Device Modeling Report

COMPONENTS: Power MOSFET (Model parameter)
PART NUMBER: TPCP8402
MANUFACTURER: TOSHIBA
Body Diode (Model parameter) / ESD Protection Diode
Remark: Silicon N&P Channel MOS Type

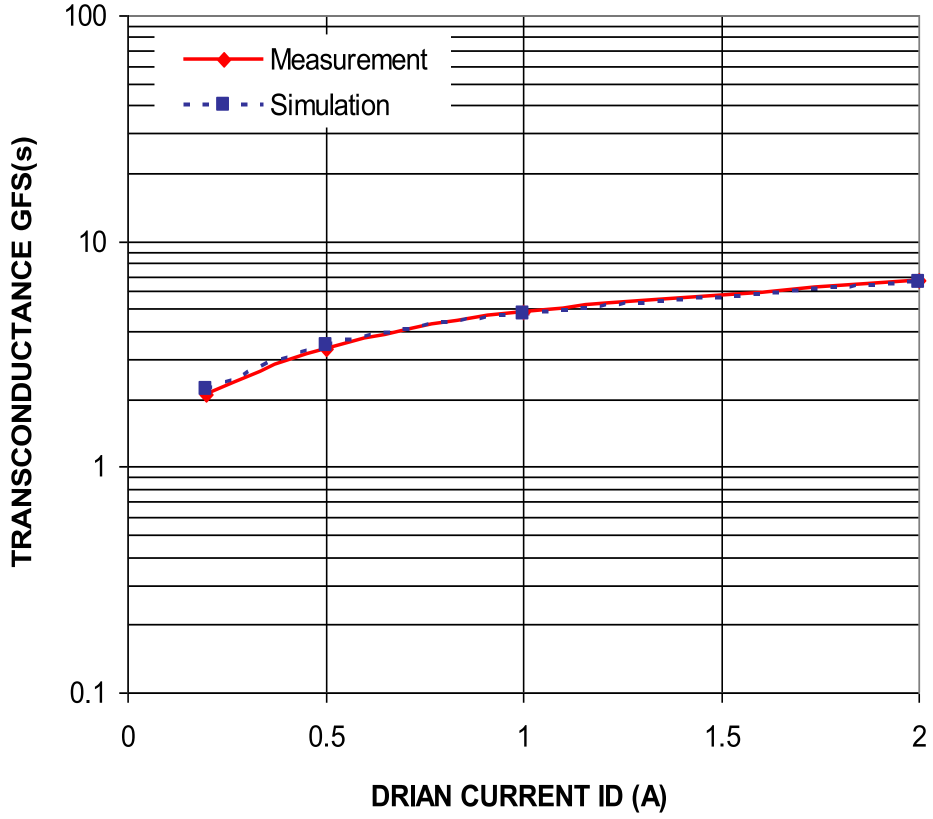
Bee Technologies Inc.

MOSFET MODEL

PSpice model parameter	Model description
LEVEL	
L	Channel Length
W	Channel Width
KP	Transconductance
RS	Source Ohmic Resistance
RD	Ohmic Drain Resistance
VTO	Zero-bias Threshold Voltage
RDS	Drain-Source Shunt Resistance
TOX	Gate Oxide Thickness
CGSO	Zero-bias Gate-Source Capacitance
CGDO	Zero-bias Gate-Drain Capacitance
CBD	Zero-bias Bulk-Drain Junction Capacitance
MJ	Bulk Junction Grading Coefficient
PB	Bulk Junction Potential
FC	Bulk Junction Forward-bias Capacitance Coefficient
RG	Gate Ohmic Resistance
IS	Bulk Junction Saturation Current
N	Bulk Junction Emission Coefficient
RB	Bulk Series Resistance
PHI	Surface Inversion Potential
GAMMA	Body-effect Parameter
DELTA	Width effect on Threshold Voltage
ETA	Static Feedback on Threshold Voltage
THETA	Mobility Modulation
KAPPA	Saturation Field Factor
VMAX	Maximum Drift Velocity of Carriers
XJ	Metallurgical Junction Depth
UO	Surface Mobility

P-Channel Model
Transconductance Characteristic

Circuit Simulation Result

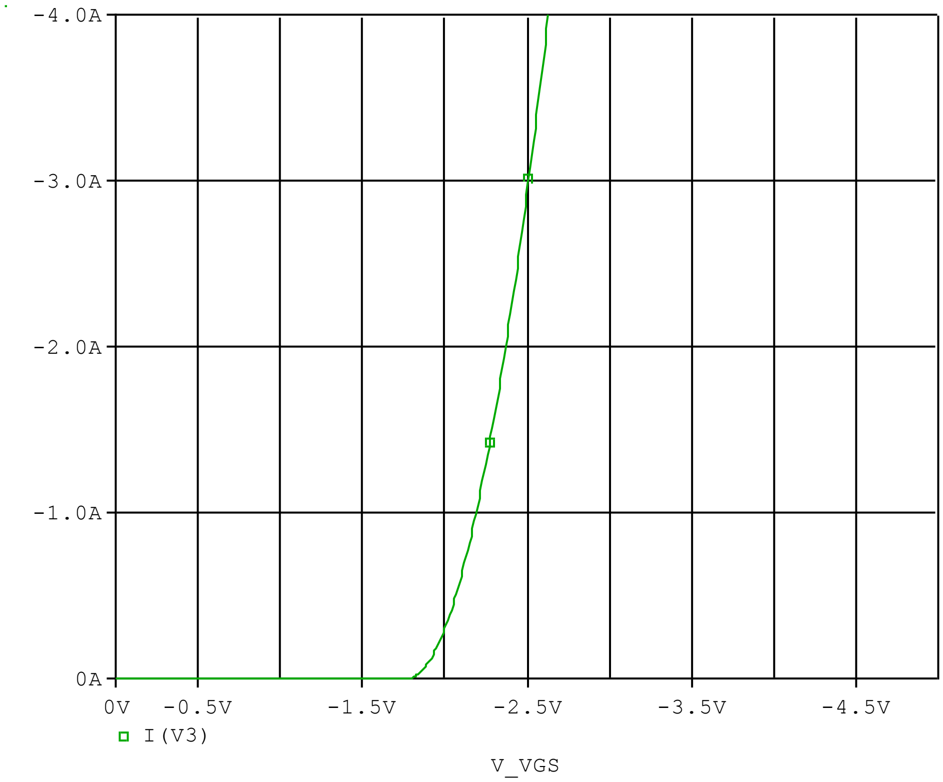


Comparison table

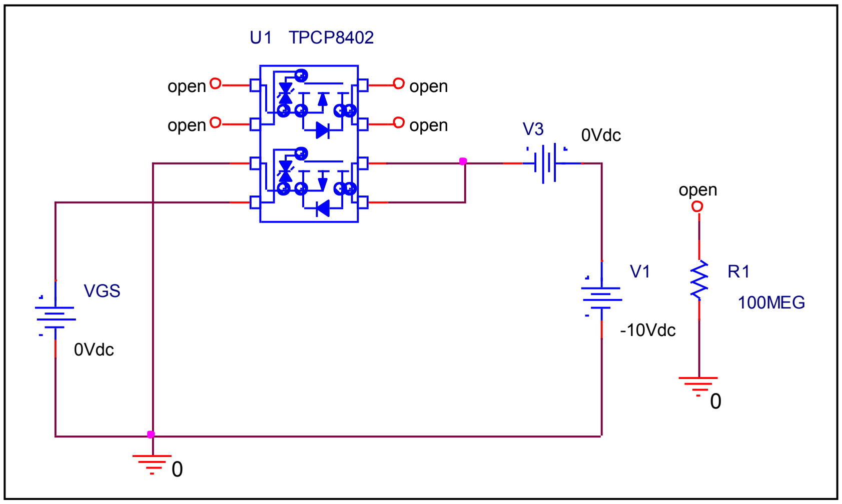
- Id(A)	gfs		Error(%)
	Measurement	Simulation	
0.2	2.11	2.20	4.51
0.5	3.33	3.45	3.50
1	4.83	4.78	-1.06
2	6.67	6.62	-0.75

P-Channel Model
Vgs-Id Characteristic

Circuit Simulation result

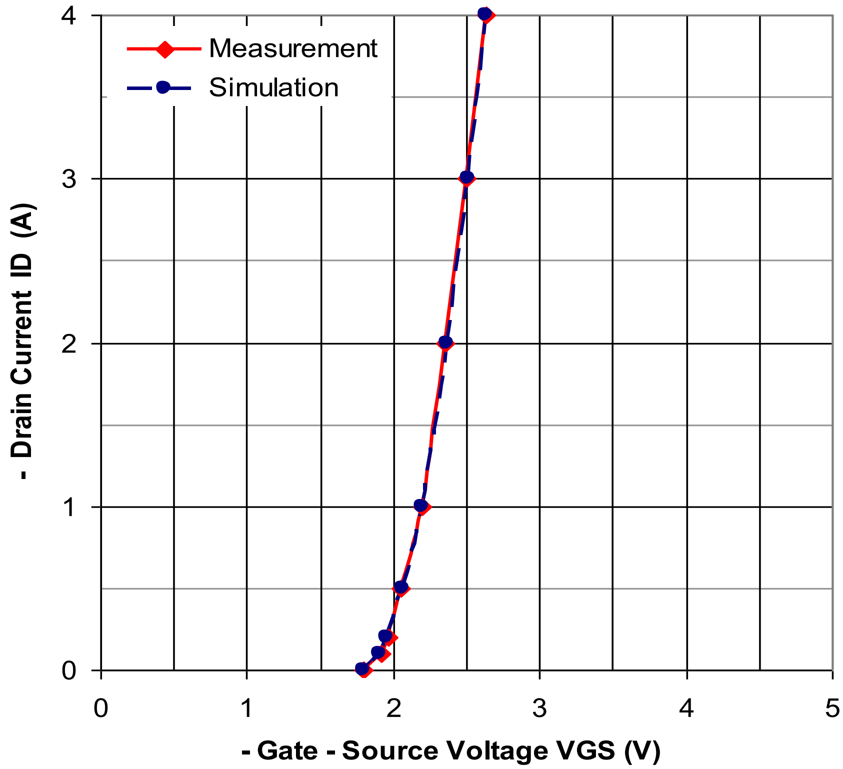


Evaluation circuit



P-Channel Model
Comparison Graph

Circuit Simulation Result

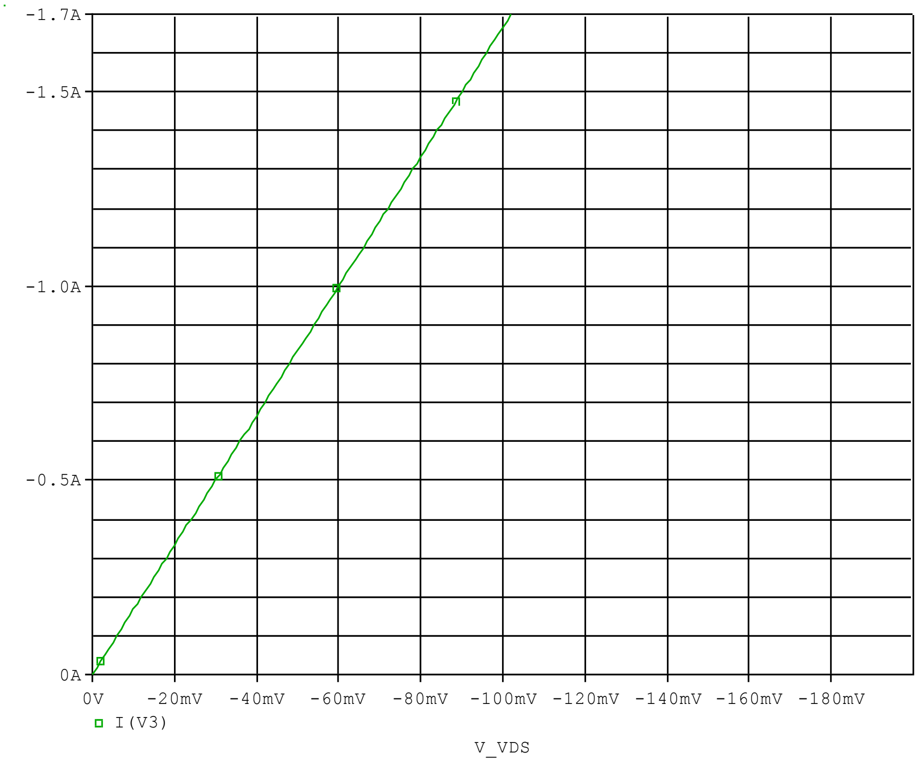


Simulation Result

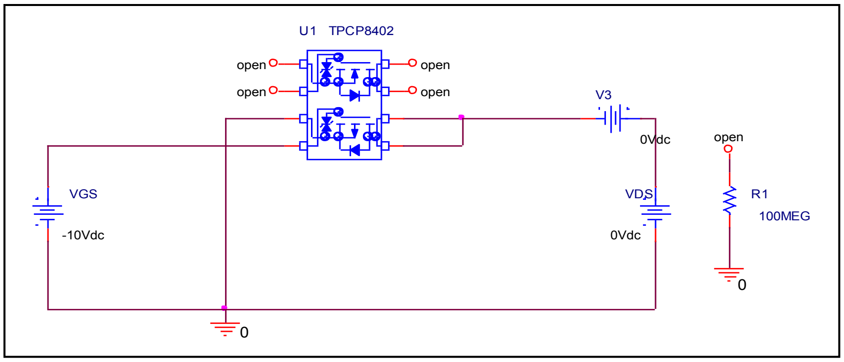
$-I_D$(A)	$-V_{GS}$(V)		Error (%)
	Measurement	Simulation	
0	1.8000	1.8000	0.0000
0.1	1.9200	1.9036	-0.8542
0.2	1.9700	1.9580	-0.6091
0.5	2.0500	2.0670	0.8293
1	2.2000	2.1914	-0.3909
2	2.3500	2.3705	0.8723
3	2.5000	2.5104	0.4160
4	2.6300	2.6300	0.0000

P-Channel Model
Rds(on) Characteristic

Circuit Simulation result



Evaluation circuit

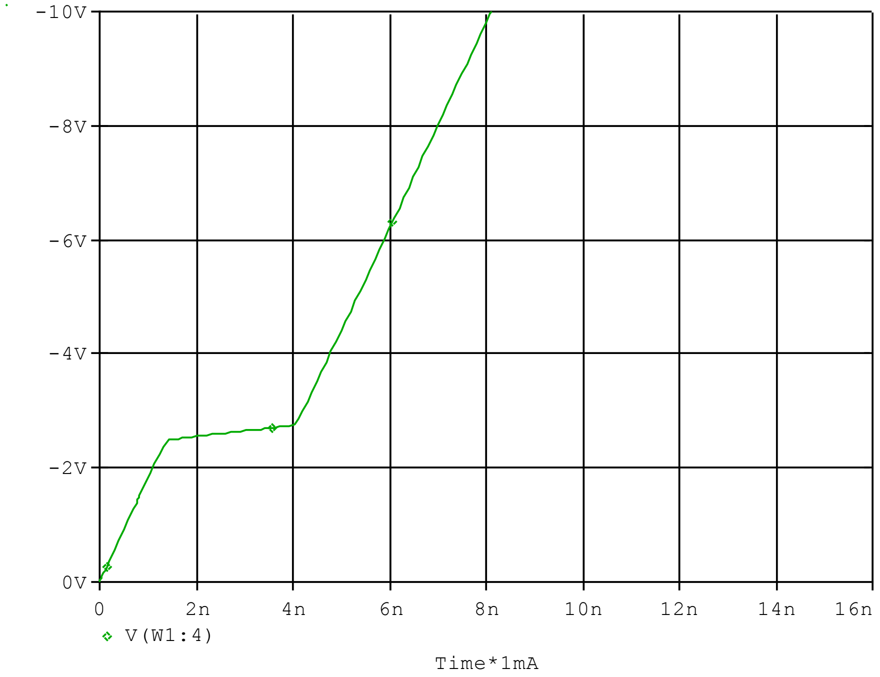


Simulation Result

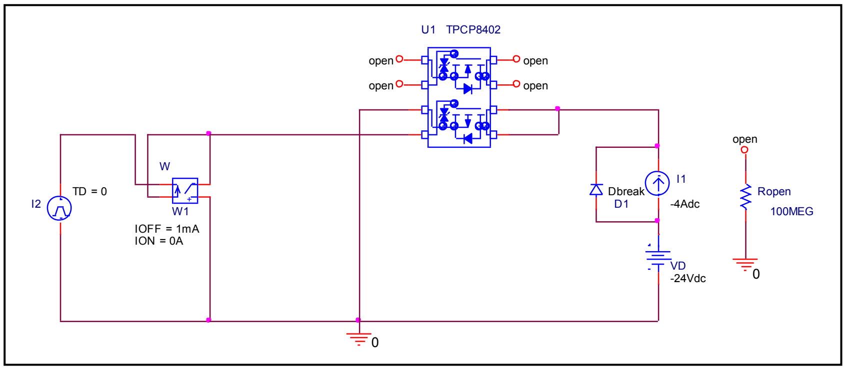
I_D=-1.7A, V_{GS}=-10V	Measurement		Simulation		Error (%)
R_{DS} (on)	60	mΩ	60	mΩ	0.000

P-Channel Model
Gate Charge Characteristic

Circuit Simulation result



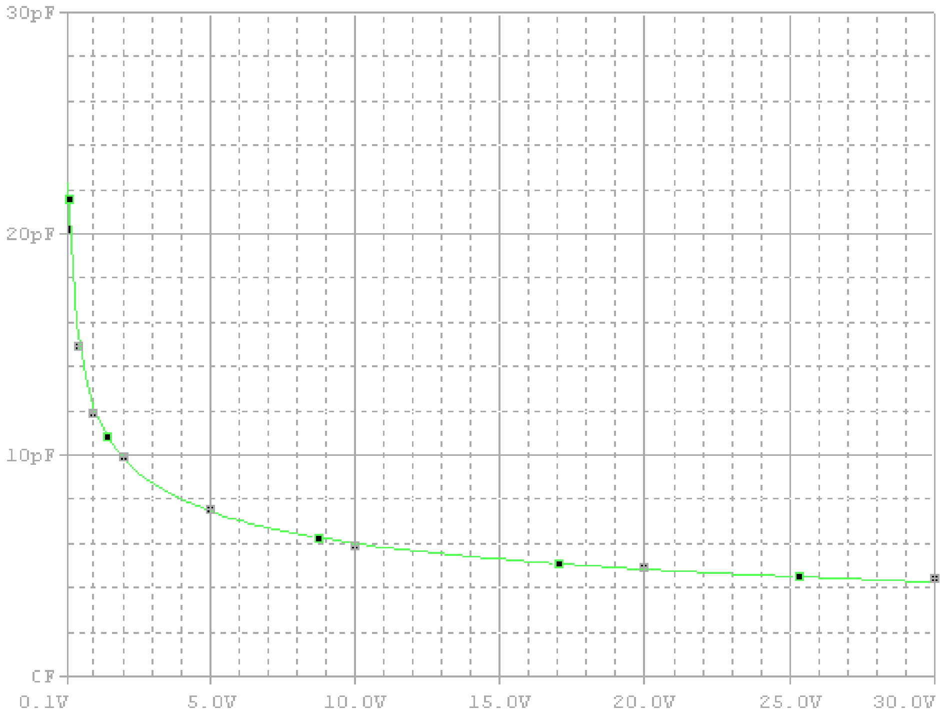
Evaluation circuit



Simulation Result

V_{DD}=-24V,I_D=-3.4A	Measurement		Simulation		Error (%)
Qgs	1.400	nC	1.4074	nC	0.529
Qgd	2.700	nC	2.6790	nC	-0.778
Qg	14.000	nC	8.1066	nC	-42.096

P-Channel Model
Capacitance Characteristic

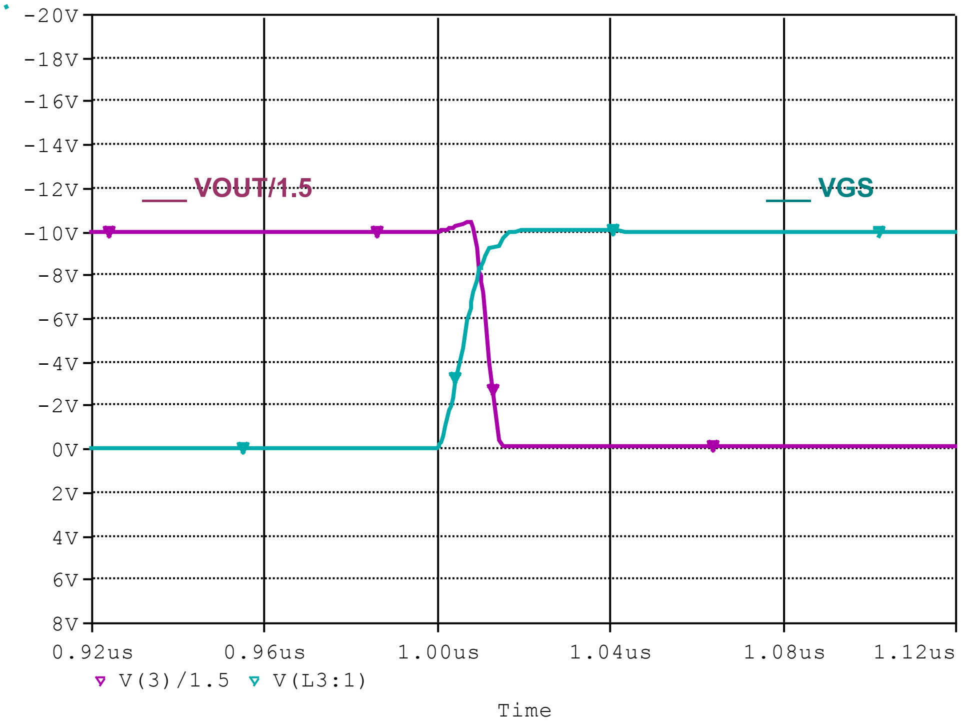


Simulation Result

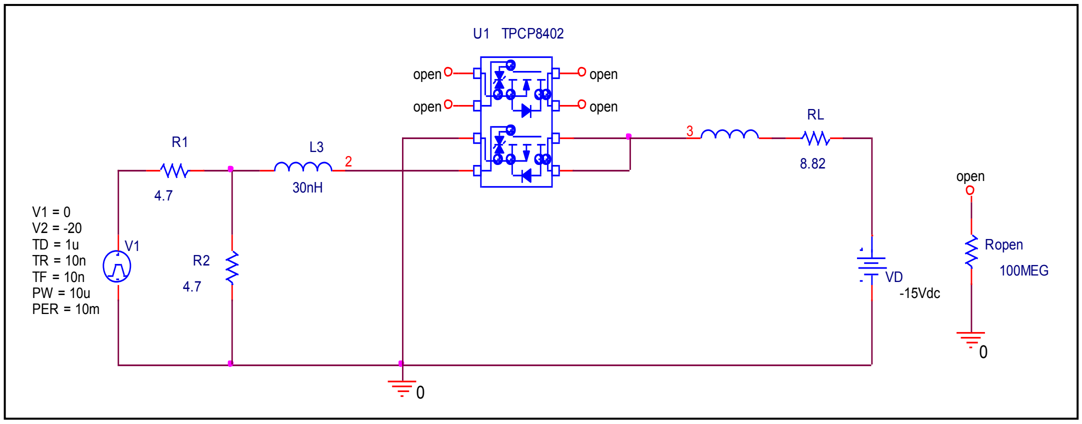
- V_{DS}(V)	Cbd(pF)		Error(%)
	Measurement	Simulation	
0.5	15.000	15.051	0.340
1	12.000	12.026	0.216
2	10.000	10.187	1.872
5	7.600	7.599	-0.014
10	6.000	6.124	2.070
20	5.000	5.059	1.175
30	4.500	4.566	1.463

P-Channel Model
Switching Time Characteristic

Circuit Simulation result



Evaluation circuit

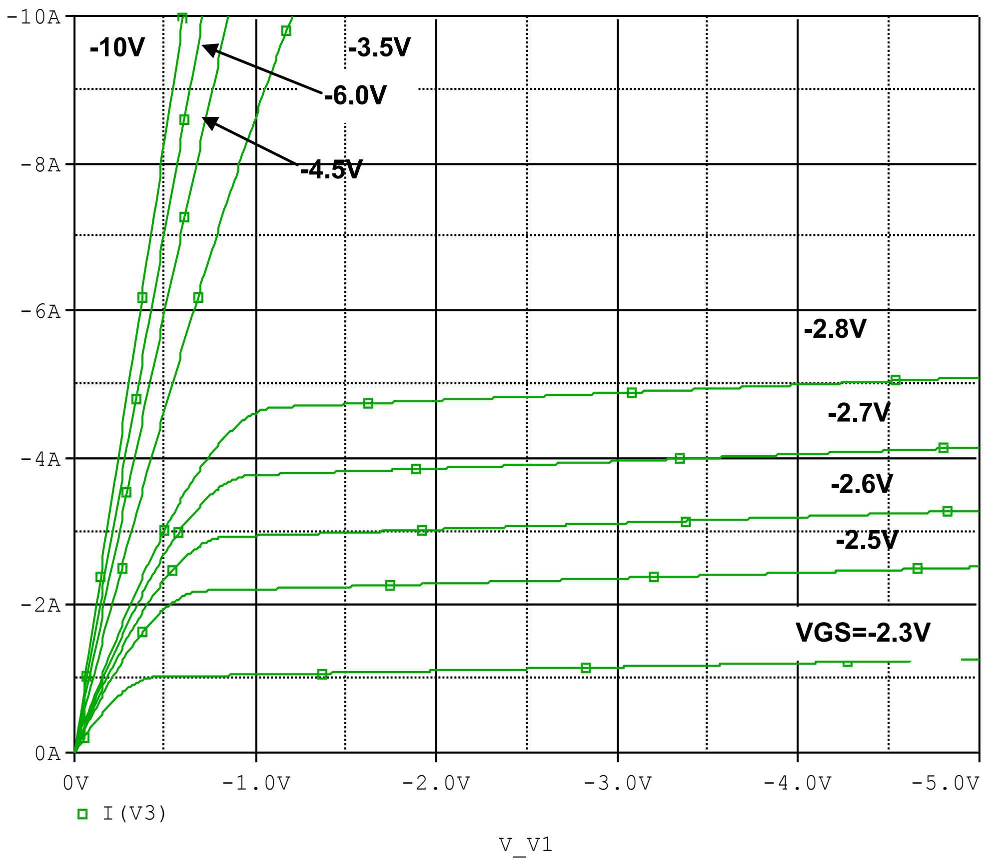


Simulation Result

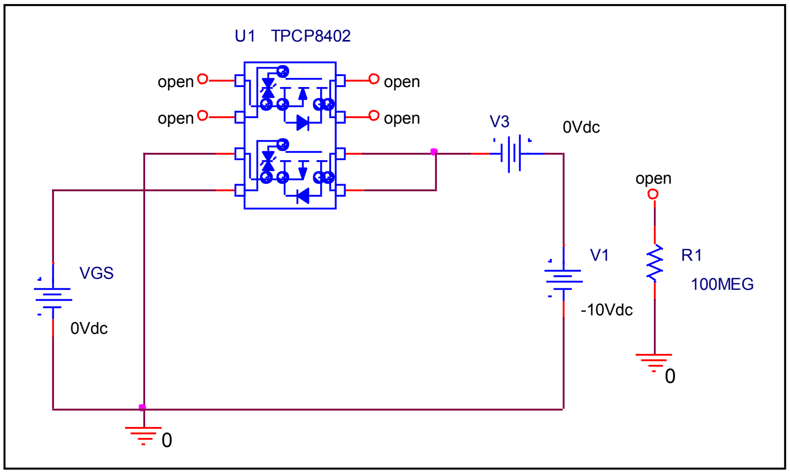
I_D= -1.7A, V_{DD}=-15V V_{GS}=0/-10V	Measurement		Simulation		Error(%)
ton	12.000	ns	11.984	ns	-0.133

P- Channel Model
Output Characteristic

Circuit Simulation result

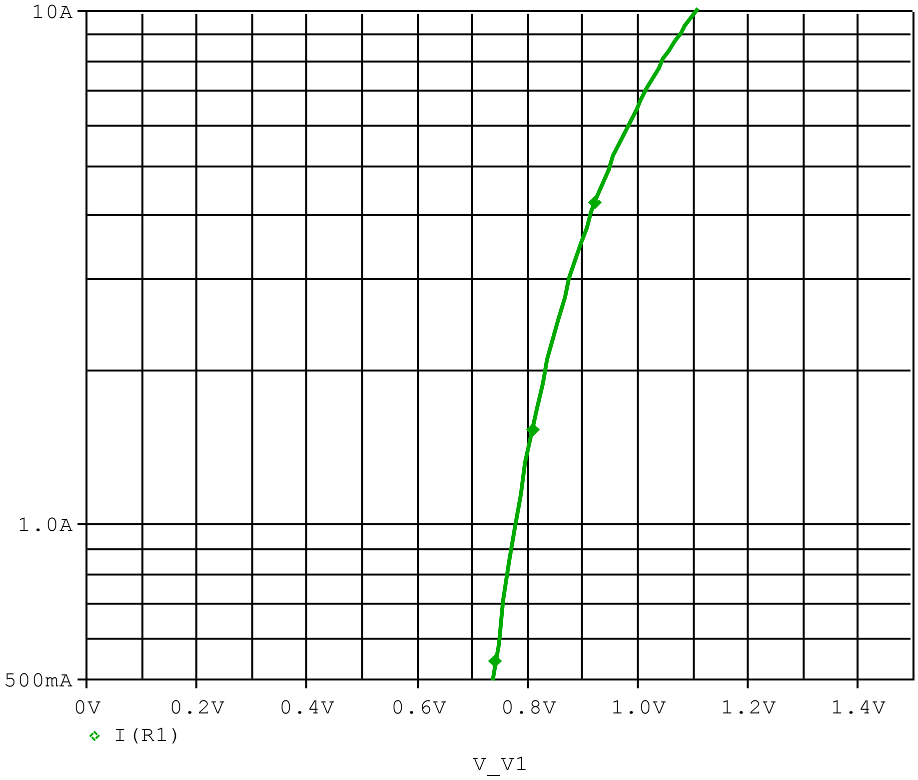


Evaluation circuit

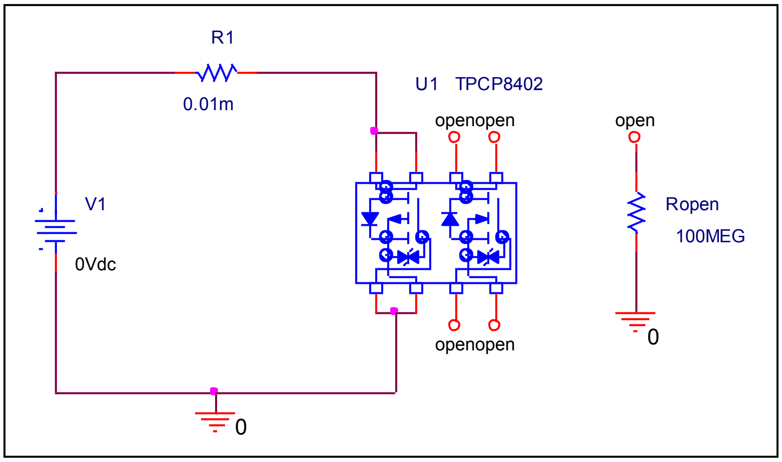


P-Channel Model
BODY DIODE
Forward Current Characteristic

Circuit Simulation Result

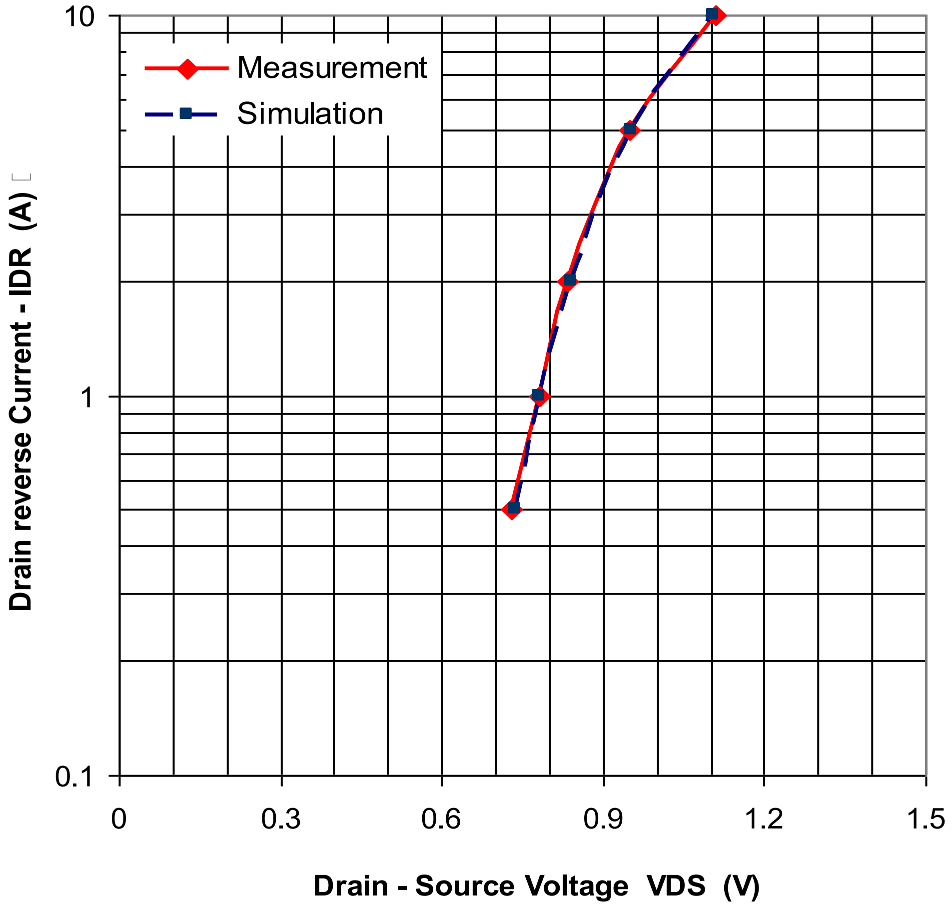


Evaluation Circuit



P-Channel Model
Comparison Graph

Circuit Simulation Result

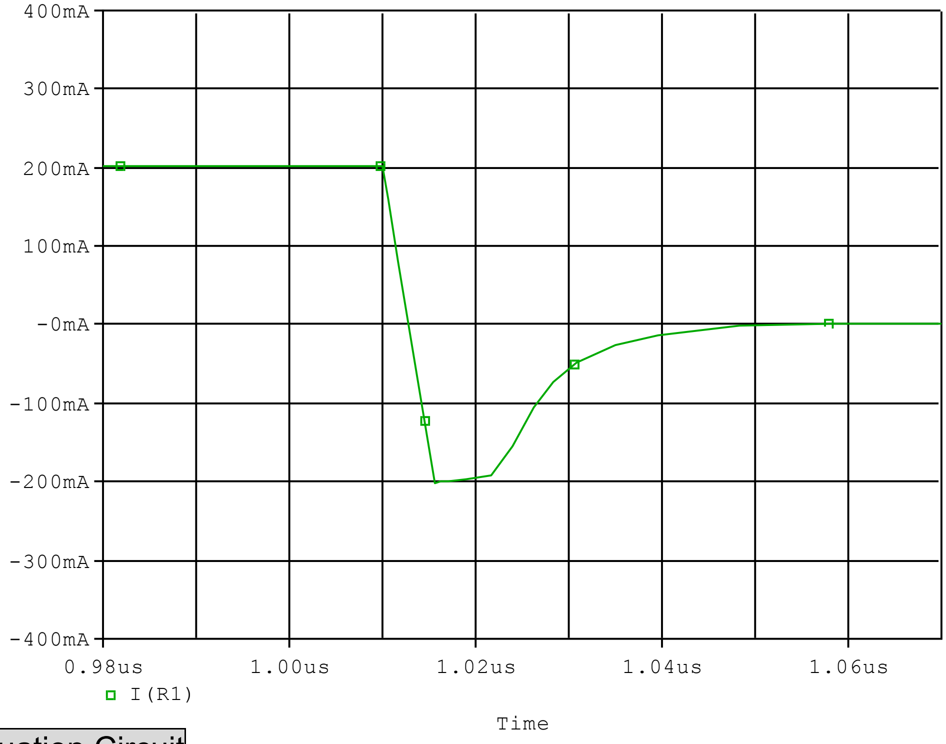


Simulation Result

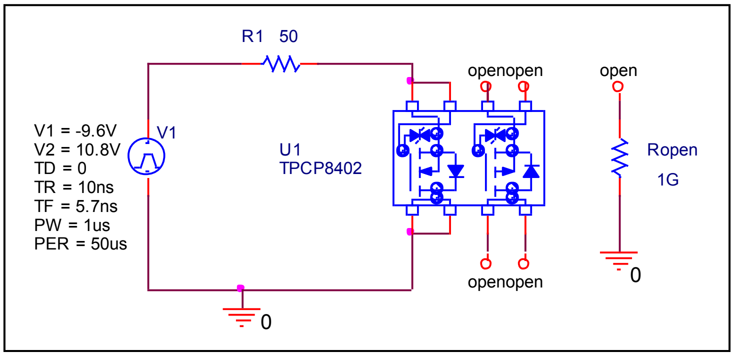
IDR(A)	VSD(V)		%Error
	Measuremen	Simulation	
0.5	0.7300	0.7382	1.1214
1	0.7800	0.7830	0.3846
2	0.8350	0.8399	0.5868
5	0.9500	0.9547	0.4947
10	1.108	1.1062	-0.1625

P-Channel Model
Reverse Recovery Characteristic

Circuit Simulation Result



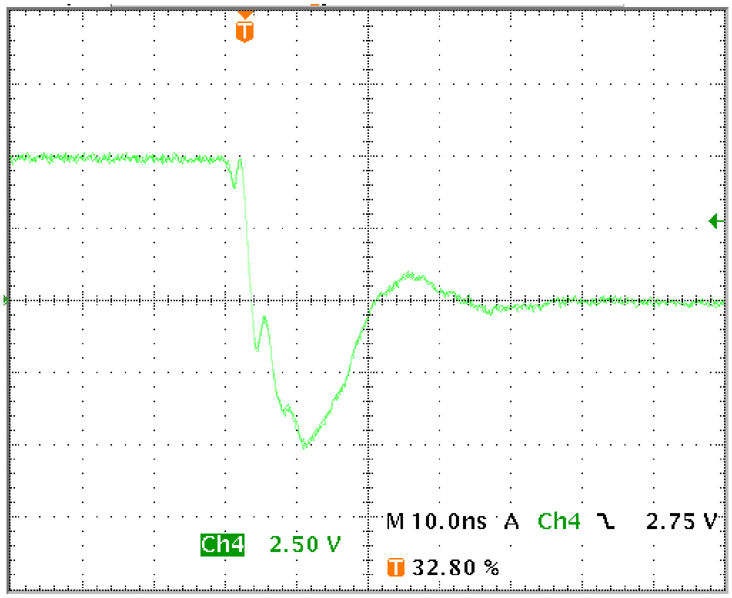
Evaluation Circuit



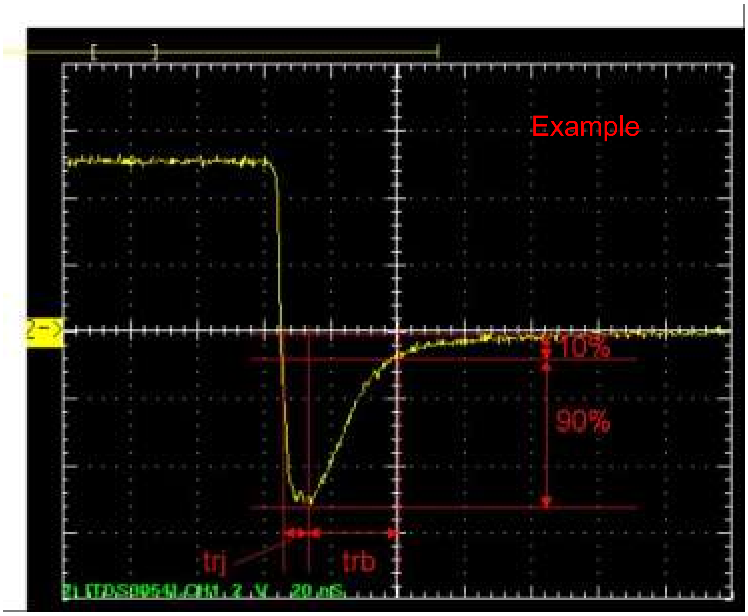
Compare Measurement vs. Simulation

trj (ns)	Measurement	Simulation	Error (%)
trj (ns)	8.600	8.6033	0.038

P-Channel Model
Reverse Recovery Characteristic Reference



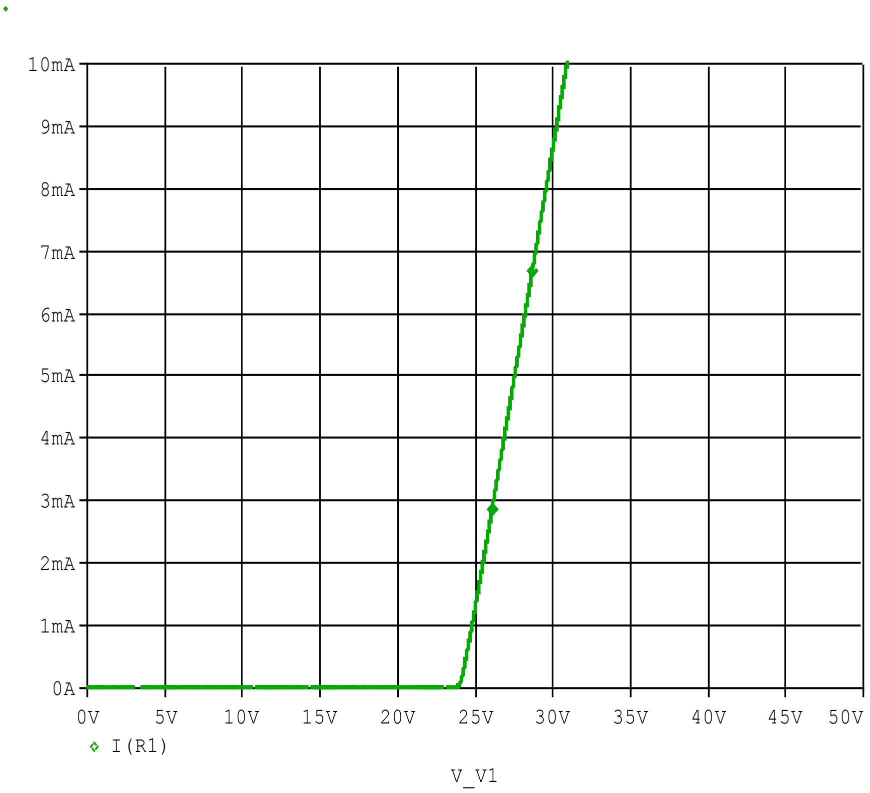
Trj=8.6 (ns)
Trb=10.2 (ns)
Conditions:Ifwd=Irev=0.2(A),Rl=50



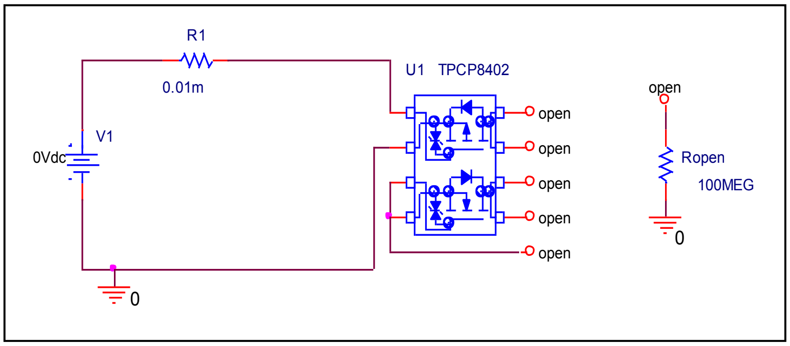
Relation between trj and trb

P-Channel Model
ESD PROTECTION DIODE
Zener Voltage Characteristic

Circuit Simulation Result



Evaluation Circuit



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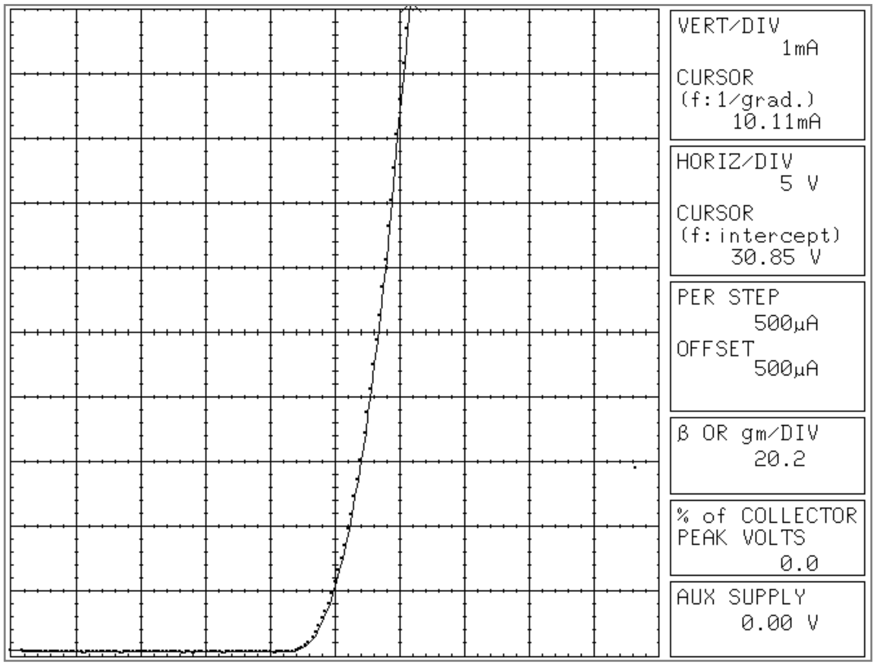
P-Channel Model

Zener Voltage Characteristic **Reference**



VERT/DIV 1mA

CURSOR (f:1/grad.) 10.11mA

HORIZ/DIV 5 V

CURSOR (f:intercept) 30.85 V

PER STEP 500µA

OFFSET 500µA

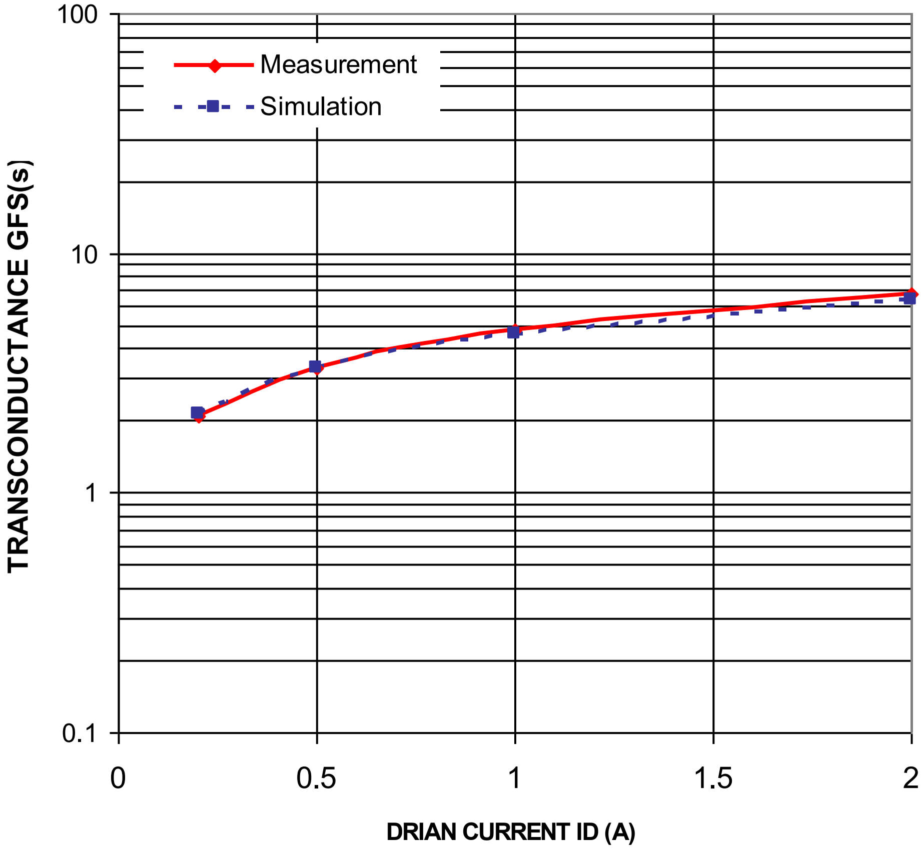
β OR gm/DIV 20.2

% of COLLECTOR PEAK VOLTS 0.0

AUX SUPPLY 0.00 V

N-Channel Model
Transconductance Characteristic

Circuit Simulation Result

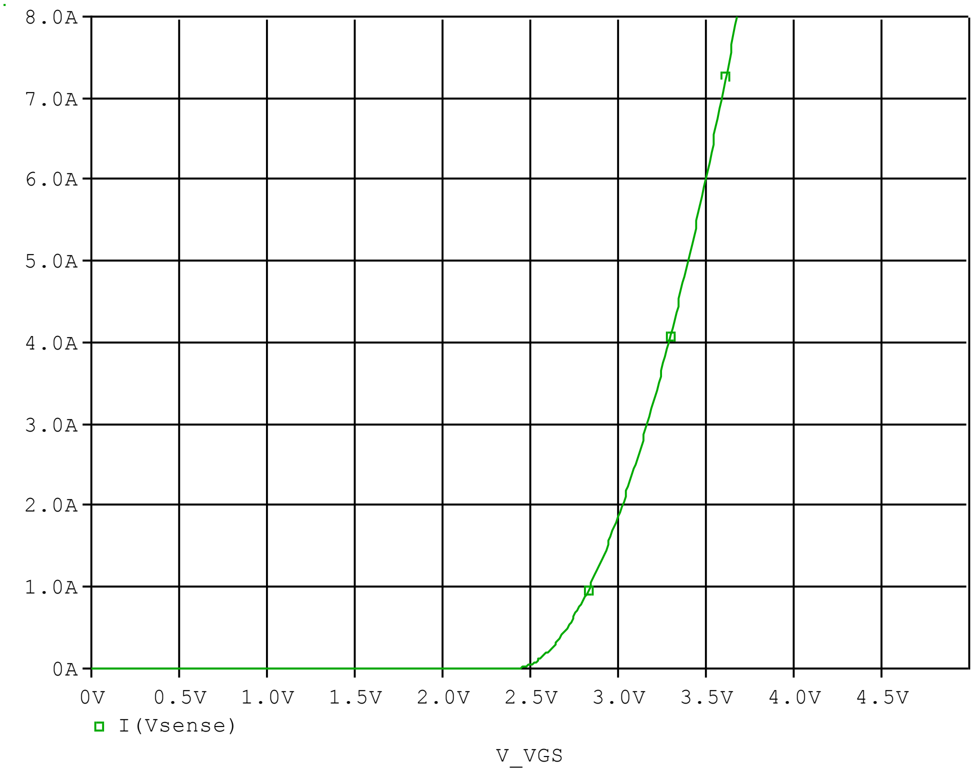


Comparison table

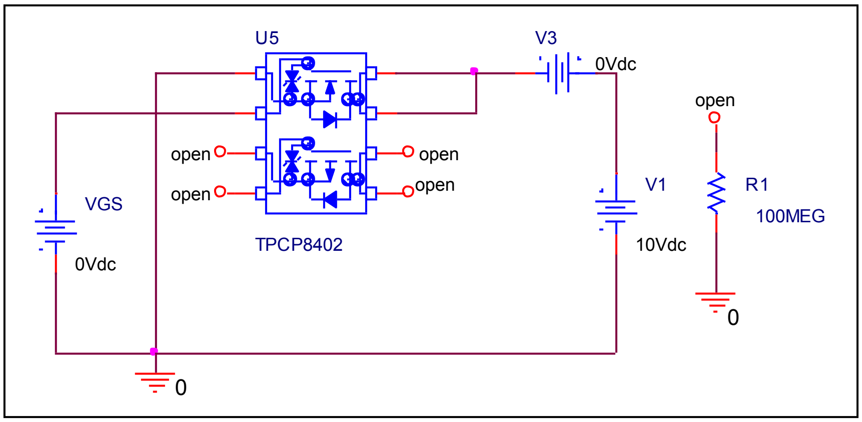
Id(A)	gfs		Error (%)
	Measurement	Simulation	
0.2	2.11	2.13	1.08
0.5	3.33	3.31	-0.66
1	4.65	4.63	-0.46
2	6.67	6.43	-3.59

N-Channel Model
Vgs-Id Characteristic

Circuit Simulation result

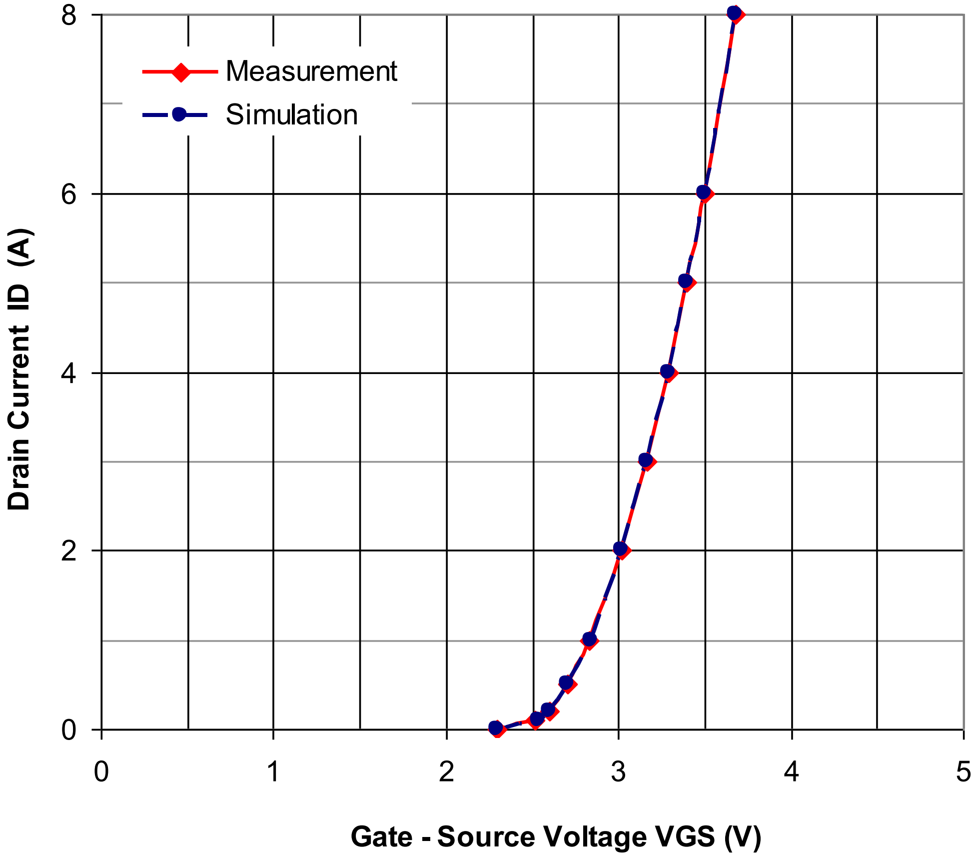


Evaluation circuit



N-Channel Model Comparison Graph

Circuit Simulation Result

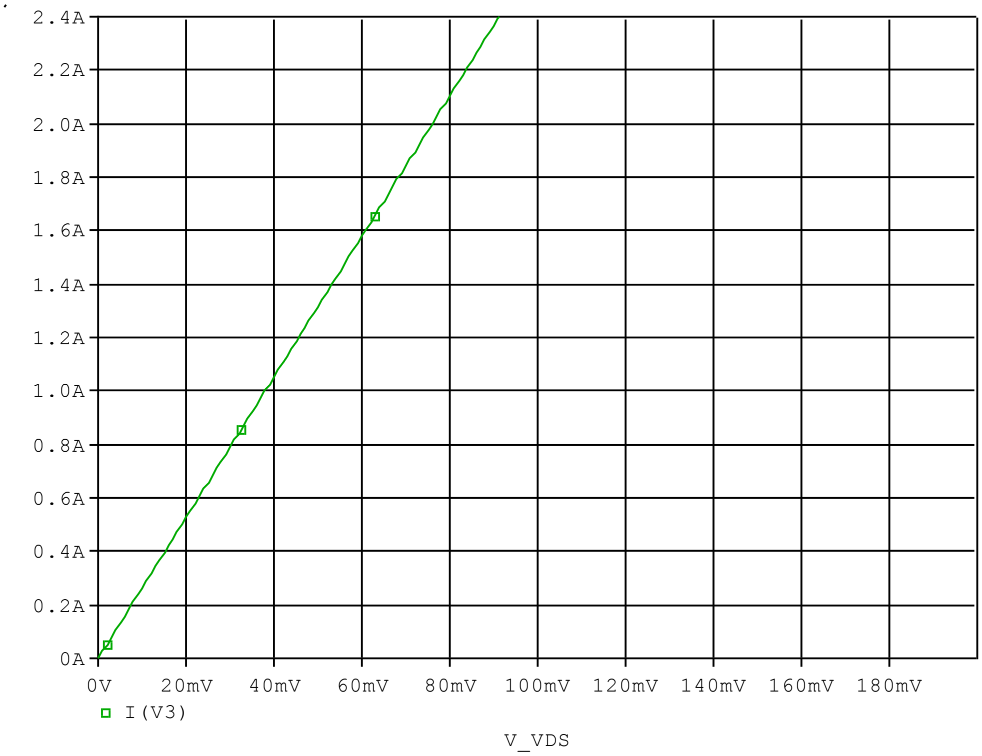


Simulation Result

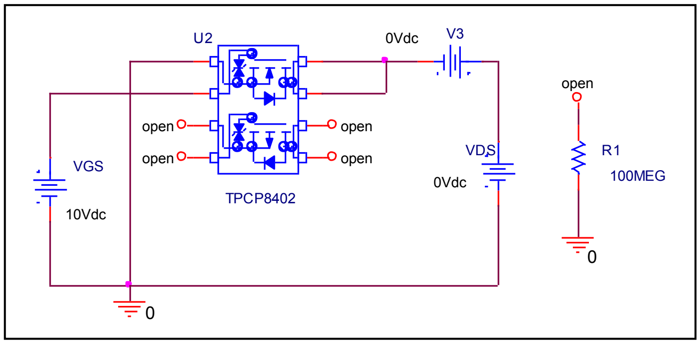
I_D(A)	V_{GS}(V)		Error (%)
	Measurement	Simulation	
0	2.3000	2.3000	0.0000
0.1	2.5200	2.5409	0.8294
0.2	2.6000	2.5971	-0.1115
0.5	2.7000	2.7096	0.3556
1	2.8300	2.8381	0.2862
2	3.0150	3.0227	0.2554
5	3.4000	3.3991	-0.0265
8	3.6800	3.6788	-0.0326

N-Channel Model
Rds(on) Characteristic

Circuit Simulation result



Evaluation circuit

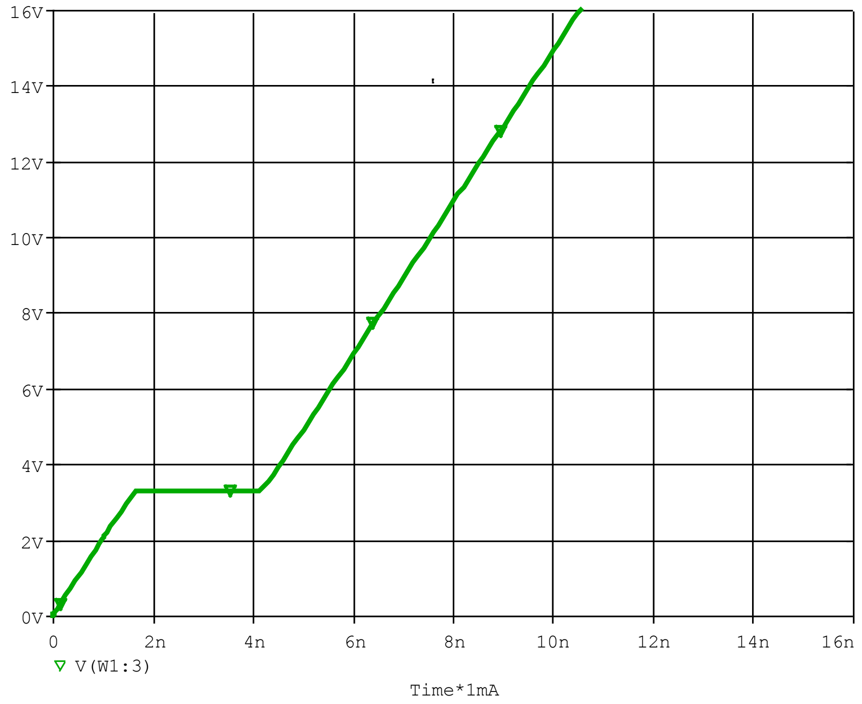


Simulation Result

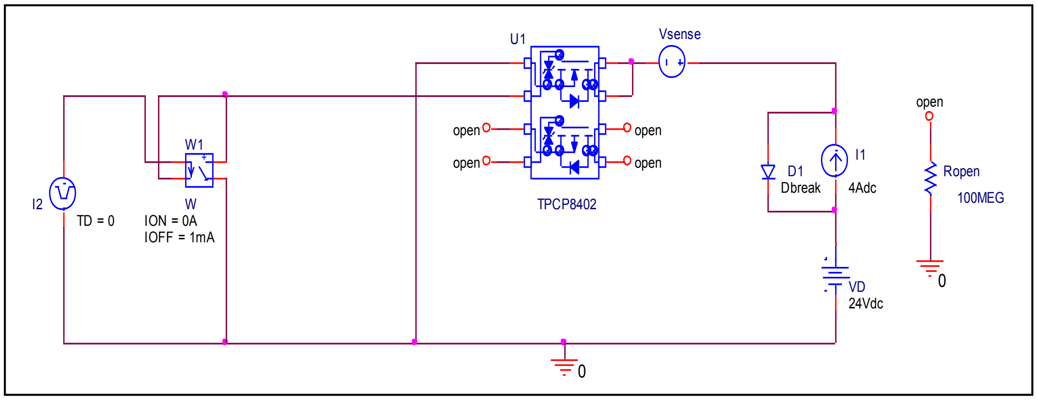
I_D=2.1A, V_{GS}=10V	Measurement		Simulation		Error (%)
R_{DS} (on)	38.000	mΩ	38.000	mΩ	0.000

N-Channel Model
Gate Charge Characteristic

Circuit Simulation result



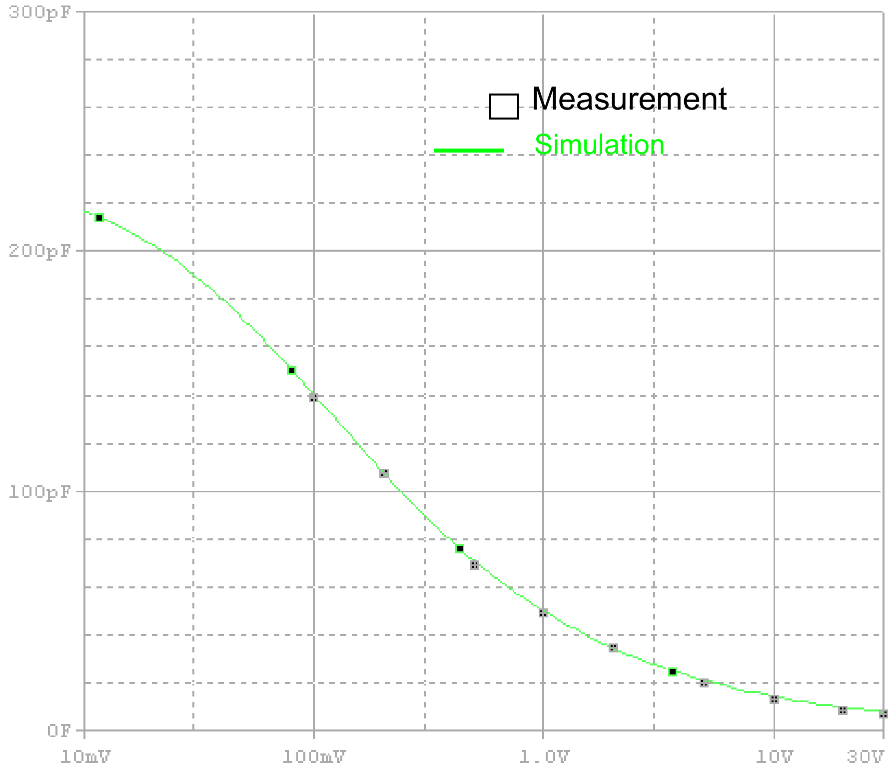
Evaluation circuit



Simulation Result

V_{DD}=24V,I_D=4.0A	Measurement		Simulation		Error (%)
Qgs	1.700	nC	1.6964	nC	-0.212
Qgd	2.400	nC	2.3978	nC	-0.092
Qg	14.000	nC	7.5500	nC	-46.071

N-Channel Model
Capacitance Characteristic

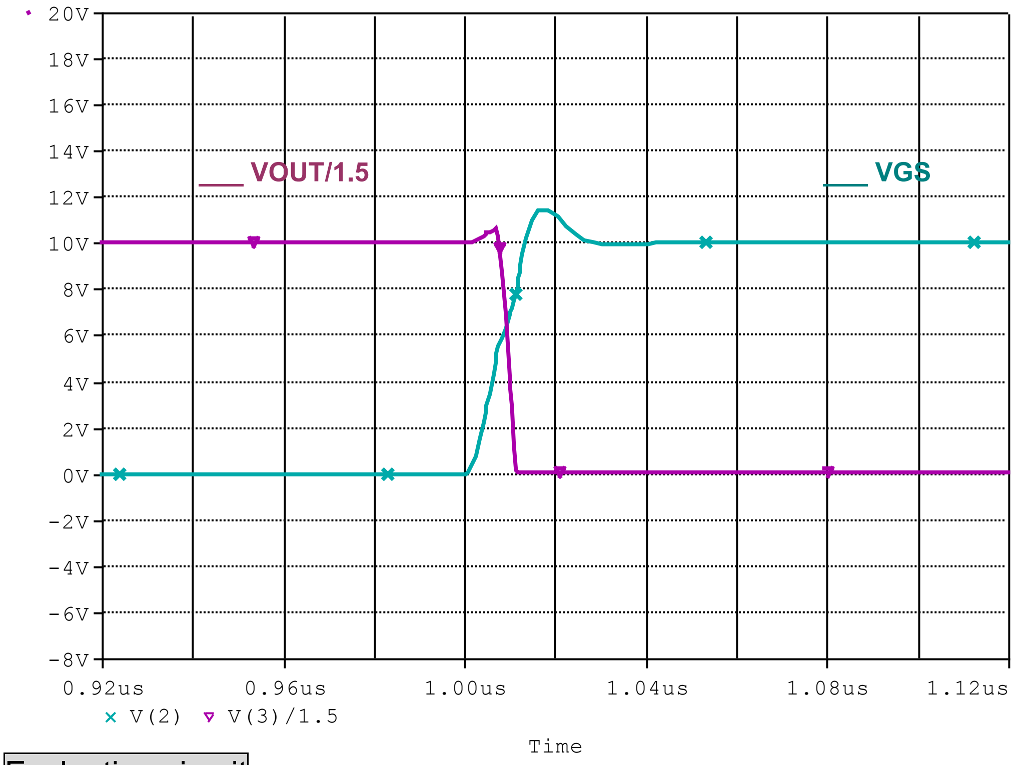


Simulation Result

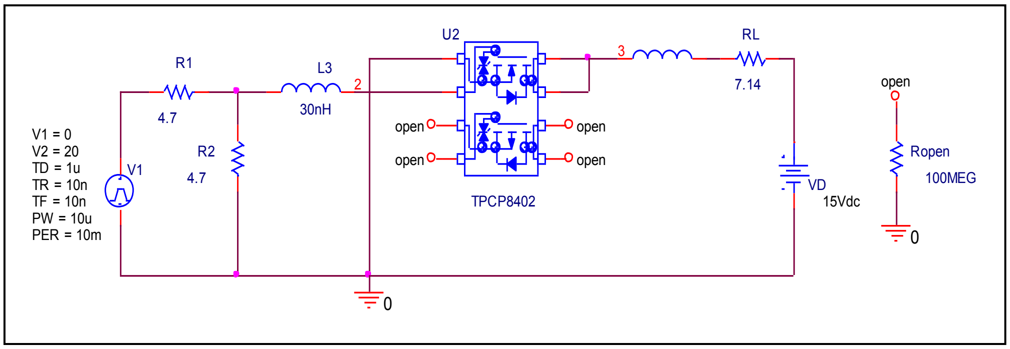
V_{DS}(V)	Cbd(pF)		Error(%)
	Measurement	**Simulation**	
0.1	**140.0000**	**141.0000**	**0.7143**
0.2	**108.0000**	**107.5000**	**-0.4630**
0.5	**70.0000**	**69.5000**	**-0.7143**
1	**50.0000**	**49.8875**	**-0.2250**
2	**35.0000**	**34.6560**	**-0.9829**
5	**21.0000**	**20.9978**	**-0.0105**
10	**14.0000**	**14.5679**	**4.0563**
20	**9.5000**	**9.6499**	**1.5774**
30	**7.5000**	**7.3527**	**-1.9642**

N-Channel Model
Switching Time Characteristic

Circuit Simulation result



Evaluation circuit

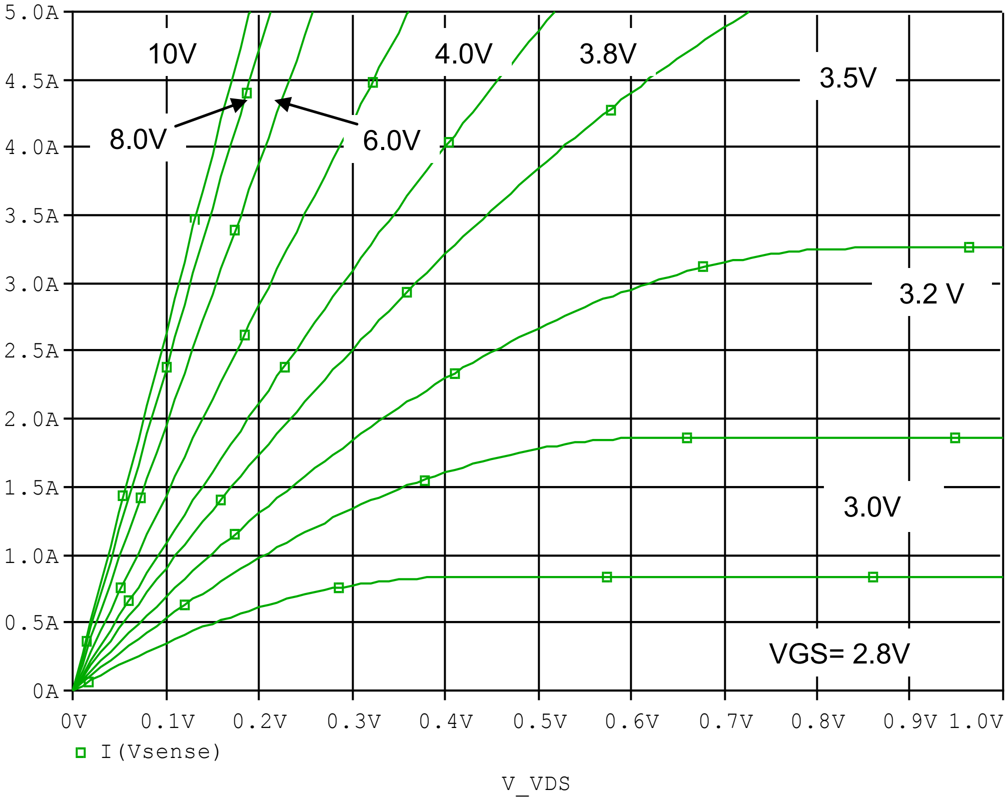


Simulation Result

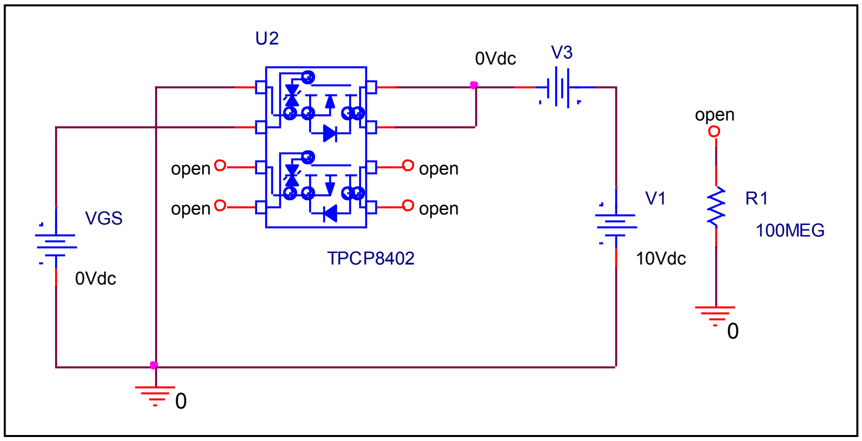
I_D= 2.1A, V_{DD}=15V V_{GS}=0/10V	Measurement		Simulation		Error(%)
ton	8.300	ns	8.2954	ns	-0.055

N-Channel Model
Output Characteristic

Circuit Simulation result

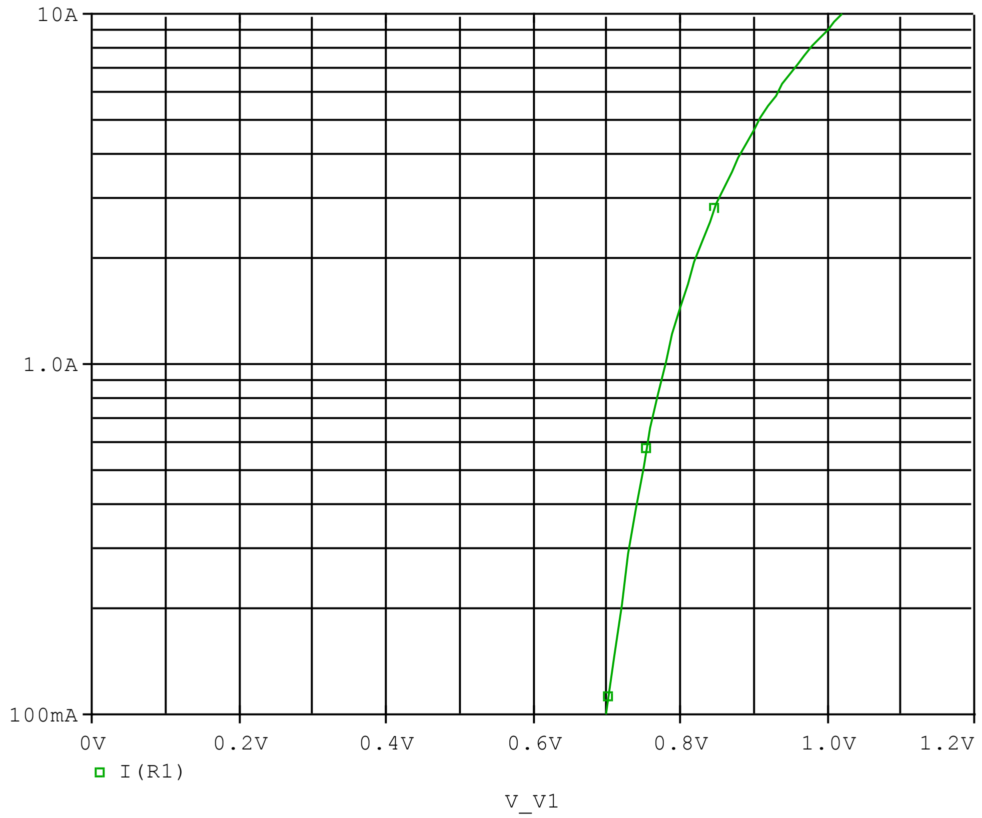


Evaluation circuit

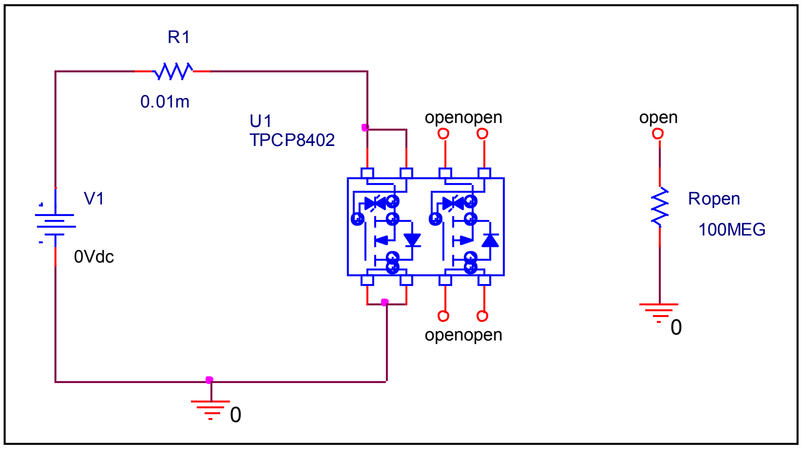


N-Channel Model
BODY DIODE Forward Current Characteristic

Circuit Simulation Result



Evaluation Circuit



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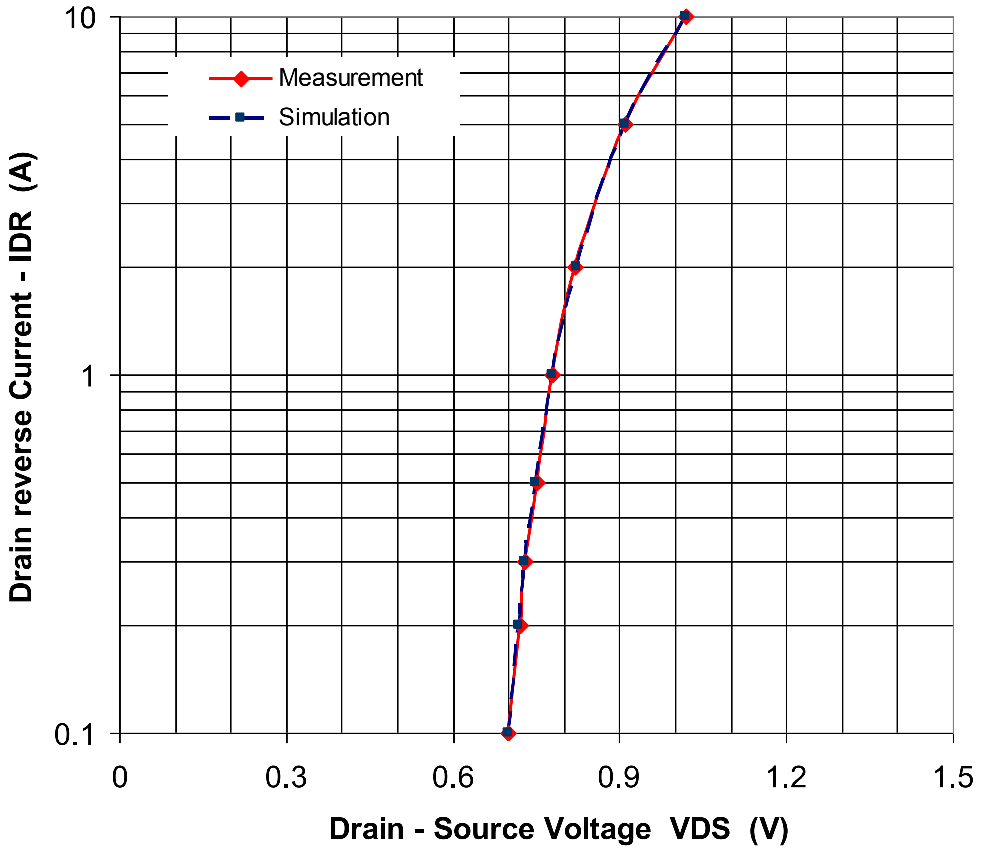
N-Channel Model
Comparison Graph

Circuit Simulation Result

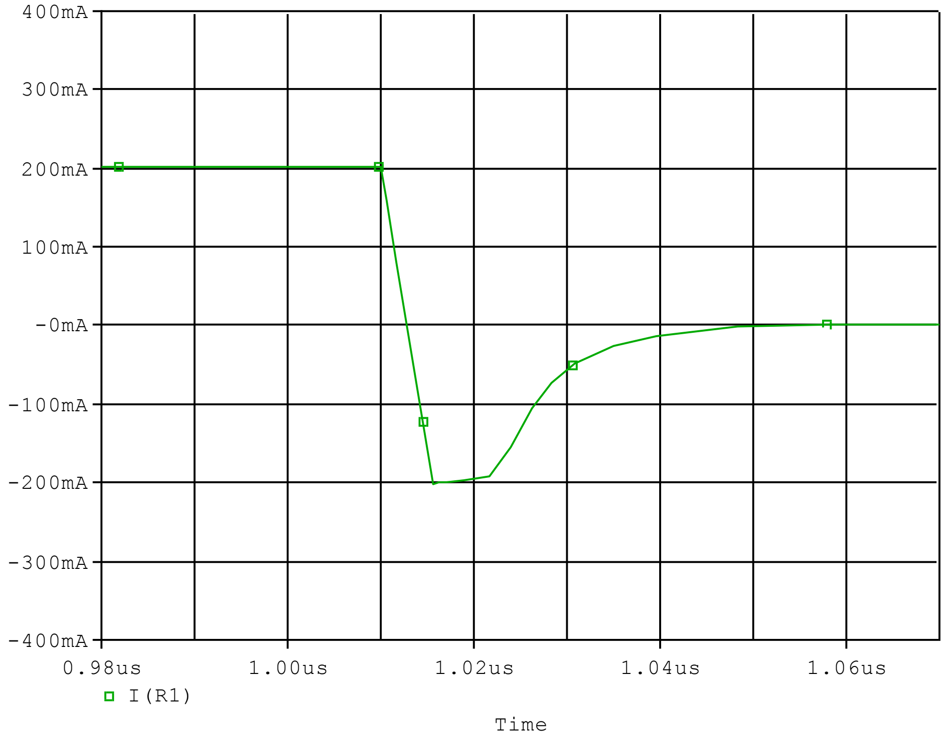


Simulation Result

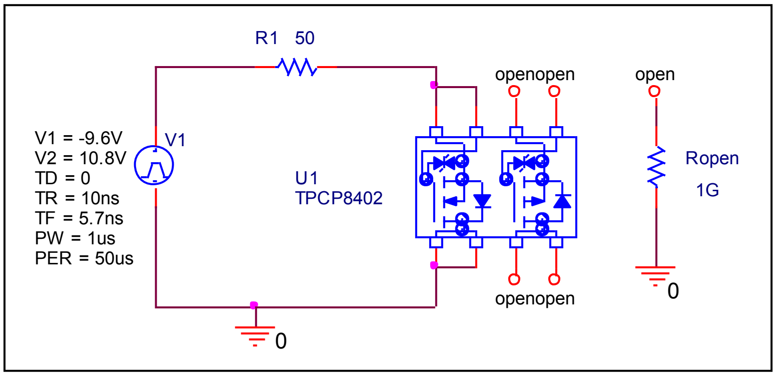
IDR(A)	VSD(V)		%Error
	Measurement	Simulation	
0.1	0.7000	0.6998	-0.0286
0.2	0.7200	0.7190	-0.1389
0.5	0.7500	0.7492	-0.1067
1	0.7800	0.7793	-0.0897
2	0.8200	0.8213	0.1585
5	0.9100	0.9089	-0.1209
10	1.02	1.0204	0.0392

N-Channel Model
Reverse Recovery Characteristic

Circuit Simulation Result



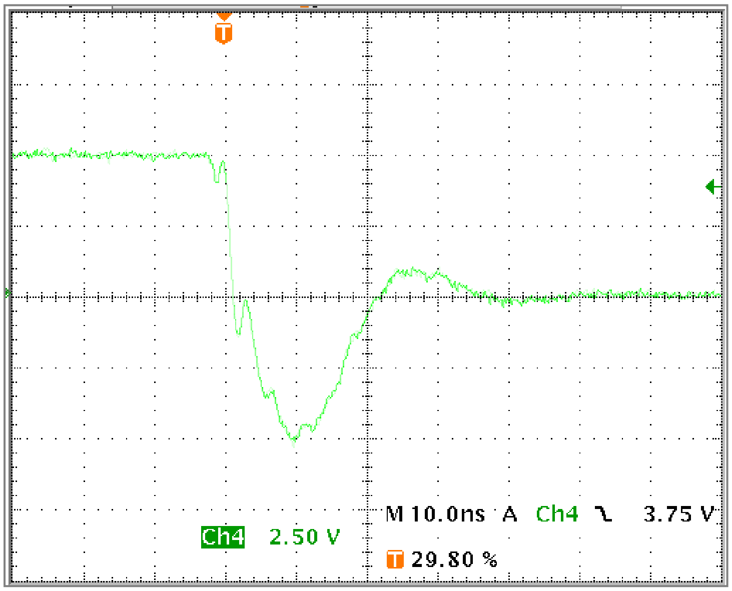
Evaluation Circuit



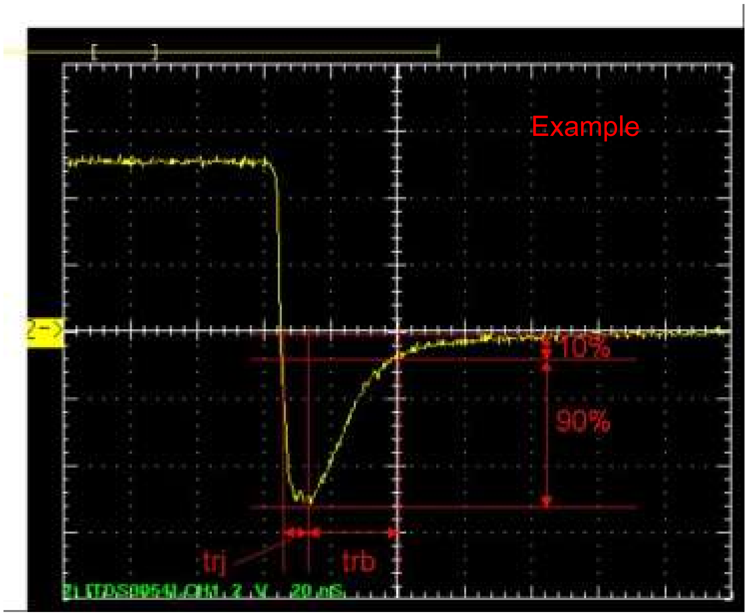
Compare Measurement vs. Simulation

trj (ns)	Measurement	Simulation	Error (%)
trj (ns)	8.600	8.6033	0.038

Reverse Recovery Characteristic   Reference



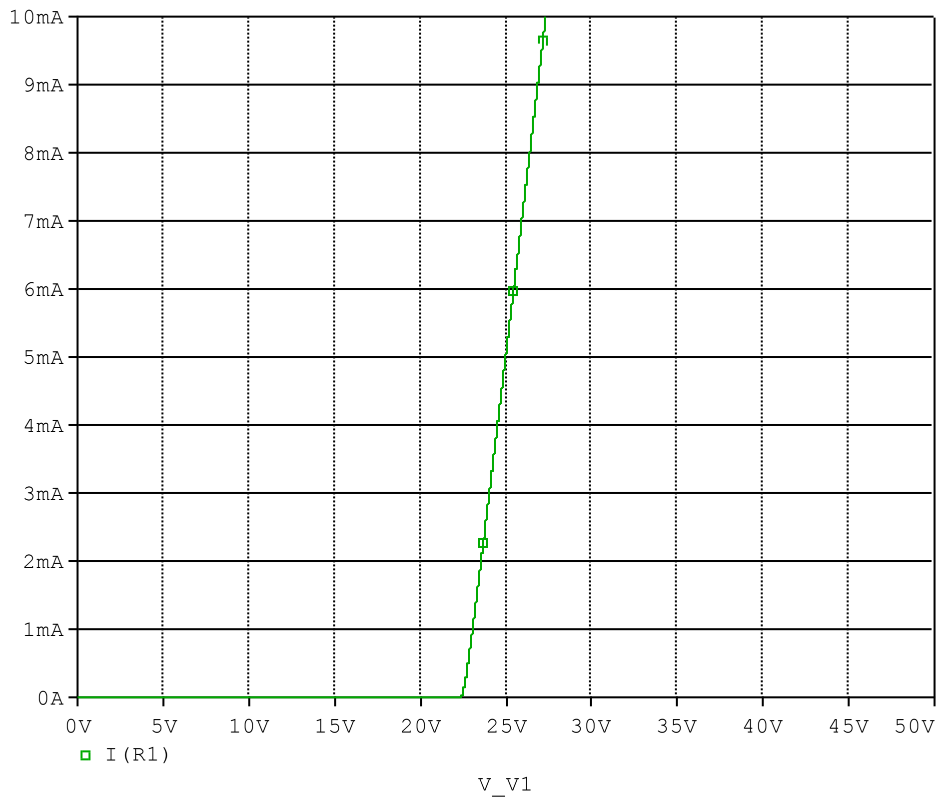
Trj=8.6(ns)
Trb=10.2(ns)
Conditions:Ifwd=Irev=0.2(A),Rl=50



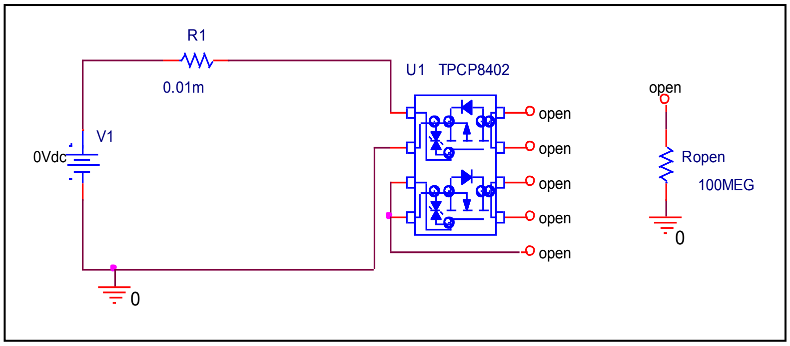
Relation between trj and trb

N-Channel Model
ESD PROTECTION DIODE
Zener Voltage Characteristic

Circuit Simulation Result



Evaluation Circuit



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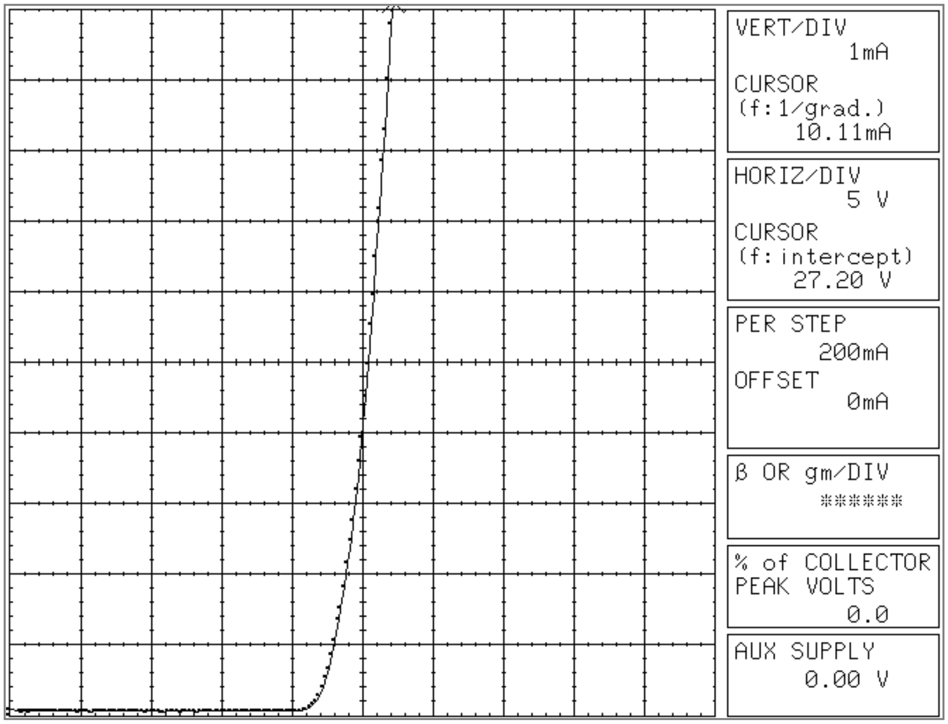
N-Channel Model
Zener Voltage Characteristic Reference



VERT/DIV
1mA
CURSOR
(f:1/grad.)
10.11mA

HORIZ/DIV
5 V
CURSOR
(f:intercept)
27.20 V

PER STEP
200mA
OFFSET
0mA

β OR gm/DIV
******

% of COLLECTOR
PEAK VOLTS
0.0

AUX SUPPLY
0.00 V