A New Resonant Gate Drive Circuit Utilizing Leakage Inductance of Transformer

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Presentation Overview

1. ***Introduction***
2. **Proposed Resonant Gate Drive Circuit**
3. **Analysis and Design Guideline**
4. **Experimental Results**
5. **Conclusions**

1. Introduction

- **Increasing demand for higher switching frequency:**
  - **Compact package**
  - **Fast loop response**
- **Gate charge loss occupies more share of total loss at high frequency application**
- **Drawbacks of conventional gate driver**
  - **Driving energy total lost**
  - **Overheat of driver**
  - **Longer turn-off transition**
  - **Higher switching loss**

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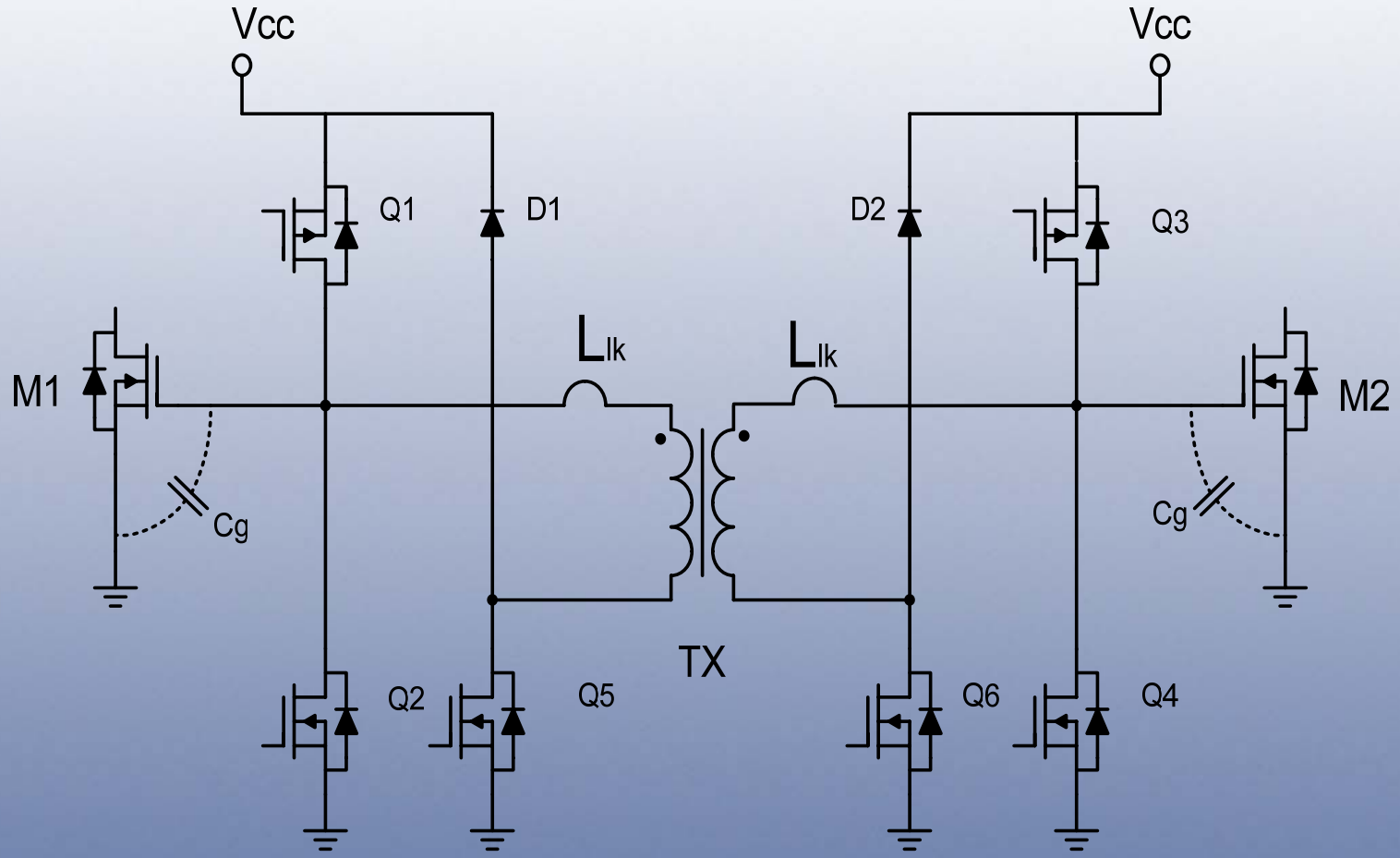
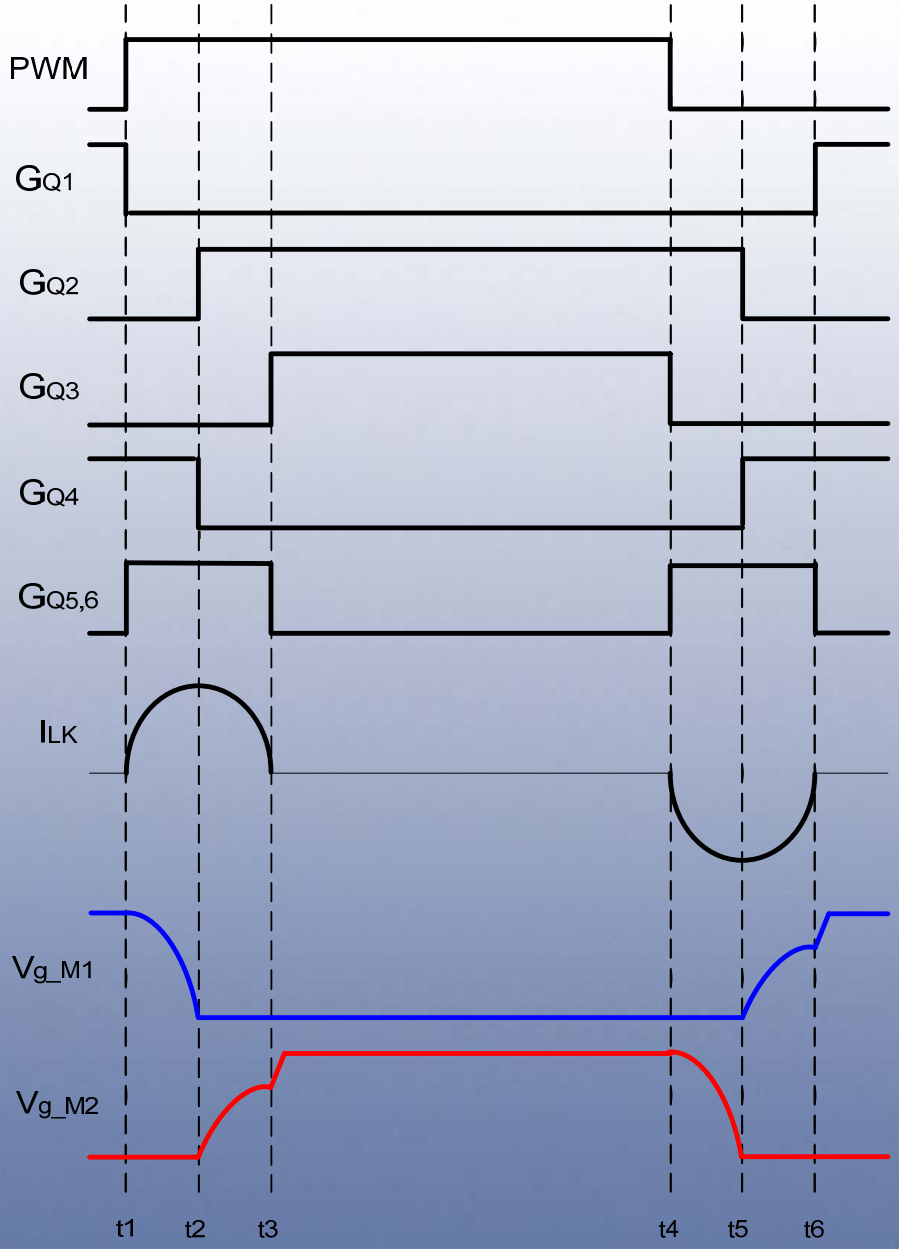
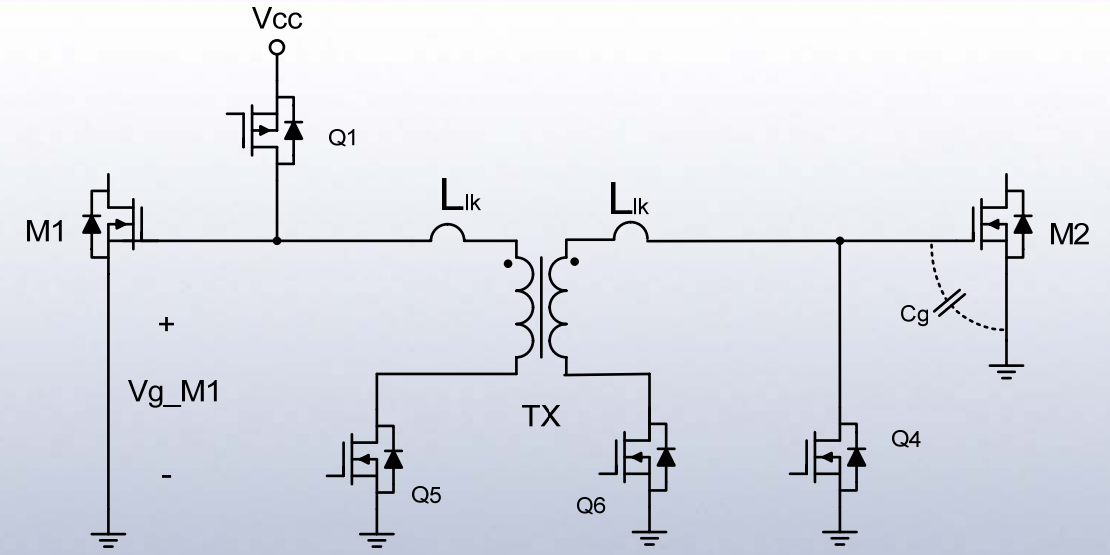
2. Proposed Resonant Gate Drive Circuit

Proposed Resonant Gate Drive Circuit



Operating Principle (Half Cycle)

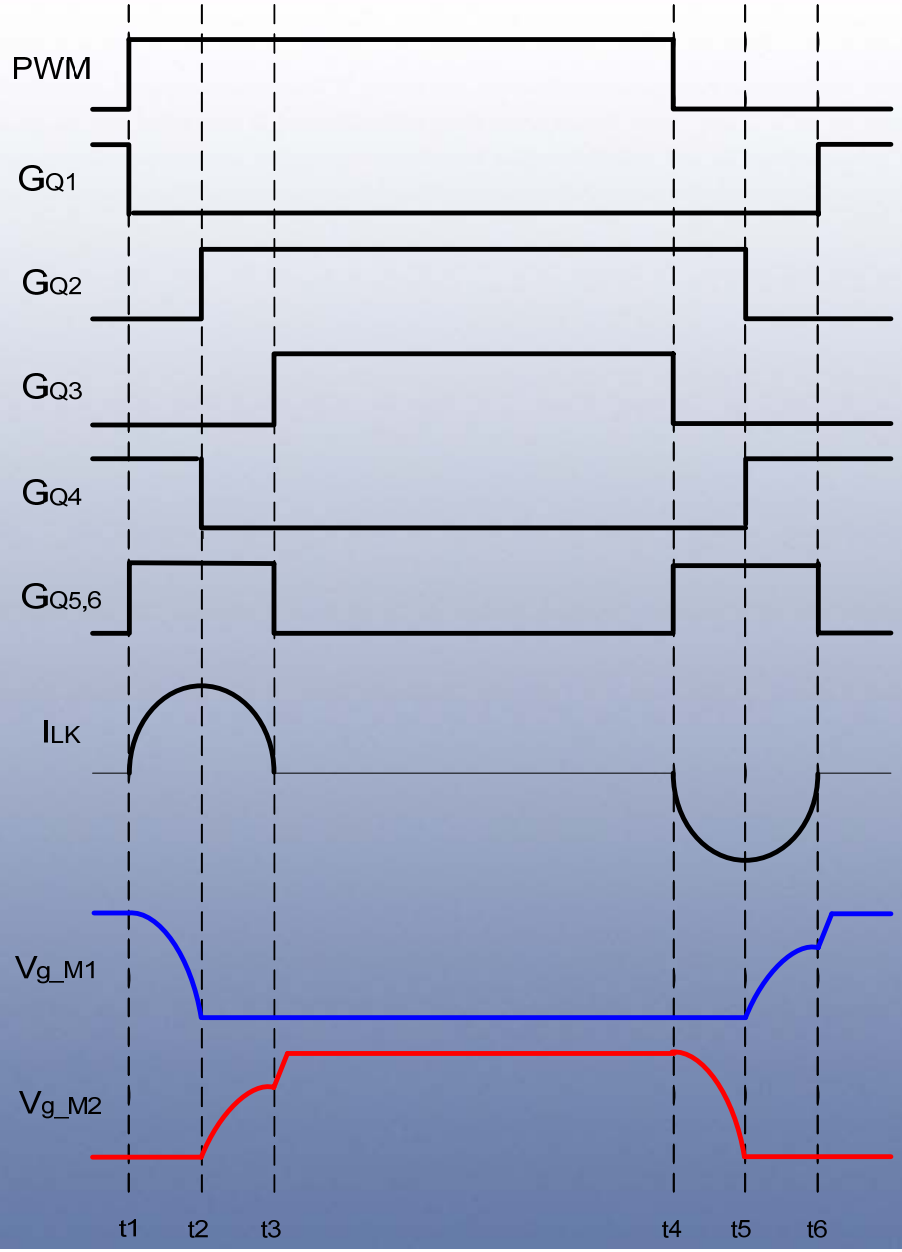


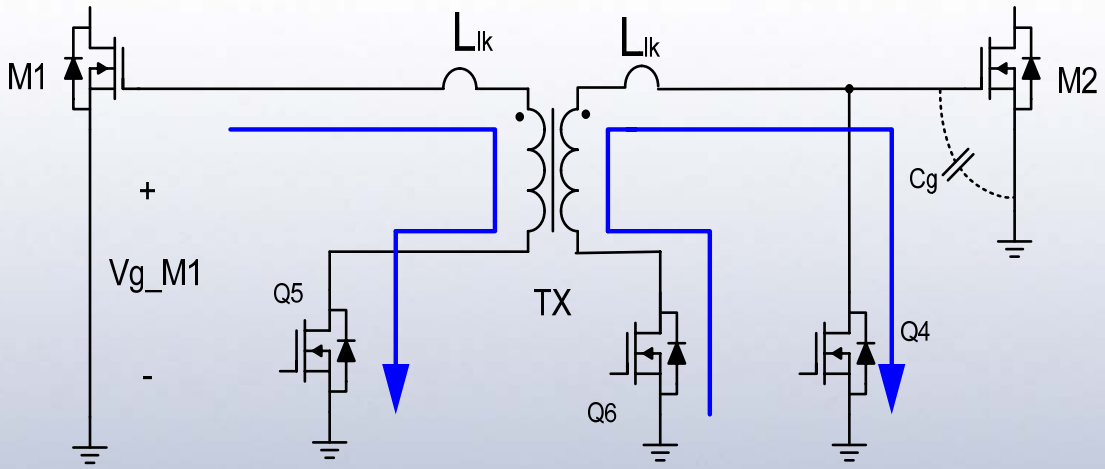


Before t1:

1. **Q1 and Q4 on**
2. **Q2, Q3, Q5 and Q6 off**
3. **M1 on, M2 off**

Operating Principle (Half Cycle)

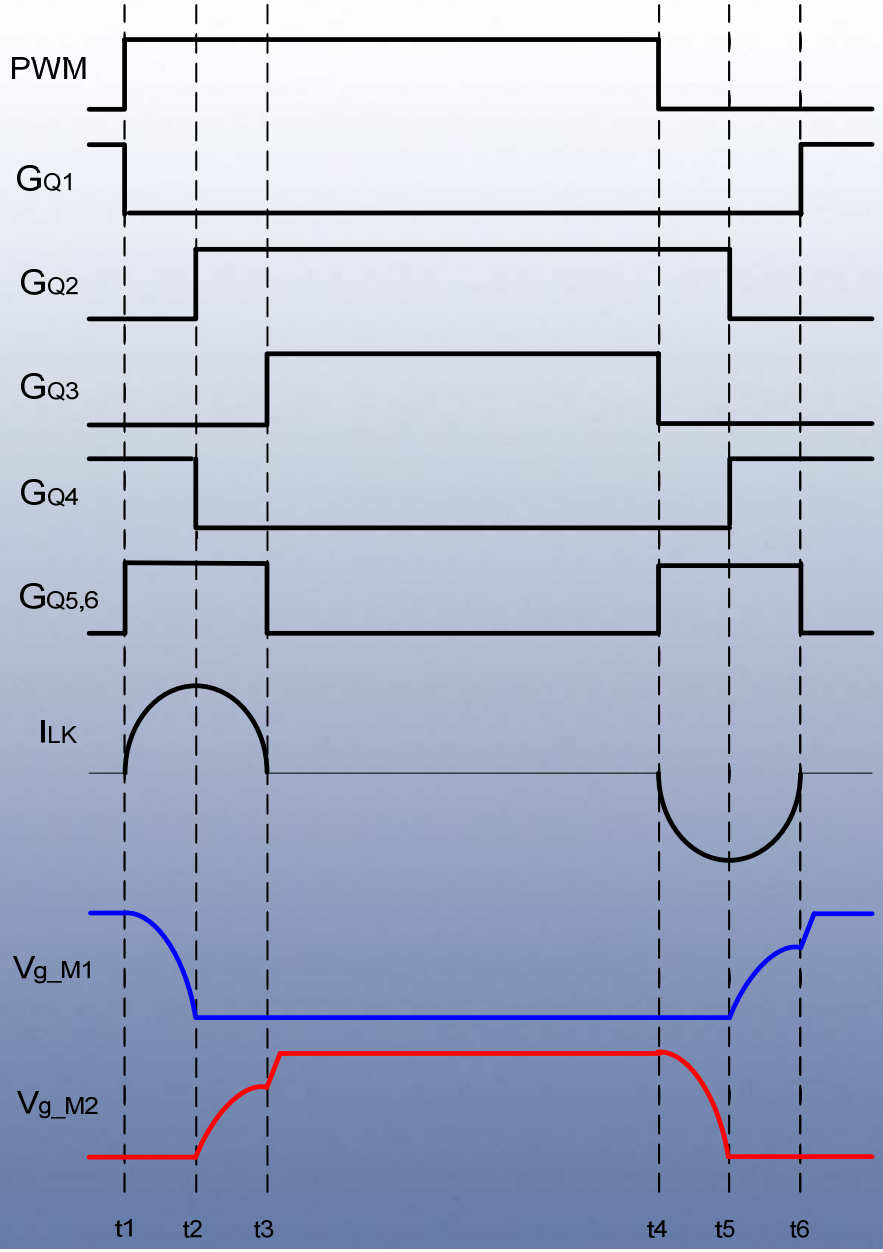


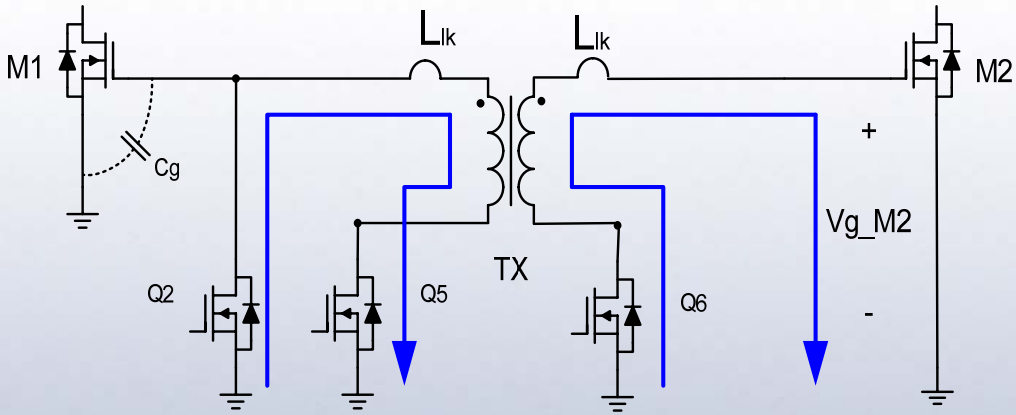


t1 ~ t2:

1. **At t1, Q1 turned off and Q5, Q6 turned on**
2. **Resonant current discharged Cg of M1**
3. **M1 is turned off**
4. **Q2 is turned on at ZVS**

Operating Principle (Half Cycle)

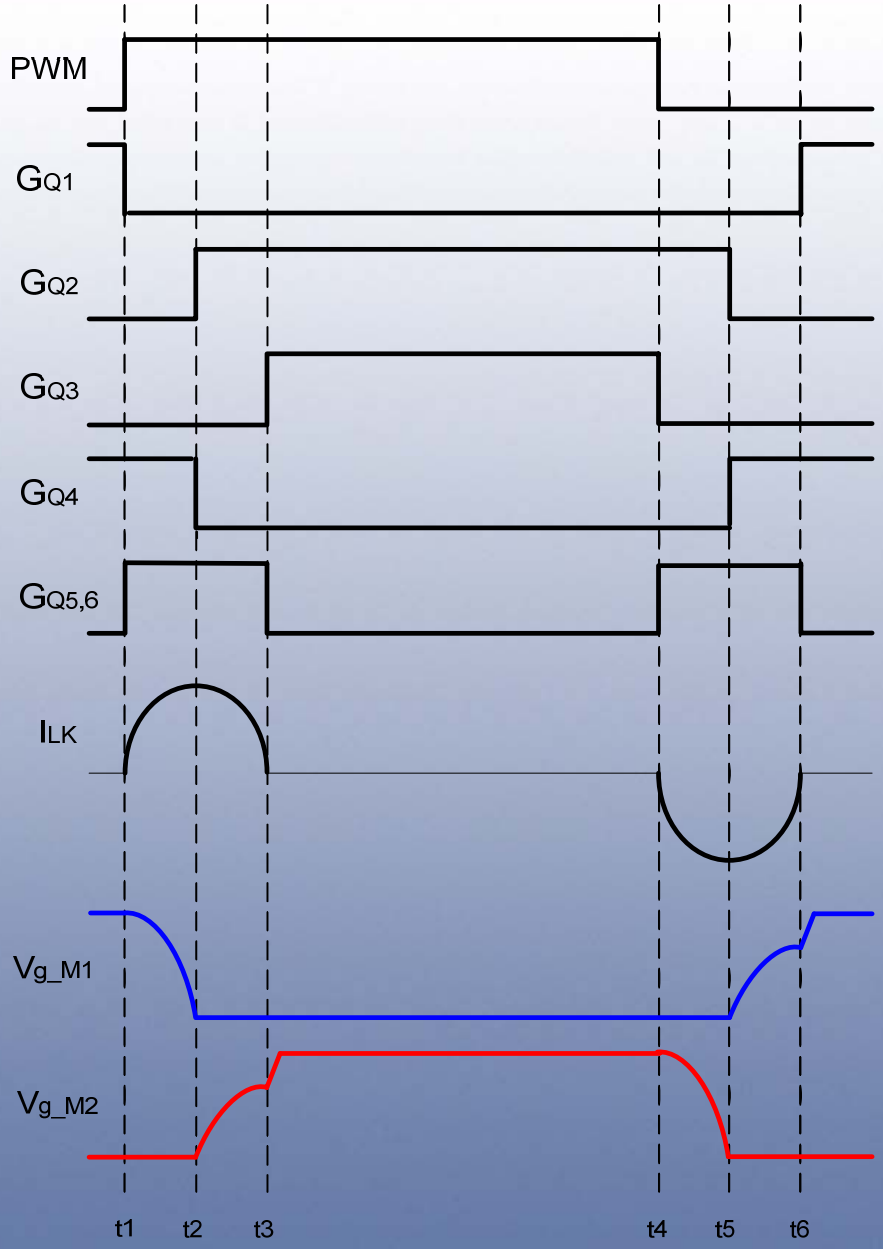


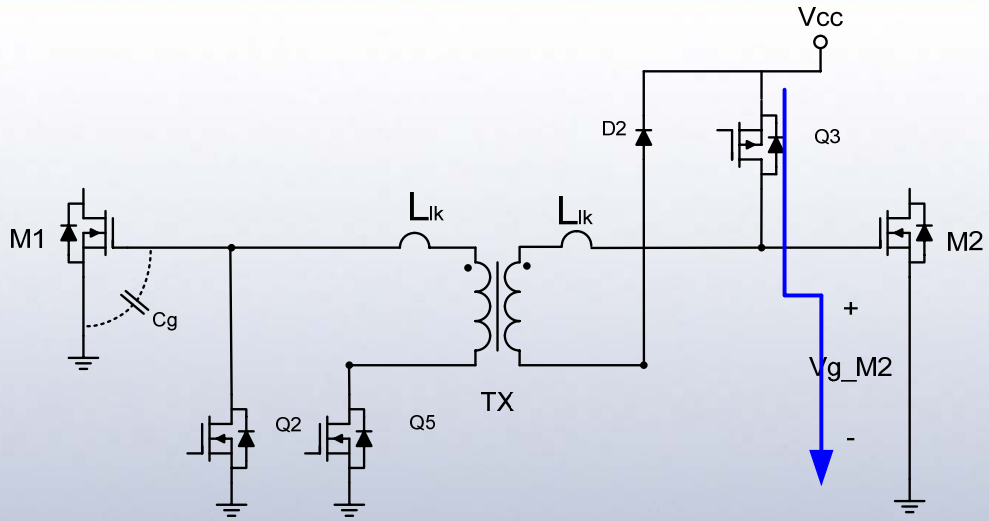


t2 ~ t3:

1. **Q4 is turned off at t2**
2. **Resonant current charges Cg of M2**
3. **M2 is turned on**

Operating Principle (Half Cycle)





t3 ~:

1. **At t3, resonant current reaches zero**
2. **Q5, Q6 turned off at ZCS**
3. **Q3 is turned on to charge the deficit voltage from Vcc**

Summary of Proposed circuit

- **Utilizing leakage inductance of transformer**
- **Pulse controlled resonance is utilized to minimize the conduction loss**
- **low voltage-second applied to transformer, minimizing driving transformer size**
- **Fast transition, minimizing duty cycle limitation**

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3. Analysis and Design Guideline

Loss distribution:

$$Pgr = P_{rms} + P_{drive} + P_{core} \qquad (2)$$

1. **Conduction loss – main contributor**
2. **Driving loss – small share**
   - **selecting small gate charge driving mosfets (Q1 to Q6)**
   - **Driving fets realize ZVS or ZCS, switching loss neglected**
3. **Core loss – neglected**
   - **Low voltage-second applied, minimizing core loss**

Conduction Loss Analysis

Conduction loss calculation:

$$I_L(t) = I_{PK} e^{-\alpha t} \sin(\omega_d t) \qquad (3)$$

$$Vc(t) = Vcc \cdot (1 - Ke^{-\alpha t} \cos(\omega_d t)) \qquad (4)$$

Where $\alpha = R_{tot} / 2L_{LK}$ $\omega_d = \sqrt{\omega_o^2 - \alpha^2}$ $\omega_o = \dfrac{1}{\sqrt{L_{LK} C_g}}$

$$K = \frac{1}{\sqrt{1-\xi^2}} \qquad \xi = \frac{R_{tot}}{2} \cdot \sqrt{\frac{C_g}{L_{LK}}}$$

$$I_{PK} = \frac{Vcc}{\sqrt{\frac{L_{LK}}{C_g} - \left(\frac{R_{tot}}{2}\right)^2}}$$

$$P_{rms} = \int i_L(t)^2 \cdot R_{tot} \cdot dt \qquad (6)$$

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Gate Driving Control Logic Implementation

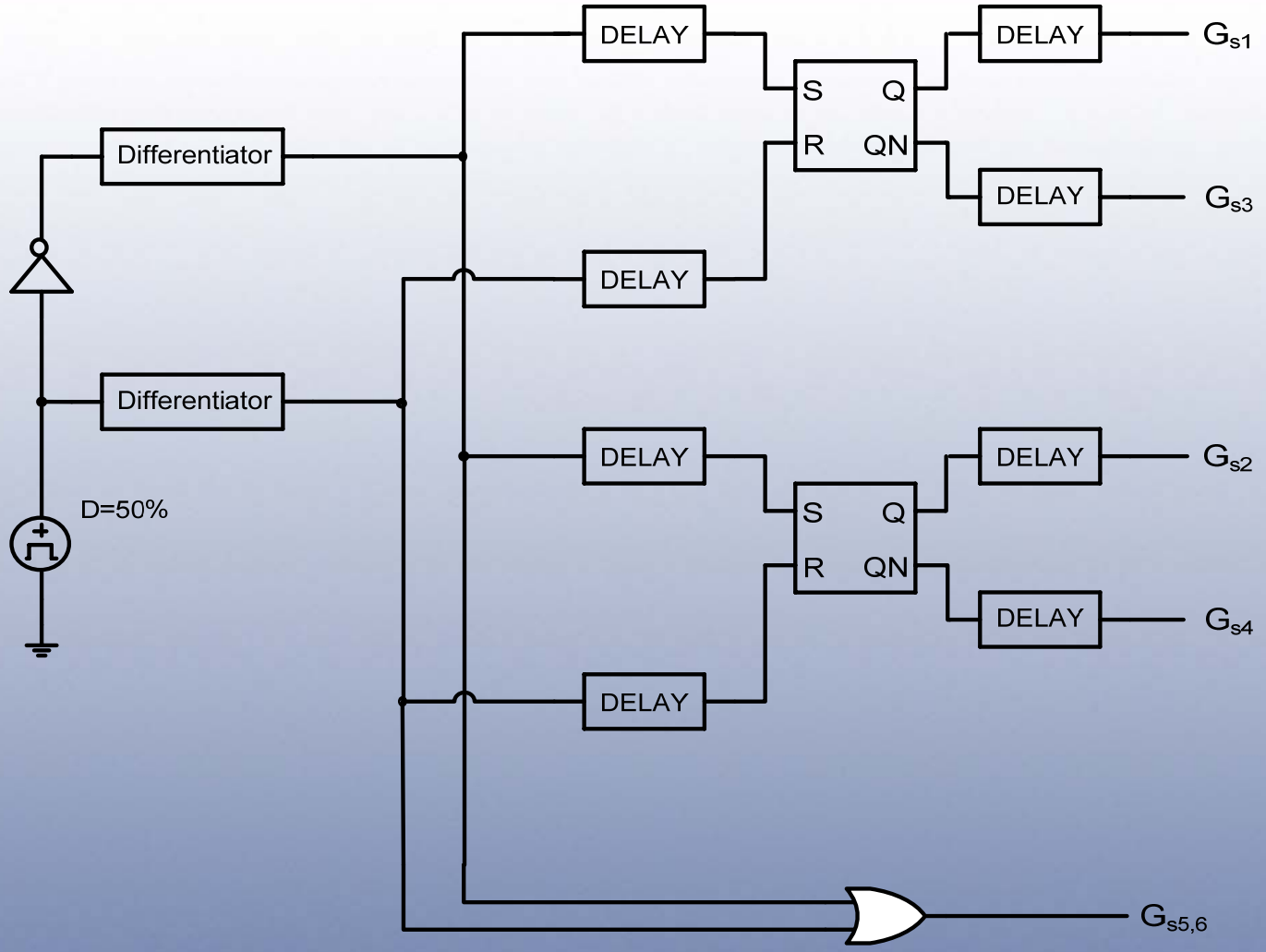

Fig 8. Logic control block for resonant gate driver

Circuit Parameters and Results

- **Circuit Parameters:**

  Vcc=5V; fs=500KHz; Llk=100nH;

  2 FDS6680 paralleled;

- **Results:**
  - **69% energy transfer Efficiency (V_{peak}^2/V_{cc}^2)**
  - **52% actual loss saving**

Result Waveforms

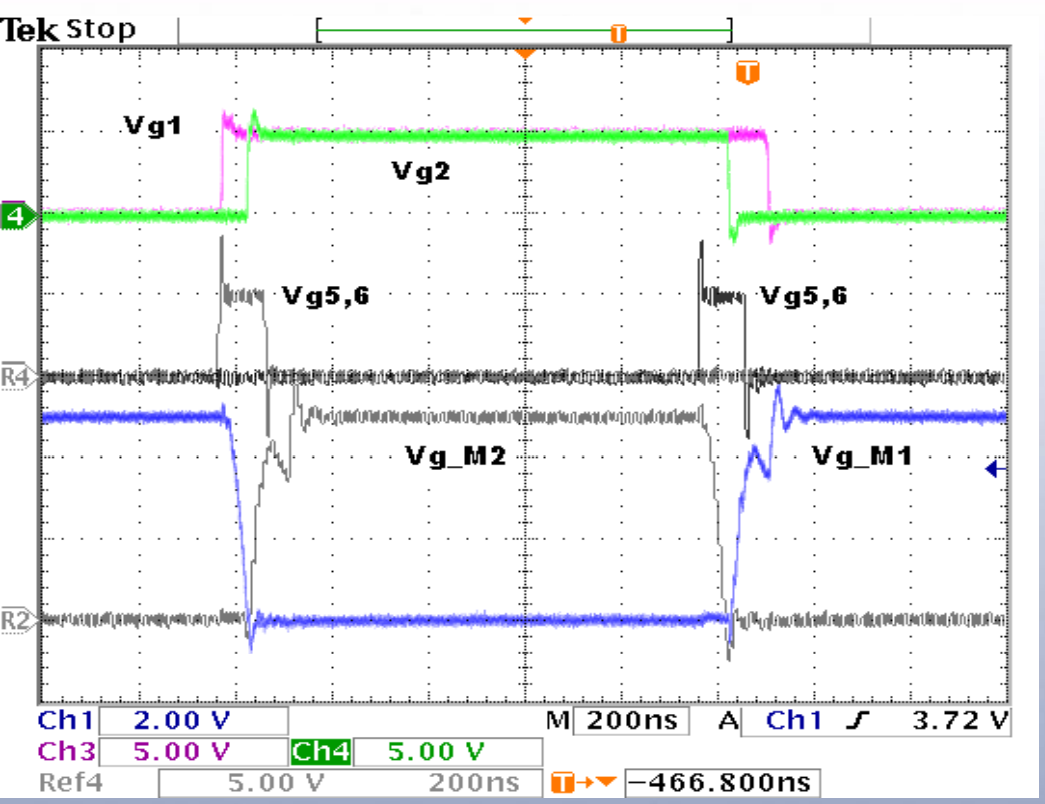

Fig 11. Key experiment waveform

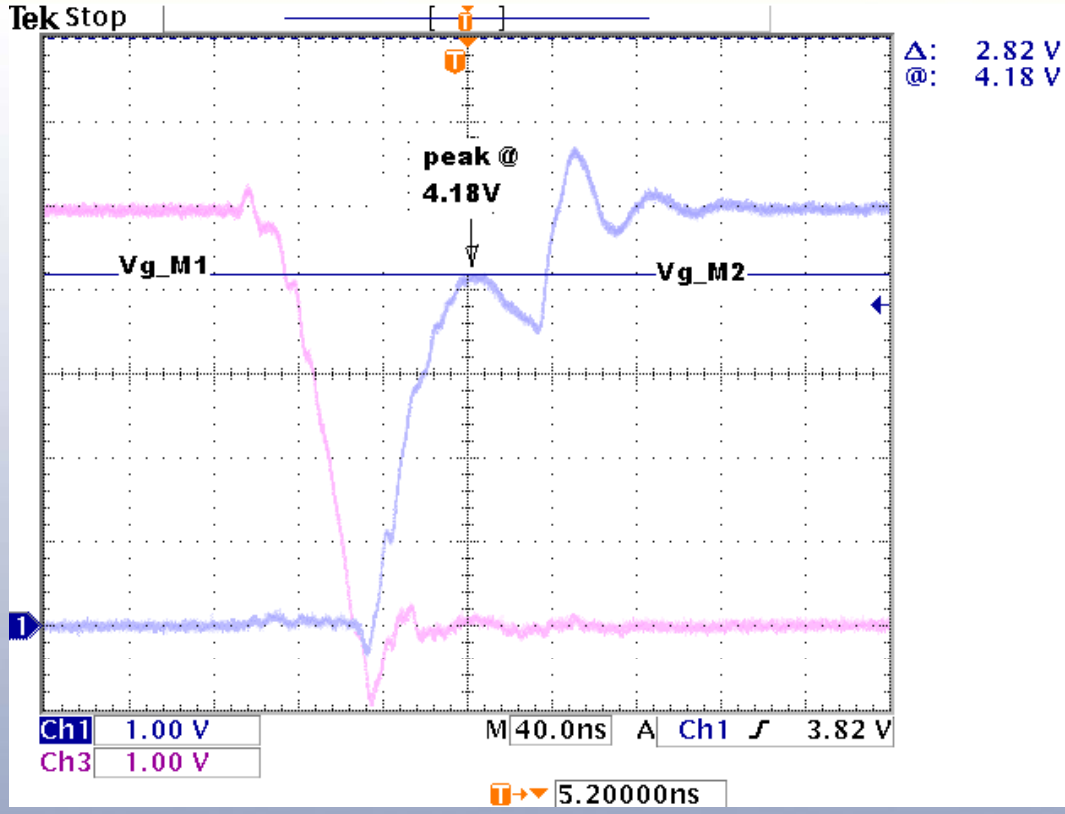

Fig 12. Detail gate voltage waveform

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5. Conclusions

- **A new resonant gate drive circuit was introduced**
- **The circuit driving a pair of MOSFETs**
- **Partial of gate driving energy is recovered**
- **Leakage inductance of transformer is utilized**
- **Pulse controlled resonance reduces the conduction loss**

5. Conclusions

- **Low voltage-second applied, minimizing transformer size**
- **Fast transition, relaxing duty cycle limitation**