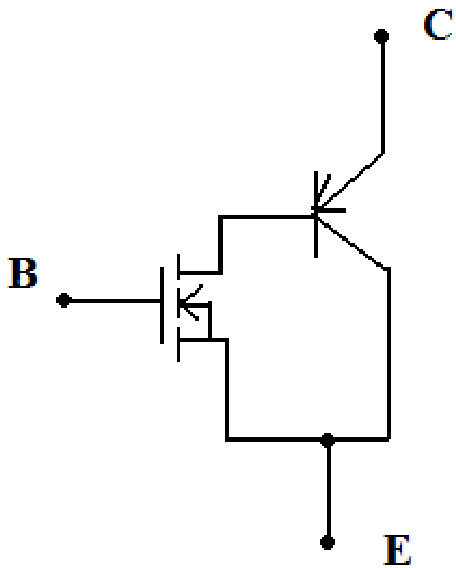
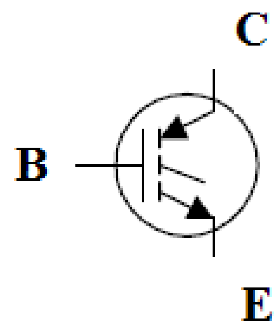
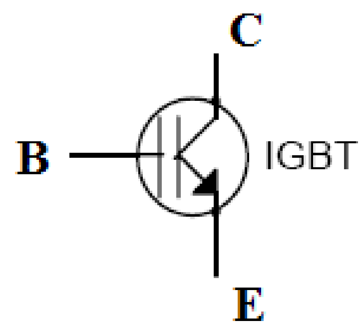
Výkonové spínací tranzistory

IGBT tranzistory







- Používají se jako výkonové spínací prvky do frekvencí 50 - 100 kHz.
- Mají výhody tranzistorů MOSFET z hlediska vstupu a výhody BJT z hlediska výstupu.
- Mají delší spínací časy než MOSFET.

Vnitřní struktura IGBT (PT & N-Channel)

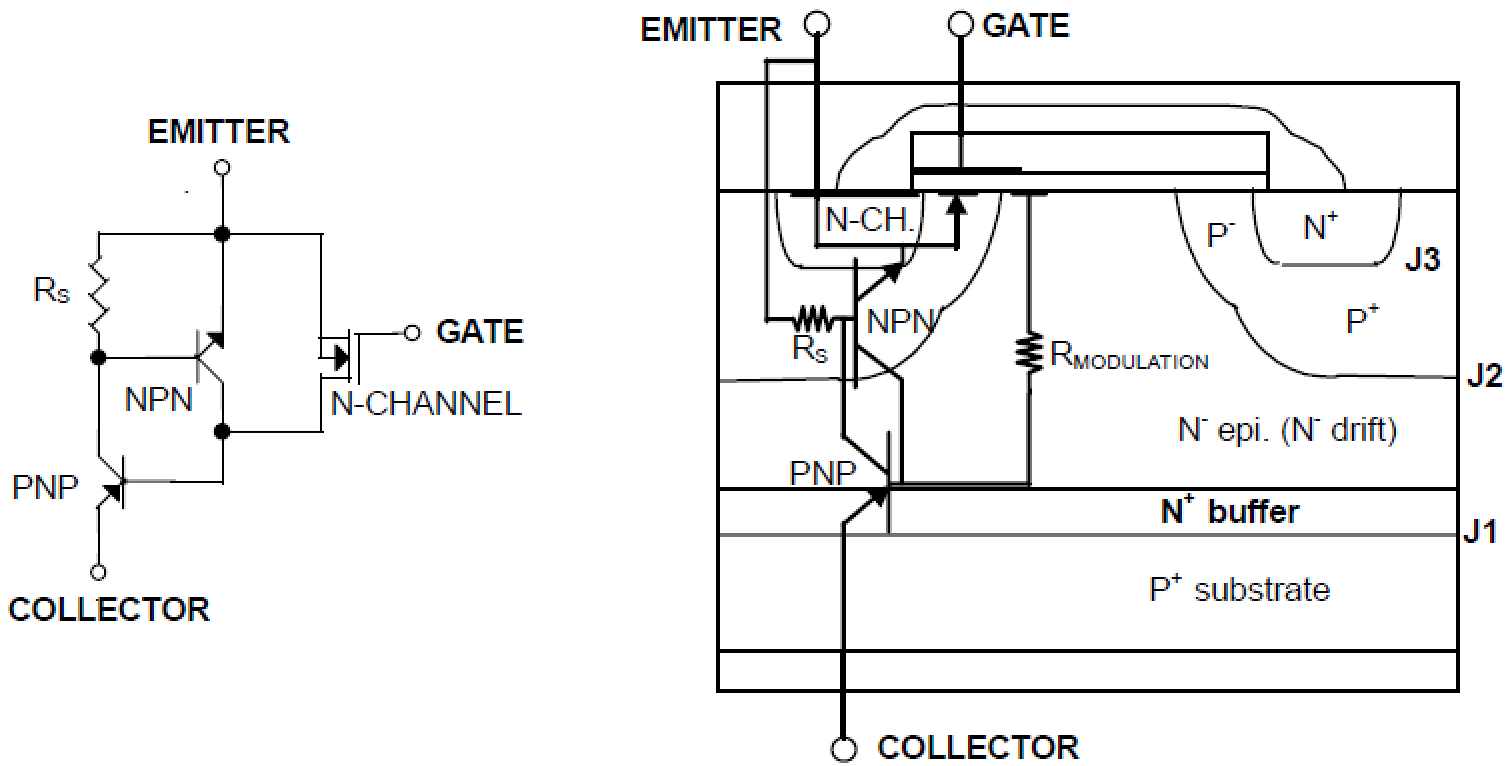
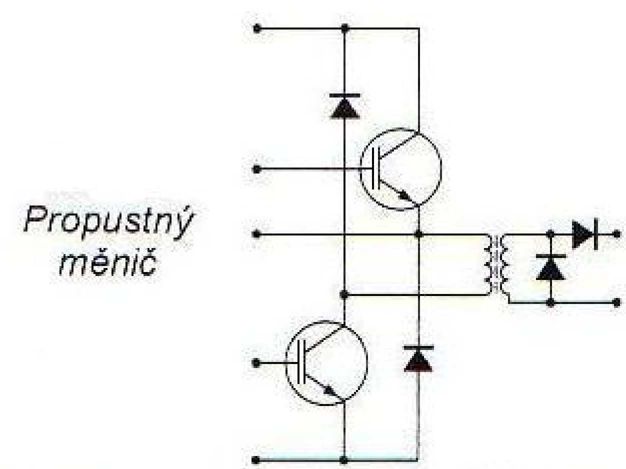


Figure 1. Equivalent Circuit for the IGBT & a Cross Section of the IGBT Structure (PT & N-Channel)

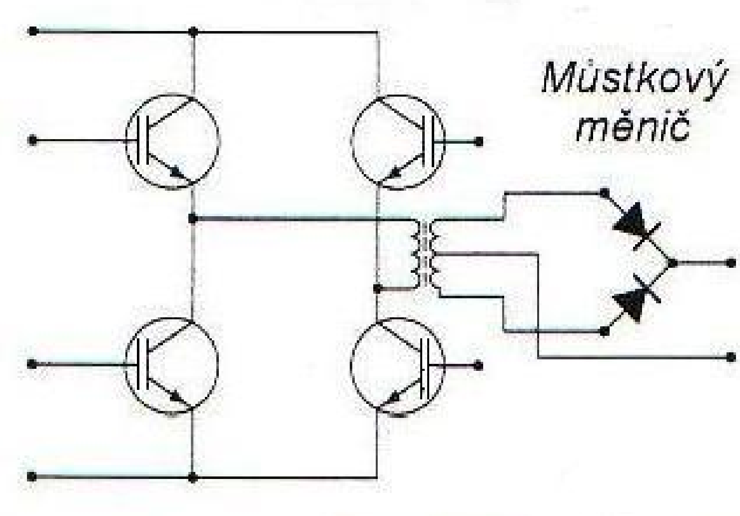
Aplikace IGBT ve spínaných zdrojích s velkým výkonem

Spínané zdroje:

- zdroje pro PC,
- svářecí invertory,
- zdroje plazmatu atd.



malé výkony



velké výkony

Porovnání velikosti úbytku napětí na IGBT a POWER MOSFET v sepnutém stavu

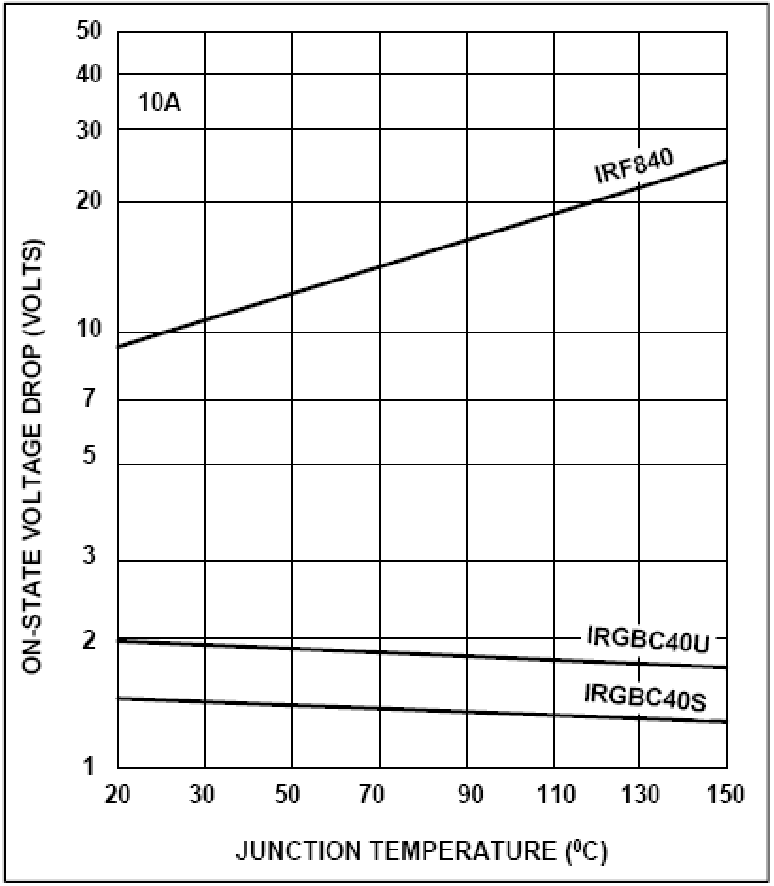


Figure 2. On-state voltage drop as temperature of two IGBTs of different switching characteristics compared to those of a HEXFET of the same die size (IRGBC40S and IRGBC40U vs IRF840). Conductivity modulation causes a dramatic improvement in the on-state voltage drop. To take the avalanche capability of the HEXFET into account, a 500V device is compared with 600V IGBTs.

Rated Voltage	IGBT	100	300	600	1200
	HEXFET®	100	250	500	1000
Typical Voltage Drop @ 1.7A/mm^2, 100^{0}C	IGBT	1.5	2.1	2.4	3.1
	HEXFET®	2.0	11.2	26.7	100

Table 1: Dependence of Voltage Drop From Voltage Rating

Spínací vlastnosti IGBT tranzistorů

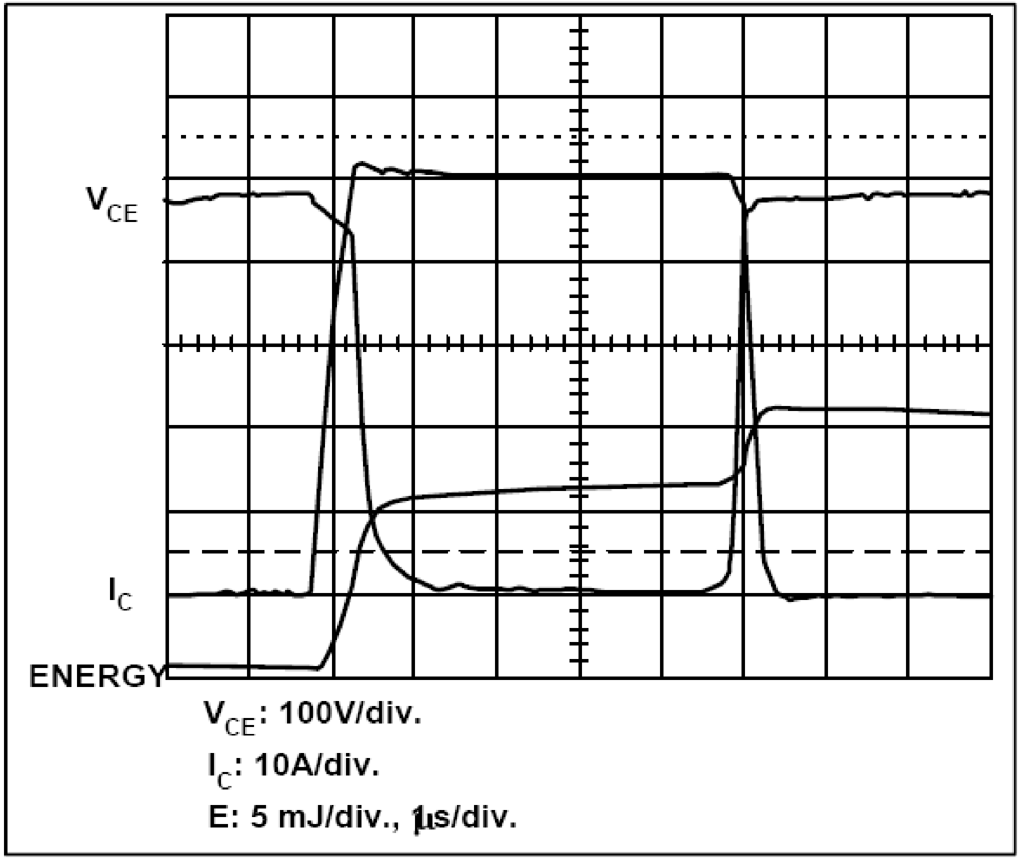


Figure 4. Switching waveforms of a commercially available IGBT with heavy lifetime killing. It takes approximately 0.5ms for the voltage to drop the last 50V. The energy plot shows that the losses at turn-on are twice as high as those at turn-off. Switching circuit as in Figure 16.

Porovnání strmosti IGBT a MOSFET

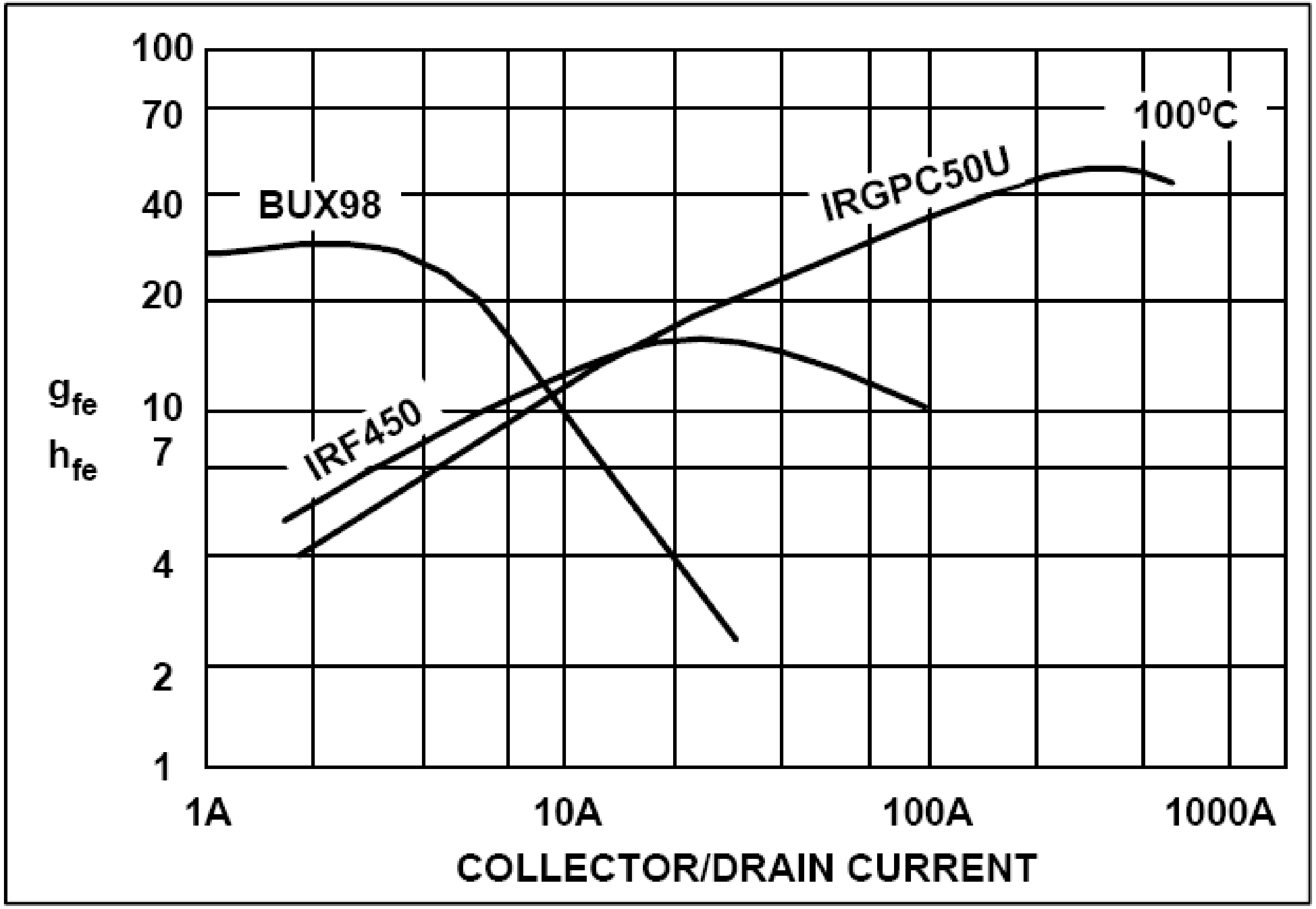
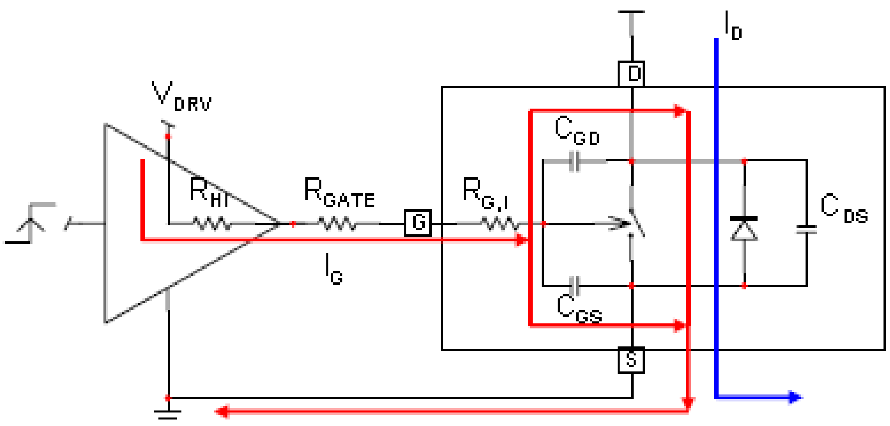


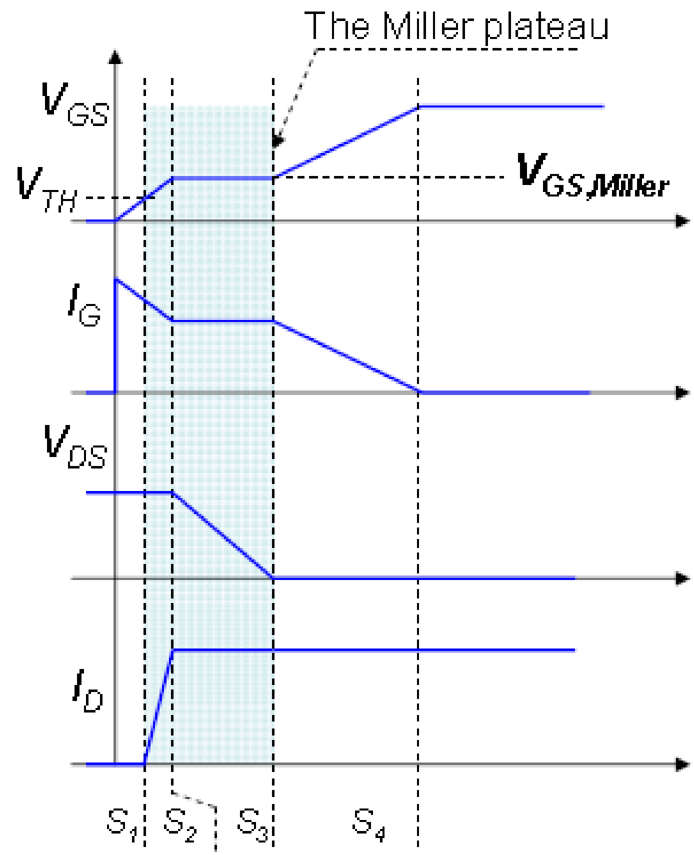
Figure 5. Current dependence of the transconductance of an IGBT compared to that of a HEXFET and to the gain of a bipolar of approximately the same die size. The IGBT, like te power MOSFET, is not "gain limited."

Rychlé a skokové “tvrdé spínání“ MOSFET nebo IGBT spínače

Turn-on Procedure for Hard-switching



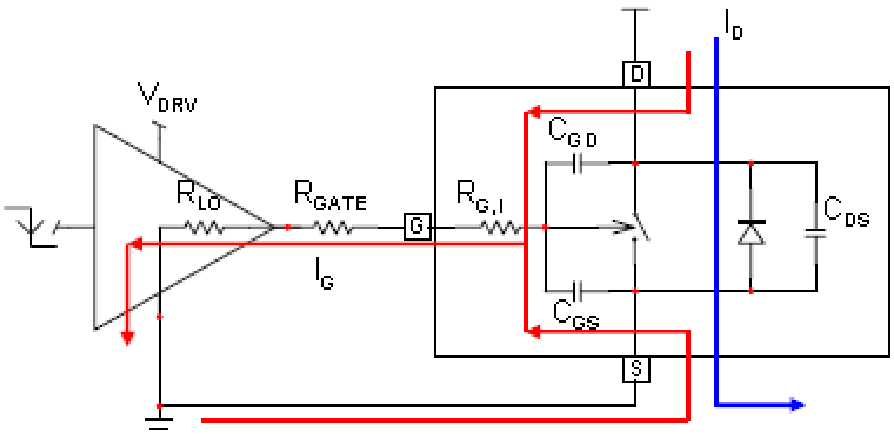
The miller plateau is caused by C_{GD}

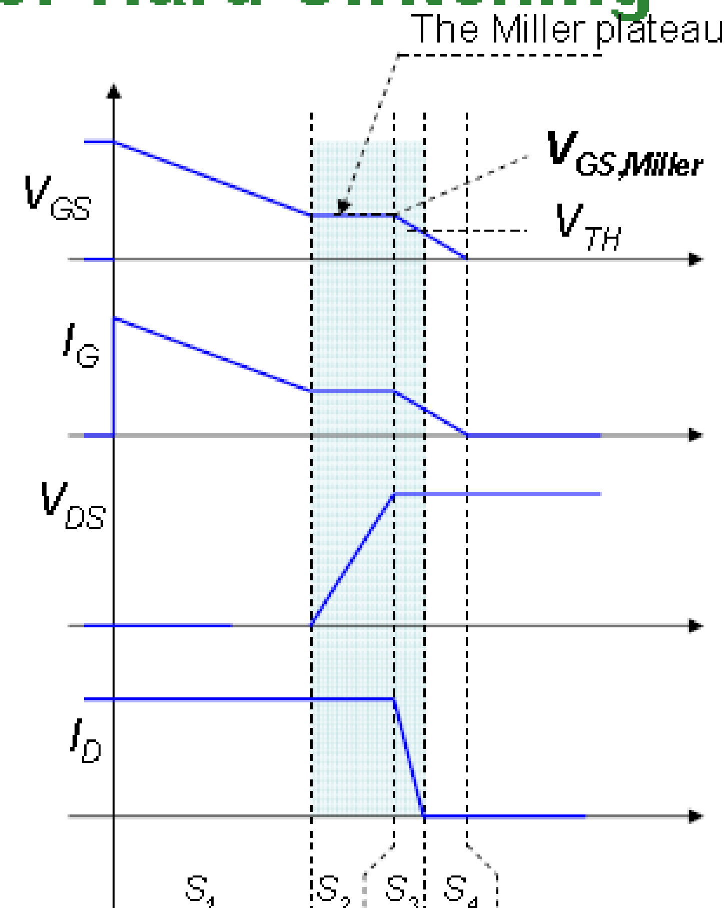


- Stages 2 and 3 dominate the switching losses of MOSFET and driver.
- DRV’s source capability as V_{GS} is around $V_{GS,Miller}$ is important.

Skokové “tvrdé” vypínání

Turn-off Procedure for Hard-switching



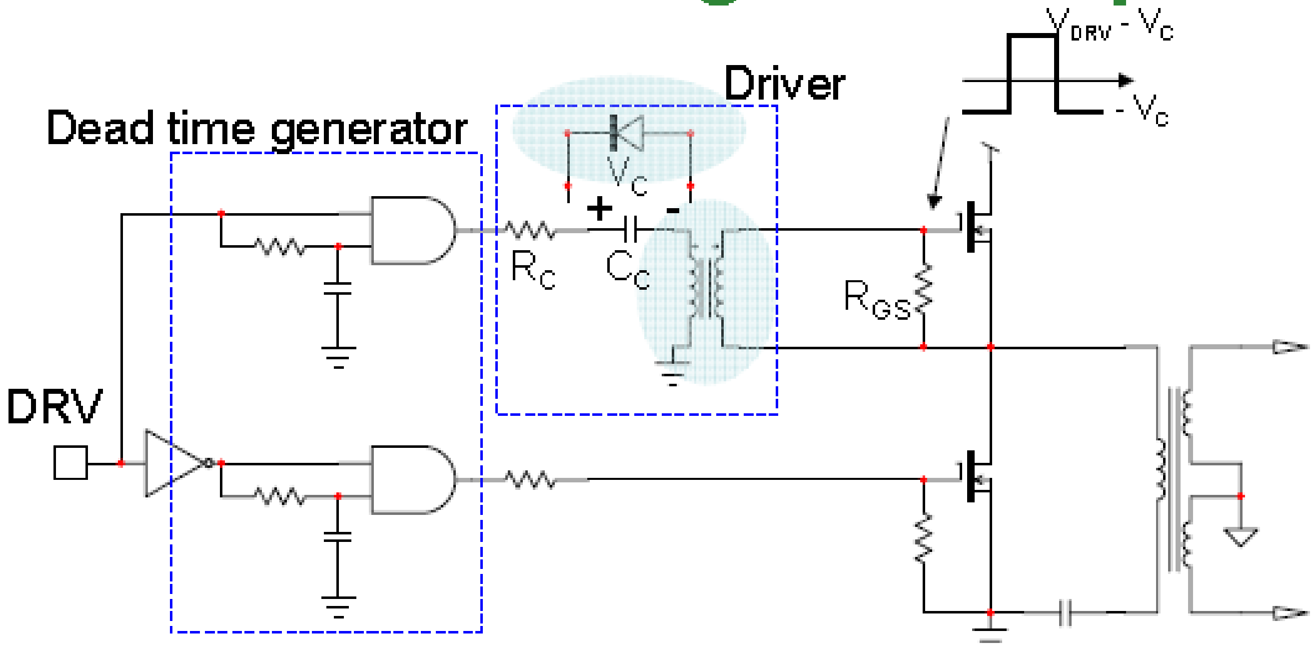


The miller plateau is caused by C_{GD}

- Stages 2 and 3 dominate the switching losses of MOSFET and driver.
- DRV’s sink capability as V_{GS} is around $V_{GS,Miller}$ is important.

Buzení MOSFET nebo IGBT přes oddělovací transformátor

Single DRV Input



$$V_C = DV_{DRV}$$

$$Q > \frac{1}{R_C}\sqrt{\frac{L_M}{C_C}} = 0.5$$

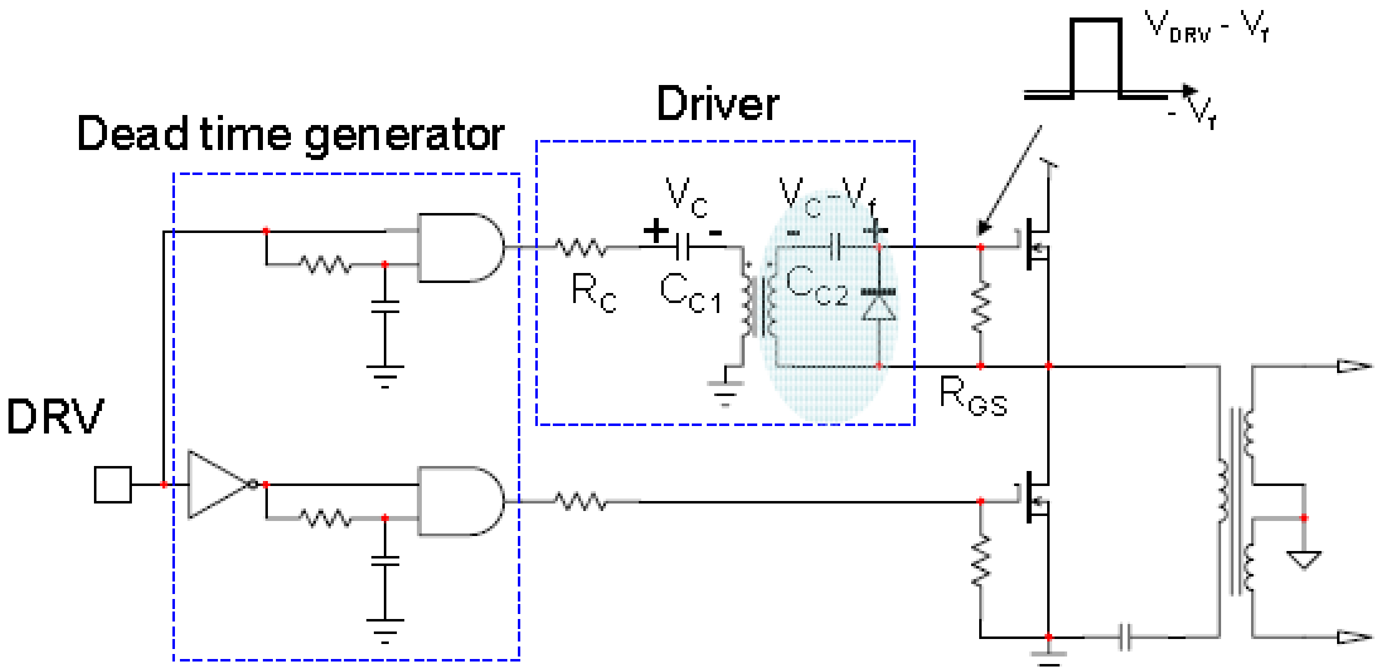
$$R_C \geq \frac{1}{Q}\sqrt{\frac{L_M}{C_C}} = 2\sqrt{\frac{L_M}{C_C}}$$

C_C to reset the driver transformer and R_C to damp the L-C resonance.

- An ac coupling capacitor (C_C) is needed to reset the driver transformer flux.
- The amplitude of V_{GS} is dependent on duty. ☹
- With ($-V_C$) to turn off at steady state, but the sink capability is limited at start-up. ☹
- Need a fast time constant ($L_M // R_{GS} * C_C$) to avoid flux walking due to the fast transient.
- Watch out the ringing between C_C and drive transformer at skip mode or UVLO, a diode is needed to damp the ringing.

Obnovitel stejnosměrné složky za oddělovacím transformátorem

Single DRV Input with DC Restore



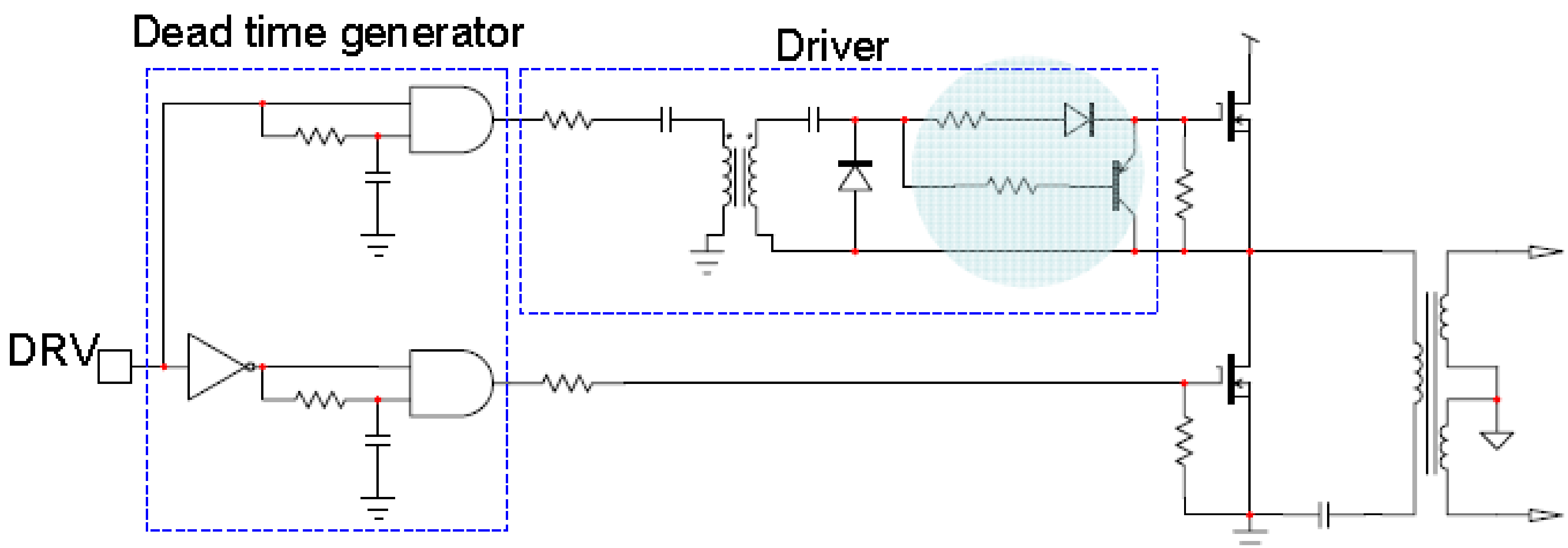
$$V_C = DV_{DRV}$$

$$R_C \geq 2\sqrt{\frac{L_M}{C_C}}$$

- V_{GS} amplitude is independent on duty ratio at steady state. ☺
- Limited sink capability. ☹

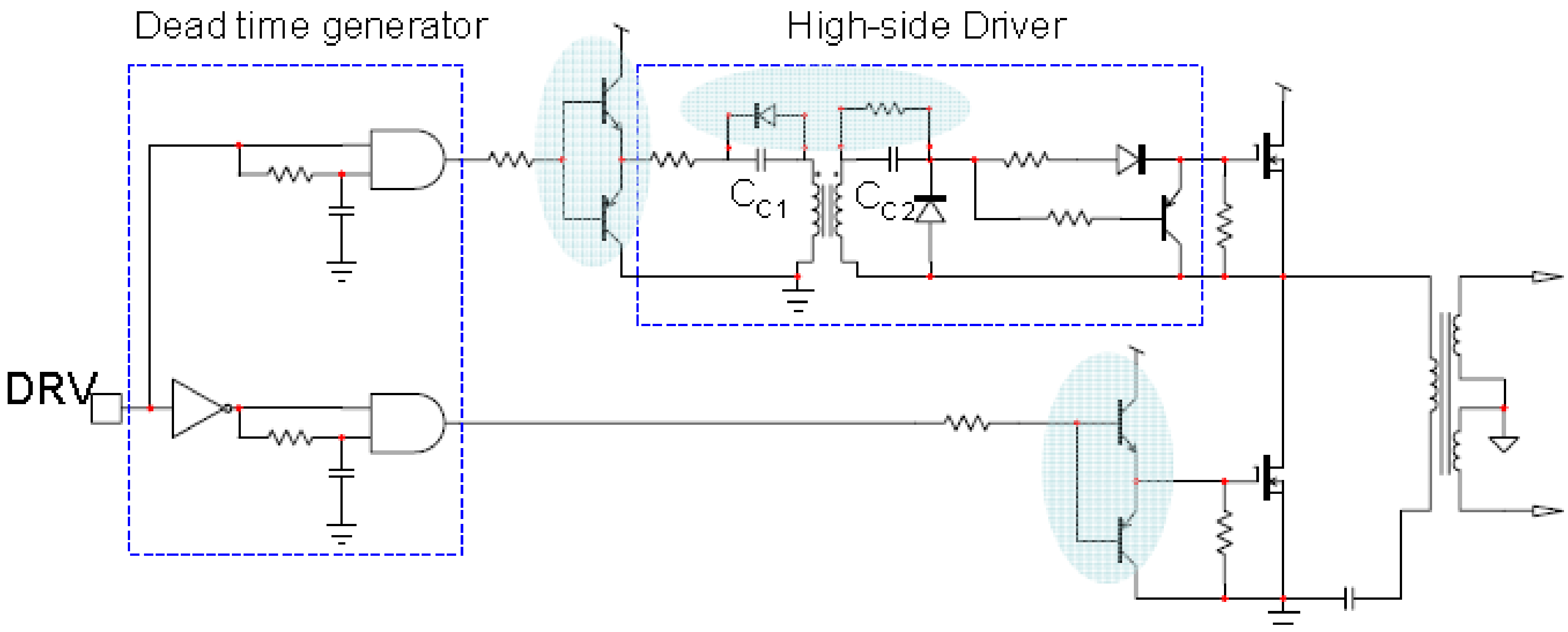
Zrychlení vypnutí spínače PNP tranzistorem

Single DRV Input with PNP Turn-Off



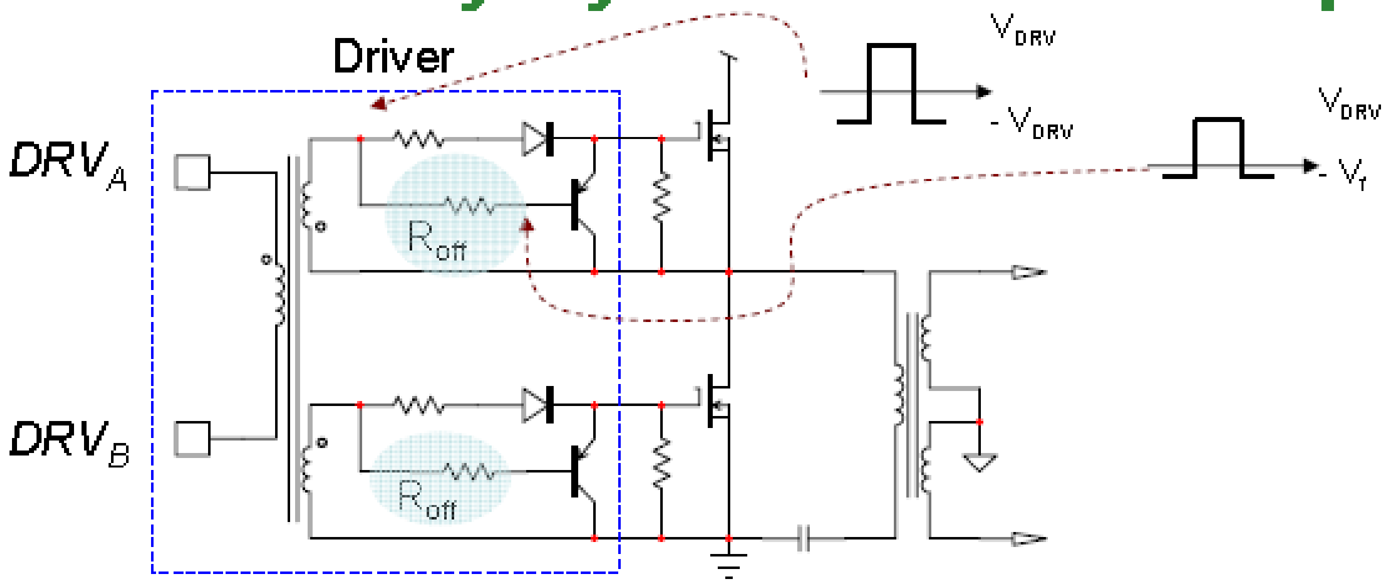
- A pnp transistor + diode help to improve the switching off.

Přidání proudového budiče za generátor pulzů



- Add the totem-pole drivers if output capability of AND gate is limited.
- Is the design finished?
  ➔ No, not yet. Pay attention to the ringing among C_{C1}, C_{C2} and driver transformer when skip or UVLO. A diode and resistor to damp the ringing. ☹

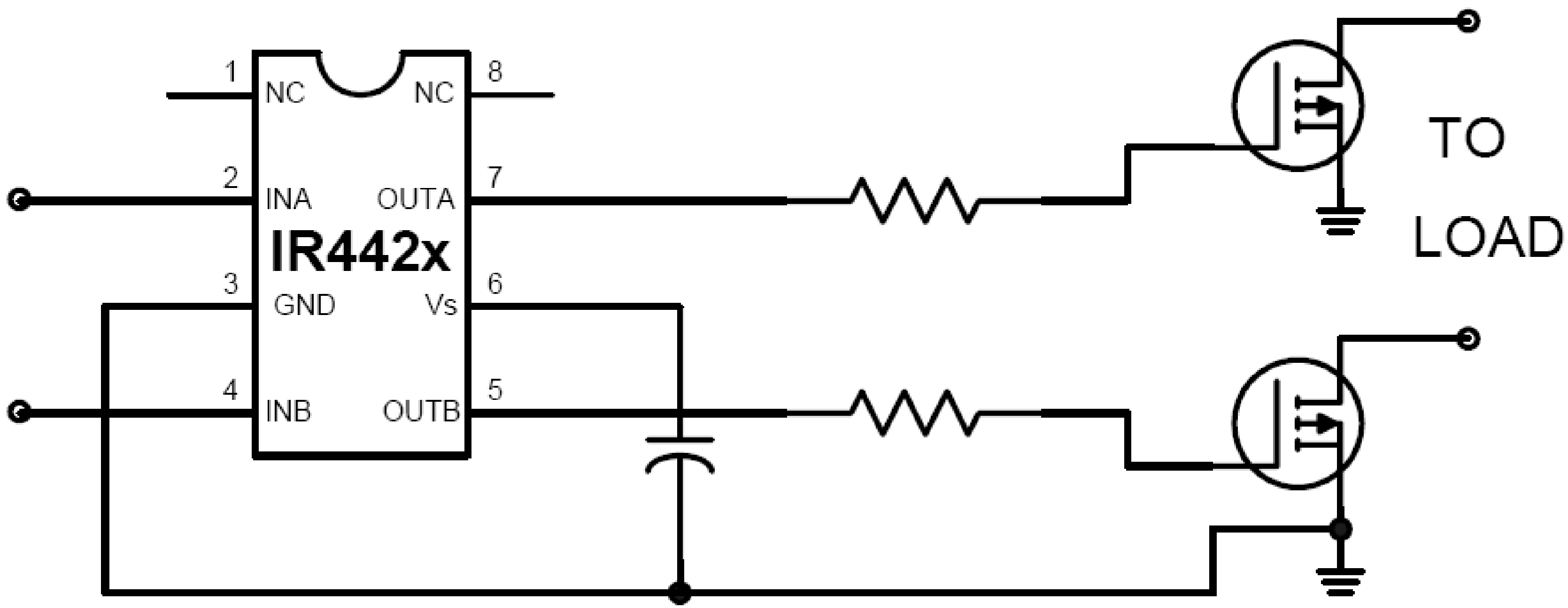
Dual Polarity Symmetrical DRV Inputs



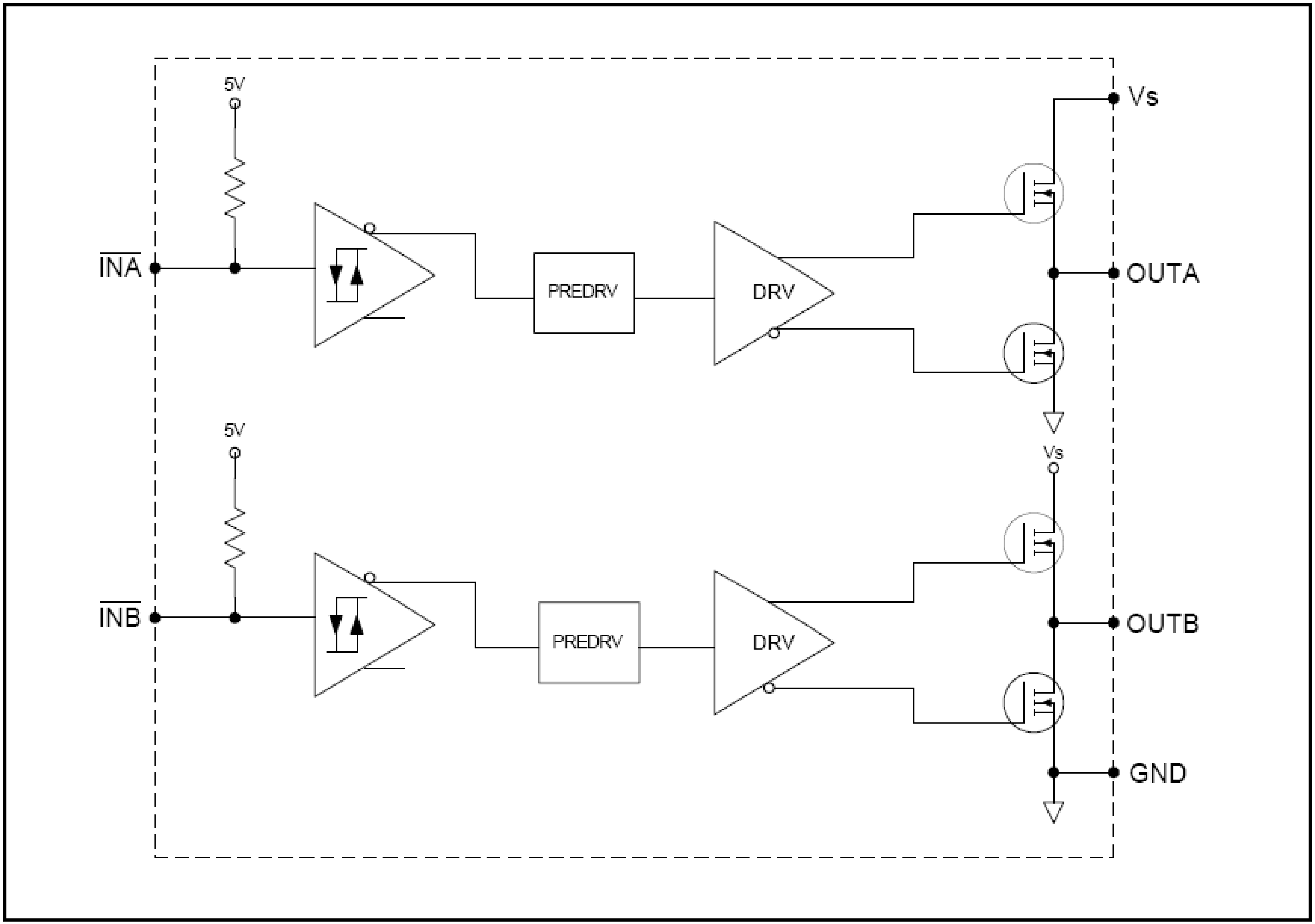
- DRV_A and DRV_B are opposite-polarity and symmetrical ➔ no ac coupling capacitor. ☺
- This is suitable for push-pull type circuit, e.g. LLC-HB, but NOT for asymmetrical type, e.g. AHB or active clamp. ☹
- Pay attention to the flux of driver transformer at line/load transient.
- The strong turn off capability is still needed. ☹
- Pay attention to the delay caused by the leakage inductance. ➔ minimize the leakage inductance and use dual output windings instead of single output winding.
- Extra losses caused by voltage drop on R_{off}. ☹

Budiče pro IGBT a MOSFET spínače.

- Integrované budiče schopné budit efektivně vstup IGBT/MOSFET tranzistoru.
- Musí být schopné dodat velký proud v pulzu na nabití kapacity C_{GE}

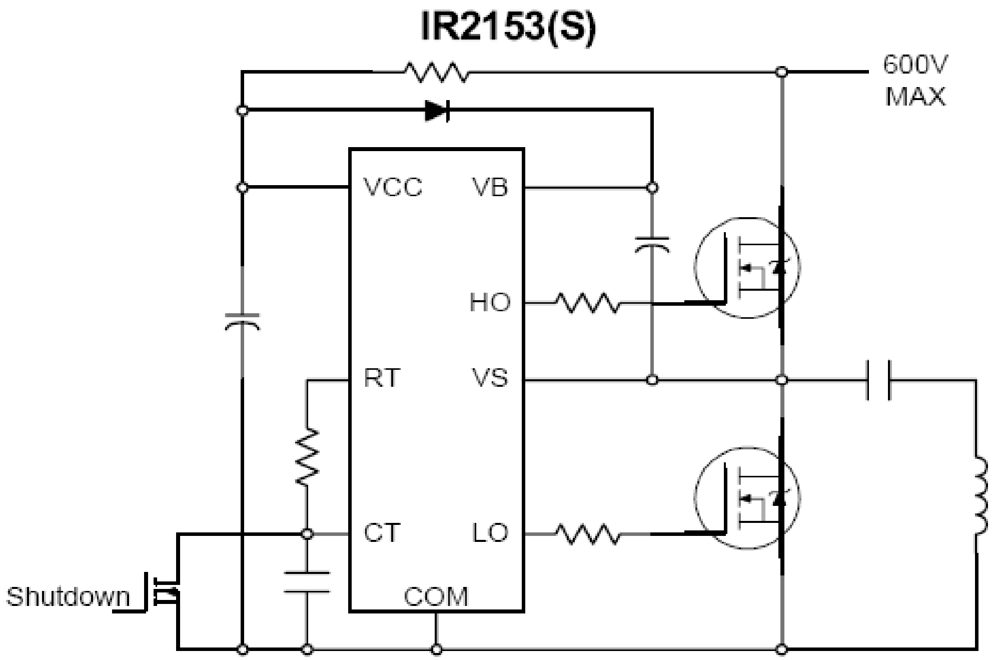


Vnitřní schéma budiče IR4426

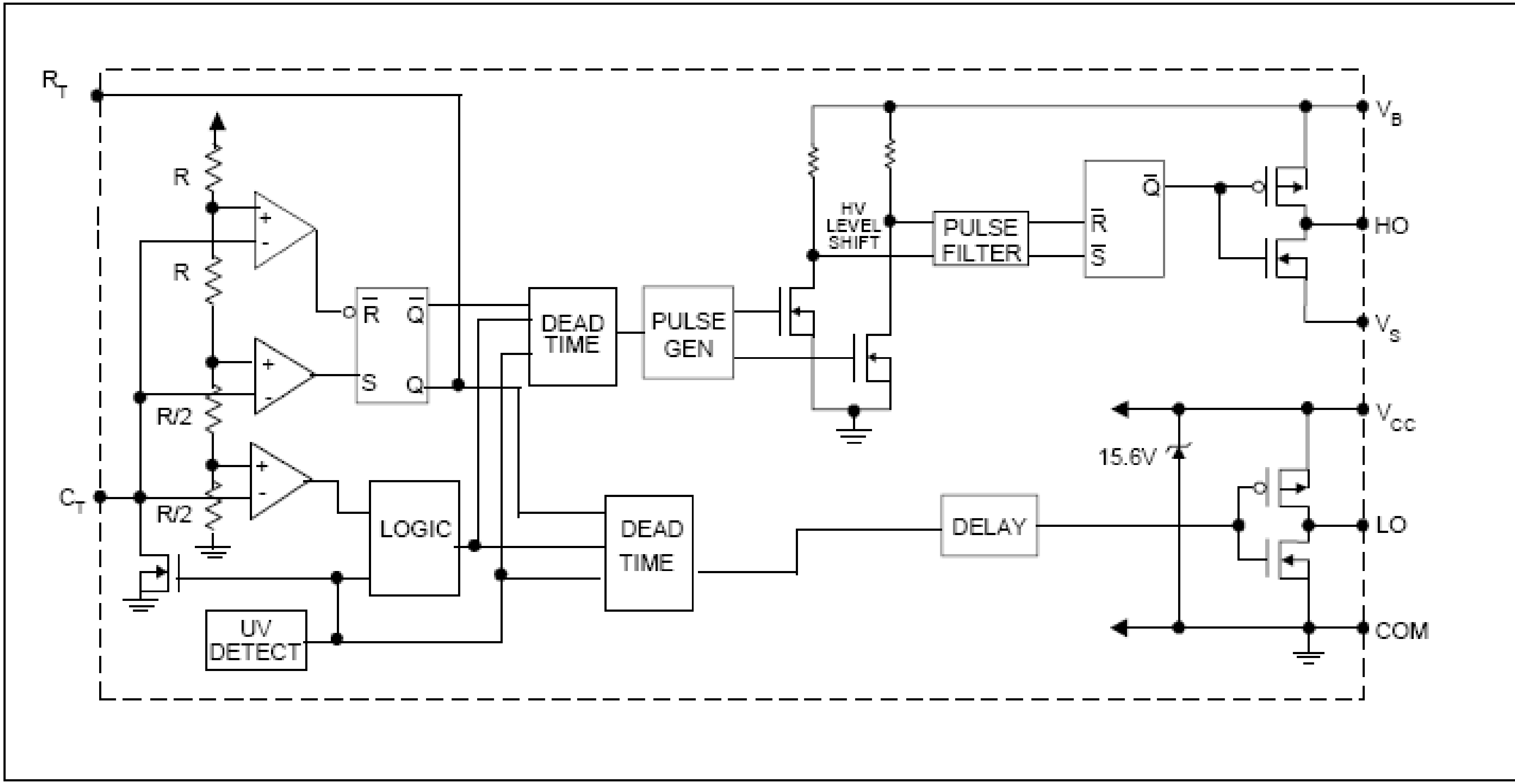


HIGH AND LOW SIDE DRIVER

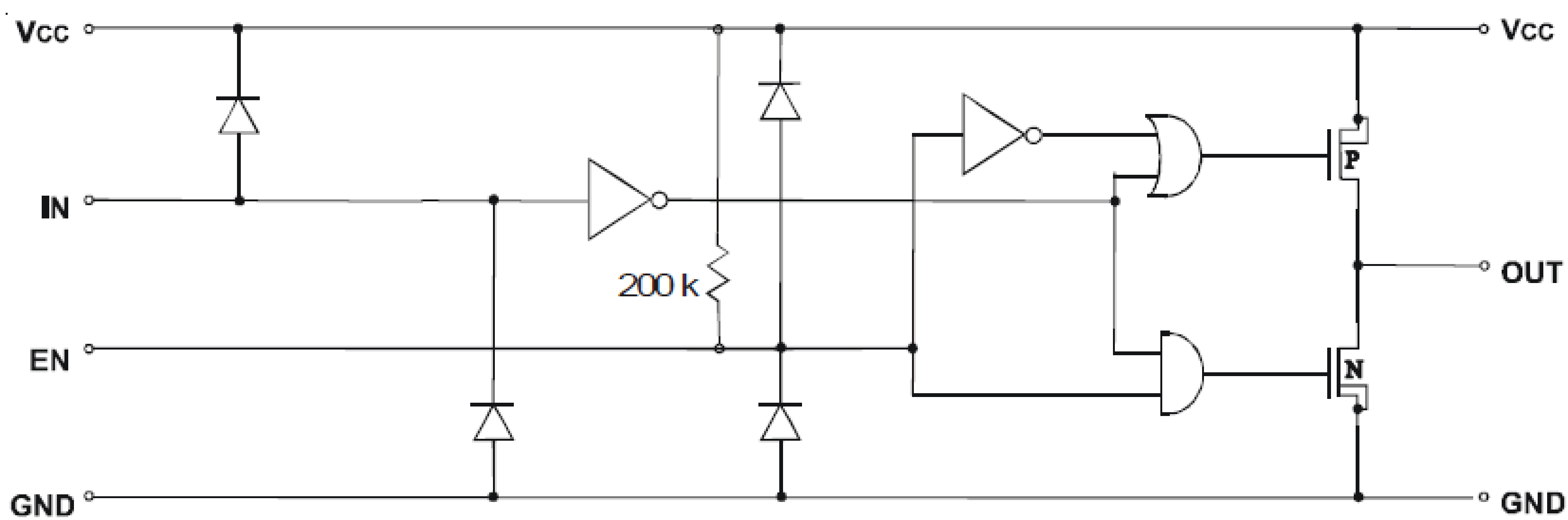
- spíná střídavě horní a dolní MOSFET/IGBT



Functional Block Diagram for IR2153(S)



IXDD414PI / 414YI / 414CI / 414SI
14 Amp Low-Side Ultrafast MOSFET Driver



Metoda zrychlení vypnutí

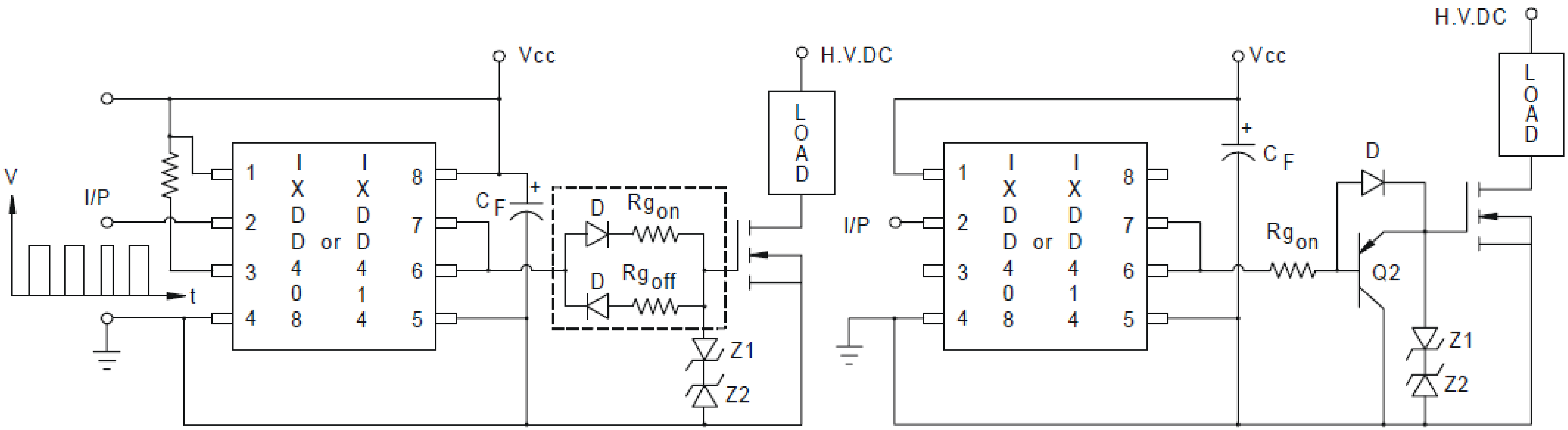


Fig (13) Turn-off enhancement methods.

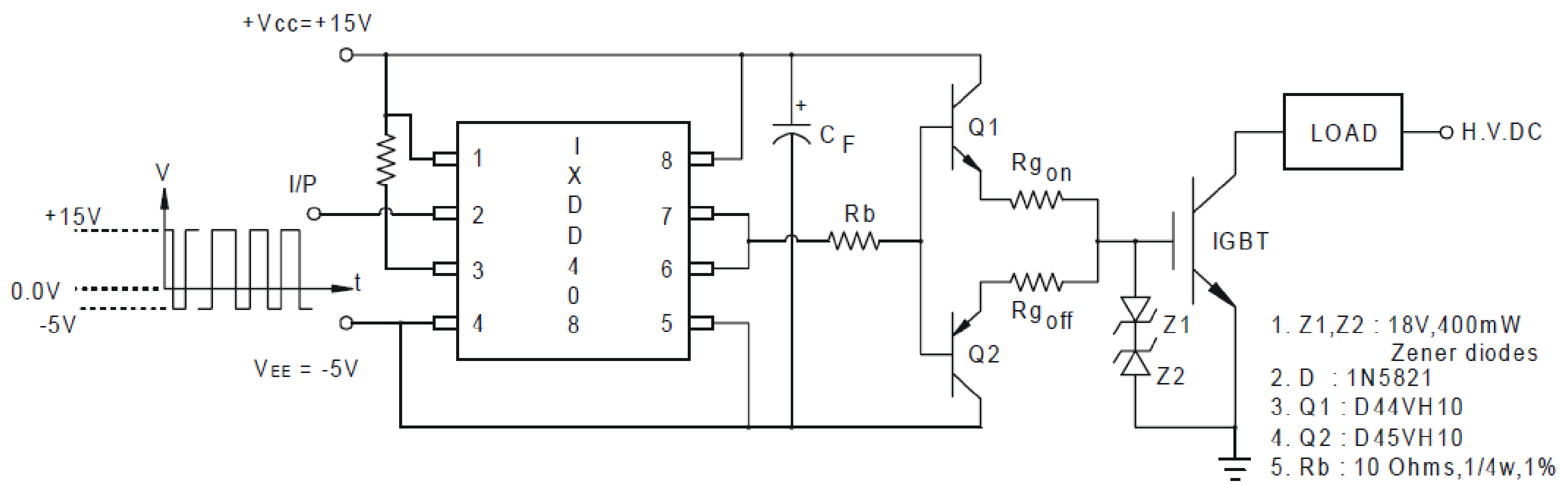


Fig. (14). Technique to boost current output and provide -ve bias to achieve faster turn off for high power MOSFET and IGBT Modules

Budiče s oddělovacími transformátory

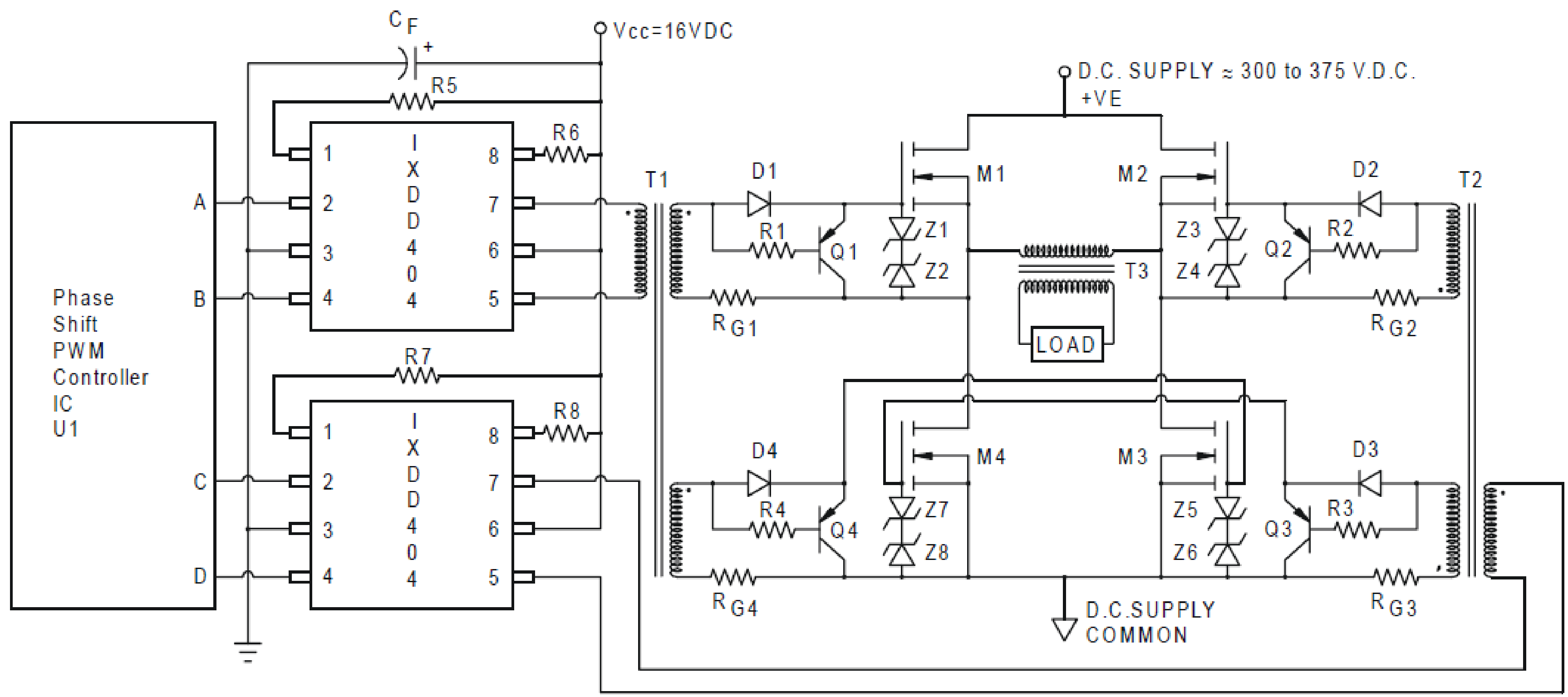


Fig. (15) Transformer coupled Gate Drive arrangement for "H" Bridge in a Phase Shift PWM Controller at fixed Switching frequency.

Spínané zdroje

- Moderní a efektivní řešení.
- Možnost použít transformace na vysoké frekvence.
- Vysoké frekvence spínání -> malé rozměry transformátoru -> malé filtrační kapacity.
- Používá se pulzně šířková modulace se zpětnou vazbou pro regulaci a stabilizaci výstupního napětí nebo proudu případně výkonu.

Základní uspořádání

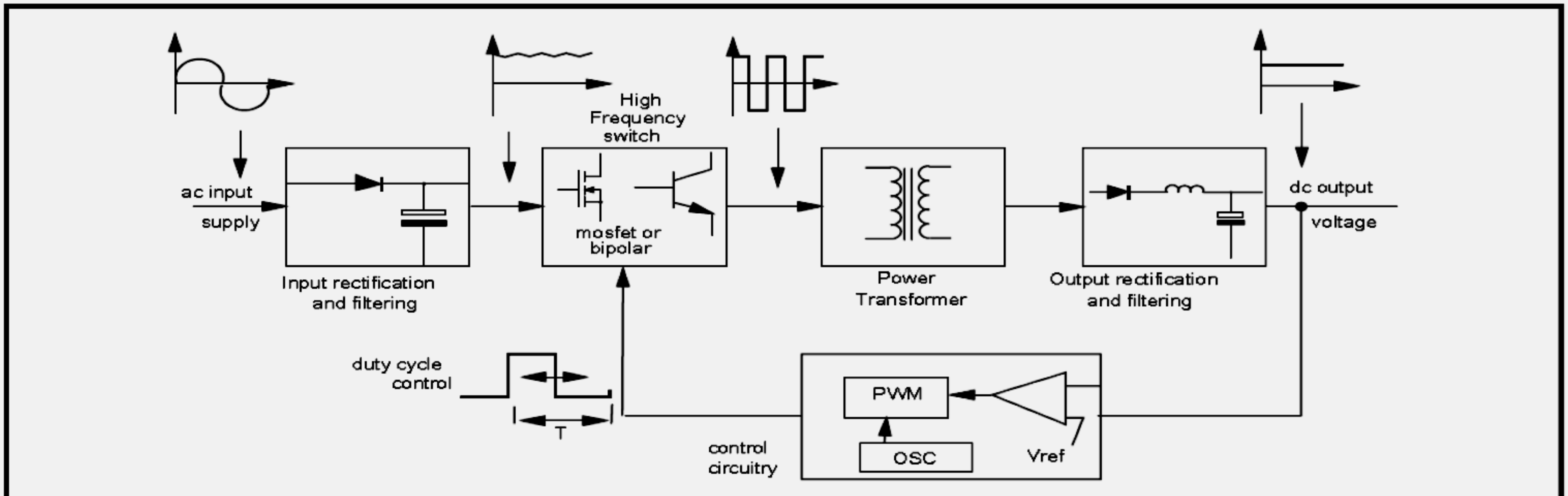


Fig. 1. Basic switched mode power supply block diagram.