

## White Paper

# Powering your FPGA Applications

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## Abstract

Field-programmable gate arrays (FPGAs) have gained much attention and widespread application in the end market. This document outlines the requirements for FPGA power supply and related issues. It will also discuss the latest digital power module from Renesas, which can be used as a power supply solution for FPGA applications, with a detailed introduction to the ISL8274M as an example.

## Introduction

FPGAs are widely used in a variety of products due to their many advantages, including short development time and flexibility during development and when reconfiguring or updating in the field. FPGAs are also cost-effective solutions.

Many new FPGAs are typically designed using advanced technology to achieve low power consumption while providing high performance. Those FPGAs use the new fabrication process that tends to require a lower core voltage, which extends the voltage range needed for its power supply with a higher supplying current capability. Many FPGAs also have varying power supply requirements. Even for the same FPGA, each power rail may have a different output requirement, which depends on factors such as the voltage and power demands for each rail, the rail's sequencing requirements, and noise sensitivity. Power devices with the ability to provide multiple voltage levels in a wider range with higher current supporting capability for high-power blocks are ideal for those applications with varying power requirements.

Power modules include the controller, FETs, inductors, and the majority of the passives encapsulated in a single package, leaving only the input and output bulk capacitors outside to complete the system design. Digital power modules combine the benefits of power modules and digital power. By using a digital power module, designers can shorten development time and quickly update power monitoring and sequencing control functions, which analog solutions cannot provide. Benefiting from improved voltage regulation accuracy and advanced digital control techniques, digital power modules are becoming more competitive in FPGA applications.

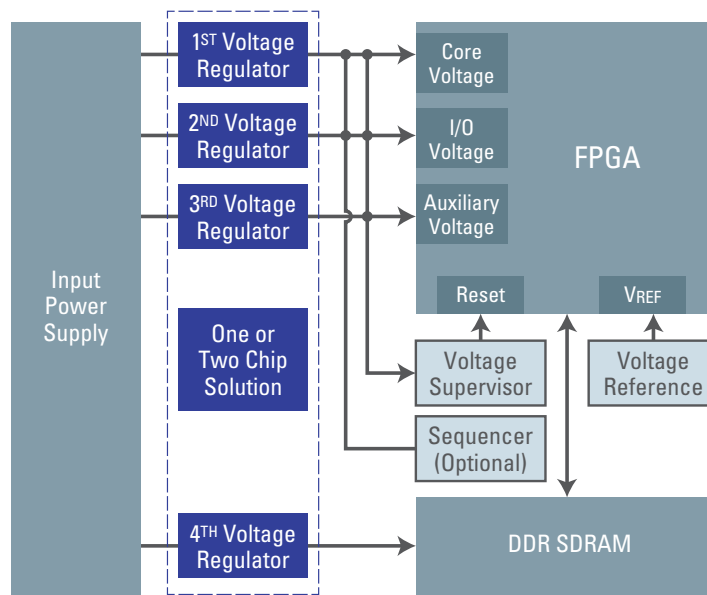
This document will discuss the general power requirements of FPGA and introduce the Intersil ISL8274M from Renesas, explaining how its main features satisfy the requirements for powering FPGAs.



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## FPGA Power Requirements

An FPGA power supply is normally used to transfer input voltage, which is usually from a DC bus supplied by a switching mode power supply (SMPS) with a typical range from 5V to 12V, down to the voltage required by FPGA sub-blocks and auxiliary circuits. Figure 1 shows the general structure of an FPGA power supply system.



**Figure 1.** General structure of FPGA power system.

There are various blocks in an FPGA. These blocks may include the core, I/O port with different voltage standards, and auxiliary circuits that encompass internal circuits such as bias circuit, phase locked loop circuit, and transceiver. The block also features external DDR memory. Below is a description of the supply voltage for each part and its specific power requirements.

### Core Voltage

Core voltage supplies the internal core of configurable logic blocks and tends to require lower supply voltage, especially for high-performance FPGAs with a low power consumption requirement. The logic core generally has the most demanding current requirements, which can be up to tens of Amps.

### I/O Voltage

I/O voltage supplies the I/O banks. Its voltage level depends on the specific I/O standard applied to the FPGA and is usually in the range of 1.2V to 3.3V. To satisfy the working condition of the parts and to optimize the power performance, the FPGA may employ a different I/O standard for each I/O port, which could require supporting multiple supply rails. The current load can be different for various cases. For UltraScale FPGA, the maximum output current needed could be up to tens of Amps.

### Auxiliary Voltage

Auxiliary voltage supplies auxiliary circuits in the FPGA, as well as some related external blocks in the system if needed. It may be completed using varying voltage levels for different manufacturer's products. This kind of supply generally needs comparatively lower current. But for some noise sensitive parts, such as clock/memory circuit, they would have a harsher voltage requirement on output variation.

Table 1 lists the specific voltage requirements of some high-performance FPGA products on the market. It is usually recommended by the FPGA manufacturer to supply FPGA with voltages within  $\pm 5\%$  or  $\pm 3\%$  of nominal. Some sensitive parts, such as PLL, could require an even lower voltage of around 2%, as shown in Table 1. This should be considered as a target in the power design stage.

**Table 1.** Some high-performance FPGAs with their voltage conditions recommended

FPGA model	Core voltage range (tolerance), V	Auxiliary voltage range (tolerance), V	I/O voltage range (tolerance), V
Spartan-7	1.0 (50 mv)	1.8 (5%)	1.2 to 3.3 (5%)
Spartan-7 (-1LI)	0.95 (30 mv)	1.8 (5%)	1.2 to 3.3 (5%)
Artix-7	1.0 (50 mv)	1.8 (5%)	1.2 to 3.3 (5%)
Artix-7 (-2LE)	0.9 (30 mv)	1.8 (5%)	1.2 to 3.3 (5%)
Kintex-7 (-2LI)	0.95 (20 mv)	1.8 (5%)	1.2 to 3.3 (5%)
Arria II-GX	0.9 (30 mv)	2.5 (VCCA_PLL) 0.9 (VCCD_PLL)	1.2 to 3.3 (5%)
Stratix IV-GX	0.9 (30 mv)	2.5 (VCCA_PLL) 0.9 (VCCD_PLL)	1.2 to 3.0 (5%)
Cyclone IV	1.2 (50 mv)/ 1.0 (30 mv)	2.5 (VCCA_PLL) 1.2/1.0 (VCCD_PLL)	1.2 to 3.3 (5%)

*Note: The data listed in the table was obtained from the datasheets of the specific FPGA models listed in Column 1.*

Even a small change in voltage causes a reasonable change to static and dynamic power. It is, therefore, important to have exact voltage control with small tolerance and good output voltage set-point resolution.

## Power Consumption

Power consumption of an actual system may vary significantly. Due to inherent FPGA flexibility, users in similar applications could end up with different power consumption based on the particular combination of performance level and specific FPGA features utilized in their design.

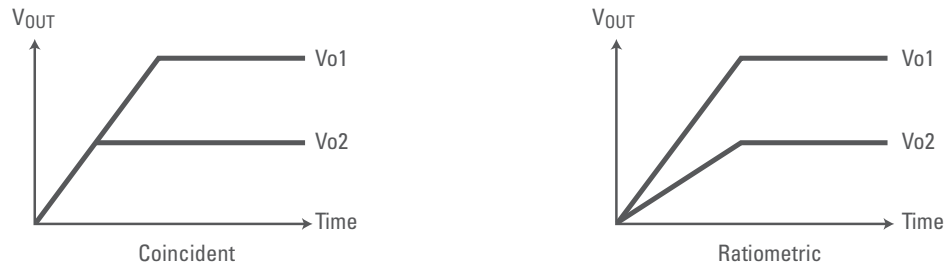
Power estimation software provided by the FPGA manufacturer can be used to estimate power consumption in the FPGA and to understand where power is dissipated. In terms of power supply design, it gives the designer a sense of the power level needed for the FPGA power supply in the product development phase and allows the designer to focus on power and thermal optimization. Generally, static and dynamic power consumed at the core and I/O cause the greatest power consumption in the FPGA. The maximum current during the worst transient and power-on process should also be considered when executing the power design.

## Startup Voltage Ramping

It is important for the FPGA power supply to have an adjustable soft-start feature with monotonic output voltage ramping to help prevent excessive inrush current during startup and possibly other functions. Most FPGAs have requirements on voltage ramp-up time for rails. A slower rising time could cause failure in the device configuration and incorrect operation. Thus, a power supply with an adjustable soft-start is preferred in FPGA power applications. The ISL8274M digital power module provides an advanced soft-start feature, allowing the designer to easily configure a wide range of soft-start times without changing any physical component.

## Tracking/Power-Up Sequence

Numerous high-performance systems place stringent demands on the order in which the power supply voltages are turned on. This is particularly true when powering FPGAs. In most cases, the I/O interface operates at a higher voltage than the core and, therefore, the core supply voltage must not exceed the I/O supply voltage according to the manufacturers' specifications. In this condition, the voltage tracking function is expected to ensure a safe power up. Figure 2 illustrates two typical tracking modes provided by the ISL8274M: coincident and ratiometric.

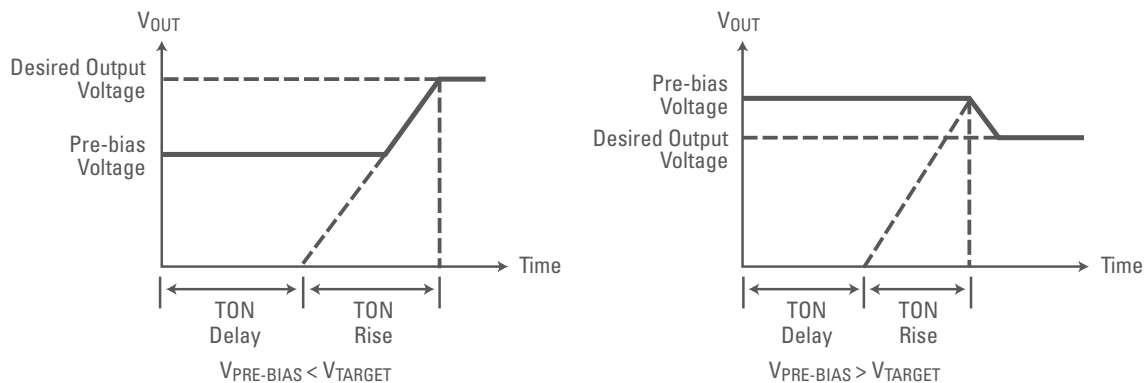


**Figure 2.** Two typical modes of voltage tracking provided by the ISL8274M.

In some conditions, it is important to have one supply reach its operating voltage before another supply reaches it in order to avoid latch-up. This requires power regulators of different rails to power up in a predetermined sequence. Therefore, a power regulator with a programmable start-up sequence would be particularly useful when powering advanced processors like FPGAs. Most manufacturers recommend a specific power-up sequence in their product documents, which can be used as a reference in power design.

## Pre-Bias Startup

An output pre-bias condition exists when an externally applied voltage is present on a power supply's output before the power supply's control IC is enabled. Figure 3 illustrates two general conditions of pre-bias startup with the bias voltage higher or lower than the reference voltage before powering up. These conditions could happen in an FPGA application as well. If the FPGA requires safe startup and the power supply regulator isn't allowed to sink current during start-up, a pre-bias startup condition should be considered in the power supply regulator to provide pre-bias protection.



**Figure 3.** Two general pre-bias startup conditions

## Multi-Channel/Interleaving

As mentioned previously, multiple power supplies are required to power different FPGA parts. Therefore, a multi-channel power regulator with an adjustable voltage level would be ideal. This would allow the designer to use one device to support multiple rails, reducing system size and the design/layout effort needed.

As the required supply voltage drops lower and lower, the current supplying capability expected for the power supply can be high. For some high current conditions, a multiphase operation would be preferred. Interleaving the connection among phases can help distribute power and thermal stress into separate phases and reduce the input/output current ripple. The ISL8274M has two channels that can be set with a distinct voltage level and configured as either two separate channels or a two-phase condition with an adjustable interleaving setting to support the same rail with a high current rating and distributed thermal dissipation.

### Synchronization/Communication Bus

For FPGA applications, power regulators are typically required to synchronize to a common clock. Communication among power regulators is expected to broadcast fault information among each other; then the fault protection can be well managed at the system level. Many power regulators have a SYNC pin to allow synchronization to a common clock or sync one part to another. The ISL8274M allows fault spreading and phase spreading functions through the Digital-DC (DDC) bus to enhance the communication among the same parts.

### Point-of-Load (POL) Solution

To power the FPGA hardware system, there are many point-of-load regulator options for power rails, including LDO, discrete voltage regulator, and power module solutions.

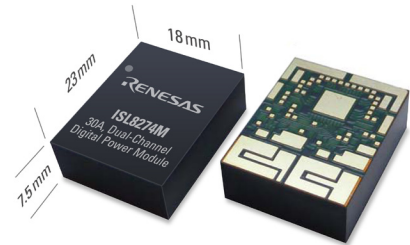
As the FPGA power requirement is usually lower output voltage and higher output current, an ideal POL solution should support a wide range of output voltages with excellent load transient response. Performance features such as efficiency under different load conditions, cost, size, package, and thermal performance should also be considered in order to make the right choice based on the definite requirements in an FPGA application. Because some systems may need updates or changes after completing the initial design, a POL solution with an adjustable output configuration and compatibility setting for adding more rails would be advantageous. System monitoring and fault protection functions are also critical for many systems, especially for some complex and high-performance applications.

There are many aspects to consider in order to achieve the optimal performance of the overall power system; unfortunately, some of them will have design trade-offs with others. This requires the designer to extend considerable effort on validating and testing during design cycles to achieve the overall optimal point. Ideally, you want to minimize the time spent on your power supply and instead focus your attention on developing the application on the FPGA. Moreover, many variables can be involved in analysis/design, which may include the tolerance or derating of the component, a change in the operating environment, or variation on the design target. Even a small change on one component may lead to spending extra time on the PCB redesign. Thus, if a power solution can be implemented with fewer components, it would deliver better reliability and a reduced BOM, which is beneficial for high-performance systems like FPGAs. All these aspects make the power module a good option for this application.

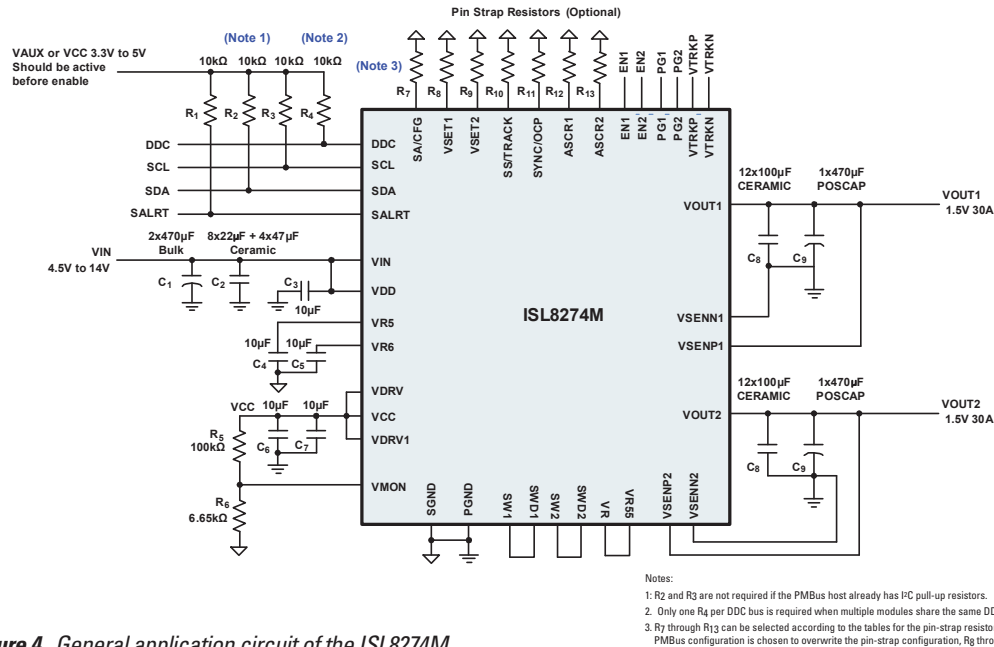
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## Renesas Digital Power Module

As a leading power IC supplier, Renesas has both analog and digital power modules that are suitable for FPGA power supply applications. Digital power management provides many benefits such as real-time monitoring, digital control with fast transient response, reduced BOM, and decreased design effort. The digital power module solution is flexible and can adapt to the changing FPGA power requirements of lower voltage, higher current, and additional rails with less effort. A new voltage rail can be easily added to the power management system through PMBus®. The Digital-DC communication bus is used to provide the communication channel between devices, enabling trouble-free communication while providing benefits for such features as sequencing and fault spreading. Nowadays, many digital power modules can achieve excellent output voltage regulation accuracy with the exact set-point reference.



The ISL8274M is a general-purpose step-down digital power module and features PMBus communications and numerous other characteristics that satisfy the requirements for FPGA power supplies. It has two channels, which can operate as two separate power rails for different FPGA parts or can be easily connected in parallel to support the same rail with a high current capability requirement. Moreover, the ISL8274M has an internal Digital-DC serial bus that enables communication between other Renesas ICs, allowing easy configuration and implementation of such functions as power-up sequence, fault protections, and monitoring. Its general application circuit is shown in Figure 4.



**Figure 4.** General application circuit of the ISL8274M

**Table 2.** Key features of the Renesas ISL8274M digital power module

ISL8274M Key Features		
<ul style="list-style-type: none"> <li>• Complete digital power supply</li> <li>• 30A/30A dual-channel output current <ul style="list-style-type: none"> <li>– 4.5V to 14V single rail input voltage</li> <li>– Up to 95.5% efficiency</li> </ul> </li> <li>• Programmable output voltage <ul style="list-style-type: none"> <li>– 0.6V to 5V output voltage settings</li> <li>– ±1.2% accuracy over line/load/temperature</li> </ul> </li> </ul>	<ul style="list-style-type: none"> <li>• ChargeMode™ control loop architecture <ul style="list-style-type: none"> <li>– 296 kHz to 1.06 MHz fixed switching frequency operations</li> <li>– No compensation required</li> <li>– Fast single clock cycle transient response</li> </ul> </li> <li>• PMBus interface and/or pin-strap mode <ul style="list-style-type: none"> <li>– Fully programmable through PMBus</li> <li>– Pin-strap mode for standard settings</li> <li>– Real-time telemetry for VIN, VOUT, IOUT, temperature, duty cycle, and switching frequency</li> </ul> </li> </ul>	<ul style="list-style-type: none"> <li>• Advanced soft-start/stop, sequencing, and tracking</li> <li>• Complete over/under voltage, current and temperature protections with fault logging</li> <li>• PowerNavigator™ support</li> <li>• Thermally enhanced HDA package</li> </ul>



## Digital ChargeMode™ Control Scheme

The ISL8274M uses Renesas' patented ChargeMode™ control scheme, which has the ability to achieve a fast response when loading the transient with a fixed switching frequency and to support an all-ceramic output cap design. Delays are reduced between the error-sampling instant and the moment the PWM is generated using a multi-rate sampling technique and digital filter. This is also an easy compensation control scheme, achieved without the need for extra passive RC components for a compensation loop design as required by an analog module. For any in-system change, new compensation can be easily reconfigured by the PMBus command or PIN-strap setting. A reference design is provided by the manufacturer for the user's convenience.

## Soft-Start with Adjustable Ramping Time

It may be necessary to set a delay from the time when an enable signal is received until the output voltage ramps to its target value. The ISL8274M provides the customer with an easy process through PowerNavigator™ to reset both the delay and ramp time periods precisely and independently. The ISL8274M also provides pre-bias protection by sampling the output voltage before initiating an output ramp in the event a pre-bias condition exists at the output stage prior to startup. Figure 5 shows the soft startup process, with startup rising time equal to 5 ms.

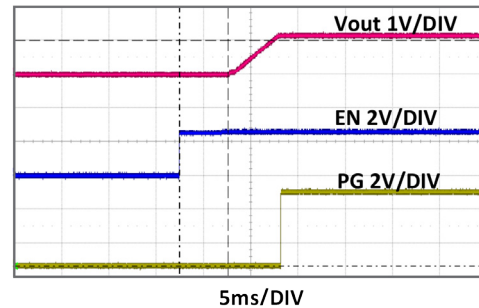


Figure 5. ISL8274M startup performance

## Power Sequencing/Voltage Tracking

A group of power modules for different rails or multiphase operation can be configured to power up in a predetermined sequence. This feature is especially useful when powering advanced processors, such as FPGAs, that require one supply to reach its operating voltage prior to another supply reaching it in order to avoid latch-up. With the ISL8274M, multiple device sequencing is configured by issuing PMBus commands to assign the preceding device in the sequencing chain, as well as the device that follows the sequence.

The ISL8274M integrates a voltage tracking scheme that allows one of its outputs (Channel 1 or Channel 2) to track a voltage that is applied to the VTRKP and VTRKN pins, with no external components required in two optional modes that are based on the specific application.

## Various Protection Functions and Monitoring

A full list of protection functions is supported by the ISL8274M, including power input UV/OV, driver voltage UV/OV, two levels of output current UC/OC (average and peak), output voltage UV/OV, and temperature UT/OT. Each protection has both a fault limit and warning limit. The user can set the corresponding fault limit value easily through PMBus commands. There are also different fault response mode options from which a customer can choose, including hiccup mode. Additionally, the user can configure the response function through the PMBus command. The ISL8274M uses PMBus commands to monitor a wide variety of system parameters.

The most complete protection functions and monitoring items are provided by the ISL8274M. These functions protect the power system operation in a safer, more robust manner and provide increased flexibility to the designer in terms of system design.

## Digital-DC Communications Bus

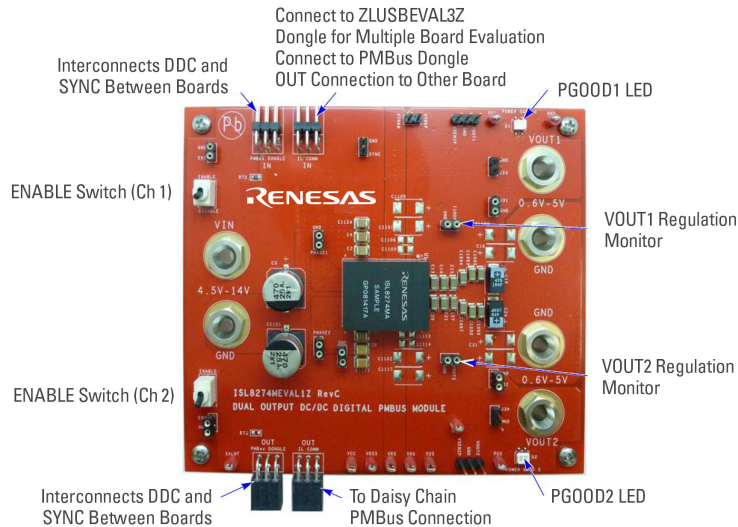
The ISL8274M has combined the Digital-DC Communications (DDC) bus used to communicate between Renesas' digital power modules and digital controllers. The DDC bus provides the communication channel between devices for features such as sequencing, interleaving, and fault spreading.

# Design Tools from Renesas

## Evaluation Board/User Guide

An evaluation board and detailed user guide for customer testing and evaluation are available for the ISL8274M. A photograph of the evaluation board is shown in Figure 6. Additional details can be obtained through the following link.

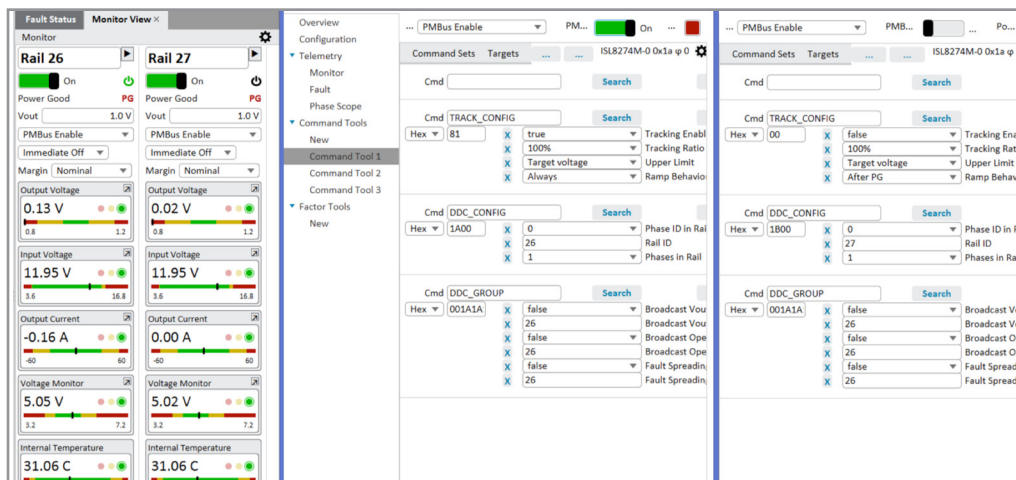
(<https://www.intersil.com/en/tools/reference-designs/isl8274meval1z.html>)



**Figure 6.** The ISL8274M Evaluation Board

## PowerNavigator™

The PowerNavigator GUI software offered by Renesas will help accelerate the design, testing, finalization, and debugging of your power design. It connects to development boards through PMBus to set various adjustable system parameters and threshold values. The final configuration is simply stored to non-volatile memory. Figure 7 shows an example of the PowerNavigator GUI software windows. ([www.intersil.com/powernavigator](http://www.intersil.com/powernavigator))

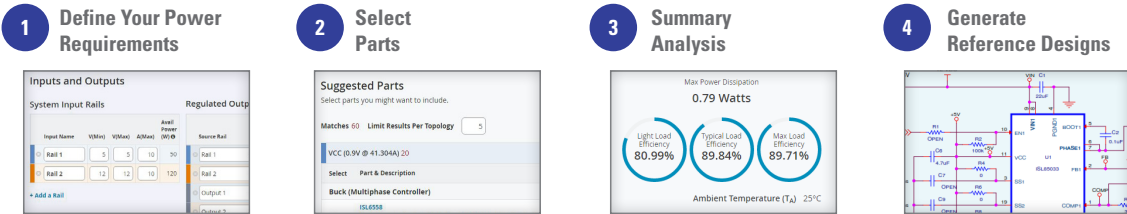


**Figure 7.** Screenshot of PowerNavigator windows



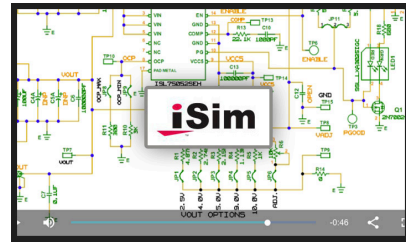
## PowerCompass™ Multi-load Configurator

The PowerCompass tool helps users quickly identify parts that match their specific requirements, set up multiple rails, perform high-level system analysis, and generate custom reference design files. The tool is available exclusively as a web app, from which users can also work offline. Detailed instructions and a video tutorial are available online and can help the user get started easily. ([www.intersil.com/powercompass](http://www.intersil.com/powercompass))



## iSim™ Design & Simulation Tool

Renesas provides a web-based power simulation tool called iSim, which is an easy-to-use, interactive power management and op-amp design tool. iSim allows the user to quickly select supporting components and design and simulate their circuit and system. Detailed instructions and a video tutorial are available online and can help with easily getting started. ([www.intersil.com/isim](http://www.intersil.com/isim))



## Additional Resources

For other online resources provided by Renesas for FPGA power design, go to: <https://www.intersil.com/en/applications/fpga-power-solutions.html>

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