Electromagnetic compatibility (EMC) in several gate charging topologies for Automotive Power Switches

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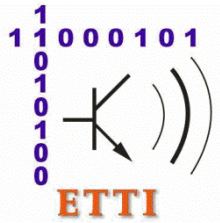

Agenda

- EMC in automotive industry
  - Electromagnetic compatibility definition
  - EMC testing
- Power switch driver
  - Top level description
  - Topology A: Constant Charge Current
  - Topology B: Stepped Charge Current
  - Topology C: Linear Charge Current
- EMC Simulations
  - Simulation setup
  - EME simulation comparison
- Conclusions

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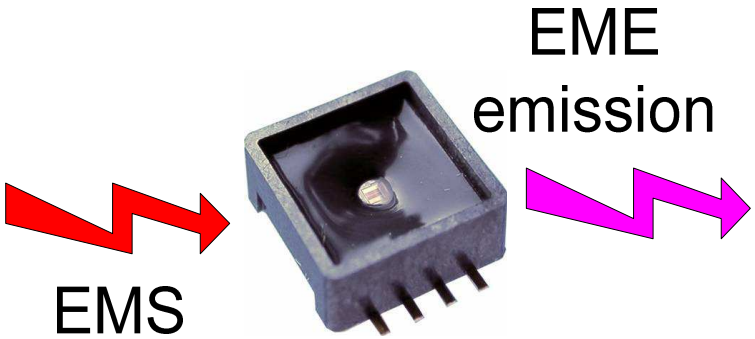
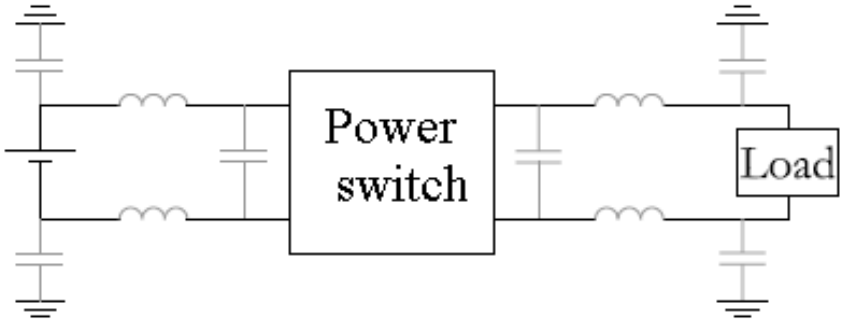
EMC in automotive

- EMC
  - Wire conducted emissions
  - Coupling emissions: capacitive & inductive
  - Electromagnetic emissions



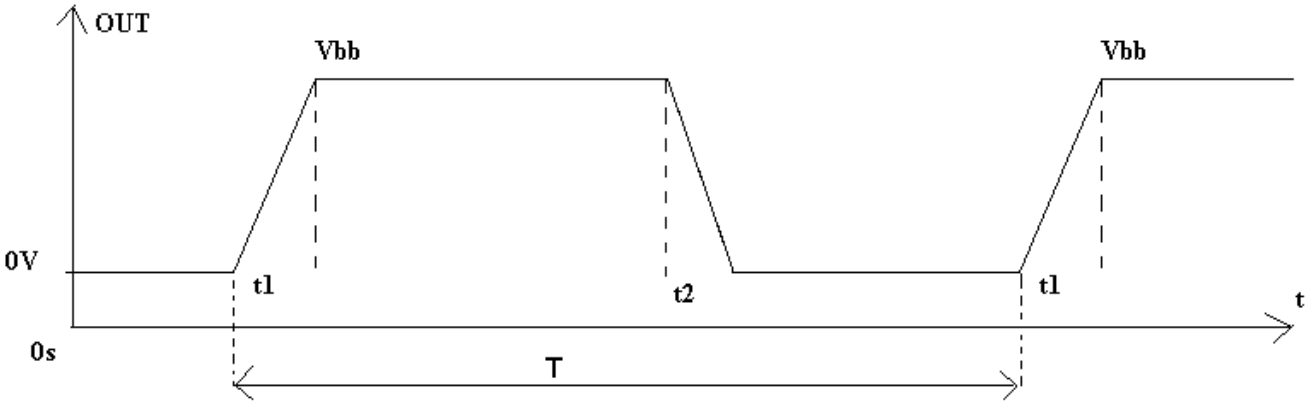
- EMC: susceptibility & emissions



$$I = C_{parasitic} \frac{dV}{dt}$$

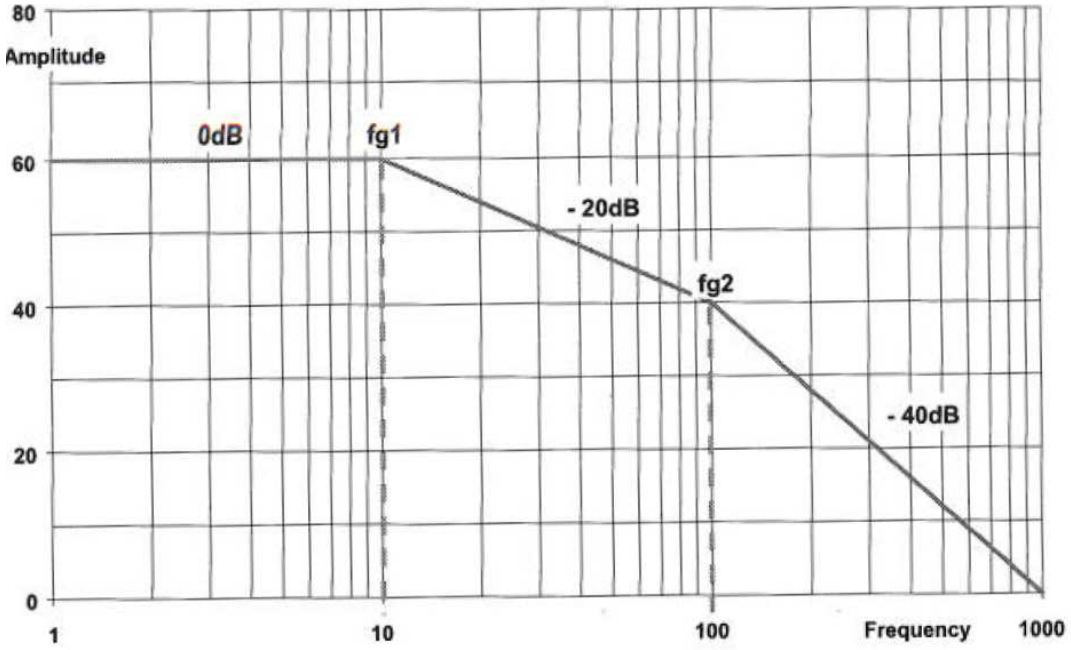
$$\frac{dV}{dt} = SR$$

EMC in PWM driving



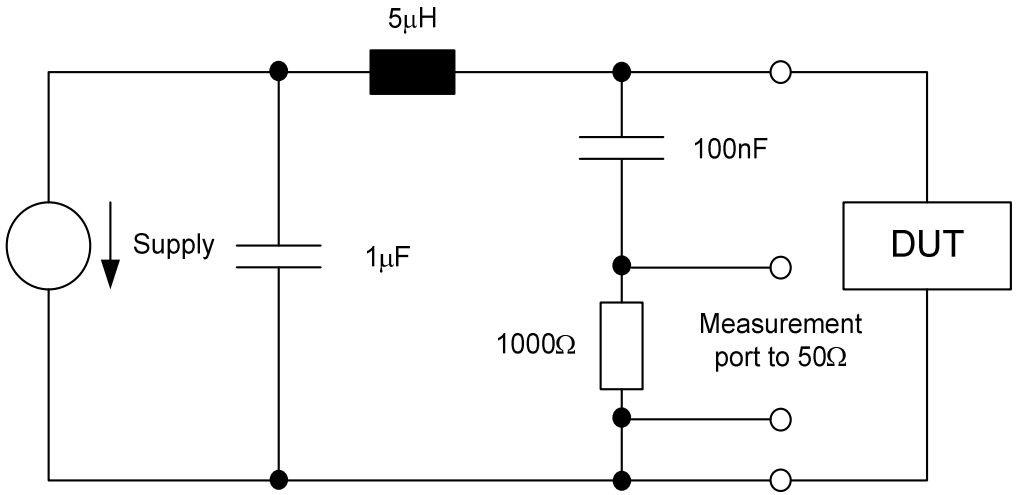
- $t_{1,2}$ rise / fall times;
- T signal period

- fg1 is given by the signal period, T
- fg2 is given by the turn on/off times,$t_{1,2}$



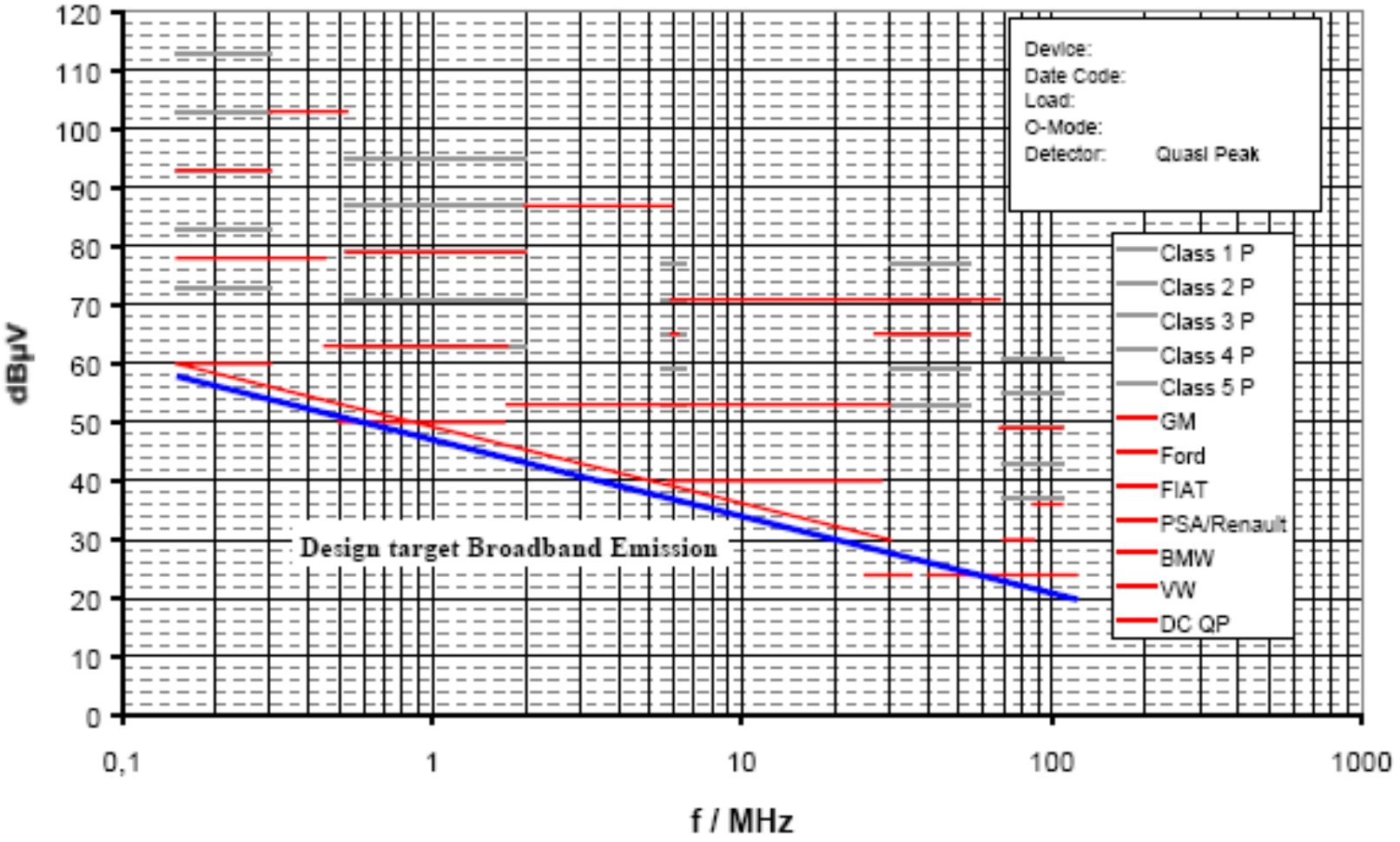
EMC measurements

Line impedance stabilization network LISN



Anechoic chamber

Emission limits in automotive



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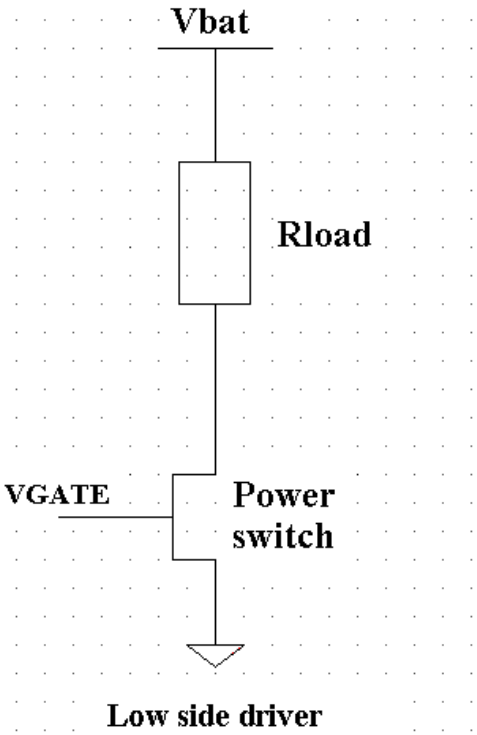
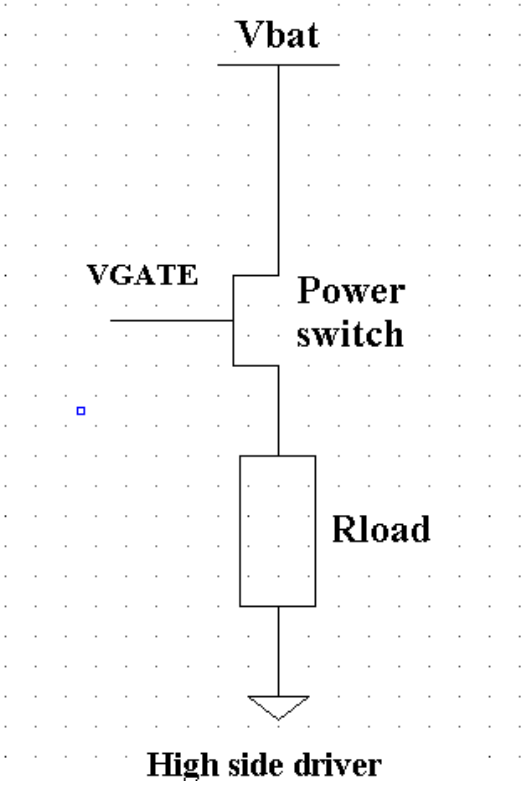
Power switch in automotive circuitry

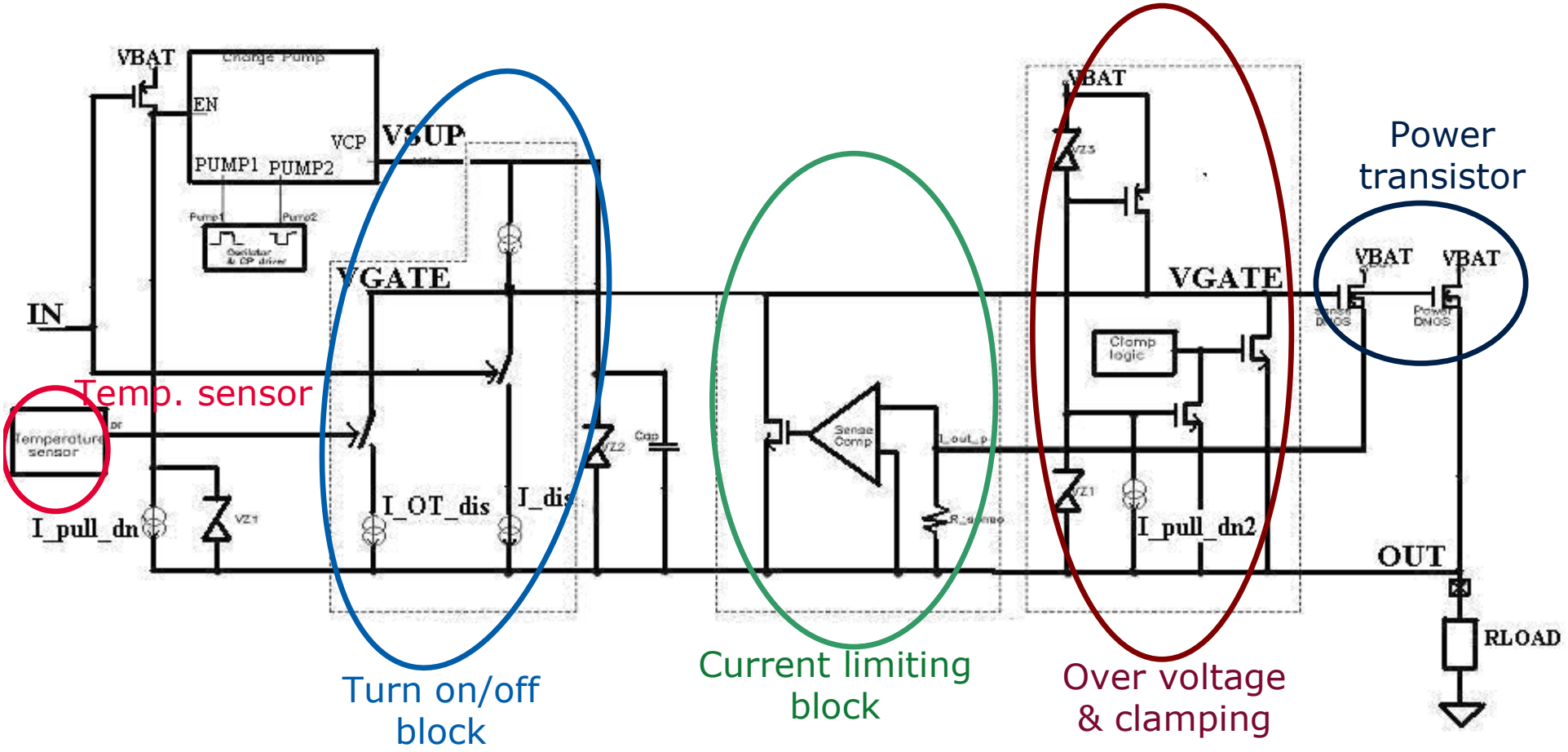




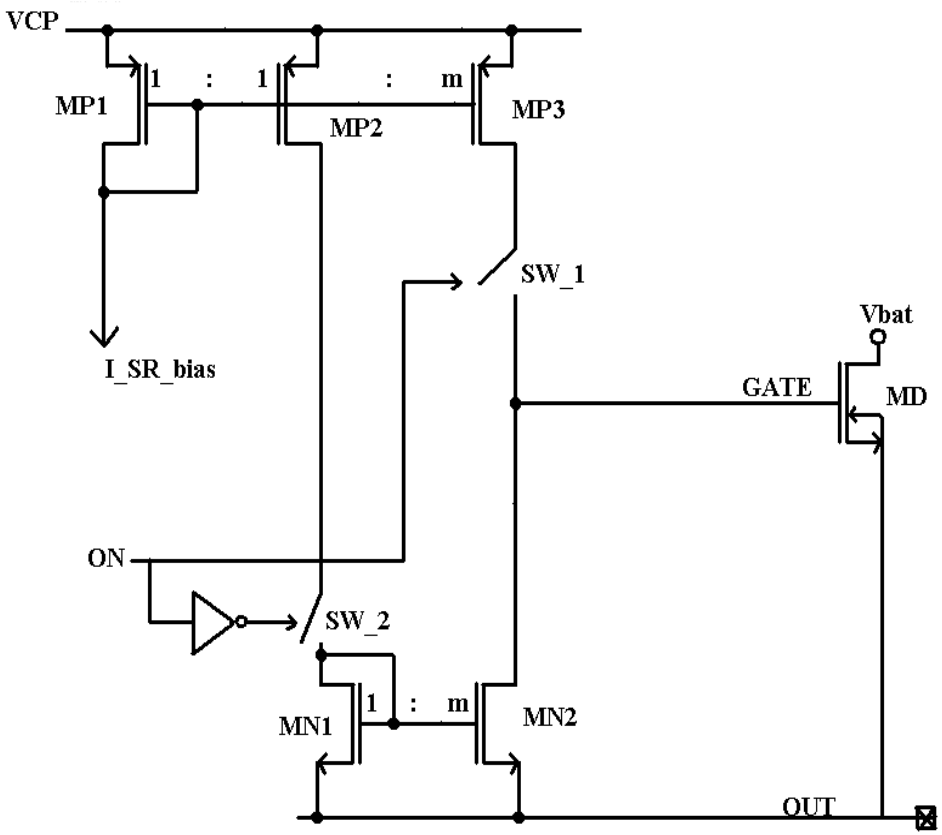
+ More robust, simpler ground
+ Less complex, cheaper
- 2 wire system
- Short to ground can destroy load
- The load is stressed

+ 1 wire system
+ Short to ground can not destroy load
+ Load not stressed
- Distributed ground
- More complex, more expensive

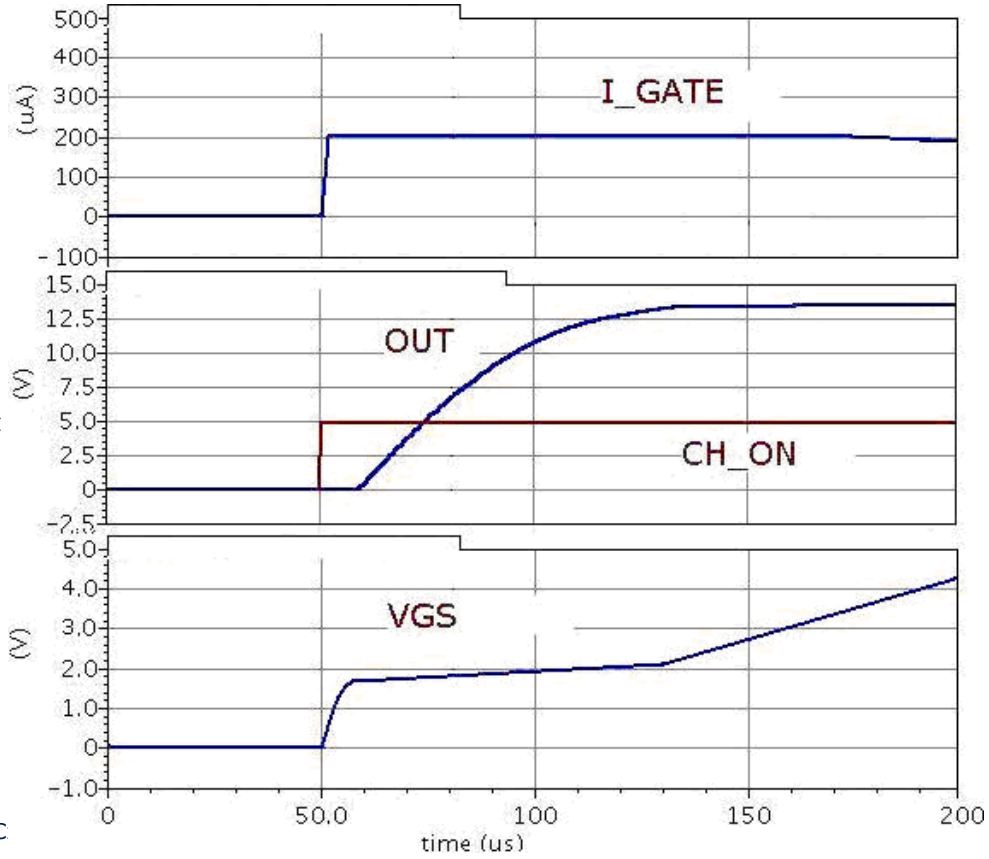
Gate Driver concept schematic



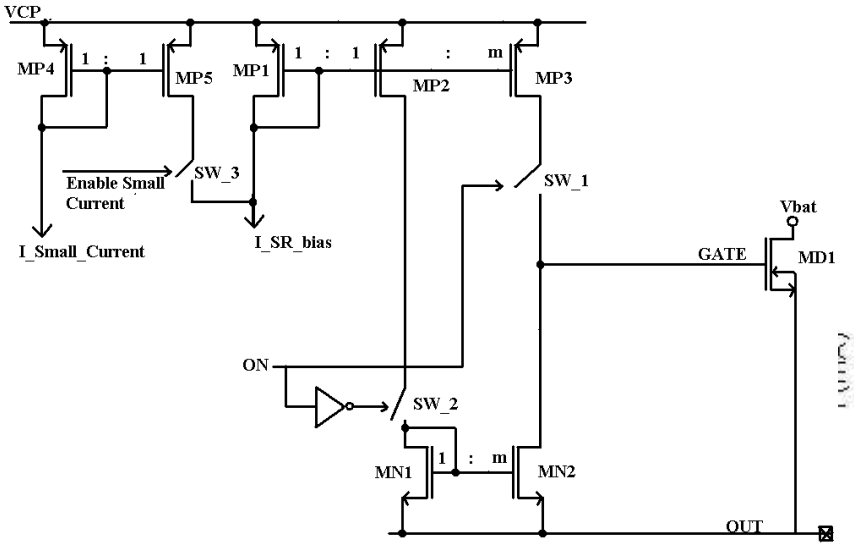
Topology A: Constant Charge Current



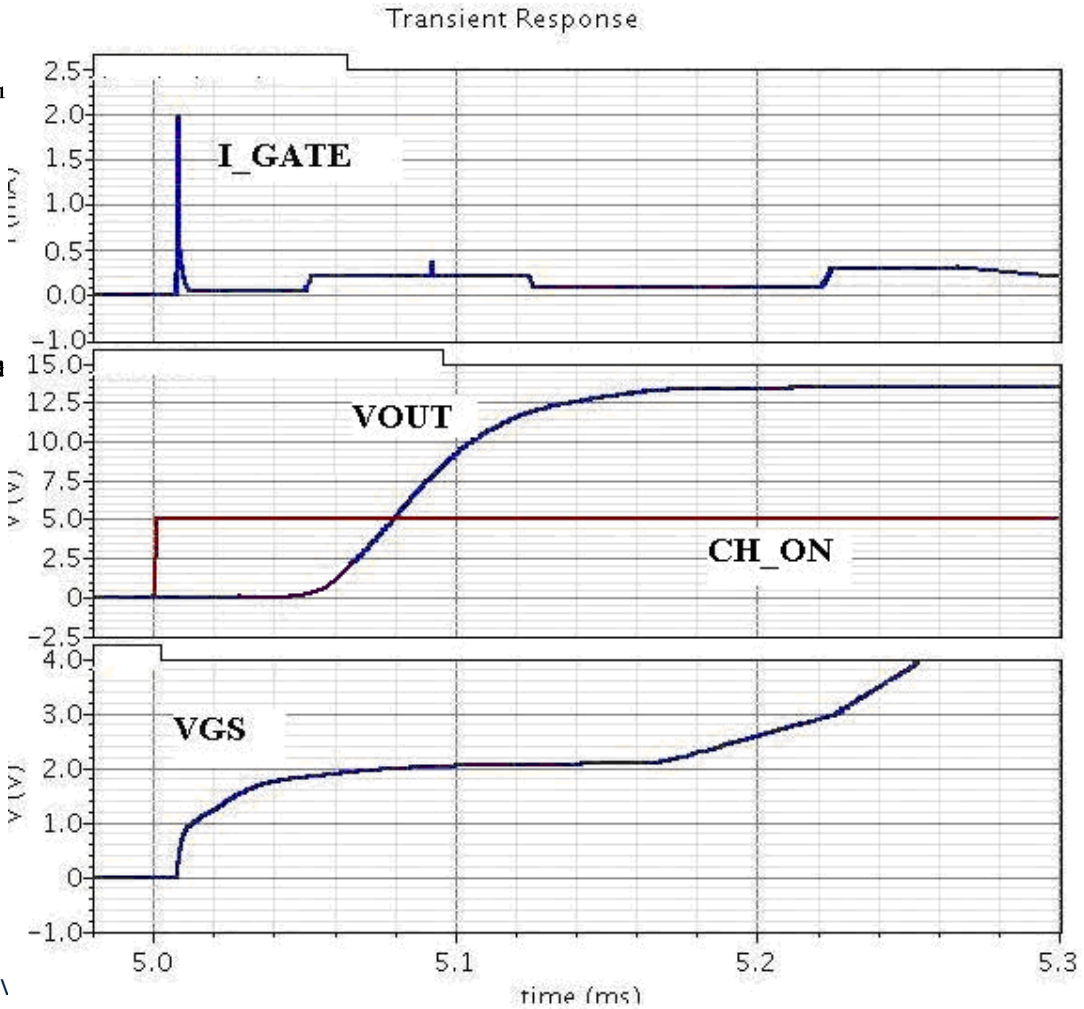
- Constant currents for charge / discharge the gate.
- The current value is given by slew rate



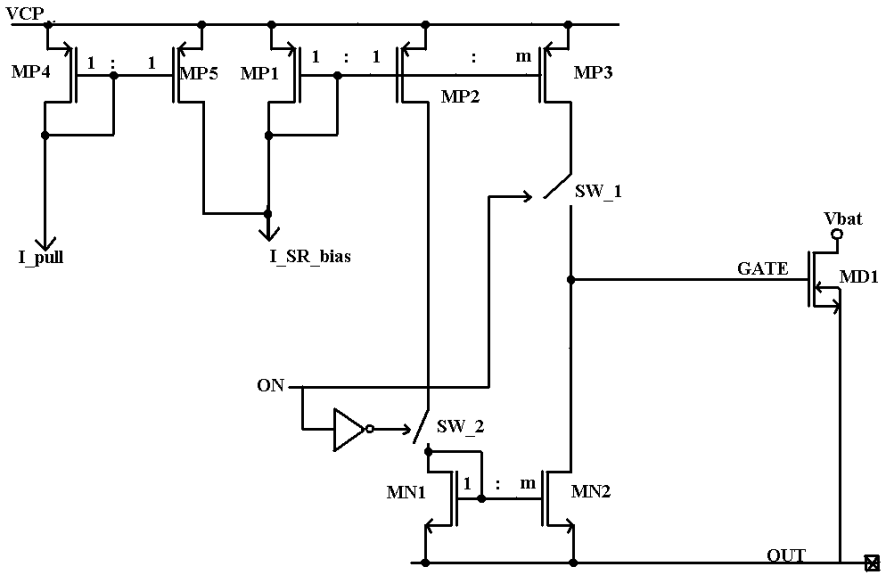
Topology B: Stepped Charge Current

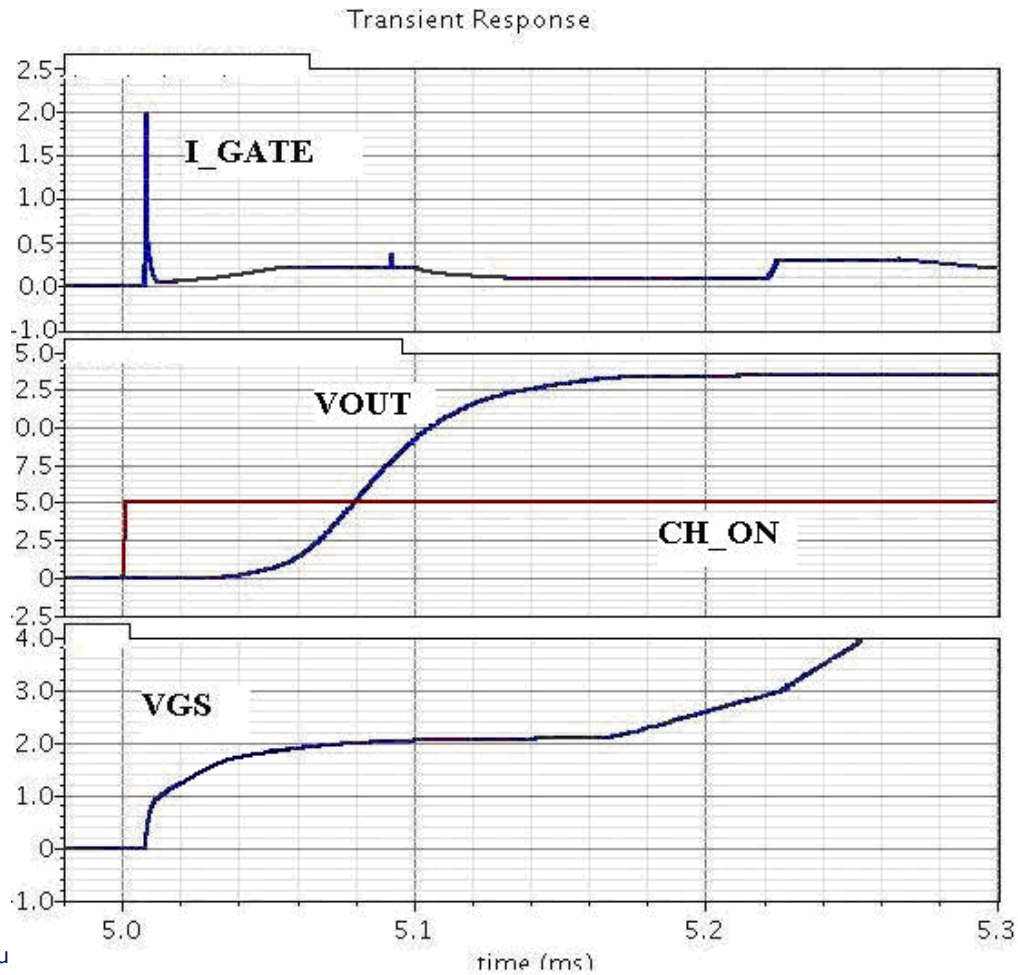


- Small charge current at the corner of output characteristic
- Large current in the slew rate region
- Extra area needed for the comparators



Topology C: Linear Charge Current





- Small charge current at low VGS
- Linearly increasing charge current to slew rate value
- Extra area needed for comparators in the generation of the linear current block

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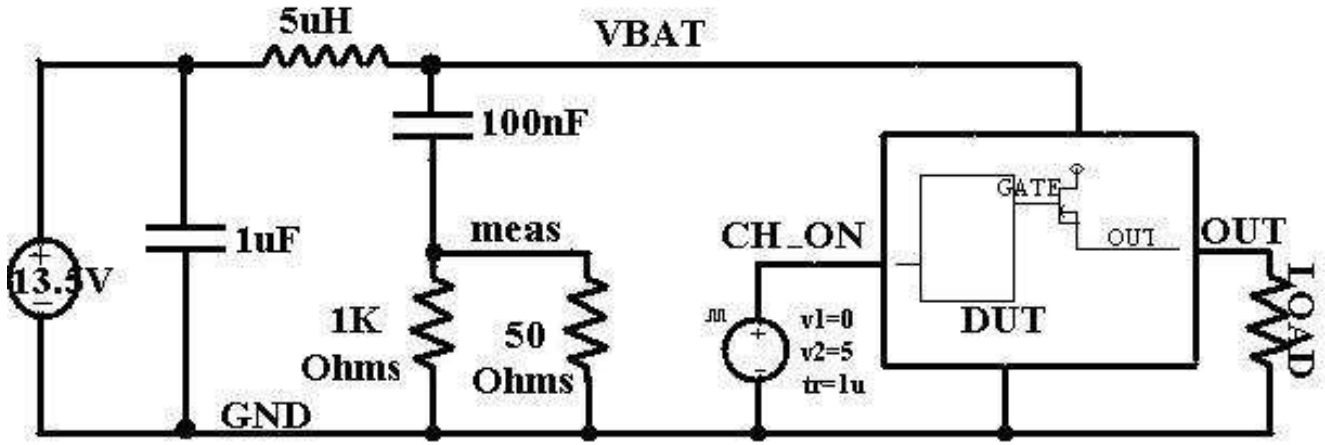
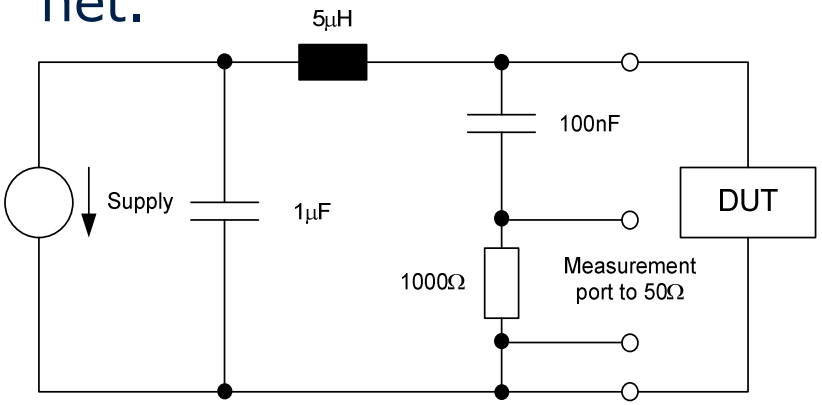
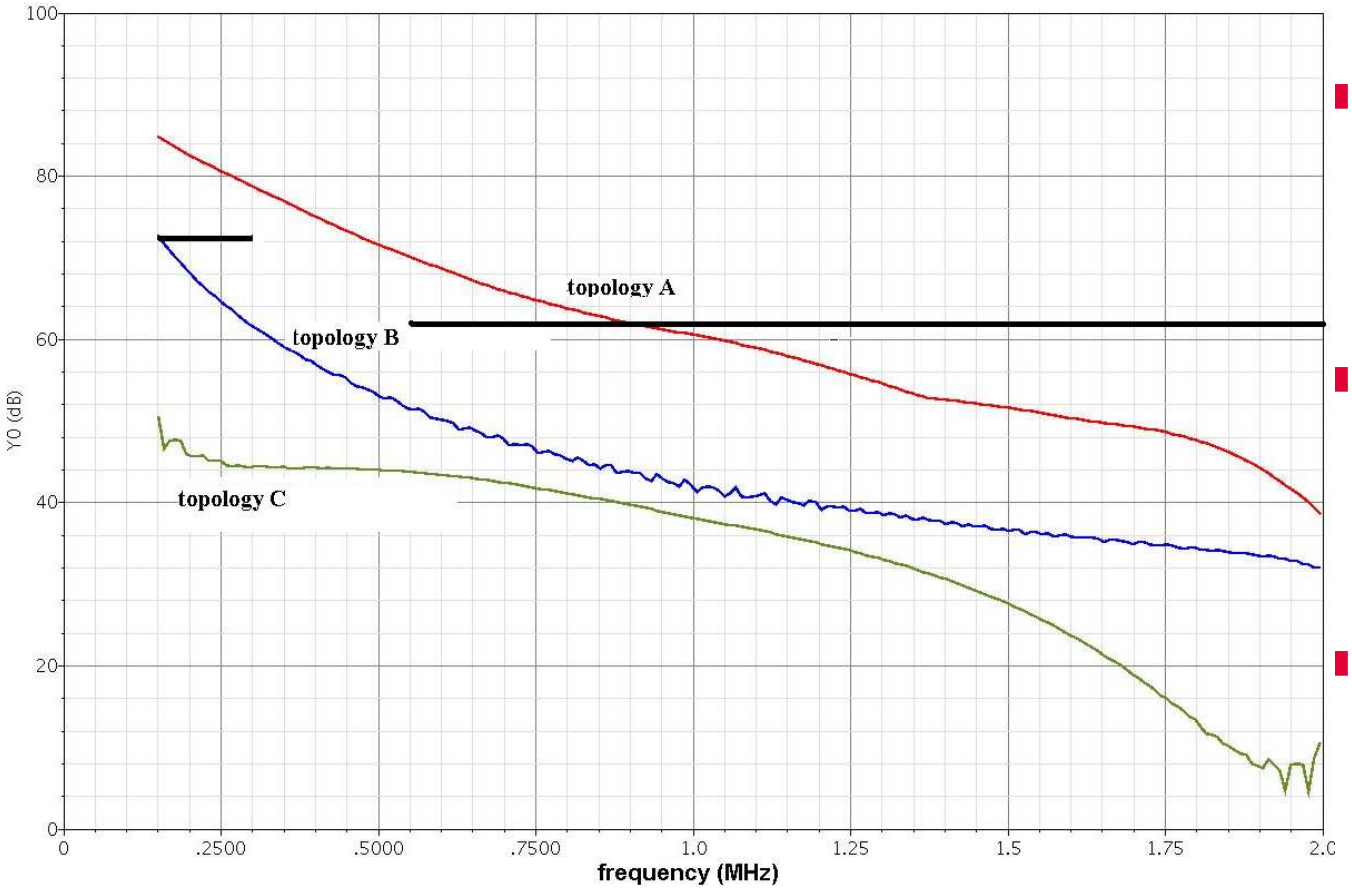
Simulation setup



- (LISN) method to measure conducted emissions.
- Pulse width modulation (PWM) driving of the device.
- Emissions measured on “meas” net.



Simulation results



- topology A – constant charge current;
- Topology B – stepped charge current;
- Topology C – linear charge current;

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Conclusions

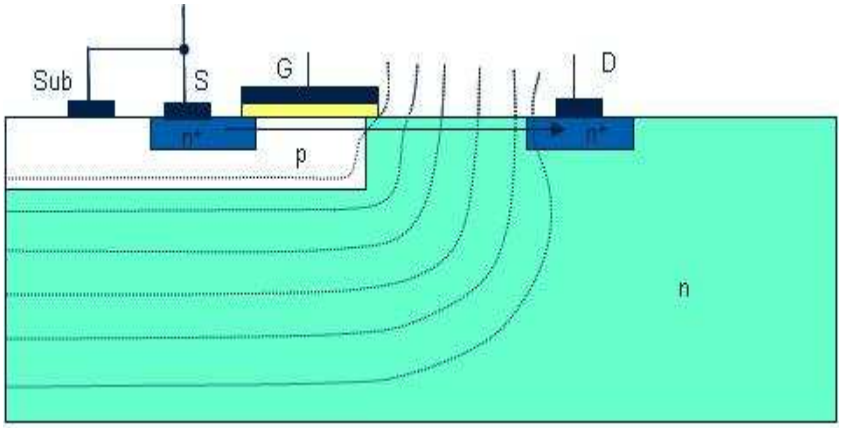
- EMC is a very important in automotive electronics.
- A trade off between EMC and PWM driving.
- Improvement of EMC: new techniques for power switch transistor driving.
- The proposed techniques are based on constant currents command.
- 3 topologies are described:
  - constant current charge (standard method);
  - stepped charge current;
  - a linear charge current.
- Comparison of emissions done with LISN method:
  - The standard method is exceeding specifications at low frequencies;
  - stepped currents is at the limit in specifications;
  - The linear current is assuring a safety margin.

Thank you

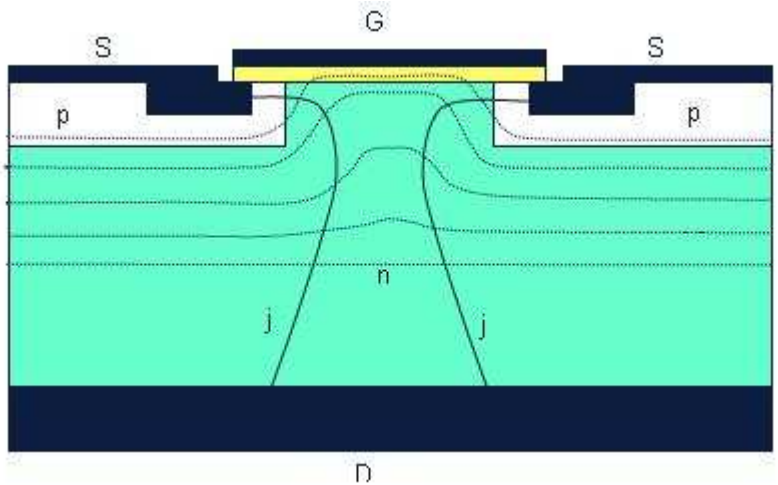
for your attention!

Questions?

DMOS structure



Lateral DMOS

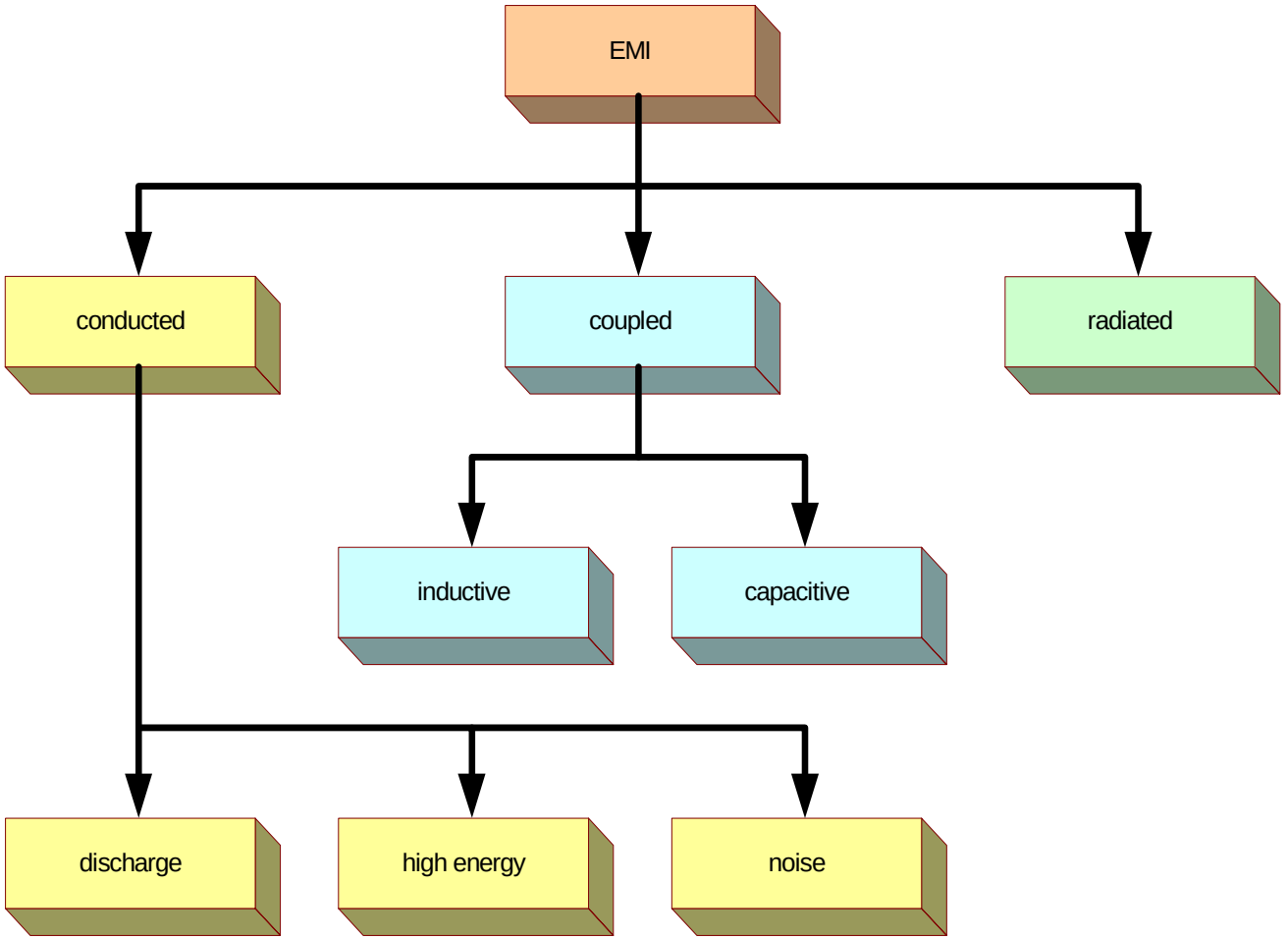


Vertical DMOS

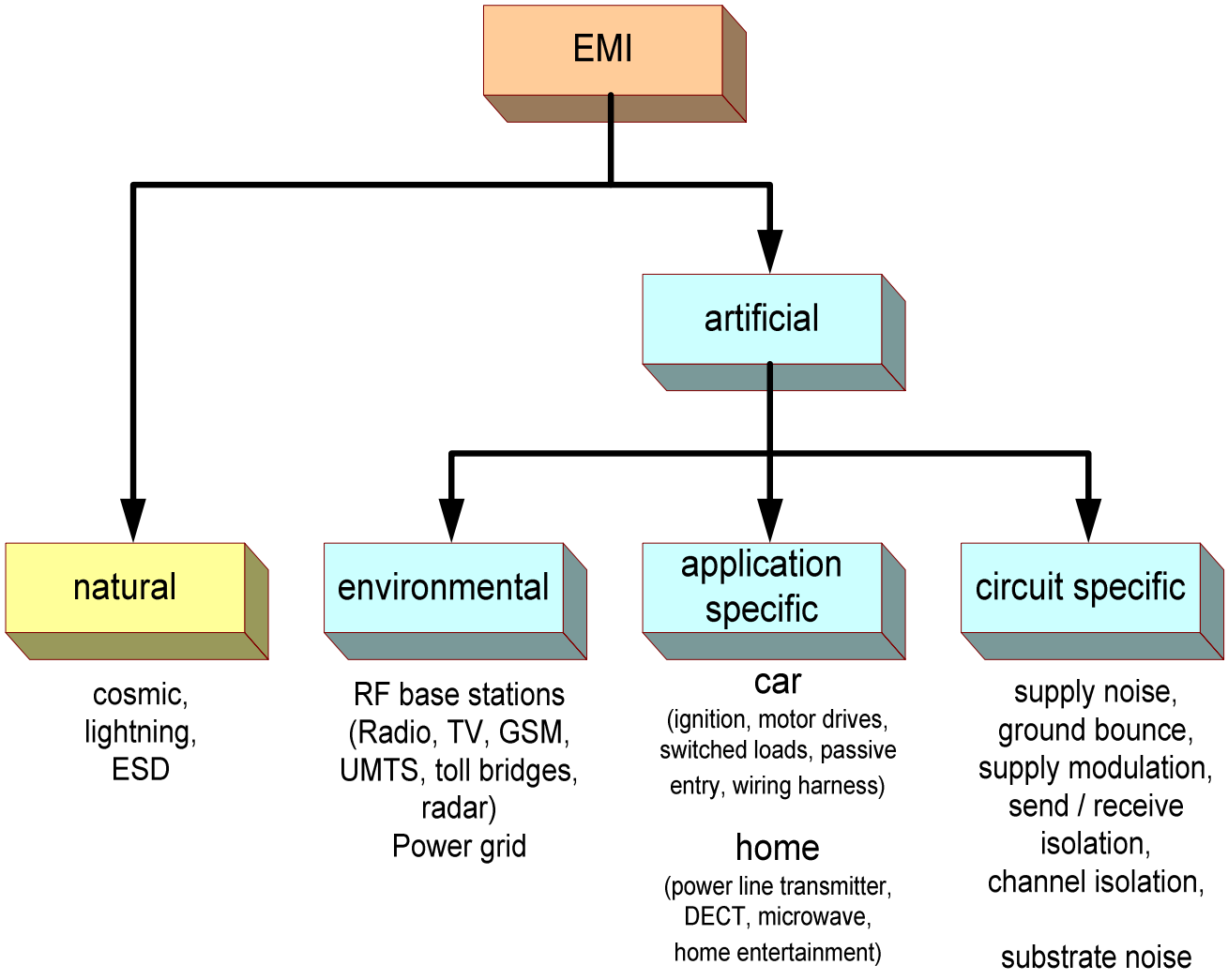
Electromagnetic Compatibility (EMC)

- EMC electromagnetic compatibility
  - The capability of electrical and electronic systems equipment and devices to operate in their intended electromagnetical environment within a defined margin of safety and design levels or performance without suffering or causing unacceptable degradation as a result of electromagnetic interference
  - ANSI (american national standard institute) C64.14-1992
- EMI electromagnetic interference

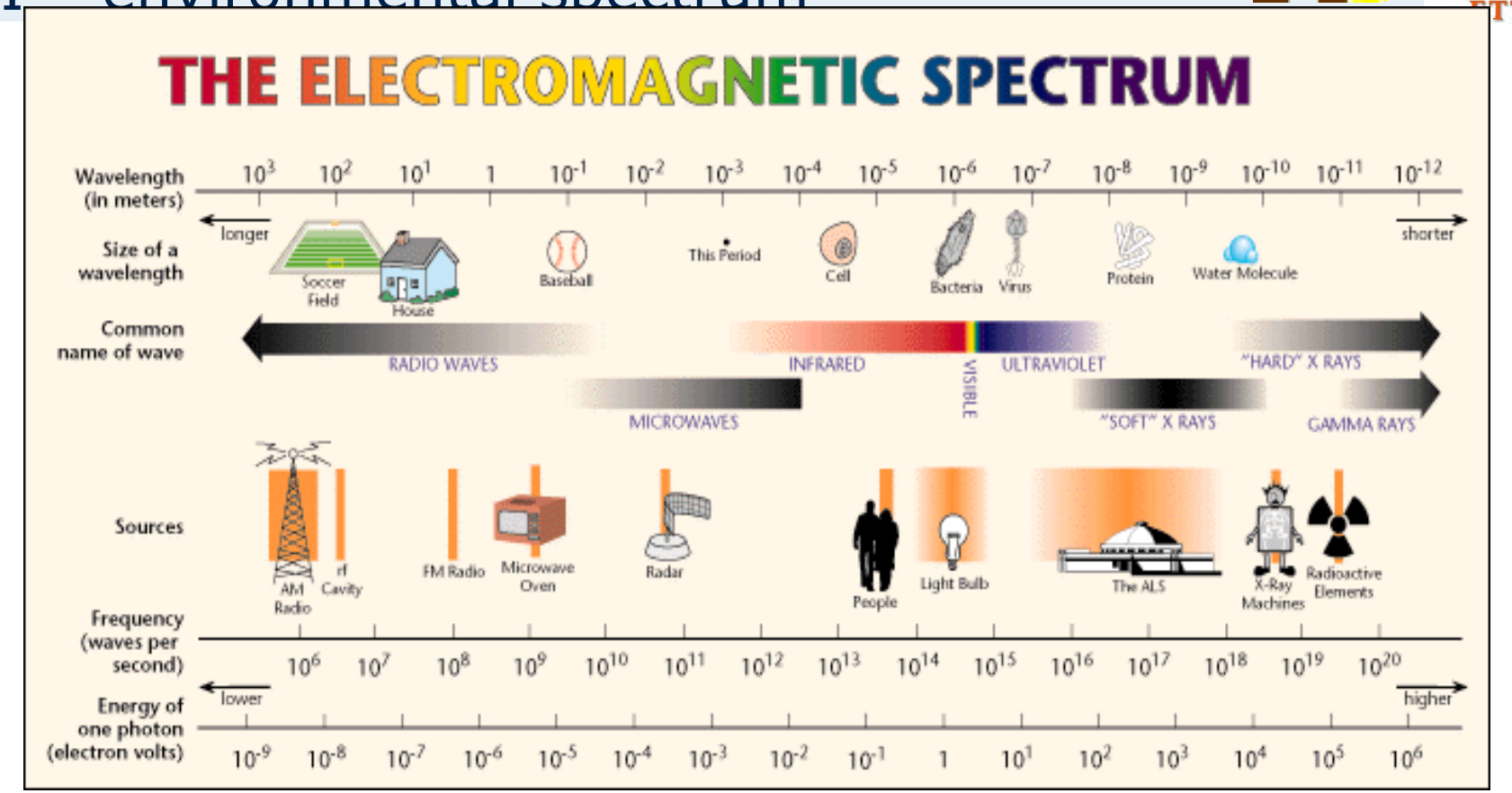
EMI – by path


EMI
conducted
coupled
radiated
inductive
capacitive
discharge
high energy
noise

EMI – by interferers



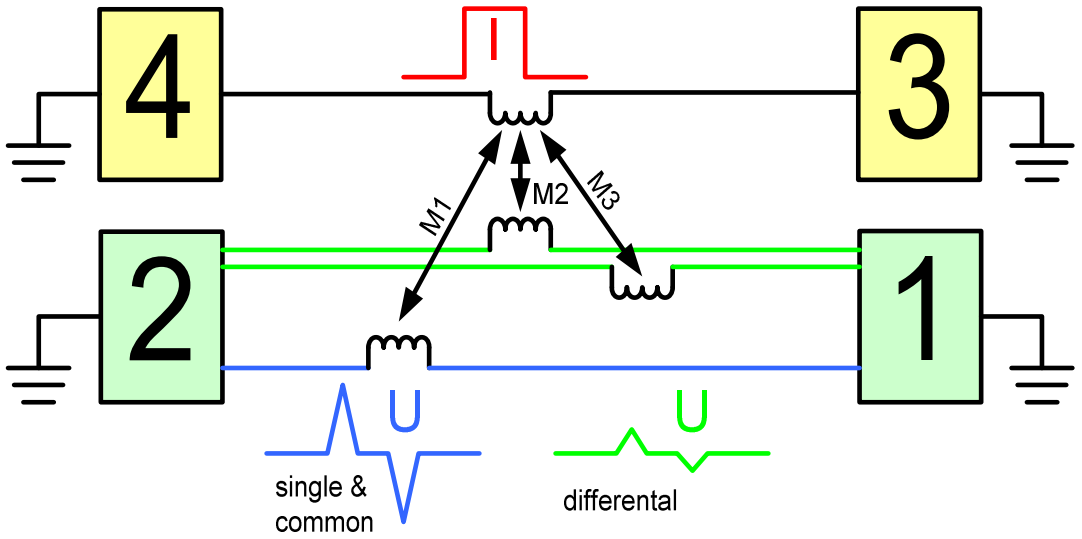
EMI – environmental spectrum



Source: Christine Anne Royce, Ed.D., Shippensburg University, PA

- EMI in its common sense is usually is related to frequencies in the range between radio waves and microwaves
- In a more general sense radiation hardness of circuits and especially memories is also an EMI topic

Inductive coupling



- Current transients cause induced voltages via mutual inductors
- The return paths of the currents define area of the loop
- Influencing factors
  - Geometry of the loops
  - Waveform of the transient (spectrum)
  - Terminating impedances on the victims I/Os
- Differential mode coupling depends on asymmetry

$$U_C = M \frac{dI}{dt}$$

Emission (conducted)

Standards

IEC CISPR 25	**(11-1995)** (CISPR/D256/CDV 7-2001)
DIN EN 55025, VDE 0879-2	**(08-1994)**
VDE 0879-3	**(04-1981)**

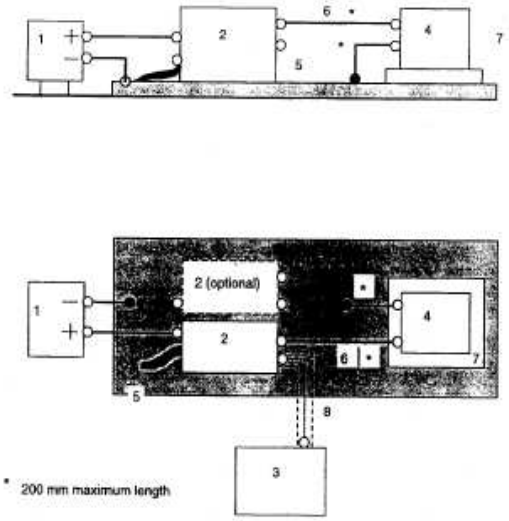
Specifications from car manufacturers

BMW:	own specification (hardest)	GS 95002 10.1999
Daimler-Chrysler:	own specification (CISPR25 class 5 QP)	MBN 10 284-203.2001
VW/Audi:	own specification (CISPR 25 class 5)	TL 965 10.1999
FIAT:	as CISPR 25 broadband class 3	07.1999
Ford:	as CISPR 25 broadband class 3	09.1998
GM:	own specification	03.1999
PSA/Renault:	as CISPR 25 plus additional frequencies	2001

Comment:

The most car manufactures refer to CISPR 25 but they have here own limit lines, which are often harder than specified in CISPR25. Overall treated, the emission is limited over the whole frequency range (150kHz-110MHz).For several applications like ABS the emission specification can change

Test Set-up conducted emission on power supply lines



1 Power supply
2 Artificial mains network (one unit, second optional)/control box/loads
3 Measuring instrument
4 EUT
5 Ground plane
6 Test harness (power leads 200 mm maximum length)
7 Insulating spacer (50 mm thick), when required in test plan
8 Coaxial cable (50 Ω)

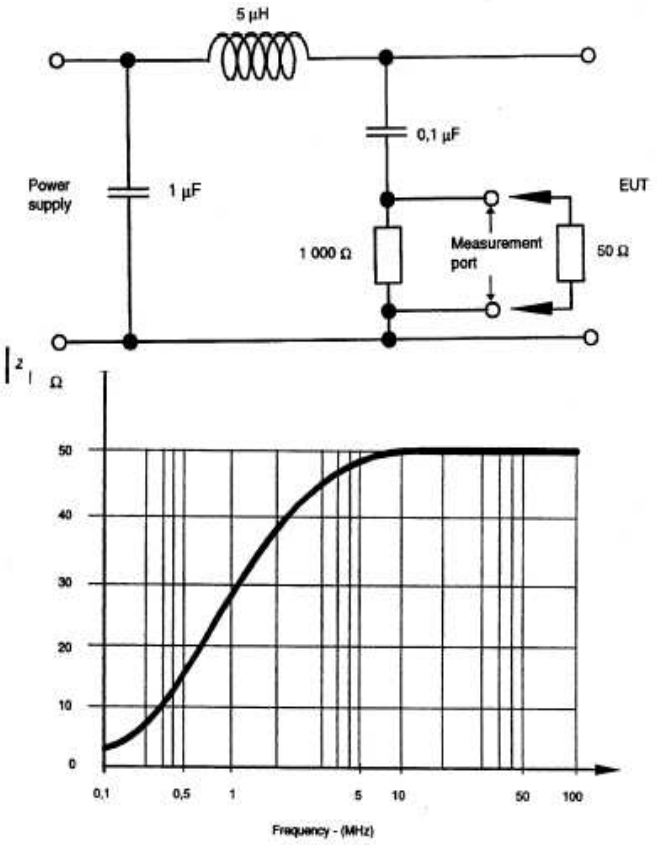


Abb.1 Artificial network: Test set-up, equivalent circuit, impedance behaviour

Limits for broadband conducted disturbances on power input terminals (peak) CISPR 25

switching frequency is smaller than the RBW of the EMI receiver,
RBW 9kHz up to 30MHz, 120kHz up to 1GHz, e.g.: switching operation at 100Hz

Class	0.15-0.3MHz	0.53-2.0MHz	5.9-6.2MHz	30-54MHz	70-108MHz
1	113	95	77	77	61
2	103	87	71	71	55
3	93	79	65	65	49
4	83	71	59	59	43
5	73	63	53	53	37
limits in dBµV, for short time broadband disturbances add 6dB to the limits					

Limits for narrowband conducted disturbances on power input terminals (peak) CISPR25

The switching frequency is higher than the RBW of the EMI receiver.
RBW 9kHz up to 30MHz, 120kHz up to 1GHz, e.g.: charge pump at 1MHz

Class	0.15-0.3MHz	0.53-2.0MHz	5.9-6.2MHz	30-54MHz	(68)70-87MHz Communications	(76)87-108MHz Broadcast
1	90	66	57	52	42	48
2	80	58	51	46	36	42
3	70	50	45	40	30	36
4	60	42	39	34	24	30
5	50	34	33	28	18	24
limits in dBµV						

Limits for broadband conducted disturbances on power input terminals (peak) VDE 0879-3
(redrawn but used as customer specification)

Class	0.15-0.3MHz	0.5-1.65MHz	5.95-26.1MHz	87.5-108MHz
1	100	82	64	48
2	90	74	58	42
3	80	66	52	36
4	70	58	46	30
5	60	50	40	24
limits in dBµV				