

Introduction

Power MOSFETs are increasingly being used to switch local power supplies on PCB assemblies. The Lattice Power and Platform Management devices can be used in several ways to provide intelligent control of these devices for power supply sequencing, monitoring, and management applications. This application note describes a few of the ways in which the Lattice Power/Platform Management devices can be interfaced to common MOSFETs, and also some of the criteria for selecting suitable devices.

See Table 1 and Table 2 for the Power/Platform Management devices applicable to this application note.

Table 1. Applicable Power Manager Devices Summary

Device	VMONs	Digital Inputs	HVOUTs	Open Drain Outputs	Trim DAC Outputs	Macrocells
ispPAC®-POWR607	6	2	2	5	None	16
ispPAC-POWR1014/A	10	4	2	12	None	24
ispPAC-POWR1220AT8	12	6	4	16	8	48

Table 2. Applicable Platform Manager™ Devices Summary

Device	VMONs	Digital Inputs	HVOUTs	Open Drain Outputs	Trim DAC Outputs	Digital I/O	CPLD Macrocells	FPGA LUTs
LPTM10-1247	12	4	4	12	6	31	48	640
LPTM10-12107	12	4	4	12	8	91	48	640
LPTM21	10	—	4	10 ¹	4	95 ²	—	1280
L-ASC10	10	—	4	9 ¹	4	—	—	—

1. Platform Manager 2 Open Drain Outputs can be configured as inputs.
2. Platform Manager 2 Digital I/O count does not include SDA_M, SCL_M, or JTAGENB pins.

A few of the more common power-switch configurations for power MOSFETs are:

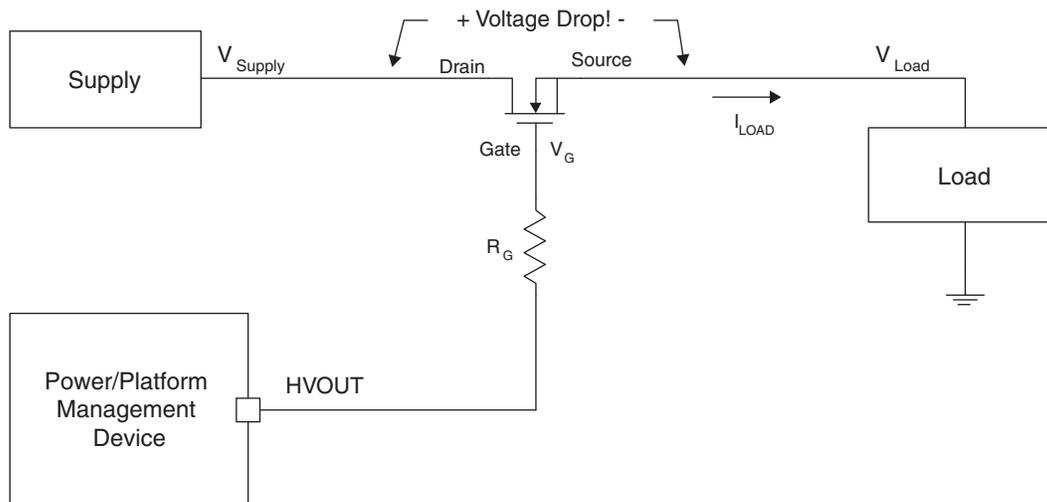
1. N-channel Positive Supply Switch
2. P-channel Positive Supply Switch
3. N-channel Negative Supply Switch

Each of these configurations has various applicability, advantages, and disadvantages, and will be individually discussed in the following sections.

N-Channel Positive Supply Switch

The Power/Platform Management devices include high-voltage MOSFET drivers that have been designed specifically to drive N-channel MOSFETs used as positive supply switches (often called ‘High-side switches’). Figure 1 shows a typical configuration.

Figure 1. N-Channel MOSFET Used as Positive Supply Switch



To turn on the MOSFET and connect the load to the power supply, the MOSFET’s gate terminal must be raised positive *with respect to the MOSFET’s source terminal*. For example, if the power supply provides 3.3 V, and 3.3 V is needed at the load, the MOSFET’s gate terminal must be raised significantly above 3.3 V, often as much as 5 V to 8 V higher. This may require that 8 V to 11 V be applied to the gate by the Power/Platform Management device. This is why you cannot drive the MOSFET from a standard PLD logic output. Exactly how much higher depends on the specifications of the particular MOSFET used. This is the primary reason for incorporating the HVOUT high-voltage drivers in the Power/Platform Management devices – they can provide a gate drive voltage as high as 12 V. An additional advantage of using these high-voltage output drivers is that their output current can be programmed to provide a controlled slew-rate voltage ramp at the MOSFET’s gate. This has the effect of providing a soft-start for the load. The LPTM21 and L-ASC10 devices also incorporate circuitry for generating gate drive voltages above 12 volts using minimal external components. These drive voltages can be used to switch power supply rails above 12 volts.

Selecting an appropriate MOSFET is crucial to successfully implementing a power switch. Some of the major selection criteria include:

- Turn-on Voltage
- Drain-Source Breakdown Voltage
- Gate-Source Breakdown Voltage
- On-Resistance (R_{DSon})
- Maximum Current
- Package (Size)
- Cost

Turn-on voltage is one of the most important selection criteria. Many older types of MOSFETs, and those designed for switched-mode power supply and motion control applications can require a significant amount (> 8 V–10 V) of gate-to-source drive. Newer devices with much lower gate-voltage requirements are now available, with devices which can be turned-on to a useful degree with as little as 1.8 V. These lower gate-drive devices are preferred for use with the Power/Platform Management devices for most power-switching applications.

Drain-to-source and gate-to-source breakdown voltages are also an important consideration. When switching power for logic supplies (1.2 V–5 V), drain-to-source breakdown voltage is not usually a problem, as most contemporary devices have breakdowns greater than 12 V.

Gate-to-source breakdown, however, is an issue which must be considered, especially as many suitable devices have low (<10 V) ratings, and could be damaged by the Power/Platform Management output drivers if used inappropriately.

On resistance, maximum current, package size and cost must be traded off against each other for a successful design. In particular, MOSFETs with low on-resistances and high maximum current ratings tend to be more expensive than those with high on-resistances and low current ratings. Additionally, MOSFETs in smaller packages tend to have lower current ratings and higher on-resistances than those in larger packages. While over-specifying a device may make for an easy design, that design may not meet board-space or economic constraints.

For this application, some of the factors driving selection are:

1. How much current do I want to switch?
2. How much voltage drop is acceptable across the MOSFET?
3. What is the voltage I am switching?

The cost of a given MOSFET correlates with its maximum current capacity, so there is some incentive to select a device with as low a current rating as will work in an application. Unfortunately, the current rating given in the data sheet refers to that which the MOSFET can handle before it is damaged, and not the amount it can switch with an arbitrarily low drain-to-source voltage drop (this voltage drop is illustrated in Figure 1) when operating at a given current level. For a current-switch, the acceptable voltage drop at operating current defines a maximum acceptable R_{DSon} value, which will tend to drive MOSFET selection more than maximum current ratings will.

The voltage being switched also impacts the selection process. Recall that in order to switch the N-channel MOSFET in Figure 1, the gate voltage must be higher than the voltage being switched, by at least enough to completely turn on the device. The devices listed in Table 1 and Table 2 can provide voltages up to either 12 V or 10 V, depending on the specific device. In the example using Figure 1 and a 3.3 V supply along with a device capable of providing 12 V of gate drive (such as L-ASC10), the MOSFET in the application must be completely turned on with ~8.7 V at the gate (12 V - 3.3 V at the source).

A concrete example will make it clear how these factors are translated into a MOSFET selection. Let us suppose that we are going to be switching a 2.5 V power supply at 3 A of load current. Also assume that the maximum voltage drop (V_{DS}) that can be tolerated across the MOSFET is 25 mV, so that the load sees at least 2.475 V.

From the desired voltage drop and the load current we can calculate a maximum MOSFET on-resistance:

$$R_{DSon} = \frac{V_{DS}}{I} = \frac{25 \text{ mV}}{3 \text{ A}} = 8.33 \text{ m}\Omega \quad (1)$$

Note that on-resistance is ALWAYS specified for a given amount of gate-to-source drive voltage. For a typical MOSFET, the higher the voltage you apply to the gate, the lower the on-resistance will be.

The next specifications are maximum current and maximum drain-to-source voltage. In many cases, where a low MOSFET drain-to-source voltage drop is needed, R_{DSon} will be the main selection criteria, rather than current, as MOSFETs with sufficiently low R_{DSon} 's will have much higher current ratings than necessary. For switching on-board power supplies for ICs, finding MOSFETs that meet the maximum voltage levels will be nearly trivial, as MOSFET drain-to-source breakdowns tend to be >12 V, while the supplies being controlled typically range from +1.2 V up to 5 V. So for our example, we will need to find a MOSFET with the following characteristics:

- $R_{DSon} < 8 \text{ m}\Omega$
- $I_{Dmax} > 3 \text{ A}$
- $V_{DSmax} > 3 \text{ V}$

Finally, a small package would be nice, as this device is going to be taking up valuable board space next to a micro-processor. Table 3 shows several MOSFETs which meet the application requirements stated above.

Table 3. Example MOSFETs for use in Design Problem

Model	Manufacturer	R_{DSon} (m Ω)	I_{MAX} (A)	V_{DSmax} (V)	V_{GSmax} ($\pm V$)	Package
Si7858	Vishay	3	18	12	8	PowerPAK™1206
IRF6633	International Rectifier	5	16	20	20	DirectMOSFET™
FDS6574A	Fairchild	6	15	20	8	SOIC-8

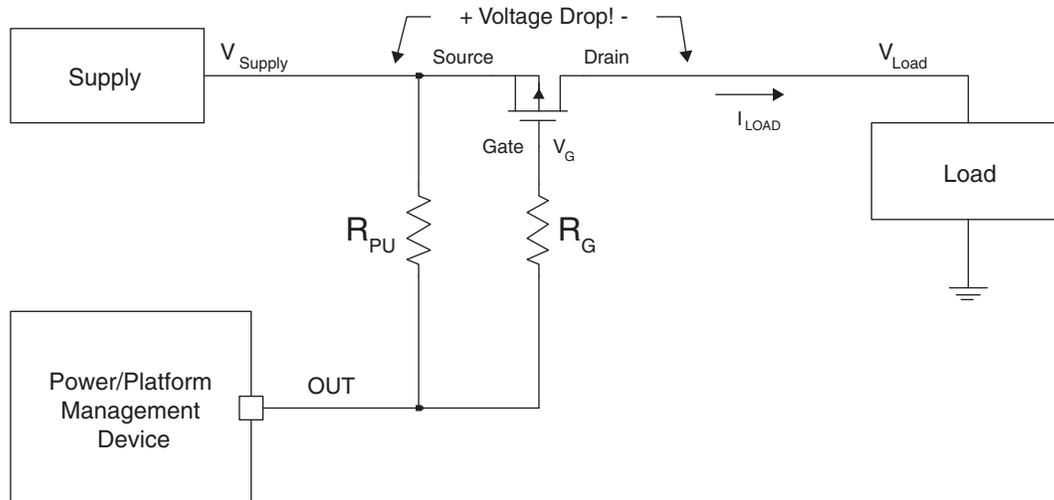
Note that the maximum gate-to-source voltage for two of these devices is only 8 V. To use these devices with the Power/Platform Management devices, you will need to set the driver output voltage so as to ensure that the MOSFET's gate-to-source voltage remains below 8 V at all times. A zener diode placed between the MOSFET's gate and ground can also be used to limit the maximum gate voltage. Also note that the maximum current ratings are considerably higher than the current we are planning on controlling. This is because in many applications, a drain-to-source voltage drop of a few hundred millivolts is acceptable, where in this application the voltage drop needs to be much lower. This results in the apparent overspecification we see here.

What if higher current is needed? The brute-force solution is to look for MOSFETs with lower R_{DSon} values. This approach becomes less effective as lower resistances are needed, and available devices become scarce. An alternative solution is to put MOSFETs in parallel. This lowers the effective on resistance by a factor of the number of MOSFETs used. For example, if we parallel three MOSFETs with 3 m Ω on resistances, we get an equivalent on resistance of 1 m Ω . This technique only works, however, when paralleling the same model of MOSFET - you cannot mix and match MOSFETs of different types and expect good results.

P-Channel Positive Supply Switch

Another common way to switch a positive power supply is with P-channel MOSFETs, as shown in Figure 2.

Figure 2. P-Channel MOSFET used as a Positive Supply Switch



To turn on the MOSFET and connect the load to the power supply in this case, the MOSFET's gate terminal must be pulled negative with respect to the MOSFET's source terminal. Since the MOSFET's source terminal is connected to the power supply, this can often be accomplished by pulling the gate to ground, at least in cases where the power supply is at a voltage higher than the MOSFET's on-state gate-source voltage. This requirement will typically limit the use of this circuit technique to situations where the supply being switched is 2.5 V or greater (at least for contemporary MOSFETs), and these cases will require the use of MOSFETs rated for 2.5 V gate drive.

In this circuit, the device GPIO outputs are used in the open-drain output configuration. When the output goes LOW, it will pull the MOSFET's gate to ground and turn it on. The R_{PU} pull-up resistor pulls the gate up to the supply voltage and turns the MOSFET off when the output goes HIGH.

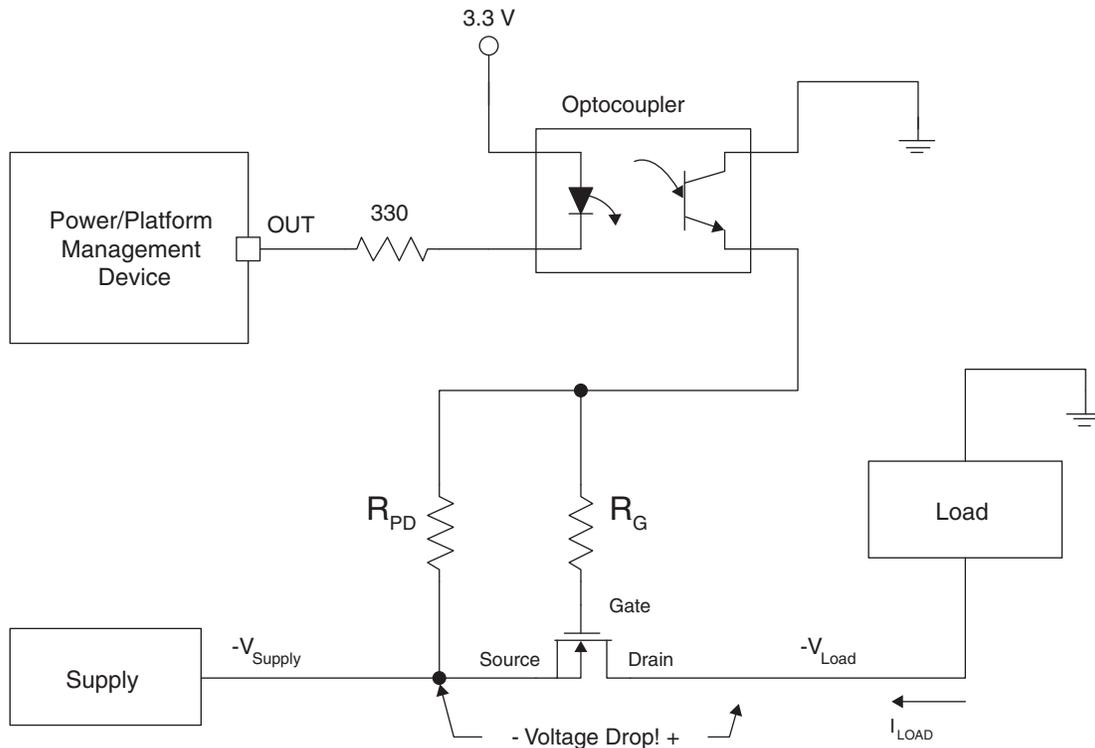
Note that all of the MOSFET considerations for current, on-resistance, breakdown and gate-drive voltages discussed above also apply to this circuit. Because this is a P-channel device, however, a negative gate-to-source voltage is required to turn the device on.

Because P-channel MOSFETs typically offer higher on-resistances and lower current ratings than N-channel devices of similar size and cost, this circuit configuration is primarily useful where lower levels of supply current and fast turn-on times are required. For most logic supply switching applications, N-channel devices with the Power/Platform Management high-voltage output drivers would be the preferred solution.

N-Channel Negative Supply Switch

It is also possible to switch negative power supplies from the device outputs. Figure 3 shows one circuit for doing so, using an N-channel MOSFET as a power switch.

Figure 3. N-Channel MOSFET Used as a Negative Supply Switch



In this circuit, an optocoupler is used to provide level translation from the positive output levels of the Power/Platform Management device to the negative voltage signals needed to drive the MOSFET. In this case, the device's open drain output is used. When the output goes low, the optocoupler is turned on, pulling the MOSFET's gate up to ground. Since the MOSFET's source is at the negative supply voltage, this creates a positive gate-to-source voltage and turns the MOSFET on. When the device's output goes high, the optocoupler is turned off, and the MOSFET's gate is pulled down to the negative supply voltage through R_{PD} .

In cases where a low value of negative supply is to be switched (e.g. $|V_S| < 2.5\text{ V}$), 'ground' may not provide a high enough gate-to-source voltage to adequately turn on the MOSFET. In cases such as these, additional drive can be provided by connecting the optocoupler's collector output pin to a higher voltage such as 3.3 V, instead of ground.

MOSFET Gate Resistor

To reduce the possibility of RF oscillation, a gate resistor (R_G) is often inserted in series with the gate of the MOSFET power switch. This resistor should be placed physically close to the MOSFET gate terminal, and connected by as short a PCB trace as is feasible. An appropriate value for these gate resistors is highly dependent on both the characteristics of the MOSFET being used and the circumstances of the application, but will often be in the range of 10 Ω to 100 Ω .

Several characteristics of the MOSFET can be used to calculate the minimum gate resistance value to use in preventing RF oscillations. Basically, the gate resistor and MOSFET input capacitance should have a time-constant that is at least twice the MOSFET's combined turn-on delay time and turn-off delay time as expressed in Equation 2. The resistance value calculated should be rounded up to the next standard resistor value, Table 4 shows the resulting gate resistor values for some example MOSFETs.

$$R_G > 2 \frac{(t_{d(on)} + t_{d(off)})}{C_{iss}} \Omega \quad (2)$$

Table 4. Example MOSFET Gate Resistor Values

MOSFET	Manufacturer	$t_{d(on)}$ (ns)	$t_{d(off)}$ (ns)	C_{iss} (pF)	R_G Calculated (Ω)	R_G Actual (Ω)
Si7858	Vishay	40	140	5700	63	65
IRF6633	International Rectifier	9.7	12	1250	35	35
FDS6574A	Fairchild	19.5	173	7657	50	50
IRLML2803GpbF	International Rectifier	3.9	9	85	304	310

Remember, the gate resistor is most effective when it is physically located as close to the MOSFET on board as possible. The value of the gate resistor is typically so small that it has virtually no effect on either the ramp-up or ramp-down time as seen by the load.

Additional Resources

Successfully choosing a MOSFET for a particular application takes more expertise than we can impart in this application note. For detailed advice we suggest you refer to the information and applications resources provided by MOSFET manufacturers. A few manufacturers of these devices include:

Fairchild Semiconductor: www.fairchildsemi.com
 International Rectifier: www.irf.com
 On Semiconductor: www.onsemi.com
 Vishay-Siliconix: www.siliconix.com

Related Literature

- DS1011, [ispPAC-POWR607 Data Sheet](#)
- DS1014, [ispPAC-POWR1014/A Data Sheet](#)
- DS1015, [ispPAC-POWR1220AT8 Data Sheet](#)
- DS1036, [Platform Manager Data Sheet](#)
- DS1043, [Platform Manager 2 Data Sheet](#)
- DS1042, [L-ASC10 Data Sheet](#)

Technical Support Assistance

Submit a technical support case through www.latticesemi.com/techsupport.

Revision History

Date	Version	Change Summary
August 2017	1.3	Moved paragraph on gate resistor (R_G) from N-Channel Positive Supply Switch section to MOSFET Gate Resistor section.
		Added MOSFET Gate Resistor section.
		Corrected Ohms (Ω) symbol displayed as "3/4".
		Updated Technical Support Assistance information.
October 2014	1.2	Updated to include Power Manager II and Platform Manager devices.
		Changed document title from "Using Power MOFSETs with Power Manager Devices" to "Using Power MOFSETs with Power/Platform Management Devices."
		Updated Related Literature section.
April 2008	01.1	Updated Technical Support Assistance information.
		Title changed from "Using Power MOFSETs with the ispPAC-POWR1208" to "Using Power MOFSETs with Power Manager Devices."
February 2003	01.0	Initial release.