Project GF2: Software
Second Interim Report
Software Design Team 1

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1 System Overview

1.1 Logic Simulator

A logic simulation package has been developed, allowing a user to define a logic circuit using a specialised, custom designed definition language and to run this circuit in a simulation, observing the output at various points in the circuit. The circuit may be run for a number of cycles, selected by the user. The simulation may then be run for some further cycles, or restarted from scratch. There is also an option to run the circuit continually, observing the output in a scrolling fashion.

The user may interactively set the value of any switches defined in the specification value and observe the effect of this change in the circuit as it continues to run.

If the user decides they would like to observe the signal at a point previously un-monitored, they may add a new monitor to the circuit. To avoid too many monitors being displayed together and causing difficulty in reading the traces, a monitor may also be removed from the circuit.

The definition file is selected from a file select dialog, allowing multiple circuits to be tested during a single session.

The logic simulator provides helpful text output at the bottom of the screen to warn the user of errors and keep track of how many simulations have been run.

1.2 Software Structure

The software is structured across a number of files in the `src` directory. The main file is `logsim.cc`, which sets up the simulation package and calls the classes in the other files as required.

When a new file is loaded, it is scanned and parsed, using objects derived from the `scanner.cc` and `parser.cc` files respectively. If the parsing is successful (the definition file contains no errors), the circuit is created using classes in the `devices.cc`, `devicetable.cc`, `monitor.cc`, `names.cc` and `network.cc` classes. Each of these files defines a class of the same name to deal with a different part of the logic simulator. There is also a header file (`filename.h`) which contains class definitions; function prototypes; and variable and type definitions for each of the classes.

`devices.cc` deals with the creation of different devices in the circuit and the specification of these devices (e.g. the number of inputs), along with setting the values of switches and calculating the output of each device for a clock cycle of the circuit.

`devicetable.cc` defines a data type for associating the devices with more meaningful names, so that the devices may be more easily access.

`monitor.cc` deals with the monitors in the circuit: creation and removal of monitors, as well as giving the signal level of each monitor point at each clock cycle.

`names.cc` translates between the internal representation of each component through an `id` and the more user friendly name given to each device, monitor, switch or clock.

`network.cc` manages the network of devices and components by creating the device outputs as required and defining the connections between device outputs and inputs.

The final file required is `gui.cc`, which operates the user interface. This is created using wxWidgets, a cross platform gui toolkit. The `MyFrame` class creates the gui and handles user interaction events and the drawing of the traces. It can make modifications to the circuit as the user specifies using the graphical options.

The whole project follows the object oriented programming methodology. This means that the code is very modular, and that different classes are not dependant on the specifics of other classes. For example, a completely different interface could be developed and use the same back-end software. Equally, a different parser could be implemented and, provided all the features were implemented in some way or another, the whole system would be identical to anyone not looking inside the parser class.

This methodology is ideal for multi-programmer projects such as this as it allows independent development of different classes with no detailed knowledge of how the other programmers are designing and implementing the internals of the other classes.

2 Teamwork Overview

The teamwork was organised such that James would lead development of the scanner and lead testing of the parser. George would lead development of the parser and testing of the scanner. I was responsible for the gui programming.

This setup worked well for the first stage of the project, allowing each of us to become familiar with a different aspect of the program. A downside of this was that it was difficult to talk through design decisions with each other since our experience and growing expertise for the project lay in different areas. It is often very helpful to talk through the suggested design before implementing it as it both clarifies in your own mind as you explain it and often the other person will think about some unconsidered problem. However, since I know almost nothing about how the parser operates, and similarly George knows little about the GUI code, it is very hard to properly discuss what we are doing.

When the maintenance task was released, each of us took on one of the new tasks. This system worked well, each new task corresponded loosely to the original split of the system development.

3 Software Development

As the lead developer on the graphical user interface (gui), the majority of my software development has been associated with `gui.cc` and its header file. These define the classes used by wxWidgets to create the application user interface and handle the graphics used to draw the traces. The `MyGLCanvas` class is derived from the `wxGLCanvas` class, which creates an area to be drawn in using OpenGL. This class has undergone fairly minor changes from what was provided. The `MyFrame` class is derived from the `wxFrame` class. There is a slight difference between the terminology used in wxWidgets and general computer speak, in that usually a window refers to an area of the screen which displays the interface for a particular program or application and is controlled by the operating system's window manager. In wxWidgets, this is referred to as a frame, and a window may control the display in a part of the frame (for example the scrollable section containing the traces is a window in wxWidgets speak).

In order to add an element to the wxWidgets frame, the element must be defined in the `MyFrame` class constructor and given an `ID` which is defined in an `enum`. For the new element to perform a useful function when the user interacts with it, it must be linked to a call-back function using the event table.

3.1 MyFrame Development

The main task of developing the gui was to create a user interface to meet the specifications, while also being intuitive to use and aesthetically pleasing. One particular design decision I made early on was that because the program was to perform a fairly limited set of functions, these should all be immediately accessible to the user without a need for using the menu bar. Each function would therefore have a widget on the gui.

For the structure of the user interface, it was decided to have the window in a vertical orientation, with the user controls at the top, trace displays in the middle and a message box to give the user feedback and useful information at the bottom. This is reflected in the final design (see figure 1).

This design was achieved by using a vertical box sizer as the top level sizer for the display. The controls for each different function provided are grouped together into a single row on the interface. For example, the top row of controls contains buttons for selecting and loading a definition file from the computer filesystem. The bottom row provides options for adding and removing monitors to the trace options. This is implemented by creating a horizontal box sizer for each set of controls and placing this sizer into the top sizer. While this design works and is fairly intuitive, it is not particularly aesthetically pleasing. More detailed planning at the beginning of the project would have helped to create a nicer interface.

In order to set a switch value, it is necessary to select both the switch to be set and the value required to be set to. This is not a very neat way of setting a switch and does not provide a good metaphor for the actual process of switching. However this method was used as the software back-end provides no way of accessing the current value of the switch setting. It is thought that a function could be provided in the devices class to return the value of a given switch. Since the menu drop down method worked, it was decided to focus efforts on other areas before coming back to improve this.

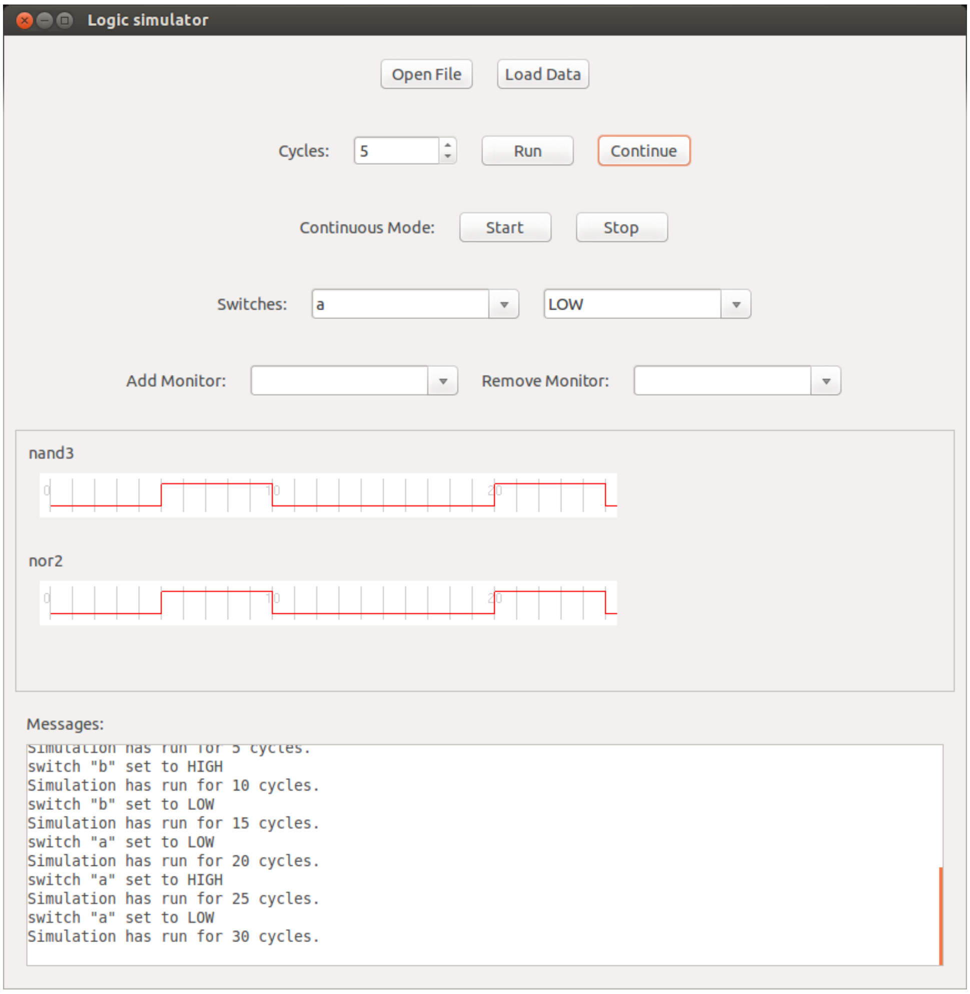

Figure 1: Screenshot of graphical user interface running under Ubuntu Unity.

There was initially some confusion over the specification for adding monitors in the user interface. Since monitors are defined in the specification file, I took "add the specified output signal to the current list of monitor points" to mean that there were two types of monitor: a displayed monitor and a hidden monitor. The add and remove monitor functions were therefore to change the state of a defined monitor from the hidden list to the displayed list and vice-versa. This method would require the user to define any points they would like to look at in the specification file, but not force them to display all of these points at once. I support this design method as it highly encourages the user to think fully about the circuit before stepping into the simulation, considering what might go wrong with their circuit and so which points may be useful to monitor *before* jumping into the simulation package. This would also allow the user to define a large number of possible monitor points (each given an obvious and intuitive name), but only select the relevant traces for viewing at a particular time, ensuring clarity of the traces which are shown. While I believe that my interpretation of the brief encouraged good design for these reasons, it came to light during the initial demonstration that the required functionality was to define a new monitor point and display it. During the final week of the project, the task of fixing this was assigned to another team member as there was a lot to be done for the gui and this task didn't require much experience with wxWidgets. At the time of writing, the functionality to add a new monitor point has been implemented, but the monitor points defined in the specification file has been lost. This should not be too hard to fix since the code previously did this well, however this has not been prioritised in the closing stages of the project.

The most difficult and time consuming part of the gui development was the display of the traces.

The standard method, and that in the supplied code, was to use a single GLCanvas to display all the traces, and allow the GL rendering code to format and display the appropriate traces. This design, however, doesn't create a consistent interface with the rest of the application and other applications as the OpenGL graphics look very different to the graphical elements defined by the wxWidgets toolkit. Since consistency is one of the primary elements of an intuitive and well designed gui, it was decided to use a method which simplified the OpenGL drawing and used wxWidgets for the organisation and display of multiple traces.

For a single trace, the required elements were a `wxStaticText` object to display the name of the trace, and a `MyGLCanvas` object to display the actual trace. These were to be grouped together in a horizontal sizer. To allow multiple of these traces to be displayed and flexibility of which monitor was displayed in which, `vector`s were used to contain each trace. The different traces (in the vectors) were then added to a vertical sizer to hold all the traces within a scrolling window. The different vector elements may be easily hidden and shown to ensure that only traces actually required are shown.

While this method works well and is highly flexible, there are a few issues. Primary among these is that the traces were not aligned with one another on the x-axis. This was overcome by putting the trace name above the trace, instead of to the left. Given more time, a better solution would be to use a grid sizer. This would allow the alignment of the traces, while simultaneously allowing arbitrarily long trace names. Grid sizers also allow easy hide and show functionality of single rows, so this could replace the current functionality of the vector of horizontal sizers. The vector of canvases would remain useful as this allows display of an arbitrary trace in each row, so the monitors may be reordered as required by the user.

This provides a good example of one of the major difficulties faced in the gui design. While it is always useful to come up with a detailed design of the system *before* beginning the implementation, I didn't know anything of how wxWidgets worked, what it could do and what its limitations were. It was therefore very difficult to come up with a good and meaningful design. As I've learned many of the wxWidgets ways of thinking and doing things over the course of the project, I now feel that I could come up with a far superior initial plan, and would plan to do the traces with a grid sizer (now that I know of its existence).

A particular challenge of the method I selected for displaying the traces was scrolling. After a large amount of trial, error and reading examples online, vertical scrolling was implemented using the `wxScrolledWindow` type. This allows the user to display more traces than can fit on the display at a time, and scroll among them. This was working well until two days before the hand in[1]. However, at the time of writing, this function seems to have been broken during the same commit as stopped the defined monitors from being displayed. This may or may not be fixed before the final hand in.

Horizontal scrolling of the window to display traces longer than the size of the frame has proved far more difficult. It is not clear why wxWidgets does not do this automatically as with the vertical scrolling. However, there do seem to be issues with the way sizers and canvases interact, and the sizers do not become aware of the size of the canvas as it changes. This seems to mean that the sizer always thinks the canvas can fit on the screen and no scrollbar is required for the horizontal direction. Much investigation has been carried out in this to no avail, it seems that scrolling and OpenGL canvases just don't play well together. To fix this, manual scrolling could be implemented, however this would need some fairly serious time investment which was not possible at this stage of the project.

The message box at the bottom of the gui is a more successful story than the trace displays. This is implemented using a read only, multiline `wxTextCtrl`. Along with the `wxStreamToTextRedirector`, this allows messages to be printed to the gui instead of to stdout. One particular challenge in this was displaying the error messages properly. The error messages are formatted to display a carat (`^`) under the symbol which is causing the error. However, by default the `wxTextCtrl` uses a variable width font. This caused the carat to be displayed in the wrong place. This was overcome by changing the font to a fixed width font. Font selection turned out to be a non-trivial problem, however the documentation of `wxFont` eventually led to a working solution.

[1] as seen in the code run by Tim Love 04/06/2013.

3.2 MyGLCanvas Development

Far less modification was required to the given `MyGLCanvas` class, however a few modifications were made.

The `Render` method of the class was modified. While the original `Render` function was to display all the traces, the modified version should display only a single monitor trace. It is therefore called with two arguments, one which selects the monitor to be displayed in that particular canvas, and the other to set the number of cycles to be displayed.

X-ticks have also been added to mark the clock transitions, and every tenth transition is marked with a number to display the number of cycles up to that point.

The functions to control mouse interaction or display particular text on the canvas have been disabled/removed.

There is a major bug in the rendering of the traces which has not yet been resolved. It was found that often the trace is not displayed properly, and despite the correct `y` values been shown in the text output, the trace is not drawn in the correct place. It appears that for some, yet unknown, reason, the trace attempts to be redrawn after display but without the correct trace being shown. It has been found that if the line `Render();` in function `MyGLCanvas::OnPaint` (line 185 in `gui.cc`) is removed, the display works correctly. However, this line is required for redrawing the traces when the window is resized. The cause behind this has not yet been established, so currently there is a decision to be made between showing wrong traces and not redrawing the traces when the window is resized. Changing the inclusion of this line verifies that both aspects of the program work, just unfortuantely not at the same time!

3.3 Continuous Display Mode

The maintenance phase of the development required the addition of a continuous display mode, where the display scrolls in the manner of an oscilloscope type trace.

In order to implement this, new versions of the `MyFrame::runnetwork` and `MyFrame::Render` methods were created. Each would increment the displayed trace by 1 and display only the previous 10 traces.

In order to continuously update the display, pressing the "Start" button begins a `wxTimer`, which may be stopped by pressing "Stop". Every period (currently set to 500ms), the timer calls an event. The event table then calls a callback function which calls the updated `runnetwork` and `Render` functions to update the display.

A screenshot of this functionality is shown in figure 2.

4 Test Procedures

For the gui, the only meaningful testing method was user testing. To this end, I tested each feature as I implemented it, along with other features which could have been broken by the new one. I also ensured James and George were using the gui whenever possible so that they could find bugs and issues that I may have missed.

Testing in the final stages showed many features to not work as required. Some of these, like the monitor additions, had previously worked, but stopped working when later features were added. The causes of these have not been fully investigated at the time of writing. Other problems, such as horizontal scrolling, have not been fully implemented so testing of these was not possible.

5 Known Bugs

I have outlined most of the known bugs relating the graphical user interface as I have detailed the design and development. These all apply at the time of writing but this does not guarantee that they will not be fixed by the time of the hand in. This section is much longer and the bugs far more serious than I'd like.

1. The defined monitors from the specification file do not appear in the monitors to add list as they should. This worked until the option to add monitors at any point in the circuit was implemented by another team member.

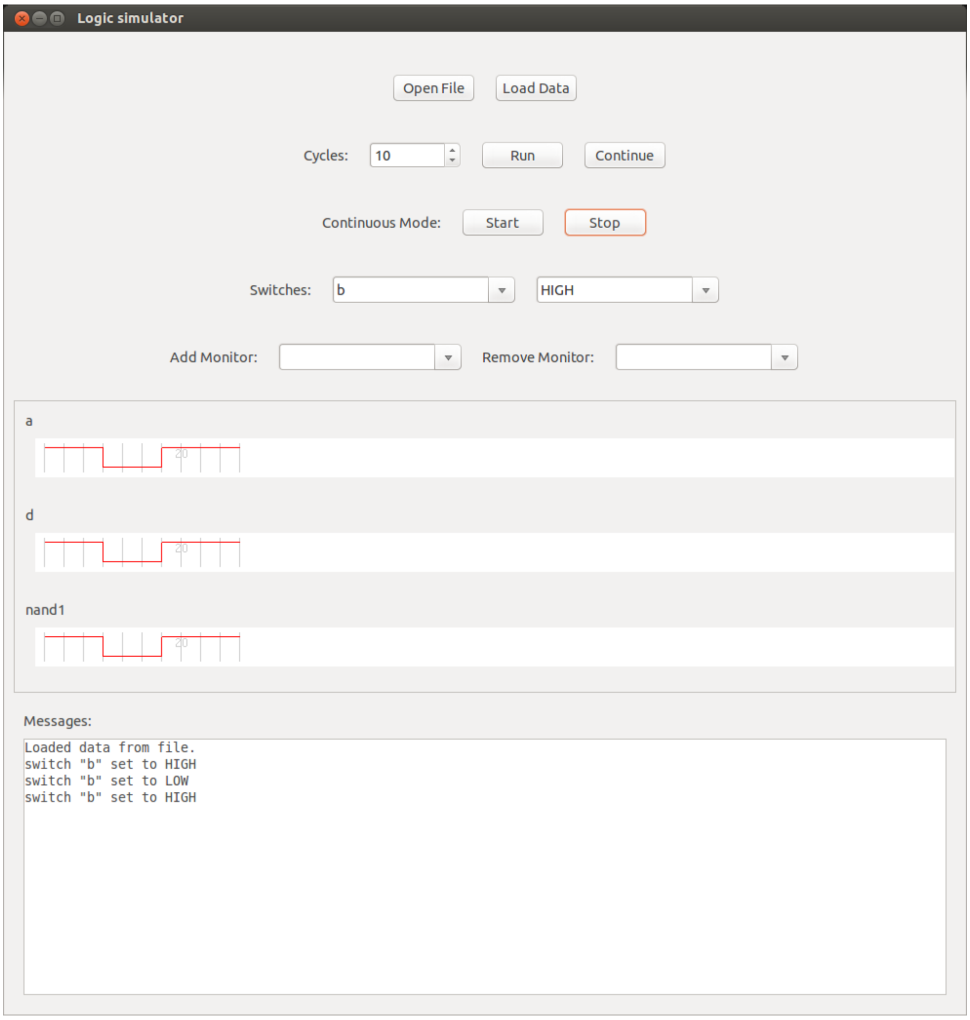

Figure 2: Screenshot showing continuous mode operation

2. There are several issues with the scrolling window. It does not scroll horizontally due to issues with wx sizers and GL canvases. Vertical scrolling has also broken, at the same time as the monitor fault occurred.

3. It does not seem to be possible to allow resizing of the trace window at the same time as actually showing valid traces in the cavases, due to an issue with the `onPaint` function.

4. Sometimes the traces just aren't drawn as they should be. This is under investigation alongside the previous issue.

6 Conclusions and Further Work

Only a partially operating logic simulation system has been delivered, and this would be unacceptable for a product release. One of the major causes of this was a lack of proper planning at the beginning of the project. Developers' lack of familiarity with the whole system also cost us highly when all working on bug fixes in the closing stages.

I do think that the project was on a good trajectory until the final week of the project, but there was too much left to do with insufficient time at the end.

Given further development time, which would be necessary to deliver a usable product, the following should be completed:

1. Develop a more intuitive method for setting switch values. This should provide a better metaphor for switching than the current system. This will require some gui modifications, but also back-end development to allow access to the current state of a switch.
2. The issues highlighted with the monitor points must be addressed. This would require investigating the changes to the relevant parts of the system in the last commit to break the software. The Git version control system that has been used throughout the project would make this fairly straightforward, but time has not been adequate to do this.
3. The method of displaying the traces in the scrolled window should be rewritten to make use of the more suitable grid sizer class. This would allow arbitrarily long names while ensuring correct alignment of the trace drawings.
4. The issues surrounding the scrolling problems should be thoroughly investigated and a solution found. This may involve a large increase in complexity of the user defined scrolling features instead of having wxWidgets take care of the scrolling.
5. The reason for the trace displays showing either the wrong trace or not resizing should also be thoroughly investigated and a solution found.
6. Further develop the continuous display mode to allow selection of both the speed and number of past cycles that are displayed.

So far, neither students or demonstrators have found an adaquate solution to the scrolling or trace display/resizing issues.

As a project, this has been challenging but enjoyable. It has been very useful to gain experience of writing user interface software as this is a very different ball game to any programming I had previously done. While this has been a steep learning curve (clearly too steep for me to deliver a working product in the time allowed), the skills have already come in useful for my other project and probably will continue to be useful in the future.

It has also been good to gain experience of programming in a team on a larger project than I had previously done. It is in this setting that the advantages of object oriented programming, version control systems and other concepts from the 3F6 course have become apparent.

A Software Listings

Please see attached Interim Report for code listings. The updated versions are available in our shared team code repository, or online at `https://github.com/JamesGlanville/GF2/tree/master/src`

B Example Circuits

B.1 Logic Gate Array

The first example test file defines a logic gate array. The circuit diagram is shown in figure 3. This circuit is defined for the logic simulator using the following definition file:

```
{
DEVICES
{
  A = SW(0);
  B = SW(1);
  C = SW(0);
  D = SW(1);
  NAND1 = NAND(2);
  NAND2 = NAND(2);
  NAND3 = NAND(2);
  OR    = OR(2);
  X1    = XOR;
  NOR1  = NOR(2);
  NOR2  = NOR(2);
  NOR3  = NOR(2);
```

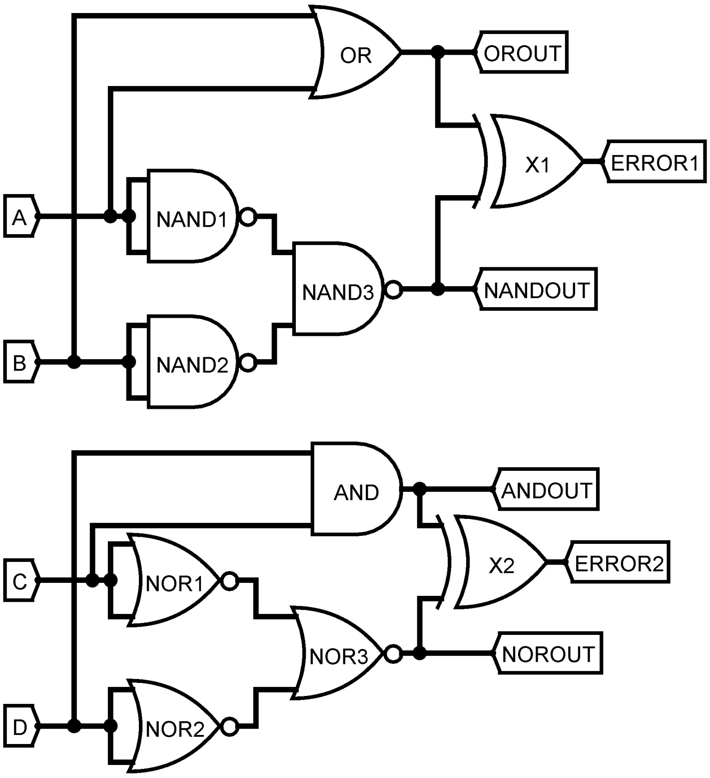

Figure 3: Logic gate array test circuit.

```
  AND    = AND(2);
  X2     = XOR;
}

CONNECTIONS
{
  OR.I1  <= A;
  OR.I2  <= B;
  NAND1.I1  <= A;
  NAND1.I2  <= A;
  NAND2.I1  <= B;
  NAND2.I2  <= B;
  NAND3.I1  <= NAND1;
  NAND3.I2  <= NAND2;
  X1.I1  <= OR;
  X1.I2  <= NAND3;

        AND.I1  <= C;
        AND.I2  <= D;
        NOR1.I1  <= C;
        NOR1.I2  <= C;
        NOR2.I1  <= D;
        NOR2.I2  <= D;
        NOR3.I1  <= NOR1;
        NOR3.I2  <= NOR2;
        X2.I1  <= AND;
        X2.I2  <= NOR3;
}

MONITORS
{
  ERROR1   <= X1;
  ERROR2   <= X2;
  ANDOUT   <= AND;
```

```
    NOROUT  <= NOR3;
    NANDOUT <= NAND3;
    OROUT <= OR;
  }
}
```

The test result obtained from the logsim package is shown in figure 4. The outputs are correct

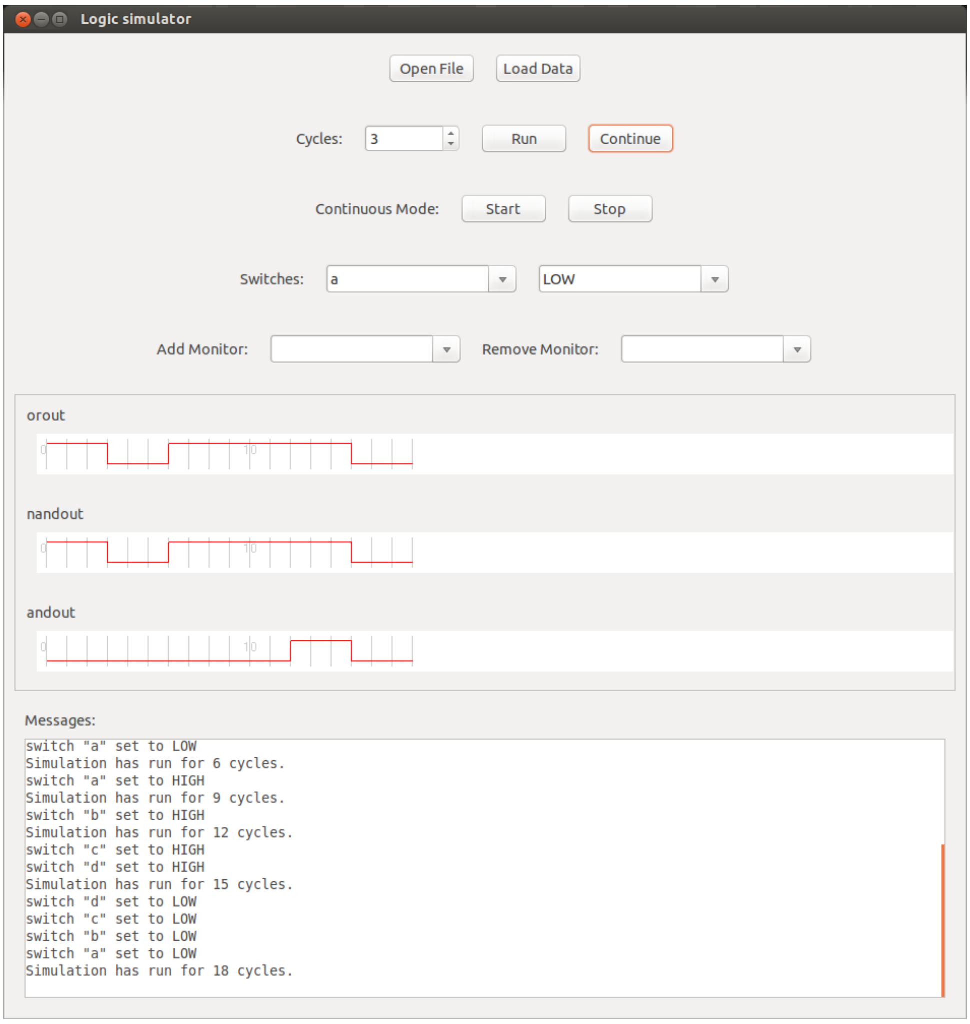

Figure 4: Screenshot showing running of logic gate array test case.

according to the values of the switches set at different points in the simulation.

B.2 Shift Register

A common sequential logic circuit is the shift register. It is frequently used for driving a serial bus from a parallel device. The circuit diagram is shown in figure 5. The definition file is as follows:

```
{
DEVICES
{
  D0 = DTYPE;
  D1 = DTYPE;
  D2 = DTYPE;
  D3 = DTYPE;
  INPUT = SW(1);
  RESET = SW(0);
```

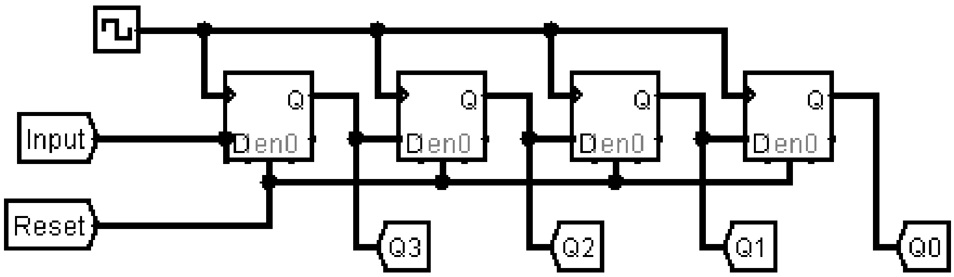

Figure 5: Shift register test circuit.

```
  ZERO  = SW(0);
  CLK1  = CLK(1);
}

CONNECTIONS
{
  D3.DATA  <= INPUT;
  D3.CLK   <= CLK1;
  D3.SET   <= ZERO; //This should always be 0 for shift register.
  D3.CLEAR <= RESET;

        D2.DATA  <= D3.Q;
        D2.CLK   <= CLK1;
        D2.SET   <= ZERO; //This should always be 0 for shift register.
        D2.CLEAR <= RESET;

        D1.DATA  <= D2.Q;
        D1.CLK   <= CLK1;
        D1.SET   <= ZERO; //This should always be 0 for shift register.
        D1.CLEAR <= RESET;

        D0.DATA  <= D1.Q;
        D0.CLK   <= CLK1;
        D0.SET   <= ZERO; //This should always be 0 for shift register.
        D0.CLEAR <= RESET;
}

MONITORS
{
  Q3 <= D3.Q;
  Q2 <= D2.Q;
  Q1 <= D1.Q;
  Q0 <= D0.Q;
}
}
```

The test result obtained from the logsim package is shown in figure 6. The output shown does not correspond to the expected output. This is due to the update to the d-type specification in the maintainance phase, where the output of the gate is random due to the input changing.

B.3 Signal Generator

The final test case considered here displays the added functionality from the maintainance case of the signal generator and the continuous output mode. The circuit is a simply signal generator feeding an inverter, as shown in figure 7. The definition file is:

```
{
DEVICES
{
  S = SIGGEN(1,0,0,0,0,1,1,1,0);
  A = SW(0);
  B = SW(1);
```

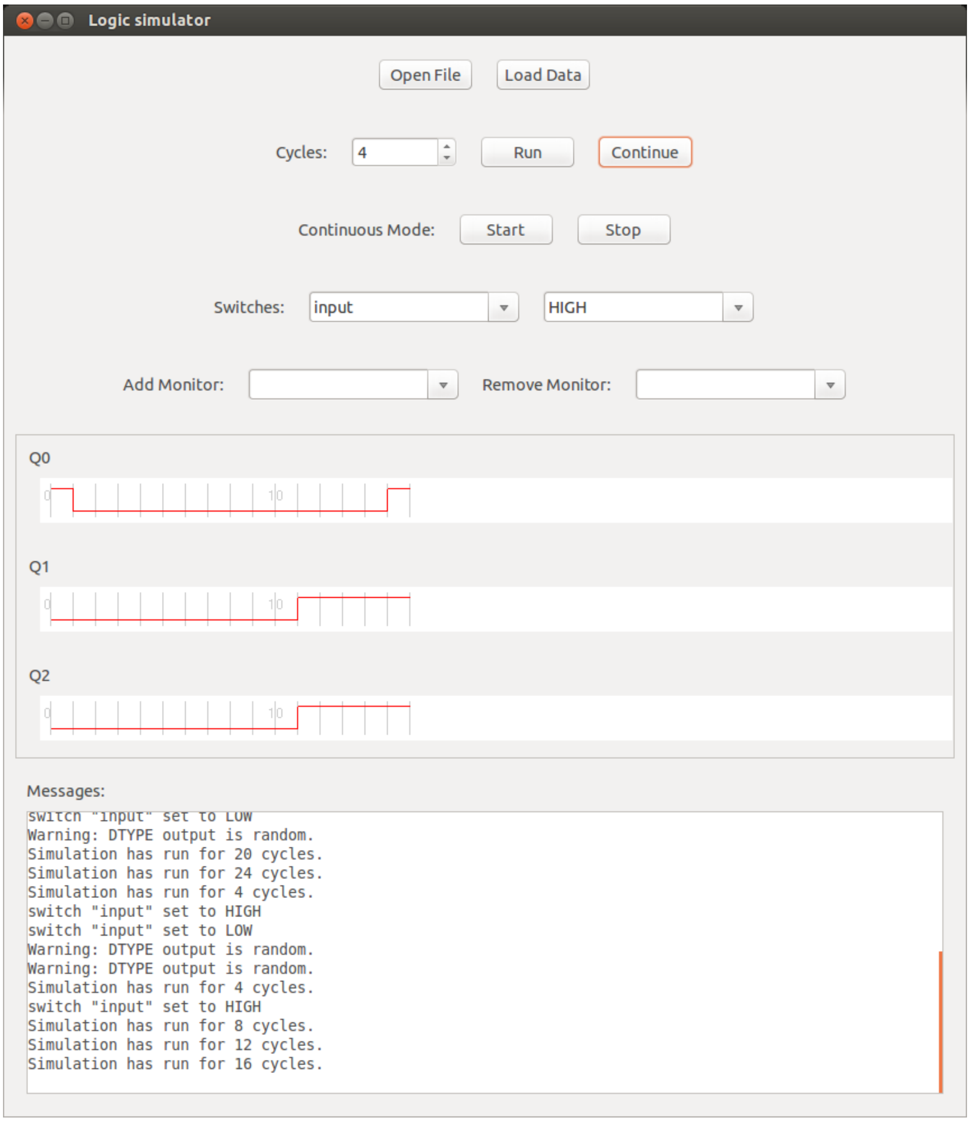

Figure 6: Screenshot showing running of shift register test case.

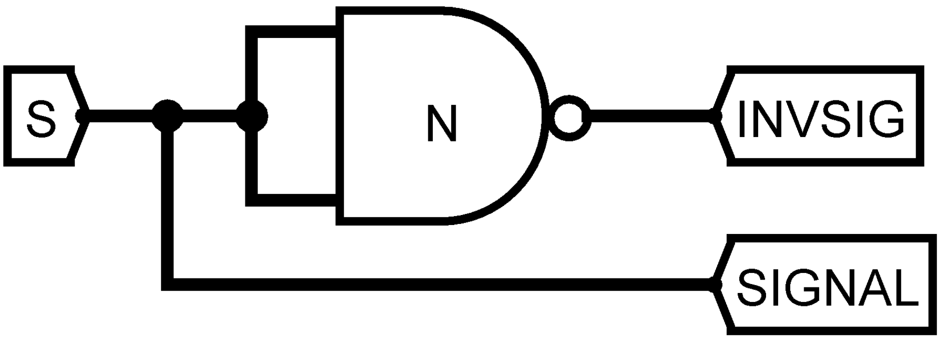

Figure 7: Signal generator test circuit.

```
C = SW(0);
D = SW(1);
```

```
  NAND1 = NAND(2);
  NAND2 = NAND(2);
  NAND3 = NAND(2);
  OR    = OR(2);
  X1    = XOR;
  NOR1  = NOR(2);
  NOR2  = NOR(2);
  NOR3  = NOR(2);
  AND   = AND(2);
  X2    = XOR;
}

CONNECTIONS
{
  OR.I1 <= A;
  OR.I2 <= S;
  NAND1.I1 <= A;
  NAND1.I2 <= A;
  NAND2.I1 <= B;
  NAND2.I2 <= B;
  NAND3.I1 <= NAND1;
  NAND3.I2 <= NAND2;
  X1.I1 <= OR;
  X1.I2 <= NAND3;

        AND.I1 <= C;
        AND.I2 <= D;
        NOR1.I1 <= C;
        NOR1.I2 <= C;
        NOR2.I1 <= D;
        NOR2.I2 <= D;
        NOR3.I1 <= NOR1;
        NOR3.I2 <= NOR2;
        X2.I1 <= AND;
        X2.I2 <= NOR3;
}

MONITORS
{
  ERROR1  <= X1;
  ERROR2  <= X2;
  ANDOUT  <= AND;
  NOROUT  <= NOR3;
  NANDOUT <= NAND3;
  OROUT <= OR;
  GEN <= S;
}
}
```

The test case is shown in figure 8. The output can be seen to be the same as the inverted signal defined in the definition file. The continuous mode is also seen to be working, the tenth period is shown near the start of the trace.

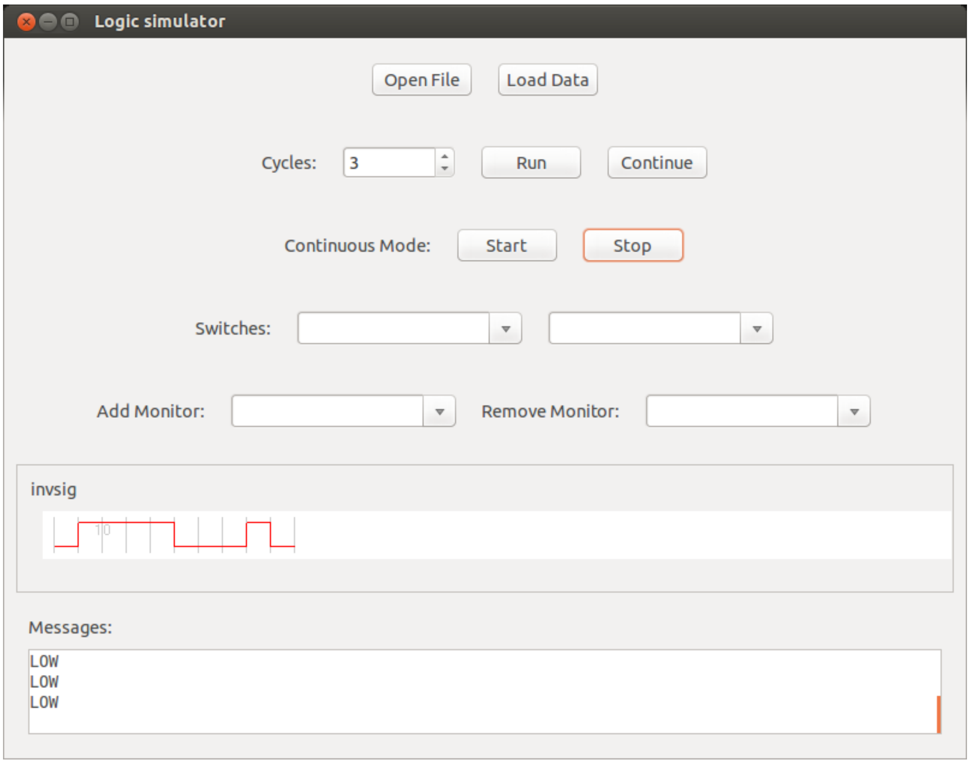

Figure 8: Screenshot showing running of signal generator test case.

C Definition File Specification

The EBNF specification for the test definition case is:

```
DEFINITION = '{' DEVICES CONNECTIONS MONITORS '}'

DEVICES =  'DEVICES' '{' device {device} '}'
device = devicename '=' devicetype [ '(' digit {digit|','} ')' ] ';'
devicename = letter {letter | digit}
devicetype = 'AND' | 'NAND' | 'OR' | 'NOR' | 'XOR' | 'DTYPE' | 'CLK' | 'SW' | 'SIGGEN'

CONNECTIONS = 'CONNECTIONS' '{' connection {connection} '}'
connection = input '<=' output ';'
input = letter {letter|digit} ['.'letter|digit{letter|digit}]
output = letter {letter|digit} ['.'letter|digit{letter|digit}]

MONITORS = 'MONITORS' '{' monitor {monitor} '}'
monitor = monitorname '<=' output ';'
monitorname = letter{letter|digit}
```

D System User Guide

The user interface is shown in figure 9. Everything in this guide apart from the starting of the program relates to interaction with this screen.

Starting the Program

The logic simulation package may be run by running the command `./logsim` in the directory of the compiled file. To load a definition file, click on the **Open File** button. This will bring up a standard file selection window. After selecting the desired file, click **OK** to return to the main screen.

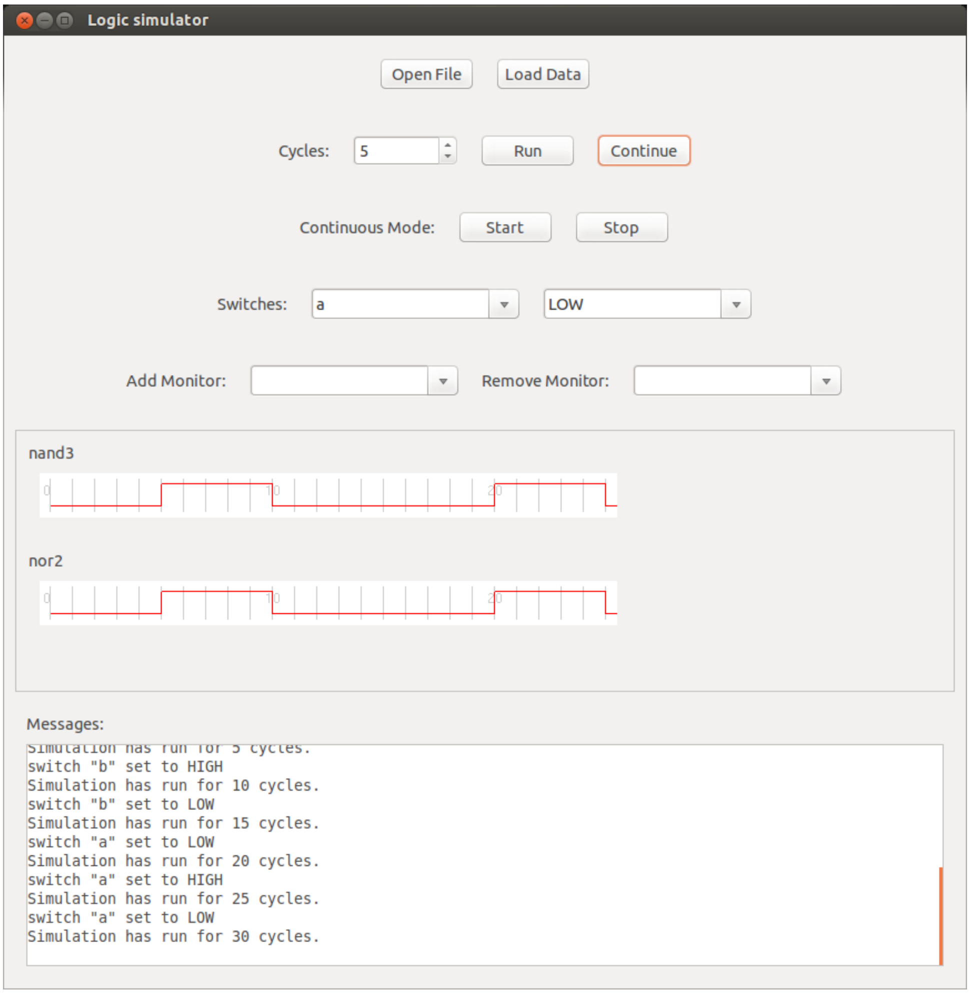

Figure 9: Main Screen on logic simulator.

Definition Errors

Any errors in the definition file will be highlighted in the message display at the bottom of the program window. This will give detailed information about the cause and location of the error, making debugging fast and efficient. Once all errors have been corrected the program may be run fully.

Setting up Monitors and Switches

Once the definition file has been loaded, the **load** button should be pressed. This populates the drop down menus with the relevant devices for selection. To add a monitor point, simply select the desired point from the list in the **add monitor** drop-down menu, then enter a name for this monitor in the pop-up window. They may be removed by selecting the monitor from the **remove monitor** menu. To ensure all required information is visible together, without many distracting and irrelevant output traces, up to 10 monitors may be observed at once. The value of a switch may be set at any time during the simulation by selecting the desired switch from the **switches** drop-down menu, followed by the level to be set from the **switch value** menu.

Running and Continuing the Simulation

To run the simulation, simply select the number of clock cycles to simulate in a single run (between 1 and 50), then press the **run** button. The traces for all defined monitors will be shown. The simulation may be **continued**, to observe the long term behaviour or to investigate the effect of a changed switch level on the circuit. The simulation may be run for up to 350 clock cycles. If the simulation is run for a large number of cycles, the traces may no longer be visible. In this case, simply drag the window to become wider and the traces will increase in size so that more clock cycles are visible.

Continuous Display Mode

In order to run the circuit continually and observe the changing signal levels, press the **Start** button. The monitors will show the values for the 10 previous clock cycles in a continually updating display until the **Stop** button is pressed.

E File Description

The important files in the shared directory are:

`logsim` The executable file to run the logic simulator.

`shift_register.def` Definition file for running the shift register example.

`siggen.def` Definition file for running the signal generator example.

`testgates.def` Definition file for running the logic gate array example.

`test/` Directory containing test files for the names class, parser and scanner.