
Qspice - Model Generators Guide by KSKelvin

KSKelvin Kelvin Leung

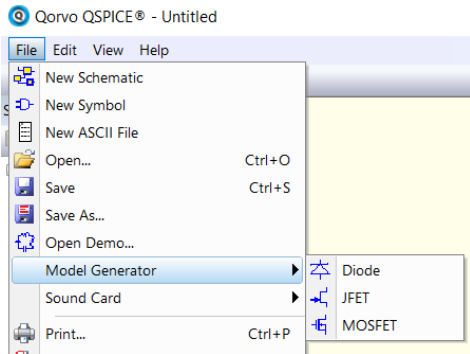
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Model Generator and Precaution in using this Guide

- Model Generator

- Model generators are in File > Model Generator > Diode/JFET/MOSFET
- Execute one of these model generators, within the subprogram, it has official HELP



- Precaution in using this Guide

- The model generator appears to still be subject to change. If you are unable to replicate the example provided in this guideline, it may be related to a change in the model generator
- I cannot guarantee the accuracy of this guideline as it heavily relies on parameter studies through these model generators. This guideline is still in its preliminary status

Technique in Digitizing Datasheet

Digitize with Crosshair Cursor and Arrow Slight Adjustment

Step #2 : [Crosshair Cursor]

- Move cursor to this area, **hold** Left mouse button
Now, the cursor become a crosshair

TYPICAL PERFORMANCE CURVES

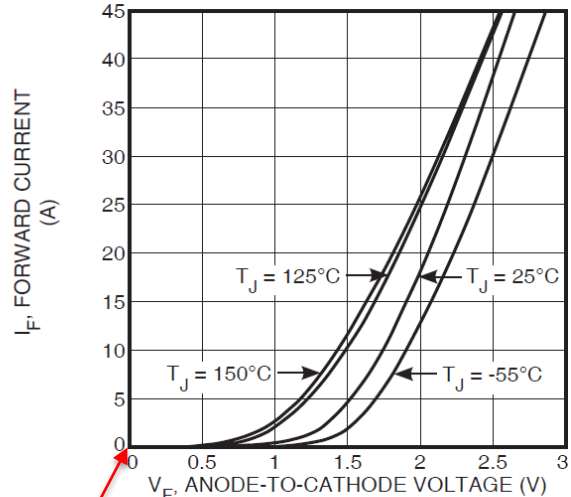
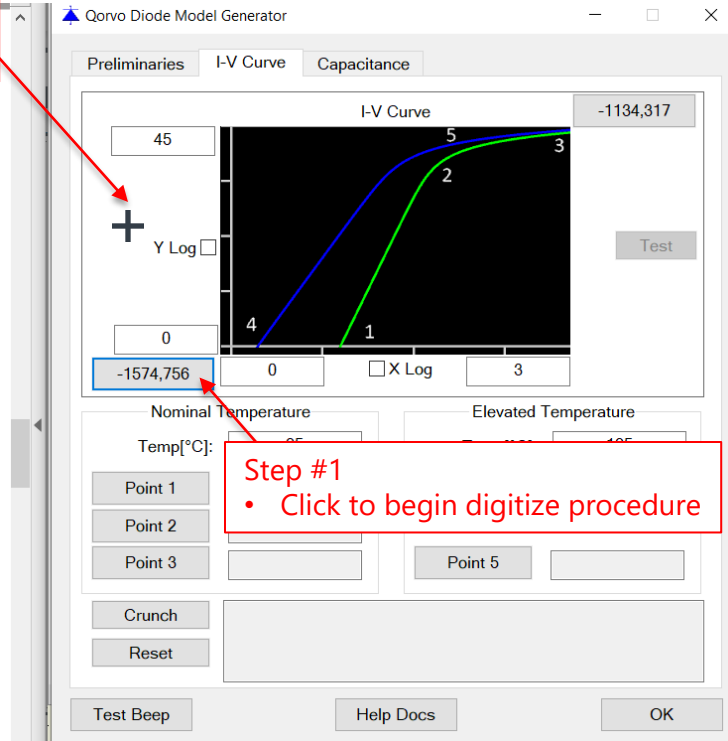


Figure 2. Forward Current vs. Forward Voltage

Step #3 :

- Move crosshair cursor to pdf to digitize lower left corner
(Can **use arrow key to adjust crosshair position precisely**)
- Release left mouse button and location is digitized
- [Repeat Step #2 and #3 until all points is digitized]

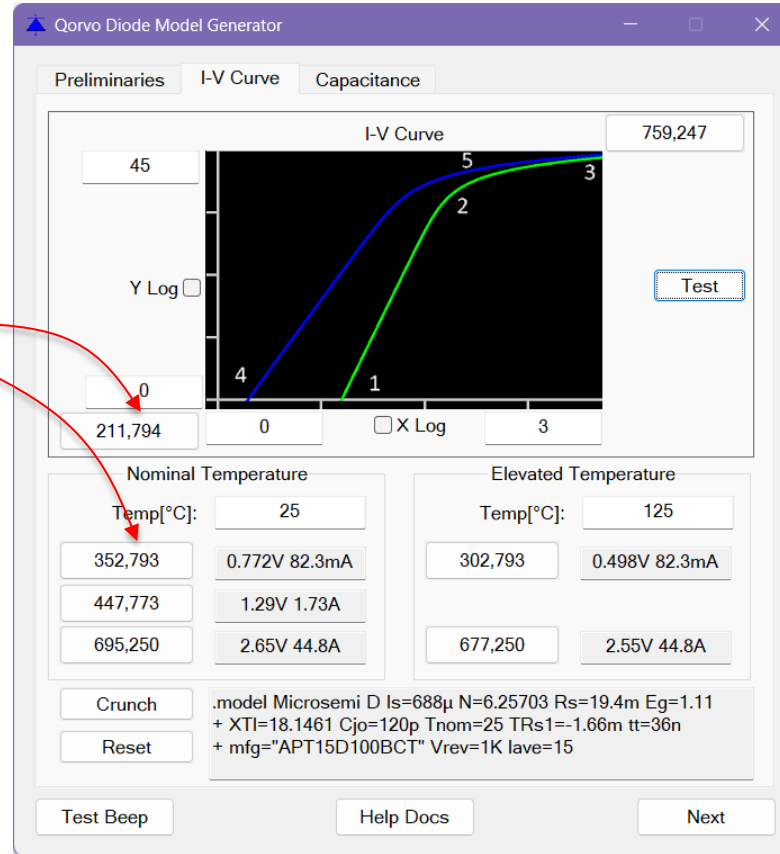


Step #1

- Click to begin digitize procedure

Useful Technique in using Digitize

To digitize a very small value on a linear scale, use the arrow keys to make fine adjustments to the cursor. Monitor the y-axis value to ensure it is one digit less than the y-axis value of the LowerLeft.



Diode Model Generator

DIODE.exe

Diode Model
Generator

Parameters
Generation

Diode Model Generator – Preliminaries Tab

Determine : mfg, lave, Vrev, Eg, tt, Cjo**, BV, IBV, NBV

$$tt = \frac{\text{Rev Recovery Charge}}{I @ \text{Rev Recovery}}$$

Calculate **NBV** {
(formula unknown)}

Qorvo DIODE Model Generator

Preliminaries I-V Curve Capacitance

Model Name: 1N4933

MFG: Vishay **mfg** (display only)

Current Rating[A]: 1 **lave** (display only)

Voltage Rating[V]: 100 **Vrev** (display only)

Technology: Silicon

Rev. Recovery Charge[C]: 400n

I @ Rev. Recovery Q[A]: 1

Zero-biased Output Cap.[F]: 12p **Cjo ****

Zener Voltage[V]: Infinite **BV**

Zener Current[A]: 1m **IBV**

Zener Impedance[Ω]: 100

Help Docs OK

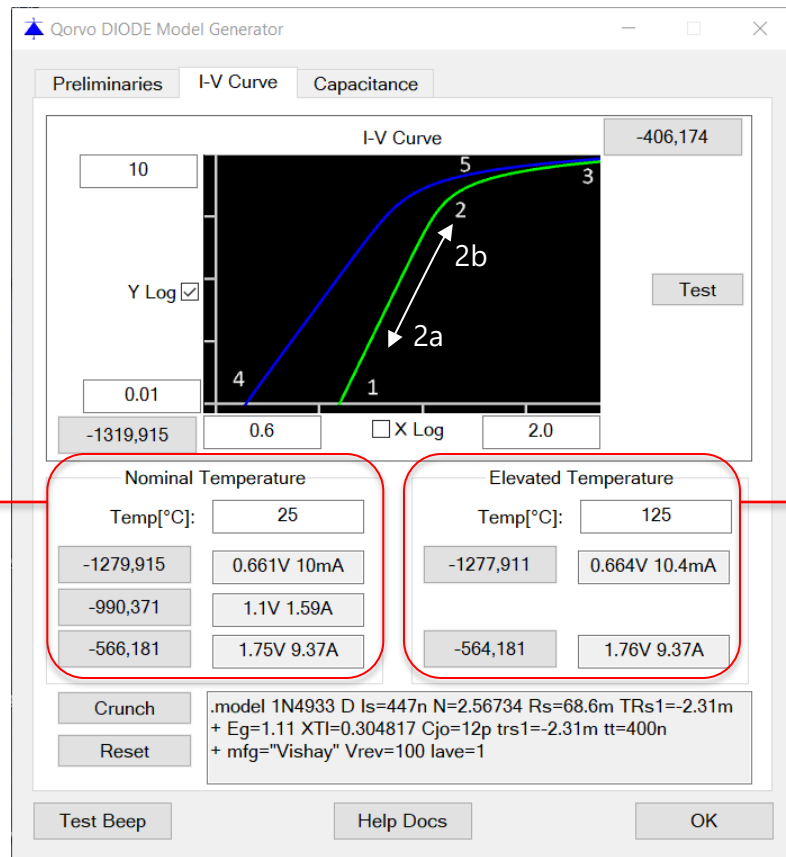
Silicon	Eg = 1.11
Schottky Barrier Diode	Eg = 0.69
Germanium	Eg = 0.67
Gallium Nitride(GaN)	Eg = 3.47
Siconon Carbide(SiC)	Eg = 3.26
Gallium Arsenide(GaAs)	Eg = 1.42

BV, IBV, NBV will be generated if this box is non-zero

Cjo : This only determine Cjo in I-V Curve digitized tab. If Capacitance digitized tab is used, this Cjo will be ignored

Diode Model Generator – I-V Curve Tab

Determine : I_s , N , R_s , $TRs1$, XTI



Determine I_s , N , R_s

Determine $TRs1$, XTI

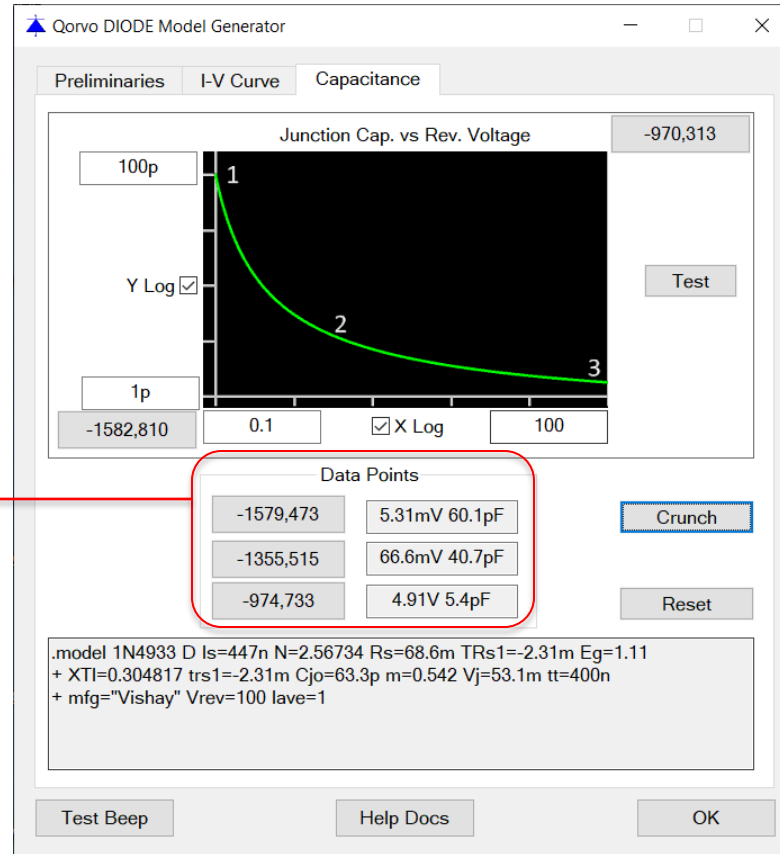
If Temp set to be identical nominal temperature, force $TRs1=0$ and $XTI=3$
(If $XTI=3$, $TRs1$ may not generated)

** where to digitize point #2 can affect I_s and N
If point #1 and #2 are closer (e.g. at #2a), I_s tends to be calculated smaller

Diode Model Generator – Capacitance Tab

Determine : C_{jo} , m , V_j

Determine C_{jo} , m and V_j



Diode Model Generator

Example – Datasheet
of Onsemi MURS1200

Example – Onsemi MURS120 Datasheet to Model Generator

MAXIMUM RATINGS					
Rating	Symbol	MURS/SURS/NRVUS			
		105T3	110T3	115T3	120T3
Peak Repetitive Reverse Voltage Working Peak Reverse Voltage DC Blocking Voltage	V_{RRM} V_{RWM} V_R	50	100	150	200
Continuous Forward Current	$I_F(DC)$	1.0 @ $T_L = 159^{\circ}C$ 2.0 @ $T_L = 139^{\circ}C$			

Qorvo DIODE Model Generator

Preliminaries I-V Curve Capacitance

Model Name:

MFG:

Current Rating[A]:

Voltage Rating[V]:

Technology:

Rev. Recovery Charge[C]:

I @ Rev. Recovery Q[A]:

Zero-biased Output Cap.[F]:

Zener Voltage[V]:

Zener Current[A]:

Zener Impedance[Ω]:

Help Docs OK

Maximum Reverse Recovery Time ($I_F = 1.0\text{ A}$, $di/dt = 50\text{ A}/\mu\text{s}$, $V_R = 30\text{ V}$) ($I_F = 0.5\text{ A}$, $I_R = 1.0\text{ A}$, I_R to 0.25 A)	t_{rr}	35 25
---	----------	----------

- Reverse Recovery Time is given at $I_F=1\text{A}$
- I @ Rev. Recovery = 1A
 - Rev. Recovery Charge = $t_{rr} * I_F = 35\text{n}$

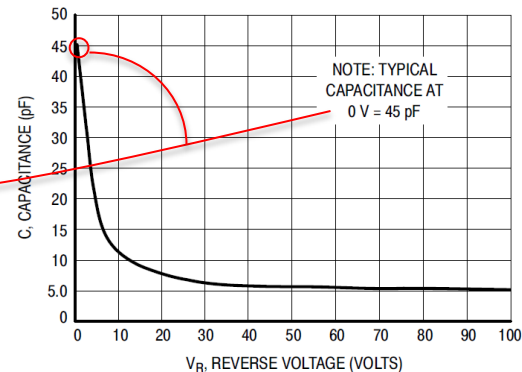


Figure 3. Typical Capacitance

Example – Onsemi MURS120 Datasheet to Model Generator

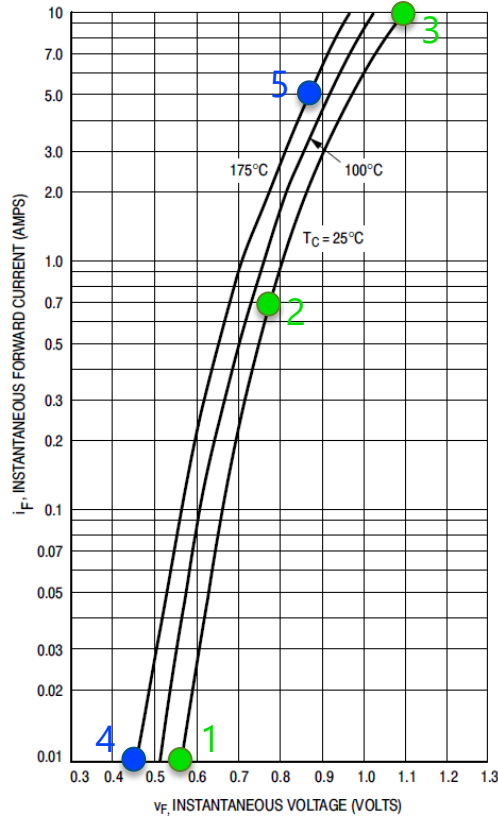
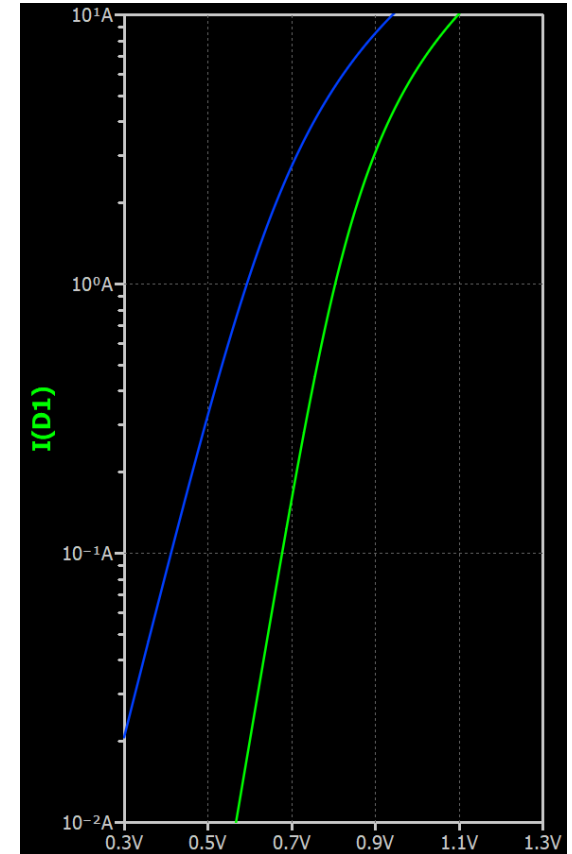
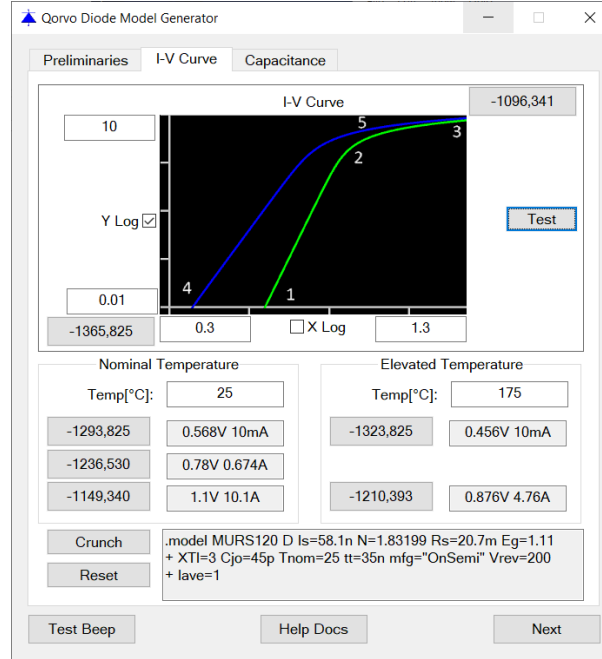


Figure 1. Typical Forward Voltage



Example – Onsemi MURS120 Datasheet to Model Generator

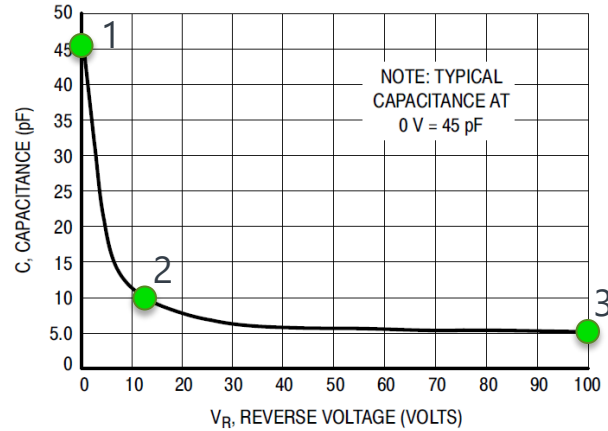
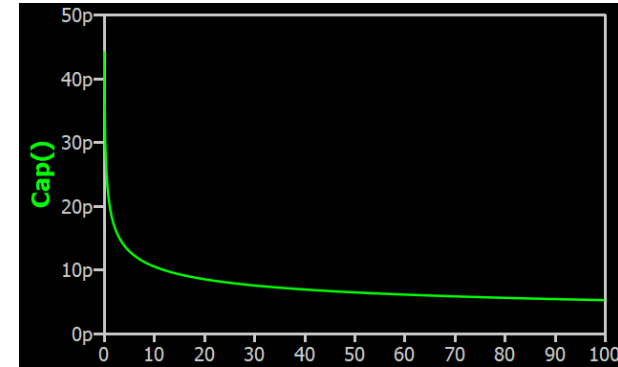
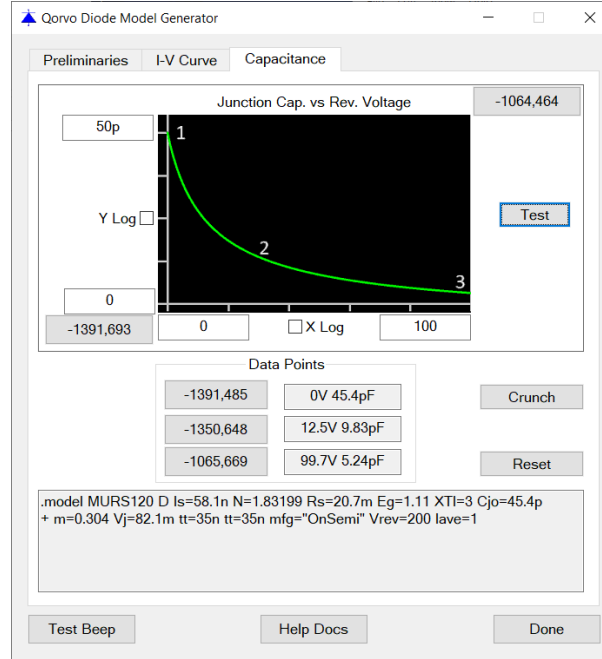


Figure 3. Typical Capacitance



Diode Model Generator

Example – Datasheet
of Microchip
APT15D100BCT

Example – Microchip APT15D100BCT Datasheet to Model Generator

MAXIMUM RATINGS					
Rating	Symbol	MURS/SURS/NRVUS			
		105T3	110T3	115T3	120T3
Peak Repetitive Reverse Voltage Working Peak Reverse Voltage DC Blocking Voltage	V_{RRM} V_{RWM} V_R	50	100	150	200
Continuous Forward Current	$I_{F(DC)}$	1.0 @ $T_L = 159^\circ\text{C}$ 2.0 @ $T_L = 139^\circ\text{C}$			

t_{rr}	Reverse Recovery Time	$I_F = 15\text{A}$, $di_F/dt = -200\text{A}/\mu\text{s}$ $V_R = 667\text{V}$, $T_C = 25^\circ\text{C}$	-	260	-	ns
Q_{rr}	Reverse Recovery Charge		-	540	-	nC
I_{RRM}	Maximum Reverse Recovery Current		-	4	-	Amps

Qorvo Diode Model Generator

Preliminaries I-V Curve Capacitance

Model Name: Microsemi
 MFG: APT15D100BCT
 Current Rating[A]: 15
 Voltage Rating[V]: 1000
 Technology: Silicon
 Rev. Recovery Charge[C]: 540n
 I @ Rev. Recovery Q[A]: 15
 Zero-biased Output Cap.[F]: 120p
 Zener Voltage[V]: Infinite
 Zener Current[A]: 1m
 Zener Impedance[Ω]: 100

Help Docs
 Next

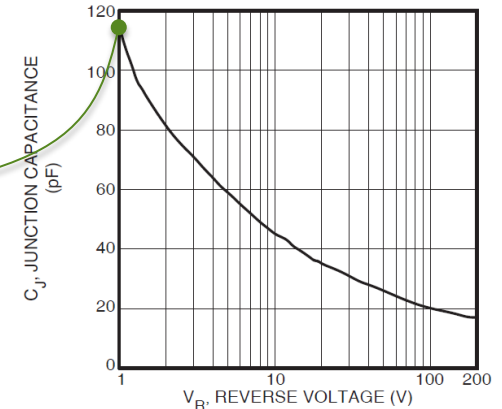


Figure 8. Junction Capacitance vs. Reverse Voltage

Example – Microchip APT15D100BCT Datasheet to Model Generator

Qspice reference is log plot (y-axis log, x-axis linear),
marker 1-5 is different if linear plot is used

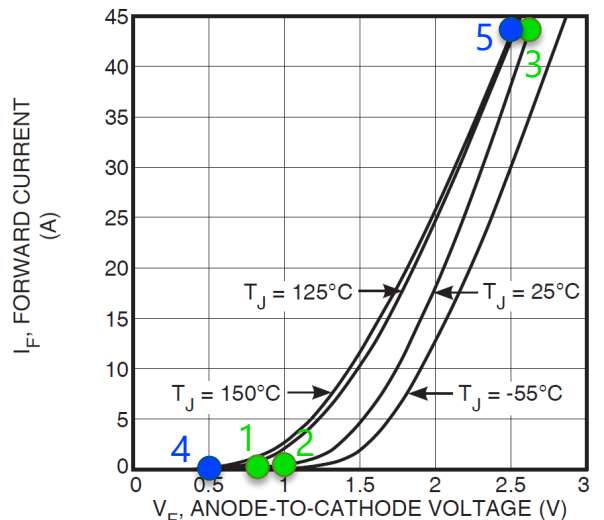
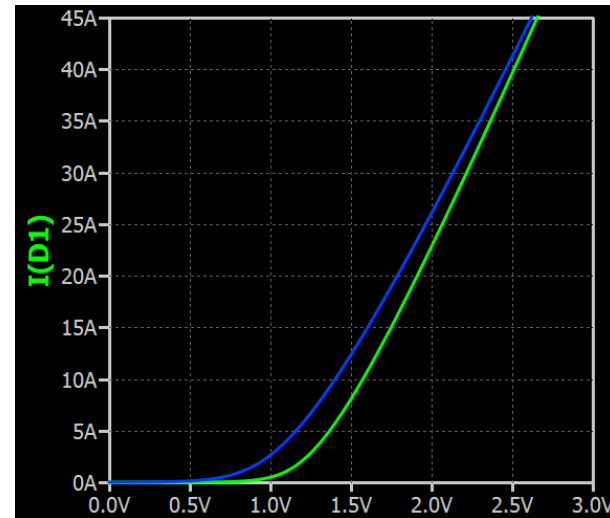
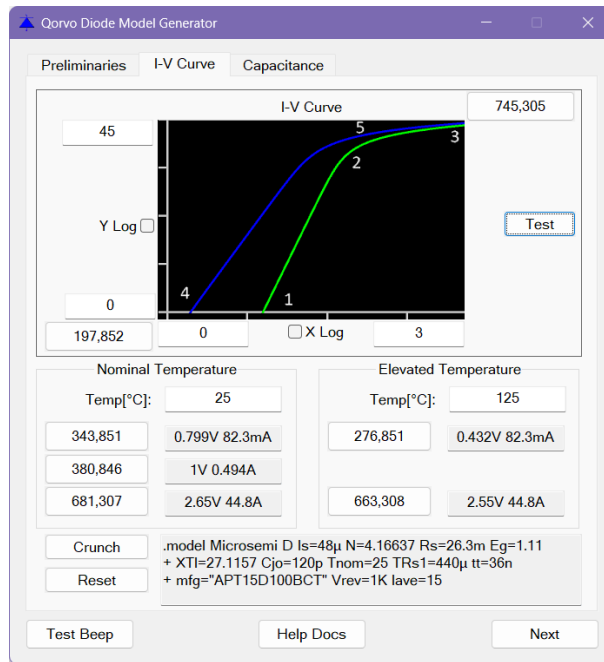


Figure 2. Forward Current vs. Forward Voltage

Marker 1 to 5 if linear plot is used
(y-axis and x-axis are both linear)



Example – Microchip APT15D100BCT Datasheet to Model Generator

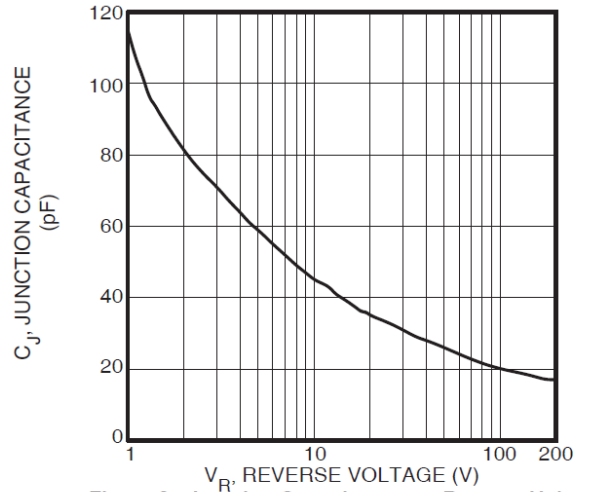
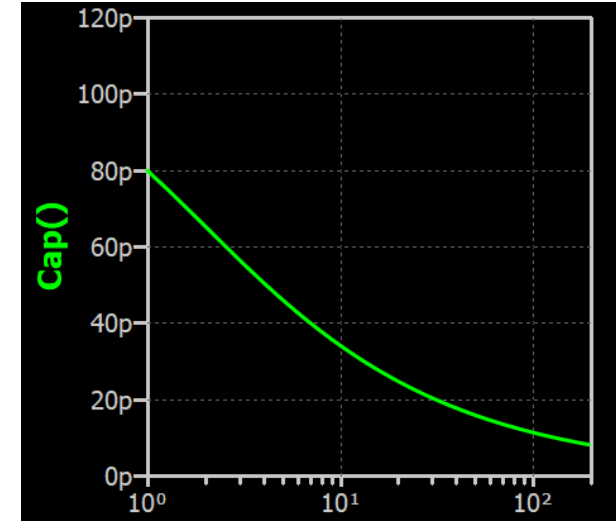
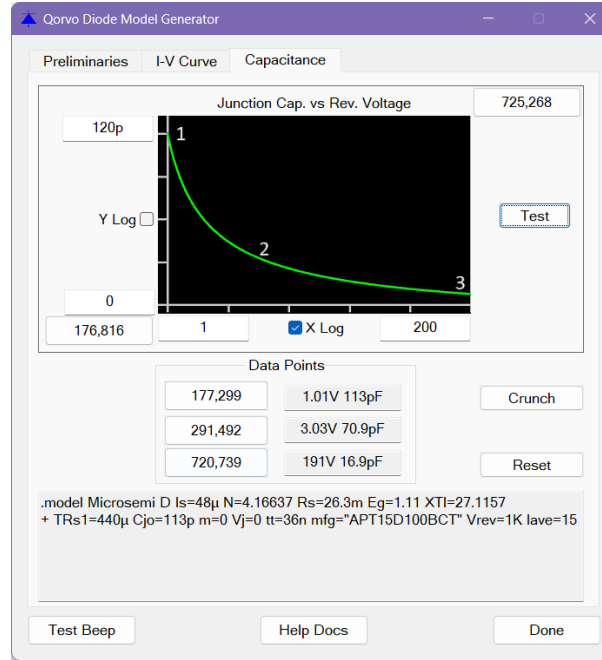


Figure 8. Junction Capacitance vs. Reverse Voltage



MOSFET Model Generator

MOSFET.exe

MOSFET Model Generator

Parameters Generation

MOSFET Model Generator – Preliminaries Tab

Determine : mfg, Ids, Vds, Qg, Rg, Rds, Rd, Rs, Eg, tt

$$R_d + R_s = R_{ds(on)} \times (R_{ext} \div (R_{ext} + R_{channel}))$$

- $R_{ext} = R_d + R_s$ (e.g. bond wire, contact)
- $R_{channel}$ is R_{ds} of MOSFET channel

Not provide by datasheet, from Mike Engelhardt experience, in ~75% of resistance is contributed by R_{ext}

$$R_d = R_{ds(on)} \times (R_{ext} \div (R_{ext} + R_{channel})) \times (R_d \div (R_d + R_s))$$

$$R_s = R_{ds(on)} \times (R_{ext} \div (R_{ext} + R_{channel})) - R_d$$

Not provided by datasheet, from Mike experience, Ratio of R_d and R_s from R_{ext} , approximate by 50%

Representation:

$$\frac{x}{x+y} \rightarrow 1 : x \gg y$$

$$\frac{x}{x+y} \rightarrow 0 : y \gg x$$

Parameter	Value	Notes
Model Name:	IRF630	
MFG:	Vishay	mfg (display only)
Ids Rating[A]:	9	Ids (display only)
Vds Rating[V]:	200	Vds (display only)
Total Gate Charge[C]:	43	Qg (display only)
Rg[Ω]:	2	Rg
Rds(on)[Ω]:	0.2	Rds (display only), but also use to calculate Rd and Rs
Vgs @ Rds(on)[V]:	10	Contribute to Calculation of RonX (formula unknown)
I @ Rds(on)[A]:	5.4	
Rext ÷ (Rext + Rchannel)	0.75	
Rd ÷ (Rd + Rs)	0.5	
Technology:	Silicon	Eg
Rev. Recovery Charge[C]:	1.1n	tt = Rev Recovery Charge / I @ Rev Recovery
I @ Rev. Recovery Q[A]:	5.9	
Zero-biased Output Cap.[F]:	1.5n	Contribute to Calculation of Cjo

MOSFET Model Generator – Output Characteristics

Determine : V_{to} , K_p , Λ , R_{onX} , η , V_{totc}



Determine V_{to} , K_p , Λ , R_{onX}

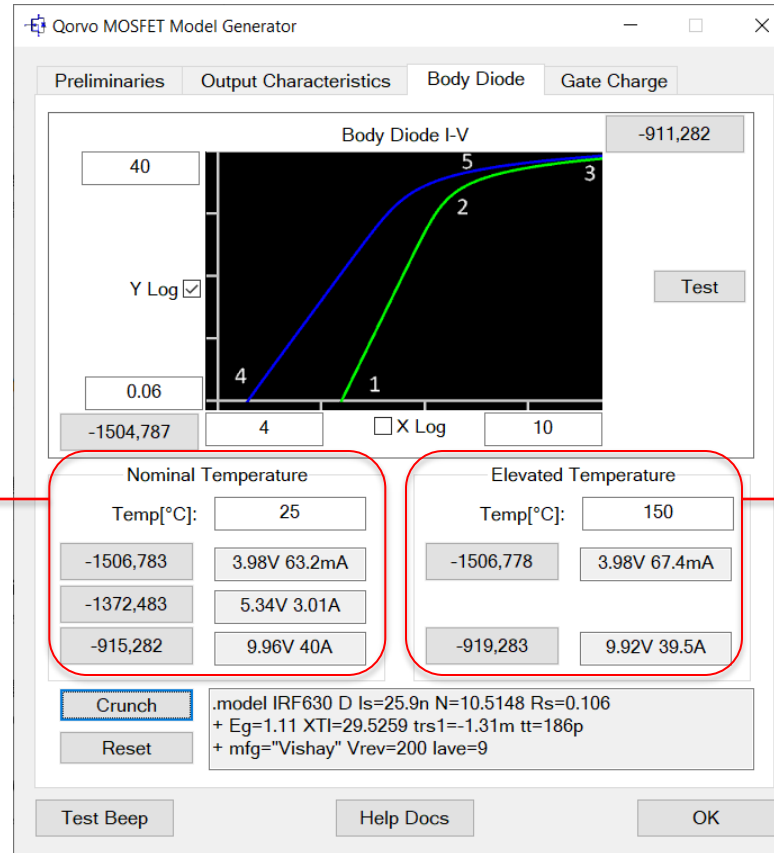
** $R_{ds,on}$ in preliminaries tab can be used to fine tuning Id vs Vds curve at lower Vds region

** η and V_{totc} seems to be fixed
 $\eta=75m$
 $V_{totc}=-2m$

MOSFET Model Generator – Body Diode

Determine : I_s , N , R_s (R_b in MOS), $TRs1$, XTI

Determine I_s , N , R_s



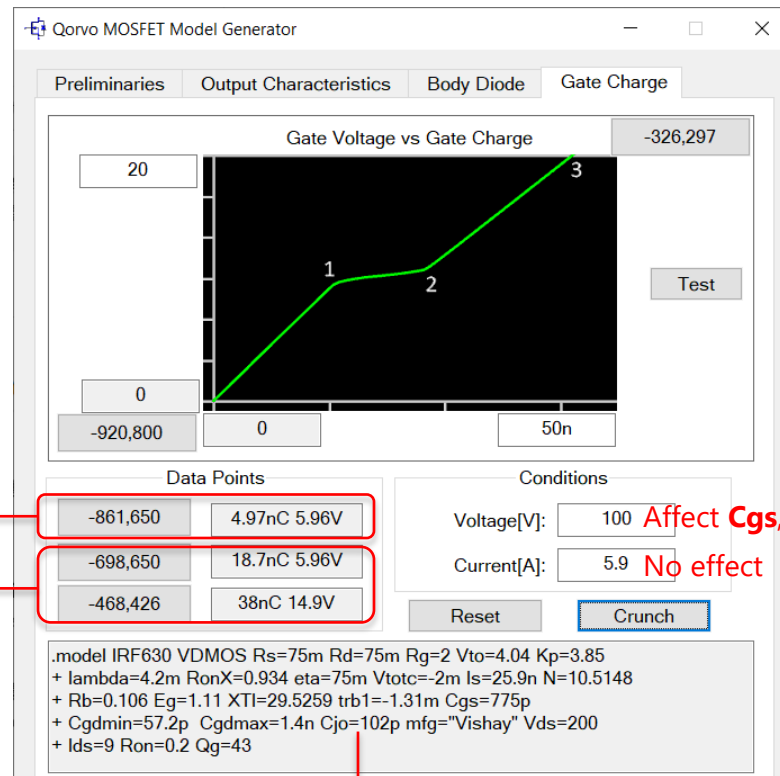
Determine $TRs1$, XTI

If Temp set to be identical nominal temperature, force $TRs1=0$ and $XTI=3$

** tt and Eg is from Preliminary tab
** R_s is series resistor in diode model, this will rename to R_b in VDMOS model in Gate Charge tab ($R_s \rightarrow$ rename to R_b)

MOSFET Model Generator – Gate Charge

Determine : C_{gs} , C_{gdmin} , C_{gdmax} , C_{jo}



mainly determine : C_{gs}

mainly determine : C_{gdmin} , C_{gdmax}

Affect C_{gs} , C_{gdmin} , C_{gdmax} , C_{jo}

No effect

C_{jo} = Zero-biased Output Cap (Preliminaries) – C_{gdmax} (min. value as 0)
[C_{jo} is body diode zero-bias capacitance]

MOSFET Model Generator

Example – Datasheet
of Vishay IRF630

Example – Vishay IRF630 Datasheet to Model Generator



Example – Vishay IRF630 Datasheet to Model Generator

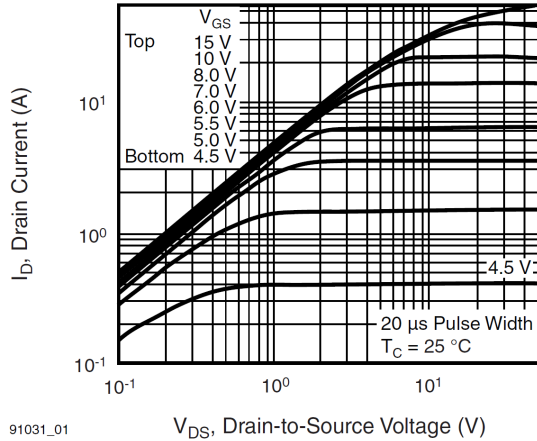
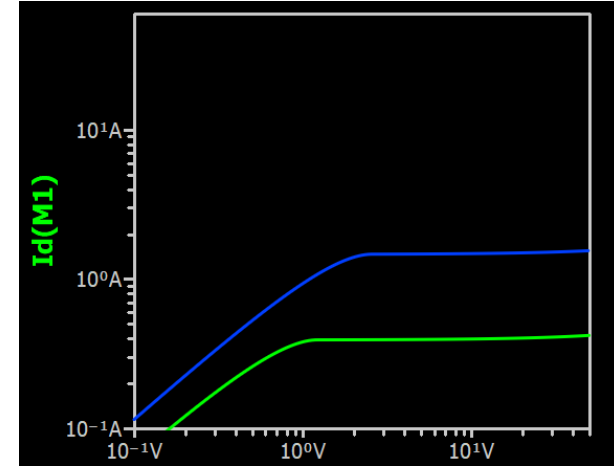


Fig. 1 - Typical Output Characteristics, $T_C = 25^\circ C$



Example – Vishay IRF630 Datasheet to Model Generator

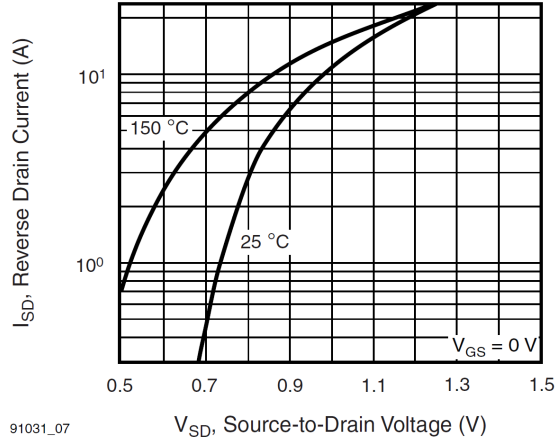
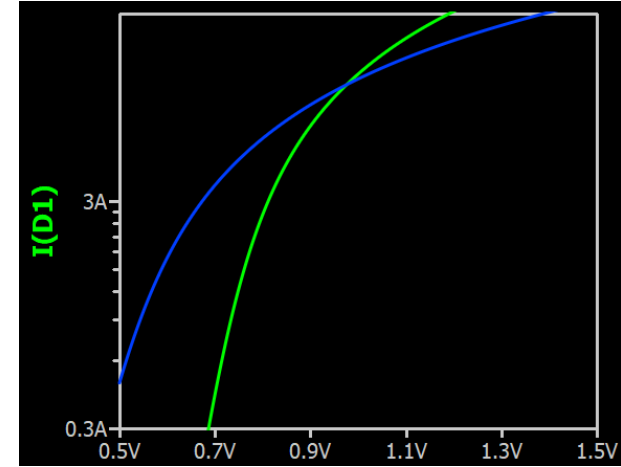
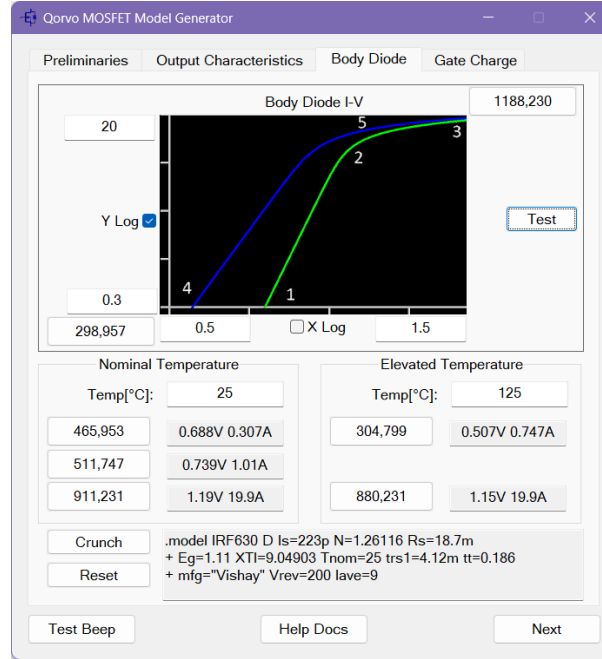
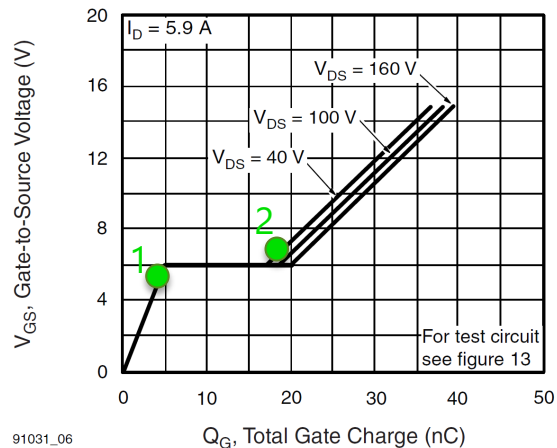


Fig. 7 - Typical Source-Drain Diode Forward Voltage



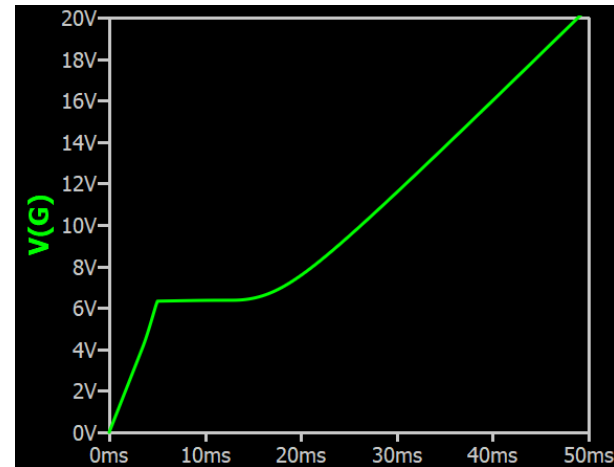
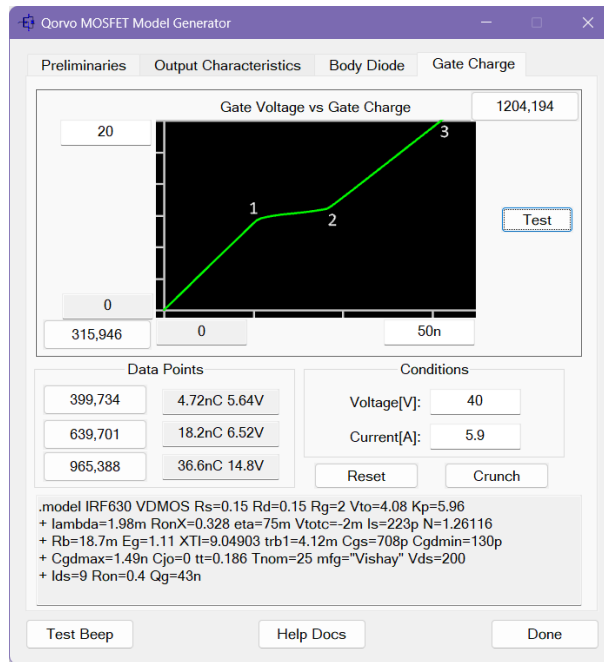
Example – Vishay IRF630 Datasheet to Model Generator



91031_06

Fig. 6 - Typical Gate Charge vs. Gate-to-Source Voltage

According to Mike, Point #1 and #2 are sampled slightly lower and slightly higher than flat region

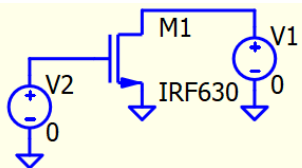


MOSFET Model Generator

Effect of Model Parameters

#1 : Output Characteristic – Rs, Rd

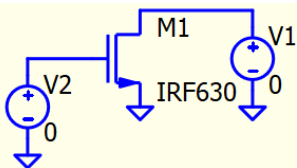
Qspice : Sensitivity Study - Output Characteristic.qsch



Rs

```
.dc V1 0.1 50 1m V2 list 4.5 5  
.model IRF630 VDMOS Rs=0.15*chg Rd=0.15  
+ Vto=4.08 Kp=5.63 Lambda=3.85m  
+ RonX=0.348 eta=75m Vtotc=-2m tt=0.186
```

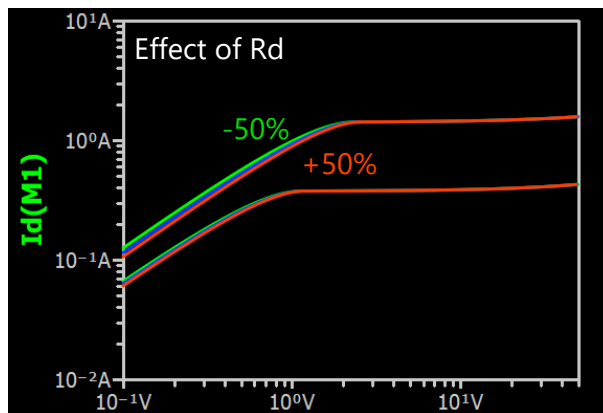
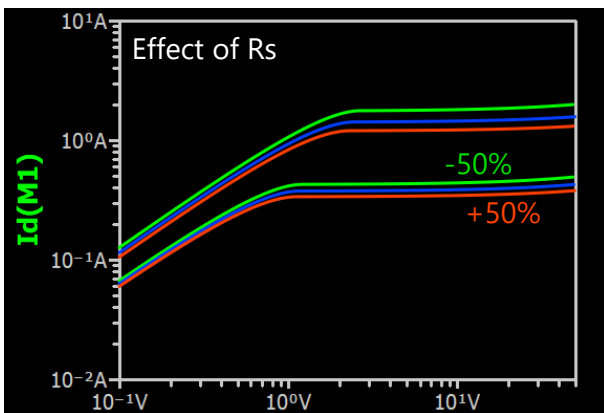
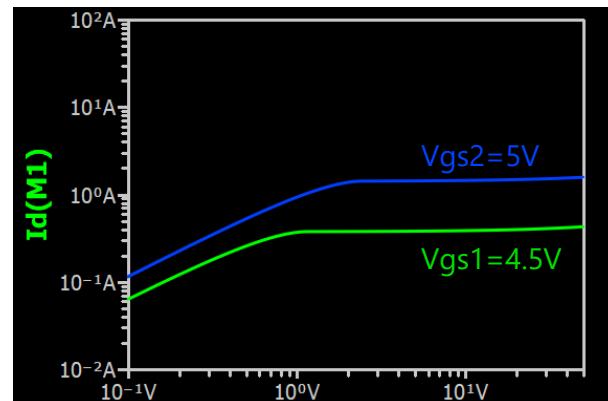
```
;multiple chg (*chg)  
.step param chg list 0.5 1 1.5
```



Rd

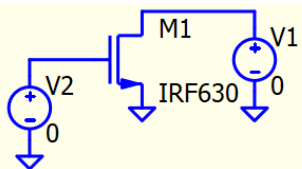
```
.dc V1 0.1 50 1m V2 list 4.5 5  
.model IRF630 VDMOS Rs=0.15 Rd=0.15*chg  
+ Vto=4.08 Kp=5.63 Lambda=3.85m  
+ RonX=0.348 eta=75m Vtotc=-2m tt=0.186
```

```
;multiple chg (*chg)  
.step param chg list 0.5 1 1.5
```



#1 : Output Characteristic – Vto, Kp, Lambda

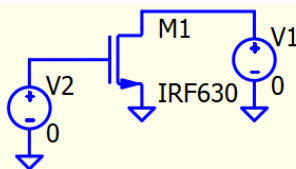
Qspice : Sensitivity Study - Output Characteristic.qsch



Vto

```
.dc V1 0.1 50 1m V2 list 4.5 5  
.model IRF630 VDMOS Rs=0.15 Rd=0.15  
+ Vto=4.08*chg Kp=5.63 Lambda=3.85m  
+ RonX=0.348 eta=75m Vtotc=-2m tt=0.186
```

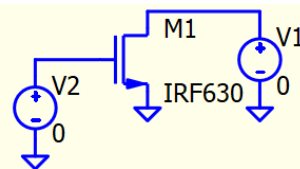
```
;multiple chg (*chg)  
.step param chg list 0.98 1 1.02
```



Kp

```
.dc V1 0.1 50 1m V2 list 4.5 5  
.model IRF630 VDMOS Rs=0.15 Rd=0.15  
+ Vto=4.08 Kp=5.63*chg Lambda=3.85m  
+ RonX=0.348 eta=75m Vtotc=-2m tt=0.186
```

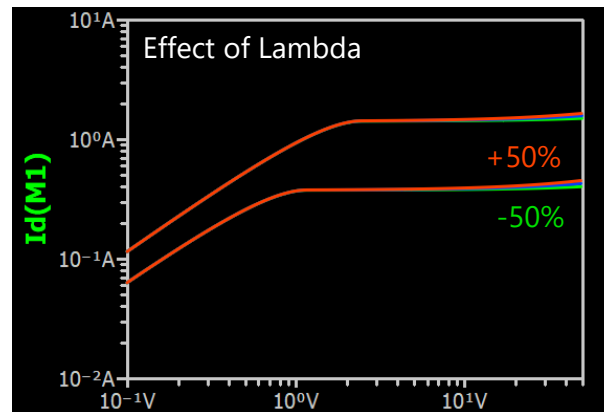
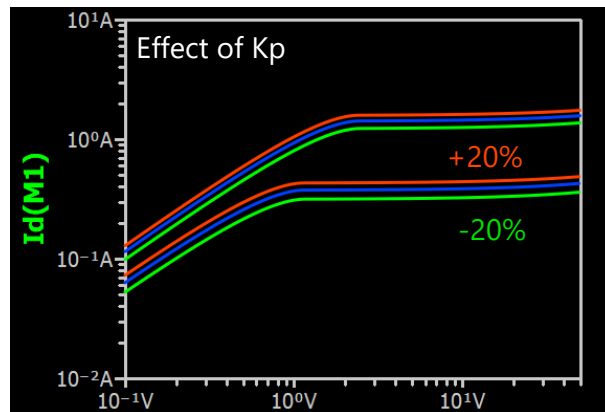
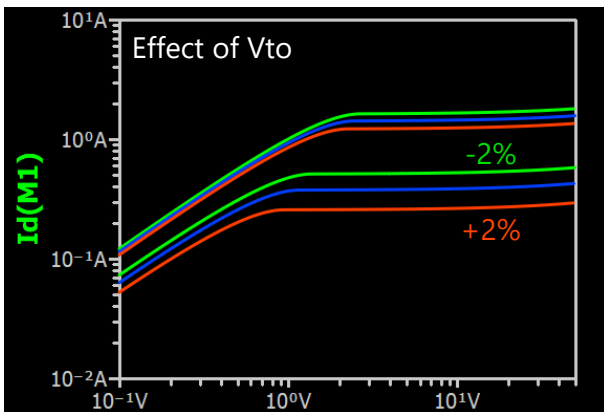
```
;multiple chg (*chg)  
.step param chg list 0.8 1 1.2
```



Lambda

```
.dc V1 0.1 50 1m V2 list 4.5 5  
.model IRF630 VDMOS Rs=0.15 Rd=0.15  
+ Vto=4.08 Kp=5.63 Lambda=3.85m*chg  
+ RonX=0.348 eta=75m Vtotc=-2m tt=0.186
```

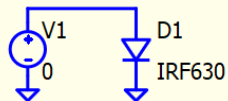
```
;multiple chg (*chg)  
.step param chg list 0.5 1 1.5
```



#2 : Bode Diode – XTI, trs1 (Temperature Effect)

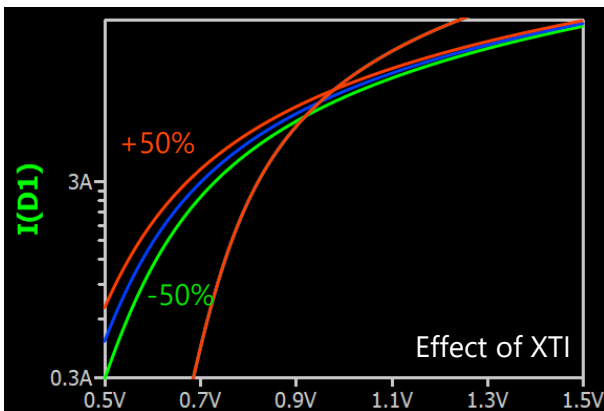
Qspice : Sensitivity Study - Body Diode.qsch

XTI



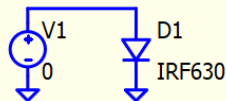
```
.dc V1 0.5 1.5 1m
;temp 25 150
.model IRF630 D Is=785p N=1.33849 Rs=21m Eg=1.11
+ XTI=4.53261*chg Tnom=25 trs1=3.56m tt=0.186
+ mfg="Vishay" Vrev=200 Iave=9

;multiple chg (*chg)
.step param temp list 25 150 param chg list 0.5 1 1.5
```



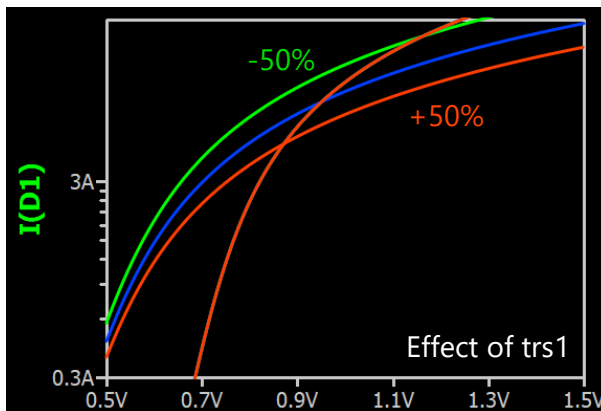
Effect of XTI

trs1

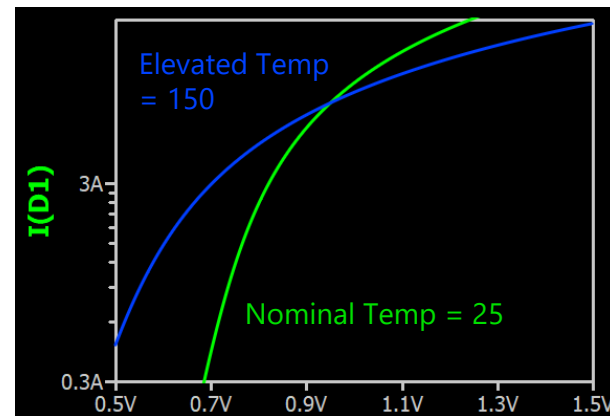


```
.dc V1 0.5 1.5 1m
;temp 25 150
.model IRF630 D Is=785p N=1.33849 Rs=21m Eg=1.11
+ XTI=4.53261 Tnom=25 trs1=3.56m*chg tt=0.186
+ mfg="Vishay" Vrev=200 Iave=9

;multiple chg (*chg)
.step param temp list 25 150 param chg list 0.5 1 1.5
```

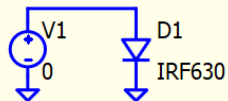


Effect of trs1



#2 : Bode Diode – Is, N, Rs (Rb in MOS)

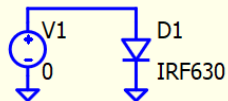
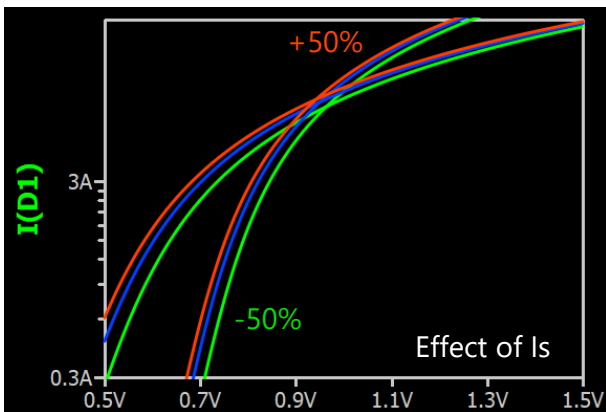
Qspice : Sensitivity Study - Body Diode.qsch



Is

```
.dc V1 0.5 1.5 1m
;temp 25 150
.model IRF630 D Is=785p*chg N=1.33849 Rs=21m Eg=1.11
+ XTI=4.53261 Tnom=25 trs1=3.56m tt=0.186
+ mfg="Vishay" Vrev=200 Iave=9

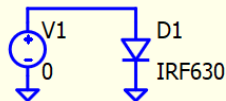
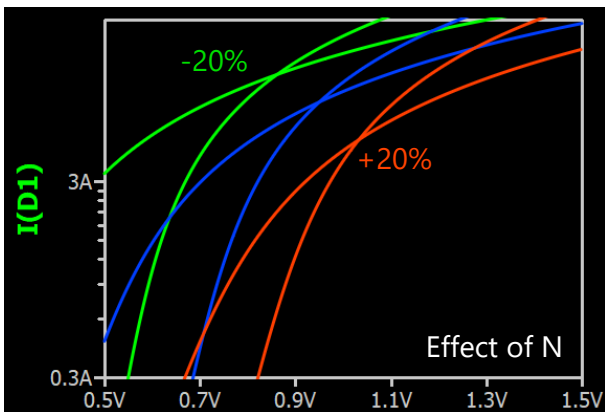
;multiple chg (*chg)
.step param temp list 25 150 param chg list 0.5 1 1.5
```



N

```
.dc V1 0.5 1.5 1m
;temp 25 150
.model IRF630 D Is=785p N=1.33849*chg Rs=21m Eg=1.11
+ XTI=4.53261 Tnom=25 trs1=3.56m tt=0.186
+ mfg="Vishay" Vrev=200 Iave=9

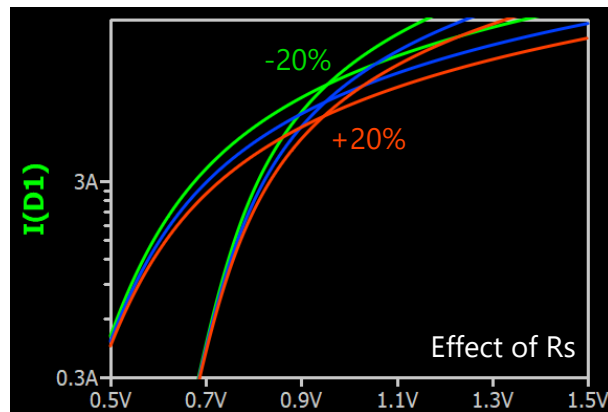
;multiple chg (*chg)
.step param temp list 25 150 param chg list 0.8 1 1.2
```



Rs (Rb in MOS)

```
.dc V1 0.5 1.5 1m
;temp 25 150
.model IRF630 D Is=785p N=1.33849 Rs=21m*chg Eg=1.11
+ XTI=4.53261 Tnom=25 trs1=3.56m tt=0.186
+ mfg="Vishay" Vrev=200 Iave=9

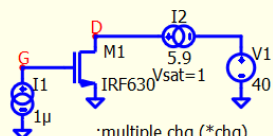
;multiple chg (*chg)
.step param temp list 25 150 param chg list 0.8 1 1.2
```



#3 : Gate Charge – Cgs, Cgdmin, Cgdmax

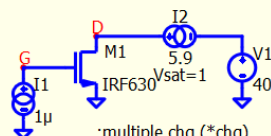
Qspice : Sensitivity Study - Gate Charge.qsch

Ggs



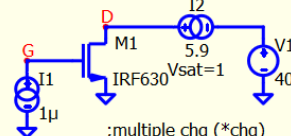
```
.tran 0.05
.ic V(G)=0
.model IRF630 VDMOS Rs=0.15 Rd=0.15 Rg=2 Vto=4.08 Kp=5.63
+ lambda=3.85m RonX=0.348 eta=75m Vt0tc=-2m Is=785p N=1.33849
+ Rb=21m Eg=1.11 XTI=4.53261 trb1=3.56m Cgs=668p*chg Cgdmin=133p
+ Cgdmax=1.57n Cjo=0 tt=0.186 Tnom=25 mfg="Vishay" Vds=200
+ Ids=9 Ron=0.4 Qg=43n
```

Ggdmin

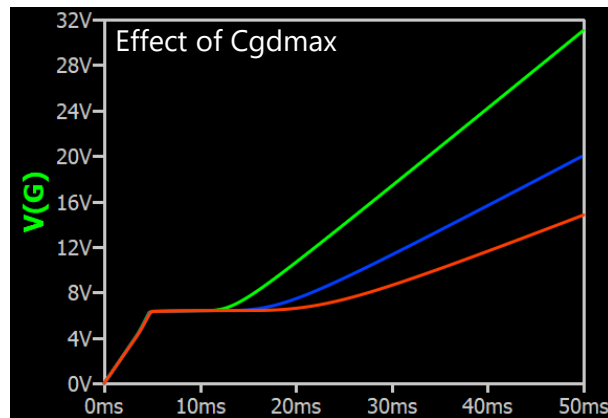
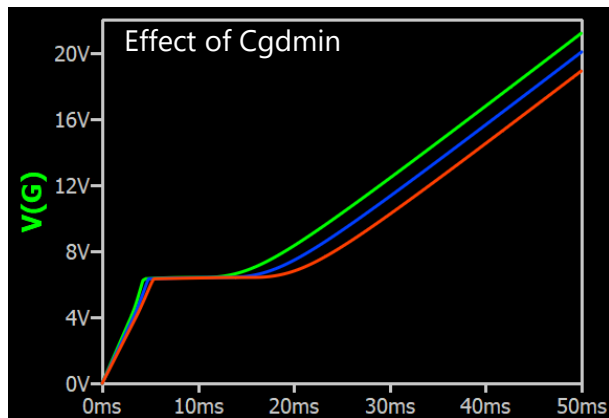
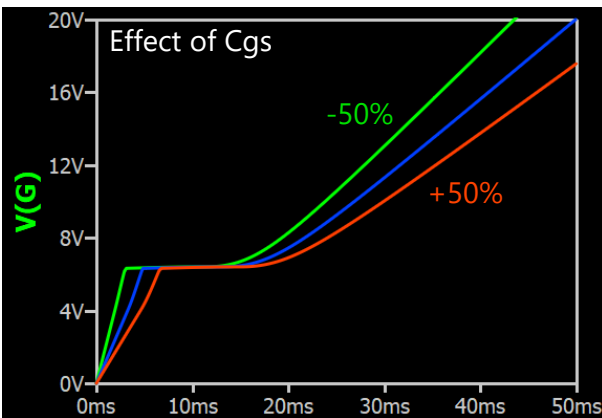


```
.tran 0.05
.ic V(G)=0
.model IRF630 VDMOS Rs=0.15 Rd=0.15 Rg=2 Vto=4.08 Kp=5.63
+ lambda=3.85m RonX=0.348 eta=75m Vt0tc=-2m Is=785p N=1.33849
+ Rb=21m Eg=1.11 XTI=4.53261 trb1=3.56m Cgs=668p Cgdmin=133p*chg
+ Cgdmax=1.57n Cjo=0 tt=0.186 Tnom=25 mfg="Vishay" Vds=200
+ Ids=9 Ron=0.4 Qg=43n
```

Ggdmax

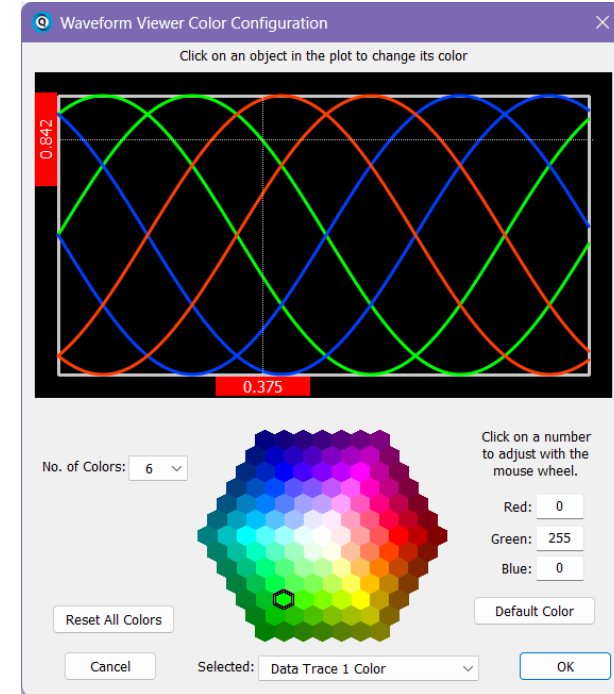


```
.tran 0.05
.ic V(G)=0
.model IRF630 VDMOS Rs=0.15 Rd=0.15 Rg=2 Vto=4.08 Kp=5.63
+ lambda=3.85m RonX=0.348 eta=75m Vt0tc=-2m Is=785p N=1.33849
+ Rb=21m Eg=1.11 XTI=4.53261 trb1=3.56m Cgs=668p Cgdmin=133p
+ Cgdmax=1.57n*chg Cjo=0 tt=0.186 Tnom=25 mfg="Vishay" Vds=200
+ Ids=9 Ron=0.4 Qg=43n
```



Waveform Viewer Color Configuration for Sensitivity Study

- In sensitivity study, as triple sweep is used in Output Characteristic and Body Diode, color trace in waveform viewer is setup as
 - Data Trace 1 Color : [0,255,0]
 - Data Trace 2 Color : [0,255,0]
 - Data Trace 3 Color : [0,63,255]
 - Data Trace 4 Color : [0,63,255]
 - Data Trace 5 Color : [255,63,0]
 - Data Trace 6 Color : [255,63,0]



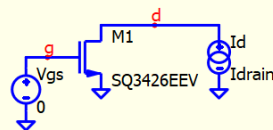
MOSFET Model Generator

Example – Recreate
from a model

Determine $R_{ds(on)}$, V_{gs} , I_{drain} @ $R_{ds(on)}$ and $R_{ext} \div (R_{ext} + R_{channel})$

Qspice : Preliminaries ($R_{ds(on)}$ V_{gs} I_{drain} and R_{ext}).qsch

- $R_{ext} : R_d + R_s$
 - $R_{ds(on)}$ is basically consist of R_{ext} (external resistance : R_d , R_s) and $R_{channel}$ (channel resistance)
- To estimate R_{ext} , fully turn ON a FET model with extreme gate-source voltage, which minimized $R_{channel}$ and $R_{ds(on)}$ is dominated by R_{ext}
- In this example, $R_s + R_d = R_{ext} = 39.8m\Omega$. And by extreme gate-source, $R_{ext} = 40.6m\Omega$



```
; force Rext >> Rchannel with extreme Vgs
; therefore, Rext = Rd + Rs
.param Idrain=1

.dc Vgs 5 50 .1 ; sweep to unrealistically high for Rext
.func Rds() V(d)/I(Id)
.plot Rds()

.meas Rds_on max Rds()
.meas Ids@Rds_on min I(Id)
.meas Vgs@Rds_on min V(g)
.meas Rext min Rds()
.meas Req Rext/(Rds_on-Rext)
```

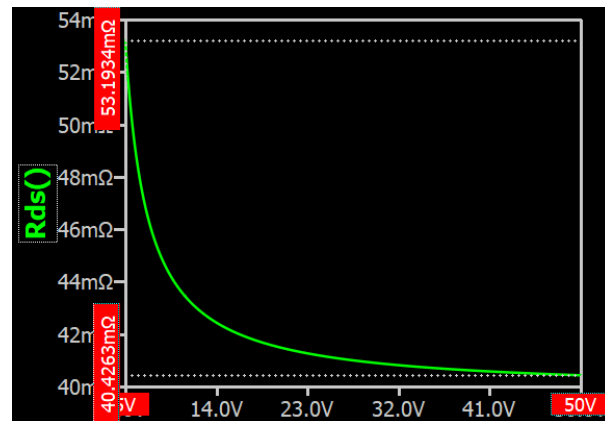
MOSFET Selection Guide

Gate Voltage:

P/N	Manufacturer	Vds[V]	Ids[A]	Rds(on)[mΩ]	Qg[nC]
BSC123N08NS3	Infineon	80	55	12.3	19.0
EPC2218	EPC	100	60	2.4	10.5
GS66508B	GaN Systems	650	30	50.0	6.1
GS66516T	GaN Systems	650	60	25.0	14.2
AO4262E	Alpha & Omega	60	16	6.6	15.0
DM2600S	ARK Microelectronics Co.	600	0	700000.0	1.6
FTA07N60	ARK Microelectronics Co.	600	7	900.0	38.6
SQ3426EEV	Vishay	60	7	57.0	7.6
UF3C065030	Qorvo	650	65	27.0	51.0

.model SQ3426EEV VDMOS Rs=19.9m Rd=19.9m Rg=2.4 Vto=2.76 Kp=14.7
+ lambda=0.123 RonX=2.3 eta=1.5 Rb=1.2362 Rb=1.4m
+ Eg=1.11 XTJ=2.60857 tbt1=1.64m Cgs=700p Cgdm=40p Cjo=200p
+ Cgdmax=700p mfg=Vishay Vds=60 Ids=7 Ron=57m Qg=7.6n

More Info Cancel OK

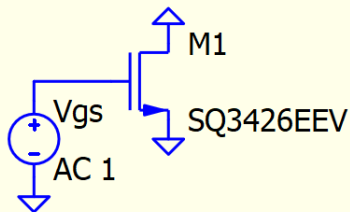


- Now put,
 - $R_{ds(on)} = 53.2m\Omega$
 - $V_{gs} @ R_{ds(on)} = 5V$
 - $I_{drain} @ R_{ds(on)} = 1A$
 - $R_{ext} = R_s + R_d = 40.6m\Omega$
 - $R_{channel} @ R_{ds(on)}$
 $= R_{ds(on)} - R_{ext}$
 $= 53.2m\Omega - 40.6m\Omega$
 $= 12.6m\Omega$
 - $R_{ext} \div (R_{ext} + R_{channel})$
 $= 40.6\Omega / (40.6\Omega + 12.6\Omega)$
 $= 0.763\Omega$

Determine R_g from a MOSFET Model

Qspice : Preliminaries - R_g .qsch

- R_g
 - R_g is series resistance in gate
 - R_g can be identified with ac analysis and only read the real part with Cartesian representation
 - Now, put
 - R_g = value of $Z_r()$



```
.ac list 1Meg  
.func Zr() re(1/-I(Vgs))  
.plot Zr()  
.meas Rg param Zr()
```

