$$
\begin{array}{lll}
\textit{variable},\ x & & \\
\textit{channel},\ ch & & \\
\textit{integer},\ n & & \\
\textit{index},\ i,\ j & & \\
\textit{arith\_expr},\ \ a & ::= & \\
 & | & x \\
 & | & n \\
 & | & a_1 + a_2 \\
 & | & a_1 * a_2 \\
 & & \\
\textit{bool\_expr},\ \ b & ::= & \\
 & | & \mathbf{true} \\
 & | & \mathbf{false} \\
 & | & a_1 \langle a_2 \\
 & & \\
\textit{commands},\ \ c & ::= & \\
 & | & \mathbf{stop} \\
 & | & \mathbf{skip} \\
 & | & x := a \\
 & | & c_1 ; c_2 \\
 & | & \mathbf{if}\ b\ \mathbf{then}\ c_1\ \mathbf{else}\ c_2\ \mathbf{end} \\
 & | & \mathbf{while}\ b\ \mathbf{do}\ c\ \mathbf{end} \\
 & | & \mathbf{read}\ x\ \mathbf{from}\ ch \\
 & | & \mathbf{write}\ x\ \mathbf{to}\ ch \\
 & & \\
\textit{memory},\ \ m & ::= & \\
 & | & \mathbf{empty} \\
 & | & m[x \mapsto n] \\
 & | & m[ch \mapsto n] \\
 & & \\
\textit{output},\ \ o & ::= & \\
 & | & \mathbf{none} \\
 & | & o :: (ch - n) \\
 & & \\
\textit{formula} & ::= & \\
 & | & \textit{judgement} \\
 & | & m(x) = n \\
 & | & m(ch) = n \\
 & | & n_1 + n_2 = n_3 \\
 & | & n_1 * n_2 = n_3 \\
 & | & n_1 \langle n_2 = \ \mathbf{true} \\
 & | & n_1 \langle n_2 = \ \mathbf{false} \\
 & & \\
\textit{terminals} & ::= & \\
 & | & \leftarrow \\
 & | & \vdash \\
 & | & \mapsto \\
 & | & \longrightarrow \\
 & | & \{ \\
 & | & \} \\
 & | & \langle
\end{array}
$$

| $\rangle$

Jop ::=

| $\langle a, m, o\rangle \longrightarrow \langle a', m', o'\rangle$
| $\langle b, m, o\rangle \longrightarrow \langle b', m', o'\rangle$
| $\langle c, m, o\rangle \longrightarrow \langle c', m', o'\rangle$

judgement ::=

| *Jop*

user_syntax ::=

| *variable*
| *channel*
| *integer*
| *index*
| *arith_expr*
| *bool_expr*
| *commands*
| *memory*
| *output*
| *formula*
| *terminals*

$\boxed{\langle a, m, o\rangle \longrightarrow \langle a', m', o'\rangle}$

$$\frac{}{\langle n, m, o\rangle \longrightarrow \langle n, m, o\rangle}\quad \text{AEXP\_INT\_CONSTANT}$$

$$\frac{m(x) = n}{\langle x, m, o\rangle \longrightarrow \langle n, m, o\rangle}\quad \text{AEXP\_LOOKUP}$$

$$\frac{\langle a_1, m, o\rangle \longrightarrow \langle a_1', m, o\rangle}{\langle a_1 + a_2, m, o\rangle \longrightarrow \langle a_1' + a_2, m, o\rangle}\quad \text{AEXP\_ADD\_AEXP\_AEXP}$$

$$\frac{\langle a_2, m, o\rangle \longrightarrow \langle a_2', m, o\rangle}{\langle n_1 + a_2, m, o\rangle \longrightarrow \langle n_1 + n_2, m, o\rangle}\quad \text{AEXP\_ADD\_INT\_AEXP}$$

$$\frac{n_1 + n_2 = n_3}{\langle n_1 + n_2, m, o\rangle \longrightarrow \langle n_3, m, o\rangle}\quad \text{AEXP\_ADD\_INT\_INT}$$

$$\frac{\langle a_1, m, o\rangle \longrightarrow \langle a_1', m, o\rangle}{\langle a_1 * a_2, m, o\rangle \longrightarrow \langle a_1' * a_2, m, o\rangle}\quad \text{AEXP\_MULT\_AEXP\_AEXP}$$

$$\frac{\langle a_2, m, o\rangle \longrightarrow \langle a_2', m, o\rangle}{\langle n_1 * a_2, m, o\rangle \longrightarrow \langle n_1 * n_2, m, o\rangle}\quad \text{AEXP\_MULT\_INT\_AEXP}$$

$$\frac{n_1 * n_2 = n_3}{\langle n_1 * n_2, m, o\rangle \longrightarrow \langle n_3, m, o\rangle}\quad \text{AEXP\_MULT\_INT\_INT}$$

$\boxed{\langle b, m, o\rangle \longrightarrow \langle b', m', o'\rangle}$

$$\frac{\langle a_1, m, o\rangle \longrightarrow \langle a_1', m, o\rangle}{\langle a_1\langle a_2, m, o\rangle \longrightarrow \langle a_1'\langle a_2, m, o\rangle}\quad \text{BEXP\_LT\_AEXP\_AEXP}$$

$$\frac{\langle a_2, m, o\rangle \longrightarrow \langle a_2', m, o\rangle}{\langle n_1\langle a_2, m, o\rangle \longrightarrow \langle n_1\langle n_2, m, o\rangle}\quad \text{BEXP\_LT\_INT\_AEXP}$$

$$\frac{n_1\langle n_2 = \ \textbf{false}}{\langle n_1\langle n_2, m, o\rangle \longrightarrow \langle \textbf{false}, m, o\rangle}\quad \text{BEXP\_LT\_INT\_INT}$$

$$\frac{n_1\langle n_2 = \ \textbf{false}}{\langle n_1\langle n_2, m, o\rangle \longrightarrow \langle \textbf{false}, m, o\rangle}\quad \text{BEXP\_LT\_INT\_INT}$$

$$\boxed{\langle c, m, o\rangle \longrightarrow \langle c', m', o'\rangle}$$

$$\frac{\langle a, m, o\rangle \longrightarrow \langle a', m, o\rangle}{\langle x := a, m, o\rangle \longrightarrow \langle x := a', m, o\rangle}\quad \text{C\_ASSIGN\_AEXP}$$

$$\frac{}{\langle x := n, m, o\rangle \longrightarrow \langle \textbf{stop}, m[x \mapsto n], o\rangle}\quad \text{C\_ASSIGN\_INT}$$

$$\frac{\langle c_1, m, o\rangle \longrightarrow \langle c_1', m', o'\rangle}{\langle c_1; c_2, m, o\rangle \longrightarrow \langle c_1'; c_2, m', o'\rangle}\quad \text{C\_SEQ1}$$

$$\frac{}{\langle \textbf{skip}; c_2, m, o\rangle \longrightarrow \langle c_2, m, o\rangle}\quad \text{C\_SEQ2}$$

$$\frac{\langle b, m, o\rangle \longrightarrow \langle b', m, o\rangle}{\langle \textbf{if}\ b\ \textbf{then}\ c_1\ \textbf{else}\ c_2\ \textbf{end}, m, o\rangle \longrightarrow \langle \textbf{if}\ b'\ \textbf{then}\ c_1\ \textbf{else}\ c_2\ \textbf{end}, m, o\rangle}\quad \text{C\_IF\_EVAL}$$

$$\frac{}{\langle \textbf{if}\ \textbf{true}\ \textbf{then}\ c_1\ \textbf{else}\ c_2\ \textbf{end}, m, o\rangle \longrightarrow \langle c_1, m, o\rangle}\quad \text{C\_IF\_TRUE}$$

$$\frac{}{\langle \textbf{if}\ \textbf{false}\ \textbf{then}\ c_1\ \textbf{else}\ c_2\ \textbf{end}, m, o\rangle \longrightarrow \langle c_2, m, o\rangle}\quad \text{C\_IF\_FALSE}$$

$$\frac{}{\langle \textbf{while}\ b\ \textbf{do}\ c\ \textbf{end}, m, o\rangle \longrightarrow \langle \textbf{if}\ b\ \textbf{then}\ c; \textbf{while}\ b\ \textbf{do}\ c\ \textbf{end}\ \textbf{else}\ \textbf{skip}\ \textbf{end}, m, o\rangle}\quad \text{C\_WHILE}$$

$$\frac{m(ch) = n}{\langle \textbf{read}\ x\ \textbf{from}\ ch, m, o\rangle \longrightarrow \langle \textbf{stop}, m[x \mapsto n], o\rangle}\quad \text{C\_READ}$$

$$\frac{m(x) = n}{\langle \textbf{write}\ x\ \textbf{to}\ ch, m, o\rangle \longrightarrow \langle \textbf{stop}, m[ch \mapsto n], o :: (ch - n)\rangle}\quad \text{C\_WRITE}$$

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Definition rules:        22 good    0 bad
Definition rule clauses: 38 good    0 bad
```