How to Protect MOSFETs – Basics Explained

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In this post we comprehensively learn how to protect mosfets and prevent mosfet burning in electronic circuits by following some basic guidelines related to correct PCB layout, and careful manual handling of these sensitive devices.

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Introduction

Even after connecting everything correctly you find the mosfets in your circuit becoming HOT and blowing off within minutes. This is quite a common issue faced by most new as well as experienced hobbyists while designing and optimizing mosfet based circuits especially the ones which involve high frequencies.

Obviously, connecting all the parts correctly as per the given details is the main thing that needs to be checked and confirmed first before assuming other issues, because unless the fundamental things are put absolutely right it would be meaningless tracing the other hidden bugs in your circuit.

Basic Mosfet protection application becomes critical specifically in those circuits which involve high frequencies in the order of many kHz. This is because high frequency applications calls for quick (within ns) turn ON and OFF of the devices which in turn demands efficient implementation of all the criteria associated directly or indirectly with the concerned switching.

So what are the main hindrances which cause improper or inefficient switching of the mosfets, let's learn comprehensively how to protect mosfets with the following points.

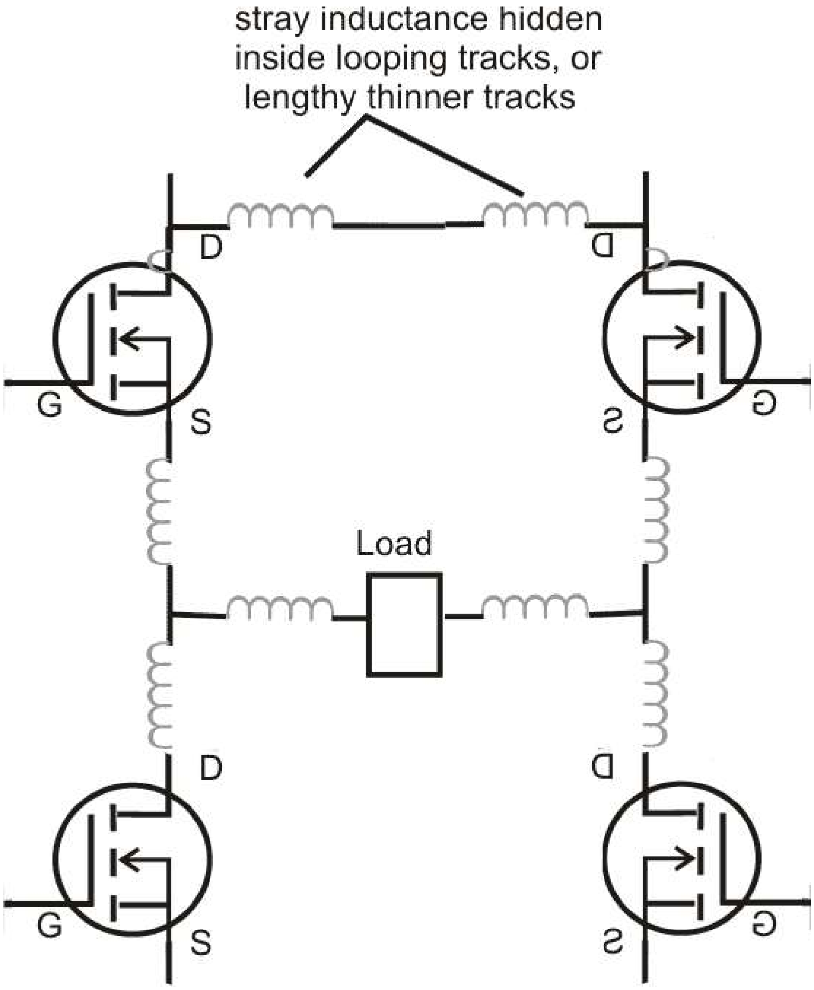
Get Rid of Stray Inductance:

The most common and prime bug in the que is the stray inductance that may be hidden within the circuit tracks. When the switching frequency and current are high, even a slightest unnecessary increase in the connecting path that is the PCB track may result in inter-linked inductance which in turn may affect the mosfet behavior drastically due to inefficient conduction, transients and spikes.

In order to get rid of this issue it's strongly recommended to keep the tracks wider and to keep the devices AS CLOSE AS POSSIBLE to each other and to the driver IC which are being used to drive the respective mosfets.

That's why SMD is preferred and is the best way of eliminating cross inductance across the components, also the use of double sided PCB helps controlling the issue due to its short "printed-through-hole" connections across the components.

Even the standing height of the mosfets must be brought to minimum by inserting the lead as deep down as possible into the PCB, using SMD is probably the best option.



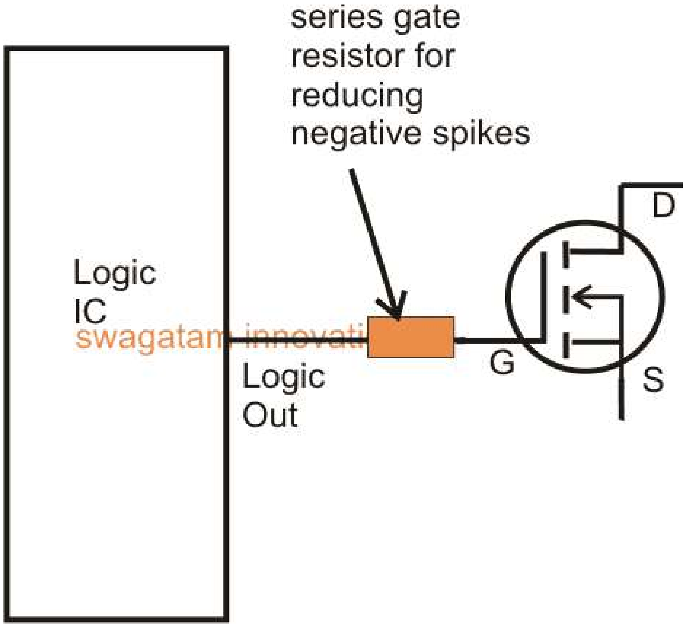
We all know that mosfets include in-built capacitors which require charging and discharging in order to make the device conduct.

Basically these capacitors are connected across the gate/source and gate/drain. Mosfets "don't like" prolonged delayed charging and discharging of its capacitance since these are directly related to its efficiency.

Connecting the mosfets directly to a logic source output might seem to solve this problem, because the logic source would easily switch and sink the capacitance from Vcc to zero quickly, and vice versa due to the absence of any obstacle in its path.

However, implementing the above consideration could also lead to the generation of transients and negative spikes with dangerous amplitudes across the drain and gate making the mosfet vulnerable to the generated spikes due to sudden high current switching across drain/source.

This could easily break the silicon separation between the sections of the mosfet rendering a short circuit inside the device, and damaging it permanently.

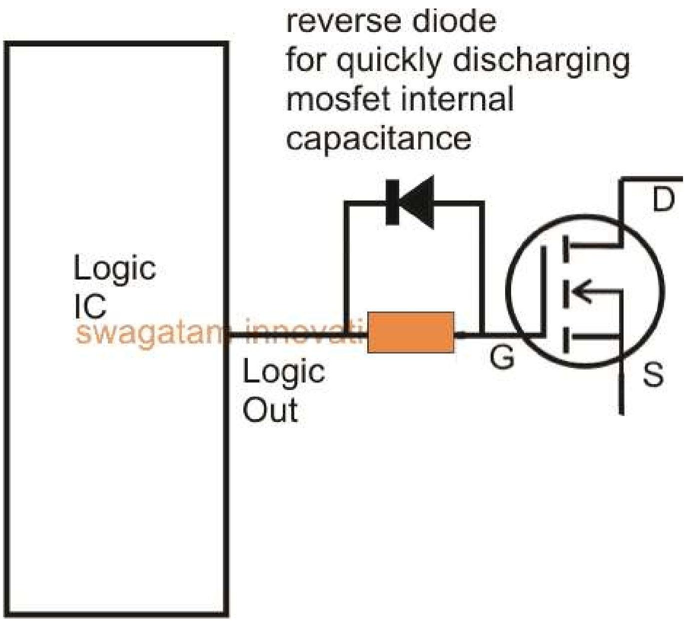


Importance of Gate Resistance:

To get rid of the above issue it is recommended to use low value resistor in series with the logic input and the mosfet gate.

With relatively lower frequencies(50 Hz to 1kHz), the value could be anywhere between 100 and 470 ohms, while for frequencies above this the value could be within 100 ohms, for much higher frequencies (10kHz and above) this must not exceed 50 ohms.

The above consideration allows exponential charging or gradual charging of the internal capacitors reducing or blunting of the chances of negative spikes across the drain/gate pins.



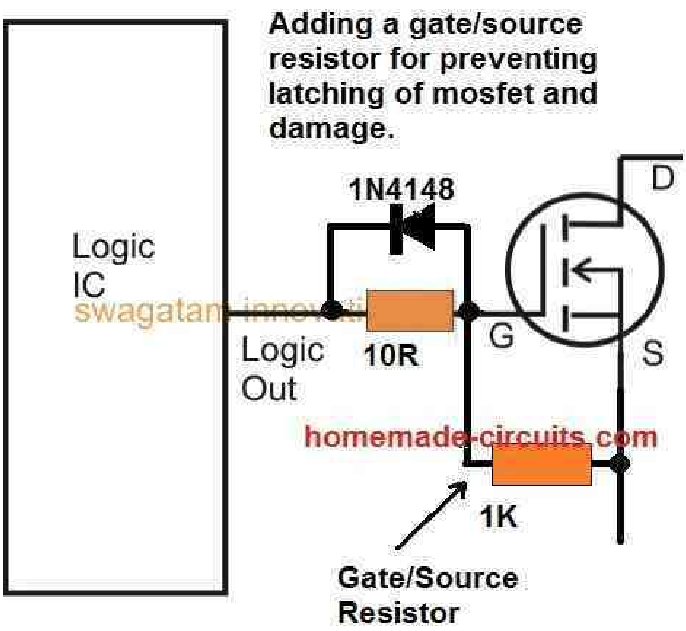
Using Reverse Diodes:

In the above consideration an exponential charging of the gate capacitance reduces the chances of spikes but that also means that the discharging of the involved capacitance would be delayed due to the resistance in the path of the logic input, every time it switches to logic zero. Causing a delayed discharging would mean forcing the mosfet to conduct under stressful conditions, making it unnecessarily warmer.

Including a reverse diode parallel with the gate resistor is always a good practice, and simply tackles the delayed discharging of the gate by providing a continuous path for the gate discharge through the diode and into the logic input.

The above mentioned points regarding correct implementation of mosfets can be easily included in any circuit in order to safeguard mosfets from mysterious malfunctions and burning.

Even in complicated applications such half-bridge or full bridge mosfet driver circuits along with some additional recommended protections.



Using a Resistor Between Gate and Source

Although we have not indicated this inclusion in the previous images, this is strongly recommended to safeguard the mosfet from blowing of under all circumstances.

So how does a resistor across gate/source provide a guaranteed protection?

Well, normally mosfets have the tendency to latch up whenever a switching voltage is applied, this latching effect can sometimes be hard to revert, and by the time an opposite switching current is applied it is already too late.

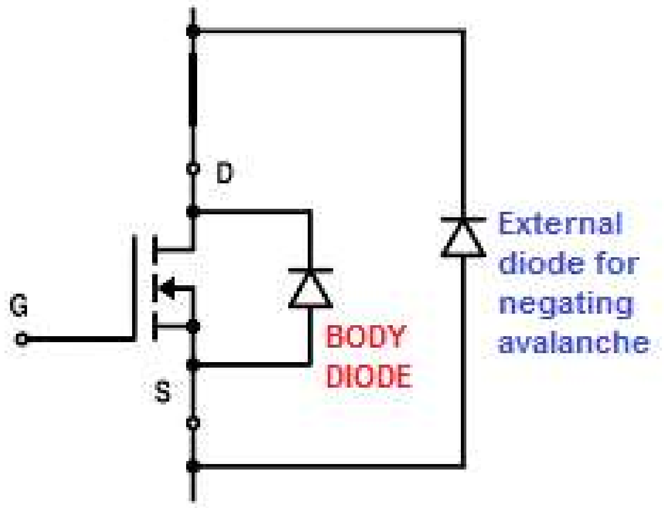
The mentioned resistor ensures that as soon as the switching signal is removed the mosfet is able to quickly turn OFF, and prevent a possible damage.

This resistor value could be anywhere between 1K and 10K, however lower values would provide better and more effective results.

Avalanche Protection

MOSFETs may get damaged if its junction temperature suddenly increases beyond the tolerable limit due to over voltage conditions across its internal body diodes. This occurrence is termed as avalanche in MOSFETs.

The problem can arise when an inductive load is used at the drain side of the device, and during the MOSFET switch OFF periods the inductor's reverse EMF passing through the MOSFET body diode becomes too high, causing a sudden rise in the MOSFET's junction temperatures, and its breakdown.



The problem can be tackled by adding an external high power diode across drain/source terminals of the MOSFETs, so that the reverse current is shared across the diodes, and excess heat generation is eliminated.

Protecting Mosfets in H-Bridge Circuits from Burning

While using a full bridge driver circuit involving a driver IC such as the IR2110 in addition to the above, the following aspects should be bored in mind (I'll discuss this in details in one of my upcoming articles soon)

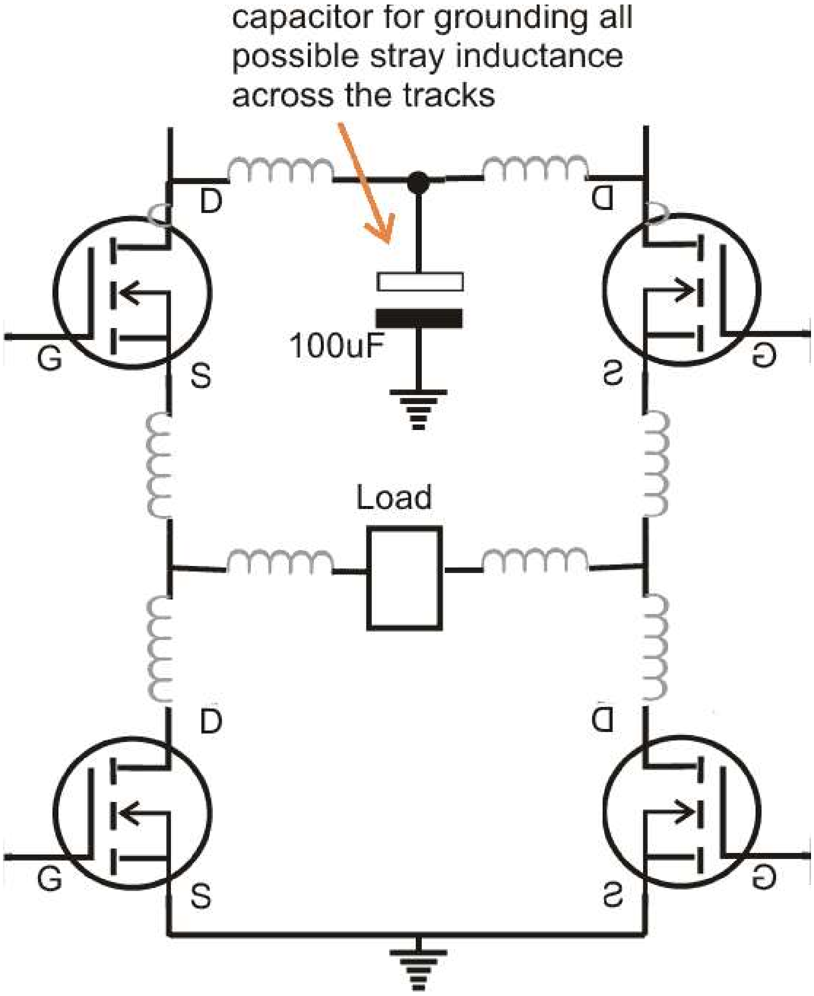
Add a decoupling capacitor close to the driver IC supply pinouts, this will reduce the switching transients across the internal supply pinouts which in turn will prevent unnatural output logic to the mosfet gates.
Always use high quality low ESD, low leakage type of capacitors for the bootstrapping capacitor and possibly use a couple of them in parallel. Use within the recommended value given in the datasheet.

Always connect the four mosfet interlinks as close as possible to each other. As explained above this will reduce stray inductance across the mosfets.

AND, connect a relatively large value capacitor across the high side positive (VDD), and the low side ground (VSS), this will effectively ground all stray inductance that may be hiding around the connections.

Join the VSS, the mosfet low side ground, and the logic input ground all together, and terminate into a single common thick ground to the supply terminal.

Last but not the least wash the board thoroughly with acetone or similar anti-flux agent in order to remove all possible traces of the soldering flux for evading hidden inter connections and shorts.



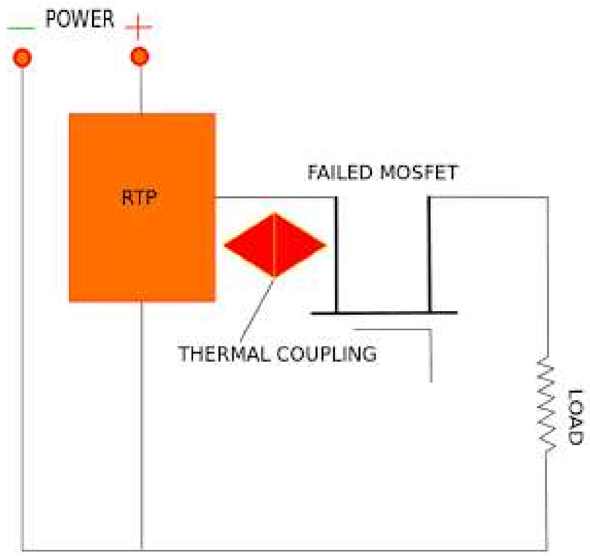
Protecting Mosfets from OverHeating

Lighting dimmers often suffer from MOSFET failures. Most dimmers used in low-temperature AC industrial applications are enclosed and often embedded in the wall. This can cause heat dissipation issues, and can result in heat build-up - leading to a thermal event. Usually, the MOSFET used for the lighting dimmer circuits fails in 'resistive mode'.

A reflow-able thermal protection or RTP from TE Connectivity provides an answer to MOSFET failure in low-temperature AC applications.

This device acts like a low-value resistor at the normal operating temperatures of the MOSFET. It is mounted almost directly on the MOSFET, and is therefore able to sense the temperature with precision. If for any reason, the MOSFET drifts into a high temperature condition, this is sensed by the RTP, and at a predefined temperature, the RTP changes into a high-value resistor.

This effectively cuts off the power to the MOSFET, saving it from destruction. Thus, a lower priced resistor sacrifices itself to save a more expensive MOSFET. A similar analogy could be the use of a fuse (low-value material) in protecting more complex circuitry (e.g. a television).



One of the most interesting aspects of the RTP from TE Connectivity is its ability to withstand enormous temperatures - up to 260ºC. This is surprising since the resistance change (to protect the MOSFET) usually occurs at around 140ºC.

This miraculous feat is accomplished via innovative design by TE Connectivity. The RTP has to be activated before it starts protecting the MOSFET. The electronic activation of the RTP occurs after the flow soldering (attachment) is completed. Each RTP has to be individually armed by sending a specified current through the arming pin of the RTP for a specified time.

The time-current characteristics are part of the specifications of the RTP. Before it is armed, the value of the resistor of the RTP will follow the specified characteristics. However, once it is armed, the arming pin will become electrically open - preventing further changes.

It is very important that the layout specified by TE Connectivity be followed when designing and mounting the MOSFET and the RTP on the PCB. Since the RTP has to sense the temperature of the MOSFET, it naturally follows that the two should remain in close proximity.

The RTP resistance will allow up to 80A of current at 120V AC through the MOSFET as long as the temperature of the MOSFET remains below the Open Temperature of the RTP, which can be between 135-145ºC.