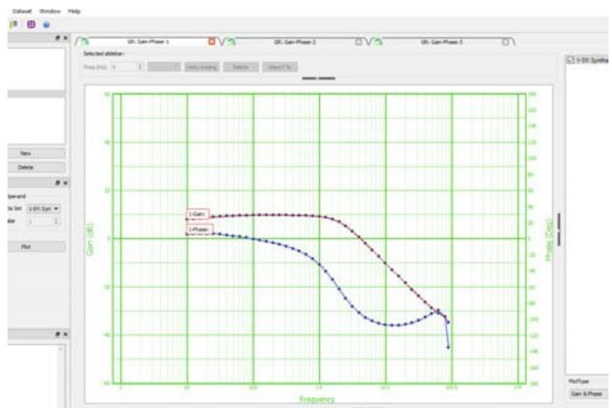
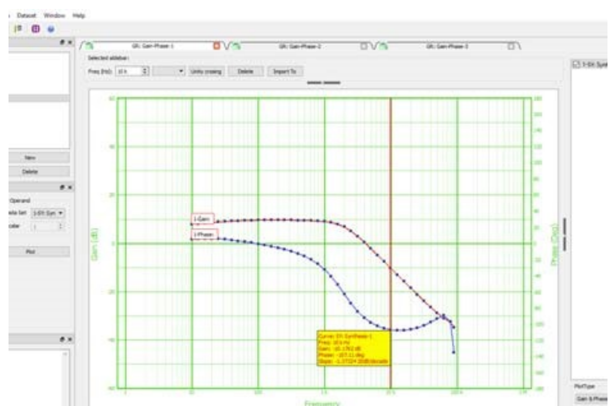
Design of a Feedback Amplifier from the Modulator Transfer Function

Once you have measured (or modeled) the modulator transfer function, you can have the Venable System software design the compensation amplifier for your desired loop. Here are the steps:

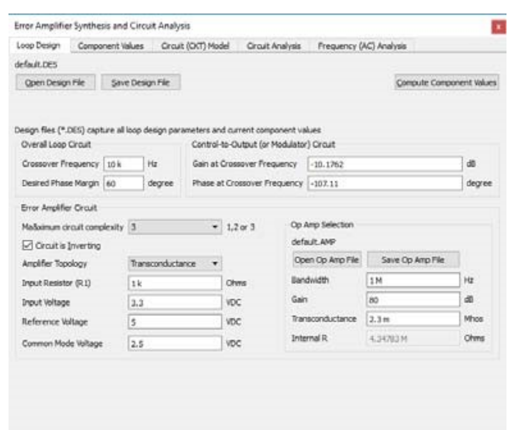
1. With the modulator (also called plant or control-to-output) transfer function displayed as a gain-phase graph and selected, click the Slide Bar icon or right-click anywhere on the open graph and click "Add Slide Bar". Note that data is "selected" by clicking anywhere on either curve of the data set or pressing the right- or left-arrow keys to toggle through the various data sets displayed. Also note that the Slide Bar option is not available if more than one data set is selected since the Slide Bar is keyed to a particular data set.



2. When the Slide Bar is added to the modulator transfer function data set, click and hold it with the left mouse button then move it to the desired loop bandwidth. In choosing loop bandwidth, remember that the response time of a system to a transient is approximately the reciprocal of the loop bandwidth. Also remember that the theoretical bandwidth limit of a switching or sampled data system is half the switching or sampled data rate. As a practical matter, even though it is theoretically possible to cross the feedback loop over at half the switching or sampling frequency, a more achievable number will be in the range of 10-20% of the switching or sampling frequency.



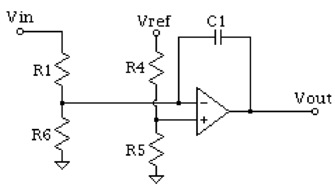
3. After choosing the desired loop bandwidth and moving the Slide Bar to that frequency, note that the text box associated with the slide bar has a button labeled "Import To". Click that button. This will open the "Error Amplifier Synthesis and Circuit Analysis Menu" window and transfer the loop crossover frequency to that window together with the modulator gain and phase measurements at that frequency.



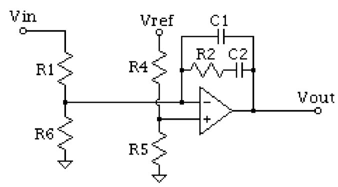
4. In the Error Amplifier Synthesis and Circuit Analysis Menu window there are a number of choices to make:

a) Phase margin – Choose a value between 45 and 72 degrees. We recommend 60 degrees as a good starting point.

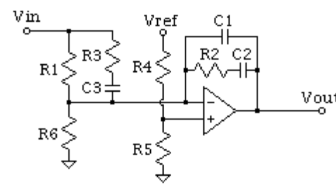
b) Maximum circuit complexity – Type 1 is a simple integrator, type 2 has a single zero-pole pair, and type 3 has two zero-pole pair. If the modulator transfer function is flat at the chosen crossover frequency, choose type 1. If the modulator transfer



Type 1



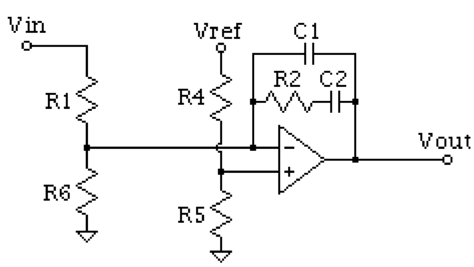
Type 2



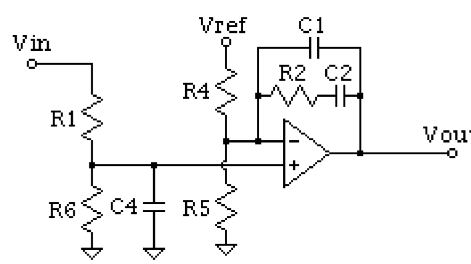
Type 3

function is falling at a -20 dB/decade slope at the chosen crossover frequency, choose type 2. If the modulator transfer function is falling at a -40 dB/decade slope at the chosen crossover frequency, choose type 3. An error message box on the next (Component Values) tab will tell you if you chose an unachievable combination.

c) "Circuit is Inverting" check box – Uncheck this box if the modulator inverts (output is 180 degrees out of phase with the input) at low frequency. Leave it checked if the modulator output is in phase with the input at low frequency. If the gain is flat at low frequency (it should be), the circuit will be either inverting or non-inverting. It will not have some in-between phase value if the test was performed correctly.

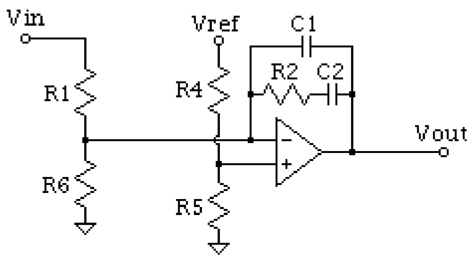


Inverting amp for non-inverting modulator

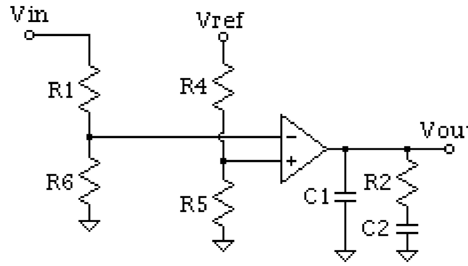


Non-Inverting amp for inverting modulator

d) Amplifier Topology – Regular is a conventional low output impedance amplifier where the feedback compensation components are connected from error amplifier output to inverting input. Transconductance is a high output impedance amplifier where the feedback compensation components are connected from error amplifier output to signal ground.



Regular



Transconductance

e) Input Resistor (R1) – this is the value of the resistor, which connects from the modulator output to the error amplifier input. All feedback compensation components scale from this resistor. If you want some other component in the compensation network to have a particular value instead, choose a round number like 1k for R1 and note the value of the component you want controlled. Then change the value of R1 to make the other component come out the value you want. All resistor values will be directly proportional to R1. All capacitor values will be inversely proportional to R1.

f) Input Voltage – this is the output voltage of the modulator or plant (which becomes the input voltage of the compensation amplifier).

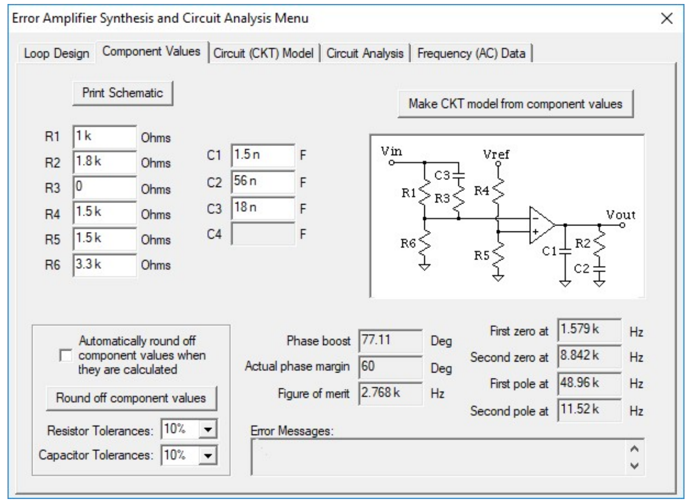
g) Reference Voltage – this is the value of the reference voltage used to control the output of the modulator. It could be a temperature-compensated zener diode, the reference pin of a control integrated circuit, or an external reference or control voltage.

h) Common Mode Voltage – this is the voltage at the inputs of the compensation amplifier. Both the inverting and non-inverting inputs of the amplifier will be at the same voltage if the circuit is operating properly. The synthesis program will determine the proper value of the resistive divider string from Reference Voltage to the amplifier inputs so that the DC resistance driving each amplifier input is the same. This is necessary for best amplifier performance.

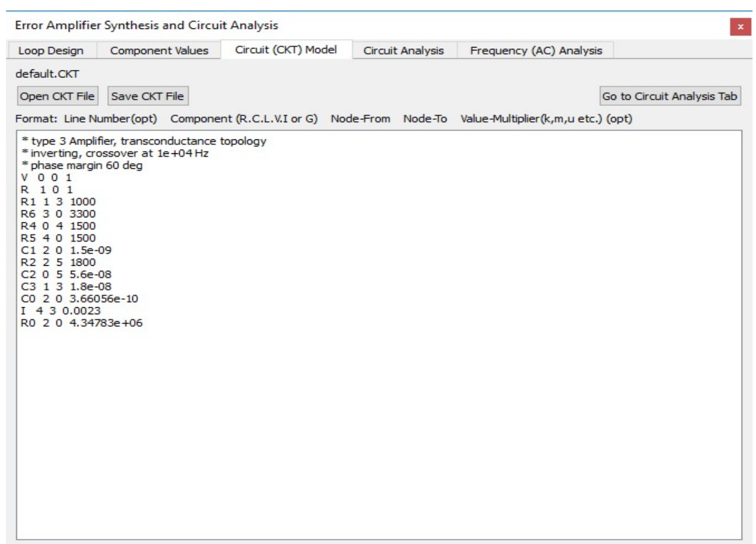
i) The only other entry is the error amplifier internal characteristics. Gain and bandwidth come from the data sheet. If you do not know the amplifier output impedance, use 1k. For transconductance amplifiers the gain, bandwidth, and transconductance are specified on the data sheet.

5. After you have entered in all the design values and choices, if you want to save the values for later use click the “Save Design File” button and you will be prompted for a file name and location. If not, go ahead and click the “Compute Component Values” button. This will send you to the next (Component Values) tab with the error amplifier compensation component values calculated already.

6. At the Component Values tab, first check the “Error messages” text box to see if anything needs fixing. If not, choose the preferred tolerances for components in your company, then click the “Round off Component Values” button to round off the values to the nearest standard value for the specified tolerance. We do not use the tolerance in calculations, so you can enter a larger tolerance if you want more standard values even though you plan to use a closer tolerance part in the final design. For example, you may prefer to have the system choose a 1k resistor instead of 910 ohms, so you can choose 10% or 20% tolerance instead of 5% which might give you a value like 910 ohms. The information boxes in the lower right quadrant of the window tell you where the poles and zeros of the amplifier transfer function will be. You can also change any particular component value if a similar value is more readily available and the new pole-zero locations will be calculated and displayed so you can judge the impact of the change on overall loop performance. Once the component values satisfy your criteria, click on the “Make CKT model from component values” button.



7. This will send you to the “Circuit (CKT) Model” tab and display a SPICE-like net list of the model of the compensation amplifier. See the schematics and models below for reference. This net list can be edited. Components can be added or removed or their types, values or connections changed. The one thing that cannot be done is that a node cannot be removed (skipped in the node number sequence). Node numbers must be sequential starting with zero (ground). If you change a circuit enough to remove a node, simply connect a resistor from the node to ground. It will not have any effect on the circuit and the analysis will still run properly. When you are happy with the net list, click the “Go to Circuit Analysis Tab” button and you will be sent to the next (Circuit Analysis) tab.



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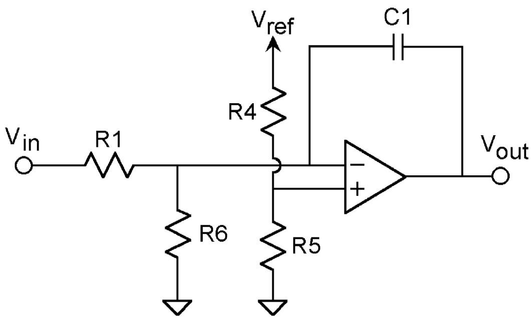
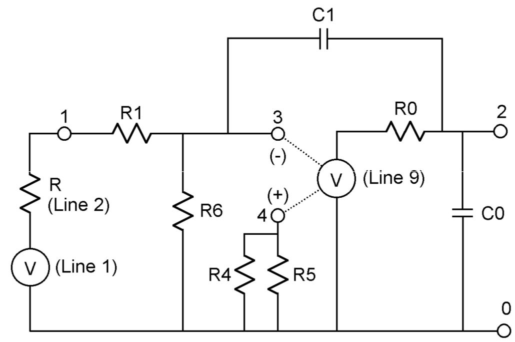
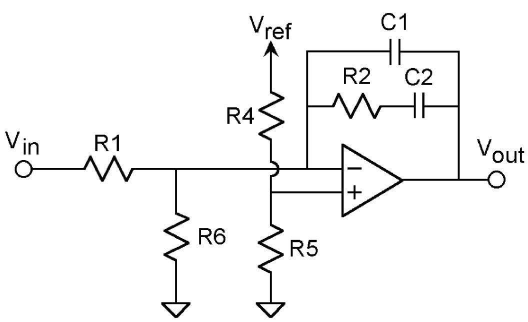
The figures below represent the amplifier schematics and models. The node numbers and component reference designators are correct. The schematics and models differ slightly for transconductance amplifiers, non-inverting amplifiers, and amplifiers where the input voltage and reference voltage have different polarities.



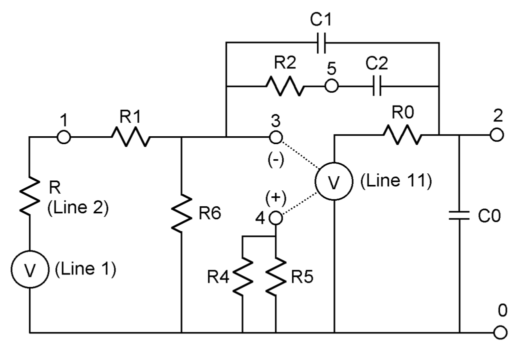
Type 1 Amplifier Schematic



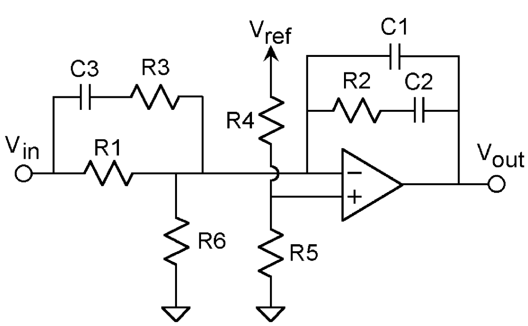
Type 1 Amplifier SPICE Model



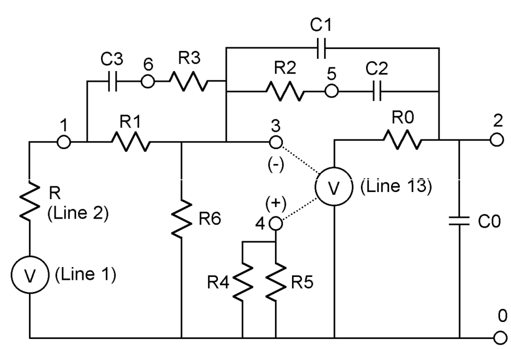
Type 2 Amplifier Schematic



Type 2 Amplifier SPICE Model



Type 3 Amplifier Schematic



Type 3 Amplifier SPICE Model

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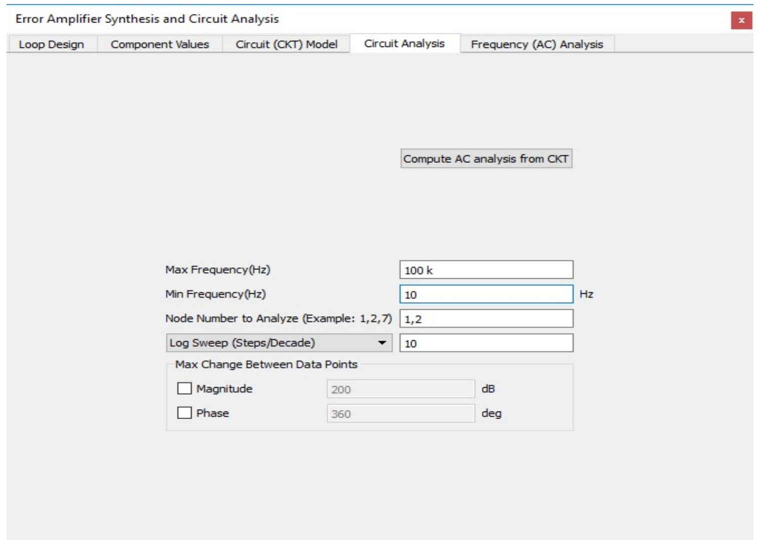
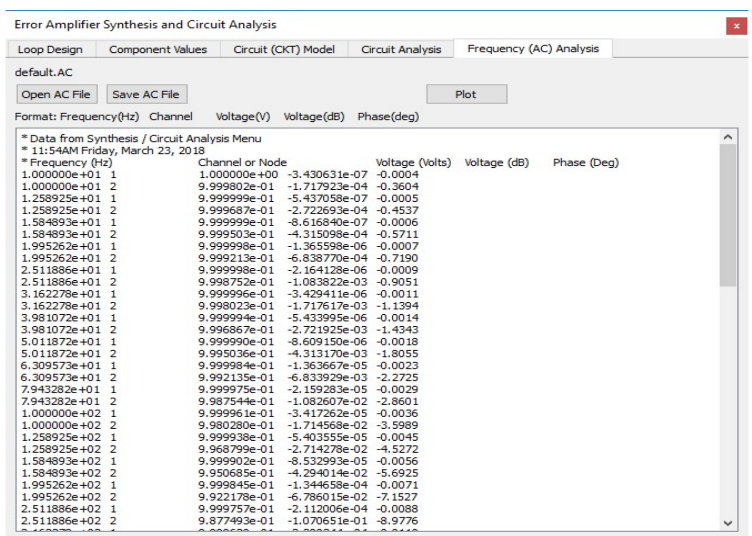
8. The Circuit Analysis tab is where you set up the parameters of the AC analysis of the net list. Choose the maximum and minimum frequency for the analysis sweep, the node numbers you want to save data for (you can save all of them if you want to), whether you want a log or linear sweep and what the resolution of the sweep is, and finally whether or not you want to activate the feature we formerly called “Max Delta Gain/Max Delta Phase”. This feature measures the change in gain and phase from one analysis point to the next, and if the gain or phase change on any node is greater than the amount specified, will cut the frequency step size in half and try again. This can happen a maximum of 5 times (steps/decade x 32) up to a maximum resolution of 2000 steps/decade.

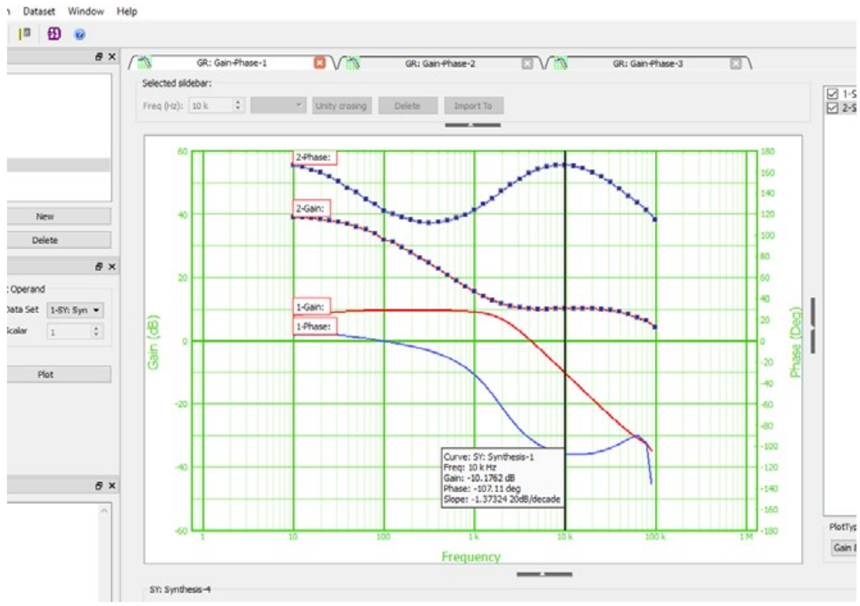


9. When the parameters of the analysis are set to your requirements, click the button labeled “Compute AC analysis from CKT”. This will take you to the final tab, “Frequency (AC) Data”. A brief description of the origin of the data will be at the top of the text display in lines starting with * (asterisk). Following the comment lines, the data will be displayed in Venable Standard Format which is 5 columns: Frequency, Node number, Voltage (volts), Voltage (dB), and Phase (degrees). There will be a row for each node selected at each frequency.



10. From the “Frequency (AC) Data” tab, click the “Import into Graph” button. If you have followed the steps up to here, a gain-phase graph of the modulator transfer function is already displayed and the data set properties sub-window, at the bottom of the plot, will display the channel ratio and scale factor. The default values are the ratio of CH2/CH1, and 1. You can also change the line style, line width, and line color of any of the selected plotted data here.

11. After closing the Synthesis menu, you will see the graph with the amplifier transfer function gain and phase superimposed on the original modulator transfer function. At the desired loop crossover frequency, the amplifier gain should be as far above (or below) the 0 dB gain axis as the modulator gain is below (or above).



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