spectrum news

Applications for Micro-Cap™ Users

Summer 2010

News

H1 vs PIN,IM2 vs PIN,IM3 vs PIN

IP2=65.6,59.1

IP3=13.4,6.9

P1dBm -5.3,-12.8

H1 (dBmW)   IM2 (dBmW)   IM3 (dBmW)
PIN (dBmW)

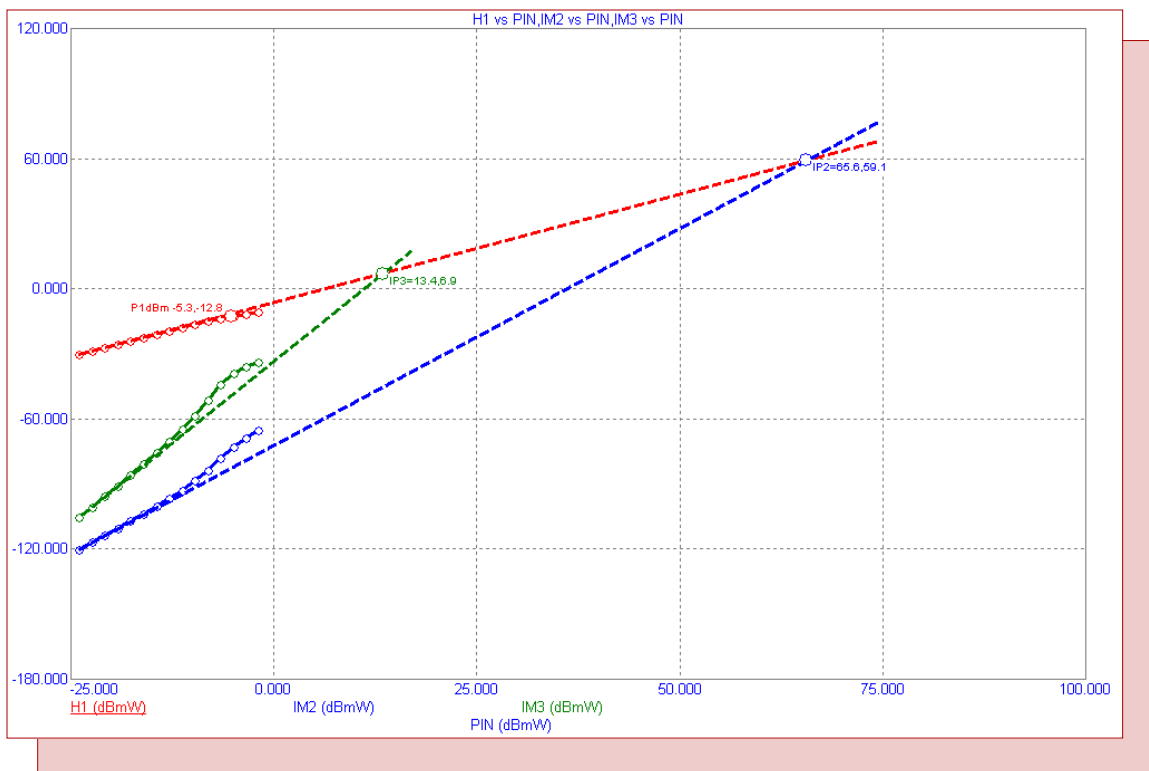## Introducing Micro-Cap 10

Featuring:
• Introducing Micro-Cap 10
• Retriggerable Monostable Multivibrator Macro
• VCO with Square Wave Output Macro

News In Preview

This newsletter's Q and A section describes how to plot the total harmonic distortion of a waveform using the THD function. The Easily Overlooked Feature section describes the Auto Scale Visible Region command that scales the vertical or Y axis of the waveforms by considering only Y values within the currently visible or displayed X region.

The first article gives a preview to the latest generation of the Micro-Cap simulator, Micro-Cap 10. This article highlights many of the new features available within the program.

The second article describes a macro for a retriggerable monostable multivibrator. The retriggering capability of the multivibrator lets the basic pulse duration of the output be extended when the input is triggered again.

The third article describes a macro for a voltage controlled oscillator that produces a square wave at its output rather than the typical sinusoidal waveform.

Contents

Book Recommendations

General SPICE
- *Computer-Aided Circuit Analysis Using SPICE*, Walter Banzhaf, Prentice Hall 1989. ISBN# 0-13-162579-9

- *Macromodeling with SPICE*, Connelly and Choi, Prentice Hall 1992. ISBN# 0-13-544941-3

- *Inside SPICE-Overcoming the Obstacles of Circuit Simulation*, Ron Kielkowski, McGraw-Hill, 1993. ISBN# 0-07-911525-X

- *The SPICE Book,* Andrei Vladimirescu, John Wiley & Sons, Inc., 1994. ISBN# 0-471-60926-9

MOSFET Modeling
- *MOSFET Models for SPICE Simulation, William Liu, Including BSIM3v3 and BSIM4*, Wiley-Interscience, ISBN# 0-471-39697-4

Signal Integrity
- *Signal Integrity and Radiated Emission of High-Speed Digital Signals*, Spartaco Caniggia, Francescaromana Maradei, A John Wiley and Sons, Ltd, First Edition, 2008 ISBN# 978-0-470-51166-4

Micro-Cap - Czech
- *Resime Elektronicke Obvody,* Dalibor Biolek, BEN, First Edition, 2004. ISBN# 80-7300-125-X

Micro-Cap - German
- *Simulation elektronischer Schaltungen mit MICRO-CAP,* Joachim Vester, Verlag Vieweg+Teubner, First Edition, 2010. ISBN# 978-3-8348-0402-0

Micro-Cap - Finnish
- *Elektroniikkasimulaattori,* Timo Haiko, Werner Soderstrom Osakeyhtio, 2002. ISBN# 951-0-25672-2

Design
- *High Performance Audio Power Amplifiers,* Ben Duncan, Newnes, 1996. ISBN# 0-7506-2629-1

- *Microelectronic Circuits,* Adel Sedra, Kenneth Smith, Fourth Edition, Oxford, 1998

High Power Electronics
- *Power Electronics,* Mohan, Undeland, Robbins, Second Edition, 1995. ISBN# 0-471-58408-8

- *Modern Power Electronics,* Trzynadlowski, 1998. ISBN# 0-471-15303-6

Switched-Mode Power Supply Simulation
- *SMPS Simulation with SPICE 3,* Steven M. Sandler, McGraw Hill, 1997. ISBN# 0-07-913227-8

- *Switch-Mode Power Supplies Spice Simulations and Practical Designs*, Christophe Basso, McGraw-Hill 2008. This book describes many of the SMPS models supplied with Micro-Cap.

Micro-Cap Questions and Answers

Question: I am simulating an audio amplifier. My transient analysis is running fine, and now I would like to measure the total harmonic distortion of my amplifier output. How do I do this measurement?

Answer: The total harmonic distortion of a waveform can be calculated through the use of the THD function. The THD function has the following syntax:

THD(S[,F])

where S is the waveform spectrum, and F is an optional parameter that specifies the fundamental frequency. If the F parameter is not specified, then the fundamental frequency is calculated through the time range specified in the FFT page of the Analysis Properties dialog box by the following equation:

F = 1/(Upper Time Limit - Lower Time Limit)

In the Transient Analysis Limits dialog box, the THD function needs to be entered on a new waveform line. Set the X Expression field to F since the distortion should be plotted versus frequency. If the THD is to be measured at node Out, the Y Expression field would be defined as:

THD(HARM(V(Out)))

The HARM(V(Out)) portion produces the waveform spectrum needed for the THD calculation. In this case, the fundamental frequency would be calculated from the FFT page of the Analysis Properties dialog box. However, if the fundamental frequency needed to be set to a specific value such as 1kHz, the expression above could be modified to:

THD(HARM(V(Out)),1k)

Run the transient simulation. The plot displays a running total of the THD measurement. For example, if the fundamental frequency is 1kHz, the data point at 4kHz would show the THD value of all of the harmonics after 1kHz up to and including the harmonic at 4kHz.

There is also an individual harmonic distortion function available in Micro-Cap. Its syntax is:

IHD(S[,F])

This function operates in the same manner as the THD function except that it shows just the individual distortion of each harmonic.

Easily Overlooked Features

This section is designed to highlight one or two features per issue that may be overlooked among all the capabilities of Micro-Cap.

Auto Scale Visible Region Command
The Auto Scale command under the Scope menu is a commonly used command that automatically determines the scale ranges in order to best display the waveforms in the plot. However, it will always scale using the data from the entire waveform which may not be appropriate in some situations. The Auto Scale Visible Region command, which is also available under the Scope menu, scales the vertical or Y axis of the waveforms by considering only Y values within the currently visible or displayed X region. This command is useful when you have zoomed in on a small part of a waveform and want to auto scale only the vertical region while maintaining the X axis scale of the original zoom.

An example of the use of the Auto Scale Visible Region command is shown in the figure below. The waveform in each plot group has been set to the same expression: V(Out). When this simulation is originally run, both the top and bottom plots are set to show the entire waveform. The top plot in the figure still maintains its original scale. The bottom plot has been zoomed in on to show the steady state operation of the output after the initial transient has passed. After the zoom in, the Auto Scale Visible Region command was then selected to produce the display shown in the bottom plot.
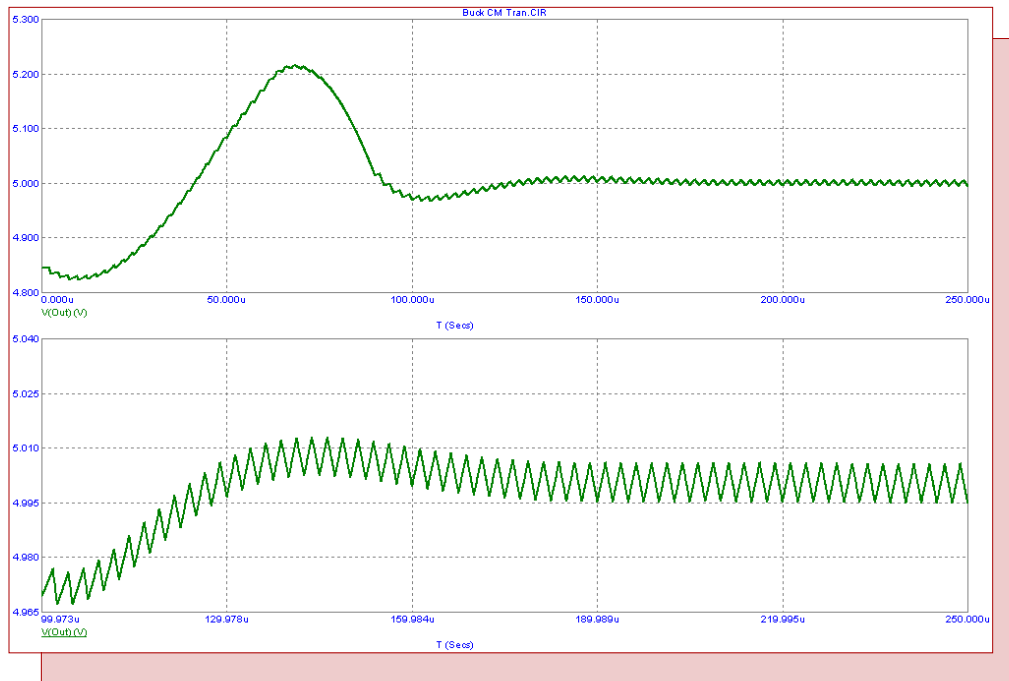

Fig. 1 - Using the Auto Scale Visible Region command

Introducing Micro-Cap 10

We are pleased to release the next generation of the Micro-Cap simulator, Micro-Cap 10. A number of new features, analyses, and models have been added to enhance the simulation power and the ease of use of the interface. A preview of some of the new features follows. Please contact our sales department for upgrade or pricing questions.

Analysis

Harmonic Distortion Analysis

Harmonic Distortion analysis is a type of transient analysis in which a single frequency sinusoidal signal is applied to an input source and the resulting distortion measured in the output. If a signal at a particular frequency is applied to the circuit input and if the circuit is not linear, signal level will be found at some frequencies other than the input frequency. In other words, distortion will occur. Harmonic Distortion analysis measures this distortion and provides plots of THD, THDN, SINAD, SNR, and Hm (m'th harmonic) vs F, and the peak and RMS versions of VIN, VOUT, PIN(Input Power), and POUT(Output Power). The analysis makes extensive use of Periodic Steady State techniques to improve accuracy and speed.
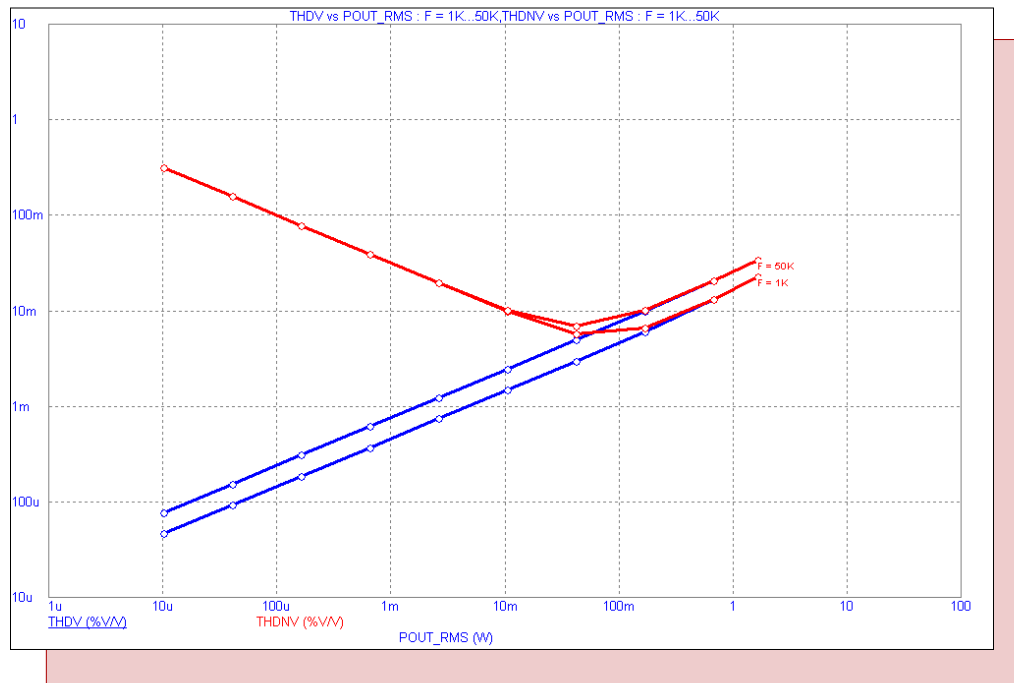

Fig. 2 - Harmonic Distortion analysis

Intermodulation Distortion Analysis

Intermodulation analysis is a type of transient analysis in which two sinusoidal signals are applied to an input source and the resulting intermodulation products at the sum and difference frequencies are computed. Plots of H1, IM2, and IM3 vs F, and both peak and RMS versions of VIN, VOUT, PIN(Input Power), and POUT(Output Power) are available.

The program will optionally find and mark the 1dBm compression point (P1dBm) and the second and third order intercepts (IP2 and IP3). The analysis also makes extensive use of Periodic Steady State techniques to improve accuracy and speed.
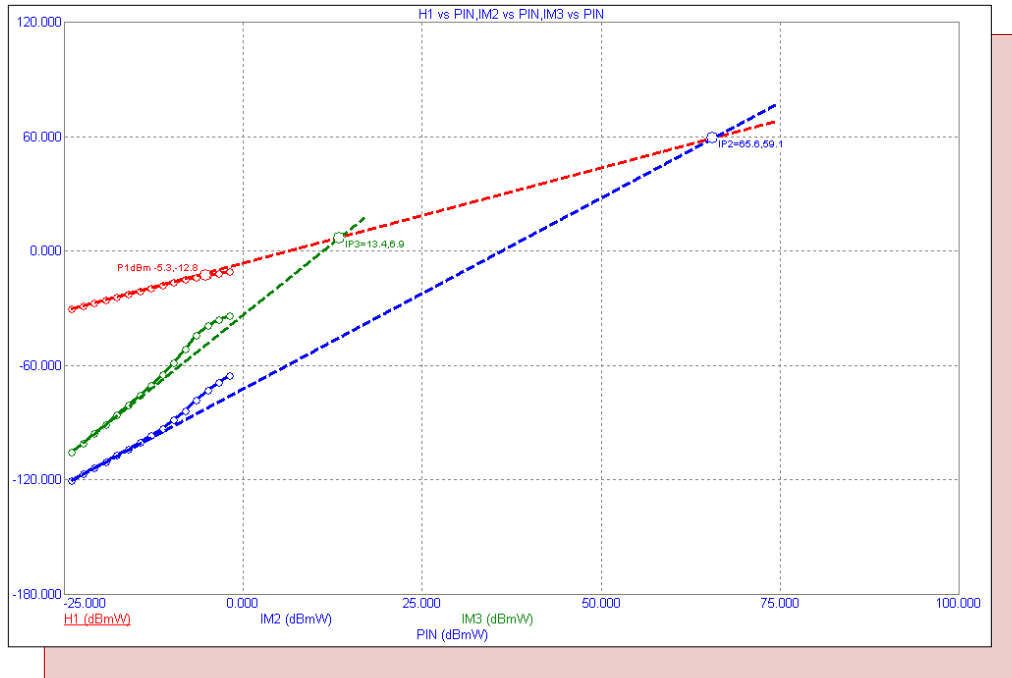
Fig. 3 - Intermodulation Distortion Analysis

Periodic Steady State (PSS)
Periodic Steady State uses techniques pioneered by Aprille and Trick to calculate the periodic steady state, removing any short term transients from the time-domain waveforms, greatly simplifying many types of circuit analysis problems. This new analysis mode was added to Transient, Harmonic Distortion, and Intermodulation Distortion. It is executed after the optional operating point and runs in lieu of the normal time domain run. PSS uses a shooting method to eliminate transients normally encountered to arrive at steady state waveforms.

Threading
Micro-Cap 10 uses threading for significant speed improvement where multiple CPU cores are available. When multiple independent analyses are requested, Micro-Cap uses threading technology to speed up the overall analyses by allocating each sub-analysis to a different CPU core. This is beneficial when stepping temperature or parameters, in Monte Carlo Analysis, and with harmonic and intermodulation distortion analysis.

New Optimization Algorithms
Optimization has been improved by the addition of three new methods. These include Hooke, Levenberg-Marquardt, and Differential Evolution. Each method has its own strength and is optimal in different kinds of problems. Together they provide powerful assistance in solving optimization problems. The new methods are available in each analysis optimization routine and in the Model program optimizer.

Optimizer Curve Fit From File
The optimizer has been expanded to allow importing data sets from a file to facilitate using the optimizer to curve fit with large data sets.

Cursor Values in Text Expression
This lets you write analysis expression text using cursor values CursorLX, CursorLY, CursorRX, CursorRY as variables.

AC Power

AC power is now calculated as P = V * Conjugate(I).

Time-domain Power

When RMS on-schematic display is requested, transient analysis power is now calculated as P = RMS(V) * RMS(I).

Import and Export of WAV files

WAV audio files can now be imported and exported allowing one to "hear" the output of an audio amplifier.
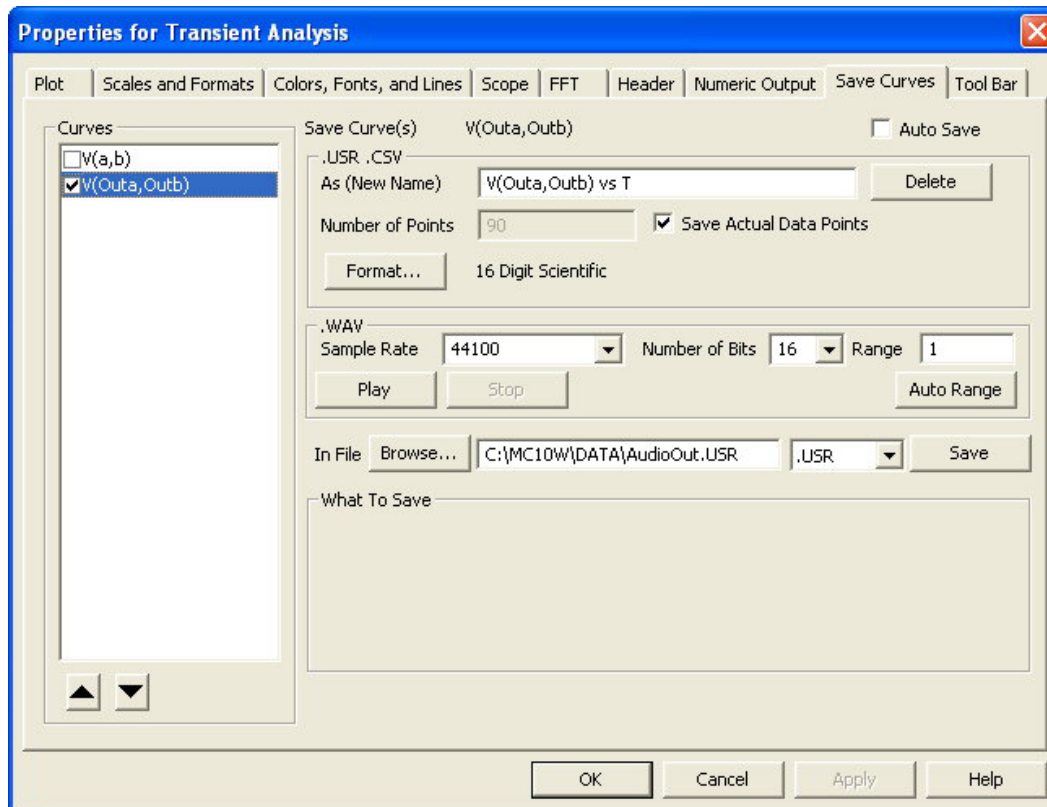
Fig. 4 - WAV, CSV, and USR file export dialog box

Save Curves Auto Save

This option automatically saves selected waveforms after each run.

Branch values in plots

This lets you plot expressions that use waveform values from different branches. A branch is a Monte-Carlo case or a stepped value. V(1)@1 - V(1)@2 plots the difference of V(1) between branch 1 and branch 2.

Point Tag Numeric Format

The X and Y numeric formats of point tags are now separately specifiable.

HSPICE Compatibility

A small step toward compatibility with HSPICE files was taken by allowing '3*V(1)' to mean the same thing as {3*V(1)}.

Plot, Save but Don't Plot, Don't Save and Don't Plot
These button options can be selected for each waveform or curve in the Analysis Limits dialog box.

Enable / Disable / Hide
By right-clicking in the Page or P (Plot) fields you can enable, hide, or disable all curves that use the Page or Plot number. Enable saves the data. Disable does not. Hide stops the plot display but saves the data.

Sort Function for Page and Plot Number
The page names and plot numbers can now be sorted alpha-numerically.

Distortion Plots Waveform Buffer
Distortion plots created in harmonic and intermodulation analyses can be saved and recalled from the Waveform Buffer.

FFT Dialog Box
The FFT panel on the Analysis Properties page (F10) has a new field called Frequency Step. Enter a value here and an adjustment is made in the Lower Time Limit value and vice versa, according to the formula, Frequency Step = 1 / (Upper Time Limit - Lower Time Limit).

FFT Auto-scaling
FFT auto scaling is now done using the FFT upper and lower time limit parameters rather than the older TMAX, TSTART.

Sweep Resistance in DC Analysis
Resistance values may now be directly swept in DC analysis.

Copy Cursor Values to Clipboard
This lets you copy the contents of the cursor table to the clipboard.

Time Data Retention
The definition of the transient analysis Time Range format of tmax, [tmin] has been changed to tmax, [tstart]. The analysis always starts at T = 0 but data points prior to tstart are now discarded after plotting. If you move the plot or rescale it after the run is over the data points prior to tstart are not replotted because they have not been saved.

Plot Expression Right-Click
Additional functions are now available by right clicking on the underlined expression text within the plot, including scales and formats, and plot line and text color.

Histogram, Performance, 3D, FFT Windows
The old limit of 10 for these windows was eliminated.

Stepping Enabled
When stepping is enabled, the Stepping button in the Analysis Limits dialog box is shown in bold.

Initial Conditions Editor Format
A Format button provides numeric format control for the .IC, Write, and Print commands.

AC Analysis Limits Default Changes
The Frequency Range method now defaults to Log, and the Number of Points now defaults to 1001.

Noise Output Nodes Prompt
Right-clicking in the Noise Output field of the AC Analysis Limits dialog box provides a list of available node names.

Improved Illegal Expression Error Messages
The error message for illegal expressions was expanded to show the entire expression and the point in the expression where the error occurred.

Error Page
A separate error page now captures all errors generated by an analysis. This is useful when errors that do not stop the run are encountered. This page keeps a record of them for later perusal. For example, a Monte Carlo run of 1000 cases may generate a few "Timestep too small" errors but the overall 1000 run sequence continues and deposits error messages here.

Function Source Extension
Function voltage and current sources can now reference the B, H, and Flux values in their expressions.

Sensitivity Analysis
The output expression limit of 10 has been removed.

Schematic Editor
On-schematic text editing
Grid text can be edited directly by double clicking the text body while holding down the Alt key.
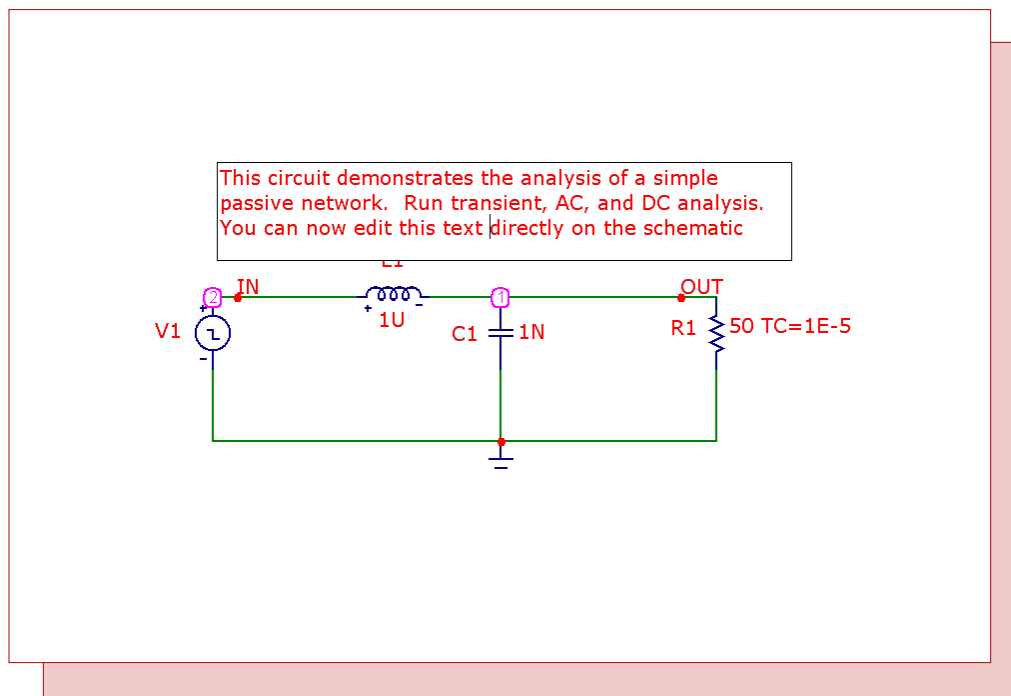

Fig. 5 - Edit grid text directly in the schematic

Favorites
A Favorites tab was added to the Component Panel. This tab keeps track of your component usage and provides a list arranged with the most often used parts at the top.

Mouse Info Box
When you hold the mouse over a part, this box shows basic information like voltages and currents. The content of the box now optionally contains much more data such as beta, capacitance, conductance, and many more values from the internal device structure.

Text Search
The text find command was elaborated to show all instances of the text, as it is being typed. The currently selected piece is highlighted with Previous and Next navigating the instances found.
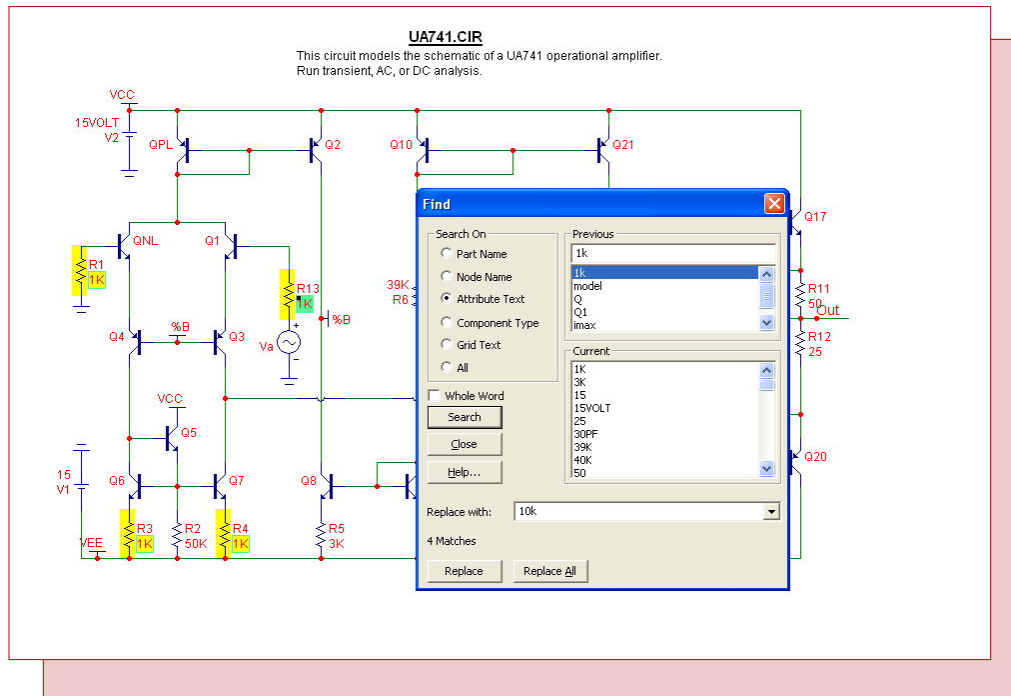
Fig. 6 - Updated Find and Replace command with highlighted matches

Find Command
This command now allows Find and Replace operations on any attribute or grid text.

Local VIP Font and Format Control
The font and numeric format of node voltages, pin currents, and power values are now controlled from the circuit Properties page (F10), rather than being global formats that apply to all circuits.

Color/Font Change
The new Change / Attribute feature has been expanded to allow simultaneous changes of color and or font of selected part attribute text.

Global Settings Default
Non-default global settings are now shown with bold printing to emphasize the change.

Text Align
This command lets you align selected grid or attribute text.

User Created Toolbar Bitmaps
Users can now create and assign new bitmaps for favorite commands.

Schematic region enable / disable

A Show/Hide capability for the boolean enable text was added as well as font/color control. On-schematic text editing was added for the enable text.

Find Component

The size of this dialog box is now adjustable to provide more space for large lists of parts that match the specified text string.

Close All Files

A command was added to close all open files.

File Save

This command now allows saving a circuit file while in an analysis.

Topology Check Option

The Path to Ground, Voltage Loop, and Floating Nodes checks are now optional.

Windows Dialog Box

A Windows dialog box was added to easily activate, close, or save open windows.

Bill of Materials Parts Grouping

The Parts can be grouped (as in earlier versions) or ungrouped according to the status of the Group Parts check box.

Automatic Check for Update

The program now automatically checks the web site to see if a newer version is available.

Model Program
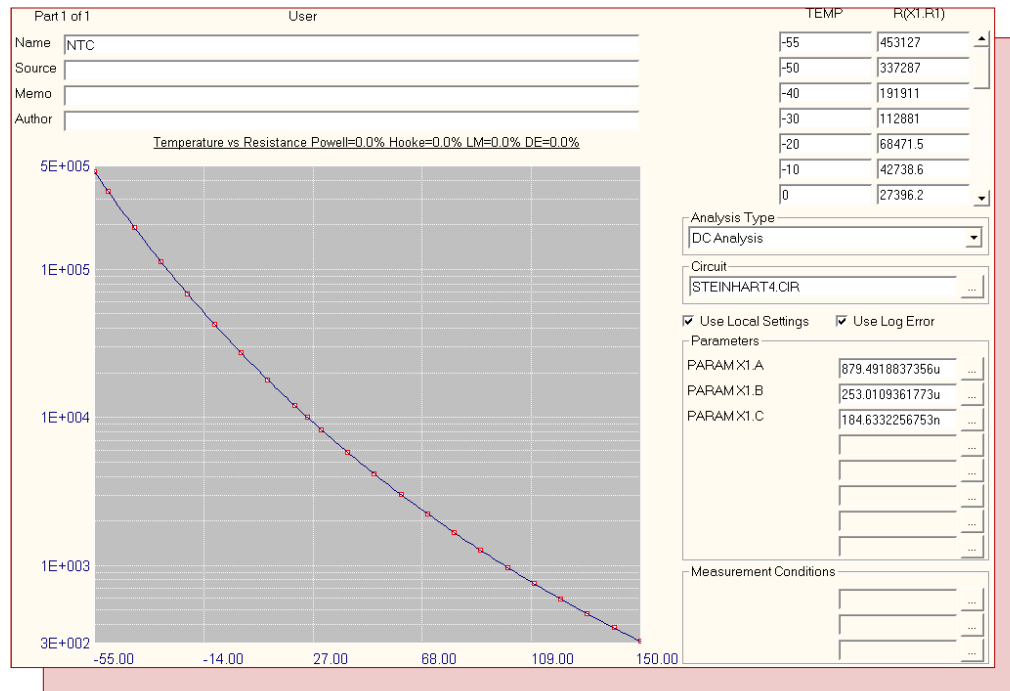
Fig. 7 - Model program optimizing an NTC subcircuit model

User-defined circuits optimizing

Model now supports optimization using user defined test circuits. No longer are you limited to determining parameters for a fixed number of devices. Test circuits can be created to determine optimized parameters for BSIM3, BSIM4, PSP, IGBT, and other devices. Subcircuits, macros, or model statements can be created from the optimized data. In Figure 7, the Steinhart and Hart parameters for an NTC subcircuit model are optimized.

More Optimizers

Model optimization has been improved by the addition of three new methods. The complete list of methods now includes:

Powell
Hooke
Levenberg-Marquardt
Differential Evolution

BJT Parameters

BJT optimized parameters now include the NK parameter.

Models

WAV File Source

This source gets its waveform from a specified .WAV file, allowing convenient importation of audio and other waveforms.
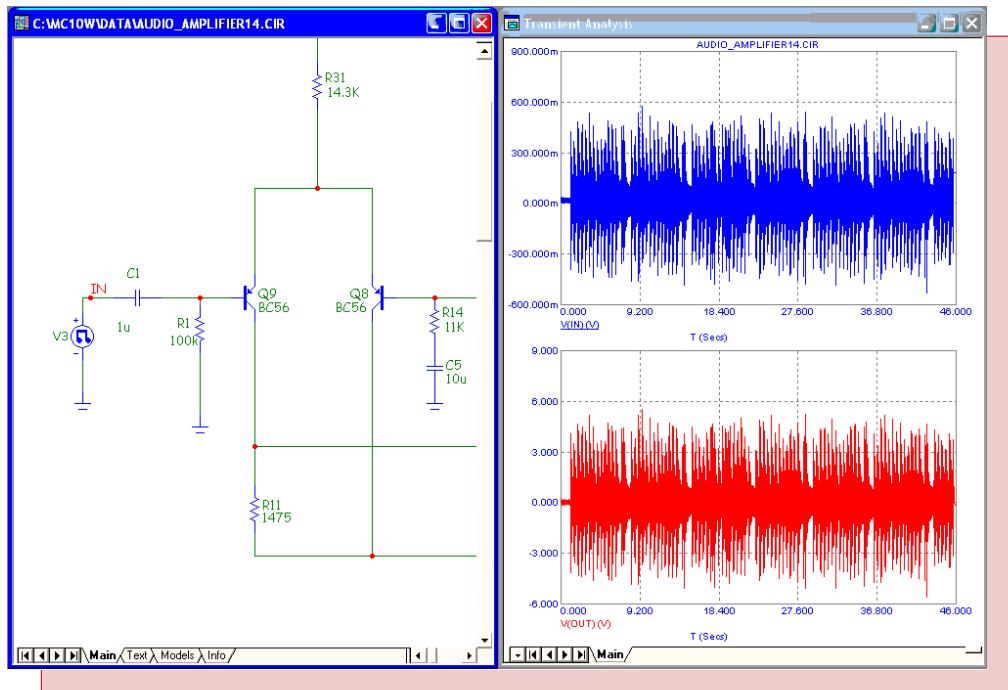
Fig. 8 - WAV File Source used to import WAV files

IBIS models

The IBIS model was expanded to handle the I/O open drain, I/O open source, I/O open sink, open drain, open source, and open sink models.

BJT Quasi-saturation model
The BJT model was expanded to handle the quasimod, rco, gamma, and vo parameters.

Monte Carlo
GAUSS and UNIF functions
The GAUSS, AGUASS, UNIF, and AUNIF functions can now be used to compactly specify a component's distribution values.

Eliminate Outliers
For Gaussian distributions, an option is now available to eliminate any values outside of the tolerance band.

User Defined Scales
Histogram X and Y scales can now be set by the user.

Bar Tops
Histogram bar tops can be annotated with either quantity found or percentage found in each bar's range.
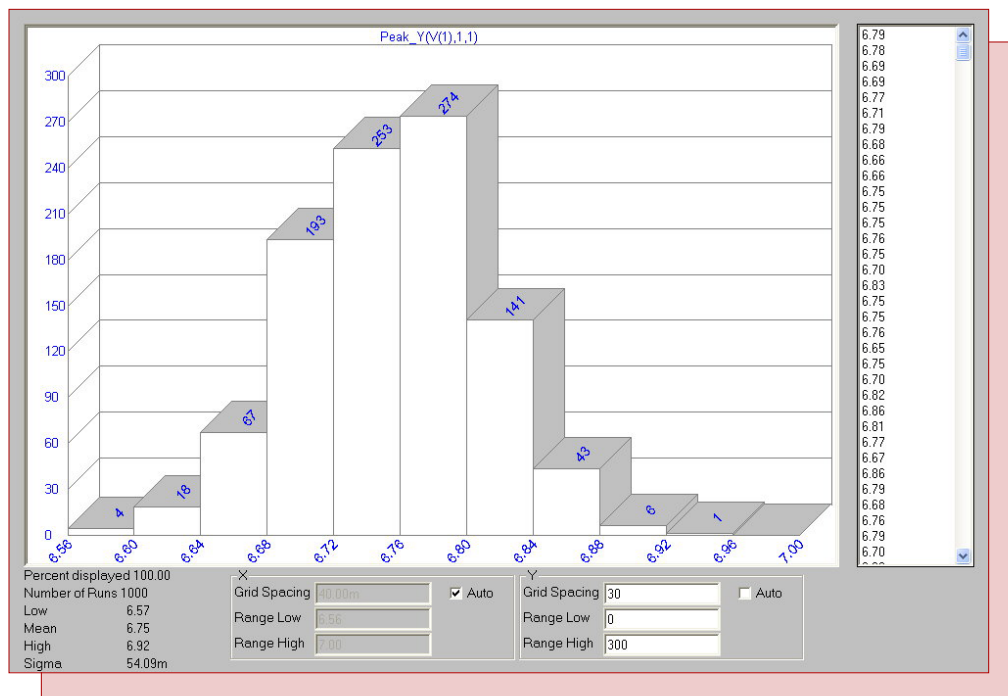
Fig. 9 - Quantity bar tops and user defined Y histogram scale

Runs Display
The histogram display includes the number of runs.

Low, Mean, High Format
These quantities are now shown in engineering notation, e.g. 10n vs 1e-8.

Statistics in Printout
The low, mean, high, and sigma (standard deviation) are now shown in the numeric output.

Expressions
Int Operator
The INT operator was added. INT(2.7) = 2.

Nint Operator
The NINT operator was added. NINT(2.7) = 3.

HarmN Function
The HARMN function was added. Its output is the same as the HARM function, but normalized to the 1st harmonic's value.

Plotting D(NODE) and V(NODE)
When you have a digital node connected to an analog node, D(NODE) plots the waveform for the digital node and V(NODE) plots the analog waveform.

## Component Editor
Improved Add Part and Import Wizards
These routines has been enhanced to show how the part will look when a template is selected.

Save and Revert Options
The Save and Revert options are now available on the tool bar, so it is no longer necessary to quit in order to save or restore the file you are working on.

Shape Editor
Find Command
A Find command facilitates locating shape names.

Picture Files
Picture files may be imported to serve as a part of a shape file.

Duplicate Command
A new Duplicate command makes an exact copy of the selected shape and assigns it a new name.

Groups
Shapes may now be assigned group names.

Save and Revert Options
The Save and Revert options are now available on the tool bar, so it is no longer necessary to quit in order to save or restore the file you are working on.

Package Editor
Auto Check
Entering a new package automatically enables it by setting its check mark.

Multiple Entries
Multiple packages can now be entered by assigning a duplicated entry to more than one package at a time.

Retriggerable Monostable Multivibrator Macro

In the Summer 2006 edition of the Spectrum Software newsletter, a macro circuit was created for a nonretriggerable monostable multivibrator. In many applications, a retriggerable monostable multivibrator is useful. The retriggering capability lets the basic pulse duration of the output be extended when the input is triggered again. For example, if the specified duration of the output pulse is 100ns, when the input is retriggered 75ns after the initial trigger occurs, the output pulse will be extended for an additional 100ns. In this case, that would produce an output pulse of 175ns. There is no limit to the number of times that the pulse may be extended. A macro model for a retriggerable monostable multivibrator appears below.
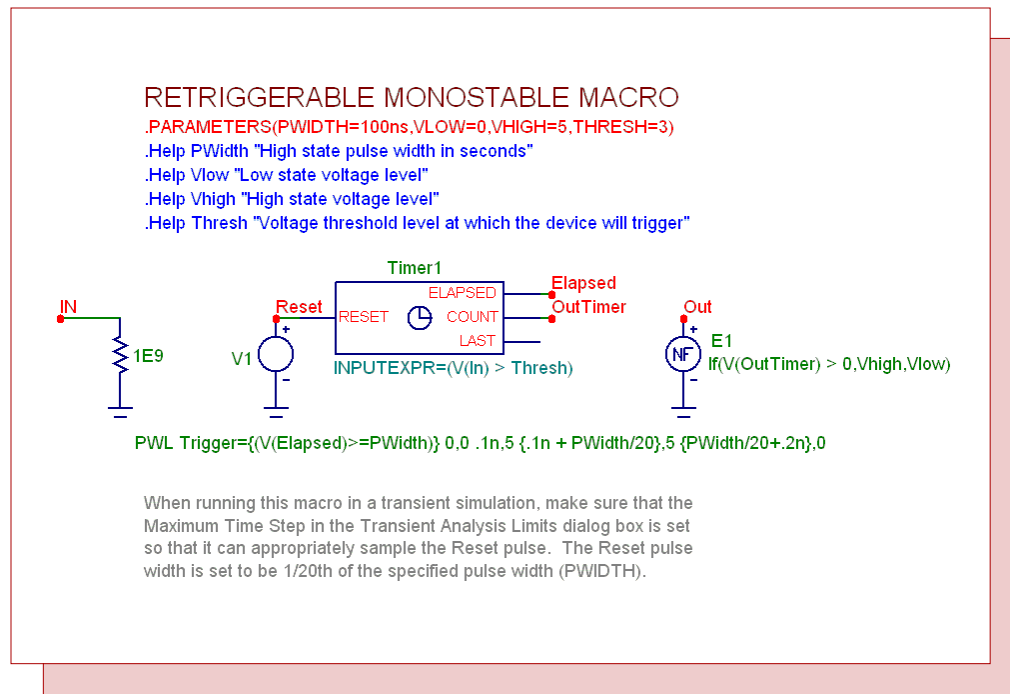
Fig. 10 - Retriggerable monostable multivibrator macro

The monostable macro has four input parameters: PWidth, Vlow, Vhigh, and Thresh. The PWidth parameter defines the length of time in seconds that the output pulse of the multivibrator will maintain its high state level for before reverting back to the stable low state, and also the amount of time that the output pulse is extended when it is retriggered. The Vlow parameter defines the voltage level for the low state output. The Vhigh parameter defines the voltage level for the high state output. The Thresh parameter defines the voltage level that the input signal will need to exceed in order to trigger the device.

The input of the macro is located at node IN. A 1G ohm resistor has been placed at this node to provide a DC path to ground. At the core of the retriggerable monostable multivibrator macro is a Timer component. The relevant attributes of the Timer component have been defined as follows:

INPUTEXPR = (V(In) > Thresh)
INCREMENT = 1
INITIAL = 0

For the Timer component, the voltage at the Count pin will be set to 0V at the beginning of a simulation and when the voltage at the Reset pin exceeds 1V. When the INPUTEXPR returns a True (non-zero) value, the voltage at the Count pin will be incremented by 1V. In this case, the input expression will become true when the voltage at node In exceeds the specified Thresh level. The Elapsed output of the Timer is also used in this macro. The Elapsed output tracks the amount of time since the last true event was triggered in the INPUTEXPR. It produces a voltage value at the Elapsed output pin equivalent to the number of seconds that have elapsed since the last true input event.

The reset signal for the timer is created by the V1 voltage source at the Reset pin of the Timer. The voltage source uses the PWL definition and has its VALUE attribute defined as:

PWL Trigger={(V(Elapsed)>=PWidth)} 0,0 .1n,5 {.1n + PWidth/20},5 {PWidth/20+.2n},0

This source defines a 5V pulse with a width of PWidth/20 seconds. This pulse will reset the voltage on the Count pin of the Timer back to 0V. The specified pulse will only occur when the expression defined for the Trigger keyword evaluates to true. The Trigger expression has the following condition that must be true for the reset pulse to occur.

V(Elapsed)>=PWidth

This condition checks that the voltage at the Elapsed output of the timer is equal to or greater than the PWidth parameter passed through to the macro. If this condition is true, that means that the output has been high for the specified pulse width time since the last trigger and needs to return to its low state.

The output signal of the monostable multivibrator macro is created by the E1 nonlinear function voltage source. The NFV source has its VALUE attribute defined as:

If(V(OutTimer) > 0,Vhigh,Vlow)

If the voltage at node OutTimer (which is at the Count output of the timer) is greater than 0V, then the source will produce a voltage of Vhigh volts. Otherwise, a voltage of Vlow volts is produced. The Vhigh and Vlow values are specified by the parameters the user passes through to the macro. Essentially, this source produces a pulse of Vhigh volts when the timer has been triggered by its input expression. Once the timer is reset back to 0V, the pulse will return to its Vlow voltage value.

To demonstrate the basic operation of the retriggerable monostable multivibrator macro, a transient analysis is run. The input of the macro is connected to two voltage sources in series that have been defined as:

Pulse 0 5 100n 1n 1n 20n 300n

and

Pulse 0 5 330n 1n 1n 20n 700n

These sources produce a series of 5V pulses that will offset in time in order to test the retriggering capability of the macro. The monostable macro has its parameters defined as:

PWIDTH=150ns
VLOW=0
VHIGH=5
THRESH=3

The resulting transient analysis is shown in the figure below. The top plot displays the series of pulses at the input of the macro. The bottom plot displays the output of the retriggerable mono-stable multivibrator. As can be seen in the plot, a single pulse at the input produces a 5V output pulse of 150ns. When the input is retriggered such as at .4us, the output pulse is extended for an additional 150ns from the retriggering point.
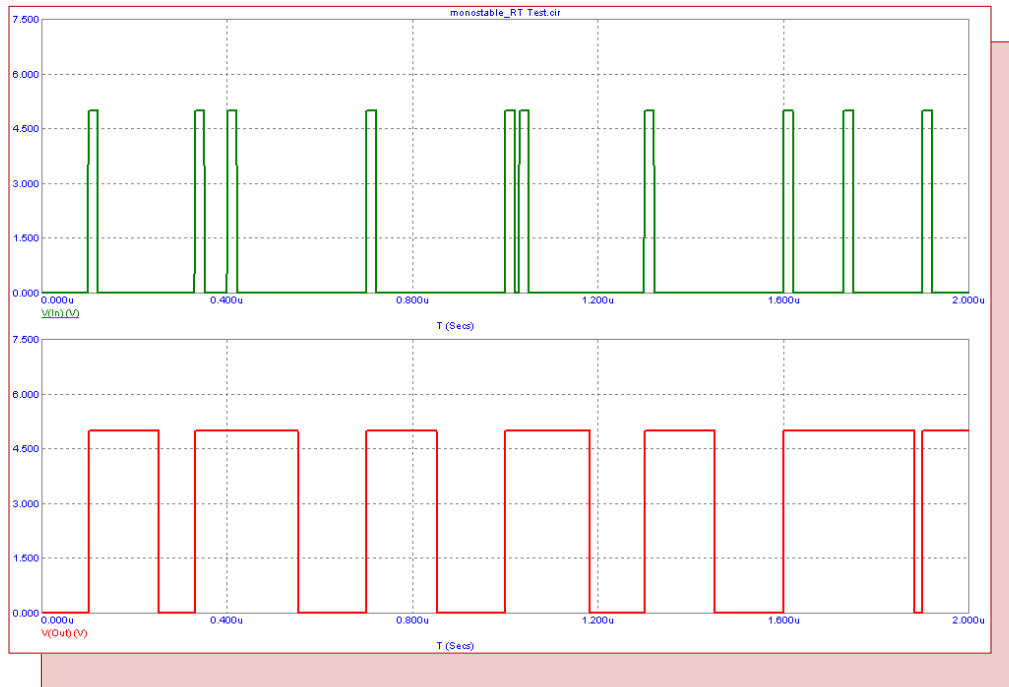
Fig. 11 - Retriggerable monostable multivibrator transient analysis

Note that when running this macro in a transient simulation, make sure that the Maximum Time Step in the Transient Analysis Limits dialog box is set so that it can appropriately sample the Reset pulse. The Reset pulse width is set to be 1/20th of the specified pulse width (PWIDTH). In the example above, the PWIDTH parameter was set to 150ns. The reset pulse within the macro would then have a width of 7.5ns. In order to sample this reset pulse adequately, the Maximum Time Step should be set to a value of 5ns or lower. If the Maximum Time Step is too large, the simulator may step over the entire width of the reset pulse with the result that the macro is never reset and the output pulse stays high.

VCO with Square Wave Output Macro

A voltage controlled oscillator produces a periodic signal at its output. The frequency of this output signal is determined by the value of the voltage at the input to the VCO. For most VCOs, the typical output is a sinusoidal waveform, however, other types of outputs such as a square wave, sawtooth, or triangle wave output may also be needed. This article describes a VCO macro that produces a square wave at its output. The macro circuit is shown below.

Fig. 12 - VCO macro with a square wave output

The square wave VCO macro has four input parameters: VH, VL, F0, and KF. The VH parameter defines the high voltage value of the output square wave. The VL parameter defines the low voltage value of the output square wave. The F0 parameter defines the center frequency of the VCO macro when the input voltage to the macro is 0V. The KF parameter defines the frequency sensitivity to the input voltage in units of Hz/Volt.

The input of the macro is at node In. The integral of the input voltage is produced at node VMOD through the use of the IofV source and 1F capacitor. The 1E6 ohm resistor is used as a voltage limiting resistor in order to keep the output voltage finite. The reason for the integrator is that the frequency of a sine wave is actually the derivative of the sine argument, so the input voltage needs to be integrated to properly modulate the frequency. The NFV source at node SineOut produces a sine wave that has been correctly modulated by the input voltage and the F0 and KF parameters. The source has been defined with the expression:

COS(2*PI*(F0*T+KF*V(VMOD)))

The waveform at the node SineOut is the traditional VCO sine wave output. Since this macro is to produce a square wave output, the sine wave needs to be converted into an equivalent square wave. The E1 NFV source at the output of the macro performs this conversion and is defined with the expression:

DC+Va*tanh(10k*(v(SineOut)))

The Tanh function is the hyperbolic tangent function whose output is limited between the values of 1 and -1. The argument to the Tanh function is 10k*(V(SineOut)). Since the 10k gain is so high, the Tanh function quickly transitions between its 1 and -1 limits which converts the sine wave to a square wave. There are a number of methods that could have been used to convert the sine wave to a square wave, but the Tanh function was selected as it provides a smooth transition that greatly aids convergence. The Va and DC parameters are used to scale and shift the output of the Tanh function so that it will match the values specified for the VH and VL parameters. The DC and Va parameters have been specified in the following define statements:

.define Va (Vh-Vl)/2
.define DC (Vh+Vl)/2

The output of this VCO macro is then a square wave whose high voltage is set at VH and whose low voltage is set at VL.

A simple test circuit is setup to test the macro. A Voltage Source is placed at the input of the VCO macro. The source is defined as a PWL type with the following specification:

PWL 0,1 .2u,1 .7u,4 .9u,4 1u,1 1.2u,1 1.7u,4 1.9u,4 2u,1

This creates a simple pulse waveform from 1V to 4V with a relatively long rise time in order to view the effects of a changing input voltage on the VCO macro output frequency. The parameters of the VCO macro are set to:

VH=5
VL=0
F0=10Meg
KF=10Meg

The square wave output of the VCO will go from 0V to 5V. When the input to the macro is 0V, the square wave output frequency will be 10MHz as specified by the F0 parameter. For each 1V change in the input voltage, the frequency of the square wave output will change by 10MHz as specified by the KF parameter. The resulting transient analysis is shown in Figure 13.

The top waveform is the voltage produced by the PWL voltage source at the input of the VCO macro.

The bottom waveform is the output of the square wave VCO. When the input voltage is at 1V, the output frequency will be at 20MHz since the frequency is calculated as F0 + Vin*KF. When the input voltage is at 4V, the output frequency is at 50MHz as expected. Two performance tags have been placed in the bottom plot to measure the frequency of the waveform at the 1st and 25th instance of the waveform. The performance tags use the following performance functions:

Frequency(V(Out),1,1)
Frequency(V(Out),1,25)

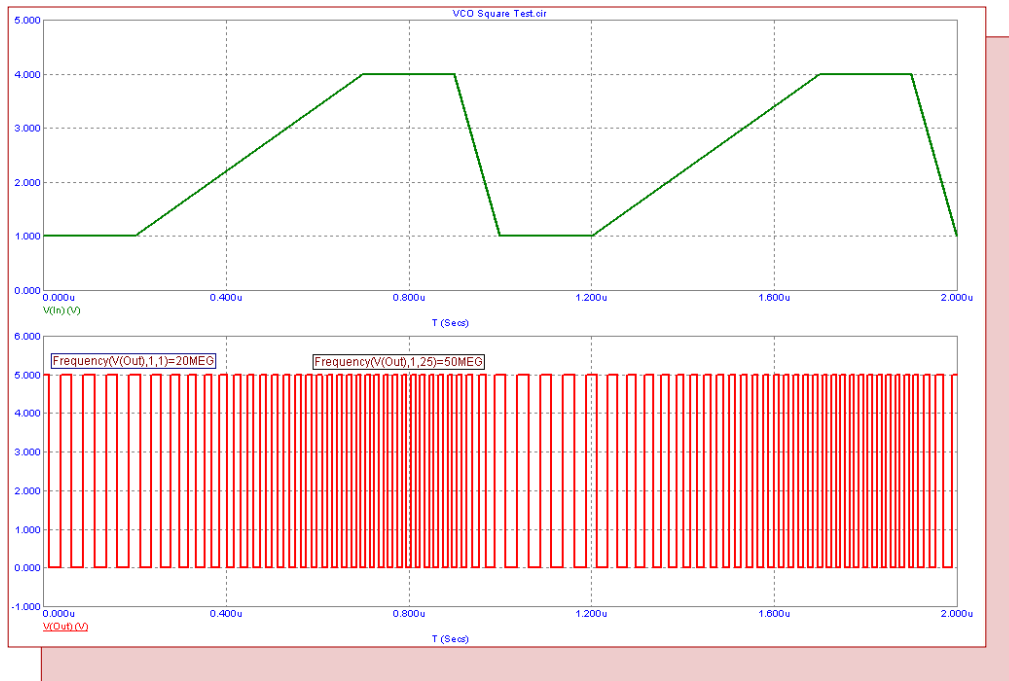These two tags confirm the expected frequencies of the output waveform.

Fig. 13 - VCO square wave output transient analysis

Product Sheet

Latest Version numbers

Micro-Cap 10 ....Version 10.0.0
Micro-Cap 9 ....Version 9.0.7
Micro-Cap 8 ....Version 8.1.3
Micro-Cap 7 ....Version 7.2.4

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