Controlling Power MOSFETs Using the ispPAC-POWR604

Introduction

The ispPAC®-POWR604 is a member of Lattice Semiconductor's family of mixed-signal power-supply manager ICs. The ispPAC-POWR604 is useful in cost-sensitive applications requiring simple control logic and which do not require the high-side MOSFET drive capabilities of the ispPAC-POWR1208. Table 1 summarizes and compares the total resources available on each of these devices. Where the full resources of the ispPAC-POWR1208 are not required, the ispPAC-POWR604 can often be an economical alternative.

*Table 1. Resource Comparison Between ispPAC-POWR604 and ispPAC-POWR1208*

Feature	ispPAC-POWR604	ispPAC-POWR1208
Analog Inputs/Comparators	6	12
Digital Inputs	4	4
Logic Macrocells	8	16
Timers	2	4
Logic Outputs	4	8
Hi-V MOSFET-driver Outputs	0	4

In applications in which power MOSFETs need to be switched, it is often possible to use the ispPAC-POWR604 despite its absence of charge-pumped FET drivers through the use of some simple and inexpensive external circuitry. This application note will describe several ways to interface the ispPAC-POWR604 to external MOSFET switches.

Driving an N-Channel MOSFET

N-channel MOSFETS are frequently used as high-side switches because of their low on-resistances and low cost. To completely turn on an n-channel MOSFET, however, requires that a positive gate-to-source voltage typically ranging from 2V to 10V be applied to the device. When the MOSFET is used as a high-side switch, this means that the voltage at the gate terminal will need to be raised significantly above the drain terminal's voltage. Because the ispPAC-POWR604's outputs are rated to a maximum voltage of 6V, this will often require the use of an external driver circuit, such as the one shown in Figure 1.

*Figure 1. Driving an N-Channel High-side Switch if High Voltage Supply is Available*
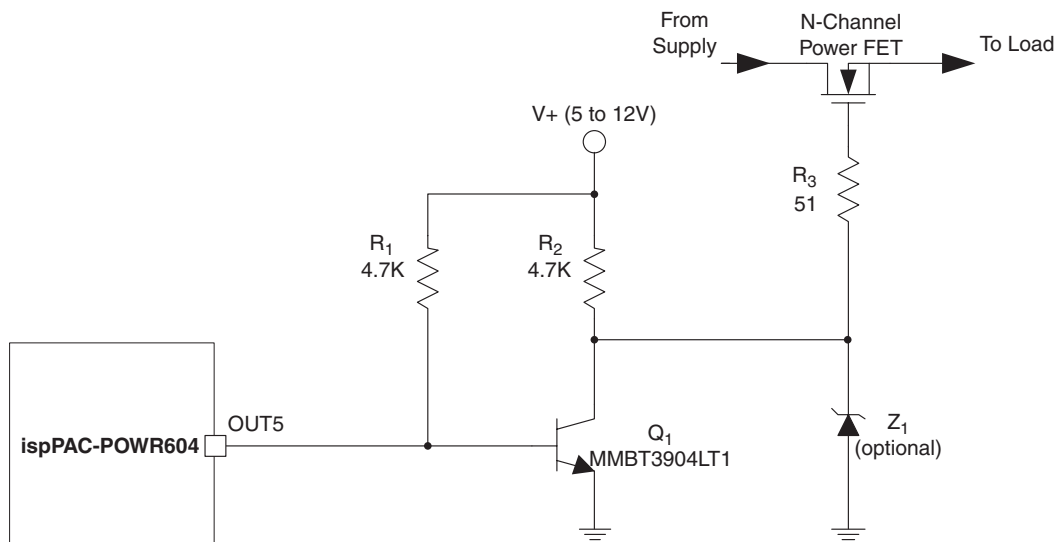
In this circuit an auxiliary high-voltage source (V+) is required to bias the MOSFET. The external transistor driver is used for two reasons. The first is to allow operation at higher voltages than the ispPAC-POWR604's outputs will withstand (6V). The second reason for using this circuit is that if the ispPAC-POWR604 is programmed to reset and start up in the HIGH state, this circuit will ensure that the MOSFET is not inadvertently turned on if the V+ supply energizes before the supply for the ispPAC-POWR604. To turn the MOSFET on requires that the ispPAC-POWR604's output go LOW.

Zener diode Z_1 is provided to ensure that the MOSFET's gate voltage does not exceed its maximum ratings. This situation can occur if a MOSFET with a low gate-source breakdown voltage is specified, and the circuit is driven from a high voltage +V supply. In many cases, the addition of the Zener diode will not be necessary. Resistor R_3 should be put in series with the MOSFET gate close to the device to help reduce the chance of spurious RF oscillation. The preferred value of this gate resistor will be a function of the particular MOSFET used and the circuitry to which it is connected.

Driving a P-Channel MOSFET

When a high voltage supply is not readily available to provide gate drive for an n-channel MOSFET, it may be possible to use a p-channel device. This is because when a p-channel MOSFET is used to switch a positive power rail, the gate must be pulled negative in relation to the source to turn it on. If the power rail is at a voltage greater than the MOSFET's turn-on voltage, this can be accomplished by pulling the gate to ground. In cases where the positive supply being switched is less than maximum output voltage of the ispPAC-POWR604, this can be accomplished by driving the MOSFET directly from the ispPAC-POWR604's output, where a LOW output signal results in turning the MOSFET on. As in the case of the previous circuit example, this will result in the circuit powering up in a 'safe' state if the ispPAC-POWR604 output is programmed to power-up HIGH. A pull-up resistor (R_1) is needed between the MOSFET's gate and source to ensure that the device turns off when the ispPAC-POWR604's output goes HIGH.

*Figure 2. Driving a P-Channel High-side Switch*
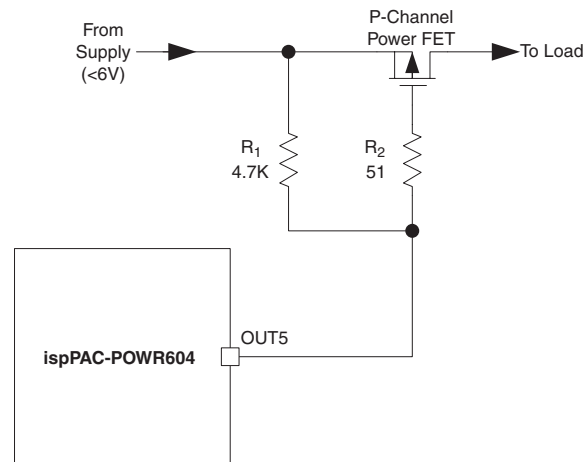
One caveat that applies to this circuit is that it is only effective in switching supply rails which are at a voltage higher than the MOSFET's on voltage. For example, if one were to try switching a 1.2V rail with this circuit, it would be extremely difficult, if not impossible, to obtain a p-channel power MOSFET which could be completely switched on with only -1.2V of gate-source drive. For this reason, this circuit solution is only presently practical for use with power rails ranging from ~2.5V to 6V.

A Simple External Charge-Pump Driver

In systems where the use of a p-channel MOSFET switch would be unsuitable and an external high-voltage source is not available for driving an n-channel device, it may be possible to generate a small amount of current at a higher voltage with the addition of some external circuitry. This external 'step-up' circuit needs to be small, inexpensive, low-power, and not generate excessive noise. While a DC-to-DC converter could be used to provide the necessary

voltage and can be implemented with a single IC and a few external components (or simply purchased as a finished module) this approach tends to be expensive. Because only a miniscule amount of current is needed to charge a MOSFET's gate, however, one alternative solution is to use a capacitive voltage multiplier. Capacitive voltage multipliers are simple, inexpensive, electrically quiet, and can be operated from small amounts of power. Figure 3 shows an example of a 3X voltage multiplier, which is driven by the ispPAC-POWR604's clock output, and generates an 8V to 9V DC gate drive voltage.

Figure 3. External Charge Pump Driver for N-Channel High-side Switch
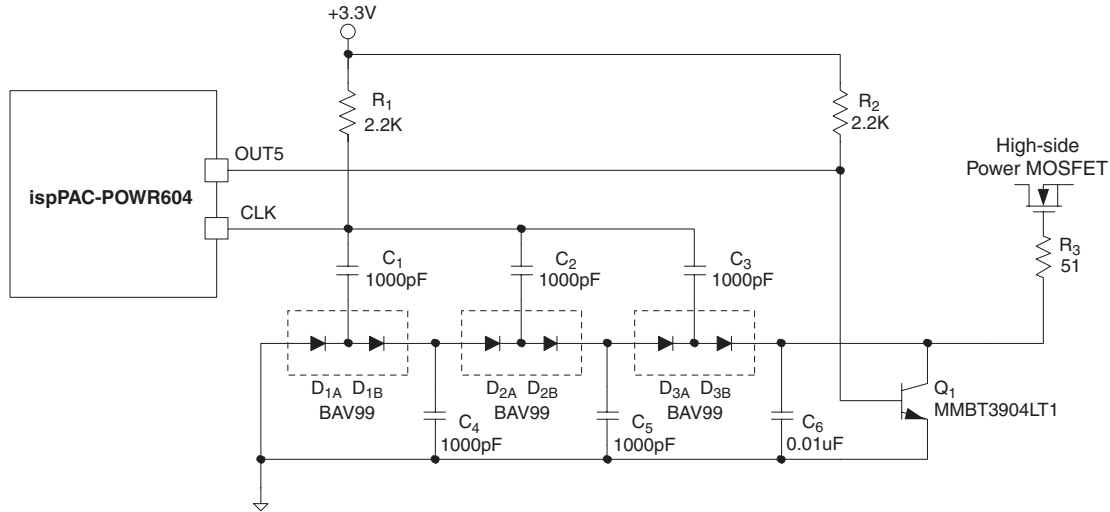
Adding a pull-up resistor to the ispPAC-POWR604's clock output results in a 3.3V peak-to-peak square wave output at the device's internal clock frequency, approximately 250 kHz. On each low-to-high cycle of the clock, more charge is forced into capacitors C_4 through C_6, gradually raising their voltages, with the highest final voltage appearing on C_6. Because of the voltage drops associated with the diodes, the output voltage is not quite 3 times the input voltage (9.9V), but will typically range from 8V to 9V.

OUT5 is used to control the MOSFET's gate. When OUT5 is LOW, transistor Q_1 is switched off, and the gate will be free to rise to the voltage multipliers maximum output, and will turn on the MOSFET. When OUT5 goes HIGH, transistor Q_1 switches on and will short the MOSFET gate terminal to ground, turning off the MOSFET.

Because the charge pump is actually powered from the ispPAC-POWR604's clock output, this circuit guarantees safe start-up conditions for the MOSFET. This is because the ispPAC-POWR604 will be at least well into power-on-reset by the time enough gate voltage is available to turn on the MOSFET.

Because the above circuit is suitable for controlling a single external MOSFET, if one wants to control multiple MOSFETs, it must be duplicated for each device being controlled. Driving multiple copies of this circuit from a single ispPAC-POWR604 clock circuit is not recommended because of potential adverse loading effects on the clock output. In cases where one needs to provide high-voltage drive to multiple MOSFETs, a better design choice would be to use the ispPAC-POWR1208, which provides four internal high-voltage MOSFET drivers.

Related Literature

- ispPAC-POWR604 Data Sheet
- AN6048 - *Using Power MOSFETs with the ispPAC-POWR1208*

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