

EECS4312 eHealth Project

Siraj Rauff (cse23188@cse.yorku.ca)
Skyler Layne (cse23170@cse.yorku.ca)

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Keep track of your revisions in the table below.

Revisions

Date	Revision	Description
date please	1.0	Initial requirements document

Requirements Document: for Patient care eHealth System

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1. System Overview

The System Under Development (SUD) is a computer system to create and manage health prescription records for Ontario.

This requirements document is specifically for prescription management. The purpose of the eHealth Patient care System is to maintain physicians, medications, patients, and patient prescriptions. The system will also control the undesirable interactions between medications, that is when two medications conflict in some way with one another. Only specialist physicians should be allowed to prescribe undesirable interactions while general physicians should be allowed to prescribe medications, as long as they do not create undesirable interactions.

2. Context Diagram

The System Under Description (SUD) is a computer *controller* to keep track of the physicians, patients, patient prescriptions, medications, and medication interactions. The monitored variables and controlled variables for this computer system can be found in Table 1 and Table 2 respectively.

The system must keep track of abstract state which isn't available to the user. For a list of the abstract states within the controller see Table ??.

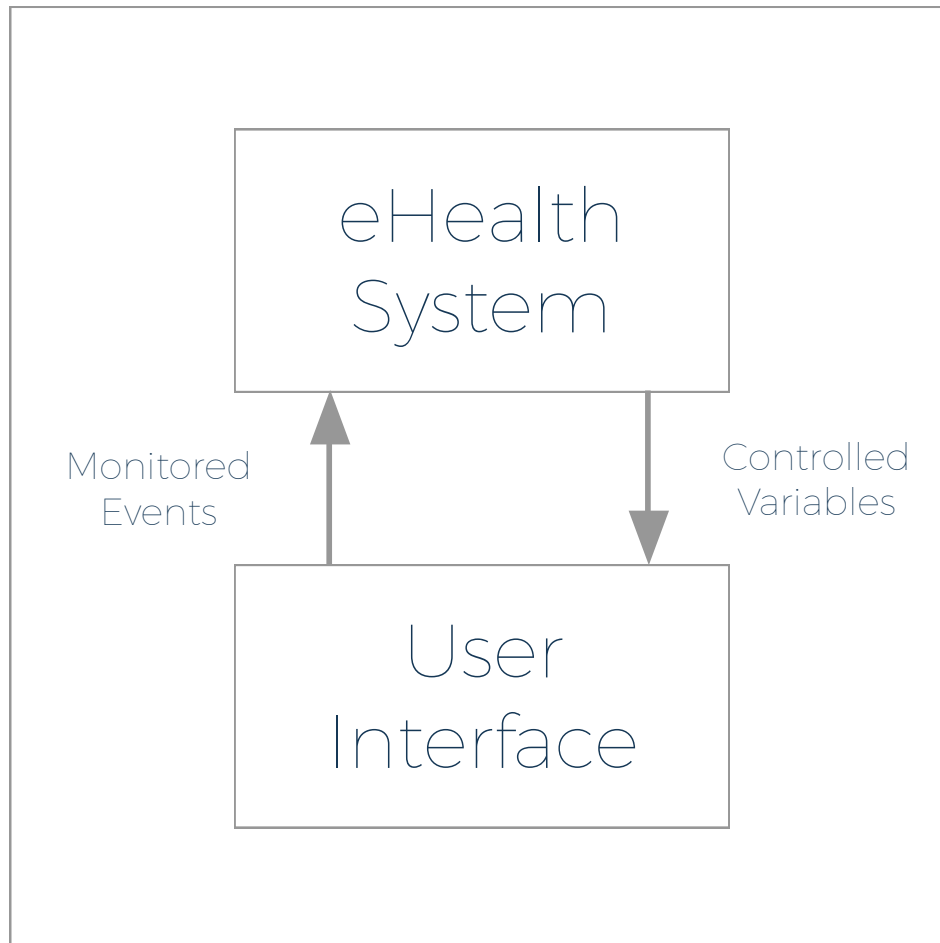


Figure 1: Context Diagram

3. Goals

The high-level goals (G) of the system are:

- G1— The user should be able to add doctors (generalists, and specialists)
- G2— The user should be able to add patients
- G3— The user should be able to add medications
- G4— The user should be able to add perscriptions
- G5— The user should be able to add interactions between medications
- G6— The user should only be able to add a prescription with a dangerous interaction if the doctor is a specialist

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4. Monitored Variables

The monitored variables are a subset of those described in [?].¹ There is a single status variable m_st that is *invalid* whenever any one of the operator inputs or temperature sensor are in a failed state. Otherwise types and ranges are as in [?].

Name	Type	Range	Units	Physical Interpretation
m_tm	\mathbb{R}	68.0 .. 105.0	°F	actual temperature of Isolette air temperature from sensor
m_dl	\mathbb{Z}	97 .. 99	°F	desired lower temperature set by operator
m_dh	\mathbb{Z}	98 .. 100	°F	desired higher temperature set by operator
m_al	\mathbb{Z}	93 .. 98	°F	lower alarm temperature set by operator
m_ah	\mathbb{Z}	99 .. 103	°F	higher alarm temperature set by operator
m_st	Enumerated	{valid, invalid}		status of sensor and operator settings
m_sw	Enumerated	{on, off}		switch set by operator

Table 1: Monitored Variables

¹With some change of nomenclature. Monitored variables have an “m” prefix.

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5. Controlled Variables

The controlled variables are a subset of those described in [?].² In addition, there is a mode display c_md and a message display c_ms .³

Name	Interpretation	Abstract State
Physicians	A list of all the Physicians currently within the system	See table 3
Patients	A list of all the Patients currently in the system	See table 3
Medications	A list of all the Medications currently within the system	See table 3
Interactions	A list of all the Interactions currently within the system	See table 3
Prescriptions	A list of all the Prescriptions within the system	See table 3
Error	A message displaying the highest priority error, or ok	See table 3

Table 2: Controlled Variables

²With some change of nomenclature. Controlled variables have a “c” prefix.

³The mode “off” is added to that of Fig. A-4 in [?], and the mode transitions have been changed.

6. Mode Diagram

REQ1 states The *controller* shall operate in one of four modes: *off*, *init*, *normal* and *fail*, shown in Fig. 2. As shown in the figure, the Isolette will begin in the *off* mode, and will enter *init* mode when the nurse flips *m_sw* into the *on* position. The Isolette will only be able to move from the *init* mode to the *normal* mode if it is properly configured such that the desired range is valid and not overlapping with the alarm levels, and both the sensors and operator controls are working (see REQ6). Once inside the *normal* mode, the controller will move to the *fail* mode if either the controls or sensor fails, as specified in REQ5, and will only return to the *normal* mode once they are both working correctly (REQ11). In any of these states, if the nurse switches *m_sw* to *off* the controller will switch to the *off* mode (REQ12).

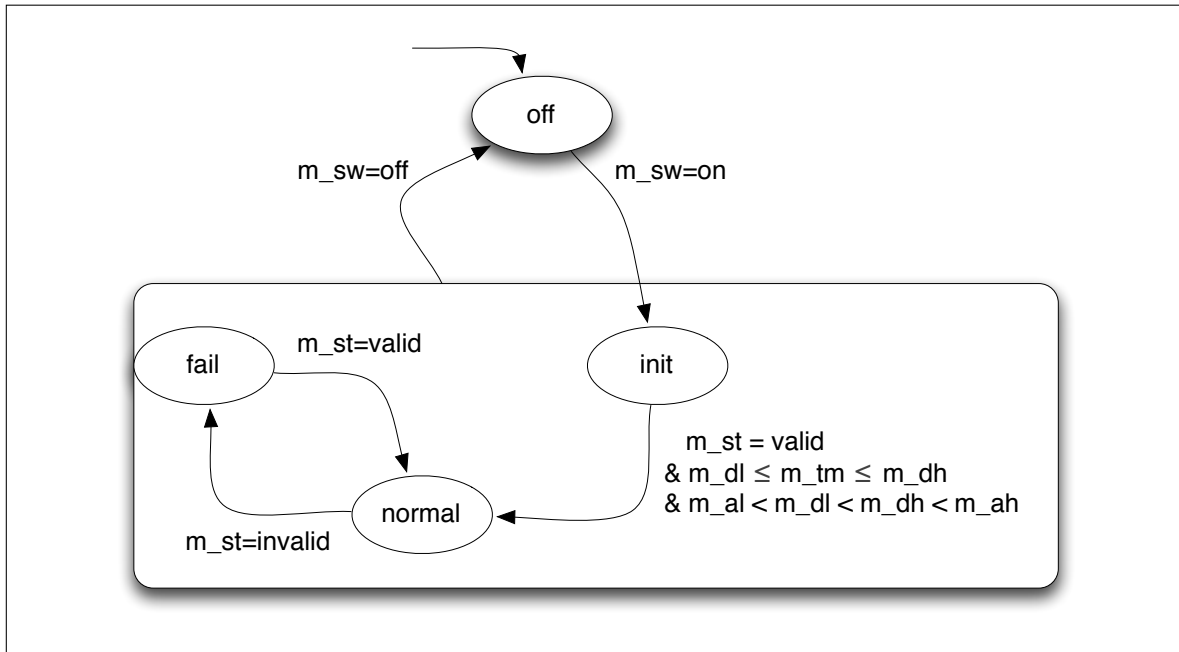


Figure 2: Statechart for the modes variable *c_md*

7. E/R-descriptions

7.1. Requirements Descriptions

REQ1	The <i>controller</i> shall operate in one of four modes: <i>off</i> , <i>init</i> , <i>normal</i> and <i>fail</i> .	See statechart in Fig. 1.
------	--	---------------------------

Rationale: The Isolette should consist of separate states to indicate to the nurse whether it is safe or not for the child to be kept inside. States should exist to the nurse as messages, either of normal status or of an error. Errors such as failed sensors or display interfaces, or an invalid configuration of the *desired temperature range* and *alarm values* should be displayed to the nurse.

REQ2	In the <i>normal</i> mode, the temperature controller shall maintain current temperature inside the Isolette within a set temperature range (the <i>desired</i> range).	The <i>desired</i> temperature range is $m_dl..m_dh$. If the current temperature m_tm is outside this range, the controller shall turn the heater on or off via the controlled variable m_hc to maintain the desired state.
------	---	--

Rationale: The *desired temperature range* will be set by the nurse to the desired range based on the infant's weight and health. The controller shall maintain the current temperature within this range under normal operation.

REQ3	<p>In <i>normal</i> mode, the controller shall activate an alarm whenever</p> <ul style="list-style-type: none"> • the current temperature falls outside the <i>alarm</i> temperature range (either through temperature fluctuation or a change in the alarm range by an operator), or • a failure is signalled in any of the input devices (temperature sensor and operator settings). 	<p>The alarm temperature range is <i>m_al</i>..<i>m_ah</i>. Monitored variable <i>m_st</i> shows “invalid” when any of the input signals fail.</p>
------	---	--

Rationale: During normal operation, if any conditions occur that could affect the wellbeing of the infant, the nurse should be notified by an alarm. This could include sensor or interface failure, or current temperature exceeding alarm values - even if this is caused by the nurse adjusting the values.

REQ4	<p>Once the alarm is activated, it becomes deactivated in one of two ways:</p> <ul style="list-style-type: none"> • The nurse turns off the Isolette; • The alarm has lasted for 10 seconds, and after 10 seconds or more the alarm conditions are removed. 	<p>The alarm <i>c_al</i>, will remain on until <i>c_md</i> goes to state off, or has been held for 10 seconds.</p>
------	---	--

Rationale: The alarm should stay on as long as the alarm condition remains. Once the conditions have been cleared, the alarm should only turn off after it has been on for at least 10 seconds to ensure that the nurse was in fact notified of the temperature fluctuation into dangerous areas or the possible failure of a component. This is because quick fluctuations in temperature or a component that could be shorting out momentarily might not occur long enough for the alarm to sound and notify the nurse.

REQ5	In <i>normal</i> mode, the controller will enter the <i>fail</i> mode if the sensors or operator controls stop working.	If monitored variable <i>m_st</i> shows “invalid”, the controller will enter the fail state. See statechart in Fig. 1.
------	---	--

Rationale: During normal operation, if the sensor or controls malfunction, the controller should enter the *fail* mode display a message through the interface indicating so. No assumptions should be made in this state as the accuracy of the monitored data can no longer be trusted to be accurate.

REQ6	<p>In <i>init</i> the controller will only be able to transition to <i>normal</i> if</p> <ul style="list-style-type: none"> • The current temperature is in the desired range and • The desired range is valid and • The alarm levels do not overlap the desired range and • The operator controls and sensors are working 	<p>The controller must only transition to <i>normal</i> if</p> <p>$m_{al} < m_{dl} < m_{dh} < m_{ah}$ and <i>m_st</i> does not show “invalid”</p>
------	--	---

Rationale: After the nurse has configured the Isolette, it should not proceed to *normal* mode before first validating the consistency of the configuration and ensuring that the environment is adjusted until it is consistent with the configuration. This ensures the proper functioning of the Isolette as well as ensuring that the desired temperature range is reached before the infant is placed inside which is critical to the infant’s wellbeing.

7.2. Environmental Descriptions

ENV7	The current temperature received from the sensor is a real number in the range 68.0 to 105.0°F.	The temperature of the system <i>m_tm</i> will only operate within the given range
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Rationale: The system will never encounter temperatures outside the range of 68.0 to 105.0°F in the environments they are deployed in, and does not have to deal with any values outside this range.

ENV8	The desired and alarm temperatures received from the operator are all in increments of 1°F.	m_{ah} , m_{al} , m_{dh} , and m_{dl} in Table 1: Monitored Variables.
------	---	--

Rationale: The operator interface for the nurse is designed in such a way that the increments of the input temperatures from the control interface must change by whole numbers.

ENV9	Failure of the sensors or operator settings will cause the status to become invalid.	If the sensor or operator settings fail, m_{st} becomes invalid.
------	--	--

Rationale: The environment has ways of detecting failures of the operator interface or the temperature sensor and indicating their status to the controller. The Isolette must constantly be monitoring the status of the sensors and controls to ensure that safe assumptions can be made on their values so as to not endanger the infant.

ENV10	The alarm levels may be set such that they are overlapping with the desired temperature range.	The range of m_{al} overlaps slightly with m_{dl} , and m_{ah} overlaps with m_{dh} , the system should account for this and ensure the Isolette is properly configured, and display a message to the nurse if it is not.
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Rationale: The operator controls allow the nurse to set m_{al} anywhere from 97 .. 98, and m_{dl} to any value in 97 .. 99. It is then possible for the nurse to set m_{al} such that it will cause an alarm while m_{tm} is in the desired range of m_{dl} .. m_{dh} . The same is true for m_{ah} and m_{dh} . The Isolette must be aware of this possibility, and display an appropriate error message to the nurse if the configuration of the Isolette is not valid.

8. Abstract variables needed for the Function Table

Name	Interpretation	Purpose
mnid	The set of all medication ids	Keep track of all the medication ids in the system
ptid	The set of all patient ids	Keep track of all the patient ids in the system
mdid	The set of all doctor ids	Keep track of all the doctor ids in the system
rxid	The set of all prescription ids	Keep track of all the prescription ids in the system
mdpt	Relationship between Doctor and Patient	Keep track of the doctor and the patient
rx	Relation between doctor patient and medication	Keep track of all the medical prescriptions between doctor and patient in the system
prs	List of all prescriptions including dosage	Keep track of all the prescriptions in the system
di	Set of dangerous interactions between medications	Keep track of all the dangerous interactions in the system
gs	The kind of doctor	Keep track of all the type of doctor
dpi	The dangerous prescription report	Notify dangerous interactions, if they exist

Figure 3: Abstract Variables used in Function Tables

9. Function Tables

9.1. Table of Error codes and Warnings

Name	Meaning
err1	physician id must be a positive integer
err2	physician id already in use
err3	name must start with a letter
err4	patient id must be a positive integer
err5	patient id already in use
err6	name must start with a letter
err7	medication id must be a positive integer
err8	medication id already in use
err9	medication name must start with a letter
err10	medication name already in use
err11	require $0 < \text{low-dose} \leq \text{hi-dose}$
err12	medication ids must be positive integers
err13	medication ids must be different
err14	medications with these ids must be registered
err15	interaction already exists
err16	first remove conflicting medicine prescribed by generalist
err17	prescription id must be a positive integer
err18	prescription id already in use
err19	physician id must be a positive integer
err20	physician with this id not registered
err21	patient id must be a positive integer
err22	patient with this id not registered
err23	prescription already exists for this physician and patient
err24	prescription id must be a positive integer
err25	prescription with this id does not exist
err26	medication id must be a positive integer
err27	medication id must be registered
err28	medication is already prescribed
err29	specialist is required to add a dangerous interaction
err30	dose is outside allowed range
err31	prescription id must be a positive integer
err32	prescription with this id does not exist
err33	medication id must be a positive integer
err34	medication id must be registered
err35	medication is not in the prescription
err36	medication id must be a positive integer
err37	medication id must be registered
warn1	There are dangerous prescriptions
warn2	There are no dangerous prescriptions

Figure 4: Table of errors and warnings

9.2. Function Table for Heat Control: c_hc

Monitored Inputs $c_md(i)$		$c_hc(i)$
$i = 0$		off
$i > 0$	$c_md(i) = off \vee \neg c1 \vee \neg c3$	off
	$\neg c_md(i) = off \wedge c1 \wedge c3$	$c2$
		$m_tm(i) < m_dl(i)$
		$m_tm(i) > m_dh(i)$

Figure 5: Function Table for heat control: c_hc

9.3. Function Table for Temperature Display: c_td

Monitored Inputs $m_tm(i)$, $c_md(i)$	$c_td(i)$
$c_md(i) = normal$	$m_tm(i)$
$\neg c_md(i) = normal$	0

Figure 6: Function Table for Temperature Display: c_td

9.4. Function Table for Mode: c_md

Monitored Inputs $m_sw(i)$, $c_md(i-1)$				$c_md(i)$
$i = 0$				off
$i > 0$	$m_sw(i) = off$			off
	$m_sw(i) = on$	$c_md(i-1) = off$		init
		$c_md(i-1) = normal \vee c_md(i-1) = failed$	$c1(i)$	normal
			$\neg c1(i)$	failed
		$c_md(i-1) = init$	$c4(i)$	init
			$\neg c4(i)$	normal

Figure 7: Function Table for Mode: c_md

9.5. Function Table for Messages: c_ms

Monitored Inputs $m_al(i)$, $m_ah(i)$, $m_tm(i)$	$c_ms(i)$
$\neg c1(i)$	invalid
$\neg c3(i)$	config
$m_tm(i) < m_al(i)$	low
$m_tm(i) > m_ah(i)$	high
ELSE	ok

Figure 8: Function Table for Messages: c_ms

9.6. Function Table for Alarm: c_{al}

Monitored Inputs $m_{al}(i)$, $m_{ah}(i)$, $m_{tm}(i)$				$c_{al}(i)$
$i = 0$				off
$i > 0$	$c_{al}(i-1) = \text{off}$	$c7(i)$		NC
		$\neg c7(i)$		on
	$c_{al}(i-1) = \text{on}$	$c8(i)$		NC
		$\neg c8(i)$	$held_for(i)$	off
			$\neg held_for(i)$	on

Figure 9: Function Table for Alarm: c_{al}

10. Validation

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You must also provide and prove in PVS one important safety invariant for the heat control c_{hc} and one important safety invariant for the alarm control c_{al} .

Include the PVS sources in the appendix to this document but summarize the proofs here (top.summary).

```

***
*** top (23:34:28 11/15/2015)
*** Generated by proveit - ProofLite-6.0.9 (3/14/14)
*** Trusted Oracles
***   MetiTarski: MetiTarski Theorem Prover via PVS proof rule metit
***
Proof summary for theory top
  Theory totals: 0 formulas, 0 attempted, 0 succeeded (0.00 s)

Proof summary for theory Time
  r2d_TCC1.....proved - complete    [shostak](0.23 s)
  d2r_TCC1.....proved - complete    [shostak](0.03 s)
  held_for_TCC1.....proved - complete [shostak](0.08 s)
  Theory totals: 3 formulas, 3 attempted, 3 succeeded (0.33 s)

Proof summary for theory isolette
  c_md_ft_TCC1.....proved - complete [shostak](0.03 s)
  c_md_ft_TCC2.....proved - complete [shostak](0.03 s)
  c_md_ft_TCC3.....proved - complete [shostak](0.05 s)
  c_md_ft_TCC4.....proved - complete [shostak](0.10 s)
  c_md_ft_TCC5.....proved - complete [shostak](0.06 s)
  c_md_ft_TCC6.....proved - complete [shostak](0.03 s)
  c_md_ft_TCC7.....proved - complete [shostak](0.02 s)
  c_md_ft_TCC8.....proved - complete [shostak](0.02 s)
  c_md_ft_TCC9.....proved - complete [shostak](0.02 s)
  c_td_ft_TCC1.....proved - complete [shostak](0.01 s)
  c_hc_ft_TCC1.....proved - complete [shostak](0.07 s)
  c_hc_ft_TCC2.....proved - complete [shostak](0.11 s)
  c_hc_ft_TCC3.....proved - complete [shostak](0.07 s)
  c_hc_ft_TCC4.....proved - complete [shostak](0.05 s)
  c_hc_ft_TCC5.....proved - complete [shostak](0.03 s)
  c_al_ft_TCC1.....proved - complete [shostak](0.03 s)
  c_al_ft_TCC2.....proved - complete [shostak](0.04 s)
  c_al_ft_TCC3.....proved - complete [shostak](0.00 s)
  c_al_ft_TCC4.....proved - complete [shostak](0.07 s)
  c_al_ft_TCC5.....proved - complete [shostak](0.04 s)
  c_al_ft_TCC6.....proved - complete [shostak](0.03 s)
  inv_hc_holds.....proved - complete [shostak](0.34 s)
  inv_al_holds.....proved - complete [shostak](2.71 s)
  Theory totals: 23 formulas, 23 attempted, 23 succeeded (3.98 s)

Grand Totals: 26 proofs, 26 attempted, 26 succeeded (4.32 s)

```

Figure 10: Validated Isolette

11. Use Cases

See Section A2 of [?] for some use cases. The use cases need to be adapted to the revised descriptions of the previous sections of this document.

12. Acceptance Tests

In this section, the use cases have to be converted into precise acceptance tests (using the function table to describe pre/post conditions) to be run when the design and implementation are complete.

13. Traceability

Matrix to show which acceptance tests passed, and which R-descriptions they checked.

14. Glossary

The definition of important terms is placed in this section. You are not required to complete this.

A. Additional Requirements

REQ11	<p>In <i>fail</i> mode, the controller shall only return to <i>normal</i> mode if</p> <ul style="list-style-type: none">• The sensor is working and• The operator controls are working	<p>In <i>fail</i> mode the controller shall return to <i>normal</i> mode when <i>m_st</i> returns “valid”</p>
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REQ12	<p>In any mode, the controller will transition to the <i>off</i> mode if the nurse turns the switch off.</p>	<p>The controller will transition to <i>off</i> mode from any mode if <i>m_sw</i> becomes <i>off</i></p>
-------	--	--

B. Isolette PVS

```

isolette[delta:posreal]: THEORY
BEGIN

  %% Import timing resolution
  importing Time[delta]
  i: VAR DTIME

  %% TYPE declarations
  SWITCH: TYPE = {on, off}
  MSTATE: TYPE = {valid, invalid}
  CONTROL: TYPE = {on, off}
  STATE: TYPE = {off, init, normal, failed}
  ERROR: TYPE = {ok, invalid, config, low, high}
  DISPLAY: TYPE = {i: nat | i = 0 OR (68 <= i AND i <= 105)}
    CONTAINING 0
  ALARM: TYPE = {on, off}
  TM: TYPE+ = {r: real | r >= 68.0 AND r <= 105.0} CONTAINING 68.0
  DL: TYPE+ = {i: nat | i >= 97 AND i <= 99} CONTAINING 97
  DH: TYPE+ = {i: nat | i >= 98 AND i <= 100} CONTAINING 98
  AL: TYPE+ = {i: nat | i >= 93 AND i <= 98} CONTAINING 93
  AH: TYPE+ = {i: nat | i >= 99 AND i <= 103} CONTAINING 99

  %% Monitored Variables
  m_tm: [DTIME -> TM]
  m_dl: [DTIME -> DL]
  m_dh: [DTIME -> DH]
  m_al: [DTIME -> AL]
  m_ah: [DTIME -> AH]
  m_st: [DTIME -> MSTATE]
  m_sw: [DTIME -> SWITCH]

  %% Controlled Variables
  c_hc: [DTIME -> CONTROL]
  c_td: [DTIME -> DISPLAY]
  c_al: [DTIME -> ALARM]
  c_md: [DTIME -> STATE]
  c_ms: [DTIME -> ERROR]

```

```

al_on(i): bool = c_al(i) = on %% Alarm is on

% General Function table conditions
c1(i): bool = m_st(i) = valid
c2(i): bool = m_dl(i) <= m_tm(i) <= m_dh(i)
c3(i): bool = m_al(i) < m_dl(i) < m_dh(i) < m_ah(i)
c4(i): bool = c1(i) AND c2(i) AND c3(i)
c5(i): bool = m_tm(i) <= m_al(i) + 0.5
c6(i): bool = m_tm(i) <= m_al(i) - 0.5
c7(i): bool = c1(i) AND c3(i) AND m_al(i) < m_tm(i) < m_ah(i)
c8(i): bool = NOT c1(i) OR NOT c3(i) OR c5(i) OR c6(i)
held_for(i): bool = held_for(al_on, 10)(i)

% Mode Function Table
c_md_ft(i): bool =
COND
    i = 0 -> c_md(i) = off,
    i > 0 ->
COND
        m_sw(i) = off -> c_md(i) = off,
        m_sw(i) = on ->
COND
            c_md(i-1) = off -> c_md(i) = init,
            c_md(i-1) = normal OR c_md(i-1) = failed ->
COND
                NOT c1(i) -> c_md(i) = failed,
                c1(i) -> c_md(i) = normal
ENDCOND,
        c_md(i-1) = init ->
COND
            NOT c4(i) -> c_md(i) = normal,
            c4(i) -> c_md(i) = init
ENDCOND
ENDCOND
ENDCOND
ENDCOND

```



```
% Temperature Display Function Table
c_td_ft(i): bool =
COND
    c_md(i) = normal -> c_td(i) = m_tm(i),
    NOT c_md(i) = normal -> c_td(i) = 0
ENDCOND

% Heat Control Function Table
c_hc_ft(i): bool =
COND
    i = 0 -> c_hc(i) = off,
    i > 0 ->
COND
    c_md(i) = off OR (NOT c1(i))
    OR (NOT c3(i)) -> c_hc(i) = off,
    (NOT c_md(i) = off) AND c1(i) AND c3(i) ->
COND
    c2(i) -> c_hc(i) = c_hc(i-1),
    m_tm(i) < m_dl(i)
    -> c_hc(i) = on,
    m_tm(i) > m_dh(i)
    -> c_hc(i) = off
ENDCOND
ENDCOND
ENDCOND
```

```

% Alarm Function Table
c_al_ft(i): bool =
COND
    i = 0 -> c_al(i) = off,
    i > 0 ->
    COND
        c_al(i-1) = off ->
        COND
            c7(i) -> c_al(i) = c_al(i-1),
            NOT c7(i) -> c_al(i) = on
        ENDCOND,
        c_al(i-1) = on ->
        COND
            c8(i) -> c_al(i) = c_al(i-1),
            NOT c8(i) ->
            COND
                held_for(i) -> c_al(i) = off,
                NOT held_for(i) -> c_al(i) = on
            ENDCOND
        ENDCOND
    ENDCOND
ENDCOND

% Message Display Function Table
c_ms_ft(i): bool =
    IF m_st(i) = invalid THEN c_ms(i) = invalid
    ELIF NOT c3(i) THEN c_ms(i) = config
    ELIF m_tm(i) < m_al(i) THEN c_ms(i) = low
    ELIF m_tm(i) > m_ah(i) THEN c_ms(i) = high
    ELSE c_ms(i) = ok
    ENDIF

% Isolette Specification
isolette(i): bool = c_hc_ft(i) AND c_td_ft(i) AND c_al_ft(i)
    AND c_md_ft(i) AND c_ms_ft(i)

```

```
% Checks
inv_hc(i): bool = NOT (c1(i) AND c3(i)) IMPLIES c_hc(i) = off
inv_hc_holds: CONJECTURE (FORALL i: isolette(i)) =>
                    (FORALL i: inv_hc(i))

inv_al(i): bool = i > 0 AND (
    (NOT al_on(i-1) AND NOT c7(i))
    OR (al_on(i-1) AND c8(i))
    OR (al_on(i-1) AND NOT c8(i) AND NOT held_for(i))
) IMPLIES c_al(i) = on
inv_al_holds: CONJECTURE (FORALL i: i>0 IMPLIES isolette(i))
                    => (FORALL i: i>0 IMPLIES inv_al(i))

END isolette
```