VeriBest Analog Automotive Library Reference Manual

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VB 99.0

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Chapter 1
Introduction

Introduction

The Analog Automotive Library is a collection of both functional and behavioral models that allow an analog automotive engineer to simulate a complete automotive system. This allows you to study interactions between subsystems, even those of different technologies.

You can simulate the electronics of a car’s harness control system, together with all actuators, sensors, transducers, and automotive industry specific components.

The models described in this manual are used in conjunction with VeriBest Analog (VBA).

Chapter 2
Control System Models

Control System Models

The following models are described in this chapter.

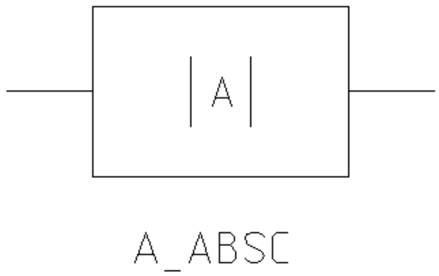
Model Name	Description
A_ABSC	Converter, absolute value
A_ALLPASS1	Filter, 1st order all-pass
A_ALLPASS2	Filter, 2nd order all-pass
A_ALLPASS3	Filter, 3rd order all-pass
A_BACKLASH	Backlash
A_BANGBANG	Controller, BangBang (on/off)
A_BIQUAD	BIQUAD circuit
A_CLIPINT	Integrator, clipped output
A_COST	Transducer, cosine
A_DL_COMP	Compensator, derivative lag
A_DZON	Deadzone functional block
A_GAINDLY	Gain delay functional block
A_GAINZD	Gain block with zero delay
A_IGRATE	Integrator
A_LAG	Compensator, lag

Model Name	Description
A_LEADLAG	Compensator, lead-lag
A_LIM	Limiter
A_MAX	Maximum value selector
A_MIN	Minimum value selector
A_MULT	Multiplier, 2-input
A_PI_COMP	Compensator, proportional integral
A_RAPOLY1	Filter, 1st order rational polynomial
A_RAPOLY2	Filter, 2nd order rational polynomial
A_RAPOLY3	Filter, 3rd order rational polynomial
A_SINT	Transducer, sine
A_SQRTC	Converter, square root
A_SUM	Summing element

A_ABSC (Absolute Value Converter)

A_ABSC models an absolute value converter. The output is the absolute value of the input scaled by a gain.

Graphic Symbol

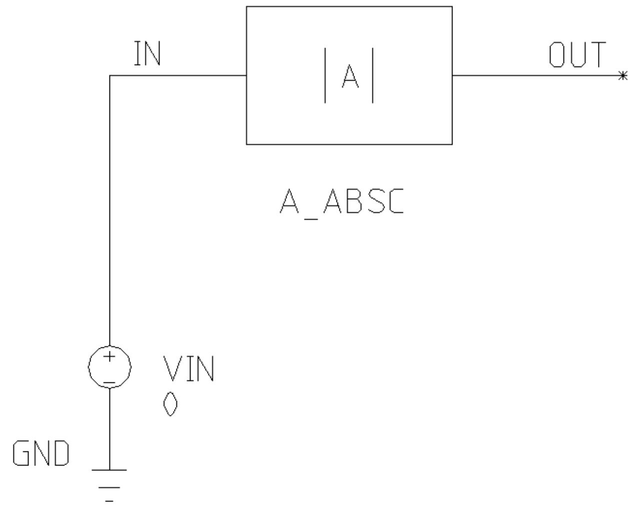


Modelled Parameters

The following parameters can be modified.

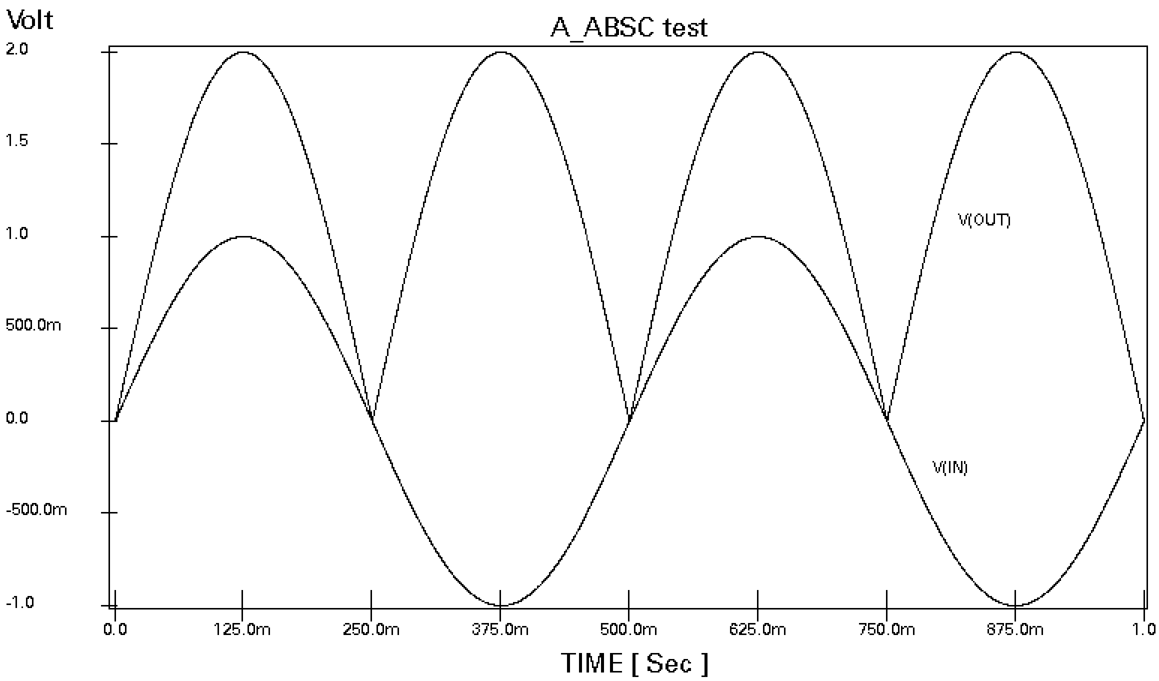
Parameter	Default Value	Unit
GAIN	1	–

Test Circuit



Test Results

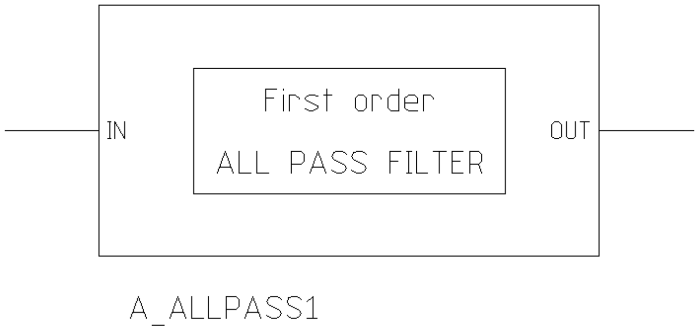
A simulation with a sine wave input and a model gain of 2 gave the following results.



A_ALLPASS1 (All-pass Filter, 1 pole, 1 zero)

This macromodel, A_ALLPASS1, is a functional, all-pass filter with one pole and one zero.

Graphic Symbol



Modelled Parameters

The following parameters can be modified.

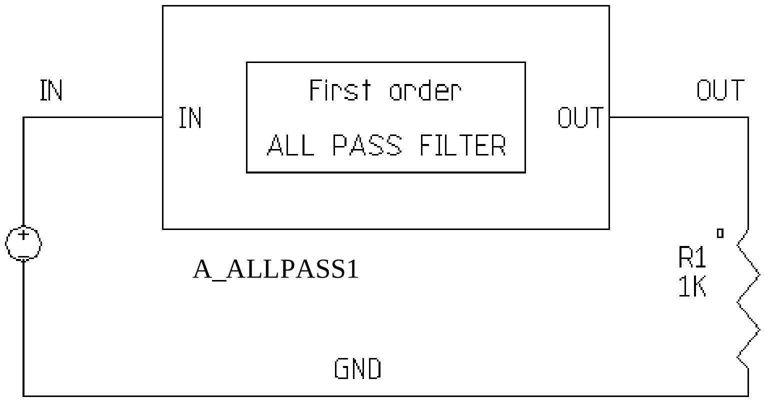
Parameter	Default Value	Unit
K (Gain)	1	–
F1 (Pole-zero pair frequency)	1K	Hz

Design Notes

The input impedance is 1GΩ and the output impedance is 0Ω.

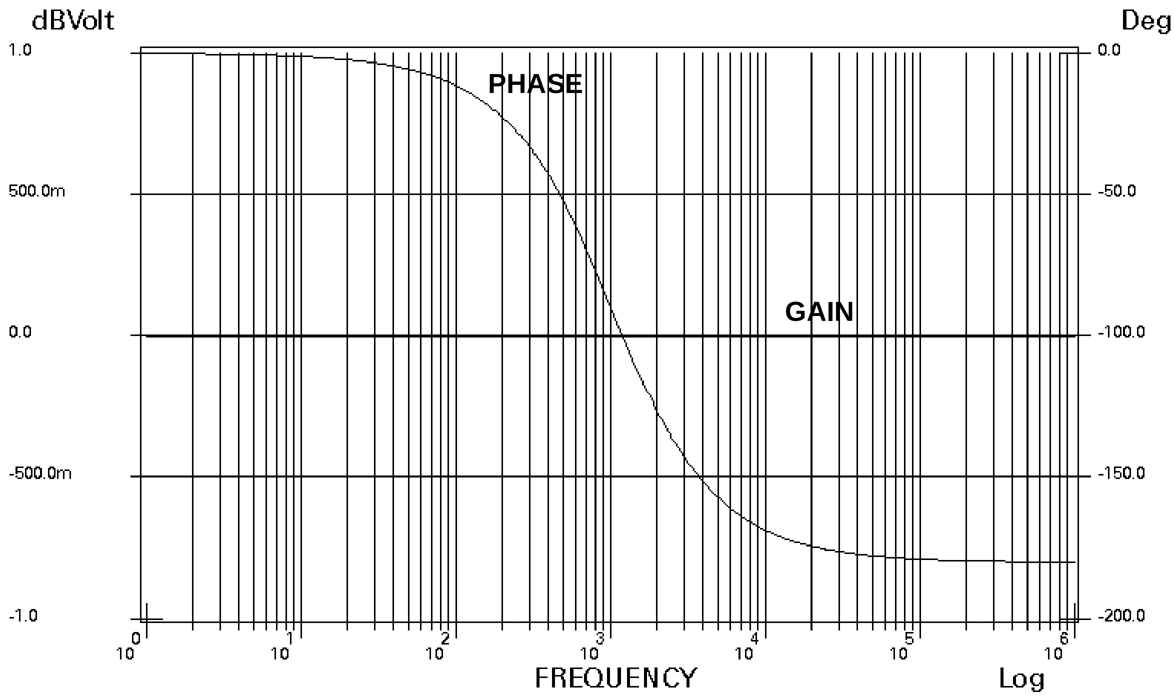
Test Circuit

The following circuit has a variable frequency response dependent on the settings of the PARSET file. With the default parameters shown on the first page of this data-sheet, the response is that shown in the Bode-plot.



Open-Loop Frequency Response

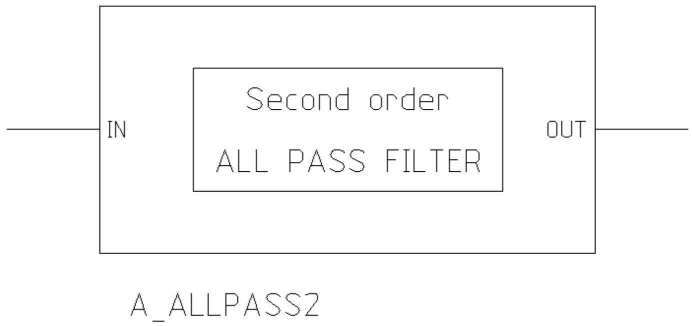
The following graph shows the frequency response of the all-pass filter with the pole-zero pairs set to the default values. Note that the gain remains constant. The all-pass filter has the same number of poles as zeros. When plotted in the s-plane, the poles and zeros are at the same frequency but the poles are on the left-hand side and the zeros on the right-hand side of the plane. The effect is that each pole-zero pair gives the same phase-change as a two-pole pair in the left-hand s-plane, but no gain reduction is present.



A_ALLPASS2 (All-pass Filter, 2 poles, 2 zeroes)

This macromodel, A_ALLPASS2, is a functional all-pass filter with two poles and two zeros.

Graphic Symbol



Modelled Parameters

The following parameters can be modified.

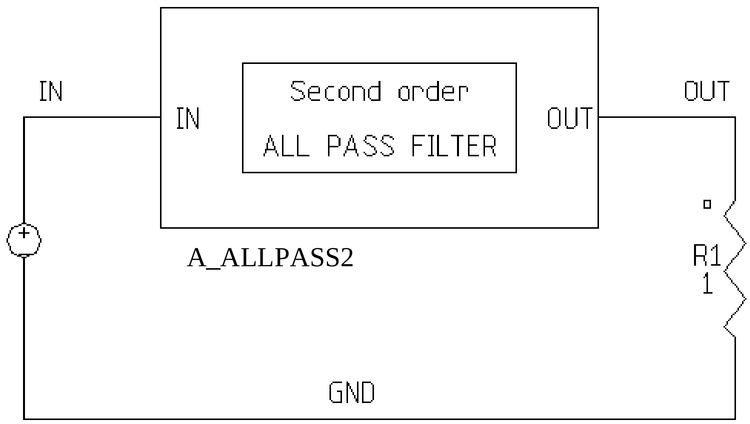
Parameter	Default Value	Unit
K (Gain)	1	–
F1 (Pole-zero pair frequency)	1K	Hz
F2 (Pole-zero pair frequency)	10K	Hz

Design Notes

The input impedance is 1GΩ and the output impedance is 0Ω.

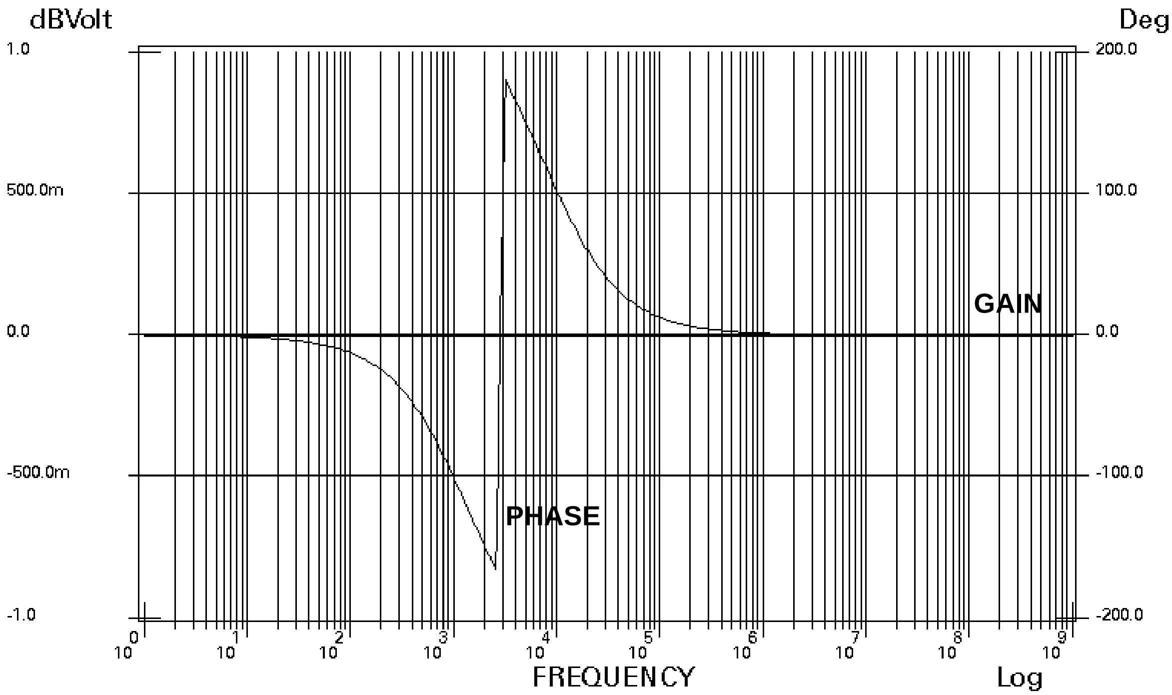
Test Circuit

The following circuit has a variable frequency response dependent on the settings of the PARSET file. With the default parameters shown on the first page of this data-sheet, the response is that shown in the Bode-plot.



Open-Loop Frequency Response

The following graph shows the frequency response of the all-pass filter with the pole-zero pairs set to the default values. Note that the gain remains constant. The all-pass filter has the same number of poles as zeros. When plotted in the s-plane, the poles and zeros are at the same frequency but the poles are on the left-hand side and the zeros on the right-hand side of the plane. The effect is that each pole-zero pair gives the same phase-change as a two-pole pair in the left-hand s-plane, but no gain reduction is present.



A_ALLPASS3 (All-pass Filter, 3 poles, 3 zeroes)

This macromodel, A_ALLPASS3, is a functional all-pass filter with three poles and three zeros.

Graphic Symbol

Modelled Parameters

The following parameters can be modified.

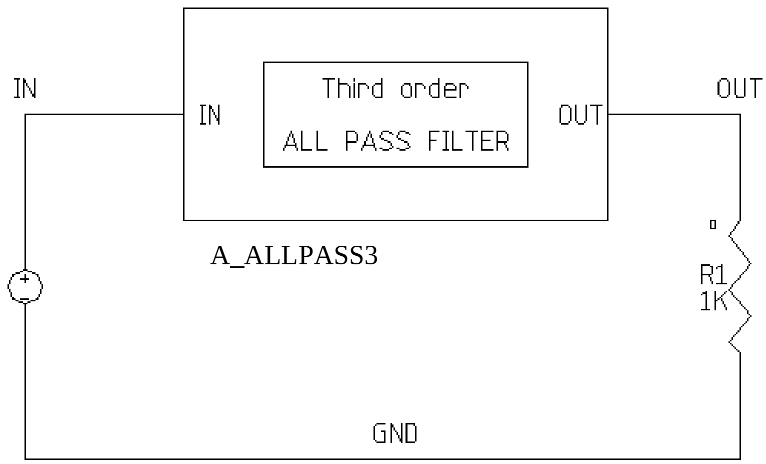
Parameter	Default Value	Unit
K (Gain)	1	–
F1 (Pole-zero pair frequency)	1K	Hz
F2 (Pole-zero pair frequency)	10K	Hz
F3 (Pole-zero pair frequency)	100K	Hz

Design Notes

The input impedance is 1GΩ and the output impedance is 0Ω.

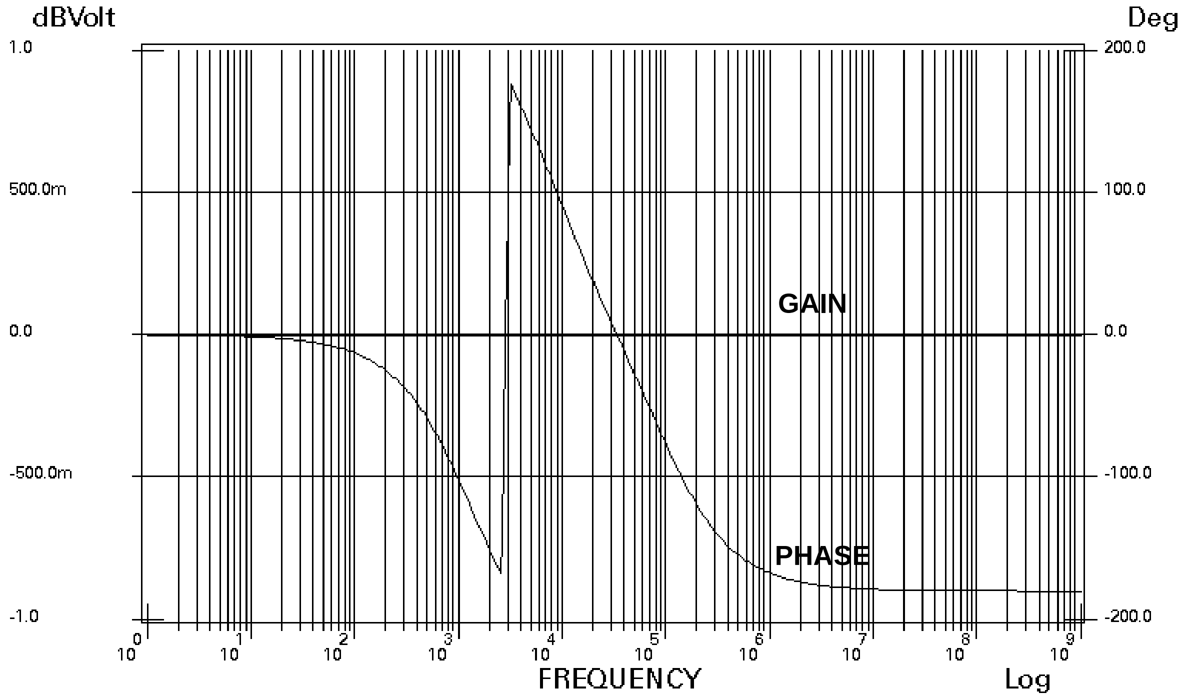
Test Circuit

The following circuit has a variable frequency response dependent on the settings of the PARSET file. With the default parameters shown on the first page of this data-sheet, the response is that shown in the Bode-plot.



Open-Loop Frequency Response

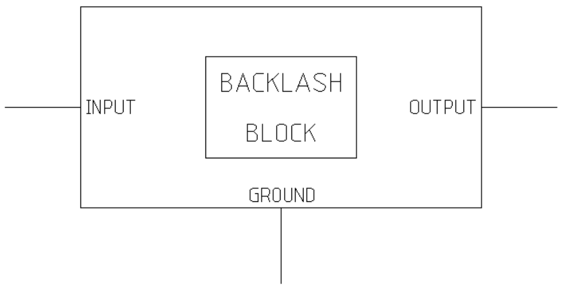
The following graph shows the frequency response of the all-pass filter with the pole-zero pairs set to the default values. Note that the gain remains constant. The all-pass filter has the same number of poles as zeros. When plotted in the s-plane, the poles and zeros are at the same frequency but the poles are on the left-hand side and the zeros on the right-hand side of the plane. The effect is that each pole-zero pair gives the same phase-change as a two-pole pair in the left-hand s-plane, but no gain reduction is present.



A_BACKLASH (Hysteresis Effects)

This component models the hysteresis effects found in many electromechanical applications. The model accounts for the deadzone effect where output remains constant for a changing input.

Graphic Symbol



A_BACKLASH

Modelled Parameters

The following parameters can be modified.

Parameter	Default Value	Unit
BACKLASH (Total Backlash end to end)	2	V

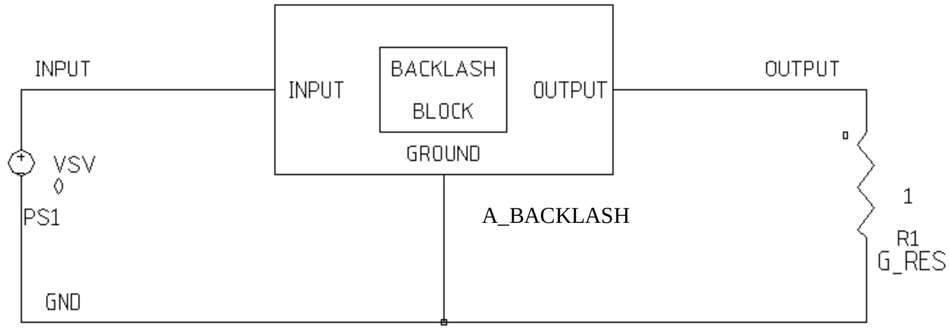
Design Notes

The Backlash element is designed to be used as described below.

- The block is designed to accept a voltage input and produce a voltage output.
- At the start of the simulation, the block converges to a point where the output is half way across the deadband region and $V_{OUTPUT} = V_{INPUT}$
- It may be necessary to limit the maximum step size parameter in the time analysis form for some simulations.
- The terminal GROUND may be allowed to float.

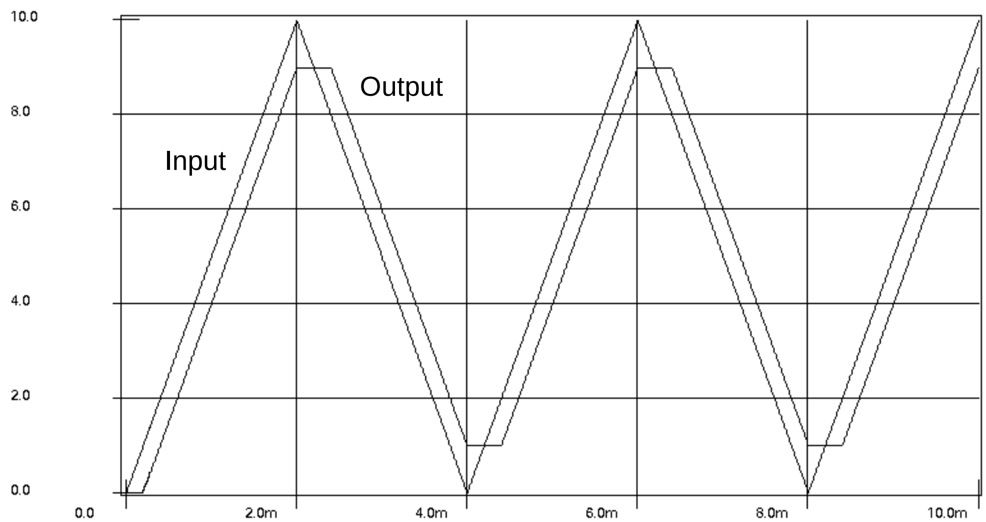
Test Circuit

The circuit shown below was used to produce the example waveforms. The voltage source on the input was set to produce the sawtooth waveform shown in the results.



Example Waveforms

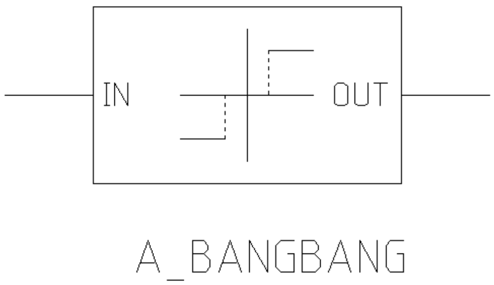
The example below shows the operation of the backlash element when a sawtooth waveform is applied to the input. The parameter BACKLASH was set to 2V for the example run.



A_BANGBANG (On/Off Controller)

A_BANGBANG models an ideal on/off controller. There are three possible output values. If the input is greater than or equal to the positive threshold value, the output is +O. If the input is between the positive and negative threshold values, the output is 0 (zero). If the input is less than or equal to the negative threshold \value, the output is -O.

Graphic Symbol

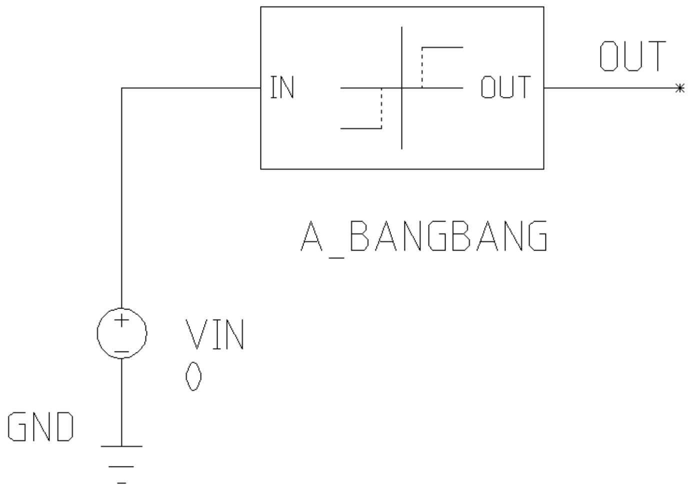


Modelled Parameters

The following parameters can be modified.

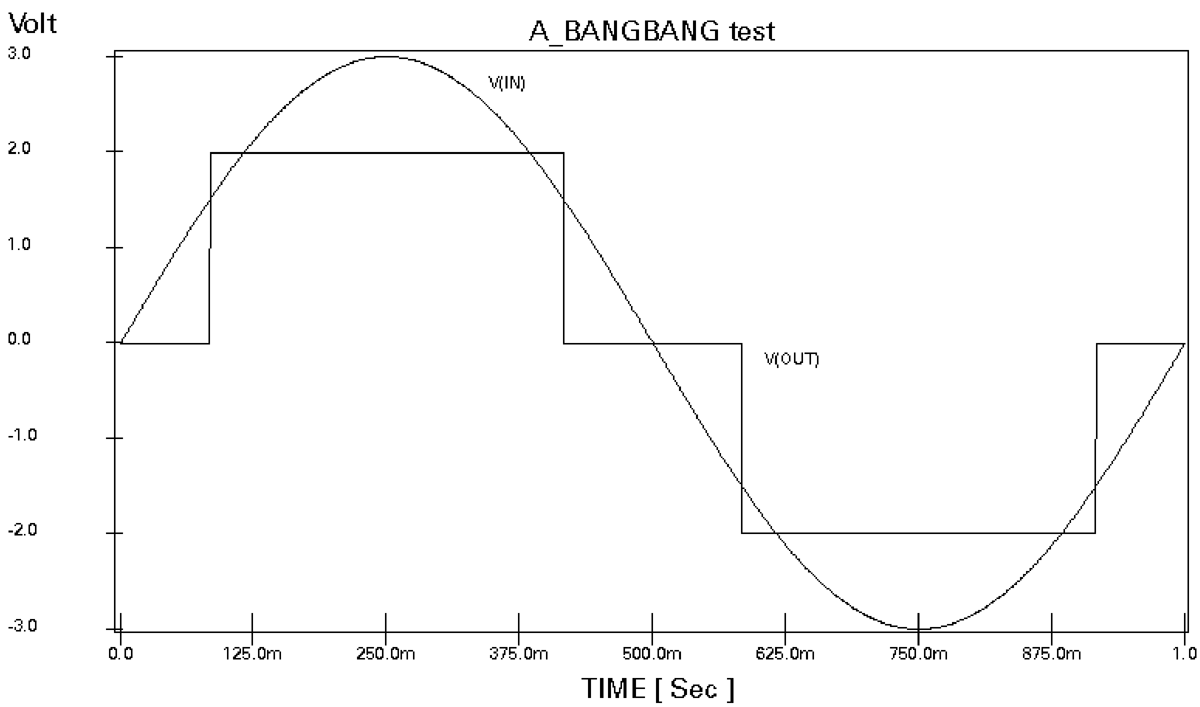
Parameter	Default Value	Unit
THRESHOLD (Threshold value)	1	V
O (Output values for ON state)	1	V

Test Circuit



Test Results

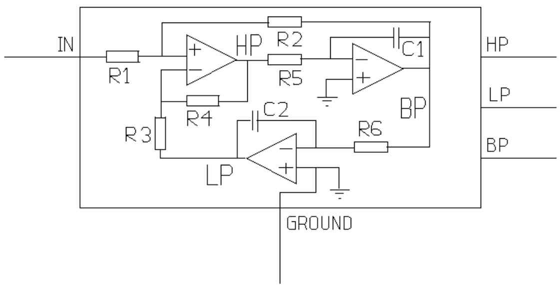
A simulation with a sine wave input with THRESHOLD =1.5 and O = 2 gave the following results.



A_BIQUAD (BIQUAD Circuit)

This macromodel of a A_BIQUAD circuit is a generic, functional model.

Graphic Symbol



A_BIQUAD

Modelled Parameters

The following parameters can be modified.

Parameter	Default Value	Unit
R1	10K	W
R2	100K	W
R3	100K	W
R4	15.8K	W
R5	1K	W
R6	10K	W
C1	1n	F
C2	1n	F

Unmodelled Characteristics

The characteristics of A_BIQUAD which are not modelled are listed below.

- operational amplifier poles and zeros
- temperature coefficient
- output impedances (all output impedances are 0 Ω)
- input impedance (the input impedance is set to 100 Meg Ω)

Design Notes

The transfer functions for the low-pass, band-pass, and high-pass outputs are as follows:

$$\frac{V_{HP}(s)}{V_{IN}(s)} = K_{HP}\frac{s^2}{s^2 + \left(\frac{\omega_p}{q_p}\right)s + \omega_p^2} \qquad K_{HP} = \frac{\frac{R_4}{R_3} + 1}{\frac{R_1}{R_2} + 1}$$

$$\frac{V_{BP}(s)}{V_{IN}(s)} = K_{BP}\frac{\left(\frac{\omega_p}{q_p}\right)s}{s^2 + \left(\frac{\omega_p}{q_p}\right)s + \omega_p^2} \qquad K_{BP} = \frac{R_2}{R_1}$$

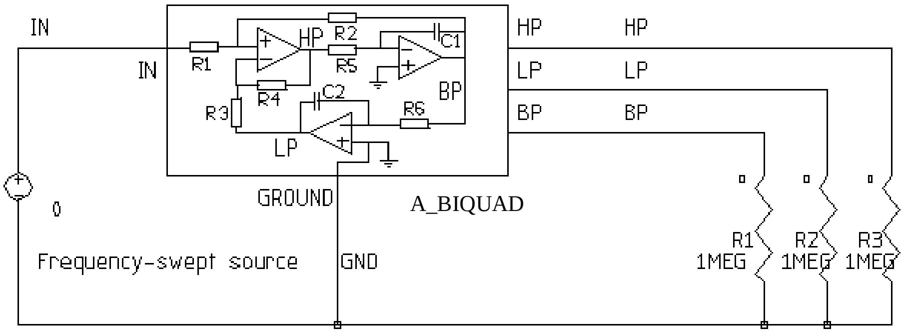
$$\frac{V_{LP}(s)}{V_{IN}(s)} = K_{LP}\frac{\omega_p^2}{s^2 + \left(\frac{\omega_p}{q_p}\right)s + \omega_p^2} \qquad K_{LP} = \frac{\frac{R_3}{R_4} + 1}{\frac{R_1}{R_2} + 1}$$

$$\omega_p^2 = \frac{R_4}{R_3 R_5 R_6 C_1 C_2} \qquad q_p = \frac{1 + \frac{R_2}{R_1}}{1 + \frac{R_4}{R_3}}\sqrt{\frac{R_4}{R_3}}$$

Note: The frequency should be varied using R_4 and q_p using R_2.

Test Circuit

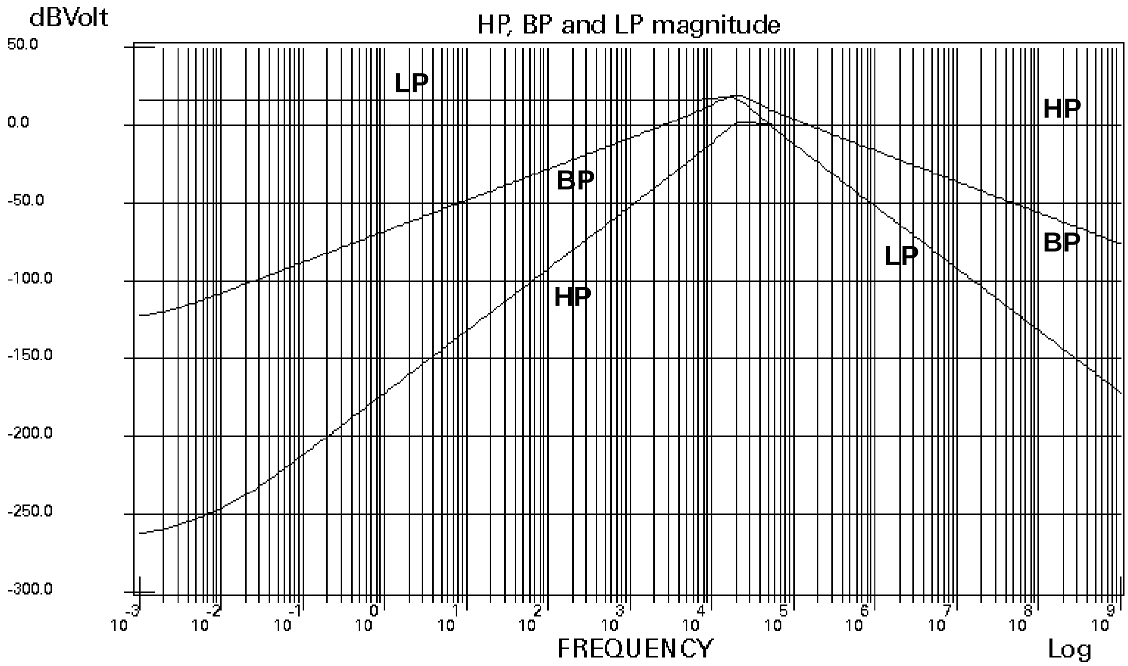
The component values used for the Biquad test circuit are the default values given in the “Modelled Parameters” section.



Open-Loop Frequency Response

The test circuit was designed to have a band-pass center frequency of 20kHz and a bandpass gain of 20dB with a Q factor of 0.6.

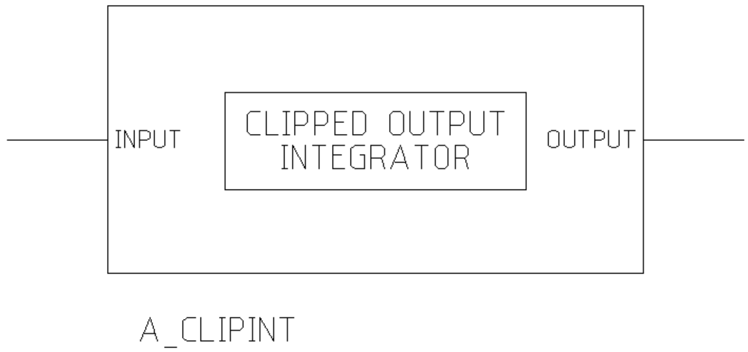
The high-pass gain K_{HP} is 0.44 dB and the low-pass gain is 16.5 dB.



A_CLIPINT (Clipped Integrator)

This macromodel, A_CLIPINT, is a functional block integrator model that clips the output voltage at an upper and lower level. You can set the initial condition and the clipping levels.

Graphic Symbol



Modelled Parameters

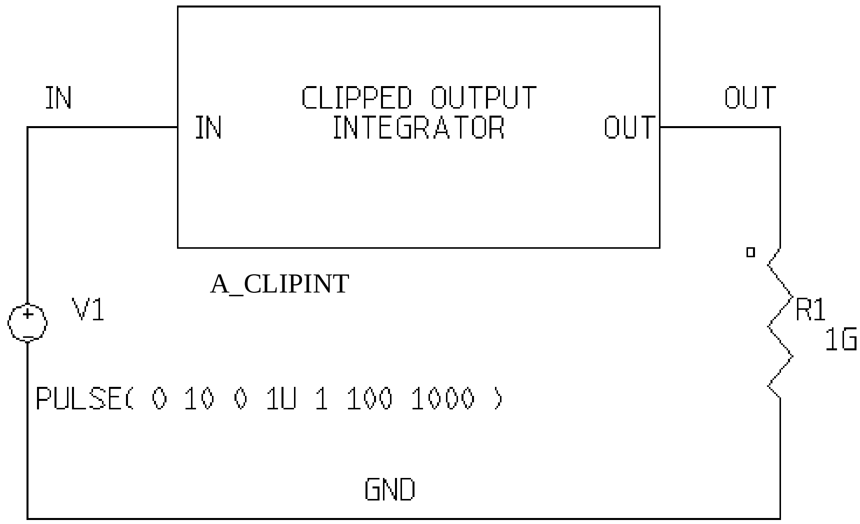
The following parameters can be modified.

Parameter	Default Value	Unit
IC (Initial condition)	0	V
V_HIGH (Upper clipping voltage)	14	V
V_LOW (Lower clipping voltage)	-14	V

Note: The initial condition is used only if IC is toggled On in the TIME form under the Analysis command.

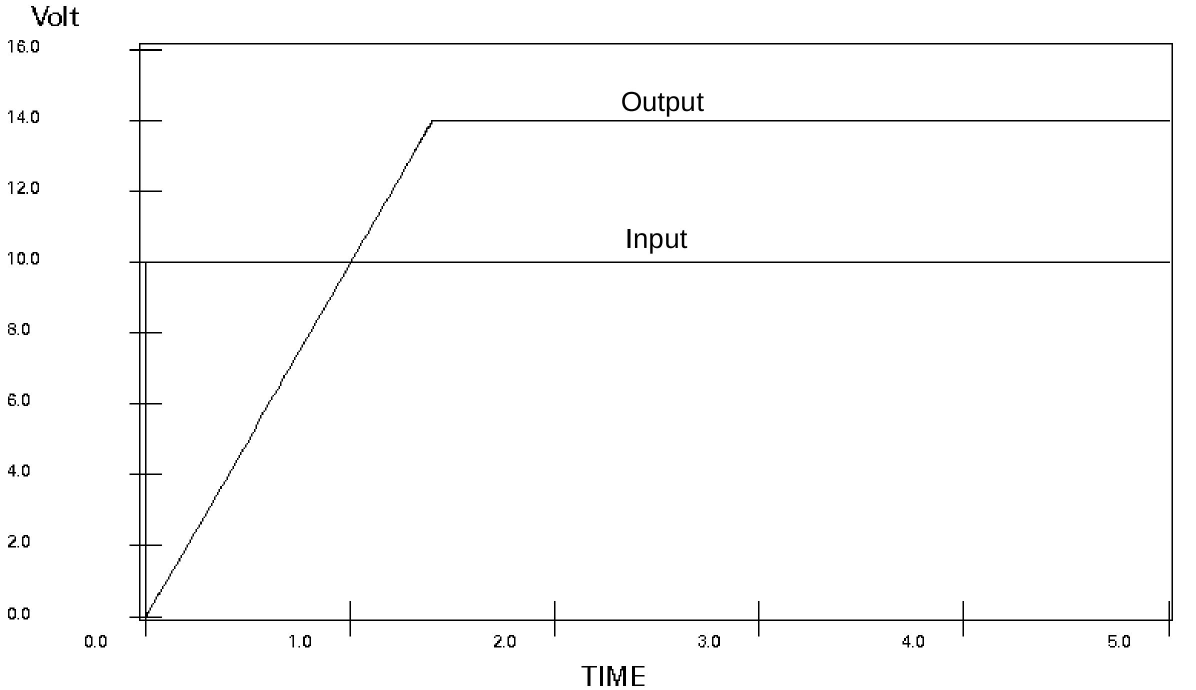
Test Circuit

The output signal is 0V (the initial condition) plus the time integral of the input voltage. The output voltage is limited to the clipping levels.



Test Results

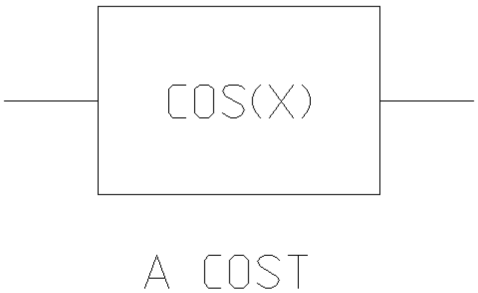
Results from a 5s simulation of the test-circuit are shown. The initial condition was set to the default value of 0 and the input voltage was stepped from zero volts to 10V at time=0. The clip levels were set at plus or minus 14V.



A_COST (Cosine Transducer)

A_COST models a cosine transducer. The output is the cosine of the input scaled by a gain.

Graphic Symbol

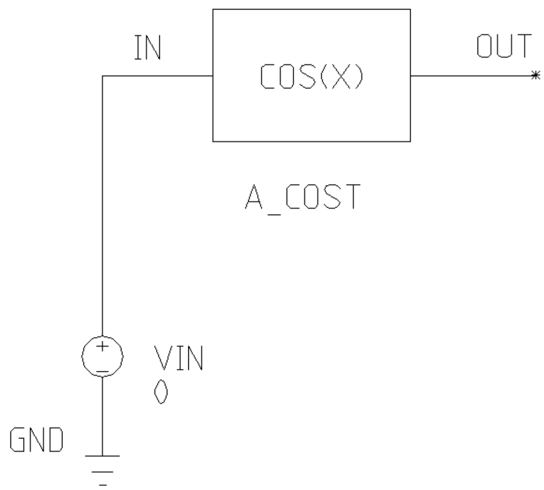


Modelled Parameters

The following parameters can be modified.

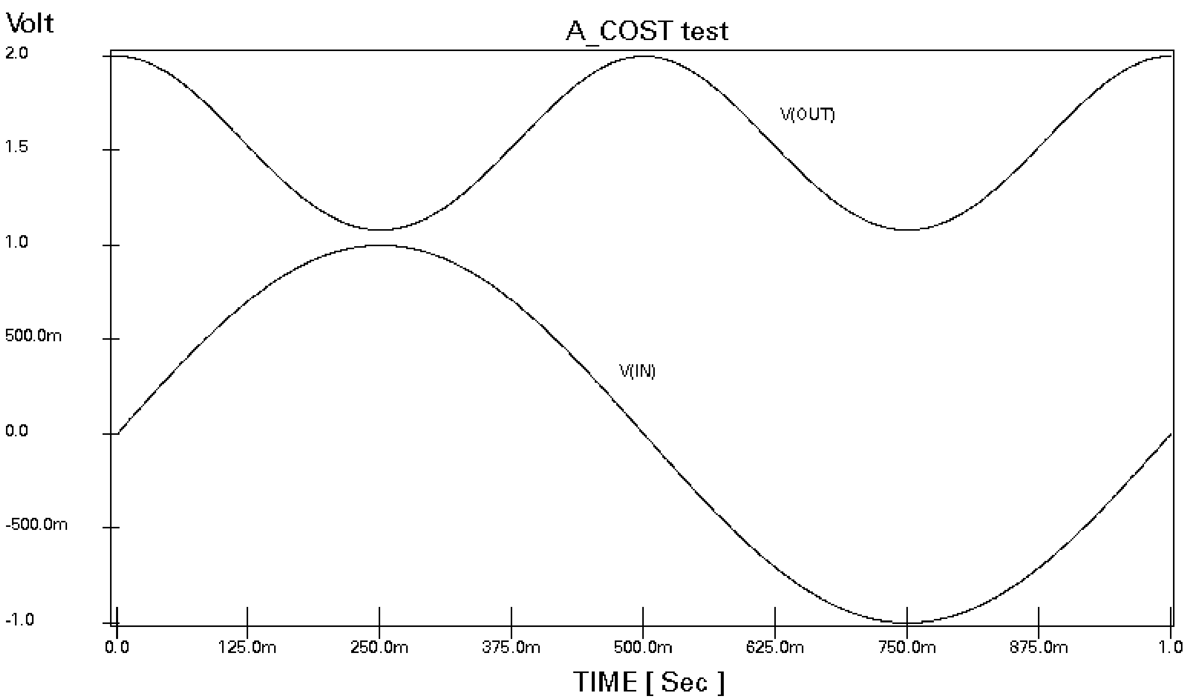
Parameter	Default Value	Unit
GAIN	1	–

Test Circuit



Test Results

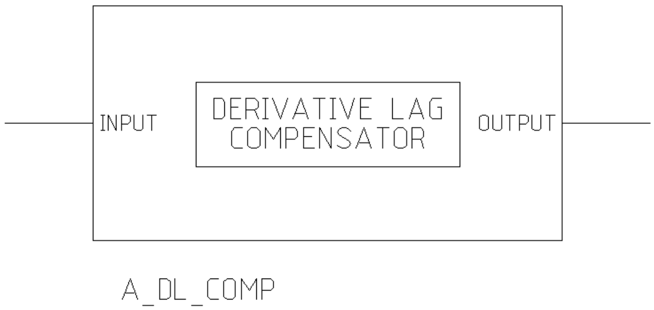
A simulation with a sine wave input and a model gain of 2 gave the following results.



A_DL_COMP (Derivative Lag Compensator)

This macromodel, A_DL_COMP, is a functional block derivative lag compensator.

Graphic Symbol



Modelled Parameters

The following parameters can be modified.

Parameter	Default Value	Unit
K (Gain)	1	–
Frequency (Pole frequency)	1K	Hz

Design Notes

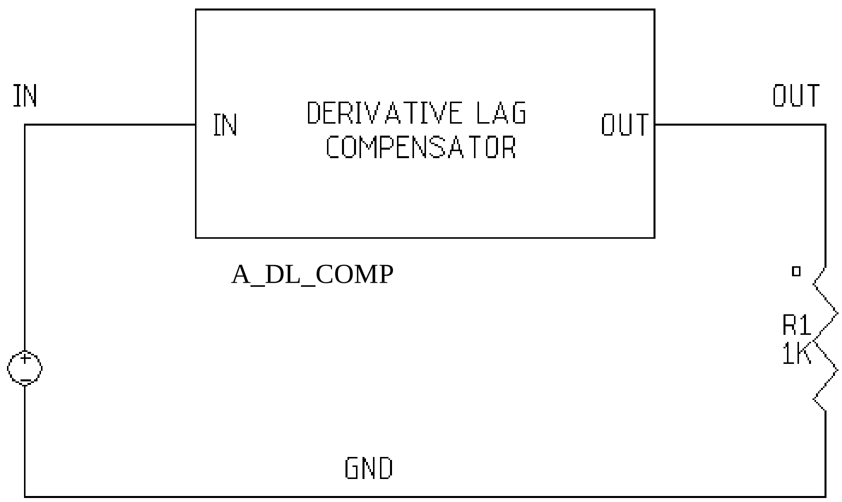
The transfer function for this compensator is as follows:

$$\frac{out}{in} = \frac{K \times \frac{s}{\omega}}{1 + \frac{s}{\omega}}$$

Where $\omega = 2\pi \times$ pole-frequency, K is the gain and s is the Laplace operator.

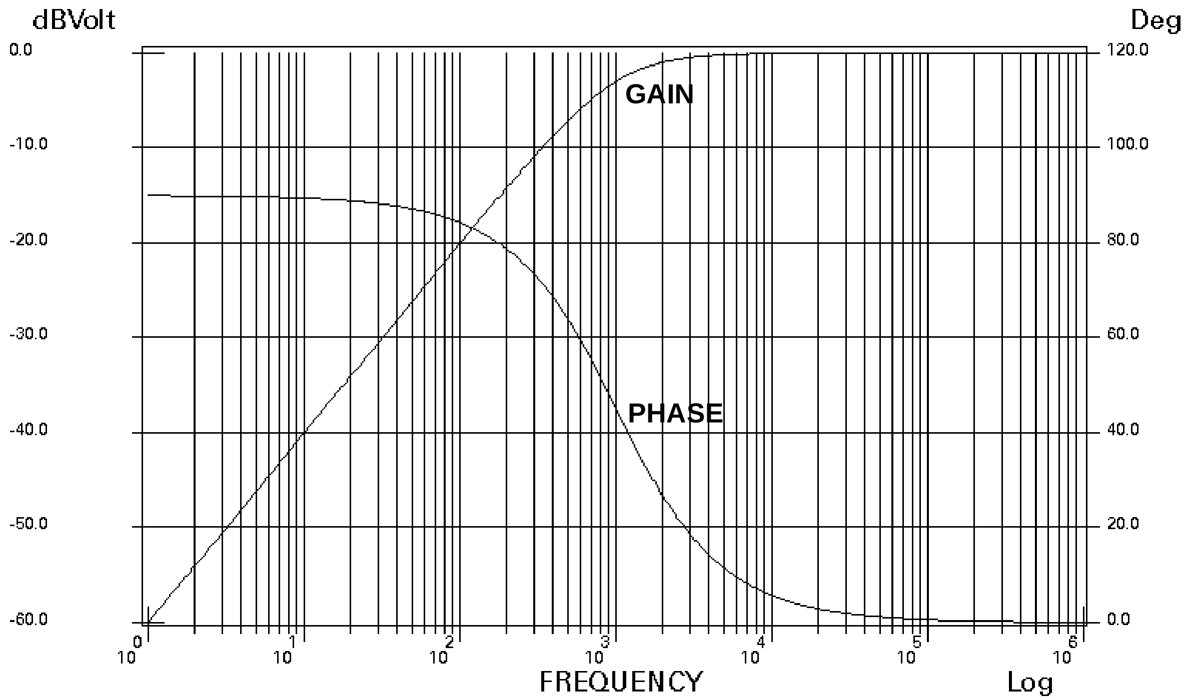
Test Circuit

The following circuit was used to determine the frequency response of the compensator.



Test Results

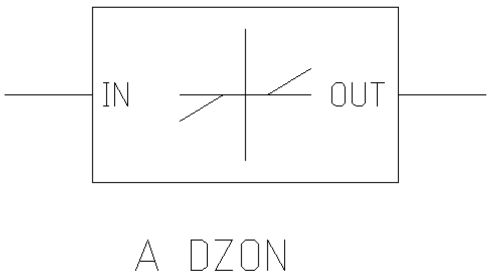
The following frequency-sweep was performed with the default settings in the PARSET file.



A_DZON (Deadzone)

A_DZON models a deadzone functional block. In the deadzone band, the output is 0. For input values above or below the deadzone, the output is a linear function of input at a constant gain.

Graphic Symbol



Modelled Parameters

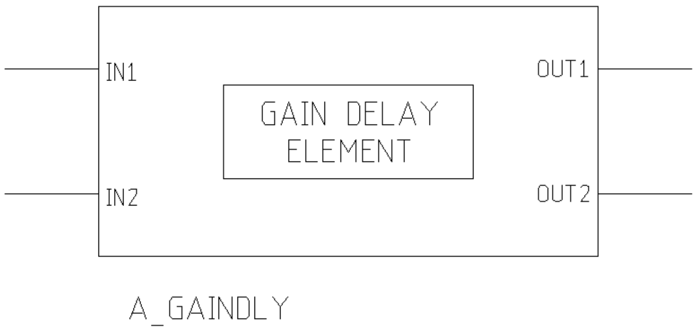
The following parameters can be modified.

Parameter	Default Value	Unit
GAIN	1	–
DEAD (deadzone boundary)	1	V

A_GAINDLY (Gain Delay)

This macromodel, A_GAINDLY, is a functional block gain and delay-line.

Graphic Symbol



Modelled Parameters

The following parameters can be modified.

Parameter	Default Value	Unit
GAIN	2	–
DELAY	1m	s
RIN (Input resistance)	1G	W
ROUT (Output resistance)	1m	W

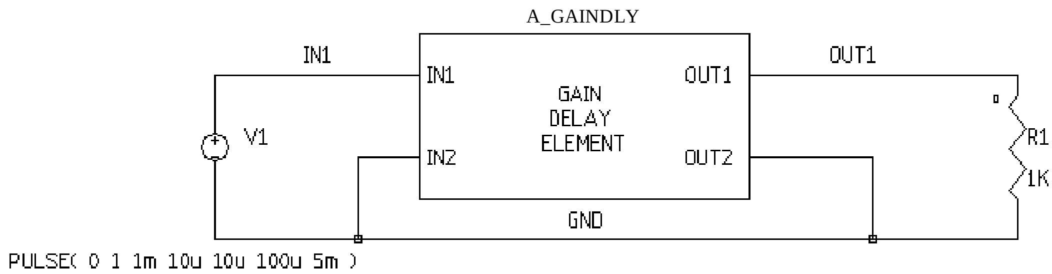
Design Notes

The maximum simulator step time is half of the delay time.

Test Circuit

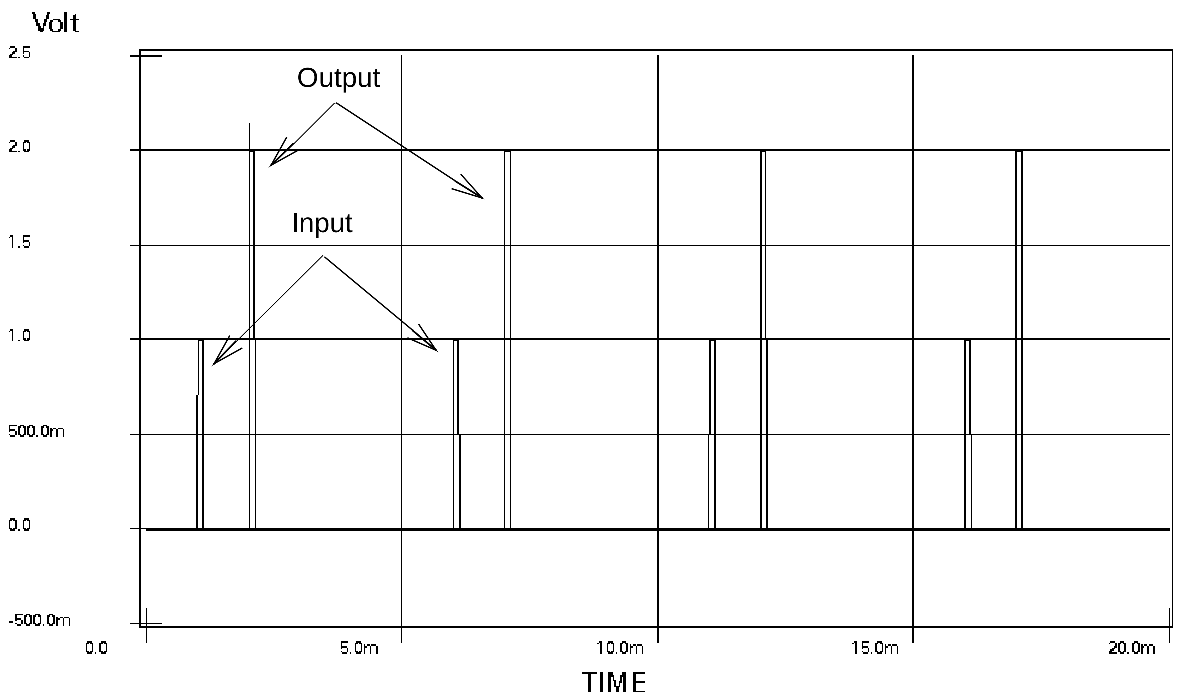
The voltage source applies 100 µs pulses of 1V amplitude at periods of 5 ms. The gain of the Gain Delay Element is 2, and the delay-time is set to 1ms.

The input resistance to the block is set to 1GΩ and the output resistance to 1mΩ.



Test Results

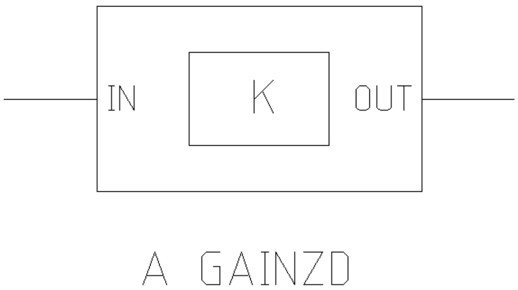
Results from a 20ms simulation of the test-circuit.



A_GAINZD (Gain Block, Zero Delay)

A_GAINZD models a gain block with no delay.

Graphic Symbol

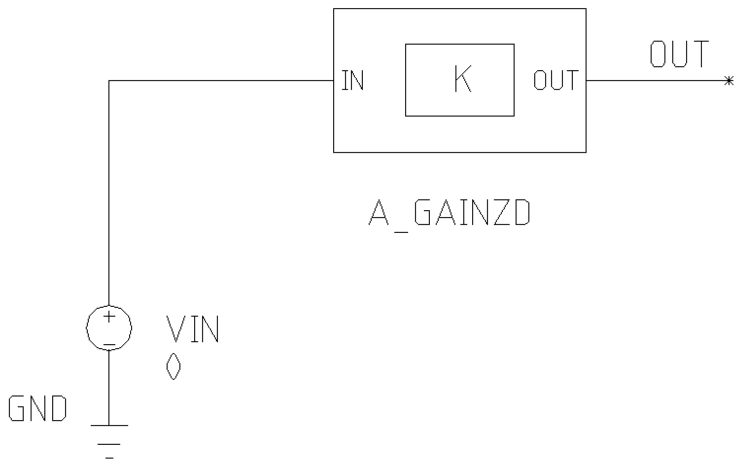


Modelled Parameters

The following parameters can be modified.

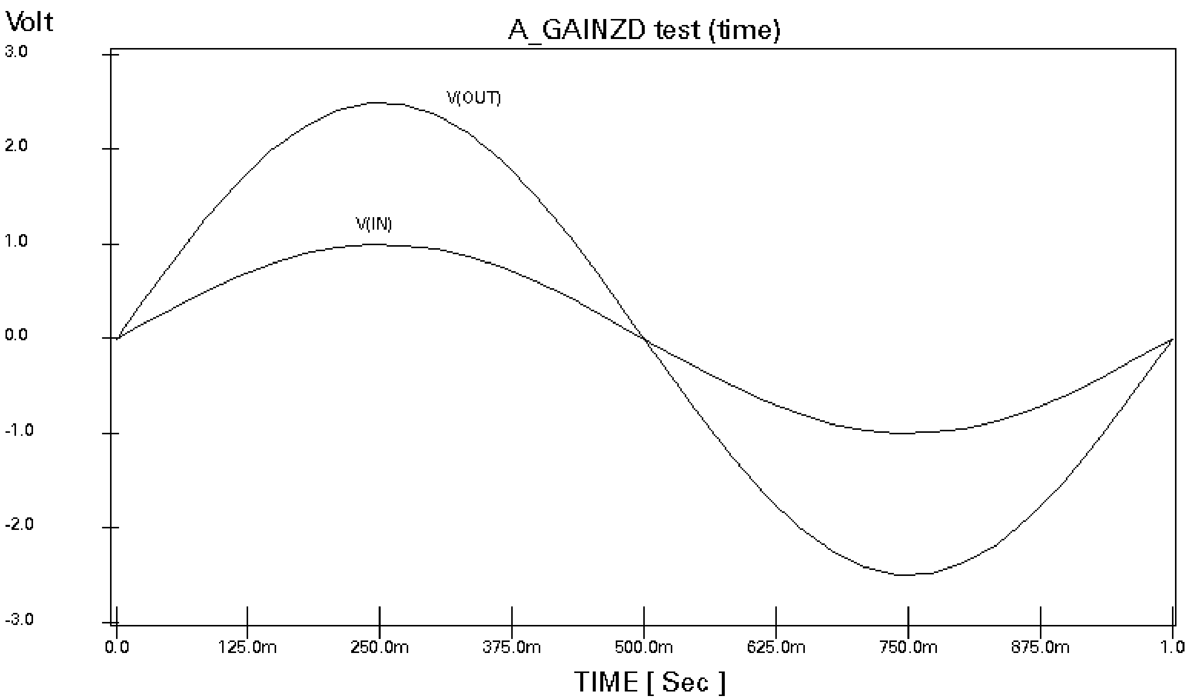
Parameter	Default Value	Unit
K (Gain)	1	–

Test Circuit

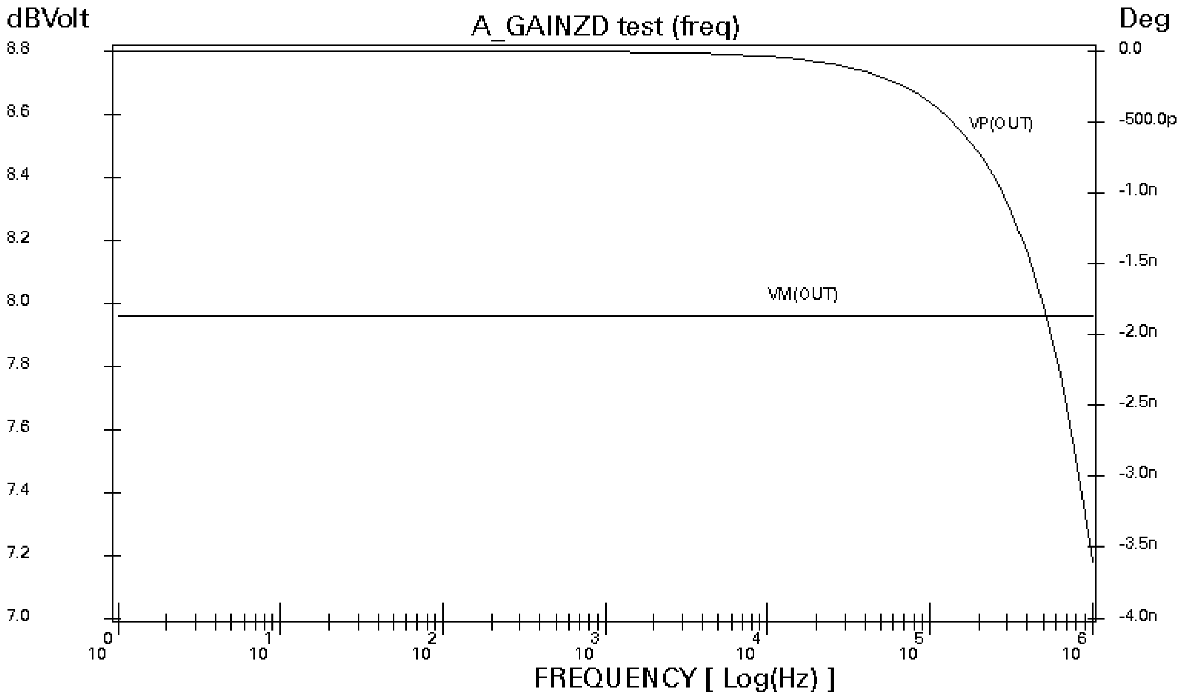


Test Results

A simulation with a sine wave input and a model gain of 2.5 gave the following results.



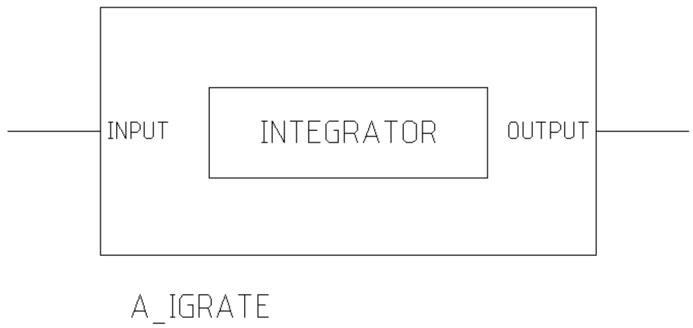
A simulation in the frequency domain with the same model gain gave the following results
.



A_IGRATE (Integrator)

This macromodel, A_IGRATE, is a functional block integrator. You can set the initial condition.

Graphic Symbol



Modelled Parameters

The following parameters can be modified.

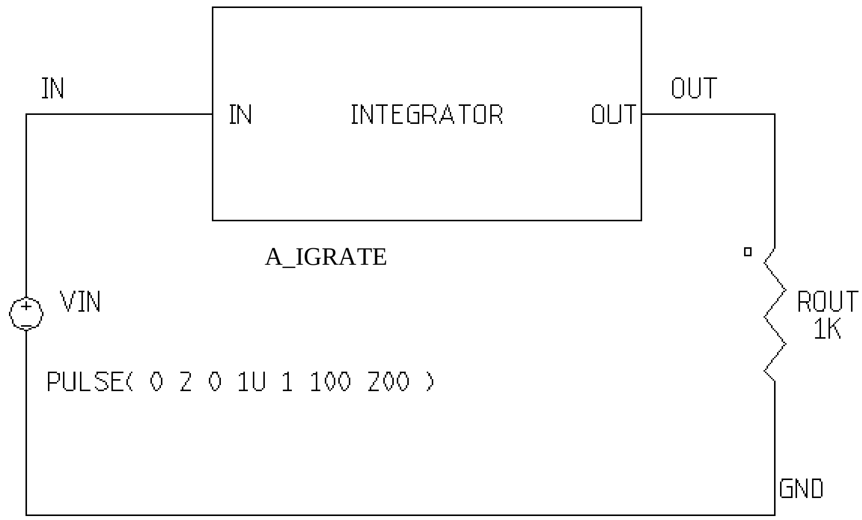
Parameter	Default Value	Unit
IC (Initial condition)	12	V

Note: The initial condition is used only if IC is toggled On in the TIME form under the Analysis command.

Test Circuit

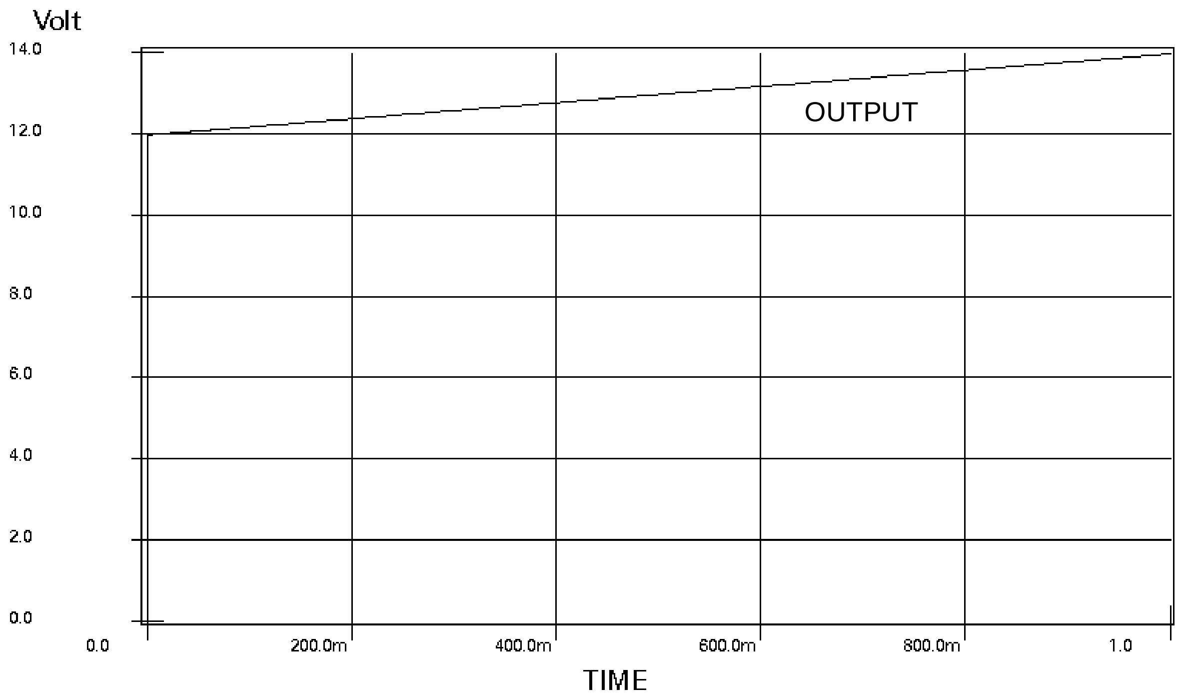
The initial condition is set to 12V. A pulse waveform is applied to the input of the integrator. The value of the pulse is initially zero, rising to 2V after the first microsecond.

The output signal is 12V plus the time integral of the input voltage.



Test Results

Results from a 1s simulation of the test-circuit are shown.

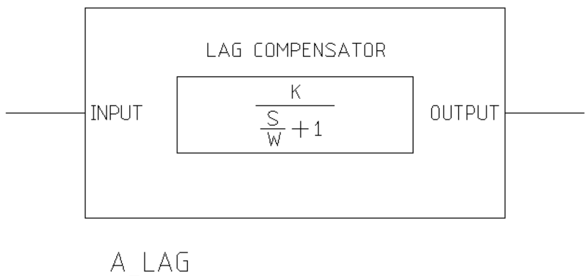


A_LAG (Lag Compensator)

A_LAG models a lag compensator whose transfer function has a single pole at a user specified angular frequency and is described by:

$$\text{out}(s) = \left[\frac{K}{\frac{S}{W} + 1}\right] \text{in}(s)$$

Graphic Symbol

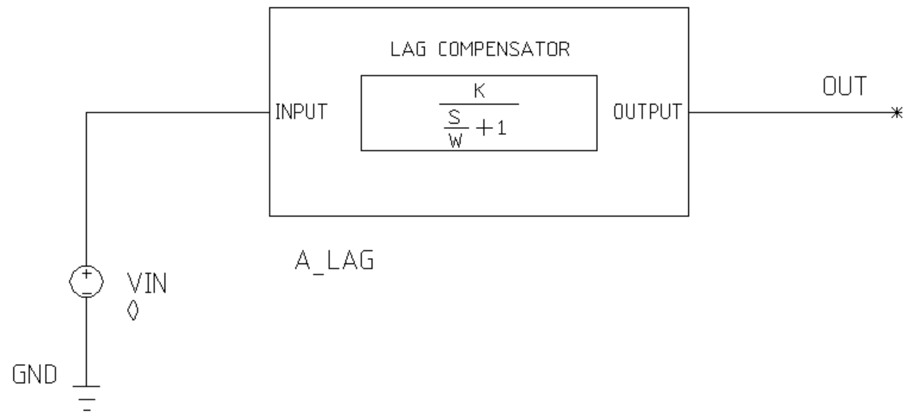


Modelled Parameters

The following parameters can be modified.

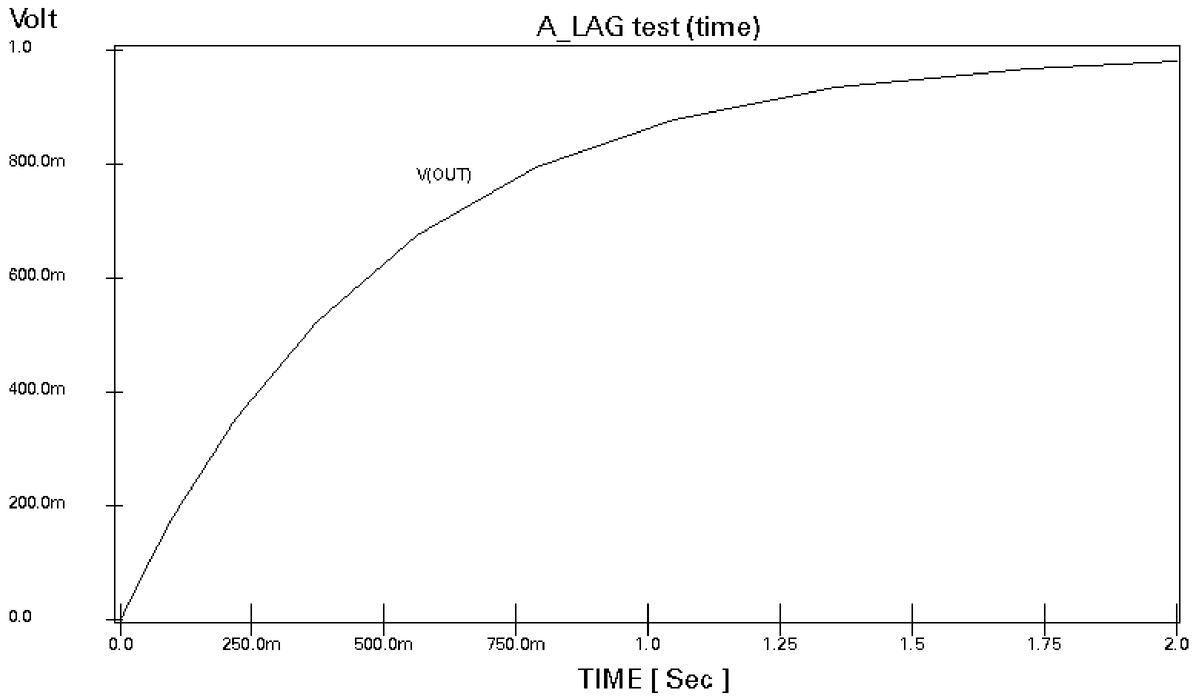
Parameter	Default Value	Unit
K (Gain)	1	–
W (Pole frequency)	1	rad/s

Test Circuit

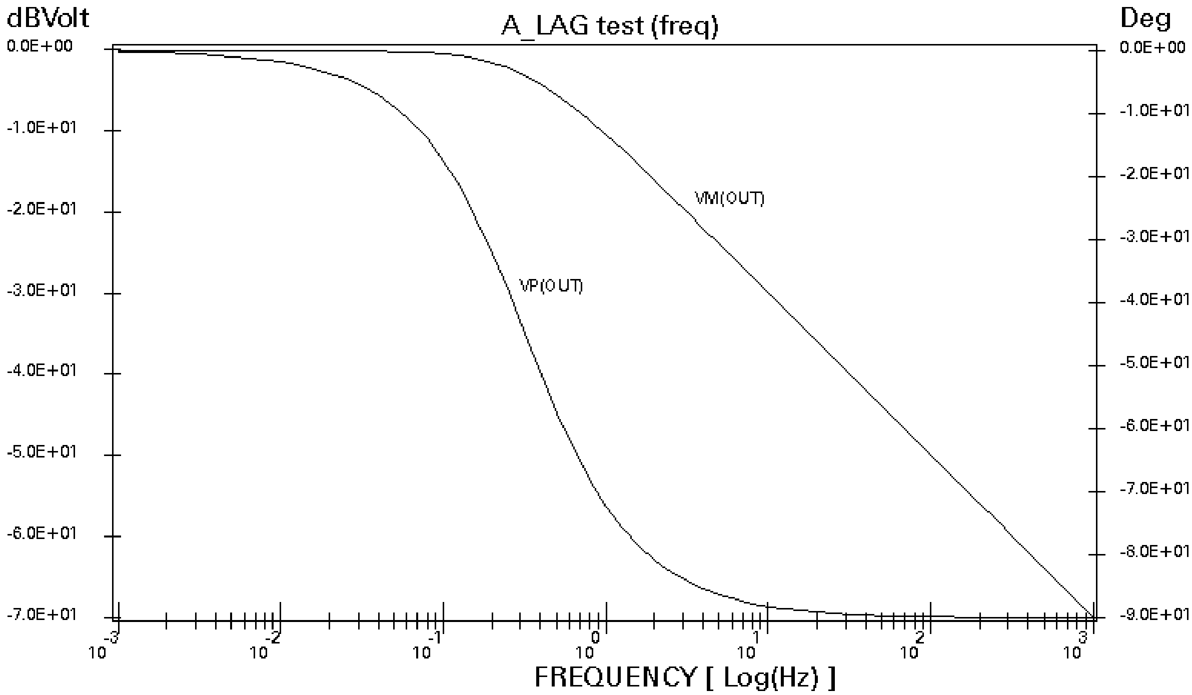


Test Results

A simulation with a step input with a model gain of 1 and a pole frequency of 2 gave the following results.



A simulation in the frequency domain with the same model gain gave the following results.

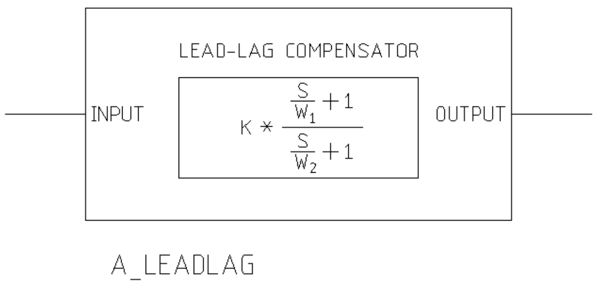


A_LEADLAG (Lead-lag Compensator)

A_LEADLAG models a lead-lag compensator whose transfer function has a single pole and a single zero at a user specified angular frequencies. It is described by:

$$\mathrm{out}(s) = K\left[\frac{\frac{S}{W_1}+1}{\frac{S}{W_2}+1}\right]\mathrm{in}(s)$$

Graphic Symbol

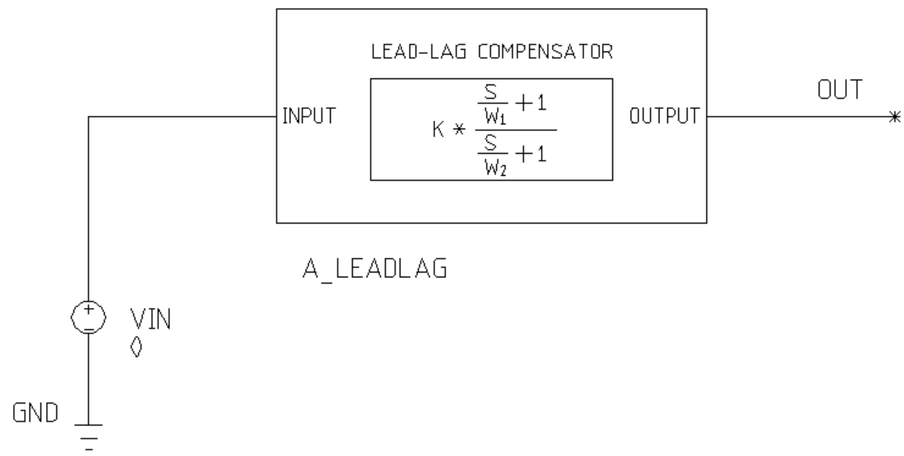


Modelled Parameters

The following parameters can be modified.

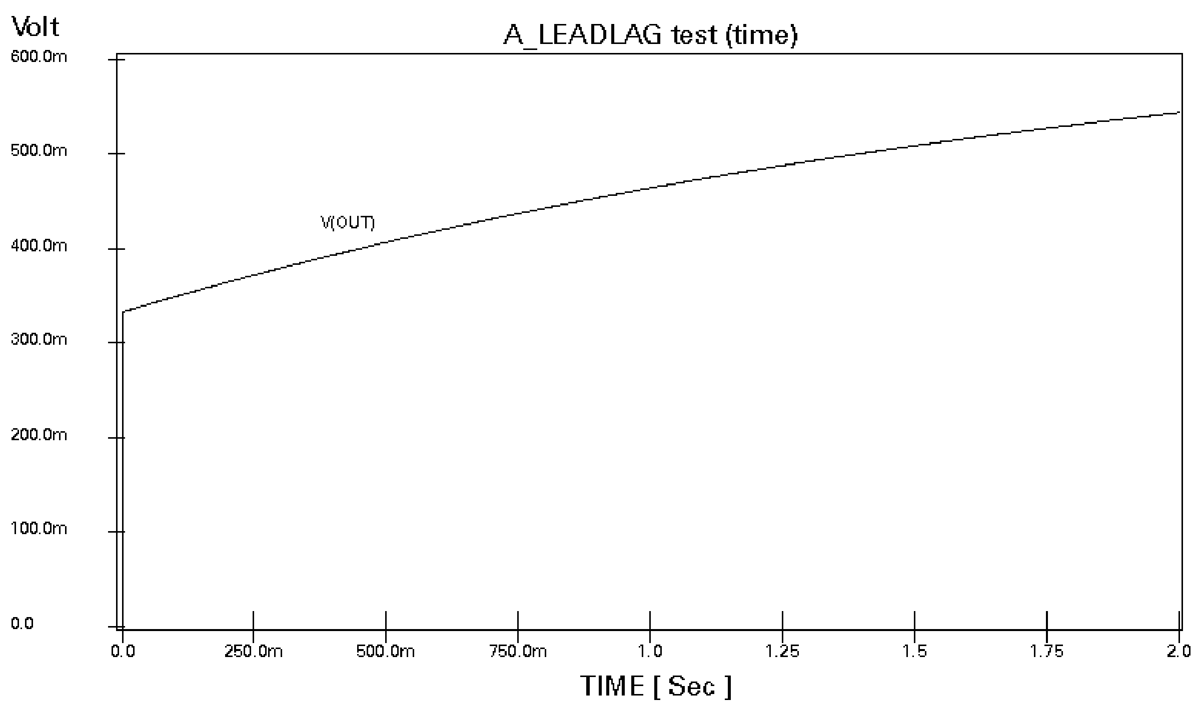
Parameter	Default Value	Unit
K (Gain)	1	–
W1 (Zero frequency)	1	rad/s
W2 (Pole frequency)	1	rad/s

Test Circuit

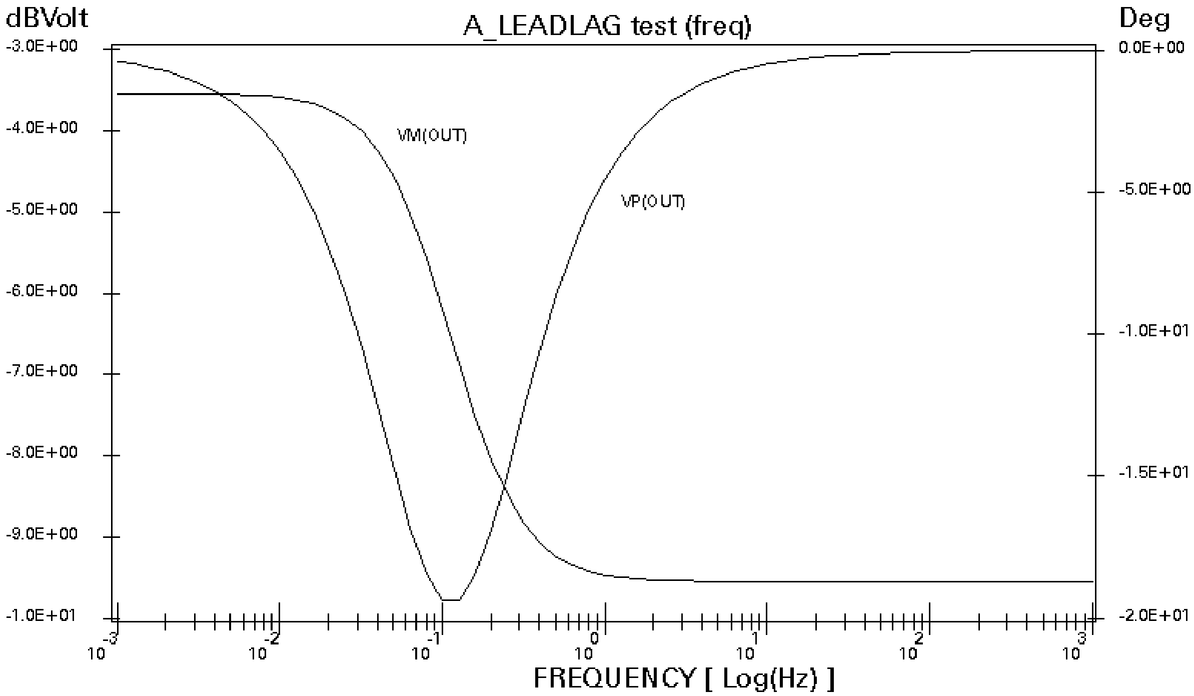


Test Results

A simulation with a step input of magnitude 1 and the component with a model gain of 2/3, a zero frequency of 1, and a pole frequency of 0.5 gave the following results.



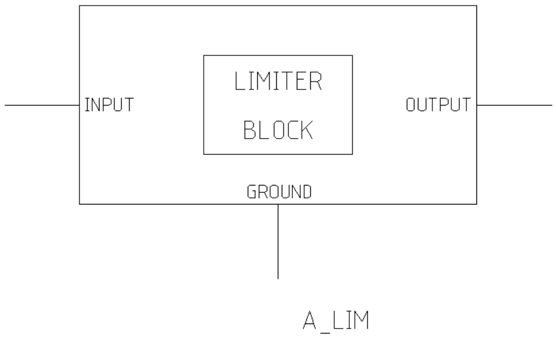
A simulation in the frequency domain with the same model gain gave the following results.



A_LIM (Limiter)

This component models the behavior of a limiter element whose output follows its input within a user specified range. Outside the range, a user definable gain is used to give a soft limit effect.

Graphic Symbol



Modelled Parameters

The following parameters can be modified.

Parameter	Default Value	Unit
HIGH_LIM (High limit)	8	V
LOW_LIM (Low limit)	2	V
GAIN (Gain outside of limits)	0.1	–

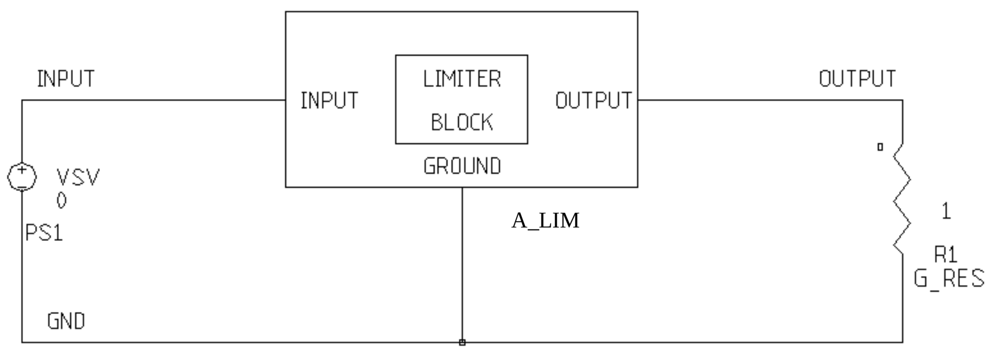
Design Notes

The Limiter element is designed to be used as described below.

- The block is designed to accept a voltage input and produce a voltage output.
- The gain parameter defines the gain of the block once either limit has been exceeded.
- It may be necessary to limit the maximum step size parameter in the time analysis form for some simulations.

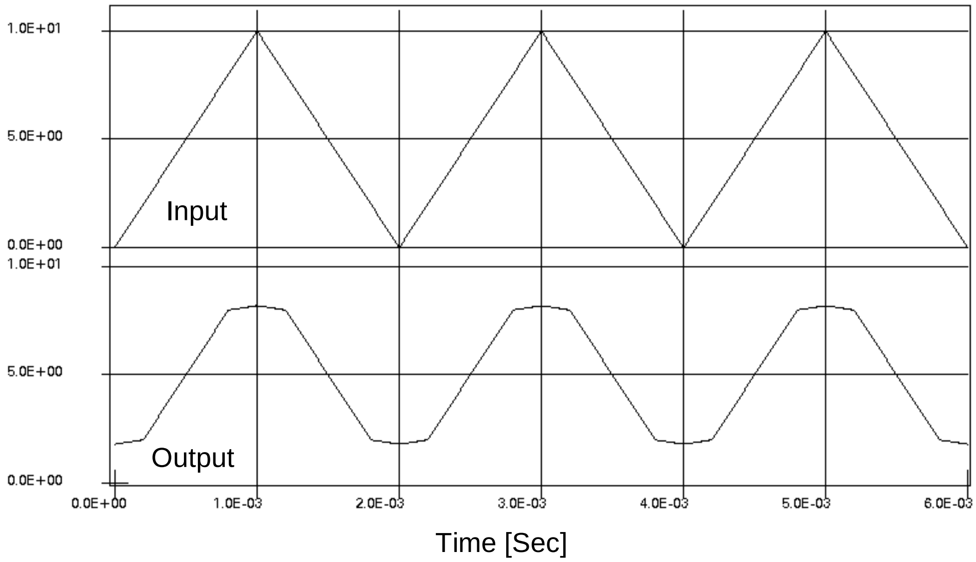
Test Circuit

The circuit shown below was used to produce the example waveforms. The voltage source on the input was set to produce the sawtooth waveform shown in the results.



Example Waveforms

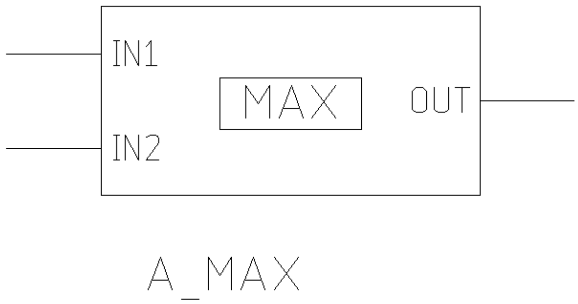
The example below shows the operation of the limiter element when a sawtooth waveform is applied to the input. The parameters of the LIMIT block were left at their default values for the simulation.



A_MAX (Maximum Value Selector)

A_MAX models a maximum value selector. The output is the larger value of the two inputs scaled by a gain.

Graphic Symbol

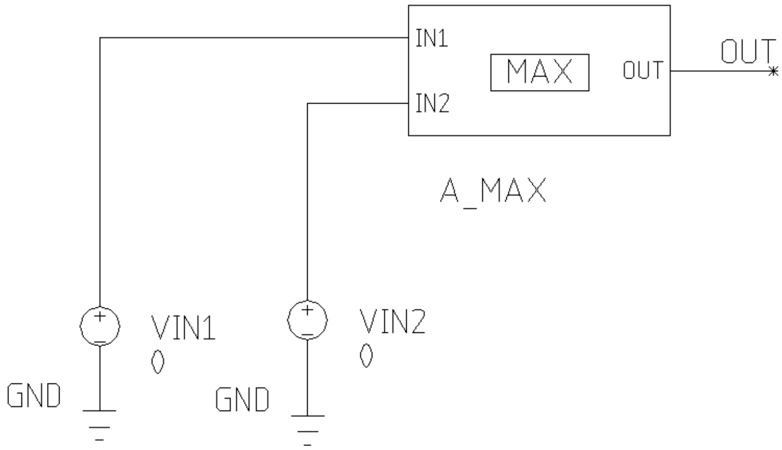


Modelled Parameters

The following parameters can be modified.

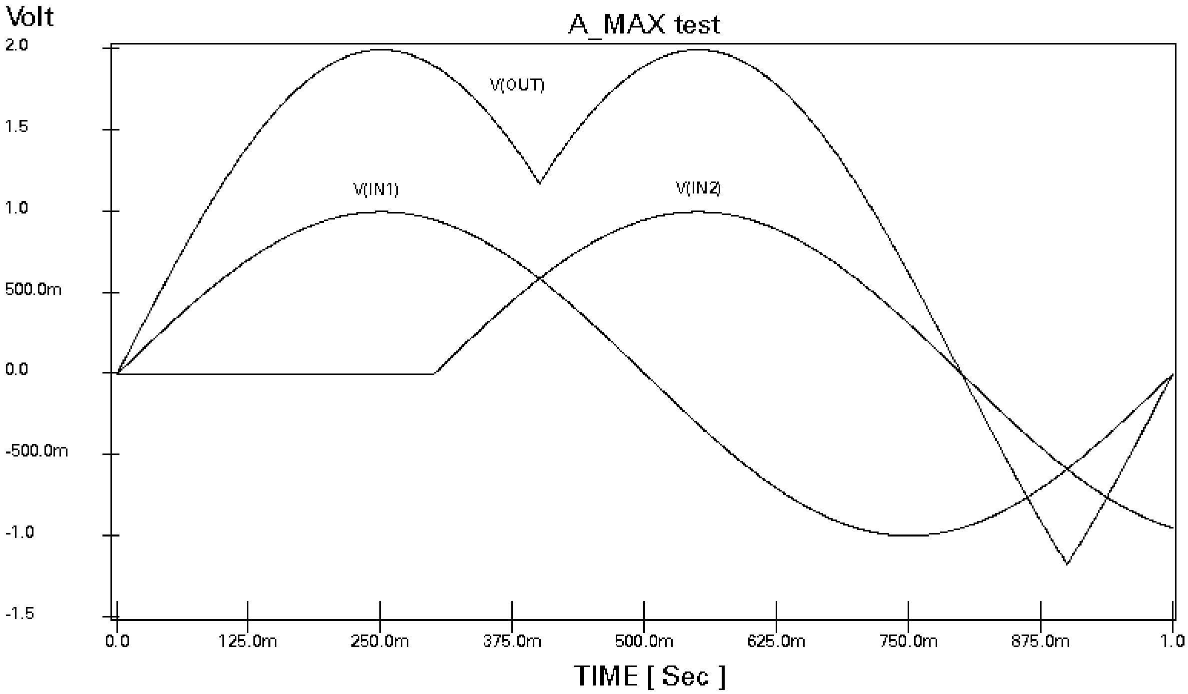
Parameter	Default Value	Unit
GAIN	1	–

Test Circuit



Test Results

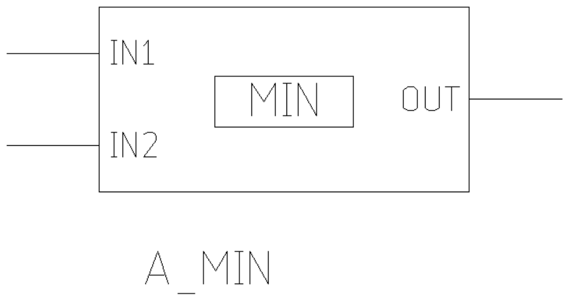
A simulation with two sine inputs (the second one delayed by 0.3 seconds) at a model gain of 2 gave the following results.



A_MIN (Minimum Value Selector)

A_MIN models a minimum value selector. The output is the smaller value of the two inputs scaled by a gain.

Graphic Symbol

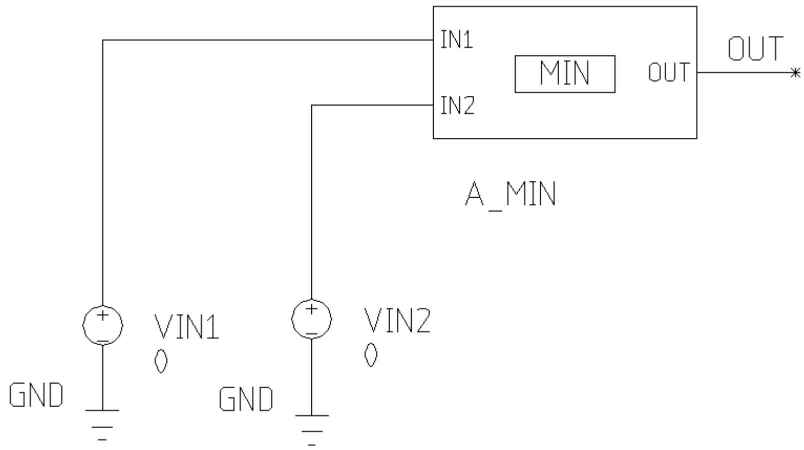


Modelled Parameters

The following parameters can be modified.

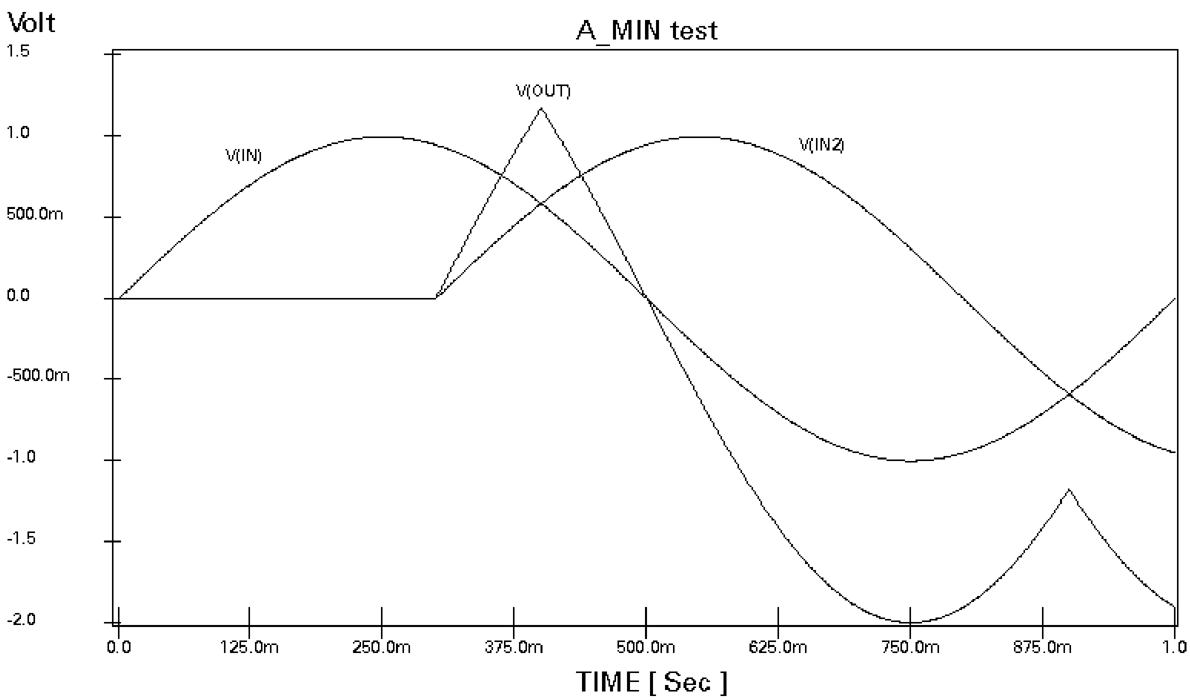
Parameter	Default Value	Unit
GAIN	1	–

Test Circuit



Test Results

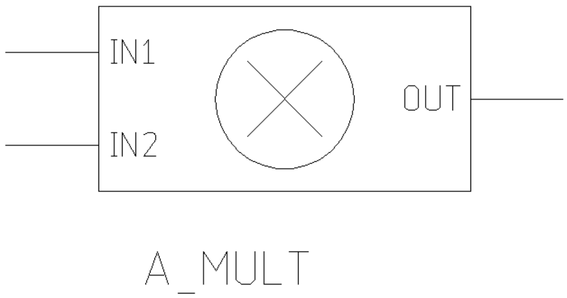
A simulation with two sine inputs (the second one delayed by 0.3 seconds) at a model gain of 2 gave the following results.



A_MULT (Multiplier, 2 Input)

A_MULT models a component whose output is the product of the two inputs scaled by a gain.

Graphic Symbol

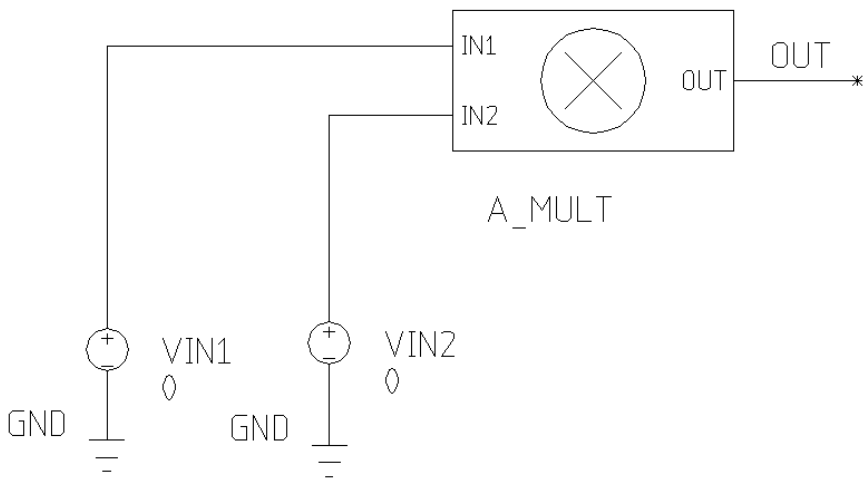


Modelled Parameters

The following parameters can be modified.

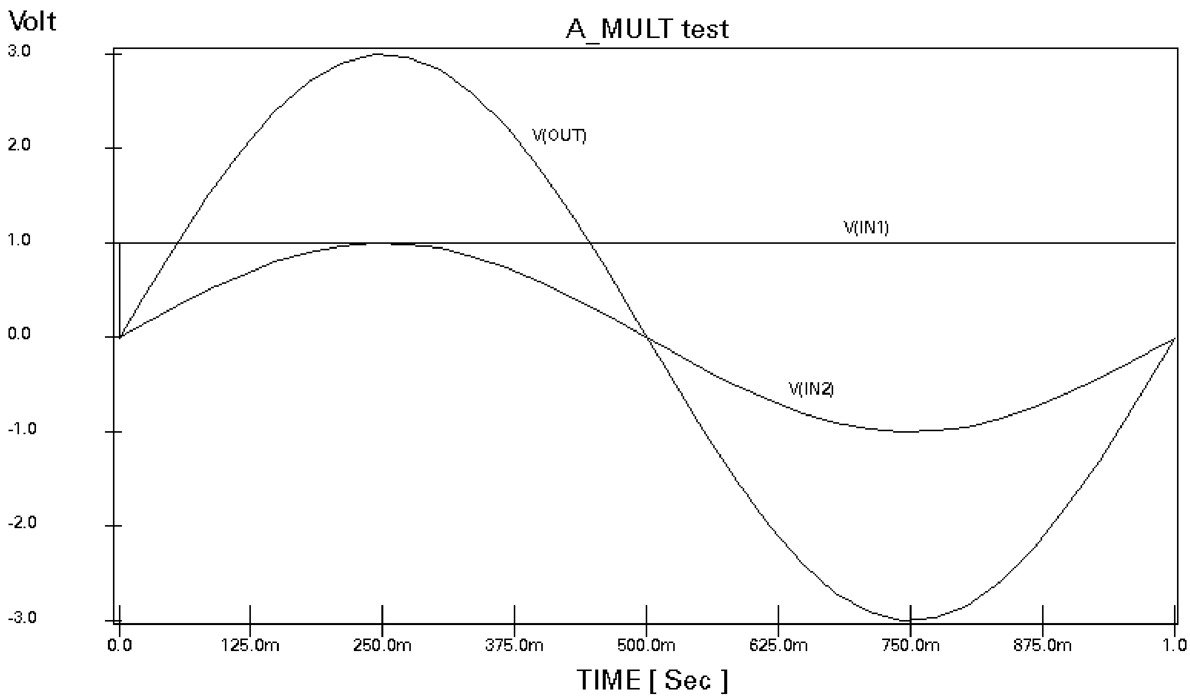
Parameter	Default Value	Unit
GAIN	1	–

Test Circuit



Test Results

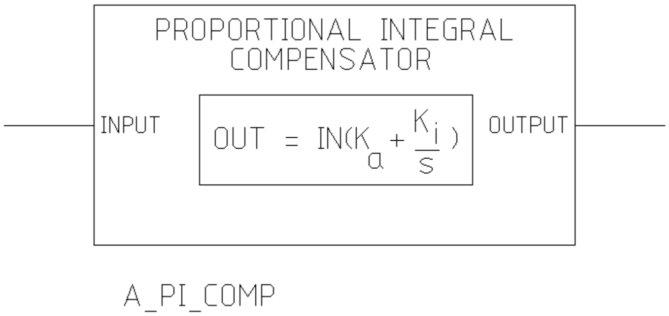
A simulation with a step input with a of magnitude 1 and a sine input with an amplitude of 1 at a model gain of 3 gave the following results.



A_PI_COMP (Proportional Integra/l Compensator)

This macromodel, A_PI_COMP, is a functional proportional-integral compensator.

Graphic Symbol



Modelled Parameters

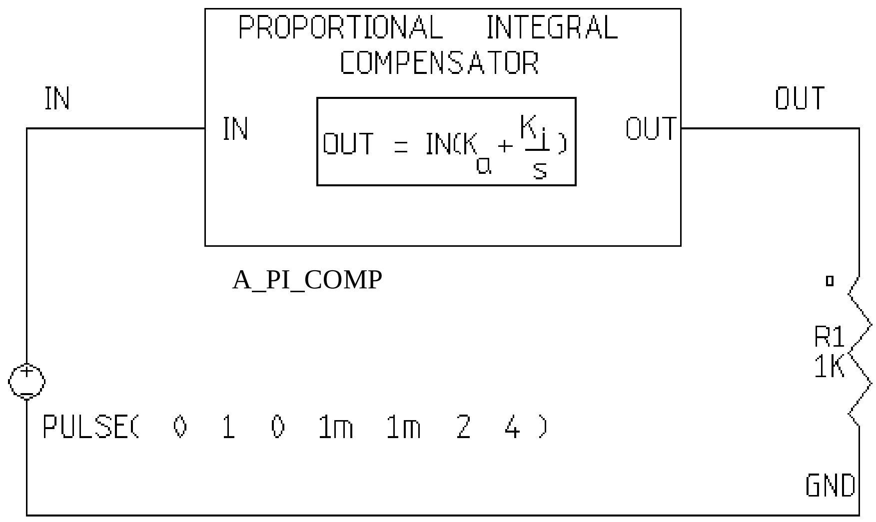
The following parameters can be modified.

Parameter	Default Value	Unit
KA (Proportional gain)	1	–
KI (Integral gain)	1	–
IC (Initial condition)	0	V

Note: The initial condition is used only if IC is toggled On in the TIME form under the Analysis command.

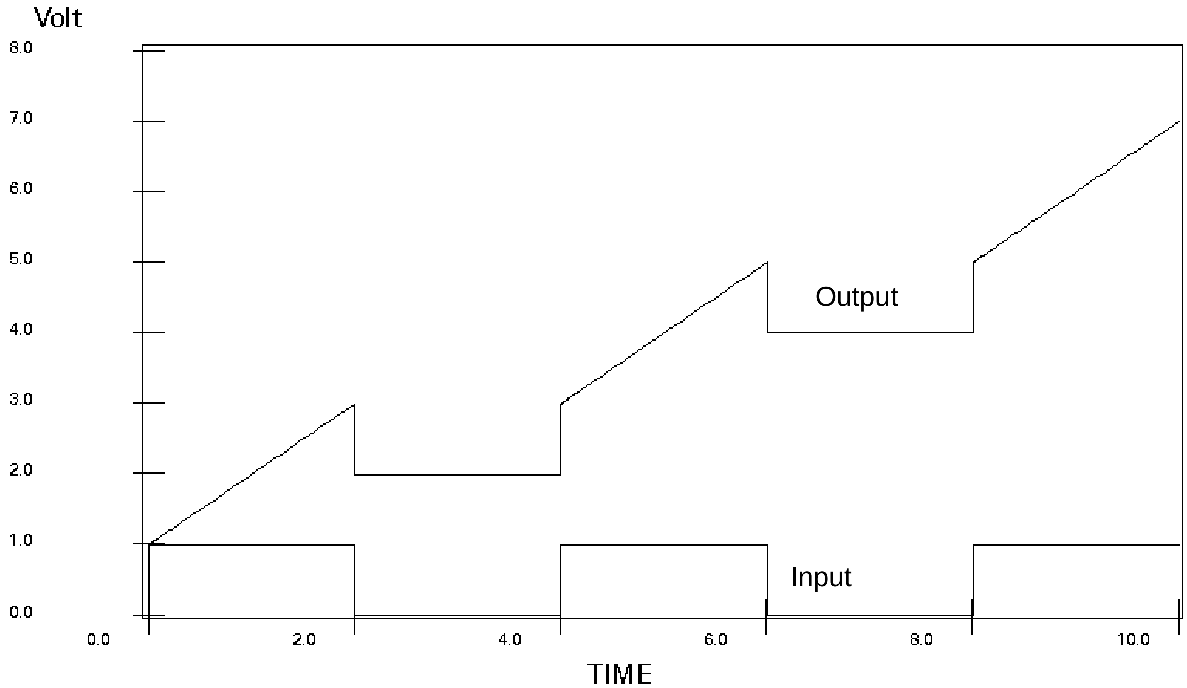
Test Circuit

The results for a time-domain analysis of this test-circuit are given in the Test Results section.



Test Results

Results from a 10s simulation of the test-circuit are shown. The initial condition was set to the default value of 0. A square-wave stepping from 0V to 1V with a period of 4s was applied to the input. The output signal has appropriate proportional and integral components. The proportional and integral gains were both set to the default value of 1.

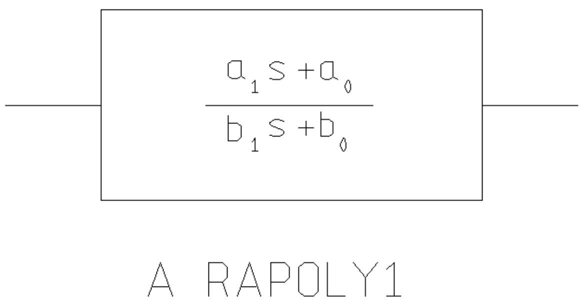


A_RAPOLY1 (Filter, 1st Order Rational Polynomial)

A_RAPOLY1 models a rational polynomial filter described by:

$$out(s) = \left[\frac{a_1 s + a_0}{b_1 s + b_0}\right] in(s)$$

Graphic Symbol

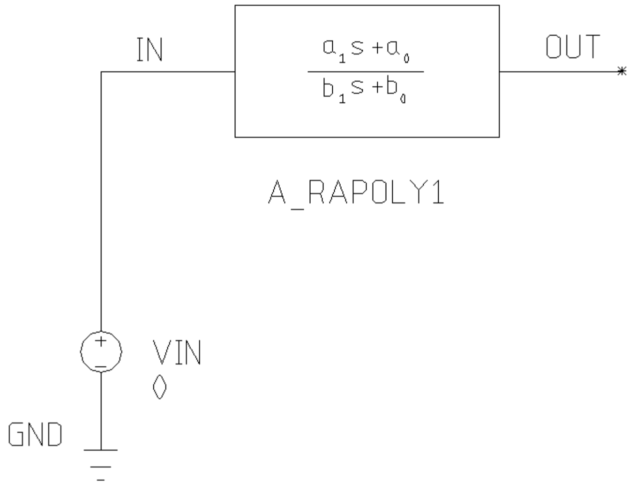


Modelled Parameters

The following parameters can be modified..

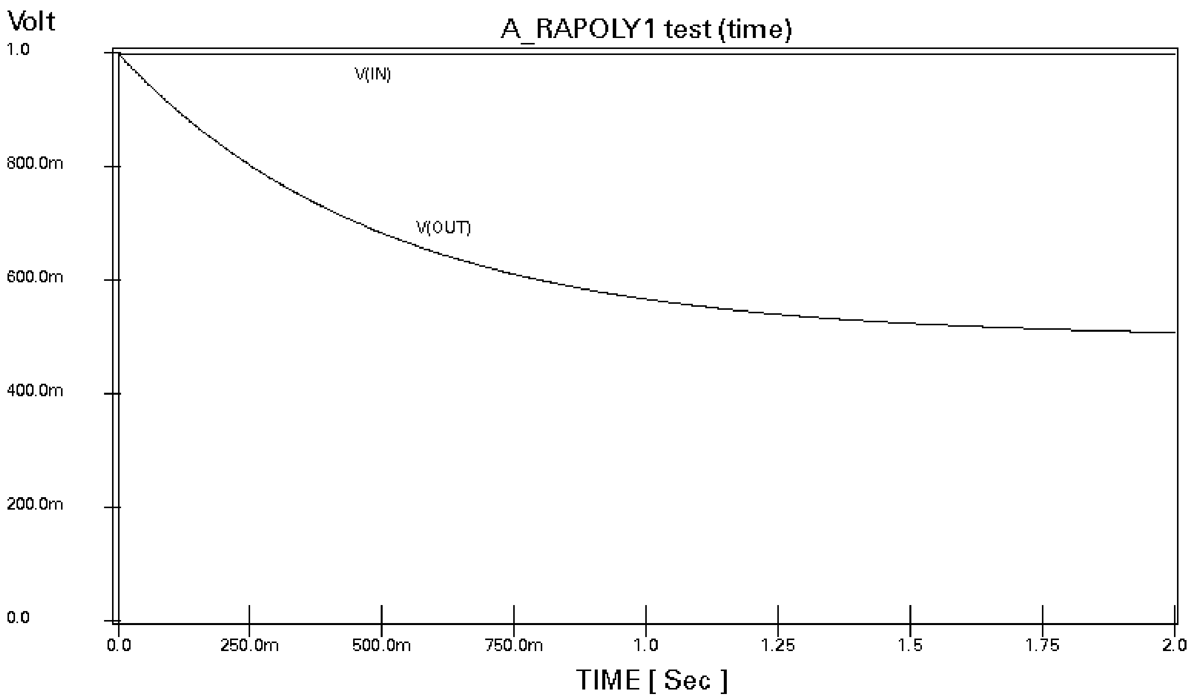
Parameter	Default Value	Unit
A0	1	–
A1	1	s
B0	1	–
B1	1	s

Test Circuit

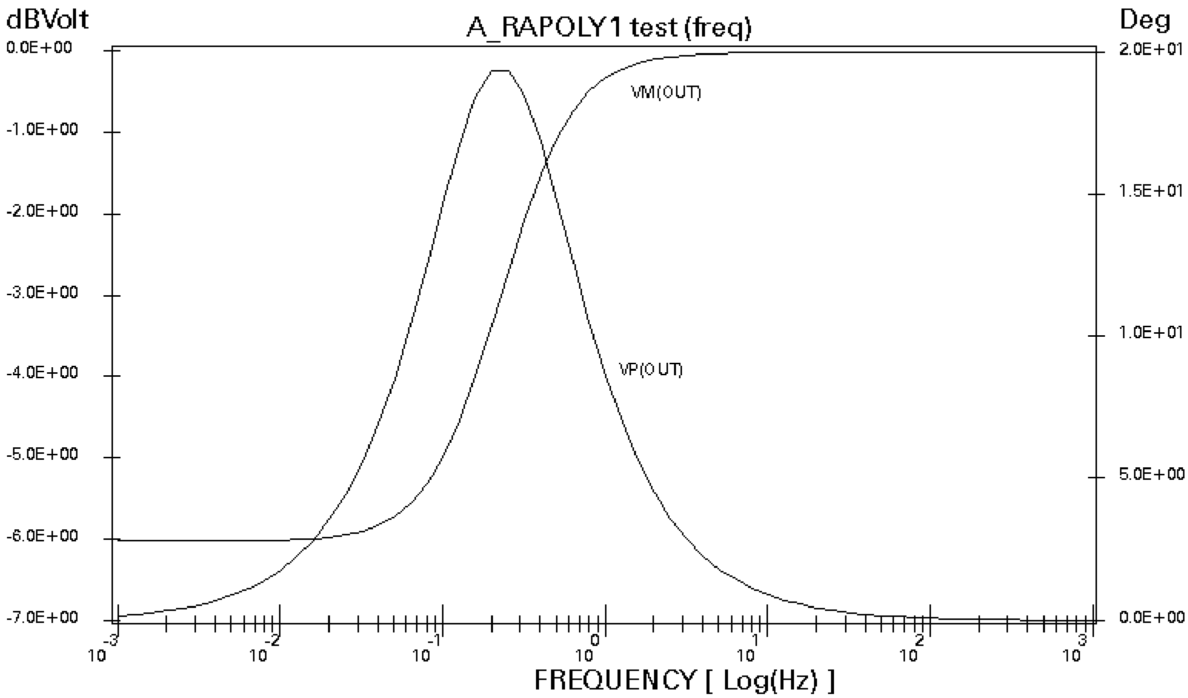


Test Results

A simulation with A0=1, A1=1, B0=2, B1=1 gave the following results. For transient analysis, the input was a step function of amplitude 1.



An AC analysis with the same parameter values gave the following results.

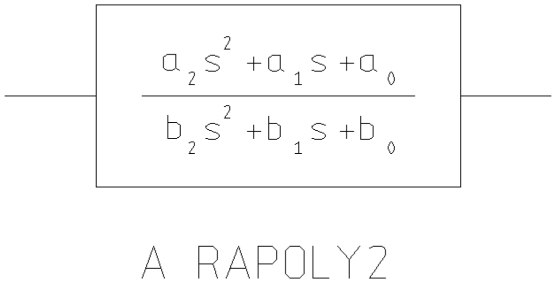


A_RAPOLY2 (Filter, 2nd Order Rational Polynomial)

A_RAPOLY2 models a rational polynomial filter described by:

$$\mathrm{out}(s) = \left[\frac{a_2 s^2 + a_1 s + a_0}{b_2 s^2 + b_1 s + b_0}\right] \mathrm{in}(s)$$

Graphic Symbol

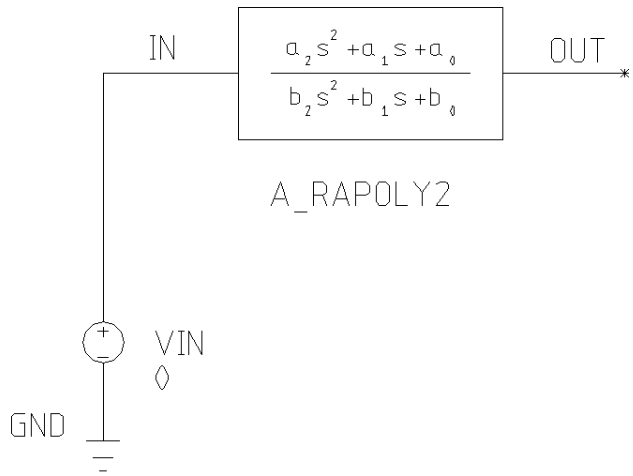


Modelled Parameters

The following parameters can be modified.

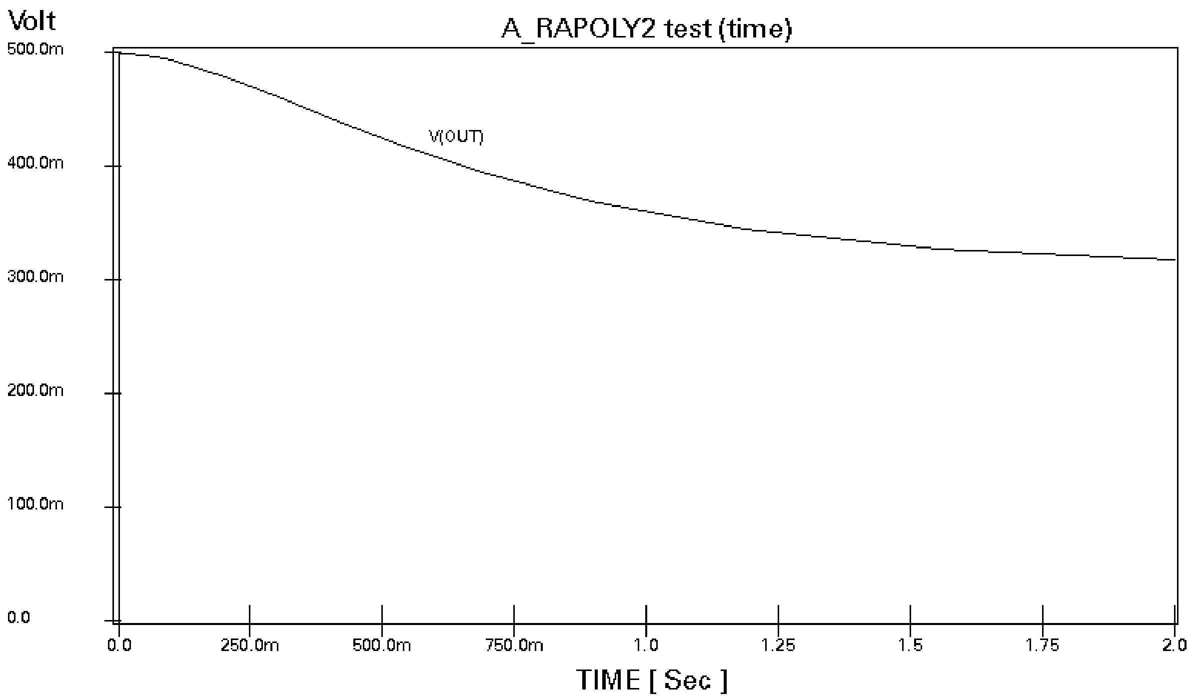
Parameter	Default Value	Unit
A0	1	–
A1	1	–
A2	1	–
B0	1	–
B1	1	–
B2	1	–

Test Circuit

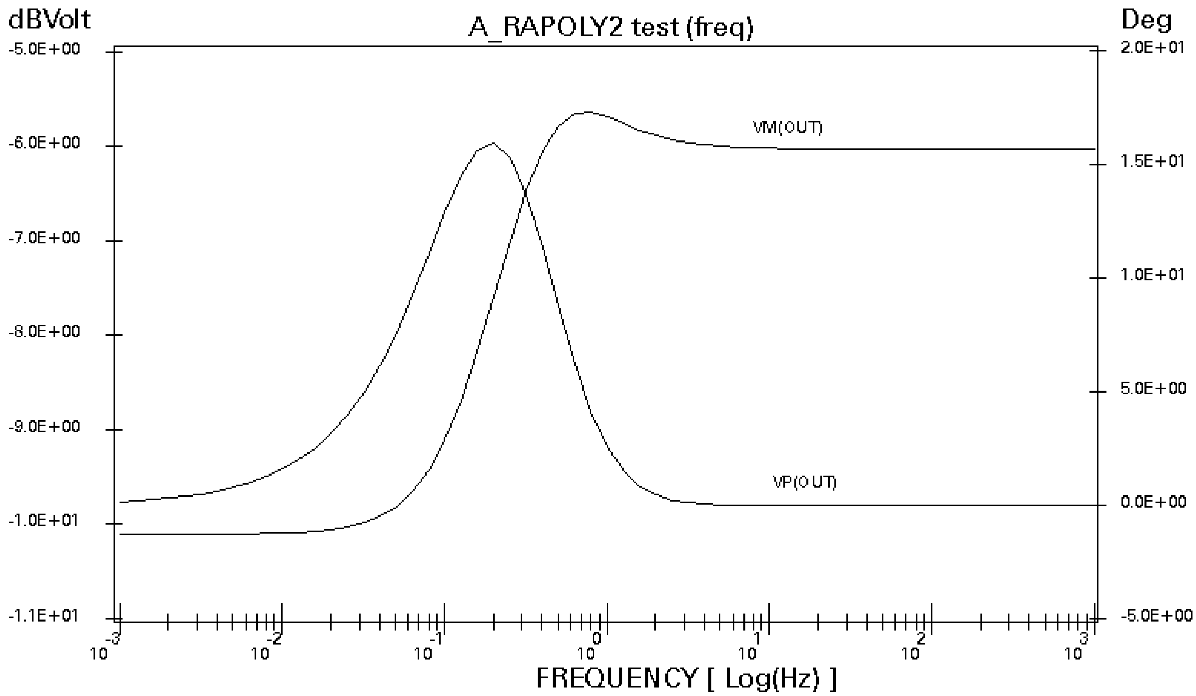


Test Results

A simulation with A0=5, A1=6, A2=1, B0=15, B1=12, B2=2 gave the following results. For transient analysis, the input was a step function of
amplitude 1.



An AC analysis with the same parameter values gave the following results.

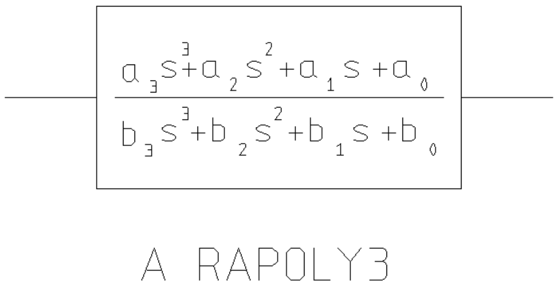

dBVolt
A_RAPOLY2 test (freq)
Deg
-5.0E+00
-6.0E+00
-7.0E+00
-8.0E+00
-9.0E+00
-1.0E+01
-1.1E+01
2.0E+01
1.5E+01
1.0E+01
5.0E+00
0.0E+00
-5.0E+00
VM(OUT)
VP(OUT)
10^{-3} 10^{-2} 10^{-1} 10^{0} 10^{1} 10^{2} 10^{3}
FREQUENCY [Log(Hz)]

A_RAPOLY3 (Filter, 3rd Order Rational Polynomial)

A_RAPOLY3 models a rational polynomial filter described by:

$$out(s) = \left[\frac{a_3s^3 + a_2s^2 + a_1s + a_0}{b_3s^3 + b_2s^2 + b_1s + b_0}\right] in(s)$$

Graphic Symbol

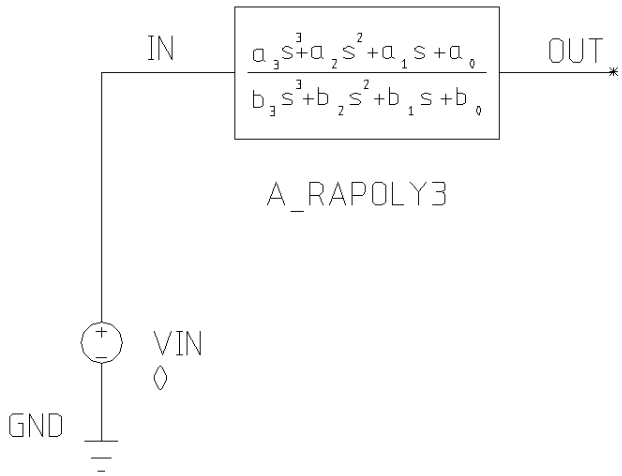


Modelled Parameters

The following parameters can be modified.

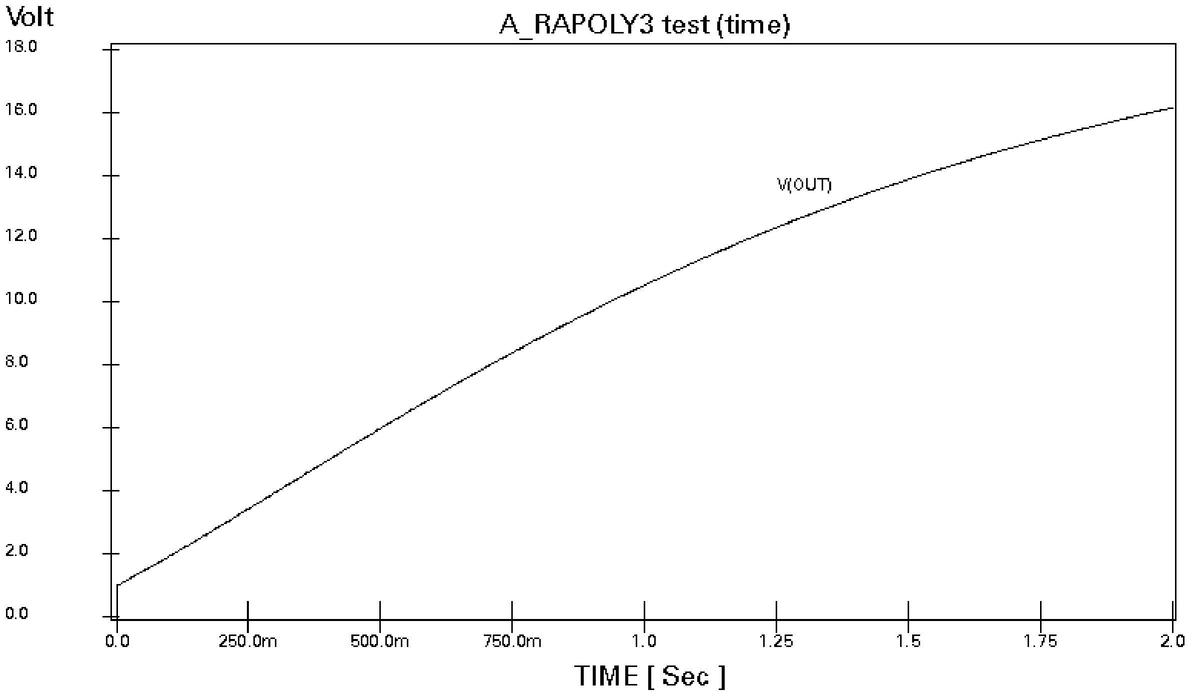
Parameter	Default Value	Unit
A0	1	–
A1	1	–
A2	1	–
A3	1	–
B0	1	–
B1	1	–
B2	1	–
B3	1	–

Test Circuit

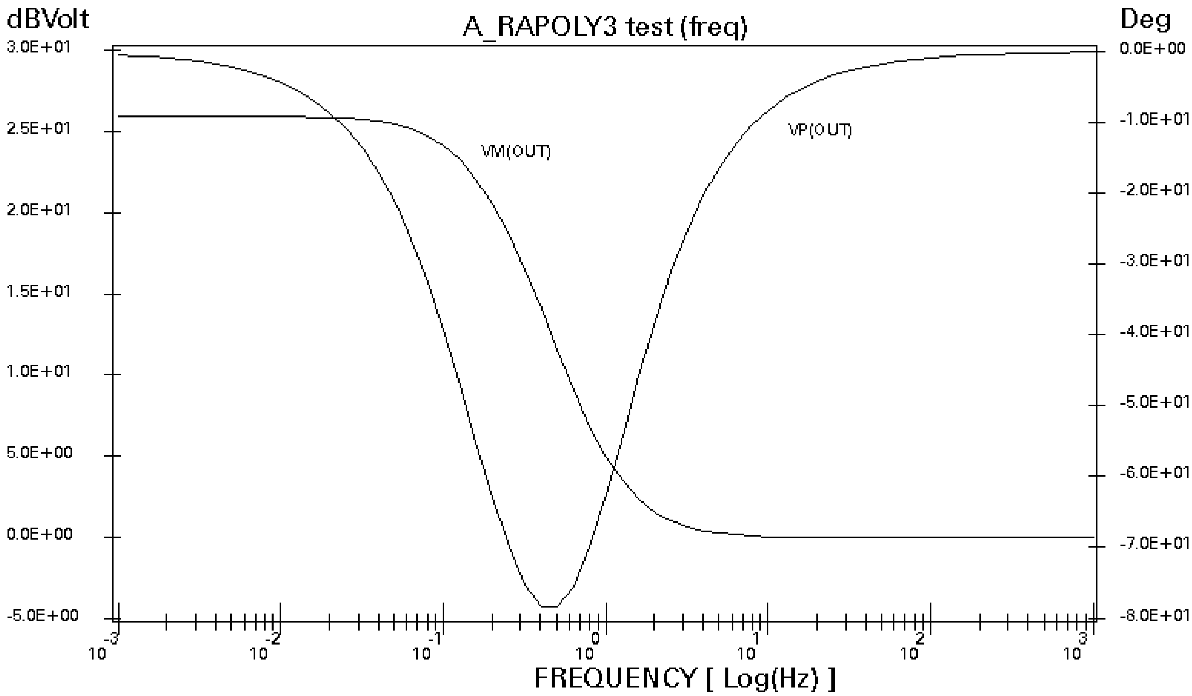


Test Results

A simulation with A0=240, A1=148, A2=30, A3=2,B0=12, B1=22, B2=12, B3=2 gave the following results. For transient analysis, the input was a step function of amplitude1.



An AC analysis with the same parameter values gave the following results.

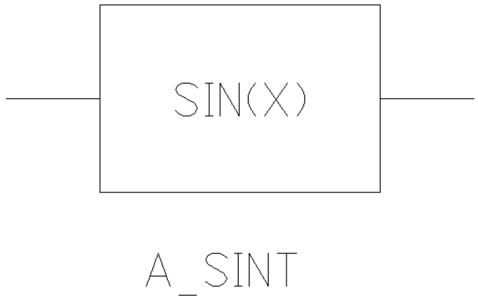


dBVolt
A_RAPOLY3 test (freq)
Deg
3.0E+01
2.5E+01
2.0E+01
1.5E+01
1.0E+01
5.0E+00
0.0E+00
-5.0E+00
0.0E+00
-1.0E+01
-2.0E+01
-3.0E+01
-4.0E+01
-5.0E+01
-6.0E+01
-7.0E+01
-8.0E+01
VM(OUT)
VP(OUT)
10^{-3}
10^{-2}
10^{-1}
10^{0}
10^{1}
10^{2}
10^{3}
FREQUENCY [Log(Hz)]

A_SINT (Sine Transducer)

A_SINT models a sine transducer. It returns the sine of the input scaled by a gain.

Graphic Symbol

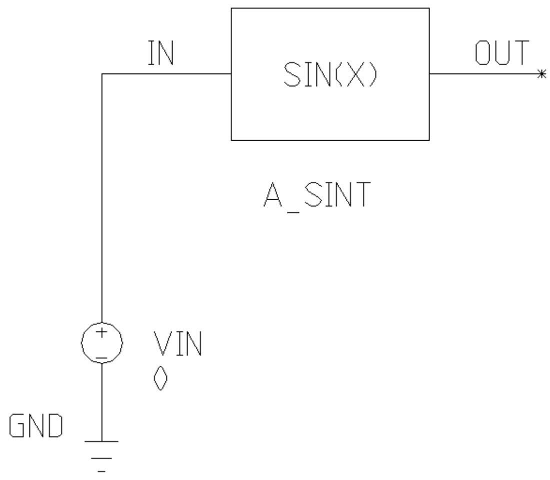


Modelled Parameters

The following parameters can be modified.

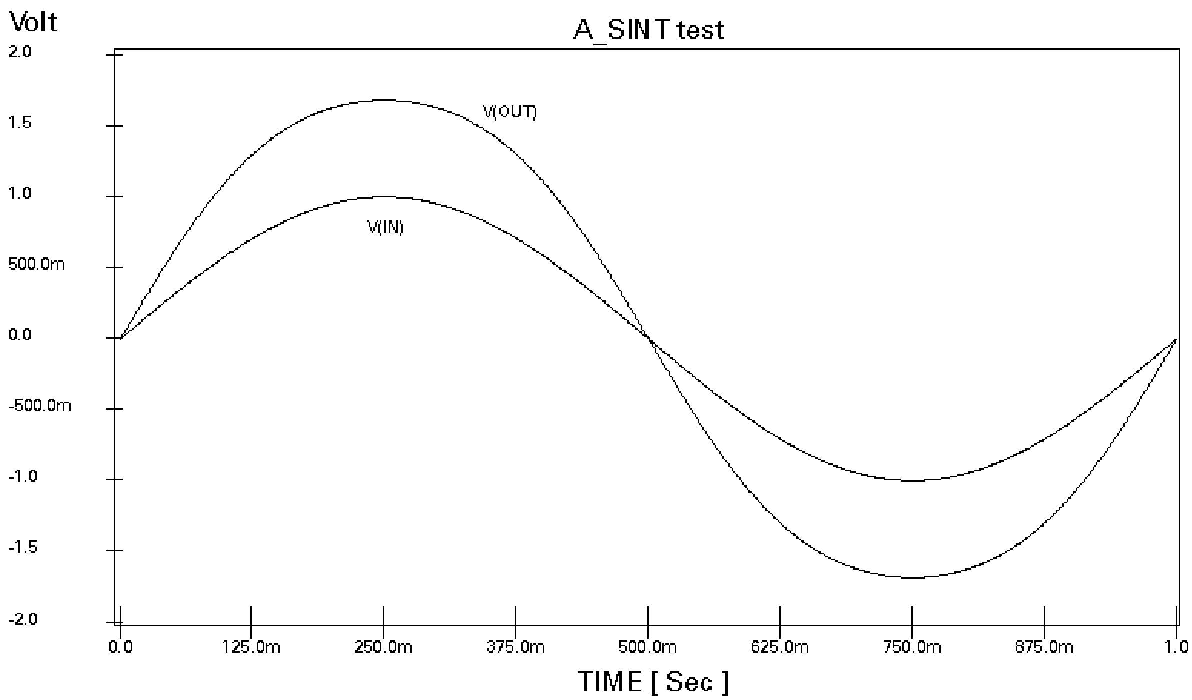
Parameter	Default Value	Unit
GAIN	1	–

Test Circuit



Test Results

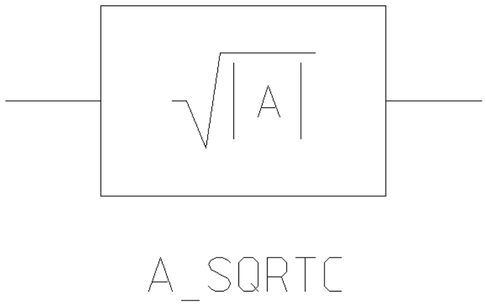
A simulation with a sine wave input and a model gain of 2 gave the following results.



A_SQRTC (Square Root Converter)

A_SQRTC models a square root converter. The output is the square root of the absolute value of the input scaled by a gain.

Graphic Symbol

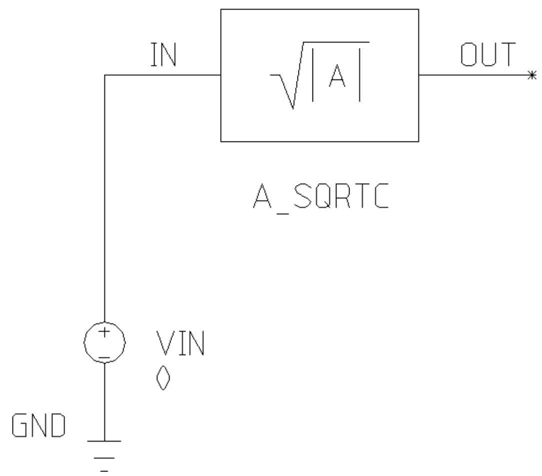


Modelled Parameters

The following parameters can be modified.

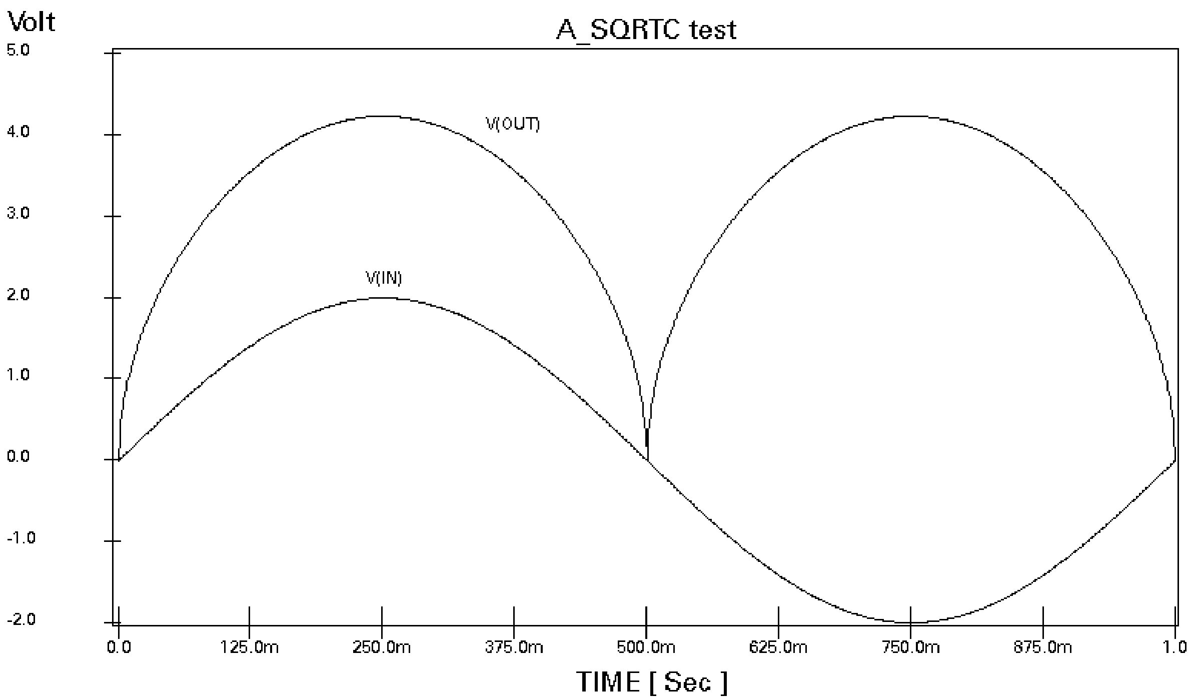
Parameter	Default Value	Unit
GAIN	1	–

Test Circuit



Test Results

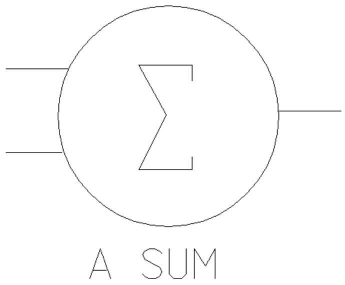
A simulation with a sine wave input of amplitude 2 and a model gain of 3 gave the following results.



A_SUM (Summing Element)

A_SUM models a component whose output is the sum of the two inputs each scaled by a gain.

Graphic Symbol

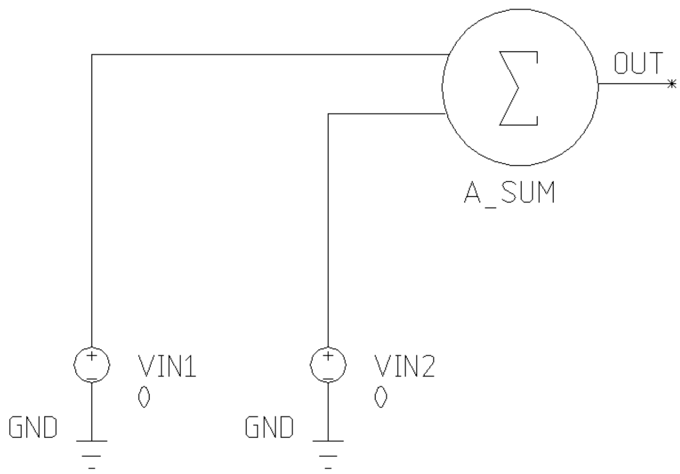


Modelled Parameters

The following parameters can be modified.

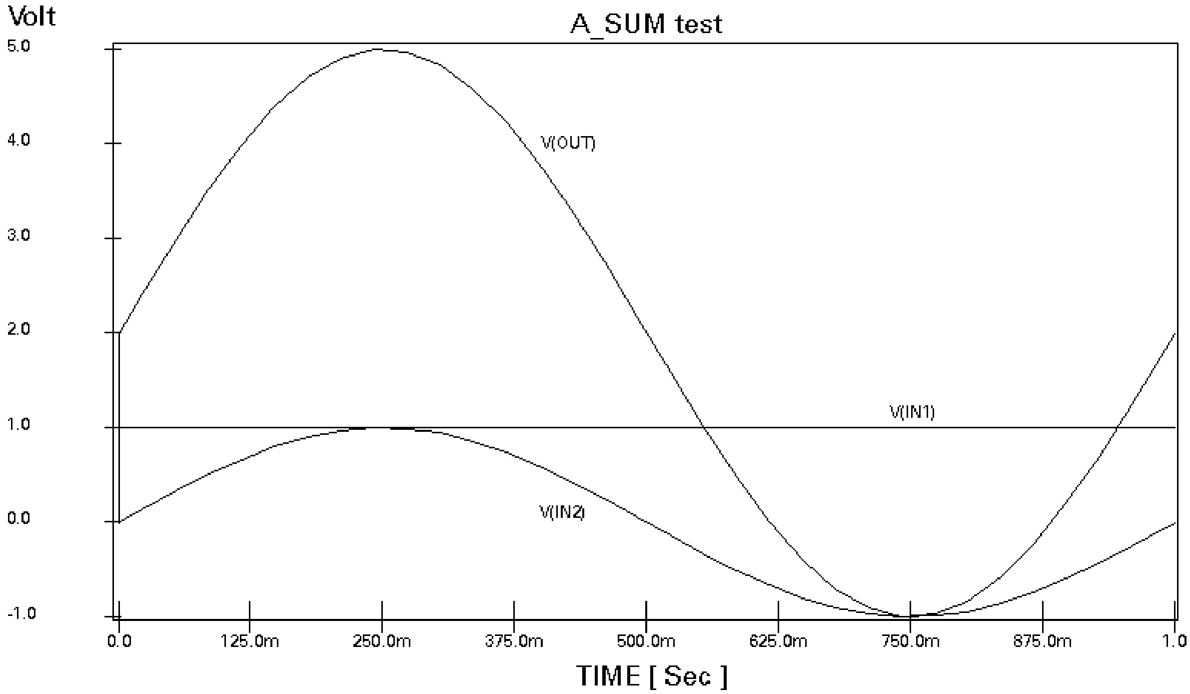
Parameter	Default Value	Unit
GAIN1 (Gain of input 1)	1	–
GAIN2 (Gain of input 2)	1	–

Test Circuit



Test Results

A simulation was performed with a step input of magnitude 1 at a model gain of 2 (GAIN1 = 2) and a sine input of amplitude 1 at a model gain of 3
(GAIN2 = 3). A transient analysis gave the following results.



Chapter 3
Detectors

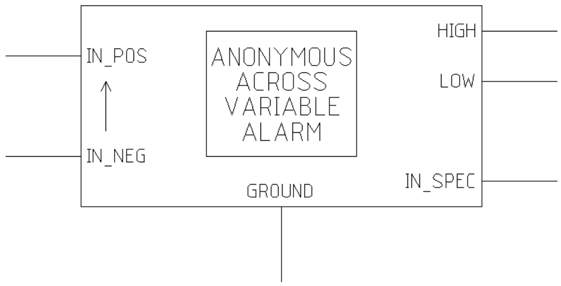
The following models are described in this chapter.

Model Name	Description
A_AAALARM	Alarm, anonymous (across-variable)
A_ATALARM	Alarm, anonymous (through-variable)
A_IALARM	Detector, current threshold
A_PALARM	Alarm, power threshold detector
A_VALARM	Alarm, voltage threshold detector

A_AAALARM (Anonymous Across-variable Alarm)

This macromodel, A_AAALARM, is an anonymous across-variable alarm. It has outputs to show whether the input is greater than or less than specified limits. A further output is available which shows when the input is within the limits.

Graphic Symbol



A_AAALARM

Modelled Parameters

The following parameters can be modified.

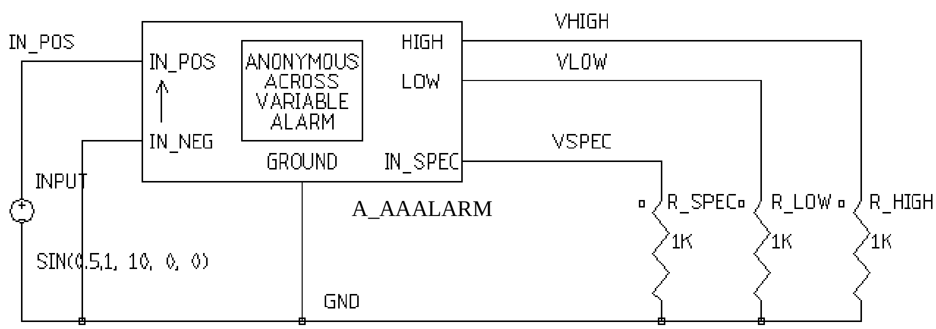
Parameter	Default Value	Unit
HIGH (High input threshold)	1	V
LOW (Low input threshold)	0	V
VOUT_H (High output voltage)	12	V
VOUT_L (Low output voltage)	0	V

Test Circuit

The anonymous across-variable alarm in this circuit is monitoring the across-value of the input signal. This signal must be applied as a voltage, but may represent any across-variable type. When the input exceeds the specified high threshold, the HIGH output switches to the high state. When the input is less than the specified low threshold, the LOW output switches to the high state, and when the input is between the thresholds, the IN_SPEC output switches to the high state.

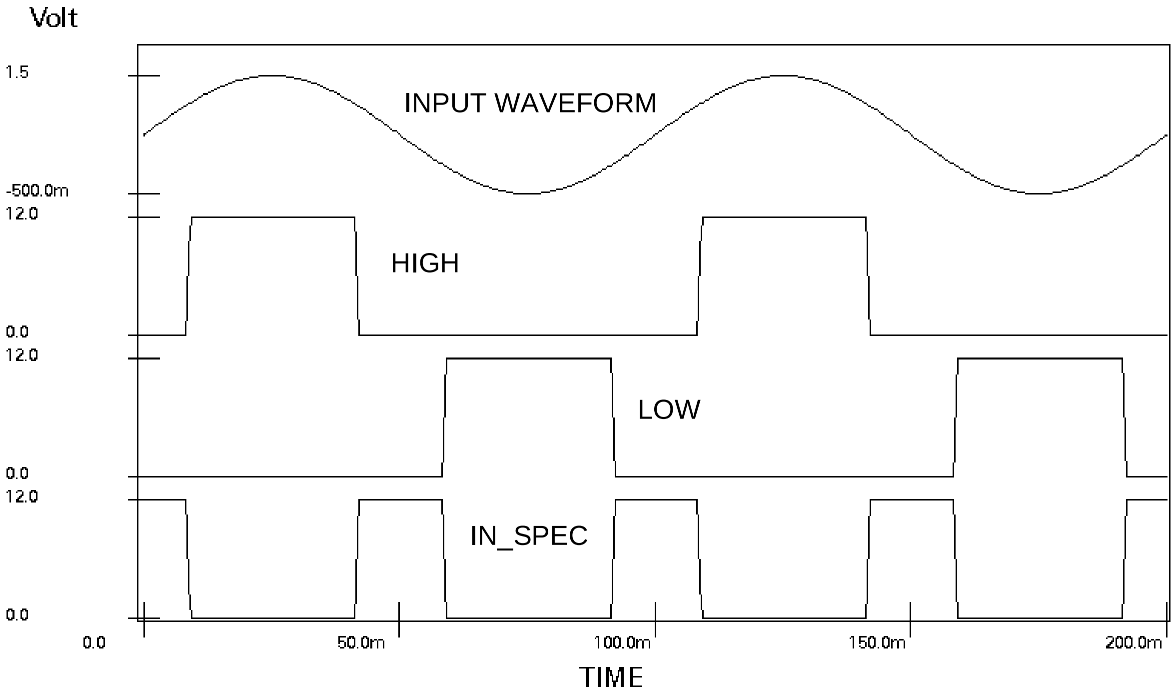
In the test circuit, the thresholds were set to the default values

In the following circuit, a sine wave voltage source was applied across IN_POS and IN_NEG. The offset value is 0.5V, the amplitude is 1V and the frequency is 10 Hz.



Test Results

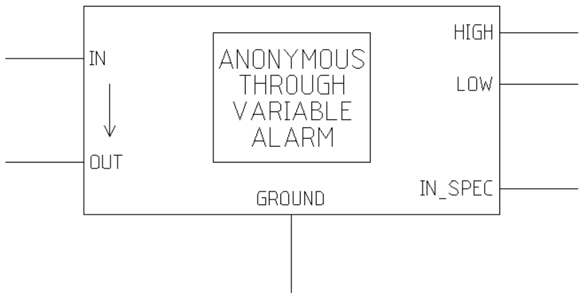
The default thresholds and output voltages were used for the simulation that gave the following results.



A_ATALARM (Anonymous Through-variable Alarm)

This macromodel, A_ATALARM, is an anonymous through-variable alarm. It has outputs to show whether the input is greater than, or less than specified limits. A further output is available which shows when the input is within the limits.

Graphic Symbol



A_ATALARM

Modelled Parameters

The following parameters can be modified.

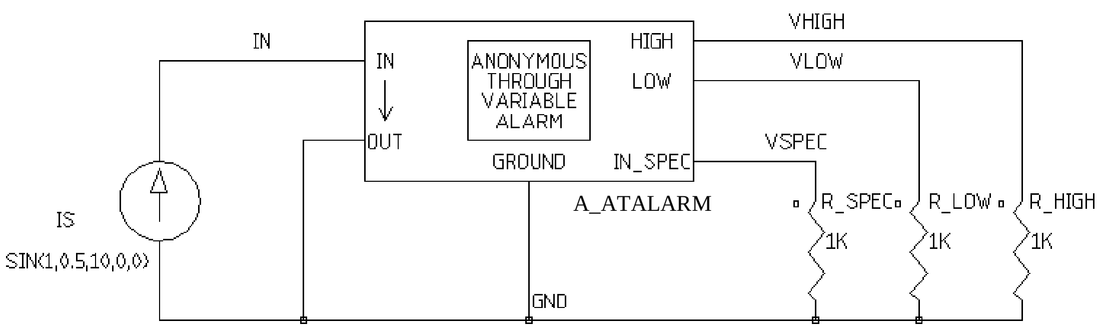
Parameter	Default Value	Unit
HIGH (High threshold)	1.25	A
LOW (Low threshold)	0.75	A
VOUT_H (High output voltage)	12	V
VOUT_L (Low output voltage)	0	V

Test Circuit

The anonymous through-variable alarm in this circuit is monitoring the value of the input signal. This signal is in the form of current, but may represent any through-variable type. When the input exceeds the specified high threshold, the HIGH output switches to the high state. When the input is less than the specified low threshold, the LOW output switches to the high state, and when the input is between the thresholds, the IN_SPEC output switches to the high state.

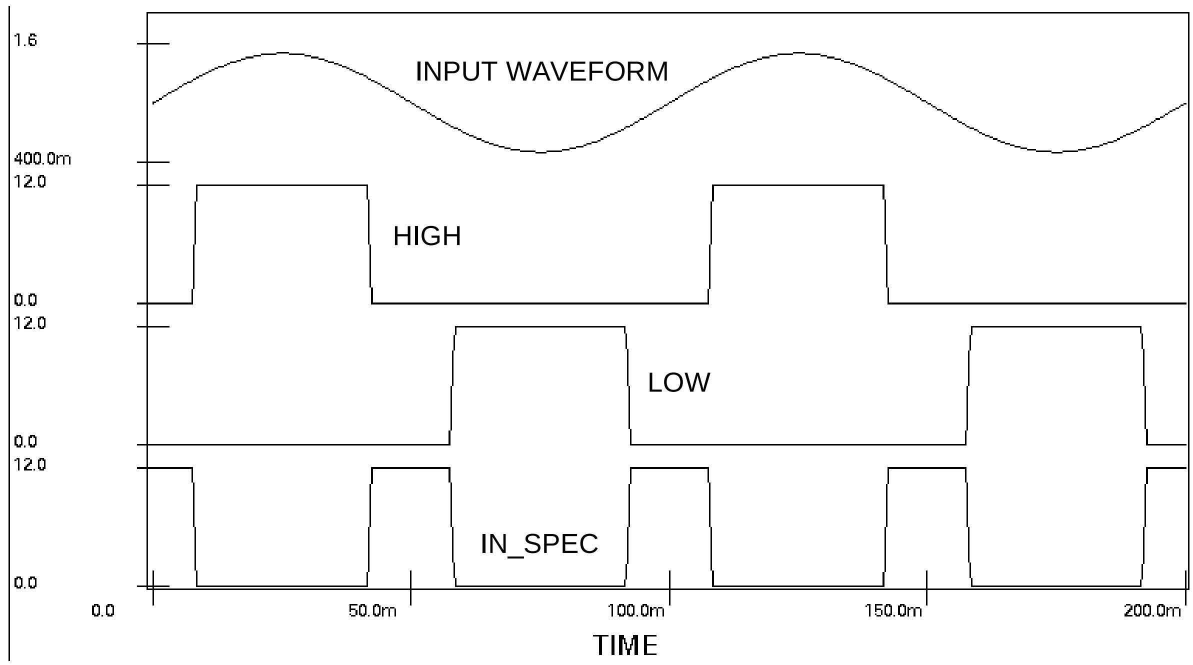
In the test circuit, the thresholds were set to the default values.

In the following circuit, a sine wave current flows through IN and OUT. The offset value is 1A, the amplitude is 0.5A and the frequency is 10 Hz.



Test Results

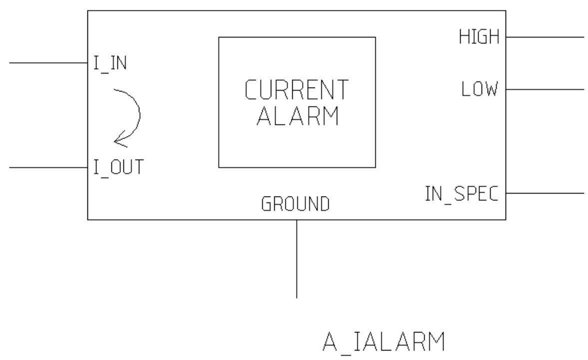
The default thresholds and output voltages were used for the simulation that gave the following results.



A_IALARM (Current Threshold Detector)

This macromodel, A_IALARM, is a current threshold detector. It has outputs to show whether the input current is greater than, or less than specified limits. A further output is available which shows that the input is within the limits.

Graphic Symbol



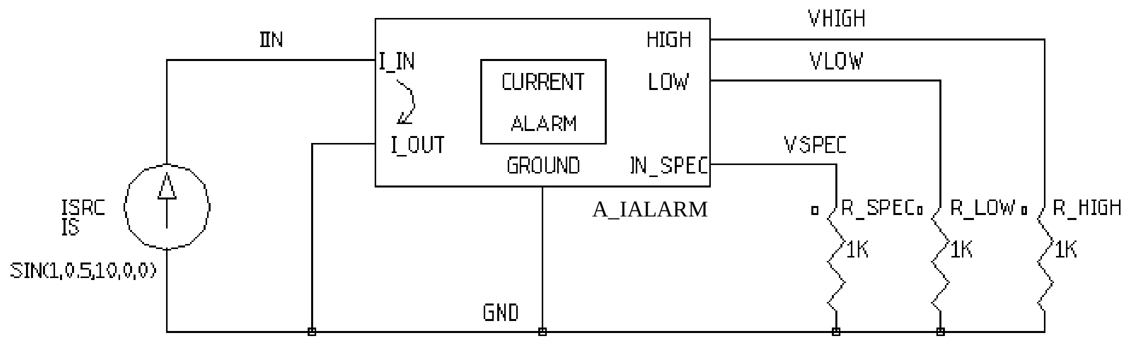
Modelled Parameters

The following parameters can be modified.

Parameter	Default Value	Unit
I_HIGH (High current threshold)	1.25	A
I_LOW (Low current threshold)	0.75	A
VOUT_H (High output voltage)	12	V
VOUT_L (Low output voltage)	0V	

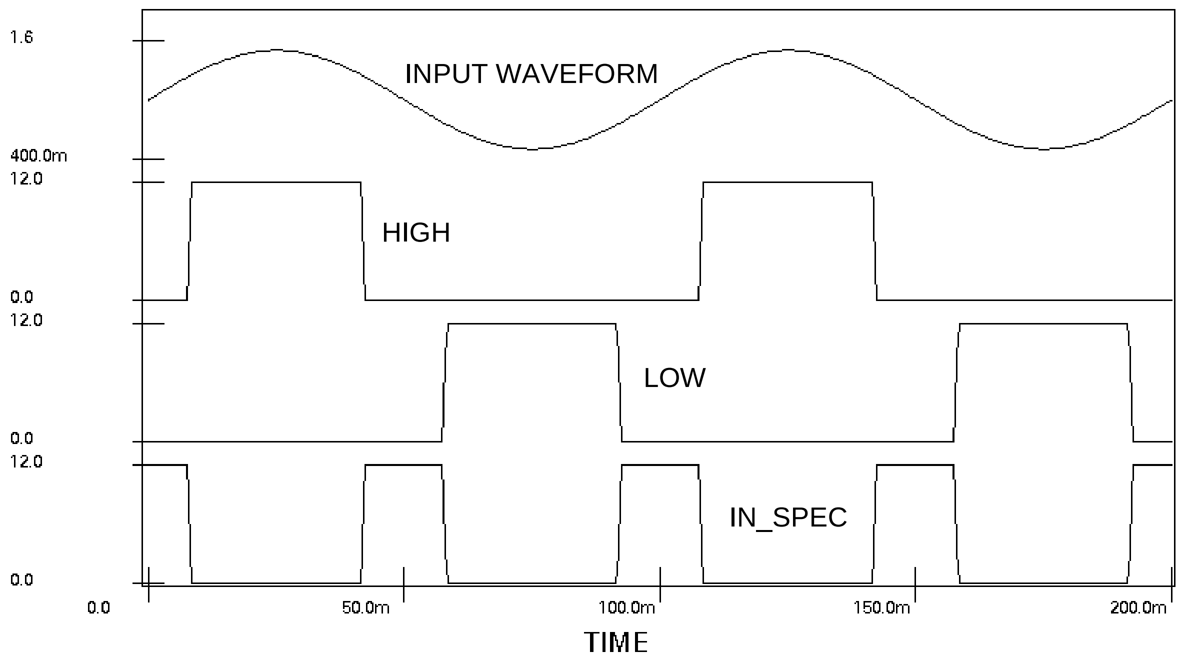
Test Circuit

The current from the I_IN to I_OUT terminals is varied using a SIN source. The offset value is 1A, the amplitude is 0.5A and the frequency is 10 Hz.



Test Results

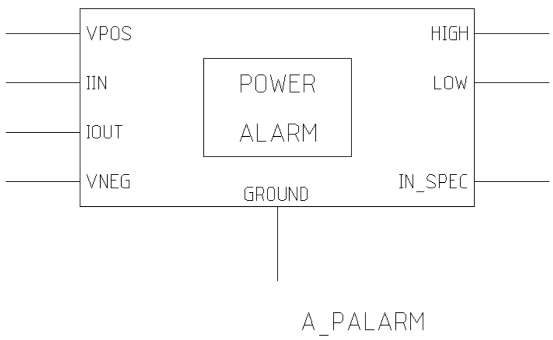
The default thresholds and output voltages were used for the simulation that gave the following results.



A_PALARM (Power Threshold Detector)

This macromodel, A_PALARM, is a power threshold detector. It has outputs to show whether the measured power is greater than, or less than specified limits. A further output is available which shows when the measured power is within the limits.

Graphic Symbol



Modelled Parameters

The following parameters can be modified.

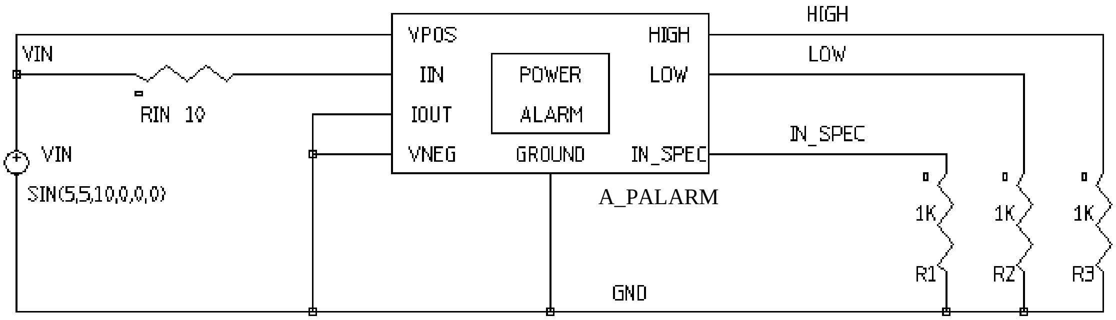
Parameter	Default Value	Unit
P_HIGH (High power threshold)	8	W
P_LOW (Low power threshold)	2	W
VOUT_H (High output voltage)	12	V
VOUT_L (Low output voltage)	0	V

Test Circuit

The power alarm in this circuit is monitoring the instantaneous power dissipated in the resistor RIN. When the power exceeds 8 W, the HIGH output switches to the high state. When the power is less than 2 W, the LOW output switches to the high state, and when the power is between 2 and 8 W, the IN_SPEC output switches to the high state.

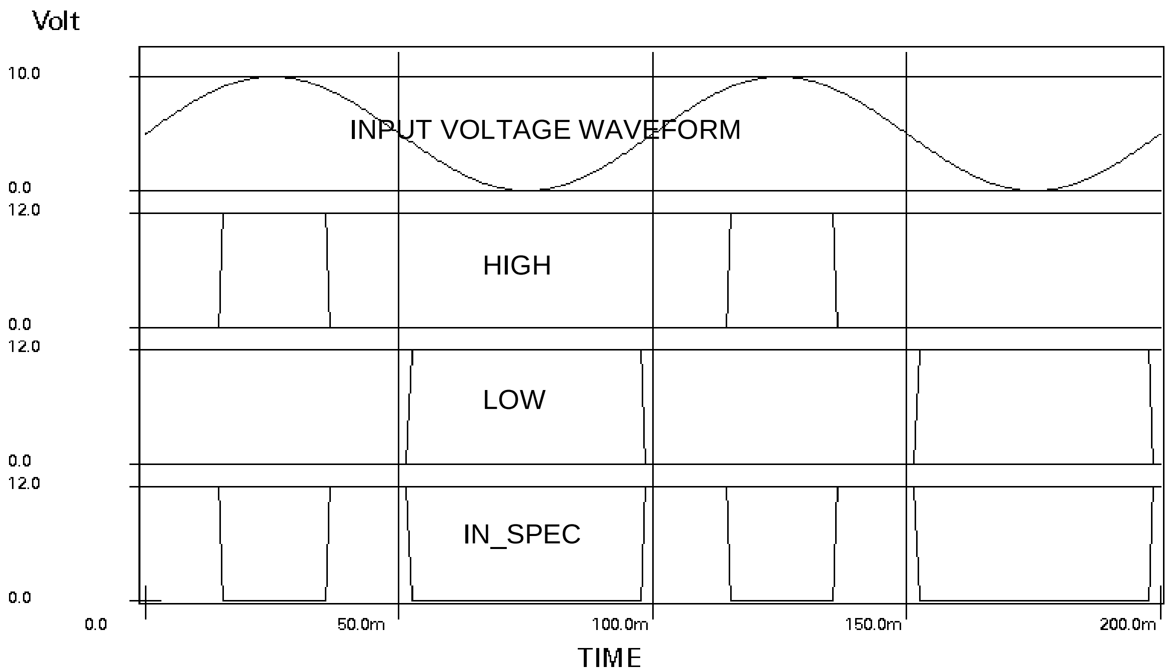
The resistance between the IIN and IOUT terminals is zero.

In the following circuit, a sine wave voltage source was applied across RIN. The offset value is 5V, the amplitude is 5V and the frequency is 10 Hz.



Test Results

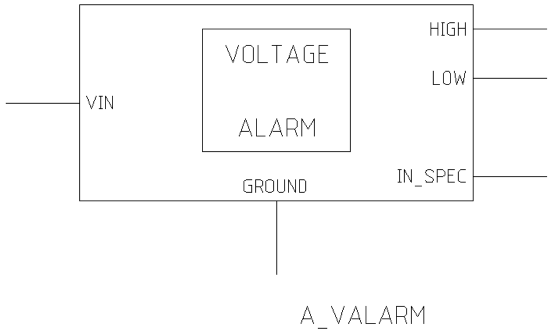
The default thresholds and output voltages were used for the simulation that gave the following results.



A_VALARM (Voltage Threshold Detector)

This macromodel, A_VALARM, is a voltage threshold detector. It has outputs to show whether the input voltage is greater than or less than specified limits. A further output is available which shows that the input is within the limits.

Graphic Symbol



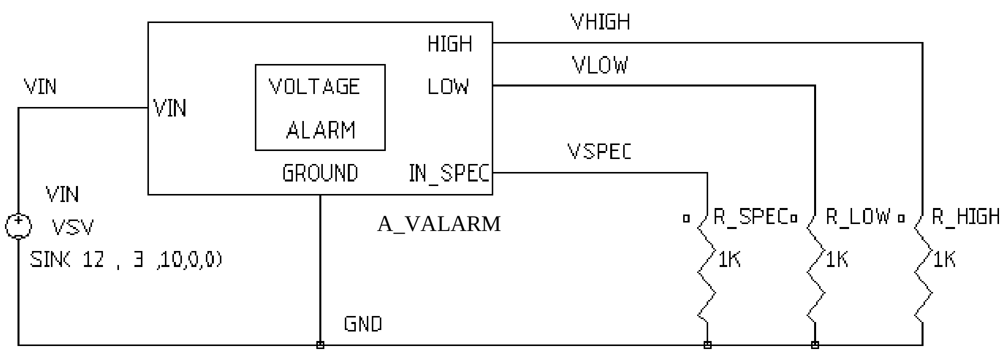
Modelled Parameters

The following parameters are modelled.

Parameter	Default Value	Unit
V_HIGH (High voltage threshold)	14	V
V_LOW (Low voltage threshold)	10	V
VOUT_H (High output voltage)	12	V
VOUT_L (Low output voltage)	0	V

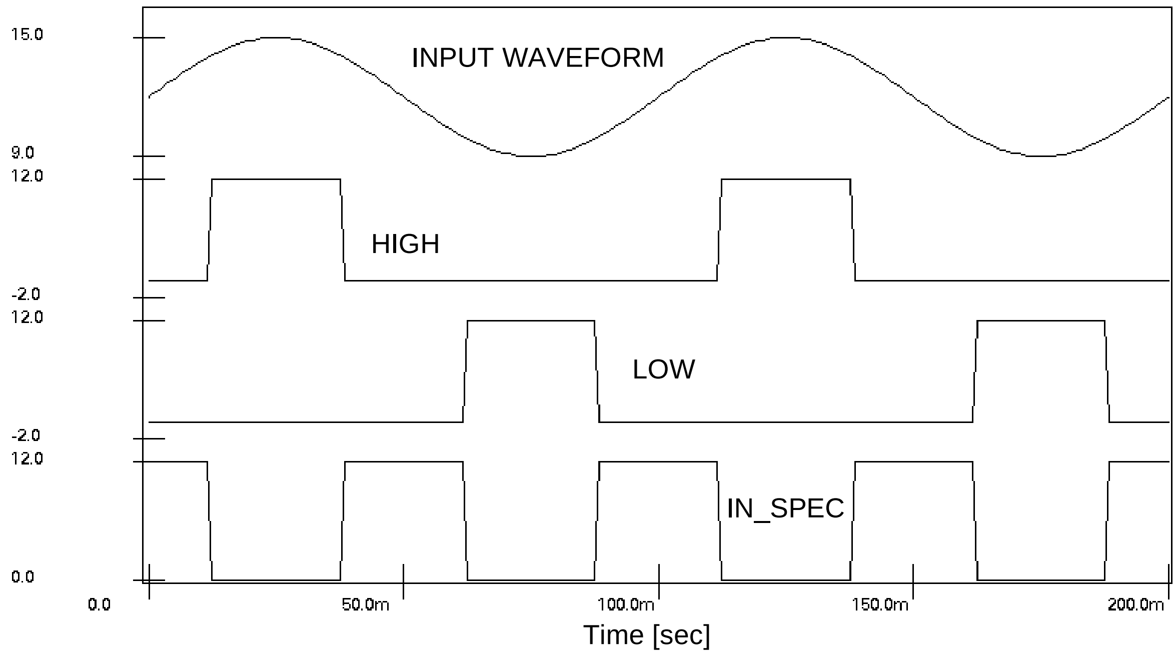
Test Circuit

The voltage on the VIN terminal was varied using a SIN source. The offset value was 12V, the amplitude was 3V, and the frequency was 10 Hz.



Test Results

The default thresholds and output voltages were used for the simulation that gave the following results.



Chapter 4
Electrical Models

The following models are described in this chapter.

Model Name	Description
A_CU_WIRE	Wire, copper
A_FUSE	Fuse
A_LAMP1F	Lamp, single filament
A_LAMP2F21-5	Lamp, 2-filament 12V, 21W, and 5W
A_WIRE	Wire, electrical

A_CU_WIRE (Copper Wire)

This macromodel of a copper wire allows you to enter the diameter of the wire in American Wire Gage (AWG), the length of the wire, and the resistivity of the conductor. The wire resistance is calculated from these parameters.

Graphic Symbol

Modelled Parameters

The following parameters can be modified.

Parameter	Default Value	Unit
GAGE (American Wire Gage)	10	AWG
LENGTH	1	m
RESISTIVITY	15.5n	Ωm

Note: The resistivity value is for pure copper.

Unmodelled Characteristics

The characteristics of A_CU_WIRE which are not modelled are listed below.

- inductance
- capacitance
- temperature effects

Design Notes

The diameter of the wire must be specified in American Wire Gage (AWG).

For sizes 0 to 36 enter the gage number unchanged in the GAGE field.
For size 00 enter -1, for size 000 enter -2 and for size 0000 enter -3.

The diameter of AWG 36 wire is 0.0050 inches, and the diameter of AWG 0000 is 0.46 inches. A decrease of one AWG number increases the diameter of the wire by 1.1229322 times. This number is given by the following equation.

$$\sqrt[39]{\frac{0.4600}{0.0050}} = 1.1229322$$

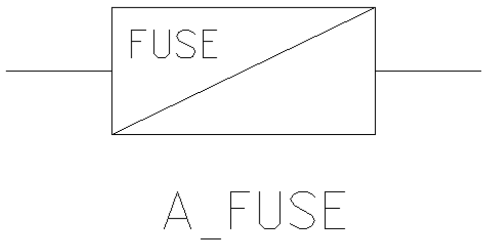
The resistivity of pure copper at 273K is $15.5 \times 10^{-9}\Omega$m. Copper wire normally has a higher resistivity than this.

Note: The unit of length used in this model is the meter.

A_FUSE (Fuse)

This macromodel models a typical, fast acting, automotive fuse.

Graphic Symbol



Modelled Parameters

The following parameters are modelled.

Parameter	Default Value	Unit
I (Rated current)	1	A
R (Resistance)	10m	W

Note: The fuse model does not blow at currents below 1.1 × rated current.

Unmodelled parameters

The following parameters are not modelled.

- inductance
- capacitance
- change in resistance with current (before the fuse blows) and arcing

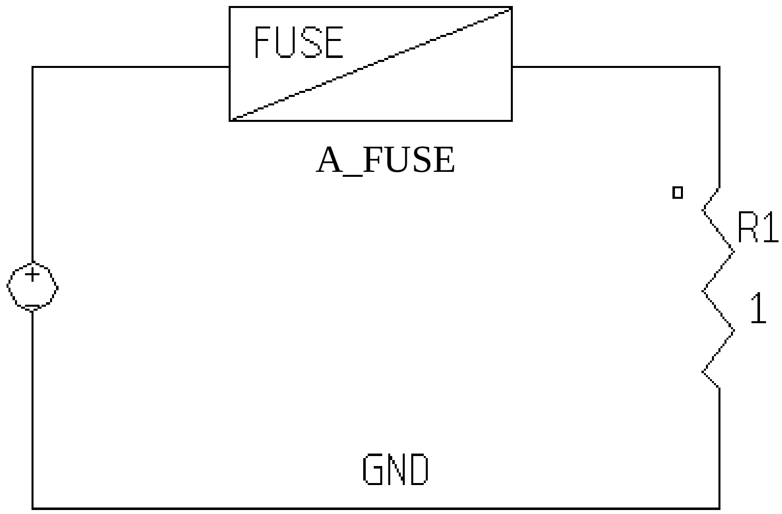
Design Notes

The fuse is designed to operate up-to and including the rated current without blowing. A performance table for the fuse is given below. The characteristics are based on those of a real automotive fuse.

The fuse never blows at currents below 1.1 × rated current. At convergence, the fuse acts as though the fuse current has been flowing for an infinite time. The following measurements are based on a 1A fuse.

Test Circuit

The following circuit was used to test the fuse. The voltage on the voltage source was pulsed from zero to a value numerically equal to the required current. A table showing the time that the fuse took to blow for different currents is given in the Test Results section.


FUSE
A_FUSE
R1
1
GND

Test results

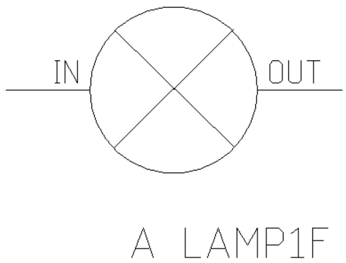
The following results were obtained by applying a voltage numerically equal to the required current to the input of the test circuit. The one-ohm resistor ensures the correct current flows. The voltage was zero at time=0 and was stepped up to the required current in one microsecond.

Current (x rating)	Time (s)
1	infinite
1.1	infinite
1.2	17.9
1.3	12.2
1.4	9
1.5	7.6
2.0	0.47
5	47m
10	14m
20	4m

A_LAMP1F (Single Filament Lamp)

This component models the electrical behavior of a single filament lamp, including inertia due to heat generation and dissipation.

Graphic Symbol



Modelled Parameters

The following parameters can be modified.

Parameter	Default Value	Unit
FU (Affects cold/hot current ratio)	10	–
UN (Nominal voltage)	12	V
PN (Nominal power)	60	W
TAU1 (Fast time constant)	50E-3	s
TAU2 (Slow time constant)	350E-3	s

Design Notes

The A_LAMP1F macromodel simulates the behavior of a single filament lamp when the lamp is switched on or off. The resistance of the filament depends on the filament temperature and changes according to the filament current rise or decay. It is assumed that the time dependency of the filament current can be described by a fast time constant and a slow time constant. Refer to the figure on the following page.

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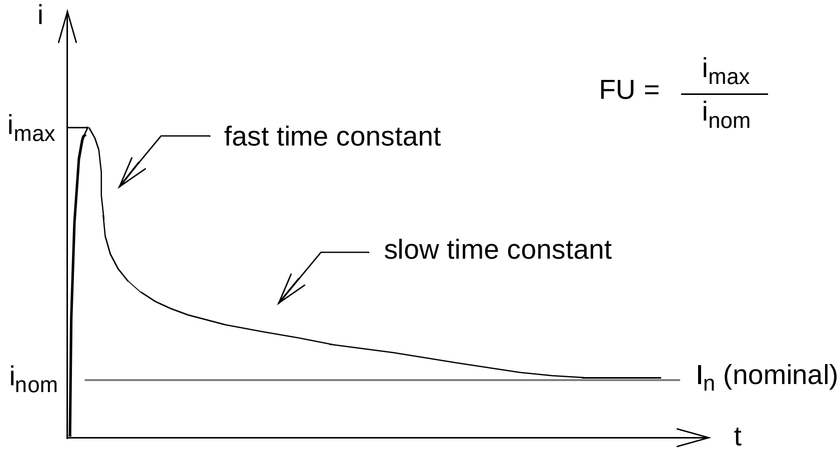


Filament current vs. time for step input voltage

The nonlinear resistance of the filament is represented by the equation:

$R_{fil} = k * \text{sqrt}(U)$

where

kis a constant
Uis the momentary filament voltage

The constant k is expressed in terms of the nominal lamp voltage, U_n, and the nominal lamp power, P_n.

$k = \text{sqrt}(U_n^3/P_n)$

It is assumed that for an input volatge $\leq 0.01 * U_n$, the filament resistance is constant and is equal to the value corresponding to the input voltage = $0.01 * U_n$.

It is also assumed that the fast and slow time constants for cooling equal the fast and slow time constants for heating.

You can set the basic macromodel parameters to adjust the macromodel behavior to correspond to the manufacturer's parameters for a specific lamp.

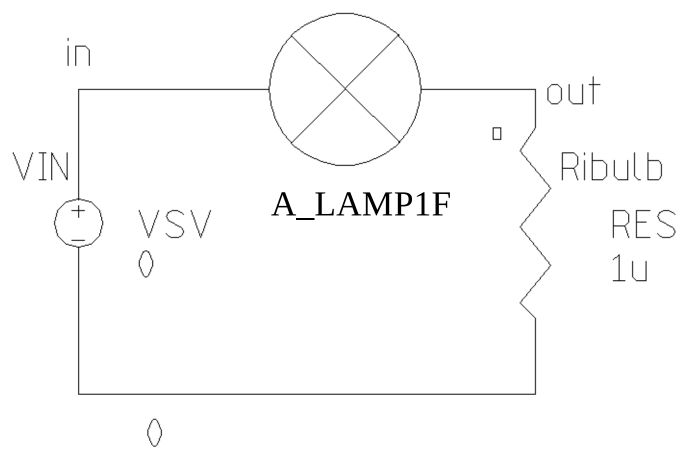
Parameter names are self explanatory. The FU parameter reflects the
cold/hot current ratio, which may be given by the manufacturer or measured by means of an oscilloscope (as for TAU1 and TAU2).

The macromodel models the first order electrical behavior of the filament only, and cannot be used for determining the filament temperature or luminance. Also, filament inductance is neglected.

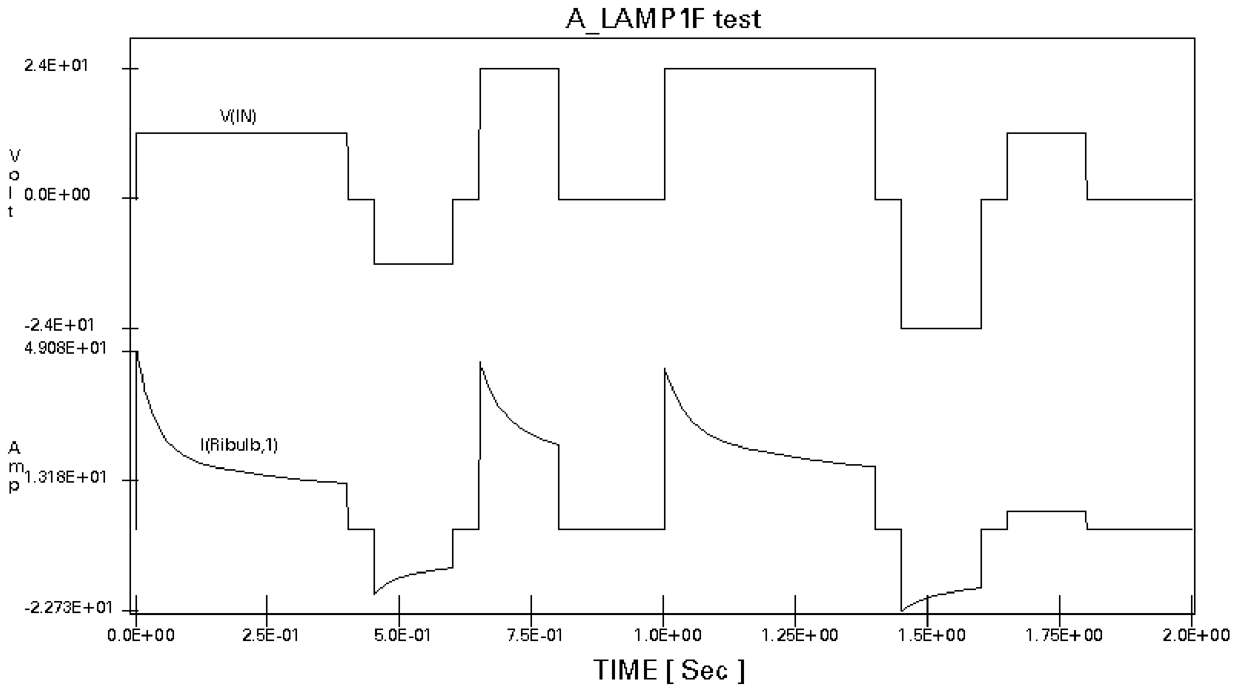
The filament current vs. time waveform is in response to the applied pulse voltage.

Test Circuit

This component is a lamp filament surrounded by a glass enclosure. Only the electrical behavior is modelled, that is, filament current versus voltage and time. Input voltage can be DC or large signal (transient analysis). This model cannot be used in any small signal AC analysis.



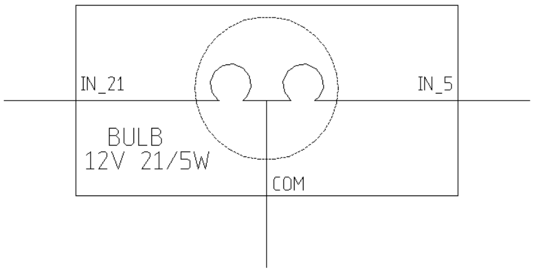
Test Results



A_LAMP2F21-5 (2 Filament Lamp, 21W and 5W)

This component models a lamp with two electrically separate, but thermally coupled, filaments. The model is based on measurements made on a
12V, 21/5 W bulb typical of that used in automotive applications.

Graphic Symbol



A_LAMP2F21-5

Modelled Parameters

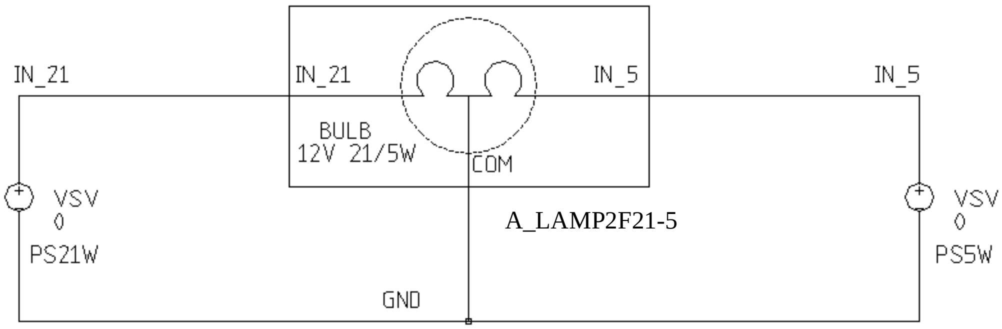
There are no parameters that you can modify.

Design Notes

- Characterization of the lamp filaments was carried out for the applied voltage range 0 to 14V. Operation of the model is not specified for voltages outside this range.
- Steady-state thermal characteristics are modelled, but thermal and electrical time constants are unmodelled.

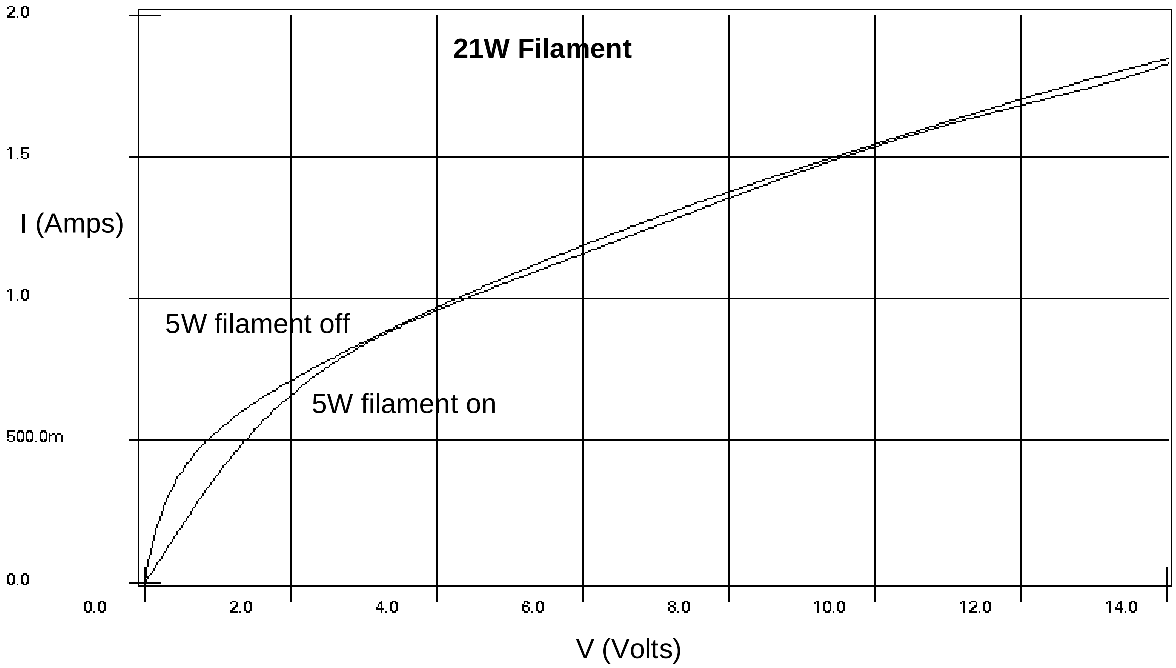
Test Circuit

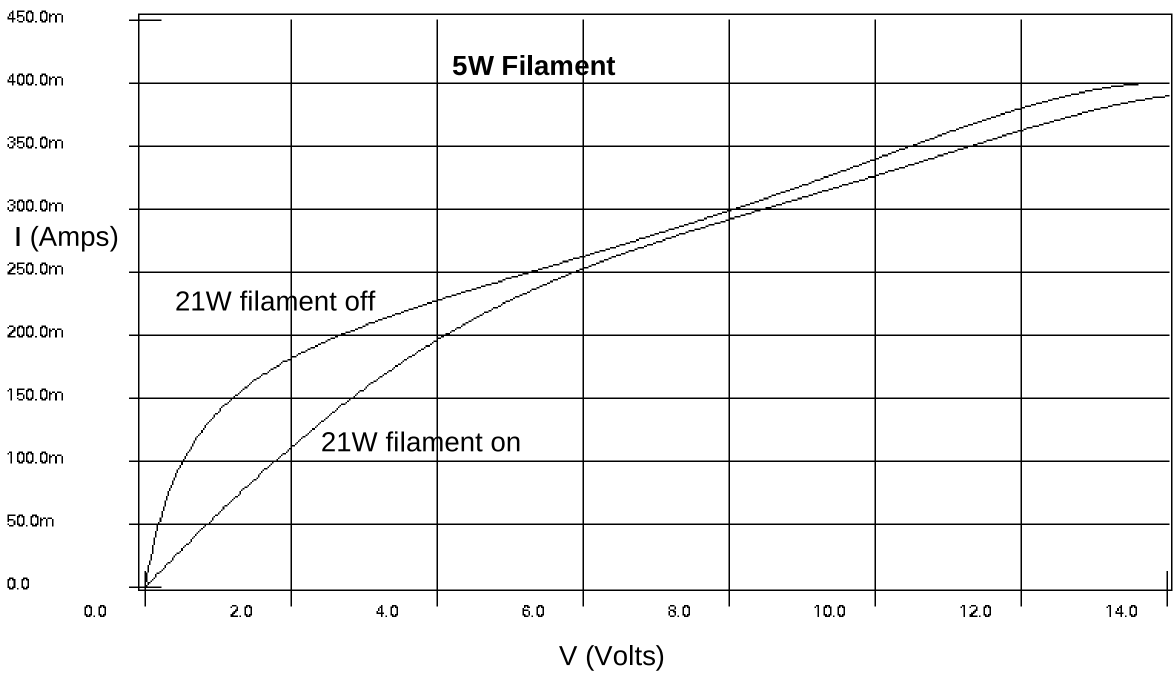
The circuit shown below was used to produce the example waveforms.



Test Results

The examples on the following page show the operation of the dual filament bulb. The voltage on the filament being tested was swept from 0 to 14V. The test was performed once with the othe filament off and once with the other filament on.

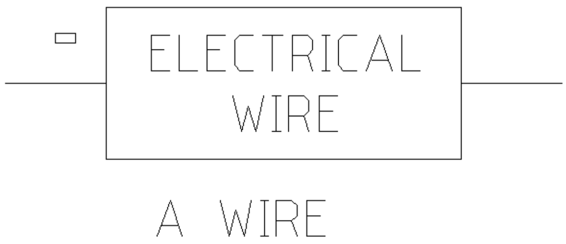

21W Filament
I (Amps)
2.0
1.5
1.0
500.0m
0.0
5W filament off
5W filament on
0.0
2.0
4.0
6.0
8.0
10.0
12.0
14.0
V (Volts)


5W Filament
I (Amps)
450.0m
400.0m
350.0m
300.0m
250.0m
200.0m
150.0m
100.0m
50.0m
0.0
21W filament off
21W filament on
0.0
2.0
4.0
6.0
8.0
10.0
12.0
14.0
V (Volts)

A_WIRE (Electrical Wire)

This macromodel of a wire allows you to enter dimensional details and the resistivity of the conductor. The wire resistance is calculated from these parameters.

Graphic Symbol



Modelled Parameters

The following parameters are modelled.

Parameter	Default Value	Unit
LENGTH	100	m
AREA (Cross section)	1u	m^2
TEMP (Temperature)	300	K
R273 (Resistivity at 273K)	15.5n	Ω m
TC_RES (Temperature coefficient)	0.44	% / K

Note: The resistivity value is for pure copper. The resistivity for copper wire is normally greater than this figure.

Unmodelled Characteristics

The characteristics of A_WIRE which are not modelled are listed below.

- inductance
- capacitance

Design Notes

The resistance of the wire at 273K is:

$$\text{Resistance} = \frac{\text{Resistivity} \times \text{Length}}{\text{Area}}$$

The resistance at temperatures other than 273K varies by the temperature coefficient multiplied by (Temperature - 273K).

Note: This macromodel allows you to see the effects of temperature by changing the value of the TEMP parameter in the model.

Chapter 5
Switches and Relays

The following models are described in this chapter.

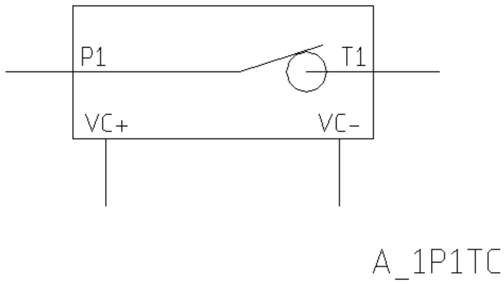
Model Name	Description
A_1P1TC	Switch, single-pole (normally closed)
A_1P1TO	Switch, single-pole (normally open)
A_1P2T	Switch, single-pole, double-throw
A_1P2TR	Relay, single-pole, double-throw
A_1P3T	Switch, single-pole, triple-throw
A_1P4T	Switch, single-pole, four-throw
A_1PRC	Relay, single-pole (normally closed)
A_1PRO	Relay, single-pole (normally open)
A_2P2TR	Relay, double-pole, double-throw
A_2PMX	Switch, two-pole matrix
A_3PMX	Switch, three-pole matrix
A_4PMX	Switch, four-pole matrix
A_CCR	Relay, cross-strap
A_CCTPM	Switch, two-pole, cross-connection
A_DG4T	Switch, 1-pole, 4-throw with digital control
A_HALLSW	Switch, functional Hall effect
A_HSW	Switch, Hall effect sensor

Model Name	**Description**
A_MSW	Switch, momentary
A_PERSW	Switch, periodic
A_REEDSW	Switch, Reed (relay)
A_REL1_2P	Relay, automotive

A_1P1TC (Switch, Single-pole, Normally Closed)

This component models a normally closed, single pole switch.

Graphic Symbol



Modelled Parameters

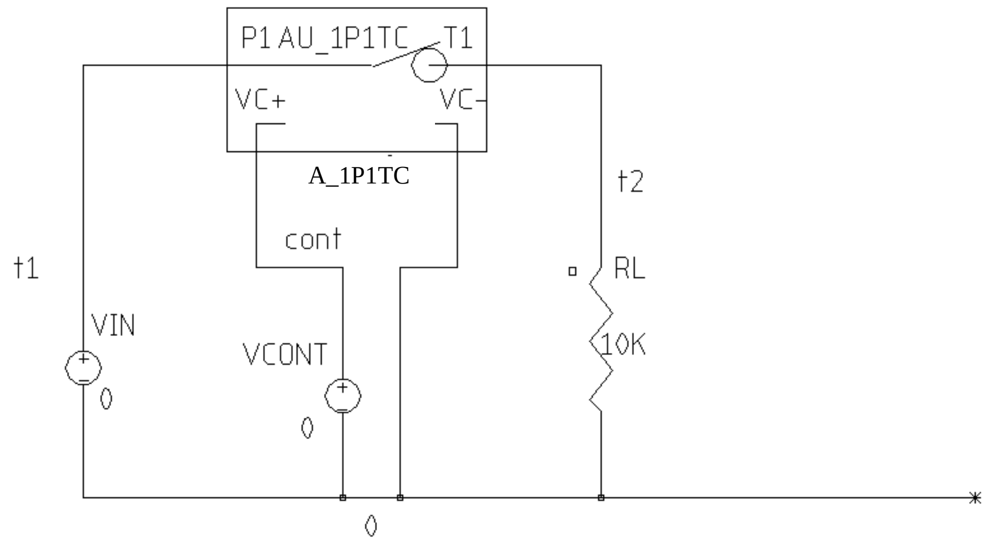
The following parameters can be modified.

Parameter	Default Value	Unit
MARG (Position voltage margin)	0.3	V
BDEL (Break delay)	0.5m	s
MDEL (Make delay)	1m	s
RON (Contact ON resistance)	10m	Ω
ROFF (Contact OFF resistance)	1G	Ω
CSW (Contact capacitance)	20p	F

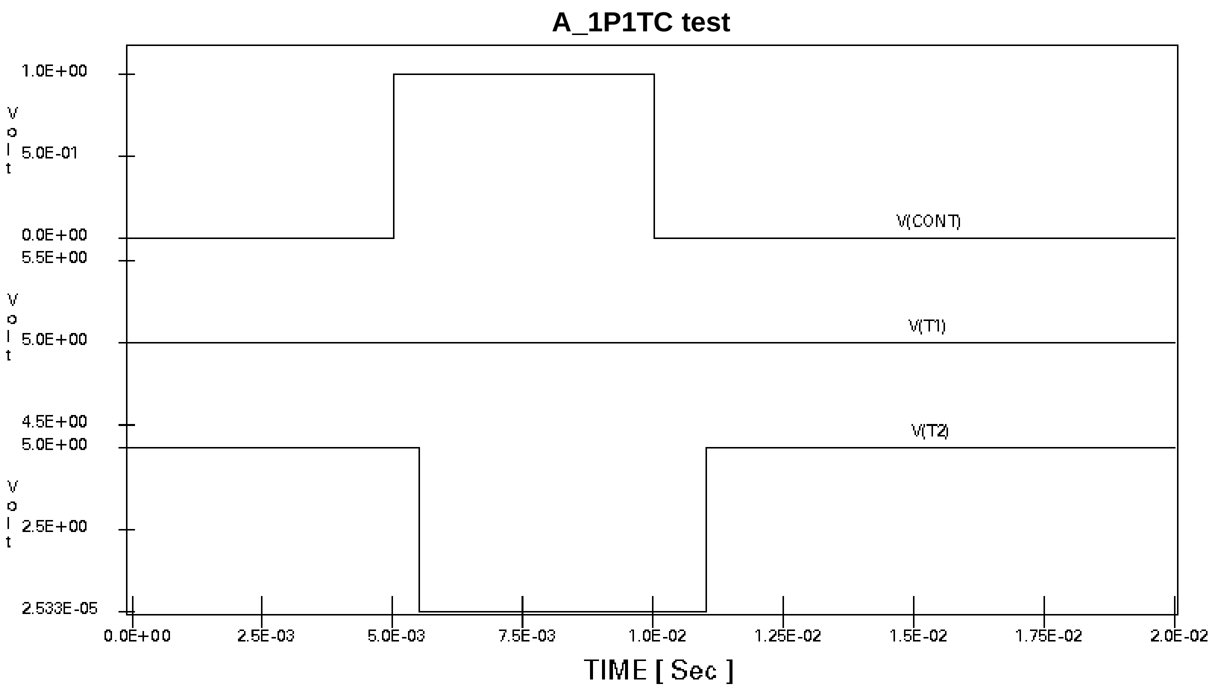
Design Notes

The switch is opened by applying a control voltage of 1V to the control input. If the control voltage falls outside the range of 1V plus or minus the margin (MARG), the switch remains closed. Make and break time delays can be set independently. The resistance transition is abrupt. The control voltage input resistance is 1G.

Test Circuit



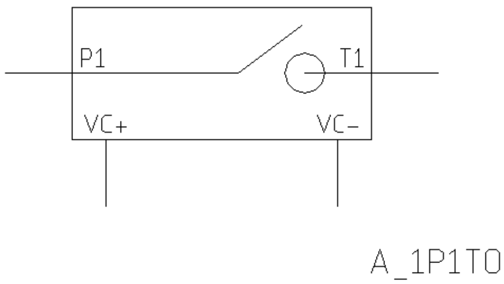
Test Results



A_1P1TO (Switch, Single-pole, Normally Open)

This component models a normally open single pole switch.

Graphic Symbol



Modelled Parameters

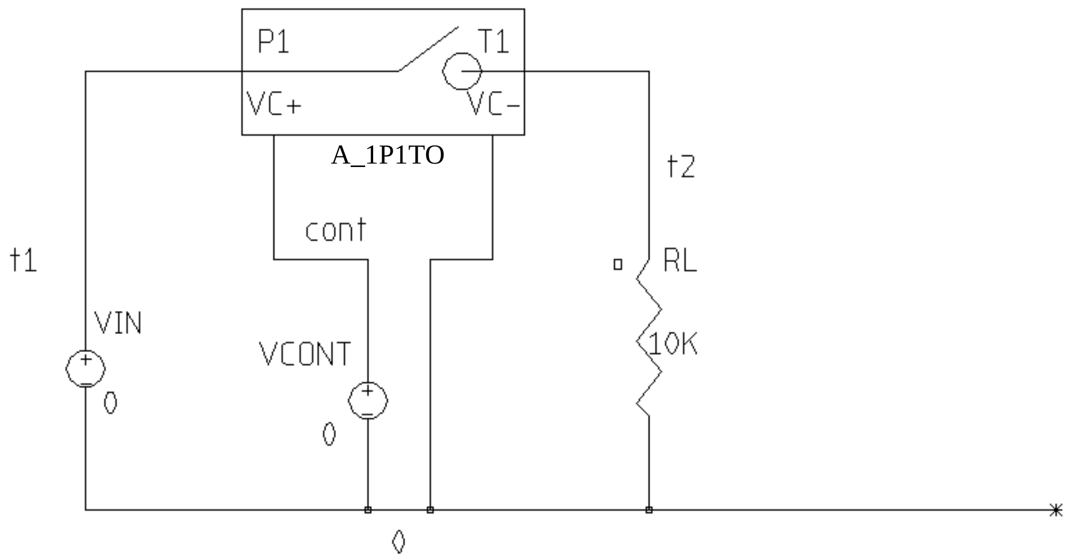
The following parameters can be modified.

Parameter	Default Value	Unit
MARG (Position voltage margin)	0.3	V
BDEL (Break delay)	0.5m	s
MDEL (Make delay)	1m	s
RON (Contact ON resistance)	10m	Ω
ROFF (Contact OFF resistance)	1G	Ω
CSW (Contact capacitance)	20p	F

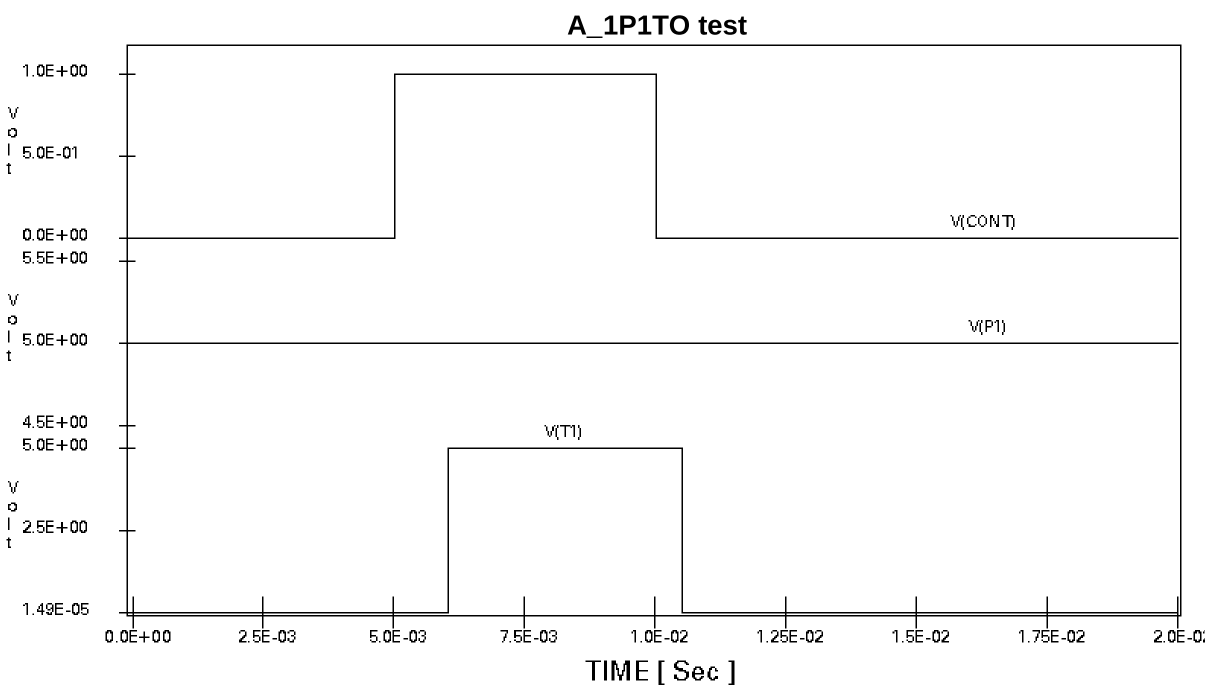
Design Notes

The switch is closed by applying a control voltage of 1V to the control input. If the control voltage is outside the range of 1V plus or minus the margin (MARG), the switch remains open. Make and break time delays can be set independently. The resistance transition is abrupt. The control voltage input resistance is 1G.

Test Circuit



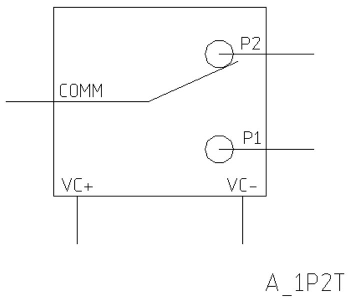
Test Results



A_1P2T (Switch, Single-pole, Double-throw)

This component models a single pole switch with two throw positions.

Graphic Symbol



Modelled Parameters

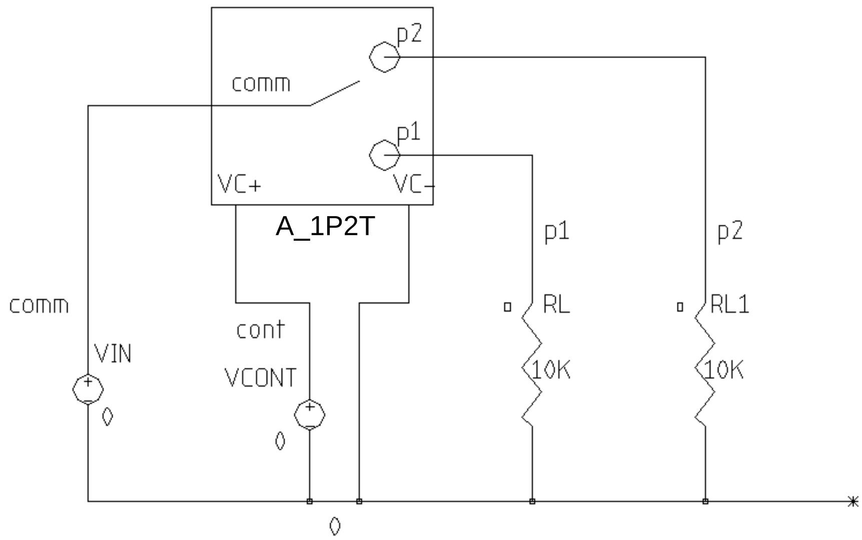
The following parameters can be modified.

Parameter	Default Value	Unit
MARG (Position voltage margin)	0.3	V
BDEL (Break delay)	1m	s
MDEL (Make delay)	2m	s
RON (Contact ON resistance)	10m	Ω
ROFF (Contact OFF resistance)	1G	Ω
CSW (Contact capacitance)	20p	F

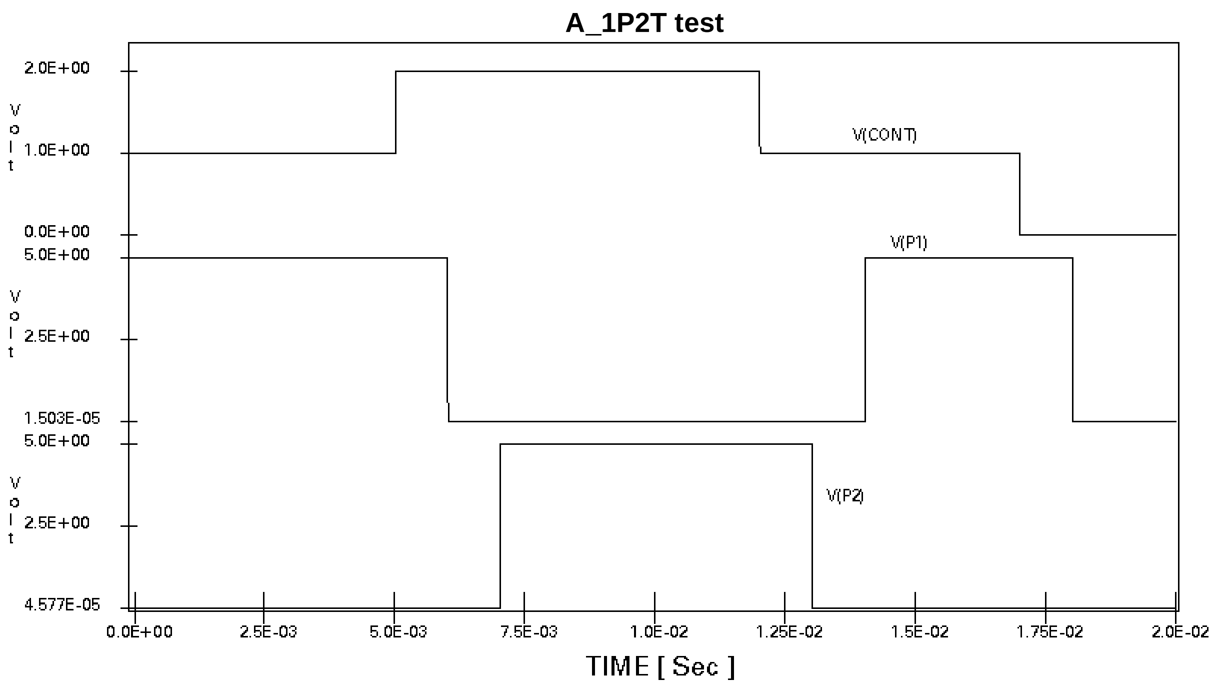
Design Notes

A switch position is selected by applying a voltage to the control input. A control voltage of 1V corresponds to the 1st position and a control voltage of 2V corresponds to the 2nd position. If the control voltage is outside the range of the needed position voltage plus or minus the margin (MARG), there is no connection at all. Make and break time delays can be set independently. The resistance transition is abrupt. The control voltage input impedance is 10G.

Test Circuit



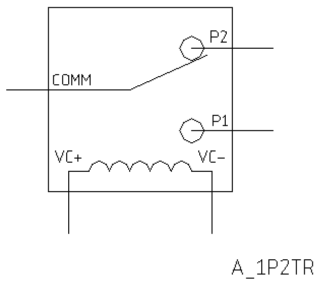
Test Results



A_1P2TR (Relay, Single-pole, Double-throw)

This component models a relay with one pole and two throw positions.

Graphic Symbol



Modelled Parameters

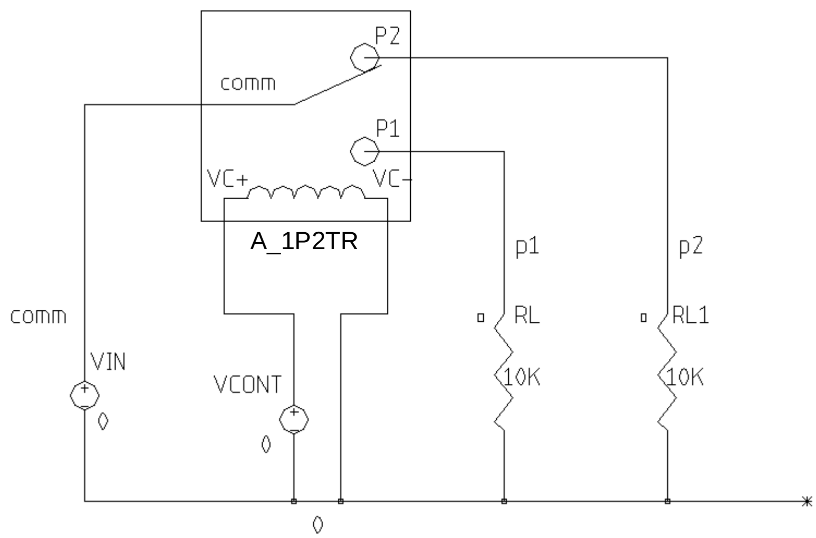
The following parameters can be modified.

Parameter	Default Value	Unit
L (Coil inductance)	0.1	H
C (Coil capacitance)	100p	F
R (Coil resistance)	120	Ω
EP (Pull-in voltage)	7.5	V
ED (Drop-out voltage)	2.5	V
BDEL (Break delay)	1m	s
MDEL (Make delay)	2m	s
RON (Contact ON resistance)	10m	Ω
ROFF (Contact OFF resistance)	1G	Ω
CSW (Contact capacitance)	20p	F

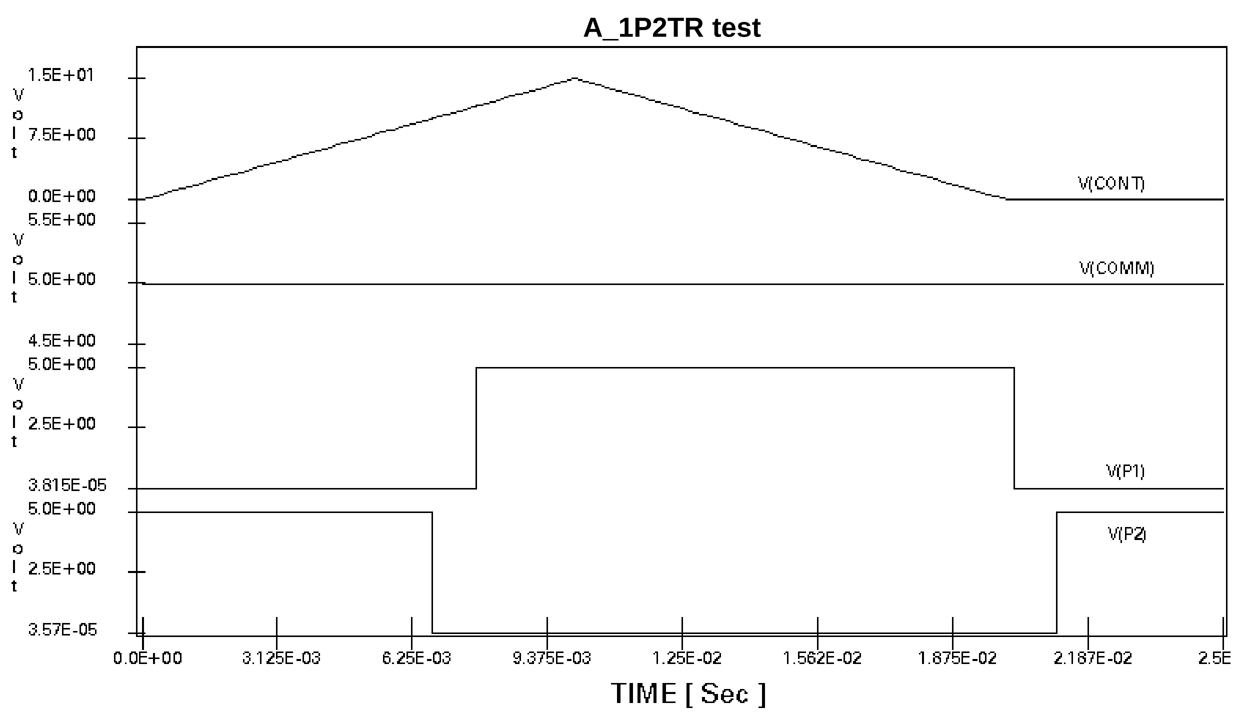
Design Notes

The resistance transitions are abrupt. Contact bouncing is not modelled.

Test Circuit



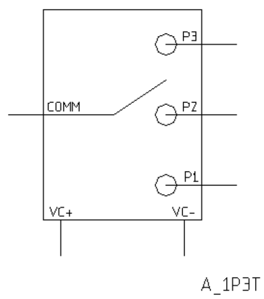
Test Results



A_1P3T (Switch, Single-pole, Triple-throw)

This component models a single pole switch with three throw positions.

Graphic Symbol



Modelled Parameters

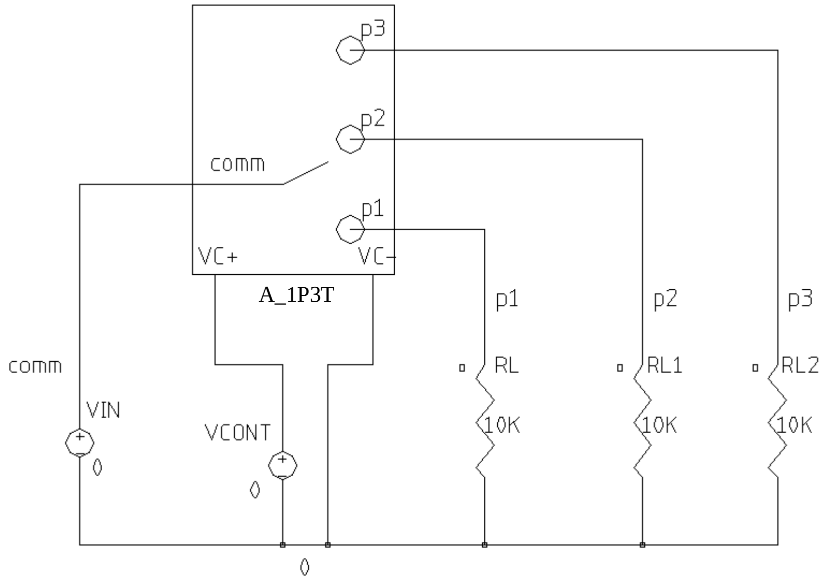
The following parameters can be modified.

Parameter	Default Value	Unit
MARG (Position voltage margin)	0.3	V
BDEL (Break delay)	0.1m	s
MDEL (Make delay)	0.2m	s
RON (Contact ON resistance)	10m	Ω
ROFF (Contact OFF resistance)	1G	Ω
CSW (Contact capacitance)	20p	F

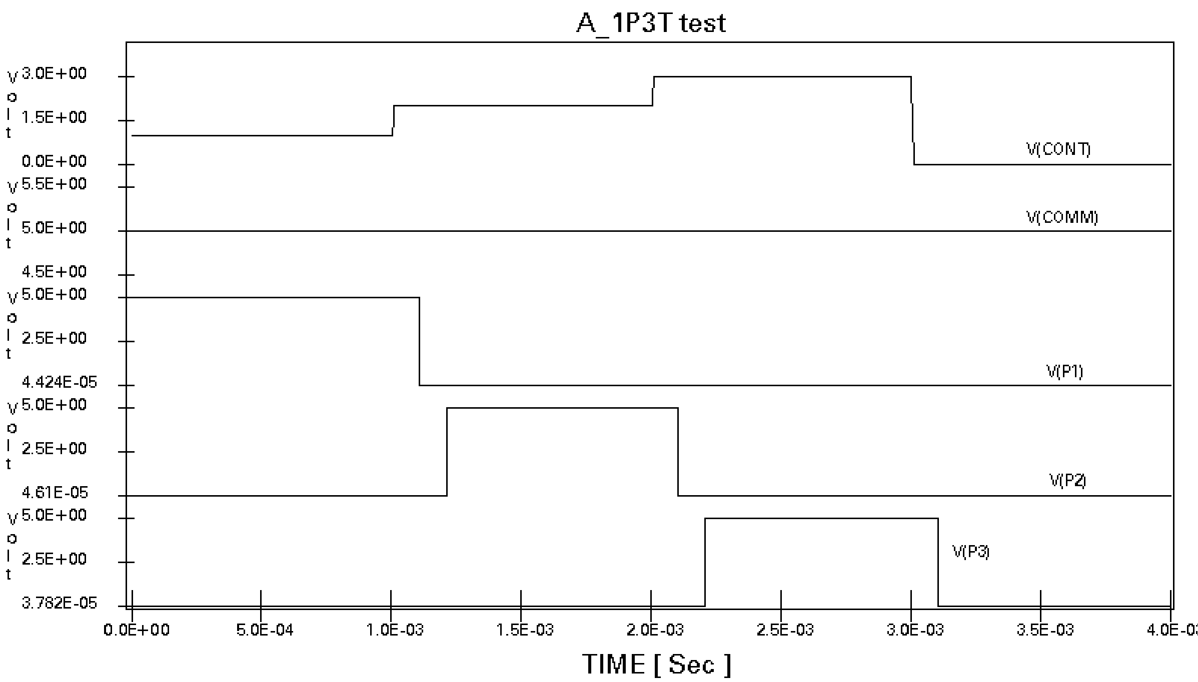
Design Notes

The switch position is selected by applying a voltage to the control input. A control voltage of 1V corresponds to the 1st position, a control voltage of 2 corresponds to the 2nd position, and a control voltage of 3V corresponds to 3rd position. If the control voltage falls outside the range of the needed position voltage plus or minus the margin (MARG), there is no connection at all. Make and break time delays can be set independently. The resistance transition is abrupt. The control voltage input resistance is 10G.

Test Circuit



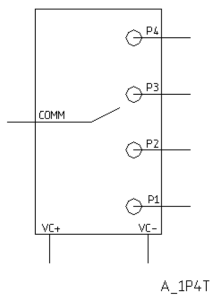
Test Results



A_1P4T (Switch, Single-pole, Four-throw)

This component models a single pole switch with four throw positions.

Graphic Symbol



Modelled Parameters

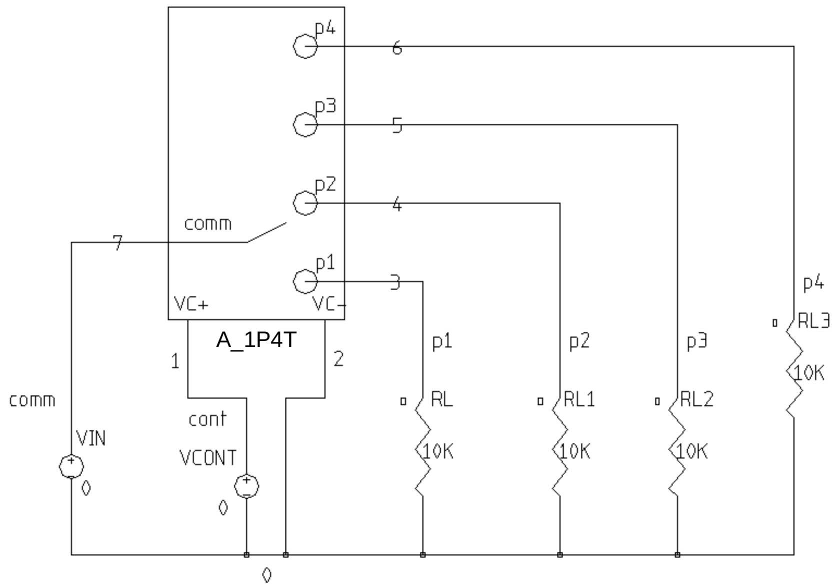
The following parameters can be modified.

Parameter	Default Value	Unit
MARG (Position voltage margin)	0.3	V
BDEL (Break delay)	0.1m	s
MDEL (Make delay)	0.2m	s
RON (Contact ON resistance)	10m	Ω
ROFF (Contact OFF resistance)	1G	Ω
CSW (Contact capacitance)	20p	F

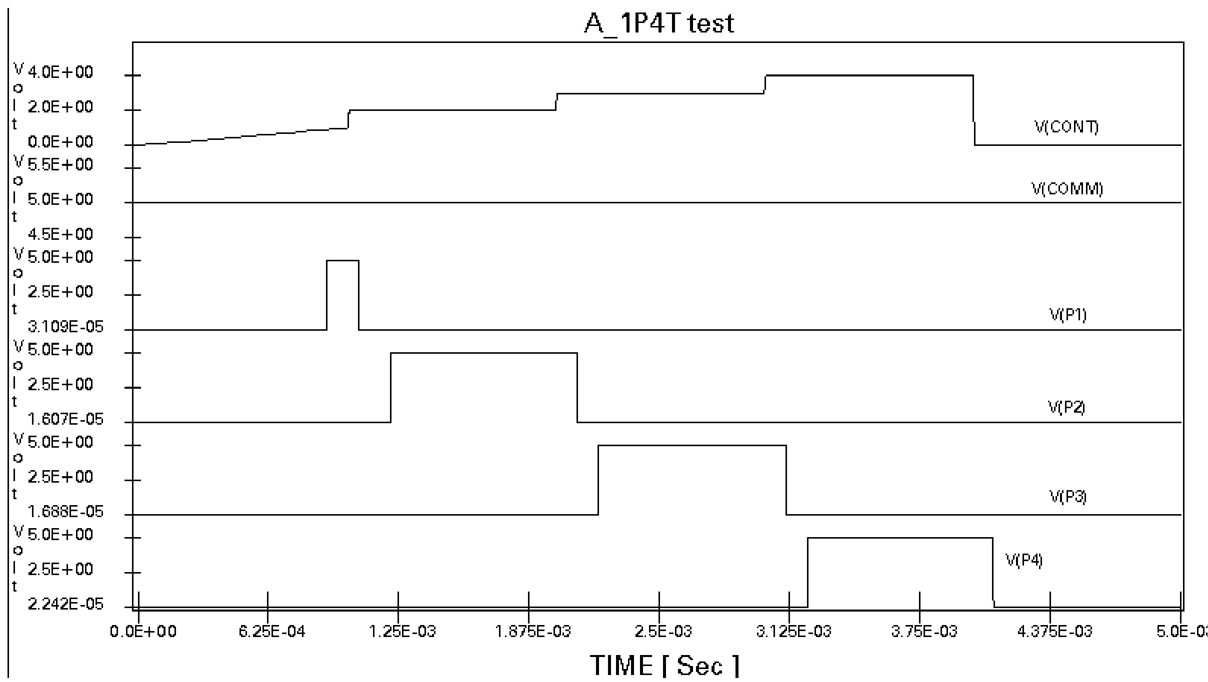
Design Notes

A switch position is selected by applying a voltage to the control input. A control voltage of 1V corresponds to the 1st position, a control voltage of 2V corresponds to the 2nd position, a control voltage of 3V corresponds to the 3rd position, etc. If the control voltage is outside the range of the needed position voltage plus or minus the margin (MARG), there is no connection at all. Make and break time delays can be set independentlly. The resistance transition is abrupt. The control voltage input resistance is 10G.

Test Circuit



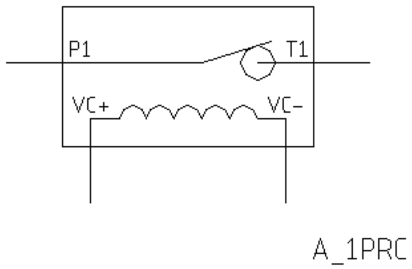
Test Results



A_1PRC (Relay, Single-pole, Normally Closed)

This component models a normally closed, single pole relay.

Graphic Symbol



Modelled Parameters

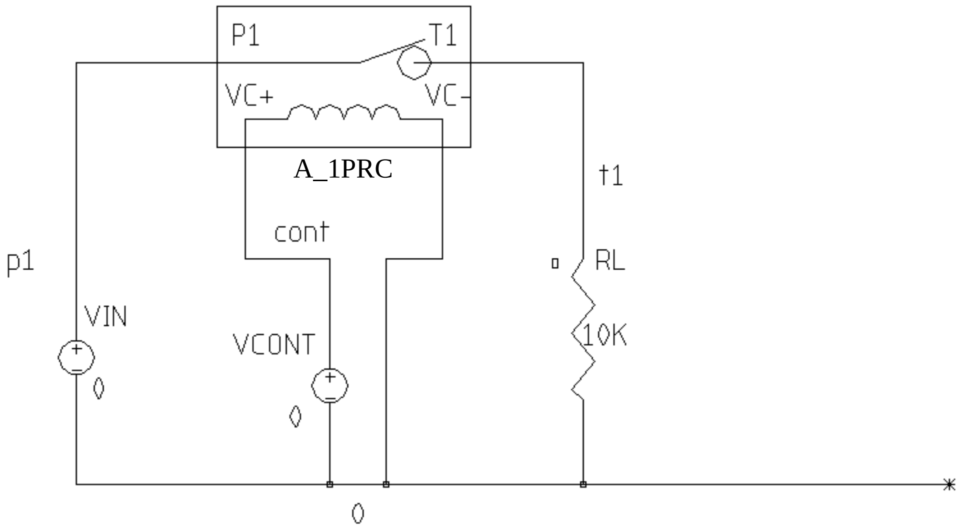
The following parameters can be modified.

Parameter	Default Value	Unit
L (Coil inductance)	0.1	H
C (Coil capacitance)	100p	F
R (Coil resistance)	120	Ω
EP (Pull-in voltage)	7.5	V
ED (Drop-out voltage)	2.5	V
BDEL (Break delay)	1m	s
MDEL (Make delay)	1m	s
RON (Contact ON resistance)	10m	Ω
ROFF (Contact OFF resistance)	1G	Ω
CSW (Contact capacitance)	20p	F

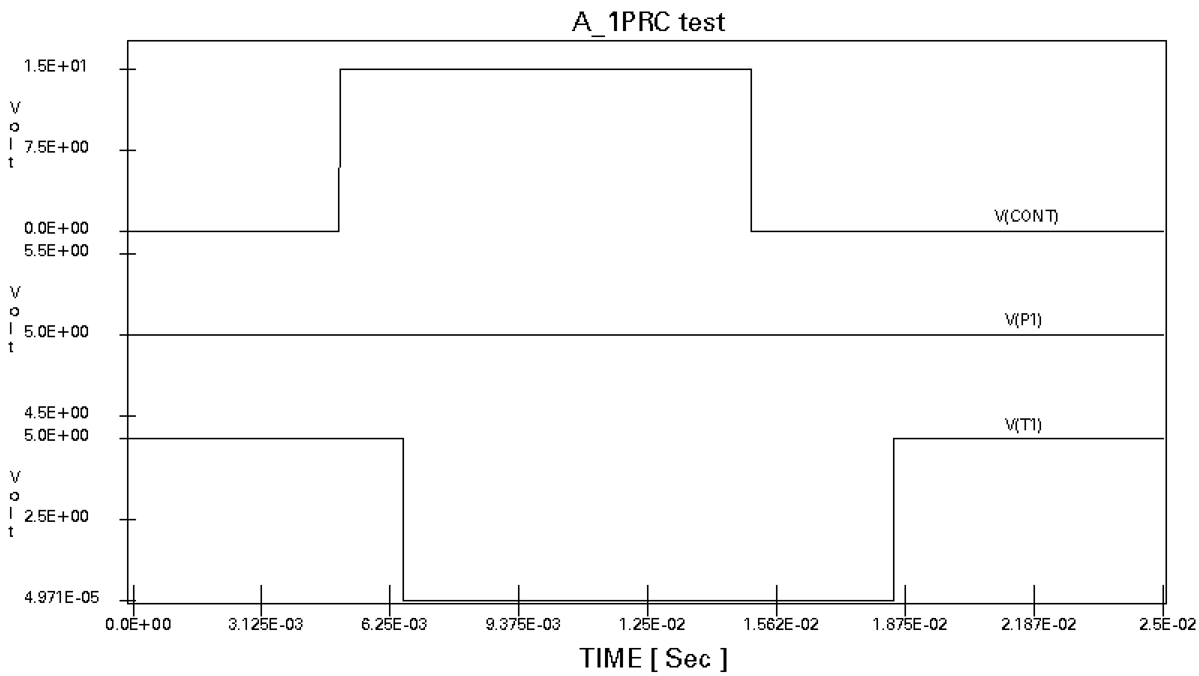
Design Notes

The resistance transitions are abrupt. Contact bouncing is not modelled.

Test Circuit



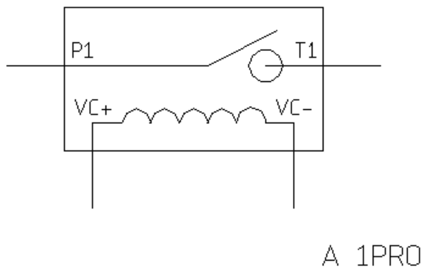
Test Results



A_1PRO (Relay, Single-pole, Normally Open)

This component models a normally open, single pole relay.

Graphic Symbol



Modelled Parameters

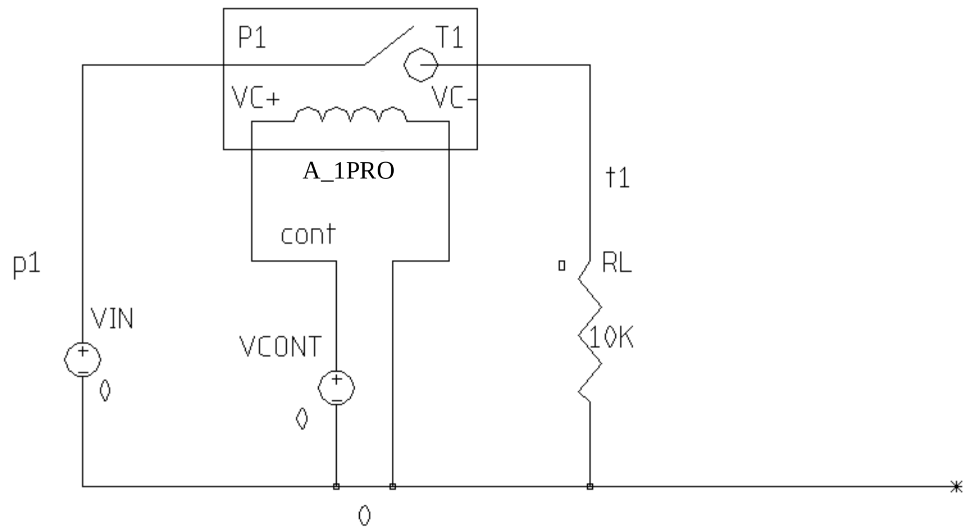
The following parameters can be modified.

Parameter	Default Value	Unit
L (Coil inductance)	0.1	H
C (Coil capacitance)	100p	F
R (Coil resistance)	120	Ω
EP (Pull-in voltage)	7.5	V
ED (Drop-out voltage)	2.5	V
BDEL (Break delay)	1m	s
MDEL (Make delay)	1m	s
RON (Contact ON resistance)	10m	Ω
ROFF (Contact OFF resistance)	1G	Ω
CSW (Contact capacitance)	20p	F

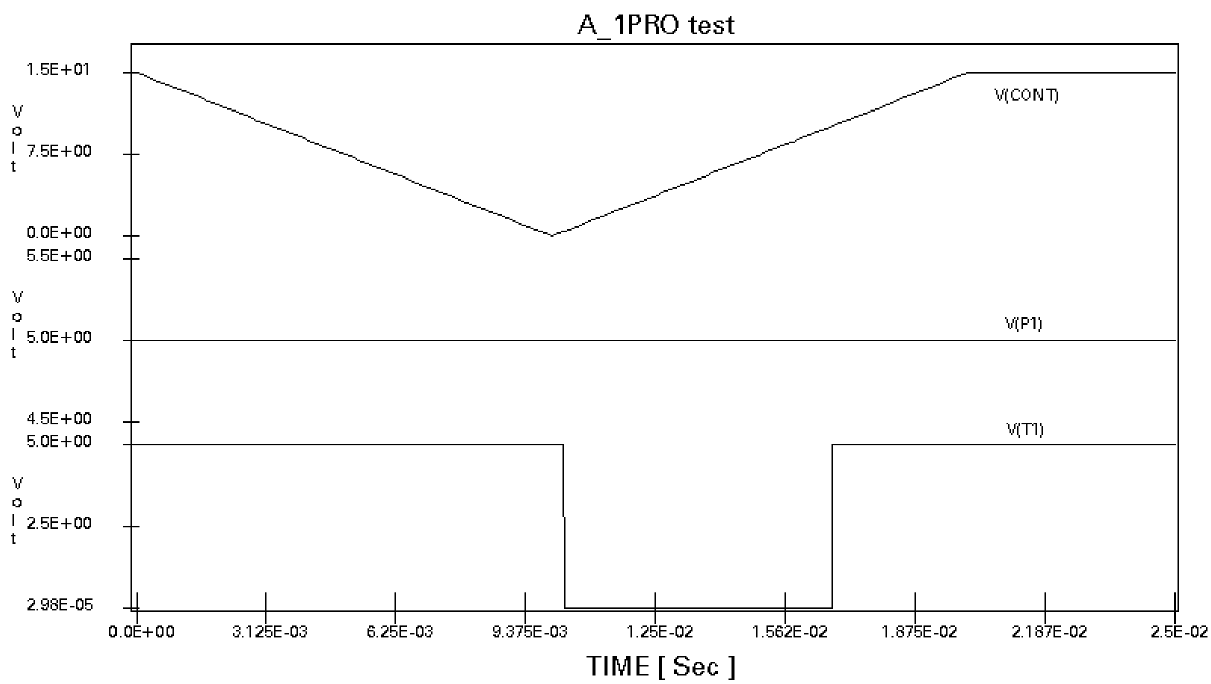
Design Notes

The resistance transitions are abrupt. Contact bouncing is not modelled.

Test Circuit



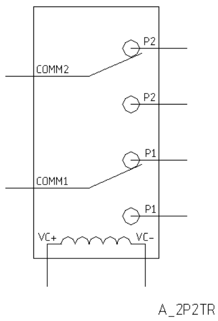
Test Results



A_2P2TR (Relay, Double-pole, Double-throw)

This component models a relay with two poles and two throw positions.

Graphic Symbol



Modelled Parameters

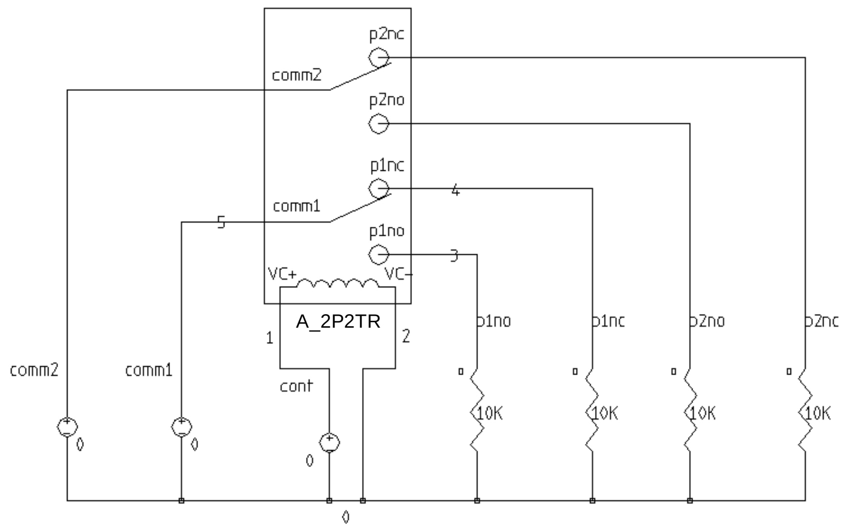
The following parameters can be modified.

Parameter	Default Value	Unit
L (Coil inductance)	0.1	H
C (Coil capacitance)	100p	F
R (Coil resistance)	120	Ω
EP (Pull-in voltage)	7.5	V
ED (Drop-out voltage)	2.5	V
BDEL (Break delay)	1m	s
MDEL (Make delay)	2m	s
RON (Contact ON resistance)	10m	Ω
ROFF (Contact OFF resistance)	1G	Ω
CSW (Contact capacitance)	20p	F

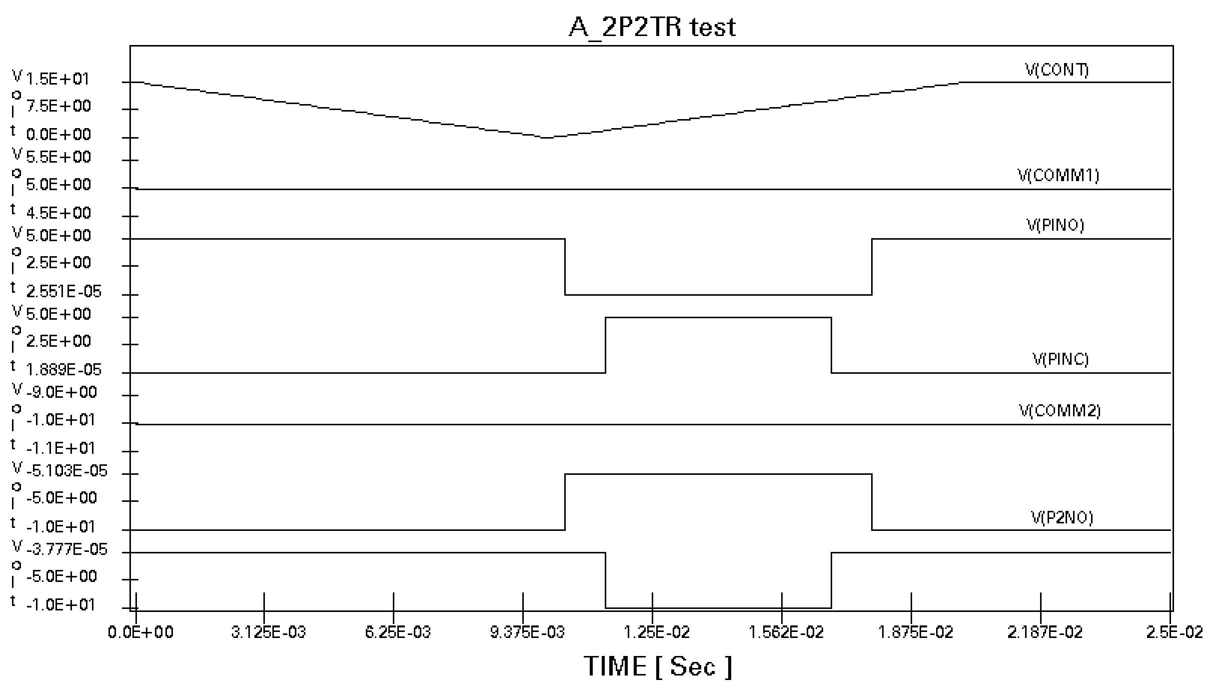
Design Notes

The resistance transitions are abrupt. Contact bouncing is not modelled.

Test Circuit



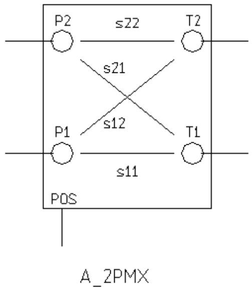
Test Results



A_2PMX (Switch, 2 Pole Matrix)

This component models a switch which has two poles with a multiple throw feature. The matrix feature allows different throw combinations to be used.

Graphic Symbol



Modelled Parameters

The following parameters can be modified.

Parameter	Default Value	Unit
RON (Contact ON resistance)	1m	Ω
ROFF (Contact OFF resistance)	1G	Ω
DEL1 (Break delay)	0.1m	s
DEL2 (Make delay)	0.2m	s
CSW (Contact capacitance)	1p	F

Design Notes

All throw positions have the same ON and OFF resistance values. The resistance transition is abrupt. Make and break time delays are the same for all throw combinations.

Programming the A_2PMX switch

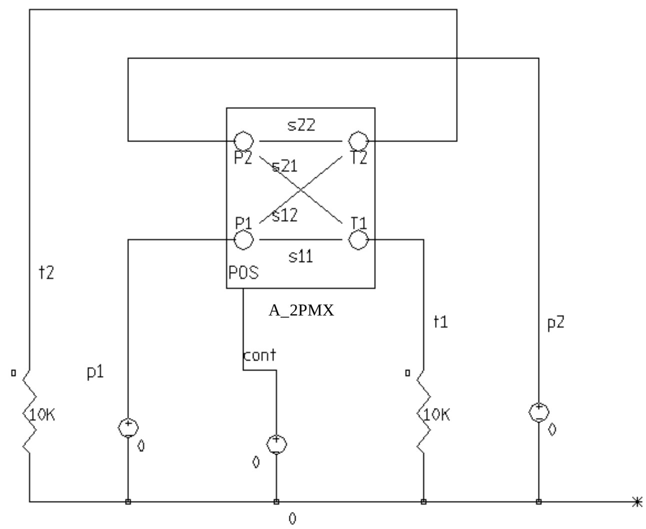
The possible throw connections for the A_2PMX switch are represented by the lines shown in the graphic symbol. The word matrix means that for each position, an individual switch (s11... s22) can be independently set *open* or *closed*. The maximum number of positions is unlimited. Programming is done by assigning a specific voltage to the pin marked *POS*. Since there are four independent switches, there are sixteen possible states of the matrix (assigned voltage values from 0 to 17, using the octal-base numbering system). Individual switches are set according to the general rule that the least significant position of the control voltage value controls switches s21, s12, and s11, and (the least significant position +1) controls switch s22.

You can determine which switches are closed and which are open by converting the position voltage value at pin *POS* from octal to its binary equivalent. For the *closed* state, assume binary number 1, and for the *open* state, assume binary number 0. For example:

Position voltage (octal)	**Binary Equivalent**	**Switch States**			
		s22	**s21**	**s12**	**s11**
11	1 0 0 1	1 (closed)	0 (open)	0 (open)	1 (closed)
13	1 0 1 1	1	0	1	1
06	0 1 1 0	0	1	1	0
05	0 1 0 1	0	1	0	1
00	0 0 0 0	0	0	0	0 (all open)
17	1 1 1 1	1	1	1	1 (all closed) etc.

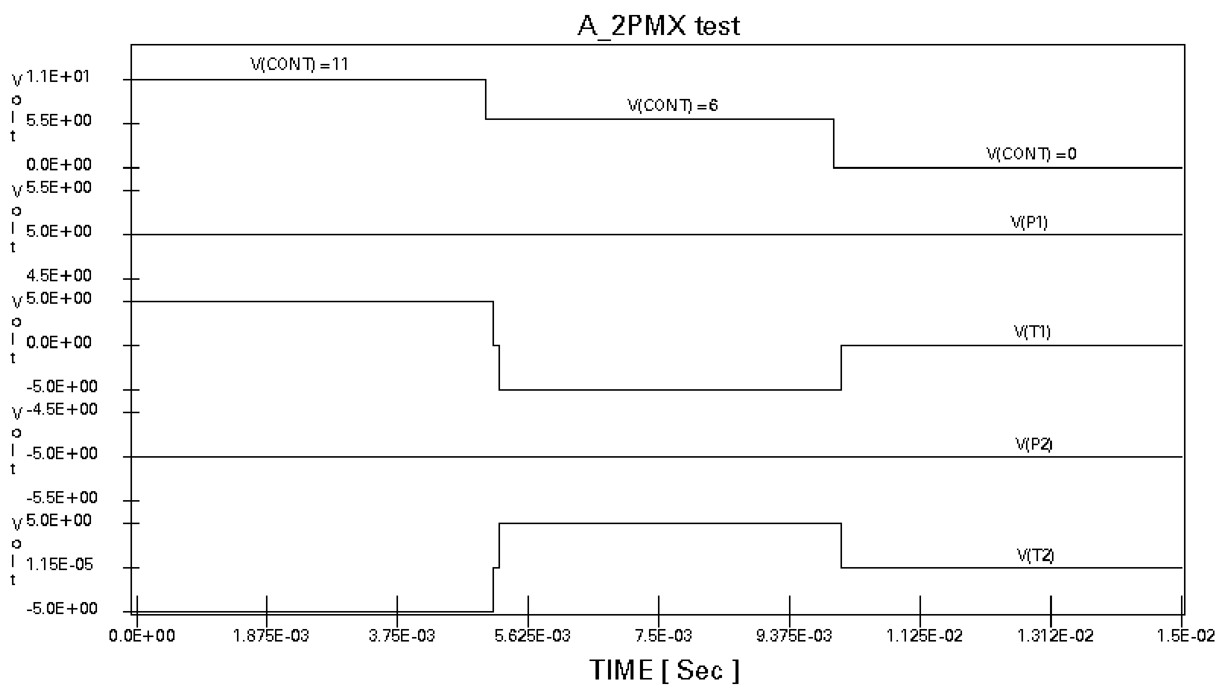
To ensure that the matrix is set to the selected states, the integer voltage at pin POS should be kept constant at least ten times longer than the DEL time value. The DEL time value is the delay of switch action related to the time point at which the POS voltage may be considered as a steady state value.

Test Circuit



Test Results

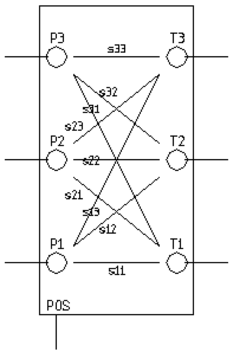
The switch response for the position sequence 11, 6, 0 is shown below. Some glitches may be seen due to recharging the switch capacitances.



A_3PMX (Switch, 3 Pole Matrix)

This component models a switch which has three poles with a multiple throw feature. The matrix feature allows different throw combinations to be used.

Graphic Symbol



A_3PMX

Modelled Parameters

The following parameters can be modified.

Parameter	Default Value	Unit
RON (Contact ON resistance)	10m	Ω
ROFF (Contact OFF resistance)	1G	Ω
DEL1 (Break delay)	0.1m	s
DEL2 (Make delay)	0.2m	s
CSW (Contact capacitance)	20p	F

Design Notes

All throw positions have the same ON and OFF resistance values. Make and break time delays are the same for all throw combinations. ON/OFF transition resistance is abrupt.

Programming the A_3PMX switch

The possible throw connections for the A_3PMX switch are represented by the lines shown in the graphic symbol. The word matrix means that for each position, an individual switch (s11... s33) can be independently set open or closed. The maximum number of positions is unlimited. Programming is done by assigning a specific voltage to the pin marked POS. Since there are nine independent switches, there are 512 possible states of the matrix (assigned voltage values from 0 to 777, using the octal-base numbering system). Individual switches are set according to the general rule that the least significant position of the control voltage value controls switches s13, s12 , s11, (the least significant position +1) controls switches s23, s22, and s21, and (the least significant position + 2) controls switches s33, s32, and s31.

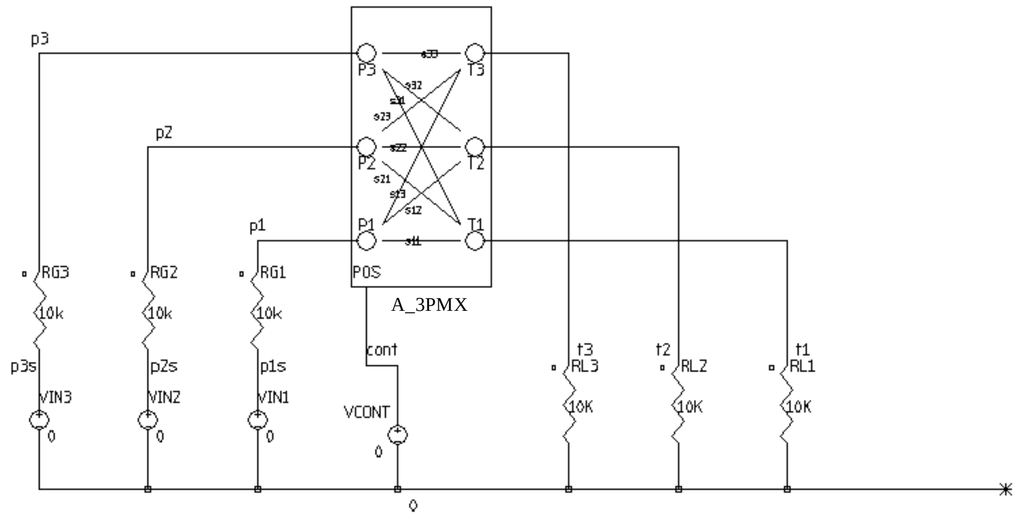
You can determine which switches are closed and which are open by converting the position voltage value at pin *POS* from octal to its binary equivalent. For the closed state, assume binary number 1, and for the open state, assume binary number 0. For example:

Position voltage (octal)	**Binary Equivalent**	**Switch States**								
		s33	**s32**	**s31**	**s23**	**s22**	**s21**	**s13**	**s12**	**s11**
111	001 001 001	0	0	1	0	0	1	0	0	1
222	010 010 010	0	1	0	0	1	0	0	1	0
475	100 111 101	1	0	0	1	1	1	1	0	1
000	000 000 000	0	0	0	0	0	0	0	0	0 (all open)
777	111 111 111	1	1	1	1	1	1	1	1	1 (all closed)

To ensure that the matrix is set to the selected states, the integer voltage at pin POS should be kept constant at least ten times longer than the DEL time value. The DEL time value is the delay of switch action related to the time point at which the POS voltage may be considered as a steady state value.

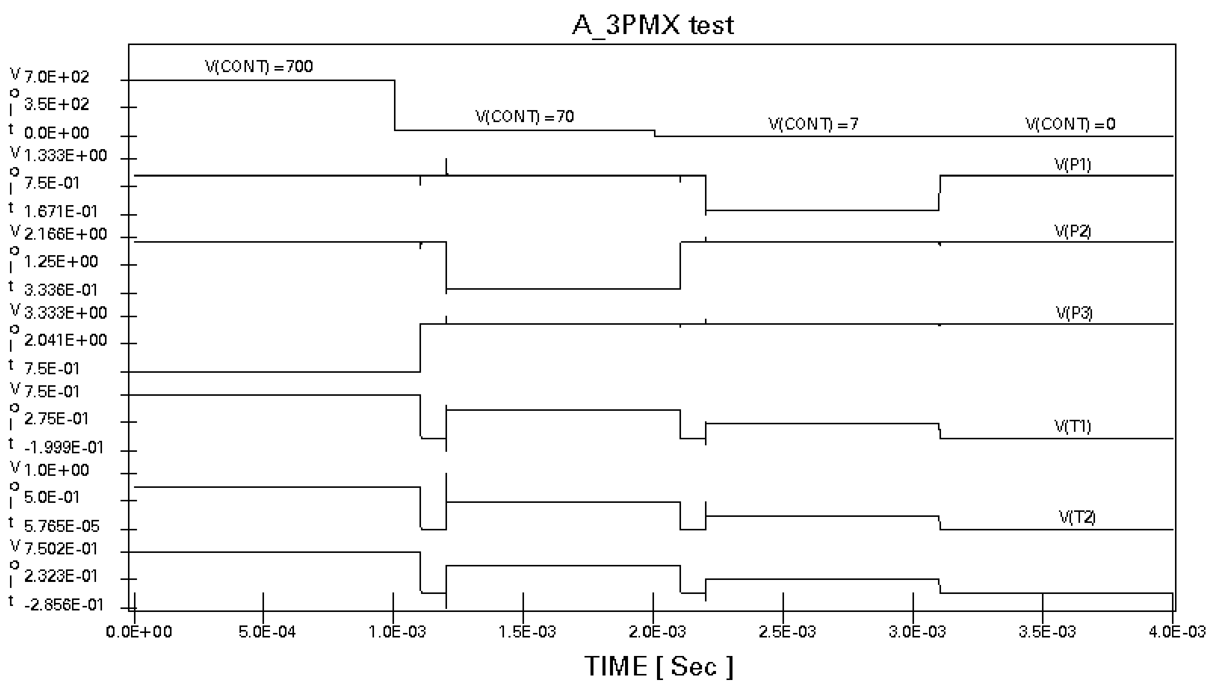
Note: Several position voltages are redundant resulting in the same physical connections. However, they may be used for connecting switches in parallel to carry high current loads.

Test Circuit



Test Results

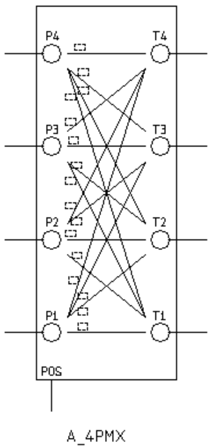
The switch response for the position sequence 700, 70, 7, 0 is shown below. Some glitches may be seen due to recharging the switch capacitances.



A_4PMX (Switch, 4 Pole Matrix)

This component models a switch which has four poles with a multiple throw feature. The matrix feature allows different throw combinations to be used.

Graphic Symbol



Modelled Parameters

The following parameters can be modified.

Parameter	Default Value	Unit
RON (Contact ON resistance)	10m	Ω
ROFF (Contact OFF resistance)	1G	
DEL1 (Break delay)	0.1m	s
DEL2 (Make delay)	0.2m	s
CSW (Contact capacitance)	20p	F

Design Notes

All throw positions have the same ON and OFF resistance values and make and break time delays. Make and break time delays are set independently. Make and break delays should not be less than 1usec and DEL2 should
be Š DEL1 (break before make). The ON/OFF transition resistance is abrupt.

Programming the A_4PMX switch

The posible throw connections for the A_3PMX switch are represented by the lines on the graphic symbol. The word matrix means that for each position, an individual switch (s11... s44) can be independently set open or closed. The maximum number of positions is limited only by system memory. Programming is done by assigning a specific voltage to the pin marked POS. Since there are sixteen independent switches, there are 65536 possible states of the matrix (assigned voltage values from 0 to 177777, using the octal-base numbering system). Individual switches are set according to the general rule that the least significant position of the control voltage value controls switches s13, s12 , and s11, (the least significant position +1) controls switches s22, s21, and s14, (the least significant position + 2) controls switches s31, s24, and s23, etc.

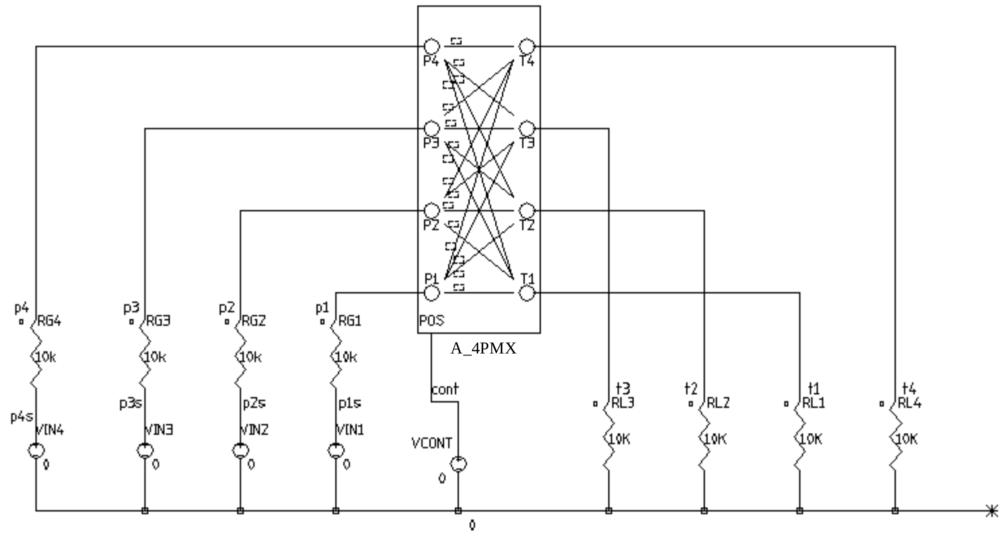
You can determine which switches are closed and which are open by converting the position voltage value at pin *POS* from octal to its binary equivalent. For the closed state, assume binary number 1, and for the open state, assume binary number 0. For example:

Position voltage (octal)	**Binary Equivalent**	**Switch States**															
		44	**43**	**42**	**41**	**34**	**33**	**32**	**31**	**24**	**23**	**22**	**21**	**14**	**13**	**12**	**11**
102041	1000010000100001	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1
012345	0001010011100101	0	0	0	1	0	1	0	0	1	1	1	0	0	1	0	1
130201	1011000010000001	1	0	1	1	0	0	0	0	1	0	0	0	0	0	0	1
000000	0000000000000000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
177777	1111111111111111	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

To ensure that the matrix is set to the selected states, the integer voltage at pin POS should be kept constant at least ten times longer than the DEL time value. The DEL time value is the delay of switch action related to the time point at which the POS voltage may be considered as a steady state value.

Note: Several position voltages are redundant resulting in the same physical connections. However, they may be used for connecting switches in parallel to carry high current loads.

Test Circuit



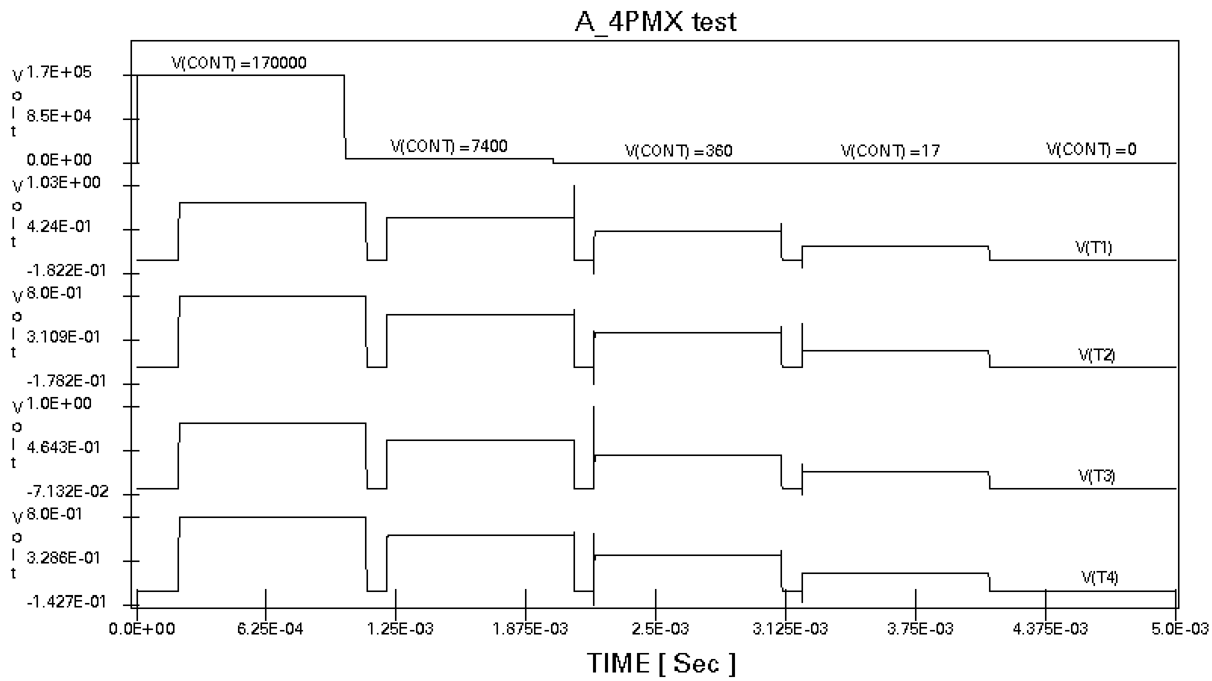
Test Results

Switch response for control voltage = 17 (Operating Point analysis)

Node name	Operating value	Unit
CONT	17.0	V
P3	2.99989	V
T3	200.067m	V
P4	3.99985	V
T4	200.067m	V
P4s	4.0	V
P1s	1.0	V
T1	200.067m	V
T2	200.067m	V
P2s	2.0	V
P3s	3.0	V

Node name	Operating value	Unit
P1	200.067m	V
P2	1.99993	V

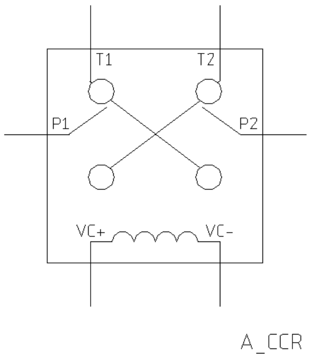
The switch response for the position sequence 17000, 7400, 360, 17, 0 is shown below. Some glitches may be seen due to recharging the switch capacitances.



A_CCR (Relay, Cross Strap)

This component models a relay where the state of the input can cause the two throw positions to exchange places.

Graphic Symbol



Modelled Parameters

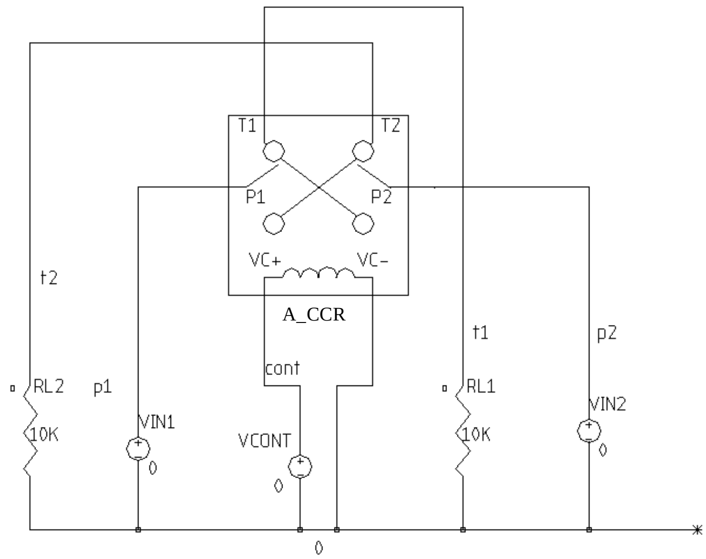
The following parameters can be modified.

Parameter	Default Value	Unit
L (Coil inductance)	0.1	H
C (Coil capacitance)	100p	F
R (Coil resistance)	120	Ω
EP (Pull-in voltage)	7.5	V
ED (Drop-out voltage)	2.5	V
BDEL (Break delay)	1m	s
MDEL (Make delay)	2m	s
RON (Contact ON resistance)	10m	Ω
ROFF (Contact OFF resistance)	1G	Ω
CSW (Contact capacitance)	20p	F

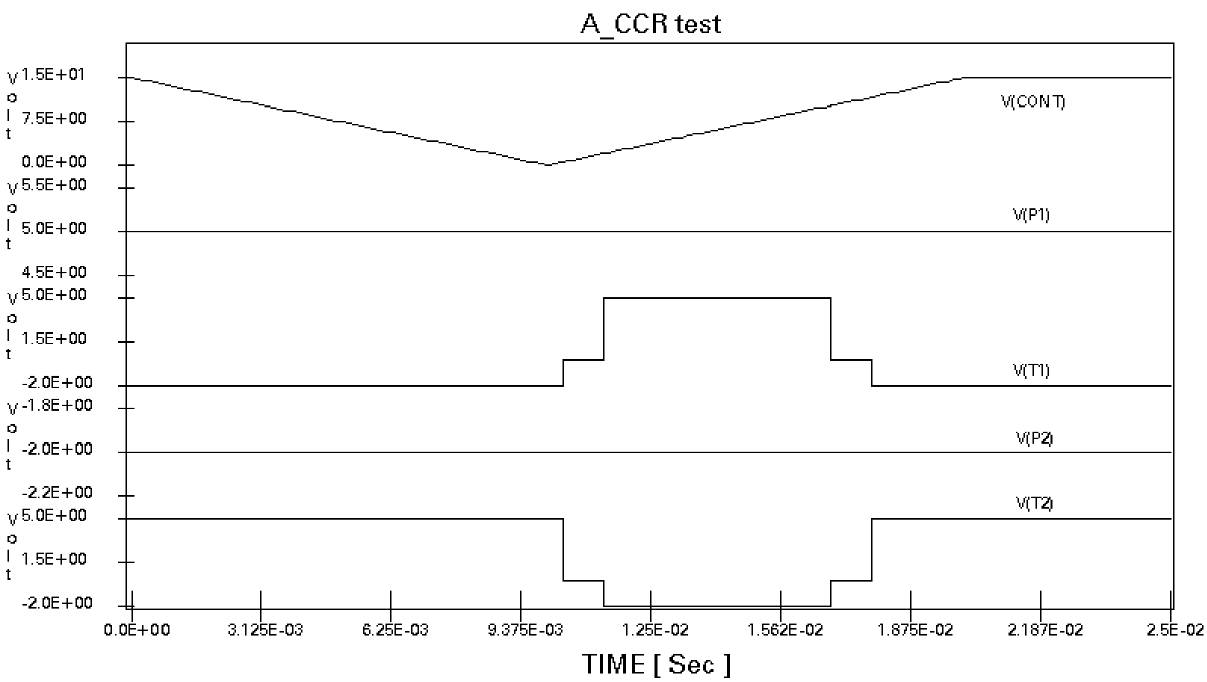
Design Notes

The resistance transitions are abrupt. Contact bouncing is not modelled.

Test Circuit



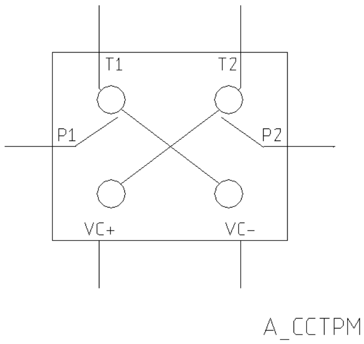
Test Results



A_CCTPM (Switch, 2 Pole, Cross-connection)

This component models a switch with two poles and two throw positions.

Graphic Symbol



Modelled Parameters

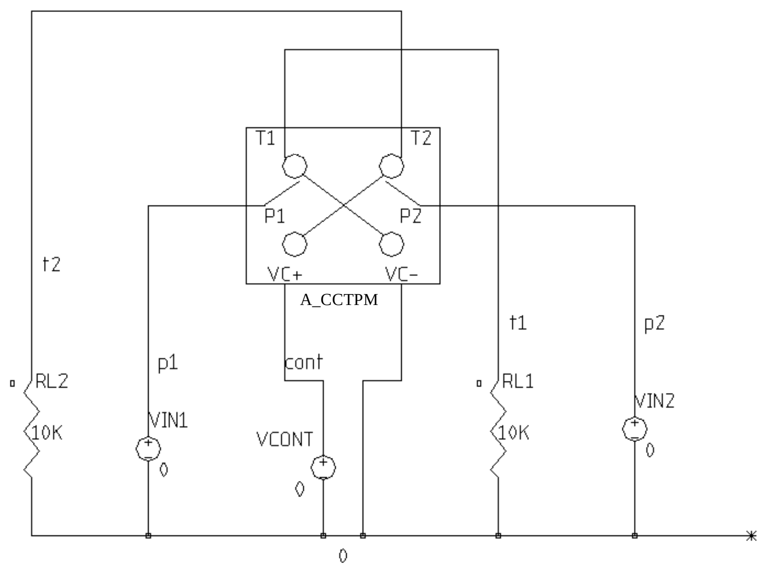
The following parameters can be modified.

Parameter	Default Value	Unit
MARG (Position voltage margin)	0.3	V
BDEL (Break delay)	0.1m	s
MDEL (Make delay)	0.2m	s
RON (Contact ON resistance)	10m	Ω
ROFF (Contact OFF resistance)	1G	Ω
CSW (Contact capacitance)	20p	F

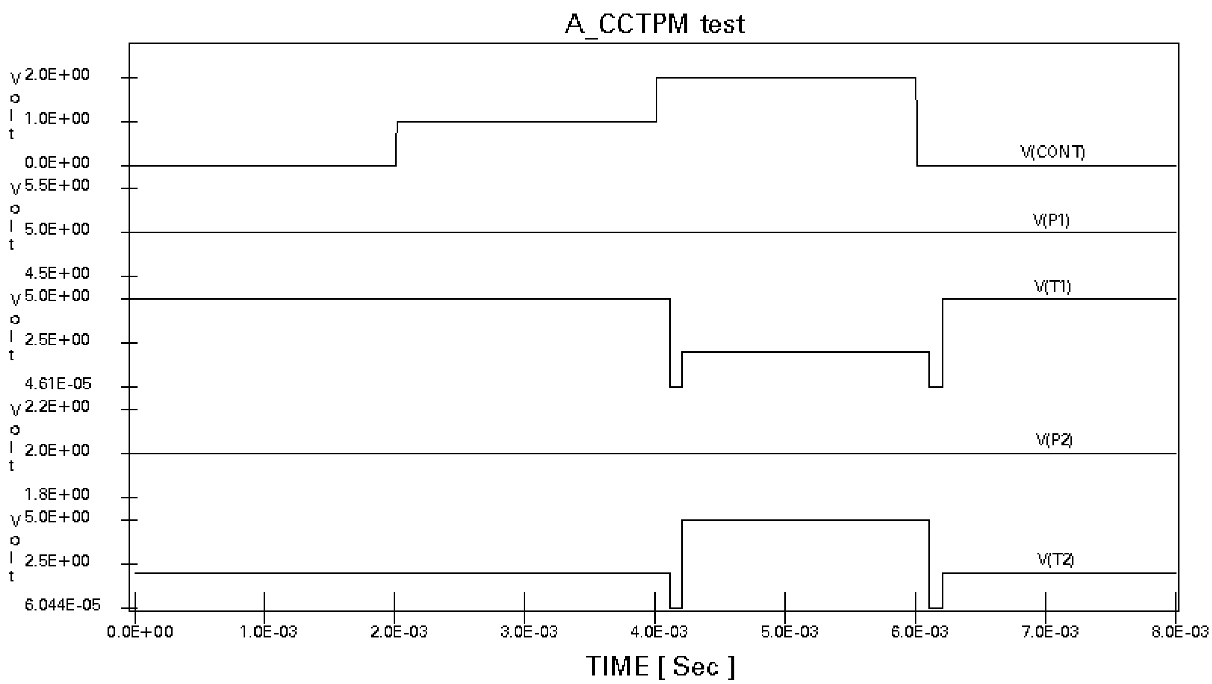
Design Notes

For a given position voltage, the switch positions are aligned (pole one to throw one and pole two to throw two). For a different position voltage, the connections are crossed. A switch position is selected by applying a voltage to the control input. A control voltage of 2V corresponds to the 2nd position. If the control voltage is outside the range of 2V plus or minus the margin (MARG), the switch is set to the 1st position. Make and break time delays can be set independently. The resistance transition is abrupt. The control voltage input resistance is 1G.

Test Circuit



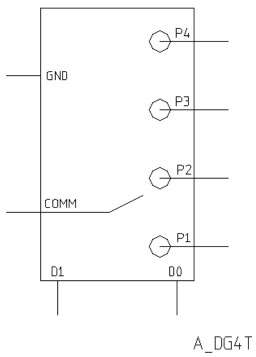
Test Results



A_ DG4T (Switch, 1 Pole, 4 Throw, Digital Control)

This component has a pair of digital inputs thus allowing for four throw positions.

Graphic Symbol



Modelled Parameters

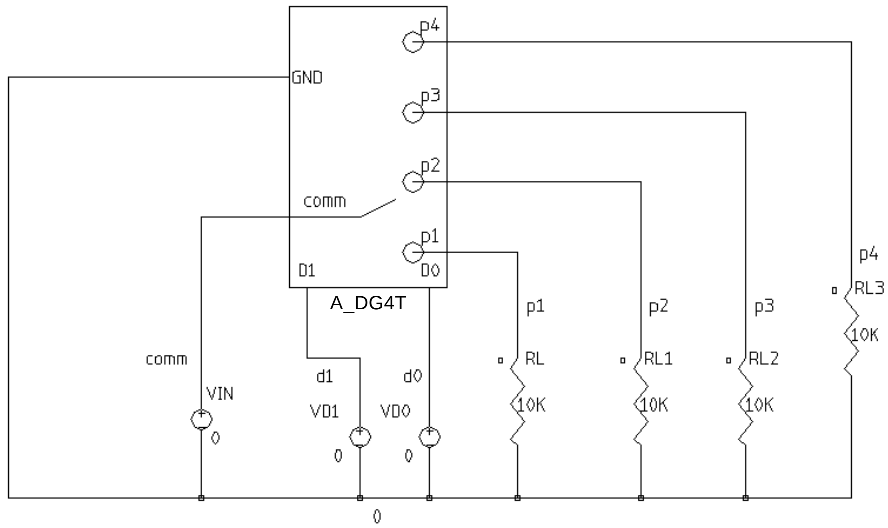
The following parameters can be modified.

Parameter	Default Value	Unit
RON (Contact ON resistance)	10m	Ω
ROFF (Contact OFF resistance)	1G	Ω
DEL1 (Break delay)	1m	s
DEL2 (Make delay)	2m	s
CSW (Contact capacitance)	10p	F

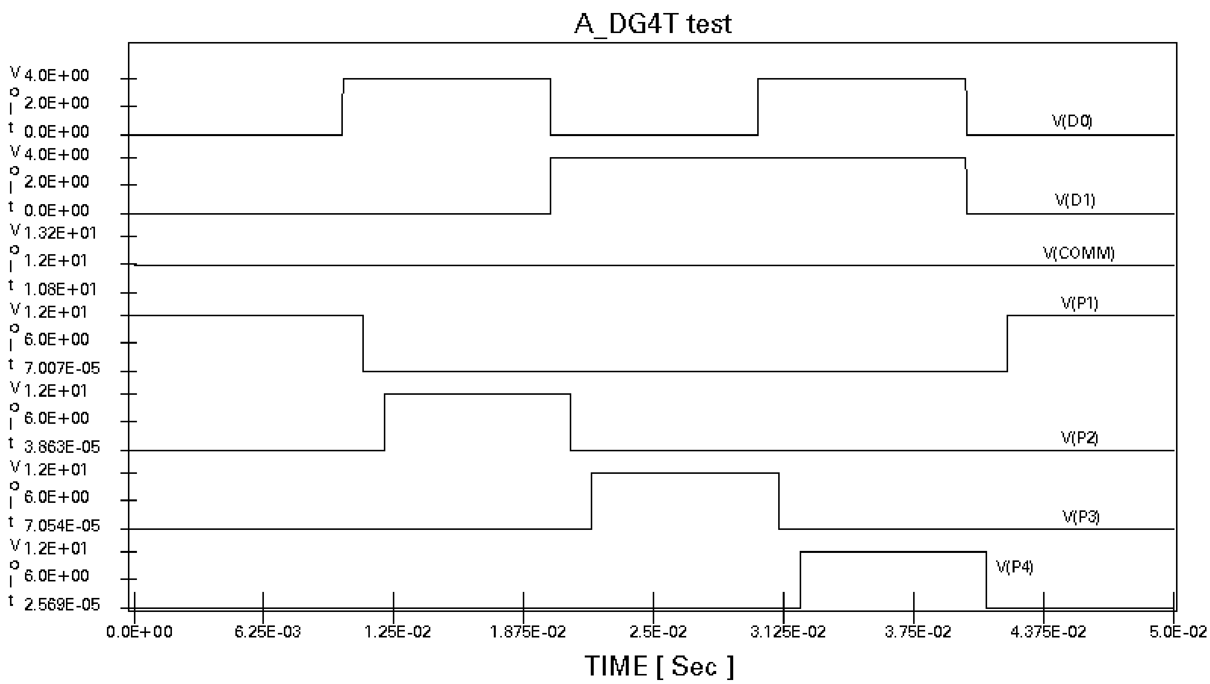
Design Notes

Digital inputs D0 and D1 have input impedances similar to a TTL gate.

Test Circuit



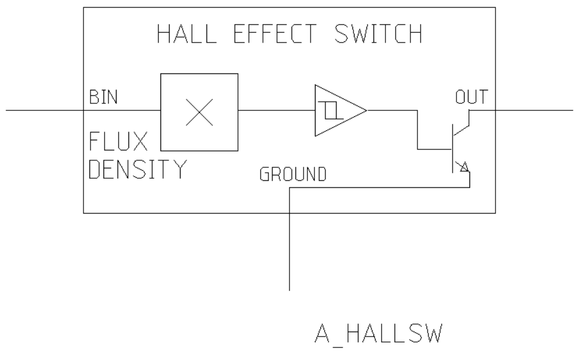
Test Results



A_HALLSW (Hall-effect Switch)

This macromodel, A_HALLSW, is a functional Hall-effect switch with built-in hysteresis.

Graphic Symbol



Modelled Parameters

The following parameters can be modified.

Parameter	Default Value	Unit
BON (Flux density to switch output high)	15m	T
BOFF (Flux density to switch output low)	-15m	T
ISAT (Max output sink current)	10m	A

Note: The flux density BIN is represented by the voltage on BIN input with conversion coefficient 1 V / T.

Unmodelled parameters

Temperature effects are unmodelled.

Design Notes

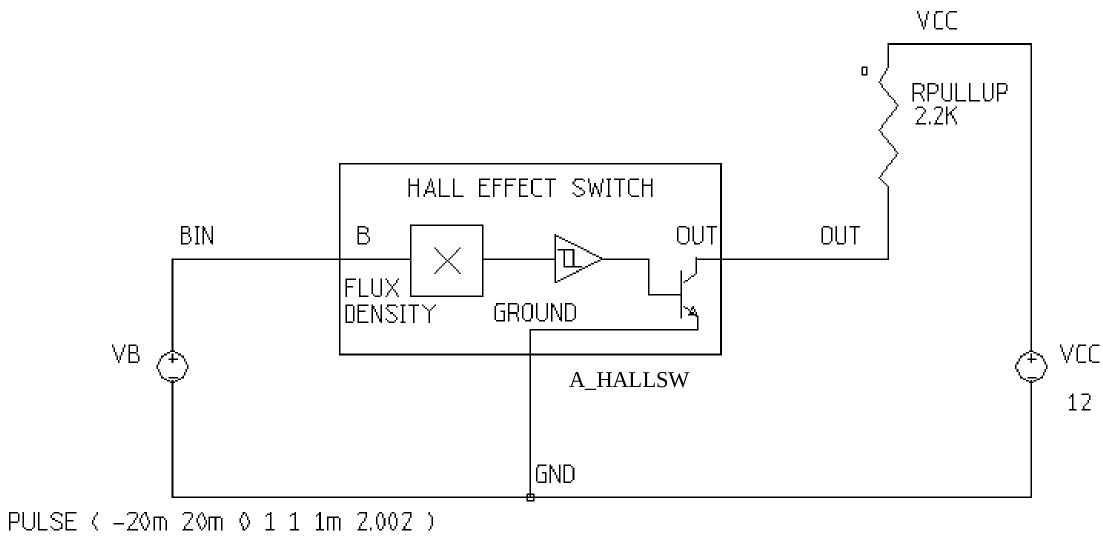
This model of a Hall-effect device with hysteresis uses an NPN transistor for the output. The parameter ISAT determines the maximum current that the transistor can sink when switched on.

The flux density, B, must be applied to the B terminal as a voltage, numerically equal to the required flux density.

It is advisable to start the model with the flux density input B set to a voltage either greater than the BON (flux density above which the switch is definitely on), or less than BOFF (flux density below which the switch is definitely off). This ensures that the flip-flop controlling the hysteresis starts in a known state.

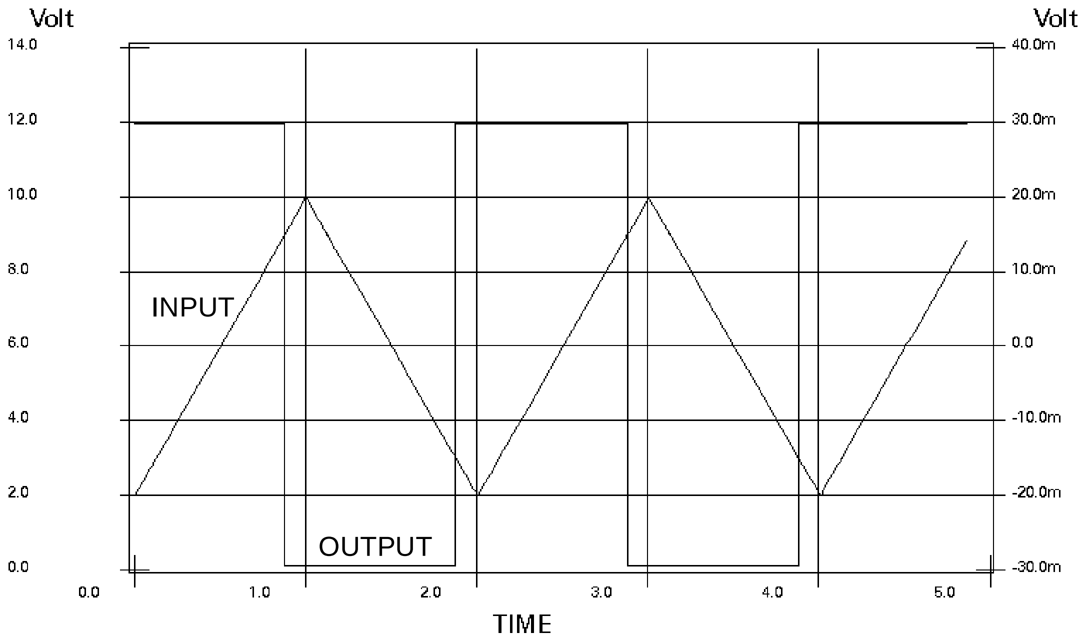
Test Circuit

The following circuit uses a voltage source (VB) to simulate an applied magnetic flux density. The parameters in the PARSET file for the model are set to the default values.



Test Results

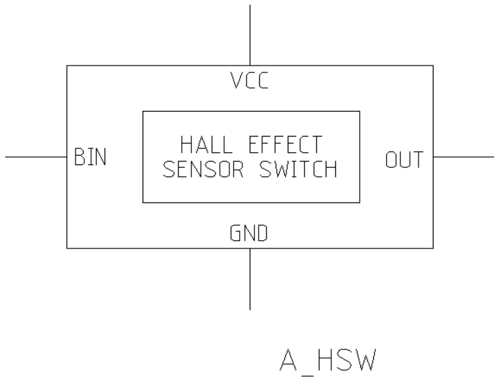
The following graph shows a time domain analysis with the flux density input changing from -20mT to +20mT (represented by a voltage changing from -20mV to 20mV) and back again as a triangle waveform.



A_HSW (Hall-effect Sensor Switch)

This component models a semiconductor switch that is controlled by magnetic flux density.

Graphic Symbol



Modelled Parameters

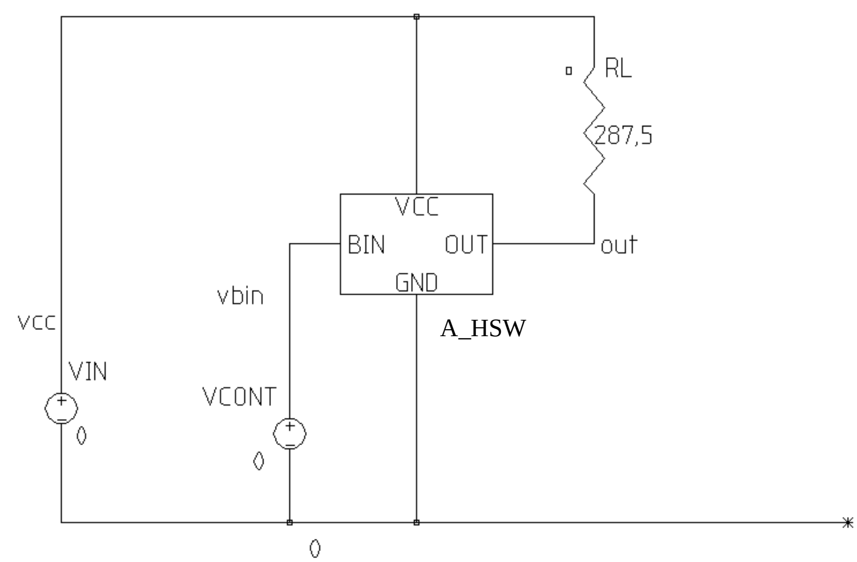
The following parameters can be modified.

Parameter	Default Value	Unit
BH (Positive magnetic flux density threshold level)	25m	T
BL (Negative magnetic flux density threshold level)	-25m	T
FMAX (Maximum switching frequency)	100k	Hz
ISINK (Maximum sink current)	16m	A
ILEAKH (OFF state leakage current)	0.1m	A
ISUP (Average supply current at VCC=VISUP)	5m	A
VISUP (Supply voltage)	5	V

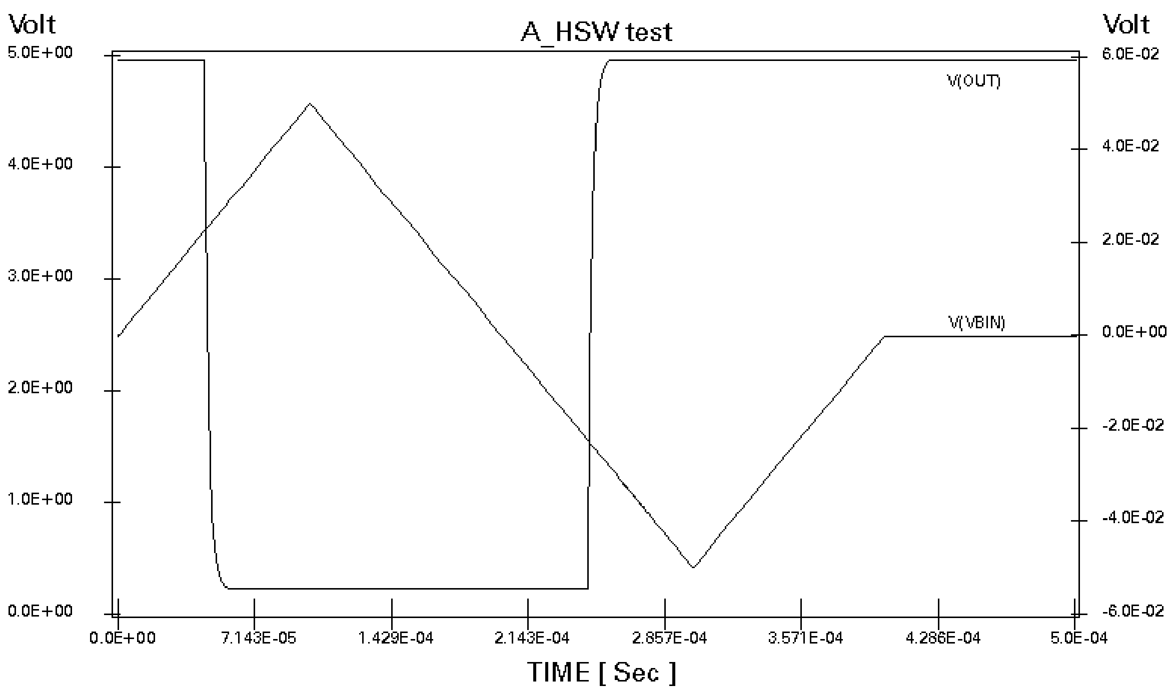
Design Notes

The magnetic flux density value is substituted with a voltage value of equal value that is applied to the control input. Maximum sink current is assumed to be less than 50mA for Vol_{max} less than 0.4V, where Vol_{max} is the maximum voltage for a digital logic low.

Test Circuit



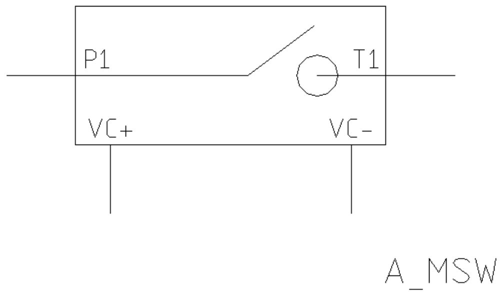
Test Results



A_MSW (Momentary Switch)

This component models a switch which is normally open but closes momentarily upon reaching a control voltage of 1V (> 0.9V) for a selected period of time.

Graphic Symbol



Modelled Parameter

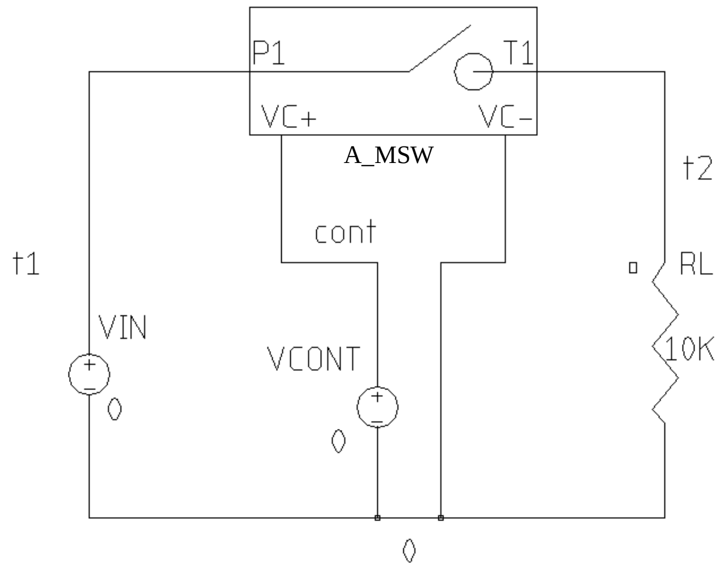
The following parameters can be modified.

Parameter	Default Value	Unit
RON (Contact ON resistance)	10m	Ω
ROFF (Contact OFF resistance)	1G	Ω
CSW (Contact capacitance)	10p	F
PW (Pulse width)	1	s

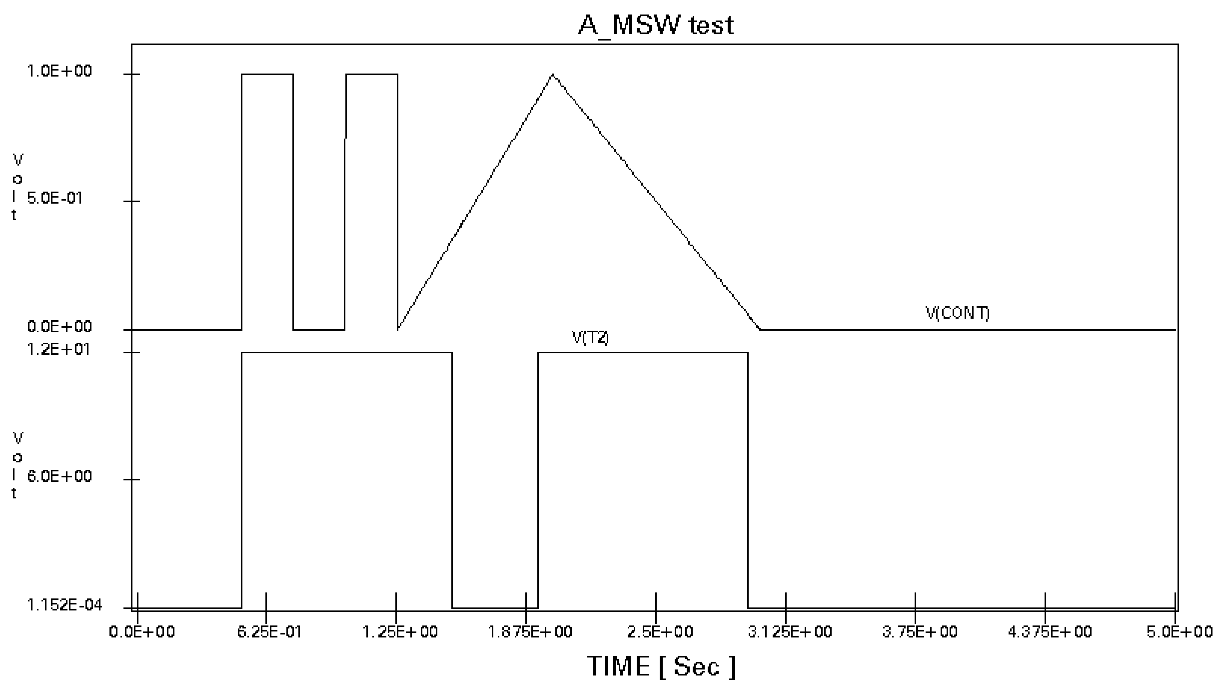
Design Notes

The device is not retriggerable. The close phase must be completed before the next trigger can be accepted.

Test Circuit



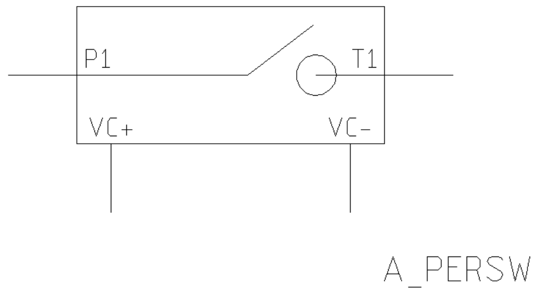
Test Results



A_PERSW (Periodic Switch)

This component models a switch whose ON/OFF position changes according to a specified duty cycle and frequency.

Graphic Symbol



Modelled Parameters

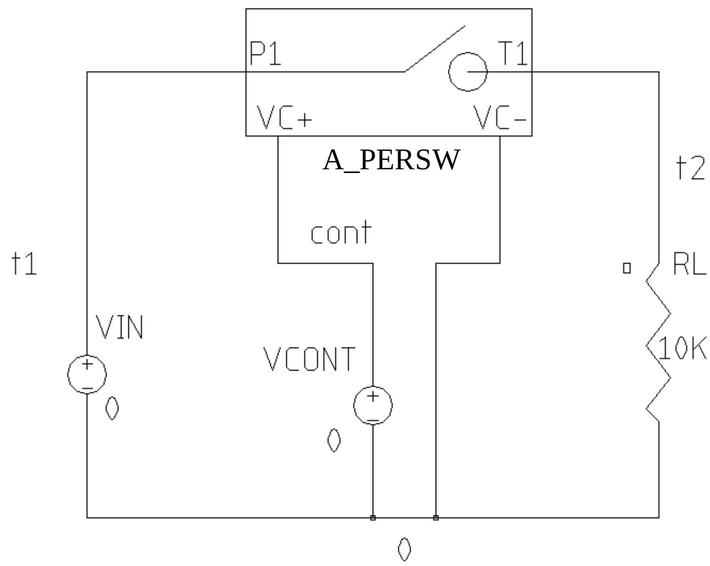
The following parameters can be modified.

Parameter	Default Value	Unit
RON (Contact ON resistance)	1m	Ω
ROFF (Contact OFF resistance)	1G	Ω
CSW (Contact capacitance)	0	F
FREQ (Switching frequency)	1	Hz
DUTY (Duty cycle)	0.5	–

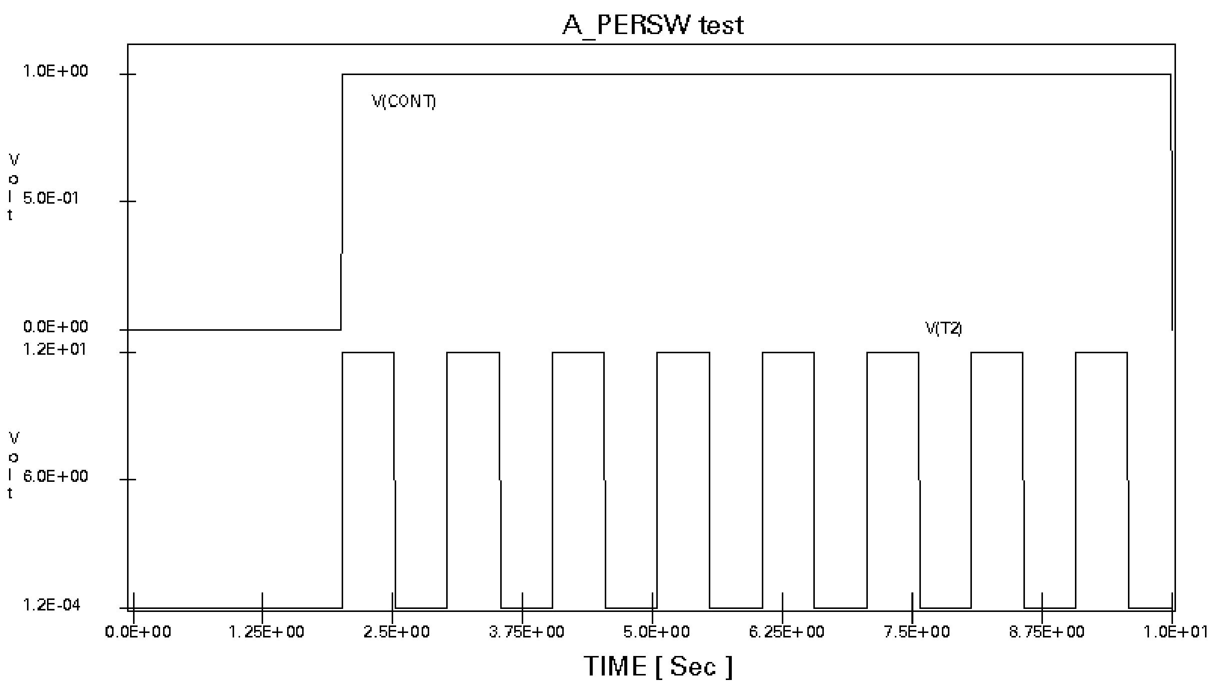
Design Notes

The duty cycle may be set within the range 0.1 - 0.9. The switch starts working if a control voltage of 1V (> 0.9V) is applied to the control input. The switch has built-in internal contact capacitance CSW_{in} = 0.1pF. The total switch capacitance is CSW + CSW_{in}.

Test Circuit



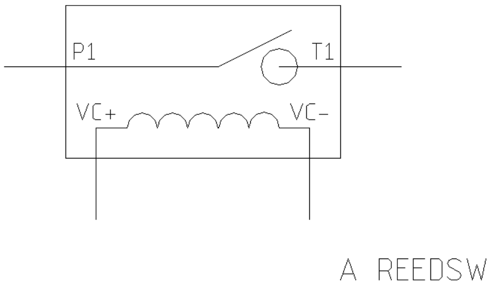
Test Results



A_REEDSW (Reed (relay) Switch)

This component models a normally open, single pole relay.

Graphic Symbol



Modelled Parameters

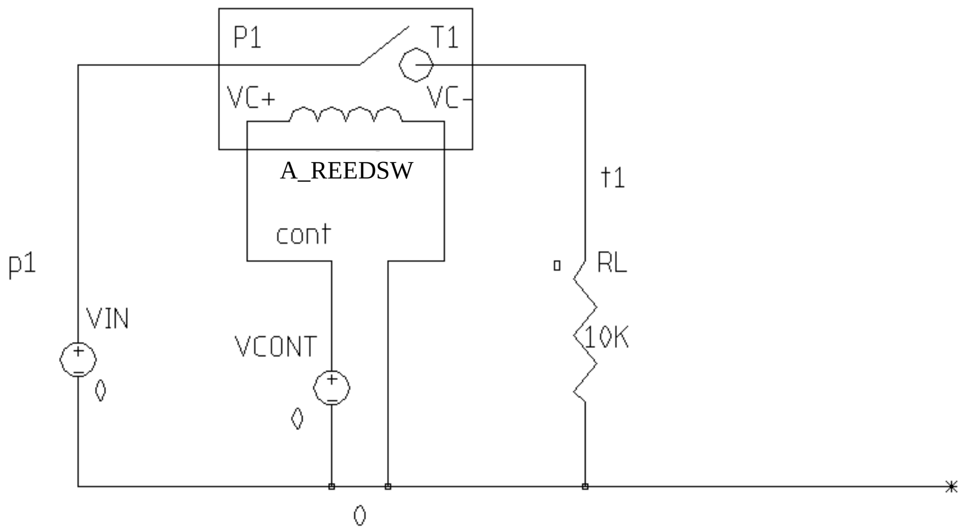
The following parameters can be modified.

Parameter	Default Value	Unit
L (Coil inductance)	0.1	H
C (Coil capacitance)	100p	F
R (Coil resistance)	120	Ω
EP (Pull-in voltage)	7.5	V
ED (Drop-out voltage)	2.5	V
BDEL (Break delay)	1m	s
MDEL (Make delay)	1m	s
RON (Contact ON resistance)	10m	Ω
ROFF (Contact OFF resistance)	1G	Ω
CSW (Contact capacitance)	20p	F

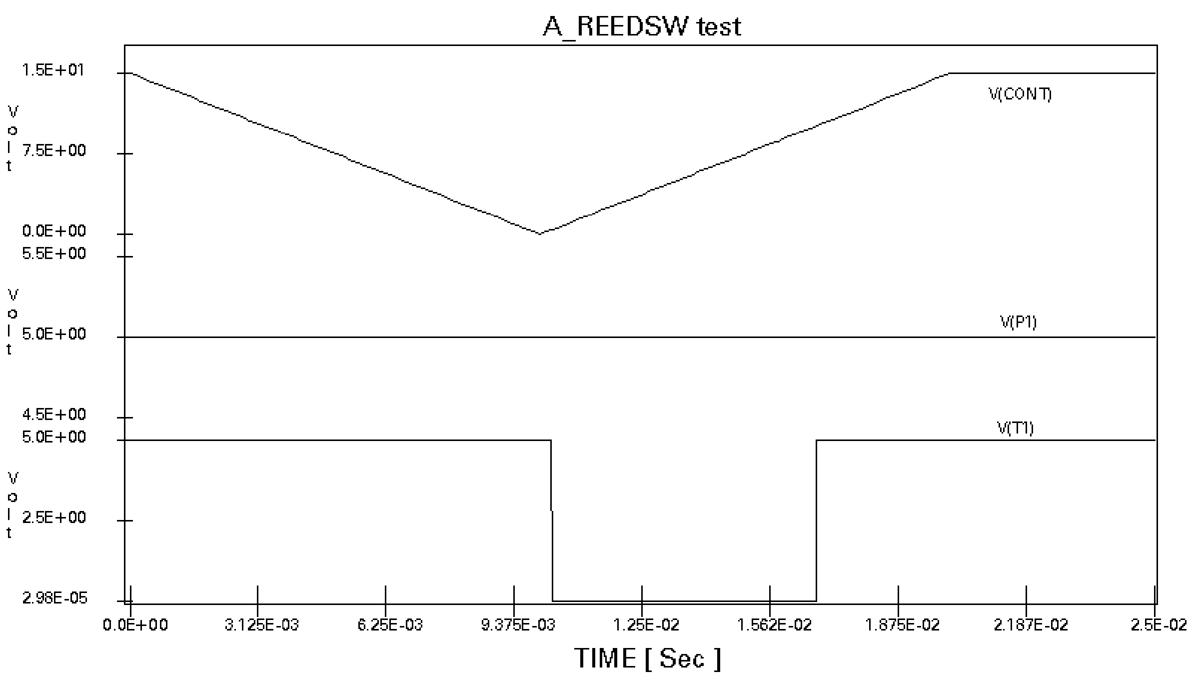
Design Notes

The resistance transitions are abrupt. Contact bouncing is not modelled.

Test Circuit



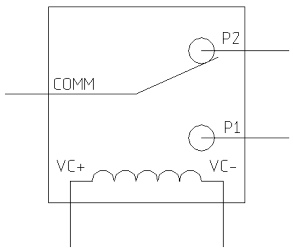
Test Results



A_REL1_2P (Automotive Relay)

This component models a relay with one pole and two throw positions.

Graphic Symbol



A_REL1_2P

Modelled Parameters

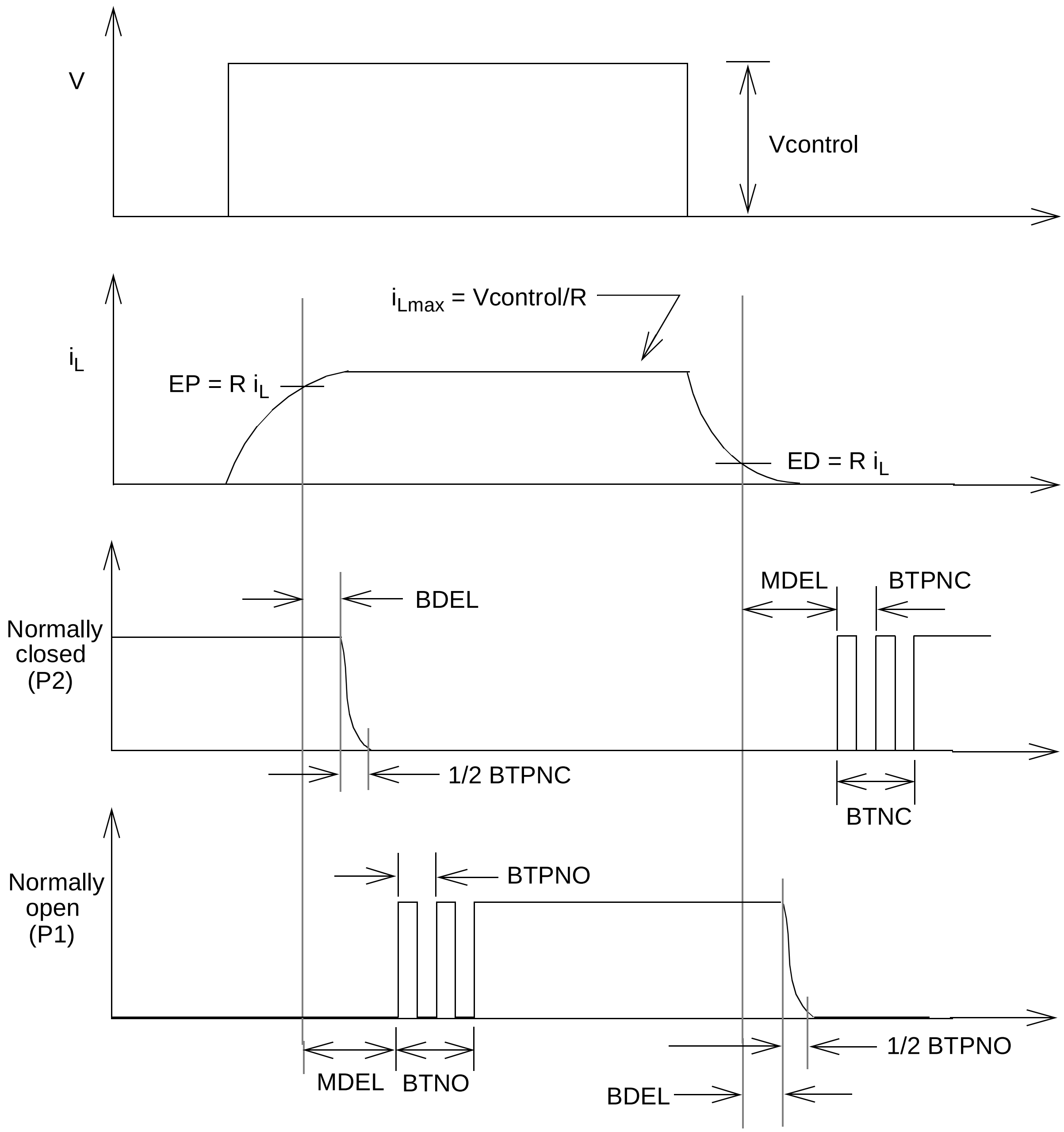
The following parameters can be modified.

Parameter	Default Value	Unit
L (coil inductance)	0.1	H
C (coil capacitance)	100p	F
R (coil resistance)	120	Ω
EP (pull-in voltage)	7.5	V
ED (drop-out voltage)	2.5	V
BDEL (break delay)	1m	s
MDEL (make delay)	2m	s
RMIN (minimum contact ON resistance)	10m	Ω
CSW (contact capacitance)	10p	F
BTNO (bouncing time for normally open contact)	1m	s
BTNC (bouncing time for normally closed contact)	2m	s

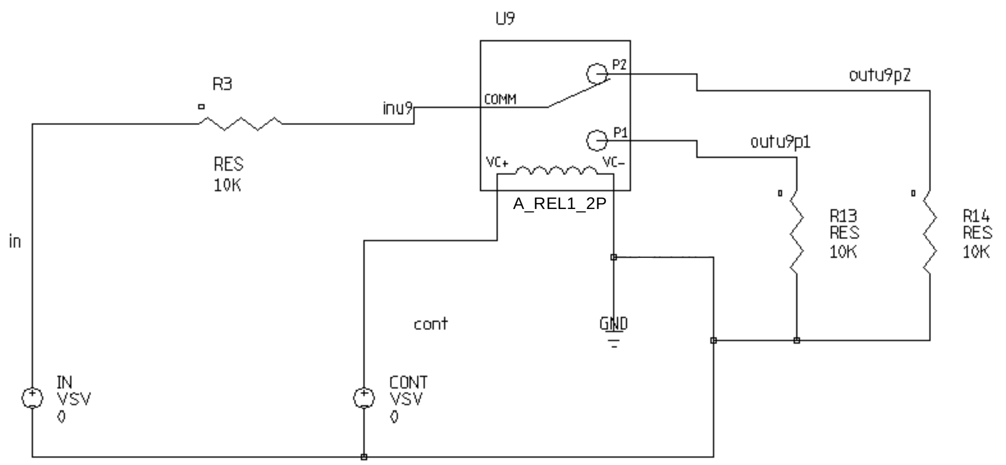
Parameter	Default Value	Unit
BTPNO (period of bouncing for normally open contact)	0.25m	s
BTPNC (period of bouncing for normally closed contact)	0.5m	s

Design Notes

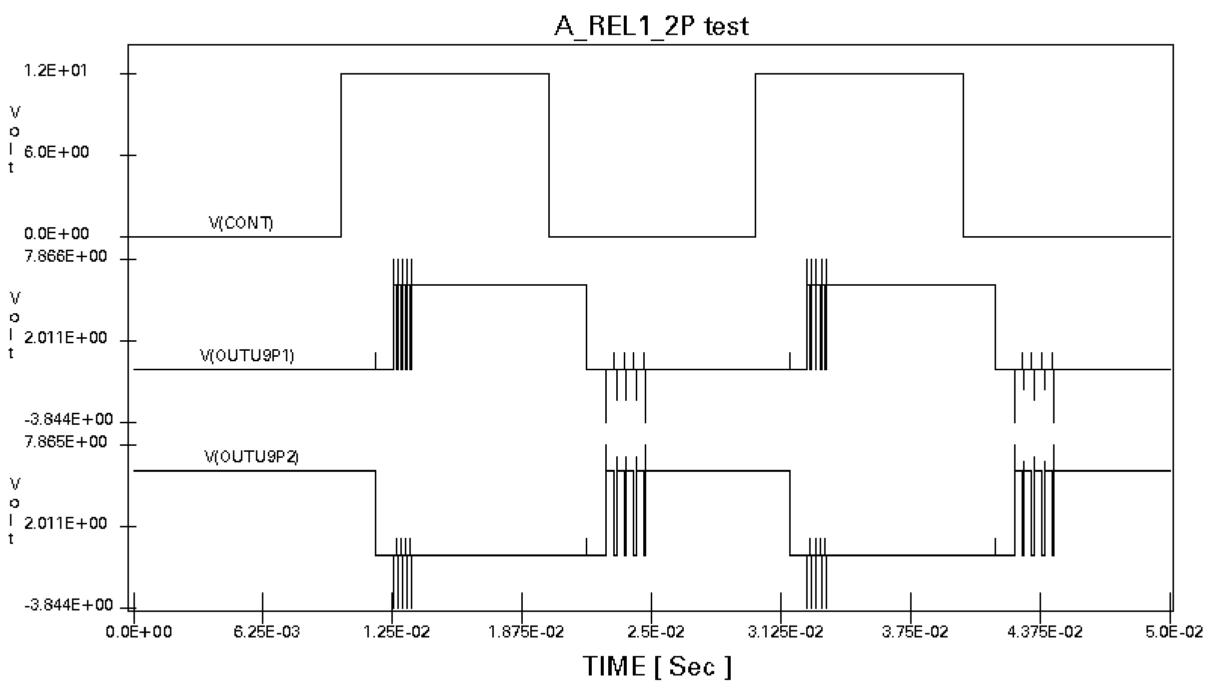
The contact resistance transition is nonlinear and continuous. The Rmax/Rmin ratio is not greater than 10E+10. Contact bouncing effect is functionally modelled; bouncing frequency and amplitude are constant during switching. For timing, refer to the figure below.



Test Circuit



Test Results



Chapter 6
Miscellaneous Models

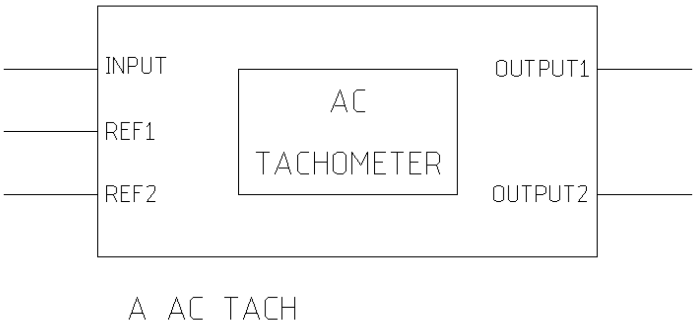
The following models are described in this chapter.

Model Name	Description
A_AC_TACH	Tachometer, AC
A_BLKBODY	Radiator, black-body
A_COND	Condensor, automotive
A_DC_M30	Motor, DC type M30
A_DC_MA	Motor, armature controlled
A_DC_MF	Motor, field controlled
A_DC_TACH	Tachometer, DC
A_MAGPICK	Magnetic pickup
A_MLOAD	Mechanical load
A_TCAP	Capacitor, thermal
A_THERMRC	Resistor with thermal connection
A_TRES	Resistor, thermal

A_AC_TACH (AC Tachometer)

This component models the behavior of an AC tachometer. An AC voltage is applied to the primary winding and the output voltage is taken from a secondary winding. The output voltage magnitude is proportional to the speed of the rotating shaft and the magnitude of the input voltage. The direction of shaft rotation is reflected in the phase of the output voltage.

Graphic Symbol



Modelled Parameters

The following parameters can be modified.

Parameter	Default Value
SCALE (Scale factor)	1

Design Notes

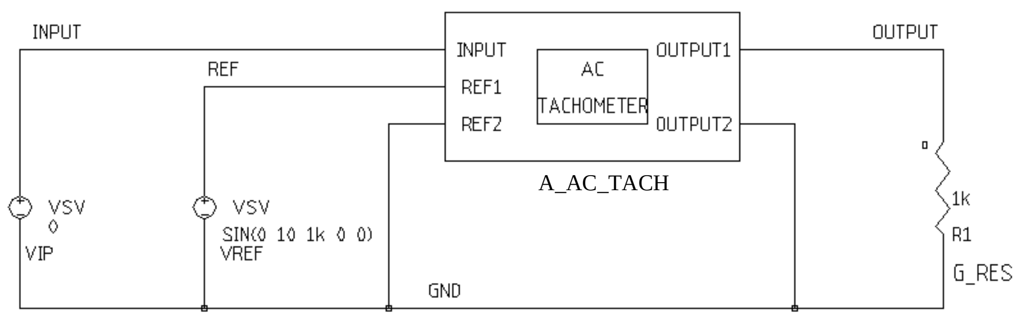
The AC tachometer is designed to be used as described below.

- The terminal INPUT is configured to accept an input voltage representing rotational speed. If used directly with the motor blocks provided in the automotive library, the rotational speed is represented by 1V / rad s^{-1}.
- An AC waveform should be applied to the terminals REF1 and REF2. The output on terminals OUTPUT1 and OUTPUT2 has the same shape as the input waveform, but with magnitude determined by the rotational speed and phase determined by direction of rotation.
- The parameter SCALE in the PARSET file allows the relationship between shaft speed and input and output voltages to be determined. The relationship is:

$$V_{out} = V_{ref} \times V_{input} \times SCALE$$

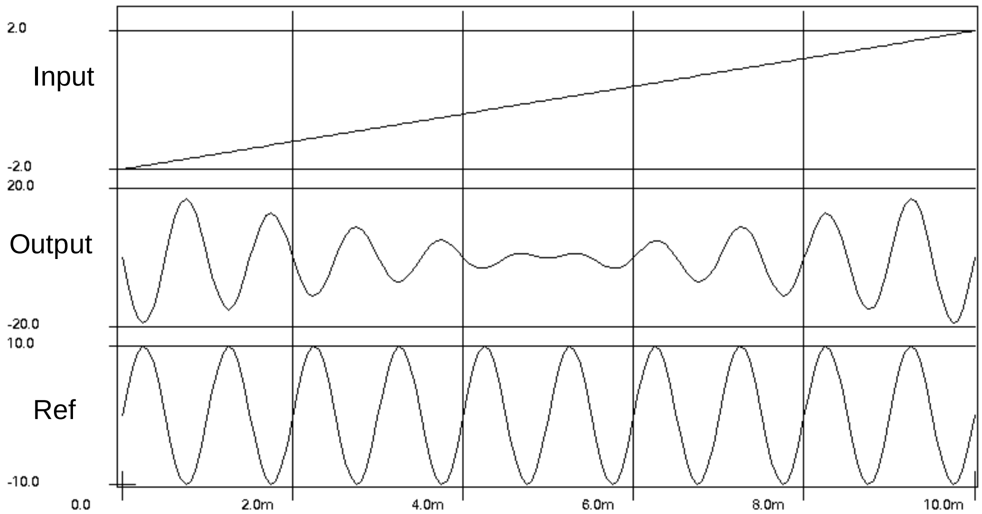
Test Circuit

The circuit shown below was used to produce the example waveforms. The input voltage was swept from -2V to +2V over 10ms.



Example Waveforms

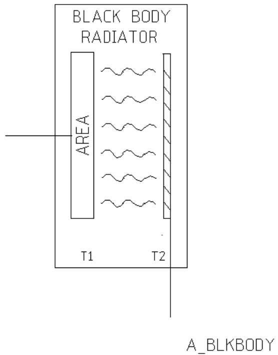
The example below shows the operation of the AC tachometer.



A_BLKBODY (Black-body Radiator)

This macromodel of a black-body radiator allows you to enter the surface area of the black-body. Energy transfer between the body and the background is modelled.

Graphic Symbol



Modelled Parameters

The following parameters can be modified.

Parameter	Default Value	Unit
AREA (Surface area of the black-body)	1	m^2

The characteristics of A_BLKBODY which are not modelled are listed below.

- convected heat energy
- thermal resistance of the body
- thermal capacitance of the body

Design Notes

Heat-flow is a through-variable and is analogous to current. Temperature is an across-variable and is analogous to voltage.

The temperature of the body and the temperature of the background to which energy is transmitted are set by the voltage on the T1 and T2 terminals respectively. These voltages should be 1V per Kelvin. The energy transferred is represented as 1A / J s^{-1} (Watt). Energy flows from the hotter to the cooler body. Both bodies are continually radiating and absorbing energy. The equation describing power radiated is:

$$P = A\zeta T^4$$

Note: ζ (zeta) is the Stefan-Boltzmann radiation constant.

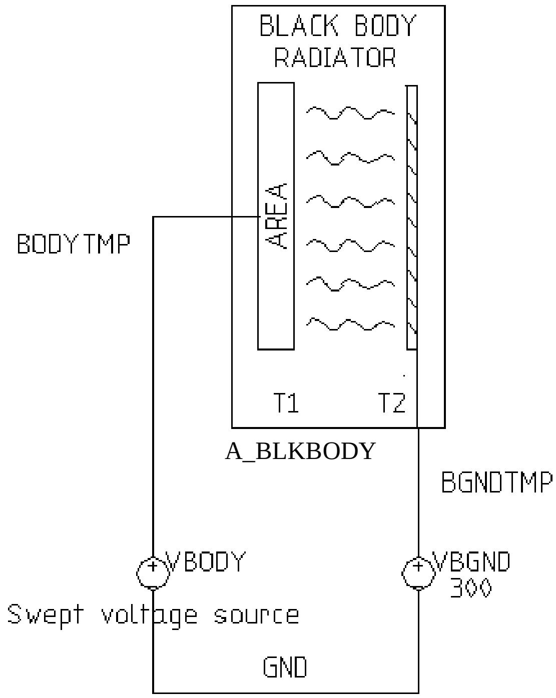
$$\zeta = 5.6696 \times 10^{-8}\ \mathrm{W\ m^{-2}\ K^{-4}}$$

T is the temperature in Kelvin, A is the surface area of the body, and P is the radiated power in Watts.

The energy absorbed by the body is governed by the same equation, but the temperature is that of the background. The energy transfer represented by the currents flowing through the T1 and T2 terminals is the sum of the energy radiated and the energy absorbed.

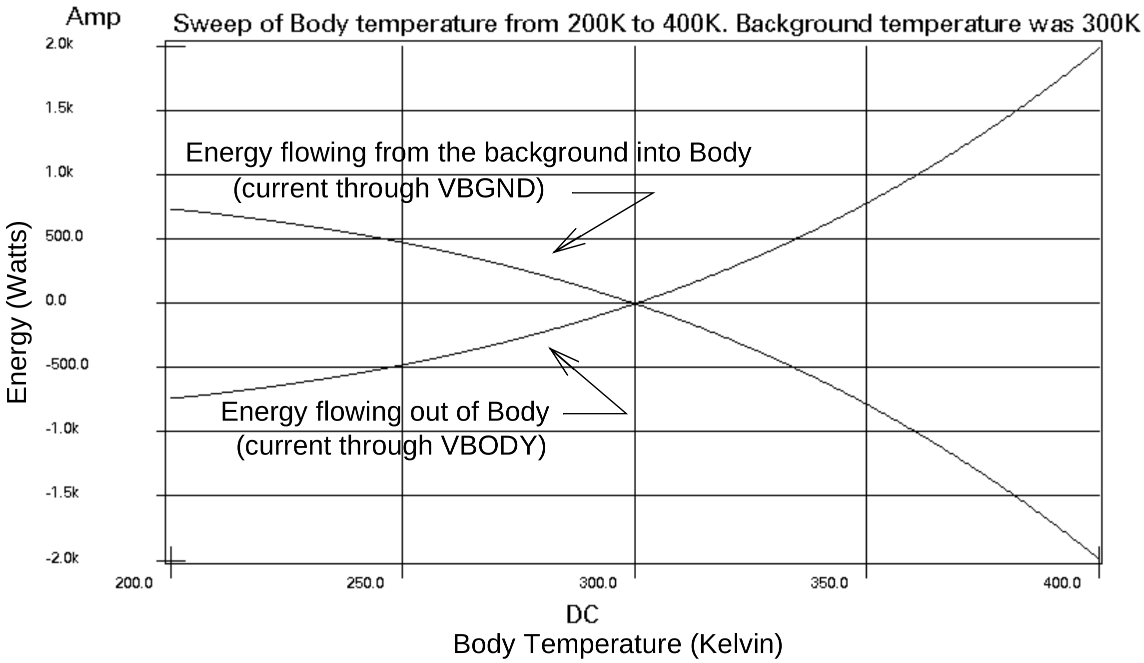
Test Circuit

The currents through VBODY and VBGND must be examined to determine the energy flow between the body and the background.



Test Results

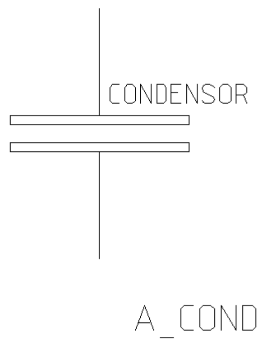
The following test results shows the energy flow from a black-body to background and vice versa. The area of the body was set to $2m^2$ and the temperature of the body was swept from 200K to 400K by varying the voltage on the T1 terminal from 200V to 400V. The temperature of the background was set to 300K. Note that when the background temperature is equal to the body-temperature, there is no net heat-flow.



A_COND (Automotive Condensor)

This macromodel, A_COND, is a model of an automotive condensor. The characteristics for the device were obtained by measuring an actual device.

Graphic Symbol



Modelled Parameters

The following parameters can be modified.

Parameter	Default Value	Unit
C (Capacitance)	220n	F
R (Series resistance)	40m	Ω

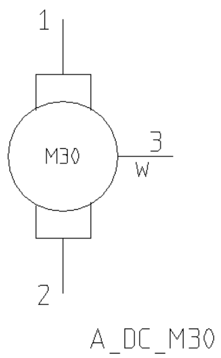
Design Notes

The condensor model comprises a capacitor and a series resistor. The parallel resistance, which is not modelled, was measured and found to be greater than 20 MΩ. The sample device was capacitive up to, and beyond 10MHz.

A_DC_M30 (DC Motor, Type M30)

This component models the behavior of the M30 armature control DC motor.

Graphic Symbol



Modelled Parameters

The following parameters can be modified.

Parameter	Default Value	Unit
RS (Series resistance)	0.193	Ω
LA (Armature inductance)	0.01	H
EC (Applied voltage)	12.5	V
I0 (Idle current)	2.41	A
W0 (Idle angular speed)	4750	RPM
T (Load torque)	0.7	N m
W (Angular speed at torque T)	2605	RPM
IR (Rotor inertia)	0.0005	kg m^2

EC, I0, W0, T, and W are taken from the current vs. torque and speed vs. torque characteristics of the motor.

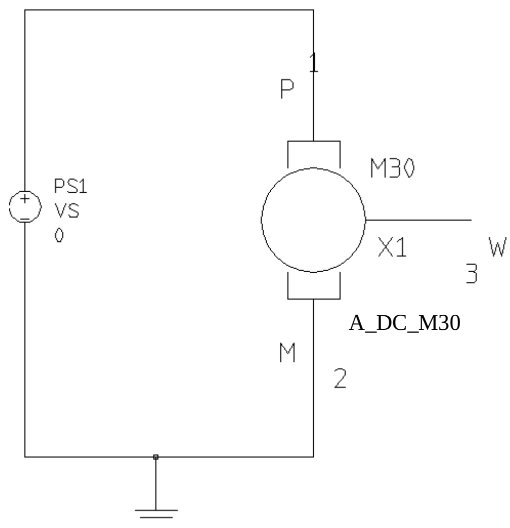
Design Notes

The M30 DC motor macromodel is designed to be used as described below.

- The input voltage is applied across the terminals P (positive) and M (mass). The polarity of the voltage determines the direction of rotation.
- The terminal W has two functions. The angular speed of the motor shaft rotation is represented as a voltage of 1V / rad s^{-1}. The motor torque is represented by 1A / N m. Using this system, inertia is represented by capacitance, and mechanical load (friction) is represented by conductance.

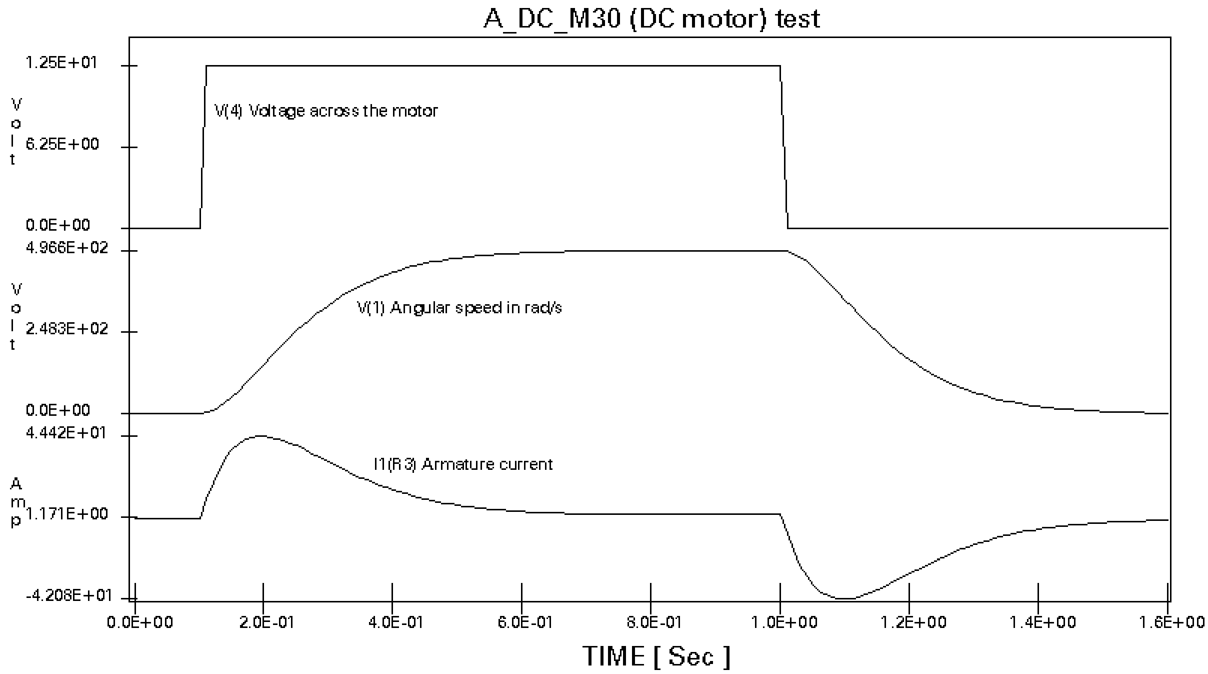
Test Circuit

The circuit shown below was used to simulate turning the unloaded motor on and off.



Test Results

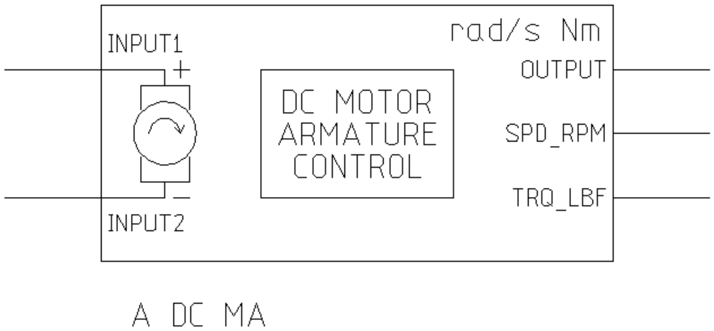
The example below shows the M30 motor running under no load condition.



A_DC_MA (DC Motor, Armature Controlled)

This component models the behavior of an armature controlled DC motor.

Graphic Symbol



Modelled Parameters

The following parameters can be modified.

Parameter	Default Value	Unit
R_ARM (Armature Resistance)	0.65	W
L_ARM (Armature Inductance)	100μ	H
J_ARM (Armature Inertia)	131μ	kg m^2
F_ARM (Armature Friction)	10.2m	kg m^2 s^{-2}
K_V (Velocity Constant)	240m	V rad $^{-1}$ s
K_T (Torque Constant)	240m	N m / A

The parameters were taken from a typical DC servo motor.

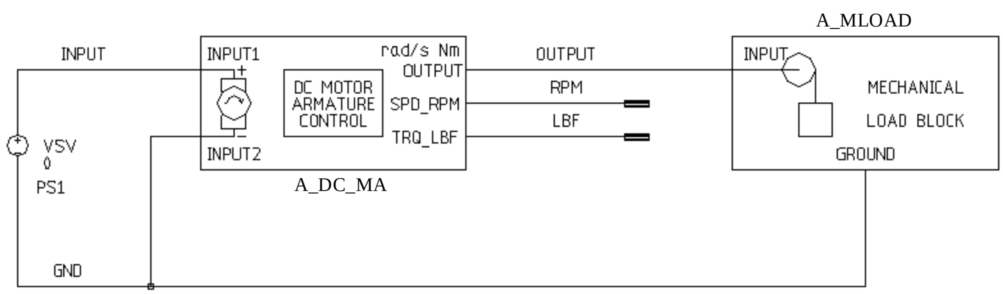
Design Notes

The armature-controlled DC motor is designed to be used as described below.

- The input voltage is applied across the terminals INPUT1 and INPUT2. The polarity of the voltage determines the direction of rotation.
- The terminal OUTPUT has two functions. The speed of rotation of the motor output shaft is represented as a voltage of 1V / rad s^{-1} . The torque is represented by 1A / N m. The polarity of the output voltage determines the direction of rotation of the output shaft. Using this system, mechanical load is represented by conductance (1/resistance), and inertia is represented by capacitance.
- Two further terminals are provided. The terminal SPD_RPM gives the speed of rotation of the output shaft in RPM represented as a voltage of 1V / RPM. The terminal TRQ_LBF gives the torque available at the output represented as a **voltage** of 1V per lbf ft.

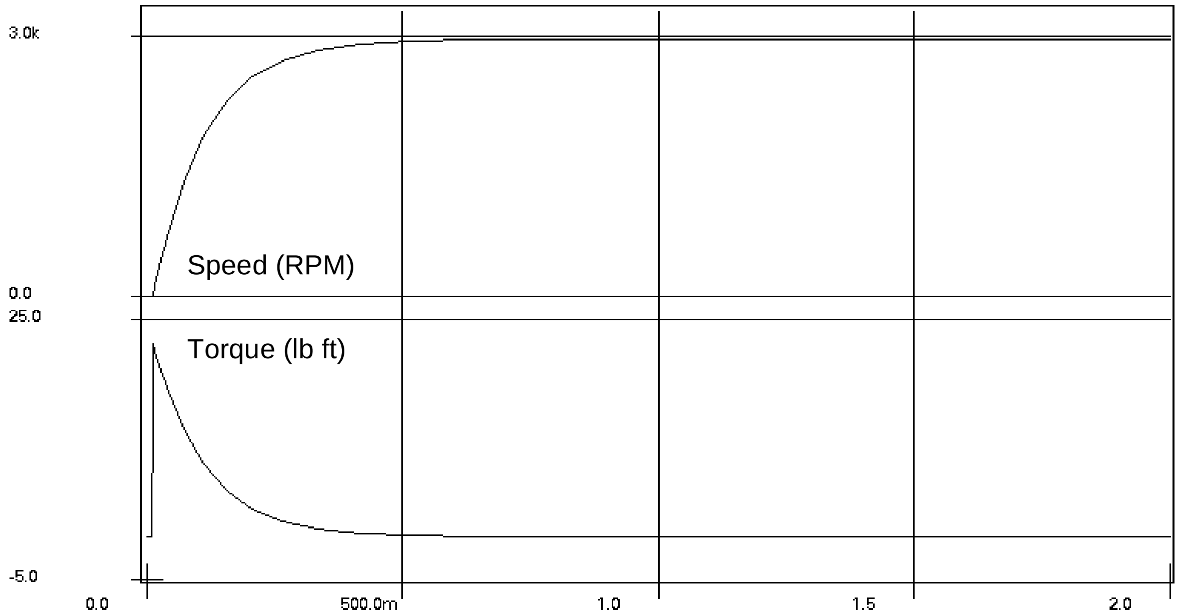
Test Circuit

The circuit shown below was used to produce the example waveforms. Please refer to the appropriate datasheet for details of the mechanical load block.



Test Results

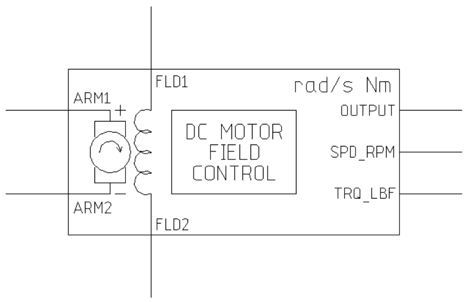
The example below shows the operation of the armature controlled DC motor running under no load condition. The input voltage to the motor was ramped from 0V to 83V over 10ms after a 10ms delay.



A_DC_MF (DC Motor, Field Controlled)

This component models the behavior of a field-controlled DC motor.

Graphic Symbol



A_DC_MF

Modelled Parameters

The following parameters can be modified.

Parameter	Default Value	Unit
R_ARM (Armature Resistance)	0.65	W
L_ARM (Armature Inductance)	100µ	H
J_ARM (Armature Inertia)	131µ	kg m^2
F_ARM (Armature Friction)	10.2m	kg m^2 s^{-2}
R_FIELD (Field Winding Resistance)	1	Ω
L_FIELD (Field Winding Inductance)	1m	H
K_V (Velocity Constant)	240m	V rad^{-1} s
K_T (Torque Constant)	240m	N m / A^2

Design Notes

The field-controlled DC motor is designed to be used as described below.

- The input voltage is applied across the terminals INPUT1 and INPUT2.
- The control voltage is applied across the terminals FIELD1 and FIELD2.
- The terminal OUTPUT has two functions. The speed of rotation of the motor output shaft is represented as a voltage of 1V / rad s^{-1}. The torque is represented by1A / N m. The polarity of the output voltage determines the direction of rotation of the output shaft. Using this system, mechanical load can be represented by conductance (1/resistance) and inertia by capacitance.
- Two further terminals are provided. The terminal SPD_RPM gives the speed of rotation of the output shaft in RPM represented as a voltage of 1V / RPM. The terminal TRQ_LBF gives the torque available at the output represented as a **voltage** of 1V / lbf ft.

Test Circuit

The circuit shown below was used to produce the example waveforms. Please refer to the appropriate datasheet for details of the mechanical load block.

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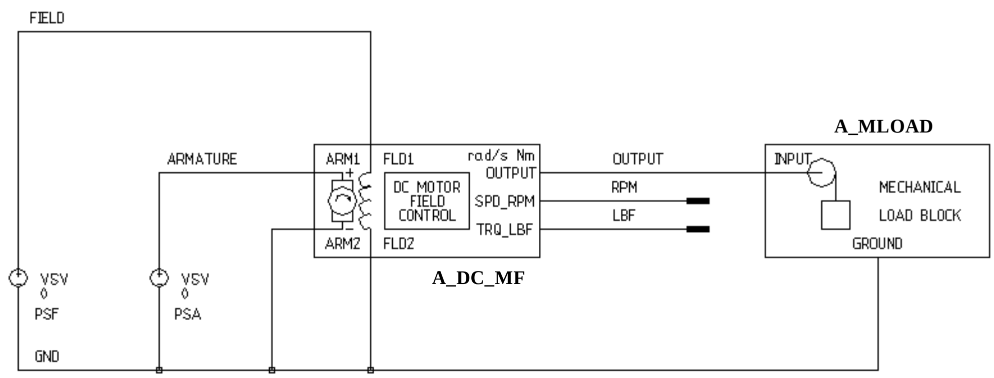
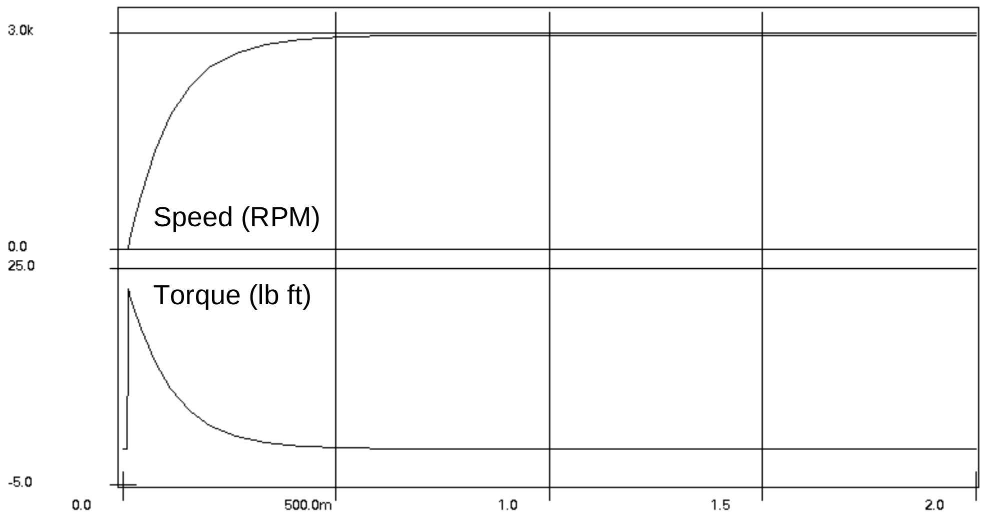


Example Waveforms

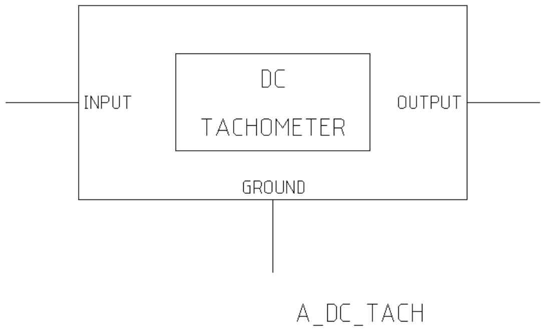
The example below shows the operation of the field controlled DC motor running under no load condition. The input voltage to the armature winding was fixed at 83 V. The field winding voltage was ramped from 0V to 1V over
200 ms after a delay of 10ms.



A_DC_TACH (DC Tachometer)

This component models the behavior of a DC tachometer.

Graphic Symbol



Modelled Parameters

The following parameters can be modified.

Parameter	Default Value	Unit
SCALE (Scale factor)	1	–

Design Notes

The DC tachometer is designed to be used as described below.

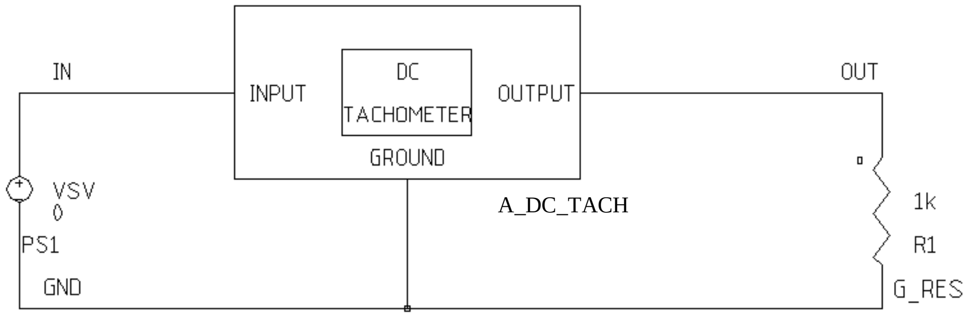
- The terminal INPUT is configured to accept an input voltage representing rotational speed. If used directly with the motor blocks provided in the automotive library, the rotational speed is represented by a voltage of 1V / rad s^{-1}.
- The parameter SCALE in the PARSET file allows the relationship between shaft speed and output voltage to be determined. The relationship is:

$$V_{out} = V_{input} \times SCALE$$

- The terminal GROUND may be allowed to float.

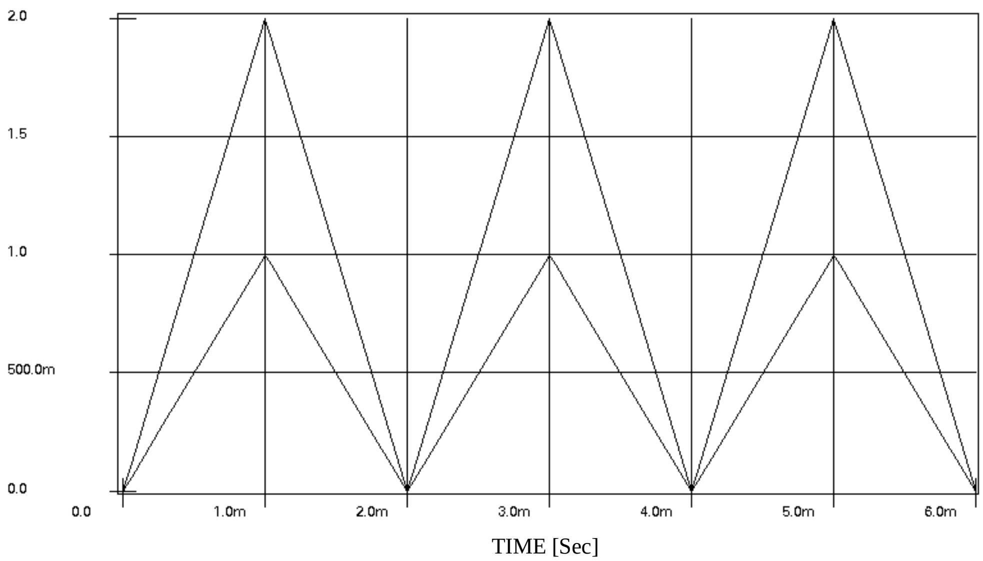
Test Circuit

The circuit shown below was used to produce the example waveforms.



Example Waveforms

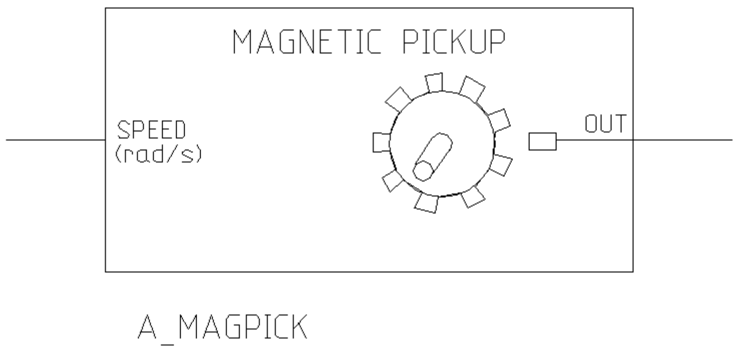
The example below shows the operation of the DC tachometer.



A_MAGPICK (Magnetic Pickup)

This macromodel, A_MAGPICK, is model of a magnetic pickup. The practical device comprises a toothed wheel where each tooth is magnetized. This model allows you to enter the number of teeth on the wheel and the maximum and minimum flux-density at the distance from the wheel where measurements are being taken. Note that the polarity of the magnetic teeth are all the same and so a 40 tooth wheel gives 40 pulses per revolution of the wheel. The output from this model is a sine-wave, the frequency of which is dependent on the input signal.

Graphic Symbol



Modelled Parameters

The following parameters can be modified.

Parameter	Default Value	Unit
TEETH (Number of teeth)	40	–
BMAX (Maximum output flux density) (see Design Notes)	20m	T
BMIN (Minimum output flux density) (see Design Notes)	-20m	T

The units of BMAX and BMIN are Tesla. The simulator represents the output flux density as a voltage, the magnitude of which, is numerically equal to the flux density in Tesla. The values given for BMAX and BMIN should be the flux density at the distance from the toothed wheel that the sensor is situated.

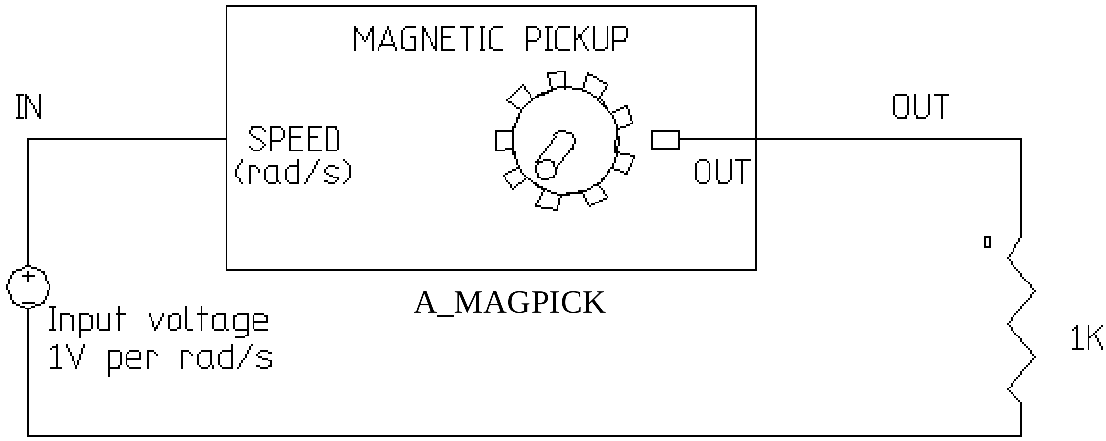
Design Notes

The input for this model is a DC voltage. The magnitude of this voltage determines the speed that the motor shaft is rotating at 1V / rad s^{-1}. The motors in the Analog Automotive Library have outputs in rad s^{-1}. These outputs are compatible with the input to this model.

The output of the model is a sine wave of a frequency equal to the number of teeth multiplied by the angular velocity defined by the input signal. The magnitude is determined by BMAX and BMIN.

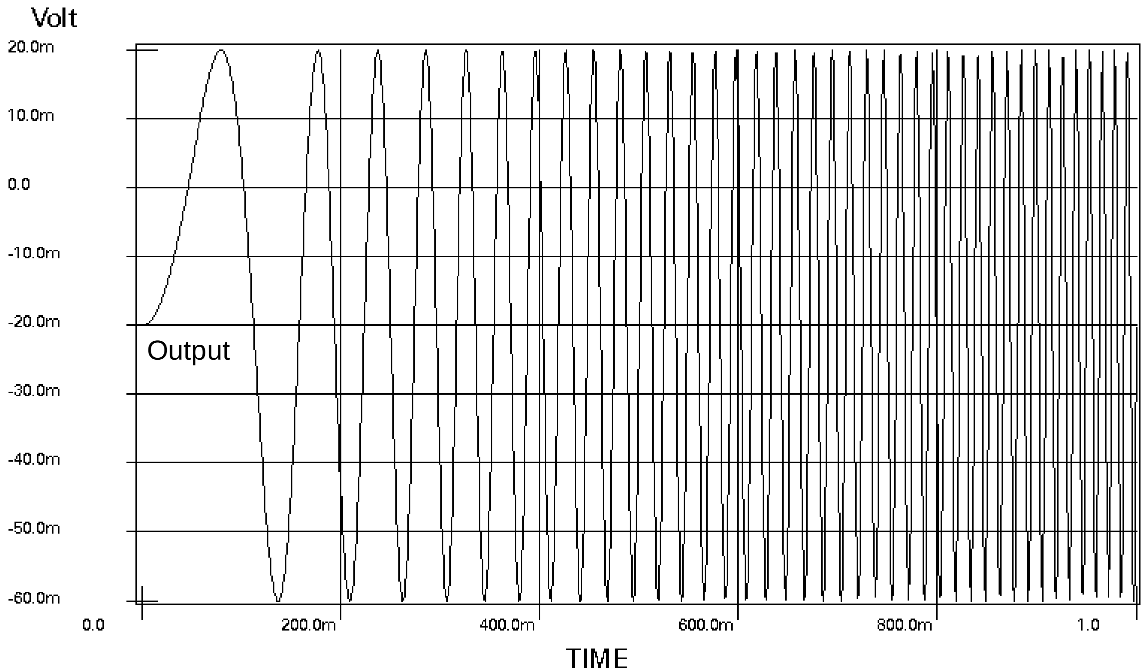
Test Circuit

The following circuit was used to test the pickup



Test Results

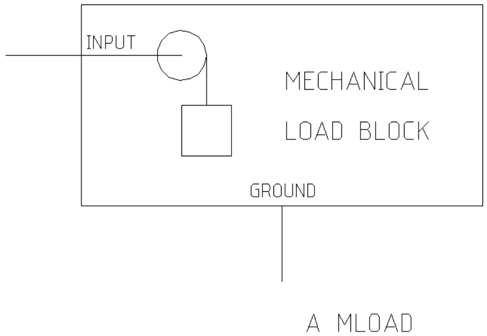
The default parameters for the PARSET file were used in the following simulation. The input signal was a ramp starting at 0V and ramping to 6.283V in
1 second. This represents a change in rotational velocity from 0 rad / s to 6.283 rad / s (0 Hz to 1 Hz).



A_MLOAD (Mechanical Load)

This component models the effect of a non-linear mechanical load. It is designed to be used with the motor models which are described separately.

Graphic Symbol



Modelled Parameters

The following parameters can be modified.

Parameter	Default Value	Unit
I (Load inertia)	1	kg m^2
N_0 (Rotational speed)	1m	rad / s
T_0 (Load Torque)	1m	N m
N_1 (Rotational speed)	1	rad / s
T_1 (Load Torque)	1	N m
N_2 (Rotational speed)	2	rad / s
T_2 (Load Torque)	3	N m
N_3 (Rotational speed)	3	rad / s
T_3 (Load Torque)	6	N m
N_4 (Rotational speed)	4	rad / s
T_4 (Load Torque)	12	N m

Parameter	Default Value	Unit
N_5 (Rotational speed)	5	rad / s
T_5 (Load Torque)	20	N m

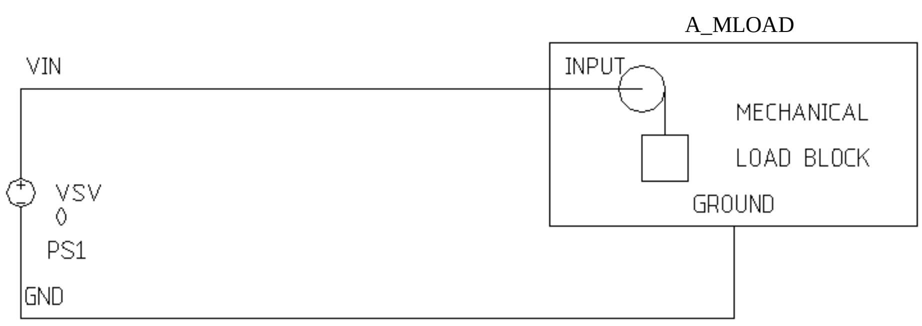
Design Notes

The mechanical load block is designed to be used as described below.

- The input to the block should be connected to the OUTPUT terminal of one of the motor models. The speed of rotation is represented as a voltage of 1 V / rad s^{-1} and the torque by 1A / N m. The polarity of the voltage determines the direction of rotation of the shaft.
- The PARSET file contains an inertia value and pairs of speed and torque values for the load. The speed and torque values are used to define a piece-wise linear representation of the load characteristic.
- The load characteristic is assumed to be the same for rotation in either direction. For any rotational speed below N_0, the torque T_0 is used for the load.
- Above rotational speed N_5, the speed-torque characteristic continues with the gradient calculated from the last pair of defined points.

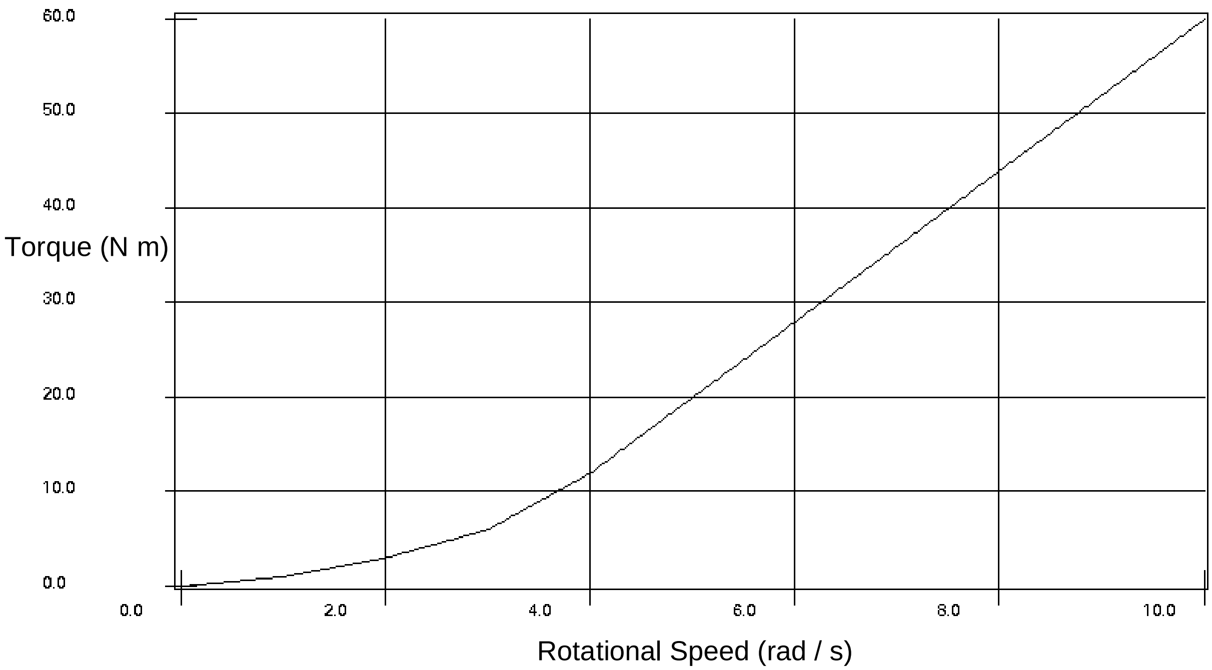
Test Circuit

The circuit shown below was used to produce the example waveforms.



Test Results

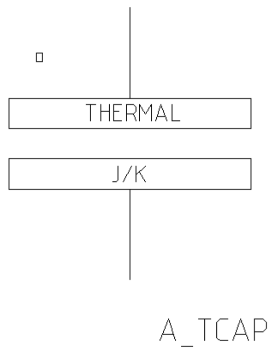
The example below shows the operation of the mechanical load block using the default parameters defined in the PARSET file.



A_TCAP (Thermal Capacitor)

This macromodel of a thermal capacitor allows you to enter the specific heat capacity and mass of a material. From these parameters the thermal capacitance is calculated.

Graphic Symbol



Modelled Parameters

The following parameters are modelled.

Parameter	Default Value	Unit
SHC (Specific Heat Capacity)	880	J kg^{-1} K^{-1}
MASS	0.1	kg

Note: For the following materials, SHC at 273K is given.

Aluminum880 J kg^{-1} K^{-1}
Copper379 J kg^{-1} K^{-1}

Unmodelled Characteristics

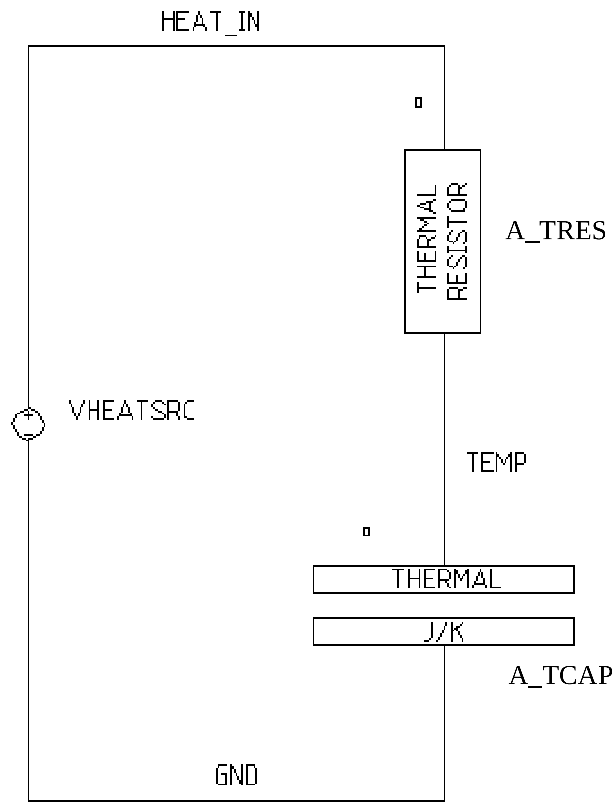
The characteristic of A_TCAP which is not modelled is the temperature coefficient of thermal capacity.

Design Notes

Heat-flow is a through-variable and is analogous to current. Temperature is an across-variable and is analogous to voltage.

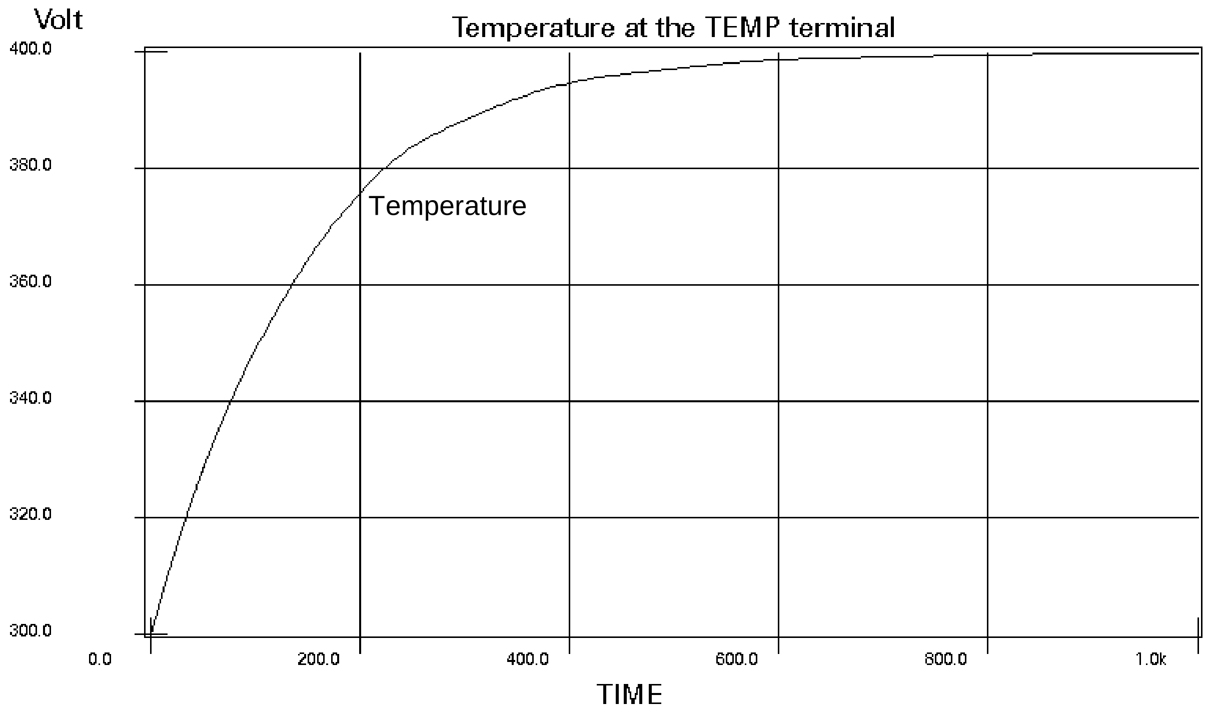
Test Circuit

The thermal resistance is 1.694 K/W and thermal capacitance is 88J/K. Therefore, the thermal time-constant is 149 seconds.



Test Results

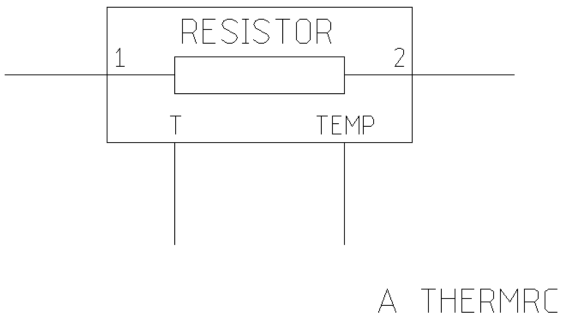
The following test shows the temperature of a mass of 0.1kg of aluminum (thermal capacity 880 J Kg^{-1} K^{-1}) connected to a thermal resistor comprising a 10mm length of aluminum of cross section $25mm^2$ (thermal conductance 236 W K^{-1} m^{-1}). At time=0, the temperature of the end of the thermal resistance not connected to the aluminum block is changed from 300K to 400K. The graph below shows the temperature of the aluminum block. The results are approximate because the thermal resistance of the block is not modelled. In reality the system consists of distributed thermal resistances and capacitances.



A_THERMRC (Resistor with Thermal Connection)

This macromodel of an electrical resistor with dynamic heating effects allows you to apply a heat-sink to the resistor. The temperature of the heatsink is determined by the power-dissipation of the resistor. The resistance of the resistor is temperature dependent.

Graphic Symbol



Modelled Parameters

The following parameters are modelled.

Parameter	Default Value	Unit
R (Resistance at temperature TNOM)	1	W
RTC (Temperature coefficient)	1m	% (K^{-1})
TRES (Thermal resistance to terminal T)	400	K W^{-1}
TCAP (Thermal capacitance of resistor)	3.75m	J K^{-1}
TNOM (Temperature that R is specified)	300	K

Design Notes

Heat-flow is a through-variable and is analogous to current. Temperature is an across-variable and is analogous to voltage.

The voltage on terminal TEMP represents the internal temperature of the resistor in Kelvin. The component includes a thermal capacitor (TCAP), representing the thermal capacitance of the resistor, and a thermal resistor (TRES) through which heat flows to the environment. Both TCAP and TRES are PARSET file parameters and can be modified.

Power dissipation is represented by a current flowing out of the model from the T terminal. The voltage on this terminal is numerically equal to the temperature (in Kelvin) of the surroundings.

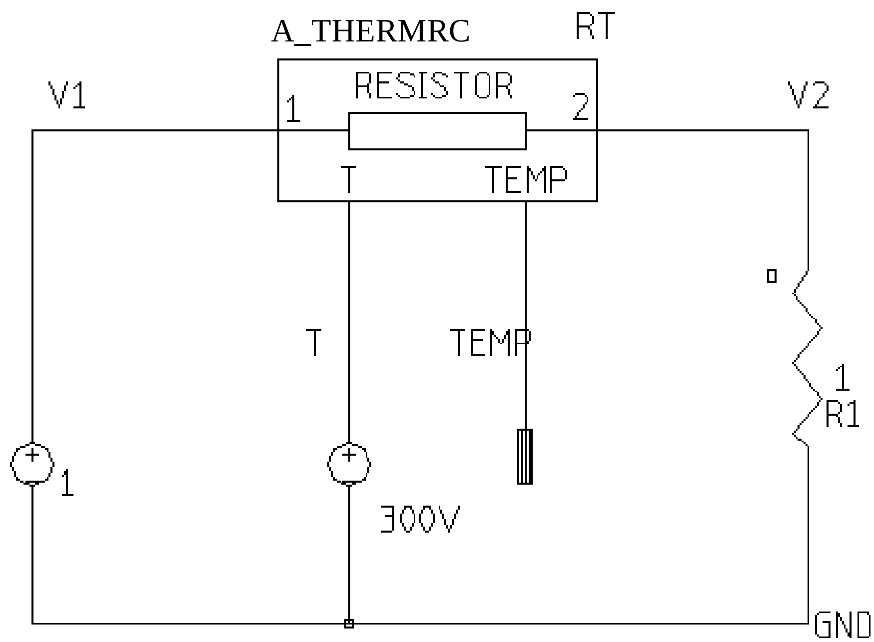
Terminal TEMP is used only to monitor the internal temperature of the component.

Terminal T should be connected to a thermal resistance, capacitance and/or a thermal source represented by a current or voltage source. A voltage of 300V on terminal T represents a temperature of 300K. A current of 1A flowing from terminal T represents a heat-flow of 1W.

If terminal T is grounded, the simulator assumes that the resistive element is at a temperature of absolute zero. Connect a 300V source to terminal T to simulate a temperature of 300K (27°C).

Test Circuit

The default parameters are used in this circuit. The input voltage was pulsed from 0V to 1V at time = 0.



Test Results

The following results are for an input voltage changing from 0V to 1V at time t = 0. Figure 1, on the following page, shows the circuit current. Note that the current falls as heating occurs inside the component. Figure 2, on the following page, shows the temperature of the component starting at 300K at switch-on and rising as power is dissipated. The resistor is connected to an infinite heatsink at 300K (represented by the 300V voltage source connected to terminal T) Figure 3 shows the power flowing into the infinite heatsink.

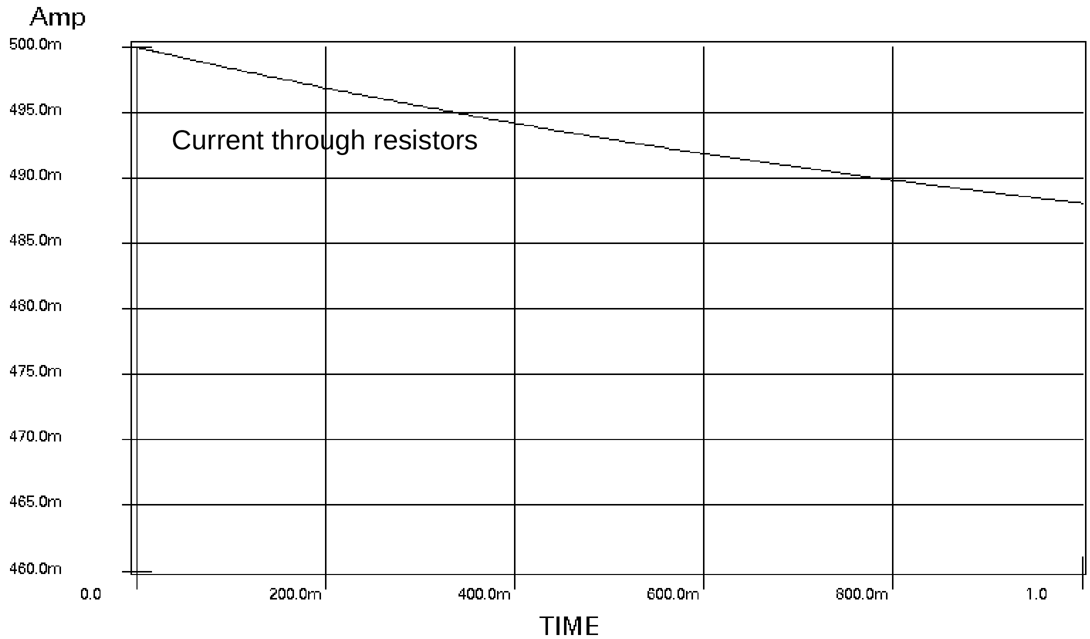


Figure 6-1: Current flow through resistors

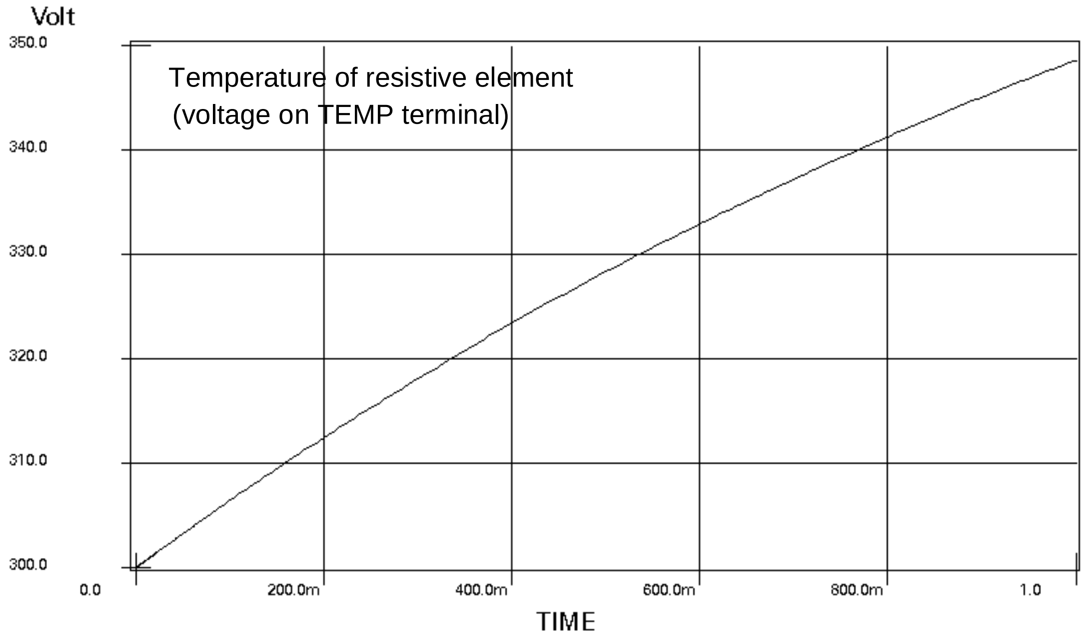


Figure 6-2: Temperature of the resistive element within the resistor

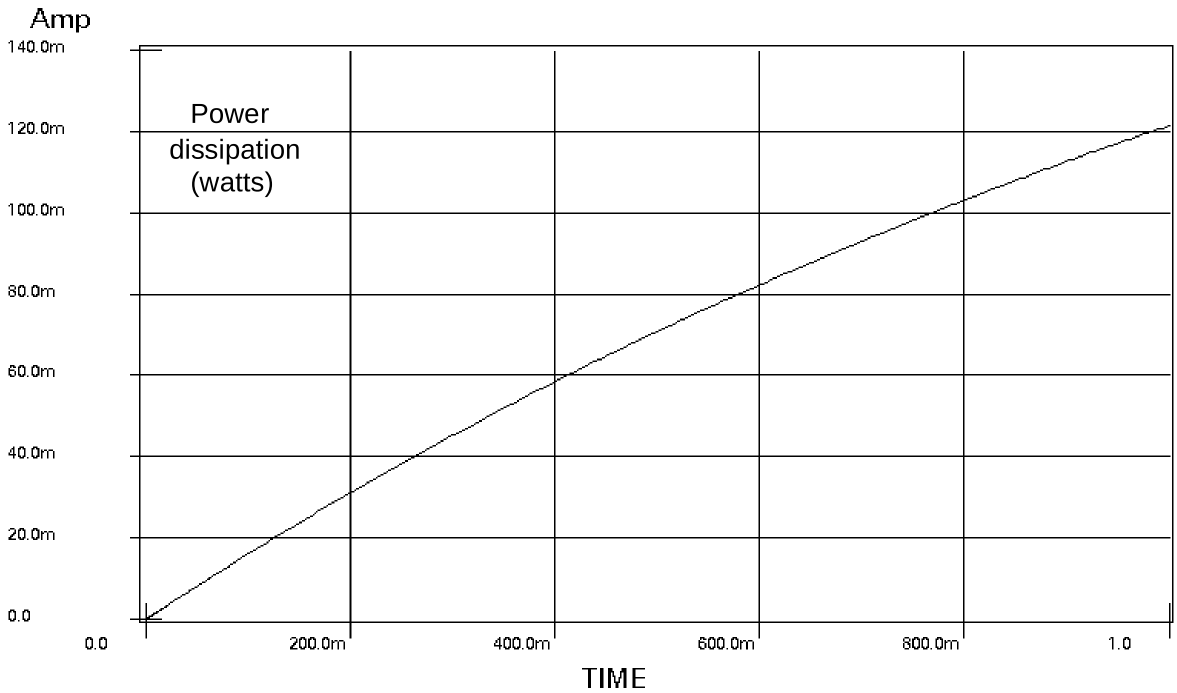
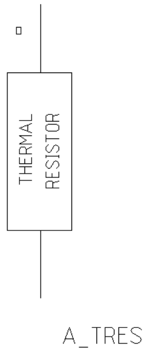


Figure 6-3: Power dissipation into the infinite heatsink

A_TRES (Thermal Resistor)

This macromodel of a thermal resistor allows you to enter the thermal conductivity, length, and cross-sectional area of a material to calculate the thermal resistance.

Graphic Symbol



Modelled Parameters

The following parameters are modelled.

Parameter	Default Value	Unit
LAMBDA (Thermal conductivity)	236	W K^{-1} m^{-1}
AREA (Cross section)	25 x 10^{-6}	m^2
LENGTH	10m	m

Note: For the following materials, Lambda at 273K, is given.

Aluminum236 W K^{-1} m^{-1}
Copper403 W K-1 m-1

Unmodelled Characteristics

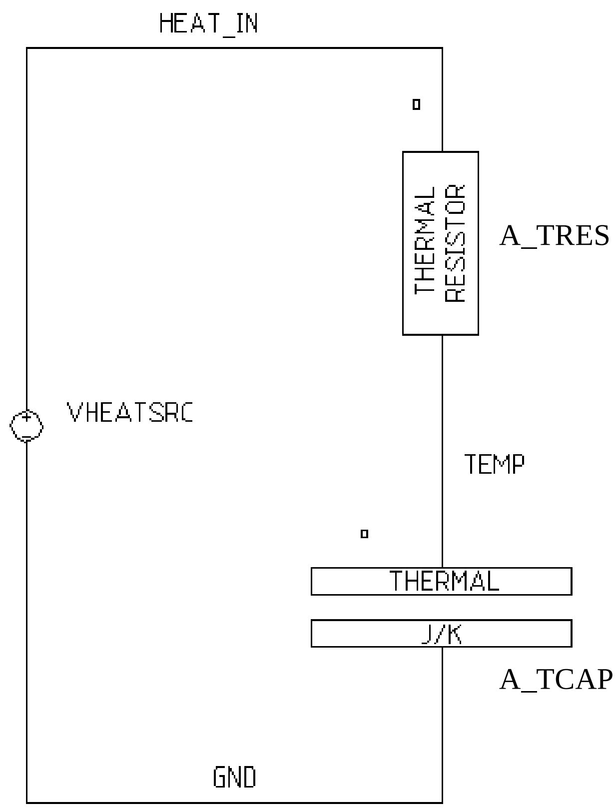
The characteristic of A_TRES which is not modelled is the temperature coefficient of thermal conductivity.

Design Notes

Heat-flow is a through-variable and is analogous to current. Temperature is an across-variable and is analogous to voltage.

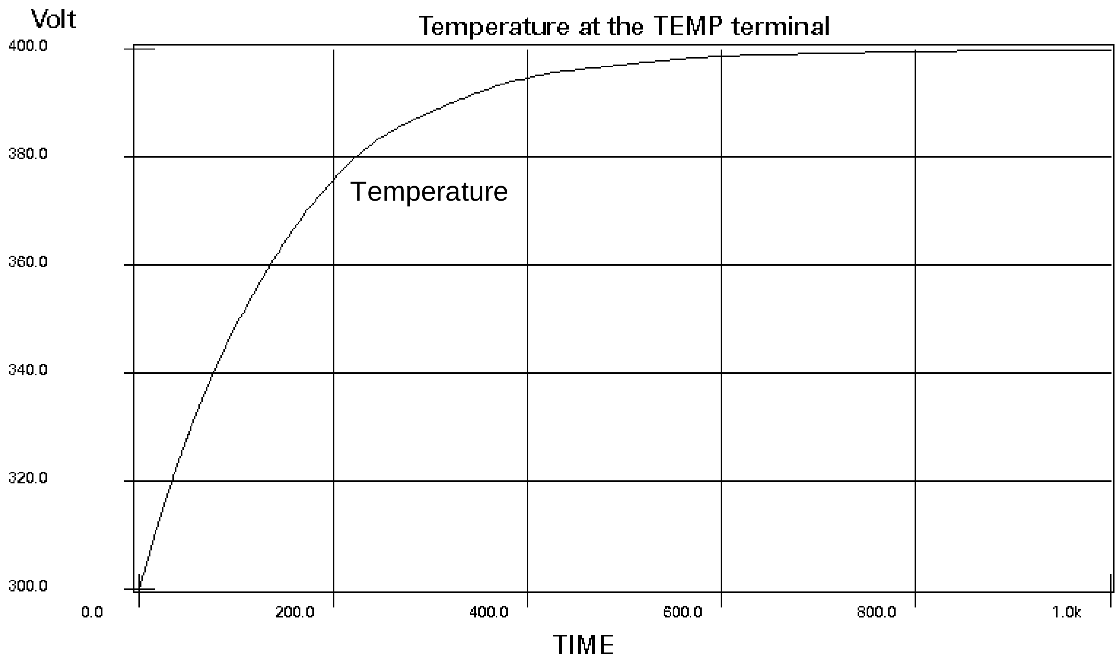
Test Circuit

The thermal resistance is 1.694 K/W and thermal capacitance is 88J/K. Therefore, the thermal time-constant is 149 seconds.



Test Results

The following test shows the temperature of a mass of 0.1kg of aluminum (thermal capacity 880 J kg^{-1} K^{-1}) connected to a thermal resistor comprising a 10mm length of aluminum of cross section 25 x 10^{-6} m^2 (thermal conductance 236 W K^{-1} m^{-1}). At time = 0, the temperature of the end of the thermal resistance not connected to the aluminum block is changed from 300K to 400K. The graph below shows the temperature of the aluminum block. The results are approximate because the thermal resistance of the block is not modelled. In reality, the system consists of distributed thermal resistance and thermal capacitance.



Chapter 7
Analog Automotive Model List

An asterisk (*) indicates a parameterized model.

Part Name		Description
A_1P1TC	*	Switch, Single-Pole (normally closed)
A_1P1TO	*	Switch, Single-Pole (normally open)
A_1P2T	*	Switch, Single-Pole, Double-Throw
A_1P2TR	*	Relay, Single-Pole, Double-Throw
A_1P3T	*	Switch, Single-Pole, Triple-Throw
A_1P4T	*	Switch, Single-Pole, Four-Throw
A_1PRC	*	Relay, Single-Pole (normally closed)
A_1PRO	*	Relay, Single-Pole (normally open)
A_2P2TR	*	Relay, Double-Pole, Double-Throw
A_2PMX	*	Switch, Two-Pole Matrix
A_3PMX	*	Switch, Three-Pole Matrix
A_4PMX	*	Switch, Four-Pole Matrix
A_AAALARM	*	Alarm, Anonymous (across-variable)
A_ABSC	*	Converter, Absolute Value
A_AC_TACH	*	Tachometer, AC
A_ALLPASS1	*	Filter, 1st Order All-Pass
A_ALLPASS2	*	Filter, 2nd Order All-Pass

Part Name		Description
A_ALLPASS3	*	Filter, 3rd Order All-Pass
A_ATALARM	*	Alarm, Anonymous (through-variable)
A_BACKLASH	*	Backlash
A_BANGBANG	*	Controller, BangBang (on/off)
A_BIQUAD	*	BIQUAD Circuit
A_BLKBODY	*	Radiator, Black-Body
A_CCR	*	Relay, Cross-Strap
A_CCTPM	*	Switch, Two-Pole, Cross-Connection
A_CLIPINT	*	Integrator, Clipped Output
A_COND	*	Condensor, Automotive
A_COST	*	Transducer, Cosine
A_CU_WIRE	*	Wire, Copper
A_DC_M30	*	Motor, DC Type M30
A_DC_MA	*	Motor, DC, Armature Controlled
A_DC_MF	*	Motor, DC, Field Controlled
A_DC_TACH	*	Tachometer, DC
A_DG4T	*	Switch, 1-Pole 4-Throw w/Digital Control
A_DL_COMP	*	Compensator, Derivative Lag
A_DZON	*	Deadzone Functional Block
A_FUSE	*	Fuse
A_GAINDLY	*	Gain Delay Functional Block
A_GAINZD	*	Gain Block with Zero Delay

Part Name		Description
A_HALLSW	*	Switch, Functional Hall Effect
A_HSW	*	Switch, Hall Effect Sensor
A_IALARM	*	Detector, Current Threshold
A_IGRATE	*	Integrator
A_LAG	*	Compensator, Lag
A_LAMP1F	*	Lamp, Single Filament
A_LAMP2F21-5		Lamp, 2-Filament 12V 21W & 5W
A_LEADLAG	*	Compensator, Lead-Lag
A_LIM	*	Limiter
A_MAGPICK	*	Magnetic Pickup
A_MAX	*	Maximum Value Selector
A_MIN	*	Minimum Value Selector
A_MLOAD	*	Mechanical Load
A_MSW	*	Switch, Momentary
A_MULT	*	Multiplier, 2-Input
A_PALARM	*	Alarm, Power Threshold Detector
A_PERSW	*	Switch, Periodic
A_PI_COMP	*	Compensator, Proportional Integral
A_RAPOLY1	*	Filter, 1st Order Rational Polynomial
A_RAPOLY2	*	Filter, 2nd Order Rational Polynomial
A_RAPOLY3	*	Filter, 3rd Order Rational Polynomial
A_REEDSW	*	Switch, Reed (relay)

Part Name		Description
A_REL1_2P	*	Relay, Automotive
A_SINT	*	Transducer, Sine
A_SQRTC	*	Converter, Square Root
A_SUM	*	Summing Element
A_TCAP	*	Capacitor, Thermal
A_THERMRC	*	Resistor with Thermal Connection
A_TRES	*	Resistor, Thermal
A_VALARM	*	Alarm, Voltage Threshold Detector
A_WIRE	*	Wire, Electrical