High Speed Switched Mode Power Supplies

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Small Efficient Power Supplies

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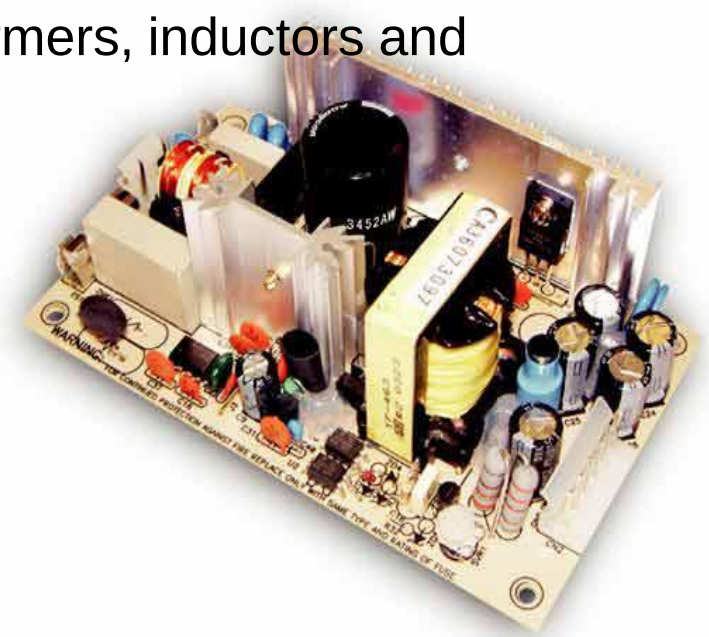
Outline

- Introduction to power supplies
- SiC and GaN devices
- Transformers for high frequency SMPS
- Challenges for high frequency SMPS
- Conclusions

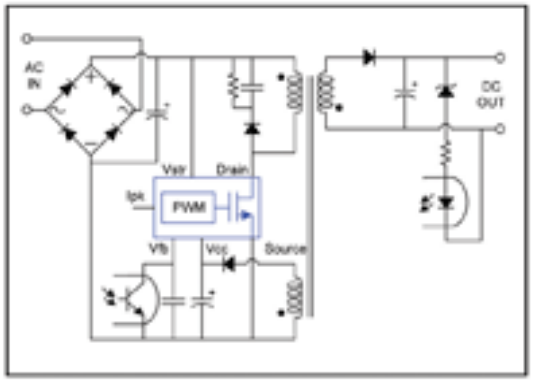
Switched Mode Power Supplies (SMPS)

- SMPS have replaced the use of line frequency transformers in AC/DC converters
  - For a giver power less energy needs to be stored in each cycle at higher frequency
  - Energy storage elements as transformers, inductors and capacitors can be designed smaller.
  - Smaller and lighter designs
  - Better energy efficiency can also be achieved
- Smaller, Better, Cheaper…



Switched Mode Power Supplies (SMPS)

- AC/DC converters nowadays typically work at 2-500kHz.
  - Aim to increase this frequency even higher.
- Flyback converter
  - Common topology for medium power applications (<200W)
  - Typically 75-85% efficiency compared to 50-60% for line frequency transformer solutions



Typical Flyback Application

SiC and GaN devices

- Better material properties for power devices
- New materials just recently commercially available
- SiC – Bulk material available
- GaN – Epitaxial material

		Si	GaAs	GaN	3C-SiC	4H-SiC	6H-SiC
v_{sat}	cm/s	$1.0 \cdot 10^7$	$2.0 \cdot 10^7$	$2.5 \cdot 10^7$	$2.0 \cdot 10^7$	$2.0 \cdot 10^7$	$2 \cdot 10^7$
μ_{0n}	Vs/cm^2	1350	8500	800	750	950	420
E_G	eV	1.12	1.4	3.39	2.2	3.2	3.0
n_{i300K}	cm^{-3}	$1 \cdot 10^{10}$	$1.8 \cdot 10^6$	$1.9 \cdot 10^{-10}$	6.9	$8.2 \cdot 10^{-10}$	$2.3 \cdot 10^{-6}$
E_{crit}	MV/cm	0.3	0.4	3.3	1	2.2	2.5
λ	W/cmK	1.7	0.5	1.3	3.6	3.7	4.9

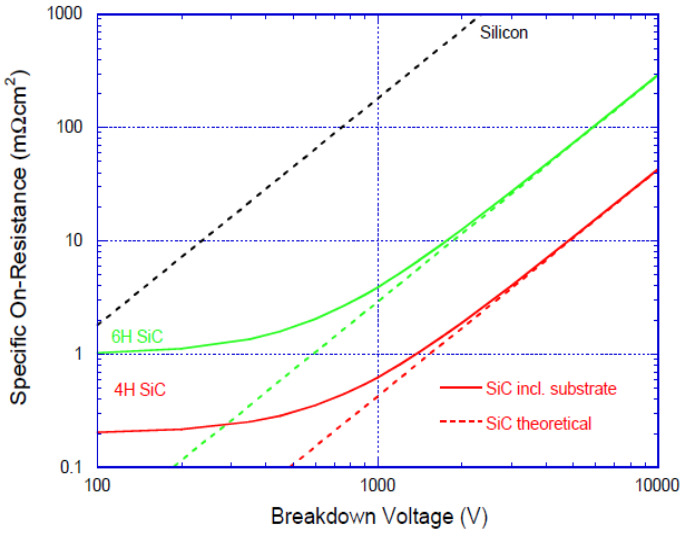
- SiC and GaN vs Silicon
- For a given voltage
  - 100 x – doping conc
  - 10 x thinner device
  - 500-1000 better conductivity
    (reduced by carrier mobility)
- For same channel resistance
  - 500 times smaller
  - 50 times less capacitance
    (10x thinner)

Depl eq. Field in depl.

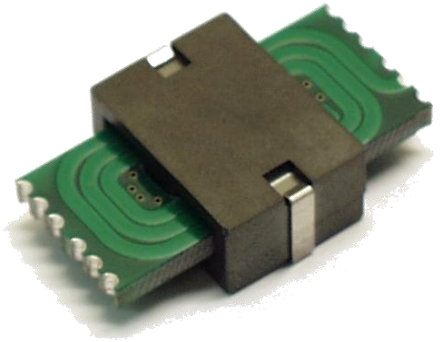
$$t = (w =) \sqrt{\frac{2\varepsilon V}{qN}} = \frac{E_{Crit}\varepsilon}{qN}$$

$$N = \frac{E_{Crit}^2 \varepsilon}{2qV}$$

$$R_{drift} = \frac{t}{Aq\mu N}$$

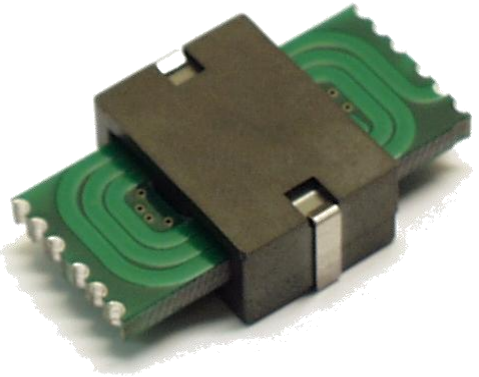


- New SiC and GaN devices could greatly improve the high frequency switching performance.
- But…
  - ”The transformers cannot be used at higher frequencies and will limit the performance”



Transformer losses

- Introducing PCB transformers have further improved the efficiency in existing converters.
  - Low profile
  - Reduced losses

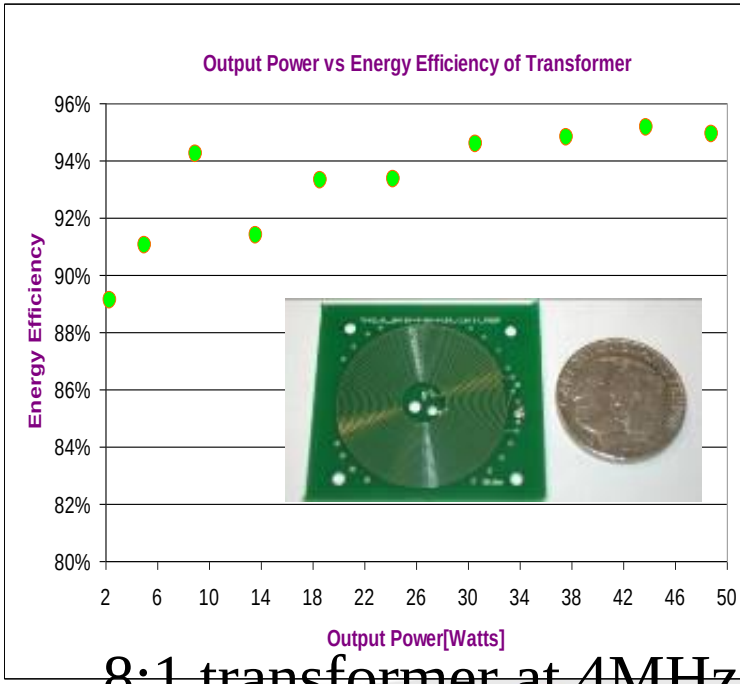


- Losses increases in the MHz range
  - Core Losses
  - Skin effect, Eddy currents, Proximity effect etc

Coreless planar transformer development

- Literature (University of Hong Kong)
  - 1:1 Transformers reported good performance in MHz region. (>95%)
  - 2:1 Step-down transformers much worse performance. (~80%)
  - Step-down (or up) transformers required in many applications

- Mid Sweden University
  - Repeated high efficiency 1:1 transformers
  - *Break-through result for up to 8:1 transformers*
- Without core the electronic circuit can be placed directly on top of the transformer realizing very compact supplies.
- Spin Off Company (SEPS Technologies AB) founded to commercialize the development.



8:1 transformer at 4MHz

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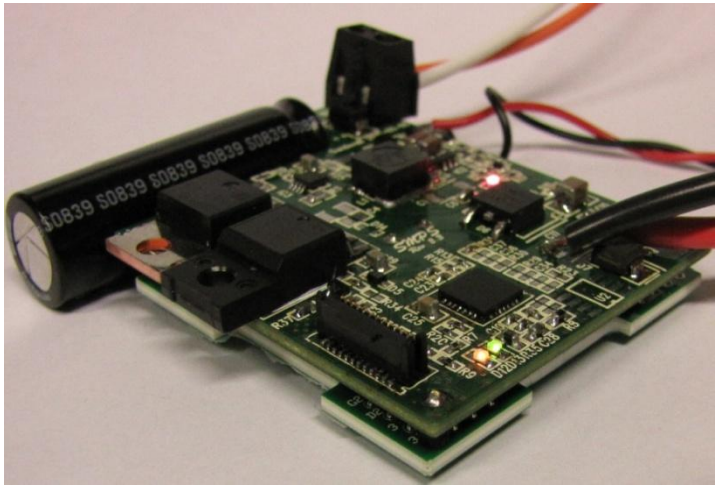
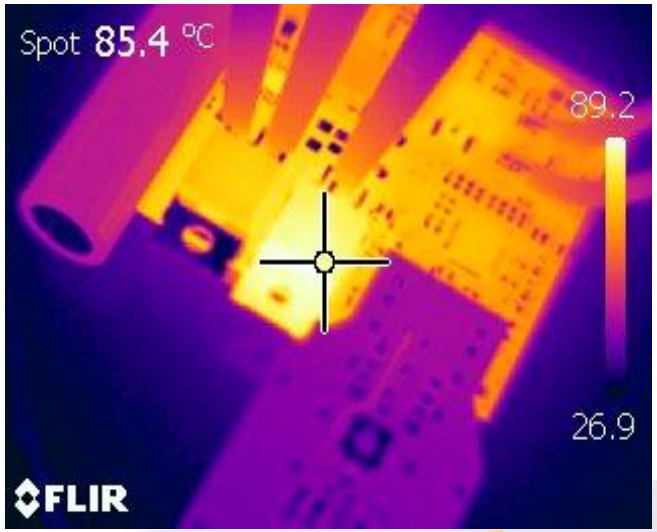
High Speed SMPS

- Transistor, and transformer losses needs to be addressed simultaneously.
  - New and improved transistors are appearing on the market
  - Transformers have been developed
- Need to develop driver that accurately controls the devices for high efficiency.
- Demonstrator of Soft Switched flyback converter





Challenges

- Efficiency
  - New EU regulations and Energy Star compliance demands higher efficiency for power supplies
  - >87% at 50W and <0.5W unloaded
- Suitable Driver IC not available
  - Microprocessor used
    - Flexible
    - Higher power consumption
    - PWM resolution low in MHz range
- Startup and self supply
- EMC

Efficiency improvements

- SiC and GaN transistors
- Soft Switched transistors
- Synchronous rectification
  - Replace diode with MOSFETs
    - Needs to be controlled over the isolation barrier
- Half-, Full-Bridge or two switch flyback
  - Need high frequency, high voltage, high side driver
    - Integrated solutions not available
    - MHz frequency gate drive transformer required

Conclusions

- Emerging SiC and GaN switching devices can further increase the switching frequency in AC/DC converters
- Transformer for isolated, high-frequency power supplies is developed
  - 8:1 transformer with 95% efficiency at 4MHz
- High frequency SMPS under development