开关电源电磁兼容仿真方案

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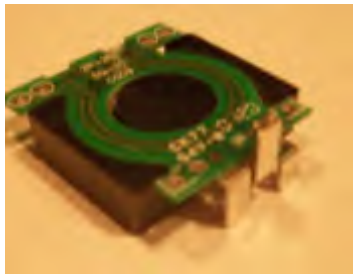
开关电源面临的技术问题

- 电感、变压器的精确设计问题
  变压器的临近效应、趋肤效应、磁扩散与饱和



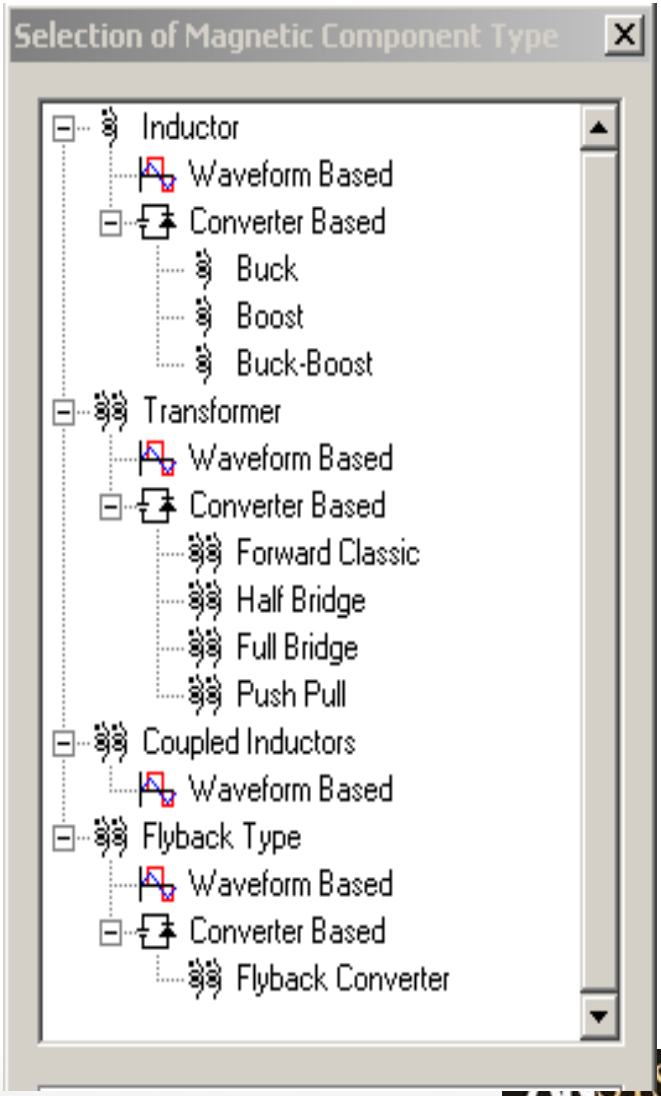
- 电源系统稳态、动态电气性能设计问题
  主电路拓扑结构和控制电路，系统效率等
  电力电子器件的非线性、开关动态过程等

- 共模、差模等滤波电感及电路设计问题

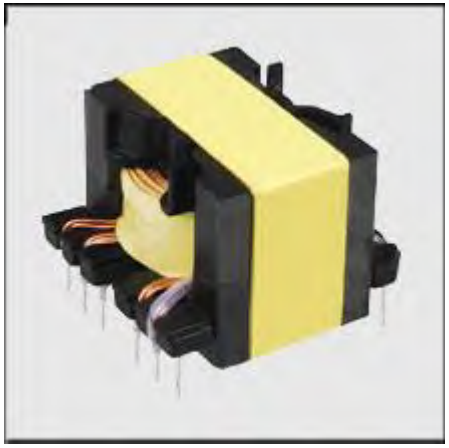
- 传导干扰及EMI/EMC问题

PExprt----电子变压器、电感设计专家

- ✓ 集成世界知名厂家库
- ✓ 磁路法快速设计和方案优选
- ✓ 有限元精确设计
- •



电感、变压器的精确设计问题



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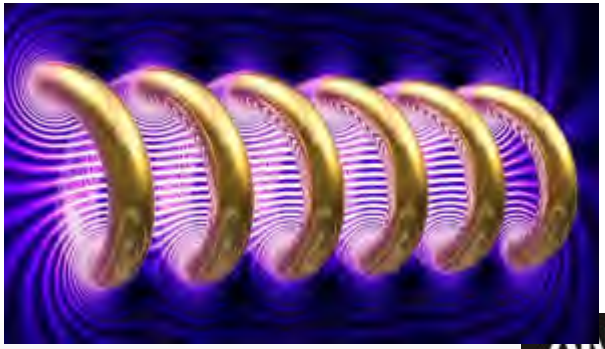
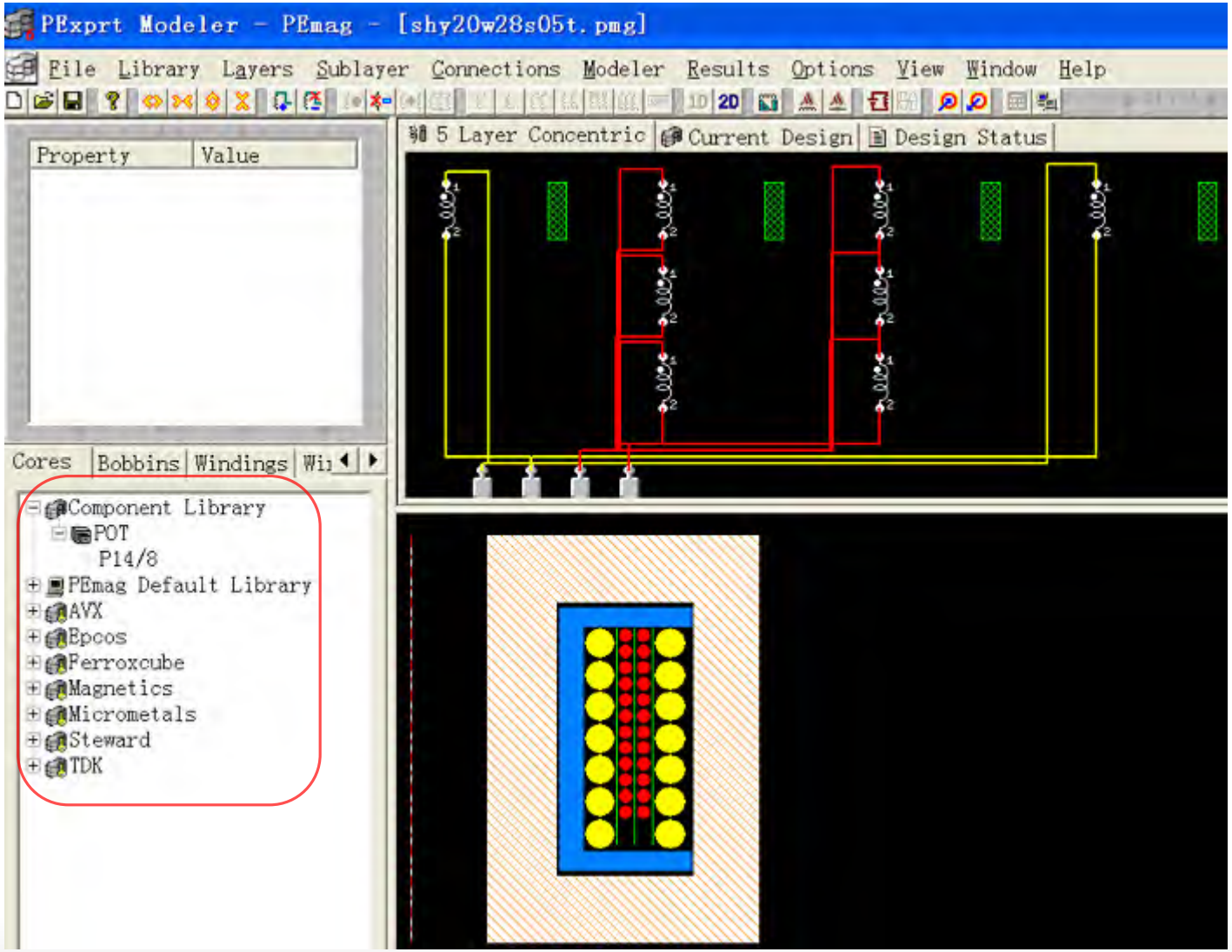
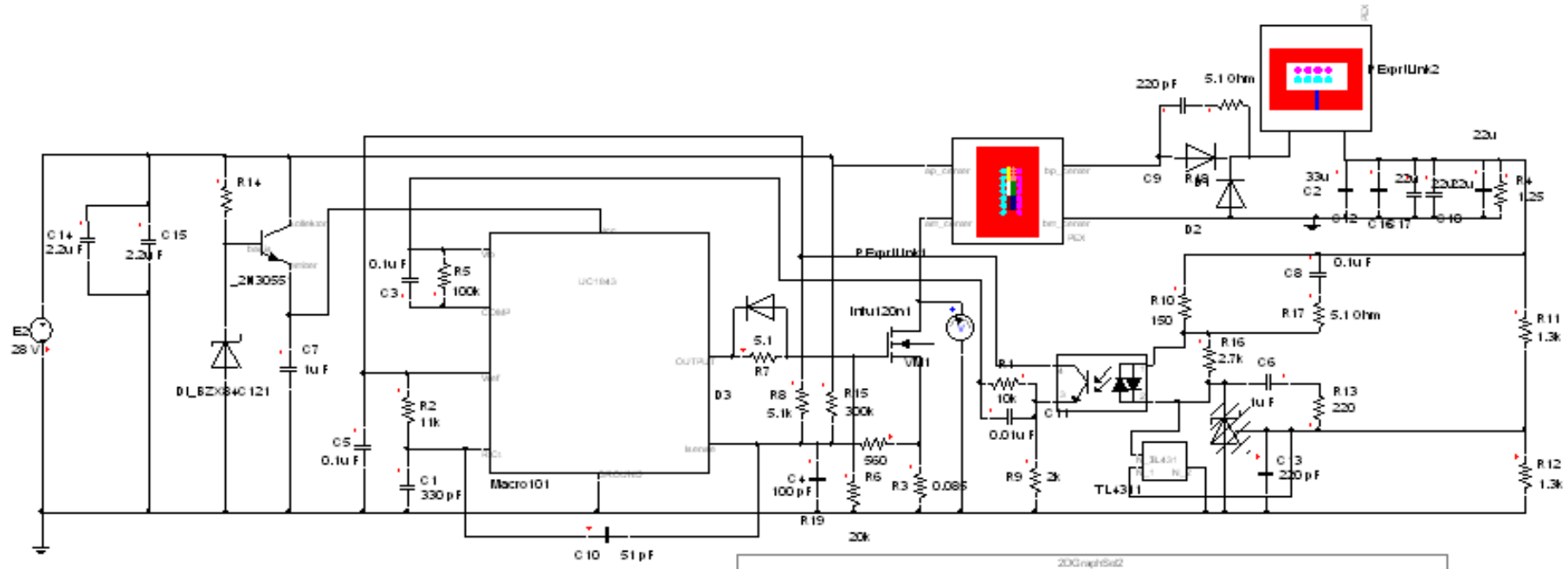
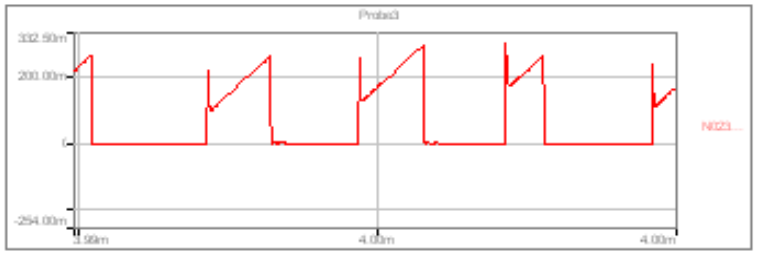


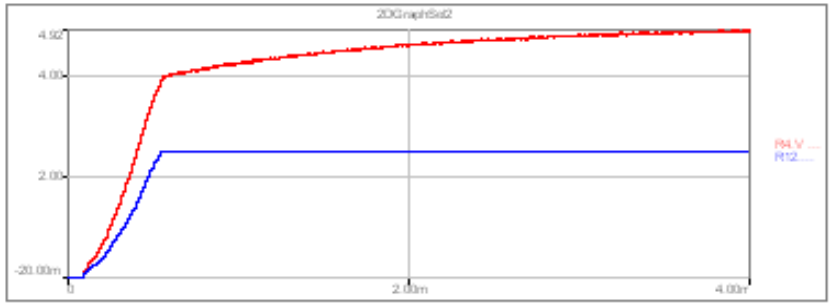
PExprt--集成世界知名厂家库



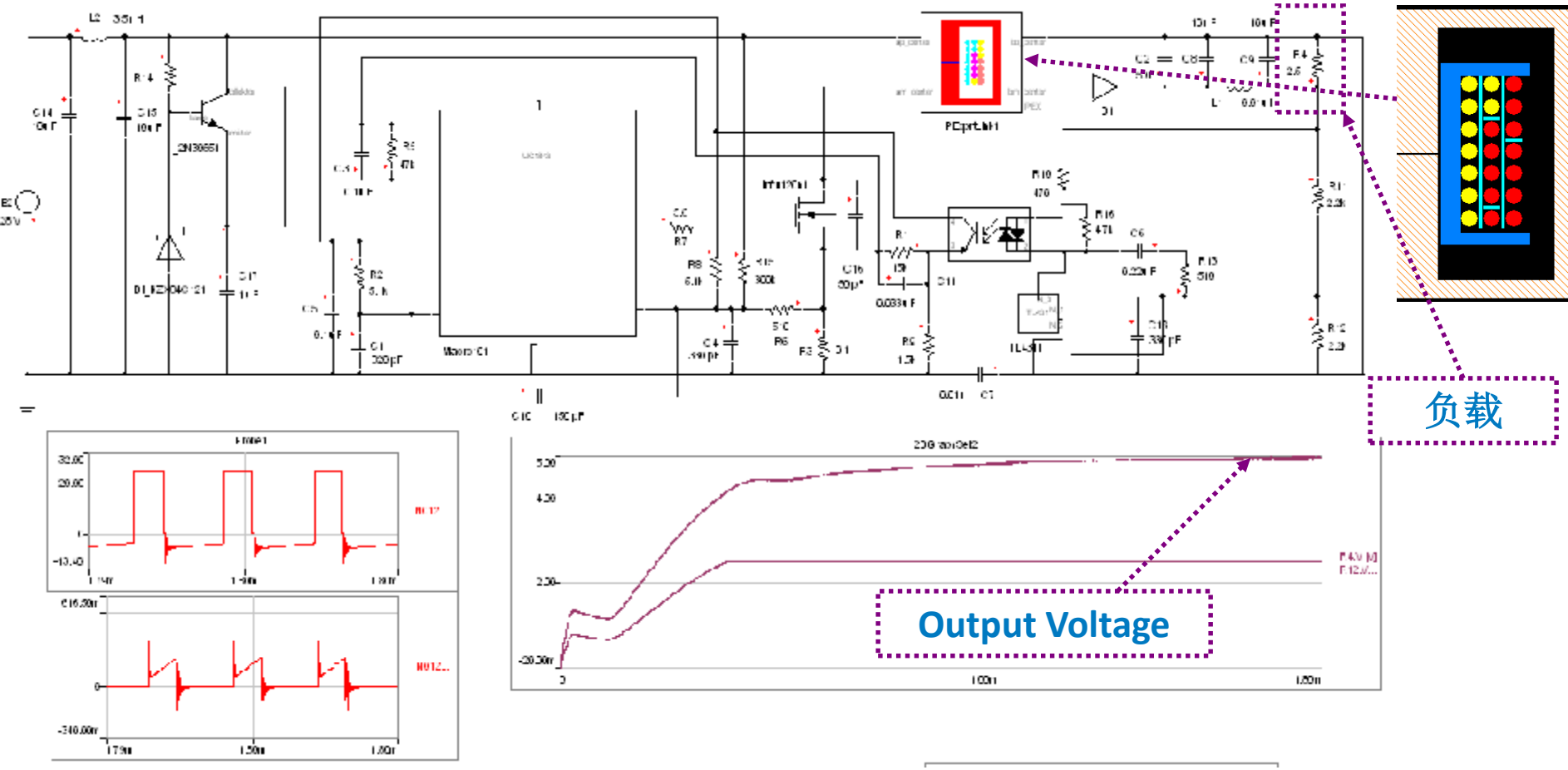
主电路拓扑结构和控制电路(Simplorer)





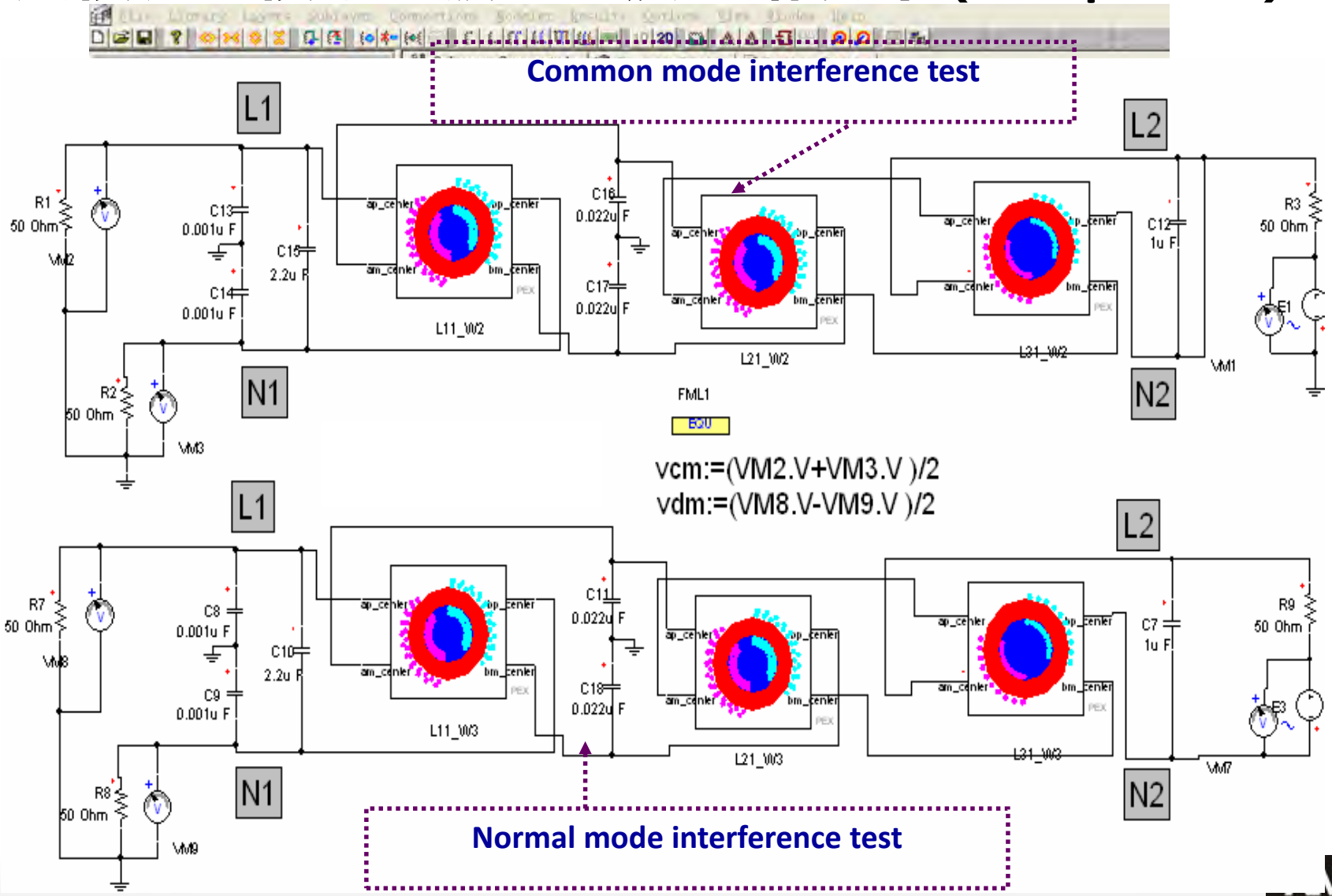


PExprt高保真阶模型直接集成到Simplorer

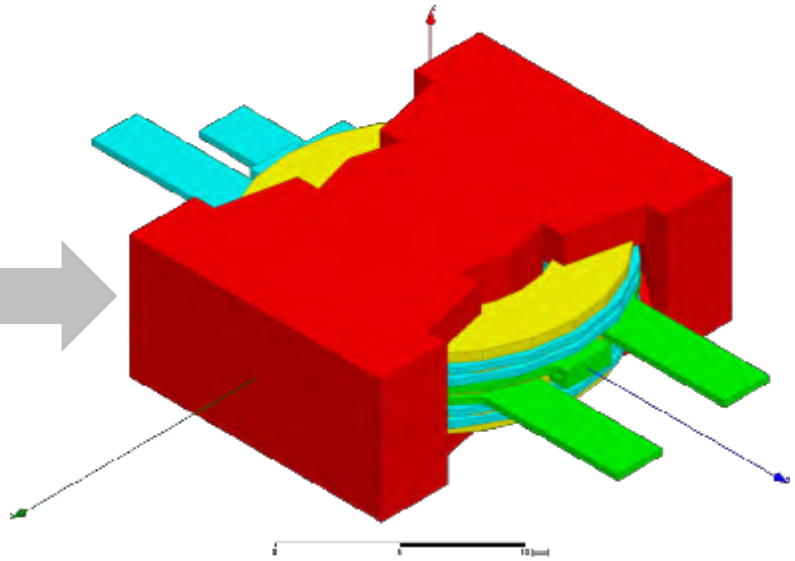


Customer's products: Flyback Simulation Circuit (10W)

共模、差模等滤波电感及电路设计（Simplorer）

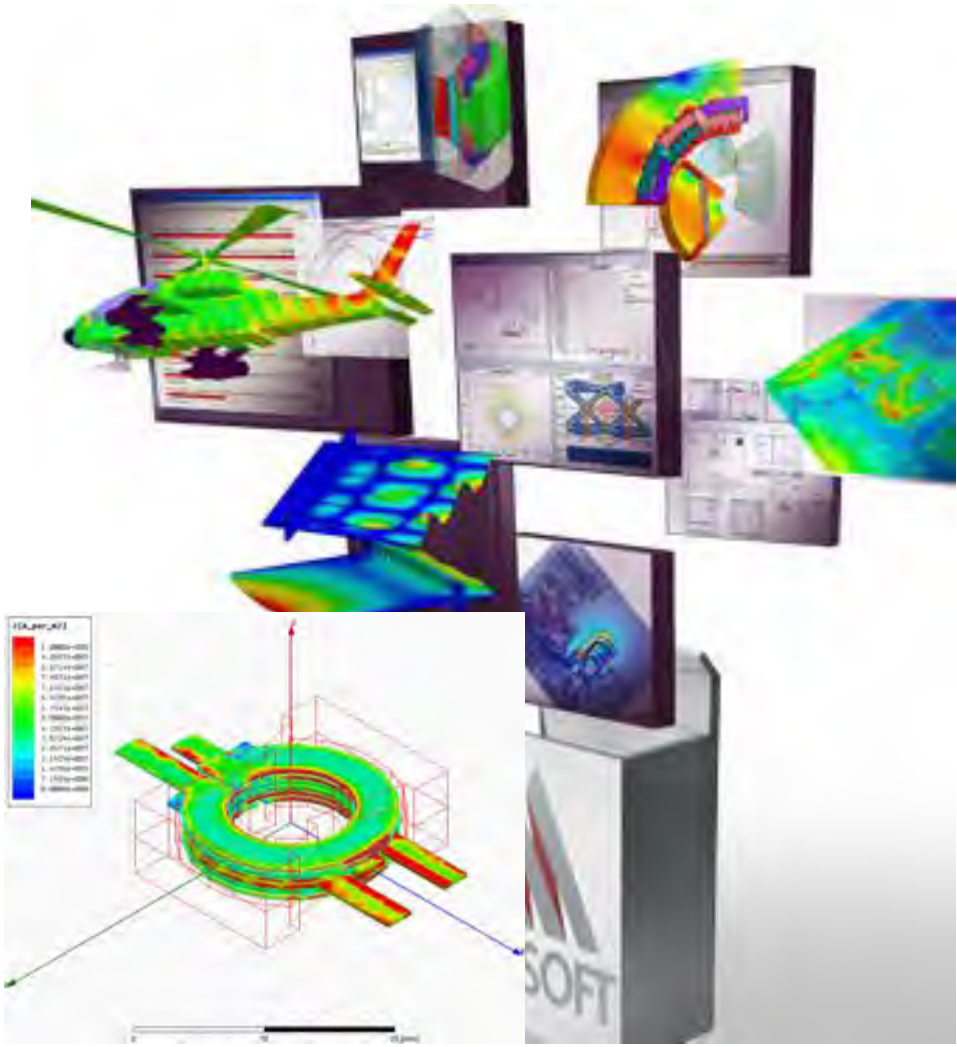


Maxwell：非常规磁性器件

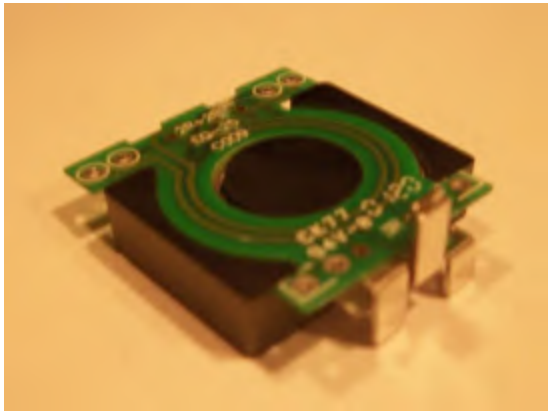


Maxwell 介绍

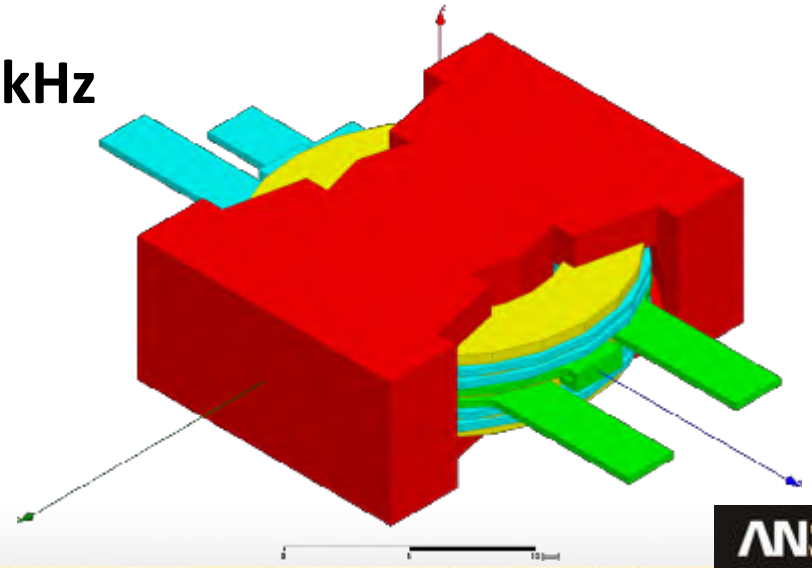
- 精确的2D/3D有限元分析
- 强大的瞬态功能
- 全面的电磁场仿真
- 自动自适应网格剖分技术



Electronic Planar Transformer

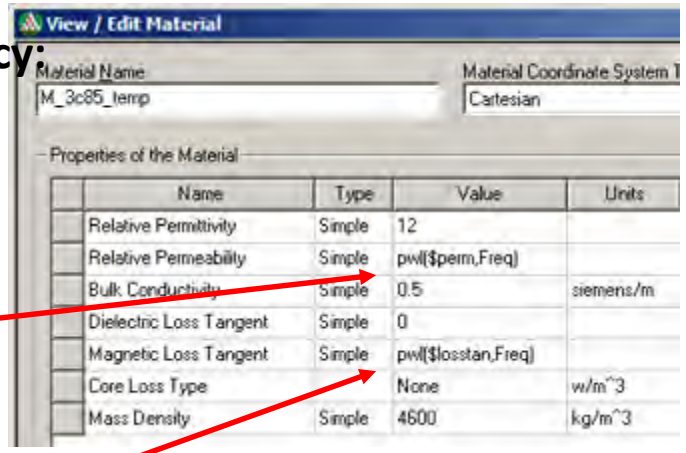


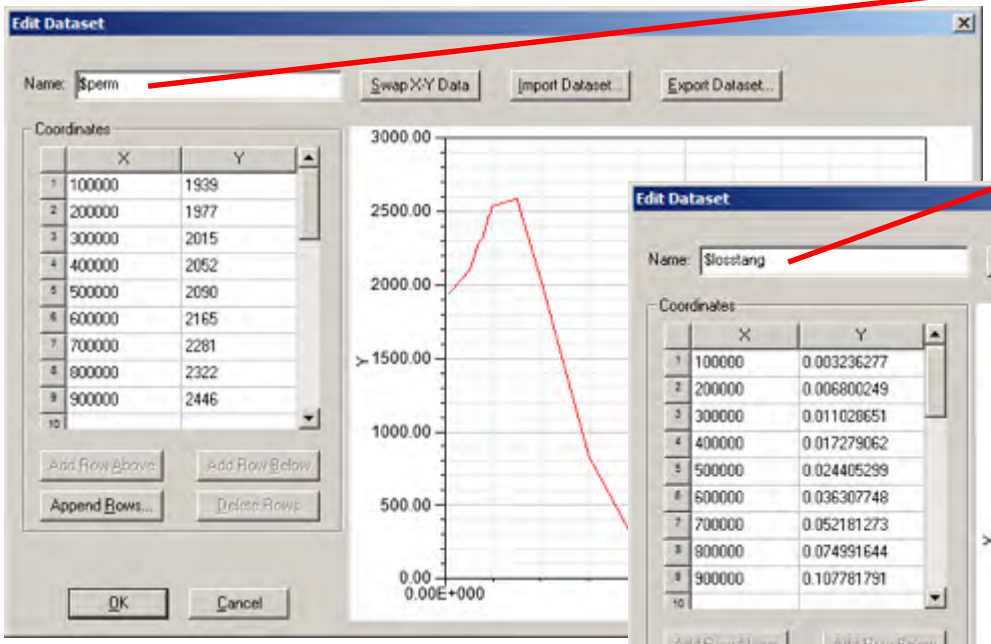
- Ferrite PQ Core
- Primary turns = 4
- Secondary turns = 2
- Insulation layers between conductors
- Fundamental Frequency = 100kHz

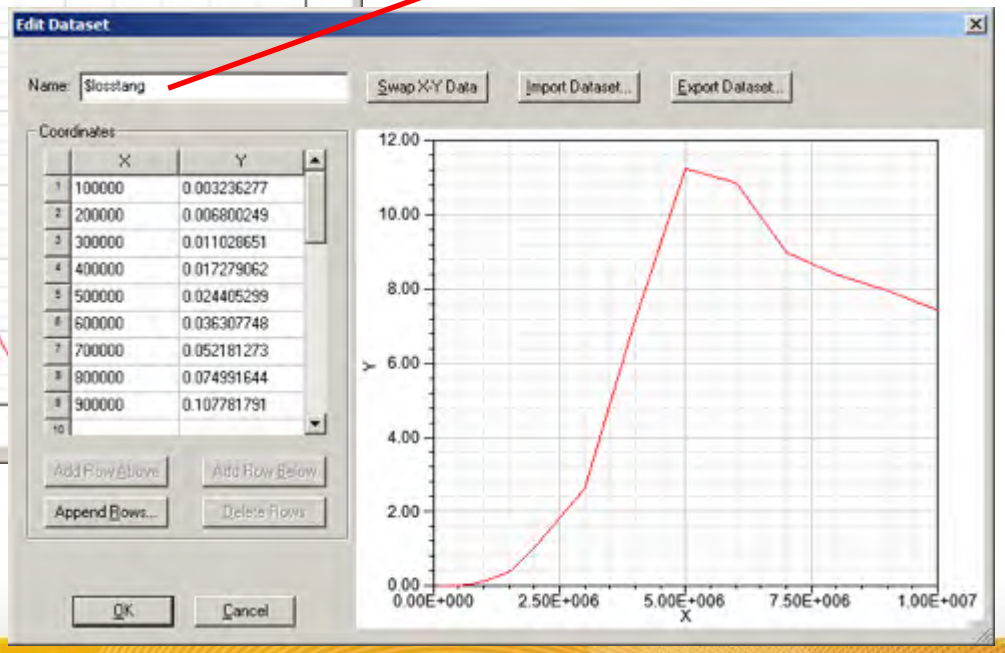


Core Material Properties - Inputs

- **Datasets used to define properties vs. frequency:**
  - Relative Permeability = pwl($perm,Freq)
  - Magnetic Loss tangent = pwl($losstan,Freq)
- **Relative permitivity = 12**
- **Conductivity = 0.5 (S/m)**

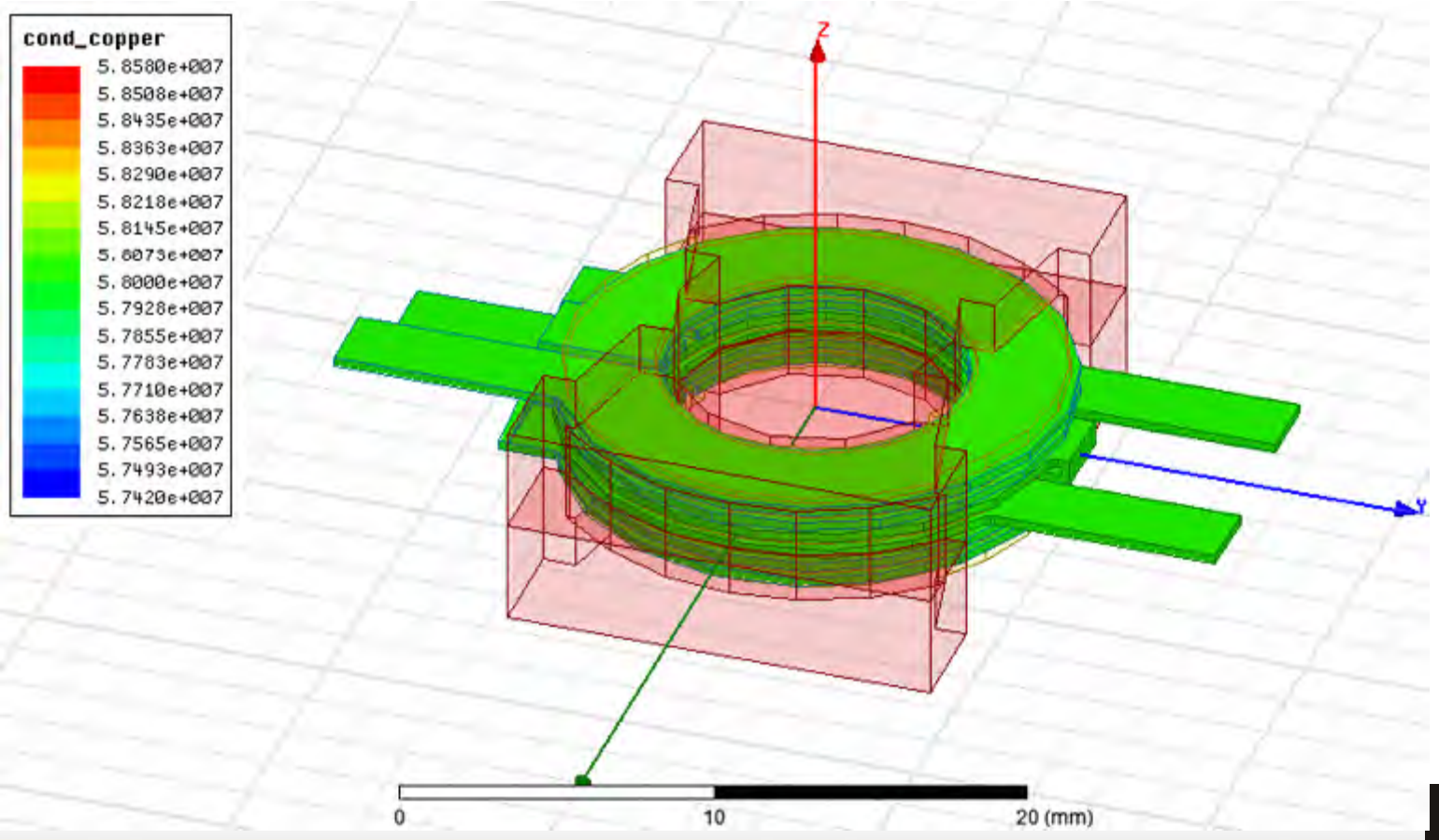




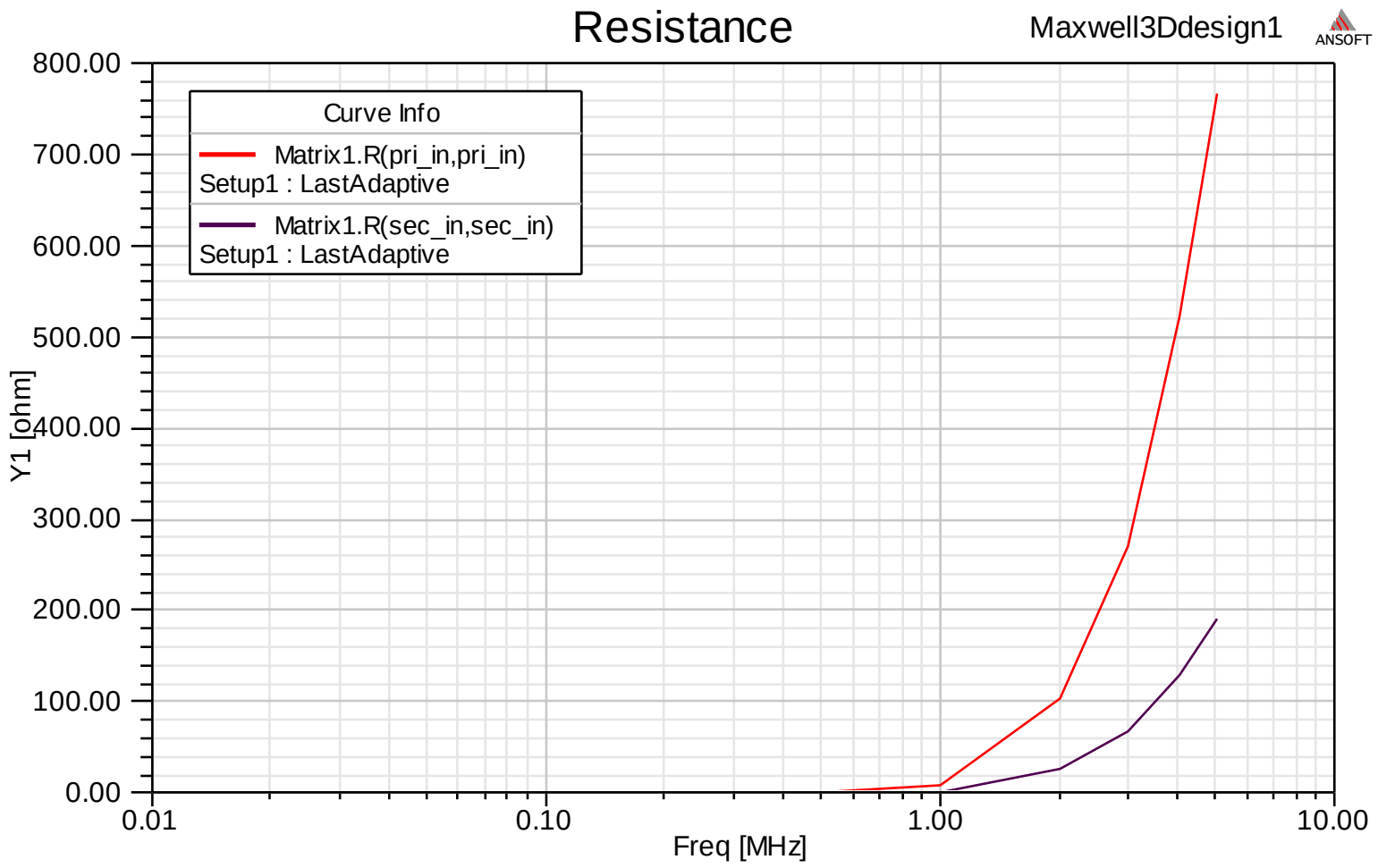


Initial Conductivity at 100kHz, 22 deg C

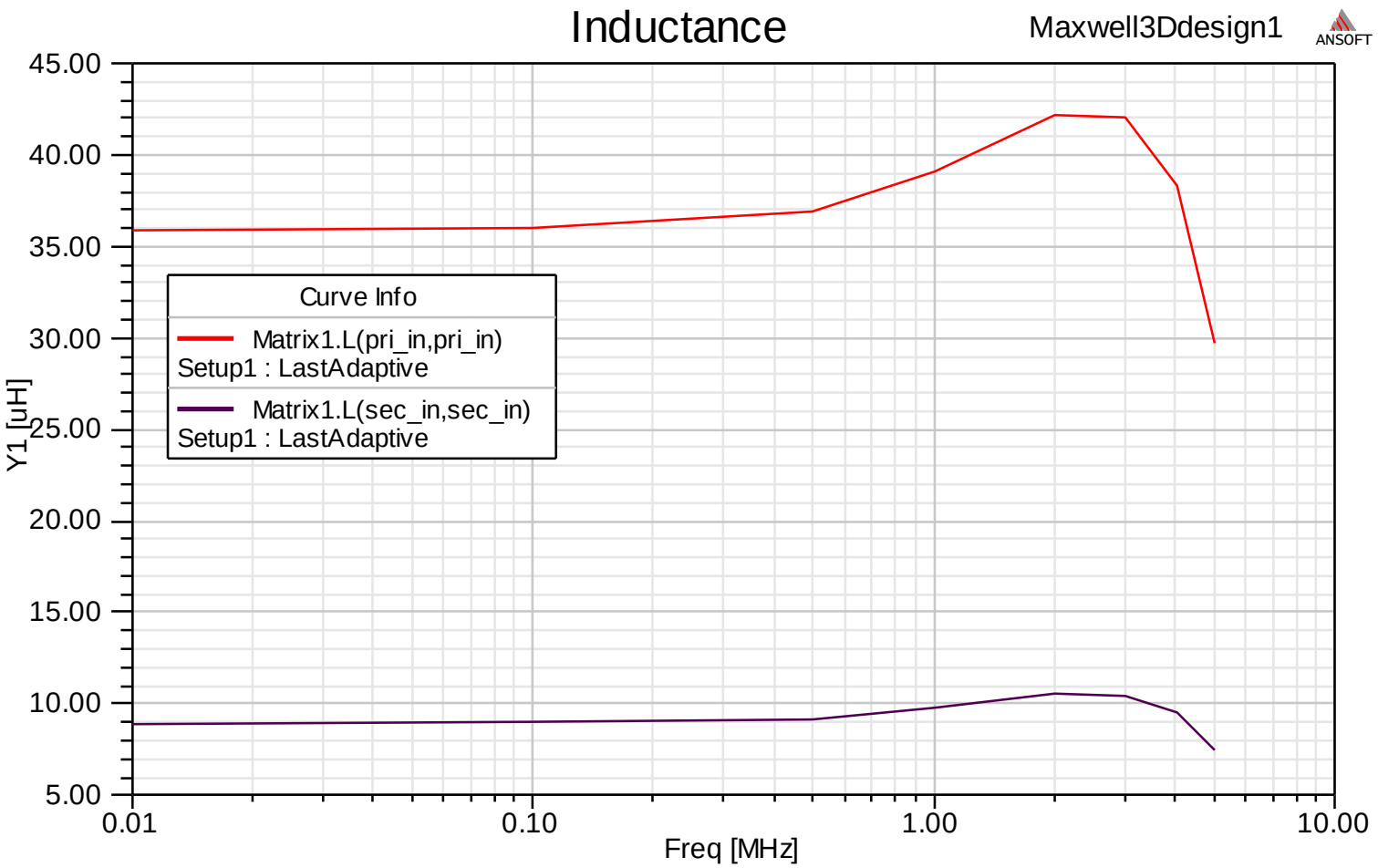
- Conductivity = $5.8e^7$ (S/m)
- Conductivity is constant throughout winding



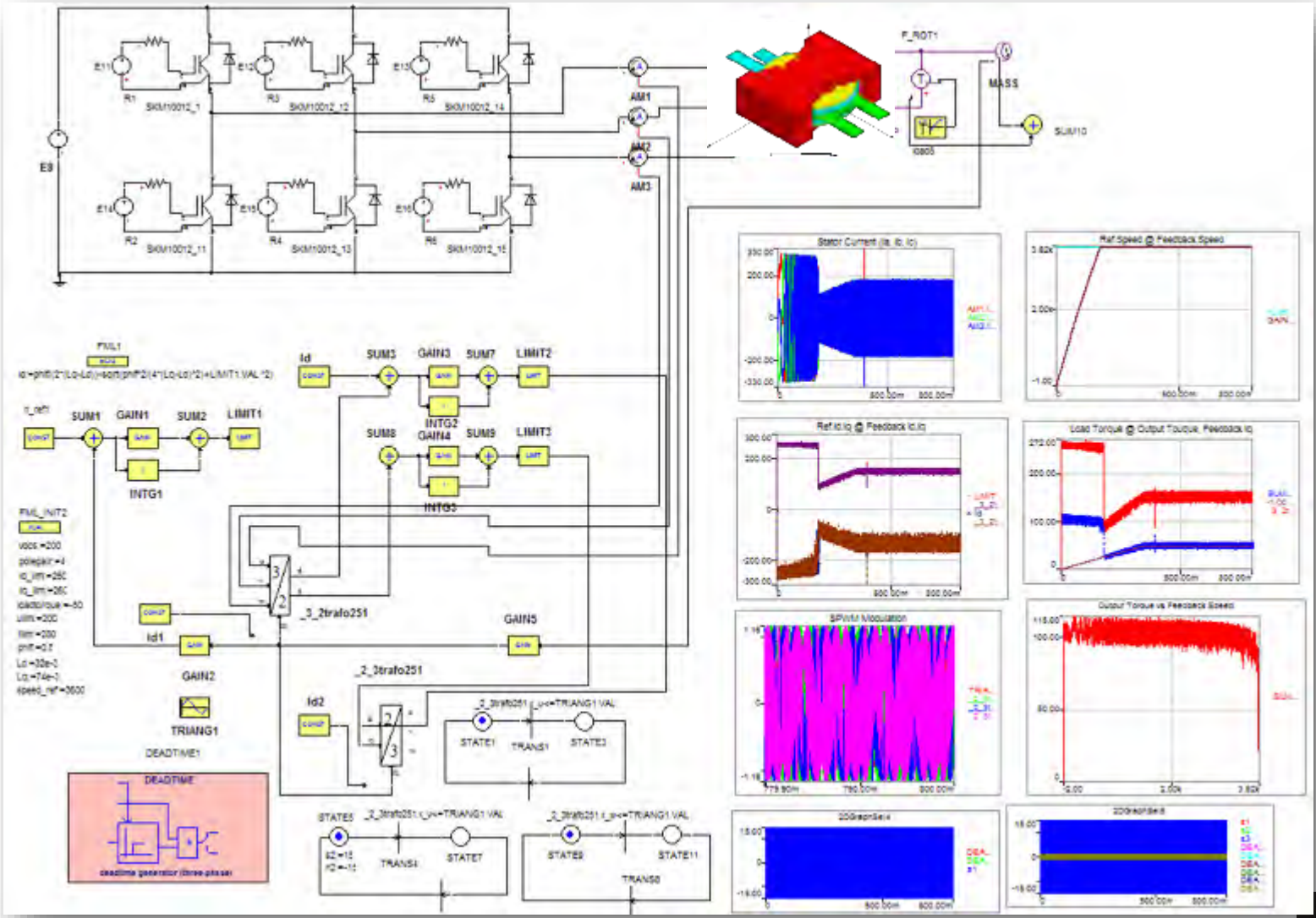
Simulated Resistance



Simulated Inductance



ANSYS System-level Simulation Example



开关器件物理原型建模

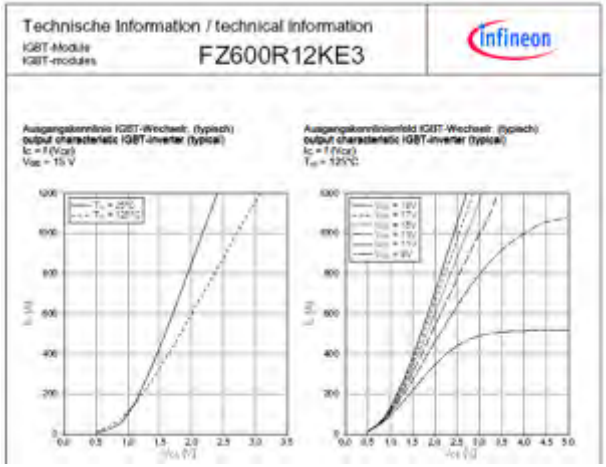
专业IGBT开关器件物理原型建模工具，可生成高精度的IGBT模型

- **输入参数**
- **高级动态模型：IGBT建模**

数据	*Vcenom, Icnom, Tjnom, Vcesat, Vgeon-off, Cin, Cr, Rgint, Rcc_ee, Ltot, Lext, Rgon-off, Cgeext, Cload.*
Sheetscan曲线	*Ic (Vge), Ic (Vce), If (Vf), Thermal impedance.*
动态、能量参数	*Eon-off, ton-off, Err, Qrr, Flux, Cos, Vos, TdG, TrG, TsG, TfG, TdI, TrI, TsI, TfI, TdV, TrV, TsV, TfV.*

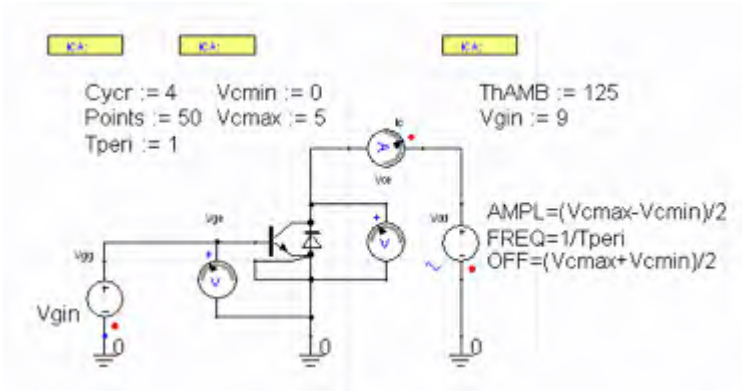
开关器件物理原型建模

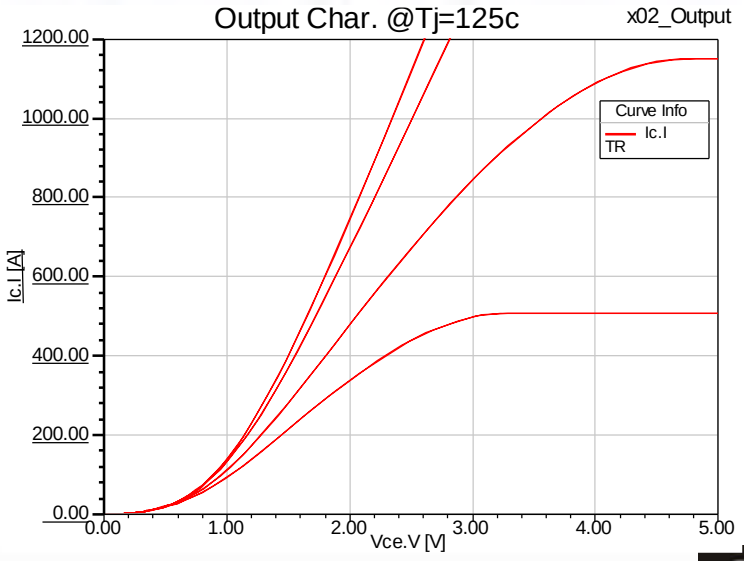
Infineon : FZ600R12KE3



数据手册

参数提取工具





输出特性曲线Vce-Ic

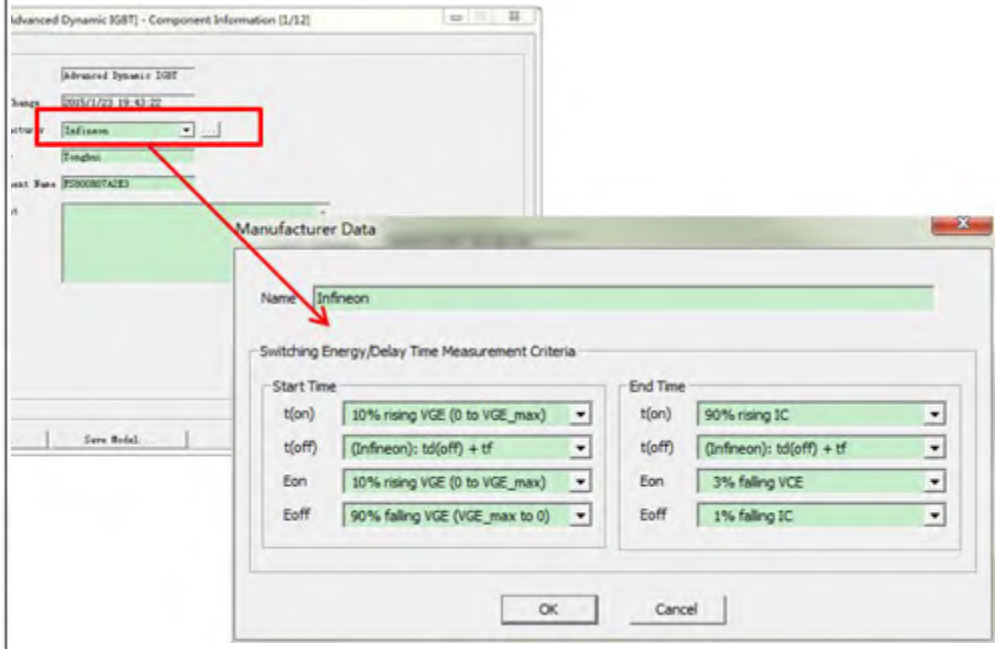
高级动态模型建模——判定标准

Höchstzulässige Werte / Maximum Rated Values

Kollektor-Emitter-Sperrspannung Collector-emitter voltage	T_{vj} = 25°C	V_{CES}	650	V
Implementierter Kollektor-Strom Implemented collector current		I_{CN}	800	A
Kollektor-Dauergleichstrom Continuous DC collector current	T_F = 75°C, T_{vj} = 175°C T_F = 25°C, T_{vj} = 175°C	$I_{C\ nom}$ I_C	550 700	A A
Periodischer Kollektor-Spitzenstrom Repetitive peak collector current	t_P = 1 ms	I_{CRM}	1000	A
Gesamt-Verlustleistung Total power dissipation	T_C = 25°C, T_{vj} = 175°C	P_{tot}	1500	W
Gate-Emitter-Spitzenspannung Gate-emitter peak voltage		V_{GES}	+/-20	V

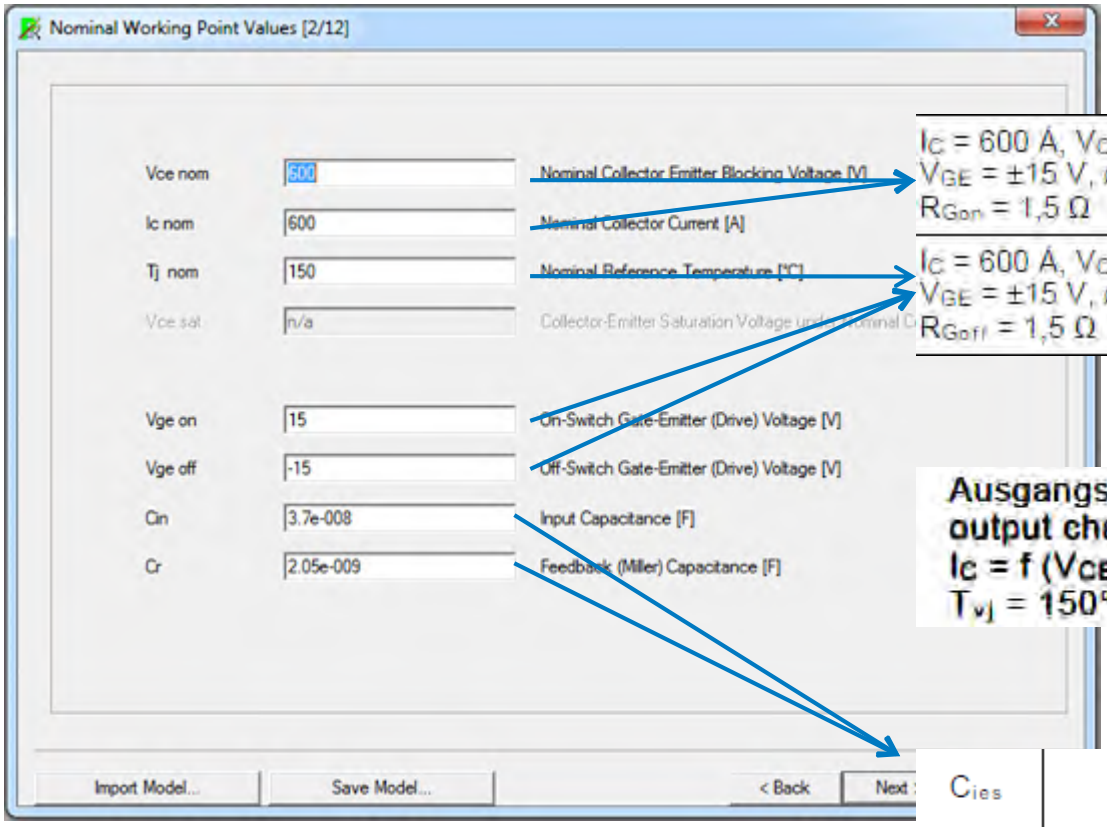
Charakteristische Werte / Characteristic Values

			min	typ.	max.	
Kollektor-Emitter-Sättigungsspannung Collector-emitter saturation voltage	I_C = 550 A, V_{GE} = 15 V, T_{vj} = 25°C I_C = 550 A, V_{GE} = 15 V, T_{vj} = 125°C I_C = 550 A, V_{GE} = 15 V, T_{vj} = 150°C	$V_{CE\ sat}$		1,30 1,35 1,40	1,60	V V V
Gate-Schwellenspannung Gate threshold voltage	I_C = 13,0 mA, V_{CE} = V_{GE}, T_{vj} = 25°C	$V_{GE(th)}$	4,9	5,8	6,5	V
Gateladung Gate charge	V_{GE} = -15 V ... +15 V	Q_G		8,00		µC
Interner Gatewiderstand Internal gate resistor	T_{vj} = 25°C	R_{Gint}		0,5		Ω
Eingangskapazität Input capacitance	f = 1 MHz, T_{vj} = 25°C, V_{CE} = 25 V, V_{GE} = 0 V	C_{ies}		52,0		nF
Rückwirkungskapazität Reverse transfer capacitance	f = 1 MHz, T_{vj} = 25°C, V_{CE} = 25 V, V_{GE} = 0 V	C_{res}		1,50		nF
Kollektor-Emitter-Reststrom Collector-emitter cut-off current	V_{CE} = 650 V, V_{GE} = 0 V, T_{vj} = 25°C	I_{CES}			5,0	mA
Gate-Emitter-Reststrom Gate-emitter leakage current	V_{CE} = 0 V, V_{GE} = 20 V, T_{vj} = 25°C	I_{GES}			400	nA
Einschaltverzögerungszeit, induktive Last Turn-on delay time, inductive load	I_C = 550 A, V_{CE} = 300 V, V_{GE} = ±15 V, R_{Gon} = 1,8 Ω, T_{vj} = 25°C T_{vj} = 125°C T_{vj} = 150°C	$t_{d\ on}$		0,12 0,12 0,13		µs µs µs
Anstiegszeit, induktive Last Rise time, inductive load	I_C = 550 A, V_{CE} = 300 V, V_{GE} = ±15 V, R_{Gon} = 1,8 Ω, T_{vj} = 25°C T_{vj} = 125°C T_{vj} = 150°C	t_r		0,10 0,10 0,10		µs µs µs
Abschaltverzögerungszeit, induktive Last Turn-off delay time, inductive load	I_C = 550 A, V_{CE} = 300 V, V_{GE} = ±15 V, R_{Goff} = 0,75 Ω, T_{vj} = 25°C T_{vj} = 125°C T_{vj} = 150°C	$t_{d\ off}$		0,51 0,63 0,66		µs µs µs
Fallzeit, induktive Last Fall time, inductive load	I_C = 550 A, V_{CE} = 300 V, V_{GE} = ±15 V, R_{Goff} = 0,75 Ω, T_{vj} = 25°C T_{vj} = 125°C T_{vj} = 150°C	t_f		0,04 0,06 0,07		µs µs µs
Einschaltverlustenergie pro Puls Turn-on energy loss per pulse	I_C = 550 A, V_{CE} = 300 V, L_S = 20 nH, V_{GE} = ±15 V, du/dt = 5500 A/µs (T_{vj}=150°C), R_{Gon} = 1,8 Ω, T_{vj} = 25°C T_{vj} = 125°C T_{vj} = 150°C	E_{on}		10,5 12,0 12,5		mJ mJ mJ
Abschaltverlustenergie pro Puls Turn-off energy loss per pulse	I_C = 550 A, V_{CE} = 300 V, L_S = 20 nH, V_{GE} = ±15 V, du/dt = 2700 V/µs (T_{vj}=150°C), T_{vj} = 25°C T_{vj} = 125°C	E_{off}		21,0 25,0		mJ mJ



数据手册

高级动态模型建模——Nom工作点参数

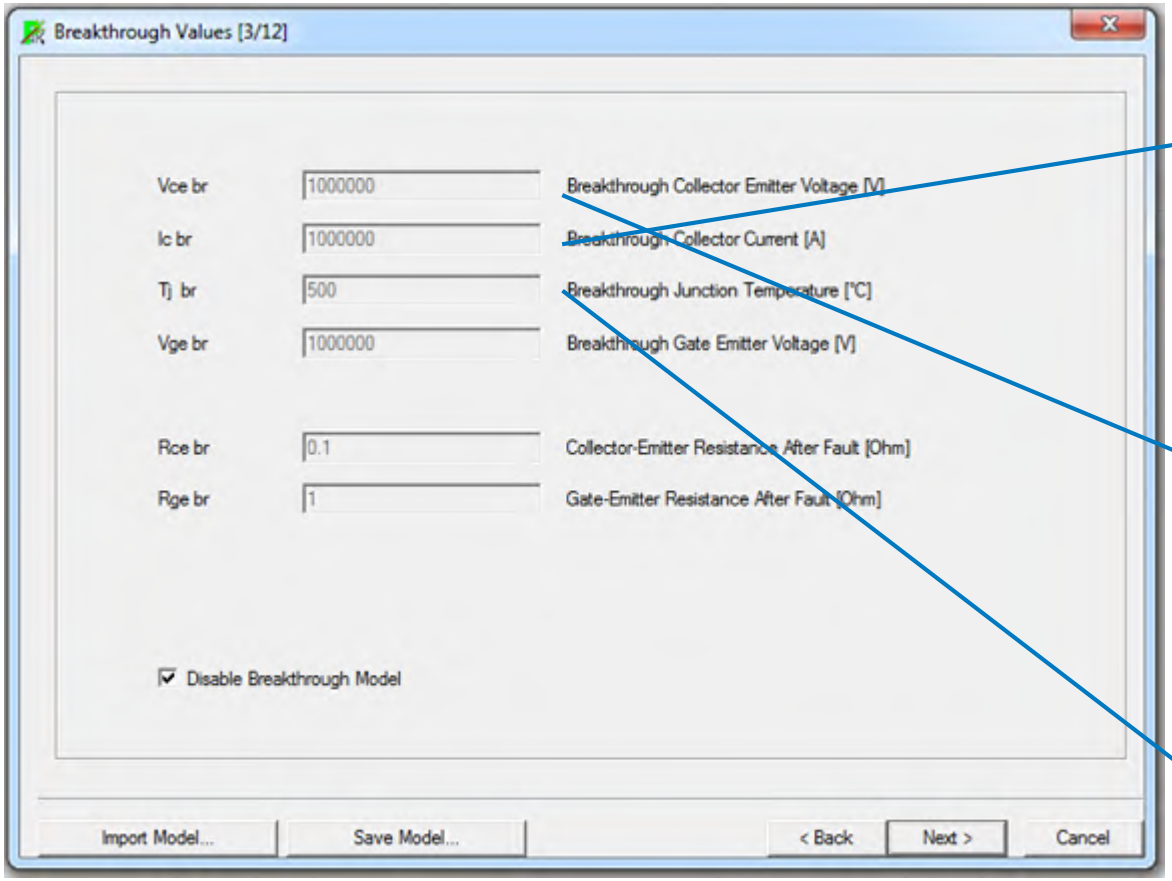


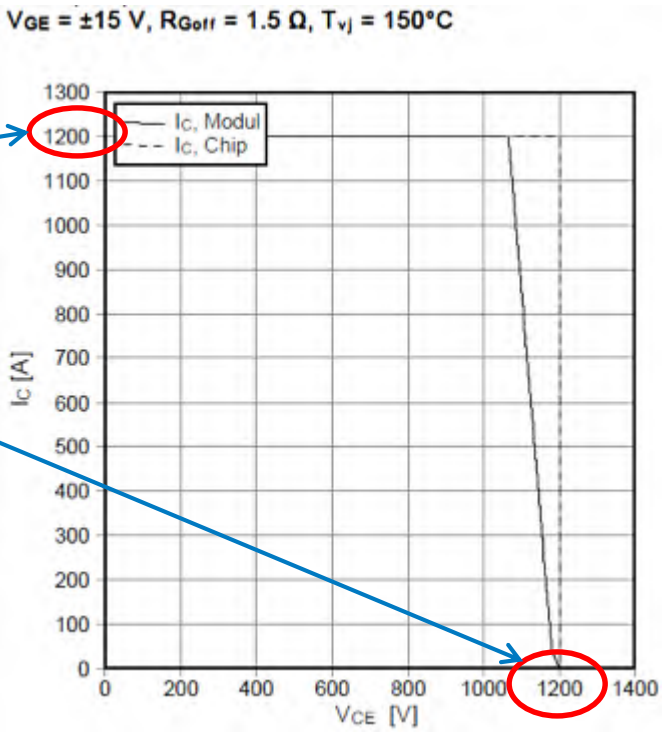
I_C = 600 A, V_{CE} = 600 V, L_S = 35 nH V_{GE} = ±15 V, di/dt = 5100 A/µs (T_{vj}=150°C) R_{Gon} = 1,5 Ω	T_{vj} = 25°C T_{vj} = 125°C T_{vj} = 150°C	E_{on}
I_C = 600 A, V_{CE} = 600 V, L_S = 35 nH V_{GE} = ±15 V, du/dt = 3700 V/µs (T_{vj}=150°C) R_{Goff} = 1,5 Ω	T_{vj} = 25°C T_{vj} = 125°C T_{vj} = 150°C	E_{off}

Ausgangskennlinienfeld IGBT-Wechselr. (typisch)
output characteristic IGBT-inverter (typical)
$I_C = f(V_{CE})$
T_{vj} = 150°C

C_{ies}		37,0		nF
C_{res}		2,05		nF

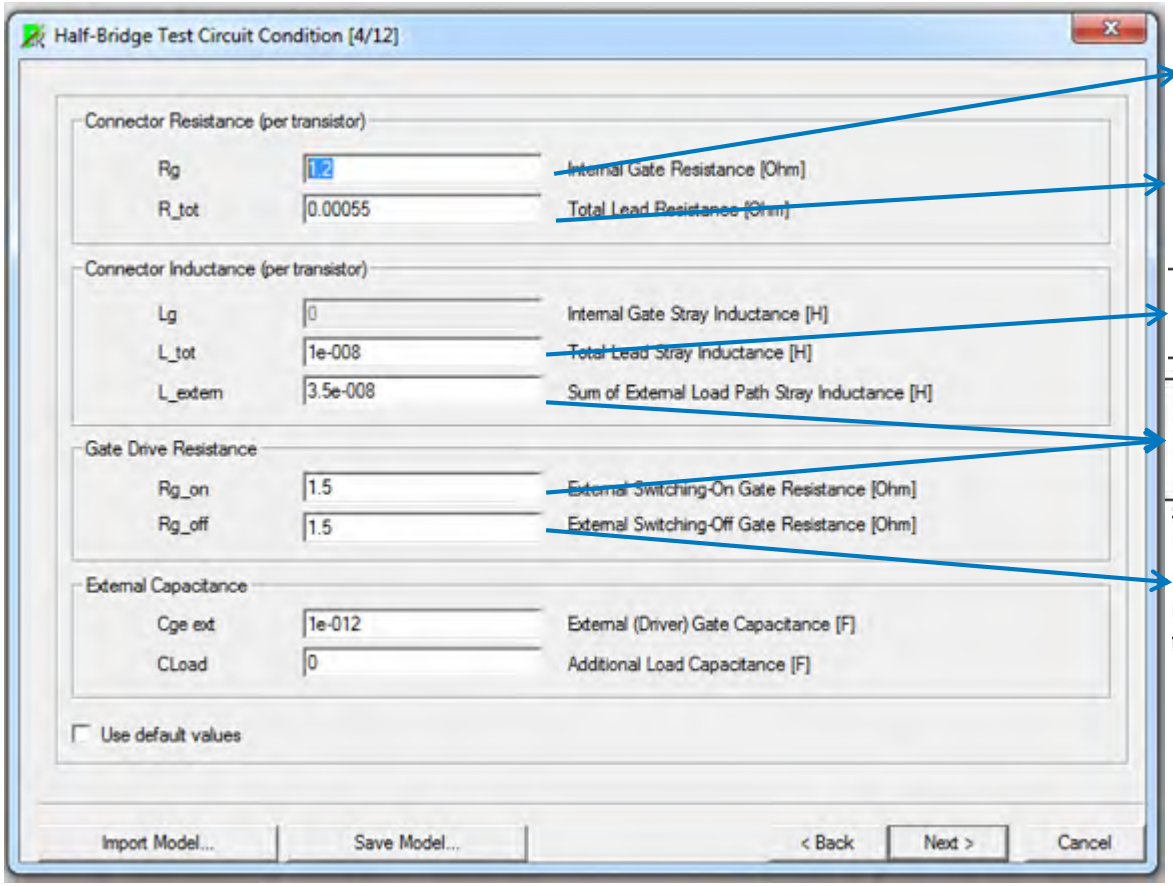
高级动态模型建模——Breakdown参数





$T_{vj\ max}$			175	°C

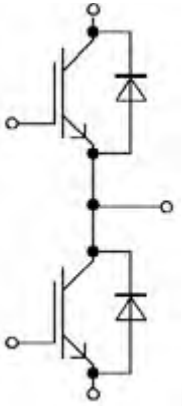
高级动态模型建模——测试电路参数



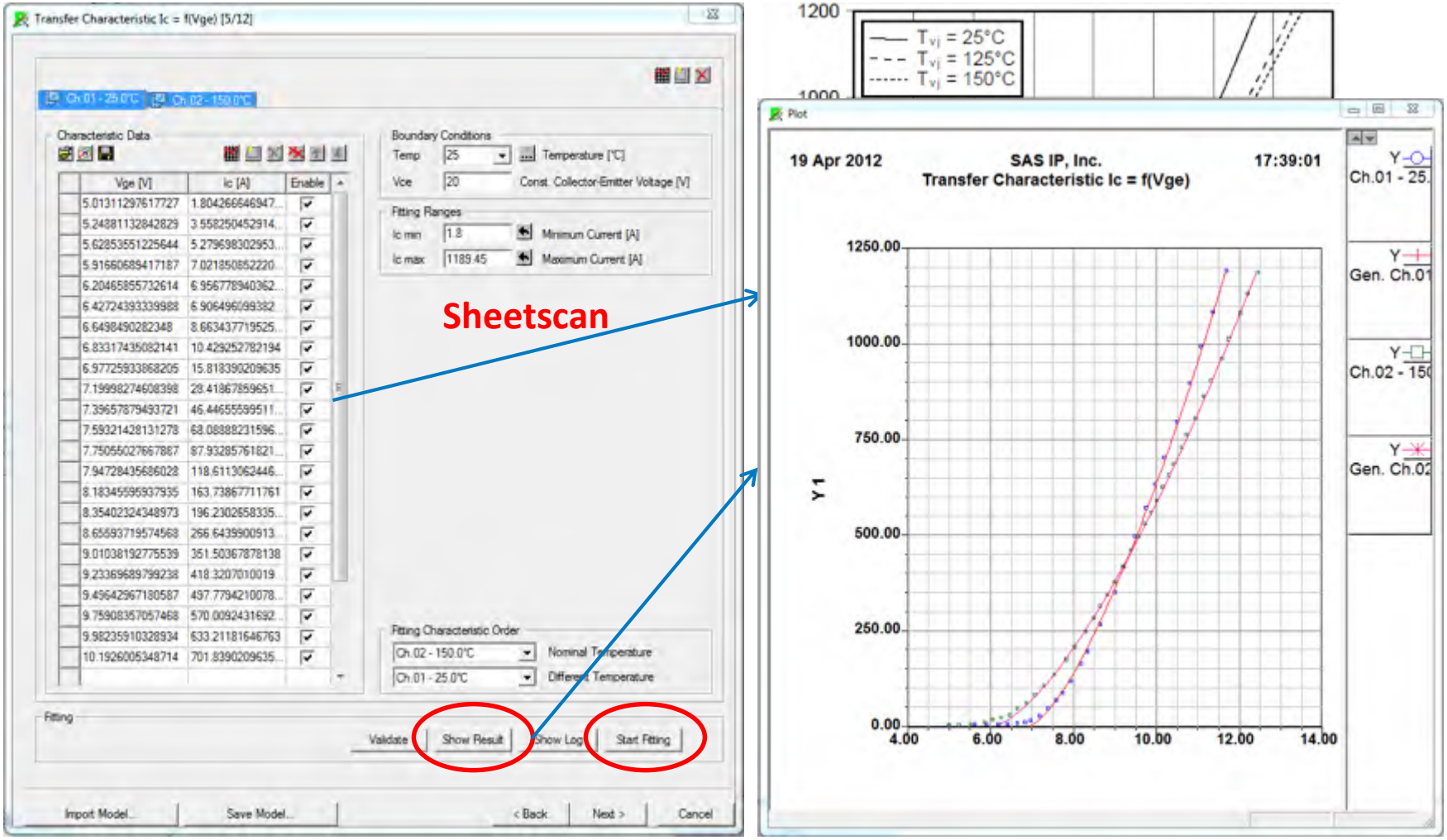
R_{Gint}		1,2		Ω
$R_{CC'+EE'}$		1,10		mΩ
L_{sCE}		20		nH

I_C = 600 A, V_{CE} = 600 V, L_S = 35 nH
V_{GE} = ±15 V, di/dt = 5100 A/µs (T_{vj}=150°C)
R_{Gon} = 1,5 Ω

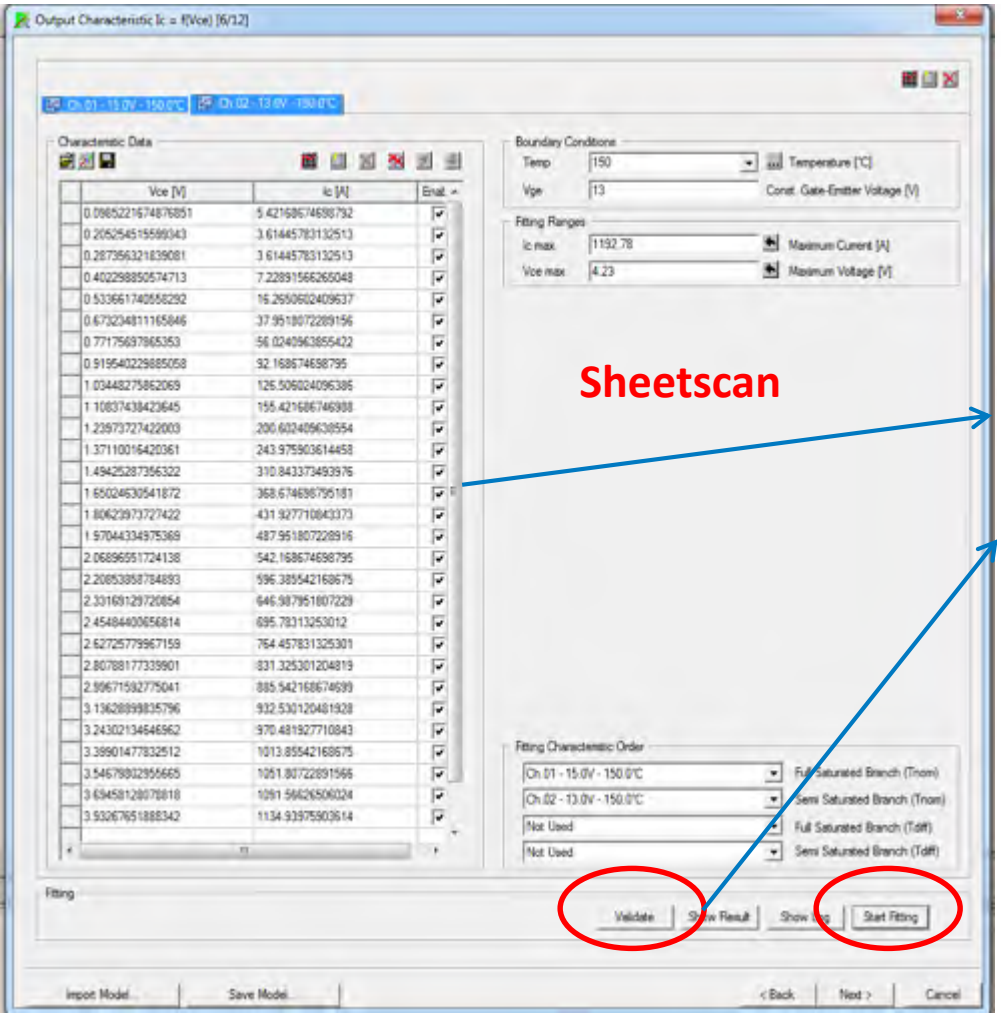
I_C = 600 A, V_{CE} = 600 V, L_S = 35 nH
V_{GE} = ±15 V, du/dt = 3700 V/µs (T_{vj}=150°C)
R_{Goff} = 1,5 Ω

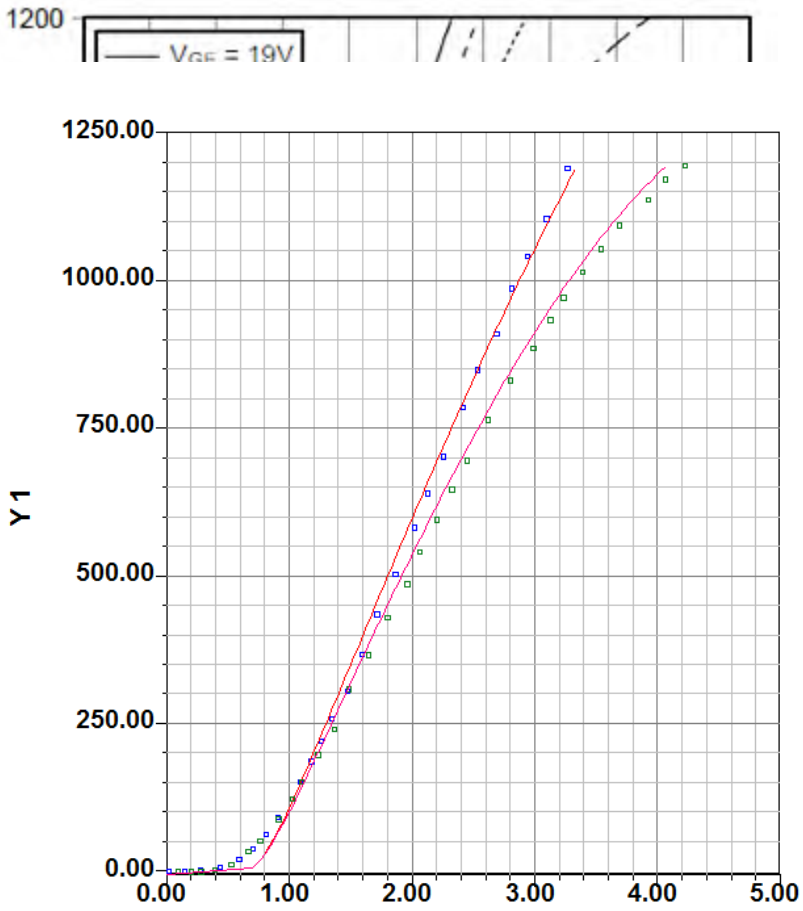


高级动态模型建模——Transfer参数

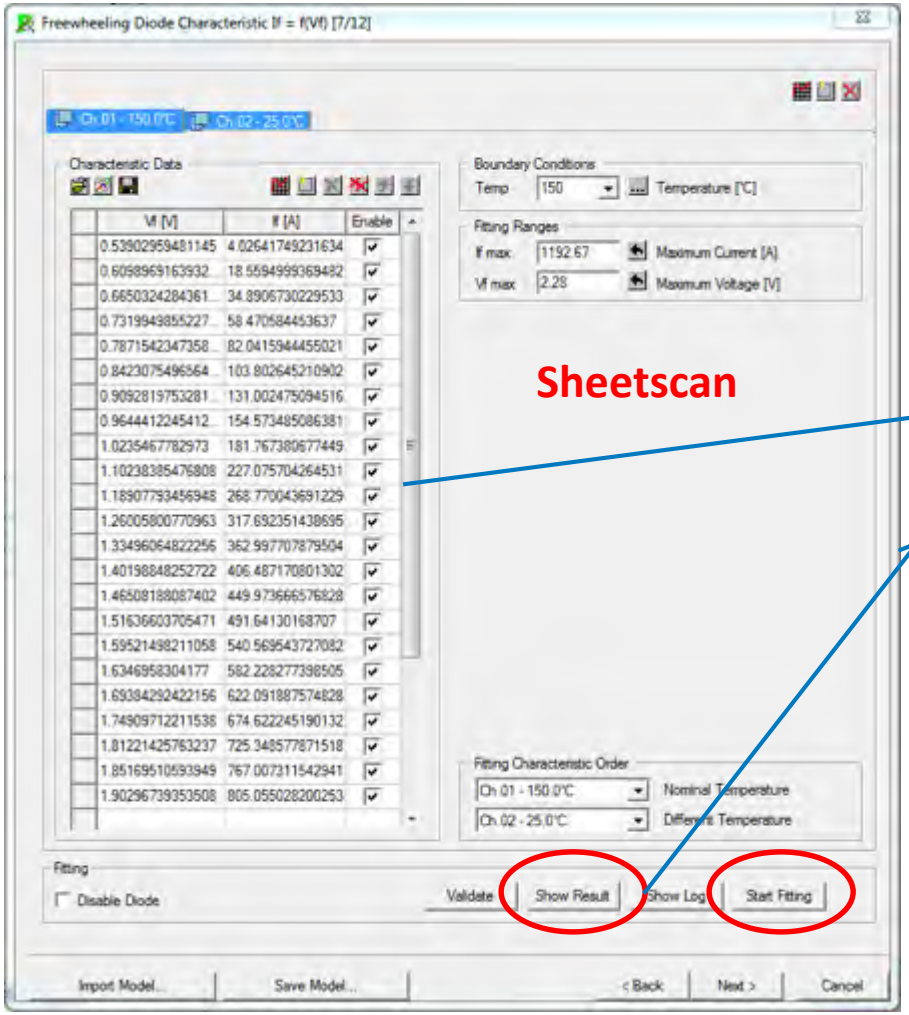


高级动态模型建模——Output曲线

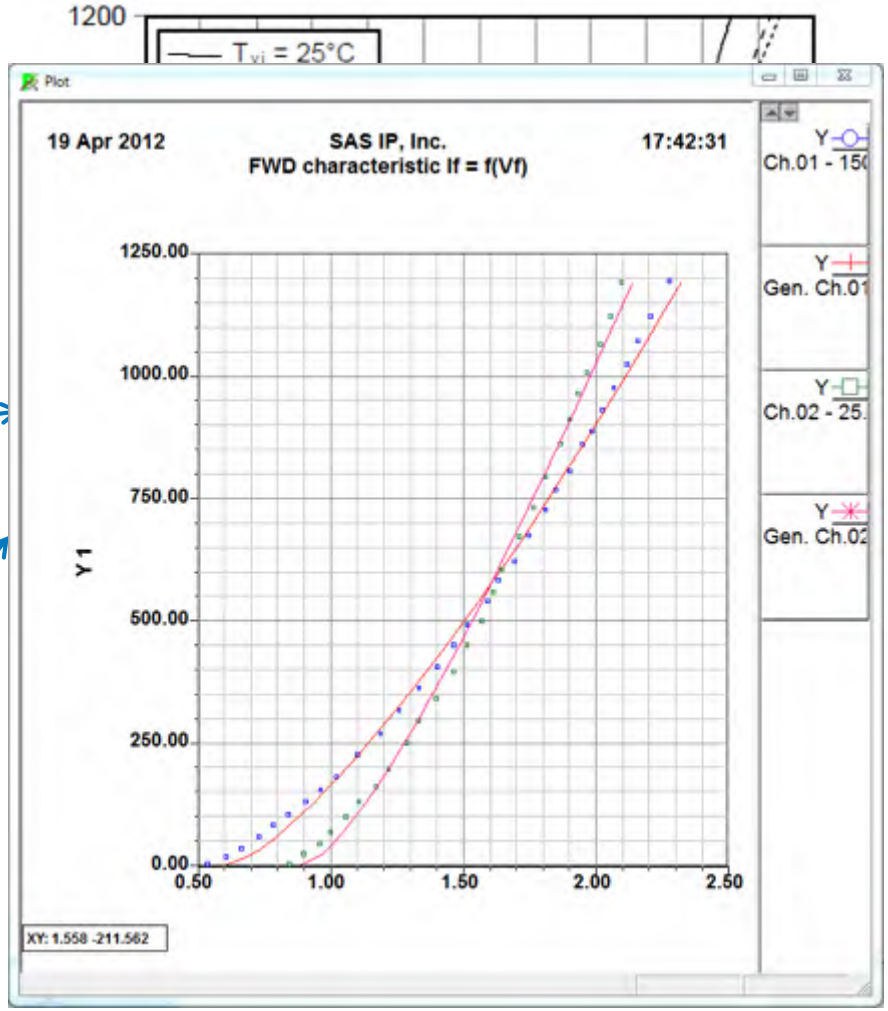




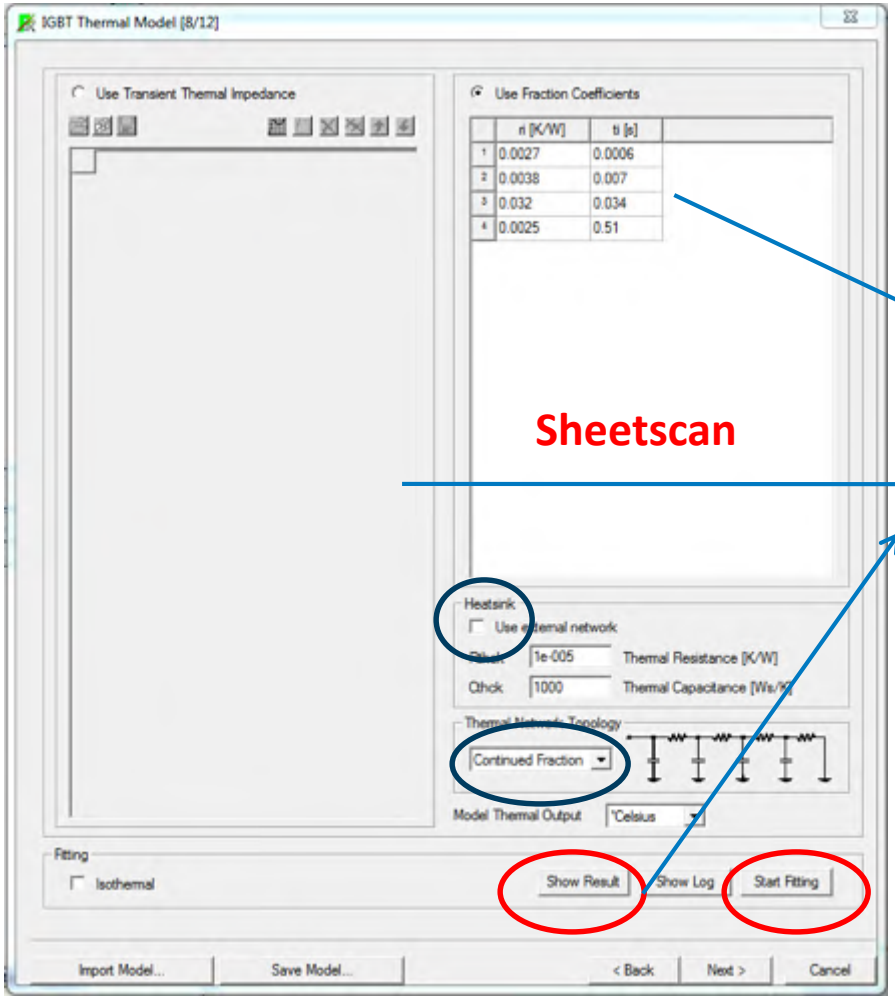
高级动态模型建模——二极管Forward



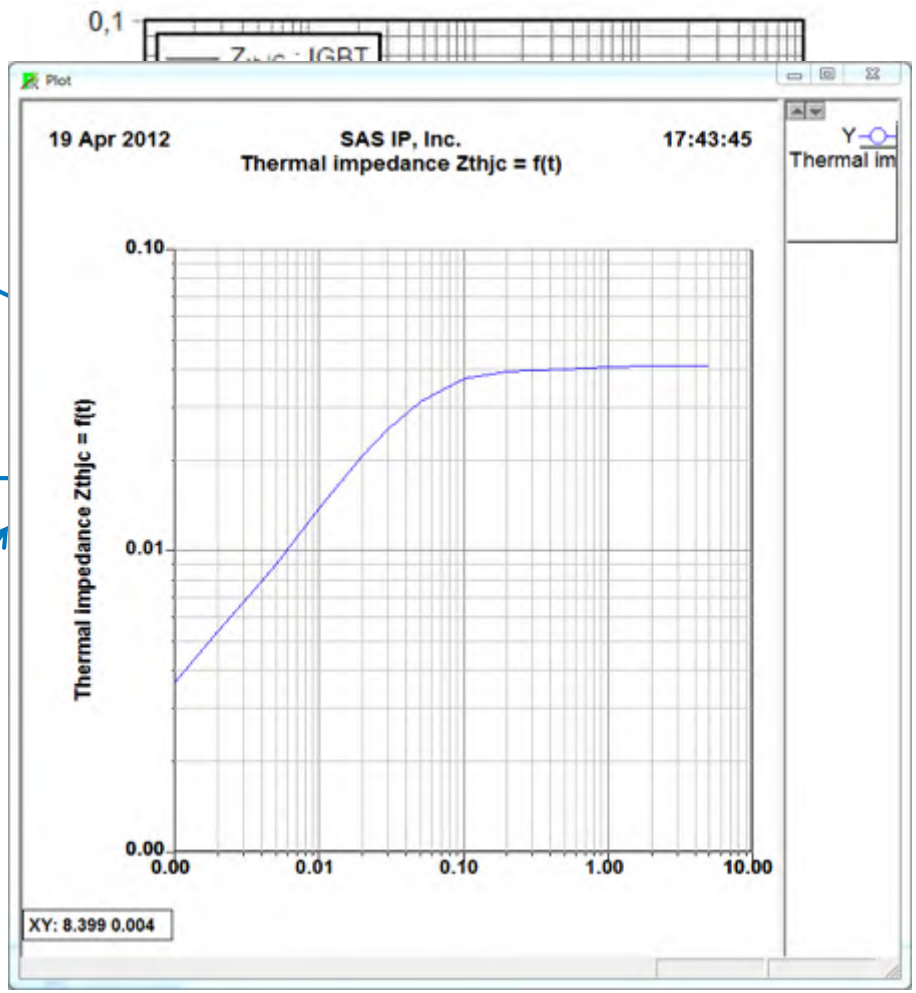
Sheetscan



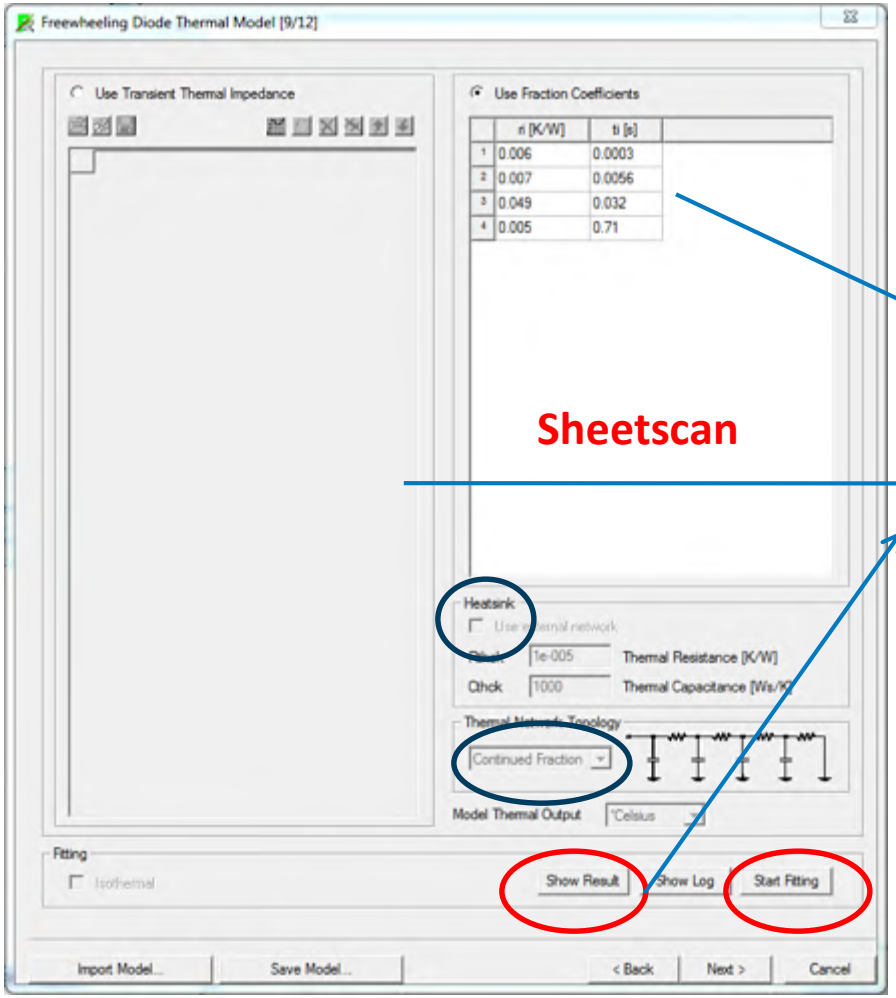
高级动态模型建模——IGBT Thermal



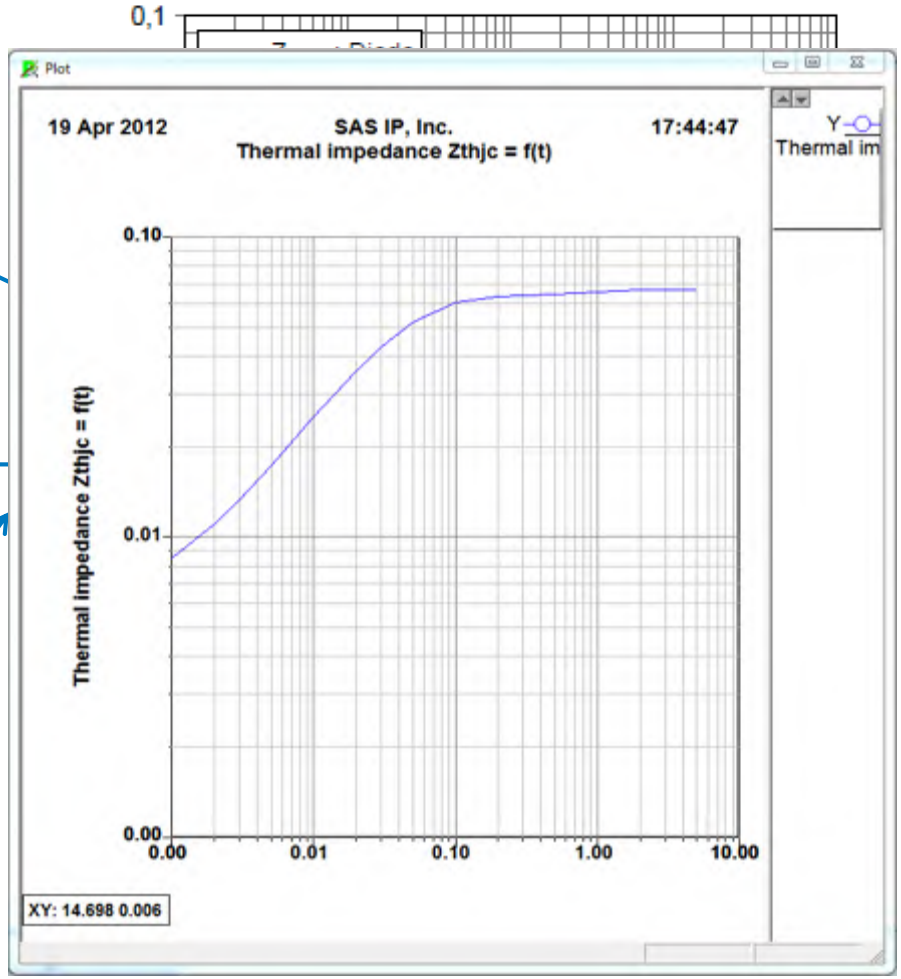
Sheetscan



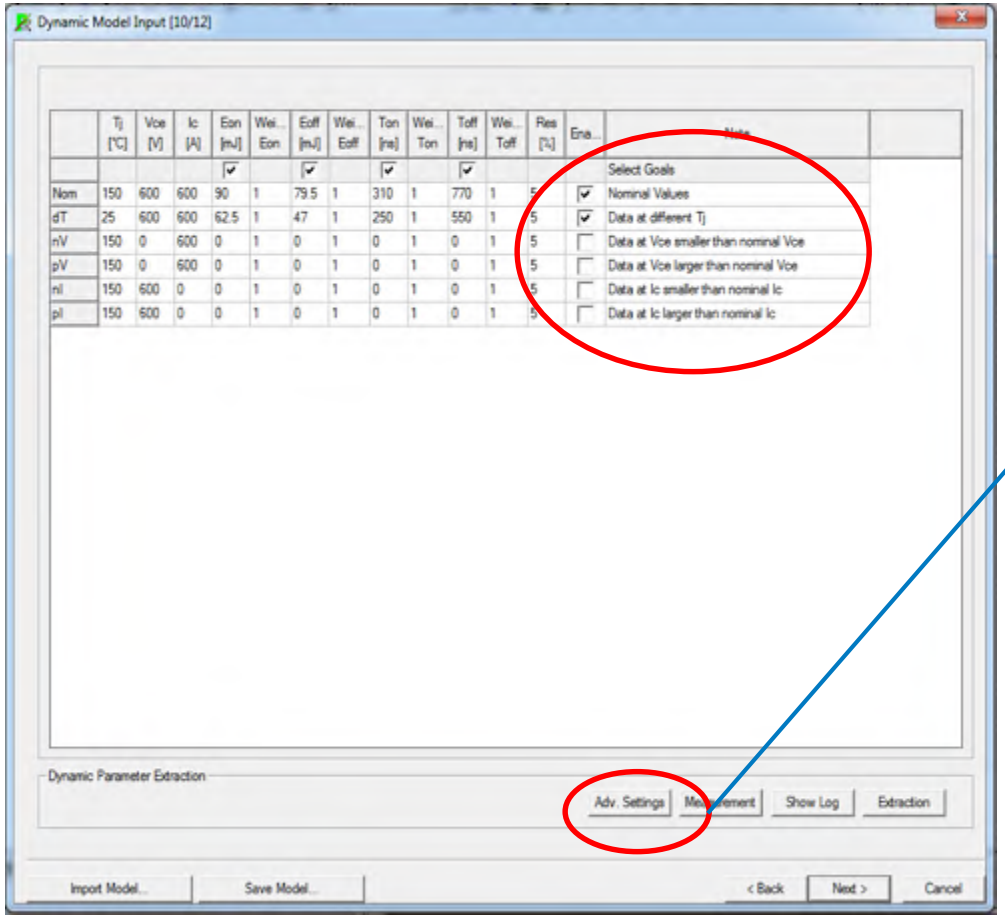
高级动态模型建模——Diode Thermal

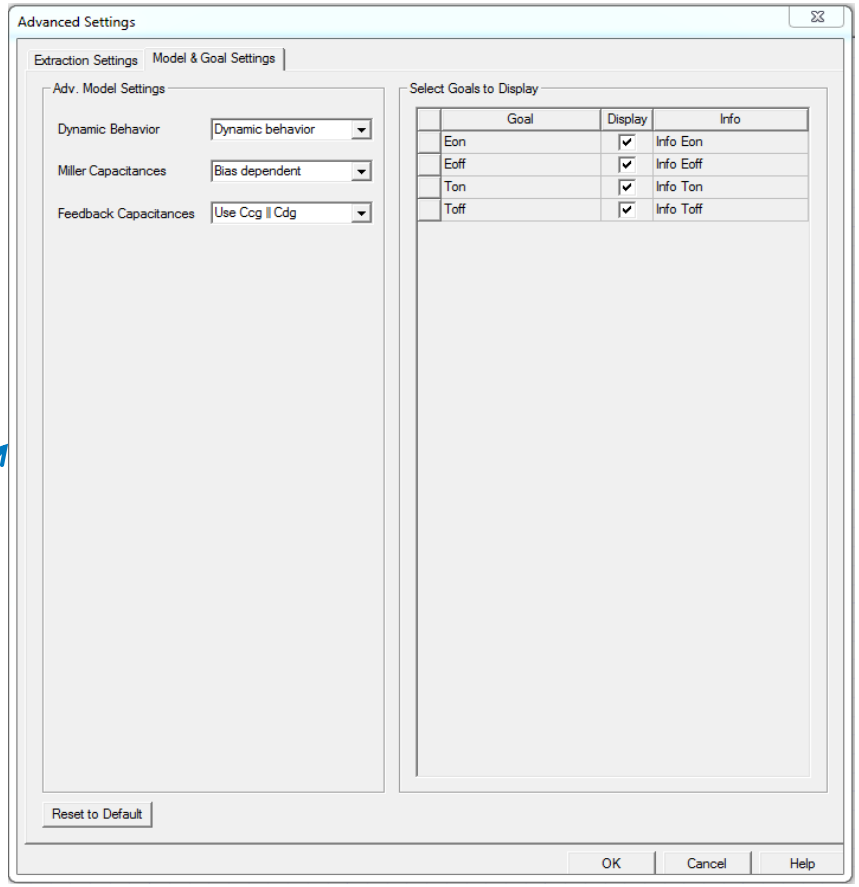


Sheetscan

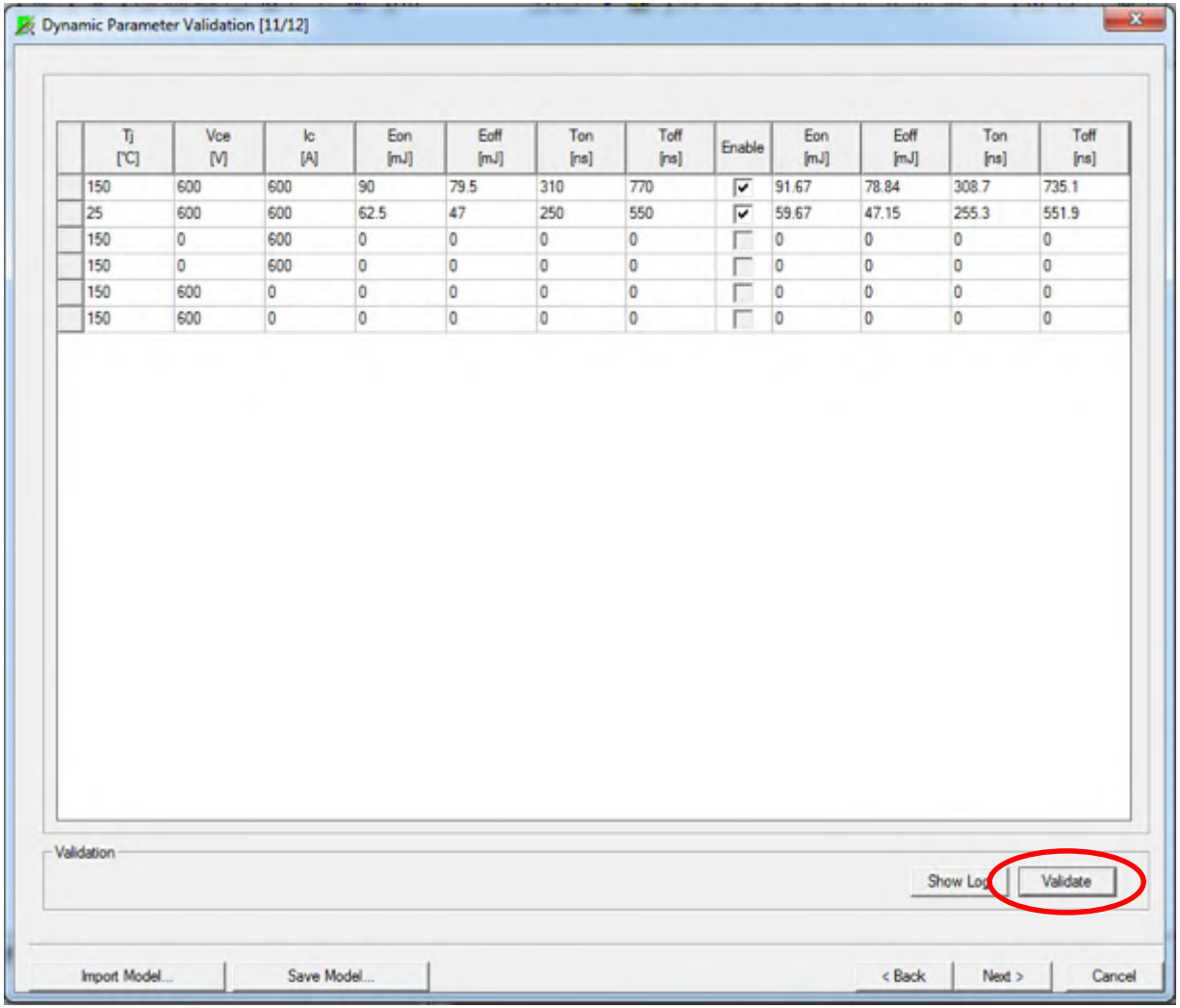


高级动态模型建模——定义抽取工况

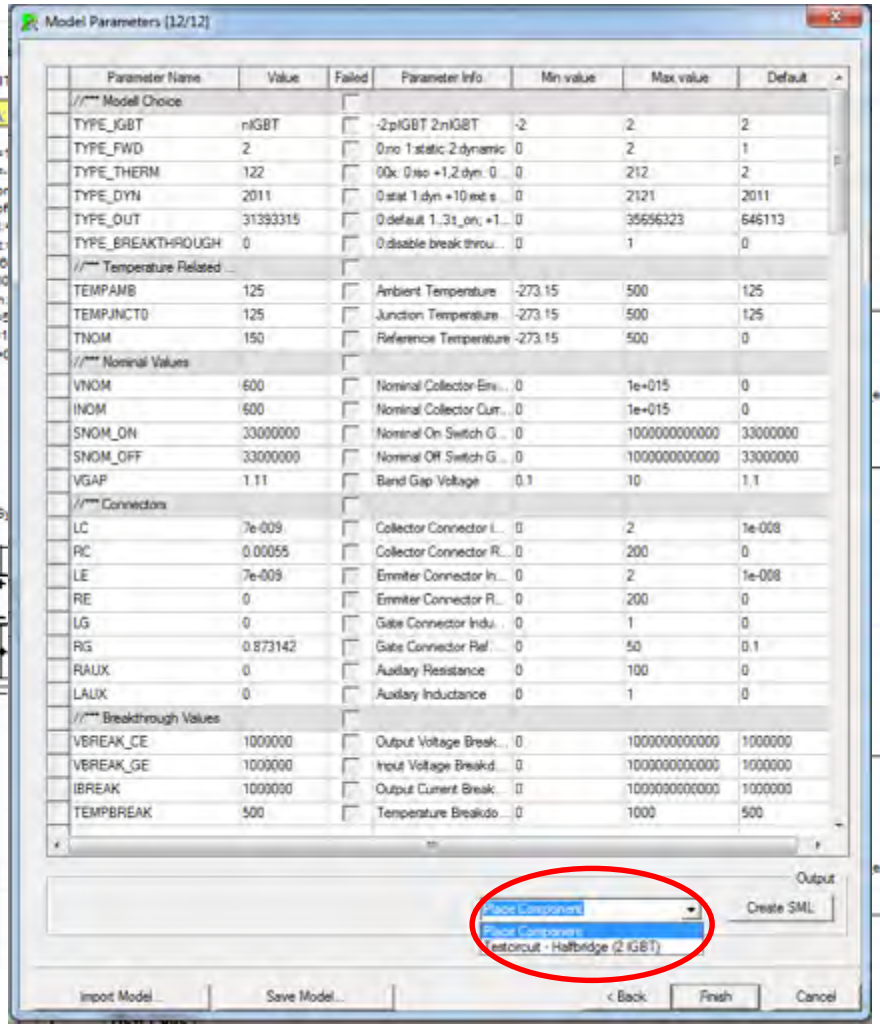


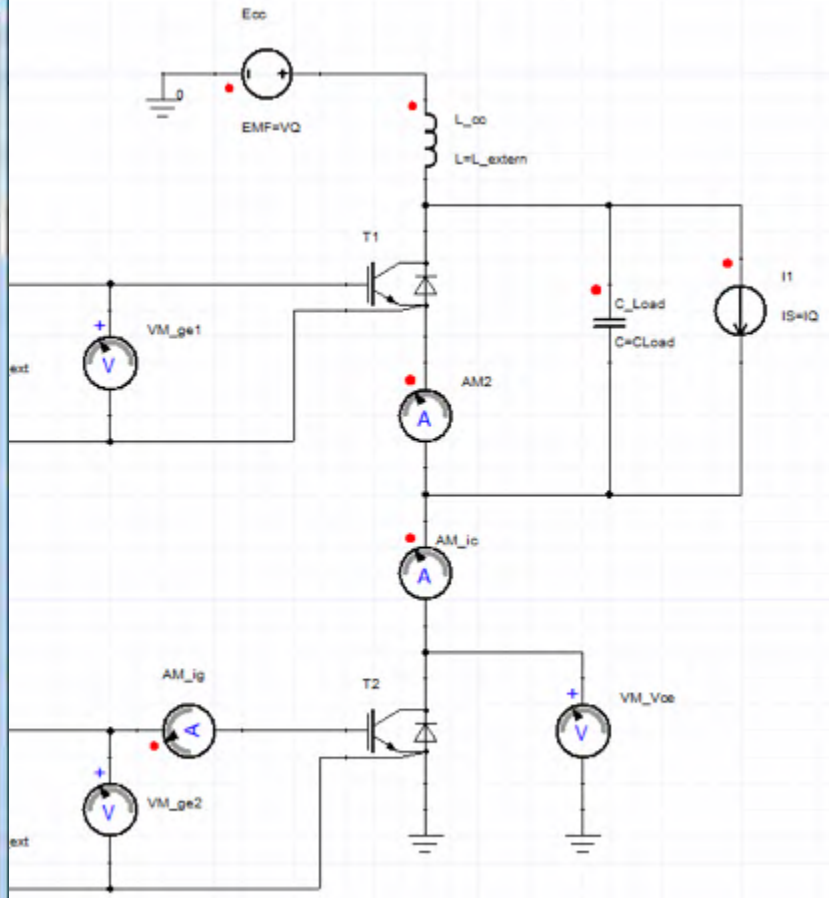


高级动态模型建模——抽取结果确认



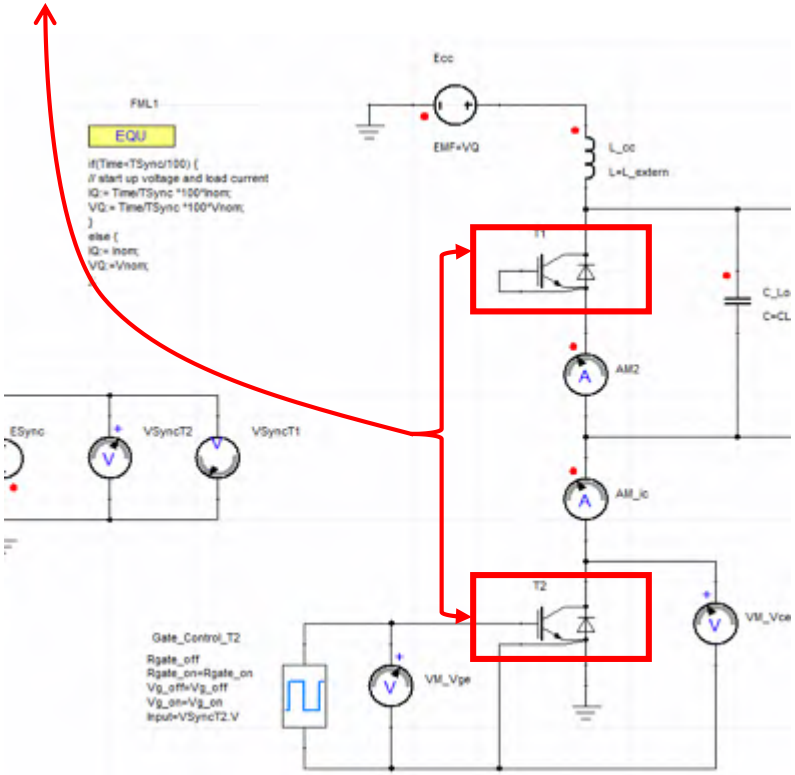
高级动态模型建模——建模完成

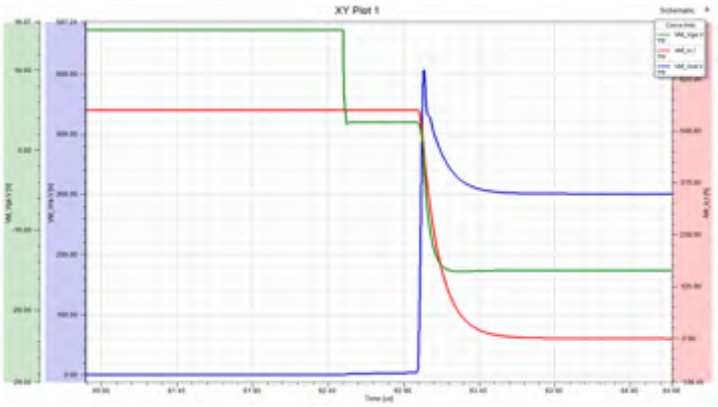




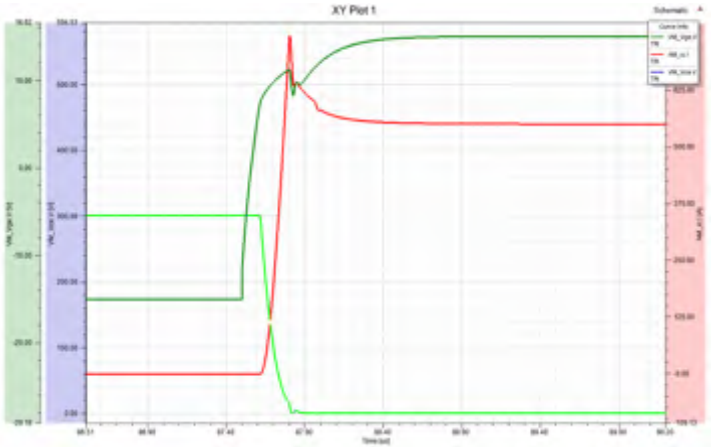
自动创建半桥测试电路

FS800R07A2E3特征化建模高级动态模型



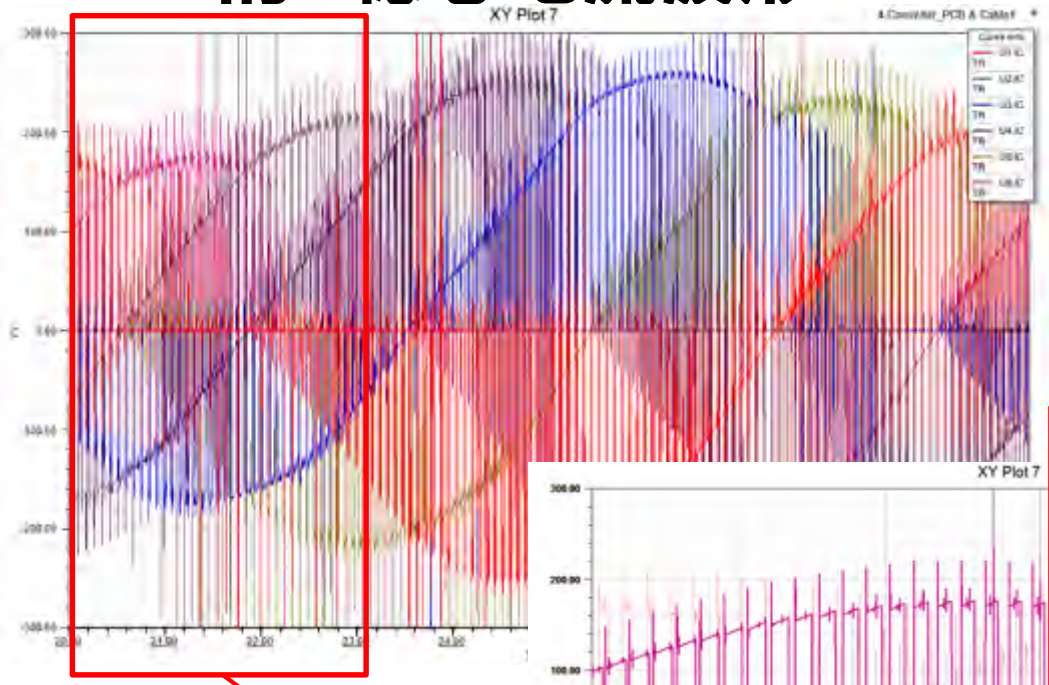


关断电压

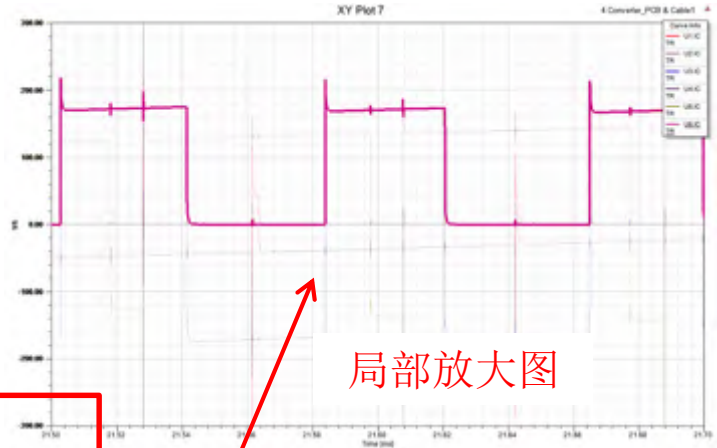


开通电流

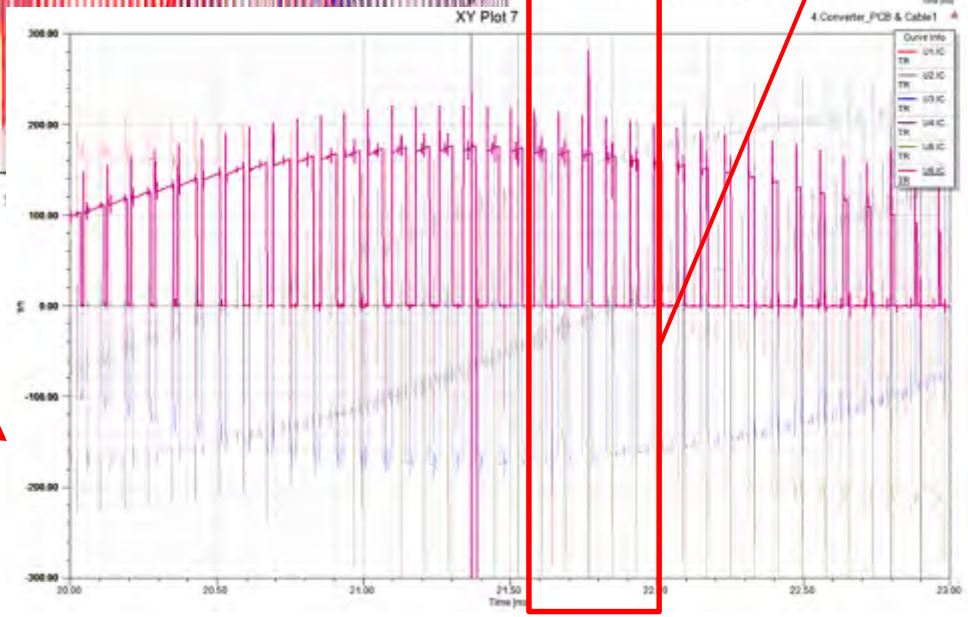
IGBT的Ic稳态电流波形



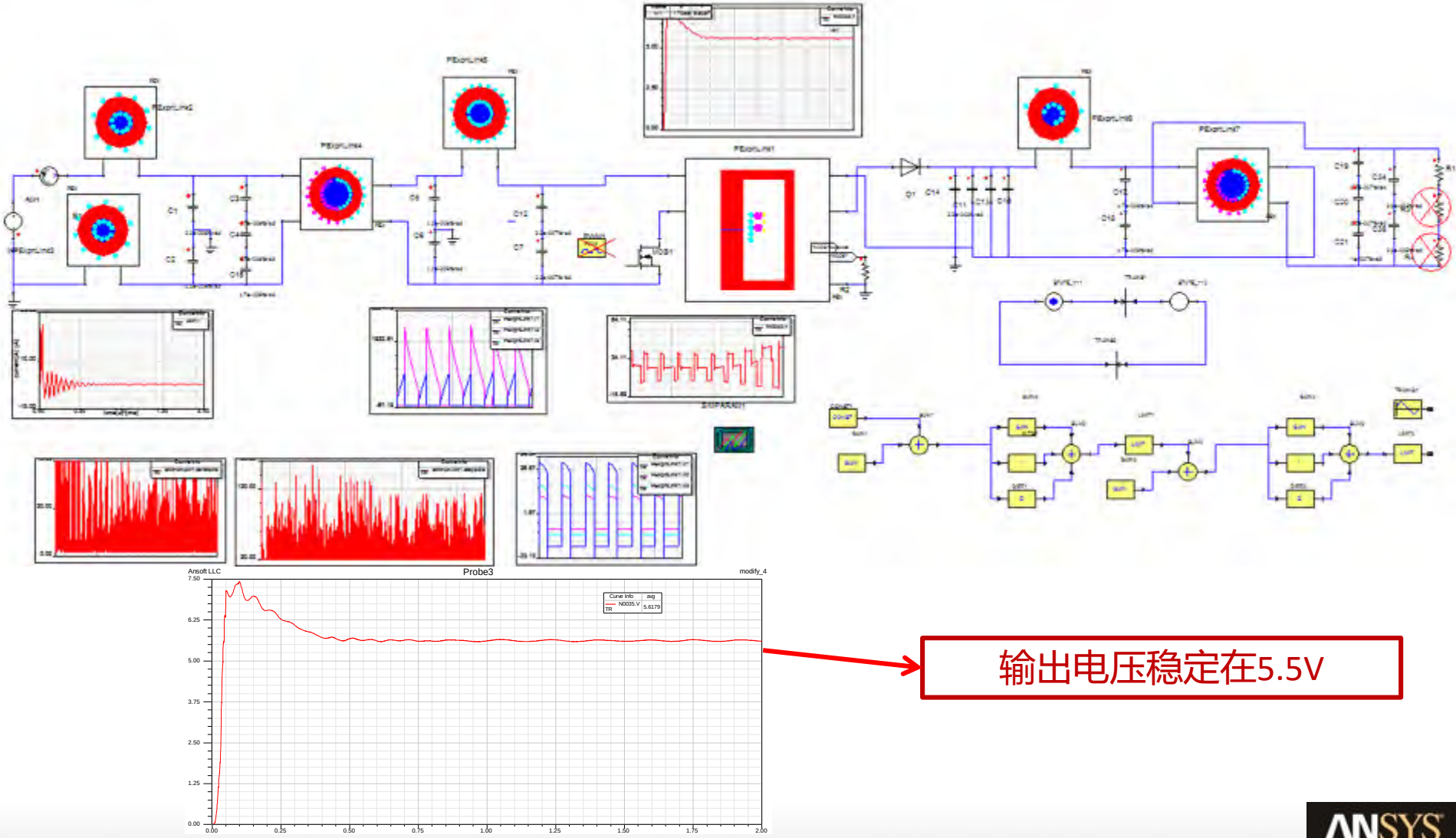
局部放大图



局部放大图

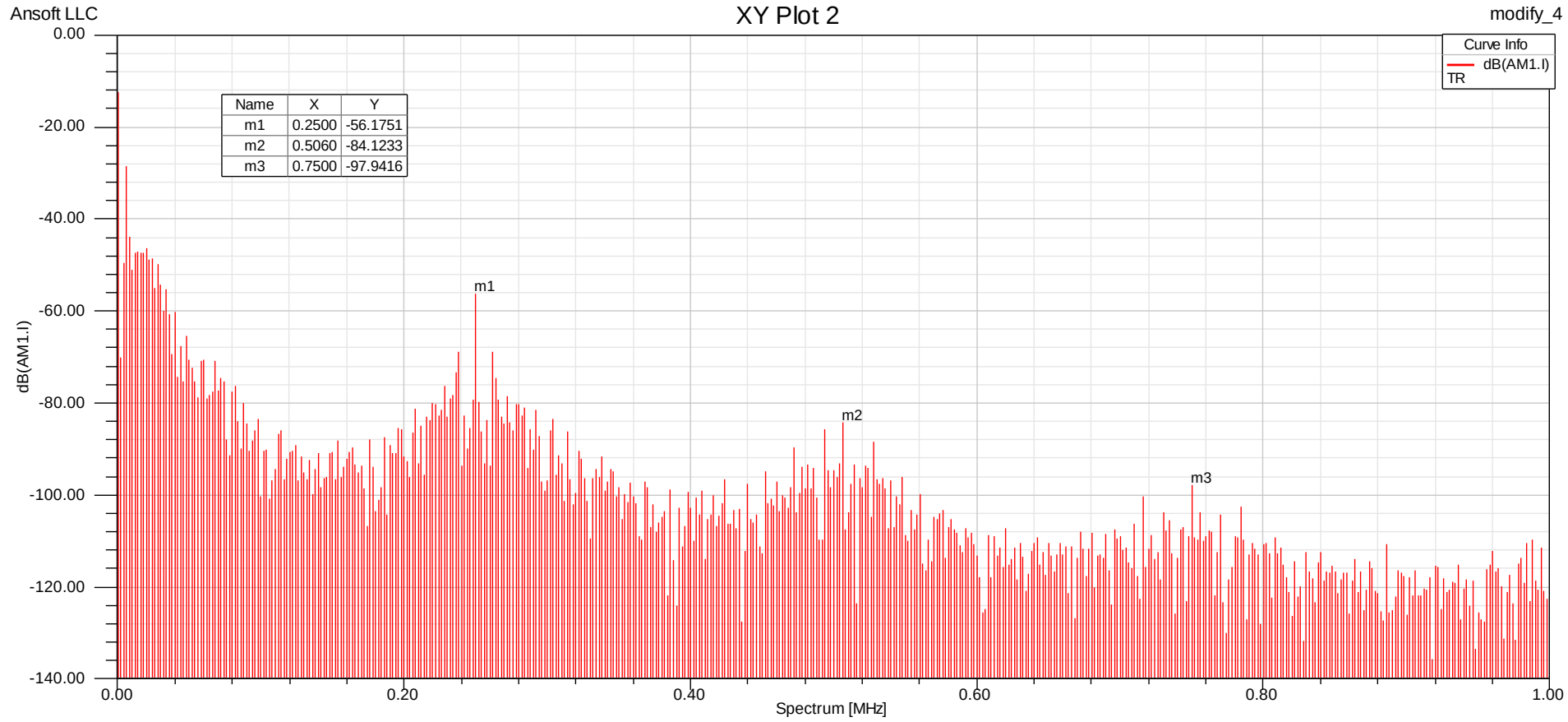


基于Simplorer集PExprt模型于一体的电路传导干扰

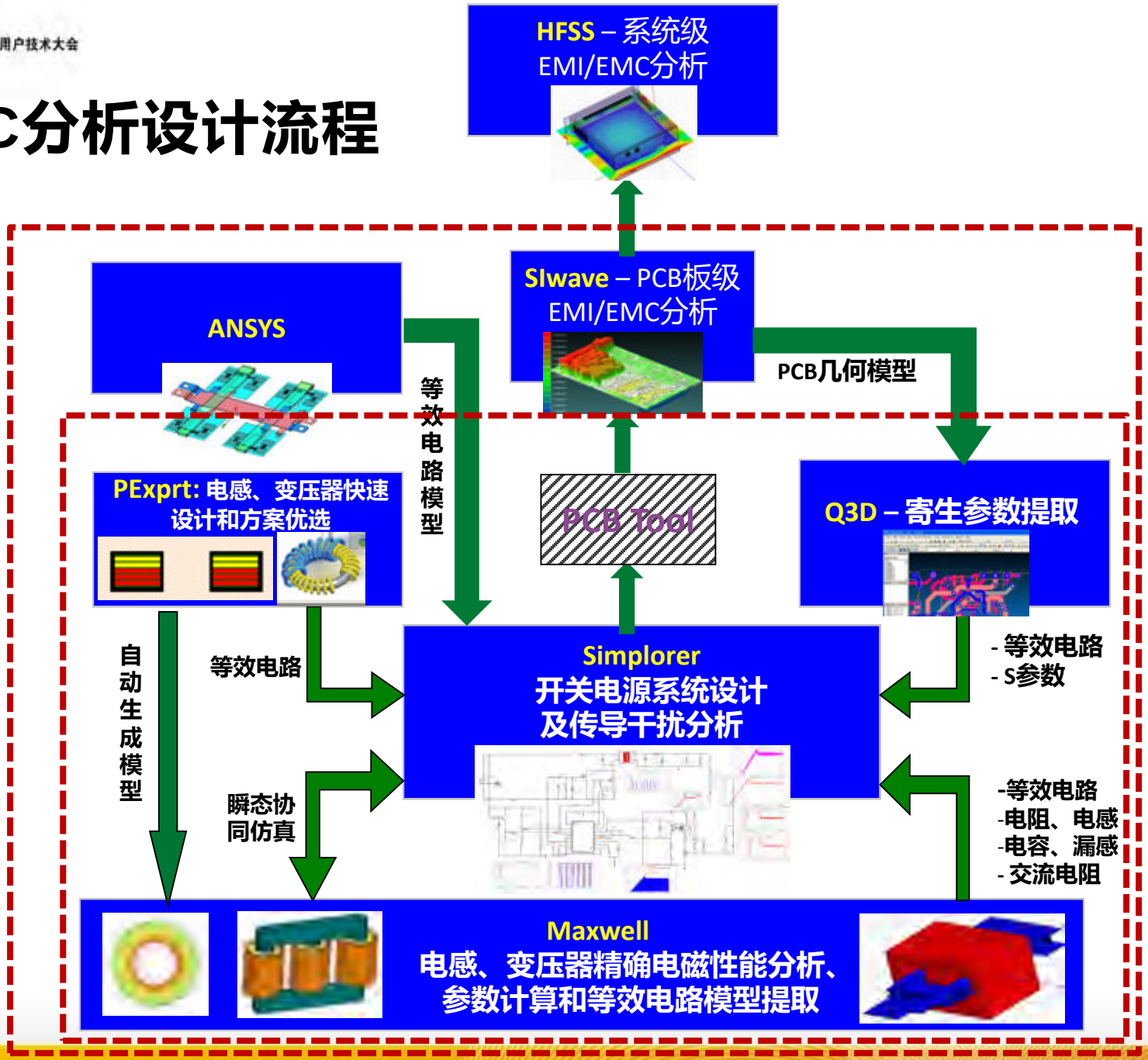


输出电压稳定在5.5V

基于Simplorer的、集PExprt模型于一体的电路传导干扰



EMC分析设计流程


HFSS – 系统级
EMI/EMC分析
SIwave – PCB板级
EMI/EMC分析
ANSYS
PCB几何模型
等效电路模型
PExprt: 电感、变压器快速设计和方案优选
PCB Tool
Q3D – 寄生参数提取
自动生成模型
等效电路
Simplorer
开关电源系统设计
及传导干扰分析
- 等效电路
- S参数
瞬态协同仿真
-等效电路
-电阻、电感
-电容、漏感
- 交流电阻
Maxwell
电感、变压器精确电磁性能分析、
参数计算和等效电路模型提取

感谢聆听