Medical Applications with Renesas GreenPAK and AnalogPAK

This white paper describes how the GreenPAK and AnalogPAK can be used for medical applications. Their capabilities, resources, and versatility are described in terms of applicability for medical technologies.

Introduction

In the dynamic industry of medical technology, innovation, adaptability, and efficiency have become key factors. In this context, Renesas GreenPAK and AnalogPAK, two programmable mixed-signal devices, can be considered as a so useful resource for innovative developments in medical applications. This whitepaper delves into the characteristics of both GreenPAK and AnalogPAK, focusing on their capabilities and the embedded resources that can be fully leveraged for medical device design.

Both programable mixed-signal ICs integrate highly configurable analog and digital components in their different variants, where it can be mentioned analog comparators (ACMPs), operational amplifiers (OPAMPs), PWM modules, Rheostats, Look-Up tables (LUTs), clocks, counter/delays, DFFs, Asynchronous State Machines (ASM), etc.

In most cases, GreenPAKs and AnalogPAKs can be considered as cost-effective non-volatile memory (NVM) configurable hardware devices that allow users to configure both analog and digital functions, enabling processing of mixed-signal inputs by performing analog signal conditioning, digital signal processing, and mixed-signal interfacing tasks. In this way, many system functions can be integrated into a single custom circuit, minimizing component count, board space, and power consumption.

In this context, as medical devices grow in complexity, the imperative for programmable solutions and precise analog signal processing with reduced power consumption and a highly efficient design becomes increasingly crucial. Thus, both GreenPAK and AnalogPAK play a key role in overcoming challenges related to customization and analog functionality.

1. AnalogPAK and GreenPAK: A dive into their capabilities for medical applications

Both devices are, at their essence, highly programmable devices that allow for implementation applications for different industries and technologies. With a versatile architecture that allows users to configure its functionality according to specific needs, they stand as very interesting options for medical applications because of their adaptability.

The advantages of GreenPAK and AnalogPAK extend beyond mere programmability, seamlessly integrating analog and digital elements. As they are designed for mixed-signal applications, their programmable matrices can be thought of as a bridge between analog and digital applications, providing a cost-effective solution for applications that demand quite sophisticated processing resources for both signal types. This can be implemented due to the availability of both analog and digital peripherals integrated into the ICs that allow to combine analog and digital processing. In Table 1, the resources of some of the devices are shown.

	SLG46534	SLG46620	SLG46826	SLG47115	SLG47004	SLG47003	SLG47011
Family	GreenPAK	GreenPAK	GreenPAK	HVPAK	AnalogPAK	AnalogPAK	AnalogPAK
# of GPIOs	12	18	17	8	8	11	14
ACMPs / Current Sense / Differential AMP	3/0/0	6/0/0	4/0/0	2/1/1	3/0/0	1/0/0	1/0/0
OPAMPs	--	--	--	--	3	2	1
Digital Rheostat	--	--	--	--	2	2	--
ADC	--	1 (8-bit)	4	--	--	--	1 (14-bit)
LUTs	17	26	19	17	20	16	31
Counters/Delays	7	10	8	5	7	5	13
DFF/Latch	8	12	17	15	18	16	31
PWM Modules	--	3	-	2	--	--	--
Internal OSC [Hz]	25k | 2M | 25M	1.7k | 25k | 2M | 25M	25k | 2M | 25M	2k | 25M	2k | 25M	2k | 10k 25M	2k | 10k 20M | 40M
ASMs	8-state	--	--	--	--	--	--
Communications	I^2C	SPI	I^2C	I^2C	I^2C	I^2C	I^2C, SPI
HV-Out	--	--	--	2	--	--	--

Table 1. GreenPAK, HVPAK and AnalogPAK IC's

Their flexibility and configurability make them suitable for a wide range of applications, especially with the introduction of the new SLG47011 IC from the Analog PAK family, which features a 14-bit, 1 Msps SAR Analog-to-Digital Converter, a 12-bit, 333 ksps Digital-to-Analog Converter, and a Math Core. This IC provides flexible analog acquisition and conditioning combined with digital processing and control—capabilities that are invaluable in medical devices requiring a combination of different types of signals.

With the same industry in mind, energy efficiency is non-negotiable. GreenPAK's low power consumption becomes a key factor for devices where battery life is critical This is the case of energy-sensitive medical devices, where it must be ensured reliability while minimizing the need for frequent battery replacements.

If more analog features are required, the SLG47001 and SLG47003 from the same AnalogPAK family emerge as the most suitable options for precision analog signal processing. They boast two operational amplifiers with ultra-low power consumption, ultra-low offset voltage, and zero offset voltage drift; two 1024-position, 100 kΩ digital rheostats with I^2C and manual control options; and an analog switch. Their capabilities in handling analog signals with accuracy and reliability make them a highly compelling solution for applications where complex signals must be processed.

As a resume, the key resources and characteristics for medical applications that make GreenPAK and AnalogPAK ICs a suitable solution are:

- Sensors and Actuators Integration: Medical applications are based on human body signals acquired with sensors (temperature, oxygen, ECG signals) and sometimes require actuators (motors, switches, buzzers). The entire GreenPAK and AnalogPAK variants include a variety of input and output interfaces.

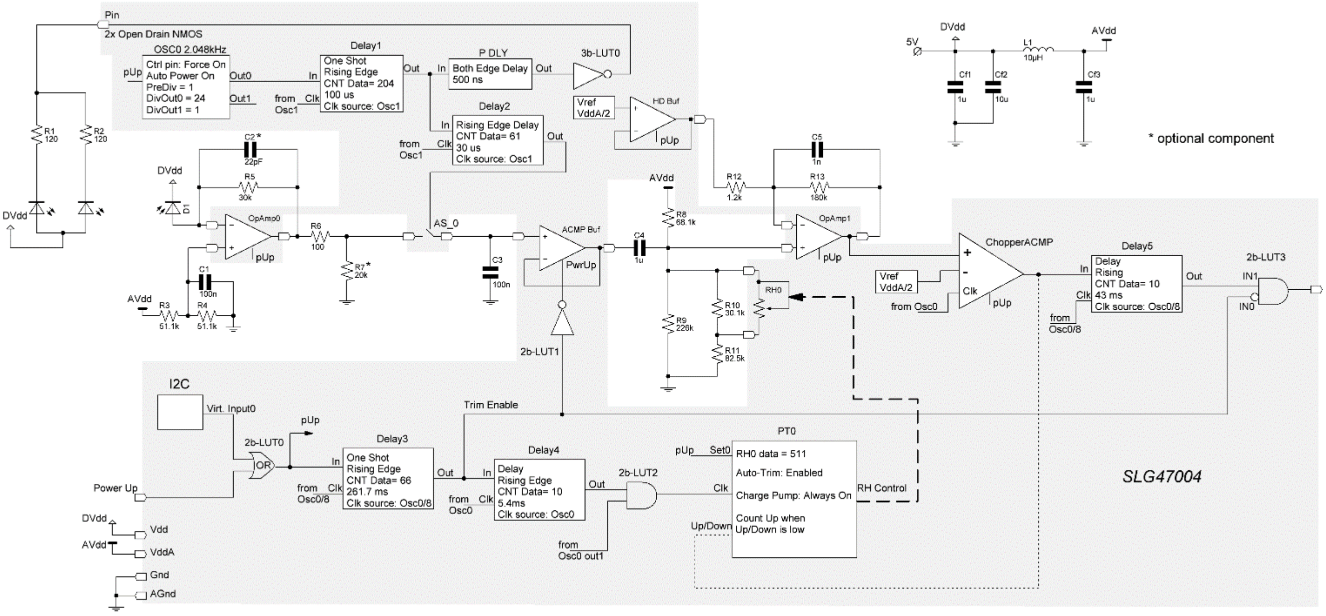
- Signal Processing: GreenPAK devices offer a variety of digital signal processing resources, such as LUTs, ASMs, and DFF, which can also be combined with analog resources such as OPAMPs and PWMs so they can be used for mixed-signal treatment applications.
- Low Latency: As medical applications can require real-time control or monitoring, low-latency signal paths are mandatory. In this context, GreenPAKs and AnalogPAKs have very low signal propagation delays.
- Security and Reliability: Medical applications must be secure and reliable as they are meant to care for humans. As the analyzed devices do not have CPU cores and programmable firmware, they cannot be hacked.
- Low Power Consumption and Small Form Factor: Some medical devices can be battery-powered or need to operate on low power to extend their operating period. Also, there are portable medical devices. The GreenPAK family is very efficient in terms of power consumption, with typical idle current consumption in the order of µA and they are offered in small TQFN and MSTQFN packages. These factors make them suitable for such types of applications.
- Compatibility: As the input and outputs of the ICs are digital or analog signals, including standardized protocols such as I^2C or SPI, they are fully compatible with other components that are usually used in these applications.

2. Case Studies

2.1 Vital Sign Monitoring System

The development and implementation of a vital sign monitoring system is based on measuring heart rate, temperature, blood pressure, and breathing rate. To do so, different sensors must be used, and analog signal conditioning must be implemented. Based on the capabilities described earlier, using both GreenPAK and AnalogPAK is a very interesting alternative for processing these signal types. This case also illustrates how they can be combined, taking advantage of their flexibility, programmability, and analog precision.

More details about an aspect of this application can be found in the Renesas Application Note AN-CM-307 Analog Front End for Heart Rate Monitor and AN-CM-326 Analog Front-End for Electrocardiogram Monitor. It shows how the heart rate can be measured, including different techniques to obtain the signal and an IC configuration to implement the analog front-end.



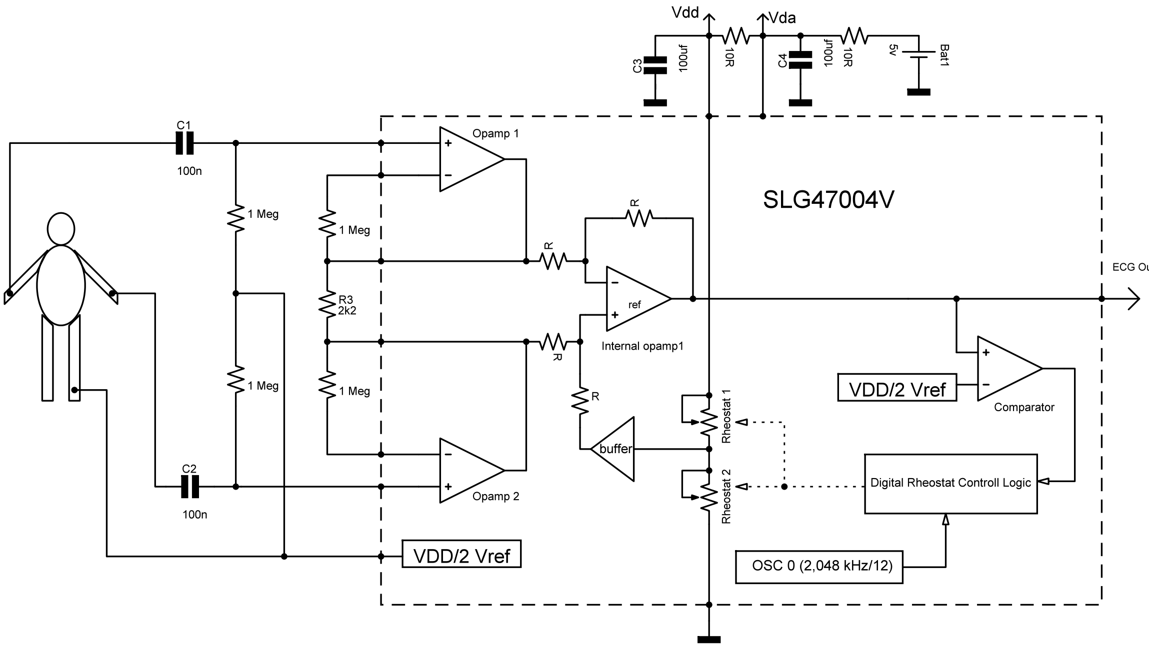


Figure 2. Analog Front-End for Electrocardiogram Monitor – Structure

For temperature and breathing rate, analog input capabilities such as the ADCs can be applied to interface with sensors to measure temperature, and digital inputs and DFFs with timing blocks can be used for breathing rate measurement.

In the case of blood pressure sensing, programmable digital logic can be used to implement control algorithms. This can include managing inflation and deflation of the cuff, and the sequence for reading sensor values and determining blood pressure levels. The analog signals from the sensors can be conditioned and acquired with the OPAMPs and processed with Analog Comparators.

2.2 Glucose Sensor and Monitor

In this case, a glucose sensor and monitor device are analyzed. This application is usually designed as a portable device, powered by a rechargeable battery, playing an important role in controlling diabetic patient's health. As a consequence, high efficiency in energy consumption is required. This is the case of AnalogPAK, which can be used for both signal conditioning and measurement as well as signal processing and user interface, with a highly efficient IC in terms of power consumption, both in the processing state and in the idle state.

More details about this application can be found in the Renesas Application Note AN-CM-222 Customized Glucometer using GreenPAK. It is shown how a disposable test strip can be measured and analyzed with a GreenPAK IC, giving the user information about his glucose level.

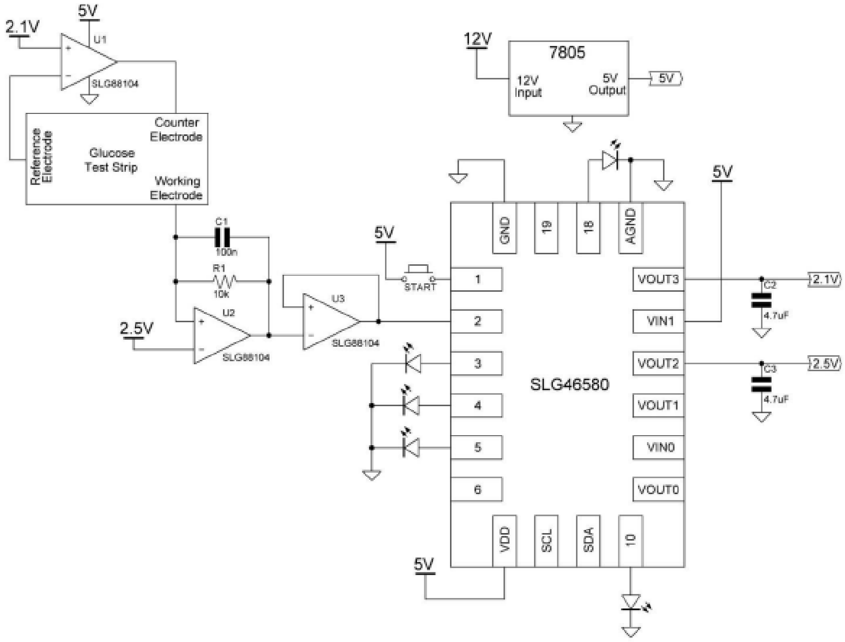


Figure 3. Customized Glucometer using GreenPAK – Hardware Schematic

2.3 Programmable Drug Delivery Device

A Programmable Drug Delivery Device (PDDD) must be able to deliver different medication regimens, with enhanced user safety and precise control over drug delivery parameters. To do so, the GreenPAK and AnalogPAK ICs can be utilized for various functions, including digital logic to implement control algorithms for drug delivery such as sequencing the opening and closing of valves or controlling the operation of a pump based on the prescribed dosage. This task must be implemented with precise timing circuits that can use programmable timers to ensure accurate and controlled drug release intervals.

Also, the OPAMPs and analog input capabilities can be applied to interface with sensors measuring parameters like drug levels, temperature, and pressure. Analog comparators and amplifiers can be configured to process sensor signals.

Finally, the PWM blocks, and their outputs, can be used to control actuators such as pumps or valves. PWM can be employed to adjust the speed of a pump or the opening/closing duration of a valve, allowing precise control over drug delivery rates.

2.4 PT100/1000 RTD Interface

The Resistance Temperature Detector (RTD) sensor PT1000 is a high-precision, cost-effective sensor with a wide temperature range, widely used in applications requiring high accuracy. This sensor is commonly employed in medical devices, particularly in applications requiring stringent temperature monitoring, such as patient warming systems, laboratory equipment, cold chain transportation, blood analyzers, and dialysis equipment, where precise temperature regulation is crucial for patient safety and effective operation. In dialysis equipment, maintaining a stable temperature ensures patient safety and comfort, while the accuracy of the RTD PT1000 ensures that blood analyzers provide reliable results.

To obtain accurate measurement results, it is also important to provide an analog front-end with precision parameters for this sensor. A unique combination of the ADC, DAC, Vref buffer, data buffers, and additional internal logic in the SLG47011 is used to achieve the highest precision in this analog interface. An additional feature that enhances measurement accuracy is noise cancellation.

Precise temperature monitoring is fundamental in the medical field, where even slight inaccuracies can have serious consequences. The variation of platinum resistance with temperature is highly linear, making the PT1000 very accurate for temperature measurement. The PT1000 interface error on the SLG47011, relative to the measurement module, is only ±0.2 °C, making it an excellent choice as an analog front-end for this sensor.

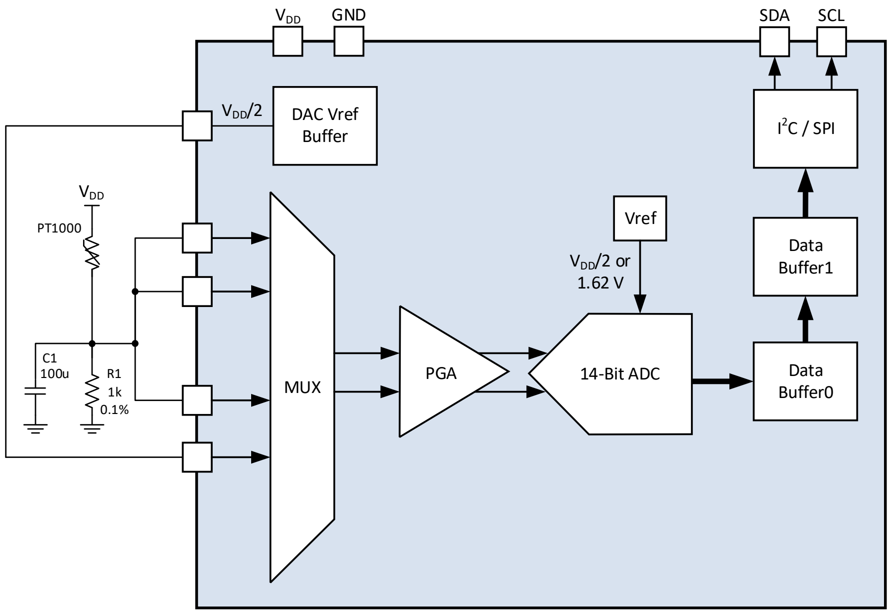


Figure 4. PT1000 Interface Simplified Block Diagram

More details about an aspect of this application can be found in the Renesas Application Note AN-CM-397 PT100/1000 RTD Interface.

2.5 Sinewave Generator with AnalogPAK

This design was developed as an analog sine wave source suitable for various applications. Some medical devices may require a sine wave reference for their circuits. Another application is its use as a signal that interacts with the human body in therapeutic electromagnetic equipment. Additionally, sine wave generators assist in testing and calibrating medical equipment.

This case demonstrates the implementation of a sine wave oscillator based on the SLG47003. Thanks to a new method of signal formation using the Extended Pattern Generator with predefined patterns, the output sinusoidal signal exhibits minimal noise and higher-order harmonics. This oscillator, utilizing a minimal amount of resources, allows for frequency, amplitude, and offset adjustments, including via I²C.

The Extended Pattern Generator also enables the generation of other waveforms, such as rectangular, triangular, and trapezoidal.

More details on this application can be found in the Renesas Application Note AN-CM-386 Sinewave Generator with AnalogPAK.

3. Conclusion

In conclusion, in this white paper, an analysis of the capabilities, applications, and collaborative potential of Renesas' GreenPAK and AnalogPAK in the continuously evolving field of medical technology is made. The programmability and analog resources of both GreenPAK and AnalogPAK make them, both individually and in collaboration, suitable technologies in medical device design.

4. Revision History

Revision	Date	Description
1.01	Feb 18, 2025	Added additional information
1.00	May 13, 2023	Initial release.

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