TSTE19 Power Electronics

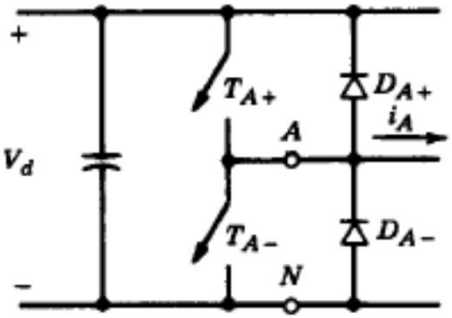
- Lecture 9
- Tomas Jonsson
- ISY/EKS

Outline

- Blanking time
- Gate and base driver circuits
- Analysis of full-bridge switching (Lab 2 prep)

Blanking time effects

- Avoid cross-conduction by delay of device turn-on (blanking time)
- Polarity dependent
- Independent on output magnitude



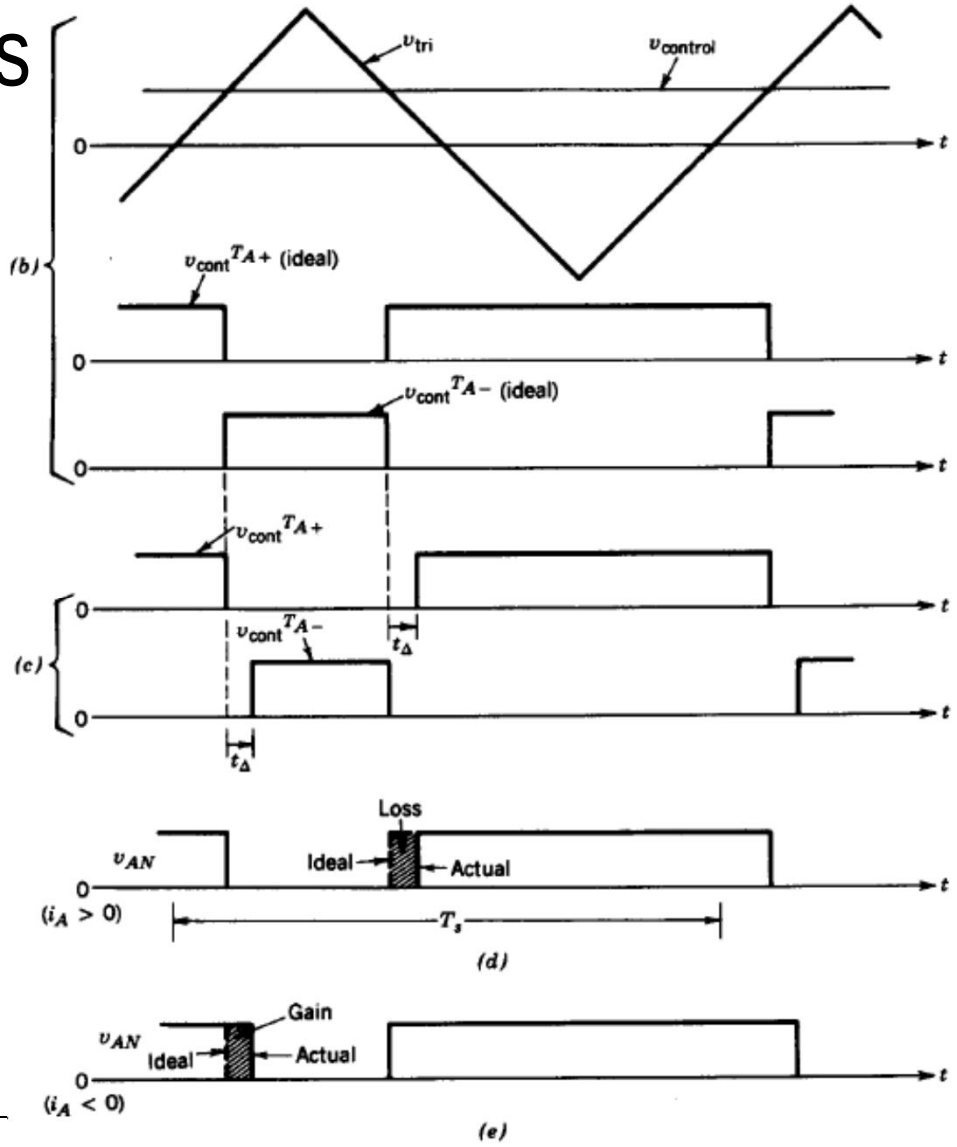
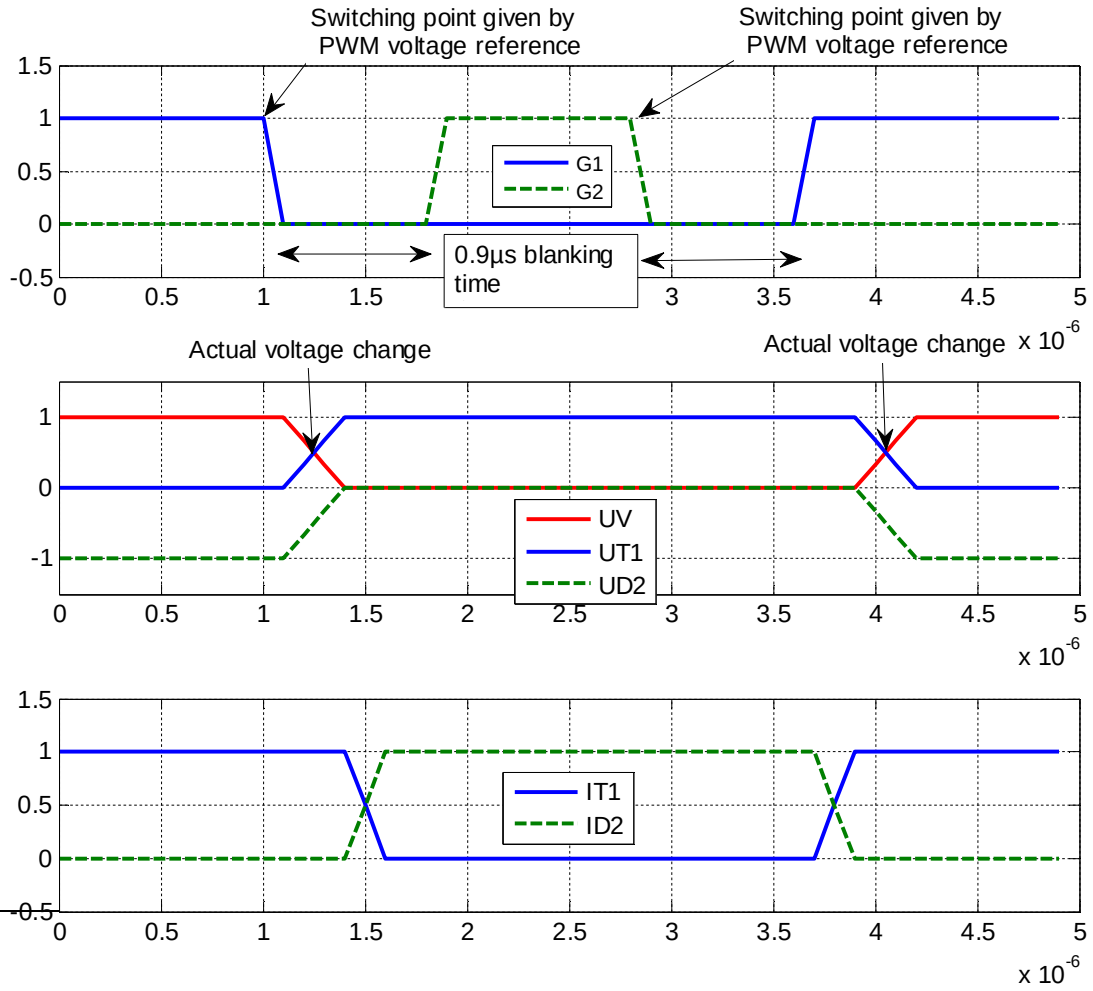


Figure 8-31 Effect of blanking time t_Δ.

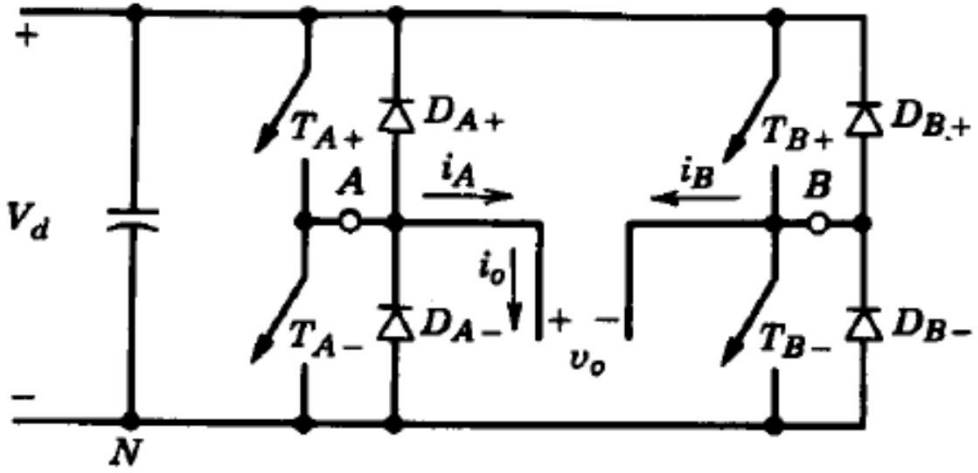
Blanking time effects 2

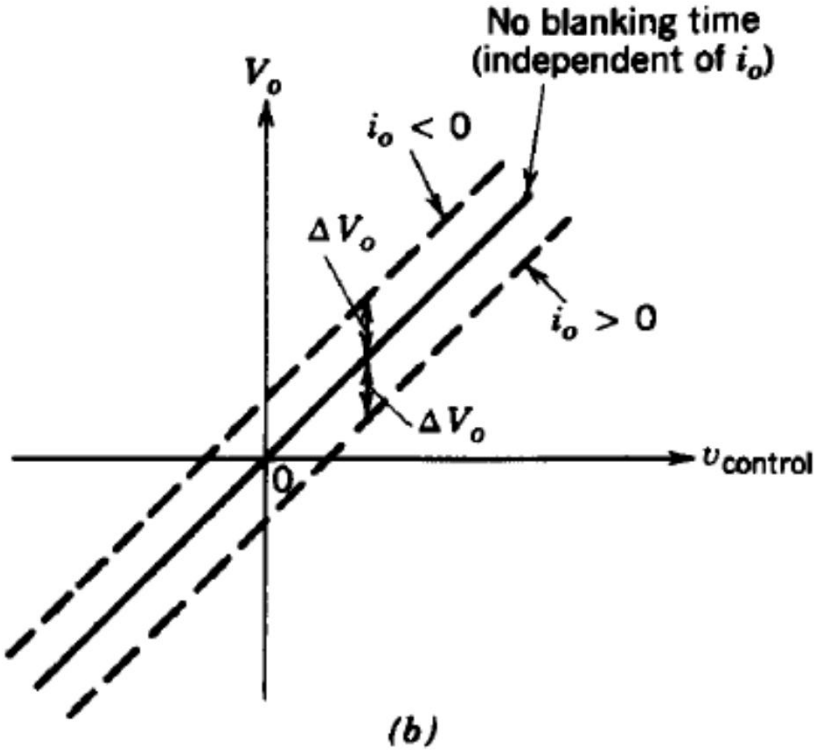
- Switching points defined by the PWM reference and triangular carrier crossing
- Actual voltage change delayed by blanking time



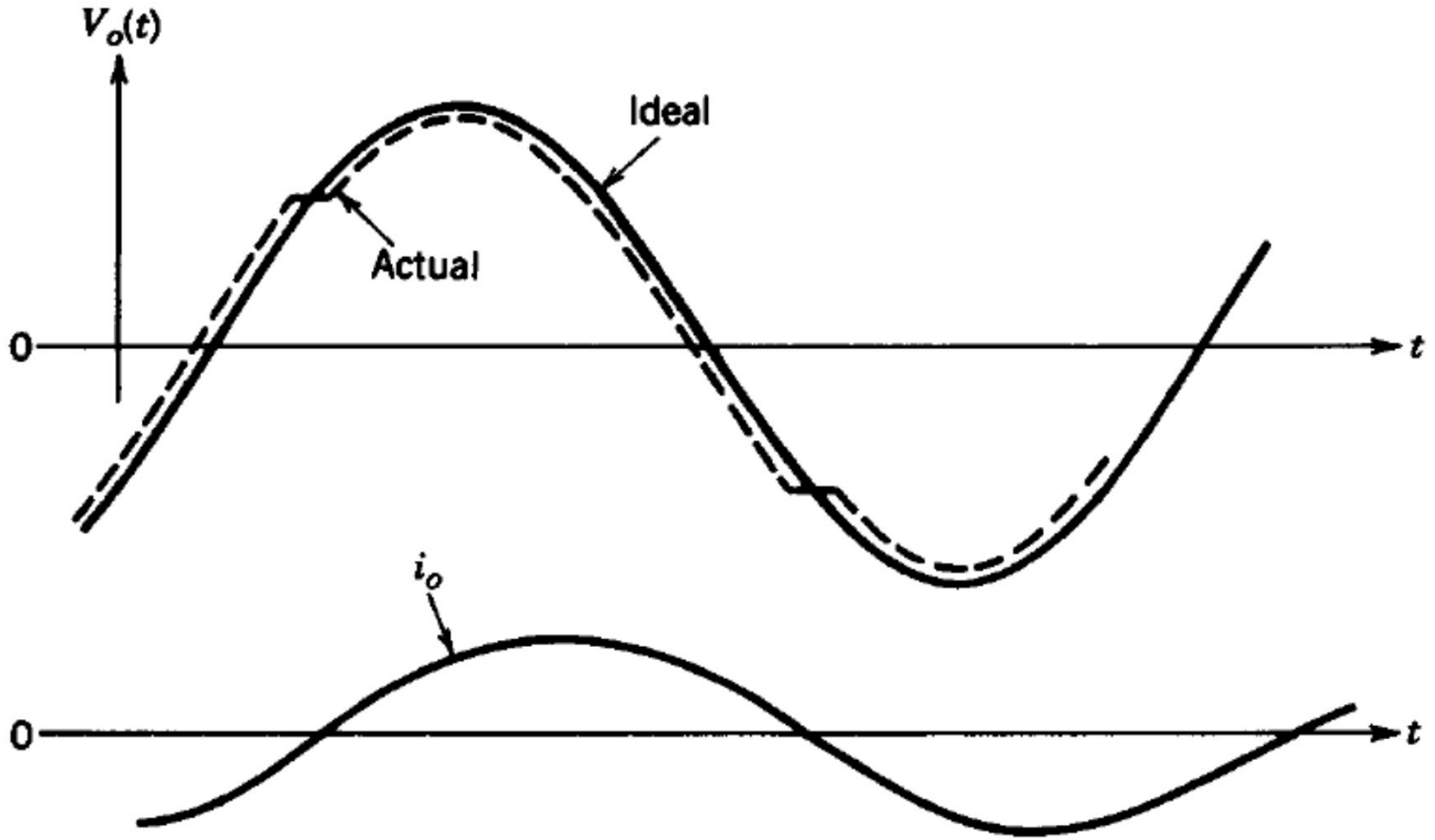
Blanking time effect on Vo

- Current polarity dictates error polarity





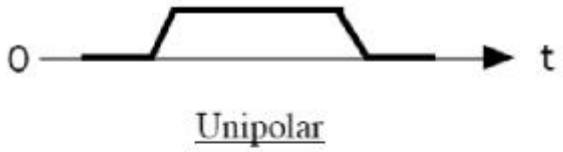
Blanking effect on sinusoidal output



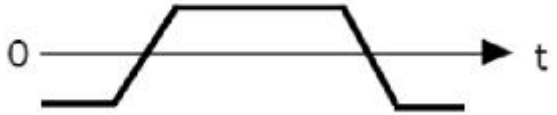
Gate and base driving circuits

- Minimize turn-on and turn-off times
  - Avoid spending time in active region with large V and I
- Controllable switches have often low current or voltage amplification factors
  - B in range of 5-10 for power BJTs
  - Must supply enough energy to keep switch on
- Protect from overvoltage and/or overcurrent conditions
- Electric insulation from control logic

Driver circuit design



Unipolar

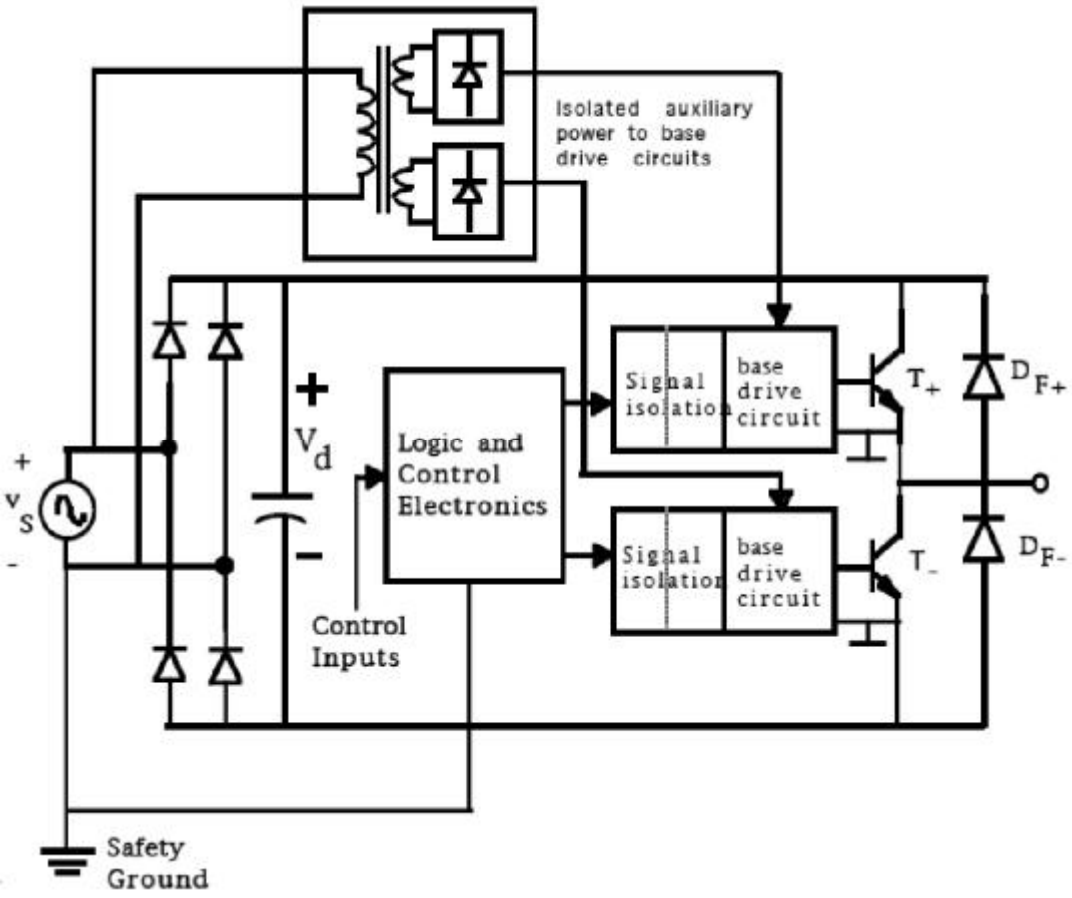


Bipolar

- Driver circuit topologies
  - Unipolar vs bipolar output signal to gate
  - AC or DC coupled
  - Shunt or series with power switch
- Gate current magnitude
  - Large I_{gon} shorten turn-on time but lengthen turn
  - Large I_{goff} shorten turn-off time but lengthen turn-on time
- Overcurrents, blanking time in bridge configurations
- Waveshaping for better switch performance
  - di/dt for diode turn-off
  - dv/dt
  - Speedup capacitors

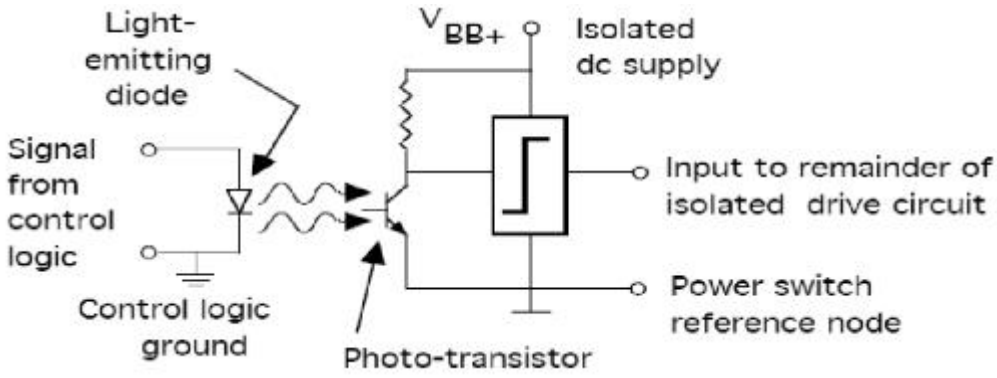
Electrical isolation of drive circuit

- V_d – potential varies with input $v_S(t)$ relative to safety ground
- Signal isolation to base drive circuit necessary

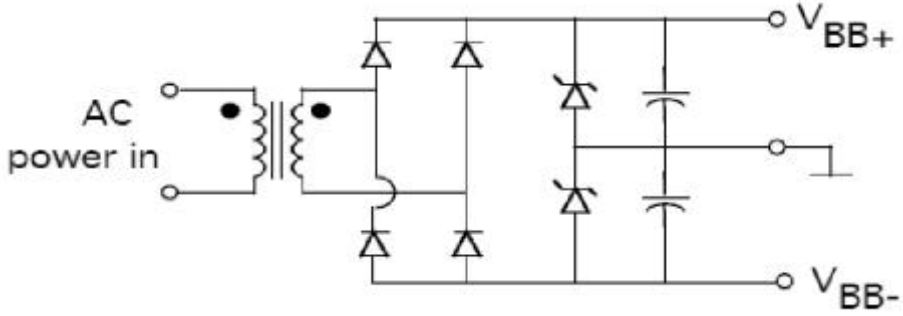


Isolation methods for gate drive

- Optical isolation of control signals
  - Opto-coupler
  - Optical fiber

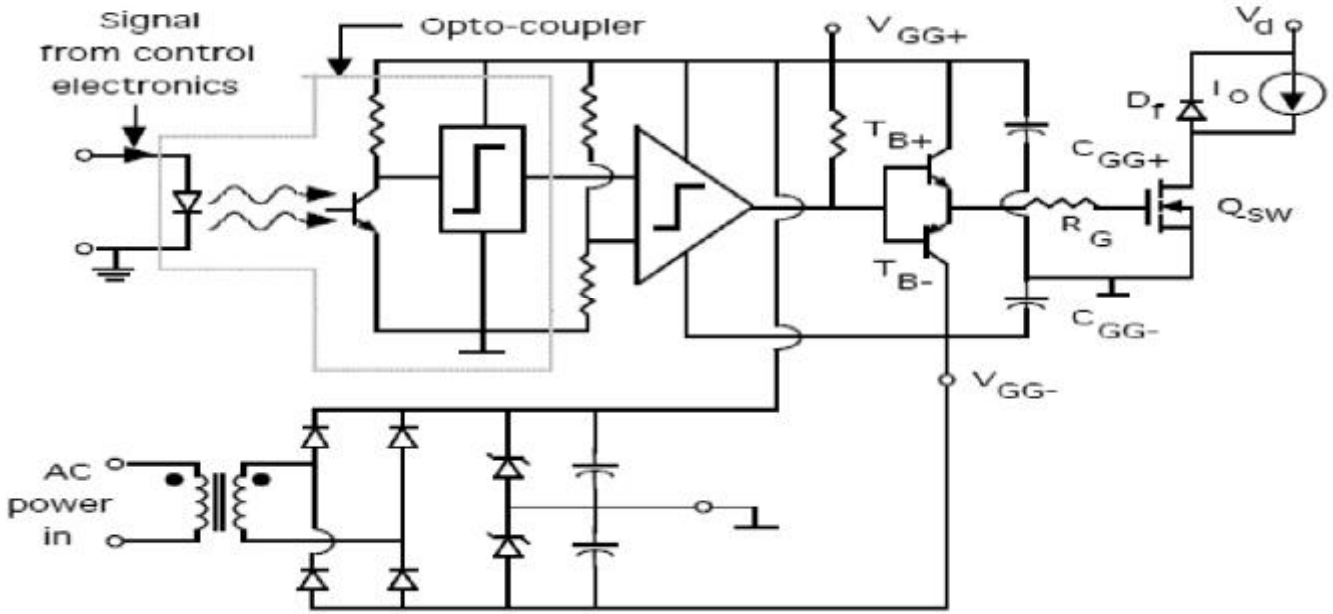


- Transformer isolation
  - Isolated dc power supply for drive circuits



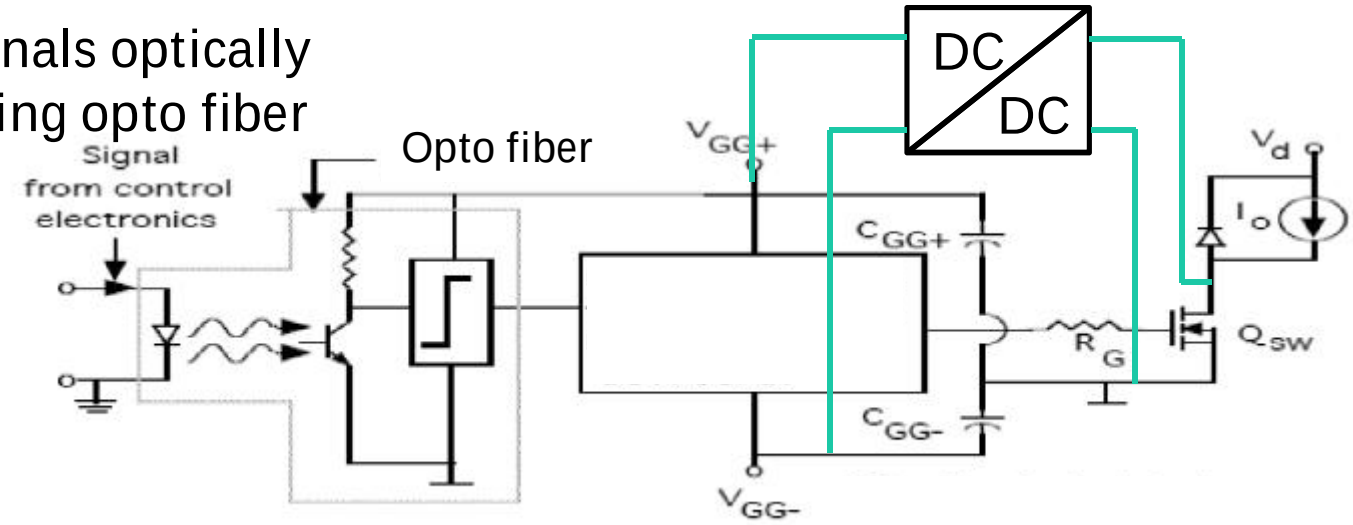
- Independent supply
  - Supply derived from voltage or current locally at the switch

Optocoupler isolated MOSFET



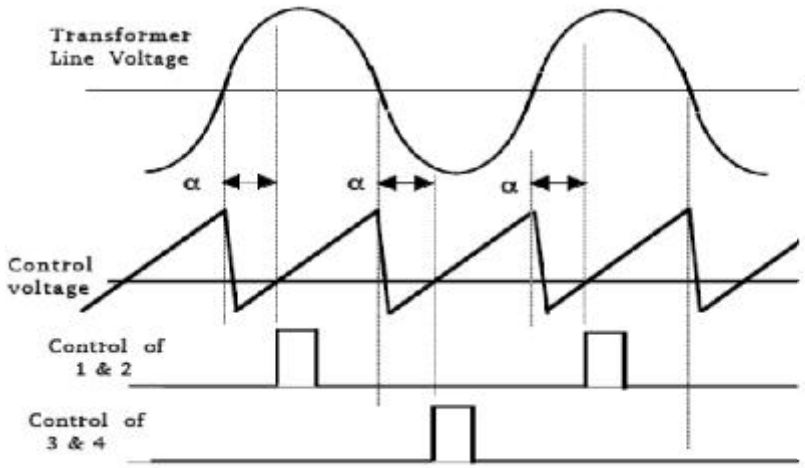
Independent gate drive supply

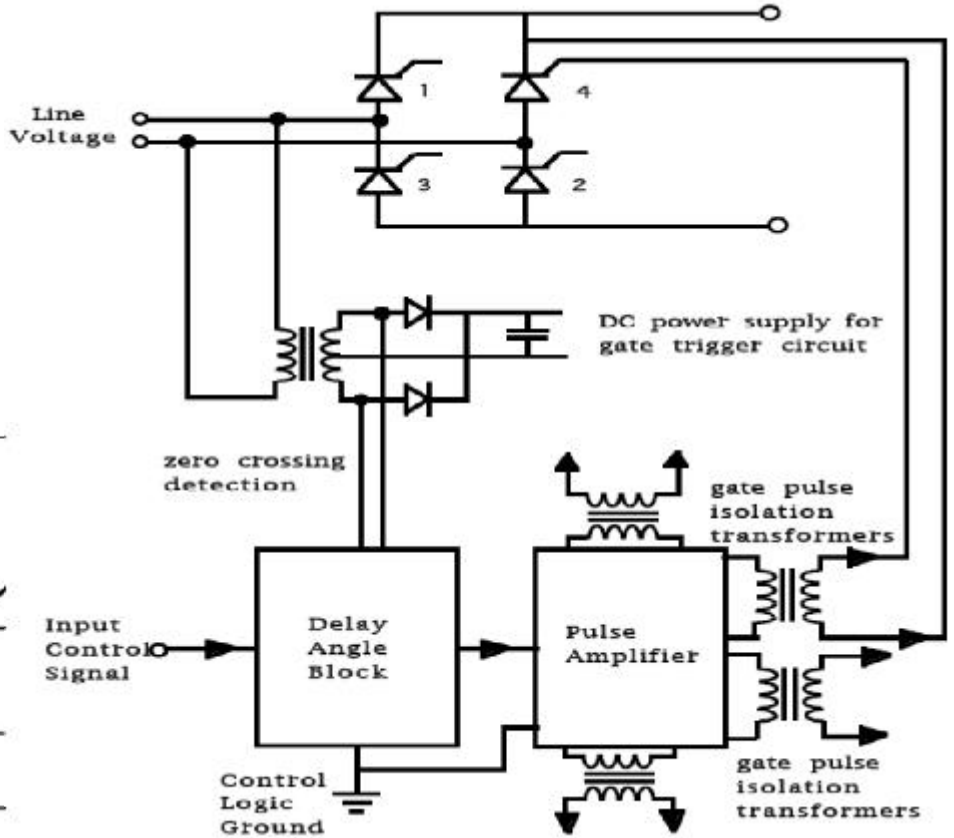
- Independent gate drive supply for high isolation voltage requirements
  - Supply derived from voltage across Q_{sw}
- Control signals optically isolated using opto fiber



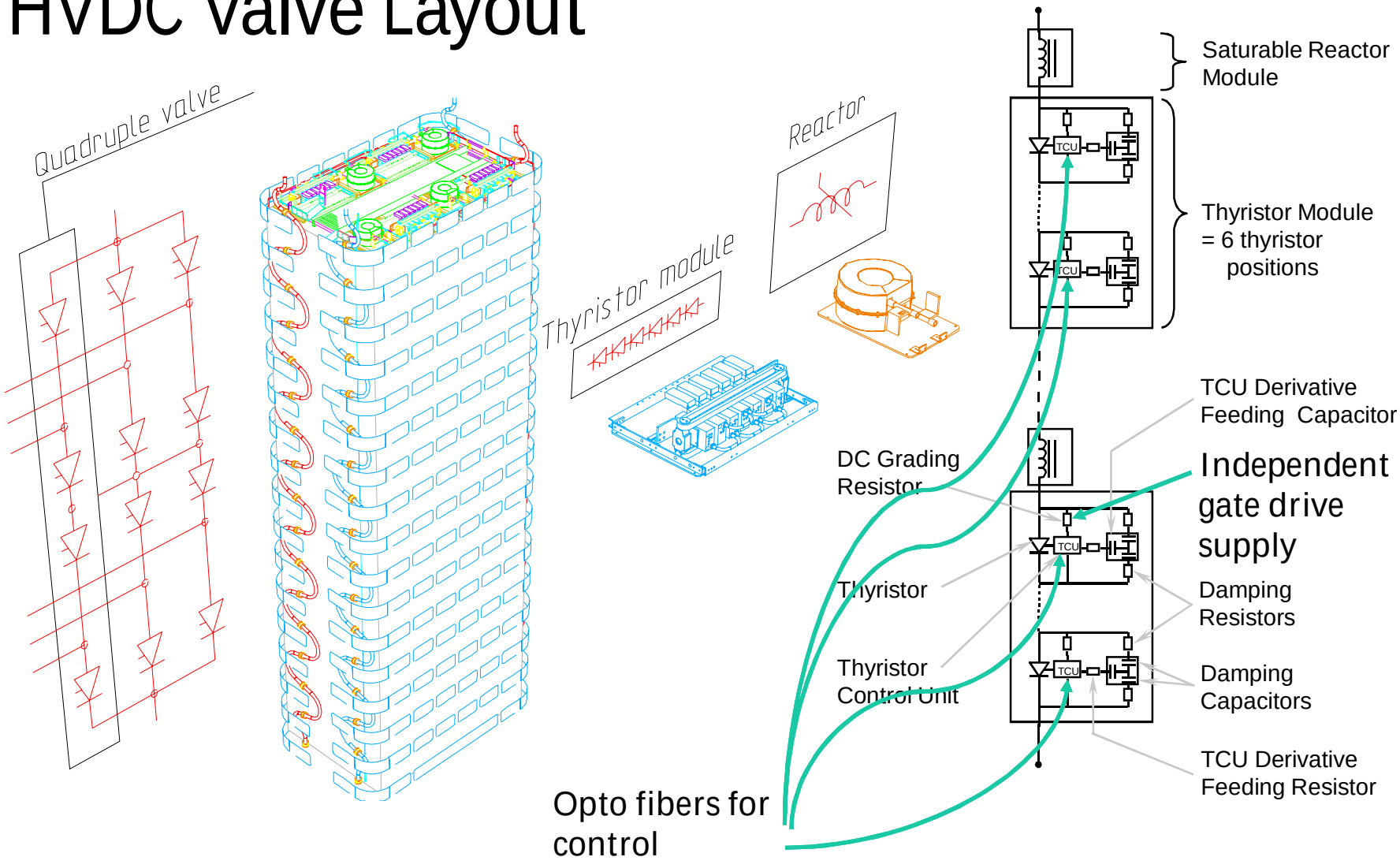
Thyristor gate drive circuit

- Gate pulses through pulse isolation transformers



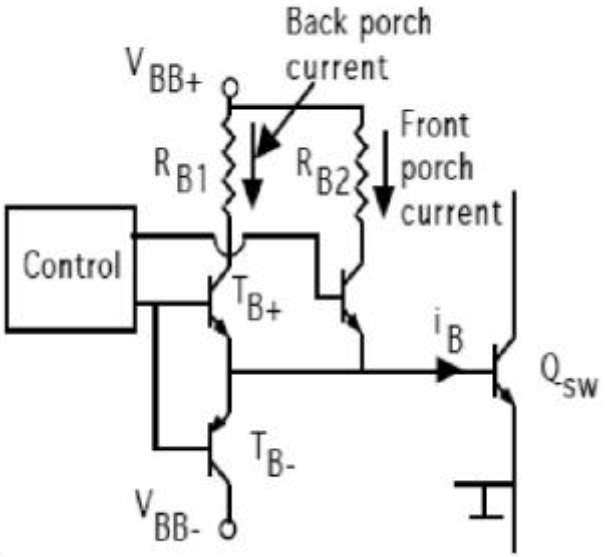


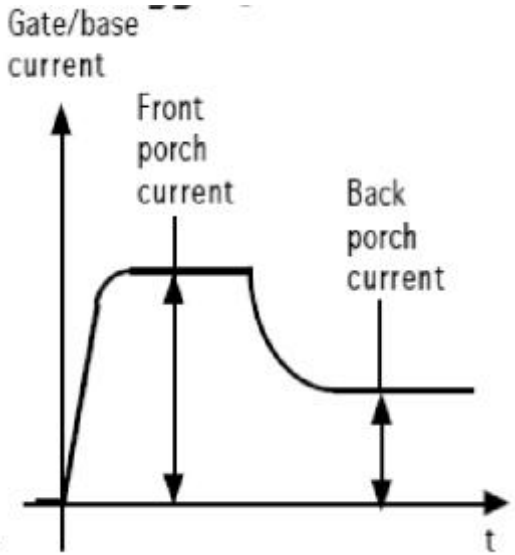
HVDC Valve Layout



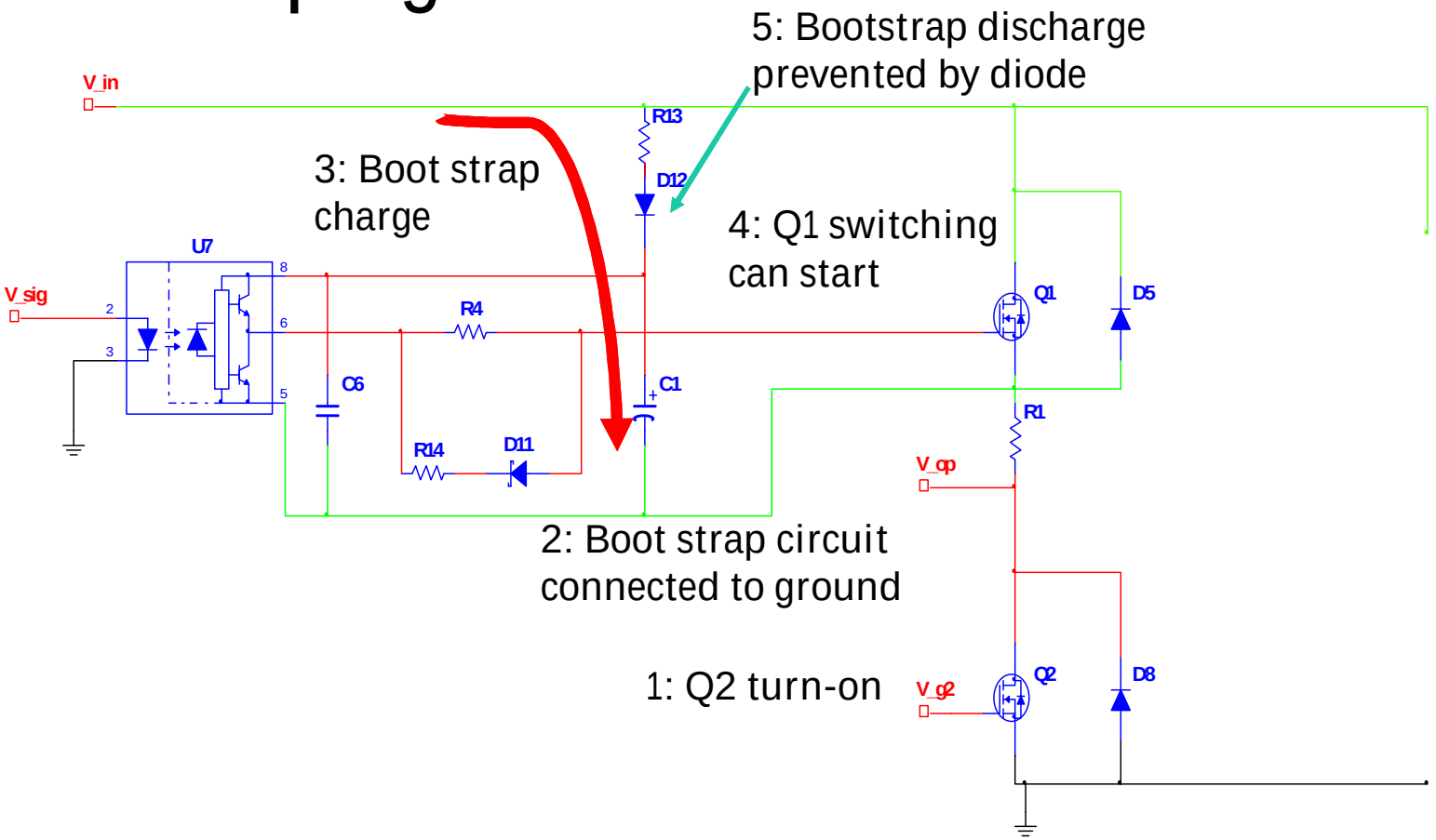
Drive circuit waveshaping

- Drive turn-on harder,
  then reduce base current at end of pulse
  - Increase turn-on speed, without increasing turn-off time

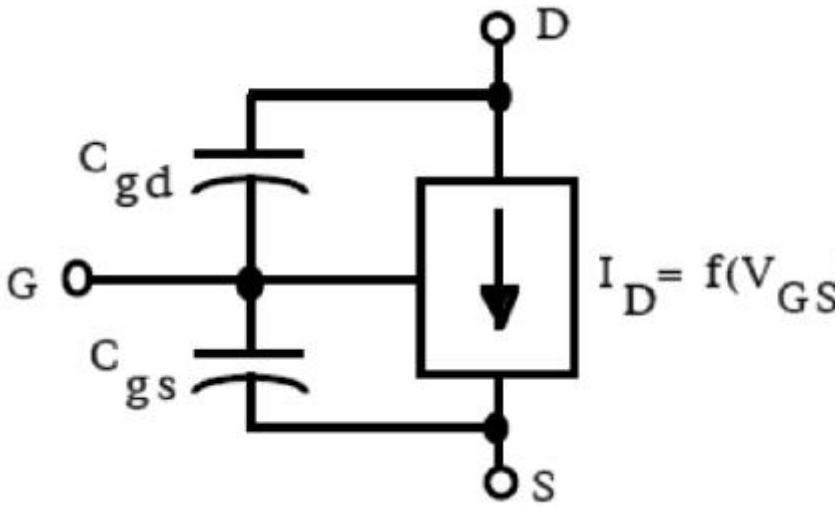


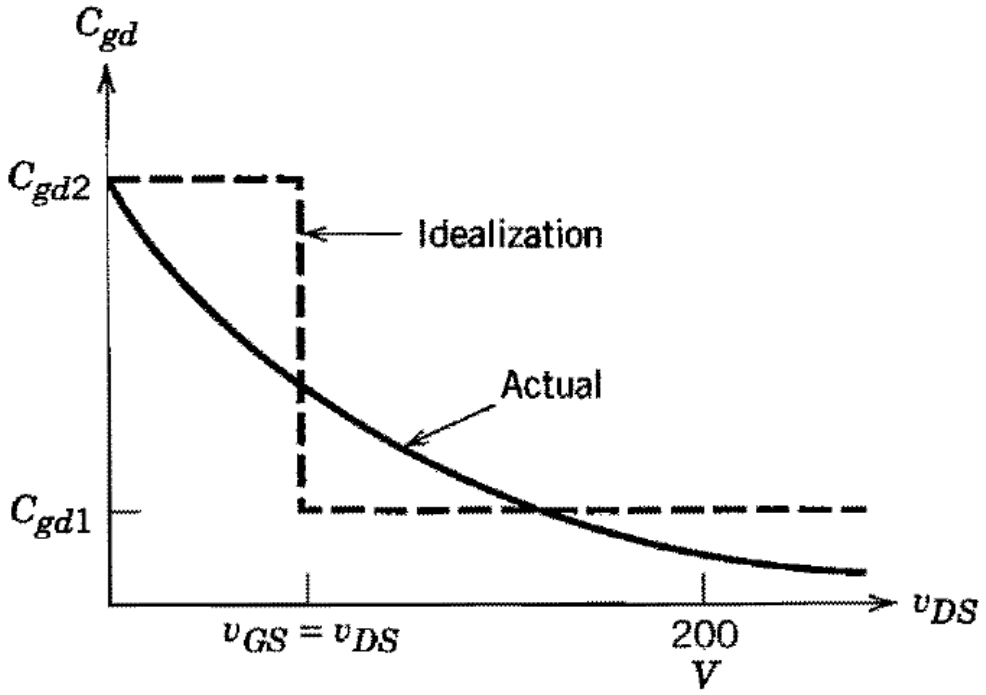


Bootstraping



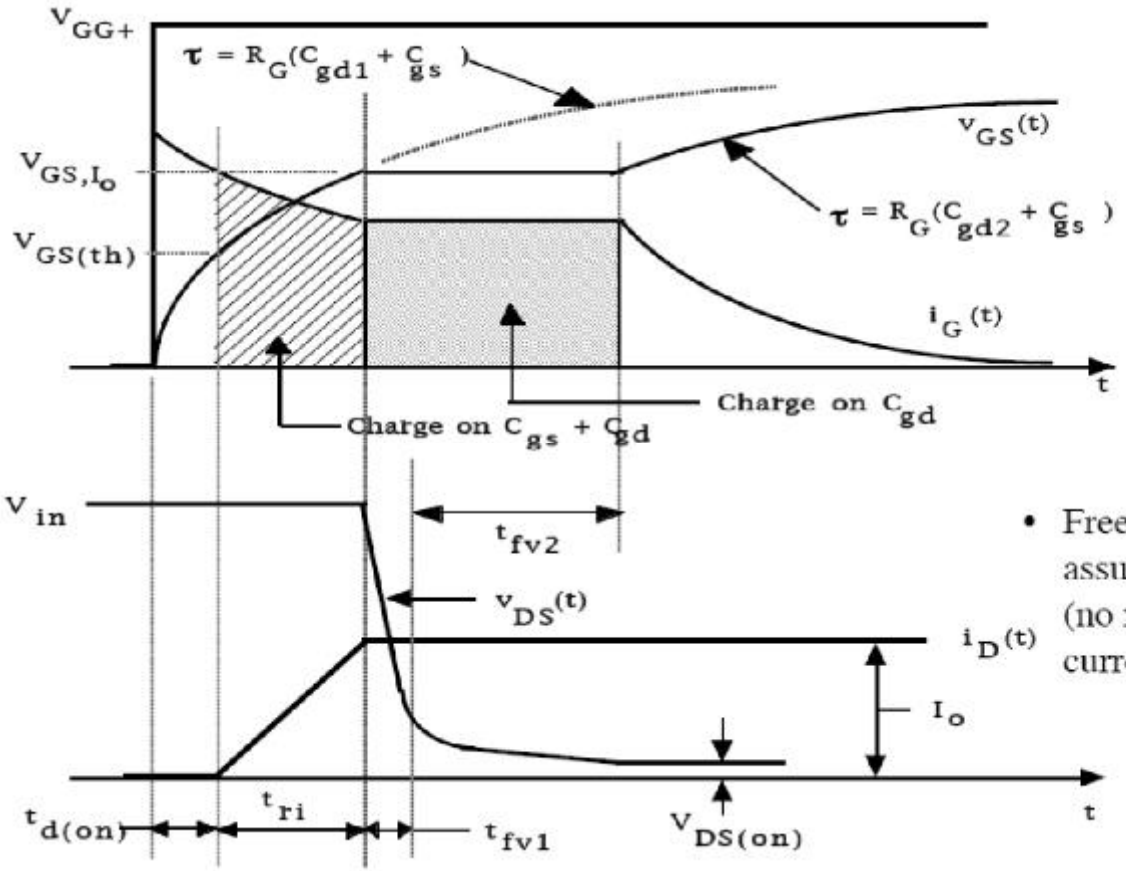
MOSFET turn-on/turn-off equivalent





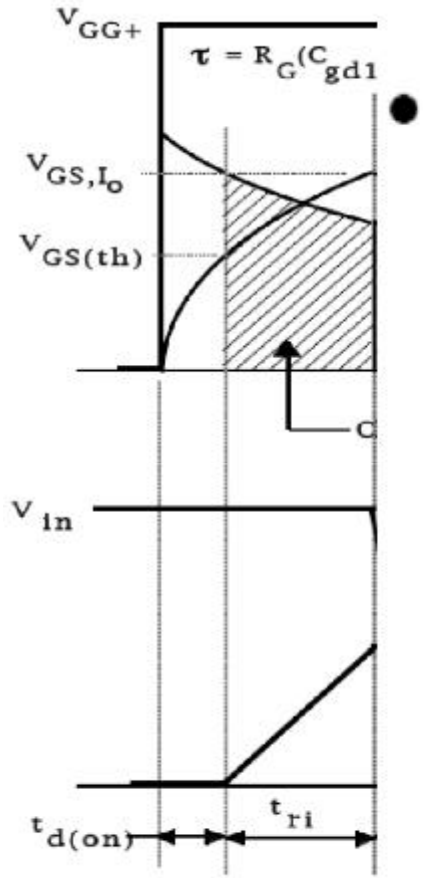
- MOSFET equivalent circuit valid for off-state (cutoff) and active region operation.

MOSFET (IGBT) turn-on wave forms

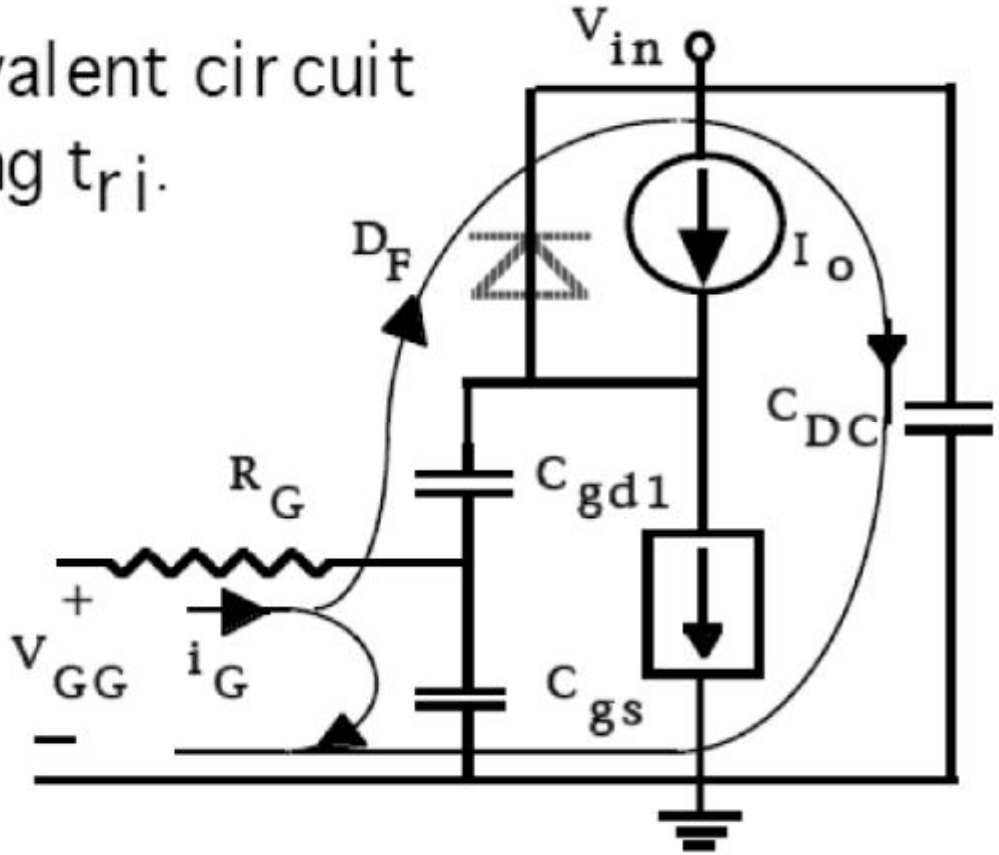


- Free-wheeling diode assumed to be ideal. (no reverse recovery current).

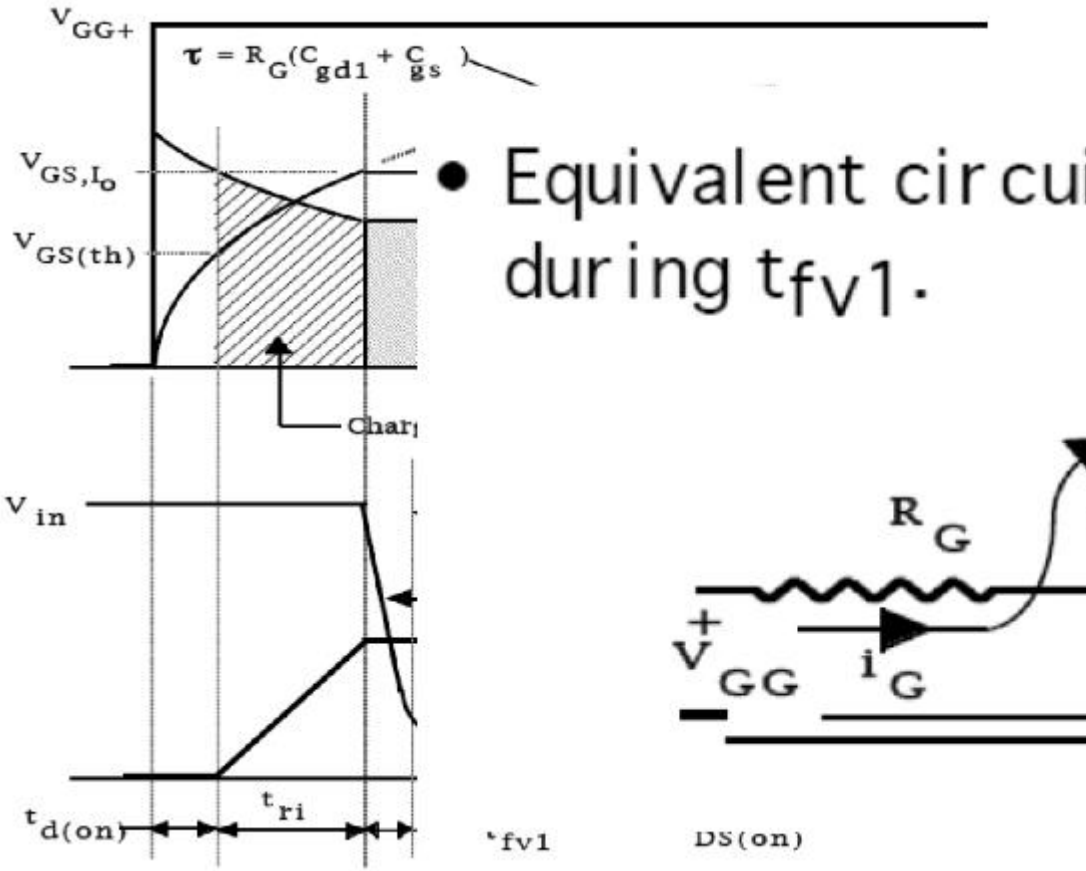
MOSFET (IGBT) turn-on wave forms



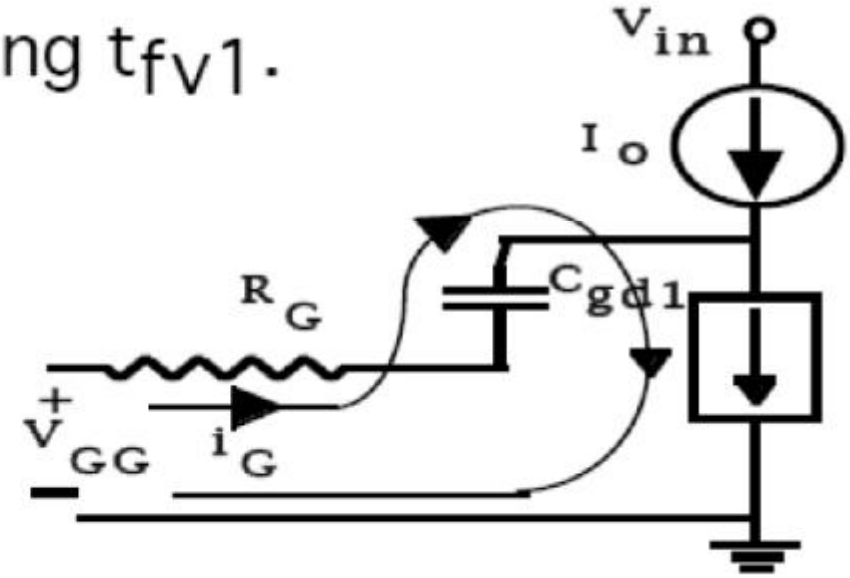
- Equivalent circuit during t_{ri}.



MOSFET (IGBT) turn-on wave forms

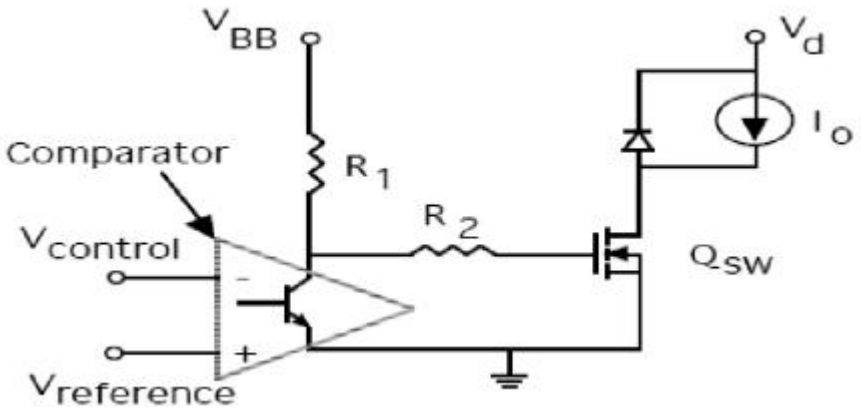


- Equivalent circuit during t_{fv1}.

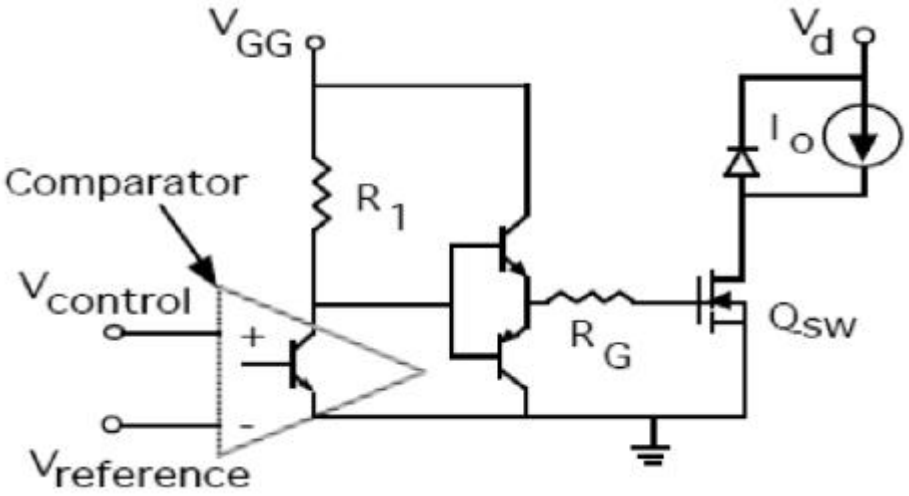


Unipolar DC-coupled driver MOSFET examples

- Simple MOSFET gate drive
  - Gate have large parasitic capacitance
  - R_1 large due to V_{BB}/R_1 flowing when switch off
  - R_1 limit turn-on time

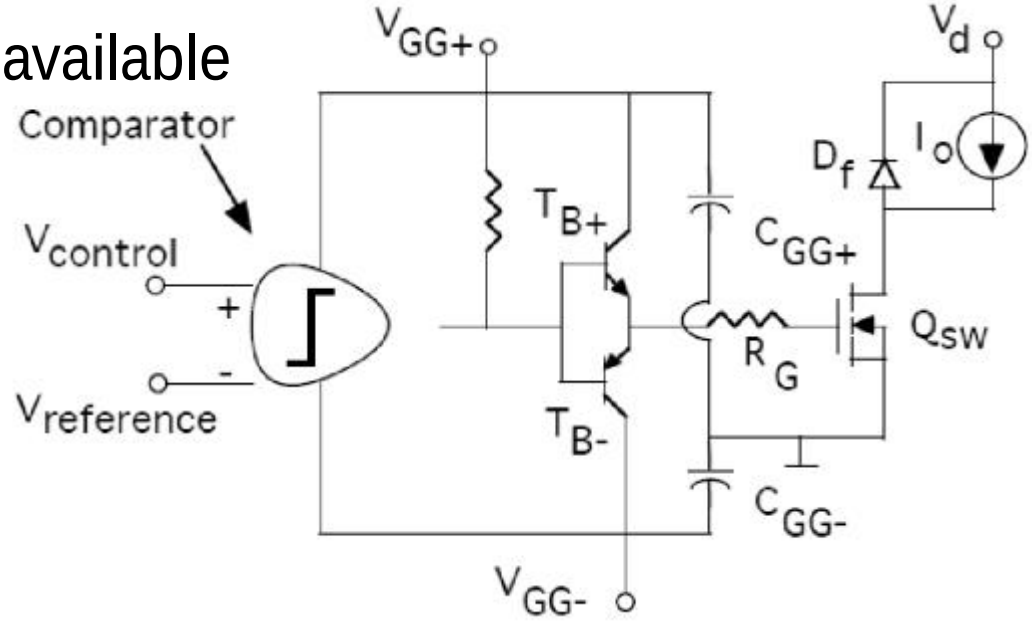


- npn-pnp totem-pole stack
  - R_G can be small, only used to charge/discharge parasitic capacitance in switch
  - Integrated circuits available with same function

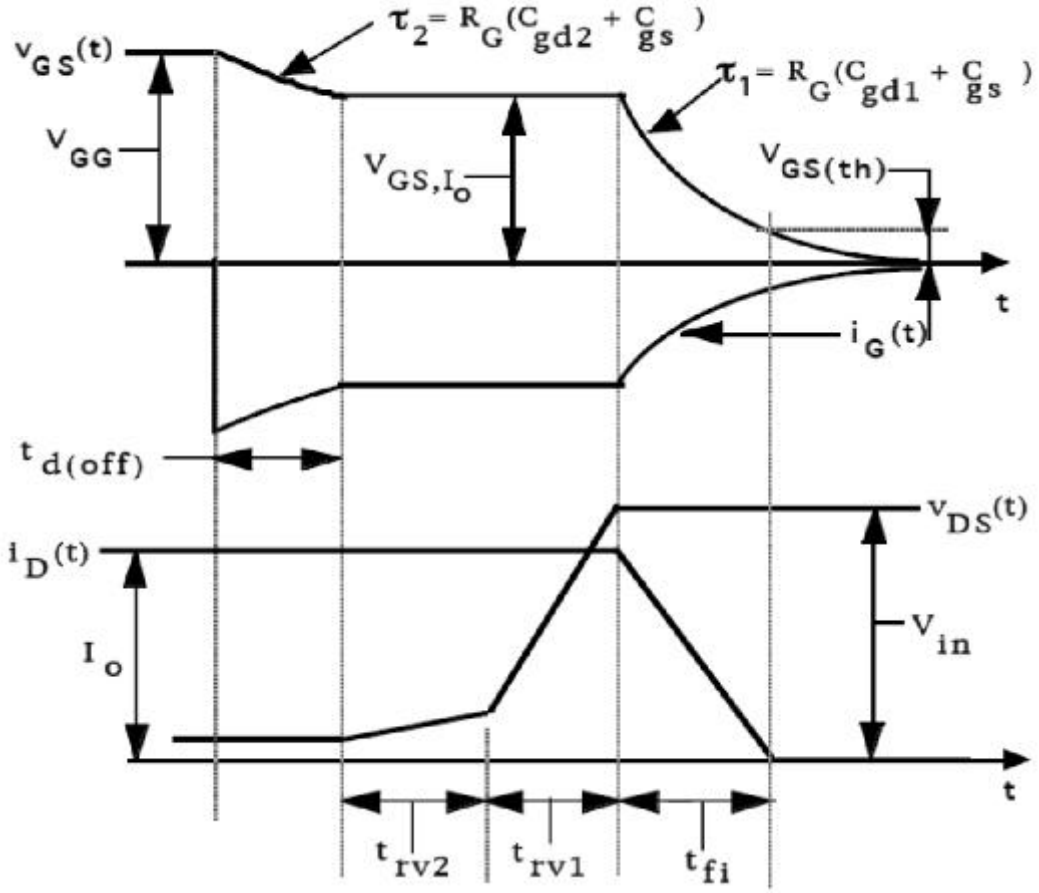


Bipolar DC-coupled Driver MOSFET example

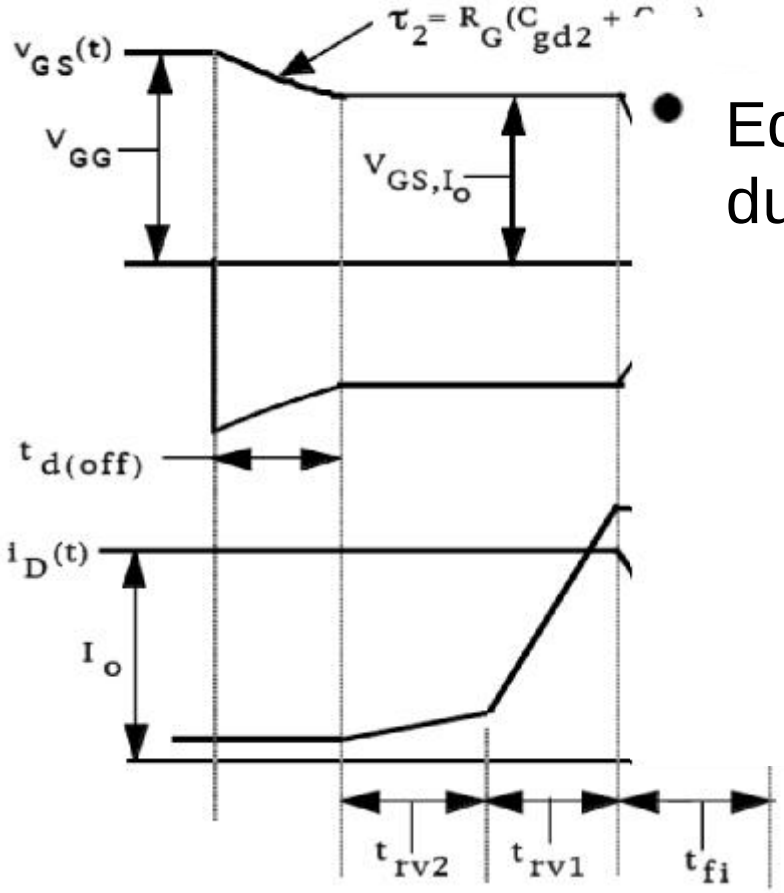
- T_{B+} and T_{B-} help charge/discharge gate capacitance of Q_{SW}
- R_G can be small
- Integrated circuits also available



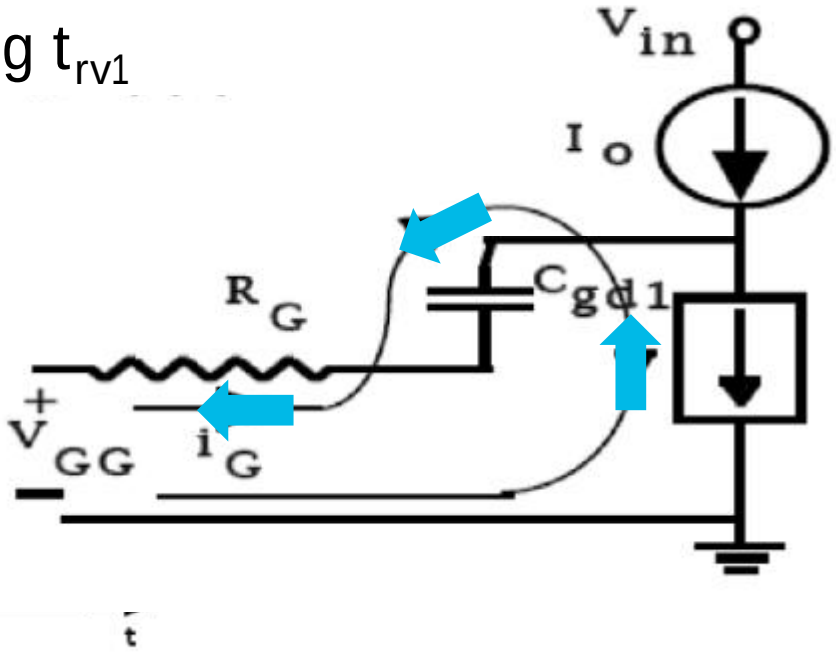
MOSFET (IGBT) turn-off wave forms



MOSFET (IGBT) turn-off wave forms

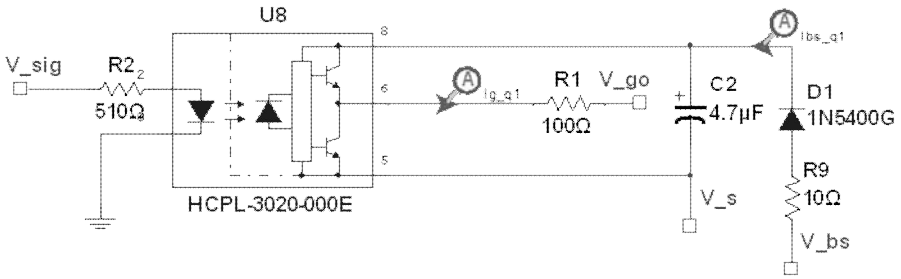


Equivalent circuit during t_{rv1}

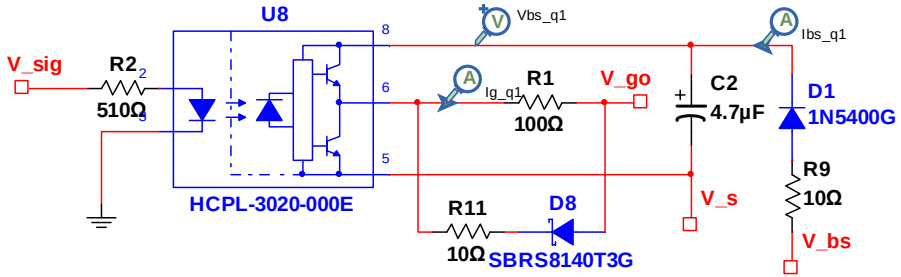


Gate resistance control

- Separate R_{gon} and R_{goff}
- Reduced R_{goff} to prevent paracitic turn-on at high dv/dt



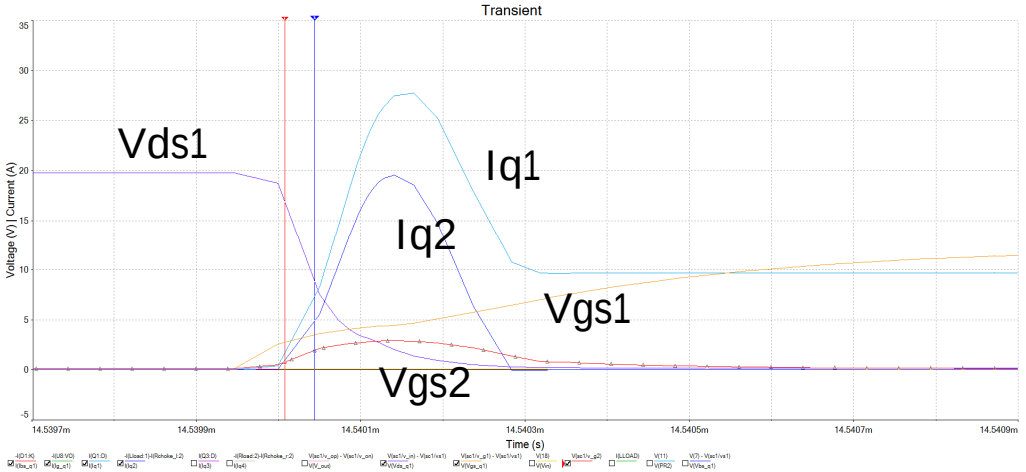
R_g=100 ohm both for turn-on and turn-off



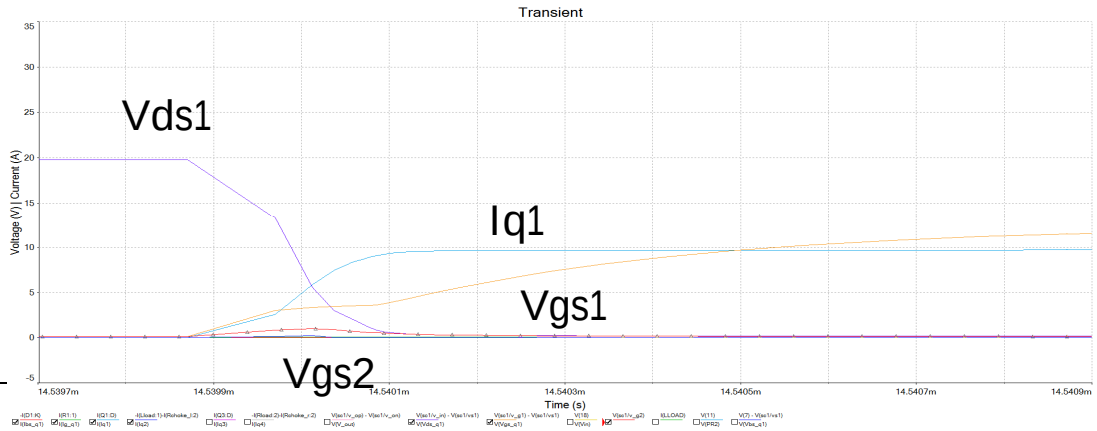
R_g=100 ohm for turn-on and
10 ohm for turn-off

Gate resistance control 2

- R_{gon}=100 ohm, R_{goff}=100 ohm

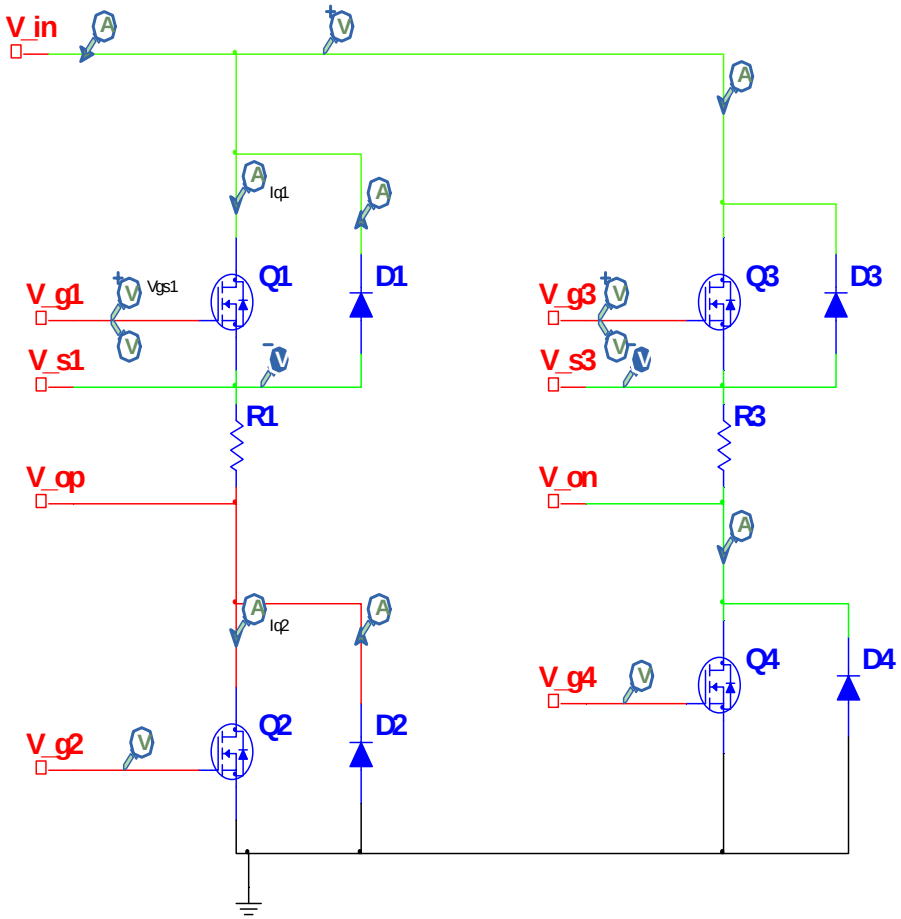


- R_{gon}=100 ohm, R_{goff}=10 ohm schottky SBRS8140

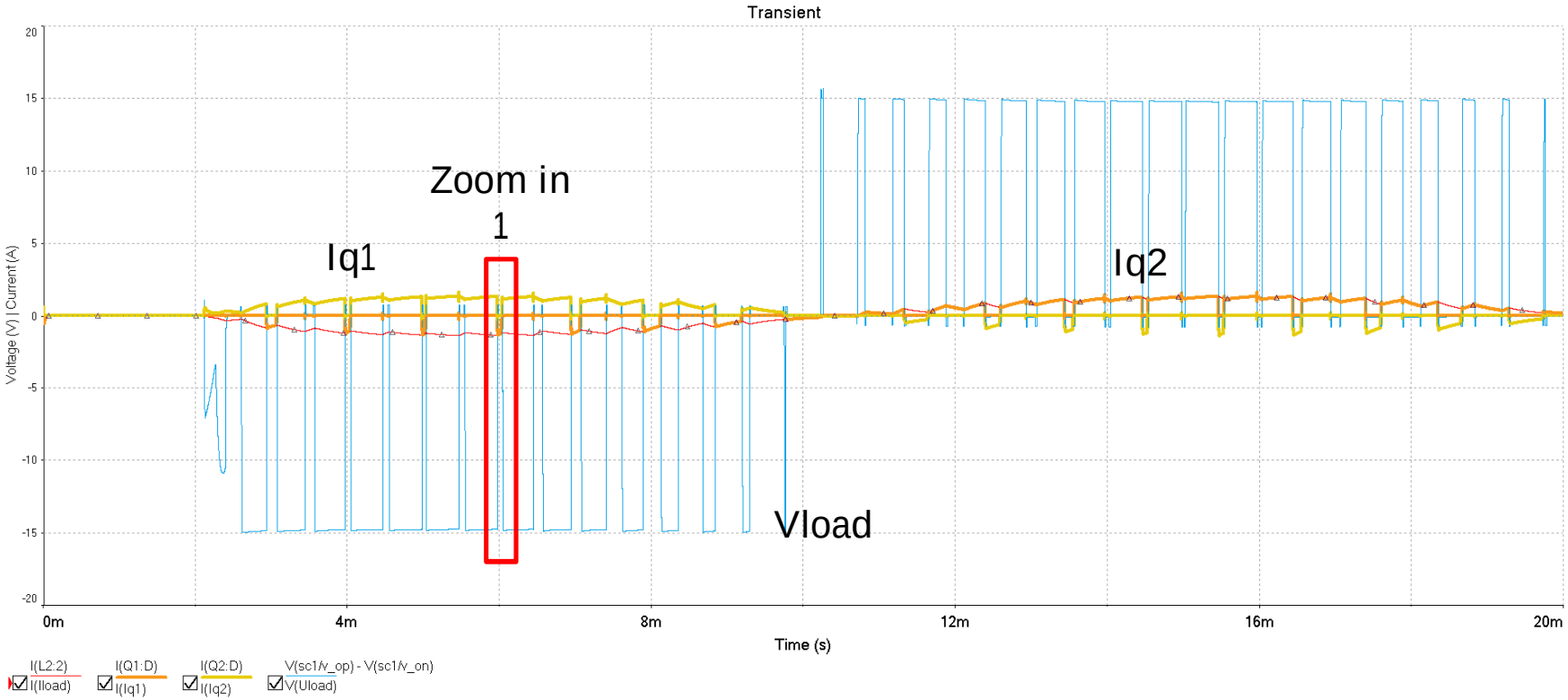


Full-bridge inverter

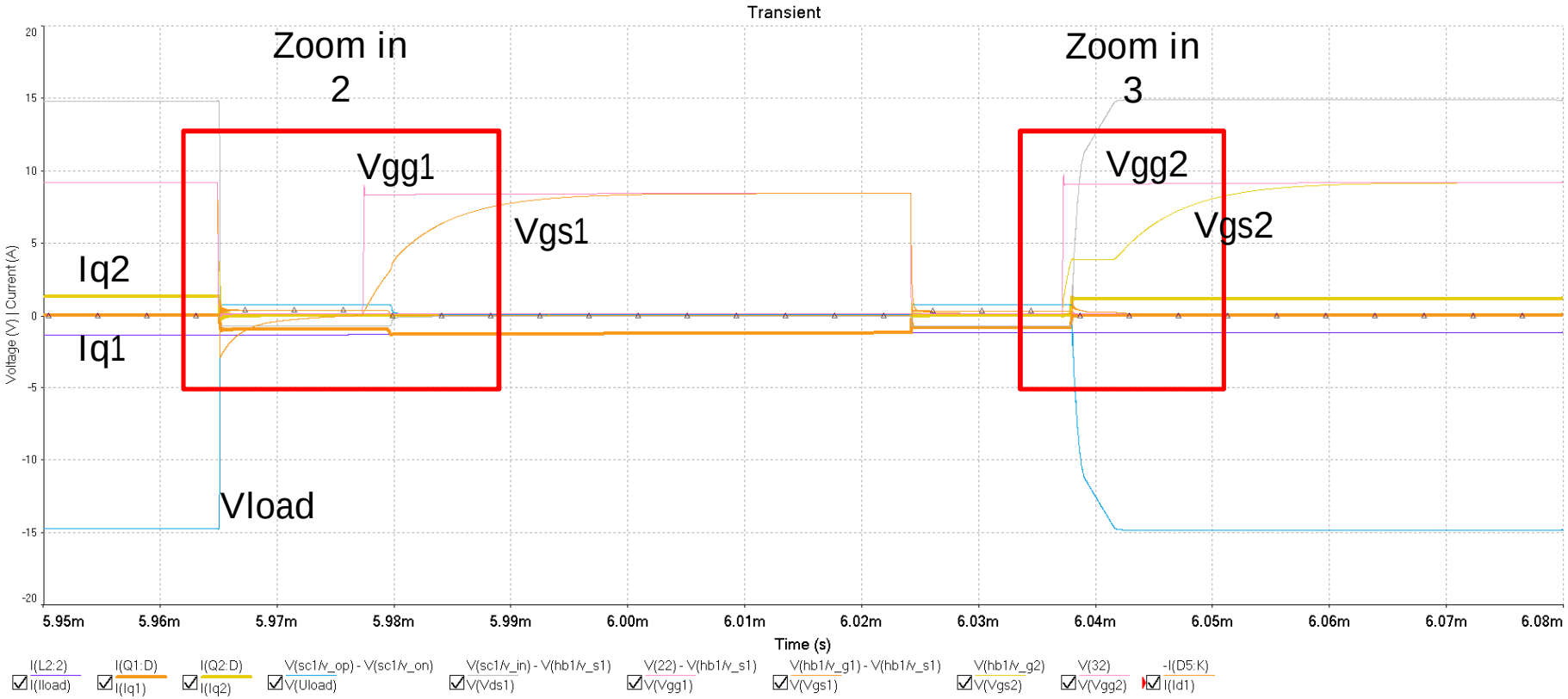
- Output voltage:
  Vload = V_op – V_on
- Load: Resistance and inductance



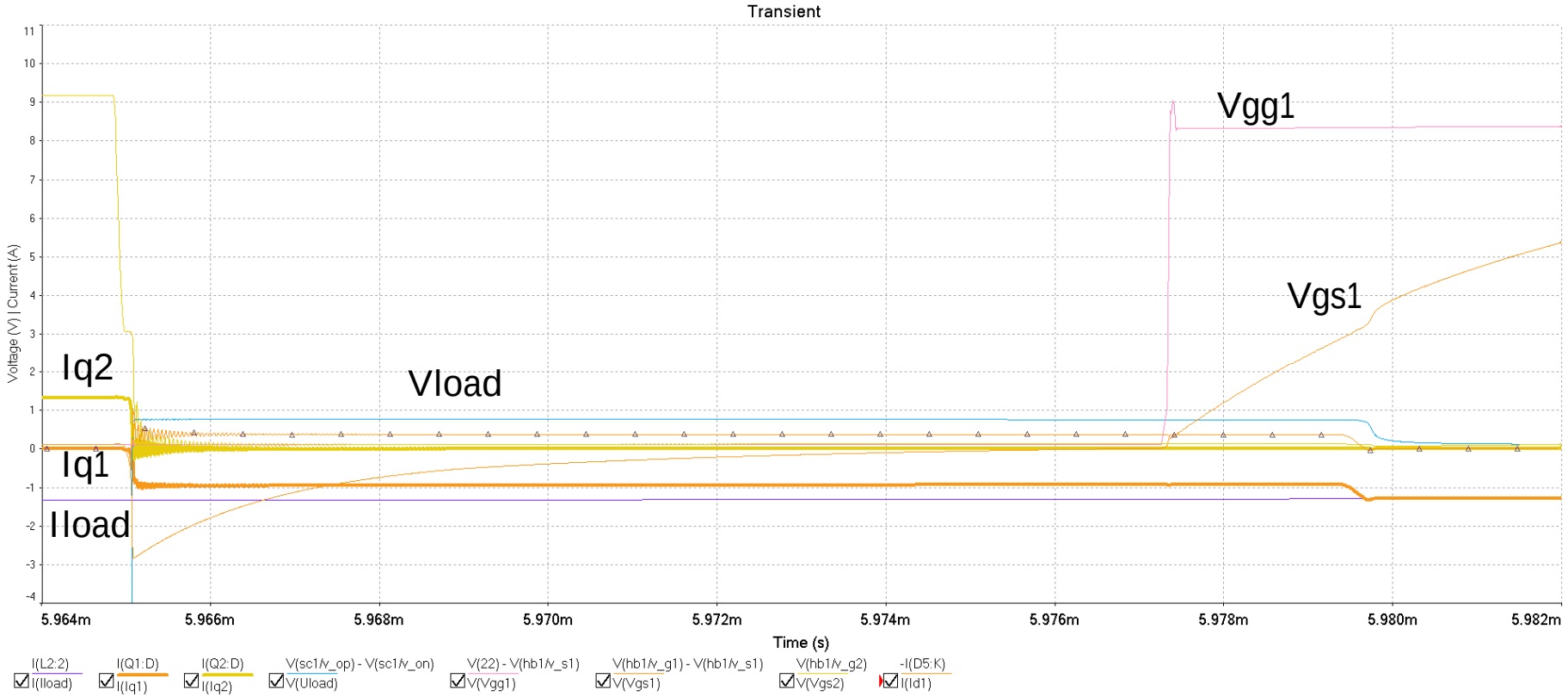
Unipolar switching, full 20ms cycle



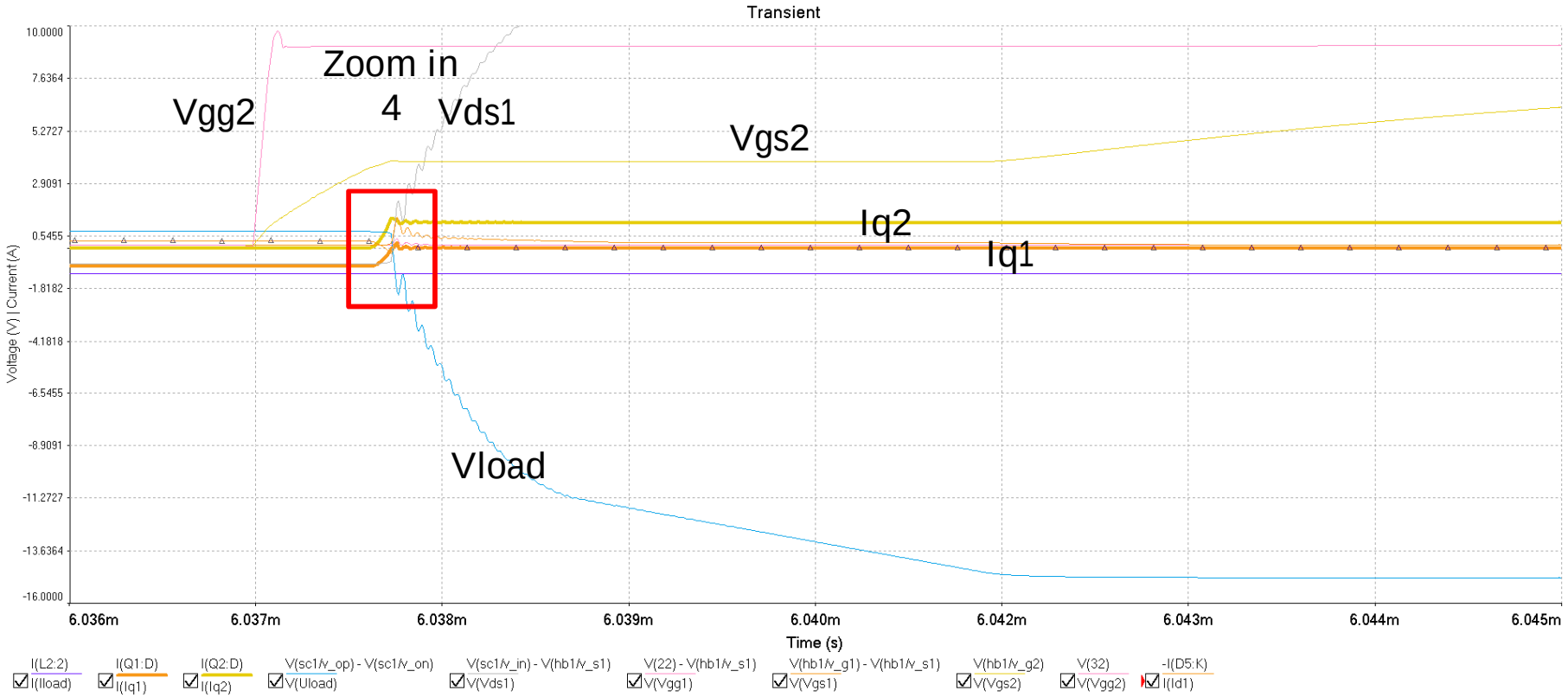
Zoom in 1: Q2 off – Q1 on – Q1 off – Q2 on



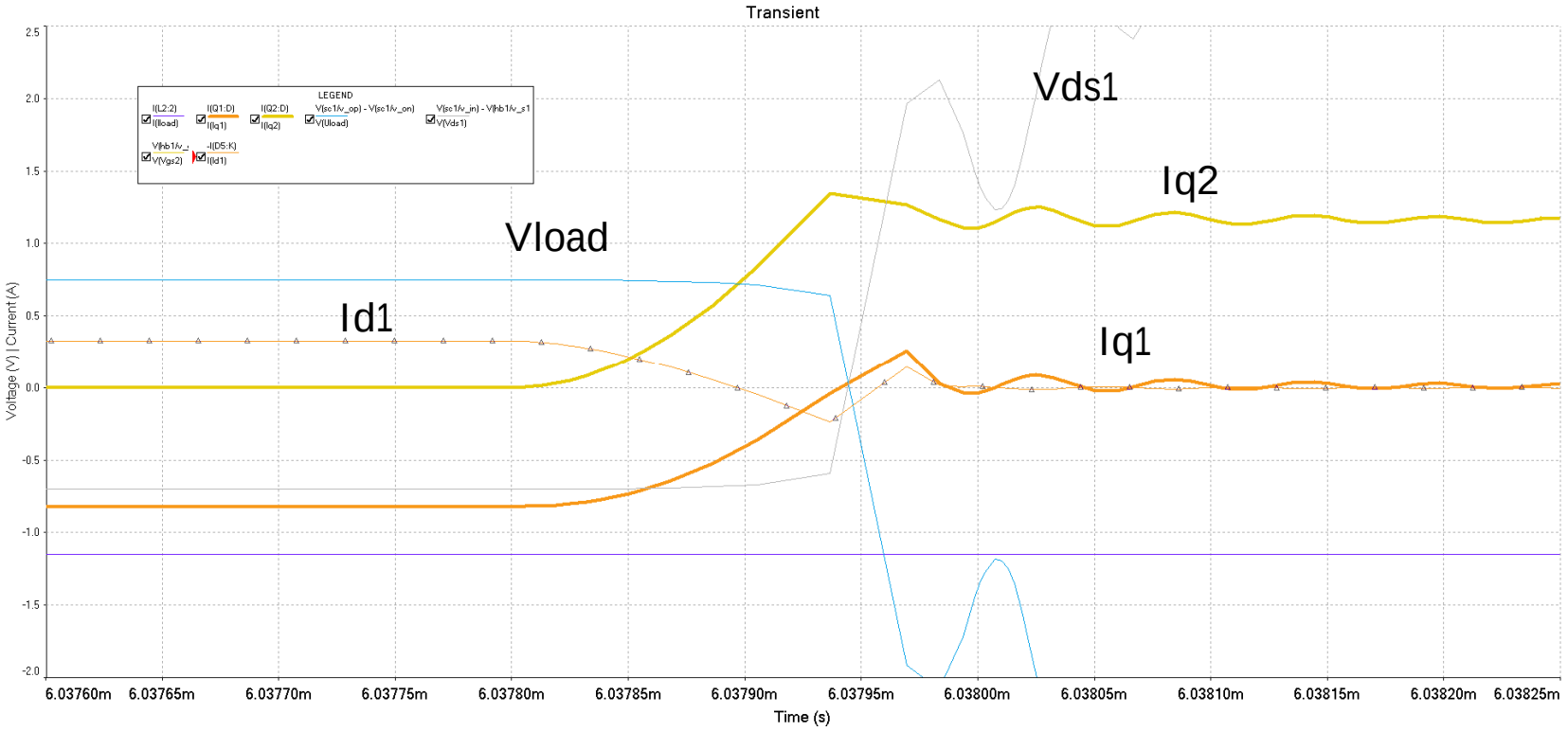
Zoom in 2: Q2 off – Q1 on



Zoom in 3: Q2 on



Zoom in 4: Q2 on



www.liu.se

LINKÖPING UNIVERSITY