DIGITAL CIRCUIT DESIGN

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1 OVERVIEW

The Digital Circuit Design program contains the basic tools for drawing digital and analog circuit schematics and analyzing the digital portion of the schematic. The analog portion of the schematic is analyzed by the Analog Circuit analysis programs. The Digital Design program contains all the drawing features of the Schematic Draw program plus much more.

The program requires 450K of base memory. The program can handle schematics with up to 500 elements (that includes text and lines) and 100 analog nodes and 100 digital nodes. The drawing area is

640 (horizontal) pixels x 400 (vertical) pixels with VGA display, or 640 x 270 pixels with EGA display. All drawing is performed on Grid that can be made visible or invisible. The drawing screen contains 80(horizontal) x 50(vertical) grid points, and can easily accommodate large circuits.

The Digital Circuit Design program calculates the Digital State of each node then plots up to 32 simultaneous waveforms. Each input and output signal is 512 bits long. The program allows the user to specify and edit each input signal, and provides programmable propagation time delay for each digital device. The calculated data can be viewed on screen, printed out, or saved on disk as a formatted ASCII file.

The program has two modes of operation: the Draw mode and the Full mode. In the Draw mode, the program becomes passive, allowing the user to draw the circuit without any interruption. In the Full mode, the program prompts the user for the parameters of each circuit element (such as node numbers, element value and tolerance) before accepting it. In the full mode, the program generates the necessary schematic file to interface with the circuit analysis programs. Schematics that are generated and saved in the draw mode cannot be used in the Circuit Analysis programs because they do not have the node, values, and tolerance information.

The program offers many attractive features such as file menus (List, Load, Save, Join, and View), Digital and Analog elements edit, both Ink/DotMtx and Laser printers support, powerful schematic edit features that includes Cut, Copy, Paste, Shift (or move) and Join (or merge). The Join feature is very useful in connecting an already saved circuit to the current circuit. The program contains other useful features such as labeling the elements and nodes and listing the elements of the circuit. The help screen provides a quick reference to program menus and features. The program requires a Microsoft compatible mouse or pointing device.

2 BASIC OPERATION

To activate the program, change to the root directory. When you see the prompt C:\>, type CD\EEWORKS then press the <Enter> key. The DOS prompt changes to C:\EEWORKS>. To activate program, you can type DIGITAL then press the <Enter> key, or you can use Windows Explorer and double click on the DIGITAL.EXE file.

The Main program screen is partitioned into several areas. The layout of the program menus and symbols is shown below.

_____ 34 Digital and Analog Circuit Symbols _____

Figure 1 Program Menu Layout

1. At the top of the screen, 34 digital and analog circuit symbols are displayed.
2. At the upper right corner, a square is displayed. This is called the viewer and usually contains a copy of the selected symbol.
3. Under the 34 symbols, 8 orientation options (`RT UP LT DN R2 U2 L2 D2`) are displayed. The RT option is initially active and is displayed in red.
4. Also, under the 34 symbols, a status line "R22 C41 FULL P1 DTMTX VGA M64K T0 E0 N0" is displayed. T is the total number of schematic elements, E is the total number of analog elements, and N is the total number of analog nodes. The DG0 DN0 status is displayed under the orientation options. DG is the total number of digital elements and DN is the total number of digital nodes.
5. The Main menu consists of 43 options that are displayed on screen. The 43 options can be grouped as follows.

>   a. Digital Analysis: CALC OUTS INPS
>   b. Digital element/circuit edit: DELD TRGD TYPD TDLY CHDN SDNN
>   c. Analog element/circuit edit : DEL1 VAL2 TOL3 TYP4 CHAN SAN8
>   d. Schematic Area edit: SHFT CUT5 CPY6 PST7
>   e. Schematic/drawing details: LBL   NOD   ANC   GRD LSTA PGN
>   f. Overall Circuit operation: ORDN CHEK ERS9
>   g. File operations: SAVE LIST LOAD JOIN NEW
>   h. Display   MUHD SCRN COLR DRAW
>   i. System operation: HELP OQT   HID   PRNT MODE PRTY

MENU OPTIONS SUMMARY

```
CALC: calculate and plot the specified nodes    DELD: delete digital element
OUTS: pick or specify the output waveforms      TRGD: change digital trigger
INPS: define or edit the input waveforms        TYPD: change digital device
SDNN: set digital node to a new number          TDLY: change propagation delay
ERS9: erase any element from schematic          CHDN: change dgtl device node
ORDN: order the schematic nodes sequentially
LBL:  show/hide the element numbers and values LIST: list files in current
NOD:  show/hide the node numbers                      directory.
ANC:  show/hide the elements anchor points      JOIN: load & merge schematic
GRD:  show/hide the grids                             with current schematic
LSTA: show/hide the elements list               CHEK: check for open nodes
PGN:  display next page of elements.            MUHD: hide the menus
DEL1: delete analog element from schematic      DRAW: redraw the schematic
VAL2: change analog element value               MODE: full (with prompts)
TOL3: change analog element tolerance                 or draw without prompts
CHAN: change analog element node number         SCRN: select EGA or VGA scrn
SAN8: set analog node to a new number           COLR: change screen colors
SHFT: move selected area (mouse/arrow keys)     TYP4: change element type RLC
CUT5: cut an area and save it in clipboard      PRTY: change printer type.
CPY6: copy an area into the clipboard           OQT,HID: Exit the program
PST7: paste from clipboard into drawing area    NEW:  erase current circuit
PRNT: print schematic, Net List, Data, or waveforms on selected printer.
SAVE: save the Circuit Schematic (.SKM), Digital Input(.DIN), or data (.DGD)
LOAD: load the Circuit Schematic (.SKM), Digital Input(.DIN), or View File
```

Initially, the LBL option is enabled which means that the program will display the element label automatically after it is entered.

STATUS LINE

The status line displays the current system settings, which are as follows.

Draw/Full	Draw mode or Full mode (set by MODE)
Px	Page number from the elements list (set by PGN) Laser/Dtmtx Laser or Ink/DotMtx printer (set by PRTY)
EGA/VGA	EGA or VGA screen (set by SCRN)
MxxK	Free Memory available
Txx	Total Number of schematic elements
Exx	Number of Analog elements only
Nxx	Number of the Analog Nodes in schematic (set by CHEK) Rxx Mouse Row position
Cxx	Mouse Column position
DGx	Total Number of Digital Elements
DNx	Number of Digital Nodes in the schematic.

MENU SELECTIONS

Unless otherwise stated, a mouse click refers to pressing and releasing the Left Mouse Button. Nearly all mouse operations are performed by clicking the left mouse button. The right mouse button is used in **one** operation only, namely, erasing an element from the drawing area.

A menu option is selected by either clicking on the option with the mouse, or by pressing its hot key which is displayed in white color. The Space Bar is the hot key for the Orientation options, while the TAB key is the hot key for the Element type selection. The Escape key cancels the selection.

DRAWING PARAMETERS, SYMBOLS, ORIENTATION, AND ANCHOR POINTS

In drawing a schematic diagram, every circuit element is assigned a unique set of Drawing Parameters that distinguish it from other elements. The unique set of Drawing Parameters are the Element Type, its Orientation, and the Anchor data. The anchor data tells the program where to connect (or attach) the anchor point of the element on the screen. The elements anchor points are shown in the Symbols area (and also in Viewer) as a small square. These three drawing parameters are all what the program needs to draw the circuit element on the screen, and they are usually saved whenever a schematic is saved. When an element is pasted in the drawing area, its anchor point is attached to a grid point. The above three parameters are selected by the mouse in both the Paste and Erase operations. Do not confuse the above Drawing Parameters with the Electrical Parameters of the element (nodes, value and tolerance).

SCHEMATIC DETAILS

The program contains five options that assist the user in drawing the schematic and show other details. They are

LBL	(for Label): shows the elements values and numerical designation.
NOD	(for Node Number): Shows the number of each node.
ANC	(for Anchor point): Shows the anchor point of each element.
GRD	(for Grid points): show the grid points on the screen.
LST	(for Elements List): shows a listing of the circuit elements.

The above five options operate in toggle fashion, and their color turns red when they are active.

SCHEMATIC DRAWING RESOLUTION

All operations are performed on half grid points that are separated by 4 pixels. The screen shows the full grid points that are separated by 8 pixels. The half grid resolution applies to elements paste, elements erase, text, lines, and all area operations (cut, copy, move, merge).

SCROLLING ENTIRE SCHEMATIC

To move a schematic in the drawing area, use the arrow keys on the keyboard. The direction of the scroll (up, down, right, left) depends on which arrow key is pressed. You can also use the SHIFT (MOVE) menu option to move the drawing or parts of it to another location.

ESCAPE

If you get stuck anywhere in the Schematic Draw program, remember to use the Escape key and/or the DRAW command. You can quit at any time by pressing the O key or clicking the OQT command. Note also that most commands have hot keys that are displayed in white color.

3   TUTORIAL

To illustrate the operation of this program, we shall analyze the operation of the Johnson counter shown below.
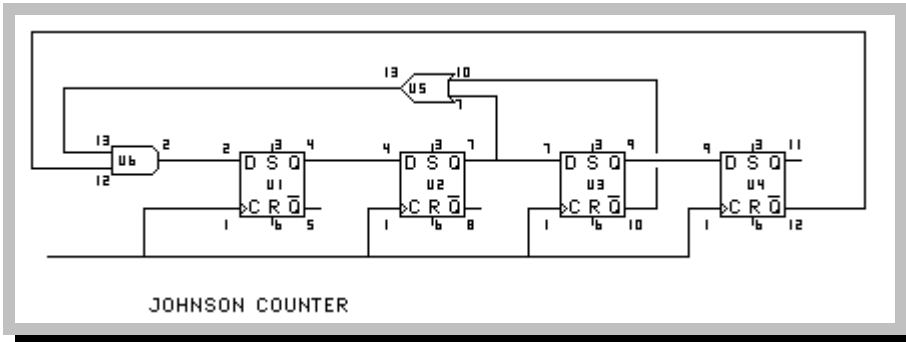
Figure 2 Tutorial Digital Circuit (Johnson Counter)

Before entering the circuit, we need to assign a unique number to each node. It is preferred that these node numbers be sequential. However, this is not mandatory, because the program will examine the nodes and order them properly. For now let us assign the node numbers as shown in figure 2. For convenience, node 1, by default, is treated, by the program, as a clock input node where a square wave is always present at that node. This clock input can be edited as will be seen later.

To see where to paste the elements in the drawing area, let us display the grid by clicking on the GRD option. In response, the program displays the grid and the GRD option is now red indicating that it is active. We also like the program to display the node numbers. So, we click on the NOD option. Now the LBL, GRD, and NOD options should all be red in color
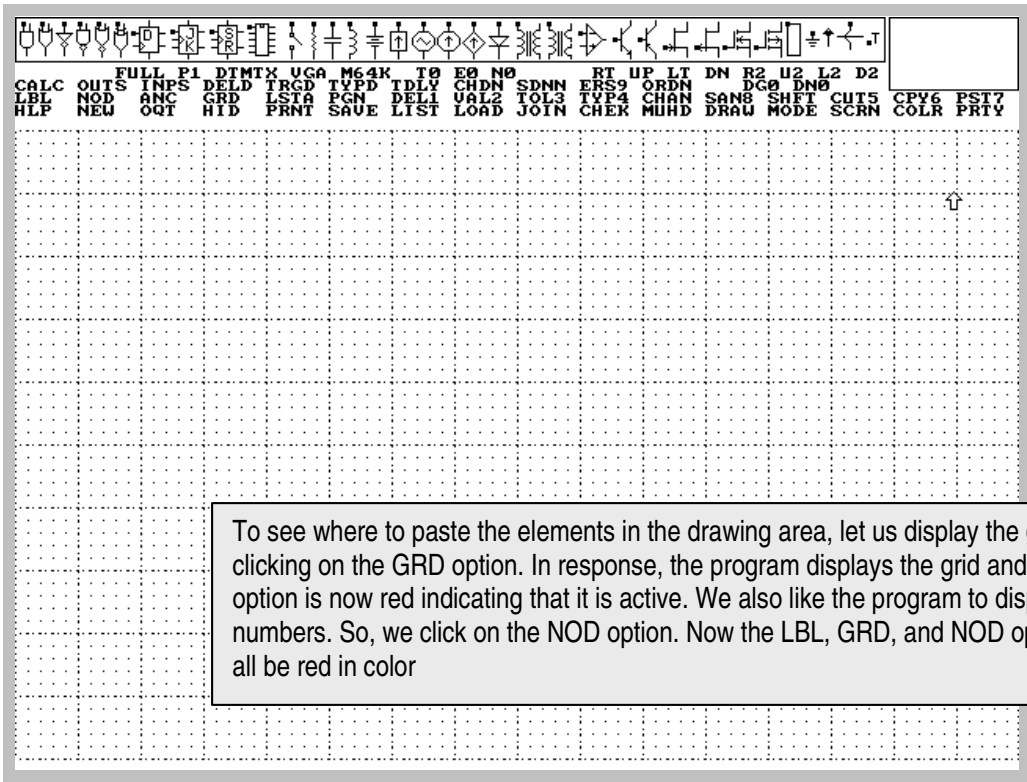
Figure 3 Start up Screen of the Digital Circuit Analysis Program

Click on the D Flip Flop symbol. The viewer now displays the RT orientation of the D-FF, since the RT orientation was already selected. To paste the D-FF, click in the drawing area at any convenient grid point. The anchor point of the D-FF will be attached to the point where the mouse was clicked.
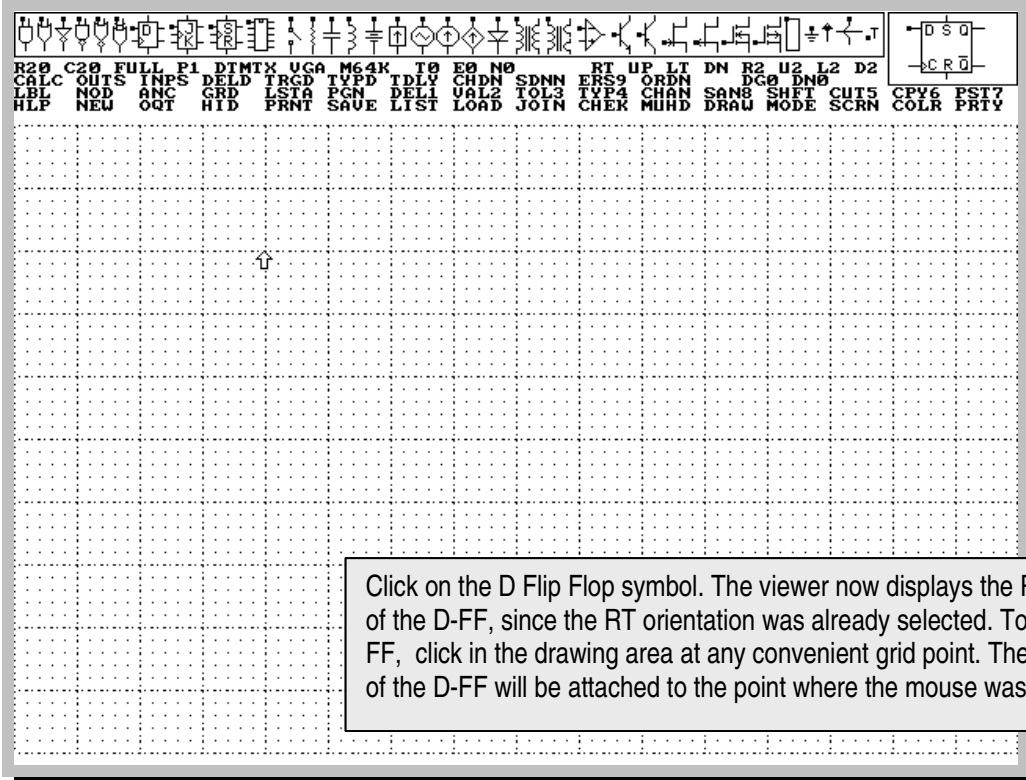
Figure 4 Selection of the D Flip Flop Symbol

The program now pastes the D-FF into the drawing area, and displays a prompt that asks for the node numbers of the D-FF terminals and its trigger type, as shown here.
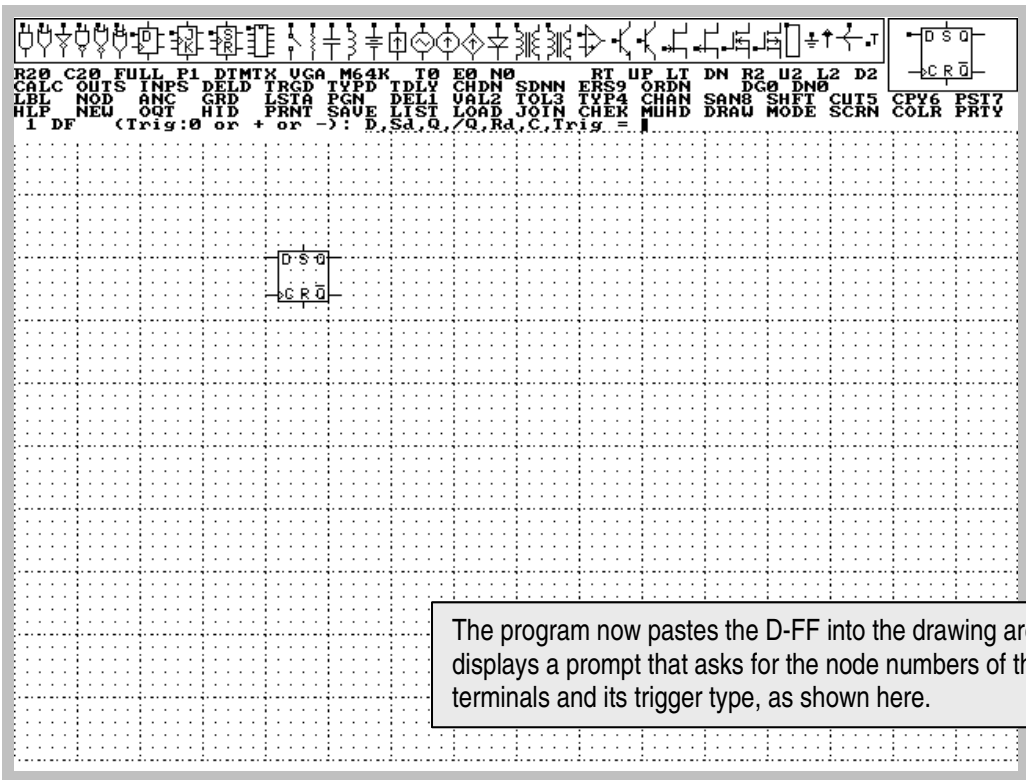
Figure 5 Pasting of the D Flip Flop Symbol
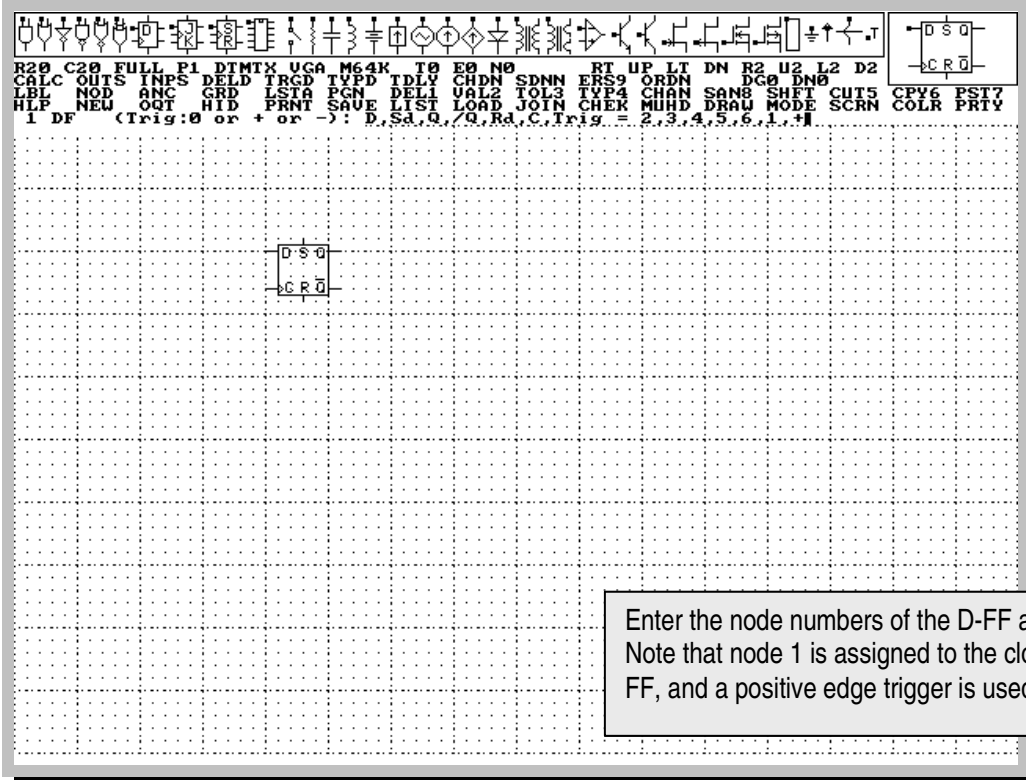
Enter the node numbers of the D-FF as shown here. Note that node 1 is assigned to the clock input of the D-FF, and a positive edge trigger is used here.

Figure 6 Entering the nodes of the D Flip Flop
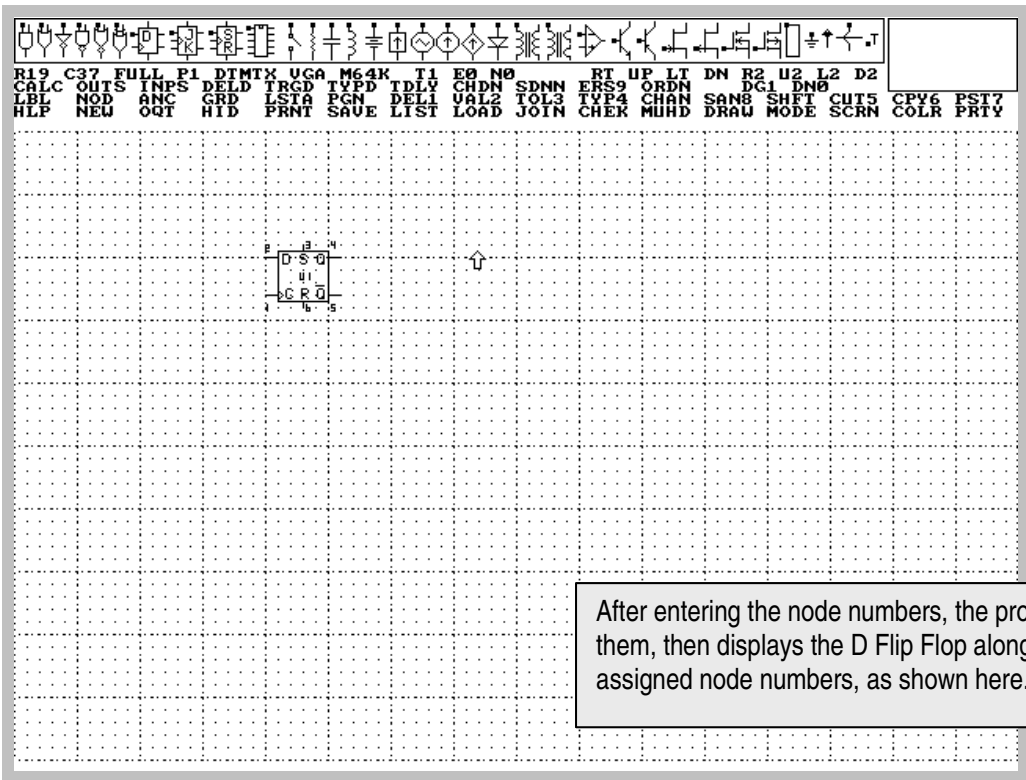
After entering the node numbers, the program checks them, then displays the D Flip Flop along with the assigned node numbers, as shown here..

Figure 7 The D Flip Flop with its assigned node numbers.

Enter the node numbers of the D-FF as shown here. Note that if two or more nodes share the same number then the nodes are connected to each other. This explains how some of the nodes of the two D-FF share the same numbers.
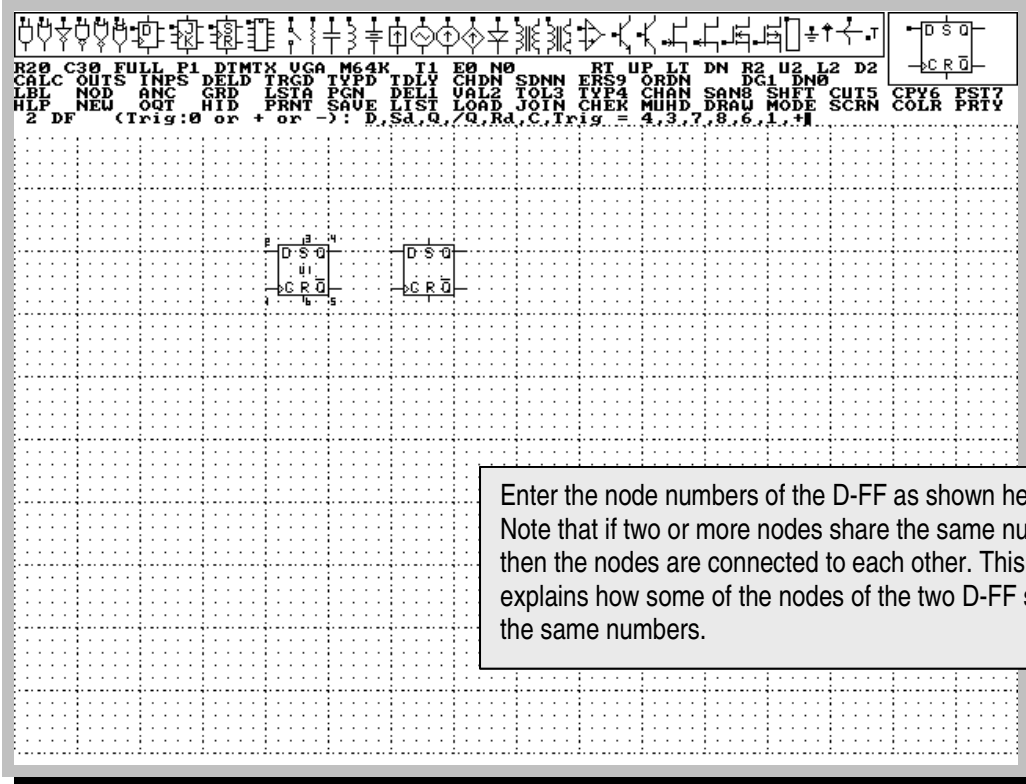
Figure 8 Entering the Second D Flip Flop

After entering the node numbers, the program checks them, then displays the second D Flip Flop along with the assigned node numbers, as shown here.
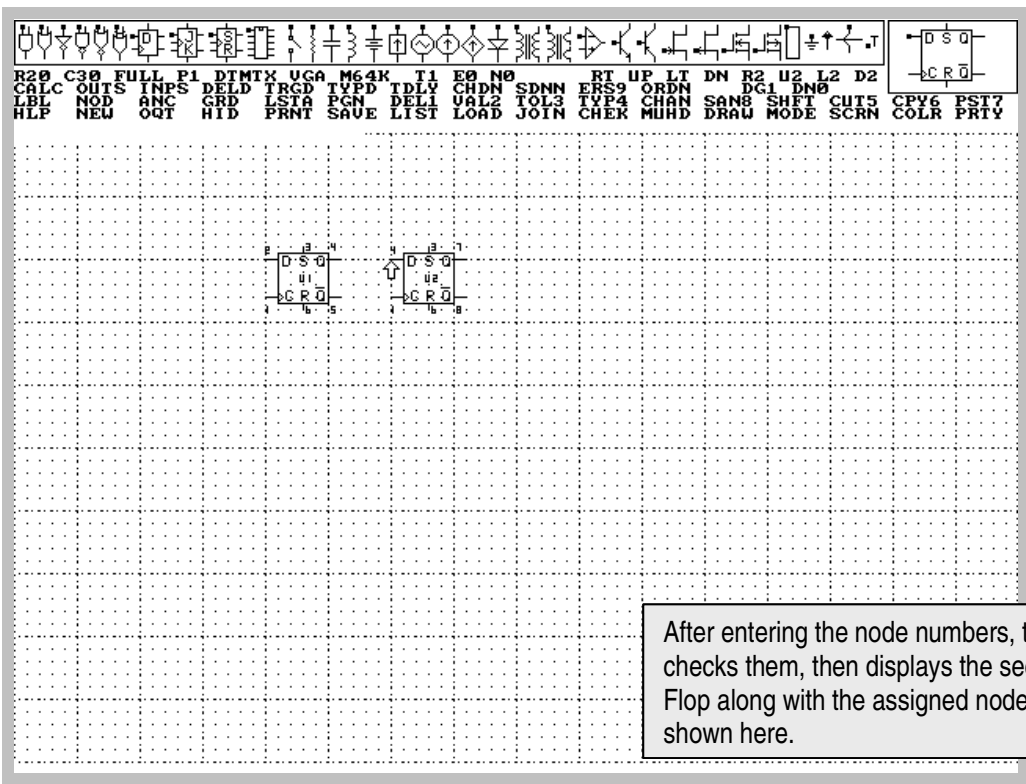
Figure 9 The Second D Flip Flop Has been Entered.
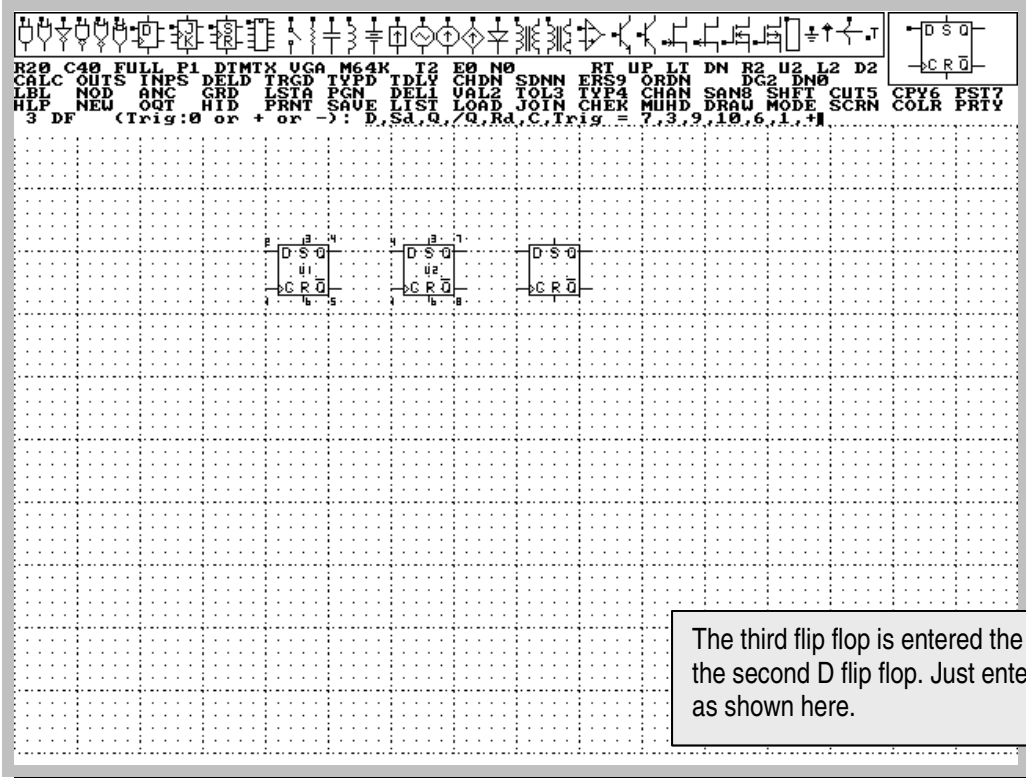
The third flip flop is entered the same way as the second D flip flop. Just enter its parameters as shown here.

Figure 10 Entering the Third D Flip Flop
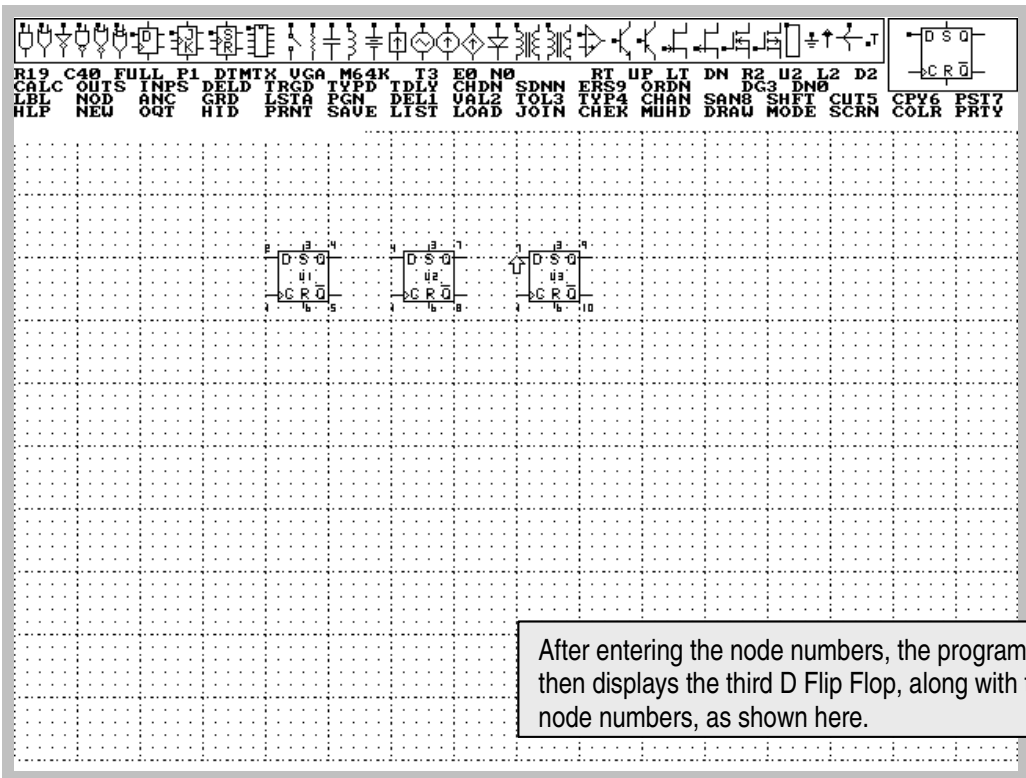
After entering the node numbers, the program checks them, then displays the third D Flip Flop, along with the assigned node numbers, as shown here.

Figure 11 The Third D Flip Flop Has been Entered.

To enter the fourth D Flip Flop, enter its parameters as shown here.
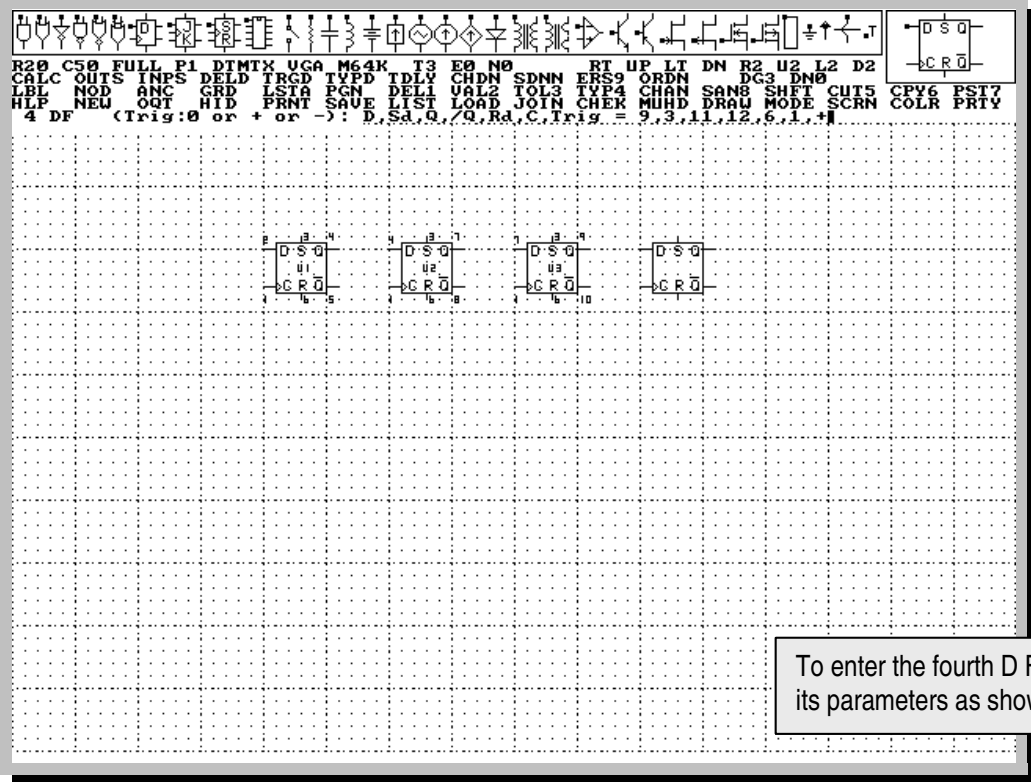
Figure 12 Entering the Fourth D Flip Flop

Now, all four flip flops have been entered. Note that they all share the clock, Set, and Reset inputs.
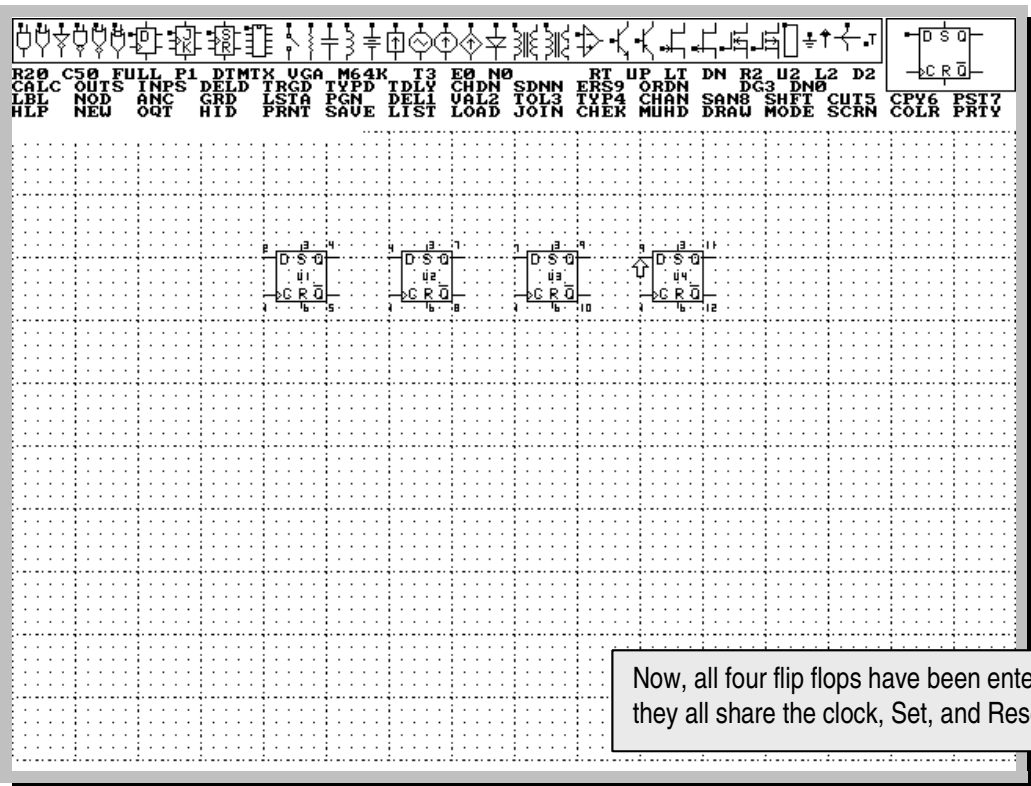
Figure 13 All four Flip Flops have been entered.
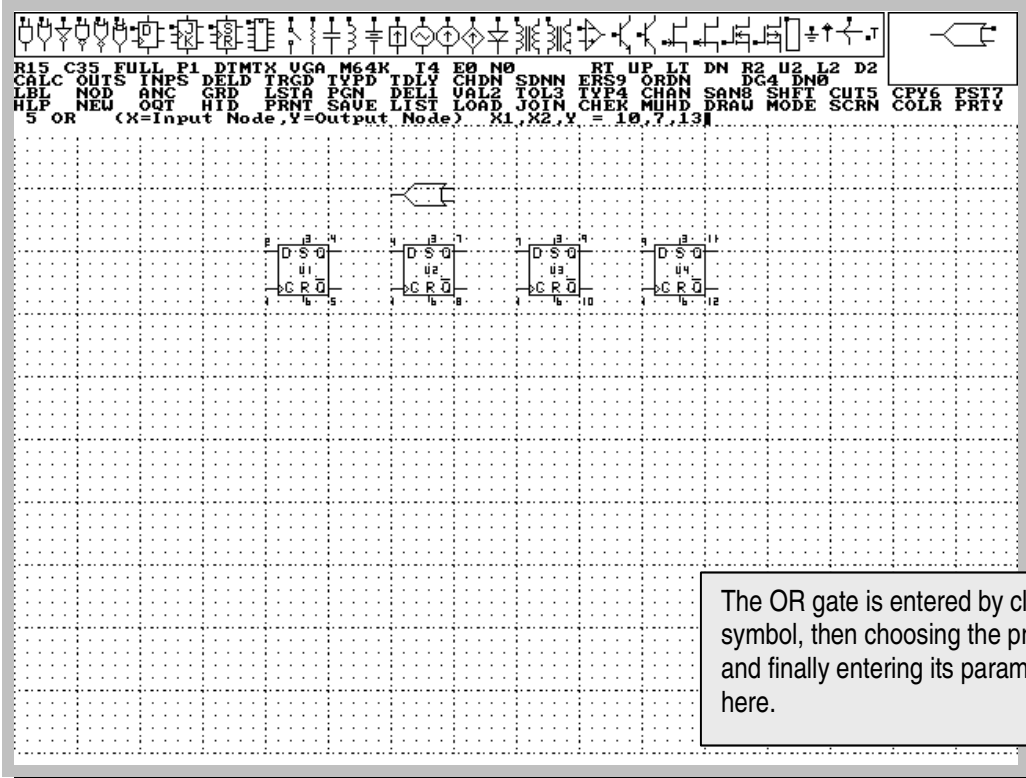
The OR gate is entered by clicking on its symbol, then choosing the proper orientation, and finally entering its parameters as shown here.

Figure 14 Entering the OR gate
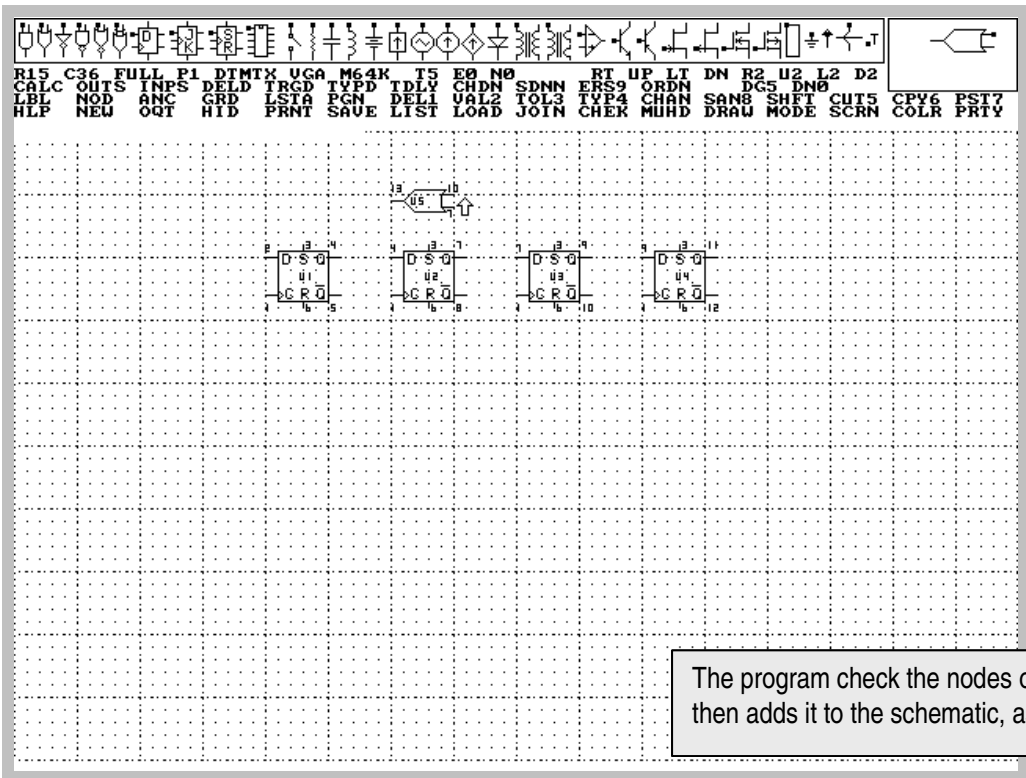
The program check the nodes of the OR gate, then adds it to the schematic, as shown here.

Figure 15 Adding the OR gate to the Schematic

The AND gate is the last electrical components to be added. To enter the AND gate, answer the prompts as shown here. Note that X1 is the anchor node here.
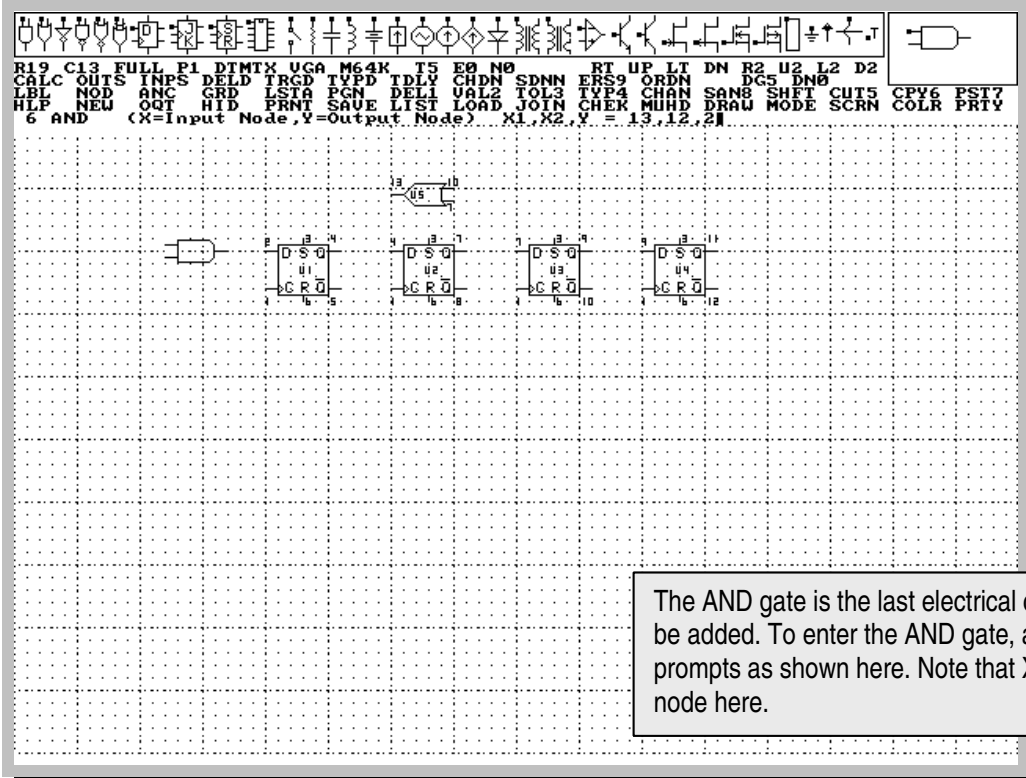
Figure 16 Entering the AND gate

The counter circuit is, electrically, complete.
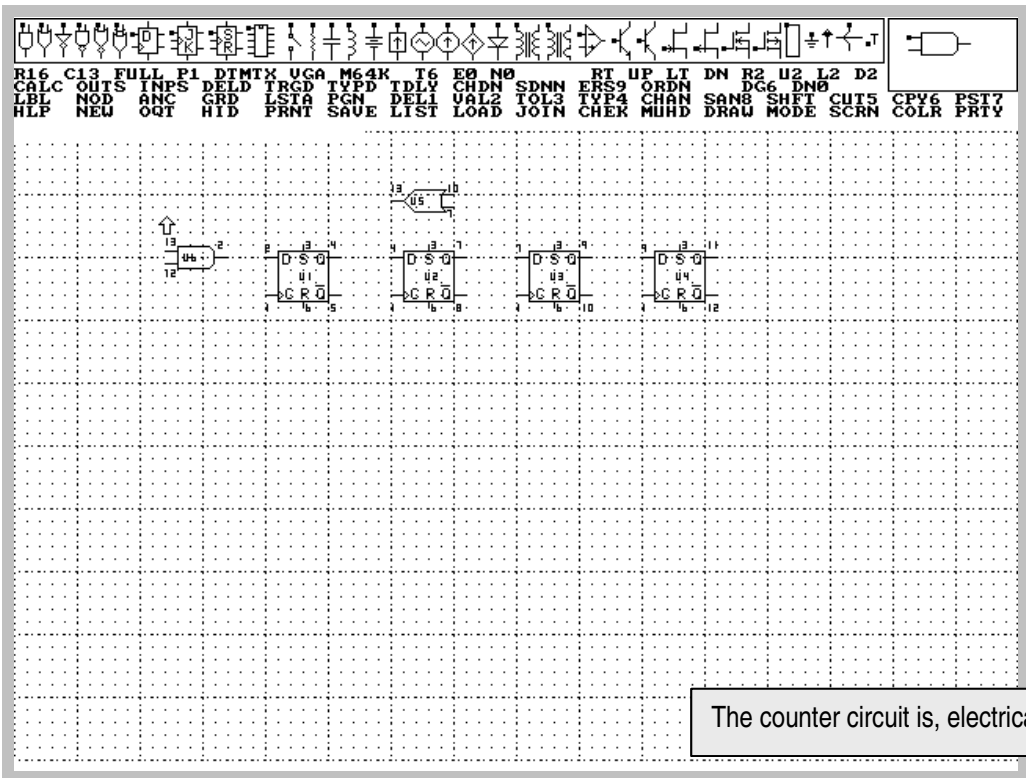
Figure 17 The Complete Counter

The schematic will look better if the flip flops were connected by actual lines. Select the line symbol (the square next to the ground symbol) and choose the LT orientation. The Line symbol will appear in the viewer as shown here. At this time, you should save the schematic. Click on SAVE, then select SAVE Schematic option, then enter COUNTER for the file name. If something goes wrong, you can always reload the schematic and continue.

Figure 18 Selecting the Line Tool

Before you connect the flip flops, practice with the line tool below the drawing. Click in the drawing area at the start of the line, then go to its end, and click again.
If the line is wrong, **Right** click on its anchor point to remove it. You can also use the CUT5 option to enclose the anchor point, and click to remove it. After you gain some confidence with the Line tool, go ahead and connect the flip flops, as shown here.

Figure 19 Connecting the Schematic together

Let us remove the Grid, now that we are done with drawing the schematic. Click on GRD and grid will disappear, as shown here.
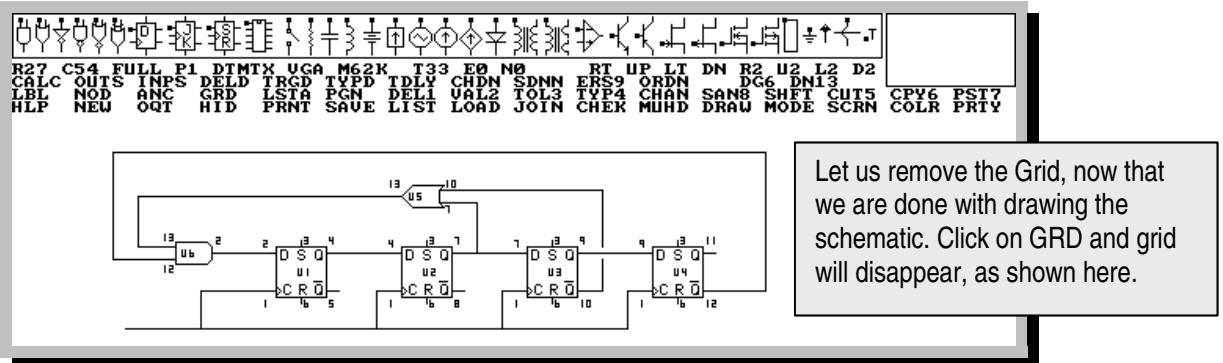
Figure 20 Removing the Grid

Open Digital Nodes: 0 5 8 11

Let us check the circuit. Click on CHEK. The program checks all the nodes, then lists the nodes that do not connect to other nodes. In this case, nodes 0,5,8,11. This is OK.
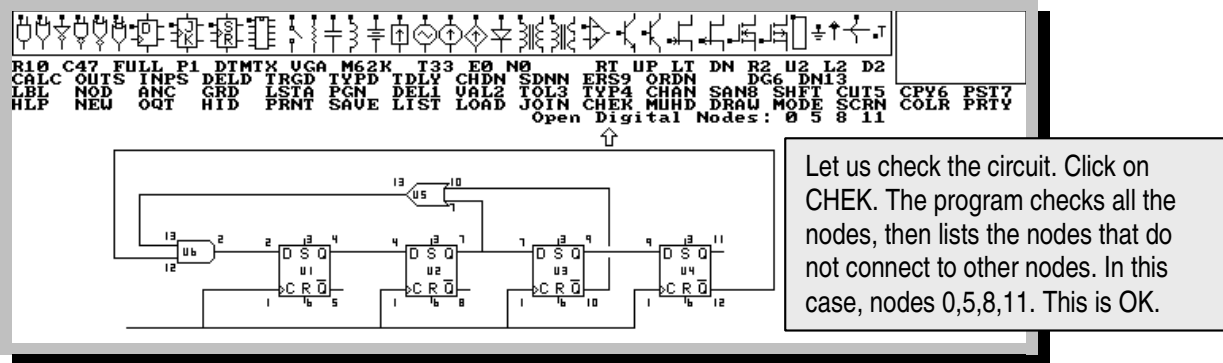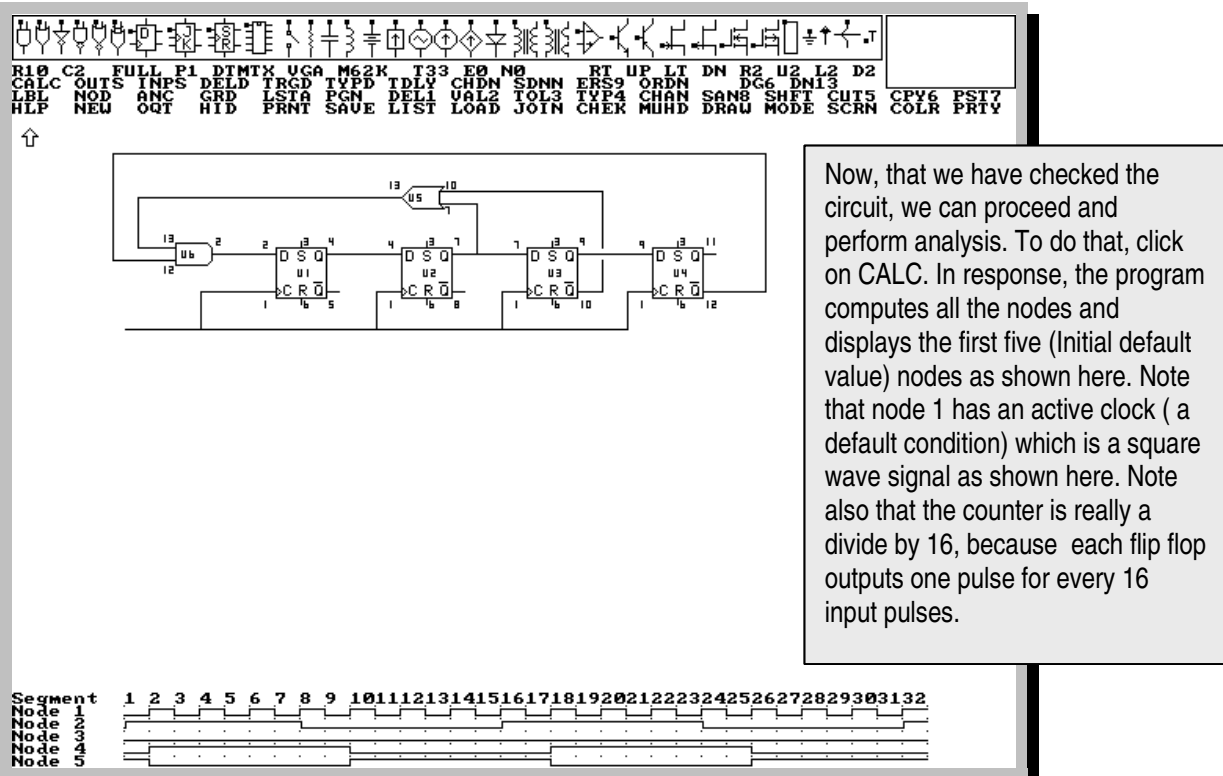
Figure 21 Performing a Circuit Check

Now, that we have checked the circuit, we can proceed and perform analysis. To do that, click on CALC. In response, the program computes all the nodes and displays the first five (Initial default value) nodes as shown here. Note that node 1 has an active clock (a default condition) which is a square wave signal as shown here. Note also that the counter is really a divide by 16, because each flip flop outputs one pulse for every 16 input pulses.

Figure 22 Initial Analysis

Let us examine the outputs at all 13 nodes. Click on OUTS. The menu shown here appears. Click on option 3=Outputs Number. The program requests the number of outputs as shown in figure 24.
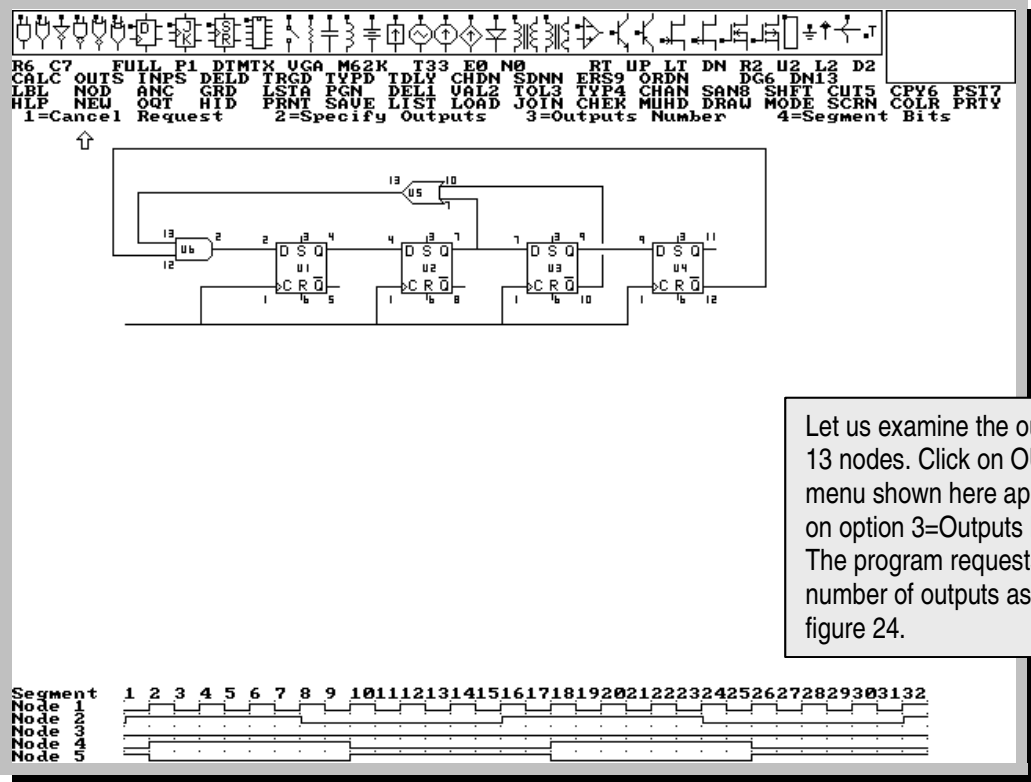
Figure 23 Using the OUTS option to increase the number of outputs to 13

Respond to the prompt by entering 13, as shown here.
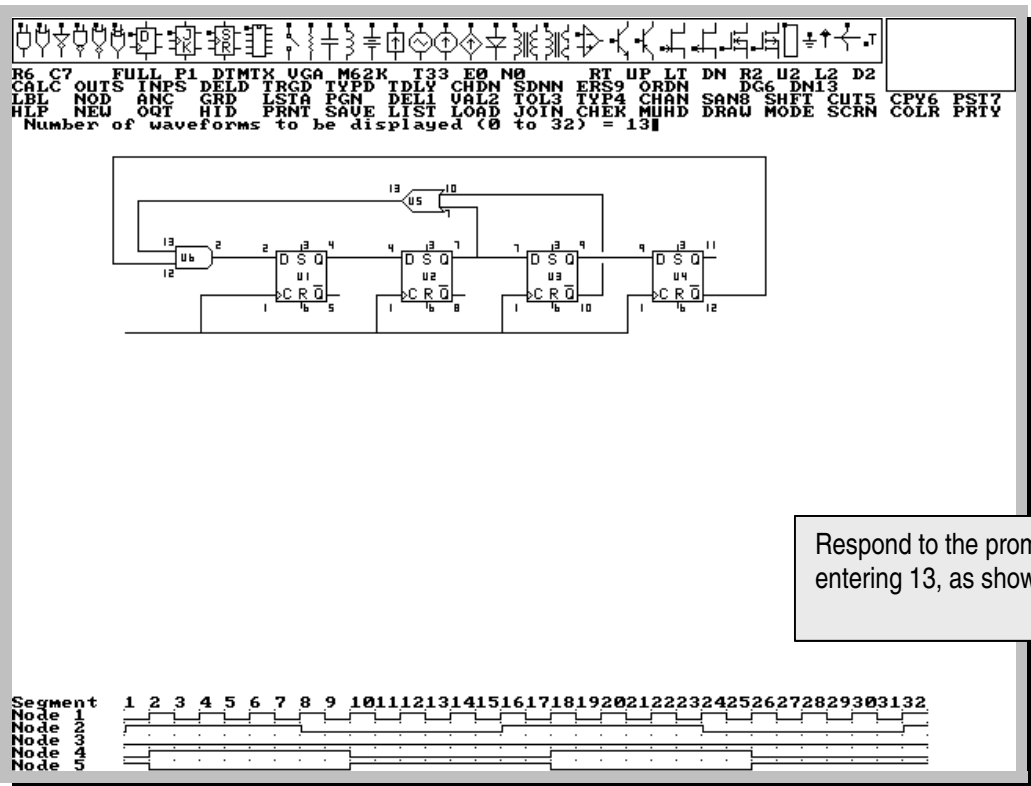
Figure 24 Requesting 13 outputs

Figure 25 Displaying the 13 Outputs
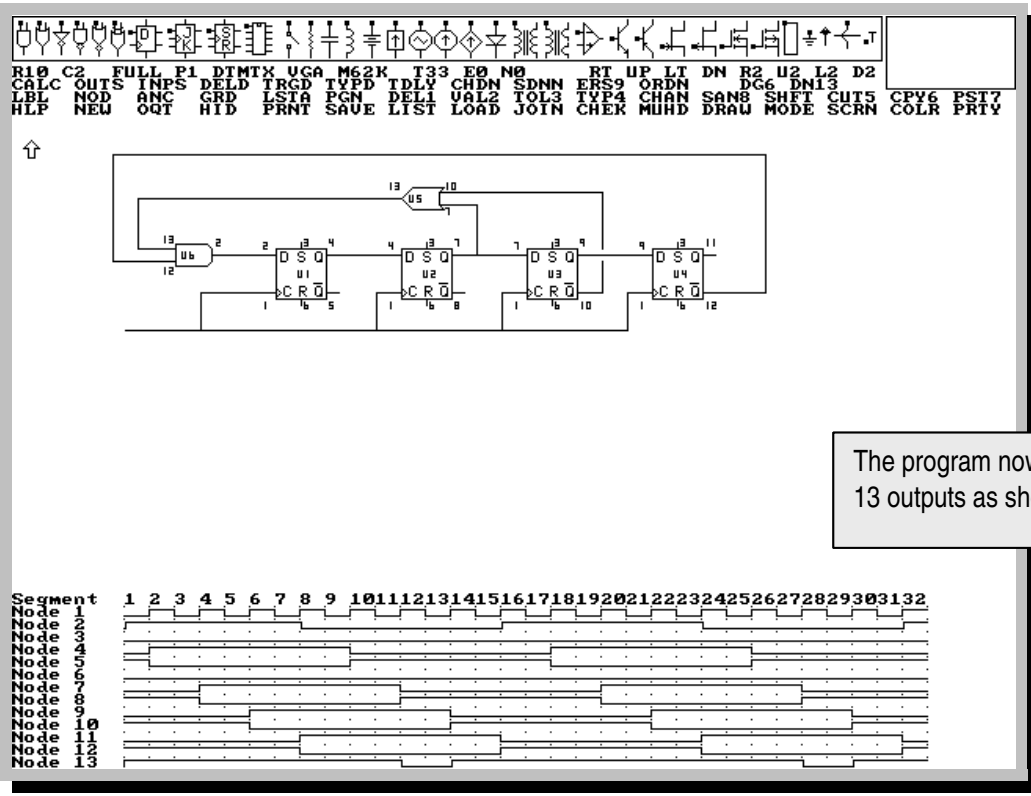
The program now displays all 13 outputs as shown here.
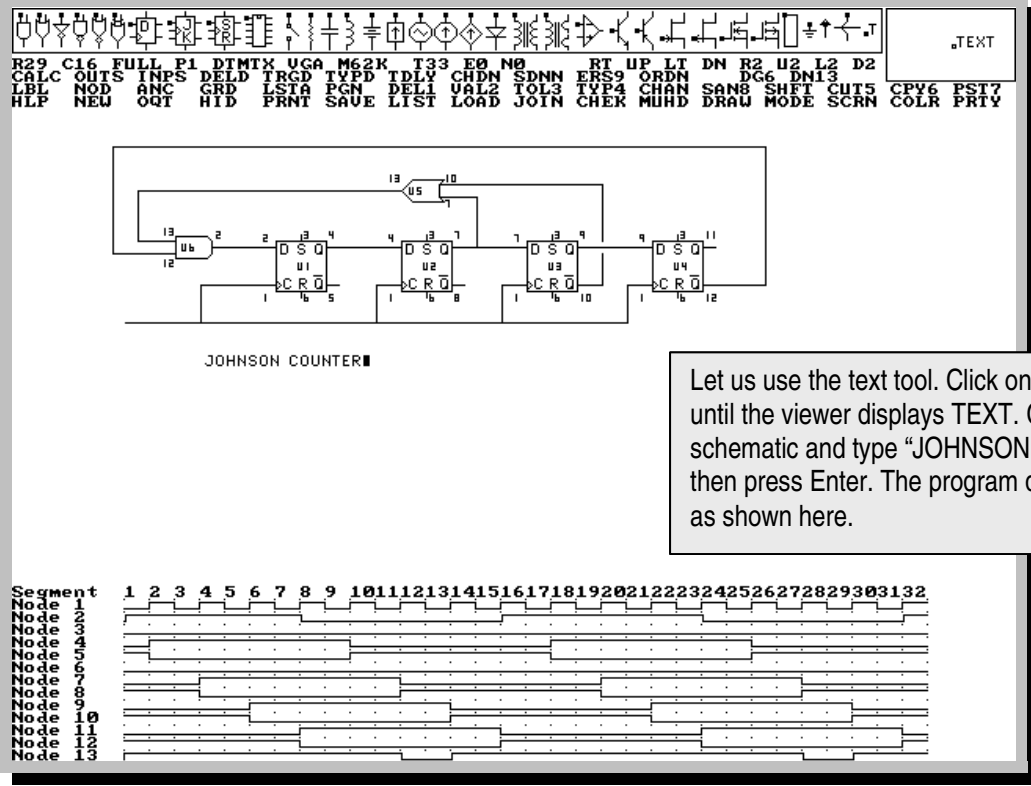
JOHNSON COUNTER

Let us use the text tool. Click on the T symbol until the viewer displays TEXT. Click below the schematic and type "JOHNSON COUNTER" then press Enter. The program displays the text as shown here.

Figure 26 Using the text Tool

Let us display the actual 1's and 0's (Micro Bits) in time segment 10. Click on OUTS. When the OUTS submenu appears, as shown here, select option 4=Segment Bits.
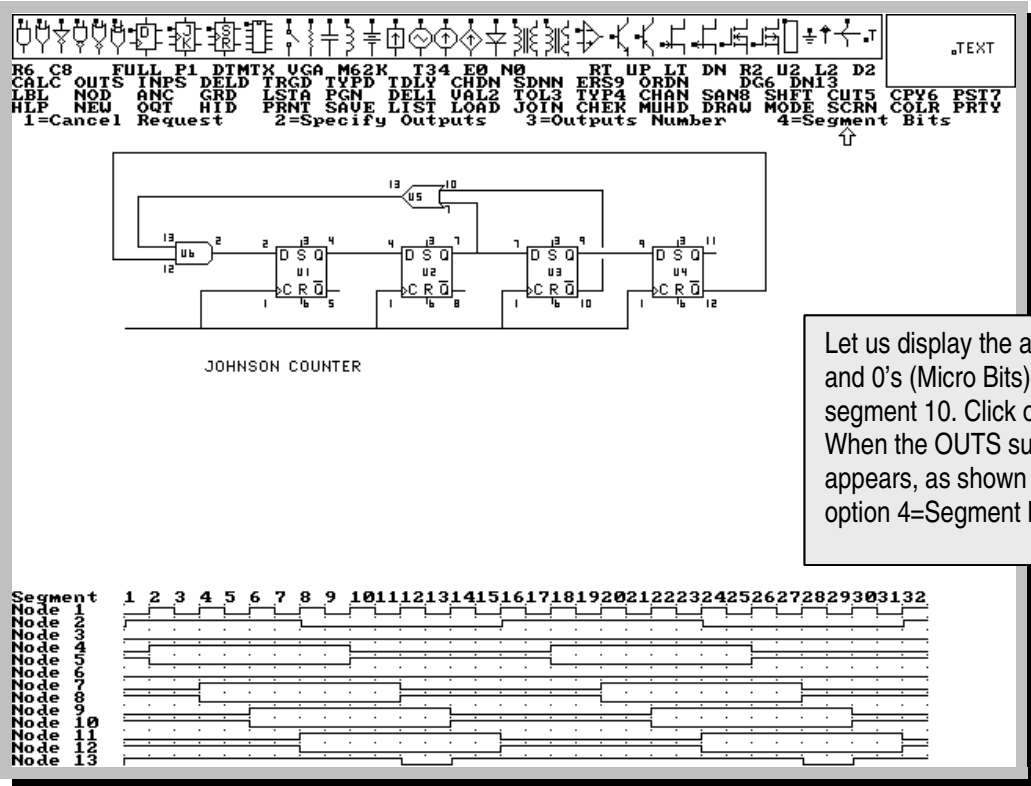
Figure 27 Requesting to view the 1's and 0's during time segment 10

To specify Time segment 10, enter 10 in response to the prompt, as shown here.
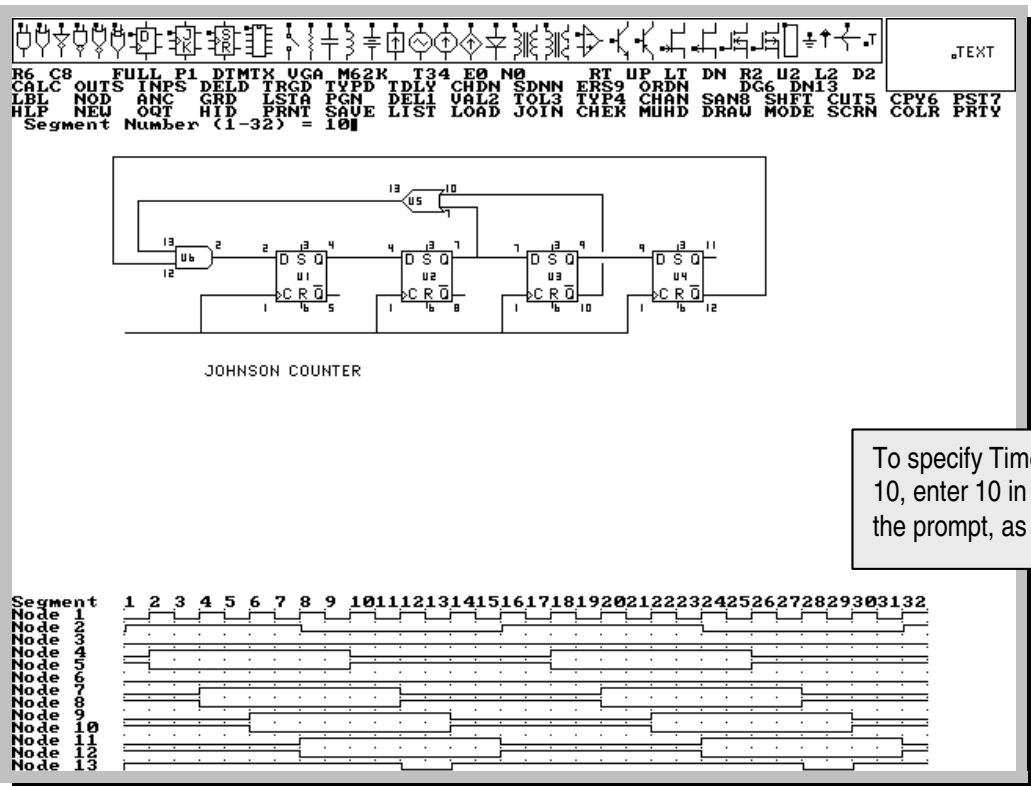
Figure 28 Specifying Time Segment 10

The program displays the Micro Bits (1's and 0's), for all 13 nodes, during time segment 10, as shown here. Note that the data was written on top of the schematic. To separate the schematic from the data, press the Left arrow key repeatedly until the schematic is separated from the Micro Bits, as shown next.
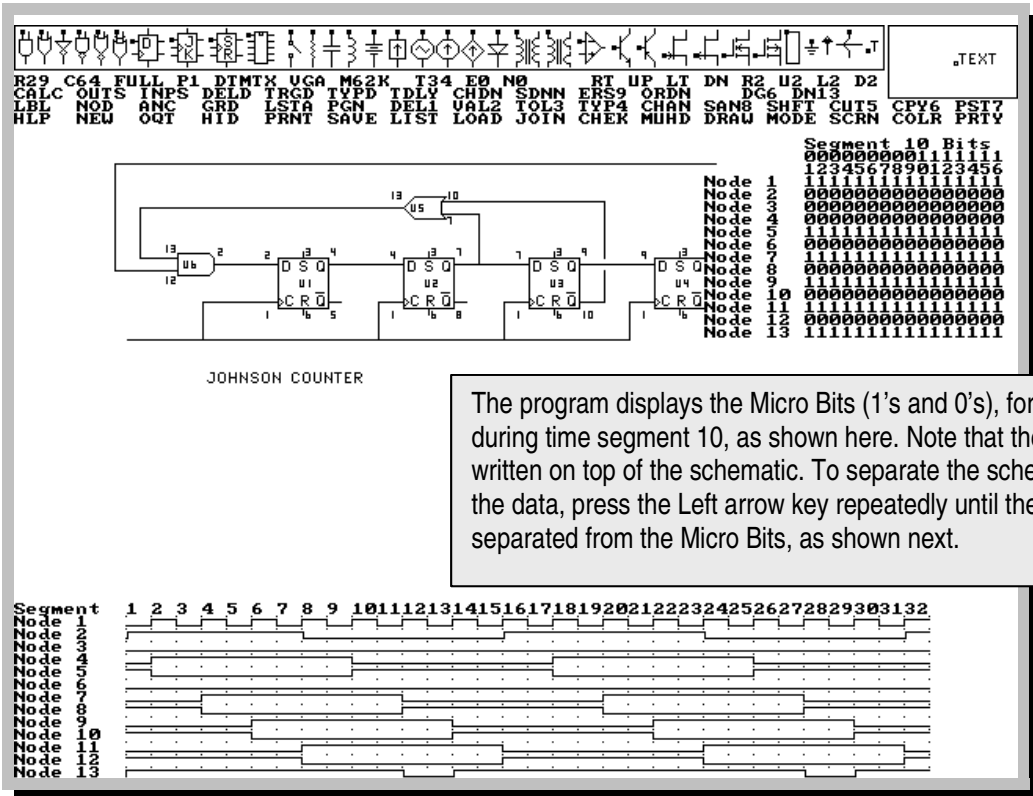
Figure 29 Displaying of the Micro Bits for time segment 10.

The Micro bits are now separated from the schematic.
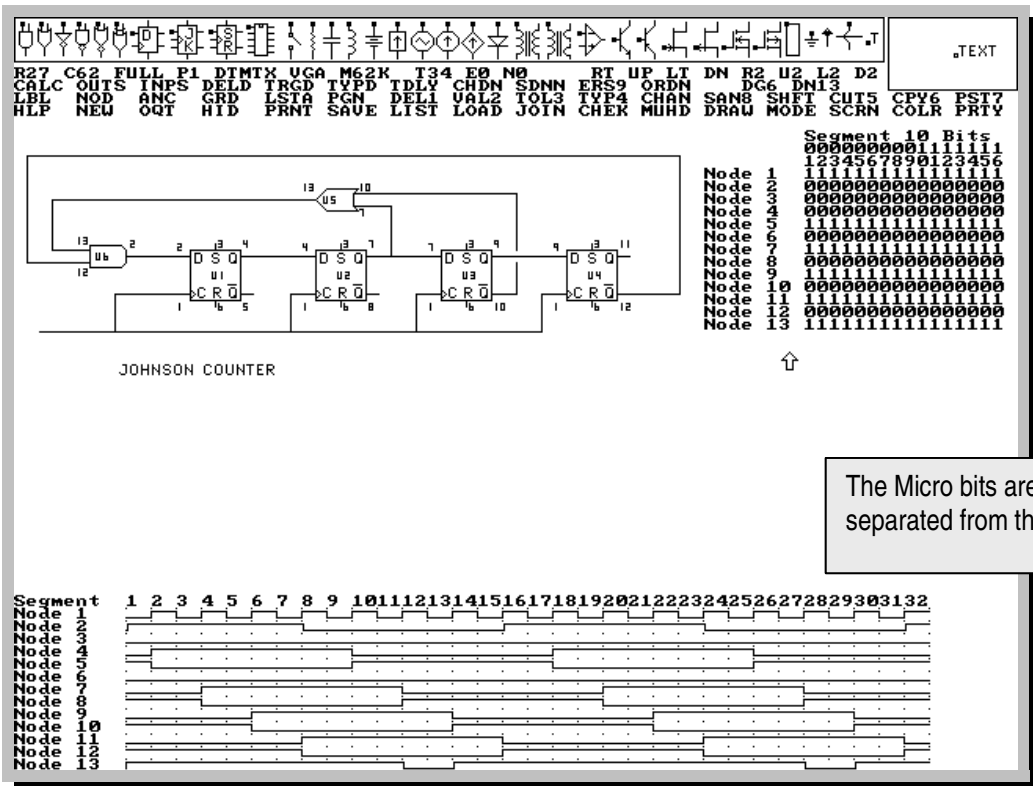
Figure 30 Separating the Micro Bits from the Schematic

Saving the schematic is very important. When you select SAVE, a submenu appears that allows you to save different things in the schematic. For now, select option 2=SaveSchematic.

Figure 31 The SAVE Submenu

To save the schematic, enter JOHNSON for the file name, as shown here.

Figure 32 Saving the Schematic

HOW ARE THE INPUT SIGNALS CODED ?

The input signal at each input node consists of 512 bits. To simplify the entry and edit of these bits, they are coded as 32 bytes (or segments or macro bits). Each byte (or segment or macro bit), consists of 16 micro bits of 1's and 0's. The total number of micro bits, in any input signal, is 32 x 16 = 512 bits. To illustrate this further, consider the following input signal.

```
Input bytes or segments:    1 0 1 0 1 0 1 0 1 0 1 0 1 0 1 0 ...…….. 0
                                | |                                   |
                   Byte 1 ___|  |___ Byte 2               Byte 32 _____|
```

The actual binary code of the input signal is as follows.

```
|---- Byte 1 -------|----- Byte 2 ------|......|----- Byte 32 -----|
|1111 1111 1111 1111 0000 0000 0000 0000 ...... 0000 0000 0000 0000|
 |___Bit 1                                              Bit 512 ___|
```

The program allows you to edit the micro bits of each byte that represents a "1". In the above example, since byte 1, or macro bit 1, is a "1", then its 16 micro bits can be edited. A macro bit of 0 has 16 zero micro bits that can not be edited. Each bit of the 16 bits can be set to either "1" or "0". Fot the input nodes, the default values of the 32 macro bits are 10101010…., and the default values of the 16 micro bits (for each macro bit of 1) are 1111 1111 1111 1111. Examples:

If the 32 macro bits are all 1's, and all 16 micro bits are 0's, then the total signal is all 0's.
If the 32 macro bits are all zeros, then the micro bits are ignored, and the total signal is all 0's.
If the 32 macro bits are all zeros except for bit 22, and the 16 micro bits are all zeros except for bit 7, then the total signal is all zeros except for bit 359 (=22x16+7) which will be 1.
If the 32 macro bits are all 1's, and all 16 micro bits are 1's, then the total signal is all 1's.

Next, let us modify the clock signal by cutting its frequency in half. Click on INPS, then select option 2=Set Input Bytes. Note that each byte, or Macro bit, is 16 micro bits long, which is equivalent to one time segment.

Figure 33 Modifying the Macro Bits of the Clock Signal at Node 1

The program requests the node number and the Macro Bits. Respond to the prompt as shown here. This changes the waveform, of the clock signal, from a square wave to a low duty factor, pulsed signal, as shown in figure 35. Press Escape to make the prompt disappear.

Figure 34 Modifying the Input Clock

When you click on CALC, the program calculates and displays all the counter waveforms as shown here. Note that the input frequency is cut in half.

Figure 35 Counter output when the frequency of the input clock is reduced by half.

Next, let us modify the clock signal. The program allows us to define the Micro Bits of any Input signal including the clock signal. We can only control the 16 Micro Bits of a signal during the time its macro bit is 1(High). For example, we can control the Micro Bits, of the input clock at node 1, during time segments 1, 3, 5, etc. because it is high. This will become clearer soon. Click on INPS, then select option 4=Define Micro Bits. When the prompt "Input Node, High Pulse 16 Micro Bits" appears, respond with 1,1100110011001100, then click CALC. The program displays all 13 outputs as shown.

Figure 36 Modifying the Micro bits of the Input Clock

Let us display the micro bits, of all 13 nodes, during time segment 7. Press OUTS, then enter 7 for the time segment. The program displays the micro bits, during time segment 7, as shown here.
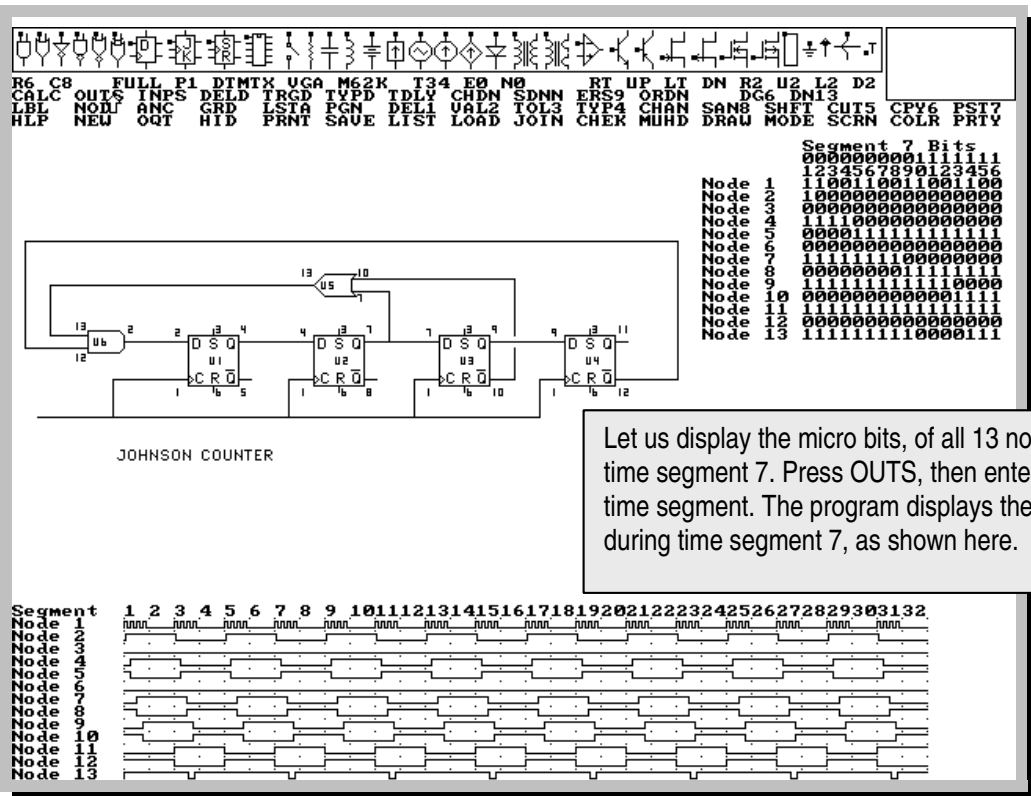
Figure 37 Response of the counter with a new Clock
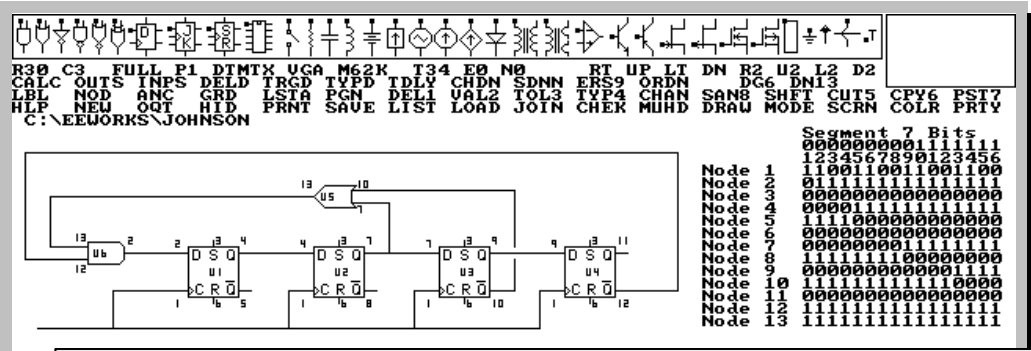
As another example, let us increase the clock frequency to that shown here. First click INPS, then select option "2=Set Input Bytes", then respond to "In Node, 32 Macro Bits (Esc = End) = " with 1,11111111111111111111111111111111. Next, click on INPS, then select option "4=Define Micro Bits". When the prompt "Input Node, High Pulse 16 Micro Bits" appears, respond with 1,1100110011001100, then click CALC. The program displays all 13 outputs as shown. Note that by setting the Macro bits and the micro bits, you can synthesize almost any digital waveform.
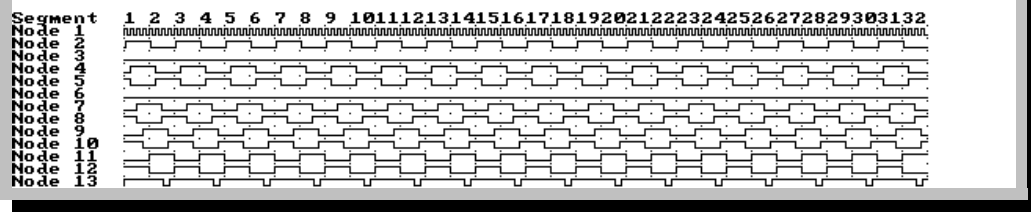
Figure 38 Response of the counter with a fast Clock
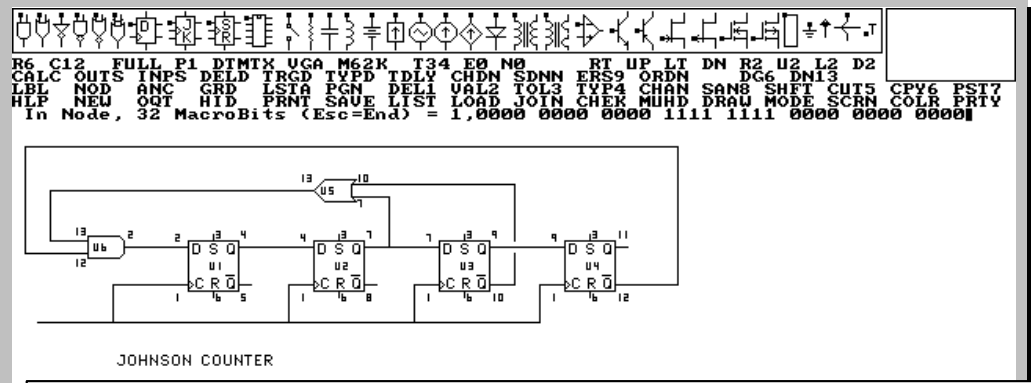
As another example, let us change the clock signal into a pulsed form. First click INPS, then select option "2=Set Input Bytes", then respond to "In Node, 32 Macro Bits (Esc = End) = " with 1,0000 0000 0000 1111 1111 0000 0000 0000, as shown here. Leave the micro bits as they are (1100 1100 1100 1100). Next, click on CALC.
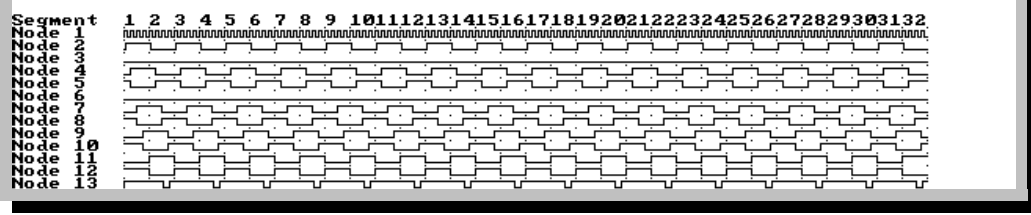
Figure 39 Changing the Input Clock to a pulsed form

The program displays all 13 outputs as shown. Note that by setting node 1 macro bits to 0000 0000 0000 1111 1111 0000 0000 0000, and the micro bits to 1100 1100 1100 1100, the clock signal becomes pulsed as shown here.
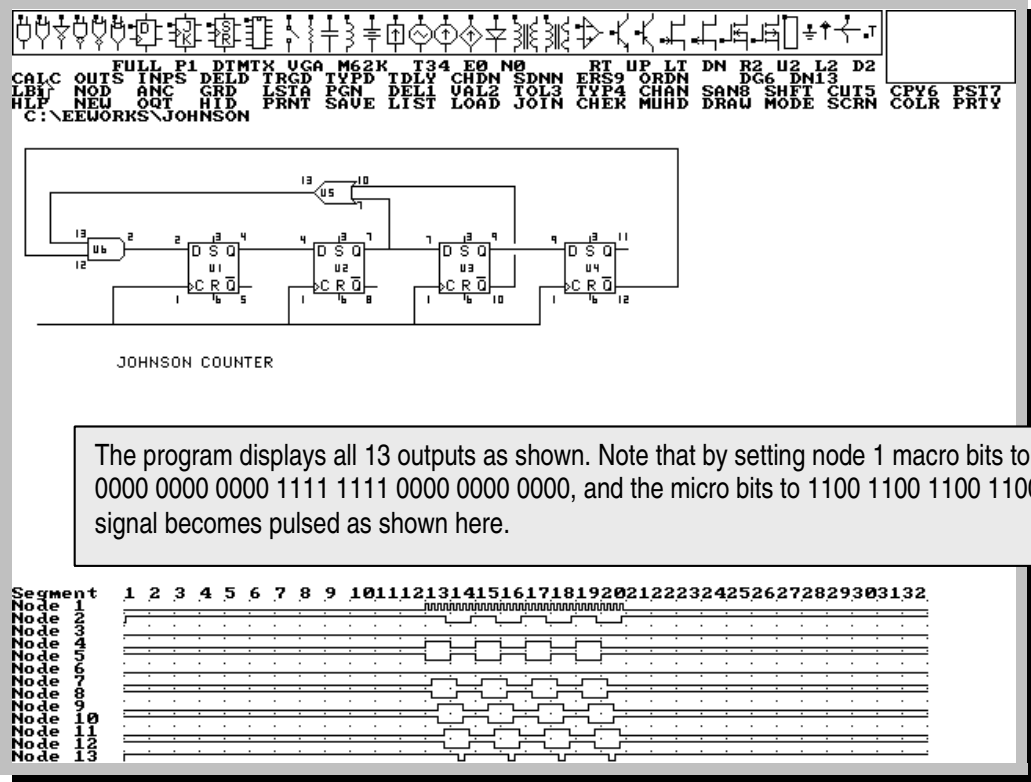
Figure 40 Response of the counter with a pulsed Clock

In this final example, use INPS to set the macro bits of node 1 to:
1100 0000 0000 0000 0000 0000 0000 0000. Leave the micro bits set to 1100 1100 1100 1100. When you click on CALC, the circuit waveforms will be as shown here.

Figure 41 Response of the counter to a short Clock

4   SINGLE ELEMENT OPERATIONS

4.1   ELEMENT PASTE/ERASE MODE

If one of the orientation options (LT, UP, L2, etc.) is red in color then the program is in the Element Paste/Erase mode. If none of the orientation options are red then the program is not in the Element Paste/Erase mode. When the Element Paste/Erase mode is active, elements can be pasted into the drawing area.

4.2   PASTING AN ELEMENT

The Paste mode is entered only after you select a symbol by clicking on it. If any of the orientation options in the viewer area are red then the program is in the Paste mode, and if none is red then the program is not in the Paste mode. Whenever an orientation is selected, the program displays it (LT, UP, RT, etc.) in red color. The Paste mode is deselected when other menu options (other than the Symbols or orientation) are selected.
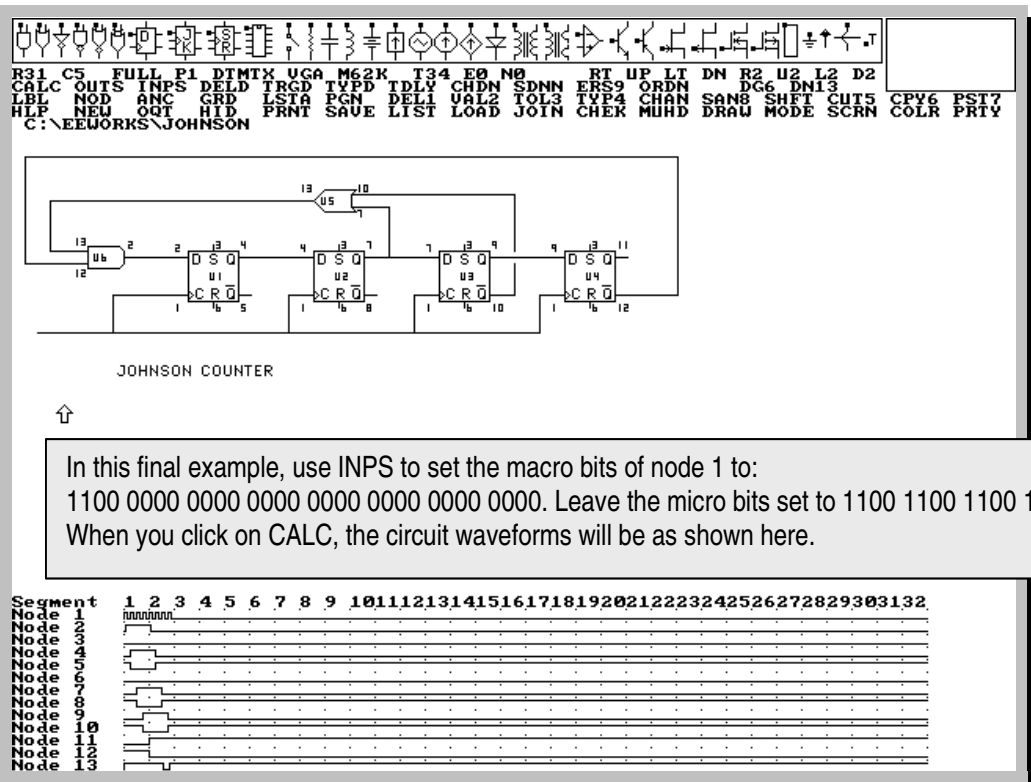
To paste an element into the drawing area, the following steps are necessary.

1. **Select Symbol**: click on the desired symbol in the Symbols area.
2. **Select Orientation**: click on one of the eight orientation options in the Viewer until you find the desired orientation. The selected orientation changes to the color red.
3. **Paste**: click at the desired position in the drawing area at which the element anchor point needs to be attached. The program computes the nearest grid point and attaches the anchor point to it.

4.3   ERASING AN ELEMENT

Elements can be erased by using the DELD for deleting digital components, DEL1 for deleting analog components, ERS9 for deleting any component (electrical or non-electrical), CUT command for removing a single or several electrical and non-electrical elements, or the mouse right button. The first three methods are discussed, in more detail, elsewhere in the manual. With ERS9, the program cycles through all the schematic elements (electrical and non-electrical), allowing you to delete any element. The right button approach is discussed below.

To erase an element using the right mouse button , the following steps are necessary.

1. **Select Symbol**: click in the symbols area at the symbol of the element to be deleted.
2. **Match Orientation**: click on one of the eight orientation options in the viewer until the orientation of the element in the viewer matches that of the element to be deleted from the drawing area.
3. **Erase**: click with the right button in the drawing area at the anchor point of the element to be deleted. The program computes the nearest grid point and removes the element whose anchor is connected to that grid point and matches the content of the Viewer.

4.4   ERASE ANY SCHEMATIC ELEMENT (ERS9)

The ERS9 option allows the user to view each schematic element and delete it if desired. The element can be electrical or non-electrical. When this option is selected, the program displays the following prompt:

Nxx   Element: SH xx Delete this element? (Y/N/Escape):

where Nxx is the total number of elements in the schematic Element: SH xx is the element being considered (in this case, SH stands for short). SH is the element type and xx is the element number which is different from the element label that appears on the screen. The program identifies the element being considered by drawing it in red color.

The program will delete the element if the <Y> key is pressed, or display the next element if the <N> key is pressed, or terminate the operation if the <Esc> key is pressed.

5   AREA OPERATIONS

5.1   THE CLIP-BOARD

The Clip-board is used for saving the elements of the Cut or Copy areas. The clipboard can store up to 300 elements. Any time a Cut or Copy operation is performed, the program automatically saves the elements of the Cut or Copy area into the clipboard.

5.2   COPY AREA

The process of copying an area is as follows.

1. Click on the Copy option. The following message appears.

    "Click the Upper Left Corner of the area to be copied with Left button"

2. When you click in the drawing area, the program places a marker on the that location, then displays the following message.

    "Click the Lower Right Corner of area to be copied with Left button"

3. Now click on the lower right corner of the area to be copied. The program encloses the selected area to be copied with a dotted rectangle, then saves the area to the clipboard.

The copy operation can be terminated at any time by pressing the <Esc> key. Note that to copy an area, it is only necessary to include the anchor points of the desired elements within the dotted rectangle.

5.3   CUT AREA

The process of deleting the elements in an area is as follows.

1. Click on the CUT option. The following message appears.

    "Click the Upper Left Corner of the area to be cut with Left button"

2. When you click in the drawing area, the program places a marker on the that location, then displays the following message.

    "Click the Lower Right Corner of the area to be cut with Left button"

3. Now click on the lower right corner of the area to be cut. The program encloses the selected area to be cut with a dotted rectangle, then saves it to the clip-board and erases it from the drawing area.

The cut operation can be terminated at any time by pressing the <Esc> key. Note that to cut an area, it is only necessary to include the anchor points of the desired elements within the dotted rectangle. The program renumbers the nodes and elements of the remaining circuit in numerical sequence. For example, if the circuit contains nodes 0 through 6 and the cut area contains nodes 3 and 4, then the node numbers are renumbered from 0 to 4. The same is true for the element numbers.

5.4   PASTE AREA

The process of pasting the contents of the clip board into the drawing area is as follows.

1. Click on the PST7 option. In response, the program displays a dotted rectangle in the drawing area. The size of this rectangle is equal to the area of the new schematic.

2. The program then displays the following message.

    "Use Arrow keys or Mouse to position new circuit. Click or Press <Enter> to paste."

3. Using the arrow keys on the keyboard or the mouse, move the rectangle to an empty area on the screen and press the <Enter> key, or click the left mouse button. A copy of the new schematic appears at that location.

The Paste operation can be terminated at any time by pressing the <Esc> key. After the paste operation, the program renumbers the newly added Elements and their nodes sequentially starting with the highest node number and element number of the original circuit. for example, if the nodes in the original circuit are numbered from 0 through 5, and the pasted circuit contains nodes 3 and 4, then the pasted circuit nodes are renumbered 6 and 7. The same is true for the element numbers.

5.5   SHIFT (MOVE) AREA

The process of moving an area is as follows.

1. Click on the SHIFT option. The following message appears.

    "Click the Upper Left Corner of the area to be moved with Left button"

2. When you click in the drawing area, the program places a marker on the that location, then displays the following message.

    "Click the Lower Right Corner of the area to moved with Left button"

3. Now click on the lower right corner of the area to be moved. The program encloses the selected area to be moved with a dotted rectangle, then displays the following message.

    "Use Arrow keys on keyboard to position the outlined area then press <Enter>"

4. Using the arrow keys on the keyboard, move the dotted rectangle to where you want then press <Enter>, or click at the location where the Upper Left corner of the selected area is to be placed. The program now moves the contents of the selected area to the new location.

The move operation can be terminated at any time by pressing the <Esc> key. Note that to move an area, it is only necessary to include the anchor points of the desired elements within the dotted rectangle. The program does not renumber the elements or nodes after the SHFT or Move operation. The resolution of the Move operation is half a grid.

5.6   JOIN (MERGE) SCHEMATIC

To merge an already saved circuit to the current circuit, the following steps are necessary.

1. 1Click on the JOIN option. In response, the program displays a prompt for the Drive\Directory then for the File name. If the displayed directory is correct then press the <Enter> key. Otherwise, type the new name directory over the displayed one. Second, if the displayed file name is correct then press <Enter>. Otherwise, type the new file name over the displayed name, then press <Enter>. There is no need to add the (.SKM) extension to the file name. The program will add it automatically. Note that the <Esc>, <Backspace>, and <Enter> keys are active.

2. After answering the two prompts, the program loads the selected file, then displays a dotted rectangle on the top left corner of the drawing screen. The size of this rectangle is equal to the area of the new schematic. The program then displays the following message.

    "Use Arrow keys to position new circuit then press <Enter> to paste."

3. Using the arrow keys on the keyboard, move the rectangle to an empty area on the screen and press the <Enter> key, or click the left mouse button at the location where the Upper Left corner of the rectangle is to be placed.. A copy of the new schematic appears at that location.

When a circuit is joined to another circuit, the node numbers and the element numbers are renumbered so that the node numbers are in numerical sequence. The merged elements and nodes are renumbered sequentially starting with the highest node number and element number of the original circuit. For example, if the nodes in the original circuit are numbered from 0 through 5, and the merge circuit contains nodes 3 and 4, then the merge circuit nodes are renumbered 6 and 7. The same is true for the element

numbers of the merge circuit.

6   LINE AND TEXT TOOLS

The line tool, which is displayed as a rectangle between the MOSFET symbol and Ground, enables us to connect the circuit elements together into a schematic. The line is not considered as an electrical short, and is never checked for node connections. In fact, the Circuit Analysis Programs totally ignore the lines in the circuit and rely only on the node parameters of the elements. Therefore, any lines drawn on the screen has no electrical significance what so ever.

The Line tool allows us to draw solid or dashed lines and rectangles. The orientation options in the viewer determine whether it is a line, rectangle, solid or dotted. To draw a line, click at the first point (upper left). The program displays a small cross at the clicked position. Next, click at the end point (lower right). The program then draws a line or rectangle from the first point to the end point. To erase the line immediately, click on the right mouse button.

The text tool is similar to the line tool in that it has no electrical significance what so ever. The text tool can be used to write notes on the schematic, label elements, etc. To place text on the screen, first select the text tool, and then click at the point where you want to place the text. When a cursor appears, type the text, and then press <Enter> to paste it on the screen. The <Esc>, <Backspace>, and <Enter> keys are active during text entry. To allow more precision, Text can also be placed at half grid points.

Lines, rectangles, and text are assigned anchor points. This means they can be copied, cut, and moved just like any other circuit element.

7   DIGITAL ANALYSIS (CALC, OUTS, INPS)

7.1   INPUT SIGNALS DESCRIPTION (INPS):

The input signal at each input node consists of 512 bits. To simplify the entry and edit of these input signals, they are coded as 32 bytes (or macro bits or segments). Each byte (or macro bit or segment) consists of 16 bits of 1's and 0's, called micro bits. The total number of bits is 32 x 16 = 512 bits. To illustrate this further, consider the following input signal.

```
Input bytes or segments:    1 0 1 0 1 0 1 0 1 0 1 0 1 0 1 0 ..... 0
                                |  |                                   |
                   Byte 1 ___|  |___ Byte 2              Byte 32 ___|
```

The actual binary code of the input signal is as follows.

```
|---- Byte 1 -------|----- Byte 2 ------|......|----- Byte 32 -----|
 1111 1111 1111 1111 0000 0000 0000 0000 ...... 0000 0000 0000 0000
 |                                                                 |
 |___ Bit 1                                      Bit 512 _____|
```

The program allows you to set the micro bits of each byte that represents a "1". In the above example,

since byte 2 is a "1", then its 16 bits can be edited. Each bit of the 16 bits can be set to either "1" or "0". The default values of the 16 bit micro code is 1111 1111 1111 1111. If the input signal has a byte of 0, then the 16 micro bits will be 0's and cannot be edited.

The input signals are defined and edited by using the INPS menu option. The INPS option displays the following menu.

   1=CancelRequest 2=SetInputBytes 3=EditInputBytes 4=DefineMicroBits

The Byte or segment or macro code of the input signal is defined by selecting option "2=SetInputBytes" which causes the following prompt to appear

   In Node, 32 MacroBits (Esc=End) =

You define the input by typing the input node number followed by the 32 bit representation of the 32 input bytes, i.e. 1,1010 1010 1010 1010 1010 1010 1010 1010. The spaces in the 32-bit code are optional. The prompt will re-appear until all the nodes have been checked, or the Escape key is pressed.

Option "3=EditInputBytes" displays the 32-bit input code at each node in the circuit. You can edit the code by typing over the displayed code. You can view all the input codes by repeatedly pressing enter. To exit this option press the Escape key. The default value of the input signals is 1010 1010 1010 1010 1010 1010 1010 1010

Option "4=DefineMicroBits" displays the 16 bits that represent a byte of "1" in the input signal. You can edit the bits by typing over them. You can view the micro-codes at other nodes by repeatedly pressing enter. To exit this option press the Escape key. The default value of the 16-bit micro- code is 1111 1111 1111 1111.

7.2   DIGITAL STATES CALCULATION PROCESS (CALC)

The program calculates the state of all nodes from t=1 to t=512. This is known as 512-bit processing. Prior to calculating the states of all nodes, the program re-numbers all the digital device numbers in a logical sequence. "Logical sequence" means that if the output of device A is connected to the input of device B, then the number A should be less than B. You should always use "yes" the first time. After re-numbering the digital devices, the program re-orders all the node numbers so that they are sequential (by executing the ORDN menu command), then uses the following procedure in initializing the nodes.

1- Set all node states to zero at t=0.
2- Set the states of the input nodes as specified by the default values or the user. The default values of all the input nodes are as follows. 1010 1010 1010 1010 1010 1010 1010 1010. The default micro bits that   correspond to each "1" in the input states is 1111 1111 1111 1111
3- Set the states of all grounded nodes (nodes labeled with 0) to zero.
4- Set the initial state of all flip flops to zero at t=0.

After the initialization is complete, the program calculates the state of each node from t=1 to t=512, starting with digital device No.1 and ending with the last device.

Note: You can manually change the digital device numbers by pressing the Comma key at the top menu. When the Comma key is pressed, the following prompt appears:

Change Digital Device Numbers (Swap): Present Number, New Number =

For example, to change digital device number 5 to 8, enter 5,8

7.3   OUTPUTS DISPLAY (OUTS)

The program displays the calculation results in the form of a Timing Diagram. The 512 bits at each node are represented by timing waveforms. The 32 time segments or bytes are clearly labeled on the screen. The 16 bits that represent each time segment can also be displayed on screen. The output display is controlled by the OUTS menu option, which displays the following menu.

1=CancelRequest 2=SpecifyOutputs 3=OutputsNumber 4=SegmentBits

Option "2=SpecifyOutputs" allows you to specify which nodes you want to view by answering the prompt "View Nodes (1,2,..)= ". Option "3=Outputs Number" causes the following prompt to appear.

Number of waveforms to be displayed (0 to 32) =

If you enter a number, say 12, then all the nodes from 1 to 12 will be displayed on screen. The last option "4=SegmentBits" allows you to view the 1's and 0's for the desired time segment.

8   DIGITAL ELEMENT EDIT (DELD, TRGD, TYPD, TDLY, CHDN, SDNN)

The program contains several commands for editing the digital elements or digital circuit. These commands are as follows. Keep in mind that the various entries must be separated by commas.

8.1   DELETE ELEMENT (DELD)

To delete a digital element, click the DELD option, then respond to the following prompt.

Enter Number of Digital Element to be Deleted: Element Number =

When you enter the element number followed by enter, the program will delete that element and re-number the remaining elements and nodes.

8.2   CHANGE TRIGGER TYPE (TRGD)

Flip flops can have any one of three trigger types. They can be triggered by a pulse or level, a positive edge, or a negative edge. To change the type of trigger of a flip flop, click on this option. The following prompt appears.

Enter Digital Element No. and New Trigger (0,+,-):Element#,Trig=

Simply enter the element number and the new trigger type followed by <enter> (i.e. 3, + <Enter>)

8.3   CHANGE TIME DELAY (TDLY)

The Propagation time delay (tpd) for all digital devices is set internally to a default value of 1 time step or 1/512. This menu option allows you to change the value of tpd to any value between 0 to 16/512. When this option is selected, the following prompt appears.

Enter Digital Element Number, New Delay (0 to 16): Element #,Delay=

To change tpd, enter the digital device number and the new delay followed by enter (i.e 3,2 <Enter>).

8.4   CHANGE DIGITAL DEVICE TYPE (TYPD)

Digital devices are grouped in the following five groups.

1. NOT, BUF
2. OR, NOR, AND, NAND, XOR, XNOR
3. QOR, QAND, QNOR, QNAND
4. DF, DFI
5. SRF, SRFI, JKF, JKFI

A digital device can be changed from one type to another within the same group. To change the device type, click on the TYPD option. The following prompt appears.

Enter Digital Element No. and New Type (OR,...):Element #,Type=

To change a device type, enter its number and new type followed by enters. i.e. 3,NOR <Enter>

8.5   CHANGE DEVICE NODES (CHDN)

To change the digital node numbers of a digital device, click on this option. The following menu appears.

Enter Digital Element Number, New Node Numbers: Element #,Nodes=

Respond to the prompt by entering the device number and its new node numbers followed by enter. Don't forget the comma separator.

8.6   CHANGE ANY DIGITAL NODE NUMBER (SDNN)

This option enables you to change any digital node number to another. When you click on this option, the following prompt appears.

UNCONDITIONAL NODE CHANGE: Present Node Number, New Node Number =

To change the node number, simply enter the old node number and new node number followed by <Enter>

9   ANALOG ELEMENT EDIT (DEL1, VAL2, TOL3, TYP4, CHAN, SAN8)

The program contains six options for quickly editing the analog elements and circuit. These options are discussed next. Remember that the various parameters must be separated by commas.

9.1   DELETE ELEMENT (DEL1)

To delete an analog element, click the DEL1 option, and then respond to the following prompt.

Enter Number of Analog Element to be Deleted: Element Number =

When you enter the element number followed by enter, the program will delete that element and re-number the remaining elements and nodes.

9.2   CHANGE VALUE (VAL2)

When you click on the VAL2 option, the following prompt appears.

Enter Analog Element Number and New Value: Element #, Valu =

To change the value of an R,L,C, etc element, enter the element number and its new value followed by enter (i.e. 3,15000 <Enter>).

9.3   CHANGE TOLERANCE (TOL3)

Click on this option to change the tolerance of an analog element. The following prompt appears.

Enter Analog Element Number and New Tolerance: Element #,Tol =

To change the tolerance of an analog element, enter the element number and its new percent tolerance followed by enter (i.e. 3,20 <Enter>).

9.4   CHANGE TYPE (TYP4)

This option allows you to change the type of analog within the group R, L, C, E, I, V, AC.

Enter Element Number and New Type (R,L,C,...): Element #,Type =

To change the element type, enter the element number then the new type (i. e. 3,R <Enter>)

9.5   CHANGE DEVICE NODES (CHAN)

To change the node numbers of an analog device, click on this option. The following menu appears.

Enter Analog Element Number, New Node Numbers: Element #,Nodes=

Respond to the prompt by entering the device number and its new node numbers followed by enter. Don't forget the comma separator.

9.6   CHANGE ANY ANALOG NODE NUMBER (SAN8)

This option enables you to change any analog node number to another. When you click on this option, the following prompt appears.

UNCONDITIONAL NODE CHANGE: Present Node Number, New Node Number =

To change the analog node number, simply enter the old node number and new node number followed by <Enter>

10   DIGITAL AND ANALOG CIRCUIT CHECKS (ORDN CHECK)

The program keeps track of the schematic by maintaining three different arrays. The first array, which is called the Schematic Array, is used for holding the complete analog/digital schematic, which includes both electrical and non-electrical elements. The second array, which is called the Analog Array, is used for the analog circuit elements only. The third array, which is called the Digital Array, is used for holding the digital circuit elements only. The contents of the first array is saved or loaded when a schematic save or load operation is requested. The analog and digital arrays are derived from the schematic array.

Any time you perform a calculation, the program extracts the analog and digital arrays from the schematic array. The commands CALC, ORDN and CHECK, in addition to generating the analog and digital arrays, they also re-order all the analog and digital nodes so that the node numbers are in numerical sequence and start with node 1.

The CHECK option goes further and examines the nodes of both the analog and digital circuits. Any node that does not connect to any other node is considered open or floating. The program then displays three different messages depending on the open nodes found. If no open nodes were found, then the message "No Open Digital Nodes" or "No Open Analog Nodes" is displayed. If the number of open nodes is less than 10, then the program will list the open nodes. If the open nodes are more than 10, then the program displays "Too Many Open Nodes".

If an open node is an input node, then you should define the signal at that node using the INPS option. If the open node is an output, then the program will calculate the state of that node. If the open node is neither an input or output node, then you should check the connection of that node. The program merely points out the nodes that are questionable. You can still perform calculations even if there are open nodes present.

11   PROGRAM MENUS

The program has 43 menu options that are continuously displayed on the screen. These menu options are described next. A menu option can be activated by clicking on the option with the left mouse button or by pressing the hot key associated with that option. The hot keys are shown in white color. Some of the menu options do not have hot key and can only be activated by the mouse. The main menu options are

displayed on screen as follows.

```
CAL OUT INP DEL TRGD TYPD TDLY CHDN SDNN ERS9 ORDN
LBL NOD ANC GRD LSTA PGN  DEL1 VAL2 TOL3 TYP4 CHAN SAN8 SHFT CUT5 CPY6 PST7
HLP NEW OQT HID PRNT SAVE LIST LOAD JOIN CHEK MUHD DRAW MODE SCRN COLR PRTY
```

Some of the menu options operate in toggle fashion. The first click turns the option on, while the second click turns the option off. The following options operate in toggle fashion: LBL, NOD, ANC, GRD, and LST. When activated, their color changes from green to red. These five menu options should be followed by the DRAW command. The <Esc> key is active throughout the menus that have prompts. When a prompt appears, pressing the <Esc> key terminates that operation. To indicate that an option is selected, the program changes the color of the menu option to red.

Option	*Function*
CALC	Calculates the 512 states of every digital node, then displays the results in a timing diagram. The calculation incorporates the input conditions specified in the INPS option, as well as, the outputs requirements specified in the OUTS option.
OUTS	Allows the user to specify the node numbers whose waveforms and micro bits will be displayed on screen. Upon selection, the following menu appears. 1=CancelRequest 2=SpecifyOutputs 3=OutputsNumber 4=SegmentBits The following prompts are used with options 2, 3, and 4. 2: Specify Nodes (1,2,..): 3: Number of waveforms to be displayed (0 to 32) = 4: Segment Number (1 to 32) =
INPS	Allows the user to define the input signals. The following menu appears. 1=CancelRequest 2=SetInputBytes 3=EditInputBytes 4=DefineMicroBits The following prompts are used with options 2, 3, and 4. 2: In Node, 32 MacroBits (Esc=End)= 3: In Node, 32 MacroBits (Esc=End)= 4: Input Node, High Pulse 16 Micro Bits =
DELD	This option allows you to delete any digital element. Once activated, the following prompt appears. *Enter Number of Digital Element to be Deleted: Element Number =* To delete a digital element, enter its number followed by <Enter>
TRGD	This option is used for the changing the type of trigger for the D, J-K, and S-R flip flops. Once activated, the following prompt appears. *Enter Digital Element No. and New Trigger(0,+,-):Element#,Trig=*

To change the trigger type, enter the flip flop number and its new trigger type followed by enter (i.e. 3,- <Enter>).

TYPD   Use this option to change the type of digital components. The digital components are grouped as follows.

1. NOT, BUF
2. OR, NOR, AND, NAND, XOR, XNOR
3. QOR, QAND, QNOR, QNAND
4. DF, DFI
5. SRF, SRFI, JKF, JKFI

A digital device can be changed from one type to another within the same group. To change the device type, click on the TYPD option. The following prompt appears.

Enter Digital Element No. and New Type (OR,...): Element #,Type=

To change a device type, enter its number and new type followed by enter.i.e. 3,NOR <Enter>

TDLY   The Propagation time delay (tpd) for all digital devices is set internally to a default value of 1 time step or 1/512. This menu option allows you to change the value of tpd to any value between 0 to 16/512. When this option is selected, the following prompt appears.

Enter Digital Element Number, New Delay (0 to 16): Element #,Delay=

To change tpd, enter the digital device number and the new delays followed by enter (i.e 3,2 <Enter>).

CHDN   This option is used for changing the nodes of any digital device.The program prompts the user for the element number and new nodes using the following prompt.

Enter Digital Element Number, New Node Numbers: Element #,Nodes=

SDNN   This option is used for changing any digital node number to another digital node number. The program prompts the user for the old node number and new node number using the following prompt.

UNCONDITIONAL NODE CHANGE: Present Node Number, New Node Number = ORDN

This option extracts the analog circuit and digital circuit elements from the schematic, then renumbers the digital nodes and analog nodes so that they are in numerical sequence starting with node 1.

ERS9   The program steps through each schematic element showing it in red color and allows the user to delete it if desired. The element can be electrical or non-electrical. The program displays this prompt as it cycles through every schematic element.

Nxx Element: SH xx Delete this element? (Y/N/Escape):

Press Y To delete the highlighted element, or press N to go to the next element. Press the

Escape key to terminate this option.

LBL	First click shows the element numbers and values, second click hides the element numbers and values.

NOD   First click shows the node numbers, second click hides them.

ANC   First click, shows the elements anchor points (tiny squares), second click hides them.

GRD   First click shows the grid points; second click hides the grids.

LST   First click shows a list of the elements, second click hides the list. Option PGN selects the page number to be displayed.

PGN   Selects and displays the next page from the elements list. Each page has 30 Elements. If the list consists of one page, then clicking this option will not do anything. The page number is displayed in the Status line as P1, P2, etc. This option works with the LST option.

DEL1   This option is used for deleting an analog element. The program prompts the user for the element number then erases the element from the schematic, and renumbers the elements and nodes. The following prompt is used.

Enter Number of Analog Element to be Deleted: Element Number =

VAL2   This option is used for changing the value of an analog element. The program prompts the user for the element number and its new value then replaces the old value with the new value. The element must be one of the following types: R, L, C, E, I, V, or AC. The following prompt is used:

Enter Analog Element Number and New Value: Element #,Valu =

TOL3   This option is used for changing the tolerance of an analog element. The program prompts the user for the element number and its new tolerance then replaces the old tolerance with the new tolerance. The following prompt is used.

Enter Analog Element Number and New Tolerance: Element #, Tol =

TYP4   This option is used for changing the type of an analog element. The program prompts the user for the element number and its new type, which can be R,L,C, E,I,V, or AC. The following prompt is used.

Enter Element Number and New Type (R,L,C,...): Element #,Type =

CHAN   This option is used for changing the nodes of an analog element. The program prompts the user for the element number and new nodes using the following prompt.

Enter Analog Element Number, New Node Numbers: Element #,Nodes=

SAN8   This option is used for changing any analog node number to another. The program prompts the user for the old node number and new node number using the following

prompt.

UNCONDITIONAL NODE CHANGE: Present Node Number, New Node Number =

SHFT   Moves the contents of a selected area to another location on the screen. The user is prompted to define the area by the following prompt

Click Upper Left Corner of the area to be MOVED with Left Button
Click Lower Right Corner of the area to be MOVED with Left Button

CUT5   Erases the contents of a selected area and saves a copy in the clipboard. The user is prompted to define the area by the following prompts.

Click Upper Left Corner of the area to be CUT with Left Button
Click Lower Right Corner of the area to be CUT with Left Button

CPY6   Copies the contents of a selected area into the clipboard.The user is prompted to define the area by the following prompts.

Click Upper Left Corner of the area to be COPIED with Left Button
Click Lower Right Corner of the area to be COPIED with Left Button

PST7   Pastes the contents of the clipboard into the drawing area. Use Arrow keys or Mouse to position Circuit. Press <Enter> or Click to Paste

HLP   Displays the help screen and gives the user the option to view the Schematic Draw manual, which is the DIGITAL.TXT file. This option has the following submenu:

<V>=View Manual   <P>=Print Manual   <R>=Register   <Esc>=Return

When the Registration Key option is selected, the following prompt appears:

Registration Key (12 characters, no Dashes) =

In response, the user should enter the Registration Key.

The HELP option displays an overview of the program features and capabilities, and allows the user to view and print the User's Manual from within the program. When this option is selected, the program initially displays an overview of the program then displays the following menu near the bottom of the screen.

Press <V> to View Manual, <P> to Print Manual, <Esc> to Return

When the <V> key is pressed, the program reads the first page of the manual file (.TXT) then displays the first page along with the following menu.

Active Keys: <PgUp> <PgDn> <Home> <Esc> Page n1 of n2

To quit viewing the manual, press the <Esc> key. To print the manual on your printer, press the <P> key. The program then displays the following message.

> Use Cut Sheet paper, Set printer to 12 CPI & Left Margin to 1 inch Press <Enter> to Print or <Esc> to Escape

> Again, to quit, press the <Esc> key.

NEW   Erases the schematic from memory and erases the drawing from the screen.

OQT HID   These two options act as Exits from the Digital Design Program. Either option will terminate the program.

PRNT   Prints the schematic, components, waveforms, or data on the selected printer as set by the PRTY option. Upon selection, the following prompt appears.

> *Laser (Ink/DotMtx) driver is in use. Press <Enter> to Print or <Esc> to Escape*

> If <enter> is pressed, then the following print menu appears.

> *1=Cancel 2=Schematic 3=Waveforms 4=Netlist 5=Data 6=All*

> The following prompt appears when option 5=Data is selected.

> *Enter Start Segment (0-31), End Segment (0,31): Start, End =*

SAVE   Prompts the user for the Drive\Directory name, then the File name. The <Esc>, <Backspace>, and <Enter> keys are active. If the displayed directory is correct then press the <Enter> key. Otherwise, type the new directory over the displayed one. Second, if the displayed file name is correct then press <Enter>. Otherwise, type the new file name over the displayed name, then press <Enter>. There is no need to add the (.SKM) extension to the file name. In Draw mode, the program saves the circuit schematic in .SKM file. In the Full mode, the program saves both the circuit schematic in .SKM file and the components list in .TXT file.

> In addition to saving the schematic, the SAVE option allows you to save the digital input signals and segments data. Once the Save option is selected, the following menu appears.

> *1=CancelSave 2=SaveSchematic 3=SaveAnalog 3=SaveDgInputs 4=SaveData*

> Option "3=SaveAnalog" allows you to save the analog portion of the schematic including line and text information. When option 4=SaveSgmntData is selected, the following prompt appears.

> *Enter Start Segment (0-31), End Segment (0,31): Start, End =*

LIST   First, the program displays the current drive and directory then prompts the user for the directory. If the displayed directory is correct, then press the <Enter> key. Otherwise, type the new drive and directory then press <Enter>. To escape, press the <Esc> key. Acceptable formats are A:\, B:\, C:\DIRECTORY, or D:\DIRECTORY. Second, the program asks for the file extension using the following Prompt.

> *FILE EXTENSION (* or UP TO THREE CHARACTERS)?*

If you press the <Enter> or <Esc>, or <*>+<Enter>, then the program will display up to 99 file names from that directory. If you want to display only the file names that have a specific file extension, then type the file extension and press <Enter>. The program then lists all the files that have that extension. For example, to list only the Schematic files, you need to enter SKM for the file extension. The File Extension prompt allows you to search for and list specific files very quickly.

Once the files are listed on the screen, the program allows you to select a schematic file from the listed files by using the mouse. The selected file name will appear as the File Name in the following File Load or File Save operations. For optimum performance of the LIST option, the number of files in your directory should not exceed 120 files.

LOAD   Prompts the user for the Drive\Directory name then the File name. The program clears the memory then loads the specified circuit schematic (.SKM) file. See Save option for entering file names. The load option displays the following menu.

1=CancelLoad 2=LoadSchematic 3=LoadDigitalInputs 4=ViewASCIfile

In addition to loading the schematic, the above load menu allows the user to load the previously saved digital inputs, or view any ASCII sequential file. When option 4=ViewASCIIfile is selected, the user is prompted to enter the file name as follows.

Enter the Complete Path and File Name (C:\PATH\NAME):

JOIN   The program prompts the user for the Drive\Directory and the File name then loads the new circuit schematic and adds it to the current circuit.

CHECK   Separates the analog and digital circuits from the schematic, then renumbers the analog and digital nodes in numerical sequence starting with node 1, then checks both the analog and digital nodes for any nodes that do not connect to other nodes (open or floating nodes). After the check, it displays any of the following messages "No open nodes", "Too many open nodes", or lists the open nodes.

MUHD   When this option is activated, the program hides the menus and leaves only the schematic on the screen. This is useful for printing the schematic using the <PrintScrn> key (this requires that the commands c:\dos\graphics and print/d:lpt1 be included in the Autoexec.bat file). To redisplay the menus, press the "U" key.

DRAW   Redraws the entire screen applying the mode of the first five options (LBL, NOD, ANC, GRD, and LST). Once activated, the following Draw menu appears.

1=Cancel 2=Schematic 3=Waveforms 4=Data 5=Draw All 6=None

You can redraw the schematic, waveforms, data, all, or none by selecting the proper option from above menu.

MODE   Selects Full or Draw mode. In Draw mode, prompts for the element parameters do not appear and Circuit Analysis cannot be performed on the resulting schematic. In Full mode, the program prompts the user for the element node numbers, value and tolerance. Circuits drawn and saved in the Full mode can be analyzed by the Circuit Analysis

Programs.

SCRN   Selects VGA (640x480) or EGA (640x350) screen display

COLR   Selects the background color of the screen. Eight colors are available.

PRTY   Selects the Laser or Ink/DotMtx printer

12   ELEMENTS ENTRY IN THE FULL MODE

In the FULL MODE, special care should be taken in entering the nodes of elements. Some users may incorrectly assume that the anchor node connects to node 1 always. In digital devices and some unpolarized elements such as resistors, capacitors and inductors, this is true. However. In most elements, the anchor point connects to the top left terminal of the element, which can be node, 1 or 2 depending on that element type. In some elements such as transistors, the anchor point connects to the base or gate terminal. In Op-amps, the anchor point connects to the inverting input terminal. Therefore, the user should activate the Show Anchor (ANC) option to see where the anchor node is located, then enter the nodes as shown next. Keep in mind that node entries must be comma separated. All digital elements have a programmable time delay with a default value of one unit delay.

The format used in entering the nodes of Digital elements is as follows.

AND, OR, NAND, NOR, XOR, XNOR Gates

        Prompt: (X=Input Node,Y=Output Node) X1,X2,Y =
        Node 1, Node 2, Node 3
        Anchor node= Node 1

NOT, BUF Gates

        Prompt: (X=Input Node,Y=Output Node) X,Y =
        Node 1, Node 2
        Anchor node= Node 1

QUAD INPUT GATES (QAND, QOR, QNAND, QNOR)

        Prompt: (X=Input Node,Y=Output Node) X1,X2,X3,X4,Y =
        Node 1, Node 2, Node 3, Node 4, Node 5
        Anchor node= Node 1

D FLIP FLOP (DF, DFI):

        Prompt: (Trig: 0 or + or -): D,Sd,Q,/Q,Rd,C,Trig =
        Node 1, Node 2, Node 3, Node 4, Node 5, Node 6, Trigger Type Anchor node= Node 1

J-K FLIP FLOP (JKF,JKFI)

        Prompt: (Trig=0 or + or -): J,Sd,Q,/Q,Rd,K,C,Trig =
        Node 1, Node 2, Node 3, Node 4, Node 5, Node 6, Node 7, Trigger Type Anchor node= Node 1

S-R FLIP FLOP (SRF,SRFI)

> Prompt: (Trig:0 or + or -): S,Sd,Q,/Q,Rd,R,C,Trig =
> Node 1, Node 2, Node 3, Node 4, Node 5, Node 6, Node 7, Trigger Type Anchor node= Node 1

The general format used in entering the electrical parameters of analog elements is as follows.

> Node 1, Node 2,...,Value, % Tolerance

The anchor node can be Node 1 or Node 2. The exact formats for the various elements, which are displayed on the screen of the Circuit Analysis Programs, are as follows.

RESISTOR (R)

> Prompt: a,c,Value(Ohm),%Tol =
> Node 1,Node 2, Value in Ohms, % Tolerance
> Anchor node =Top Left Terminal = Node 1

CAPACITOR (C)

> Prompt: a,c,Value(Far),%Tol =
> Node 1,Node 2, Value in Farads, % Tolerance
> Anchor node= Top Left Terminal = Node 1

INDUCTOR (L)

> Prompt: a,c,Value(Hen),%Tol
> Node 1,Node 2, Value in Henries, % Tolerance
> Anchor node= Top Left Terminal = Node 1

DIODE (D)

> Prompt: Anode,Cathode,%Tol =
> Anode node,Cathode node, % Tolerance
> Anchor node= Top Left terminal (can be Anode or Cathode node)

DC VOLTAGE SOURCE (E)

> Prompt: p,n,Value(Vdc),%Tol =
> Positive node, Negative node, Value in Volts, %Tolerance
> Anchor node= Top Left Terminal (can be positive or negative node)

AC VOLTAGE SOURCE (V)

> Prompt: a,c,Value(Adc),%Tol =
> Node 1,Node 2, Value in Volts, % Tolerance
> Anchor node= Node 1

DC CURRENT SOURCE (I)

Prompt: From-node,To-node,Value(Adc),%Tol =
positive from-node, negative to-node (where arrow points to), Value in Amps, %Tolerance
Anchor node= Top Left Terminal (can be positive or negative node)

AC CURRENT SOURCE (AC)

Prompt: From-node,To-node,Value(Aac),%Tol =
From-node, To-node (where arrow points to), Value in Amps AC, %Tolerance Anchor node=
Top Left Terminal (can be from-node or to-node)

DEPENDENT AC/DC CURRENT SOURCE (DI)

Prompt: From-node,To-node,p,n,K(gain) =
from-node, to-node (where arrow points), Positive Voltage node, Negative Voltage node, Gain
Factor K (=Amps/volts)
Anchor node= Top Left Terminal (can be from-node or to-node)

IDEAL TRANSFORMER

T, Primary node 1, Primary node 2, Secondary node 1, Secondary node 2, Turns Ratio
[=N(sec)/N(pri)] <Enter>
Example: T,1,2,3,4,0.1

MULTI-WINDING TRANSFORMER

M, Primary node 1, Primary node 2, Secondary1 node 1, Secondary1 node 2, Secondary2 node 1,
Secondary2 node 2, T(sec1)/T(primary),   T(sec2)/T(primary) <Enter>
Example: M,1,0,2,0,0,3,0.1,0.1

OPERATIONAL AMPLIFIER (A)

Prompt: p,n,o,%Tol =
Positive (non-inverting) node, Negative (Inverting) node, Output node, % Tolerance of
parameters
Anchor node= negative inverting node

NPN TRANSISTOR (N)

Prompt: e,b,c,%Tol =
Emitter node, Base node, Collector node, % Tolerance
Anchor node= Base Node

PNP TRANSISTOR (P)

Prompt: e,b,c,%Tol =
Emitter node, Base node, Collector node, % Tolerance
Anchor node= Base Node

N-CHANNEL JUNCTION FET TRANSISTOR (NJ)

Prompt: s,g,d,%Tol
Source node, Gate node, Drain node, % Tolerance
Anchor node= Gate Node

P-CHANNEL JUNCTION FET TRANSISTOR (PJ)

Prompt: s,g,d,%Tol
Source node, Gate node, Drain node, % Tolerance
Anchor node= Gate Node

N-CHANNEL MOSFET TRANSISTOR (NM)

Prompt: s,g,d,%Tol
Source node, Gate node, Drain node, % Tolerance
Anchor node= Gate Node

P-CHANNEL MOSFET TRANSISTOR (PM)

Prompt: s,g,d,%Tol
Source node, Gate node, Drain node, % Tolerance
Anchor node= Gate Node

13   FLIP FLOPS MODELS

The Flip Flops used in this program are general purpose flip flops commonly found in most Digital Data Books. The models used in this program fully represent the following flip flops.

Flip Flop	Type	Trigger	Direct Set/Reset
CD4013	DF	Positive Edge	Active High
SN7474	DFI	Positive Edge	Active Low (Inverted)
CD4027,CD4095/CD4096	JKF	Positive Edge	Active High
74129	JKFI	Positive Edge	Active Low (Inverted)
7472,7476,7478	JKFI	Pulse Level	Active Low (Inverted)
74112,74111	JKFI	Pulse Level	Active Low (Inverted)
74LS76A,74LS78A,74122,74126	JKFI	Negative Edge	Active Low (Inverted)
74128,74112,74114	JKFI	Negative Edge	Active Low (Inverted)
74L71	SRFI	Pulse Level	Active Low (Inverted)

The models can also simulate many other flip flops not listed above. For example, the SN74103 and SN74107 are negative edge JK flip flops with Clear only. The two flip flops can be easily simulated by using the JKFI model and setting the Direct Set input high. Also, the SN74113, which is a negative edge J-K flip flop with Preset only, can be simulated by using the JKFI model and setting the Direct Reset input High. Note that some books use the term "Preset" for Direct Set, and "Clear" for Direct Reset. TRUTH TABLES: Tr means that the proper Flip Flop trigger is present.

```
DF_____          DFI_____
Sd Rd CK  D   Q   /Q         Sd Rd CK  D   Q   /Q
H  H  X   X   H    H          L  L  X   X   H    H
H  L  X   X   H    L          L  H  X   X   H    L
```

```
L  H  X  X  L   H              H  L  X  X  L   H
L  L  Tr H  H   L              H  H  Tr H  H   L
L  L  Tr L  L   H              H  H  Tr L  L   H
L  L  L  X  Q  /Q              H  H  L  X  Q  /Q

JKF_____           JKFI_____
Sd Rd C  J K  Q  /Q            Sd Rd C  J K  Q  /Q
H  L  X  X X  H  L             L  H  X  X X  H  L
L  H  X  X X  L  H             H  L  X  X X  L  H
H  H  X  X X  L* L*            L  L  X  X X  H  H
L  L  Tr L L  Q  /Q            H  H  Tr L L  Q  /Q
L  L  Tr H L  H  L             H  H  Tr H L  H  L
L  L  Tr L H  L  H             H  H  Tr L H  L  H
L  L  Tr H H  /Q Q             H  H  Tr H H  /Q Q
L  L  L  X X  Q  /Q            H  H  L  X X  Q  /Q
*H H FOR CD4027

SRF_____           SRFI_____
Sd Rd C  S R  Q  /Q            Sd Rd C  S R  Q  /Q
H  L  X  X X  H  L             L  H  X  X X  H  L
L  H  X  X X  L  H             H  L  X  X X  L  H
H  H  X  X X  L  L             L  L  X  X X  H  H
L  L  Tr L L  Q  /Q            H  H  Tr L L  Q  /Q
L  L  Tr H L  H  L             H  H  Tr H L  H  L
L  L  Tr L H  L  H             H  H  Tr L H  L  H
L  L  Tr H H  Q  /Q            H  H  Tr H H  Q  /Q
L  L  L  X X  Q  /Q            H  H  L  X X  Q  /Q
```

14   LIST OF SYMBOLS

SYMBOL	RT	UP	LT	DN	R2	U2	L2	D2
AND/QAND	AND	AND	AND	AND	QAND	QAND	QAND	QAND
OR/QOR	OR	OR	OR	OR	QOR	QOR	QOR	QOR
NOT/BUF	NOT	NOT	NOT	NOT	BUF	BUF	BUF	BUF
NAND/QNAND	NAND	NAND	NAND	NAND	QNAND	QNAND	QNAND	QNAND
NOR/QNOR	NOR	NOR	NOR	NOR	QNOR	QNOR	QNOR	QNOR
XOR/XNOR	XOR	XOR	XOR	XOR	XNOR	XNOR	XNOR	XNOR
DF/DFI	DF	DF	DF	DF	DFI	DFI	DFI	DFI
JKF/JKFI	JKF	JKF	JKF	JKF	JKFI	JKFI	JKFI	JKFI
SRF/SRFI	SRF	SRF	SRF	SRF	SRFI	SRFI	SRFI	SRFI
DIP	DIP	DIP	DIP	DIP				
SWH 1Pos/2Pos	1POS	1POS	2TERM	2TERM	2POS	2POS	2POS	2POS
RESISTOR	R	R	HTR	HTR	R*	R*	HTR*	HTR*
CAPACITOR/POLARIZED	C	C	C*	C*	POLAR	POLAR	POLAR	POLAR
L(INDUCTOR/COUPLED)	L	L	L	L	COUPL	COUPL	COUPL	COUPL
E(DC VOLT)	E	E	E	E	E	E	E	E
I(DC CURRENT)	I	I	I	I	I	I	I	I
V(AC VOLT)	V	V	V*	V*	V*	V*	V*	V*
AC(AC CURRENT)	AC	AC	AC	AC	AC	AC	AC	AC
DI(DEPENDENT)	DI	DI	DI	DI	DI	DI	DI	DI
D(DIODE)	DIODE	DIODE	DIODE	DIODE	ZENER	ZENER	ZENER	ZENER
T(IDEAL TRANSF)	T	T	T	T	T*	T*	T*	T*

|								
M(COUPLED TRANSF)	M	M	M	M	M*	M*	M*	M*
A(OP-AMP)	A	A	A	A	A	A	A	A
N(NPN BIPOLAR)	N	N	N	N	N	N	N	N
P(PNP BIPOLAR)	P	P	P	P	P	P	P	P
NJ(N-CHAN JFET)	NJ	NJ	NJ	NJ	NJ	NJ	NJ	NJ
PJ(P-CHAN JFET)	PJ	PJ	PJ	PJ	PJ	PJ	PJ	PJ
NM(N-CHAN MOSFET)	NM	NM	NM	NM	NM	NM	NM	NM
PM(P-CHAN MOSFET)	PM	PM	PM	PM	PM	PM	PM	PM
LINE/RECTANGLE	REC	REC...	LINE	LINE...	REC2	REC3	LINE2	LINE3
GND/TERMINAL	GND	GND	GND	DIAM	TERM	TERM	TERM	TERM
ARROW	ARROW	ARROW	ARROW	ARROW	ARROW	ARROW	ARROW	ARROW
JUNCTION	JUNCTN	JUNCTN	JUNCTN	JUNCTN	JUNCTN	JUNCTN	JUNCTN	JUNCTN
TEXT	TEXT*	TEXT*	TEXT*	TEXT*	TEXT*	TEXT*	TEXT*	TEXT*
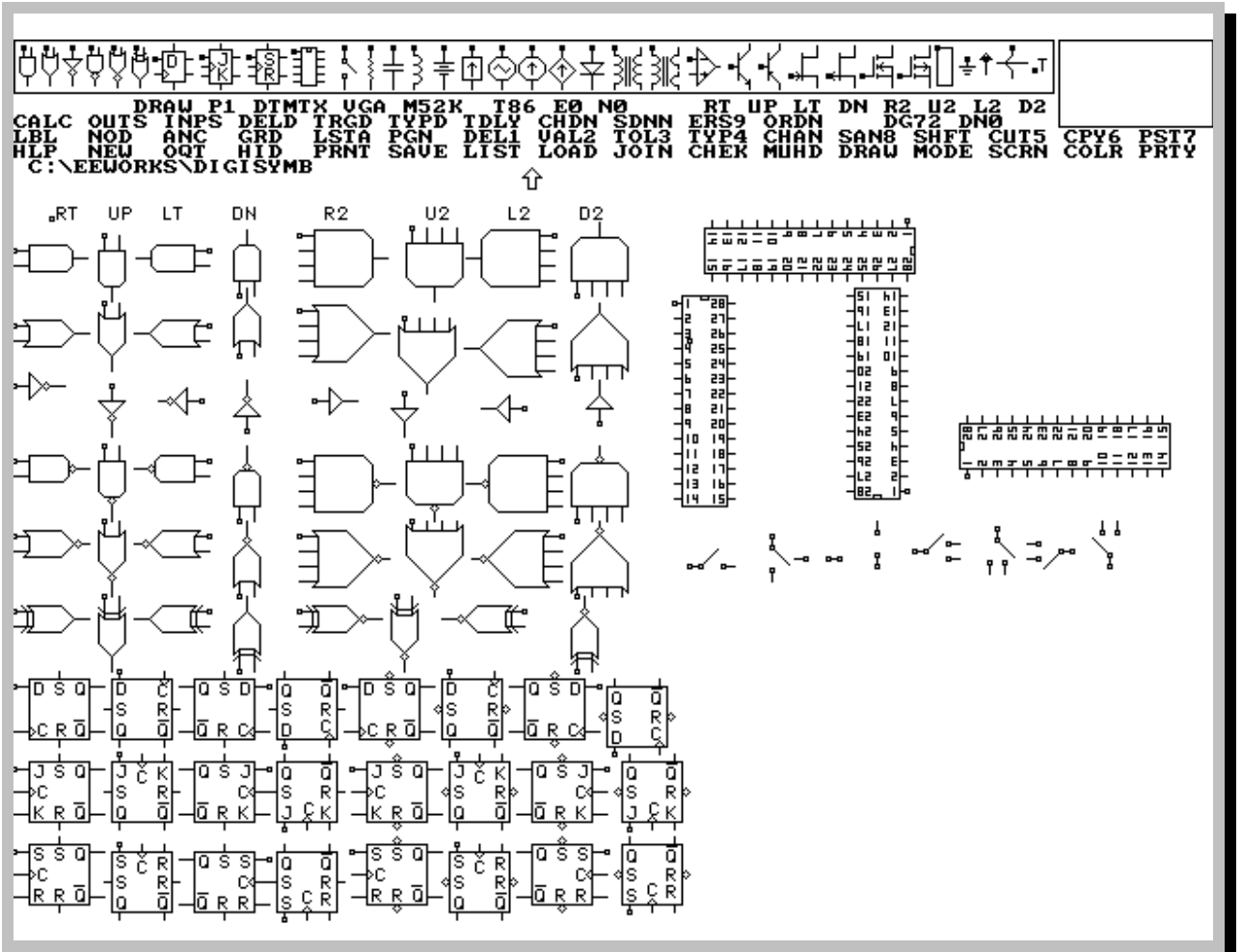
Figure 42 Digital Components Symbols
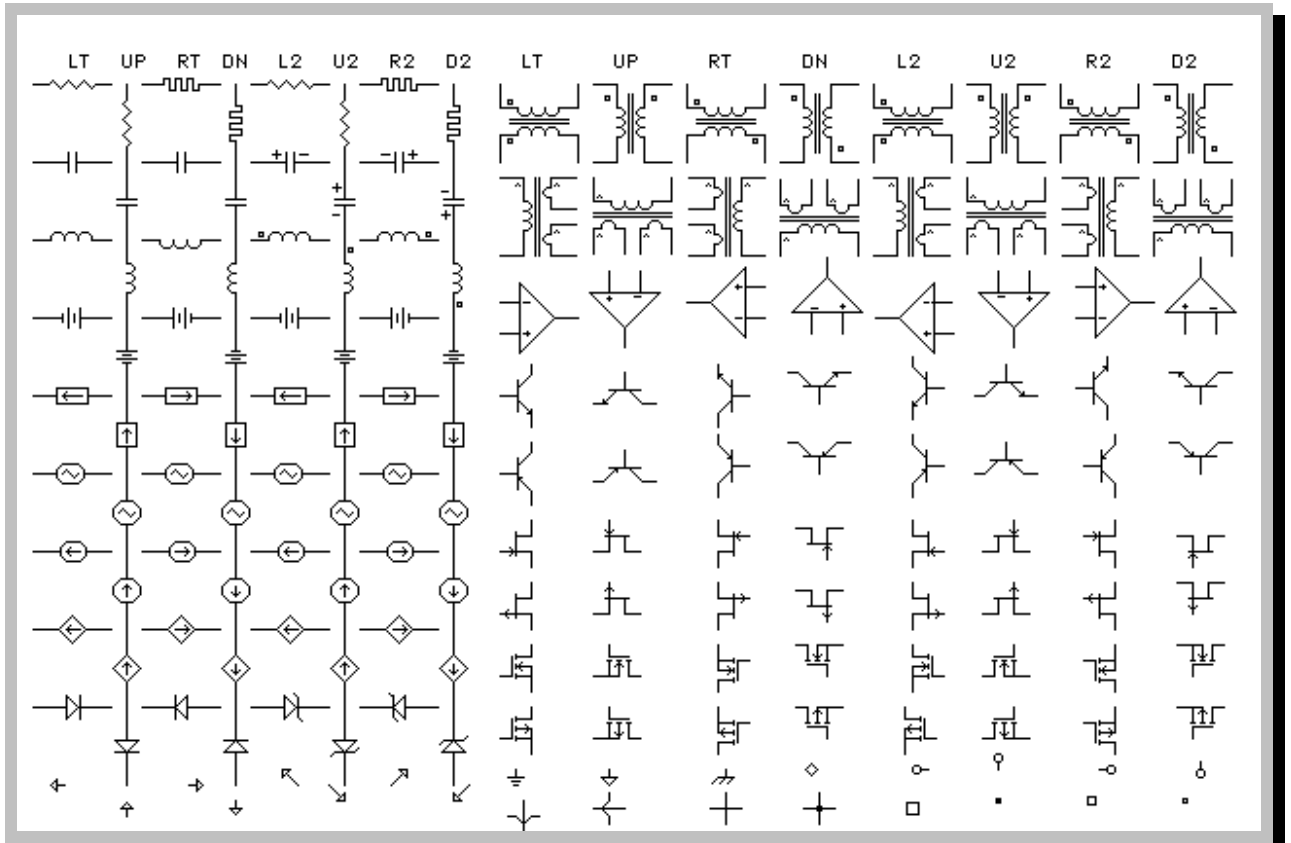
Figure 43 Analog Components Symbols