Device Modeling Report

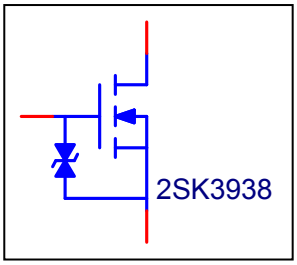
COMPONENTS: MOSFET (Professional Model)
PART NUMBER: 2SK3938
MANUFACTURER: Panasonic
Body Diode (Professional) / ESD Protection Diode

Bee Technologies Inc.

SPICE MODEL

```
*$
*PART NUMBER: 2SK3938
*MANUFACTURER: Panasonic
*VDSS=30, IDSS=100mA
*All Rights Reserved Copyright (c) Bee Technologies Inc. 2006
*               Gate
*               | Source
*               | | Drain
*               | | |
.SUBCKT 2SK3938   1 2 3
X_U1        3 1 2  M3938_PRO
X_U2        2 3 D3938_PRO
X_U3        1 2 DZ3938
.ENDS
*****MOSFET PACKAGE MODEL*****
*$
```

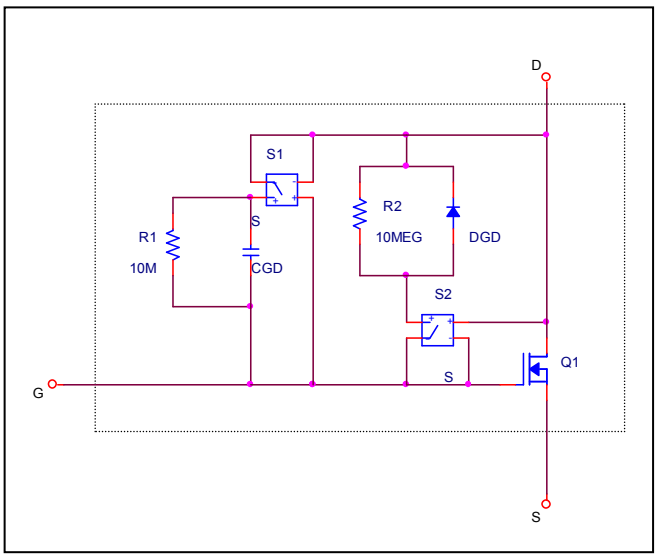
Circuit Configuration



POWER MOSFET SPICE MODEL

```
*$
.SUBCKT M3938_PRO D G S
CGD   1       G 493p
R1    1       G 1E7
S1    1 D G D SMOD1
D1    2       D DGD
R2    D       2 1E7
S2    2 G D G SMOD1
M1 D   G      S       S M3938
.MODEL SMOD1 VSWITCH( VON=0V VOFF=-10mV RON=1m ROFF=1E12)
.MODEL DGD D( CJO=150.000E-12 M=.41548 VJ=.60162 )
.MODEL M3938 NMOS
+ LEVEL=3 L=720.00E-9 W=.2129 KP=479.00E-9 RS=10.000E-3
+ RD=1.935 VTO=1.6582 RDS=7.5000E12 TOX=4.0000E-8
+ CGSO=150E-12 CGDO=10E-12
+ CBD=11.584E-12 MJ=.36649 PB=.35374
+ RG=875
+ GAMMA=0 ETA=20.000E-5 KAPPA=0
+ IS=1.0E-18 N=5 RB=1.0E-3
.ENDS
*****MOSFET PROFESSIONAL MODEL*****
*$
```

Equivalent Circuit

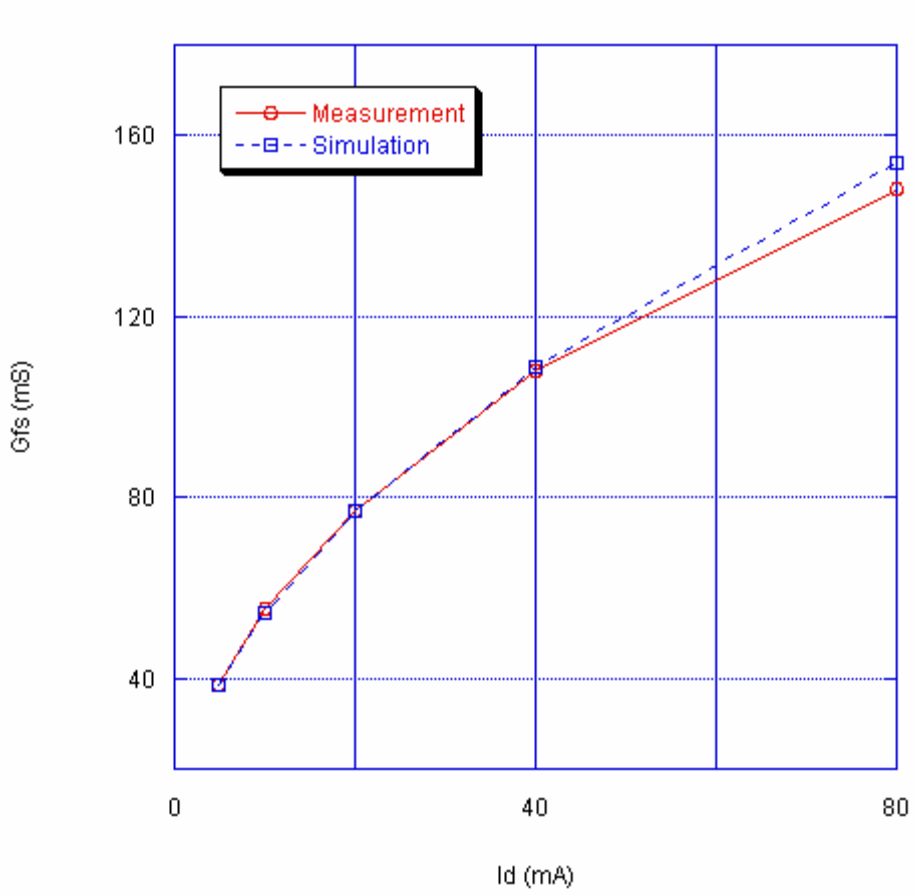


MOSFET MODEL

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

Transconductance Characteristic

Circuit Simulation Result

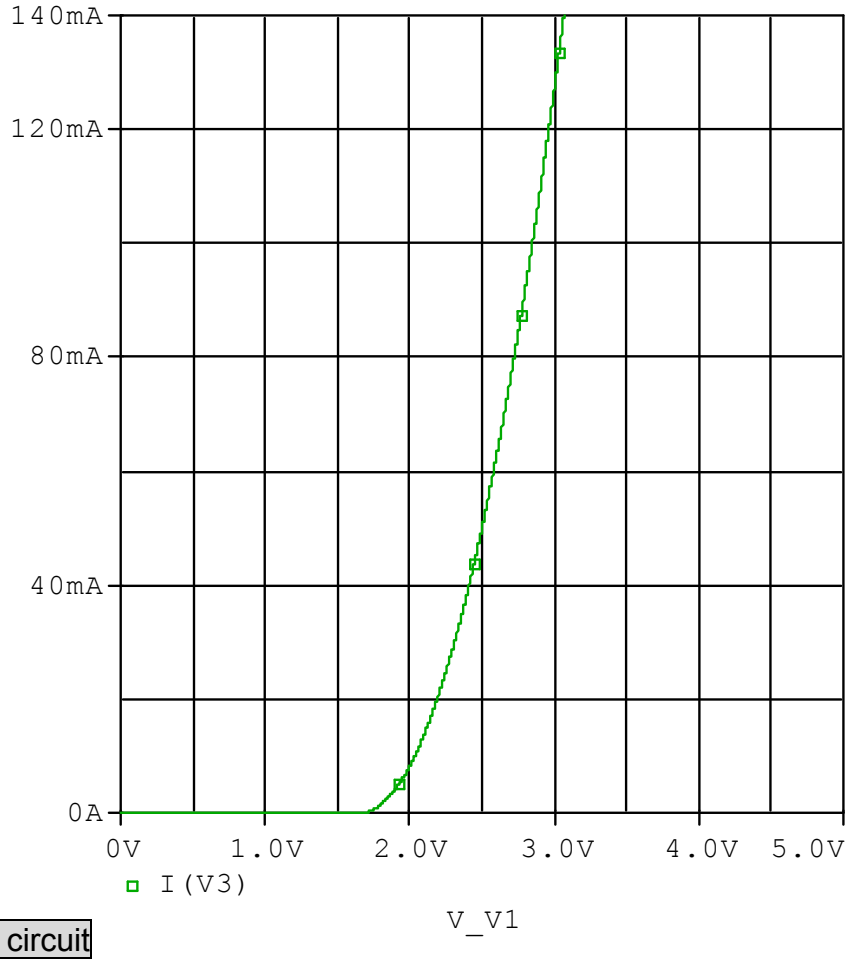


Comparison table

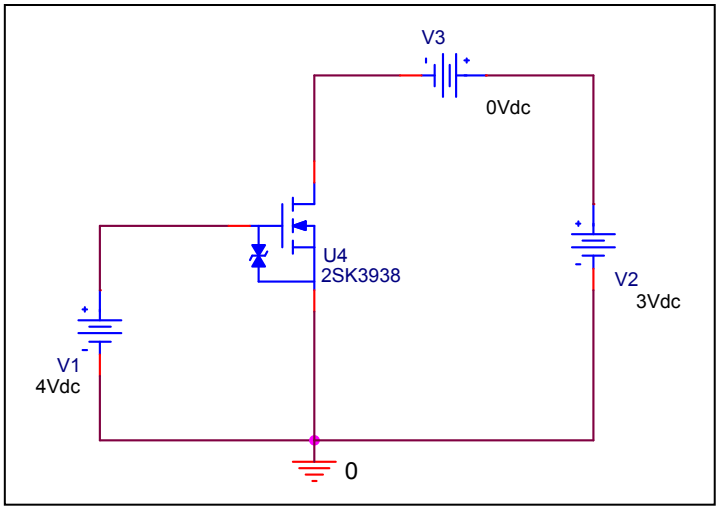
Id(mA)	gfs (ms)		Error(%)
	Measurement	Simulation	
5.000	38.462	38.462	0.000
10.000	55.556	54.348	-2.174
20.000	76.923	77.220	0.386
40.000	108.110	108.992	0.817
80.000	148.150	154.143	4.046

Vgs-Id Characteristic

Circuit Simulation result

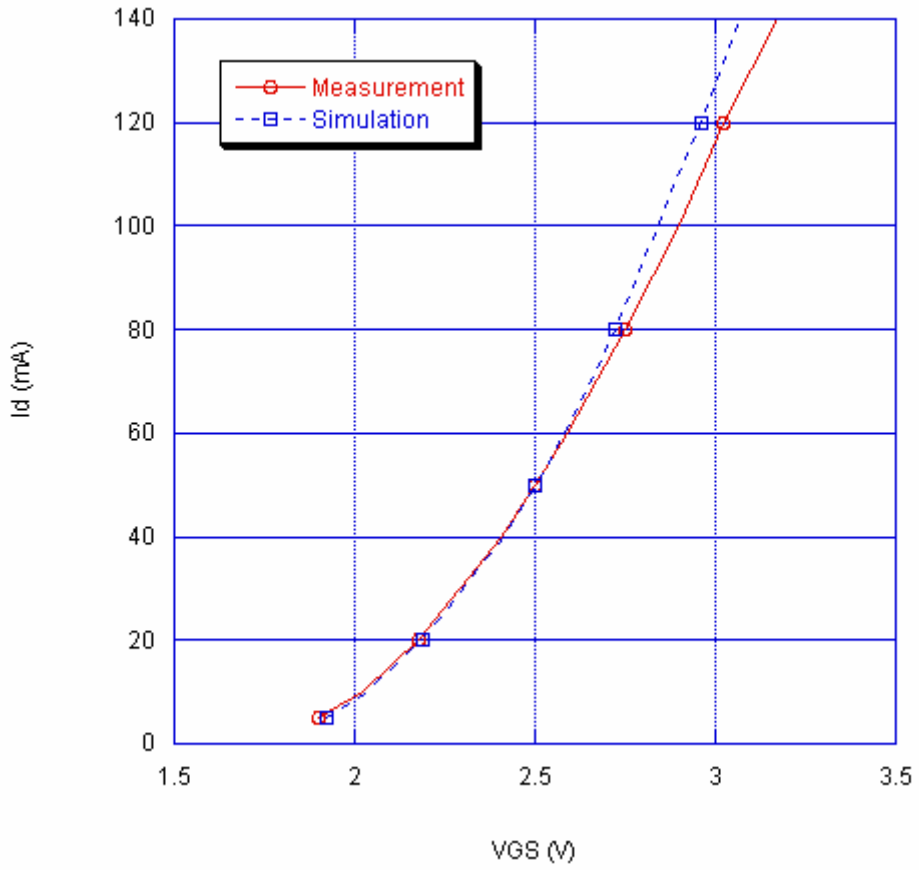


Evaluation circuit



Comparison Graph

Circuit Simulation Result

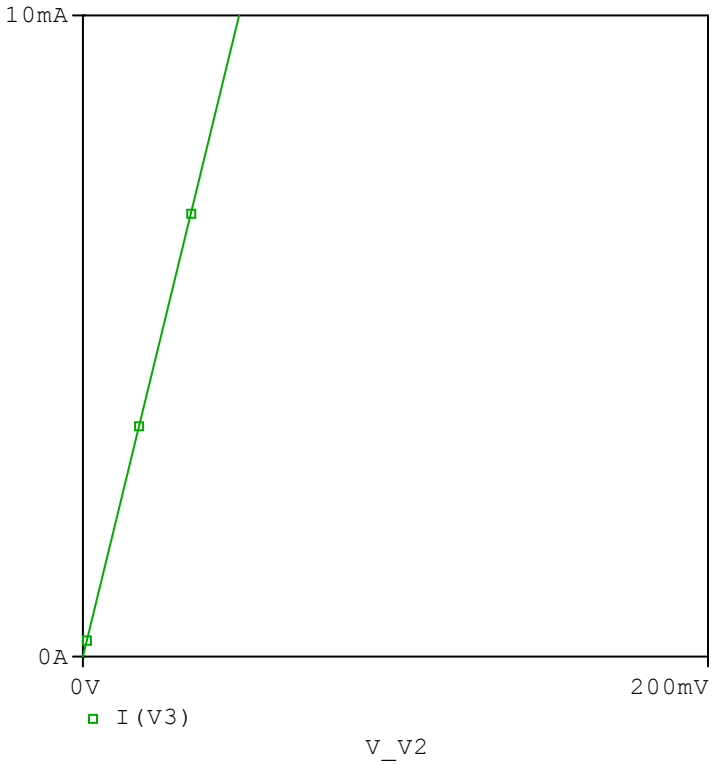


Simulation Result

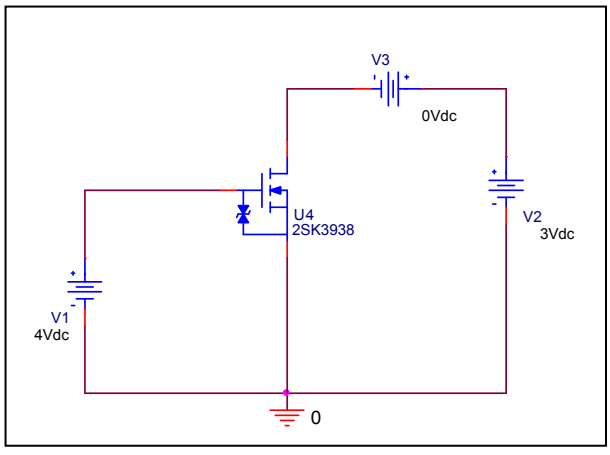
I_D(mA)	V_{GS}(V)		Error (%)
	Measurement	Simulation	
5.000	1.900	1.924	1.263
10.000	2.020	2.034	0.693
20.000	2.180	2.190	0.459
50.000	2.500	2.499	-0.040
100.000	2.900	2.847	-1.828

Rds(on) Characteristic

Circuit Simulation result



Evaluation circuit

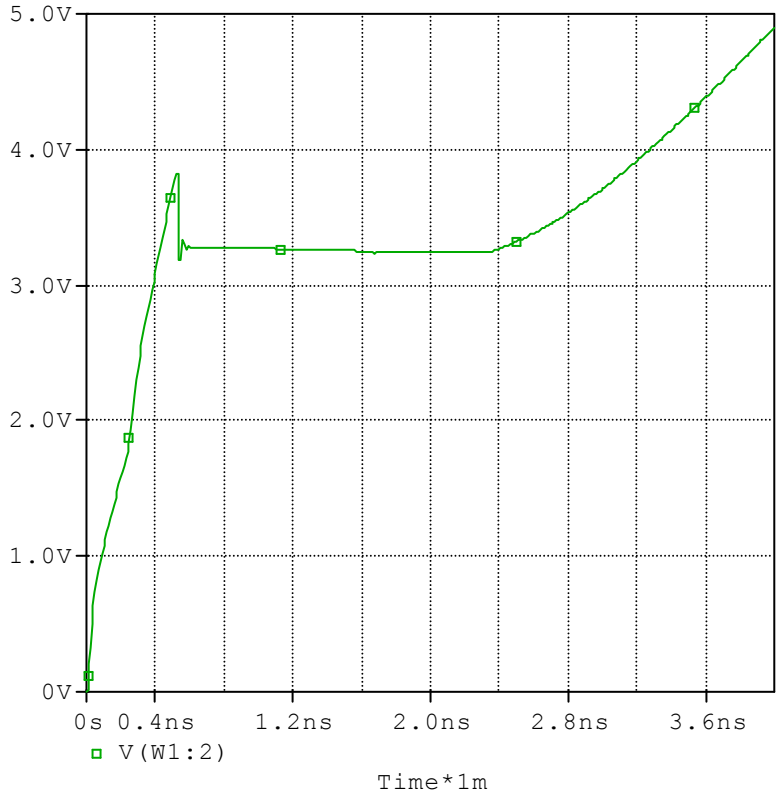


Simulation Result

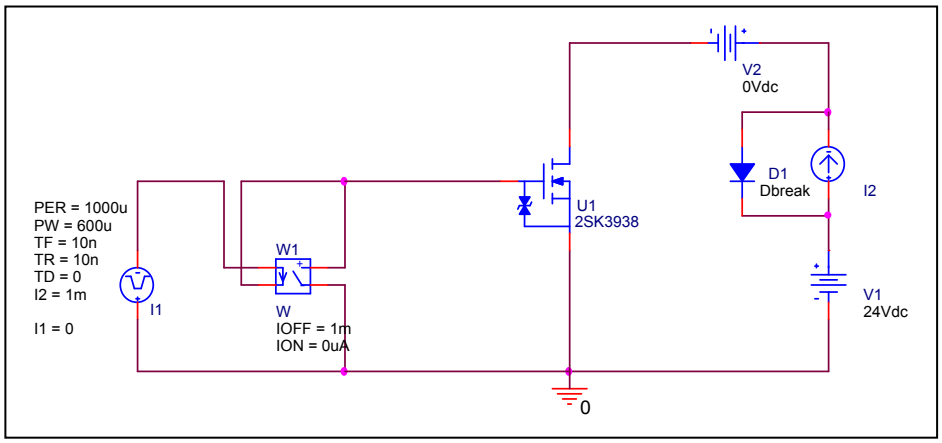
I_D=10mA, V_{GS}=4.0V	Measurement		Simulation		Error (%)
R_{DS} (on)	5.000	Ω	5.000	Ω	0.000

Gate Charge Characteristic

Circuit Simulation result



Evaluation circuit

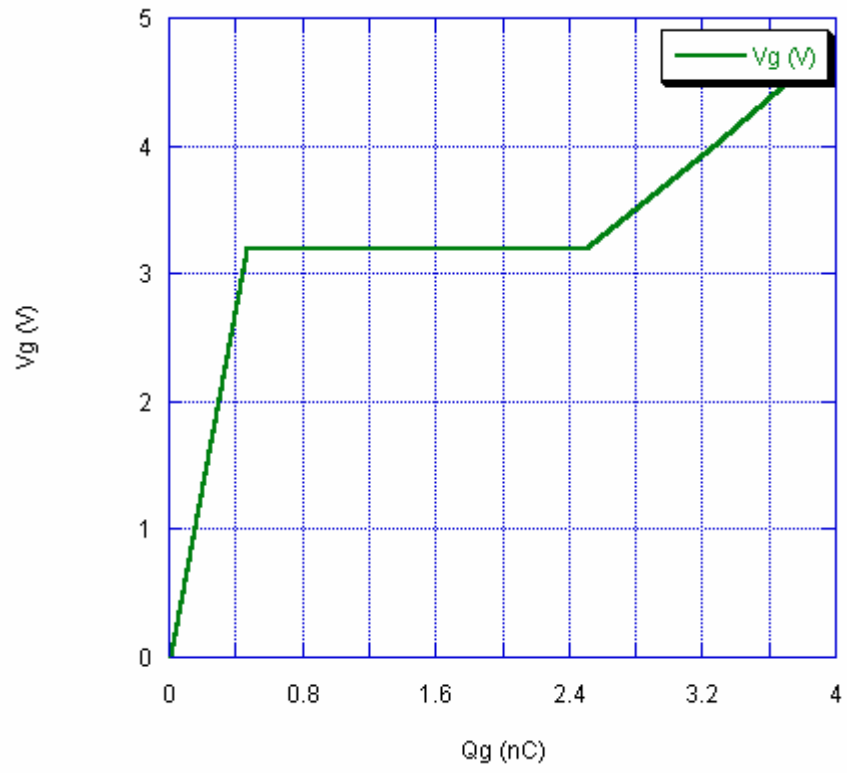


Simulation Result

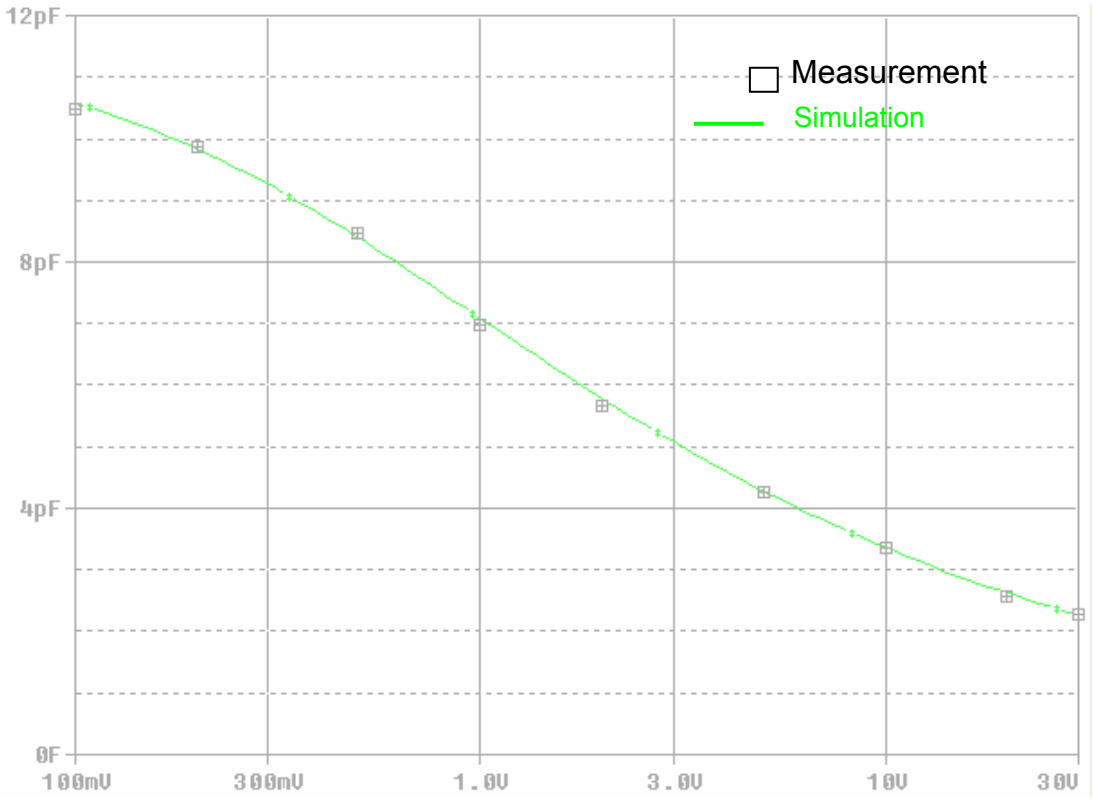
V_{DD}=24V,I_D=0.1A ,V_G=4V	Measurement		Simulation		Error (%)
Qgs	0.464	nC	0.465	nC	0.216
Qgd	1.936	nC	1.930	nC	-0.310
Qg	3.270	nC	3.275	nC	0.153

Gate Charge Characteristic

Reference



Capacitance Characteristic

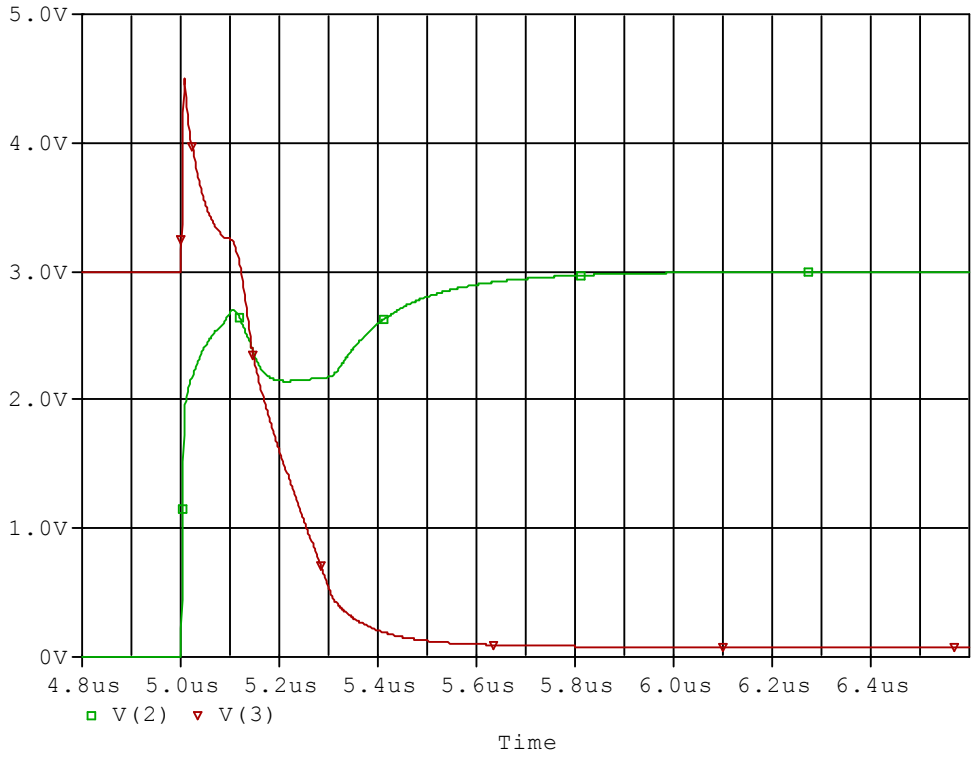


Simulation Result

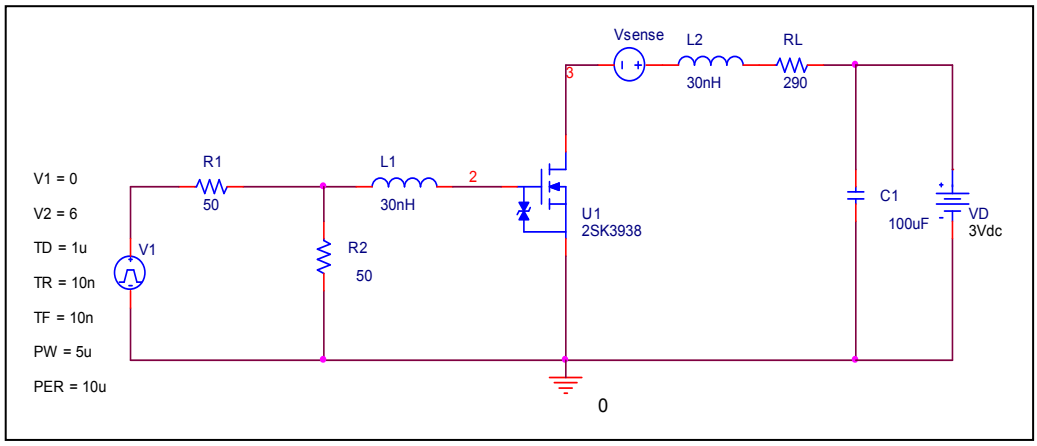
V_{DS}(V)	Cbd(pF)		Error(%)
	Measurement	Simulation	
0.100	10.500	10.580	0.762
0.200	9.900	9.830	-0.707
0.500	8.500	8.400	-1.176
1.000	7.000	7.100	1.429
2.000	5.700	5.790	1.579
5.000	4.300	4.280	-0.465
10.000	3.400	3.360	-1.176
20.000	2.600	2.630	1.154

Switching Time Characteristic

Circuit Simulation result



Evaluation circuit

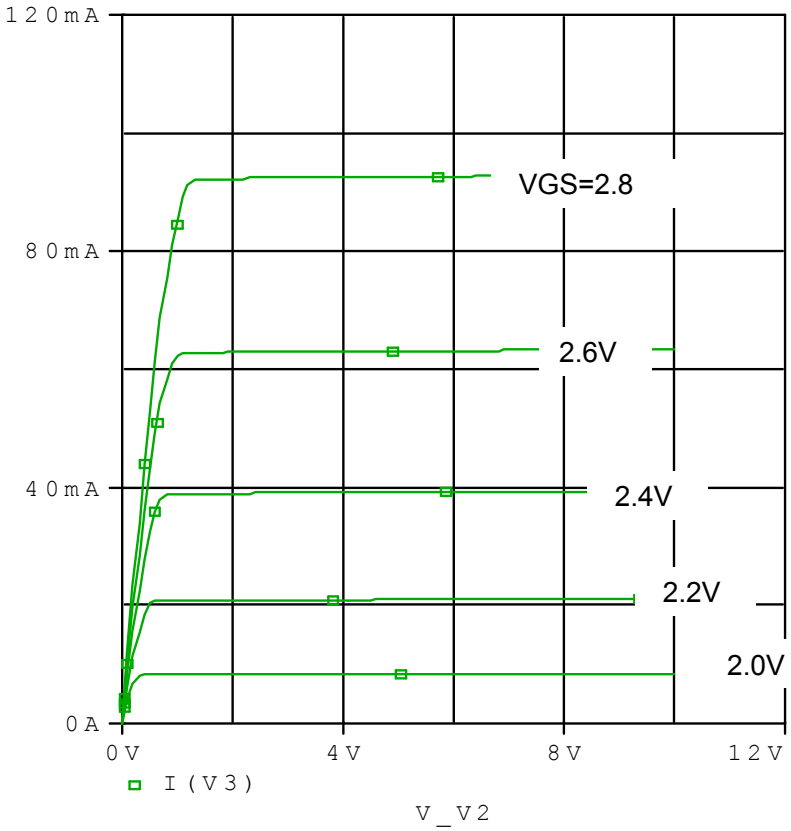


Simulation Result

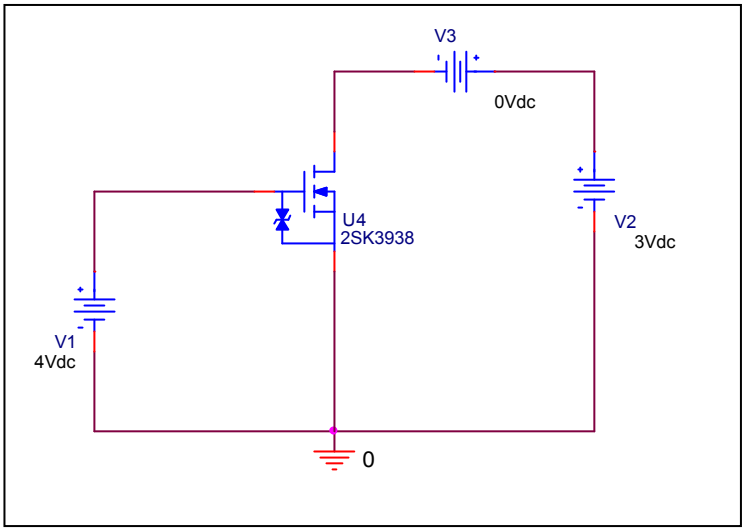
I_D=10mA, V_{DD}=3V V_{GS}=0V~3V	Measurement		Simulation		Error(%)
ton	350.000	ns	350.698	ns	0.199

Output Characteristic

Circuit Simulation result



Evaluation circuit



BODY DIODE SPICE MODEL

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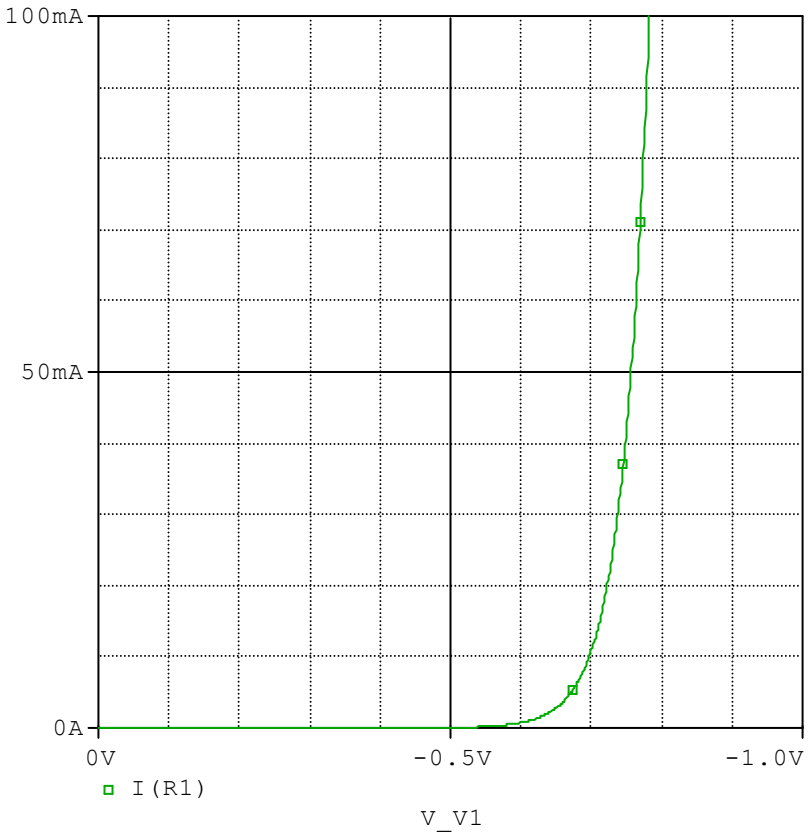
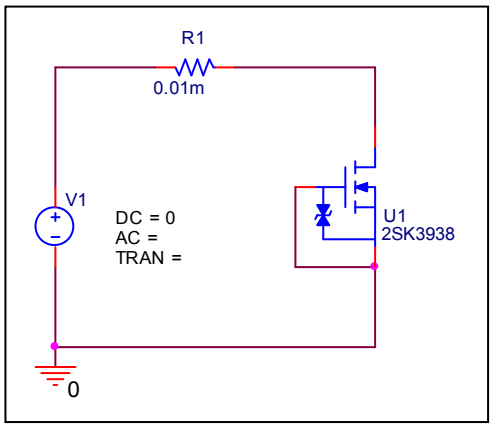
*$
.SUBCKT D3938_PRO A K
R_R2  5     6  100
R_R1  3     4  1
C_C1  5     6  127p
E_E1  5 K 3 4 1
S_S1  6 K 4 K _S1
RS_S1 4     K 1G
.MODEL _S1 VSWITCH Roff=50MEG Ron=1m Voff=90mV Von=175mV
G_G1  K     A VALUE { V(3,4)-V(5,6) }
D_D1  2     K D3938
D_D2  4     K D3938
F_F1  K     3 VF_F1 1
VF_F1 A     2 0V
.MODEL D3938 D
+ IS=67.535E-12 N=1.4324 RS=1.0003E-6
+ CJO=3E-14 ISR=0 BV=42 IBV=10E-6 TT=15E-9
.ENDS
*****BODY DIODE PROFESSIONAL MODEL****
*$
```

Forward Current Characteristic

Circuit Simulation Result

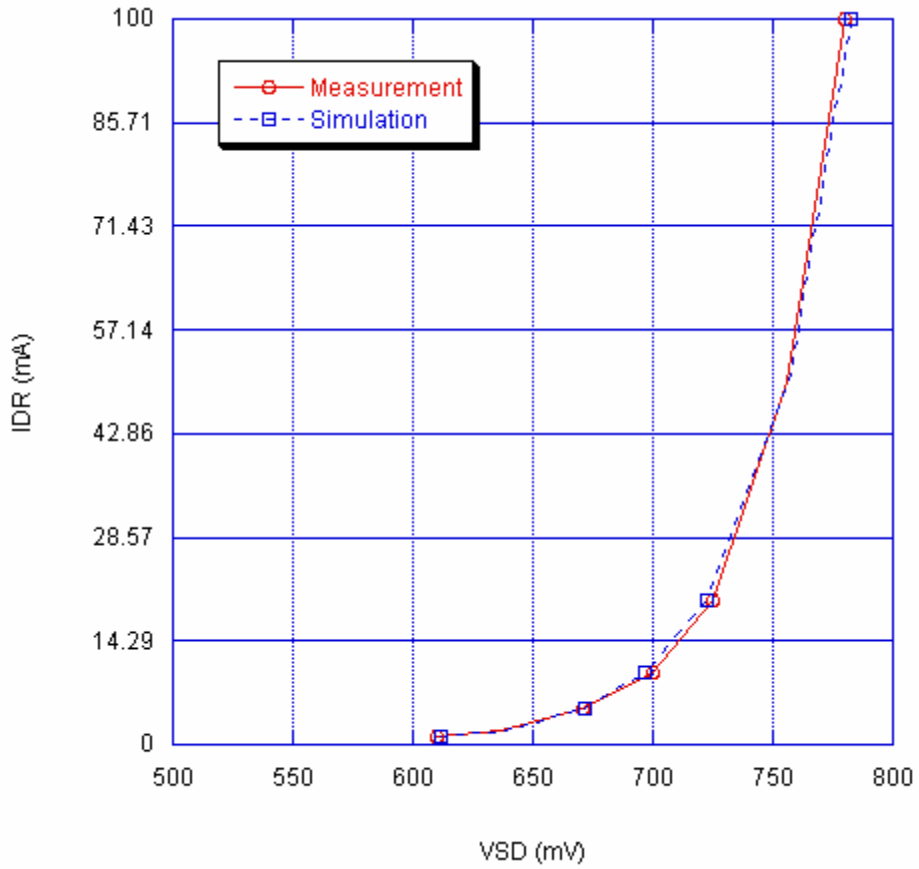


Evaluation Circuit



Comparison Graph

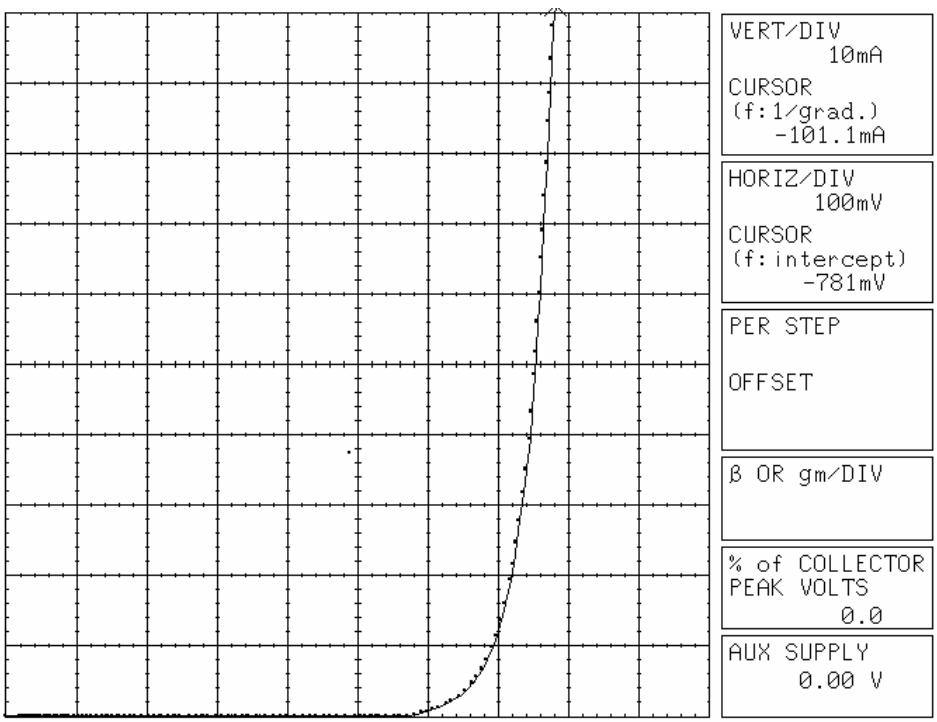
Circuit Simulation Result



Simulation Result

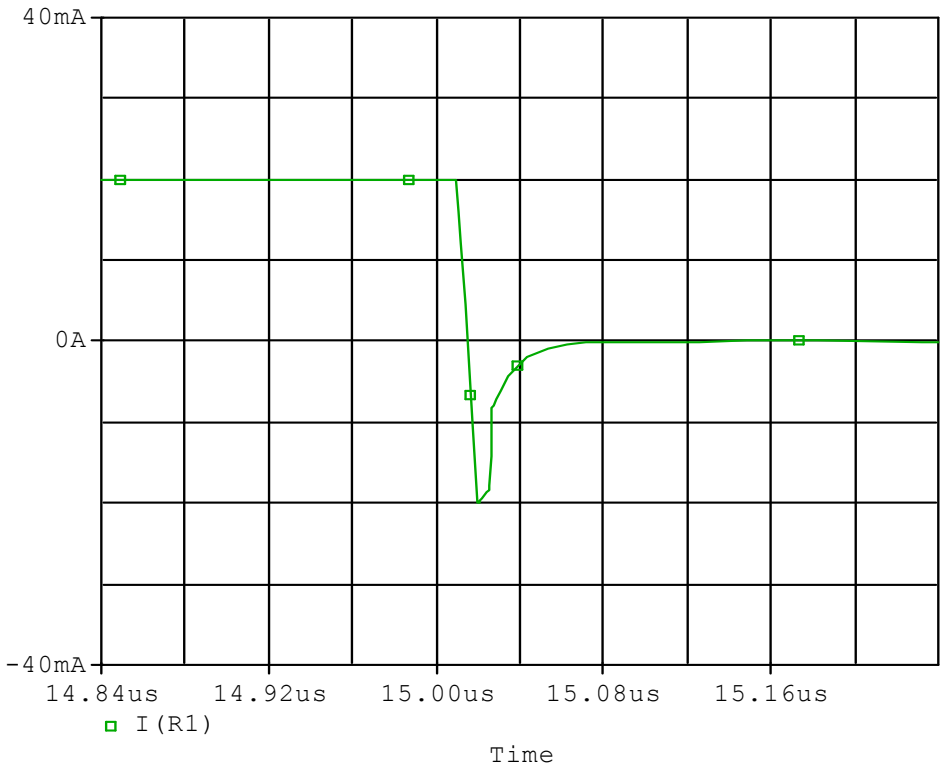
IDR (mA)	VSD (mV)		%Error
	Measurement	Simulation	
1.000	610.000	611.680	0.275
2.000	637.000	637.360	0.057
5.000	671.000	671.307	0.046
10.000	700.000	696.989	-0.430
20.000	725.000	722.666	-0.322
50.000	756.000	756.613	0.081
100.000	780.000	782.293	0.294

Forward Current Characteristic Reference

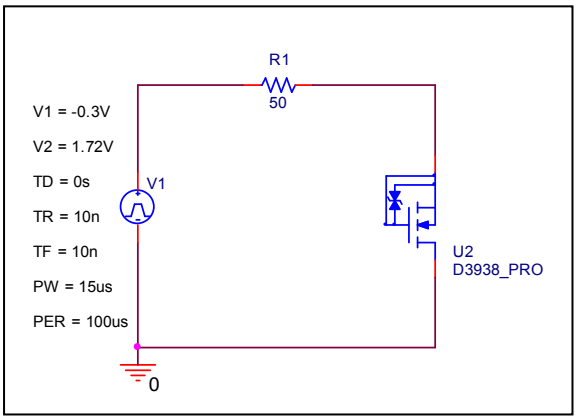


Reverse Recovery Characteristic

Circuit Simulation Result



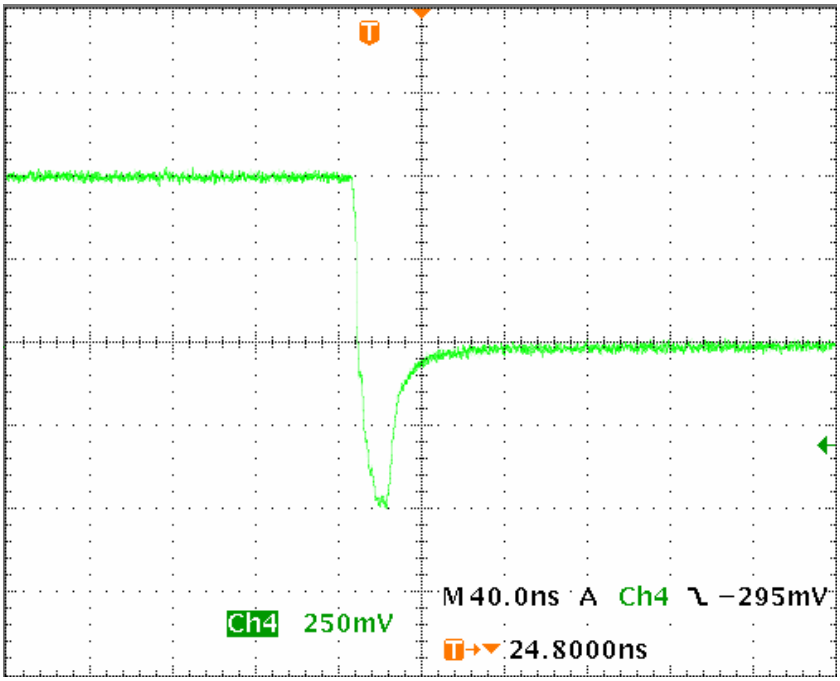
Evaluation Circuit



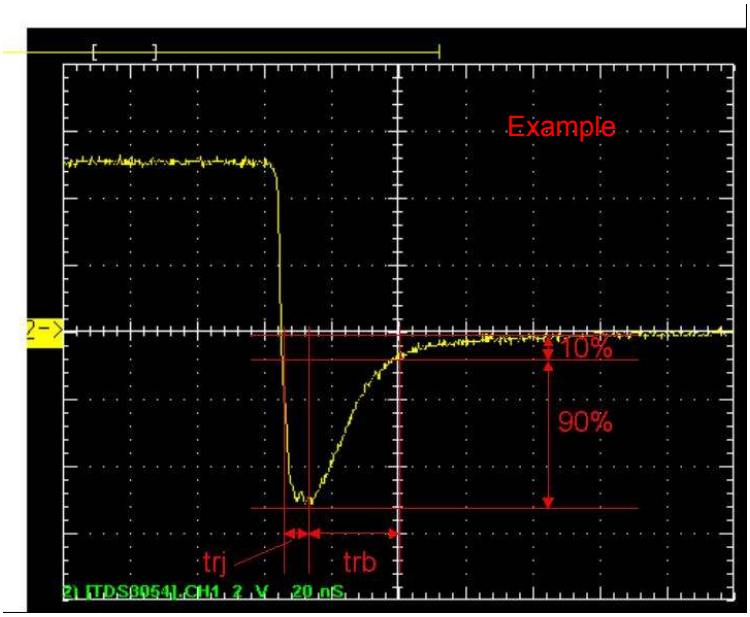
Compare Measurement vs. Simulation

	Measurement		Simulation		Error (%)
trj	**8.800**	**ns**	**8.861**	**ns**	**0.693**
trb	**20.800**	**ns**	**20.703**	**ns**	**-0.466**
trr	**29.600**	**ns**	**29.564**	**ns**	**-0.122**

Reverse Recovery Characteristic Reference



Trj=8.8(ns)
Trb=20.8(ns)
Conditions:Ifwd=Irev=0.02(A),Rl=50



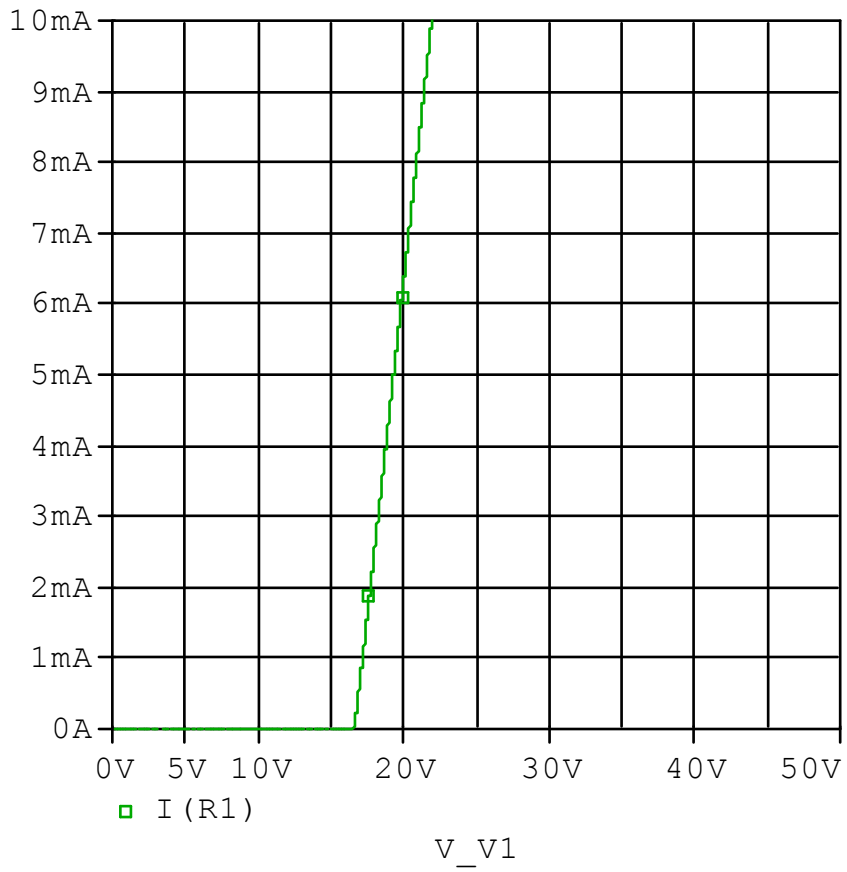
Relation between trj and trb

ESD PROTECTION DIODE SPICE MODEL

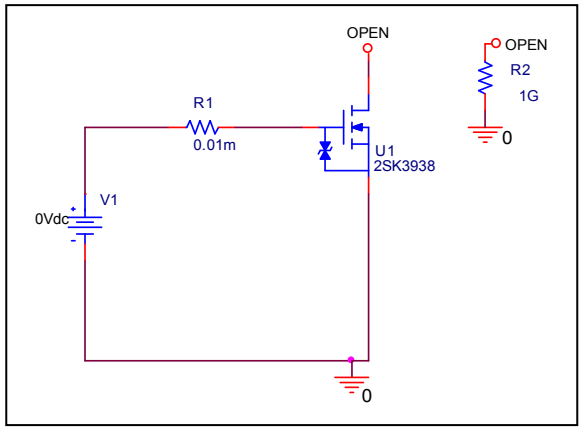
```
*$
.subckt DZ3938 1 2
D2 1 3 DZ2
D1 2 3 DZ1
.model DZ1 D
+ IS=0.01p N=0.1 ISR=0 CJO=3E-15
+ BV=16.612 IBV=0.00093 RS=0
.model DZ2 D
+ IS=0.01p N=0.1 ISR=0 CJO=3E-15
+ BV=16.612 IBV=0.00093 RS=520.134
.ENDS
*****PROTECTION DIODE*****
*$
```

Zener Voltage Characteristic

Circuit Simulation Result



Evaluation Circuit



Zener Voltage Characteristic

Reference