

Bodo's Power Systems®

Optimizing MOSFET Selection in Handset and Portable DC Load Applications

Trench 4 process targeting low voltage P-Channel MOSFET

There are many applications where load switches are used for sequencing, protection, power management and distribution, etc. and each of these has their own characteristics. As portable electronics such as cell phones, portable media players, personal navigation devices, etc. continue to shrink in form factor, there is a continued need for smaller electronic components to match this trend. At the same time, the expectation of component performance remains the same. This trend is no different for power applications using MOSFET devices.

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In those areas where a switching regulator is required, there are several topologies based on cost, from the very basic P-ch MOSFET paired with a Schottky diode to the use of two N-ch MOSFETS to provide the highest efficiency possible. In those circuits, the industry has developed a figure-of-merit (FOM) to compare one device from another and it is defined as $FOM = Q_g \times R_{ds(on)}$. In the case of a load switch application where switching losses do not play a significant role, the main point of comparison has been the $R_{ds(on)}$ at a certain bias voltage (V_{gs}), but that does not really tell you the whole picture. We believe a better figure of merit to describe a load switch is the $R_{ds(on)}$ the part can provide for a given package or footprint area, hence $FOM_p = R_{ds(on)} \times \text{Footprint}$. As a result, the part with

the lowest $R_{ds(on)}$ and the smallest footprint, will be able to provide the best power density for a given DC load in portable devices, where real estate and battery life are key requirements.

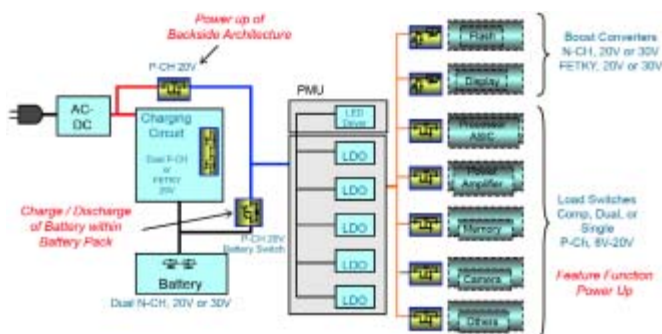


Figure 1: Typical System Architecture

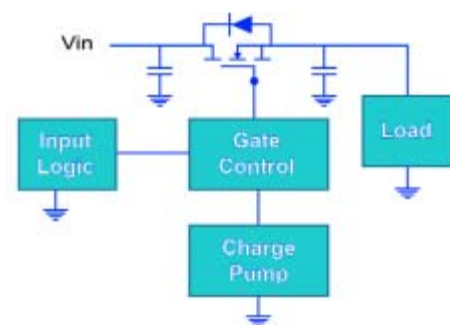


Figure 2: A N-channel High Side Load Switch

Power applications within handset and portable products often use MOSFETs for a variety of uses. Some common sockets and the types of MOSFETs used can be seen in Figure 1. The most prevalent socket includes a DC load switch for power management of different feature sets, battery charge / discharge, and general power architecture management.

The most commonly used device for portable applications is the P-Channel MOSFET. This preference arises from the fact that portable architectures are battery power and the positive rail makes a solid reference point compared to power supply operated systems where ground is the solid reference point. Although a P-channel MOSFET, due to carrier mobility, is a larger die for an equivalent Rds(on) specification point compared to an N-channel MOSFET, the drive circuitry is much more simple. An N-Channel MOSFET can be either used as a low side switch or if used as a high side switch it requires a boost or bootstrap type topology (see figure 2). Because of this fact, the overall circuit cost to meet performance requirements can lean towards a P-Channel discrete FET as opposed to N-Channel gate plus drive circuit.

When choosing an appropriate drain to source (Vds) and gate to source (Vgs) maximum voltage tolerances, handset and portable designers need to consider the system level maximum voltage seen. Vgs(max) is often predicated on the voltage of single cell batteries in these products. Many times, the MOSFETs are driven directly off of the battery. Typical Li-Ion single cell battery voltages can vary from 2.7V to 4.2V. A solid Rds(on) performance at Vgs =2.5V with room above 4.2V to avoid damage to the MOSFET is a good design guideline for selecting Vgs(max). A device with a VGS=±8V is a preferable target to look for on this specification. Vds(max) is commonly dictated by the output voltage especially in circuits where the device is used in a boost converter. Some handset / portable applications can drive the MOSFET with internal rails operating off of the battery (3.3V or 1.2V) and drive the various load as well from a tightly control internal rail. This could allow for safe operation of the MOSFETs with a Vgs(max) as low as ±5V and Vds(max) as low as -8V.

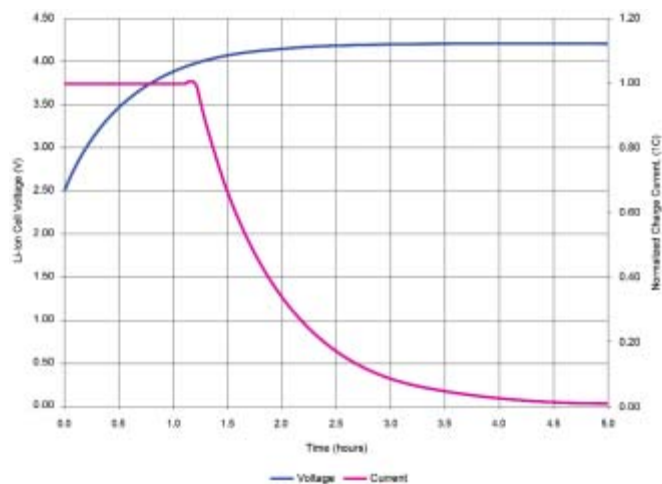


Figure 3 - Typical Lithium-Ion Charge profile (CC-CV)

With a P-Channel, -20V Vds(max) and ±8V Vgs(max) MOSFET as a very common product selection for handset and portable DC load applications, the next most common design guidelines involve the tradeoff between (FOMp) Rds(on) performance vs. footprint area. The Rds(on) targets for the designer will be largely based on the current of the loads and the efficiency performance targeted. Very common Rds(on) targets are <50mOhm for front end power management switches. These switches often power off the entire backside architecture of a handset / portable device when in standby mode. Because this power rail supplies several loads, the current typically is

high. Requiring lower Rds(on) and high current carrying capability sometimes in the 2-8A peak for distributed systems. In the same manner, charge of the battery typically requires higher current carrying capability and efficiency for example in Lithium-Ion batteries you can have 1A continuous for up to 1 hour (See Figure 3).

Also using USB ports to power up accessories you have to be able to handle 5V and supply a load current anywhere from 100mA to 500mA continuously. For the individual loads, the MOSFET can be sized depending on three main factors, the current requirements, the output voltage, and the type of load. The ON resistance and the current determine the drop out voltage, so you must keep in mind the maximum drop out voltage that your system can tolerate. Some applications could often require a 100mOhm to roughly 300mOhm while very low current loads could operate effectively with as high as 1 to 5 Ohms. The type of load also will help in defining the in-rush current capability of the MOSFET. Capacitive loads in particular can give high current surges that can be controlled by slowly switching them ON. In order to do so it is common to use a large P-ch MOSFET to handle the load and a small signal N-ch MOSFET to control the turn on speed using a resistor to control the slew rate (R2). This is also often the case when the drive signals are different from the supply voltage.

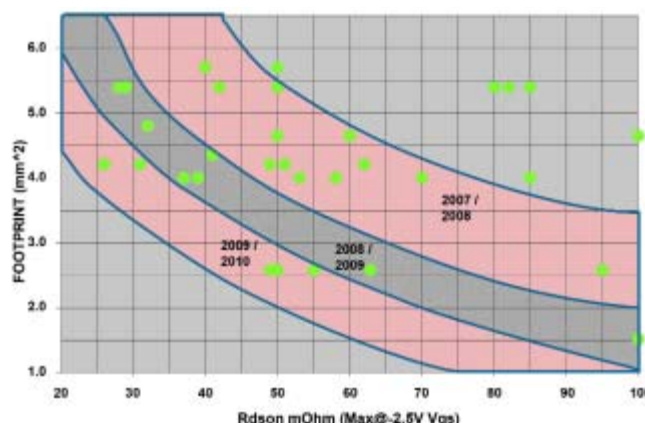


Figure 4: Rdson (mOhms) vs. Footprint (mm²) of Key Product Releases of P-Ch -20V Vds / ±8 or 12V Vgs MOSFETs

Figure 4 shows the trend of P-Channel -20V Vds / +8V Vgs MOSFETs from several vendors in very small packaging that is commonly seen in handset / portable market spaces. Rough groupings of the release dates of these products are shown. As seen in the figure, there is a general trend of lower Rds(on) and smaller package footprint to maintain the trend of improved power density in handset / portable market spaces for DC applications.

ON Semiconductor, in order to maintain an industry leading position in power density figure of merit, has recently released products on a Trench 4 process targeting low voltage P-Channel MOSFET applications with -20V Vds(max) and ±8V Vgs(max). This represents a 40%+ shrink in Rdson from previous ON Semiconductor P-Channel technologies.

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