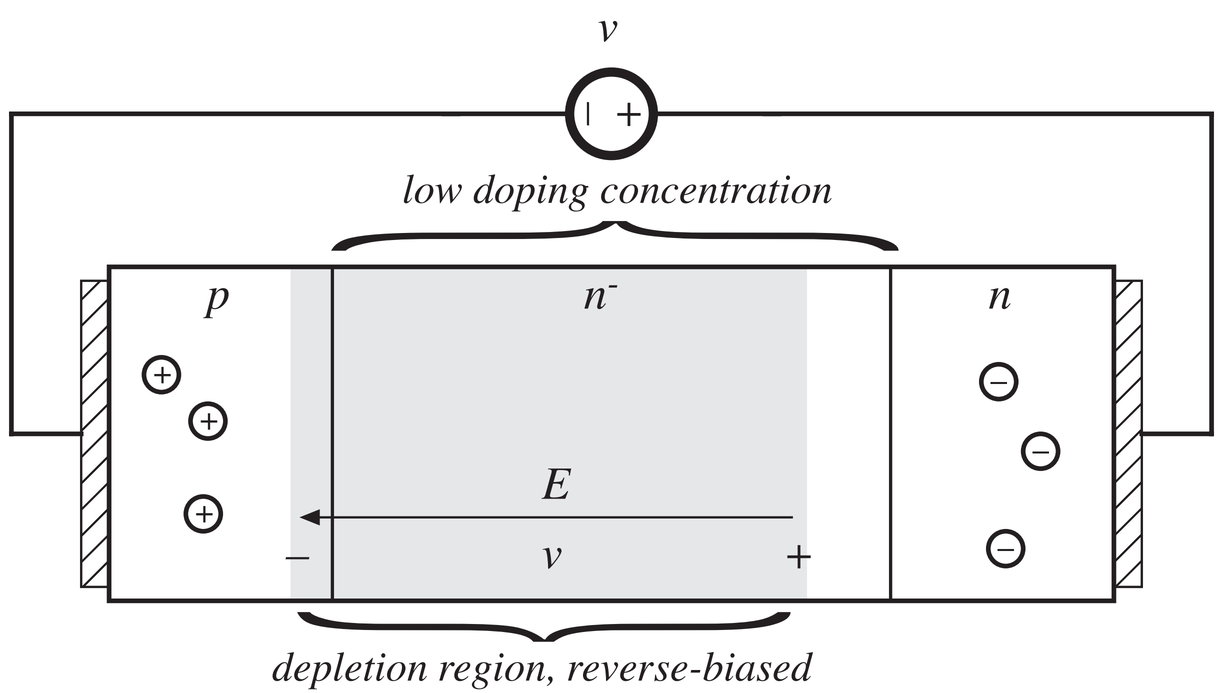
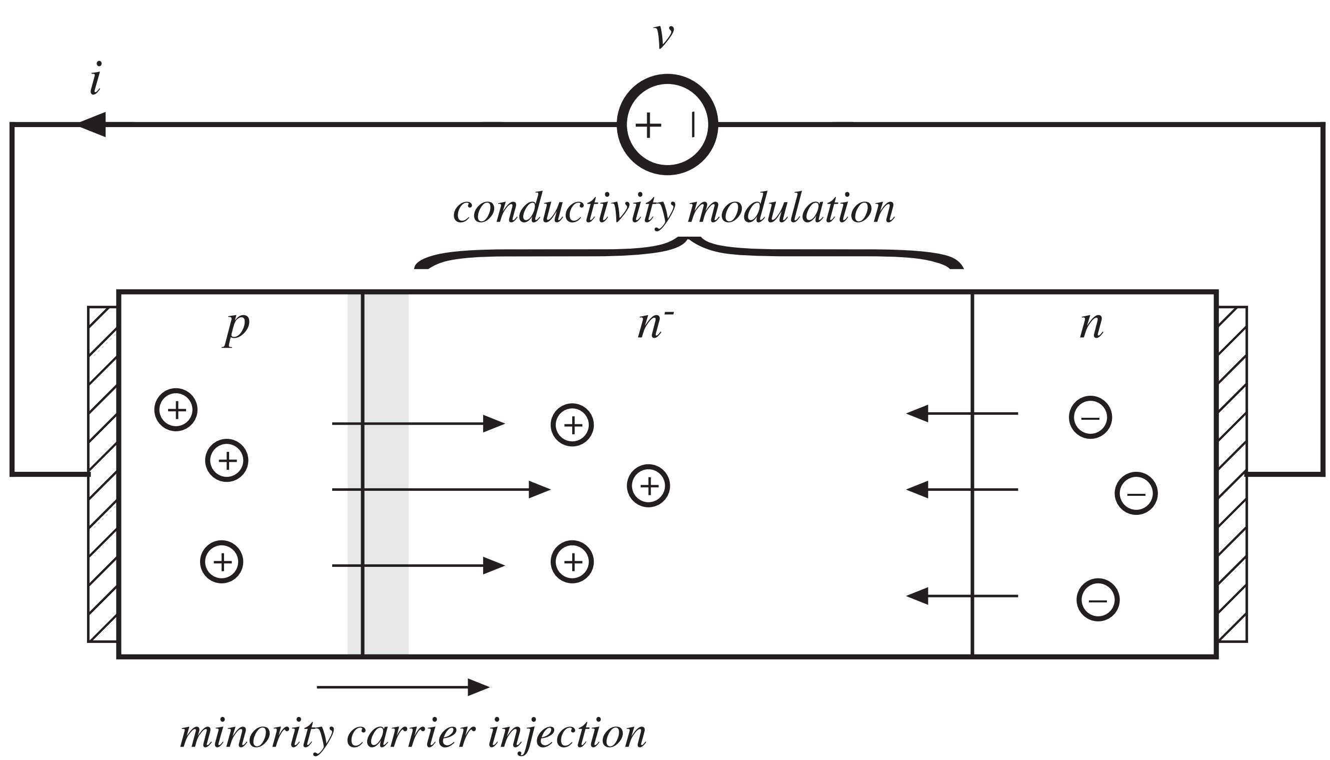
4.2.1. Power diodes

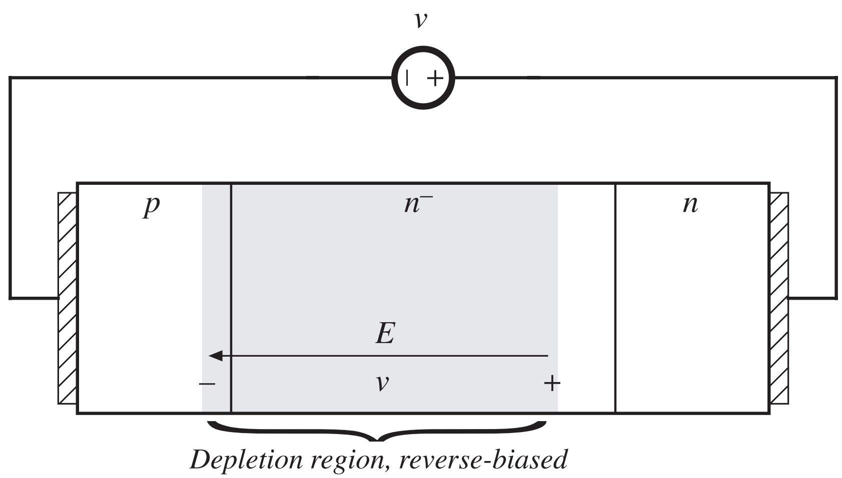
A power diode, under reverse-biased conditions:

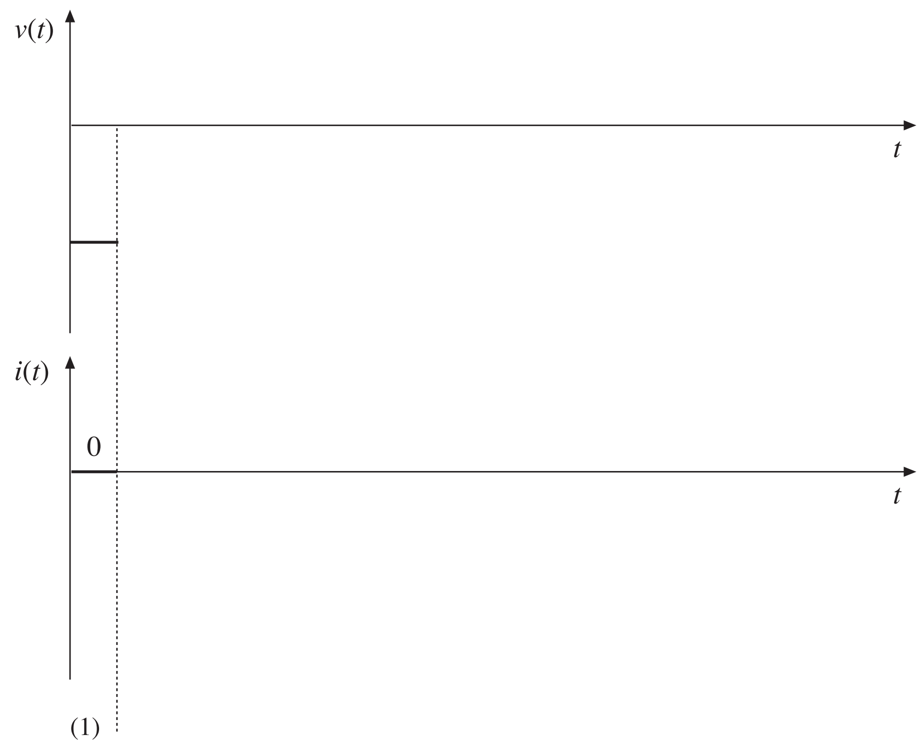


Forward-biased power diode



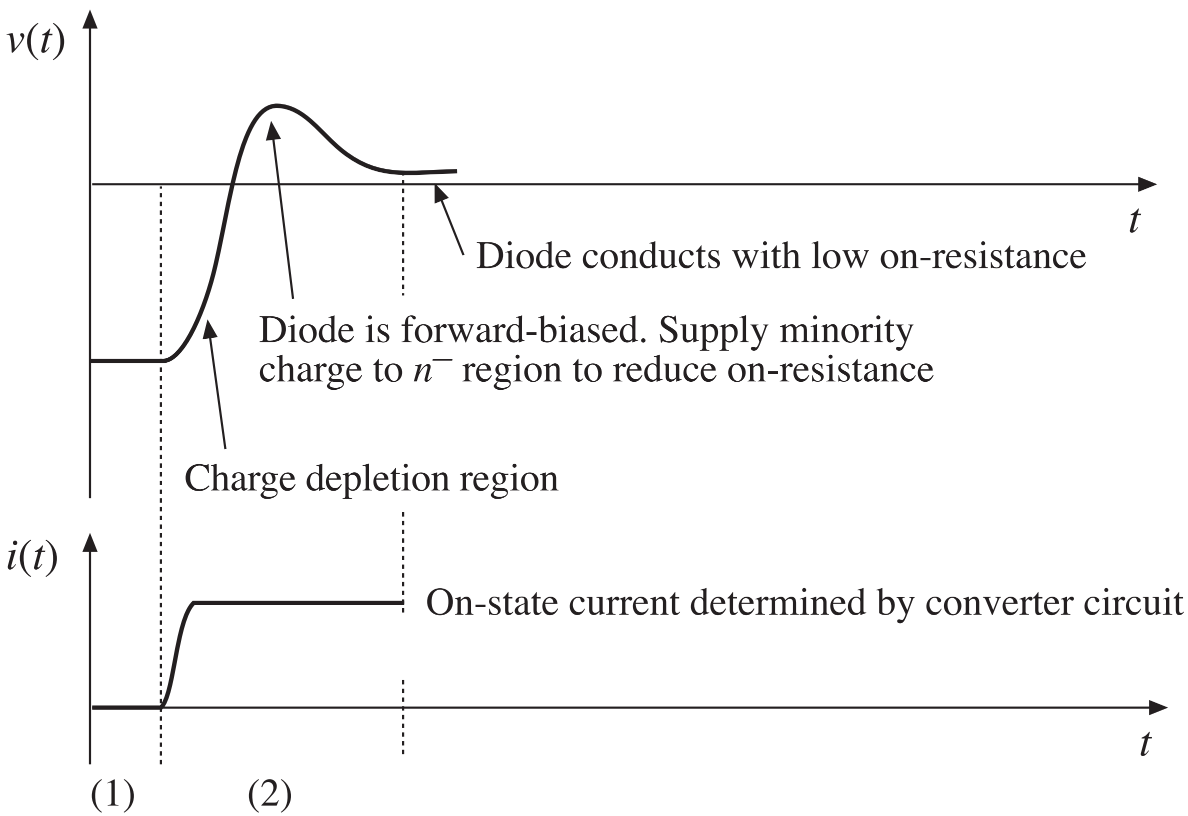
Diode in OFF state: reversed-biased, blocking voltage





- Diode is reverse-biased
- No stored minority charge: $q = 0$
- Depletion region blocks applied reverse voltage; charge is stored in capacitance of depletion region

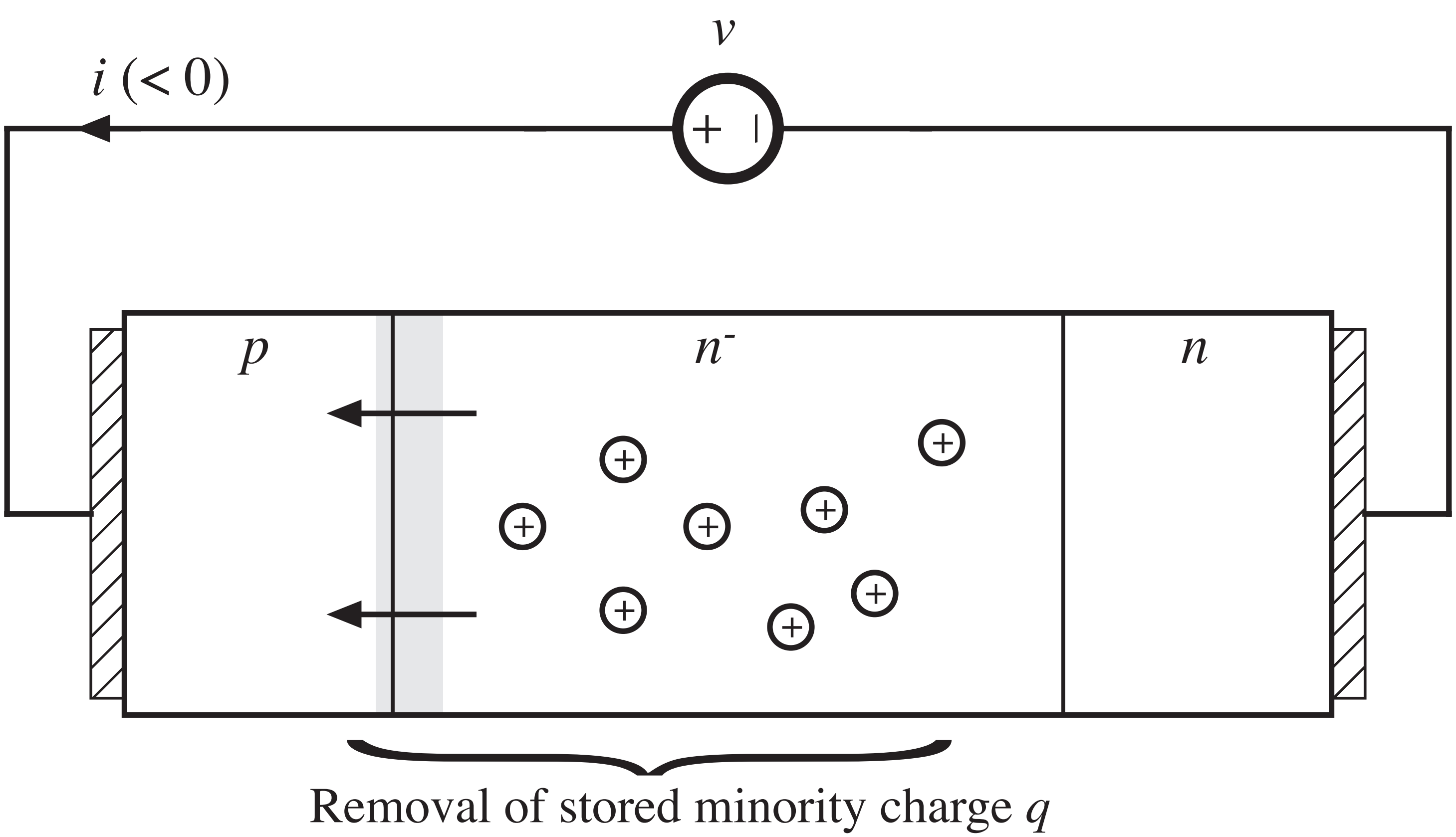
Turn-on transient



The current $i(t)$ is determined by the converter circuit. This current supplies:

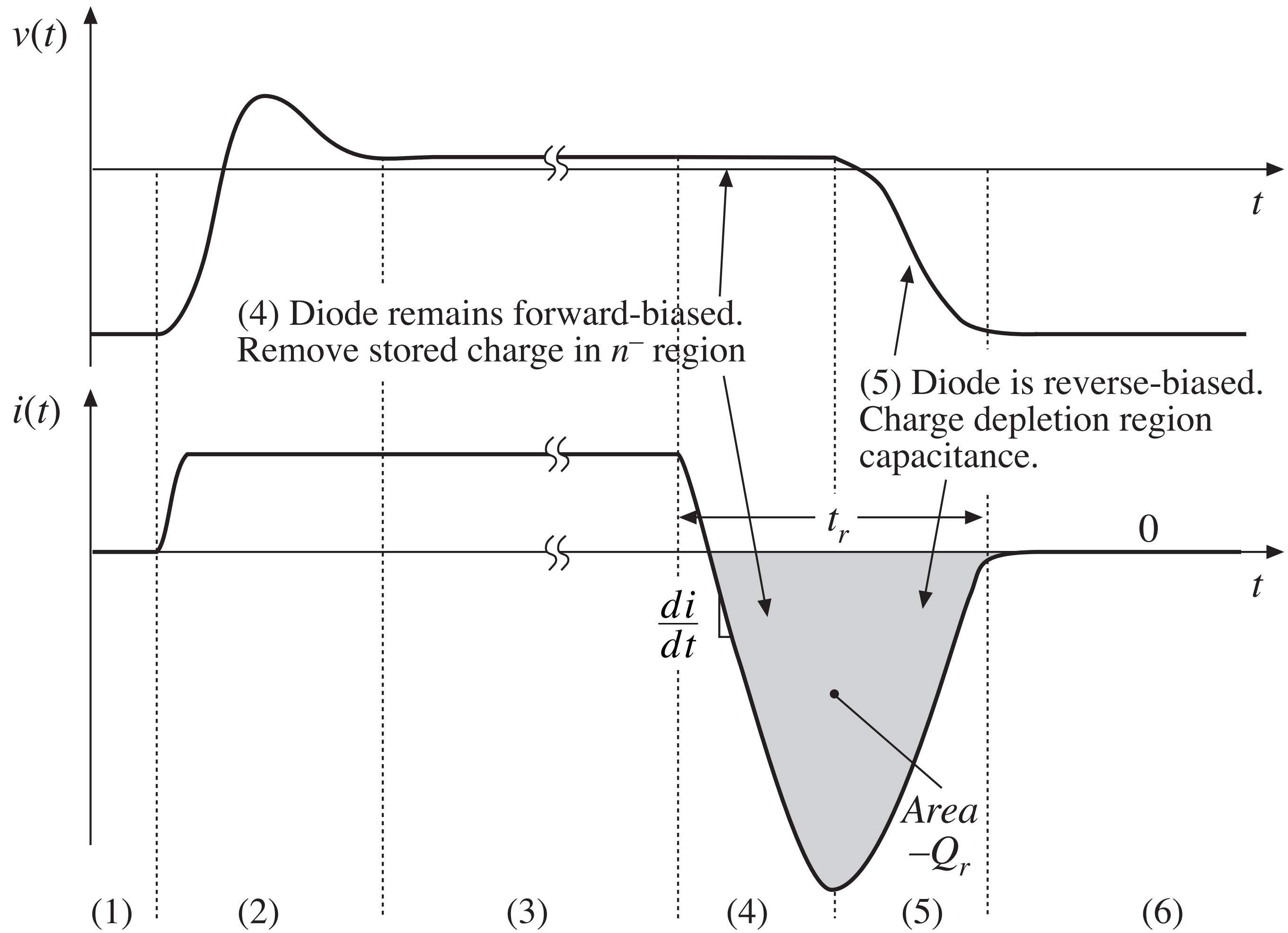
- charge to increase voltage across depletion region
- charge needed to support the on-state current
- charge to reduce on-resistance of n^{-} region

Turn-off transient

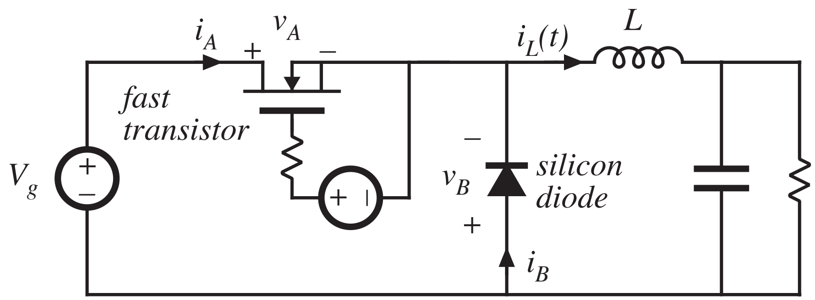


Diode turn-off transient

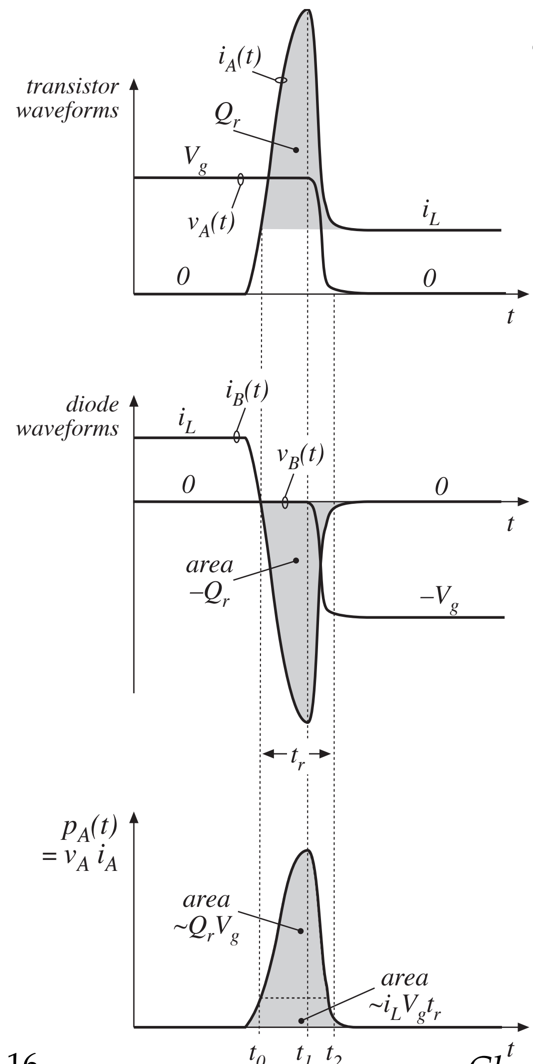
continued



The diode switching transients induce switching loss in the transistor



see Section 4.3.2



- Diode recovered stored charge Q_r flows through transistor during transistor turn-on transition, inducing switching loss
- Q_r depends on diode on-state forward current, and on the rate-of-change of diode current during diode turn-off transition

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.

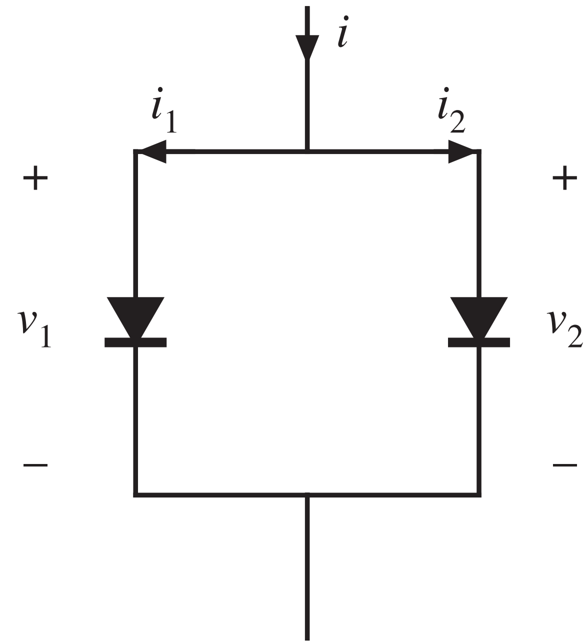
Reason: thermal instability caused by temperature dependence of the diode equation.

Increased temperature leads to increased current, or reduced voltage.

One diode will hog the current.

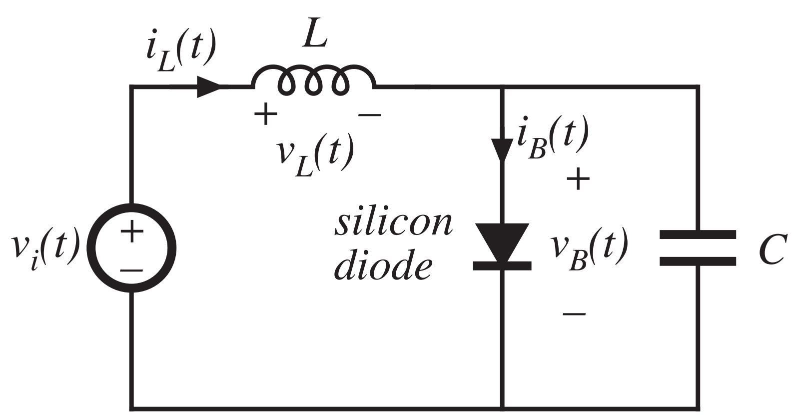
To get the diodes to share the current, heroic measures are required:

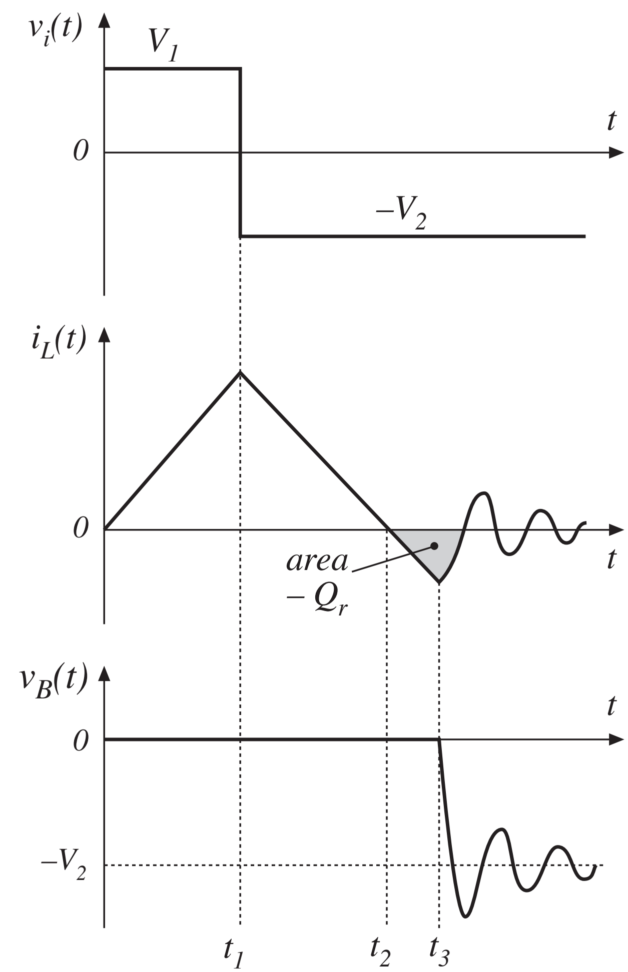
- Select matched devices
- Package on common thermal substrate
- Build external circuitry that forces the currents to balance



Ringing induced by diode stored charge

see Section 4.3.3





- Diode is forward-biased while $i_L(t) > 0$
- Negative inductor current removes diode stored charge Q_r
- When diode becomes reverse-biased, negative inductor current flows through capacitor C.
- Ringing of L-C network is damped by parasitic losses. Ringing energy is lost.

Energy associated with ringing

Recovered charge is $Q_r = -\int_{t_2}^{t_3} i_L(t)\, dt$

Energy stored in inductor during interval $t_2 \le t \le t_3$:

$$W_L = \int_{t_2}^{t_3} v_L(t)\, i_L(t)\, dt$$

Applied inductor voltage during interval $t_2 \le t \le t_3$:

$$v_L(t) = L \frac{di_L(t)}{dt} = -V_2$$

Hence,

$$W_L = \int_{t_2}^{t_3} L \frac{di_L(t)}{dt}\, i_L(t)\, dt = \int_{t_2}^{t_3} (-V_2)\, i_L(t)\, dt$$

$$W_L = \tfrac{1}{2} L\, i_L^2(t_3) = V_2\, Q_r$$