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48V 2-stage System Efficiency Optimization by using STC Converter with Dynamic Converting Ratio

Sam Yang
Associate Direct of Power Design Dept.
Wiwynn
2-Stage Architecture for 48-to-PoL Power Delivery – Ratio Adjustable STC Converter

- Google’s proprietary STC 48V Bus intermediate STC (Switched Tank Converter) enables high efficiency high density 48V 1st stage conversion in 2-stage architecture.

- To further optimize system efficiency over all the load range Wiwynn propose dynamically change STC converting ratio based on output power condition:
  - High converting ratio for lower power application
  - Low converting ratio for higher power application
2-Stage Separate Efficiency Chart

1\textsuperscript{st} STC Efficiency vs Output Power

- 1\textsuperscript{st} stage STC eff:
  - Higher eff with low converting ratio at high output power
  - Moderate eff difference at lower load

2\textsuperscript{nd} VR Efficiency vs Output Power

- 2\textsuperscript{nd} stage VR eff:
  - Higher eff with lower Vin in light load
  - Moderate eff difference at heavy load
• Higher converting ratio gives better efficiency at lower load while reducing converting ratio can effectively gain higher efficiency at heavier load.

• With dynamic adjusted STC converting ratio, system efficiency can be optimized over all load range.
### EV-board measurement data

<table>
<thead>
<tr>
<th>Stage</th>
<th>Io_50A</th>
<th>Io_100A</th>
<th>Io_200A</th>
<th>Io_300A</th>
<th>Io_350A</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Efficiency</td>
<td>P_loss(W)</td>
<td>Efficiency</td>
<td>P_loss(W)</td>
<td>Efficiency</td>
</tr>
<tr>
<td>1st Stage</td>
<td>97.889%</td>
<td>2.058</td>
<td>98.453%</td>
<td>2.798</td>
<td>98.114%</td>
</tr>
<tr>
<td>2nd Stage</td>
<td>94.309%</td>
<td>5.545</td>
<td>94.298%</td>
<td>10.077</td>
<td>92.764%</td>
</tr>
<tr>
<td>Overall</td>
<td>92.318%</td>
<td>7.60</td>
<td>92.839%</td>
<td>12.89</td>
<td>91.014%</td>
</tr>
<tr>
<td>1st Stage</td>
<td>97.86%</td>
<td>2.071</td>
<td>97.34%</td>
<td>4.792</td>
<td>94.877%</td>
</tr>
<tr>
<td>2nd Stage</td>
<td>96.14%</td>
<td>3.693</td>
<td>95.623%</td>
<td>7.757</td>
<td>93.068%</td>
</tr>
<tr>
<td>Overall</td>
<td>94.075%</td>
<td>5.764</td>
<td>93.085%</td>
<td>12.549</td>
<td>88.3%</td>
</tr>
</tbody>
</table>
• Q1, Q3, Q5, Q8 and Q9 turn on/off at the same time with 50% duty cycle.
• Q2, Q4, Q6, Q7 and Q10 are complementary signal for the remaining 50% duty cycle.
• Cr1 and Cr2 are resonant capacitors with inductance constitute resonant tank.
• Cf1 is DC flying capacitor with much lower voltage ripples.
Adjustable STC Converting Ratio

8-to-1 Operation
Flying cap replaced by res. cap

4-to-1 Operation
Parallel resonant to step down the converting ration
Resonant Current Comparison in 4:1 and Paralleled 4:1

- Io is distributed in each resonant leg due to parallel operation, conduction losses is cut by half.
- Resonant Freq keeps the same due to parallel operation.
## EV-Board Dimension 1.2KW Peak power

### Component List

<table>
<thead>
<tr>
<th>Component</th>
<th>PN</th>
<th>Company</th>
</tr>
</thead>
<tbody>
<tr>
<td>Main switch 1</td>
<td>BSC015NE2LS5I</td>
<td>Infineon</td>
</tr>
<tr>
<td>Main switch 2</td>
<td>BSC022N04LS6</td>
<td>Infineon</td>
</tr>
<tr>
<td>Driver</td>
<td>2EDF7275K</td>
<td>Infineon</td>
</tr>
<tr>
<td>HB</td>
<td>BSZ011NE2LS5I</td>
<td>Infineon</td>
</tr>
<tr>
<td>Choke</td>
<td>BPMIWN06068032NK0E</td>
<td>Chilisin</td>
</tr>
<tr>
<td>DSP controller</td>
<td>F28035</td>
<td>TI</td>
</tr>
<tr>
<td>Resonant Cap1, 100V 2.2uF</td>
<td>SC2D2U100V6KX-1</td>
<td>Murata</td>
</tr>
<tr>
<td>Resonant Cap2, 100V 1uF</td>
<td>SC1U100V5KX</td>
<td>Murata</td>
</tr>
<tr>
<td>Resonant Cap3, 50V 2.2uF</td>
<td>SC2D2U50V6KX-4</td>
<td>Murata</td>
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<tr>
<td>Resonant Cap4, 50V 1uF</td>
<td>CL21B105KBFNNNE</td>
<td>Samsung</td>
</tr>
</tbody>
</table>

**Main Switch MOSFET:** 5.15*5.95mm²  
**Inductor:** 5.7*5.7mm²  
**Half Bridge MOSFET:** 3.2*3.2mm²
Developing Roadmap

- **2018 Q3**: “Flexible Converting Ratio” Patent preview
- **2018 Q4**: Simulation for steady state operation
- **2019 Q1**: 1st prototype EBV Evaluation done (discrete solution)
- **2019 Q2**: 1st Rev. EV board with DSP Controller (2/11 done)
- **2019 Q3**: Converting ratio transition simulation done and 2nd EV-board build
- **2019 Q4**: 1st engineer sample ready (new IC co-worked with the partner)
Summarize

• STC employ LC resonant tank to realize high efficiency DCDC power conversion for 2 stage 48V system, flexible converting ratio can further improve 2-stage overall efficiency by dynamically alter converting ratio based on power requirement
  • High converting ratio reducing 2\textsuperscript{nd} stage VRs voltage stress in lower load
  • Low converting ratio and parallel resonant legs to reduce 1\textsuperscript{st} stage current stress in heavy load

• Future work:
  • Simplified main switches driver design and reduce choke/board size.
  • Looking for integral solution for ZCS exact switching timing.
  • Define converting ratio switching point and hysteresis
Question?
Google’s 48V 2-Stage Conversion Approach

- STC enables high efficiency 2-stage conversion, more 2nd stage VRs supported by STC, higher board efficiency is.
- Current Design Targeting 600W for STC 48V to VR with different converting ratios:
  - 4:1 (Intel)
  - 8:1 (Google)
- With increasing CPU/DDR power, higher STC power is needed.
Converting Ratio Changes

8:1 change to 6:1
- Ires1=Ires2=Ires3= 1/3lo
- Ires4=Ires5=Ires6=Ires7= 1/6lo

6:1 change to 4:1
- Ires1=Ires2=...=Ires7= 1/4 lo

Remain off