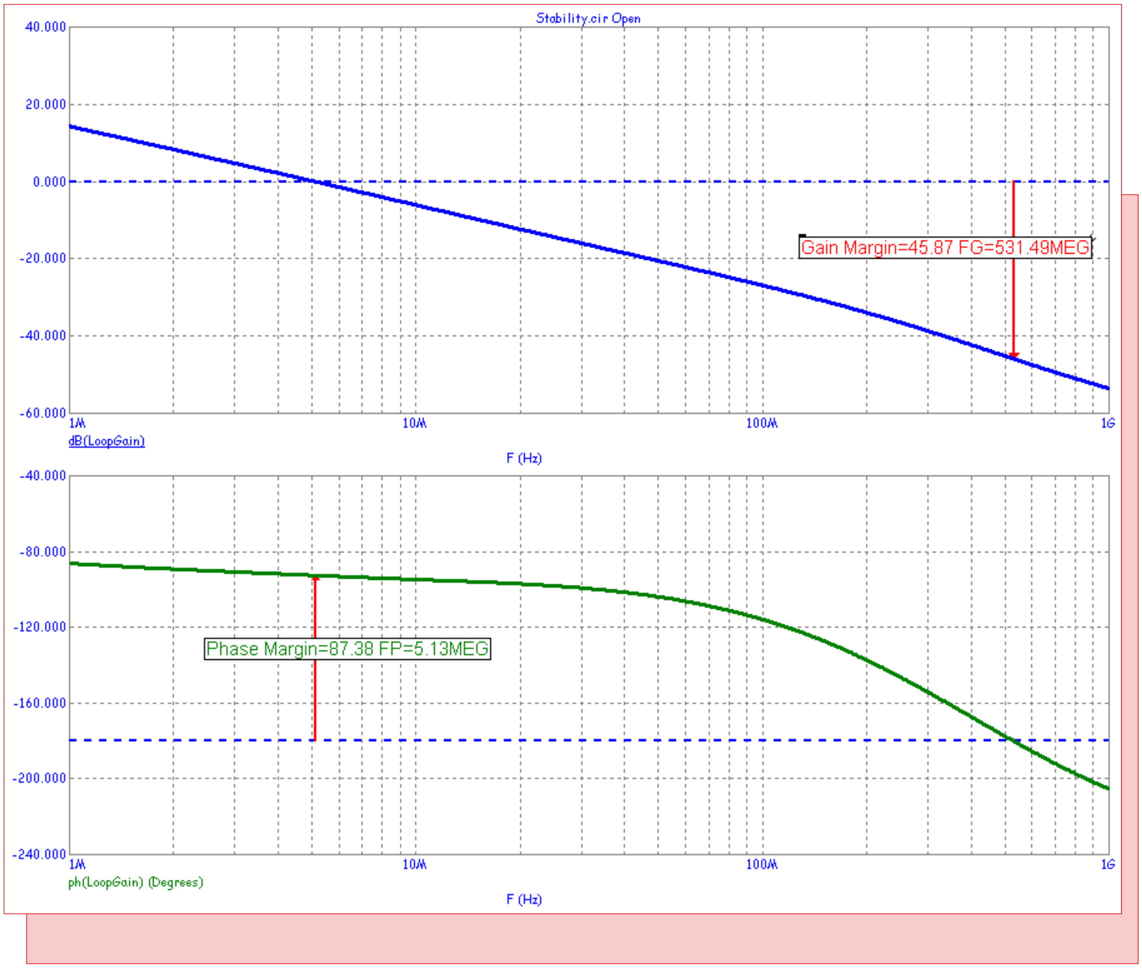
spectrum news

Applications for Micro-Cap™ Users

Fall 2013

Introducing Micro-Cap 11



Stability Analysis Plot

Featuring:

- Worst Case Analysis
- Stability Analysis
- .Measure Commands
- Fourier Window Functions

News In Preview

This newsletter's Q and A section describes how to create a three-phase sinusoidal source for use in power simulations.

The first article describes the Worst Case analysis feature of Micro-Cap 11. This type of analysis assesses a circuit's performance limits over initial and lifetime exposure tolerances.

The second article describes the Stability Analysis feature of Micro-Cap 11. This analysis mode computes gain margin and phase margin as a measure of stability.

The third article describes the .Measure command set that is available in Micro-Cap 11. Measure commands let you estimate important performance characteristics of your circuit.

The third article describes the new Fourier windowing functions and shows how they may be used to extract closely spaced signals.

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

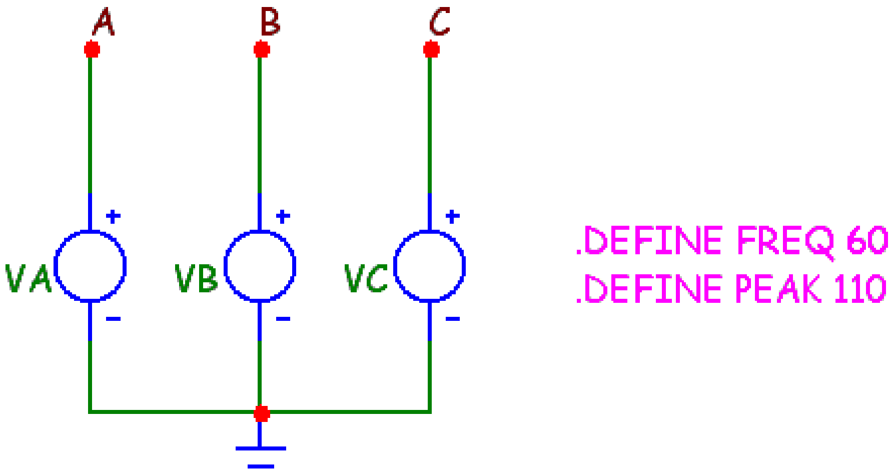
- *SMPS Simulation with SPICE 3,* Steven M. Sandler, McGraw Hill, 1997. ISBN# 0-07-913227-8

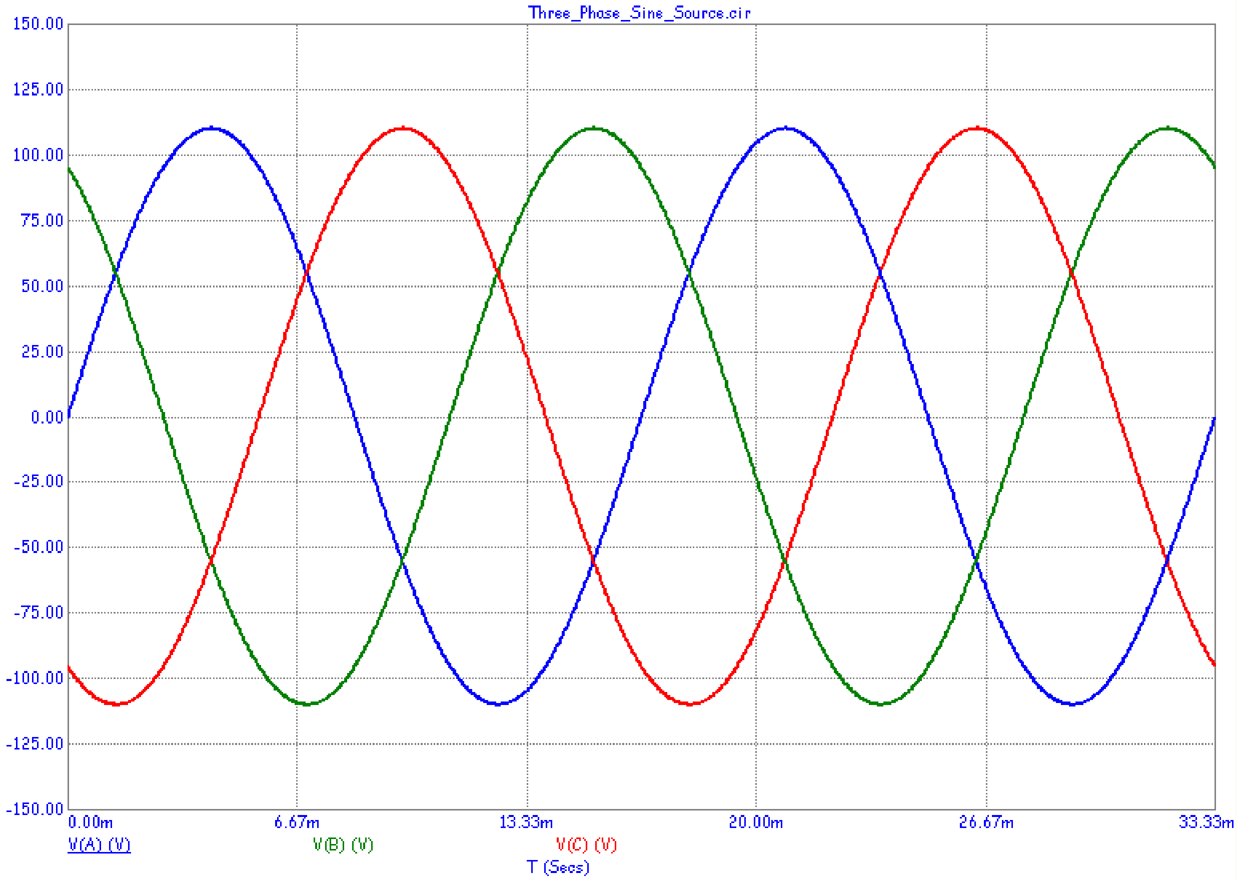
- *Switch-Mode Power Supplies Spice Simulations and Practical Designs*, Christophe Basso, McGraw-Hill 2008. This book describes many of the SMPS models supplied with Micro-Cap.

Micro-Cap Questions and Answers

Question: I am trying to create a three-phase source for use in my simulations. I can't find such a source in the library. How can I do this?

Answer: On the Component menu select Analog Primitives / Waveform Sources / Voltage Source. Place three of these in your circuit. Ground the three negative sides. Double-click on each source and assign your preferred amplitude. Assign a phase of 0 to the first, 120 to the second, and 240 to the third. Phase is in degrees. That's all there is to it. Here is what the circuit and its simulation looks like:

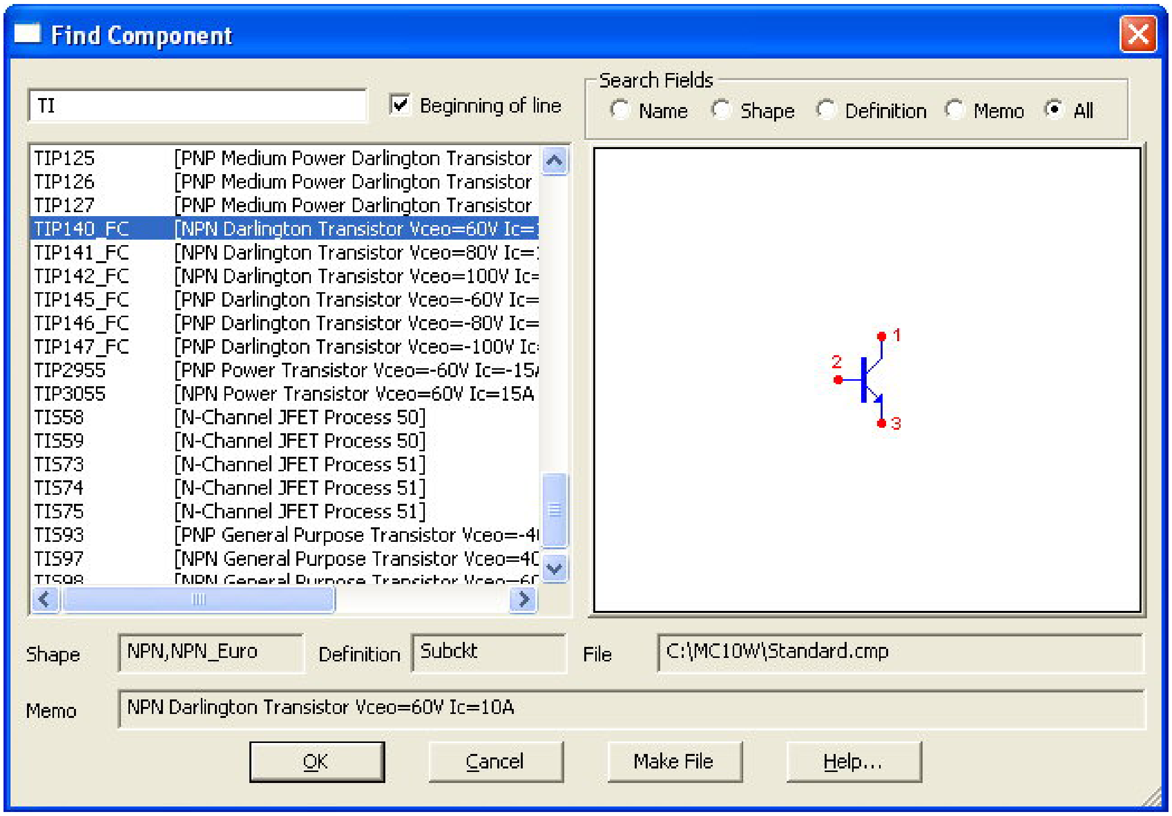




Easily Overlooked Features

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

One feature that often gets missed is the Find Component command. It can be found on the Component menu or invoked with CTRL+Shift+F. It is used to search the Component library for any text including the component name. Its dialog box looks like this:



TI

☑ Beginning of line

Search Fields: ○ Name ○ Shape ○ Definition ○ Memo ● All

TIP125	[PNP Medium Power Darlington Transistor
TIP126	[PNP Medium Power Darlington Transistor
TIP127	[PNP Medium Power Darlington Transistor
TIP140_FC	[NPN Darlington Transistor Vceo=60V Ic=
TIP141_FC	[NPN Darlington Transistor Vceo=80V Ic=
TIP142_FC	[NPN Darlington Transistor Vceo=100V Ic=
TIP145_FC	[PNP Darlington Transistor Vceo=-60V Ic=
TIP146_FC	[PNP Darlington Transistor Vceo=-80V Ic=
TIP147_FC	[PNP Darlington Transistor Vceo=-100V Ic
TIP2955	[PNP Power Transistor Vceo=-60V Ic=-15
TIP3055	[NPN Power Transistor Vceo=60V Ic=15A
TIS58	[N-Channel JFET Process 50]
TIS59	[N-Channel JFET Process 50]
TIS73	[N-Channel JFET Process 51]
TIS74	[N-Channel JFET Process 51]
TIS75	[N-Channel JFET Process 51]
TIS93	[PNP General Purpose Transistor Vceo=-4
TIS97	[NPN General Purpose Transistor Vceo=4
TIS98	[NPN General Purpose Transistor Vceo=6

Shape: NPN,NPN_Euro

Definition: Subckt

File: C:\MC10W\Standard.cmp

Memo: NPN Darlington Transistor Vceo=60V Ic=10A

Sometimes you only know part of the name of function that you want. Simply select the All option and the command searches for any instance of the text in any field, not just the part name. This can be useful for finding parts that meet some criteria like Regulator.

Typing a part of the name will show all instances that start with the specified letters. For example, typing in LT3 shows LT318, LT318A, LT318A_LT, and LT31858. This is often useful in finding similar parts.

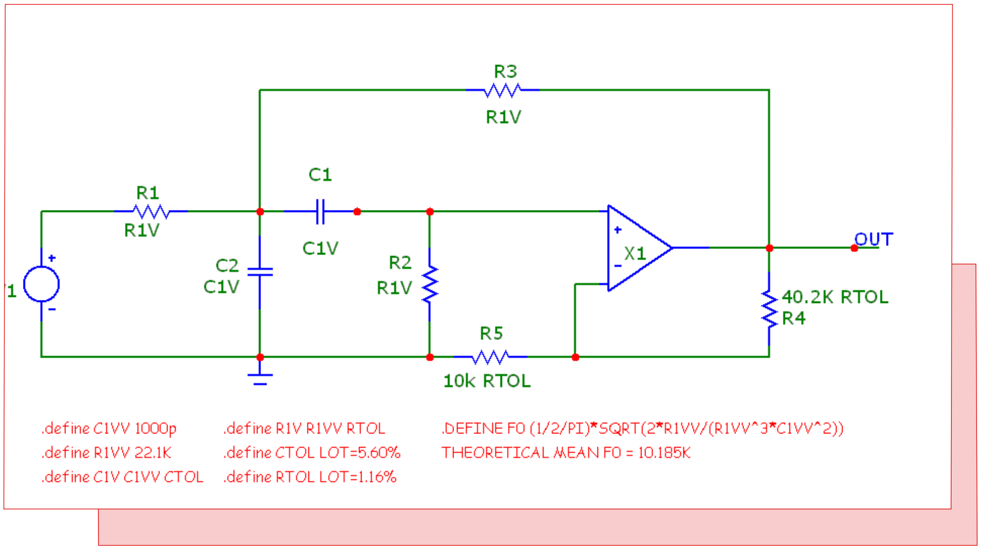
Worst Case Analysis

This type of analysis, which is new in MC11, provides three measures of a circuit's limiting performance:

- Root Sum Square (RSS). This computation is an estimate of the probable worst case limits of the circuit's performance function.
- Monte Carlo Analysis (MCA). This is an estimate of the probable worst case limits of the circuit's performance function derived from a Monte Carlo run.
- Extreme Value Analysis (EVA). This is an estimate of the most extreme limits of the circuit's performance function. There is standard EVA based upon sensitivities and EVA Optimizer which finds the extreme values through the use of the internal optimizer function.

Worst Case is available for AC, DC, DC operating point, and transient analysis.

How would you use this type of analysis? Consider this bandpass filter.

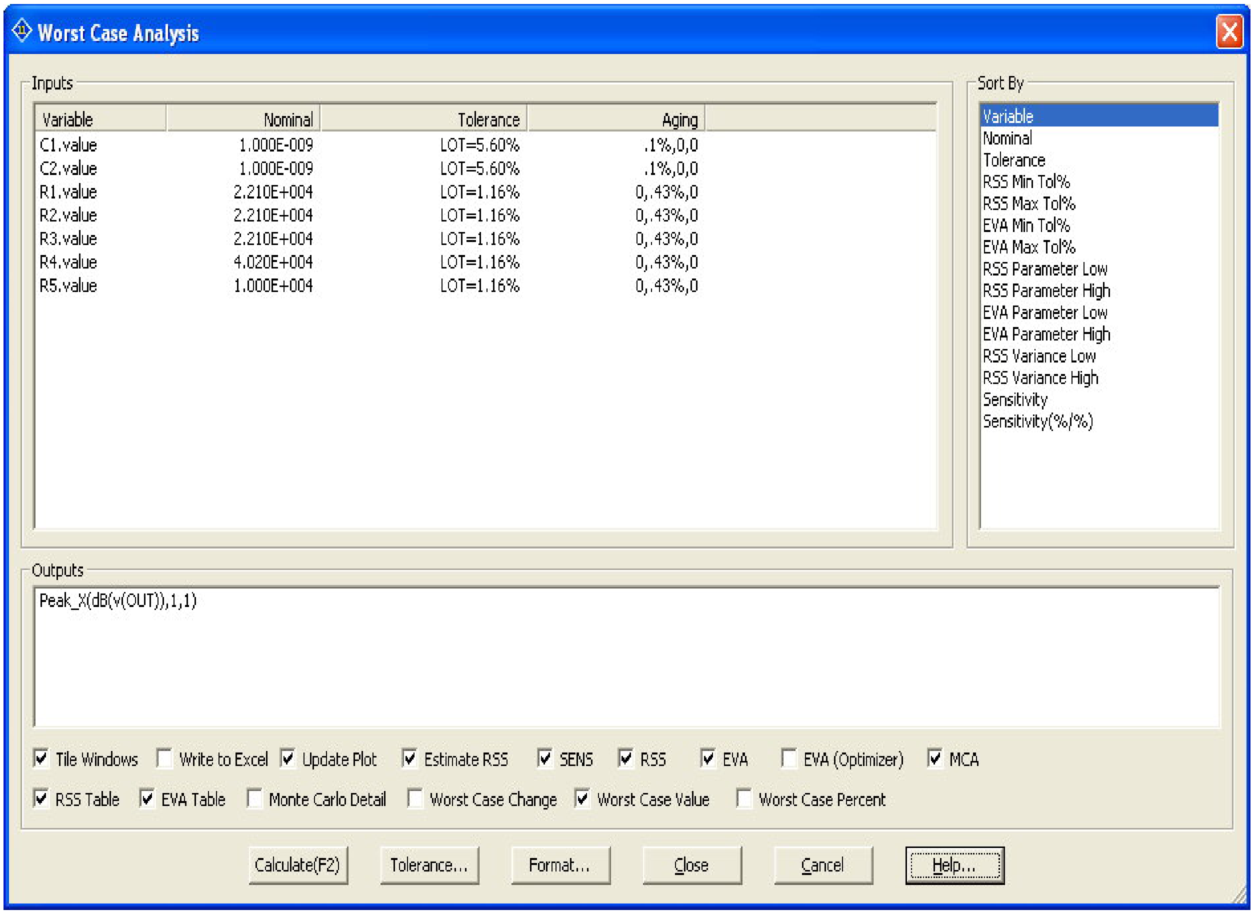


```
.define C1VV 1000p      .define R1V R1VV RTOL      .DEFINE F0 (1/2/PI)*SQRT(2*R1VV/(R1VV^3*C1VV^2))
.define R1VV 22.1K      .define CTOL LOT=5.60%     THEORETICAL MEAN F0 = 10.185K
.define C1V C1VV CTOL   .define RTOL LOT=1.16%
```

Fig. 1 - Worst Case analysis of a bandpass filter

One important performance characteristic is the filter's center frequency. The nominal center frequency is easily calculated as 10.185KHz, but what about the worst case? We treat the OPAMP as ideal, so the tolerances are limited to the resistors and capacitors.

These have initial tolerances and one type of bias tolerance called Aging. All of these tolerances add up to a shifting center frequency. To see how, let's run this circuit in AC analysis Worst Case. To do so you first select AC analysis (or use Alt+2), then select the Worst Case option from the AC menu (or use Alt+6). The display looks like this:



Variable	Nominal	Tolerance	Aging
C1.value	1.000E-009	LOT=5.60%	.1%,0,0
C2.value	1.000E-009	LOT=5.60%	.1%,0,0
R1.value	2.210E+004	LOT=1.16%	0,.43%,0
R2.value	2.210E+004	LOT=1.16%	0,.43%,0
R3.value	2.210E+004	LOT=1.16%	0,.43%,0
R4.value	4.020E+004	LOT=1.16%	0,.43%,0
R5.value	1.000E+004	LOT=1.16%	0,.43%,0

Peak_X(dB(v(OUT)),1,1)

☑ Tile Windows ☐ Write to Excel ☑ Update Plot ☑ Estimate RSS ☑ SENS ☑ RSS ☑ EVA ☐ EVA (Optimizer) ☑ MCA

☑ RSS Table ☑ EVA Table ☐ Monte Carlo Detail ☐ Worst Case Change ☑ Worst Case Value ☐ Worst Case Percent

Fig. 2 - AC Worst Case analysis dialog box

This dialog box shows the toleranced components. There are five resistors with an initial tolerance of 1.16% and two capacitors with an initial tolerance of 5.6%. In addition, the resistors have a negative aging bias tolerance of 0.43% and the capacitors have a positive aging bias tolerance of 0.1%. The aging bias tolerances are displayed as a triplet of values that represent a negative value, a positive value, and a random value:

Neg, Pos, Rnd

Either Neg or Pos must be zero. Each of these can be absolute or a percentage of the initial parameter. A positive or negative bias tolerance means an automatic drift that can always be expected and that is added in before any statistical effects are considered. Components can have any number of bias tolerances to account for different lifetime exposure effects like aging, humidity, temperature, voltage stress, and radiation.

Press F2 and the program will compute the three measures of worst case. Here is a summary of the results:

```
AC Worst Case

Output Function = Peak_X(dB(v(OUT)),1,1)
Nominal value = 10.185K

Worst case value of Peak_X(dB(v(OUT)),1,1)
By Root Sum Squared Low       +9.736K
By Root Sum Squared High     +10.600K
By Monte Carlo Analysis Low   +9.798K
By Monte Carlo Analysis High +10.536K
By Extreme Value Low          +9.494K
By Extreme Value High        +10.927K
```

The RSS results suggest that the center frequency limits expected to within the SD tolerance (in this case SD=2.58 reflecting a 1% expected failure rate) are:

Low = 9.736K
High = 10.600K

The Monte Carlo results largely agree and suggest that the center frequency limits expected to within the SD tolerance (in this case SD=2.58 reflecting a 1% expected failure rate) are:

Low = 9.798K
High = 10.536K

Finally, the extreme value analysis (EVA) results suggest that the absolute worst case center frequency limits expected are:

Low = 9.494K
High = 10.927K

If each toleranced parameter has a 1% chance of being exceeded, and if there are five such uncorrelated parameters (R4 and R5 don't impact the center frequency), then the chance of these EVA limits being exceeded is

Chance = .01^5 = 1e-10

Stability Analysis

Stability analysis uses either the Middlebrook or Tian method to calculate the closed loop Gain Margin and Phase Margin. To use this method the user chooses a place in the circuit to insert a probe. The program breaks the loop at this probe point and measures the appropriate parameters needed in the calculation. To demonstrate the use of Stability Analysis we'll use the file, STABILITY.CIR. It looks like this:

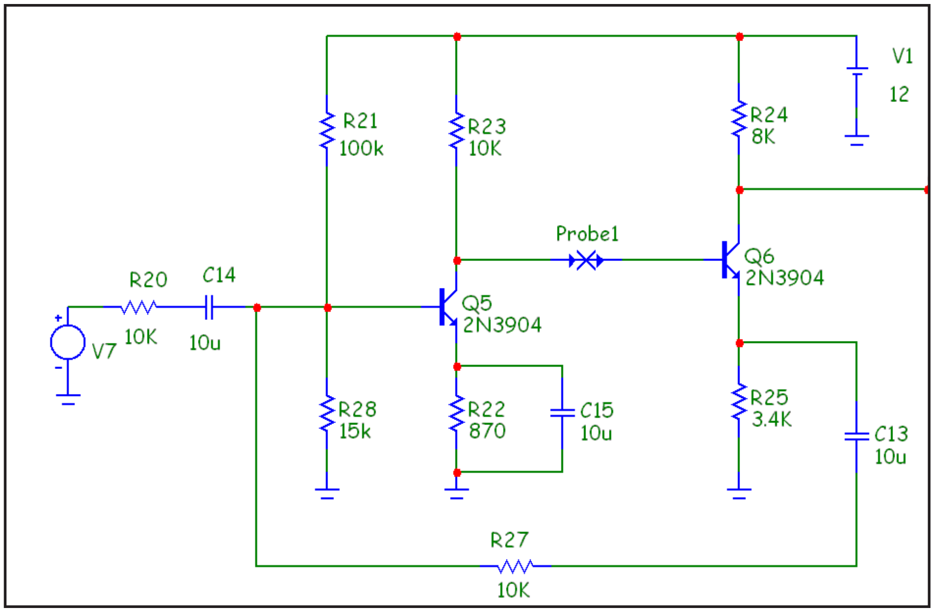


Figure 3 The Stability circuit

In this feedback amplifier we want to find the gain and phase margins. Press Alt+0 to select Stability Analysis. Press F2 to start the run and you'll see this:

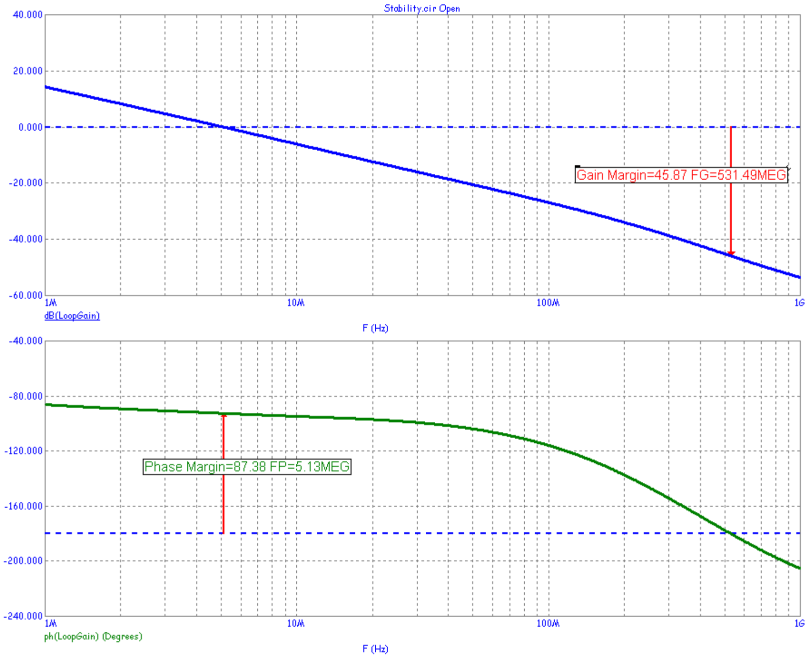


Figure 4 Stability analysis plot

The Gain Margin is measured at 45.87 dB and the Phase Margin at 87.38 degrees.

How does it work? The user inserts the probe component at any point in the loop. At the point of this probe, MC11 replaces the probe component with suitable voltage and current sources to measure closed loop voltage and current gains. During the run the variable Loop is stepped from 1 to 2 and the sources Vinj and Iinj take on these AC values:

if Loop==1 iol = 0 vol = 1
if Loop==2 iol = 1 vol = 0

The Tian method uses the following equation to determine the margins:

LoopGain = -1/(1-1/(2*(I(Vinj)@1*V(ol)@2-V(ol)@1*I(Vinj)@2)+V(ol)@1+I(Vinj)@2))

The equation in the LoopGain variable was derived from the Tian article. It uses the step selection operator @ to combine the waveform results from different steps. For example:

V(ol)@2 specifies the voltage at node ol during the second step of the simulation.

I(Vinj)@1 specifies the current through the source Vinj during the first step.

Together, the quantities V(ol)@1, V(ol)@2, and I(Vinj)@1 determine the variable LoopGain and its plot is examined to determine the gain and phase margins.

The gain margin is computed as follows:

Gain Margin = -dB(LoopGain) where Phase(LoopGain) equals -180.

The phase margin is computed as follows:

Phase Margin = 180+Phase(LoopGain) where dB(Loopgain) equals 0.

For those who would like to read more of the theory behind these methods, we recommend these references:

1) Tian Method:
"Striving for Small-Signal Stability", Michael Tian, V. Visvanathan, Jeffrey Hantgan, and Kenneth Kundert, Circuits & Devices, January 2001.

2) Middlebrook Method:
"Measurement of Loop Gain in Feedback Systems", David Middlebrook, International Journal of Electronics (volume 38, no. 4, pages 485-512, April 1975).

.Measure Commands

The .Measure commands, popularized by HSPICE, are now available in Micro-Cap 11. .Measure commands are a set of tools that, like performance functions, make measurements on curves generated by the analyses.

.Measure commands are similar to those used in other simulators. Their inclusion in Micro-Cap is intended to make it easier for users familiar with them. Many of the functions used in the .measure commands are also available as Performance functions. .Measure statements can be easily built using the Build command within the text dialog box. This convenient dialog box lets you fill in the blanks and it creates the .Measure statement for you.

You can see .measure variables by

1) Plotting them in the analysis. Values are computed at the end of the analysis and then plotted as straight lines.

2) Viewing them in the Scope Menu / Measurements window.

3) Printing them in analysis text as in

```
Delay1= [dly1]
```

where dly1 would be a defined result variable from a .measure command. Don't forget to check the Formula option in the Text dialog box when creating the text.

Note that there are a group of .measure functions stored in the measure.lib and these are available to any circuit. Users may add to these as needed. Note also that .measure functions are extensible. Unlike Performance functions, they can be extended and new ones invented as needed.

Here are some examples of the .Measure command:

```
.MEASURE TRAN SUM1 AVG V(1)*2 FROM=0 TO=1000N
```

This example computes the average of the expression V(1)*2 from 0 to 1000n in transient analysis and assigns the value to SUM1.

```
.MEASURE TRAN IN1 INTEG V(V1)*I(V1) FROM=200n TO=1000N
```

This computes the integral of the expression V(V1)*I(V1) from 200n to 1000n in transient analysis and assigns the value to IN1.

```
.MEASURE TRAN BIG MAX V(OUT)/2 FROM=1E-7  TO=1E-6
```

This computes the largest value of the expression V(OUT)/2 from 1e-7 to 1e-6 in transient analysis and assigns the value to BIG.

```
.MEASURE TRAN SMALL MIN V(IN1) FROM=1E-3  TO=1E-2
```

This computes the smallest value of the expression V(IN1) from 1e-3 to 1e-2 in transient analysis and assigns the value to SMALL.

```
.MEASURE TRAN PP1 PP V(OUT) FROM=0  TO=5U
```

This computes the peak-to-peak value of the expression V(OUT) from 0 to 5u in transient analysis and assigns the value to PP1.

```
.MEASURE TRAN RR1 RMS V(IN) FROM=0  TO=5U
```

This computes the RMS value of the expression V(IN) from 0 to 5u in transient analysis and assigns the value to RR1.

```
.MEASURE AC DD1 DERIV V(out) AT=1e6
```

This computes the derivative of the expression V(OUT) at F=1E6 in AC analysis and assigns the value to DD1.

```
.MEASURE TRAN DERA DERIV V(A) WHEN V(A)=V(B) CROSS=3
```

This assigns the value of the time derivative of the expression V(A) to DERA when V(A)=V(B) for the third time in transient analysis.

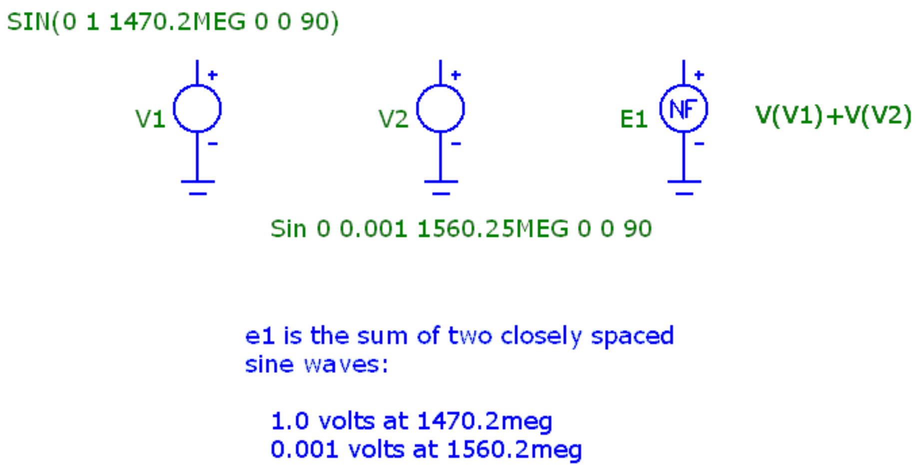
Well, you get the idea. Micro-Cap 11 adds to the basic idea of .measure commands by allowing the use of extensible libraries of these functions and by automatically displaying many of then in a Measurements window.

Fourier Window Functions

Window functions have been added to MC11 to facilitate signal selectivity. Here is a list of the new window functions.

Rectangular
Bartlett-Hann
Blackman
Blackman-Harris
Blackman-Nuttal
Cosine
Falttop
Gaussian
Hamming
Hanning
Kaiser
Lanscos
Nuttal
Triangular
Tukey

Window functions are useful in many ways but spectral analysis is one particularly useful function. Here is a circuit that has a source with which the sum of two closely spaced sinusoids.



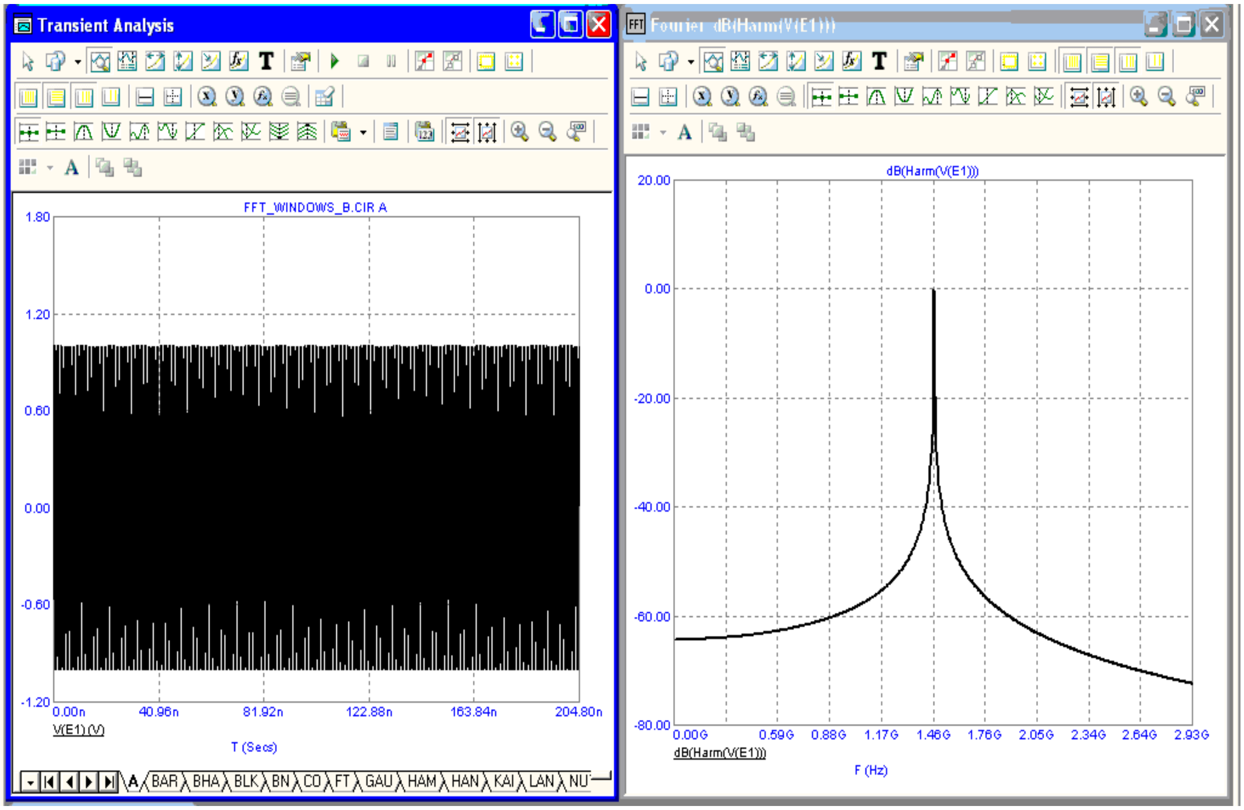
e1 is the sum of two closely spaced sine waves:

1.0 volts at 1470.2meg
0.001 volts at 1560.2meg

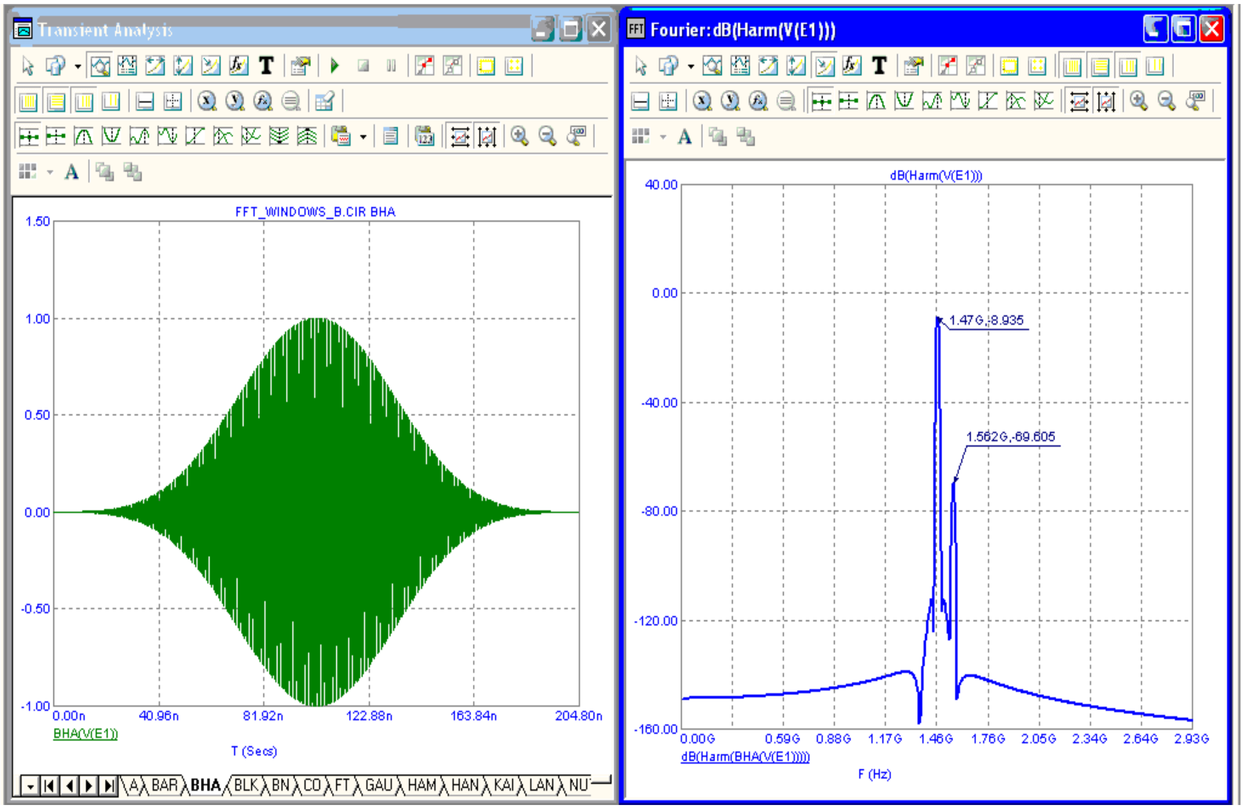
The sinusoids are:

1.0 volts at 1470.2meg
0.001 volts at 1560.2meg

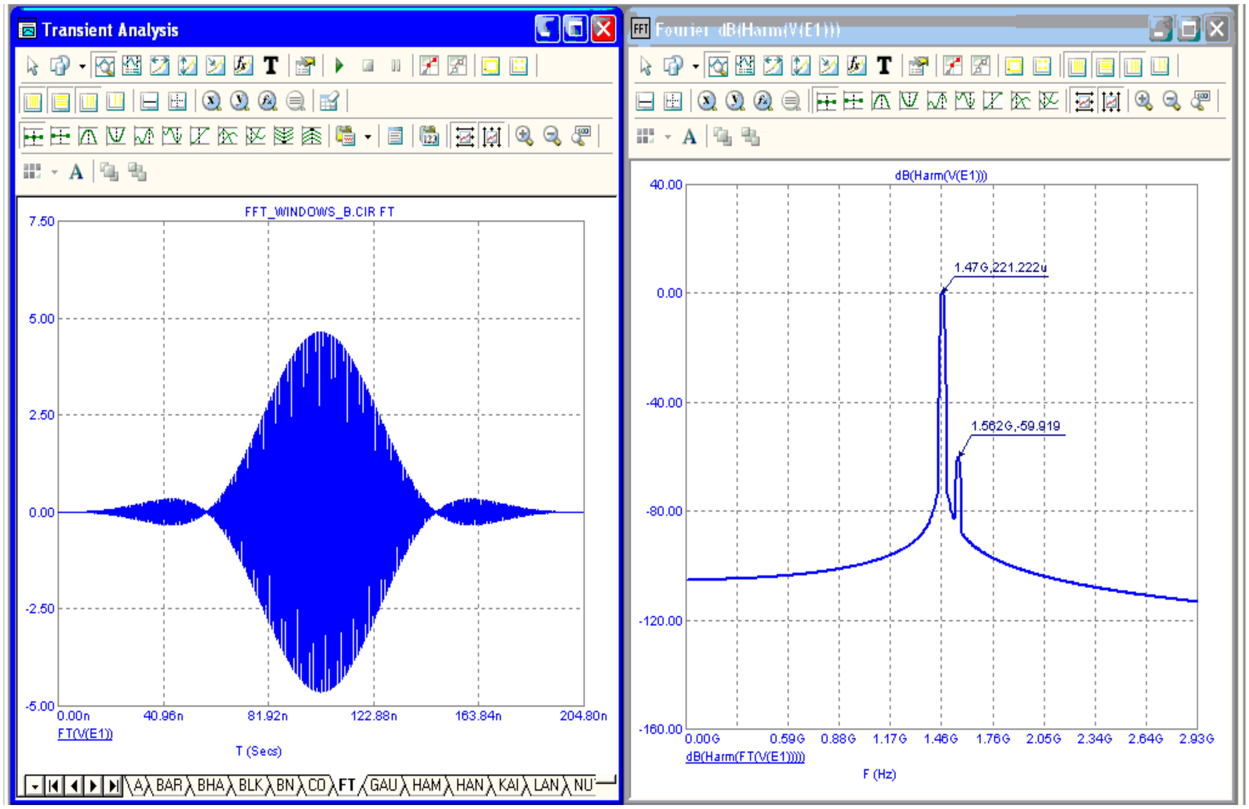
If you run a Fourier analysis of the e1 voltage you get this:



Only the 1.0volt 1470.2MHz signal is evident in the Fourier plot. Now apply a Blackman-Harris window and we get this:



Now the .001 signal at about 1560MHz is evident. In this case several window functions would have been effective in showing the small signal. Here is a what the Flattop function produces:



In this circuit Blackman, Gaussian, Nuttal, Blackman-Harris, Blackman-Nuttal, and Flattop all proved effective in showing the smaller signal.

Product Sheet

Latest Version numbers

Micro-Cap 11	Version 11.0.0.0
Micro-Cap 10	Version 10.1.0.2
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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