```
/*

SDL-2000 Design Contest
3rd SDL And MSC Workshop

Specification of a Railway Crossing

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May 11 2002

*/
```
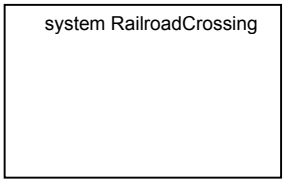
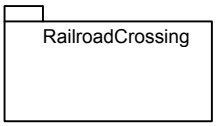
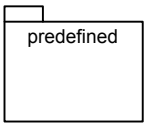







Package predefined 1(4)

```
NEWTYPE Boolean
  LITERALS
    true,false;
  OPERATORS
    "not": Boolean          -> Boolean;
    "and": Boolean, Boolean -> Boolean;
    "or" : Boolean, Boolean -> Boolean;
    "xor": Boolean, Boolean -> Boolean;
    "=>" : Boolean, Boolean -> Boolean;
ENDNEWTYPE Boolean;

NEWTYPE Integer
  LITERALS
    NAMECLASS ('0':'9')+;
  OPERATORS
    "-"  : Integer          -> Integer;
    "+"  : Integer, Integer -> Integer;
    "-"  : Integer, Integer -> Integer;
    "*"  : Integer, Integer -> Integer;
    "/"  : Integer, Integer -> Integer;
    "mod": Integer, Integer -> Integer;
    "rem": Integer, Integer -> Integer;
    "<"  : Integer, Integer -> Boolean;
    ">"  : Integer, Integer -> Boolean;
    "<=" : Integer, Integer -> Boolean;
    ">=" : Integer, Integer -> Boolean;
    float: Integer          -> Real;
    fix  : Real             -> Integer;
ENDNEWTYPE Integer;

SYNTYPE Natural = Integer
  CONSTANTS >= 0
ENDSYNTYPE Natural;


NEWTYPE Real
  LITERALS
    NAMECLASS (('0':'9')+) OR (('0':'9')*'.'('0':'9')+);
  OPERATORS
    "-"  : Real          -> Real;
    "+"  : Real,Real     -> Real;
    "-"  : Real,Real     -> Real;
    "*"  : Real,Real     -> Real;
    "/"  : Real,Real     -> Real;
    "<"  : Real,Real     -> Boolean;
    ">"  : Real,Real     -> Boolean;
    "<=" : Real,Real     -> Boolean;
    ">=" : Real,Real     -> Boolean;
/* ASN.1 operator: */
    power: Integer, Integer -> Real;
ENDNEWTYPE Real;

NEWTYPE PId
  LITERALS
    null;
  OPERATORS
    unique! : PId -> PId;
ENDNEWTYPE PId;
```

```
NEWTYPE Character
  LITERALS
    NUL, SOH, STX, ETX, EOT, ENQ, ACK, BEL,
    BS,  HT,  LF,  VT,  FF,  CR,  SO,  SI,
    DLE, DC1, DC2, DC3, DC4, NAK, SYN, ETB,
    CAN, EM,  SUB, ESC, FS,  GS,  RS,  US,
    ' ', '!', '"', '#', '$', '%', '&', '"',
    '(', ')', '*', '+', ',', '-', '.', '/',
    '0', '1', '2', '3', '4', '5', '6', '7',
    '8', '9', ':', ';', '<', '=', '>', '?',
    '@', 'A', 'B', 'C', 'D', 'E', 'F', 'G',
    'H', 'I', 'J', 'K', 'L', 'M', 'N', 'O',
    'P', 'Q', 'R', 'S', 'T', 'U', 'V', 'W',
    'X', 'Y', 'Z', '[', '\', ']', '^', '_',
    '`', 'a', 'b', 'c', 'd', 'e', 'f', 'g',
    'h', 'i', 'j', 'k', 'l', 'm', 'n', 'o',
    'p', 'q', 'r', 's', 't', 'u', 'v', 'w',
    'x', 'y', 'z', '{', '|', '}', '~', DEL;
      /* '"' is an apostrophe, ' ' is a space, '~' is a tilde */
  OPERATORS
    chr  : Integer -> Character;
    num  : Character -> Integer;
    "<"  : Character, Character -> Boolean;
    "<=" : Character, Character -> Boolean;
    ">"  : Character, Character -> Boolean;
    ">=" : Character, Character -> Boolean;
ENDNEWTYPE Character;

NEWTYPE Charstring String (Character,'')
  ADDING LITERALS
      NAMECLASS '"' (( ':'&') OR '"'" OR ('('':'~'))+ '"';
ENDNEWTYPE Charstring;

NEWTYPE Duration
  LITERALS
    NAMECLASS (('0':'9')+) OR (('0':'9')*'.'('0':'9')+);
  OPERATORS
    duration!: Real          -> Duration;
    "+"  : Duration, Duration -> Duration;
    "-"  : Duration          -> Duration;
    "-"  : Duration, Duration -> Duration;
    "*"  : Real,     Duration -> Duration;
    "*"  : Duration, Real     -> Duration;
    "/"  : Duration, Real     -> Duration;
    "<"  : Duration, Duration -> Boolean;
    ">"  : Duration, Duration -> Boolean;
    "<=" : Duration, Duration -> Boolean;
    ">=" : Duration, Duration -> Boolean;
ENDNEWTYPE Duration;

NEWTYPE Time
  LITERALS
    NAMECLASS (('0':'9')+) OR (('0':'9')*'.'('0':'9')+);
  OPERATORS
    time!: Duration       -> Time;
    "<"  : Time, Time     -> Boolean;
    "<=" : Time, Time     -> Boolean;
    ">"  : Time, Time     -> Boolean;
    ">=" : Time, Time     -> Boolean;
    "+"  : Duration, Time -> Time;
    "+"  : Time, Duration -> Time;
    "-"  : Time, Duration -> Time;
    "-"  : Time, Time     -> Duration;
ENDNEWTYPE Time;
```

```
GENERATOR equality(TYPE item)
  OPERATORS
  "=" : equality, equality -> Boolean;
  "/=": equality, equality -> Boolean;
/*!Z105*/
 encode: equality -> Bitstring;
 encode: equality, Encoding -> Bitstring;
 decode: Bitstring -> equality;
 decode: Bitstring, Encoding -> equality;
/*!Z105END*/
ENDGENERATOR;


GENERATOR ordered(TYPE item)
  OPERATORS
    "<"  : ordered, ordered -> Boolean;
    ">"  : ordered, ordered -> Boolean;
    "<=" : ordered, ordered -> Boolean;
    ">=" : ordered, ordered -> Boolean;
ENDGENERATOR;

GENERATOR String(TYPE Itemsort LITERAL emptystring)
  /* Strings are "indexed" from one */
  LITERALS
    emptystring;
  OPERATORS
    mkstring : Itemsort                -> String;
    length   : String                  -> Integer;
    first    : String                  -> Itemsort;
    last     : String                  -> Itemsort;
    "//"     : String, String          -> String;
    extract! : String, Integer         -> Itemsort;
    modify!  : String, Integer, Itemsort -> String;
    substring: String, Integer, Integer  -> String;
ENDGENERATOR String;

GENERATOR Powerset(TYPE Itemsort)
  LITERALS
    empty;
  OPERATORS
    "in"     : Itemsort, Powerset -> Boolean;
    incl     : Itemsort, Powerset -> Powerset;
    del      : Itemsort, Powerset -> Powerset;
    "<"      : Powerset, Powerset -> Boolean;
    ">"      : Powerset, Powerset -> Boolean;
    "<="     : Powerset, Powerset -> Boolean;
    ">="     : Powerset, Powerset -> Boolean;
    "and"    : Powerset, Powerset -> Powerset;
    "or"     : Powerset, Powerset -> Powerset;
ENDGENERATOR Powerset;



GENERATOR Array(TYPE Index, TYPE Itemsort)
  OPERATORS
    make!   : Itemsort              -> Array;
    modify! : Array, Index, Itemsort -> Array;
    extract!: Array, Index          -> Itemsort;
ENDGENERATOR Array;
```

```
/*!Z105*/ /* Don't change this line */
/* ASN.1 types */
SYNTYPE
  IA5String = Charstring
ENDSYNTYPE;

SYNTYPE
  NumericString = Charstring (from ("0".."9"))
ENDSYNTYPE;

SYNTYPE
  Printablestring = Visiblestring
ENDSYNTYPE;

SYNTYPE
  Visiblestring = Charstring (from
("A".."Z"|"a".."z"|"0".."9"|"""','(',')','+',',','-','.','/',':','=','?'))
ENDSYNTYPE;

NEWTYPE Graphicstring
  inherits Charstring
  operators all;
ENDNEWTYPE Graphicstring;

NEWTYPE Universalstring
  inherits Charstring
  operators all;
ENDNEWTYPE Universalstring;

NEWTYPE Enumeration
  operators
    pred  : Enumeration -> Enumeration;
    succ  : Enumeration -> Enumeration;
    first : Enumeration -> Enumeration;
    last  : Enumeration -> Enumeration;
    num   : Enumeration -> Integer;
    "<"   : Enumeration, Enumeration -> Boolean;
    "<="  : Enumeration, Enumeration -> Boolean;
    ">"   : Enumeration, Enumeration -> Boolean;
    ">="  : Enumeration, Enumeration -> Boolean;
ENDNEWTYPE Enumeration;

SYNONYM PLUS_INFINITY  Real = external;
SYNONYM MINUS_INFINITY Real = external;
```

```
/*!Z105*/ /* Don't change this line */
NEWTYPE Bit
  inherits Boolean
  literals 0 = false, 1 = true;
  operators all;
ENDNEWTYPE Bit;

Encoding ::=  ENUMERATED{BER,CER,DER,PER};

NEWTYPE Bitstring String0(Bit,"B);
  adding
    literals nameclass('0' or '1')*'B',
             nameclass(('0':'9') or ('A':'F'))*'H';
  operators
    "not": Bitstring              -> Bitstring;
    "and": Bitstring, Bitstring -> Bitstring;
    "or" : Bitstring, Bitstring -> Bitstring;
    "xor": Bitstring, Bitstring -> Bitstring;
    "=>" : Bitstring, Bitstring -> Bitstring;
ENDNEWTYPE Bitstring;

SYNTYPE Octet = Bitstring constants size (8)
ENDSYNTYPE Octet;

NEWTYPE Octetstring String(Octet,"B)
    literals nameclass(('0' or '1')8)+'B',
             nameclass((('0':'9') or ('A':'F'))2)+'H';
    operators
      bitstring   : Octetstring -> Bitstring;
      octetstring : Bitstring -> Octetstring;
      Bit_String   : Octetstring -> Bitstring; /* SDL 96 version */
      Octet_String : Bitstring -> Octetstring; /* SDL 96 version */
ENDNEWTYPE Octetstring;

syntype Octet_String = Octetstring endsyntype;
syntype Bit_String = Bitstring endsyntype;

NEWTYPE NULL
  literals null;
ENDNEWTYPE NULL;

NEWTYPE Object_element
  literals nameclass ('0':'9')+;
ENDNEWTYPE Object_element;

NEWTYPE Object_identifier String(Object_element,emptystring)
ENDNEWTYPE Object_identifier;

NEWTYPE Any_type
ENDNEWTYPE Any_type;

GeneralizedTime        ::=        Visiblestring;
ATCTime ::= Visiblestring;
UTCTime ::= Visiblestring;
EXTERNAL_Type ::= sequence
        { direct_reference      Object_identifier optional,
          indirect_reference    Integer           optional,
          data_value_descriptor ObjectDescriptor  optional,
          encoding choice { single_ASN1_type Any_type,
                            octet_aligned    Octetstring,
                            arbitrary        Bitstring
                          }
        };
ObjectDescriptor ::= Graphicstring;
```

Package predefined 4(4)

```
/***** ASN.1 GENERATORS *****/
GENERATOR String0(TYPE Itemsort, LITERAL Emptystring)
    String(Itemsort,Emptystring)
ENDGENERATOR;

GENERATOR Bag(type Itemsort)
  literals Empty;
  operators
    incl   : Itemsort, Bag -> Bag;
    del    : Itemsort, Bag -> Bag;
    length : Bag           -> Integer;
    take   : Bag           -> Itemsort;
    makebag: Itemsort      -> Bag;
    "in"   : Itemsort, Bag -> Boolean;
    "<"    : Bag, Bag      -> Boolean;
    ">"    : Bag, Bag      -> Boolean;
    "<="   : Bag, Bag      -> Boolean;
    ">="   : Bag, Bag      -> Boolean;
    "and"  : Bag, Bag      -> Bag;
    "or"   : Bag, Bag      -> Bag;
ENDGENERATOR;

/*!SDL2000*/ /* Don't change this line */
exception
        OutOfRange,          /* A range check has failed. */
        InvalidReference,    /* Null was used incorrectly. Wrong Pid for this signal. */
        NoMatchingAnswer,    /* No answer matched in a decision without else part. */
        UndefinedVariable,   /* A variable was used that is "undefined". */
        UndefinedField,      /* An undefined field of a choice or struct was accessed. */
        InvalidIndex,        /* A String or Array was accessed with an incorrect index. */
        DivisionByZero,      /* An Integer or Real division by zero was attempted. */
        Empty;               /* No element could be returned. */
```

Package RailroadCrossing 1(2)

```
/* signal definitions */

signal openGate;
signal closeGate;
signal gateOpen;
signal gateClosed;

signal trainApproaching( TrackId );
signal trainLeaving( TrackId );
signal detectLeaving( TrackId );
signal detectApproaching( TrackId );

signal trainSignal( SignalStatus );
signal setSignals( TrackList, SignalStatus );
signal settingDone( TrackList, SignalStatus );
signal leaving;

signal carsWaiting;
signal manyCarsWaiting;

signal trackAnnounce( TrackId,Real );
signal inSight( TrackId,PId );
signal position( Real,Real );

/* signallist definitions */

signallist trainSensor=detectApproaching, detectLeaving;
signallist trainDetection=trainApproaching, trainLeaving;
signallist carSensor=carsWaiting, manyCarsWaiting;
signallist gateControl=closeGate,openGate;
signallist gateStatus=gateClosed, gateOpen;
```

```
/* track layout */

synonym posSensor1 Real=3000;
      /* position of the "approaching sensor" */
synonym posSignal Real=4000;
      /* position of the "signal" */
synonym posSensor2 Real=4500;
      /* position of the "leaving sensor" */
synonym posEnd Real=5000;
      /* end of the track*/

/* track parameters */

synonym fastSpeed Real=80;
      /* maximal speed of fast trains*/
synonym regularSpeed Real=50;
      /* maximal speed of regular trains*/
```

Package RailroadCrossing 2(2)

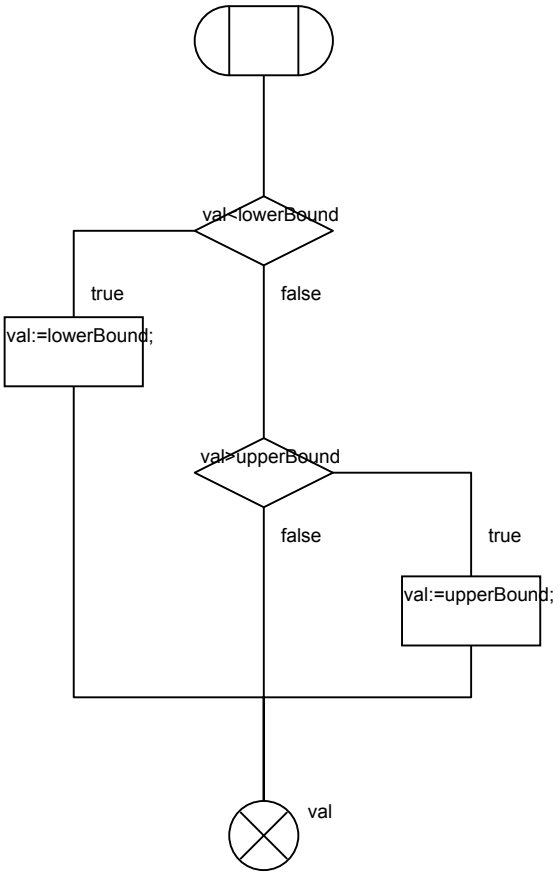
```
/* type definitions */

/* signal status */
value type SignalStatus;
  literals red, green
endvalue type;

/* track identifier */
syntype
  TrackId=PId
endsyntype;

/* list of all tracks */
syntype
  TrackList=String(TrackId,Emptylist)
endsyntype;

/* information about a track */
value type TrackInfo
  struct
    speed Real; /* maximal speed */
    count Integer; /* number of trains between the sensors*/
    sight PId; /* trains which ist in range of sight of signal */
    sig SignalStatus; /* signal status */
endvalue type;

syntype
  TrackTable=Array(TrackId,TrackInfo)
endsyntype;
```

```
/* general purpose procedures*/
```

minmax

Procedure minmax 1(1)

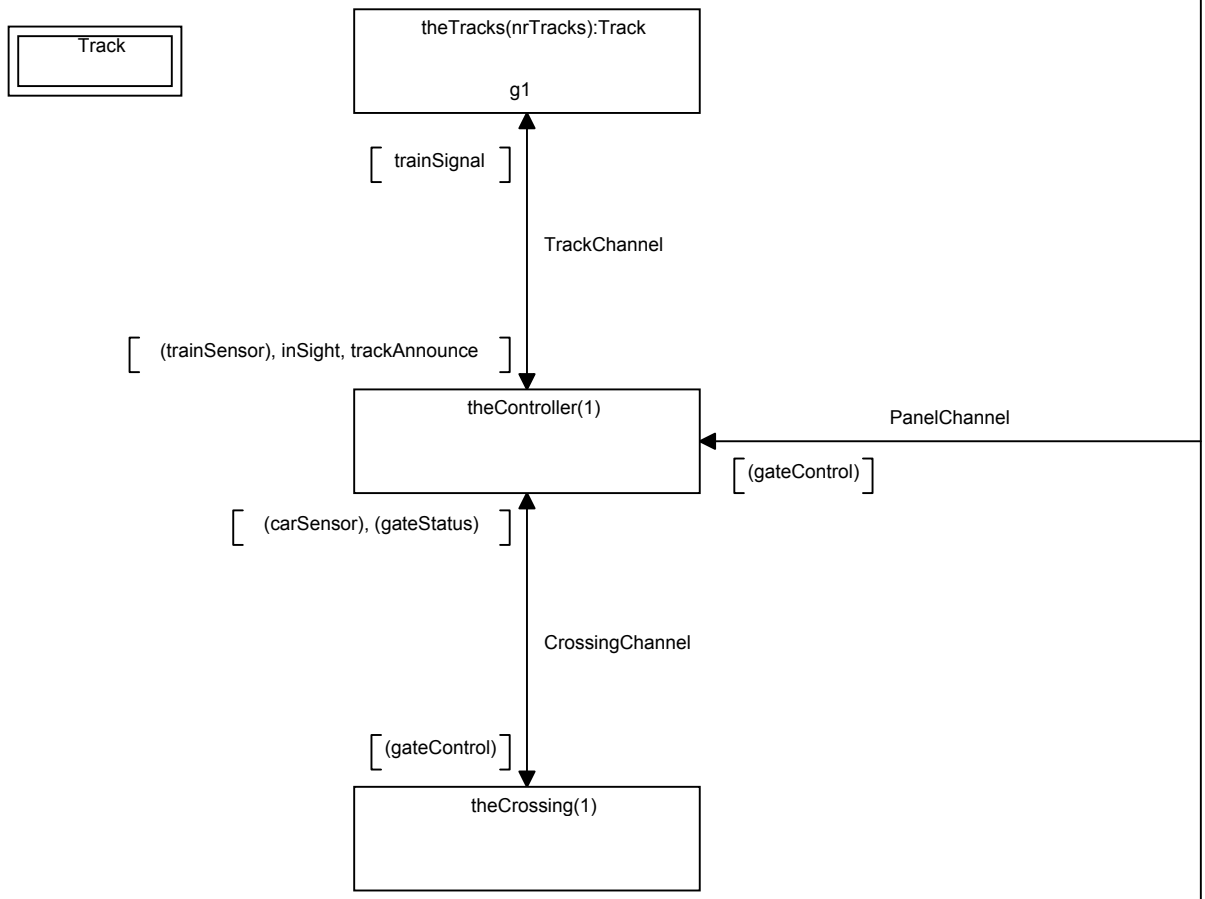
fpar lowerBound Real, upperBound Real, val Real; returns Real

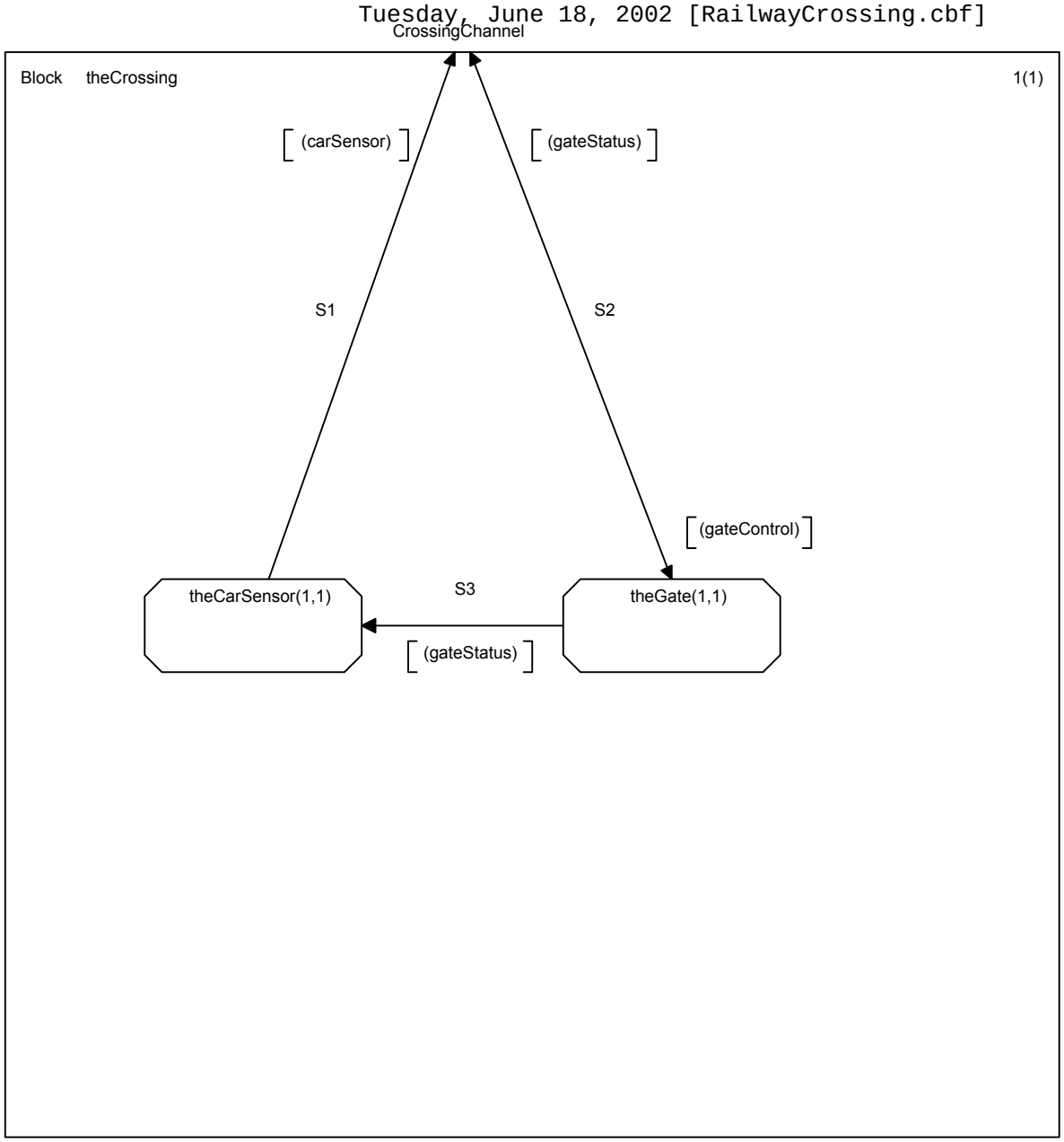


use RailroadCrossing;

System RailroadCrossing 1(1)

synonym nrTracks Integer=4;
/* number of tracks */

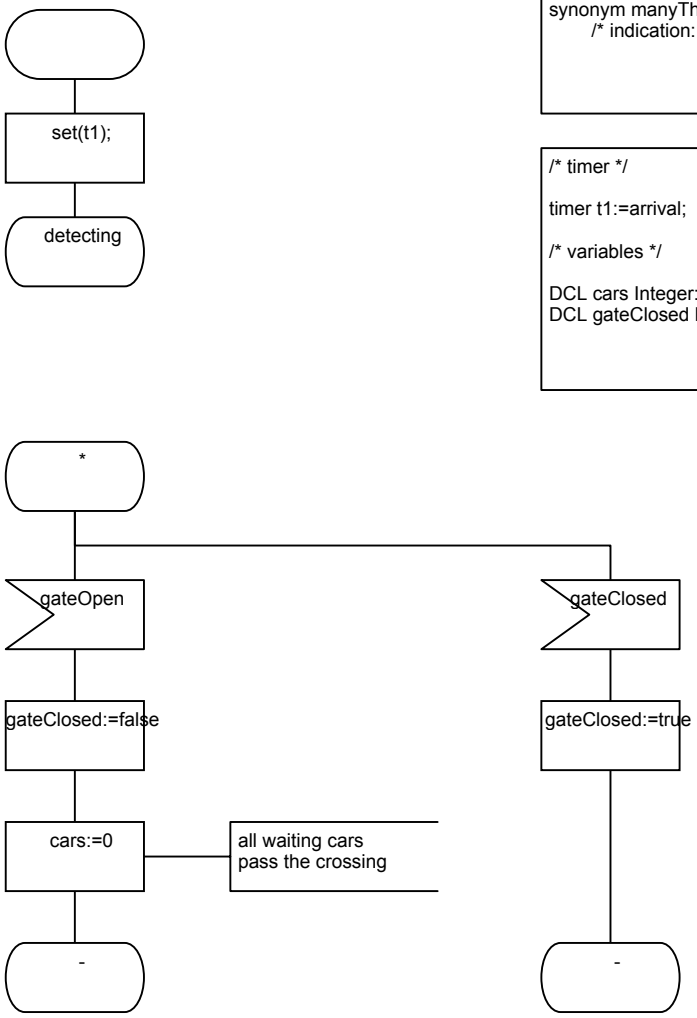


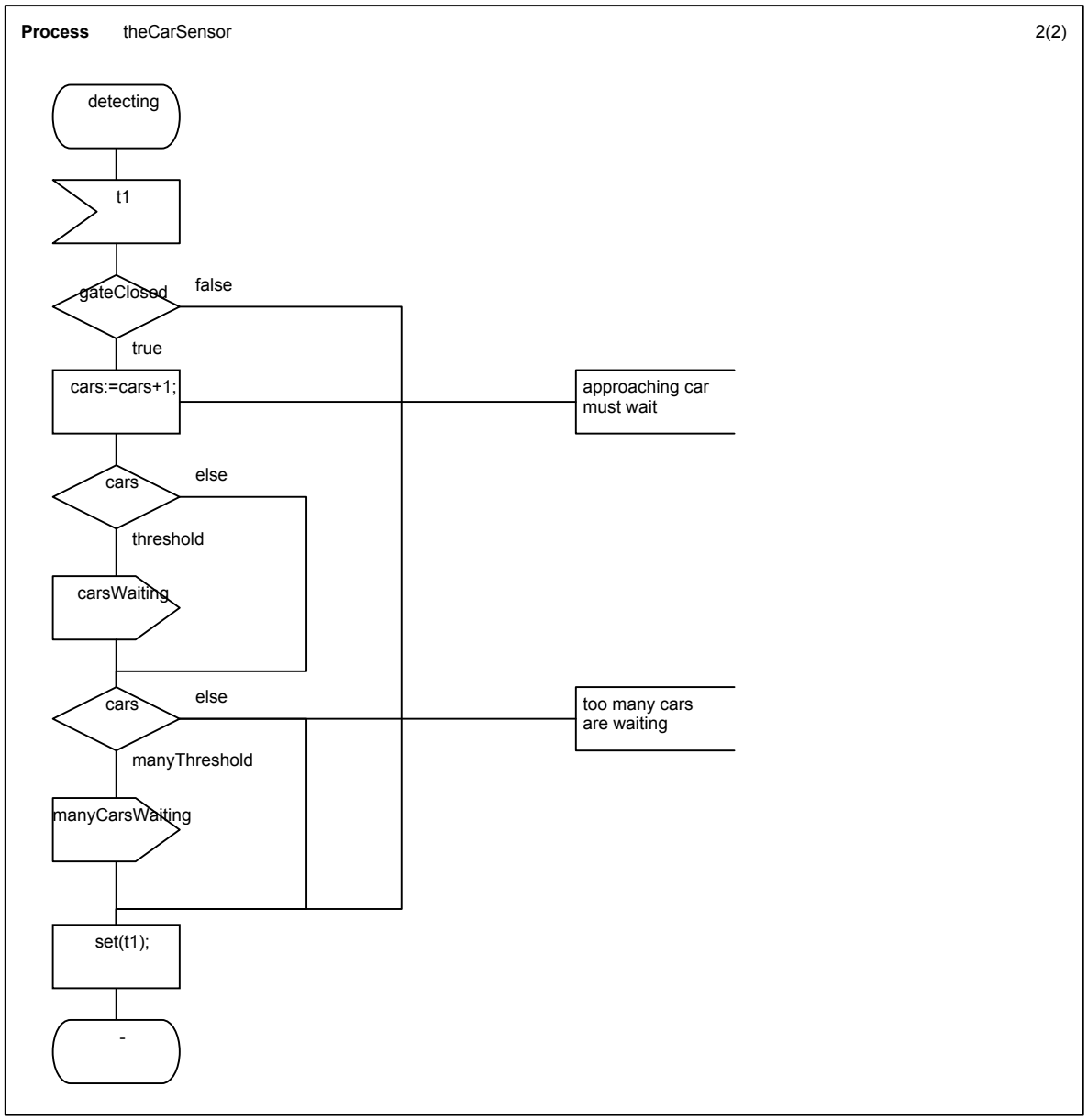

CrossingChannel
Block theCrossing
1(1)
(carSensor)
(gateStatus)
S1
S2
(gateControl)
theCarSensor(1,1)
S3
theGate(1,1)
(gateStatus)

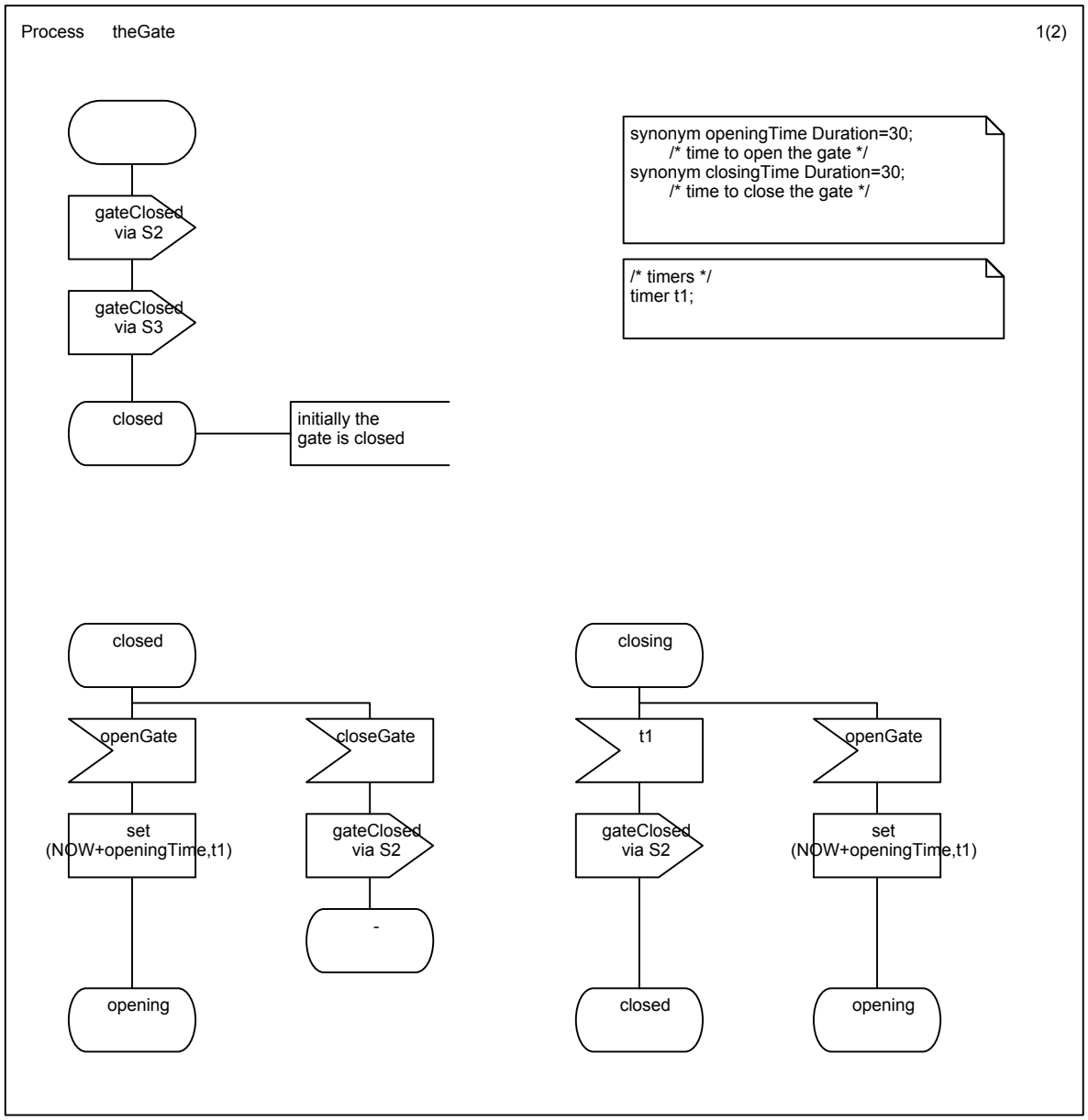
Process theCarSensor 1(2)

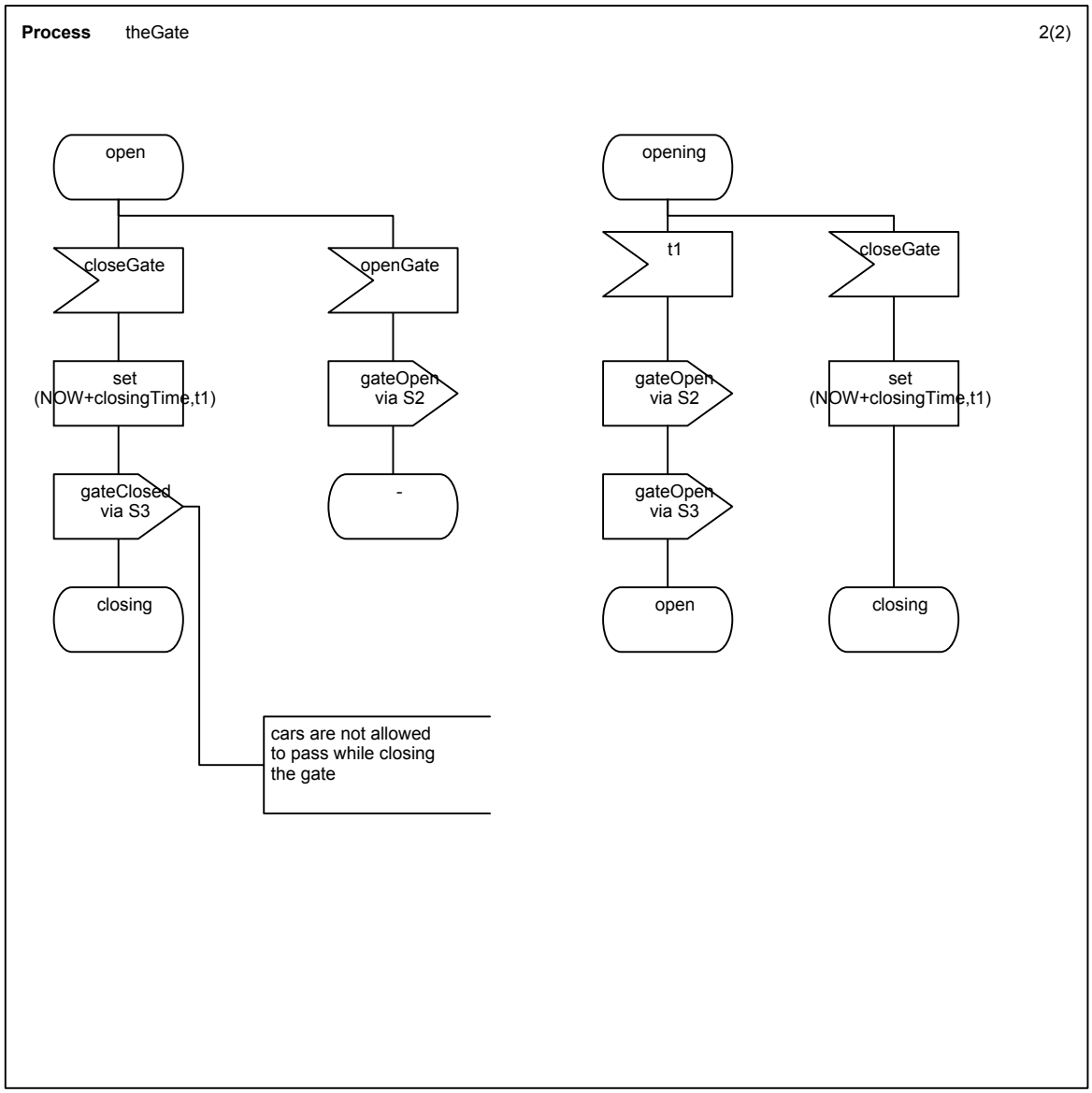
```
synonym arrival Duration=30;
        /* delay between the cars */
synonym threshold Integer=2;
        /* minimum #cars the sensors detects */
synonym manyThreshold Integer=10;
        /* indication: too many cars */
```

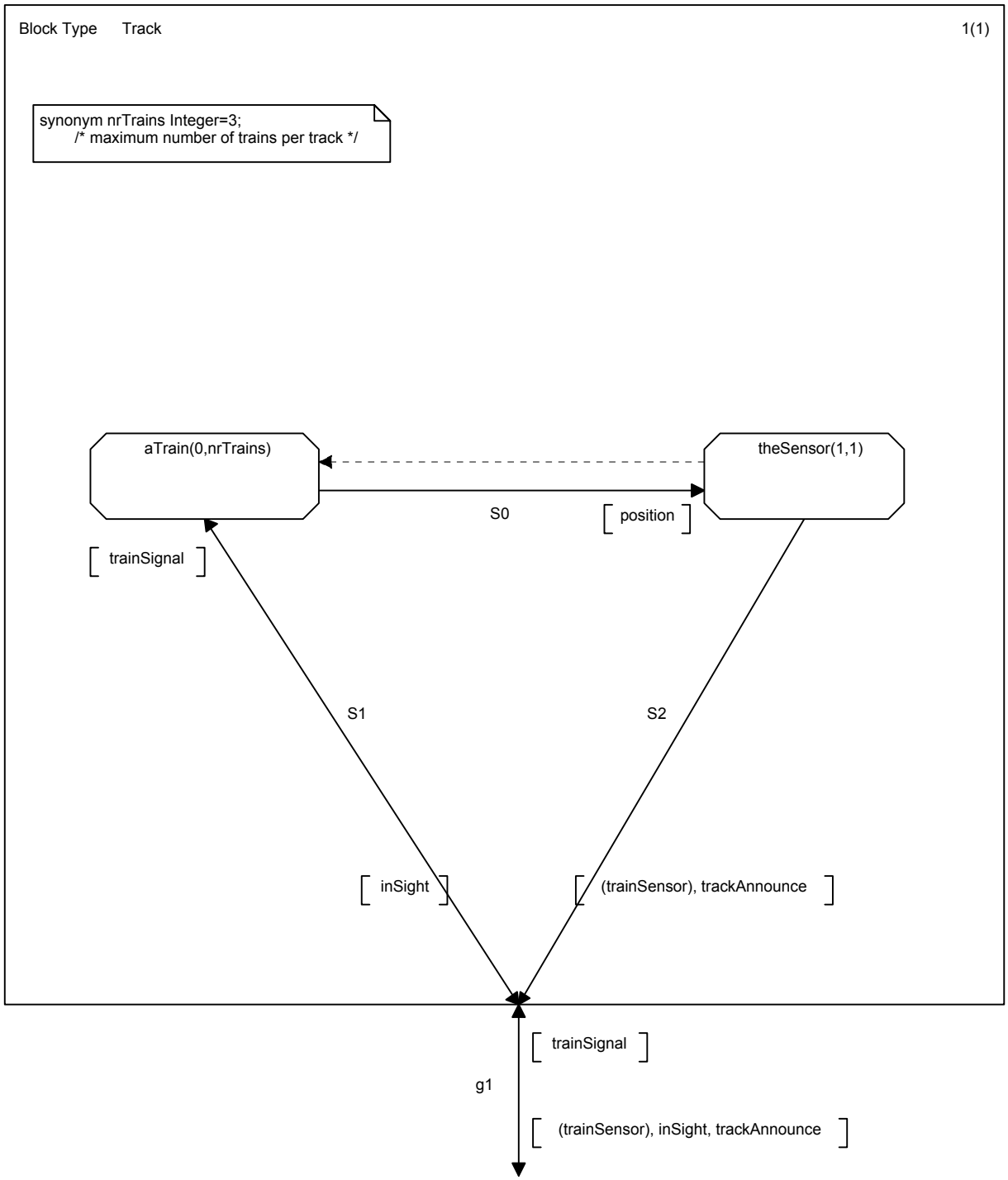
```
/* timer */

timer t1:=arrival;

/* variables */

DCL cars Integer:=0;
DCL gateClosed Boolean:=true;
```

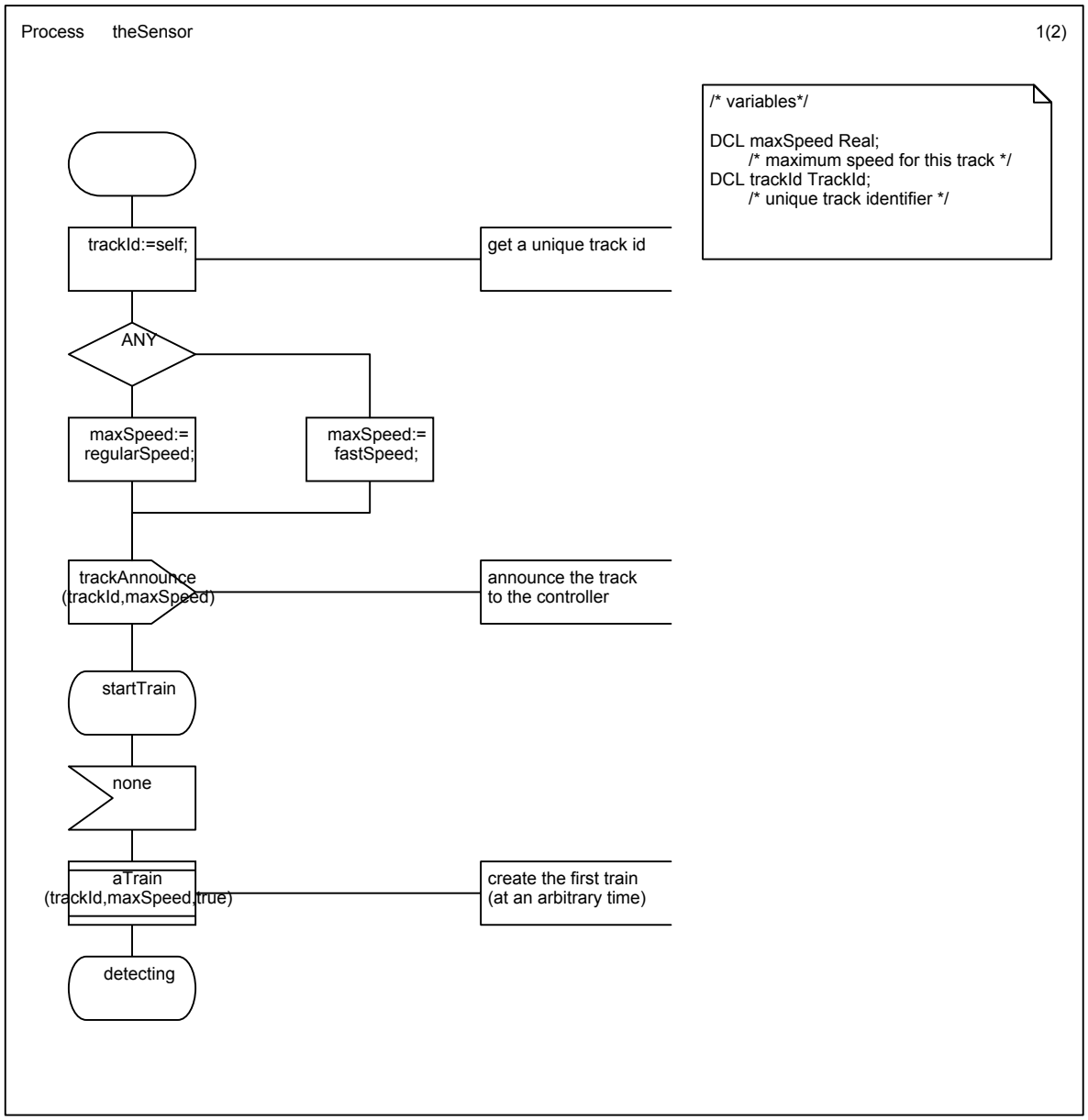


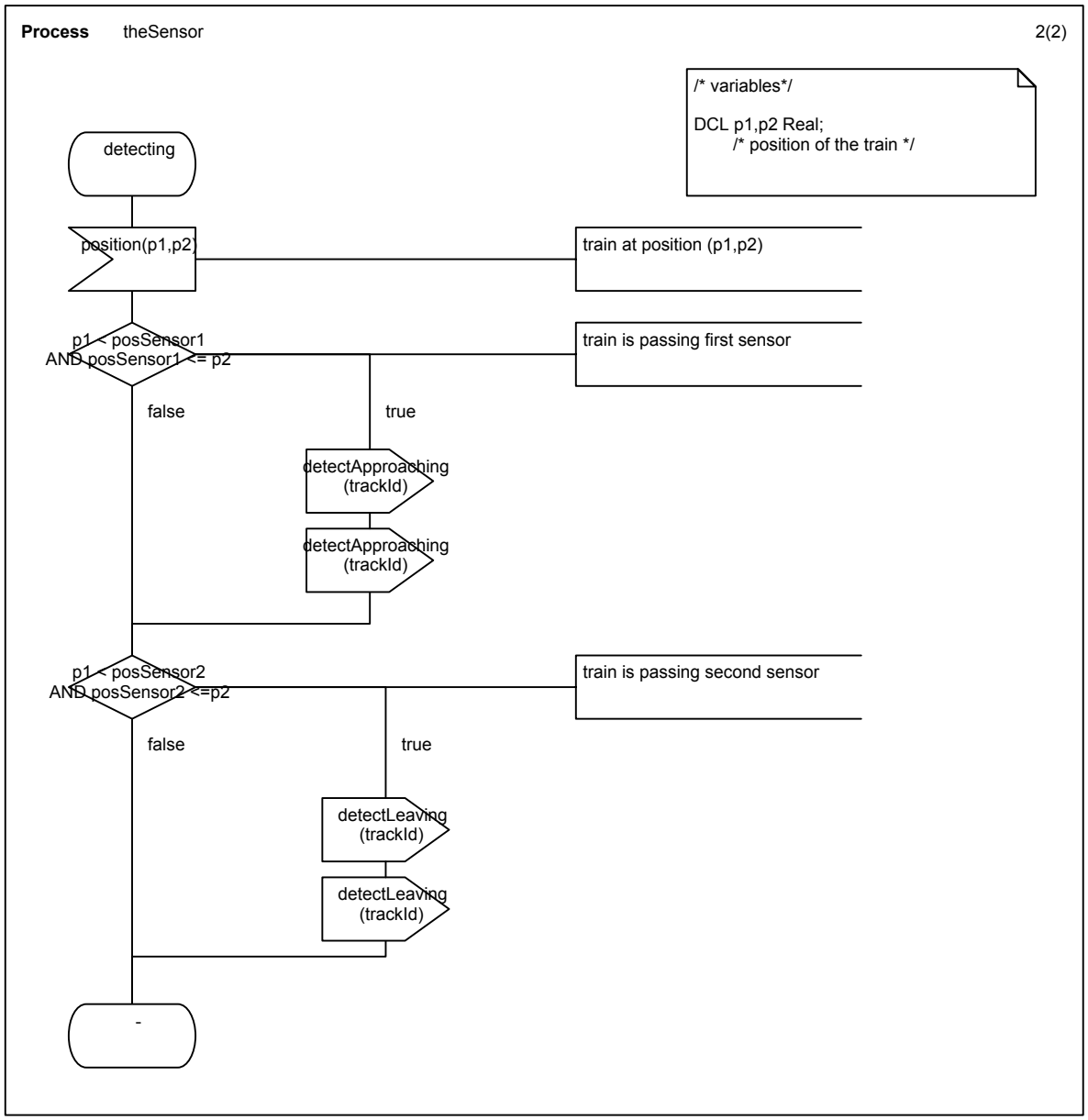

Process theCarSensor
2(2)
detecting
t1
gateClosed
false
true
cars:=cars+1;
approaching car must wait
cars
else
threshold
carsWaiting
cars
else
too many cars are waiting
manyThreshold
manyCarsWaiting
set(t1);
-


Process theGate
1(2)
gateClosed via S2
gateClosed via S3
closed
initially the gate is closed
synonym openingTime Duration=30;
/* time to open the gate */
synonym closingTime Duration=30;
/* time to close the gate */
/* timers */
timer t1;
closed
openGate
closeGate
set (NOW+openingTime,t1)
gateClosed via S2
-
opening
closing
t1
openGate
gateClosed via S2
set (NOW+openingTime,t1)
closed
opening


Process theGate
2(2)
open
closeGate
set
(NOW+closingTime,t1)
gateClosed
via S3
closing
openGate
gateOpen
via S2
-
cars are not allowed
to pass while closing
the gate
opening
t1
gateOpen
via S2
gateOpen
via S3
open
closeGate
set
(NOW+closingTime,t1)
closing

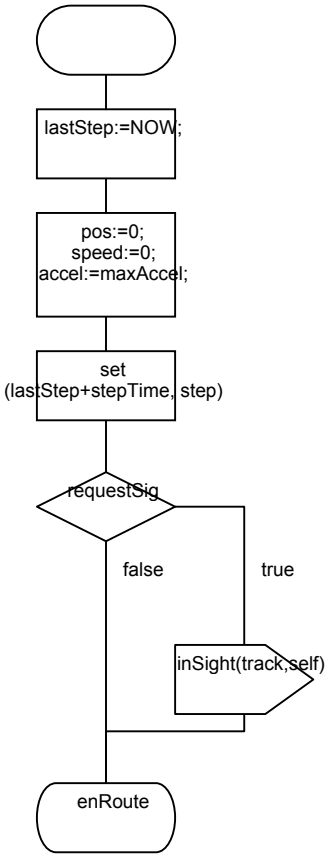

Block Type Track
1(1)
synonym nrTrains Integer=3;
/* maximum number of trains per track */
aTrain(0,nrTrains)
theSensor(1,1)
S0
[position]
[trainSignal]
S1
S2
[inSight]
[(trainSensor), trackAnnounce]
[trainSignal]
g1
[(trainSensor), inSight, trackAnnounce]


Process theSensor
1(2)
/* variables*/
DCL maxSpeed Real;
/* maximum speed for this track */
DCL trackId TrackId;
/* unique track identifier */
trackId:=self;
get a unique track id
ANY
maxSpeed:=
regularSpeed;
maxSpeed:=
fastSpeed;
trackAnnounce
(trackId,maxSpeed)
announce the track
to the controller
startTrain
none
aTrain
(trackId,maxSpeed,true)
create the first train
(at an arbitrary time)
detecting


Process theSensor
2(2)
/* variables*/
DCL p1,p2 Real;
/* position of the train */
detecting
position(p1,p2)
train at position (p1,p2)
p1 < posSensor1
AND posSensor1 <= p2
train is passing first sensor
false
true
detectApproaching
(trackId)
detectApproaching
(trackId)
p1 < posSensor2
AND posSensor2 <=p2
train is passing second sensor
false
true
detectLeaving
(trackId)
detectLeaving
(trackId)
-

Process aTrain 1(4)

fpar track TrackId, maxSpeed Real, requestSig Boolean;



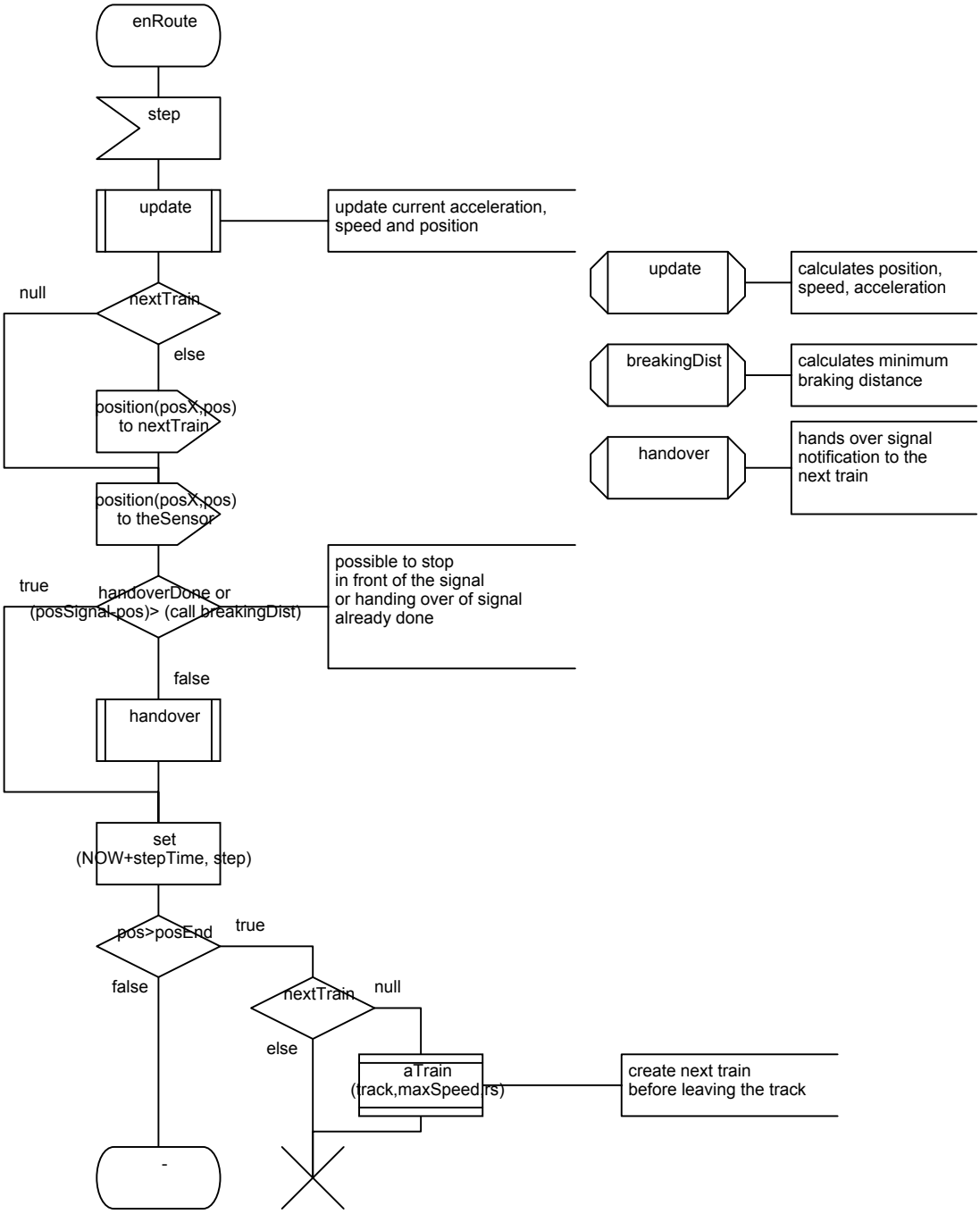

```
synonym maxAccel Real=3;
        /* maximum acceleration */
synonym minAccel Real=-10;
        /* maximum brake acceleration */
synonym minSpeed Real=0;
        /* minimum speed */
synonym minDist Real=100;
        /* minimum distance between the trains */
```

```
/* extend input alphabet */

signalset position;
        /* inter train communication */
```

```
/* timer */

timer step;
DCL lastStep Time;
synonym stepTime Duration=10;

/* variables */

DCL pos, posX Real;
        /* current position */
DCL pposX, ppos Real :=-1;
        /* current position of previous train */
DCL speed Real;
        /* current speed */
DCL accel Real;
        /* current acceleration */
DCL sigAccel Real:=maxAccel;
        /* maximum acceleration permitted by the signal */
DCL nextTrain PId:=null;
        /* next train */
DCL rs Boolean:=false;
        /* next train has to request signal */
DCL handoverDone Boolean:=false;
        /* handing over of signal notification done */
```

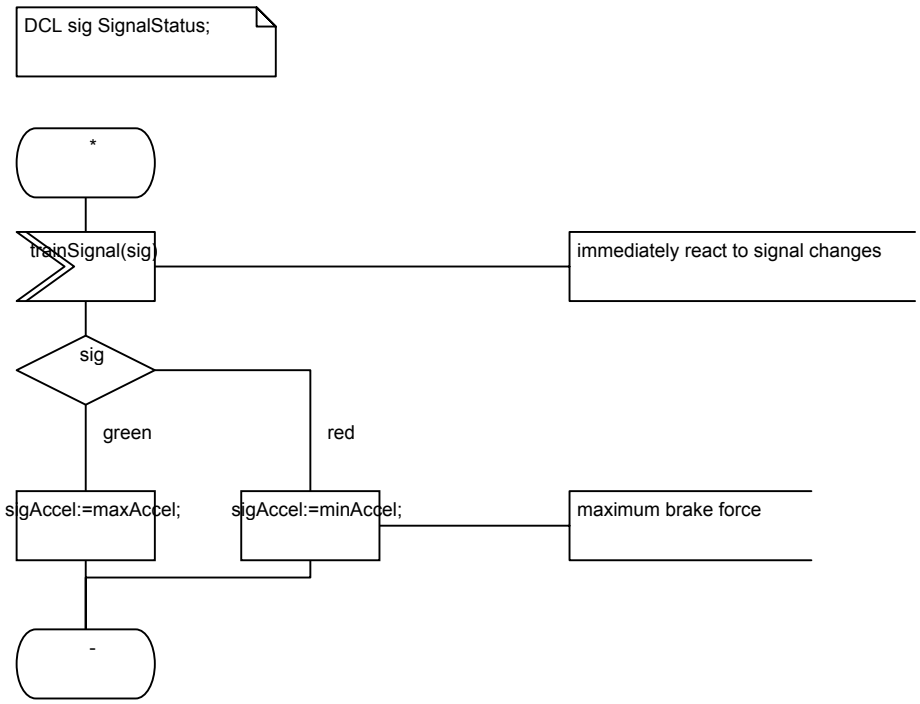
Process aTrain 2(4)

fpar track TrackId, maxSpeed Real, requestSig Boolean;



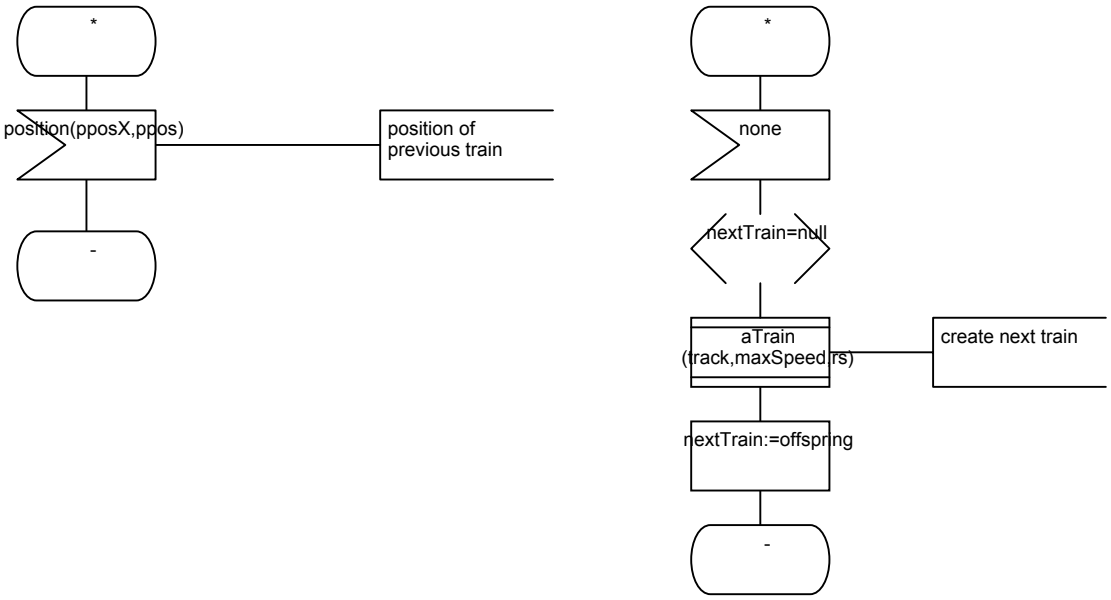
Process aTrain 3(4)

fpar track TrackId, maxSpeed Real, requestSig Boolean;

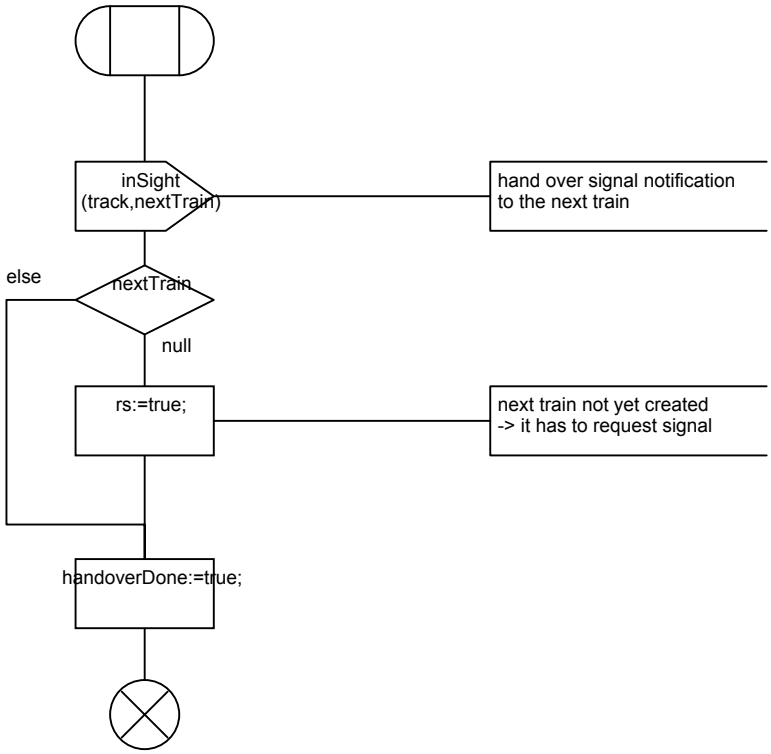


Process aTrain 4(4)

fpar track TrackId, maxSpeed Real, requestSig Boolean;

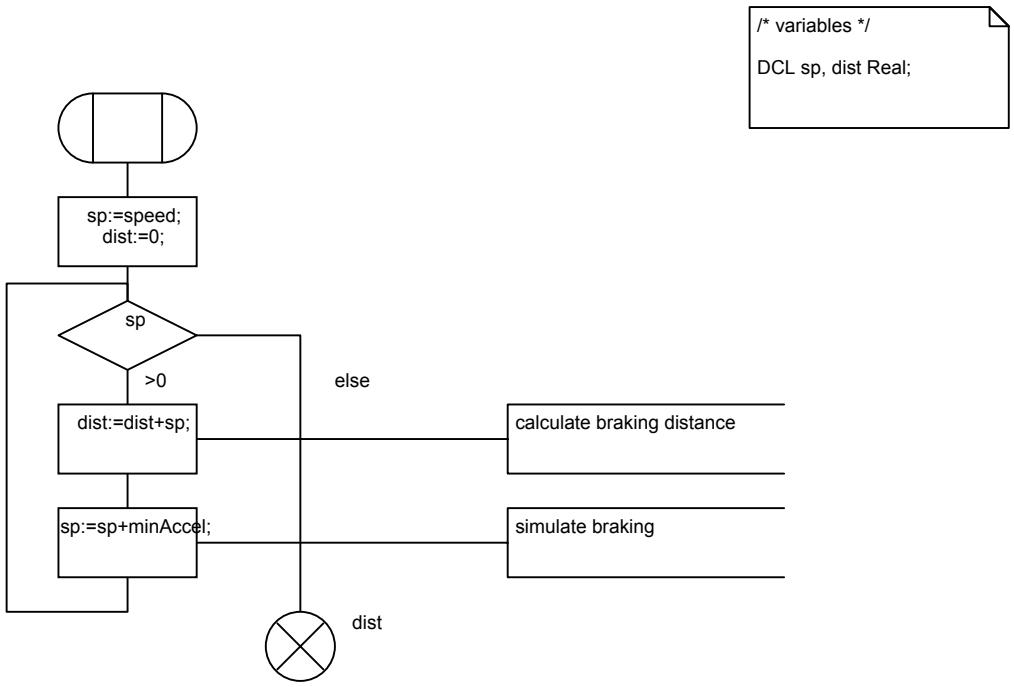


Procedure handover 1(1)

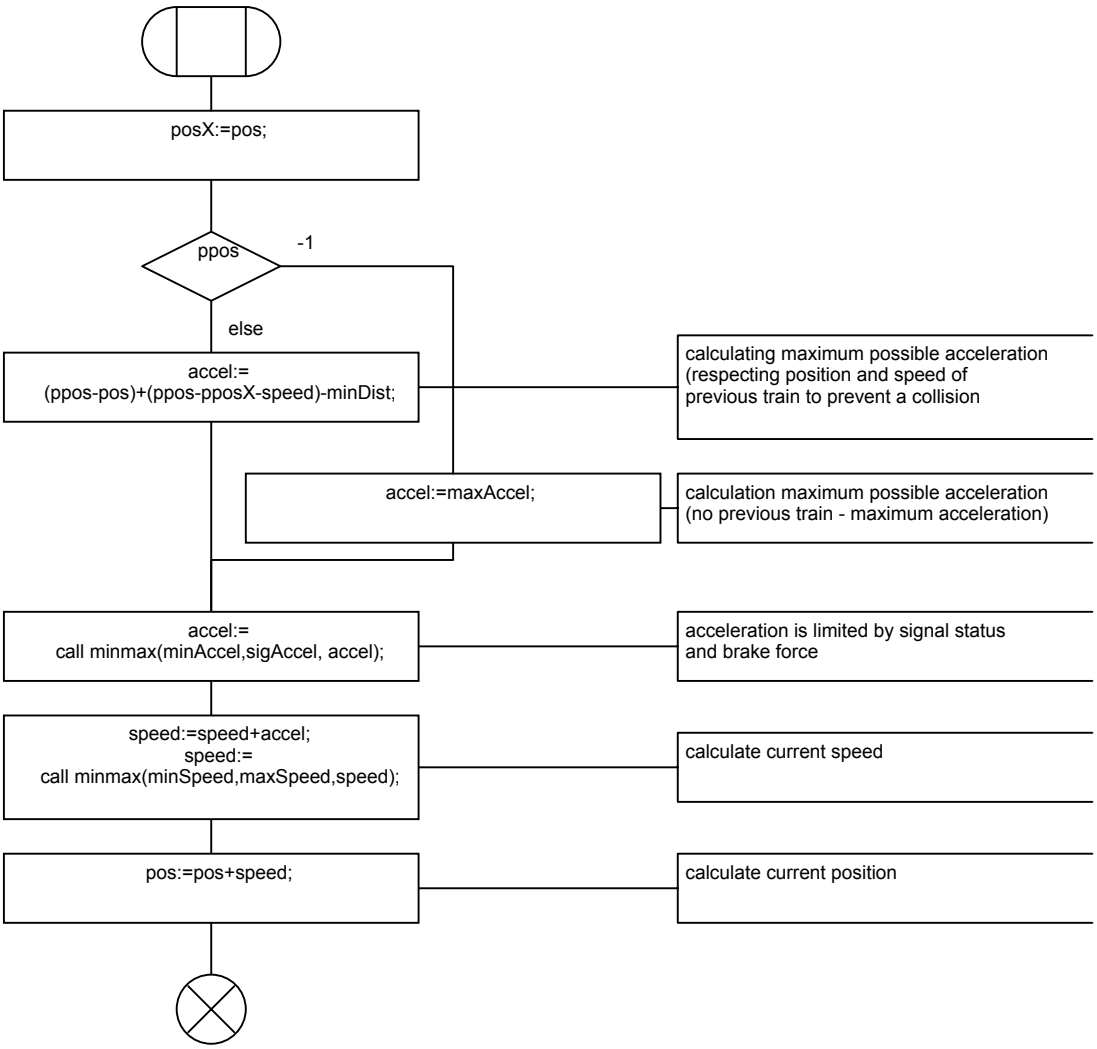


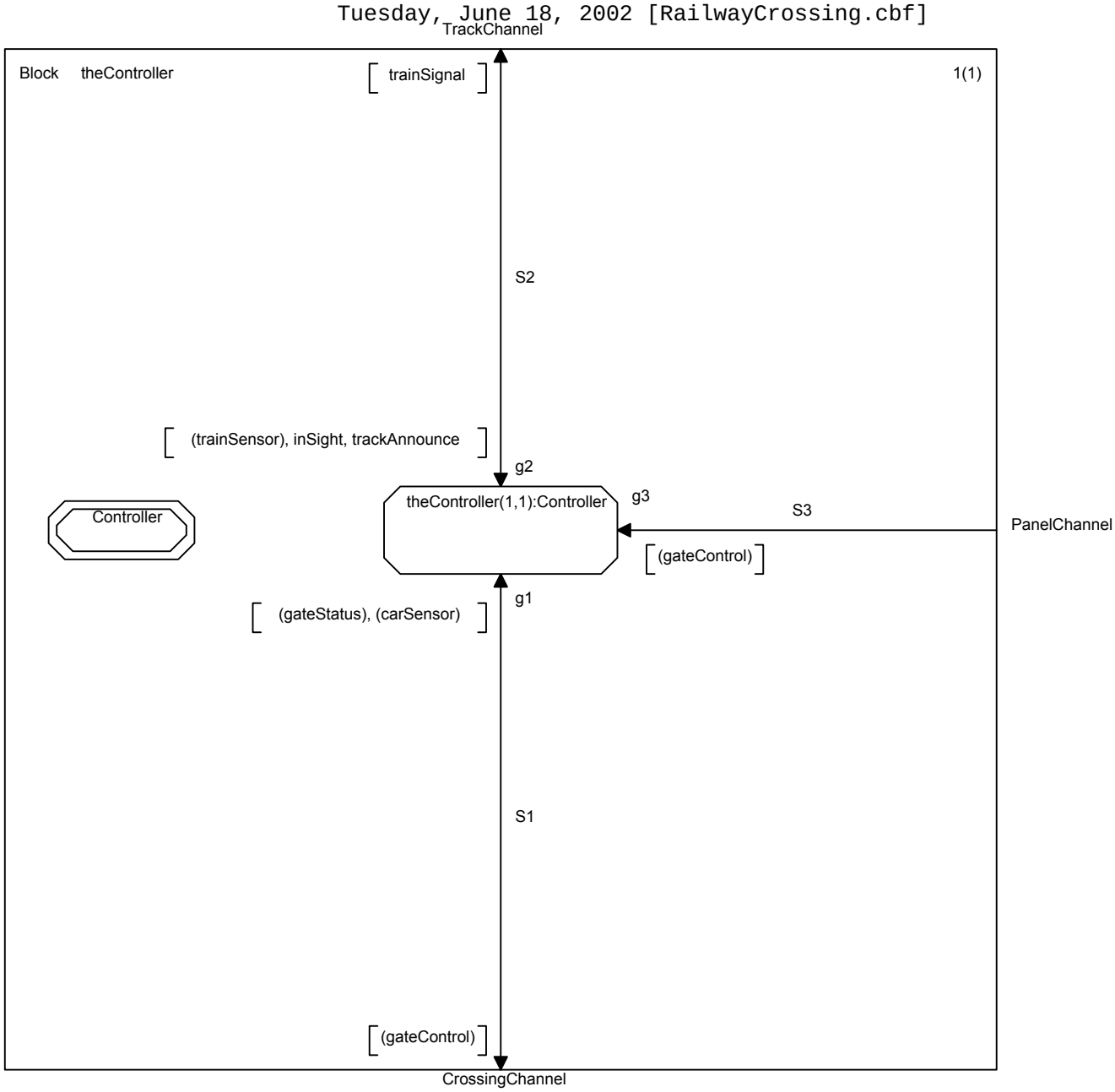
Procedure breakingDist 1(1)

returns Real



Procedure update 1(1)




TrackChannel
Block theController
1(1)
trainSignal
S2
(trainSensor), inSight, trackAnnounce
g2
Controller
theController(1,1):Controller
g3
S3
PanelChannel
(gateControl)
g1
(gateStatus), (carSensor)
S1
(gateControl)
CrossingChannel

Process Type Controller 1(1)

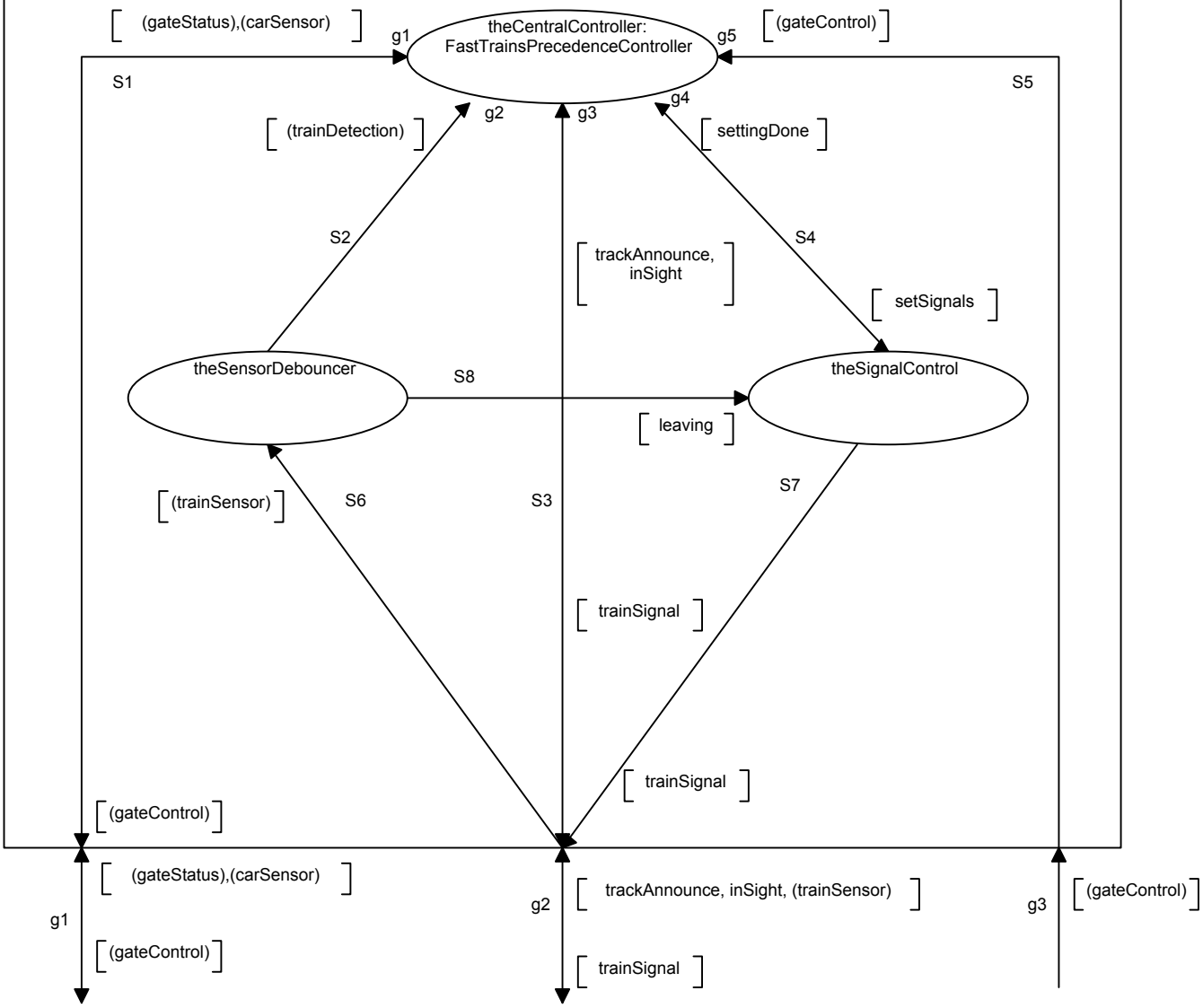
```
DCL trackLst TrackList:=Emptylist;
      /* tracks of the system */

DCL trackTbl TrackTable:=(. (. 0,0,null,green .) .);
      /* information about all the tracks */
```

BasicController — basic functionality of all controllers

TrainsPrecedenceController — all trains take precedence

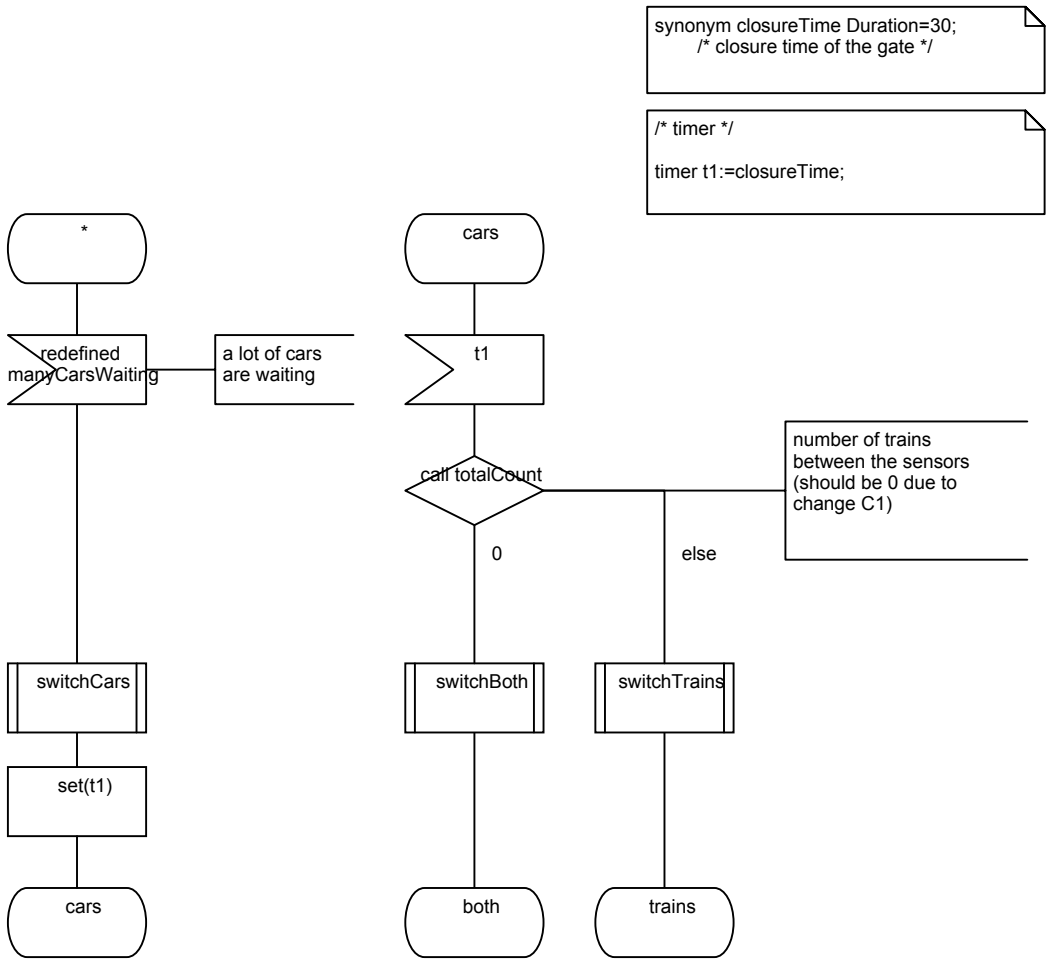
ManyCarsPrecedenceController — cars take precedence, if there are too many waiting

FastTrainsPrecedenceController — regular trains wait for fast trains



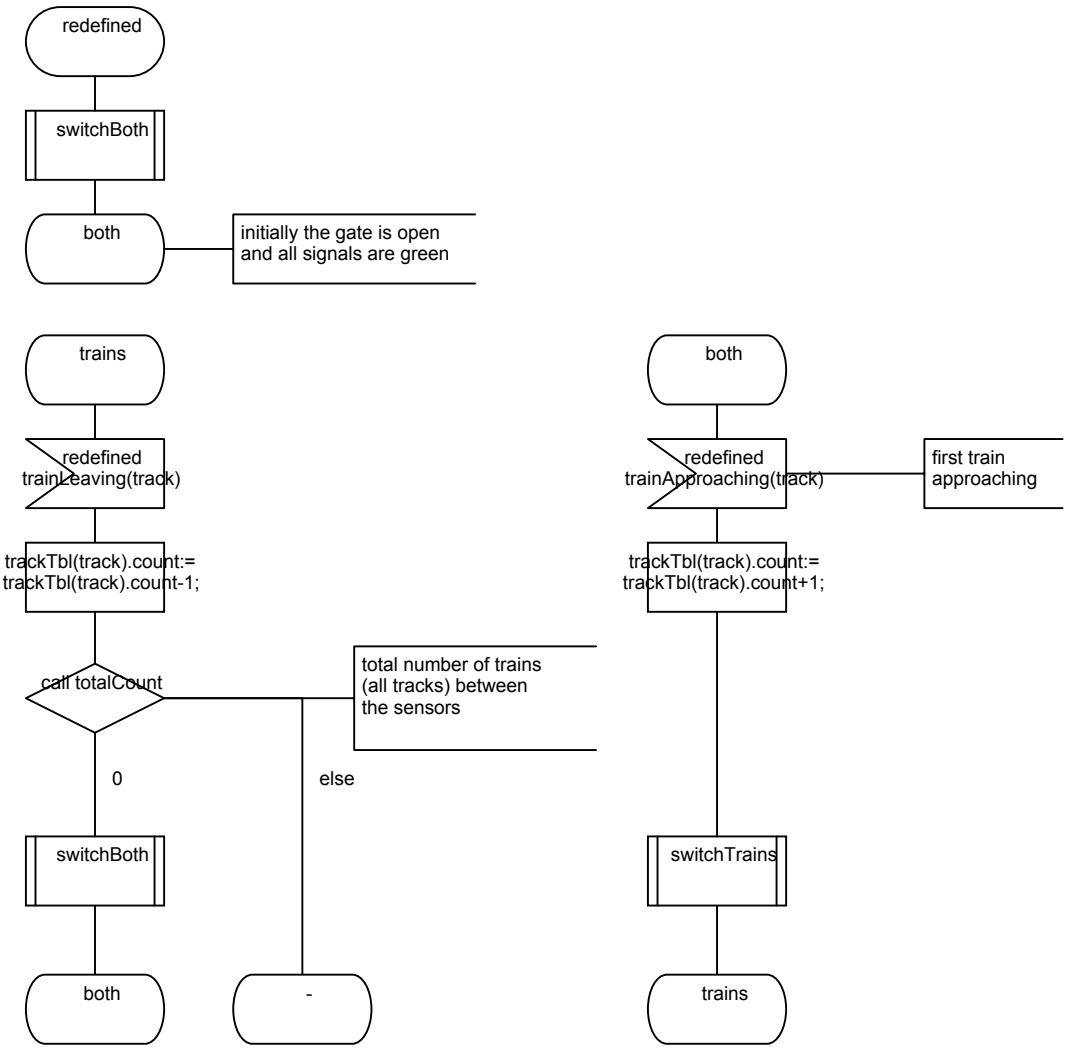
Service Type ManyCarsPrecedenceController 1(1)

inherits TrainsPrecedenceController



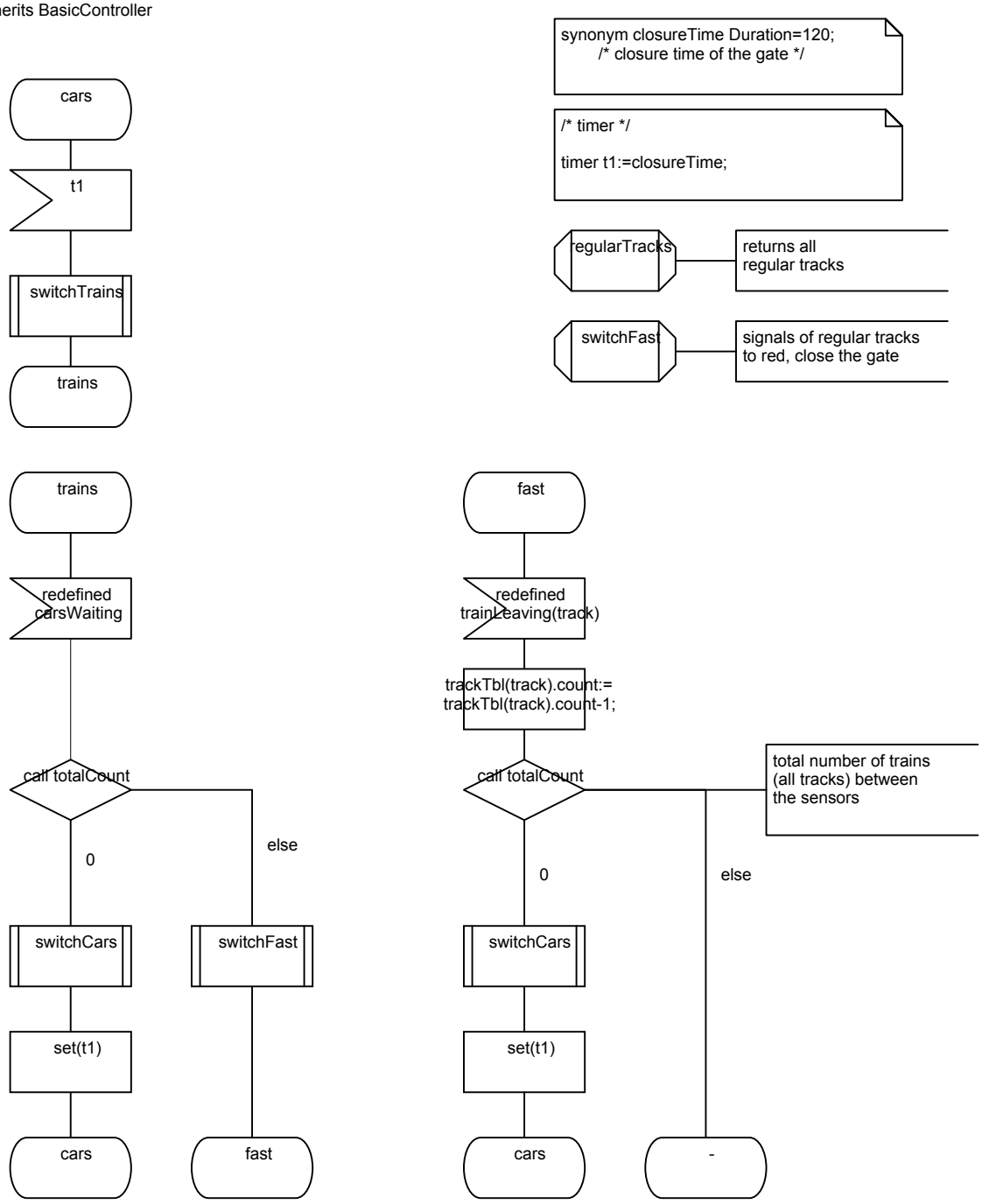
Service Type TrainsPrecedenceController 1(1)

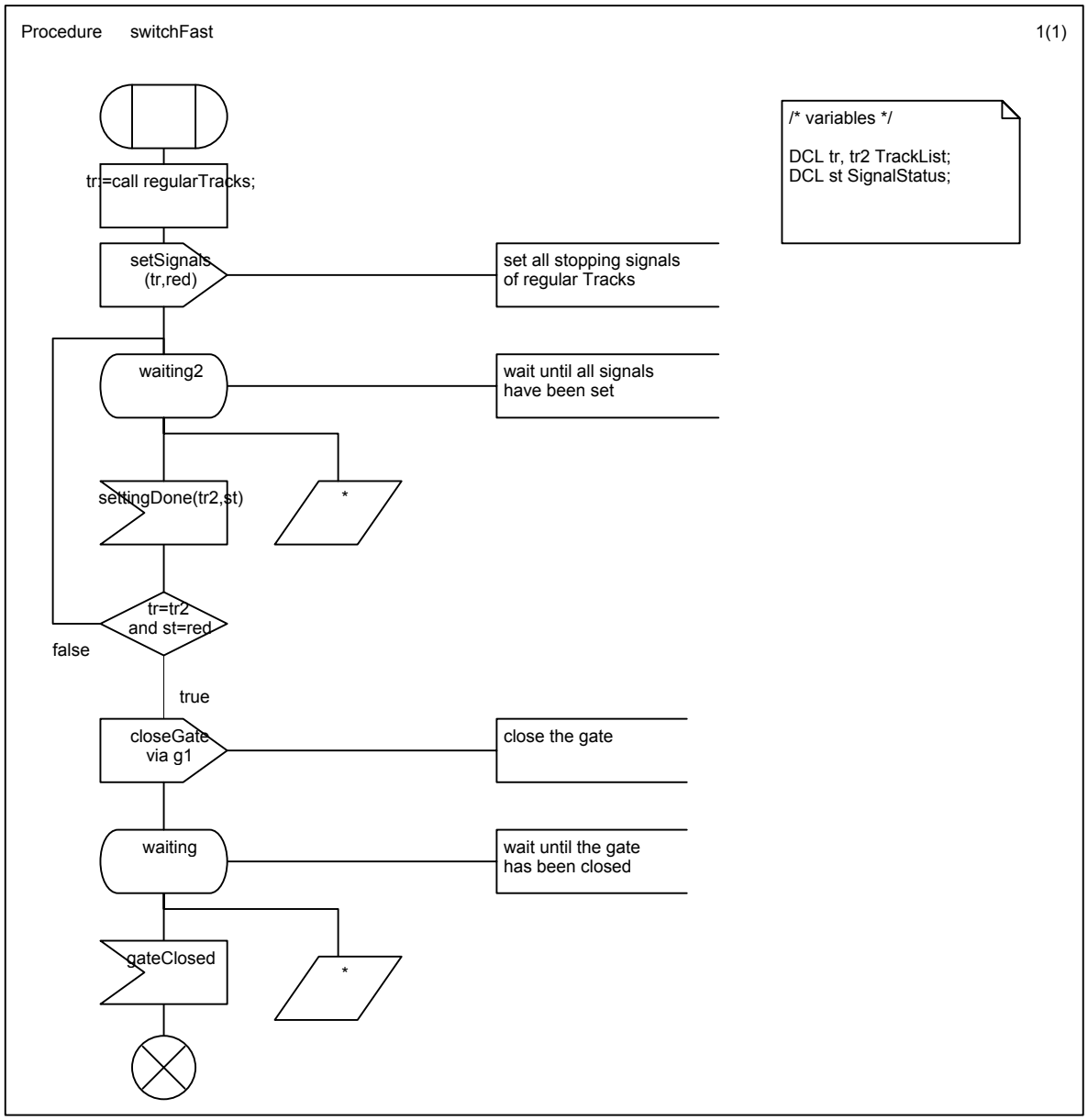
inherits BasicController



Service Type FastTrainsPrecedenceController 1(1)

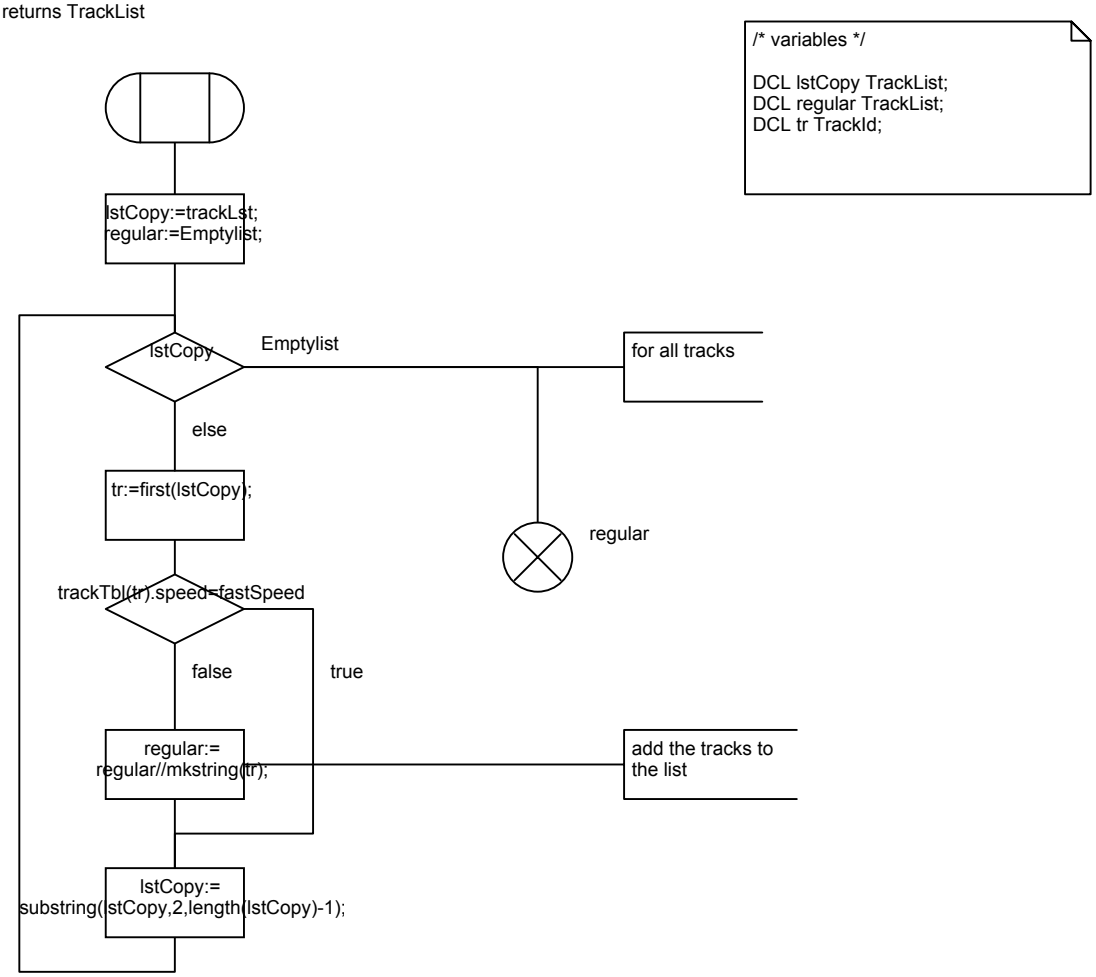
inherits BasicController

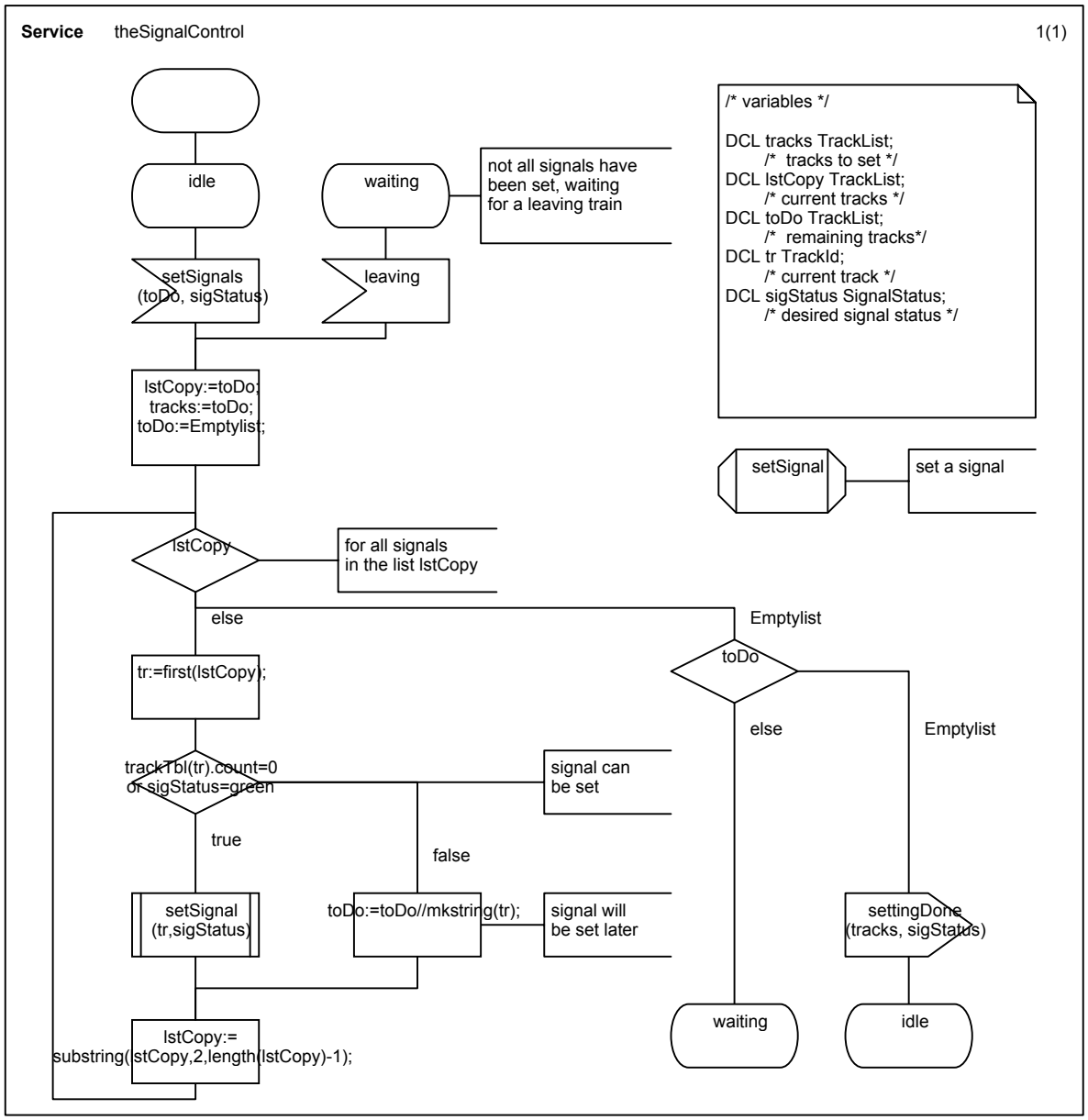



Procedure switchFast
1(1)
/* variables */
DCL tr, tr2 TrackList;
DCL st SignalStatus;
tr=call regularTracks;
setSignals (tr,red)
set all stopping signals of regular Tracks
waiting2
wait until all signals have been set
settingDone(tr2,st)
*
tr=tr2 and st=red
false
true
closeGate via g1
close the gate
waiting
wait until the gate has been closed
gateClosed
*

Procedure regularTracks 1(1)

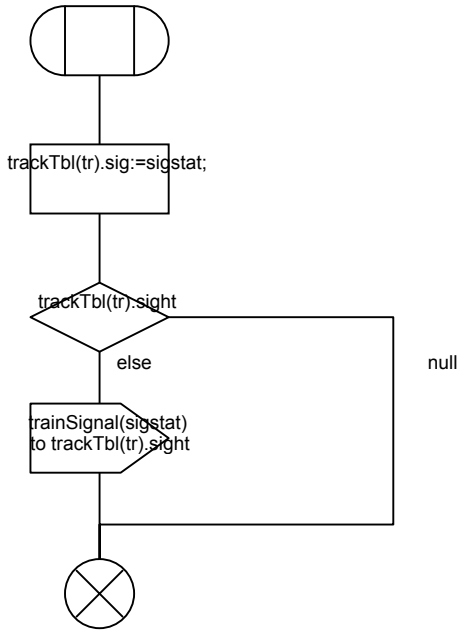
returns TrackList

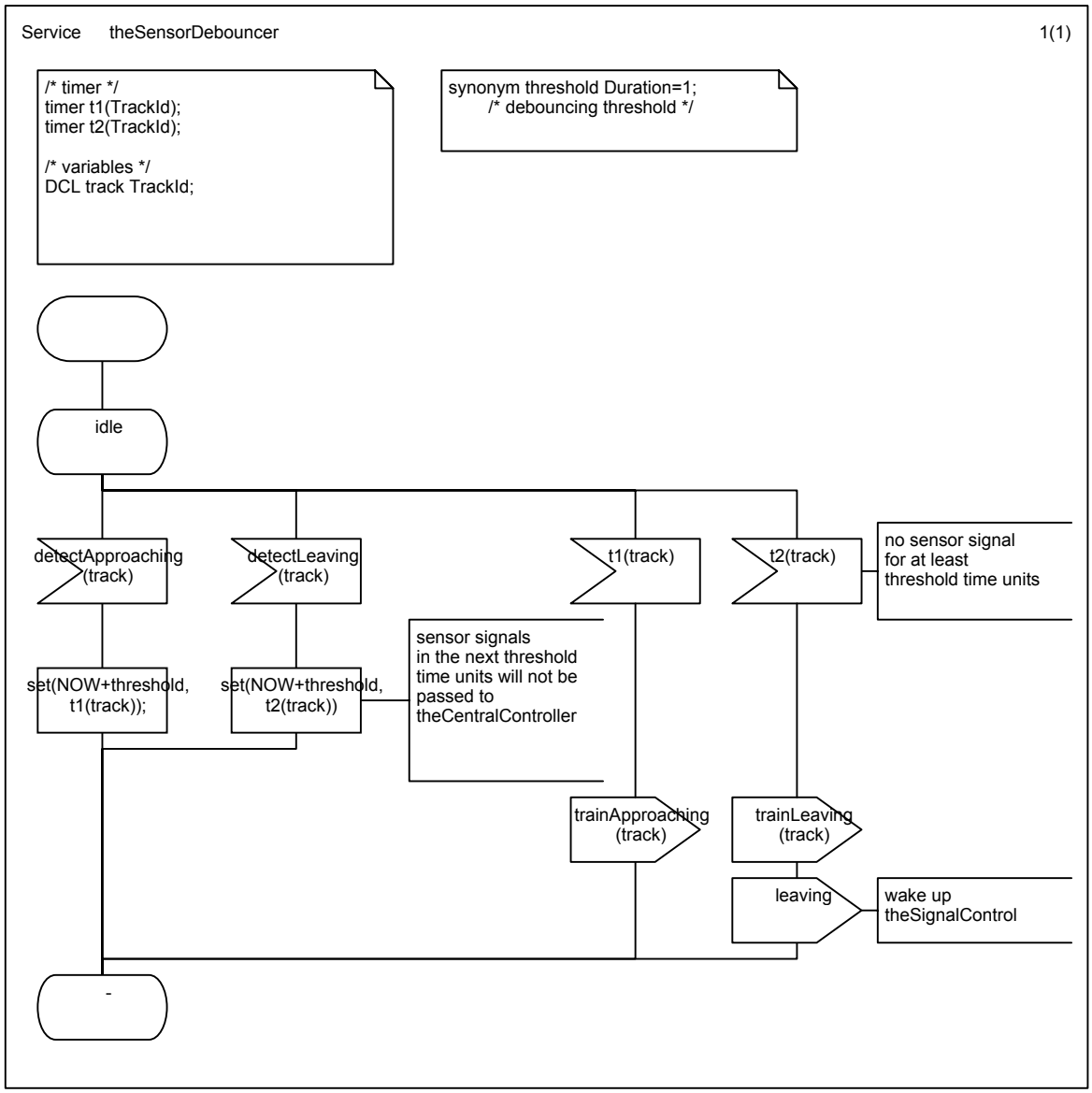


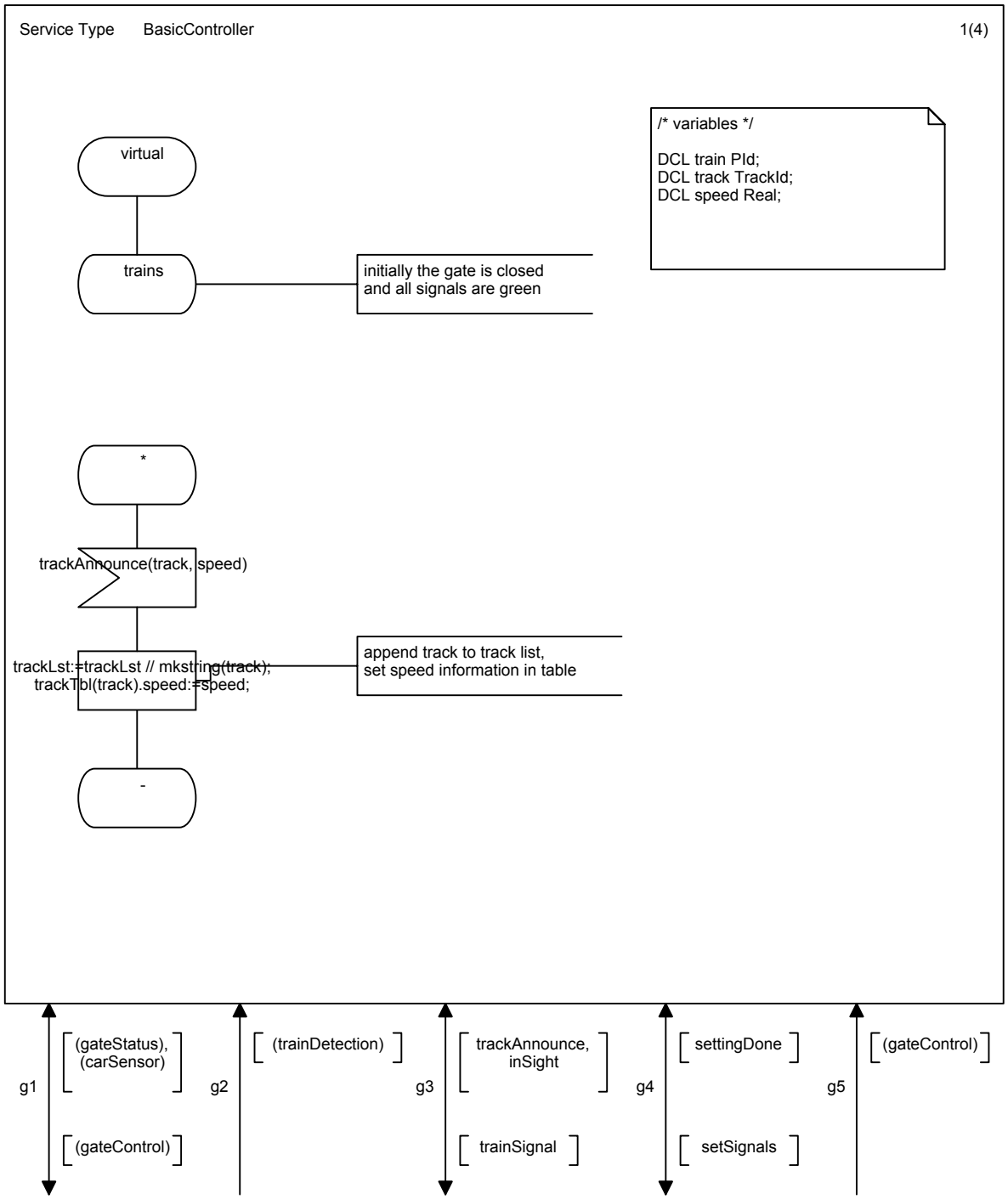

Service theSignalControl
1(1)
idle
waiting
not all signals have been set, waiting for a leaving train
setSignals (toDo, sigStatus)
leaving
lstCopy:=toDo; tracks:=toDo; toDo:=Emptylist;
/* variables */
DCL tracks TrackList;
/* tracks to set */
DCL lstCopy TrackList;
/* current tracks */
DCL toDo TrackList;
/* remaining tracks*/
DCL tr TrackId;
/* current track */
DCL sigStatus SignalStatus;
/* desired signal status */
setSignal
set a signal
lstCopy
for all signals in the list lstCopy
else
Emptylist
toDo
tr:=first(lstCopy);
else
Emptylist
trackTbl(tr).count=0 or sigStatus=green
signal can be set
true
false
setSignal (tr,sigStatus)
toDo:=toDo//mkstring(tr);
signal will be set later
settingDone (tracks, sigStatus)
lstCopy:= substring(lstCopy,2,length(lstCopy)-1);
waiting
idle

Procedure setSignal 1(1)

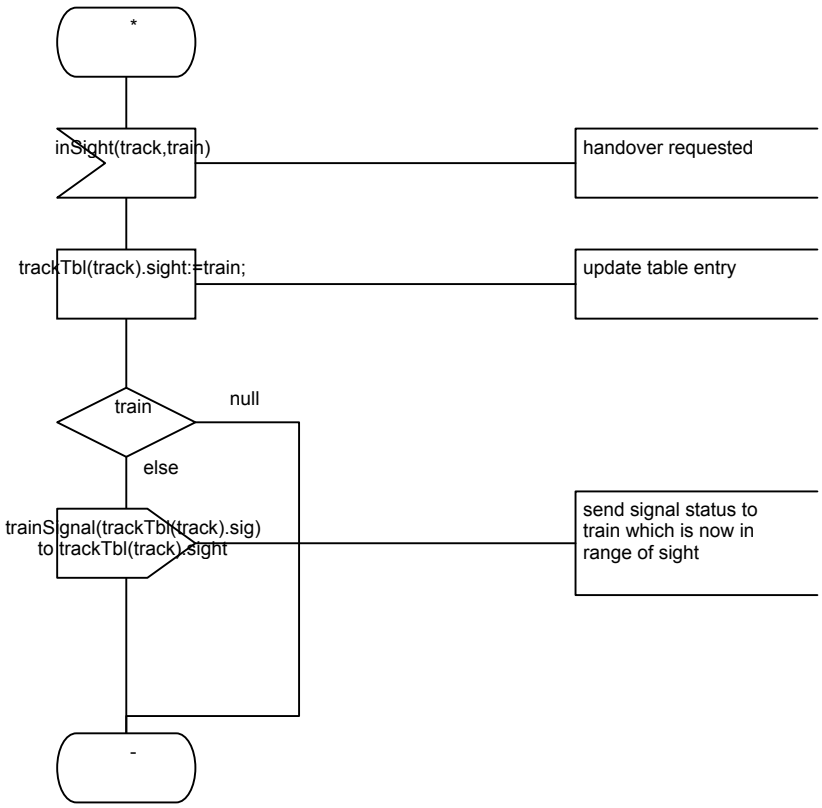
fpar tr TrackId, sigstat SignalStatus;



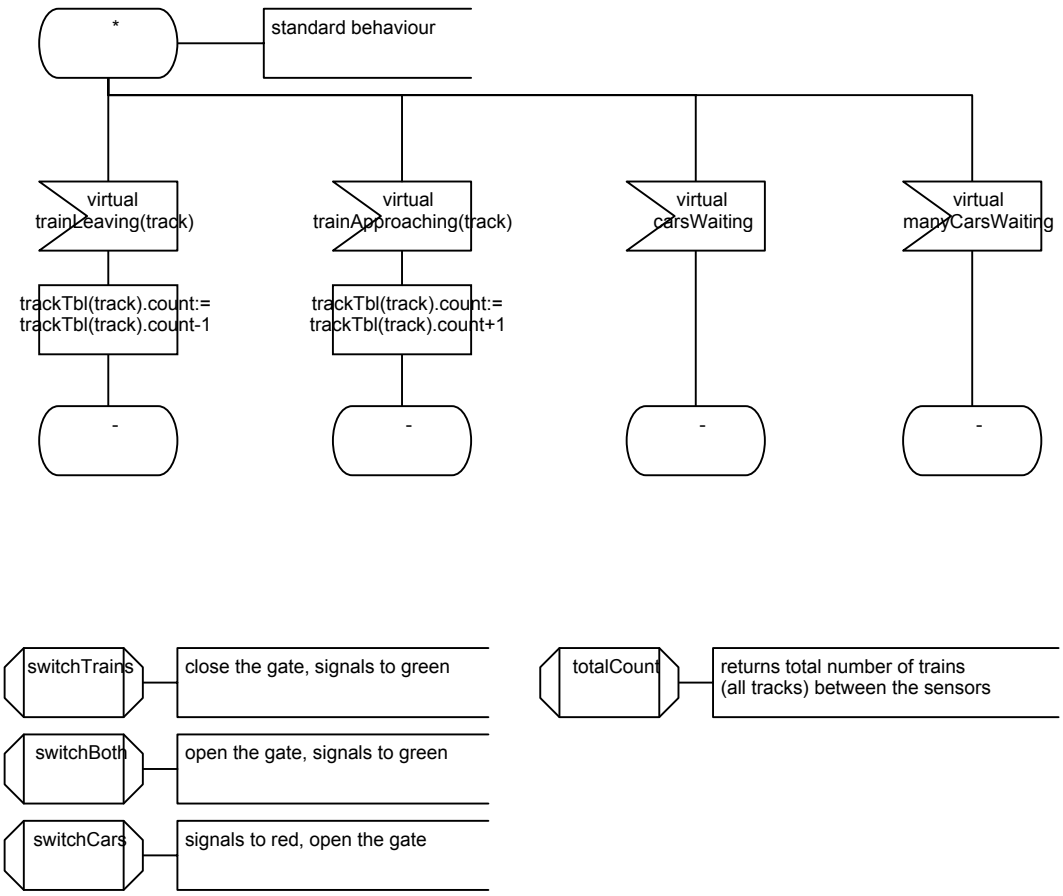

Service theSensorDebouncer
1(1)
/* timer */
timer t1(TrackId);
timer t2(TrackId);
/* variables */
DCL track TrackId;
synonym threshold Duration=1;
/* debouncing threshold */
idle
detectApproaching (track)
detectLeaving (track)
t1(track)
t2(track)
no sensor signal for at least threshold time units
set(NOW+threshold, t1(track));
set(NOW+threshold, t2(track))
sensor signals in the next threshold time units will not be passed to theCentralController
trainApproaching (track)
trainLeaving (track)
leaving
wake up theSignalControl
-


Service Type BasicController
1(4)
/* variables */
DCL train PId;
DCL track TrackId;
DCL speed Real;
virtual
trains
initially the gate is closed
and all signals are green
*
trackAnnounce(track, speed)
trackLst:=trackLst // mkstring(track);
trackTbl(track).speed:=speed;
append track to track list,
set speed information in table
-
g1
(gateStatus),
(carSensor)
(gateControl)
g2
(trainDetection)
g3
trackAnnounce,
inSight
trainSignal
g4
settingDone
setSignals
g5
(gateControl)

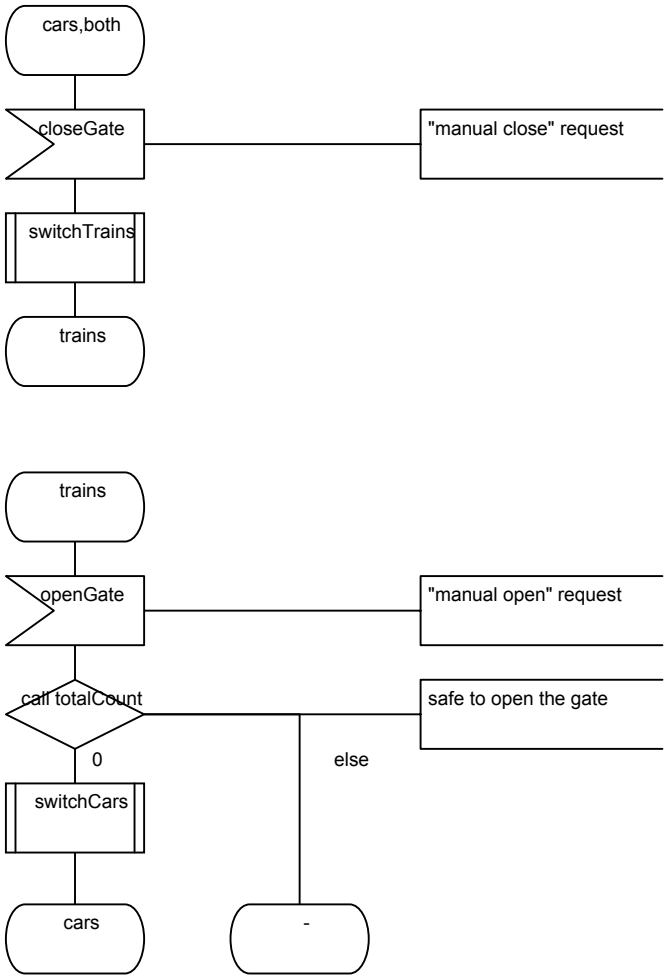
Service Type BasicController 2(4)



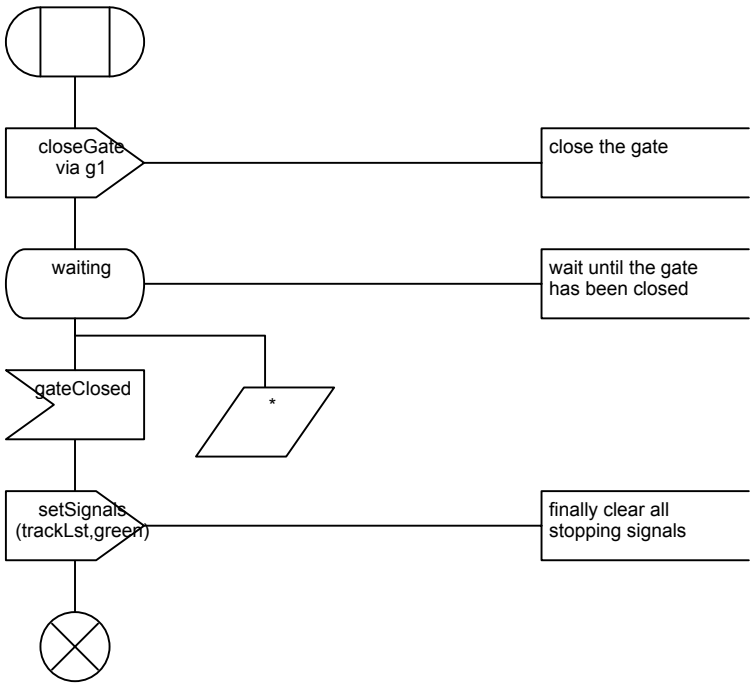
Service Type BasicController 3(4)



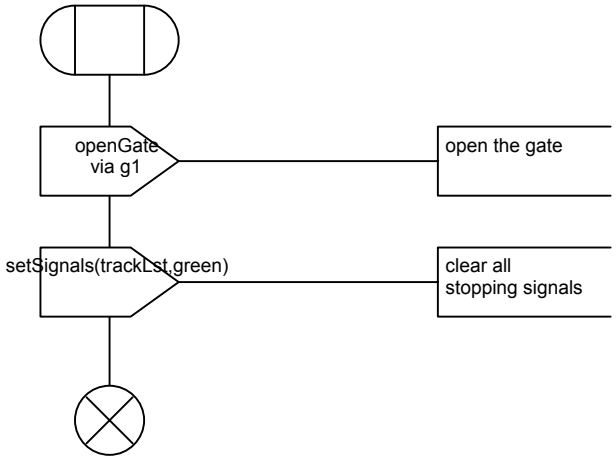
Service Type BasicController 4(4)

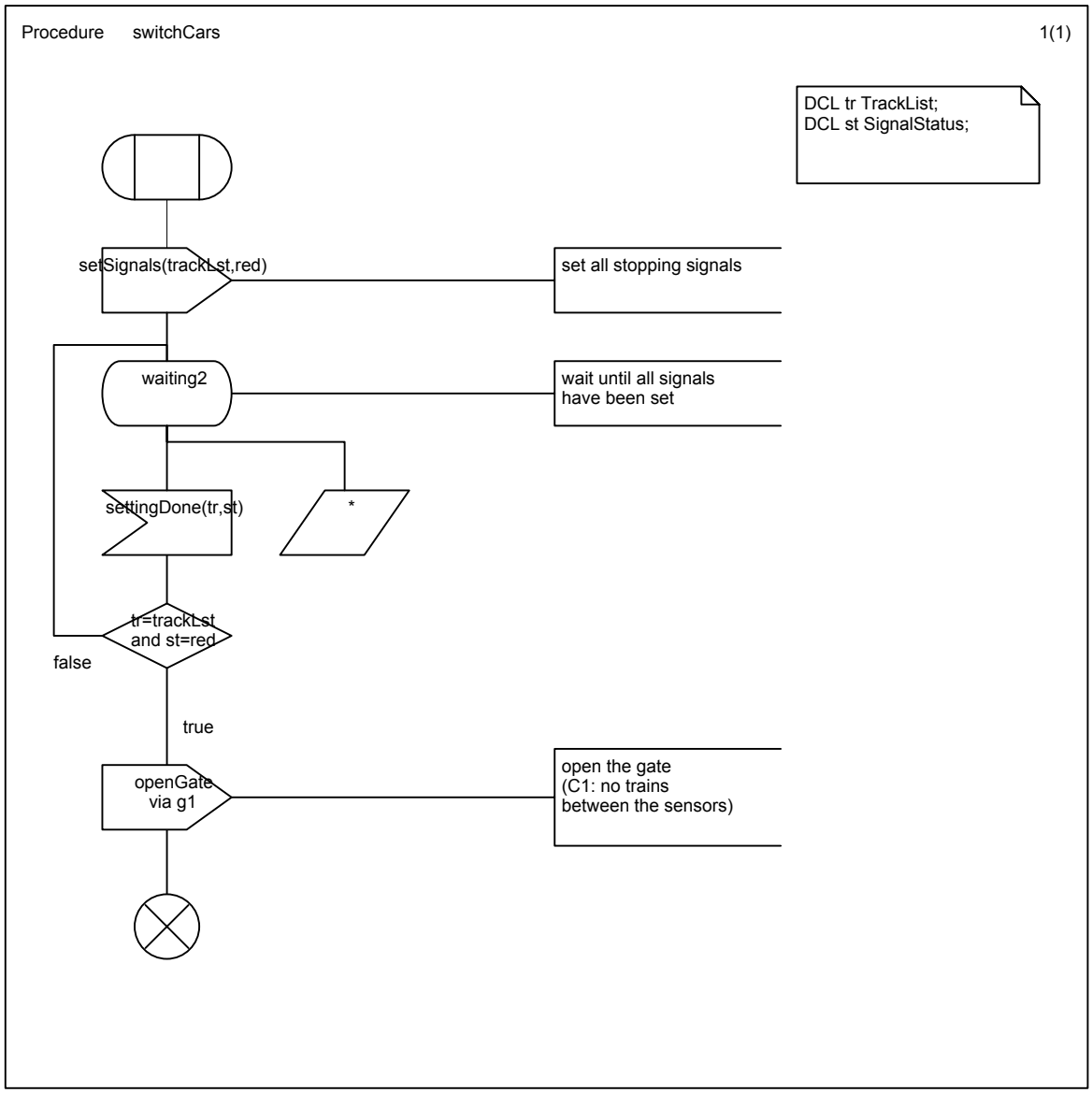


Procedure switchTrains 1(1)



Procedure switchBoth 1(1)




Procedure switchCars
1(1)
DCL tr TrackList;
DCL st SignalStatus;
setSignals(trackLst,red)
set all stopping signals
waiting2
wait until all signals
have been set
settingDone(tr,st)
*
tr=trackLst
and st=red
false
true
openGate
via g1
open the gate
(C1: no trains
between the sensors)

Procedure totalCount 1(1)

returns Integer