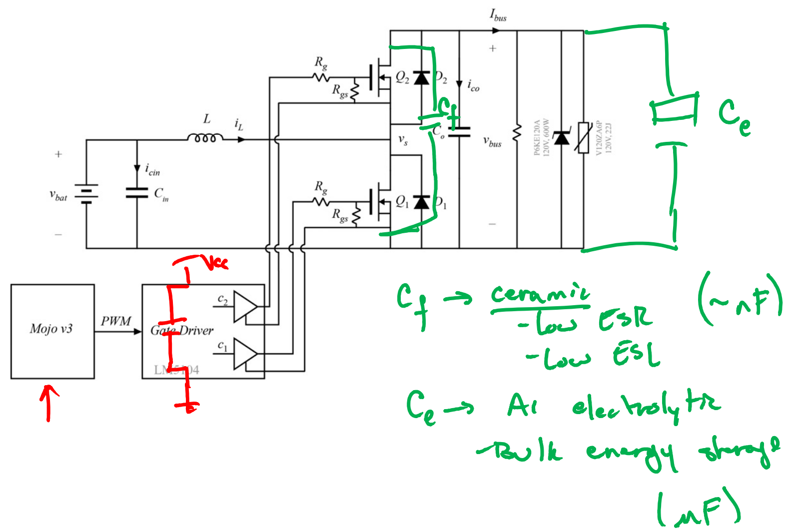
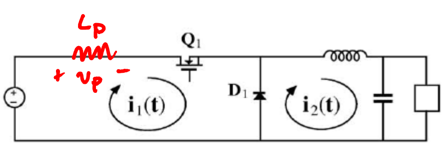
Experiment 3: Open Loop Boost

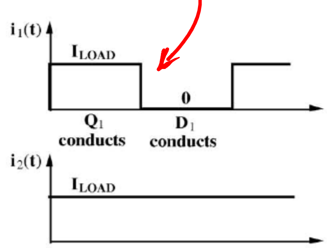


Power Converter Layout: Buck Example

Use loop analysis

$v_p = L_p \frac{di_1}{dt}$





switched input current $i_1(t)$ contains large high frequency harmonics

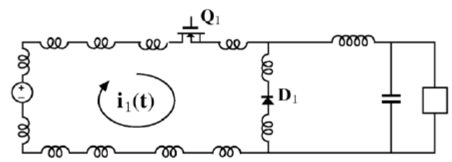
—hence inductance of input loop is critical

inductance causes ringing, voltage spikes, switching loss, generation of B- and E-fields, radiated EMI

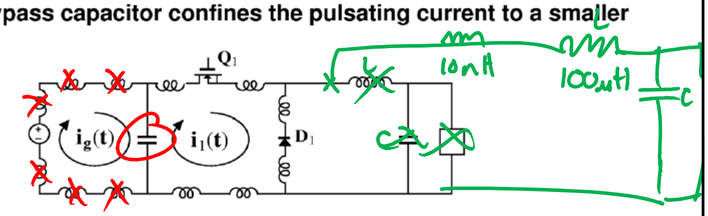
the second loop contains a filter inductor, and hence its current $i_2(t)$ is nearly dc

—hence additional inductance is not a significant problem in the second loop

Parasitic inductances of input loop explicitly shown:

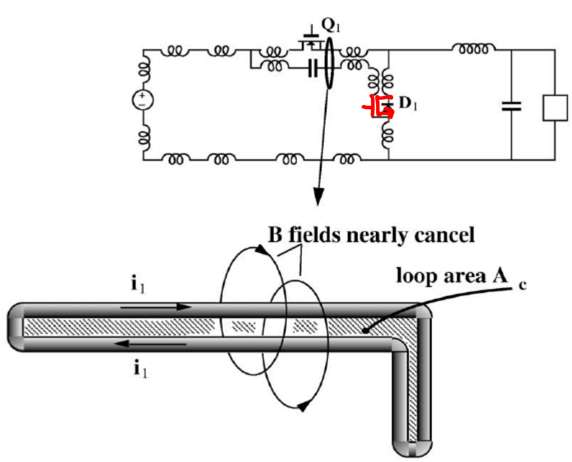


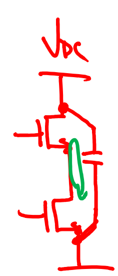
Addition of bypass capacitor confines the pulsating current to a smaller loop:



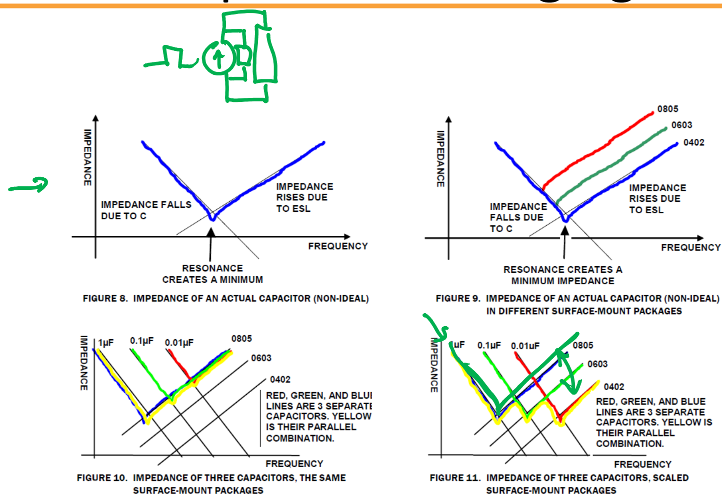
high frequency currents are shunted through capacitor instead of input source

Even better: minimize area of the high frequency loop, thereby minimizing its inductance





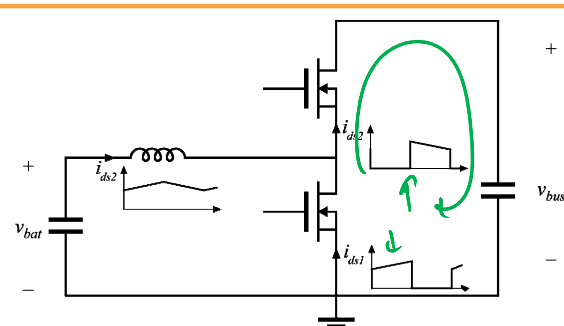
Capacitor Packaging



using smaller packages

Also: use better materials

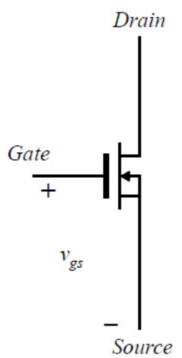
Boost Converter RMS Currents



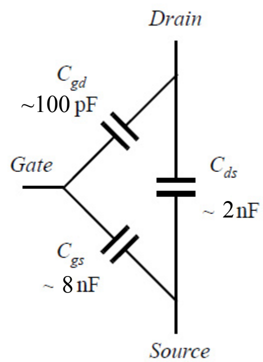
- MOSFET conduction losses due to $(r_{ds})_{on}$ depend given as

$$P_{cond,FET} = {I_{d,rms}}^2 (r_{ds})_{on}$$

Driving a Power MOSFET Switch



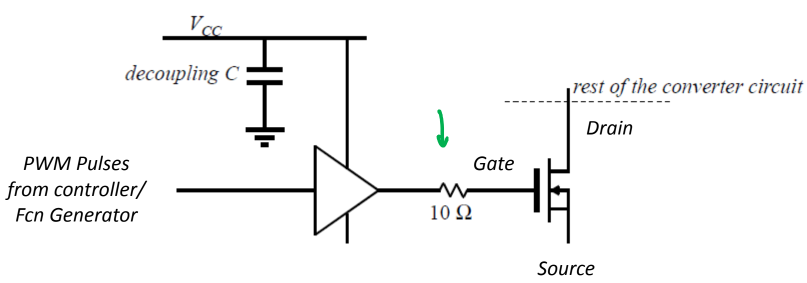
Power MOSFET



MOSFET capacitances

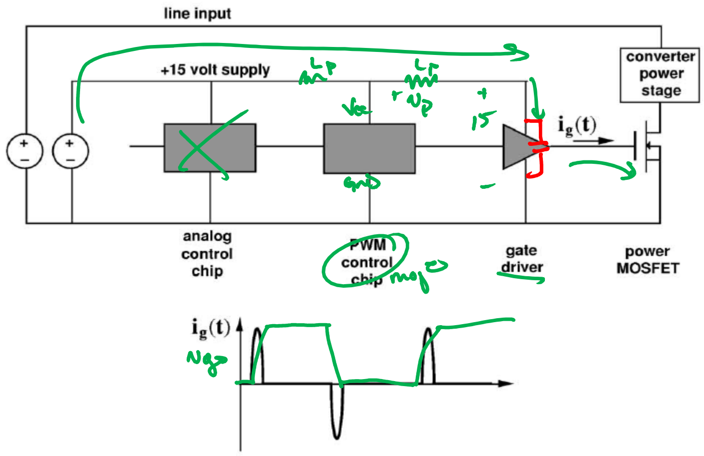
- MOSFET is off when $v_{gs} < V_{th} \approx$ 3 V
- MOSFET fully on when v_{gs} is sufficiently large (10-15 V)
- Warning: MOSFET gate oxide breaks down and the device fails when v_{gs} > 20 V.
- Fast turn on or turn off (10's of ns) requires a large spike (1-2 A) of gate current to charge or discharge the gate capacitance
- MOSFET gate driver is a logic buffer that has high output current capability

Driving a Power MOSFET Switch

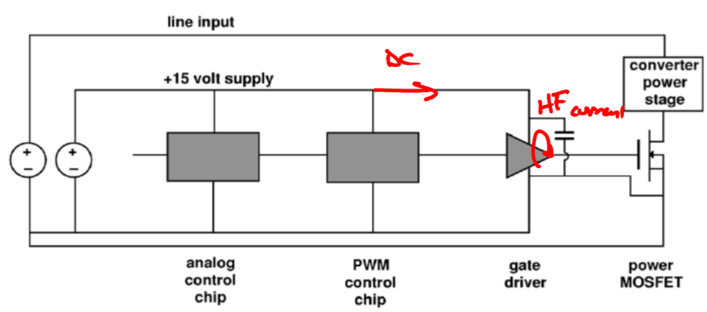


- MOSFET gate driver is used as a logic buffer with high output current (~1.8 A) capability
- The amplitude of the gate voltage equals the supply voltage *VCC*
- Decoupling capacitors are necessary at all supply pins of LM5104 (and all ICs)
- Gate resistance used to slow dv/dt at switch node

Gate Driver Example



Solution: bypass capacitor and close coupling of gate and return leads



High frequency components of gate drive current are confined to a small loop

A dc component of current is still drawn output of 15V supply, and flows past the control chips. Hence, return conductor size must be sufficiently large

Op-amp Pulsed Decoupling

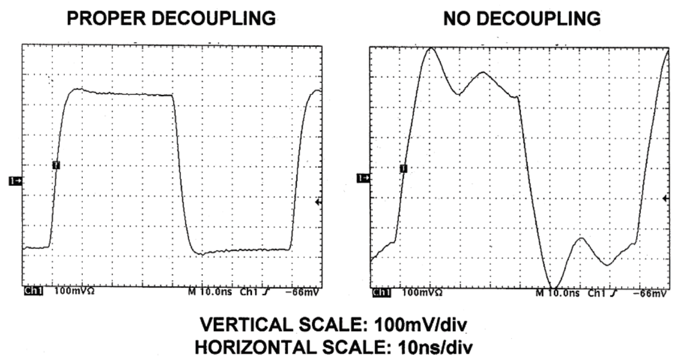
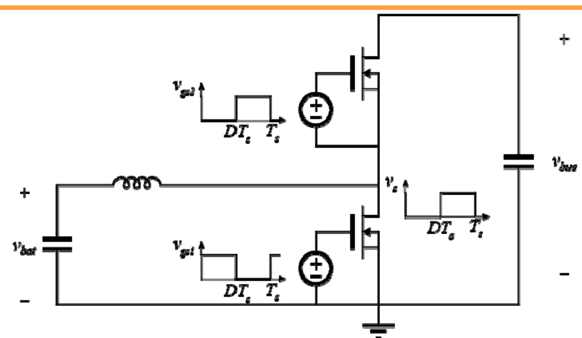


Figure 12.68: *Effects of Inadequate Decoupling on the Phase Response of the AD9631 Op Amp*

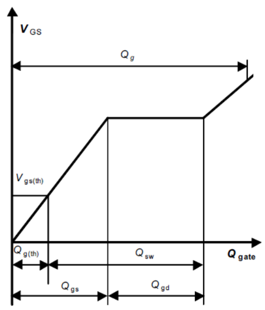
Half Bridge Gate Drive Waveforms

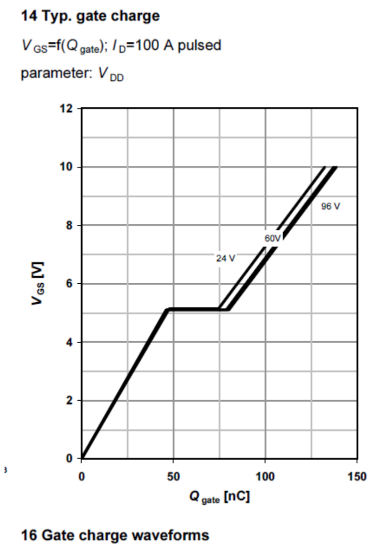


- Gate driver chip must implement v_{gs} waveforms
- Sources will have pulsating currents and need decoupling

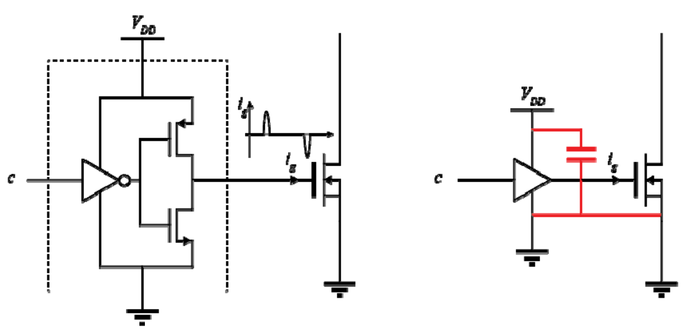
MOSFET Gate Charge

- Charge is supplied to both C_{gs} and C_{gd} in order to move gate voltage and switch MOSFET
- Would like to supply the charge in minimum time to quickly switch FET
- Results in high peak currents



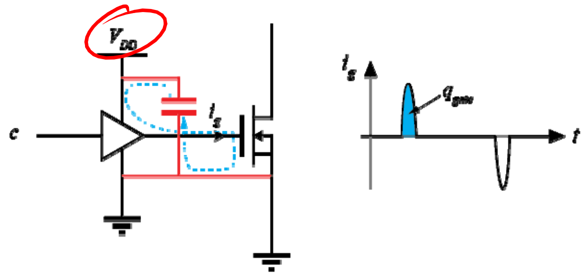


Gate Drive Implementation



- Gate driver is cascades back half-bridges of decreasing size to obtain quick rise times
- Reminder: keep loops which handle pulsating current small by decoupling and making close connections

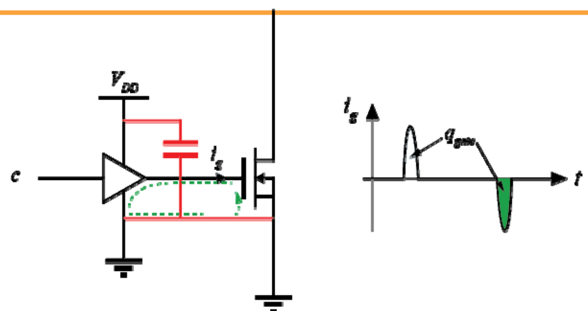
Capacitor Sizing Notes



$$\frac{q_{gate}}{\Delta V_{DD}} = C$$

- Area of current pulse is total charge supplied to gate of capacitor
- All charge must be supplied from gate drive decoupling capacitor

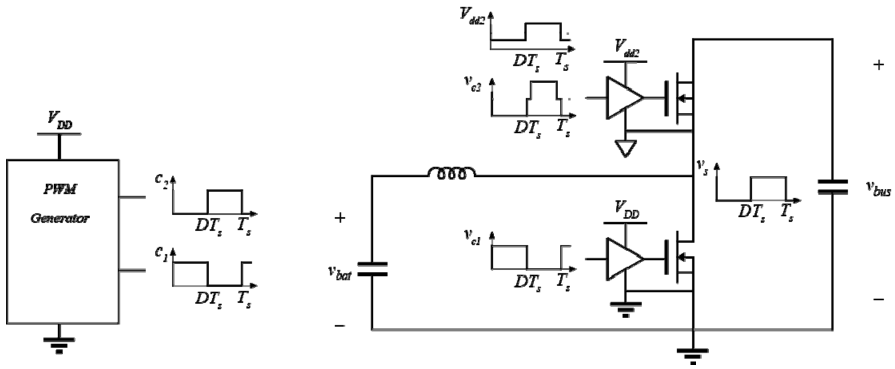
Gate Drive Losses



$$E_{loss} = q_{gate} V_{DD}$$
$$P_{sw,g} = E_{loss} f_s$$

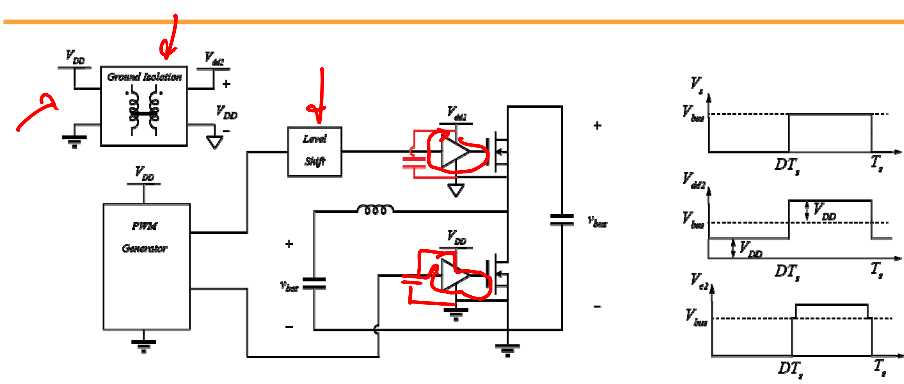
- Gate charge is supplied through driver resistance during switch turn-on
- Gate charge is dissipated in gate driver on switch turn-off

High Side Signal Ground

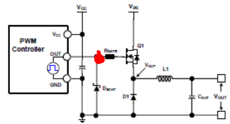
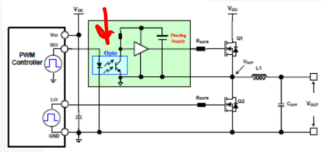
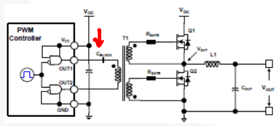
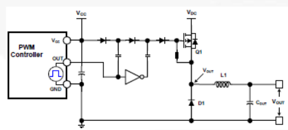
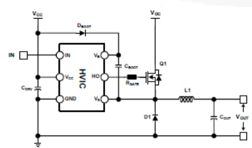


- Gate driver chip must implement v_{gs} waveforms
- Issue: source of Q_2 is not grounded

Generating Floating Supply



- Isolated supplies sometimes used; Isolated DC-DC, batteries
- Bootstrap concept: capacitor can be charged when V_s is low, then switched

Direct Drive		Easiest high-side application the MOSFEF and can be driven directly by the PWM controller or by a ground referenced driver, but it must meet two conditions, as follows: $V_{CC} < V_{GS,MAX}$ and $V_{DC} < V_{CC} - V_{GS,Miller}$
Floating Supply Gate Drive		Cost impact of isolated supply is significant. Opto-coupler tends to be relatively expensive, limited in bandwidth, and noise sensitive.
Transformer Coupled Drive		Gives full gate control for an indefinite period of time, but is somewhat limited in switching performance. This can be improved with added complexity.
Charge Pump Drive		The turn-on times tend to be long for switching applications. Inefficiencies in the voltage multiplication circuit may require more than low stages of pumping.
Bootstrap Drive		Simple and inexpensive with limitations; such as, the duty cycle and on-time are both constrained by the need to refresh the bootstrap capacitor. Requires level shift, with the associated difficulties. *Fairchild Semi App Note AN-6076*

LM5104 Gate Driver

8.2 Typical Application

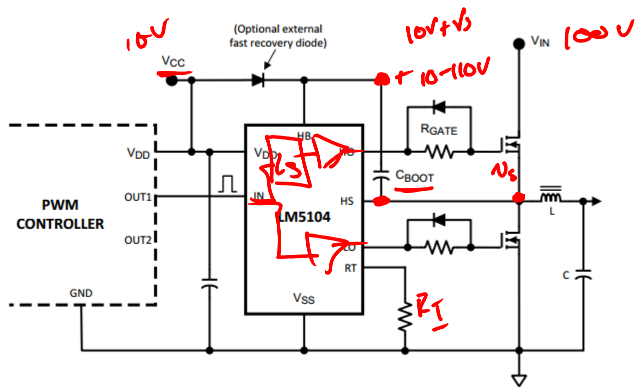
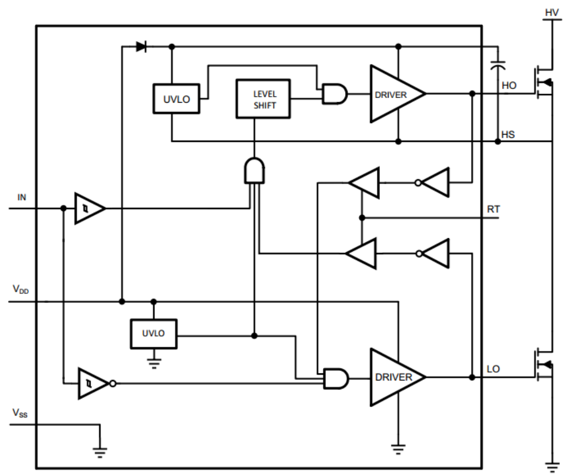


Figure 15. LM5104 Driving MOSFETs Connected in Synchronous Buck Configuration

LM5104 Internal Block Diagram

7.2 Functional Block Diagram



Bootstrap Diode Loss

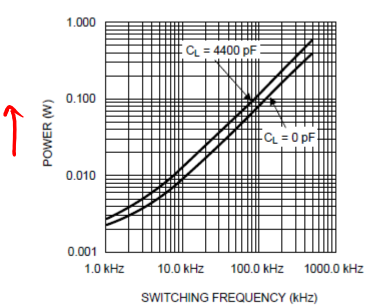
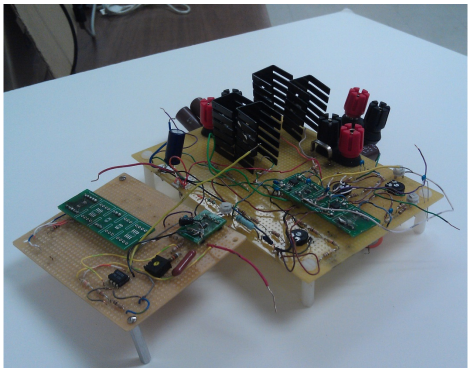


Figure 5. Diode Power Dissipation V_{IN} = 80V

- Conduction losses due to pulsating currents are relatively small
- Switching losses are significant
- Diode capacitance and reverse recovery play a role

Wiring Advice

- Take the time to wire board cleanly



- Very difficult to find a short in sloppy-wired circuit