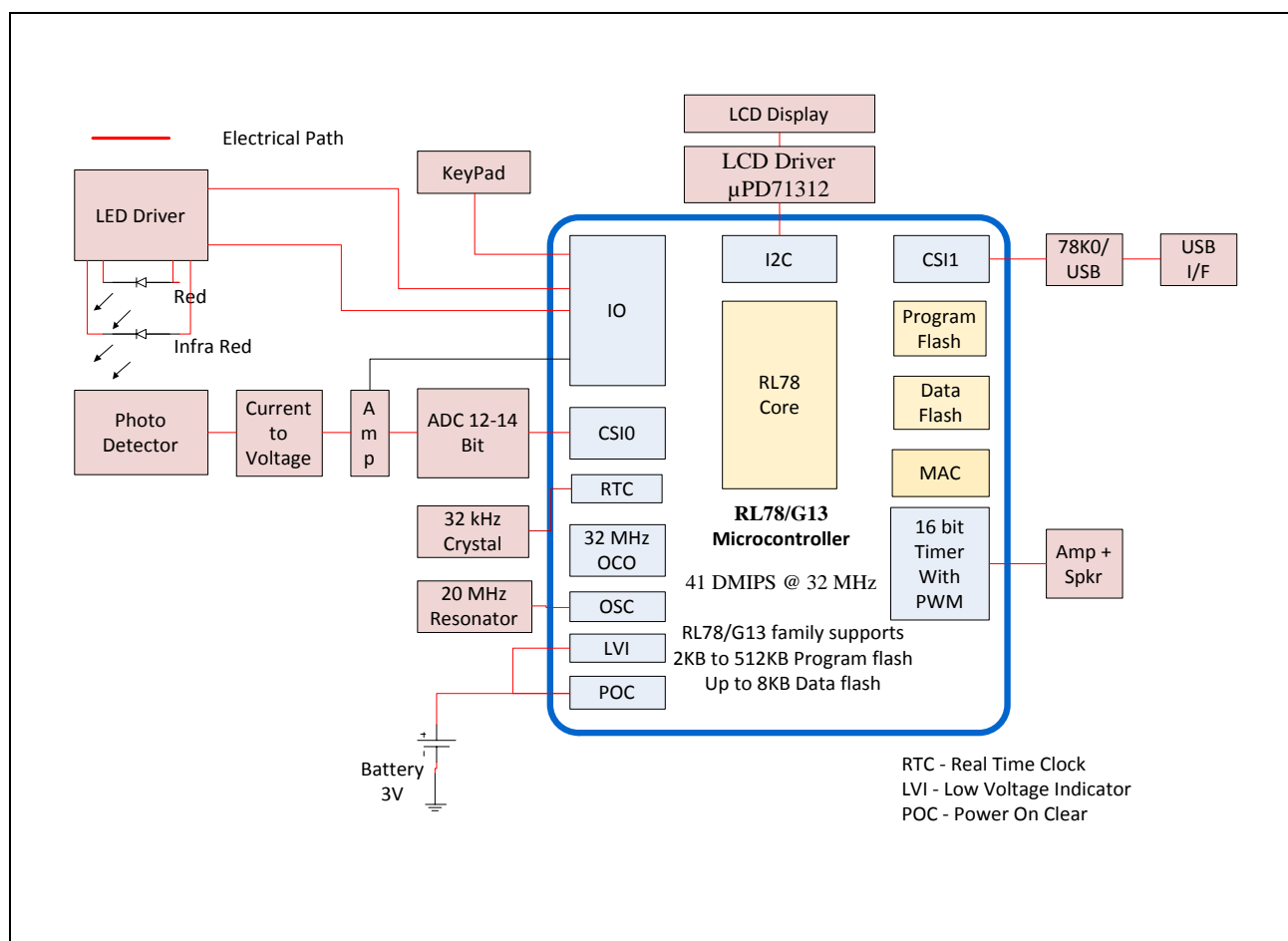


Figure 6 Reference implementation of Low power Multipurpose Pulse Oximeter

Table 5 Pulse Oximeter applicable Renesas Devices

Microcontroller	78K0R/Lx3	RL78/G13
Analog Components	On-chip Op Amp	Op-amp (CMOS) HA1630xxx Series
Power Management	Zener Diodes RD series Backflow prevention HRV103A, HRV103B, HRV104B	
Protection	ESD protection diodes NNCD and NSAD Series	
LCD Controller	On-chip	μPD71312

Table 6 Pulse Oximeter Related Microcontroller

Feature	78K0R/Lx3	RL78/G13
Processor core	16-bit	16-bit
Performance	0.95DMIPS/MHz 19 DMIPS @ 20 MHz	1.27DMIPS/MHz 41 DMIPS @ 32 MHz
Flash	64KB to 128KB	2KB to 512KB
Data Flash	None	Up to 8KB
RAM	4KB to 7KB	2KB to 32KB
Operating Voltage	1.8V to 5.5V	1.6V to 5.5V
Power consumption	190uA @ 1MHz, 5mA @ 20MHz, 0.37μA stop mode	66 μA @ 1MHz ¹ , 2.1 mA @ 32 MHz 0.2 μA stop mode

¹ MCU is executing NOPs

Table 7 Pulse Oximeter related Tools and Technologies

	Low End Solution	High End Solution
Microcontroller	78K0R/Lx3	RL78/G13
Evaluation Boards	QB-78K0RLH3-TB	QB-R5F100LE-TB
Software Libraries	<ul style="list-style-type: none"> ADPCM-SP Self-Programming EEPROM Emulation library 	<ul style="list-style-type: none"> ADPCM-SP Self-Programming EEPROM Emulation library Data flash access library 256 point FFT library
Software Development Tools	Cube suite, PM+, IAR, Applilet code generator	Cube suite+, IAR, Applilet code generator
Hardware Debugger	Minicube2	E1
Application Notes	ADPCM-SP Voice Compression/Expansion Software Package	Portable to RL78 as it uses 78K0R core
	78K0R/Kx3-L Low Power Consumption Operation	RL78 Low Power MCU Application Note
	Flash Protection and security setting guide	Flash Protection and security setting guide

1.3 Digital Blood Pressure Monitor

The measurement of the arterial blood pressure is of great clinical significance mainly for the detection and follow-up of hypertension which affects about one third of the adult population in the western world. Blood pressure varies considerably throughout the day and frequent blood pressure monitoring is required in many home healthcare situations.

Most of the commercial noninvasive automatic blood pressure monitors use either oscillometry or automatic detection of Korotkoff sounds or both. Both methods use a cuff to the upper arm and the systolic and diastolic pressures are determined automatically using an electronic instrument. The instrument has an electric pump and a pressure release valve apart from the electronics required to convert and display blood pressure readings. The cuff is inflated by an electric pump and deflated by a pressure-release valve. Proprietary algorithms are used to calculate systolic and diastolic blood pressure values. Automatic oscillometric blood pressure monitors are the dominant types of noninvasive blood pressure devices. High end blood pressure monitors are multipurpose instruments and support measurement of many vital signs. High end machines also include measurements like heart rate, temperature and respiration. More advanced machines with graphical display capability also combine ECG monitoring along with blood pressure measurement. As the position of the arm affects the accuracy of the blood pressure measurements, MEMS technology is used to detect the position of the arm relative to the heart and necessary corrections can be applied to make the measurement more accurate.

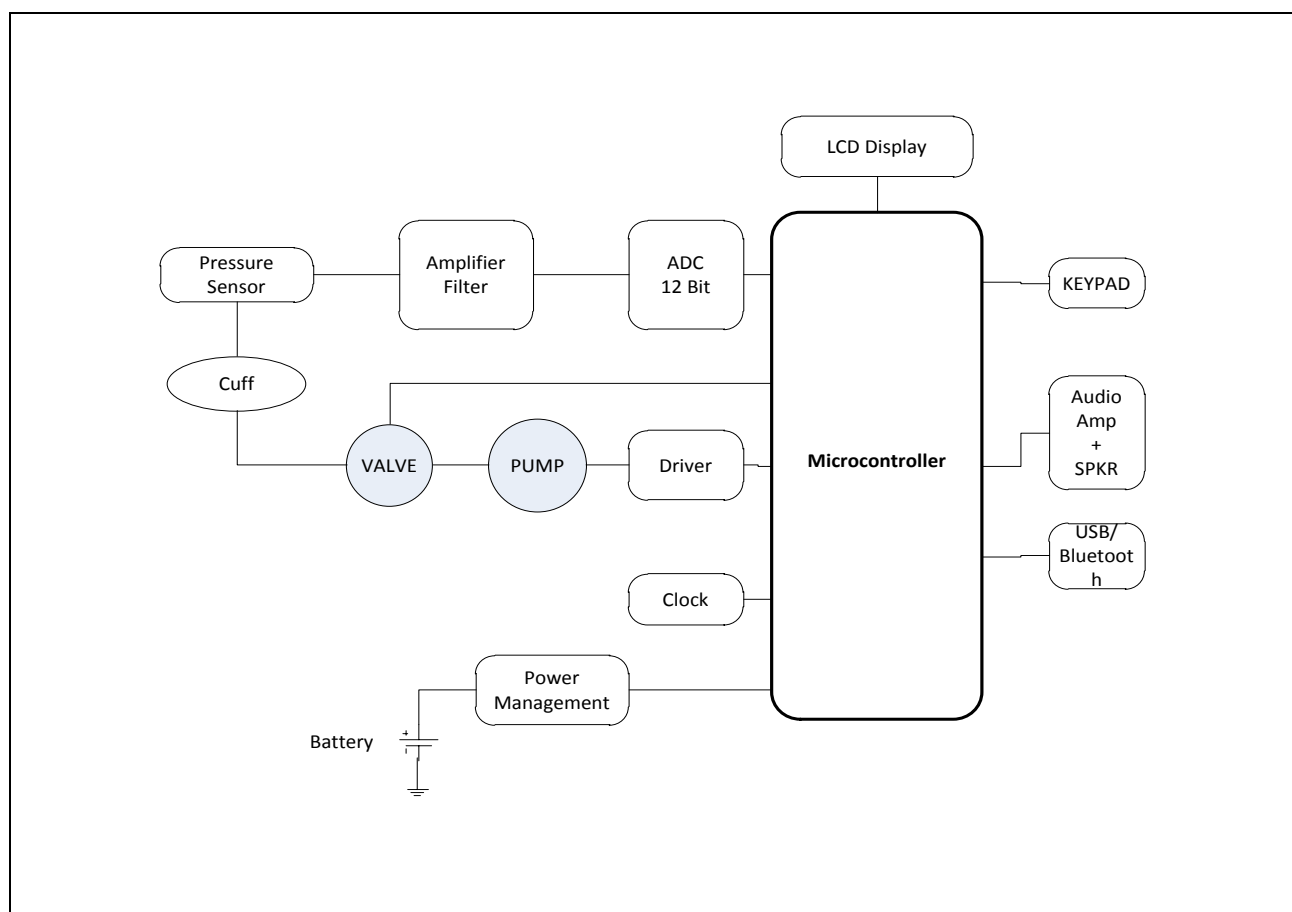


Figure 7 Block diagram of Blood Pressure Monitor

A low cost solution for blood pressure measurement can be implemented using 78K0R/Lx3 family of microcontroller as shown in Figure 8. 78K0R/Lx3 has on-chip operational amplifiers which can be used for implementing the amplification and filtering of the signal. The on-chip 12-bit ADC helps in realizing a cost effective instrument with precise pressure measurement. The pressure release control valve and the pump can be controlled by using digital IO lines.

Key features of 78K0R/Lx3 are

- 16-bit processor core with maximum frequency at 20MHz
- No need for external reset and voltage-detection
- Supports 3 different LCD drive options, to optimize LCD panel appearance, and to save standby current
- 78K0R/Lx3 Flash Memory has security protection
- Flexible clocking scheme and multiple clocking sources for CPU and peripherals for low power
- Integrated operational amplifiers lower system cost and facilitate signal conditioning
- Integrated 12-bit ADC and 12-bit DAC
- Low power consumption : 3.7 μ A @ 32KHz, 190 μ A @ 1 MHz, 5 mA @ 20 MHz
- Performance is at 19 DMIPS @ 20 MHz

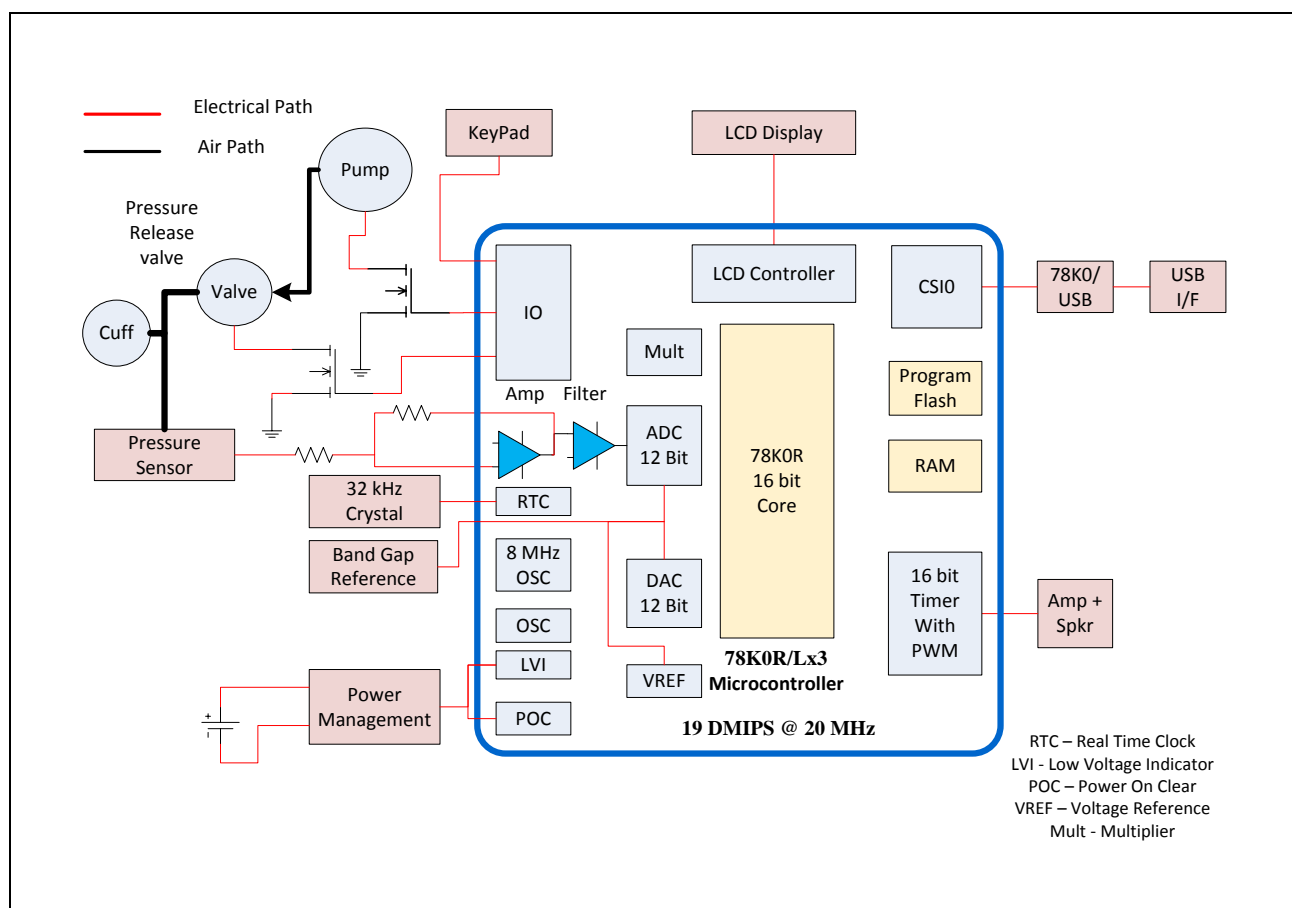


Figure 8 Low cost implementation using 78K0R/Lx3 device

A high end reference design with more accurate dedicated analog front end and an accelerometer (MEMs) to detect the elevation of the arm to the heart is shown in Figure 9. These high end systems require more processing and uses V850ES/JG3-L with USB to implement blood pressure monitor. This microcontroller uses an external analog front end with 12-16 bit ADC to capture the signal. This chip has a maximum of 1024 KB flash which provides ample storage space to implement multi-lingual fonts, data archiving and trend display. Available 32-bit computing power and flash size supports inclusion of more software functionality including the support to process other vital signal data such as ECG and arm elevation. Further it has USB function that which can support **Continua™** for an end-to-end communication architecture that delivers patients data to the doctors. Its low power operation supports a long life for the battery operation.

Key features of V850ES/JG3-L with USB are

- Delivers 38 DMIPS performance @ 20 MHz
- Up to 1MB Flash
- Integrated USB function
- 1.5 μ A in STOP mode
- Internal Oscillator for WDT

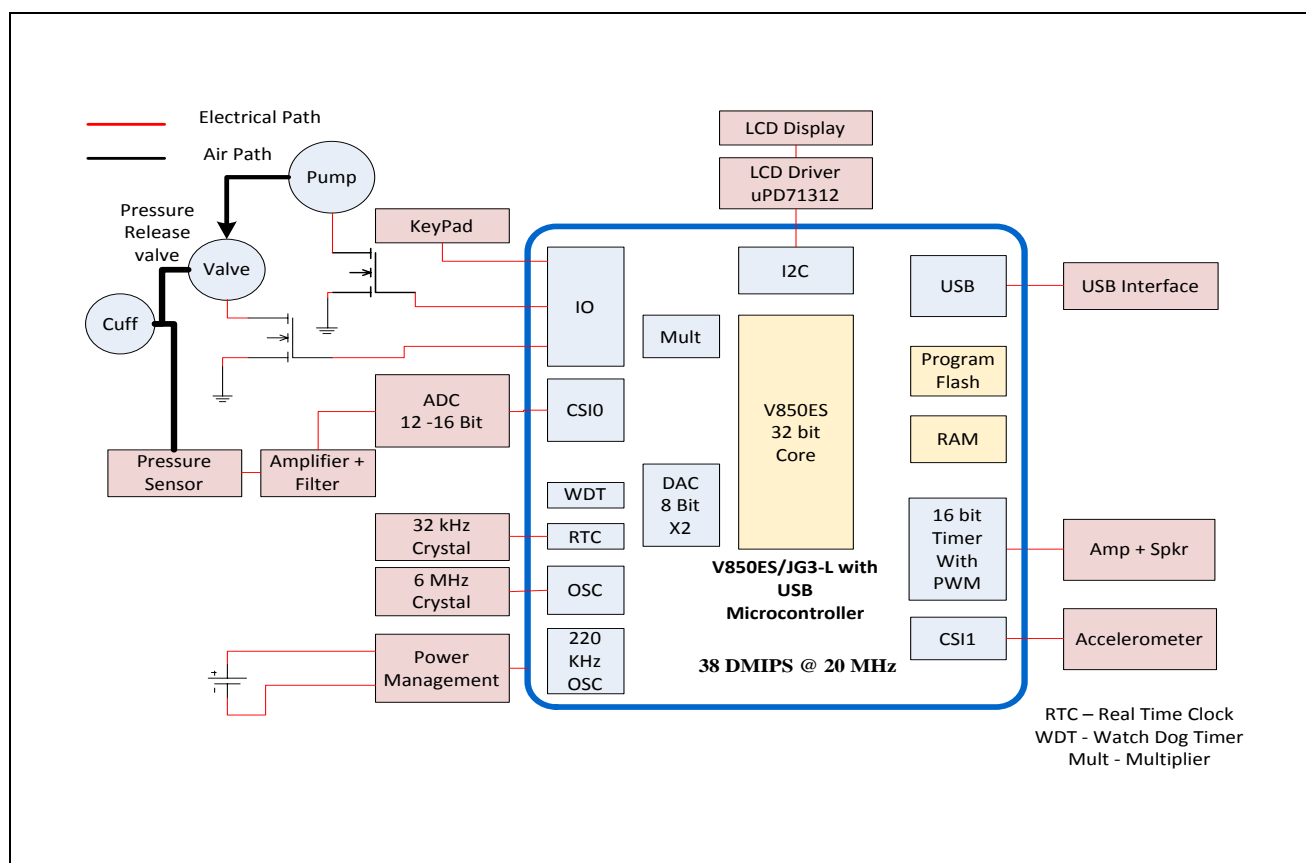


Figure 9 Hardware Implementation Diagram using V850ES/JG3-L with USB

Table 8 Blood Pressure Monitor applicable Renesas Devices

Microcontroller	78K0R/Lx3	V850ES/JG3-L with USB
Analog Components	On-chip Op Amp	Op-amp (CMOS) HA1630xxx Series
Power Management	Zener Diodes RD series Backflow prevention HRV103A, HRV103B, HRV104B	Zener Diodes RD series Backflow prevention HRV103A, HRV103B, HRV104B
Protection	ESD protection diodes NNCD and NSAD Series	ESD protection diodes NNCD and NSAD Series
Motor Control	BLDC Motor with MOSFETs configured as H- Bridge	BLDC Motor with MOSFETs configured as H- Bridge
LCD Controller	On-chip	μPD71312

Table 9 Blood Pressure Monitor related Microcontroller family

Feature	78K0R/Lx3	V850ES/JG3-L with USB
Processor core	16-bit	32-bit
Performance	0.95 DMIPS/MHz 19 DMIPS @ 20 MHz	1.9 DMIPS/MHz 38 DMIPS @ 20 MHz
Flash	64KB to 128KB	256KB to 1024 KB
Data Flash	None	None
RAM	4KB to 7KB	40KB to 80KB
Operating Voltage	1.8V to 5.5V	2V to 3.6 V
Power consumption	190uA @ 1MHz, 5mA @20MHz, 0.37μA stop mode	6 mA @ 10 MHz, 14 mA @ 20MHz 1.5μA stop mode

Table 10 Blood Pressure Monitor related Tools and Technologies

	Low End Solution	High End Solution
Microcontroller	78K0R/Lx3	V850ES/JG3-L with USB
Evaluation Boards	QB-78K0RLH3-TB	QB-V850ESJG3LUSB-TB
Software Libraries	<ul style="list-style-type: none"> ADPCM-SP Self-Programming EEPROM Emulation library 	<ul style="list-style-type: none"> ADPCM-SP Self-Programming
Software Development Tools	Cube suite, PM+, Applilet code generator	IAR, Cube suite, Applilet code generator
Hardware Debugger	Minicube2	E1, Minicube2
Application Notes	78K0R/Kx3-L Low Power Consumption Operation	
	ADPCM-SP Voice Compression/Expansion Software Package	
	Flash Protection and security setting guide	Flash Protection and security setting guide
Solution Platform		Continua Demonstration platform with V850ES/Jx3-L (for more information ,contact sales)

1.4 Digital Blood Glucose Monitor

Most of the consumer grade digital blood glucose meters use electrochemical type strips to find the glucose level in units of mg/dL or mmol/L. These strips have electrodes to which a precise bias voltage is applied with a digital-to-analog converter (DAC), and a current proportional to the glucose in the blood is measured as a result of the electrochemical reaction on the test strip. There is a need for calibration of the meter before taking reading and this can be applied by inputting the type number of the strip which in turn defines the parameters to get accurate readings. The test strips are temperature dependent so ambient temperature measurement and temperature compensation are required. Digital blood glucose meters normally require a custom LCD display with very few user interface buttons. They should record the reading along with actual time of the test and able to provide a month of information on recall. High end meters support graphical display and provide a trend graph of the readings. They will have a USB or wireless connectivity to transfer archived data to a computer on demand.

Portable meters are normally powered by lithium coin cell or alkaline batteries. As long battery life is the main requirement, the electronics should consume very little power and microcontroller should support good power saving modes.

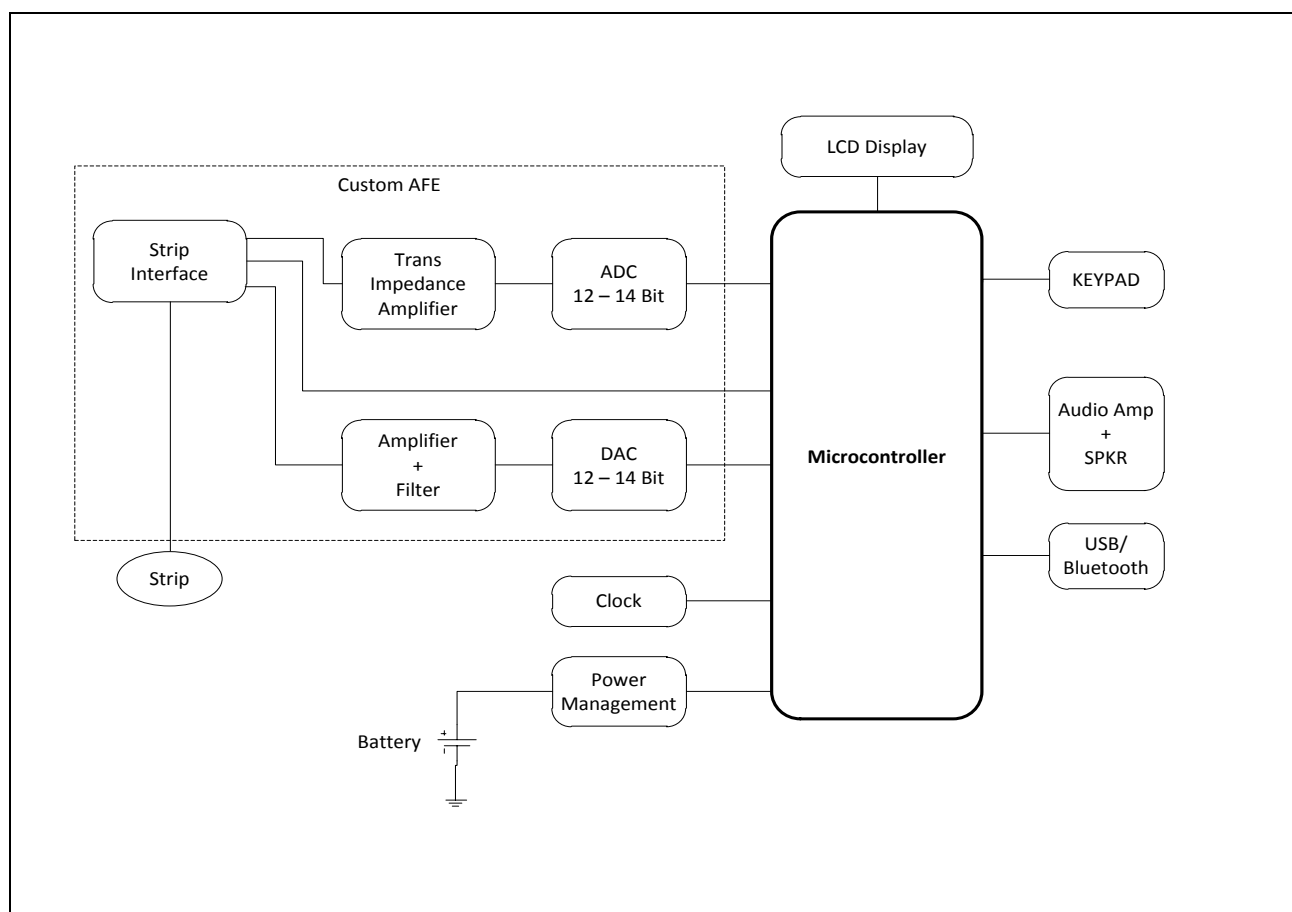


Figure 10 Block Diagram of Digital Blood Glucose Monitor

A low cost solution using 78K0R/Lx3 is presented in Figure 11. The transimpedance amplifier required to read the current from the test strip is implemented using the on-board op amps to reduce system cost. On chip 12-bit DAC is used to generate the necessary potential required for the electrodes in the strip. Integrated 12-bit ADC is used to digitize the analog signal from the amplifier.

Key features of 78K0R/Lx3 are

- 16-bit processor core with maximum frequency at 20MHz
- No need for external reset and voltage-detection
- Supports 3 different LCD drive options, to optimize LCD panel appearance, and to save standby current
- 78K0R/Lx3 Flash Memory has security protection
- Flexible clocking scheme and multiple clocking sources for CPU and peripherals for low power
- Integrated operational amplifiers lower system cost and facilitate signal conditioning
- Integrated 12-bit ADC and 12-bit DAC
- Low power consumption : 3.7 μA @ 32KHz, 190 μA @ 1 MHz, 5 mA @ 20 MHz
- Performance is at 19 DMIPS @ 20 MHz

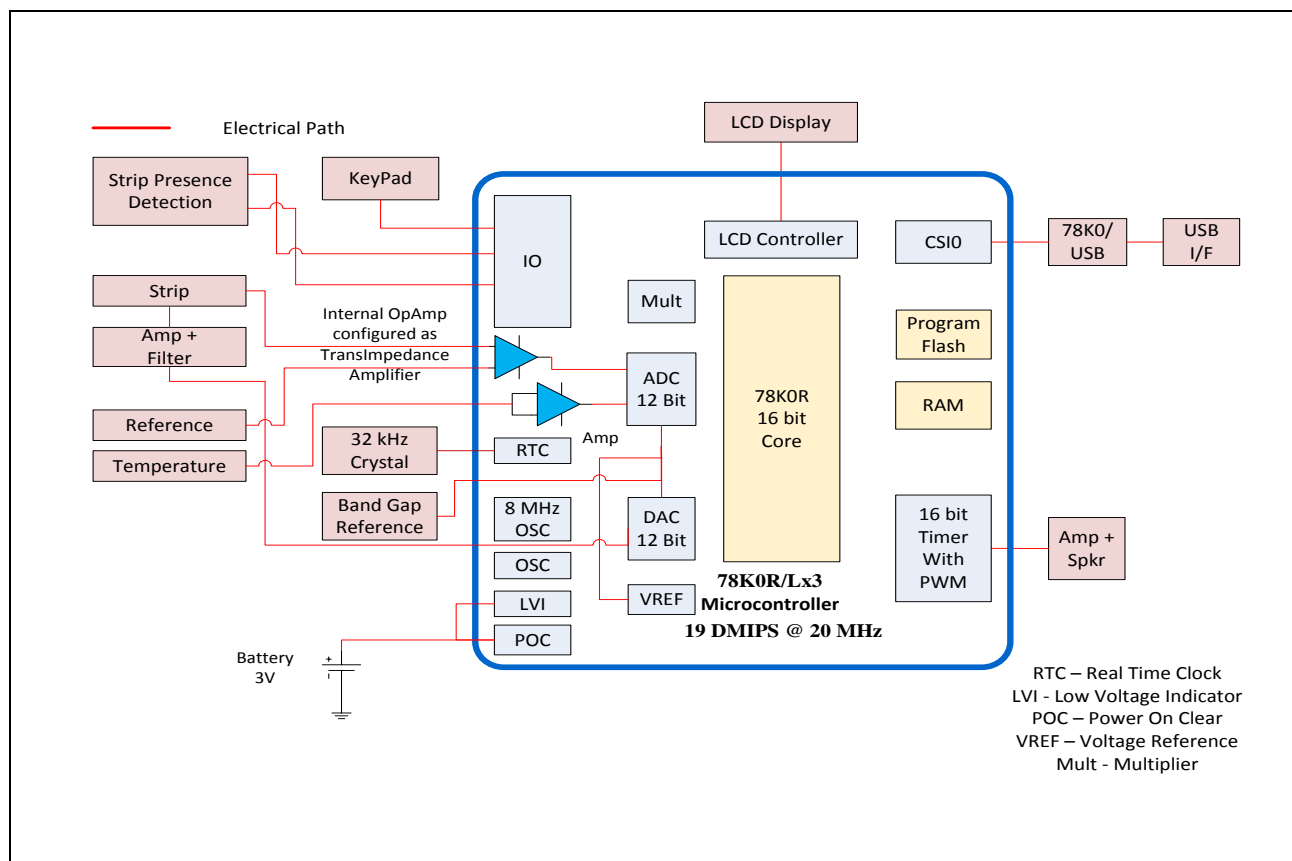


Figure 11 Reference implementation of Low cost Blood Glucose Meter

An alternative design which can address high end market is presented in Figure 12. This design is based on 32-bit V850ES/JG3-L with USB. It has an integrated USB for support of **Continua™** which enables an end-to-end communication architecture to automatically send data from patients to doctors. This design uses an advanced front end for more accuracy. The 32-bit microcontroller is faster and energy efficient to support additional features (blood sugar level trending etc.). With up to 1MB Flash memory, the processor can support high end functionality like multi-lingual fonts. A Blood Glucose Meter Continua Platform is available for demonstration.

Key features of V850ES/JG3-L are

- Low power and energy efficient, consuming 0.3mA/DMIPS
- Delivers 1.9DMIPS/MHz
- Up to 1MB Flash
- Integrated USB function
- 1.5 μ A in STOP mode
- Internal Oscillator for WDT

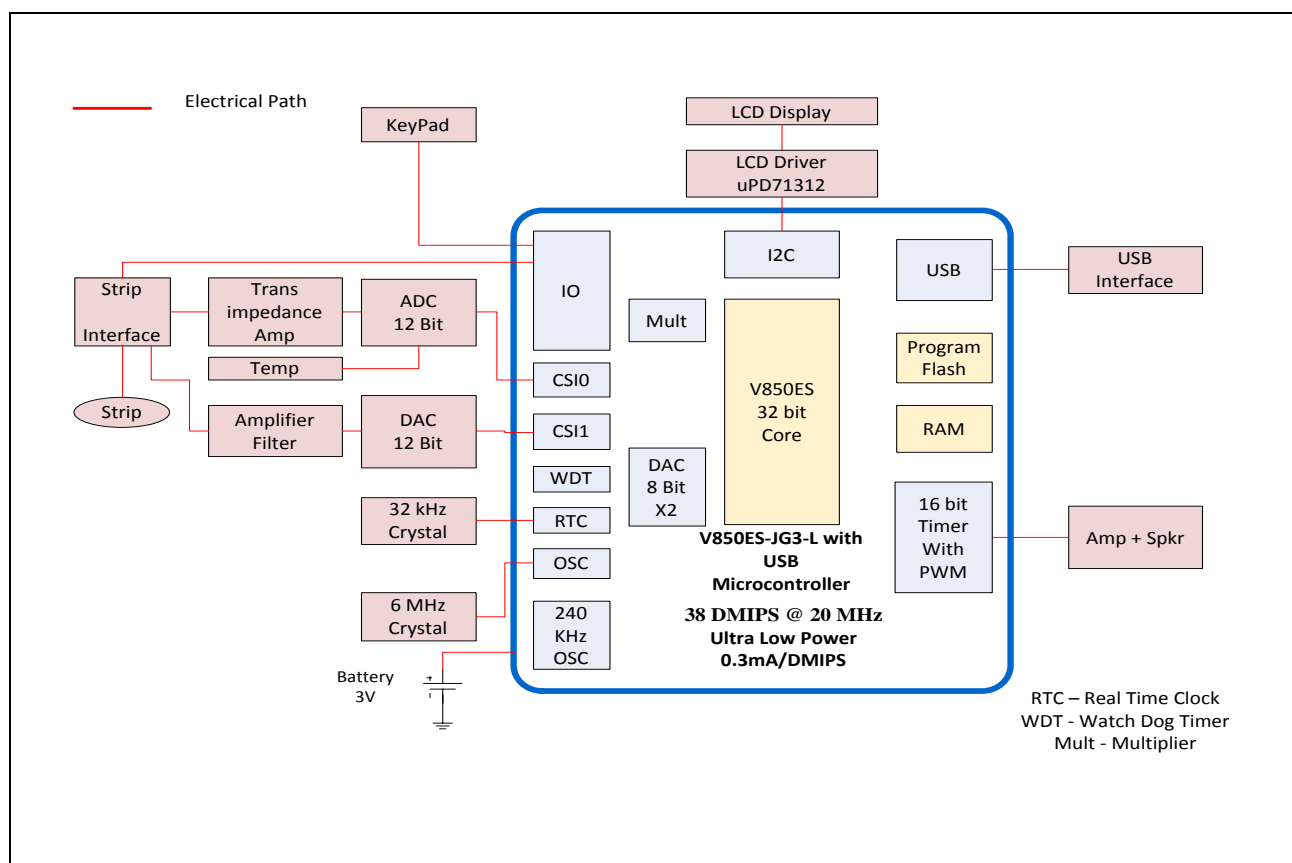


Figure 12 Reference implementation of High End Digital Blood Glucose Monitor

Table 11 Blood Glucose Monitor applicable Renesas Devices

Microcontroller	78K0R/Lx3	V850ES/JG3-L with USB
Analog Components	On-chip	Op-amp (CMOS) HA1630xxx Series
Power Management	Zener Diodes RD series Backflow prevention HRV103A, HRV103B, HRV104B	
Protection	ESD protection diodes NNCD and NSAD Series	
LCD Controller	On-chip LCD segment driver	μPD71312

Table 12 Blood Glucose Monitor related Microcontroller family

Feature	78K0R/Lx3	V850ES/JG3-L with USB
Processor core	16-bit	32-bit
Performance	0.95 DMIPS/MHz 19 DMIPS @ 20 MHz	1.9 DMIPS/MHz 38 DMIPS @ 20 MHz
Flash	4KB to 512KB	256KB to 1MB
RAM	4KB to 7KB	40KB to 80KB
Operating Voltage	1.8V to 5.5V	2V to 3.6 V
Power consumption	190uA @ 1MHz, 5mA @20MHz, 0.37uA stop mode	6 mA @ 10 MHz, 14 mA @ 20MHz 1.5uA stop mode

Table 13 Blood Glucose Monitor related Tools and Technologies

	Low cost solution	High end solution
Microcontroller	78K0R/Lx3	V850ES/JG3-L with USB
Evaluation Boards	Target board	Target board
Software Libraries	<ul style="list-style-type: none"> ADPCM-SP Self-Programming EEPROM Emulation library 	<ul style="list-style-type: none"> ADPCM-SP Self-Programming
Software Development Tools	IAR, Cube suite, PM+, Applilet code generator	IAR, Cube suite, PM+, Applilet code generator
Hardware Debugger	Minicube2	Miniube2
Application Notes	ADPCM-SP Voice Compression/Expansion Software Package	V850 Improves BGM design
	78K0R/Kx3-L Low Power Consumption Operation	-
	Flash Protection and security setting guide	Flash Protection and security setting guide
Solution Platform	-	Continua Demonstration platform with V850ES/Jx3-L (for more information, contact sales)

1.5 Portable Digital Pulse / Heart Rate monitor

The heart rate is a simple indicator of cardiac function during daily life and exercise. The heart rate is the number of contractions of the heart per minute, and the pulse rate is defined as the number of arterial pulses per minute. Usually both rates are same for a healthy person. Heart rates can be measured using either a finger photoplethysmography (PPG) sensor or by acquiring the electro cardiogram (ECG). For portable applications, different type of sensor technologies to monitor vibration, mechanical force can be used. These portable instruments operate on battery and very low power consumption is essential. Low power wireless technologies are used to transmit heart rate to a monitor during exercise routines to measure the heart rate variation.

A block diagram of a typical finger heart rate / pulse rate monitor is shown in Figure 13.

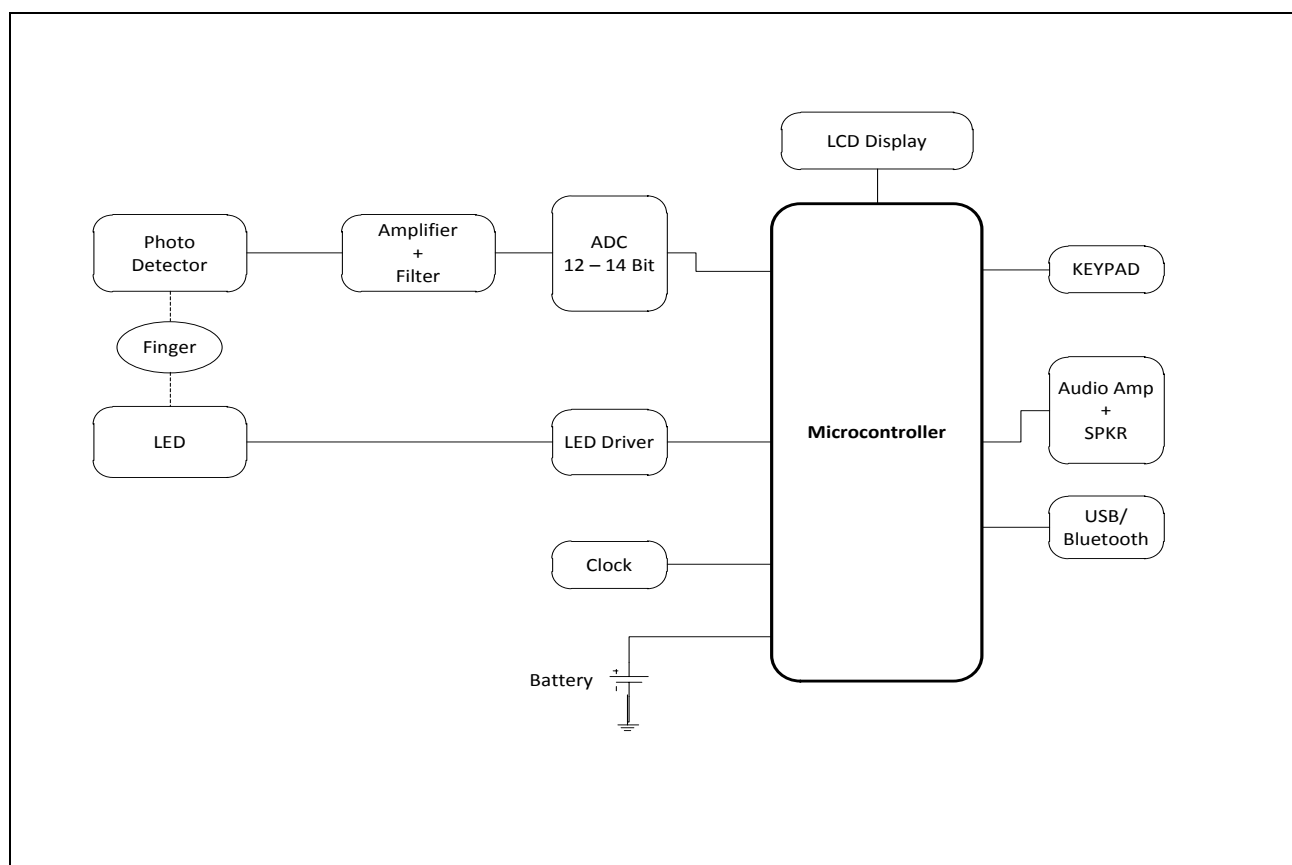


Figure 13 Block Diagram of Digital Pulse / Heart Rate monitor using finger tip

A low cost implementation using 78K0R/Lx3 is shown in Figure 14. 78K0R/Lx3 with on-chip operational amplifiers and 12-bit ADC provide most of the hardware required for the design. The signal from the finger probe is converted to voltage and amplified by on chip operational amplifiers before digitized by the 12-bit ADC. The digitized signal is further processed in the digital domain to derive accurate heart rate and pulse rate. On-chip LCD segment driver provides the display capability.

Key features of 78K0R/Lx3 are

- 16-bit processor core with maximum frequency at 20MHz
- No need for external reset and voltage-detection
- Supports 3 different LCD Drive options, to optimize LCD panel appearance, and to save standby current
- 78K0R/Lx3 Flash Memory has security protection
- Flexible clocking scheme and multiple clocking sources for CPU and peripherals for low power
- Integrated operational amplifiers lower system cost and facilitate signal conditioning
- Integrated 12-bit ADC and 12-bit DAC
- Low power consumption : 3.7 μ A @ 32kHz, 190 μ A @ 1 MHz, 5 mA @ 20 MHz
- Performance is 19 DMIPS @ 20 MHz

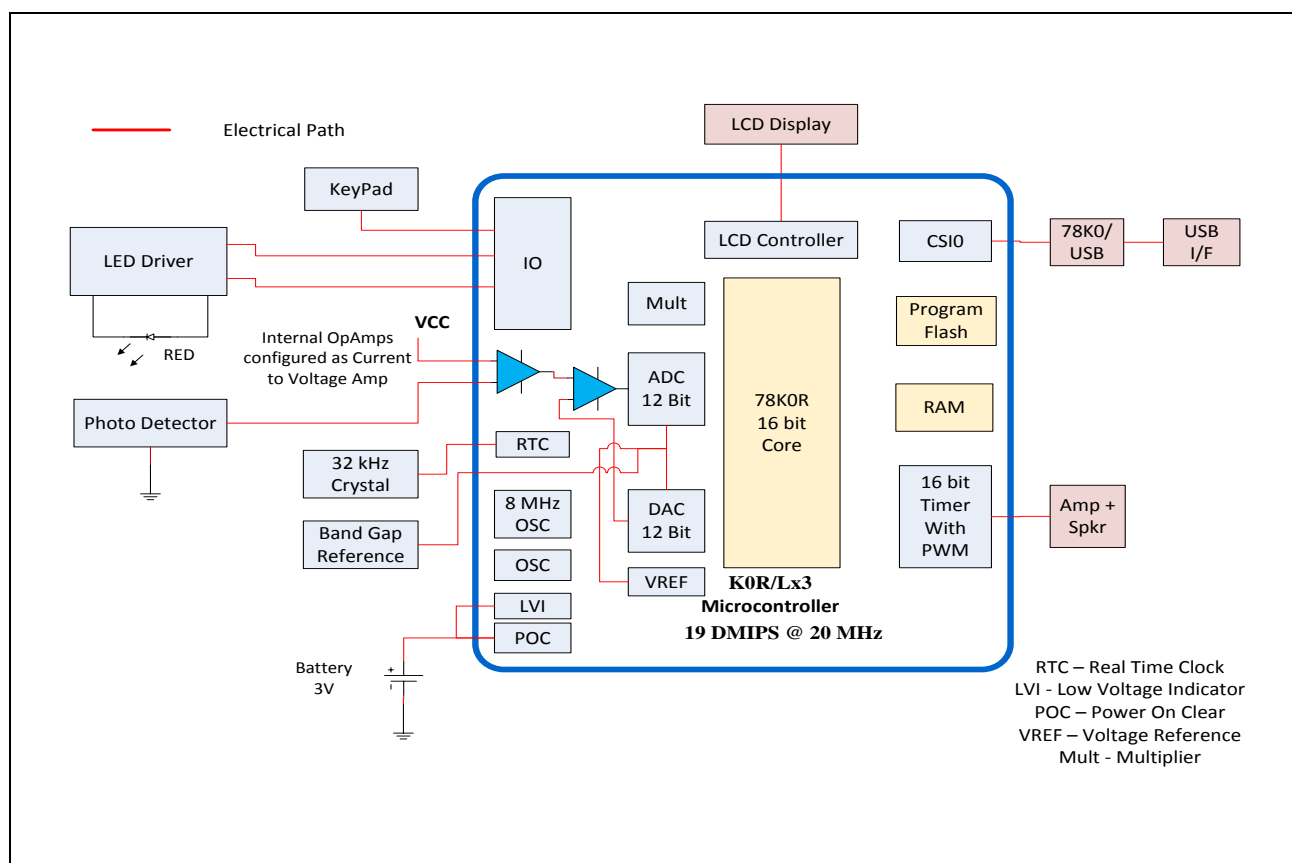


Figure 14 Reference implementation of low cost Heart rate / Pulse rate monitor

A high end heart rate/pulse rate monitor implementation with dedicated analog front end and Bluetooth wireless connectivity implemented using low power RL78/G13 is shown in Figure 15. RL78/G13 with on chip MAC unit is used in this design to provide more signal processing power to detect the heart rate/ pulse rate. The signal from the finger probe is digitized by an external 12-bit analog to digital converter and digitally processed by RL78/G13. An external 20 MHz resonator is used to improve the stability and accuracy of the clock required for high accuracy system. With a stable clock, signal processing like oversampling and averaging can be applied to get better accuracy of the measurement. To simplify implementation of detection and recovery from system anomalies, RL78/G13 has features such as clock monitoring, flash memory integrity check using CRC before execution, RAM parity check during execution, invalid memory access detection, write protection on RAM and System Function Registers and ADC self-check.

Key features of RL78/G13 are

- 16-bit processor core with 1.27DMIPS/MHz with maximum frequency at 32MHz
- On-chip hardware multiplier and accumulator
- On-chip oscillator with +/- 1% over temperature and voltage range
- Data flash for storing calibration data, and archival of measured data
- Very low power consumption: operational at 66μA/MHz (executing NOPs) and 0.57μA with only RTC and LVD on
- Special Snooze Mode where ADC and serial interface can operate when the MCU is stopped.
- Safety features such as clock monitoring, Flash and RAM check

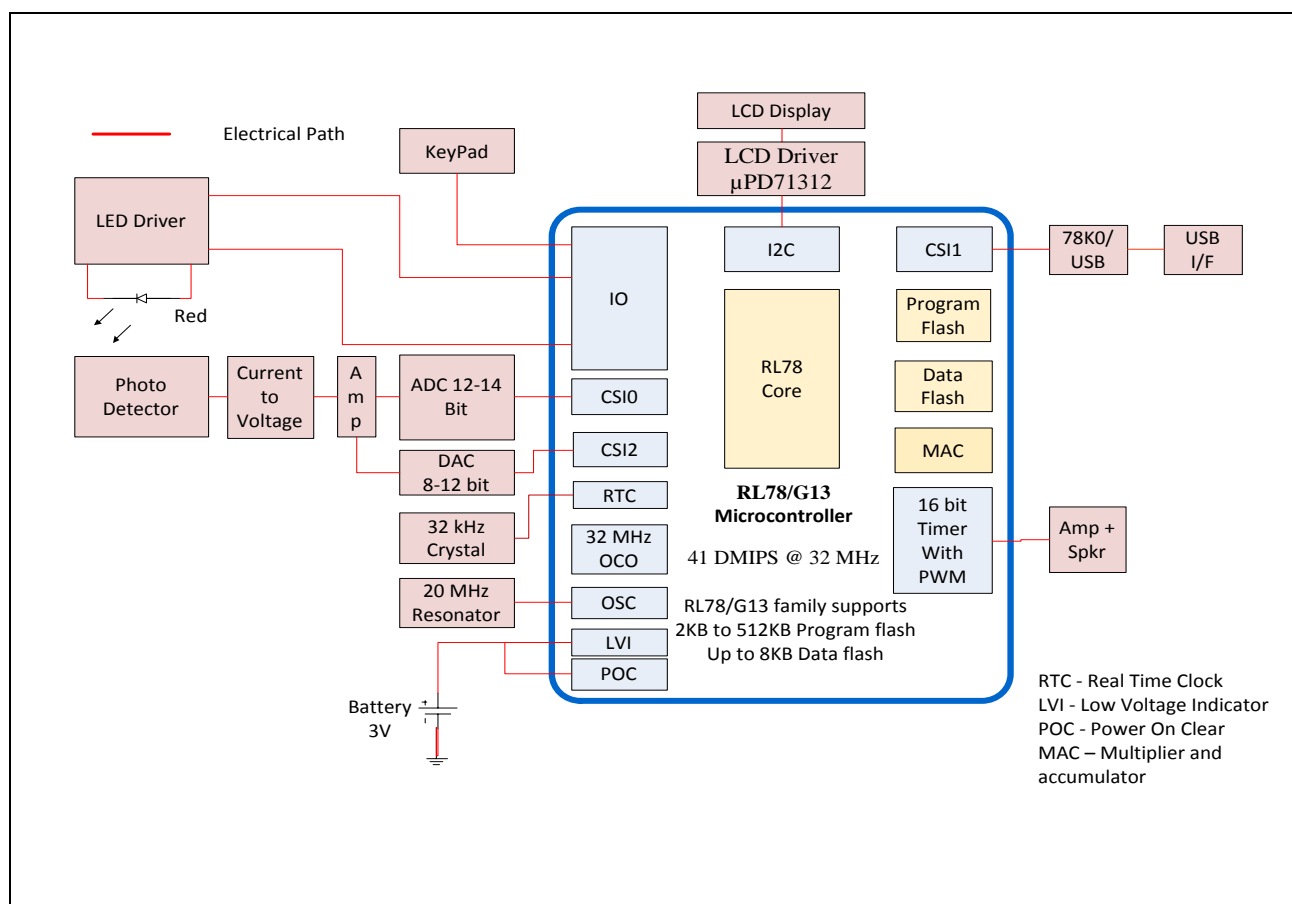


Figure 15 Reference implementation of Low power Digital Pulse / Heart Monitor

Table 14 Heart Rate Monitor applicable Renesas Devices

Microcontroller	78K0R/Lx3	RL78/G13
Analog Components	On-chip	Op-amp (CMOS) HA1630xxx Series
Power Management	Zener Diodes RD series Backflow prevention HRV103A, HRV103B, HRV104B	
Protection	ESD protection diodes NNCD and NSAD Series	
LCD Controller	On Chip LCD segment driver	μPD71312

Table 15 Heart Rate Monitor related Microcontroller family

Feature	78K0R/Lx3	RL78/G13
Processor core	16 bit	16 bit
Performance	0.95 DMIPS/MHz 19 DMIPS @ 20 MHz	1.27DMIPS/MHz, Max 32 MHz 41 DMIPS @ 32 MHz
Flash	64KB to 128KB	2KB to 512KB
Data Flash	None	Up to 8KB
RAM	4KB to 7KB	2KB to 32KB
Operating Voltage	1.8V to 5.5V	1.6V to 5.5V
Power consumption	190uA @ 1MHz 5mA @20MHZ 0.37uA stop mode	66 μA @ 1MHz ¹ 2.1 mA@32 MHz 0.2 μA stop mode

¹MCU is executing NOPs

Table 16 Heart Rate Monitor related Tools and Technologies

	Low cost solution	Low power solution
Microcontroller	78K0R/Lx3	RL78/G13
Evaluation Boards	QB-78K0RLH3-TB	QB-R5F100LE-TB
Software Libraries	<ul style="list-style-type: none"> ADPCM-SP Self-Programming EEPROM Emulation library 	<ul style="list-style-type: none"> ADPCM-SP Self-Programming EEPROM Emulation library Data flash access library
Software Development Tools	IAR, Cube suite , PM+, Applilet code generator	IAR, Cube suite+, Applilet code generator
Hardware Debugger	Minicube2	E1
Application Notes	ADPCM-SP Voice Compression/Expansion Software Package	Portable to RL78 as it uses 78K0R core
	78K0R/Kx3-L Low Power Consumption Operation	RL78 Low Power MCU Application Note
	Flash Protection and security setting guide	Flash Protection and security setting guide

2. Patient Monitoring, Diagnostics and Therapy

This segment of medical technology is used in home or clinical environments to help diagnosing and providing therapy and monitor vital parameters. In these devices, microcontroller is used for interfacing various sensors and implement motor control technologies.

Here is the list of Patient Monitoring, Diagnostics and Therapy medical devices

- Automated External Defibrillator
- CPAP
- ECG Electrocardiogram
- Patient Monitoring
- Digital Stethoscope
- Ventilators and Respirators

Table 17 Patient Monitoring, Diagnostics and Therapy Devices

Instrument	Key Requirements	Renesas Microcontroller	Key Features
Automatic External Defibrillator	<ul style="list-style-type: none"> • High quality audio required to give voice prompts and metronome features • LCD for visual communication • Large button inputs 	SH7264	<ul style="list-style-type: none"> • 32- bit processor core with 345DMIPS @ 144 MHz • double precision FPU • 32 bit X 32 bit multiplier • External memory interface for SDRAM, NOR flash, PCMCIA • High speed USB2.0 Host and Function support • RGB565 progressive video output • High quality audio support (I2S and SPDIF)
CPAP machine	<ul style="list-style-type: none"> • Simple user interface • LCD Display • Advanced motor control algorithms for control and comfort • Storage for calibration tables and archive measurement data. • Communication port • Patient Safety 	RX62T	<ul style="list-style-type: none"> • 32-bit processor core with 165 DMIPS @ 100 MHz • Single precision FPU and hardware MAC • Zero wait state Flash operating up to 100MHz • Built-in 100 MHz multipurpose timer for motor control • RTC with support for full calendar functionality • Dead time insertion and quadrature encoder inputs • POE module to force PWM output pins of the MTU (Multi-Function Timer Pulse unit) and large current output pins of the GPT (General PWM Timer) into a high impedance state, regardless of the state of the rest of the CPU for safety. • Anomaly detection support for system clock failure , flash memory integrity, and ADC self-check

Electro Cardiogram (ECG)	<ul style="list-style-type: none"> Simple user interface LCD Display Storage for calibration tables and archive measurement data. Communication port Low power for portable use 	RX621	<ul style="list-style-type: none"> 32-bit processor core with 165 DMIPS @ 100 MHz Single precision FPU and hardware MAC Zero wait state Flash operating up to 100MHz Built-in 8 channel 12 bit ADC with 1μSec conversion time. RTC with support- for full calendar functionality Full speed USB2.0 Host and function EXDMA controller to support WQVGA TFT LCD Anomaly detection support for system clock failure , flash memory integrity, and ADC self-check
Patient Monitoring	<ul style="list-style-type: none"> Video Display Audio support Storage for calibration tables and archive measurement data. Communication port 	SH7264	<ul style="list-style-type: none"> 32- bit processor core with 345DMIPS @ 144 MHz double precision FPU 32 bit X 32 bit multiplier External memory interface for SDRAM, NOR flash, PCMCIA High speed USB2.0 Host and Function support RGB565 progressive video output High quality audio support (I2S and SPDIF)
Simple Digital Stethoscope	<ul style="list-style-type: none"> Capture Signal processing Send signal out for post-processing Low power audio play back support Simple LCD display Low cost on-chip storage for calibration tables, filter coefficients and archive processed data. USB connectivity 	RL78/G13	<ul style="list-style-type: none"> 16-bit processor core with 41 DMIPS @ 32 MHz On-chip Data Flash Hardware MAC Special Snooze power mode where ADC and serial interface can operate when the MCU is stopped. Anomaly detection support for system clock failure , flash memory integrity, RAM parity check, invalid memory access detection, write protection to RAM/SFR, and ADC self-check
Digital Stethoscope with built in graphics display	<ul style="list-style-type: none"> Hardware Signal processing High quality Audio play back support Storage for calibration tables, filter coefficients and archive measurement data. Communication port 	RX62N/RX621	<ul style="list-style-type: none"> 32-bit processor core with 165 DMIPS @ 100 MHz Single precision FPU and hardware MAC Zero wait state Flash operating up to 100MHz Built-in 8 channel 12 bit ADC with 1μSec conversion time. RTC with support- for full calendar functionality Full speed USB2.0 Host and function EXDMA controller to support

			WQVGA TFT LCD <ul style="list-style-type: none"> Anomaly detection support for system clock failure, flash memory integrity, and ADC self-check
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2.1 Automatic External Defibrillator

Ventricular fibrillation is a lethal malfunction of the heart. The most effective way of preventing death on the onset of fibrillation is to apply a strong electric shock to the heart within the first few minutes. Devices that can deliver such shocks are called defibrillators. A typical defibrillator must deliver high amount of energy to the heart, first by charging a large capacitor, and then discharging it through RLC circuit, two metal plates, and finally through the heart at approximately a 50 ohm load.

A basic defibrillator consists of a battery, a high voltage circuit to raise the voltage to charge the capacitor and high voltage switching circuit to generate biphasic wave form. Automatic defibrillator can decide itself if defibrillation is necessary. AED monitors the electrocardiogram and analyze the ECG to decide if the ventricles are fibrillating. If they are, AED will indicate the care giver to shock the patient. AED need to support both visual and audio indicators to assist the caregiver. Some AEDs support synchronization of application of the shock to the ECG of the patient. This ensures that the shock is applied during QRS complex portion of the ECG to prevent complications.

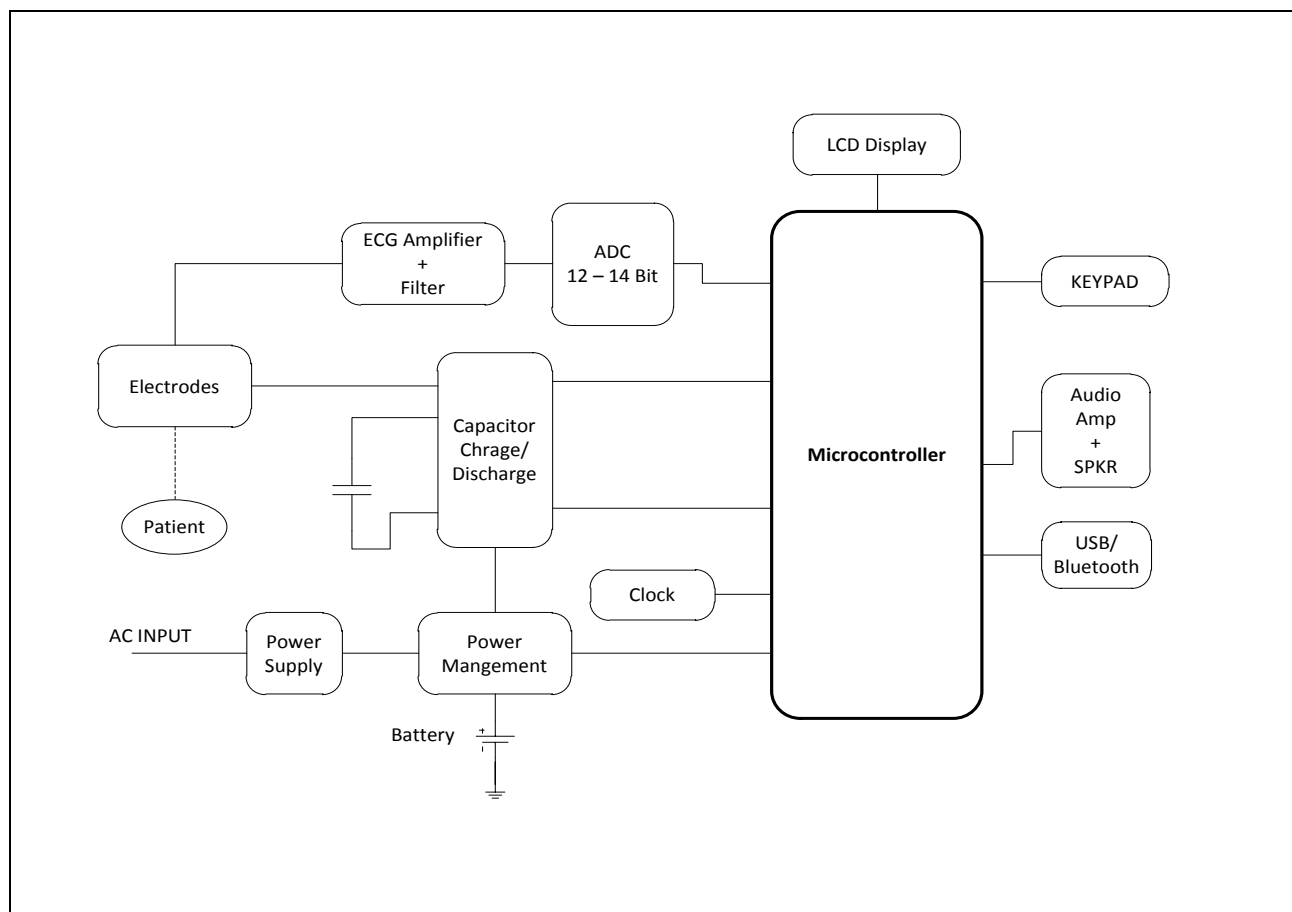


Figure 16 Block Diagram of Automatic External Defibrillator

A reference design based on SH7264 is shown in Figure 17. SH7264 with VGA graphics display controller and good audio interfaces enhance the user interface of the AED and help reduce user error. This implementation can take user input from a touchpad or few hardware buttons. The audio support can play back instruction and warning message. SH7264 supports I2S and SPDIF audio interfaces which support high quality audio playback using external codecs. SH7264 needs NAND flash memory to boot and program

is executed in its internal memory. This monitor has ECG functionality implemented by using an external high resolution ADC connected through the external bus interface to take advantage of high speed data transfer. SH7264 has double precision FPU that assists in calculating voltage, time duration of pulse and other algorithms. The benefit of using a double precision FPU is to allow the algorithm to use floating point arithmetic without converting to fixed point simplifying implementation, improvement and maintenance of the algorithm.

Key features of SH7264 are

- double precision FPU
- 32 bit X 32 bit multiplier
- 64KB on-chip high-speed single cycle memory
- On-chip large capacity RAM for display area and work area (640KB/1MB)
- Bootable NAND or serial SPI flash
- External memory interface for SDRAM, NOR flash, PCMCIA
- High quality audio support (I2S and SPDIF)
- High speed USB2.0 Host and Function support
- Performance 345DMIPS @ 144 MHz
- RGB565 progressive video output

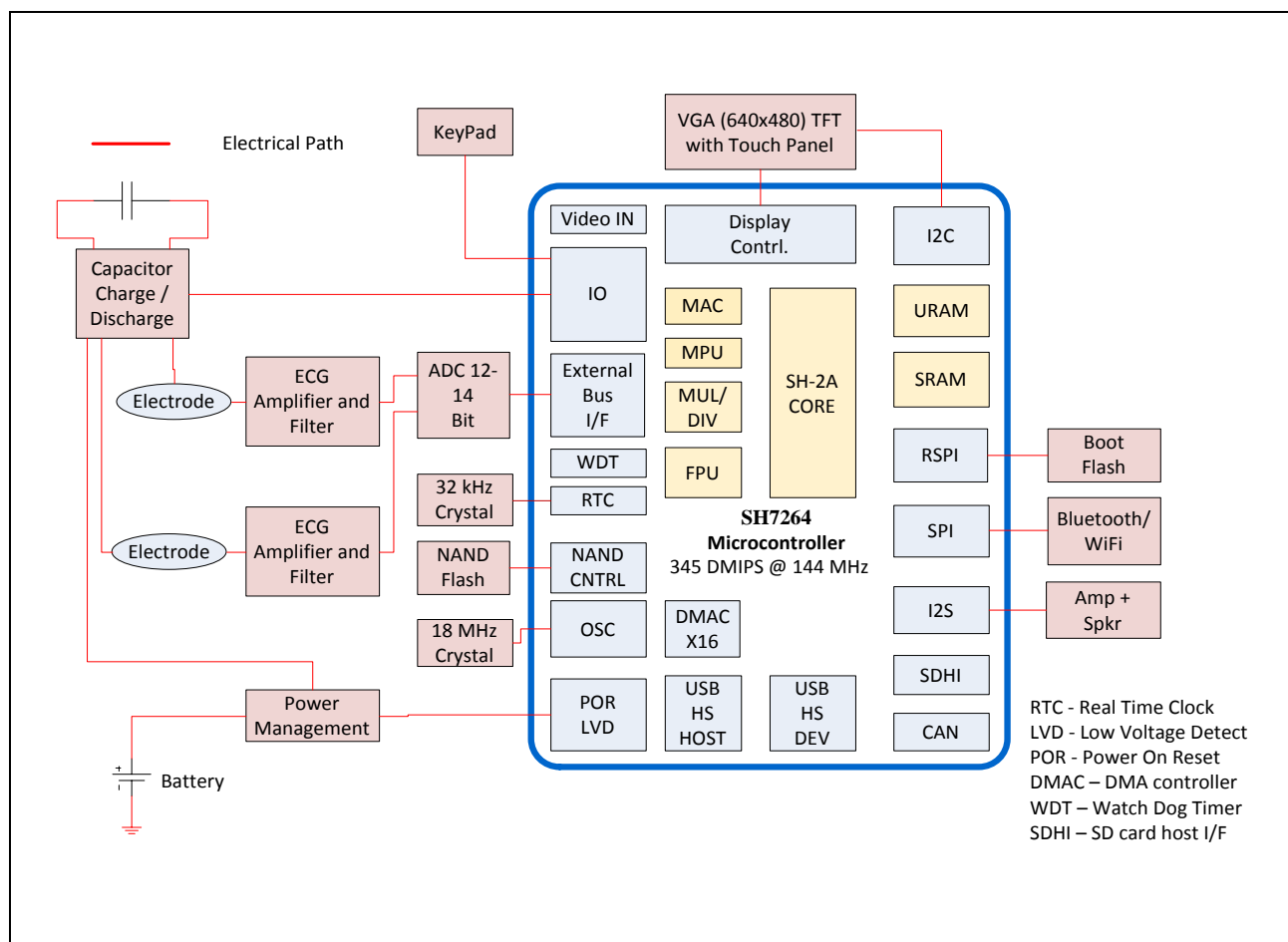


Figure 17 Implementation Diagram of AED using SH7264

Table 18 AED applicable Renesas Devices

Microcontroller	SH7264
Analog Components	Op-amp (CMOS) HA1630xxx Series
Power Management	Zener Diodes RD series Backflow prevention HRV103A, HRV103B, HRV104B
Protection	ESD protection diodes NNCD and NSAD Series
LCD Controller	On chip graphical controller, on chip frame buffer, video input

Table 19 AED related microcontroller family

Feature	SH7264
Processor core	32-bit, double precision FPU, DSP instructions
Cache	8KB I CACHE, 8 KB D CACHE
Performance	345 DMIPS @ 144 MHz
Flash	None, Boot from NAND
Data Flash	32 KB
RAM	64 KB On-chip high-speed RAM ¹ Either 1MB or 640KB on-chip RAM ¹ used for display frame buffer and scratch pad work area
Operating Voltage	3.3V

¹ All memory can be used for instruction or data

Table 20 AED related Tools and Technologies

	Solution
Microcontroller	SH7264
Evaluation Boards	R0K572643S000BE
Software Libraries	Graphics, CAN,DSP, fixed point
Software Development Tools	IAR, HEW IDE
Hardware Debugger	E10A,E200F
Application Notes	Video Display Controller 3, How to Use the α (Alpha) Blending Window Function
	Video Display Controller 3 TFT-LCD Interfacing Example
	Video Display Controller 3 Video Recording Example
	Video Display Controller 3 Video Display Example
Solution Platform	Renesas Starter Kit2+ for SH7264

2.2 CPAP

Apnea is defined as an absence of respiratory movements for a period of time. These respiratory movements may be categorized as central (no respiratory effort), obstructive (respiratory effort with absent airflow) or mixed (central pause greater than 2 seconds with obstructed respiratory efforts). Sleep Apnea is treated by using a CPAP machine. CPAP machines have incorporated technology to improve the comfort and self-regulating capability to deliver therapy as needed.

CPAP is currently the first line of treatment and is indicated for reversal of sleep induced abnormal upper airway behavior, provided it is severe and results in disruption of sleep with negative day time consequences. The machine consists of a comfortable, lightweight, flexible good nasal mask during sleep, through the headband fixed on the patient's nose (excluding mouth), then a soft nasal mask airway connected to a blower to produce high-speed airflow through the hose into the upper respiratory tract, in throat partially to form a positive pressure.

A block diagram of CPAP machine is shown in Figure 18.

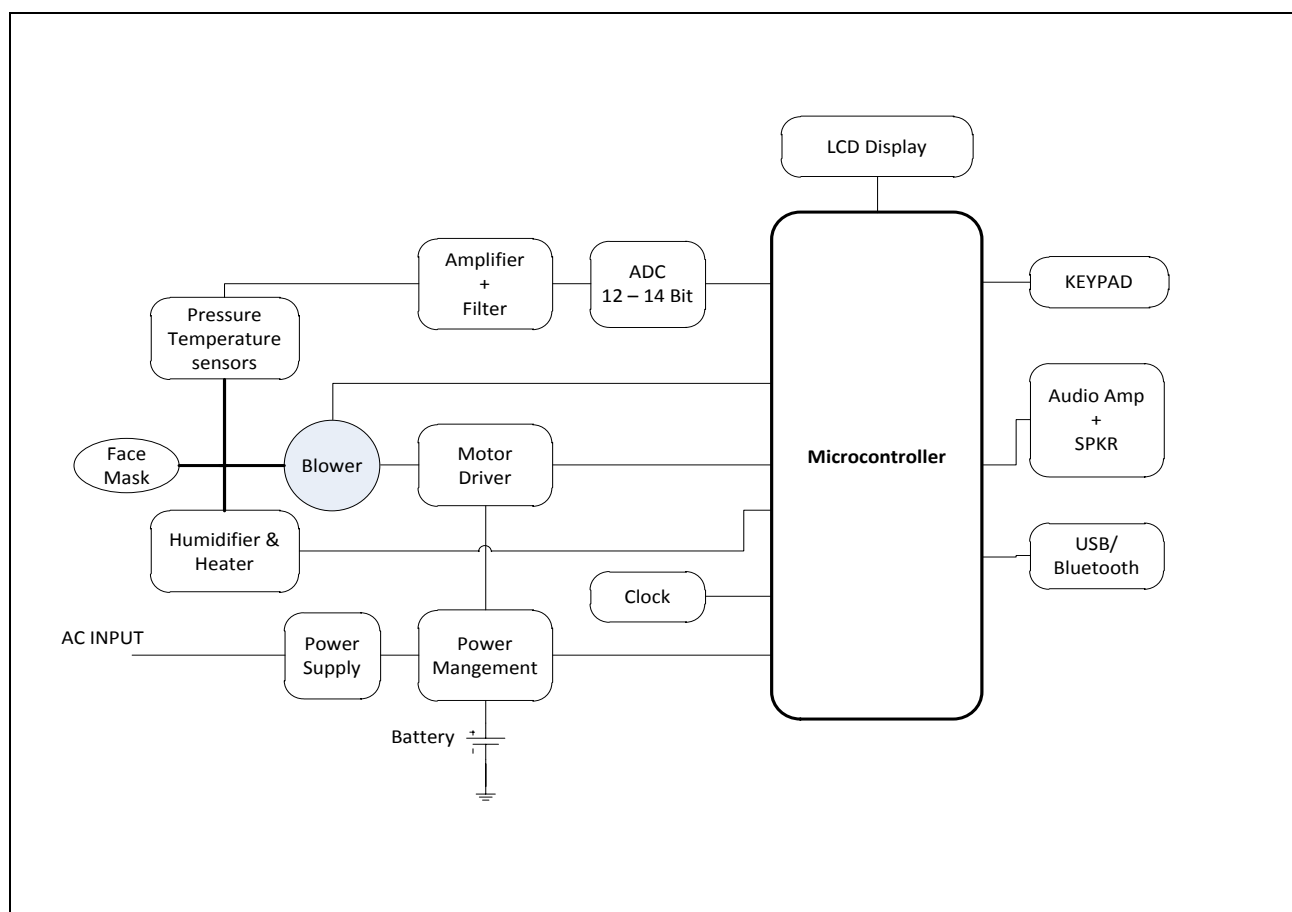


Figure 18 Block Diagram of CPAP

A reference implementation using RX62T is shown in Figure 19. RX62T has hardware necessary for motor control application. It has 100 MHz multipurpose timer and 12 bit ADC. It can generate complimentary PWM outputs which are reset synchronized. It supports dead time insertion and can take quadrature encoder inputs. The single precision floating point unit simplifies complex motor control algorithm implementation to achieve patient comfort.

The control of heater and humidifier can be implemented using digital input/output pins. The signals from pressure and temperature sensors in the face mask are amplified and filtered before digitization by the on chip 12 -bit ADC. These measured values are used in the control loop software to adjust the blower speed and heater/ humidifier control to maintain the prescribed pressure values. An external LCD controller is connected using I2C port to drive a LCD display for user interface. High speed serial port interface also can be used to support chip-on LCD. The RTC with full calendar support is useful to log Apnea events with time stamp for further analysis and can also be used for the usage log required for compliance. A CPAP machine typically gathers a large amount of data for processing, analysis and usage log. The zero wait state operation of both RAM and Flash ensures fast processing to reduce any unnecessary buffering that could impact the overall system real time analysis requirement. An external microcontroller implementing full speed USB2.0 function is connected to the serial interface to provide the USB connectivity. A Bluetooth or Wi-Fi module can be connected using SPI interface to provide wireless capabilities.

Main features of RX62T are

- Single precision FPU and hardware MAC
- Zero wait state Flash operating up to 100MHz
- 8KB/32KB data flash
- Built-in 100 MHz multipurpose timer for motor control

- RTC with support for full calendar functionality
- Dead time insertion and quadrature encoder inputs
- Safety features like clock monitoring, Flash CRC check and POE module to force PWM output pins to high impedance

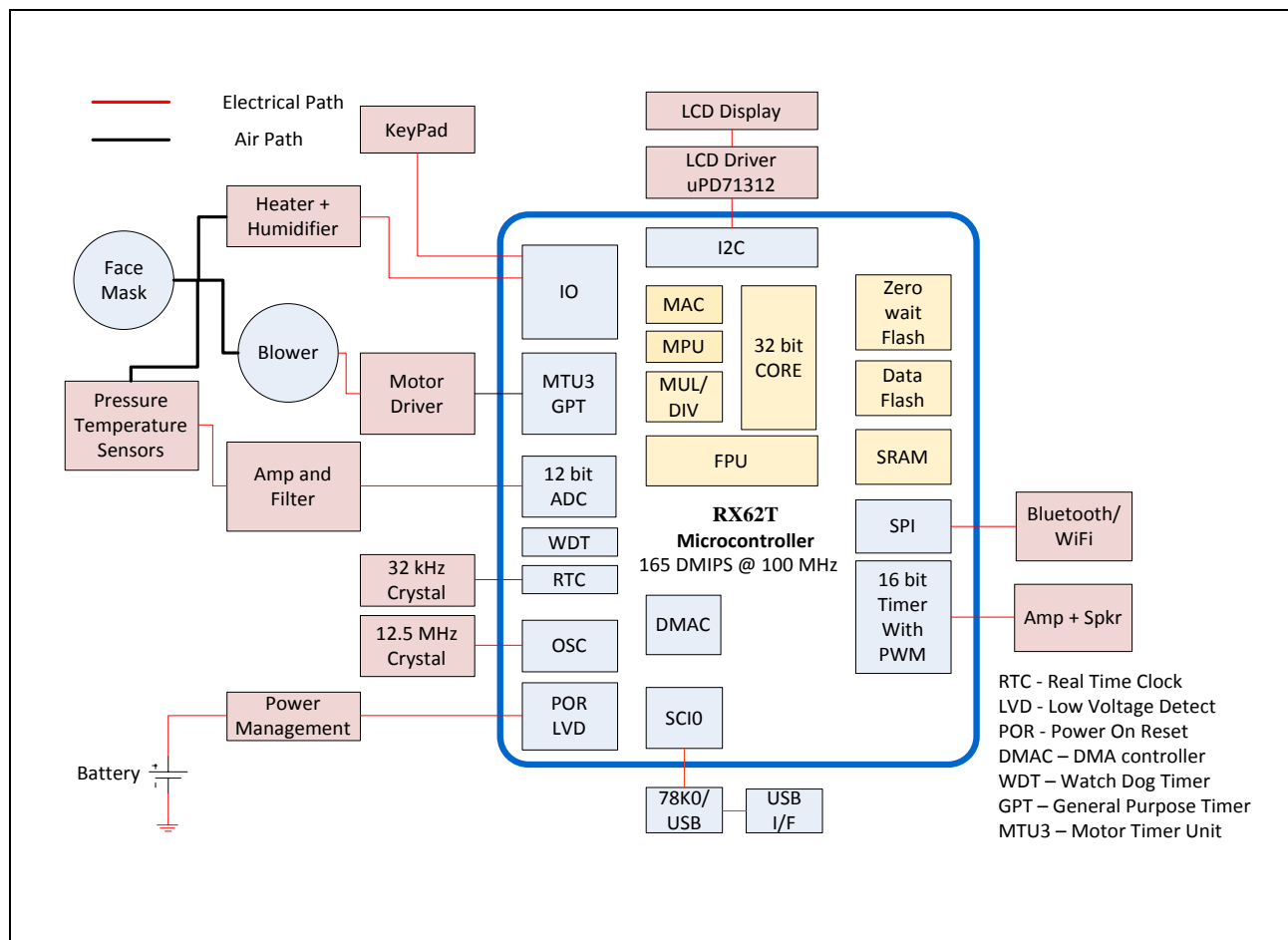


Figure 19 Implementation Diagram of a CPAP machine

Table 21 CPAP applicable Renesas Devices

Microcontroller	RX62T
Analog Components	Op-amp (CMOS) HA1630xxx Series
Power Management	Zener Diodes RD series Backflow prevention HRV103A, HRV103B, HRV104B
Protection	ESD protection diodes NNCD and NSAD Series
LCD Controller	External Controller

Table 22 CPAP related Microcontroller family

Feature	RX62T
Processor core	32-bit
Performance	165 DMIPS at 100MHz
Flash	64KB to 256KB
Data Flash	8KB/32KB
RAM	8KB to 16KB
Operating Voltage	3.3 / 5 V
Power consumption	<ul style="list-style-type: none"> • 0.5 mA/ MHz • 50 mA @ 100 MHz • 21 μA stop mode

Table 23 CPAP related Tools and Technologies

	Renesas Solution
Microcontroller	RX62T
Evaluation Boards	R0K5562T0S000BE
Software Libraries	Motor control, DSP,TCP/IP, Renesas Peripheral Driver Library
Software Development Tools	IAR, HEW
Hardware Debugger	E1
Application Notes	Low Cost Motor Control Demo Board based on RX62T
	SPWM Motor Control
	Using Multiply-Accumulate Operation Instructions
	MTU3 Complementary PWM Mode
	IEC60730 Self-test Code for RX62T Group MCU
Solution Platform	Low Cost Motor Control Demo Board based on RX62T (MCRP07)

2.3 ECG Electrocardiogram

The electro cardiogram (ECG) gives important cardiac information. Computer processing of ECG signals, which are analog in nature with low amplitudes (few mV) and low frequency content (0.05Hz to 150Hz) involves digitization with at least 12 bit resolution analog to digital converter. Further processing involves digital filtering, removal of power line and biological artifacts, averaging and automatic measurement of amplitudes and duration of various parts of the signal. Further processing can done by a computer to detect anomalies and aid in the diagnosis. In the high end systems, the microcontroller itself can perform real time analysis of these signals and generate alarms or trigger corrective actions.

Tele monitoring of ECG signals is a growing field which improves the quality, increase the efficiency, and expand access of the health care delivery system. It will support mobile patient monitoring, post hospital patient monitoring, and home care monitoring.

An example for a portable ECG monitor is the popular Holter monitor. It is a capable of recording of a patient's ECG for 24 hr. Since it can be worn during the patient's regular daily activities, it helps the physician correlate symptoms of dizziness, palpitations, and syncope with intermittent cardiac arrhythmias. The recorder can store signals from three or more ECG leads in a flash card which can be analyzed using custom software in a computer. Further, the information can be sent wirelessly to a computer for real-time analysis. A block diagram of Holter recorder is shown in Figure 20.

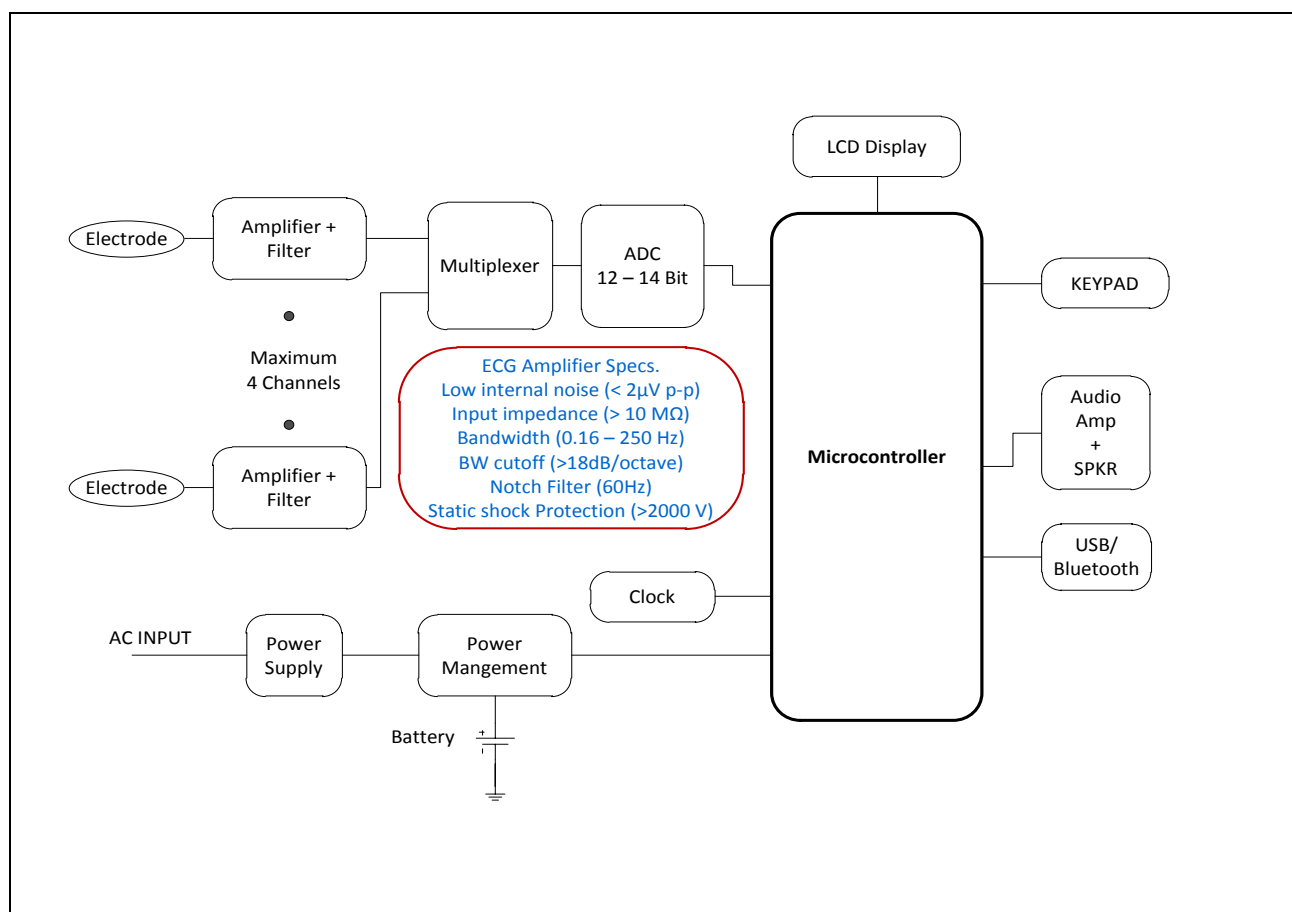


Figure 20 Block Diagram of Holter Recorder (ECG Recorder)

An ECG recorder for up to 8 channel monitoring is shown in Figure 21. This design is implemented using RX621 with built in 8 channel 12 bit ADC to reduce cost. RX621 has an ample computational power supported by FPU and hardware MAC which can be used to implement signal processing algorithms to process ECG data. Keeping the algorithm in floating point simplifies implementation, upgrade and maintenance. Moreover, the RX621 CPU can execute with the 100MHz on-chip Flash with zero wait state and can ensure deterministic computation of the real time ECG signals. Typically clinical ECG has signal bandwidth of about 0.05 to 100 Hz with recommended sampling rate of 500 Hz. Assuming 500 Hz sampling rate, data storage requirement for 8 channel ECG for 1 second is $500 * 2 * 8 = 800$ Bytes. For 24 hours recording, total space requirement will be $24 * 60 * 60 * 800 = 69120000$ bytes i.e approximately 66 Mbytes. The ECG data can be saved to a removable flash connected by using the USB host function. Data can also be sent wirelessly by using the RX621 high speed ports connecting to a Bluetooth or a WIFI module. RX621 has an external DMA controller (EXDMA) which enables data transfer from external SDRAM to TFT LCD without the intervention of the CPU. This method can support a WVGA TFT display without an external TFT driver.

Key features of RX621 are

- Single precision FPU and hardware MAC
- Zero wait state Flash operating up to 100MHz
- Built-in 8 channel 12 bit ADC with $1\mu\text{Sec}$ conversion time.
- RTC with support- for full calendar functionality
- Full speed USB2.0 Host and function
- EXDMA controller can support TFT LCD of WQVGA resolution

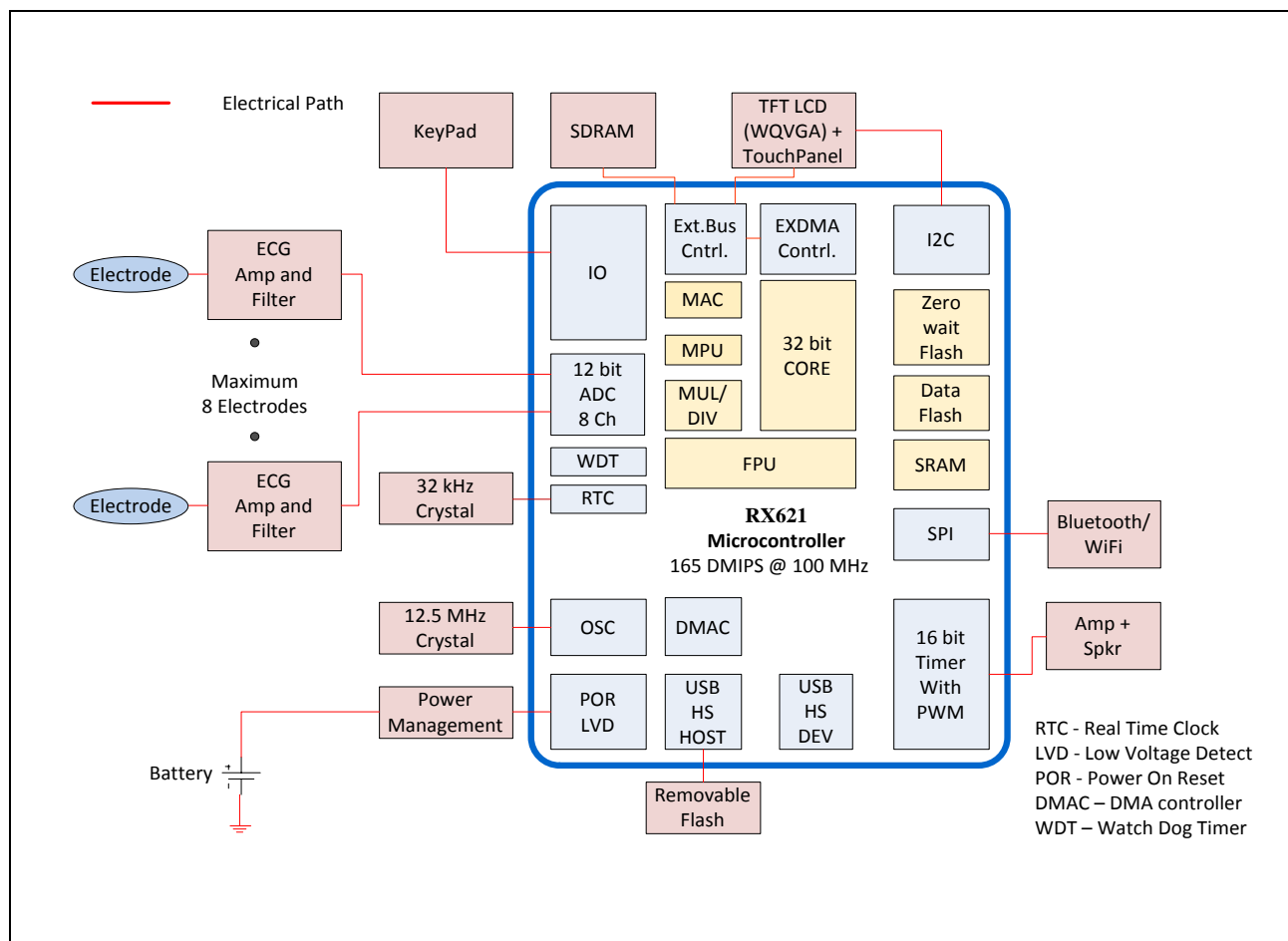


Figure 21 Implementation Diagram of 8 channel ECG Recorder

Table 24 ECG applicable Renesas Devices

Microcontroller	RX621
Analog Components	Op-amp (CMOS) HA1630xxx Series
Power Management	Zener Diodes RD series Backflow prevention HRV103A, HRV103B, HRV104B
Protection	ESD protection diodes NNCD and NSAD Series
LCD Controller	Direct Drive TFT supporting up to WVGA resolution

Table 25 ECG related Microcontroller family

Feature	RX621
Processor core	32bit
Performance	165 DMIPS at 100MHz
Flash	256KB to 512KB
Data flash	Up to 32KB
RAM	64KB to 96KB
Operating Voltage	2.7V to 3.6 V
Power consumption	0.5 mA @ 1 MHz 50 mA @ 100 MHz 21 μ A stop mode

Table 26 ECG related Tools and Technologies

	Solution
Microcontroller	RX621
Evaluation Boards	R0K5562N0S000BE
Software Libraries	Graphics API
Software Development Tools	IAR, HEW
Hardware Debugger	E1
Application Notes	ADPCM Audio Compression Record and Playback
	Using Multiply-Accumulate Operation Instructions
Solution Platform	Ultra Low Power Wi-Fi. Starter Kit for RX62N (RD-RX62N-2201)
	TFT-LCD Direct-Drive solution Kit for RX600 MCUs (YLCDRSKRX62NS)

2.4 Patient Monitoring

Patient monitors are used in the hospital environment including intensive care units to monitor, display a fixed set of patient's vital signs (ECG, noninvasive blood pressure, SpO₂, respiration and temperature) and perform automatic analysis on them. Additionally it has features for dose calculations, cardiac calculations and pulmonary calculations. It can also display several parameter waveforms on the screen. Most of these monitors are used at the patient's bedside. These can be networked to share common computing and analysis resources.

A block diagram of the patient monitor is shown in Figure 22.

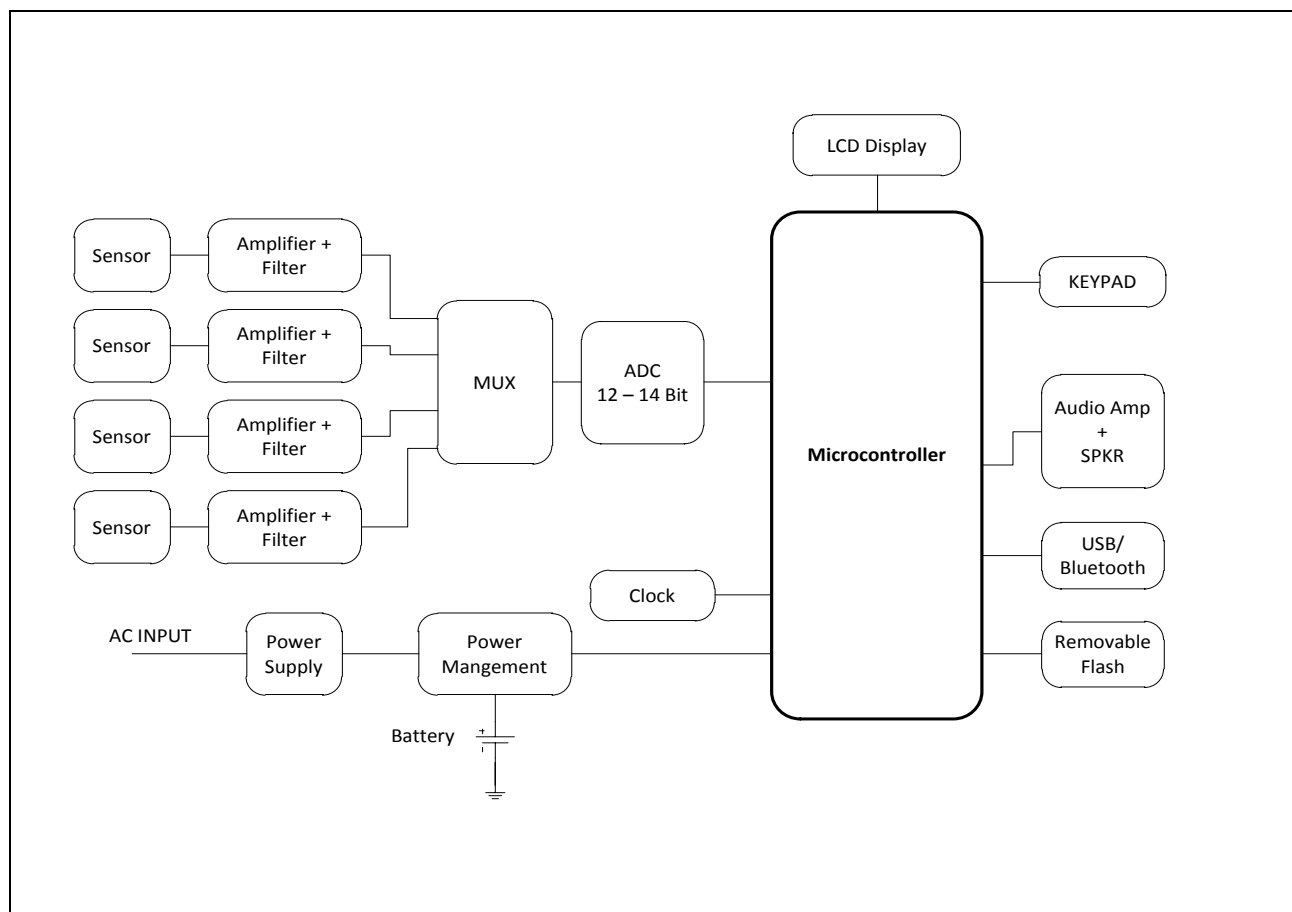


Figure 22 Block Diagram of Patient Monitor

A reference design for a patient monitor based on SH7264 is shown in Figure 23. SH7264 with graphics display controller, video input and high quality audio interfaces is a good fit for implementing the patient monitor. SH7264 uses NAND flash as boot memory and the program resides in the on-chip RAM after boot

up. The display controller can support up to VGA (640x480) resolution. This enables monitoring of vital parameters graphically using a built-in VGA LCD display. Further SH7264 with built-in video input functionality can be connected to a camera to visually monitor the patients (epilepsy type etc.) continuously to correlate the vital parameter data with visual observation. SH7264 supports I2S and SPDIF audio interfaces which support high quality audio playback using external codecs. The audio support can play back instruction and warning message. User interface is provided by touch panel which is connected to the I2C port. This reference design implemented built-in ECG functionality using a high resolution external ADC connected through high speed external bus interface. Double precision FPU in SH7264 aids in the signal processing as well as used to execute complex algorithms required in the drug dosage etc. calculations by medical personnel.

SH7264 supports high speed USB2.0 Host as well as Function ports. USB port can be used to retrieve data to a removable flash device for archiving or further analysis. SH7264 has SD card interface which can also be used to upload and retrieve information. A Wi-Fi module interfaced using SPI port is used to provide the networking capability to aid the data transfer to the hospital network. This feature is very useful for the physicians as and nurses to remotely monitor the patient condition.

Key features of SH7264 are

- double precision FPU
- 32 bit X 32 bit multiplier
- 64KB on-chip high-speed single cycle memory
- On-chip large capacity RAM for display area and work area (640KB/1MB)
- Bootable NAND or serial SPI flash
- External memory interface for SDRAM, NOR flash, PCMCIA
- High quality audio support (I2S and SPDIF)
- USB Host and Function support
- Performance 345DMIPS @ 144 MHz

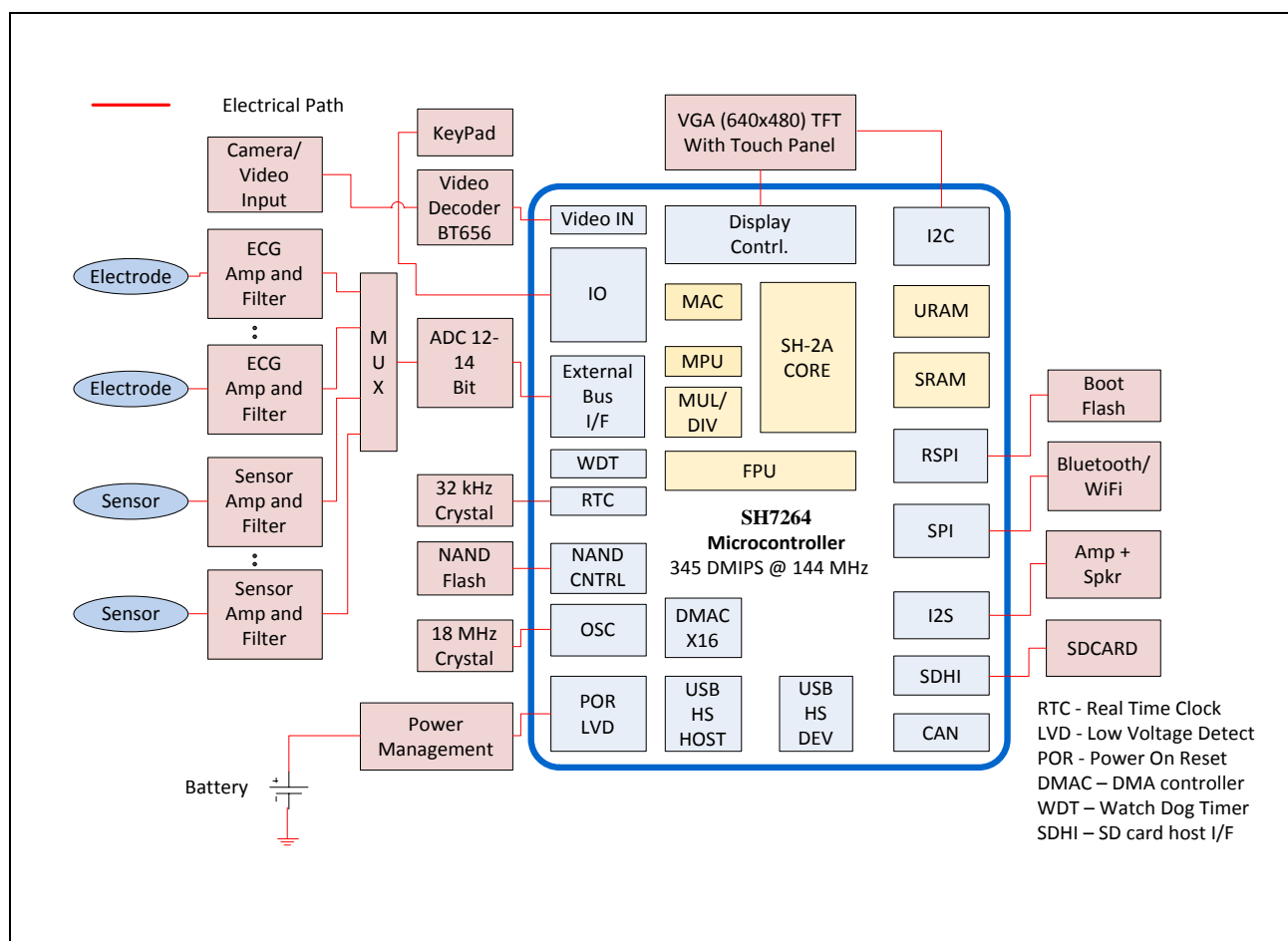


Figure 23 Implementation Diagram of Patient Monitor

Table 27 Patient Monitor applicable Renesas Devices

Microcontroller	SH7264
Analog Components	Op-amp (CMOS) HA1630xxx Series
Power Management	Zener Diodes RD series Backflow prevention HRV103A, HRV103B, HRV104B
Protection	ESD protection diodes NNCD and NSAD Series
LCD Controller	On-chip graphical controller, on chip frame buffer, video input

Table 28 Patient Monitor related Microcontroller family

Feature	SH7264
Processor core	32-bit, double precision FPU, DSP instructions
Cache	8KB I CACHE, 8 KB D CACHE
Performance	144 MHz
Flash	None, Boot from NAND
Data Flash	32 KB
RAM	64 KB On-chip high-speed RAM ¹ Either 1MB or 640KB on-chip RAM ¹ used for display frame buffer and scratch pad work area
Operating Voltage	3.3V

¹ All memory can be used for instruction or data

Table 29 Patient Monitor related Tools and Technologies

	High End Solution
Microcontroller	SH7264
Evaluation Boards	R0K572643S000BE
Software Libraries	Graphics, CAN,DSP, fixed point
Software Development Tools	IAR, HEW IDE
Hardware Debugger	E10A,E200F
Application Notes	Video Display Controller 3, How to use the α (Alpha) Blending window function
	Video Display Controller 3 TFT-LCD Interfacing Example
	Video Display Controller 3 Video Recording Example
	Video Display Controller 3 Video Display Example
Solution Platform	Renesas Starter Kit2+ for SH7264

2.5 Digital Stethoscope

A stethoscope is used to transmit heart and lung sounds from chest wall to human ear. A digital stethoscope combines the simplicity of acoustic stethoscope with advanced electronics and information technology to facilitate better performance, recording of the heart and lung sounds and analysis of the recorded signals. Most of these stethoscopes are intended for observation and recording of heart sounds and murmurs as well as lung and airway sounds. By providing connectivity solutions either wired or wireless, a digital stethoscope can be used in telemedicine applications facilitating remote diagnosis by specialists. The recorded signals can further be spectrally analyzed and used for automated cardiac auscultation and interpretation by a specialist with aid from a computer with suitable analysis software.

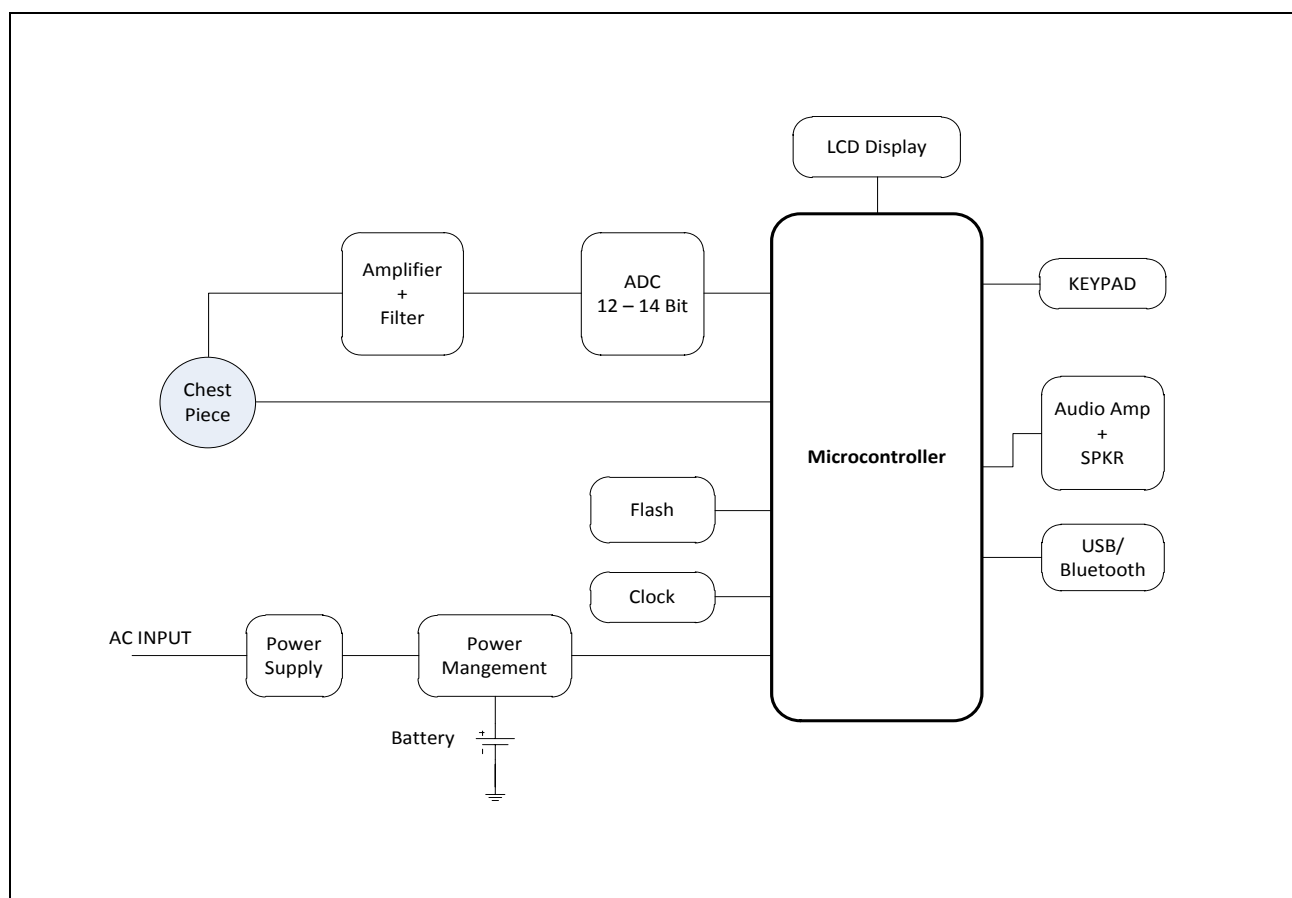


Figure 24 Block diagram of Digital Stethoscope

A digital stethoscope has the following essential components to capture process and play back the heart sounds. The sounds are captured by a microphone built within the chest piece, with adjustable amplification and filtering. The electronic chest piece also allows for easy switching between diaphragm and bell modes. The captured audio signals can be processed by a microcontroller to eliminate artifacts and disturbances and can be stored locally or sent wirelessly to a computer. The processed signals will be played back by miniature speakers to the air tips for the physician. A simplified block diagram is shown in Figure 24.

A low cost implementation of digital stethoscope is shown in Figure 25. This system captures the heart sounds and allows the physician to select simple digital filtering to enhance the signals in real time for listening. Further the processed data can be sent out for further analysis by a specialist. This design uses RL78/G13 which has low power consumption and an on-chip MAC unit which is useful for implementing digital signal processing of the heart sound. This also supports data flash of 8KB which can be used for recording of small sample of the processed heart sound for later analysis. This design can be used as standalone unit with playback of audio implemented using the external 12 bit DAC connected through CSI port. The stored data can be transferred to a computer using external USB chip for later analysis. A small custom LCD display and few pushbuttons will provide simple user interface. An external 20 MHz resonator is used to improve the stability and accuracy of the clock required for high accuracy system. With a stable clock, signal processing like oversampling and averaging can be applied to get better accuracy of the measurement.

Key features of RL78/G13 are

- 16-bit processor core with 1.27DMIPS/MHz with maximum frequency at 32MHz
- On-chip hardware multiplier and accumulator
- On-chip oscillator with +/- 1% over temperature and voltage range
- Data flash for storing calibration data, and archival of measured data
- Very low power consumption: operational at 66μA/MHz (executing NOPs) and 0.57μA with only RTC and LVD on
- Special Snooze Mode where ADC and serial interface can operate when the MCU is stopped.
- Operating voltage is down to 1.6V to extend battery life

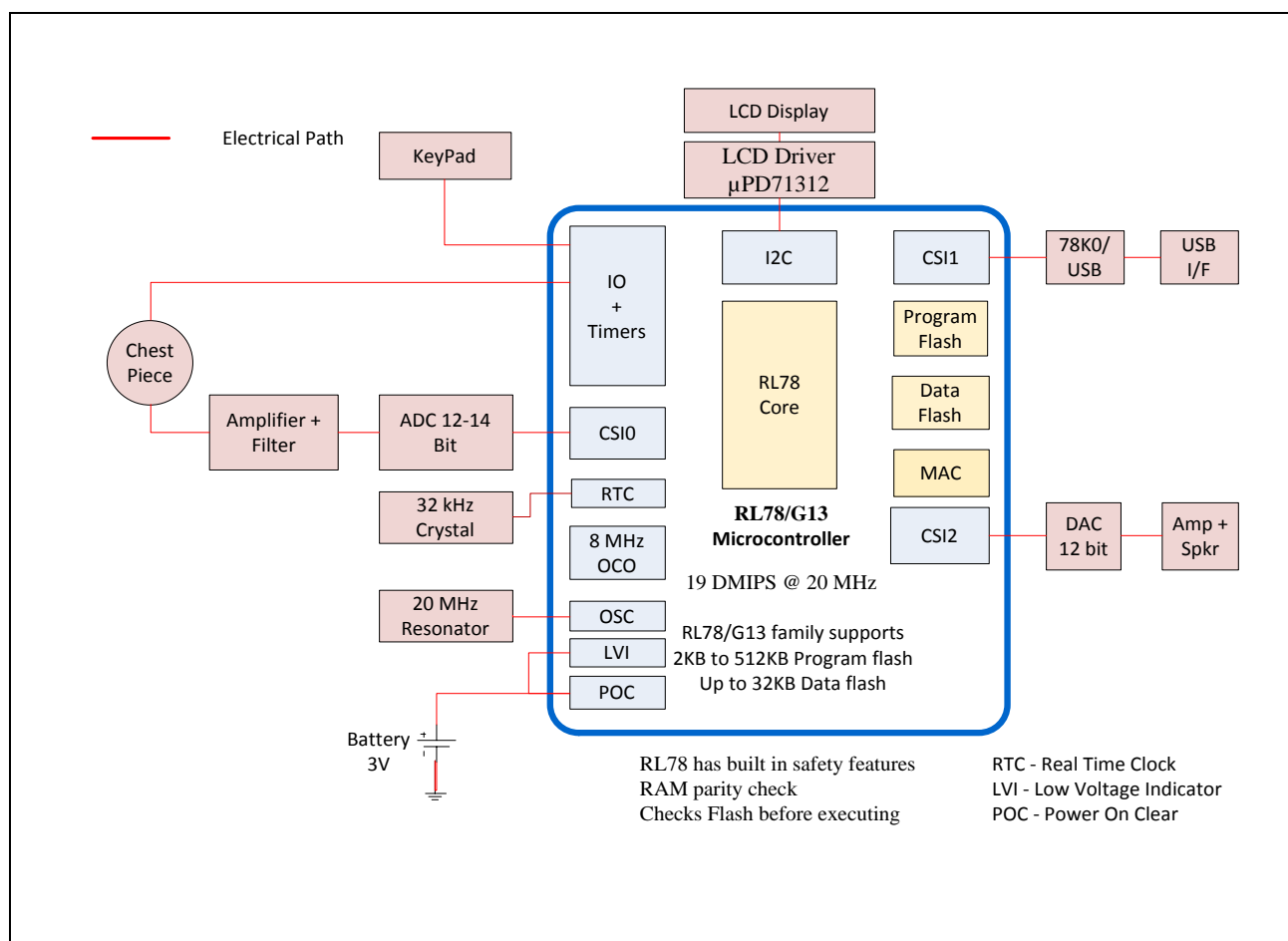


Figure 25 Reference implementation diagram for simple digital stethoscope

Compared to the low end digital stethoscope which provides simple processing of the heart sound, a more advanced digital stethoscope with graphical display and touch panel user interface is shown in Figure 26. Integrated single precision FPU and hardware MAC in RX62N makes this implementation capable of executing sophisticated algorithms in extracting valuable information from the heart and other sounds being monitored. On chip 12-bit ADC is used to digitize the signals coming from the chest piece and an external 12-bit DAC to reproduce sounds after processing. Zero wait state flash memory and the CPU operating up to 100MHz in RX62N enables the signal processing in real time. RX62N has an external DMA controller (EXDMA) which enables data transfer from external SDRAM to TFT LCD without the intervention of the CPU. This method can support a WVGA TFT display without an external TFT driver. The color TFT LCD display along with touch panel greatly facilitates user interface including the visual display of the captured as well as processed signals. The touch panel connected to an I2C port further enhances user interface functionality. RX62N supports 32KB data flash which can be used to store the processed data. Further RX62N support of full speed USB Host functionality which can be used to support writing captured signals to a removable flash for playback and further analysis. A Wi-Fi module connected using the high speed serial port gives the networking capability which in turn enables the device to participate in cloud services for storage and applications.

Main features of RX62N/RX621 are

- Single precision FPU and hardware MAC
- Hardware MAC
- Zero wait state Flash
- Built-in 8 channel 12 bit ADC with 1 μ Sec conversion time.
- Supports full calendar functionality

- High speed USB Host and function
- 16 bit timer

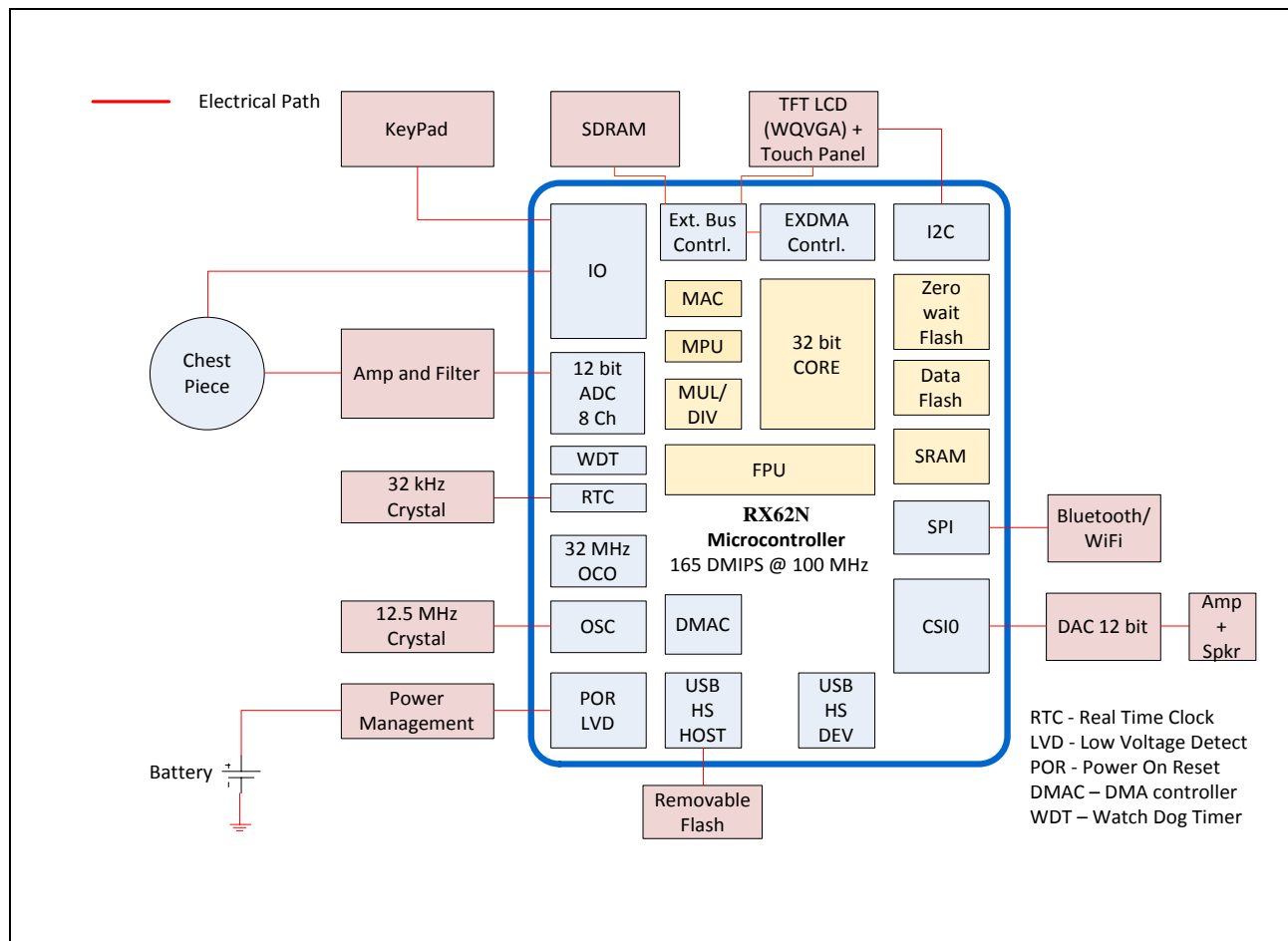


Figure 26 Digital Stethoscope with Graphical Display

Table 30 Digital Stethoscope Applicable Renesas Devices

Microcontroller	RL78/G13	RX62N/RX621
Analog Components	On-chip	Op-amp (CMOS) HA1630xxx Series
Power Management	Zener Diodes RD series Backflow prevention HRV103A, HRV103B, HRV104B	
Protection	ESD protection diodes NNCD and NSAD Series	
LCD Controller	μPD71312	On Chip TFT-LCD Controller

Table 31 Digital Stethoscope related Micro controller family

Feature	RL78/G13	RX62N/RX621
Processor core	16 bit	32 bit
Performance	1.27DMIPS/MHz, Max 32 MHz 41 DMIPS @ 32 MHz	1.65 DMIPS /MHz, Max 100 MHz 160 DMIPS @ 100 MHz
Flash	2K to 512K	Up to 2MB
Data Flash	Up to 8KB	32KB
RAM	2KB to 32KB	96KB to 128KB
Operating Voltage	1.6V – 5.5V	2.7V to 3.6 V
Power consumption	66 μ A @ 1MHz ¹ 2.1mA @ 32MHz 0.2 μ A stop mode	0.52 mA @ 1 MHz 52 mA at 100 MHz 21 μ A stop mode

¹MCU is executing NOPs

Table 32 Digital Stethoscope related tools and technologies

	Low End Solution	High End Solution
Microcontroller	RL78/G13	RX62N/RX621
Evaluation Boards	QB-R5F100LE-TB	R0K5562N0S000BE
Software Libraries	ADPCM-SP Self-Programming EEPROM Emulation library Data flash access library	DSP, Graphics, TCP/IP, USB
Software Development Tools	Cube suite with code generator, PM+	IAR
Hardware Debugger	Minicube2	E1
Application Notes	ADPCM Audio Compression Portable to RL78 as it uses 78K0R core	ADPCM Audio Compression Record and Playback
	RL78 Low Power MCU Application Note	Using Multiply-Accumulate Operation Instructions
Solution	-	Ultra Low Power Wi-Fi. Starter Kit for RX62N (RD-RX62N-2201)
	-	TFT-LCD Direct-Drive solution Kit for RX600 MCUs (YLCDRSKRX62NS)

3. Medical Instruments

This category of medical equipment is generally classified as instruments and used exclusively used in the hospital and clinical laboratory environments. This includes diagnostic as well as surgery equipment. Diagnostic laboratory uses different types of analytical instruments and only a general case is presented here. This is applicable most of the analytical instruments.

Here is the list of Medical Instruments

- Confocal Microscopy
- Endoscope
- Analytical instruments
- Portable Blood Gas Meter
- Electro surgery
- Hospital beds

Table 33 Medical Instruments

Instrument	Key Requirements	Renesas Microcontroller	Key Features
Confocal Microscopy	<ul style="list-style-type: none"> High performance processor core Floating point support Video Display Removable Storage Communication port 	SH7264	<ul style="list-style-type: none"> 32- bit processor core with 345DMIPS @ 144 MHz double precision FPU 32 bit X 32 bit multiplier External memory interface for SDRAM, NOR flash, PCMCIA High speed USB2.0 Host and Function support RGB565 progressive video output High quality audio support (I2S and SPDIF)
Endoscope	<ul style="list-style-type: none"> Video input Video display Floating point support Communication port Removable storage 	SH7264	<ul style="list-style-type: none"> 32- bit processor core with 345DMIPS @ 144 MHz double precision FPU 32 bit X 32 bit multiplier External memory interface for SDRAM, NOR flash, PCMCIA High speed USB2.0 Host and Function support RGB565 progressive video output High quality audio support (I2S and SPDIF)
Analytical Instruments	<ul style="list-style-type: none"> LCD Display 12-bit Analog to digital converter Floating point support Communication port 	RX62N	<ul style="list-style-type: none"> 32-bit processor core with 165 DMIPS @ 100 MHz Single precision FPU and hardware MAC Zero wait state Flash operating up to 100MHz Built-in 8 channel 12 bit ADC with 1µSec conversion time.

			<ul style="list-style-type: none"> • RTC with support- for full calendar functionality • High speed USB Host and function • EXDMA controller to support WQVGA TFT LCD
Portable Blood Gas Meter	<ul style="list-style-type: none"> • Simple user interface • LCD display • High Safety features 	RL78/G13	<ul style="list-style-type: none"> • 16-bit processor core with 41 DMIPS @ 32 MHz • On-chip Data Flash • Hardware MAC • Special Snooze power mode where ADC and serial interface can operate when the MCU is stopped. • Anomaly detection support for system clock failure , flash memory integrity, RAM parity check, invalid memory access detection, write protection to RAM/SFR and ADC self-check
Hospital Bed	<ul style="list-style-type: none"> • User interface • Video input • Video display • Removable Memory support • High quality Audio playback • CAN bus interface 	SH7264	<ul style="list-style-type: none"> • 32- bit processor core with 345DMIPS @ 144 MHz • double precision FPU • 32 bit X 32 bit multiplier • External memory interface for SDRAM, NOR flash, PCMCIA • High speed USB2.0 Host and Function support • RGB565 progressive video output • High quality audio support (I2S and SPDIF)
	<ul style="list-style-type: none"> • Reliable Motor control • High Safety features • CAN bus interface 	RX62T	<ul style="list-style-type: none"> • 32-bit processor core with 165 DMIPS @ 100 MHz • Single precision FPU and hardware MAC • Zero wait state Flash operating up to 100MHz • Built-in 100 MHz multipurpose timer for motor control • RTC with support for full calendar functionality • Dead time insertion and quadrature encoder inputs • POE module to force PWM output pins of the MTU (Multi-Function Timer Pulse unit) and large current output pins of the GPT (General PWM Timer) into a high impedance state, regardless of the state of the rest of the CPU for safety. • Anomaly detection support for system clock failure , flash memory integrity, and ADC self-check

3.1 Confocal Microscopy

The technique of laser scanning and spinning disk confocal microscopy is an essential tool in biomedical sciences. These provide several advantages over conventional wide field optical microscopy, including the ability to control the depth of field, reduction of background information. By using modern fluorochromes, it is possible to identify cells and submicroscopic cellular components with high degree of specificity amid nonfluorescing material.

A simplified block diagram of Confocal microscope is shown in Figure 27.

It consists of optical path and electronics needed for controlling and image processing. This device need a fairly powerful microcontroller/microprocessor capable of capturing and processing the image signals as well as executing various control algorithms to manipulate physical devices.

The functionality can be split in to two processors, one implementing the controls and the other doing the capture and processing of the images. Most of the controls are for DC motor or stepper motor. The signal processing path need power, gain and offset adjustments which can be implemented using DAC.

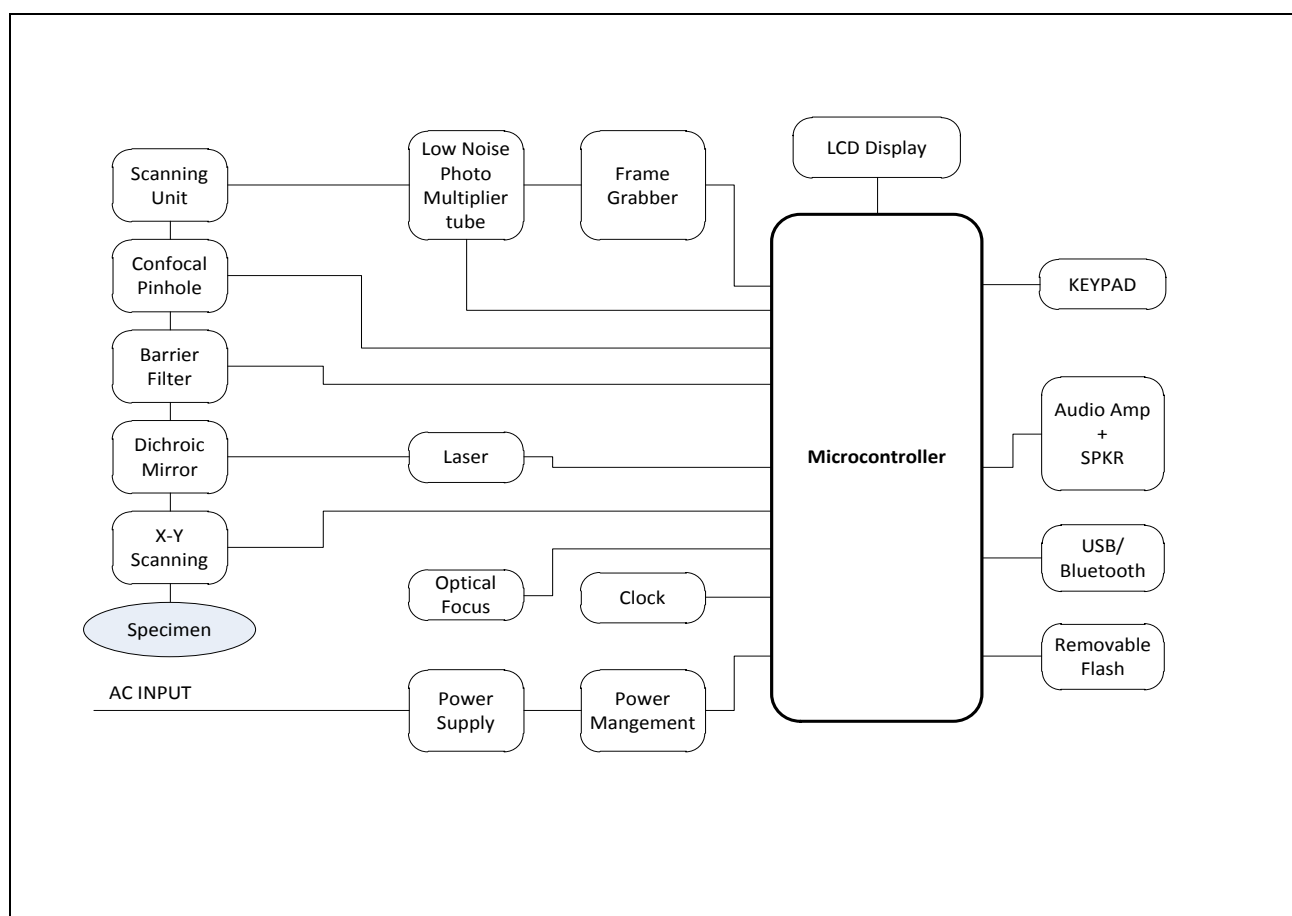


Figure 27 Block Diagram of Confocal Microscope

A simplified implementation using SH-2 family microprocessor is shown in Figure 28. SH7264 is a device with graphics display controller and floating point unit. The microscope needs lot of controls including laser power control. SH7264 digital ports as well on chip are used to provide these signals. All operations can be controlled by the keypad as well as touchpad. The image processing and control execution is handled by using the floating point unit. The whole system is complex and there is a scope to distribute the work among smaller microcontroller to share the tasks and the main microcontroller can take up only User Interface.

Key features of SH7264 are

- double precision FPU

- 32 bit X 32 bit multiplier
- 64KB on-chip high-speed single cycle memory
- On-chip large capacity RAM for display area and work area (640KB/1MB)
- Bootable NAND or serial SPI flash
- External memory interface for SDRAM, NOR flash, PCMCIA
- High quality audio support (I2S and SPDIF)
- USB Host and Function support
- Performance 345DMIPS @ 144 MHz

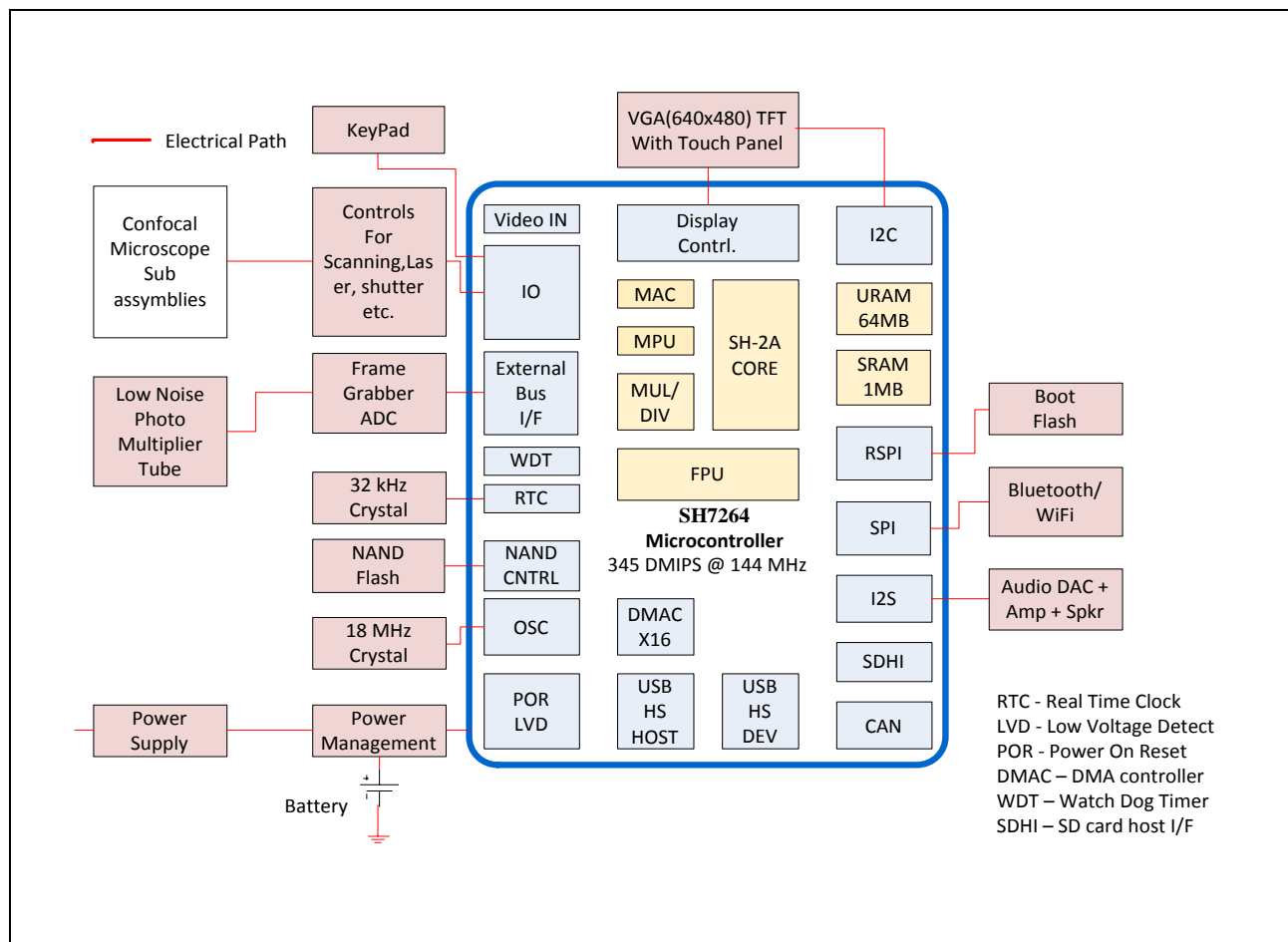


Figure 28 Implementation Diagram of Confocal Microscope

Table 34 Confocal Microscope Applicable Renesas Devices

Microcontroller	SH7264
Analog Components	Op-amp (CMOS) HA1630xxx Series
Power Management	Zener Diodes RD series Backflow prevention HRV103A, HRV103B, HRV104B
Protection	ESD protection diodes NNCD and NSAD Series
LCD Controller	On chip graphical controller, on chip frame buffer, video input

Table 35 Confocal Microscope related Micro controller family

Feature	SH7264
Processor core	32-bit, single and double precision FPU, DSP instructions
Cache	8KB I CACHE, 8KB DATA CACHE
Performance	345 DMIPS @ 144 MHz,
Flash	None, Boot from NAND
Data Flash	Up to 32KB
RAM	64 KB On-chip high-speed RAM ¹ Either 1MB or 640KB on-chip RAM ¹ used for display frame buffer and scratch pad work area
Operating Voltage	3.3V

¹ All memory can be used for instruction or data

Table 36 Confocal Microscope related Tools and Technologies

	High End Solution
Microcontroller	SH7264
Evaluation Boards	R0K572643S000BE
Software Libraries	Graphics, CAN,DSP, fixed point
Software Development Tools	IAR, HEW IDE
Hardware Debugger	E10A,E200F
Application Notes	Video Display Controller 3, How to Use the α (Alpha) Blending Window Function
	Video Display Controller 3 TFT-LCD Interfacing Example
	Video Display Controller 3 Video Recording Example
	Video Display Controller 3 Video Display Example
Solution Platform	Renesas Starter Kit2+ for SH7264

3.2 Endoscope

Endoscope is an instrument which enables the physician to visually examine the interior of a hollow organ or cavity of the body. It is largely responsible for the field of minimally invasive surgery. Optical fibers used in endoscope allowed physicians to direct light in to the body where it was not thought possible, and even to direct laser light to perform microsurgeries in regions previously too delicate or intricate to access. Endoscopy is used in arthroscopy, bronchoscopy, cardiology, cystoscopy, Fetoscopy, gastrointestinal endoscopy, colonoscopy, laparoscopy, neurosurgery, and otolaryngology. Light and different types of lasers are used depending on the application.

A general block diagram of an endoscope is shown in Figure 29. It consists of a light/laser source, an image processing hardware with display and a fiber optic cable with a camera at the farther end. The light is piped through the optical fiber and the visible video from the camera is received by the image processing electronics and an enhanced image video is shown on the display. In addition, some mechanical manipulators are provided at the patient end to perform surgical procedures. These instruments are operated by the physician by using remote control mechanism in the instrument. The surgical instruments may use stepper

motor or DC motor to operate. The base unit will provide control for these motors. All mechanisms including camera are miniaturized such that whole thing can be inserted easily during the procedure.

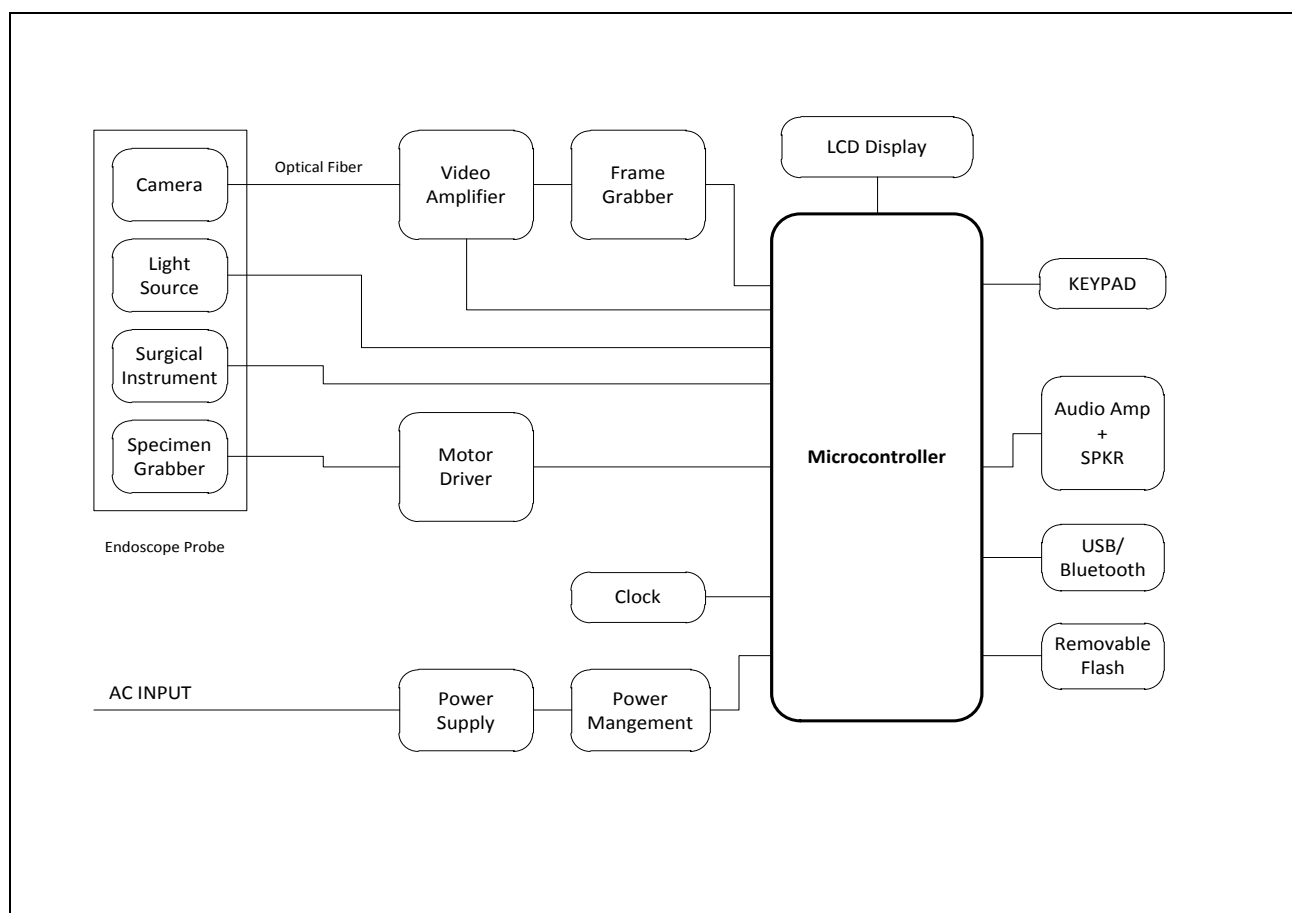


Figure 29 Block diagram of an Endoscope

A typical implementation is shown in Figure 30. This design uses SH7264 to implement the functionality required. The endoscope probe contains a light source, fiber optic cable, surgical instruments controlled by small motors, and specimen extractor. These can be controlled by motor control and IO ports of SH7264. The video coming from the tip camera can be sent to SH7264 video input port to be displayed using built-in VGA graphics display controller. User interface is provided by touch panel connected to the I2C port. User Interface can be enhanced by using some dedicated hard buttons required to control the specimen extractor. SH7264 needs NAND flash memory to boot and program is executed in its internal memory. SH7264 has double precision FPU which allows the implementation of various algorithms using floating point arithmetic without converting to fixed point and thus simplify implementation, improvement and maintenance of the algorithms. SH7264 supports high speed USB2.0 Host as well as Function ports. USB port can be used to retrieve data to a removable flash device for archiving or further analysis. SH7264 has SD card interface which can also be used to upload and retrieve program and static images.

Key features of SH7264 are

- double precision FPU
- 32 bit X 32 bit multiplier
- 64KB on-chip high-speed single cycle memory
- On-chip large capacity RAM for display area and work area (640KB/1MB)
- Bootable NAND or serial SPI flash
- External memory interface for SDRAM, NOR flash, PCMCIA

- High quality audio support (I2S and SPDIF)
- USB Host and Function support
- Performance 345DMIPS @ 144 MHz

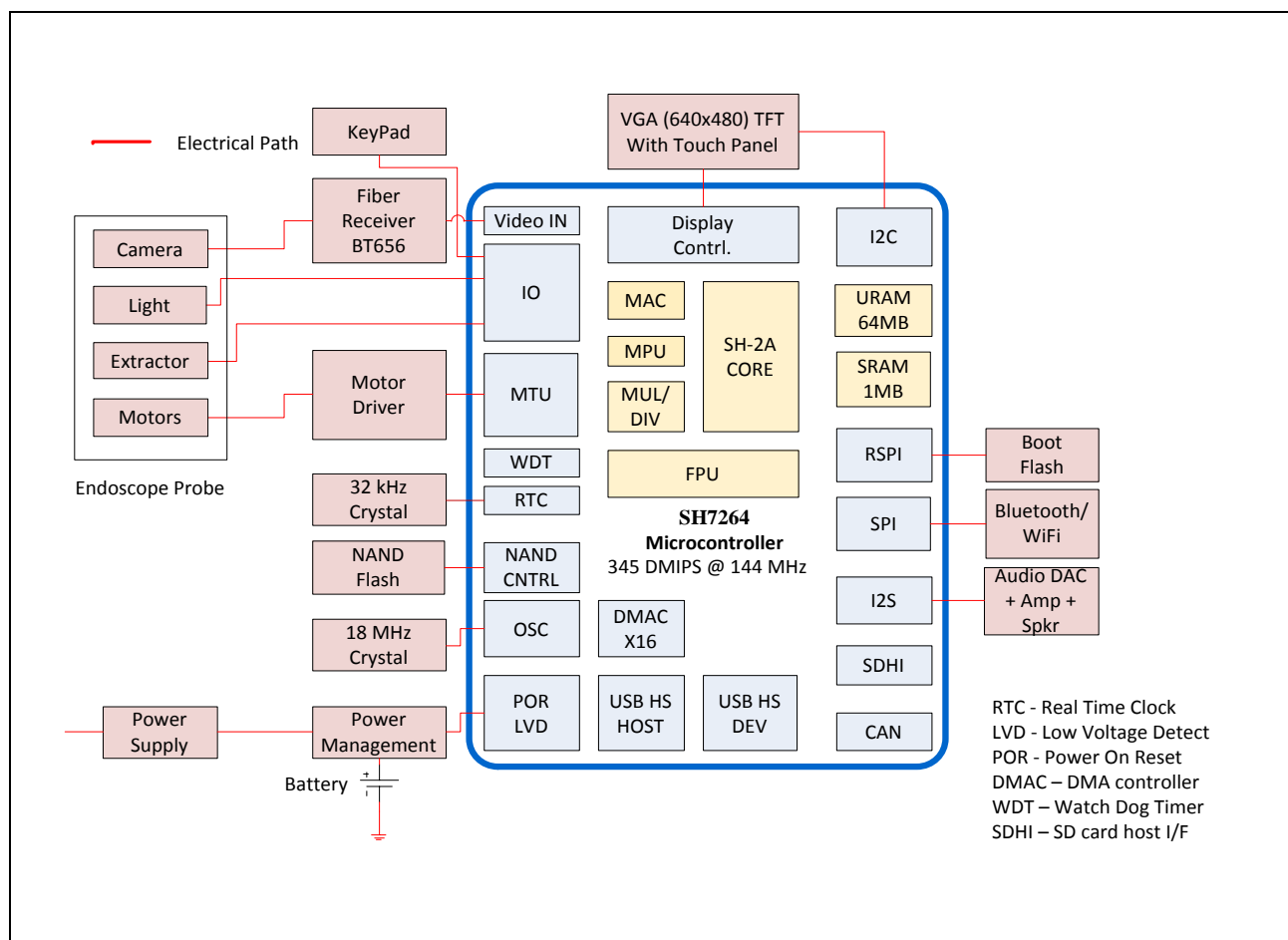


Figure 30 Implementation Diagram of Endoscope

Table 37 Endoscope Applicable Renesas Devices

Microcontroller	SH7264
Analog Components	Op-amp (CMOS) HA1630xxx Series
Power Management	Zener Diodes RD series Backflow prevention HRV103A, HRV103B, HRV104B
Protection	ESD protection diodes NNCD and NSAD Series
LCD Controller	On chip graphical controller, on chip frame buffer, video input

Table 38 Endoscope related Micro controller family

Feature	SH7264
Processor core	32-bit, single and double precision FPU, DSP instructions
Cache	8KB I CACHE, 8KB DATA CACHE
Performance	345 DMIPS @ 144 MHz,
Flash	None, Boot from NAND
Data Flash	32KB
RAM	64 KB On-chip high-speed RAM ¹ Either 1MB or 640KB on-chip RAM ¹ used for display frame buffer and scratch pad work area
Operating Voltage	3.3 V

¹ All memory can be used for instruction or data

Table 39 Endoscope related Tools and Technologies

	High End Solution
Microcontroller	SH7264
Evaluation Boards	R0K572643S000BE
Software Libraries	Graphics, CAN,DSP, fixed point
Software Development Tools	IAR, HEW IDE
Hardware Debugger	E10A,E200F
Application Notes	Video Display Controller 3, How to Use the α (Alpha) Blending Window Function
	Video Display Controller 3 TFT-LCD Interfacing Example
	Video Display Controller 3 Video Recording Example
	Video Display Controller 3 Video Display Example
Solution Platform	Renesas Starter Kit2+ for SH7264

3.3 Analytical Instruments

Chemical composition of blood, urine, spinal fluid and sweat provide a wealth of information on the well-being or illness of the individual. The presence, concentration and activity of various chemical constituents are indicators of various organ functions. Various analytical instruments are available to perform the required analysis. Most of these analyzers can perform multiple tests simultaneously on the samples and provide integrated report. Some of the instruments are chemistry analyzers, Immunoassay analyzers, critical care analyzers and point of care test analyzers. Table 40 shows various parameters measured by these instruments.

Table 40 List of Analytical Instruments

Type of Instrument	Tests
Chemistry Analyzers	Electrolytes, BUN, Glucose, Creatinine, Protein, Albumin, Lipids, Iron, Therapeutic drug monitoring
Immunoassay Analyzer	Tumor marker, Cardiac marker, Anemia, B12, Folate, and Endocrine tests
Critical Care	Blood Gases, Cooximetry, Electrolytes Ionized calcium, Lactate, Hematocrit
Point of care	Bedside Glucose test, Coagulation, Focal occult blood, Urinalysis

The basic block diagram of these analyzers is shown in Figure 31. These instruments have analog front end to process signal from various bio sensors and the digitized signal is further processed and recorded to provide information about the sample analyzed. Some of the instruments can do real time measurement of essential parameters and can communicate to the central computer. The microcontroller required is medium performance with support hardware digital signal processing. A graphical display controller provides the required capability to present the information on a screen with touchpad support for user interface.

Communication with central computer can be provided using Ethernet or wireless technologies like Wi-Fi. Point of care instruments may support USB or Bluetooth.

These instruments can be standalone or part of a modular system. These instruments can process the data locally or send it to a computer for further processing. These can interface to laboratory automation system to further improve their performance.

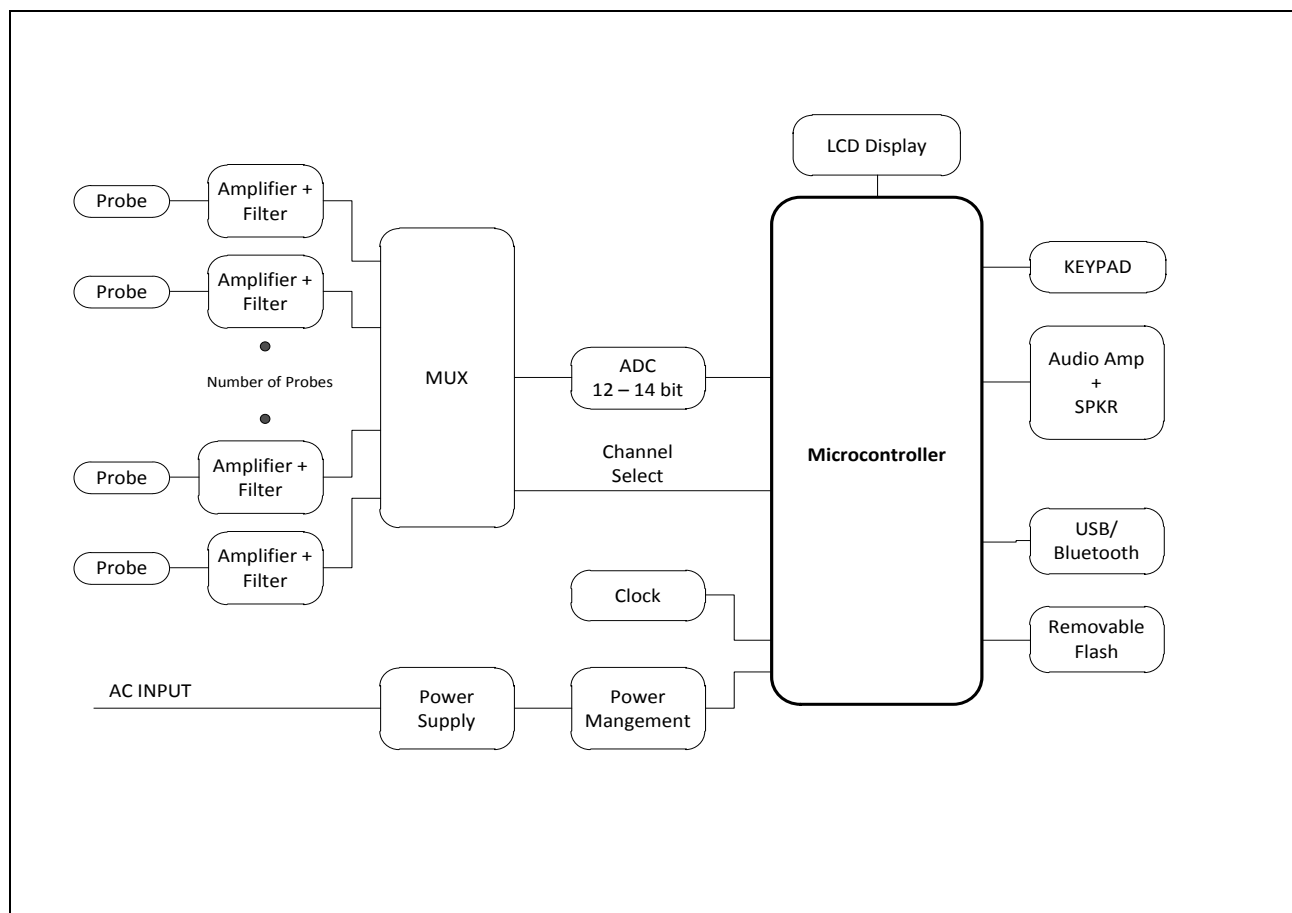


Figure 31 General Block Diagram of an Analytical Instrument

A reference design using RX621 is shown in Figure 32. RX621 with 8 channel 12 bit ADC can be used to monitor 8 probes and record the signals. The computing power of RX621 with single precision FPU can be used to process the signal and calculate necessary parameters. The full calendar functionality can be used to do real time stamping of the measurements. The external amplifier offset or gain can be adjusted using 10 bit DAC and using a de-multiplexer. The USB Host port can be used to transfer the data between external flash device and the instrument. RX621 has an external DMA controller (EXDMA) which enables data transfer from external SDRAM to TFT LCD without the intervention of the CPU. This method can support a WVGA TFT display without an external TFT driver. A touch panel can be interfaced to I2C to provide user interface. Network Connectivity solution can be provided by on chip Ethernet MAC along with an external Ethernet physical device.

Key features of RX621 are

- 165 DMIPS at 100 MHz
- Single precision Floating point and MAC units
- 100 MHz zero wait state flash memory access
- Color TFT-LCD controller up to WQVGA resolution
- Data flash up to 32 KB

- 8 channel 12 bit ADC with 1 μ S conversion time

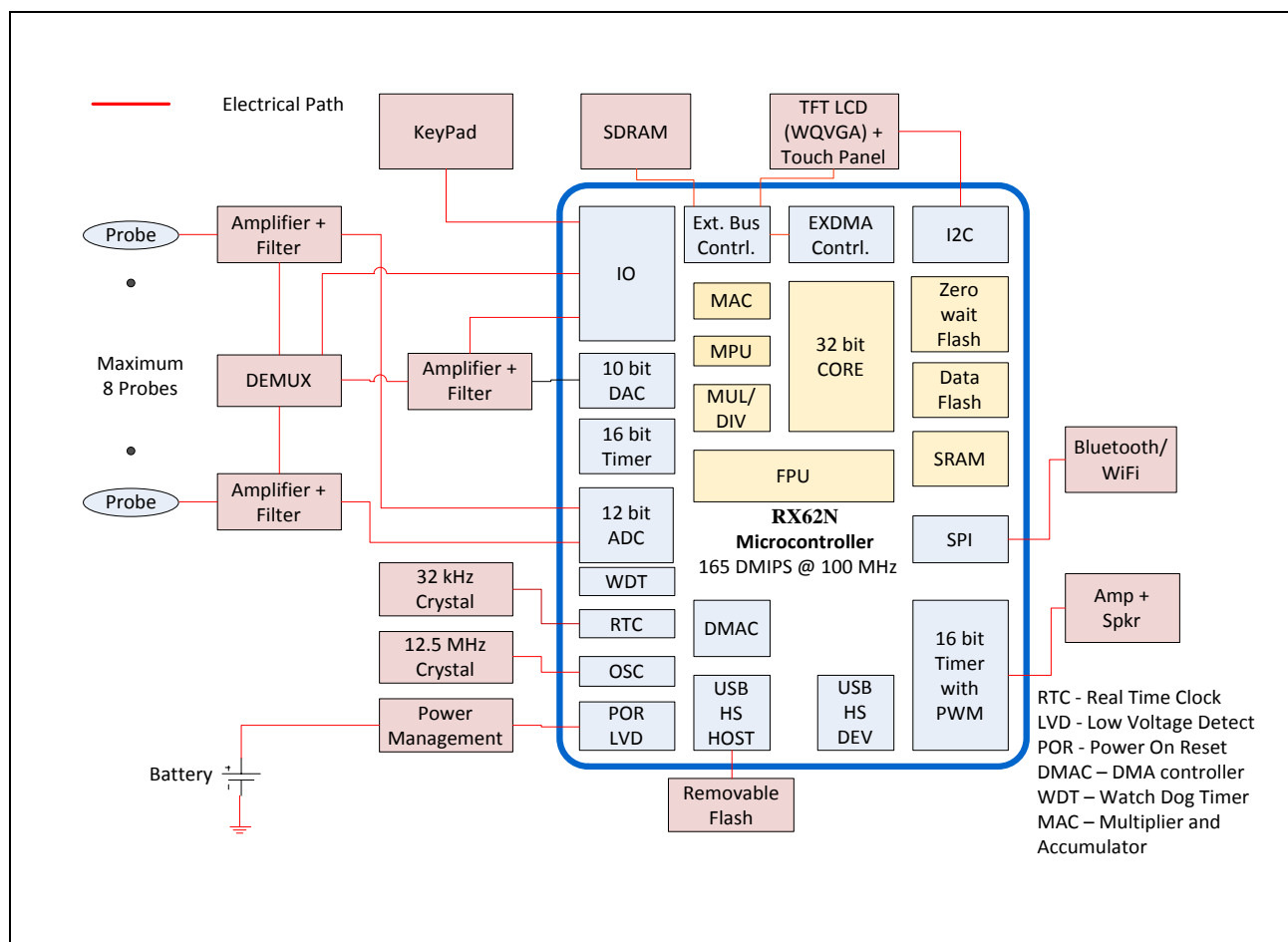


Figure 32 Implementation Diagram of an Analytical instrument

Table 41 Analytical Instruments Applicable Renesas Devices

Microcontroller	RX62N/RX621
Analog Components	Op-amp (CMOS) HA1630xxx Series
Power Management	Zener Diodes RD series Backflow prevention HRV103A, HRV103B, HRV104B
Protection	ESD protection diodes NNCD and NSAD Series
LCD Controller	On chip TFT-LCD controller

Table 42 Analytical Instruments related Micro controller family

Feature	RX62N/RX621
Processor core	32 bit
Performance	1.65 DMIPS /MHz, Max 100 MHz
Flash	Up to 2MB
Data Flash	32KB
RAM	96KB to 128KB
Operating Voltage	2.7V to 3.6 V
Power consumption	52 mA at 100 MHz

Table 43 Analytical Instrument related Tools and Technologies

	Solution
Microcontroller	RX62N/RX621
Evaluation Boards	R0K5562N0S000BE
Software Libraries	Graphics, DSP, TCP/IP
Software Development Tools	IAR, HEW
Hardware Debugger	E1
Application Notes	ADPCM Audio Compression Record and Playback
	Using Multiply-Accumulate Operation Instructions
Solution Platform	Ultra Low Power Wi-Fi. Starter Kit for RX62N (RD-RX62N-2201)
	TFT-LCD Direct-Drive solution Kit for RX600 MCUs (YLCDRSKRX62NS)

3.4 Portable Blood Gas Monitor

Blood gas meters are used in anesthesia, intensive and critical care facilities, and cardiorespiratory research laboratories. An integrated sensor is used to measure blood gases using continuous Intravascular Blood Gas Monitoring (CIBM). Typically one optical sensor for pO₂, an optode sensor for pCO₂, a pH sensor, and a thermocouple for measuring the temperature integrated into a single probe. This integrated sensor generates electrical signals proportional to the parameter to be measured. This can be interfaced to a microcontroller with a 12 bit ADC after amplification and filtering. The temperature information is used to apply necessary correction to the readings obtained to get accurate values for the gases present in the blood.

A typical Intravascular Blood Gas monitor is shown in the Figure 33.

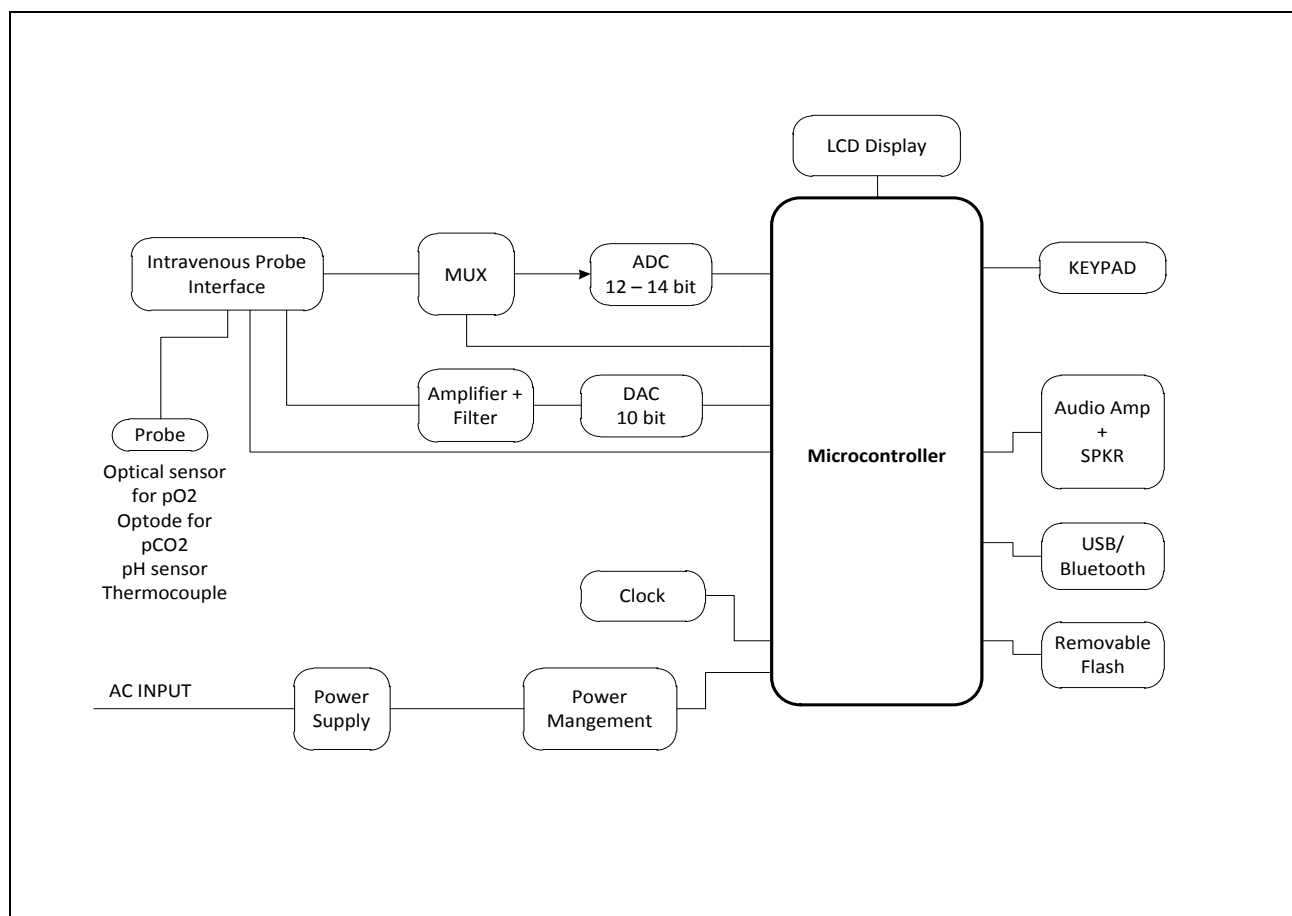


Figure 33 Block Diagram of Portable Blood Gas Meter

A low power microcontroller RL78/G13 is used in the reference implementation shown in Figure 34. An external front end consisting of necessary amplifiers and filters process the signals from various sensors and digitized by an external ADC. The digitized signals are further processed in the digital domain by RL78/G13 with on-chip MAC unit to derive the values for main blood gas analysis. The temperature measurement signal is used to apply necessary corrections to the values obtained for various gas parameters. An external 20 MHz resonator is used to improve the stability and accuracy of the clock required for high accuracy system. With a stable clock, signal processing like oversampling and averaging can be applied to get better accuracy of the measurement. RL78/G13 has anomaly detection support features for system clock failure, flash memory integrity, RAM parity check, and invalid memory access; write protection to RAM/SFR and ADC self-check which ensure proper and safe operation of the system.

Key features of RL78/G13 are

- 16-bit processor core with 1.27DMIPS/MHz with maximum frequency at 32MHz
- On-chip hardware multiplier and accumulator
- On-chip oscillator with +/- 1% over temperature and voltage range
- Data flash for storing calibration data, and archival of measured data
- Very low power consumption: operational at 66 μ A/MHz (executing NOPs) and 0.57 μ A with only RTC and LVD on
- Special Snooze Mode where ADC and serial interface can operate when the MCU is stopped.
- Operating voltage is down to 1.6V to extend battery life

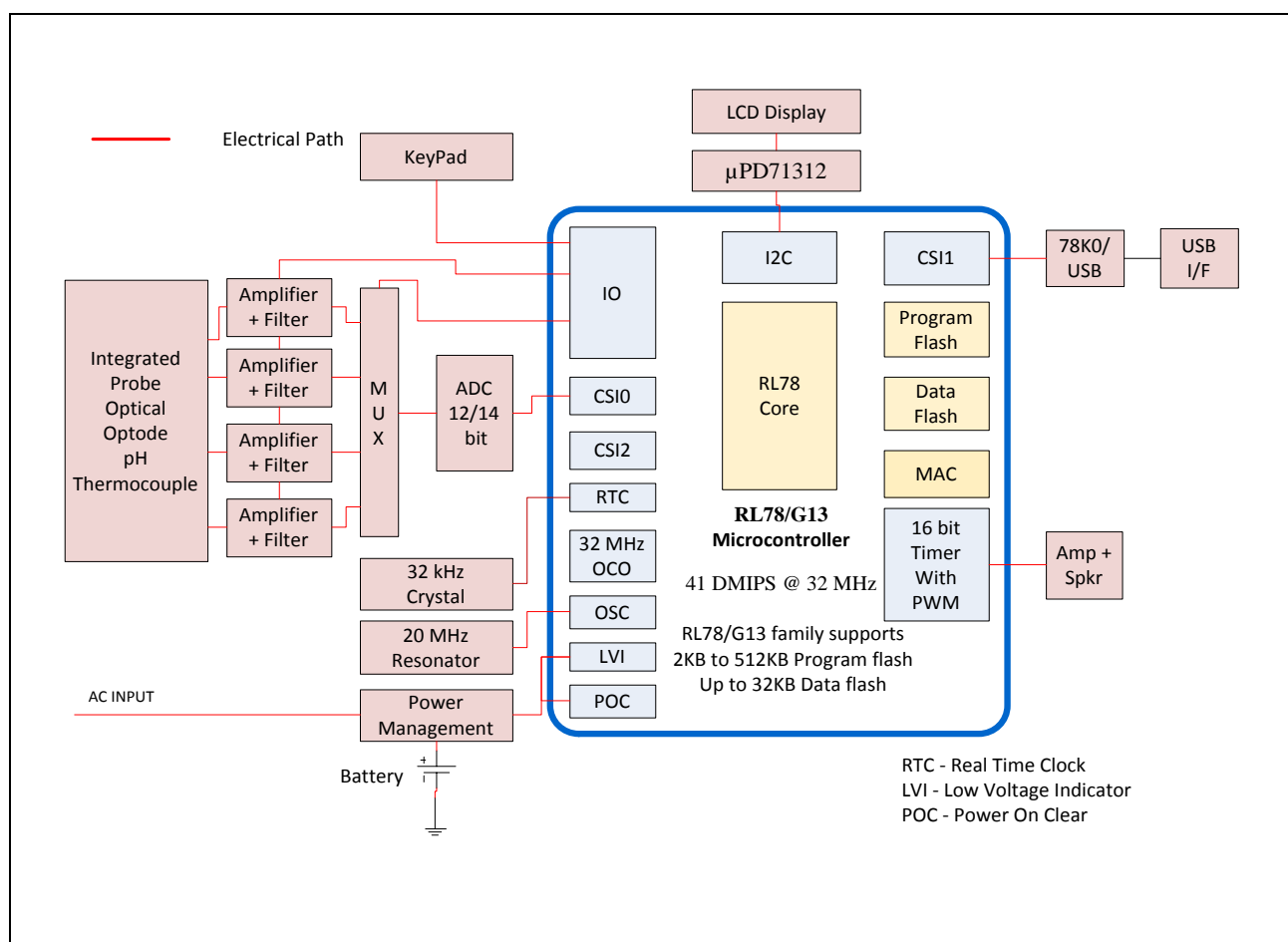


Figure 34 Reference implementation of Low power Multipurpose Blood Gas Analyzer

Table 44 Blood Gas Monitor applicable Renesas Devices

Microcontroller	RL78/G13
Analog Components	Op-amp (CMOS) HA1630xxx Series
Power Management	Zener Diodes RD series Backflow prevention HRV103A, HRV103B, HRV104B
Protection	ESD protection diodes NNCD and NSAD Series
LCD Controller	μPD71312

Table 45 Blood Gas Monitor related Microcontroller family

Feature	RL78/G13
Processor core	16-bit
Performance	41 DMIPS @ 32 MHz
Flash	2KB to 512KB
Data Flash	Up to 32KB
RAM	0.25KB to 32KB
Operating Voltage	1.6V to 5.5V
Power consumption	66 μA @ 1MHz ¹ 2.1mA @ 32MHz 0.2 μA stop mode

¹MCU is executing NOPs

Table 46 Blood Gas Monitor related Tools and Technologies

	Low power solution
Microcontroller	RL78/G13
Evaluation Boards	QB-R5F100LE-TB
Software Libraries	ADPCM-SP Self-Programming EEPROM Emulation library Data flash access library
Software Development Tools	IAR, Cube suite+, Applilet code generator
Hardware Debugger	E1

3.5 Hospital Beds

Hospital bed is a complex system requiring a number of electronic subassemblies and devices to provide comfort to the patient as well as enabling the medical personnel to perform their tasks with ease. It consists of the bed frame which can be positioned in different ways and can be adjusted with a push of a button. This functionality is implemented by using mechanical gear mechanism with DC motors providing the necessary drive controls. The hospital can have a provision to monitor patient vital signs and the required displays need to be conveniently mounted. The patient monitor system can display medical parameters from the local instruments as well as data available from the Hospital local area network. Some of the beds will have integrated information and entertainment console for the patient comfort. Some have interface to infusion devices also.

A typical system diagram is shown in Figure 35. It shows different micro controller and microcomputer based sub-assemblies connected together using CAN bus for communication.

Basic hospital bed control user interface can be implemented using RX62N. This design with built-in support of TFT LCD driver interface is a cost effective solution. The user input can be implemented using a touch panel connected to I2C port as well as few hard buttons. This module can communicate with the motor control modules using CAN bus. The motor control modules are implemented using RX62T which can control up to two motors. For enhanced functionalities like patient monitoring in addition to the basic bed controls, a reference implementation of an enhanced hospital bed controller is shown in Figure 36.

This uses SH7264 as the main processor with display and user interface provided by both touchpad and convenient buttons to control the bed. SH7264 with graphics display controller, video input and high quality audio interfaces is a good fit for implementing the enhanced hospital bed user interface with patient monitoring capabilities. SH7264 uses NAND flash as boot memory and the program resides in the on-chip RAM after boot up. The display controller can support up to VGA (640x480) resolution. This enables monitoring of vital parameters graphically using a built-in VGA LCD display. Further SH7264 with built-in video input functionality can be connected to a camera to visually monitor the patients (epilepsy type etc.) continuously to correlate the vital parameter data with visual observation. SH7264 supports I2S and SPDIF audio interfaces which support high quality audio playback using external codecs. The audio support can play back instruction and warning message. The position mechanisms of various parts of the bed are controlled by DC motors. The motor control modules are implemented using RX62T which can control two motors. SH7264 communicate to these modules using built-in CAN controller.

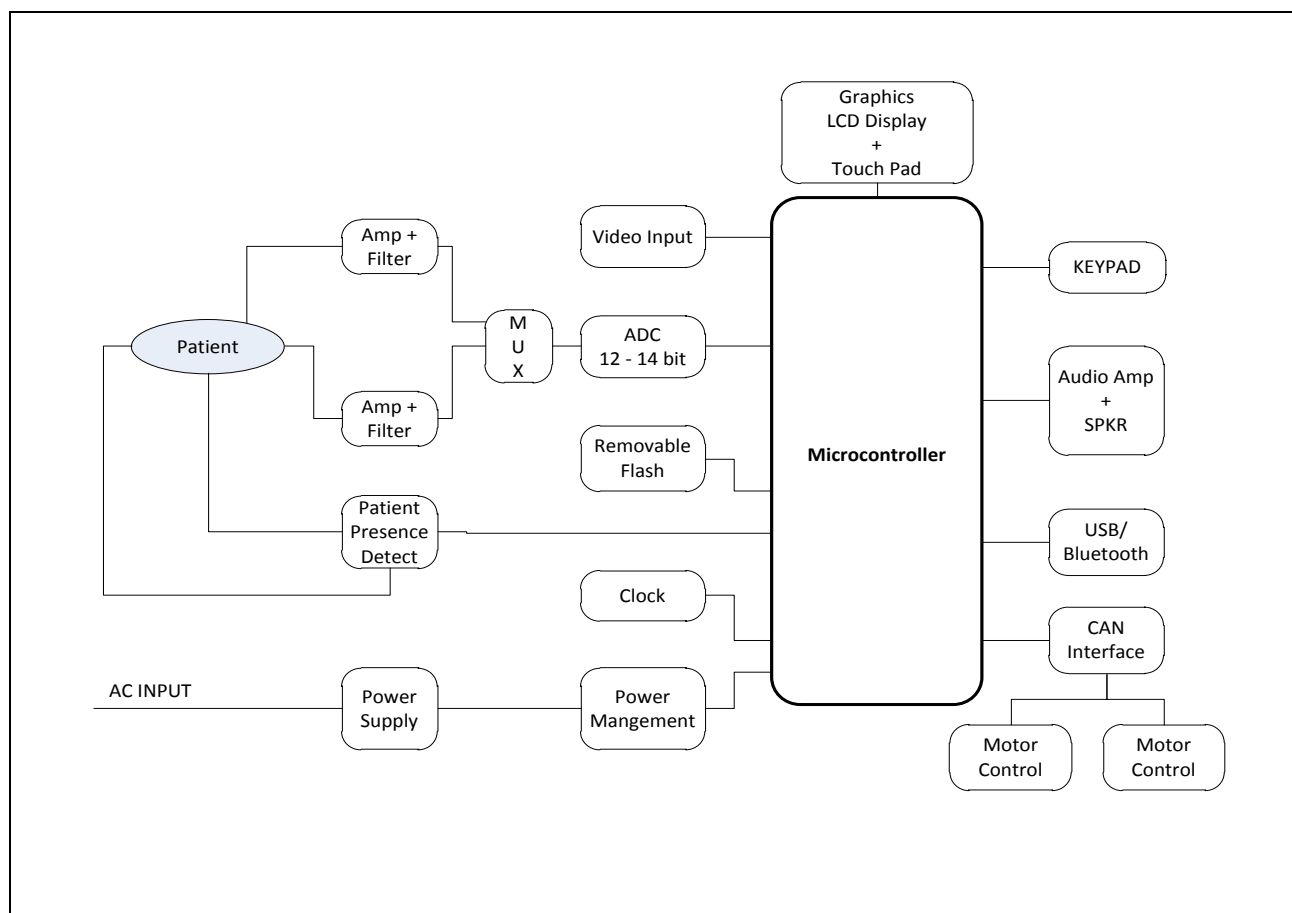


Figure 35 Block Diagram a Hospital Bed system

This reference design implemented built-in ECG functionality using a high resolution external ADC connected through high speed external bus interface. Double precision FPU in SH7264 aids in the signal processing as well as used to execute complex algorithms required in the drug dosage etc. calculations by medical personnel.

SH7264 supports high speed USB2.0 Host as well as Function ports. USB port can be used to retrieve data to a removable flash device for archiving or further analysis. SH7264 has SD card interface which can also be used to upload and retrieve information. A Wi-Fi module interfaced using SPI port is used to provide the networking capability to aid the data transfer to the hospital network. This feature is very useful for the physicians as and nurses to remotely monitor the patient condition.

Key features of SH7264 are

- double precision FPU

- 32 bit X 32 bit multiplier
- 64KB on-chip high-speed single cycle memory
- On-chip large capacity RAM for display area and work area (640KB/1MB)
- Bootable NAND or serial SPI flash
- External memory interface for SDRAM, NOR flash, PCMCIA
- High quality audio support (I2S and SPDIF)
- USB Host and Function support
- Performance 345DMIPS@ 144 MHz

The bed position, tilt etc. mechanisms are driven by dc motors. These motors are controlled by hardware implemented using RX62T microcontroller. This hardware communicates with the main board using CAN bus interface. RX62T has support for controlling up to two motors. It has 100 MHz multipurpose timer unit and a 12 bit ADC. It can generate complimentary PWM outputs which are reset synchronized. It supports dead time insertion and can take quadrature encoder inputs. RX62T has built in safety features like Port Output Enable (POE) module which can be used to force PWM output pins of the MTU (Multi-Function Timer Pulse unit) and large current output pins of the GPT (General PWM Timer) into a high impedance state, regardless of the state of the rest of the CPU. This is a great feature that can be utilized to ensure safety of controlling external loads. The single precision floating point unit in RX62T simplifies complex motor control algorithm implementation to achieve patient comfort.

Main features of RX62T are

- Single precision FPU and hardware MAC
- Zero wait state Flash operating up to 100MHz
- Built-in 100 MHz multipurpose timer for motor control
- RTC with support for full calendar functionality
- Dead time insertion and quadrature encoder inputs for motor control
- Safety features like clock monitoring, Flash CRC check and POE module to force PWM output pins to high impedance
- 8KB/32KB Data flash

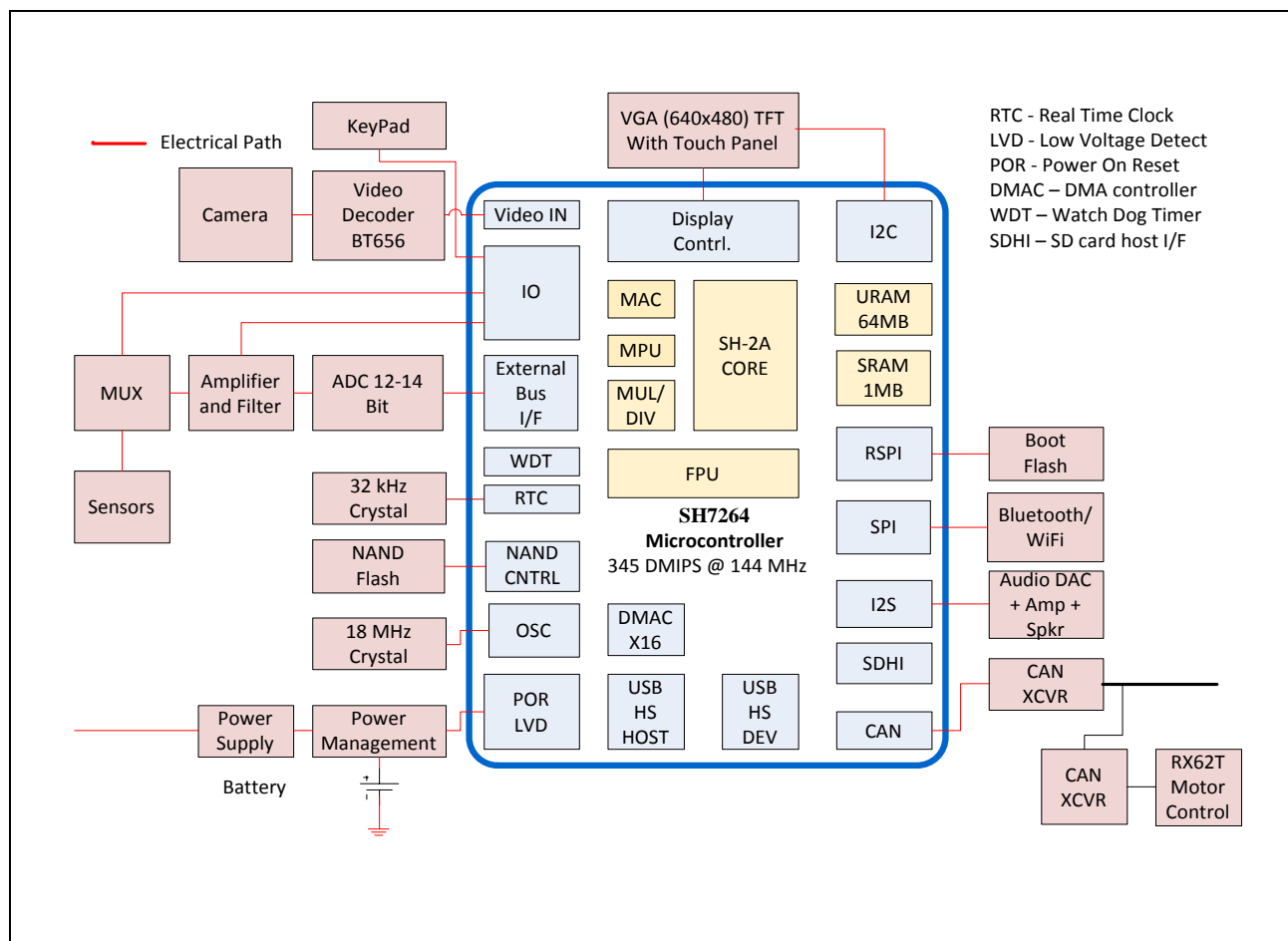


Figure 36 Implementation Diagram of a Hospital Bed controller

Table 47 Hospital Bed Applicable Renesas Devices

Microcontroller	SH7264,RX62T
Analog Components	Op-amp (CMOS) HA1630xxx Series
Power Management	Zener Diodes RD series Backflow prevention HRV103A, HRV103B, HRV104B
Protection	ESD protection diodes NNCD and NSAD Series
LCD Controller	On chip graphical controller, on chip frame buffer, video input

Table 48 Hospital Bed related Micro controller family

Feature	RX62T	SH7264
Processor core	32-bit	32-bit, single and double precision FPU, DSP instructions
Cache	None	8KB I CACHE, 8KB DATA CACHE
Performance	165 DMIPS @ 100MHz	345 DMIPS @ 144 MHz
Flash	64KB to 256KB	None, Boot from NAND
Data Flash	8KB/32KB	32KB
RAM	8KB to 16KB	64 KB On-chip high-speed RAM ¹ Either 1MB or 640KB on-chip RAM ¹ used for display frame buffer and scratch pad work area
Operating Voltage	3.3 / 5 V	3.3 V

¹ All memory can be used for instruction or data

Table 49 Hospital Bed related Tools and Technologies

	Motor Control	Main Processor
Microcontroller	RX62T	SH7264
Evaluation Boards	R0K5562T0S000BE	R0K572643S000BE
Software Libraries	Motor control, DSP,TCP/IP	Graphics, CAN, DSP, fixed point
Software Development Tools	IAR, Cube suite	IAR, HEW IDE
Hardware Debugger	E1, Minicube2	E10A, E200F
Application Notes	Low Cost Motor Control Demo Board based on RX62T	Video Display Controller 3, How to Use the α (Alpha) Blending Window Function
	SPWM Motor Control	Video Display Controller 3 TFT-LCD Interfacing Example
	Using Multiply-Accumulate Operation Instructions	Video Display Controller 3 Video Recording Example
	CAN Application Programming Interface	Video Display Controller 3 Video Display Example
Solution Platform	Low Cost Motor Control Demo Board based on RX62T (MCRP07)	Renesas Starter Kit2+ for SH7264

4. Renesas Microcontroller Solutions

Renesas provides many starter kits, demonstration platforms and evaluation boards to support development of products using Renesas MCUs. They also include application specific demonstration kits for connectivity, user interface and authentication. In addition industry standard application demonstration kits are also available. Below are the tables listing various kits and boards available from Renesas useful for medical device development.

Table 50 Connected Medical Device demo platforms

Name	Description	Part Number
Continua Demonstration Platform	Continua Demonstration platform implemented using energy efficient V850ES/Jx3-L, delivering 1.9DMIPS/MHz with memory up to 1MB with USB support	Contact Sales
ANT+ Demonstration Platform	ANT+ demonstration platform implemented using RL78/G13, delivering 1.27DMIPS/MHz	Contact Sales

Table 51 Connectivity demo platforms

Name	Description	Part Number
Wi-Fi Evaluation Kit	Ultra Low Power Wi-Fi Starter Kit for R8C/25	RS-R8C25-2200
Wi-Fi Evaluation Kit	Ultra Low Power Wi-Fi. Starter Kit for RX62N	RD-RX62N-2201
Ethernet Evaluation Kit	Low-cost RX62N Ethernet demonstration kit	YRDXXKX62N

Table 52 User interface demo platforms

Name	Description	Part Number
TFT-LCD Direct-Drive solution Kit for RX600 MCUs	LCD Development Kit (RX62N) w/ Sharp Display and E1. This shows how to use Direct connection to RGB signals of TFT-LCD panel to drive up to WQVGA resolution, 16 bpp color depth, 60Hz refresh rate	YLCDRSKRX62NS
Capacitive Touch Evaluation System	Capacitive Touch Kit for R8C/33T	YR8C33TKIT02
SH Video	Renesas Starter Kit2+ for SH7264	YR0K572643S000BE-L

Table 53 Authentication demo platforms

Name	Description	Part Number
Board ID Demonstration Kit	To evaluate the state-of-the art Machine-to-Machine authentication capability of the Board ID device.	YBIDKITSV2

Table 54 Promotional Kits

Name	Description	Part Number
RL78/G13	RL78/G13 Promotional Board	Contact Sales
V850ES/JG3-L	V850ES Promotional and Low Power Demonstrator Kit	V850/JG3LLPD

Table 55 Starter and Evaluation Kits

MCU	Description	Part Number
78K0R/Lx3	Demo Kit for 78K0R LH3 UPD78F1508	QB-MINI2-K0R/LH3
RL78/G13	Renesas Starter Kit for RL78/G13 with IAR workbench	YR0K50100LS000BE
RX621	Renesas Starter Kit+ for RX62N	R0K5562N0S000BE
RX62N	Renesas Starter Kit+ for RX62N	R0K5562N0S000BE
RX62T	Renesas Starter Kit for RX62T w/ E1	R0K5562T0S000BE
RX200	Renesas Starter Kit for RX210	R0K505210S000BE
V850ES/JG3-L	V850/JG3-L Starter Kit	QB-MINI2-V850/JG3L
SH7264	Renesas Starter Kit+ for SH7264	YR0K572643S000BE-L

Table 56 Demonstration Boards

MCU	Description	Part Number
78K0R/Lx3	78K0R/Lx3 - Sense it!	78K0RLX3-SENSEIT
V850ES/JG3-L	Low Power Demonstrator Kit	V850/JG3LLPD
RX62N	Low-cost RX62N demonstration and evaluation kit	YRDKRX62N
RX62T	Low Cost Motor Control Demo Board based on RX62T	MCRP07
SH	Renesas Starter Kit2+ for SH7264	YR0K572643S000BE-L

5. Renesas Product Selection

5.1 Renesas products

Table 57 Renesas

MCU	Description	Document Number
Selected MCUs	Easy List – a 11-page summary of our current Microcontrollers offering. June 2011 Edition	REU01A0007-0200-03
RL78/G13	Low Power Platform for 8-/16- bit Applications RL78Microcontrollers	R01PF0039EU0100
V850ES/JG3-L	32-bit MCUs for Energy-efficient Designs V850 J Series Microcontrollers	R01PF0037EU0100
RX600	The Core Difference in Your Design RX600Microcontroller	R01PF0016EU0100
RX200	The Core Difference in Your Design RX200 Microcontrollers	RO1CP0008EU0000_RX200
Board ID	Board ID™Demonstration Kit A Powerful, Flexible Solution for Machine-to-Machine Authentication (M2M)	R30PF0005EU0100
Capacitive Touch-key Solution	Hardware-assisted Capacitive Touch-key Solutions	R01PF0037EU0100-01

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Revision Record

Rev.	Date	Description	
		Page	Summary
1.00	Dec.15.2011	—	First edition issued

General Precautions in the Handling of MPU/MCU Products

The following usage notes are applicable to all MPU/MCU products from Renesas. For detailed usage notes on the products covered by this manual, refer to the relevant sections of the manual. If the descriptions under General Precautions in the Handling of MPU/MCU Products and in the body of the manual differ from each other, the description in the body of the manual takes precedence.

1. Handling of Unused Pins

Handle unused pins in accord with the directions given under Handling of Unused Pins in the manual.

The input pins of CMOS products are generally in the high-impedance state. In operation with an unused pin in the open-circuit state, extra electromagnetic noise is induced in the vicinity of LSI, an associated shoot-through current flows internally, and malfunctions occur due to the false recognition of the pin state as an input signal become possible. Unused pins should be handled as described under Handling of Unused Pins in the manual.

2. Processing at Power-on

The state of the product is undefined at the moment when power is supplied.

The states of internal circuits in the LSI are indeterminate and the states of register settings and pins are undefined at the moment when power is supplied.

In a finished product where the reset signal is applied to the external reset pin, the states of pins are not guaranteed from the moment when power is supplied until the reset process is completed.

In a similar way, the states of pins in a product that is reset by an on-chip power-on reset function are not guaranteed from the moment when power is supplied until the power reaches the level at which resetting has been specified.

3. Prohibition of Access to Reserved Addresses

Access to reserved addresses is prohibited.

The reserved addresses are provided for the possible future expansion of functions. Do not access these addresses; the correct operation of LSI is not guaranteed if they are accessed.

4. Clock Signals

After applying a reset, only release the reset line after the operating clock signal has become stable. When switching the clock signal during program execution, wait until the target clock signal has stabilized.

When the clock signal is generated with an external resonator (or from an external oscillator) during a reset, ensure that the reset line is only released after full stabilization of the clock signal. Moreover, when switching to a clock signal produced with an external resonator (or by an external oscillator) while program execution is in progress, wait until the target clock signal is stable.

5. Differences between Products

Before changing from one product to another, i.e. to one with a different type number, confirm that the change will not lead to problems.

The characteristics of MPU/MCU in the same group but having different type numbers may differ because of the differences in internal memory capacity and layout pattern. When changing to products of different type numbers, implement a system-evaluation test for each of the products.

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Renesas Electronics America Inc.

2880 Scott Boulevard Santa Clara, CA 95050-2554, U.S.A.
Tel: +1-408-588-8000, Fax: +1-408-588-6130

Renesas Electronics Canada Limited

1101 Nicholson Road, Newmarket, Ontario L3Y 9C3, Canada
Tel: +1-905-898-5441, Fax: +1-905-898-3220

Renesas Electronics Europe Limited

Dukes Meadow, Millboard Road, Bourne End, Buckinghamshire, SL8 5FH, U.K.
Tel: +44-1628-585-100, Fax: +44-1628-585-900

Renesas Electronics Europe GmbH

Arcadiastrasse 10, 40472 Düsseldorf, Germany
Tel: +49-211-65030, Fax: +49-211-6503-1327

Renesas Electronics (China) Co., Ltd.

7th Floor, Quantum Plaza, No.27 Zhichunlu Haidian District, Beijing 100083, P.R.China
Tel: +86-10-8235-1155, Fax: +86-10-8235-7679

Renesas Electronics (Shanghai) Co., Ltd.

Unit 204, 205, AZIA Center, No.1233 Lujiazui Ring Rd., Pudong District, Shanghai 200120, China
Tel: +86-21-5877-1818, Fax: +86-21-6887-7858 / -7898

Renesas Electronics Hong Kong Limited

Unit 1601-1613, 16/F., Tower 2, Grand Century Place, 193 Prince Edward Road West, Mongkok, Kowloon, Hong Kong
Tel: +852-2886-9318, Fax: +852-2886-9022/9044

Renesas Electronics Taiwan Co., Ltd.

13F, No. 363, Fu Shing North Road, Taipei, Taiwan
Tel: +886-2-8175-9600, Fax: +886-2-8175-9670

Renesas Electronics Singapore Pte. Ltd.

1 HarbourFront Avenue, #08-10, Keppel Bay Tower, Singapore 098632
Tel: +65-6213-0200, Fax: +65-6278-8001

Renesas Electronics Malaysia Sdn.Bhd.

Unit 906, Block B, Menara Amcorp, Amcorp Trade Centre, No. 18, Jin Persiaran Barat, 46050 Petaling Jaya, Selangor Darul Ehsan, Malaysia
Tel: +60-3-7955-9390, Fax: +60-3-7955-9510

Renesas Electronics Korea Co., Ltd.

11F., Samik Lavied' or Bldg., 720-2 Yeoksam-Dong, Kangnam-Ku, Seoul 135-080, Korea
Tel: +82-2-558-3737, Fax: +82-2-558-5141