Device Modeling Report

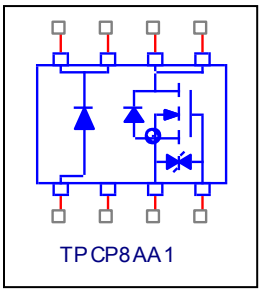
COMPONENTS: Power MOSFET (Professional) /
Schottky Rectifier (Professional)
PART NUMBER: TPCP8AA1
MANUFACTURER: TOSHIBA
REMARK: Body Diode (Standard) / ESD Protection Diode

Bee Technologies Inc.

SPICE MODEL

```
*$
*PART NUMBER: TPCP8AA1
*MANUFACTURER: TOSHIBA
*VDSS=20V, ID=1.6A
*REMARK: Body Diode Standard
*All Rights Reserved Copyright (C) Bee Technologies Inc. 2005
.SUBCKT TPCP8AA1 1 2 3 4 5 6 7 8
X_U1 D 4 3 MTPCP8AA1
X_U2 4 3   DZ8AA1
D_D1 3 D   D8AA1
X_U3 A K   SBD8AA1
R_R1 1 A   0.01m
R_R2 2 0   100MEG
R_R5 5 D   0.01m
R_R6 6 D   0.01m
R_R7 7 K   0.01m
R_R8 8 K   0.01m
.ENDS
*****IC PACKAGE MODEL*****
*$
```

Circuit Configuration



POWER MOSFET SPICE MODEL

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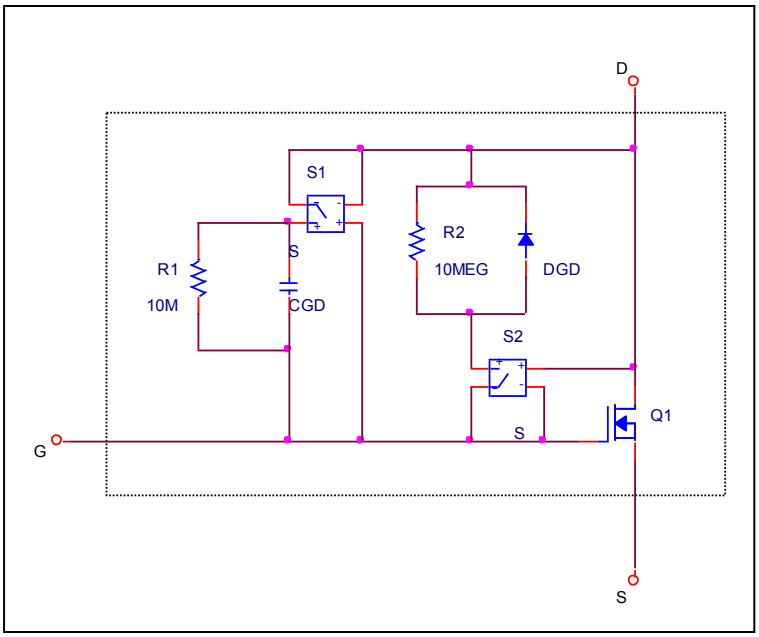
*$
*PART NUMBER: TPCP8AA1
*MANUFACTURER: TOSHIBA
*VDSS=20V, ID=1.6A
*All Rights Reserved Copyright (C) Bee Technologies Inc. 2005
.SUBCKT MTPCP8AA1 D G S
CGD   1       G 0.2897n
R1    1       G 10MEG
S1    1 D G D SMOD1
D1    2       D DGD
R2    D       2 10MEG
S2    2 G D G SMOD1
M1 D   G       S       S M8AA1
.MODEL SMOD1 VSWITCH( VON=0V VOFF=-10mV RON=1m ROFF=1E12)
.MODEL DGD D( CJO=231.63E-12 M=.52774 VJ=.37147)
.MODEL M8AA1 NMOS
+ LEVEL=3 L=720.00E-9 W=.2192 KP=43.00E-6 RS=10.000E-3
+ RD=50.000E-3 VTO=1.175 RDS=10.000E9 TOX=40.000E-9
+ CGSO=1.476E-9 CGDO=10.807E-12
+ CBD=69.65E-12 MJ=.37 PB=1.1346 RG=6.27
+ ETA=.0012 NFS=7.4E+11
+ IS=1.0000E-15 N=5 RB=1
.ENDS
*****MOSFET PROFESSIONAL MODEL*****
*$
```

Equivalent Circuit

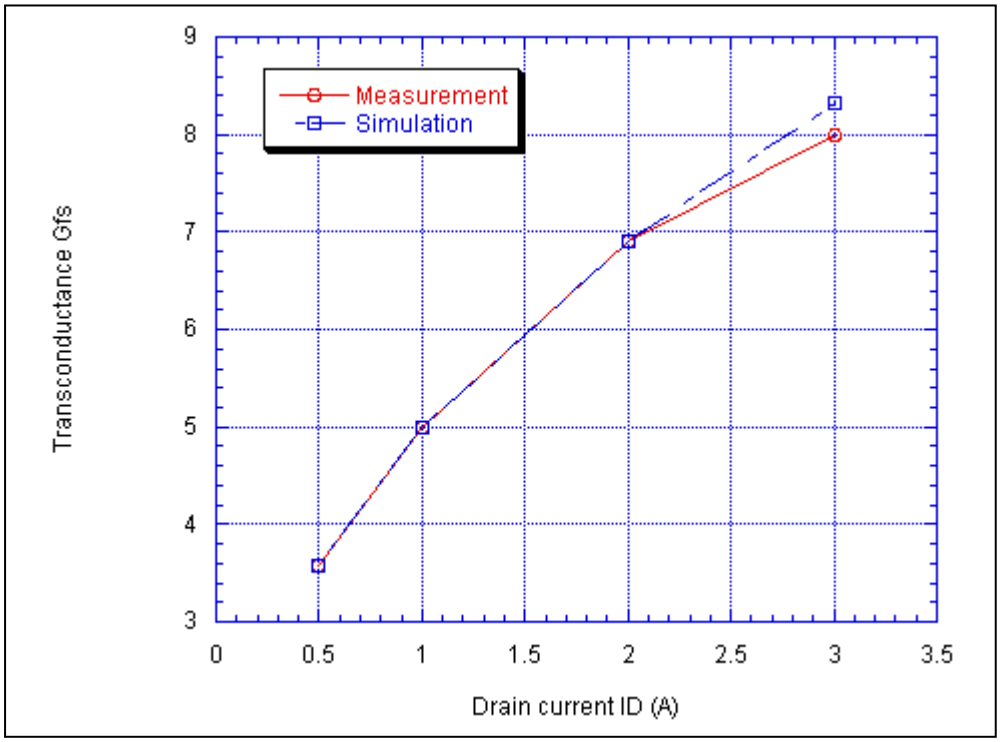


MOSFET MODEL

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	Modility Modulation
KAPPA	Saturation Field Factor
VMAX	Maximum Drift Velocity of Carriers
XJ	Metallurgical Junction Depth
UO	Surface Mobility

Transconductance Characteristic

Circuit Simulation Result

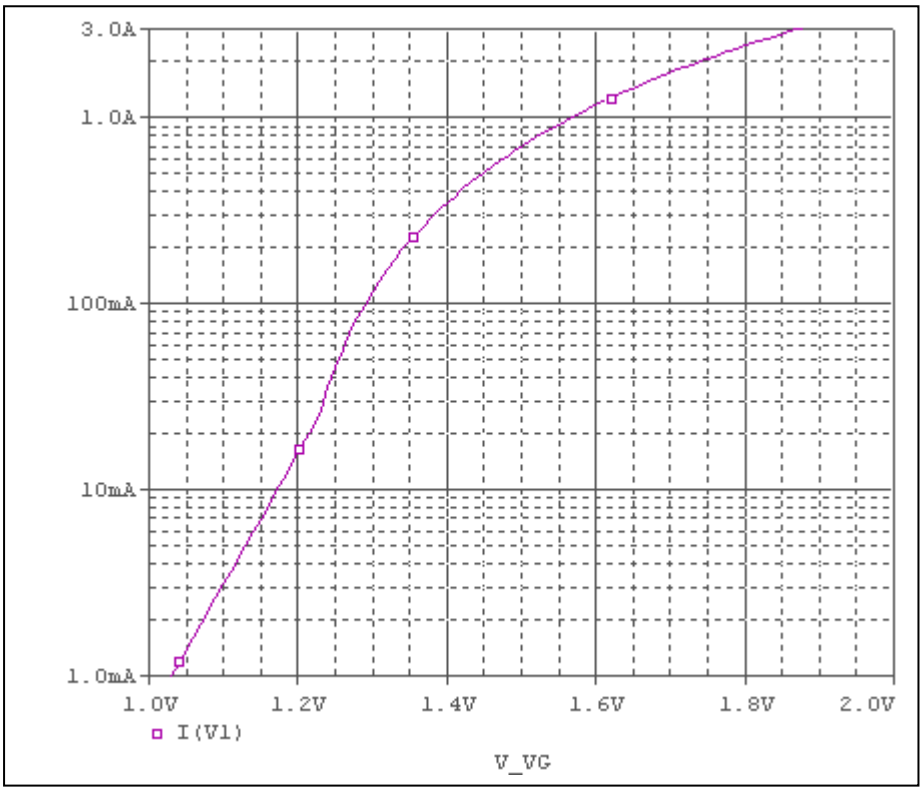


Comparison table

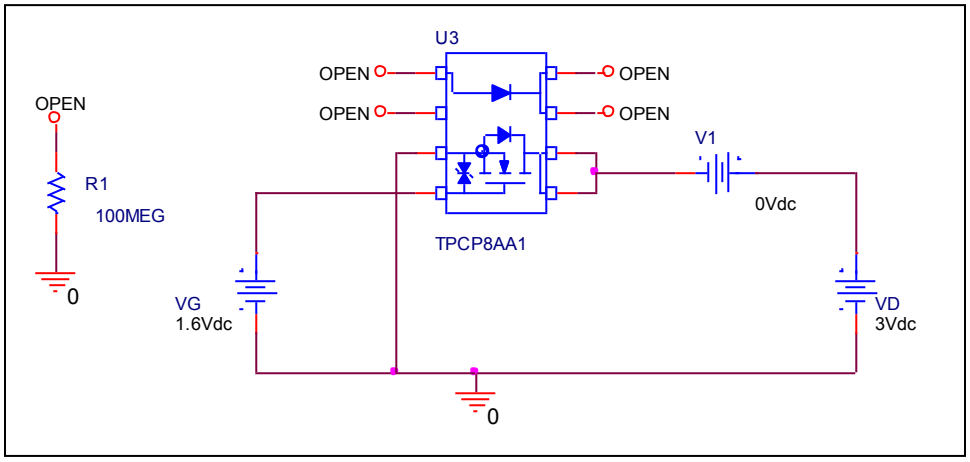
Id(A)	gfs		Error(%)
	Measurement	Simulation	
0.5	3.571	3.586	0.42005
1	5	4.9986	-0.028
2	6.897	6.908	0.15949
3	8	8.313	3.9125

Vgs-Id Characteristic

Circuit Simulation result

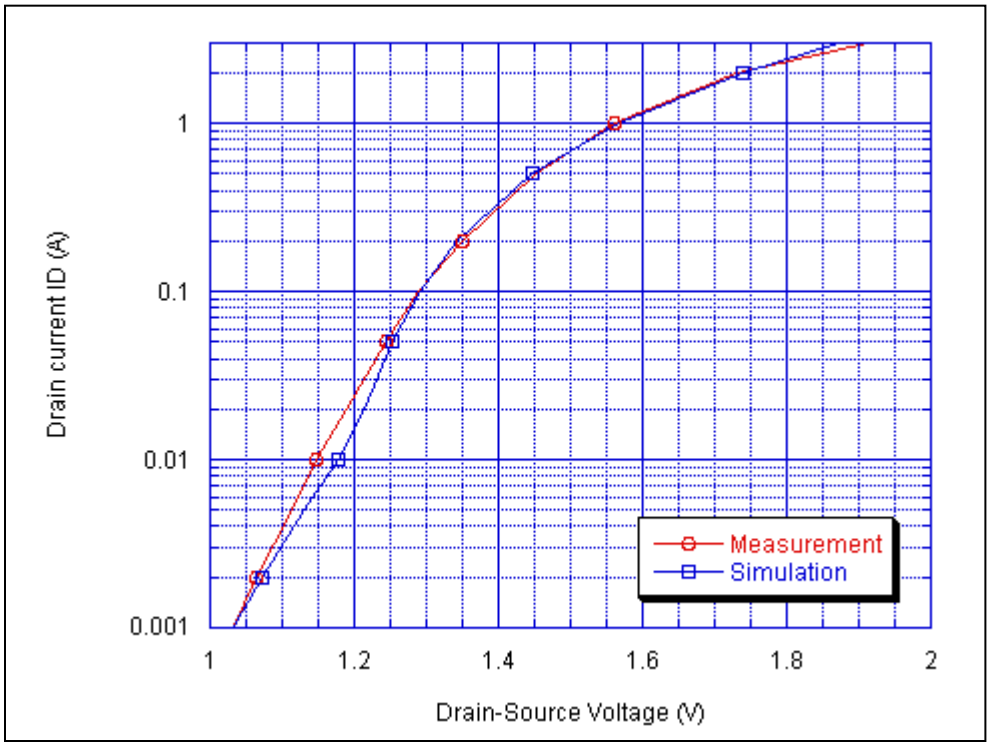


Evaluation circuit



Comparison Graph

Circuit Simulation Result

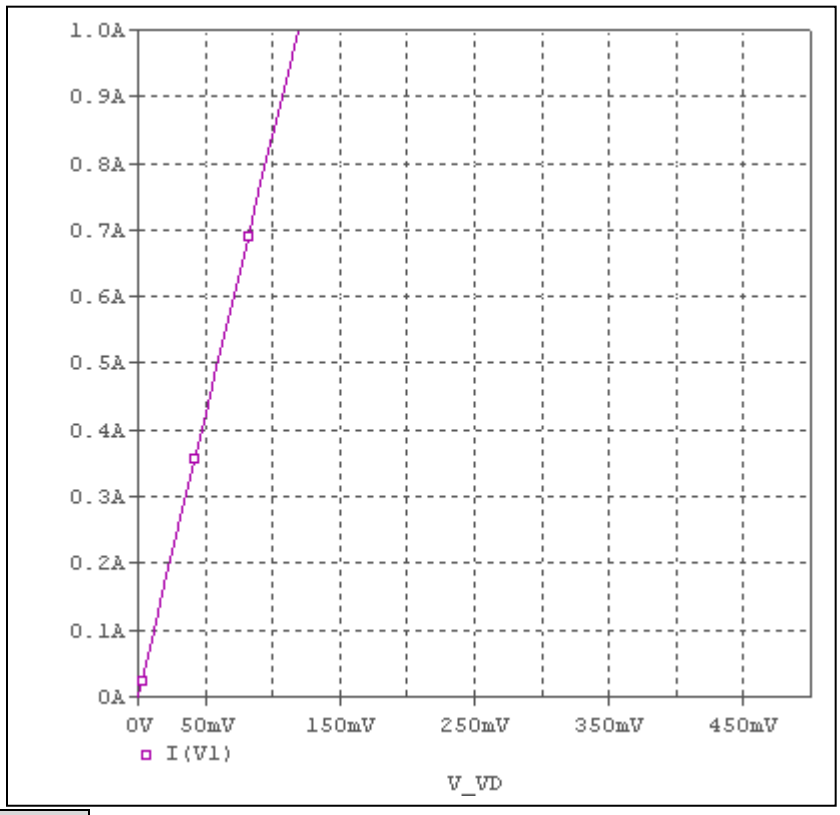


Simulation Result

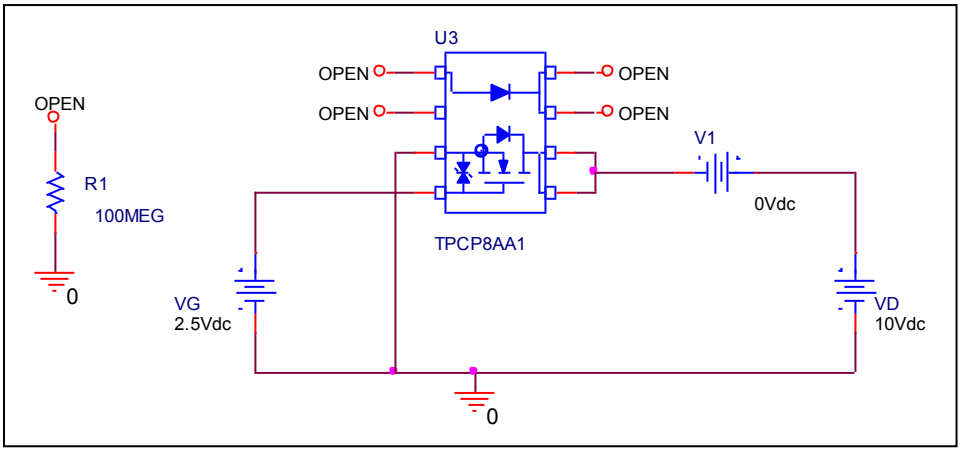
I_D(A)	V_{GS}(V)		Error (%)
	Measurement	Simulation	
0.001	1.03	1.0303	0.029126
0.002	1.065	1.0728	0.732394
0.005	1.114	1.1293	1.373429
0.010	1.148	1.1781	2.621951
0.020	1.188	1.2144	2.222222
0.050	1.244	1.2537	0.779743
0.10	1.29	1.2905	0.03876
0.20	1.35	1.3427	-0.54074
0.50	1.454	1.4473	-0.4608
1.000	1.56	1.5669	0.442308
2.000	1.73	1.739	0.520231

Id-Rds(on) Characteristic

Circuit Simulation result



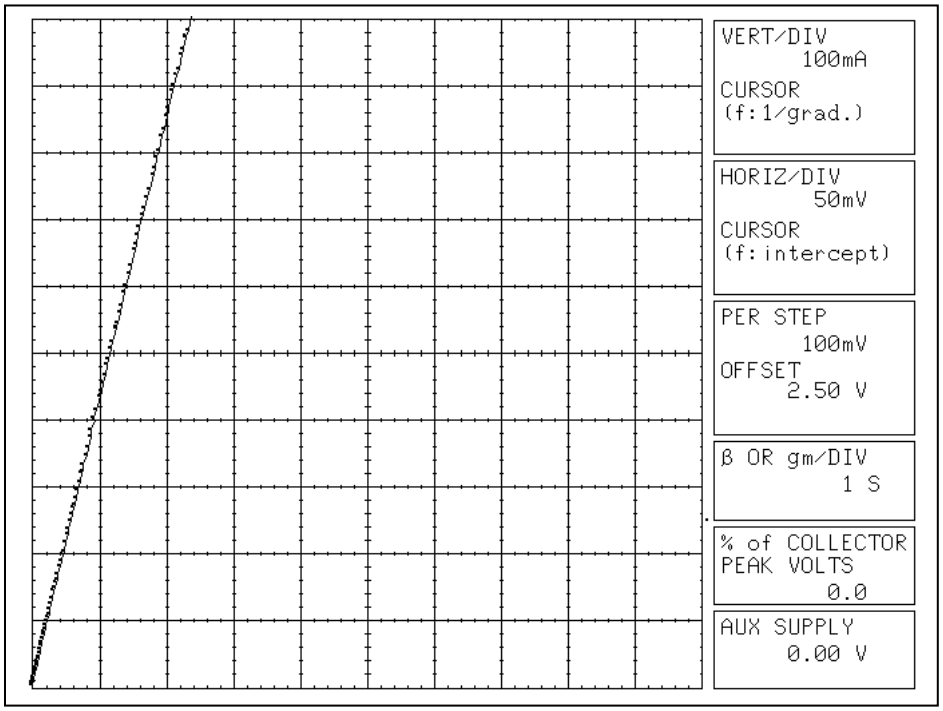
Evaluation circuit



Simulation Result

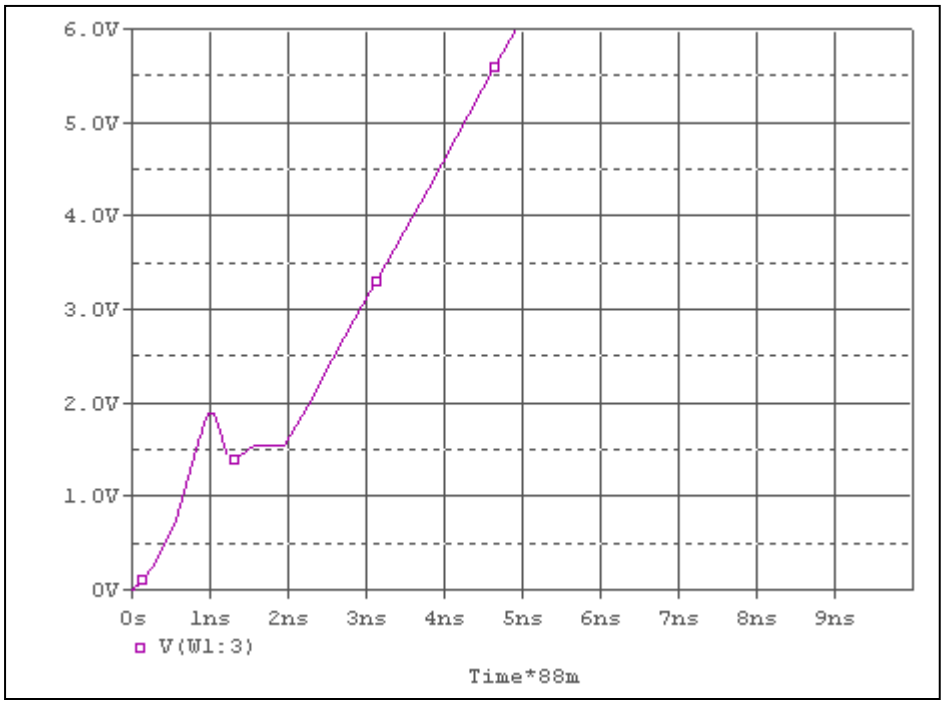
I_D=1.5A, V_{GS}=2.5V	Measurement		Simulation		Error (%)
R_{DS} (on)	119.0625	mΩ	119.0625	mΩ	0.00

Id-Rds(on) Characteristic Reference

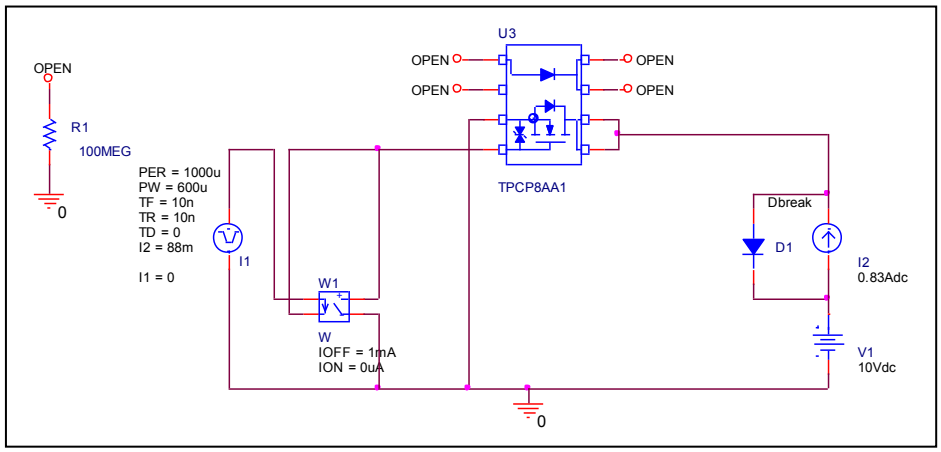


Gate Charge Characteristic

Circuit Simulation result



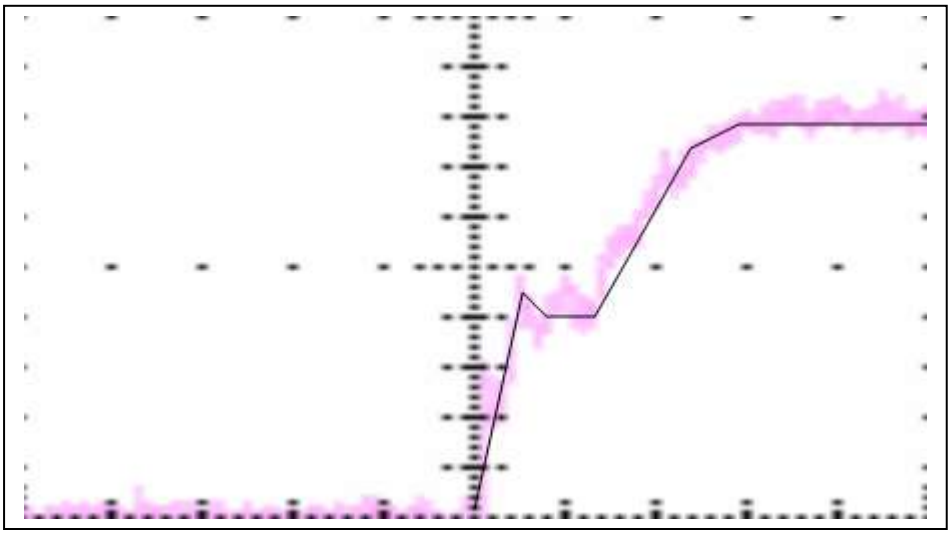
Evaluation circuit



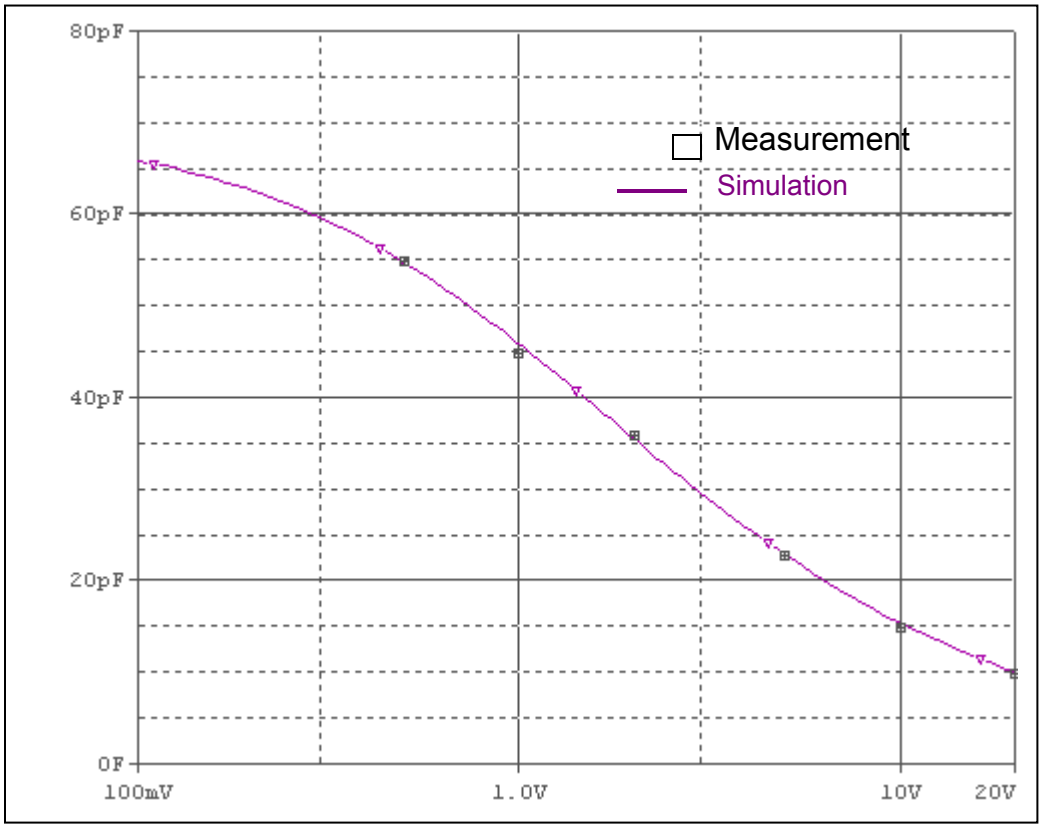
Simulation Result

V_{DD}=10V,I_D=0.83A ,V_{GS}=6V	Measurement		Simulation		Error (%)
Qgs	0.83	nC	0.83037	nC	0.044578
Qgd	1.13	nC	1.1294	nC	-0.0531
Qg	4.92	nC	4.918	nC	-0.04065

Gate Charge Characteristic **Reference**



Capacitance Characteristic

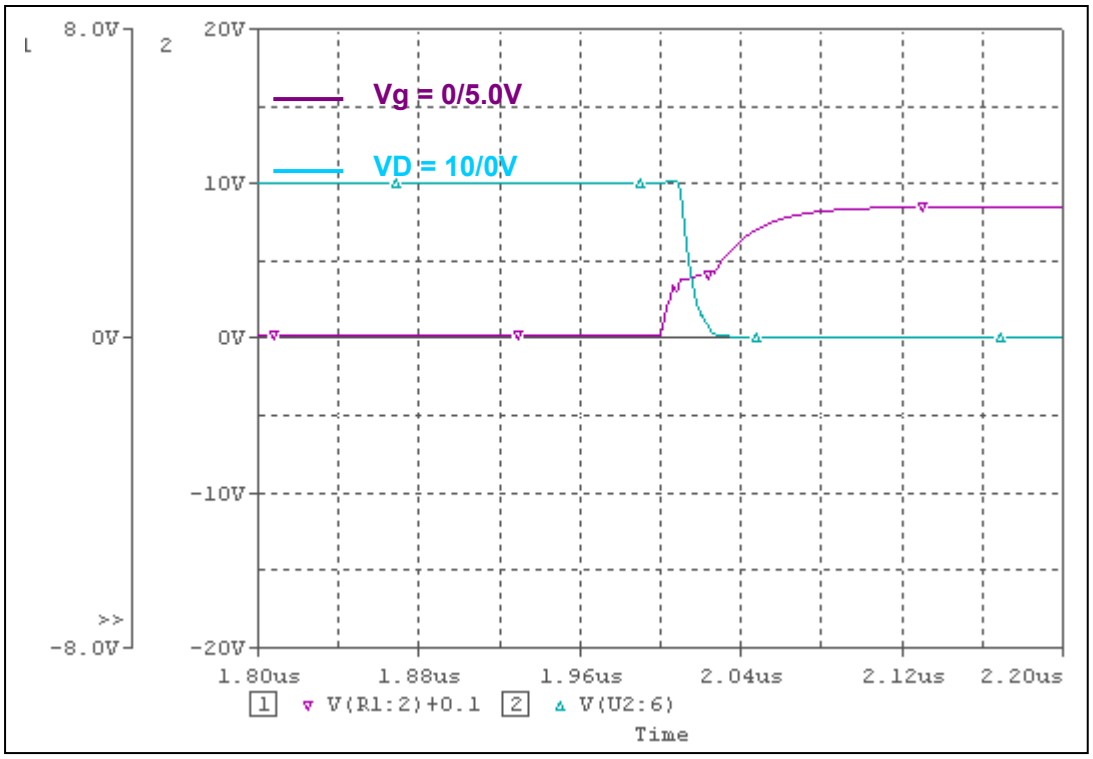


Simulation Result

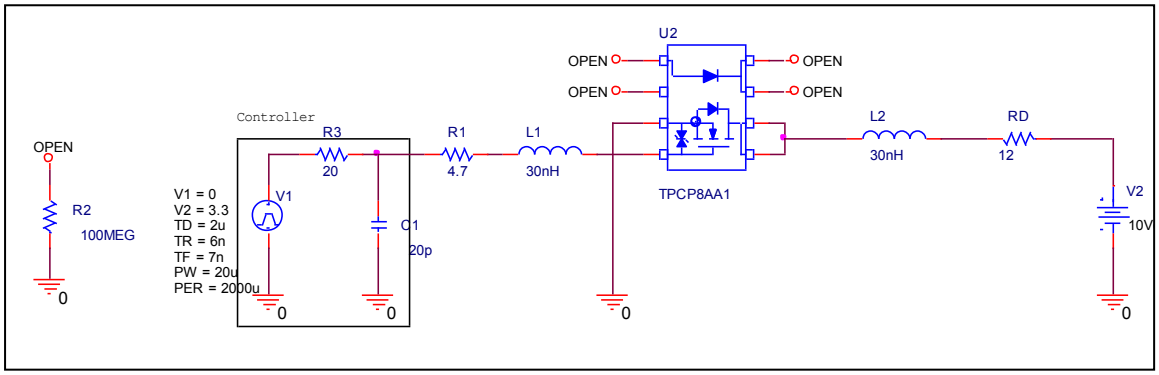
V_{DS}(V)	Cbd(pF)		Error(%)
	Measurement	Simulation	
0.5	55	54.65	-0.636
1.0	45	45.70	1.556
2.0	36	35.50	-1.388
5.0	23	22.93	-0.304
10.0	15	15.53	3.533
20.0	10	10.00	0.000

Switching Time Characteristic

Circuit Simulation result



Evaluation circuit

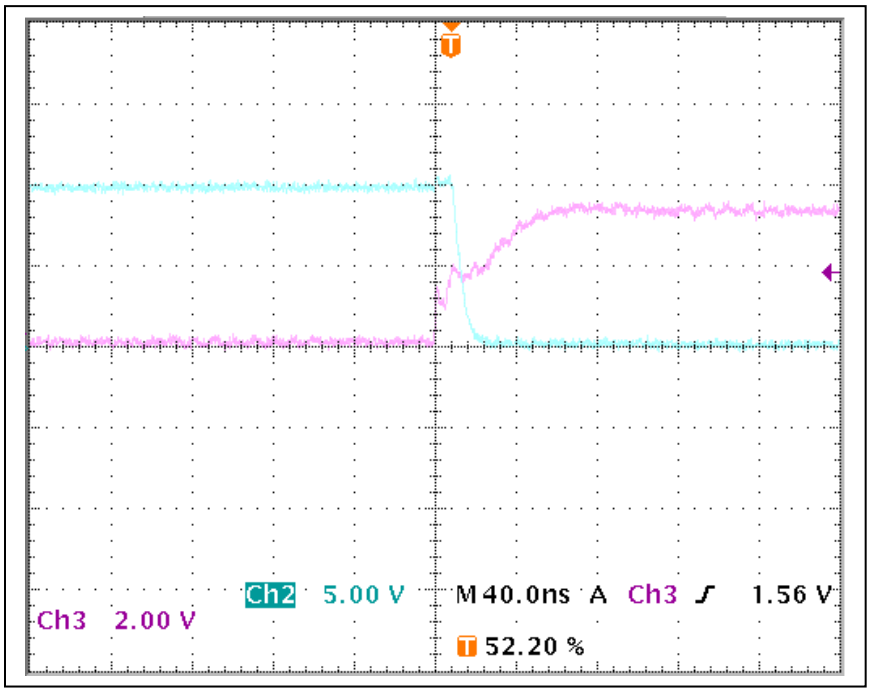


Simulation Result

I_D=1.5 A, V_{DD}=10V V_{GS}=0/5V	Measurement		Simulation		Error(%)
ton	7.5	ns	7.5055	ns	0.0733

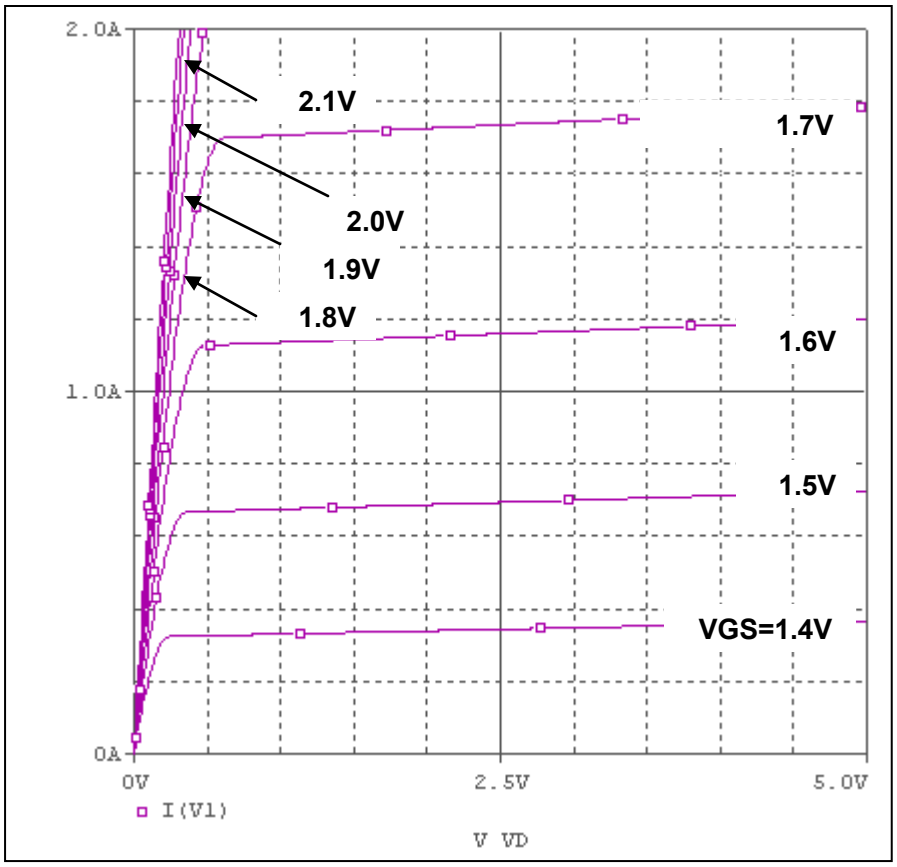
Switching Time Characteristic

Reference

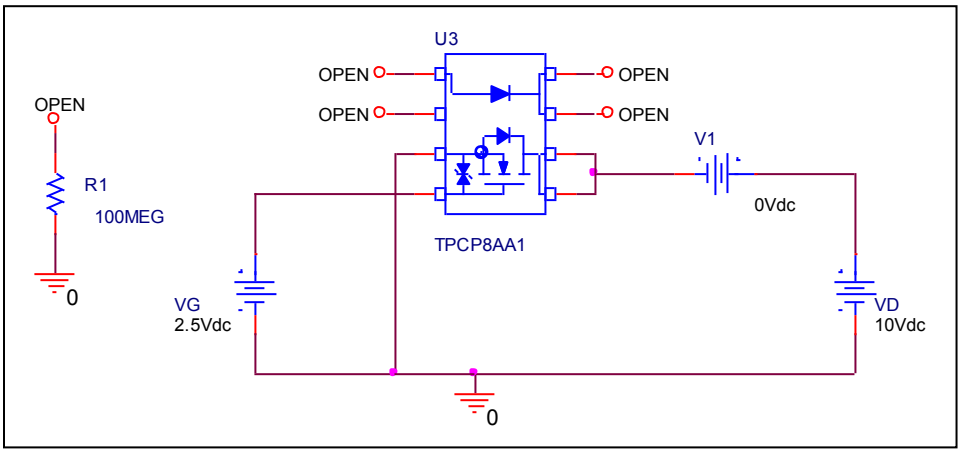


Output Characteristic

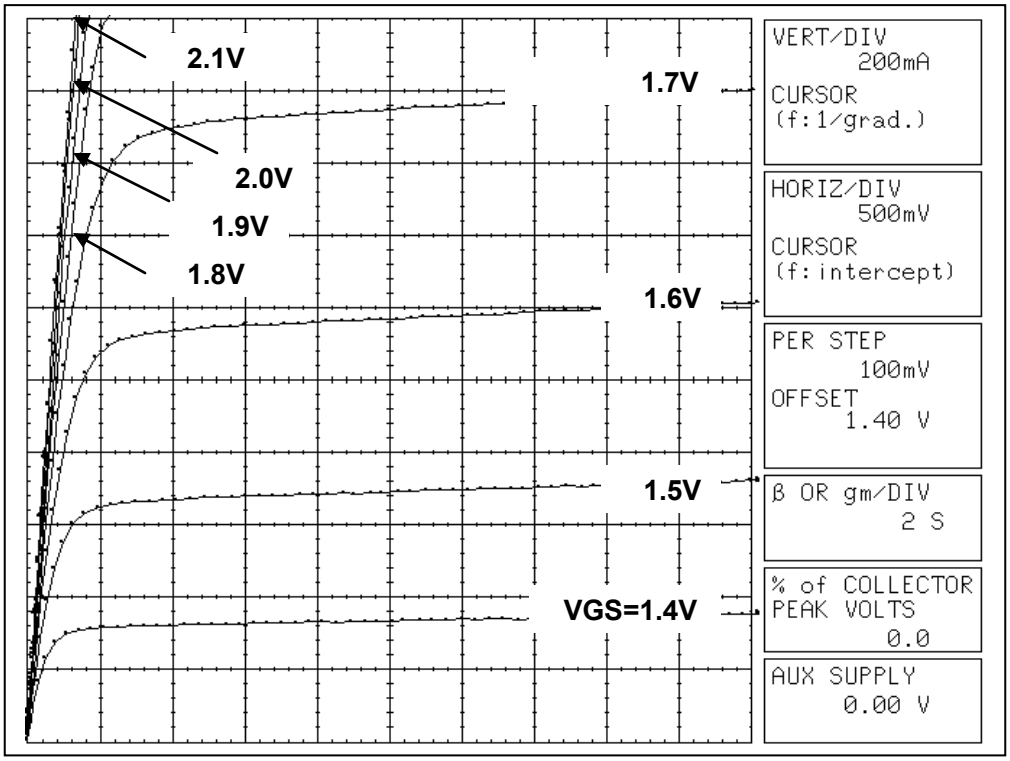
Circuit Simulation result



Evaluation circuit



Output Characteristics Reference



BODY DIODE SPICE MODEL

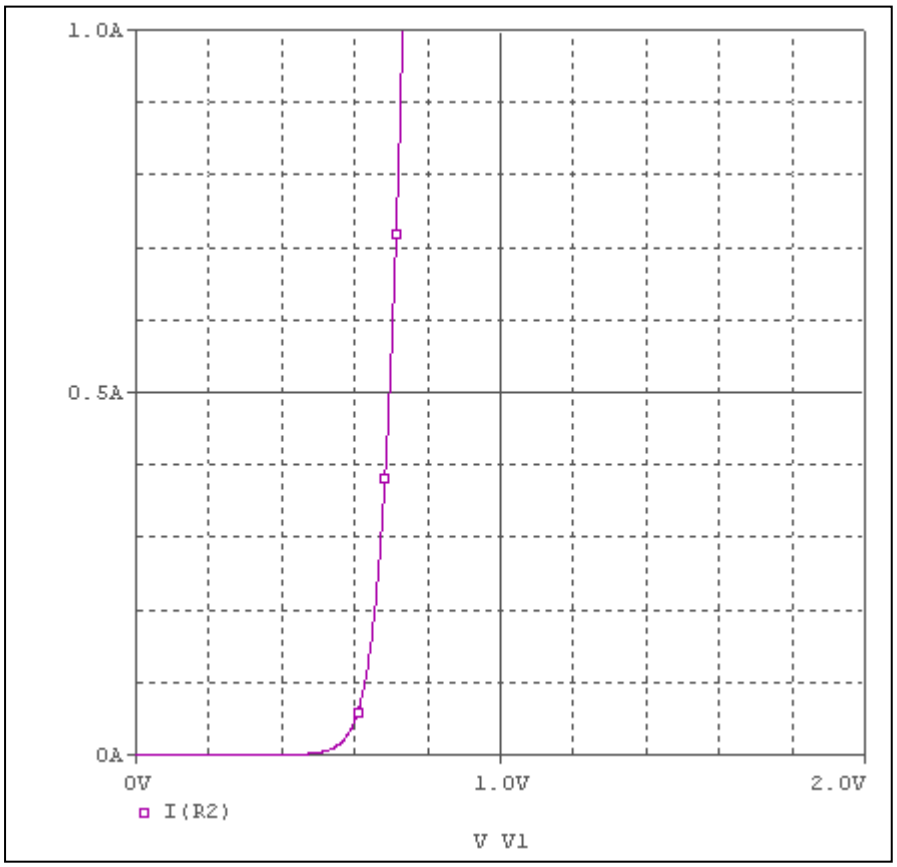
```
*$
*PART NUMBER: TPCP8AA1
*MANUFACTURER: TOSHIBA
*VDSS=20V, ID=1.6A
*All Rights Reserved Copyright (C) Bee Technologies Inc. 2005
.MODEL D8AA1 D
+ IS=2.2098E-9
+ N=1.3716
+ RS=1.0000E-3
+ IKF=.68389
+ CJO=0
+ ISR=0
+ BV=20
+ IBV=0.37E-6
+ TT=6.7E-9
*****BODY DIODE STANDARD MODEL****
*$
```

Body Diode Model

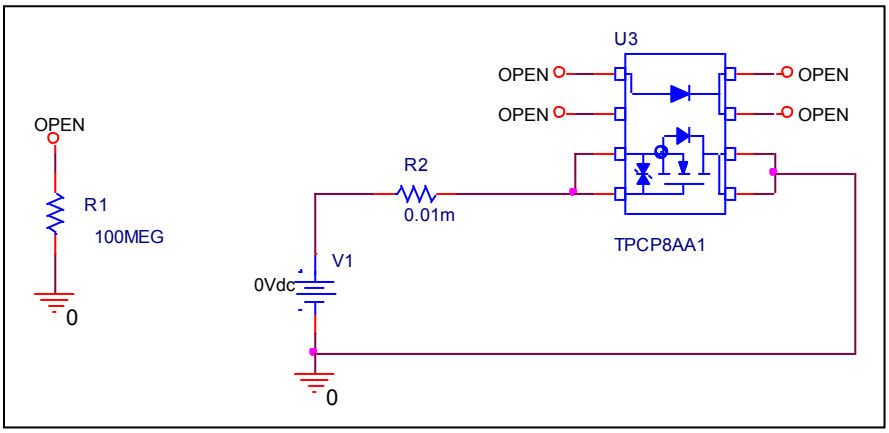
Pspice model parameter	Model description
IS	Saturation Current
N	Emission Coefficient
RS	Series Resistance
IKF	High-injection Knee Current
CJO	Zero-bias Junction Capacitance
M	Junction Grading Coefficient
VJ	Junction Potential
ISR	Recombination Current Saturation Value
BV	Reverse Breakdown Voltage(a positive value)
IBV	Reverse Breakdown Current(a positive value)
TT	Transit Time

Forward Current Characteristic

Circuit Simulation Result

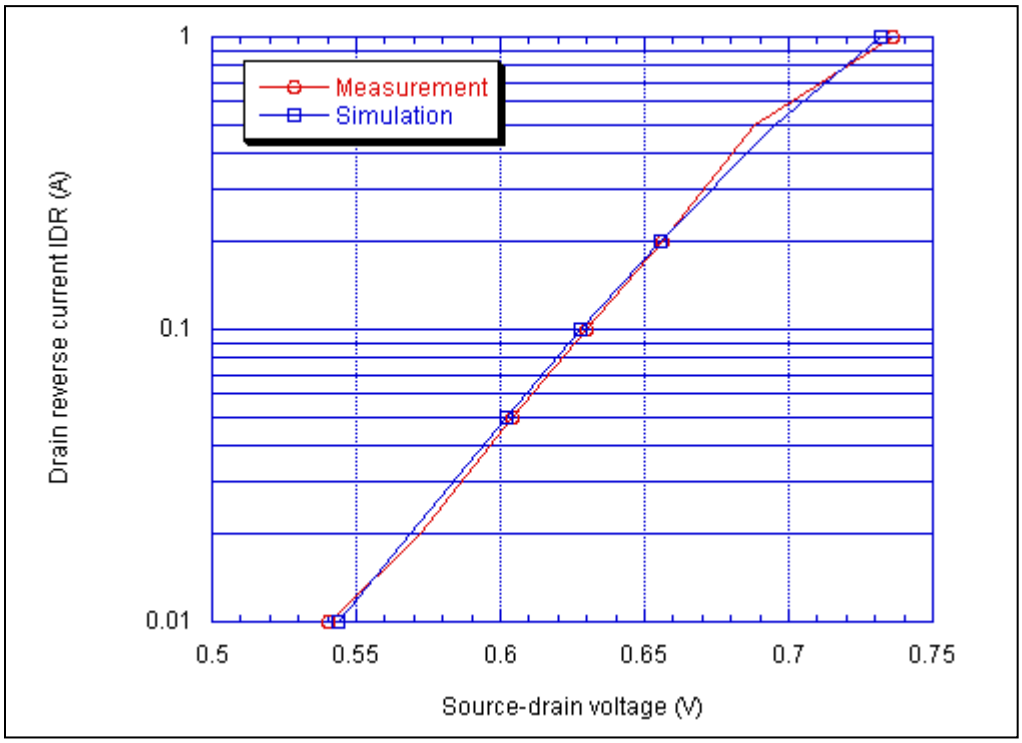


Evaluation Circuit



Comparison Graph

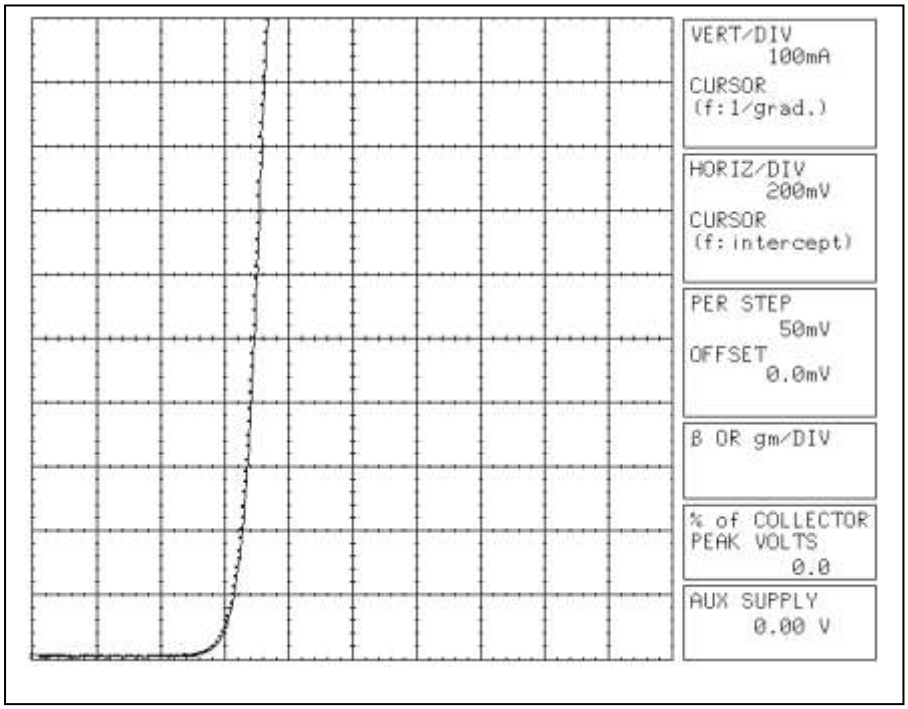
Circuit Simulation Result



Simulation Result

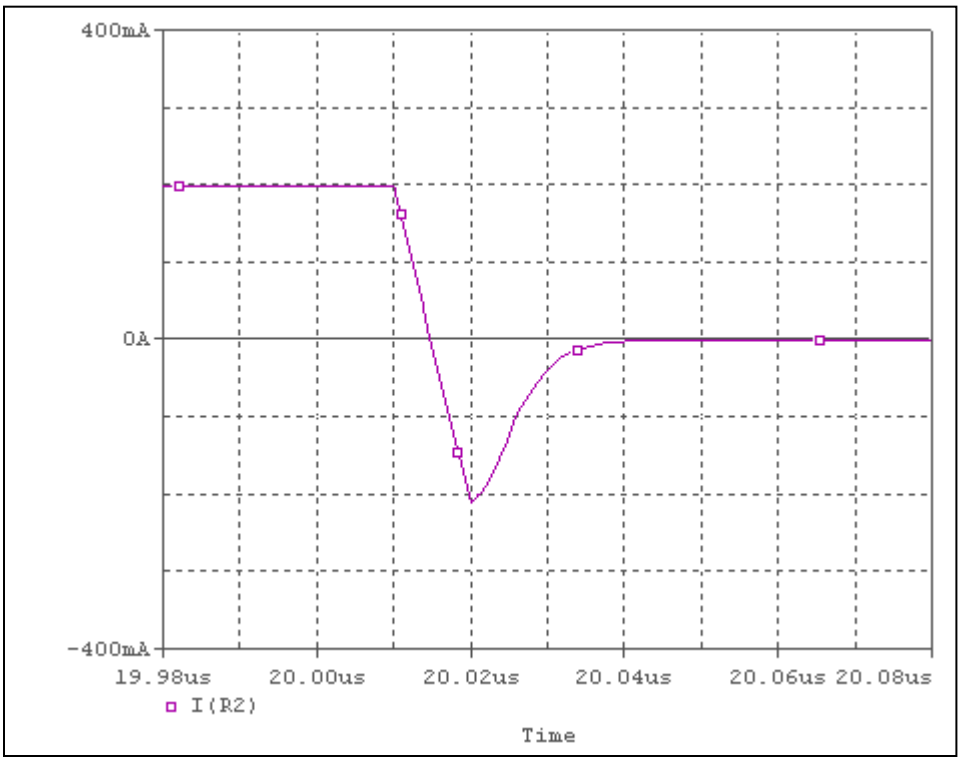
Ifwd(A)	Vfwd(V) Measurement	Vfwd(V) Simulation	%Error
0.01	0.54	0.544	0.740741
0.02	0.572	0.569	-0.52448
0.05	0.604	0.602	-0.33113
0.1	0.63	0.628	-0.31746
0.2	0.656	0.6553	-0.10671
0.5	0.688	0.695	1.017442
1	0.736	0.732	-0.54348

Forward Current Characteristic Reference

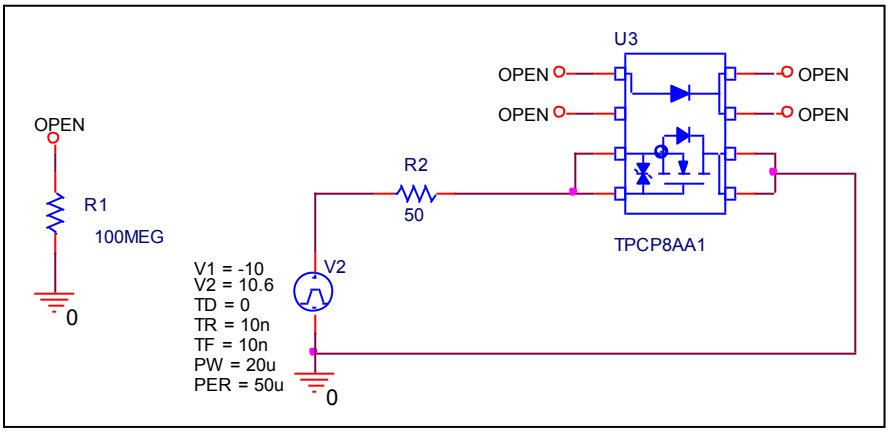


Reverse Recovery Characteristic

Circuit Simulation Result



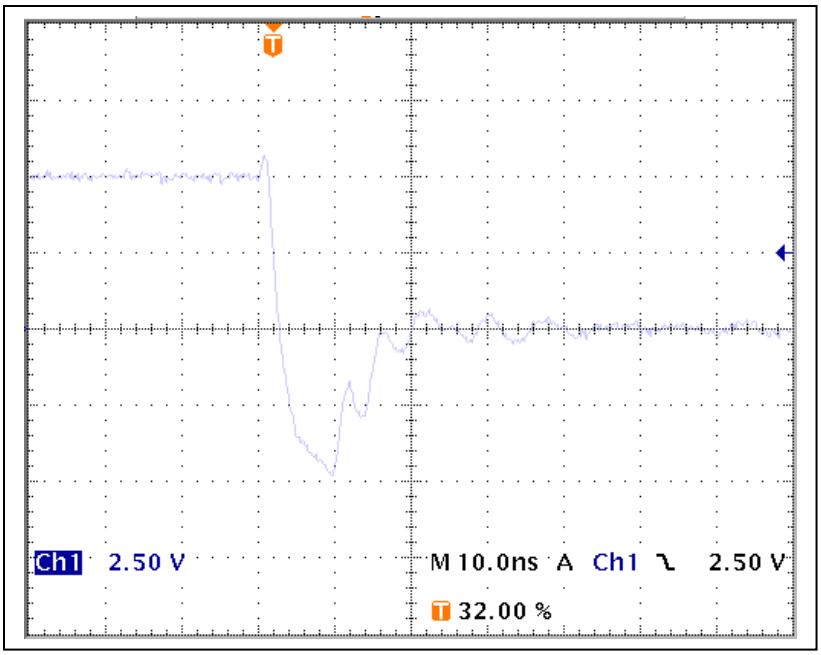
Evaluation Circuit



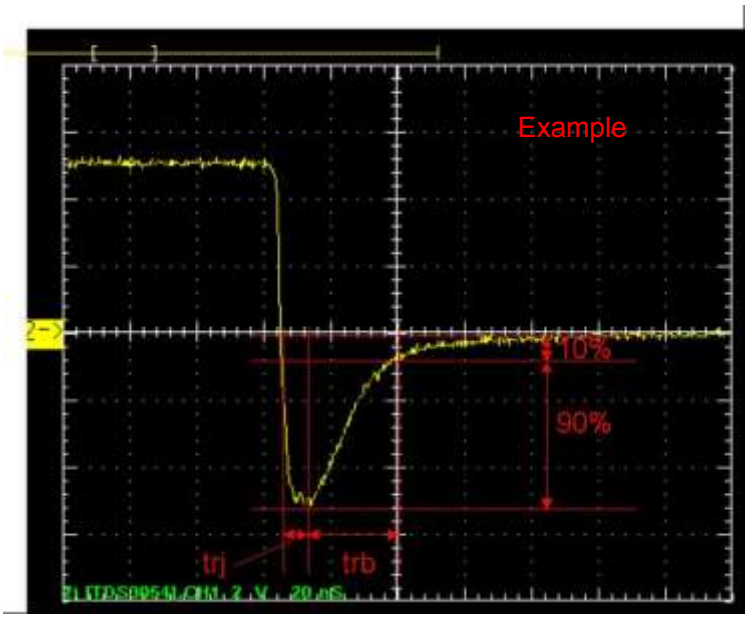
Compare Measurement vs. Simulation

	Measurement		Simulation		Error (%)
trr=trj+trb	**17**	**ns**	**17.075**	**ns**	**0.44**

Reverse Recovery Characteristic Reference



Trj=6.6(ns)
Trb=10.4(ns)
Conditions:Ifwd=Irev=0.2(A),Rl=50



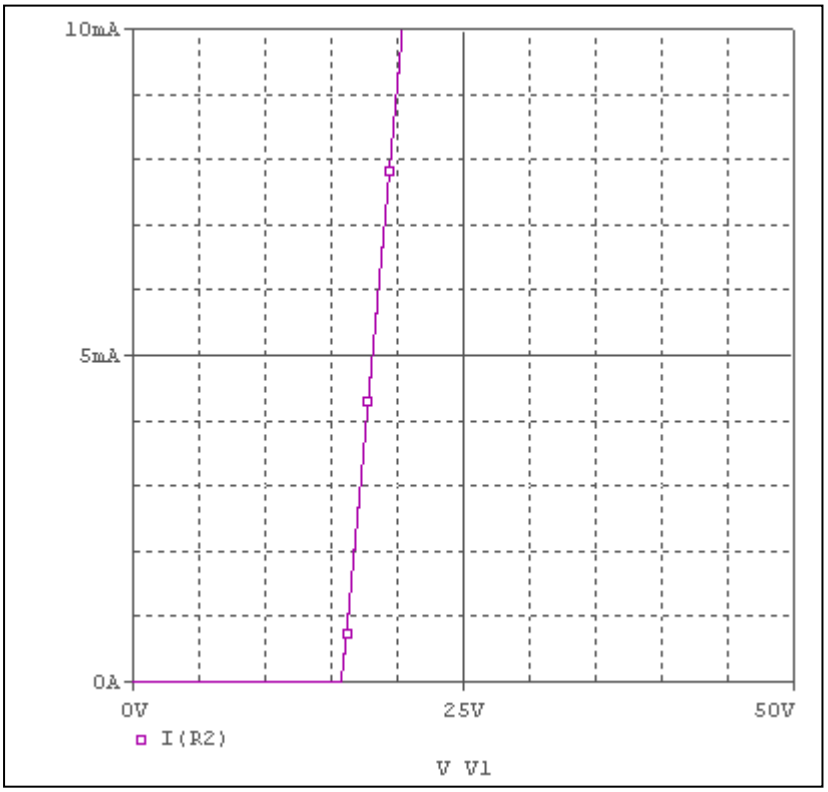
Relation between trj and trb

ESD PROTECTION DIODE SPICE MODEL

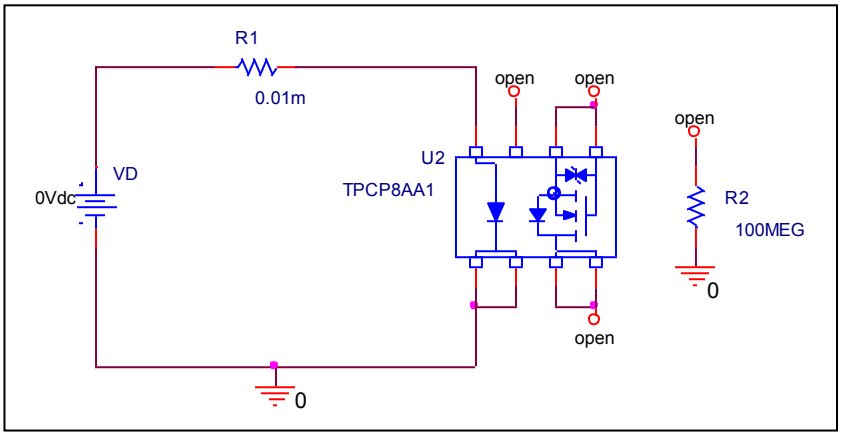
```
*$
*PART NUMBER: TPCP8AA1
*MANUFACTURER: TOSHIBA
*VGSS=12V
*All Rights Reserved Copyright (C) Bee Technologies Inc. 2005
.SUBCKT DZ8AA1 1 2
D1        1 3 DZ
D2        2 3 DZ1
.MODEL DZ D
+ IS=0.01p N=0.1 ISR=0 IBV=0.001 BV=15.75
+ RS=450 XTI=0 EG=0
.MODEL DZ1 D
+ IS=0.01p N=0.1 ISR=0 IBV=0.001 BV=15.75 RS=0
+ XTI=0 EG=0
.ENDS
*****PROTECTION DIODE*****
*$
```

Zener Voltage Characteristic

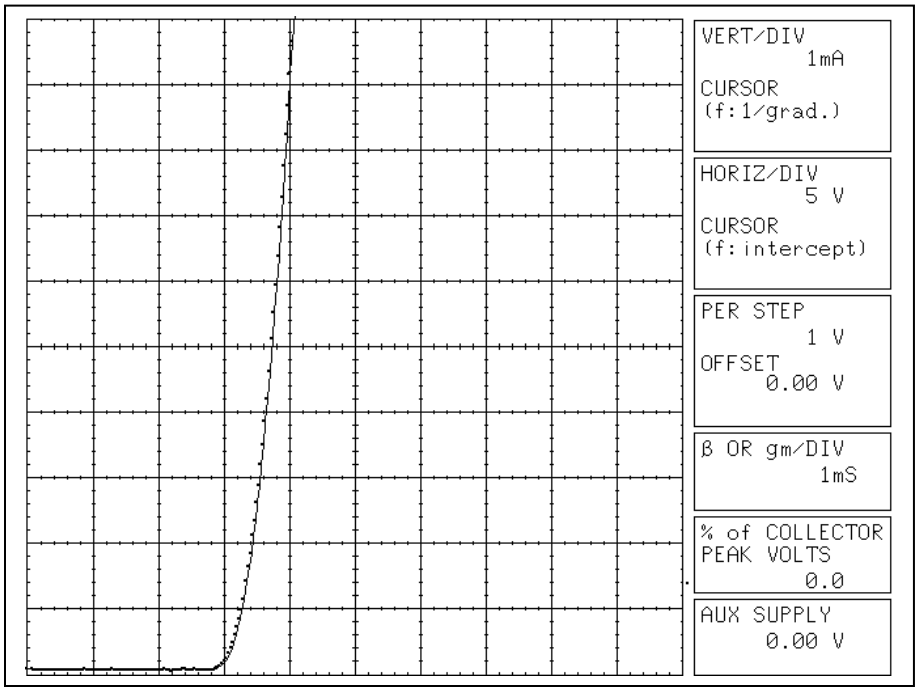
Circuit Simulation Result



Evaluation Circuit



Zener Voltage Characteristic Reference



DIODE SCHOTTKY SPICE MODEL

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*$
* PART NUMBER: TPCP8AA1
* MANUFACTURER: TOSHIBA
* VRM=25, Io=0.7A, IFSM= 4A
* All Rights Reserved Copyright (C) Bee Technologies Inc. 2005
.SUBCKT RB160L-60  A K
V_V_I        A N00040 0Vdc
V_V_Ifwd        IN2 K 0Vdc
E_E1        VREV 0 VALUE { IF(V(A,K)>0, 0,V(A,K)) }
E_E3        I_REV0 0 VALUE { 7.2067e-06*exp(0.12869*(-V(Vrev)))}
E_E4        I_REV 0 VALUE { V(I_rev0)*V(Vr_small)-(-I(V_V_Irev)) }
E_E6        IN K VALUE { IF(V(A,K)>0, V(A,K),0) }
V_V_Irev        VREV1 VREV 0Vdc
G_ABMI1        N00040 K VALUE { I(V_V_Ifwd)-V(I_rev)    }
E_E2        VR_SMALL 0 TABLE { V(Vrev) }
+ ((-0.2,0.62) (0,0))
R_R1        0 VR_SMALL  10MEG
R_R2        0 I_REV0  10MEG
R_R3        0 I_REV  10MEG
D_D4        IN IN2 DTPCP8AA1
D_D5        VREV1 0 DTPCP8AA1
.MODEL TPCP8AA1 D
+ IS=9.2500E-6 RS=31.532E-3 IKF=.11614
+ CJO=103.44E-12 M=3.5311 VJ=9.9900
+ ISR=0 N=1 EG=.69 BV=25 IBV=100.00E-6
+ TT=0
.ENDS
*$
```
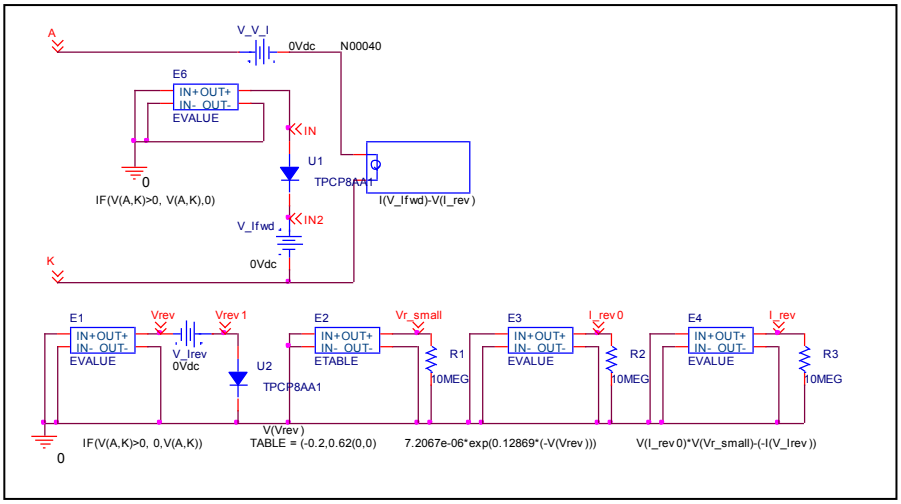
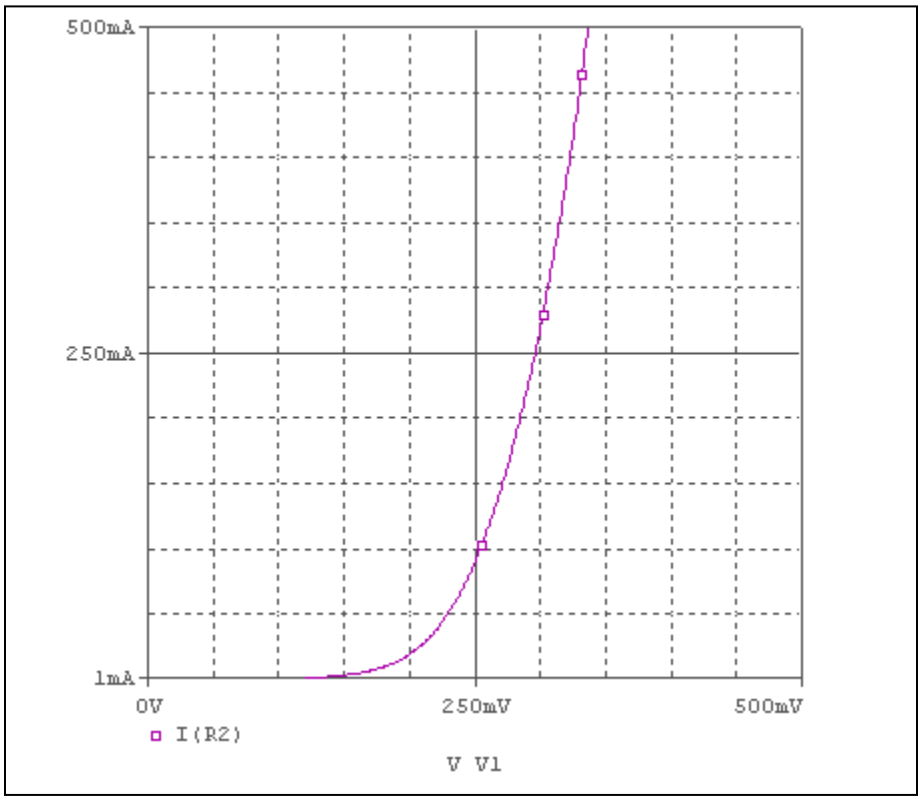

EQUIVALENT CUIRCUIT

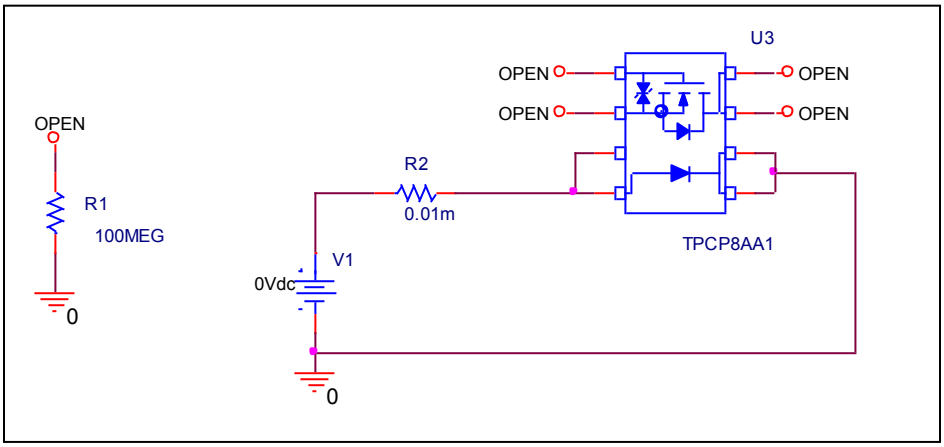


Forward Current Characteristic

Circuit Simulation Result

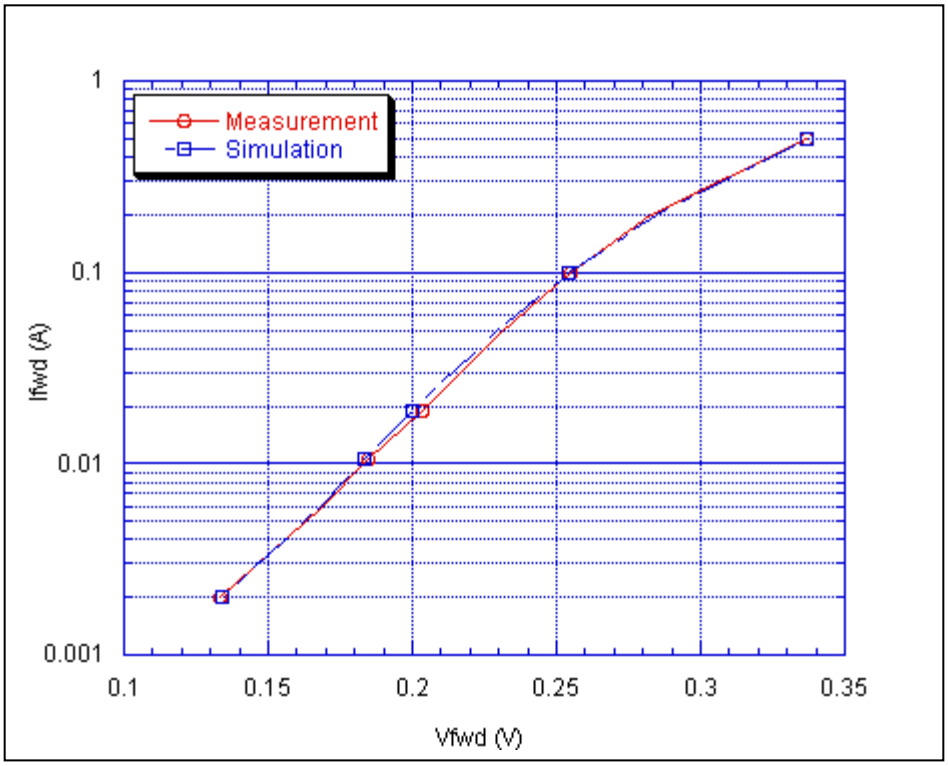


Evaluation Circuit



Comparison Graph

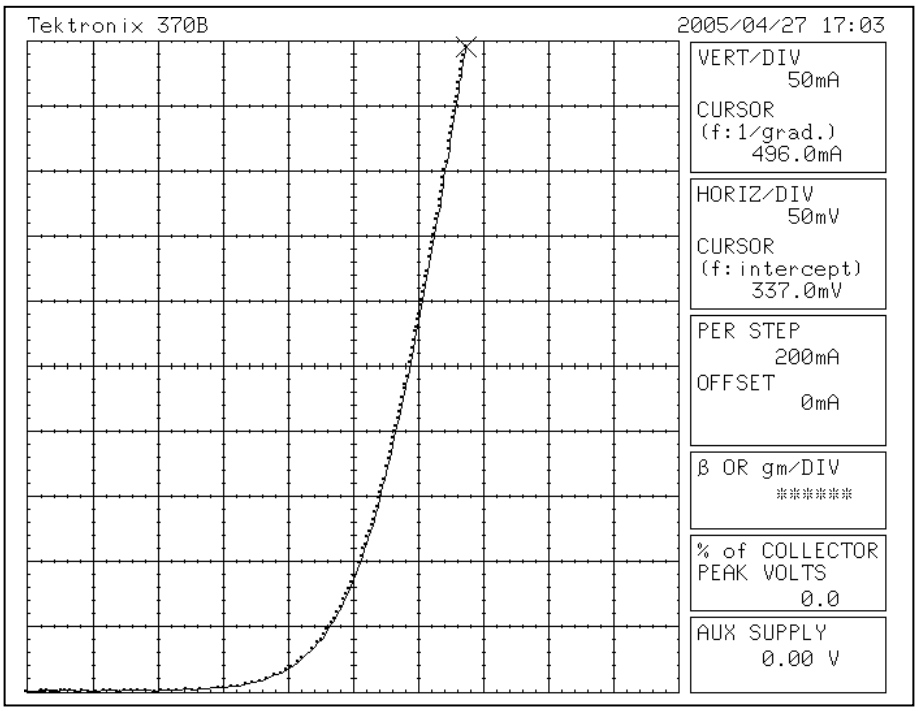
Circuit Simulation Result



Simulation Result

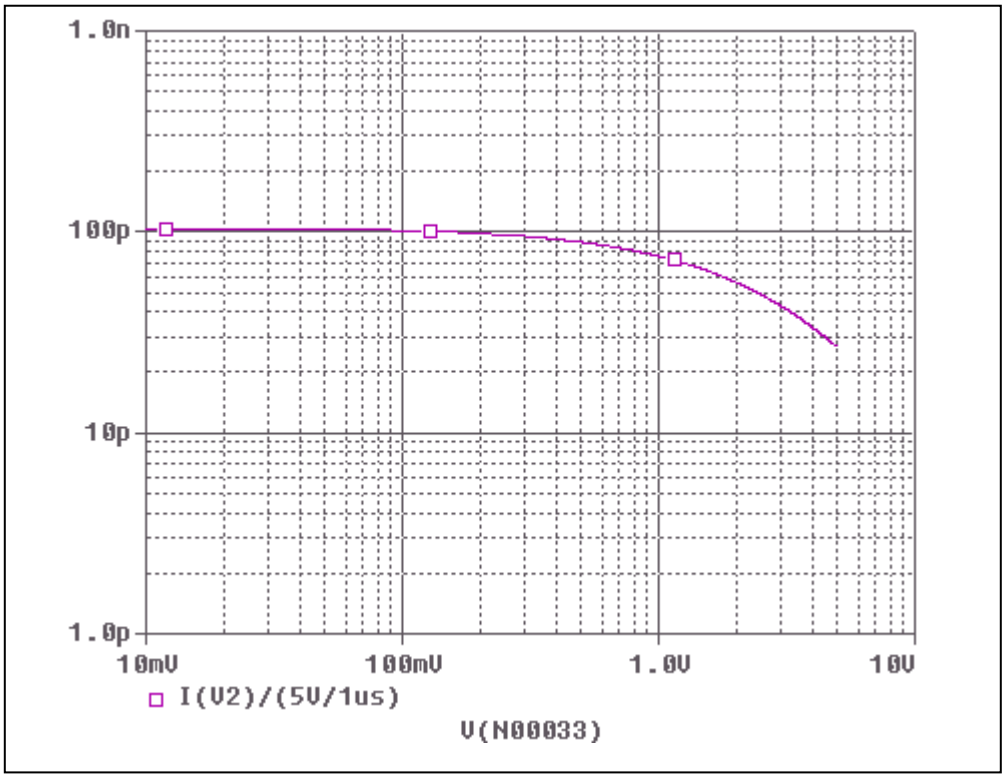
Ifwd (A)	Vfwd (V)		%Error
	Measurement	Simulation	
0.002	0.1335	0.1339	0.2996
0.006	0.1685	0.1683	- 0.1186
0.0105	0.1845	0.1834	- 0.5962
0.019	0.2035	0.2000	- 1.7199
0.0485	0.2305	0.2284	- 0.9110
0.0995	0.255	0.2540	- 0.3921
0.2	0.2825	0.2846	0.7433
0.5	0.337	0.3366	- 0.1186

Forward Current Characteristic Reference

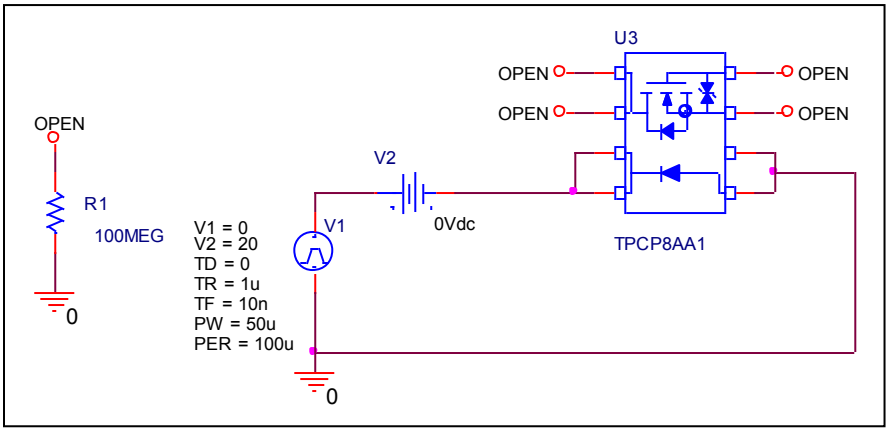


Junction Capacitance Characteristic

Circuit Simulation Result

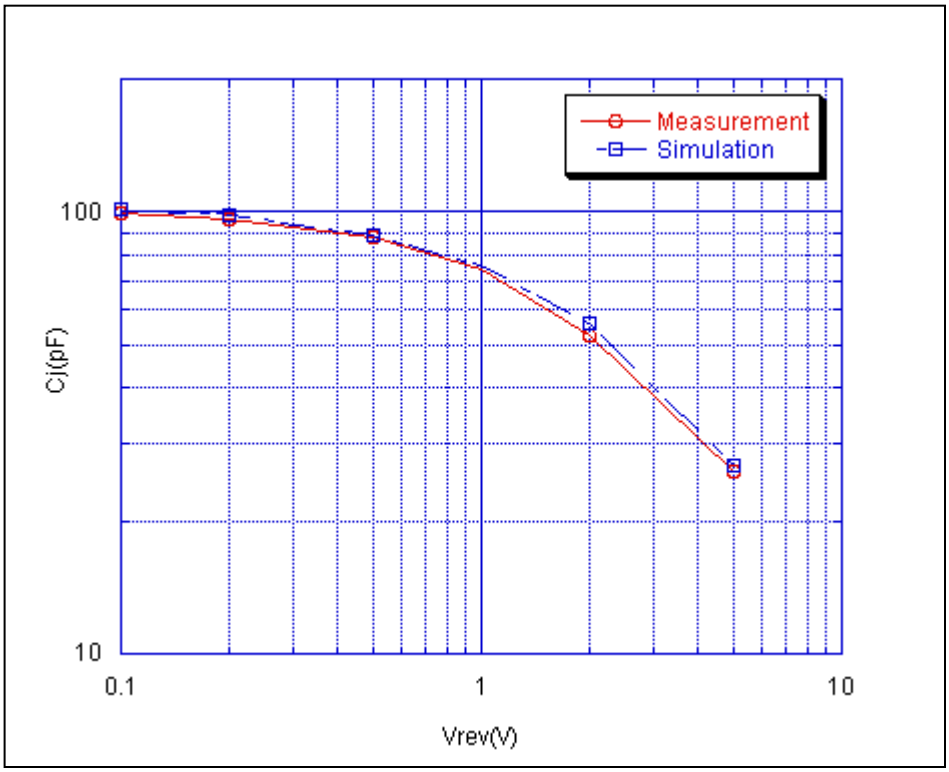


Evaluation Circuit



Comparison Graph

Circuit Simulation Result

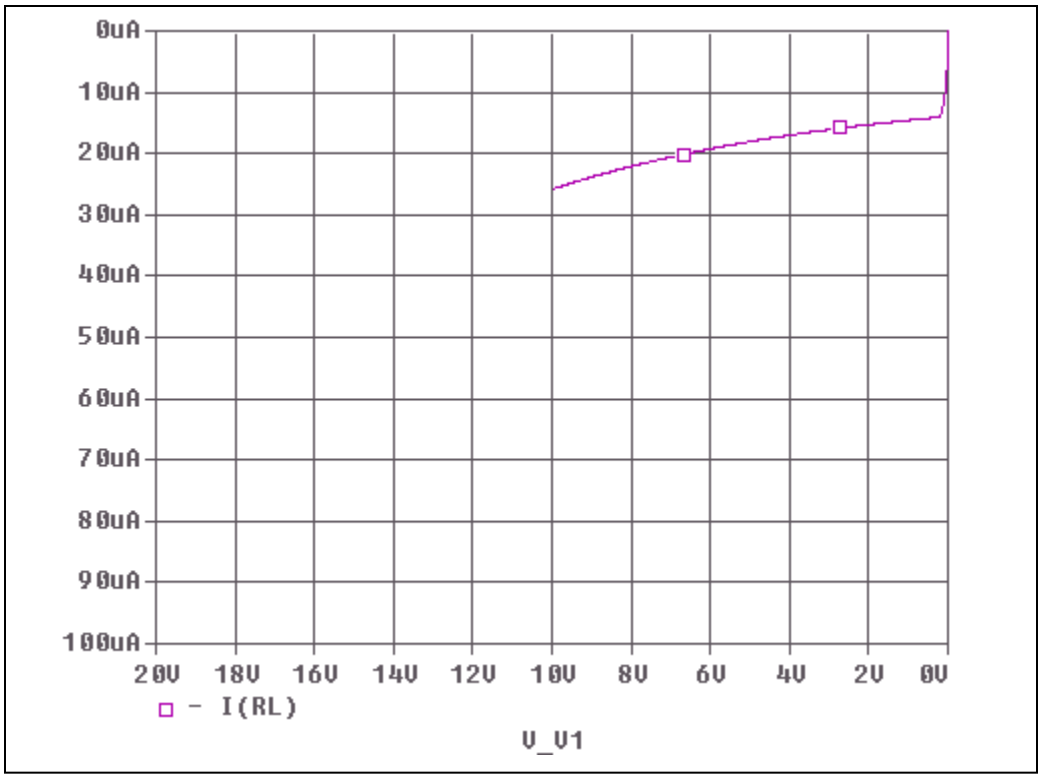


Simulation Result

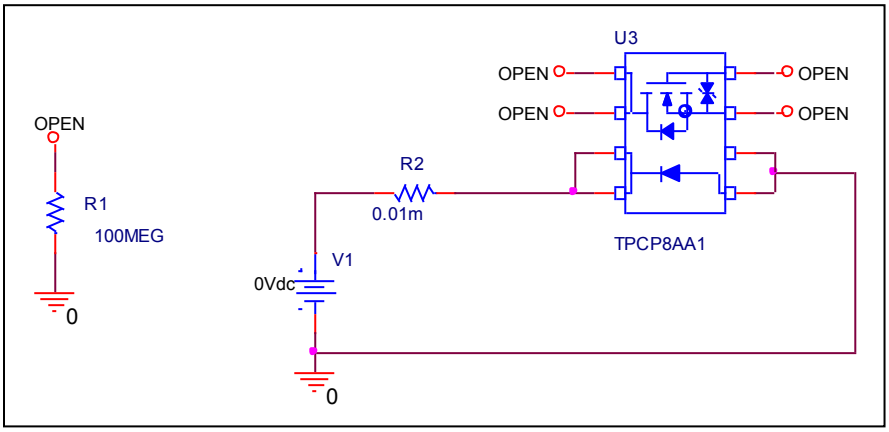
Vrev(V)	Cj(pF)		%Error
	Measurement	Simulation	
0	103.62	103.620	0.0000
0.1	99.524	101.764	2.2507
0.2	96.701	98.391	1.7476
0.5	87.313	89.032	1.9687
1	74.087	75.671	2.1380
2	52.873	56.228	2.5627
5	25.806	26561	1.7441

Reverse Characteristic

Circuit Simulation Result

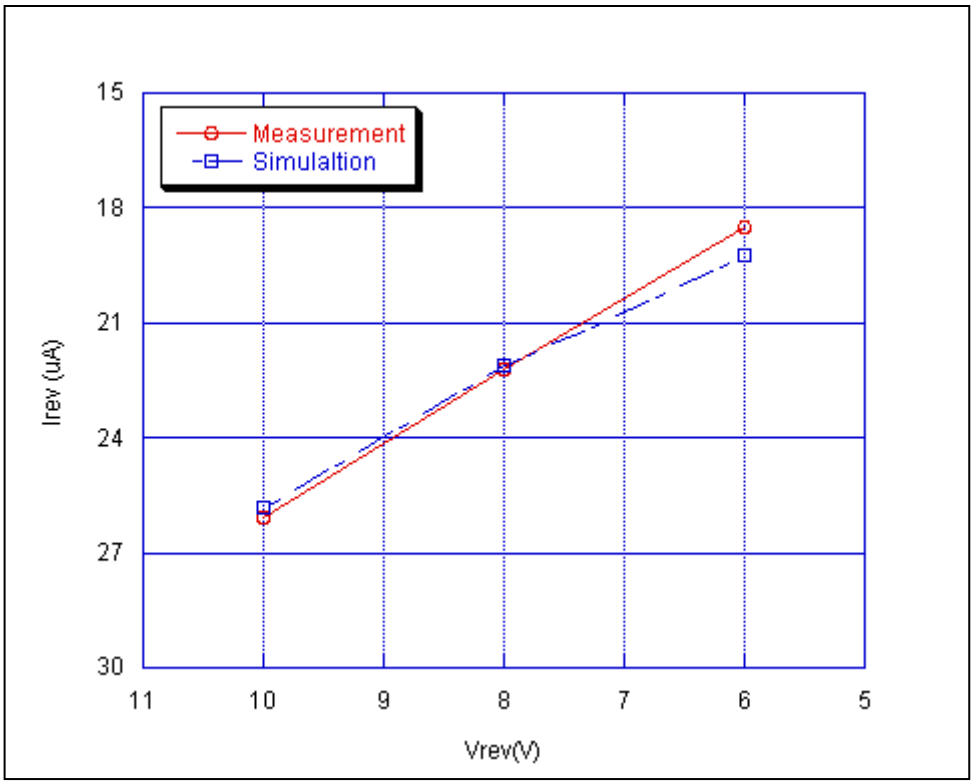


Evaluation Circuit



Comparison Graph

Circuit Simulation Result



Simulation Result

Vrev(V)	Irev (uA)		%Error
	Measurement	Simulation	
6	18.5	19.23	3.94594
8	22.2	22.09	- 0.49549
10	26.1	25.81	- 1.11111

Reverse Current Characteristic Reference