Frequency, where we are today, and where we need to go

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OUTLINE

- Directions in topologies and operation frequency
- Magnetic limitations at high frequency
- Example of magnetic optimization for high frequency
- Magnetic structures for very high frequency
TRENDS IN TOLOPOGIES
TRENDS IN TOPOLOGIES

- Trends in Operation Frequency
- Resonant derived topologies
- "True" Soft Transition topologies
- Future Trends
Switching Losses on the primary switchers

The energy contained in the parasitic capacitance of the transformer/layout is quite often higher than the energy contained in Coss.

SiC and GaN technologies will not eliminate the need for Soft Switching.
45W Flyback Transformer for adapters

Intra-Winding 49pF
Rompower

750W Transformer for DC-DC Converter

Intra-Winding 157pF
Resonant Derived Converter

Reverse Recovery Effect in a Double Ended Converter

TYPICAL WAVEFORM

\[ V_s \]

\[ I_{D01} \]

\[ I_{D02} \]

\[ t_0 \quad t_1 \quad t_2 \quad t_3 \quad t_4 \]

\[ I_{D01} (t_2) > 0 \quad I_{D02} (t_4) > 0 \]
Current Shaping Effect in a Double Ended Converter
HARD SWITCHING HALF BRIDGE TOPOLOGY

Diagram showing the components of a hard switching half bridge topology, including capacitors (C1, C2), inductors (L1, L2), switches (M1, M2), and voltage sources (Vin, Vo). The diagram also illustrates the waveforms for various voltages (VcM1, VcM2, VcSR1, VcSR2, VdsM1) and currents (i(Lo2), Im) over time (t0 to t4).
HARD SWITCHING HALF BRIDGE TOPOLOGY
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$$t_2 - t_3$$
SOFT SWITCHING HALF BRIDGE TOPOLOGY
SOFT SWITCHING HALF BRIDGE TOPOLOGY

[8]
SOFT SWITCHING HALF BRIDGE TOPOLOGY
SOFT SWITCHING HALF BRIDGE TOPOLOGY
Experimental Data

Figure 1: Vin=240V, Iout=15A, Vout=14V
Blue is Syncro Drain, Red is Primary Gate, Yellow is Primary Drain

Figure 2: Vin=345V, Iout=90A, Vout=14V
Blue is Syncro Drain, Red is Primary Gate, Yellow is Primary Drain

Figure 3: Vin=405V, Iout=120A, Vout=14V
Blue is Syncro Drain, Red is Primary Gate, Yellow is Primary Drain
FUTURE TRENDS

- “True” Soft Switching topologies suitable for frequency range from 250Khz to 1Mhz will be the preferred choice.

- Resonant topologies such as LLC will maintain popularity due to the “idealization” of the switching devices.

- “True” soft switching topologies through sizing and control have the advantage of simplicity, low cost and in most of applications better efficiency than resonant topologies.

Figure 2: Vin=345V, Iout=90A, Vout=14V
Blue is Syncro Drain, Red is Primary Gate, Yellow is Primary Drain
In the future the topology may be a Soft Switching Cell operating at Z.V.S at turn on and Z.C.S at turn off. The operating frequency may be very high in Mhz range.

The regulation may be done in train of pulses with a frequency in hundreds of KHz range. The PWM regulation is the same, the difference is that during the “on” time energy will be delivered at very high frequency.
PRESENT MAGNETIC LIMITATIONS
LEAKAGE & STRAY INDUCTANCE
HOW TO MINIMIZE THE LEAKAGE INDUCTANCE

\[ L_{\text{leak}} = 4 \cdot \Pi \cdot 10^4 \frac{N^2 l_w}{M^2 Y} \left( \frac{\Sigma x}{3} + \Sigma x \Delta \right) \]
TOP AND BOTTOM LAYERS OF THE 25W DC-DC FLYBACK CONVERTER
IMPLEMENTATION OF THE 25W DC-DC FLYBACK CONVERTER

Layer 1: Components
Layer 2: Secondary
Layer 3: Primary
Layer 4: Secondary
Layer 5: Primary
Layer 6: Secondary
Layer 7: Shield
Layer 8: Components
EXPERIMENTAL WAVE FORMS OF THE 25W DC-DC FLYBACK CONVERTER

Voltage across Q1
Vin = 13.7V
Io = 0.2A

Voltage across Q1
Vin = 13.7V
Io = 0.6A
• THE STRAY INDUCTANCE ASSOCIATED WITH THE AC LOOP, PLAY A VERY IMPORTANT ROLE IN THE CONVERTER PERFORMANCE.

• THE EFFECT OF THE STRAY INDUCTANCE CAN BE STRONGER THAN THE EFFECT OF LEAKAGE INDUCTANCE.
THE IMPACT OF THE STRAY INDUCTANCE

\[ n = \frac{N_1}{N_2} = 8:1 \]

\[ \text{Leakage} = 0.63\mu\text{H} \quad L_{\text{Stray}} = 0.0088\mu\text{H} \]

\[ L_{\text{leakage\_total}} = L_{\text{leakage}} + n^2 \times L_{\text{Stray}} \]

\[ L_{\text{leakage\_total}} = 1.2\mu\text{H} \]
MAGNETIC OPTIMIZATION AND ELIMINATION OF THE END EFFECTS
- Significant reduction of the footprint
- Reduction of the magnetic core volume
1V2/100A HC_QB
Winding Termination Effects
Winding Termination Effects
NEW FORM OF DISTRIBUTED MAGNETICS
“N” WINDINGS CONCEPT 1/N TURNS
NEW FORM OF DISTRIBUTED MAGNETIC
ELECTRICAL EQUIVALENCY

Magnetic Distribution Techniques
A NOVEL FORM OF DISTRIBUTED MAGNETIC
MAGNETIC STRUCTURES FOR HIGHER FREQUENCIES
Magnetic Structures for High Efficiency
Magnetic Structures for High Efficiency

[1]
Printed Circuit Transformer

Top Core Pieces

9 Secondary Windings

Primary Winding

Bottom Core Pieces
## Magnetic Structures for Very High Frequency

### Rac/Rdc Characteristics

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<th>K[%]</th>
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[0 1 2 3 4 5 6 7 8 9 0 0.5 1 1.5 2 2.5 3 3.5 4 4.5 5 0 1 2 3 4]

### Multi-Legged Magnetic Structure
CONCLUSION

● The main target is efficiency and smaller size which may lead to lower cost.

● Reduction of number of turns towards one turn secondary.

● For efficiency and size minimization present “true” soft switching topologies operate between 300KHz towards 1MHz with new semiconductor technologies.

● The new semiconductor technologies allows operation above 5MHz but it may require high efficiency air core magnetic structures.
Thanks!
References


Some of the technologies presented in this seminar may be the subject of patent applications, please contact Rompower Energy Systems for further details.