Mechanical Schematic + Overview

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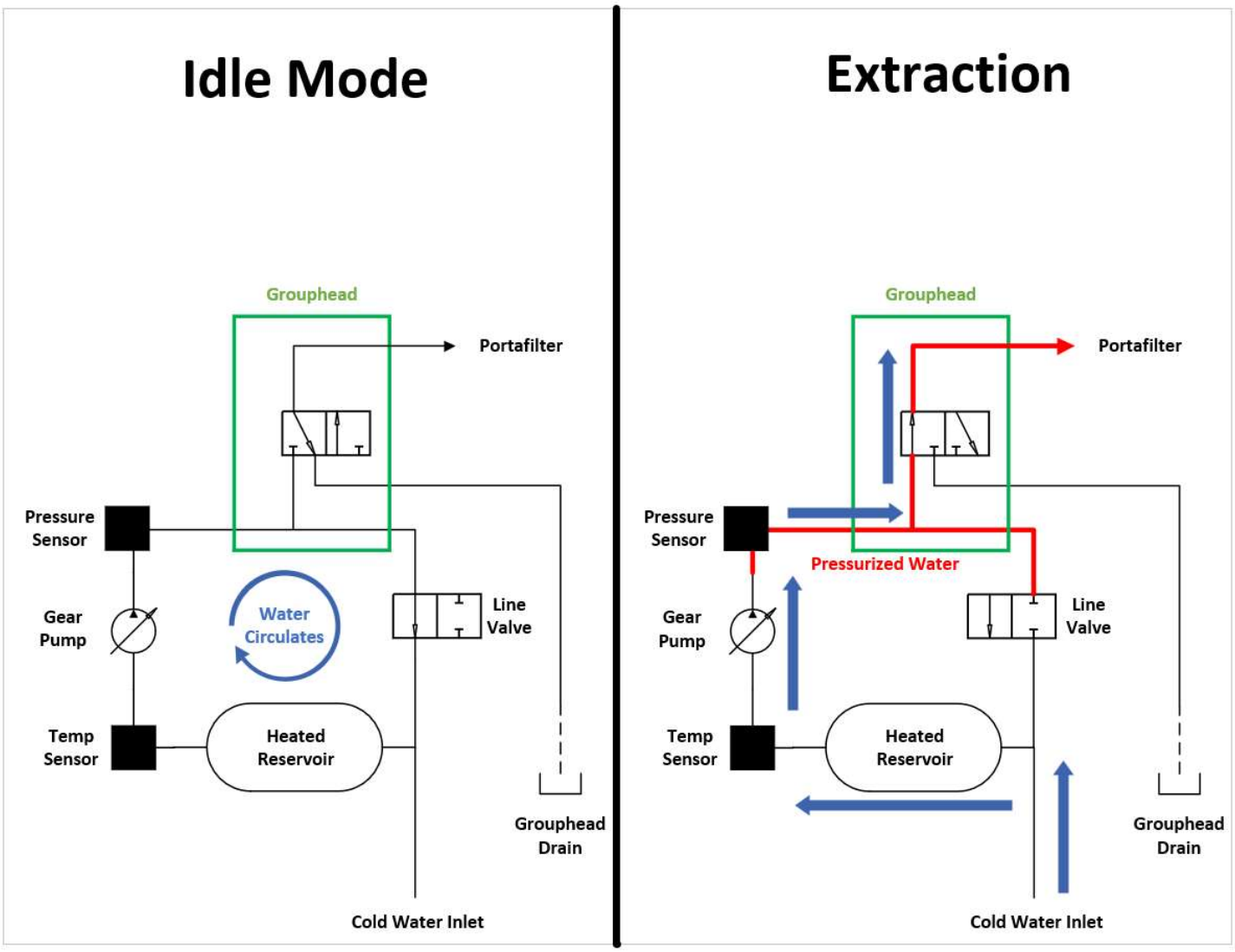
- Key functions of an espresso machine
  - Push water into espresso puck
  - Precise/controlled temperature
  - Precise/controlled pressure

- General design
  - Idle Mode
    - Circulates water though reservoir
    - Everything preheats due to flowing water through components
    - 3/2 valve in the grouphead vents the portafilter to the drain
  - Extraction
    - Line valves closes to isolate the loop and form a pressurized size
    - 3/2 valve in the grouphead lets water flow into the portafilter and closes the drain
    - Water in the loop is replaced by cold water flowing into the water inlet



Control Hierarchy

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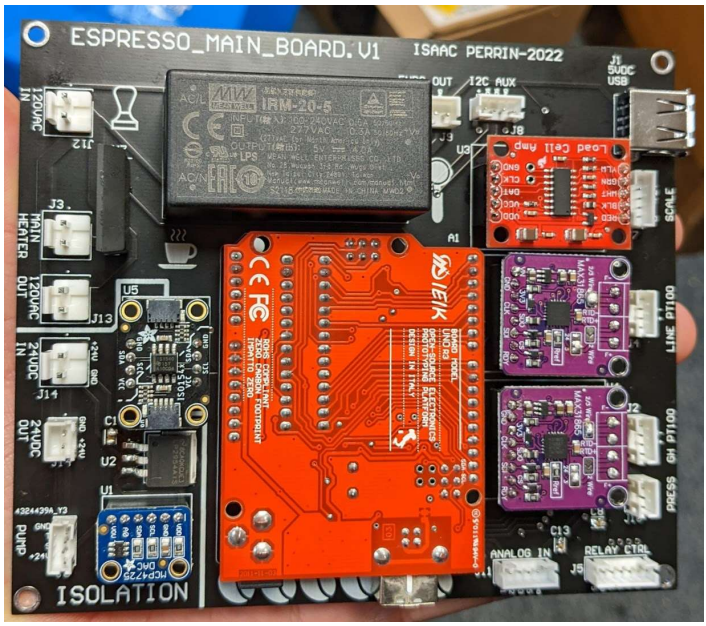
Windows GUI - High Level Control

2-Way Serial Communication

Requested State

Actual State

Arduino - Low Level Control



Hardware

Serial Communication Protocol

- GUI => Arduino
  - "SVVMMMMTTTK"
  - S start character
  - VV valve states 1/0 represent on/off
  - MMMM motor state - first character is M/P to represent pressure vs speed setting
  - TTT desired temperature in tenths (0 represents temperature control off)
  - K termination character

- Arduino => GUI
  - "SPPPPPPPPTTTTTTTTGGGGGGGGWWWWWWWWFFFFFFFF\n" - 42 characters
  - S start character "S"
  - PPPPPPPP (pressure+1000)*100 (with leading zeros)
  - TTTTTTTT (temperature+1000)*100 (with leading zeros)
  - GGGGGGGG (temperature+1000)*100 (with leading zeros)
  - WWWWWWWW (weight+1000)*100 (with leading zeros)
  - FFFFFFFF (frequency+1000)*100 (with leading zeros)

Electrical Schematic

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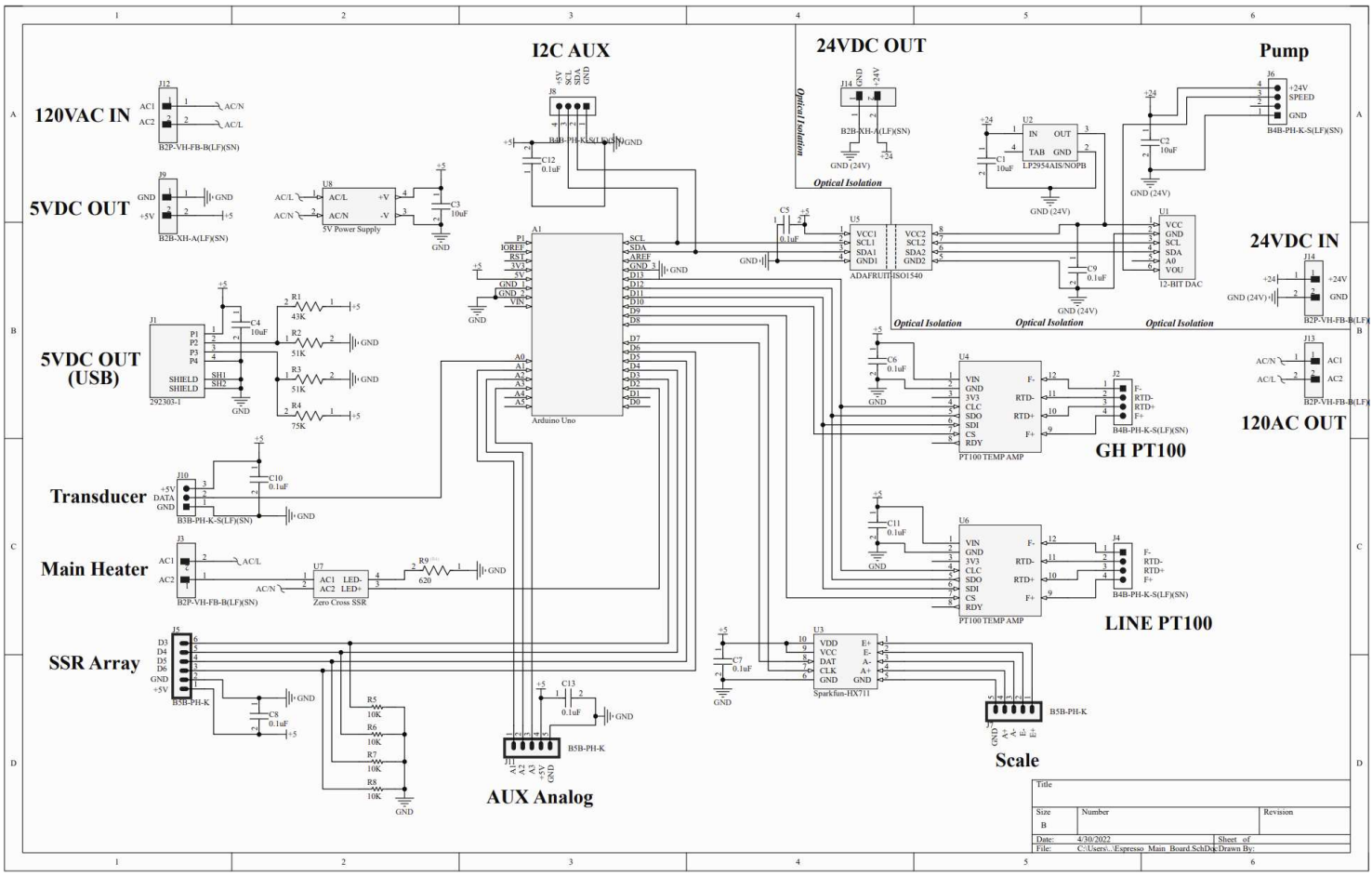
- Most components are connect to or are mounted on the main PCB
- Not shown on PCB/schematic
  - 120VAC out and 24VDC IN connect to 24V DC Power Supply
  - 24VDC Out goes to an optically isolated FET controlled by a pin on the SSR array out - used to throttle the grouphead heater - will be put on the board in future iteration



Mechanical Components

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Item	Spec	Purpose	Link
Gear Pump	Diener Extreme Series Gear Pump 24VDC power 0-5V analog in control 35 Watt BLDC Motor PEEK Gears	Pressurize the water	https://dienerprecisionpumps.com/precision-gear-pumps/ (purchased used on ebay)
Grouphead	Faema E98/2A	Connect to portafilter and direct water	https://www.coffeeparts.com.au/faema-spare-parts-1-group-head-e98-1a-2a (purchased used on offerup)
Line Solenoid Valve	Asco 1/4" Solenoid Valve (Normally Open)	Close the water loop so the portafilter can pressurize	https://www.grainger.com/product/ASCO-110-120V-AC-Brass-Solenoid-4EKZ6 (purchased used on ebay)
Heaters	In electrical components		
Plumbing Connections	Various		

Electrical Components

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Item	Spec	Purpose	Link
Main Heater	120VAC - 500 Watts	Heat the water	https://www.amazon.com/DERNORD-Immersion-Cartridge-Heating-Replacement/dp/B074K98XR7/ref=sr_1_1?crid=2ESVBUEMQ5BW0&keywords=cartridge+heater+1%2F2+npt+500w&qid=1651349830&sprefix=cartidge+heater+1%2F2+npt+500w%2Caps%2C154&sr=8-1
Grouphead Heater	24V 50 Watt 3D printer cartridge heater	Heat the grouphead	https://www.amazon.com/gp/product/B086JM394F/ref=ppx_yo_dt_b_search_asin_title?ie=UTF8&psc=1
Pressure Sensor	5VDC Analog Signal 0-200PSI	Measure pressure in the grouphead	https://www.amazon.com/gp/product/B0748CVN3F/ref=ppx_yo_dt_b_search_asin_title?ie=UTF8&th=1
Water Temperature Sensor	PT100 Thermister - 3 Wire	Measure GH temp	https://www.amazon.com/gp/product/B07DP3X8BC/ref=ppx_yo_dt_b_search_asin_title?ie=UTF8&th=1
Grouphead Temperature Sensor	PT 100 Thermister - 3 Wire	Measure water temp	https://www.amazon.com/gp/product/B0711WRM4X/ref=ppx_yo_dt_b_search_asin_title?ie=UTF8&th=1
I2C Optical Isolator	5VDC	Electrically isolate the pump to minimize noise	https://www.adafruit.com/product/4903
I2C DAC	5VDC Analog Out	Give analog input to the pump to set speed	https://www.adafruit.com/product/4470
PT100 Amplifier	5VDC Thermister Amplifier SPI Bus	Measure the PT100 resistance to get temperature readings	https://www.adafruit.com/product/3328
Load Cell	4 Wire - 300g Single Point Weight Beam	Measure espresso mass	https://www.amazon.com/gp/product/B07NRVML17/ref=ppx_yo_dt_b_search_asin_title?ie=UTF8&psc=1
Load Cell Amplifier	HX711 - 5 VDC 2-wire GPIO com	Measure load cell wheatstone bridge state to get mass	https://www.sparkfun.com/products/13879
Zero Cross SSR	SPST NO 5A	Controls the main heater	https://www.digikey.com/en/products/detail/ixys-integrated-circuits-division/CPC1998J/2561233
24V Power Supply	100-150Watts power out	Power for the pump and GH heater	https://www.amazon.com/gp/product/B08D3QVTNY/ref=ppx_yo_dt_b_search_asin_title?ie=UTF8&psc=1
Optically Isolated FET	Generic	Control the grouphead	Standard FET and optocoupler circuit

Circuit		heater	

Common Grouphead/Heater Cycles

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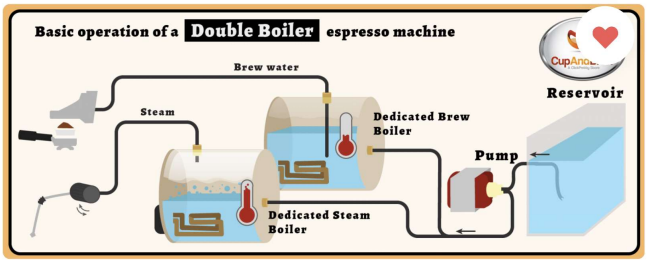
Dedicated Brew Boiler (Dual Boiler) (E98)

- Running espresso brewing on a single boiler at the brew temperature
- No need for syphons or complex methods to cool the grouphead below water temperature
- Fine control on grouphead temperature
- Usually a supply and return line goes to the grouphead to allow passive convective heat transfer to preheat the grouphead



Advanced Dual Boiler

- Synesso machines and Decent
- Run a dedicated brew boiler at a relatively lower end of espresso temps
- Use mixing valves to combine water from both boilers and/or a heat exchanger in the steam boiler to get a source of cold and hot water
- Good thermal control
- Can rapidly change temperatures

Thermosyphon/HX Design (E61)

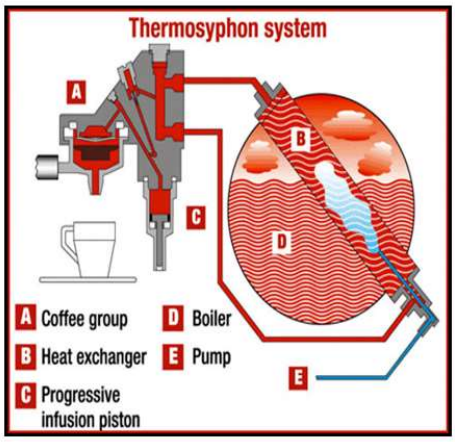
- For running a steam/espresso machine on a single steam boiler
- Complex thermosyphon/HX design is used to get grouphead at a specific temperature for extraction (less than boiler temperature)
- Lack of fine control on grouphead temperature

HX/ Heat-Exchanger

Pump (E) inactivated= the water in it tends to raise its temperature at the same level with the surrounding water

Pump(E) activated=we have a complex water boiling process as well as a blend of cold and hot boiling water

Everything is based on liquid thermodynamics, having as a result an appropriate extracting temperature



Thermoblock (Breville Barista Pro)

- In low cost machines
- Preheating doesn't include water, just the block
- Lowest amount of control
- Heats water as used and injects directly into grouphead (one way) or into steam wand

Resources

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- Resources
  - https://build-its-inprogress.blogspot.com/search/label/Espresso%20Machine
  - https://www.reddit.com/r/Coffee/comments/63k31b/diy_espresso_machine_what_are_the_key_elements_to/
  - Product Review: Decent DE1+ Espresso Machine