Verilog Size Checking

Path

Definition of paths and their relation to sub-expressions.

Expressions

- $\mathcal{A}$ is the set of atoms in an expression. In the AST, they correspond to leaves. In System-Verilog, they refer to what the standard calls an "operand" (variables, integers, function calls, slices of a variable, etc.).
- $\mathcal{R}$ is the set of resizable expressions. It corresponds to the expression whose top level is one of: atom, cast, comparisons, logic operation, reduction, assignments, shift assignments, concatenation, replication and inside operation.
- $\mathcal{E}$ is the set of System-Verilog expressions. We have $\mathcal{A} \subset \mathcal{E}$. An expression either contains an expression or is an atom.

Rules

We use the following notations:

- Γ maps atoms to their size,
- Φ maps lvalues to their size,
- The statement $e \Rightarrow t \dashv f$ means "e has size t, with f mapping each sub-expressions of e to their size",
- The statement $e \Leftarrow t \dashv f$ means "e can be resized to t, with f mapping each sub-expressions of e to their size".

Function combinator

$$\text{Binary}(t, f, g) : \begin{cases} [] & \mapsto & t \\ \text{Left} :: p & \mapsto & f(p) \\ \text{Right} :: p & \mapsto & g(p) \end{cases} \qquad \text{Unary}(f, t) : \begin{cases} [] & \mapsto & t \\ \text{Arg} :: p & \mapsto & f(p) \end{cases}$$

$$\text{Narry}(t, f_1, \ldots, f_k) : \begin{cases} [] & \mapsto & t \\ \text{Args}(i) :: p & \mapsto & f_i(p) \end{cases} \qquad \text{Ternary}(t, f, g, h) : \begin{cases} [] & \mapsto & t \\ \text{Arg} :: p & \mapsto & f(p) \\ \text{Left} :: p & \mapsto & g(p) \\ \text{Right} :: p & \mapsto & h(p) \end{cases}$$

Base case

$$\frac{\Gamma(e) = s \qquad e \in \mathcal{A}}{e \Rightarrow s \dashv \{[] \mapsto s\}} \text{ Atom}{\Rightarrow}$$

Resize case

$$\frac{e \Rightarrow s \dashv f \qquad s \leqslant t \qquad e \in \mathcal{R}}{e \Leftarrow t \dashv f\left[[] \mapsto t\right]} \text{ Resize}{\Leftarrow}$$

Operators

- $\oplus \in \{\texttt{+}, \texttt{-}, \texttt{*}, \texttt{/}, \texttt{\%}, \texttt{\&}, \texttt{|}, \texttt{\^{}}, \texttt{\^{}\~{}}, \texttt{\~{}\^{}}\}$:

$$\frac{a \Rightarrow t \dashv f_a \qquad b \Leftarrow t \dashv f_b}{a \oplus b \Rightarrow t \dashv \text{Binary}(t, f_a, f_b)} \text{ LBinOp}{\Rightarrow} \qquad \frac{a \Leftarrow t \dashv f_a \qquad b \Rightarrow t \dashv f_b}{a \oplus b \Rightarrow t \dashv \text{Binary}(t, f_a, f_b)} \text{ RBinOp}{\Rightarrow}$$

$$\frac{a \Leftarrow t \dashv f_a \qquad b \Leftarrow t \dashv f_b}{a \oplus b \Leftarrow t \dashv \text{Binary}(t, f_a, f_b)} \text{ BinOp}{\Leftarrow}$$

- $\oplus \in \{\texttt{+}, \texttt{-}, \texttt{++}, \texttt{--}, \texttt{\~{}}\}$:

$$\frac{e \Rightarrow t \dashv f}{\oplus e \Rightarrow t \dashv \text{Unary}(t, f)} \text{ UnOp}{\Rightarrow} \qquad \frac{e \Leftarrow t \dashv f}{\oplus e \Leftarrow t \dashv \text{Unary}(t, f)} \text{ UnOp}{\Leftarrow}$$

- $\oplus \in \{\texttt{\$signed}, \texttt{\$unsigned}\}$:

$$\frac{e \Rightarrow t \dashv f}{\oplus(e) \Rightarrow t \dashv \text{Unary}(t, f)}\ \text{Cast}{\Rightarrow}$$

- $\oplus \in \{\texttt{===}, \texttt{!==}, \texttt{==?}, \texttt{!=?}, \texttt{==}, \texttt{!=}, \texttt{>}, \texttt{>=}, \texttt{<}, \texttt{<=}\}$:

$$\frac{a \Rightarrow t \dashv f_a \qquad b \Leftarrow t \dashv f_b}{a \oplus b \Rightarrow 1 \dashv \text{Binary}(1, f_a, f_b)}\ \text{LCmp}{\Rightarrow} \qquad \frac{a \Leftarrow t \dashv f_a \qquad b \Rightarrow t \dashv f_b}{a \oplus b \Rightarrow 1 \dashv \text{Binary}(1, f_a, f_b)}\ \text{RCmp}{\Rightarrow}$$

- $\oplus \in \{\texttt{\&\&}, \texttt{||}, \texttt{->}, \texttt{<->}\}$:

$$\frac{a \Rightarrow t_a \dashv f_a \qquad b \Rightarrow t_b \dashv f_b}{a \oplus b \Rightarrow 1 \dashv \text{Binary}(1, f_a, f_b)}\ \text{Logic}{\Rightarrow}$$

- $\oplus \in \{\texttt{\&}, \texttt{\~{}\&}, \texttt{|}, \texttt{\~{}|}, \texttt{\^{}}, \texttt{\~{}\^{}}, \texttt{\^{}\~{}}, \texttt{!}\}$:

$$\frac{e \Rightarrow t \dashv f}{\oplus e \Rightarrow 1 \dashv \text{Unary}(1, f)}\ \text{Red}{\Rightarrow}$$

- $\oplus \in \{\texttt{>>}, \texttt{<<}, \texttt{**}, \texttt{>>>}, \texttt{<<<}\}$:

$$\frac{a \Rightarrow t \dashv f_a \qquad b \Rightarrow t_b \dashv f_b}{a \oplus b \Rightarrow t \dashv \text{Binary}(t, f_a, f_b)}\ \text{Shift}{\Rightarrow} \qquad \frac{a \Leftarrow t \dashv f_a \qquad b \Rightarrow t_b \dashv f_b}{a \oplus b \Leftarrow t \dashv \text{Binary}(t, f_a, f_b)}\ \text{Shift}{\Leftarrow}$$

- $\oplus \in \{\texttt{=}, \texttt{+=}, \texttt{-=}, \texttt{*=}, \texttt{/=}, \texttt{\%=}, \texttt{\&=}, \texttt{|=}, \texttt{\^{}=}\}$:

$$\frac{\phi(l) = t \qquad e \Leftarrow t \dashv f}{l \oplus e \Rightarrow t \dashv \text{Unary}(t, f)}\ \text{LAssign}{\Rightarrow} \qquad \frac{\phi(l) = t \qquad e \Rightarrow t_e \dashv f \qquad t < t_e}{l \oplus e \Rightarrow t \dashv \text{Unary}(t, f)}\ \text{RAssign}{\Rightarrow}$$

- $\oplus \in \{\texttt{<<=}, \texttt{>>=}, \texttt{<<<=}, \texttt{>>>=}\}$:

$$\frac{\phi(l) = t \qquad e \Rightarrow t_e \dashv f}{l \oplus e \Rightarrow t \dashv \text{Unary}(t, f)}\ \text{AssignShift}{\Rightarrow}$$

- If expression:

$$\frac{e \Rightarrow t_e \dashv f_e \qquad a \Rightarrow t \dashv f_a \qquad b \Leftarrow t \dashv f_b}{e?a\!:\!b \Rightarrow t \dashv \text{Ternary}(t, f_e, f_a, f_b)}\ \text{LCond}{\Rightarrow} \qquad \frac{e \Rightarrow t_e \dashv f_e \qquad a \Leftarrow t \dashv f_a \qquad b \Rightarrow t \dashv f_b}{e?a\!:\!b \Rightarrow t \dashv \text{Ternary}(t, f_e, f_a, f_b)}\ \text{RCond}{\Rightarrow}$$

$$\frac{e \Rightarrow t_e \dashv f_e \qquad a \Leftarrow t \dashv f_a \qquad b \Leftarrow t \dashv f_b}{e?a\!:\!b \Leftarrow t \dashv \text{Ternary}(t, f_e, f_a, f_b)}\ \text{Cond}{\Leftarrow}$$

- Concatenation:

$$\frac{e_1 \Rightarrow t_1 \dashv f_i \qquad \ldots \qquad e_k \Rightarrow t_k \dashv f_k \qquad t = t_1 + \cdots + t_k}{\{e_1, \ldots, e_k\} \Rightarrow t \dashv \text{Narry}(t, f_1, \ldots, f_k)}\ \text{Concat}{\Rightarrow}$$

- Replication:

$$\frac{i \in \mathbb{N} \qquad e \Rightarrow t_e \dashv f \qquad t = i \times t_e}{\{i\ e\} \Rightarrow t \dashv \text{Unary}(t, f)}\ \text{Repl}{\Rightarrow}$$