Forward Biased Diode

Diode Stored Charge

The diode equation:
\[ q(t) = Q_0 \left( e^{\lambda V(t)} - 1 \right) \]

Charge control equation:
\[ \frac{dq(t)}{dt} = i(t) - \frac{q(t)}{\tau_L} \]

With:
- \( \lambda = 1/(26 \text{ mV}) \) at 300 K
- \( \tau_L \) = minority carrier lifetime

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

In equilibrium: \( dq/dt = 0 \), and hence
\[ i(t) = \frac{q(t)}{\tau_L} = \frac{Q_0}{\tau_L} \left( e^{\lambda V(t)} - 1 \right) = I_0 \left( e^{\lambda V(t)} - 1 \right) \]
Diode Turn-On

Diode Turn-Off

Diagram showing the turn-on and turn-off behavior of a diode with respect to voltage and time. The diagrams include labels such as depletion region, reverse bias, and the removal of stored minority charge.
Diode Reverse Recovery

![Diode Reverse Recovery Diagram]

Datasheet RR Characteristics

![Datasheet RR Characteristics Diagram]

Fig. 9 - Typical Reverse Recovery Time vs. \frac{di}{dt}

Fig. 10 - Typical Stored Charge vs. \frac{di}{dt}
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
Schottky Diode

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<th>f_s</th>
<th>Diode</th>
<th>η (Sim)</th>
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<td>22μF</td>
<td>202k</td>
<td>Si (FR)</td>
<td>93.9%</td>
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<tr>
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Simulation Waveforms
Switching Transition

Power MOSFET
MOSFET Cross Section

MOSFET Static Characteristics
MOSFET Depletion capacitance

MOSFET Equivalent Circuit
Nonlinear Coss

![Nonlinear Coss Graph](image)

Power MOSFET: Conclusions

- A majority-carrier device: fast switching speed
- Typical switching frequencies: tens and hundreds of kHz
- On-resistance increases rapidly with rated blocking voltage
- Easy to drive
- The device of choice for blocking voltages less than 500V
- 1000V devices are available, but are useful only at low power levels (100W)
- Part number is selected on the basis of on-resistance rather than current rating