Predicted Efficiency vs Duty Cycle

- Switching frequency 100 kHz
- Input voltage 24 V
- Load resistance 15 Ω
- Recovered charge 0.75 μCoul
- Reverse recovery time 75 nsec

- (no attempt is made here to model how the reverse recovery process varies with inductor current)

- Substantial degradation of efficiency
- Poor efficiency at low duty cycle

Buck converter with diode reverse recovery

Paralleling Diodes

Attempts to parallel diodes, and share the current so that \( i_1 = i_2 = \frac{i}{2} \), 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
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)

Schottky Diode

\[ P_{RE} = E_{2R} f_{S} \]

<table>
<thead>
<tr>
<th>$L$</th>
<th>$C_{out}$</th>
<th>$f_{S}$</th>
<th>Diode</th>
<th>$\eta$ (Sim)</th>
</tr>
</thead>
<tbody>
<tr>
<td>22uH</td>
<td>22uF</td>
<td>200k</td>
<td>Si (FR)</td>
<td>93.9%</td>
</tr>
<tr>
<td>22uH</td>
<td>22uF</td>
<td>200k</td>
<td>Si Schottky</td>
<td>96.9%</td>
</tr>
</tbody>
</table>
Simulation Waveforms

Switching Transition
Power MOSFET

MOSFET Cross Section
Power MOSFET in Ohmic Region

MOSFET Static Characteristics

MOSFET's conduction capability assessed by $\text{Ron}$, not $I_{\text{max}}$.

- $V_{\text{BR}} = V_{DS \text{max}}$ is absolute maximum
- $V_{th} = 3-4\text{V}$
MOSFET in Cutoff Region

MOSFET Equivalent Circuit