NETLIST STRUCTURE

TITLE

DESCRIPTION OF SOURCES

DESCRIPTION OF ELEMENTS

SOLUTION CONTROL

OUTPUT CONTROL

END STATEMENT
CIRCUIT DESCRIPTION

- The first letter identifies the element type followed by a name limited to 7 characters

<table>
<thead>
<tr>
<th>Rxx</th>
<th>Resistor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cxx</td>
<td>Capacitor</td>
</tr>
<tr>
<td>Lxx</td>
<td>Inductor</td>
</tr>
<tr>
<td>Vxx</td>
<td>Voltage source</td>
</tr>
<tr>
<td>Ixx</td>
<td>Current source</td>
</tr>
<tr>
<td>Dxx</td>
<td>Diode</td>
</tr>
<tr>
<td>Qxx</td>
<td>BJT</td>
</tr>
<tr>
<td>Mxx</td>
<td>MOSFET</td>
</tr>
</tbody>
</table>

Node numbering

- All nodes numbered with nonnegative integers between 0 and 9999

- Ground node must be labeled 0

- SPICE allows to assign several numbers for the same node
PASSIVE ELEMENT STATEMENT

\[ X<\text{name}> \quad N^+ \quad N^- \quad \text{value} \quad <\text{IC}=xx> \]

\( X \) is the reserved letter \( R, L, \) or \( C \)
\<\text{name}>\) is number or string

\( N^+ \) and \( N^- \) denote polarity of voltage across the element or current direction
\( N^+ \) corresponds to more positive potential

\textit{value} is specified in Ohms \([\Omega]\), Henries \([H]\)
or Farads \([F]\) correspondingly

\<\text{IC (VC or IL)}=xx> is the initial condition: capacitive voltage or inductive current at the time \(t=0\)
PASSIVE ELEMENTS

Resistor

\[ V_R = R \cdot I_R, \quad R[\Omega] \]

Capacitor

\[ V_C = \frac{1}{C} \int_{0}^{t_1} I_C \cdot dt \rightarrow V_C = \frac{1}{j\omega C} \cdot I_C \]

\[ X_C = \frac{1}{j\omega C}, \quad C[F] \]

Inductor

\[ V_L = L \frac{d}{dt} I_L \rightarrow V_L = j\omega L \cdot I_L \]

\[ X_L = j\omega L, \quad L[H] \]
# POWER-OF-TEN NUMERICAL SUFFIXES IN PSPICE

<table>
<thead>
<tr>
<th>Suffix</th>
<th>Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>T</td>
<td>$10^{12}$</td>
</tr>
<tr>
<td>G</td>
<td>$10^9$</td>
</tr>
<tr>
<td>MEG</td>
<td>$10^6$</td>
</tr>
<tr>
<td>K</td>
<td>$10^3$</td>
</tr>
<tr>
<td>M</td>
<td>$10^{-3}$</td>
</tr>
<tr>
<td>U</td>
<td>$10^{-6}$</td>
</tr>
<tr>
<td>N</td>
<td>$10^{-9}$</td>
</tr>
<tr>
<td>P</td>
<td>$10^{-12}$</td>
</tr>
<tr>
<td>F</td>
<td>$10^{-15}$</td>
</tr>
</tbody>
</table>
SOURCE STATEMENT

Voltage

Current

Sources

Independent

Dependent

V_{xx}

Current Dependent

Voltage Dependent

源泉声明

电压

电流

源

独立

依赖

V_{xx}

电流依赖

电压依赖

图示
PARAMETERS OF VOLTAGE AND CURRENT SOURCES

\textit{DC sources}

\begin{align*}
V & \ <\text{name}> \ N+ \ N- \ DC \ <\text{value}> \\
I & \ <\text{name}> \ N+ \ N- \ DC \ <\text{value}> \\
\end{align*}

\begin{figure}
\centering
\begin{tikzpicture}
\node[shape=rectangle, draw, minimum height=2cm, minimum width=0.5cm] (V1) at (-1.5,0) {V1};
\node[shape=rectangle, draw, minimum height=0.5cm, minimum width=0.5cm] (V2) at (0,0) {V2};
\node[shape=rectangle, draw, minimum height=0.5cm, minimum width=0.5cm, fill=gray] (I1) at (1.5,0) {I1};
\draw[->] (-3,0.8) -- (-2.5,0.8) node[right] {Value};
\draw[->] (0.5,-1) -- (0.5,1) node[above] {Time};
\end{tikzpicture}
\caption{Diagram of voltage and current sources.}
\end{figure}
III. AC sources

For analysis in time domain

\[ V_{<name>} N+ N- \text{ SIN}(V_{\text{off}} V_{\text{amp}} <freq> <TD> <damp>) \]

For analysis in frequency domain

\[ V_{<name>} N+ N- \text{ AC } <V_{\text{amp}}> \]
**SOLUTION CONTROL**

*Operating Point Analysis*
Determination of the Quiescent point (Q-point)

**.OP**

**DC analysis**
Circuit performance with DC sweeping

```
.DC snm1 str1 stp1 inc1 <snm2 str2 stp2 inc2>
```

- *snm* specify Voltage or Current source name
- *str, stp* and *inc*: Start, End and Increment values in Volts or Amps

**AC analysis**
Circuit performance in *frequency* domain

```
.AC sweep num freq1 freq2
```

- *sweep*: LINE (linear), DEC (decade) or OCT (octave)
- *num*: number of points per decade, octave or total
- *freq1, freq2*: Start and End frequencies in Hertz

Examples:  
- .DC V1 0 10 0.1 I1 10u 100u 10u
- .AC DEC 20 10K 100MEG
SOLUTION CONTROL

Transient analysis
Circuit performance in time domain

.TRAN Tinc Tstop

Tinc: Time increment in seconds
Tstop: Final time analyzed

Example: .TRAN 10n 2u

.PROBE

Store results of simulation in an output file for the future graphical representation

.END

Ends the SPICE input file. Can be placed in any part of file for debugging.
OUTPUT CONTROL

- The list of voltages and currents between nodes can be plotted using PROBE tool.
- The following suffix may be appended to variable names to extract specific parameters

<table>
<thead>
<tr>
<th>Suffix</th>
<th>Meaning</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>DB</td>
<td>Magnitude in $dB$</td>
<td>V1DB(1,0)</td>
</tr>
<tr>
<td>M</td>
<td>Magnitude $V_m$</td>
<td>IM(V1)</td>
</tr>
<tr>
<td>P</td>
<td>Phase $\phi$</td>
<td>V1P(1,0)</td>
</tr>
<tr>
<td>R</td>
<td>Real part $V_{Re}$</td>
<td>V1R(1,0)</td>
</tr>
<tr>
<td>I</td>
<td>Imaginary part $V_{Im}$</td>
<td>V1I(1,0)</td>
</tr>
</tbody>
</table>

Decibell: $V_m [dB] = 20 \ lg \ V_m [Volts]$

Phasor: $V = V_m [Volts] e^{i\phi [Degrees]} = V_{Re} + jV_{Im}$
EXAMPLE

Write down a PSPICE netlist to perform the operating point analysis for the circuit in Figure below:

The Input File (Netlist):

Voltage divider
V1 1 0 DC 12
R1 1 2 1K
R2 2 0 2K
.OP
.END
Kirchhoff Voltage Law

\[ V_1 + V_2 + V_3 = 0 \]

The algebraic sum of the voltage drops around closed path is zero

\[ \sum_{i} V_i = 0 \]

- The polarity of voltage across every element may be assigned *arbitrary*
- KVL is satisfied for *AC* signals
Kirchhoff Current Law

The algebraic sum of currents entering any node is zero

\[ I_1 + I_2 + I_3 = 0 \]

- Direction of current through every element can be chosen arbitrarily
- KCL is satisfied for AC signals
Analog Multimeter

Voltage Measurements

- Floating nodes: we can ignore the common mode voltage
- Low accuracy:
  - Low input resistance for voltage measurements
  - Low input conductance for current measurements
- Needs to be calibrated for resistance measurements for every scale
Digital Multimeter

Voltage Measurements

\[ R_{in} > 10 \, \text{M} \Omega \]

Current Measurements

\[ R_{sh} < 0.1 \, \Omega \]

- *Virtually grounded*: the common mode voltage should be minimized!
- *High accuracy*:
  - *High input resistance* for voltage measurements
  - *High input conductance* for current measurements
Voltage and Current Measurements

**Voltage Measurements**

- Voltmeter $V$ is connected *in parallel* to the element of the circuit

**Current Measurements**

- The power must be *switched off* and the circuit must be *open* first
- Ammeter is *always* connected *in series* to the element of the circuit
- Then the power is switched on
Taking Measurements with DMM Fluke 45

- *Dual* display of Digital Multi Meter (DMM) *Fluke 45* allows one to take *
  two simultaneous* measurements which is very useful

### Dual Display Applications

<table>
<thead>
<tr>
<th>Primary Display</th>
<th>Secondary Display</th>
<th>Applications</th>
</tr>
</thead>
</table>
| Volts DC        | Current DC        | • Measurements of I-V characteristics  
                  |                   | • Check power supply load regulation  |
| Volts AC        | Current AC        | • Power Line –Load test  
                  |                   | • Transformer (magnetic circuit) saturation test  |
| Volts DC        | Volts AC          | • Monitor DC level and ripple of power supply  |
| Volts AC        | Current DC        | • Check AC/DC or DC/AC converters  |
| Volts AC        | Frequency         | • Frequency response  |
| Volts dB        | Frequency         | • Quick Bode plots  |
| Relative        | Actual value      | • Show actual measurements and the difference between this value and the relative base  
                  |                   | • Select and sort resistors  |
| HOLD            | Actual value      | • Show actual value while holding a previous measurement  |
Voltage Measurements

- Only *voltage measurements* can be taken
- One node is *always grounded*: the common mode voltage *must be zero*!

In order to measure the voltage across the element with both terminals hot: two terminals must be measured separately with respect to the ground and the results are subtracted

- Good accuracy: high input resistance
**AC (periodical) signals**

**Determination of the Phase Shift**

- **Period** is the shortest distance in time between two points with the same phase. It is convenient to measure the period between maxima or minima.
- **Frequency** is a value reciprocal to period: \( f \text{[Hz]} = \frac{1}{T} \)
- **Angular frequency** shows the number of radians per sec: \( \omega \text{[s}^{-1}] = 2\pi f \)
- **Phase shift** is determined in the following way:

\[
\Delta \Phi = \Phi_2 - \Phi_1 = \frac{t}{T} \cdot 2\pi \text{[rad]} = \frac{t}{T} \cdot 360 \text{[degrees]}
\]

- **Phase shift** is determined with \( 2\pi \) accuracy
- Note the **sign** of the phase shift: in example above \( V_2 \text{ is leading } V_1 \)
Phasor Diagram

Exponential form of periodical *in time* signal:

\[ V(t) = \text{Re}\{V_m \cdot e^{j(\omega t + \phi)}\} = \text{Re}\{\overline{V} \cdot e^{j\omega t}\} \]

\[ \overline{V} = V_m \cdot e^{j\phi} \]

*Phasor* is a *complex number*

expressing the amplitude and the phase of a signal

- *Phasor* is a time-independent part of a signal
- The *amplitude* of sinusoid is the *magnitude* of its phasor
- The *phase angle* of the sinusoid is the *angle* of its phasor
- Phasor simplifies circuit analysis using *complex number* algebra
Properties of Complex Numbers

- A complex number has a geometrical meaning and can be uniquely represented as a point on a complex plane.

\[ X = A + jB = M e^{j\phi} \]

- Euler equation: 
  \[ e^{j\phi} = \cos \phi + j \sin \phi \]

\[ M = (A^2 + B^2)^{1/2}, \quad \phi = \arctan (B/A) \]

\[ j^2 = -1, \quad j = e^{j\pi/2} \]
Operation with Complex Numbers

\[ X_1 = A_1 + jB_1 = M_1 e^{j\phi_1} \]
\[ X_2 = A_2 + jB_2 = M_2 e^{j\phi_2} \]

1) Sum of Complex Numbers:
\[ X_1 + X_2 = (A_1 + A_2) + j(B_1 + B_2) \]

2) Product of Complex Numbers:
\[ X_1 X_2 = M_1 M_2 e^{j(\phi_1 + \phi_2)} \]
\[ X_1 X_2 = (A_1A_2 - B_1B_2) + j(A_1B_2 + B_1A_2) \]

3) Ratio of Complex Numbers:
\[ \frac{X_1}{X_2} = \{(A_1A_2 + B_1B_2) + j(A_2B_1 - A_1B_2)\}/(A_2^2 + B_2^2) \]
\[ X_1 X_2 = (M_1/M_2) e^{j(\phi_1 - \phi_2)} \]
Voltage and Current Shift in Passive Elements

**Resistor** \( V_R = R \cdot I \),

\[
\begin{align*}
V_R &= R \cdot I \\
I_R &= I \\
\end{align*}
\]

**Capacitor** \( V_C = \frac{1}{j\omega C} \cdot I_C \)

\[
\begin{align*}
V_C &= \frac{1}{j\omega C} \cdot I_c \\
I_C &= I_c \\
\end{align*}
\]

**Inductor** \( V_L = j\omega L \cdot I_L \)

\[
\begin{align*}
V_L &= j\omega L \cdot I_L \\
I_L &= I_L \\
\end{align*}
\]
AC signals

Mean value

\[
\langle V \rangle_T = \frac{1}{T} \int_{0}^{T} V(t) \, dt
\]

Root Mean Square (RMS)

\[
V_{RMS} = \sqrt{\langle V^2(t) \rangle}
\]

Example: \( V = V_m \sin(\omega t) \)

\[
\langle |V| \rangle = 2V_m / \pi = 0.637V_m
\]

\[
V_{RMS} = V_m / \sqrt{2} = 0.707V_m
\]
$V_{\text{RMS}} = \frac{1}{\sqrt{2}} V_{\text{max}} = 0.707 V_{\text{max}}$

$V_{\text{mean}} = \frac{2}{\pi} V_{\text{max}} = 0.637 V_{\text{max}}$