

# Device Modeling Report

COMPONENTS: Power MOSFET (Professional Model)  
PART NUMBER: 2SK4077  
MANUFACTURER: NEC  
REMARK: Body Diode (Professional Model) /  
ESD Protection Diode



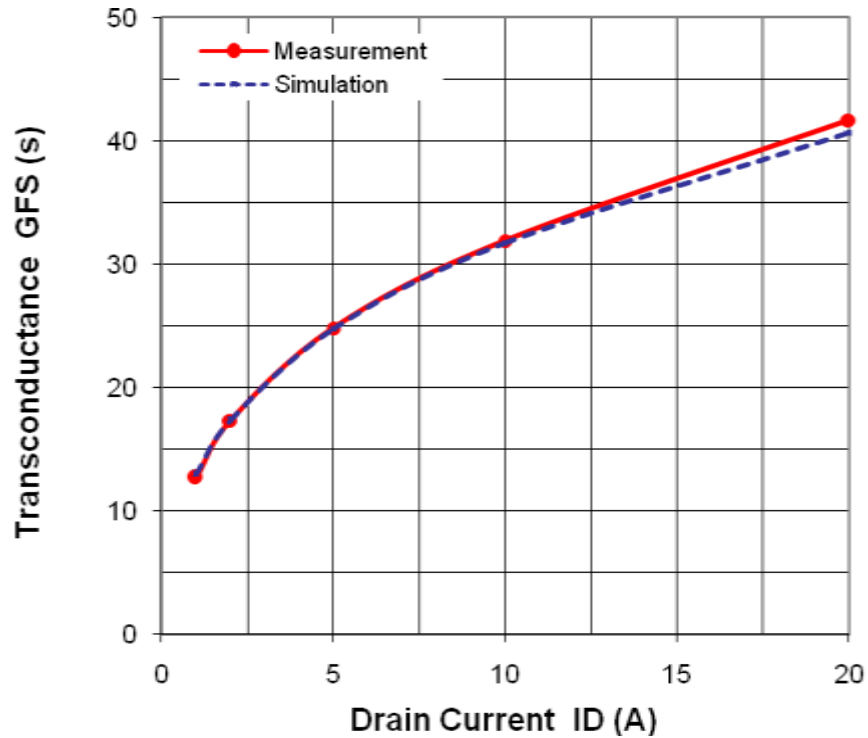
**Bee Technologies Inc.**

## 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                                   |

## Transconductance Characteristic

### Circuit Simulation Result

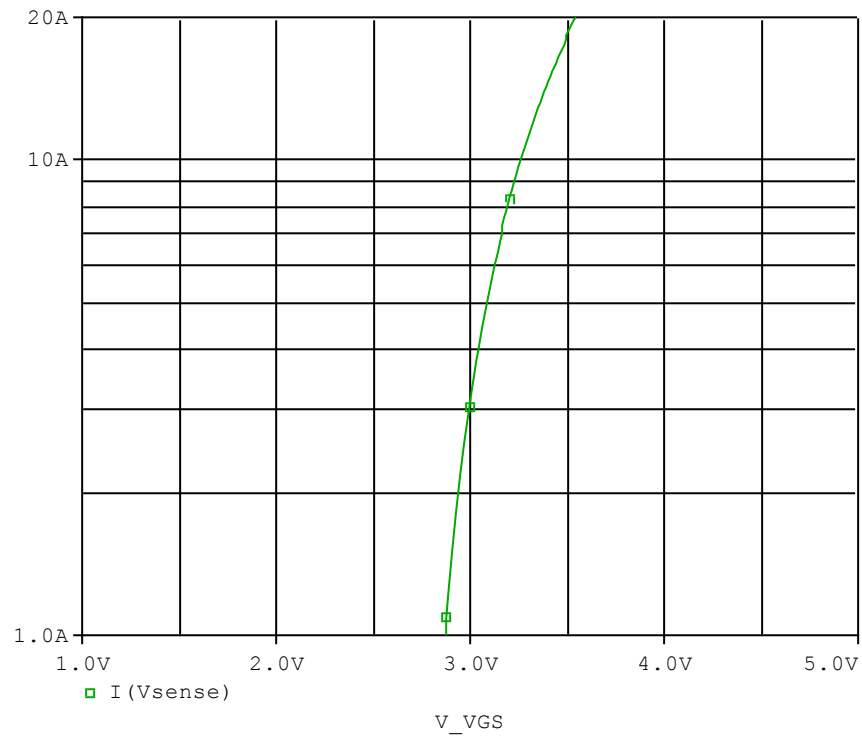


### Comparison table

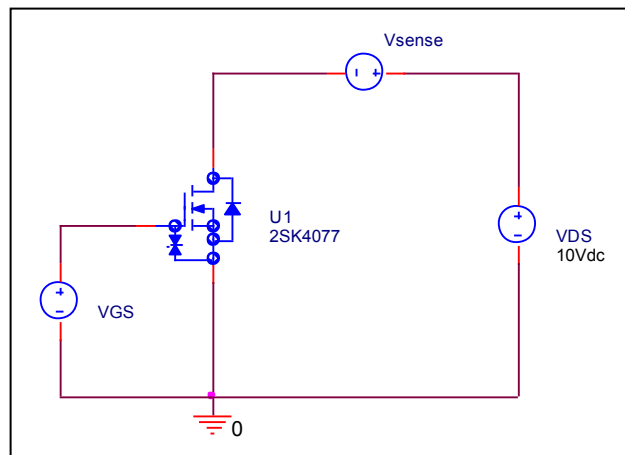
| Id(A)  | gfs         |            | Error(%) |
|--------|-------------|------------|----------|
|        | Measurement | Simulation |          |
| 1.000  | 12.667      | 12.987     | 2.53     |
| 2.000  | 17.333      | 17.391     | 0.33     |
| 5.000  | 24.800      | 24.752     | -0.19    |
| 10.000 | 31.880      | 31.676     | -0.64    |
| 20.000 | 41.667      | 40.650     | -2.44    |

## Vgs-Id Characteristic

Circuit Simulation result

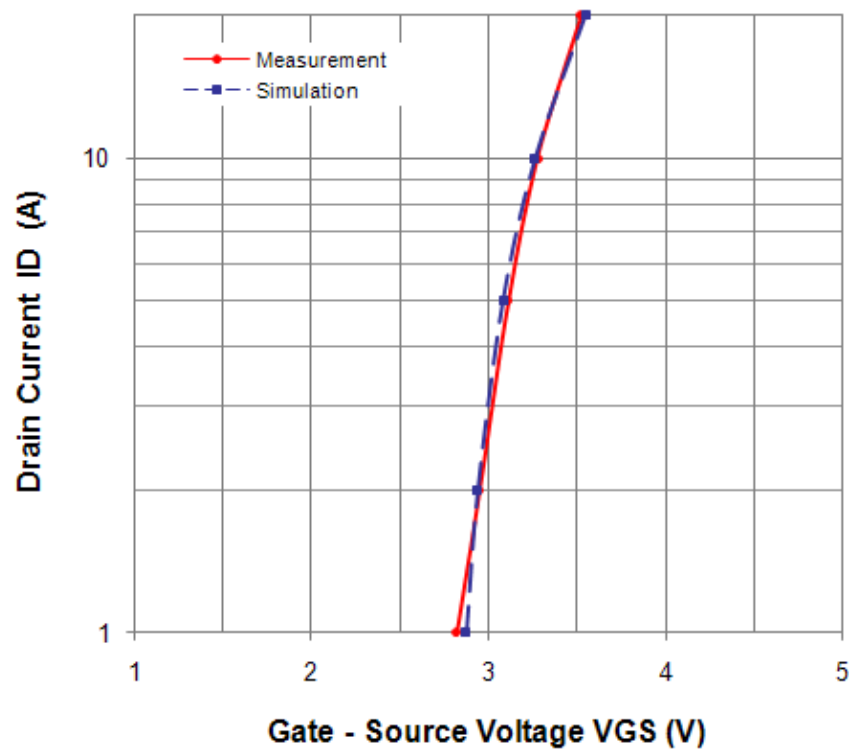


Evaluation circuit



# Comparison Graph

## Circuit Simulation Result

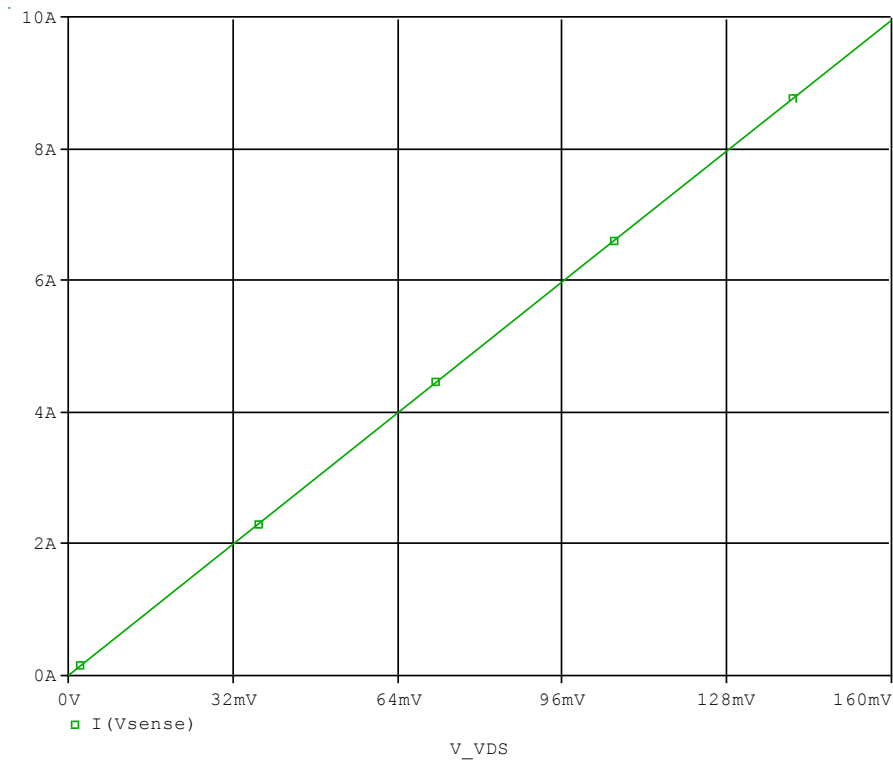


## Simulation Result

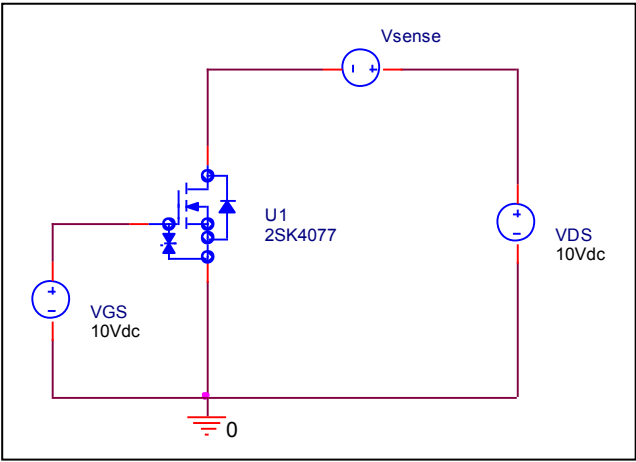
| I <sub>D</sub> (A) | V <sub>GS</sub> (V) |            | Error (%) |
|--------------------|---------------------|------------|-----------|
|                    | Measurement         | Simulation |           |
| 1.000              | 2.820               | 2.874      | 1.92      |
| 2.000              | 2.950               | 2.941      | -0.32     |
| 5.000              | 3.110               | 3.083      | -0.86     |
| 10.000             | 3.280               | 3.262      | -0.56     |
| 20.000             | 3.520               | 3.547      | 0.76      |

# Rds(on) Characteristic

## Circuit Simulation result



## Evaluation circuit

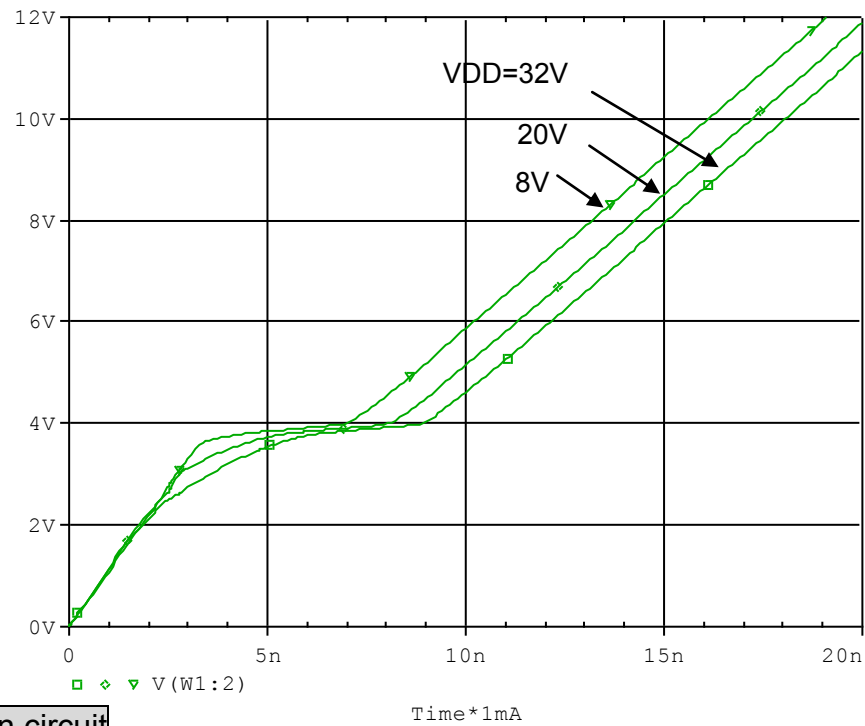


## Simulation Result

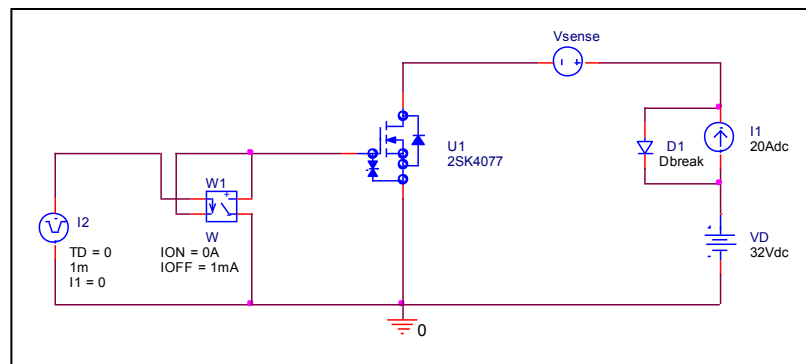
| $I_D = 10A, V_{GS} = 10V$ |            | Measurement | Simulation | Error (%) |
|---------------------------|------------|-------------|------------|-----------|
| $R_{DS(on)}$              | m $\Omega$ | 16          | 16         | 0.00      |

# Gate Charge Characteristic

## Circuit Simulation result



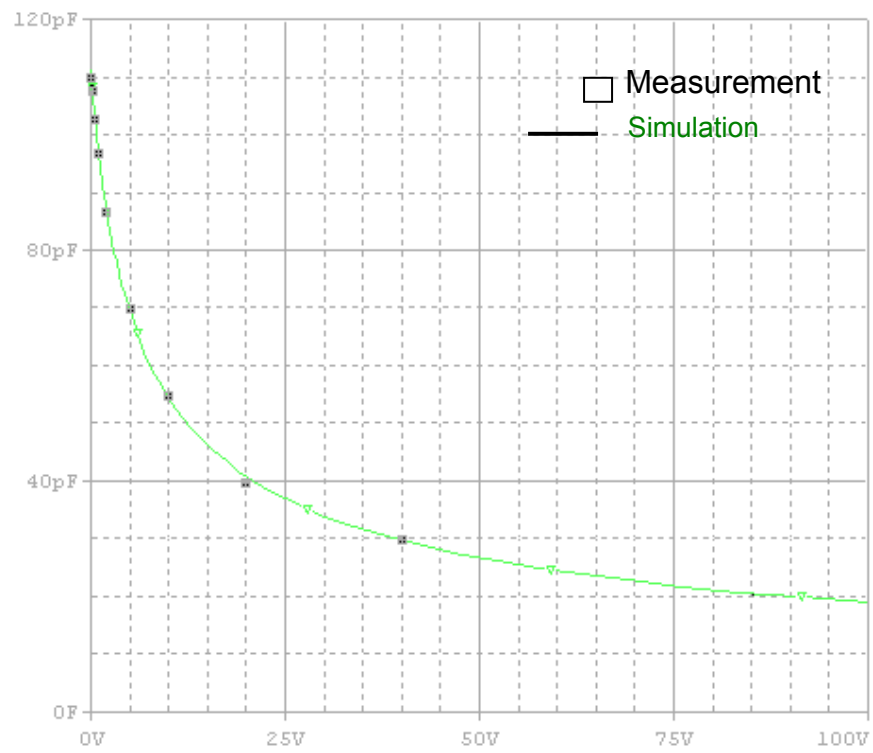
## Evaluation circuit



## Simulation Result

| $V_{DD}=32V, I_D=20A, V_{GS}=10V$ |    | Measurement | Simulation | Error (%) |
|-----------------------------------|----|-------------|------------|-----------|
| Qgs                               | nC | 3.00        | 2.98       | -0.67     |
| Qgd                               | nC | 6.00        | 5.97       | -0.50     |
| Qg                                | nC | 18.00       | 18.00      | 0.00      |

## Capacitance Characteristic

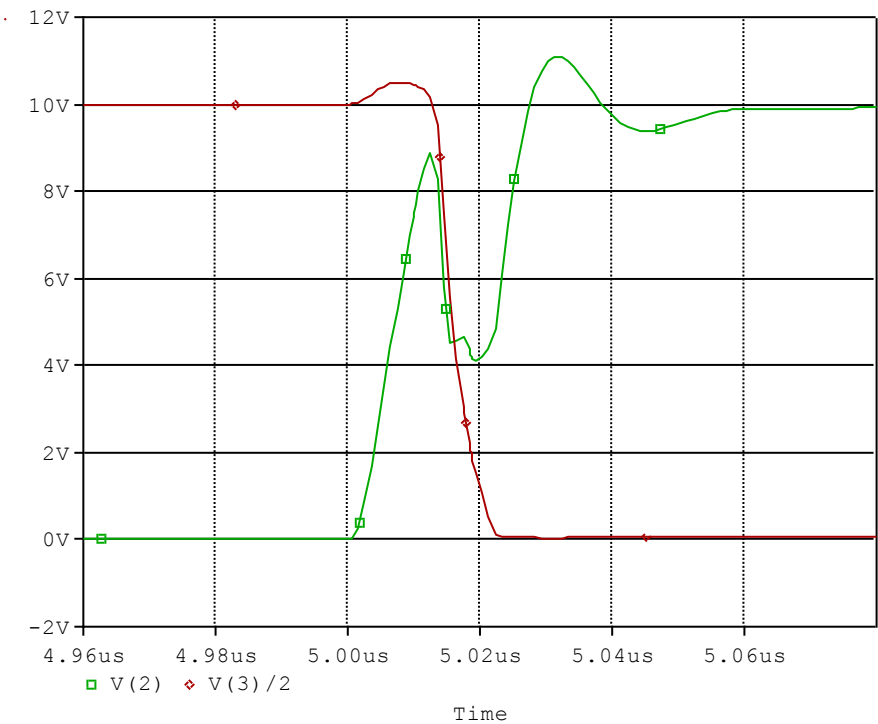


### Simulation Result

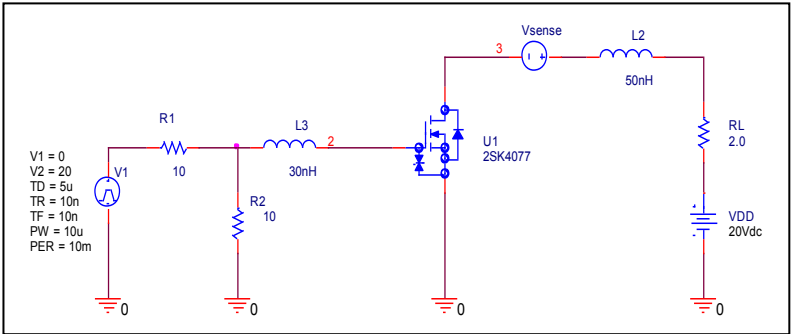
| V <sub>DS</sub> (V) | Cbd (pF)    |            | Error(%) |
|---------------------|-------------|------------|----------|
|                     | Measurement | Simulation |          |
| 0.1                 | 110.00      | 106.00     | 3.77     |
| 0.2                 | 108.00      | 110.00     | -1.82    |
| 0.5                 | 100.00      | 101.00     | -0.99    |
| 1                   | 90.00       | 91.00      | -1.10    |
| 2                   | 82.00       | 84.00      | -2.38    |
| 5                   | 70.00       | 69.00      | 1.45     |
| 10                  | 55.00       | 54.00      | 1.85     |
| 20                  | 40.00       | 41.50      | -3.61    |
| 40                  | 28.00       | 27.60      | 1.45     |

# Switching Time Characteristic

Circuit Simulation result



Evaluation circuit

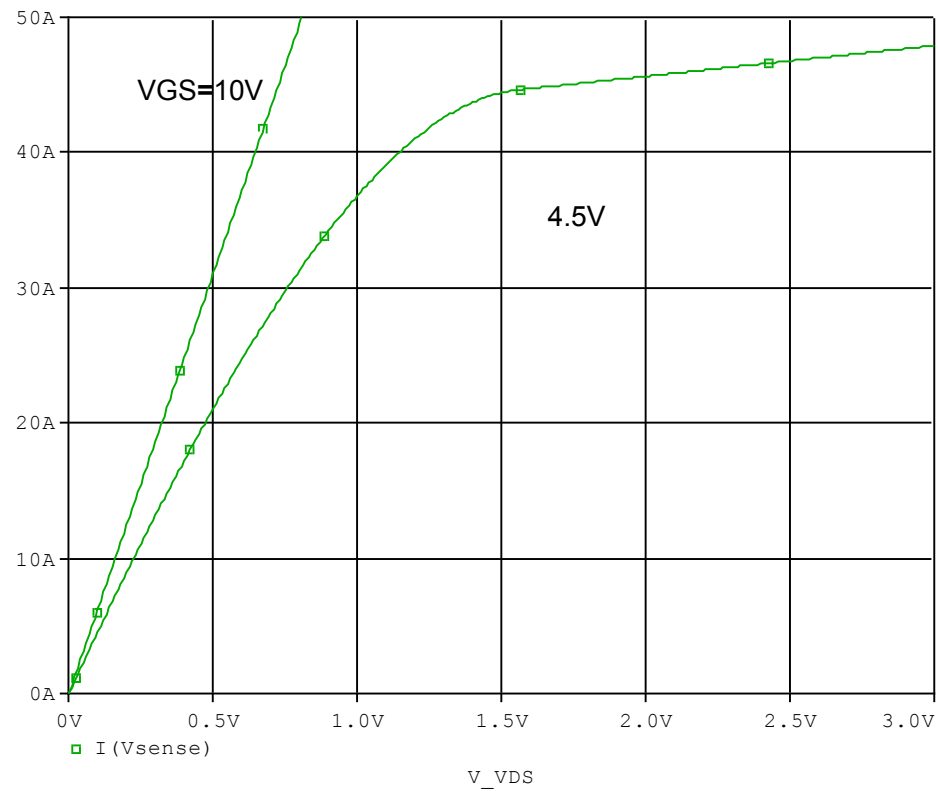


Simulation Result

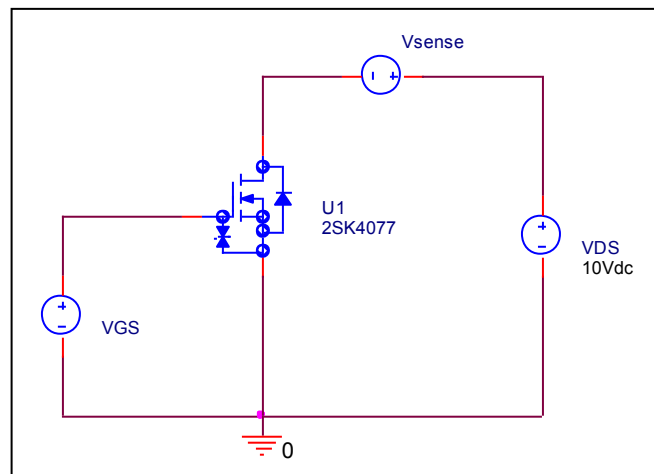
| $I_D=10\text{ A}$ , $V_{DD}=20\text{ V}$<br>$V_{GS}=0/10\text{ V}$ |    | Measurement | Simulation | Error(%) |
|--------------------------------------------------------------------|----|-------------|------------|----------|
| td(on)                                                             | ns | 11.00       | 10.97      | -0.27    |

## Output Characteristic

### Circuit Simulation result

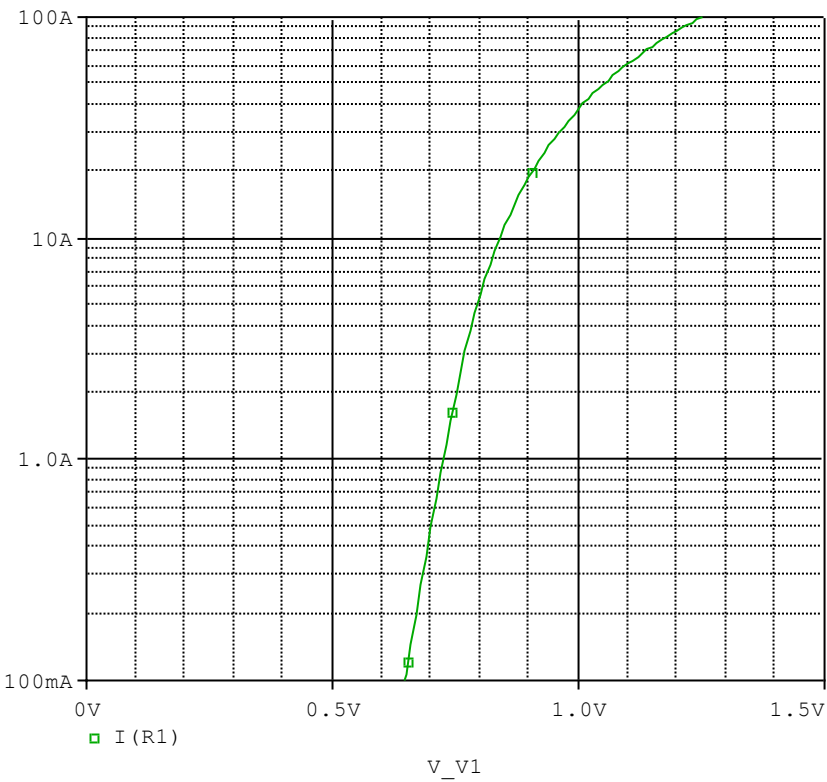


### Evaluation circuit

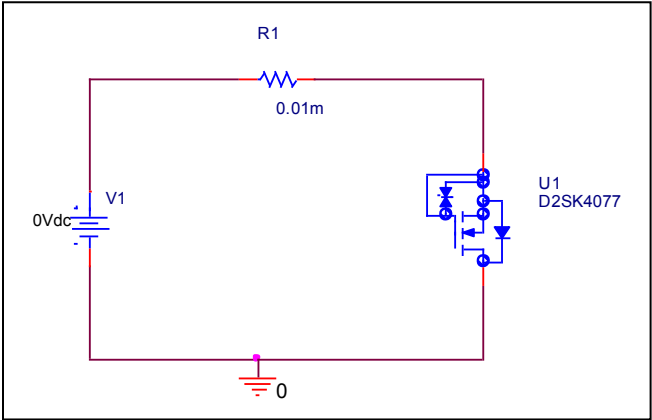


# Forward Current Characteristic

## Circuit Simulation Result

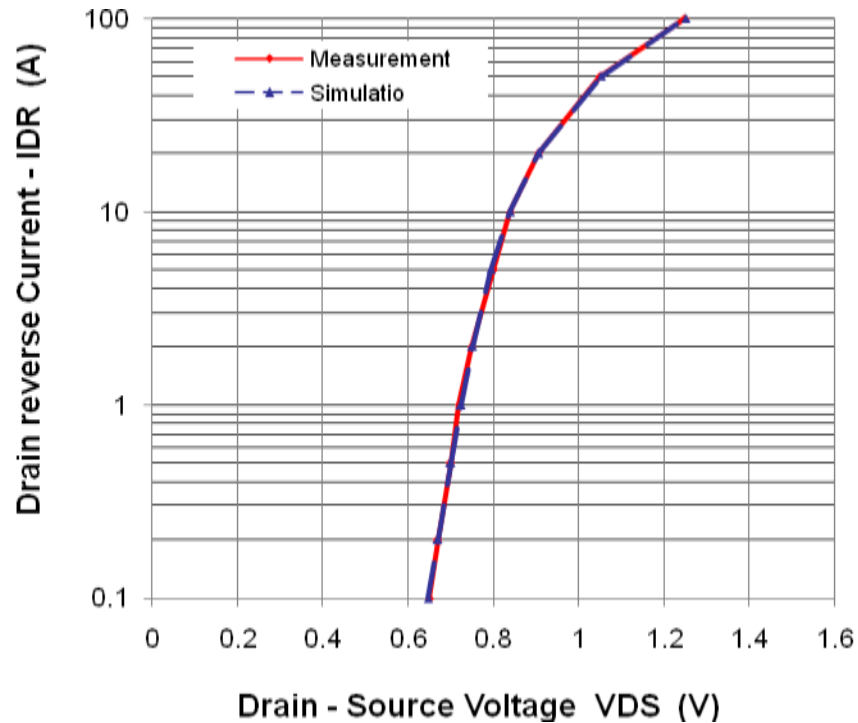


## Evaluation Circuit



## Comparison Graph

### Circuit Simulation Result

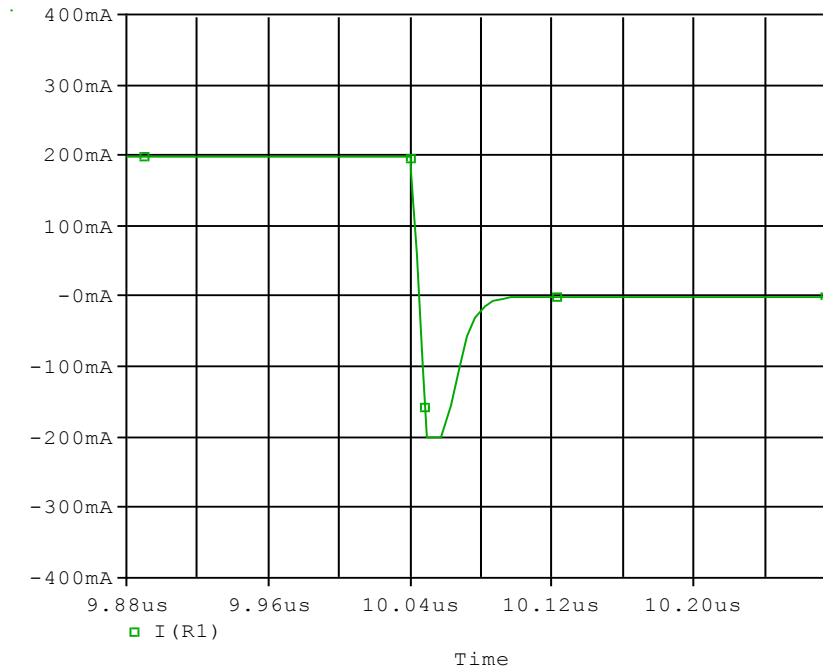


### Simulation Result

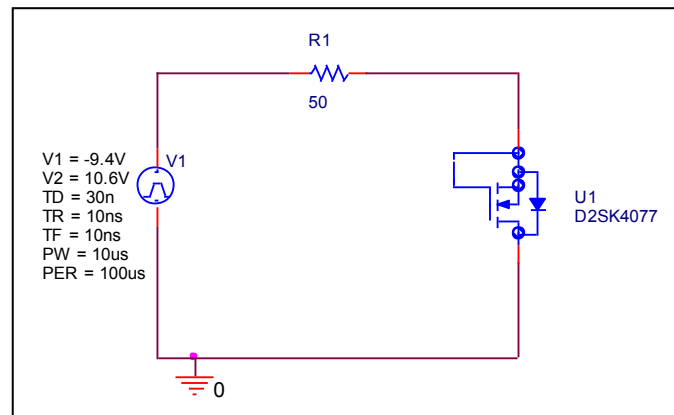
| IDR(A) | VSD(V)      |            | %Error |
|--------|-------------|------------|--------|
|        | Measurement | Simulation |        |
| 0.10   | 0.650       | 0.648      | -0.34  |
| 0.20   | 0.670       | 0.670      | 0.03   |
| 0.50   | 0.700       | 0.700      | 0.00   |
| 1.00   | 0.720       | 0.724      | 0.56   |
| 2.00   | 0.750       | 0.751      | 0.15   |
| 5.00   | 0.800       | 0.794      | -0.72  |
| 10.00  | 0.840       | 0.840      | -0.05  |
| 20.00  | 0.905       | 0.906      | 0.08   |
| 50.00  | 1.050       | 1.052      | 0.22   |
| 100.00 | 1.250       | 1.250      | 0.02   |

## Reverse Recovery Characteristics (Body Diode)

### Circuit Simulation Result



### Evaluation Circuit

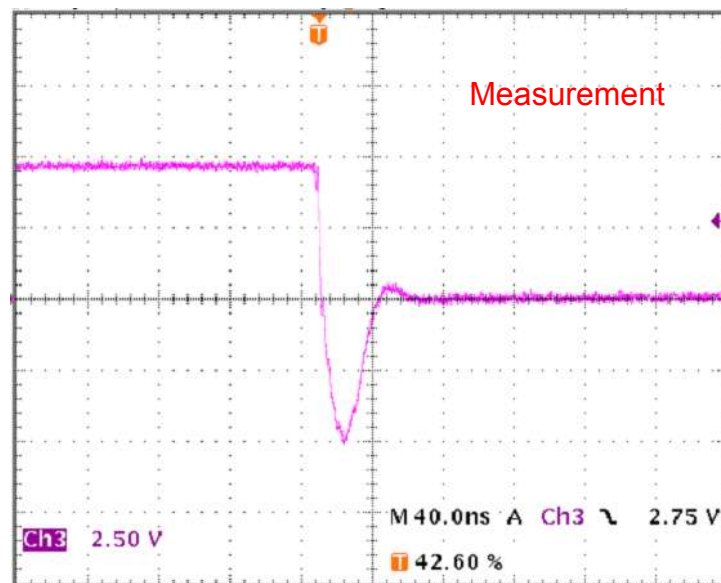


### Compare Measurement vs. Simulation

|     |    | Measurement | Simulation | Error (%) |
|-----|----|-------------|------------|-----------|
| trj | ns | 12.80       | 12.68      | -0.94     |
| Trb | ns | 19.00       | 18.97      | -0.16     |
| trr | ns | 31.80       | 31.65      | -0.47     |

## Reverse Recovery Characteristic

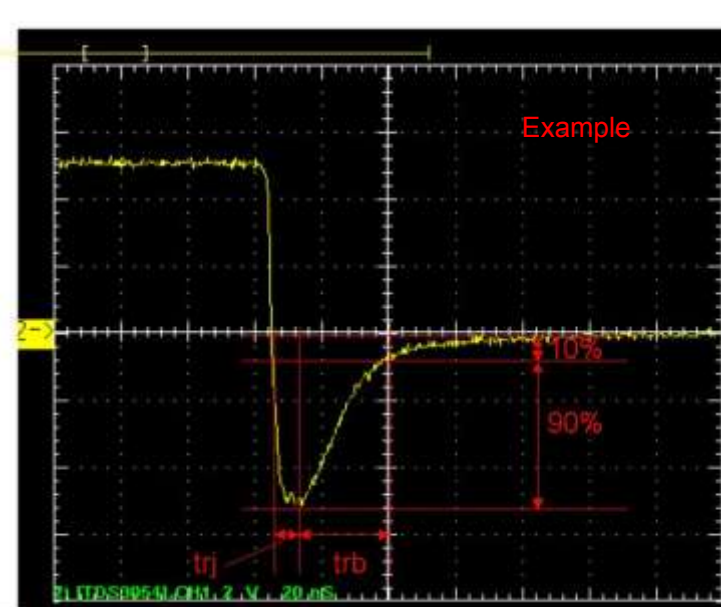
## Reference



$T_{rr}=12.8(\text{ns})$

$T_{rb}=19.0(\text{ns})$

Conditions:  $I_{fwd}=I_{rev}=0.2(\text{A})$ ,  $R_I=50$

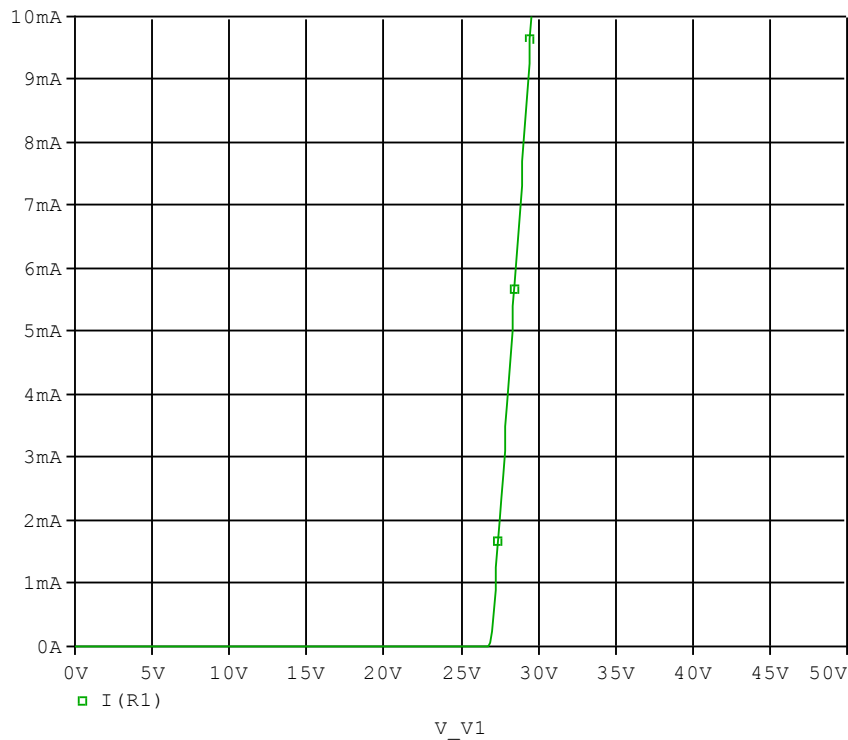


Relation between  $t_{rr}$  and  $t_{rb}$

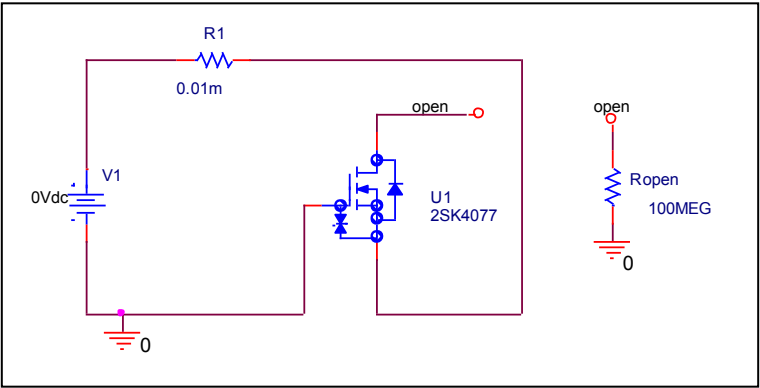
# ESD PROTECTION DIODE SPICE MODEL

## Zener Voltage Characteristic

### Circuit Simulation Result



### Evaluation Circuit



Zener Voltage Characteristic

Reference

