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Kingston, Ontario, Canada
www.queenspowergroup.com

A New Resonant Gate Drive Circuit with Efficient Energy Recovery and Low Conduction Loss

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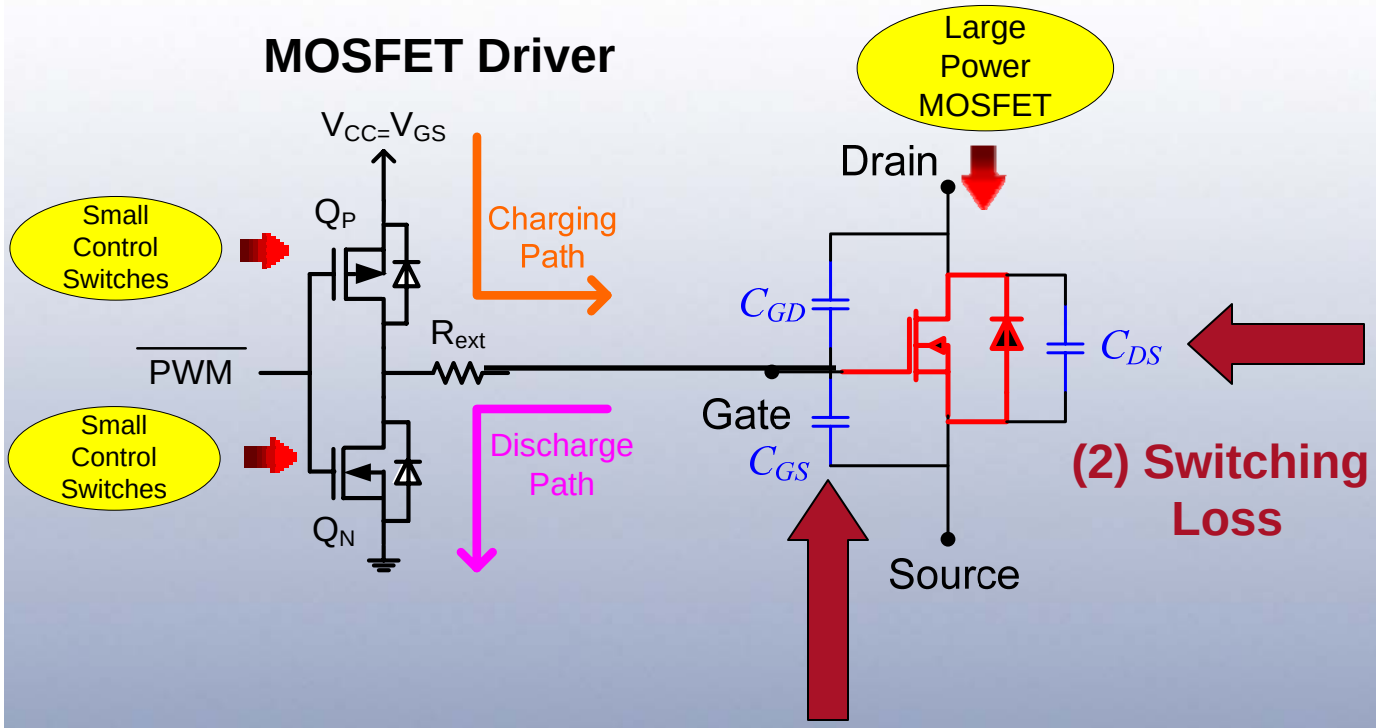
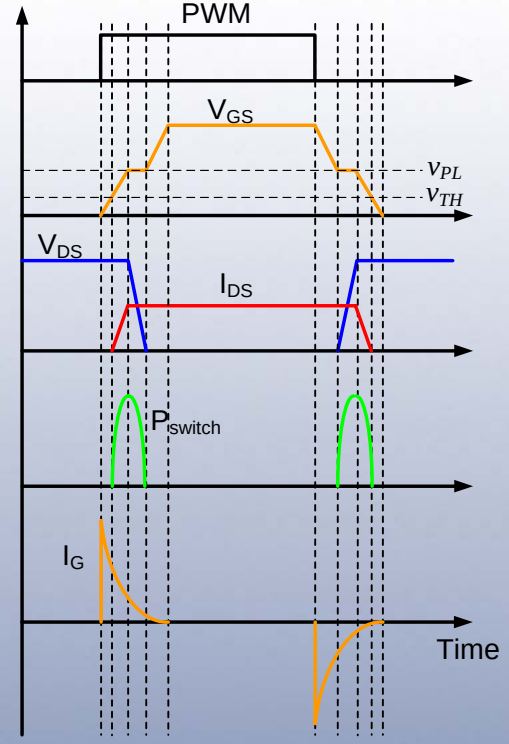
Presentation Overview

1. *Introduction*
2. Proposed Circuit and Waveforms
3. Logic Implementation
4. Loss Analysis
5. Design Procedure
6. Design Example
7. Simulation Results
8. Conclusions

Conventional Lossy RC-Type Voltage Drive





$$P_{gate} = Q_g V_{GS} f_S$$

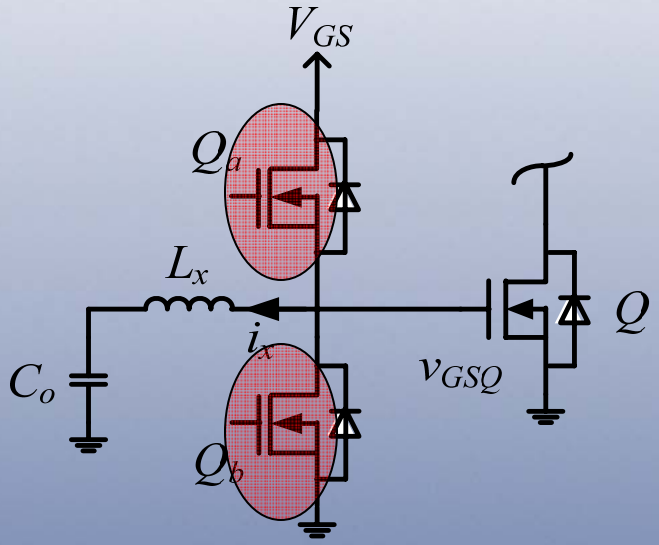
$$P_{switch} = K(t_{rise} + t_{fall}) V_{DS} I_{DS} f_S$$

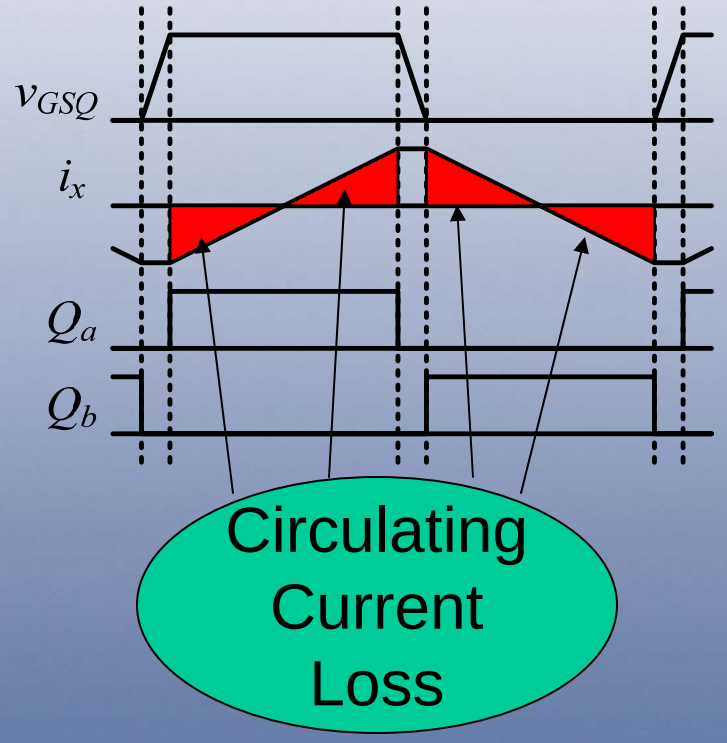
$$P_{out} = \frac{1}{2} C_{DS} V_{DS}^2 f_S$$

Resonant Gate Drive Review

Existing techniques suffer from at least one of three problems:

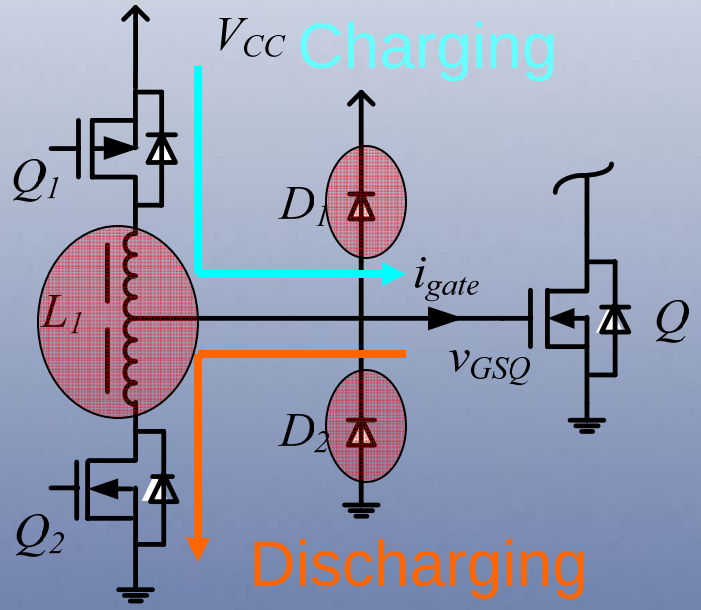
1. **Circulating current conduction loss [1]**



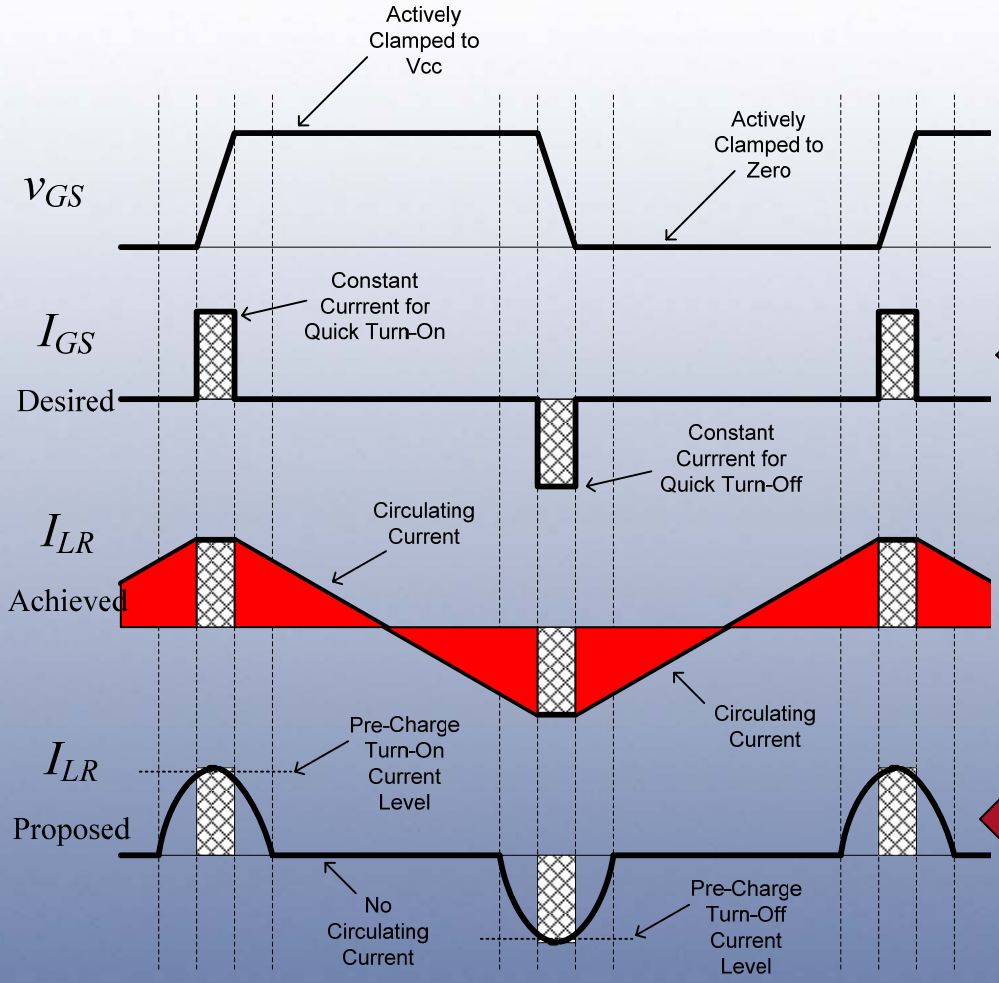


Resonant Gate Drive Review

2. **Slow turn-on and/or turn-off through inductance [2]-[9]**
3. **Gate not actively clamped high and/or low, so false triggering (Cdv/dt) can result [2]-[7],[9]**



Evolution of the Proposed Driver



Current Source Drive For Speed

Discontinuous Inductor Current With Pre-Charge Minimizes Conduction Loss

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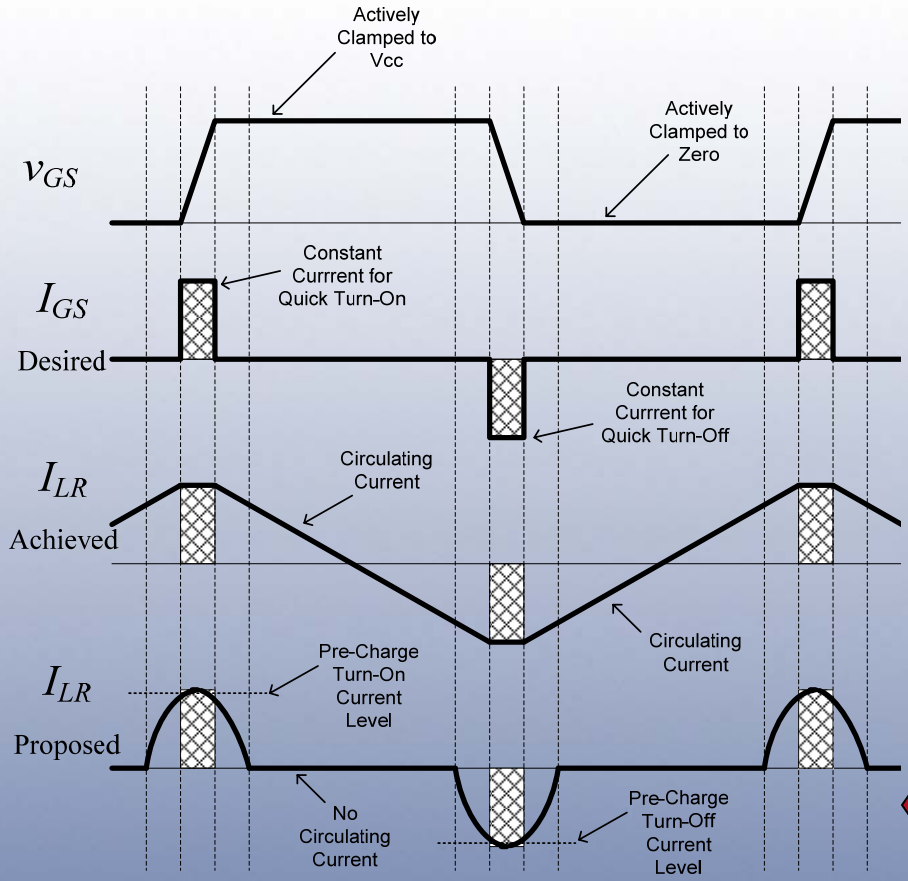
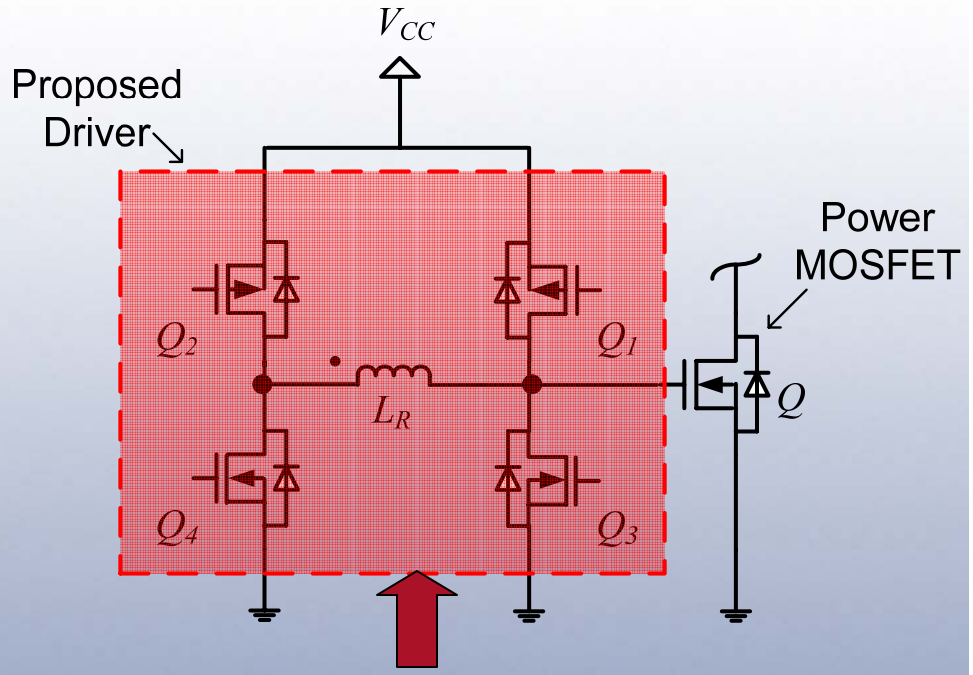
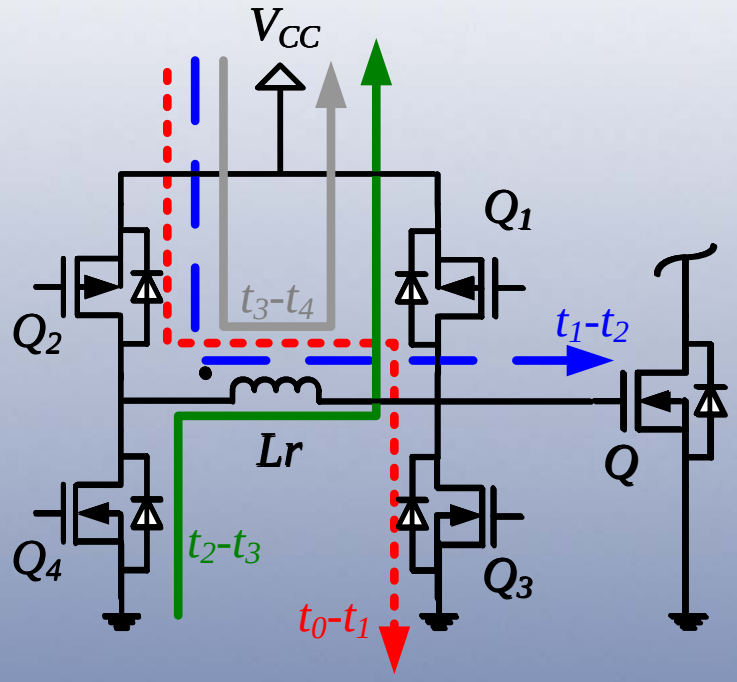
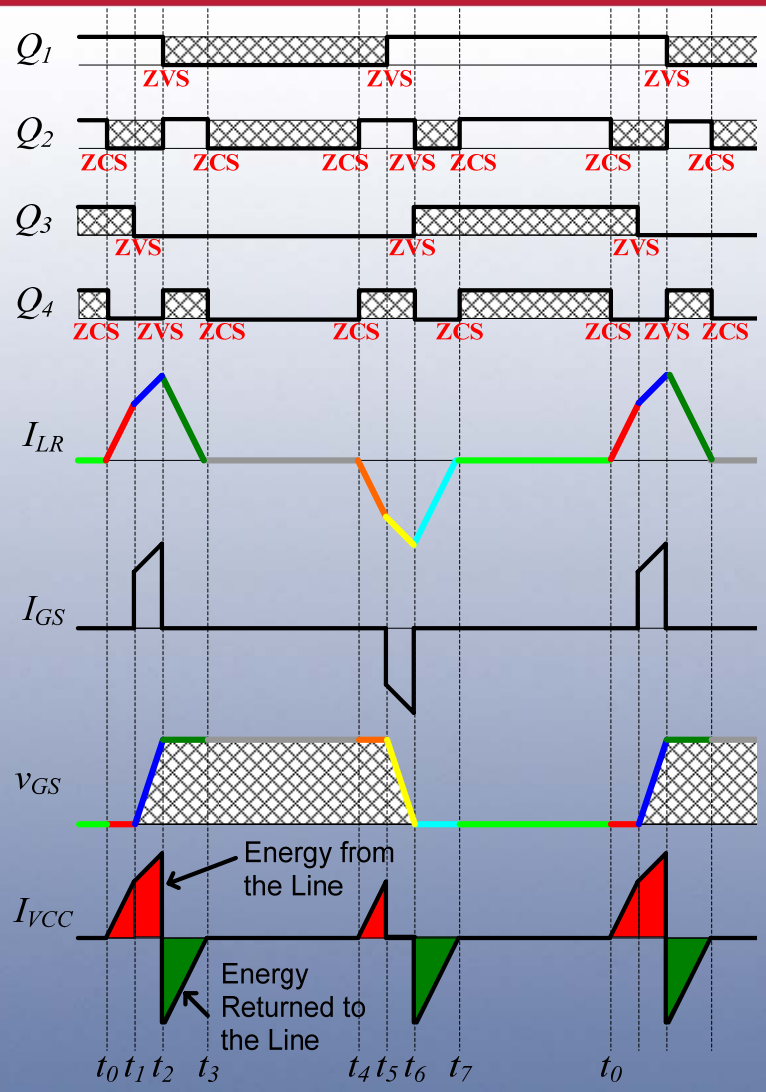




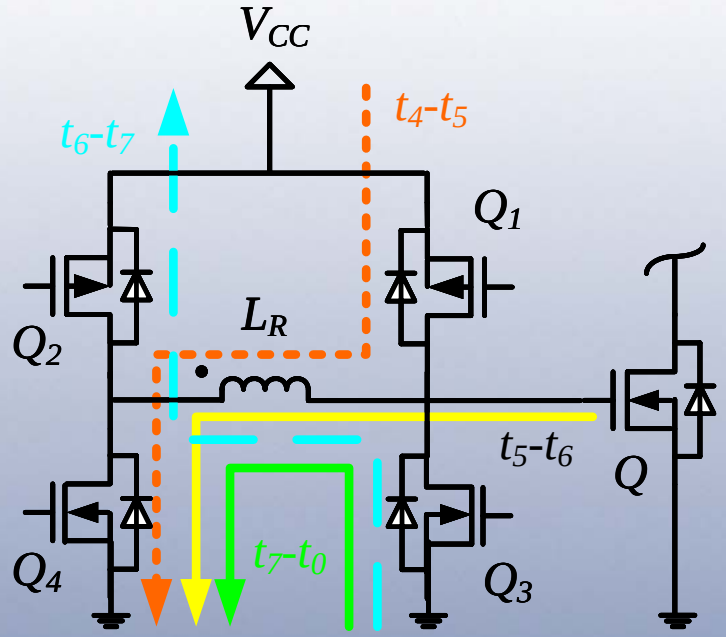
Discontinuous Current By Controlling 4 Control Switches Q1-Q4

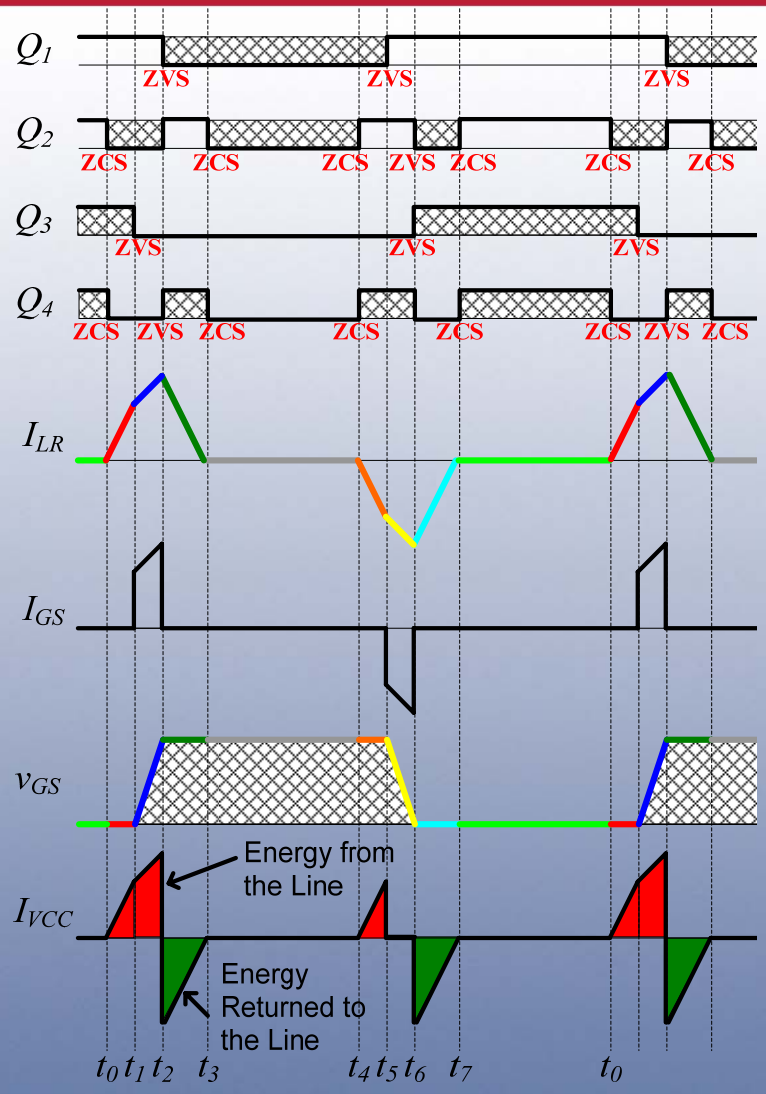
Switch Control of Proposed Driver: Turn-On Sequence





Switch Control of Proposed Driver: Turn-Off Sequence





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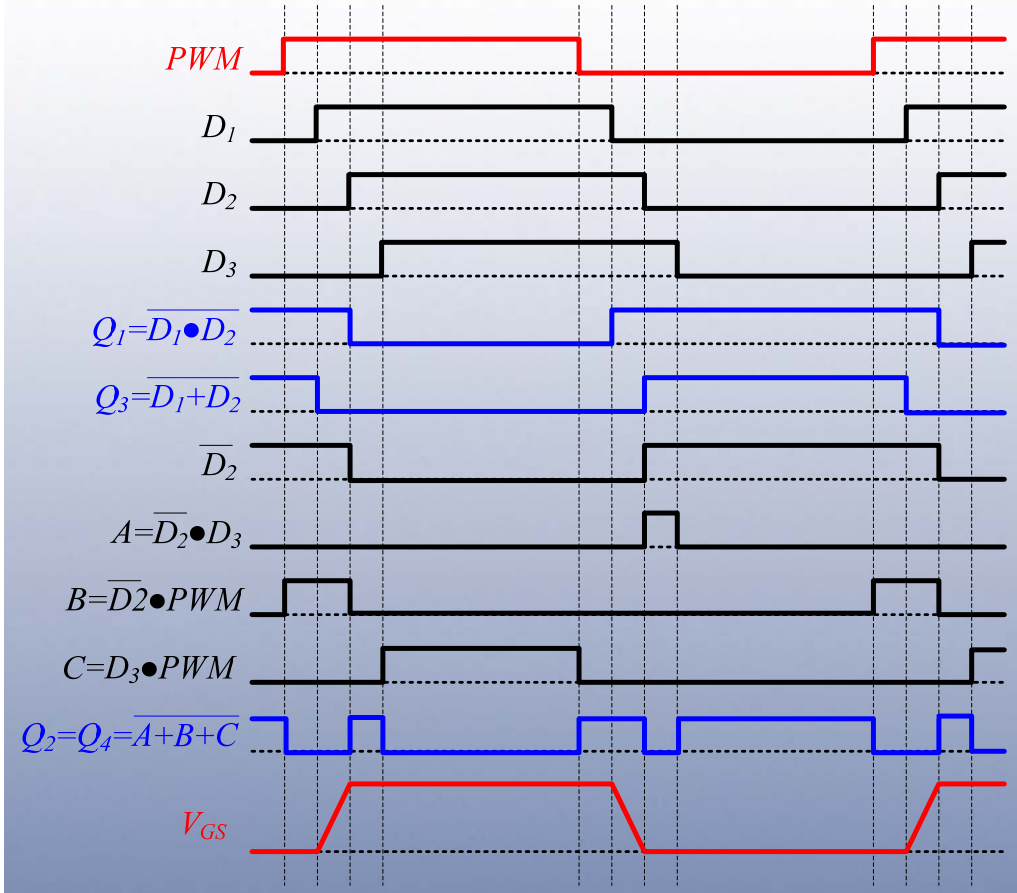
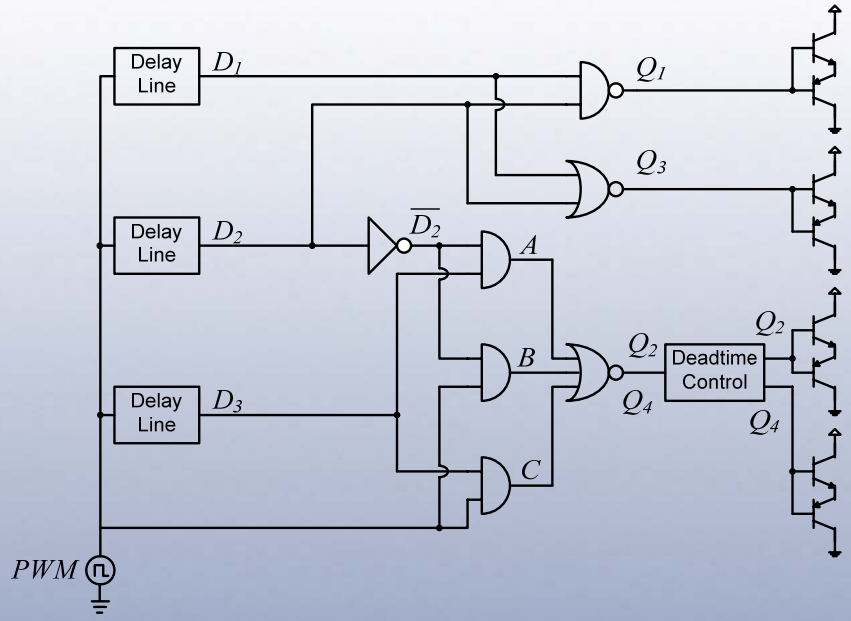
Logic Implementation





7 logic components
3 delay elements

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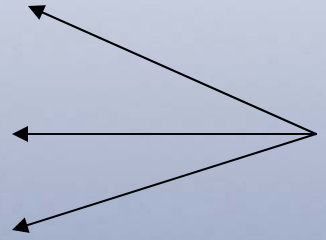

More In The Paper

Losses

1. **Conduction loss in switches, inductor & Rg; MOSFET Rg biggest contributor**
2. **Q2/Q4 gate loss at 3 times switching frequency**
3. **Some CV^2 loss at 2 times switching frequency in Q2/Q4**
4. **Turn-off loss in Q2/Q4 at switching frequency**
5. **Inductor core loss**

Design Procedure and Example

1. **Calculate optimized inductance: 170nH**
2. **Calculate optimized delay times: t1=24ns, t2=90ns, t3=149ns**

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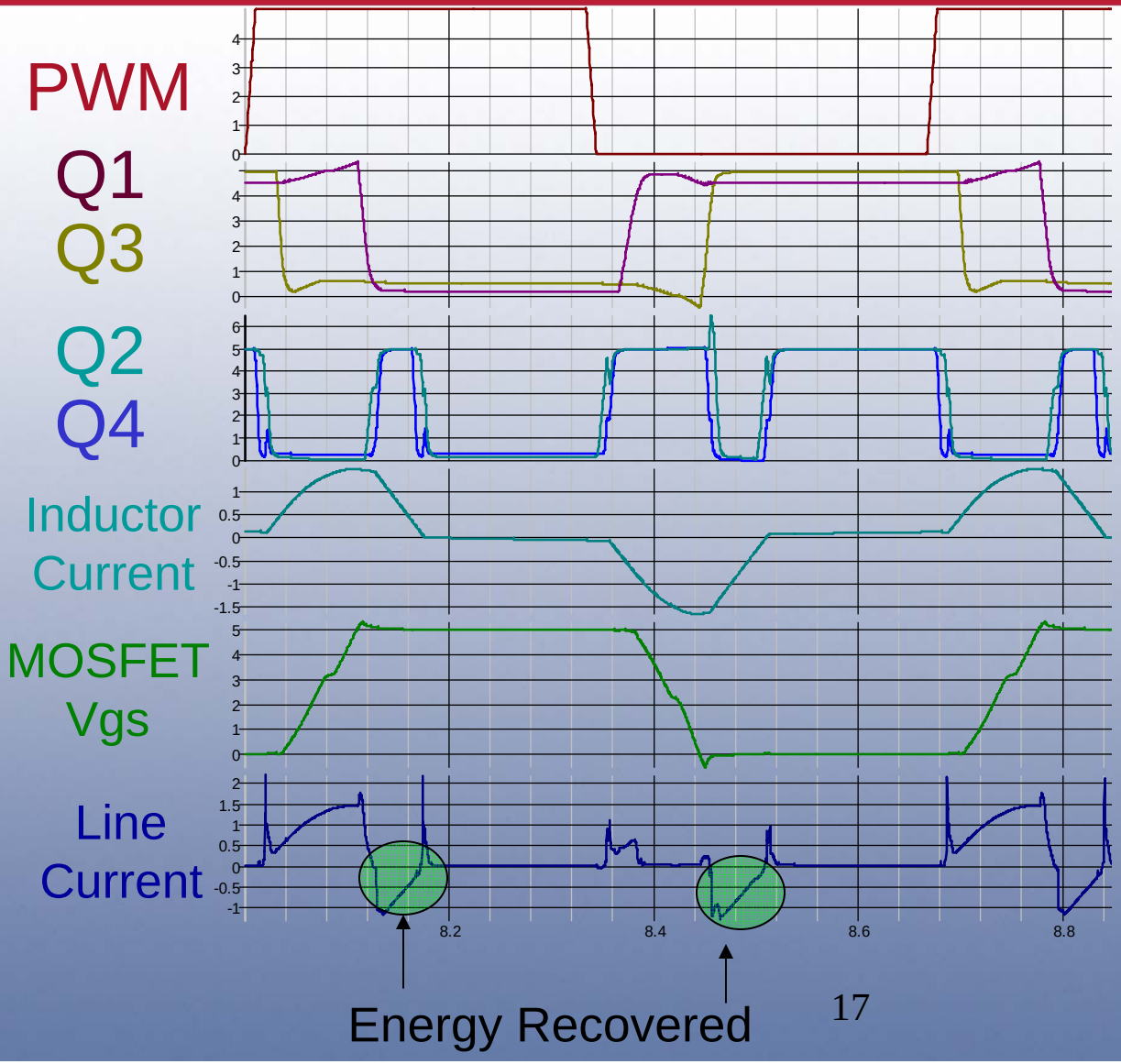
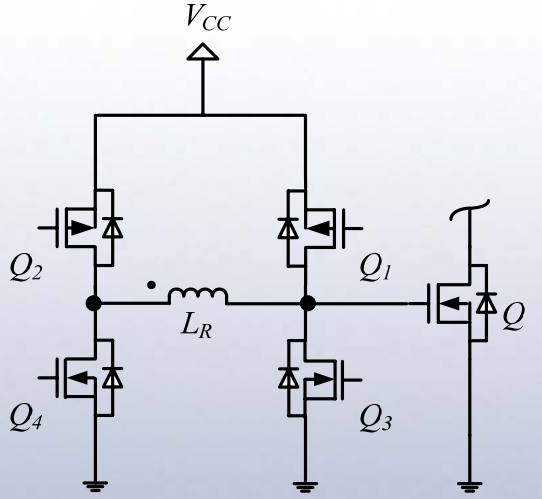
SIMetrix Simulation Results

1.5MHz, L_R=170nH, 2-IRF6691 MOSFETs





- **Conventional driver gate loss: 1.2W+**
- **Proposed driver loss: 496mW**
- **59% recovery**

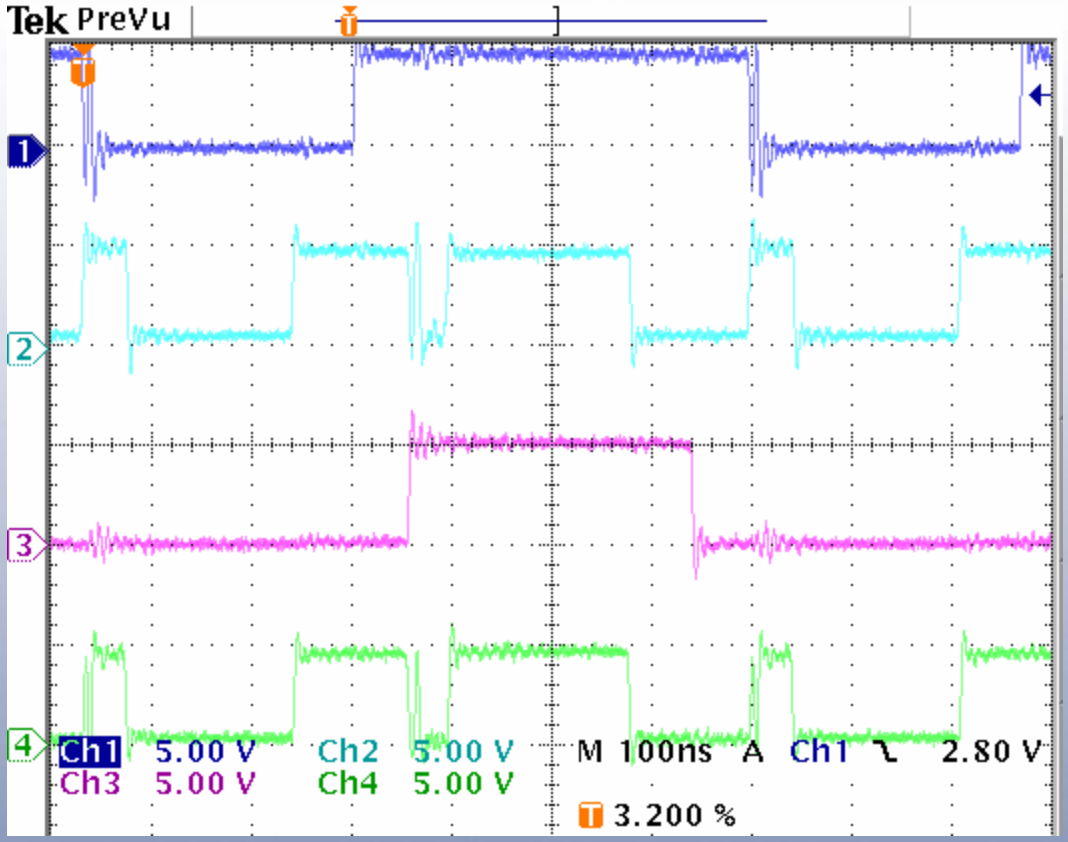
Experimental Results

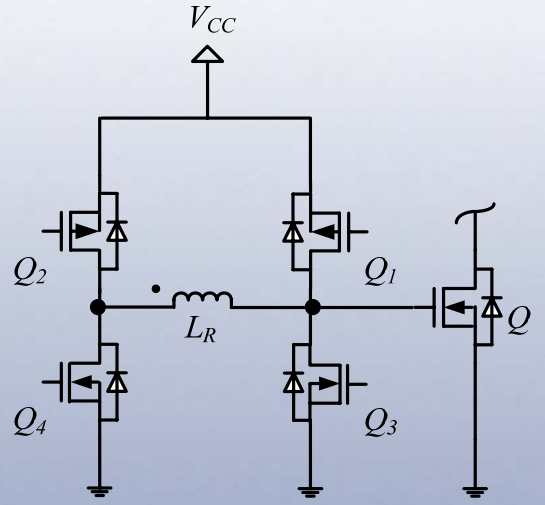
Q1

Q2

Q3

Q4





Preliminary Results: more at APEC 06

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Conclusions

- **New resonant gate driver proposed**
- **Solves problems of existing drivers:**
  1. **High conduction loss**
     - **SOLUTION: discontinuous inductor current**
  2. **Slow turn-on/turn-off**
     - **SOLUTION: pre-charge current before switching**
  3. **Poor Cdv/dt immunity (false triggering)**
     - **SOLUTION: actively clamping power MOSFET gate through low impedance control switches**
- **Partial gate energy recovery**
- **Reduction in switching loss by fast switching – SIGNIFICANT!**

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Thank You For Your Time

Stay Tuned for More on this Driver and others from The Queen's Power Group at APEC 06 in Dallas

Questions?