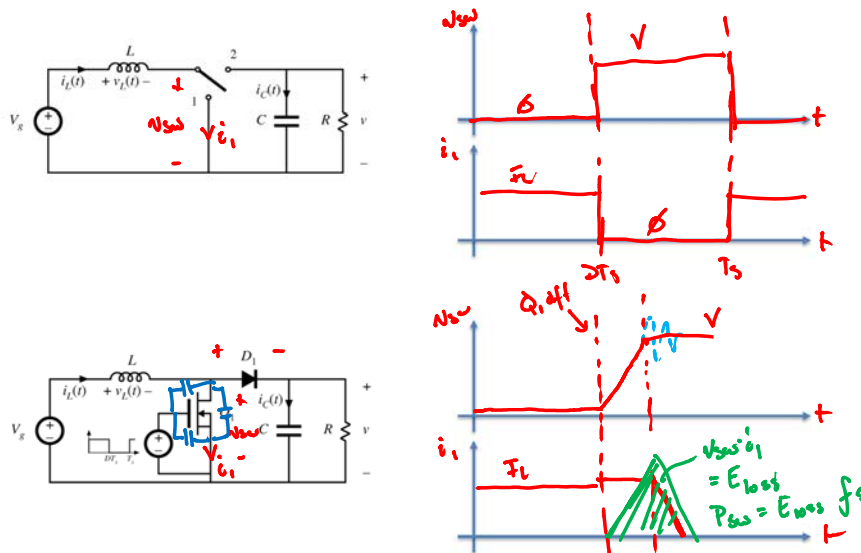


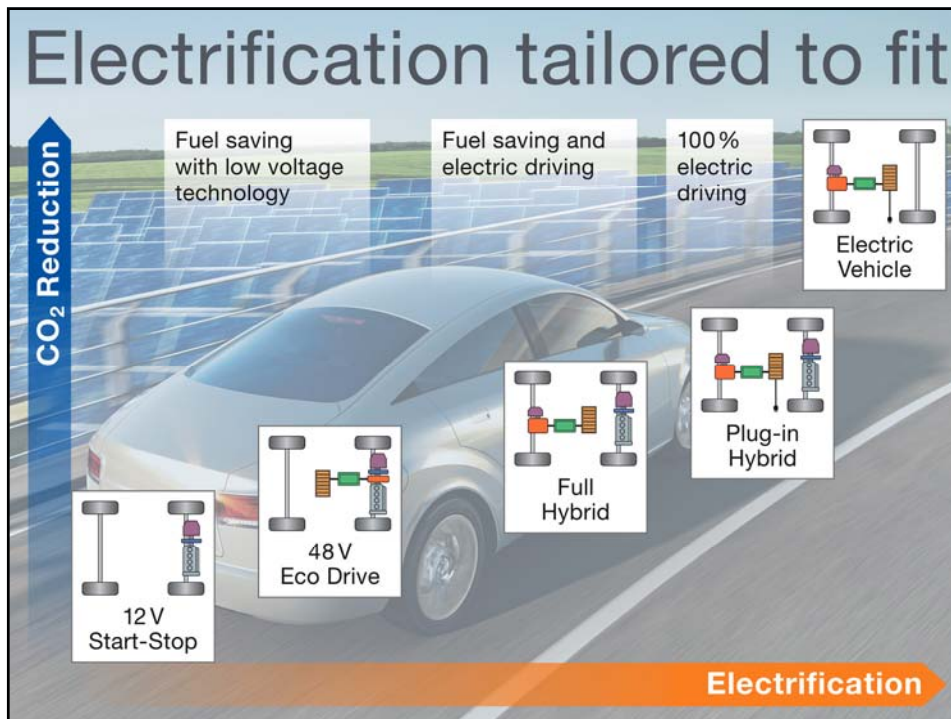
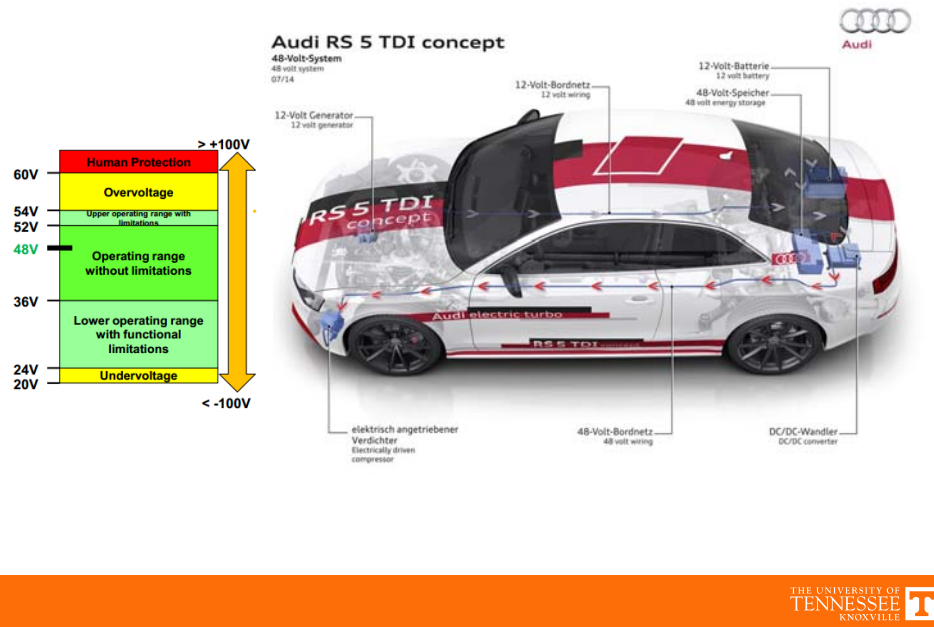
Announcements

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

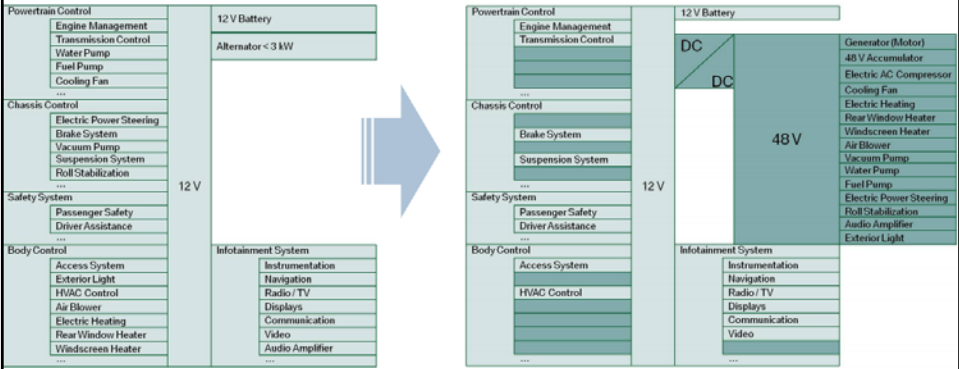
Switching Nonidealities



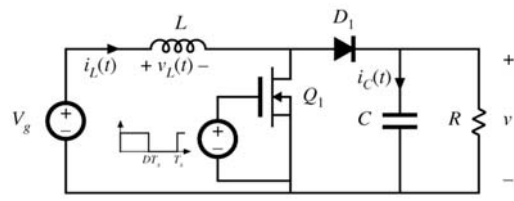
Application Example: EV LV Bus



EV Networks



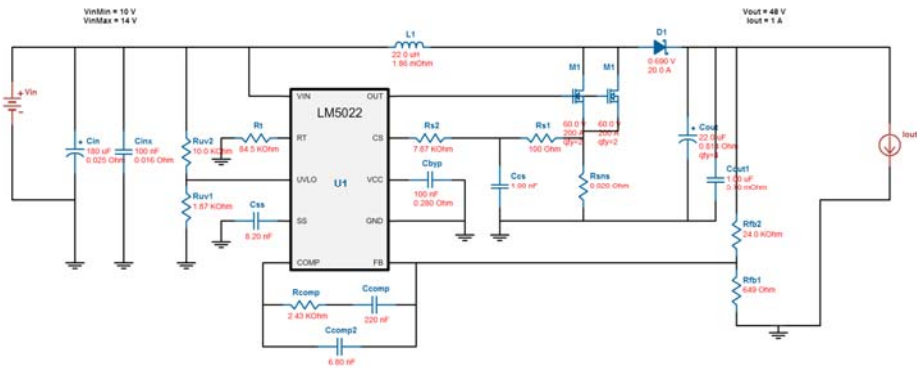
System to Design



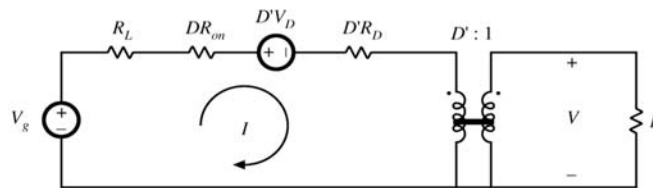
Param	Value
V_g	12 V
V_{out}	48 V
R_{out}	48 Ω
ΔV_{out}	0.1 V

Baseline Design

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



Equivalent Circuit Model



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

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

Device Parameters

Diode

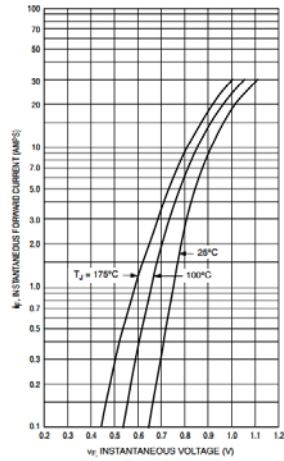
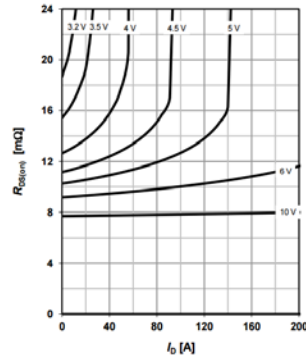


Figure 1. Typical Forward Voltage

MOSFET



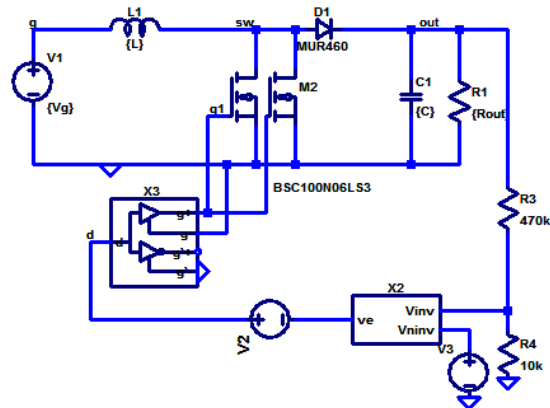
Inductor

Part number ¹	Inductance ² $\pm 10\%$ (μH)	DCR ³ (mΩhms) nom 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

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LTSpice Simulation

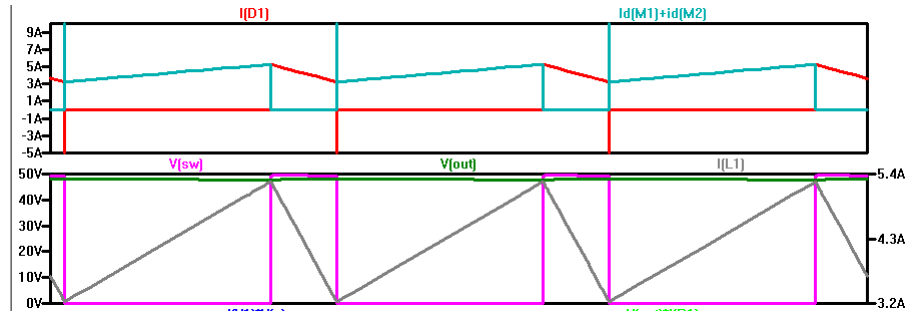


L	C_{out}	f_s	η (Sim)
22μH	22μF	202k	93.9%

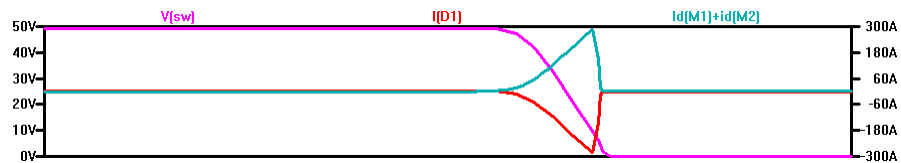
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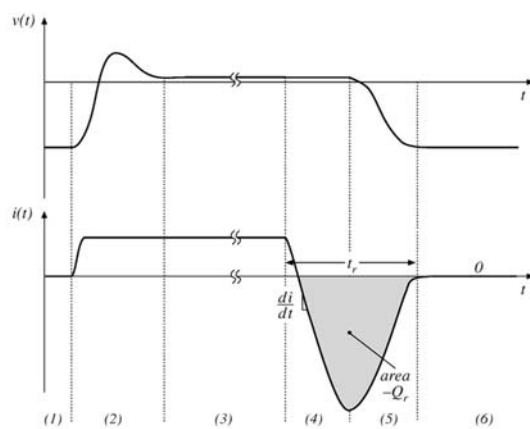
LTSpice Simulation



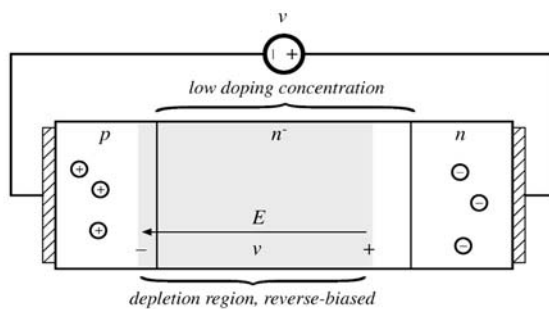
Switching Transition



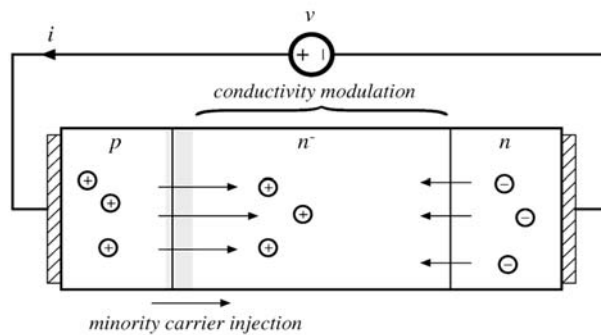
Diode Switching Waveforms



Power Diodes



Forward Biased Diode



Diode Stored Charge

The diode equation:

$$q(t) = Q_0(e^{\lambda v(t)} - 1)$$

Charge control equation:

$$\frac{dq(t)}{dt} = i(t) - \frac{q(t)}{\tau_L}$$

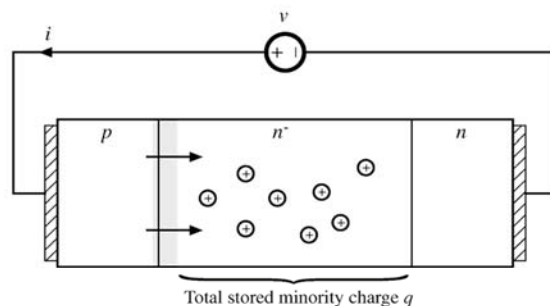
With:

$\lambda = 1/(26 \text{ mV})$ at 300 K

τ_L = minority carrier lifetime

(above equations don't include current that charges depletion region capacitance)

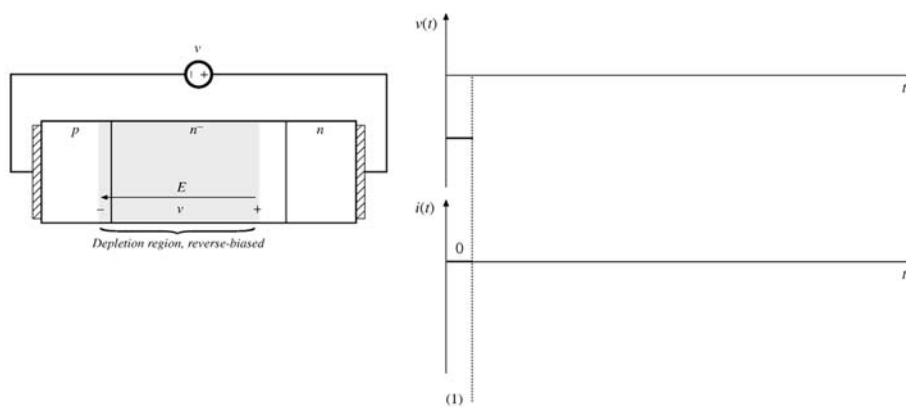
Fundamentals of Power Electronics



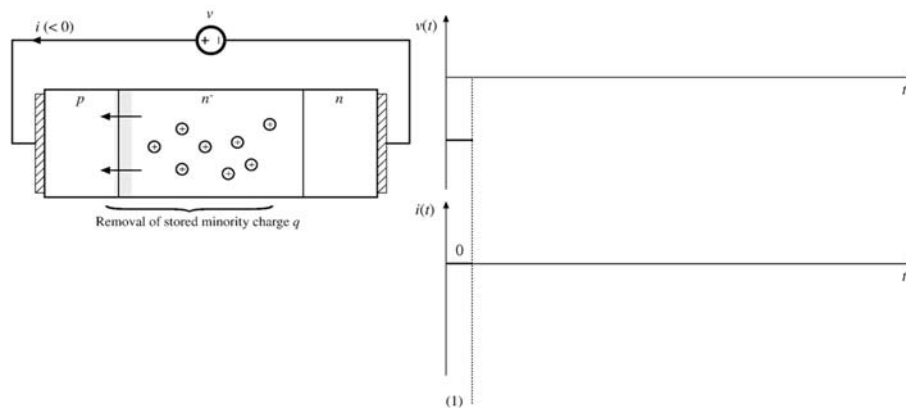
In equilibrium: $dq/dt = 0$, and hence

$$i(t) = \frac{q(t)}{\tau_L} = \frac{Q_0}{\tau_L} (e^{\lambda v(t)} - 1) = I_0 (e^{\lambda v(t)} - 1)$$

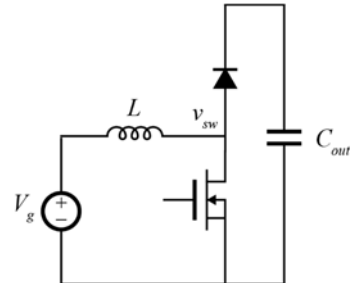
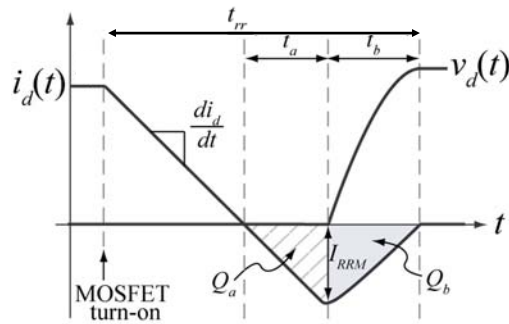
Diode Turn-On



Diode Turn-Off



Diode Reverse Recovery



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Datasheet RR Characteristics

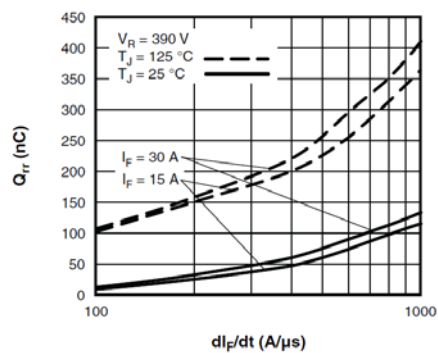


Fig. 10 - Typical Stored Charge vs. di/dt

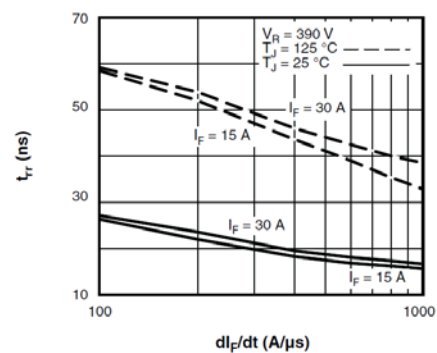


Fig. 9 - Typical Reverse Recovery Time vs. di/dt

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Types of Power Diodes

Standard recovery

Reverse recovery time not specified, intended for 50/60Hz

Fast recovery and ultra-fast recovery

Reverse recovery time and recovered charge specified
Intended for converter applications

Schottky diode

A majority carrier device
Essentially no recovered charge
Model with equilibrium i - v characteristic, in parallel with depletion region capacitance
Restricted to low voltage (few devices can block 100V or more)

Paralleling Diodes

Attempts to parallel diodes, and share the current so that $i_1 = i_2 = i/2$, generally don't work.

Reason: thermal instability caused by temperature dependence of the diode equation.

Increased temperature leads to increased current, or reduced voltage.

One diode will hog the current.

To get the diodes to share the current, heroic measures are required:

- Select matched devices
- Package on common thermal substrate
- Build external circuitry that forces the currents to balance

