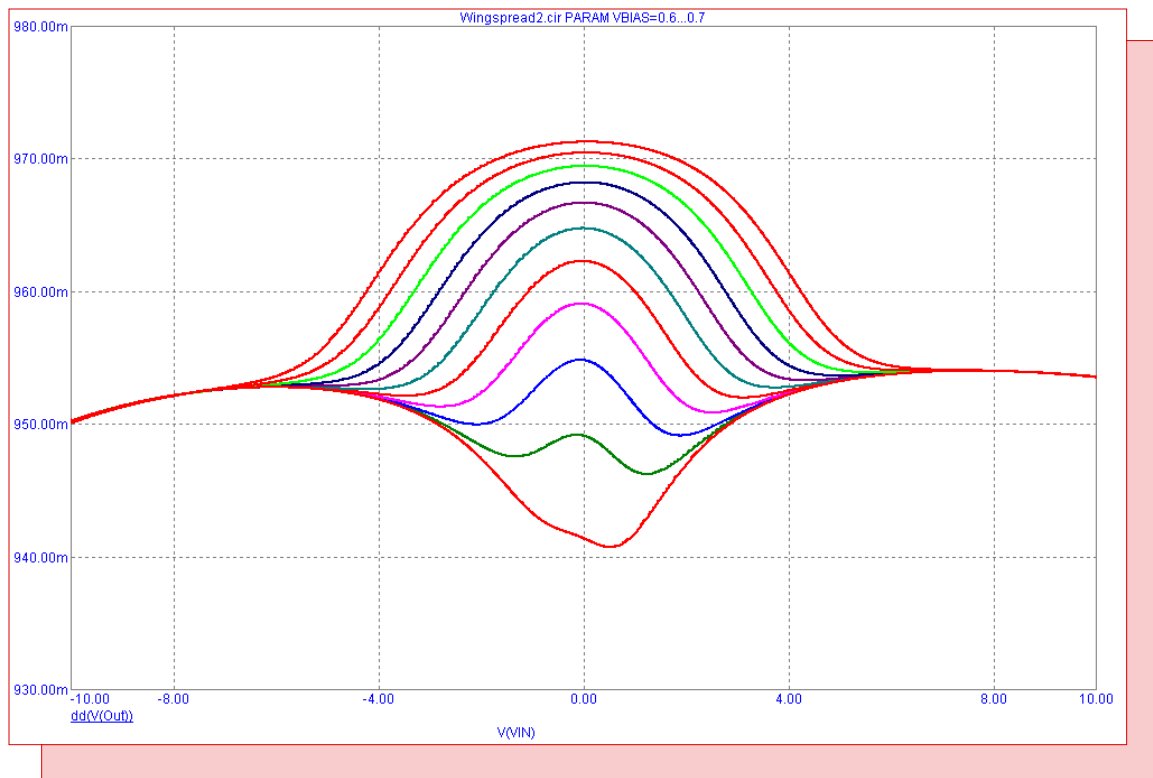


## Fall 2011

## News



## Creating Wingspread Plots

Featuring:

- Creating Wingspread Plots
- Importing and Exporting WAV Files
- Comb Filter Macro

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## News In Preview

This newsletter's Q and A section describes why the number of data points in a transient simulation may be reduced at the end of the run. The Easily Overlooked Feature section describes the cursor variables which can be used within analysis text formulas to include the X or Y values of the cursors in an expression.

The first article describes how to create wingspread plots to simulate crossover distortion in a DC analysis run.

The second article describes how to import a WAV audio file and use it as a voltage source input. It also describes how to take the output of a circuit and convert that to a WAV file to be able to listen to the simulation results.

The third article describes a comb filter macro which adds a delayed version of a signal to itself in order to cause either constructive or destructive interference to the signal.

## Contents

News In Preview .....	2
Book Recommendations .....	3
Micro-Cap Questions and Answers .....	4
Easily Overlooked Features .....	5
Creating Wingspread Plots .....	6
Importing and Exporting WAV Files.....	8
Comb Filter Macro .....	11
Product Sheet.....	16

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## 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 Elektronické Obvody*, Dalibor Bielek, 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.

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## Micro-Cap Questions and Answers

**Question:** I am running a transient simulation for 10ms. The Maximum Time Step has been set to 1us so I expect to get a minimum of ten thousand data points in the plot. While the simulation is running, the expected number of data points seems to be present, but once the simulation is finished, Micro-Cap reduces the number of available data points. Why are the data points being reduced?

**Answer:** There are two possible reasons for the data point reduction.

1) The Reduce Data Points settings have been modified:

Under the Transient menu, there is a Reduce Data Points command. This command controls the number of data points that are retained at the end of the simulation. The default setting is to keep all data points that have been calculated. In order to keep all available data points, both the Save and Display fields should be set to 1st.

2) A waveform using a Fourier function is being plotted:

If one of the waveforms specified in the Transient Analysis Limits dialog box uses a Fourier function (HARM, FFT, THD, IHD, etc), all of the waveforms will be resampled at the end of the simulation so that the Fourier functions can be processed.

For the Fourier calculations, the number of data points that the waveforms will be resampled to is set in the FFT page of the Analysis Properties dialog box. The Number of Points field in this page controls the number of sampled data points, and the value set in this field must be a power of 2. If no Fourier waveforms are being plotted, the settings in this page are ignored.

The FFT Window can be used to create a Fourier waveform which will not resample all of the waveforms specified in the analysis limits. The FFT Window can plot the basic Fourier functions such as the harmonics, the real and imaginary portions of the FFT, the total harmonic distortion, the individual harmonic distortion, and the FFT phase. An FFT Window can be created through the Transient / FFT Windows / Add FFT Window command or by right clicking on the expression string in the plot window and selecting Add FFT Window in the popup menu.

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## 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.

### Cursor Variables

The cursor variables are variables that display the X and Y values of the current locations of the two cursors in a plot window. The variables available are:

CursorRX: This variable displays the current X location of the right cursor.

CursorRY: This variable displays the current Y location of the right cursor.

CursorLX: This variable displays the current X location of the left cursor.

CursorLY: This variable displays the current Y location of the left cursor.

These variables can be used within analysis text to create formulas that are dependent on the position of the cursors. Analysis formula text can be created by enabling the Formula option in the Text dialog box. An expression within the specified delimiters will be evaluated and its value placed in the plot in place of the expression string. In the following examples, the formula delimiters are the square brackets, [ ].

Width = [CursorRX - CursorLX]

This expression would display the X distance between the two cursors.

Peak to Peak = [CursorLY - CursorRY]

This expression would display the Y distance between the two cursors.

Slope = [(CursorRY - CursorLY) / (CursorRX - CursorLX)]

This expression would display the slope of a line between the two cursors.

Of course, the usefulness of the calculated results will depend on the user placing the cursors in the appropriate positions. The analysis formula text will be updated each time the cursor is moved.

When the simulation has finished, the initial placements of the cursors will have the left cursor at the first data point of the simulation, and the right cursor at the last data point of the simulation. Any analysis formula text that uses the cursor variables will use the values at these two points even before Cursor mode has been activated.

## Creating Wingspread Plots

The wingspread plot is a type of plot used to display the large signal linearity of an output stage. It derives its name from the fact that the waveform plotted looks similar to the look of a simple drawing of a bird. It is typically used in audio amplifier design and is quite useful in simulating the crossover distortion. The wingspread plot helps in determining the optimal quiescent conditions that should be used in order to minimize the gain deviations around the crossover point for a specific load resistance. The following example uses a technique to simulate wingspread plots that is described in Bob Cordell's book " Designing Audio Power Amplifiers".

The circuit below is a class AB output stage. It uses a complementary pair of transistors from ON Semiconductor: the NJW3281G NPN transistor and the NJW1302G PNP transistor. The Vin battery defines the input voltage to the stage. The Vbiasp and Vbiasn batteries bias the output stage and set the quiescent bias current for the circuit. Both of the batteries have their VALUE attribute set as Vbias whose value is specified by the following define statement:

```
.define Vbias .7
```

The class AB output stage is powered by +/- 12V power supplies and is driving an 8 ohm load resistance.

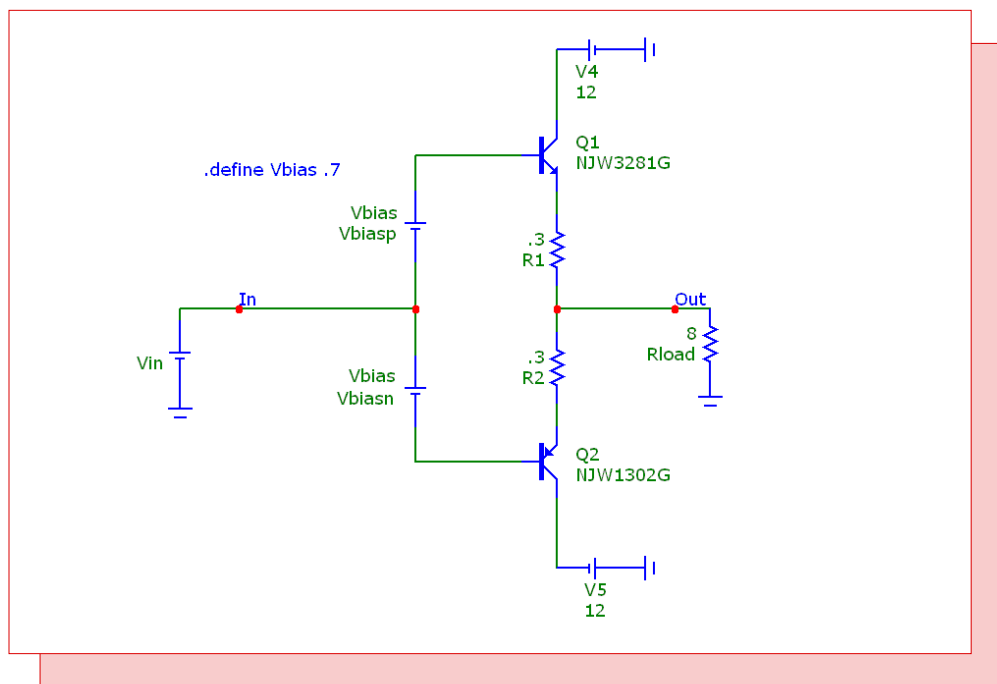


Fig. 1 - Class AB output stage

The wingspread plots are created in DC analysis. The input voltage is swept over a range of -10V to 10V in steps of 10mV. In the DC Analysis Limits, the Variable 1 fields are set to the following:

Method: Linear  
Name: Vin  
Range: 10,-10,.01

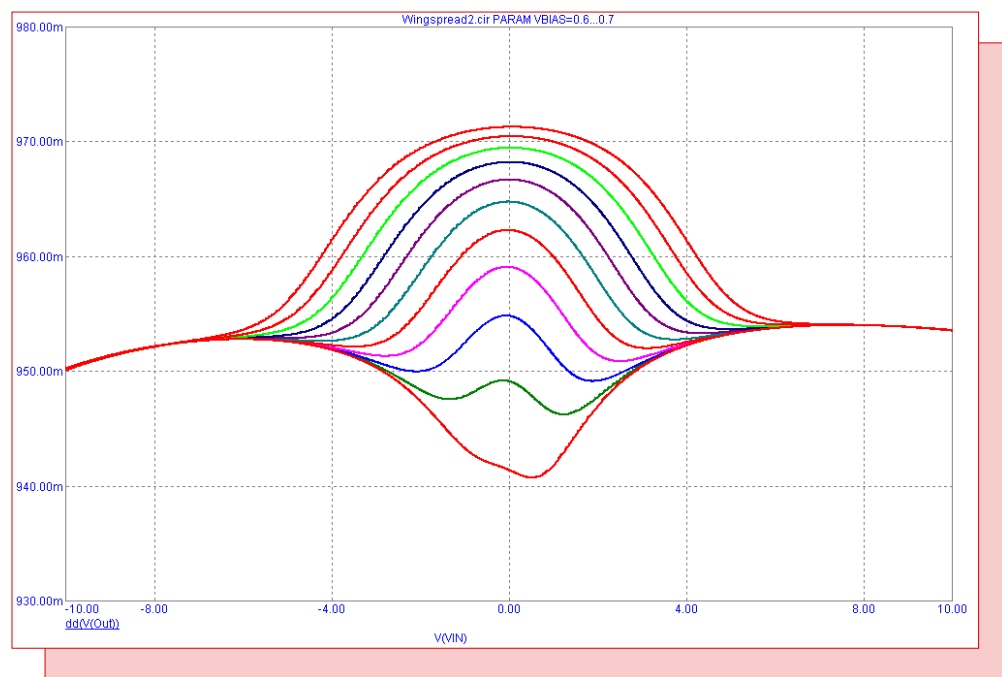
Sweeping the input voltage will create a single wingspread waveform. In most cases, it is useful to view a range of these waveforms by stepping the bias conditions of the circuit in order to determine the appropriate bias condition. For this circuit, stepping the Vbias parameter from .6V to .7V in steps of 10mV creates a nice set of waveforms. In the DC Analysis Limits, the Vbias parameter is stepped by setting the Variable 2 fields to the following:

Method: Linear  
Name: Param VBias  
Range: .7,.6,.01

The gain of the output stage can be plotted by using an expression that takes the derivative of the output voltage with respect to the input voltage. The expression:

$dd(V(\text{Out}))$

will produce the desired output. The  $dd()$  operator calculates the numerical derivative of the specified expression with respect to the parameter being swept in the Variable 1 field which in this case is the input voltage. When the simulation is run, the following wingspread plot is created.



*Fig. 2 - Wingspread plot*

As can be seen in the plot, small changes in the bias can create quite a bit of crossover distortion in the output gain. The optimal bias for this particular circuit appears to be at around .62V

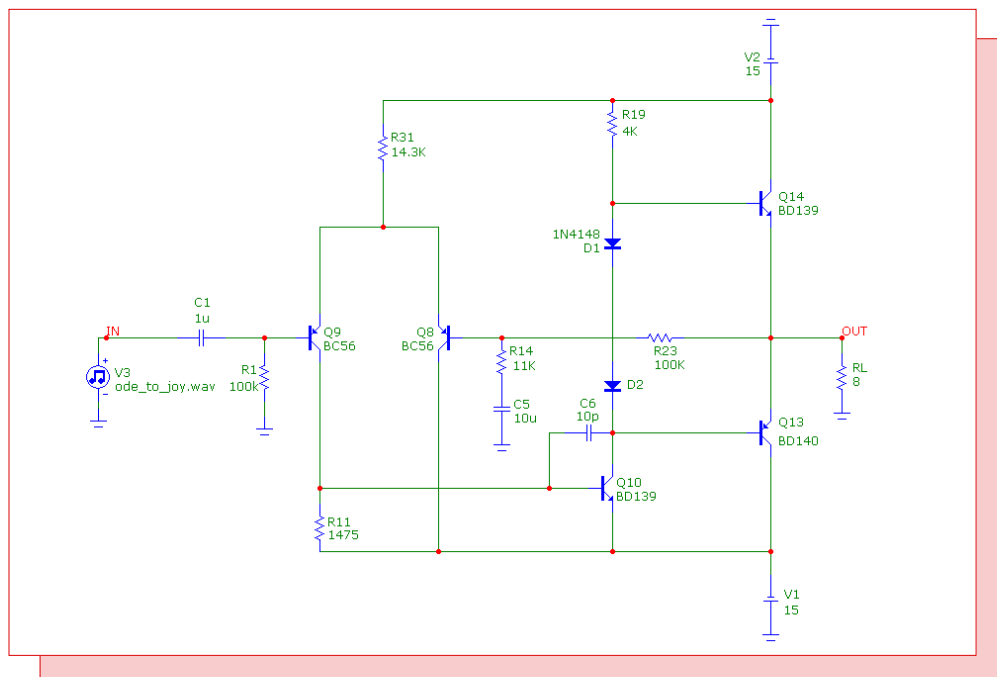
References:

- 1) Designing Audio Power Amplifiers, Bob Cordell, McGraw Hill, ISBN 978-0-07-164024-3

## Importing and Exporting WAV Files

The Waveform Audio File Format (WAV file) is one of the most common file formats for storing uncompressed audio data in. Micro-Cap has the capability to import this type of file as a voltage source input in a schematic and also to export a plotted waveform to this audio format. Essentially, the input and output of a transient simulation can be an audio file. For example, a user can input a WAV file into an audio amplifier schematic, and then listen to the output of the amplifier.

To demonstrate these capabilities, the WAVSource.cir file that is distributed with Micro-Cap 10 will be used. The schematic is shown in the figure below. The circuit is a basic audio amplifier (Ref 1). The Q8 and Q9 transistors create the differential amplifier input stage. The Q10 transistor operates as the gain stage with a common emitter amplifier configuration. Finally, the Q13 and Q14 transistors operate as a push-pull output buffer stage. The input to this circuit is the V3 voltage source. This source is the WAV File Source that is available in the Analog Primitives / Waveform Sources section of the Component menu.



*Fig. 3 - WAV file example circuit*

The WAV File Source is the source that will import a WAV file to define the resulting voltage waveform. This source has the following attributes:

**FILE:** This attribute specifies the WAV file name and path that will be imported. For this example, the file specified is called `Ode_to_Joy.wav`. This file contains a portion of Ludwig van Beethoven's song Ode to Joy from his Ninth Symphony.

**CHANNEL:** A WAV file can contain multiple channels. The number of channels can be as high as 65536 but a typical WAV file will often have just 2. A WAV File source can only import one channel. This attribute determines which channel the source will import. The first channel is specified by the value 0.

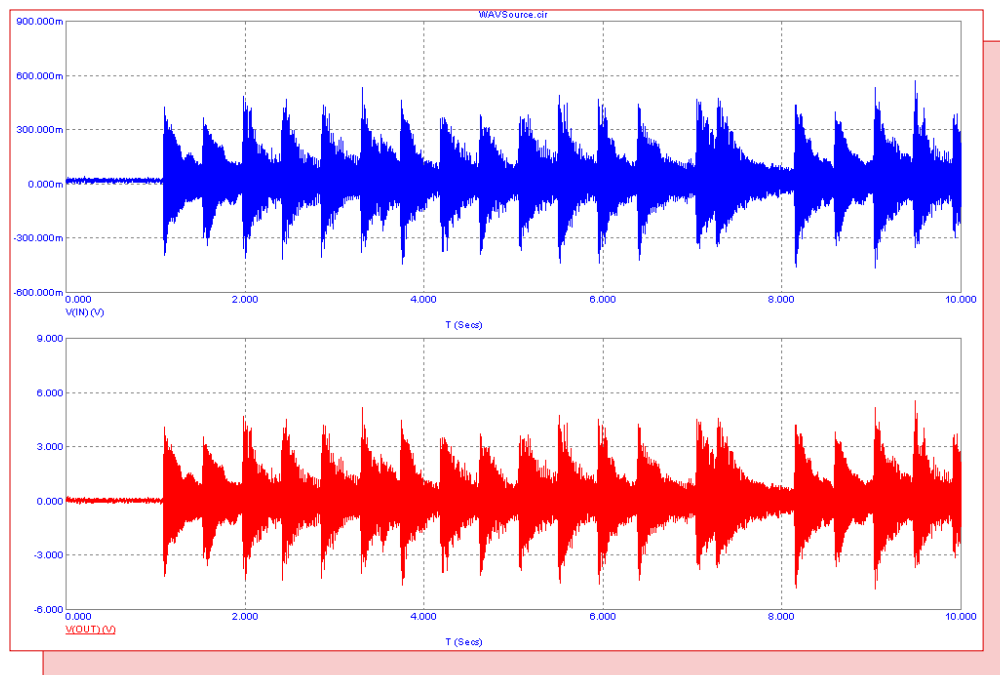


**SCALE:** The WAV file data will be converted into a voltage waveform with a range of 1V to -1V. This attribute lets you scale the data to a different range.

**REPEAT:** This attribute determines the number of times that the WAV file data will be repeated during the transient simulation.

**ENABLE\_EXPR:** This attribute defines a trigger expression that will initiate the waveform. The expression should be a boolean or conditional expression. When the expression evaluates to True, the waveform will start playing. For example, if the waveform was to be delayed for 1s at the beginning of the simulation, the expression  $T > 1$  could be used which evaluates to True when the simulation time is greater than 1s. The default value for this attribute is 1 which always evaluates to True.

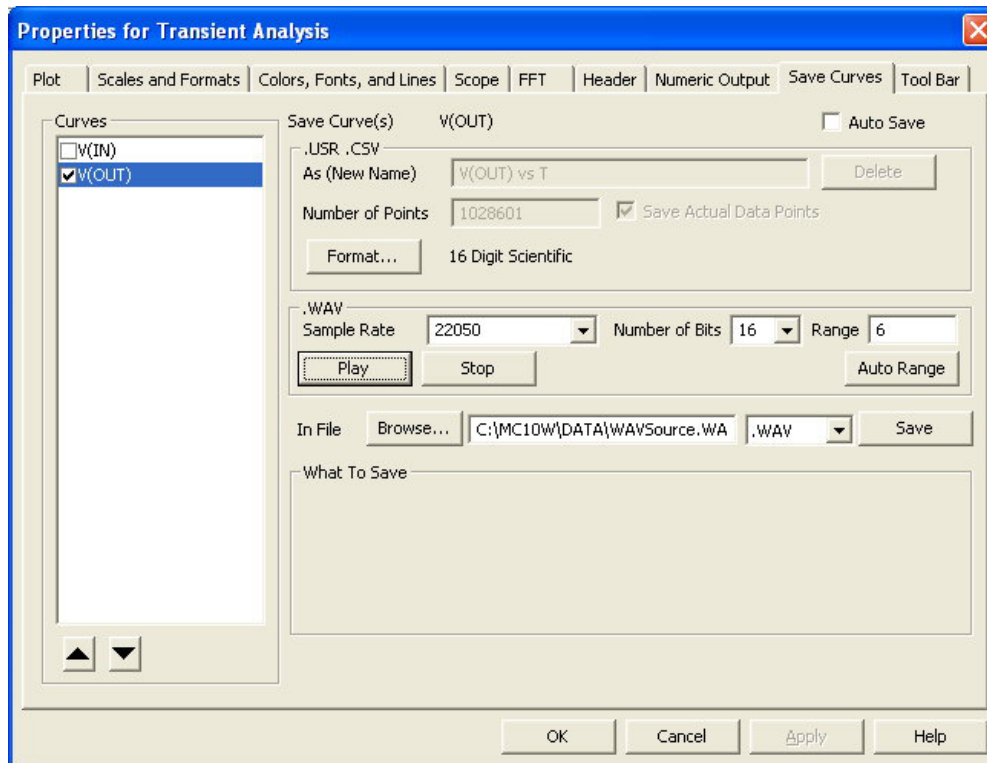
The resulting transient analysis for this circuit is shown in the figure below. The simulation time was set to 10s to get a good sampling of the music. The top plot shows the voltage waveform produced by the WAV File source. The bottom plot shows the output voltage waveform of the audio amplifier circuit.



*Fig. 4 - Audio amplifier input and output waveforms*

The output waveform looks like a good reproduction of the input waveform with a gain of approximately 20dB. At this point, the output voltage waveform can be saved to a WAV file in order to listen to the output in order to notice any possible issues such as audible distortion.

The Save Curves page within the Analysis Properties dialog box controls the settings for producing files from one or more plotted waveforms. The three file formats available to create from this page are the Micro-Cap User Source files, Comma Separated Value (CSV) files, and WAV files. The Save Curves page is shown in Figure 5.



*Fig. 5 - Save Curves page in the Properties dialog box*

The list on the left hand side of the dialog box displays all of the waveforms that are available to be saved to a file. Clicking on the box next to the waveform name enables or disables the waveform for the file.

For the WAV file, the .WAV section sets the format that will be used within the file. The Sample Rate field controls the number of samples per second from the enabled waveforms that will be stored in the file. The list for this field displays the commonly used sample rates for a WAV file, but the user can also type in their own custom sampling rate directly in the field. The Number of Bits field controls the amount of bits used for each sampled data. The options are 8, 16, 24, and 32 bits. The Range field sets the amplitude range that will be used to create the WAV data. In this example, the Range is set to 6 to ensure that all of the values from the V(Out) waveform are stored in the WAV file without being clipped. If the Range was set to 1 for this waveform, any voltage value above 1 or below -1 would be clipped to the maximum value in the WAV file, and the resulting audio file would have a lot of distortion. The Auto Range button scans the enabled waveforms and places the largest value of the waveform in the field. The Play button lets you hear the WAV results without actually having to write the WAV file. The Stop button stops the WAV sample that is currently being played.

The In File section sets the file name and file type that is to be saved. For a WAV file, select .WAV from the extension list. The Save button needs to be clicked to actually save the file to the hard drive. In the upper right corner of the page is an Auto Save checkbox. When this is enabled, the file will automatically be created at the end of each simulation using the specified settings.

#### References:

- 1) "Basic Audio Amplifier", eCircuit Center, [http://www.ecircuitcenter.com/Circuits\\_Audio\\_Amp/Basic\\_Amplifier/Basic\\_Audio\\_Amplifier.htm](http://www.ecircuitcenter.com/Circuits_Audio_Amp/Basic_Amplifier/Basic_Audio_Amplifier.htm)

## Comb Filter Macro

A comb filter adds a delayed version of a signal to itself in order to cause either constructive or destructive interference to the signal. Comb filters are used in a number of signal processing applications such as CIC filters, television decoders, and audio effects. There are two main types of comb filters: feed forward comb filters and feedback comb filters. The feed forward comb filter adds a delayed version of the input signal to itself and is represented by the equation:

$$y(t) = x(t) + b * x(t - \tau)$$

where  $b$  scales the delayed waveform and  $\tau$  is the delay in seconds. The feedback comb filter adds a delayed version of the output signal of the filter to the input signal and is represented by the equation:

$$y(t) = x(t) + b * y(t - \tau)$$

Both of these comb filter types can be easily modeled in Micro-Cap using three macro components that are available in the program.

The figure below shows the circuit configuration for a feed forward comb filter. The circuit consists of a Delay macro, an Amp macro, and a Sum macro. The Delay macro provides the delay on the input signal to the macro and models the  $\tau$  variable in the first equation above. The Delay parameter in the macro delays the input to the macro by a specified value in seconds. The output of the Delay macro is then fed into the input of an Amp macro. The Amp macro simply scales the input to the macro by a constant specified in the Gain parameter. This macro models the  $b$  variable in the feed forward equation. Finally, this delayed, scaled waveform is then summed with the original input waveform by the Sum macro completing the model of the feed forward equation.

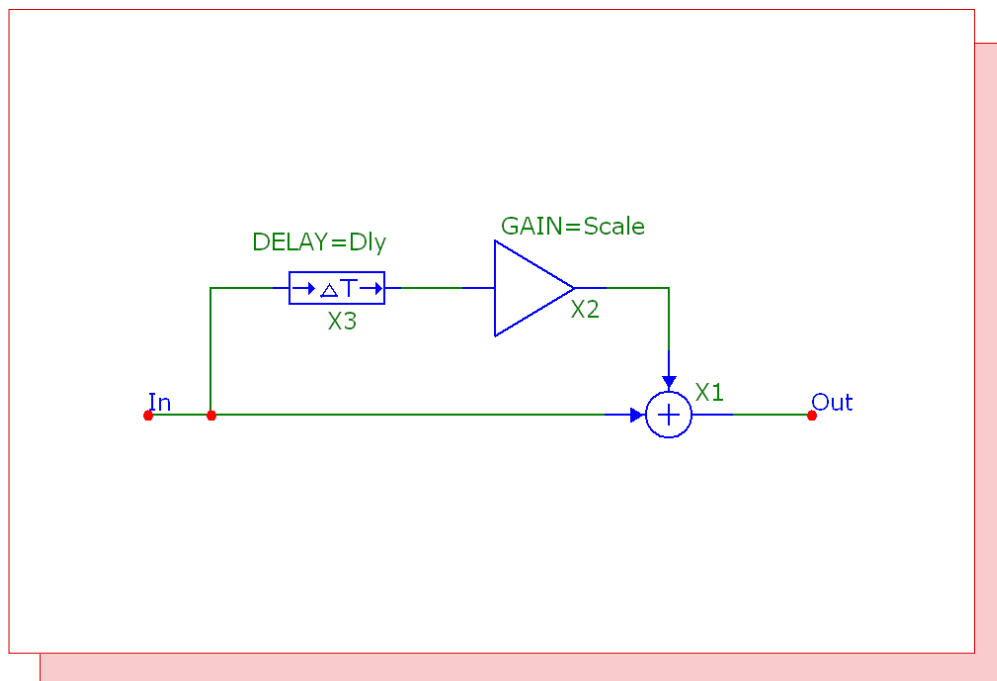


Fig. 6 - Feed forward comb filter

The feedback comb filter uses the exact same components but with a different configuration. The feedback comb filter appears in the figure below. For this type, the Delay and Amp macros delay and scale the output signal of the filter. This modified signal is then summed with the input signal to the filter to complete the feedback equation.

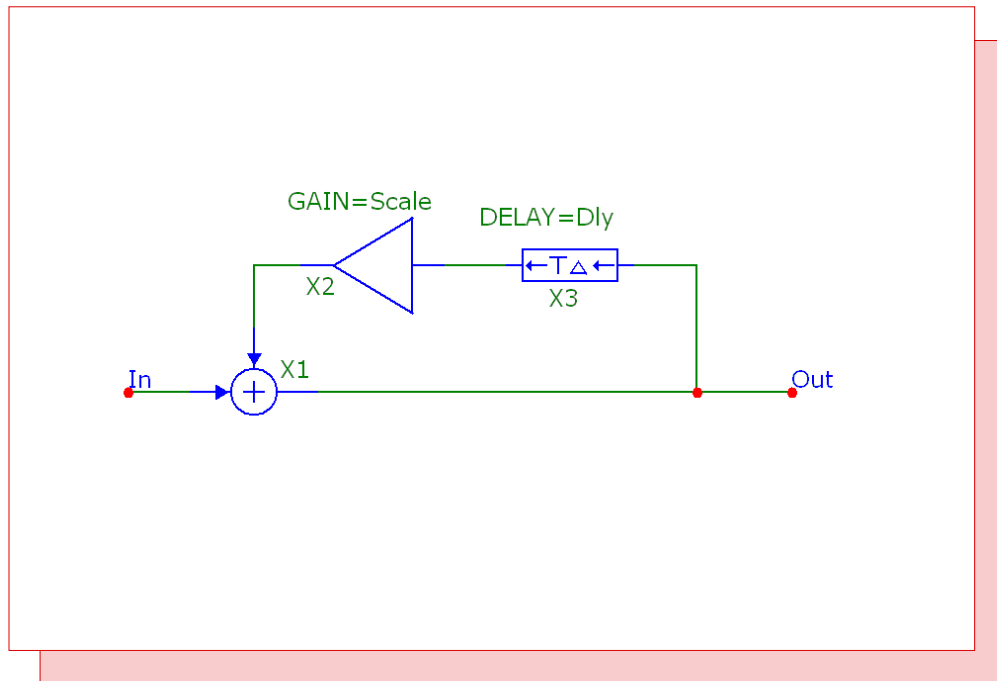


Fig. 7 - Feedback comb filter

In order to make the comb filter easier to implement in a circuit, a macro circuit was created that can simulate either the feed forward comb filter or the feedback comb filter. The macro circuit appears in Figure 8.

The comb filter macro circuit has three parameters. The Scale parameter sets the value that the delayed signal will be scaled by. The Dly parameter sets the time in seconds that the signal will be delayed. The Type parameter determines whether the feed forward or feedback type will be used. When the Type parameter is set to 1, the feed forward comb filter will be used, and when the Type parameter is set to 2, the feedback comb filter will be used.

The circuit uses a combination of both of the previous circuit configurations. The Scale parameter plugs in directly to the Gain parameter of the Amp macros. The Dly parameter plugs in directly to the Delay parameter of the Delay macros. The macro circuit then uses the enable region capability to switch between the feed forward type and the feedback type. An enable region uses a boolean expression to determine whether the circuitry within the region will be enabled for a simulation. When the expression evaluates to True, then the circuitry will be enabled, and when the expression evaluates to False, then the circuitry will be disabled. In this macro, an enable region has been drawn around each of the Delay and Amp pairs. For the feed forward Delay and Amp pair, the enable region has been defined with the following expression:

Type < 1.5

When the Type parameter is below 1.5, the circuitry within the region will be enabled. For the feedback Delay and Amp pair, the enable region has been defined with the following expression:

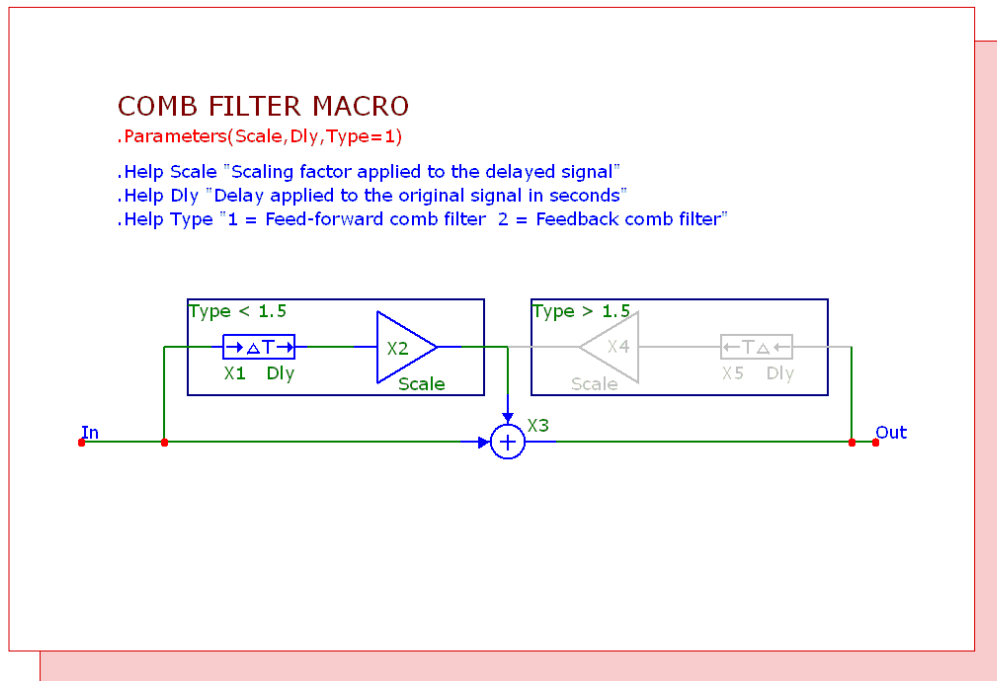


Fig. 8 - Comb filter macro

Type > 1.5

When the Type parameter is above 1.5, the circuitry within the region will be enabled. Changing the Type parameter between 1 and 2 when using the macro in a circuit just switches between the two configurations.

To see the frequency response of the comb filter, an AC analysis was run on a simple example circuit that just has a voltage source at the input of the comb filter macro. The analysis plot in Figure 9 displays the frequency response of the feed forward comb filter where the macro parameters are set to:

Type = 1  
 Dly = 200n  
 Scale = Scale

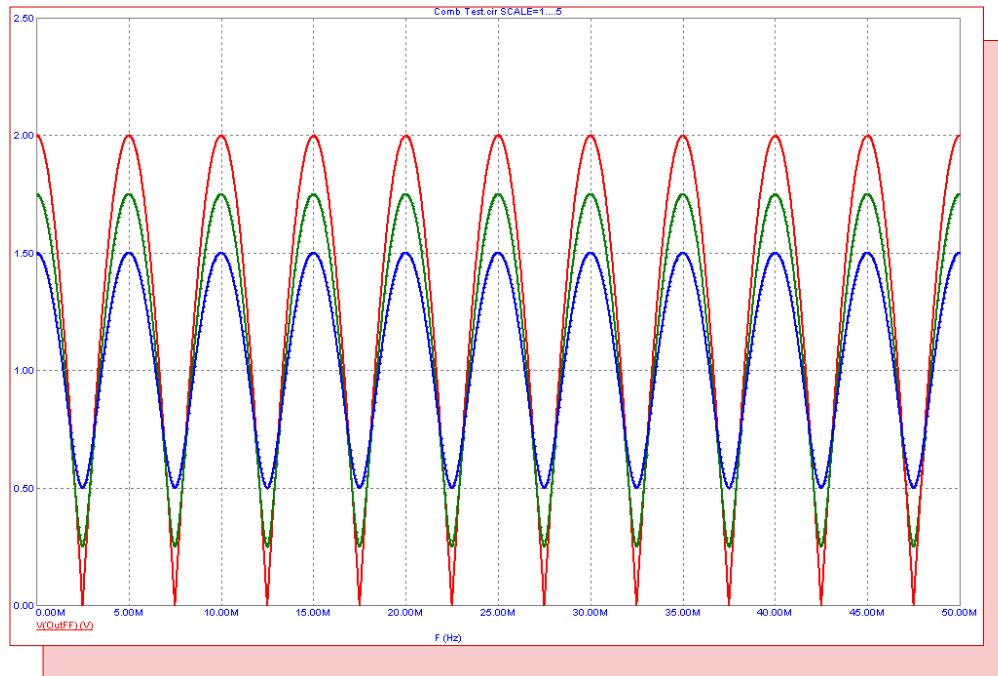
where the Scale variable is set by a define statement. In the AC analysis, the Scale variable is then stepped through the values 1, .75, and .5. When the scale value is positive, the local maximums in the frequency response occur at:

0, 1/Dly, 2/Dly, 3/Dly, ...

and the local minimums occur at:

1/(2\*Dly), 3/(2\*Dly), 5/(2\*Dly), ...

With the Dly value set to 200ns, the local maximums occur at the expected 0Hz, 5MHz, 10MHz, 15MHz, etc, and the local minimums occur at the expected 2.5MHz, 7.5MHz, 12.5MHz, etc. If the Scale value is set to a negative number, then the maximum and minimum frequencies are swapped.

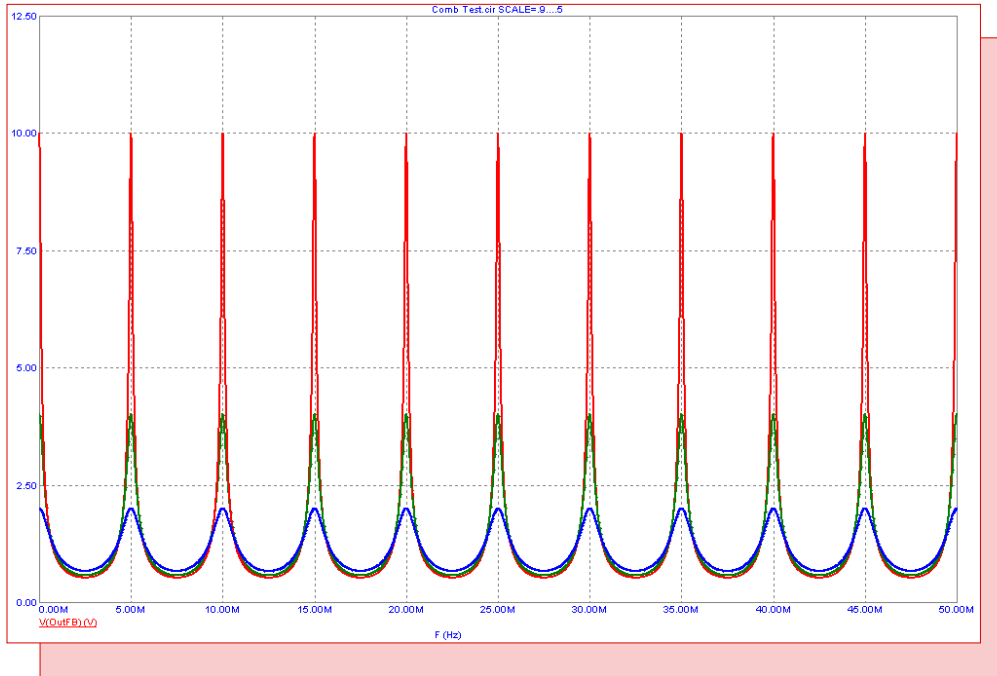


*Fig. 9 - Feed forward comb filter frequency response*

The analysis plot in Figure 10 displays the frequency response of the feedback comb filter. In this case, the macro parameters are set to:

Type = 2  
 Dly = 200n  
 Scale = Scale

In the AC analysis, the Scale variable is then stepped through the values .9, .75, and .5. For the feedback type, the comb filter is only stable when the absolute value of the scale factor is less than 1. The local maximum and local minimum frequencies are calculated in the same manner as the feed forward type.



*Fig. 10 - Feedback comb filter frequency response*

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## Product Sheet

### Latest Version numbers

Micro-Cap 10 .....Version 10.0.6  
Micro-Cap 9 .....Version 9.0.8  
Micro-Cap 8 .....Version 8.1.3  
Micro-Cap 7 .....Version 7.2.4

### Spectrum's numbers

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