

V850ES/JG3-L

R01AN0714EU0100

Rev.1.00

November 15, 2011

Continuous Positive Airway Pressure Machine Reference Design

Introduction

The sleep apnea syndrome is a disease which occurs in millions of people and is common after the age of 65. It is characterized by disturbed sleep with frequent periods of apnea or ineffective breathing terminated usually by arousal from the sleep. The intermittent hypoxia that occurs during apneas is a risk factor for cardiovascular diseases such as hypertension and heart attacks.

The apneas that occur are of two kinds. First one is the central apneas in which breathing movements cease and the second is obstructed apneas in which breathing movements are present but airflow in to lungs is prevented by blockage of the upper airways. Obstructive apneas can be treated with devices that apply a continuous positive pressure to the airways during sleep.

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 Continuous Positive Airway Pressure (CPAP) machine. The advantages of CPAP are that if tolerated it provides a relatively risk free route symptomatic relief to a serious disorder. CPAP machines have incorporated technology as it has become available to improve the comfort and self-regulating capability to deliver therapy as needed.

Contents

1. CPAP Machine:	3
2. Sleep Apnea Device Requirements	6
3. Renesas V850ES/JG3-L Device Architecture Overview.....	8
4. Reference Design Architecture	12
5. Software Flowcharts.....	14
Appendix A - References	17

List of Figures

Figure 1 Example of a CPAP Machine and Mask..... 3
Figure 2 CPAP machine Signal Flow Diagram..... 4
Figure 3 Block diagram of Sleep Apnea Device..... 5
Figure 4 Device Architecture diagram 9
Figure 5 Hardware Implementation Diagram..... 12
Figure 6 Software Architecture 13
Figure 7 CPAP Initialization..... 14
Figure 8 CPAP Blower control 15
Figure 9 CPAP Apnea event record..... 15
Figure 10 CPAP Data Archival..... 16
Figure 11 CPAP Data Retrieval 16

1. CPAP Machine:



Figure 1 Example of a CPAP Machine and Mask

1.1 Theory of Operation

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.

The clinical prescription of CPAP is usually given as a single therapeutic pressure value. The following are the normal control strategies followed by most manufacturers to control the pressure [1].

1. The controller sets a constant pressure at the machine (constant blower speed). This pressure is slightly higher than the patient's need to account for the maximum leak condition.
2. The controller is driven by active feedback from the pressure measured at the mask. This feedback will cause the blower to continuously vary pressure (at the blower) so as to maintain it constant at the mask. Either blower speed or valve opening may be varied to achieve the constant pressure at the mask.
3. Control of pressure as exerted at the machine is based on assumptions about how the pressure will change as it travels along the tubing that connects the blower to the mask. Blower speed can be used to calculate a predicted drop in pressure between patient and machine, creating a deliberately variable higher pressure than prescribed to deliver constant therapeutic target.

The latest CPAP machines or APAP machines modify the pressure they deliver within individual breaths as a function of the instantaneous flow. This will improve pressure induced discomfort, by limiting unnecessary rises in pressure above the prescribed value during expiration. The simplest way to accomplish this is to vary the blower speed in response to fluctuations detected in the measured pressure. A constant trade-off exists between the need to optimally set CPAP for a stable physiologic state and the need to respond with a rapid change in CPAP to state changes affecting the airway. The algorithms vary with manufacturer and are proprietary in nature [1].

Manufacturers have constantly been improving the comfort and self-regulating capability of the machines to deliver therapy as needed, to match the changing conditions that occur during a night of sleep and over time. To accomplish this, device should include capabilities to tailor the pressure of the therapy to the patient’s needs [1]. These advanced machines have improved control algorithms, usability features to give good performance and provide compliance records [1].

Presently, the blower driven by a DC brushless (BLDC) motor has been widely used for generating the air source and controlling the airway pressure and air flow rate nearby the nasal mask by directly adjusting the speed of the motor. In addition, this kind of motor and blower can be made small-size, inexpensive and easy-to-use [3]. A two degree-of-freedom control method for achieving bi-level positive airway pressure (Bi-PAP) of an obstructive sleep apnea (OSA) treatment system is presented in [3]. In this approach, a mathematical model of the overall open-loop system is established based on the input-output data and its system parameters are sequentially determined using the recursive least-squares (RLS) approach. A two degree-of-freedom (DOF) controller, including a nonlinear feed forward controller and a feedback proportional-integral-derivative controller (PID controller) with gain scheduling, is proposed to maintain and follow the desired bi-level pressure set points [3].

1.2 Signal Processing

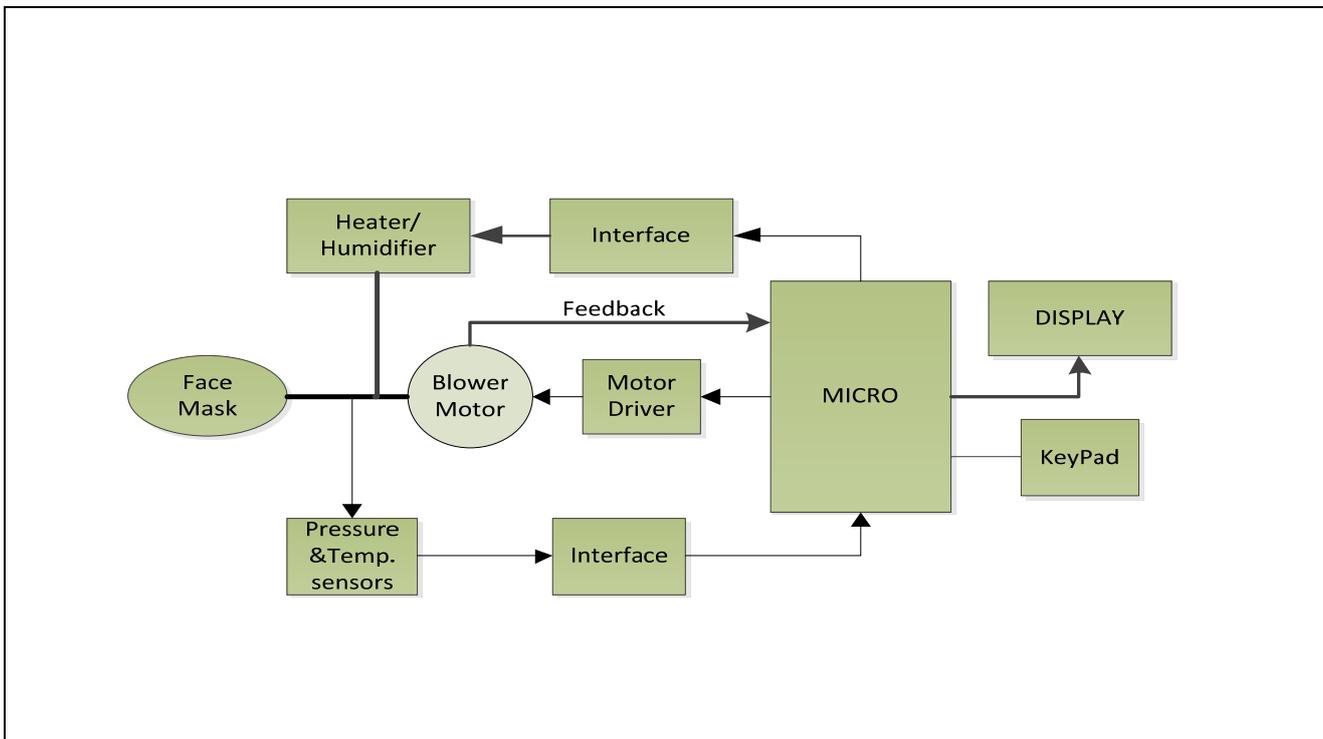


Figure 2 CPAP machine Signal Flow Diagram

The signal flow diagram shown in Figure 2 represents a typical CPAP machine. The air blower motor speed is controlled by the microcontroller using a motor driver circuit. The pressure at the mask is measured by the sensor and related analog and digital processing. The motor speed is varied to maintain the prescribed pressure at the face mask by using a proprietary algorithm. The temperature and humidity are measured and heater/humidifier is controlled to maintain comfortable levels for the user.

The signals from the sensors are processed using both analog and digital elements to derive the average values to be used for the computations in the control loop. The control algorithms are very sophisticated and proprietary. Some of the algorithms use mathematical models to achieve the objective.

As pointed out earlier, BLDC is used to control the blower to maintain the pressure at the face mask. The control algorithm differs from manufacturer to manufacturer and proprietary in nature. An extensive treatment of motor control required is covered in [2].

1.3 Block Diagram of Sleep Apnea Device

A typical CPAP machine using a microcontroller is shown in Figure 3. CPAP machine is a complex device implementing many proprietary algorithms to achieve its main objective of providing comfortable pressure at the face mask to assist the user to get a good night sleep.

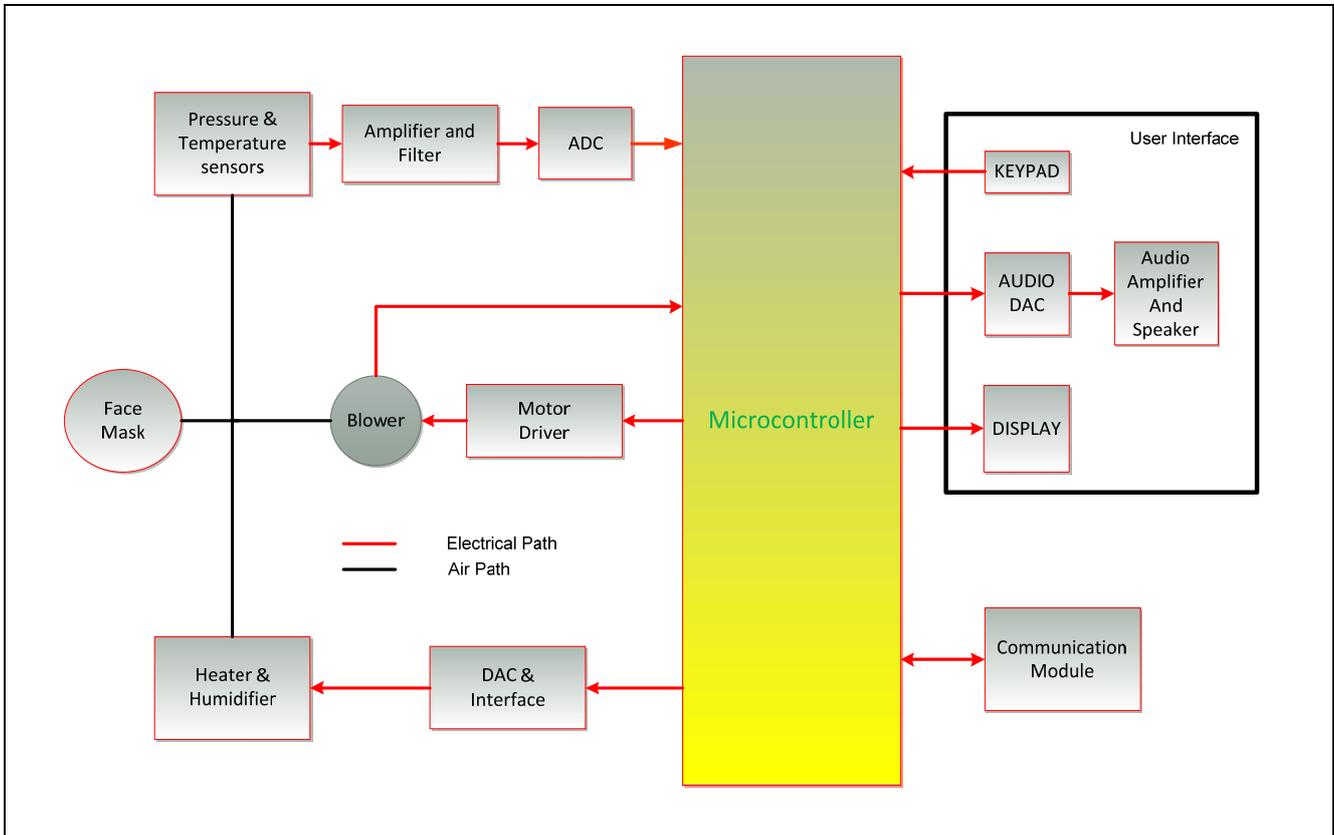


Figure 3 Block diagram of Sleep Apnea Device

2. Sleep Apnea Device Requirements

2.1 Sensor Requirements

The main sensors used in the CPAP machine are pressure, temperature and relative humidity. Analog amplification and filtering is required before interfacing these sensors to the ADC.

2.2 Signal Processing Requirements

The main objective of the CPAP machine is maintaining the prescribed pressure at the face mask. In order to achieve this, the blower motor speed is varied depending on the pressure measured at the face mask. In some designs, there is no measurement of the pressure. Instead the speed is varied depending on the back pressure. Some of the advanced CPAP machines provide temperature and humidity adjustment. Sensors are placed in the path way to measure these parameters and adjust correspondingly. All these sensors need filtering and amplification before digitization. Digital filtering may be required to implement control algorithms.

2.3 Blower and BLDC motor control requirements

According to the design guidelines and rules from American Thoracic Society and the ISO-17510, there are many regulations for treating the OSA patients; one of them is that the OSA treatment machine or equipment must offer required pressure ranging from 4 cmH₂O to 20 cm H₂O, and the required amount of air flow rate up to 120 liters per minute (LPM). The BLDC motor must have low inertia and fast acceleration in order to quickly change its speed and then alter the pressure to meet the patient's requirement. Furthermore, the motor driver must have a good ability to deal with the speed feedback loop control [3]. The main goals of motor control required for CPAP are reliability, quiet operation, dynamic and efficient operation [2].

2.4 Processing Requirements

The processing requirements include some support for digital signal processing. The processor can be a low power 8/16/32 bit device with support for 12 bit ADC. Digital signal processing capabilities are required to do signal processing and implement motor control algorithms.

2.5 Storage Requirements

Information on breathing, pressure levels delivered, apneas, etc. is required to be stored for later retrieval to help determine the effectiveness of CPAP therapy. The CPAP Host Software also allows the user and the Physician to analyze recorded data for any night view the data on an hour by hour basis. This feature needs a local flash storage. Some advanced machines support data storage on the removable flash cards.

2.6 Display Requirements

Machines that display advanced tracking through the on machine display allow for fast review of therapy metrics. Many people like to use on screen display to check every morning what their AHI and leak rate were through the previous night, to see if adjustments need to be made just as readjusting their mask. The information provided on the on machine screen is usually average values over different time frames, such as 1 day (last night), 7 night, 30 nights, etc. These requirements need a large, easy-to-read custom LCD display with backlight to display values and error indicators. Graphical LCD support is required for advanced CPAP machines.

2.7 Power Requirements

CPAP machines are normally operated using the mains power supply. However portable machines used for travel purpose may use rechargeable batteries. These machines have a blower whose motor speed is controlled to keep the pressure stable. The design should use motor with low consumption to get a good battery cycle life. The power supply should be designed to use AC power to charge the battery and operate the machine.

2.8 Connectivity Requirements

CPAP machines record important data for the user and their Physicians. This data need to be accessed by the Physician for therapy and compliance purpose. These machines should have minimum USB connectivity to interface to a computer. User should be able to retrieve the secure data and send it to the Physician. However with wireless connectivity and internet, Physicians can access the data without user intervention. Low end machines should have USB and High end machines can support internet connectivity using Wi-Fi / Bluetooth.

2.9 User interface requirements

User interface is required to manage the storage of values as well as displaying the archived values on user prompt. Displaying status while conducting the measurement will be helpful for the user. The user interaction is provided by a keypad and LCD display.

2.10 Other requirements

The CPAP treatment should be comfortable to the user and to achieve this lot of manufacturers spend lot time and effort in designing the face mask and the control algorithms. The machine should operate very quietly as not to disturb the sleep of the user. These machines should be able to operate with batteries to make them portable and can be used while travelling.

2.11 Future Trends

The future for CPAP machines is leading to auto adjusting machines. These systems are also intended for long term treatment. Their goal is to improve effectiveness and/or reduce side effects by ensuring that the instantaneous pressure is always close to optimal [4]. Most of the future advances will take place in the control algorithms in order to provide a comfortable pressure and in the connectivity solutions for the retrieval of the data to be used for personalizing therapy and for compliance purposes.

Other areas for future advances are the battery operation and quiet blower operation as not to disturb the sleep of the user.

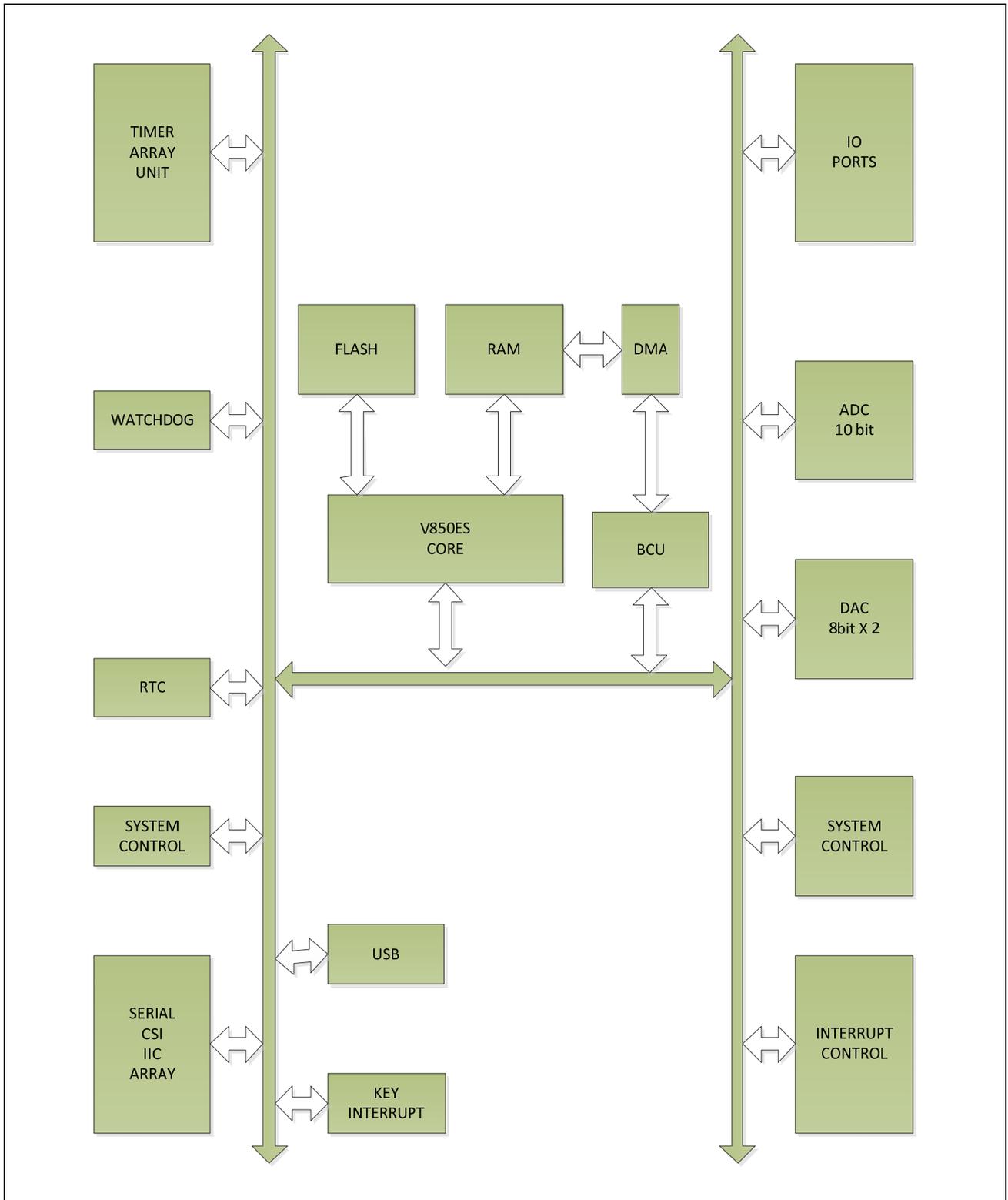


Figure 4 Device Architecture diagram

Processor

The V850ES/JG3-L is a 32-bit single-chip microcontroller that includes the V850ES CPU core and peripheral functions such as ROM/RAM, timer/counters, serial interfaces, an A/D converter, a D/A converter, USB function controller. In addition to high real-time response characteristics and 1-clock-pitch basic instructions, the V850ES/JG3-L features multiply instructions, saturated operation instructions, bit manipulation instructions, etc., realized by a hardware multiplier, as optimum instructions for digital servo control applications.

Memory

For instruction addressing, up to a combined total of 16 MB of external memory area and internal ROM area, plus an internal RAM area, are supported in a linear address space (program space) of up to 64 MB. For operand addressing (data access), up to 4 GB of a linear address space (data space) is supported. The 4 GB address space, however, is viewed as 64 images of a 64 MB physical address space. This means that the same 64 MB physical address space is accessed regardless of the value of bits 31 to 26. A user accessible 40KB internal RAM is provided in V850ES/JG3-L devices.

Flash memory

The internal flash memory of the V850ES/JG3-L can be rewritten by using the rewrite function of the dedicated flash memory programmer, regardless of whether the V850ES/JG3-L has already been mounted on the target system or not (off-board/on-board programming). A security function that prohibits rewriting the user program written to the internal flash memory is also supported, so that the program cannot be changed by an unauthorized person. The rewrite function using the user program (self-programming) is ideal for an application where it is assumed that the program will be changed after production/shipment of the target system. A boot swap function that rewrites the entire flash memory area safely is also supported. In addition, interrupt servicing can be executed during self-programming, so that the flash memory can be rewritten under various conditions, such as while communicating with an external device.

Bus Controller

The external bus interface function is used to connect external devices to areas other than the internal ROM, RAM, or on-chip I/O registers. These ports control address/data I/O, the read/write strobe signal, waits, the clock output, bus hold, and the address strobe signal. This can be used to interface external memories such as ROM and RAM, and external I/O devices.

Timers

The V850ES/JG3-L has seven timer/event counter channels which support the following modes.

1. Interval timer
TMPn generates an interrupt at a preset interval and can output a square wave.
2. External event counter
TMPn counts the number of externally input signal pulses.
3. External trigger pulse output
TMPn starts counting and outputs a pulse when the specified external signal is input.
4. One-shot pulse output
TMPn outputs a one-shot pulse with an output width that can be freely specified.
5. PWM output
TMPn outputs a pulse with a constant cycle whose active width can be changed. The pulse duty can also be changed freely even while the timer is operating.
6. Free-running timer
TMPn counts from 0000H to FFFFH and then resets.
7. Pulse width measurement
TMPn can be used to measure the pulses of a signal input externally.

Apart from the above, it also supports a 16-bit interval timer and a watchdog timer.

RTC

The V850ES/JG3-L provides real-time counter (RTC) which has the following features.

1. Counting up to 99 years using year, month, day-of-week, day, hour, minute, and second sub-counters provided
2. Year, month, day-of-week, day, hour, minute, and second counter display using BCD codes
3. Alarm interrupt function
4. Constant-period interrupt function (period: 1 month to 0.5 second)
5. Interval interrupt function (period: 1.95 ms to 125 ms)
6. Pin output function of 1 Hz
7. Pin output function of 32.768 kHz
8. Pin output function of 512 Hz or 16.384 kHz
9. Watch error correction function
10. Sub clock operation or main clock operation

ADC

The Successive approximation A/D converter converts analog input signals into digital values with a resolution of 10 bits, and can handle 12 analog input signal channels.

DAC

V850ES/JG3-L, provides two eight bit R-2R ladder type D/A converter channels with a maximum conversion time of 3 micro second.

Ports

The V850ES/JG3-L has a total of 80 I/O port pins to provide port functions. Some of these pins support 5V input tolerable and some provide selectable N-channel open-drain output. The input/output is specifiable in 1 bit units.

USB

The V850ES/JG3-L supports an internal USB function controller (USBF) conforming to the Universal Serial Bus Specification. Data communication using the polling method is performed between the USB function controller and external host device by using a token-based protocol. It supports 12 Mbps (full-speed) transfer. Bulk and interrupt transfer endpoints are supported.

4. Reference Design Architecture

Table 1 Requirements Table

CPAP Machine Requirements	Relevance	Renesas Device V850ES/JG3-L	External Hardware
Amplifier	High	None	External Required
Analog Filter	High	None	External Required
12 bit ADC	High	10 bit ADC	External ADC
Signal Processing	High	Multiplier	
Motor Control	High	SW Available	External Driver
DAC	Medium	8 bit ,3uS R-2R	
LCD Controller	High	None	
Data Storage	High	Small On Chip Flash	External Required
Connectivity	High	USB	wireless

4.1 Hardware Architecture

A typical implementation of CPAP using Renesas V850ES/JG3-L device is shown in Figure 5. A motor driver circuit is required to drive the BLDC motor which runs the blower. Pressure at the mask is monitored by a sensor whose output is amplified and filtered before digitization by internal ADC. An external circuit is required to control the heater and humidifier. This interface in turn can be controlled by PWM signals from V850ES/JG3-L. The built in 8 bit DAC is used to generate audio alarm signals. An external LCD controller is used to drive the custom made LCD display. User input can be given using the external keypad interfaced to V850ES/JG3-L device. The power to all components is provided by the onboard power supply. This power supply can be driven by AC mains or by a rechargeable battery pack. The charger circuit is built in to the power supply.

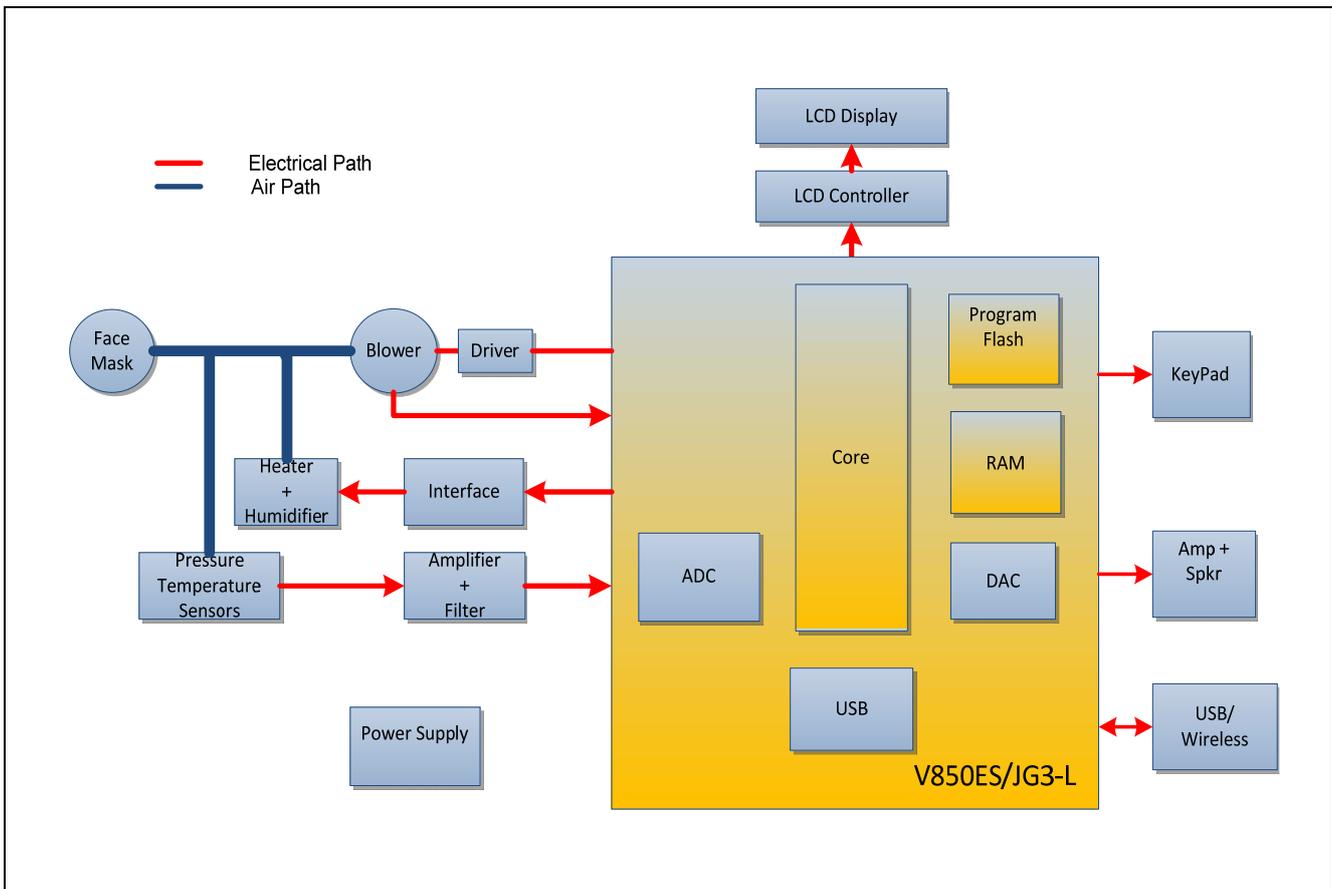


Figure 5 Hardware Implementation Diagram

4.2 Software Architecture

V850ES/JG3-L Continuous Positive Airway Pressure Machine Reference Design

The low level software includes drivers for blower motor, heater and humidifier control. The middle ware consists of control algorithms for blower, heater/ humidifier and signal processing for sensors like pressure, temperature and humidity. Data archiving and recall is to be implemented in the middleware which controls the onboard flash driver. The display driver controls the custom LCD including backlight to provide user display functionality. Power management is critical software which optimizes the resources to prolong the battery life. The USB driver along with Continua USB stack provides the connectivity need of the device. The main CPAP application implements the final user application which provides the user interface.

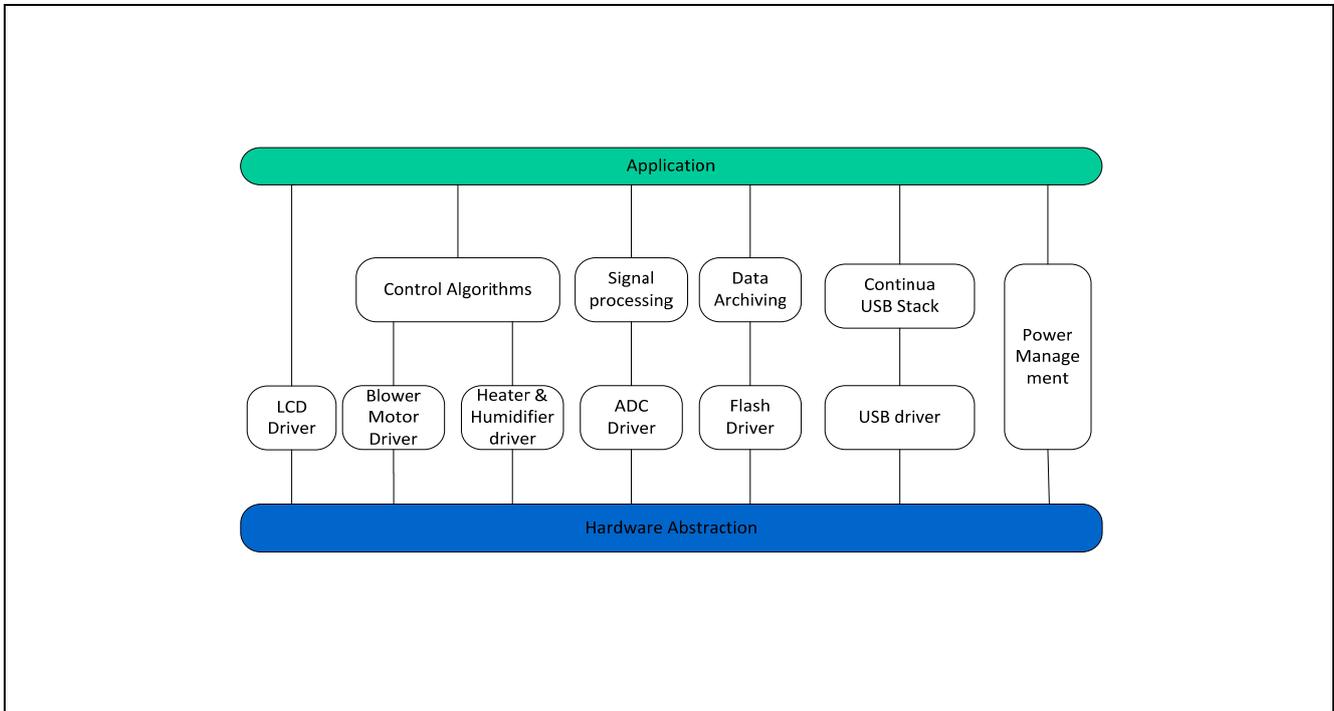


Figure 6 Software Architecture

5. Software Flowcharts

The following flow charts show high level software implementation.

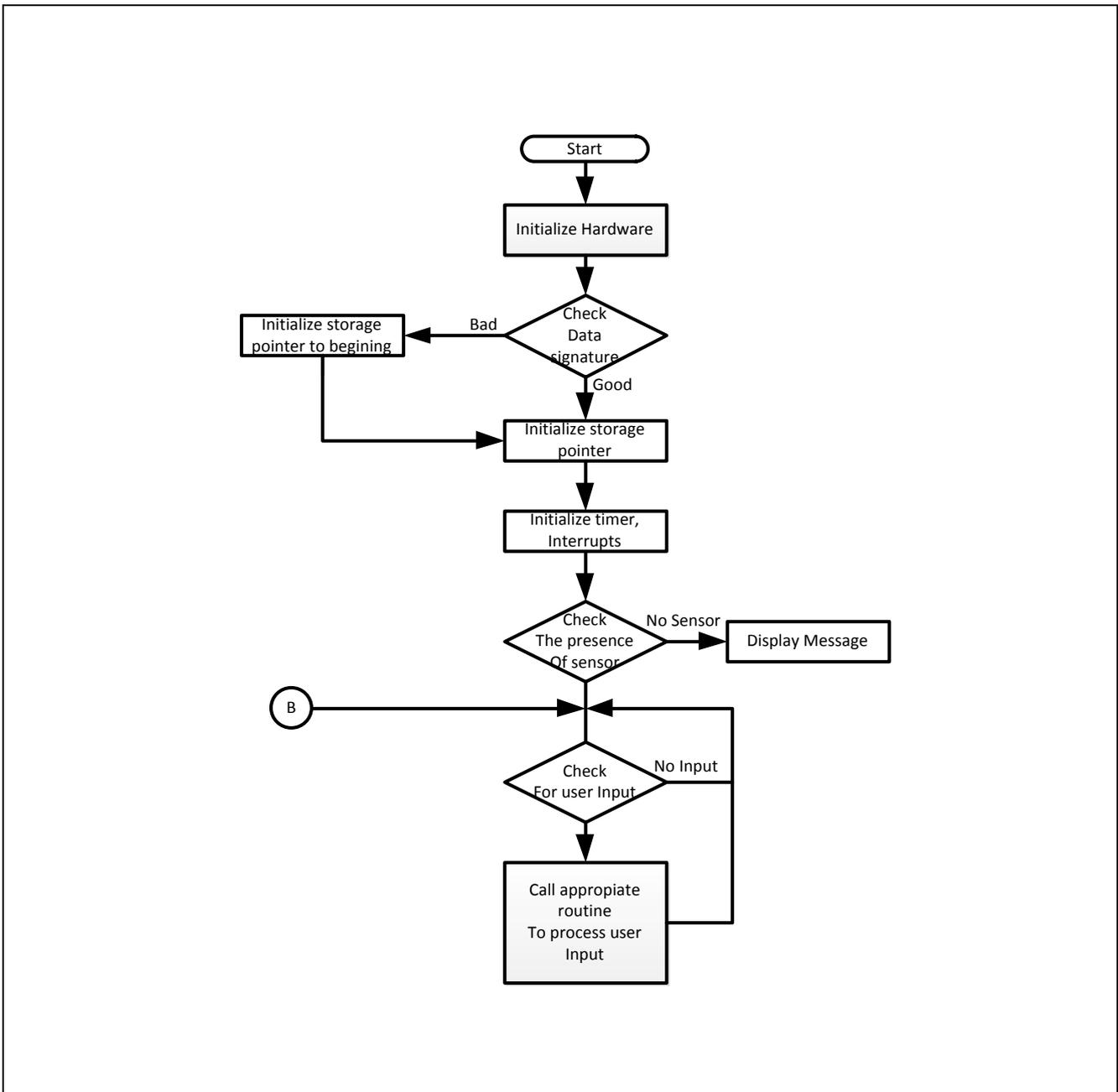


Figure 7 CPAP Initialization

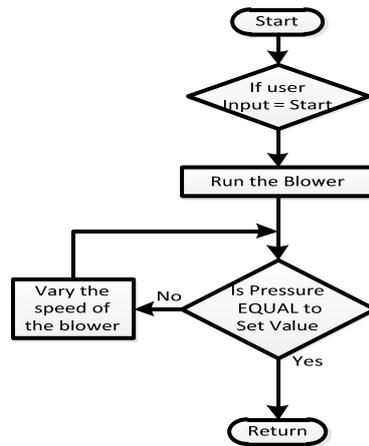


Figure 8 CPAP Blower control

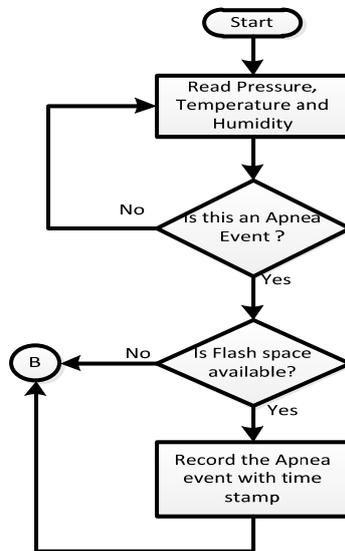


Figure 9 CPAP Apnea event record

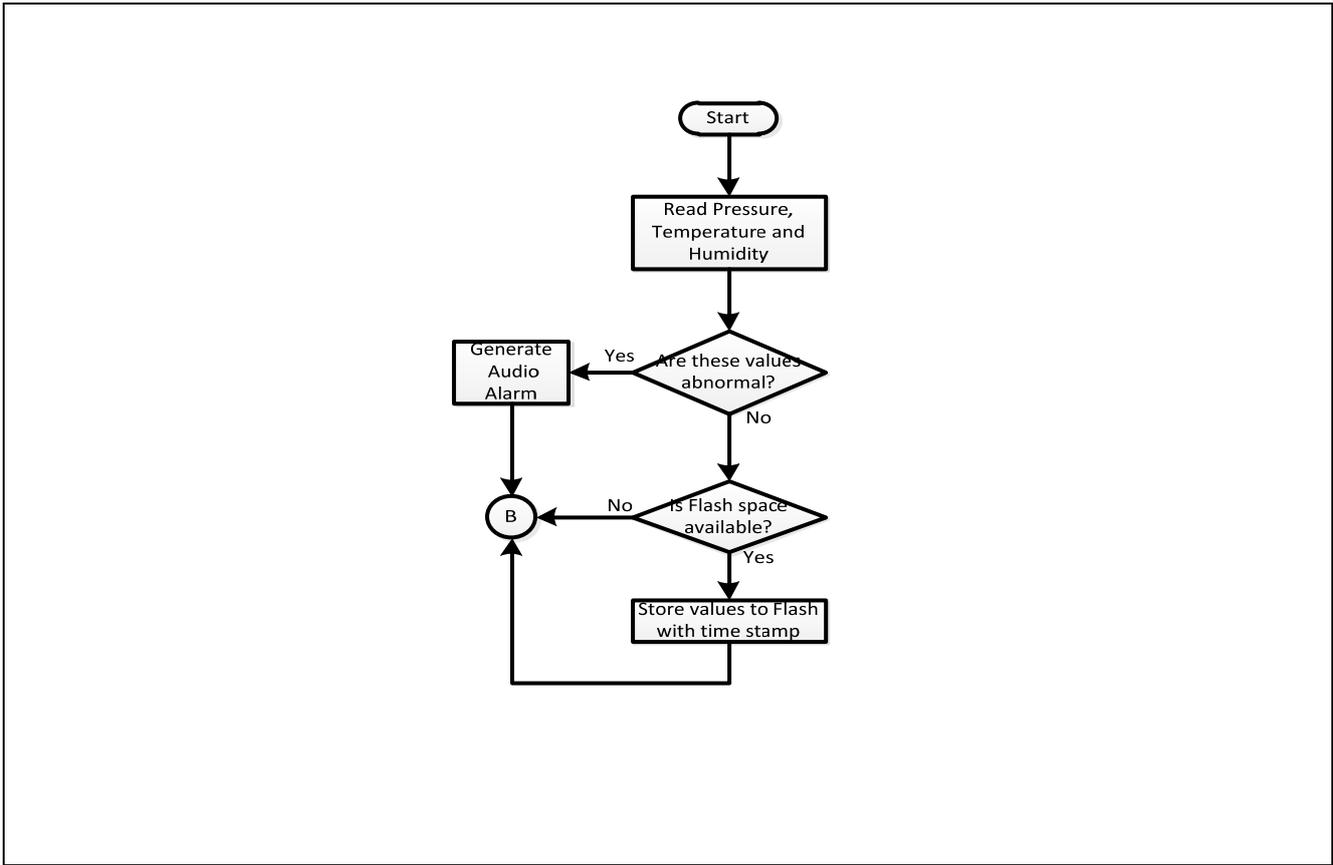


Figure 10 CPAP Data Archival

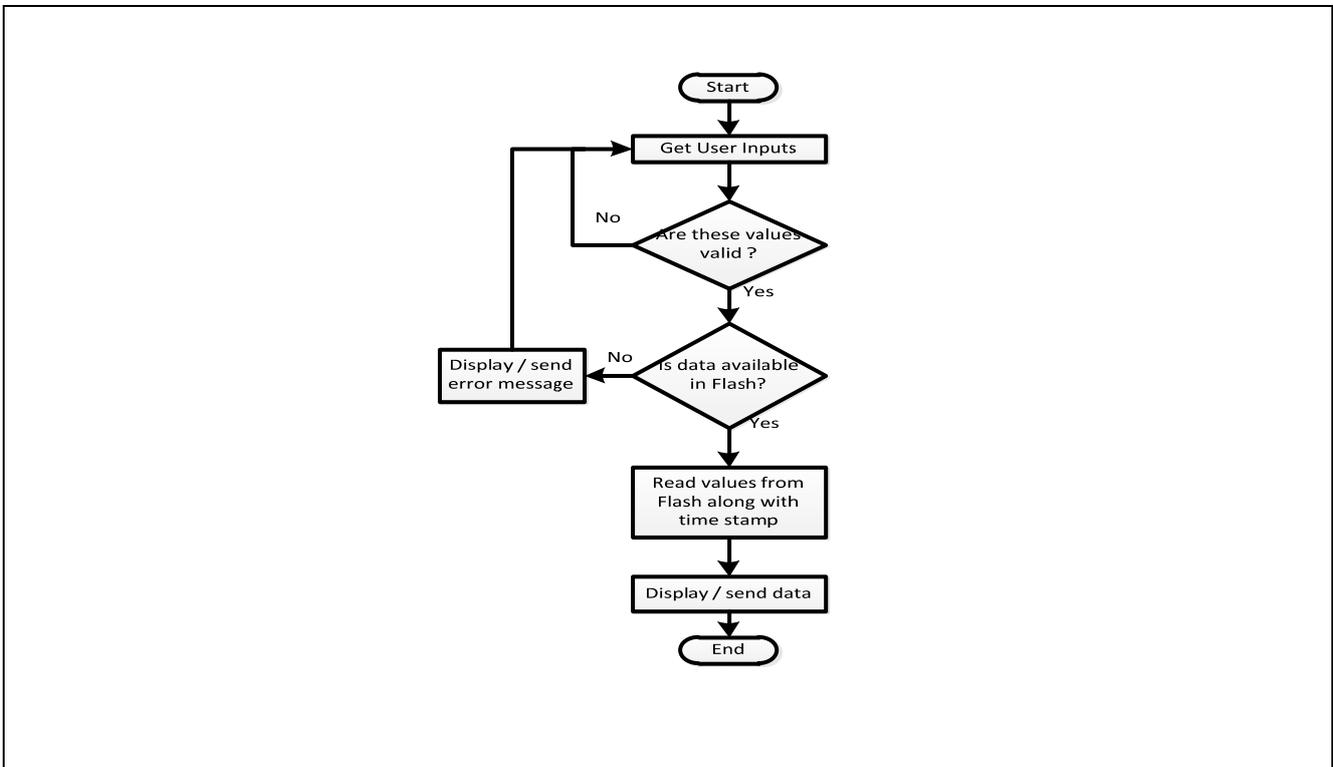


Figure 11 CPAP Data Retrieval

Appendix A - References

[1] David M. Rapoport, Ron S. Leder , " Continuous positive Airway Pressure ", in Encyclopedia of Medical Devices and Instrumentation, Second edition, Vol. 2, Wiley-Interscience, 2006, pp. 329-336.

[2] Renesas, Implementing PAP Machine for treating Apnea using RX62N, Renesas Electronics Application Note, January, 2011

[3] Ching-Chih Tsai, Zen-Chung Wang, Chih-Sung Chen, Two Degree-of-freedom Control for Bi-level Positive Air way Pressure of an Obstructive Sleep Apnea, The 33rd Annual Conference of the IEEE Industrial Electronics Society (IECON), Nov. 5-8, 2007, Taipei, Taiwan

[4] Daniela Boisteanu, Raluca Vasiluta, Andrei Cernomaz, Corina Mucenica, Home monitoring of sleep apnea treatment: benefits of intelligent CPAP devices, Advanced Technologies for Enhanced Quality of Life, 2009

Website and Support

Renesas Electronics Website

<http://www.renesas.com/>

Inquiries

<http://www.renesas.com/inquiry>

All trademarks and registered trademarks are the property of their respective owners.

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.

Notice

1. All information included in this document is current as of the date this document is issued. Such information, however, is subject to change without any prior notice. Before purchasing or using any Renesas Electronics products listed herein, please confirm the latest product information with a Renesas Electronics sales office. Also, please pay regular and careful attention to additional and different information to be disclosed by Renesas Electronics such as that disclosed through our website.
 2. Renesas Electronics does not assume any liability for infringement of patents, copyrights, or other intellectual property rights of third parties by or arising from the use of Renesas Electronics products or technical information described in this document. No license, express, implied or otherwise, is granted hereby under any patents, copyrights or other intellectual property rights of Renesas Electronics or others.
 3. You should not alter, modify, copy, or otherwise misappropriate any Renesas Electronics product, whether in whole or in part.
 4. Descriptions of circuits, software and other related information in this document are provided only to illustrate the operation of semiconductor products and application examples. You are fully responsible for the incorporation of these circuits, software, and information in the design of your equipment. Renesas Electronics assumes no responsibility for any losses incurred by you or third parties arising from the use of these circuits, software, or information.
 5. When exporting the products or technology described in this document, you should comply with the applicable export control laws and regulations and follow the procedures required by such laws and regulations. You should not use Renesas Electronics products or the technology described in this document for any purpose relating to military applications or use by the military, including but not limited to the development of weapons of mass destruction. Renesas Electronics products and technology may not be used for or incorporated into any products or systems whose manufacture, use, or sale is prohibited under any applicable domestic or foreign laws or regulations.
 6. Renesas Electronics has used reasonable care in preparing the information included in this document, but Renesas Electronics does not warrant that such information is error free. Renesas Electronics assumes no liability whatsoever for any damages incurred by you resulting from errors in or omissions from the information included herein.
 7. Renesas Electronics products are classified according to the following three quality grades: "Standard", "High Quality", and "Specific". The recommended applications for each Renesas Electronics product depends on the product's quality grade, as indicated below. You must check the quality grade of each Renesas Electronics product before using it in a particular application. You may not use any Renesas Electronics product for any application categorized as "Specific" without the prior written consent of Renesas Electronics. Further, you may not use any Renesas Electronics product for any application for which it is not intended without the prior written consent of Renesas Electronics. Renesas Electronics shall not be in any way liable for any damages or losses incurred by you or third parties arising from the use of any Renesas Electronics product for an application categorized as "Specific" or for which the product is not intended where you have failed to obtain the prior written consent of Renesas Electronics. The quality grade of each Renesas Electronics product is "Standard" unless otherwise expressly specified in a Renesas Electronics data sheet or data books, etc.
"Standard": Computers; office equipment; communications equipment; test and measurement equipment; audio and visual equipment; home electronic appliances; machine tools; personal electronic equipment; and industrial robots.
"High Quality": Transportation equipment (automobiles, trains, ships, etc.); traffic control systems; anti-disaster systems; anti-crime systems; safety equipment; and medical equipment not specifically designed for life support.
"Specific": Aircraft; aerospace equipment; submersible repeaters; nuclear reactor control systems; medical equipment or systems for life support (e.g. artificial life support devices or systems), surgical implantations, or healthcare intervention (e.g. excision, etc.), and any other applications or purposes that pose a direct threat to human life.
 8. You should use the Renesas Electronics products described in this document within the range specified by Renesas Electronics, especially with respect to the maximum rating, operating supply voltage range, movement power voltage range, heat radiation characteristics, installation and other product characteristics. Renesas Electronics shall have no liability for malfunctions or damages arising out of the use of Renesas Electronics products beyond such specified ranges.
 9. Although Renesas Electronics endeavors to improve the quality and reliability of its products, semiconductor products have specific characteristics such as the occurrence of failure at a certain rate and malfunctions under certain use conditions. Further, Renesas Electronics products are not subject to radiation resistance design. Please be sure to implement safety measures to guard them against the possibility of physical injury, and injury or damage caused by fire in the event of the failure of a Renesas Electronics product, such as safety design for hardware and software including but not limited to redundancy, fire control and malfunction prevention, appropriate treatment for aging degradation or any other appropriate measures. Because the evaluation of microcomputer software alone is very difficult, please evaluate the safety of the final products or system manufactured by you.
 10. Please contact a Renesas Electronics sales office for details as to environmental matters such as the environmental compatibility of each Renesas Electronics product. Please use Renesas Electronics products in compliance with all applicable laws and regulations that regulate the inclusion or use of controlled substances, including without limitation, the EU RoHS Directive. Renesas Electronics assumes no liability for damages or losses occurring as a result of your noncompliance with applicable laws and regulations.
 11. This document may not be reproduced or duplicated, in any form, in whole or in part, without prior written consent of Renesas Electronics.
 12. Please contact a Renesas Electronics sales office if you have any questions regarding the information contained in this document or Renesas Electronics products, or if you have any other inquiries.
- (Note 1) "Renesas Electronics" as used in this document means Renesas Electronics Corporation and also includes its majority-owned subsidiaries.
(Note 2) "Renesas Electronics product(s)" means any product developed or manufactured by or for Renesas Electronics.



SALES OFFICES

Renesas Electronics Corporation

<http://www.renesas.com>

Refer to "<http://www.renesas.com/>" for the latest and detailed information.

Renesas Electronics America Inc.

2880 Scott Boulevard Santa Clara, CA 95050-2554, U.S.A.
Tel: +1-408-588-6000, 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, #06-10, 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, Jln 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