

# Optimize Power Distribution in Low Voltage Applications with Integrated Load Switches



Rachel Richardson

High-speed, low-power memory banks and processors are becoming more common with innovation in Smartphones, 5G, IoT, automotive infotainment, and ADAS. As the trend towards low-voltage rails continues, finding a switching solution that can operate from input voltages below 1.8 V is imperative. When a system calls for specific power distribution, power sequencing, or power savings, a load switch can be used to meet these specific timing or power savings requirements.

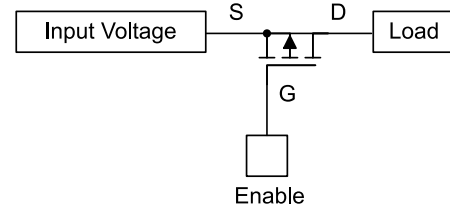
A load switch is a device that passes power from the supply to the load. The key benefits of using an integrated load switch when input voltage is less than 1.5 V are that the load switch maintains low on-resistance, reduces BOM count, and provides additional integrated features, as shown in Table 1-1. This document presents three switching solutions and explains how an integrated load switch optimizes low-input voltage applications.

**Table 1-1. Low-Input Voltage Switching Solutions**

	V <sub>IN</sub> < 1.5 V	Low R <sub>DS(on)</sub>	Integrated Features	BOM Count
TI Integrated Load Switch	✓	✓	✓	1
Discrete PMOS	✗	✗	✗	6+
Discrete NMOS	✓	✓	✗	3+

## Discrete MOSFET Solutions

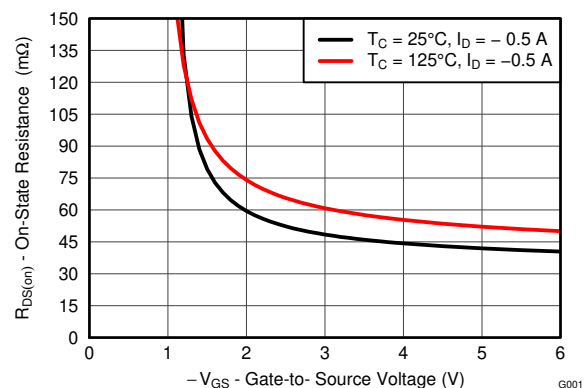
The simplest and most common discrete power-switching solutions use a PMOS transistor to pass power from input to output. As shown in Figure 1, the enable signal drives the pass FET gate while the input voltage is tied to the pass FET source. To turn on the FET, the enable signal must be pulled low. When the active low-enable signal is activated, the FET turns on and the load connects to the input voltage supply.



**Figure 1. Discrete PMOS Switch**

One of the drawbacks of using a PMOS transistor, is the transistor does not perform well in low input voltage applications. For the PMOS to turn on, the gate-to-source voltage must be less than the threshold voltage ( $V_{GS} < V_{TH}$ ). When  $V_{GS}$  is close in value to  $V_{TH}$ , the FET partially turns on. With the pass FET not fully on, the device on-resistance ( $R_{DS(on)}$ ) is very high. The resulting large voltage drop and high-power dissipation across the FET leads to reduced efficiency and thermal management concerns.

For example, consider the TI PMOS device, CSD23202W10, that has a threshold voltage of  $V_{TH} = -0.6$  V. By applying 0.65 V at the input of the CSD23202W10, the application limits the maximum  $V_{GS}$  to  $-0.65$  V, and the FET only turns on partially. Figure 2 shows the corresponding exponential increase in  $R_{DS(on)}$  when the input voltage is less than 1.5 V.

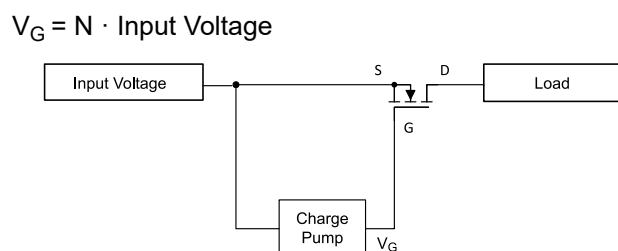


**Figure 2. On-Resistance vs.  $V_{GS}$  for CSD23202W10**

While the [CSD23202W10](#) is a switching solution with good performance metrics when input voltage is greater than 1.5 V, it is not ideal for low-input voltage applications. Even with various configurations of additional resistors, capacitors, and NMOS transistors, the discrete PMOS solution continues to have diminished performance at lower input voltages.

The second type of switching solution uses an NMOS transistor as the main power switch. To turn on an NMOS, the gate-to-source voltage must be higher than the threshold voltage ( $V_{GS} > V_{TH}$ ). To meet this condition, the gate voltage is raised above the input voltage through a higher voltage rail within the system or a charge pump, as shown in [Figure 3](#). The active high-gate voltage ensures that even low-input voltage can pass through the switch while also maintaining a low on-resistance.

**Figure 3. Discrete NMOS Switch**



However, the additional required components lead to a larger PCB footprint, increased BOM count, and higher cost. While this tech note only covers two discrete solutions, the application report [Integrated Load Switches Versus Discrete MOSFETs](#) compares the performance of numerous discrete switching solutions with the integrated load switch.

### Achieve Optimal Low Voltage Performance Using Integrated Load Switches

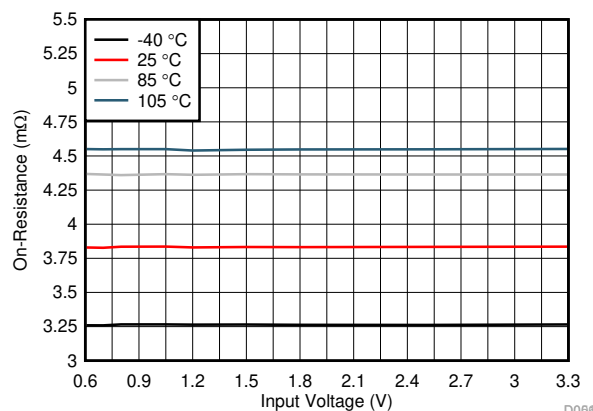
When compared with discrete switching solutions, integrated load switches maintain a constant  $R_{DS(on)}$  across a spectrum of input voltages without added circuit complexity, which contributes to reduced solution size and cost savings. On-resistance is maintained across the entire input voltage range due to the inclusion of a bias voltage, VBIAS, which is higher than the input voltage to provide power to run the internal functions of the device.

For example, [Table 1-2](#) shows different load switch options that support input voltages as low as 0.6 V while maintaining a steady  $R_{DS(on)}$  at room temperature.

**Table 1-2. Integrated Load Switch Features**

Device	Input Voltage Range (V)		$R_{DS(on)}$ (mΩ)	Channel Count	VBIAS
	MIN	MAX			
TPS22990	0.6	5.5	3.9	Single	✓
TPS22975		5.7	16	Single	✓
TPS22976			14	Dual	✓

Sustaining low on-resistance reduces the voltage drop across the device, ensuring that all the input voltage is transmitted to the load. Therefore, load switches maintain high efficiency and performance regardless of low VIN. [Figure 4](#) illustrates the constant on-resistance the [TPS22990](#) maintains across the entire input voltage range at different temperatures. In contrast, PMOS solutions such as the [CSD23202W10](#) experience an exponential increase in  $R_{DS(on)}$  when used as a load switch at lower input voltages.



**Figure 4. On-Resistance vs. VIN for TPS22990**

Integrated load switches also provide additional features not available with discrete switching solutions such as quick output discharge, configurable rise time, and thermal shutdown. Common design challenges and how to solve them with integrated power switches are further addressed in [11 Ways to Protect Your Power Path](#).

### Conclusion

As industry develops more processors and memory banks with lower core voltage and I/O rails, low input voltage switching solutions contribute to power management across various end equipments. Integrated load switches optimize power performance by maintaining low on-resistance and incorporating additional features that fine-tune efficiency. Integrated load switch options that enhance power distribution and savings in low-input voltage applications can be found on the TI.com portal at [Load Switches](#).

## IMPORTANT NOTICE AND DISCLAIMER

TI PROVIDES TECHNICAL AND RELIABILITY DATA (INCLUDING DATASHEETS), DESIGN RESOURCES (INCLUDING REFERENCE DESIGNS), APPLICATION OR OTHER DESIGN ADVICE, WEB TOOLS, SAFETY INFORMATION, AND OTHER RESOURCES "AS IS" AND WITH ALL FAULTS, AND DISCLAIMS ALL WARRANTIES, EXPRESS AND IMPLIED, INCLUDING WITHOUT LIMITATION ANY IMPLIED WARRANTIES OF MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE OR NON-INFRINGEMENT OF THIRD PARTY INTELLECTUAL PROPERTY RIGHTS.

These resources are intended for skilled developers designing with TI products. You are solely responsible for (1) selecting the appropriate TI products for your application, (2) designing, validating and testing your application, and (3) ensuring your application meets applicable standards, and any other safety, security, or other requirements. These resources are subject to change without notice. TI grants you permission to use these resources only for development of an application that uses the TI products described in the resource. Other reproduction and display of these resources is prohibited. No license is granted to any other TI intellectual property right or to any third party intellectual property right. TI disclaims responsibility for, and you will fully indemnify TI and its representatives against, any claims, damages, costs, losses, and liabilities arising out of your use of these resources.

TI's products are provided subject to TI's Terms of Sale ([www.ti.com/legal/termsofsale.html](http://www.ti.com/legal/termsofsale.html)) or other applicable terms available either on [ti.com](http://ti.com) or provided in conjunction with such TI products. TI's provision of these resources does not expand or otherwise alter TI's applicable warranties or warranty disclaimers for TI products.

Mailing Address: Texas Instruments, Post Office Box 655303, Dallas, Texas 75265  
Copyright © 2020, Texas Instruments Incorporated