Medical Electronics Drive Move to Home Care

By Pavitra Ramanujam and Shamik Mehta, Cypress Semiconductor Corp.

There's a growing trend of patient care moving away from hospitals and clinics and into homes. Healthcare providers are also driving this, as home care can help in improving efficiency and reducing costs incurred by doctors and hospitals. Portable medical electronics technology can expedite this process.

In the most basic form, portable medical devices are all battery-operated, microcontrolled handheld devices that take and analyze measurements using various bio-sensors on a patient.

There are several functional blocks that are common to most portable home-based and consumer medical devices:

- Bio-sensor(s) or bio transducers
- Amplification and analog-to-digital conversion of the sensor input
- Power management: system power control and power sequencing
- Microcontroller: low-power operation and control.
- User interface: display and human machine interface: keypads, scrollwheels, buttons and switches

Additional requirements may drive needs for:

- Storage: interface to multiple standards
- Interfaces: wireless and wired
- Audio feedback or notification

Portable medical devices must offer low-power consumption to extend battery life. Making the device robust and adhering to health governance rules are additional requirements. And like all designs, faster time-to-market, low cost, reliability and small form factors are important.

While engineering is generally about making trade-offs between opposing features, specifications, and space constraints, such trade-offs are generally difficult to make in the portable medical arena. The requirements in this market are often incongruous—the need for a small form factor along with high functionality; low power consumption along with high-performance analog; and long battery life along with high processing capability.

An excellent example system is a portable Patient Vital Signs Monitor, which measures blood pressure, heart rate, pulse oxygen and temperature using IR thermometry. Using a programmable system-on-chip (PSoC) in this design reduces design complexity by offering configurable integration of the complete signal chain for analog signal processing, resulting in significant space and cost savings. A single PSoC can accomplish all the control functions needed in this design, performing different tasks at different times depending on the operation taking place.

A Patient Vital Signs Monitor using PSoC has the advantage of emulating most of the required peripherals inside one chip. A single PSoC includes Flash and SRAM memory, an MCU, ADCs, PWM, filters, USB control and capacitive sensing. LCD drive is integrated in the PSoC. Only the pressure transducer and the LCD display are external to PSoC. Clearly, there is an immediate component count reduction, with most peripheral components integrated into the SOC.

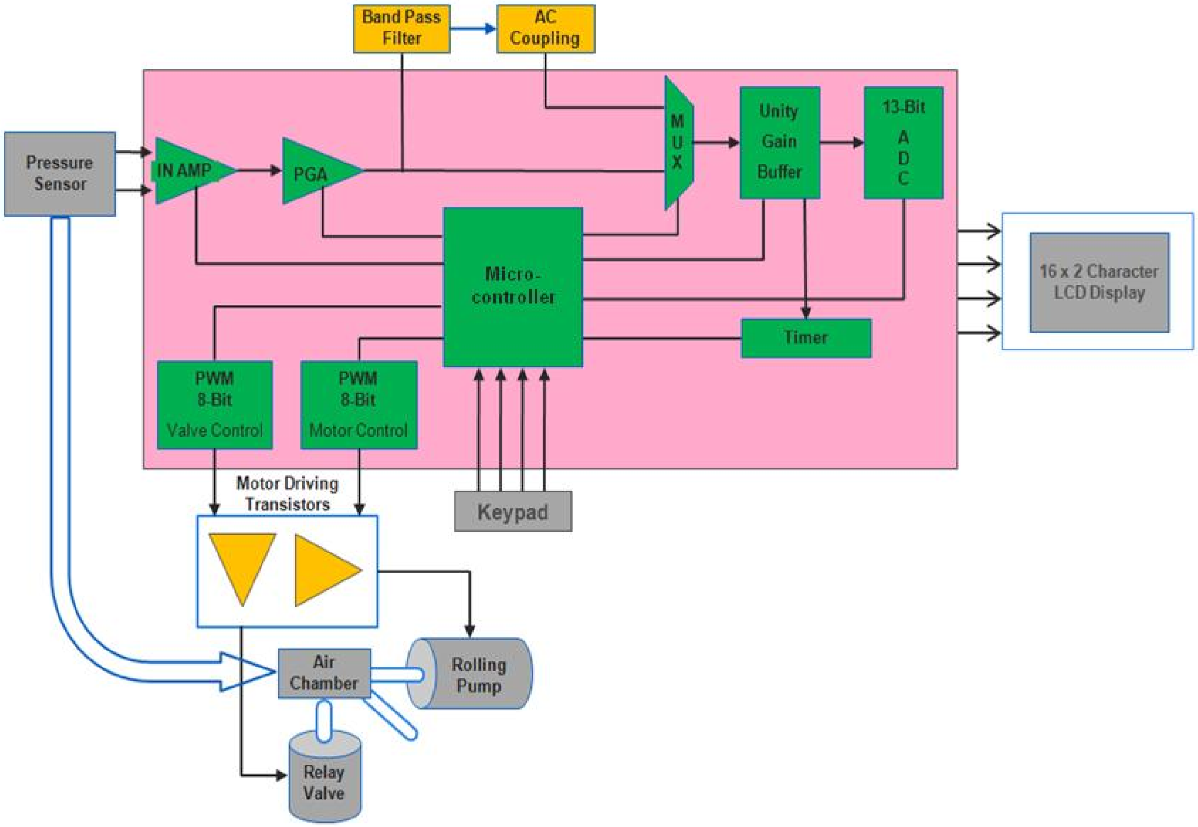

Figure 1. Blood Pressure Monitor using PSoC

The entire signal chain for analog signal processing of blood pressure pulses is configured inside PSoC. This design interfaces to an external pressure transducer and the blood pressure cuff, and motors for driving the airflow in the air chamber with a relay valve and rolling pump. An external display interfaces to PSoC to provide better readability of physiological data.

Blood Pressure measurement

Blood pressure is measured using the oscillometric method, where intra-arterial pulsations are transmitted to the cuff via a pressure transducer. Systolic and Diastolic blood pressure is measured from the amplitudes of the oscillations. Systolic Blood Pressure (SBP) and Diastolic Blood Pressure (DBP) are obtained by identifying the region where there is a rapid increase then decrease in the amplitude of the pulses. Mean Arterial Pressure (MAP) is located at the point of maximum oscillation. The cuff pressure signal is of very small magnitude; in millivolts. Hence the raw cuff pressure signal goes through a two-stage amplification to obtain maximum gain. A filter is necessary to filter out unnecessary pulsations produced by the artery, which is in ranges higher than the cuff pressure signal. A band pass filter achieves this. Next, a DC level is provided as a baseline for oscillations and for the ADC to read the signal with respect to this baseline reference level. The baseline has to be maintained at the same level, or the amplitude of the oscillations may not get measured correctly and with respect to the same reference.

The actual calculations are done by software running in the PSoC's microcontroller.

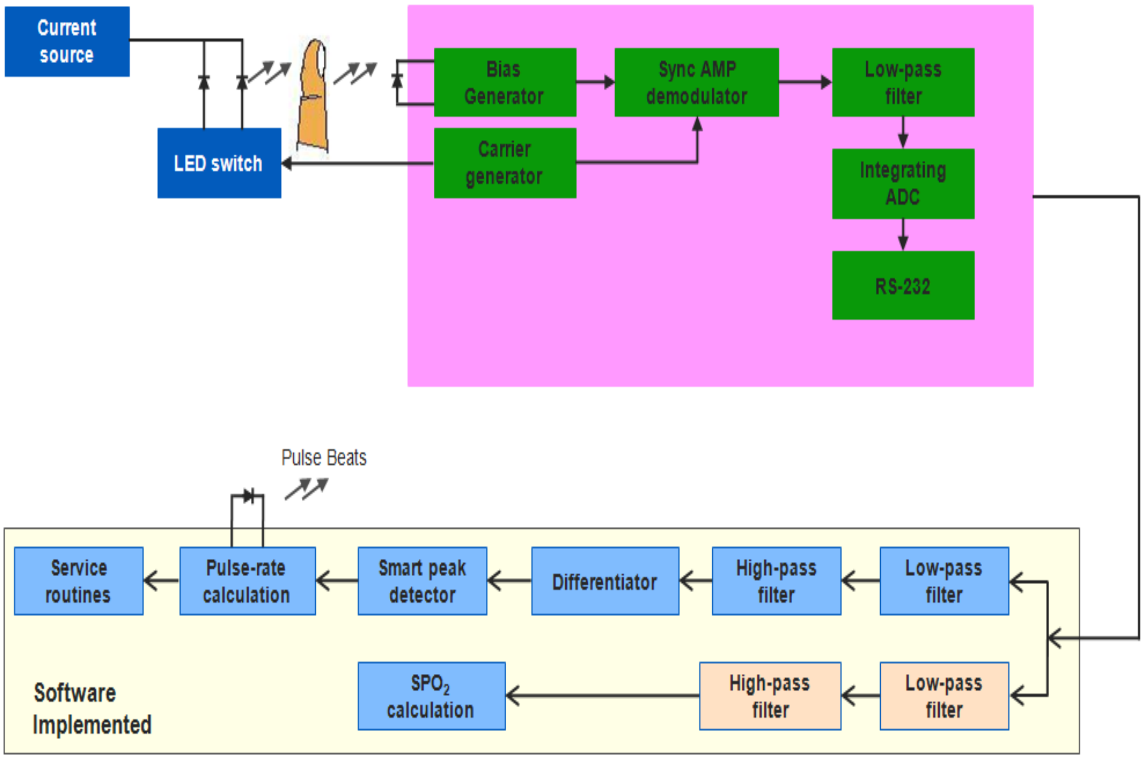

Figure 2. Pulse Oximeter using PSoC

Pulse Oximetry uses oxygen saturation. Oxygen saturation, often known as SaO2 or SpO2, is the ratio of oxyhemoglobin (HbO2) to the total concentration of hemoglobin present in the blood (oxyhemoglobin + reduced hemoglobin). The wavelength range in the near infra red part of the electromagnetic spectrum is the range for which there is least attenuation of light by body tissues (tissue and pigmentation absorb blue, green and yellow light; water absorbs the longer infrared wavelength).

With pulse oximetry, only that part of the signal directly related to the inflow of arterial blood into the body segment is used for calculating oxygen saturation. A pulsatile signal, which varies in time with the heart beat, is superimposed on a DC level. This is a cardiac−synchronous pulsatile signal. If we assume that the *increase* in attenuation of light is caused only by the inflow of arterial blood into the fingertip, we can calculate the oxygen saturation of the arterial blood by subtracting the DC component of the attenuation from the total attenuation, leaving only the cardiac−synchronous pulsatile component for the dual−wavelength determination of oxygen saturation.

The only external components required are Infrared and red LEDs, photo detectors capable of detecting the LED emissions and discrete components to match and tune the characteristic LEDs and detector. External LED drivers are required to produce maximum current transfer to match illumination conditions.

The calculations are again done in software run by the microcontroller inside the chip.

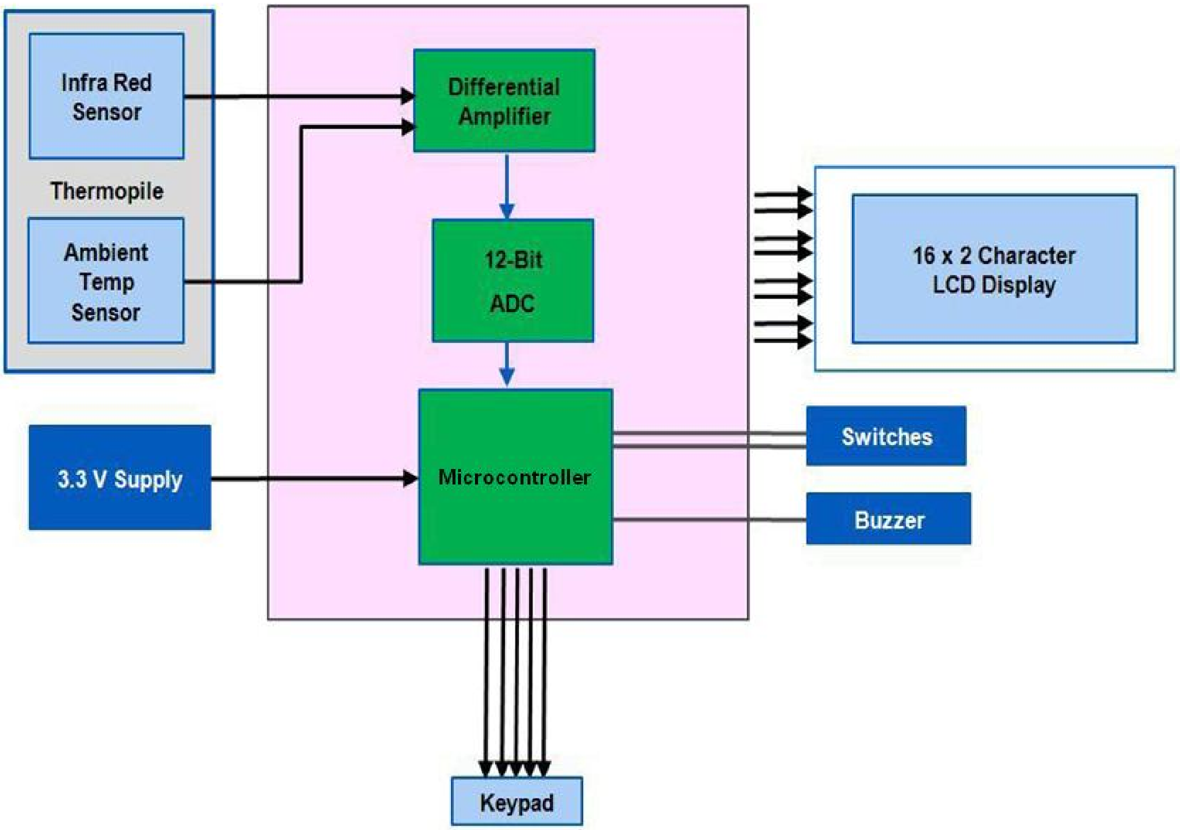

Figure 3. IR Thermometer using PSoC

This design uses an Infrared sensor, which is little more than a thermopile, with a micro-machined membrane embedded with thermocouple junctions to measure ambient temperature. The thermocouple provides a temperature differential between hot and cold junctions. A DC voltage corresponding to the temperature difference is generated by the thermocouple. An electric potential is created in the thermopile junction as a result of the temperature difference in the membrane. The sensor also has an integrated thermistor to compensate for ambient temperature.

Temperature is calculated in software by using a Correlated Double Sampling algorithm which is effective in analyzing slow varying analog signals in presence of large volumes of low frequency noise and DC voltage offsets.

Software Tools

PSoC Designer is an integrated design environment tool that combines drag-and-drop conveniences with the ability to add C or Assembly language code on the fly. The software has many pre-characterized and configured analog and digital user modules to shorten development time. It has an integrated JTAG programmer and debugger which allows for real time emulation of the program plus code download to the processor’s non-volatile memory. Using this tool, a designer selects components (counters, PWM, ADC, DAC, etc.) from a catalog, and then can modify the design using an integrated C/Assembler editor, and then program and debug the design. .

Conclusion

All three functionalities of the Patient Vital Signs Monitor use the same external peripherals like LCD, keypad and power sources. The only variables are the transducer sections. In all three functions, the signal chain is emulated inside the chip and software calculations for signal processing runs in the PSoC's microcontroller. Thus, using one PSoC and some peripherals, all three functionalities are implemented in one device. This design approach reduces components which also reduces noise induction and power consumption. It also allows for fast and easy changes, even late in the design cycle.

Cypress Semiconductor
198 Champion Court
San Jose, CA 95134-1709
Phone: 408-943-2600
Fax: 408-943-4730
http://www.cypress.com