

Analog to Digital Converters, Microcontrollers, and Health Monitoring Systems

Introduction

Size, weight, and cost are key factors affecting the mobility, ease of use, and accessibility of effective consumer and industrial products. However, minimizing these key factors can neither compromise the integrity nor accuracy of a product. In other words, it cannot interfere with the product's ability to perform its intended tasks. For non-contact health monitoring systems (NCHMSs) which need to gather and analyze variable health data, there is debate between using microcontroller units (MCUs) with on-board analog to digital converters (ADCs) or the existing technology an MCU with an external ADC. This paper reviews the financial viability and performances of state-of-the-art MCUs with internal ADCs and MCUs with external ADCs.

NCSHMS Target Specifications for MCUs and ADCs

NCHMSs require high precision ADCs since they must be able to filter out noise and digitize signals like heart beats and respiration rates which have a wide range of nuanced values [1]. Therefore, high data rates and resolution for the individual components are imperative to the design.

NAHOM

The Non-Contact Analysis of Health-Informatics via Observable Metrics (NAHOM) team of spring 2018 found that the target specifications for ADCs were: a minimum sampling rate of 1000 samples/channel/s with eight channels, a minimum 16-bit resolution, and a maximum required power of 5V, while the target specifications for the MCU were a minimum 24kB/s SPI data rate, USB port, dedicated floating point unit, and maximum 5V power supply [2]. NAHOM achieved the majority of these specifications with STMicroelectronics' STM32F446ZEJ6 microcontroller which used SPI (serial peripheral interface) to control an Analog Devices' AD7770 analog to digital converter. The specification that was not realized was for the ADC's required power supply, which exceeded the target by 7 V. The market prices for individual STM32F446ZEJ6 and an AD7770 evaluation boards were \$316.80 and \$124.99, respectively. Typical commercial applications for the STM32F446ZEJ6 are in alarm systems, HVAC, and medical equipment [3]. For the AD7770, the typical applications lie in protection relays, general-purpose data acquisition and industrial process control [4].

Competing ADCs

According to [4], the ADC that NAHOM chose is most typically not used for medical equipment. ADCs whose typical applications lie more in the medical field are Texas Instruments' ADS122U04 and Analog Devices' AD7768. The ADS122U04 is used in patient monitoring systems for body temperature and blood pressure and has 24-bit resolution, 4-channel simultaneous sampling, and a 2.3 to 5.5 V power supply [5]. Its market price is \$7.61 per unit for one unit, and \$6.40 per unit for 50 units [6]. For the

AD7768, its common medical application is for high precision medical EEG/EMG/ECG, and its market price ranges from \$12.83 – \$35.01 per unit for one unit, and \$10.54 – \$31.05 per unit for 50 units [7], [8]. The AD7768 has 24-bit resolution, 8-/4-channel simultaneous sampling and a power supply of 5 V. These ADCs have the same bit resolution as the one used by NAHOM, but require less power supply and are more commonly used in medical practices. More information for these ADCs can be found in [4], [5], [7].

MCUs with on-board ADCs

There are a variety of companies, like Renesas, Infineon, Analog Devices and STMicroelectronics, who produce MCUs with on-board ADCs, each with their own advantages. In general, they allow for “better integration” and “more compact switching solutions,” but most lack the resolution needed for high precision devices [9]. However, Analog Devices, the same company NAHOM used for their ADC, in stands out. Analog Devices’ ADuCM362 MCU with on-board ADC achieves the required precision with its dual 24-bit resolution, 6 differential or 12 single-ended input channels, simultaneous 50Hz/60Hz noise rejection, power supply range of 1.8 to 3.6 V. Its commercial applications include industrial automation and process control, intelligent precision sensing systems, smart sensor systems, and most notably: medical devices and patient monitoring [10]. The market price for just the ADuCM362 is \$12.92 per unit for one unit and \$11.87 per unit for 20 units, while the ADuCM362 Evaluation Board is \$119 for one unit [11], [12]. Evaluation boards are beneficial in that they help the engineer become better acquainted with the microprocessor and programming it.

Conclusion

Of the ADCs more commonly used in the medical field (ADS122U04, AD7768, ADuCM362), the target power supply voltage is met, and all four ADCs mentioned have the 24-bit resolution necessary for high precision data systems, even the internal ADC of the ADuCM362. However, according to [13], the accuracy of on-board ADCs is often subpar, with “an error of 4 or 5 bits (counts).” Therefore, the 24-bit resolution for the ADuCM362 may actually only have a 16-bit resolution. The datasheets for this MCU ADC must be more thoroughly studied to confirm its accuracy as there are many factors that affect it.

With the target specifications for NCHMSs mostly met by the STM32F446ZEJ6 MCU and external AD7770 ADC combination that has already been bought by the NAHOM team, it is more cost efficient to go with the MCU with external ADC. Furthermore, when dealing with medical equipment, like NCHMSs which take in data readings with high ranges of values, it is more prudent to utilize external ADCs for higher resolution and accuracy, confirming the use of the STM32F446ZEJ6 MCU and external AD7770 ADC. However, for more precision, the replacement of the AD7770 should be considered since there are ADCs whose specifications are tailored more towards medical equipment, like the ADS122U04 and AD7768.

References

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