

PC Programs FOR ENGINEERS

STAINS—Symbolic Two-Port Analysis via Internal Node Suppression

This column describes a program and website that is concerned with symbolic analysis. What is symbolic analysis? It's the counterpart of numerical analysis! For example, to describe a 1-mH inductor, we would write $Z(s)=10^{-3}s$ as a numerical description. The symbolic description would be $Z(s)=Ls$, and the numerical value typically wouldn't be added until required for some later analysis step. There are many applications of symbolic analysis. The determination of sensitivities and the use of optimization techniques in design are two of the most commonly encountered ones. This column describes a new program for performing symbolic analysis. It is interesting because it uses the Microsoft Excel spreadsheet to make the determination. This makes it easy to enter the circuit data. The program also takes advantage of the many capabilities of MATLAB to display the network characteristics.

Program: STAINS—Symbolic Two-port Analysis via Internal Node Suppression

Purpose: This program is designed to use Microsoft's Excel spreadsheet to perform symbolic analysis on analog circuits. Some of the properties of the program include:

- ◆ The program allows the following circuit elements: resistors, capacitors, inductors, impedances, admittances, voltage-controlled voltage and current sources, current-controlled voltage and current sources, and ideal op amps.

- ◆ The functions computed by the program are voltage transfer function, input admittance, and output admittance.
- ◆ The circuit element type, its description, and its node connection information is entered directly into the cells of the spreadsheet. The circuit data can be saved as an ASCII file and edited outside the spreadsheet.
- ◆ Four different output formats are available: a compact sequence of expressions (which has the smallest number of arithmetic operations but contains fractions), a fractionless sequence of expressions, a rational sequence of expressions, or just the compacted modified node admittance matrix.
- ◆ Output expressions are available for the open-circuit voltage transfer function, the input admittance, and the output admittance.
- ◆ An option can be selected to create MATLAB files containing the output. These are plain text (ASCII) files. They are a .DAT file containing the nominal element values of the components, a .SEQ file containing the required sequence of expressions, and, a .NAM file that contains the compacted modified node admittance matrix.

Information:

Dr. Benedykt S. Rodanski
Lecturer and Head,
Electrical Engineering Program
Faculty of Engineering
University of Technology, Sydney (UTS)
Building 1, Level 24, P. O. Box 1123

Broadway NSW 2007, Australia
E-mail: benr@eng.uts.edu.au

Technical Data: The program requires Microsoft Excel 97 or higher running on a PC. In Excel, the "Analysis Tool Pack" and the "Analysis Tool Pack - VBA" options must be operational. This is done by checking the appropriate boxes in the Tools - Add Ins window.

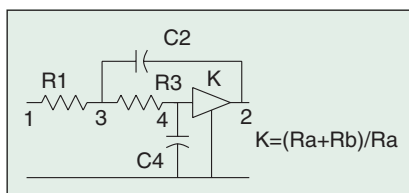
Availability: The STAINS program and many sample data files can be downloaded from the website

<http://www.eng.uts.edu.au/~benr/symbolic/index.htm>.

The downloaded file contains two versions of STAINS, namely STAINS2.4 and STAINS3.2. In this column we describe only the 2.4 version. The downloaded file also contains several sample circuit input files including bandpass filters (with ideal op amps or with linear op-amp micro-models), the KHN (Kerwin, Huelsman, Newcomb) filter, Sallen and Key filters, dc and ac small signal equivalent models of μA 741 op amps, and many others. A complete user's manual is included as a .pdf file.

The website also contains many other resources, including schematics and descriptions of various filter circuits, and links to other symbolic programs.

Lawrence P. Huelsman, Editor



1. A low-pass Sallen and Key filter.

STAINS 2.4a

Circuit data

Title: A low-pass Salen-Key filter

of nodes: 5

Data File: D:\stains\salkeylp.cir

ELEMENT	Node 1	Node 2	Node 3	Node 4	Value
r1	1	3			1
r3	3	4			1
ra	5	0			1
rb	5	2			0.586
c2	3	2			1
c4	4	0			1
n1	4	5	2	0	
inp	1	0			
out	2	0			

2. The Excel description of the filter provided by loading the sample data circuit file salkeylp.cir.

STAINS 2.4a: Compacted Modified Node Admittance Matrix

A low-pass Salen-Key filter

	1	2	3	4+5
1	G1		-G1	
3	-G1	-s*C2	G1+G3+s*C2	-G3
4			-G3	G3+s*C4
5		-Gb		Ga+Gb

STAINS 2.4a: Compact sequence of expressions for the O/C Voltage Ratio

```
d1 = -Gb/(Ga+Gb)
x1 = G3*d1-s*C2
x2 = -(G3+s*C4)*d1
d2 = -x2/(G3)
x3 = G1*d2
x4 = x1-(G1+G3+s*C2)*d2
Tv = G1/(x4)
```

Terms: 7
Mults: 7
Adds: 2
Flops: 60

3. The compact sequence of expressions output for the open-circuit voltage transfer function.

```
% This MATLAB file was generated by STAINS 2.4a
% On 9/27/01 at 10:58:01
```

```
% A low-pass Salen-Key filter
```

```
% Component values:
```

```
R1=1; G1=1/R1;
R3=1; G3=1/R3;
Ra=1; Ga=1/Ra;
Rb=0.586; Gb=1/Rb;
C2=1;
C4=1;
```

4. The MATLAB data file generated by the program

```
% This MATLAB file was generated by STAINS 2.4a
% On 9/27/01 at 10:58:01
```

```
% A low-pass Salen-Key filter
```

```
% Compact sequence of expressions
```

```
d1 = -Gb/(Ga+Gb);
x1 = G3*d1-s*C2;
x2 = -(G3+s*C4)*d1;
d2 = -x2/(G3);
x3 = G1*d2;
x4 = x1-(G1+G3+s*C2)*d2;
```

```
% O/C Voltage Ratio:
```

```
Tv = G1/(x4);
```

5. The MATLAB compact sequence of expressions file.

```
>> s=tf('s')
```

```
Transfer function:
s
```

```
>> salkeylpdat
>> salkeylpseq
>> Tv
```

```
Transfer function:
1
```

```
-----
0.6305 s^2 + 0.8916 s + 0.6305
```

6. The script for running MATLAB and invoking the files generated by STAINS and the resulting output data.

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voltage level of a node following a voltage transient induced by a heavy-ion strike. Combined with their low power requirements, CMOS circuits are often the choice for space applications. Still, unhardened CMOS SRAMs may experience upsets at a rate of 10^{-5} to 10^{-3} errors/(bit-day), which represents an upset every hour for a satellite with a large memory element in low-Earth orbit that passes through the South Atlantic Anomaly, an area of exceptionally high proton density that overlies much of South America and the South Atlantic Ocean.

Dynamic circuits are generally very sensitive to SEU and are not used in critical space applications. In dynamic circuits, such as DRAMs (dynamic random access memories) and CCDs (charge-coupled devices), information is represented as charge stored on a circuit node. In DRAMs this charge gradually leaks off the storage node and must be refreshed periodically. Upset in these devices occurs if sufficient charge is collected at a struck node to compensate the original stored charge. Although DRAMs and CCDs are not recommended for critical circuit applications, they have found increasing use in

solid-state data recorders and imaging systems where robust ECC can restore corrupted data.

References

- [1] P. Winokur, "Why Semiconductors must be hardened for space deployment," *IEEE Nuclear Plasma and Sciences Society News*, June 2000. (<http://www.ieee.org/organizations/pubs/newsletters/npss/june2000/semi.htm>).
- [2] G. Anelli et al., "Radiation tolerant VLSI circuits in standard deep submicron CMOS technologies for the LHC experiments: Practical design aspects," *IEEE Trans. Nuclear Sci.*, vol. 46, pp. 1690-1696, Dec. 1999 (<http://rd49.web.cern.ch/RD49/>). CD■

PC PROGRAMS FOR ENGINEERS

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Application Examples: As an example of the use of STAINS, consider the low-pass Sallen and Key filter shown in Fig. 1. The Excel description of the filter provided by loading the sample data circuit file *salkeylp.cir* is shown in Fig. 2. The compact sequence of expressions output for the open-circuit voltage transfer function is shown in Fig. 3. The MATLAB data file generated by the program is shown in Fig. 4. The MATLAB compact sequence of expressions file generated is shown in Fig. 5.

The two MATLAB files were renamed as *salkeylpdat.m* and *salkeylpseq.m*, respectively. The script for running MATLAB and invoking the files generated by STAINS and the resulting output data from MATLAB is shown in Fig. 6. This output corresponds with the well-known result for this circuit, namely a normalized second-order Butterworth function:

$$V_2(s)/V_1(s) = 1.586/(s^2 + (2s + 1)).$$

The STAINS program has been added to the PCPE master CD-ROM that contains all of the programs (63) and all the PCPE columns that have appeared since the inception of the column (November 1989). This master CD is described more fully in the March 2001 issue of this column. The master CD is available for a shipping and handling charge of \$25.00 (U.S. dollars) inside the United States or \$30.00 outside the United States. Checks must be on a U.S. bank or a bank with a US correspondent bank and be made payable to "The University of Arizona."

Licensing: The program is copyrighted. It may be freely used and distributed by individuals as long as no charge is made. All

other rights, including commercial usage, are reserved by the author.

For More Information: Dr. Rodanski has developed a very useful and easy-to-use program that is an important computational tool for the practicing engineer. A description of the basic theory of the program may be found in the paper "Generation of Sequential Symbolic Network Functions for Large-Scale Networks by Circuit Reduction to a Two-Port," *IEEE Transactions on Circuits and Systems - I: Fundamental Theory and Applications*, vol. 48, no. 7, pp. 906-909, July 2001. An extended version of the paper can be obtained from the website of the author (in PDF format) at

<http://www.eng.uts.edu.au/benr/papers/publist.htm>. CD■