# Active PFC Boost Rectifier

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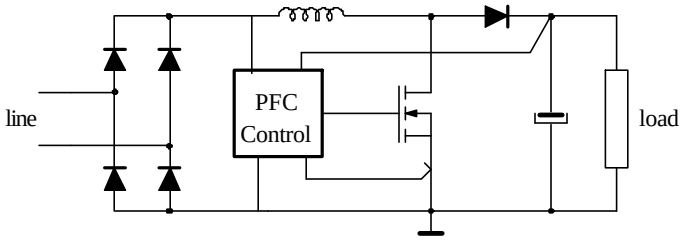
Power section




***CHARACTERISTICS:***

| | |
|---|---|
| **Input voltage:** | **$V_{in}$ = 90-260$V_{RMS}$** |
| **Output voltage:** | **$V_o$ = 380V** |
| **Output power:** | **$P_o$ = 600W** |
| **Switching frequency:** | **$f_s$ = 70kHz** |

***VALUES:***

| | |
|---|---|
| **Output capacitor:** | **C = 680 μF** |
| **Inductor:** | **L = 600 μH** |
| **Mosfet:** | **IRFP450** |
| **Diode:** | **RURP1560** |
| **Controller:** | **L4981A** |

# Active PFC Boost Rectifier

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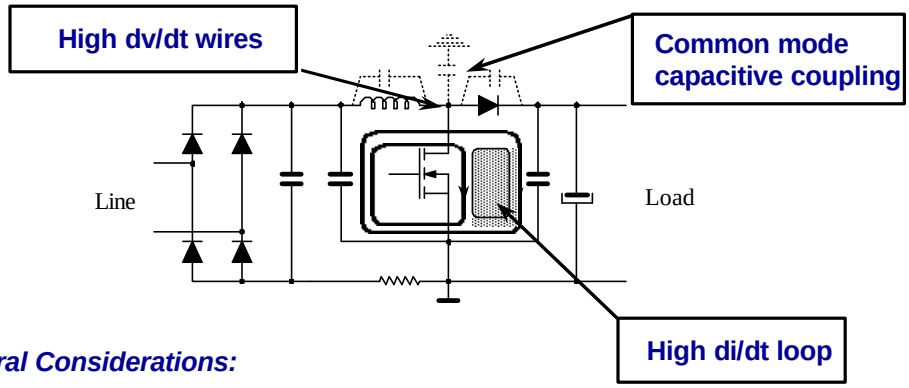
Power section and related EMI aspects




***General Considerations:***

***MOSFET and DIODE are the main noise generators***

- **Short wires where high dv/dt**
- **Small area of fast di/dt loops**
- **Short paths for return currents**

***Careful Layout***

# Circuit Layout (components)

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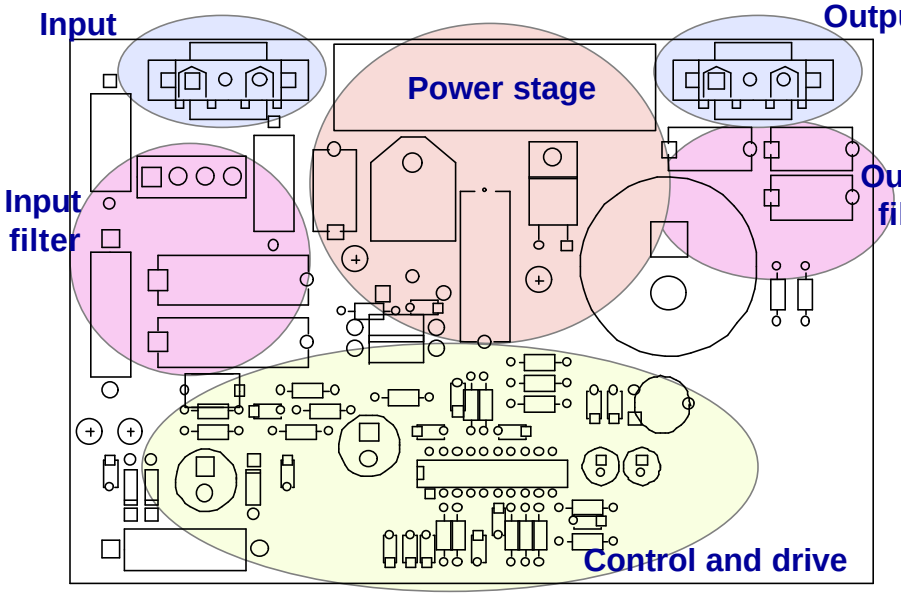


# Active PFC Boost Rectifier

Circuit Layout (solder layer)

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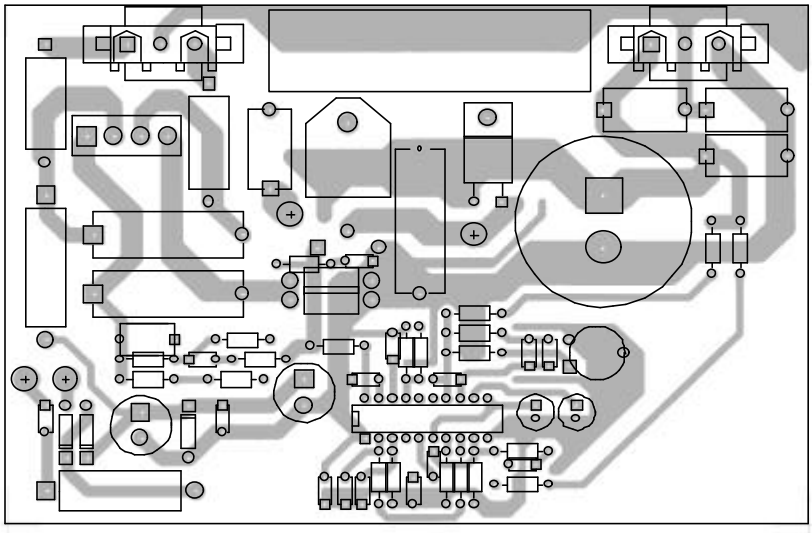

# Active PFC Boost Rectifier

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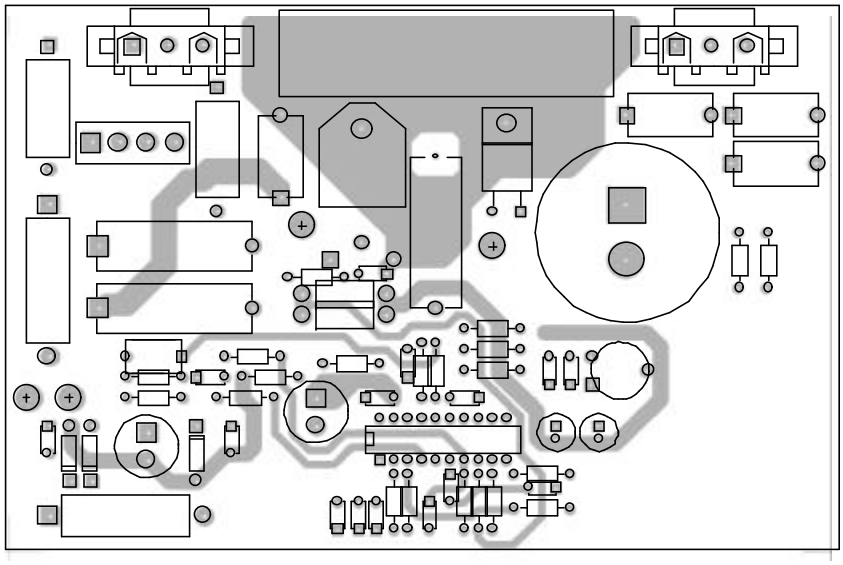
Circuit Layout (component layer)



# Active PFC Boost Rectifier

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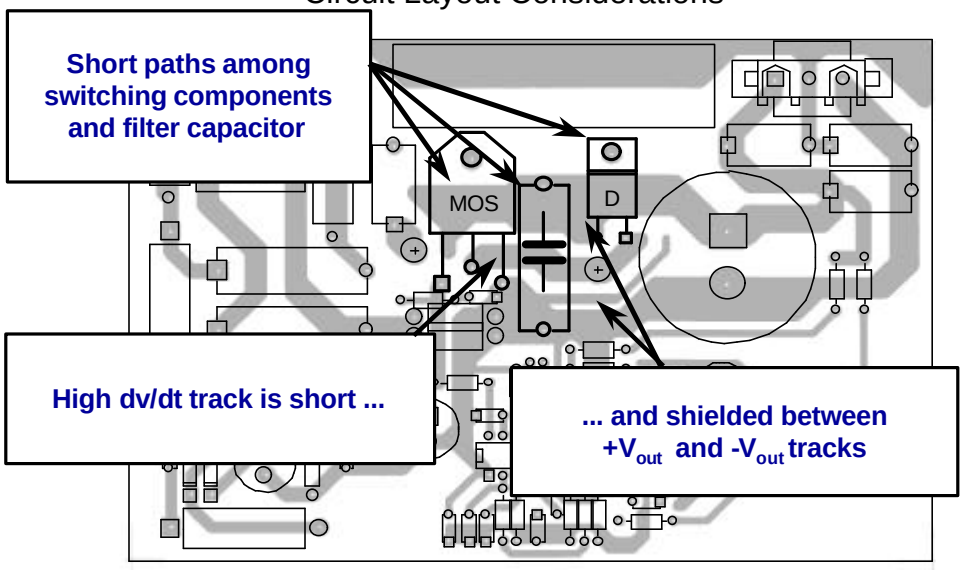
Circuit Layout Considerations



# Active PFC Boost Rectifier

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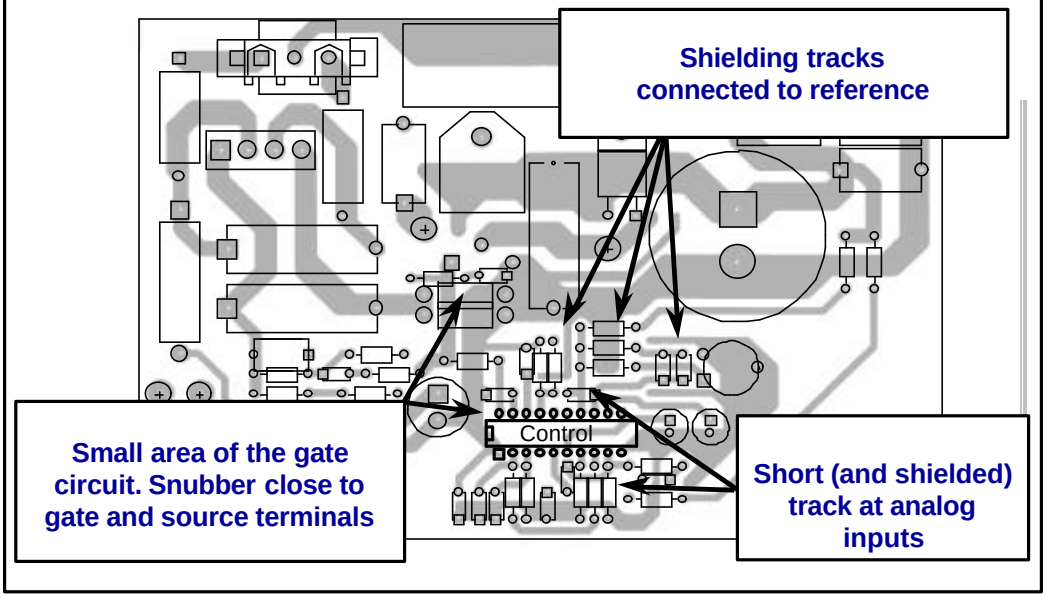
Circuit Layout Considerations




# Active PFC Boost Rectifier

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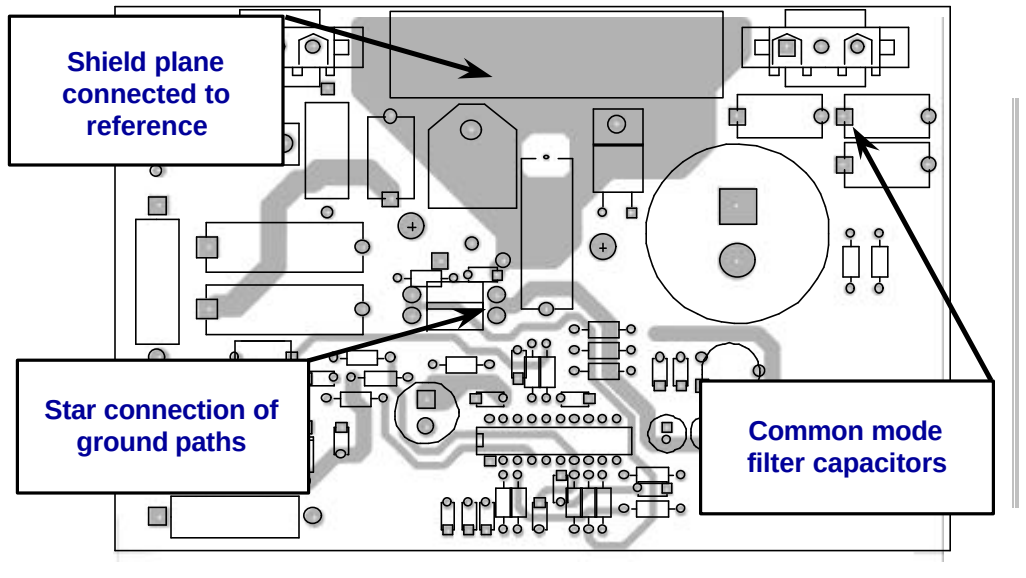
Circuit Layout Considerations



# Active PFC Boost Rectifier

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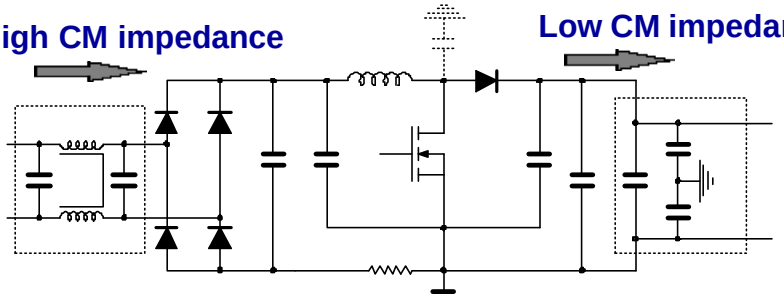
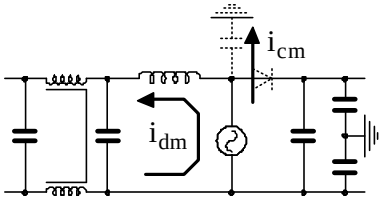
## Power section with EMI Filters

**High CM impedance**

**Low CM impedance**






**Coupled inductors show high common mode inductance but low differential mode inductance:**

**Ex: 6.8 mH CM, 70 µH DM**

# Active PFC Boost Rectifier

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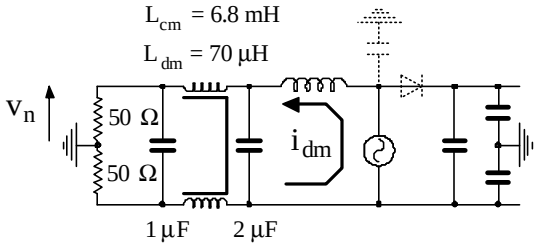
## Input filter design - Differential Mode

**Ripple amplitude**

$$\Delta I_{max} = \frac{U_{out}}{8 f_s L} \cong 1.13A$$

**triangular waveform**




**Differential mode input noise (peak values):**

| | |
|---|---|
| ***70 kHz,*** | ***87 dB µV*** |
| ***140 kHz,*** | ***57 dB µV*** |
| **210 kHz,** | **40 dB µV** |
| **280 kHz,** | **26 dB µV** |
| **350 kHz,** | **19 dB µV** |
| **420 kHz,** | **9 dB µV** |

**a suitable margin (20 dB µV) is maintained for the commom mode noise and possible resonances**

# Active PFC Boost Rectifier

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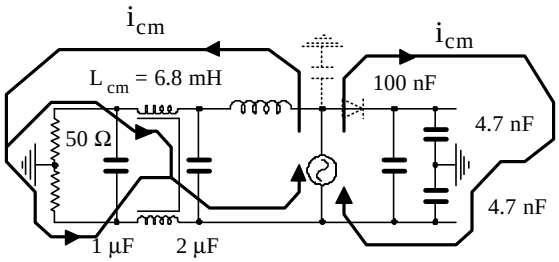
## Input filter design - Common Mode




- **Several current return paths are present**
- **The main one is on the output side of the PFC**
- **High value of filter inductor reduces current term at the input side**
- **CM input side current generates DM input noise due to asymmetrical converter topology**
- ***Adding CM capacitors at the input side reduces input CM voltage noise but the increased CM current causes additional DM noise***

# Prototype Tests

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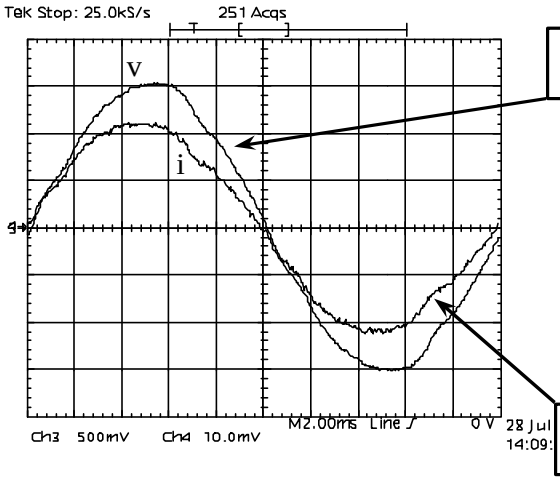
## Input behavior




**Line Voltage**

**100 V/div.**

**2 A/div.**

**Line current**

# Prototype Tests

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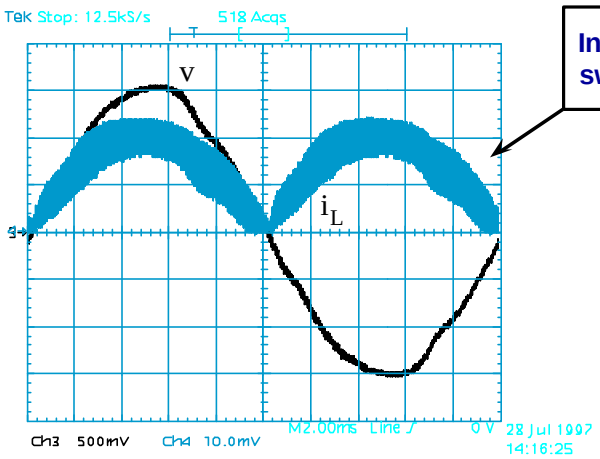
Line Voltage and Inductor Current
(peak to peak sampling)




**Inductor current switching ripple**

# Prototype Tests

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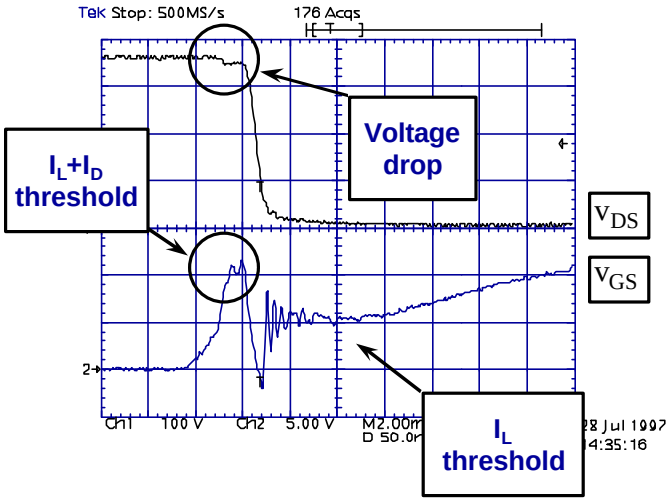
Gate drive circuit



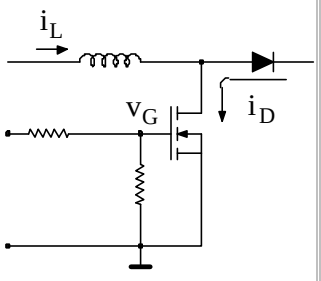

**$I_L$+$I_D$ threshold**

**Voltage drop**

**$I_L$ threshold**

$v_{DS}$

$v_{GS}$



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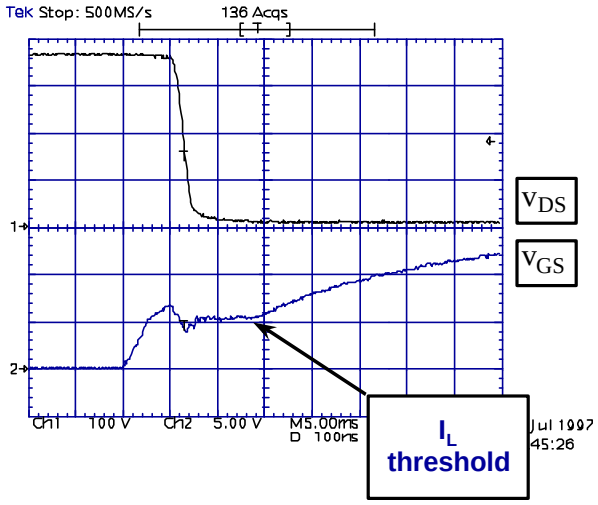
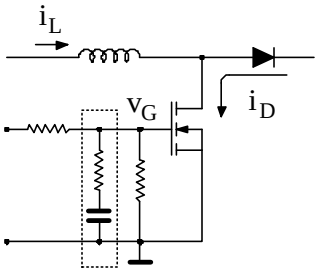
# Prototype Tests

Gate drive circuit




***Commutation is slowed-down***

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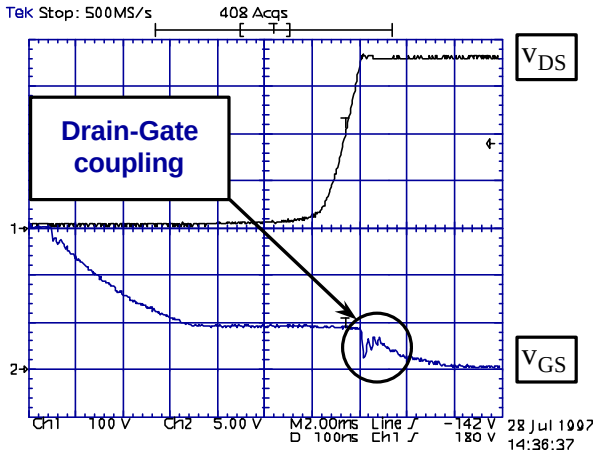
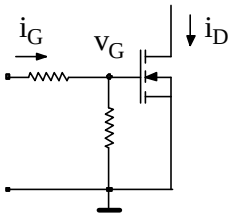
# Prototype Tests

Gate drive circuit



# Prototype Tests

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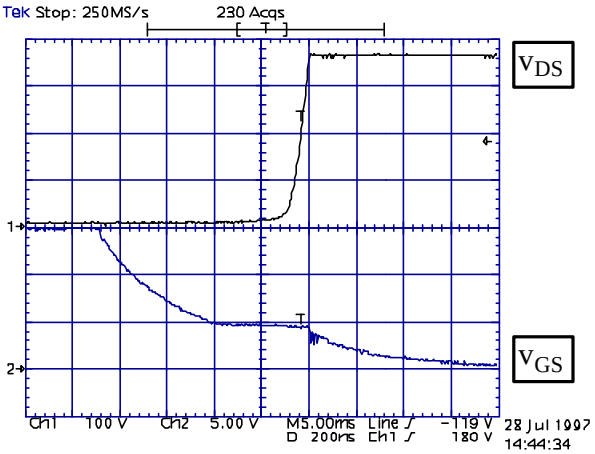
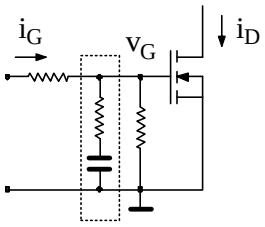
Gate drive circuit




# Prototype Tests

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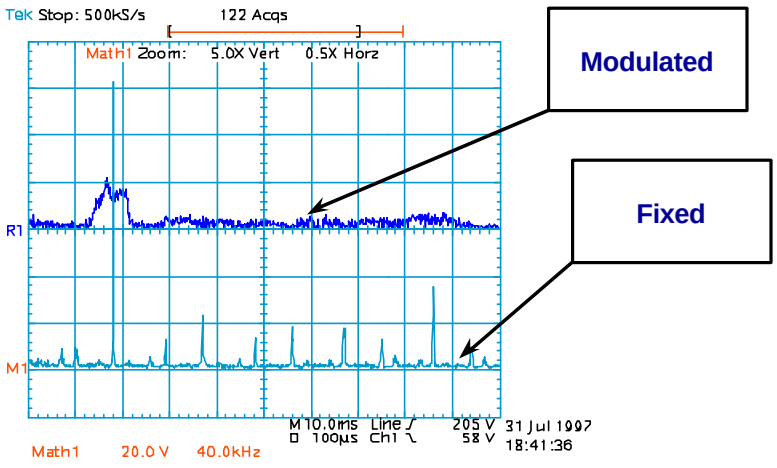
Modulation of Switching Frequency
$V_{DS}$ Spectra



# Prototype EMI Tests

Conducted noise (peak measure)

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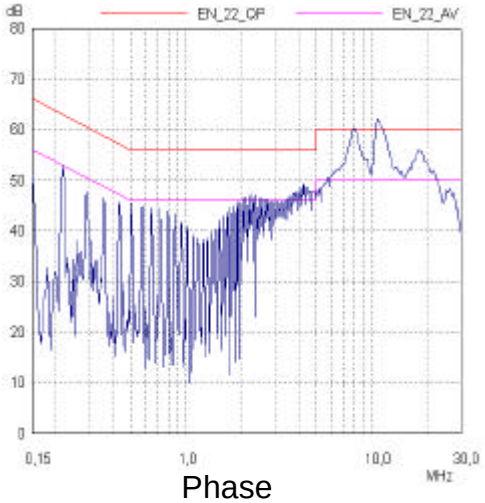
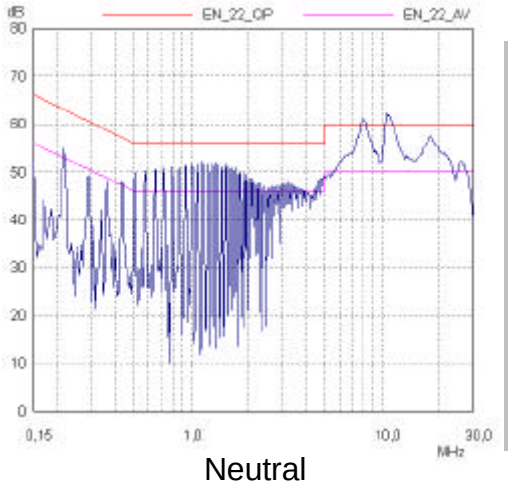



Phase




Neutral

# Prototype EMI Tests

Conducted noise (peak measure)

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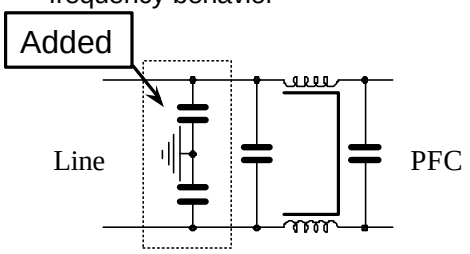
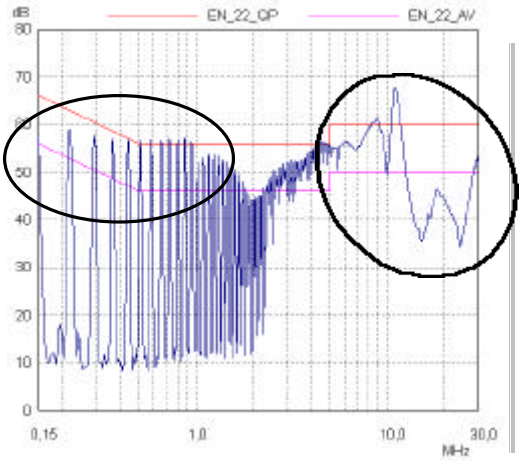
Introducing input-side common-mode filter capacitors

- Differential noise increases *(circuit is not symmetrical)* and low-frequency behavior is worse
- A resonance, between input and output CM filter capacitors and the inductances of their connections, appears, modifying the high-frequency behavior



# Prototype EMI Tests

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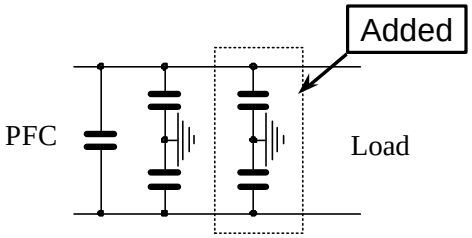
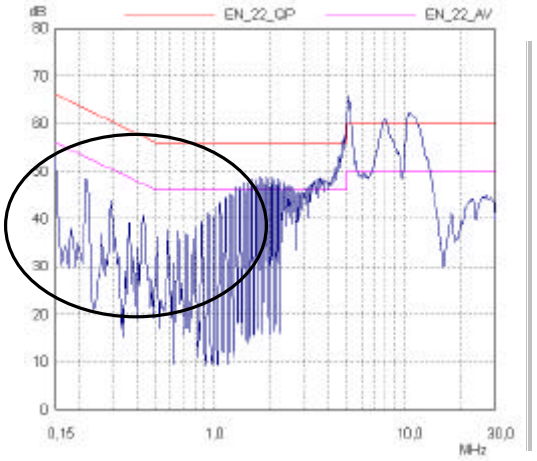
Conducted noise (peak measure)

Increased output-side common-mode capacitors

- Common mode currents are closed on the output side *(no additional voltage drop on the input filter occurs)*
- Low-frequency behavior is improved
- High-frequency behavior becomes worse due to resonance of two CM filter capacitors and their connections




# Prototype EMI Tests

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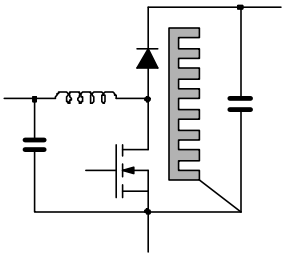
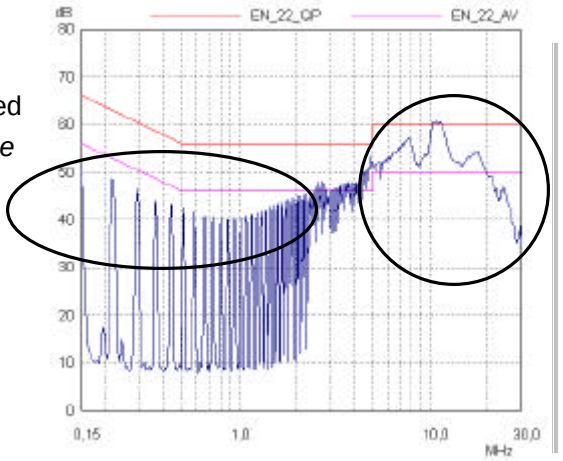
Conducted noise (peak measure)

By connecting the heatsink to the negative rail *(capacitive currents are closed "near" to the Mosfet source):*

- Low-frequency behaviour is improved
- High-frequency behavior is good *(the heatsink shields all circuitry)*





# Prototype EMI Tests

Conducted noise (peak measure)

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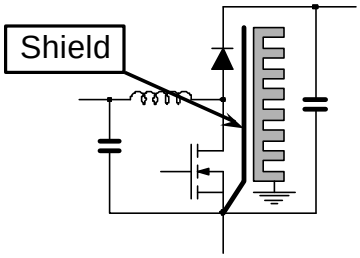
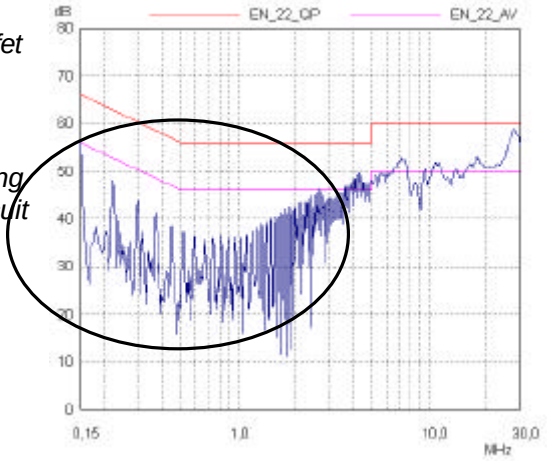
By inserting a shield, between Mosfet and heatsink, connected to Mosfet source *(drain coupled capacitive currents are closed directly to the Mosfet source)*

•Low-frequency behavior is improved *(common mode noise is reduced)*

•High-frequency behavior is good *(Using the heatsink as shield of the whole circuit gives however better results)*




# Prototype EMI Tests

Conducted noise (peak measure)

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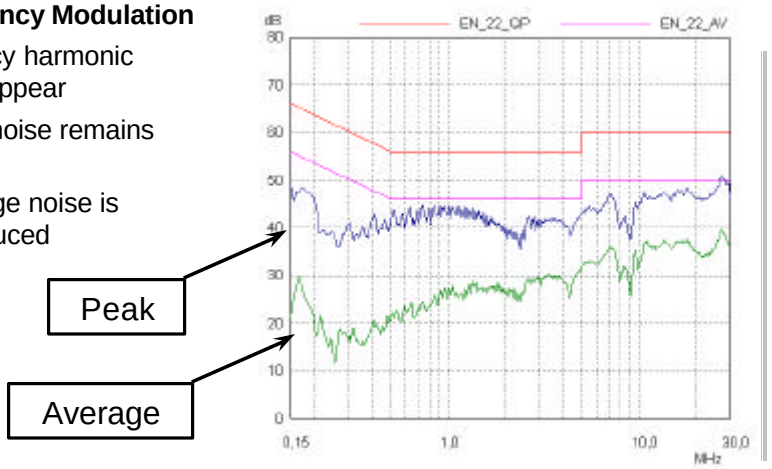
**Switching Frequency Modulation**

Switching frequency harmonic components disappear

- Measured peak noise remains unchanged
- Measured average noise is considerably reduced



# Prototype EMI Tests

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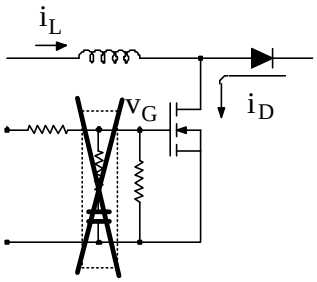
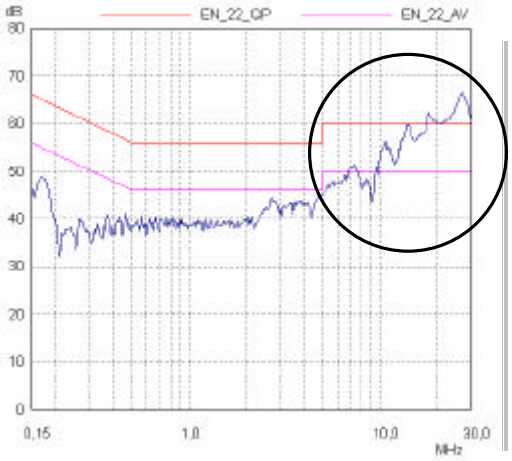
Conducted noise (peak measure)

Effect of **Diode Reverse Recovery**
*(Disconnecting gate snubber)*

- Low-frequency behavior is almost unchanged
- High-frequency behavior is heavily worsened




# Prototype EMI Tests

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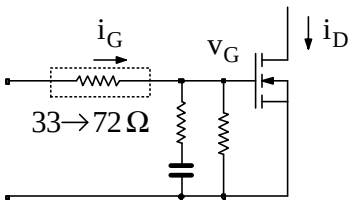
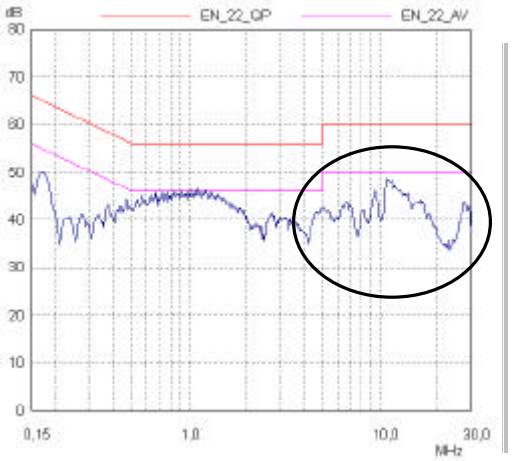
Conducted noise (peak measure)

Increasing **gate resistor**

- Low-frequency behavior remains unchanged
- High-frequency behavior is improved *(MOSFET commutation slows down)*



# Prototype EMI Tests

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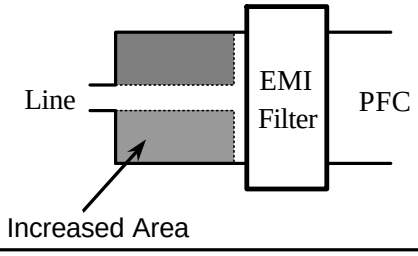
By spreading the ac wires close to the input filter (filter inductors inside plastic can)

- Low-frequency behavior becomes worse *(input wires capture leakage magnetic field of filter inductor)*
- High-frequency behavior remains unchanged




Increased Area