Electronics Tutorial about MOSFET's as Switches

MOSFET as a Switch

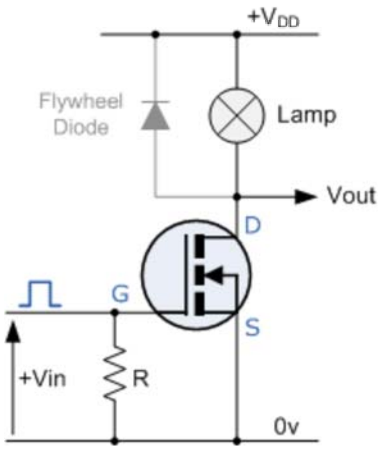
The MOSFET as a Switch

We saw previously, that the N-channel, Enhancement-mode MOSFET operates using a positive input voltage and has an extremely high input resistance (almost infinite) making it possible to interface with nearly any logic gate or driver capable of producing a positive output. Also, due to this very high input (Gate) resistance we can parallel together many different MOSFET's until we achieve the current handling limit required. While connecting together various MOSFET's may enable us to switch high current or high voltage loads, doing so becomes expensive and impractical in both components and circuit board space. To overcome this problem **Power Field Effect Transistors** or **Power FET's** where developed.

We now know that there are two main differences between FET's, Depletion-mode for JFET's and Enhancement-mode for MOSFET's and on this page we will look at using the Enhancement-mode MOSFET as a Switch.

By applying a suitable drive voltage to the Gate of an FET the resistance of the Drain-Source channel can be varied from an "OFF-resistance" of many hundreds of kΩ's, effectively an open circuit, to an "ON-resistance" of less than 1Ω, effectively a short circuit. We can also drive the MOSFET to turn "ON" fast or slow, or to pass high currents or low currents. This ability to turn the power MOSFET "ON" and "OFF" allows the device to be used as a very efficient switch with switching speeds much faster than standard bipolar junction transistors.

An example of using the MOSFET as a switch



In this circuit arrangement an Enhancement-mode N-channel MOSFET is being used to switch a simple lamp "ON" and "OFF" (could also be an LED). The gate input voltage V_{GS} is taken to an appropriate positive voltage level to turn the device and the lamp either fully "ON", (V_{GS} = +ve) or a zero voltage level to turn the device fully "OFF", ($V_{GS} = 0$).

If the resistive load of the lamp was to be replaced by an inductive load such as a coil or solenoid, a "Flywheel" diode would be required in parallel with the load to protect the MOSFET from any back-emf.

Above shows a very simple circuit for switching a resistive load such as a lamp or LED. But when using power MOSFET's to switch either inductive or capacitive loads some form of protection is required to prevent the MOSFET device from becoming damaged. Driving an inductive load has the opposite effect from driving a capacitive load. For example, a capacitor without an electrical charge is a short circuit, resulting in a high "inrush" of current and when we remove the voltage from an inductive load we have a large reverse voltage build up as the magnetic field collapses, resulting in an induced back-emf in the windings of the inductor.

For the power MOSFET to operate as an analogue switching device, it needs to be switched between its "Cut-off Region" where $V_{GS} = 0$ and its "Saturation Region" where $V_{GS(on)}$ = +ve. The power dissipated in the MOSFET (P_D) depends upon the current flowing through the channel I_D at saturation and also the "ON-resistance" of the channel given as $R_{DS(on)}$. For example.

Example No1

Lets assume that the lamp is rated at 6v, 24W and is fully "ON" and the standard MOSFET has a channel "ON-resistance" ($R_{DS(on)}$) value of 0.1ohms. Calculate the power dissipated in the MOSFET switch.

The current flowing through the lamp is calculated as:

$$P = V \times I, \text{ therefore, } I_D = \frac{P}{V} = \frac{24}{6} = 4\text{ amps}$$

Then the power dissipated in the MOSFET will be given as:

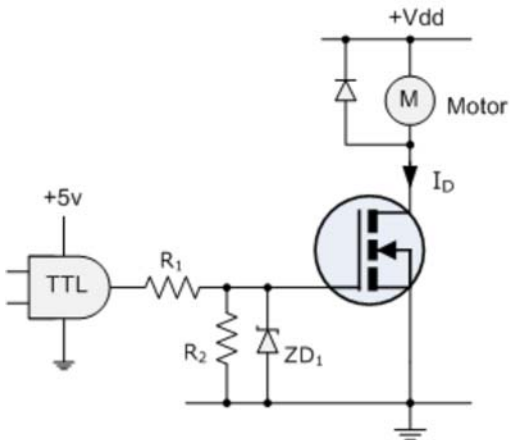
$$P_D = I_D^2 \times R_{DS}, \text{ therefore, } P_D = 4^2 \times 0.1 = 1.6\text{ watts}$$

You may think, well so what!, but when using the MOSFET as a switch to control DC motors or high inrush current devices the "ON" channel resistance ($R_{DS(on)}$) is very important. For example, MOSFET's that control DC motors, are subjected to a high in-rush current as the motor first begins to rotate. Then a high $R_{DS(on)}$ channel resistance value would simply result in large amounts of power being dissipated within the MOSFET itself resulting in an excessive temperature rise, and which in turn could result in the MOSFET becoming very hot and damaged due to a thermal overload. But a low $R_{DS(on)}$ value on the other hand is also desirable to help reduce the effective saturation voltage ($V_{DS(sat)} = I_D \times R_{DS(on)}$) across the MOSFET. When using MOSFET´s or any type of Field Effect Transistor for that matter as a switching device, it is always advisable to select ones that have a very low $R_{DS(on)}$ value or at least mount them onto a suitable heatsink to help reduce any thermal runaway and damage.

Power MOSFET Motor Control

Because of the extremely high input or Gate resistance that the MOSFET has, its very fast switching speeds and the ease at which they can be driven makes them ideal to interface with op-amps or standard logic gates. However, care must be taken to ensure that the gate-source input voltage is correctly chosen because when using the **MOSFET as a switch** the device must obtain a low $R_{DS(on)}$ channel resistance in proportion to this input gate voltage. For example, do not apply a 12v signal if a 5v signal voltage is required. Power MOSFET´s can be used to control the movement of DC motors or brushless stepper motors directly from computer logic or Pulse-width Modulation (PWM) type controllers. As a DC motor offers high starting torque and which is also proportional to the armature current, MOSFET switches along with a PWM can be used as a very good speed controller that would provide smooth and quiet motor operation.

Simple Power MOSFET Motor Controller



As the motor load is inductive, a simple "Free-wheeling" diode is connected across the load to dissipate any back emf generated by the motor when the MOSFET turns it "OFF".
The Zener diode is used to prevent excessive gate-source input voltages.

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External Links about using the MOSFET as a Switch

MOSFET Switch Drivers - Good Tutorial Explaining how to use the MOSFET as a Switch.
Purdue University
IGFET´s - pdf File Explaining how to use and Connect IGFET´s.
Socratic Electronics
Using a MOSFET as a Switch - Tutorial about using a MOSFET as a Switch.
Burning Software
MOSFET´s and their Applications - Introduction to Power MOSFET's and their Applications.
National Semiconductor

Link to us : http://www.electronics-tutorials.ws/transistor/tran_7.html

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