6.375 Tutorial 2

Guards and Scheduling

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Overview

- BSV reviews/notes
- Guard lifting
- EHRs
- Scheduling
- Lab 3

Expressions vs. Actions

- Expressions
  - Have no side effects (state changes)
  - Can be used outside of rules and modules in assignments
- Actions
  - Can have side effects
  - Can only take effect when used inside of rules
  - Can be found in other places intended to be called from rules
    - Action/ActionValue methods
    - functions that return actions

Variable vs. States

- Variables are used to name intermediate values
- Do not hold values over time
- Variable are **bound** to values
  - Statically elaborated

```
Bit#(32) firstElem = aQ.first();
rule process;
    aReg <= firstElem;
endrule
```

Scoping

- Any use of an identifier refers to its declaration in the nearest textually surrounding scope

```
Bit#(32) a = 1;
rule process;
    aReg <= a;
endrule
```

```
module mkShift( Shift#(a) );
   function Bit#(32) f();
     return fromInteger(valueOf(a))<<2;
   endfunction
   rule process;
     aReg <= f();
   endrule
endmodule
```

  - Functions can take variables from surrounding scope

Guard Lifting

- Last Time: implicit/explicit guards
  - But there is more to it when there are conditionals (if/else) within a rule
- Compiler option `-aggressive-conditions` tells the compiler to peek into the rule to generate more aggressive enable signals
  - Almost always used

Guard Examples

```
rule process;
   if (aReg==True)
      aQ.deq();
   else
      bQ.deq();
   $display("fire");
endrule
```

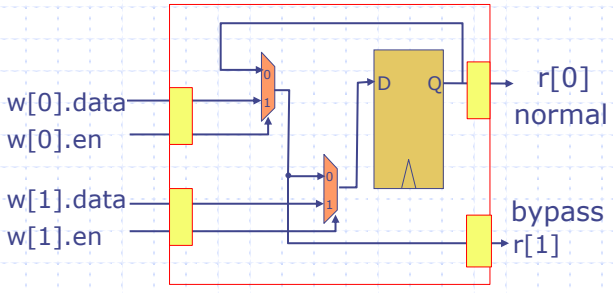
(aReg==True && aQ.notEmpty) ||
(aReg==False && bQ.notEmpty) ||

```
rule process;
   aQ.deq();
   $display("fire");
endrule
```

```
rule process;
   if (aQ.notEmpty)
      aQ.deq();
   $display("fire");
endrule
```

(aQ.notEmpty && aQ.notEmpty) ||
(!aQ.notEmpty) ➔ Always fires

Ephemeral History Register (EHR)



r[0] < w[0] | r[1] < w[1] | w[0] < w[1] < ....

- Encode a notion of "priority" when there are concurrent writes/reads

Design Example

An Up/Down Counter

Up/Down Counter
Design example

- Some modules have inherently conflicting methods that need to be concurrent
  - This example will show a couple of ways to handle it

```
interface Counter;
    Bit#(8) read;
    Action increment;
    Action decrement;
endinterface
```

Inherently conflicting

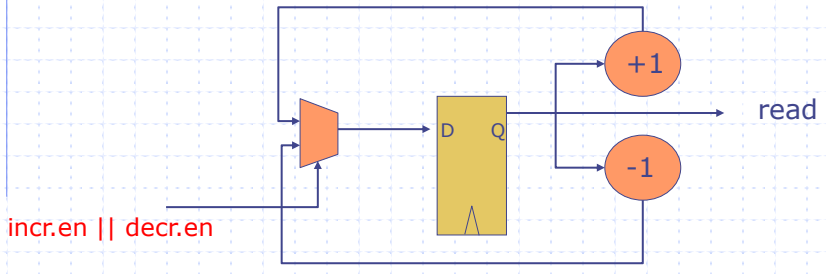
Up/Down Counter
Conflicting design

```
module mkCounter( Counter );
    Reg#(Bit#(8)) count <- mkReg(0);

    method Bit#(8) read;
        return count;
    endmethod
    method Action increment;
        count <= count + 1;
    endmethod
    method Action decrement;
        count <= count - 1;
    endmethod
endmodule
```

Can't fire in the same cycle

Up/Down Counter
Conflicting design



Concurrent Design
A general technique

- Replace conflicting registers with EHRs
- Choose an order for the methods
- Assign ports of the EHR sequentially to the methods depending on the desired schedule

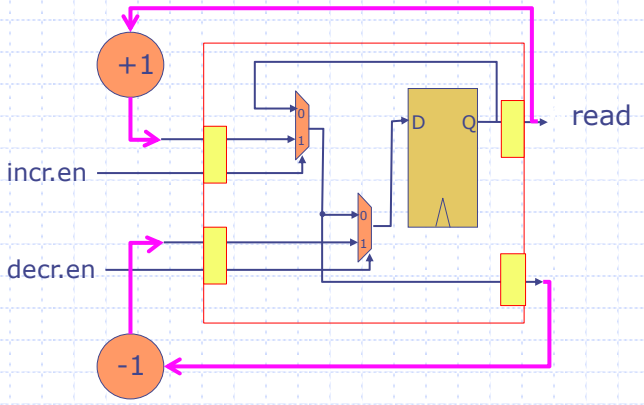
Up/Down Counter
Concurrent design: read < inc < dec

```
module mkCounter( Counter );
    Ehr#(2, Bit#(8)) count <- mkEhr(0);

    method Bit#(8) read;
        return count[0];
    endmethod
    method Action increment;
        count[0] <= count[0] + 1;
    endmethod
    method Action decrement;
        count[1] <= count[1] - 1;
    endmethod
endmodule
```

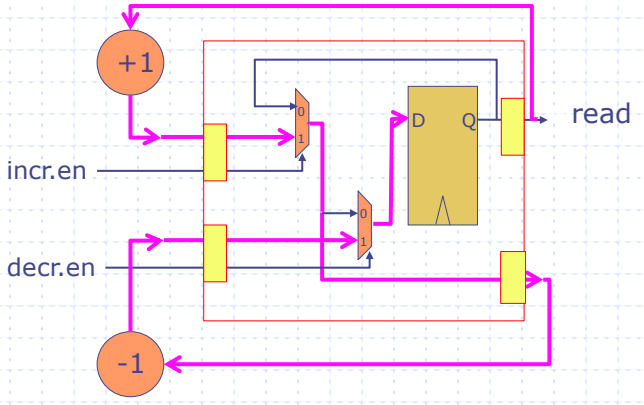
Up/Down Counter

Concurrent design: read < inc < dec



Up/Down Counter

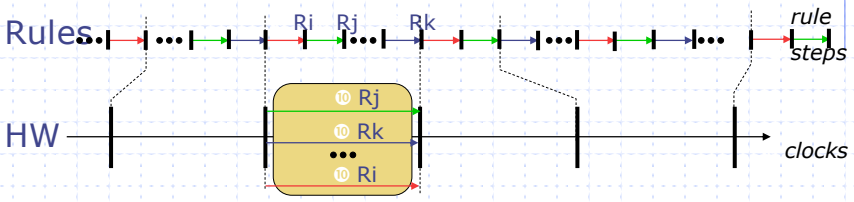
Concurrent design: read < inc < dec



Valid Concurrent Rules

- A set of rules r_i can fire concurrently if there exists a total order between the rules such that all the method calls within each of the rules can happen in that given order
  - Rules r_1, r_2, r_3 can fire concurrently if there is an order r_i, r_j, r_k such that $r_i < r_j$, $r_j < r_k$, and $r_i < r_k$ are all valid

Concurrent rule firing



- Concurrently executable rules are scheduled to fire in the same cycle
- In HW, states change only at clock edges

Rule Scheduling Intuitions

- Can these rules fire in the same cycle?

```
rule r1 (a);
    x <= 1;
endrule

rule r2 (!a);
    x <= 2;
endrule
```

No, guards are mutually exclusive

Rule Scheduling Intuitions

- Can these rules fire in the same cycle?

```
rule r1;
    y <= 1;
endrule

rule r2;
    x <= 1;
endrule
```

Yes, methods are unrelated (conflict free)

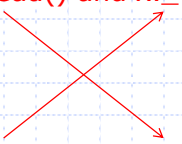
Rule Scheduling Intuitions

- Is it legal?
- Can these rules fire in the same cycle?

```
rule increment;
    x <= x + 1;
endrule

rule decrement;
    x <= x - 1;
endrule
```

Calls x._read() and x._write()



Calls x._read() and x._write()

increment C decrement, so the two rules will never fire in parallel

Rule Scheduling Intuitions

- Can these rules fire in the same cycle?

```
rule r1;
    x <= y;
endrule

rule r2;
    y <= x;
endrule
```

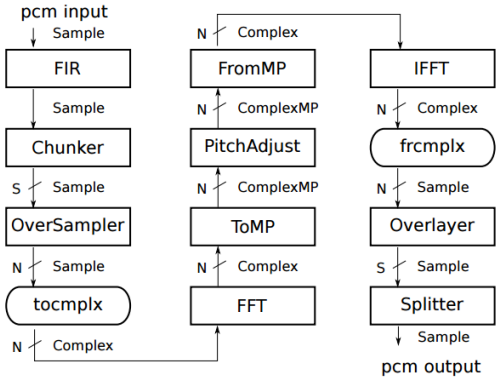
Calls y._read() and x._write()

Calls x._read() and y._write()

r1 C r2, so the two rules will never fire in parallel

Lab 3: Overview

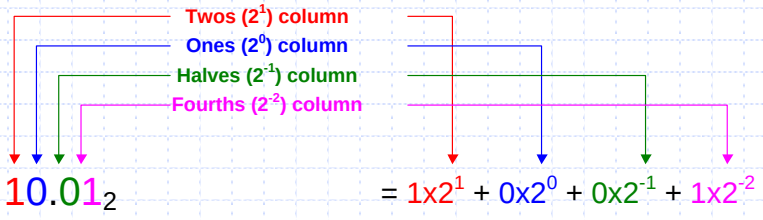
- Completing the audio pipeline:
  - PitchAdjust
  - FromMP, ToMP



Converting C to Hardware

- Think about what states you need to keep
- Loops in C are sequentially executed; loops in BSV are statically elaborated
  - Unrolled

Fixed Point




```
typedef struct {
  Bit#(isize) i;
  Bit#(fsize) f;
} FixedPoint#(numeric type isize, numeric type fsize )
```


Fixed Point Arithmetic

- Useful FixedPoint functions:
  - fxptGetInt: extracts integer portion
  - fxptMult: full precision multiply
  - *: full multiply followed by rounding/saturation to the output size
- Other useful bit-wise functions:
  - truncate, truncateLSB
  - zeroExtend, extend

BSV Debugging
Display Statements

- See a bug, not sure what causes it
- Add display statements
- Recompile
- Run
- Still see bug, but you have narrowed it down to a smaller portion of code
- Repeat with more display statements…
- Find bug, fix bug, and remove display statements

BSV Display Statements

- The $display() command is an action that prints statements to the simulation console
- Examples:
  - `$display("Hello World!");`
  - `$display("The value of x is %d", x);`
  - `$display("The value of y is ", fshow(y));`

Ways to Display Values
Format Specifiers

- %d – decimal
- %b – binary
- %o – octal
- %h – hexadecimal
- %0d, %0b, %0o, %0h
  - Show value without extra whitespace padding

Ways to Display Values
fshow

- fshow is a function in the FShow typeclass
- It can be derived for enumerations and structures
  - FixedPoint is also a FShow typeclass
- Example:

```
typedef enum {Red, Blue} Colors deriving(FShow);
Color c = Red;
$display("c is ", fshow(c));
```

Prints "c is Red"

Warning about $display

- $display is an Action within a rule
- Guarded methods called by $display will be part of implicit guard of rule

```
rule process;
   if (aQ.notEmpty)
      aQ.deq();
   $display("first elem is %x", aQ.first);
endrule
```


Extra Stuff

BSV Debugging
Waveform Viewer

- Simulation executables can dump VCD waveforms
  - `./simMyTest -V test.vcd`
- Produces test.vcd containing the values of all the signals used in the simulator
  - Not the same as normal BSV signals
- VCD files can be viewed by a waveform viewer
  - Such as gtkwave
- The signal names and values in test.vcd can be hard to understand
  - Especially for structures and enumerations

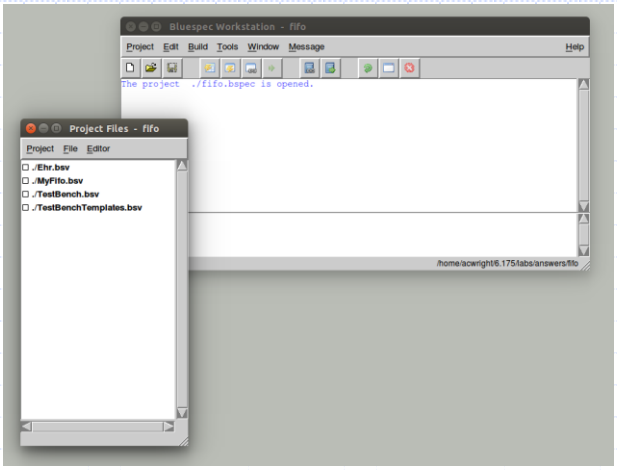
Step 1
Generate VCD File

- Run `./sim`*`TestName`* `-V test.vcd`

Step 2

Open Bluespec GUI

- Run "bluespec fifo.bspec"



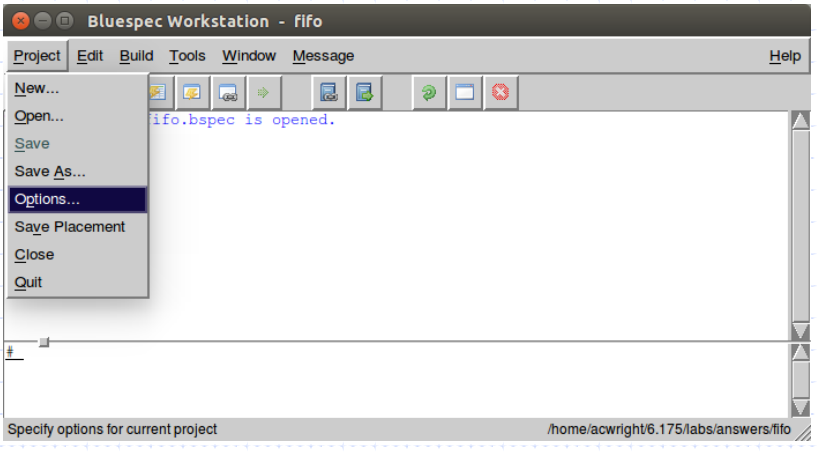
Note, to run the GUI remotely, you need to SSH into the servers with the "ssh –X" command

For the fifo lab, fifo.bspec can be found in

Step 3

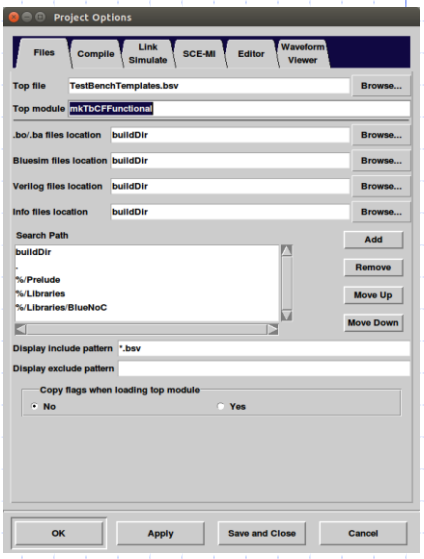
Set top module name

- Open project options

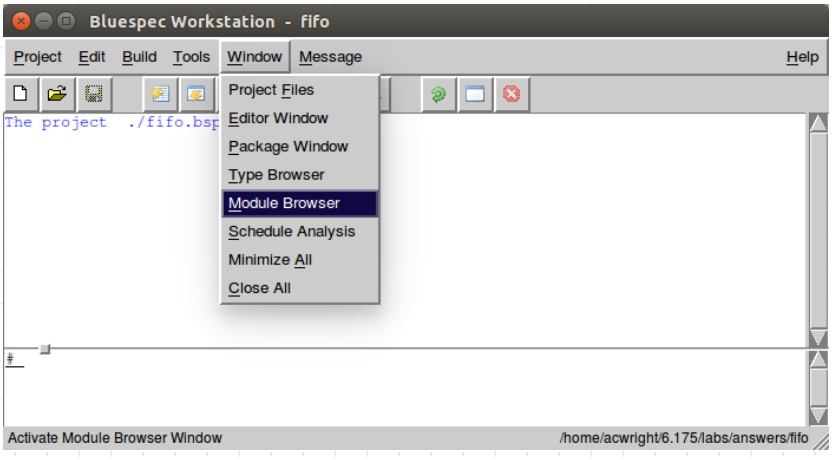


Step 3
Set top module name

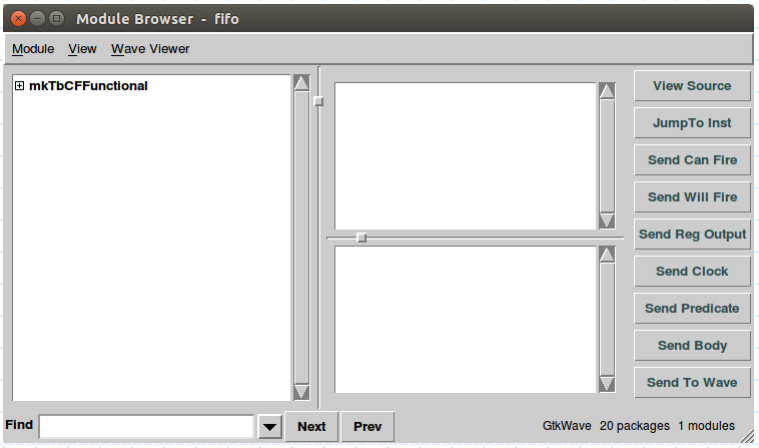
- Set the top module name to match the compiled module in TestBench.bsv



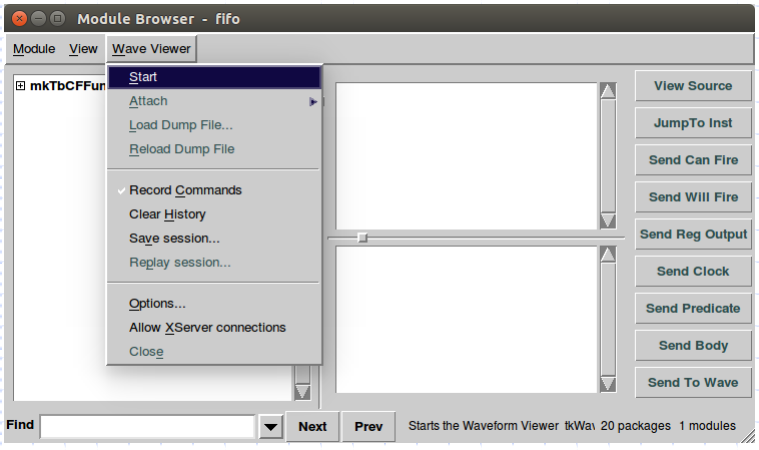
Step 4
Open Module Viewer



Step 4
Open Module Viewer



Step 5
Open Wave Viewer



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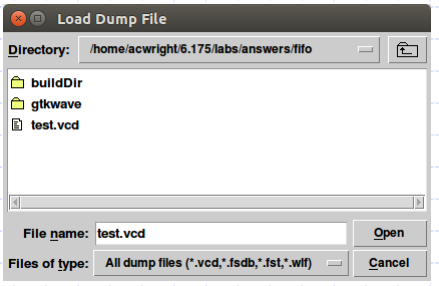
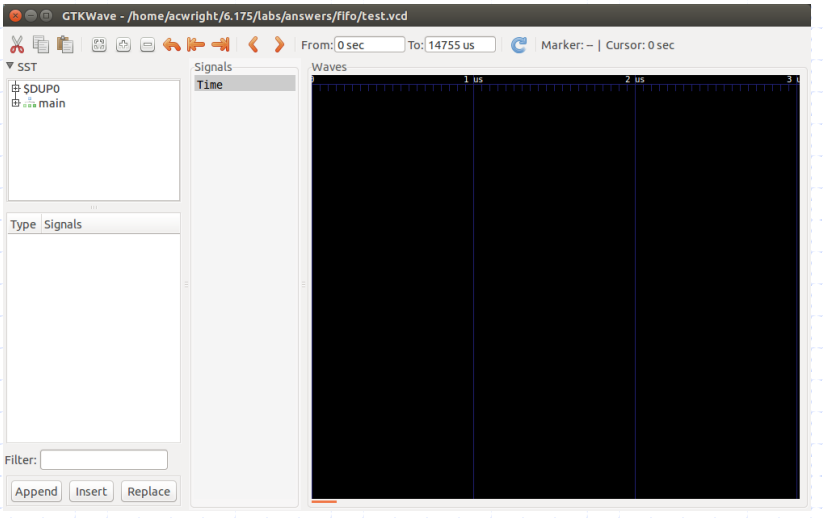
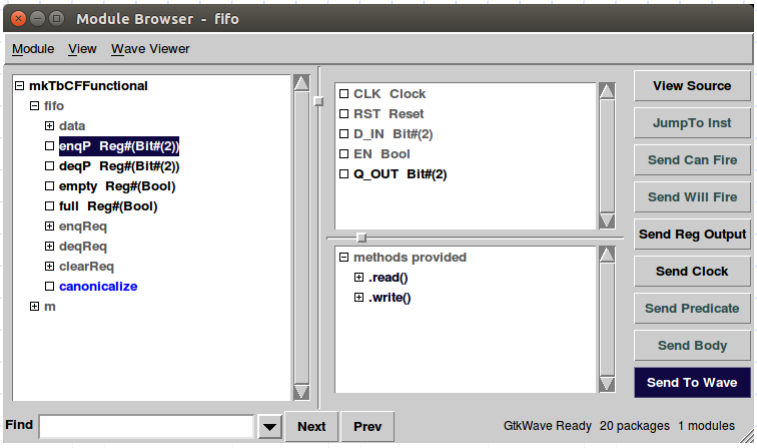


Step 6
Open Wave Viewer



Step 6
Add Some Signals



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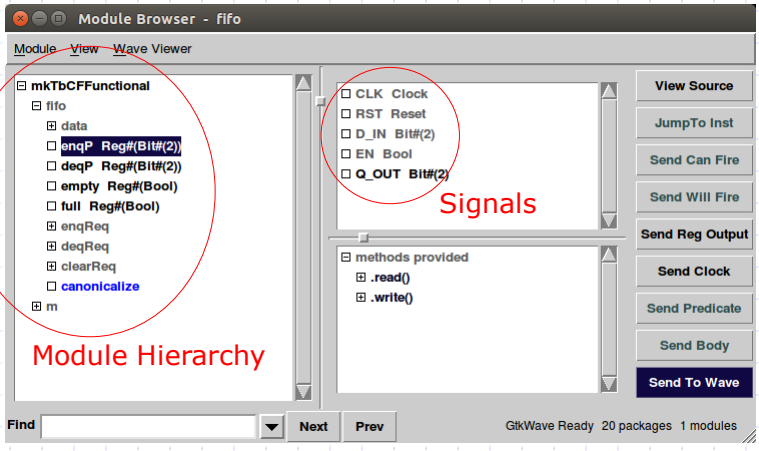
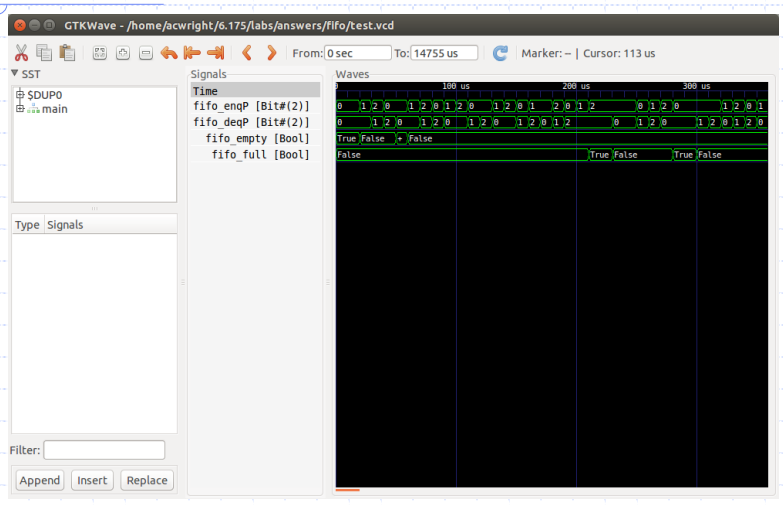


Step 7
Look at the Waveforms



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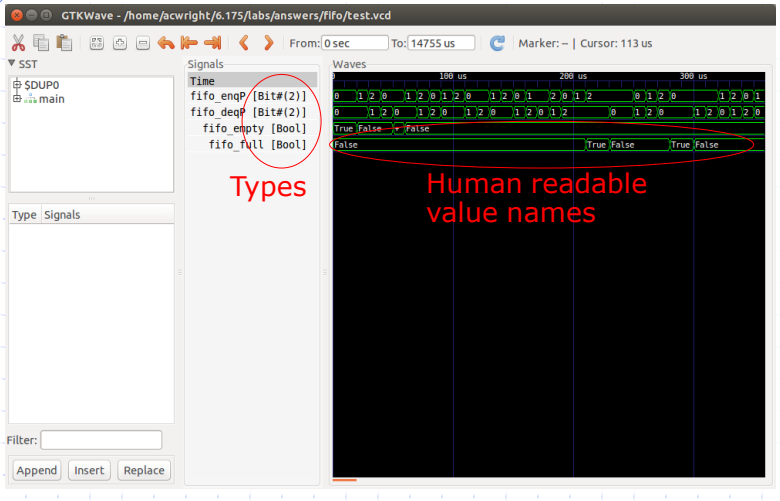

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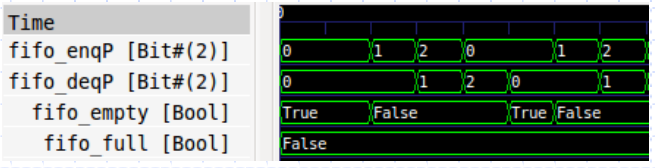
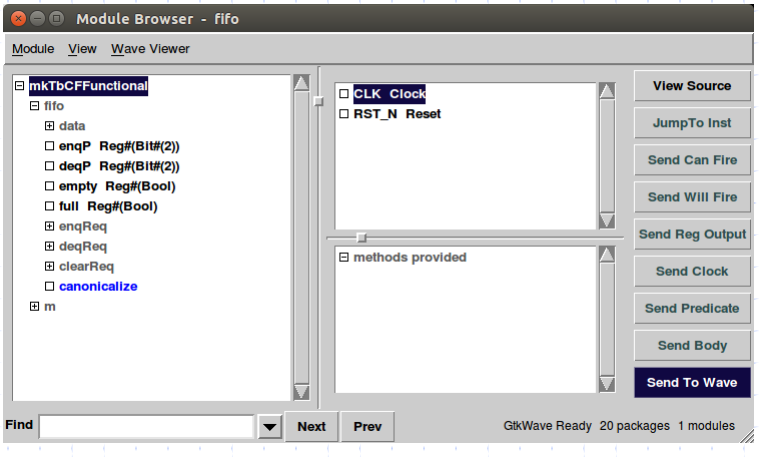


Step 8
Add Some More Signals



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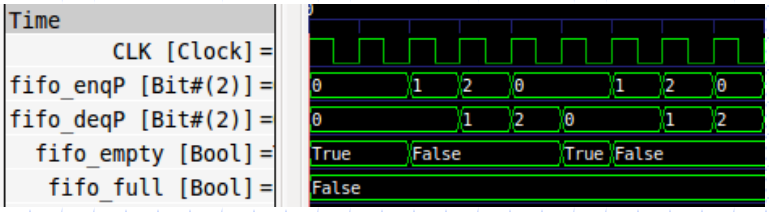
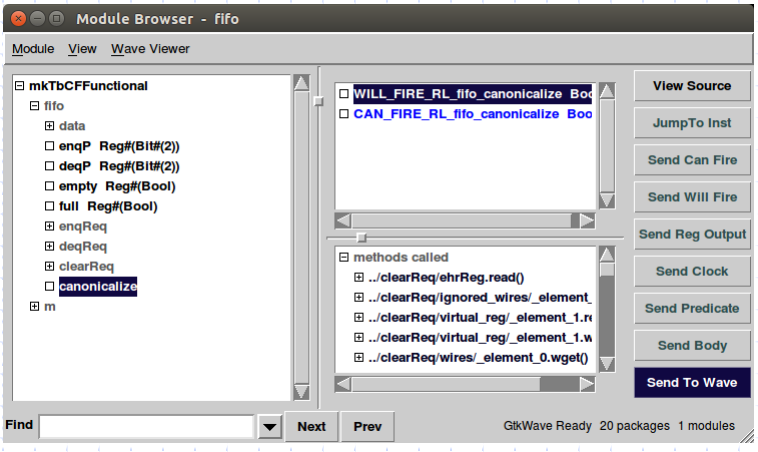


Step 9
Add Rules Too



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Add Rules Too