Application Report
SLVA193–August 2004

Using the TPS2231 ExpressCard™ Power Switch/Controller

David A. Arciniega — *PMP Systems Power*

ABSTRACT

An ExpressCard™ module is an add-in card with a serial interface based on PCI Express™ and/or Universal Serial Bus (USB) technologies. Power to the ExpressCard slot is provided by the host system as defined in the ExpressCard Standard. The TPS2231 ExpressCard power switch/controller simplifies the host design by providing a fully integrated solution for controlling power to an ExpressCard slot.

1 Designing With the TPS2231 ExpressCard Power Switch/Controller

A design with the TPS2231 ExpressCard power switch/controller is as simple as the application drawing shown in Figure 1. Because the TPS2231 ExpressCard power switch is fully integrated, the only external components needed for the basic design are the input and output capacitors as shown in Figure 1.

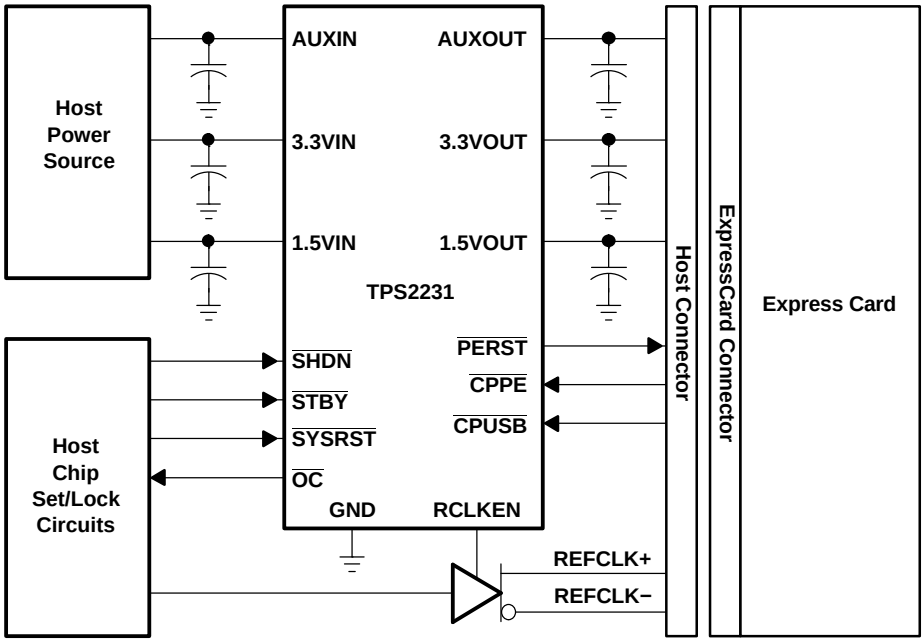


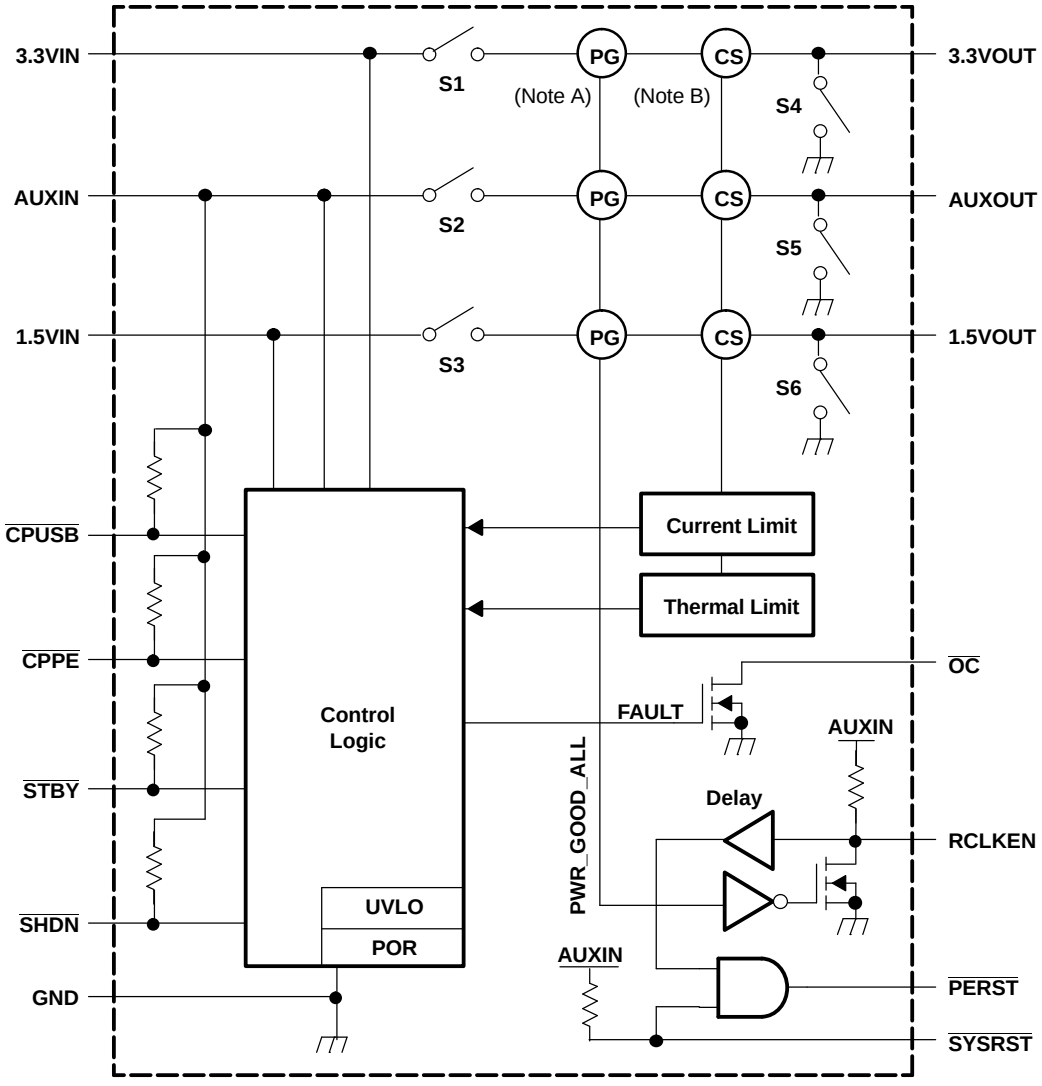
Figure 1. TPS2231 ExpressCard Power Switch/Controller Application Drawing

PCI Express is a trademark of PCI-SIG Corporation.
ExpressCard is a trademark of Personal Computer Memory Card Interface Association.

The ExpressCard Standard limits the maximum capacitance allowed by the host at each of the output voltage rails to 20 µF. The amount of output capacitance on the host is implementation specific; however, it is recommended that a 0.1-µF capacitor in parallel with at least a 4.7-µF capacitor be placed on each of the voltage rails

The input voltage rails to the TPS2231 ExpressCard power switch/controller should also have some type of filtering close to the input voltage pins of the TPS2231 ExpressCard power switch/controller. Again, a 0.1-µF capacitor in parallel with at least a 4.7-µF capacitor is recommended at the input of each voltage rail. This is especially important if long trace runs and/or long wiring exists between the bulk capacitance at the output of the voltage source and the input to the TPS2231 ExpressCard power switch/controller.

All discrete inputs to the TPS2231 ExpressCard power switch/controller have an internal pullup to the AUXIN voltage source (see Figure 2), which places that input in the default state. Therefore, if a particular discrete input function is not implemented, then that input can be left unconnected with no adverse effect.



Note A: PG = power good
Note B: CS = current sense

Figure 2. Block Diagram for the TPS2231 ExpressCard Power Switch/Controller

2 The TPS2231 ExpressCard Power Switch/Controller Operation

The TPS2231 ExpressCard power switch/controller resides on the host, and its main function is to control when to send power to the ExpressCard slot. The TPS2231 ExpressCard power switch makes this decision based on the state of the host system, as defined by the primary and auxiliary voltage rails, and the state of the logic inputs as shown in Table 1.

Table 1. Truth Table for Voltage Outputs

VOLTAGE INPUTS(1)			LOGIC INPUTS			VOLTAGE OUTPUTS(2)			MODE(3)
AUXIN	3.3VIN	1.5VIN	$\overline{\text{SHDN}}$	$\overline{\text{STBY}}$	$\overline{\text{CP}}$ (4)	AUXOUT	3.3VOUT	1.5VOUT	
Off	x	x	x	x	x	Off	Off	Off	OFF
On	x	x	0	x	x	GND	GND	GND	Shutdown
On	x	x	1	x	1	GND	GND	GND	No Card
On	On	On	1	0	0	On	Off	Off	Standby
On	On	On	1	1	0	On	On	On	Card Inserted

(1) For input voltages, *On* means the respective input voltage is higher than its turnon threshold voltage; otherwise, the voltage is *Off* (for AUX input, *Off* means the voltage is close to 0 V).

(2) For output voltages, *On* means the respective power switch is turned on so the input voltage is connected to the output; *Off* means the power switch and its output discharge FET are both off; *GND* means the power switch is off but the output discharge FET is on so that the voltage on the output is pulled down to 0 V.

(3) *Mode* assigns each set of input conditions and respective output voltage results to a different name. These modes are referred to as input conditions in Table 2.

(4) $\overline{\text{CP}}$ = $\overline{\text{CPUSB}}$ and $\overline{\text{CPPE}}$ is equal to 1 when both $\overline{\text{CPUSB}}$ and $\overline{\text{CPPE}}$ signals are logic high, or equal to 0 when either $\overline{\text{CPUSB}}$ or $\overline{\text{CPPE}}$ is low.

Regarding the voltage inputs, if both primary power (3.3VIN and 1.5VIN) and auxiliary power (AUXIN) at the input of the TPS2231 ExpressCard power switch/controller are off, then all output voltages going to the ExpressCard connector are also off, regardless of whether a card is present. Because the AUXIN voltage rail is used by the TPS2231 ExpressCard power switch/controller for device operation, the truth table in Table 1 shows that the primary power voltage rails may be present and the TPS2231 still does not provide power on its output if AUXIN is not available. The *Off* designation signifies that the voltage outputs of the TPS2231 ExpressCard power switch/controller are in a high-impedance state.

If AUXIN is available and no card is present, all the voltage outputs to the ExpressCard slot are kept off; however, in this case, the outputs have a low impedance path to ground. This low impedance path is a result of the *discharge FETs* (S4, S5, and S6 in Figure 2) being activated to discharge any residual voltage from output capacitors.

The same effect takes place if the $\overline{\text{SHDN}}$ input to the TPS2231 ExpressCard power switch/controller is asserted. This is a feature that can be used to safely remove an ExpressCard. By asserting $\overline{\text{SHDN}}$ prior to removing the ExpressCard, the user ensures that all output voltages are off and all input capacitors to the ExpressCard are discharged.

If both primary power and auxiliary power at the input of the TPS2231 ExpressCard power switch/controller are available, then power is only applied to the ExpressCard slot after the TPS2231 ExpressCard power switch/controller detects that a card is present.

After power is applied to the ExpressCard slot, if the $\overline{\text{STBY}}$ input of the TPS2231 ExpressCard power switch/controller is asserted, then both the 3.3VOUT and 1.5VOUT are turned off, placing these outputs in a high-impedance state. AUXOUT is still supplied to the card which can be used to keep standby circuitry powered. This feature can be used to place the ExpressCard in standby mode without having to remove primary power from the input of the TPS2231 ExpressCard power switch/controller.

If primary power (either +3.3 V or +1.5 V) at the input of the TPS2231 ExpressCard power switch/controller is off and auxiliary power at the input is available, then the TPS2231 ExpressCard power switch/controller outputs are dependent on the state of the host system and on the state of the Card Present inputs.

- If a card is not present, then no power is applied to the ExpressCard slot.
- If the card is inserted after the system has entered this power state, then no power is applied to the ExpressCard slot.

- If the card is inserted prior to the removal of the primary power (either +3.3 V or +1.5 V or both) at the input of the ExpressCard power switch/controller, then only the primary power (both +3.3 V and +1.5 V) is removed and the auxiliary power is still sent to the ExpressCard slot.

3 Logic Signal Functionality

The Card Present signals, $\overline{\text{CPPE}}$ and $\overline{\text{CPUSB}}$, are inputs to the host and the ExpressCard power switch from the ExpressCard module. They signal the host when a card has been inserted. The ExpressCard Standard requires that both these inputs be pulled up by the host. The TPS2231 ExpressCard power switch/controller has integrated a pullup resistor on both of these inputs; therefore, no external pullups are needed. The pullup resistors on these inputs are connected to the AUXIN voltage rail. These pullups have enough drive capability to allow $\overline{\text{CPPE}}$ or $\overline{\text{CPUSB}}$ to connect to another input on the host. Host systems may be designed to use the Card Present inputs as a means of detecting the insertion of a card. If additional drive is needed, an external pullup resistor can be connected in parallel with the internal pullup.

The $\overline{\text{PERST}}$ signal is an output from the host and is used by PCI ExpressCard-based modules as a reset signal. $\overline{\text{PERST}}$ is a power-good indicator: during power up, power down, or whenever power to the ExpressCard module is not stable or within voltage tolerance limits, it is asserted as required by the ExpressCard Standard. This output from the TPS2231 ExpressCard power switch/controller is a TTL signal; therefore, it requires no external resistors.

The $\overline{\text{SYSRST}}$ input to the TPS2231 ExpressCard power switch/controller can also be used by the host to place the ExpressCard module in a reset state. Asserting $\overline{\text{SYSRST}}$ automatically generates a $\overline{\text{PERST}}$. Generating a $\overline{\text{PERST}}$ by asserting $\overline{\text{SYSRST}}$ does not disrupt the voltage rails; instead, it causes the ExpressCard module to perform a *warm* reset. In a *cold* start situation, $\overline{\text{SYSRST}}$ can also be used to extend the length of time that $\overline{\text{PERST}}$ is asserted. This is an actual requirement in the ExpressCard Standard. Because $\overline{\text{SYSRST}}$ is an input to the TPS2231 ExpressCard power switch/controller, it has an internal pullup to place it in the default state

RCLKEN is both an input and an output to the ExpressCard power switch. As an output, RCLKEN can be used to enable a clock driver or control logic that enables sending out the REFCLK to the ExpressCard module (see Figure 1). The ExpressCard Standard specifies that the REFCLK has to be up and running at least 100 µs prior to $\overline{\text{PERST}}$ being deasserted. Because RCLKEN is also a power-good indicator and, unlike $\overline{\text{PERST}}$, has no added delay, the host designer can use RCLKEN to control the enabling of REFCLK to the ExpressCard module. This gives the host designer the added assurance that the REFCLK is only enabled after all the voltages to the ExpressCard module are within tolerance.

As an input, RCLKEN can be used to extend the length of $\overline{\text{PERST}}$. By using an open-drain external FET (see Figure 1-3), the host can use this input to control the assertion of $\overline{\text{PERST}}$. The transition of RCLKEN from a low to a high state starts an internal timer for the purpose of deasserting $\overline{\text{PERST}}$. Therefore, if RCLKEN is kept at a low state, $\overline{\text{PERST}}$ also is kept at a low state.

With external logic, RCLKEN can also be used with the $\overline{\text{CLKREQ}}$ output from the ExpressCard module to enable REFCLK. Again, this ensures that if the ExpressCard module is requesting the PCI Express clock, then the module only receives the REFCLK after all voltage rails to the ExpressCard module are within tolerance (see Figure 4).

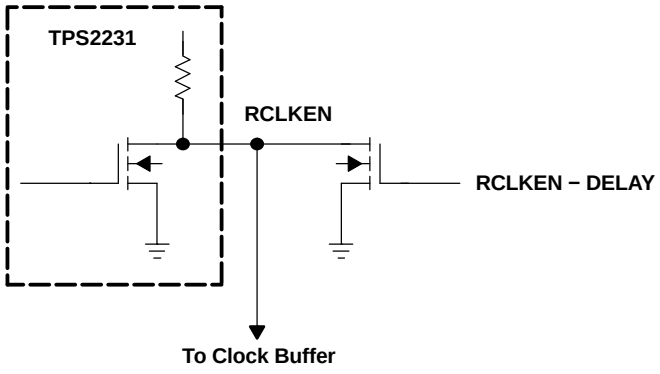


Figure 3. RCLKEN With an External FET

The truth table shown in Table 2 summarizes the logic signal functionality. Because RCLKEN is both an input and an output, it is shown in both the input and output section of the truth table.

Table 2. Truth Table for Logic Outputs

INPUT CONDITIONS			LOGIC OUTPUTS	
MODE	**$\overline{\text{SYSRST}}$**	**RCLKEN(1)**	**$\overline{\text{PERST}}$**	**RCLKEN(2)**
OFF	X	X	0	0
Shutdown				
No Card				
Standby				
Card Inserted	0	Hi-Z	0	1
	0	0	0	0
	1	Hi-Z	1	1
	1	0	0	0

(1) RCLKEN is a logic input in this column. RCLKEN is an I/O pin, and it can be driven low externally, left open, or connected to high-impedance terminals, such as the gate of a MOSFET. It must not be driven high externally.
(2) RCLKEN is a logic output in this column.

The only other signal not previously mentioned is the $\overline{\text{OC}}$ output. This is the overcurrent status indicator which is asserted whenever any of the voltage outputs are in current limit. Because this is an open-drain output, an external pullup resistor is needed to drive this signal to the inactive state. If an ExpressCard module draws too much current from any of the voltage rails for whatever reason, the $\overline{\text{OC}}$ output can be used to alert the host. Once alerted, the host can remove power to the ExpressCard module by asserting $\overline{\text{SHDN}}$. This is especially important for battery-operated systems so that the drain on the battery can be minimized.

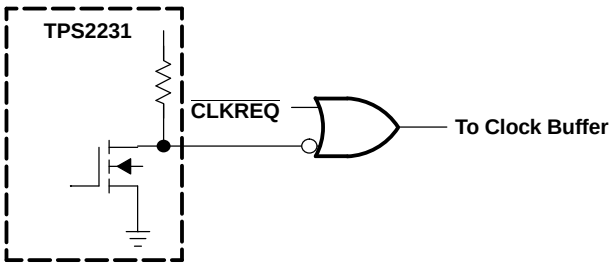


Figure 4. RCLKEN and $\overline{\text{CLKREQ}}$

4 Conclusion

The TPS2231 ExpressCard power switch/controller makes design of power management by host systems supporting ExpressCard slots easy. With its fully integrated design and user-friendly features, the TPS2231 ExpressCard power switch/controller is the ideal solution for any host system.

For applications requiring two ExpressCard slots, the host designer can elect to use either two TPS2231 ExpressCard power switch/controllers or one TPS2236 dual-slot ExpressCard switch/controller.

IMPORTANT NOTICE

Texas Instruments Incorporated and its subsidiaries (TI) reserve the right to make corrections, modifications, enhancements, improvements, and other changes to its products and services at any time and to discontinue any product or service without notice. Customers should obtain the latest relevant information before placing orders and should verify that such information is current and complete. All products are sold subject to TI's terms and conditions of sale supplied at the time of order acknowledgment.

TI warrants performance of its hardware products to the specifications applicable at the time of sale in accordance with TI's standard warranty. Testing and other quality control techniques are used to the extent TI deems necessary to support this warranty. Except where mandated by government requirements, testing of all parameters of each product is not necessarily performed.

TI assumes no liability for applications assistance or customer product design. Customers are responsible for their products and applications using TI components. To minimize the risks associated with customer products and applications, customers should provide adequate design and operating safeguards.

TI does not warrant or represent that any license, either express or implied, is granted under any TI patent right, copyright, mask work right, or other TI intellectual property right relating to any combination, machine, or process in which TI products or services are used. Information published by TI regarding third-party products or services does not constitute a license from TI to use such products or services or a warranty or endorsement thereof. Use of such information may require a license from a third party under the patents or other intellectual property of the third party, or a license from TI under the patents or other intellectual property of TI.

Reproduction of information in TI data books or data sheets is permissible only if reproduction is without alteration and is accompanied by all associated warranties, conditions, limitations, and notices. Reproduction of this information with alteration is an unfair and deceptive business practice. TI is not responsible or liable for such altered documentation.

Resale of TI products or services with statements different from or beyond the parameters stated by TI for that product or service voids all express and any implied warranties for the associated TI product or service and is an unfair and deceptive business practice. TI is not responsible or liable for any such statements.

Following are URLs where you can obtain information on other Texas Instruments products and application solutions:

Products		**Applications**	
Amplifiers	amplifier.ti.com	Audio	www.ti.com/audio
Data Converters	dataconverter.ti.com	Automotive	www.ti.com/automotive
DSP	dsp.ti.com	Broadband	www.ti.com/broadband
Interface	interface.ti.com	Digital Control	www.ti.com/digitalcontrol
Logic	logic.ti.com	Military	www.ti.com/military
Power Mgmt	power.ti.com	Optical Networking	www.ti.com/opticalnetwork
Microcontrollers	microcontroller.ti.com	Security	www.ti.com/security
		Telephony	www.ti.com/telephony
		Video & Imaging	www.ti.com/video
		Wireless	www.ti.com/wireless

Mailing Address: Texas Instruments
Post Office Box 655303 Dallas, Texas 75265