Switching Frequency Vs. XF Size

As switching frequency increases from 25 kHz to 250 kHz, core size is dramatically reduced.

As switching frequency increases from 400 kHz to 1 MHz, core size increases.

FURTHER TOPICS IN POWER ELECTRONICS
Practical Issues in PE: Parasitics

Use loop analysis

Switched input current $i_1(t)$ contains large high frequency harmonics

- hence inductance of input loop is critical
- inductance causes ringing, voltage spikes, switching loss, generation of B- and E-fields, radiated EMI

The second loop contains a filter inductor, and hence its current $i_2(t)$ is nearly dc

- hence additional inductance is not a significant problem in the second loop

Decoupling

Parasitic inductances of input loop explicitly shown:

Addition of bypass capacitor confines the pulsating current to a smaller loop:

High frequency currents are shunted through capacitor instead of input source
Real Switching Waveforms

Cross-talk between of one device causes spike in Vgs of other device

Input Filter Design

- Filter can seriously degrade converter control system behavior
- Use extra element theorem to derive conditions which ensure that converter dynamics are not affected by input filter
- Must design input filter having adequate damping
Damped Input Filters

*Design criteria derived via Extra Element theorem:*

![Diagram of filter design criteria](image)

*Two-section damped input filter design:*

- [Diagram of two-section filter design](image)

- \[ Z(j\omega) \gg Z_L(j\omega) \]
- \[ Z(j\omega) \gg Z_R(j\omega) \]

Current Programmed Control

- Chapter 12
- A very popular method for controlling PWM converters
- Transistor turns off when its current \( i_s(t) \) is equal to the control input \( i_d(t) \)
- Simpler dynamics, more robust compensator

![Diagram of current programmed control](image)
Buck Converter With CPM

Comparison of control-to-output transfer functions

Averaged switch model used in PSPICE simulations

Digital Control of SMPS

- Digital Control can improve noise immunity, element variation, size/cost
- Advanced tuning algorithms can be included to change compensator dynamically or over lifetime
- Can model power stage without averaging assumptions
- Need to include sampling, delay, saturation, and quantization effects
Resonant and Soft-Switching Topologies

Converters with Significant ZVS Interval
### Power Electronics Courses at UTK

<table>
<thead>
<tr>
<th>Junior</th>
<th>Senior</th>
<th>Graduate</th>
</tr>
</thead>
<tbody>
<tr>
<td>ECE 325 Electric Energy System Components</td>
<td>ECE 481 Power Electronics</td>
<td>ECE 623 Advanced Power Electronics and Drives</td>
</tr>
<tr>
<td>ECE 482 Power Electronic Circuits</td>
<td>ECE 523 Power Electronics and Drives</td>
<td>ECE 625 Utility Applications of Power Electronics</td>
</tr>
<tr>
<td>ECE 581 High Frequency Power Electronics</td>
<td>ECE 525 Alternative Energy Sources</td>
<td>ECE 626 Solid State Power Semiconductors</td>
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<td>ECE 692 Power Electronics Technologies I</td>
<td>ECE 692 Power Electronics Technologies I</td>
<td>+ 4 more</td>
</tr>
</tbody>
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**APPLICATION OF ECE481 THEORY**
Example: Low-Power AC Adapters

Goals:
• Produce regulated DC Voltage from universal input (85 to 276 Vrms, 47-63 Hz)
• Maintain high power factor / Low EMI
• High efficiency to allow small size

Design Constraints:
• Single converter needs power stage which can operate over wide input voltage range
• For $V_{dc} = +5$ V (USB output) need very large step-down capability ($M = 0.018$)
• Isolation may be necessary for safety

Flyback Implementation

• Flyback selected as a simple, low part-count topology
• Used almost exclusively in Ac-to-LVDC applications at power levels less than ~100W
• DCM may be used for reduced diode RR and increased $f_s$
• Pulsating input current requires filtering
• If unity power factor is obtained, significant output ripple results

Practical Issue: Ringing in Flyback

- Practical transformer implementation has nonzero leakage inductance
- When MOSFET switches off, it interrupts leakage current
- Inductor energy dumped into MOSFET output capacitance
- Lossy, high EMI, Potentially can over-voltage MOSFET Q₁

Snubber Design

- Goal is to provide a path for leakage current to circulate
Snubber Design

- Goal is to provide a path for leakage current to circulate

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Apple Power Adapter Implementation

Example:
- 5 Watt AC-to-5V adapter

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Apple Adapter Schematic

Example Waveforms

L. Huber and M. Jovanovic, "Evaluation of Flyback Topologies for Notebook AC/DC Adapter/Charger Applications"