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Personal Computer
Circuit Design
Tools

NEWSLETTER

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With the introduction of **SPICE_NET**, our schematic entry program, the software and hardware needed for publishing integrated design reports is in place. Using desktop publishing techniques will help you produce quality design documentation. Improving the quality of documentation in the initial project phase leads to

better designs by improving communications and reducing the duplication of effort in the transition to production. Having experienced the evolution of the CAD desk top publishing technology, we would like to share some tips and describe the hardware and software that we use.

First, our hardware configuration is as follows:

| | |
|------------------|-------------------------------|
| Computer: | Compaq Deskpro 386 |
| Graphics: | Compaq EGA |
| Mouse: | Microsoft |
| Printer: | Apple LaserWriter Plus |

There are other printers, plotters, etc that we use; but this is our basic system for desk top publishing. The Compaq -386 computer and Apple LaserWriter were the only devices of this class available when we started. Before this combination was available, it was necessary to send our word processor files out for typesetting, or switch over to an Apple Macintosh system. The wide use of the Macintosh in the printing industry was a strong factor in our software selection.

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For software we use our own simulation and schematic entry products along with the following:

| | |
|-------------------------|---|
| Word Processing: | Several, all with disadvantages. |
| Page Layout: | Aldus PageMaker |
| Art Work: | Micrografx Draw! |

As you can see, we are not all together happy with word processors and do not wish to have any appearance of making a recommendation. PageMaker accepts most word processor files. The most important combination here is the PageMaker software and the PostScript driven laser printer. Pagemaker lets us move between Apple and IBM and work easily with our suppliers. PostScript unlocks the full power of the laser printer and can also drive higher resolution typesetting machines. Unfortunately, the Windows environment, under which PageMaker operates on IBM machines, is very slow. To compensate it is almost necessary to run on a 386 based machine. The Draw! program lets us make things like the buttons seen on page 4. Various canned art can be purchased and edited with Draw!.

In order to produce a publication it is necessary to know something about the printing industry. Most importantly, the size and spacing of fonts are measured in points. One point is 1/72 inch. The character spacing or pitch in most type set fonts are variable. In fact, some character combinations have intercharacter spaces adjusted or kerned to improve appearance. When switching from typewriter to type set fonts, the variable pitch can be quite confusing.

The font size is a measure of the height from the lowest descender to the top part of capital letters. The space between lines, called leading, is also measured in points and is usually 120% of the font size. With PageMaker and a PostScript printer, you can control leading to within .5 points and font size to 1 point.

PostScript is a computer language especially designed for describing pages of type set information. It works something like Forth, using a hierarchy of dictionary definitions. As part of the PostScript interface, a partial language definition is transmitted to

the printer. Using PostScript reduces the information rate transmitted to the printer and makes a specific knowledge of the printer unnecessary. Images can be described as filled shapes, converted to raster scanned output in the printer, which is ideal for schematic drawings and varying font sizes. PageMaker takes care of these details. What you see on the screen is pretty close to the final printer output.

Here are some of the problems we have encountered and our solutions.

1. Selecting a Font: We prefer Helvetica for publications and New Century Schoolbook for correspondence. The rationale is that Helvetica produces the most readable high density characters. This is desirable for most publications. The usually accepted single column letter size page for correspondence needs a larger type to avoid excessively long lines. More than 70 characters per line becomes difficult to read. New Century Schoolbook is pleasant when enlarged and has the appearance of a high quality typewriter.

2. Font Size: For a first cut we select a size to get 60 characters per column average. We then adjust point size and leading to get a match between text, tables and figures.

3. Using other Fonts:

For SPICE listings, we use bold Courier, reduced about 2 points below our text font. This is done to get uniform pitch and make the character density approximate the text density.

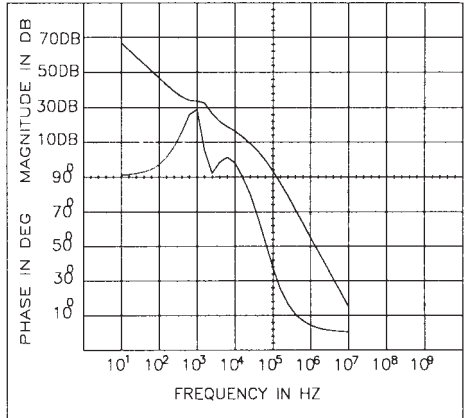
Minus signs and asterisks are done in the Symbol font. Type set minus signs are printed as short dashes and asterisks are set too high, the Symbol Font corrects these problems.

Titles for figures and tables use bold Helvetica, reduced one or 2 point sizes.

If you have time to fine tune a publication, it helps to reduce the point size in long strings of capital letters.

Macro for 10 cycle log

We have had several requests for a method to make Bode Plots over a greater span than the 3 cycle log default of Intu_Scope. The keystroke macro capability of Intu_Scope can be used to create different graph formats. The figure at the right was taken from an Intu_Scope file. The keystroke macro shown below was used to change the linear scale in



the x-axis to a 10 cycle log scale. The graph, without labels can be plotted with Intu_Scope. If you have SPICE_NET, then place the waveforms in the FRAME4 symbol to get the figure shown above. We used the

| Key Strokes | Resulting Functions |
|----------------|--|
| C W ▲ 98 W S 1 | places wfm.0 in the stack, saves wfm.0 in wfm.98, 1 in accumulator |
| 0 | pushes 0 in stack, 1 in accumulator |
| 1 | |
| ; DRAW | draws a straight line, origin to 1 at xmax |
| ; # | gets number of x elements |
| 1 - ; GETX | gets last x element in accumulator |
| * 0 | scales the line and put 0 in accumulator |
| ; GETX | gets first x element in accumulator |
| 0 | push 0 in accumulator |
| ; GETY | get first y element, |
| - + ; LGT | adjust offset and take log base 10 of wfm.o |
| 98 W | places wfm.98 in accumulator |
| ; TOX | sends new xaxis to wfm.98 and brings result back to wfm.0 |
| ; GETSCALE | gets scaling info |
| ▼▼ 1 | pops x scales off the stack and place 1 in the accumulator |
| 5 | places 5 in the accumulator |
| ; SCALE | rescales for first data at 1 Hz, center at 100KHz, end is 10GHz |

“.PIC” output from SPICE_NET to resize the figure and insert it in this newsletter.

To enter the macro, type each line as shown, terminating with a carriage return. Do not enter any spaces, they are shown for clarity only.

To use the macro, select an AC analysis and a linear grid. Then display the waveform and execute the macro. If the y axis was not in dB, you can escape back to the scaling menu and press L to log compress, then press carriage return to display the waveform again. The x axis information is compressed to log base 10, frequency is then 10^x .

Spiceing up Subcircuits with Parameters

Making an effective circuit library requires some means to reconfigure element parameters. This may not be obvious for diodes, transistors or operational amplifiers, however, one cannot deal with library functions like wires or transformers without being faced with an infinite number of wire lengths or turns ratios. Even transistors, when used in certain IC's must be configured as subcircuits. In a subcircuit configuration, SPICE can no longer handle geometrical variations external to the subcircuit. SPICE simply cries out for a method to get parameters into subcircuits along the same lines used to specify model parameters.

Once this capability is in place, the need for thousands of different models is eliminated. Zener diodes, for example, can be called by a family name with breakdown as a parameter. Unwieldy Gummel-Poon model coefficients can be replaced by data sheet parameters.

Here is how Intusoft solved the problem with the PRE_SPICE software. First, the method of identifying parameters in SPICE

models was applied to subcircuits. The parenthesis were replaced by curly braces, {}. Several examples are shown following.

| | |
|---|--|
| <code>X1 1 2 POLE {K=-1.0 FP=1KHZ}</code> | First order pole with gain, K and 3dB cutoff at FP |
| <code>X2 5 6 LZEN {VZ=5.6}</code> | Low voltage Zener diode, breakdown at 5.6 Volts |
| <code>XQ2 5 6 7 NBJT {FT=300MEG + COB=7P TS=20N IMA=300MA}</code> | Transistor specified by data sheet parameters. |

Next it is necessary to create a subcircuit that uses these parameters. This is done by expressing element values in algebraic equations as functions of the passed parameters and constants. The equations are evaluated before running SPICE, by the PARAM.EXE program. The next equation shows how zener diode series resistance, RS, is described in the LZEN model:

```
.MODEL DZEN D(RS={0.5*(3.8263+27.7*ZV-9.0796*ZV^2  
+ + .9678*ZV^3-.03237*ZV^4)})  
+ ...)
```

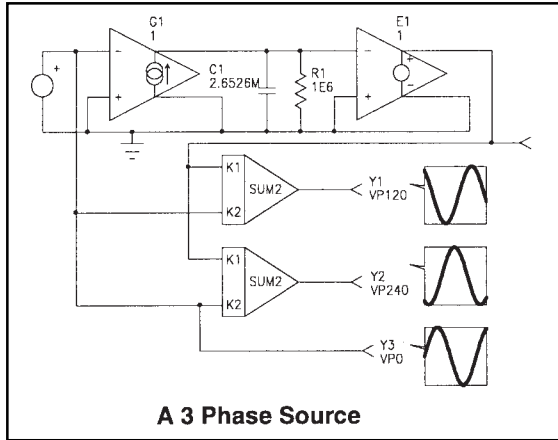
Notice that the curly braces are also used in the subcircuit to delimit each equation. Only the symbols within the curly braces are considered. It is, therefore, permissible to use symbols that are duplicates of SPICE model names. The resistance, RS, was calculated using a polynomial function of breakdown voltage. Polynomial coefficients were found using the polynomial regression feature of Intu_Scope.

Running the program called PARAM.EXE causes these expressions to be evaluated. The resulting syntax is then SPICE compatible. An interesting feature is the ability to create additional subcircuits when model parameters are different. If your circuit used 2 zener diodes with different breakdown voltages, the PARAM program would install 2 subcircuits called LZEN#0 and LZEN#1, one for each different model. This technique can also be applied to Monte Carlo analysis. If parameters are evaluated after the insertion of Monte Carlo tolerances, then additional subcir-

circuits will be made for each different set of parameters. Furthermore, different transistor models can be created by placing the model within a subcircuit and giving model parameters, such as BF, tolerances.

Making a 3 Phase Power Source

SPICE sine wave sources can be delayed in order to get different phases. The delayed sources, however, remain at the start value until the simulation reaches the specified delay. The following circuit is proposed to get a source that starts all 3 phases at the beginning of the simulation. In this circuit, a sinusoidal source starting with zero delay is integrated using a capacitor fed from a current source. This 90 degree lagging signal is then summed with various weighting constants to give the desired waveforms.



using a capacitor fed from a current source. This 90 degree lagging signal is then summed with various weighting constants to give the desired waveforms.

Several things must be done to make this a useful library element. First, the capacitor initial condition must be computed automatically and second, the generator needs to be controlled as though it were a piece of laboratory test equipment. The following parameter list was chosen.

| | |
|---------------|---|
| FREQ | Defines the generator Frequency. |
| VGEN | The Phase to Neutral peak amplitude. |
| DPHASE | Phase disturbance in degrees. |
| DMAG | Amplitude unbalance in percent. |

Controlling phase and magnitude error signals makes it possible to evaluate performance parameters that may not be seen in the laboratory. Test equipment that performs these operations is not commonly available. In instances like this, the power of the

IS_SPICE simulator can be applied to help make correct design decisions early. Decisions that may otherwise have been made without adequate technical information.

Next, the algebraic expressions using these parameters must be made in order to define the various subcircuit element values. VGEN controls the amplitude of the sine wave generator, $V_s = \text{VGEN} * \text{SIN}(\omega t)$. FREQ is used directly in the sine wave generator and algebraically to define the phase shifting capacitor value. The phase shifting capacitor is used to form a generator, $V_c = \text{VGEN} * \text{COS}(\omega t)$. With both sine and cosine components, the following equations are used to combine the 2 signals for each of the 3 phases.

$$V(\phi = 0 \text{ Deg.}) = V_s$$

$$V(\phi = 120 \text{ Deg}) = \text{COS}(\phi)V_s + \text{SIN}(\phi)V_c = -.866V_s - .5V_c$$

$$V(\phi = -120 \text{ Deg}) = -.866V_s + .5V_c$$

When a small phase error is introduced, then ϕ is replaced by $\phi + \delta$, and the small angle trigonometric series approximation for δ is substituted as follows:

$$\begin{aligned} \text{SIN}(\phi + \delta) &= \text{SIN}(\phi)\text{COS}(\delta) + \text{COS}(\phi)\text{SIN}(\delta) \\ &= \text{SIN}(\phi)(1 - \delta^2/2) + \text{COS}(\phi)(\delta - \delta^3/6) \end{aligned}$$

The sign of the cosine term must be adjusted to account for the lag in the generator. Notice that the cosine generator must start initially at VGEN. The pulse generator, I1, initializes the capacitor at time $t = 0^-$ and turns off at $t = 0^+$.

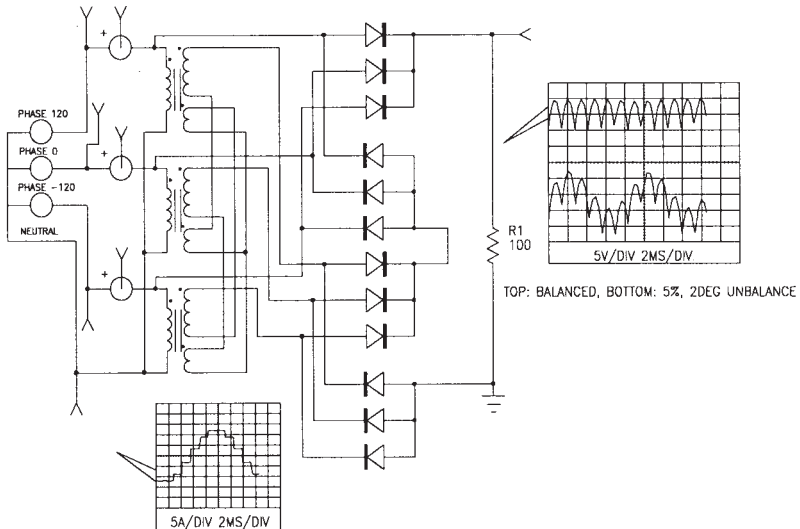
Constants are used in the algebraic expressions for conversion from degrees to radians, percent to fractions and for the series expansion coefficients.

The listing in table 2 is the final subcircuit, GEN3.

The circuit was then tested in an application that used auxiliary transformers to make a 12 phase rectifier. This type of rectifier has advantages in improved power factor and reduced output ripple. The simulation can be used to evaluate the effectiveness of these improvements under the conditions of unbalanced input power. The first cut of the analysis shown next illustrates a significant second harmonic ripple in the output.

Table 1, 3 Phase Generator Subcircuit Listing

```
.SUBCKT GEN3 3 7 1 20
*3 PHASE GENERATOR
* FREQ = {FREQ}
* AMPLITUDE = {VGEN}
C1 2 20 {1/(6.28319K*FREQ)}
R1 2 20 1E6
I1 20 2 PULSE {VGEN*1U} 0
* MAKES UIC UNNECESSARY
E1 5 20 20 2 1
V1 3 20 SIN 0 {VGEN} {FREQ}
E2 7 20 POLY(2) 5 20 3 20 0 -866.00M -500.00M
E3 1 20 POLY(2) 5 20 3 20 0
+ {(1+.01*MAGERR)*(.866*(1-.5*(.0174533*PHASE)^2)
+ -.5*.0174533*PHASE*(1+.166667*
+ (.0174533*PHASE)^2))}
+ {(1+.01*MAGERR)*(-.5*(1-.5*(.0174533*PHASE)^2)
+ -.866*.0174533*PHASE*(1+.166667*
+ (.0174533*PHASE)^2))}
G1 20 2 20 3 1M
R2 7 0 100MEG
R3 1 0 100MEG
R4 3 0 100MEG
R5 5 0 100MEG
.ENDS
```



Three phase generator used to evaluate a transformer rectifier circuit