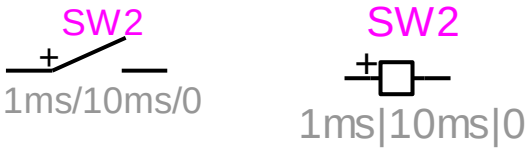
Ideal switch



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1 Available versions

This device can be 1-phase or 3-phase. The 3-phase version of this device is the equivalent of 3 independent 1-phase devices with separate data.
The library contains two versions of this device: Ideal switch and Ideal closed switch. The second version is provided for convenience since the switch drawing changes automatically to reflect the steady-state status of the switch.

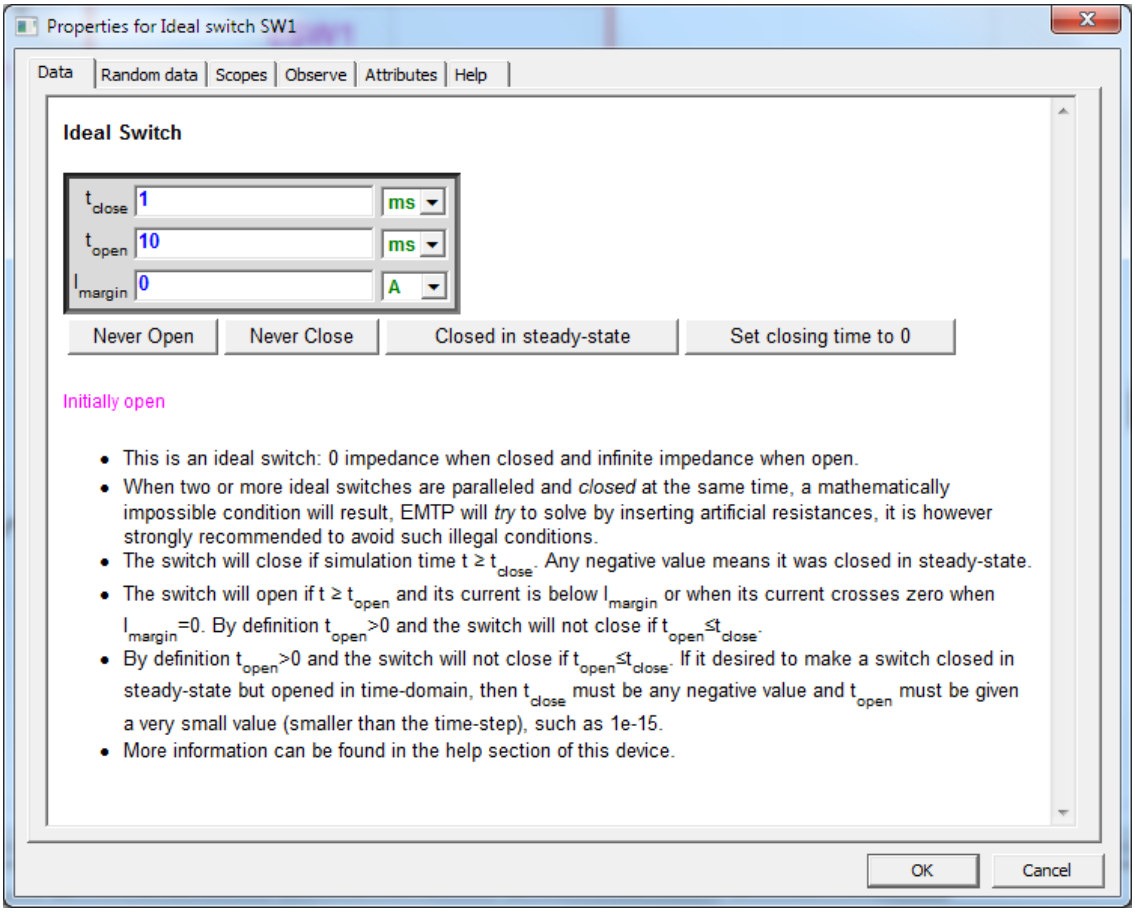
1.1 When changing phases

It is allowed to switch from 1-phase to 3-phase or from 3-phase to 1-phase. The user must verify data and scope requests according to requirements. If the device becomes 3-phase from 1-phase without opening and changing its data, the initial 1-phase data is propagated to all phases. If the device becomes 1-phase after being 3-phase without opening and changing its data, the phase-a data is retained.

2 Description

This device is an ideal switch. It has a zero resistance and zero voltage drop when closed and infinite resistance when open.
This device has random data capability.

3 Parameters and rules



3.1 Data tab

The first tab is used to enter the standard switch data:

- t_{close} is the switch closing time. The switch will close if the simulation time t is greater or equal to t_{close}. Any negative value means that the switch is closed in steady-state
- t_{open} is the switch opening time. The switch will open if $t \geq t_{open}$ and its current falls below I_{margin} or when its current crosses zero when $I_{margin} = 0$.
- I_{margin} is the absolute current margin.

By definition $t_{open} > 0$ and the switch will not close if $t_{open} \leq t_{close}$. If it is desired to make a switch closed in steady-state but opened in time-domain, then t_{close} must be any negative value and t_{open} must be given a very small value (smaller than the time-step), such as $1e-15$. Such a switch can be used as an initialization trick.

3.2 Random tab

- **Random data law**: Selects the random data law for this switch. This is the method used for generating random numbers. There are three options: Uniform, Gaussian and Systematic. More explanations are given below.
- **Dependency** is used to create random data dependency.

- **Reference switch name** is the switch on which the current switch depends when it is not a Master switch. Clicking on the hyperlink provides rules for naming the reference switch. It is noticed that if the switch is 3-phase, then it is allowed to refer from one phase to the other.
  - It is not allowed to refer to a non-random data switch or to any other non-random data based device.
- **Random Closing** time or **Random Opening** time.
  - When **Random Closing** time is selected, then the switch closing time t_{close} becomes a random variable. The switch is initialized as being open. The switch opening time t_{open} is not changed and remains active. The switch may open after t_{open}. The user must also check that $t_{open} > t_{close}$ if desired.
  - When **Random Opening** time is selected, then the switch opening time t_{open} becomes a random variable. The switch opening rules described above remain applicable. The switch is initialized as closed and t_{close} is set to -1.
- **Mean**: This field has different definitions depending on the selections above.
  - The mean (μ) of the Gaussian or Uniform law when this switch is a Master.
  - The mean (μ) of delay of the Gaussian or Uniform law when this switch is a Slave.
  - The Start time of the Systematic law when this switch is a Master.
  - The Start time delay of the Systematic law when this switch is a Slave.
- **Standard deviation**: This field has different definitions depending on the selections above.
  - The Standard deviation (σ) of the Gaussian or Uniform law when this switch is a Master.
  - The Standard deviation of delay (σ) of the Gaussian or Uniform law when this switch is a Slave.
  - The Step size (ΔT) of the Systematic law when this switch is a Master or Slave.
- **Number of steps**: This field is only used for the Systematic law. It indicates the number of steps performed for this switch in the Systematic switching process.

In the 3-phase case there are 3 Random data tables, one for each phase. The phases can be interdependent and depend on other switches. It is however illegal to create dependency loops and will result in an error message on EMTP side.

3.2.1 Gaussian and Uniform laws

For a Master switch the random data generator calculates the random data T_{master} (t_{close} or t_{open}) using the specified Mean μ and Standard deviation σ entries.

For a Slave switch, the random data generator first generates the random data T_{slave}^{delay} for the slave switch and then adds it to the master switch. The following relation is established for an arbitrary pair of Slave and Master switches:

$$T_{slave} = T_{master} + T_{slave}^{delay}$$

It is allowed to have a negative T_{slave}^{delay} and it is allowed to specify a negative Mean for the Slave switch. It is noticed however that the Mean of a Master switch cannot be negative since it will step into the steady-state solution domain. Generally speaking, the calculated random time T of any switch (Slave or Master) should be bounded to make a significant event:

$$t_{dice} < T < t_{max} \quad (1)$$

The t_{max} is the maximum simulation time and t_{dice} is the "Time of dice roll" which is set in the "Stat Options" device. The t_{dice} is the starting time of all random simulations (energizations) in a case. It is greater or equal to zero. More information on the setting of this parameter can be found in the Help section of "Stat Options". For a random closing switch the random time T corresponds to the actual (real switching time T_{real}) closing time. For a random opening switch the random time T is the time after which the switch is allowed to open based on

its current I_{margin} condition, thus the real switching time may be different and fall outside the interval given by equation (1).

If the Uniform law is used, the user can pre-calculate the random data interval by using the following formulas:

$$T_{min} = \mu - \sqrt{3}\sigma$$

$$T_{max} = \mu + \sqrt{3}\sigma$$

When the T_{real} of a switch falls outside the interval of equation (1), EMTP still performs the simulation. For a random closing switch, there will be no actual closing, but the switch may open based on t_{open} and I_{margin}. For a random opening switch, there will be no opening and the switch will remain closed for the given random simulation.

3.2.2 Systematic law

In this case the switch random time T_{master} (becomes t_{close} or t_{open}) for each switch is computed from the following equation for an arbitrary Master switch:

$$T_{master} = T_{master}^{start} + (n_{master} - 1)\Delta T_{master}$$

where T_{master}^{start} is the Start time, n_{master} is the Number of steps and ΔT_{master} is the step size. The minimum value of n_{master} is 1. All these numbers are positive for a Master switch. ΔT_{master} can be zero and n_{master} can be 1.

If there are several systematic switches in a design, then EMTP must perform all switching combinations and the maximum number of systematic simulations is given by the following formula:

$$N_{simulations}^{syst} = \prod_{i=1}^{n_{syst}} n_i$$

where n_{syst} is the number of systematic switches (Master or Slave) and n_i is the Number of steps for each systematic switch. This number can become very high and the user must be careful with selections. More options are available through the “Stat Options” device.

For a Slave systematic switch, the T_{slave} is calculated as follows:

$$T_{slave} = T_{master} + T_{slave}^{delay} + (n_{slave} - 1)\Delta T_{slave}$$

It is now allowed to use a negative T_{slave}^{delay}. In most cases it is just required to specify a simple delay by setting n_{slave} to 1.

The rules indicated by equation (1) remain applicable.

3.2.3 Base Case

The Base Case option that can be selected in the “Stat Options” device is for performing a standard simulation before starting random simulations (random data based simulations).

This “Ideal switch” device does not calculate any random data in the Base Case simulation. The following settings are automatically applied for a Gaussian or Uniform law switch:

- If the switch is a closing switch: $t_{close} = \mu$, the switch is initialized as open, but t_{open} remains active.
- If the switch is an opening switch: $t_{open} = \mu$, the switch is initialized as closed and t_{close} is set to -1.

When the switch is using a Systematic law, then the Mean time μ above is replaced by the Start time. All dependency rules are maintained.

3.3 Scopes tab

The first section of this tab is for providing access to standard scopes. The second section “Random data” is for optionally saving the “Random switching times” and “Real switching times” for each simulation. As explained earlier, the “Random switching times” are the switching times T calculated by the random number generator. It includes dependency. The “Real switching times” is for saving T_{real}, the actual event occurrence due to the model of the device. This variable is reset to 0 at each new simulation startup. Which means that if the event never occurs, it stays at 0.

It is also noticed that due to floating point precision and internal computation delays, there could be a minor difference between T and T_{real} in situations where these numbers must theoretically coincide.

4 Rules

It is not allowed to delete any pins.

This is an ideal device. Placing several switches in parallel is acceptable if the switches are not closed at the same time. When paralleled switches are closed at the same time, mathematically impossible conditions will result and EMTP will *try* to solve such cases by inserting dummy resistances.

5 Netlist format

```
_Sw0;SWSTAT;2;2;s7,s8,
1ms,10ms,0,1,1,REFERENCE,1,.1,.001,5,?v,?i,?p,?t,?T,>v,>i,>p,>S,
```

Field	Description
_Sw0	Part name
SWSTAT	Instance name, any name.
2	Total number of pins
2	Number of pins given in this data section
s7	Signal name connected to k-pin, any name
s8	Signal name connected to m-pin, any name
t_{close}	Closing time
t_{open}	Opening time
I_{margin}	Current margin
Law	Random data law, 0 is no random data, 1 is Uniform, 2 is Gaussian, 3 is Systematic
Dependency	0 is Master, 1 is Slave
Reference name	Reference name for a slave switch
Close or Open	1 is closing switch, 2 is opening switch
Mean	As described above
Standard deviation	As described above
Number of steps	As described above
?v, ?i, ?p,?t,?T	Optional scope requests
>v, >i, >p, >S	Optional observe requests

Device data fields are saved into the ParamsA device attribute. The 3-phase versions saves data into ParamsB and ParamsC. The 3-phase appends the phase name character and creates 3 separate data switches.

6 Steady-state model and initial conditions

If the switch is closed in the steady-state solution ($t_{close} < 0$), it is modeled as an ideal closed switch. It is an open-circuit otherwise.

7 Frequency Scan model

Similar to the steady-state.

8 Time-domain model

The switch is modeled by a zero resistance when conducting and by an infinite resistance when turned off.