

# Device Modeling Report

COMPONENTS: Power MOSFET (Professional)  
PART NUMBER: TPCP8401  
MANUFACTURER: TOSHIBA  
Body Diode (Professional) / ESD Protection Diode  
REMARK: Silicon N&P Channel MOS Type



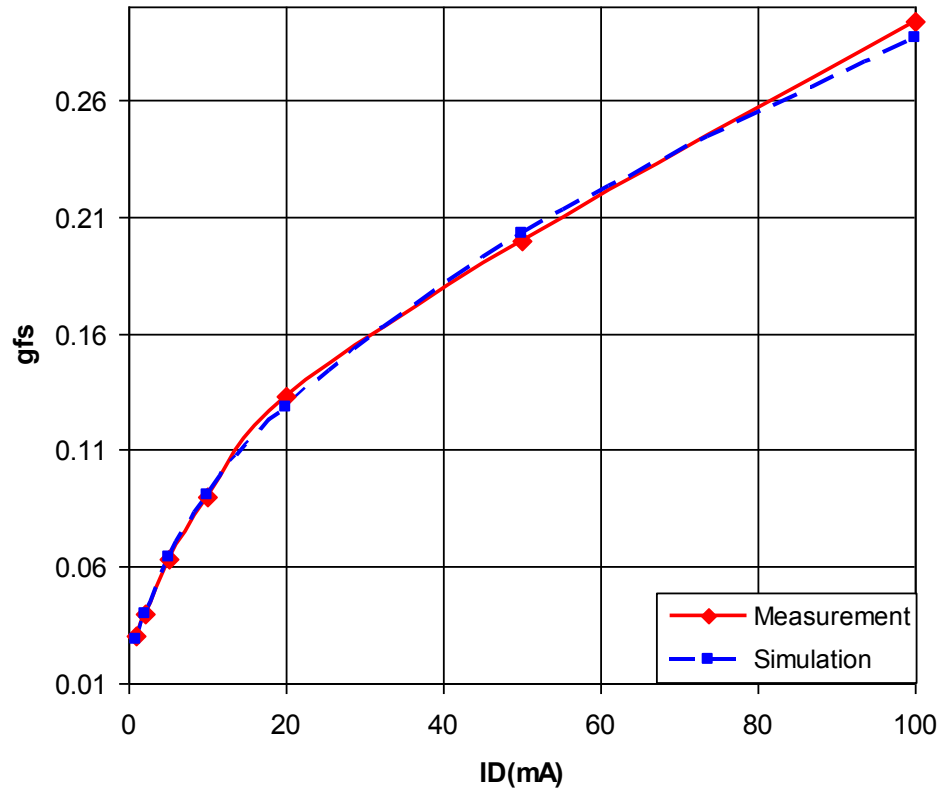
## MOSFET MODEL

| 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                                   |

## N-Channel Model

### Transconductance Characteristic

Circuit Simulation Result

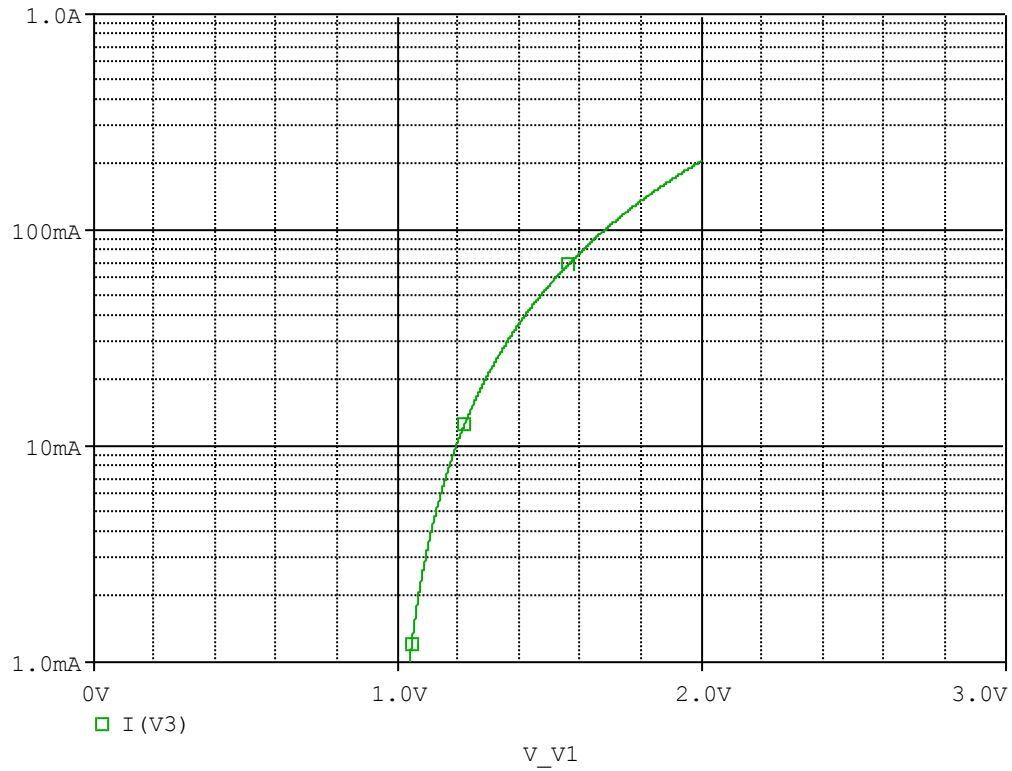


Comparison table

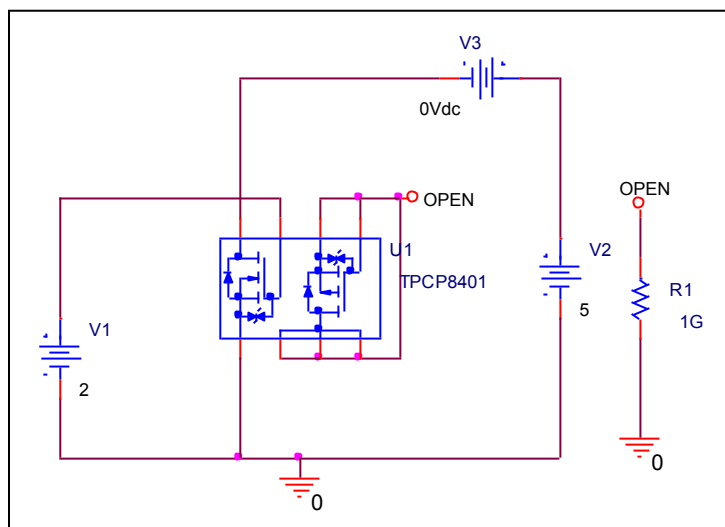
| Id(mA) | gfs         |            | Error (%) |
|--------|-------------|------------|-----------|
|        | Measurement | Simulation |           |
| 1      | 0.030       | 0.029      | -3.333    |
| 2      | 0.040       | 0.040      | 0         |
| 5      | 0.063       | 0.064      | 1.587     |
| 10     | 0.090       | 0.091      | 1.111     |
| 20     | 0.133       | 0.128      | -3.759    |
| 50     | 0.200       | 0.203      | 1.500     |
| 100    | 0.294       | 0.287      | -2.381    |

## V<sub>gs</sub>-I<sub>d</sub> Characteristic

Circuit Simulation result

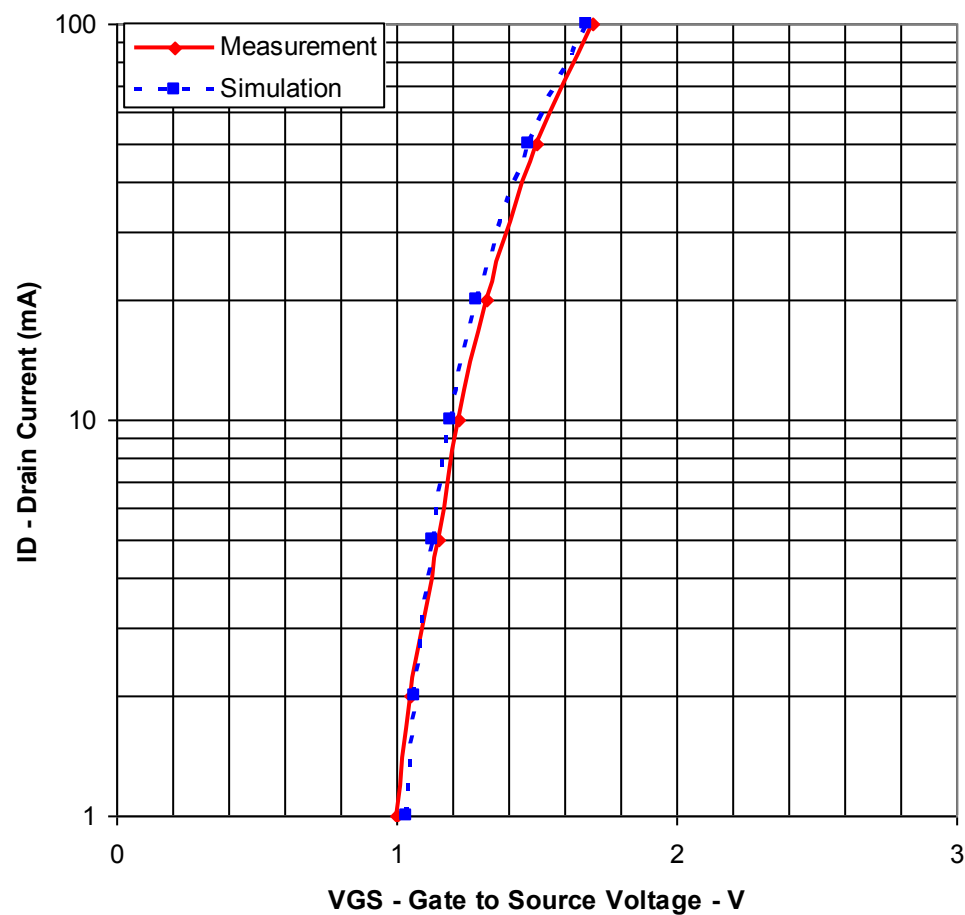


Evaluation circuit



# Comparison Graph

Circuit Simulation Result

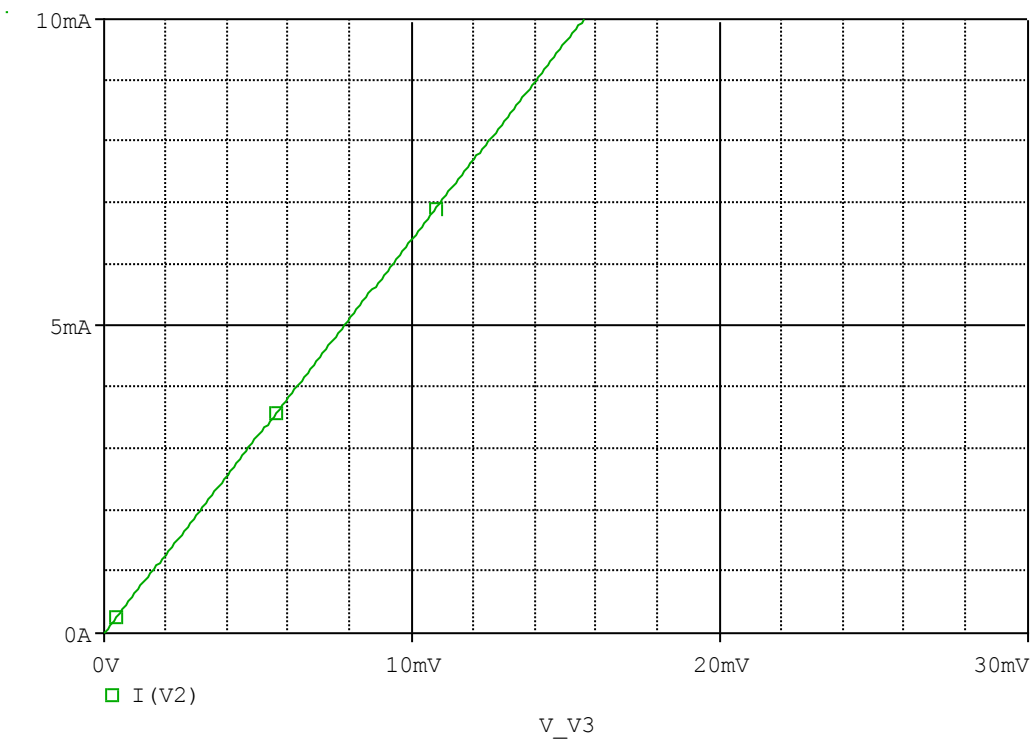


Simulation Result

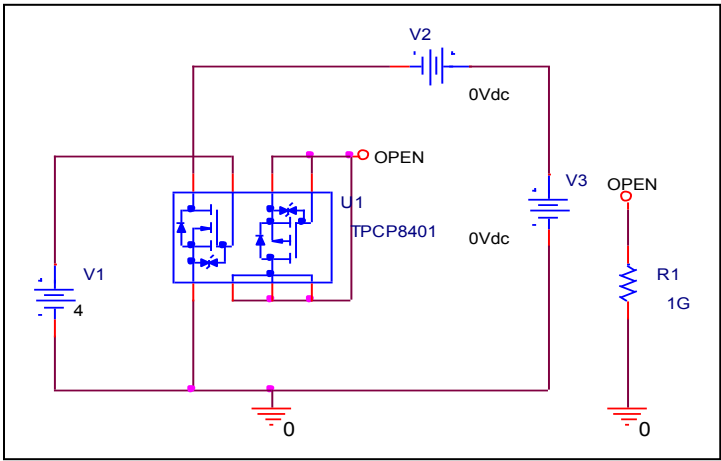
| $I_D$ (mA) | $V_{GS}$ (V) |            | Error (%) |
|------------|--------------|------------|-----------|
|            | Measurement  | Simulation |           |
| 1          | 1            | 1.0373     | 3.730     |
| 2          | 1.05         | 1.0668     | 1.600     |
| 5          | 1.15         | 1.1254     | -2.139    |
| 10         | 1.22         | 1.1914     | -2.344    |
| 20         | 1.32         | 1.2847     | -2.674    |
| 50         | 1.5          | 1.47       | -2.000    |
| 100        | 1.7          | 1.6790     | -1.235    |

# Rds(on) Characteristic

Circuit Simulation result



Evaluation circuit

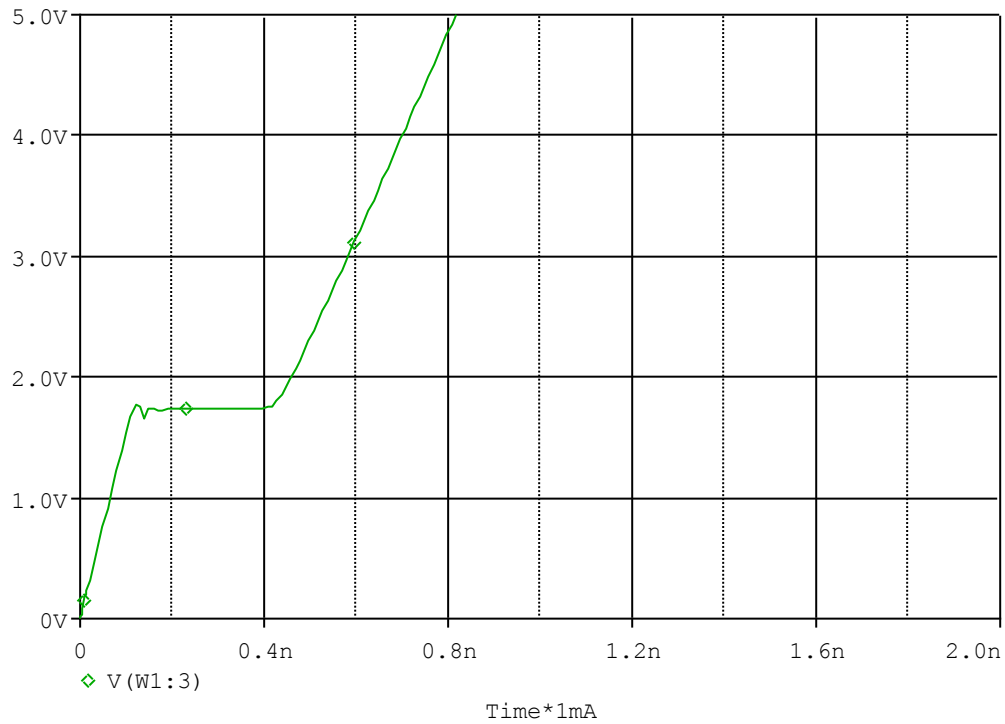


Simulation Result

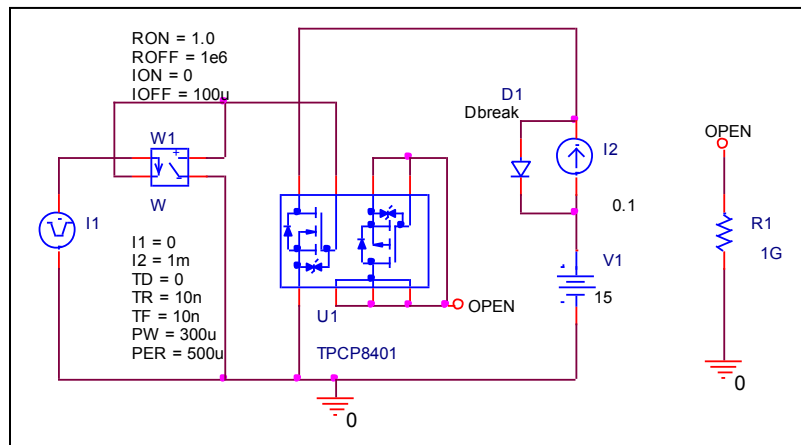
| $I_D=10\text{mA}, V_{GS}=4\text{V}$ | Measurement |          | Simulation |          | Error (%) |
|-------------------------------------|-------------|----------|------------|----------|-----------|
| $R_{DS(on)}$                        | 1.5         | $\Omega$ | 1.5577     | $\Omega$ | 3.847     |

# Gate Charge Characteristic

## Circuit Simulation result



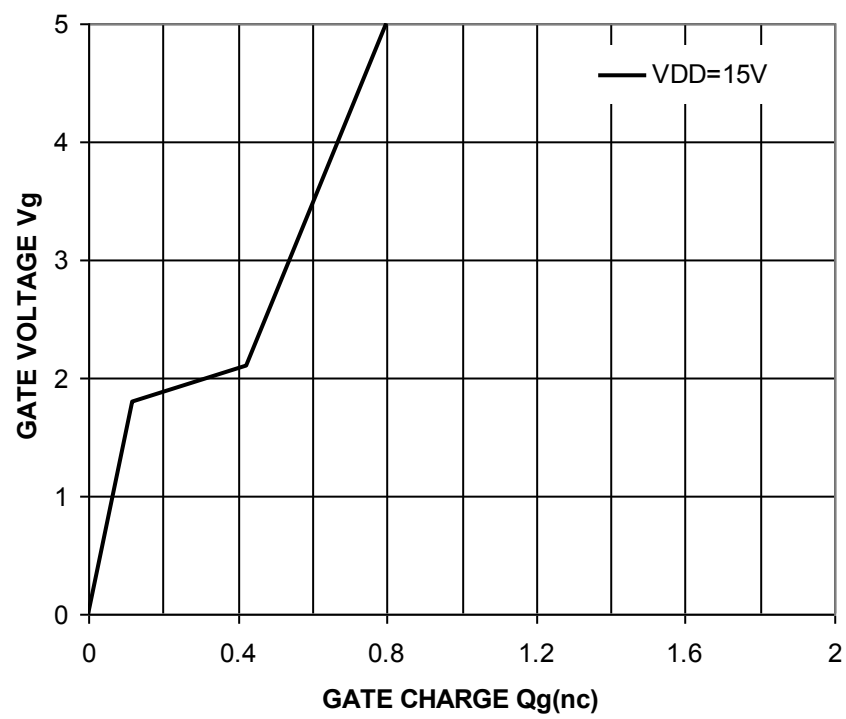
## Evaluation circuit



## Simulation Result

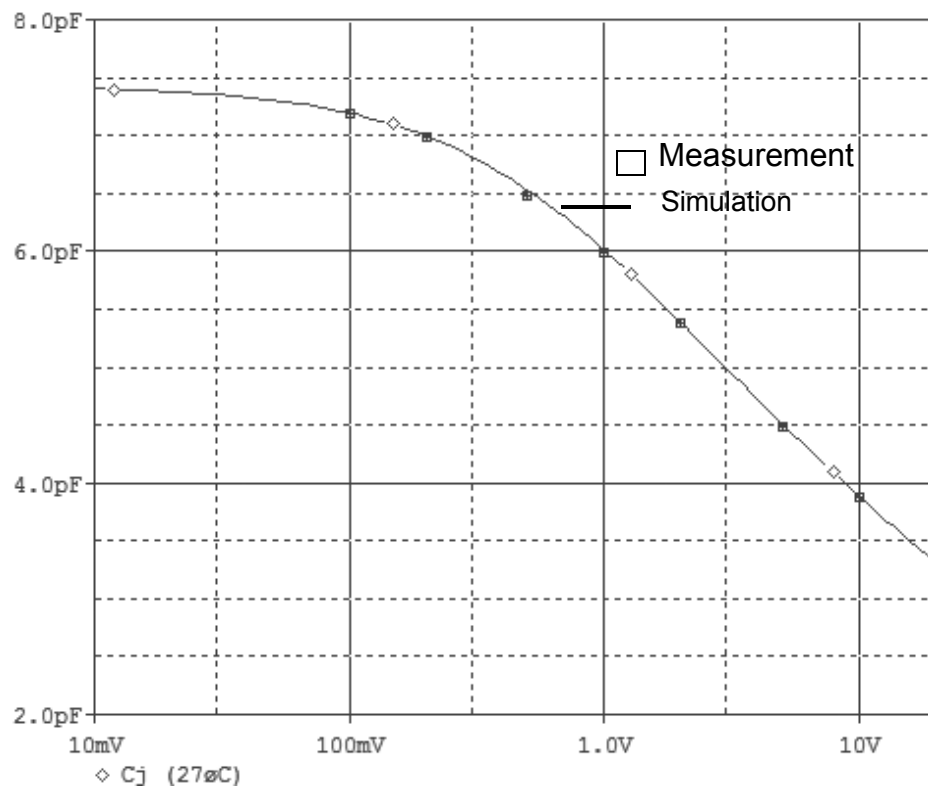
| $V_{DD}=15V, I_D=0.1A$ | Measurement  |           | Simulation    |           | Error (%)     |
|------------------------|--------------|-----------|---------------|-----------|---------------|
| <b>Qgs</b>             | <b>0.12</b>  | <b>nC</b> | <b>0.1196</b> | <b>nC</b> | <b>-0.333</b> |
| <b>Qgd</b>             | <b>0.304</b> | <b>nC</b> | <b>0.299</b>  | <b>nC</b> | <b>-1.645</b> |
| <b>Qg</b>              | <b>0.8</b>   | <b>nC</b> | <b>0.816</b>  | <b>nC</b> | <b>2.000</b>  |

Reference





## Capacitance Characteristic

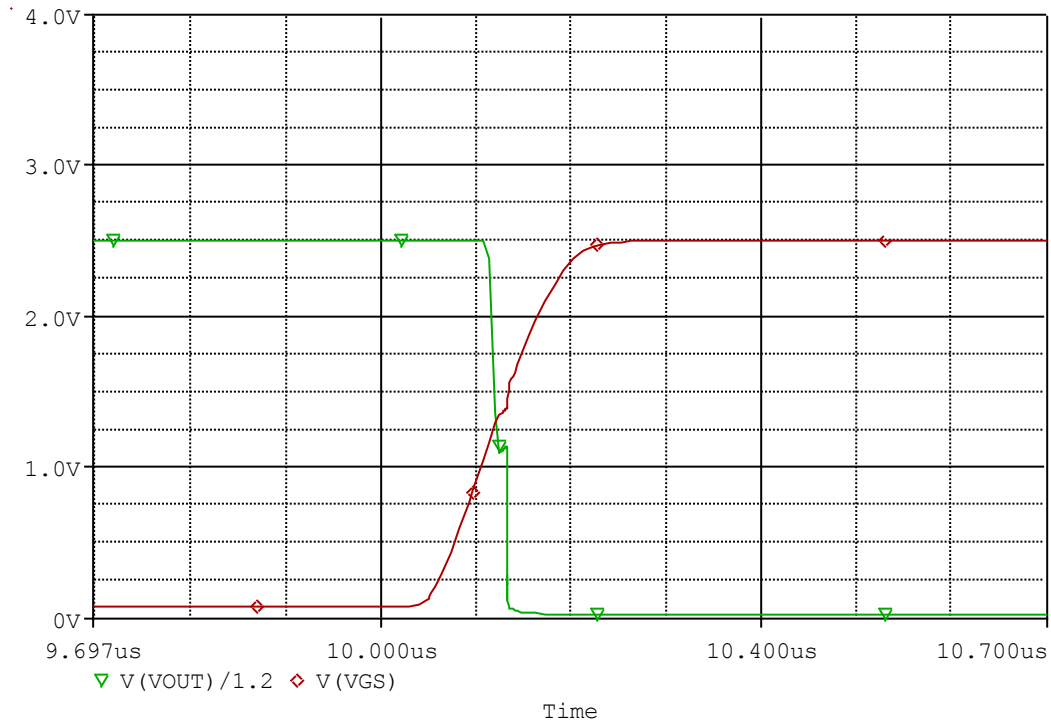


### Simulation Result

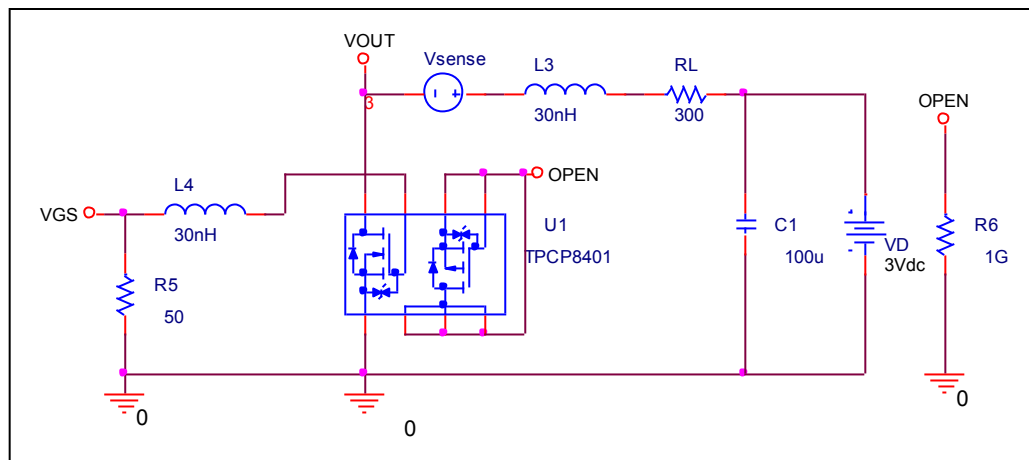
| V <sub>DS</sub> (V) | Cbd(pF)     |            | Error(%) |
|---------------------|-------------|------------|----------|
|                     | Measurement | Simulation |          |
| 0.1                 | 7.2         | 7.19       | -0.139   |
| 0.2                 | 7           | 7          | 0        |
| 0.5                 | 6.5         | 6.53       | 0.462    |
| 1                   | 6           | 6          | 0.000    |
| 2                   | 5.4         | 5.37       | -0.556   |
| 5                   | 4.5         | 4.51       | 0.222    |
| 10                  | 3.9         | 3.88       | -0.513   |
| 20                  | 3.3         | 3.32       | 0.606    |

## Switching Time Characteristic

### Circuit Simulation result



### Evaluation circuit

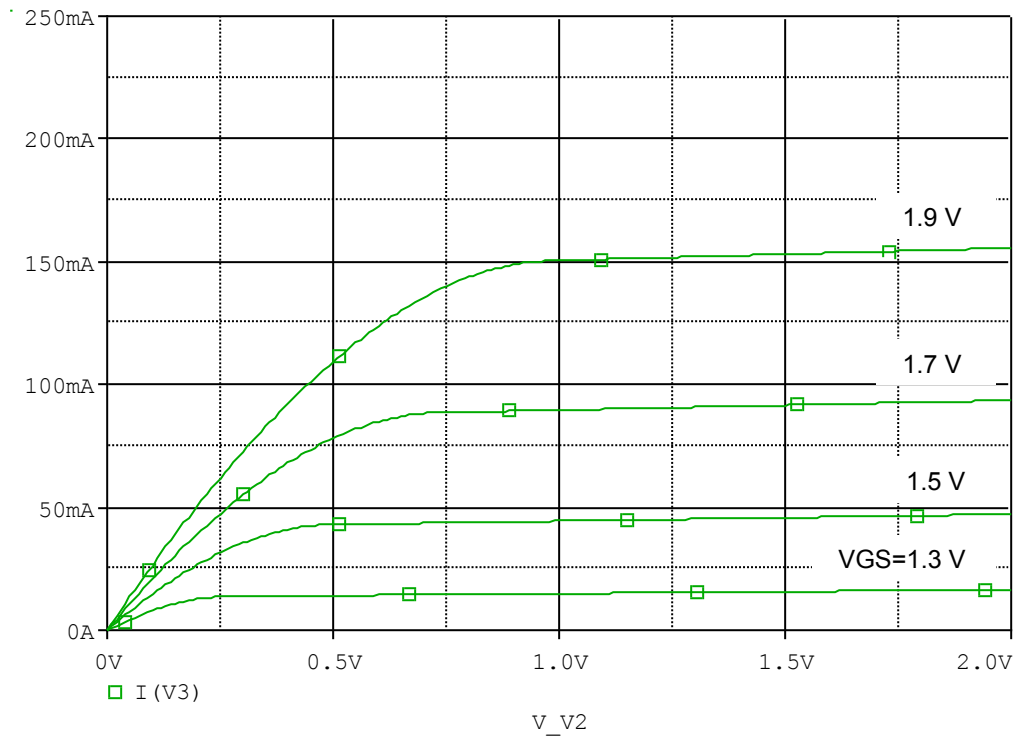


### Simulation Result

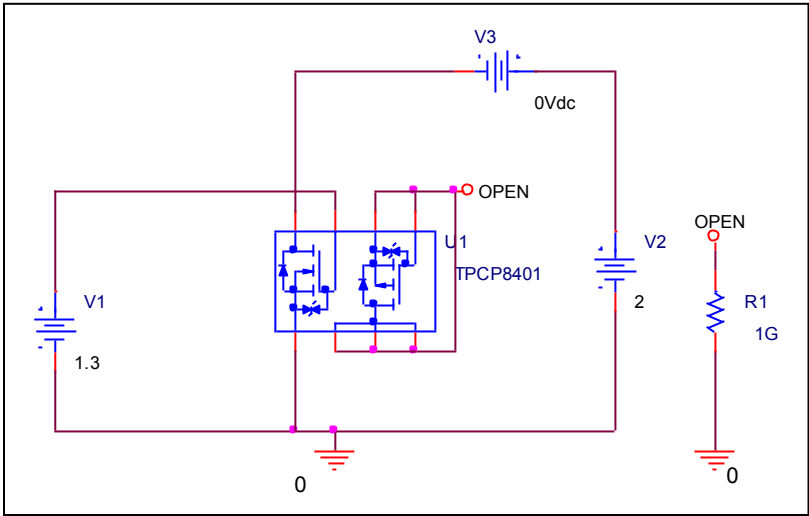
| $I_D=10\text{m A}$ , $V_{DD}=3\text{V}$<br>$V_{GS}=0/2.5\text{V}$ | Measurement |    | Simulation |    | Error(%) |
|-------------------------------------------------------------------|-------------|----|------------|----|----------|
| ton                                                               | 70.000      | ns | 72.416     | ns | 3.451    |

# Output Characteristic

## Circuit Simulation result

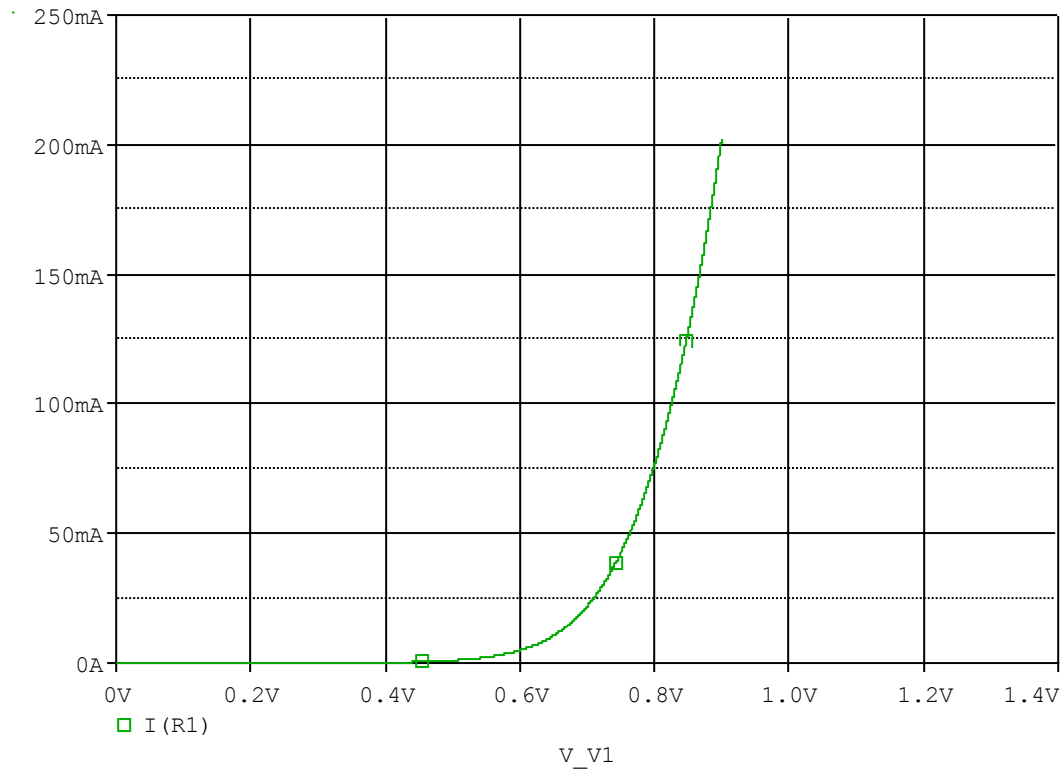


## Evaluation circuit

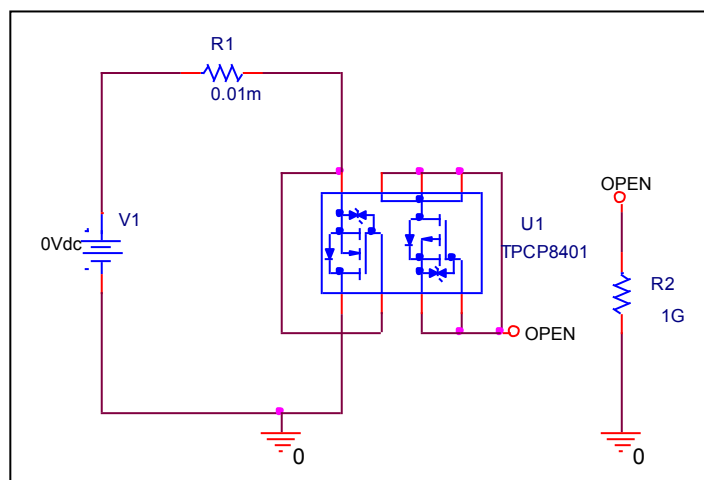


## Forward Current Characteristic

### Circuit Simulation Result

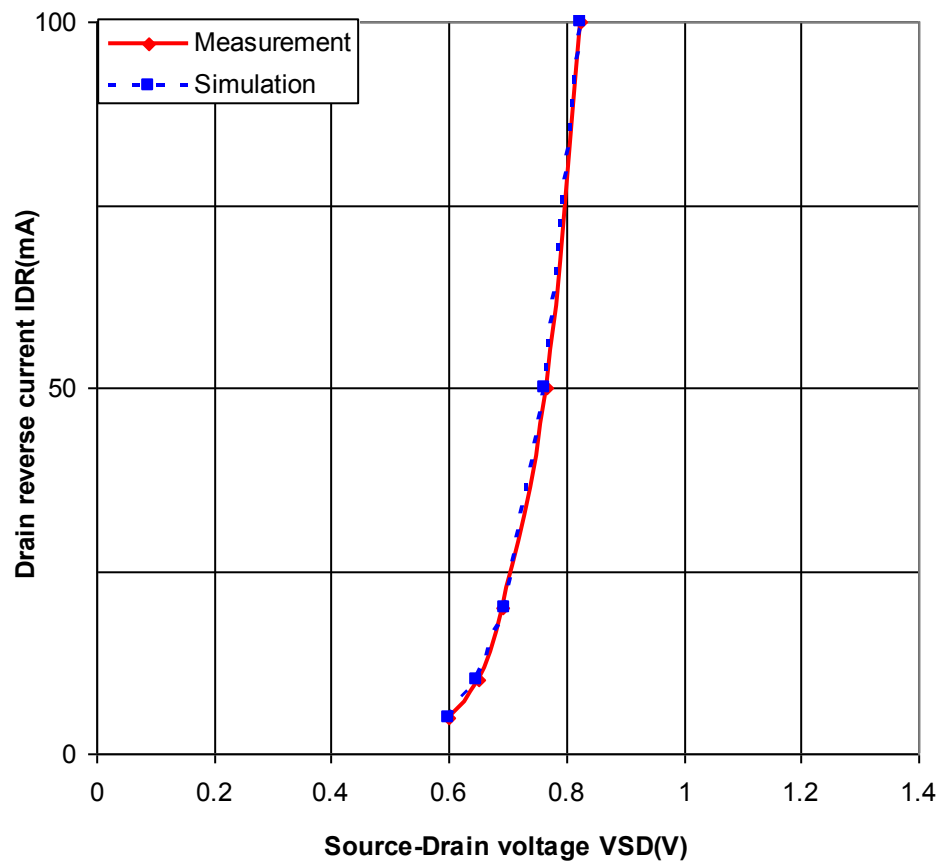


### Evaluation Circuit



## Comparison Graph

Circuit Simulation Result

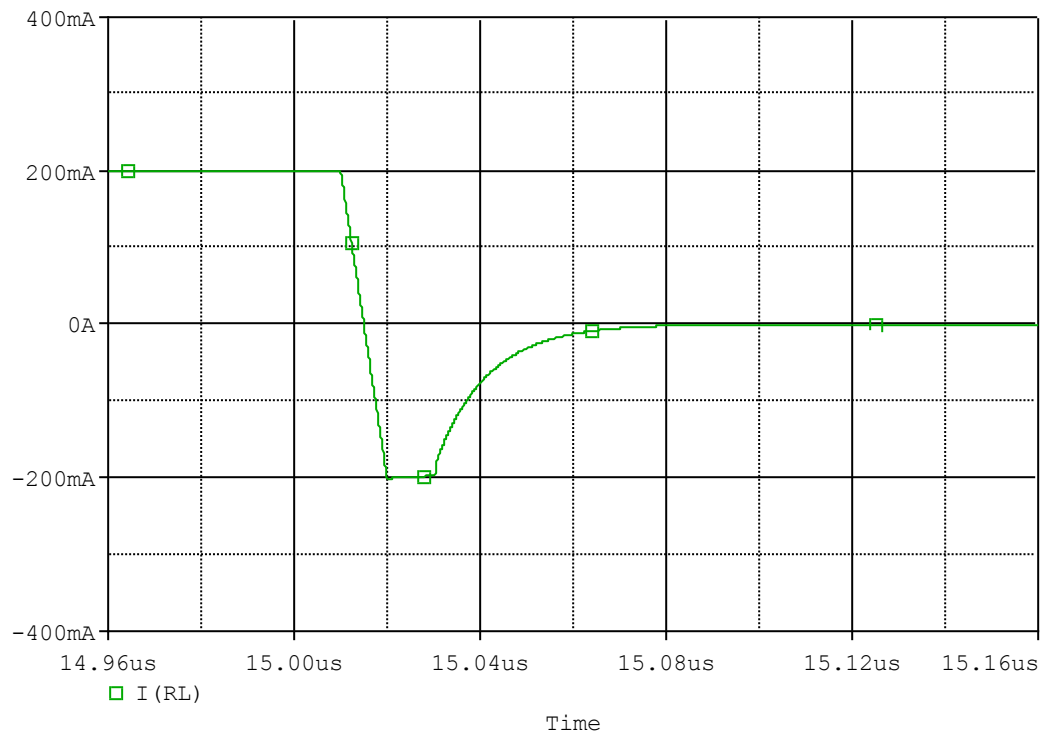


Simulation Result

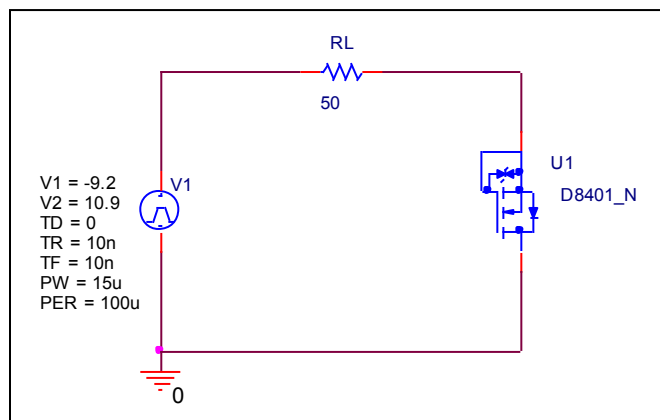
| Ifwd(mA) | VSD(V)      |            | %Error |
|----------|-------------|------------|--------|
|          | Measurement | Simulation |        |
| 5        | 0.6         | 0.601      | 0.167  |
| 10       | 0.65        | 0.646      | -0.615 |
| 20       | 0.69        | 0.694      | 0.580  |
| 50       | 0.765       | 0.763      | -0.261 |
| 100      | 0.825       | 0.826      | 0.121  |

## Reverse Recovery Characteristic

### Circuit Simulation Result



### Evaluation Circuit

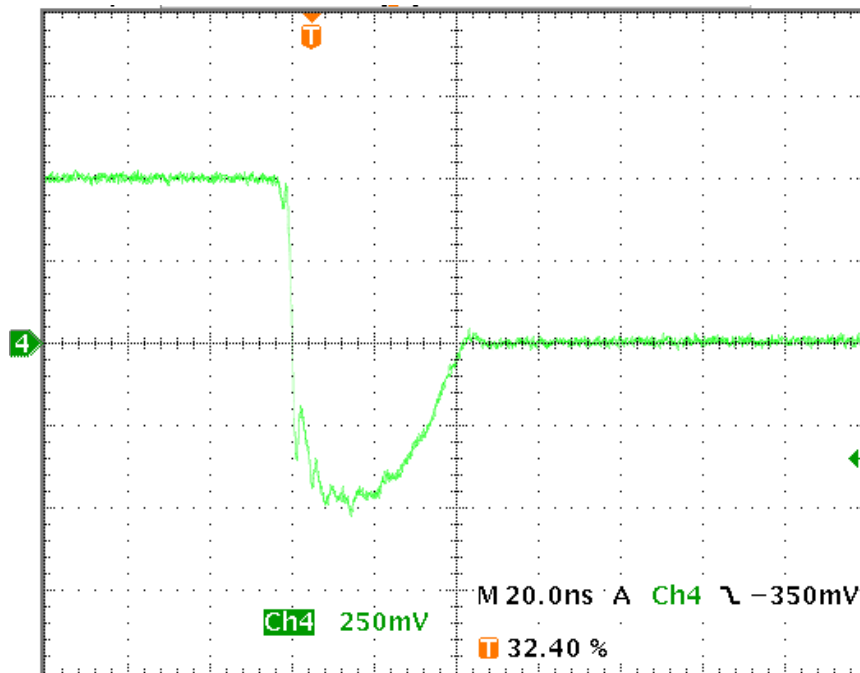


### Compare Measurement vs. Simulation

|                | Measurement | Simulation    | Error (%)     |
|----------------|-------------|---------------|---------------|
| <b>Trj(ns)</b> | <b>14</b>   | <b>14.001</b> | <b>0.007</b>  |
| <b>Trb(ns)</b> | <b>25.6</b> | <b>25.594</b> | <b>-0.023</b> |
| <b>Trr(ns)</b> | <b>39.6</b> | <b>39.595</b> | <b>-0.013</b> |

## Reverse Recovery Characteristic

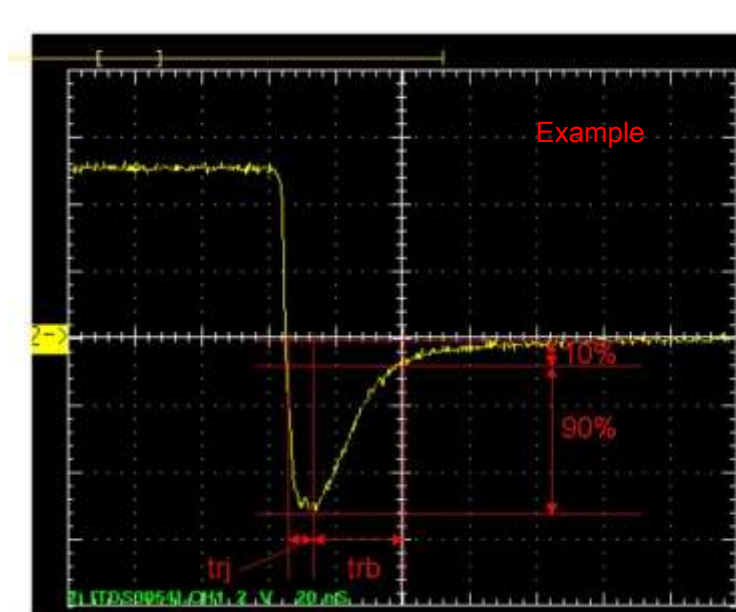
## Reference



$T_{rr}=14(\text{ns})$

$T_{rb}=25.6(\text{ns})$

Conditions:  $I_{fwd}=I_{rev}=0.02(\text{A})$ ,  $R_I=50$

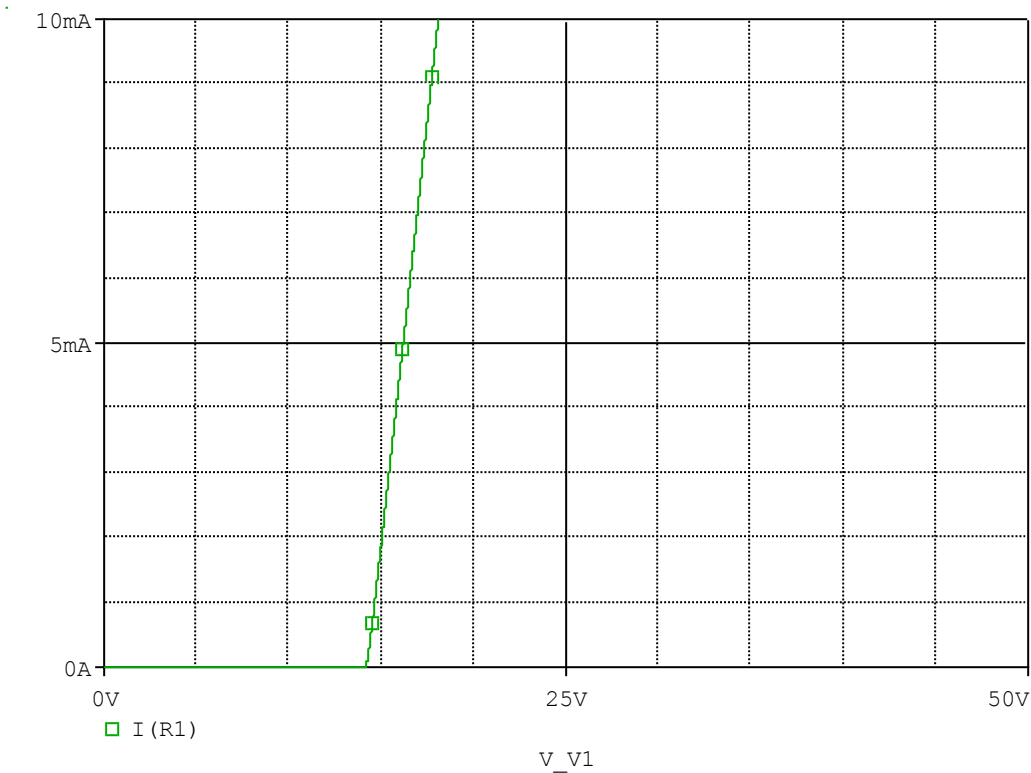


Relation between  $t_{rr}$  and  $t_{rb}$

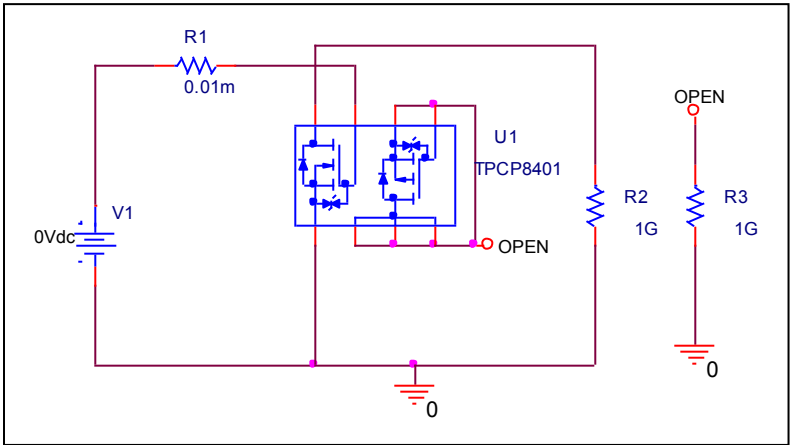
# ESD PROTECTION DIODE

## Zener Voltage Characteristic

### Circuit Simulation Result



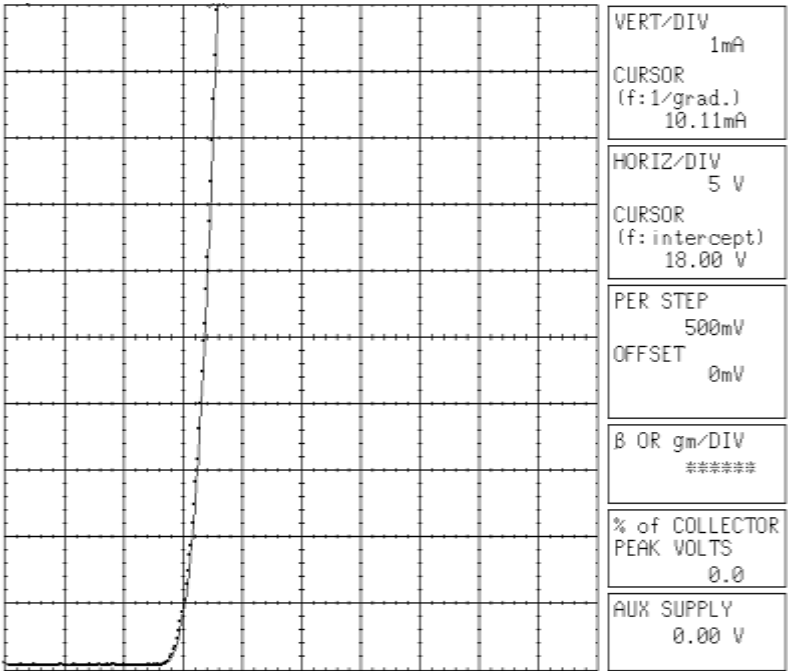
### Evaluation Circuit





Zener Voltage Characteristic

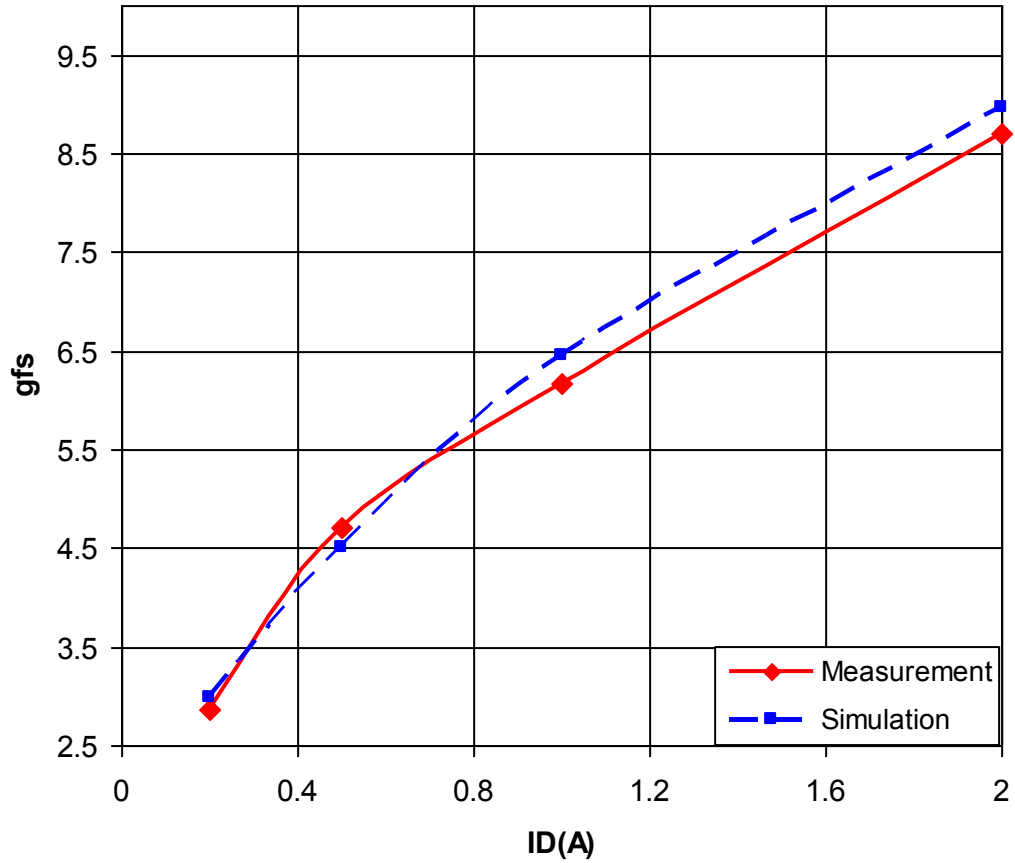
Reference



## P-Channel Model

### Transconductance Characteristic

Circuit Simulation Result

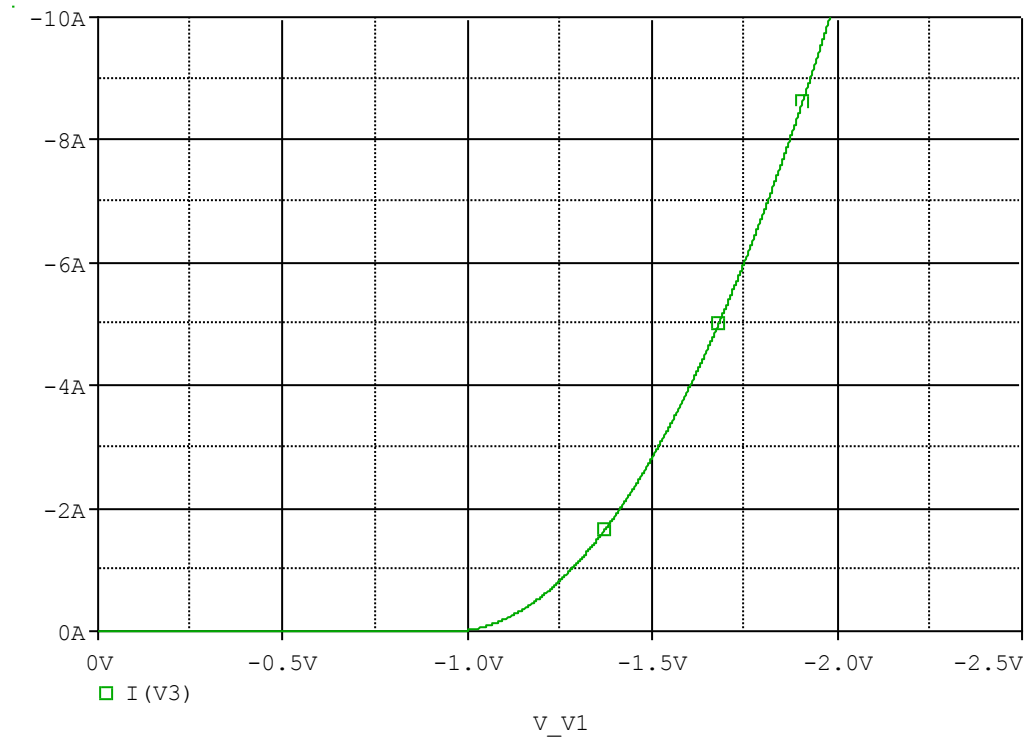


Comparison table

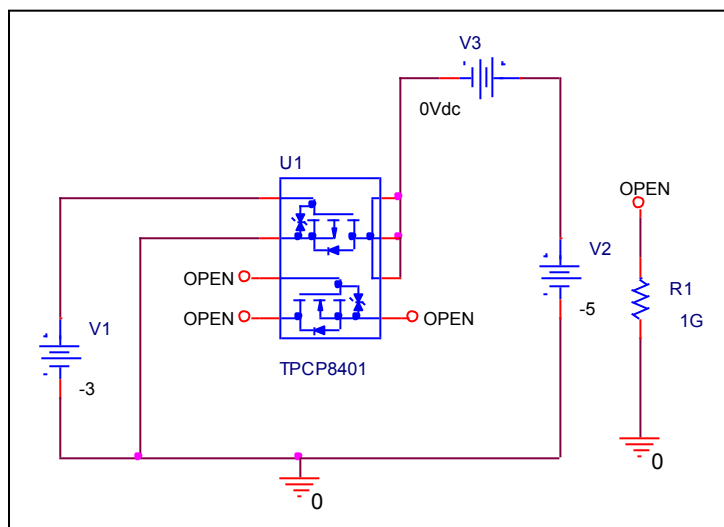
| - Id(mA) | gfs         |            | Error(%) |
|----------|-------------|------------|----------|
|          | Measurement | Simulation |          |
| 0.2      | 2.857       | 2.985      | 4.480    |
| 0.5      | 4.717       | 4.505      | -4.494   |
| 1        | 6.173       | 6.452      | 4.520    |
| 2        | 8.696       | 8.969      | 3.139    |

## V<sub>gs</sub>-I<sub>d</sub> Characteristic

Circuit Simulation result

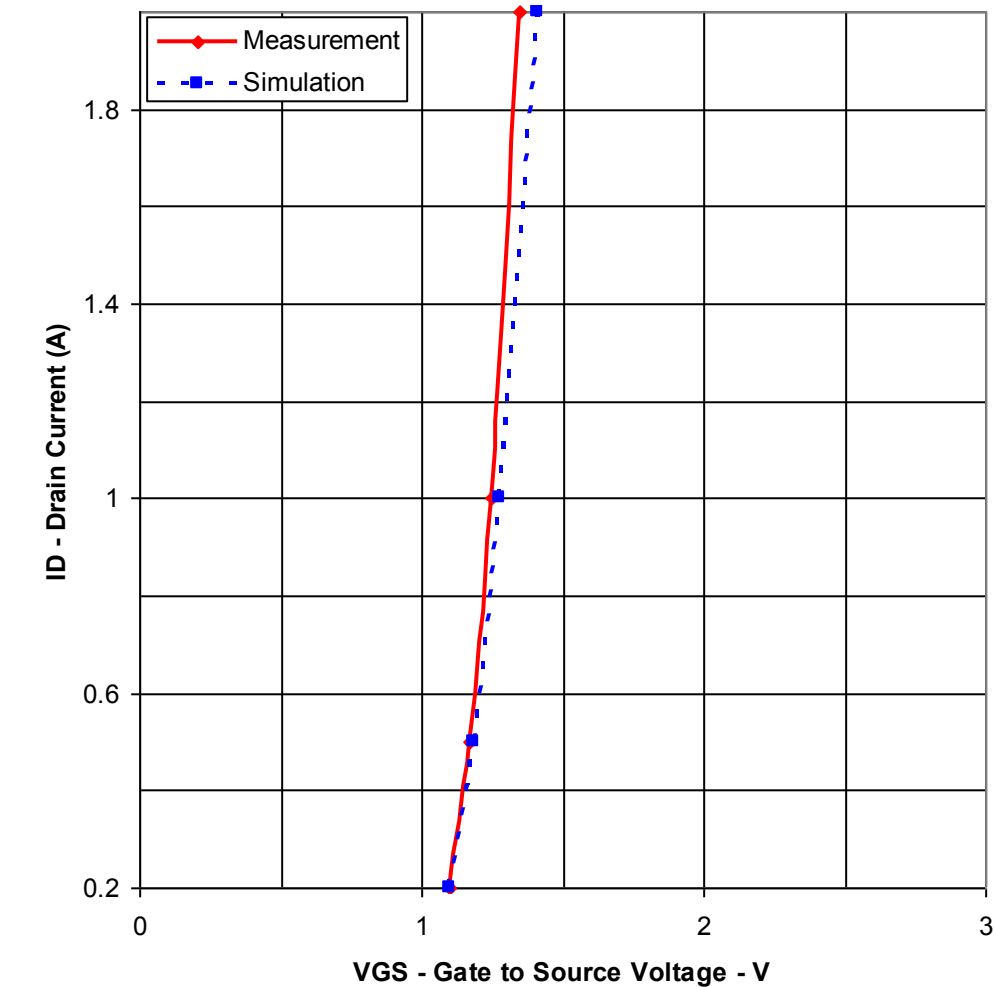


Evaluation circuit



# Comparison Graph

Circuit Simulation Result

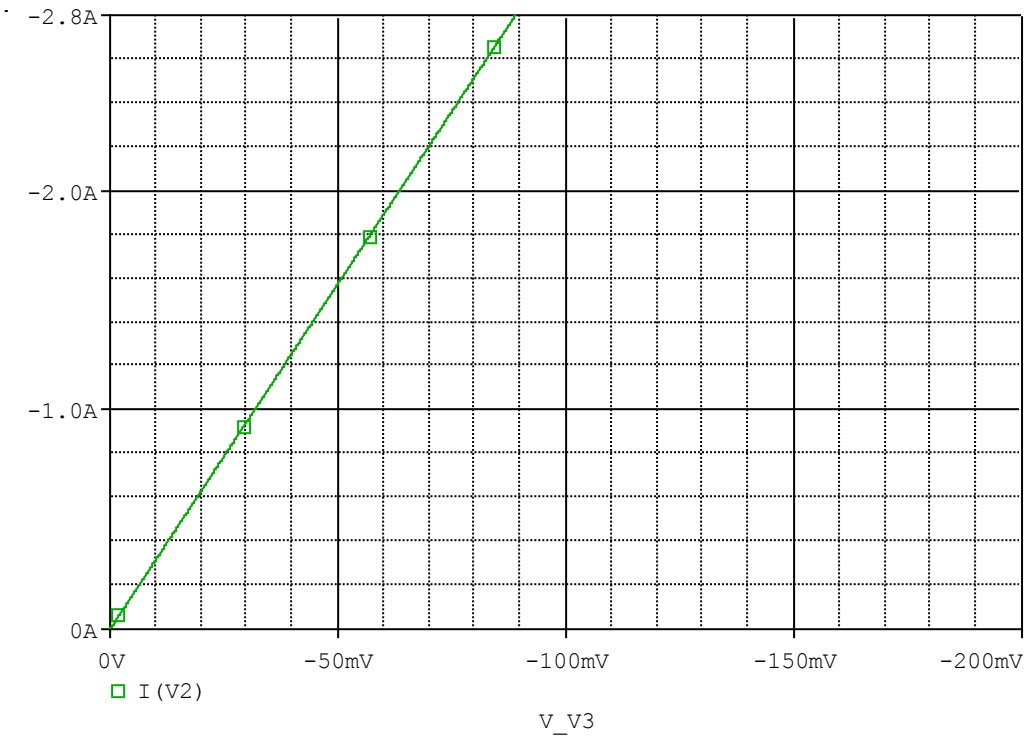


Simulation Result

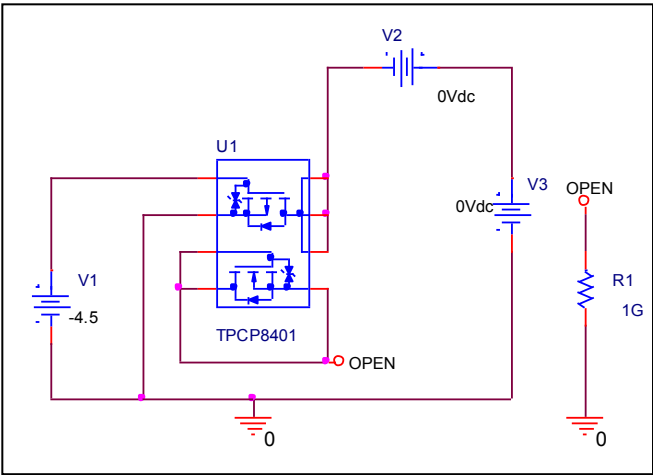
| - ID(mA) | - VGS(V)    |            | Error (%) |
|----------|-------------|------------|-----------|
|          | Measurement | Simulation |           |
| 0.2      | 1.1         | 1.1027     | 0.245     |
| 0.5      | 1.17        | 1.1857     | 1.342     |
| 1        | 1.25        | 1.28       | 2.400     |
| 2        | 1.35        | 1.4131     | 4.674     |

# Rds(on) Characteristic

## Circuit Simulation result



## Evaluation circuit

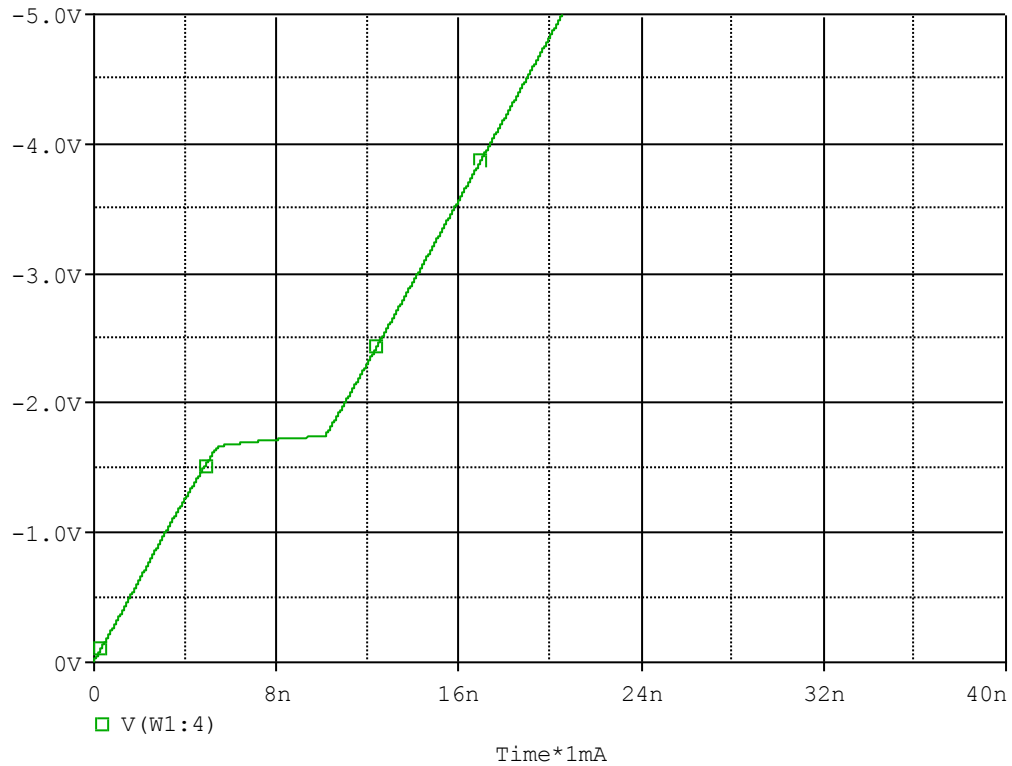


## Simulation Result

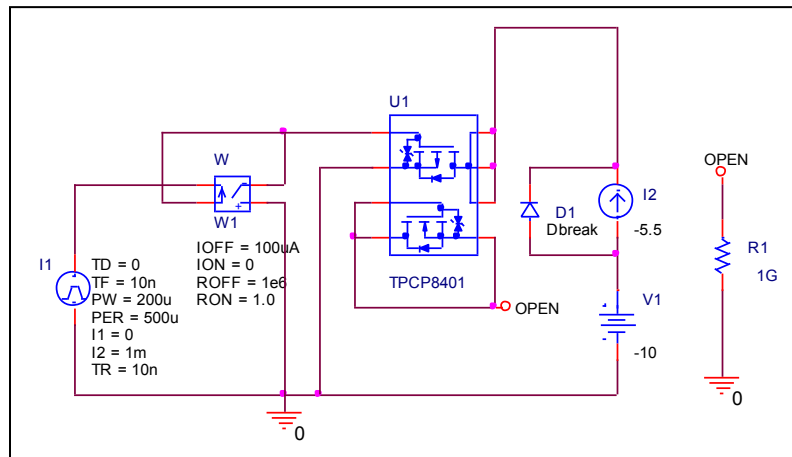
| $I_D=-2.8A, V_{GS}=-4.5V$ | Measurement |    | Simulation |    | Error (%) |
|---------------------------|-------------|----|------------|----|-----------|
| $R_{DS(on)}$              | 31.000      | mΩ | 31.761     | mΩ | 2.455     |

# Gate Charge Characteristic

## Circuit Simulation result



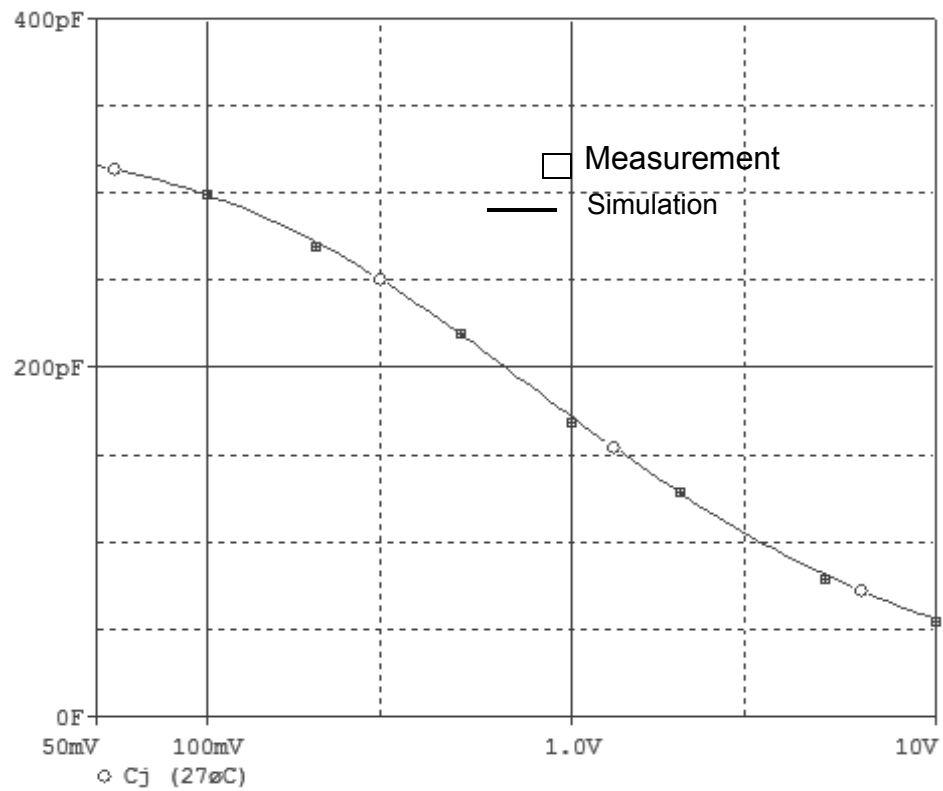
## Evaluation circuit



## Simulation Result

| $V_{DD}=-10V, I_D=-5.5A$<br>$V_{GS}=-5V$ | Measurement | Simulation    | Error (%)     |
|------------------------------------------|-------------|---------------|---------------|
| <b>Qgs(nC)</b>                           | <b>5.5</b>  | <b>5.4732</b> | <b>-0.487</b> |
| <b>Qgd(nC)</b>                           | <b>4.5</b>  | <b>4.6618</b> | <b>3.596</b>  |
| <b>Qg(nC)</b>                            | <b>20.5</b> | <b>20.547</b> | <b>0.229</b>  |

## Capacitance Characteristic

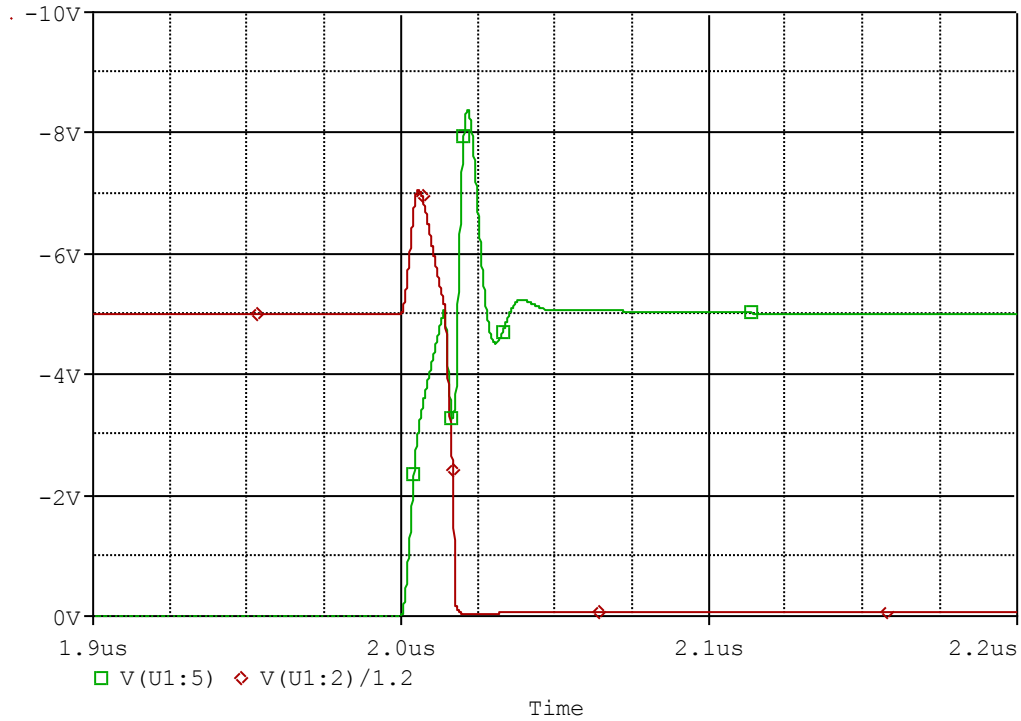


### Simulation Result

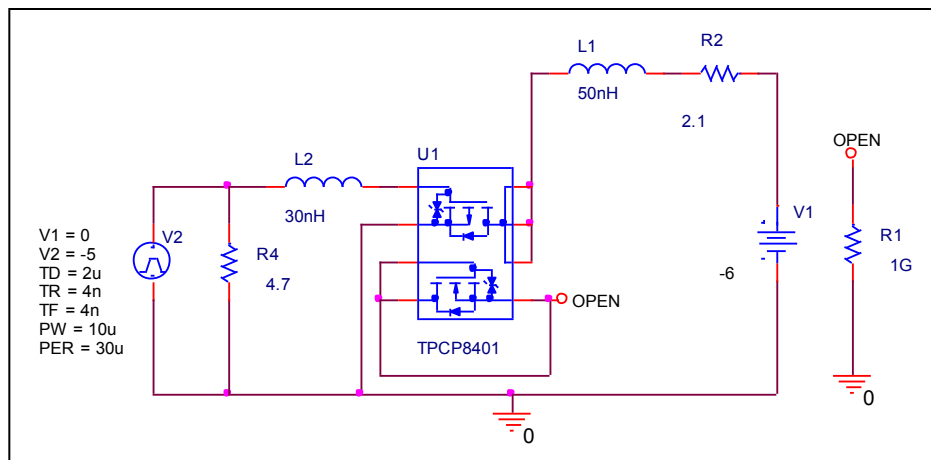
| - $V_{DS}$ (V) | Cbd(pF)     |            | Error(%) |
|----------------|-------------|------------|----------|
|                | Measurement | Simulation |          |
| 0.1            | 300         | 298        | -0.667   |
| 0.2            | 270         | 273        | 1.111    |
| 0.5            | 220         | 218        | -0.909   |
| 1              | 170         | 173        | 1.765    |
| 2              | 130         | 127        | -2.308   |
| 5              | 80          | 81         | 1.250    |
| 10             | 55          | 56         | 1.818    |

## Switching Time Characteristic

### Circuit Simulation result



### Evaluation circuit



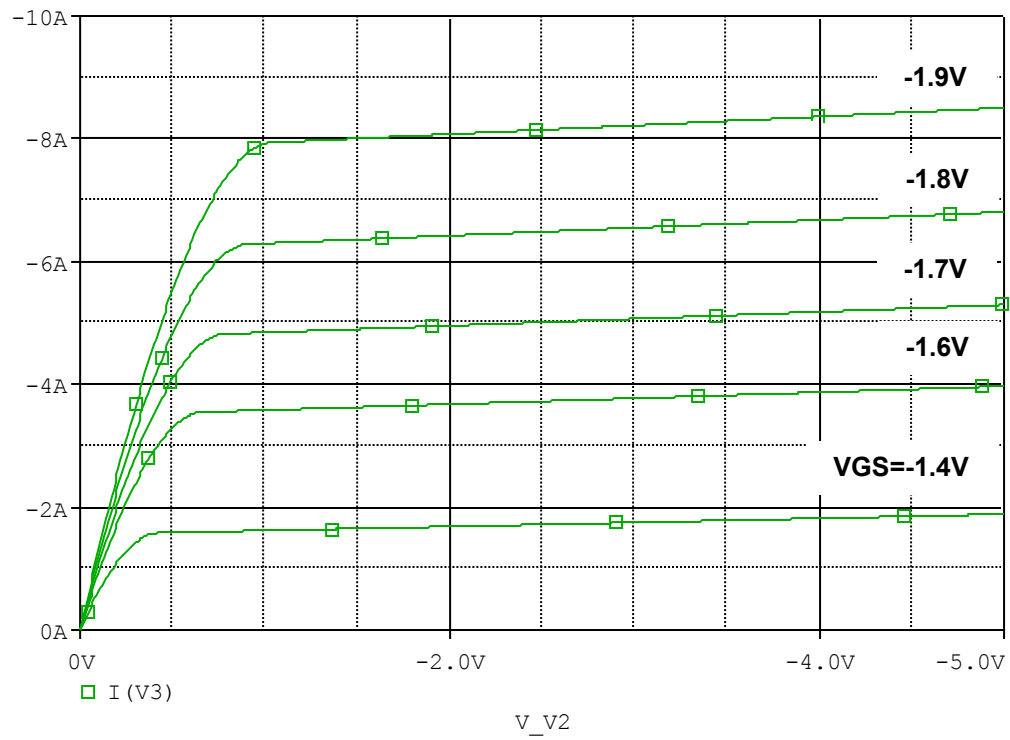
### Simulation Result

| $I_D = -2.8 \text{ A}$ , $V_{DD} = -6 \text{ V}$<br>$V_{GS} = 0/-5 \text{ V}$ | Measurement | Simulation | Error(%) |
|-------------------------------------------------------------------------------|-------------|------------|----------|
| Ton(ns)                                                                       | 16          | 16.039     | 0.244    |

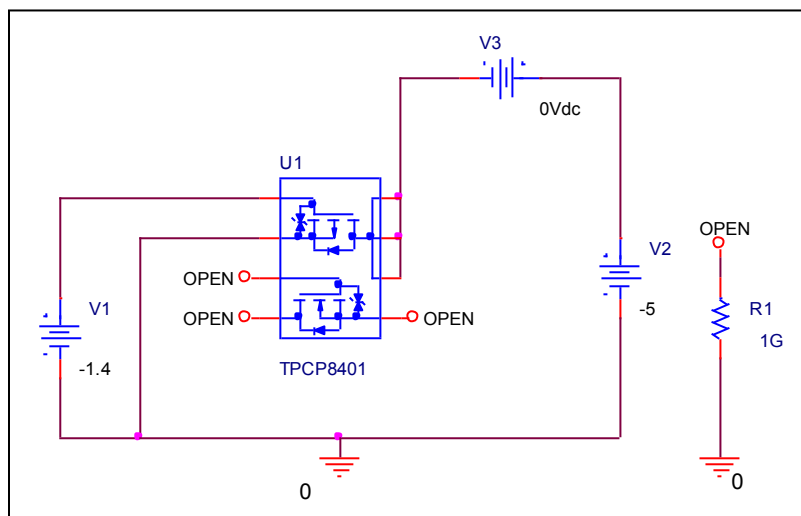


## Output Characteristic

Circuit Simulation result

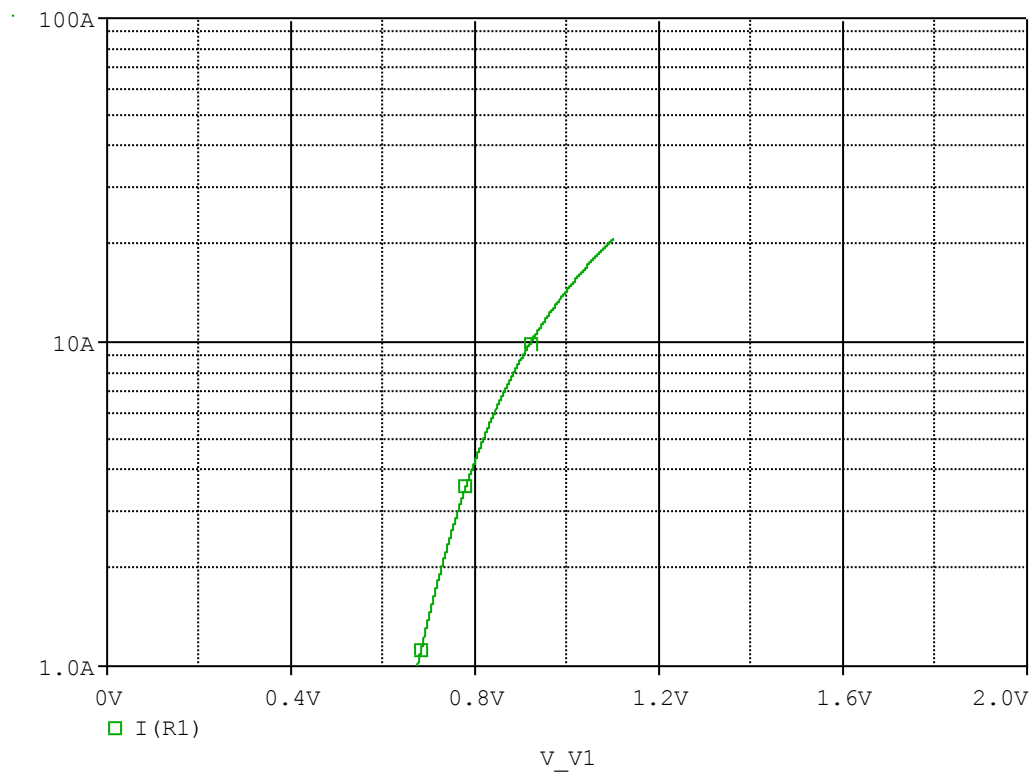


Evaluation circuit

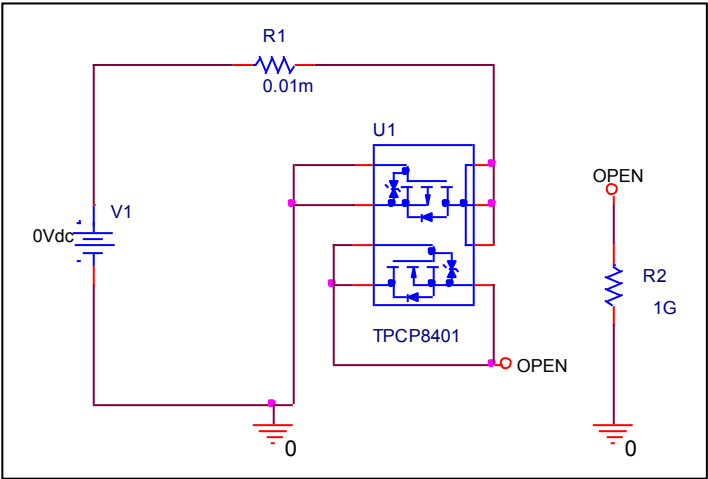


# Forward Current Characteristic

## Circuit Simulation Result

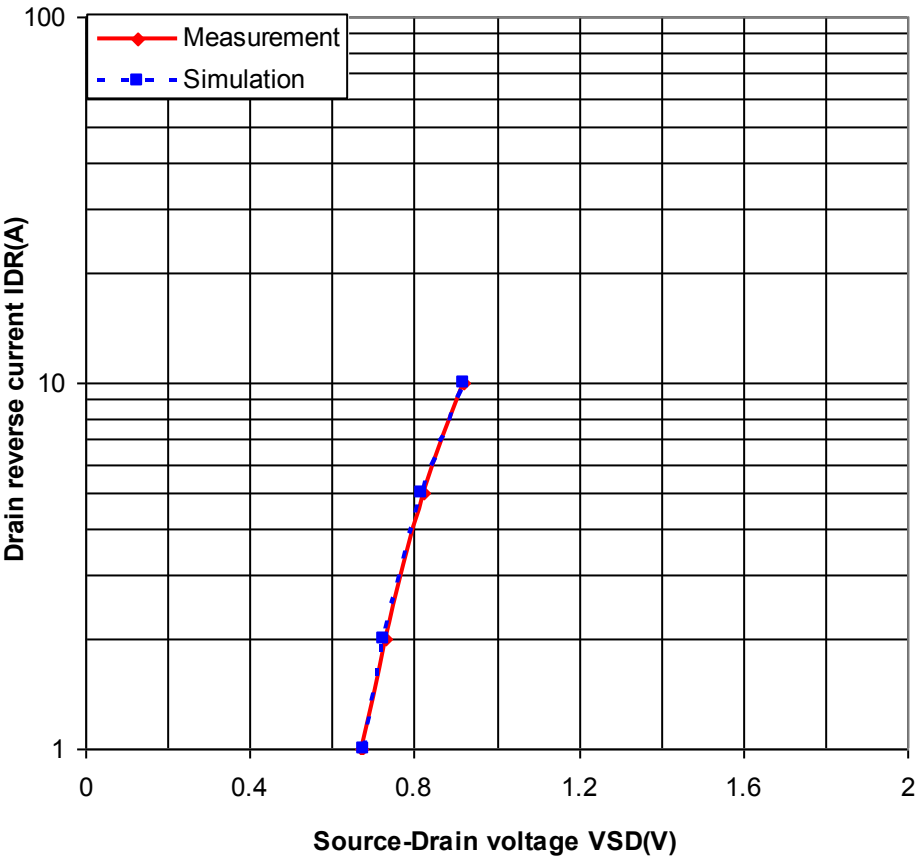


## Evaluation Circuit



# Comparison Graph

Circuit Simulation Result

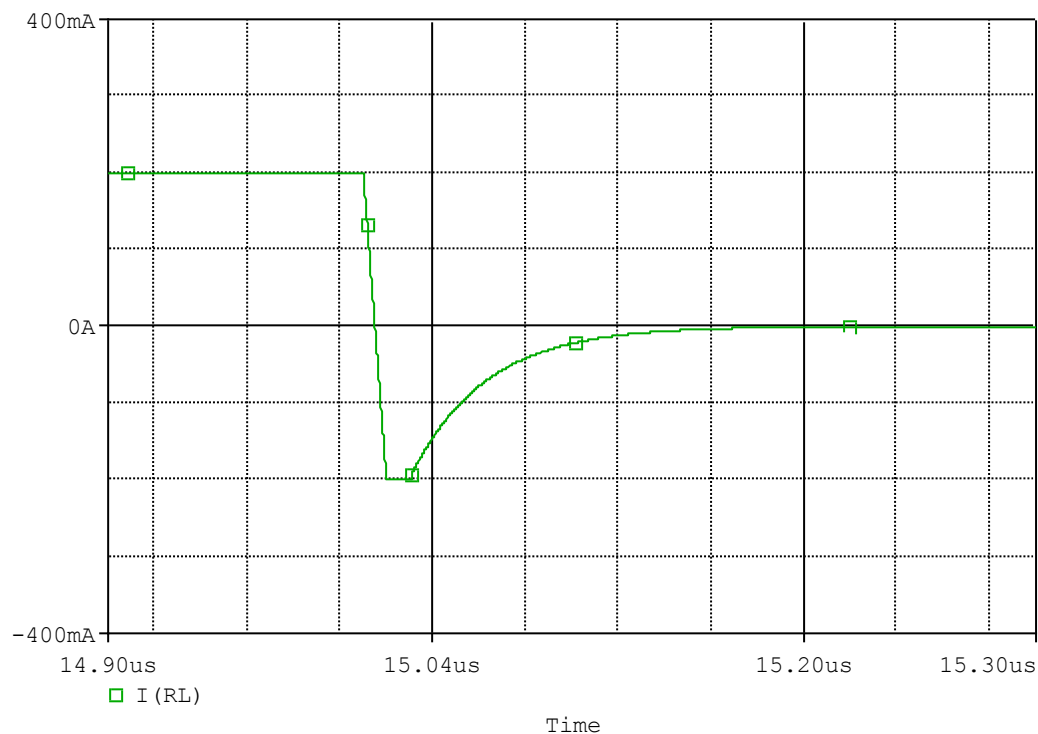


Simulation Result

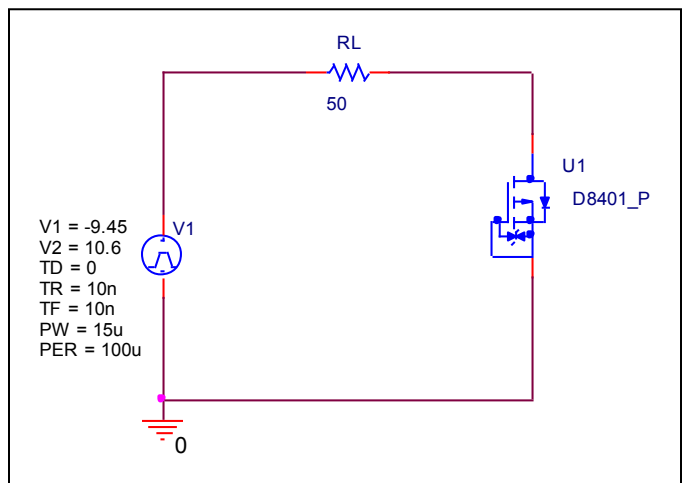
| IDR(A) | VSD(V)     |            | %Error |
|--------|------------|------------|--------|
|        | Measuremen | Simulation |        |
| 1      | 0.67       | 0.675      | 0.746  |
| 2      | 0.73       | 0.727      | -0.411 |
| 5      | 0.82       | 0.818      | -0.244 |
| 10     | 0.92       | 0.922      | 0.217  |

# Reverse Recovery Characteristic

## Circuit Simulation Result



## Evaluation Circuit

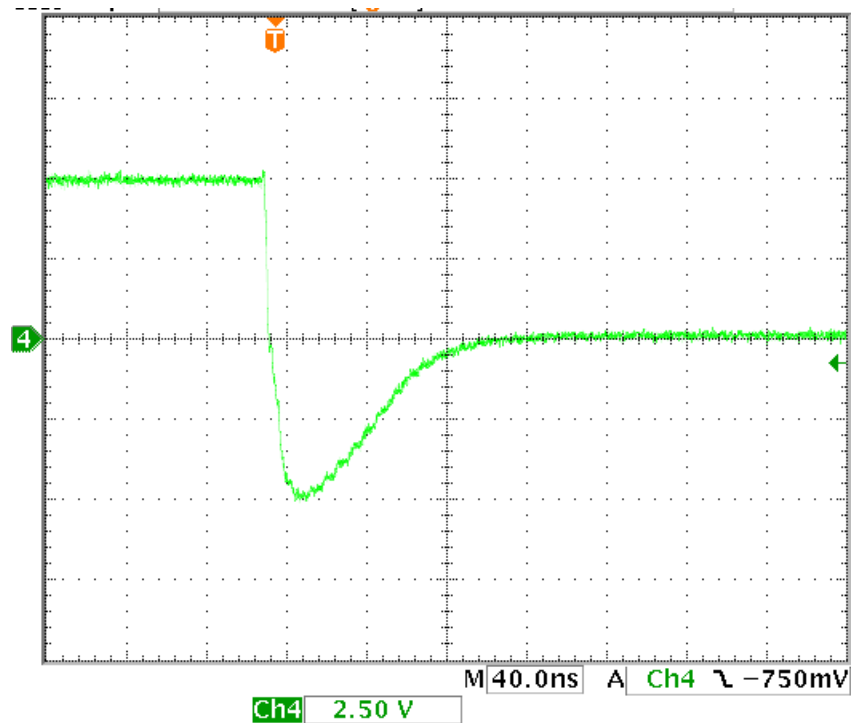


## Compare Measurement vs. Simulation

|         | Measurement | Simulation | Error (%) |
|---------|-------------|------------|-----------|
| Trj(ns) | 15.2        | 15.2       | 0         |
| Trb(ns) | 72.8        | 72.842     | 0.058     |
| Trr(ns) | 88          | 88.042     | 0.048     |

## Reverse Recovery Characteristic

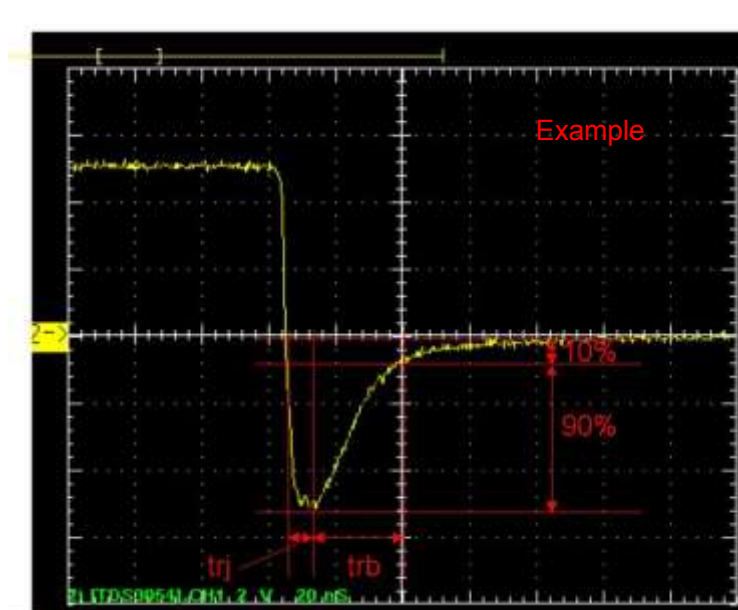
## Reference



$T_{rr}=15.2(\text{ns})$

$T_{rb}=72.8(\text{ns})$

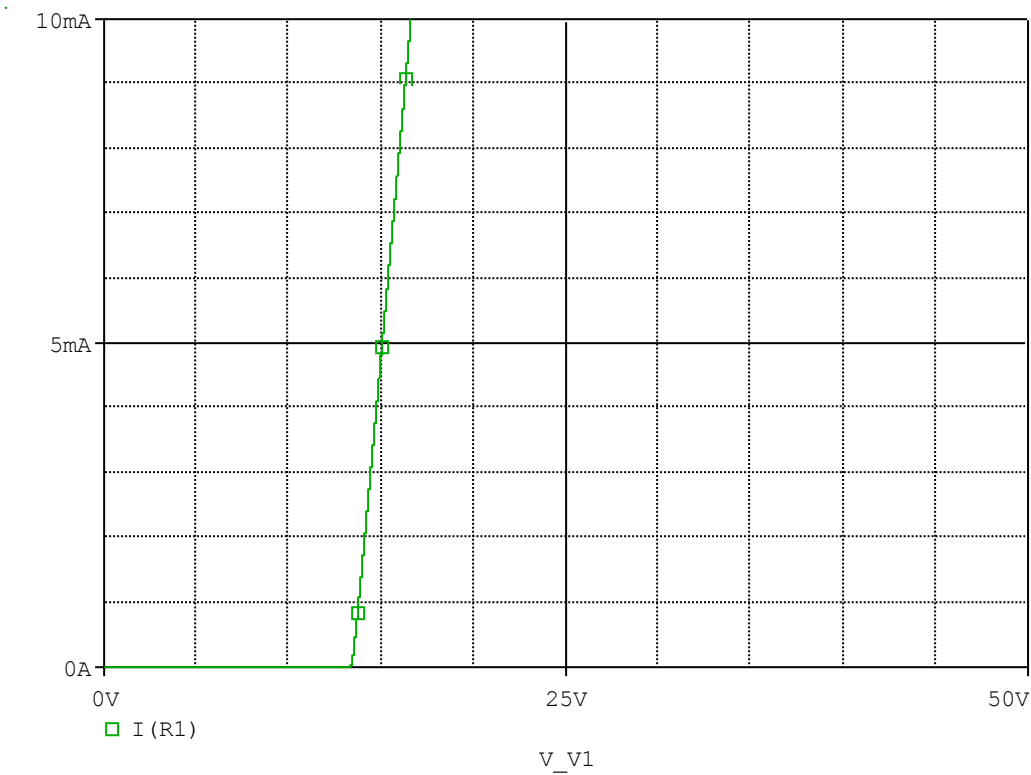
Conditions:  $I_{fwd}=I_{rev}=0.2(\text{A})$ ,  $R_I=50$



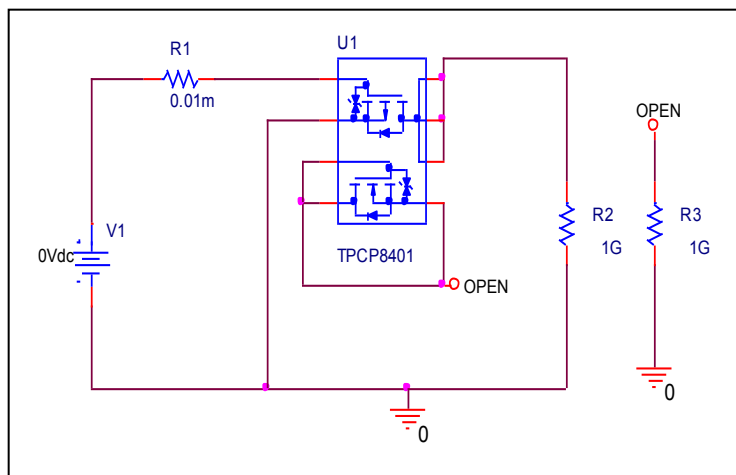
Relation between  $t_{rr}$  and  $t_{rb}$

# Zener Voltage Characteristic

## Circuit Simulation Result



## Evaluation Circuit



Zener Voltage Characteristic

Reference

