

MACHINE

```

actions      // Abstract model of the C11 operational semantics
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```

SEES

```
c0
```

VARIABLES

```

D
tid
var
rdval
wrval
mo
rf
sb
init
iwr      // initial writes

```

INVARIANTS

```

inv1  :  $D \subseteq \text{EVT}$ 
inv2  :  $\text{tid} \in D \rightarrow T$ 
inv3  :  $\text{var} \in D \rightarrow \text{VAR}$ 
inv4  :  $\text{rdval} \in (D \cap (\text{rd} \cup \text{rdA} \cup \text{upd})) \rightarrow \text{VAL}$ 
inv19 :  $\text{wrval} \in (D \cap (\text{wr} \cup \text{wrR} \cup \text{upd})) \rightarrow \text{VAL}$ 
inv6  :  $\text{mo} \in (D \cap (\text{wr} \cup \text{wrR} \cup \text{upd})) \leftrightarrow (D \cap (\text{wr} \cup \text{wrR} \cup \text{upd}))$ 
inv7  :  $\text{rf} \in (D \cap (\text{wr} \cup \text{wrR} \cup \text{upd})) \leftrightarrow (D \cap (\text{rd} \cup \text{rdA} \cup \text{upd}))$ 
inv8  :  $\text{sb} \in D \leftrightarrow D$ 
inv20 :  $\text{init} \in \text{B00L}$ 
inv21 :  $\text{iwr} \subseteq (D \cap (\text{wr} \cup \text{wrR}))$ 
inv22 :  $\text{init} = \text{FALSE} \Rightarrow D = \emptyset$ 

```

EVENTS

```
INITIALISATION  $\triangleq$ 
```

```
  STATUS
```

```
  ordinary
```

```
BEGIN
```

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act1  :  $D := \emptyset$ 
act2  :  $\text{tid} := \emptyset$ 
act3  :  $\text{var} := \emptyset$ 
act4  :  $\text{rdval} := \emptyset$ 
act17 :  $\text{wrval} := \emptyset$ 
act6  :  $\text{mo} := \emptyset$ 
act7  :  $\text{rf} := \emptyset$ 
act8  :  $\text{sb} := \emptyset$ 
act18 :  $\text{init} := \text{FALSE}$ 
act19 :  $\text{iwr} := \emptyset$ 

```

```
END
```

```
init_t  $\triangleq$ 
```

```
  STATUS
```

```
  ordinary
```

```
ANY
```

```

vars      // initialising variable
vals
wrs       // write events
fvar
ftid
fwrval

```

```
WHERE
```

```

grd1  :  $\text{vars} \subseteq \text{VAR}$ 
grd2  :  $\text{wrs} \subseteq \text{wr}$ 
grd10 :  $\text{vals} \subseteq \text{VAL}$ 
grd5  :  $\text{wrs} \neq \emptyset$ 
grd6  :  $\text{vars} \neq \emptyset$ 
grd7  :  $\text{fvar} \in \text{wrs} \rightarrow \text{vars}$ 
grd8  :  $\text{ftid} \in \text{wrs} \rightarrow T$ 
grd11 :  $\text{fwrval} \in \text{wrs} \rightarrow \text{vals}$ 
grd9  :  $\text{init} = \text{FALSE}$ 

```

```
THEN
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```
act1  :  $\text{var} := \text{fvar}$ 
```

```

act2 : D := wrs
act3 : tid := ftid
act5 : wrval := fwrval
act4 : init := TRUE
act6 : iwr := wrs
END

rd ≐
STATUS
ordinary
ANY
e
t
x
n
w
hb_rfc
eco_rfc
ewt
owt
cw
fr
eco
sw
hb
WHERE
grd1 : e ∈ (rd ∪ rdA) \ D
grd2 : t ∈ T \ {t0}
grd3 : x ∈ VAR
grd19 : w ∈ Dn(wr ∪ wrR ∪ upd)
grd6 : var(w) = x // w ∈ OW(t)
grd7 : wrval(w) = n
grd8 : init = TRUE
grd15 : fr = (rf~;mo)\id
grd16 : eco = cls(mo ∪ rf ∪ fr)
grd17 : sw = rf ∩ ((wrR ∪ upd) × (rdA ∪ upd))
grd18 : hb = cls(sb ∪ sw)
grd9 : hb_rfc = hb ∪ {e0↦e0 | e0 ∈ D}
grd10 : eco_rfc = eco ∪ {e0↦e0 | e0 ∈ D}
grd11 : ewt = {w0 | w0 ∈ (D ∩ (wr ∪ wrR ∪ upd)) ∧ (∃e0·e0 ∈ D ∧ tid(e0)=t ∧ w0↦e0 ∈ (eco_rfc;hb_rfc))}
grd12 : owt = {w0 | w0 ∈ (D ∩ (wr ∪ wrR ∪ upd)) ∧ (∀ww·ww ∈ ewt ⇒ w0↦ww ∈ mo)}
grd13 : cw = {w0 | w0 ∈ (D ∩ (wr ∪ wrR ∪ upd)) ∧ ∃u·u ∈ upd ∧ w0↦u ∈ rf}
grd14 : w ∈ owt
grd4 : n ∈ VAL
THEN
act1 : D := D ∪ {e}
act2 : tid(e) := t
act3 : var(e) := x
act4 : rdval(e) := n
act5 : rf := rf ∪ {w↦e}
act12 : sb := sb ∪ ({e1↦e2 | e2 = e ∧ e1 ∈ D ∧ tid(e1) ∈ {t, t0}})
END

wr ≐
STATUS
ordinary
ANY
e
t
x
n
w
hb_rfc
eco_rfc
ewt
owt
cw
fr

```

```

eco
sw
hb
WHERE
grd1 : e ∈ (wr u wrR) \ D
grd2 : t ∈ T \ {t0}
grd3 : x ∈ VAR
grd4 : n ∈ VAL
grd7 : w ∈ D // w ∈ OW(t) \ CW
grd6 : var(w) = x
grd8 : init = TRUE
grd9 : hb_rfc = hb u {e0 ↦ e0 | e0 ∈ D}
grd10 : eco_rfc = eco u {e0 ↦ e0 | e0 ∈ D}
grd11 : ewt = {w0 | w0 ∈ (D n (wr u wrR u upd)) ∧ (∃ e0 · e0 ∈ D ∧ tid(e0) = t ∧ w0 ↦ e0 ∈
(eco_rfc; hb_rfc))}
grd12 : owt = {w0 | w0 ∈ (D n (wr u wrR u upd)) ∧ (∀ ww · ww ∈ ewt ⇒ w0 ↦ ww ∉ mo)}
grd13 : cw = {w0 | w0 ∈ (D n (wr u wrR u upd)) ∧ ∃ u · u ∈ upd ∧ w0 ↦ u ∈ rf}
grd14 : w ∈ owt \ cw
grd15 : fr = (rf ~; mo) \ id
grd16 : eco = cls(mo u rf u fr)
grd17 : sw = rf n ((wrR u upd) × (rdA u upd))
grd18 : hb = cls(sb u sw)
THEN
act1 : var(e) := x
act2 : wrval(e) := n
act3 : D := D u {e}
act4 : tid(e) := t
act5 : mo := mo u (({w} u mo ~ [{w}]) × {e}) u ({e} × mo [{w}])
act6 : rf := rf
act7 : sb := sb u ({e1 ↦ e2 | e2 = e ∧ e1 ∈ D ∧ tid(e1) ∈ {t, t0}})
END

upd ≐
STATUS
ordinary
ANY
e
t
x
n
m
w
hb_rfc
eco_rfc
ewt
owt
cw
fr
eco
sw
hb
WHERE
grd1 : e ∈ upd \ D
grd2 : t ∈ T \ {t0}
grd3 : x ∈ VAR
grd4 : n ∈ VAL
grd19 : m ∈ VAL
grd7 : w ∈ D n (wr u wrR u upd)
grd6 : var(w) = x
grd20 : wrval(w) = m
grd8 : init = TRUE
grd9 : hb_rfc = hb u {e0 ↦ e0 | e0 ∈ D}
grd10 : eco_rfc = eco u {e0 ↦ e0 | e0 ∈ D}
grd11 : ewt = {w0 | w0 ∈ (D n (wr u wrR u upd)) ∧ (∃ e0 · e0 ∈ D ∧ tid(e0) = t ∧ w0 ↦ e0 ∈
(eco_rfc; hb_rfc))}
grd12 : owt = {w0 | w0 ∈ (D n (wr u wrR u upd)) ∧ (∀ ww · ww ∈ ewt ⇒ w0 ↦ ww ∉ mo)}
grd13 : cw = {w0 | w0 ∈ (D n (wr u wrR u upd)) ∧ ∃ u · u ∈ upd ∧ w0 ↦ u ∈ rf}
grd14 : w ∈ owt \ cw
grd15 : fr = (rf ~; mo) \ id

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grd16 :   eco = cls(mo u rf u fr)
grd17 :   sw = rf n ((wrR u upd) × (rdA u upd))
grd18 :   hb = cls(sb u sw)
THEN
act1  :   var(e) := x
act2  :   wrval(e) := n
act8  :   rdval(e) := m
act3  :   D := D u {e}
act4  :   tid(e) := t
act5  :   mo := mo u (({w} u mo~[{w}]) × {e}) u ({e} × mo[{w}])
act6  :   rf := rf u {w→e}
act7  :   sb := sb u ({e1→e2 | e2 = e ∧ e1 ∈ D ∧ tid(e1) ∈ {t, t0}})
END
END

```