PERSONAL PORTABLE WET PROCESS CONTROL LAB

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ASSEMBLY INSTRUCTIONS

Introduction

The assembly of the lab hardware has been subdivided into three main steps. Step 1 can be executed by the students if they are in a classroom where the instructor can provide components (mounting tape, aluminum reinforced epoxy putty) and tools (wire strippers, zip tie tensioning tool) to be shared. Although step 2 could be considerably executed by the students under very close instructor supervision, it is recommended that at least the wire splitting and the connection to the relay be done by the instructor or trained personnel. Step 3 can be can executed by the students at their homes. The small amount of mounting tape and electrical tape needed, can be added later in class.

Step 1: Mounting the Can and Attaching Its Components

Materials Needed:

1. *1 ¾" diameter 4 ¾" height Aluminum Can (http://www.aluminumbottles.com/wp-content/uploads/2014/02/ElementalSpec_ScrewCapCans.pdf) Price: $1.23 (case of 160: $196.64)*
2. *6" X 3" Aluminum Kitchen Tile (https://www.amazon.com/Art3d-100-Pieces-Kitchen-Backsplash-Aluminium/dp/B01D37E00W) Price: $1.00 ($99.99 for 100)*
3. *12" of 1"- wide Scotch Extreme Mounting Tape, 1-inch X 400-inches (https://www.amazon.com/Scotch-Extreme-Mounting-400-inches-414-LONGDC/dp/B00FUEN2GK) Price: $0.60 ($19.97 for 400")*
4. *125 W Lewis N. Clark Immersion Heater (https://lewisnclark.com/immersion-heater/) Price: $7.04 (12% discount from bulk price of $8.00)*
5. *Aluminum Reinforced Epoxy Putty (https://www.zoro.com/blue-magic-aluminum-epoxy-putty-2-oz-16402/i/G1481532/) Price: $0.73 ($7.30 for material for 10 units)*
6. *¼" of Wood Craft Stick (https://www.amazon.com/Simply-Art-Wood-Craft-Sticks/dp/B003BRZ8II) Price: $0.00 ($5.64 for 150 4.5"pieces)*
7. *Disposable Nitrile Gloves (https://www.amazon.com/Superior-RDCNPF-KeepKleen-Glove-Disposable/dp/B00BHMBDF6) Price: $0.10 ($9.50 for 100)*
8. *Waterproof DS18B20 Temperature Probe (https://www.amazon.com/ELENKER-Waterproof-Temperature-Thermometer-Resistance/dp/B01DQQPR2A?pldnSite=1) Price: $2.40 ($11.99 for 5)*
9. *Long (20 cm) DuPont Male/Male Jumper Wires – Note: Only 3 are used here, the rest are used in step 3. Each packet supports two students*

(https://www.adafruit.com/product/1957)
Price: $1.76 (for order of 100+)

10. *Three Screw On Wire Connectors*
(https://www.amazon.com/Morris-Products-23171-Screw-Connector/dp/B01LVTJYJJ)
Price: $ 0.05 (1000 for $17.35)
11. *3" Stainless Steel Flat Bar*
(https://www.speedymetals.com/pc-2536-8259-18-x-12-316-stainless-steel-annealed-pickled.aspx)
Price: $1.65 ($205 + shipping for 130)
12. *6" 85 ˚C Cable Tie*
*(*https://www.lowes.com/pd/Morris-Products-100-Pack-6-in-Nylon-Cable-Ties/4618316*)*
Price: $0.08 ($8.44 for 100)
13. *Two Evercool EC8025M05CA 5V DC 180 mA fans*
(http://www.evercoolusa.com/?p=710)
Price: $10.00 (for 250+)
14. *Two 9 mm x 16" Zip Cable Ties*
(https://www.amazon.com/100-Pack-Heavy-Cable-Strap-Black/dp/B00QSNY53Q)
Price: $0.36 ($17.85 for 100)

Tools Needed:

a. *Straight Edge Scissors*
b. *Wire Stripper for 0.5 mm and 0.8 mm Wires with a Wire-Cutting Section*
c. *Putty Knife*
d. *Tie Gun Tensioning and Cutting Tool*
(https://www.amazon.com/8milelake-Tensioning-Cutting-Plastic-Fasteners/dp/B00V49XUL2)
e. *Ruler*
f. *3"x6" Guide Plate with a 1 7/8" Hole in the Center (This can be 3-D printed or constructed from corrugated paper)*

1. Remove the plastic cover of the tile.
2. Using about 1" of Scotch Extreme mounting tape attach the bottom of the aluminum can to the center of the aluminum tile. The guide plate is useful for centering the can.
3. Using QuikSteel aluminum-reinforced putty, attach the heater to the lip of the can making sure that the heater coils do not touch the can wall.
    a. Position the heater to the can lip so that the plastic claw faces the 6" side of the tile.
    b. Using the wire cutter, cut an approximately ¼" long section of a 10 mm wide craft stick.
    c. Put nitrile disposable gloves on your hands, open the putty container, remove the putty wrapping from one end and cut an approximately 2 mm section with a putty knife.
    d. Roll, knead and mix it for 2-3 minutes.

e. Place the craft stick section between the claw and the can wall. Pressing the lower part of the claw towards the can so that the heater coils do not touch the wall, use the putty to fill in the gaps and completely cover the claw. Then continue pressing the lower part of the claw until the putty starts hardening and keeps the heater's position so that the coils do not touch the can wall.

f. Place the tile with the can in a safe place and let the putty cure. Note the time. Remove and dispose of the gloves.

4. Pull out the black plastic from one end of a **20 cm** yellow M/M wire and, using a **0.8** mm diameter wire stripper, strip to leave about 5 mm of exposed wire. Similarly strip the end of the yellow wire of the DS18B20 temperature sensor using a **0.5** mm diameter wire stripper. Align the two stripped parts and twist them together clockwise. Then cap them with a wire connector and twist clockwise until the connection is secure and the wire is twisted outside the connector. The wires should not disconnect by pulling.

5. Repeat step 4 using a red **20 cm** M/M wire and the red wire of the DS18B20 temperature sensor.

6. Repeat step 4 using a black **20 cm** M/M wire and the black wire of the DS18B20 temperature sensor.

7. Cut a slightly smaller than 1/2" piece of mounting tape and attach it to approximately the middle of the 3"x1/2"x1/8" stainless steel flat bar. Do not remove the red covering.

8. Using a 4" or 6" zip cable tie with maximum operating temperature 85 °C tightly secure the metal part of the temperature probe over the red covering of the mounting tape. The buckle of the mounting tape should be on the side of the probe and the extra cable should be cut off.

9. Cut two slightly smaller than 1/2" pieces of mounting tape and attach them on the other side of the flat bar, one just above the zip tie and the other at the bottom of the flat bar.

10. Determine the location of the flat bar that positions the tip of the probe approximately parallel to upper edge of inner circle of the heater (90° clockwise angle with the heater claw). Peel off the mounting tape that is above the can lid and cut it with the scissors. Then remove the mounting tape coverings and carefully attach the probe in that location (parallel to the heater loop).

11. Put nitrile disposable gloves on your hands, open the putty container, remove the putty wrapping from one end and cut an approximately 1 mm section with a putty knife (as small an amount as possible).

12. Roll, knead and mix it for 1-2 minutes and then use the putty to securely bridge the outside of the can with the part of the flat bar that is above the lid.

13. Wait until 20 minutes have passed from the end of step 2. Place a fan on one edge of the aluminum tile that houses the can so that the label faces the can and so that the fan wires are on the upper corner of the side of the heater cable. Put a small piece of mounting tape (about 1/2" wide) at the bottom of the fan and align the fan with the edge of the tile. Then secure the fan on the tile by using an 8 mm x 16" nylon zip cable tie.

14. Repeat step 13 with the other fan.

Step 2: Electronics Housing and the Solid State Relay

Materials Needed:

1. *6"L x 5"W x 3"H White Corrugated Mailing Box*
   (https://www.amazon.com/dp/B01D9WVE96)
   Price: $0.75 (case of 50: $37.45)
2. *Omron G3NA-210B DC5-24 Relay*
   (https://www.todaycomponents.com/omron-g3na-210b-dc5-24-relay.html)
   Price: $14.54 including $2.13 for shipping (for 100+)
3. *6 ft Polarized two-Prong Extension Cord*
   *(*http://www.acehardware.com/product/index.jsp?productId=52844366*)*
   Price: $2.00
4. *Scotch Extreme Mounting Tape, 1-inch X 400-inches*
   (https://www.amazon.com/Scotch-Extreme-Mounting-400-inches-414-LONGDC/dp/B00FUEN2GK)

Tools Needed:

a. *Knife*
b. *Wood Support for Cutting*
c. *12 AWG Wire Stripper with Wire Cutter*
c. *Straight Edge Scissors*
d. *Large Flat Screwdriver*
e. *Ruler*

1. Assemble the 6" x 5" x 3" mailing box

2. **For safety, a professional or an experienced instructor should perform steps a-c.**

   a. This step will splice apart the hot (smooth) wire from the neutral (ribbed) wire from about 1" from the outlet to 2 ¼" from the outlet. **It is critical that this be done carefully so as not to strip insulation and expose bare wire.** A good method is to start by placing the extension cord on a wood piece and then use the knife to make a small cut between the two wires at approximately 1 5/8" from the outlet. Follow this by several small cuts on either side of the original cut to expand the separation distance to about ¾". At this point, you should be able to pull apart the two wires for a total separation of about 1 ¼".

   b. Cut in the middle the separated hot wire and strip both ends.

   c. Attach securely with no bare wire exposed the two stripped ends to the SSR LOAD screw terminals (identified by numbers 1 and 2) with the long cord in terminal 2. Make sure the wires are tightened so that there is no possibility that these connections will come apart.

   d. Using about ¾" of mounting tape attach the power cord single outlet on the upper right corner of the left side of the corrugated box.

e. Using two pieces of mounting tape, each approximately ½", on the right side of the SSR (the bottom should be free for cooling), attach the SSR near the end of the left side of the box, some distance from the bottom.

Step 3: Mounting the Microcontroller and Breadboard, Inserting the Components, and Wiring

Previously constructed: The can assembly from Step 1 and the box assembly from Step2

Other Materials Needed:

1. *Arduino and Breadboard Holder*
   (https://www.sparkfun.com/products/11235)
   Price: $3.56 (for order of 100+)
2. *Arduino UNO R3 or Arduino UNO R3 Clone with USB Cable*
   The Elegoo UNO R3 with the included USB cable was used by 35 students in a semester-long class, and there were no issues. The Arduino.CC costs twice as much and does not include the cable.
   (https://www.amazon.com/Elegoo-Board-ATmega328P-ATMEGA16U2-Arduino/dp/B01EWOE0UU)
   Price: $10.99
3. *Quality Half-Size Breadboard*
   (https://www.arrow.com/en/products/bb400/busboard-prototype-systems)
   Price: $3.894
4. *MOSFET 60V N-Channel QFET Logic Level*
   (https://www.amazon.com/MOSFET-N-Channel-Logic-Level-pieces/dp/B00LUF4V90#detail-bullets)
   Price: $1.80 (100 for $179.85)
5. *10 kΩ Resistor*
   (https://www.amazon.com/E-Projects-100EP51410K0-10k-Resistors-Pack/dp/B0185FGYQA)
   Price: $0.06 (100 for $6.16)
6. *220 Ω Resistor*
   (https://www.amazon.com/E-Projects-100EP514220R-220-Resistors-Pack/dp/B0185FGNWK)
   Price: $0.05 (100 for $5.16)
7. *4.7 kΩ Resistor*
   (https://www.amazon.com/Uxcell-a11122200ux0101-Axial-Metal-Resistors/dp/B008DFUFOU)
   Price: $0.09 (100 for $9.03)
8. *Two Rectifier Diodes*
   (https://www.amazon.com/1000V-Rectifier-Diodes-1N4007-DO-41/dp/B01AOX72D0)
   Price: $0.12 (100 for $5.99)
9. *Short (10 cm) DuPont Male/Male Jumper Wires*
   (https://www.adafruit.com/product/1956)
   Price: $1.56 (for order of 100+)
10. *Long (20 cm) DuPont Male/Male Jumper Wires*
    (https://www.adafruit.com/product/1957)

Price: $1.76 (for order of 10+)

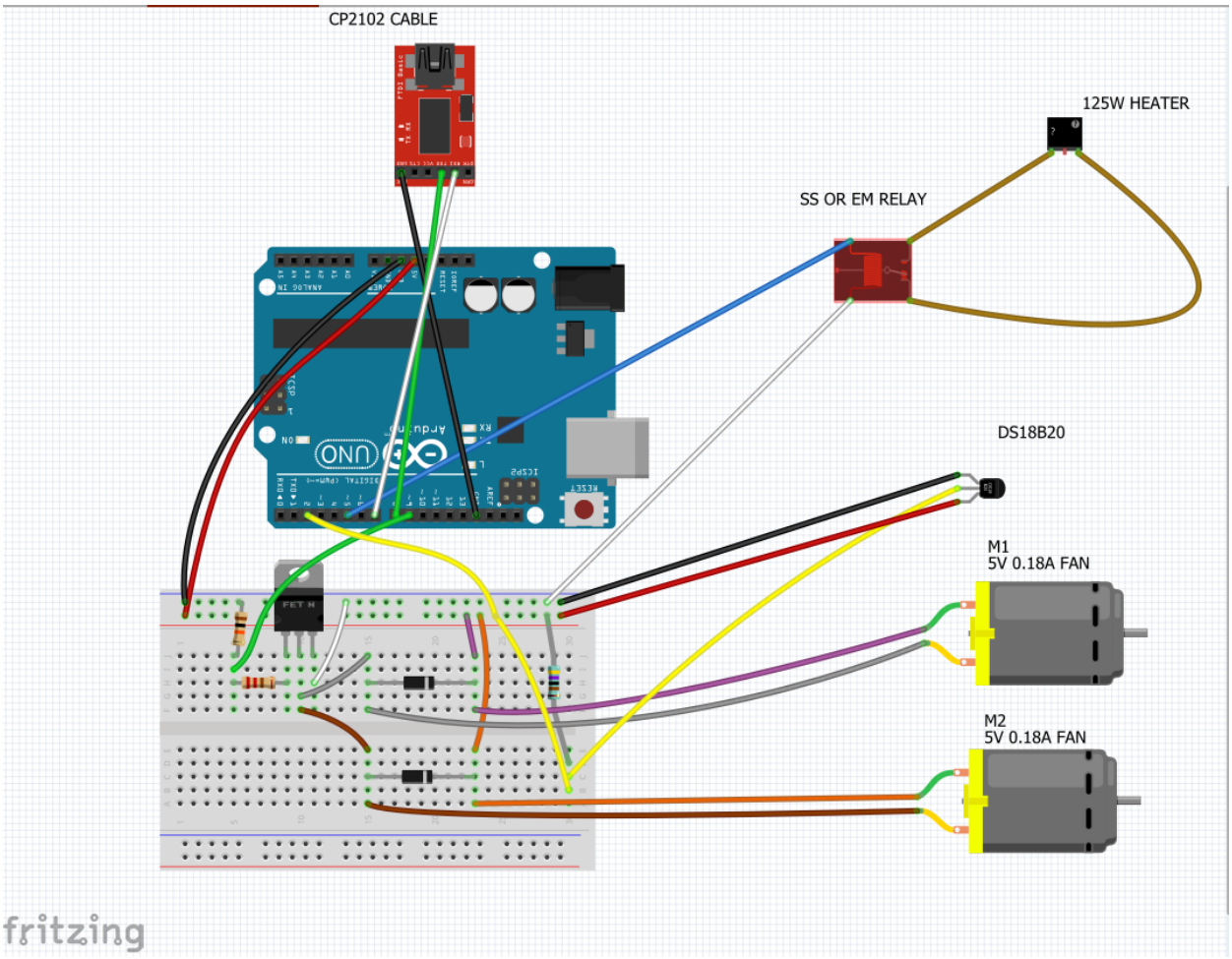
11. *CP2102 USB to TTL Serial Cable*
    (https://www.adafruit.com/product/954)
    Price: $8.95
12. *Vinyl Electrical Tape*
    (https://www.amazon.com/Scotch-Super-Vinyl-Electrical-Tape/dp/B00004WCCL)
    Price: $0.01 ($6.05 for 66')
13. *Scotch Extreme Mounting Tape, 1-inch X 400-inches*
    (https://www.amazon.com/Scotch-Extreme-Mounting-400-inches-414-LONGDC/dp/B00FUEN2GK)
14. *Two 6" Cable Ties*
    *(*https://www.lowes.com/pd/Morris-Products-100-Pack-6-in-Nylon-Cable-Ties/4618316*)*
    Price: $0.08 ($8.44 for 100)
15. *(Optional) Office Scotch Tape*

Tools Needed:

a. *Straight Edge Scissors*
b. *Phillips Screwdriver*
c. *Flat Screwdriver*
d. *Ruler*

1. Place the UNO on the Sparkfun holder with the USB port facing the sparkfun label and secure it with the two provided screws placed on the bottom right and top left holes. Peel off the bottom paper from the breadboard and place it on the holder with row 30 on the side of the sparkfun label.

2. The Fritzing diagram below shows all the wiring with the recommended coloring. Steps 3 and 4 give detailed step-by-step instructions for the wiring and if in doubt you can consult the Fritzing diagram.


CP2102 CABLE
125W HEATER
SS OR EM RELAY
DS18B20
M1
5V 0.18A FAN
M2
5V 0.18A FAN
FET N
UNO
fritzing

3. Populate the breadboard with all the components.

   a. Place the MOSFET firmly in sockets j9 to j11.

   b. Place the 10 kΩ resistor in sockets -5 and j5.

   c. Place the 220 Ω resistor in sockets h5 and h9.

   d. Place the 4.7 kΩ resistor in sockets +24 and d30.

   e. Place a rectifier diode in sockets h15 and h23 with the band on the side of h23.

   f. Place a rectifier diode in sockets c15 and c23 with the band on the side of c23.

4. Place the DuPont jumper wires on the UNO and the breadboard.

   a. Use a 10 cm black M/M wire to connect the second Arduino GND pin to the breadboard -1 socket.

   b. Use a 10 cm red M/M wire to connect the Arduino 5V pin to the breadboard +1 socket.

   c. Use a 10 cm yellow M/M wire to connect the Arduino digital pin 2 to the breadboard b30 socket.

   d. Use a 10 cm green M/M wire to connect the Arduino digital pin 9 to the breadboard i5 socket.

   e. Connect a 10 cm black M/M wire to the black (ground) socket of the CP2102 cable.

   f. Connect a 10 cm white M/M wire to the white (RX) socket of the CP2102 cable.

   g. Connect a 10 cm green M/M wire to the green (TX) socket of the CP2102 cable.

   h. Secure the three connections by wrapping them together with vinyl electrical tape. The red socket of the CP2102 cable is not connected.

   i. Connect the black wire of step e to the Arduino GND pin on the digital side (after pin 13).

   j. Connect the white wire of step f to the Arduino digital pin 7.

   k. Connect the green wire of step g to the Arduino digital pin 8.

   l. Connect a **20 cm** blue M/M wire to Arduino digital pin 5. (It will be connected with the SSR).

   m. Connect a **20 cm** white M/M wire to the breadboard -24 socket. Pass the wire through the upper part of the 1 3/8" hole to the outside of the larger box. (It will be connected with the SSR).

   n. Use a 10 cm white M/M wire to connect the breadboard -11 socket to the breadboard h11 socket.

o. Use a 10 cm gray M/M wire to connect the breadboard g10 socket to the breadboard j15 socket.

p. Use a 10 cm purple M/M wire to connect the breadboard +19 socket to the breadboard j23 socket.

q. Use a 10 cm brown M/M wire to connect the breadboard f10 socket to the breadboard e15 socket.

r. Use a 10 cm orange M/M wire to connect the breadboard +20 socket to the breadboard e23 socket.

s. Insert a purple **20 cm** M/M wire into the breadboard f23 socket. (This will be connected with the red wire of the first fan).

t. Insert a gray **20 cm** M/M wire into the breadboard f15 socket. (This will be connected with the black wire of the first fan).

u. Insert an orange **20 cm** M/M wire into the breadboard a23 socket. (This will be connected with the red wire of the second fan).

v. Insert a brown **20 cm** M/M wire into the breadboard a15 socket. (This will be connected with the black wire of the second fan).

x. Place approximately 1" of mounting tape at the center of the back of the Sparkfun holder and remove the red cover.

y. Mount the Sparkfun holder inside the box with breadboard row 1 being flush against the front wall (leaving maximum space between the USB socket and the back wall). Plug into the Uno microcontroller the blue USB cable.

z. Connect the blue wire of step 3l to terminal 3 of the SSR.

aa. Connect the white wire of step 3m to terminal 4 of the SSR.

ab. Connect the purple wire of step 3s to the red wire of the left fan.

ac. Connect the gray wire of step 3t to the black wire of the left fan.

ad. Connect the orange wire of step 3u to the red wire of the right fan.

ae. Connect the brown wire of step 3v to the black wire of the right fan.

af. Insert the black wire of the temperature probe into the breadboard -25 socket.

ag. Insert the red wire of the temperature probe into the breadboard +25 socket.

ah. Insert the yellow wire of the temperature probe into the breadboard c30 socket.

4. a. Pass the two USB cords over the right wall, and secure their position with a thin strip of mounting tape (without removing the red cover).

b. Pass the three temperature probe wires and the four fan wires over the left wall, and secure their position with a thing strip of mounting tape (without removing the red cover).

c. In the SSR outlet, plug in the heater. Use two 6" zip ties to bundle together the wires between the box and the can, so as to avoid future entanglements.

d. Optional: Use Scotch tape to create a latch for the box. (Put tape on the box and have the latch tape attach to that tape to avoid damage to the box