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

Rxx	Resistor
Cxx	Capacitor
Lxx	Inductor
Vxx	Voltage source
Ixx	Current source
Dxx	Diode
Qxx	BJT
Mxx	MOSFET

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<name> N+ N- value <IC=xx>

X is the reserved letter *R*, *L*, or *C*
<*name*> is number or string

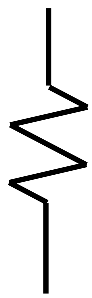
N+ and *N-* denote polarity of voltage across the element or current direction
N+ corresponds to more positive potential

value is specified in Ohms [Ω], Henries [*H*] or Farads [*F*] correspondingly

<IC (VC or IL) = xx> is the initial condition: capacitive voltage or inductive current at the time *t=0*

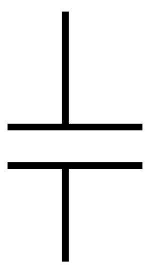
PASSIVE ELEMENTS

Resistor



$$V_R = R \cdot I_R, \qquad R[\Omega]$$

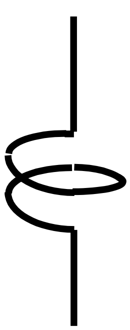
Capacitor



$$V_C = \frac{1}{C}\int_0^{t_1} I_C \cdot dt \rightarrow V_C = \frac{1}{j\omega C} \cdot I_C$$

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

Inductor

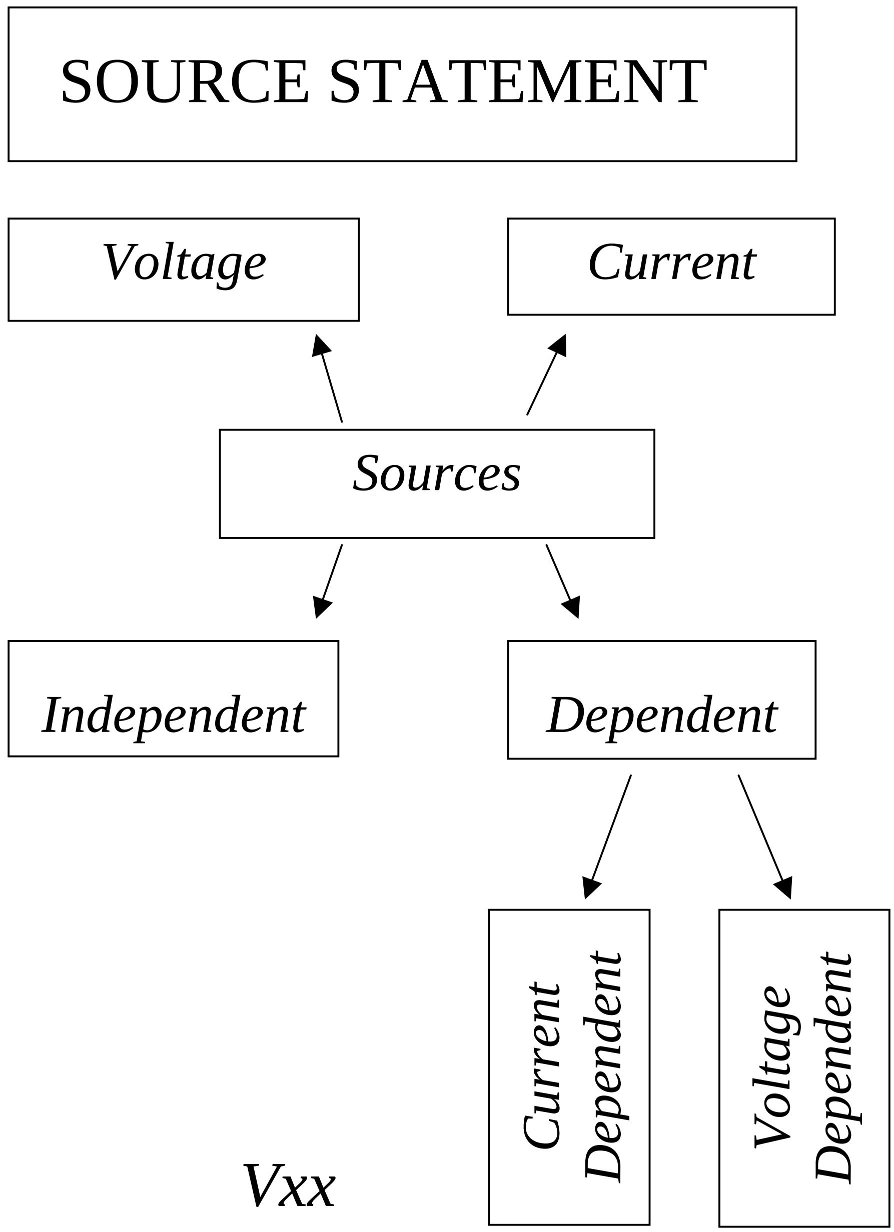


$$V_L = L\frac{d}{dt} I_L \rightarrow V_L = j\omega L \cdot I_L$$

$$X_L = j\omega L, \qquad L[H]$$

POWER-OF-TEN NUMERICAL SUFFIXES IN PSPICE

Suffix	Factor
T	10^{12}
G	10^{9}
MEG	10^{6}
K	10^{3}
M	10^{-3}
U	10^{-6}
N	10^{-9}
P	10^{-12}
F	10^{-15}


SOURCE STATEMENT
Voltage
Current
Sources
Independent
Dependent
Current Dependent
Voltage Dependent

Vxx


+
-

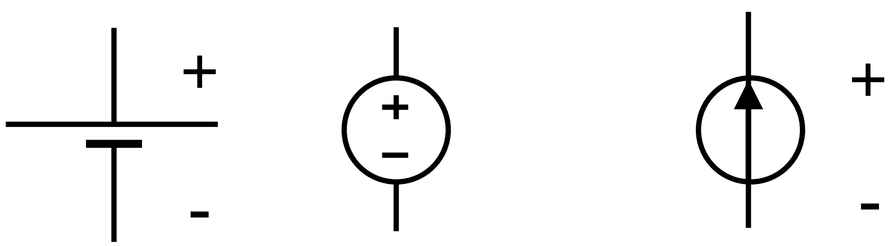
PARAMETERS OF VOLTAGE AND CURRENT SOURCES

DC sources

V <*name*> *N*+ *N*- DC <*value*>
I <*name*> *N*+ *N*- DC <*value*>

Voltage Source Current Source

V1 V2 I1



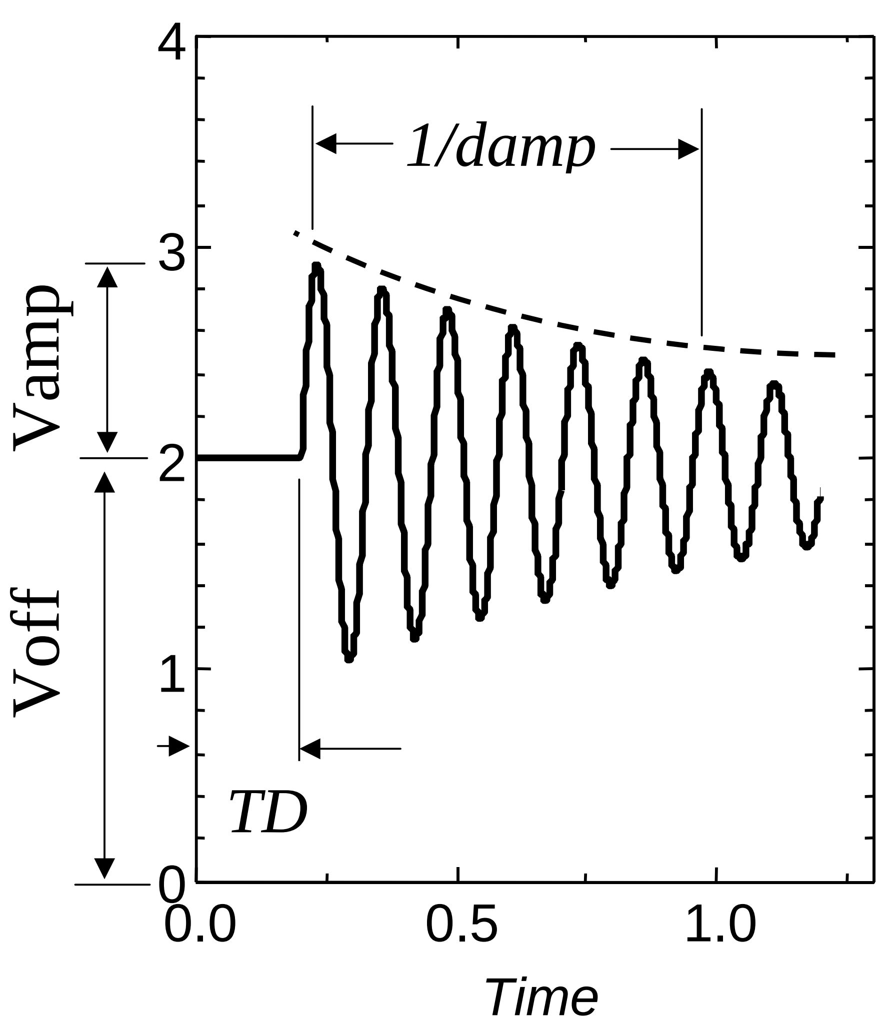
III. AC sources

For analysis in *time* domain

V<*name*> *N*+ *N*- SIN(*Voff Vamp* <*freq*> <*TD*> <*damp*>*)*

For analysis in *frequency* domain

V<*name*> *N*+ *N*- AC <*Vamp*>



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

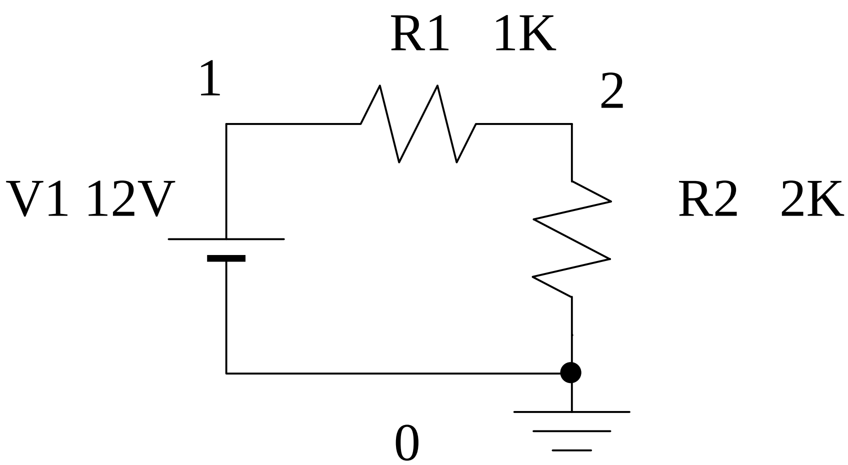
Suffix	Meaning	Example
DB	Magnitude in *dB*	V1DB(1,0)
M	Magnitude V_m	IM(V1)
P	Phase φ	V1P(1,0)
R	Real part V_{Re}	V1R(1,0)
I	Imaginary part V_{Im}	V1I(1,0)

$$\text{Decibell: } V_m\,[\text{dB}] = 20\, lg\, V_m\,[\text{Volts}]$$

$$\text{Phasor: } V = V_m\,[\text{Volts}]\, e^{j\varphi\,[\text{Degrees}]} = V_{Re} + jV_{Im}$$

EXAMPLE

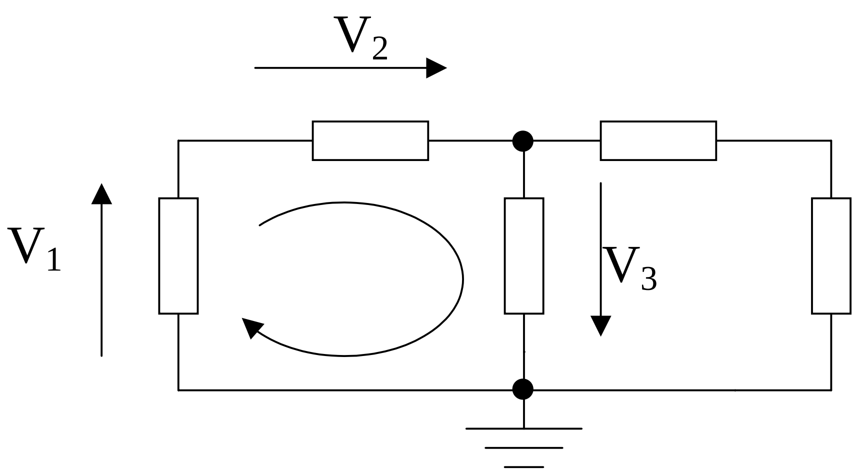
Write down a PSPICE netlist to perform the operating point analysis for the circuit in Figure below:



The Input File (Netlist):

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

Kirchhoff Voltage Law



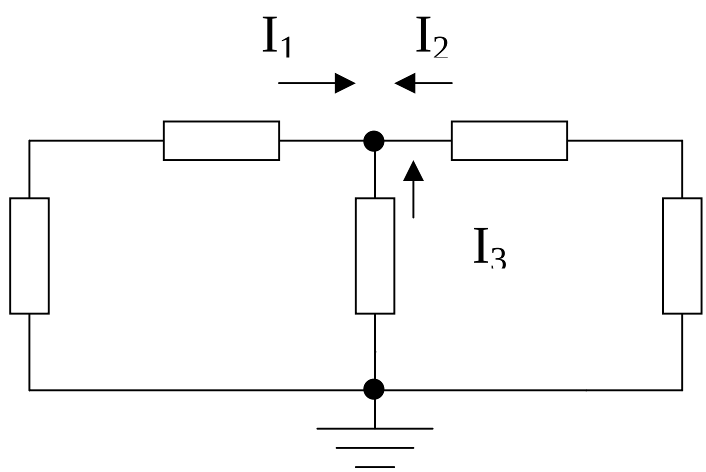
$$V_1 + V_2 + V_3 = 0$$

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



$$I_1 + I_2 + I_3 = 0$$

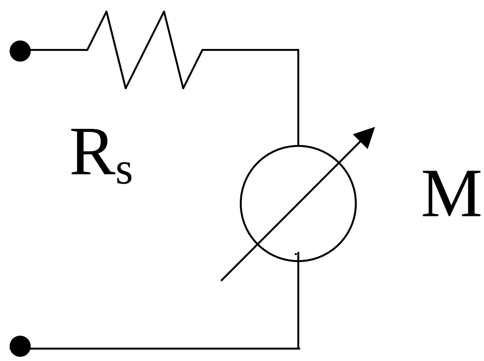
The algebraic sum of currents entering any node is zero

$$\sum_i I_i = 0$$

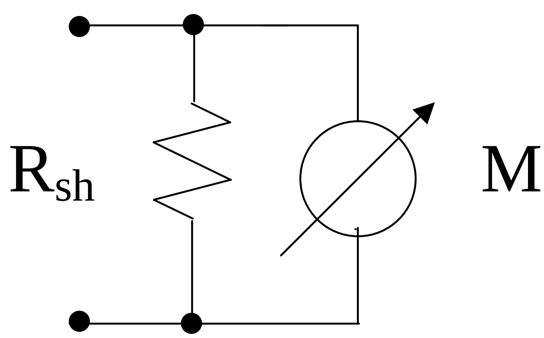
- Direction of current through every element can be chosen arbitrarily
- KCL is satisfied for AC signals

Analog Multimeter

Voltage Measurements



Current Measurements



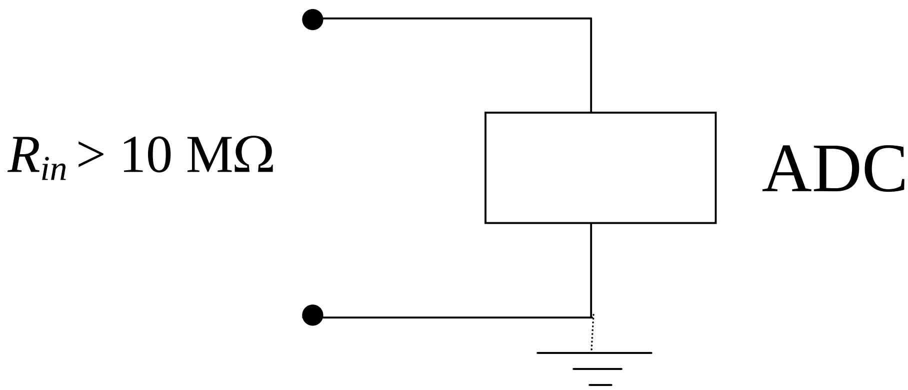
- *Floating* nodes: we can ignore the common mode voltage
- *Low accuracy:*

  Low input resistance for voltage measurements

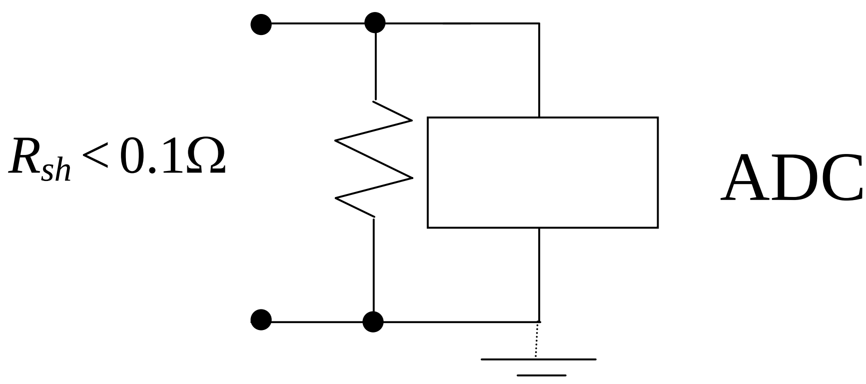
  Low input conductance for current measurements
- *Needs to be calibrated* for resistance measurements *for every scale*

Digital Multimeter

Voltage Measurements



Current Measurements



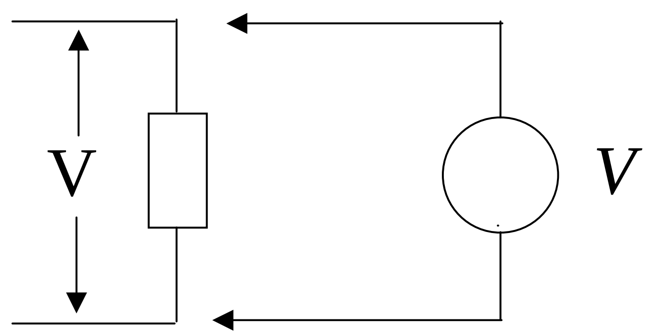
- *Virtually grounded*: the common mode voltage should be minimized!
- *High accuracy:*

  High input resistance for voltage measurements

  High input conductance for current measurements

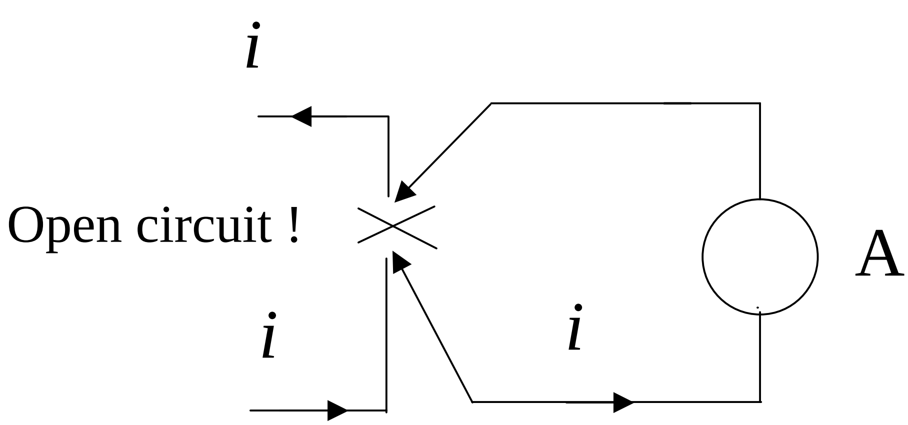
Voltage and Current Measurements

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

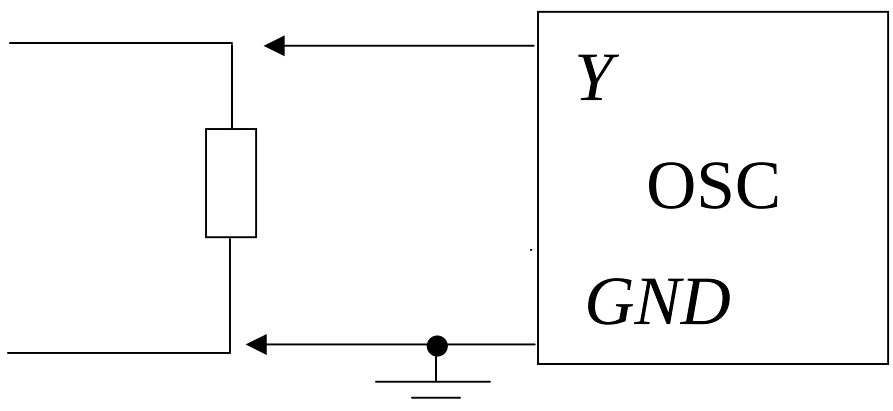
- *Dual* display of Digital Multi Meter (DMM) *Fluke 45* allows one to take ***two simultaneous*** measurements which is very useful

Dual Display Applications

Primary Display	Secondary Display	Applications
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

Oscilloscope

Voltage Measurements



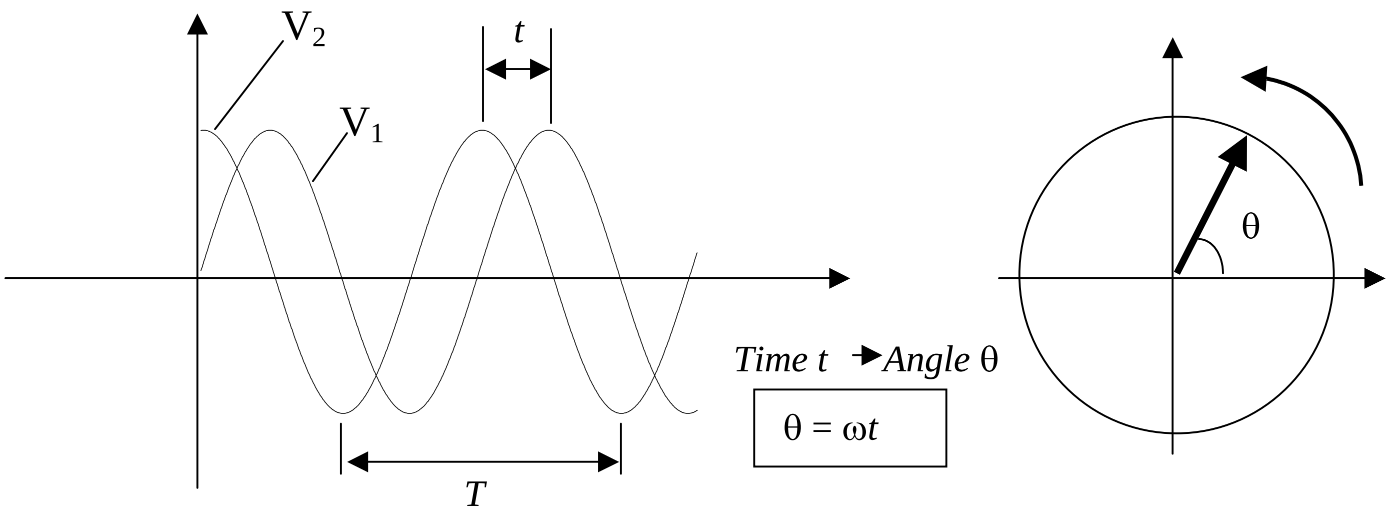
- Only *voltage measurements* can be taken
- One node is *always grounded*: the common mode voltage *must be zero*!

> 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* [Hz]= *1/T*
- *Angular frequency* shows the number of radians per sec: ω [s^{-1}] = *2π f*
- *Phase shift* is determined in the following way:

$$\Delta\Phi = \Phi_2 - \Phi_1 = \frac{t}{T}\cdot 2\pi\,[rad] = \frac{t}{T}\cdot 360[\deg rees]$$

- *Phase shift* is determined with *2π* accuracy
- Note the *sign* of the phase shift: in example above *V_2 is leading V_1*

Phasor Diagram

Exponential form of periodical *in time* signal:

$$V(t) = \mathrm{Re}\{V_m \cdot e^{j(\omega t + \varphi)}\} = \mathrm{Re}\{\overline{V} \cdot e^{j\omega t}\}$$

$$\overline{V} = V_m \cdot e^{j\varphi}$$

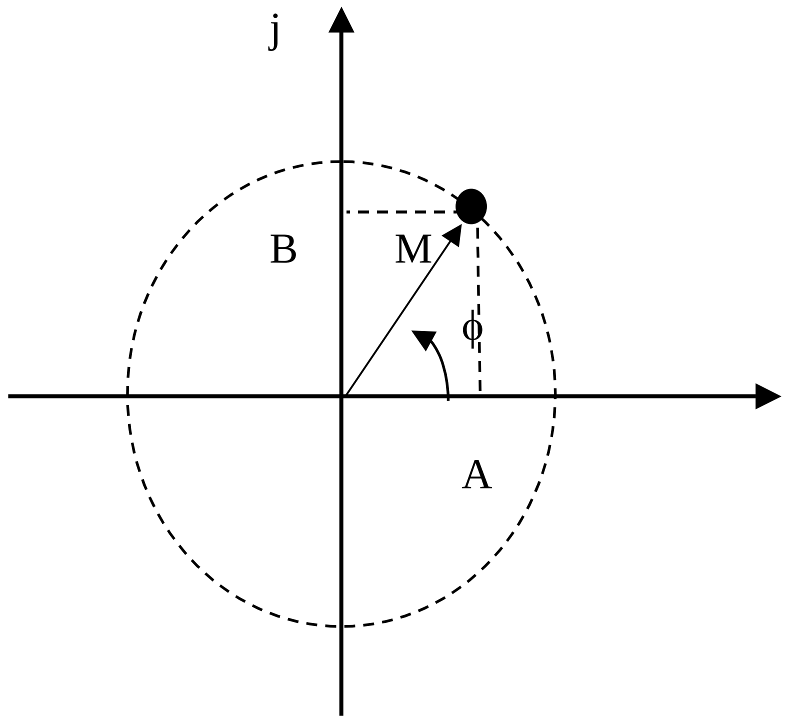
Phasor is a *complex number*

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*



$$X = A + jB = M\,e^{j\varphi}$$

- Eiler equation: $e^{j\phi} = \cos\phi + j\sin\phi$

$$M = (A^2 + B^2)^{1/2}, \quad \varphi = \arctan(B/A)$$

$$j^2 = -1, \quad j = e^{j\pi/2}$$

Operation with Complex Numbers

$$X_1 = A_1 + jB_1 = M_1\, e^{j\varphi 1}$$

$$X_2 = A_2 + jB_2 = M_2\, e^{j\varphi 2}$$

1) Sum of Complex Numbers:

$$X_1 + X_2 = (A_1 + A_2) + j\,(B_1 + B_2)$$

2) Product of Complex Numbers:

$$X_1 X_2 = M_1 M_2\, e^{j\,(\varphi 1+\varphi 2)}$$

$$X_1 X_2 = (A_1A_2 - B_1B_2) + j(A_1B_2 + B_1A_2)$$

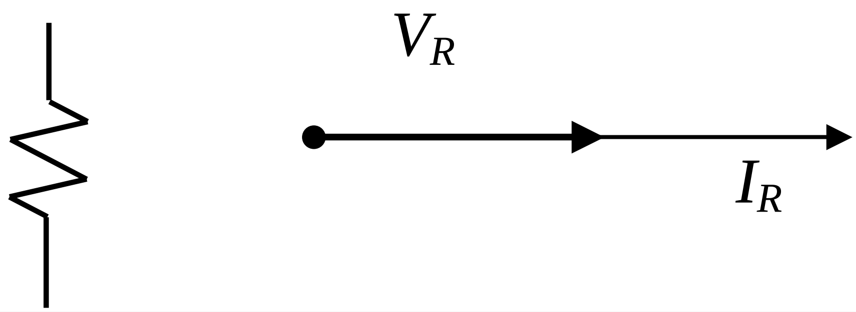
3)Ratio of Complex Numbers:

$$X_1/X_2 = \{(A_1A_2 + B_1B_2) + j(A_2B_1 - A_1B_2)\}/(A_2^2 + B_2^2)$$

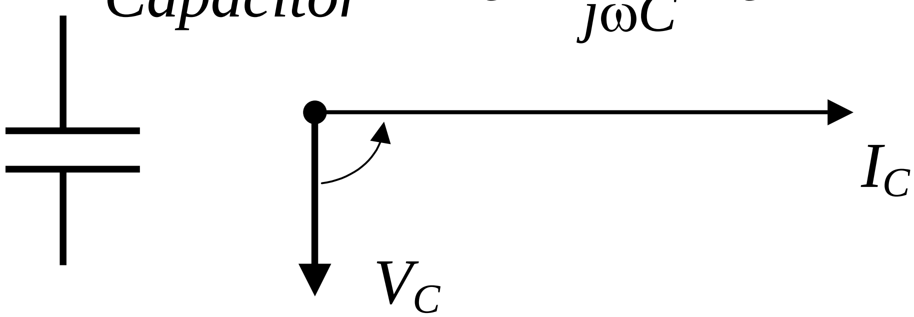
$$X_1 X_2 = (M_1 / M_2)\, e^{j\,(\varphi 1-\varphi 2)}$$

Voltage and Current Shift in Passive Elements

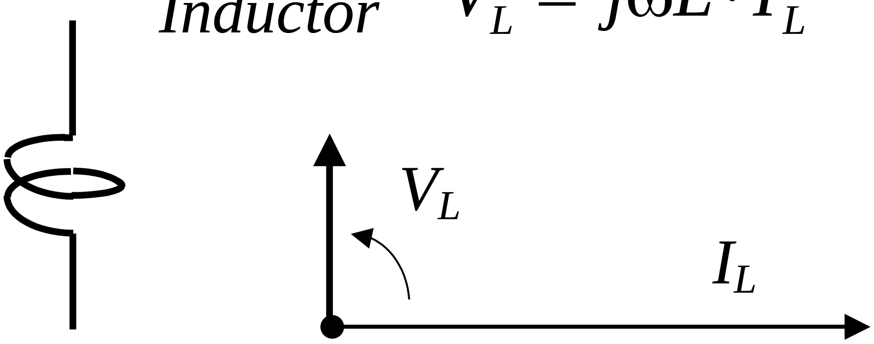
Resistor $V_R = R \cdot I,$



Capacitor $V_C = \frac{1}{j\omega C} \cdot I_C$



Inductor $V_L = j\omega L \cdot I_L$



AC signals

Mean value

$$\langle V \rangle_T = \frac{1}{T}\int_0^T V(t)\,dt$$

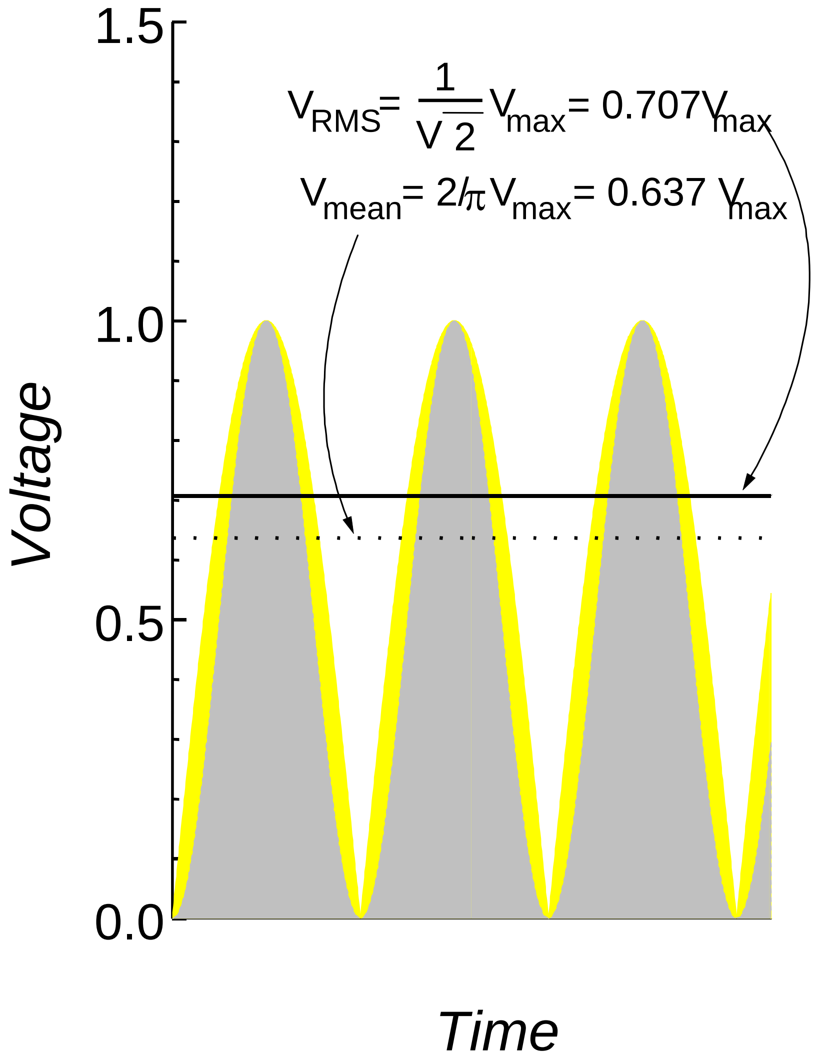
Root Mean Square (RMS)

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

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

$<|V|> = 2V_m/\pi = 0.637V_m$

$V_{RMS} = V_m/\sqrt{(2)} = 0.707V_m$


1.5
1.0
0.5
0.0
Voltage
Time
$V_{RMS} = \frac{1}{\sqrt{2}} V_{max} = 0.707 V_{max}$
$V_{mean} = 2/\pi V_{max} = 0.637\ V_{max}$