TA0340
Technical article

STM32L Cortex-M3 microcontroller for usage in low-power healthcare applications

Changes in the structure of the populations of the Western civilization and changing habits in Asian countries lead to increasing demands for portable diagnostic devices. On top of that, the Net Generation is more willing to communicate with their physician through electronic devices than previous generations where the only possibility was a personal visit to the doctor. Fueled by the cost pressure in the public health sector, local diagnostic and remote surveillance via internet have become a central point for cost reduction.

Beyond that, healthcare and medical applications have very specific needs in terms of energy consumption, analog to digital converter (ADC) and digital to analog converter (DAC), and require state-of-the art communication interfaces such as USB. Many devices are battery-operated, but even if mains-operated they often feature a battery-powered backup mode.

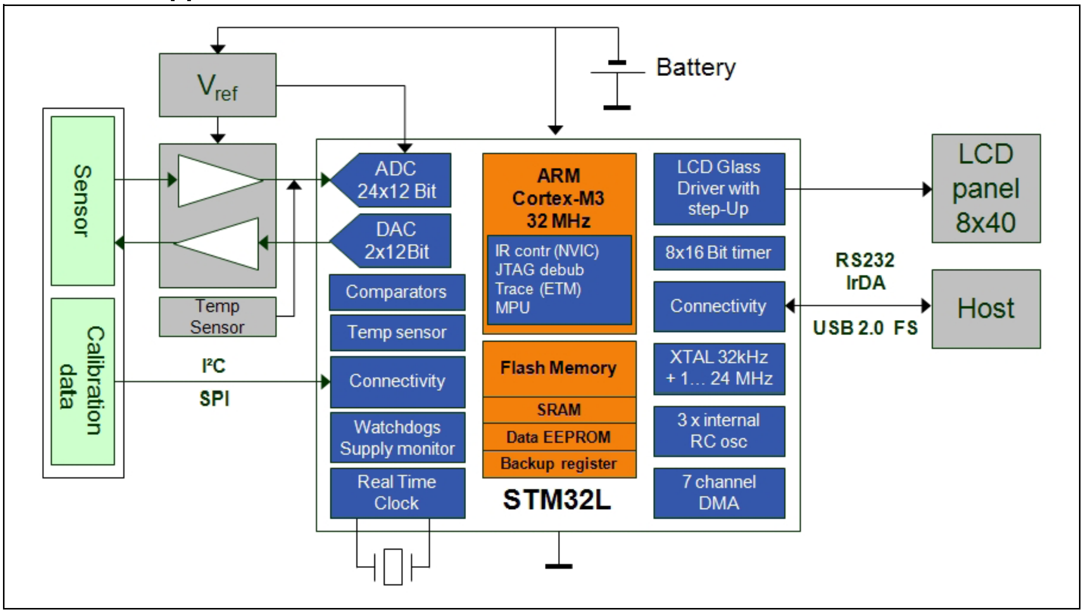
The STM32L ultra low power microcontroller family is the most recent member of STMicroelectronics' Cortex-M3 based family of STM32 microcontrollers. With an important number of peripheral blocks it offers a high level of integration, leading to low system costs. It pairs high processing power with low energy consumption and thus ideally matches the requirements of this kind of equipment.

STM32L brings integration to a new level

A typical portable medical application is usually having at least two subsystems:

- an analog part for control and measurement of sensors
- a digital part, covering analysis algorithms and display as the main functions, as well as calibration and result storage, communication, time keeping and other functions (e.g. power management)

Figure 1. Glucose meter block diagram as a typical example for healthcare applications



The proprietary mixed signal EEPROM technology used in the STM32L permits to integrate many of the components on a single chip leading to a reduction of the bill of material, and simplifying the power consumption and battery management.

The STM32L features a 24 channel 12-bit ADC and two 12-bit DACs. An external standard voltage reference can be used, keeping a very good isolation between the noisier digital part and the analog blocks.

The AD-converter with its very fast conversion time can handle all the measurements, from the electrochemical or optical sensor to the temperature and power monitoring. With over sampling techniques up to 14 bit ADC accuracy can reached thus meeting the most demanding requirements in this domain.

The 12-bit DACs can be used to finely control the sensor bias and an internal data EEPROM memory simplifies data logging. The integrated real time clock offers the same performances as a high end stand-alone RTC.

A complete choice of communication ports is available, allowing digital communication with the sensors via I²C and SPI as well as data transfer to a host through RS232, IrDA or USB.

The LCD glass controller features can directly drive up to 8x40 segments and significantly reduces the need of external components due to an integrated step-up converter.

STM32L – ultra low power architecture

Low power microcontroller applications are usually characterized by a continuous alternation of

- idle mode – with minimal power consumption and very low power continuous functions (e.g. time keeping, low power LCD display) and
- run mode – microcontroller is active, executes application tasks.

The STM32L allows reducing the overall energy consumption inside such an application by

1. reducing the power in run mode
2. reducing the power in sleep mode
3. minimizing the time spent in run mode

Usually 1. and 3. are opposed. In order to reduce the time spent in run mode, a highly performing CPU is needed with usually a higher consumption. The STM32L microcontroller takes advantage of the following elements in order to overcome this contradiction.

STM32L CPU

The ARM Cortex-M3 CPU displays a very good energy to performance ratio to be expressed in µA/DMIPS (Dhrystone Million Instructions Per Second). This value is more representative for the energy needed to complete a software task than the µA/MHz which is not accounting for the number of cycles per instruction or the efficiency of the instruction itself. Here the 32-bit architecture outperforms 8- and 16-bit architectures that are eventually better in µA/Mhz, but worse in µA/DMIPS.

Further time savings in run mode result from Cortex M3-specific low interrupt latency, automatic context save and restore and tail-chaining (consecutive interrupts are executed without extra context save and restore).

Advanced low voltage technology and programmable LDO regulator

One of the characteristics of CMOS technology is that in active mode, most energy is used to charge and discharge a huge number of very small value capacitors intrinsic to the technology. The energy for charging these capacitors is:

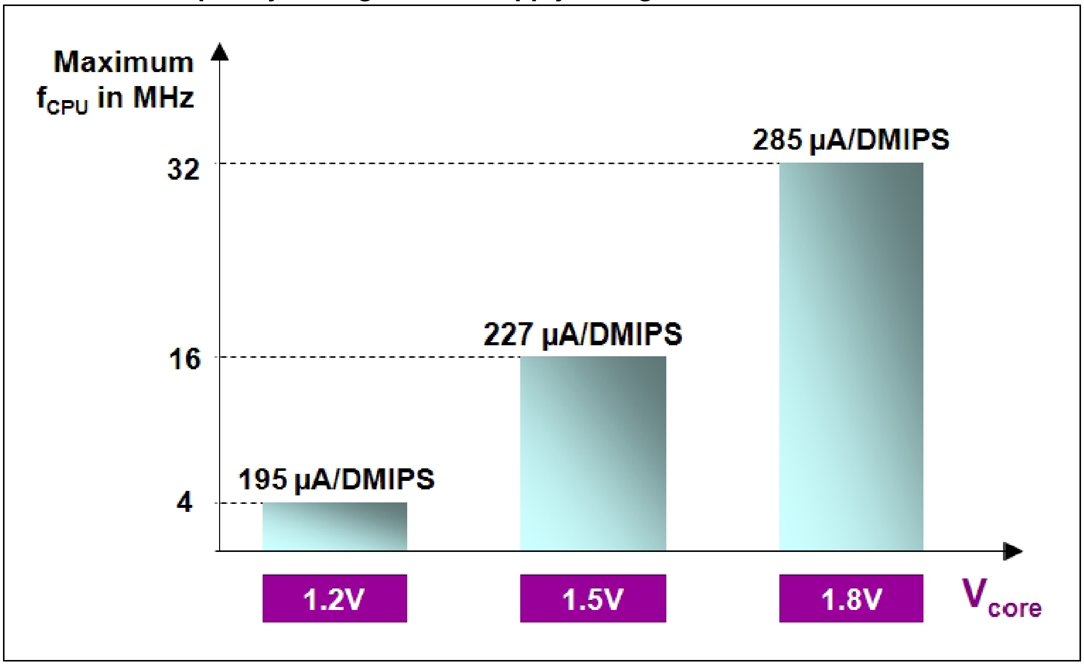
$$E = V_{core} \times Q = (V_{core})^2 \times C$$

where V_{core} is the supply voltage of the digital part of the microcontroller and C is the sum of the capacitance of all the active nodes in the circuit.

The advanced 130 nm technology of the STM32L, allows minimizing the individual nodes' capacitance, the compactness of the Cortex-M3 core being beneficial for the total number of nodes. In addition, clock gating allows cutting the dynamic consumption of unused parts of the circuit.

An internal low dropout (LDO) regulator and voltage scaling contribute to reducing the V_{core}. The internal LDO ensures that the digital part is always supplied with the minimum required voltage to ensure a certain performance. It can be programmed at three discrete voltage levels. As it can be seen in *Figure 2*, the best current-to-performance ratio is obtained at V_{core}=1.2 V.

Figure 2. Current consumption/processing performance and maximum CPU clock frequency vs. digital core supply voltage



The idea is to keep the STM32L running at V_{core}=1.2 V and to switch to a higher performance range only when the microcontroller needs to perform a specific task in a limited time. As both V_{core} and clock speed are easily programmable, this allows the user to dynamically adjust the energy vs. performance during runtime.

Sleep mode power consumption

The sleep mode, a low power idle mode is usually the longest period in a portable application's life. Even though the consumption in this mode is several orders of magnitude lower than in run mode, it still can make a difference in the total energy consumption.

On the STM32L, a number of low power modes are implemented, allowing the application designer to optimize his implementation according to the energy budget (i.e. battery size) and application needs.

Table 1. The low power modes of the STM32L

Mode	Active (run) from FLASH	Active (run) from RAM	Low Power run @ 32 kHz	Low Power sleep + 1 timer	Stop with/without RTC	Standby with/without RTC
Typ. consumption at 25 °C	230 µA/MHz	186 µA/MHz	10,4 µA	6,1 µA	1,3 / 0,43 µA	1,0 / 0,27 µA

The ultra low power option of the used 130 nm technology together with low power modes of the internal LDO lead finally to 430 nA typical consumption with the entire system configuration retained, featuring a very fast start-up of few µs and no context loss.

Specific care for low power consumption has also been taken when designing the LCD controller of the STM32L which is an important feature in portable healthcare applications. It integrates a very low power step-up converter that allows keeping the display active for long periods of time on a wide range of VDD values.

A/D converter optimized for low power

The resolution of the successive approximation converter is 12 bits, at a conversion speed of 1 MSPS. The 24 single-ended inputs have a range of 0 to V_{REF+}. The resolution can be reduced to 10, 8 and 6 bits, allowing speeding up the conversion.

Apart from advanced features as conversion injection, multiple trigger sources, DMA, selectable sampling time for each channel and auto calibration, it specifically supports the low power operation of the application. The ADC is supplied from the high speed internal RC oscillator and can thus run independently from the rest of the MCU which may be in power down while the ADC is still converting. On the other hand, by entering power down automatically after the programmed conversions, the ADC reduces the consumption to the minimum required. At 32 kHz CPU clock for instance, an instruction may take 31 µs. Assuming 5 ADC conversions at 1 µs, the ADC can go in power down after 5 µs before the CPU command is even executed and thus minimize the power consumption.

Applications, which require better resolution of acquired data, may use a technique, called oversampling. The method is described in the STMicroelectronics' application note AN2668. The oversampling uses the inherent noise or artificially added signal (by e.g. triangular or white-like noise modulation available from the integrated DACs) to the one being measured, sampling of such signal with higher sampling rate and for instance fast averaging of the data. This allows, to some extent, overcoming the limits of the quantization. The number of samples required to extend the ADC resolution differs for the dithering signals: the linear triangular voltage sweep across 1 LSB requires 2^{P+1}-times higher sampling speed, while white noise modulation requires 4^{P}-times higher sampling speed, P being no. of additional bits. Reasonable accuracy enhancement with the STM32L is possible up to 14 bits, still keeping a high effective conversion rate and short active time of the ADC.

STM32L and USB in Medical Applications

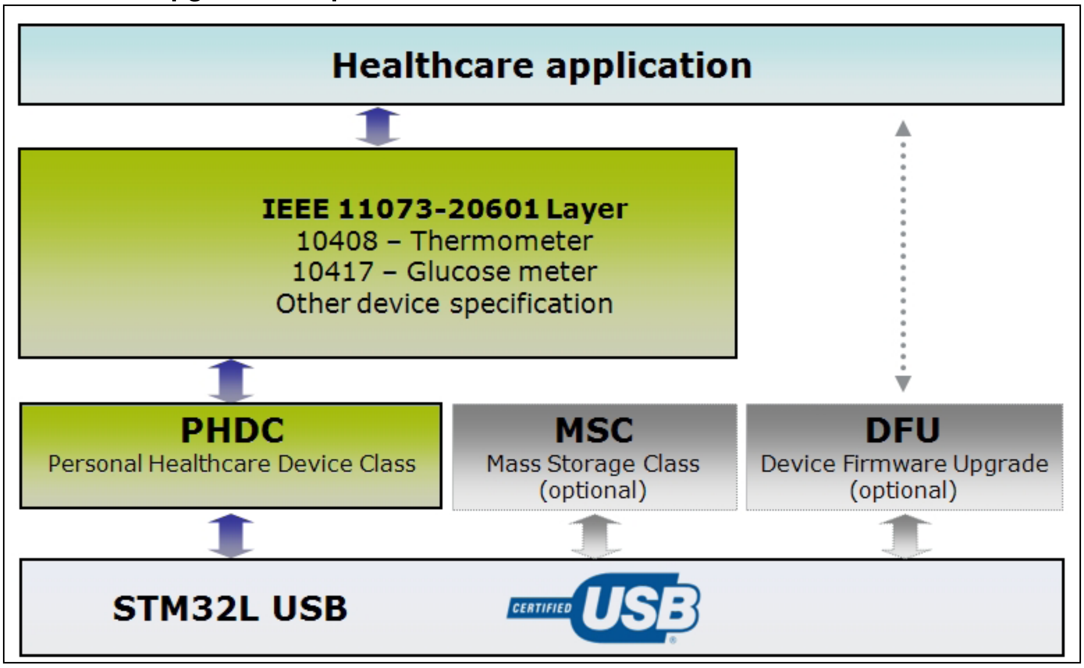
The USB communication protocol is no longer reserved to classic PC peripherals and is nowadays the most common wired channel for the next-generation UART in embedded systems that are connected to a host PC and in some cases via this host to the internet.

The success of USB in medical applications has called for standardization and as a result the dedicated device class called Personal Healthcare Device Class (PHDC) has been defined through the USB- implementers' forum. This new class enables health related devices such as exercise watches, blood pressure monitors, thermometers, weighing scales, glucose meters etc. to connect to a host and ease the communication between individual and fitness coach or patient and doctor. The USB PHDC was the first wired communication transport layer approved and adopted by the Continua Health alliance, an open industry consortium with more than 200 member companies around the world with the goal to harmonize the developments in the healthcare sector.

STMicroelectronics is member of Continua and provides the PHDC USB package with the medical applications USB Stack on for the STM32L MCUs along with a complete set of USB classes such as mass storage, human interface devices, audio and DFU for firmware updates on the field. This stack (*Figure 3*) is based on USB PHDC and IEEE-11073 standards and enables communication between the device and the host according to Continua standards.

Two example applications featuring, thermometer (IEEE-11073:10408) and glucose meter (IEEE-11073:10417) are included to run out-of the box on STM32L152-EVAL evaluation board connected to the Continua reference software (Continua Enabling Software Library) emulated on a personal computer.

Figure 3. STM32L USB stack for healthcare devices. Mass storage and firmware upgrade are optional.



This package from STMicroelectronics allows medical devices manufacturers to concentrate on developing medical applications instead of implementing USB stacks and low-layer firmware while gaining valuable time when going to certify their end-products with recognized standards.

Summary

Due to a high level of integration, the STM32L allows a reduction of the bill of material in healthcare applications, leading to a significant reduction of the system cost. Its consequent low power architecture paired with high processing performance ideally matches the requirements of this kind of equipment. STMicroelectronics supports the cost efficient and rapid development of healthcare and medical devices with a complete set of development tool and free of charge software libraries.

The usage of future-proof technologies and industry standards ensures a long term availability of this microcontroller that is matching the development cycles and product life times of this market segment.

Revision history

Table 2. Document revision history

Date	Revision	Changes
01-Feb-2011	1	Initial release.

Please Read Carefully: