Single Channel Smart Load Switch Use and Selection

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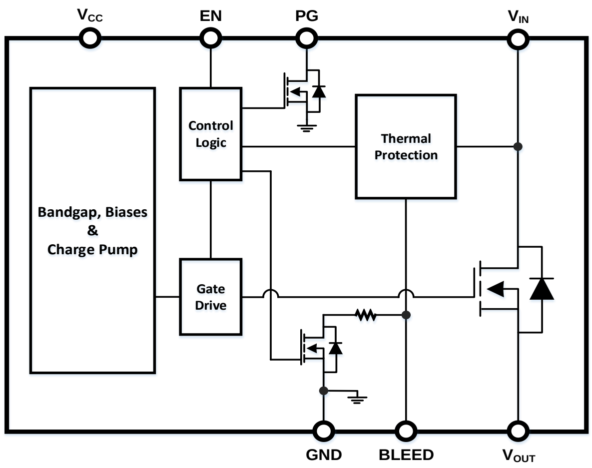
Summary

Single Channel Smart load switch provides a component and area-reducing solution for efficient power domain switching. In addition to integrated control functionality with ultra-low on−resistance (<15 mΩ), this device offers system safeguards and monitoring via the fault protection (Short circuit protection, SCP) and power good signal. This cost effective solution is ideal for power management and hot-swap applications requiring low power consumption in a small footprint.

The Basic Smart Load Switch

Integrated smart load switch contain an integrated Power MOSFET that allows power to be delivered from V_{IN} to V_{OUT} when pulling EN high.

Figure1 shows a general block diagram representing the primary functions of a Smart Load Switch



*Not present on all Smart Load switch products

Figure 1. Basic Smart Load Switch

The integrated Power MOSFET is the primary component of the Smart Load Switch. All other blocks shown in Figure1 support the Power MOSFET in its function of delivering power from V_{IN} (input) to V_{OUT} (output).

Charge Pump -The charge pump provides the voltage and current to charge the Power MOSFET gate when turning the Power MOSFET on, minimizing the on-resistance of the Power MOSFET.

Delay and Slew Rate control -Turning on the Power MOSFET too quickly can damage the output device by producing an in-rush current spike to deliver the output device. The charging of a Smart Load Switch for Power MOSFET gate is controlled, thereby controlling the in-rush current and the rise time of the V_{OUT} voltage.

Control Logic -The control logic block dictates the timing and order of faults, turn on, and turn off events. The EN signal enables the control logic.

Fault Protection - Thermal protection, under-voltage lockout (UVLO), and short circuit protection (SCP) are offered on many Smart Load Switch products.

Bleed Resistor -The internal bleed resistor allows for fast discharge of the output load and is controlled by the control logic.

All of these features play a part in the load switch function. Many Smart Load Switch families are offered the system designer with the optimal fit for their application.

The Load Switch Parameter

There are six key parameters (On resistance, Max V_{OUT} Current, Response Time, Quiescent Current, Leakage current, and V_{IN} Operation Range) that a system designer should consider when using an integrated Power MOSFET based load switch.

On Resistance

On resistance is directly in-line, source to Load. The voltage drop from V_{IN} to V_{OUT} of the load switch and power loss are directly proportional to the load switch's on-resistance. Actually, the lower on-resistance is the better. A reduction in this resistance results in direct power saving.

Max V_{OUT} Current

Load switch are limited in the amount of current they can deliver the load. This is inherent due to the parasitic on-resistance of the power MOSFET. Current through a resistance dissipates power through heat. Un-dissipated high levels of sustained heat damages load switch. Larger Power MOSFETs are able to supply more current to the load, however, a larger Power MOSFET inherently has larger gate capacitance and requires more energy and time to turn on.

Response Time

Response time relates to turn ON/OFF timing, and fault protection timing. The size of the load switch Power MOSFET is directly proportional to the energy and time it takes to turn it on. Power used to charge the gate of the Power MOSFET finally consumes the power budget of the system. Most applications of the load switch benefit from a slower transition from OFF to ON.

Quiescent Current

Quiescent current is defined by the amount of the current the load switch uses when it is statically on, or off. This is in addition to any power consumer by the load switch when the Power MOSFET is on, and should be minimized.

Leakage Current

Leakage current from the V_{IN} to V_{OUT} when the load switch is OFF also consume the system power budget. Smart Load switches are designed to supply the very small leakage current.

V_{IN} Operation Range

The V_{IN} Operation Range of the load switch should be bigger than the application V_{IN} supply range to provide margin. The Smart Load Switch offers the minimum voltage of 1V and lower, with maximum voltage to support 5V and 12V applications.

The Advantage of Smart Load Switch

Controlled Power On/Power Off

A load circuit is at the mercy of supply transients that could be unpredictable upon power up and power down. The Smart Load Switch prevents in-rush current spikes and ramps the supply voltage to the load in a controlled fashion. This is ideal for hot-swap application where transients for power up and power down are unpredictable. On power up, the Smart Load Switch provides a soft start, where the slew rate is controlled. The Smart Load Switch products are available with programmable slew rate control.

Economic Cost

A discrete implementation providing base functionality uses various components, adding cost to the build of materials and PCB real estate to the design. The Smart Load Switch comes in package options from 2x2 mm to 3x3 mm. At a part of the cost, the Smart Load Switch provides a best solution in class performance with additional features. Figure2 shows DML3009 is an example implementation for solution.

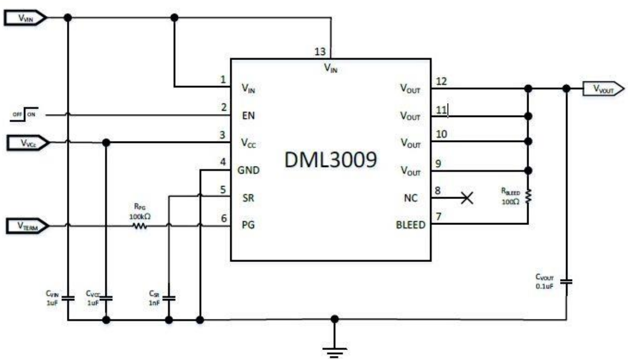


Figure 2. Basic Smart Load Switch

Reduced Leakage Current

Many system designs have multiple power domains supplying sub-systems that are not needed 100% of the time. Non-critical sub-systems could be powered off by using the Smart Load Switch. This decreases the leakage current from the powered off sub-system. Load Switches also allow for controlled sequencing of sub-systems.

System protection

Load Switches could prevent damage to system loads and supplies by disconnecting them in the event of an otherwise catastrophic failure. The Smart Load Switch provides the following:

- The short circuit protection features protect the device and system from sudden peak-current events, such as V_{OUT} being shorted to ground or load malfunction.

- Undervoltage lockout (UVLO) prevents a connection from V_{IN} to V_{OUT} when the supply voltage is too low.

- Overtemperature protection (OTP) could stop the connection from V_{IN} to V_{OUT} if the junction temperature of the Smart Load Switch exceeds 145℃ to protect the device, system, and supply in the event of an incorrect connection or over heating device.

Examples for Design and Application

Load Switches could be used in a wide variety of applications. The Smart Load Switch series strengthen the application spectrum. The following example below shows typical load switch applications. Load switches allow for controlled safe power multiplexing.

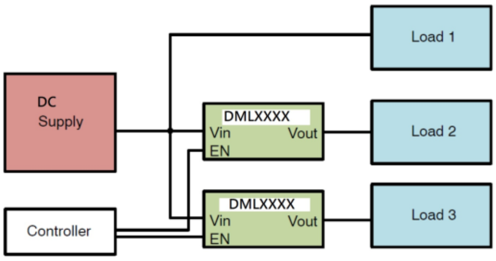


Figure3. Basic Diagram Showing Supply Domain Management Using the Smart Load Switch

Figure 3 show 1 supply multiplexed to 3 loads. A system controller signal could be used in this application to drive the EN pin to control which load gets power and when to turn on. The power for each load could be connected or disconnected to load level for the system power and boost efficiency.

Basic Load Switch Calculations

The following calculations could be used when determining the specifications required the load switch.

Voltage Drop

Voltage drop requirements from V_{IN} to V_{OUT} dictate the acceptable Ron specification. Use equation1 to determine acceptable Ron maximum.

$$R_{ON,MAX} = \frac{V_{DROP}}{I_{OUT}} \qquad (eq.1)$$

In-rush Current

The total load capacitance presented to the load switch determines the in-rush current where the initial current (I_{OUT} at t=0) is very large. The Smart Load Switch has slew rate control (or soft start) to limit the initial current to a known acceptable value which meets the corresponding SOA curve. Equation 2 below is used to define the controlled in-rush current.

$$\mathrm{I}_{\mathrm{in-rush}} -= \frac{dv}{dt} \times C_L \quad (eq.2)$$

Where:

dv/dt is the slew rate setting, programmable on most Smart Load Switch series

C_L is the total capacitive load

Power Dissipation

Equation 3 below is used to calculate the total power dissipation of the load when delivered through the load switch.

$$P_D = \mathrm{VIN} \times I_Q + IOUT^2 \times R_{ON}\ (eq.3)$$

Where:

V_{IN} is the input supply voltage

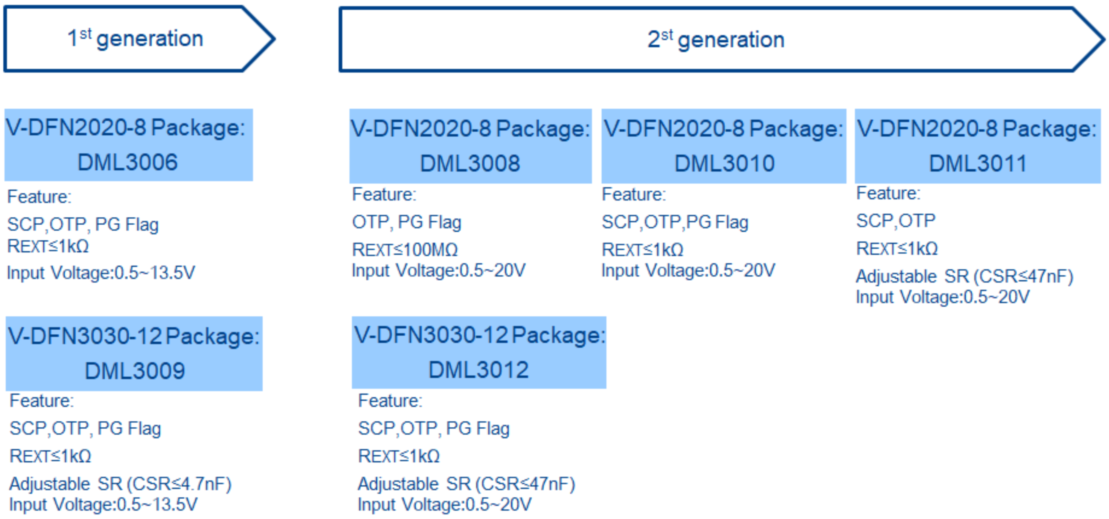
I_Q is the quiescent current

I_{OUT} is the output current

R_{ON} is the on resistance of the load switch

When the load switch is disabled , is limited to the standby current, and is limited to any leakage current from V_{IN} to V_{OUT} through the disabled load switch, which is quickly bled down as any charge held by the total load capacitance is discharged through the Smart Load Switch internal bleed resistor.

DML30XX Series Evolution and Feature



Power Sequence

The first generation for DML 30xxSeries can only support a power sequence:

V_{VCC} →V_{IN}→V_{EN}

The second generation for DML30xx Series can support two sequences:

1.) V_{VCC} →V_{IN}→V_{EN}

2.) V_{IN} → V_{VCC} →V_{EN}

Every power sequence interval must keep minimum 100us for all DML30xx series. Figure 4 show real waveforms for those two power sequences. Because of mass production, other power sequences could have some unknown application risk. If customer application must use other sequenced as system design, we suggest FAE discuss the rise time and interval of the customer setting sequence with IC designer. Let IC designer confirm and reply this power sequence from circuit design and simulation.

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