

# **Qspice - General Reference Guide by KSKelvin**

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# QSPICE

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- QSPICE
  - Author : Mike Engelhardt
  - Download : <https://www.qorvo.com/design-hub/design-tools/interactive/qspice>
- Topic Included in this guideline
  - Shortcut Key
  - Hierarchical and Sub-circuit
  - Waveform Viewer
  - Symbol Viewer
  - Simulation Technique



## **Part 1**

### **Shortcut Key**

# Schematic Editor Keyboard Shortcuts

## HELP > Schematic Capture > Schematic Editor > Keyboard Shortcuts

| Key            | Command                   |
|----------------|---------------------------|
| Spacebar       | Zoom to fit               |
| B <sup>1</sup> | Behavioral source         |
| C <sup>1</sup> | Capacitor                 |
| D <sup>1</sup> | Diode                     |
| E <sup>1</sup> | E-source                  |
| F              | F-source                  |
| G <sup>2</sup> | Ground, G-source          |
| H              | H-source                  |
| I              | Current Source            |
| J <sup>1</sup> | JFET                      |
| L <sup>1</sup> | Inductor                  |
| M <sup>1</sup> | MOSFET                    |
| Q <sup>1</sup> | Bipolar Transistor        |
| R <sup>1</sup> | Resistor                  |
| S <sup>1</sup> | Voltage Controlled Switch |
| T <sup>3</sup> | Place Text                |
| V <sup>1</sup> | Voltage Source            |
| W              | Start a wire              |
| Y              | Piezoelectric Crystal     |
| Z <sup>1</sup> | MESFET                    |

|            |  |
|------------|--|
| Ctrl-A     | Draw an arc(graphical annotation)                    |
| Ctrl-B     | Draw a box(graphical annotation)                     |
| Ctrl-C     | Copy selected object(s) to clipboard                 |
| Ctrl-F     | Find   |
| Ctrl-G     | Toggle display of grid dots                          |
| Ctrl-L     | Draw a line(graphical annotation)                    |
| Ctrl-M     | Mirror selected object(s)                            |
| Ctrl-R     | Rotate selected object(s)                            |
| Alt-Ctrl-R | Rotate in 45° increments                             |
| Ctrl-V     | Paste  |
| Ctrl-X     | Cut  |
| Ctrl-Y     | Redo   |
| Ctrl-Z     | Undo   |
| Ctrl-3     | Draw a triangle(graphical annotation)                |
| ;          | Toggle a text graphic's comment status               |
| F2         | Toggle visibility of the Symbol and IP Browser pane. |
| F3         | Toggle visibility of the Symbol Properties pane.     |
| F4         | Toggle visibility of the output console.             |
| F5         | Run the simulation.                                  |

[1] Repeated depressions of the key cycles through different versions of the symbol.

[2] Repeated depressions of 'G' cycles through different versions of the ground symbol and then G-source symbols.

[3] The period key, '.', is accepted as a synonym for 'T'.

# Symbol Editor and Waveform Viewer Keyboard Shortcuts

HELP > Waveform Viewer > Keyboard Shortcuts / HELP > Schematic Capture > Symbol Editor > Keyboard Shortcuts

## Waveform Viewer Keyboard Shortcuts

| Key    | Command  |
|--------|--|
| Delete | Delete attached cursor if pointing to a readout or delete selected plot labels |
| F      | Zoom to fit(all panes)   |
| F4     | Toggle visibility of the console display                                       |
| F5     | Rerun the simulation   |
| ←      | Reload Plot configuration file   |
| ←      | Move attached cursor left  |
| →      | Move attached cursor right   |
| ↑      | Move attached cursor to next step  |
| ↓      | Move attached cursor to previous step  |
| Ctrl-A | Add a trace  |
| Ctrl-C | Copy   |
| Ctrl-D | Delete a plotting pane   |
| Ctrl-F | Find   |
| Ctrl-G | Turn Grid On/Off   |
| Ctrl-V | Paste  |
| Ctrl-P | Print  |
| Ctrl-W | Add a plotting pane  |
| Ctrl-X | Cut  |
| Ctrl-Y | Redo   |
| Ctrl-Z | Undo   |

## Symbol Editor Keyboard Shortcuts

| Key          | Command                                   |
|--------------|---|
| Ctrl-A       | Draw an arc defined by three points       |
| Shift-Ctrl-A | Draw an arc defined by four points        |
| Ctrl-B       | Draw a box(or a box for an image)         |
| Ctrl-C       | Copy selection(s) to clipboard            |
| E            | Draw an Ellipse                           |
| Ctrl-F       | Find                                      |
| Ctrl-L       | Draw a line                               |
| Ctrl-M       | Mirror selected objects                   |
| P            | Place a pin                               |
| Ctrl-R       | Rotate selected objects                   |
| T            | Place a text attribute                    |
| Ctrl-V       | Paste                                     |
| Ctrl-X       | Cut                                       |
| Ctrl-Y       | Redo                                      |
| Ctrl-Z       | Undo                                      |
| Ctrl-3       | Draw a triangle                           |
| F3           | Toggle visibility of the Properties pane. |

\*\* Hold down ALT key (after simulation is ran and with an active waveform viewer)

Click on a node for voltage or device for current – Can prevent accidentally move wire or device

Click on a node and drag to another node – Can measure differentiate voltage, i.e. V(N001,N002)

\*\* Hold down SHIFT key to probe current – invert the sign of a current quantity

# Waveform Viewer Functions and Keywords (.func , .meas)

## HELP > Waveform Viewer > Waveform Expressions

The following functions, constants, and keywords are recognized in expressions of waveform data.

### Waveform Viewer Functions and Keywords

| Syntax                  | Description                        |
|-------------------------|------------------------------------|
| ABS(x)                  | Absolute value of x                |
| ACOS(x)                 | Inverse cosine of x                |
| ACOSH(x)                | Inverse hyperbolic cosine of x     |
| ARCCOS(x)               | Inverse cosine of x                |
| ARCCOSH(x)              | Inverse hyperbolic cosine of x     |
| ARCSIN(x)               | Inverse sine of x                  |
| ARCSINH(x)              | Inverse hyperbolic sine of x       |
| ARCTAN(x)               | Inverse tangent of x               |
| ARCTANH(x)              | Inverse hyperbolic tangent of x    |
| ASIN(x)                 | Inverse sine of x                  |
| ASINH(x)                | Inverse hyperbolic sine of x       |
| ATAN(x)                 | Inverse tangent of x               |
| ATAN2(x,y) <sup>1</sup> | Four quadrant inverse tangent of x |
| ATANH(x)                | Inverse hyperbolic tangent of x    |
| BUF(x)                  | $x > .5 ? 1 : 0$                   |
| CBRT(x)                 | Cube root of x                     |
| CEIL(x)                 | x rounded up to nearest integer    |
| COS(x)                  | $\cos x$                           |
| COSH(x)                 | Hyperbolic cosine of x             |
| COT(x)                  | Cotangent of x                     |
| D(x)                    | Derivative of x                    |
| DD(x)                   | Second derivative of x             |
| D <sup>2</sup> (x)      | Second derivative of x             |
| E                       | 2.7182818284590452354              |
| ERF(x)                  | Error function of x                |
| ERFC(x)                 | Complementary error function of x  |
| EXP(x)                  | $e^x$                              |
| EXP10(x)                | $10^x$                             |
| FABS(x)                 | Absolute value of x                |
| FLOOR(x)                | x rounded down to nearest integer  |

← simulation variable (reserve word)

← important constant (reserve word)

|              |  |
|--------------|--|
| FREQ         | Frequency  |
| FREQUENCY    | Frequency  |
| GAMMA(x)     | Gamma function of x  |
| HYPOT(x,y)   | $\sqrt{x^2 + y^2}$   |
| IF(x,y,z)    | $(x > .5) ? y : z$   |
| ILOGB(x)     | Unbiased exponent of x                                       |
| IM(x)        | Imaginary part of x  |
| IMAG(x)      | Imaginary part of x  |
| INT(x)       | x rounded to nearest integer                                 |
| INV(x)       | $x > .5 ? 0 : 1$   |
| INVSQRT(x)   | $1/\sqrt{x}$   |
| ISNAN(x)     | One if x is not a number, otherwise zero                     |
| J            | $\sqrt{-1}$  |
| J0(x)        | Zero order Bessel function of the first kind at x            |
| J1(x)        | First order Bessel function of the first kind at x           |
| JN(x,n)      | N <sup>th</sup> order Bessel function of the first kind at x |
| K            | 1.380649e-23 J/K   |
| LGAMMA(x)    | Log-gamma function of x                                      |
| LIMIT(x,y,z) | Mutually intermediate value of x,y, and z                    |
| LN(x)        | Natural logarithm of x                                       |
| LOG(x)       | Natural logarithm of x                                       |
| LOG10(x)     | Logarithm of x in base 10                                    |
| LOG1P(x)     | Natural logarithm of (x + 1)                                 |
| LOG2(x)      | Logarithm of x in base 2                                     |
| LOGB(x)      | LOG2(ABS(x))   |
| MAG(x)       | Absolute value of x  |
| MAX(x,y)     | Maximum of x and y   |
| MAXMAG(x,y)  | x or y with maximum magnitude                                |
| NAN          | A value guaranteed to be not a number                        |
| MIN(x,y)     | Minimum of x and y   |
| MINMAG(x,y)  | x or y with minimum magnitude                                |

|                    |   |  |
|--------------------|---|--|
| PH(x)              | $\angle x$  | Phase of x                                 |
| PHASE(x)           | $\angle x$  | Phase of x                                 |
| PI                 | 3.14159265358979323846  |  |
| POW(x,y)           | $x^y$   | x raised to the y power                    |
| PWR(x,y)           | $ x ^y$   | x raised to the nearest integer value of y |
| PWRS(x,y)          | $x >= 0 ? x^y : -x^y$   | Absolute value of x raised to the y power  |
| Q                  | 1.602176487e-19 Coulomb                                       |  |
| RE(x)              | re(x)   | Real part of x                             |
| REAL(x)            | Real part of x  | Real part of x                             |
| RINT(x)            | x rounded to the nearest integer                              | x rounded to the nearest integer           |
| ROUND(x)           | x rounded to the nearest integer                              | x rounded to the nearest integer           |
| SGN(x)             | Sign of x   | Sign of x                                  |
| SIGN(x)            | Sign of x   | Sign of x                                  |
| SIN(x)             | Sine of x   | Sine of x                                  |
| SINH(x)            | Hyperbolic sine of x  | Hyperbolic sine of x                       |
| SQRT(x)            | $\sqrt{x}$  | Square root of x                           |
| TABLE(x,x1,y1,...) | Interpolate the table given as x1,y1, x2,y2,... at point x    |  |
| TAN(x)             | $\tan x$  | Tangent of x                               |
| TANH(x)            | Hyperbolic tangent of x                                       |  |
| TAUGRP(x)          | Group delay of x  |  |
| TBL(x,x1,y1,...)   | Interpolate the table given as x1,y1, x2,y2,... at point x    |  |
| TEMP               | TEMP  | Circuit temperature                        |
| TG(x)              | Group delay of x  |  |
| TIME               | TIME  | Time                                       |
| TRUNC(x)           | Integer part of s   |  |
| URAMP(x)           | $x > 0 ? x : 0$   |  |
| USTEP(x)           | $x > 0 ? 1 : 0$   |  |
| Y0(x)              | Zero order Bessel function of the second kind at x            |  |
| Y1(x)              | First order Bessel function of the second kind at x           |  |
| YN(x)              | N <sup>th</sup> order Bessel function of the second kind at x |  |

<sup>1]</sup> For complex data, the syntax is ATAN2(z). The meaning is ATAN2(IMAG(z),REAL(z)).

# Function and Operators for Behavioral V and I Sources

## HELP > Simulator > Device Reference > B. Behavioral Sources

### Functions

| Name                      | Description  |
|---------------------------|--|
| abs(x)                    | Absolute value of x  |
| acos(x)                   | arc cosine of x  |
| arccos(x)                 | Synonym for acos()   |
| acosh(x)                  | arc hyperbolic cosine of x   |
| asin(x)                   | arc sine of x  |
| arcsin(x)                 | Synonym for asin()   |
| asinh(x)                  | Arc hyperbolic sine  |
| atan(x)                   | Arc tangent of x   |
| arctan(x)                 | Synonym for atan()   |
| atan2(y,x)                | Four quadrant arc tangent of y/x   |
| atanh(x)                  | Arc hyperbolic tangent   |
| buf(x)                    | 1 if $x > .5$ , else 0   |
| ceil(x)                   | Integer equal or greater than x  |
| cos(x)                    | Cosine of x  |
| cosh(x)                   | Hyperbolic cosine of x   |
| ddt(x)                    | Time derivative x  |
| delay(x,y)                | x delayed by y   |
| delay(x,y,z) <sup>1</sup> | x delayed by y, but store no more than z history   |
| dlim(x,y,z)               | x bounded by y which it asymptotically starts to approach at y+z as a first inverse order Laurent series |
| exp(x)                    | $e^x$ e to the x   |
| floor(x)                  | Integer equal to or less than x  |
| hypot(x,y)                | $\sqrt{x^2 + y^2}$ sqrt( $x^2 + y^2$ )   |
| idt(x,y,z)                | Time integral of x with initial condition of y reset when $z > .5$                                       |
| $\int x \, dtimes + y$    |  |

|                      |   |
|----------------------|---|
| if(x,y,z)            | If $x > .5$ , then y else z   |
| int(x)               | Convert x to integer  |
| inv(x)               | 0. if $x > .5$ , else 1.  |
| limit(x,y,z)         | Intermediate value of x, y, and z   |
| ln(x)                | Natural logarithm of x  |
| log(x)               | Alternate syntax for ln()   |
| log10(x)             | Base 10 logarithm   |
| max(x,y)             | The greater of x or y   |
| min(x,y)             | The smaller of x or y   |
| pow(x,y)             | $x^y$   |
| pwr(x,y)             | $ x ^y$   |
| pwrs(x,y)            | $abs(x)^y$<br>$sgn(x)*abs(x)^y$   |
| random(x)            | Random number from 0. to 1. depending on the integer value of x.<br>Interpolation between random numbers is linear for non-integer x. |
| sin(x)               | Sin x   |
| sinh(x)              | Hyperbolic sine of x  |
| sqrt(x)              | $\sqrt{x}$  |
| table(x,a,b,c,d,...) | Interpolate x from the look-up table given as a set of pairs of constant values.  |
| tan(x)               | Tangent of x.   |
| tanh(x)              | Hyperbolic tangent of x   |
| ulim(x,y,z)          | x bounded by y which it asymptotically starts to approach at y-z as a first inverse order Laurent series                              |

### Operators grouped in reverse order of precedence of evaluation

| Operand | Description  |
|---------|--|
| &       | Boolean AND  |
|         | Boolean OR   |
| >       | True if expression on the left is greater than the expression on the right.          |
| <       | True if expression on the left is less than the expression on the right.             |
| >=      | True if expression on the left is greater than or equal the expression on the right. |
| <=      | True if expression on the left is less than or equal the expression on the right.    |
| +       | Addition   |
| -       | Subtraction  |
| *       | Multiplication   |
| /       | Division   |
| **      | ** / ^ Raise left hand side to power of right hand side. Same as '^'.                |
| !       | Boolean not the following expression.  |

### Available Function in B source not listed

- Trunc(x) ; floor(x) ; int(x) : rounded down integer
- Rint(x) ; round(x) : rounded to nearest integer
- Ceil(x) : rounded up integer
- Ustep(x) :  $x > 0 ? 1 : 0$
- Uramp(x) :  $x > 0 ? x : 0$

# Ctrl-Shift-V : Paste Netlist as Graphical Symbols on Schematic

## Ctrl-Shift-V : Paste Without Increment Node Names

### Netlist (Ctrl-C to Copy)

```
* C:\QspiceKSKelvin\01.t  
V1 N01 0 1  
R1 N01 N02 1K  
R2 N02 0 1K  
C1 N02 0 1μ  
.end
```

### Paste with Ctrl-Shift-V



#### Revision History

01/13/2024 You can now paste fragments of a netlist copied to the clipboard as graphical symbols on a schematic by typing shift-control-V.

### Paste with Ctrl-V

```
V1 N01 0 1  
R1 N01 N02 1K  
R2 N02 0 1K  
C1 N02 0 1μ
```

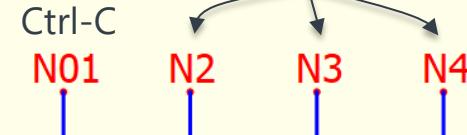
- Increment node name
  - Shift+Ctrl+V pastes without increment node names.

#### Ctrl-Shift-V



Without Increment with Ctrl-Shift-V

#### Ctrl-V

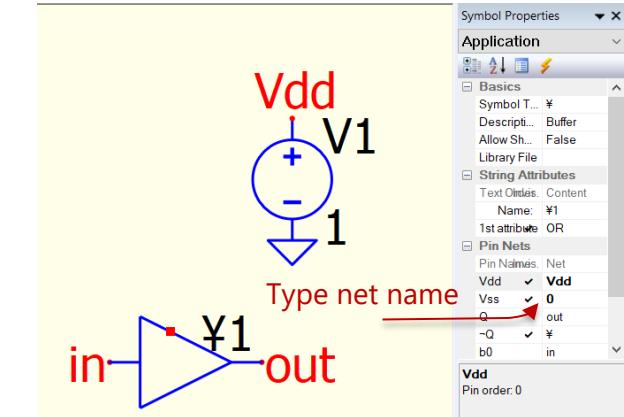
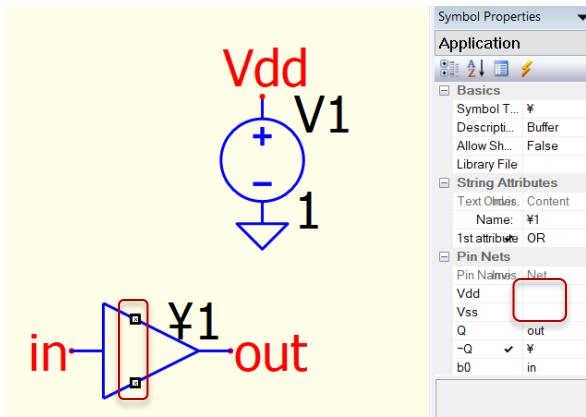


Increment with Ctrl-V

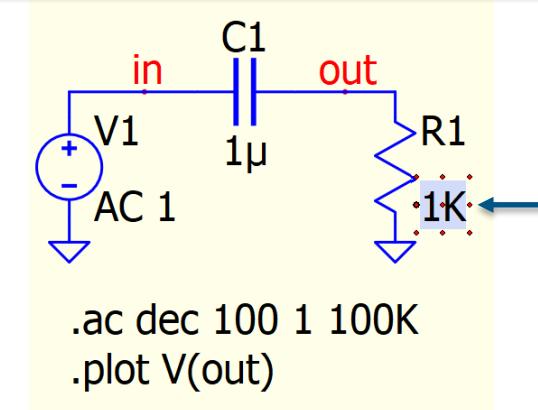
# Hide Symbol Pins

## ALT-Mousewheel – Delimited numbers

- Hide Symbol Pins
  - If you directly type a net name into the Net field, the corresponding pin in the symbol will be set to invisible and connected to that net name
  - This allows users to simplify the outlook of the schematic



- ALT-Mousewheel
  - Delimited numbers in schematic or netlist
  - Highlight number by selecting its (double click in schematic), key pressing ALT and rotate mousewheel

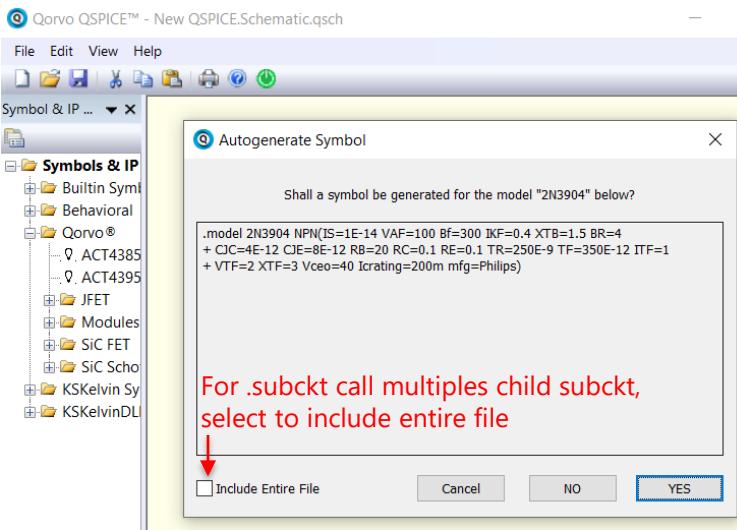


# Quick Way to Create a Symbol (example from .model) Symbol (.qsym) to share for other projects

**Step 1 :** Assume you have a .model statement, which can copy and paste into Qspice and create a symbol in schematic, for example  
.model 2N3904 NPN(IS=1E-14 VAF=100 Bf=300 IKF=0.4 XTB=1.5 BR=4 CJC=4E-12 CJE=8E-12 RB=20 RC=0.1 RE=0.1 TR=250E-9 TF=350E-12 ITF=1 VTF=2 XTF=3 Vceo=40 Icrating=200m mfg=Philips)

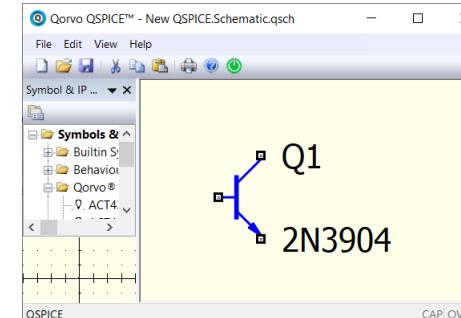
## Step 2

- Copy entire .model text statement (or .subckt)
- In **Schematic Window**  
Ctrl-V to paste, Select Yes in Autogenerate Symbol



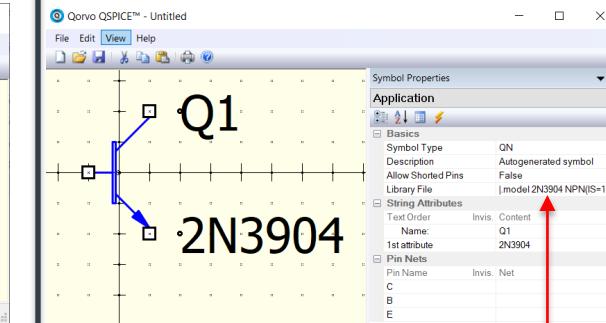
## Step 3

- A symbol is created
- Select this symbol, Copy-C to copy
- In menu, File -> New Symbol



## Step 4

- In **Symbol window**, Ctrl-V to paste
- In menu, File > Save  
Save into a .qsym (symbol file)

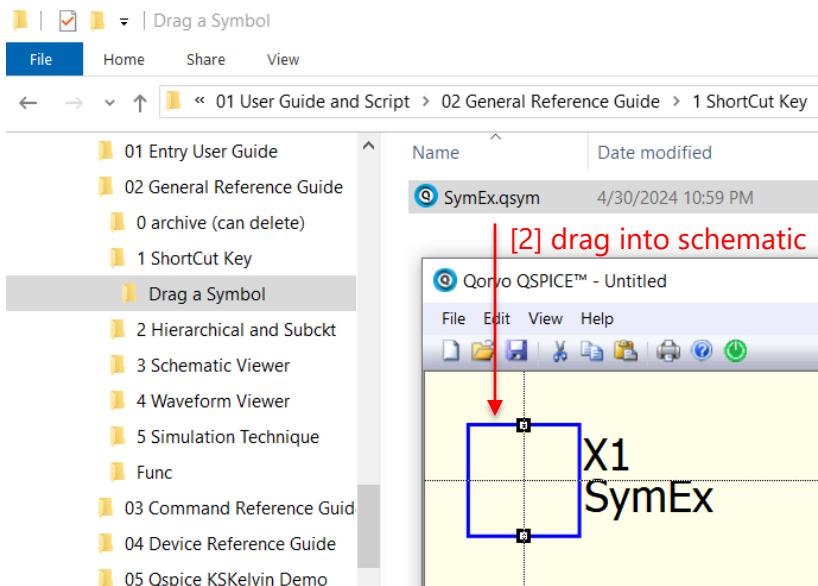


With this method, Qspice can embed .model or .subckt into symbol file, therefore, only share symbol file have all necessary detail to run simulation

# Drag a Symbol into Schematic (Two Methods)

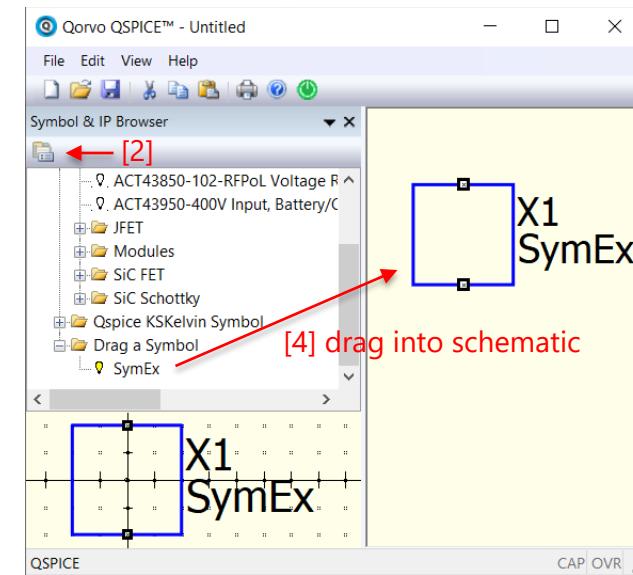
## Method 1 : Drag from File Explorer

- [1] Open the symbol folder using File Explorer
- [2] Drag the symbol files (.qsym) into the schematic



## Method 2 : Drag from Symbol & IP Browser

- [1] Go to View > Symbol & IP Browser [or use the shortcut F2].
- [2] Select the folder containing the symbol files (.qsym).
- [3] If a folder with .qsym files is selected, a new tree path will be displayed.
- [4] Drag the symbol from the Symbol & IP Browser into the schematic.



## **Part 2**

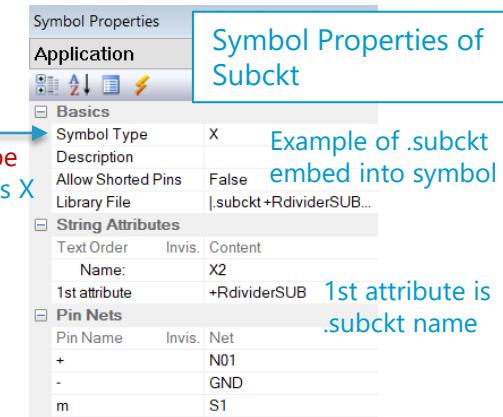
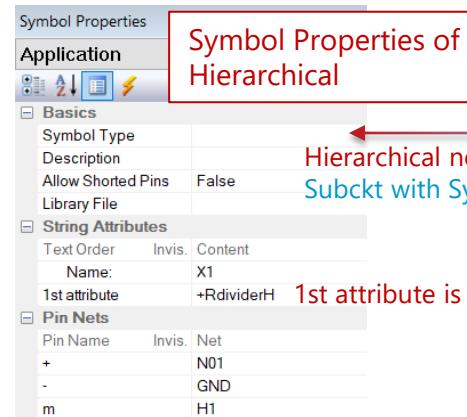
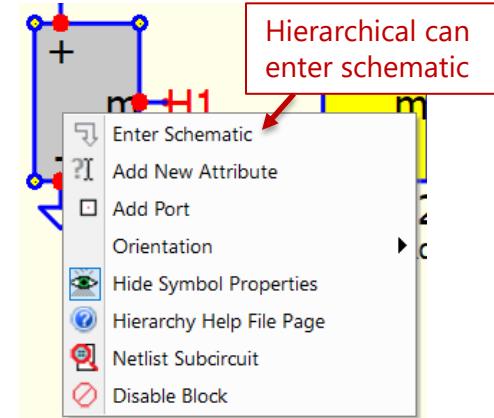
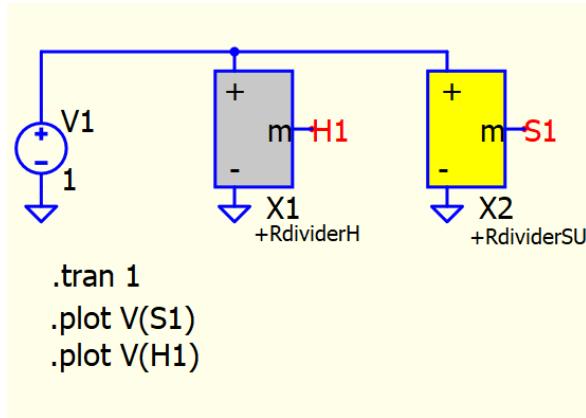
### **Hierarchical and Sub-circuit**

# Hierarchical and Sub-circuit : Comparison

Qspice : parent - hierarchical and subckt.qsch | +RdividerH.qsch

- Hierarchical and Sub-circuit

- They are similar and both support by .qsym symbol, but two different concepts
- Hierarchical
  - Call a child schematic (.qsch) for simulation
  - Waveform viewer can probe simulation result in child schematic directly
- Sub-circuit (.subckt)
  - Call a sub-circuit (.subckt netlist) for simulation
  - Waveform viewer cannot probe simulation result directly
    - Results are stored, just offer to add trace indirectly
  - In Qspice, .subckt netlist can embed into a symbol in the field of library file (i.e. no need to share library file)

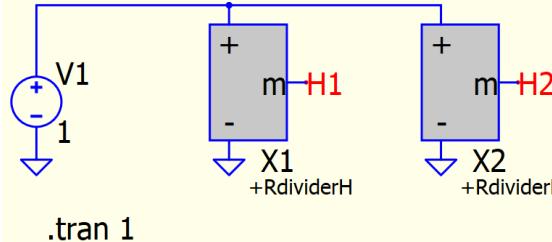


# Hierarchical and Sub-circuit : Comparison

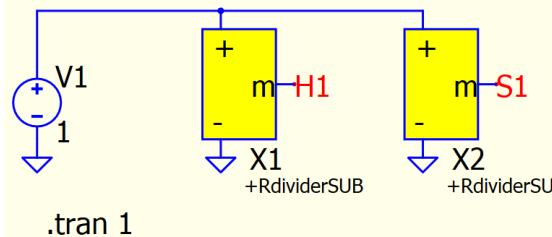
Qspice : parent - hierarchical and subckt (dual hierarchical/subckt).qsch

- Hierarchical and Sub-circuit
  - In netlist, both Hierarchical and Sub-circuit call .subckt syntax
  - Hierarchical
    - Child schematic is a .subckt in Parent netlist
    - Symbol calls this child schematic name
  - Sub-circuit (.subckt)
    - Each symbol calls an individual .subckt by naming its by adding prefix as Xnnn•<subckt name>

Hierarchical Block



Sub-Circuit (.subckt)



```
* C:\QspiceKSKelvin\01 User Guide and Script\02  
V1 N01 0 1  
X1 N01 0 H1 +RdividerH  
X2 N01 0 H2 +RdividerH  
.subckt +RdividerH + - m  
R1 + m 1K  
R2 m - 1K  
.ends +RdividerH  
.tran 1  
.end
```

.subckt for X1 and X2  
<child schematic name>

```
* C:\QspiceKSKelvin\01 User Guide and Script\02  
V1 N01 0 1  
.subckt X1+RdividerSUB + - m  
R1 + m 1K  
R2 m - 1K  
.ends +Rdivider  
X1 N01 0 H1 X1+RdividerSUB  
.subckt X2+RdividerSUB + - m  
R1 + m 1K  
R2 m - 1K  
.ends +Rdivider  
X2 N01 0 S1 X2+RdividerSUB  
.tran 1  
.end
```

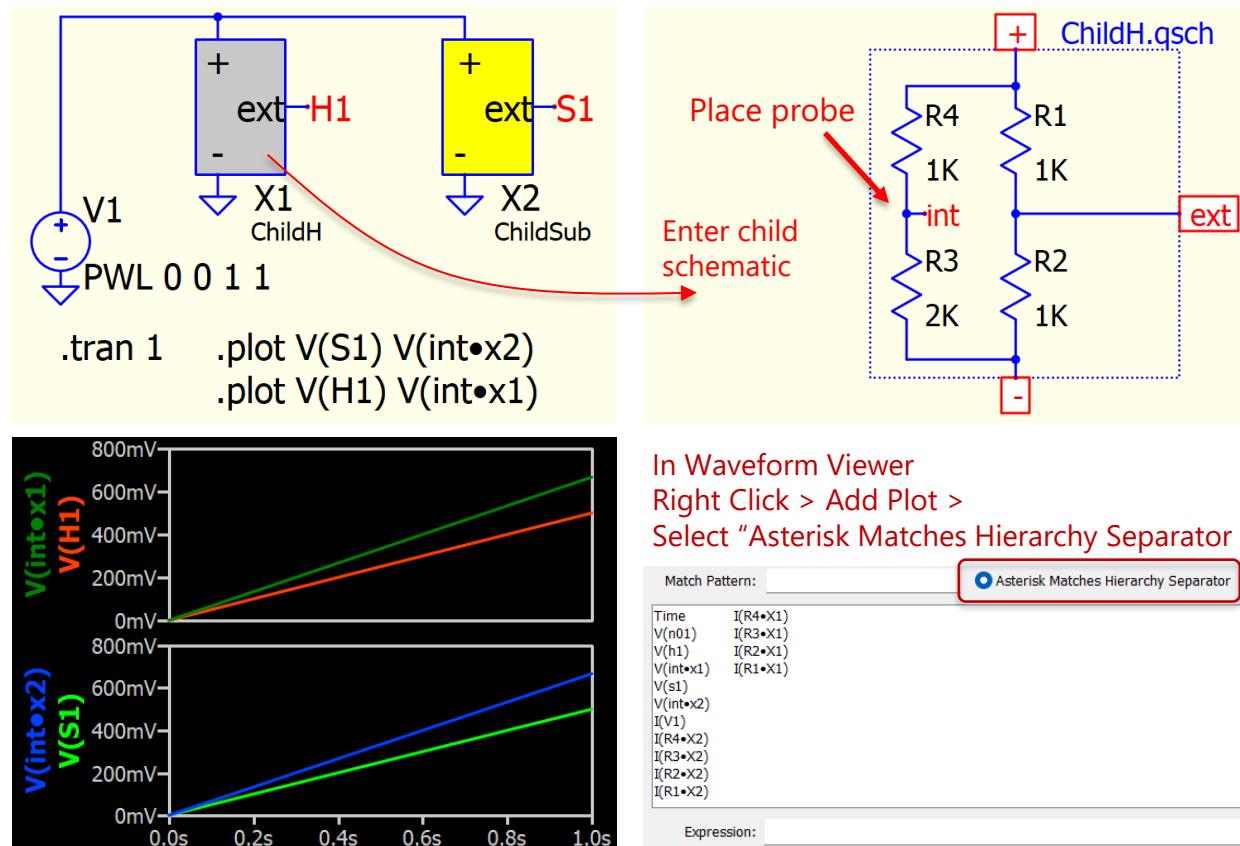
.subckt for X1  
X1+<subckt name>

.subckt for X2  
X2+<subckt name>

# Hierarchical and Sub-circuit : Probe in Waveform Viewer

Qspice : Probe Hierarchical and Subckt.qsch | ChildH.qsch

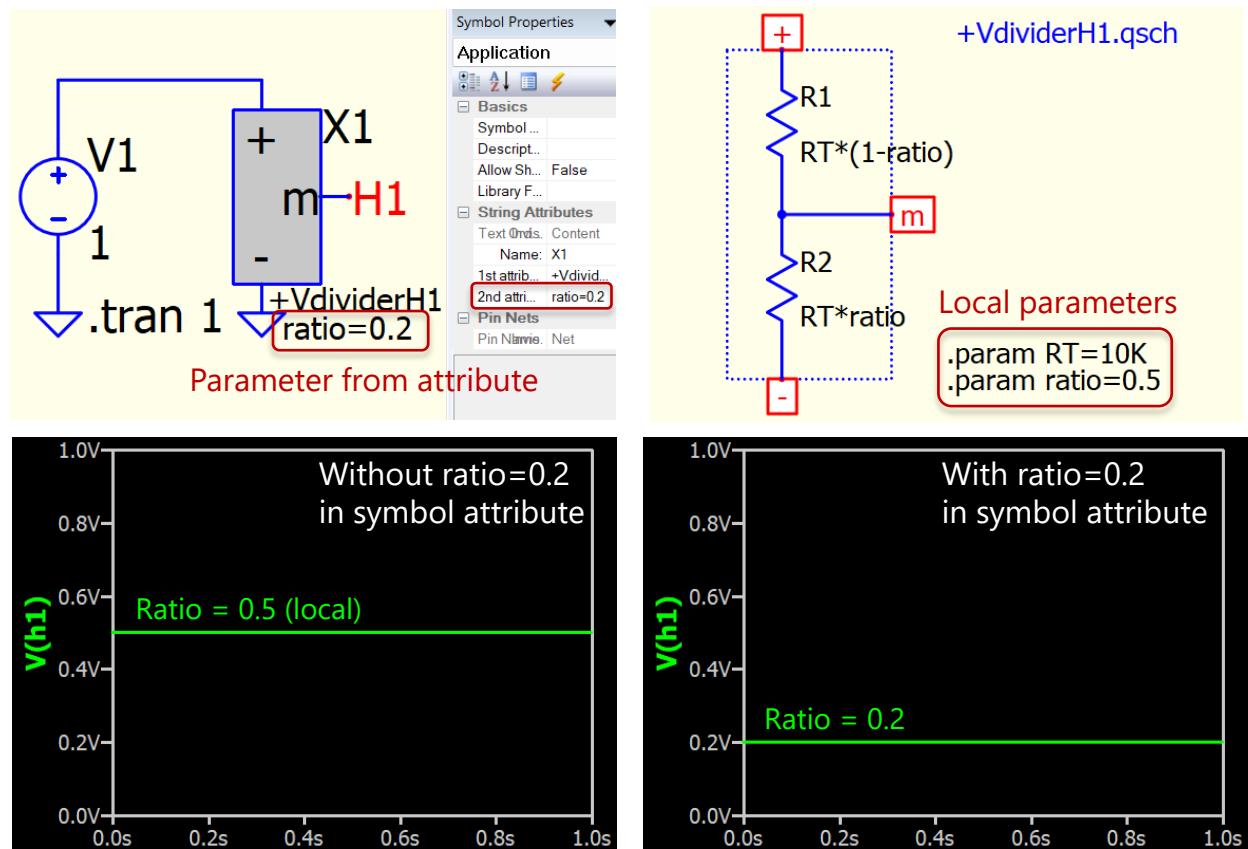
- Probe Hierarchical and Sub-circuit
  - Expression to probe for hierarchical and subckt symbol are identical
    - $V : <\text{netname}> \bullet <\text{Xn}>$
    - $I : <\text{devicename}> \bullet <\text{Xn}>$
  - Hierarchical allow user to enter child schematic and add probe
  - Sub-circuit is in netlist and can only be probe by
    - .plot directive
    - In waveform viewer, Add Plot and enable "Asterisk Matches Hierarchy Separator"



# Hierarchical and Sub-circuit : Passing Parameters

Qspice : parent-PassParamHierarchical.qsch | +VdividerH1.qsch

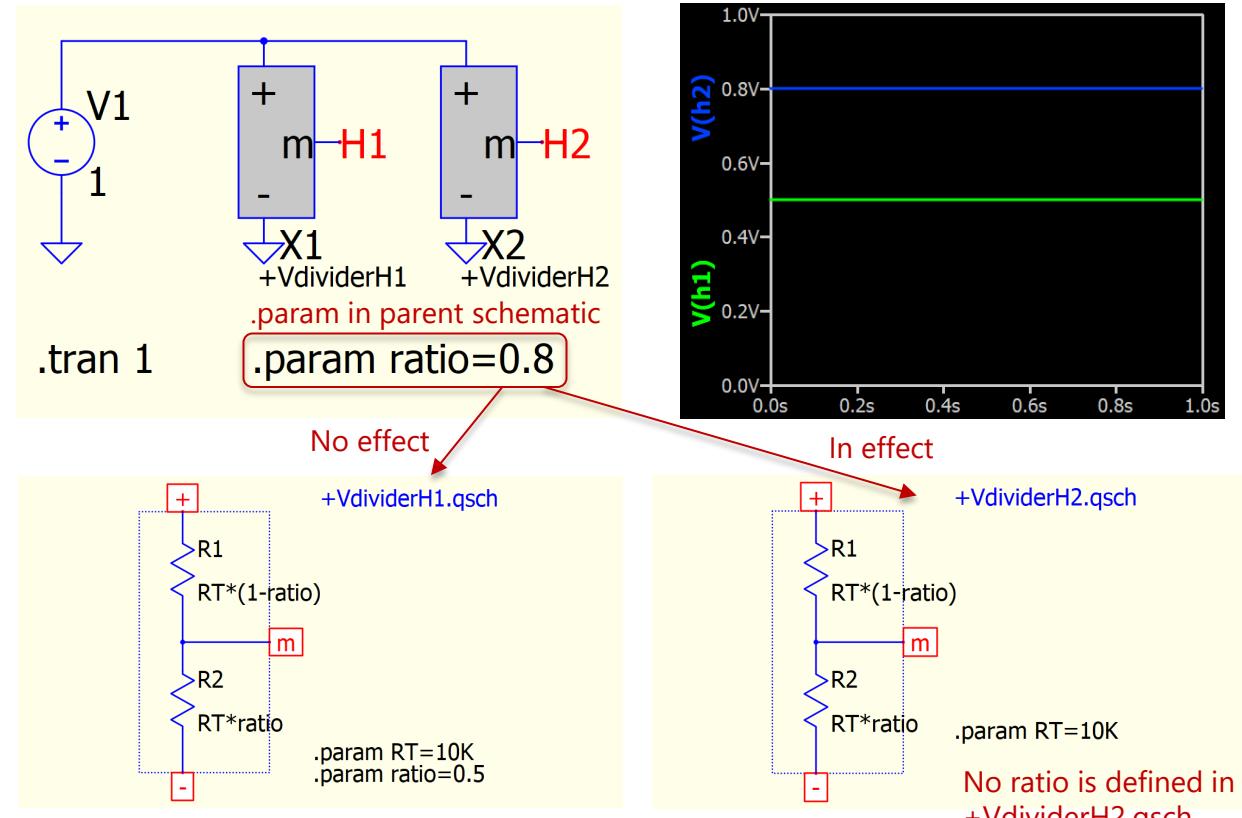
- Passing Parameters
  - Hierarchical and subcircuits work in the same way
  - By default, .subckt or child schematics load their local parameters from the .param (not a must to have local parameters)
  - In the parent schematic, add a new attribute to the symbol can pass parameters; this will override local parameters within the .subckt or child schematic



# Parameter Passing with Global .param from parent

Qspice : parent-PassGlobalParam.qsch | +VdividerH1.qsch | +VdividerH2.qsch

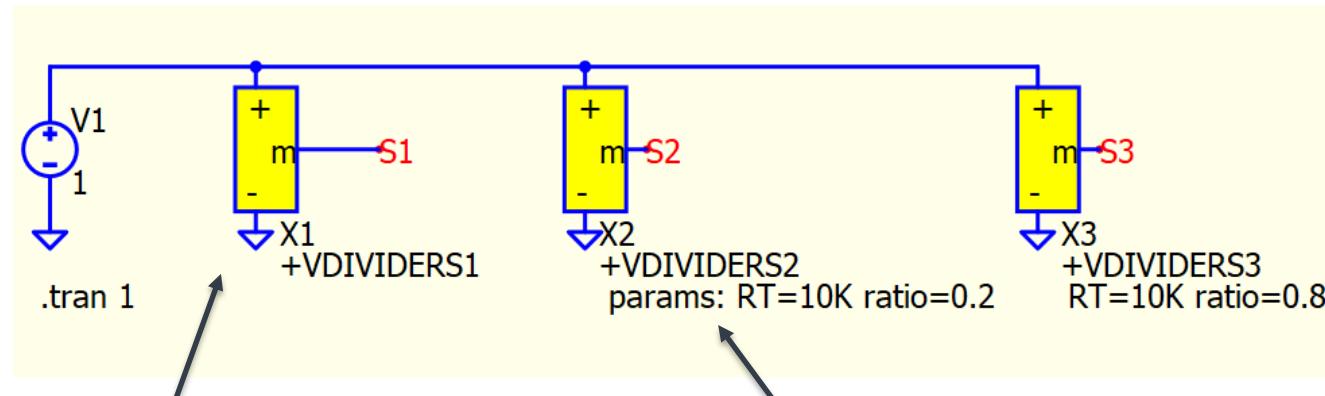
- .param from Parent
  - Global .param passing from parent into a child schematic depends whether this child schematic has the parameter defined
  - If no such parameter is defined in child schematic, global .param override
  - If parameter is defined in child, global .param is ignored. Only string attribute in symbol has ability to override child schematic defined parameter



# Three Way to Define Default Parameters in .subckt

Qspice : parent-PassParamSubckt.qsch | +VdividerS.txt

- Three Way to Define Default Parameters in .subckt



```
.subckt +VdividerS1 + - m  
R1 + m RT*(1-ratio)  
R2 m - RT*ratio  
.param RT=10K  
.param ratio=0.5  
.ends +VdividerS1
```

```
.subckt +VdividerS2 + - m params: RT=10K ratio=0.5  
R1 + m RT*(1-ratio)  
R2 m - RT*ratio  
.ends +VdividerS2
```

```
.subckt +VdividerS3 + - m RT=10K ratio=0.5  
R1 + m RT*(1-ratio)  
R2 m - RT*ratio  
.ends +VdividerS3
```

For this version, if removes .param lines, param can be added in symbol in string attribute

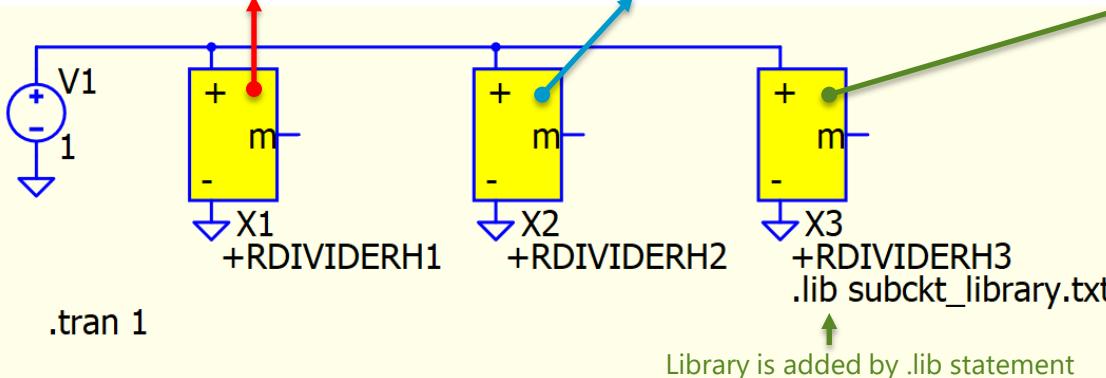
Right Click on symbol > Add New Attribute

## Three Type of Sub-Circuit (.subckt) Symbol (.qsym)

## **Qspice : parent - 3 type subckt symbol.qsch**

## Embedded SUBCKT [y to share, just one .qsym]

| Symbol Properties                   |                                       |
|-------------------------------------|---------------------------------------|
| <b>Application</b>                  |                                       |
|                                     |                                       |
| <input checked="" type="checkbox"/> | Symbol Type                           |
| <input type="checkbox"/>            | Description                           |
| <input type="checkbox"/>            | Allow Shorted Pins                    |
| <input type="checkbox"/>            | Library File                          |
| <input type="checkbox"/>            | .subckt is in library file properties |
| <input type="checkbox"/>            |                                       |
| <b>Basics</b>                       |                                       |
| Symbol Type                         | X                                     |
| Description                         |                                       |
| Allow Shorted Pins                  | False                                 |
| Library File                        | .subckt +RdividerH1 +- m\nR...        |
| <b>String Attributes</b>            |                                       |
| Text Order                          | Invis.                                |
| Name:                               | Content                               |
| 1st attribute                       | X1                                    |
|                                     | +RDIVIDERH1                           |



## **Link to Library [Recommend for complex .subckt]**

| Symbol Properties                          |   |
|--|---|
| <b>Application</b>                         |   |
|  |   |
| <input checked="" type="checkbox"/> Basics | X Library is in library file properties |
| Symbol Type                                | X                                       |
| Description                                |   |
| Allow Shorted Pins                         | False                                   |
| Library File                               | subckt_library.txt                      |
| <b>String Attributes</b>                   |   |
| Text Order                                 | Invis.                                  |
| Name:                                      | X2                                      |
| 1st attribute                              | +RDIMIDERH2                             |

Library is added by .lib statement

## No Embed or Link [For universal symbol]

| Symbol Properties   |   |             |        |         |       |    |             |               |  |  |
|---|---|-------------|--------|---------|-------|----|-------------|---------------|--|--|
| <b>Application</b>  |   |             |        |         |       |    |             |               |  |  |
|    |   |             |        |         |       |    |             |               |  |  |
| <input checked="" type="checkbox"/> Basics  | <p>Symbol Type <span style="float: right;">X</span></p> <p>Description</p> <p>Allow Shorted Pins <span style="float: right;">False</span></p> <p>Library File</p>   |             |        |         |       |    |             |               |  |  |
| <input checked="" type="checkbox"/> String Attributes   | <table><thead><tr><th>Text Order</th><th>Invis.</th><th>Content</th></tr></thead><tbody><tr><td>Name:</td><td>X3</td><td>+RDIVIDERH3</td></tr><tr><td>1st attribute</td><td></td><td></td></tr></tbody></table> | Text Order  | Invis. | Content | Name: | X3 | +RDIVIDERH3 | 1st attribute |  |  |
| Text Order  | Invis.  | Content     |        |         |       |    |             |               |  |  |
| Name:   | X3  | +RDIVIDERH3 |        |         |       |    |             |               |  |  |
| 1st attribute   |   |             |        |         |       |    |             |               |  |  |

```
subckt_library.txt

1 .subckt +RdividerH2 + - m
2 R1 + m 1K
3 R2 m - 2K
4 .ends +RdividerH2

5
6 .subckt +RdividerH3 + - m
7 R1 + m 1K
8 R2 m - 3K
9 .ends +RdividerH3
```

# Hierarchical and Sub-circuit Sub-Topics

---

- Part 2A : Hierarchical Block
  - Create hierarchical block from child to parent or parent to child schematic
  - Create symbol for hierarchical block
  - Get .subckt from hierarchical block to convert into an embedded subckt symbol
- Part 2B : Symbol for Subckt [Embedded Subckt]
- Part 2C : Symbol for Subckt [Link to Library]
- Part 2D : Convert MOSFET M to subckt Symbol
  - Demonstrate how to convert a MOSFET M symbol into subckt to save effort in creating a MOSFET symbol for .subckt MOSFET model from 3<sup>rd</sup> party vendor
- Part 2E : Bus and Hierarchical Block

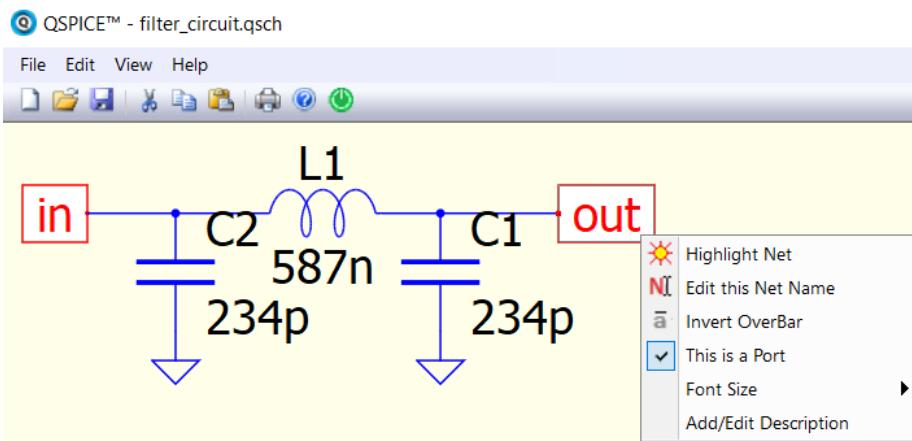
## **Part 2A**

### **Hierarchical Block**

# Hierarchical Block : From Child to Parent

Qspice : filter\_circuit.qsch | filter\_circuit\_app.qsch

- [1] Create a child schematic (.qsch) with circuit and net label
- [2] Right click on net label and select "This is a Port"

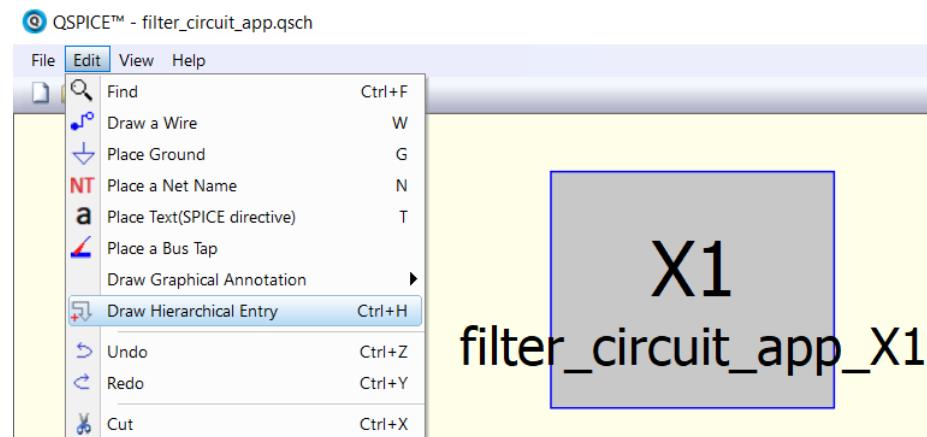


## Method #1

- [3] Create a new schematic which will call to use hierarchical
- [4] Edit → Draw Hierarchical Entry

## Method #2

- [3] In child schematic, Right click > Open Parent Schematic  
This will automatically create a parent schematic contains hierarchical symbol, with all Port automatically created



# Hierarchical Block : From Child to Parent

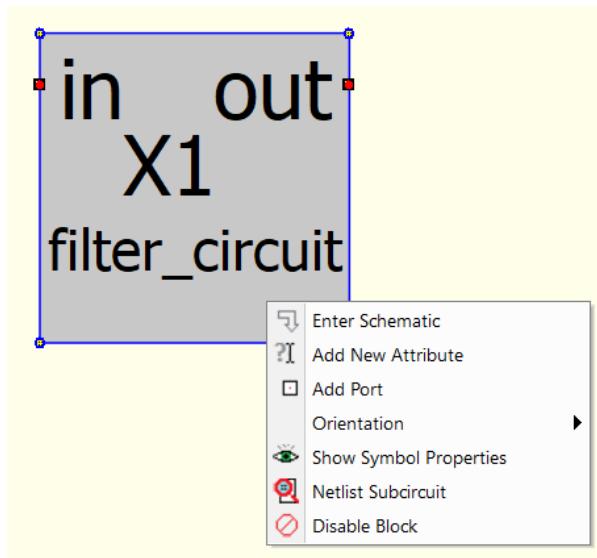
Qspice : filter\_circuit.qsch | filter\_circuit\_app.qsch

[5] Change component text (1<sup>st</sup> attribute) to match child schematic name

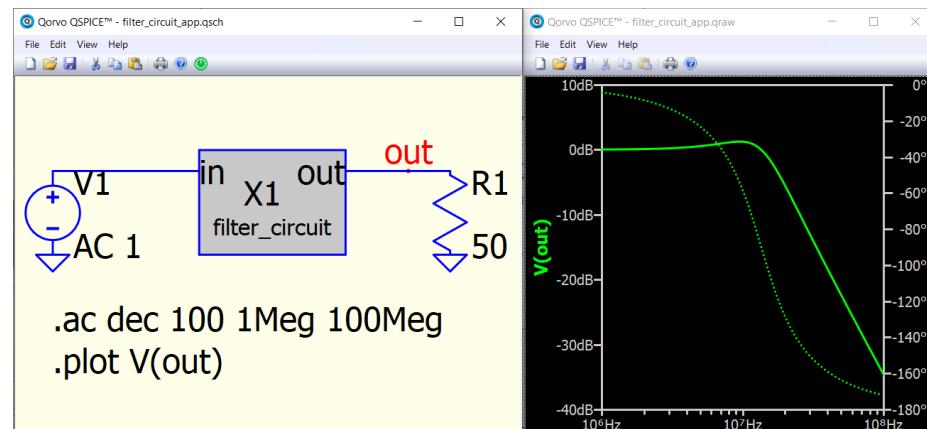
[6] Right click hierarchy component and "Add Port"

[7] Name ports as port name defined in child schematic

[8] Right click hierarchy component and "Enter Schematic" should open child schematic

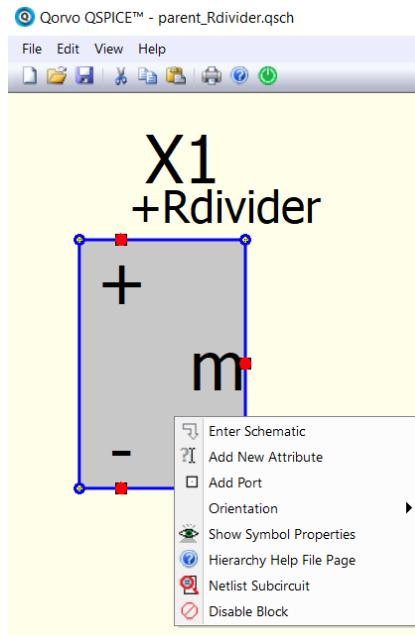


A completed example

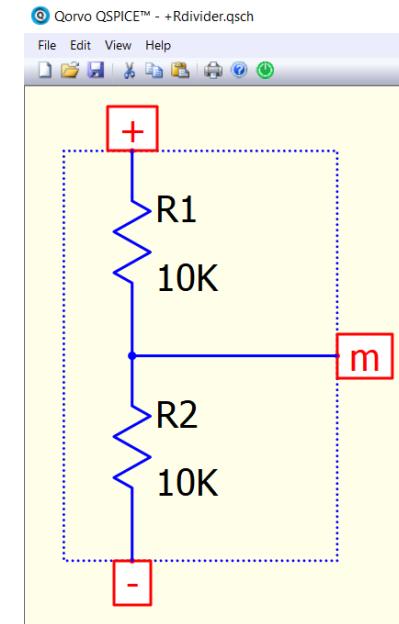


# Hierarchical Block : From Parent to Child

- [1] Right click > Draw Hierarchical Entry
- [2] Rename component text (1<sup>st</sup> attribute) to child schematic name  
\*\* Child schematic will be created later
- [3] Right click within Hierarchical Block > Add Port
- [4] Right click > Enter Schematic, it will create a child .qsch



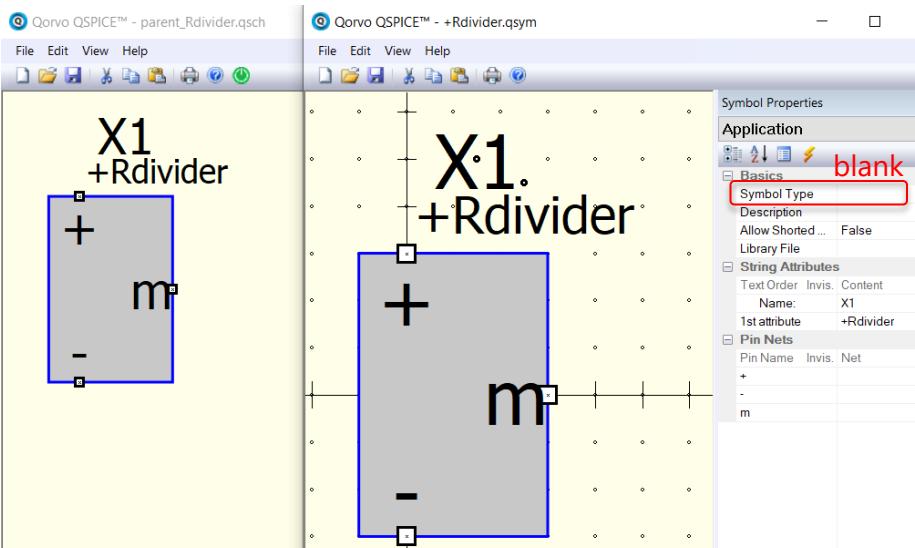
- [5] Create circuit in child schematic



# Hierarchical Block : Create Symbol (.qsym) for Hierarchical

Qspice : parent\_Rdivider.qsch | +Rdivider.qsym

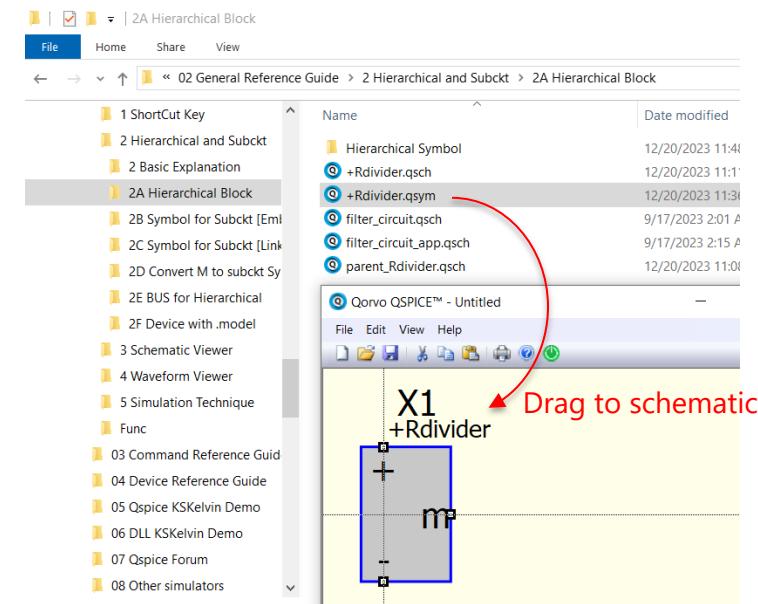
- [1] In a parent schematic which contains a hierarchical block
- [2] Hold Shift, draw a selection box to select Hierarchical
- [3] Press Ctrl-C to copy
- [4] File > New > New Symbol
- [5] In New Symbol window, Press Ctrl-V to paste
- [6] A symbol for a hierarchical block has been created, and now you have the option to edit this symbol. However, please keep in mind that the "Symbol Type" field must be left blank for a hierarchical symbol



- [7] Save this symbol (.qsym) in the same directory as the hierarchical schematic (.qsch)

## How to use .qsym with .qsch

- [8] To place this symbol in the schematic window, drag it from the File Explorer and drop it into the schematic window



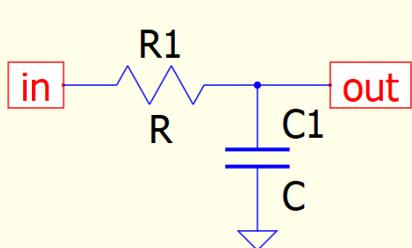
# Create Hierarchical Symbol (.qsym) for Hierarchical : Method #1

Qspice : RC\_sch.qsym ; RC\_sch.qsch

[1] Draw a schematic

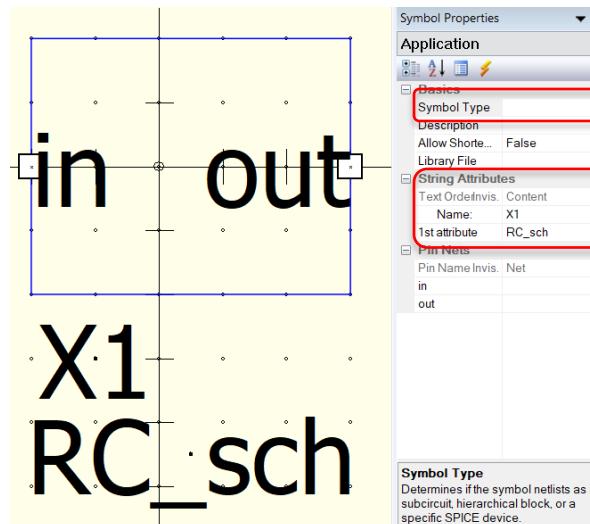
This example has

- Two ports : **in** and **out**



[2] Create a symbol

- Pin name needs to match schematic ports (order not important)
- Use Text to assign
  - Name : X1
  - 1<sup>st</sup> attribute : [schematic name]
- Symbol Type : Blank (nothing)**
  - Don't assign a X (X for subckt), hierarchical entry no symbol type



**Remark :**

**Major Different for Symbol to call schematic (hierarchical entry) and subckt**

- To call schematic (hierarchical entry)
  - Symbol Type : Blank
  - Name : X1
  - 1<sup>st</sup> attribute : schematic name
- To call subckt
  - Symbol Type : X
  - Name : X1
  - 1<sup>st</sup> attribute : subckt name

# Create Hierarchical Symbol (.qsym) for Hierarchical : Method #2

Qspice : RC\_sch.qsym ; RC\_sch.qsch

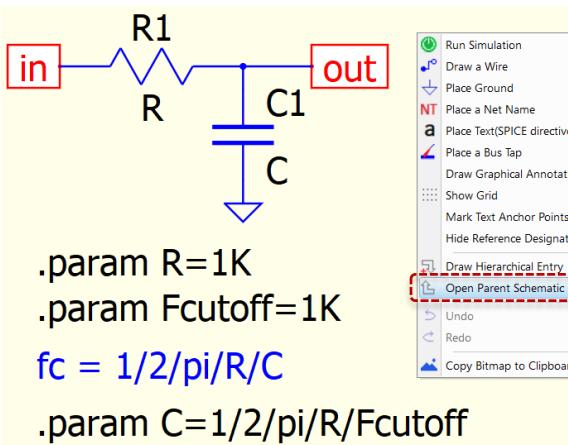
[1] Draw a schematic

This example has

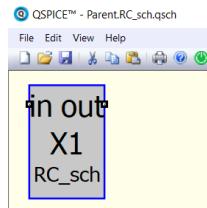
- Two ports : **in** and **out**
- Right click these nets and select "This is a port" (only these ports will auto generate hierarchical entry)

[2] Right Click > Open Parent Schematic

It will ask to automatically generate a parent schematic



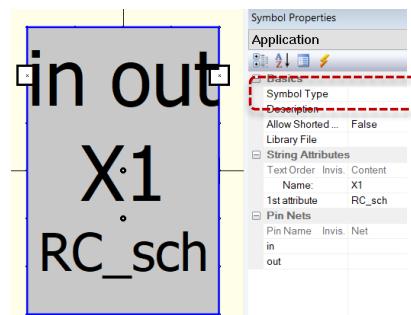
[3] Copy hierarchical block in parent with Ctrl-C



[4] File > New > New Symbol, paste with Ctrl-V

**\*\* Symbol Type : Blank (nothing)**

- Don't assign a X (X for subckt), hierarchical no symbol type. If you re-open a hierarchical symbol, please pay attention in here as it may auto assign an X into Symbol Type



[5] Save as a .qsym symbol

**Remark :**

**Major Different for Symbol to call schematic (hierarchical entry) and subckt**

- To call schematic (hierarchical)
  - Symbol Type : Blank
  - Name : X1
  - 1<sup>st</sup> attribute : schematic name
- To call subckt
  - Symbol Type : X
  - Name : X1
  - 1<sup>st</sup> attribute : subckt name

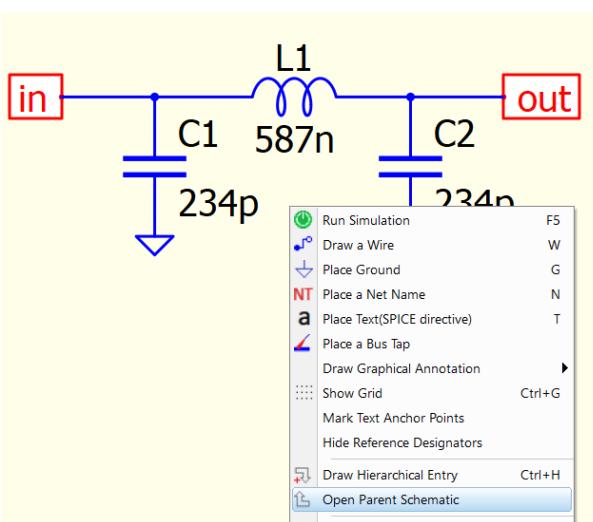
**Qspice HELP Reference**

Help > Schematic Capture > Schematic Hierarchy

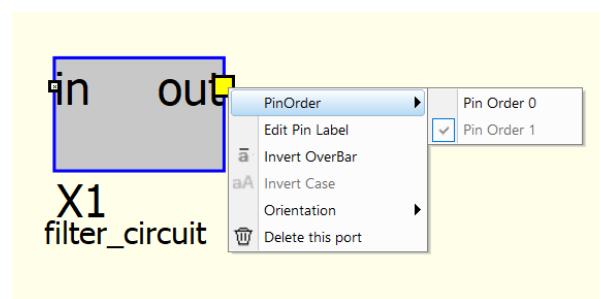
# Create Subckt Symbol (.qsym) from Hierarchical Circuit (.qsch)

## [Step 1 to 4]

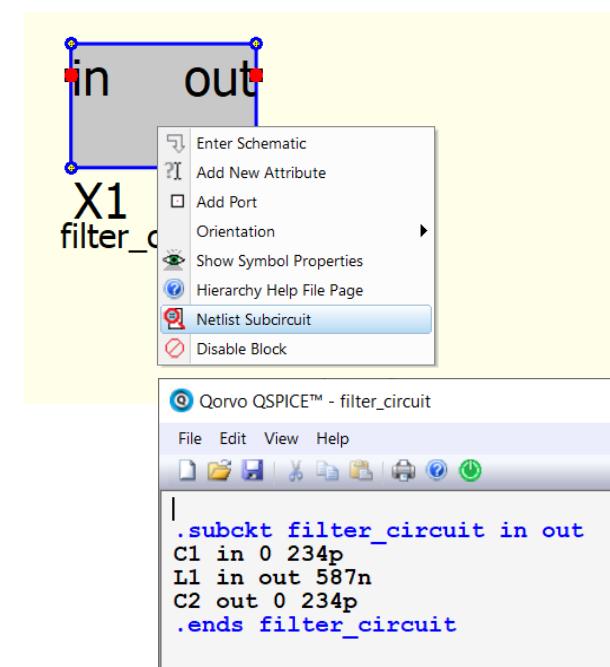
[1] In hierarchical schematic  
Right Click > Open Parent Schematic  
It will generate a .qsch with prefix Parent.



[2] In Parent Schematic, verify/change Pin Order if a particular pin name order you need for .subckt



[3] Right Click on Hierarchical Symbol, select Netlist Subcircuit  
[4] select all and copy .subckt netlist with Ctrl-C

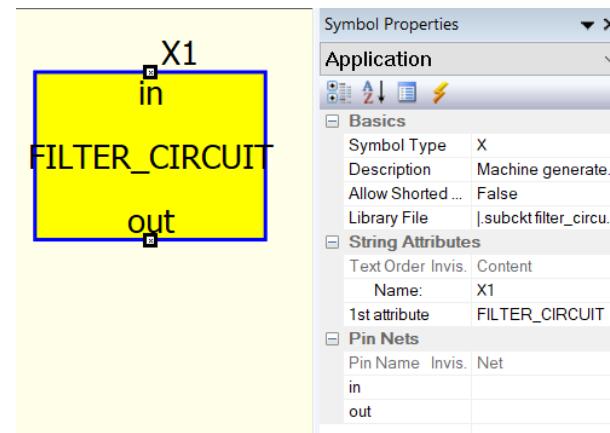
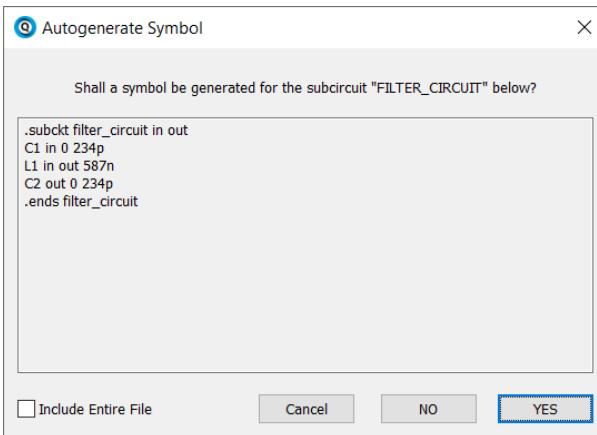


# Create Subckt Symbol (.qsym) from Hierarchical Circuit (.qsch)

## [Step 5 to 6]

[5] Ctrl-V to paste the text into a schematic (or a blank symbol) to invoke the 3rd party import routine

[6] A subckt symbol is generated with embedded .subckt which contain the circuitry that you can use in any schematic in any directory



## **Part 2B**

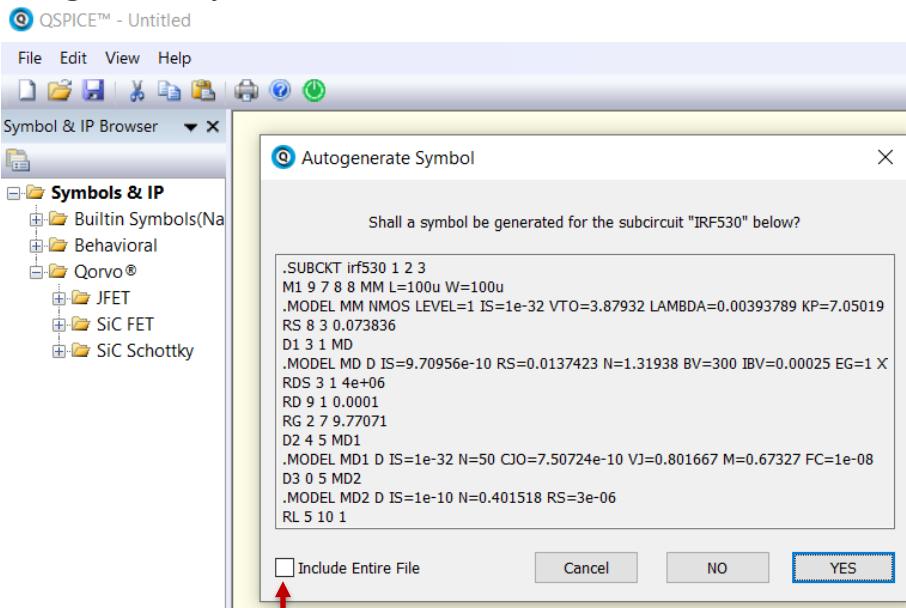
### **Symbol for Subckt**

#### **[Embedded Subckt]**

# Symbol for Subckt [Embedded Subckt]

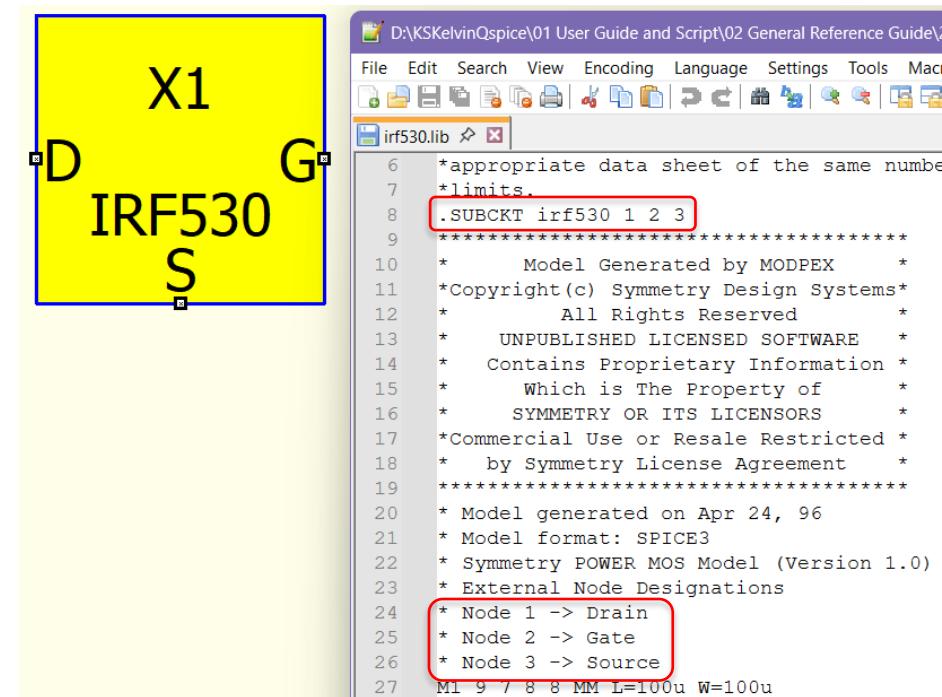
## Procedure for : Autogenerate symbol → Customize symbol

- [1] Assume user has a subcircuit .subckt in netlist (.txt / .lib etc)
- [2] Use a text editor to open library file, copy text for subcircuit
- [3] In **Schematic Window**, paste the text (Ctrl-V) to autogenerate symbol



\*\* If the subcircuit relies on other .subckt,  
click on this block to include entire file

- [4] (Optional Step) Rename pins by referring to descriptions in model file



# Symbol for Subckt [Embedded Subckt]

Procedure for : Autogenerate symbol → Customize symbol

[5] File > New Symbol to open a **Symbol Window**

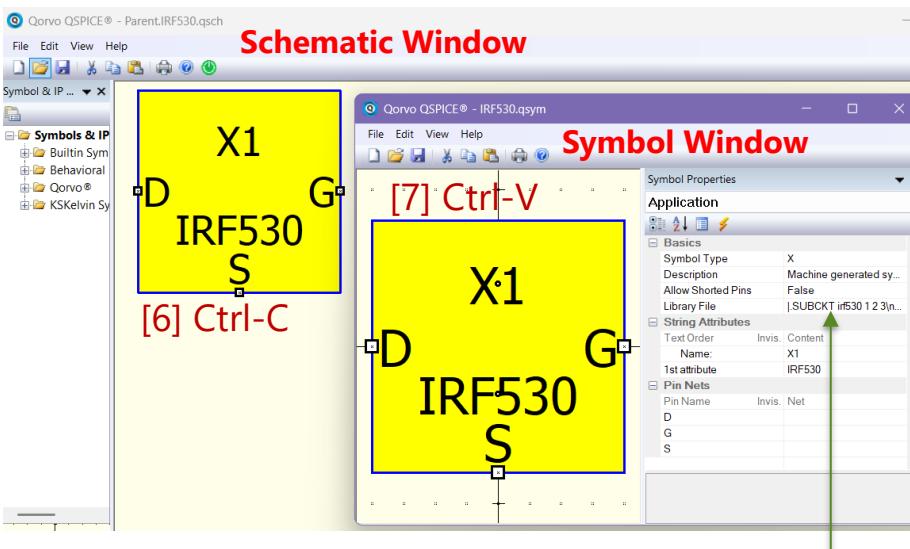
[6] In schematic, Ctrl-C to copy device X1

[7] Goto **Symbol Window**, Ctrl-V to paste component

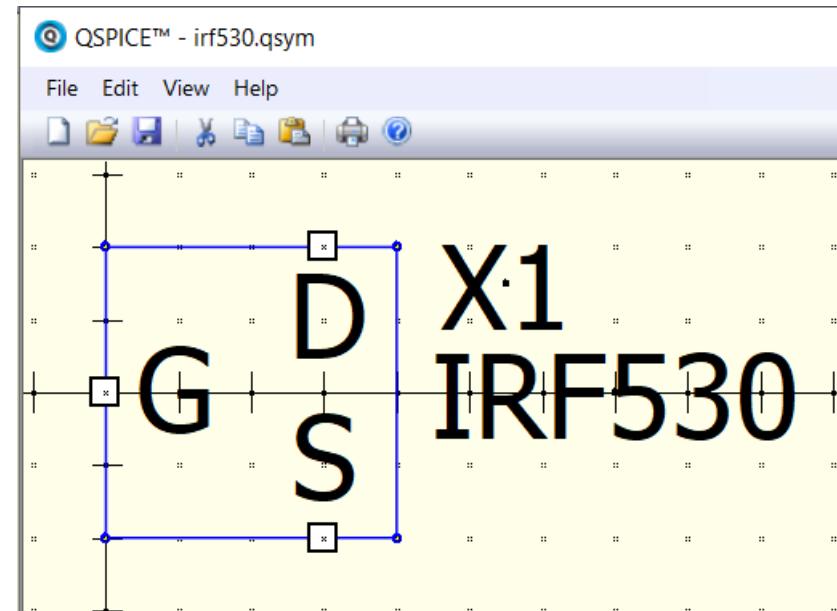
[8] Now rearrange pins location and re-draw the symbol

\*\* But don't change pin order!

[9] Save as a Qspice symbol (file extension as .qsym)



\*\* .subckt netlist is embedded into symbol in the field of "Library File"



# Symbol for Subckt [Embedded Subckt]

Procedure for : Autogenerate symbol → Customize symbol

[10] In **Schematic Window**, open **Symbol & IP Browser** (shortcut F2)

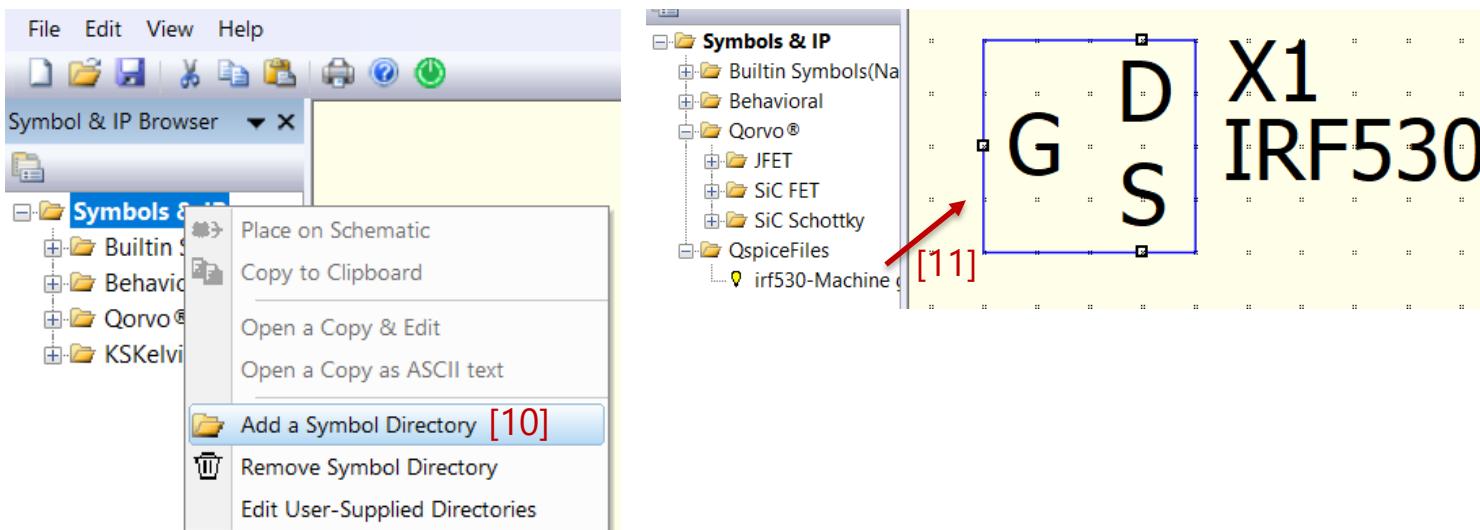
Right Click "Symbols & IP" > "Add a symbol directory"

Add directory that contains your symbol (.qsym) files

[11] Now, you can drag custom symbol to schematic from this browser

(Alternative method : You can also directly drag a .qsym symbol file from **File Explorer** to schematic)

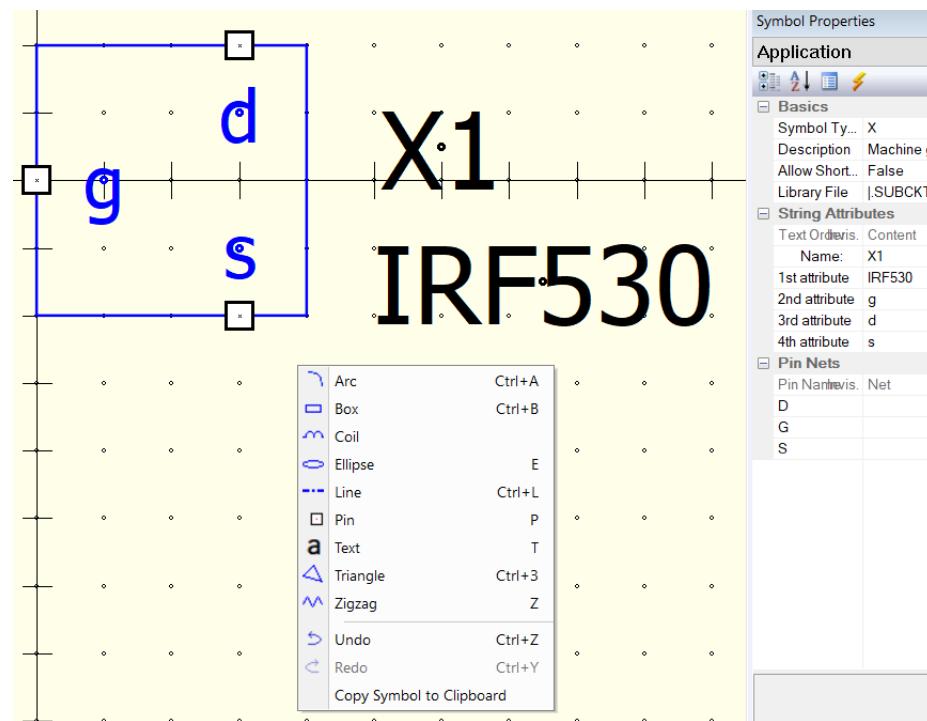
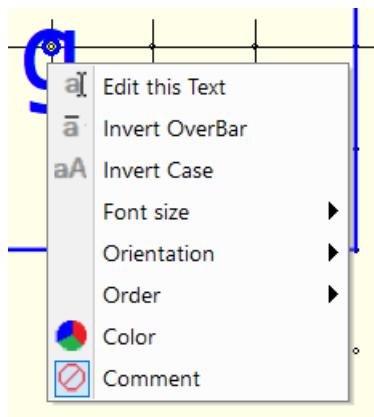
[12] \*\* netlist library is no longer required as .subckt is integrated into symbol



# Symbol for Subckt [Embedded Subckt] : Label with Text

Qspice : irf530 with text.qsym

- Text can be used in label
  - For example, instead of changing net name, you can
    - Right click > Text
    - Right click on text > Select "Comment"
      - Text not comment will become valid item in netlist
      - Can change font size and color
    - Be careful 1<sup>st</sup> attribute is device name (e.g. IRF530 in example), and doesn't comment it



## \*\* Procedure to Create embedded SUBCKT symbol from Hierarchy : Method #1

### Qspice : RC\_sch.qsch

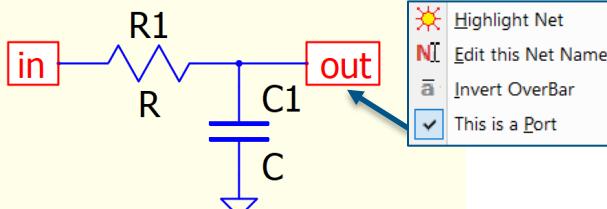
[1] Draw a schematic (hierarchy)

This example has

- Two ports : **in** and **out**  
(for subckt I/O port, right click net name, set "This is a Port")
- Two input params : **R** and **Fcutoff**  
(comment input parameter, we will add it from symbol later)
- One calculated parameter : **C**

; input parameters

```
.param R=1K  
.param Fcutoff=1K
```



; calculated parameters

```
.param C=1/2/pi/R/Fcutoff
```

[2] Right click on schematic > Open Parent Schematic

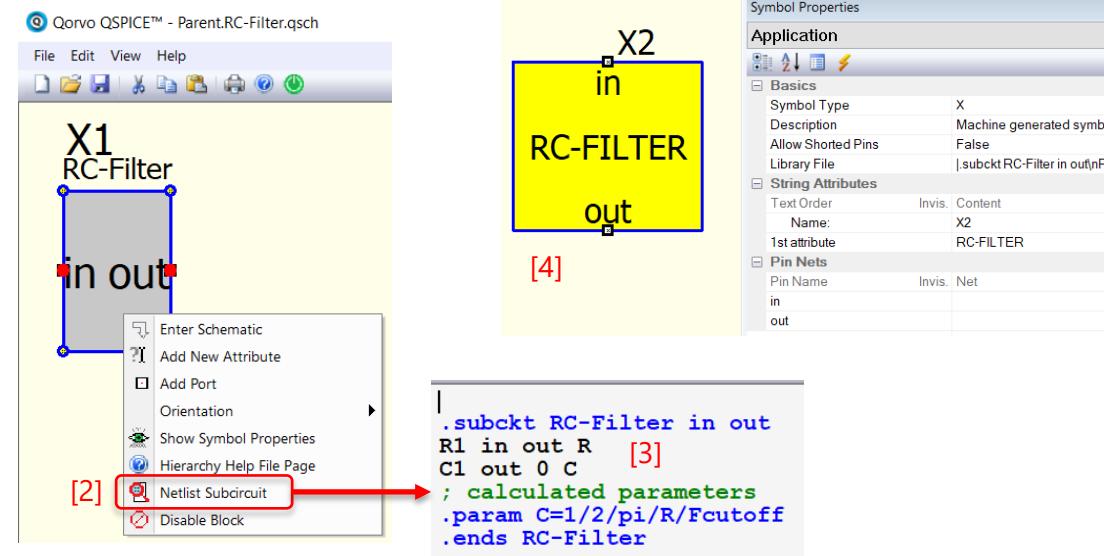
- this will auto generate a Parent hierarchical block

[3] In .suckt netlist, Ctrl-A to select all and Ctrl-C to copy

[4] Return to schematic, Ctrl-V to paste netlist and auto generate a symbol  
- this is a symbol with embedded .subckt

[5] Click on this symbol, Ctrl-C to copy it

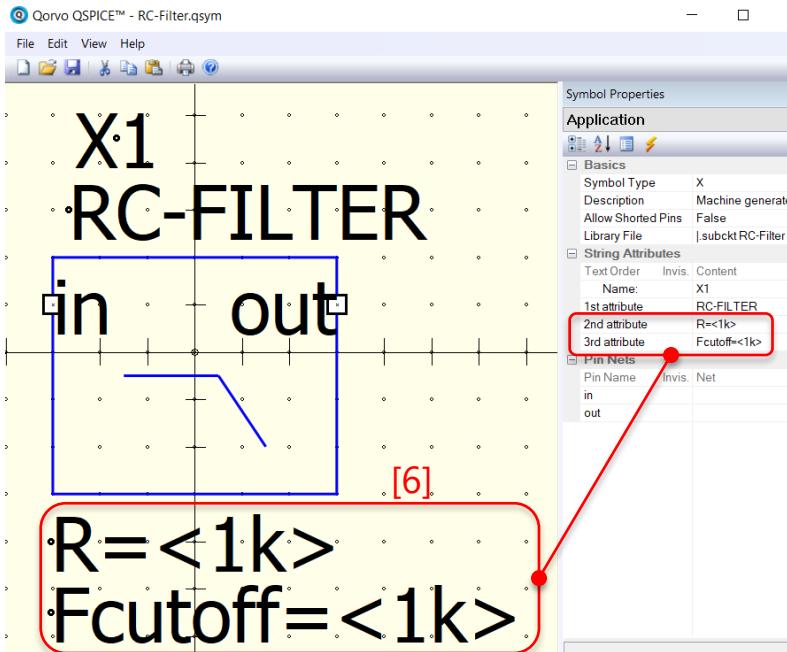
[6] File > New > New Symbol , Ctrl-V to paste symbol in Symbol Viewer



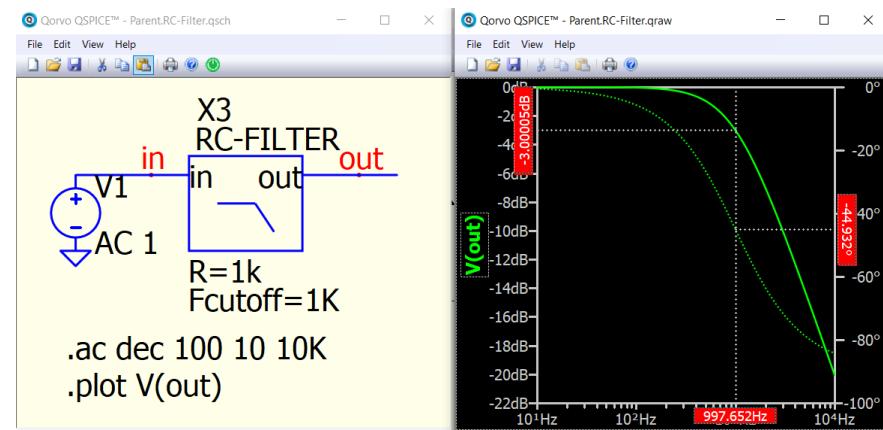
## \*\* Procedure to Create embedded SUBCKT symbol from Hierarchy : Method #1

### Qspice : RC\_sch.qsch

- [7] In Symbol Viewer, re-arrange symbol layout as you want  
[8] To add input parameter R and Fcutoff, type "T" to enter new attribute. In this example, two attributes are added, and with arrow brackets <>. This syntax allows only to change value when this symbol is called



- [9] Now, you can use this symbol for simulation



### Technique if hierarchy circuit needs update

It is not required to re-draw the symbol. When hierarchy is updated, re-perform step [1] to [4]. Right click new auto generated symbol to show symbol properties. Click on .subckt in library file, Ctrl-A to select all, Ctrl-C to copy it. Open symbol .qsym, replace Library File with this new embedded .subckt line.

## \*\* Procedure to Create embedded SUBCKT symbol from Hierarchy : Method #2

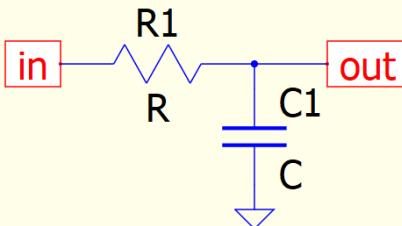
Qspice : RC\_Params.qsym | RC\_sch.qsch

\*\* This method was used before Qspice new feature added, for reference ONLY

[1] Draw a schematic (hierarchy)

This example has

- Two ports : **in** and **out**
- Two input params : R and Fcutoff
- One calculated parameter : C



```
.param R=1K  
.param Fcutoff=1K  
fc = 1/2/pi/R/C  
.param C=1/2/pi/R/Fcutoff
```

[2] View > Netlist, copy this netlist

```
* C:\QspiceKSKelvin\01 User G
R1 in out R
C1 out 0 C
.param R=1K
.param Fcutoff=1K
.param C=1/2/pi/R/Fcutoff
.ends
```

### Subcircuit Definition

Syntax: .subckt NAME N1 N2 N3 ...  
...  
...  
.ends NAME

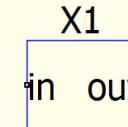
[3 : Method#1] Convert netlist to subckt

- First line add **.subckt**
- **RC** is NAME of subckt determined by user
- Follow with ports (net) : **in out**
- Follow with params : **R=1K Fcutoff=1K**
- Remove **.param R=1K** and **.param Fcutoff=1K**
- Last line add **.ends RC**

This is the finished version

```
.subckt RC in out params: R=1K Fcutoff=1K
R1 in out R
C1 out 0 C
.param C=1/2/pi/R/Fcutoff
.ends RC
```

Copy and paste .subckt script to schematic, then follow standard symbol creation procedure for embedded SUBCKT symbol creation



params: R=1K Fcutoff=1K

## \*\* Procedure to Create embedded SUBCKT symbol from Hierarchy : Method #2

### Qspice : RC\_noParams.qsym

[3 : Method#2] Convert netlist to subckt

- First line add `.subckt`
- **RC** is NAME of subckt determined by user
- Follow with ports (net) : **in out**
- Remove `.param R=1K` and `.param Fcutoff=1K`
- Last line add `.ends RC`

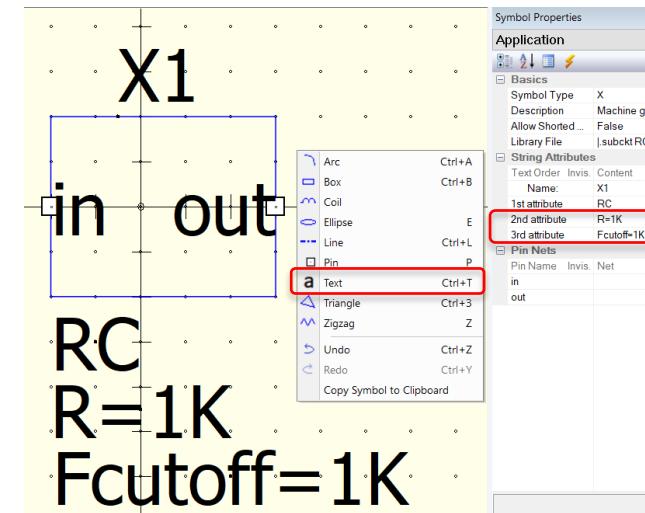
This is the finished version

```
.subckt RC in out
R1 in out R
C1 out 0 C
.param C=1/2/pi/R/Fcutoff
.ends RC
```

Copy and paste `.subckt` script to schematic, then follow standard symbol creation procedure for embedded SUBCKT symbol creation

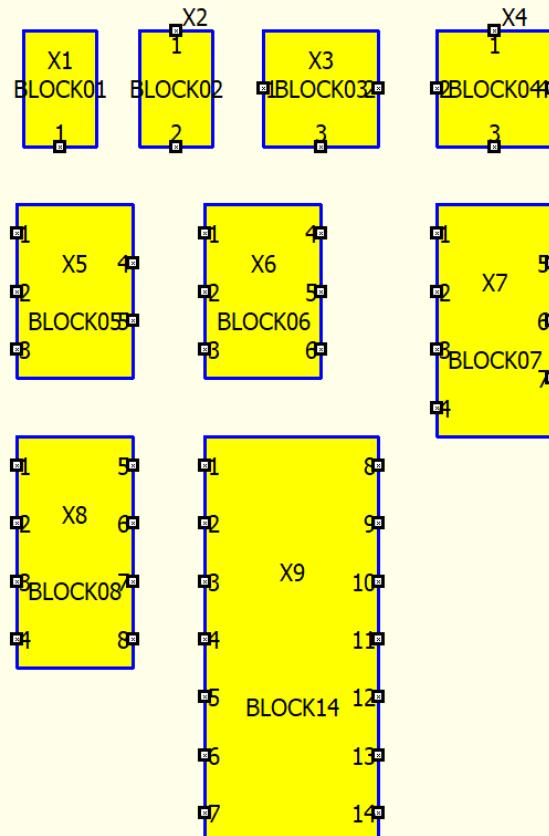
[4 : Method#2] Add input param into symbol

- Two input params : **R=1K** and **Fcutoff=1K**
- Type T or Right Click > Text, input
  - **R=1K**
  - **Fcutoff=1K**
- This will create 2<sup>nd</sup> and 3<sup>rd</sup> attribute in String Attributes, where you can select to visible or not in symbol



# Autogenerate Symbol Pin Assignment

Qspice : Autogenerate Symbol Pin Assignment.qsch



```
.subckt Block01 1  
.ends Block01
```

```
.subckt Block02 1 2  
.ends Block02
```

```
.subckt Block03 1 2 3  
.ends Block03
```

```
.subckt Block04 1 2 3 4  
.ends Block04
```

```
.subckt Block05 1 2 3 4 5  
.ends Block05
```

```
.subckt Block06 1 2 3 4 5 6  
.ends Block06
```

```
.subckt Block07 1 2 3 4 5 6 7  
.ends Block07
```

```
.subckt Block08 1 2 3 4 5 6 7 8  
.ends Block08
```

```
.subckt Block14 1 2 3 4 5 6 7 8 9 10 11 12 13 14  
.ends Block14
```

## **Part 2C**

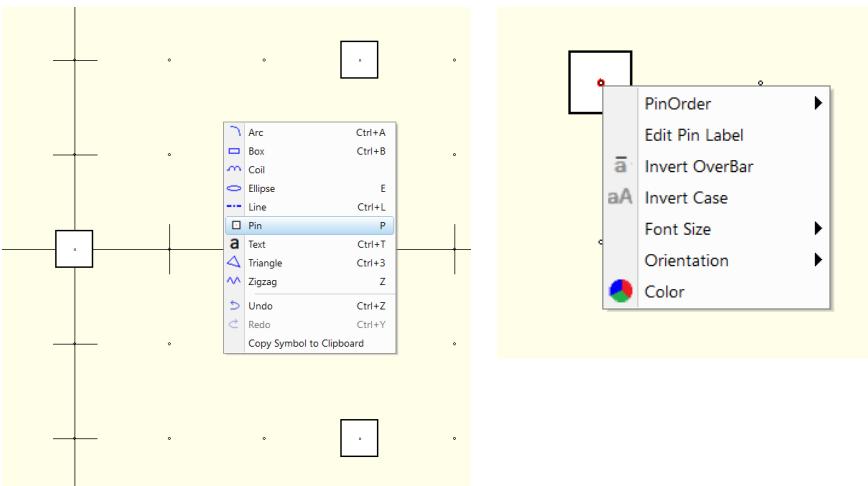
### **Symbol for Subckt**

**[Link to Library]**

# Symbol for Subckt [Create Symbol and Link to Library]

## Example to create subckt symbol for irf530

- [1] File → New → New Symbol
- [2] Right Click → Pin (to add 3 pins with order D, G, S)
- [3] Right Click at center of Pin to review PinOrder and PinLabel



```
irf530.lib x
1 *Feb 16, 2010
2 *Doc. ID: 90181, Rev. A
3 *File Name: part irf530_PS.txt and part irf
4 *This document is intended as a SPICE model
5 *constitute a commercial product data sheet
6 *appropriate data sheet of the same number
7 *limits.
8 .SUBCKT irf530 1 2 3
9 ****
10 *      Model Generated by MODPEX      *
11 *Copyright(c) Symmetry Design Systems*
12 *          All Rights Reserved        *
13 *          UNPUBLISHED LICENSED SOFTWARE  *
14 *          Contains Proprietary Information *
15 *          Which is The Property of      *
16 *          SYMMETRY OR ITS LICENSORS      *
17 *Commercial Use or Resale Restricted   *
18 *      by Symmetry License Agreement    *
19 ****
20 * Model generated on Apr 24, 96
21 * Model format: SPICE3
22 * Symmetry POWER MOS Model (Version 1.0)
23 * External Node Designations
24 * Node 1 -> Drain
25 * Node 2 -> Gate
26 * Node 3 -> Source
27 M1 9 7 8 8 MM L=100u W=100u
28 * Default values used in MM:
```

# Symbol for Subckt [Create Symbol and Link to Library]

[4] Draw a box for outline

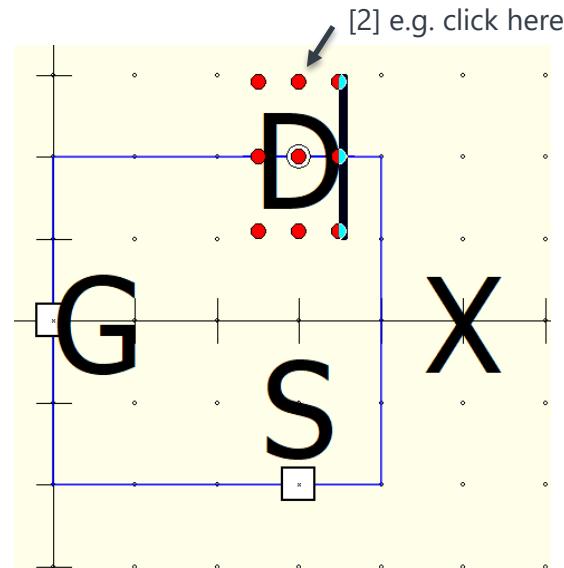
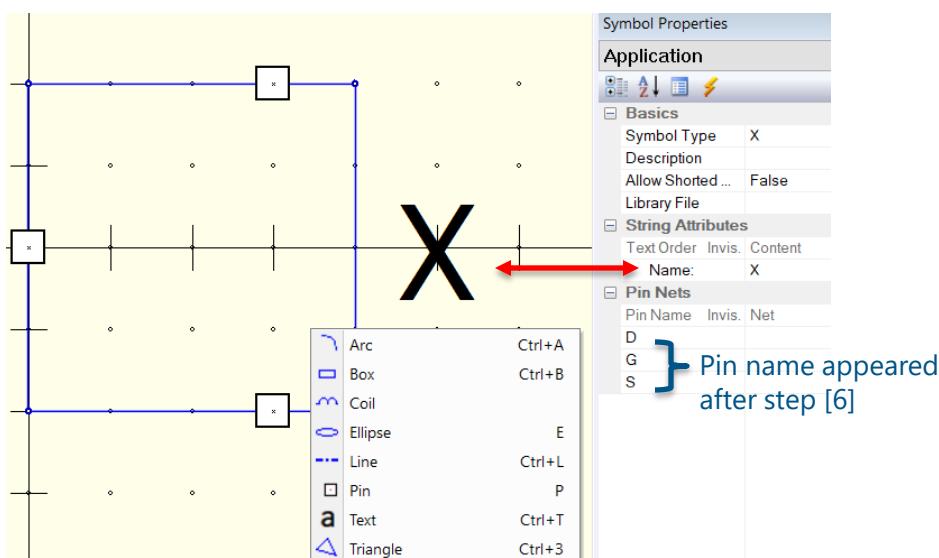
[5] Put an "X" in Symbol Type in Symbol Properties

[6] Right Click → Text → Put an "X"

[7] To justify Pin label, double click center of Pin

[8] Click red dot other than its centered justification

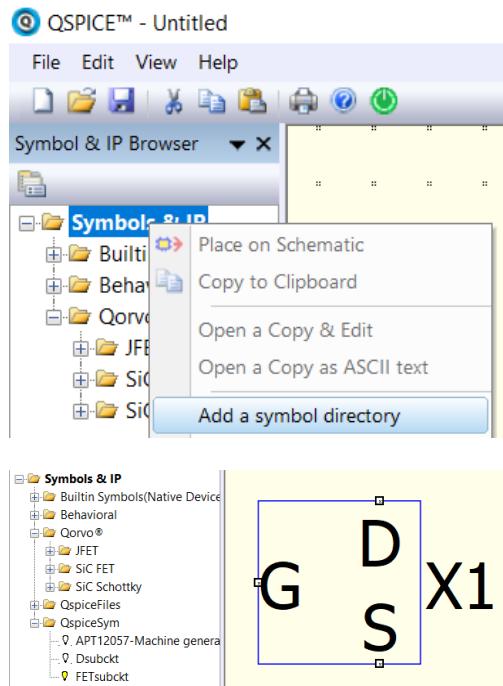
[9] Save symbol file as .qsym



# Symbol for Subckt [Create Symbol and Link to Library]

[10] In Schematic, Symbol & IP Browser, Right Click to "Add a symbol directory"

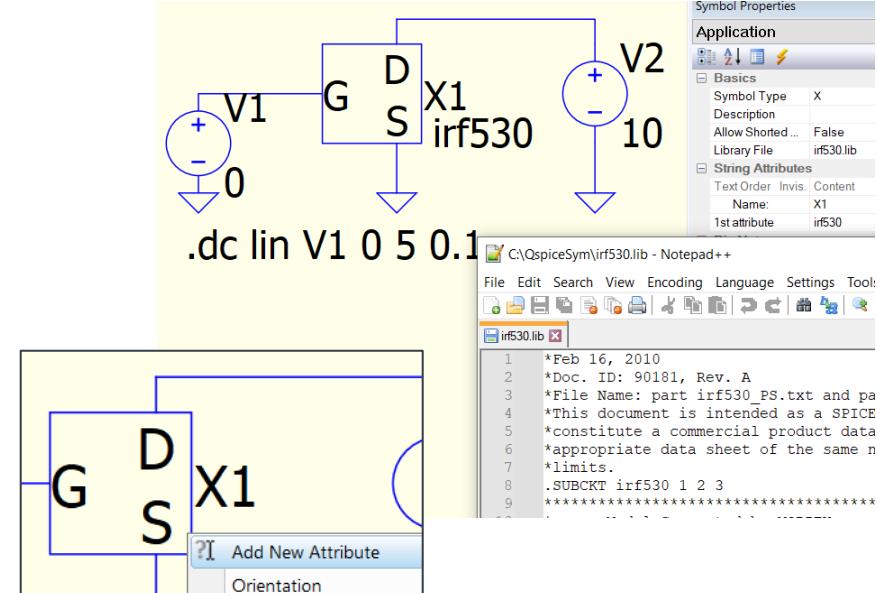
[11] Drag created component to schematic



[12] Right Click on symbol, "Add New Attribute" as irf530

[13] In Symbol Properties, add irf530.lib to the field of "Library File" OR, add ".lib irf530.lib" into schematic for library link

\*\* library file is required to be put in schematic directory or symbol directory added in Symbols & IP browser

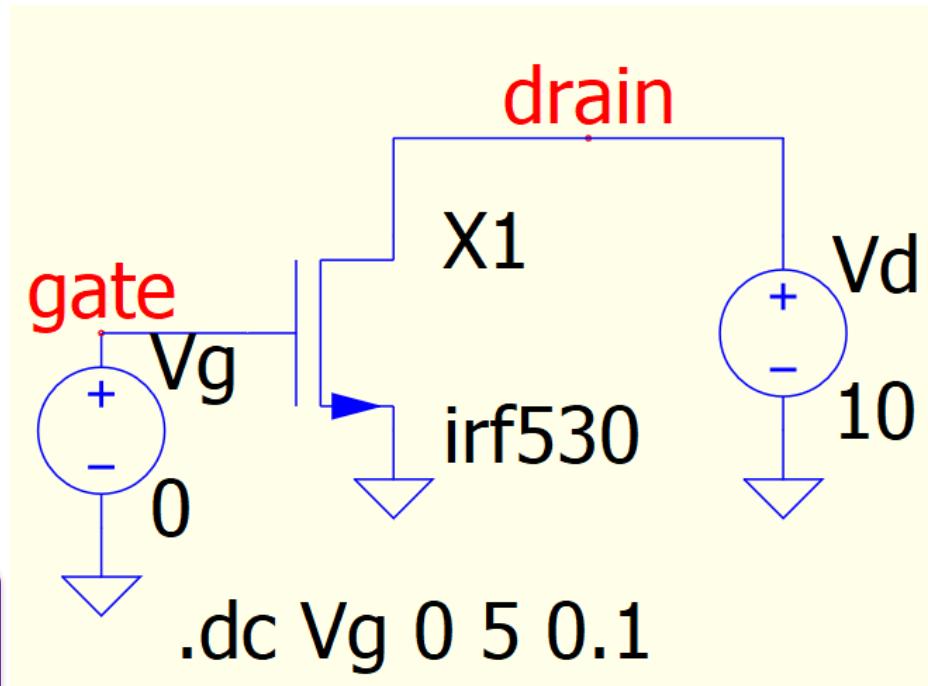
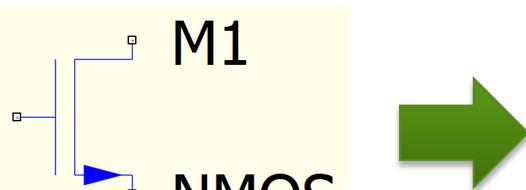


## Part 2D

### Convert MOSFET M to subckt Symbol

# Convert MOSFET M to subckt Symbol

Qspice : Call Lib from M.qsch



Symbol Properties

Application

Basics

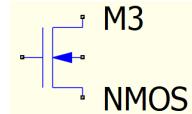
- Symbol Type: X
- Description: N-Channel MOSF...
- Allow Shorted ...: False
- Library File: irf530.lib

String Attributes

- Text Order Invis. Content
- Name: X1
- 1st attribute: irf530

Pin Nets

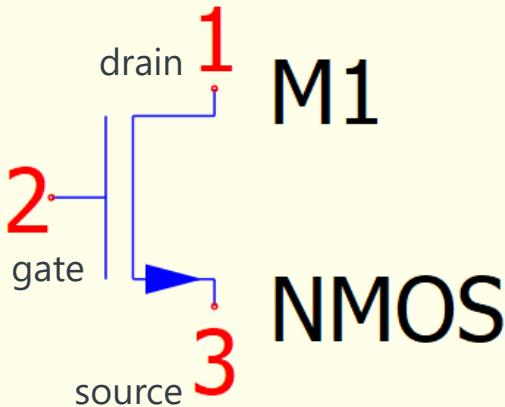
| Pin Name | Invis. | Net   |
|----------|--------|-------|
| D        |        | drain |
| G        |        | gate  |
| S        |        | GND   |



\*\* this alternative symbol is 4 pins (+ base), which cannot support 3 pin subckt

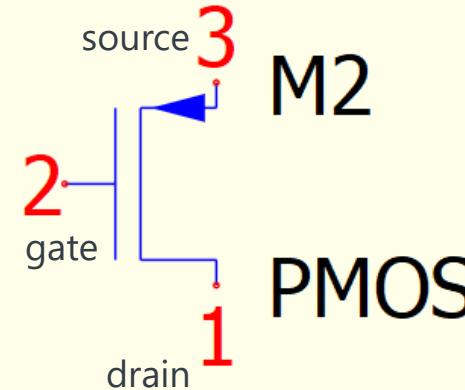
# Pin Order in Symbol MN and MP

## Pin Order for Symbol MN (NMOS)



| Application              |                   |                   |     |
|--------------------------|-------------------|-------------------|-----|
|                          |                   |                   |     |
|                          |                   |                   |     |
| <input type="checkbox"/> | Basics            |                   |     |
|                          | Symbol Type       | MN                |     |
|                          | Description       | N-Channel MOSF... |     |
|                          | Allow Shorted ... | False             |     |
|                          | Library File      | NMOS.txt          |     |
| <input type="checkbox"/> | String Attributes |                   |     |
|                          | Text Order Invis. | Content           |     |
|                          | Name:             | M1                |     |
|                          | 1st attribute     | NMOS              |     |
| <input type="checkbox"/> | Pin Nets          |                   |     |
|                          | Pin Name          | Invis.            | Net |
| D                        |                   | 1                 |     |
| G                        |                   | 2                 |     |
| S                        |                   | 3                 |     |

## Pin Order for Symbol MP (PMOS)



| Application              |                   |                   |     |
|--------------------------|-------------------|-------------------|-----|
|                          |                   |                   |     |
|                          |                   |                   |     |
| <input type="checkbox"/> | Basics            |                   |     |
|                          | Symbol Type       | MP                |     |
|                          | Description       | P-Channel MOSF... |     |
|                          | Allow Shorted ... | False             |     |
|                          | Library File      | PMOS.txt          |     |
| <input type="checkbox"/> | String Attributes |                   |     |
|                          | Text Order Invis. | Content           |     |
|                          | Name:             | M2                |     |
|                          | 1st attribute     | PMOS              |     |
| <input type="checkbox"/> | Pin Nets          |                   |     |
|                          | Pin Name          | Invis.            | Net |
| D                        |                   | 1                 |     |
| G                        |                   | 2                 |     |
| S                        |                   | 3                 |     |

## **Part 2E**

### **Bus and Hierarchical Block**

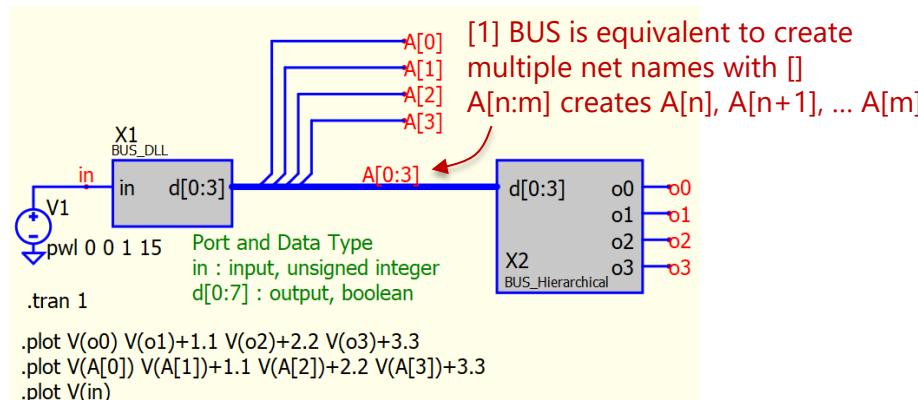
# Bus and Hierarchical Block

---

- Bus and Hierarchical Block
  - With Bus, data is defined as Data[n:m]
  - In Qspice, this net name format create a series of net names from Data[n] to Data[m]
    - If  $n < m$ , net name are Data[n], Data[n+1], Data[n+2], ... , Data[m]
    - If  $n > m$ , net name are Data[n], Data[n-1], Data[n-2], ... , Data[m]
  - For hierarchical block, subckt bus net names are assigned according to index sequence
  - To use data bus, it is recommending bus, hierarchical block and subckt with same data bus index, which can prevent unexpected behavior in net assignment

# Bus and Hierarchical Block

Qspice : Parent-BUS.qsch / BUS\_Hierarchical.qsch / bus\_dll.cpp



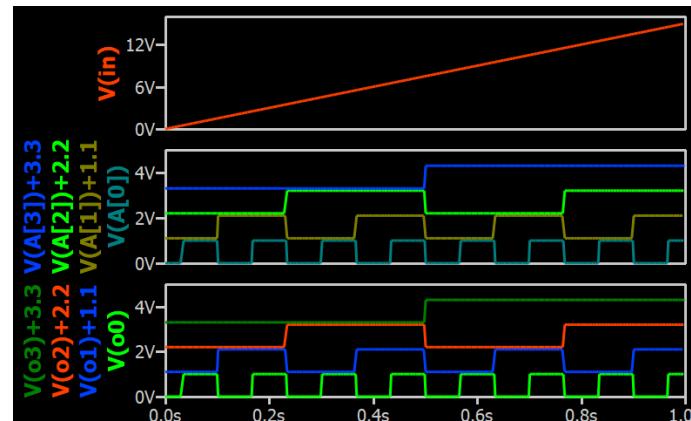
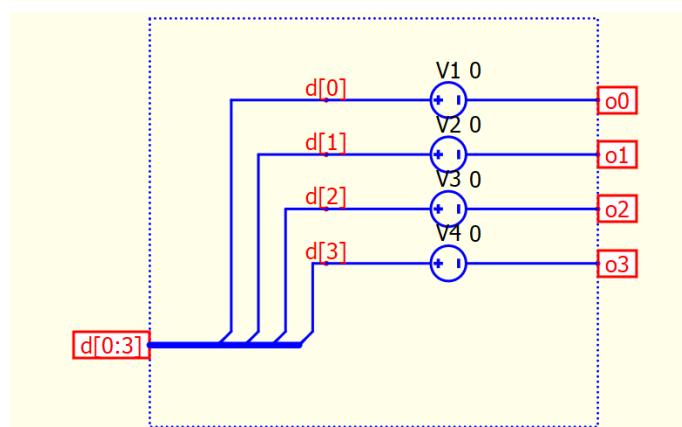
```

  /* C:\QspiceKSKelvin\01 User Guide and Script\01 Qspice Reference \01
  Ø†X1 «in'ui» «A[0]'b A[1]'b A[2]'b A[3]'b» »» BUS_DLL
  V1 in 0 pwl 0 0 1 15
  X2 A[0] A[1] A[2] A[3] o0 o1 o2 o3 BUS_Hierarchical

  .subckt BUS_Hierarchical d[0] d[1] d[2] d[3] o0 o1 o2 o3
  V1 d[0] o0 0
  V2 d[1] o1 0
  V3 d[2] o2 0
  V4 d[3] o3 0
  .ends BUS_Hierarchical

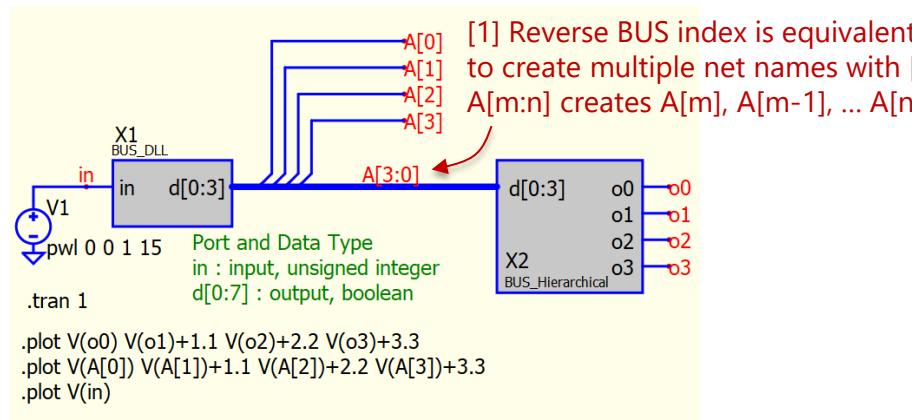
  .tran 1
  .plot V(o0) V(o1)+1.1 V(o2)+2.2 V(o3)+3.3
  .plot V(A[0]) V(A[1])+1.1 V(A[2])+2.2 V(A[3])+3.3
  .plot V(in)
  .end
  
```

[2] Subckt X1, hierarchical X2 are all feed in same name and order



# Bus and Hierarchical Block : Change BUS name order

Qspice : Parent-BUS.qsch / BUS\_Hierarchical.qsch / bus\_dll.cpp

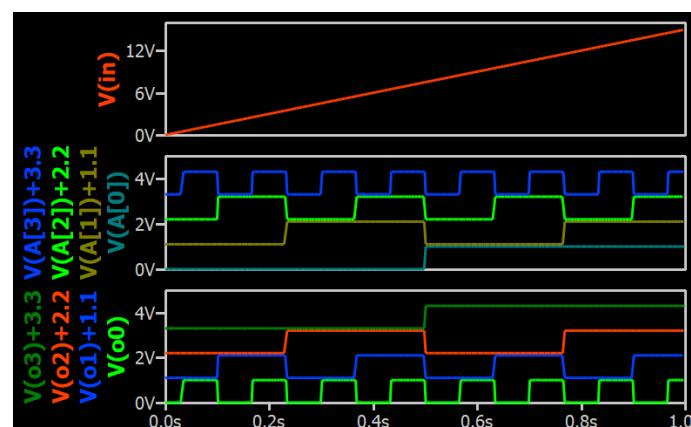
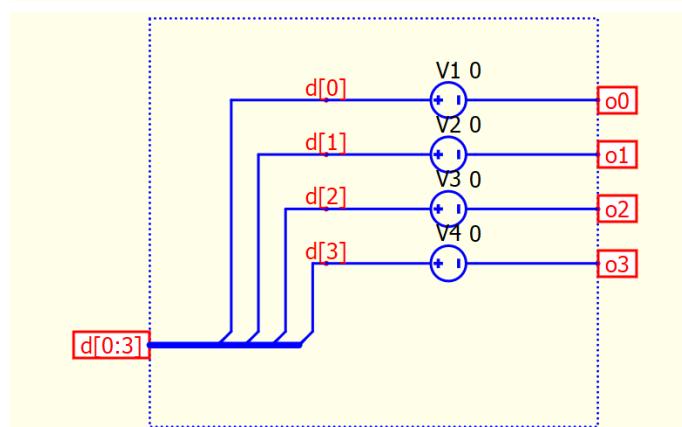


```

  /* C:\QspiceKSKelvin\01_User_Guide_and_Script\01_Qspice Reference \01
  \01\bus_and_hierarchical.qsch
  *+X1 ``in`ui`` «A[3]`b A[2]`b A[1]`b A[0]`b» »» BUS_DLL
  V1 in 0 pwl 0 0 1 15
  X2 A[3] A[2] A[1] A[0] o0 o1 o2 o3 BUS_Hierarchical

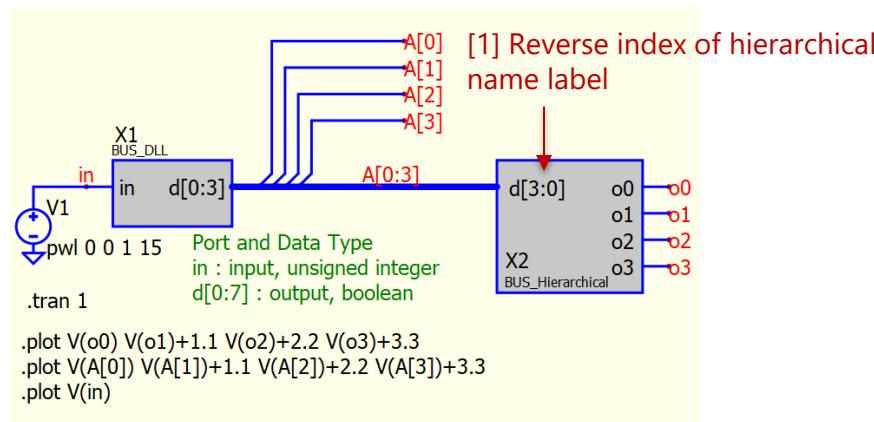
  .subckt BUS_Hierarchical d[0] d[1] d[2] d[3] o0 o1 o2 o3
  V1 d[0] o0 0
  V2 d[1] o1 0
  V3 d[2] o2 0
  V4 d[3] o3 0
  .ends BUS_Hierarchical
  [2] Subckt X1-d[0] is connected to A[3]
  [3] This order is feed into hierarchical block
  X2, e.g. A[3] is feed into X2-d[0]

  .tran 1
  .plot V(o0) V(o1)+1.1 V(o2)+2.2 V(o3)+3.3
  .plot V(A[0]) V(A[1])+1.1 V(A[2])+2.2 V(A[3])+3.3
  .plot V(in)
  .end
  
```



# Bus and Hierarchical Block : Change Hierarchical net label order

Qspice : Parent-BUS.qsch / BUS\_Hierarchical.qsch / bus\_dll.cpp

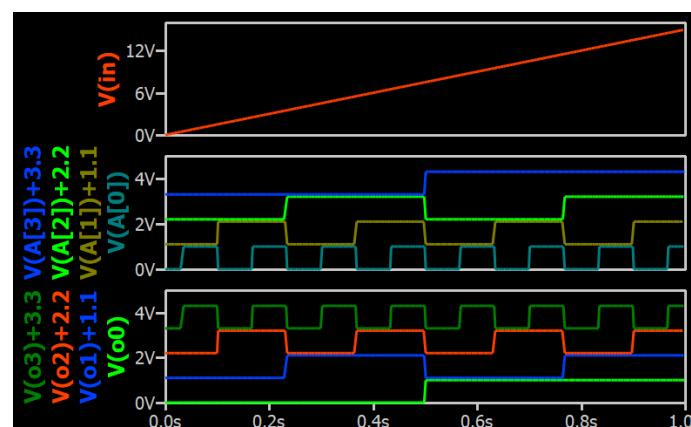
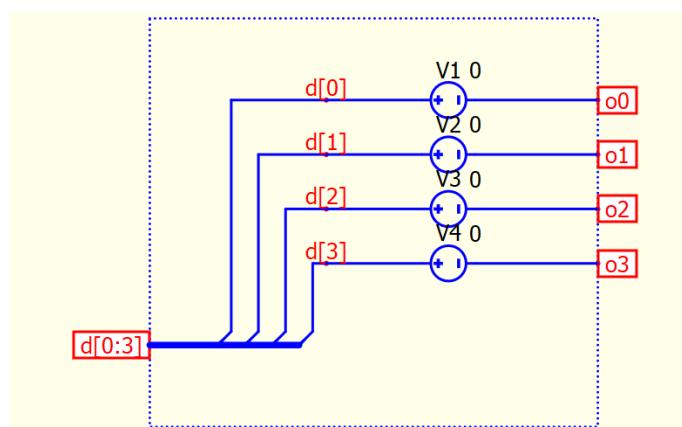


```
* C:\QspiceKSKelvin\01 User Guide and Script\01 Qspice Reference \0
Ø†X1 «in'ui» «A[0] 'b A[1] 'b A[2] 'b A[3] 'b» »» BUS_DLL
V1 in 0 pwl 0 0 1 15
X2 A[0] A[1] A[2] A[3] o0 o1 o2 o3 BUS_Hierarchical

.subckt BUS_Hierarchical d[3] d[2] d[1] d[0] o0 o1 o2 o3
V1 d[0] o0 0
V2 d[1] o1 0
V3 d[2] o2 0
V4 d[3] o3 0
.ends BUS_Hierarchical

.tran 1
.plot V(o0) V(o1)+1.1 V(o2)+2.2 V(o3)+3.3
.plot V(A[0]) V(A[1])+1.1 V(A[2])+2.2 V(A[3])+3.3
.plot V(in)
.end
```

[2] Hierarchical block X2 name is reversed, but Hierarchical / Subckt net assignment is based on order, therefore, A[0] is feed to hierarchical subckt d[3] in this case



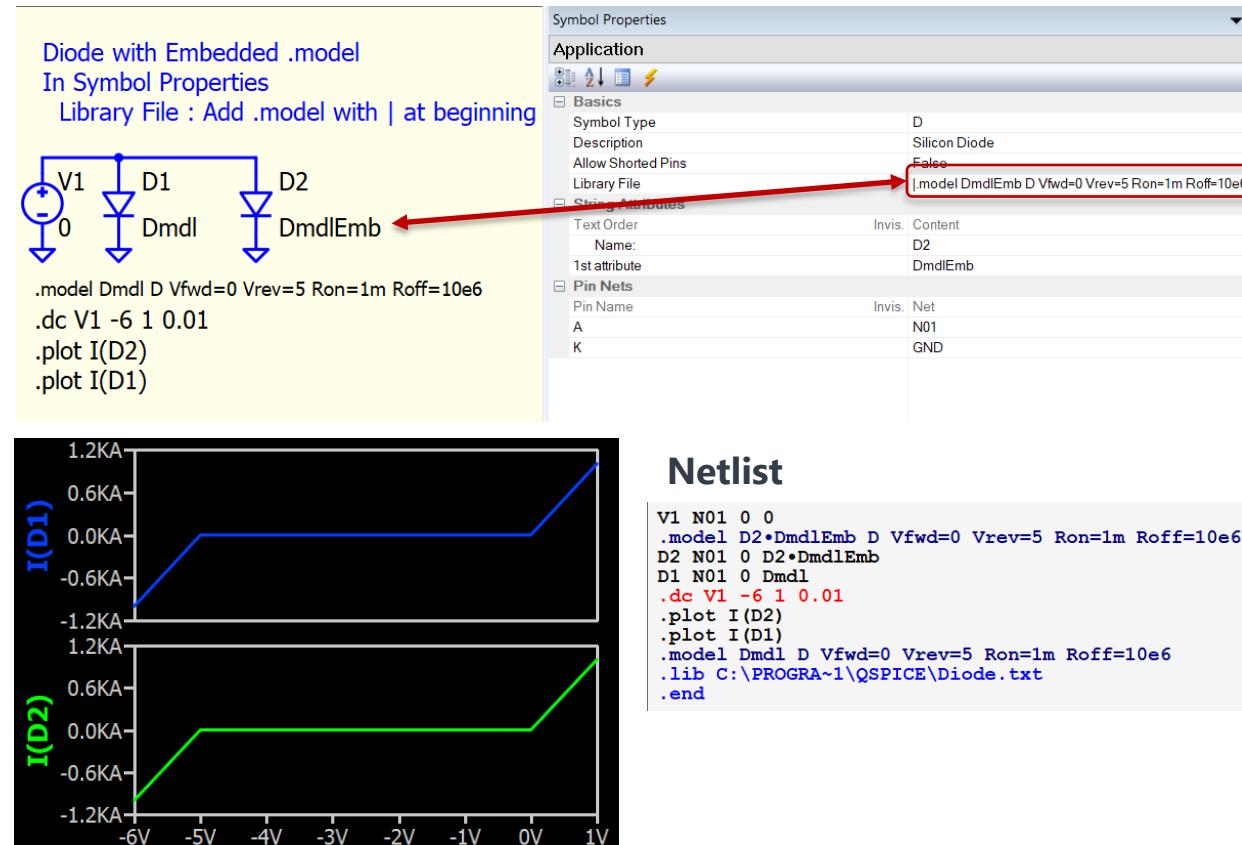
## **Part 2F**

### **Device with .model**

# Device with .model

Qspice : Diode - .model and embedded .model.qsch

- Device with .model
  - .model can be added with a text in schematic
  - For embedded .model, the symbol character “|” need to be added at beginning of .model in Symbol Properties > Library File
    - Without symbol “|”, .lib will be used in netlist to look for a library file name in this field
  - Alternative method
    - Copy .model statement, paste into schematic with autogenerate symbol method



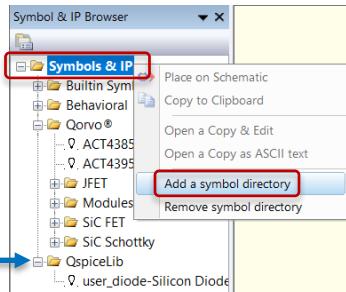
# Schematic Viewer

# Selection Guide for Qspice symbols and library files

1. Assume user has a user-supplied library files in C:\QspiceLib



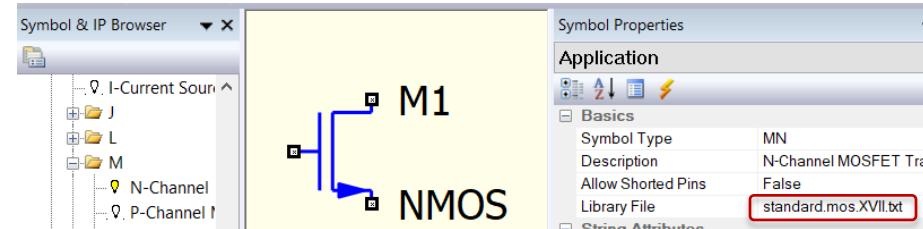
2. In Qspice : View > Symbol & IP Browser
  - Right click "Symbols & IP", Add a symbol directory
  - Add C:\QspiceLib



\*\* If a path without .qsym, it will not show in Symbols & IP browser. But the path can still be added. **Right Click > Edit User-Supplied Directories** will shown that

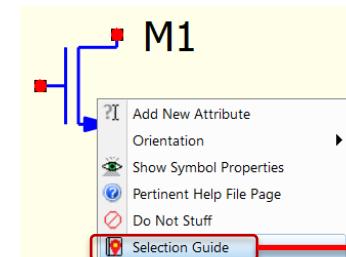
3. Place Qspice symbol to schematic

- Place Qspice symbol, replace Library File name with user-supplied library name



In this example, replace NMOS.txt to standard.mos.XVII.txt

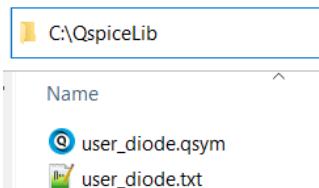
4. Selection Guide



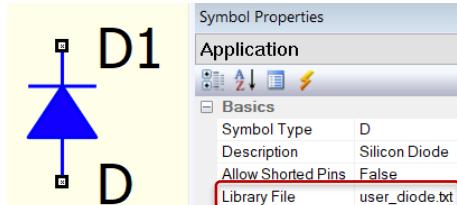
| P/N        | Manufacturer | Vds[V] | Ids[A]   | Rds(on)[mΩ] | Qg[nC] |
|------------|--------------|--------|----------|-------------|--------|
| VT6K1_AB   | ROHM         | 20     | 3000.0   | 0.7         |        |
| FDY301N_AB | Fairchild    | 25     | 5000.0   | 0.7         |        |
| KP505A     | USSR         | 50     | 300.0    |             |        |
| kp505g     | USSR         | 8      | 1000.0   |             |        |
| KP301B     | USSR         | -20    | 100000.0 |             |        |
| KP305      | USSR         | 15     |          |             |        |
| KP723A     | INTEGRAL     | 60     | 28.0     |             |        |
| KP723G     | INTEGRAL     | 60     | 28.0     |             |        |
| KP501A     | USSR         | 240    | 10000.0  |             |        |

# Selection Guide for user-supplied symbols and library files

1. Assume user has a user-supplied symbols and library files in C:\QspiceLib

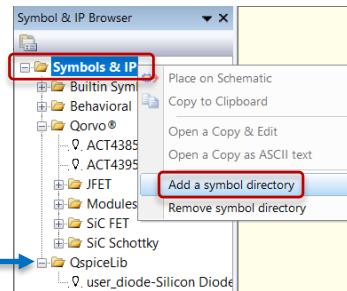


[1] Symbol and Library in same directory



[2] Library File in user symbol is library name (e.g. user\_diode.txt)

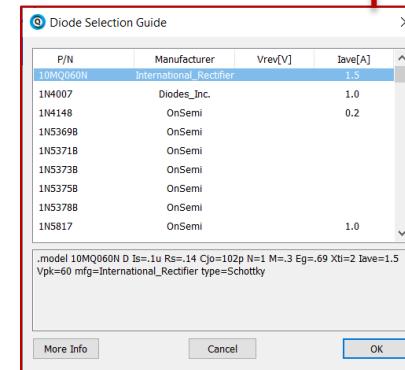
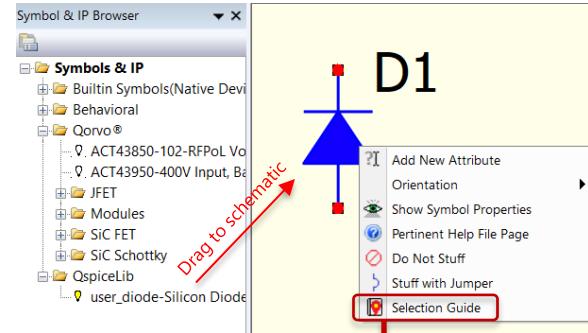
2. In Qspice : View > Symbol & IP Browser
  - Right click "Symbols & IP", Add a symbol directory
  - Add C:\QspiceLib



When add a symbol directory, it will add following in netlist .libpath "C:\QspiceLib" →

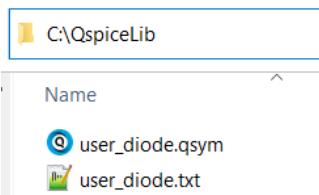
3. Drag user symbol to schematic

- Right click on symbol, "Selection Guide" is available

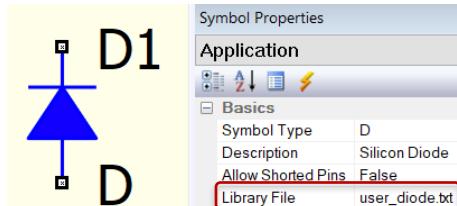


# Eliminate the use of absolute path in user-symbols

1. Assume user has a user-supplied symbols and library files in C:\QspiceLib

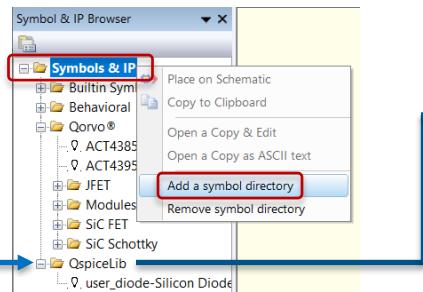


[1] Symbol and Library in same directory



[2] Library File in user symbol is library name (Not absolute path)

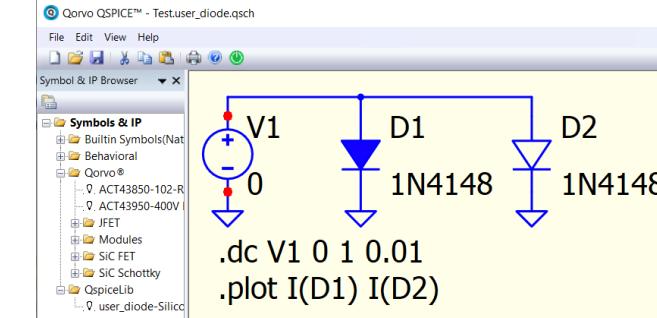
2. In Qspice : View > Symbol & IP Browser
  - Right click "Symbols & IP", Add a symbol directory
  - Add C:\QspiceLib



When add a symbol directory, it will add following in netlist  
.libpath "C:\QspiceLib"

3. Draw a schematic in other folder

- Now you can use user-symbol or Qspice symbol but change library file from diode.txt to user\_diode.txt



```
V1 N01 0 0
D1 N01 0 1N4148
.dc V1 0 1 0.01
.plot I(D1)
.lib user_diode.txt
.end
```

## Qspice search path for files

1. If specified as an absolute path, only that is used.
2. Current working directory
3. Directories supplied in .libpath command(s)
4. QSPICE installation directory

# Waveform Viewer

# Waveform Viewer Plot Config File (\*.pfg) and .plot directive

- Waveform Viewer Config File (\*.pfg) and .plot
  - In waveform viewer, plot config can be saved with File > Save Config : [qschname].pfg
    - This config file save windows, traces and axis setting
    - Press spacebar in waveform viewer can re-load config file [qschname].pfg
  - Two unique feature [qschname].pfg can provide but not support by .plot
    - Pre-define x-axis Quantity
    - Pre-define x and y-axis range

| Waveform Viewer          | Plot Config File [1]<br>[qschname].pfg | .plot command<br>in schematic | Outcome  |
|--------------------------|--|-------------------------------|--|
| Closed before Simulation | No                                     | No                            | A blank waveform viewer  |
|                          | No                                     | Yes                           | Plot according to .plot command                                    |
|                          | Yes                                    | [ignore]                      | Plot according to [qschname].pfg config                            |
| Opened before Simulation | [ignore]                               | [ignore]                      | Keep windows and traces setting from last plot, reset x and y-axis |

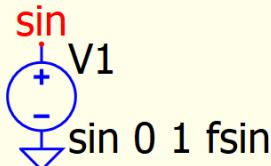
[1] Save plot config in Waveform Viewer : File > Save Config

\*\* In Waveform Viewer, press Spacebar to reload [qschname].pfg plot config file

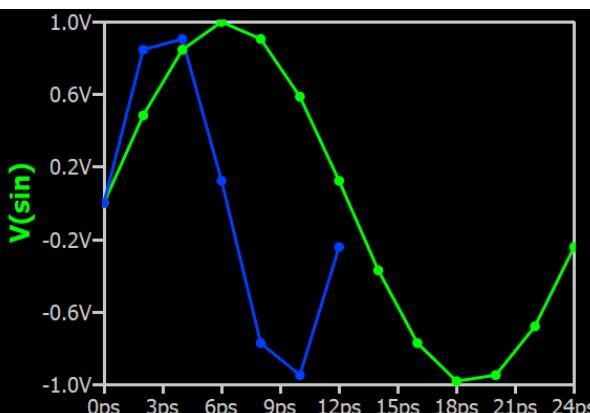
\*\* to use .plot, delete [qschname].pfg and close waveform viewer before run of simulation

# Data Export in Waveform Viewer – with @ in expression for .step

Qspice : waveform - with @ for step.qsch



```
.step param fsin list 40G 80G  
.tran 1/fsin  
.plot V(sin)
```



- Data Export
- Setup Data Export
  - File > Export Data
  - Number Points : All
  - Expression(s) : V(sin),FSIN
- Data Export with @
  - File > Export Data
  - Number Points : All
  - Expression(s) : V(sin)@1,V(sin)@2

```
Time,V(sin),FSIN  
0,0,400000000000  
2.001953125e-12,0.482183772079123,400000000000  
4.00390624999999e-12,0.844853565249706,400000000000  
6.00585937500001e-12,0.998118112900149,400000000000  
8.00781250000003e-12,0.903989293123441,400000000000  
1.0009765625e-11,0.58579785745643,400000000000  
1.20117187500001e-11,0.122410675199201,400000000000  
1.40136718750001e-11,-0.371317193951856,400000000000  
1.6015625e-11,-0.773010453362737,400000000000  
1.80175781249999e-11,-0.983105487431211,400000000000  
2.00195312499998e-11,-0.949528180593055,400000000000  
2.20214843749997e-11,-0.680600997795516,400000000000  
2.4023437499995e-11,-0.242980179903377,400000000000  
0,0,800000000000  
2.001953125e-12,0.844853565249706,800000000000  
4.00390625000001e-12,0.903989293123441,800000000000  
6.00585937500003e-12,0.122410675199201,800000000000  
8.0078125e-12,-0.773010453362736,800000000000  
1.00097656249999e-11,-0.949528180593055,800000000000  
1.20117187499998e-11,-0.242980179903377,800000000000
```

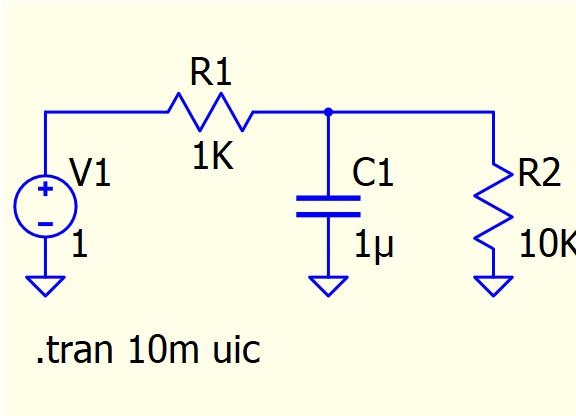
```
Time,V(sin)@1,V(sin)@2  
0,0,0  
2.001953125e-12,0.482183772079123,0.844853565249706  
4.00390624999999e-12,0.844853565249706,0.903989293123441  
6.00585937500001e-12,0.998118112900149,0.122410675199201  
8.00781250000003e-12,0.903989293123441,-0.773010453362739  
1.0009765625e-11,0.58579785745643,-0.9495281805930593  
1.20117187500001e-11,0.122410675199201,-0.596254180248215  
1.40136718750001e-11,-0.371317193951856,-0.596254180248215  
1.6015625e-11,-0.773010453362737,-0.596254180248215  
1.80175781249999e-11,-0.983105487431211,-0.596254180248215  
2.00195312499998e-11,-0.949528180593055,-0.596254180248215  
2.20214843749997e-11,-0.680600997795516,-0.596254180248215  
2.4023437499995e-11,-0.242980179903377,-0.596254180248215  
0,0,0  
2.001953125e-12,0.482183772079122,0.844853565249706  
4.00390625000001e-12,0.844853565249707,0.903989293123441  
6.00585937500003e-12,0.998118112900148,0.122410675199201  
8.0078125e-12,-0.773010453362736,-0.773010453362736  
1.00097656249999e-11,0.585797857456455,-0.949528180593055  
1.20117187499998e-11,0.122410675199269,-0.242980179903377
```

# Snapshot Data Method – Export Data with Single Number Points

Qspice : waveform - time snapshot.qsch

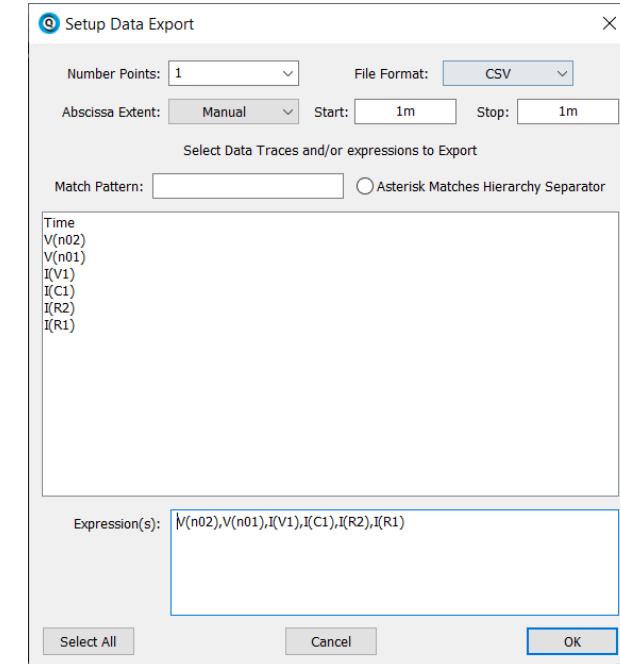
- Snapshot Data

- To create a snapshot dataset (e.g. all calculated results at particular time)
- This example demonstrate a snapshot data in csv format with export data method
- Idea is to force number points in data export to 1
  - Output two row but both are identical if start and stop are same
  - If start and stop are not same, output two row with time=start and time=stop



In waveform viewer

1. File > Export Data
2. Change Number Points to 1
3. File Format : CSV
4. Abscissa Extent : 1, Start = Stop
5. Select All



Result in exported csv

| Time  | V(n02) | V(n01)   | I(V1)    | I(C1)    | I(R2)    | I(R1)    |
|-------|--------|----------|----------|----------|----------|----------|
| 0.001 | 1      | 0.606398 | -0.00039 | 0.000333 | 6.06E-05 | 0.000394 |
| 0.001 | 1      | 0.606398 | -0.00039 | 0.000333 | 6.06E-05 | 0.000394 |

# Data export in .ac analysis – Complex format

Qspice : waveform - complex format (.ac).qsch

- Data export in .ac analysis

- Data export in waveform viewer from .ac analysis is complex format

- In .qraw data file, Flags : complex

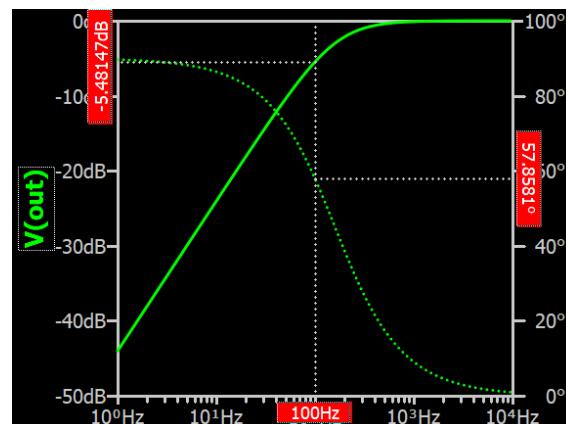
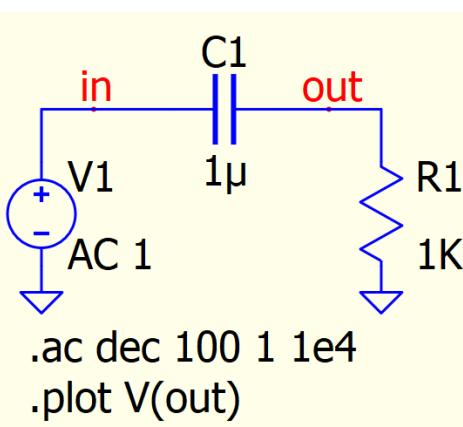
- Complex format data in ascii (.csv) is as R,X
  - where R is real and X is imaginary

- If assume data is complex voltage  $V_{complex} = V_r + jV_x$

- $|V_{complex}| = \sqrt{V_r^2 + V_x^2} = \text{abs}(V_{complex})$

- Magnitude in dB :  $V_{complex,dB} = 20 \log_{10} |V_{complex}| = 20 * \log_{10} (\text{abs}(V_{complex}))$

- $\angle V_{complex} = \tan^{-1} \frac{V_x}{V_r} = \text{atan2d}(\text{imag}(V_{complex}), \text{real}(V_{complex})) = \text{angle}(V_{complex}) * 180/\pi$



```
vout = 0.2830 + 0.4505i
vout_db = -5.4815 dB @ 100Hz
vout_ph = 57.8585 Phase @ 100Hz
```

| Frequency, V(out) | Real                 | Imaginary                            |
|-------------------|----------------------|--------------------------------------|
| 1                 | 3.94768591214272e-05 | 0.00628293726675837                  |
| 2                 | 1.02329299228075     | 4.13372692659287e-05                 |
| 3                 |                      |                                      |
| 4                 |                      |                                      |
| 5                 |                      |                                      |
| 6                 | 97.7237220955805     | 0.273792005193308, 0.445903513201606 |
| 7                 | 99.9999999999995     | 0.2830431996751, 0.450477243368387   |
| 8                 | 102.329299228075     | 0.292481088087185, 0.45490207869224  |
| 9                 | 104.712854805089     | 0.302101072770688, 0.459168830171961 |

@100Hz,  $V(\text{out}) = 0.28304 + j*0.45048$

# Waveform Viewer – FFT (Fast Fourier Transform)

Qspice : waveform - FFT.qsch

- FFT
  - Fast Fourier Transform (FFT) is a right-click option in waveform viewer
  - A Setup FFT window will pop up to select which expression for FFT, number of points (affect post-processing time), window function etc...

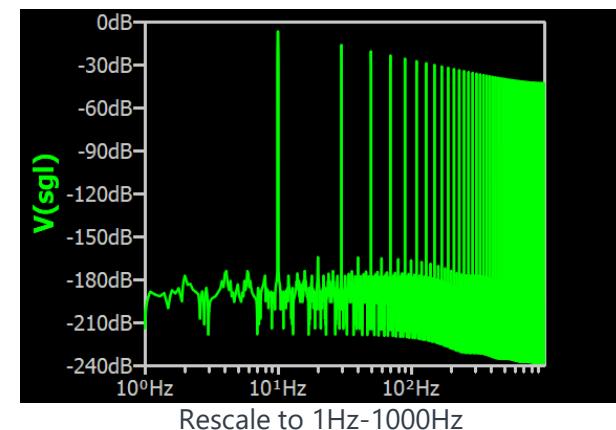
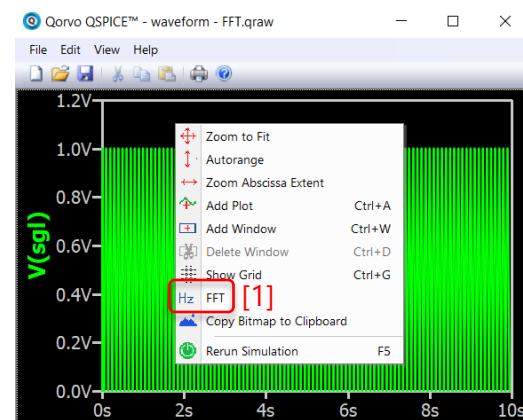
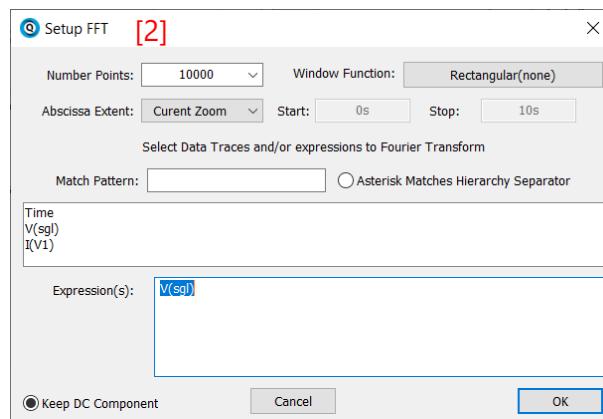
sgl  
V1

pulse 0 1 0 1n 1n duty/frq 1/frq

.param duty=0.5 frq=10

.tran 100/frq

.plot V(sgl)



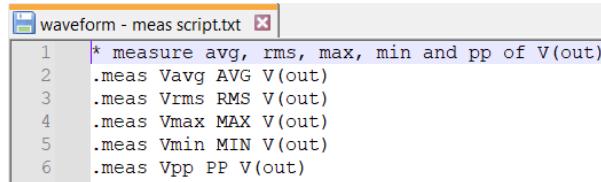
# Waveform Viewer – Run a .meas script

Qspice : waveform - meas script.qsch | waveform - meas script.txt

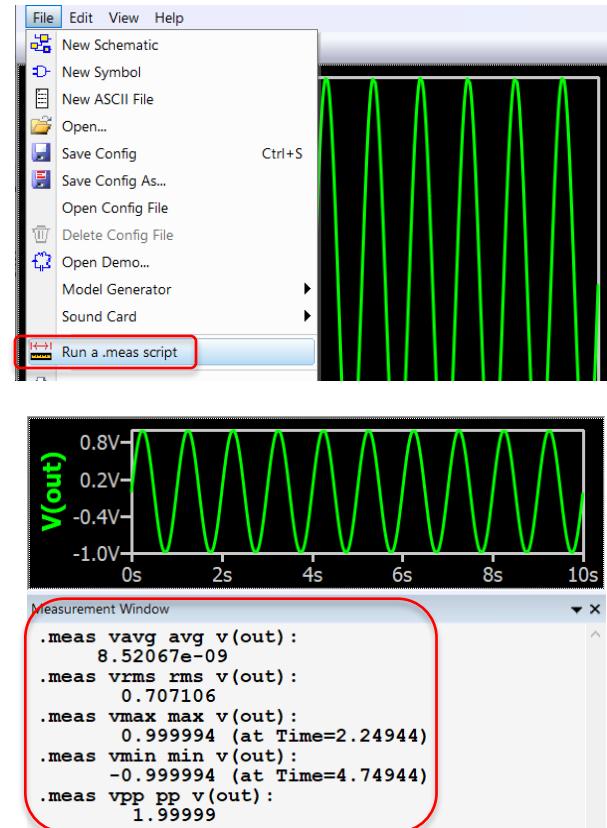
- Run a .meas script
  - File > Run a .meas script
    - load a .meas script from a text file to post-processing (QPOST.exe) the waveform
  - Preparation of .meas script
    - First line needs to be comment (add a \* at beginning) as this line will be ignored

.meas script in text file

\*\* first line needs to be comment



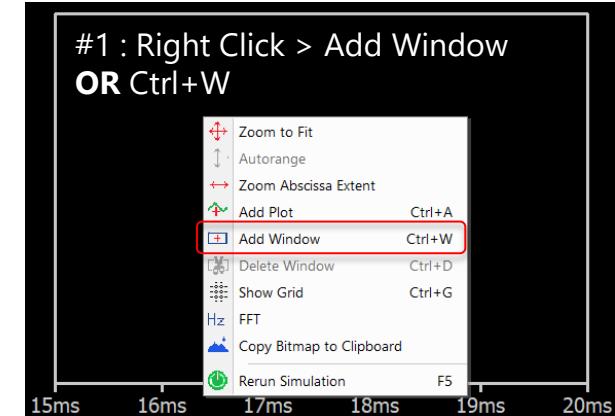
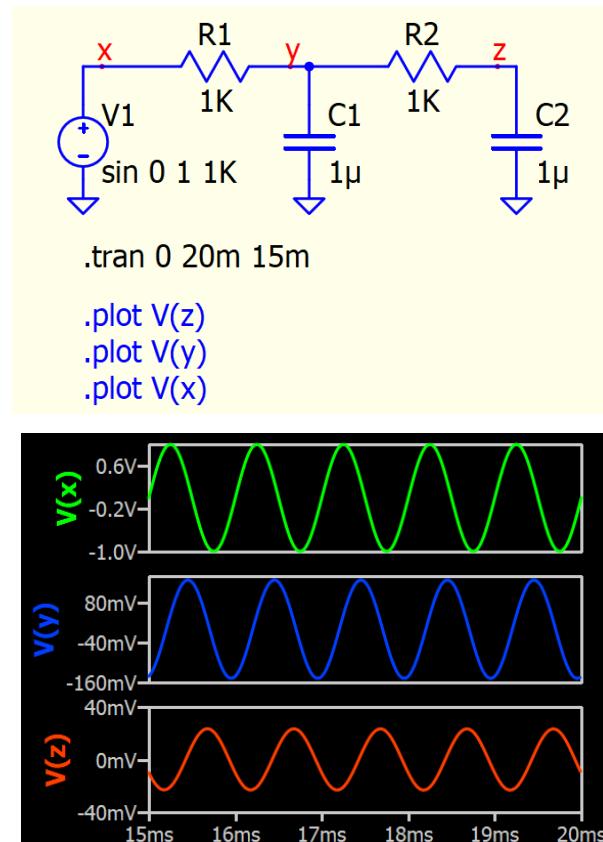
```
1 * measure avg, rms, max, min and pp of V(out)
2 .meas Vavg AVG V(out)
3 .meas Vrms RMS V(out)
4 .meas Vmax MAX V(out)
5 .meas Vmin MIN V(out)
6 .meas Vpp PP V(out)
```



# Waveform Viewer – Add Multiple Windows

Qspice : waveform - multiple windows.qsch

- Add Window
  - To plot multiple windows in a single waveform viewer, follow these steps in the Waveform Viewer
    - [1] Right Click > Add Window (or Ctrl+W)
    - [2] Click on the corresponding window and probe or add a plot
  - This can be automatically done with multiple .plot commands

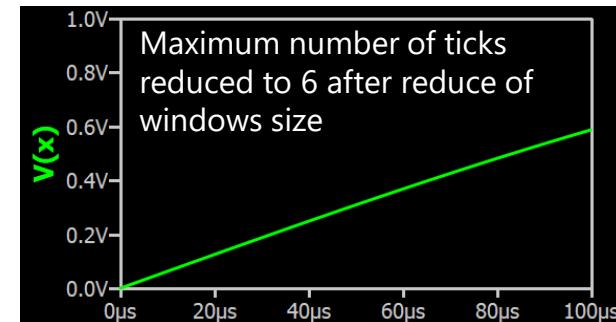
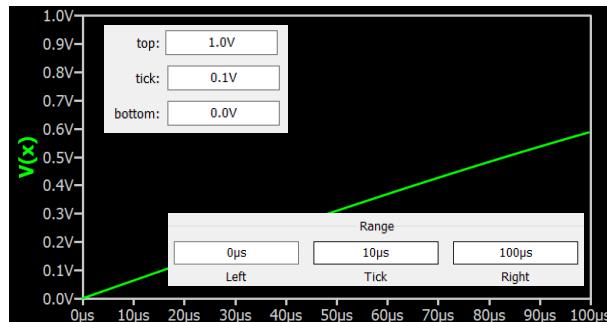


#2 : Click on corresponding windows and probe or add plot

# Waveform Viewer – Minimum Tick and Waveform Measure

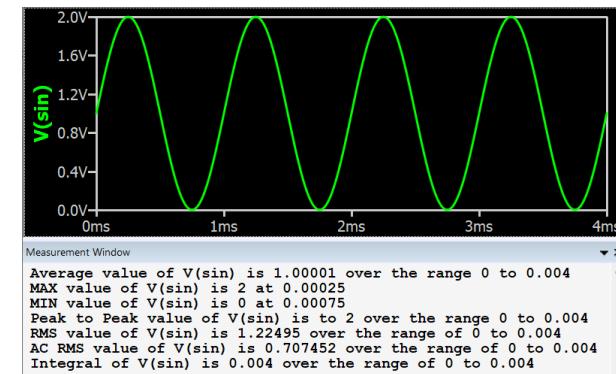
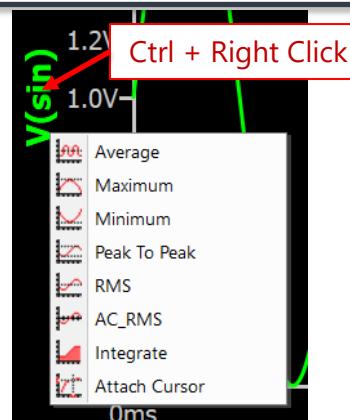
- Minimum Tick

- Maximum number of ticks in x- and y-axis are 11
- Depends on windows size, maximum number of ticks can reduce to 6
- Therefore, minimum allowable tick is  $\frac{\text{Right}-\text{Left}}{10}$  or  $\frac{\text{top}-\text{bottom}}{10}$



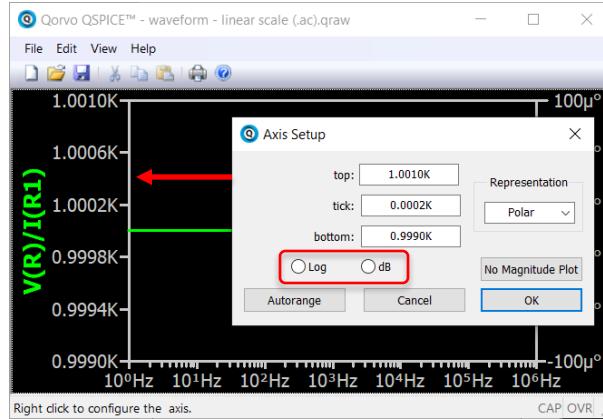
- Waveform Measure

- Ctrl + Right Click on plot label
- 7-types of measurement
  - Average
  - Maximum
  - Minimum
  - Peak-to-Peak
  - RMS
  - AC\_RMS
  - Integrate

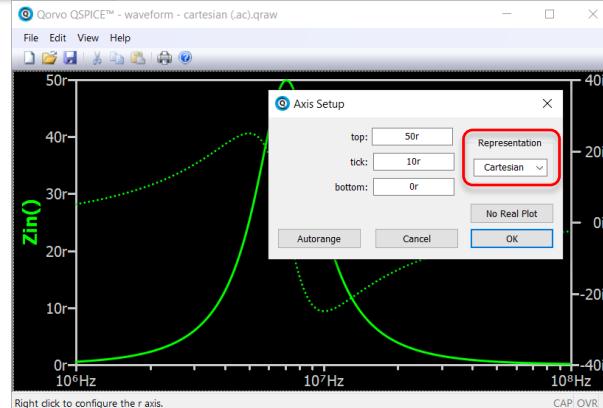


# Waveform Viewer – Linear Scale in .AC, Polar vs Cartesian

- Linear Scale in .ac
  - Right Click on Y-axis
  - In Axis Setup, de-select both Log and dB
  - In Polar representation, left y-axis is magnitude which represent value is always absolute (no negative value)



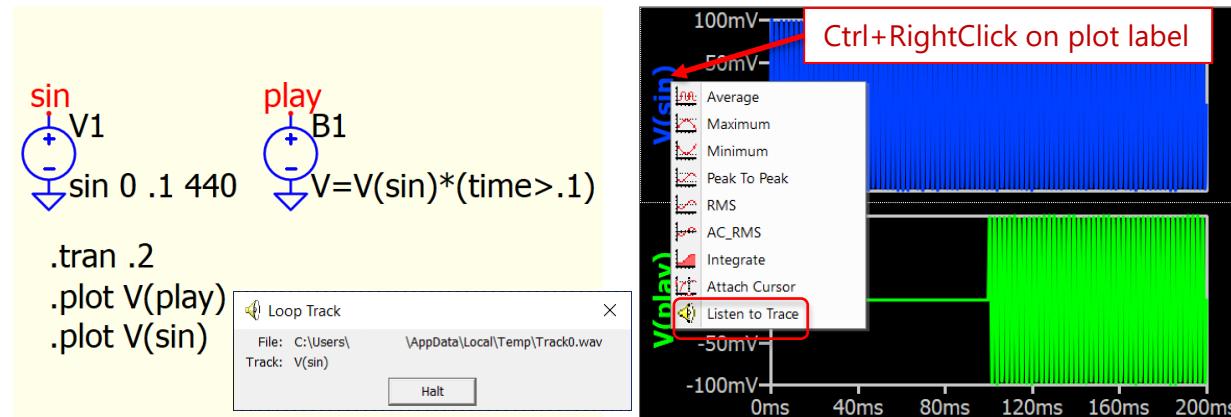
- Polar vs Cartesian
  - Waveform viewer default representation of .ac is Polar representation (mag,phase)
  - Right Click on Y-axis to change to Cartesian representation (real,imag)
  - Polar is normally for bode plot and cartesian is for impedance plot



# Waveform Viewer – Listen to Trace

Qspice : waveform - Listen to Trace.qsch

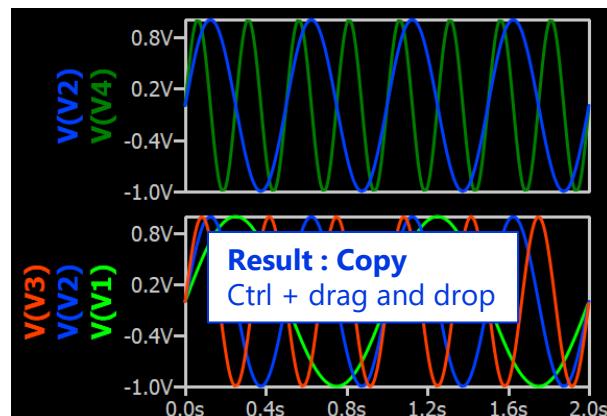
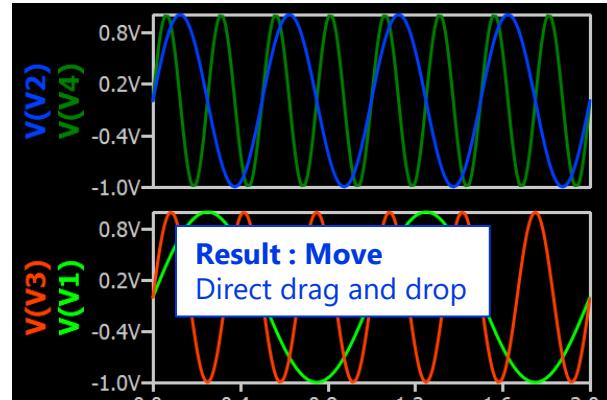
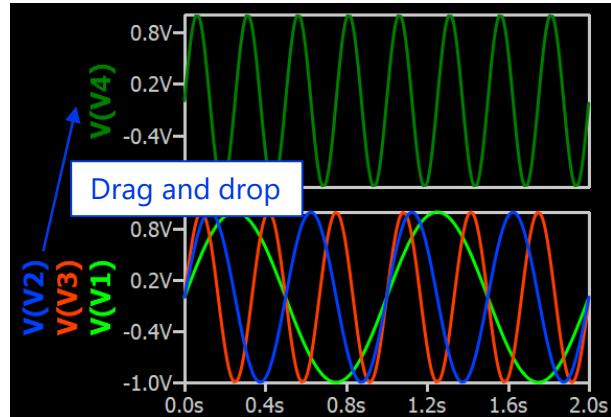
- Listen to Trace
  - Send a time domain data trace to the sound card
    - This option is only available for data  $\geq 1\text{ms}$
  - In waveform window, **Ctrl + Right Click** on the plot label, then select **Listen to Trace**
  - The playback keeps looping



# Traces manipulation

Qspice : waveform - drag traces.qsch

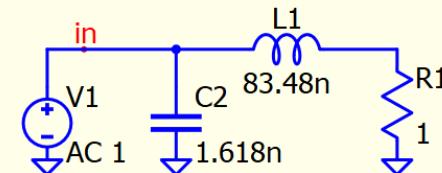
- Traces manipulation
  - Delete
    - Click a trace label, press delete
  - Cut and Paste
    - Click a trace label
    - Copy : Ctrl+C
    - Cut : Ctrl+X
    - Paste : Ctrl+V
  - Drag and Drop (Move)
    - Left click to drag and drop
  - Drag and Drop (Copy)
    - Hold Ctrl + Left click to drag and drop



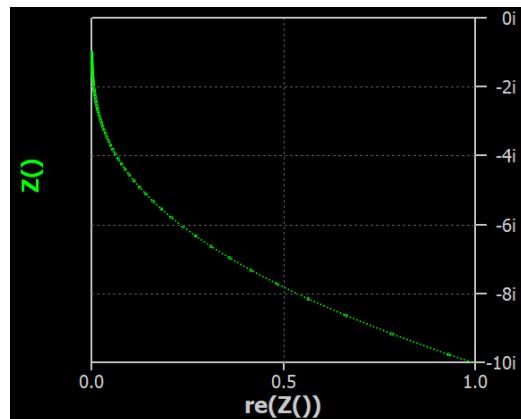
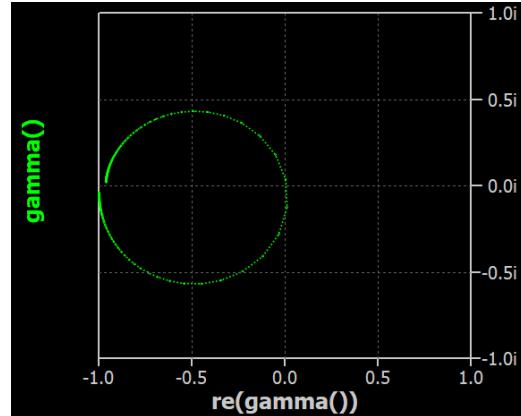
# Waveform Viewer – Plot Reflection Coefficient ( $\Gamma$ )

Qspice : waveform - cartesian (Gamma).qsch

- Impedance Trajectory
  - .ac analysis can be used to calculate impedance Z or reflection coefficient
$$\Gamma = \frac{Z - Z_o}{Z + Z_o}$$
  - Trajectory can be plot with Cartesian plot by setting x-axis to plot real part and y-axis to plot imaginary part
    - Right-axis : Cartesian
    - Left-axis : No Real Plot
    - X-axis : Quantity changed to Re(<var>)

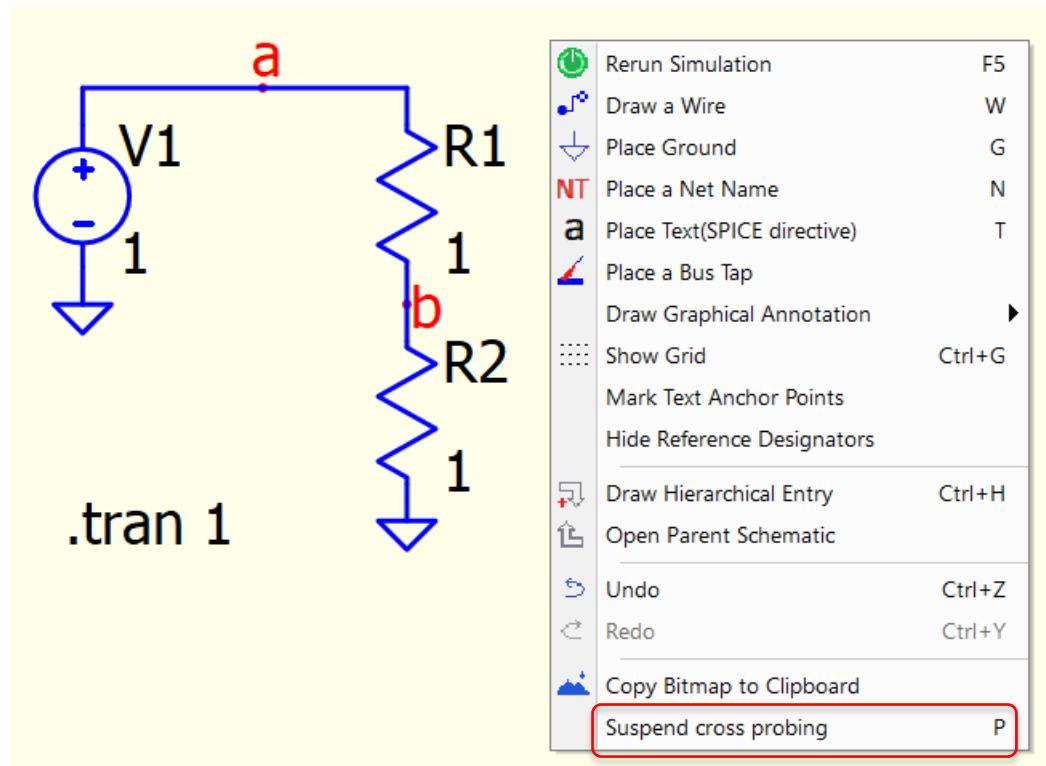


```
.ac dec 100 1Meg 100Meg  
; Calculate Reflection Coefficient  
.func Z() V(in)/-I(V1)  
.func gamma() (Z()-50)/(Z()+50)  
.plot gamma()
```



# Waveform Viewer – Suspend Cross Probing (Shortcut : P)

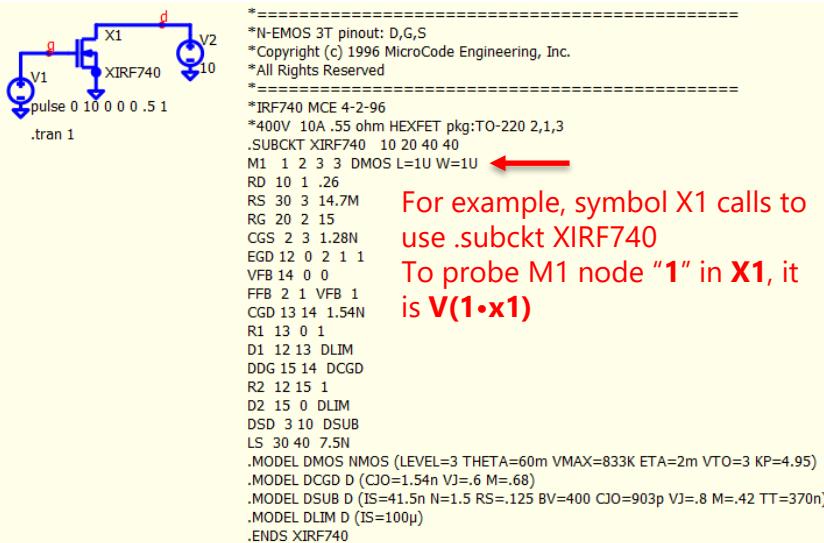
- Suspend cross probing
  - After a simulation run, a new trace can be inserted into the waveform viewer by clicking on a node or device, but this action may unintentionally disrupt the waveform configuration
  - To edit a schematic without altering the waveform setup, right-click in the schematic window and select "Suspend Cross-Probing"
    - This option will only appear in an active waveform window that has cross-probing to the schematic after a simulation run



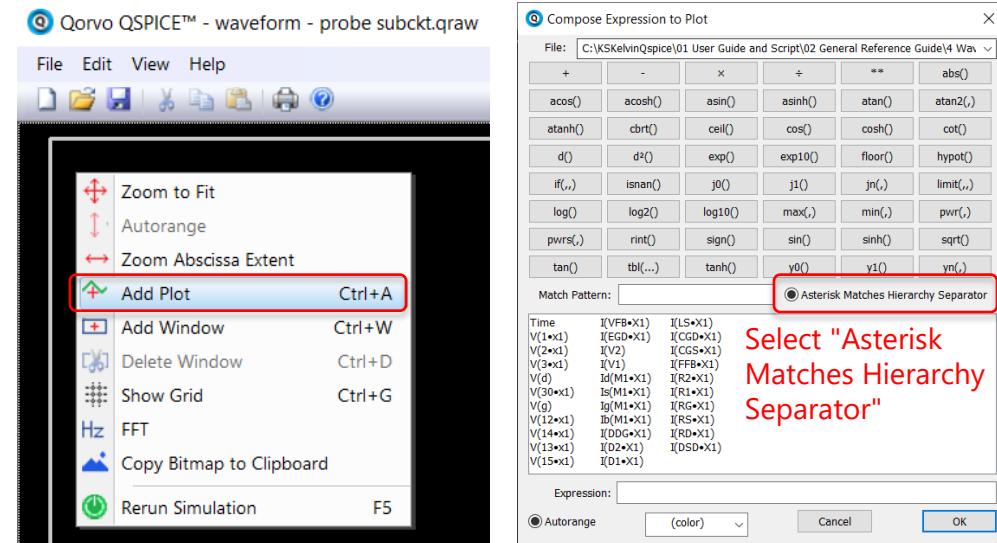
# Probe .subckt or hierarchy voltage and current

Qspice : waveform - probe subckt.qsch

- Probe .subckt or hierarchy voltage and current
  - In default, Qspice only returns parent schematic voltage and current expression
  - However, if you open a .qraw data file, you can observe that the voltage and current expressions for .subckt or hierarchical components are stored, such as in the format V(1•x1)
  - In the waveform viewer, **right-click > add plot > "Asterisk Matches Hierarchy Separator"** to enable probing into subckt or hierarchical components



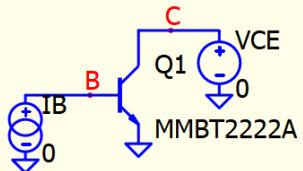
For example, symbol X1 calls to use .subckt XIRF740  
To probe M1 node "1" in X1, it is **V(1•x1)**



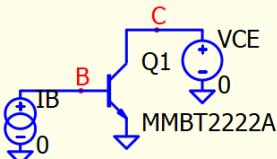
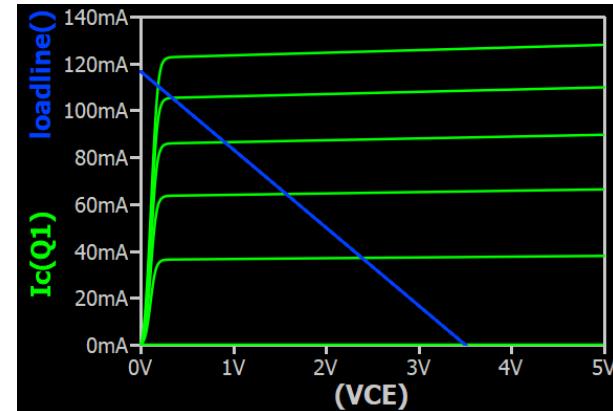
# Waveform Viewer – Draw a Line

Qspice : waveform - draw loadline.qsch | waveform - draw line with table.qsch

- Draw a Line
  - .func can be used to plot a line in the waveform viewer where this line follows a mathematical formula or table relationship

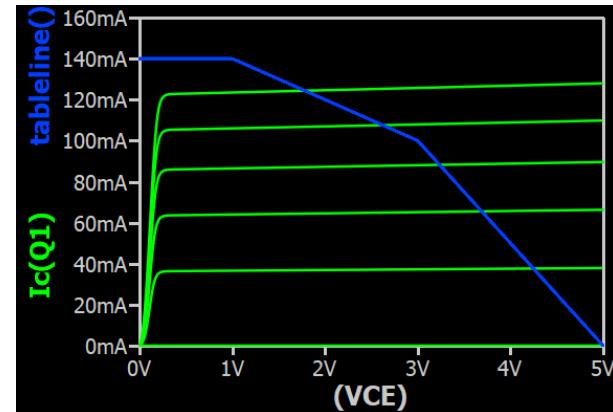


```
.dc VCE 0 5 0.01 IB 0 1m 1m/5  
.param VCC=3.5  
.param RL=30  
.func loadline() (-1/RL*V(C)+VCC/RL)/1V*1A  
  
.plot Ic(Q1) loadline()
```



```
table  
B1  
V=table(V(C),0,0.14, 1,.14, 3,.1, 5,0)  
.func tableline() V(table)/1V*1A
```

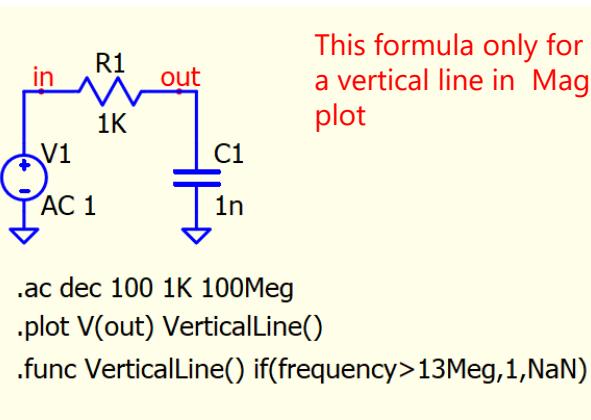
```
.dc VCE 0 5 0.01 IB 0 1m 1m/5  
.plot Ic(Q1) tableline()
```



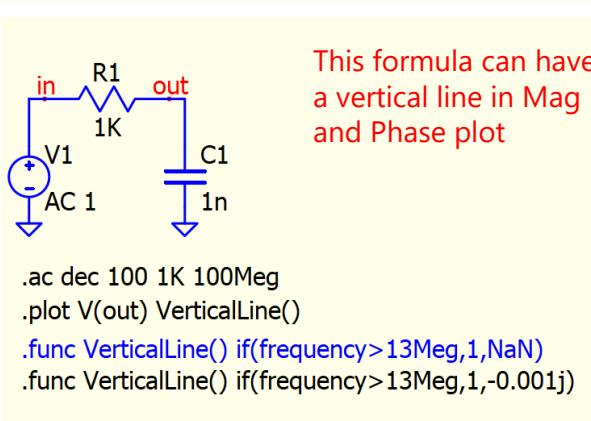
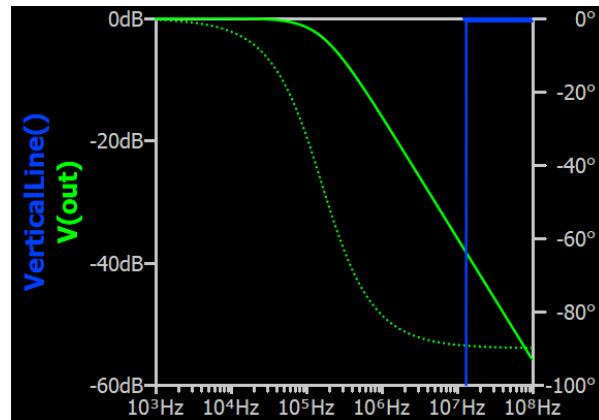
# Waveform Viewer – Draw a Line

Qspice : waveform - draw vertical line.qsch

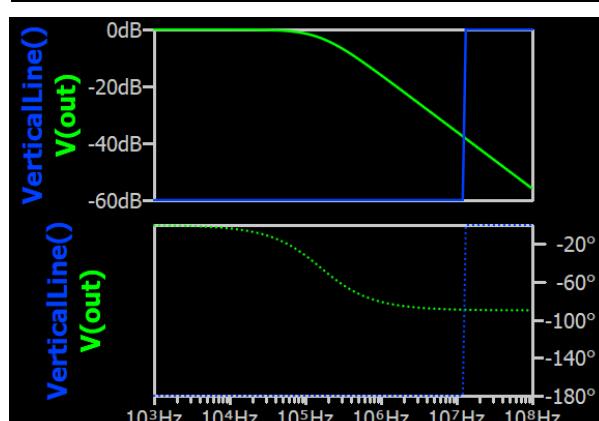
- Draw a Line
  - Example to draw vertical line with if(x,y,z) function



This formula only for a vertical line in Mag plot



This formula can have a vertical line in Mag and Phase plot

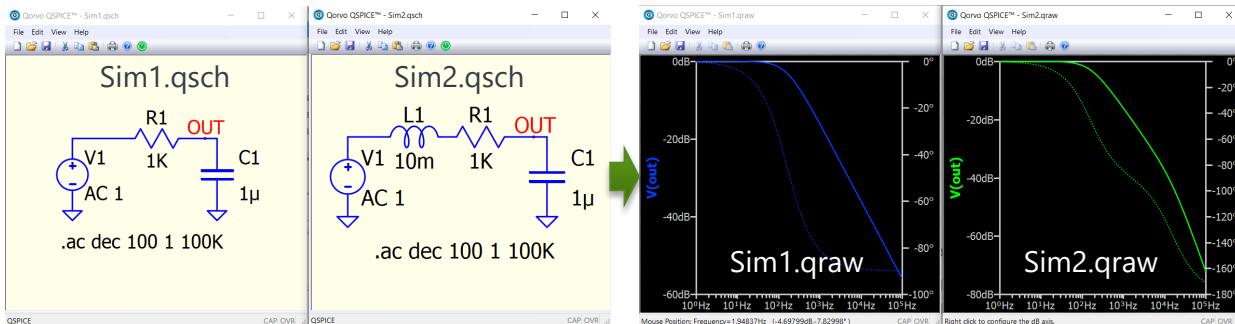


# Waveform Viewer – Overlay (method 1)

Qspice : (Folder : overlay) Sim1.qsch | Sim2.qsch

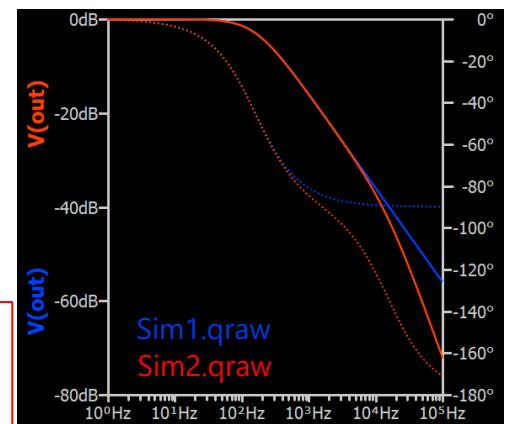
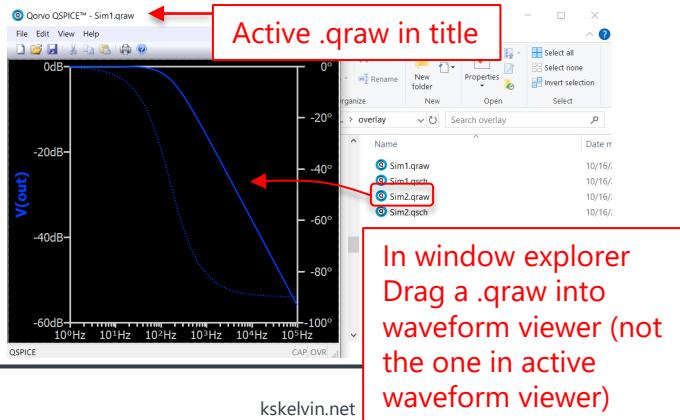
- Overlay – method 1
  - In waveform viewer, multiple .qraw data files can be drag into waveform viewer for overlay comparison
  - In an overlay condition
    - Ctrl-L : toggle plotting overlay data, it can toggle .qraw data which drag into active waveform viewer
    - Ctrl-O : manage overlay datasets

Step 1 : Run simulation (e.g. two different .qsch) to generate multiple .qraw data files



Step 2

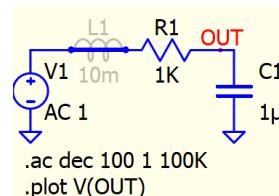
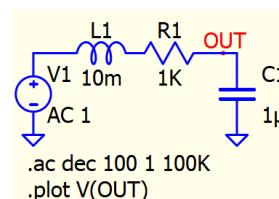
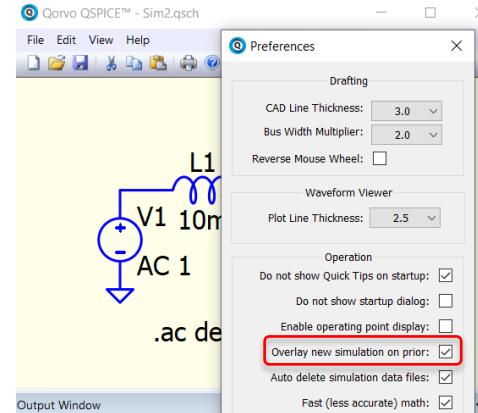
- Keep one active waveform viewer
- Drag other .qraw into this waveform viewer



# Waveform Viewer – Overlay (method 2)

Qspice : (Folder : overlay) Sim2.qsch

- Overlay – method 2
  - In Preferences, enable “Overlay new simulation on prior”
  - Now, each time you run simulation, it will generate a new .qraw with [fname].n.qraw, where n = 0,1,2,3,...



Run simulation to generate xxx.0.qraw

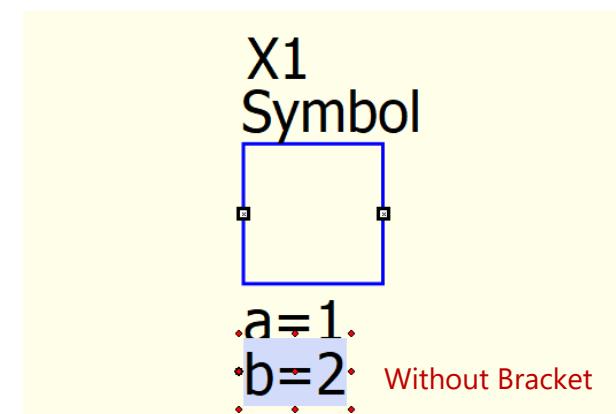
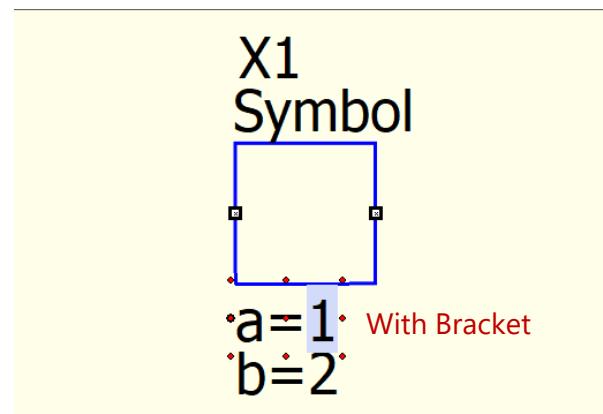
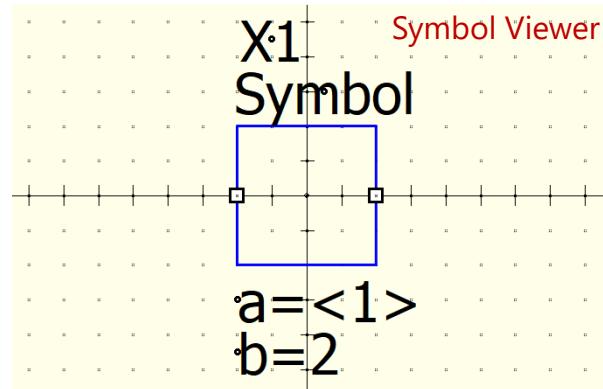
Change something, Run simulation to generate xxx.1.qraw

\*\* Right click can view its .qraw name  
Compose Expression to Plot

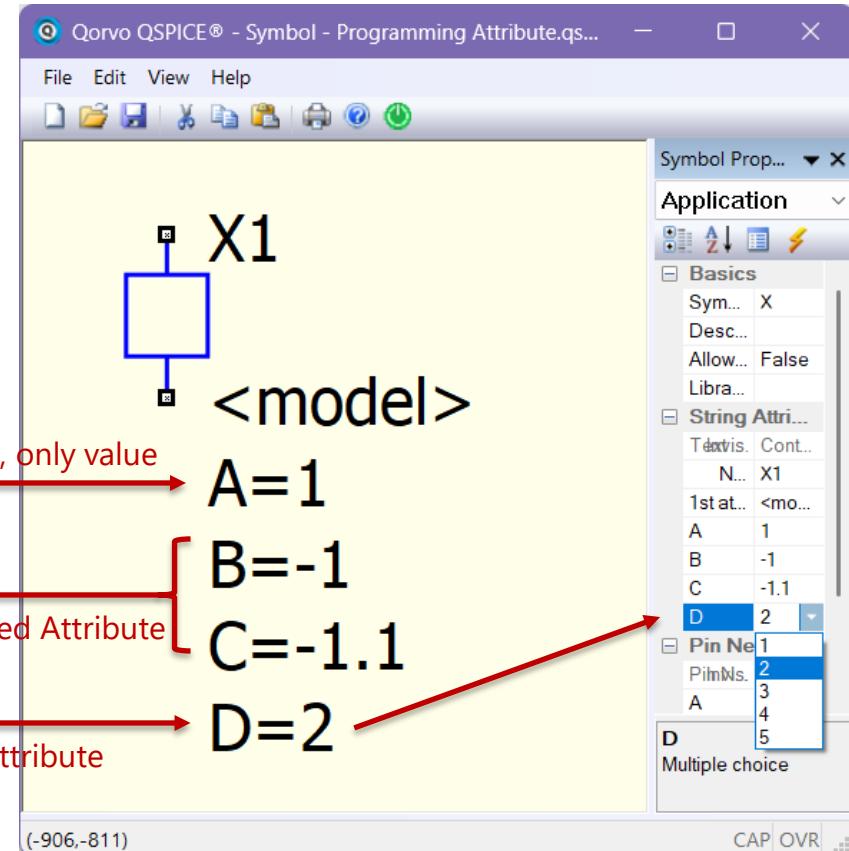
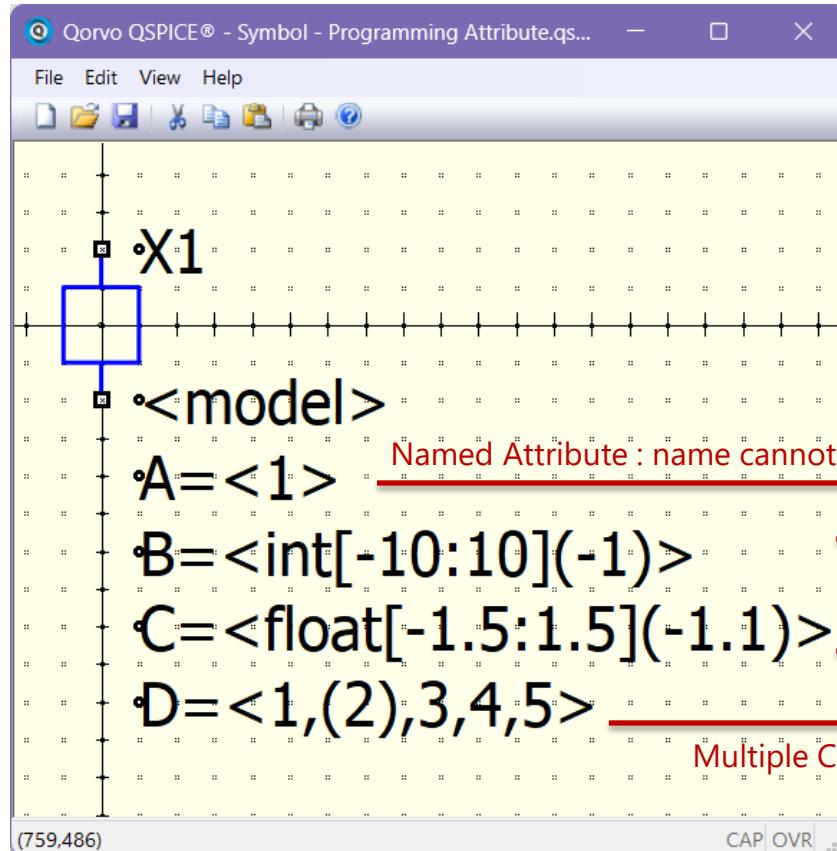
# Symbol Viewer

# Attribute with Angle Brackets < >

- Attribute with brackets
  - The 1st attribute of a symbol is its model name, and starting from the 2nd attribute are the instance parameters
  - When angle brackets (< >) are used for instance parameters, they can restrict the user-editable section of the text attribute
  - Each attribute only allows for one bracket; any text after the bracket is ignored

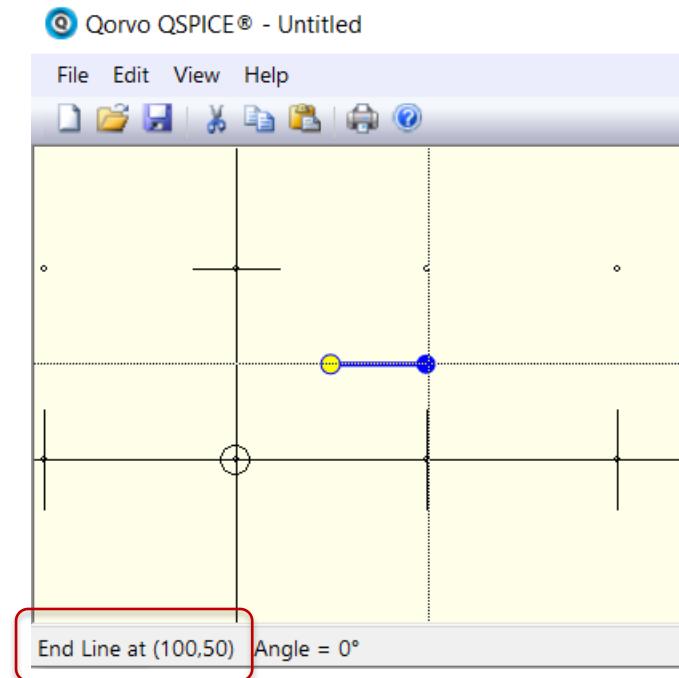


# Programming Attributes



# Placement Resolution in Symbol Window

- Placement Resolution
  - In the symbol window, coordinates are displayed in status bar
  - To place an arc, box, line etc., the minimum resolution can be changed by holding the **Ctrl**, **Alt** or **Shift** key as follows
    - No holding key : step by 50
    - Holding one key : step by 10
    - Holding any two keys : step by 5
    - Holding all three keys : step by 1
  - However, Pin always stick to the major grid, which is set at a step of 100



# Simulation Technique

# Max Time Step in .tran (and .bode) : Two methods

Qspice : MaxTimeStep.qsch

V1G



`.plot V(V1G)`

Method 1 : Traditional Berkeley Syntax

`.tran IGNORED TSTOP [TSTART [MAXSTEP]] [UIC]`

`.tran 0 10n 0 10p`

↑ Max Time Step

Method 2 : MAXSTEP in Simulator Option

`.tran 10n`

`.options MAXSTEP=10p`

↑ Max Time Step  
(this method apply to .tran and .bode)

400mV

300mV

200mV

100mV

0mV

-100mV

\*\* Qspice uses adaptive step size algorithms, each time step can less than maximum time step size

V(V1G)

0ps

10ps

20ps

30ps

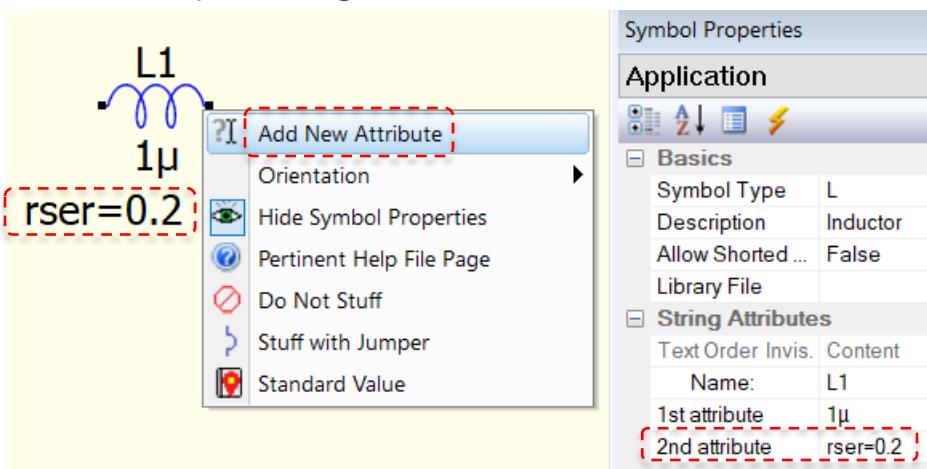
40ps

50ps

# Add Attribute [e.g. add instance parameters]

1. Right Click on Component
2. Select "Add New Attribute"
3. Type parameter name and value [refer to help for full list of instance parameters]

This is an example to assign 0.2 ohms series resistance to inductor L1



Inductor Instance Parameters

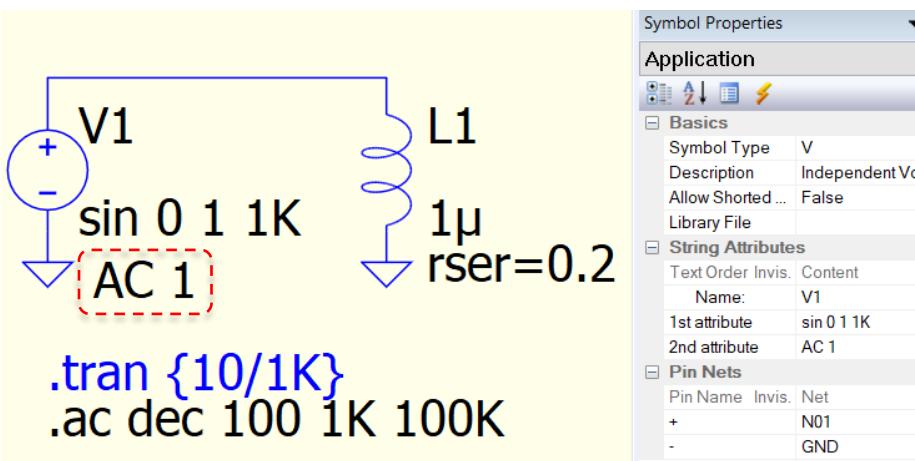
| Name       | Description   | Units | Default           |
|------------|---|-------|-------------------|
| AG         | Wire or stripline is made of gold                                   |       |                   |
| AL         | Wire or stripline is made of aluminum                               |       | see below         |
| AU         | Wire or stripline is made of silver                                 |       |                   |
| BEND       | Fractional inductance correction for wire bend or proximity effects |       | 1.                |
| CPAR       | Parallel capacitance  | F     | 0.                |
| CU         | Wire or stripline is made of copper                                 |       | see below         |
| DIAMETER   | Diameter of wire or air coil  | m     |                   |
| FREQUENCY  | Frequency at Q. Also used to compute Rser due to skin effect        |       |                   |
| HEIGHT     | Height of PCB stripline above ground plane                          | m     |                   |
| IC         | Initial current if uic is specified on .tran statement              | A     | none              |
| INDUCTANCE | Inductance of inductor  | H     | 0.0               |
| ISAT       | Current causing inductance to drop to SATFRAC×INDUCTANCE            | A     | Infinite          |
| LENGTH     | Length of wire, stripline, or air coil                              | m     |                   |
| LSAT       | Inductance asymptotically approached in saturation                  | H     | 10% of INDUCTANCE |
| M          | Number of parallel inductors  |       | 1.0               |
| NI         | Wire is made of nickel  |       |                   |
| Q          | Quality factor at FREQUENCY   |       |                   |
| RPAR       | Equivalent parallel resistance                                      | Ω     | Infinite          |
| RSER       | Equivalent series resistance  | Ω     | 0.0               |
| SATFRAC    | Fractional drop in inductance at ISAT                               |       | 0.7               |
| THICK      | Thickness of stripline on top of a PCB                              | m     | 0.0               |
| TURNS      | Number of turns of an air coil                                      |       |                   |
| VERBOSE    | Print wire L, Rser, Rpar results on the console                     |       | (not set)         |
| WIDTH      | Width of stripline on top of a PCB                                  | m     |                   |

# AC and DC Attribute in Source

Qspice : AC with Transient Source.qsch ; AC with Bias.qsch

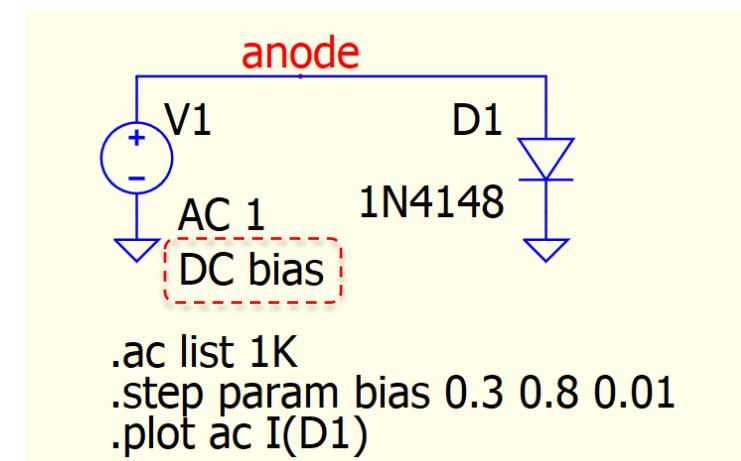
## Technique to perform AC analysis with a transient source

1. Right Click on Voltage/Current source
2. Select "Add New Attribute"
3. Type "AC 1" to define a 1V source for AC sweep
4. Add a .ac analysis statement, and comment transient analysis



## Technique to perform AC analysis with DC in source

1. Right Click on Voltage/Current Source, Add New Attribute
2. To add DC source, type "DC ..."
  - If without DC, simulator may not interpret the DC voltage during simulation. Best practice is to add DC



# Laplace Time and Frequency Domain Simulation

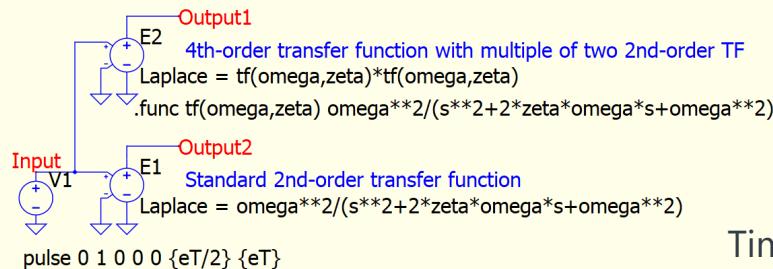
Qspice : Laplace Simulation - Fdomain.qsch ; Laplace Simulation - Tdomain.qsch

2nd-order system step response

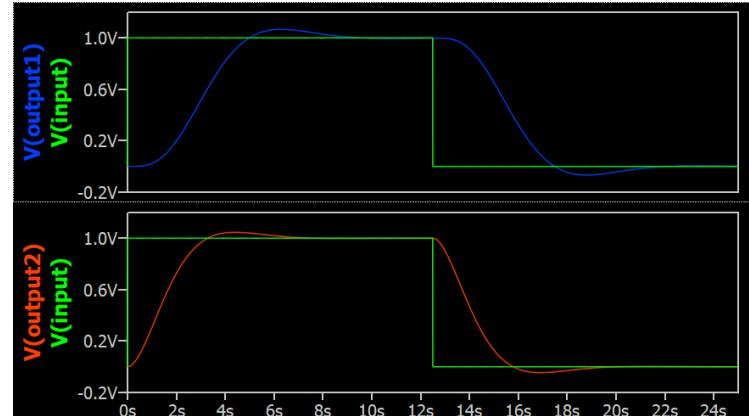
transfer function :  $\omega^2/(s^2+2\zeta\omega s+\omega^2)$

```
.param zeta = 0.7
.param omega = 1
```

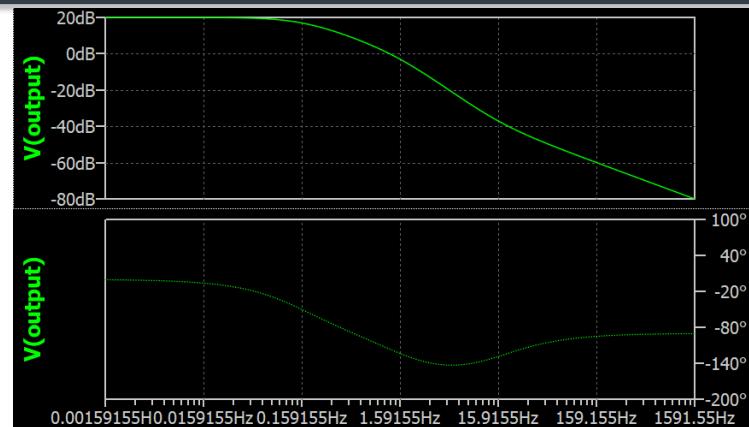
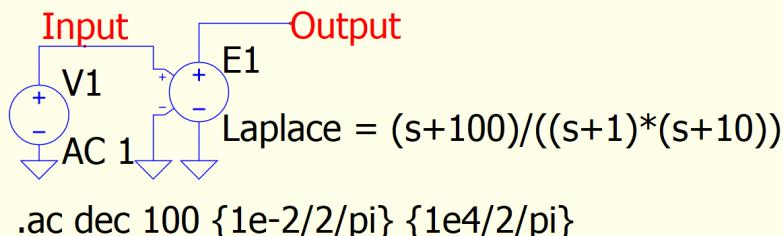
```
.tran {eT}
.param eT=25
```



Time Domain



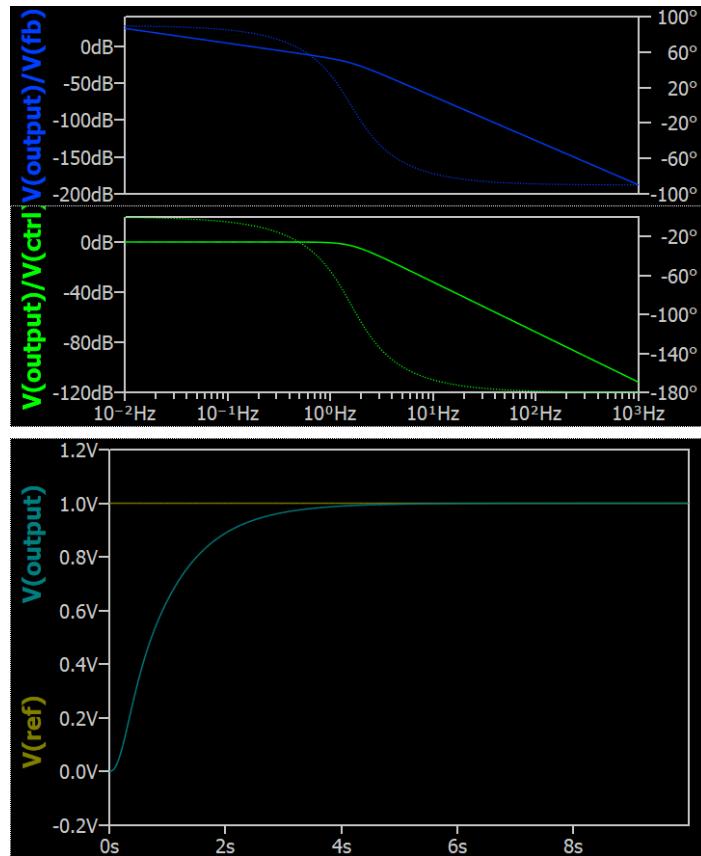
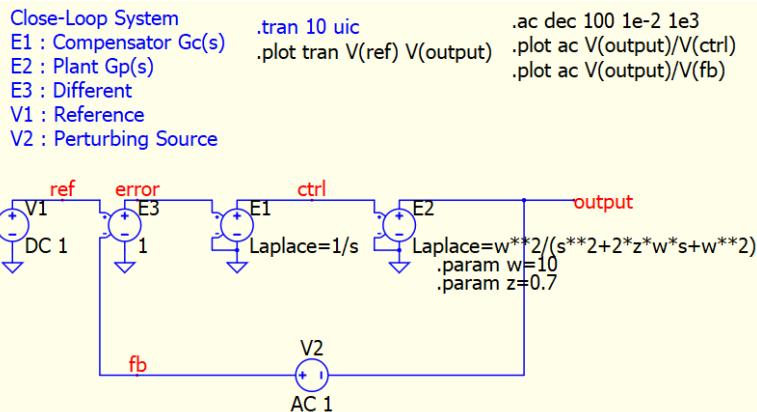
Frequency Domain



# Laplace Time and Frequency Domain Simulation

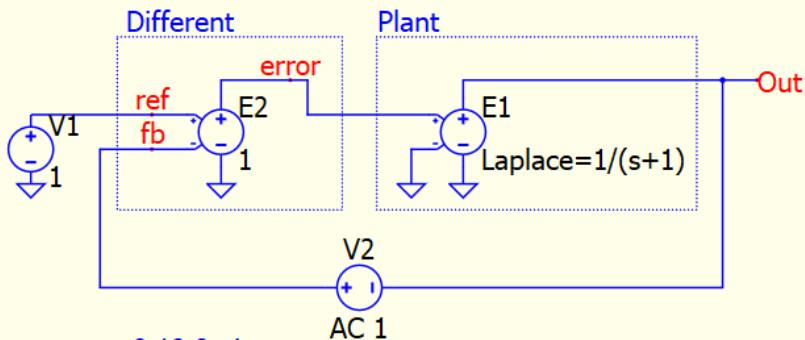
Qspice : Laplace Close Loop.qsch

- Close Loop System Time and Bode
  - A technique to get  $G_p(s)$  and  $G_H(s)$  is to add a perturbing source between output and feedback and perform ac analysis
  - In this example, Laplace function can collect in series for both .tran and .ac directive



# AC (.ac) and Frequency Response Analysis (.bode)

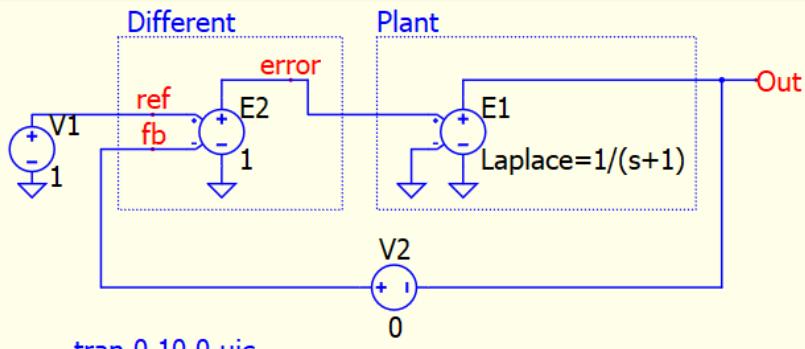
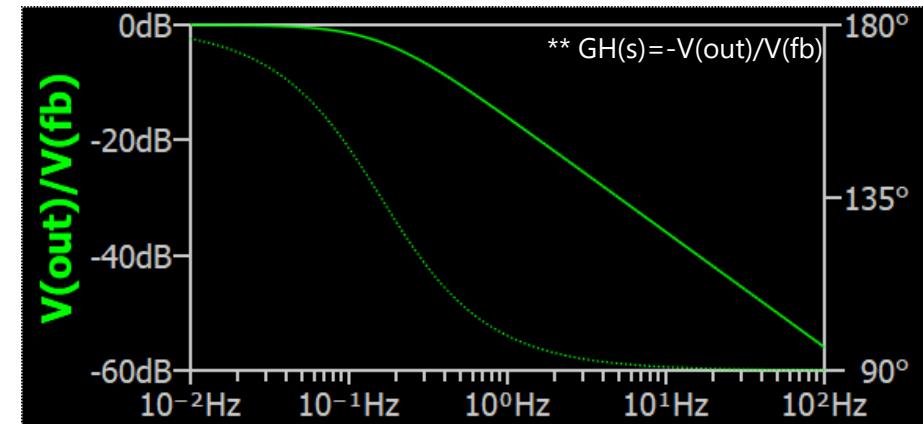
Qspice : ACmethod.qsch ; BODEmethod.qsch



.tran 0 10 0 uic  
.ac dec 100 1e-2 100

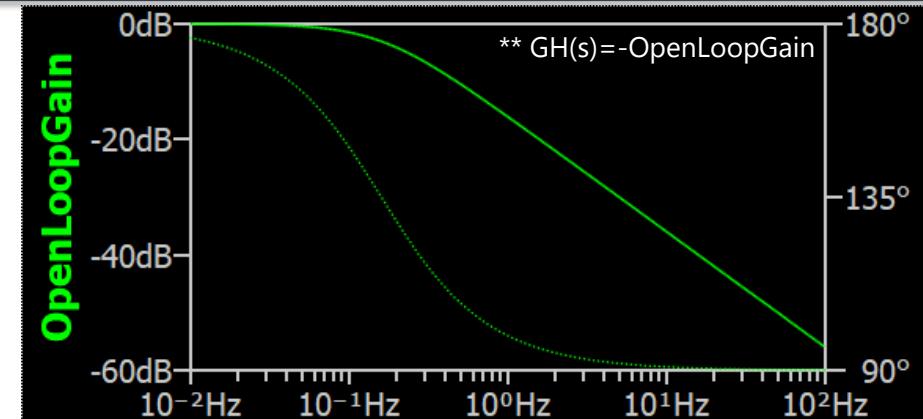
AC 1

.plot ac V(out)/V(fb)



.tran 0 10 0 uic  
.bode V2 10 1e-2 100

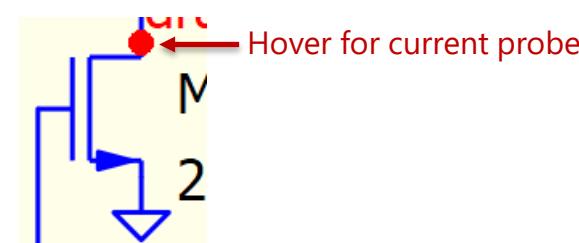
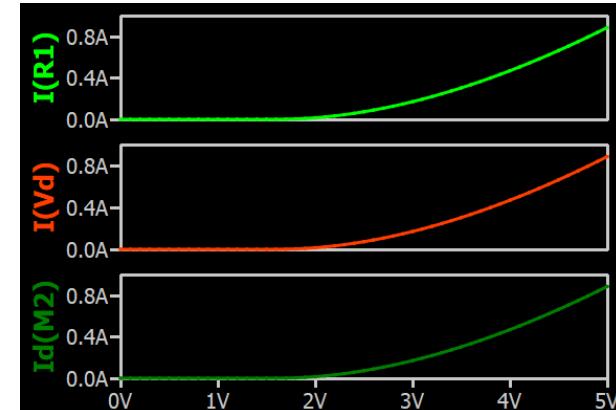
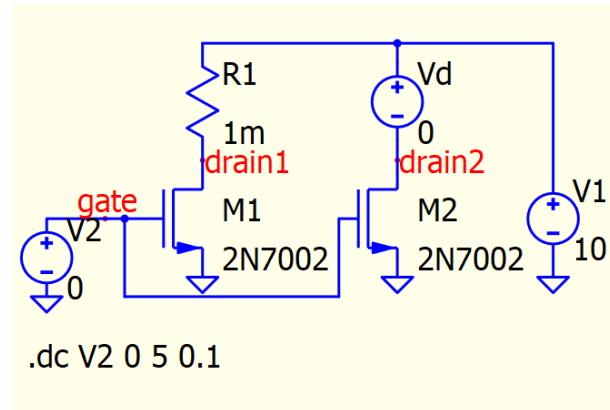
0



# Technique to Probe NMOS Drain Current / General Current Probe

Qspice : Current Probe Method.qsch

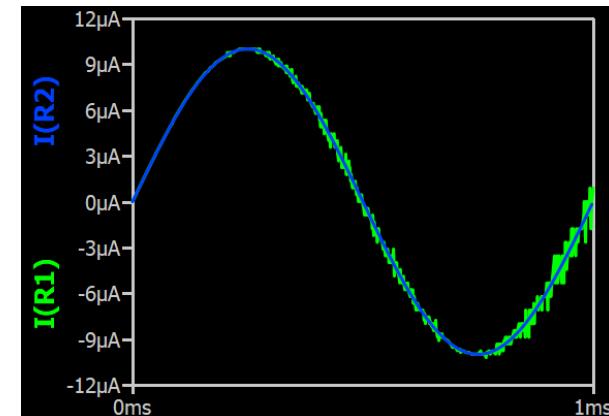
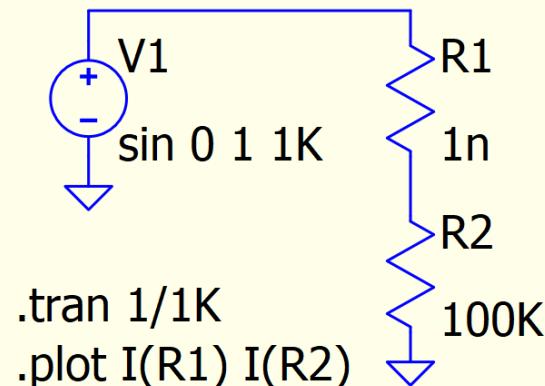
- Current probe method
  - Method #1 : Resistor
    - Add a series resistor (small value) and probe R current
  - Method #2 : 0V Voltage
    - Add 0V voltage source and probe current of this voltage source.
    - +ve represent current flow from + to – direction within symbol (i.e. +ve current represent current flow downward in this example)
  - Hold SHIFT key in Qspice to probe voltage source current can give default +ve current, otherwise it will assign –ve to current
- Method #3 : Probing
  - Probe current by hover point at device terminal
  - Not support sub-circuit yet
  - OR Ctrl-A (Add Plot) in waveform viewer and select  $I_d(Mnnn)$



# Technique to Probe NMOS Drain Current / General Current Probe

## Qspice : Current Probe with Resistor - Limitation

- Limitation in R current
  - If sensing resistor with extremely small value compares to its measurement object, current reading from this resistor will be incorrect
  - Use 0V voltage source approach as replacement



- Explanation – by frank.widmann in Qspice forum
  - <https://forum.qorvo.com/t/persistent-bug-warning-singular-matrix-check-node-b/17636/21>



frank.wiedmann

30m

Here is the explanation for the behavior observed by @KSKelvin : SPICE uses [Modified nodal analysis](#) - [Wikipedia](#) which directly calculates the node voltages and the currents through voltage sources. The current through the small resistor, on the other hand, is calculated indirectly by dividing the voltage difference between its terminals by its resistance. With a resistance of 1u, the tolerances of the voltages are almost as large as the voltage difference, causing the observed imprecise results.

# B-Source as Comparator

Qspice : B-Source as Comparator.qsch

- Concept of Ideal Comparator with Behavioral Voltage Source
  - Formula of B-source is : if( $V(\text{pos}) > V(\text{neg})$ , $V(V_{dd})$ , $V(V_{ss})$ )
  - Practical comparator output normally is open-drain configuration, this is just for simulation purpose



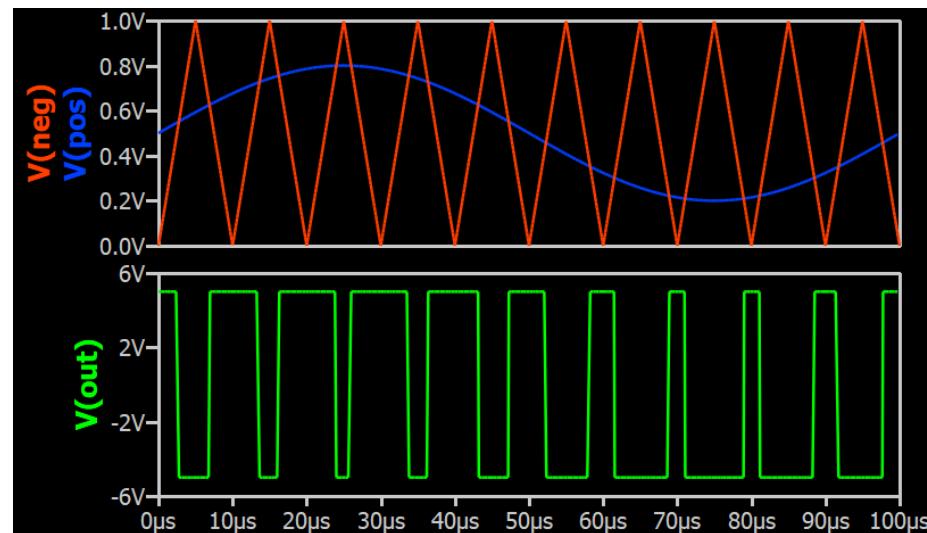
```
.tran 1/Fsgl  
.plot V(out)  
.plot V(pos) V(neg)
```

```
pos  
V3((V3)) --> pos  
.param Fsgl=10K  
sin 0.5 0.3 Fsgl
```

```
neg  
V4((V4)) --> neg  
.param Fsw=100K  
pulse 0 1 0 0.5/Fsw 0.5/Fsw 0 1/Fsw
```

```
B1((B1)) --> out  
V = if(V(pos) > V(neg), V(Vdd), V(Vss))
```

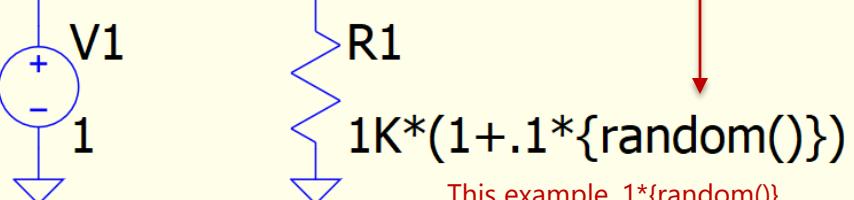
**B-source as Ideal Comparator**



# Monte Carlo

Qspice : Monte Carlo.qsch

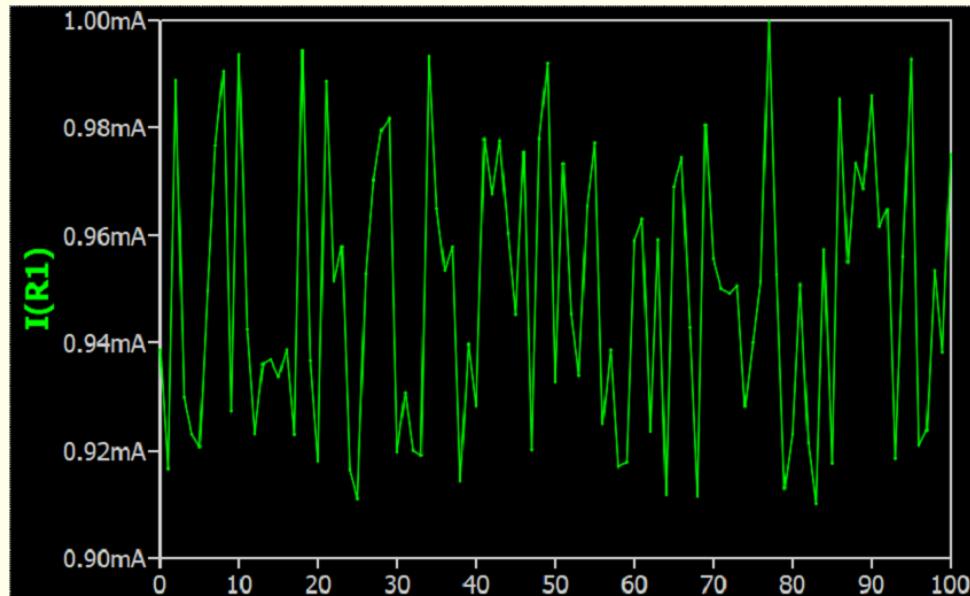
Random number from 0 to 1 depending on the seed



This example  $.1*{\text{random}()}$   
equivalent +0% to +10% change

```
.op  
.step param dummy 0 100 1  
.plot I(R1)
```

```
.options seedclock ← This enable random seed to  
be generated  
.options seed=5 ← This assign manual seed
```



Engelhardt Ⓛ

OK, I just implemented

.options seedclock

It convolutes a 10MHz system clock with the simulation process ID to generate a physically random integer to seed the Mersenne Twister.

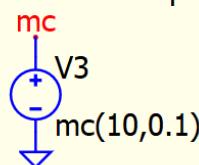
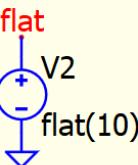
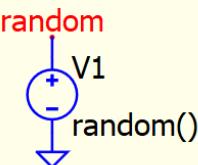
9-4-2023

# Flat(x) and MC(x,y) functions equivalent to Ltspice

Qspice : Flat and MC Function.qsch

- Uniform random distribution
  - LTspice offers flat(x) and mc(x,y) functions, but not in Qspice (last check 10-3-2023)
- Function for flat(x) and mc(x,y)
  - `.func flat(x) x*((random()*2)-1)` ← Generate random [-x, x]
  - `.func mc(x,y) x*(1+y*(random()*2-1))` ← Generate random [x\*(1-y), x\*(1+y)]

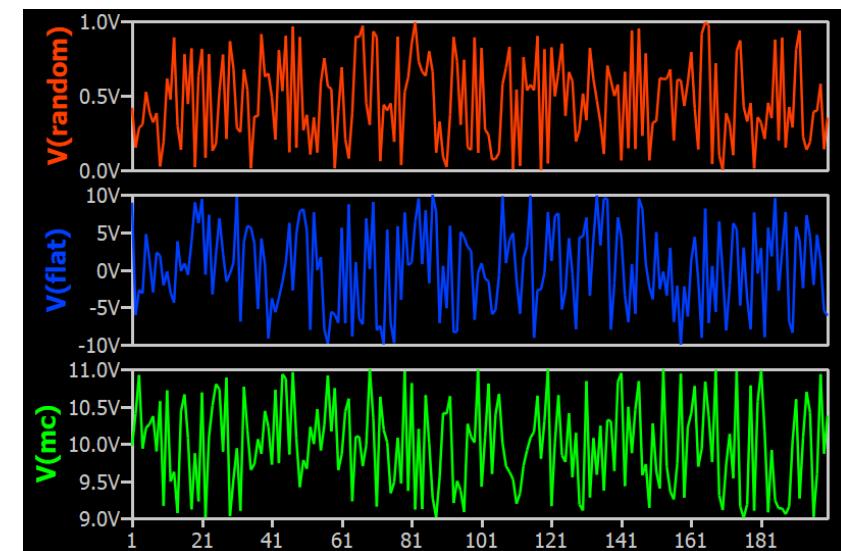
```
.step param x 1 200 1 Dummy For Loop  
.op
```



```
.plot V(mc)  
.plot V(flat)  
.plot V(random)
```

`flat(x)` : Random number between -x and x with uniform distribution  
`.func flat(x) x*((random()*2)-1)`

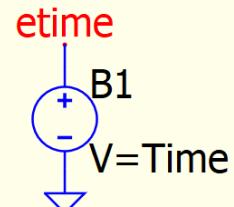
`mc(x,y)` : A random number between  
 $x*(1+y)$  and  $x*(1-y)$  with uniform distribution  
`.func mc(x,y) x*(1+y*(random()*2-1))`



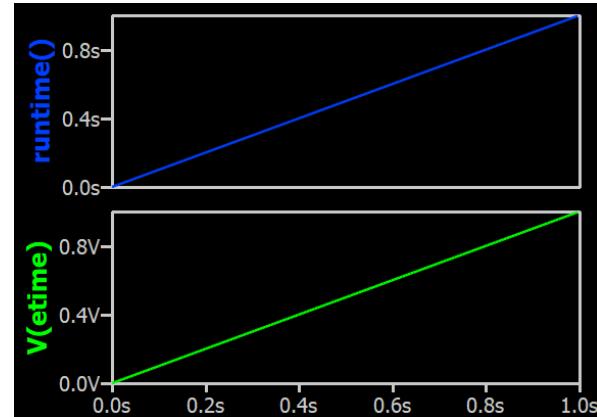
# Time in .tran and Logic Diagram in Waveform Viewer with .plot

Qspice : Time in .tran.qsch ; Logic Signal Plot.qsch

- Time in .tran
  - In .tran, simulation time is stored as a parameter named **Time**
  - Therefore, use a B-source can convert Time into a voltage
  - Time can also be used in function

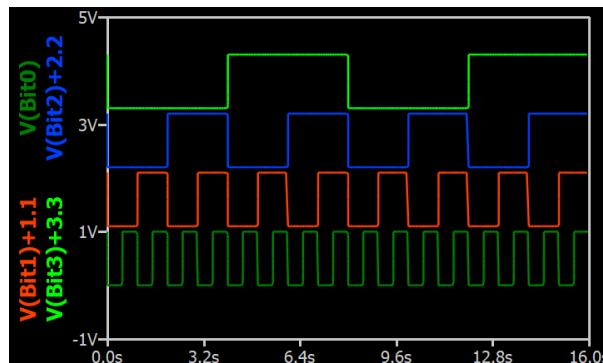


```
.tran 1 .func runtime() Time  
.plot V(etime)  
.plot runtime()
```



- Logic Diagram
  - A simple idea to plot logic signal into logic diagram format
  - Idea is to add an offset for each logic in .plot

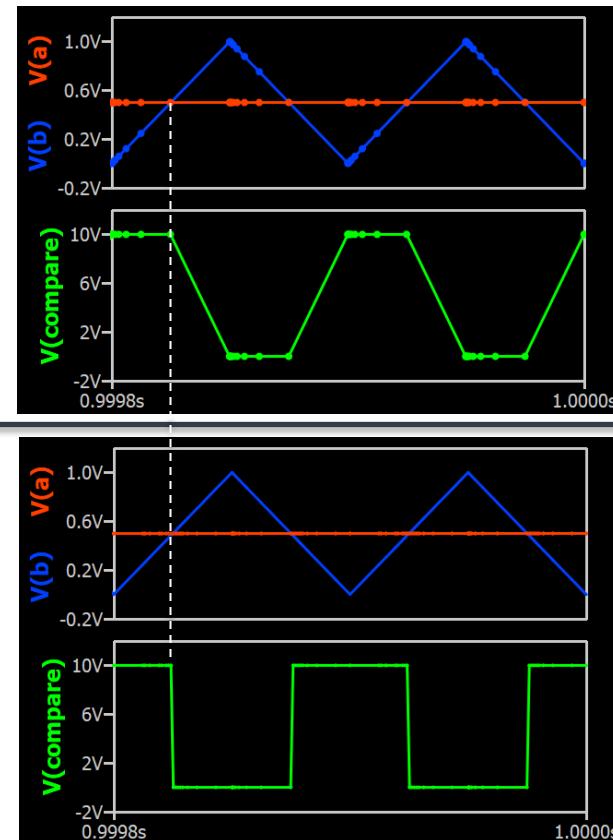
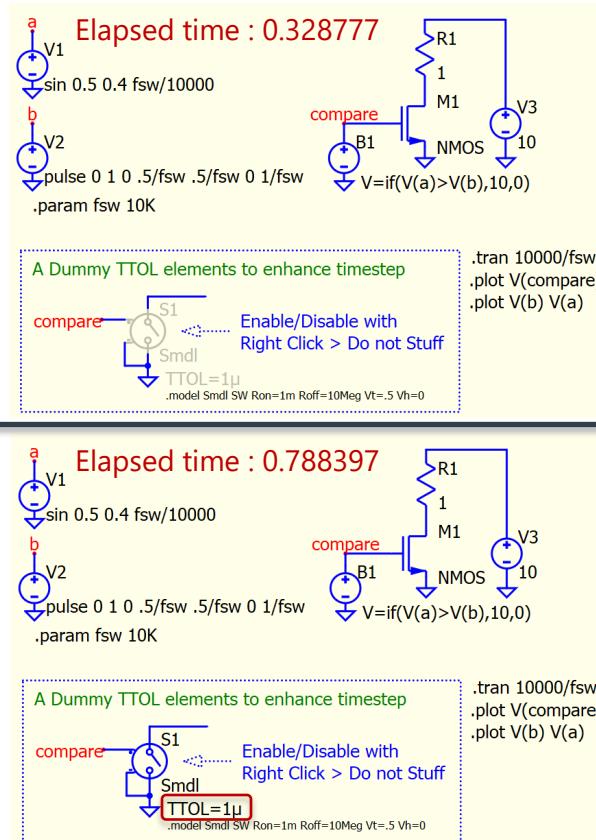
```
Bit0  
V1  
pulse 1 0 0 0 0 0.5/f 1/f  
Bit1  
V2  
pulse 1 0 0 0 0 0.5/f*2 1/f*2  
Bit2  
V3  
pulse 1 0 0 0 0 0.5/f*4 1/f*4  
Bit3  
V4  
pulse 1 0 0 0 0 0.5/f*8 1/f*8  
.param f=1  
.tran 1/f*16  
.plot V(Bit3)+3.3 V(Bit2)+2.2 V(Bit1)+1.1 V(Bit0)
```



# Dummy TTOL device to help in adaptive timestep

## Qspice : TTOL - Dummy TTOL element - Enhance Timestep.qsch

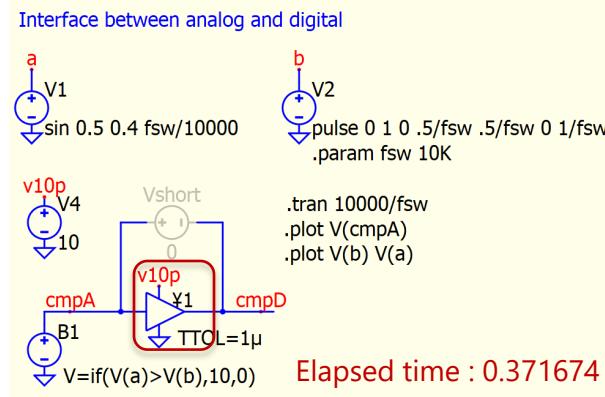
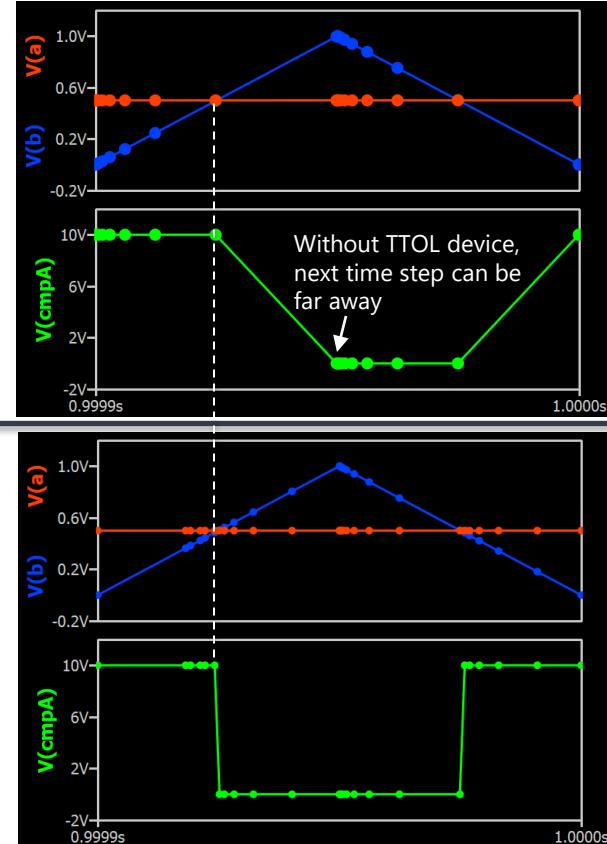
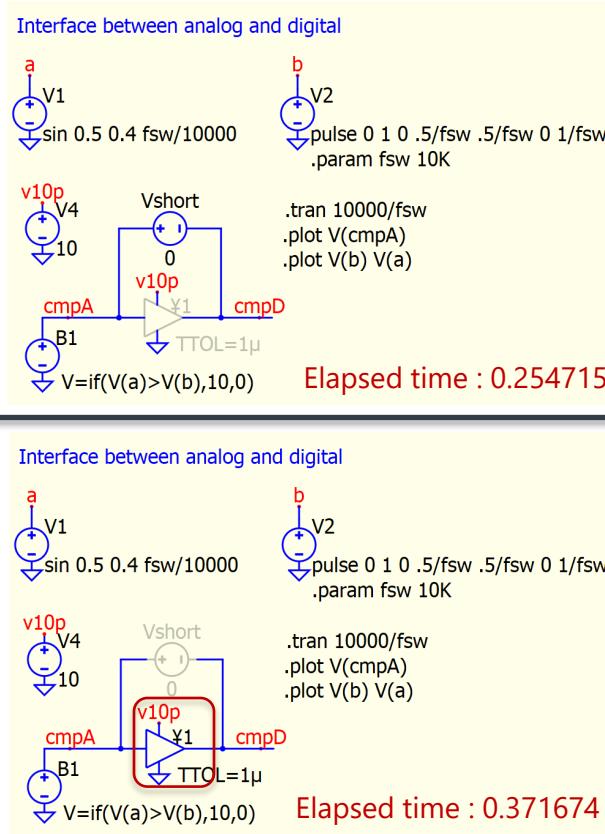
- Dummy TTOL device
  - Qspice uses adaptive timestep
  - If a circuit uses a B-source, if(x,y,z) as a comparator, without TTOL device, its simulation timestep can far from compare instance and output looks weird
    - Example on Top Row
    - Precise time instance at compare action, but as no extra timestep after compare action, output looks like ramping as next timestep is far away (interpolation)
- To resolve this without using MAXSTEP to limit timestep, a dummy TTOL device can be used (e.g. Switch), with TTOL instance parameters included
  - Example on Bottom Row
  - Extra time steps are added after V(compare) flip the switch, with additional time steps, output looks reasonable
  - Smaller TTOL value can yield a better results but with longer elapsed time



# TTOL device to help in adaptive timestep (e.g. function IF)

Qspice : TTOL - TTOL device to Interface Analog and Digital.qsch

- TTOL device interface
  - Qspice uses adaptive timestep
  - If a circuit uses a B-source, if(x,y,z) as a comparator, without TTOL device, its simulation timestep can far from compare instance and output looks weird
    - Example in Top Figure
    - Precise time instance at compare action, but as no extra timestep at compare action, output looks like trapezoidal as next timestep is far away
  - To resolve this without using MAXSTEP to limit timestep, a TTOL device can be used (e.g. buffer, with default TTOL=1μ)
    - Example in Bottom Figure
    - Extra time steps are added after V(cmpA) flip the buffer, with additional time steps, output looks square waveform
    - Smaller TTOL value can yield a better results but with longer elapsed time



# TTOL device to help in adaptive timestep (e.g. function DELAY)

Qspice : TTOL - TTOL for Pulse Delay.qsch

- TTOL device interface

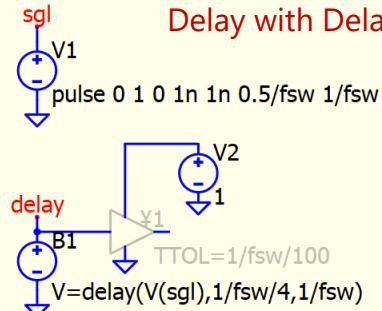
- Pulse source has instance parameter TimeCtrl to determine timestep at each breakpoint (default is TimeCtrl=Limits), therefore, extra timestep at its rising/falling edge

- Example in Top Figure
- But the edge of delayed signal from behavioral source has no information of extra timestep is required, therefore, delayed signal looks like trapezoid

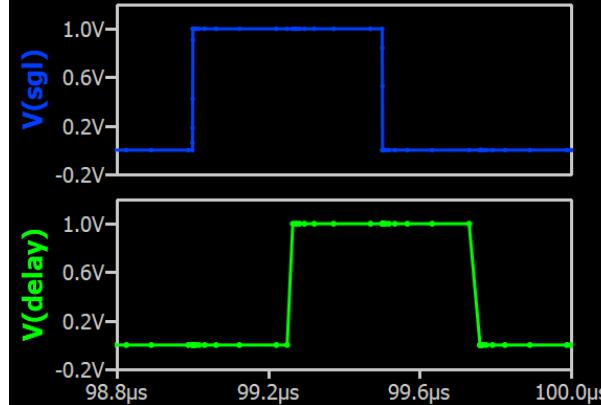
- A buffer with TTOL is used to improve sharpness of pulse edge

- Example in Bottom Figure
- Buffer is triggered when its input cross REF voltage, with TTOL instance parameter, extra timestep is added at such moment

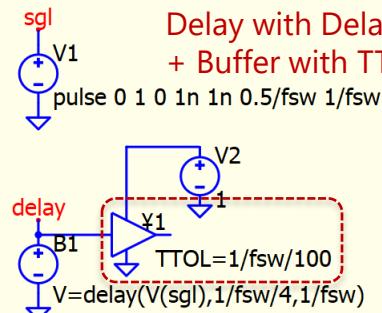
### Delay with Delay(x,y,z)



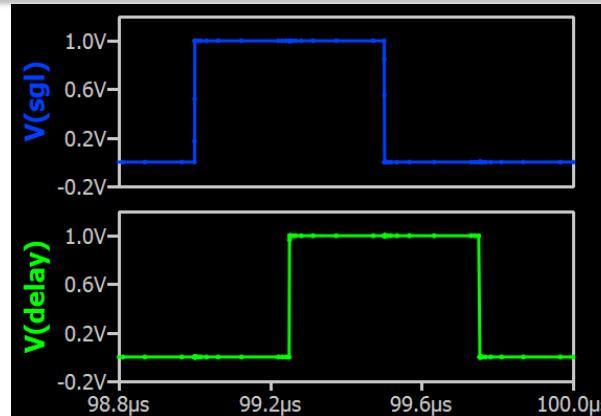
```
.param fsw=1Meg  
.tran 100/fsw  
.plot V(delay)  
.plot V(sgl)
```



### Delay with Delay(x,y,z) + Buffer with TTOL



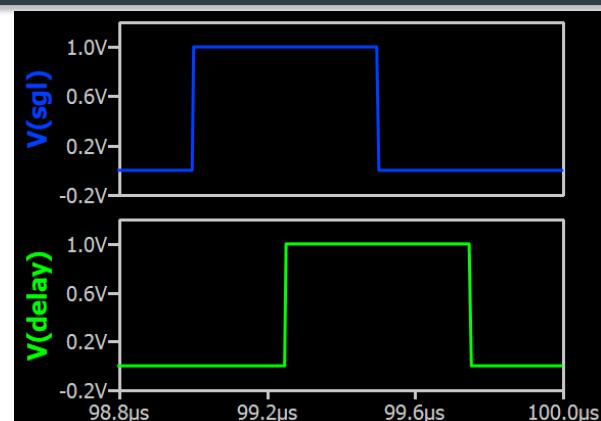
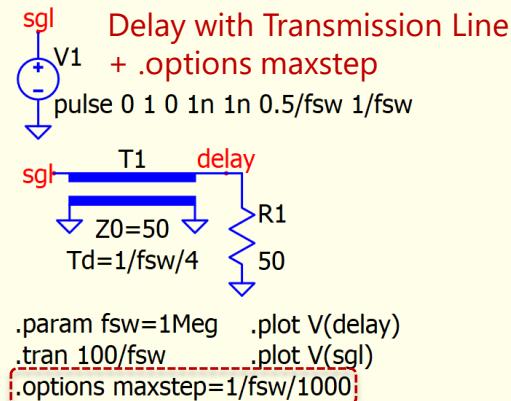
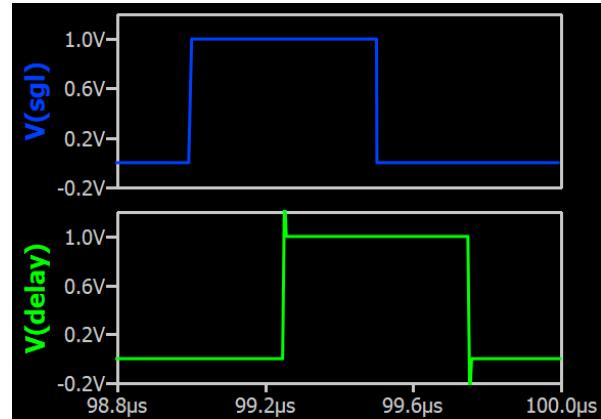
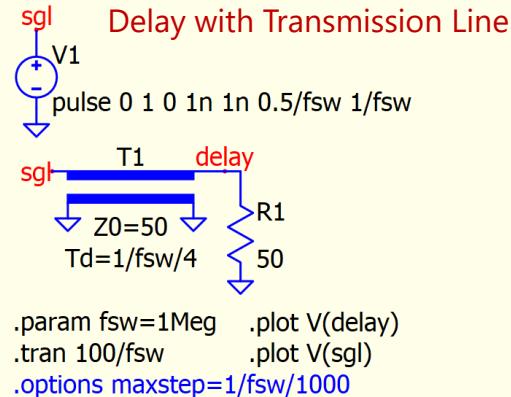
```
.param fsw=1Meg  
.tran 100/fsw  
.plot V(delay)  
.plot V(sgl)
```



# Delay with Transmission Line (alternative way for delay function)

Qspice : Transmission Line for Pulse Delay.qsch

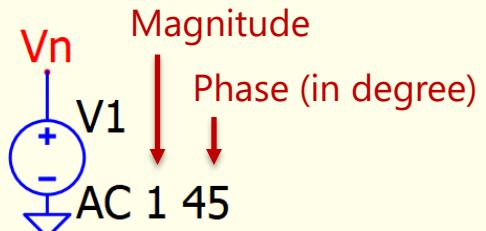
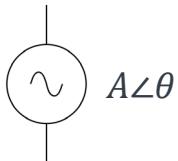
- Delay with Transmission Line
  - Beside of `delay(x,y,z)` function in behavioral source, delay can be generated with transmission line terminate with  $Z_0$
  - However, this approach may generate overshoot/undershoot if maximum time step is not defined, this crux is related to Qspice design as a trade between simulation time and accuracy



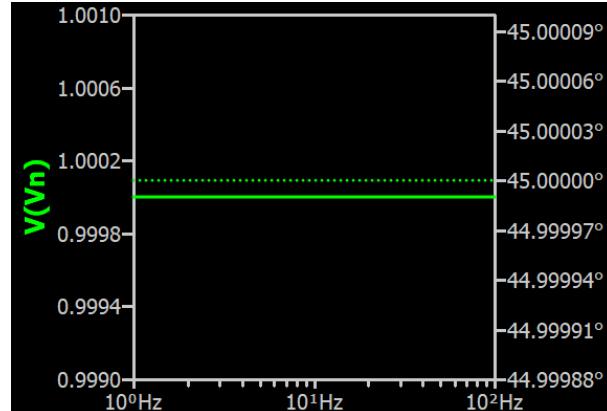
# Phasor simulation technique in .ac

Qspice : Phasor - Source.qsch | Phasor - Dependent Source with j.qsch

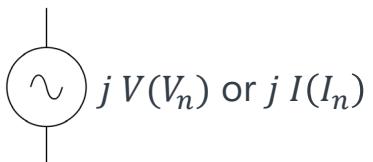
- Active Source
  - Voltage / Current Source
  - With formula  $A\angle\theta$



```
.ac dec 100 1 100  
.plot V(Vn)
```



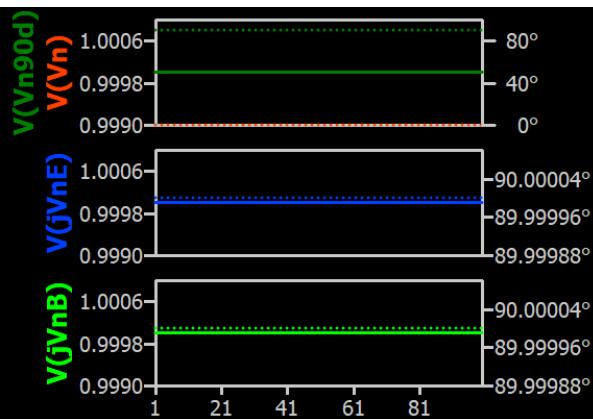
- Dependent Source
  - A dependent source with  $j$  to an active source



```
Vn  
V1 .plot V(jVnB)  
AC 1 .plot V(jVnE)  
Vn90d .plot V(Vn) V(Vn90d)  
V2 .step param freq 1 100 1  
AC 90 .ac list freq  
.param omega=2*pi*freq
```

**Laplace Transform:**

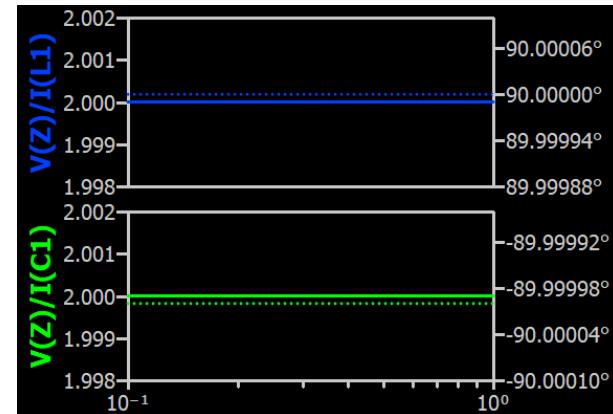
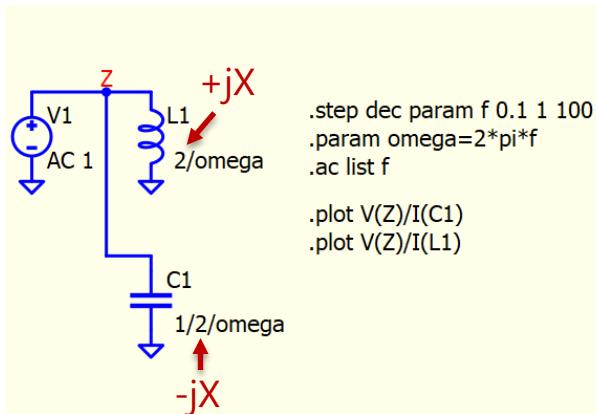
|   |  |
|---|--|
| $jVnE$<br>E1<br>Laplace=s/omega         | Use Laplace for $j$ part in .ac analysis<br>In definition, $s=j*\omega$<br>Therefore, $jVnE = j*Vn$ in E1 and B1 |
| $jVnB$<br>B1<br>V=V(Vn) Laplace=s/omega |  |



# Phasor simulation technique in .ac

Qspice : Phasor - jX.qsch

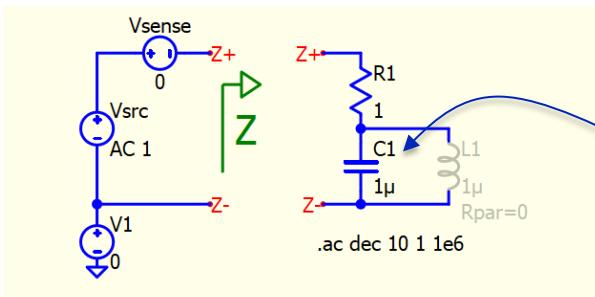
- $+jX$  or  $-jX$
- $jX$  and  $-jX$  can be simulate with normalized inductance and capacitance
- $jX_L = j\omega L \rightarrow L = \frac{X_L}{\omega}$
- $-jX_C = -j\frac{1}{\omega C} \rightarrow C = \frac{1}{\omega X_C}$



# General form of impedance calculation in .ac (series model)

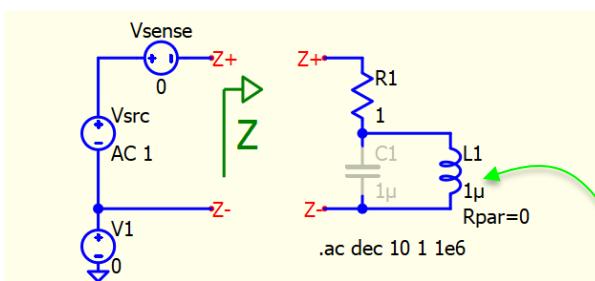
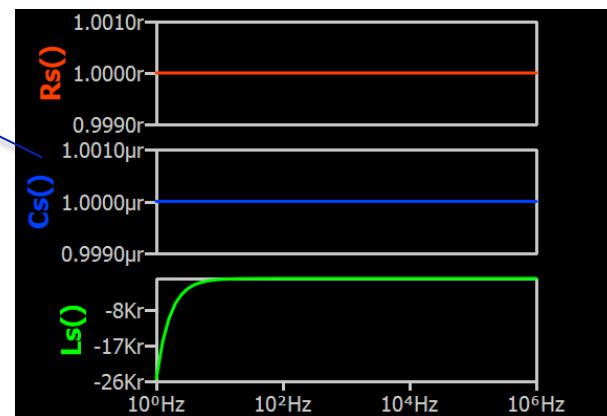
Qspice : General Form  $R_s$ - $C_s$  Or  $R_s$ - $L_s$  in .ac.qsch

- Impedance in .ac
  - Impedance
    - $Z = \frac{V}{I}$
  - $R_s$ - $C_s$  model
    - $R_s = \text{re}(Z)$
    - $C_s = -\frac{1}{2\pi f \times \text{im}(Z)}$
  - $R_s$ - $L_s$  model
    - $L_s = \frac{\text{im}(Z)}{2\pi f}$



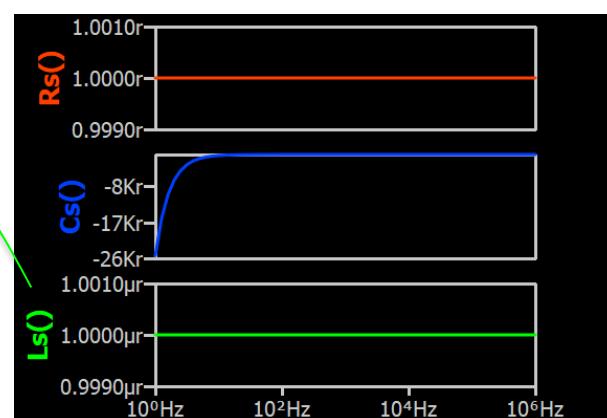
Equivalent Rs-Cs or Rs-Ls from Vsrc

```
.func Z() V(Z+,Z-)/I(Vsense)
.func Rs() re(Z())
.func Cs() -1/2/pi/freq/im(Z())
.func Ls() im(Z())/2/pi/freq
```



Equivalent Rs-Cs or Rs-Ls from Vsrc

```
.func Z() V(Z+,Z-)/I(Vsense)
.func Rs() re(Z())
.func Cs() -1/2/pi/freq/im(Z())
.func Ls() im(Z())/2/pi/freq
```



# General form of admittance calculation in .ac (parallel model)

Qspice : General Form Rp-Cp Or Rp-Lp in .ac.qsch

- Admittance in .ac

- Admittance

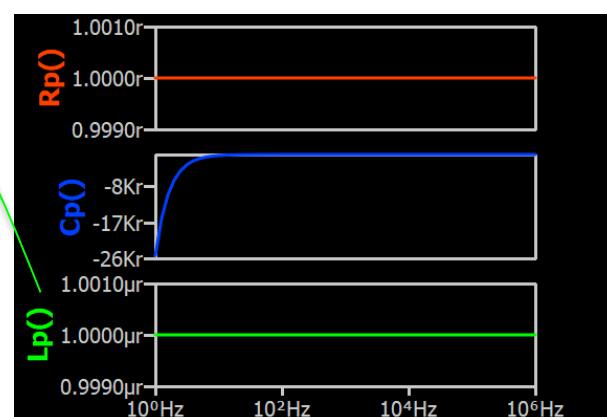
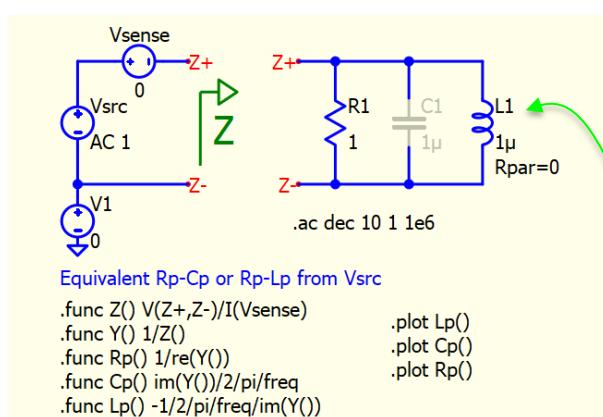
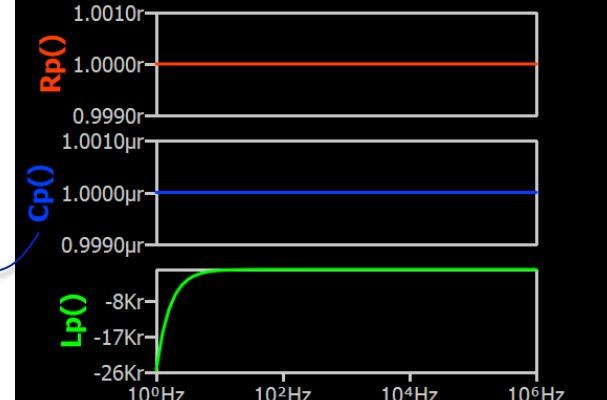
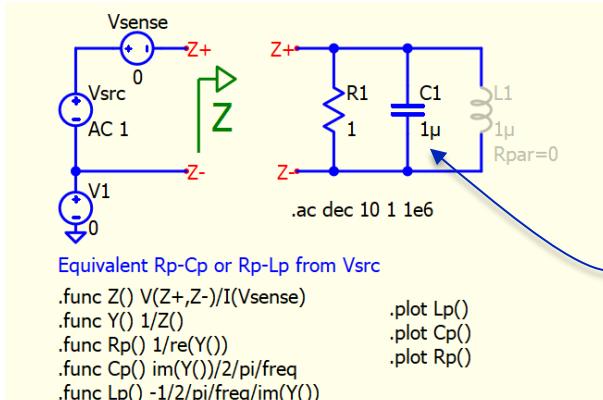
- $Z = \frac{V}{I}$
- $Y = \frac{1}{Z}$

- Rp-Cp model

- $R_p = \frac{1}{\text{re}(Y)}$
- $C_p = \frac{\text{im}(Y)}{2\pi f}$

- Rp-Lp model

- $L_p = -\frac{1}{2\pi f \times \text{im}(Y)}$



# General form of impedance / admittance calculation in .ac

---

- Qspice function formula : 2 elements series model

```
.func Z() V(Z+,Z-)/I(Vsense)  
.func Rs() re(Z())  
.func Cs() -1/2/pi/freq/im(Z())  
.func Ls() im(Z())/2/pi/freq
```

- Qspice function formula : 2 elements parallel model

```
.func Z() V(Z+,Z-)/I(Vsense)  
.func Y() 1/Z()  
.func Rp() 1/re(Y())  
.func Cp() im(Y())/2/pi/freq  
.func Lp() -1/2/pi/freq/im(Y())
```

# Impedance calculation in .ac with frequency or DC sweep

Qspice : Rs-Cs in .ac (vs freq).qsch | Rs-Cs in .ac (vs dc).qsch

- Calculate Rs-Cs in .ac

- Impedance of Rs-Cs model

- $Z = \frac{V}{I} = R_s + \frac{1}{j2\pi f C_s}$

- $R_s = \text{re}\left(\frac{V}{I}\right)$

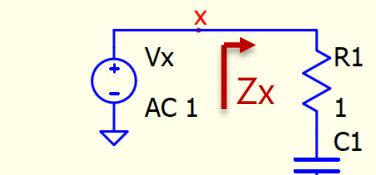
- $C_s = -\frac{1}{2\pi f \times \text{im}\left(\frac{V}{I}\right)}$

- Example #1

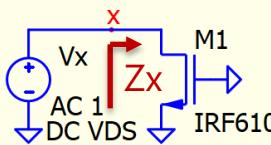
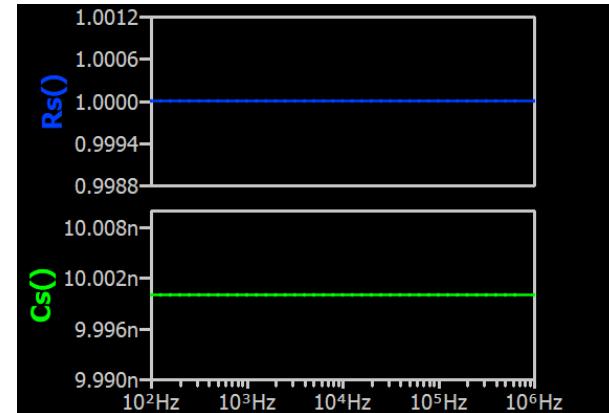
- In .ac analysis, FREQ is a reserved variable. Utilize it to assist in calculating Cs

- Example #2

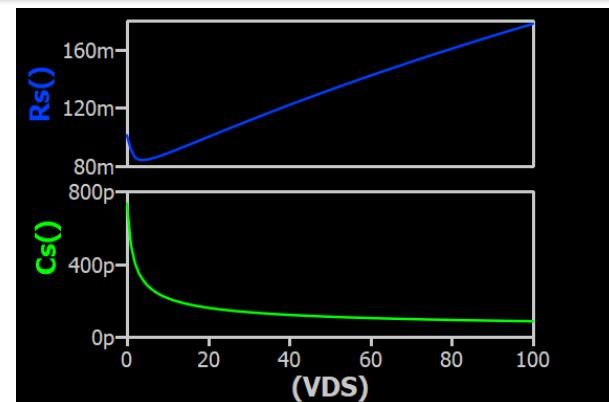
- To sweep DC voltage, set .ac to a single frequency measurement (.ac list 1Meg) and employ .step to sweep the DC voltage



```
.ac dec 10 100 1Meg  
;plot I(Vx)  
.func Rs() re(V(x)/-I(Vx))  
.func Cs() -1/2/pi/freq/im(V(x)/-I(Vx))  
.plot Cs()  
.plot Rs()
```



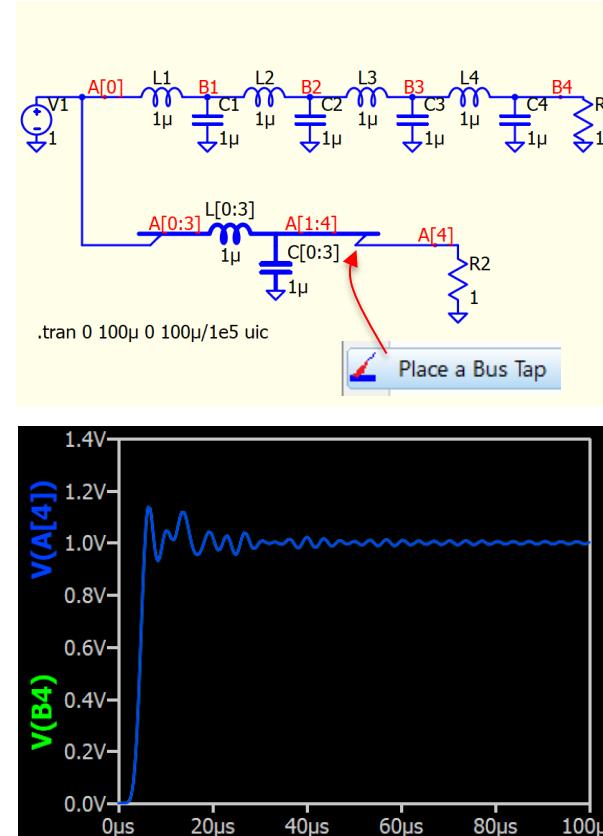
```
.step param VDS 0 100 1  
.param frq=1Meg  
.ac list frq  
;plot I(Vx)  
.func Rs() re(V(x)/-I(Vx))  
.func Cs() -1/2/pi/frq/im(V(x)/-I(Vx))  
.plot Cs()  
.plot Rs()
```



# Bussing of Connections and Array of Components

Qspice : Array - LC example.qsch

- Bus and Array
  - Arrays can be defined with square brackets [n:m], which can be used for bus connections or component definitions
  - This example demonstrates using the array method to replicate a lumped LC filter network
  - To tap a single node from a bus, right-click and place a bus tap on the bus wire
  - It is recommended for the user to verify the array structure from the netlist

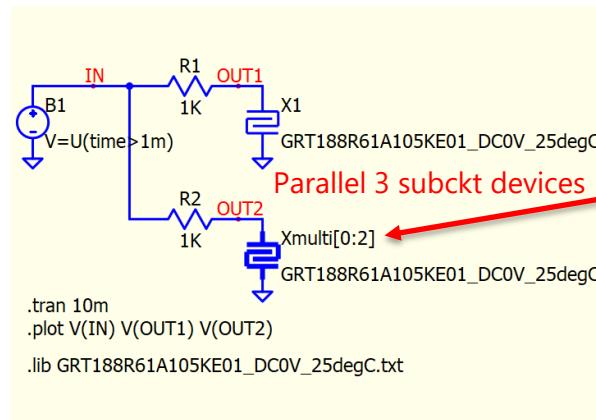


## Netlist

```
L1 A[0] B1 1μ
C1 B1 0 1μ
L2 B1 B2 1μ
C2 B2 0 1μ
L3 B2 B3 1μ
C3 B3 0 1μ
L4 B3 B4 1μ
C4 B4 0 1μ
R1 B4 0 1
L[0] A[0] A[1] 1μ
L[1] A[1] A[2] 1μ
L[2] A[2] A[3] 1μ
L[3] A[3] A[4] 1μ
C[0] A[1] 0 1μ
C[1] A[2] 0 1μ
C[2] A[3] 0 1μ
C[3] A[4] 0 1μ
R2 A[4] 0 1
V1 A[0] 0 1
.tran 0 100μ 0 100μ/1e5 uic
.plot V(B4) V(A[4])
.end
```

# Bussing of Connections and Array of Components

- Array
  - An array of components can be used to simplify paralleling .subckt X-device



R1 IN OUT1 1K  
B1 IN 0 V=U(time>1m)  
R2 IN OUT2 1K  
Xmulti[0] OUT2 0 GRT188R61A105KE01\_DC0V\_25degC  
Xmulti[1] OUT2 0 GRT188R61A105KE01\_DC0V\_25degC  
Xmulti[2] OUT2 0 GRT188R61A105KE01\_DC0V\_25degC  
X1 OUT1 0 GRT188R61A105KE01\_DC0V\_25degC  
.lib GRT188R61A105KE01\_DC0V\_25degC.txt  
.tran 10m  
.plot V(IN) V(OUT1) V(OUT2)  
.end

