blooRTLs

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1 Introduction

The Behavioral Language for Object-Oriented Register Transfer Level Specs (blooRTLs) is a high-level RTL description language geared towards catalyzing the development, simulation, and synthesis of RTL specs.

While blooRTLs does not embody the structure of an established “object-oriented” language, it does use the notion of objects (as described in Section 3.4), and in a general sense of the “object-oriented” programming style, blooRTLs does contribute a modular approach to the RTL design domain.

In regards to simulation and synthesis of the RTL design, the source code of blooRTLs must be precompiled (as explained in Section 4) before it can be compiled to VHDL. The compiler assumes that a reasonable clock frequency is to be used for the desired RTL spec. As a result, the complexity and types of arithmetic operations that can be performed within a given cycle has been limited by the blooRTLs syntax. Just as an RTL implementation that uses a reasonable clock frequency (i.e. MHz range) cannot load a register with data that has propagated through a substantial number of gates within the same clock cycle, blooRTLs does not permit multiple arithmetic operations to be performed within the same assignment expression. The legal expressions are discussed further in Section 3.6.

Overall, the modular and syntactical styles of blooRTLs offer an efficient and effective means of developing synthesizable bit manipulation methods and RTL algorithms. The following reference manual borrows the framework of Dennis Ritchie’s *C Reference Manual* to afford readers a better understanding of blooRTLs [1].
2 Language Tutorial

blooRTLs was developed on Linux Ubuntu 14.04. The following section provides a tutorial on how to run programs with the precompiler. Although the precompiler does not print out VHDL (that is the job of the compiler), it is an effective means of testing an RTL algorithm or spec. Both the precompiler and compiler are discussed in Section 4

2.1 Running the Precompiler

To compile and run the precompiler execute the following:

0. Extract the tar.gz file

1. Navigate to the working directory in the terminal

2. Run the make file in the terminal (\$ make)

3. Execute $ ./blooRTLs<tutorial1.txt (Note: tutorial1.txt contains the blooRTLs source code of Tutorial 1, which is described in the next subsection)

2.2 Tutorial Example 1: Addition of Objects

A quick tutorial on the language is provided through the following addition example:

Listing 1: Tutorial Example 1: Addition of Objects

```
BINMAP var {
    msb := [7];
    lsb := [0];
    middle2bits:= [4][3];
}

var := 10000001;

var.middle2bits := var.msb * var.lsb;

PRINT var.middle2bits;
PRINT var;
```
In Tutorial Example 1, the terminology is described as follows.

- **var** is denoted as the *root variable*
- **msb**, **lsb**, and **middle2bits** are denoted as the **objects** of **var**.
- The **BINMAP** declaration, then, is used to declare the bit indices that the objects will represent.

Using the terminology, as described above, the **BINMAP var** declaration, for example, assigns object **lsb** to bit 0 of the root variable **var**. By the same principle, **msb** is assigned bit 7 of **var**, and **middle2bits** is assigned bit 4 of **var**. This concept is illustrated in the figure.

![Figure 1: Objects of Tutorial Example 1](image)

It is worth noting that **BINMAP** can be called multiple times throughout the program as long as it does not attempt to change the indicies of a previously assigned object. Additionally, **BINMAP** can be invoked on multiple root variables. In these cases, multiple root variables are permitted to use the same object identifiers because objects are unique root variables (i.e. **var.obj** and **var2.obj** are permmissable if they were to be implemented into the same program).

Additionally, it is worth noting that whitespace within an index yields unexpected results. (i.e. **nibble0 := [3 ][ 2 ][ 1 ][ 0 ]** is not the same as **nibble0 := [3][2][1][0]**, so it behooves users to avoid using the former representation).
The first assignment following var’s BINMAP declaration is a load. In particular, var is loaded with the bits 10000001. When this occurs, the blooRTLs precompiler enters a dynamic check and assign routine to confirm that the overall assignment is valid. The checking routine for this assignment is described as follows.

- First, the precompiler checks if the indices of the previously declared objects fall within the dimensions of the root variable. For Tutorial Example 1, the precompiler asks if the indices of lsb, msb, and middle2bits fall within the indices of the root variable var.
- Upon the passing the first check, the precompiler assigns the root variable with the bits, 10000001.
- The dynamic assignments then occur. The precompiler iterates through the objects of the variable that was just updated (in this case var was just updated with 10000001) and assigns new values to the objects whose indices fall within the updated variable. In the case of Tutorial Example 1, when var is assigned with 10000001, var.lsb is assigned 1, var.msb is assigned 1, and var.middle2bits is assigned 00.
- The same dynamic assignment routine would occur if an object (as opposed to a variable) were to be updated. If this were the case, the precompiler would iterate through all other objects in addition to the root variable and make assignment changes as necessary. However, Tutorial Example 1 does have any of these object assignments. (to refresh, an example object assignment would be var.msb := 0

It is worth noting that the blooRTLs language supports up to 32-bit assignments. Unexpected behavior occurs beyond when variables are assigned dimensions beyond this length.

It is also worth noting that the blooRTLs precompiler raises errors if overflow and underflow occur (i.e. if var.lsb := 2d [Note: 2d implies ”2 as a decimal”], then var.lsb would overflow because it embodies a 1 bit number.

Running Example 1 with the precompiler outputs the following:

![Figure 2: Executing Tutorial Example 1](image-url)
Tutorial Example 2 is provided in the tar.gz file in addition to the Tutorial Example 1. The source is seen as follows:

Listing 2: Tutorial Example 2: DNA Sequencing

```
BINMAP var1 {
    nucleotide := [1][0];
}

var1 := 1001110000000100110011011110101;
eldedummy := 0;
adenosine := 000000;
cytosine := 000000;
thymine := 000000;
guanine := 000000;

REPEAT (  
    IF (var1.nucleotide = 00) THEN (   
        adenosine := adenosine + 1d;   
    ) ELSE (eldedummy := 0;)

    IF (var1.nucleotide = 01) THEN (   
        cytosine := cytosine + 1d;   
    ) ELSE (eldedummy := 0;)

    IF (var1.nucleotide = 10) THEN (   
        thymine := thymine + 1d;   
    ) ELSE (   
        guanine := guanine + 1d;  )

    var1 := var1 >> 2d;
) UNTIL (var1 = 0d)

PRINT adenosine;
PRINT cytosine;
PRINT thymine;
PRINT guanine;
```
3 Language Reference Manual

3.1 Lexical Conventions

The lexical conventions implemented in blooRTLs consist of comments, identifiers, keywords, and constants.

3.1.1 Comments

The characters /* introduce a comment, which terminates with the characters */.

3.1.2 Identifiers (Names)

An identifier is a sequence of letters and digits used to represent a register in the RTL design; all characters must be lower case.

3.1.3 Keywords

The following identifiers are reserved for use as keywords, and may not be used otherwise (case-sensitive):

BINMAP THEN
REPEAT ELSE
UNTIL
IF PRINT

3.1.4 Constants

There are two types of constants, as follows:

- **Binary Constants**: A binary constant is a series of ones (1) and zeros (0).
- **Integer Constants**: An integer constant is a series of numerical digits (0-9), followed by the letter d (i.e. 4d) with no preceding sign character.
3.2 Syntax Notation

In the syntax notation used in this manual, syntactic categories are indicated by italic type, and literal words and characters in the typewriter style.

3.3 What’s in a Name?

- blooRTLs supports one fundamental identifier type, which takes the form of the binary constant
- BINMAP: the BINMAP type creates objects, as defined in Section 3.4, from identifiers

3.4 Identifiers and Objects

Identifiers and Objects are related and defined, as follows:

- identifier: An identifier is interpreted as a binary constant that is assumed to be loaded into a region of storage within the RTL design (i.e. a register)
- identifier.object: An object is an indexed component of the Identifier.

Since identifiers are used to represent storage components within the data path of the RTL design, all identifiers are technically objects. However, identifiers and objects are not fully equivalent structures. When identifiers are segmented into smaller regions of storage, these resulting components are referred to as the objects. The means of partitioning identifiers into objects is discussed in Section 3.7.

3.5 Conversions

blooRTLs has one conversion operator:

3.5.1 The decimal operator (d)

d is shorthand for decimal. It’s implementation is as follows:

```plaintext
var := 9d;
/* var holds the binary constant value of 1001 */
```
3.6 Expressions

3.6.1 Primary Expression

\[
p_{\text{primary-expression}} : \\
\quad \text{identifier} \\
\quad \text{constant} \\
\quad (\text{expression})
\]

- An \textit{identifier} is a primary expression, provided it has been suitably declared as discussed in Section 3.7.
- A \textit{constant} is either a binary or an integer constant, as specified in Section 3.1.4.
- An \textit{(expression)} is an expression that takes the highest precedence.

3.6.2 Unary Expression

Unary expressions group left to right and are listed as follows

\[
\begin{align*}
\text{expression} + \text{expression} & : \text{binary constant add} \\
\text{expression} - \text{expression} & : \text{binary constant subtract} \\
\text{expression} \times \text{expression} & : \text{binary constant multiply} \\
\text{expression} >> \text{expression} & : \text{binary constant shift right} \\
\text{expression} << \text{expression} & : \text{binary constant shift left}
\end{align*}
\]

3.6.3 Assignment

\[
\text{identifier} := \text{expression}
\]

3.6.4 Relational

\[
\text{expression} = \text{expression} : \text{returns boolean true if equal}
\]
3.7 Declarations

 Declarations take the general form indicated, as follows:

\[
\text{declaration:} \\
\quad \text{decl-specifiers declarator-list}
\]

\[
\text{decl-specifiers:} \\
\quad \text{BINMAP} \\
\quad \text{expression}
\]

\[
\text{declarator-list:} \\
\quad \text{declarator} \\
\quad \text{declarator, declarator-list}
\]

\[
\text{declarator:} \\
\quad \text{identifier} \\
\quad \text{identifier.object} \\
\quad \text{declarator( )} \\
\quad (\text{declarator})
\]

3.7.1 BINMAP

 The BINMAP decl-specifier creates an object within an identifier, which enables usage of the identifier.object declarator. This idea is illustrated in the following example:

```c
/* Within the identifier ''var'', BINMAP is used to declare an object called ''LSB'' that indexes bit location 0, and ''MSB,'' which indexes bit location 4 */
BINMAP var{
    lsb := [0];
    msb := [4];
}
var := 1000;
var.lsb := 1;
var.msb := 0;
/* var now holds the binary value 0001 */
```
3.8 Statements

Statements are executed in sequence.

3.8.1 Expression statement

Most statements are expression statements, which have the following form:

\[ expression; \]

Usually expression statements are assignments or function calls.

3.8.2 Compound statement

The use of several statements, where one is expected, is noted as follows:

\[ compound-statement: \]
\[ statement \]

\[ statement-list: \]
\[ statement \]
\[ statement statement-list \]

3.8.3 Conditional statement

The two forms of the conditional statement are listed as follows:

\[ if ( expression ) statement \]
\[ if ( expression ) statement else statement \]

3.8.4 repeat until statement

The \texttt{repeat until} takes the following form:

\[ repeat ( expression ) until ( expression ) \]

3.9 Scope

blooRTLs source text must be kept in a single file.
4 Project Plan

Disclaimer: the compiler is not working, however, the following section takes into account various considerations for the compiler’s implementation.

4.1 VHDL Library Considerations

When VHDL began, the main logic type was called the `std_logic_vector`, which embodies a sequence of bits that hold no numerical value. As a result, in the early 1990s, Synopsys, an ASIC design tool vendor, developed three libraries that could assign numerical values to the `std_logic_vector` with the hope of easing the arithmetic syntax in VHDL. The libraries are listed as follows:

Listing 3: Non-standardized VHDL libraries by Synopsys

```vhdl
library ieee;
use ieee.std_logic_arith.all;
use ieee.std_logic_unsigned.all;
use ieee.std_logic_signed.all;
```

Although these libraries ease the arithmetic syntax of VHDL, these libraries are mistaken to have been standardized by the IEEE. As a result, the various tools and platforms offered by vendors interpret these libraries differently in simulation and synthesis.

The better option is to use the IEEE’s standardized libraries as follows:

Listing 4: Standardized IEEE VHDL libraries

```vhdl
library ieee;
use ieee.std_logic_1164.all;
use ieee.numeric_std.all;
```

Because these libraries have been standardized, they perform (for the most part) identically regardless of vendor. However, interpreting blooRTLs into VHDL is not trivial. The following arithmetic examples in the numeric library raise errors when compiled.

Listing 5: Error: Adding with different lengths

```vhdl
-- sum is length 1 downto 0
-- a is length 1
-- b is length 1
sum <= std_logic_vector( ("0" & a) + ("0" & b) );
```
Listing 6: Error: Multiplying with different lengths

```vhdl
-- product is length 4 downto 0
-- (must be twice the length of its operands)
-- a is length 1
-- b is length 1
product <= std_logic_vector( "0" & a ) * ("0" & b );
```

Oddly, the following two scenarios work

Listing 7: Success: Adding with different lengths

```vhdl
-- sum is length 1 downto 0
-- a is length 2
-- b is length 1
... 
sum <= std_logic_vector( a + ("0" & b ) );
```

Listing 8: Success: Multiplying with different lengths

```vhdl
-- product is length 3 downto 0
-- (must be twice the length of its operands)
-- a is length 2
-- b is length 1
product <= std_logic_vector( a * ("0" & b ) );
```

But these two successes do not cover all cases. In order to cover all cases, a clever trick was implemented.

Listing 9: Clever “dummy” Trick to cover all multiplication cases

```vhdl
-- product is length 3 downto 0
-- one_2 := "01"
-- a is length 1
-- b is length 1
product <= std_logic_vector( one_2 * ("0" & a ) * ("0" & b ) );
```

Listing 10: Clever “dummy” Trick to cover all sum cases

```vhdl
-- sum is length 1 downto 0
-- zero_2 := "00"
-- a is length 1
-- b is length 1
sum <= std_logic_vector( zero_2 + ("0" & a ) + ("0" & b ) );
```

Obviously, the zero_2 and one_2 can be replaced by zero_N and one_N depending on the situation. While this is quirky on behalf of the VHDL compiler, this trick must be used when necessary, considering the reliability of the numeric library at the simulation and synthesis stages.
4.2 Example: Compiling a simple blooRTLs program

The following diagram walks through the compiling of a blooRTLs program:

Figure 3: Compiling a simple blooRTLs program
4.3 Sequential VHDL Consideration

Listing 11: Sequential VHDL Framework

```vhdl
library ieee;
use ieee.std_logic_1164.all;
use ieee.numeric_std.all;

entity moore is
  port (  
    Clock : in STD_LOGIC;
    Resetn : in STD_LOGIC;

    -- declare all inputs/outputs & vector length  
    -- Arbitrary examples to illustrate syntax:  
    input0 : in std_logic_vector (7 downto 0);  
    input1 : in std_logic; -- 1 bit  
    output0 : out std_logic_vector(2 downto 0));
  end moore;

architecture rtl of moore is
  type State_type is (A,B,C); --Declare RTL states  
  signal state : State_type;

  -- declare all signals & vector lengths  
  -- Arbitrary examples to illustrate syntax:  
  signal signal0 : std_logic_vector (5 downto 0);  
  signal signal1 : std_logic_vector (2 downto 0) := "000";  
  signal signal2 : std_logic := '1';

begin
  process (Resetn, Clock)
  begin
    if Resetn = '0' then
      state <= A;
    elsif (Clock'EVENT AND Clock = '1') then
      case state is
        when 'A' =>
          if ( ... ) then
            -- some statements/code...
            state <= A;
          else
```

```
```vhdl
state <= B;
end if;

'B' State
when B =>
  -- some statements/code..

'C' State
when C =>
  -- some statements/code..
end case;
end if;
end process;

-- push the desired logic to the output port. Arbitrary example
output0 <= "001" when state = C else "000";
end rtl;
```
### 4.4 Precompiler

When using the VHDL numeric library, the VHDL compiler does not detect overflows, nor does it detect underflows. Hence the need for a precompiler.

The goal of the precompiler was to cache and log the vector lengths of all the variables and objects. The basic architecture of this “database” takes the following form:

<table>
<thead>
<tr>
<th>Keys (Variables)</th>
<th>Values (Maps)</th>
</tr>
</thead>
<tbody>
<tr>
<td>“var” →</td>
<td>Keys (Objects)</td>
</tr>
<tr>
<td></td>
<td>“un” → (137, [7;6;5;4;3;2;1;0], [1;0;0;0;1;0;0;1], 0)</td>
</tr>
<tr>
<td></td>
<td>“msb” → (1, [7], [1], 0)</td>
</tr>
<tr>
<td></td>
<td>“lsb” → (1, [4;3], [0;1], 0)</td>
</tr>
<tr>
<td></td>
<td>“middle2bits” →</td>
</tr>
</tbody>
</table>

Figure 4: Ocaml “Database” of Vars and Objs

```ocaml
let binmap = mapUpdate "var" "" (137, [7;6;5;4;3;2;1;0], [1;0;0;0;1;0;0;1], 0) binmap;
val binmap : (int * int list * int list * int) NameMap.t NameMap.t = <abstr>
```

Figure 5:
4. Project Plan

4.1 Planning, Specification, and Development

All members of our team contributed to all parts of the project equally according to their responsibilities. Originally, because we understand the summer term is short, we plan to meet every time after class, every Friday or even on weekends if necessary. However, after a few weeks, after we divided roles, we figure out that it would be more efficient to work individually and frequently update progress to group members via email and cellphone.

4.2 Programming Style and Development Environment Used

Each group member uses different computer system environment, some of us use Linux for faster coding and some other use Windows for development. All of us use OCaml, OCamllex, and OCamllyacc for design and develop our pre-compiler. Two of members in our group are familiar with VHDL, and the other two are willing to learn VHDL while developing the project.

4.3 Team responsibilities

<table>
<thead>
<tr>
<th>Team Member</th>
<th>Roles</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peter Burrows</td>
<td>Designer, actively contribute to all processes</td>
</tr>
<tr>
<td>Apurv Gaurav</td>
<td>Test Designer, Debug</td>
</tr>
<tr>
<td>Pinhong He</td>
<td>Scanner, Parser, AST</td>
</tr>
<tr>
<td>Zhibo Wan</td>
<td>Manager, Lexical Analysis</td>
</tr>
</tbody>
</table>

4.4 Project Timeline

<table>
<thead>
<tr>
<th>Date</th>
<th>Accomplishment</th>
</tr>
</thead>
<tbody>
<tr>
<td>6/3/15</td>
<td>Proposal Submitted</td>
</tr>
<tr>
<td>6/8/15</td>
<td>Scanner</td>
</tr>
<tr>
<td>6/10/15</td>
<td>Parser</td>
</tr>
<tr>
<td>6/11/15</td>
<td>AST</td>
</tr>
<tr>
<td>6/14/15</td>
<td>Pre-complier done</td>
</tr>
<tr>
<td>6/30/15</td>
<td>Test, Debug</td>
</tr>
<tr>
<td>7/2/15</td>
<td>Final report, slices submitted</td>
</tr>
</tbody>
</table>

What I learnt:

**Pinhong He:** I really enjoy learning from scratch to how to actually design and develop a compiler. Although I was totally unfamiliar with OCaml and it took me a while to understand it, however I really like it after I see how it works and helps to develop our language compiler. For the teamwork, I like working with my teammates, although some of us have time conflicts and a busy schedule, but it all worked out at the end. It is a pity that we could not finish what we expected at the beginning, but if we got more time, I believe our language will be useful!

**Zhibo Wan** learned:

Computer Science is more than just coding. And this project “forced” us to jump out of the mainstream code such as C++, Java, python, and let me have a big picture of how programing language, as a whole, looks like. Ocaml is not that bad, it can do some work amazingly efficient, especially recursion function.
Test Cases
The blooRTLs compiler accepts a blooRTLs program and generates a VHDL program (.v output file and the test bench file). Our system test suite takes a list of simple, representative blooRTLs programs and compiles those programs into their runtime output and translates the programs to the appropriate VHDL files (the actual .v output file and the test bench file). These VHDL output files and their corresponding test bench are then run to produce a waveform. If the VHDL program files are correct, the runtime output and generated waveform will match with the expected waveform. Hence, we are system testing our compiler after integrating all its parts together.

I have divided the test cases as follows. The arithmetic test cases individually test the various operations of our program, from basic addition, subtraction, and multiplication to shifting. The binary map test cases will illustrate one of blooRTLs key features, the ability to map a binary sequence into its bits and the ability to manipulate those bits. Finally, our feature test case will combine the various features of the language into a real life application - mapping and encoding our DNA!

1. Arithmetic Test Cases

AddBinary:
Operation: 5 + 4 = 9; Note that here, I created a third register var3 to hold the sum of var1 + var2. Creating a third register allows blooRTLs to pad var1 and var2 with an extra “zero” on its MSB so that we don’t get an overflow, since 9 is (1001)₂ which is one extra bit than either var1, which is (101)₂ or var2, which is (100)₂.

blooRTLs:
var1 := 5d;
var2 := 4d;
var3 := var1 + var2;

VHDL:
library IEEE;
use IEEE.STD_LOGIC_1164.ALL;
use IEEE.NUMERIC_STD.ALL;
entity AddBinary is
    Port (Num1 : in STD_LOGIC_VECTOR (4 downto 0) := “00000”
        Num2 : in STD_LOGIC_VECTOR (4 downto 0) := “00000”
        Sum : out STD_LOGIC_VECTOR (4 downto 0));
end AddBinary;
architecture Structure of AddBinary is
begin
    Sum <= Num1 + Num2;
end Structure;

Testbench:
blooRTLs enters in 0101 for A and 0100 for B, automatically padding A and B with an extra zero

AddBinary - Overflow Error Detection:
Operation: 5 + 4 = 9; Instead of creating a third register var3 to hold the sum of var1 + var2 as in the previous test case, I will simply let var1 = var1 + var2. This will cause an overflow error, since the sum, 9, is (1001)₂ which is one more bit than what var1 could store. Since var1...
since the sum, 9, is (1001)₂ which is one more bit than what var1 could store. Since var1 was originally created to store just three bits, for (101)₂. Were it not for blooRTL to point out the error, VHDL would run anyway producing a resulting sum that would be truncated to not reflect the fourth digit. In this blooRTLs is able to inform the user of semantic errors in a code that VHDL could not do.

blooRTLS:
var1 := 5d;
var2 := 4d;
var1 := var1 + var2;
PRINT var1;

SubtractBinary:
Operation:
5 - 4 = 1; Since I am subtracting a smaller number from a larger one, I know that the number of bits required to store the difference is less than or equal to the number of bits to store either 5 or 4. Thus, I can simply do var1 = var1 - var2.

blooRTLS:
var1 := 5d;
var2 := 4d;
var1 := var1 - var2;
PRINT var1;

VHDL:
library IEEE;
use IEEE.STD_LOGIC_1164.ALL;
use IEEE.NUMERIC_STD.ALL;
entity SubtractBinary is
  Port (
    Num1 : in STD_LOGIC_VECTOR (3 downto 0) := "0000";
    Num2 : in STD_LOGIC_VECTOR (3 downto 0) := "0000";
    Diff : out STD_LOGIC_VECTOR (3 downto 0));
end SubtractBinary;
architecture Structure of SubtractBinary is
begin
  Diff <= Num1 - Num2;
end Structure;

Testbench:
I will enter in 101 for A and 100 for B

Multiplication:
Operation:
5 * 4 =; I will have a third variable, var3 store the product. var3 will automatically have double the number of bits as the factors.

blooRTLS:
var1 = 5d;
var2 = 4d;
var3 = var1 * var2;
PRINT var3;

VHDL:
library IEEE;
use IEEE.STD_LOGIC_1164.ALL;
use IEEE.NUMERIC_STD.ALL;
entity Multiplication is
  Port (
    Num1 : in STD_LOGIC_VECTOR (4 downto 0) := "00000";
    Num2: in STD_LOGIC_VECTOR (4 downto 0) := "00000";
    Product: in STD_LOGIC_VECTOR (4 downto 0));
end Multiplication;
architecture Structure of Multiplication is
begin
Product <= Num1 * Num2;
end Structure;

Testbench:
I will enter in 00101 for A and 00100 for B

**Multiplication Overflow Error:**

**Operation:**
It is important to note that once variables are created in blooRTLs, the variables will always maintain the same number of bits as when it was created. Thus, if I store 5 in var1, and 4 in var2, both var1 and var2 will contain 3 bits each.

**blooRTLs:**

var1 = 5d;
var2 = 4d;
var1 = var1 * var2;
PRINT var1;

---

**Shifting a sequence left**

**Operation:** Taking the sequence 10001100 and shifting it 3 bits to the left would give us 01100000. *Zeroes are automatically padded in to maintain the bit length.*

**blooRTLs:**

var1 := 10001100
var1 := var1<<3d;
PRINT var1;

---

**Shifting a sequence right**

**Operation:** Taking the sequence 10001100 and shifting it 3 bits to the right would give us 00010001. *Zeroes are automatically padded in to maintain the bit length.*

**blooRTLs:**

var1 := 10001100
PRINT var1;
var1 := var1>>3d;
PRINT var1;

---

**Up Counter**

**Operation:**
This blooRTLs program will count up from 0 to 15 with a change in number every x seconds. The blooRTLs language is designed such that each line of the code takes x seconds sequentially, but with the INPUT and OUTPUT lines being read first. Thus, in the following code, the number display changes to display + 1, every x seconds.

**blooRTLs:**

INPUT datastream := 0000;
display := datastream;
display := display + 1d;
display := display + 1d;
display := display + 1d;
display := display + 1d;
display := display + 1d;
display := display + 1d;
display := display + 1d;
display := display + 1d;
display := display + 1d;
display := display + 1d;
display := display + 1d;
display := display + 1d;
display := display + 1d;
display := display + 1d;
Down Counter
Operation:
This is like the Up Counter except the program counts down.

**blooRTLs:**
INPUT datastream := 0000;
var := datastream;
var := var - 1;
var := var - 1;
var := var - 1;
var := var - 1;
var := var - 1;
var := var - 1;
var := var - 1;
var := var - 1;
var := var - 1;
var := var - 1;
var := var - 1;
var := var - 1;
var := var - 1;
var := var - 1;
var := var - 1;
var := var - 1;
OUTPUT outstream := var

II. Binary Map Cases

**BINMAP - Changing the indices of a binary string**
**Operation:** We take a binary number, 10001110, map the first four indices as ‘nibble’ using BINMAP, and change those bits so that they are 0000. The output is 10000000, as expected

**blooRTLs:**
BINMAP var1 {
  nibble:=[3][2][1][0];
} 
var1 := 10001110;
var1.nibble := 0000;

**BINMAP - Left-to-Right Sequence Reader**
**Operation:** Using the fact that each line of the blooRTL, excluding the Input and Output declaration, takes x seconds and flows sequentially, we can build a sequence reader so that the sequence is “read” one or more bits at a time. Here, the program takes the sequence 10001110 and reads it two bits at a time from the left to right. Thus, the program displays 10 the first x seconds, 00 the next x seconds, 11 the next seconds, and 10 the final x seconds.

**blooRTL:**
INPUT datastream := 10001110;
BINMAP sequence {
  display:=[7][6];
sequence := datastream;
sequence.display := sequence.display << 2;
sequence.display := sequence.display << 2;
sequence.display := sequence.display << 2;
OUTPUT outstream := sequence.display;

**BINMAP - Left-to-Right Sequence Reader Using Repeat-Until Loop**

**Operation:** We will once again build a program that takes the sequence 10001110 and reads it two bits at a time from the left to right. However, instead of relying on the computer’s time per line to display the count, we will use the repeat-until loop with each iteration printing two bits.

blooRTL:
BINMAP sequence {
    display:=[7][6];
}
sequence := 10001110;
PRINT sequence.display;
REPEAT
    sequence.display := sequence.display << 2;
    PRINT sequence.display;
UNTIL (sequence = 00000000)

**BINMAP - Overflow Error Detection:**

**Operation:**
We take a binary number, 10001110, map the first four indices as ‘nibble’ using BINMAP, and try to change those bits so that they are 10000. However, since 10000 is five bits instead of the four allotted for ‘nibble’, the compiler will notify the user of an overflow.

blooRTLS:
BINMAP var1 {
    nibble := [3][2][1][0];
}
var1 := 10001110;
var1.nibble := 10000;

**BINMAP - Floating Point Multiplication:**

**Operation:**
Computers often convert large numbers into floating point form to perform multiplication with less running time. The following program demonstrates the ease with which blooRTL can be used to convert two integers into floating point using BINMAP, and then be multiplied. The decimal equivalent of the two floating point numbers are 1224 and 45. Their product, 55080, will be shown in floating point form as 01000110101011001000000000000000.

blooRTL:
fp1 := 01000100100110010000000000000000; // decimal equivalent = 1224
fp2 := 01000010001101000000000000000000; // decimal equivalent = 45
/
Floating Point Numbers is of the form (+/- 1.Mantissa * 2^exponent), with sign = 0 for positive and sign = 1 for negative. As an example, fp1’s sign is 0, its exponent 10001001, and Mantissa as 01100100000000000000000000. This translates to the number 1224 in decimal representation
/*
BINMAP var1 {
    sign := [32];
    exponent := [31][30][29]..[23];
    mantissa := [22][21]..[0];
}
BINMAP var2 {
    sign := [32];
    exponent := [31][30][29]..[23];
    mantissa := [22][21]..[0];
}
BINMAP out {
    sign := [32];
    exponent := [31][30][29]..[23];
    mantissa := [22][21]..[0];
}

out := BINARY (0) // In order to Initialize the product variable
var1: = fp1;
var2: = fp2;
out.exponent := var1.exponent + var2.exponent;
out.sign := var1.sign XOR var2.sign;
PRINT out;

III. Argumentative Test Cases

Up Counter Using Repeat-Until Loop
Operation:
Once again the blooRTLs program will count up from 0 to 15. However, instead of using
the delay of reading each line to display the count, we will use a repeat-until loop.
blooRTLs:
data := 0000
REPEAT
    (data := data + 1d;
    PRINT data;)
UNTIL (data = 1111)

Down Counter Using Repeat-Until Loop
Operation:
Once again the blooRTLs program will count up from 0 to 15. However, instead of using
the delay of reading each line to display the count, we will use a repeat-until loop.
blooRTLs:
data := 1111
REPEAT
    (data := data - 1d;
    PRINT data;)
UNTIL (data = 0000)

If-Then-Else Switch statement:
Operation:
Here we will design a situation where a binary number is read. Then using If-Then-Else
statements, we design cases for what the number could be. Please note that since an ‘Else’
is compulsory in an If-Then-Else statement, we will use a dummy variable to fill in an
is compulsory in an If-Then-Else statement, we will use a dummy variable to fill in an 'Else' condition when we do not need:

```
var1 := 01;
zero := 0;
one := 1;
two := 2;
three := 3;
elsedummy := 0;
IF (var1 = 00) THEN
  (PRINT zero;)
ELSE (elsedummy := 0;)
IF (var1 = 01) THEN
  (PRINT one;)
ELSE (elsedummy := 0;)
IF (var1 = 10) THEN
  (PRINT two;)
ELSE (elsedummy := 0;)
IF (var1 = 11) THEN
  (PRINT three;)
ELSE (elsedummy := 0;)
The One’s Counter
Operation:
We will count the number of 1’s in a sequence by using an if-then statement with counter embedded inside a repeat-until loop:
```
```
blooreTTLs:
BINMAP var1 {  
    lsb := [0];  
}  
var1 := 10001110;
counter := 000  
REPEAT (  
      IF (var.lsb = 1) THEN  
        (  
          counter = counter + 1d;  
          var1 := var1 >> 1d;  
        )  
      ELSE  
        (var1 := var1 >> 1d;)  
      )  
UNTIL (var1 = 00000000)  
PRINT counter;
```
```
Sequence Detection (Overlapping):
Operation:
Given the sequence 1101110101, detect 1011:
```
```
blooreTTLs
BINMAP var1 {  
    detectbits := [3][2][1][0];  
}  
var1 := 1101110101;
counter := 000;
REPEAT (  
    IF (detectbits = 1011)  
    THEN (  
      counter := counter + 1d;  
      var1 := var1 >> 1d;  
    )  
    ELSE (var1 := var1 >> 1d;  
```
```
```
UNTIL (var1 = 0d)
PRINT counter;

III. Feature Test Case

**DNA Nucleotide Counter**

**Operation:**
This is a part of our featured test case. DNA uses four nucleotides - Adenosine (A), Cytosine (C), Thymine (T), and Guanine (G) in building a sequence that is our genetic code. We will take a DNA sequence that has been encoded into binary numbers and count how many of each nucleotide there are. Adenosine is encoded as 00, Cytosine as 01, Thymine as 10, and Guanine as 11.

```plaintext
blooRTLs
BINMAP var1 {
    nucleotide := [1][0];
}
var1 := 0110011011110101;
elsedummy := 0;
adenosine := 000000;
cytosine := 000000;
thymine := 000000;
guanine := 000000;
REPEAT (
    IF (var1.nucleotide = 00) THEN (adenosine := adenosine + 1d;
    ) ELSE (elsedummy := 0d;)
    IF (var1.nucleotide = 01) THEN (cytosine := cytosine + 1d;
    ) ELSE (elsedummy := 0d;)
    IF (var1.nucleotide = 10) THEN (thymine := thymine + 1d;
    ) ELSE (guanine := guanine + 1d;)
    var1 := var1 >> 2d;
) UNTIL (var1 = 0d)
PRINT adenosine;
PRINT cytosine;
PRINT thymine;
PRINT guanine
```

**Optimized DNA Encoder:**

**Operation:**
In this program, we will use the results of the previous program, the count of each nucleotide in a DNA sequence to re-encode the DNA. The re-encoding is based on the famous Huffman algorithm, which allows for more efficient encoding, minimizing the number of bits to store the same information. In order to do that, I will encode the nucleotide with the highest frequency with ‘0’, the second highest frequency with ‘10’ the third highest frequency with ‘110’ and the lowest frequency nucleotide with ‘111’. For purposes of this test case, let’s assume the highest to lowest frequency of nucleotides were cytosine, adenosine, thymine, guanine.

```plaintext
blooRTLs:
BINMAP oldseq {
    nucleotide := [1][0];
}
oldseq := 0110011011110101;
BINMAP newseq {
    cbits := [16];
```
tbits := [17][16];
gbits := [18][17][16];
abits := [18][17][16];
}
newseq := 0d;
seqlength := 0d;
elsedummy := 0;
REPEAT (
  IF (oldseq.nucleotide = 01) THEN (  
    newseq.ebits := 0;
    oldseq := oldseq >> 2d;
    newseq := newseq >> 1d;
    seqlength := seqlength + 1d;
  )  
ELSE (elsedummy := 0;)
  IF (oldseq.nucleotide = 10) THEN (  
    newseq.tbits := 10;
    oldseq := oldseq >> 2d;
    newseq := newseq >> 2d;
    seqlength := seqlength + 2d;
  )  
ELSE (elsedummy := 0;)
  IF (var1.nucleotide = 00) THEN (  
    newseq.abits := 110;
    oldseq := oldseq >> 2d;
    newseq := newseq >> 3d;
    seqlength := seqlength + 3d;
  )  
ELSE  
  (  
    newseq.gbits := 111;
    oldseq := oldseq >> 2d;
    newseq := newseq >> 3d;
    seqlength := seqlength + 3d;
  )
UNTIL (var1 = 0d)
PRINT newseq;
PRINT seqlength;
References


Appendix

Listing 12: scanner.mll

```plaintext
{ open Parser }

rule token = parse
    [' ' 't' 'r' 'n'] { token lexbuf }
    ['+' { PLUS }
    ['-'] { MINUS }
    ['*'] { TIMES }
    '>>' { SHIFTR }
    '<<' { SHIFTL }
    '=' { ASSIGN }
    ':' { EQU }
    ';' { SEMI }
    '(' { LP }
    ')' { RP }
    '{' { LCB }
    '}' { RCB }
    '.' { PERIOD }
    ['0' '9'] as decimal { DEC (decimal) }
    ['0' '1'] as bits { BITS (bits) }
    ['a' 'z'][ '0' '9'] as lxm { ID(lxm) }
    "PRINT" { PRINT }
    "INPUT" { INPUT }
    "REPEAT" { REPEAT }
    "UNTIL" { UNTIL }
    "IF" { IF }
    "THEN" { THEN }
    "ELSE" { ELSE }
    "BINMAP" { BINMAP }

    ['0' '9'][ '0' '9'] as ind
    { IND(int_of_char ind.\[1\] - 48) }
    ['0' '9'][ '0' '9'] as ind
    { IND((10*(int_of_char ind.\[1\] - 48))
      +(int_of_char ind.\[2\] - 48)) } }
    ['0' '9'][ '0' '9'][ '0' '9'] as ind
    { IND((100*(int_of_char ind.\[1\] - 48))
      +10*(int_of_char ind.\[2\] - 48))
      +(int_of_char ind.\[3\] - 48) } }
    ['0' '9'][ '0' '9'][ '0' '9'][ '0' '9'] as ind
    { IND((1000*(int_of_char ind.\[1\] - 48))
      +(100*(int_of_char ind.\[2\] - 48))
      +10*(int_of_char ind.\[3\] - 48))
      +(int_of_char ind.\[4\] - 48)) } }
    ['0' '9'][ '0' '9'][ '0' '9'][ '0' '9'][ '0' '9'][ '0' '9'][ '0' '9'] as ind
```

20
{ IND((10000*(int_of_char ind.[1] - 48))
  +(1000*(int_of_char ind.[2] - 48))
  +(100*(int_of_char ind.[3] - 48))
  +(10*(int_of_char ind.[4] - 48))
  +(((int_of_char ind.[5] - 48)) )
  )
  | ['[0' - '9'][0' - '9'][0' - '9'][0' - '9'][0' - '9'][0' - '9']' as ind
  |  { IND((1000000*(int_of_char ind.[1] - 48))
        +(100000*(int_of_char ind.[2] - 48))
        +(10000*(int_of_char ind.[3] - 48))
        +(100*(int_of_char ind.[5] - 48))
        +(((int_of_char ind.[6] - 48)) )
    )
    | ['[0' - '9'][0' - '9'][0' - '9'][0' - '9'][0' - '9'][0' - '9']' as ind
    |  { IND((100000000*(int_of_char ind.[1] - 48))
            +(10000000*(int_of_char ind.[2] - 48))
            +(1000000*(int_of_char ind.[3] - 48))
            +(100000*(int_of_char ind.[4] - 48))
            +(10000*(int_of_char ind.[5] - 48))
            +(((int_of_char ind.[7] - 48)) )
        )
        | ['[0' - '9'][0' - '9'][0' - '9'][0' - '9'][0' - '9'][0' - '9']' as ind
        |  { IND((10000000000*(int_of_char ind.[1] - 48))
                +(1000000000*(int_of_char ind.[2] - 48))
                +(100000000*(int_of_char ind.[3] - 48))
                +(10000000*(int_of_char ind.[4] - 48))
                +(1000000*(int_of_char ind.[5] - 48))
                +(1000000*(int_of_char ind.[6] - 48))
                +(1000000*(int_of_char ind.[7] - 48))
                +(((int_of_char ind.[8] - 48)) )
            )
            | ['[0' - '9'][0' - '9'][0' - '9'][0' - '9'][0' - '9'][0' - '9']' as ind
            |  { IND((100000000000*(int_of_char ind.[1] - 48))
                    +(10000000000*(int_of_char ind.[2] - 48))
                    +(1000000000*(int_of_char ind.[3] - 48))
                    +(1000000000*(int_of_char ind.[4] - 48))
                    +(1000000000*(int_of_char ind.[5] - 48))
                    +(1000000000*(int_of_char ind.[6] - 48))
                    +(1000000000*(int_of_char ind.[7] - 48))
                    +(1000000000*(int_of_char ind.[8] - 48))
                    +(((int_of_char ind.[9] - 48)) )
                )
                | ['[0' - '9'][0' - '9'][0' - '9'][0' - '9'][0' - '9'][0' - '9']'
as ind

{ IND( (10000000000*(int of char ind.[1] - 48))
    + (1000000000*(int of char ind.[2] - 48))
    + (100000000*(int of char ind.[3] - 48))
    + (1000000*(int of char ind.[4] - 48))
    + (100000*(int of char ind.[5] - 48))
    + (10000*(int of char ind.[6] - 48))
    + (1000*(int of char ind.[7] - 48))
    + (100*(int of char ind.[8] - 48))
    + (10*(int of char ind.[9] - 48))
    + ((int of char ind.[10] - 48)) )

    | ' [' '0' '–' '9'] ['0' '–' '9'] ['0' '–' '9'] ['0' '–' '9'] ['0' '–' '9'] ['0' '–' '9'] ['0' '–' '9'] ['0' '–' '9'] ['0' '–' '9'] ['0' '–' '9'] ['0' '–' '9'] ['0' '–' '9']
    }

| as ind

{ IND( (10000000000*(int of char ind.[1] - 48))
    + (1000000000*(int of char ind.[2] - 48))
    + (100000000*(int of char ind.[3] - 48))
    + (10000000*(int of char ind.[4] - 48))
    + (1000000*(int of char ind.[5] - 48))
    + (1000000*(int of char ind.[6] - 48))
    + (1000000*(int of char ind.[7] - 48))
    + (1000000*(int of char ind.[8] - 48))
    + (1000000*(int of char ind.[9] - 48))
    + (1000000*(int of char ind.[10] - 48))
    + ((int of char ind.[11] - 48)) )

| eof { EOF }

Listing 13: ast.mli

type operator = Add | Sub | Mul | Shiftr | Shiftl

type expr =
    Lit of string
    | Bits of string (* binary string *)
    | AsnRoot of string * expr
    | AsnObj of string * string * expr
    | IdenRoot of string
    | IdenObj of string * string
    | Binop of expr * operator * expr
    | Exprseq of expr * expr

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type objdecl =
    Objdeclseq of string * objdecl * objdecl
| Objmap of string * objdecl
| Indices of int
| Indseq of int * objdecl

type statement =
    Binmap of string * objdecl
| Expr of expr
| Stmtseq of statement * statement
| Print of string * string
| Printvar of string
| Ifthen of expr * expr * statement * statement
| Repeat of statement * expr * expr

(*
| objdecl SEMI objdecl          { Objdeclseq($1,$3) }

| expr SEMI expr                { Seq($1, $3) }
| INPUT expr SEMI INPUT expr    { Seq($2, $5) }
| expr SEMI                     { Expr($1) }
| INPUT expr SEMI               { Expr($2) }

| Seq of expr * expr
| Expr of expr
| Binop of expr * operator * expr
Listing 14: parser.mly

%
{
open Ast %
}

%token PLUS MINUS TIMES SEMI ASSIGN INPUT EOF LP RP PERIOD BINMAP LCB RCB SHIFTR SHIFTL PRINT EQU I F THEN ELSE REPEAT UNTIL
%token <int> LITERAL IND VARIABLE
%token <string> ID BITS DEC

%left SEMI
%right ASSIGN INPUT
%left PLUS MINUS
%left TIMES DIVIDE

%start statement
%type < Ast.statement> statement
%type < Ast.objdecl> objdecl
%type < Ast.expr> expr

%%
statement:
  BINMAP ID LCB objdecl RCB { Binmap ($2, $4) }
  | expr ({$1}) }
  | statement statement { Stmtseq ($1, $2) }
  | PRINT ID ID SEMI { Print ($2, $3) }
  | PRINT ID SEMI { Printvar ($2) }
  | IF LP expr EQU expr RP THEN
    | statement statement { Ifthen ($3, $5, $9, $13) }
    ELSE LP statement RP}
  | REPEAT LP statement RP
    | UNTIL LP expr EQU expr RP { Repeat ($3, $7, $9) }

objdecl:
  ID ASSIGN objdecl SEMI { Objmap($1,$3) }
  |
  ID ASSIGN objdecl SEMI objdecl { Objdeclseq($1,$3,$5) }
  | IND { Indices($1) }
  | IND objdecl { Indseq($1,$2) }

expr:
  | BITS { Bits($1) }
  | DEC { Lit($1) }
  | ID ASSIGN expr SEMI { AsnRoot($1,$3) }
  | ID PERIOD ID ASSIGN expr SEMI { AsnObj($1,$3,$5) }
  | ID { IdenRoot($1) }
  | ID PERIOD ID { IdenObj($1,$3) }
  | expr PLUS expr , $3) } { Binop($1, Add , $3) }
  | expr MINUS expr , $3) } { Binop($1, Sub , $3) }
  | expr TIMES expr , $3) } { Binop($1, Mul , $3) }
  | expr SHIFTR expr { Binop($1, Shiftr , $3) }
  | expr SHIFTL expr { Binop($1, Shiftl , $3) }
open Ast
(* TITLE: THE PRECOMPILER *)
(* AUTHOR: PETER BURROWS *)
(* DATE: 7/2/15 *)

(*================= THE ENVIRONMENT =============*)

module NameMap = Map.Make(struct
type t = string
  let compare x y = Pervasives.compare x y
end)

let binmap = NameMap.empty;;

let objects = NameMap.empty;;

(*
-----------------------------------------------
NOTE: binmap takes the following module form ->
   (string [variables] * module [objects])

NOTE: objects take the following tuple form ->
   (string [object], (int [value] * int array [bit
   indices]))

----------------------------------------------- *)

(* Creating/Updating the environment: *)

(* Initialize mapUpdate:
  - Note: this is a place holder for other global functions to
    initialize
  - mapUpdate is defined later *)

let mapUpdate = (fun var obj tuplVal map ->
    if (NameMap.mem var map) then
        let objects = NameMap.find var map in
        let objects = NameMap.add obj tuplVal objects in
        let map = NameMap.add var objects map in
    map

Listing 15: blooRTLs.ml
else
    let objects = NameMap.add obj tuplVal objects
    in
    let map = NameMap.add var objects map in map);

(* Subfunctions to retrieve the value and bit indices of an object *)
let gettuple = (fun var obj map -> NameMap.find obj (NameMap.find var map) );;
let getIntVal = (fun (w,x,y,z) -> w);;
let getBitIndices = (fun (w,x,y,z) -> x);;
let getBinlist = (fun (w,x,y,z) -> y);;
let getSpecialvar = (fun (w,x,y,z) -> z);;

(* -----------------------------updateBinlist--------------------------------------*)
(* Update object 'a' given the new value of new object 'newb' and output the new 'a' *)
let getInd = (fun (x,y) -> x);;
let getBit = (fun (x,y) -> y);;

let rec comp a b inc =
    match a with
    | [] -> []
    | hd::tl ->
      if ( (getInd (hd)) = (getInd (List.nth b inc) ) )
      then (List.nth b inc) :: comp tl b (inc) else (hd)::
              comp tl b (inc) ; ;

let rec compall a b inc =
    if inc > -1 then compall (comp a b inc) b (inc-1) else a;;

let updateBinlist a newb =
    compall a newb ( (List.length newb) - 1) ; ;

(* ------------------------lists2tuplelist--------------------------------------*)
(* Merge the binary indices list and binary list to a combined tuple list*
  i.e. [1;2;3] [4;5;6] -> [(1,4);(2,5);(3,6)] *)
(* NOTE: l1 and l2 must be the same length *)
let rec lists2tuplelist l1 l2 =
match l1 with
  | [] -> []
  | hd::tl -> (hd,List.hd l2):: lists2tuplelist tl (List.tl l2);

(* ------------------------------- tuplelist2list ---------------------------------
(* Convert the tuple lists to lists *)
let rec tuplelist2list l ind =
  match l with
  | [] -> []
  | hd::tl -> if ind = 0 then (fun (x,y) -> x) hd ::
              tuplelist2list tl ind
         else if ind = 1 then (fun (x,y) -> y)
                hd :: tuplelist2list tl ind
         else [];;

(* ============================== TYPE CONVERSIONS =================================
(* ===== binstr2binlist: Convert binary string to binary int list: 
   i.e. "110010" -> [1;1;0;0;1;0]

let binstr2binlist s =
  let str2charlist s =
      let rec exp i l =
          if i < 0 then l else exp (i - 1) (s.[i] :: l) in
      exp (String.length s - 1) [] in
    List.map (fun a -> (int_of_char a) - 48) (str2charlist s);;

(* ===== binlist2int : Convert binary int list to integer: 
   i.e. [1;0;0;0] -> 8

let binlist2int binlist =
  let converted_binlist = List.map float_of_int binlist in
  let helper converted_binlist =
      let rec eval i = function
          | [] -> []
          | hd::tl -> if i < 0. then tl else (hd *. 2. ** i) :: eval (i
            -. 1.) tl in
      eval (float_of_int(List.length converted_binlist - 1))
  converted_binlist in
int_of_float (List.fold_left (fun s e -> s +. e) 0. (helper converted_binlist)) ;

(* ====== int2binlist: Convert int to a binary list

i.e. 18 -> [1;0;0;1;0]

let int2binlist intVal =
let intVal = float_of_int intVal in
let rec eval l intVal =
    let quot = (intVal) /. 2. in
    let flquot = floor(quot) in
    let r = 2. *. (quot -. flquot) in
    if quot < 1. then r::l else r::eval l flquot in
let l = eval [] intVal in
List.map int_of_float l ;;

(* =============== END OF TYPE CONVERSIONS
===================================*)

(* ========= CONSTRUCTED SHIFT OPERATORS *)
(* ====== shiftR: i.e shiftR [1;1;1] 1 -> [0;1;1] *)
let shiftR l byX =
let rec helper fill l byX =
    match l with
    [] -> fill
    | hd::tl ->
        if (byX > 0) then (helper (0::fill) tl (byX-1))
        else
            fill@(List.rev(l)) in
helper [] (List.rev(l)) byX;;

(* ====== shiftL: i.e shiftL [1;1;1] 1 -> [1;1;0] *)
let shiftL l byX =
let rec helper fill l byX =
    match l with
    [] -> fill
    | hd::tl ->
        if (byX > 0) then (helper (0::fill) tl (byX-1))
        else
            (1)@fill in
helper [] (1) byX;;

(* ------------------------- mapUpdate -------------------------*)
exception Failure of string;;

(* ===== updater : *)
- the final subfunction executed by mapUpdate
- updater updates the values of all objects within a root variable,
given a change in the root variable, or one of the objects *)

(* ===== gettuplelist - retrieves the indices and binary list from the environment *)
let gettuplelist var obj map =
lists2tuplelist
(getBitIndices (gettuple var obj map)) (getBinlist (gettuple var obj map));;

(* ===== updaterhelper: subfunction called within updater *)
let rec updaterhelper var newObj objNames map =
match objNames with
[] -> map
| hd::tl -> let old = gettuplelist var hd map in
  let old = updateBinlist old newObj in
  let map = mapUpdate var hd
  (binlist2int (tuplelist2list old 1),
  (tuplelist2list old 0),
  (tuplelist2list old 1),
  (getSpecialvar (gettuple var hd map))
  )
  map in updaterhelper var newObj tl map;;

(* ===== updater *)
let updater var newObj map =
updaterhelper var newObj (List.rev (NameMap.fold (fun s c out ->
  s::out)
  (NameMap. find var map) []) map;;
let check var obj tuplVal map =

(* general check to make sure that the objects do not use duplicate indices *)
let rec duplicates l =
match l with
[|[] -> []
|hd::tl -> hd::(duplicates (List.filter (fun x -> x <> hd) tl))

let out = duplicates(getBitIndices(tuplVal))
in
if ((List.length out) < (List.length (getBitIndices(tuplVal))))
then (raise (Failure ((var)\"\".(obj)\"\" uses duplicate indices\") ))
else [];

(* general check to make sure that the objects have identical indices *)
if ((obj <> "") && (NameMap.mem var map)) then (if (getBitIndices(gettuple var obj map)) <> (getBitIndices(tuplVal))
then (raise (Failure ((var)\"\".(obj)\"\" overflow\") ))
else [];

if (NameMap.mem obj (NameMap.find var map)) then (if (getBitIndices(gettuple var obj map)) <> (getBitIndices(tuplVal))
then (raise (Failure ((var)\"\".(obj)\"\" changed its previous bounds\") ))
else []
else [];

(* if the variable has already been declared and if it is the root *)
if ((NameMap.mem var map) && (obj = ";") then (if (getBitIndices(gettuple var ";" map)) <> (List.nth (getBitIndices(tuplVal)) 0)
then (raise (Failure ((var)\"\".(obj)\"\" previous bounds\") ))
else []
else [];

(* if the root has already been declared, make sure the new declaration does not exceed its previous value.. *)
if (((NameMap.mem ";" (NameMap.find var map)) && (List.nth (getBitIndices(gettuple var ";" map)) 0) <
(List.nth (getBitIndices(tuplVal)) 0)) then (raise (Failure ((var)\"\".(obj)\"\" overflow\") ))
else []
else [];

(* if the variable has already been declared, make sure the new declaration does not exceed its previous value.. *)
if (((NameMap.mem var map) && (obj = ";") then (if (getBitIndices(gettuple var obj map)) <> (getBitIndices(tuplVal))
then (raise (Failure ((var)\"\".(obj)\"\" overflow\") ))
else []
else [];

(* if the root has already been declared, make sure the new declaration does not exceed its previous value.. *)
if (((NameMap.mem ";" (NameMap.find var map)) && (List.nth (getBitIndices(gettuple var ";" map)) 0) <
(List.nth (getBitIndices(tuplVal)) 0)) then (raise (Failure ((var)\"\".(obj)\"\" overflow\") ))
else []
else [];

(* if the root has already been declared, make sure the new declaration does not exceed its previous value.. *)
if (((NameMap.mem var map) && (obj = ";") then (if (getBitIndices(gettuple var obj map)) <> (getBitIndices(tuplVal))
then (raise (Failure ((var)\"\".(obj)\"\" overflow\") ))
else []
else [];

(* if the root has already been declared, make sure the new declaration does not exceed its previous value.. *)
if (((NameMap.mem ";" (NameMap.find var map)) && (List.nth (getBitIndices(gettuple var ";" map)) 0) <
(List.nth (getBitIndices(tuplVal)) 0)) then (raise (Failure ((var)\"\".(obj)\"\" overflow\") ))
else []
else [];
raise (Failure ((var)"exceeds its previous bounds") )

(* ...else if the new root has less indices than its previous value.. *)
) else if ((NameMap.mem "" (NameMap.find var map)) &&
( (List.nth (getBitIndices (gettuple var "" map)) 0) >
( List.nth (getBitIndices (tuplVal)) 0 ) ) then ( (* do nothing -> the root indices will be reformatted in mapUpdate’s 1st check *)
[]

(* ...else compare new root to existing objects (if any) *)
) else ( let rec outer objname =
match objname with
[ ] -> []
| hd::tl ->
(* compare root to all of the indices of all of the objects *)
let rec compareObjs ind =
if ((ind > -1) && ( (List.nth (getBitIndices (tuplVal)) 0) <
( List.nth (getBitIndices (gettuple var hd map)) ind) ) ) then ( raise (Failure ((hd)"exceeds the bounds of" (var)))
) else if (ind > -1) then ( compareObjs (ind -1)
) else outer tl in
compareObjs ((List.length (getBitIndices (gettuple var hd map))) -1) in
outer (List.rev (NameMap.fold (fun s c out -> s::out) (NameMap.find var map) [])) )

(* if the variable has already been declared and the object is not the root,
 but the root does exist *)
) else if ( (NameMap.mem var map) && ( NameMap.mem "" (NameMap.find var map)) ) then ( let rec compareObj2root newObjIndices =
match newObjIndices with
[ ] -> []
| hd::tl -> if ( hd > (List.nth (getBitIndices (gettuple var "" map)) 0) ) then ( raise ( Failure ((obj)
if the variable has not been declared *)
) else [];;

(* ===== mapUpdateHelper 1: called within mapUpdateHelper0, which is
seen below *)
let rec mapUpdateHelper1 = (fun var obj tuplVal map ->
(* Check the bounds of the new object *)
let _ = check var obj tuplVal map in
if (NameMap.mem var map) then ( 
let objects = NameMap.find var map in
(* If objects exists *)
if (NameMap.mem obj objects) then ( 
(* diff MISMATCH procedure left pads zeros to maintain the
binary array, as needed *)
let diff = ((List.length (getBinlist(NameMap.find obj objects )))
- (List.length (getBinlist(tuplVal)))) in
if (diff < 0) then
  raise (Failure ((var)"."^(obj)""^length mismatch/overflow") )
else if (diff > 0) then ( (* concat based on diff and add
indices *)
  let rec append l n =
  if n = 0 then 1 else 0::append l (n-1) in
  let appended = append (getBinlist(tuplVal)) diff in
  let objects = NameMap.add obj
    (binlist2int(appended),
    (getBitIndices(NameMap.find obj objects)),
    (appended),
    (getSpecialvar(NameMap.find obj objects))
  ) objects in
  let map = NameMap.add var objects map in map
  (* populate the map with the modified object *)
else
  let objects = NameMap.add obj tuplVal objects
)
let map = NameMap.add var objects map in map)

(*) else load a new variable and object/root *)
else ( 
    let objects = NameMap.add obj tuplVal objects in
    let map = NameMap.add var objects map in map)
)

(*) else load a new variable and object/root *)
else ( 
    let objects = NameMap.add obj tuplVal objects in
    let map = NameMap.add var objects map in map)

(* ====== mapUpdateHelper0: first subfunction called by mapUpdate *)
let mapUpdateHelper0 var obj tuplVal map =

(* First Check: *)
- reformat the root variable if its new indices are smaller
  than its previous indices *)
if ( (obj ="") \&\& (NameMap.mem var map) \&\& (NameMap.mem "" (NameMap.
find var map)) \&\&
    ( (List.nth (getBitIndices(gettuple var "" map)) 0) >=
      (List.nth (getBitIndices(tuplVal)) 0) )
  ) then ( (* compare new root indices with the old *)
    let rec compareRootInds newRoot ind =
    match newRoot with
      [ ] \to [ ]
      | hd::tl \to if (hd = (List.nth
        (List.rev(getBitIndices
          (gettuple var "" map
            ))) ind)) then ( compareRootInds tl (ind
            +1)
      ) else ( raise (Failure ((var)ˆ"'
        's indices have
      changed") ) ) in
    compareRootInds (List.rev (getBitIndices(tuplVal))) 0;

  (* then update the map using prior root indices *)

  (mapUpdateHelper1 var obj
    (getIntVal(tuplVal),
      getBitIndices(gettuple var "" map),
      getBinlist(tuplVal),
      s))
getSpecialVar(tuplVal) }
map)

) else mapUpdateHelper1 var obj tuplVal map;;

(* ====== mapUpdate *)
let mapUpdate var obj tuplVal map =
  let map = mapUpdateHelper0 var obj tuplVal map in
  let map = updater var (gettuplelist var obj map) map in
map;;

(* ---------------- END OF mapUpdate ------------------ *)

(* =========== Additional global functions ============ *)

(* ===== mkIndices -> makes an int list given a length
  i.e. mkIndices [4;2;3] (List.length [4;2;3])
  -> [2;1;0] *)
let rec mkIndices l len =
  if (len > -1) then (len :: mkIndices l (len -1))
  else l;;

(* print_list -> used for debugging *)
let rec print_list = function
  [] -> print_endline ""
  | e :: l -> print_int e ;
  if (List.length l = 0) then
    print_string ""
  else print_string ";" ;
  print_list l;;

(* print_string_list -> used for debugging *)
let rec print_string_list = function
  [] -> print_endline ""
  | e :: l -> print_string e ;
  if (List.length l = 0) then
    print_string ""
  else print_string ";" ;
  print_string_list l;;

(* checktotaloperations ->

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Check length of the IR vhdl string list. If too many assignment
operations
(i.e. var := a+b+c), then raise an error *)
let checktotaloperations = (fun appendvhdl ->
  let checktotaloperations =
    if ( (List.length (appendvhdl)) > 8 ) then (  
      let rev = List.rev (appendvhdl) in
      let var = List.hd (rev) in
      let obj = List.hd (List.tl rev) in
      raise (Failure("Too many arithmetic operators assigned to",(var)",".(obj)) )
    ) else [] in checktotaloperations););

(* print -> i.e. print var obj -> prints to screen *)
let print var obj binmap = [];  
  print_endline "\n";
  print_string var; print_string "."; print_string obj;
  print_endline "\=";
  print_string "\tInteger Representation:\t\t";
  print_endline (string_of_int (getIntVal(  
    gettuple var obj binmap)));
  print_string "\tBinary Indices:\t\t\t";
  print_string "\t";
  print_list (getBitIndices(gettuple var obj binmap));
  print_string "\tBinary Representation:\t\t";
  print_string "\t";
  print_list (getBinlist(gettuple var obj binmap)));
  (*print_string "\tType (In/Out/Signal):\t\t";
  print_endline (string_of_int (getSpecialvar(  
    gettuple var obj binmap)));*)
  print_endline "\n";;

(* ================ END OF Additional global functions
 ===============*)

(* INITIALIZE THE VHDL IR FOR EVALUATION *)
print_string "\n--------------------------\blooRTLS--
--------------------------\n";;
let vhdl = NameMap.empty;;
let vhdlcount = "0";;
let vhdl = NameMap.add vhdlcount ("":[]) vhdl;;
let increment = (function count -> string_of_int((int_of_string count) + 1));

(* -------------------------------------------------------------- *)
(* })
(* ----------------------------------------------------------------*)
(* ----------------------------------------------------------------*)
(* *)
(* ========= evaluates BINMAP statements *)
let rec evalBinmap var obj indices binmap = (function
Objdeclseq(obj,decl1,decl2) -> ( (*print_string "\nObjdeclseq(
    obj,decl1,decl2) ->"; *)
    let var, obj, indices, binmap = evalBinmap var obj indices
    binmap decl1 in
    let var, obj, indices, binmap = evalBinmap var obj indices
    decl2 in
    var, obj, indices, binmap )
| Objmap(obj,decl) -> ( (*print_string "\nObjmap(obj,decl) -> "; *)
    let var, obj, indices, binmap = evalBinmap var obj indices
    binmap decl in
    var, obj, indices, binmap )
| Indseq(ind,decl) -> ( (*print_string "\n\tIndexSeq(i,decl) -> "; *)
    let var, obj, indices, binmap = evalBinmap var obj (ind::
    indices) binmap decl in
    var, obj, indices, binmap )
| Indices(ind) -> ( (* print_string "Index(i) -> "; *)
    let ind = ind::indices in
    let dummybits = List.map (fun x -> x-x) ind in
    let tupl = (0,List.rev(ind),dummybits,0) in
    ( (* if the variable already exits... *)
    if ((NameMap.mem var binmap) &&
        (NameMap.mem "" ((NameMap.find var binmap))))
    then ( (* retrieve all values from the root variable... *)
        let originaltupl = gettuple var "" binmap in
        (* then, update the new object indices to the map... *)
        let binmap = mapUpdate var obj tupl binmap in
    )

(* ----------------------------------------------------------------*)
(* ----------------------------------------------------------------*)
(* ----------------------------------------------------------------*)
let binmap = mapUpdate var "" originaltupl binmap in

let rec eval var obj binmap vhdl vhdlcount = (function

case: (* all types return (tuplVal, map) *)

| Bits(b) -> ( (* print_string "LoadBits(b) -> ";* )
  let binlist = binstr2binlist b in
  let x = binlist2int binlist in
  let bitIndices = mkIndices [] ((String.length b)−1) in
  let appendvhdl = NameMap.find vhdlcount vhdl in
  let appendvhdl = b::"BITS"::appendvhdl in
  let vhdl = NameMap.add vhdlcount appendvhdl vhdl in
  (var, obj, vhdl, vhdlcount, (x, bitIndices, binlist, −1), binmap ) )

| Lit(x) -> ( (* print_string "LoadInt(i) -> ";* )
  (* convert [’0’− ’9’]+’d’ to integer *)
  let intx =
  let removeD s =
    let rec helper s i out =
      if ( i < 0 ) then ( out )
    else ( helper s (i−1) (out + ( int_of_char s.[i]) − 48)*
      int_of_float(10.**(float_of_int(((
      String.length s) − 2) − i)))) ) in

  )

  (* finally, restore original values of the root to the map *)
  let binmap = mapUpdate var "" originaltupl binmap in

  (* return: *)
  var, obj, indices, binmap

  (* otherwise, initialize the object loading the dummy bit values *)
  ) else ( let binmap = mapUpdate var obj tupl binmap in

  (* return: *)
  var, obj, indices, binmap ) )

(* ==== evaluates Arithmetic Expressions/Assignments *)
helper s (((String.length s) - 2)) 0 in
removeD x in

(* APPEND VHDL *)
let appendvhdl = NameMap.find vhdlcount vhdl in
let appendvhdl = (string_of_int intx)::"INT"::
appendvhdl in
let vhdl = NameMap.add vhdlcount appendvhdl vhdl in

(* return the tupl and binmap *)
var, obj, vhdl, vhdlcount, (intx, [], (int2binlist intx), -1), binmap)

| IdenRoot(var) -> ( (*print_string "IdenRoot(var) -> "; *)

    if ( (NameMap.mem var binmap) && (NameMap.mem "" (NameMap.find
    var binmap)) ) then ( 
        let newintVal = getintVal (gettuple var "" binmap) in
        let newBitIndices = getBitIndices (gettuple var "" binmap) in
        let newBinlist = getBinlist (gettuple var "" binmap) in
        let newSpecialVar = getSpecialvar (gettuple var "" binmap) in

        (* APPEND VHDL *)
        let appendvhdl = NameMap.find vhdlcount vhdl in
        let appendvhdl = ""::var::appendvhdl in
        let vhdl = NameMap.add vhdlcount appendvhdl vhdl in

        var, obj, vhdl, vhdlcount, (newintVal, newBitIndices, newBinlist,
        newSpecialVar), binmap
    (* if iden not found, then raise an error! *)
    ) else (raise (Failure ((var)"_has_no_value"))) )

| IdenObj(var, obj) -> ( (*print_string "IdenObj(var, obj) -> "; *)

    if ( (NameMap.mem var binmap) && (NameMap.mem obj (NameMap.find
    var binmap)) ) then ( 
        let newintVal = getintVal (gettuple var obj binmap) in
        let newBitIndices = getBitIndices (gettuple var obj
        binmap) in
        let newBinlist = getBinlist (gettuple var obj binmap)
        in
        let newSpecialVar = getSpecialvar (gettuple var obj
        binmap) in

            39
let appendvhdl = NameMap.find vhdlcount vhdl in
let appendvhdl = obj::var::appendvhdl in
let vhdl = NameMap.add vhdlcount appendvhdl vhdl in

var, obj, vhdl,vhdlcount,(newintVal,newBitIndices,newBinlist,newSpecialVar), binmap

(* if iden not found, then raise an error! *)
) else (raise (Failure ((var)".""(obj)""_has_no_value")))

| AsnRoot(var,e) -> ( (* Retrieve the root variable *)
  let asnvar = var in
  let asnobj = "" in

  (* APPEND PREVIOUS VHDL LINE *)
  let appendvhdl = NameMap.find vhdlcount vhdl in
  let appendvhdl = ";"::appendvhdl in
  (* Check length of of the string list! If too many operations
   (i.e. var := a+b+c), then raise an error!!
   let checklen = checktotaloperations appendvhdl in *)

  let vhdl = NameMap.add vhdlcount appendvhdl vhdl in
  (* Used for debugging
   print_string "\n\t+ IR LINE "; print_string vhdlcount;
   print_string ";";
   print_string_list (List.rev (NameMap.find vhdlcount vhdl));

   print_string "\nAsnRoot (var,exp) -> ";*)

  (* BEGIN APPENDING A NEW VHDL LINE *)
  (* first increment the vhdl line counter *)
  let vhdlcount = increment vhdlcount in
  let appendvhdl = "<="::"":var::[] in
    let vhdl = NameMap.add vhdlcount appendvhdl vhdl in

  let var, obj, vhdl,vhdlcount, tupl_rx,binmap = eval asnvar
    asnobj binmap vhdl vhdlcount e in
let newbitIndices =
    (* get the bit indices from the map if they exist *)
    if ( (NameMap.mem var binmap) & &
         (NameMap.mem "" (NameMap.find var binmap)) )
    then ( getBitIndices(gettuple var "$" binmap)
    (* if no indices list exists, make a list *)
    )
    else ( mkIndices [] (List.length (getBinlist(tupl_rx))−1) )
    in

    (* making the new tupl (slightly different than in the AsnObj
    procedure) *)
    let newtupl =
        ((getintVal(tupl_rx)), (newbitIndices), getBinlist(tupl_rx), 0)
    in

    (* NEED TO INDICATE WHETHER OR NOT THE ROOT IS A SPECIAL VAR?
    *)
    (* update the binmap with the new variable and tuple *)
    let binmap = mapUpdate var "$" newtupl binmap in

    (* return*)
    var, obj, vhdl, vhdlcount, newtupl, binmap)

| AsnObj(var, obj, e) -> (  

    (* APPEND PREVIOUS VHDL LINE *)
    let appendvhdl = NameMap.find vhdlcount vhdl in
    let appendvhdl = ""::appendvhdl in

    (* Check length of of the string list! If too many
    operations
    (i.e. var := a+b+c), then raise an error!!
    let checklen = checktotaloperations appendvhdl
    in *)

    let vhdl = NameMap.add vhdlcount appendvhdl vhdl in
    (* Used for debugging *)
    (*
    print_string "\n\tIR LINE "; print_string vhdlcount;
    print_string " : [";
    print_string_list (List.rev (NameMap.find vhdlcount
    vhdl));")

    (* print_string "\nAsnObj(var, obj, exp) -> ";*)
    (* BEGIN APPENDING A NEW VHDL LINE *)
    (* first increment the vhdl line counter *)
let vhdlcount = increment vhdlcount in
let appendvhdl = "<="::obj::var::[] in
    let vhdl = NameMap.add vhdlcount appendvhdl vhdl in

let var, obj, vhdl, vhdlcount, tupl_rx, binmap = eval var obj binmap vhdl vhdlcount e in

let newbitIndices =
    (* get the bit indices from the map *)
    if ( (NameMap.mem var binmap) &&
        (NameMap.mem obj (NameMap.find var binmap)) )
    then (getBitIndices(gettuple var obj binmap))
    (* if no indices list exists, throw failure *)
else (raise (Failure ((var)^"."^(obj)^"has not been declared"))) in

(* NOTE: NEED TO CONVERT ID INT TO BINLIST BEFORE UPDATING!
       OTHERWISE OVERFLOW!! *)
let newintVal = getIntVal (tupl_rx) in
let newBinlist = int2binlist newintVal
let newtupl = (newintVal,(newbitIndices),newBinlist,0) in

(* update the binmap with the new variable and tuple *)
let binmap = mapUpdate var obj newtupl binmap in

(* return *)
var, obj, vhdl, vhdlcount, newtupl, binmap)

| Binop(e1, op, e2) -> ( (* print_endline \nBinop(e1,op,e2) -> "; *

    (* Retrieve the length of the variable and object being assigned *)
    let asnvar = var in
    let asnobj = obj in

    (* print_endline "VAR"; print_endline var; print_endline obj; *)

    let var1, obj1, vhdl, vhdlcount, rxtupl1, binmap = eval var obj binmap vhdl vhdlcount e1 in
let var2, obj2, vhdl, vhdlcount, rxtupl2, binmap = eval var obj binmap vhdl vhdlcount e2 in

let newintVal = match op with
  (* check lengths before executing the operation *)
  Add -> ( getIntVal(rxtupl1) + getIntVal(rxtupl2) )
  | Mul -> ( getIntVal(rxtupl1) * getIntVal(rxtupl2) )
  | Sub -> ( let checksub = if (getIntVal(rxtupl1) < getIntVal(rxtupl2) )
  then ( raise (Failure ((var)^"."^(obj)^"_subtraction_underflow"))
  ) else ( getIntVal(rxtupl1) - getIntVal(rxtupl2) ) in checksub
  )
  | Shiftr -> ( let shiftedVal = shiftR (getBinlist(rxtupl1)) ( getIntVal(rxtupl2) )
  ( binlist2int shiftedVal )
  )
  | Shifl -> ( let shiftedVal = shiftL (getBinlist(rxtupl1)) ( getIntVal(rxtupl2) )
  in
  ( binlist2int shiftedVal)
  )
  |
  Exprseq(e1, e2) ->( (* print_string "\nExprseq(exp1,exp2) -> "; *)
  let var, obj, vhdl,vhdlcount, tupl_rx, binmap = eval var obj
  binmap vhdl vhdlcount e1 in
  let var, obj, vhdl,vhdlcount, tupl_rx, binmap = eval var obj
  binmap vhdl vhdlcount e2 in
  var, obj, vhdl,vhdlcount, tupl_rx, binmap )
)
(* Reads in the statements from the input text and handles them accordingly *)

let rec evalstatements var obj tuplr x binmap vhdl vhdlcount = (function
  Binmap(var, objdecl) -> (!*)
    let var, obj, indices, binmap = evalBinmap var "" [] binmap
    objdecl in
    var, obj, tuplr x, vhdl, binmap )

|  Expr(e) -> (!*)
  let var, obj, vhdl, vhdlcount, tuplr x, binmap = eval var
  obj binmap vhdl vhdlcount e in

(*) APPEND PREVIOUS VHDL LINE *)
let appendvhdl = NameMap.find vhdlcount vhdl in
let appendvhdl = ";" :: appendvhdl in

(* Check length of the string list! If too many operations
  (i.e. var := a+b+c), then raise an error!!
  let checklen = checktotaloperations appendvhdl in *)
let vhdl = NameMap.add vhdlcount appendvhdl vhdl in

(* Used for debugging *)
(* print_string "\n\n\nt+ IR LINE "; print_string
  vhdlcount; print_string ": [";
print_string_list (List.rev (NameMap.find vhdlcount
  vhdl));
print_endline "\n"; *)

(* Update the binmap with the received tuple *)
let rev = List.rev (appendvhdl) in
let var = List.hd (rev) in
let obj = List.hd (List.tl rev) in
let binmap = mapUpdate var obj tuplr x binmap in

  var, obj, tuplr x, vhdl, binmap )

| Stmtseq(st1, st2) -> (!*)
  let var, obj, tuplr x, vhdl, binmap =
  evalstatements var obj tuplr x binmap vhdl
  vhdlcount st1 in
let var, obj, tuplrx, vhdl, binmap =
evalstatements var obj tuplrx binmap vhdl
vhdlcount st2 in
var, obj, tuplrx, vhdl, binmap)

| Print(var, obj) -> (print var obj binmap;
var, obj, tuplrx, vhdl, binmap)
| Printvar(var) -> (print var " " binmap;
var, obj, tuplrx, vhdl, binmap)

| Ifthen(condition1, condition2, ifstmt, elsestmt) -> (
(* APPEND DUMMY VHDL? *)

let var, obj, vhdl, vhdlcount, tuplrx1, binmap =
eval var obj binmap vhdl vhdlcount condition1 in
let var, obj, vhdl, vhdlcount, tuplrx2, binmap =
eval var obj binmap vhdl vhdlcount condition2 in

let var, obj, tuplrx, vhdl, binmap =
if (getintVal(tuplrx1) = getintVal(tuplrx2)) then (
 evalstatements var obj tuplrx binmap vhdl
 vhdlcount ifstmt
) else (evalstatements var obj tuplrx binmap vhdl
vhdlcount elsestmt) in

var, obj, tuplrx, vhdl, binmap)

| Repeat(repeatstmt, condition1, condition2) -> (

let var, obj, vhdl, vhdlcount, tuplrx1, binmap =
eval var obj binmap vhdl vhdlcount condition1 in
let var, obj, vhdl, vhdlcount, tuplrx2, binmap =
eval var obj binmap vhdl vhdlcount condition2 in

let cond1 = getintVal(tuplrx1) in
let cond2 = getintVal(tuplrx2) in

let binmap =
letrec loop binmap var obj vhdl vhdlcount repeatstmt cond1
cond2 out =

if (cond1 = cond2) then (binmap
) else (}

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let var, obj, tuplrx, vhdl, binmap = evalstatements var obj tuplrx
                        binmap vhdl vhdlcount
                        repeatstmt in

let _, _, _, _, tuplrx2, _ =
                        eval var obj binmap vhdl
                        vhdlcount condition1 in

let _, _, _, _, tuplrx1, _ =
                        eval var obj binmap vhdl
                        vhdlcount condition2 in

let cond1 = getintVal (tuplrx1) in
let cond2 = getintVal (tuplrx2) in

(* let intUpdate = getintVal (gettuple var obj binmap) *)
let intUpdate = getintVal (tuplrx) in

print_string "\nVAL var:\t";
print_int (getintVal (gettuple "var"
                        "" binmap ));

print_string "\nVAL var2:\t";
print_int (intUpdate);

(* check binary map *)
let binmap = mapUpdate var obj tuplrx
                        binmap in*)

loop binmap var obj vhdl (increment vhdlcount) repeatstmt cond1 cond2 out ) in
loop binmap var obj vhdl vhdlcount repeatstmt cond1
                        cond2 [] in

var, obj, tuplrx, vhdl, binmap
)
)

let _ =
let lexbuf = Lexing.from_channel stdin in
let statement = Parser.statement Scanner.token lexbuf in

let var, obj, tuplrx, vhdl, binmap = evalstatements "" "" (0,[],[],0) binmap vhdl vhdlcount
  statement in
let var = "var1" in
let obj = "" in []