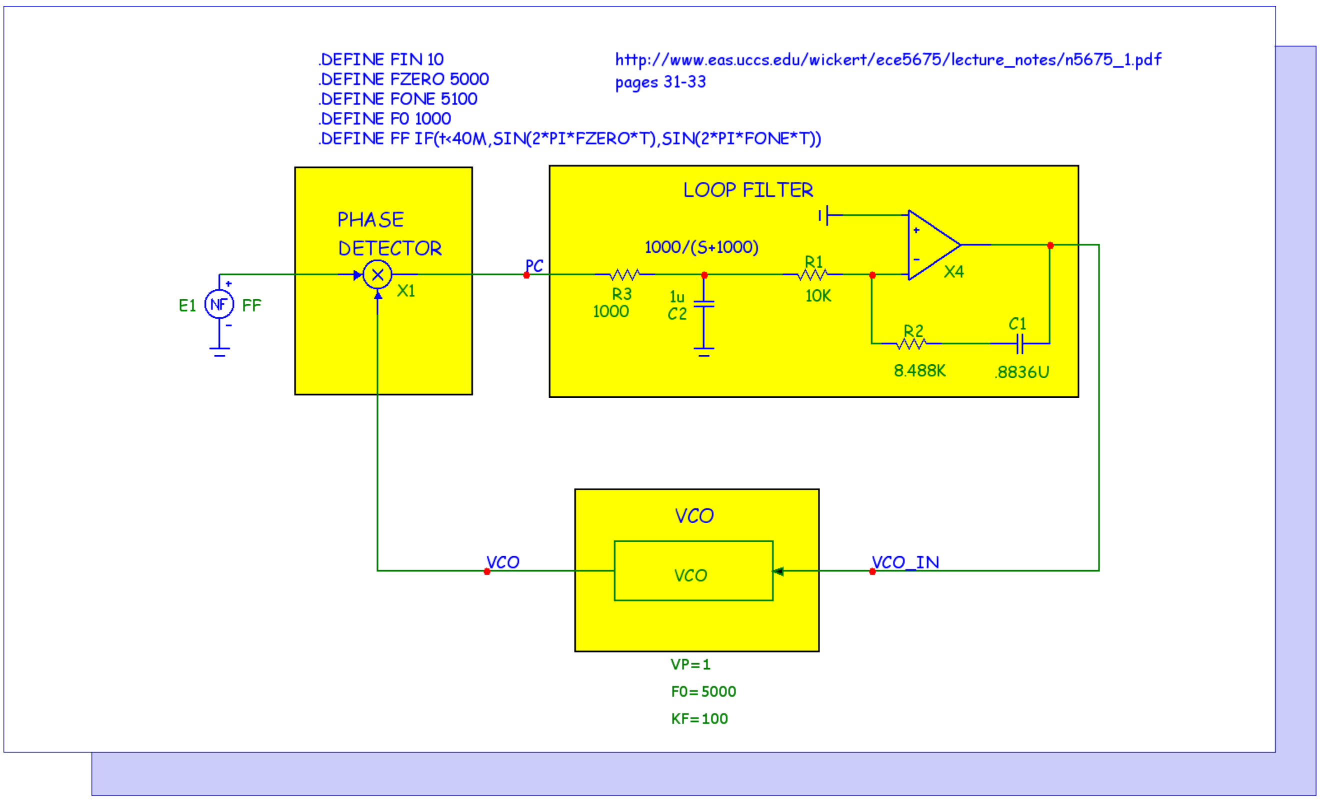
spectrum news

Applications for Micro-Cap™ Users

Winter 2014



Featuring:
- Phase Locked Loops
- FSK System Using a PLL
- Batch Files

News In Preview

This newsletter's Q and A section describes several Micro-Cap installation issues. The Easily Overlooked Feature section describes the new capabilities of the Calculator. In addition to complex math and finding derivatives, it can now draw 2D and 3D plots.

The first article describes the implementation of an analog phase locked loop (PLL) in Micro-Cap.

The second article describes how to build an FSK system using phase locked loop (PLL) techniques.

The third article describes the use of batch files for automating circuit analysis.

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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 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: Does Micro-Cap come with a node-locked or a floating license?

Answer: First of all, a few definitions:

Node-locked license: This is a license that allows the user to install the program on only one machine. Micro-Cap does NOT currently use node-locked licenses. Micro-Cap may be installed on as many machines as desired. However, it will only run simultaneously on as many machines as there are licensed seats.

Floating license: This is a license that allows the user to install the program anywhere he likes. This is the only type of license that Micro-Cap currently uses.

Question: We are trying to use the Check for Updates feature to update our Micro-Cap 10. When we attempt to use it we are getting this message:

File update failed

Uncompress: Can't open c:program File (x86)\Spectrum\MC10\dlmcapver.exe

What are we doing wrong?

Answer: Most likely you are attempting to operate out of a folder that is write-protected. You can get around this in two ways:

1) Obtain administrative privileges (usually from your IP department) which allow you to both read and write to Micro-Cap folders. The problem with this is that your admin privileges may be revoked at any time by IP "maintainence updates".

2) Install Micro-Cap in a folder that is always writable, something like C:\MC10. This is the recommended approach.

Micro-Cap must be able to write to all of its folders, including the main folder (where the Micro-Cap executable is), the DATA folders, and LIBRARY folders.

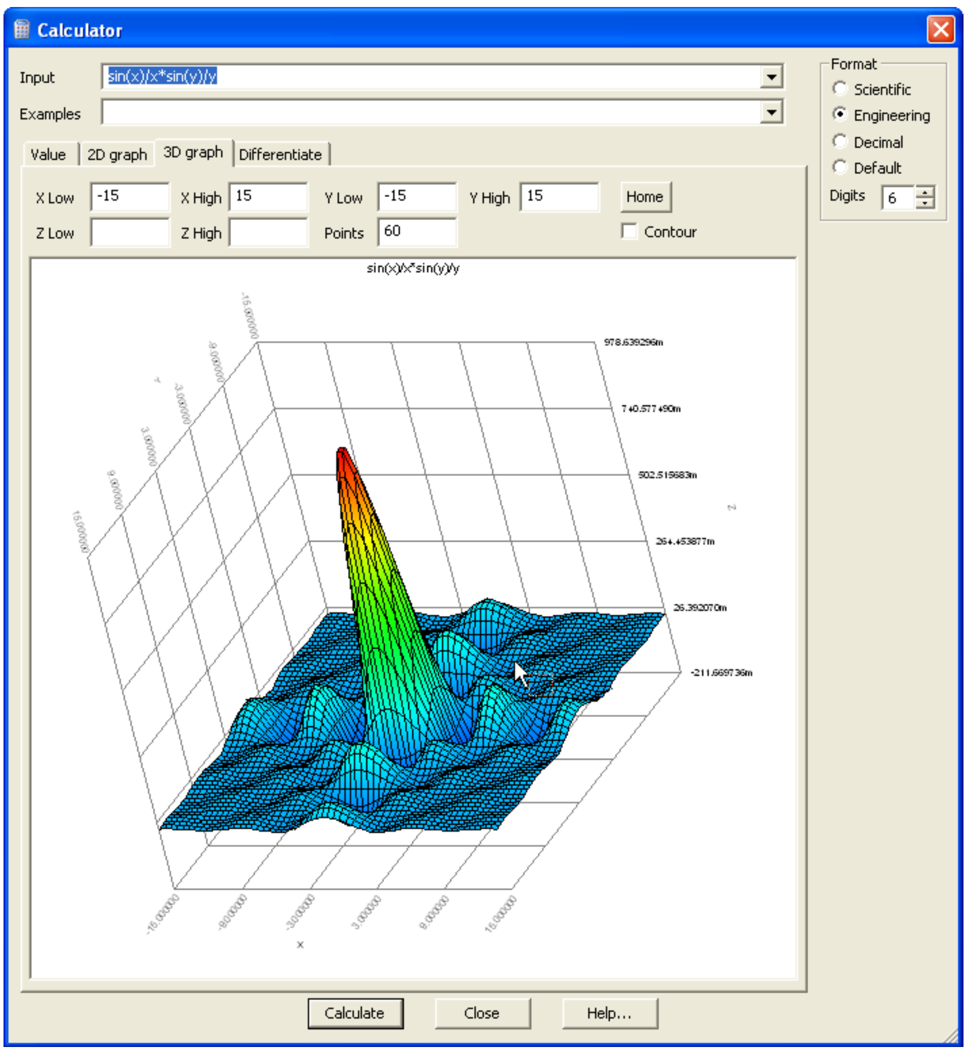
Easily Overlooked Features

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

If you haven't already used the Micro-Cap 11 Calculator you'll be surprised at some of the new capabilities. In addition to doing complex math and derivatives, it can now plot 2D and 3D expressions.

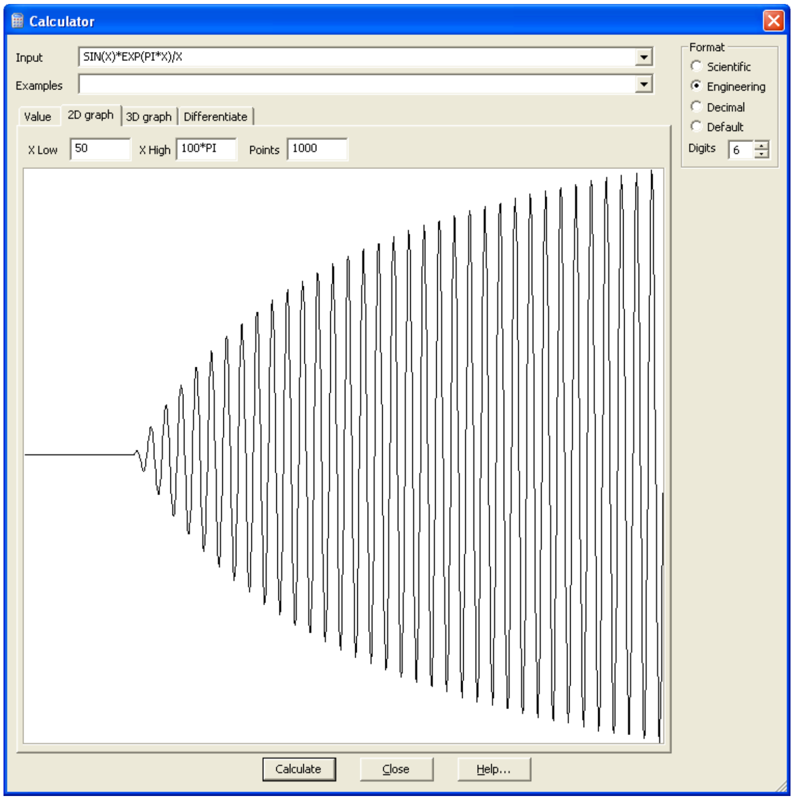
Here is one example, a three-dimensional plot of the SINC function.

SIN(X)/X*SIN(Y)/Y

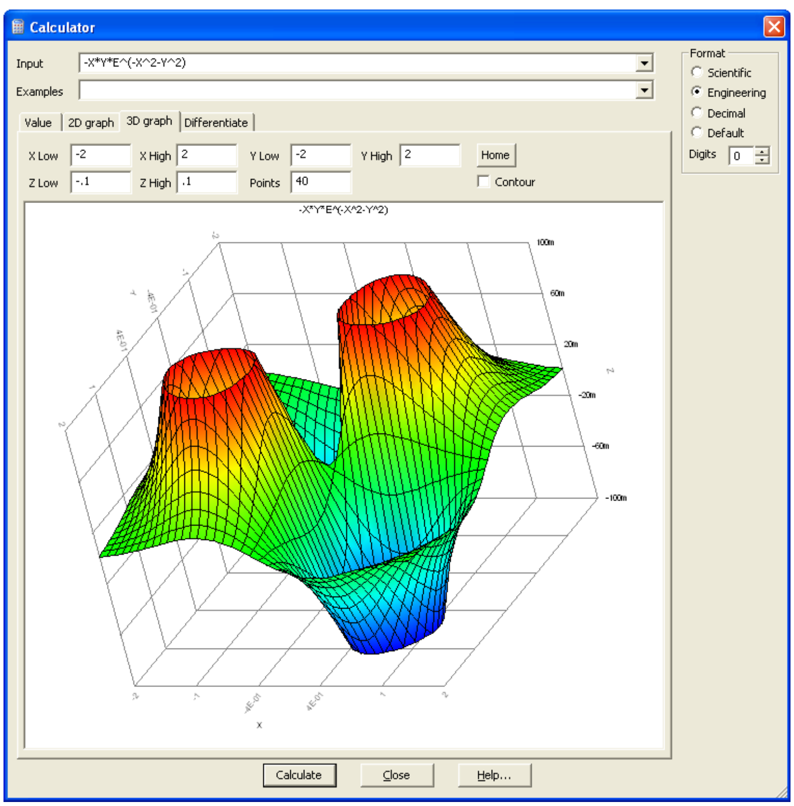


Enter an expression using only X and it will draw a 2-dimensional plot. Enter an expression using X and Y and it will draw a 3-dimensional plot. You can let it auto scale or you can control the scales manually. You can rotate the 3D plot by clicking the right mouse button and dragging the mouse.

Here is a 2-dimensional plot of SIN(X)*EXP(PI*X)/X



Here is another 3D plot illustrating the Z-Axis clipping.



Phase Locked Loops

How do you do a phase locked loop in Micro-Cap? There are many types of PLLs. Here are some of them:

APLL: An analog PLL with no digital components operating in the continuous time domain.

DPLL: An analog PLL with a digital phase detector.

ADPLL: An all digital PLL with digital only signals.

In this article we will cover the first type, the APLL. It uses a block diagram that looks like this:

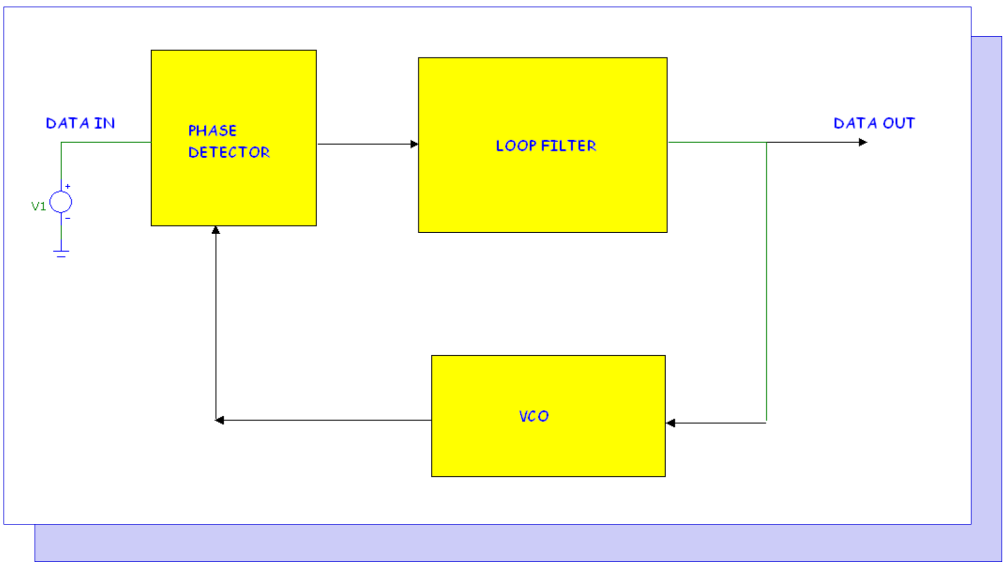


Fig. 1 -PLL block diagram

Phase Detector: The PLL employs an analog multiplier as a phase detector, often implemented as a Gilbert cell. In this example we will use a simple macro called the MUL. It simply multiplies two signals together. The multiplication produces both sum and difference frequencies so for input frequencies of say 5K and 5.1K, the phase detector outputs frequencies of 100Hz and 10.1KHz.

Loop Filter: The principal job of the loop filter is to remove or at least minimize the sum frequency component.

VCO: The job of the VCO is to translate an input DC voltage to a sinusoidal signal.

Here is how the PLL components can be implemented in Micro-Cap. This design is based one at:

http://www.eas.uccs.edu/wickert/ece5675/lecture_notes/n5675_1.pdf...pages 31-33

The phase detector uses the multiplier (MUL) macro which internally looks like this:

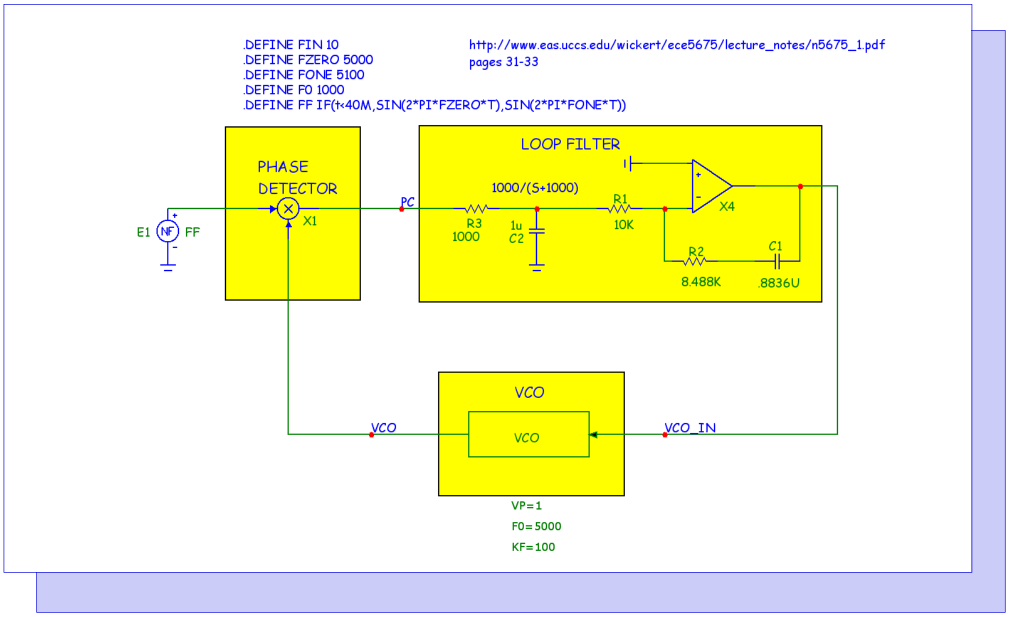


Fig. 2 - The PLL implementation

The MUL macro is a NFV source whose formula is SCALE*V(PINA)*V(PINB). It multiplies the

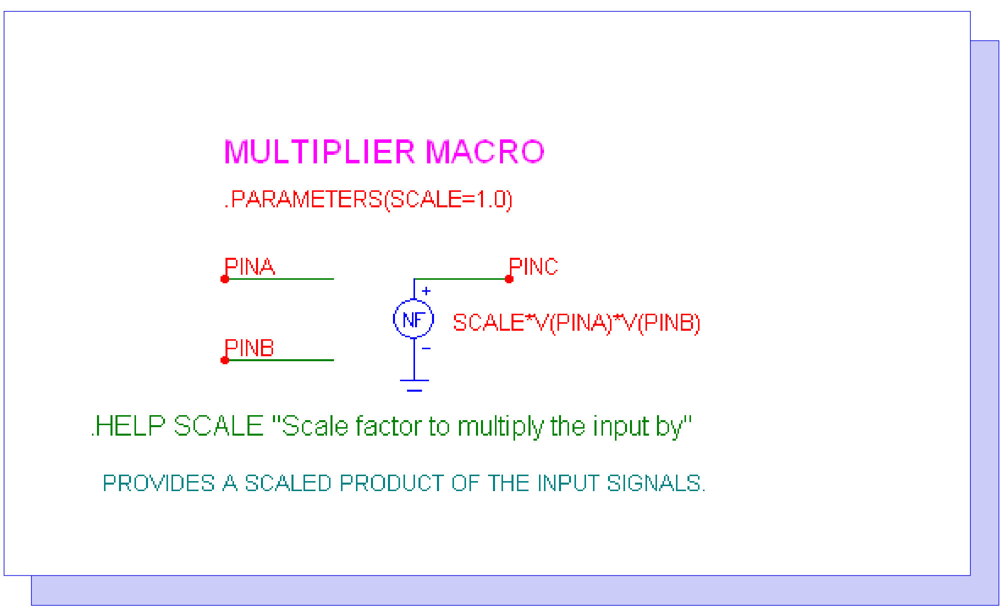


Fig. 3 - The MUL macro

two input voltages together and then scales the product by the input parameter SCALE value.

The next component is the loop filter. In this design the loop filter is a concatenation of a simple low pass filter and an integrator. It looks like this:

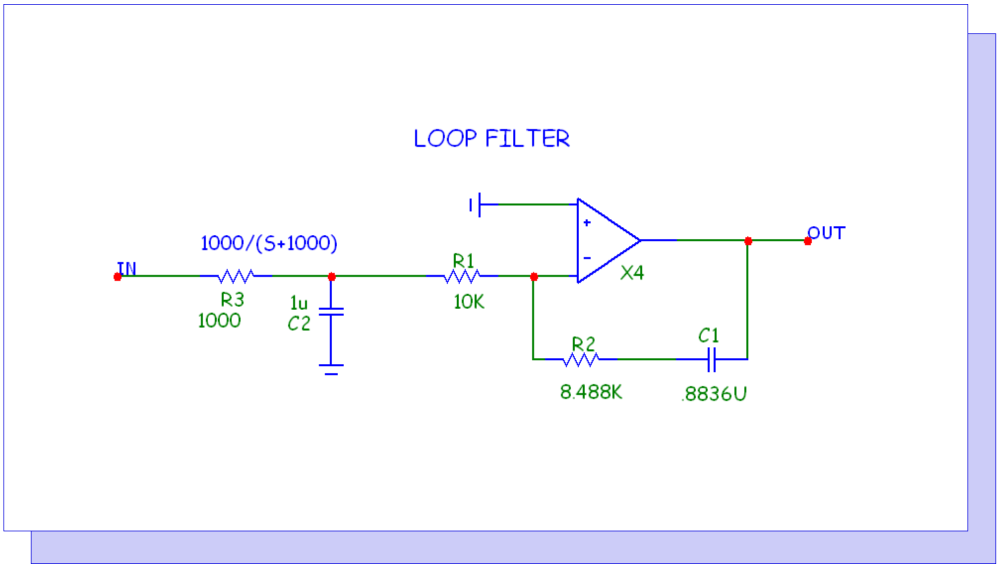


Fig. 4 - The loop filter

The loop filter is implemented, not as a macro, but in discrete form. The transfer function is approximately this:

1000/(1000+S)*(1+S*TAU1)/(S*TAU2)

Its AC Bode plot looks like this:
The final component is the VCO macro. It looks like this:

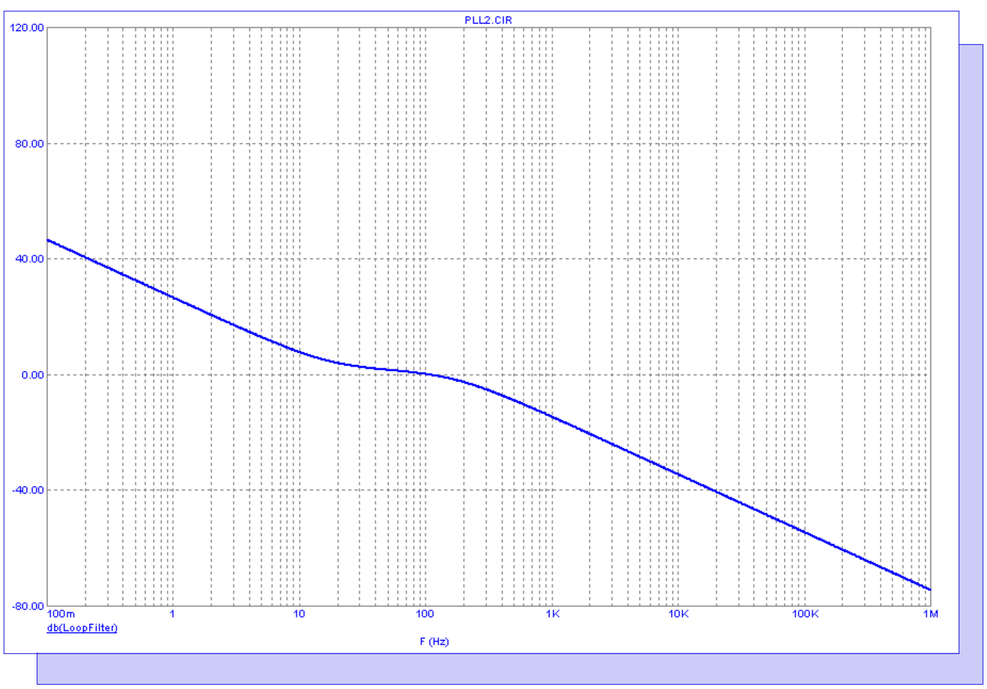


Fig. 5 - AC Bode plot for the loop filter

This macro is a slightly modified version of the standard VCO macro provided in the Micro-Cap

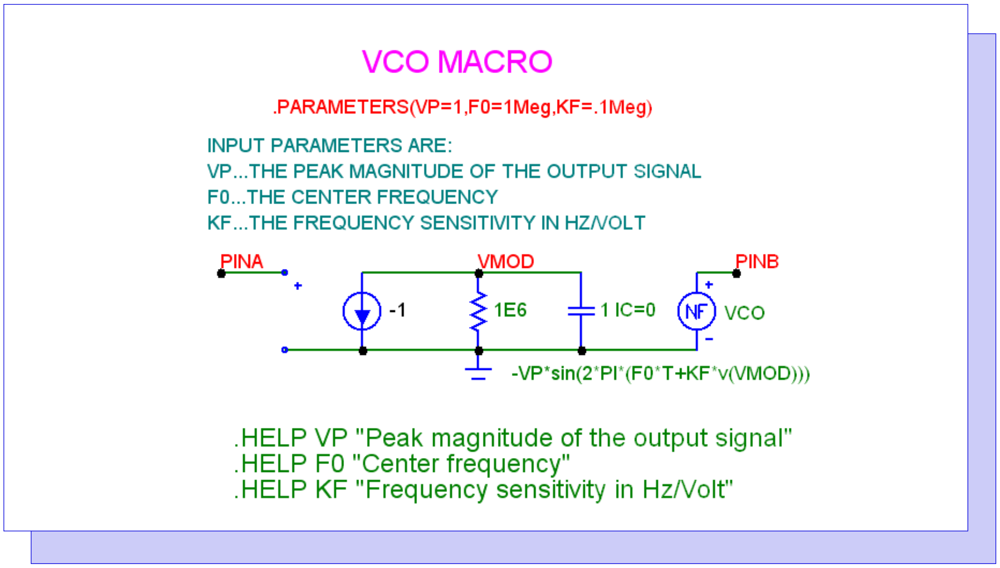


Fig. 6 - The VCO macro

library. Here we use a -SIN() in lieu of a COS() function. There are three parameters. VP is the amplitude, F0 is the center frequency, and KF is the scale factor translating input DC voltage to output frequency.

Here we are using the following VCO parameters.

VP =1
F0=5000
KF=100

So for a VCO input of 0.0 we should get a VCO sinusoid of 5000Hz. If the input moves to 1.0 volts, the output frequency should be:

Fout = F0 + KF*VIN = 5000 + 100*1 = 5100Hz.

All of the macros used are available from the Component menu / Analog Primitives / Macros.
The next figure shows the PLL response with an input sinusoid that changes abruptly from 5000Hz

to 5100Hz at T=40ms. We are plotting the input to the VCO which is also the loop filter output. For T < 40ms the input sinusoid is at 5000Hz and the VCO input eventually arrives at 0.0 volts

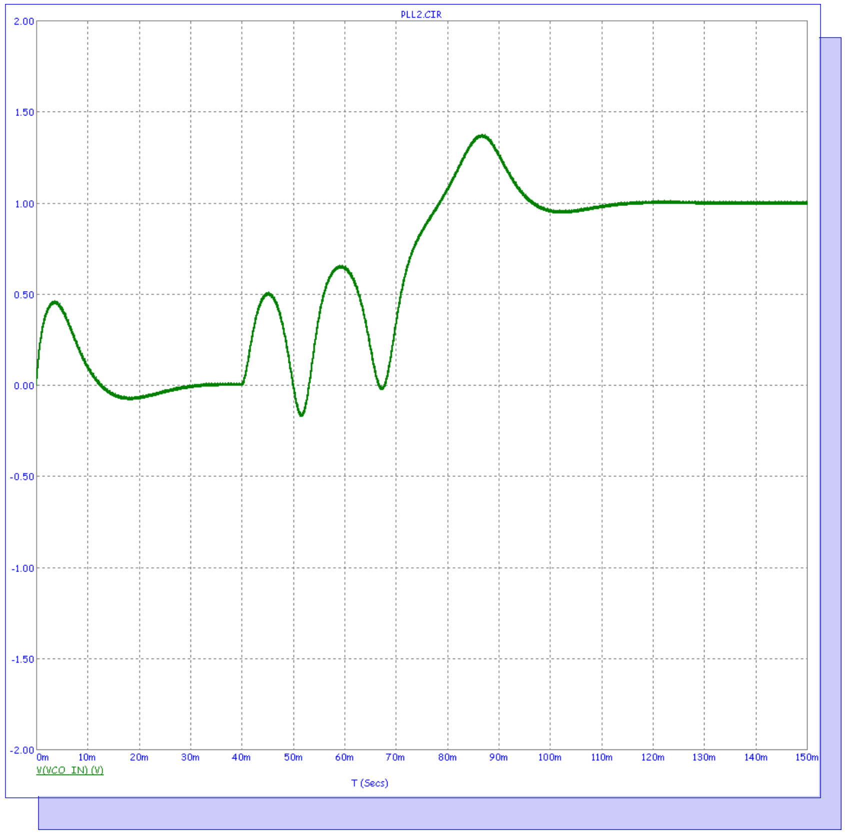


Fig. 7 - PLL response for an input step change from 5000Hz to 5100Hz

causing the VCO output to stabilize at 5000Hz.

For T>=40ms the input sinusoid switches to 5100Hz. The VCO input goes through the complex adjustment transient shown in the plot causing the VCO output to stabilize at 5100Hz.

FSK System Using a PLL

The PLL can be used in many applications. Here's a circuit that uses the PLL to implement an FSK system. Its general block diagram is as follows:

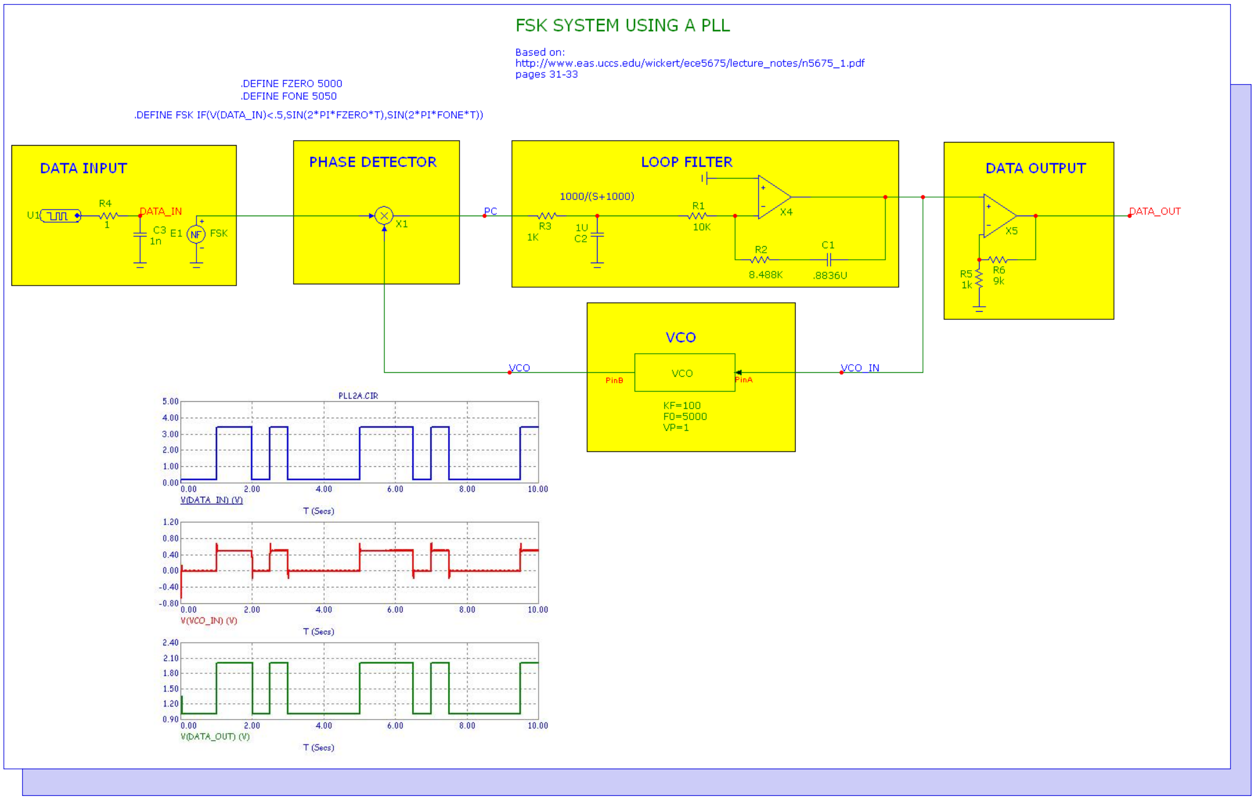


Fig. 8 - FSK system using a PLL

The heart of the system is the PLL discussed in the first article. The front end looks like this:

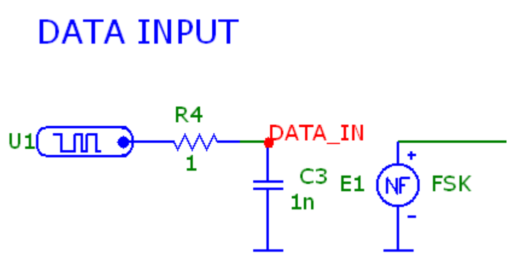


Fig. 9 - The FSK data generator at the front end

This is a simple digital data source that drives an analog RC network. Its voltage is used to control an NFV source with the definition:

.DEFINE FSK IF(V(DATA_IN)<.5,SIN(2*PI*FZERO*T),SIN(2*PI*FONE*T))

The NFV source looks at the analog end of the digital gate and simply switches the frequency of a sinusoid between 5000 Hz and 5100 Hz depending on the data stream. This creates the FSK encoded signal that is fed to the PLL input phase detector.

Ideally, if the input frequency is 5000 Hz then the system outputs a "0". If the input frequency is 5100 Hz then the system outputs a "1".

Here is what the output looks like for one input data stream.

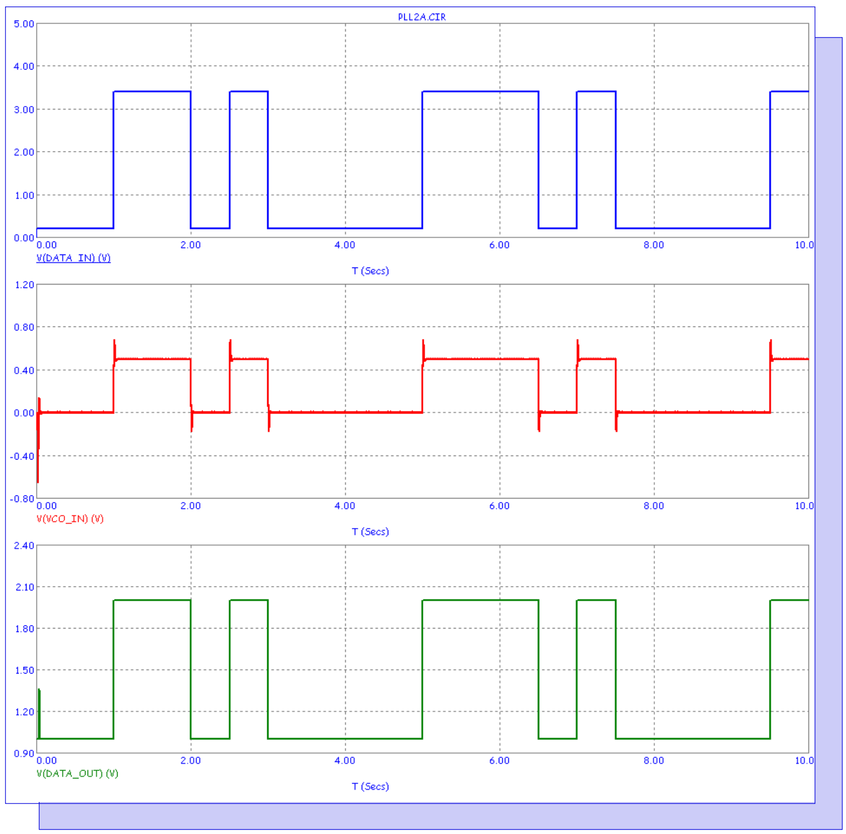


Fig. 10 -The FSK input and output waveforms

As the FSK shifts frequency to represent the two states, the PLL tracks by changing the filter output / VCO input voltage, reconstructing the original data waveform. The output buffer waveshapes the signal, removing overshoot and other noise.

The main part of the filter output signal noise is coming from the sum component of the phase detector. It can be removed with a stronger filter at the expense of transition time.

Batch Files

Micro-Cap 11 is designed to run primarily in an interactive mode, but it can also be run as a script or batch process from either the Program Manager command line or from Analysis menu / Run Script.

Either of two formats may be used.

MC11 [F1[.EXT]]...[FN[.EXT]]

MC11 [/S | /R] [/P] [/PC] [/PA] [@BATCH.BAT]

In the first format, F1, ...FN are the names of one or more circuit files to be loaded. The program loads the circuit files and awaits further commands.

In the second format, circuits can be simulated in batch mode by including the circuit name and the analysis type, /T(transient), /A(AC), or /D(DC) on a line in a text file. The syntax of the circuit line inside the batch file is:

cname [/DEF "x val"] [/NOF "fn"] [analysis] [/S | /R] [/P] [/PC] [/PA]

Command options for analysis

/T Run transient analysis on the circuit.
/A Run AC analysis on the circuit.
/D Run DC analysis on the circuit.
/HD Run Harmonic Distortion analysis on the circuit.
/ID Run Intermodulation Distortion analysis on the circuit.
/DYNAMIC_AC Run Dynamic AC analysis on the circuit.
/DYNAMIC_DC Run Dynamic DC analysis on the circuit.
/STABILITY Run Stability Analysis on the circuit.

Command options for Worst Case Analysis

```
BEGIN_COMMAND
cname /WC
/DCOP  OR  / T  OR /AC  OR /DC
   /Output=expression
            /RSS_LOW  /Value=v1 /ErrorTol=e1
            /RSS_HIGH /Value=v2 /ErrorTol=e2
            /MCA_LOW  /Value=v3 /ErrorTol=e3
            /MCA_HIGH /Value=v4 /ErrorTol=e4
            /EVA_LOW  /Value=v5 /ErrorTol=e5
            /EVA_HIGH /Value=v6 /ErrorTol=e6
END_COMMAND
```

This runs the requested worst case analysis on cname and prints the RSS, MCA, and EVA results to the file cname.owc, generating error messages if the specified values are not within the ErrorTol value.

Other commands

/S Save the analysis run to disk for later recall.
/R Retrieve the analysis run from disk and plot the waveforms specified in the Analysis Limits dialog box.
/PC Print the circuit diagram.

/PA Print the circuit analysis plot.
/P Print the circuit diagram and analysis plot.
/DEF "x val" Sets the variable x to val, for use within cname. cname must have a .DEFINE X... statement.
/NOF "fn" Provides a unique numeric output file name, fn, so that multiple runs of cname do not overwrite the standard numeric output file cname.*NO. fn is the desired file name without an extension. MC11 will add the appropriate extension (.TNO, .ANO, or .DNO) to fn.

The save, retrieve, and print commands may be applied globally for all circuits in the batch file by placing them on the Program Manager command line, or locally to a particular circuit file by placing them on a circuit line within the batch file.

Image commands

/IC Page="<page name>" Output="<file name>"
Creates an image file of the specified schematic page.
/IC Page="<page name>" Section="<section name>" Output="<file name>"
Creates an image file of the specified schematic page in the specified macro section.
/IA Page="<page name>" Output="<file name>"
Creates an image file of the analysis plots in the specified analysis page.
/IP Window="<window name>" Output="<file name>"
Creates an image of the specified performance plot window.
/IF Window="<window name>" Output="<file name>"
Creates an image of the specified FFT plot window.
/I3 Window="<window name>" Output="<file name>"
Creates an image of the specified 3D plot window.
/IH Window="<window name>" Output="<file name>"
Creates an image of the specified histogram plot window.

The Output specifies the image file name that is to be created. The type of image file created is based upon the extension of the file name. The types of image files available are the same as those available in the Copy Entire Window to a Picture File under the Edit menu. The Window parameter uses the name of the performance plot, FFT plot, 3D plot, or histogram plot. This name is defined in the Title field within the Plot page of the Properties dialog box for each plot. The analysis/plot window image commands need to be used in conjunction with the appropriate command option for an analysis. For example:

Diffamp /t /ic Page="Page1" Output="cir.gif" /ia Page="Main" Output="tran.jpg"

would export the schematic in the page named Page1 to a GIF file called cir.gif. It would then run transient analysis, and export the analysis plots in the analysis page Main to a JPEG file called tran.jpg. Note that when the image commands are used on a line, there should only be a single analysis command option specified. If you want to run multiple analyses on a circuit while saving the image files, each analysis should have its own batch line.

In the second format, MC11 must be invoked with the name of the batch file preceded by the character '@'. For example, consider a text file called TEST.BAT containing these lines:

```
PRLC /A /T
SENSOR.CKT /A /IA Page="Main" Output="Sense.jpg"
LOGIC /DEF "DELAY 1E-7" /NOF "DELAYA" /T
LOGIC /DEF "DELAY 2E-7" /NOF "DELAYB" /T
```

If MC11 is invoked with the command line, MC11 @TEST.BAT, it will:

1. Load the PRLC.CIR circuit and run an AC and transient analysis.
2. Load the SENSOR.CKT circuit and run an AC analysis. Create a JPEG file called Sense.jpg that contains an image of the analysis plots in the analysis page called Main.
3. Load the LOGIC.CIR circuit with the variable DELAY set to 1E-7, then run transient analysis. Save the numeric output in the file DELAYA.TNO.
4. Load the LOGIC.CIR circuit with the variable DELAY set to 2E-7, then run transient analysis. Save the numeric output in the file DELAYB.TNO.

As an alternative you can load the batch file from within MC11 and then select the Run Script option from the Analysis menu.

During these analyses, the expressions specified in the circuit file would be plotted during the run and be visible on the screen, but the results would not be saved to disk.

Note that the default circuit file name extension is .CIR.

By appending an '/S' to the command line, all of the analyses specified in the batch file will be run and the results saved to disk for later recall. By appending an '/R' to the command line the analyses are bypassed and the results merely recalled and plotted.

By appending a '/P' to the command line, all of the analyses specified in the batch file will be run and the circuit and analysis plot printed.

In the batch file, a line can get lengthy if multiple commands are implemented. The batch file can use the keywords BEGIN_COMMAND and END_COMMAND to make a line easier to read. All of the text within these keywords will be considered to be just a single command line. For example, you can modify the above batch file this way:

```
PRLC /A /T
SENSOR.CKT /A /IA Page="Main" Output="Sense.jpg"
BEGIN_COMMAND
LOGIC /DEF "DELAY 1E-7"
/NOF "DELAYA"
/T
END_COMMAND
LOGIC /DEF "DELAY 2E-7" /NOF "DELAYB" /T
```

and the results would be the same as described before.

Here is an example that loads a circuit called batch1.cir, runs AC analysis and saves images of the circuit, the analysis plot, two performance plots and a 3D plot.

```
BEGIN_COMMAND

;Run AC analysis
batch1.cir /a

;Save the Schematic Page Main as batch1.jpg
/ic Page="Main" Output="batch1.jpg"

;Save the AC analysis Page a as batch1_ac.jpg
```

/ia Page="a" Output="batch1_ac.jpg"

;Save the Peak performance plot as batch1_acpf1.jpg
/ip Window="Peak_Y(RE(v(OUT)),1,1) vs Temperature" Output="batch1_acpf1.jpg"

;Save the Valley performance plot as batch1_acpf2.jpg
/ip Window="Valley_Y(IM(v(OUT)),1,1) vs Temperature" Output="batch1_acpf2.jpg"

;Save the 3D plot as batch1_ac_3d.jpg. Only one 3d Plot so no need to specify the Window
/i3 Output="batch1_ac_3d.jpg"

END_COMMAND

Here is the set of images the batch1.bat file produced.

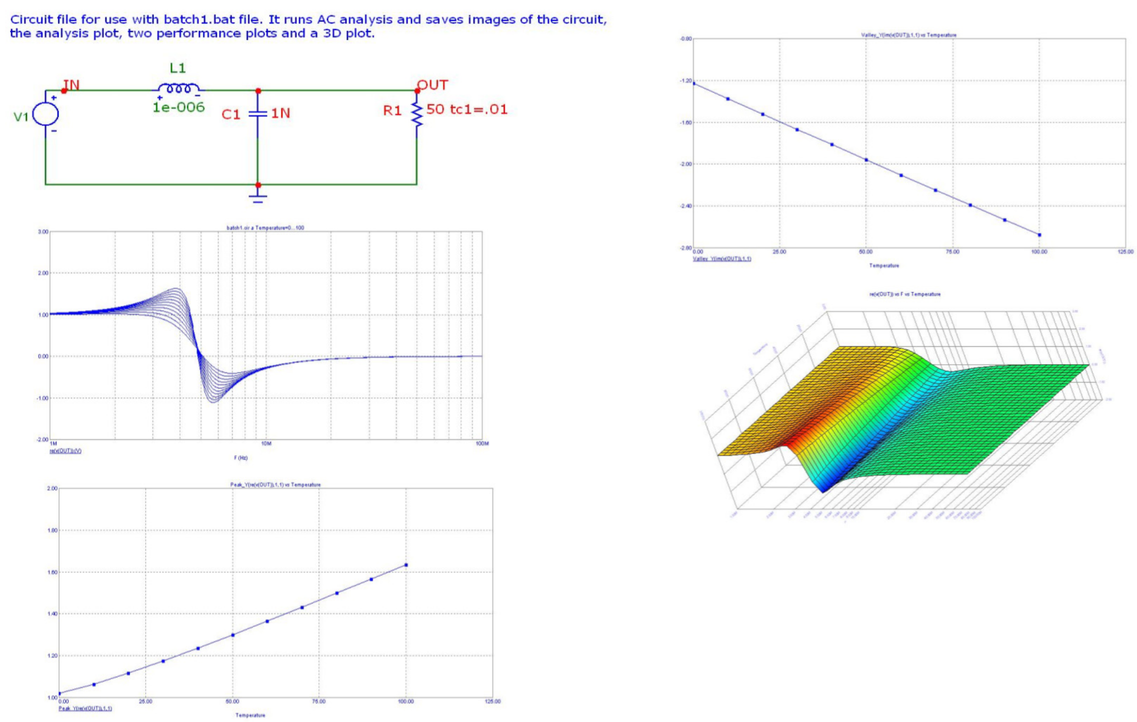


Fig. 11 -The images produced by the batch file

Each of these five images is saved in the DATA folder where they may be used individually or as a part of a schematic like this one (batch1_pics.cir) whose only function is to display a collection of plots. Alternatively they might be part of a report detailing simulation results.

Product Sheet

Latest Version numbers

Micro-Cap 10 .... Version 11.0.0.2
Micro-Cap 10 .... Version 10.1.0.2
Micro-Cap 9 .... Version 9.0.9.0
Micro-Cap 8 .... Version 8.1.3
Micro-Cap 7 .... Version 7.2.4

Spectrum's numbers

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