0.3 Power electronic switches

A power electronic switch integrates a combination of power electronic components or power semiconductors and a driver for the actively switchable power semiconductors. The internal functional correlations and interactions of this integrated system determine several characteristics of the switch.

Figure 0.5 shows the power electronic switch system with its interfaces to the external electric circuitry (normally high potential) and to the control unit (information processing, auxiliary power supply). The necessary potential separation is supported by optical or inductive transmitters.
The possible combinations of power semiconductors differing from each other by switch current and voltage direction are shown in Figure 0.6.

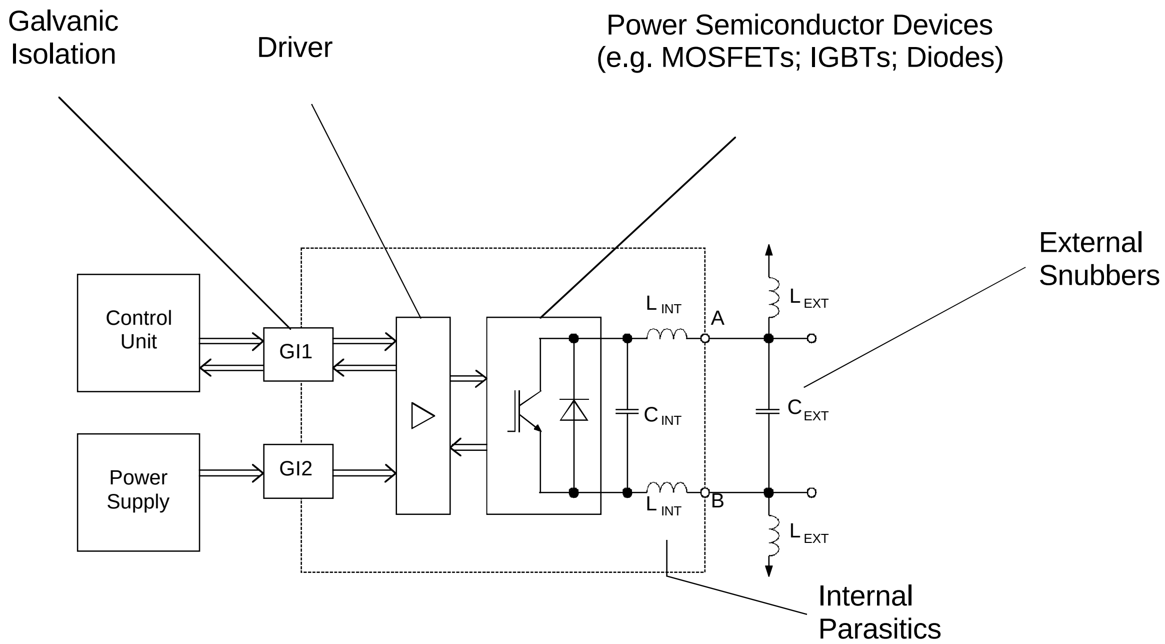
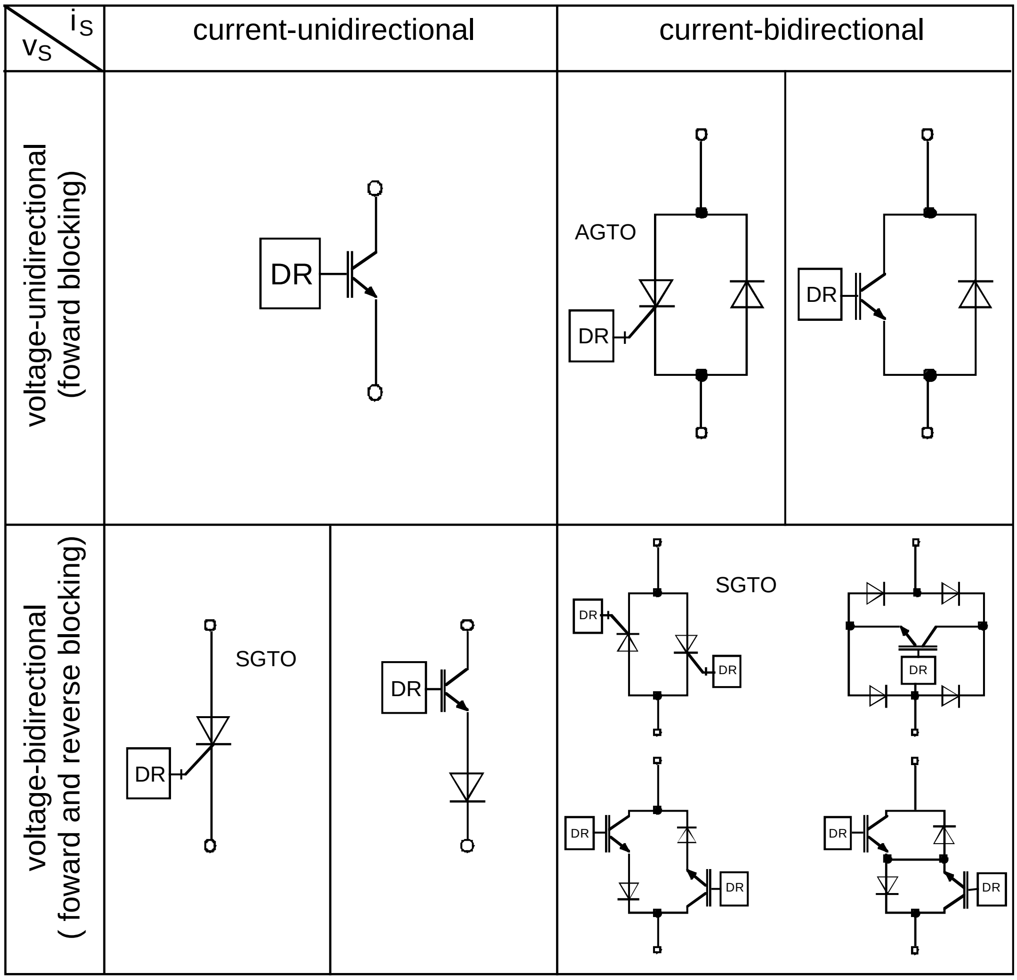


Figure 0.5 Power electronic switch system

On the one hand, the parameters of a complete switch result from the switching behaviour of the semiconductor which, by design of the semiconductor chips, has to be adapted to the operation mode of the whole switch. On the other hand, the driver unit is responsible for all main parameters of the switch and takes charge the most important protectional functions.



SGTO = symmetrical GTO

AGTO = asymmetrical GTO

Figure 0.6 Possible combinations of power semiconductors

Basic types of power electronic switches

Due to the operational principles of power semiconductors, which are mainly responsible for the dominant characteristics of the circuits, power electronic switches may be split up into the following basic types. The main current and voltage directions result from individual circuit requirements.

Hard switch (HS, Figure 0.7)

Except for the theoretical case of pure ohmic load, a single switch with hard turn-on and turn-off switching behaviour can be used only together with a neutrally switchable power semiconductor in a commutation circuit with a minimum passive energy store (C_{Kmin}; L_{Kmin}). Compared to the neutral switch which does not have any control possibility, the hard switch may be equipped with two control possibilites, namely individually adjustable turn-on and turn-off. Figure 0.7 shows the possible switch configurations. As for the symmetrical switch arrangements, only one alternating current-carrying switch will operate acitvely with two control possibilities while the other one switches neutrally.

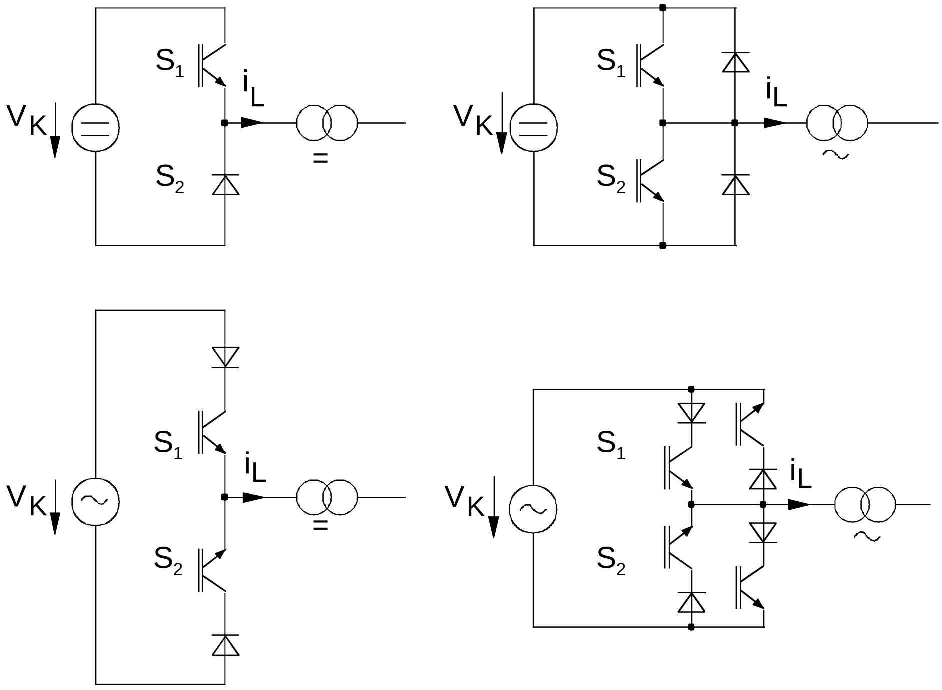


Figure 0.7 HS commutation circuits

Zero-current-switch (ZCS, Figure 0.8)

Power semiconductors in zero-current-switches are turned on actively and turned off passively. Accepting the loss of one control possibility compared to HS, active switching may proceed with considerably decreased power losses due to sufficient series inductance. Figure 0.8 shows the possible switch configurations of a ZCS in an equivalent commutation circuit, which are also applicable in circuits with cyclic switching without commutation. Such circuits are characterized by continuous inductive commutation processes, i.e. active turn-on is followed by passive turn-off.

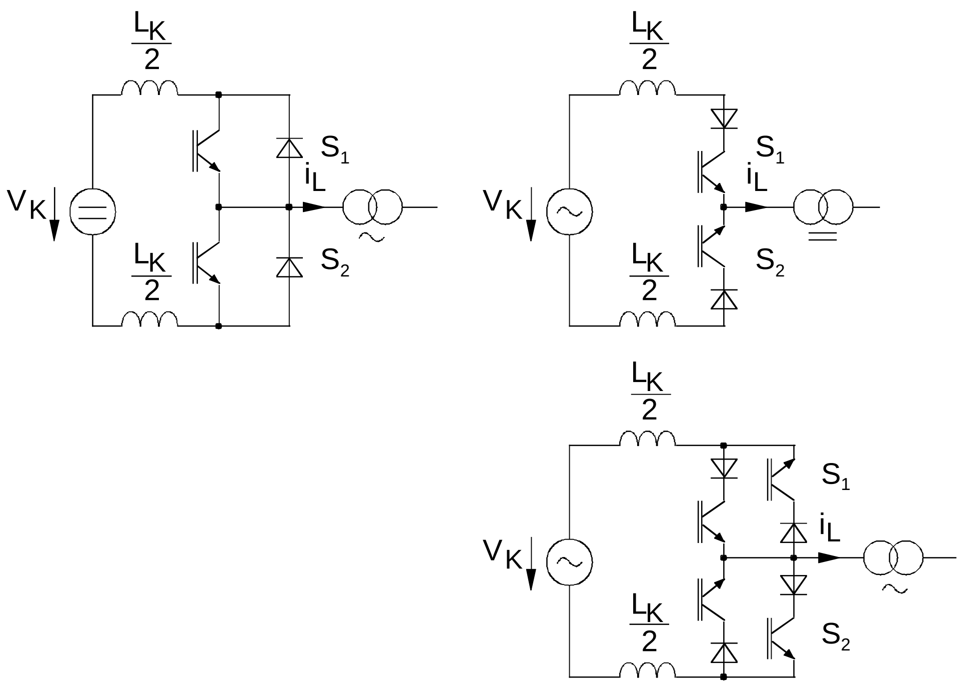


Figure 0.8 ZCS commutation circuits

Zero-voltage-switch (ZVS, Figure 0.9)

Zero-voltage-switches are designed in such a way that they may be turned off actively and turned on passively when the switch voltage drops to zero. Active turn-off may just cause very low losses, if the parallel capacitance has been chosen high enough. Compared to HS a decrease of power losses is possible by accepting the loss of control possibility. Figure 0.9 shows the possible switching arrangements of zero-voltage-switches in capacitive commutation circuits. However, zero-voltage-switches may also be applied in circuits without commutation, where active turn-off and passive turn-on of the same switch are alternating.

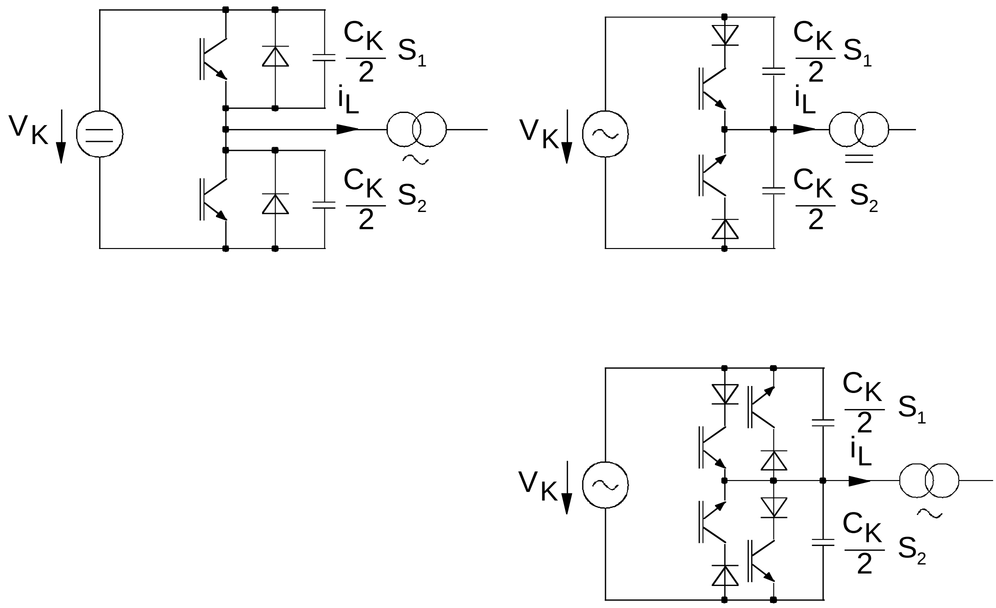


Figure 0.9 ZVS commutation circuits

Zero-current-resonant-switch (ZCRS, Figure 0.10)

If a zero-current-switch is controlled in such a way that active turn-on is started exactly when current is at zero-crossing, there will be no current commutation. Consequently, even if there is a minimum commutation inductance, the power losses are lower than in zero-current-switches; they are just caused by the still necessary change in charge of the junction capacitances of the power semiconductors. The further power loss reduction compared to ZCS demands, at the same time, another loss of controllability, since the turn-on moment is not controllable, but is triggered by the zero-current-crossing given by the outer circuitry. Energy flow can only be controlled indirectly with ZCRS, either conducting or rejecting several current cycles.

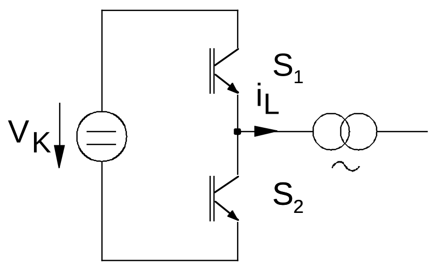


Figure 0.10 ZCRS commutation circuit

Zero-voltage-resonant-switch (ZVRS, Figure 0.11)

This basic type of switch is a borderline case of the ZVS. If a ZVS actively turns off exactly at zero-crossing of the applied commutation alternating voltage, the increasing switch voltage will trigger the current commutation process. Even in the case of minimum commutation capacitance power losses are reduced, however at the expense of active controllability. Indirect control is also possible with the ZVRS, if several commutation voltage cycles are connected through or rejected.

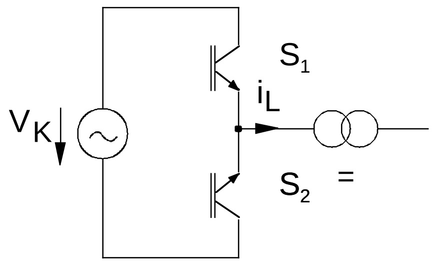


Figure 0.11 ZVRS commutation circuit

Neutral switch (NS, Figure 0.12)

A commutation process is finished by neutral turn-on or turn-off of a neutral switch. In this case current and voltage drop to zero. Generally, a diode already includes these features. A neutral switch with actively switchable power semiconductors owes this special features to a special driver circuit.

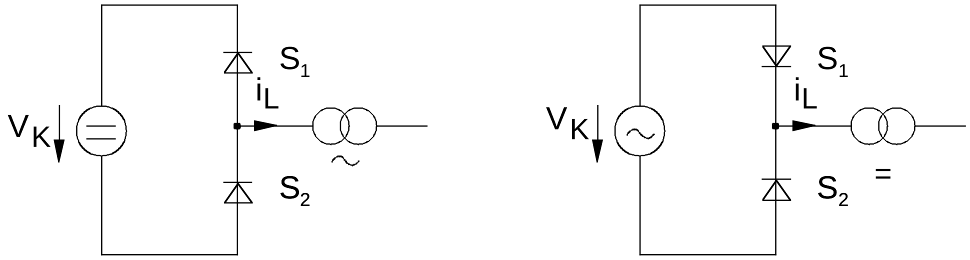


Figure 0.12 NS commutation circuits

Figure 0.13 shows a summary of all basic types of power electronic switches. The blank squares are modifications of the basic types, which are required in almost all applications. If the resonant conditions in a circuit working with soft or resonant switches are broken, the switches will have to cope with hard switching apart from their original features (modified ZVS = MZVS; modified ZCS = MZCS), in order to keep up operation of the whole system (see also chapter 3.8). Mostly, the switches are operated in this deviating mode only for a very short time. In the case of hard active turn-off of a ZVS or hard active turn-on of a ZCS, the switches are operated as ZVHS and ZCHS, respectively.

OFF \ ON	hard	soft L_K in Series	Resonant $i_L = 0$	neutral $V_S = 0$
hard	HS	MZCS		ZVHS
soft C_K in Parallel	MZVS			ZVS
resonant $V_K = 0$				ZVRS
neutral $i_S = 0$	ZCHS	ZCS	ZCRS	NS

Figure 0.13 Power electronic switches