Verilog Size Checking

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.).
- $\mathcal{E}$ is the set of System-Verilog expressions. We have $\mathcal{A} \subset \mathcal{E}$. An expression either contains an expression or is an atom.

Contexts

- Set of contexts identifiers: $\mathcal{C} \simeq \mathbb{N}$.
- A context $q \subseteq \mathcal{Q}$ with:

$$\mathcal{Q} \coloneqq \underbrace{\{\text{Size}\, s \mid s \in \mathbb{N}\}}_{\text{Atomic size}} \sqcup \underbrace{\{\text{Id}\, c \mid c \in \mathcal{C}\}}_{\text{Identity dependencies}} \sqcup \underbrace{\{\text{Add}\,(c_1, c_2) \mid c_1 \in \mathcal{C}, c_2 \in \mathcal{C}\}}_{\text{Additive dependencies}} \sqcup \underbrace{\{\text{Mul}\,(s, c) \mid c \in \mathcal{C}, s \in \mathbb{N}\}}_{\text{Multiplicative dependencies}}$$

  A context represent all the information needed to compute the size of associated expressions.

- $\Pi : \mathcal{C} \rightharpoonup 2^{\mathcal{Q}}$ a partial mapping from context identifiers to the smallest possible context set. This means that:

$$\Pi(c) \subset \Pi'(c) \implies \Pi(c) = \Pi'(c)$$

Rules

The statement $\Pi \vdash e : c$ means:

In the context environment Π, all the information needed to compute the size of the expression e is in the context-set identified by c in Π.

We use the following notations:

- Γ compute the size of an atom.
- Φ compute the size of a lvalue.

Base case

$$\frac{s = \Gamma(e) \qquad \Pi = \{c \mapsto q\} \qquad \text{Size}\, s \in q \qquad e \in \mathcal{A}}{\Pi \vdash e : c}$$

Operators

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

$$\frac{\Pi \vdash a : c \qquad \Pi \vdash b : c}{\Pi \vdash a \oplus b : c}$$

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

$$\frac{\Pi \vdash e : c}{\Pi \vdash \oplus e : c}$$

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

$$\frac{\Pi' \vdash e : c' \qquad c \notin \text{dom}\, \Pi' \qquad \Pi = \Pi' \sqcup \{c \mapsto q\} \qquad \text{Id}\, c' \in q}{\Pi \vdash \oplus\,(e) : c}$$

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

$$\frac{\Pi' \vdash a : c' \qquad \Pi' \vdash b : c' \qquad c \notin \text{dom}\, \Pi' \qquad \Pi = \Pi' \sqcup \{c \mapsto q\} \qquad \text{Size}\, 1 \in q}{\Pi \vdash a \oplus b : c}$$

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

$$\frac{\Pi_1 \vdash a : c_1 \qquad \Pi_2 \vdash b : c_2 \qquad \text{dom}\, \Pi_1 \cap \text{dom}\, \Pi_2 = \emptyset \qquad c \notin \text{dom}\, \Pi_1 \sqcup \text{dom}\, \Pi_2 \qquad \Pi = \Pi_1 \sqcup \Pi_2 \sqcup \{c \mapsto q\} \qquad \text{Size}\, 1 \in q}{\Pi \vdash a \oplus b : c}$$

- $\oplus \in \{\texttt{\&}, \texttt{\textasciitilde\&}, \texttt{|}, \texttt{\textasciitilde|}, \texttt{\textasciicircum}, \texttt{\textasciitilde\textasciicircum}, \texttt{\textasciicircum\textasciitilde}, \texttt{!}\}$:

$$\frac{\Pi' \vdash a : c' \qquad c \notin \operatorname{dom} \Pi' \qquad \Pi = \Pi' \sqcup \{c \mapsto q\} \qquad \text{Size } 1 \in q}{\Pi \vdash \oplus a : c}$$

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

$$\frac{\Pi_1 \vdash a : c \qquad \Pi_2 \vdash b : c' \qquad \Pi = \Pi_1 \sqcup \Pi_2 \qquad \operatorname{dom} \Pi_1 \cap \operatorname{dom} \Pi_2 = \emptyset}{\Pi \vdash a \oplus b : c}$$

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

$$\frac{s = \Phi(l) \qquad \Pi' \vdash b : c' \qquad \text{Size } s \in \Pi'(c') \qquad c \notin \operatorname{dom} \Pi' \qquad \Pi = \Pi' \sqcup \{c \mapsto q\} \qquad \text{Size } s \in q}{\Pi \vdash l \oplus b : c}$$

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

$$\frac{s = \Phi(l) \qquad \Pi' \vdash b : c' \qquad c \notin \operatorname{dom} \Pi' \qquad \Pi = \Pi' \sqcup \{c \mapsto q\} \qquad \text{Size } s \in q}{\Pi \vdash l \oplus b : c}$$

- If expression:

$$\frac{\Pi_1 \vdash e : c' \qquad \Pi_2 \vdash a : c \qquad \Pi_2 \vdash b : c \qquad \Pi = \Pi_1 \sqcup \Pi_2 \qquad \operatorname{dom} \Pi_1 \cap \operatorname{dom} \Pi_2 = \emptyset}{\Pi \vdash e \texttt{?} a \texttt{:} b : c}$$

- Concatenation:

$$\frac{\Pi_1 \vdash e_1 : c_1 \qquad \Pi_2 \vdash e_2 : c_2 \qquad \operatorname{dom} \Pi_1 \cap \operatorname{dom} \Pi_2 = \emptyset \qquad c \notin \operatorname{dom} \Pi_1 \sqcup \operatorname{dom} \Pi_2 \qquad \Pi = \Pi_1 \sqcup \Pi_2 \sqcup \{c \mapsto q\} \qquad \text{Add } (c_1, c_2) \in q}{\Pi \vdash \texttt{\{}e_1, e_2\texttt{\}} : c}$$

- Replication:

$$\frac{i \in \mathbb{N} \qquad \Pi' \vdash e : c' \qquad c \notin \operatorname{dom} \Pi' \qquad \Pi = \Pi' \sqcup \{c \mapsto q\} \qquad \text{Mul } (i, c') \in q}{\Pi \vdash \texttt{\{}i\ e\texttt{\}} : c}$$