

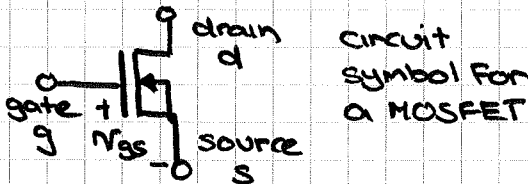
12R009 HIGH-SIDE GATE DRIVERS

8-FEB-12

Aim - high-side gate drivers are commonly used in power electronic circuits, this paper discusses their operation

1. MOSFET/IGBT DRIVERS

MOSFETs and IGBTs are voltage-controlled devices, the key voltage being the gate-source voltage V_{GS}



typically values of V_{GS} of about 3-5V is required to just turn-on the MOSFET, to ensure it is fully-on, values of 10-15V are usually used

to fully turn-off the MOSFET, the gate voltage should be reduced below 1-2V

the MOSFET gate acts like a capacitor, with a typical gate to source capacitance of several nF.

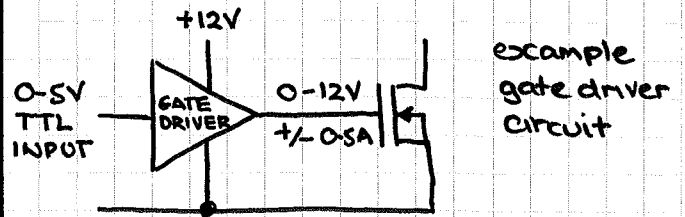
example - consider the ^{equivalent} gate-source capacitance of a MOSFET is 4nF, to change the V_{GS} from 0 to 15V in 100ns takes a current of:

$$i = C \cdot \frac{dv}{dt} = C \cdot \frac{\Delta V}{\Delta t}$$

$$= 4\text{nF} \times 15\text{V}/100\text{ns} = \underline{0.6\text{A}}$$

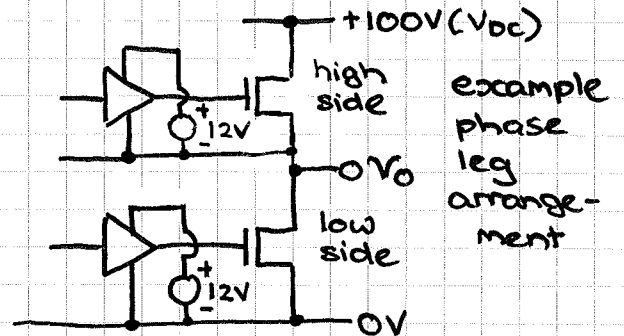
the MOSFET needs to be turned off and on rapidly to reduce switching loss, to do this means the gate driver needs to be capable of supplying and absorbing currents in the range of 0.1-1A absolute

note - the maximum values for V_{GS} are typically +/- 20V, larger values can cause damage



Sometimes a resistor is placed between the gate driver and the gate, e.g. 47 Ω , this is used to deliberately slow the switching of the MOSFET to reduce the overvoltages produced by stray inductance in the circuit

2. LOW AND HIGH-SIDE DRIVERS



a phase leg consists of a high side switch and a low side switch

the low side transistor has its source connected to 0V which makes it easy to drive as the gate driver can be referenced to 0V too

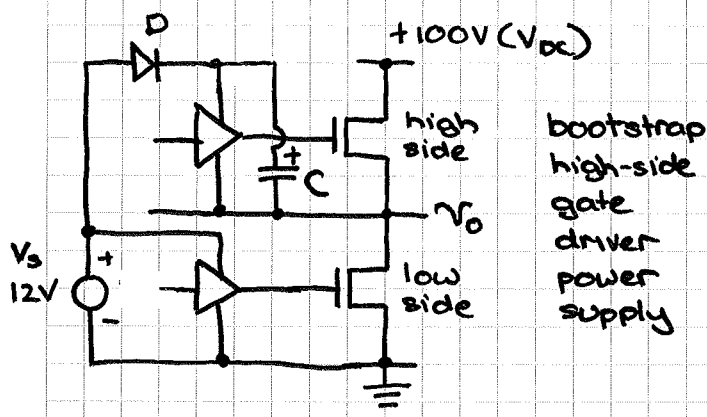
the high side transistor has its source connected to the output V_0 whose voltage rapidly varies between 0 and V_{DC} , the gate driver and its power supply must be referenced to V_0

one method to implement this is to use a DC/DC converter to produce the required isolated power supply for the high side gate driver, with an opto-isolator used to transmit the gate drive signal

a 3ph inverter would require 3 DC/DC converters and opto-isolators

a simpler and cheaper solution is to use an integrated bootstrap gate driver to drive the high-side switch

3. BOOTSTRAP HIGH-SIDE DRIVER



the bootstrap power supply for the high side gate driver consists of the diode D and capacitor C, when the low side switch is on, the output voltage $V_o = 0V$ and the capacitor charges to 12V through the diode

when the high side switch turns on, the output voltage $V_o = V_{oc}$, the diode turns off and the capacitor supplies power to the gate driver

Capacitor (bootstrap)

- needs to hold sufficient charge to power gate driver in worst-case conditions (max pulse length)
- low series resistance (ESR) as gate driver needs large pulses of current to drive gate
- voltage rating somewhat larger than gate drive power supply V_s
- typical values 0.1-1 μF , 25V, tantalum electrolytic capacitor or ceramic capacitor

diode (bootstrap)

- reverse voltage rating greater than $(V_{oc} + V_s)$
- current rating 1A or greater

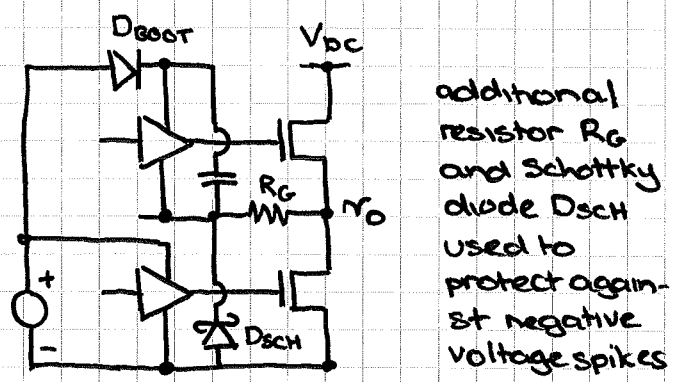
- fast recovery - to prevent the capacitor discharging before the diode turns off

issues and concerns

- a) initialisation - should turn low side switch on first to charge bootstrap capacitor, before turning on high side switch
- if there is no low-side switch (eg. buck converter) and if the output voltage is present before the DC link voltage (eg. battery charger) then start-up problems can occur

- b) negative voltage spikes on output - these occur due to stray inductance in the low-side free-wheeling diode current path causing V_o to go significantly below 0V

this can cause over-voltage of the bootstrap capacitor and/or incorrect operation of the gate driver chip (latch-up)



R_g - sets turn-on/off speeds of MOSFET and limits current in Schottky diode when $V_o < 0$

D_{sch} - prevents over-voltage of bootstrap capacitor and under-voltage of gate driver

c) maximum duty-cycle - with a bootstrap charge arrangement it is not possible to keep the high side device on indefinitely, this sets a limit on the maximum allowable duty-cycle

for more information - please see the manufacturer's application notes and datasheets for the gate drivers