LTSPICE2MATLAB

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function raw_data = LTspice2Matlab(filename, varargin)

21/03/19 Modified to work withLTspice XVII (fopen 'UTF16LE') This could be causing some data to corrupt and appear as NaN - This codification is no available Disabled warnings ecause of the non availability.

LTSPICE2MATLAB -- Reads an LTspice IV .RAW waveform file containing data from a Transient Analysis (.tran) or AC Analysis (.ac) simulation, and converts voltages and currents vs. time into Matlab variables. This function can read compressed binary, uncompressed binary, and ASCII file formats. It does not currently support files saved in the Fast Access Format. In the case of compressed binary, the data is automatically uncompressed using fast quadratic point insertion.

LTspice IV is an excellent Spice III simulator & schematic capture tool freely avaliable for download at www.linear.com/designtools/software. It is optimized for simulation of switching regulators, but an simulate many other types of circuits as well and comes with a wide variety of component models. Note that the LTspice uses a lossy compression format (enabled by default) with user adjustable error bounds.

Use LTSPICE2MATLAB to import LTspice waveforms into Matlab for additional analysis or to compare with measured data.

This function has been tested with LTspice IV version 4.01p, and Matlab versions 6.1 and 7.5. Regression testing has been used to expose the function to a wide range of LTspice settings. Author: Paul Wagner 4/25/2009 JCCopyrights Summer 2019

Calling Convention:

RAW_DATA = LTSPICE2MATLAB(FILENAME); %Returns all variables found in FILENAME

(or)

RAW_DATA = LTSPICE2MATLAB(FILENAME, SELECTED_VARS); %Returns only those variables covered by SELECTED_VARS Set SELECTED_VARS to [] to quickly determine the number and names of variables present in FILENAME without actually loading the variables.

(or)

RAW_DATA = LTSPICE2MATLAB(FILENAME, SELECTED_VARS, N); Returns variables listed in SELECTED_VARS, with all waveforms downsampled by N. Set N > 1 to load very large data files using less memory, at the price of degraded waveform accuracy and possible aliasing.

Inputs:

FILENAME is a string containing the name and path of the LTspiceIV .raw file to be converted.

SELECTED_VARS (optional) is a vector of indexes indicating which variables to extract from the .raw file. For example, if a .raw file has 14 variables and SELECTED_VARS is [1 8 9], then the output RAW_DATA.VARIABLE_MAT will be a 3 x NUM_DATA_PNTS matrix containing waveforms for variables 1, 8, and 9 only. Note that SELECTED_VARS does not cover the time (or frequency) variable (index 0), which is returned separately in RAW_DATA.TIME_VECT (or RAW_DATA.FREQ_VECT). Extracting only of subset of variables is a way to use less memory when loading very large simulation files.

If this parameter is not specified, then all variables are returned by default. Setting SELECTED_VARS to 'all' will also cause all variables to be returned.

- To quickly determine the number and names of variables present in a .raw file, call LTspice2Matlab with SELECTED_VARS set to []. In this case, all fields in RAW_DATA will be populated, except .TIME_VECT (or .FREQ_VECT) and .VARIABLE_MAT, which will both be empty ([]). Since only the header is read, the function call should execute very quickly, even for large files.

N (optional) must be a positive integer >= 1. If N is specified, then SELECTED_VARS must also be specified. If N is unspecified, it defaults to 1, which does not change the sampling rate. If this value is 2 or larger, the returned voltage, current, and time data will be downsampled by keeping every N-th sample in the original data, starting with the first. Caution: No lowpass filtering is applied prior to downsampling, so aliasing may occur. Also, in many cases LTspice saves data with a non-constant sampling rate, in which case downsampling can result in substantial waveform distortion. This option should only be used if the waveform of interest is initially oversampled.

Outputs:

RAW_DATA is a Matlab structure containing the following fields ...

title: String containing the title appearing in the .RAW file header.

date: String containing the date appearing in the .RAW file header.

plotname: String indicating simulation type ('Transient Analysis', 'AC Analysis')

conversion_notes: Description of modifications (if any) done to the data during conversion.

num_variables: Number of variables (does not include the "time" or "frequency" variable)

variable_type_list: A cell of strings indicating the variable type (i.e. voltage, current etc.)

variable_name_list: A cell of strings indicating the name of each variable.

selected_vars: A vector of indicies referencing VARIABLE_TYPE_LIST cells, corresponding to each row in VARIABLE_MAT.

num_data_pnts: Number of data points for each variable.

variable_mat: Double precision matrix with NUM_VARIABLES rows and NUM_DATA_PNTS columns. This matrix contains node voltages (in Volts) and device currents (in Amps) for each variable and each time point listed in TIME_VECT (or FREQ_VECT). For AC Analysis simulations, VARIABLE_MAT will have complex values showing the real and imaginary components of the voltage or current at the corresponding frequency. To convert this to log magnitude and normalized phase representation used in LTspice plots, use the following formulas: Log_Magnitude_dB = 20*log10(abs(variable_mat)) Norm_Phase_degrees = angle(variable_mat)*180/pi

time_vect: [Field returned for Transient Analysis only] Double precision row vector of time values (in seconds) at each simulation point

(or)

freq_vect: [Field returned for AC Analysis only] Double precision row vector of frequency values (in Hz) at each simulation point

Currently this function is able to import results from Transient Analysis (.tran) and AC Analysis (.ac) simulations only.

Examples

These examples assume you've run a .TRAN simulation in LTspice for a hypothetical file called BASIC_CIRCUIT.ASC, and that an output file called BASIC_CIRCUIT.RAW has been created. It also assumes your current Matlab directory is pointing to the directory where the .RAW file is located (or that you prepended the full path to the input parameter FILENAME).

To import BASIC_CIRCUIT.RAW into Matlab and create a labeled plot of a single variable vs. time:

```
raw_data = LTspice2Matlab('BASIC_CIRCUIT.RAW');
variable_to_plot = 1;   %This example plots the first variable in the
plot(raw_data.time_vect, raw_data.variable_mat(variable_to_plot,:), '
title(sprintf('Waveform %s', raw_data.variable_name_list{variable_to_
ylabel(raw_data.variable_type_list{variable_to_plot} );
xlabel('Time (sec)' );
```

To superimpose all variables in BASIC_CIRCUIT.RAW on a single graph with a legend:

```
raw_data = LTspice2Matlab('BASIC_CIRCUIT.RAW');
plot(raw_data.time_vect, raw_data.variable_mat);
title(sprintf( 'File:  %s', raw_data.title));
legend(raw_data.variable_name_list);
ylabel('Voltage (V) or Current (A)');
xlabel('Time (sec)');
```

To quickly determine the number and names of variables in BASIC_CIRCUIT.RAW without loading the entire file:

```
raw_data = LTspice2Matlab('BASIC_CIRCUIT.RAW', []);
disp(sprintf( '\n\nThis file contains %.0f variables:\n', raw_data.nu
disp(sprintf('NAME         TYPE\n------------------------'));
disp([char(raw_data.variable_name_list), char(zeros(raw_data.num_vari
```

```
%%Code

function raw_data = LTspice2Matlab( filename, varargin )
    raw_data = [];  %Initialize the output structure.
    if nargin==0,
        error( 'LTspice2Matlab takes 1, 2, or 3 input parameters.
 Type "help LTspice2Matlab" for details' );
    elseif nargin==1,
        selected_vars = 'all';
```

```
        downsamp_N = 1;
    elseif nargin==2,
        selected_vars = varargin{1};
        if ischar(selected_vars),  selected_vars =
lower(selected_vars);  end
        downsamp_N = 1;
    elseif nargin==3,
        selected_vars = varargin{1};
        if ischar(selected_vars),  selected_vars =
lower(selected_vars);  end
        downsamp_N = varargin{2};
    else
        error( 'LTspice2Matlab takes only 1, 2, or 3 input parameters.
 Type "help LTspice2Matlab" for details' );
    end


    if length(downsamp_N)~=1 | ~isnumeric(downsamp_N) |
isnan(downsamp_N) | mod(downsamp_N,1)~=0.0 | downsamp_N<=0,
        error( 'Optional parameter DOWNSAMP_N must be a positive
integer >= 1' );
    end


    filename = fliplr(deblank(fliplr(deblank(filename))));   %Remove
leading and trailing spaces from filename.
%fid = fopen(filename, 'rb'); %ltspiceiv
warning('off');
fid = fopen(filename, 'rb', 'n', 'UTF16LE');
warning('on') %Just to avoid the non sense warning
    if length(fid)==1 & isnumeric(fid) & fid==-1,
        %try to append ".raw" to the file name ...
        %fid = fopen(sprintf( '%s.raw', filename ), 'rb'); %ltspice iv
 warning('off');
 fid = fopen(sprintf( '%s.raw', filename ), 'rb', 'n', 'UTF16LE');
 warning('on') %Just to avoid the non sense warning
        if length(fid)==1 & isnumeric(fid) & fid==-1,
            error( sprintf( 'Could not open file "%s"', filename ) );
        end
    end


[filename, the_permision, machineformat] = fopen(fid);
    %Load header tags & information
    variable_name_list = {};  variable_type_list = {};   %These
include voltages and currents only.  Does not include the time
vector.
    variable_flag = 0;
    file_format = '';
    while 1,
        the_line = fgetl(fid);
        if length(the_line)==1 & isnumeric(the_line) &
double(the_line)==-1,
            try fclose( fid );  catch  end
```

```
            error( sprintf( 'Format error in LTspice file "%s" ... End
of file unexpectedly encountered', filename ));
        end

        the_line = char(the_line);

        if length(strfind( the_line, 'Binary:' ))~=0,  file_format
= 'binary';  break;  end
        if length(strfind( the_line, 'Values:' ))~=0,  file_format
= 'ascii';   break;  end

        if variable_flag==0,  %Non-variable header section
            if length(the_line)==0,  colon_index = [];
            else,  colon_index = find( the_line == ':' );  end
            if length(colon_index)==0,
                try fclose( fid );  catch end
                error( sprintf( 'Format error in LTspice file "%s"',
filename ));
            end
            var_name = the_line(1:(colon_index(1)-1));
            var_value =
fliplr(deblank(fliplr(deblank(the_line((colon_index(1)+1):end)))));
            vn_keep_index = find( var_name~=' ' & var_name~='.' &
var_name~=char(9) & var_name~=char(10) & var_name~=char(13) );
            var_name = lower(var_name(vn_keep_index));
            if length(var_name)==0 | (var_name(1)>='0' &
var_name(1)<='9'),
                try fclose( fid );  catch end
                error( sprintf('Format error in LTspice file "%s" ...
Bad tag name found', filename ));
            end
            if strcmpi( var_name, 'variables' ) |
strcmpi( var_name, 'variable' ),  variable_flag = 1;  continue;  end
            value_try = str2num(var_value);
            try
                if length(value_try)==0,  raw_data =
setfield( raw_data, var_name, var_value );
                else raw_data = setfield( raw_data, var_name,
value_try );  end
            catch
                try fclose( fid );  catch end
                error( sprintf('Format error in LTspice file "%s" ...
Bad tag name found', filename ));
            end

        else  %Variable header section
            leading_ch_index = find( (the_line(1:end-1)=='
' | the_line(1:end-1)==char(9)) & (the_line(2:end)~=' ' &
the_line(2:end)~=char(9)) );
            if length(leading_ch_index)~=3,
                try fclose( fid );  catch end
                error( sprintf('Format error in LTspice file "%s" ...
Wrong number of columns in the variable define section', filename ));
            end
```

```
            part1 =
fliplr(deblank(fliplr(deblank(the_line( (leading_ch_index(1)+1) :
leading_ch_index(2) )))));
            part2 =
fliplr(deblank(fliplr(deblank(the_line( (leading_ch_index(2)+1) :
leading_ch_index(3) )))));
            part3 =
fliplr(deblank(fliplr(deblank(the_line( (leading_ch_index(3)+1) :
end ))))));

            if str2num(part1)~=length(variable_name_list),
                try fclose( fid );  catch end
                error( sprintf('Format error in LTspice file "%s" ...
Inconsistency found in the variable define section', filename ));
            end
            variable_name_list{end+1} = part2;
            variable_type_list{end+1} = part3;
        end
    end

    %Check raw_data structure for required fields
    expected_tags      =
{'title', 'date', 'plotname', 'flags', 'novariables',   'nopoints'
 };
    expected_tags_full = {'Title', 'Date', 'Plotname', 'Flags', 'No.
Variables', 'No. Points'  };
    for q=1:length(expected_tags),
        if ~isfield( raw_data, lower(expected_tags{q}) ),
            try fclose( fid );  catch end
            error( sprintf('Format error in LTspice file "%s" ... tag
"%s" not found', filename, expected_tags_full{q} ));
        end
    end

    raw_data.conversion_notes = '';
    raw_data.num_data_pnts = raw_data.nopoints;  raw_data =
rmfield( raw_data, 'nopoints' );
    raw_data.num_variables = raw_data.novariables-1;  raw_data =
rmfield( raw_data, 'novariables' );
    %"raw_data.num_variables" does not include the time vector (index
0 in the .raw file)
    if isfield( raw_data, 'command' ),  raw_data =
rmfield( raw_data, 'command' );  end
    if isfield( raw_data, 'backannotation' ),  raw_data =
rmfield( raw_data, 'backannotation' );  end
    if isfield( raw_data, 'offset' ),
        general_offset = raw_data.offset;  %(sec)
        raw_data = rmfield( raw_data, 'offset' );
    else
        general_offset = 0.0;
    end
```

```
   raw_data.variable_name_list = {variable_name_list{2:end}};
 %cut off the time variable.
   raw_data.variable_type_list = {variable_type_list{2:end}};

   simulation_type = '';
   if     length(strfind( lower(raw_data.plotname), 'transient
analysis' ))~=0,           simulation_type = '.tran';   %SUPPORTED
   elseif length(strfind( lower(raw_data.plotname), 'ac analysis'
))~=0,                  simulation_type = '.ac';     %SUPPORTED
   elseif length(strfind( lower(raw_data.plotname), 'dc transfer
characteristic' ))~=0,   simulation_type = '.dc';     %This is a DC
sweep (Not supported)
   elseif length(strfind( lower(raw_data.plotname), 'operating point'
))~=0,              simulation_type = '.op';     %This is a DC
operating point (Not supported)
   end

   if length(simulation_type)==0 |
~(strcmpi(simulation_type, '.tran') |
strcmpi(simulation_type, '.ac')),
       try fclose( fid );  catch end
       error( 'Currently LTspice2Matlab is only able to import
results from Transient Analysis (.tran) and AC Analysis (.ac)
simulations.' );
   end
   if length(strfind( lower(raw_data.flags), 'fastaccess' ))~=0,
       try fclose( fid );  catch end
       error( 'LTspice2Matlab cannot convert files saved in the "Fast
Access" format.' );
   end
   if strcmpi(simulation_type, '.tran') &
length(strfind( lower(raw_data.flags), 'real' ))==0,
       try fclose( fid );  catch end
       error( 'Expected to find "real" flag for a Transient Analysis
(.tran) simulation.  Unsure how to convert the data' );
   end
   if strcmpi(simulation_type, '.tran') &
length(strfind( lower(raw_data.flags), 'forward' ))==0,
       try fclose( fid );  catch end
       error( 'Expected to find "forward" flag for a Transient
Analysis (.tran) simulation.  Unsure how to convert the data' );
   end

   if strcmpi(simulation_type, '.ac') &
length(strfind( lower(raw_data.flags), 'complex' ))==0,
       try fclose( fid );  catch end
       error( 'Expected to find "complex" flag for an AC Analysis
(.ac) simulation.  Unsure how to convert the data' );
   end
   if strcmpi(simulation_type, '.ac') &
length(strfind( lower(raw_data.flags), 'forward' ))==0,
       try fclose( fid );  catch end
       error( 'Expected to find "forward" flag for an AC Analysis
(.ac) simulation.  Unsure how to convert the data' );
```

```
   end
   if isfield( raw_data, 'flags' ),  raw_data =
rmfield( raw_data, 'flags' );  end

   if ischar(selected_vars),
       if strcmpi(selected_vars, 'all')
| strcmpi(selected_vars, 'everything') |
strcmpi(selected_vars, 'complete') | strcmpi(selected_vars, 'all
variables') | ...
                strcmpi(selected_vars, 'all
vars') | strcmpi(selected_vars, 'every thing') |
strcmpi(selected_vars, 'every'),
           selected_vars = 1:raw_data.num_variables;     %Return all
variables
       else
           try fclose( fid );  catch end
           error( 'Bad value for optional input parameter
SELECTED_VARS' );
       end
   end


   if size(selected_vars,1)==0 | size(selected_vars,2)==0,
       raw_data.selected_vars = [];
       raw_data.variable_mat = [];
       raw_data.time_vect = [];
       try fclose( fid );  catch end
       return;
   end
   if size(selected_vars,1)>1 & size(selected_vars,2)>1,
       try fclose( fid );  catch end
       error( 'SELECTED_VARS must be a row or column vector, not a
matrix' );
   end
   if length(find(selected_vars==0))~=0,
       try fclose( fid );  catch end
       error( 'The time vector (index 0) is returned separately.  \n
 Values in input parameter SELECTED_VARS must be positive integers >=
1 and <= NUM_VARIABLES' );
   end
   non_integer_index = find(isnan(selected_vars) |
~isnumeric(selected_vars) | mod( selected_vars, 1 )~=0.0);
   if length(non_integer_index)~=0,
       try fclose( fid );  catch end
       error( 'Values in input parameter SELECTED_VARS must be
positive integers >= 1 and <= NUM_VARIABLES' );
   end
   missing_index = find( ~ismember( selected_vars,
1:raw_data.num_variables ) );
   if length(missing_index)~=0,
       try fclose( fid );  catch end
       error( 'Error in input parameter SELECTED_VARS ... Out of
range value(s) found' );
   end
```

```
   selected_vars = unique(selected_vars);   %remove duplicates and
sort in ascending order.
   raw_data.selected_vars = selected_vars;

   NumPnts = raw_data.num_data_pnts;
   NumPnts_DS = floor(NumPnts/downsamp_N);
   raw_data.num_data_pnts = NumPnts_DS;   %Updated # of points
   NumVars = raw_data.num_variables+1;


   %READ IN THE ACTUAL WAVEFORM DATA
   if strcmpi(file_format, 'binary'),
       binary_start = ftell(fid);   %start of binary data section.

       if strcmpi( simulation_type, '.tran' ),
           % For Transient Analysis simulations, the time data is
stored in double precision floating point binary format,
           % and everything else is stored in single precision
format.
           %Extract the binary data in the fewest possible number of
contiguous blocks
           if length(selected_vars)>1,
               g_border = find( [2, diff(selected_vars), 2]~=1 );
               block_list = {};
               for k=1:length(g_border)-1,  block_list{k} =
g_border(k):(g_border(k+1)-1);  end
           else
               block_list = {1:length(selected_vars)};
           end
           raw_data.variable_mat = zeros(length(selected_vars),
NumPnts_DS);  %Initialize.
           for k=1:length(block_list),
               target_var_index = selected_vars(block_list{k});
               fseek(fid, binary_start +
(target_var_index(1)+1)*4, 'bof');
               TVIL = length(target_var_index);
               bytes_skip = (NumVars+1-TVIL)*4  +
(downsamp_N-1)*(NumVars+1)*4;
               precision_str = sprintf('%.0f*float',TVIL);
               raw_data.variable_mat(block_list{k},:) =
reshape( fread(fid, NumPnts_DS*TVIL, precision_str, bytes_skip,
machineformat), TVIL, NumPnts_DS );
           end
           fseek(fid, binary_start, 'bof');    %rewind to start, then
extract the time vector.
           raw_data.time_vect = fread( fid, NumPnts_DS, 'double',
(NumVars-1)*4 + (downsamp_N-1)*(NumVars+1)*4, machineformat ).';
           if downsamp_N==1,  raw_data.conversion_notes = 'Converted
from Binary format';
           else raw_data.conversion_notes = sprintf( 'Converted from
Binary format.  Downsampled from %.0f to %.0f points', NumPnts,
NumPnts_DS );  end
```

```
       elseif strcmpi( simulation_type, '.ac' ),
           % For AC Analysis simulations, the frequency data is
stored in double precision floating point binary format (8 bytes),
           % and the variables are stored as complex double precision
arrays (8 bytes real followed by 8 bytes imag)

           %Extract the binary data in the fewest possible number of
contiguous blocks
           if length(selected_vars)>1,
               g_border = find( [2, diff(selected_vars), 2]~=1 );
               block_list = {};
               for k=1:length(g_border)-1,  block_list{k} =
g_border(k):(g_border(k+1)-1);  end
           else
               block_list = {1:length(selected_vars)};
           end
           raw_data.variable_mat = zeros(length(selected_vars),
NumPnts_DS);  %Initialize.
           if prod(size(raw_data.variable_mat))~=0,
raw_data.variable_mat(1,1) = 0.0 + j*0.0;  end  %Allocate memory for
complex double.
           for k=1:length(block_list),
               target_var_index = selected_vars(block_list{k});
               fseek(fid, binary_start +
target_var_index(1)*16, 'bof');
               TVIL = length(target_var_index);
               bytes_skip = (NumVars-TVIL)*16  +
(downsamp_N-1)*NumVars*16;
               precision_str = sprintf('%.0f*double',TVIL*2);
               temp_buff = reshape(fread(fid, NumPnts_DS*TVIL*2,
precision_str, bytes_skip, machineformat), TVIL*2, NumPnts_DS );
               raw_data.variable_mat(block_list{k},:) =
temp_buff(1:2:end-1,:) + j*temp_buff(2:2:end,:);
               clear temp_buff;
           end
           fseek(fid, binary_start, 'bof');    %rewind to start, then
extract the time vector.
           raw_data.freq_vect = fread( fid, NumPnts_DS, 'double',
(NumVars-1)*16 + 8 + (downsamp_N-1)*NumVars*16, machineformat ).';

       else
           try fclose( fid );  catch end
           error( sprintf('Simulation type (%s) not currently
supported', simulation_type ));
       end


   elseif strcmpi(file_format, 'ascii' ),

       if strcmpi( simulation_type, '.tran' ),
           %Format:  point number, time value, var1, var2, var3 ...
varN
```

```
            raw_data.variable_mat = fscanf( fid, '%g',
 [raw_data.num_variables+2, raw_data.num_data_pnts] );   %matrix is
 filled in column order.
            if (size(raw_data.variable_mat,1)~=raw_data.num_variables
+2) | (size(raw_data.variable_mat,2)~=raw_data.num_data_pnts),
                error( sprintf('Format error in ASCII Transient
 Analysis LTspice file "%s" ... Incorrect number of data values read',
 filename ));
            end
            raw_data.time_vect =
 raw_data.variable_mat(2,1:downsamp_N:end);
            raw_data.variable_mat =
 raw_data.variable_mat(2+selected_vars,1:downsamp_N:end);

        elseif strcmpi( simulation_type, '.ac' ),
            %Format:  point number, freq value, 0, var1 real, var1
 imag, var2 real, var2 imag, var3 real, var3 imag ... varN real, varN
 imag
            all_data = fread( fid, inf, 'uchar' );
            all_data( find( all_data == ',' ) ) = sprintf( '\t' );
  %Replace commas with tab characters
            raw_data.variable_mat = sscanf( char(all_data), '%g',
 [3+2*raw_data.num_variables, raw_data.num_data_pnts] );
            clear all_data;
            %raw_data.variable_mat = fscanf( fid, '%g',
 [3+2*raw_data.num_variables, raw_data.num_data_pnts] );   %matrix is
 filled in column order.

            if
 (size(raw_data.variable_mat,1)~=(3+2*raw_data.num_variables)) |
 (size(raw_data.variable_mat,2)~=raw_data.num_data_pnts),
                error( sprintf('Format error in ASCII AC Analysis
 LTspice file "%s" ... Incorrect number of data values read',
 filename ));
            end
            raw_data.freq_vect =
 raw_data.variable_mat(2,1:downsamp_N:end);
            raw_data.variable_mat =
 raw_data.variable_mat(3+selected_vars*2-1,1:downsamp_N:end) +
 j*raw_data.variable_mat(3+selected_vars*2,1:downsamp_N:end);

        else
            try fclose( fid );  catch end
            error( sprintf('Simulation type (%s) not currently
 supported', simulation_type ));
        end

        if downsamp_N==1,  raw_data.conversion_notes = 'Converted from
 ASCII format';
        else raw_data.conversion_notes = sprintf( 'Converted from
 ASCII format.  Downsampled from %.0f to %.0f points', NumPnts,
 NumPnts_DS );  end

    else
```

```
       try fclose( fid );  catch end
       error( sprintf('Format error in LTspice file "%s" ... Data
type ID tag not found', filename ));
   end
   try fclose( fid );  catch end



   %Deal with potential compression in Transient Analysis simulations
   if strcmpi( simulation_type, '.tran' ) &
(min(diff(raw_data.time_vect)) < 0.0),   %Check to see if the time
vector is monotonically increasing.

       if downsamp_N~=1,  %If we have already downsampled then we
can't uncompress.
           raw_data.time_vect = abs(raw_data.time_vect);

       else
           %The binary file contains 2nd order compression ...
use 2nd-order interpolation to add data points in the vicinity of
negative time points
           t_vect = raw_data.time_vect;   %We will add in the offset
later.
           neg_pnt_index = find( t_vect < 0.0 &
[0,ones(1,length(t_vect)-1)] );
           t_vect = abs(t_vect);
           x1 = t_vect(neg_pnt_index-1);  x2 = t_vect(neg_pnt_index);
 x3 = t_vect(neg_pnt_index+1);
           x_new = [(2*x1 + x2)/3;  (x1 + 2*x2)/3;  (2*x2 + x3)/3;
(x2 + 2*x3)/3];   %New sample points
           t_vect_big = NaN*zeros(6,length(t_vect));
           t_vect_big(1,:) = t_vect;
           t_vect_big(4,neg_pnt_index) = t_vect(neg_pnt_index);
           t_vect_big(1,neg_pnt_index) = NaN;
           t_vect_big([2 3 5 6],neg_pnt_index) = x_new;
           full_index = find(~isnan(t_vect_big));
           time_vect_new = t_vect_big(full_index).';   %This is the
new time vector with the inserted points.
           t_vect_big([1,4],:) = NaN;
           nan_vect = isnan(t_vect_big(full_index));
           new_index = find( ~nan_vect );  %Index into time_vect_new
indicating the new points only.
           old_index = find( nan_vect );
           clear t_vect t_vect_big full_index nan_vect;
           x1sqr = repmat( x1.^2, [4,1] );  x2sqr = repmat( x2.^2,
[4,1] );  x3sqr = repmat( x3.^2, [4,1] );
           x1 = repmat( x1, [4,1] );  x2 = repmat( x2, [4,1] );  x3 =
repmat( x3, [4,1] );
           denom = (x1sqr-x2sqr).*(x2-x3) - (x2sqr-x3sqr).*(x1-x2);
           r1 = (x_new.^2 - x1sqr)./denom;
           r2 = (x_new - x1)./denom;
           p1 = (x2-x3).*r1 - (x2sqr-x3sqr).*r2;
           p3 = (x1-x2).*r1 - (x1sqr-x2sqr).*r2;
           p2 = -p1 - p3;
```

```
            p1 = p1 + 1;
            clear x_new x1sqr x2sqr x3sqr x1 x2 x3 denom r1 r2;
            raw_data.variable_mat(:,end+1:length(time_vect_new)) =
 0.0;   %Init the memory
            for k=1:size(raw_data.variable_mat,1),
                y_vect =
 raw_data.variable_mat(k,1:length(raw_data.time_vect));
                raw_data.variable_mat(k,old_index) = y_vect;
                y_new = repmat(y_vect(neg_pnt_index-1),
[4,1]).*p1  +  repmat(y_vect(neg_pnt_index),[4,1]).*p2  +
 repmat(y_vect(neg_pnt_index+1),[4,1]).*p3;
                raw_data.variable_mat(k,new_index) = y_new(:).';
            end
            raw_data.time_vect = time_vect_new;

 clear time_vect_new y_vect y_new new_index old_index neg_pnt_index p1 p2 p3;
            raw_data.conversion_notes = sprintf( 'Converted from
 Binary format with 2nd Order compression.  Upsampled waveforms from
 %.0f to %.0f points', ...
                raw_data.num_data_pnts, length(raw_data.time_vect) );
            raw_data.num_data_pnts = length(raw_data.time_vect);
        end

    end

    if isfield( raw_data, 'time_vect' ),      raw_data.time_vect =
 raw_data.time_vect + general_offset;
    elseif isfield( raw_data, 'freq_vect' ),  raw_data.freq_vect =
 raw_data.freq_vect + general_offset;
    end
```

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