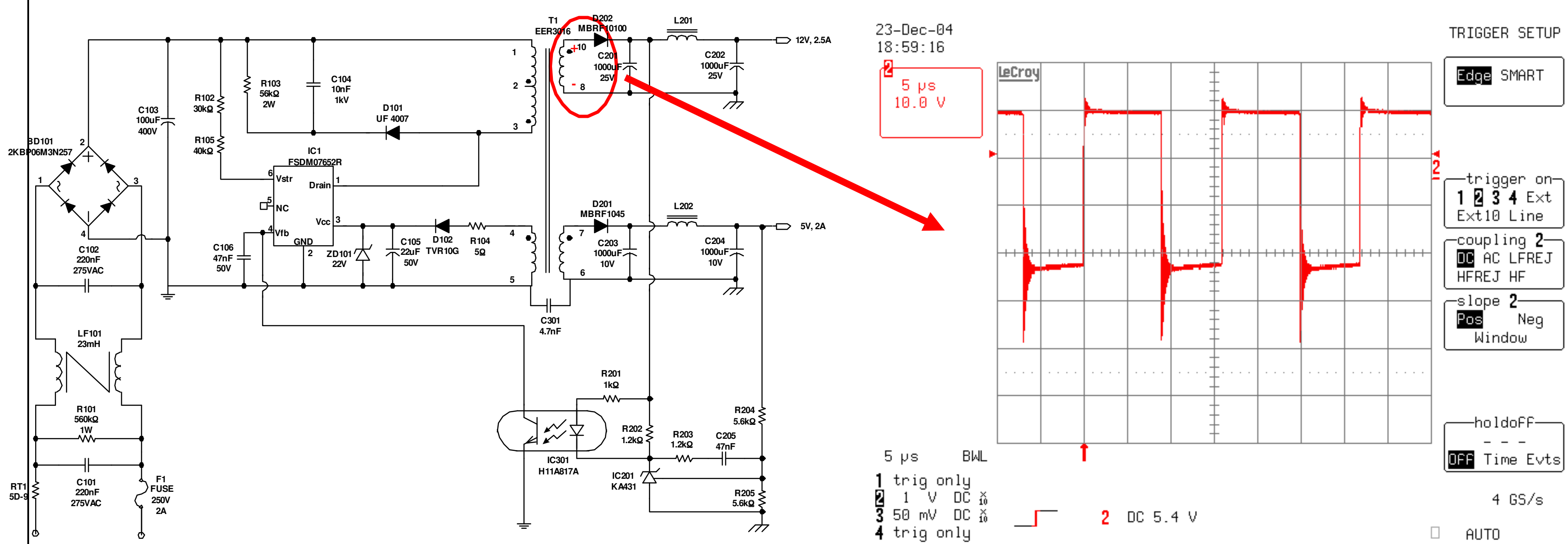
4. Snubber design (RC snubber)

❑ RC snubber → Secondary side diode

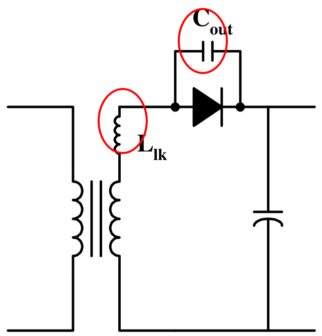


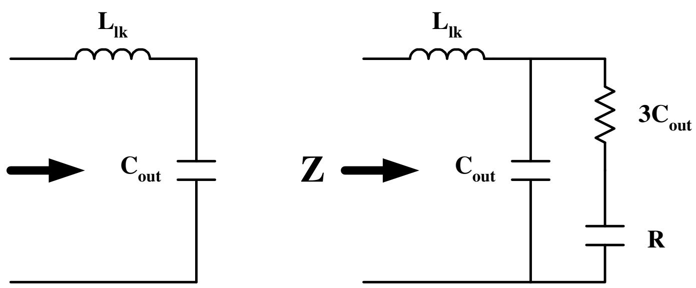
4. Snubber design (RC snubber)

❑ **Why Diode voltage oscillates when turned off?**

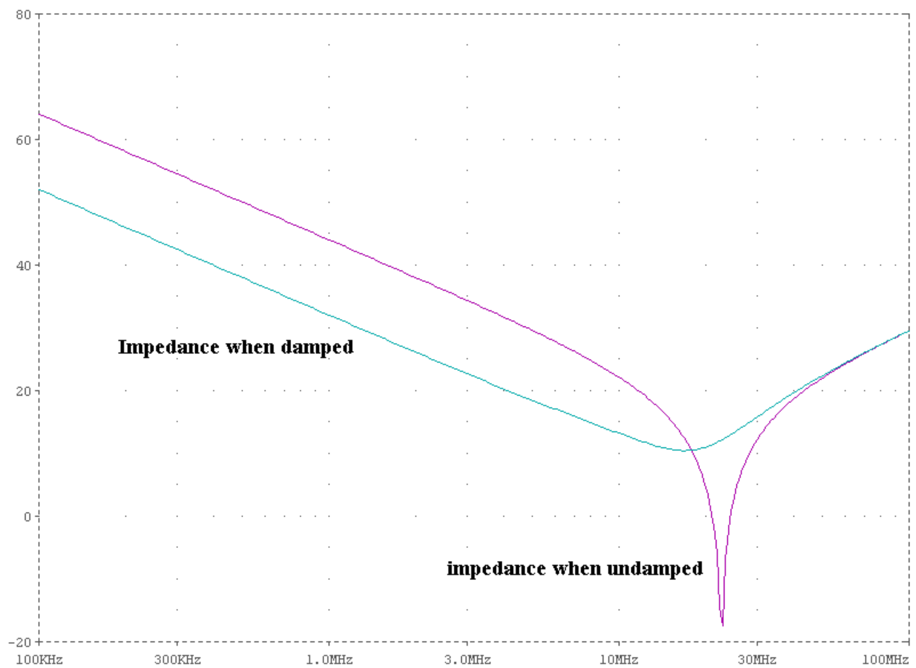
→ **Oscillation between the leakage inductance and diode output capacitance**

→ **Need to be damped with additional resonant network**



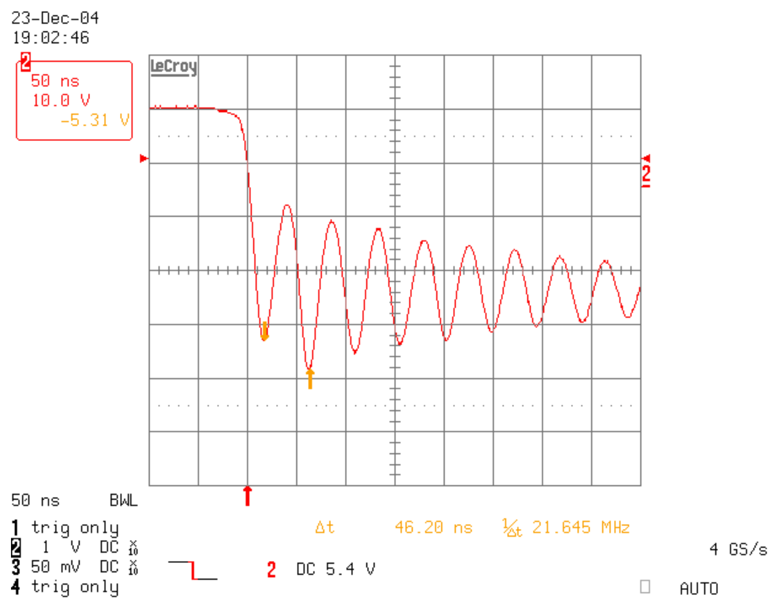


$$R = \sqrt{\frac{L_{lk}}{C_{out}}} = \frac{\sqrt{L_{lk}C_{out}}}{C_{out}} = \frac{1}{2\pi f_r C_{out}}$$



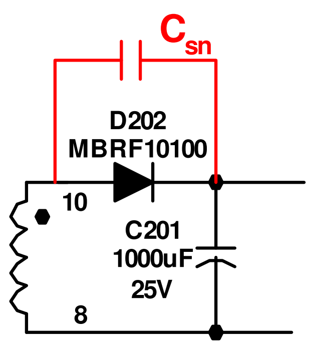
4. Snubber design (RC snubber)

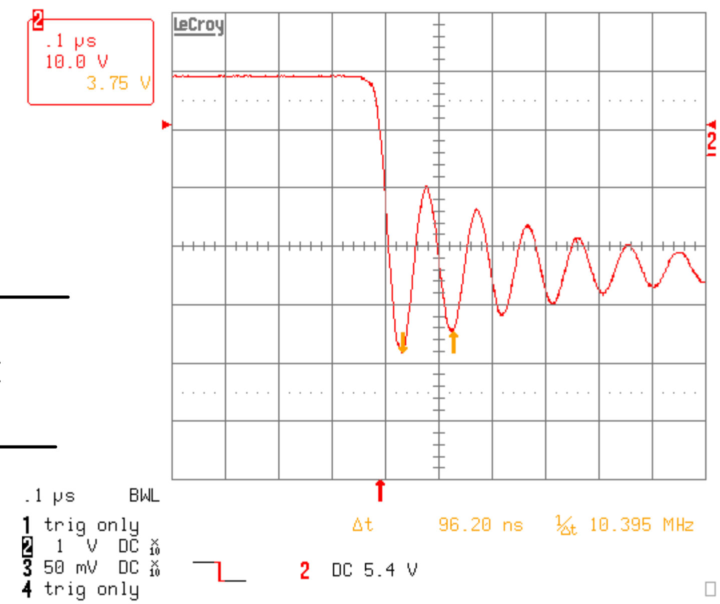
(1) Measure the original resonance period (Tr) of the diode voltage waveforms.



→ Tr=46ns

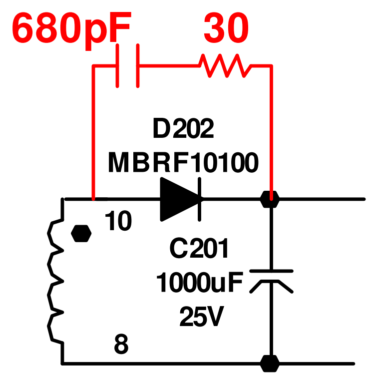
(2) Find a capacitor value that doubles the resonance period when connected in parallel with the diode.





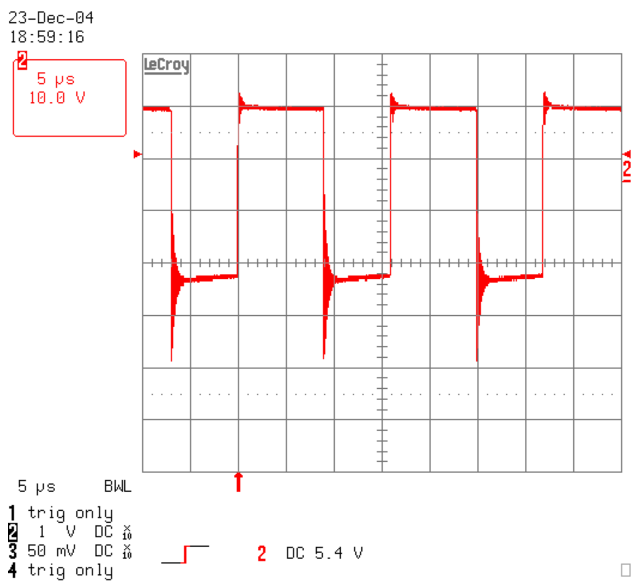
→ With 680pF capacitor, the resonance period is approximately doubled (46ns → 96ns)

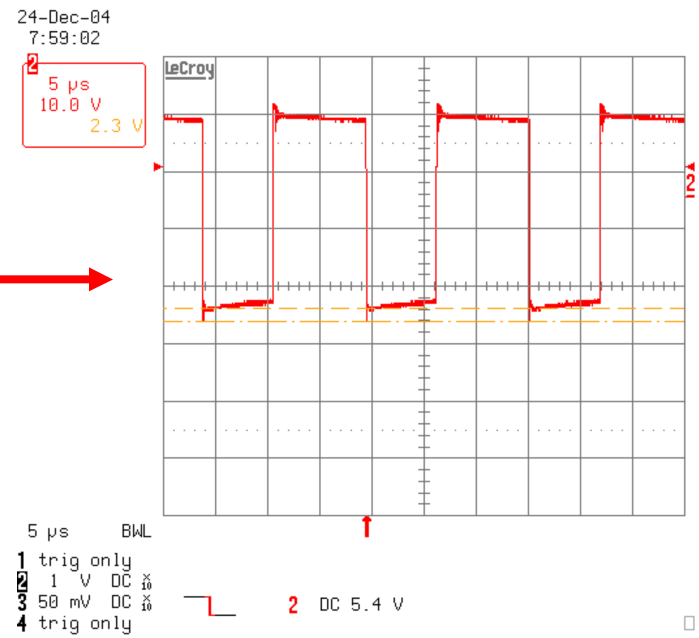
4. Snubber design (RC snubber)



(3) Calculate the snubber resistor with the following equation.

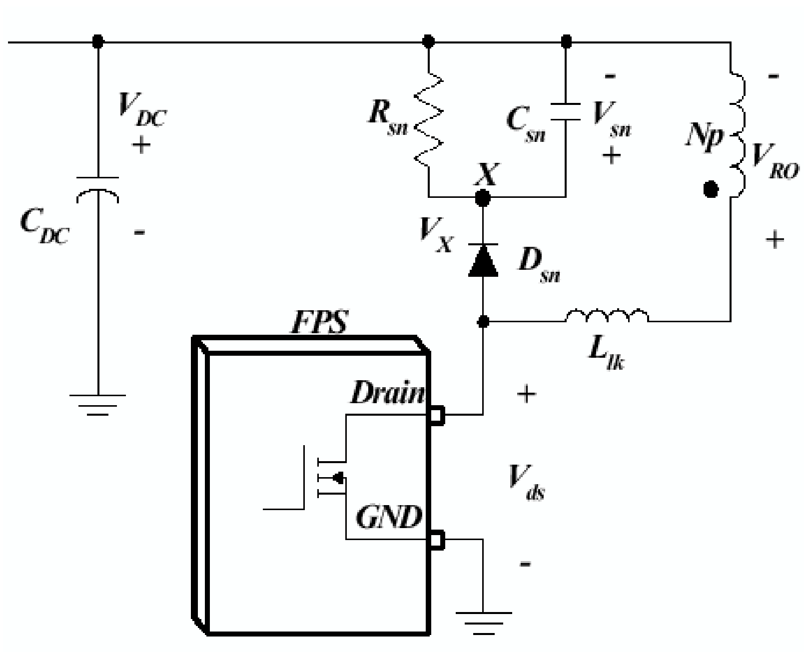
$$R_{sn} = \frac{3T_r}{2\pi C_{sn}} = \frac{3 \cdot 46ns}{2\pi \cdot 0.68nF} = 32\Omega \quad \text{(Use 30 ohms resistor)}$$

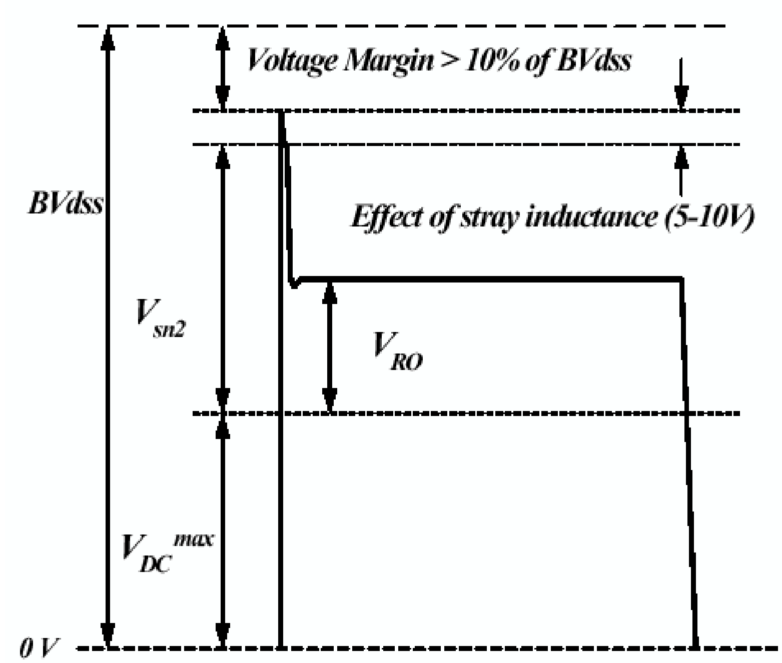




4. Snubber design (RCD snubber)

❑ RCD snubber → Primary side

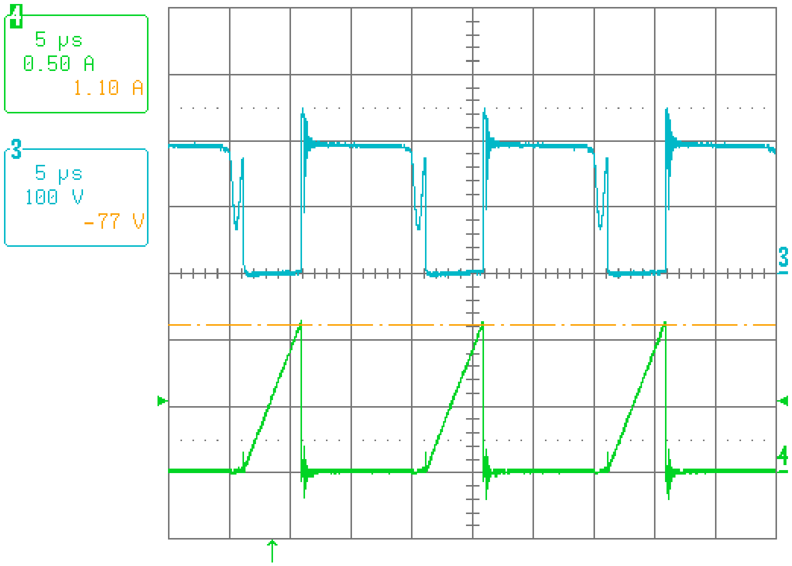




$$P_{sn} = \frac{(V_{sn})^2}{R_{sn}} = \frac{1}{2} f_s L_{lK} (I_{ds}^{peak})^2 \frac{V_{sn}}{V_{sn} - V_{RO}}$$

4. Snubber design (RCD snubber)

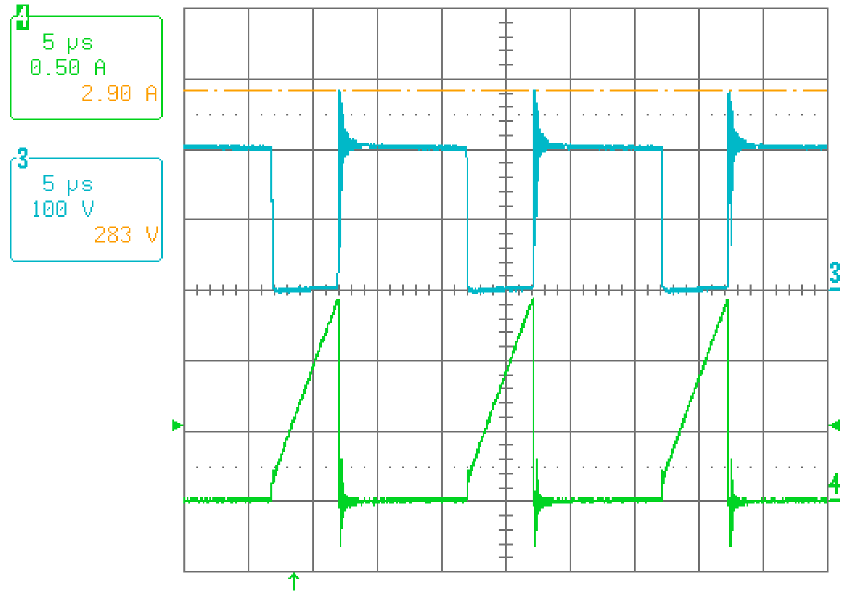
- Experimental results (Csn=2.2nF, Rsn=56kΩ, fs=66kHz)



VDC=140V, VRO=65V, Vsn=122V, Ipk=1.1A, Llk=3uH

$$\frac{V_{sn}{}^2}{R_{sn}} = \frac{122^2}{56k} = 0.266W$$

$$\frac{1}{2} L_{lk} I_{pk}{}^2 f_s \frac{V_{sn}}{V_{sn} - V_{RO}} = \frac{1}{2}(3u) \times 1.1^2 \times 66k \times \frac{122}{122-65} = 0.256W$$



VDC=140V, VRO=65V, Vsn=143V, Ipk=1.41A, Llk=3uH

$$\frac{V_{sn}{}^2}{R_{sn}} = \frac{143^2}{56k} = 0.365W$$

$$\frac{1}{2} L_{lk} I_{pk}{}^2 f_s \frac{V_{sn}}{V_{sn} - V_{RO}} = \frac{1}{2}(3u) \times 1.41^2 \times 66k \times \frac{143}{143-65} = 0.360W$$

4. Snubber design (RCD snubber)

- **Design Procedure**
  - ✓ **Measure the leakage inductance : measure the primary side inductance with all other windings shorted**
    - **LCR meter is not always correct (Normally 50% error) especially the leakage inductance is small**
  - ✓ **Determine the snubber capacitor voltage (V_{sn}) considering voltage margin of BVdss**
  - ✓ **Calculate the snubber resistor using**

$$R_{sn} = \frac{2V_{sn}(V_{sn} - V_{RO})}{L_{lk} f_s I_{pk}^2}$$

  - ✓ **Determine the snubber capacitor considering the snubber capacitor voltage ripple (1~10nF)**
  - ✓ **If the measured drain voltage is different from the designed value, leakage inductance should be calibrated using**

$$L_{lk} = \frac{2V_{sn}(V_{sn} - V_{RO})}{R_{sn} f_s I_{pk}^2}$$

4. Snubber design (RCD snubber)

- **Design Example (V_{RO}=65V, V_{in}=265V_{ac}(V_{DC}=370V), I_{pk}=1.5A)**

  - ✓ **Measure the leakage inductance with LCR meter: 5uH @ 70kHz**

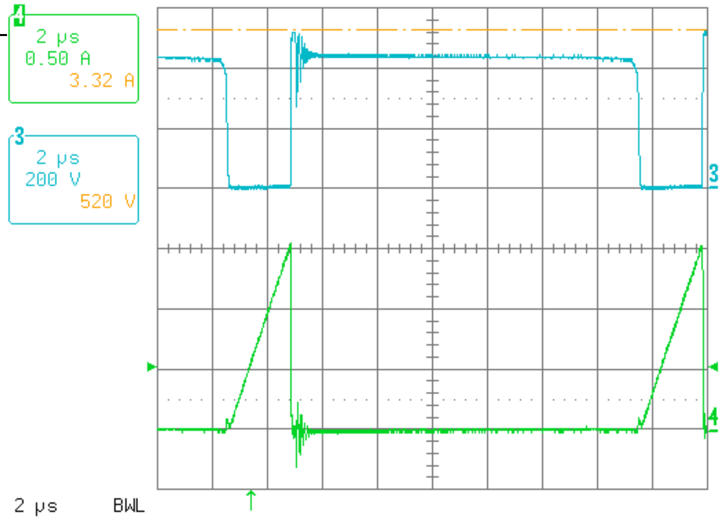
  - ✓ **Determine the snubber capacitor voltage considering voltage margin of BVdss : V_{sn}=182V (V_{sn}+V_{DC}=182+370=552V :85% of 650V)**

  - ✓ **Calculate the snubber resistor**

$$R_{sn} = \frac{2V_{sn}(V_{sn} - V_{RO})}{L_{lk} f_s I_{pk}^{\ 2}} = \frac{2 \times 182 \times (182 - 65)}{5u \times 66k \times 1.5^2} = 57k\Omega$$

4. Snubber design (RCD snubber)

- ✓ Determine the snubber capacitor considering the snubber capacitor voltage ripple : C_{sn}=2.2nF
- ✓ Measured the peak drain voltage : 520V (V_{sn}=146V)



R_{sn}=56kΩ, C_{sn}=2.2nF

V_{sn}=520-370=150V

V_{sn} is different from the designed value

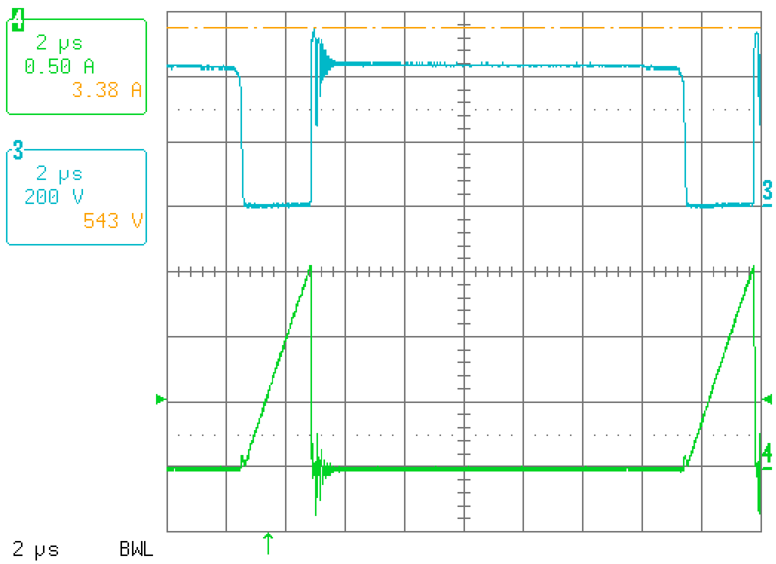
- ✓ Recalculate the leakage inductance with measured V_{sn}

$$L_{lk} = \frac{2V_{sn}(V_{sn} - V_{RO})}{R_{sn} f_s I_{pk}^{\ 2}} = \frac{2 \times 150 \times (150 - 65)}{56k \times 66k \times 1.5^2} = 3uH$$

4. Snubber design (RCD snubber)

- ✓ **Recalculate snubber resistor**

$$R_{sn} = \frac{2V_{sn}(V_{sn} - V_{RO})}{L_{lk} f_s I_{pk}^{\ 2}} = \frac{2\times 182\times(182-65)}{3u\times 66k\times 1.5^2} = 95k\Omega$$



R_{sn}=96kΩ, C_{sn}=2.2nF
V_{sn}=543-370=173V

- ✓ **The drain voltage is lower than the designed value by 9V due to the stray resistance (Measured:543V, Designed:552)**