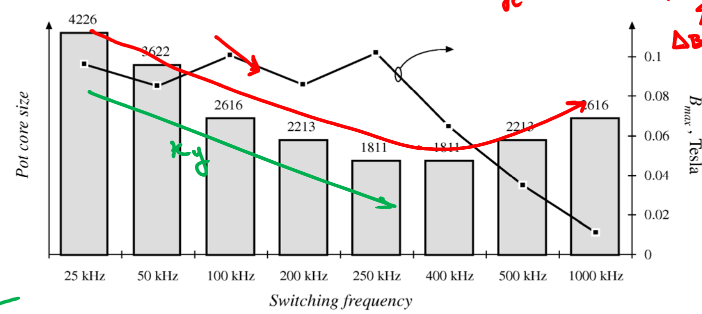
Switching Frequency Vs. XF Size



- As switching frequency is increased from 25 kHz to 250 kHz, core size is dramatically reduced
- As switching frequency is increased from 400 kHz to 1 MHz, core size increases

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FURTHER TOPICS IN POWER ELECTRONICS

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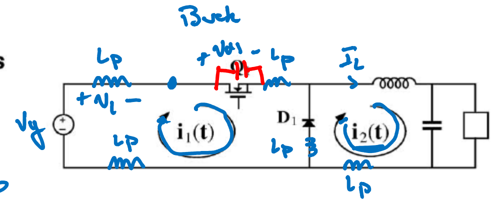
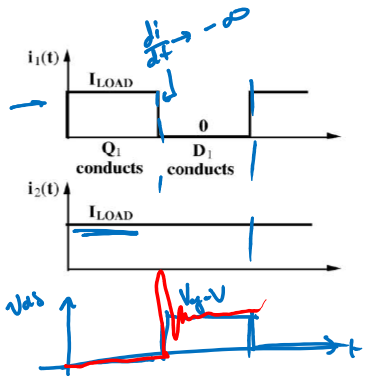
Practical Issues in PE: Parasitics

Use loop analysis





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

—hence inductance of input loop is critical

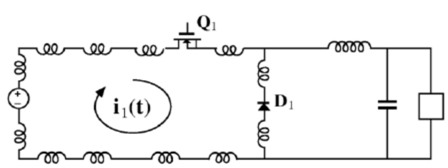
inductance causes ringing, voltage spikes, switching loss, generation of B- and E-fields, radiated EMI

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

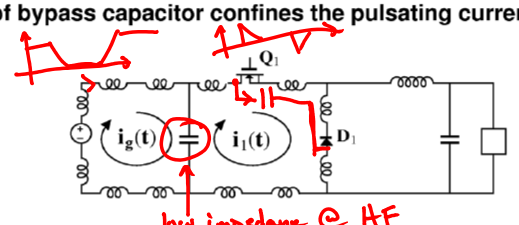
—hence additional inductance is not a significant problem in the second loop

Decoupling

Parasitic inductances of input loop explicitly shown:

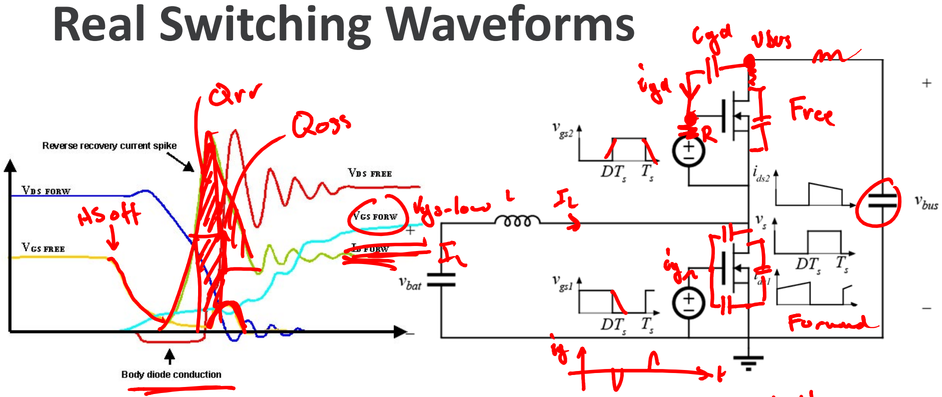


Addition of bypass capacitor confines the pulsating current to a smaller loop:



high frequency currents are shunted through capacitor instead of input source

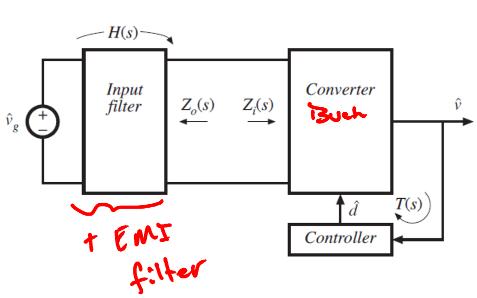
Real Switching Waveforms

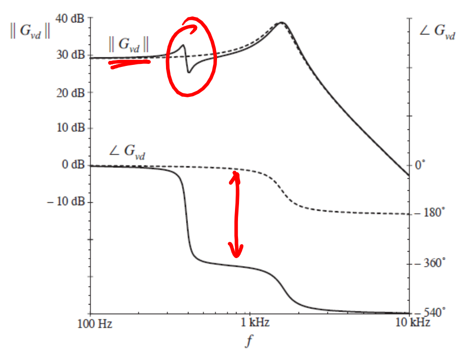


Cross-talk
→ turn-on of one device causes spike in Vgs of other device

Input Filter Design

Ch 10

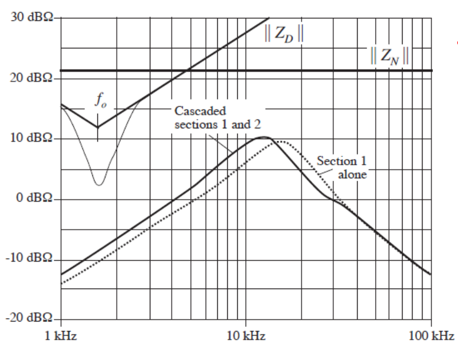




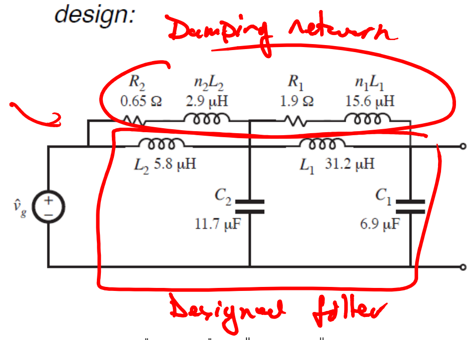
- Filter can seriously degrade converter control system behavior
- Use extra element theorem to derive conditions which ensure that converter dynamics are not affected by input filter
- Must design input filter having adequate damping

Damped Input Filters

Design criteria derived via Extra Element theorem:



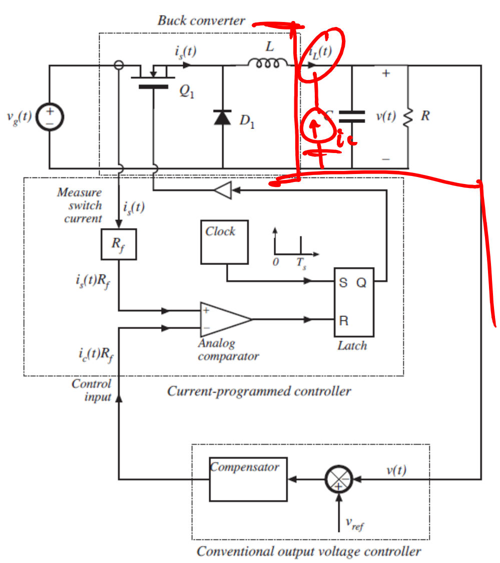
Two-section damped input filter design:



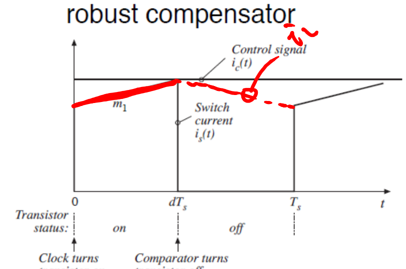
$$\| Z(j\omega) \| \gg \| Z_N(j\omega) \|$$

$$\| Z(j\omega) \| \gg \| Z_D(j\omega) \|$$

Current Programmed Control

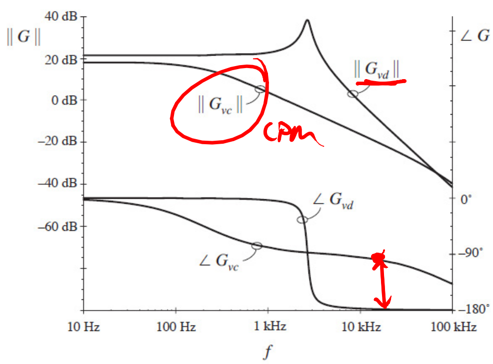


- Chapter 12
- A very popular method for controlling PWM converters
- Transistor turns off when its current $i_s(t)$ is equal to the control input $i_c(t)$
- Simpler dynamics, more robust compensator

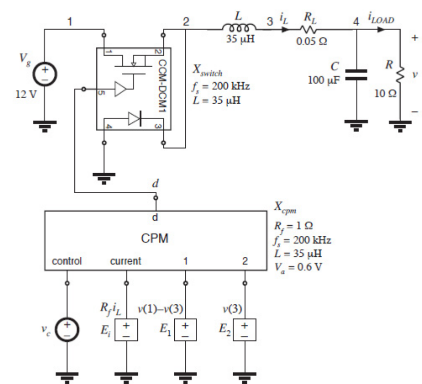


Buck Converter With CPM

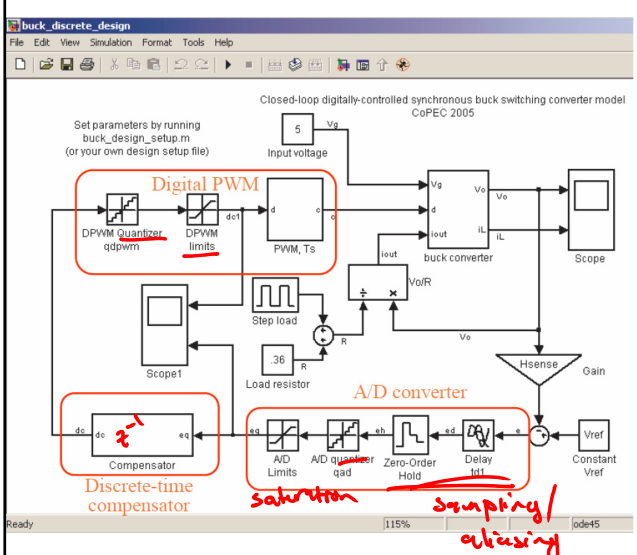
Comparison of control-to-output transfer functions



Averaged switch model used in PSPICE simulations

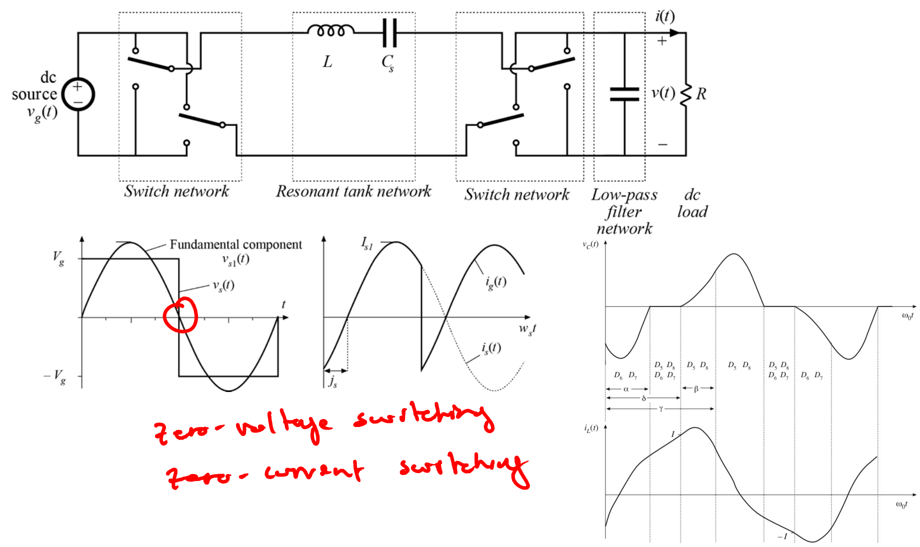


Digital Control of SMPS

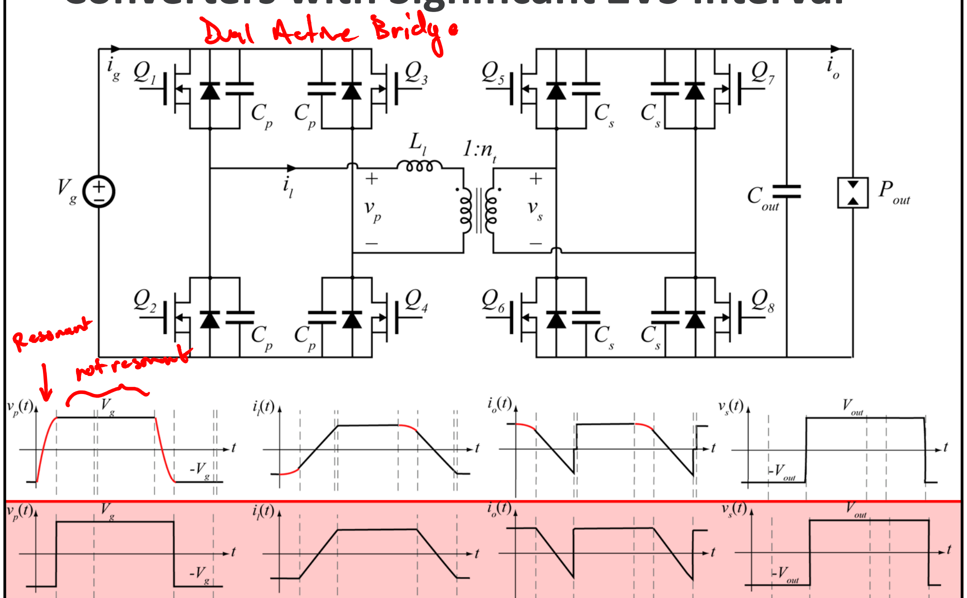


- Digital Control can improve noise immunity, element variation, size/cost
- Advanced tuning algorithms can be included to change compensator dynamically or over lifetime
- Can model power stage without averaging assumptions
- Need to include sampling, delay, saturation, and quantization effects

Resonant and Soft-Switching Topologies



Converters with Significant ZVS Interval



Power Electronics Courses at UTK

Junior	Senior	Graduate	
ECE 325 Electric Energy System Components	ECE 481 Power Electronics	ECE 523 Power Electronics and Drives	ECE 623 Advanced Power Electronics and Drives
	ECE 482 Power Electronic Circuits	ECE 525 Alternative Energy Sources	ECE 625 Utility Applications of Power Electronics
		ECE 581 High Frequency Power Electronics	ECE 626 Solid State Power Semiconductors
		ECE 692 Power Electronics Technologies I	ECE 692 Power Electronics Technologies I
		+ 4 more	

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APPLICATION OF ECE481 THEORY

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Example: Low-Power AC Adapters

Apple "Ultracompact USB Power Adapter"

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

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
- low cost!

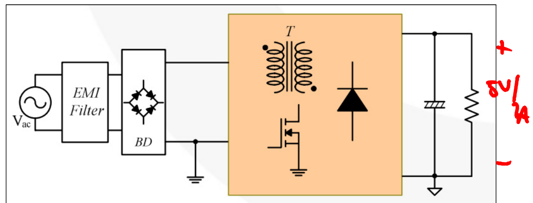


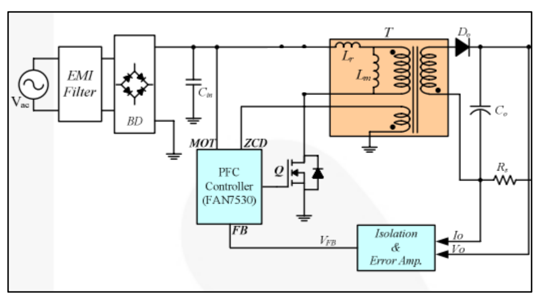
Figure 1. Single-Stage AC-DC Converter

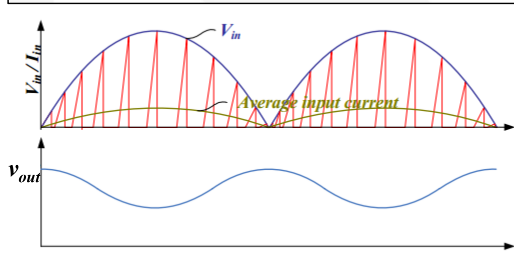
Fairchild Semi, "Design Guideline of Single-Stage Flyback AC-DC Converter Using FAN7530 for LED Lighting"

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

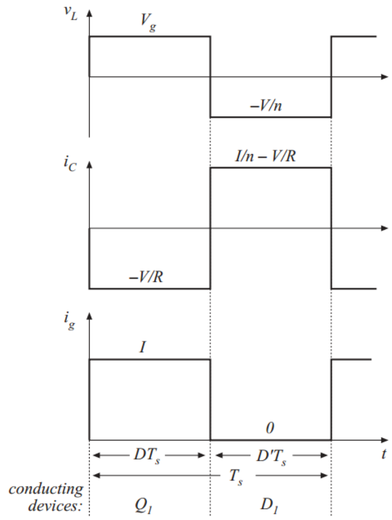
- Pulsating input current requires filtering
- If unity power factor is obtained, significant output ripple results

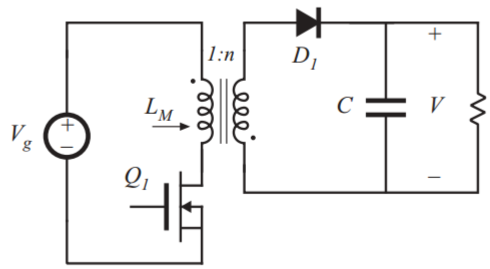




Fairchild Semi, "Design Guideline of Single-Stage Flyback AC-DC Converter Using FAN7530 for LED Lighting"

Practical Issue: Ringing in Flyback

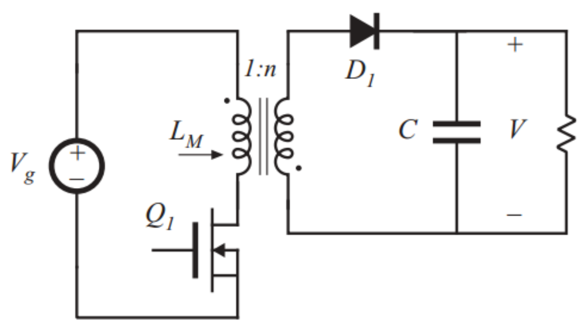




- Practical transformer implementation has nonzero leakage inductance
- When MOSFET switches off, it interrupts leakage current
- Inductor energy dumped into MOSFET output capacitance
- Lossy, high EMI, Potentially can over-voltage MOSFET Q_1

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

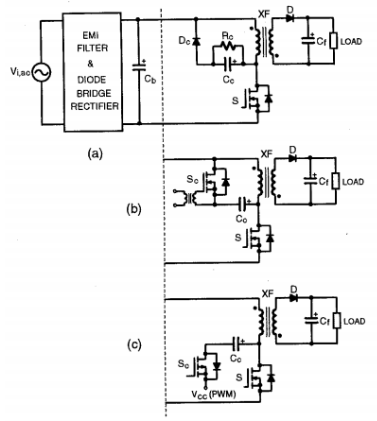
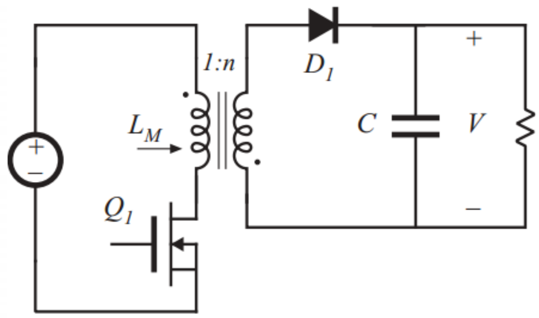


Fig. 1 Simplified circuit diagram of (a) RCD-clamp, (b) NMOS active-clamp, and (c) PMOS active-clamp flyback adapter/charger

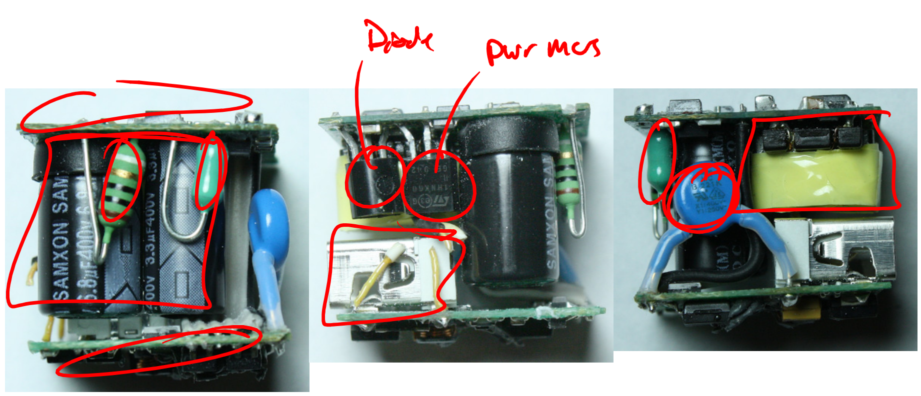


L Huber and M Jovanovic, “Evaluation of Flyback Topologies for Notebook AC/DC Adapter/Charger Applications

Apple Power Adapter Implementation

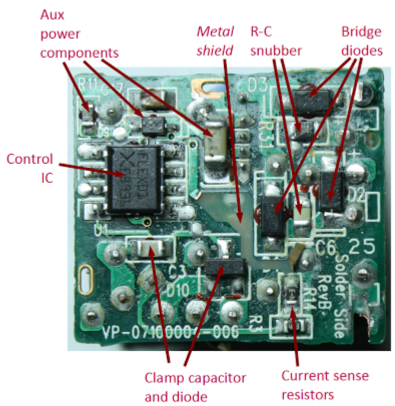
Example:

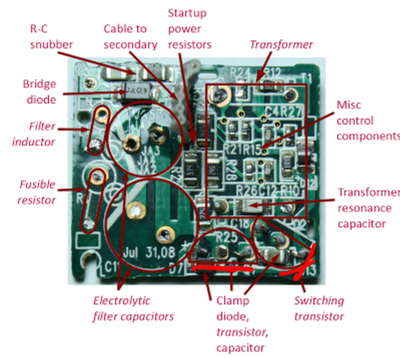
- 5 Watt AC-to-5V adapter



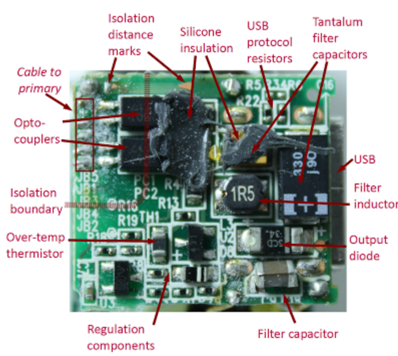
K Shirriff, “Apple iPhone charger teardown: quality in a tiny expensive package”

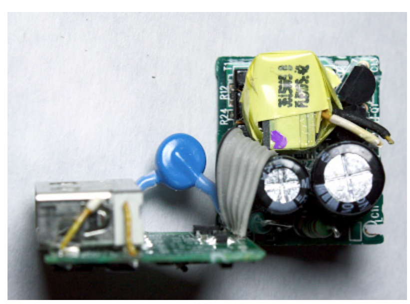
Apple Circuit Primary



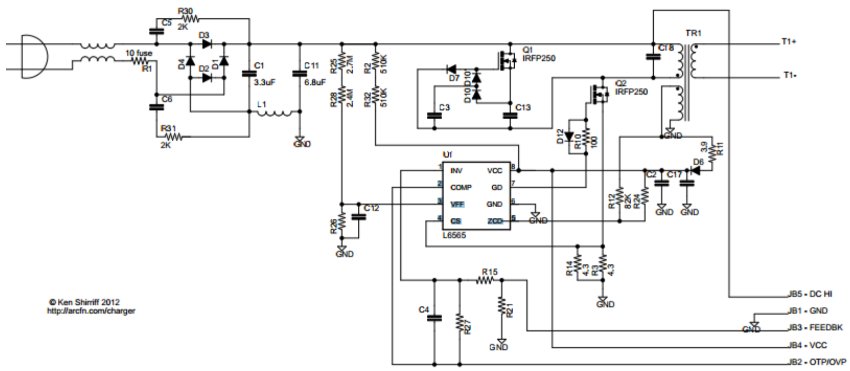


Apple Circuit Secondary

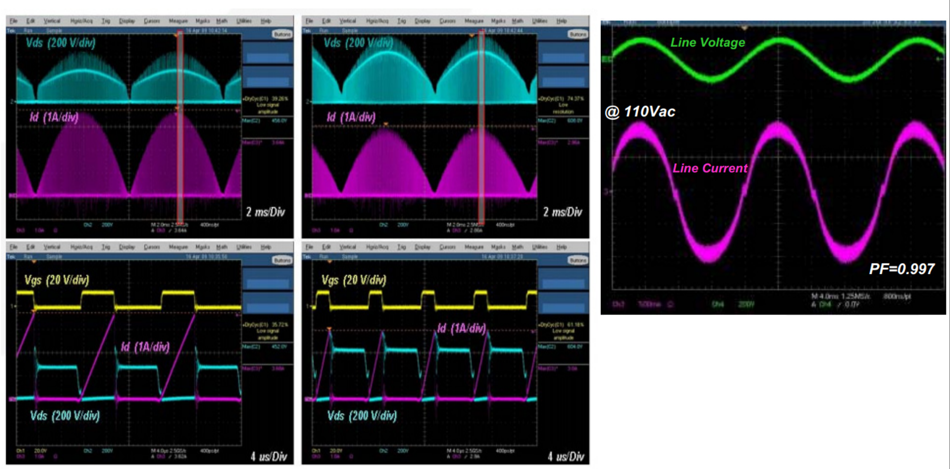




Apple Adapter Schematic



Example Waveforms



(a) at 110 V_{ac} Input (b) at 220 V_{ac} Input

Figure 12. Switching Voltage and Current

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