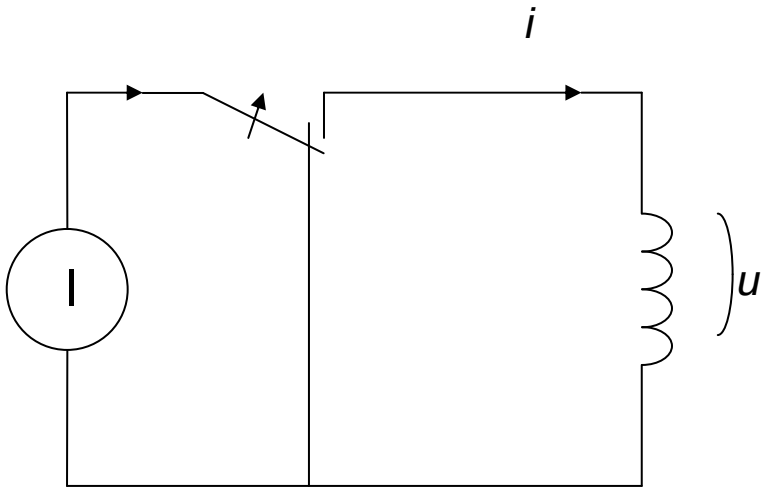
Switching, snubbers

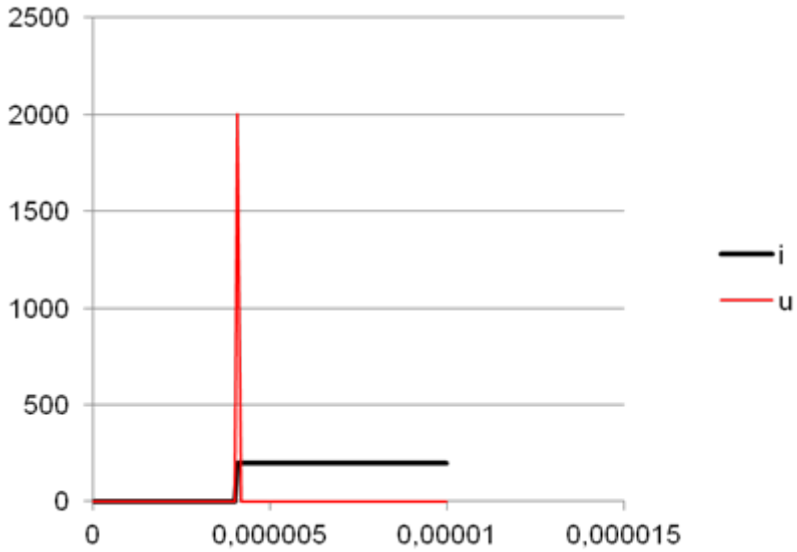
or

turn-on and turn off
the
effect of inductance

BASIC

turn on a current step, inductive load.

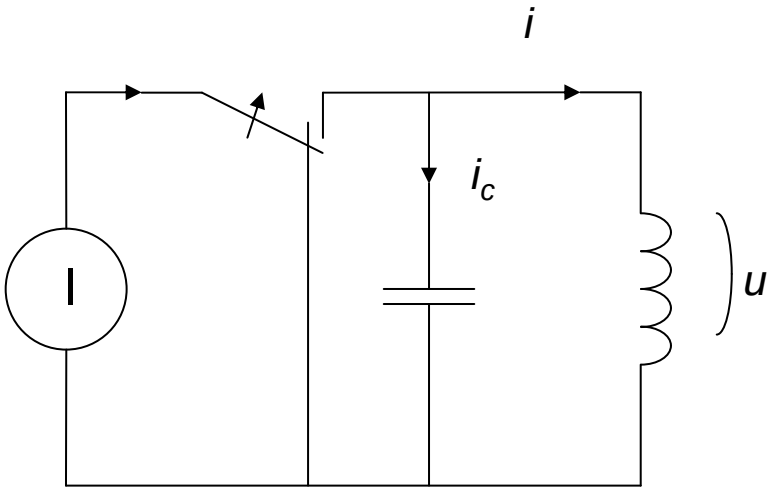




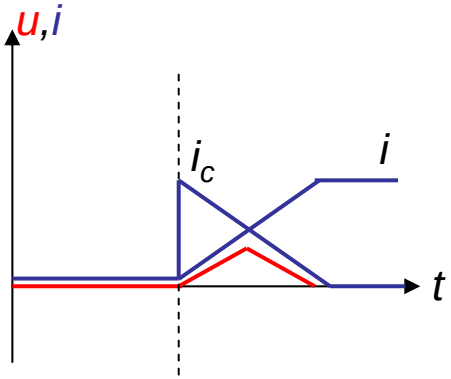
$$u = L \cdot \frac{di}{dt}$$

BASIC

turn on current step, inductive load. Counter measure with capacitor

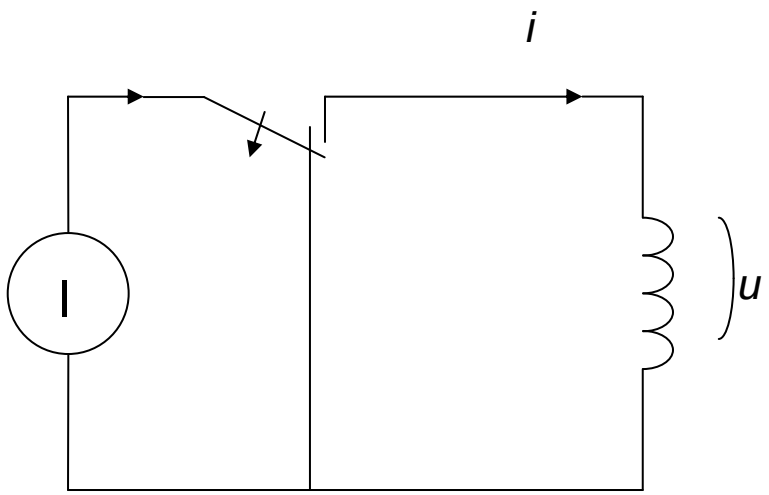


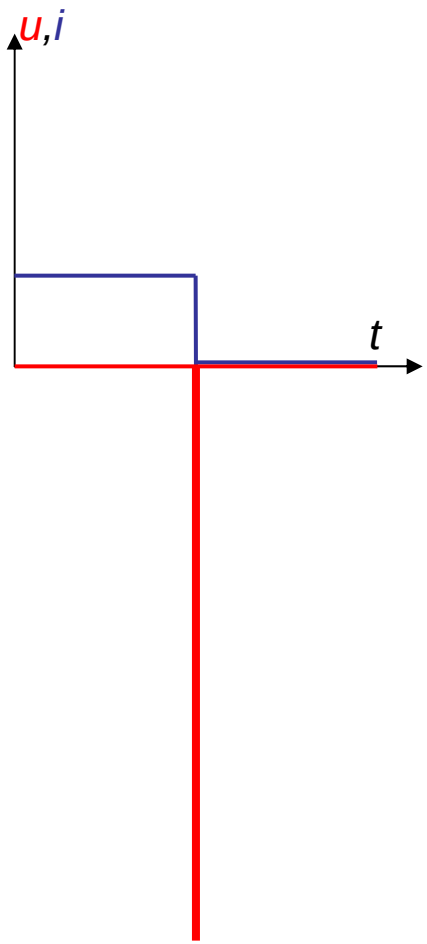
$$u = L \cdot \frac{di}{dt}$$



BASIC

turn off a current step, inductive load.

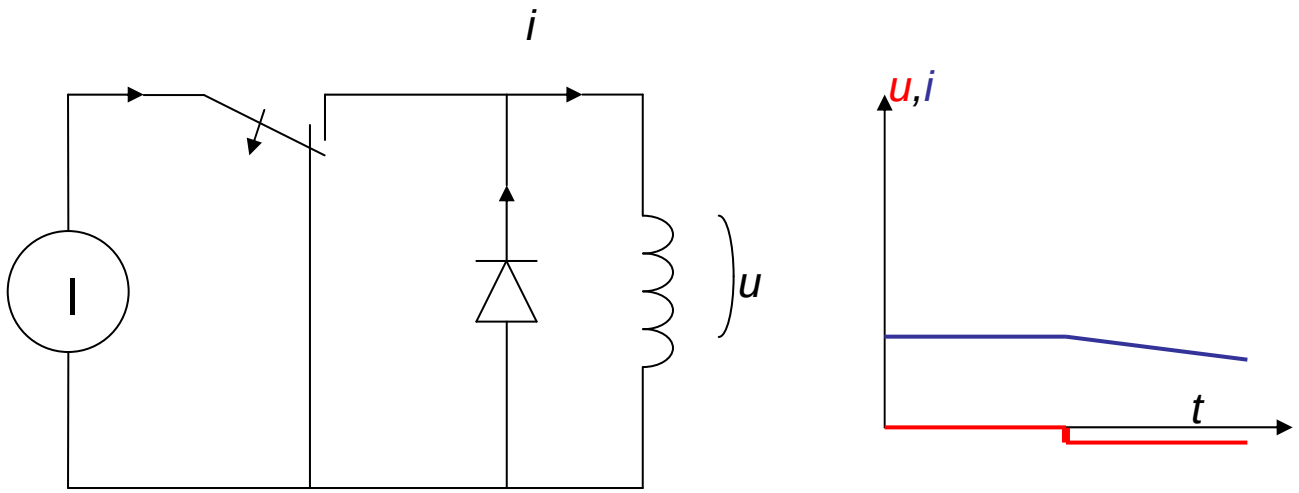




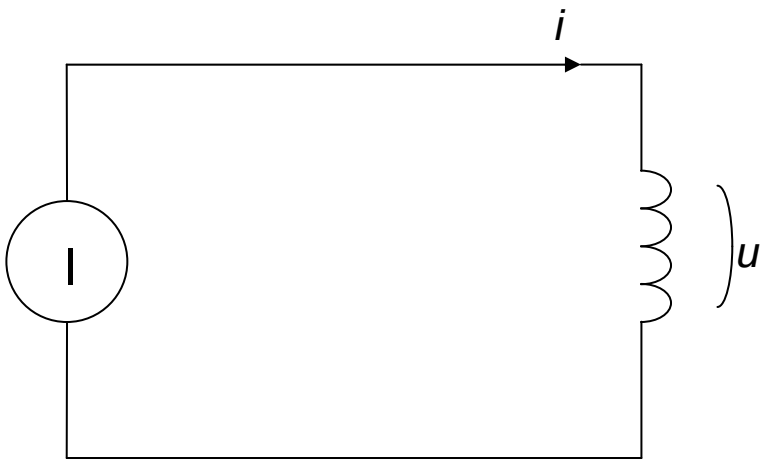
$$u = L \cdot \frac{di}{dt}$$

BASIC

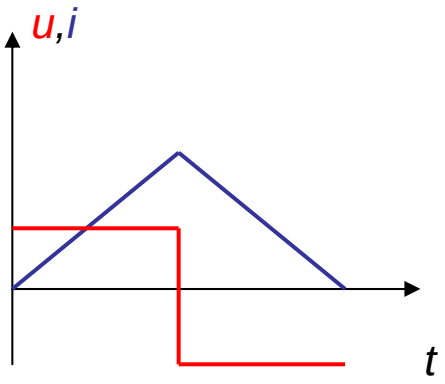
turn off current step, inductive load. Counter measure with freewheeling diode



BASIC
current ramp, inductive load

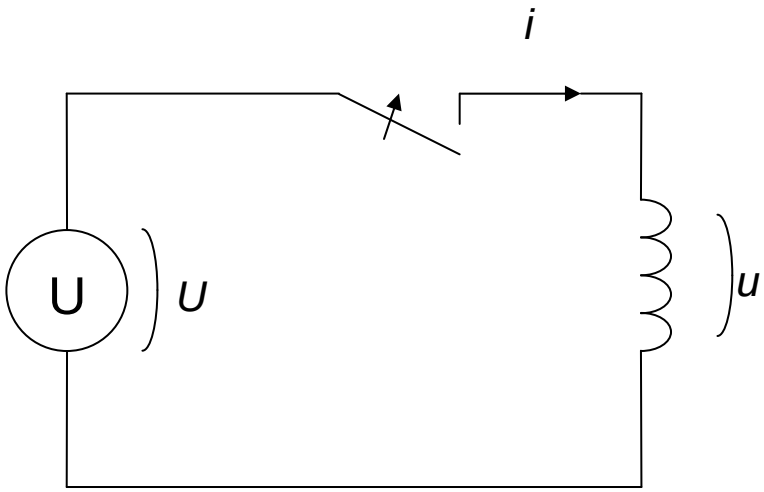


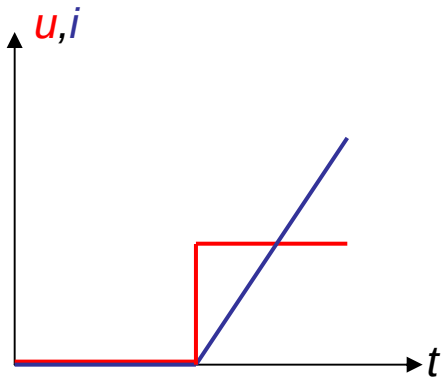
$$u = L \cdot \frac{di}{dt}$$



BASIC

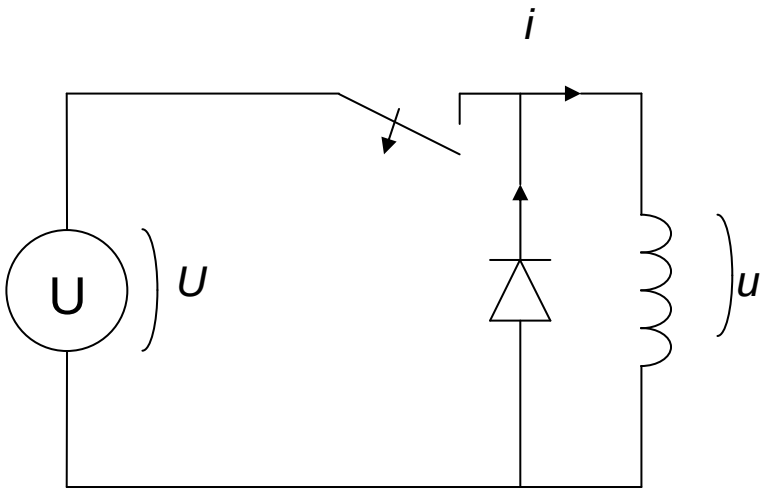
turn on voltage step with inductive load.
No problem



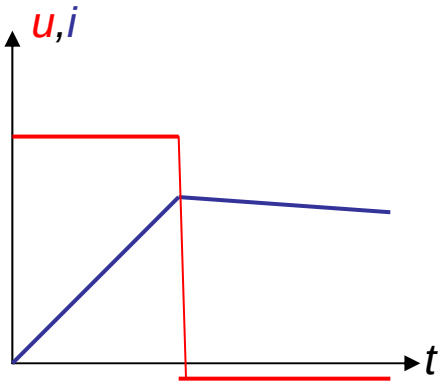


$$u = L \cdot \frac{di}{dt}$$

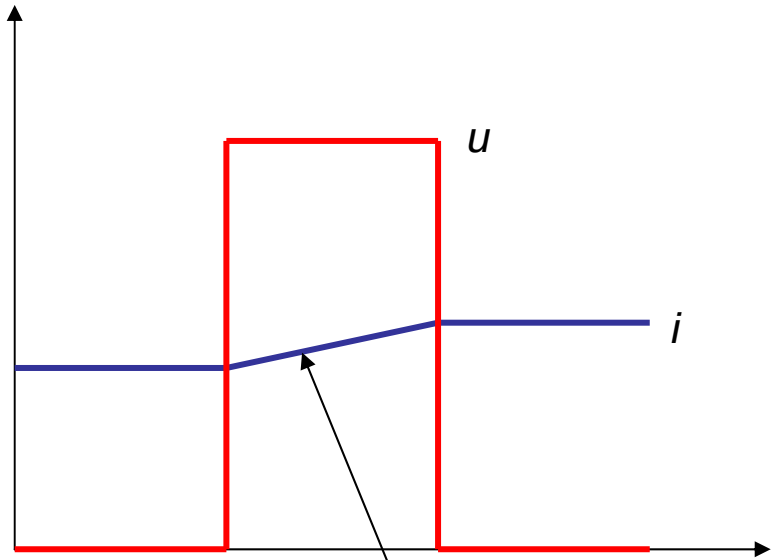
BASIC
turn off voltage step, inductive load



$$u = L \cdot \frac{di}{dt}$$

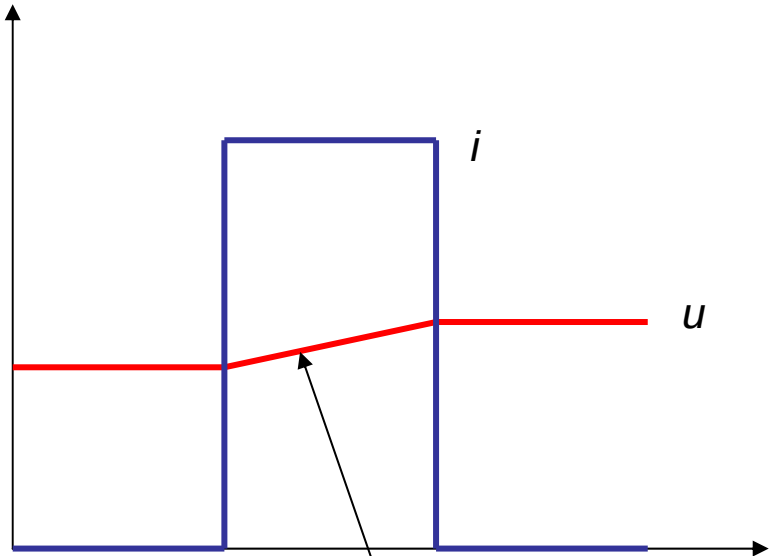


Summary
An inductance keeps a current ”constant”



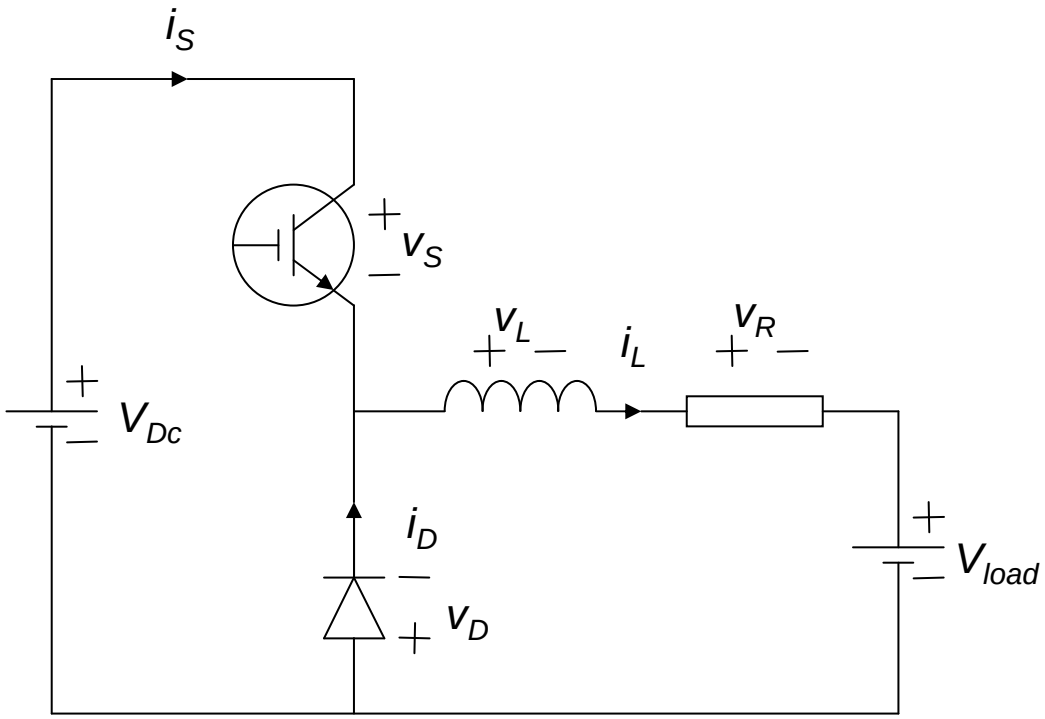
$$\frac{di}{dt} = \frac{u}{L}$$

Summary
A capacitance keeps a voltage ”constant”

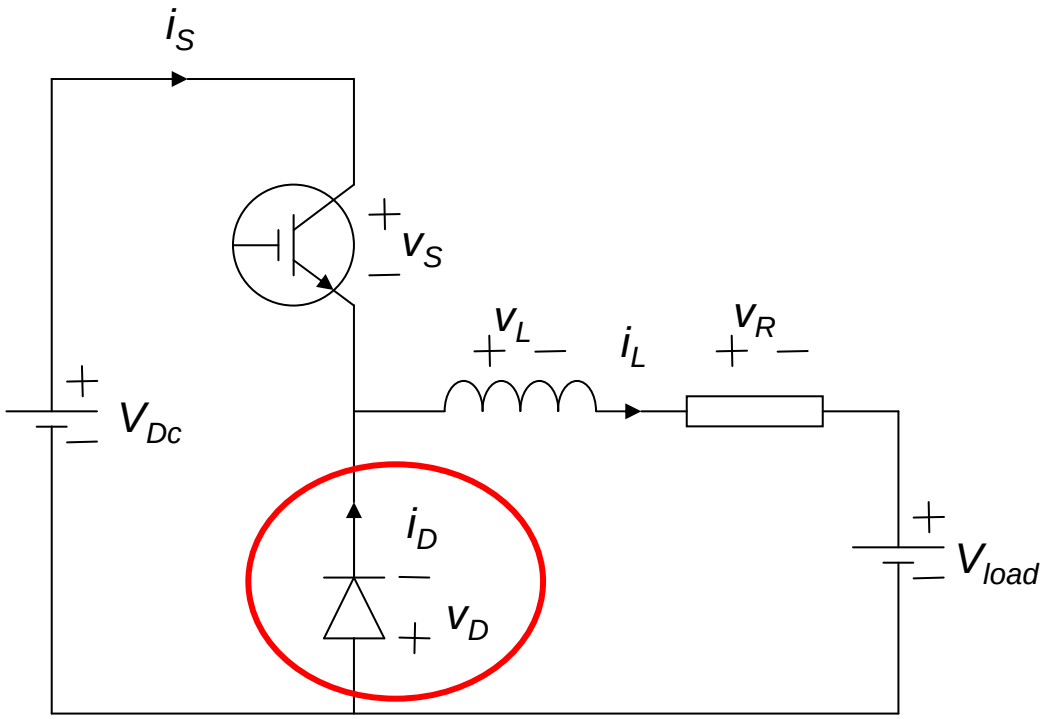


$$\frac{du}{dt} = \frac{i}{C}$$

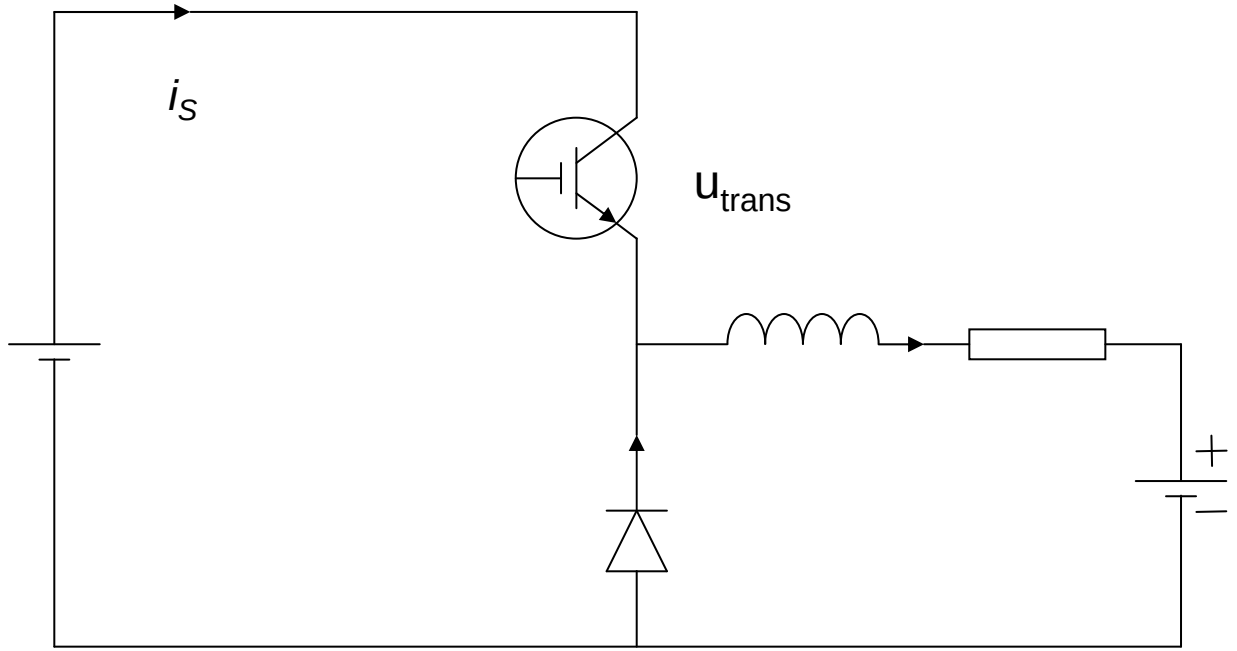
Step-down chopper

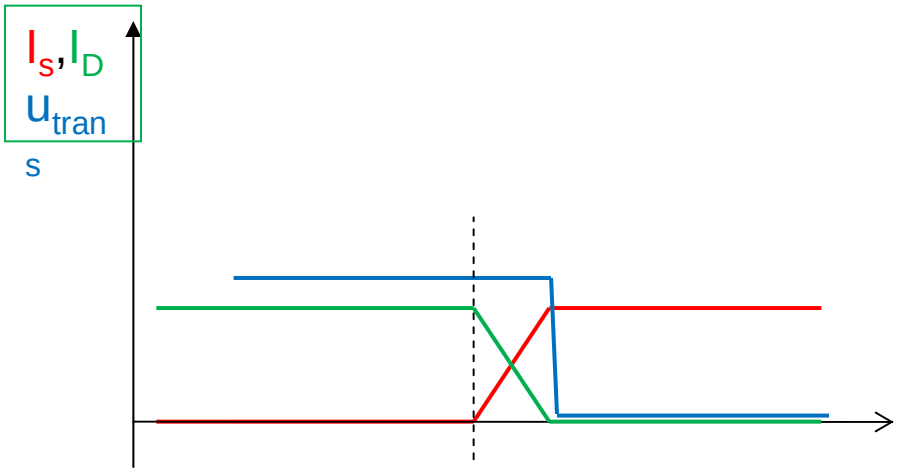


Switching diodes

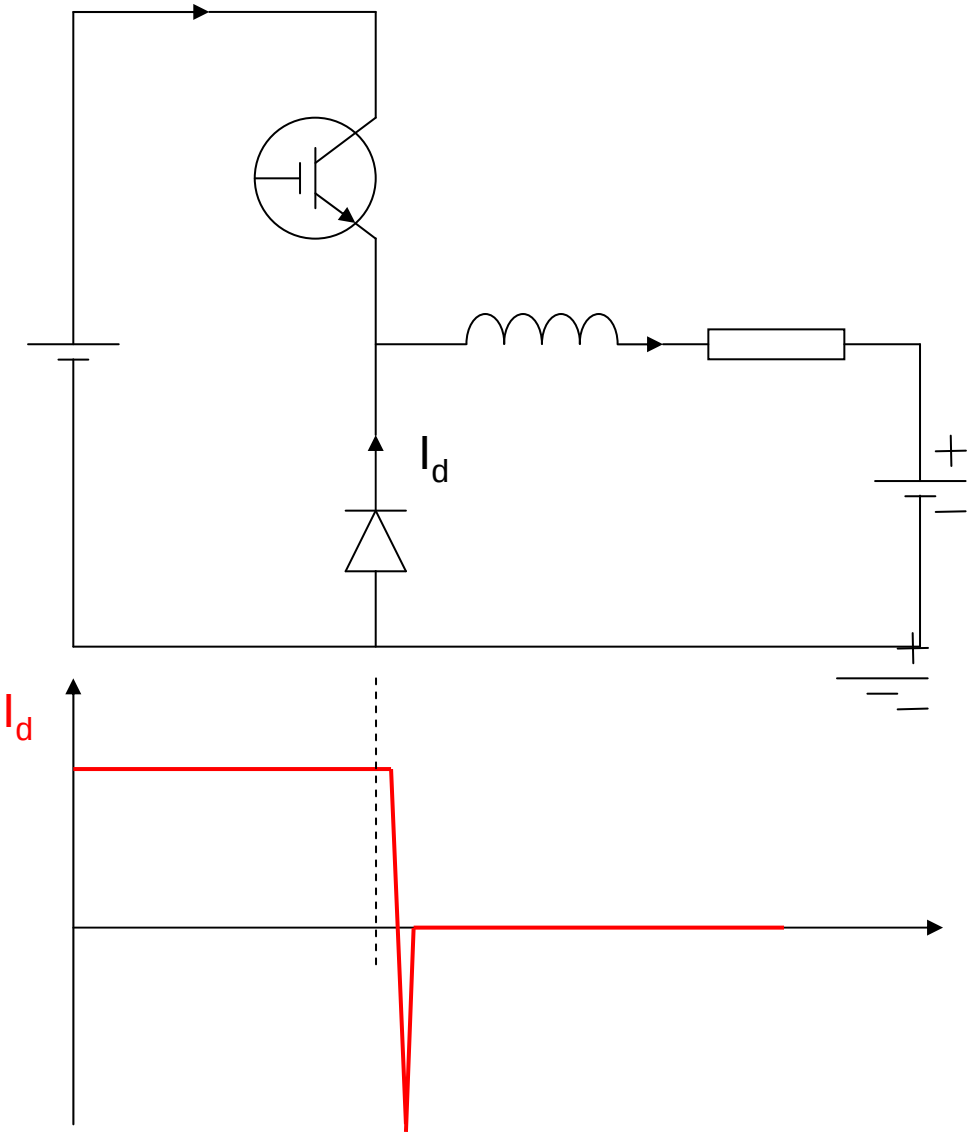


Transistor turn on

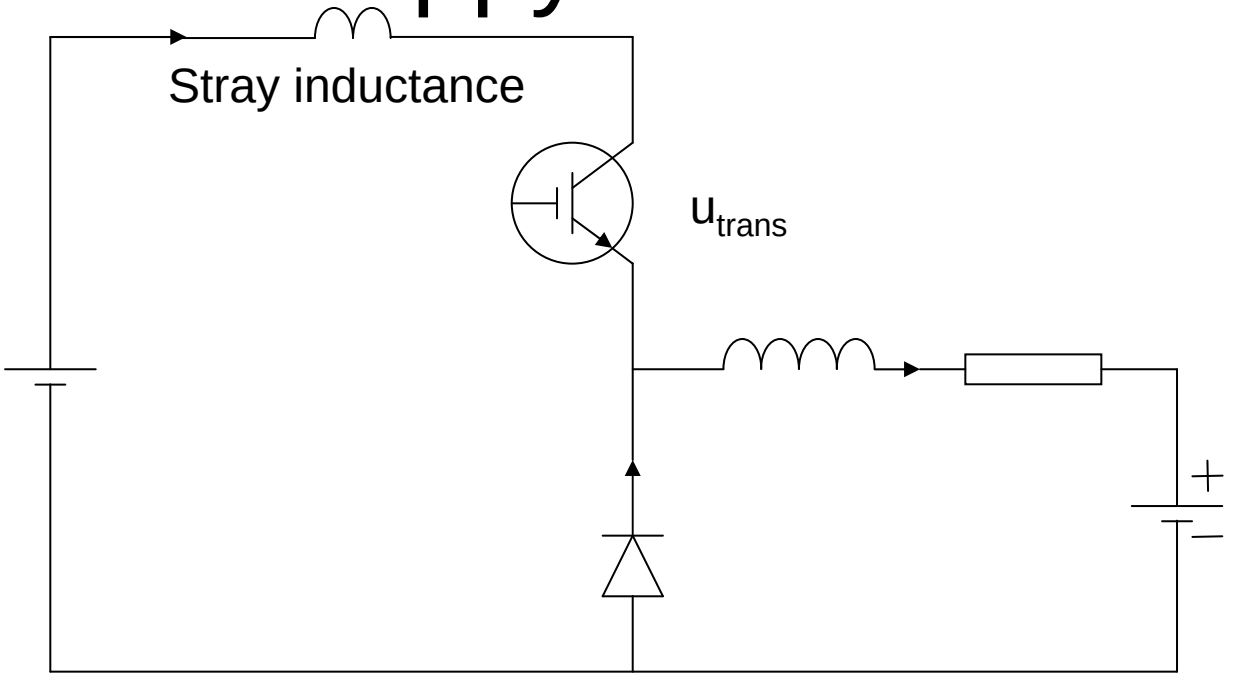


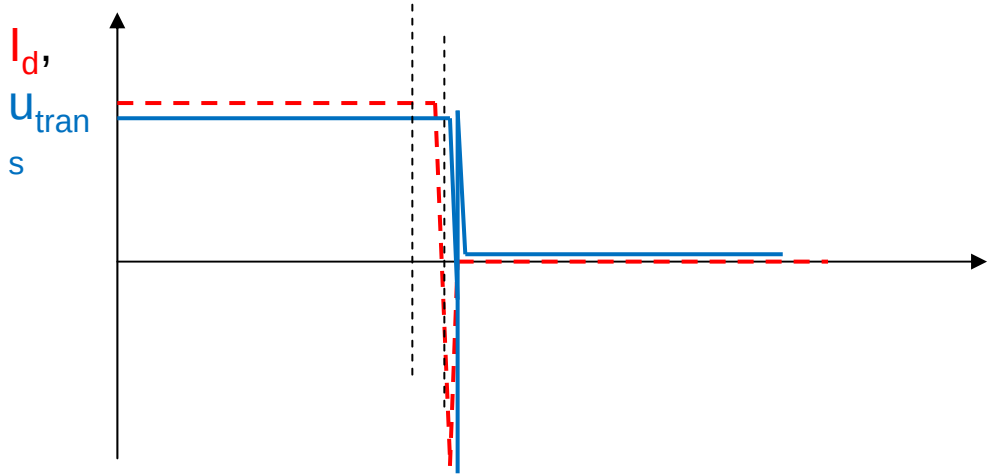


Transistor turn on. Reverse recovery 1

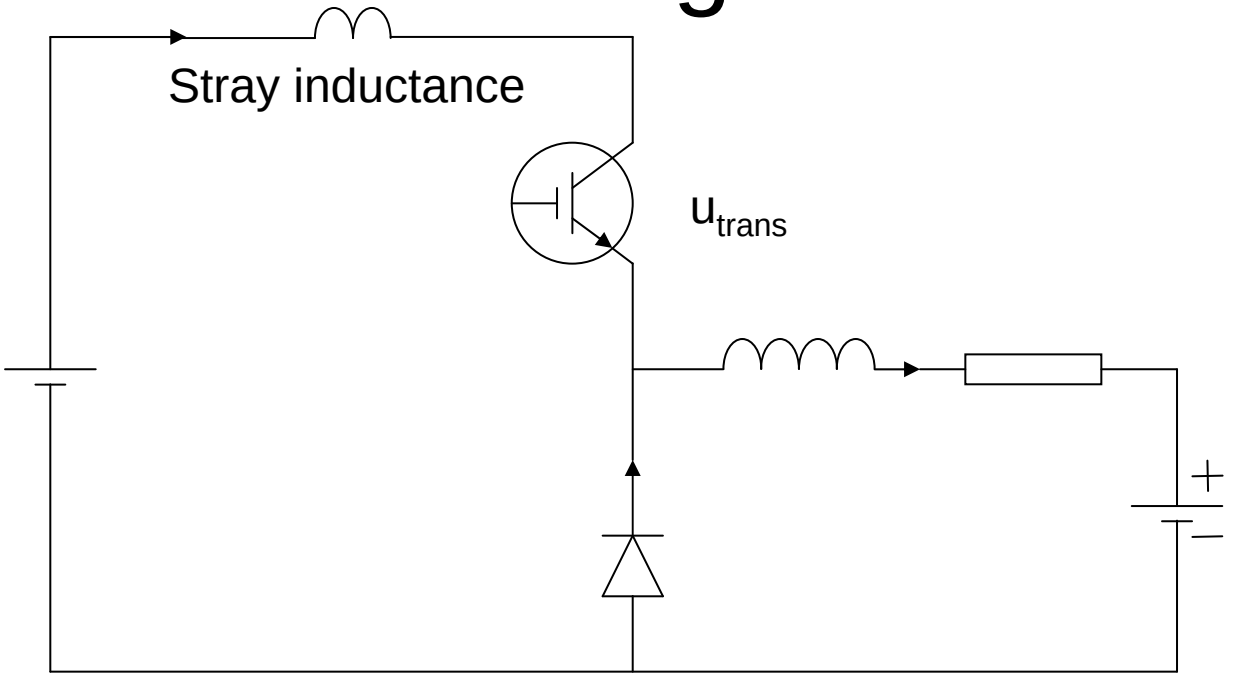


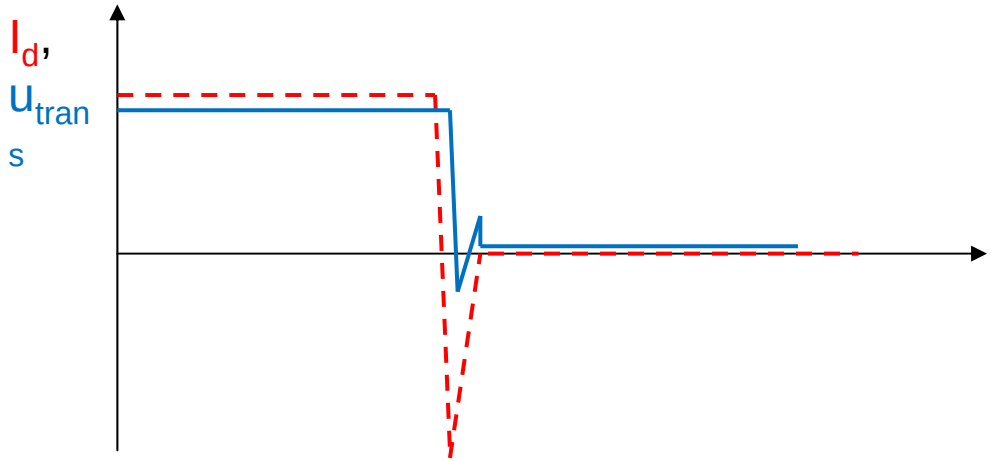
Transistor turn on. Reverse recovery 2, ”snappy” diode



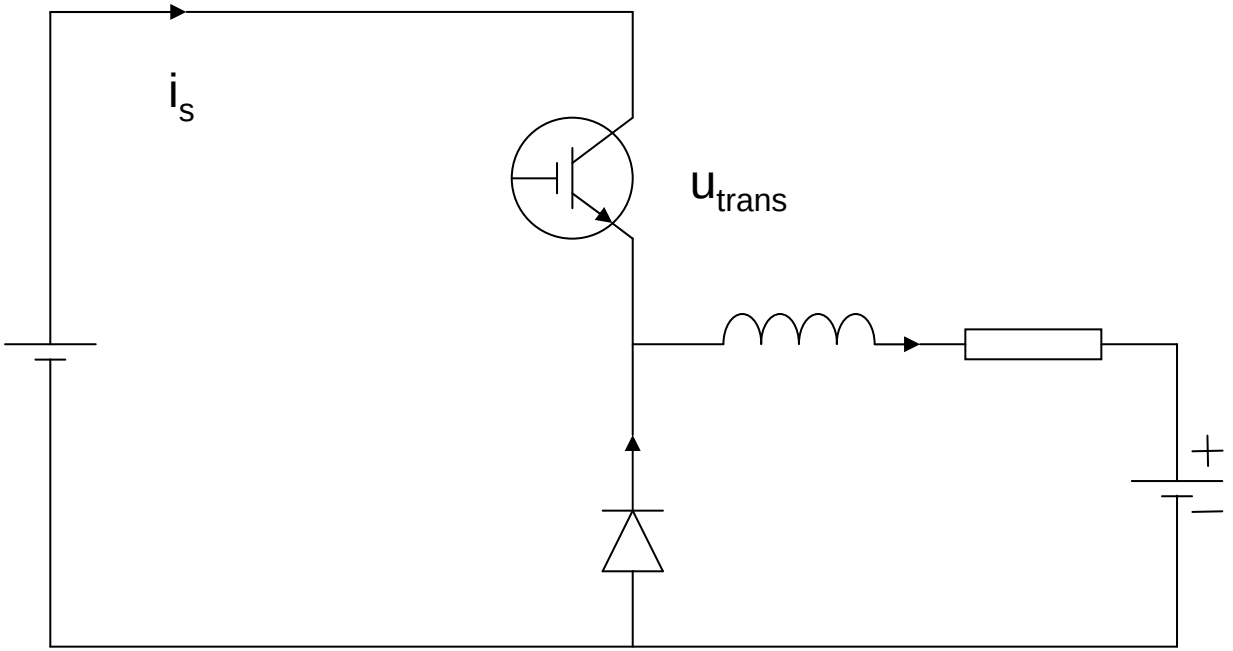


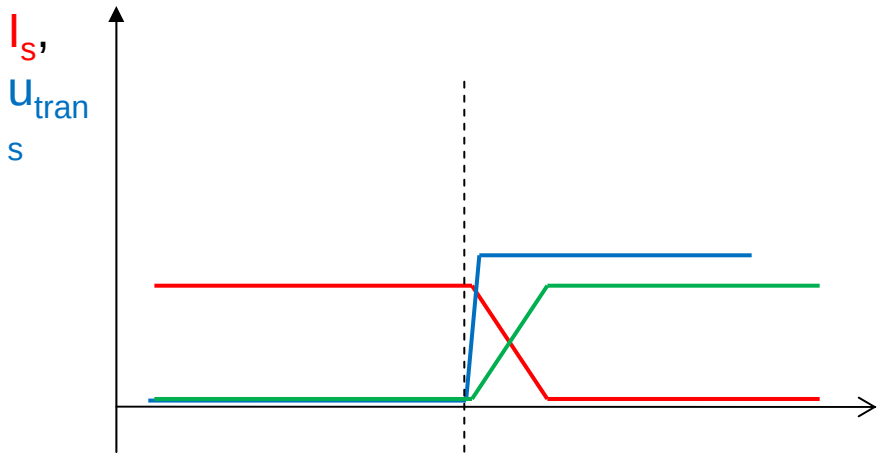
Transistor turn on. Reverse recovery 3, ”soft switching” diode



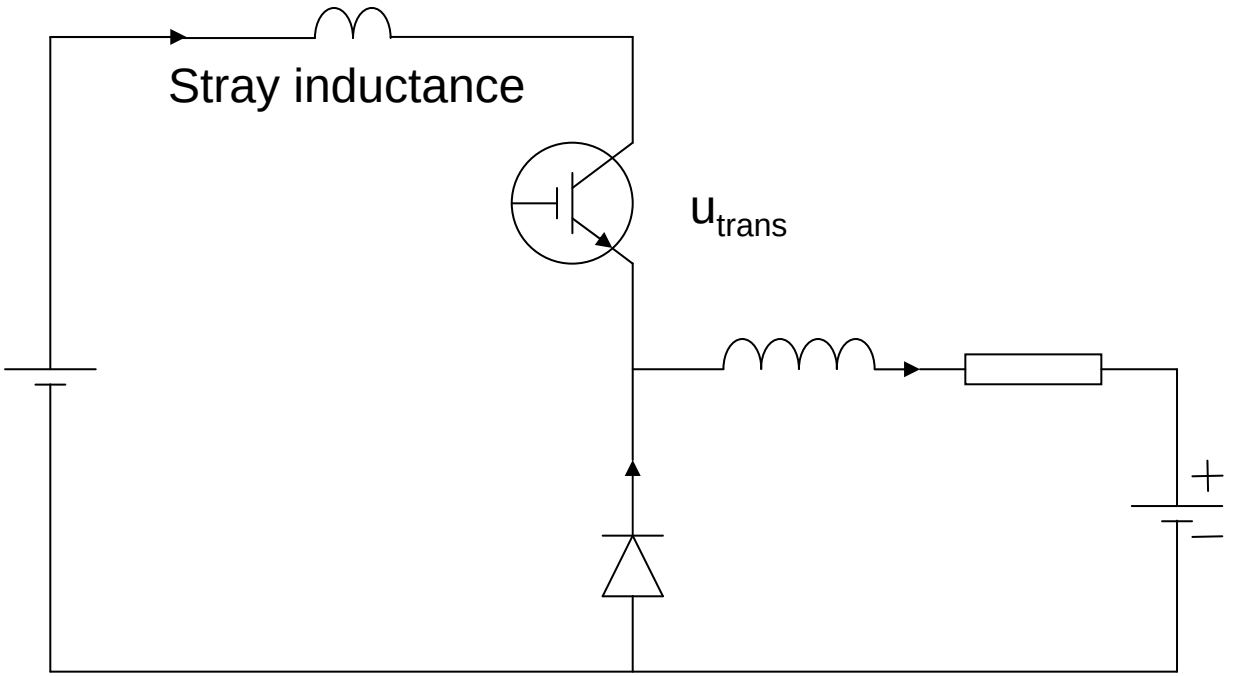


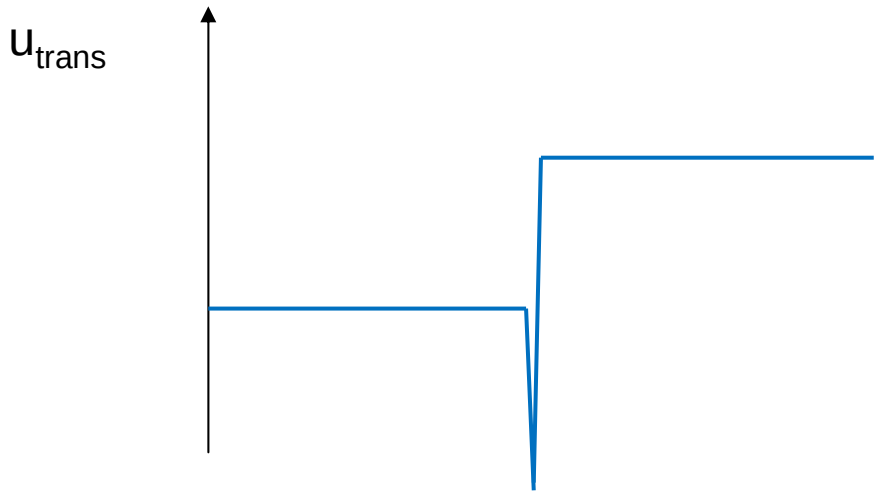
Transistor turn off



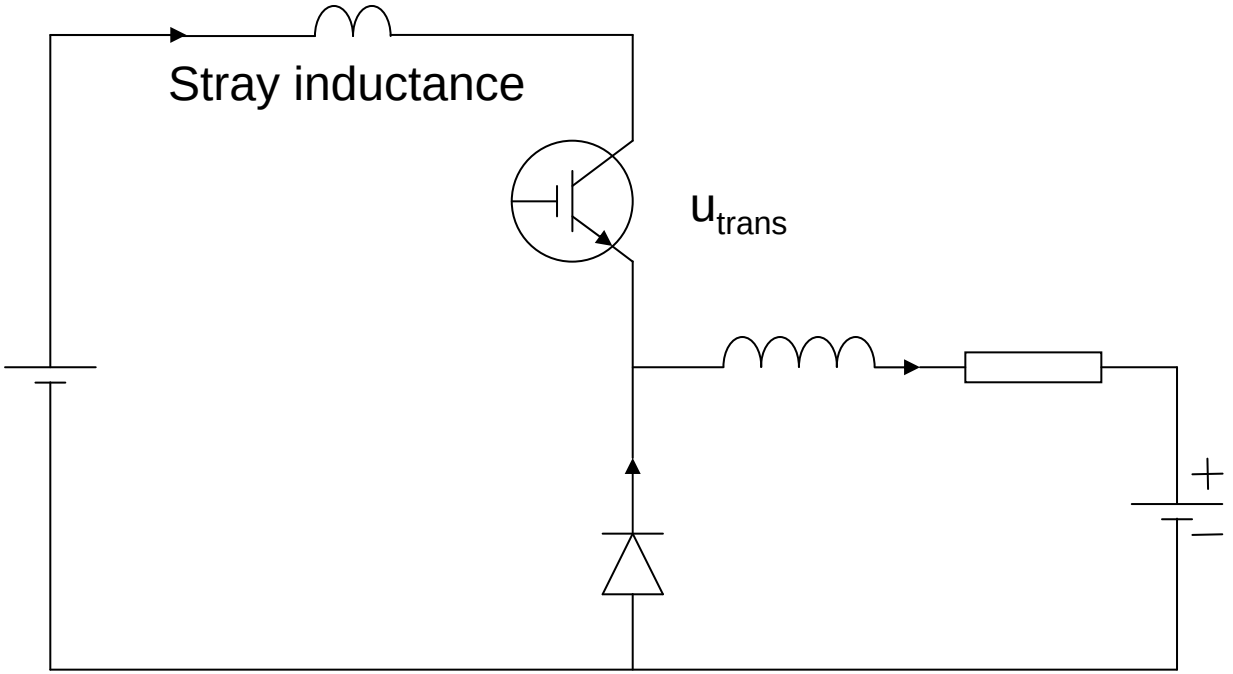


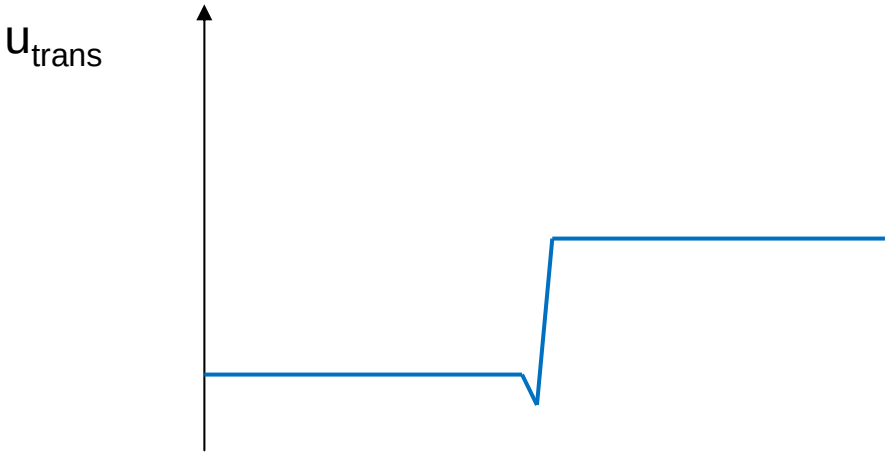
Transistor turn off 1. Fast



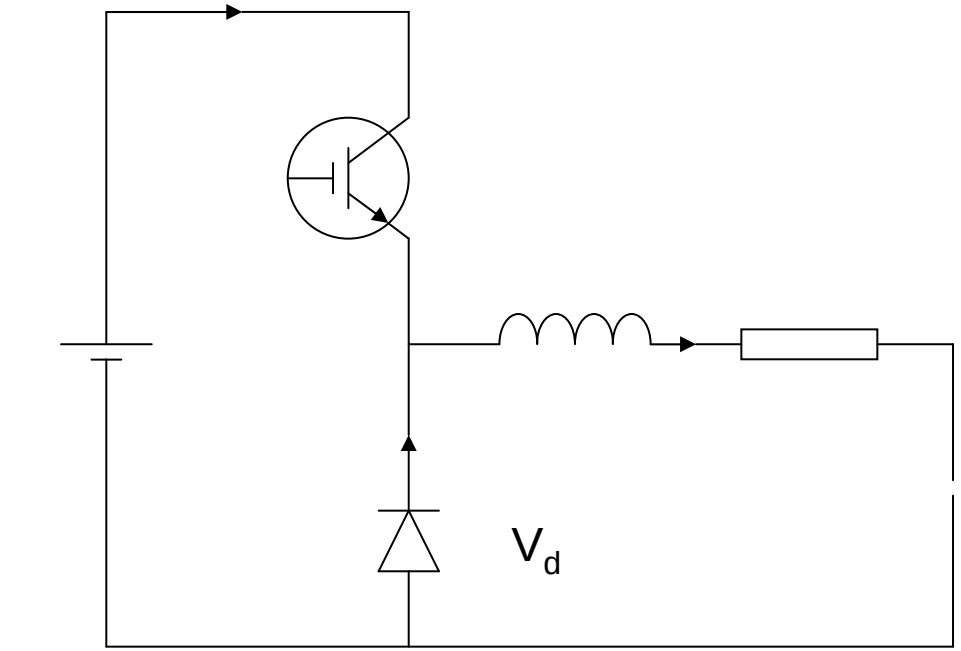


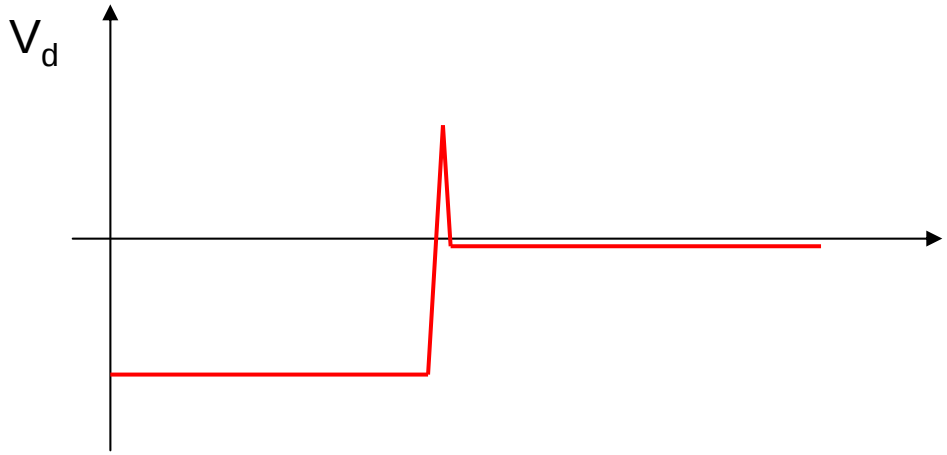
Transistor turn off 2. Slow



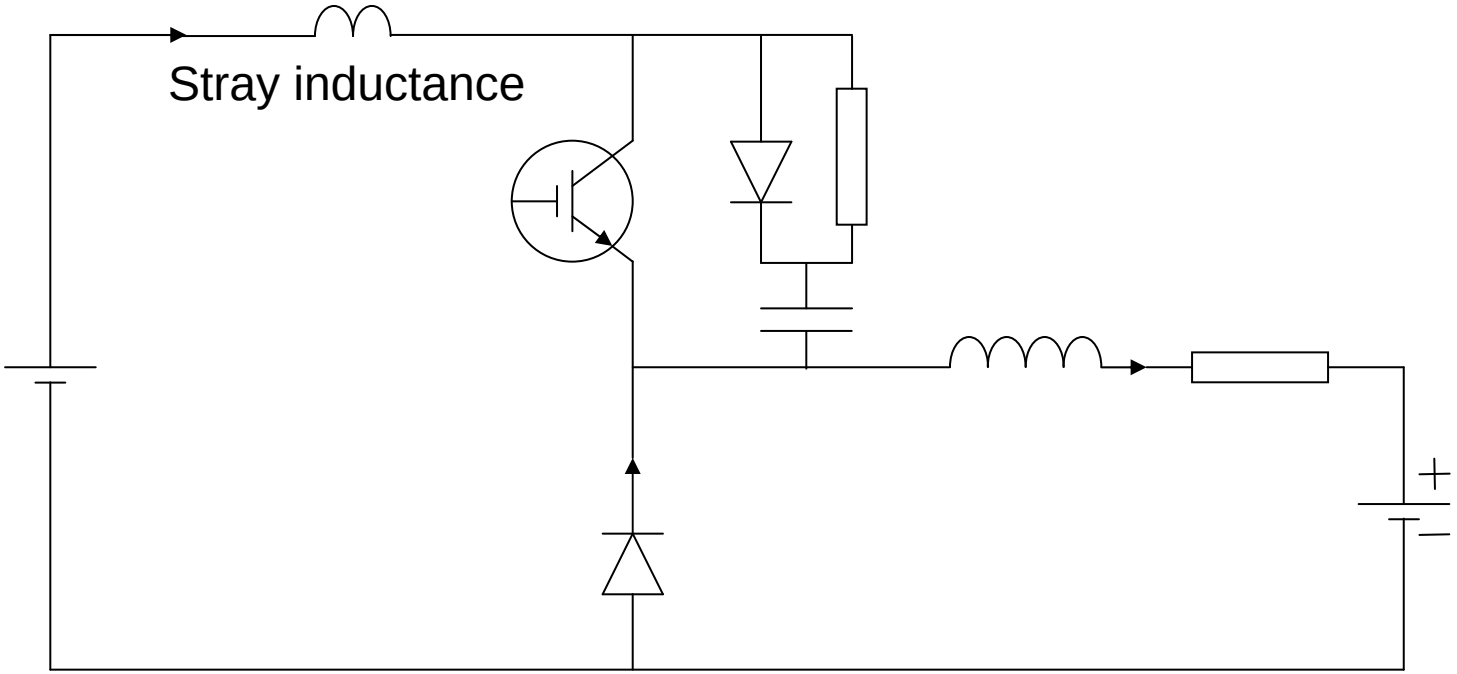


Transistor turn off.
Forward recovery





RCD snubber



Exercise

Calculate the snubber capacitor for the commutation time 0.1 ms.
The load current is 10 A, assumed constant during the commutation.
The dclink voltage is 500 V. Low voltage is 250 V.

Calculate the snubber resistor so the discharge time (3 time constants) of the snubber capacitor is less than the IGBT on state time.
The switch frequency is 1 kHz

$$i = C \cdot \frac{du}{dt} \Rightarrow C = \frac{i \cdot \Delta t}{\Delta u} = \frac{10 \cdot 0.1 \cdot 10^{-3}}{500} = \frac{10}{5} \cdot 10^{-3-1-2} = 2\,\mu F$$

$$Duty\,cycle\,is\,50\%, turn\,on\,time = 0.5\,ms. Time\,const = \frac{0.5\,ms}{3} = 0.17\,ms$$

$$R = \frac{0.17 \cdot 10^{-3}}{2 \cdot 10^{-6}} = 85\,\Omega$$

Clamp snubber