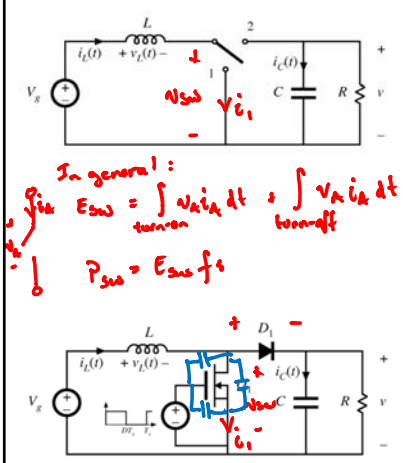
Announcements

- Office Hours:
  - Shortened office hours today: 1:30-2:20
  - Earlier office hours tomorrow: 8:30-9:30

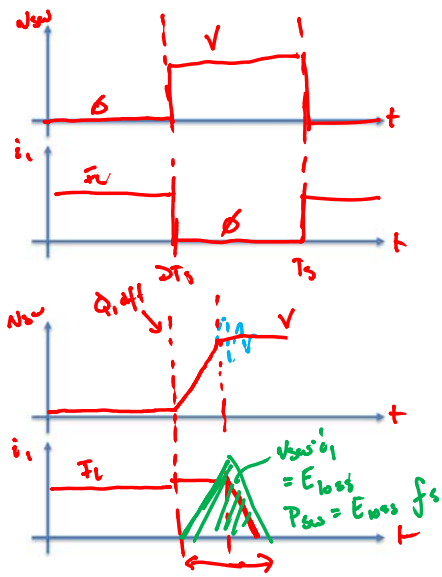
Switching Nonidealities



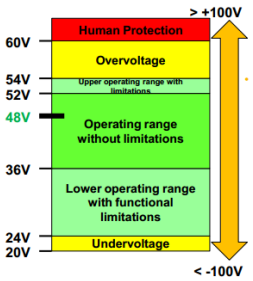
In general:

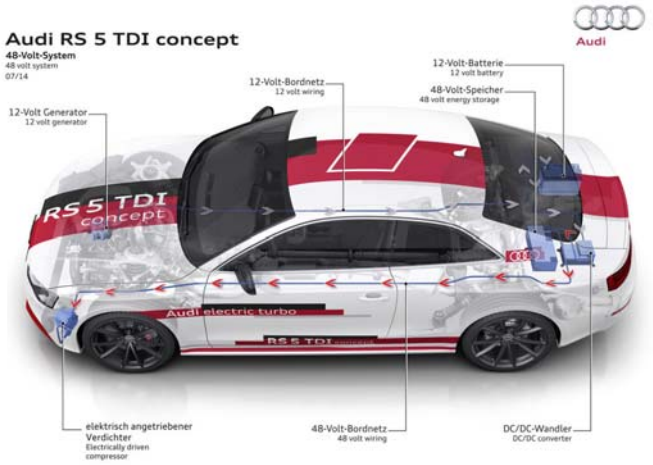
$E_{sw} = \int_{turn\text{-}on} v_A i_A \, dt + \int_{turn\text{-}off} v_A i_A \, dt$

$P_{sw} = E_{sw} f_s$

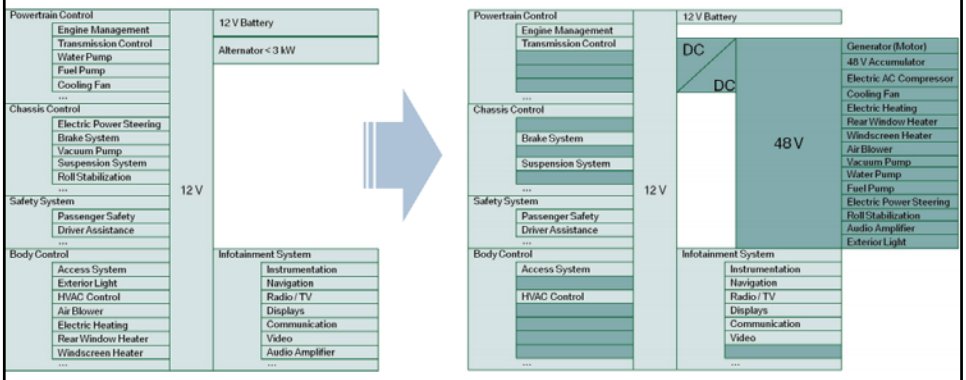


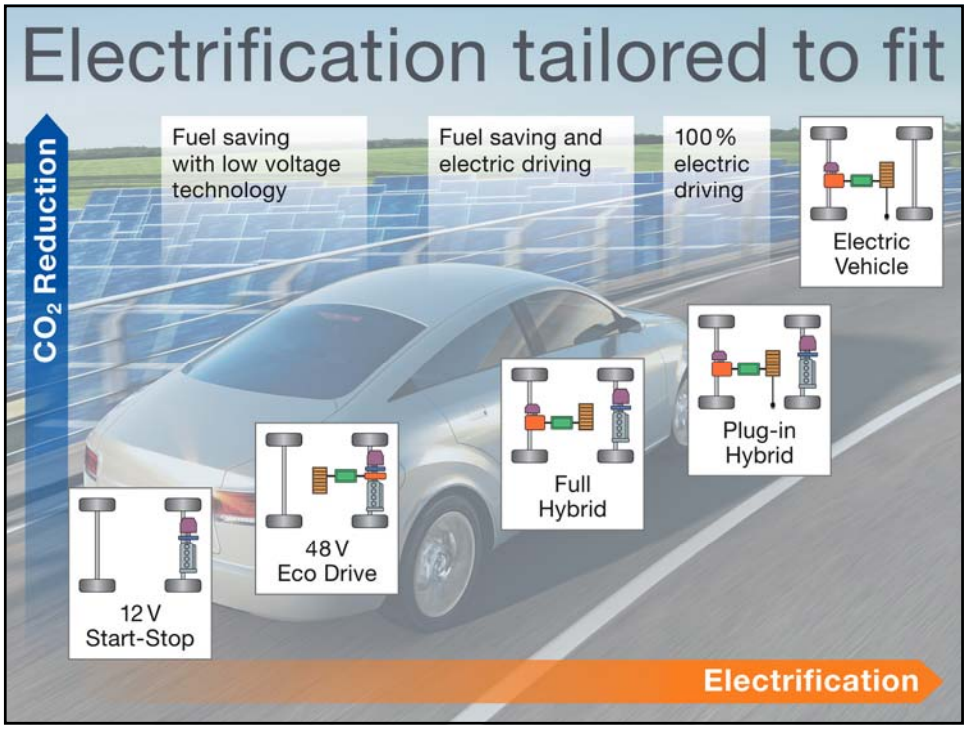
Application Example: EV LV Bus



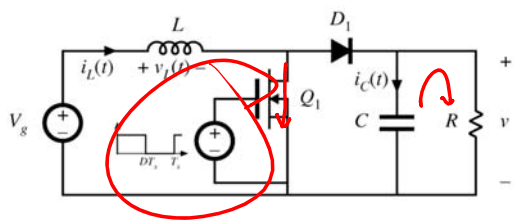


EV Networks





System to Design

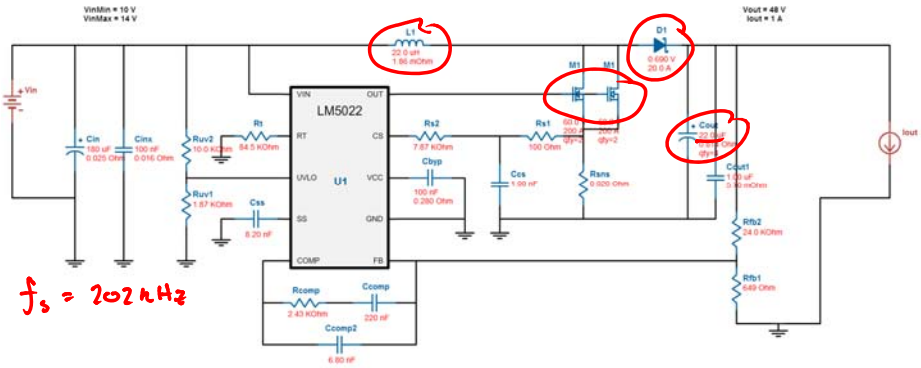


Param	Value
V_g	12 V
V_{out}	48 V
R_{out}	48 Ω
ΔV_{out}	0.1 V

Baseline Design

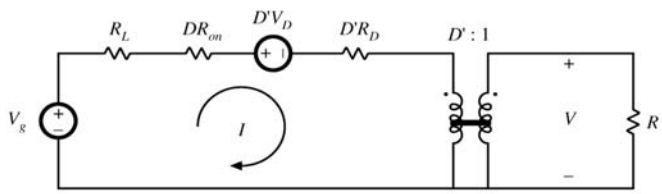
$2\Delta V = \frac{1}{C} D T_s \frac{V}{R}$ $D_{ideal} \rightarrow 1 - \frac{V_g}{V} = 0.75$ $C > 186\,\mu F$

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



$f_s = 202\,kHz$

Equivalent Circuit Model



$$V = \left(\frac{1}{D'}\right)\left(V_g - D'V_D\right)\left(\frac{D'^2R}{D'^2R + R_L + DR_{on} + D'R_D}\right) \rightarrow D_{real} = 0.756$$

$$\frac{V}{V_g} = \left(\frac{1}{D'}\right)\overbrace{\left(1 - \frac{D'V_D}{V_g}\right)}^{\text{Ideal}}\overbrace{\left(\frac{1}{1 + \frac{R_L + DR_{on} + D'R_D}{D'^2R}}\right)}^{\eta} \rightarrow \eta = 97.6\%$$

Plug in Loss Params

Device Parameters

Diode

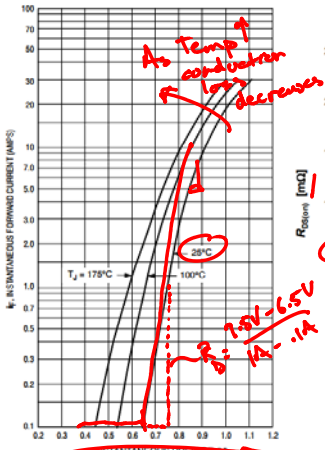
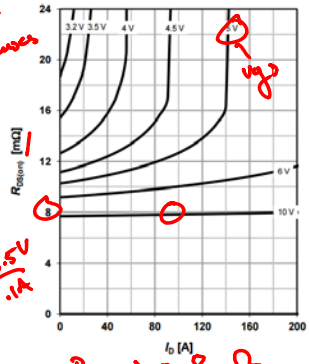


Figure 1. Typical Forward Voltage

$V_{D0} = 0.65V$
$R_D = 1.11\Omega$

MOSFET



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

$R_{on} = 4m\Omega$

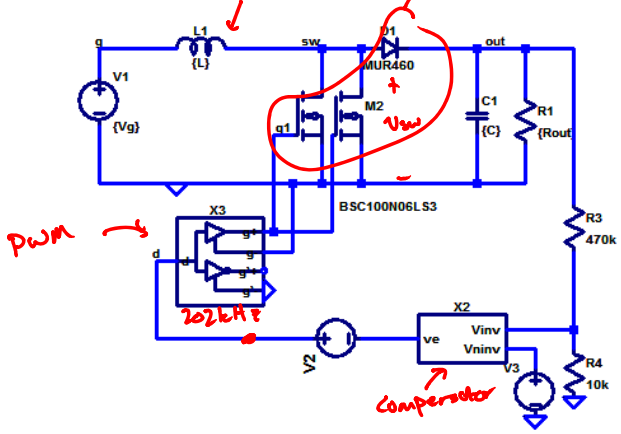
Inductor

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

$R_L = 1.65m\Omega$

LTSpice Simulation

V_D, R_D, R_{on} + parasitics & nonlinearities

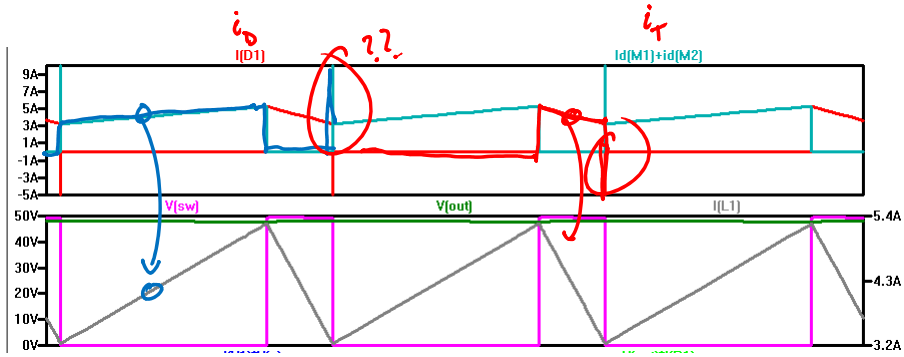


L	C_{out}	f_s	η (Sim)
22uH	22uF	202k	93.9%

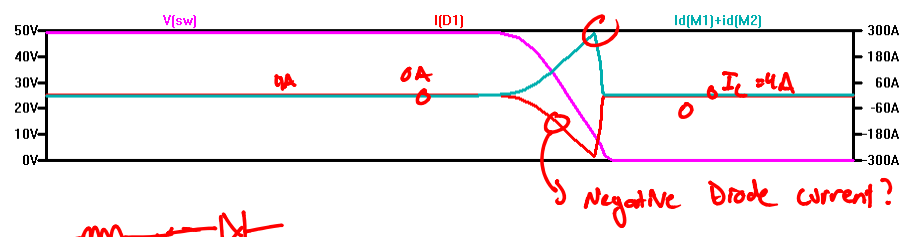
!!

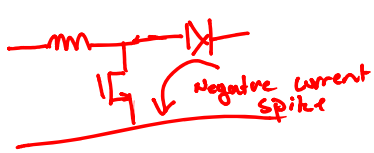
3x predicted Losses!

LTSpice Simulation

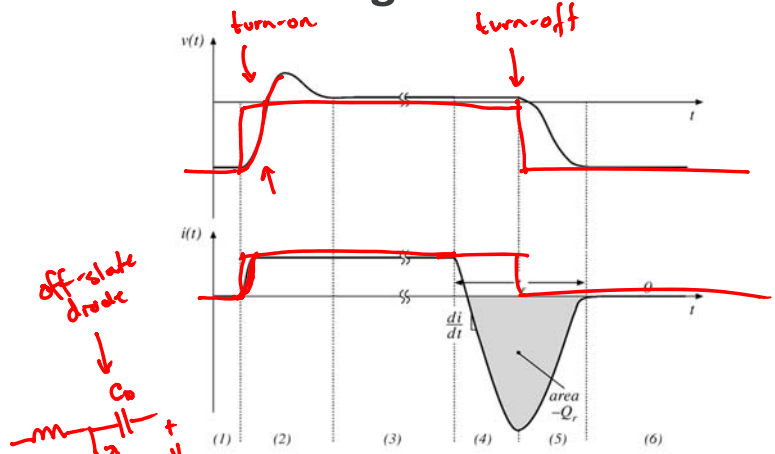


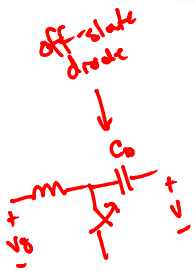
Switching Transition



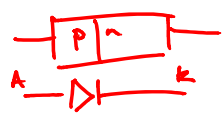


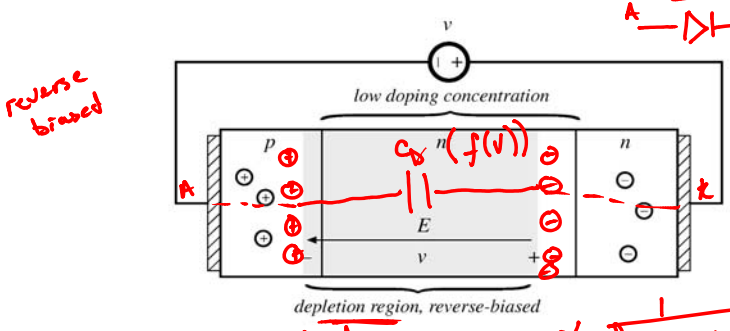
Diode Switching Waveforms





Power Diodes





width of depletion region $\propto \frac{1}{\text{doping concentration}}$

for silicon $E_{BR} = 3 \times 10^5 \frac{V}{cm}$