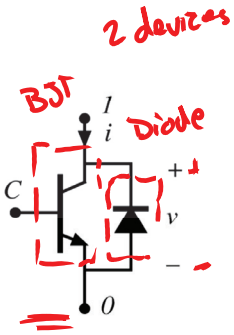
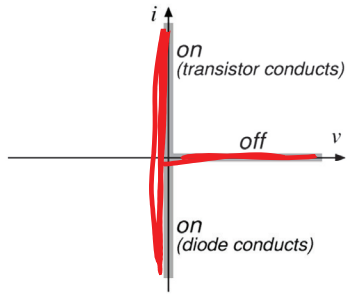
Current Bidirectional Two-Quadrant



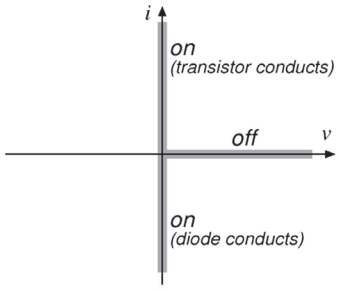
BJT / anti-parallel diode realization



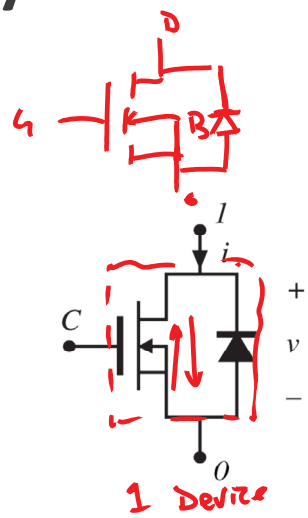
instantaneous i-v characteristic

- *Usually an active switch, controlled by terminal C*
- *Normally operated as two-quadrant switch:*
- *can conduct positive or negative on-state current*
- *can block positive off-state voltage*
- *provided that the intended on-state and off-state operating points lie on the composite i-v characteristic, then switch can be realized as shown*

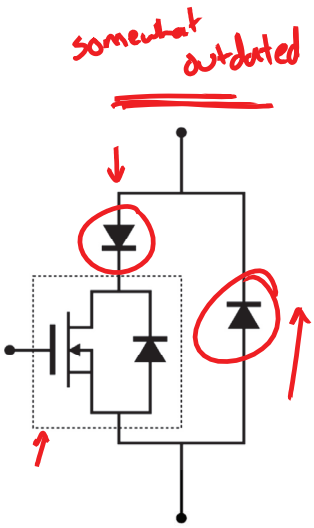
MOSFET Body Diode



Power MOSFET characteristics

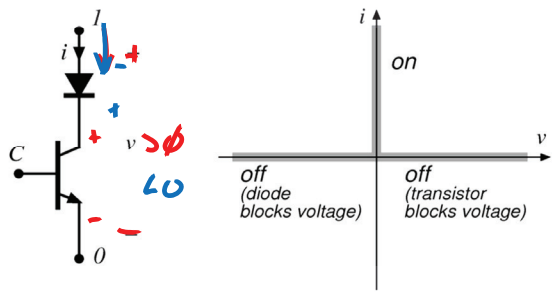


Power MOSFET, and its integral body diode



Use of external diodes to prevent conduction of body diode

Voltage-bidirectional Two-Quadrant

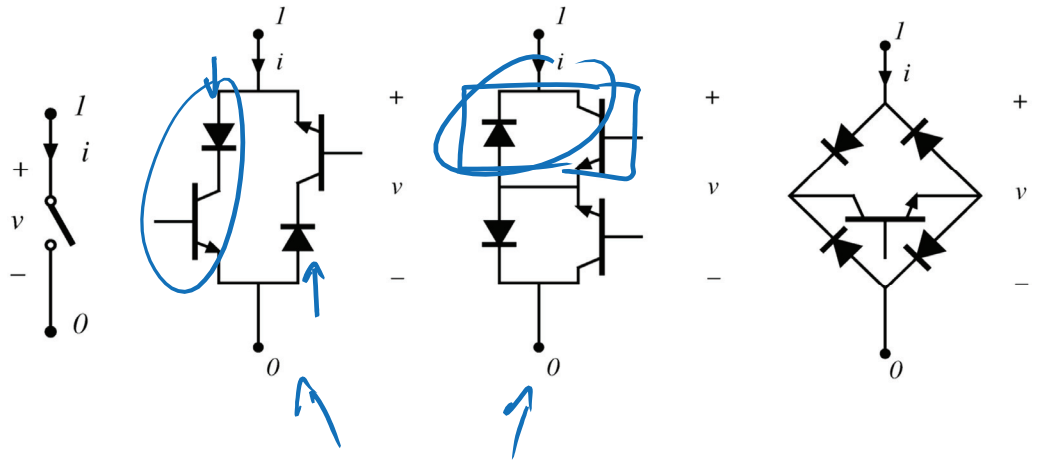


BJT / series diode realization

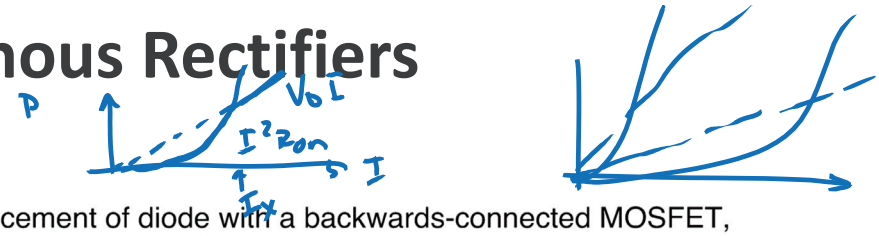
instantaneous i-v characteristic

- *Usually an active switch, controlled by terminal C*
- *Normally operated as two-quadrant switch:*
- *can conduct positive on-state current*
- *can block positive or negative off-state voltage*
- *provided that the intended on-state and off-state operating points lie on the composite i-v characteristic, then switch can be realized as shown*
- *The SCR is such a device, without controlled turn-off*

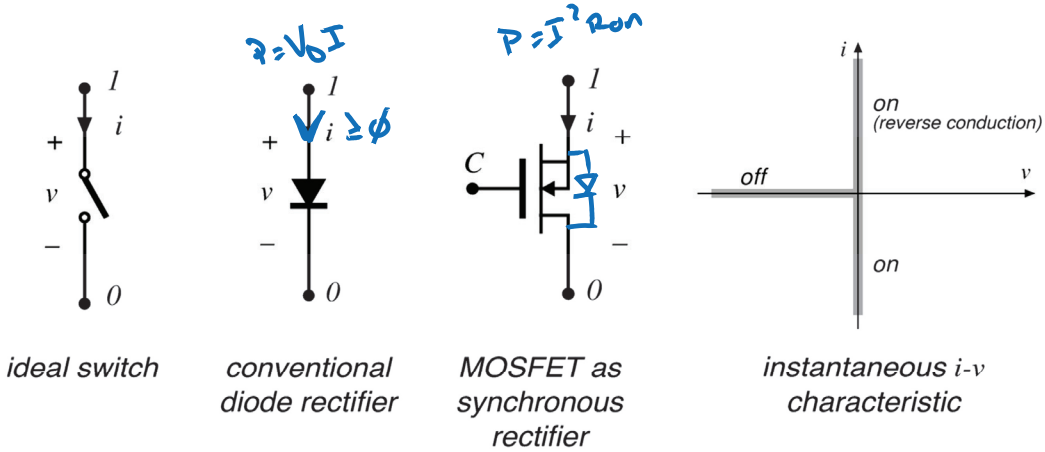
Four-Quadrant Switches



Synchronous Rectifiers



Replacement of diode with a backwards-connected MOSFET, to obtain reduced conduction loss



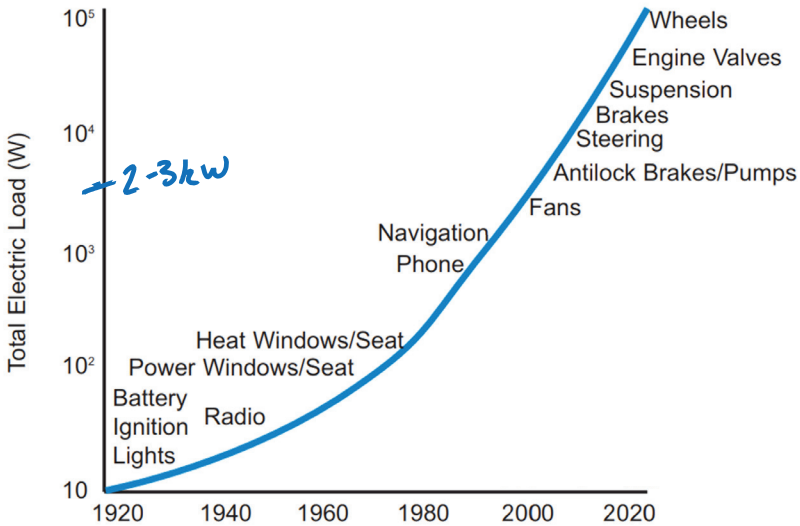
ideal switch | conventional diode rectifier | MOSFET as synchronous rectifier | instantaneous i-v characteristic

Example Application

48V VEHICLE ELECTRICAL SYSTEM

Automobile 12V Power

Figure 3. Electrification of the Auto

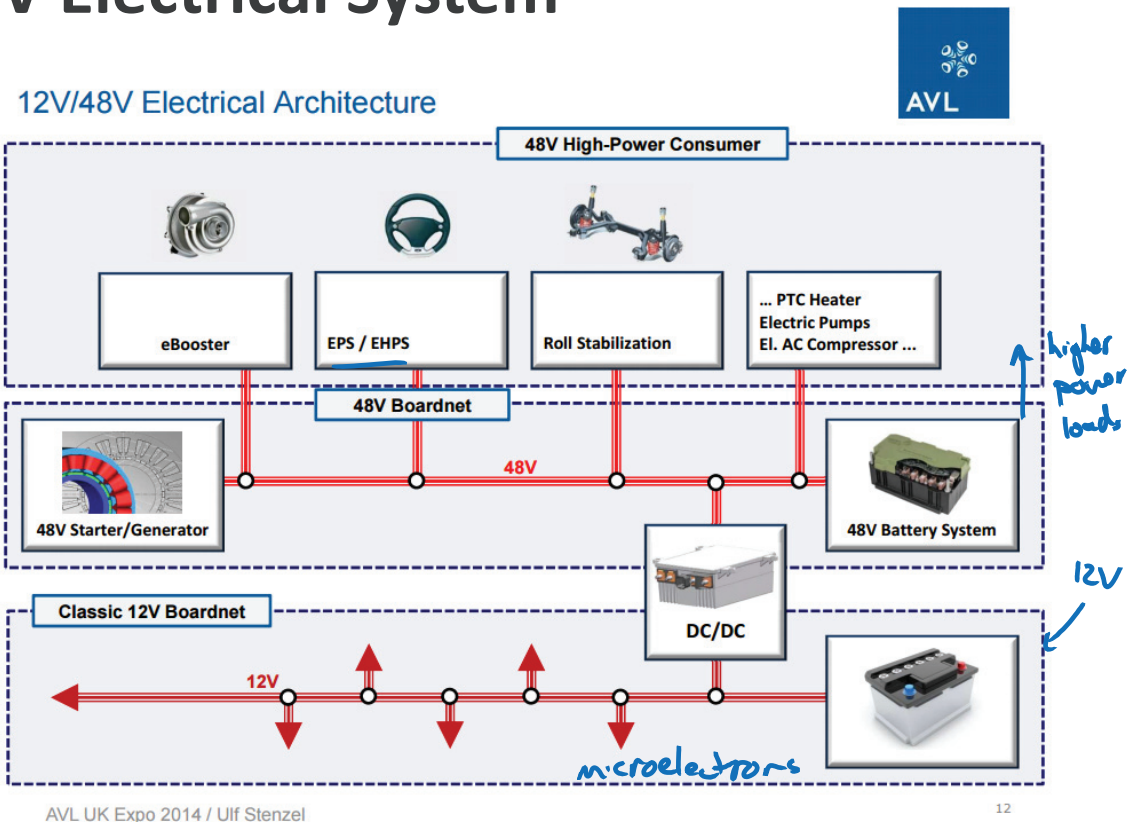


Source: Kasakian, Miller, and Traub, "Automotive Electronics Power Up," IEEE Spectrum (May 2000).

10kW @ 12V ≈ 850A

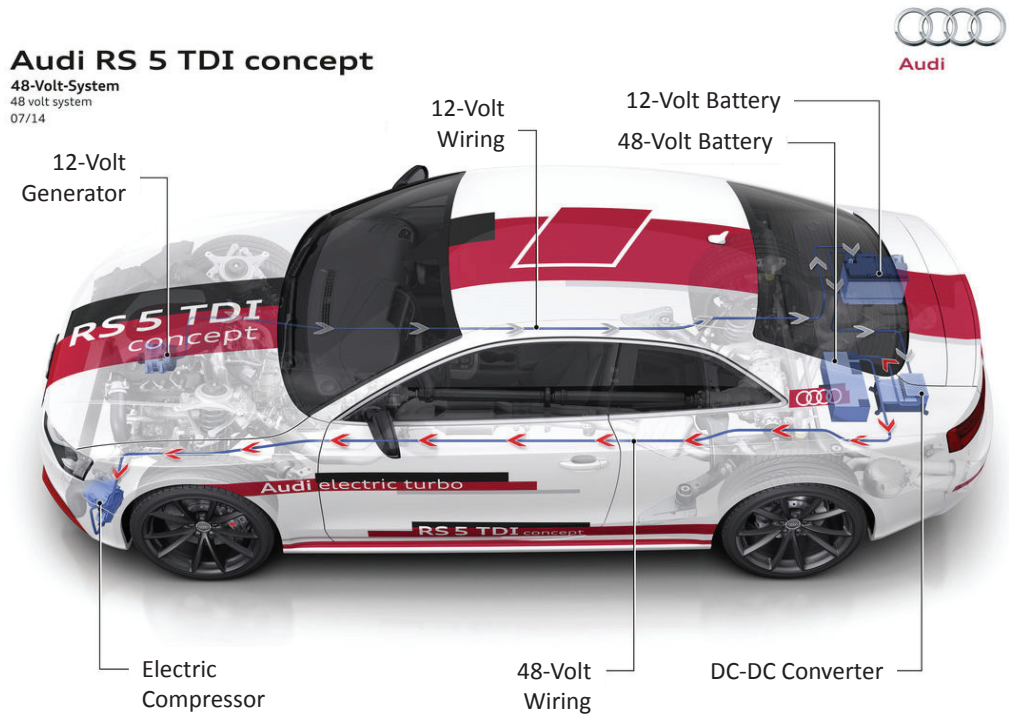
Move towards ~48V bus in vehicles

48V Electrical System

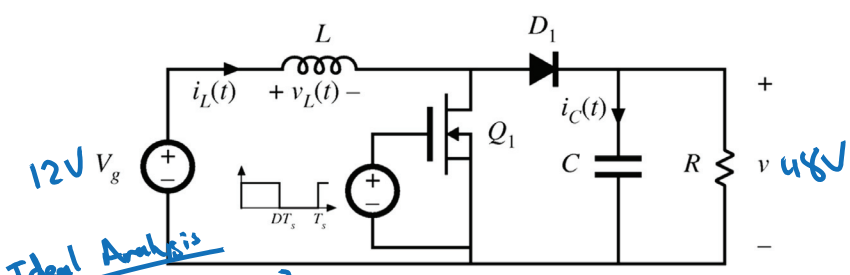


NXP Semi, "Semiconductors – enablers of future mobility concepts", 2011
Audi, "Electric biturbo and hybridization", 2014
AVL, "48V Mild Hybrid Systems"

Example 12/48 V Vehicle



System to Design



Param	Value
V_g	12 V
V_{out}	48 V
R_{out}	48 Ω
ΔV_{out}	0.1 V

Ideal Analysis

$P_{out} = \frac{V_{out}^2}{R} = 48W$

$\frac{V}{V_g} = \frac{1}{D'} \rightarrow D = 0.75$

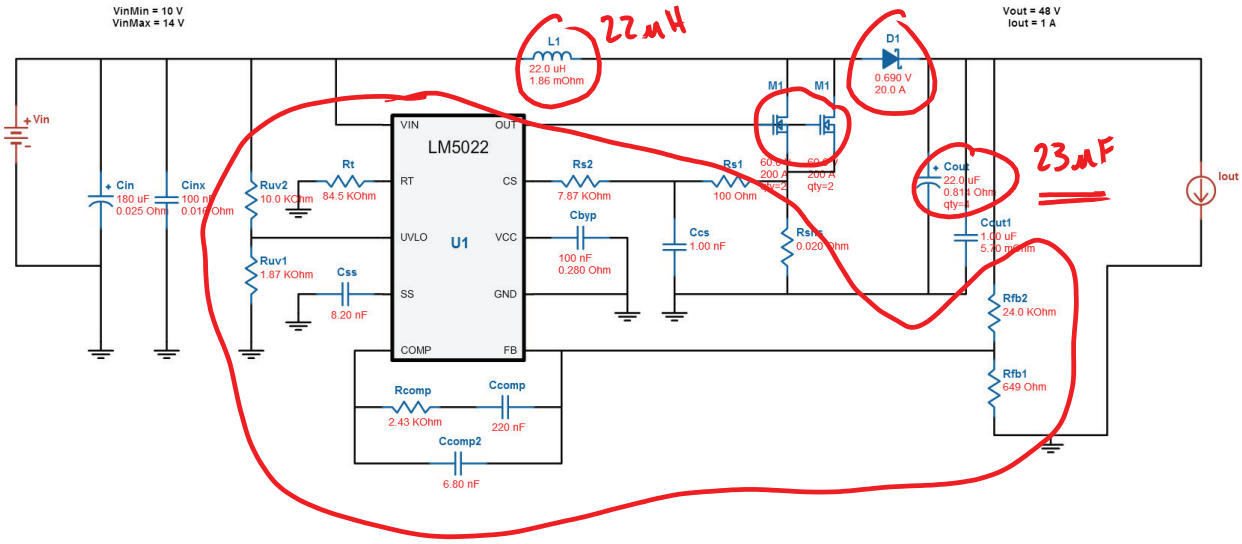
$2\Delta v_c = \frac{V/R}{C} D T_s \rightarrow \Delta v_c = \frac{V/R}{2C} D T_s \rightarrow C = \frac{1}{2 \cdot \frac{1}{10}} \cdot 0.75\ T_s$

$C = \frac{30}{8} T_s = 186\,\mu F$ @ 200kHz

Baseline Design

$f_s = 200kHz$

- Use TI WebBench (webench.ti.com) to get a baseline design



Device Parameters

Diode

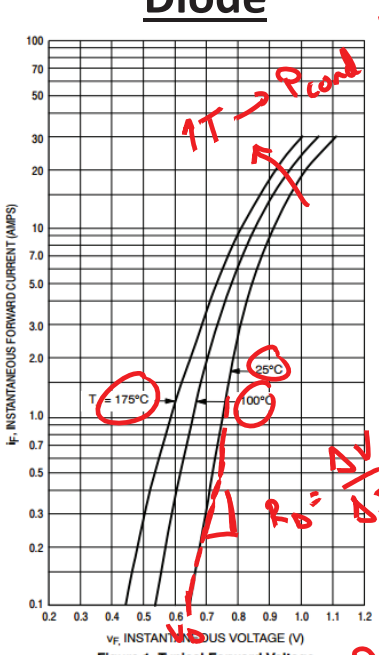
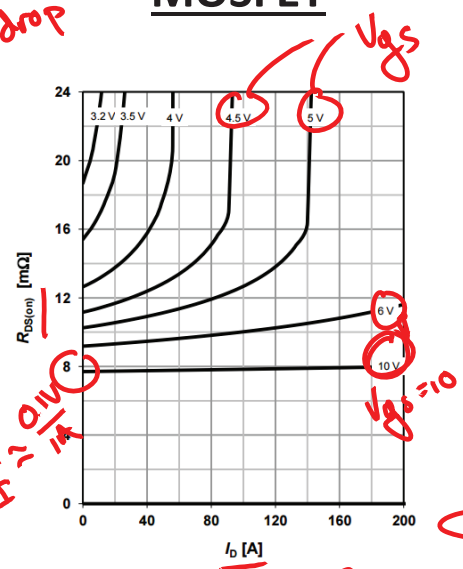


Figure 1. Typical Forward Voltage

$V_D \approx 0.65V$

$R_D \approx 0.1\Omega$

MOSFET



$R_{DS(on)} = 8m\Omega$

2 in parallel

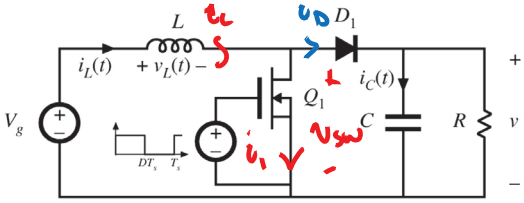
$R_{on} = 4m\Omega$

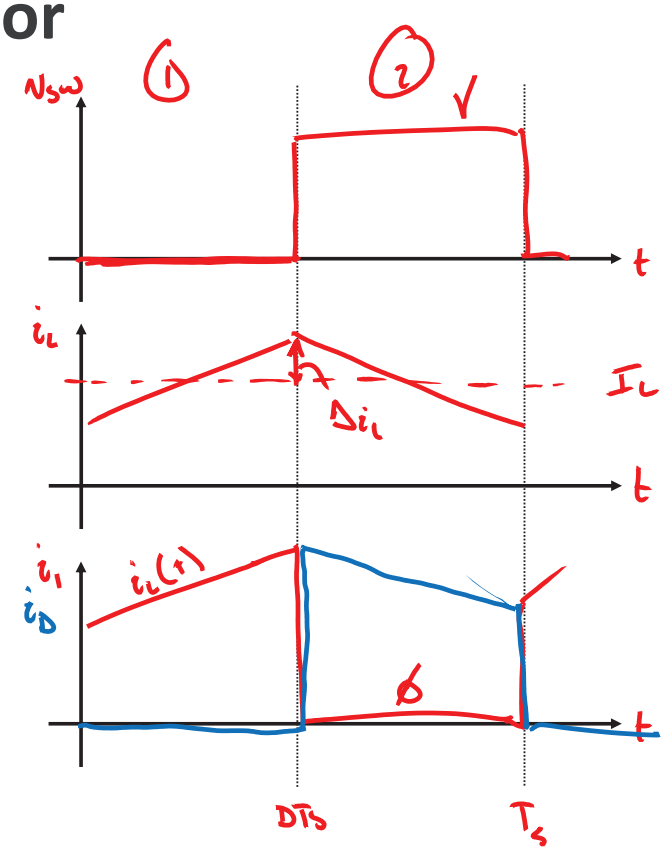
Inductor

Part number[1]	Inductance[2] ±10% (μH)	DCR[3] (mOhms) nom	DCR[3] (mOhms) max	SRF typ[4] (MHz)
SER2915L-152KL	1.5	1.50	1.65	60
SER2915H-222KL	2.2	1.86	2.05	40
SER2915L-222KL	2.2	1.50	1.65	50
SER2918H-332KL	3.3	2.60	2.86	40
SER2915H-332KL	3.3	1.86	2.05	30
SER2915L-332KL	3.3	1.50	1.65	40
SER2918H-472KL	4.7	2.60	2.86	30
SER2915H-472KL	4.7	1.86	2.05	25
SER2915L-472KL	4.7	1.50	1.65	30
SER2918H-682KL	6.8	2.60	2.86	25
SER2915H-682KL	6.8	1.86	2.05	20
SER2915L-682KL	6.8	1.50	1.65	25
SER2918H-103KL	10	2.60	2.86	20
SER2915H-103KL	10	1.86	2.05	15
SER2915L-103KL	10	1.50	1.65	20
SER2918H-153KL	15	2.60	2.86	16
SER2915H-153KL	15	1.86	2.05	12
SER2915L-153KL	15	1.50	1.65	15
SER2918H-223KL	22	2.60	2.86	15
SER2915H-223KL	22	1.86	2.05	10
SER2915L-223KL	22	1.50	1.65	10
SER2918H-333KL	33	2.60	2.86	10
SER2915H-333KL	33	1.86	2.05	8
SER2915L-333KL	33	1.50	1.65	7

$R_L = 1.86m\Omega$

Expected Behavior





Ideally:

$I_L = \frac{V}{RD'} = 4A$

$2\Delta i_L = \frac{V_g}{L} DT_s \rightsquigarrow \Delta i_L = 1A$