GreenPAK Power Sequencer

Scope

This guide explains how to design and implement power-sequencing solutions using GreenPAK™ programmable mixed-signal ICs. It compares the available sequencing technologies, outlines a typical design flow, and presents three ready-to-use reference designs, together with guidance on device selection, fault management, and runtime configuration. It is intended for hardware and power-management engineers who are familiar with basic electronics but may be new to GreenPAK.

Terms and Definitions

The following abbreviations are used throughout this guide:

ADC	Analog-to-Digital Converter
ASM	Asynchronous State Machine
DAC	Digital-to-Analog Converter
FPGA	Field-Programmable Gate Array
GPIO	General-Purpose Input/Output
I/O	Input/Output
I²C	Inter-Integrated Circuit serial bus
LUT	Look Up Table
MCU	Microcontroller Unit
PCB	Printed Circuit Board
PG	Power-Good
PGA	Programmable Gain Amplifier
PMIC	Power Management Integrated Circuit
POR	Power-On Reset
UVLO	Undervoltage Lockout

Introduction

Modern electronic systems often require multiple power rails to support processors, FPGAs, memories, communication interfaces, and peripheral devices. To ensure reliable operation, these power rails must be enabled and disabled in a predefined sequence while meeting specific timing and voltage requirements.

Improper power-up or power-down sequencing can result in excessive inrush current, system instability, incorrect device initialization, or even permanent damage to sensitive components. Therefore, power sequencing has become an essential function in many embedded, industrial, and communication systems.

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A Power Sequencer manages the activation and deactivation of power rails by controlling enable signals, monitoring Power-Good status, and implementing programmable delays between sequencing stages. This approach improves system reliability, reduces unnecessary power consumption, and simplifies overall power management.

Renesas GreenPAK™ devices provide a compact and flexible platform for implementing custom power sequencing solutions. Using programmable logic, timers, counters, comparators, and GPIO resources, GreenPAK devices can realize sophisticated sequencing algorithms. When combined with GreenFET™ load switches, they offer an efficient solution with minimal board space and low power consumption.

GreenPAK Benefits for Power Sequencing

- **Enhances System Stability** – No code to avoid errors, hang-ups, or missed reset events, and the integration of many components ensures fewer points of failure.
- **Reduces Board Size** – At sizes as small as 1.2 mm², GreenPAK is a perfect solution for mobile and wearable electronics.
- **Lowers Power Consumption** – GreenPAK can run continuously without ruining the system power budget.
- **Maximizes GPIO Flexibility** – Configurable GPIOs (pull-up/down resistors, push-pull, open-drain) with flexible routing minimize PCB complexity, while integrated components generate the custom timing and logic required by many power-sequencer designs.

1. Power Sequencing Technologies Comparison

Power sequencing can be implemented using several different technologies, each with its own trade-offs in integration, power consumption, timing precision, fault handling, cost, and flexibility. The most common approaches include GreenPAK configurable mixed-signal ICs, general-purpose microcontrollers (MCUs), dedicated sequencer ICs, and discrete RC-based solutions.

The table below summarizes how these technologies compare across the key parameters that matter most in real-world power-management designs, helping designers select the most appropriate solution for their application.

Feature	GreenPAK	MCU	Sequencer IC	Discrete RC
Integration	**Very High**	Low	Moderate	Lowest
Power (standby)	**Extremely low (µA)**	High (mA)	Moderate–High (mA)	Low
Timing Control	**Very Precise (80 ns)**	Good (jitter)	Excellent	Poor (drift)
Fault Detection Accuracy	**High**	Very High	Highest	None
Fault Response	**Fastest (ns, async)**	Slow (ms, limited by firmware execution loops)	Fast (µs)	---
Cost	**Low**	Mod–High	High	Low
Reliability	**Excellent (no firmware required)**	Good	Excellent	Low
Flexibility	**High (GUI config)**	Very High (SW)	Moderate	None
Implementation	**Simple (GUI)**	Slow (code)	Moderate	Simplest
Power-Down Seq.	**Yes (configurable)**	Yes (code req.)	Yes	Yes
PCB Footprint	**Small**	Medium	Small	Space-consuming

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As shown in the comparison, GreenPAK offers a well-balanced combination of high integration, ultra-low power consumption, flexible and accurate timing tuning, and the fastest asynchronous fault response, while remaining low-cost and easy to configure through a free GUI-based tool. This makes GreenPAK an attractive choice for designers who need the reliability and flexibility of a programmable solution without the overhead of firmware development or the area and cost of a dedicated sequencer IC.

2. Implementing a Power Sequencer Using GreenPAK

The design of a GreenPAK-based Power Sequencer starts with defining the power requirements of the target system. This includes identifying the number of power rails, determining the required power-up and power-down sequence, and establishing any timing constraints between rails.

GreenPAK devices provide a versatile set of configurable resources, including counters, delay generators, logic elements, analog comparators, and GPIOs. These building blocks can be combined to create custom power sequencing solutions tailored to specific application requirements.

Depending on the system needs, sequencing can be implemented using:

- Fixed time delays
- Power-Good signals
- Voltage monitoring
- I²C Acknowledge
- A combination of these methods

Common Power Sequencing Methods

Fixed Timing. One method for sequencing multiple subsystems is to allot a fixed amount of time for each start-up stage. This is appropriate for systems that do not feature a Power-Good signal. Finding a discrete solution with the exact delay timings needed can take hours, but with GreenPAK's configurable logic and timing resources, developing a custom system is easy. Key design considerations are the **delay time**, addressed across a wide range using GreenPAK's internal oscillators and CNT/DLY blocks, and the **ON-signal polarity**, which can be configured as active-high or active-low using integrated inverters and LUTs.

Power-Good. Many ICs can produce a Power-Good (PG) signal once their respective systems have finished their start-up routine. This is useful in systems where start-up time is not fixed and may depend on multiple variables. The key design consideration is the **ON and PG signal polarity**, which GreenPAK can configure as active-high or active-low using integrated inverters and LUTs.

Voltage Sensing. To ensure system stability, many SoCs, DSPs, and FPGAs require a minimum voltage for start-up. Monitoring the level of a rail is done simply using GreenPAK's configurable analog comparators. Key design considerations include the **overvoltage/undervoltage threshold**, where integrated ACMPs enable reliable sequencing over a wide range of user-specified conditions; **time-sensitive voltage limits**, where configurable CNT/DLY blocks reject reset events below a wide range of time thresholds; and **hysteresis**, where GreenPAK's ACMPs can be configured with 25, 50, or 200 mV.

I²C Acknowledge. In programmable systems with I²C, a command can be sent to the power sequencer to indicate that start-up completed successfully. Using GreenPAK's I²C virtual inputs, an I²C command is easily treated just like a digital Power-Good signal. Key design considerations are the **I²C speed**, which GreenPAK supports up to 400 kHz, and the **I²C address**, with up to 16 unique addresses available.

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Typical Design Flow

1. Define the power rails and their dependencies.
2. Determine startup and shutdown timing requirements.
3. Select the appropriate GreenPAK device.
4. Configure counters and delay blocks.
5. Implement the sequencing logic. Add Power-Good or voltage-monitoring feedback if required.
6. Verify the design through simulation and hardware testing.

Following this methodology enables the implementation of reliable power sequencing solutions while minimizing component count, PCB area, and power consumption.

The actual implementation may vary depending on the number of power rails, sequencing requirements, and overall system complexity. The following section presents several practical examples based on Renesas reference designs, illustrating different approaches to power sequencing and power management.

3. Basic Power Sequencer

A Basic Power Sequencer can be implemented using GreenPAK delay blocks and logic resources. Each power rail is enabled after a predefined delay, ensuring a controlled power-up sequence. This simple architecture provides a compact and **cost-effective solution for systems requiring sequential power-up control.**

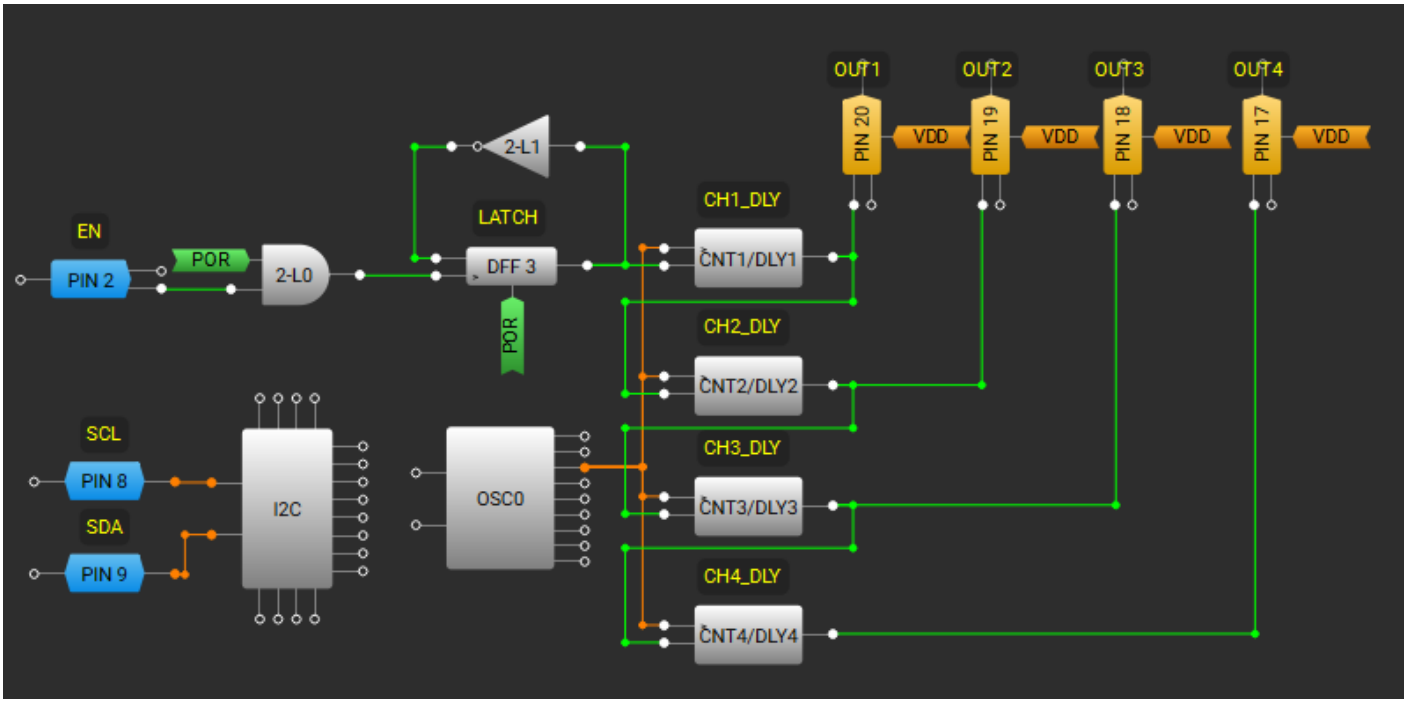


Figure 1. Basic Power Sequencer

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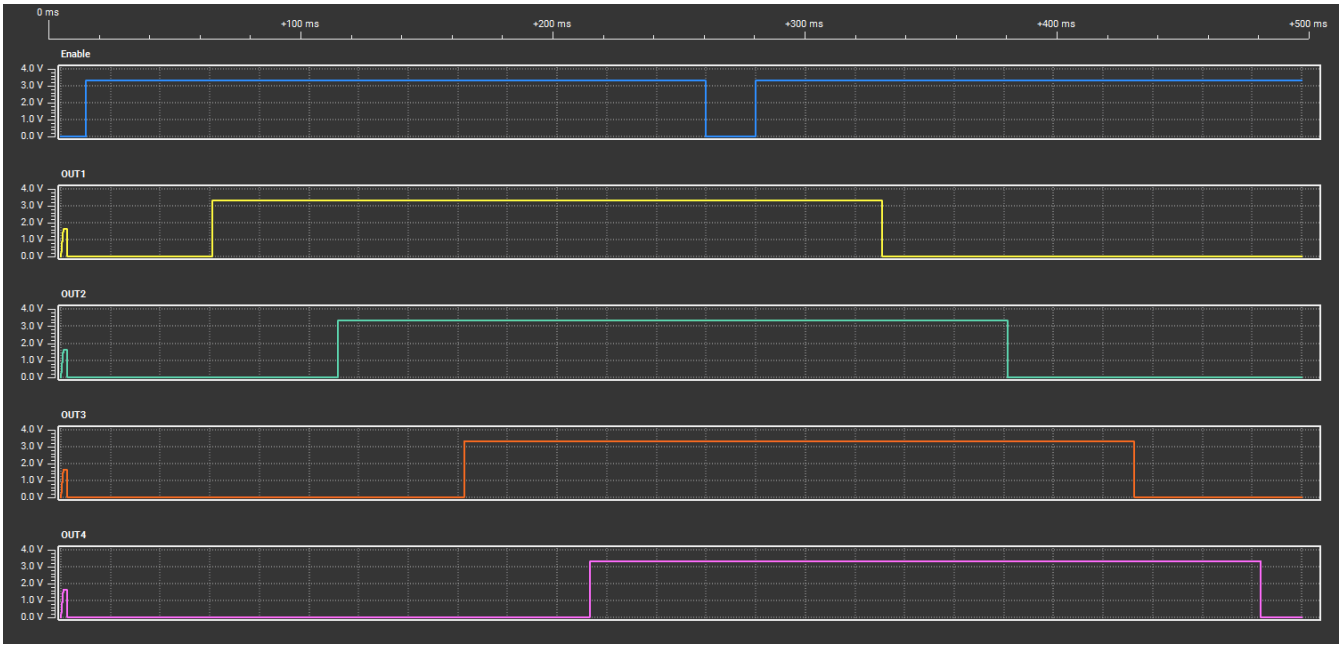


Figure 2. Basic Power Sequencer Simulation Results

The complete project, built in our free, GUI-based Go Configure Software Hub, is available for download here: **Basic Sequencer Design File**.

4. Power Sequencer with Voltage Monitoring

This design extends the basic sequencing approach by incorporating voltage monitoring functionality. Instead of relying solely on fixed timing delays, the GreenPAK device continuously monitors each power rail and enables the next stage only after the required voltage threshold has been reached.

By using integrated analog comparators, the sequencer can verify proper regulator startup and detect undervoltage conditions. This method improves system reliability and ensures that dependent subsystems are powered only when the preceding power rail is operating within specification.

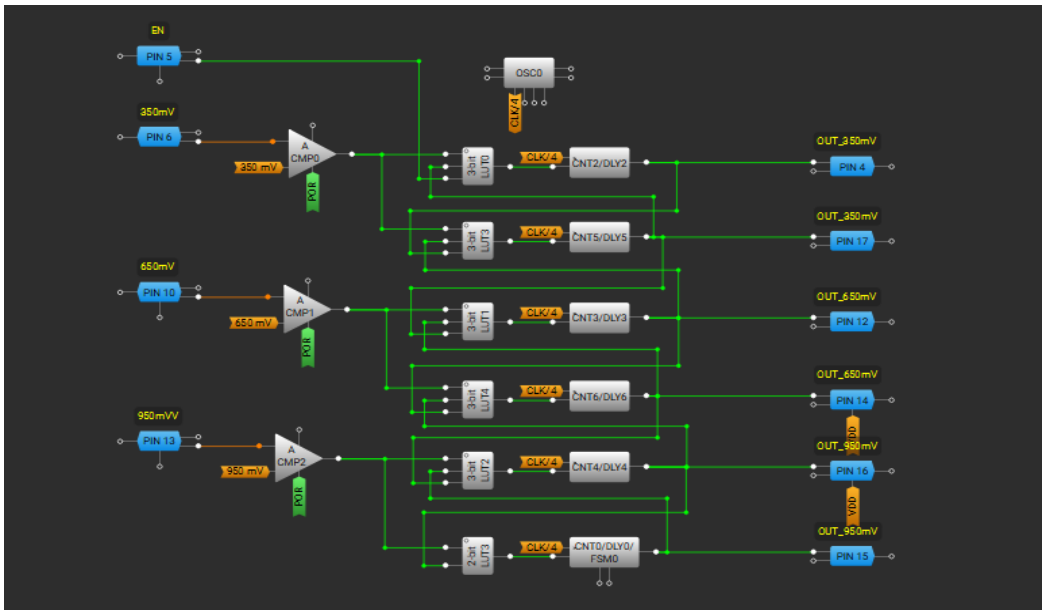


Figure 3. Power Sequencer with Voltage Monitoring

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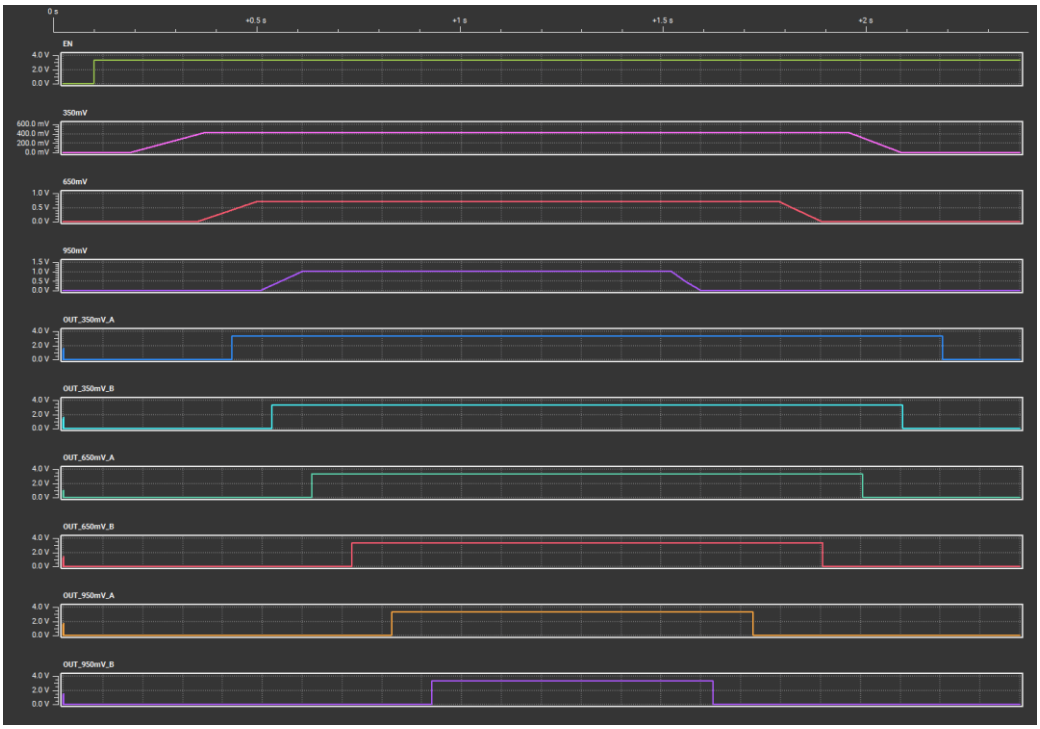


Figure 4. Power Sequencer with Voltage Monitoring Simulation Results

The complete project, built in our free, GUI-based Go Configure Software Hub, is available for download here: **Power Sequencer with Voltage Monitoring Design File**.

5. Six-Channel Power Sequencer based on Asynchronous State Machine

This design implements a six-channel Power Sequencer using the GreenPAK ASM (Asynchronous State Machine) block together with Up and Down control signals. The ASM operates as a finite-state machine, where each state corresponds to a specific stage of the power sequence.

When the Up command is asserted, the state machine advances through consecutive states, enabling the six power rails one by one according to the predefined sequence. A programmable delay of 1 ms is inserted between state transitions to ensure stable power rail startup and to prevent excessive inrush current.

When the Down command is activated, the ASM transitions in the opposite direction, disabling the power rails in reverse order with the same 1 ms delay between stages, providing a controlled and reliable shutdown sequence.

This approach provides a flexible and reliable solution for managing both power-up and power-down sequences while requiring only a single GreenPAK device.

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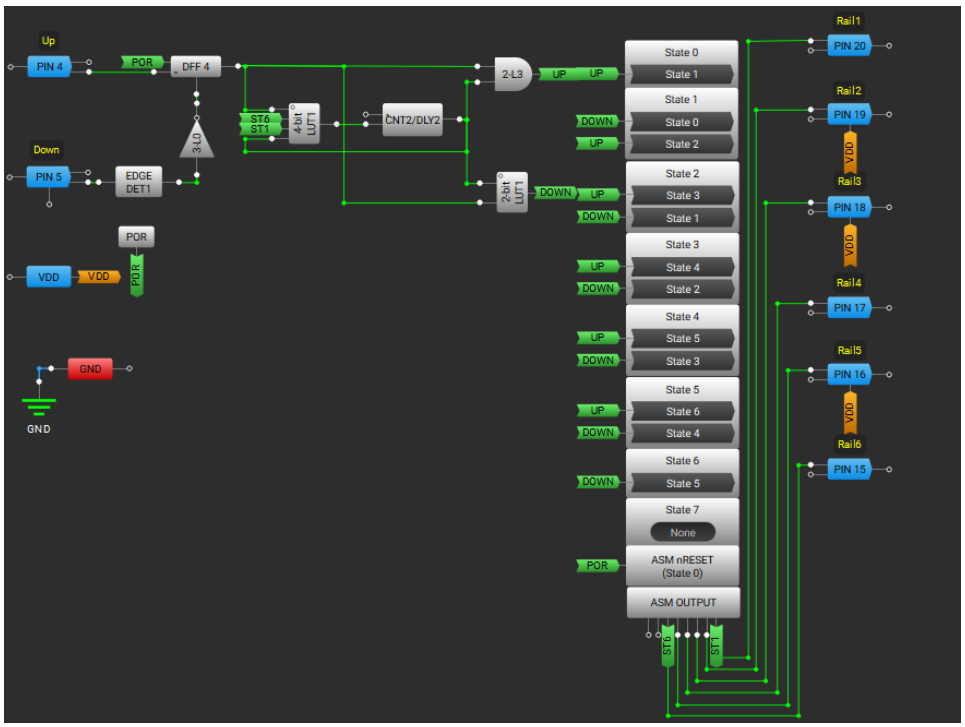


Figure 5. Six-Channel Power Sequencer based on ASM

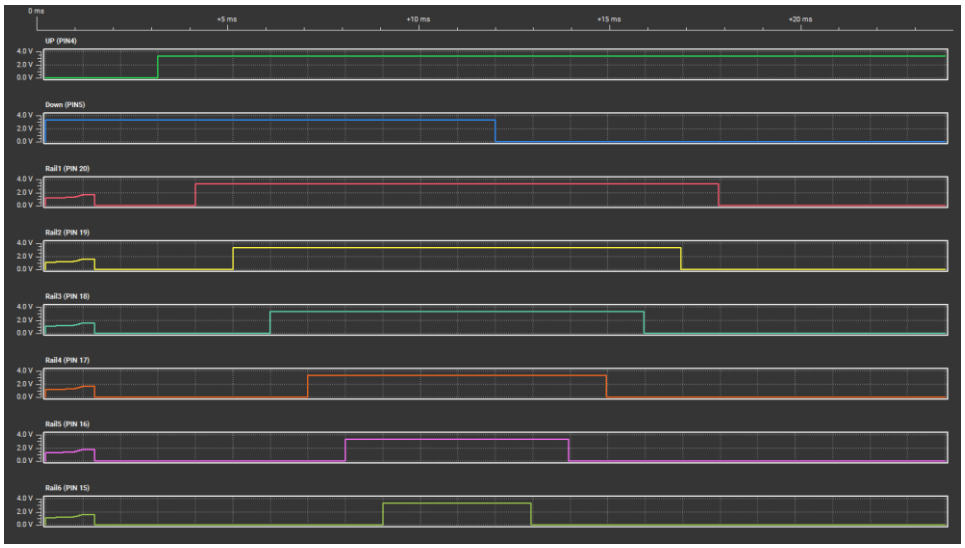


Figure 6. Six-Channel Power Sequencer based on ASM Simulation Results

The complete project, built in our free, GUI-based Go Configure Software Hub, is available for download here: **Cascaded Sequencer Design File**.

6. Device Selection Guidance

Selecting the right GreenPAK device is a key step in any power-sequencing design. The choice depends primarily on the number of power rails to be controlled, the number of available GPIOs, whether analog comparators are required for voltage monitoring, and whether runtime reconfiguration over I²C is needed. Small designs with two or three rails and fixed timing can be served by a compact, low-pin-count device, while designs with many rails, voltage monitoring, or an asynchronous state machine benefit from a larger device offering more macrocells, comparators, and an I²C interface.

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Part Number	Description	Key Advantages	Power Sequencer Type
SLG46108V	VDD Range: 1.71-5.5V, 6 GPIOs	**Smallest GreenPAK – 1.0 mm x 1.2 mm**	Output: up to 4 channels Feedback: up to 5 digital rails
SLG46534V	VDD Range: 1.71-5.5V, 12 GPIOs, I²C	**ASM (8 states), 3x ACMP, 7x DLY, I²C**	Output: up to 7 channels Feedback: 3 analog rails, up to 9 digital rails
SLG46620V	VDD Range: 1.71-5.5V, 18 GPIOs	**6x ACMP, 10x DLY, 8-bit SAR ADC, 3x PWM**	Output: up to 10 channels Feedback: 6 analog rails, 12 digital rails
SLG46855V	VDD Range: 2.3-5.5V, 12 GPIOs, I²C	**4x ACMP, 8x DLY, I²C**	Output: up to 8 channels Feedback: 4 analog rails, 8 digital rails
SLG46881V	VDD Range: 2.3-5.5V, VDD2 Range: 0.95-1.98V, 28 GPIOs, I²C	**Fault bus logging, up to 28 GPIO, I²C, ASM (12 states)**	Output: up to 5 channels Feedback: 4 analog rails, 16 digital rails

To reduce the number of sequenced channels without modifying the hardware design, unused outputs can be disabled in the GreenPAK configuration or left unassigned in the sequence logic. For designs with an I²C interface, individual rails can also be enabled or disabled through runtime configuration, allowing the same PCB and device selection to support several product variants with fewer active channels while preserving the original power-sequencing architecture.

For the actual switching of each rail, GreenPAK sequencing logic is commonly paired with Renesas GreenFET load switches, which provide controlled inrush current, low on-resistance, and integrated protection while keeping board area small. The full portfolio of GreenFET ICs can be found at Product Selector: Load Switches | Renesas.

7. Fault Detection and Fault Management

Beyond simply ordering the power rails, a robust sequencer must detect and respond to fault conditions, such as a rail failing to reach its Power-Good threshold, an undervoltage event, or an overcurrent indication from a load switch. GreenPAK devices implement fault detection using their integrated analog comparators to monitor each rail against programmable thresholds.

Because the GreenPAK fault response is handled in hardware through the Asynchronous State Machine and/or logic resources, it reacts within nanoseconds - far faster than a firmware-based microcontroller loop. On detecting a fault, the sequencer can immediately disable downstream rails, trigger a controlled shutdown sequence, and assert a fault flag on a GPIO to notify the host system.

8. Fault Logging Feature

GreenPAK can also support fault logging by saving the number of rails that failed during startup or normal operation. Before disabling the full system, the sequencer can latch this fault information, allowing the host controller or technician to identify which rail caused the shutdown and simplify system debugging.

9. Runtime Configuration via I²C

GreenPAK devices that include an I²C interface allow selected parameters to be adjusted at runtime without changing the hardware. This makes it possible to fine-tune inter-rail delays, change voltage thresholds, or enable and disable individual rails directly from the host processor. It is especially useful during board bring-up, for supporting multiple product variants from a single design, and for adapting the sequence in the field.

A detailed I²C runtime-configuration guide can be found in each datasheet for GreenPAK ICs.

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10. Power-Down and Shutdown Sequencing

Just as power-up order matters, many systems require a controlled power-down sequence to avoid back-powering, latch-up, or data corruption. In general, rails are disabled in the reverse order of power-up, with defined delays between stages. The six-channel ASM design above already demonstrates this reverse sequencing; the same principle can be added to the basic and voltage-monitoring designs by routing the disable signals through additional delay blocks or state-machine states.

Conclusions

Power sequencing is an essential function in modern electronic systems with multiple power rails, ensuring reliable startup and shutdown operation while protecting sensitive components from improper power conditions.

GreenPAK devices provide a flexible and cost-effective platform for implementing custom power sequencing solutions. By combining programmable logic, timing resources, analog functions, and GPIOs, a wide range of sequencing schemes can be realized, from simple delay-based implementations to advanced solutions incorporating voltage monitoring and fault management.

In addition, GreenPAK devices that include an I²C interface enable runtime configuration of selected parameters, allowing system designers to adjust timing settings, control thresholds, or other operational parameters without modifying the hardware design.

GreenPAK-based power sequencers offer a compact, low-power, and highly configurable solution for power management in embedded, industrial, communication, and FPGA-based applications.

Design Resources and References

For further details, design files, and configuration software, refer to the following Renesas resources:

- **GreenPAK Product Family Overview**
- **Go Configure™ Software Hub (free GUI-based design tool)**
- **GreenFET Load-Switch Product Family**

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Revision History

Revision	Date	Description
1.00	Jul 22, 2026	Initial release.

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