User manual

11-03-2017

Version 1.0

Company Information

Document Revisions

Date	Version Number	Document Changes
11/03/2017	1.0	First draft

Table of Contents

Safety & Precaution

Ensure that the product is always used within the specifications

Do not use product close to flammable and explosive gas otherwise injury from explosion may occur

Never disassemble, modify, or touch any of the internal part to avoid electric shock or malfunctions

Do not use the relay over their life cycle and do not exceed the rated load of the outputs

Do not touch the terminals at least while power is being supplied. Doing so may occasionally result in injury due to electric shock.

 Do not allow pieces of metal, wire clippings, or fine metallic shaving or filings from installation to enter the product.

Do not allow water or any liquid enter the product. Enclosure is not water prof

The board is sold as a DIY standalone component and people buying should take care of connecting and integrating with their own system. The manula connection diagram and short explanations but minimum expertise in electric circuit is needed.

The board is powered by **High Voltage 220/110V** so you must be very careful and all connections are at your own risk. If you are not familiar with electricity and power please ask a technician to help you. I'm not responsible for any damage or risk you can create

1 SmartPID SPC1000 overview

1.1 Scope and Purpose

The purpose of this document is to describe in detail the user application software called home brewing smart app. The document provide the support to configure the application SW and run all different use cases

For the HW installation and basic configuration (including wifi) please refer to proper manuals.

1.2 SmartPID overview

The smartPID controller has been designed to replace low cost simple thermoregulator with a smart controller that can be programmed and adapted to any process. In the specific case the brewing process has been fully automated.

Using the Same DIN enclosure SmartPID microcontroller could replace almost plug an play the standard thermostat in brewing application with providing following key feature

- process enhancement and full automation (step mash/profile/recipe management)
- flexible programming (mashing/fermenting , different set up)
- Higher accuracy (PID control)
- Wide variety of HW (Electric Heating/Gas Heating, Relay/SSR)
- Remote control via dedicated smartphone app or web

In term of technical characteristic SmartPID support

- Dual Independent channels
- PID control and ON/OFF control with hysteresis
- 2x Relays output
- 1 SSR Output
- 2 x 12V 2A power output
- 2 Digital temperature probe input OR NTC input (configurable)
- OLED graphic display
- On Board EEPROM for data logging and parameter configuration/recipe store
- Process data logging
- SW update and loading via USB
- WiFi connection to remote server
- Buzzer events indication
- 4 push button interaction
- 220V power supply

The SmartPID controller is complemented by the **dedicated smartphone app** that allow the user to remote control the brewing process

For details on how to pair the smartPID with the app and configure wifi and thingspeak service please refer to installation and integration manual

2 SmartPID Homebrewing application

Via HW set up configuration SmartPID can be adapted to manage different brewing setup, the HW configuration allows to assign different processes/logicalchannels to different physical HW resources. This provide great flexibility to manage different heting method (gas or electric) and different pump / stirrer (220AC or 12V DC)

Two main configuration support

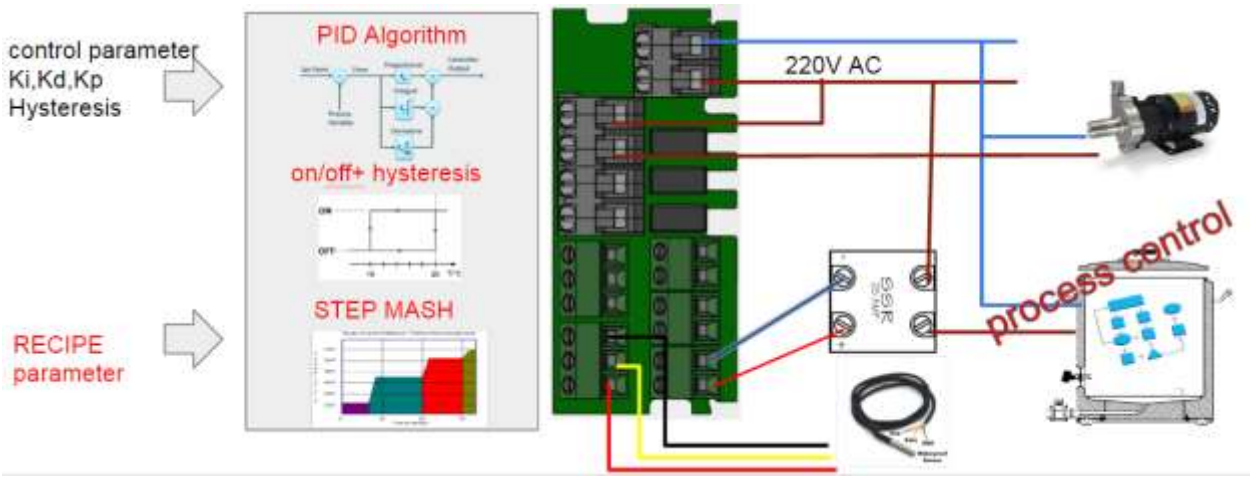
a) BIAB/RIMS - PID or ON/OFF, single vessel system (one temperature + one heating element)
b) BIAB/RIMS process + HLT management , dual vessel dual PID (2 temp probe + 2 heating element)

Below some example to illustrate the flexibility and multiple configurations possible

BIAB/RIMS single PID (on/off) control - heating (gas or electric) + pump

SmartPID reads temperature from 1 probe and drive the heating element via SSR out to automate all steps with temperature control

Pump to recirculate wort or a motor stirred is controlled during all process automatically or manually



Possible heating output configurations

- SSR for electric heating [PID+PWM control algorithm]
- 220V AC relay for electric heating [ON/OFF algorithm]
- Direct solenoid valve drive for GAS heating [ON/OFF algorithm]

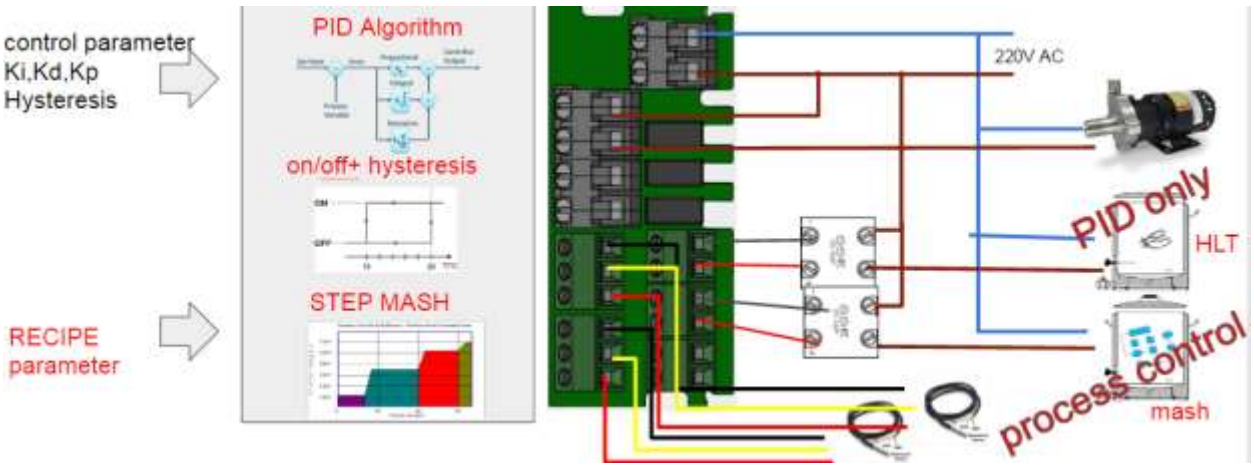
Automatic or manual (soft switch) pump drive with 2 possible configurations

- 220V AC relay pump drive
- 12V DC direct pump drive

BIAB/RIMS dual PID (on/off) control - heating (gas or electric) - pump

SmartPID reads temperature from 2 probe and drive 2 heating element interdependently the mash tun with full process automation and hot liquor tank for sparge water temperature control

Pump/Stirrer can be controlled automatically or manually as in single vessel process



Possible heating output configurations

- 2 x SSR for electric heating [PID+PWM control algorithm]
- 2 x 220V AC relay OR direct solenoid valve drive for GAS heating [on/off]

Automatic or manual (soft switch) pump drive with 2 possible configurations

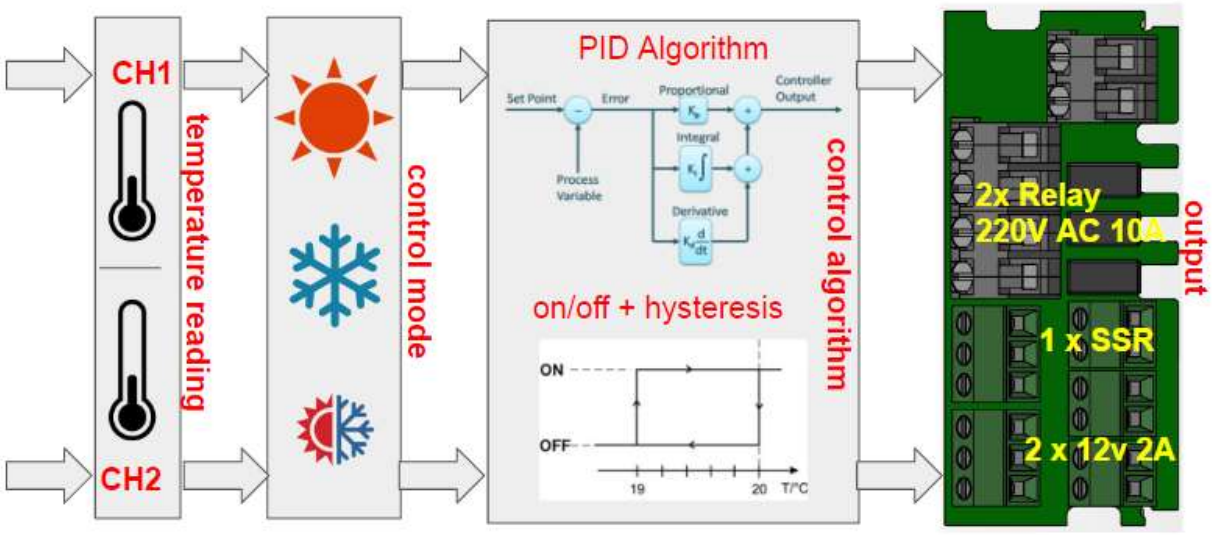
- 220V AC relay pump drive
- 12V DC direct pump drive

3 Smart HomeBrewing application SW

In this chapter the application SW installed and running on the controller is described in order to provide to end user the full understanding about how the brewing process automation has been implemented

3.1 Basic control principle

The core of this application is to implement a temperature control logic either to drive the heating element (electric or gas fired) in an heating process OR to drive a cooling system (typically a fridge) in a cooling process.



The main variable is the setpoint temperature selected by push buttons and this temperature is the input for the controlling algorithm that can be

1. PID algorithm + PWM control [Electric heating element]

Set point is compared with current temperature and the Proportional Integrative Derivative calculation are performed.

Ki,Kp,Kd must be configured or an auto tuning process is be started during set up phase (optional)

PID output drive a PWM power control block in charge to vary the duty cycle of PWM signals from 0 to 100%. The PWM output will drive the load via SSR. In this way a fine control of electric heating element can be performed

Two other relevant parameter can be configure and impact PID behavior

n) Window Size --> Period of the PWM signal

o) Sample Time --> PID sample time

2. ON/OFF algorithm [Gas heating and fridge cooling]

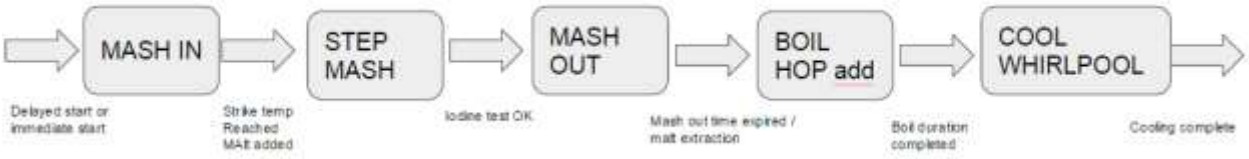
In this case set point is compared with current temperature and depending if the value is over or under the target the output is put in ON or OFF state driving either the mechanical relay or SSR

In order to avoid oscillations near the set point an hysteresis / dead zone should be implemented. The range of hysteresis should be configurable.

The ON/OFF control will be applied directly to heating systems gas fired via a gas ball valve

3.2 Brewing application principle

The brewing application implement a complete workflow in order to allow a fully automatic (or semi-automatic) brew day



The process is typically "linear" in time with execution of step by step sub process conditioned by some user defined parameter that represent the "recipe"

The process can be decomposed in following sub-process to execute sequentially

1. **Recipe LOAD / set up**

   Before starting the process a recipe must be loaded and/or configured. The user is first requested if he wants to define a new recipe or to load a recipe either form EEPROM local repository or for external USB.

   In case of new recipe the proper "recipe management" sw is recalled.

   Once the recipe is finally selected the user is requested if he wants to start the process immediately or to activate a "delayed start".

   In the second case a proper delay can be configured (up to 12h) with up/down buttons in step of minutes. After the delay expiration the mash in process start normally.

2. **MASH IN**

   During this mandatory step the water is heated in order to reach the mash in temperature (recipe parameter) while the recirculating pump, depending on proper set up parameter, is activated in order to have uniform heating of water.

   Before starting the process the user is requested mandatory to confirm the water addition in order not to start dry heating. Immediately after a pump prime process is executed with 3 ON->OFF→ON short pump cycle in order to eliminate from the circuit air bubble.

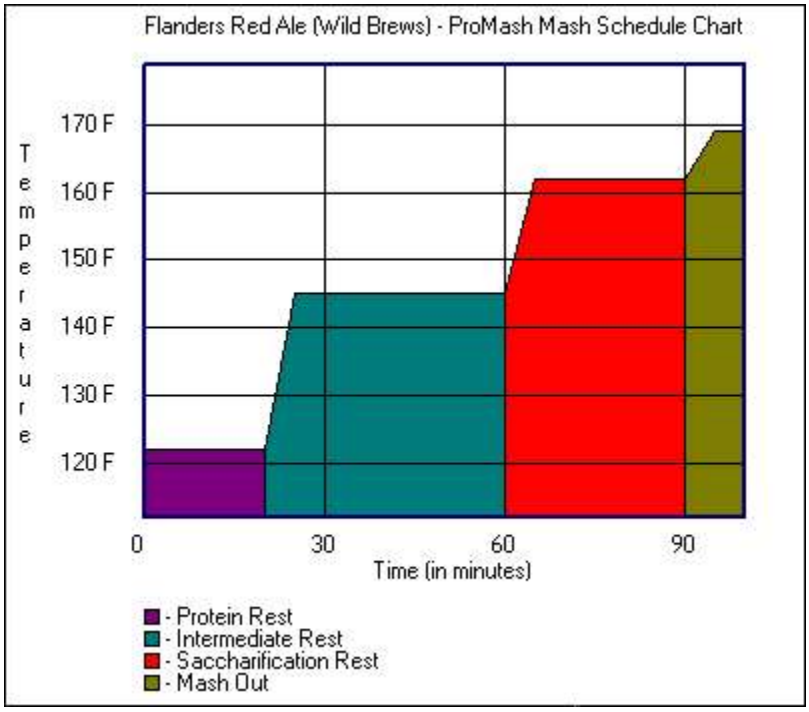
   During the process run the recipe pre-defined set point (Mash IN temp) can be changed anytime with Up/Down buttons.

Heating control is performed according to Unit and HW set up parameter (PID or ON/OFF algorithm). When the Mash IN temperature is reached a beep is played via buzzer, pump is stopped and system enter in “standby” waiting for the confirmation of the next step

NB during the standby time the temperature is maintained constant controlling the heating element

3. STEP MASH

This is the core of the process, the water is mixed with crushed grains and is heated in a step process with defined temperature and duration described in the recipe in order to allow starch conversion into sugar



From controller point of view the heating element is managed according the algorithm selected (PID or ON/OFF) in order to reach the proper temperature, keep it stable for the step duration and then move to the next step.

Before entering the step mash the user should confirm that the malt has been added to the water .

According to pump configuration parameter a pump ON/OFF cycle run in background independently from temperature and step mash.

Manually override of recipe temperature set point can be done anytime with Up/Down button

At the start (target temperature reached) and end (time expired) of each step a beep is played via buzzer.

Once last step is completed the system enter “standby” mode waiting for confirmation of mash out and keeping the last temperature constant.

A-Amilasi2 step is mandatory , the other step can be skipped putting duration=0 in the recipe

The program performs some integrity check and try to avoid user mistakes in configuration: if some input value are not coherent (ie a step with lower SetPoint than the previous one) the step is automatically skipped.

4. MASH OUT

In this mandatory step temperature is raised as soon as possible to the mash out temperature defined in the recipe. This temperature is kept for the duration inserted in the recipe.

Before entering this step the user is requested to confirm iodine test execution that provide evidence of the starch conversion.

During this step PUMP is managed according to parameter configuration either OFF or with ON/OFF cycle like in step mash

Once the mash out time is expired a beep is played via buzzer and then the system enter in "standby" waiting confirmation for boiling phase. Temperature should be kept constant all the time.

5. BOIL AND HOP ADDITION

After mash out the wort is heated until full boil and then the boiling phase start for a period defined in the recipe. During the boil phase multiple hop additions are executed.

Before entering in the boil mode the user is requested to confirm the malt removal/filtering execution.

Since there is no need of fine temperature control, after mash out the heating element is fully powered until reaching the boiling point temperature (defined in the recipe). When temperature is reached a beep is played and timer for boil duration started

The heating element in this phase is manually and statically controlled (no temperature control) using PWM algorithm that allow to throttle power from 0% to 100%.

Pump is controlled according the set up configuration either fully OFF or ON upon certain temperature (safe limit temp for the pump)

The hop addition process runs in parallel and provide a sound beep/display advice every time hop should be added . The number of hops to be added and time are part of the recipe parameter. The time parameter is used as a countdown and the value provide exactly reaming boiling time

After boil time expiration heating element is switched off, as well pump and system enter in cooling mode

6. COOLING/WHIRPOOL

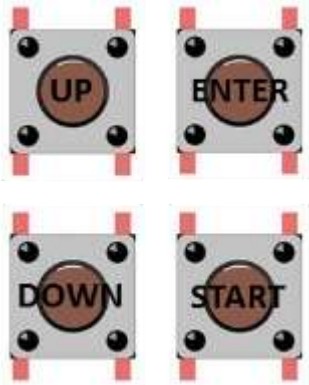
after boil time completion heating element is switched off and beer is cooled up to temperature defined in process parameter and temperature is reported on the display. In this phase pump is switched on or off according to whirlpool parameter in process parameter configuration

It's possible to perform hot or cold whirpool

4 Menu navigation

In following chapter the complete menu structure and navigation is reported, navigation trough menu and selection is performed via tactile switch on the front panel

Each button get its own functions and meaning in the proper context



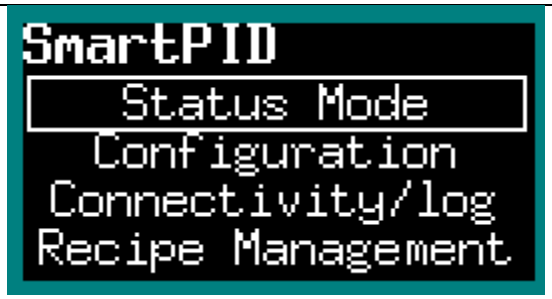
a) UP/DOWN
   a. Scroll in configuration menu
   b. Increase decrease temperature value
   c. Scroll in value in configuration menu

a) ENTER
   d. Select/enter a specific menu
   e. Select/confirm a specific value
   f. Confirm action upon prompt request

b) Start/Stop
   g. Start process
   h. Stop Process

4.1 Main Menu

After the boot smartPID enter in a standby mode with all outputs off and the user can select the main menu items

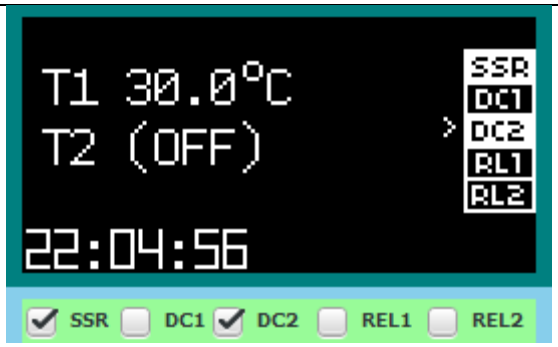


The top level menu corresponds to the main SmartPID functions

1. Status Mode --> it's a simple status where the temperature of the two channels is reported and user can activate / deactivate manually all the outputs (soft switch function)
2. Configuration Menu--> under this menu all the specific smartPID and process parameter configuration is performed
3. Connectivity and Log--> in this menu the user can configure all the wifi parameters, see the connection status, configure the remote server for the data logging. This functions are performed in cooperation with the smartphone app [See installation and configuration manual for details]

4. Recipe Management --> this menu allow the user to enter/edit/view the recipe for the brewing process either the step mash profile or the boil/hop addition schedule.
5. Run Mode--> trough this menu user start the process either in manual or fully automated mode

4.2 Status Mode

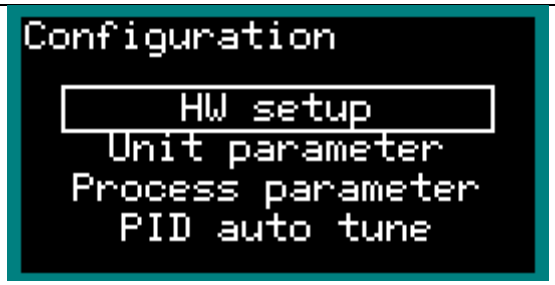


In the status mode the temperature of the T1 and T2 ports is reported as well as the time from the boot of the application. If no temperature probe is connected an error is reported

Moving with UP/DOWN button user can select any output and pressing SET the output can be activated and deactivated. On the OLED the relative label changes the color

To exit the status mode long press S/S button

4.3 Configuration



This menu is dedicated to all the configuration operations that typically are done once during the initialization / setup

1. HW setup --> the HW resources are configured and assigned to I/O process
2. Unit Parameter--> the main parameter that control the PID process behavior are configured in this menu
3. Process parameter--> homebrewing process specific parameter are configured in this menu
4. PID auto tune--> this is a special section to configure and run the auto tune process to help end user to calculate critical parameters Kp,Ki,Kd that regulate PID behavior

4.3.1 HW setup

This section allow to configure physical resources and assign properly to process/channels

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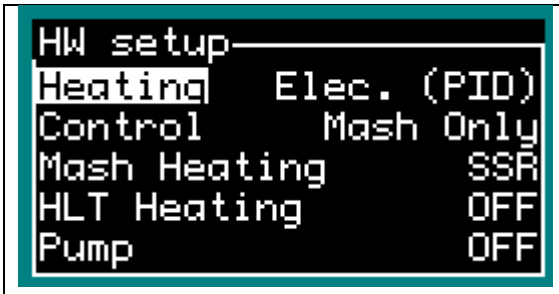
<td> 
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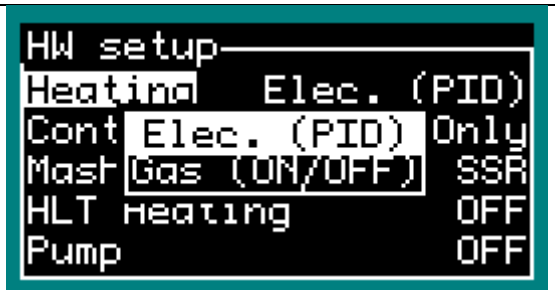
<tr>
<td>Heating Mode

User can select the control mode for the heating element

-Electric (PID algorithm)

-Gas (ON/OFF algorithm)</td>
<td> 
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<tr>
<td>Control Mode

User can select the proper set up of his brewing system deciding to use one or two control channels

-Single Vessel - Mash Only

-Dual Vessels – Mash + HLT</td>
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<tr>
<td>Mash Heating

Through this menu is possible to assign to the mash channel/process the specific output among all possible</td>
<td> 
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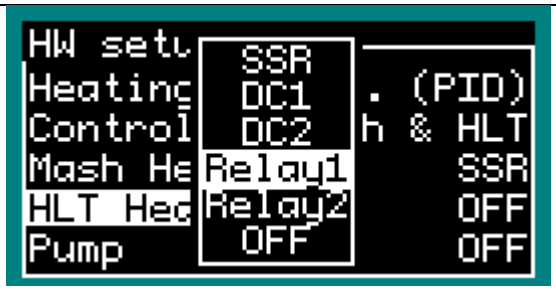
<tr>
<td>HLT Heating

Through this menu is possible to assign to the HLT channel/process the specific output among all possible

Notice that this is possible if control mode has been selected MASH+HLT</td>
<td> 
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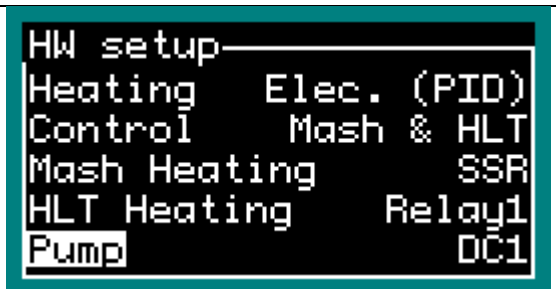
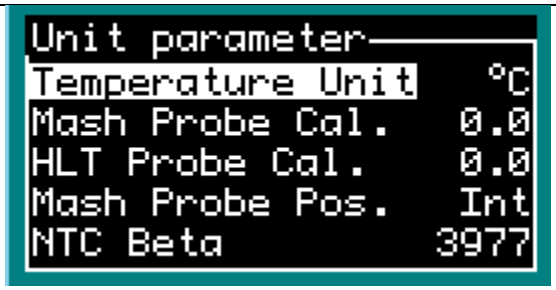
PUMP (stirrer) Finally the pump output should be assigned to a physical resources Note that in order to avoid conflict the resources already assigned can't be selected	
Button Beep Pressing the front panel button generate a short "beep" , through this option is possible to silent the smaprtPID Process sound advice are generated anyway	
Mash Probe The proper temperature sensor is selected and assigned to mash process/ channel -digital one wire sensor DS18B20 -NTC sensors 10K	
HLT Probe The proper temperature sensor is selected and assigned to HLT process/ channel Sensor type can be different from mash one since two channels are independent	

4.3.2 Unit Parameter

This section allow the user to configure global parameter that regulates the overall SmartpPID behavior



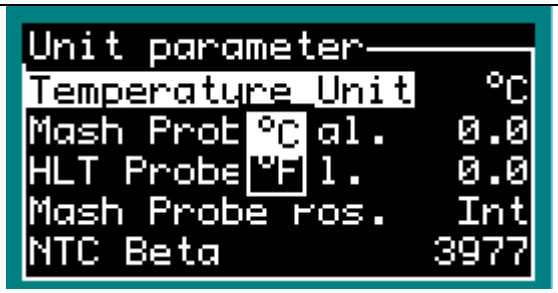
Temperature unit

This menu allow the user to select the proper measurement unit

-Celsisus

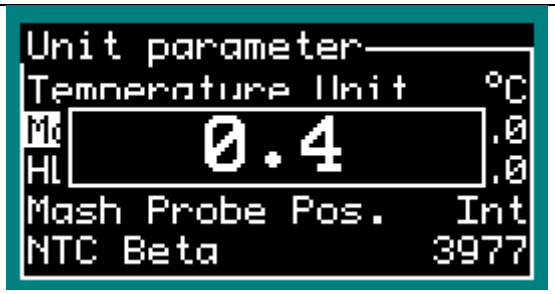
-Fahrenheit

Same configuration should be reported on the smartphone app



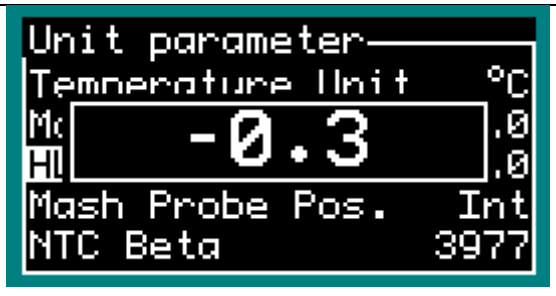
Mash Probe Calibration

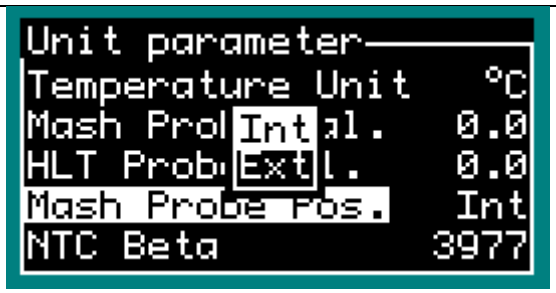
It's possible to add an offset of +- 5c to the mash temperature probe reading to compensate any measurement error



HLT calibration

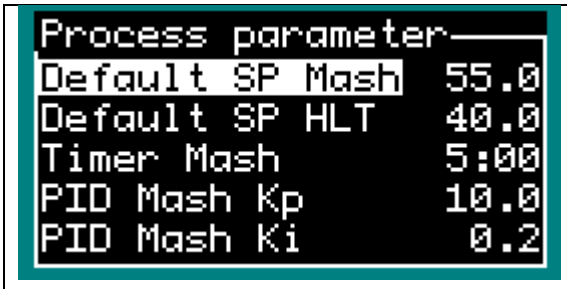
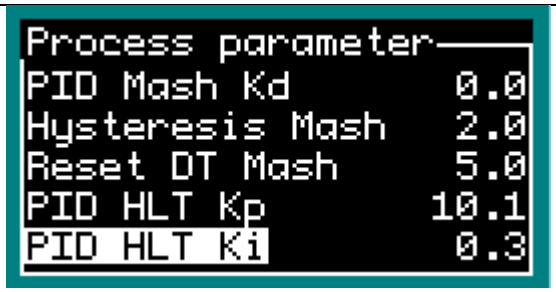
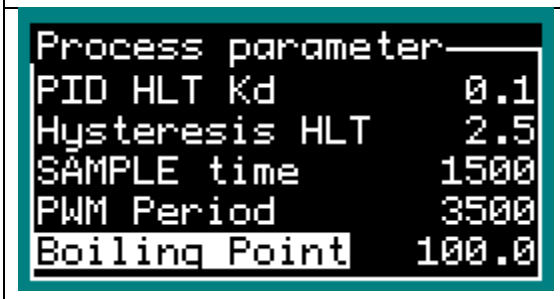
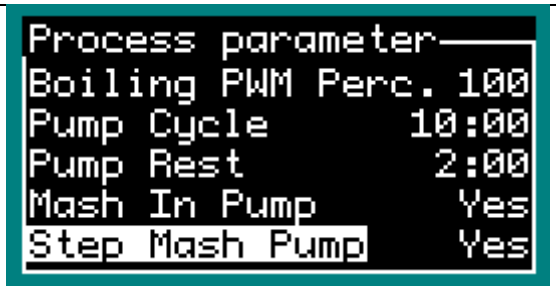
It's possible to add an offset of +- 5c to the HLT temperature probe reading to compensate any measurement error

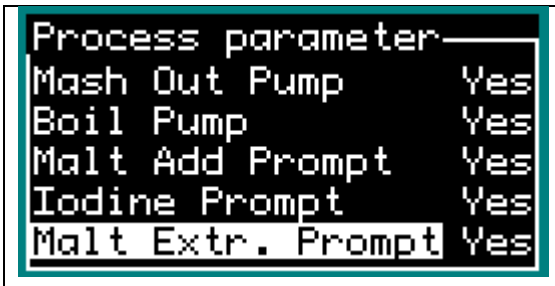


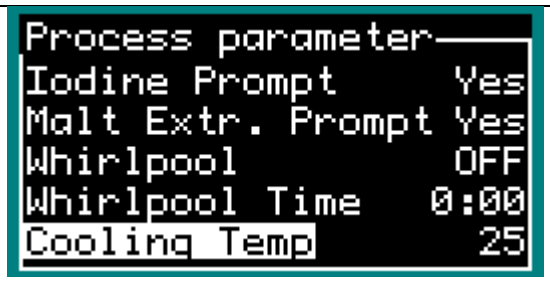
Mash Probe position This is an important parameter that defines where is located the mash temperature probe -internally to the mash tun -externally in the recirculating circuit See appendix for pump cycle descriptio	
NTC beta User can select the Beta coefficient for NTC sensor , most common value are reported Beta will affect the temperature reading and so the precision, try to find the proper one according to spec of your NTC	

4.3.3 Process parameter

This section allow the user to configure all the parameter that are specific for the home brewing process, each of them influence the workflow and overall process execution





Below table reports for each parameter a short description and the range of valid value

Parameter Type	Parameter	Description	Range	default
BIAB parameter	Boiling Point	Define the temperature considered as start of the boiling process	95c-105c	100c
	PWM% @ Boilnig	Define the PWM output % to apply when the temperature reach the boiling point	70%-100%	100%
	PUMP cycle	Define the duration time in minute for the pump ON	5m-20m	10m
	PUMP rest	Define the duration time in minute of the pump OFF	1m-5m	2m
	Pump stage	Define in what stage pump should be used. For each stage Y/N flag should be configured	Mash In Y/N Step Mash Y/N Mash Out Y/N Boil Y/N	Yes all stages
	User Prompt	Define in what stage transition the system enter stand by and ask for explicit confirmation to continue Y → ask confirmation N→ proceed without	Malt Addition Y/N Iodine test Y/N Malt Extraction Y/N	Yes all stages

		confirmation		
	Whirlpool	Define whether to apply or not the whir pool and in case if it's hot or cold whirlpool	OFF Cold Hot	OFF
	Whirlpool duration	Define the whirlpool duration in minutes	0m-30m	5m
	Cooling Temperature	Define temperature where the cooling process end.	10c-30c	25c
Process Parameter	Kp/Ki/Kd For MASH and HLT	Define the proper constant value for the PID algorithm	Kp x—y Ki x—y Kd x—y	
	SAMPLE time	Define the sample time of temperature in ms	1000ms 4000ms	1500ms
	PWM Frequency	Define the PWM period/window size for PWM control in ms	500ms 7000ms	3500ms
	Hysteresis For MASH and HLT	Define the hysteresis in ON/OFF control in C/F	0c 5c	2c
	Default SP For MASH and HLT	Default temperature set point	0-100C	50c

4.3.4 PID auto tuning

This is a special advanced menu that allow to start a specific SW algorithm that try to estimate the best value of KpKiKd constant considering the specific setup

In this section is not reported the complete theory behind this algorithm but just how to configure and start . There are few resources on the internet that explain the Ziegler-Nichols method implemented, as resource starting point refers to Wikipedia page

https://en.wikipedia.org/wiki/PID_controller

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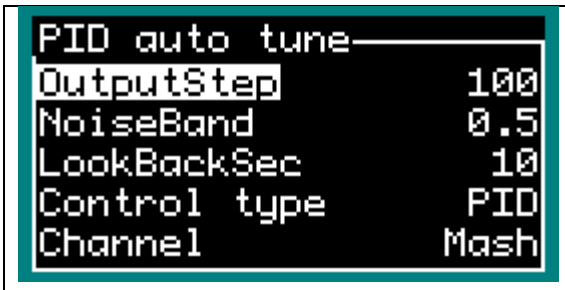
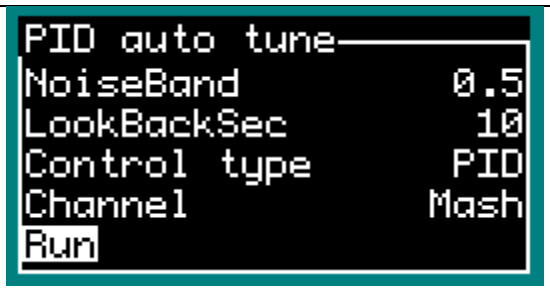
<td> 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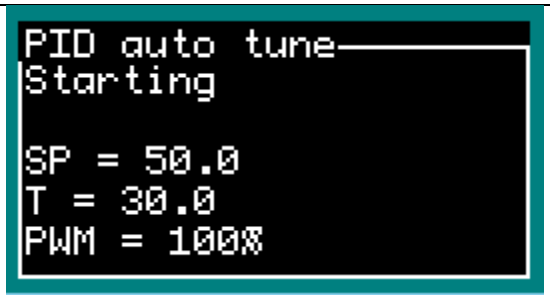
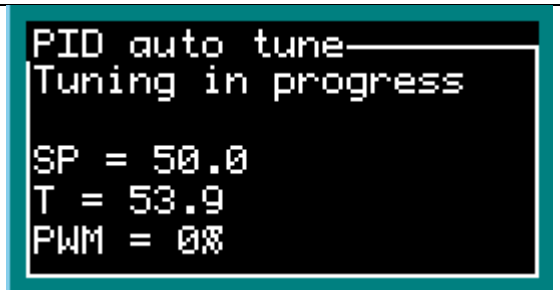
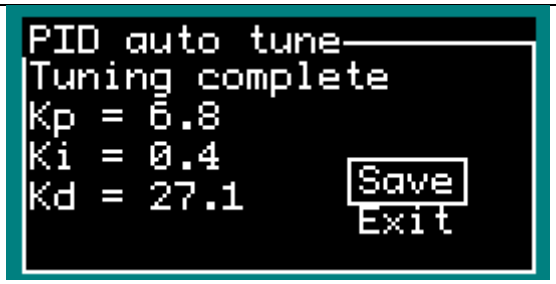
<tr>
<td>PID auto tune RUN

Whene the autotune is in run mode the PID try first to reach the set point using the default parameters</td>
<td> 
</td>
</tr>
<tr>
<td>PID auto tune progress

Once the set point is reached the auto tune starts some step cycle with OutputStep increase and decrease calcualting the time to reach SP+- NoiseBand temperature value and evalaute system reaction</td>
<td> 
</td>
</tr>
<tr>
<td>PID auto tune complete

If the alghoritm converge (it can take also one hour) the Kp,Ki,Kd calcualted are reported and user can save as default value

Notice that the auto tuning process is per channel</td>
<td> 
</td>
</tr>
</table>

4.4 Recipe Management

The brewing process automation is based on a concept of "recipe" that defines the input parameter to the controller

Through this section is possible

VIEW→ load recipe from local EEPROM selecting index number and allow to display the full set of parameter in each sub-menu

EDIT /DELETE→ load recipe from local EEPROM selecting index number and allow to change/modify/delete all parameter in each sub menu. At the end of the modification user can save on the same index (replace) or with a new index (clone).

NEW → allow user to define a new recipe from scratch and add all parameters divided in two submenu. For parameter list see the doc spec chatper 3.3.3

At the end of the recipe definition the entire recipe can be saved in the EEPROM with a proper index

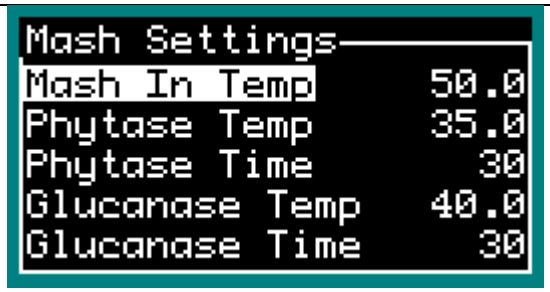
When a new recipe is inserted two main section should be edited

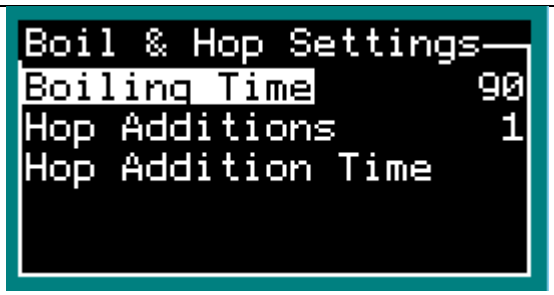
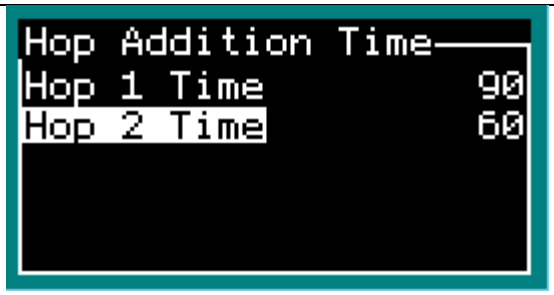
Mashing

For each step of the mash program a couple of temperature/time value should be entered

If the time is set to 0 the step is skipped

See below table for more details



Boil & Hop Settings The toal boil duration should be specified as well the number of hop additions	
Hop Addition Time For each hop additions defined in previous menu the total boiling duration is configured	

Following table reports the step mash structure of a generic recipe. Each recipe is made by the complete set of parameter.

In red the mandatory parameter

Parameter Type	**Parameter**	**Description**	**Range**	**default**
Mashing	Mash IN temperature	Define the temperature for mash IN step	20c-78c	50c
	Fitasi Temp/Duration	Define the temperature and step duration in minute	25c-55c	35c
	Glucanasi Temp/Duration	Define the temperature and step duration in minute	35c-50c	40c
	Protesi Temp/Duration	Define the temperature and step duration in minute	45c-60c	50c
	B-Amilasi Temp/Duration	Define the temperature and step duration in minute	50c-70c	63c

	A-Amilasi1 Temp/Duration	Define the temperature and step duration in minute	60c-76c	67c
	A-Amilasi2 Temp/Duration	Define the temperature and step duration in minute	60c-76c	73c
	Mash Out Temp	Define the temperature for mash out step	70c-80c	77c
Boiling&Hop addition	Boil Duration	Define the duration of the boil phase in minute	30m-180m	90m
	#Hop Additions	Define how may hop addition are needed	0-10	1
	Hop(x) time	Define the time in minute when hop #x should be added	0m-Boli duration	Boil duration

Some consistency check are performed during the input of the parameter

- Temperature consistency check→ each step should have a starting point temperature > temperature end point of the previous step. Example: if the proteasi is set to 55c the next step like B-amilasi can start over 55c so the range will be 55c-70c.

  The only exceptions is mashIN step that can exceed 4c the next step temperature
- Time consistency check → in boil addition the total boil time should be dived in slot according to number of hop additions. Each hop time should be < previous time. Example: boil duration 120min , 3 hops, 1st hop 60min → 2nd should be < 60min

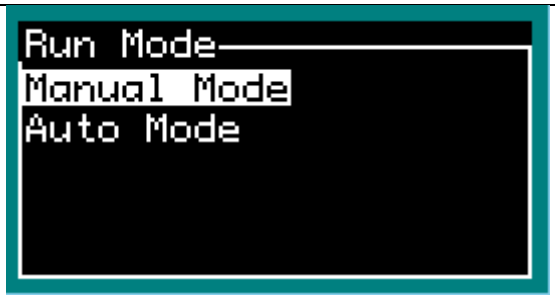
4.5 Run mode

Entering the run mode allow the user to start the brewing process

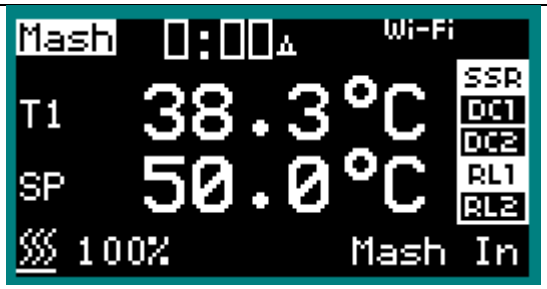
Two possible run mode are possible

MANUAL MODE--> no step mash and automation is implemented, the temperature is controlled to reach the set point while the pump can be manually activated by long press of SET button

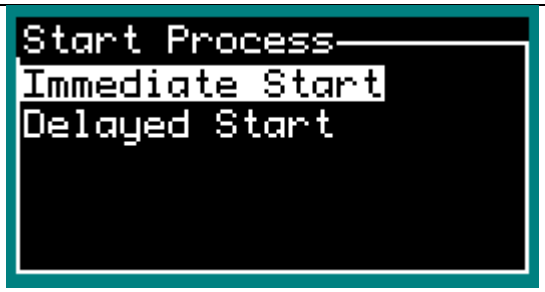
AUTO MODE --> a recipe is loaded and executed step by step

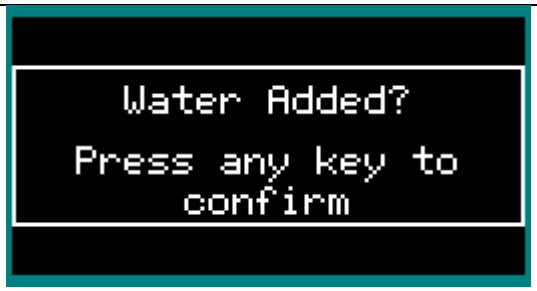
<table>
<tr><td colspan="2"> 
</td></tr>
<tr><td>Manual Mode

The system enter the run mode and starts controlling the heating elements / pump

See process execution chapter for details of the information reported on the display</td><td> 
</td></tr>
<tr><td>Auto Mode

Before entering the auto mode user is requested to load a recipe from the memory or define a new one</td><td> 
</td></tr>
<tr><td>Delay Start

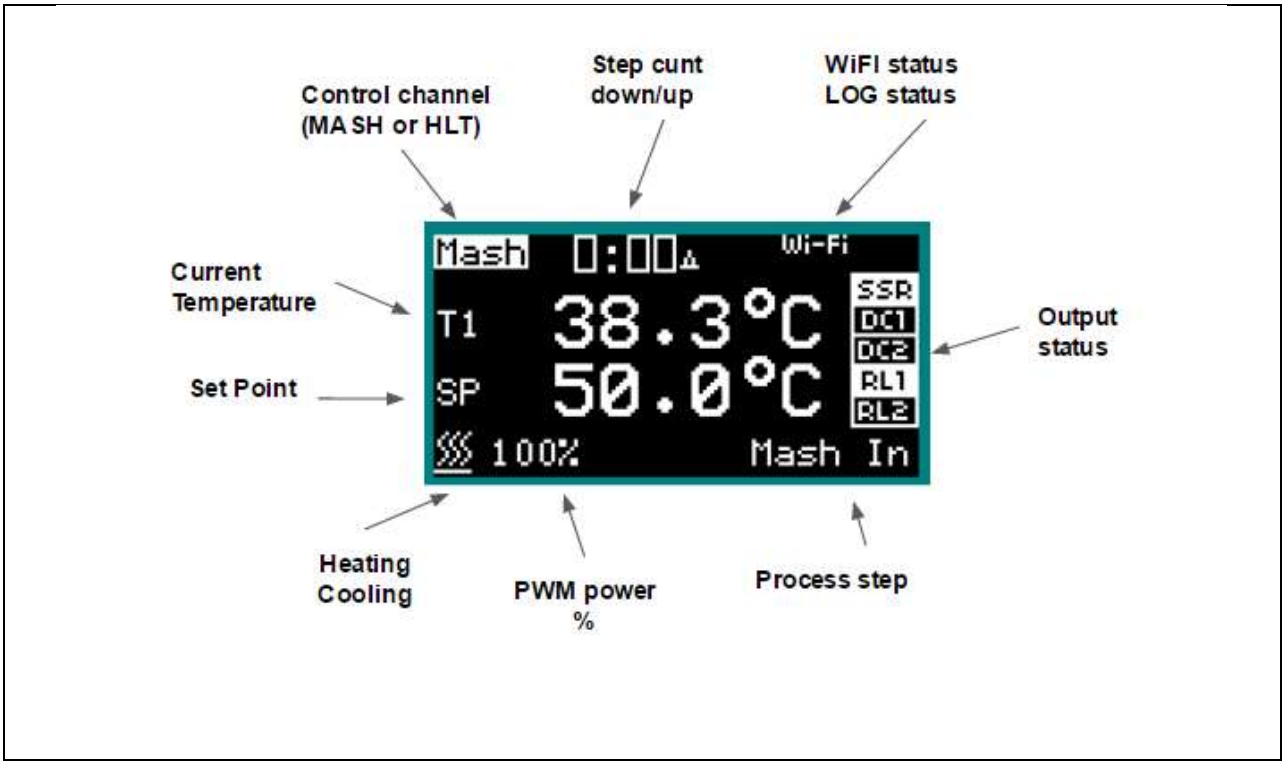
Next step allow the user to define a delay start for the process or to start immediately</td><td> 
</td></tr>
</table>

Delay start setting Entering the delay start menu a timer should be configured with UP/DOWN buttons	
Water Added prompt Before starting the process a final check is performed to make sure that water has been added in order to avoid to damage the heating element.	

5 Process Execution

Once the controller has started the run mode auto all the steps described in 3.2 are executed sequentially. Depending on the parameter configured in the process parameter section the user is prompted at each step or the process can be executed without any intervention

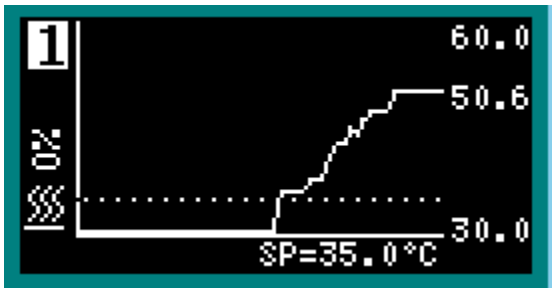
The main screen in run mode report following information



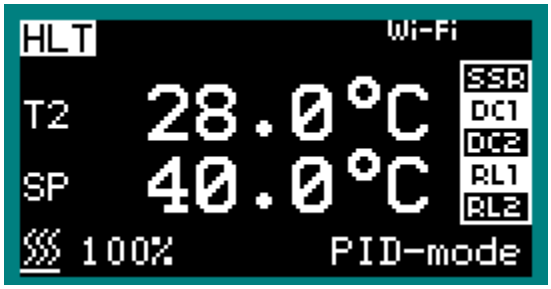
via the push button is possible to

- Switch to the graphic mode --> press SET
- Switch between count UP and count DOWN --> press S/S
- Modify the set point temperature --> UP/DOWN buttons
- Exit the process --> long press S/S button

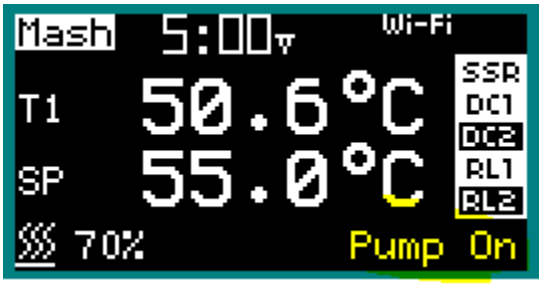
The graphic mode reports the real time temperature and the set point, graph is automatically updated and scalded



Pressing SET button it's possible to move to the HLT screen (if MASH+HLT has been configured) , the info provided are quite similar to the mash apart form the fact that the count up and down is not present and process step is substituted by control mode



In **manual mode** the OLED report same info , it's possible to activate and deactivate manually the PUMP/ stirrer by long press the SET button, pump status is reported in the bottom right corner



6 Appendix

6.1 Pump Cycle management

Following table reports the PUMP status in the different step of the process considering the temperature sensor position.

	sensor position	
Process Stage	**INTERNAL**	**EXTERNAL**
recipe load	pump off	pump off
delay start	pump off	pump off
pump prime	Execute always pump prime immediately after start	Execute always pump prime immediately after start
mash IN	Pump stage mash IN = Y activate pump continusly (no pump cycle) Pump stage mash IN = N Pump OFF	PUMP always on until reach the the mash IN temperature
malt addition	pump is OFF for the whole duration of malt addition	pump is OFF for the whole duration of malt addition
step mash	Pump stage step mash = Y activate pump and execute pump cycle / pump rest Pump stage step mash = N Pump OFF	Execute always pump cycle and pump rest during pump rest the mash heating element is off (PID not invoked)
iodine test	pump is OFF for the whole duration of iodine test	pump is OFF for the whole duration of iodine test
mash OUT	Pump stage mash out = Y activate pump and execute pump cycle / pump rest Pump stage mash = N Pump OFF	PUMP always on until reach the mash OUT temperature
malt extraction	pum is OFF for the whole duration of malt extraction	pump is OFF for the whole duration of malt extraction

boil	Pump stage Boil = Y activate pump continuously up to PUMP STOP temperature Pump stage boil = N Pump OFF	PUMP always on untill reach of the boil temperature (PUMP stop temp ignored)
cooling	PUMP can be activated or deactivated manually soft switch like in manual mode	PUMP always on until reach of the cooling temperature
whirpool	PUMP is activated for the duration of the whirlpool (parameter whirlpool duration) It should be possible to stop the pump (stop the whirlpool) and reset the count down	PUMP is activated for the duration of the whirlpool (parameter whirlpool duration) It should be possible to stop the pump (stop the whirlpool) and reset the count down

6.2 Zeigler-Nichols PID tune

Another heuristic tuning method is formally known as the Ziegler–Nichols method, introduced by John G. Ziegler and Nathaniel B. Nichols in the 1940s. As in the method above, the Ki and Kd gains are first set to zero. The proportional gain is increased until it reaches the ultimate Ku, a which the output of the loop starts to oscillate. Tu and the oscillation period are used to set the gains as shown:

Ziegler–Nichols method

Control Type	K_p	K_i	K_d
P	$0.50K_u$	-	-
PI	$0.45K_u$	$0.54K_u/T_u$	-
PID	$0.60K_u$	$1.2K_u/T_u$	$3K_uT_u/40$

These gains apply to the ideal, parallel form of the PID controller. When applied to the standard PI form, the integral and derivative time parameters Ti and Td are only dependent on the oscillation period Tu

6.3 Data Logging structure

The main process parameter are logged either on the EEPROM or pushed to the external server via wifi (currently using the thingspeak service)

The information stored are the following for each channel

a) time stamp (format Epoch, ISO 8601, MySQL)
b) channel number (CH1 or CH2)
c) control mode (heating or cooling)
d) heating or cooling mode (PID or ON-OFF)
e) set point temperature
f) current temperature
g) PWM percentage
h) PID direction (cooling/heating or ON/OFF)