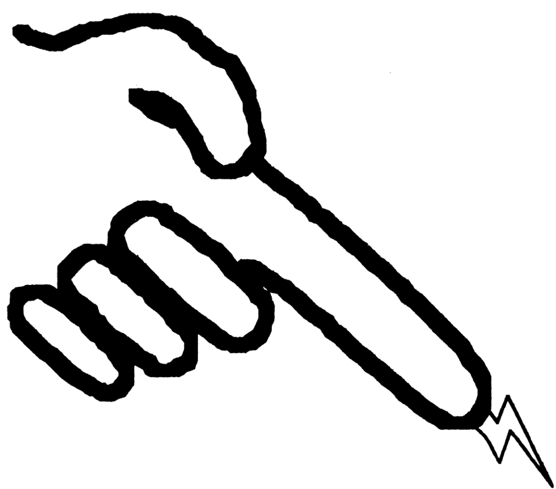
VERBB™

By Micro Nation Software™

For HP 48SX Calculators



Manual
Version 1.0

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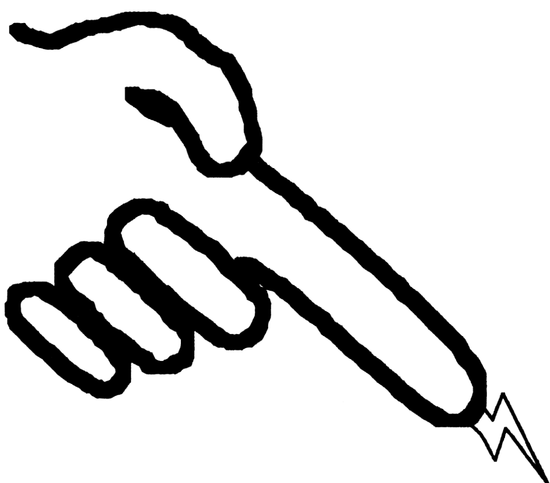


Manual
Version 1.0

VERBB™ a product of: **Micro Nation Software™**
P.O. Box 430772
Houston, TX 77243
(713) 782-1207

Introduction to VERBB

VERBB was designed to be a useful circuit design and analysis tool for your HP 48SX. It is a set of four integrated applications: a circuit editor and evaluator, a Bode plotter, a Fourier series analysis tool, and a transfer function manipulator.

VERBB derives exact s-domain transfer functions that reliably represent the circuit being analyzed. It uses the same type of circuit models that electrical engineers learn to use when analyzing circuits by hand.

VERBB's circuit editor lets you draw circuits directly onto your HP 48SX screen. You won't waste time making Spice-like net lists to describe your circuit. The circuit editor provides simple menu commands and a graphical cursor that make entering circuits easy. Circuits are not limited to the size of the screen; the screen scrolls as the cursor moves close to a side.

VERBB can derive any type of s-domain transfer function from any valid linear circuit, even non-plainer circuits. It can generate V/V, V/I, I/V, and I/I transfer functions and input or output impedance equations are no problem.

The Bode plotter can draw the exact Bode plots (both magnitude and phase) of any transfer function. Up to 10 decades can be displayed on the HP 48SX screen at one time, or the plot data can be sent via a serial link to a PC or Mac to generate larger Bode plots.

VERBB also performs Fourier analysis. You can choose one of seven different input signals with many variable parameters. The Fourier series evaluator will plot the time-domain input and output signals on the HP 48SX screen or the data can be sent to a PC or Mac to generate larger plots.

The transfer function manipulator allows you to combine transfer functions, directly enter externally derived transfer functions, or perform transfer function arithmetic.

About the Manual

This manual was designed to be explicit and instructive, not impressively large as is so often the case with complicated software. It is hoped that you will find the manual complements the software rather than discourages its use.

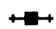
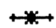
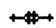
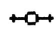
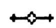
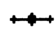
This manual assumes that you have some knowledge or that you are in the process of learning circuit analysis. You must know what you are doing in order to use VERBB, but you need not know everything in order to start using it. If you encounter some unfamiliar concepts in this manual, you can easily find explanations in modern electrical engineering texts because the terminology used in this manual is identical to that used in the texts.

Chapter 1
The Circuit Editor

The Circuit Editor allows you to graphically create or edit a circuit directly on the screen of the HP 48SX. The fastest way to learn to use something is to use it, so this chapter is organized to that end. First there is an explanation of the Circuit Editor nomenclature and symbols, an abbreviated explanation of each Circuit Editor command, an explanation of a few circuit modeling concepts, and then there are several tutorial examples that you can follow along with on your calculator and learn to use VERBB in a minimum amount of time.

Circuit Editor Symbols and Nomenclature

The Circuit Editor allows you to draw circuits on the screen of your calculator with components oriented in any direction. In order to make this possible with the low resolution of the HP 48SX screen, VERBB uses slightly different symbols for circuit components.

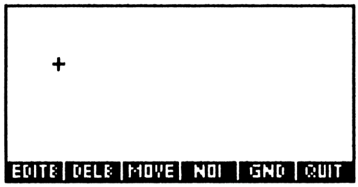
resistor 
capacitor 
inductor 
voltage source 
dependent voltage source 
current source 
dependent current source 

If VERBB had to use conventional symbols it would be very difficult to draw, say, an inductor or a resistor that spanned two points at some odd angle. The new symbols simplify and speed up the calculator's task of drawing the circuit. They are also very compact and allow more of a circuit to be viewed at one time. If you follow the examples at the end of this chapter you will quickly become familiar with VERBB's circuit symbols.

The following terms are used in the rest of this manual and are defined here for clarity:
end-point — The terminal of a component. Each component has two end-points. A node or essential node may be composed of one or more end-points.
node of interest — A node that is typically not an essential node, but one that VERBB includes as one of the nodes that may be used later to specify a transfer function.

Circuit Editor Commands

The Circuit Editor Screen and its menu commands are shown here.



EDITB **Edit Branch** Selects the current position of the cursor as one end-point of the branch to be edited. Move the cursor and press 'Enter' to select the other end-point of the branch to be edited. If no branch connects the two end-points, a new one is created. After a branch is selected, it can be changed to a different type, the value of a passive component can be changed, the polarity of a voltage source can be changed, etc. . . .

DELB **Delete Branch** Selects the current position of the cursor as one end-point of the branch to be deleted. Move the cursor and press 'Enter' to select the other end-point of the branch to be deleted. If no branch connects the two end-points, the command is ignored.

MOVE **Move End-Point** Selects the end-point at the current position of the cursor as the end-point to be moved. If an end-point does not exist at this position, the command is ignored. Using the arrow keys, the cursor is moved to select the new location for the end-point. Pressing Enter at this point selects the location. If an end-point already exists at the new location, the command is ignored.

NOI **Node Of Interest** Marks the end-points that have been selected as nodes of interest. The menu bar changes to this: [ADD | DEL | | | | EXIT]. Pressing ADD selects the end-point at the current position of the cursor and makes it a node of interest. Pressing DEL unselects the end-point at the current position of the cursor as a node of interest. Pressing EXIT returns control to the Circuit Editor menu.

GND **Ground** Marks the end-points that have been selected as grounded nodes. The menu bar changes to this: [ADD | DEL | | | | EXIT]. Pressing ADD selects the end-point at the current position of the cursor, makes it a grounded node, and gives a menu bar asking which way you want the ground symbol to point: [← | → | ↑ | ↓ | |]. Pressing DEL unselects the end-point at the current position of the cursor as a grounded node and erases the ground symbol. Pressing EXIT returns control to the Circuit Editor menu.

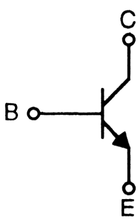
EVAL **Evaluate Circuit** Evaluates the circuit. If any errors are found, they are reported and control is returned to the Circuit Editor. If there are no errors, control is transferred to the transfer function selector. Select as many transfer functions as you want and save them under different names.

QUIT **Quit** Allows you to save the circuit and then returns control to the VERBB main menu.

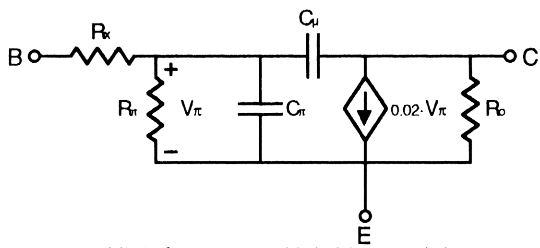
Circuit Modeling Concepts

The only components that can be used with VERBB are the resistor, capacitor, inductor, voltage source, current source, dependent voltage source, and dependent current source. But this does not mean that you cannot use VERBB to analyze circuits that contain transistors, op-ams, transformers, or non-linear devices. You simply have to understand how to create circuit models of the devices you want VERBB to analyze. Electrical engineers learns to use these same models when analyzing circuits by hand. To fully explain the use of these models is beyond the scope of this manual— any modern text on electronics will have several chapters devoted to the hybrid-π and other circuit models.

For example, transistors are typically modeled with the hybrid-π equivalent circuit. The high frequency version of the hybrid-π model is shown here.



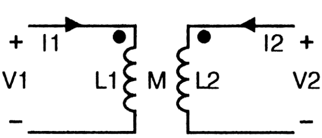
NPN transistor



High frequency, Hybrid-π model of transistor

The components Ro, Rπ, Rx, Cμ, and Cπ represent the internal resistances and capacitances of the transistor. The component values depend on the type of transistor and its specific operating point.

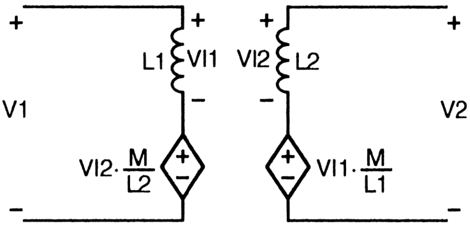
When you model transformers or flux-linked inductors, you will need to use some special technics. The following figure show how the voltages across two flux linked inductors are determined.



$$V1 = I1 \cdot s \cdot L1 + I2 \cdot s \cdot M$$

$$V2 = I2 \cdot s \cdot L2 + I1 \cdot s \cdot M$$

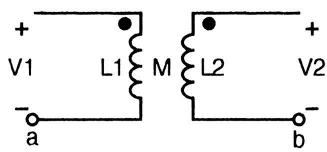
Notice that in the equations for V1 and V2 the first term gives the voltage contribution from the inductor's self inductance and the second term gives the voltage contribution from the mutual inductance. VERBB will automatically handle the inductors' self inductances, but the addition of voltage from mutual inductance must be enforced by placing a dependent voltage source in series with each inductor. This technic to model mutual inductance is shown in the following figure.

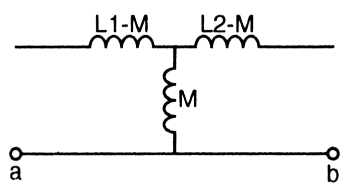


$$I2\cdot s\cdot M = \frac{Vl2}{s\cdot L2}\cdot s\cdot M = Vl2\cdot\frac{M}{L2}$$

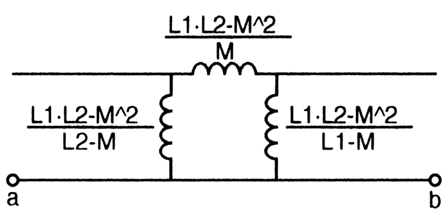
Notice that the dependency equations for the dependent voltage sources are very simple. Their derivation is shown on the right of the figure. The creation of dependent sources is demonstrated in the tutorial examples 1.2 through 1.4. Keep in mind that isolated current loops in a circuit must have at least one common node. This is necessary for VERBB to be able to solve the set of simultaneous equations for a circuit.

You can also use other equivalent circuits, namely the T-equivalent and the π-equivalent circuits for magnetically coupled coils. These two models are shown in the following figure.





T-equivalent circuit



π-equivalent circuit

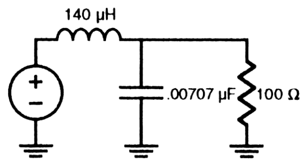
These two models are easier to use than the first model because they do not involve dependent sources, but they are less flexible because they require the two points ‘a’ and ‘b’ to be at the same voltage.

Circuit Editor Tutorial Examples

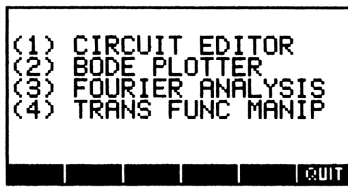
Our goal for these examples is to fully demonstrate each command in VERBB's Circuit Editor. The Circuit Editor is rather easy to use once it is understood— some operations require only one or two key presses. If you examine or follow along with these examples you will master the Circuit Editor in a short time.

Example 1.1

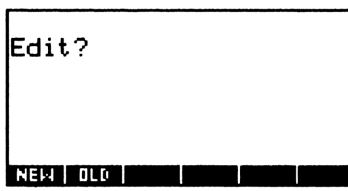
For the first example we will construct the Low-Pass RLC filter shown here and get several transfer functions from it. Start by putting your calculator in the directory where VERBB was attached. Then open the Library menu and press the menu key under VERBB.



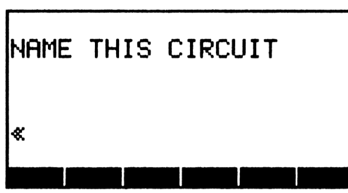
You will see the VERBB main menu. Press (1) to go to the Circuit Editor.



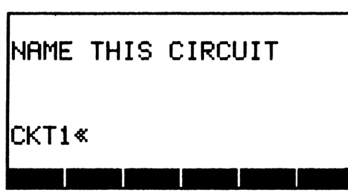
You'll see a screen asking you if you want to create a new circuit or edit an old one.
Press NEW to start a new circuit.



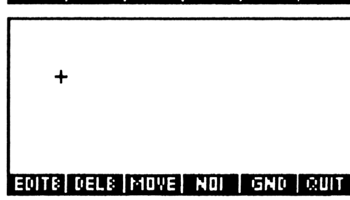
You'll see a screen asking you to name the new circuit.
The '«' symbol is used to prompt for keyboard entry.
Type CKT1.



Press ENTER.



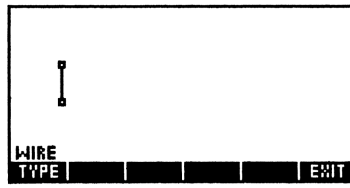
You're now in the Circuit Editor and you're ready to enter a circuit.
Notice the graphical cursor.
We'll start by making a voltage source.
Press EDITB.



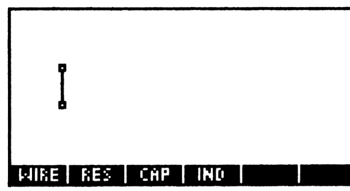
A selected end-point has been placed under the cursor. We want the voltage source to be oriented vertically, so we'll move the cursor down.
Press the down arrow.

Now we have the cursor in position to select the location of the voltage source's second end-point.
Press ENTER.

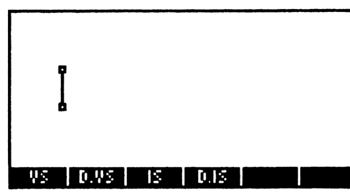
You are now in the branch editor. The branch you're editing will always have both its end-points selected. Whenever you create a new component, it starts its life as a wire and you change it to another type if need be.
We want a voltage source.
Press TYPE.



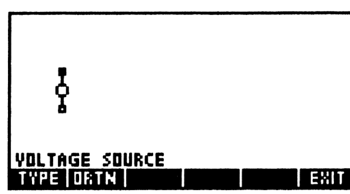
You see the menu bar change to a list of passive component types. The TYPE menu is the only two page menu in the VERBB program.
Press NXT.



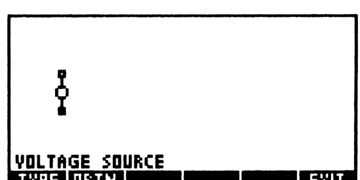
The menu bar has changed to the list of sources.
Press VS to select voltage source.



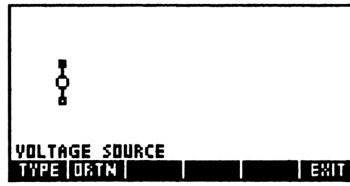
You're now back in the branch editor. The branch has been changed to a voltage source and the menu bar has changed to commands that are relevant to the type of component we are editing. The new command, ORTN, toggles the orientation of the source.
Press ORTN.



Now the bottom selected end-point is filled in. This means that the bottom end-point is the positive terminal of the voltage source. A filled in selected end-point always indicates positive polarity in VERBB. We want the top to be positive. Press ORTN again.



Now we have edited this branch to the way we want it— a voltage source with the positive terminal at the top.
To go back to the Circuit Editor main menu, press EXIT.

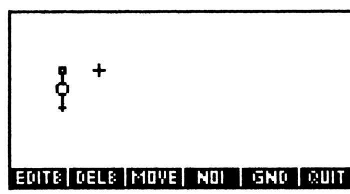


You're back in the Circuit Editor main menu and the cursor is sitting on top of the bottom end-point of the voltage source. We want to attach an inductor to the top end-point of the volt source.
Press the up arrow.

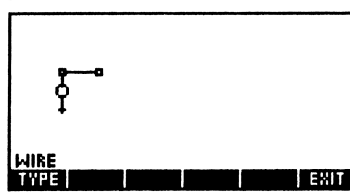
To create the branch that will become an inductor press EDITB.

The end-point under the cursor has been selected. We want the inductor to be oriented horizontally, so we'll move the cursor right.
Press the right arrow.

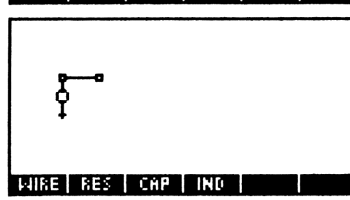
Now we have the cursor in position to select the location of the inductor's second end-point.
Press ENTER.



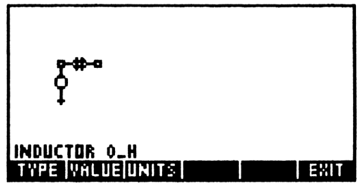
You are now back in the branch editor. We want to change the branch to an inductor.
Press TYPE.



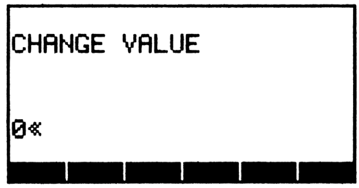
You see the menu bar change to a list of passive component types.
For an inductor press IND.



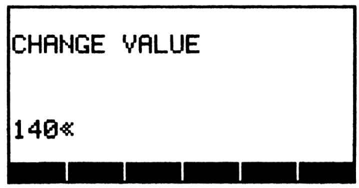
Now you're back in the branch editor, the component has changed to an inductor, and the menu bar has changed to commands that are relevant to an inductor. We want a 140_µH inductor. Press VALUE.



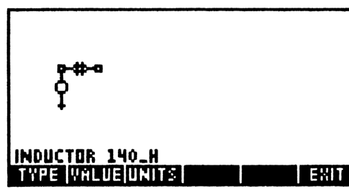
Whenever you are prompted for keyboard entry, the Backspace key deletes a character and the DEL key deletes the line.
Press Backspace and then type 140.



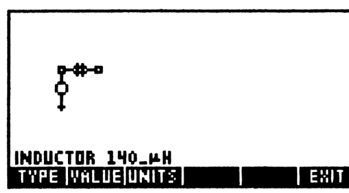
Press Enter.



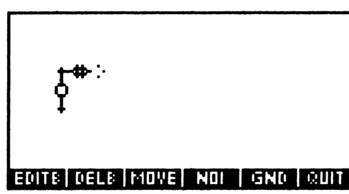
The UNITS key rotates the units. Press the UNITS key until you see 140_µH.



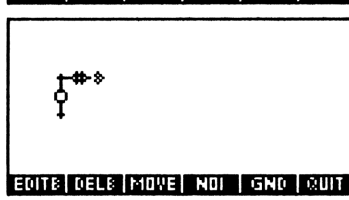
Now we have edited this branch to be the way we want it.
To go back to the Circuit Editor main menu, press EXIT.



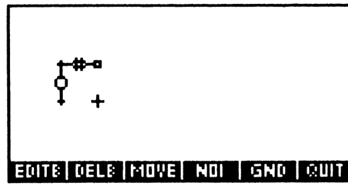
You're back in the Circuit Editor main menu and the cursor is still where we left it. We want to attach a capacitor to the end-point under the cursor.
Press EDITB.



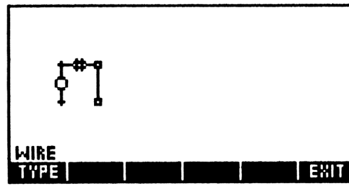
Press the down arrow.



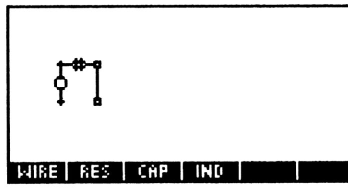
Press ENTER.



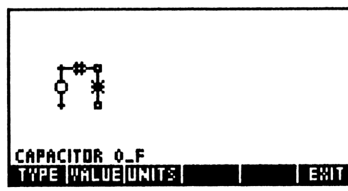
We want a capacitor, so press TYPE.



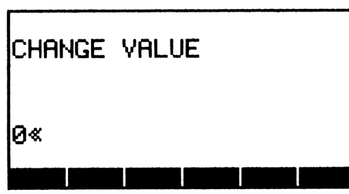
Press CAP.



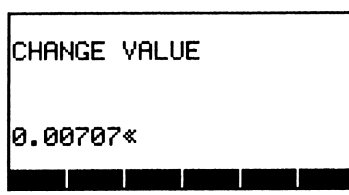
Press VALUE.



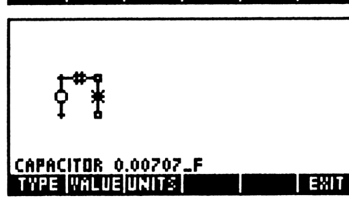
Type .00707



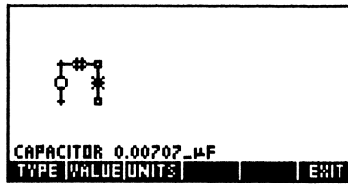
Press ENTER.



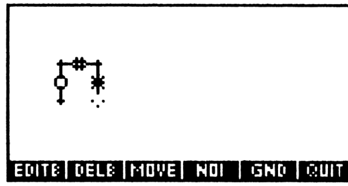
Press UNITS until you see 0.00707_μF.



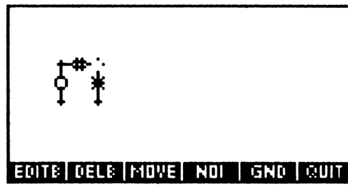
We have the capacitor the way we want it. To go back to the Circuit Editor main menu, press EXIT.



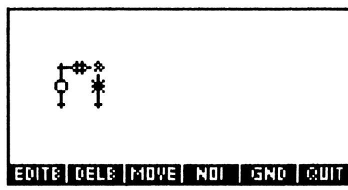
We want to place a resistor in parallel with the capacitor.
Press the up arrow.



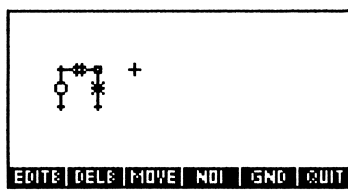
First we'll add a wire.
Press EDITB.



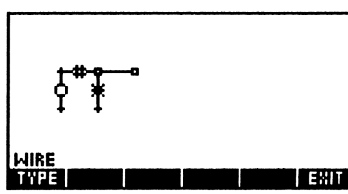
Press the right arrow.



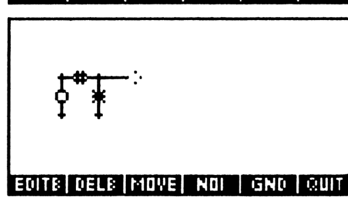
Press ENTER.



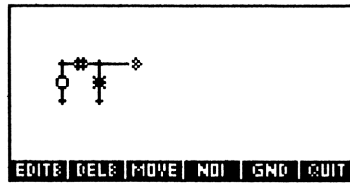
No changes are necessary.
Press EXIT.



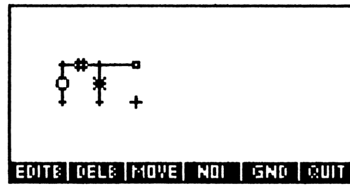
We'll hang our resistor off this end-point.
Press EDITB



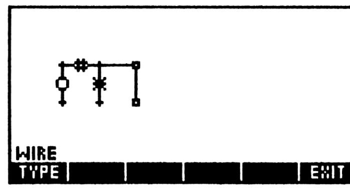
Press the down arrow.



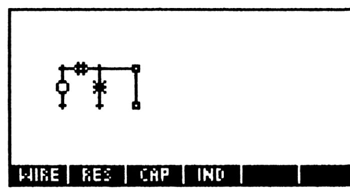
Press ENTER.



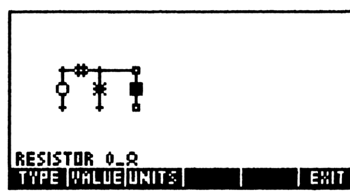
This will become our resistor.
Press TYPE.



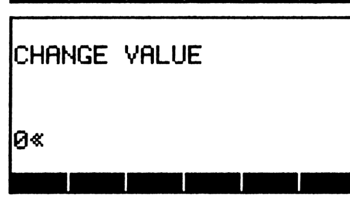
Press RES.



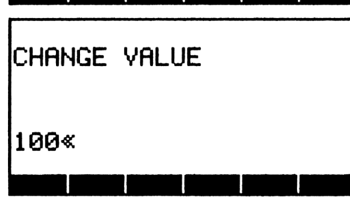
Press VALUE



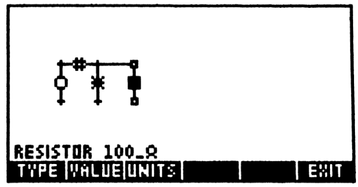
Press Backspace.
Type 100.



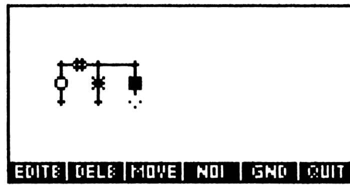
Press ENTER



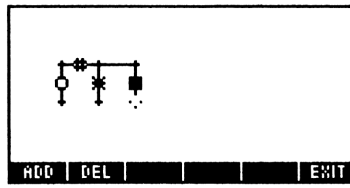
No more changes.
Press EXIT



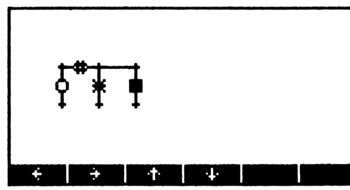
To connect the three dangling end-points we will connect them all to ground.
Press GND.



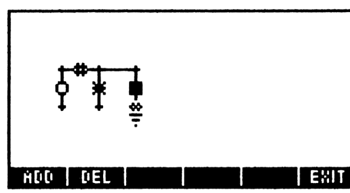
We can now move the cursor around and ground the end-points we want. The one under the cursor must be grounded.
Press ADD.



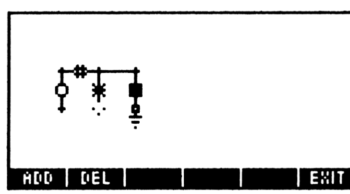
The menu bar has changed to one that asks you which way you want the grounding symbol to point. Down would be good.
Press the menu key labeled '↓'



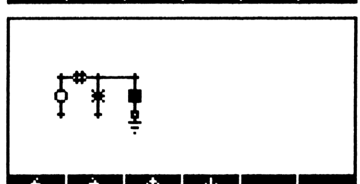
O.K. on to the next one.
Press the left arrow.



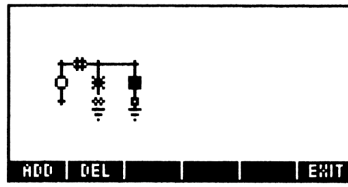
Press ADD.



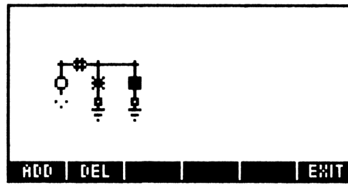
Press the menu key labeled '↓'



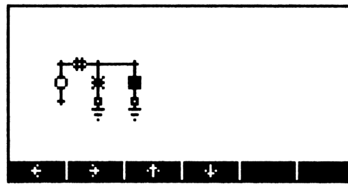
Press the left arrow.



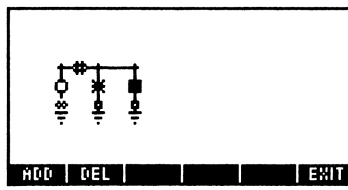
Press ADD.



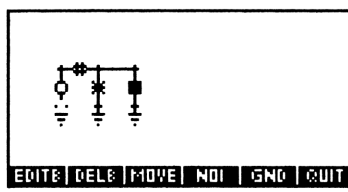
Press the menu key labeled '↓'



Now we've grounded all the end-points we care to.
Press EXIT.

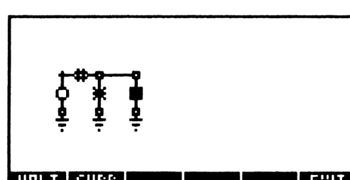


Here is the complete Low-Pass filter. The input is the voltage source and the output is the voltage across the resistor. We want VERBB to derive this transfer function.
Press the EVAL key.

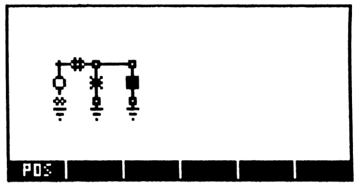


While you see a count from ZERO to FIVE, VERBB is solving the set of equations that are derived from your circuit. Larger circuits take more time to evaluate— the count from ZERO to FIVE will let you know the progress of the evaluation.

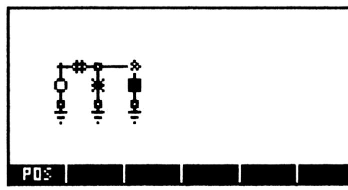
Less than a minute after you press the EVAL key you will see the circuit with the end-points of evaluated nodes marked as selected end-points. You can now select a transfer function.
Press VOLT.



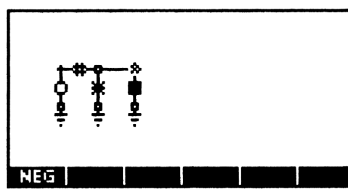
VERBB knows that the input signal to the transfer function must be a voltage signal because the independent source in the circuit is a voltage source. We want the output of our transfer function to be a voltage signal (that is why you pressed VOLT in the previous step) and what we'll get is a V/V transfer function. Notice the cursor has returned. We'll use it to select the specific output voltage we want. Move the cursor to the top of the resistor.
Press right arrow, right arrow, and then up arrow.



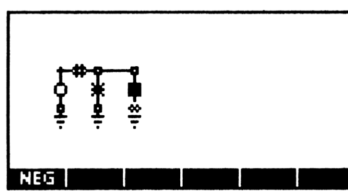
The first end-point we select will be the positive polarity point for the output signal.
Press ENTER.



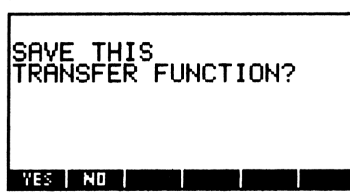
The second end-point we select will be the negative polarity point for the output signal.
Press the down arrow.



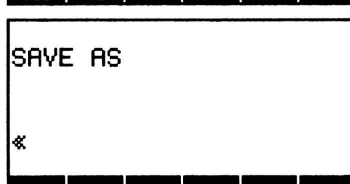
Press ENTER.



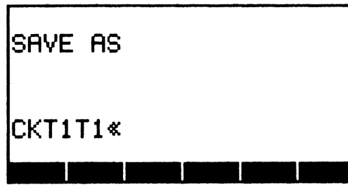
Press YES.



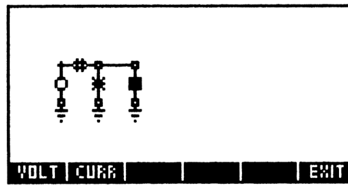
We name the transfer function that was just created so that we can use it later in the Bode Plotter, Fourier Analysis, and Transfer Function Manipulator parts of VERBB.
Type CKT1T1



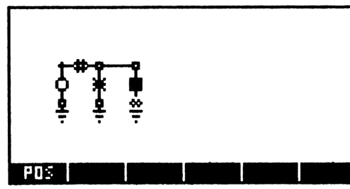
We will use this transfer function in examples in chapters 2 through 4.
Press ENTER.



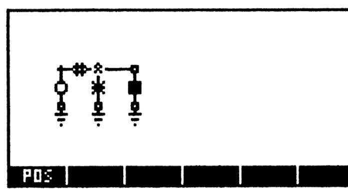
Now let's get the transfer function of the current going through the capacitor versus the input voltage.
Press CURR.



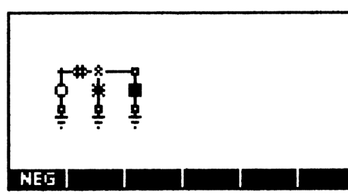
To select the branch with the particular current we want, we must use the cursor to select end-points that immediately bound one and only one passive component.
Press the left arrow and then the up arrow.



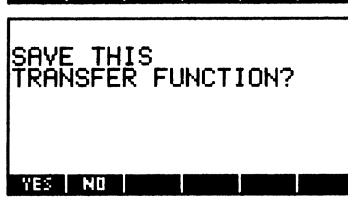
VERBB uses the passive sign convention, so positive current will flow in the direction of a voltage drop. We want the transfer function to indicate positive current flowing from the top of the capacitor to ground. We will select the top end-point of the capacitor as the positive polarity of the output.
Press ENTER.



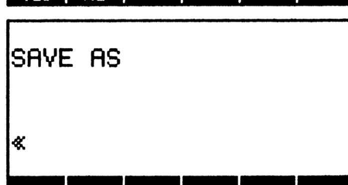
The negative polarity will be at the bottom end-point of the capacitor.
Press the down arrow and then ENTER.



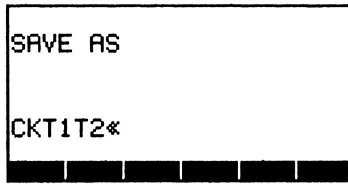
Press YES.



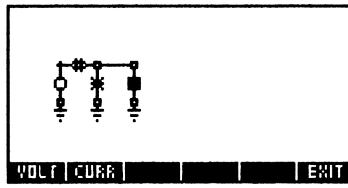
Type CKT1T2



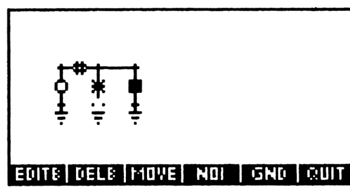
Press ENTER.



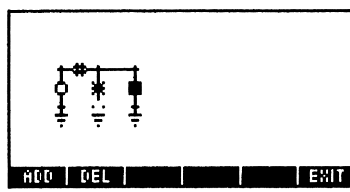
You've probably noticed that where the voltage source attaches to the inductor there is an end-point that is not selected and therefore cannot be used to select a transfer function. This is because VERBB only evaluates the voltage at "essential nodes" (nodes that have three or more components attached to them) You can force VERBB to evaluate the voltage at a non-essential node by marking it as a "node of interest".To do this we leave the transfer function selector and return to the Circuit Editor. Press EXIT.



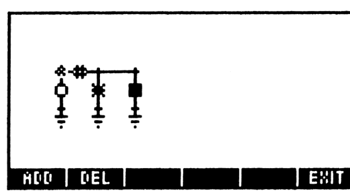
We're finally back in the Circuit Editor. To select nodes of interest press NOI.



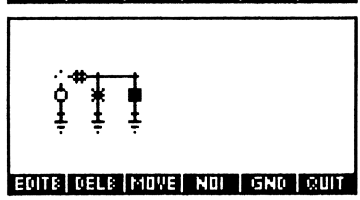
Move the cursor to the end-point we want to select as a node of interest.
Press the up arrow.
Press the left arrow.
Press ADD.



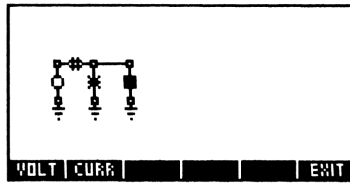
The end-point has become a node of interest.
Press EXIT.



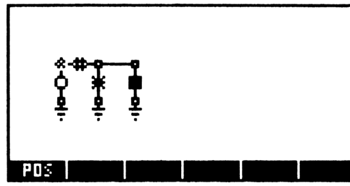
Now, if we evaluate the circuit we will be able to use this end-point to select a transfer function.
Press EVAL.



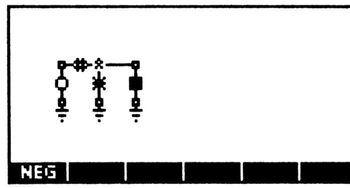
We'll get the transfer function of the voltage across the inductor versus the input voltage.
Press VOLT.



The cursor is already in position to select the positive polarity of the transfer function.
Press ENTER.
Press the right arrow.

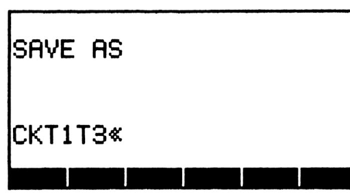


To select the negative polarity of the transfer function.
Press Enter.

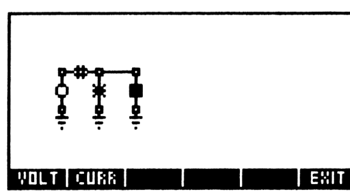


Press YES.
Type CKT1T3.

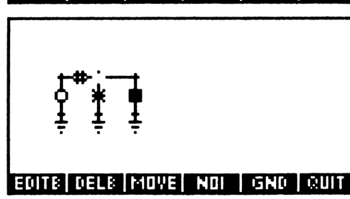
Press ENTER.



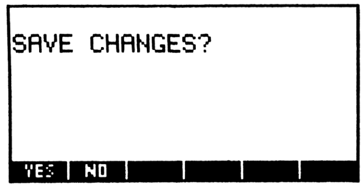
Press EXIT.



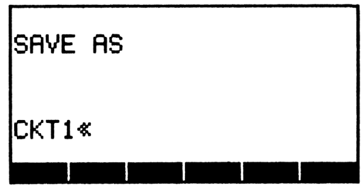
To Leave the Circuit Editor press QUIT.



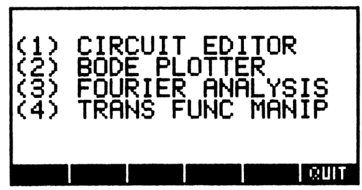
Press YES.



The name of the circuit appears and you can edit it to save the circuit under a different name. But since the circuit has not yet been saved, just press ENTER.

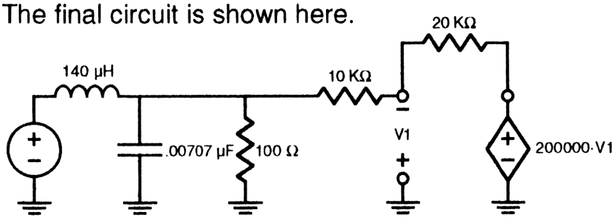


This completes Example 1.1
Please proceed immediately to Example 1.2 as you have not yet been exposed to all of the features of the Circuit Editor.

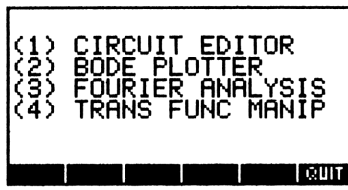


Example 1.2

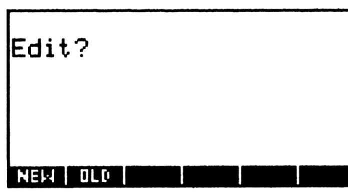
This example assumes that you have completed Example 1.1 and are familiar with the technics presented there. In this example we will use the circuit created in Example 1.1 and add an Op-amp to its output. The Op-amp will be in the inverting configuration and have a gain of -2 V/V. We will assume an ideal Op-amp except the open loop gain will be finite (A=200000). To model the Op-amp, we will use a dependent voltage source . The final circuit is shown here.



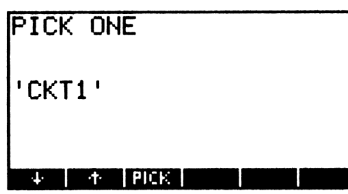
Start VERBB by pressing its Library menu button.
Press (1) for the Circuit Editor.



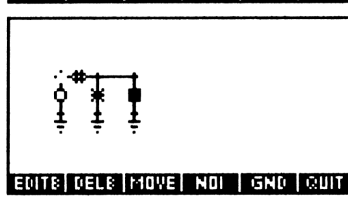
We're loading a previously created circuit.
Press OLD.



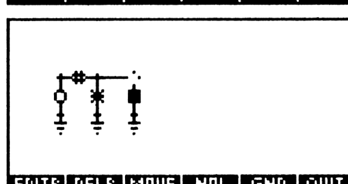
Unless you have created other circuits besides CKT1, the screen will look like this. The ↓ and ↑ menu keys are for moving up and down in the list of circuit names. The PICK menu key loads the circuit whose name is displayed.
Press PICK.



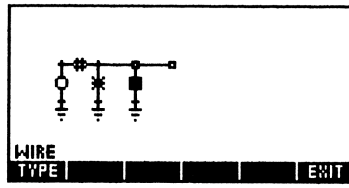
Here's CKT1.
Move the cursor to the top of the resistor. That's where we want to attach the 10KΩ resistor.
Press the right arrow twice.



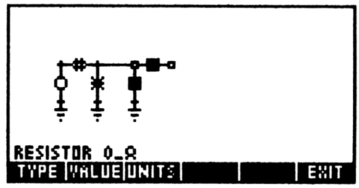
Press EDITB.
Press the right arrow.
Press ENTER.



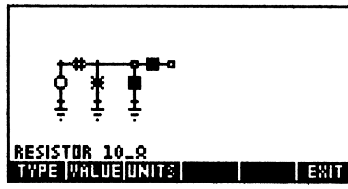
We want a resistor.
Press TYPE.
Press RES.



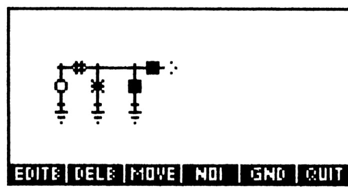
We want a 10KΩ resistor.
Press VALUE.
Press backspace.
Type 10.
Press ENTER.



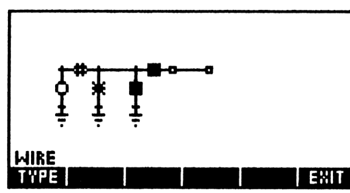
To change the units to KΩ.
Press UNITS.
Press EXIT.



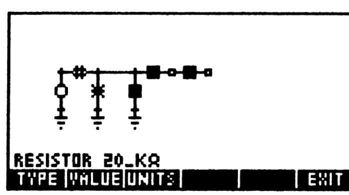
We'll add the 20KΩ resistor here.
Press EDITB.
Press the right arrow.
Press ENTER.



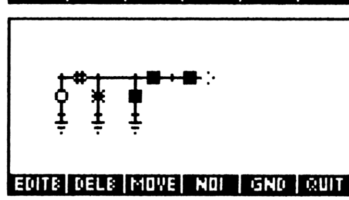
Press TYPE.
Press RES.
Press VALUE.
Press backspace.
Type 20.
Press ENTER.
Press UNITS.



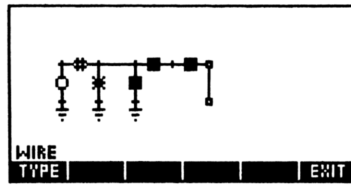
O.K.
Press EXIT.



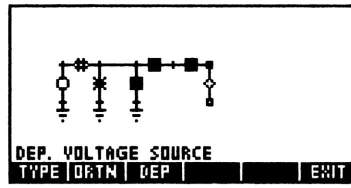
We'll add the dependent voltage source here.
Press EDITB.
Press the down arrow.
Press ENTER.



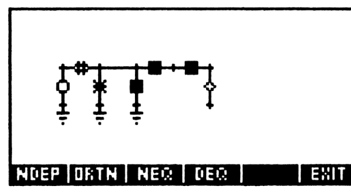
Press TYPE.
Press NXT.
Press D.VS (dependent voltage source)



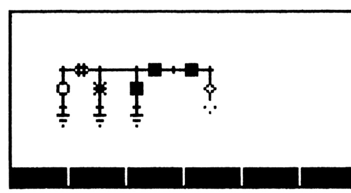
Notice that the selected node at the top of the dependent voltage source is filled in, indicating that it is the positive polarity of the source. Now we must select the dependency of the source. The dependency of a dependent source is the specific voltage that it depends on (marked V1 in the schematic at the beginning of this example) and an equation that is multiplied with this voltage.
Press DEP.



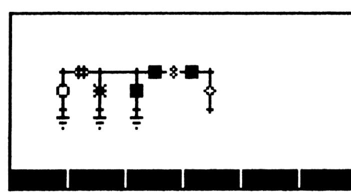
The end-points around the dependent voltage source have been unselected and the menu bar has changed. We are now editing the source's dependency. We will now select the specific dependency voltage.
Press NDEP.



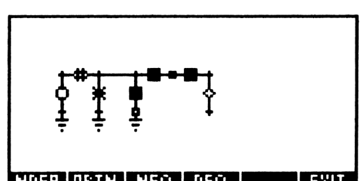
The cursor has returned. Move the cursor to the end-point between the two new resistors.
Press the left arrow.
Press the up arrow.
Press ENTER.



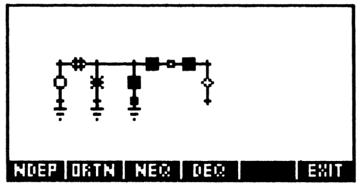
Now move the cursor to an end-point that's connected to ground.
Press the down arrow.
Press the left arrow.
Press ENTER.



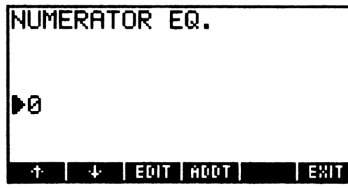
The two selected end-points indicate the dependency voltage. The ORTN menu key in this menu bar applies to the dependency voltage and not the source voltage. According to the schematic of our circuit, we want the polarity to change.
Press ORTN.



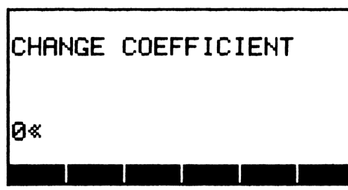
O.K.
Now we must specify the dependency equation. In VERBB, the dependency equation is separated into a numerator polynomial and a denominator polynomial. These polynomials are equations of 's' that can be of any order.
To edit the numerator equation:
Press NEQ.



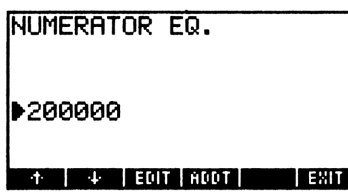
The numerator equation is now '0' and has order zero. The ADDT menu key adds terms to the equation and you use the arrow menu keys to select the term whose coefficient will be edited when the EDIT key is pressed.
For this source the dependency equation must be 200000·V1. So, there is no need to add terms. Dependency equations of higher order will be demonstrated in later examples.
Press the EDIT menu key.



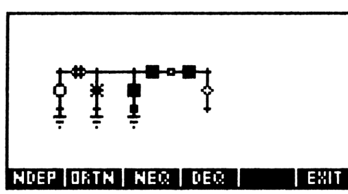
Press backspace.
Type 200000.
Press ENTER.



O.K.
Press EXIT.

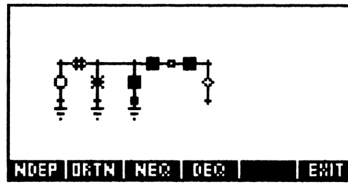


Now, just for the experience, press DEQ.

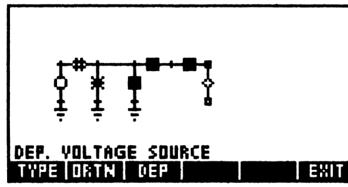


The denominator equation of a dependent source is always set to '1' when it is created. This is what we presently want.
Press EXIT.

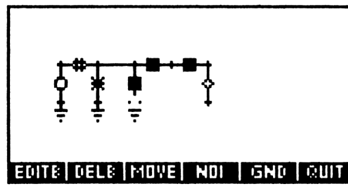
The dependency of the source has been properly set.
Press EXIT.



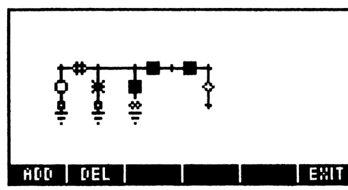
No more changes are necessary for the dependent source.
Press EXIT



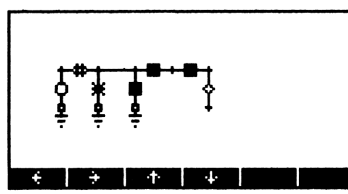
Back in the Circuit Editor.
Now, we must ground the bottom of the dependent voltage source.
Press GND.



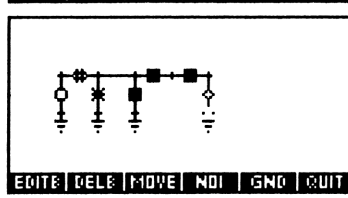
Move the cursor to the bottom of the dependent voltage source.
Press the right arrow twice.
Press ADD.



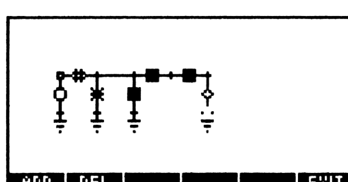
Press the menu key labeled '↓'.
Press EXIT.



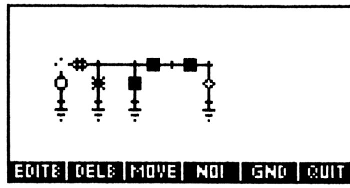
Almost done.
Notice that the end-point at the top of the dependent voltage source is not an essential node and therefore will not be evaluated by VERBB unless we make it a "node of interest". We are interested in it because it is the positive polarity of our circuit's output voltage.
Press NOI.



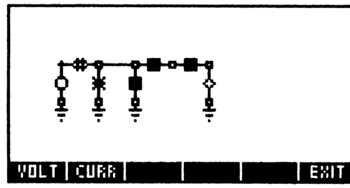
Press the up arrow.
Press ADD.
Remove the node of interest above the input voltage source.
Press the left arrow four times.
Press DEL
Press EXIT.



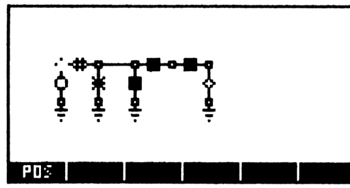
Now we're ready to evaluate the circuit.
Press EVAL.



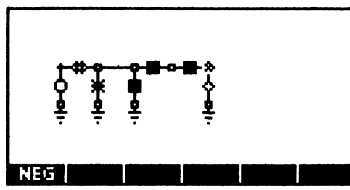
After the evaluation is done, we can select a transfer function.
Press VOLT.



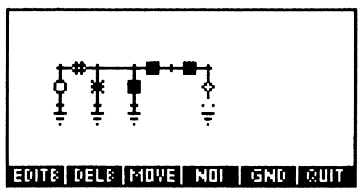
The voltage across the dependent source will be our output signal.
Position the cursor over its top end-point.
Press the right arrow four times.
Press ENTER.



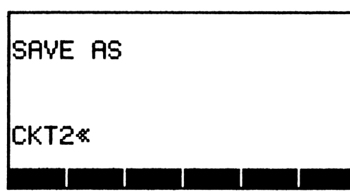
Press the down arrow.
Press enter.
Save the transfer Function.
Press YES.
Type CKT2T1.
Press ENTER.
Press EXIT.



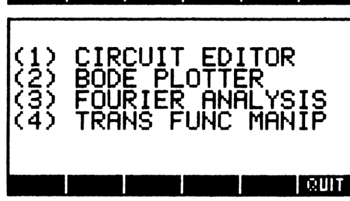
Press QUIT.
Save the changes to the circuit.
Press YES.
Save the circuit under a different name.
Press backspace.
Type 1.



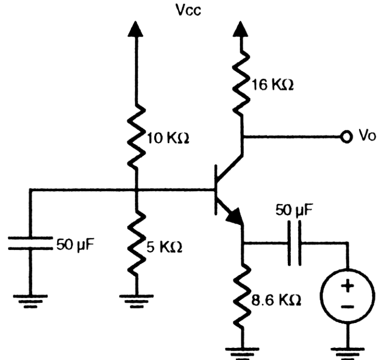
Press ENTER.



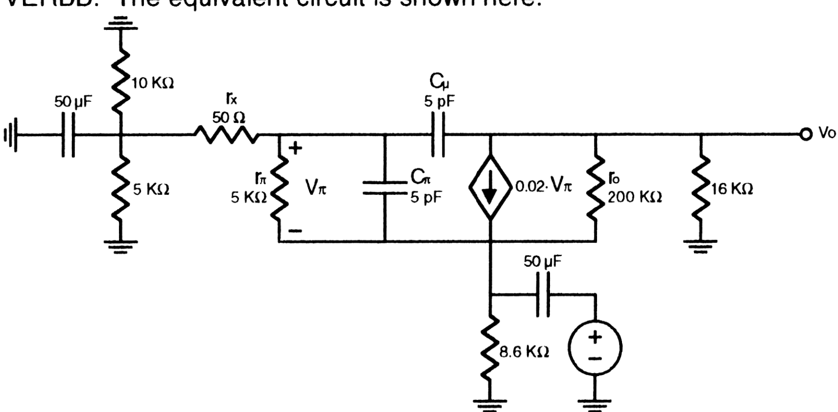
This completes Example 1.2.
The transfer function we got from this example will be used in examples in later chapters.



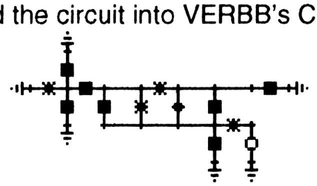
Example 1.3
This example assumes that you have completed the first two examples and are familiar with the technics presented there. In this example we will create a circuit that models the common-base transistor amplifier shown here.



The first step is to create the equivalent circuit. The common-base configuration typically has a rather large bandwidth, so to model the transistor we'll use a high frequency hybrid-π model. This model accurately models the transistor behavior at higher frequencies because it includes the internal capacitances Cμ and Cπ and the internal resistances Rx and Ro. There are many texts available that explain the details of other, more accurate, high frequency models, which of course can be used with VERBB. The equivalent circuit is shown here.

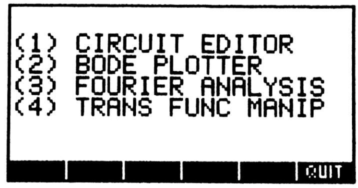


When we have entered the circuit into VERBB's Circuit Editor it will be laid out like this:

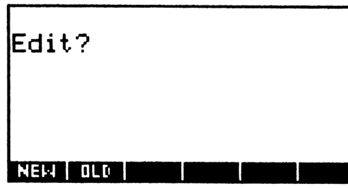


If you want, you might try entering the circuit on your own. Then, if you get stuck or want to check your work, you can go through the guided explanation of entering the circuit that starts on the next page.

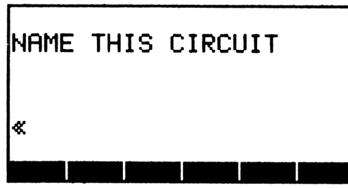
Start VERBB from the Library menu.
Press (1).



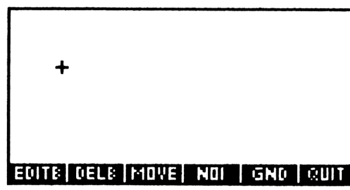
Press NEW.



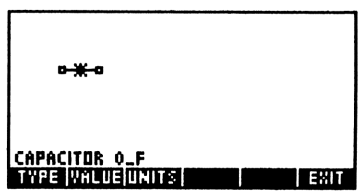
Type CKT3.
Press ENTER.



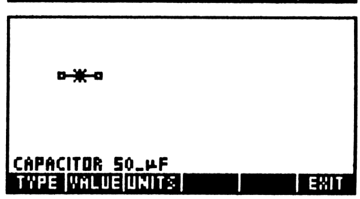
We'll place the 50 μF capacitor here.
Press EDITB.
Press the right arrow.
Press ENTER.
Press TYPE.
Press CAP.



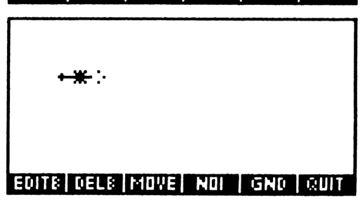
Press VALUE.
Press backspace.
Type 50
Press ENTER.
Press UNITS.



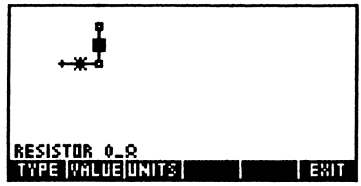
Press EXIT.



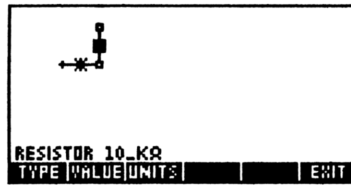
Press EDITB.
Press the up arrow.
Press ENTER.
Press TYPE.
Press RES.



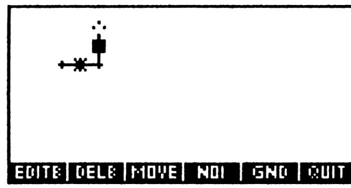
Press VALUE.
Press backspace.
Type 10
Press ENTER.
Press UNITS.



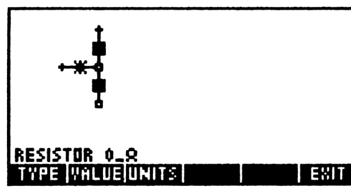
Press EXIT.



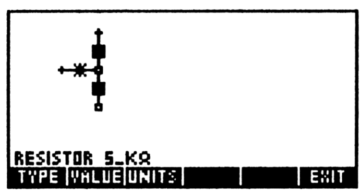
Press the down arrow.
Press EDITB.
Press the down arrow.
Press ENTER.
Press TYPE.
Press RES.



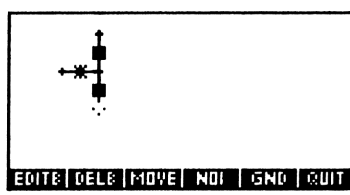
Press VALUE.
Press backspace.
Type 5
Press ENTER.
Press UNITS.



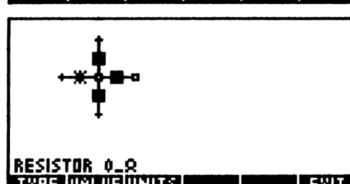
Press EXIT.



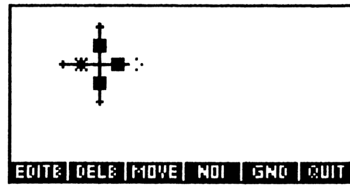
Press the up arrow.
Press EDITB.
Press the right arrow.
Press ENTER.
Press TYPE.
Press RES.



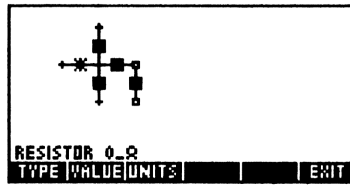
Press VALUE.
Press backspace.
Type 50
Press ENTER
Press EXIT.



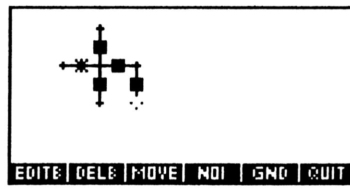
Now we add the resistor Rπ.
Press EDITB.
Press the down arrow.
Press ENTER.
Press TYPE.
Press RES.



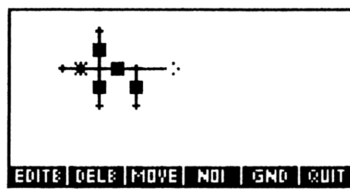
Press VALUE.
Press backspace.
Type 5
Press ENTER.
Press UNITS.
Press EXIT.



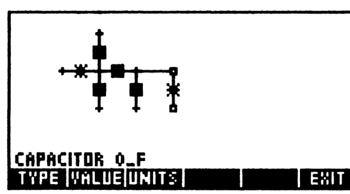
Press the up arrow.
Press EDITB.
Press the right arrow.
Press ENTER.
Press EXIT.



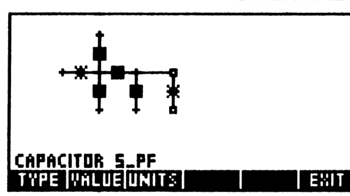
Now we add the capacitor Cπ.
Press EDITB.
Press the down arrow.
Press ENTER.
Press TYPE.
Press CAP.



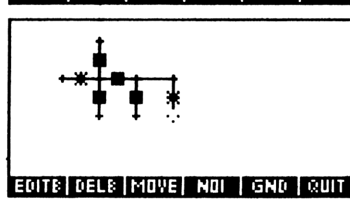
Press VALUE.
Press backspace.
Type 5
Press ENTER.
Press UNITS until you see 5_pF.



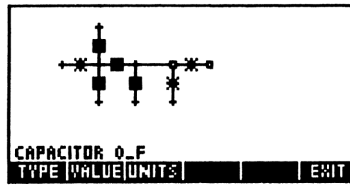
Press EXIT.



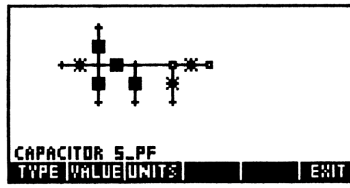
Now we add the capacitor Cμ.
Press the up arrow.
Press EDITB.
Press the right arrow.
Press ENTER.
Press TYPE.
Press CAP.



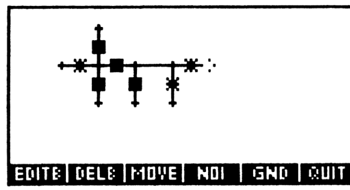
Press VALUE.
Press backspace.
Type 5
Press ENTER.
Press UNITS twice.



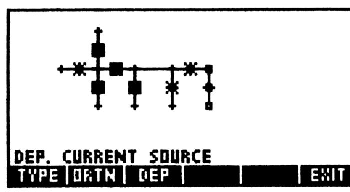
Press Exit.



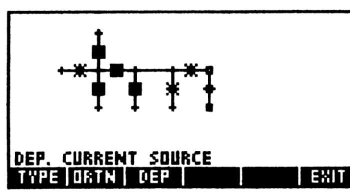
Now we'll add the dependent current source here.
Press EDITB.
Press the down arrow.
Press ENTER.
Press TYPE.
Press NXT.
Press D.IS.



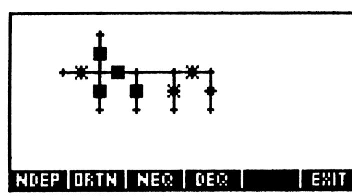
We want this source's positive current to flow from top to bottom. Therefore, the positive polarity of the source must be at the bottom.
Press ORTN.



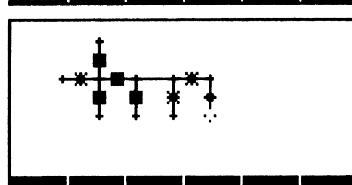
We now set the dependency as indicated in the schematic.
Press DEP.



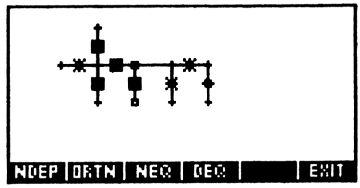
Press NDEP.



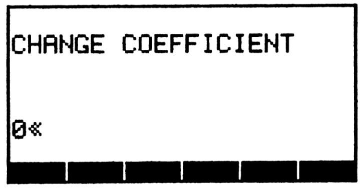
Move the cursor to the top of the resistor Rπ.
Press the left arrow twice.
Press the up arrow.
Press ENTER.
Press the down arrow.
Press ENTER.



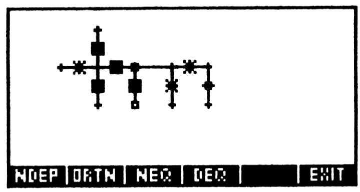
The orientation of the dependency voltage is as we want it.
Now we must set the dependency equation of the dependent current source.
Press NEQ.
Press EDIT.



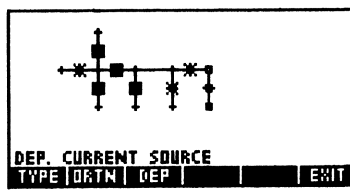
Press backspace.
Type 0.02
Press ENTER.
Press EXIT.



Press EXIT.

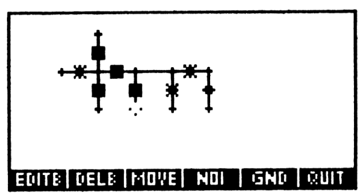


Press EXIT.

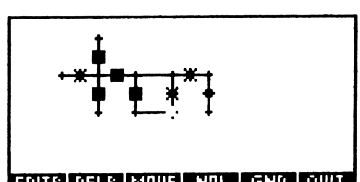


Now we need to connect the bottom end-points of Rπ, Cπ, and the current source with wires.

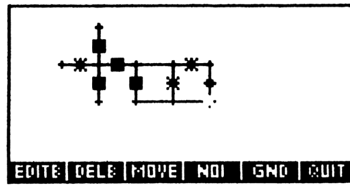
NOTE: If we stretched one wire from where the cursor is now to the bottom of the current source, the wire would pass over the bottom end-point of the capacitor Cπ, but it would NOT be connected to it. So, we must connect end-points explicitly.
Press EDITB.
Press the right arrow.
Press ENTER.
Press EXIT.



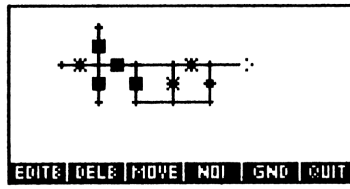
Press EDITB.
Press the right arrow.
Press ENTER.
Press EXIT.



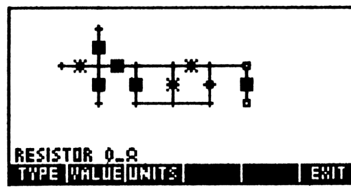
Press the up arrow.
Press EDITB.
Press the right arrow.
Press ENTER.
Press EXIT.



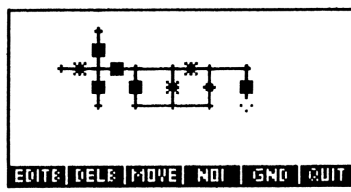
Now we can add Ro.
Press EDITB.
Press the down arrow.
Press ENTER.
Press TYPE.
Press RES.



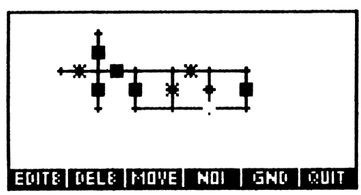
Press VALUE.
Press backspace.
Type 200
Press ENTER.
Press UNITS.
Press EXIT.



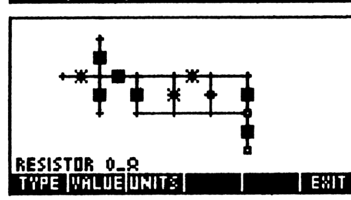
Press EDITB.
Press the left arrow.
Press ENTER.
Press EXIT.



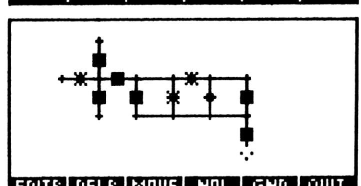
Press the right arrow.
Press EDITB.
Press the down arrow.
Press ENTER.
Press TYPE.
Press RES.



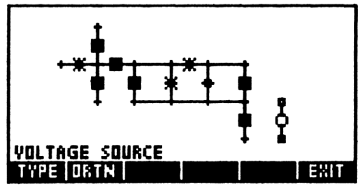
Press VALUE.
Press backspace.
Type 8.6
Press ENTER.
Press UNITS.
Press EXIT.



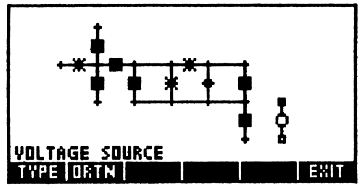
Press the right arrow.
Press EDITB.
Press the up arrow.
Press ENTER.
Press TYPE.
Press NXT.
Press VS.



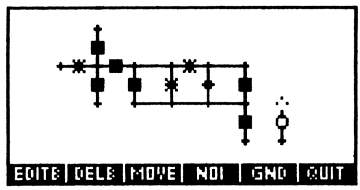
We want the top to be the positive polarity for the source.
Press ORTN.



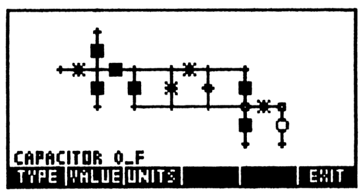
O.K.
Press EXIT.



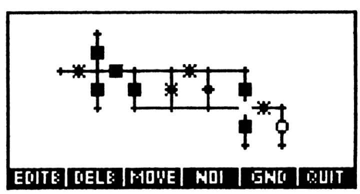
Press EDITB.
Press the left arrow.
Press ENTER.
Press TYPE.
Press CAP.



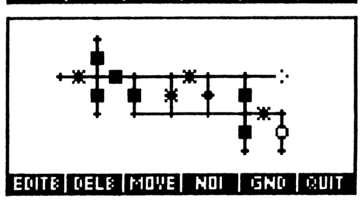
Press VALUE.
Press backspace.
Type 50
Press ENTER.
Press UNITS.
Press EXIT.



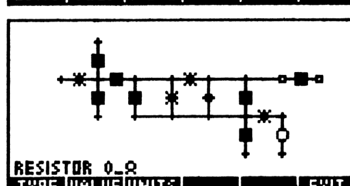
Press the up arrow.
Press EDITB.
Press the right arrow.
Press ENTER.
Press EXIT.



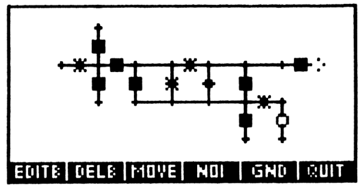
Press EDITB.
Press the right arrow.
Press ENTER.
Press TYPE.
Press RES.



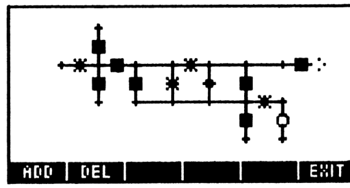
Press VALUE.
Press backspace.
Type 16
Press ENTER.
Press UNITS.
Press EXIT.



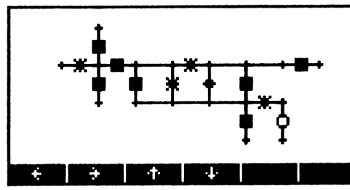
We now need to ground the necessary end-points.
Press GND.



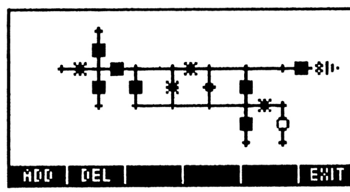
Ground the end-point where the cursor is.
Press ADD.



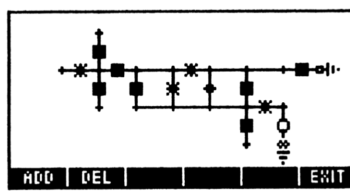
Press the key labeled '→'.



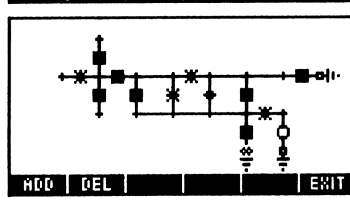
Press the down arrow twice.
Press the left arrow.
Press ADD.
Press the key labeled '↓'.



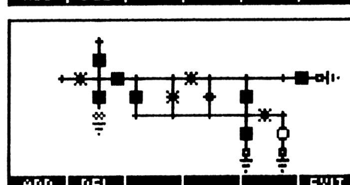
Press the left arrow.
Press ADD.
Press the key labeled '↓'.



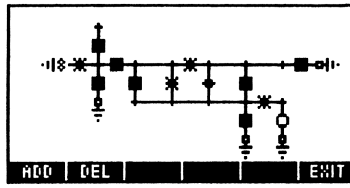
Press the left arrow four times.
Press the up arrow.
Press ADD.
Press the key labeled '↓'.



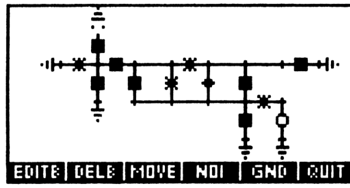
Press the left arrow.
Press the up arrow.
Press ADD.
Press the key labeled '←'.



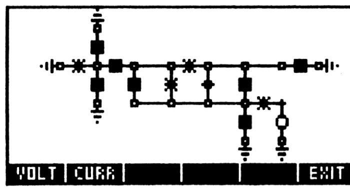
Press the right arrow.
Press the up arrow.
Press ADD.
Press the key labeled '↑'.
Press EXIT.



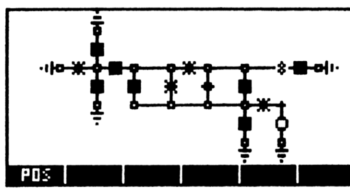
O.K. the circuit is complete.
Press EVAL.
This circuit will take a bit longer to evaluate, about eight minutes. There are five essential nodes in this circuit, which means that VERBB must solve four simultaneous equations.



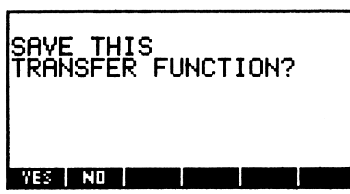
When the evaluation is finished we will select the transfer function of the voltage Vo versus the input voltage.
Press VOLT.
Press the right arrow five times.
Press the down arrow.



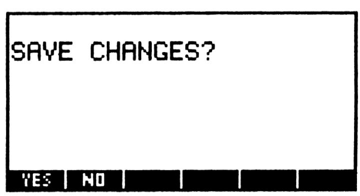
Press ENTER.
Press the right arrow.
Press ENTER.



Press YES.
Type CKT3T1
Press ENTER.
Press EXIT.
Press QUIT.

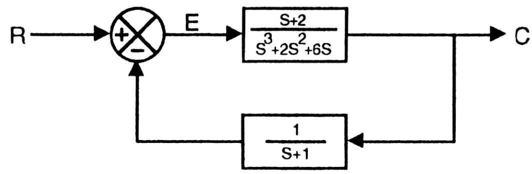


Press Yes.
Press ENTER.



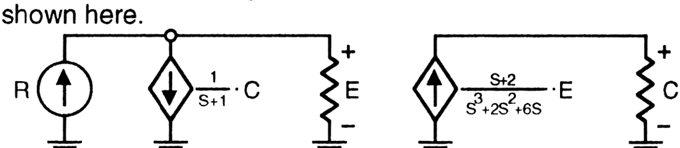
Example 1.4

This example assumes that you have completed at least the first two examples and are familiar with the technics presented there. In this example we will create a circuit that models the block diagram shown here.

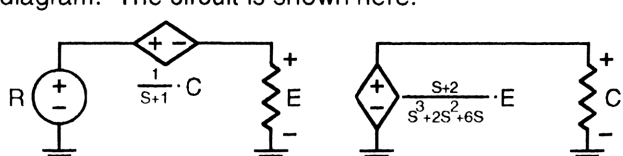


This example will show you how to create dependent sources that have dependency equations that are higher order polynomials of ‘s’. Also, this example will demonstrate two errors that can occur during circuit evaluation and you will learn how they can be avoided by thoughtfully placing ‘nodes of interest’.

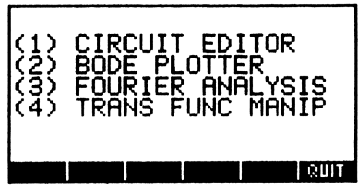
Block diagrams are used mostly in control engineering to model automatic control systems. These control systems can be anything from a robotic arm controller to a missile guidance system. The block diagram shown above represents a simple negative feedback control system. The input signal is labeled ‘R’, the output is ‘C’ and the arrows indicate the direction of signal flow. The equations in the blocks are multiplied by the block’s input signal and the result is the block’s output signal. It is important to remember that each block is independent of the others and presents no loading to the others, neither is it loaded by the others. To model the block diagrams with circuits in VERBB we use dependent sources. One possible way to do this is with current sources. An equivalent circuit to our block diagram was implemented with current sources and is shown here.



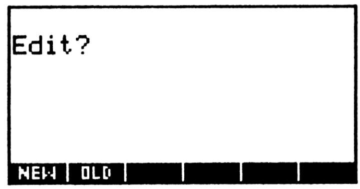
Notice how the feedback signal is subtracted from the input signal by connecting the current sources at one node, which is similar to the way signals are added or subtracted in block diagrams. The resistors are 1Ω and are necessary to give the current some place to go. To implement a block diagram you can use any combination of dependent current or voltage sources. For this example we will use voltage sources to model our block diagram. The circuit is shown here.



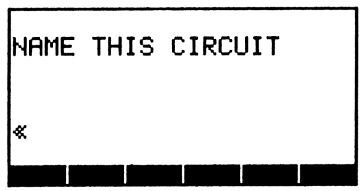
Start VERBB from the Library menu.
Press (1) to go to the Circuit Editor.



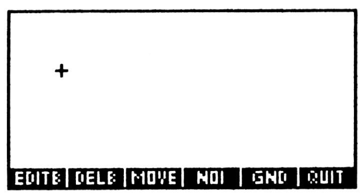
Press NEW.



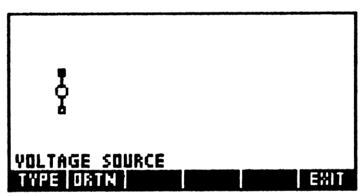
Type CKT4.
Press ENTER.



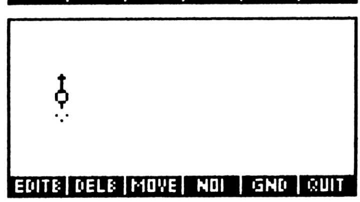
We'll place the independent voltage source here.
Press EDITB.
Press the down arrow.
Press ENTER.
Press TYPE.
Press NXT.
Press VS.



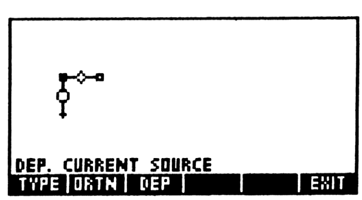
The polarity is as we want it.
Press EXIT.



Press the up arrow.
Press EDITB.
Press the right arrow.
Press ENTER.
Press TYPE.
Press NXT.
Press D.VS.

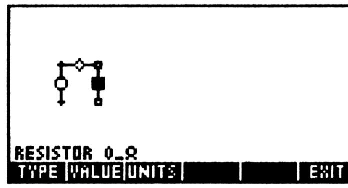


The polarity is as we want it, but we cannot set the dependency yet because the rest of the circuit needs to be entered first. We'll come back to it later.
Press EXIT.

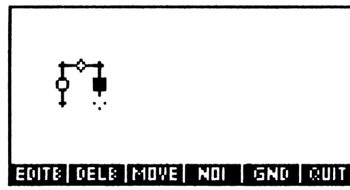


Now we'll add a resistor.
Press EDITB.
Press the down arrow.
Press ENTER.
Press TYPE.
Press RES.

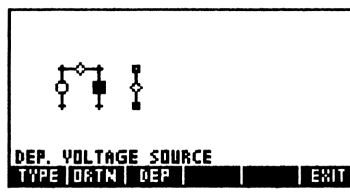
Press VALUE.
Press backspace.
Type 1
Press ENTER.
Press EXIT.



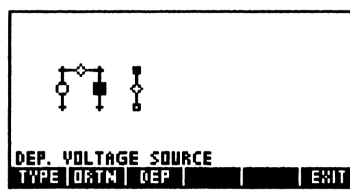
Press the right arrow.
Press EDITB.
Press the up arrow.
Press ENTER.
Press TYPE.
Press NXT.
Press D.VS.



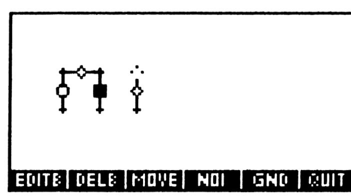
We must change the polarity.
Press ORTN.



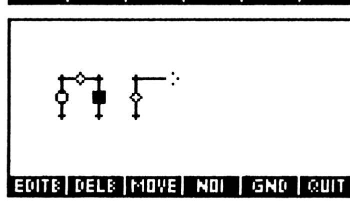
We'll set the dependency later.
Press EXIT.



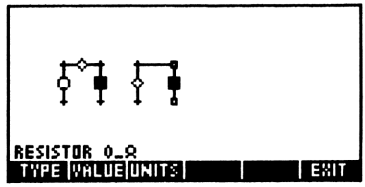
Press EDITB.
Press the right arrow.
Press ENTER.
Press EXIT.



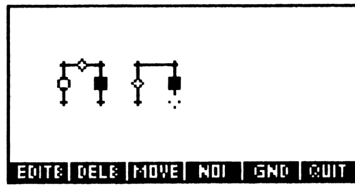
Press EDITB.
Press the down arrow.
Press ENTER.
Press TYPE.
Press RES.



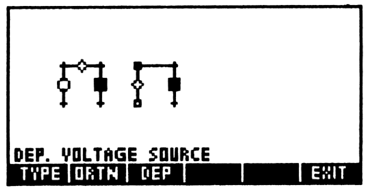
Press VALUE.
Press backspace.
Type 1
Press ENTER
Press EXIT.



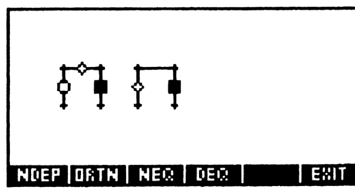
Now we'll set the dependency on the two dependent voltage sources.
Press the left arrow.
Press EDITB.
Press the up arrow.
Press ENTER.



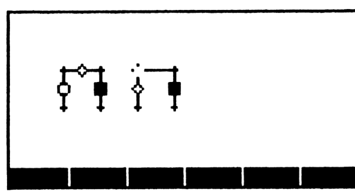
Press DEP.



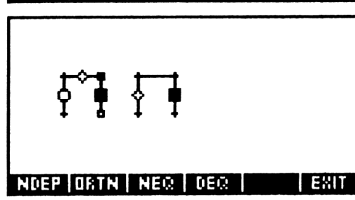
We now select the specific dependency voltage.
Press NDEP.



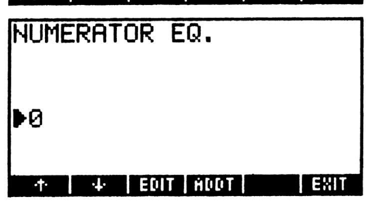
Press the left arrow.
Press ENTER.
Press the down arrow.
Press ENTER.



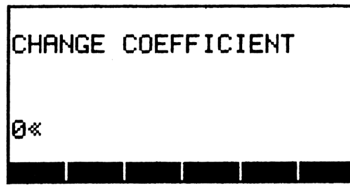
The dependency equation must now be set. We'll start with the numerator equation.
Press NEQ.



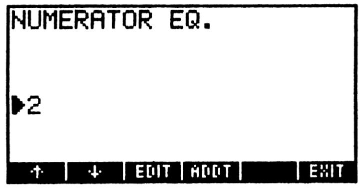
The numerator equation for this source must be 's+2'. The pointer is pointing to the lowest order coefficient which must be changed to '2'.
Press EDIT.



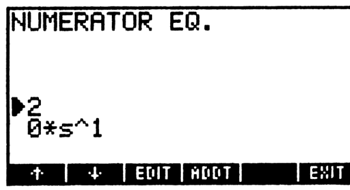
Press backspace.
Type 2
Press ENTER.



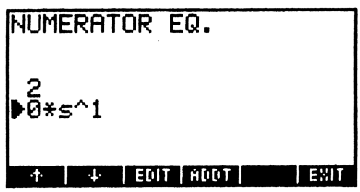
Now we need to add one higher order term.
Press ADDT.



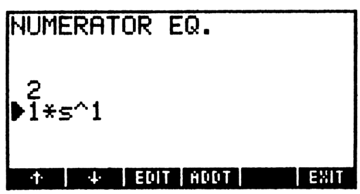
Now we must edit the coefficient of the new term.
Press the menu key labeled '↓'.



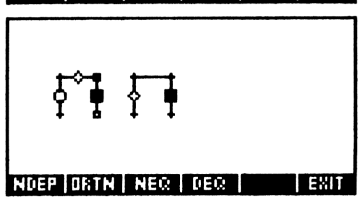
Press EDIT.
Press backspace.
Type 1
Press ENTER.



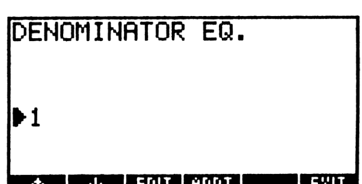
The numerator equation has been set.
Press EXIT.



Now we must set the denominator equation.
Press DEQ.

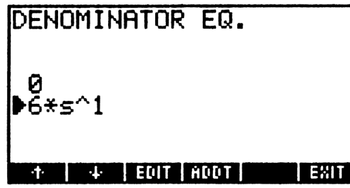


The denominator equation for this source must be 's^3+2s^2+6s'. The pointer is pointing to the lowest order coefficient which must be changed to '0'.
Press EDIT.
Press backspace.
Type 0

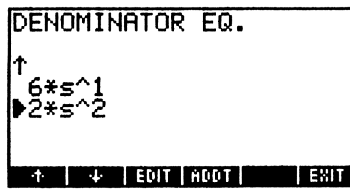


Now we add another term and edit it.
Press ADDT.
Press the menu key labeled '↓'.
Press EDIT.
Press backspace.
Type 6
Press ENTER.

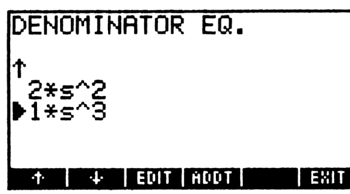
Now for the next term.
Press ADDT.
Press the menu key labeled '↓'.
Press EDIT.
Press backspace.
Type 2
Press ENTER.



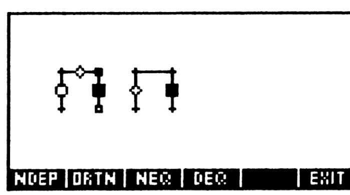
Now for the next term.
Press ADDT.
Press the menu key labeled '↓'.
Press EDIT.
Press backspace.
Type 1
Press ENTER.



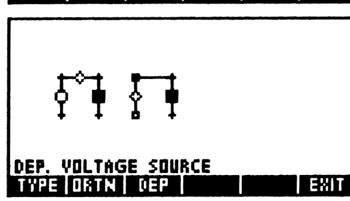
If you need to, you can press the menu key labeled '↑' to scroll the terms back down to view or edit them.
Press EXIT.



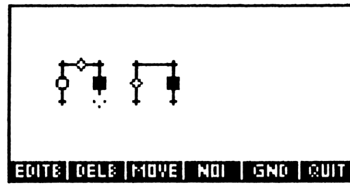
Press EXIT.



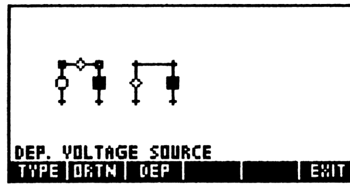
Everything has been set for this source.
Press EXIT.



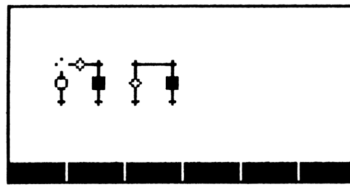
Now we need to set the dependency on the other dependent source.
Press the up arrow.
Press EDITB.
Press the left arrow.
Press ENTER.



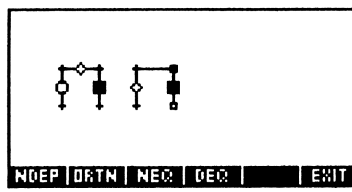
Press DEP.
Press NDEP.



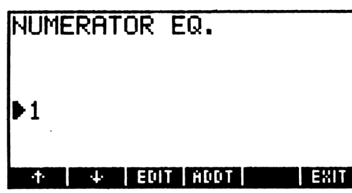
Press the right arrow three times.
Press ENTER.
Press the down arrow.
Press ENTER.



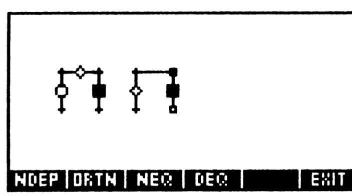
The numerator equation is simply '1'.
Press NEQ.
Press EDIT
Press backspace.
Type 1
Press ENTER.



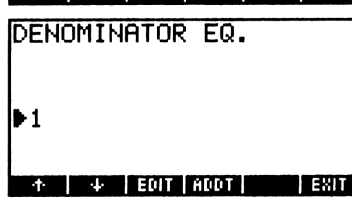
O.K.
Press EXIT.



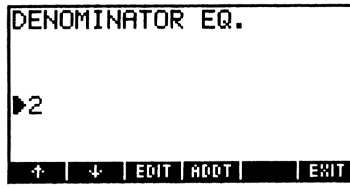
The denominator equation for this source must be 's+2'.
Press DEQ.



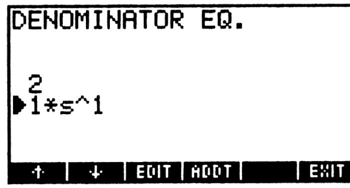
The coefficient of the lowest order term must be '2'.
Press EDIT.
Press backspace.
Type 2
Press ENTER.



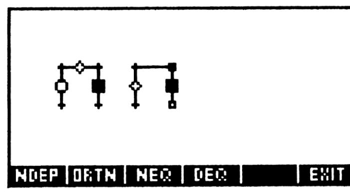
We need one higher order term.
Press ADDT.
Press the menu key labeled '↓'.
Press EDIT.
Press backspace.
Type 1
Press ENTER.



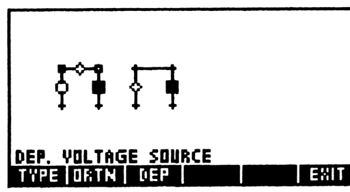
O.K.
Press EXIT.



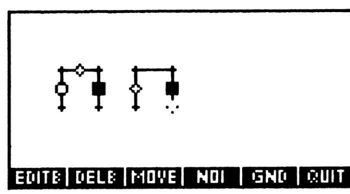
The dependency of this source has been set to the way we want it.
Press EXIT.



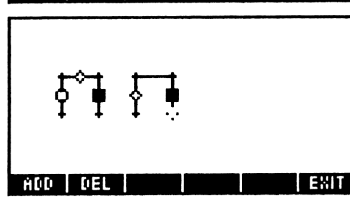
This source has been edited to just the way we want it.
Press EXIT.



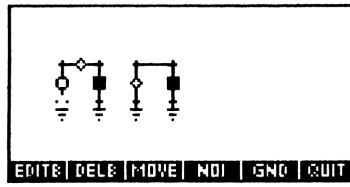
Now, because it's the only thing left to do, we must ground the dangling end-points.
Press GND.



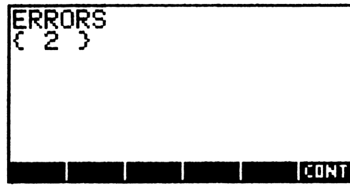
Press ADD.
Press the menu key labeled '↓'.
Press the left arrow.
Press ADD.
Press the menu key labeled '↓'.
Press the left arrow.
Press ADD.
Press the menu key labeled '↓'.
Press the left arrow.
Press ADD.
Press the menu key labeled '↓'.
Press EXIT



Now we can evaluate the circuit.
Press the EVAL key.

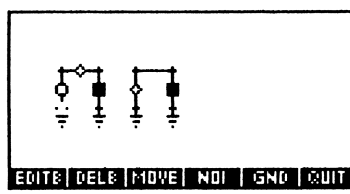


You will see the count on the screen that indicates the progress of the evaluation. But the count will be interupted before it has finished and you will see the screen shown here.

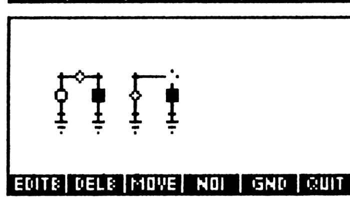


Look up error #2 in the appendix and read the explanation. The reason for the error is the isolated current loop on the right half of the circuit that contains no independant source and only one essential node— the node connected to ground. VERBB must evaluate at least two nodes in the isolated current loop in order to evaluate this circuit. In this case the isolated current loop only contains one non-essenial node in addition to the essential node. So the solution is simple, we need to select the one non-essential node as a node of interest. You may wonder why VERBB doesn't take care of this automatically, the reason is that an isolated current loop may contain more than one choice as the node of interest. If VERBB rendomly picked one choice and then continued with the evaluation, there would be a waste of time if the choice were wrong. Let us now continue.
Press CONT.

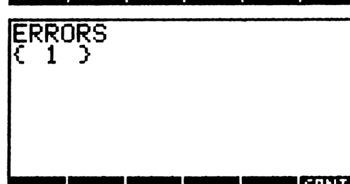
Press the right arrow three times.
Press the up arrow.
Press NOI.
Press ADD.
Press EXIT.



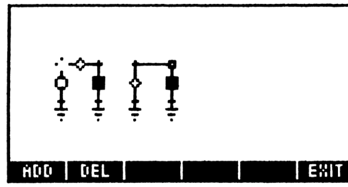
Now we can try to evaluate the circuit again. You should get the second, but different, error that was promised at the beginning of this example.
Press EVAL.



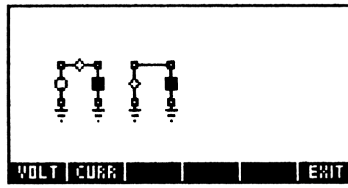
Error #1 means that you have a branch that contains two sources. This refers to the two sources in the left half of the circuit. We simply need to place a node of interest between them.
Press NOI.
Press the left arrow three times.



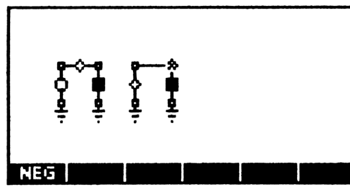
Press ADD.
Press EXIT.
Now we try evaluating it again.
Press EVAL.



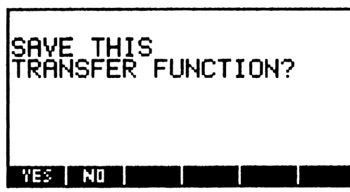
No we can select the transfer function that we want.
Press VOLT.
Press the right arrow three times.
Press ENTER.



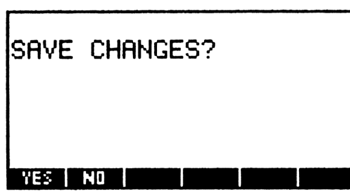
Press the down arrow.
Press ENTER.



Press YES.
Type CKT4T1
Press ENTER.
Press EXIT.
Press QUIT.



Press YES.
Press ENTER.



The lesson of the errors in this example is that most unexpected errors can be fixed by thoughtfully placing nodes of interest.

Chapter 2
The Bode Plotter

The Bode Plotter allows you to plot the exact Bode plots, both magnitude and phase, of a transfer function. You must already have a transfer function saved in memory to use the Bode Plotter. This chapter assumes that you have completed at least one of the tutorial examples in chapter 1, therefore you should have a transfer function in memory. The first part of this chapter describes each control available in the Bode Plotter and the last section is a tutorial example that shows each key press and the resulting screen.

Selecting a Transfer Function

To enter the Bode Plotter you must start VERBB from the Library menu. Then, from the VERBB main menu, press (2) to enter the Bode Plotter. The first thing you must do is select a transfer function. If you completed all of the examples in chapter 1, you should see the following screen.

```
PICK ONE

'CKT4T1'
↓

 ↓  | ↑  |PICK|    |    |
```

The transfer function named 'CKT4T1' is shown because it was the last one saved in the tutorial examples in chapter 1. To move around in the list of transfer functions, use the the menu keys labeled '↓' and '↑'. When the desired transfer function's name is shown, press the menu key labeled PICK.

Setting the Plot Parameters

The screen will change to show the list of plot parameters.

```
(1) START 10^1
(2) DECADES  2
(3) PNTS/DEC 10
(4) MAX DB   20
(5) MIN DB   -20
(6) FREQ. IN RADIANS
(7) PHASE IN RADIANS
PLOT|SPLOT|MAG■|PHS■|    |QUIT
```

To change any parameter, just press the number next to it. The plot parameters are explained here.

START the starting frequency of the Bode plot.
DECADES the number of cycles of the Bode plot.
PNTS/DEC the number of points plotted in each decade of the Bode plot.
MAX DB the maximum value of the vertical magnitude axis.

MIN DB the minimum value of the vertical magnitude axis.
FREQ. the units of frequency— either radians or Hz.
PHASE the units of the vertical phase axis—either radians of degrees.

The menu bar commands are explained here.
PLOT generates the Bode plot on the screen.
SPLOT generates Bode plot data to be sent out the serial port.
MAG when marked, the magnitude plot is generated.
PHS when marked, the phase plot is generated.

Plotting to the Calculator or a PC

Bode plot data, in the form of a text file, can be sent out the serial port to another computer that is running KERMIT. The other computer can use the data to generate larger plots, perform analysis, etc. The file name will be BODE.DAT. The format of a line of data in the text file is shown here:

" *frequency* , *magnitude* , *phase* <line feed> "

The numbers in each line are separated by commas. Each number contains five decimal digits, a sign if negative, and an exponent if needed. If only one part of the Bode plot is generated (either the magnitude or phase) then the text file lines will simply not include the other data field.

The file will contain a starting line of HP generated characters that may need to be removed when the file is read by a program that will, say, use the data to generate a larger Bode plot.

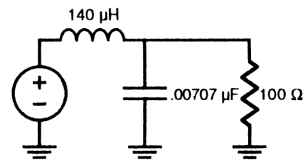
The tutorial example that starts on the next page will show you explicitly how to send Bode plot data to another computer.

Bode Plotter Tutorial Example

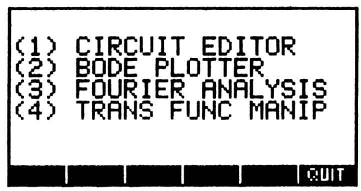
Our goal for this example is to fully demonstrate each command in VERBB's Bode plotter. We will select a transfer function, set the plot parameters, generate the Bode plot on the calculator screen, and then send the Bode plot data to another computer to create a larger plot.

Example 2.1

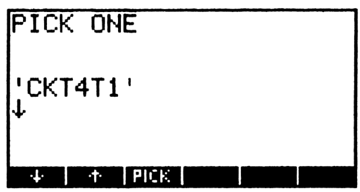
For this example we will use a transfer function that was derived in Example 1.1. We constructed the Low-Pass RLC filter shown here. We'll use the transfer function that expressed the voltage across the resistor vs. the input voltage.



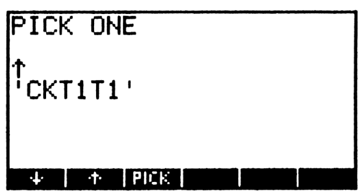
Start by putting your calculator in the directory where VERBB was attached. Then open the Library menu and press the menu key under VERBB.
You will see the VERBB main menu.
Press (2) to go to the Bode plotter.



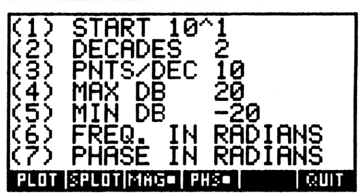
Now we need to select the transfer function we want. If you have more than one transfer function saved, you will only see the one at the top of the list.
Press '↓' until you see 'CKT1T1'.



Press PICK.

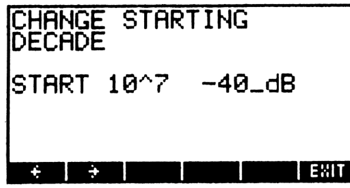


You're now in the Bode plotter.
The first step is to set the plot parameters. We'll set the starting decade now.
Press (1).

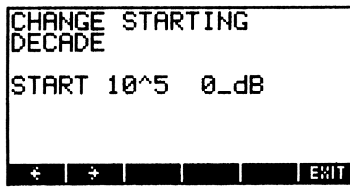


Shown to the right of the decade number is the magnitude of the function at that specific frequency. Watch the magnitude value as you increase the starting frequency.
Press the menu key '→' six times.

You will see the magnitude start to decrease when the frequency gets to 10^6, then when you stop at 10^7 the magnitude will be -40_dB. Being able to see the magnitude while you change the starting decade allows you to plan your Bode plot. From what we have seen, we know that the cutoff frequency for the circuit is somewhere around 1MHz. So, let us set the plot parameters so that we get a Bode plot starting at 10^5 radians/s and ending at 10^7. Set the starting decade to 10^5.
Press the menu key '←' twice.

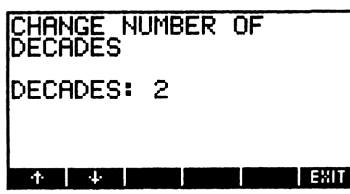


Press EXIT.



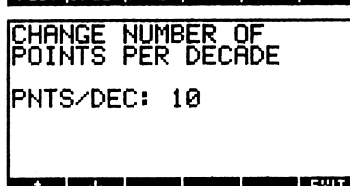
The number of decades is already set to what we want, but just for your edification. . .
Press (2).

The Bode plotter can only make plots that have 1,2,4,5, or 10 decades. If you press the '↑' or '↓' key several times you will see the number of decades cycle through these numbers. Make sure the number is back to 2 before you press EXIT.

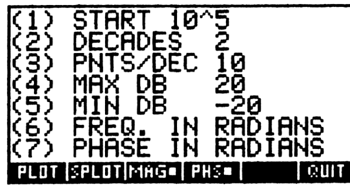


Now we'll set the points per decade.
Press (3).

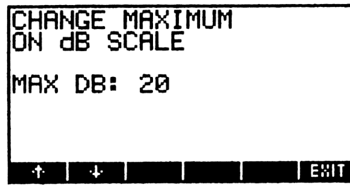
More points per decade gives more detail, but takes longer to plot. Depending on the number of decades you're plotting, there are three choices for the points per decade. Press the '↓' key three times to see all three options.
Press EXIT.



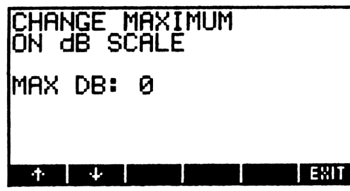
Now we'll set the maximum value of the vertical magnitude axis.
Press (4).



We know that the magnitude never went above zero when we set the starting decade. The max. dB value can change in increments of 10.
Press the '↓' key twice.

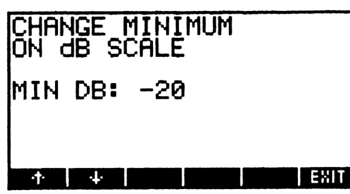


Press EXIT.

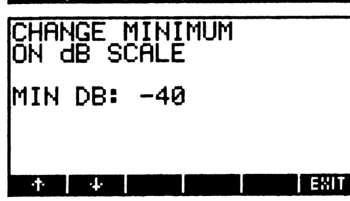


Now we'll set the minimum value of the vertical magnitude axis.
Press (5).

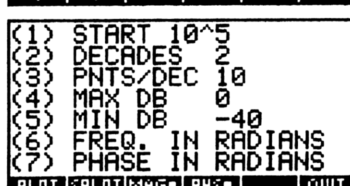
We know that the magnitude went down to -40_dB at a frequency of 10^7. The min. dB value can change in increments of 10.
Press the '↓' key twice.



Press EXIT.

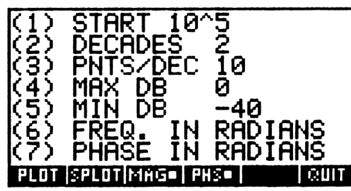


We will leave the frequency in radians and the phase in radians.
We will leave selected the menu keys labeled 'MAG' and 'PHS' because we want both magnitude and phase plots to be generated.
We will now generate the plot.
Press PLOT.



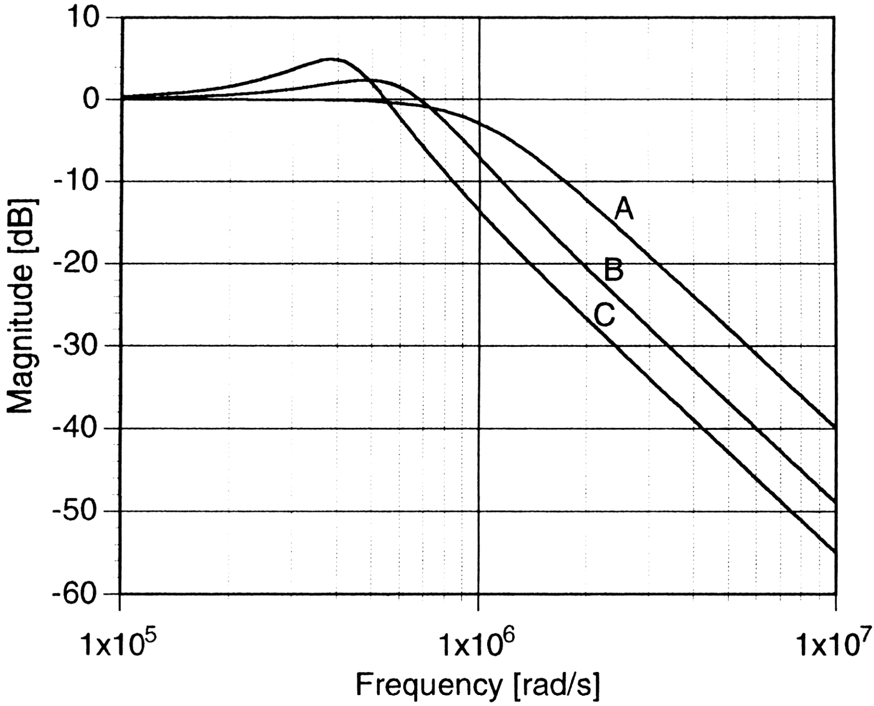
The screen should look like this.
To get the frequency response at specific frequencies, use the Transfer Function Manipulator.
The ability to quickly generate Bode plots like this is extremely useful, especially in the lab. But sometimes you may want to make a permanent copy for a report, a larger plot that shows more detail, or several plots on the same graph that compare a change in frequency response to a change in component values , etc. To accomplish this you must send the Bode plot data to a larger computer.
Press EXIT.

Press SPLOT.



Connect the serial cable and start KERMIT on your PC or MAC.
Execute the RECEIVE command in KERMIT.
Press CONT.

The plot data is now stored in your computer in a text file under the name BODE.DAT. You can look at the data with a word processor or import the data into a spreadsheet/graphing program and make more graphs. The graph on the next page illustrates one application.



The plot on this page was made by plotting magnitude data from three transfer functions on the same graph. The line labeled 'A' is from the same transfer function used in this example. The lines 'B' and 'C' are graphs of transfer functions derived from the same circuit, but with the capacitor value changed to .02μF and .04μF respectively. This type of graph can be used to do sensitivity analysis. Hmmmm!

Chapter 3
Fourier Analysis

The Fourier analysis part of VERBB allows you to see the time-domain response of your circuits to seven different types of input signals. You must already have a transfer function saved in memory to use the Fourier analysis. This chapter assumes that you have completed at least one of the tutorial examples in chapter 1, therefore you should have a transfer function in memory. The first part of this chapter describes each control available in the Fourier analysis and the last section is a tutorial example that shows each key press and the resulting screen.

Selecting a Transfer Function

To enter the Fourier analysis part you must start VERBB from the Library menu. Then, from the VERBB main menu, press (3) to enter the Fourier analysis part. The first thing you must do is select a transfer function. If you completed all of the examples in chapter 1, you should see the following screen.

```
PICK ONE

'CKT4T1'
↓

 ↓ | ↑ |PICK|    |    |
```

The transfer function named 'CKT4T1' is shown because it was the last one saved in the tutorial examples in chapter 1. To move around in the list of transfer functions, use the the menu keys labeled '↓' and '↑'. When the desired transfer function's name is shown, press the menu key labeled PICK.

Setting the Input Function Parameters

The screen will change to show the list of Input Function Parameters.

```
SQUARE WAVE
(1) FREQ.  Hz 1000
(2) PERIOD    .001
(3) DUTY CYC. 50%
(4) AMPLITUDE 1
(5) DC OFFSET 0
(6) DC COMPNT .5
PLOT|PPAR|FUNC|FUNIT|    |QUIT
```

The first line of this screen shows the currently selected input function. To change any parameter, just press the number next to it. The Input Function Parameters are explained here.

FREQ. the fundamental frequency of the input function.
PERIOD the period of the input function measured in seconds.
DUTY CYC. the duty cycle of certain input function signals.

AMPLITUDE the vertical swing of the input function or half the vertical swing for Sine.

DC OFFSET the base value or most negative point in all input functions except for Sine.

DC COMPNT the actual DC component or the average value of the input function.

The menu bar commands are explained here.

PLOT begins the evaluation of the Fourier series and then allows you to plot the result on the screen or send the data through the serial port to a larger computer.

PPAR sends control to the plot parameter menu.

FUNC allows you to change the type of input function.

FUNIT toggles the frequency units between Hz and rad/s.

Points to remember when changing input function parameters:

- When the frequency value is changed, the value of the period will be automatically recalculated and vise versa.
- When the duty cycle, amplitude, or dc offset is changed, the value of the dc component will be automatically recalculated.
- When the dc component is changed, only the value of the dc offset will be automatically recalculated. The values of the duty cycle and amplitude will remain the same.
- The duty cycle value is not applicable to certain input functions—namely: the half rectified sine, the fully rectified sine, and sine.
- When the units of frequency are changed, say, from Hz to rad/s, the Hz frequency value is converted to rad/s and vise versa. The frequency value is also edited in its current units. There is no need to awkwardly multiply or divide by 2π.
- Many common circuits have transfer functions that result in an infinite dc response. If you have selected such a transfer function, the values of dc offset and dc component will be suppressed and the message "∞ DC RESPONSE" will appear in their place. You can still perform Fourier analysis, but the series will be evaluated as if the dc component of the input signal was exactly zero.

Selecting an Input Function

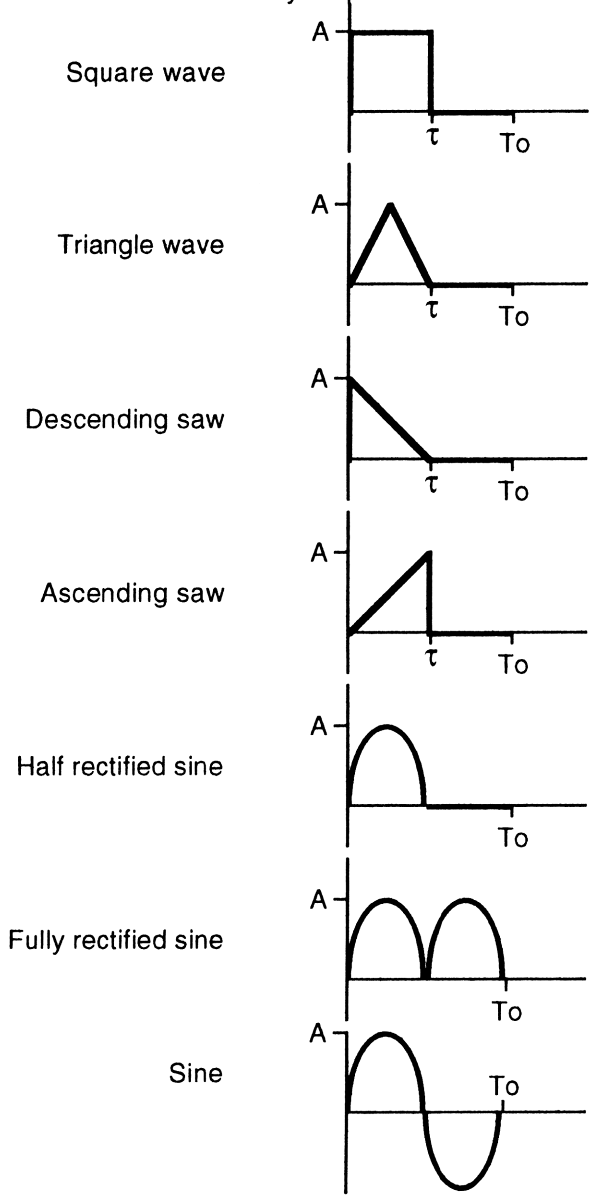
If you press the menu key labeled FUNC, you will be able to select a different input function. There are seven input functions available. The screen will change and appear as you see it here.

```
<1> SQUARE WAVE
<2> TRIANGLE WAVE
<3> DESCENDING SAW
<4> ASCENDING SAW
<5> HALF RECT SINE
<6> FULL RECT SINE
<7> SINE
```

Press the number next to the desired input function.

Seven Input Functions Defined

The seven available input functions are defined here and graphs are shown for one period of each function. The graphs were drawn with the duty cycle set to 50% and the dc offset set to zero. The dc components are, of course, non-zero, except for sine where the dc component and dc offset are always equal.



The 'A' symbol in each graph shows the amplitude, 'To' shows the period, and the duty cycle is defined by 100·To/τ.

Setting the Plot Parameters

The plot parameter menu allows you to change the time interval that you want to evaluate, the number of equally spaced points within the time interval that will be evaluated, and the number of Fourier series terms that will be used during the evaluation. To set the plot parameters press the menu key labeled PPAR. The screen will change to the one shown here.

```
{1} START  0
{2} END    .001
{3} POINTS 50
{4} TERMS  20

ONE |    |    |    |    | EXIT
```

The Plot Parameters are explained here.

START the starting time for the time interval.

END the ending time for the time interval.

POINTS the number of equally spaced points within the time interval.

TERMS the number of Fourier series terms that will be used during the evaluation.

The menu bar commands are explained here.

ONE recalculates the start and end value so that the time interval will include exactly one period.

Points to remember when changing Plot Parameters:

- Doubling the number of points doubles the resolution of the plot, but also doubles the time required to evaluate the series.
- Doubling the number of Fourier terms may only result in a negligible increase in the accuracy of the plot while doubling the time required to evaluate the series. Try fewer terms first, then increase the number if higher harmonics are necessary.
- Always check the plot parameters before you evaluate the series. If you change the frequency, make sure the time interval is the desired one.

Plotting to the Calculator or a PC

Plot data, in the form of a text file, can be sent out the serial port to another computer that is running KERMIT. The other computer can use the data to generate larger plots, perform analysis, etc. The file name will be FOUR.DAT. The format of a line of data in the text file is shown here:

" *time ord.* , *input ord.* , *output ord.* <line feed> "

The numbers in each line are separated by commas. Each number contains five decimal digits, a sign if negative, and an exponent if needed. If only one plot is generated (either the input or output) then the text file lines will simply not include the other data field.

The file will contain a starting line of HP generated characters that may need to be removed when the file is read by a program that will, say, use the data to generate a larger plot.

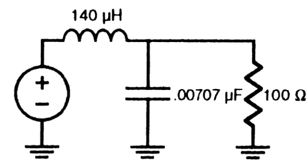
The tutorial example that starts on the next page will show you explicitly how to send plot data to another computer.

Fourier Analysis Tutorial Example

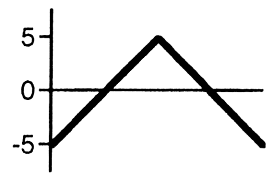
Our goal for this example is to fully demonstrate each command in VERBB's Fourier analysis part. We will select a transfer function, set the input function parameters, set the plot parameters, generate the plot on the calculator screen, and then send the plot data to another computer to create a larger plot.

<u>Example 3.1</u>

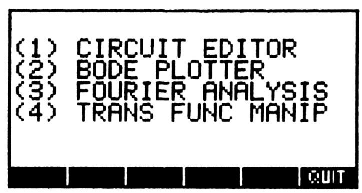
For this example we will use a transfer function that was derived in Example 1.1. We constructed the Low-Pass RLC filter shown here. We'll use the transfer function that expressed the voltage across the resistor vs. the input voltage.



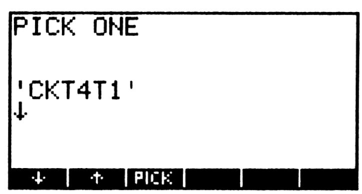
We will find the output signal that results from a triangle wave input signal with a frequency of 7.5×10^5 rad/s, an amplitude of 10, a duty cycle of 100%, and a dc component of zero. One period of the input signal is shown here.



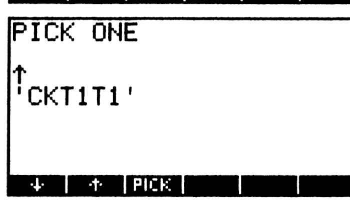
Start by putting your calculator in the directory where VERBB was attached. Then open the Library menu and press the menu key under VERBB.
You will see the VERBB main menu.
Press (3) for Fourier analysis.



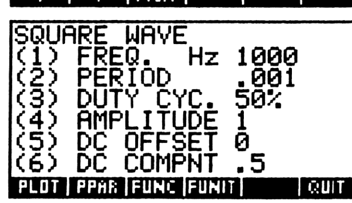
Now we need to select the transfer function we want. If you have more than one transfer function saved, you will only see the one at the top of the list. Press '↓' until you see 'CKT1T1'.



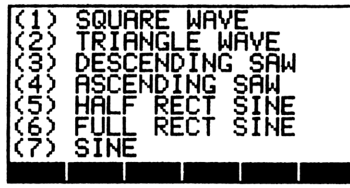
Press PICK.



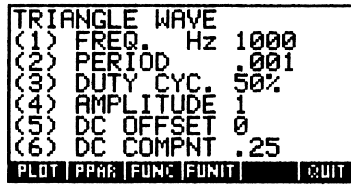
We must change the input function to a triangle wave.
Press FUNC.



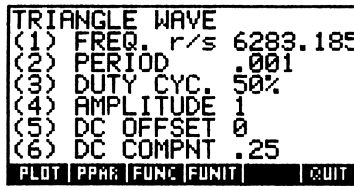
Press (2) to select triangle wave.



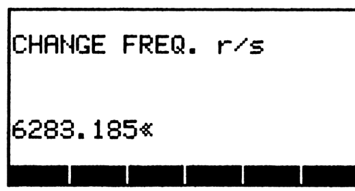
Notice that the dc component value was recalculated when the input function type was changed. We need to change the frequency of the input function to 7.5×10^5 rad/s. First we'll change the units.
Press FUNIT.



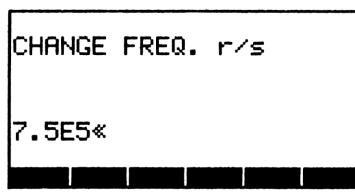
Press (1) to change the frequency.



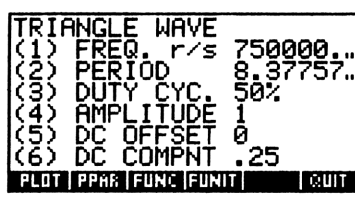
Press the DEL key.
Type 7.5
Press the EEX key.
Type 5



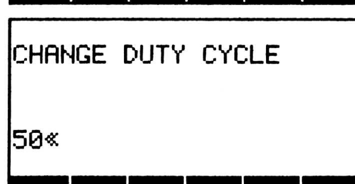
Press ENTER.



Notice that the period has been automatically recalculated.
Now we must change the duty cycle to 100%.
Press (3).



Press the DEL key.
Type 100
Press ENTER.



Notice that the dc component was automatically recalculated. Now we'll set the amplitude to 10.
Press (4).

```
TRIANGLE WAVE
(1) FREQ. r/s  750000.…
(2) PERIOD      8.37757…
(3) DUTY CYC.  100%
(4) AMPLITUDE  1
(5) DC OFFSET  0
(6) DC COMPNT  .5
PLOT | PPAR | FUNC | FUNIT |  | QUIT
```

Type 0
Press ENTER.

```
CHANGE AMPLITUDE

1«
```

Notice that the dc component was automatically recalculated again.
Now we're going to set the dc component to zero.
Press (6).

```
TRIANGLE WAVE
(1) FREQ. r/s  750000.…
(2) PERIOD      8.37757…
(3) DUTY CYC.  100%
(4) AMPLITUDE  10
(5) DC OFFSET  0
(6) DC COMPNT  5
PLOT | PPAR | FUNC | FUNIT |  | QUIT
```

Press the backspace key.
Type 0
Press ENTER.

```
CHANGE DC COMPONENT

5«
```

Verify to yourself that the input function parameters represent the input function that was described at the beginning of this example.
Now we can set the plot parameters.
Press PPAR.

```
TRIANGLE WAVE
(1) FREQ. r/s  750000.…
(2) PERIOD      8.37757…
(3) DUTY CYC.  100%
(4) AMPLITUDE  10
(5) DC OFFSET  -5
(6) DC COMPNT  0
PLOT | PPAR | FUNC | FUNIT |  | QUIT
```

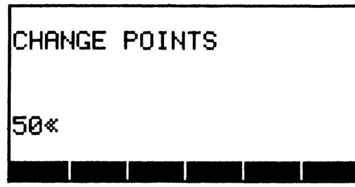
The values shown are the default values. We want a plot to be generated for one period.
Press ONE.

```
(1) START   0
(2) END     .001
(3) POINTS  50
(4) TERMS   20

ONE |  |  |  |  | EXIT
```

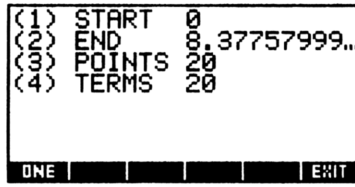
The ending value for the plot has been recalculated from the current value of the period.
We'll change the number of points that the series will be evaluated for.
Press (3).

```
(1) START   0
(2) END     8.37757999…
(3) POINTS  50
(4) TERMS   20

ONE |  |  |  |  | EXIT
```

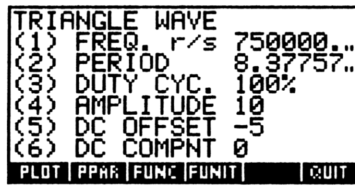
Press DEL.
Type 20
Press ENTER.



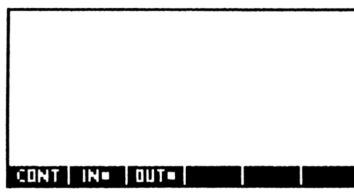
Press EXIT.



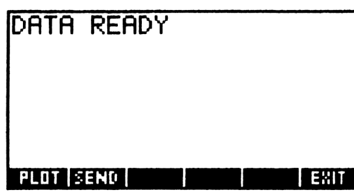
Now we're ready to evaluate the series and plot the result.
Press PLOT.



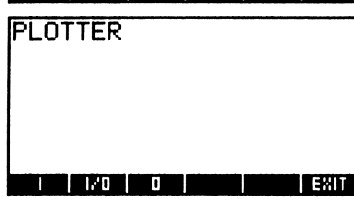
This new menu bar allows you to select which series will be evaluated. We'll leave both the input and output selected for this example.
Press CONT.



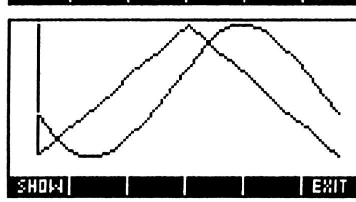
After the evaluation is complete you will see the screen shown here. At this point you can either plot the data to the calculator's screen or send the plot data out the serial port. First we'll plot to the screen. Press PLOT.



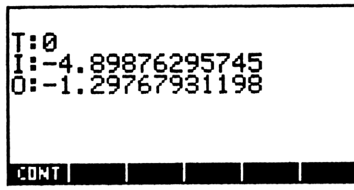
From this menu bar pressing 'I' generates a plot of just the input, pressing 'I/O' generates a plot of the input and output, and pressing 'O' generates a plot of just the output.
Press I/O.



Here you see the input and output signals plotted. Different vertical scaling factors are used for each signal so that they both fill the screen. Pressing SHOW displays the values of time, input, and output at the current position of the vertical line.
Press SHOW.

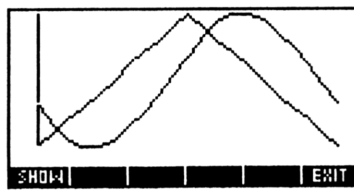


The vertical line was at the far left end of the plots. That point in time was 0 time, the input function's value was evaluated to be -4.89876295745, and the output was -1.29767931198.

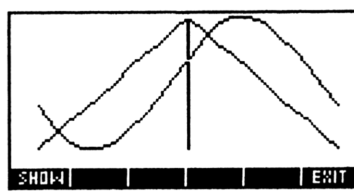


Why is the input function at this point not exactly -5 and why is it composed of slightly wavy lines rather than perfectly straight lines?
Because the Fourier series was only evaluated for 20 harmonics. If you increase the number of terms, the accuracy will increase.
Press CONT.

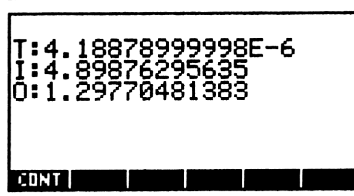
Why is the output like a sinusoid?
Because all the Fourier terms above the fundamental frequency are attenuated so much by the low pass filter that their contribution to the output is negligible. Notice also that the apparent phase shift of the output agrees with the Bode plot that was created in Example 2.1.
Press the right arrow ten times.



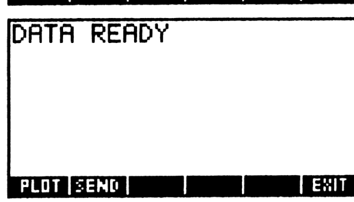
The vertical line has moved to the middle of the time interval. Now we can see the values at this point.
Press SHOW.



Press CONT.
Press EXIT.
Press EXIT.



Now we will send the plot data out the serial port.
Press SEND.



Connect the serial cable and start KERMIT on your PC or MAC.
Execute the RECEIVE command in KERMIT.
Press CONT.

The plot data is now stored in your computer in a text file under the name FOUR.DAT. You can look at the data with a word processor or import the data into a spreadsheet/graphing program and make more graphs.

Chapter 4

The Transfer Function Manipulator

The Transfer Function Manipulator is a gathering of miscellaneous tools that make VERBB more versatile. To start the Transfer Function Manipulator, press (4) from the VERBB main menu.

```
(1) DC RESPONSE
(2) AC RESPONSE
(3) T.F. EDITOR
(4) T.F. ARITHMATIC
(5) T.F. →STACK
(6) T.F. DELETE

|     |     |     |     |     | QUIT |
```

To use any tool, press the number next to it.

Getting the DC Response of a Transfer Function

Press (1) to get the DC response of a transfer function. Then select a transfer function. The screen will show the DC response.

```
THE DC RESPONSE
OF 'CKT1T1'
IS: 1

| →STK |     |     |     |     | EXIT |
```

Press →STK to have the value of the DC response placed on the stack. The value will be tagged like this:

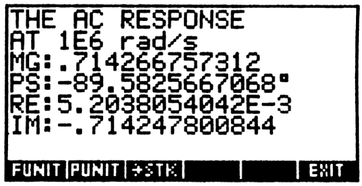
```
:DCRESP:1
```

Getting the AC Response of a Transfer Function

Press (2) to get the AC or phasor response of a transfer function, select the desired transfer function, then enter the desired frequency and press ENTER. For this example the frequency 1x10^6 was entered.

```
ENTER THE FREQUENCY

1E6«
```

The screen will then show the AC response.

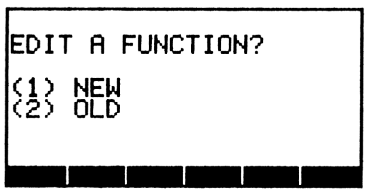


The response is shown in magnitude, phase, real part, and imaginary part. Notice that the frequency starts out in rad/s and the phase value is shown in degrees. Press FUNIT to toggle the units of frequency between Hz and rad/s. Press PUNIT to toggle the units of phase between degrees and radians. Press →STK to have the value of the AC response placed on the stack. The value will be a complex number and tagged like this:

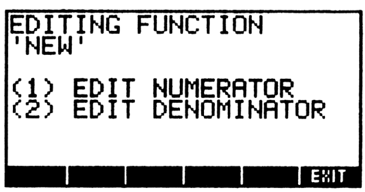
:ACRESP:(5.2038054042E-3,-.714247800844).

Editing a Transfer Function

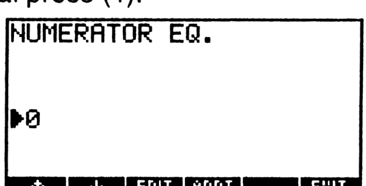
Press (3) to edit a transfer function.



Then press (1) to create a new transfer function or press (2) to select and edit an old transfer function.



The numerator and denominator polynomials of a transfer function are edited separately. The transfer function editor works in exactly the same way as the dependent-source-dependency-equation-editor in VERBB's Circuit Editor. (see Examples 1.2 to 1.4) To edit the numerator polynomial press (1).



The numerator of a new transfer function starts out as zero. Press

ADDT to add another higher order term to the numerator. Press EDIT to edit the coefficient of the term being pointed to by the arrow. Press the up and down arrows to move the arrow between the terms of the polynomial. After you have edited the numerator and denominator to the way you want them and you wish to save the transfer function, you must enter a new name for the function and then press ENTER.

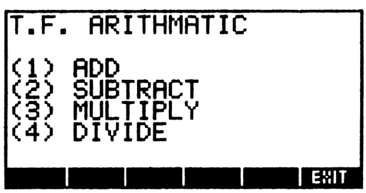
Transfer Function Arithmetic

Transfer function arithmetic allows you to add, subtract, multiply or divide two transfer functions and then save the result under a new name.

There are several applications of transfer function arithmetic:

- You may wish to find a transfer function that expresses the current that is supplied by a voltage source. Depending on your circuit, this may involve adding the currents in two branches leaving a node in order to find the current in a third branch that enters the node. If this third branch is a voltage source, the circuit editor will not be able to solve for its current directly, so you must add the transfer functions that express the currents leaving one of its nodes.
- You may wish to find the input or output impedance of a circuit. To do this you must divide a voltage transfer function by a current transfer function.

Press (4) to use transfer function arithmetic.



Press the number next to the desired function. For each, you must select two transfer functions and then enter a name for the result.

Putting a Transfer Function On the Stack

You may wish to use a transfer function for some other purpose. Press (5) from the Transfer Function Manipulator main menu to put a transfer function on the stack. After you have selected a transfer function, VERBB will place an equation on the user stack of your HP 48SX.

Deleting a Transfer Function

You may wish to delete a transfer function that you no longer want. Press (6) from the Transfer Function Manipulator main menu to delete a transfer function. After you have selected a transfer function and confirmed that you want to delete it, it will be purged.

Appendix

This appendix explains the error codes that can be generated during circuit evaluation. Example 1.4 explains two errors and shows you how they are fixed.

1 There are two sources in one essential branch. The solution is to place a "node of interest" between the sources. (see example 1.4)

2 The circuit contains components through which no current can flow. In the circuit there is either a component that is not attached at both its end-points or an isolated current loop that contains no essential node or no source. (see example 1.4)

3 The circuit is not a circuit or it is indeterminate. Check to see if you have a short circuit or an open circuit.

4 A source is not loaded or is directly shorted.

5 The circuit contains more than one independent source. In order to derive transfer functions VERBB must have only one input source.

6 The circuit contains no independent source.

7 The circuit contains a resistor with a zero value.

8 The circuit contains a capacitor with a zero value.

9 The circuit contains an inductor with a zero value.

10 The circuit contains a dependent source that has no specified dependency.

11 The circuit contains a dependent source that has an erroneous dependency. The specified dependency may be across to points that are actually the same node and therefore have zero potential between them.

12 The circuit contains a dependent source that has an erroneous dependency equation. The dependency equation may have a numerator or denominator polynomial that is zero.