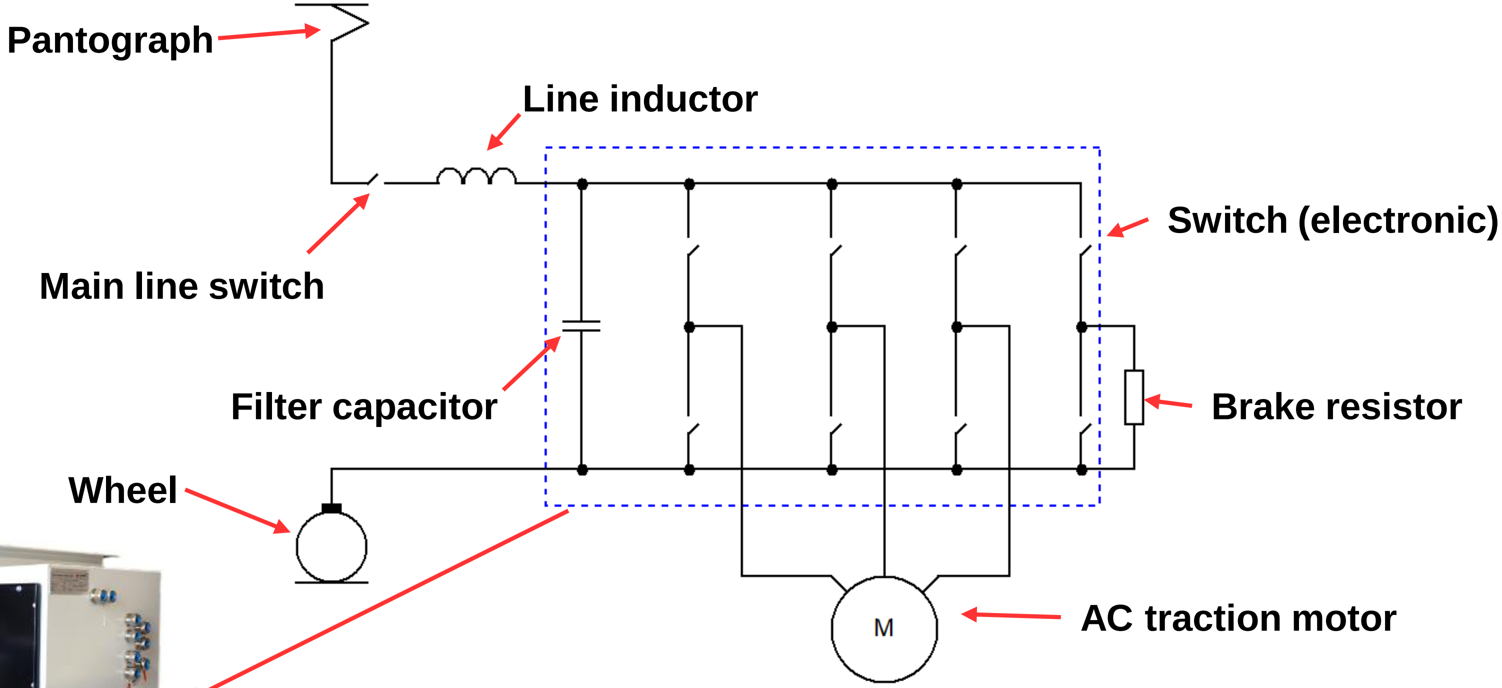
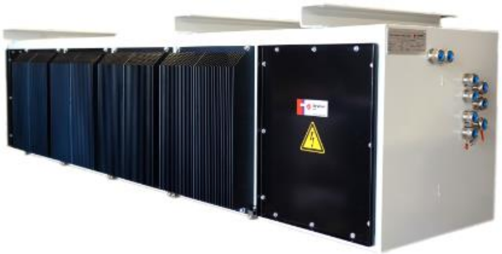
Simuleren of experimenteren?

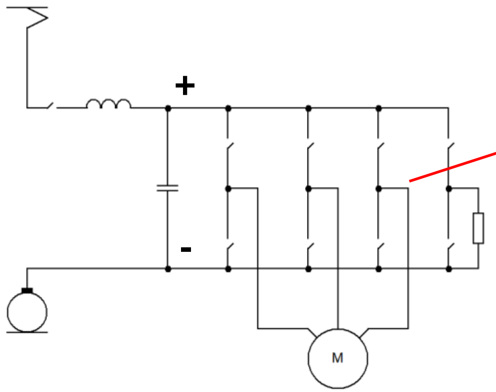
Wim Platschorre
8 juni 2018
2

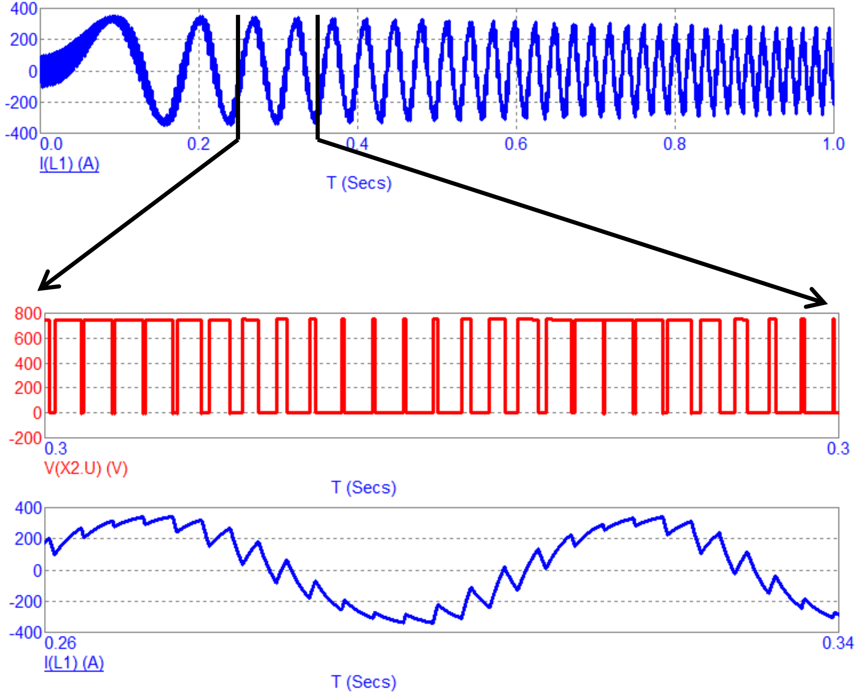
Basic traction drive circuit





DC-AC converter: inverter + brake chopper

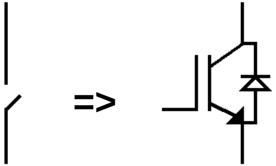




Phase current

Zoom phase voltage

Zoom phase current



Switch => IGBT

V_{CE} = 4500 V
I_C = 1200 A

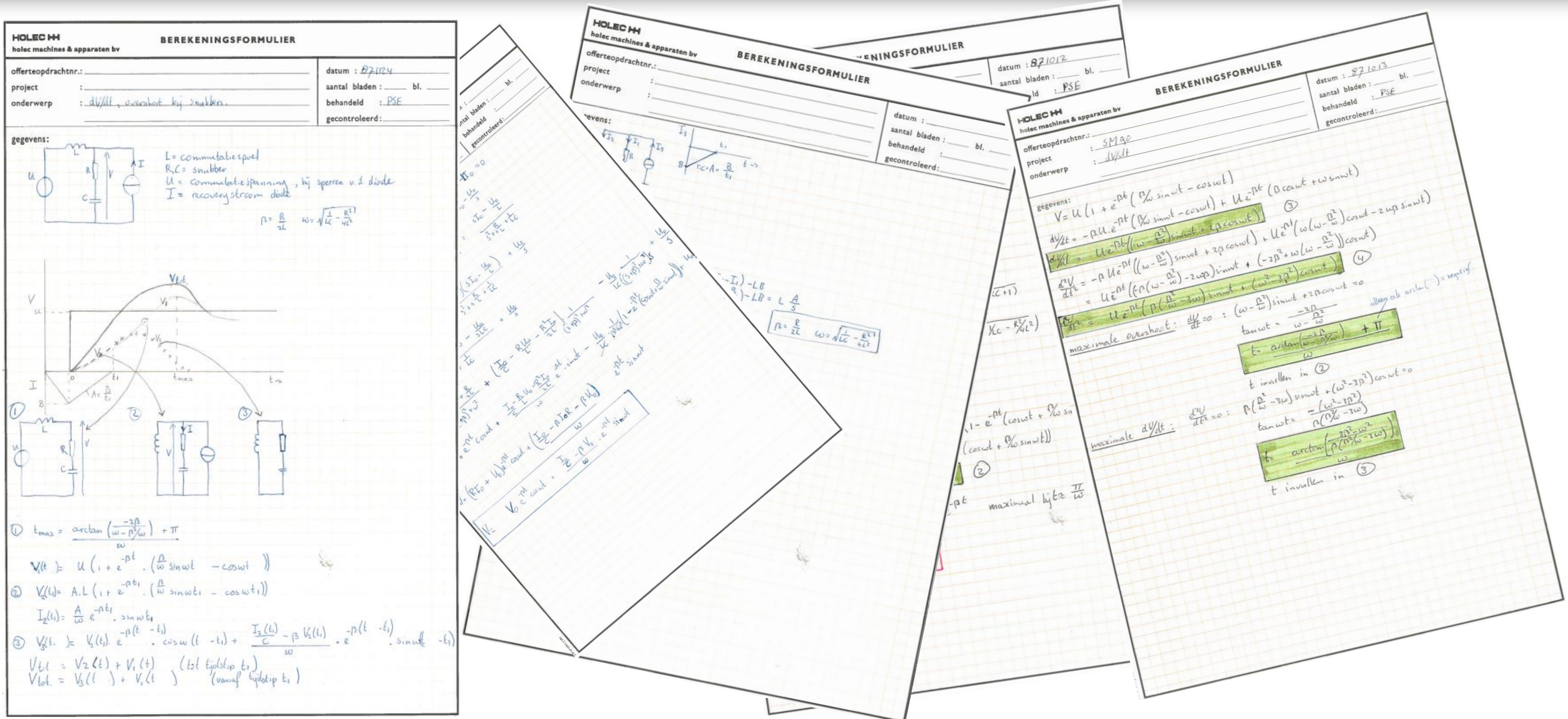
ABB HiPak™

IGBT Module
5SNA 1200G450300

Doc. No. 5SYA 1401-03 04-2012

- Ultra low-loss, rugged SPT⁺ chip-set
- Smooth switching SPT⁺ chip-set for good EMC
- Industry standard package
- High power density
- AlSiC base-plate for high power cycling capability
- AlN substrate for low thermal resistance

30 jaar geleden: handwerk



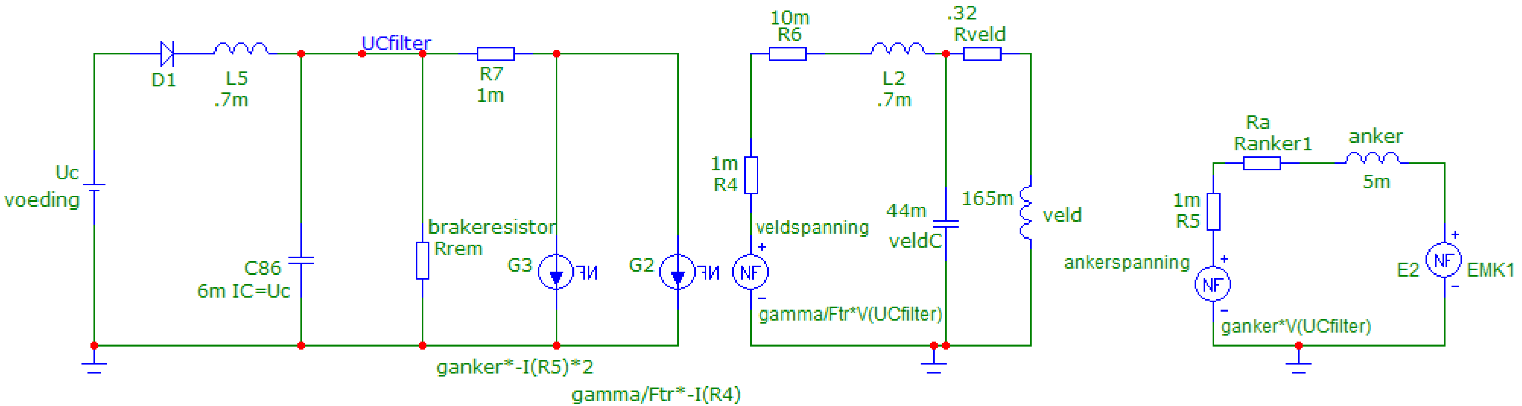
Waarom simuleren?

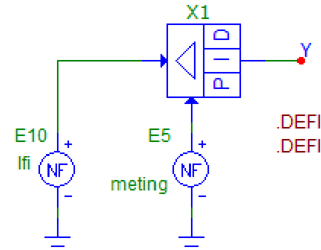
Onmogelijk om elk parasitair effect te berekenen. Beperkingen afhankelijk van het doel en de te simuleren tijdsduur.

Daarom 3 niveaus voor (elektrische) simulatie:

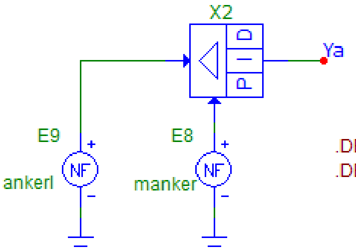
doel	model
Regelgedrag	Lineair omzettermodel
Circuitgedrag	Eenvoudig, snel schakelaarmodel, diode met reverse recovery
Halfgeleidergedrag t.b.v. driverontwerp	Gedragsmodel of fysisch model

Lineair omzettermodel: chopper voor DC-motor





.DEFINE meting I(veld)
.DEFINE gamma LIMIT(V(Y),1,0)



.DEFINE manker I(Ranker1)
.DEFINE ganker LIMIT(V(Ya),1,0)

.DEFINE KP 0.006
.DEFINE KI .01
.DEFINE KD 0

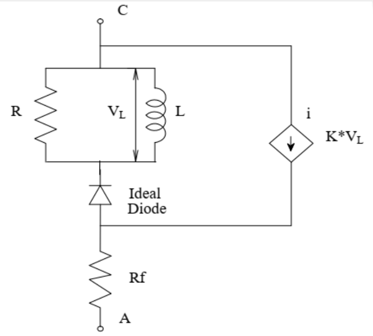
.DEFINE KPa 0.0015
.DEFINE KIa .05
.DEFINE KDa 0

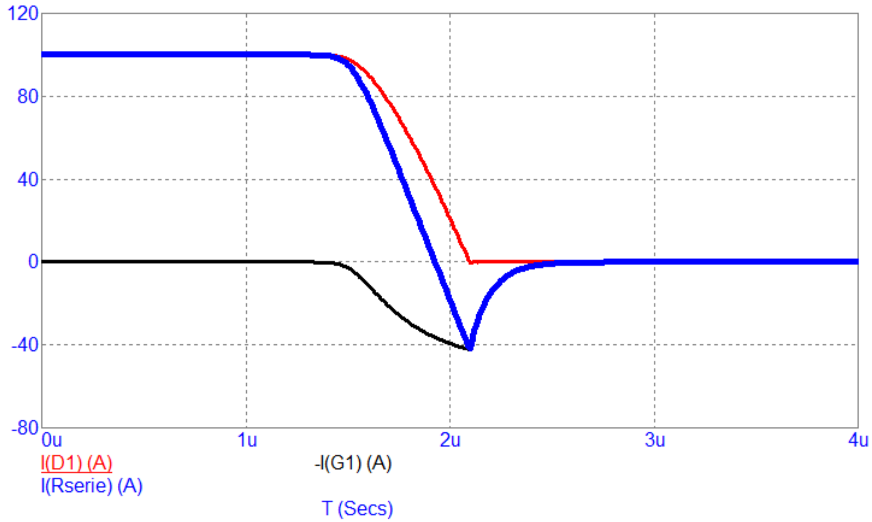
Gedragsmodel: diode reverse recovery

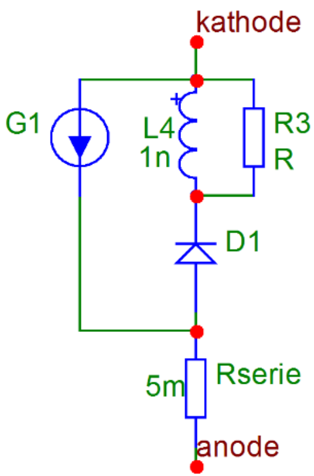
Proceedings of the 7th WSEAS International Conference on Power Systems, Beijing, China, September 15-17, 2007 48

A New Macro-Model for Power Diodes Reverse Recovery

ALI DASTFAN
Department of Electrical & Robotic Engineering
Shahrood University of Technology
Shahrood, Iran

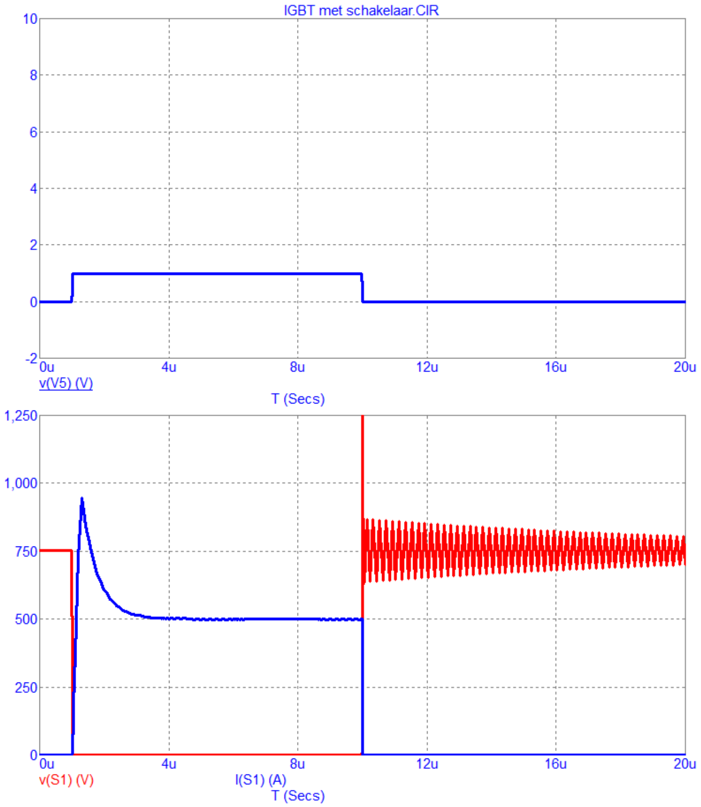






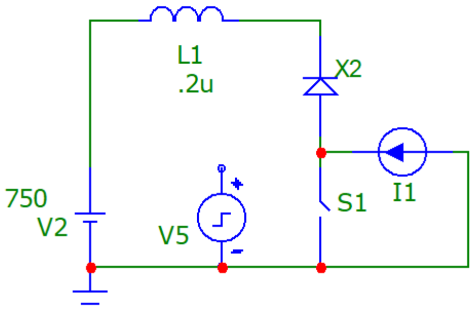
.parameters (K,R)

Standaard schakelaar

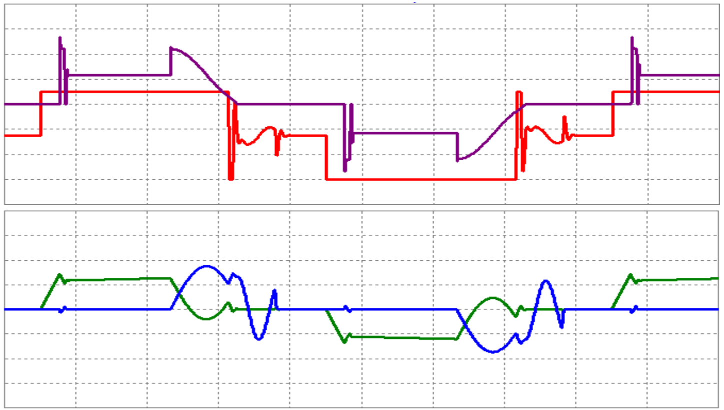


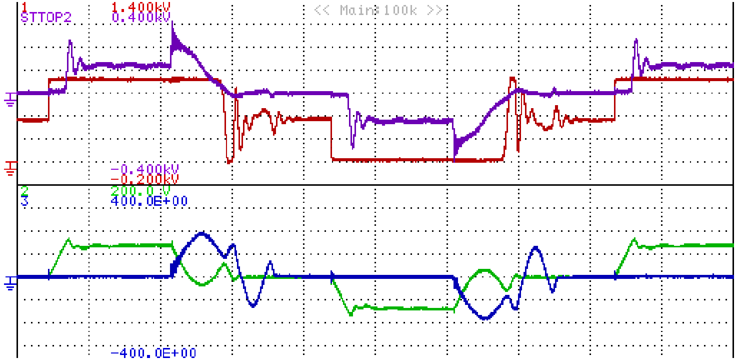
Oscillaties vertragen de simulatie: snubber nodig

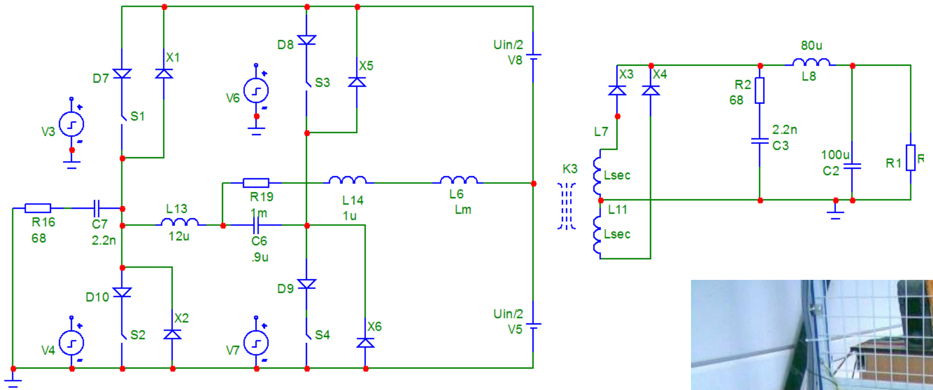
.DEFINE K 600
.DEFINE R 0.002
.DEFINE current 500

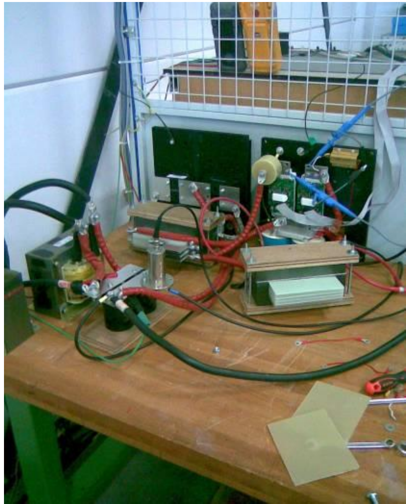


Voorbeeld: HF dc-dc omzetter



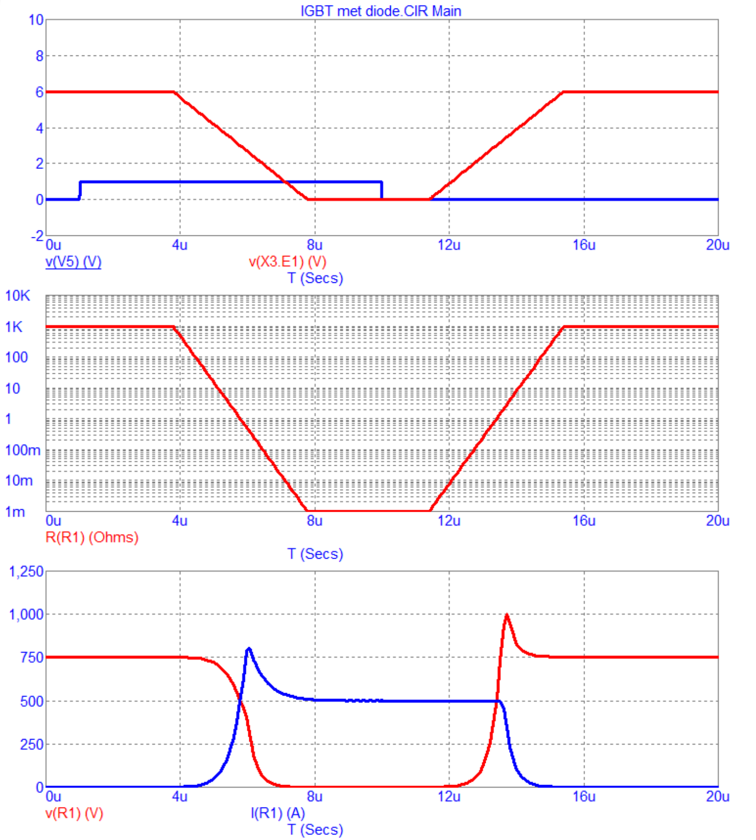


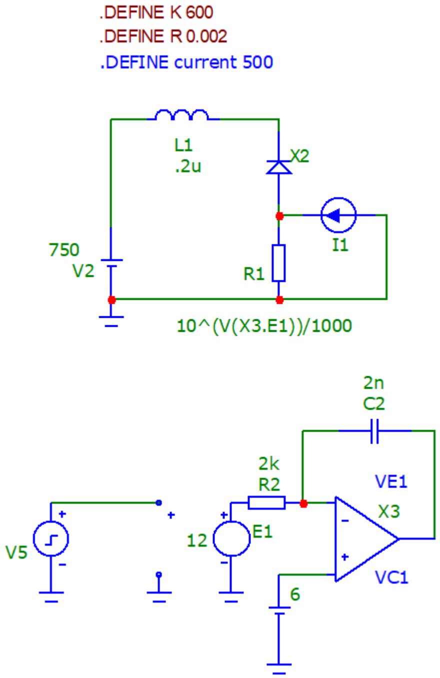




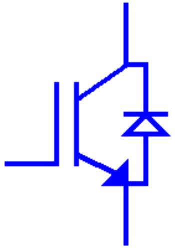
8: secundaire fasespanning [100V/div]
1: primaire fasespanning [200V/div]
2: primaire fasestroom [50A/div]
3: resonante stroom [50A/div]

Met variabele weerstand: veel beter



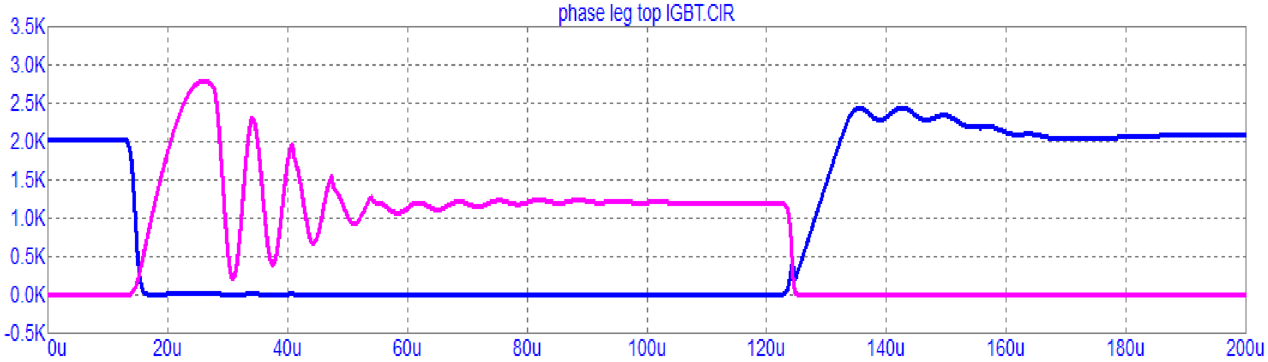


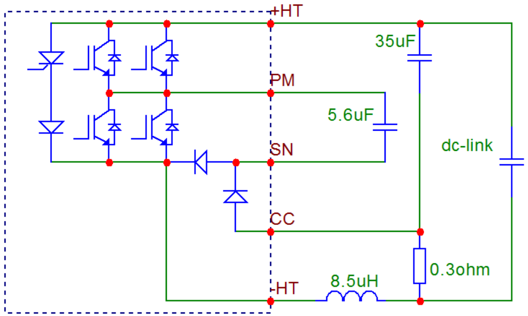
$R = 10^V/1000$
met V=6V: $R=10^6/1000=1k\Omega$
met V=0V: $R=10^0/1000=1m\Omega$

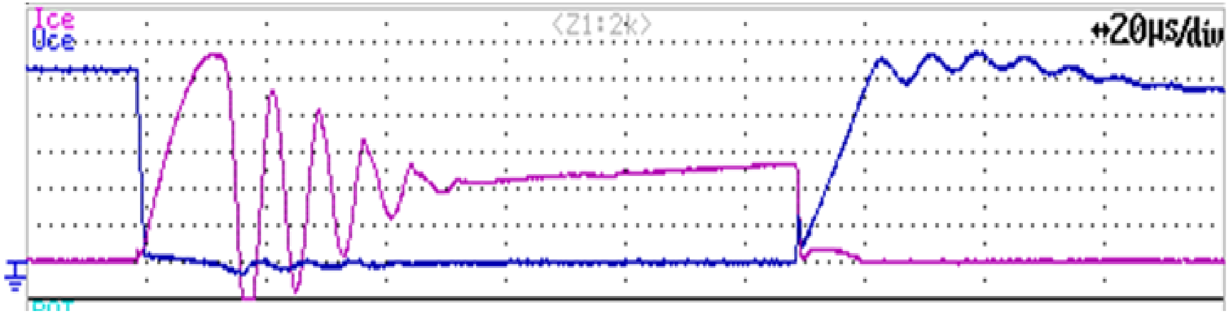


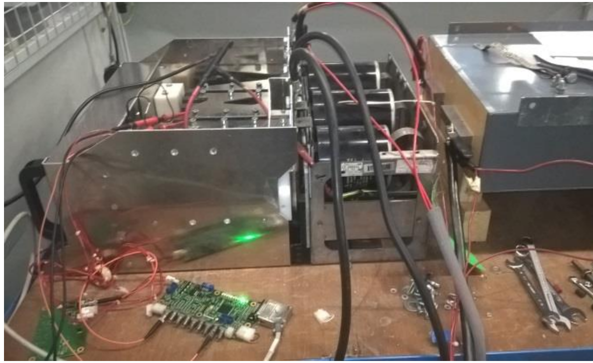
Strukton Rail

Voorbeeld: gesnubberde IGBT

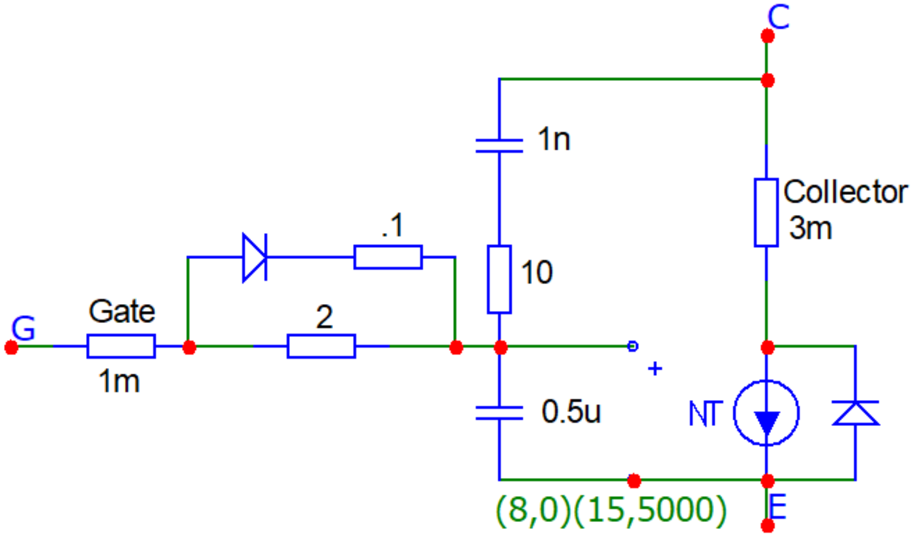








Gedragsmodel IGBT



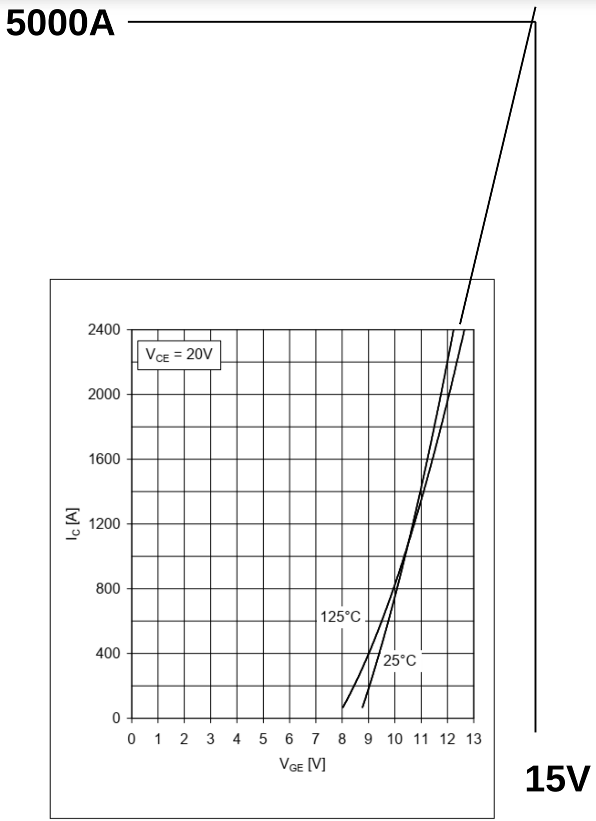


Fig. 2 Typical transfer characteristics, chip level

Fysisch model IGBT

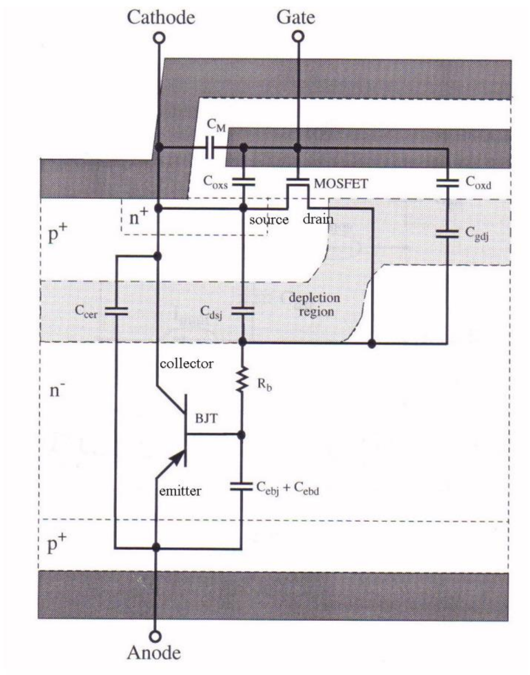


Figure 2.2: Phenomonological IGBT equivalent circuit [44].

Table 2.1: Micro-Cap 9 IGBT Modeling Parameters

Parameter	Description	Units
AGD	Gate-drain overlap area	m^2
BVN	Avalanche multiplication exponent	
JSNE	Emitter saturation current density	A/cm^2
MUN	Electron mobility	$cm^2/(V \cdot s)$
VT	Threshold area	V
AREA	Device area	m^2
CGS	Gate-source capacitance per unit area	F/cm^2
KF	Triode region factor	
MUP	Hole mobility	$cm^2/(V \cdot s)$
TAU	Ambipolar recombination lifetime	s
VTD	Gate-drain overlap depletion threshold	V
BVF	Avalanche uniformity factor	
COXD	Gate-drain oxide capacitance per unit area	F/cm^2
KP	MOS transconductance	A/V^2
NB	Base doping	cm^{-3}
THETA	Transverse field factor	V^{-1}
WB	Metallurgical base width	m

Source: Local page 'Models'

AGD	7m	AREA	7m	BVF	1
BVN	10	CGS	1	COXD	1
JSNE	20p	KF	1	KP	1200
MUN	20k	MUP	400	NB	20T
T_ABS	undefined	T_MEASURED	undefined	T_REL_GLOBAL	undefined
T_REL_LOCAL	undefined	TAU	1	THETA	10
VT	10	VTD	0	WB	80u

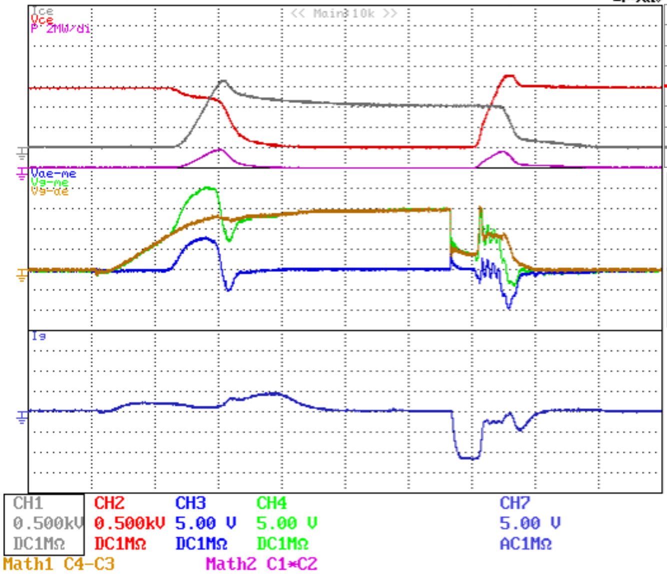
Parameters moeilijk te verkrijgen
=> eindeloos uitproberen

Strukton Rail

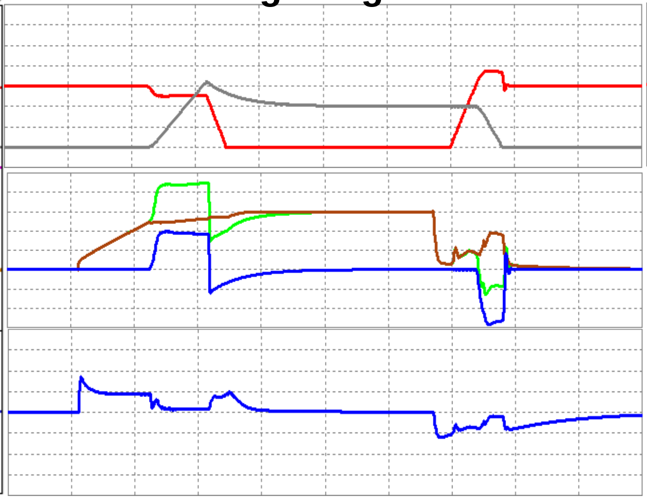
Experiment en simulatie

Meting: 1kA @1,5kV in en uit

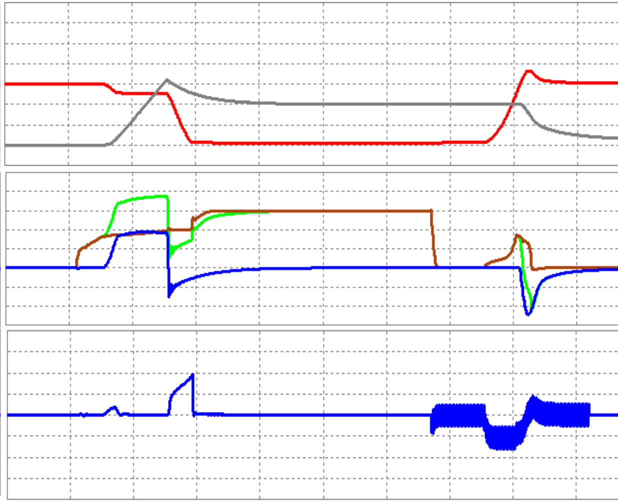
1µs/div

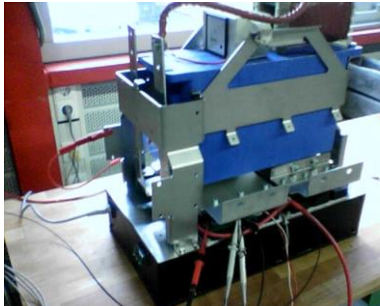


Simulatie met gedragsmodel



Simulatie met fysisch model





Nieuwe generatie IGBT's

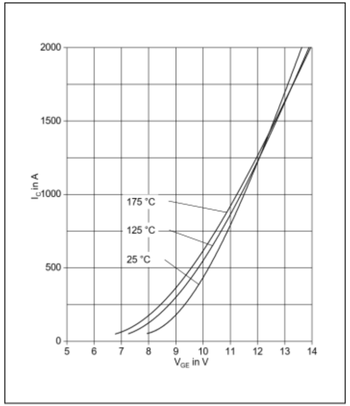
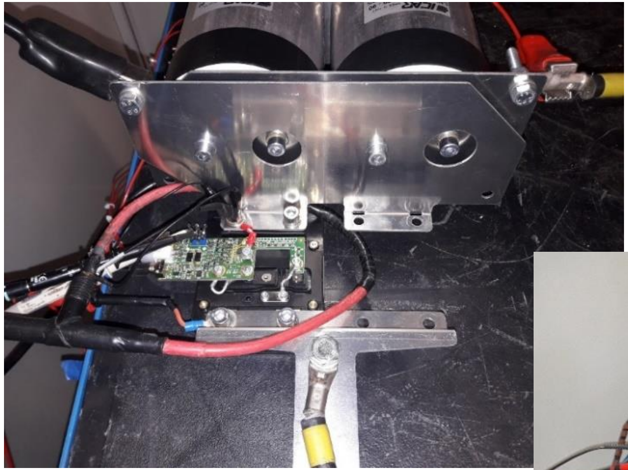
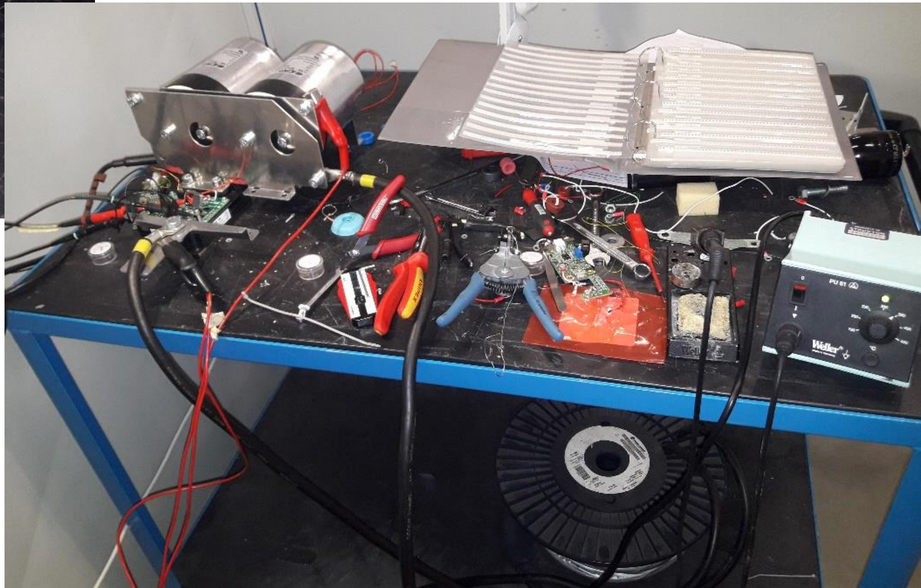
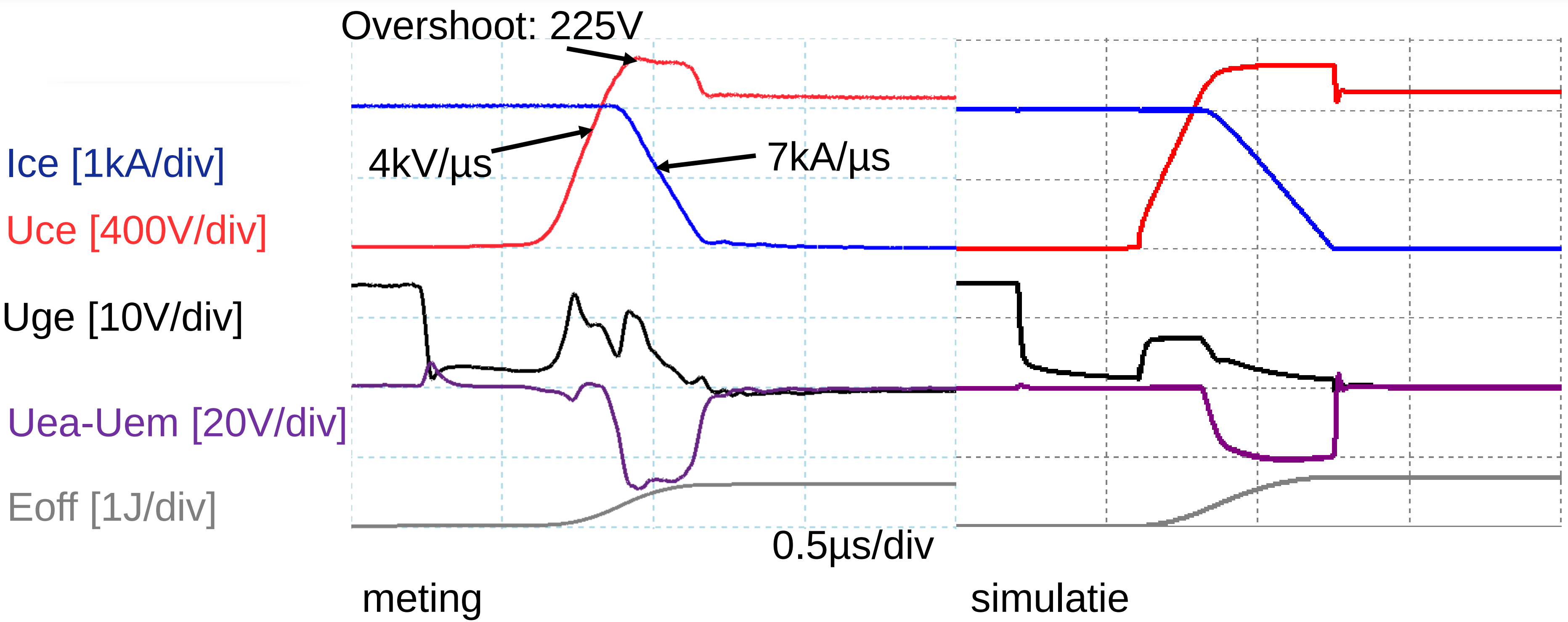


Fig. 2 Typical transfer characteristics, chip level

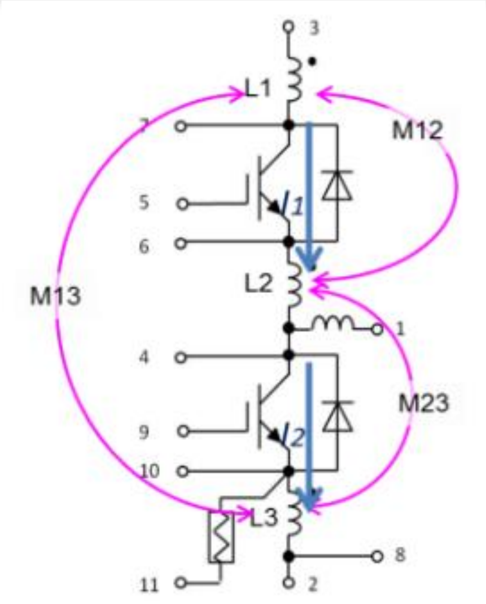




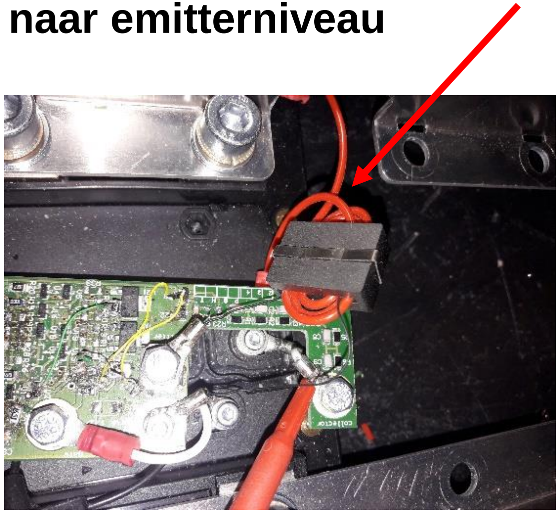
Resultaat 2000A uitschakelen

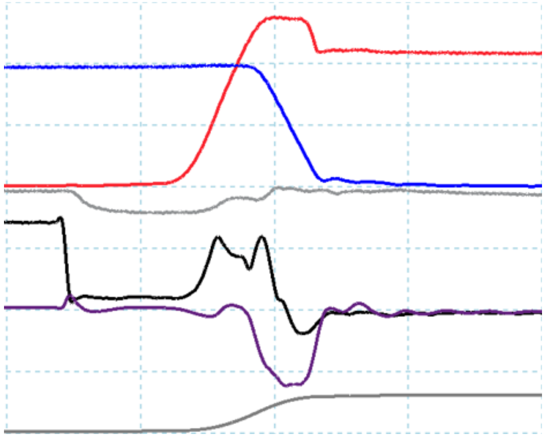


Trafo: niet simuleren, alleen experimenteren



Probleem: L2≈0
Oplossing: U(L1) transformeren naar emitterniveau





High side

Vragen?

wim.platschorre@strukton.com