Ag Irrigation-Pump Remote Control

Using Arduino-UNO and Digi-Xbee RF

Written By: Thomas G (01/2017)

Feel free to use: no strings attached (text content only / images respectfully referenced)

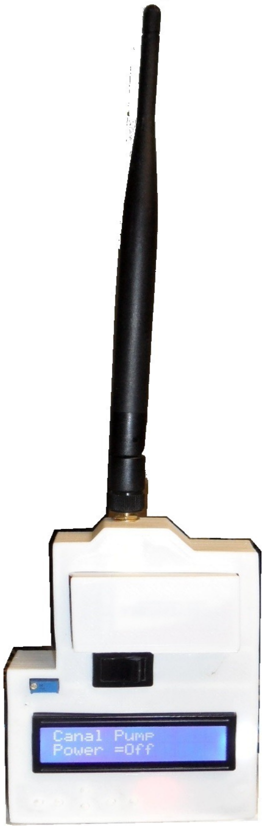

Illustration 1: HandRemote

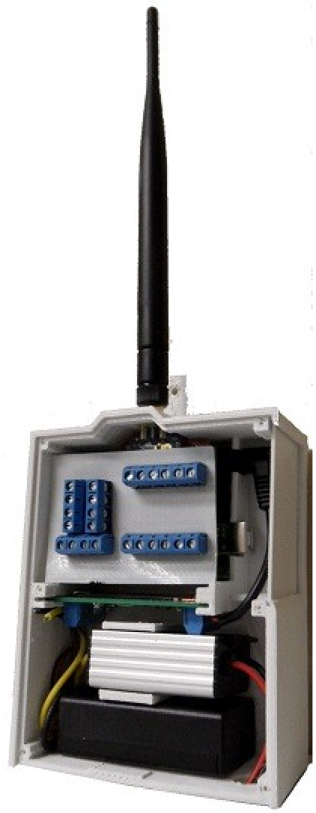

Illustration 2: PumpController

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1. INTRODUCTION

The "***Ag Irrigation Pump Remote Control***" project's goal is to provide RF remote control and monitoring features of an Agriculture-Industry Irrigation Pump; typically used in wheel-line and hand-line irrigation setups. The project uses Xbee RF radio's with up to a 28-mile range (More practically a mile or two at ground level). The project consists of a Hand-Held "***Hand Remote***" and a pole mounted "***Pump Controller***" as well as high voltage control electrical components to be added inside the pumps electrical panel.

- ✔ The project is Open Source and Resides at: https://github.com/tgit23/AgIrrigationRemoteControl
- ✔ The most recent version of this document is at: https://github.com/tgit23/AgIrrigationRemoteControl/docs/AgIrrigationPumpRemoteControl.pdf

1.1 Bill Of Materials (BOM) - $267.66

A. Pump-Panel Components ($95.74)

Illustration 3: (1) Power Supply

Illustration 4: (1) Solid State Relay

Illustration 5: (1) DIN Rail

- ○ (1) 12VDC Power Supply – Main power for each PumpController
  - ▪ Buying Options (Recommended; *the RHINO & Fulree Converter for practical usage and pricing*)
    - ▫ RHINO switching Power supply, 24 VDC output, 2.5A, 60W, 320-600 VAC input, 3-phase, 35mm DIN rail mount.
      - ▫ https://www.automationdirect.com/adc/Shopping/Catalog/Power_Products_(Electrical)/DC_Power_Supplies/24VDC,_3-Phase_Input/PSB24-060S-3 ($59.00/EA)
      - ▫ RHINO Requires; (24 → 12VDC) Fulree Converter (*see Electronic Control Section below*) ($7.99/EA)
    - ▫ TDK Lamda Rail Power Supplies 120W 12V 10A DIN Rail 380-480VAC
      - ▫ www.mouser.com/ProductDetail/TDK-Lambda/DPP120-12-3/ ($104.04/EA)

- ○ (1) Solid state relay, 35mm DIN-rail, 3-32 VDC input, SPST, normally open SCR, 10A contact rating, 48-480 VAC load voltage – for each Pump
  - ▪ https://www.automationdirect.com/adc/Shopping/Catalog/Relays_-z-_Timers/Solid_State_Relays/DIN_Mount_Relays_(AD-SSR8_-z-_AD-SSR2_-z-_AD-SSR6_-z-_AD-HSSR8_Series)/General_Purpose_10A_-_65A,_(AD-SSR8_-z-_AD-SSR2_-z-_AD-SSR6_Series)/AD-SSR810-DC-48Z ($20.75/EA)

- ○ (1) 6" of DIN rail, slotted, 35mm, 10 mm height – for mounting Power Supply and Solid State Relay of each Pump
  - ▪ https://www.automationdirect.com/adc/Shopping/Catalog/Enclosures_-z-_Subpanels_-z-_Thermal_Management_-z-_Lighting/Enclosure_Subpanels_-a-_Internal_Mounting_Accessories/DIN_Rails/DN-R35SAL1-2 ($8.00/2x 1-Meter Pieces)

B. Electronic Control ($39.10)

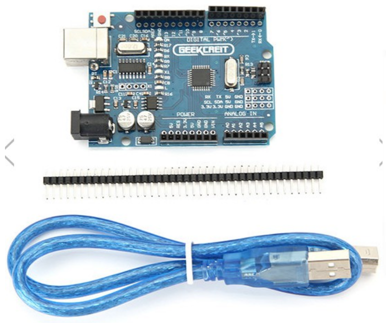


Illustration 6: (2) Arduino UNO R3

Illustration 7: (1) LCD Keypad Shield

Illustration 8: (2) Zigbee Shield

- ○ (2) UNO R3 Atmega328P Development Board with Male Pin Header and USB Cable - (1) for each HandRemote and (1) for each PumpController

- https://www.aliexpress.com/item/Free-shipping-high-quality-UNO-R3-MEGA328P-CH340-CH340G-for-Arduino-UNO-R3-USB-CABLE/32353698284.html ($3.80/ea)

○ (1) Keypad Shield Blue Backlight for Arduino Robot LCD 1602 Board – Display for each HandRemote
- https://www.aliexpress.com/item/Free-Shipping1PCS-LCD-Keypad-Shield-LCD1602-LCD-1602-Module-Display-for-arduino-ATMEGA328-ATMEGA2560-raspberry-NO/32787414048.html ($2.19 / ea)
- DFRobot Wiki LCD @ https://www.dfrobot.com/wiki/index.php/Arduino_LCD_KeyPad_Shield_(SKU:_DFR0009)
- Schematic @ http://image.dfrobot.com/image/data/DFR0009/LCDKeypad%20Shield%20V1.0%20SCH.pdf
- Layout @ https://raw.githubusercontent.com/Arduinolibrary/DFRobot_LCD_keypad/master/DFR0009_Layout.png

○ (2) Zigbee Shield RF Wireless Module Expansion Board for Arduino Xbee - (1) for each HandRemote and (1) for each PumpController
- http://www.banggood.com/Zigbee-Shield-RF-Wireless-Module-Expansion-Board-For-Arduino-XBee-p-916226.htm l ($4.83/ea)
- Schematic @ https://www.arduino.cc/en/uploads/Main/XbeeShieldSchematic.pdf
- Tutorial @ https://www.cooking-hacks.com/documentation/tutorials/xbee-arduino-raspberry-pi-tutorial/

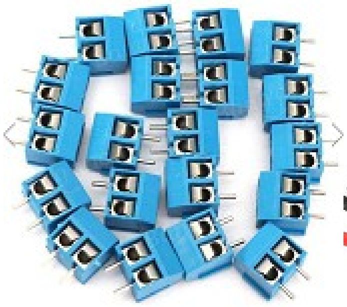


Illustration 9: (15)5.08mm Screw Terminal

Illustration 10: (1) DC-to-DC Converter

○ (15) 2x Pin Plug-in Screw Terminal Block Connector 5.08mm Pitch - External I/O connections for each PumpController
- http://www.banggood.com/20pcs-2-Pin-Plug-in-Screw-Terminal-Block-Connector-5_08mm-Pitch-p-993197.html ($2.15 / 20pcs)

○ (1) Fulree DC 8-35V to 1.5-24V Adjustable Buck Converter Power Supply Voltage Regulator – For the RHINO Power Supply purchase ONLY
- http://www.banggood.com/DC-8-35V-to-1_5-24V-Adjustable-Buck-Converter-Power-Supply-Voltage-Regulator-For-Car-Truck-Boat-p-1087176.html *(Price listed with Pump Panel)*

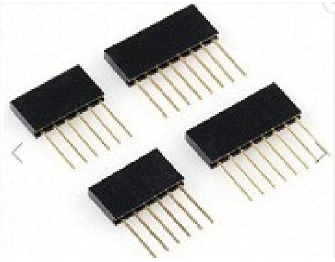


Illustration 11: Female Pin Headers

Illustration 12: Rocker Switch

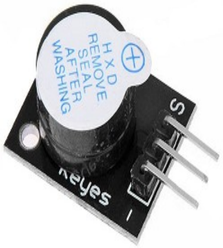


Illustration 13: Active Buzzer

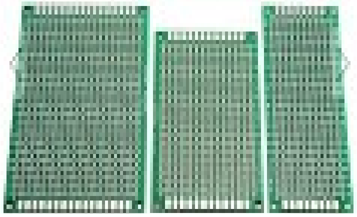


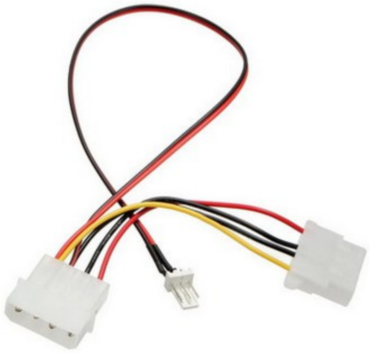
Illustration 14: 50 / 30cm x 70cm Perfboard

○ (4) Pin Headers 2.54mm pitch - For each PumpController
- (1) 4-PIN Male - Zigbee->Perfboard POWER ($NA / Included with Arduino Kit - Male headers can be cut to length)
- (2) 6-PIN Male - Zigbee->Perfboard (1) for Analog (1) for Digital ($NA)
- (1) 4-PIN Female - Zigbee->Perfboard RX/TX
    - https://www.aliexpress.com/item/10-pcs-4P-4pin-Female-Single-Row-Straight-Header-Strip-Socket-Connector-Pitch-2-54mm/32442087495.html ($0.79 / 10pcs)

○ (1) Black Snap-in On/Off Rocker Switch – For each HandRemote
- https://www.aliexpress.com/item/New-Black-Push-Button-Mini-Switch-6A-10A-110V-250V-KCD1-2Pin-Snap-in-On-Off/32670615106.html ($0.86 / 5pcs)

○ (1) Active Speaker Buzzer Alarm – For each HandRemote
- https://www.aliexpress.com/item/KEYES-KY-012-Active-Buzzer-Module-FOR-The-ARDUINO-AVR-PIC/32740686896.html ($0.60 / ea)

○ (1) FR-4 Double Side 50cm x 70cm Prototype PCB Printed Circuit Board - (1) 50cm x 70cm for each PumpController
- https://www.aliexpress.com/item/Free-Shipping-4pcs-5x7-4x6-3x7-2x8-cm-double-Side-Copper-prototype-pcb-Universal-Board-for/32730636287.html ($1.56/ 4pcs)



- (2) Resistors; One valued at 1/3 the other - Recommend above 10K-Ohms – (2) for each HandRemote
  - http://www.banggood.com/300Pcs-1-14W-Metal-Film-Resistor-Resistance-30-Values-Assortment-Kit-p-1091920.html ($2.28 / 300pcs)

- (1) Right-Angle 9Vdc Power Plug for Arduino Power Jack
  - https://www.amazon.com/gp/product/B0111M6PIQ/ ($4.51 / 10pcs)

- (1) Computer power connector
  - http://www.banggood.com/CPU-Fan-4Pins-Patch-Cord-to-34-Pins-Power-Adapter-Cable-Lead-Wire-p-998249.html ($1.99 / ea)

- (5) #4 Small Screws no longer than 10mm or bigger than 3.5mm for Display and Case covers
  - https://www.boltdepot.com/Sheet_metal_screws_Phillips_pan_head_Zinc_plated_steel_4.aspx ($0.05/ea)

C. RF Electronics ($80.88)

- (2) Xbee-Pro 900Hp S3B Digimesh, 900Mhz, 250Mw, Rpsma Connector, 200Kbps – (1) for each HandRemote and (1) for each PumpController
  - https://www.arrow.com/en/products/xbp9b-dmst-002/digi-international ($36.11/EA)

- (2) Antenna Helical 3dB Gain 900MHz – (1) for each HandRemote and (1) for each PumpController
  - https://www.arrow.com/en/products/w1063/pulse-electronics-corporation ($4.33/ea)

D. Wire ($51.94)

- (~10-feet) **600V** 12-AWG wire for all "Inside" the Pump Panel power supply and control wiring – Enough to connect RHINO P.S., SSR and Exit Panel
  - https://www.amazon.com/GREEN-12AWG-Stranded-600V-Hook/dp/B005643KCK/ref=sr_1_3 ($21.99 / 25ft)

- (~30-feet) 24-AWG outdoor direct burial wire for Pump-Controller wiring – Enough to connect all accessory/power devices to the Pump-Controller
  - https://www.amazon.com/BULKRAW-Outdoor-Outside-Waterproof-Cable/dp/B00C2J04KS/ref=sr_1_4 ($29.95 / 40ft)

E. Tools Required ($NA)

- ○ 3D-Printer (*may be optional if other casing solutions are available*)
- ○ Soldering Iron / Solder / Connecting Wire
- ○ Screw Driver

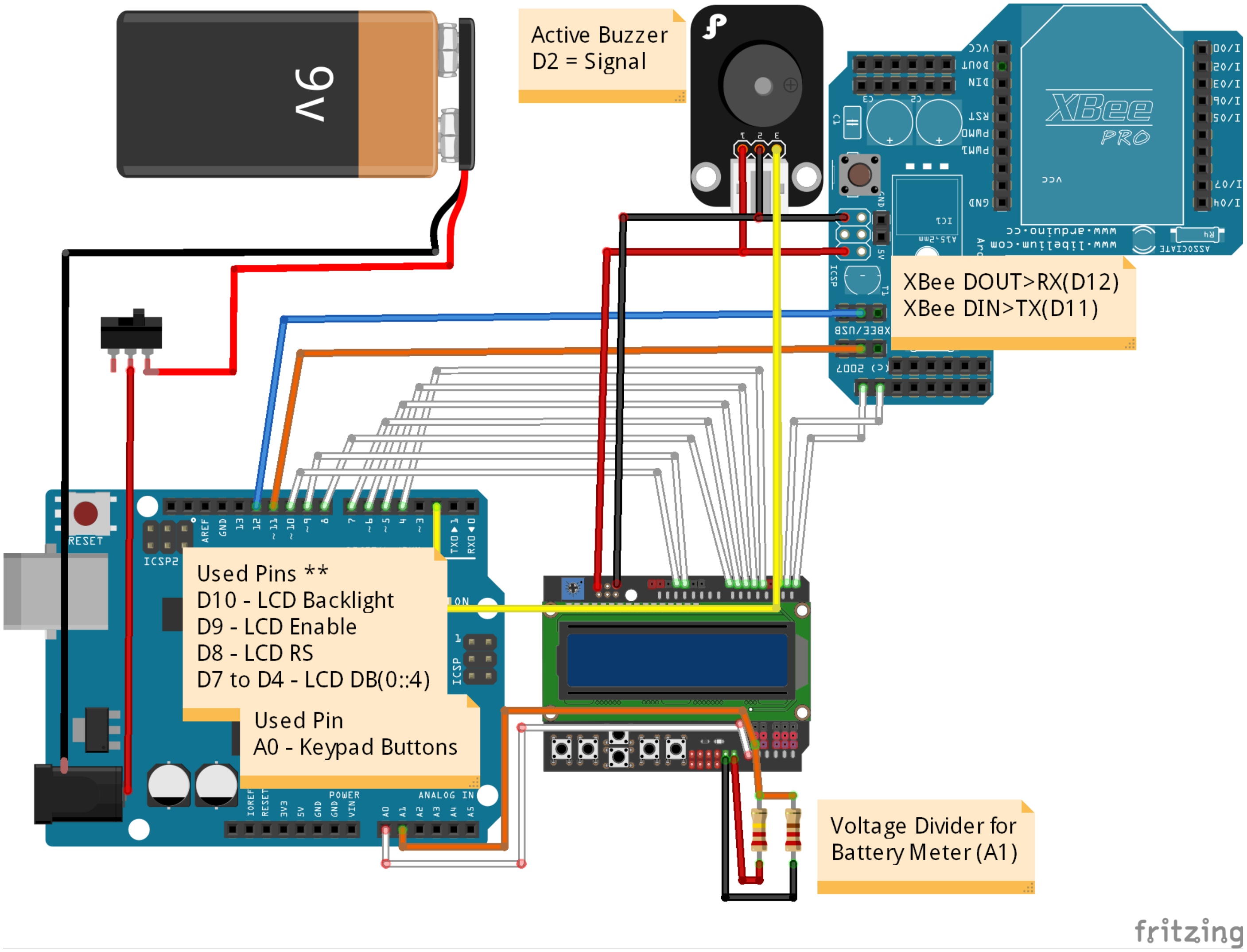
2. HAND-REMOTE

The HandRemote is the remote controller unit used to control and monitor an irrigation pump remotely.

- ✔ Features
  - ○ Buzzer alarm settings for monitored values
  - ○ Battery level indicator (9V-Battery Powered)
  - ○ Programmable Interface through USB

2.1 Electronics Assembly

- ✔ The HandRemote uses the following electronic parts
  - ○ 1- Arduino UNO R3 Board
  - ○ 1- LCD Keypad Shield
  - ○ 1- Zigbee Shield
  - ○ 1- Xbee-Pro 900Hp S3B Module and High Gain Helical Antenna
  - ○ 1- 9Vdc Battery Connector
  - ○ 1- Active Buzzer
  - ○ 2- Resistors



Active Buzzer
D2 = Signal

XBee DOUT>RX(D12)
XBee DIN>TX(D11)

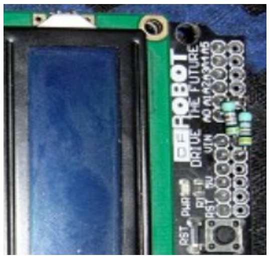
Used Pins **
D10 - LCD Backlight
D9 - LCD Enable
D8 - LCD RS
D7 to D4 - LCD DB(0::4)

Used Pin
A0 - Keypad Buttons

Voltage Divider for
Battery Meter (A1)

A. LCD Keypad Shield

1. Wire the Battery-Meter Voltage-Divider
    a) Select (2) Resistors; One-Value being 1/3 the other (10K-ohm up to 1M-ohm is recommended)
    b) Solder First Resistor (Full Value) on the top of the LCD Shield from **VIN** → **A1**
    c) Solder Other Resistor (1/3 Value) from **A1** → **GND** (Solder hole just left of VIN)
    d) Snip off the excess back-side leads

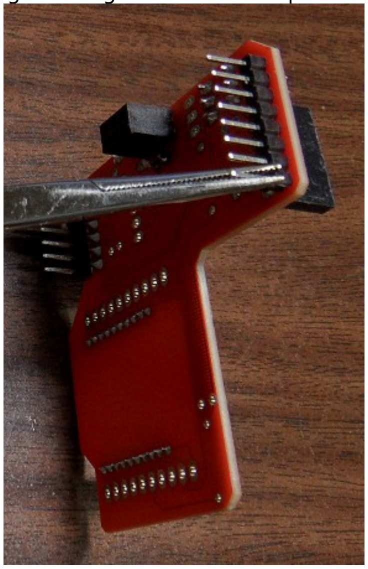


The two resistors setup a voltage divider from the 9Vdc battery (which we will attach to VIN). Analog inputs on the Arduino should never exceed 5Vdc. The voltage divider will split the battery voltage to 1/3 its actual voltage. This will allow the hand-remote to monitor the battery level. The larger the resistor values the less drain on the battery; but too-large a value resistors may affect accuracy.

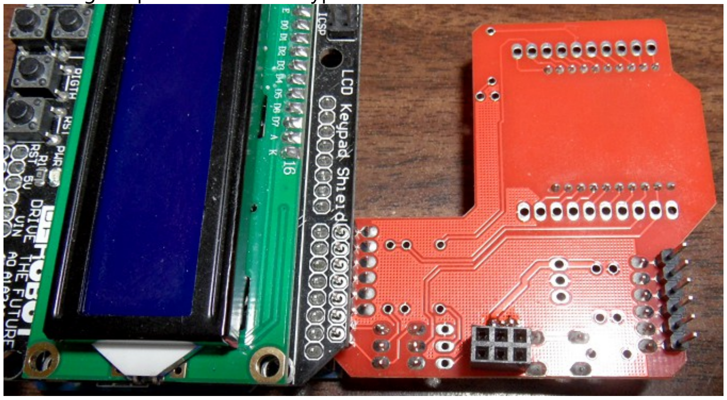
2. Plug the LCD Keypad Shield onto the Arduino UNO

B. Zigbee/Xbee Shield

1. Remove Header Pin **D7** From Zigbee Shield
    a) Using Needle Nose pliers clamp onto Pin D7 of the back of the Zigbee Shield
    b) Using Soldering Iron – Heat the top of the pins solder pad and pull the pin from the board



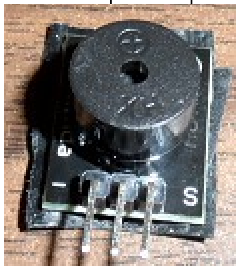
2. Solder Zigbee Shield to the LCD Keypad (Flipped upside down)
    a) Insert pins D0 → D6 (D7 removed in Step #1) into the Top Solder holes of the LCD Keypad Shield
    b) Position the Zigbee Shield flat with LCD Shield and Up against the LCD Shield – Requires bending the header pins a little (**with UNO Attached**)
    c) Solder the Zigbee pins to the LCD Keypad Shield



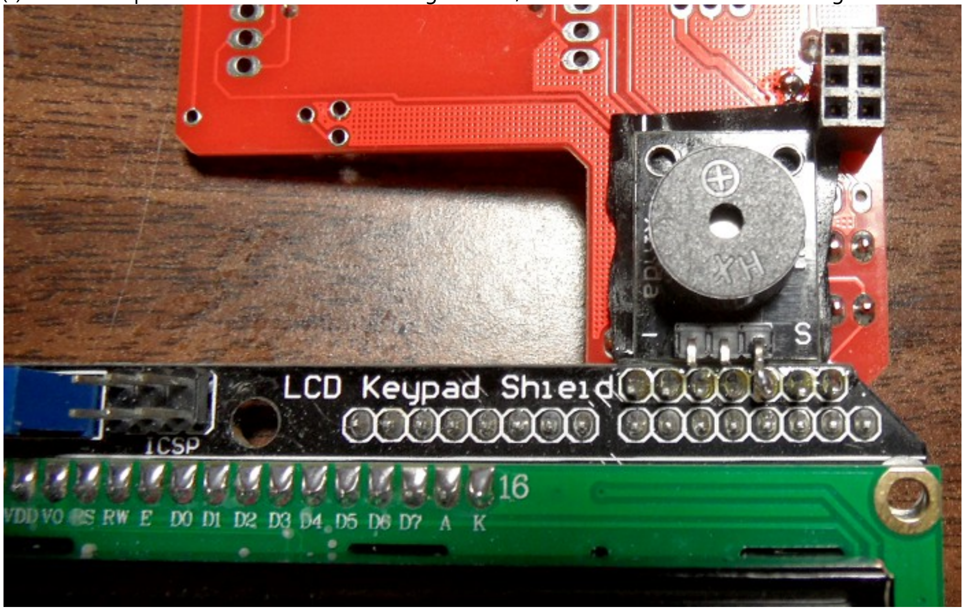
✔ Further Reading for the Curious
- https://www.arduino.cc/en/Main/ArduinoXbeeShield
- https://www.arduino.cc/en/Guide/ArduinoXbeeShield

C. Active Buzzer

1. Solder Active Buzzer to LCD Keypad Shield
   a) Either print a small piece of plastic or add Black tape to the Back-Side of the Active Buzzer to prevent shorting against the Zigbee Shield.



   b) Solder the **'S' pin** on the Active Buzzer to **D2** (3rd Left Pin – LCD Face Up) on the LCD Shield
   c) Cut the (-) and center pins of the Active Buzzer leaving about 1/8" for connection but short enough not to touch D3 & D4.



2. Wire Power to the Active Buzzer and Zigbee Shield

a) Bend the first and last pins closest to the edge of the LCD Keypad Shields ICSP pin header

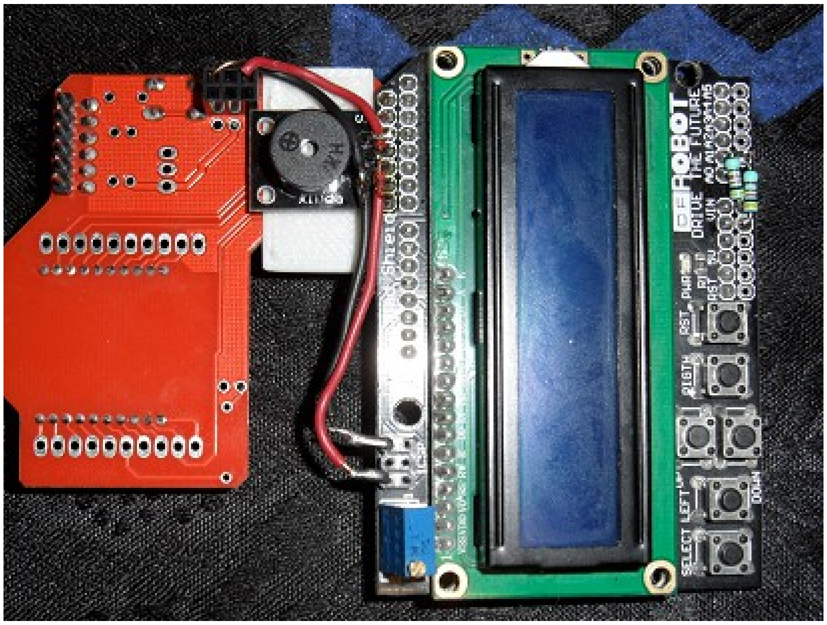
b) Solder one end of a **Red** wire → Left-Most Pin of the LCD Keypad Shields ICSP pin header (**5V+**)

- Pull wire to **Active Buzzer (+)** Pin (Center Pin), strip insulation and solder
- Pull wire to Lower-Right of the **Zigbee ICSP (5V+)** plug, strip insulation, cut to length and insert into plug

c) Solder one end of a **Black** wire → Right-Most Pin of the LCD Keypad Shields ICSP pin header (**5V+**)

- Pull wire to Active **Buzzer Left-Pin (-)**, strip insulation and solder
- Pull wire to Top-Right of the **Zigbee ICSP (GND)** plug, strip insulation, cut to length and insert into plug

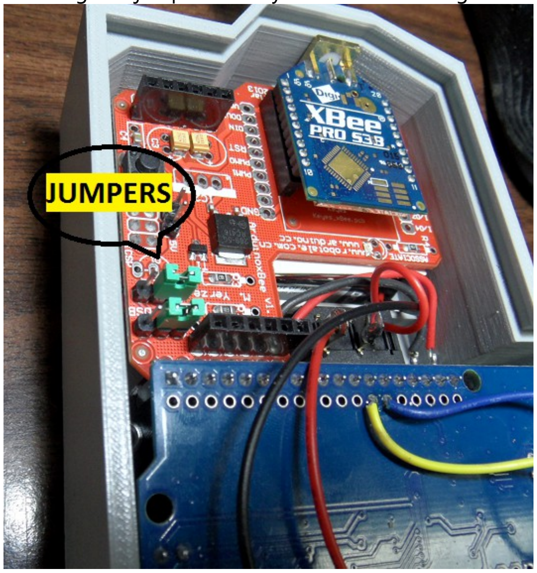
Red/Black wires were not cut but the insulation was split using automatic wire strippers. The Center and Left Pins of the Buzzer were cut just long enough to solder wires to them.



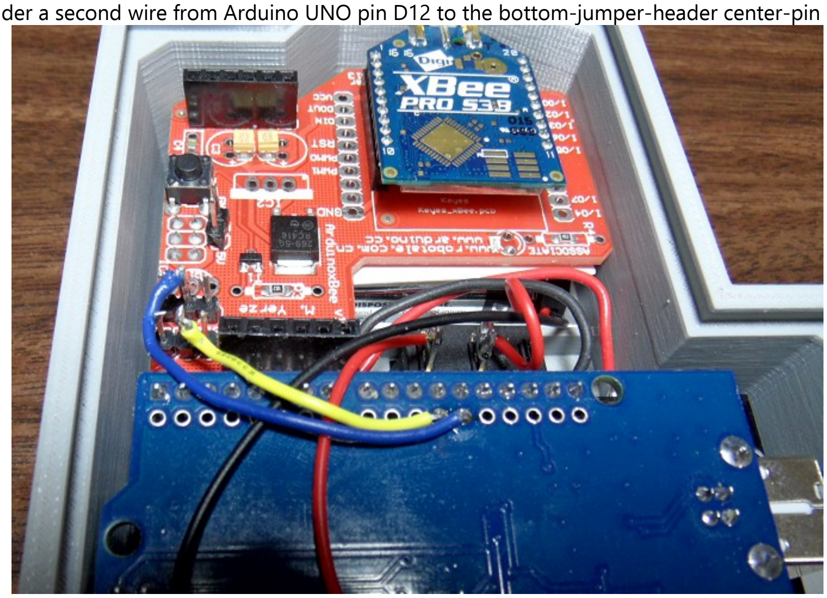
3. Cut the remaining ICSP pins as short as possible to allow the unit to fit inside the case

D. Communications

1. Remove the two green jumpers factory installed on the Zigbee shield



2. Connect Arduino UNO pins D11 & D12 to the Zigbee Communication Header
   a) From an upside-down view; left-top of Arduino UNO; Count the pin holes to the right D0,D1,D2.... to D11
   b) Solder a wire from Arduino UNO pin D11 to the top-jumper-header center-pin of the Zigbee shield
   c) Solder a second wire from Arduino UNO pin D12 to the bottom-jumper-header center-pin of the Zigbee shield



✔ Further Details for the Curious

- ○ Xbee and Arduino both use Serial Communications –- **but** they both cannot use the same Serial Port at the same time.
  - ▪ In order to Upload Firmware to the Arduino the Xbee must be disconnected from the lines (No Jumpers)
  - ▪ In order to Connect to the Xbee through USB Serial the Arduino Microcontroller must be disconnected (*UN-usable for our Arduino UNO*)
  - ▪ Thus; We add Jumper-wires to put the Xbee on a different "Serial Port" when we need access to both Serial Devices.

- ○ The Factory Jumpers on the Zigbee Shield come with two modes of operations
  - ▪ Xbee Position = Xbee UART Serial connects to Arduino Serial
  - ▪ USB Position = Xbee UART Serial connects to USB Serial (Computer); Requiring the removal of the micro-controller.

- ○ Jumper-Wires for Debug
  - ▪ Computer USB Serial → Arduino - When NO jumpers exist; the Xbee is disconnected from RX/TX Pins and thus allows clean USB Serial Monitor.
  - ▪ Routes Xbee UART → D11 & D12 - The SoftwareSerial Library allows UART communications on D8 & D9 which is wire-jumped to the Xbee RX/TX.

- ○ Pin Orientation
  - ▪ The Jumpers on the Zigbee Shield are aligned Top->Bottom Exactly the same as the Xbee Plug labeled DIN/DOUT are aligned
    - ▫ On the shield (DIN is the closest jumper to Digital Pins Header on the Shield)

2.2 Hardware Assembly

A. 3D-Prints

✔ Print the Following Models on a 3D-Printer

- ○ /HandRemote/3D-Prints-STL/HandRemote-Case.stl
- ○ /HandRemote/3D-Prints-STL/HandRemote-Buttons.stl
- ○ /HandRemote/3D-Prints-STL/HandRemote-BackCover.stl
- ○ /HandRemote/3D-Prints-STL/HandRemote-BatteryCover.stl
- ○ /HandRemote/3D-Prints-STL/HandRemote-BatteryInsulatorPlate.stl
- ○ /HandRemote/3D-Prints-STL/HandRemote-SideCover.stl

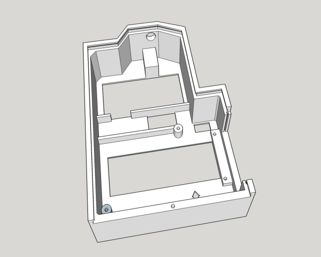


Illustration 15: Case.stl

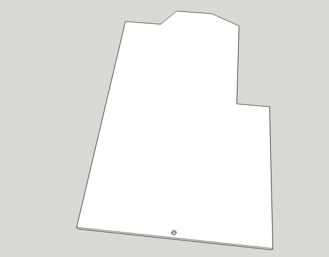


Illustration 16: BackCover.stl

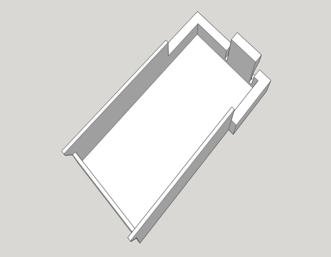


Illustration 17: Battery Cover

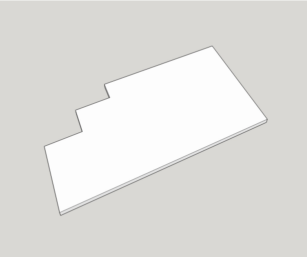


Illustration 18: BatteryInsulatorPlate.stl

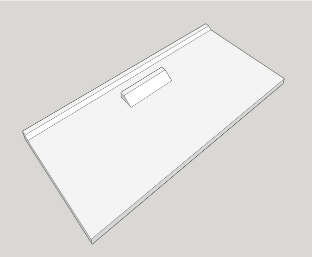


Illustration 19: SideCover.stl

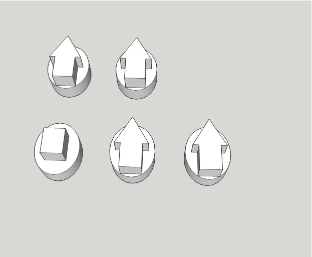
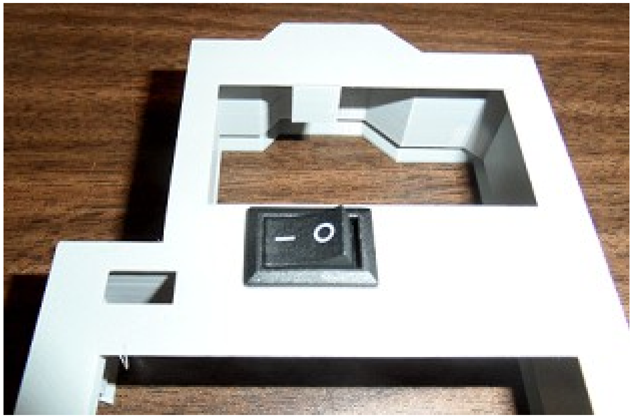


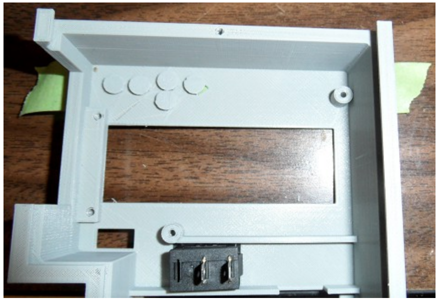
Illustration 20: Buttons.stl

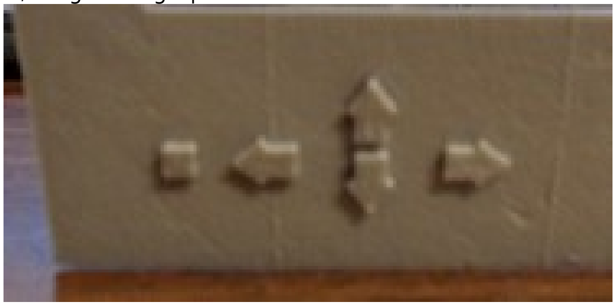
B. Install Electronics

1. Insert the Power ON/OFF Rocker Switch into the front of the case

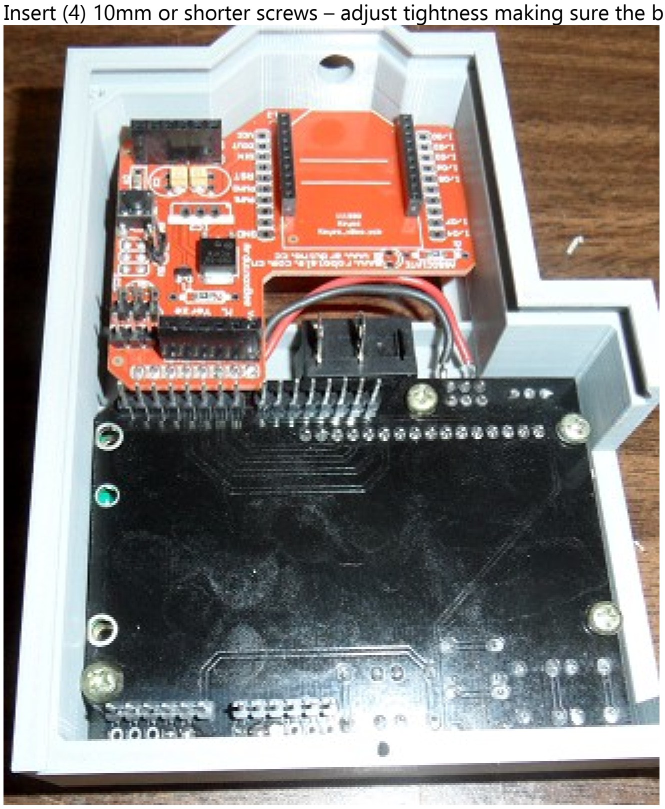


2. Place the buttons in their proper place inside the case; using masking tape on the front-side to hold the buttons in their place





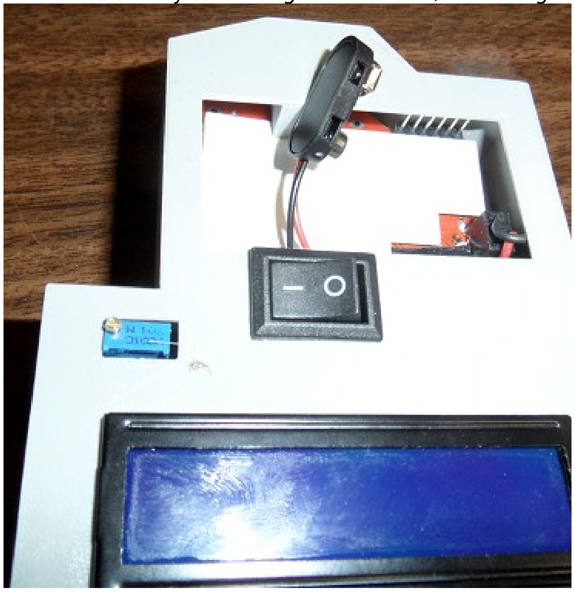
3. Install the LCD, Buzzer, Zigbee **Electronics Assembly** (from Step #2.1) into the Case (Arduino UNO Removed)
   a) Insert (4) 10mm or shorter screws – adjust tightness making sure the buttons still click (*too tight will pinch buttons down permanently*)



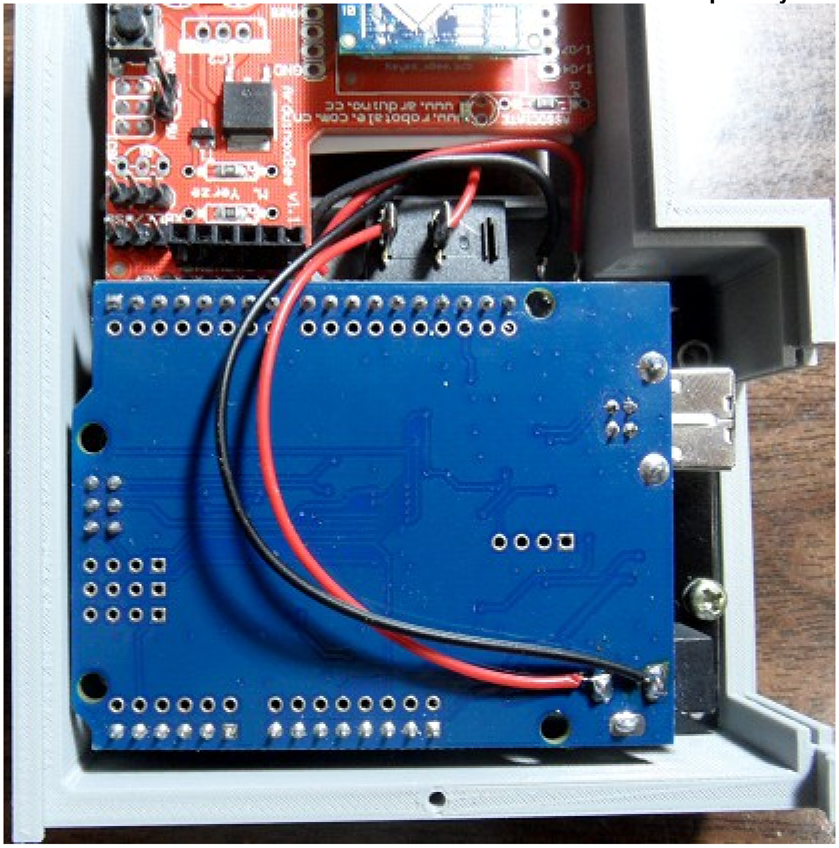
4. Plug the Arduino UNO back onto the LCD Keypad Shield
5. Slide the Xbee into the Top-Hole and then plug into the Zigbee Shield
6. Attach the Antenna to the Xbee RPSMA Connector

C. Wire in Battery Power

1. Install Plugs
   a) Insert the HANDREMOTE-BATTERYINSULATORPLATE.STL 3D-Print inside the battery hole
   b) Route the 9Vdc Battery Power Plug from the front, around Zigbee shield, to the back



2. Wire in the Switch and Power to the Arduino UNO
   a) Solder the **Black wire** to the **closest to UNO power-jack backside pin** (as pictured)
   b) Leaving an inch-or-so slack on the 9VDC plug; measure and cut the **Red wire** on the **closest rocker-switch connector**
   c) Strip the end and solder the wire to the rocker switch connector
   d) Strip the end of the **cut left-over red wire** and solder it into the **"other" connector on the rocker-switch**
   e) Solder the other end of the **cut left-over red wire** wire to the **farther to UNO power-jack backside pin** (as pictured)



3. Check for Power
   a) Plug in a 9V-Battery into the 9V plug
   b) Flip the rocker-switch to power-on (marked with a "-") and verify that the LCD display lights

4. Attach Covers to Case
   a) Insert the HandRemote-BatteryCover.stl 3D-Print into the cases battery-hole and snap down
   b) Slide the HandRemote-BackCover.stl 3D-Print in from the bottom then insert a screw in the bottom-center
   c) Slide the HandRemote-SideCover.stl 3D-Print in the USB side until it snaps into place

2.3 Operating Instructions

Notice: Firmware must be uploaded to a newly assembled unit before it can operate; visit #4.1.A SYSTEM OPERATIONS| Firmware | Uploading for details

A. Introduction

The main screen has "Menu Items" like Pump, Power, Water Level, Battery Level, Water Pressure and etc..
After the unit is idle (No buttons pressed) for a time - The "Menu Items" will iterate and items value will be retrieved from the Pump-Controller.

MENU ITEM	*SET*	*PIN*	*LOW ALARM*	*HI ALARM*
Pump	Canal/Ditch (Options)	PumpID	Equals (=)	NOT Equal (ǂ)
Power	ON/OFF (Options)	D7	Equals (=)	NOT Equal (ǂ)
Water Level	DISABLED	V64(Trig=D6,Echo=D5)	Less Than (<)	Greater Than (>)
Battery	DISABLED	A2	Less Than (<)	Greater Than (>)
Pressure	DISABLED	A3	Less Than (<)	Greater Than (>)

* Note: V64 is Virtual Pin #64; Virtual Pins are memory spaces inside the Pump-Controller and therefore the Pump-Controller firmware actually identifies the connecting pins. This is used when Pump-Controller processing is done before a legitimate value can be determined.

B. Pump Control

To Set the Pump-Controller the Hand-Remote will communicate with; press the UP/DOWN until Menu Item “Pump” is selected.
Then press the RIGHT to SET the pump.
Then press UP/DOWN to select the desired Pump-Controller
Then press the SQUARE (Select) button to actually SET the pump selected.

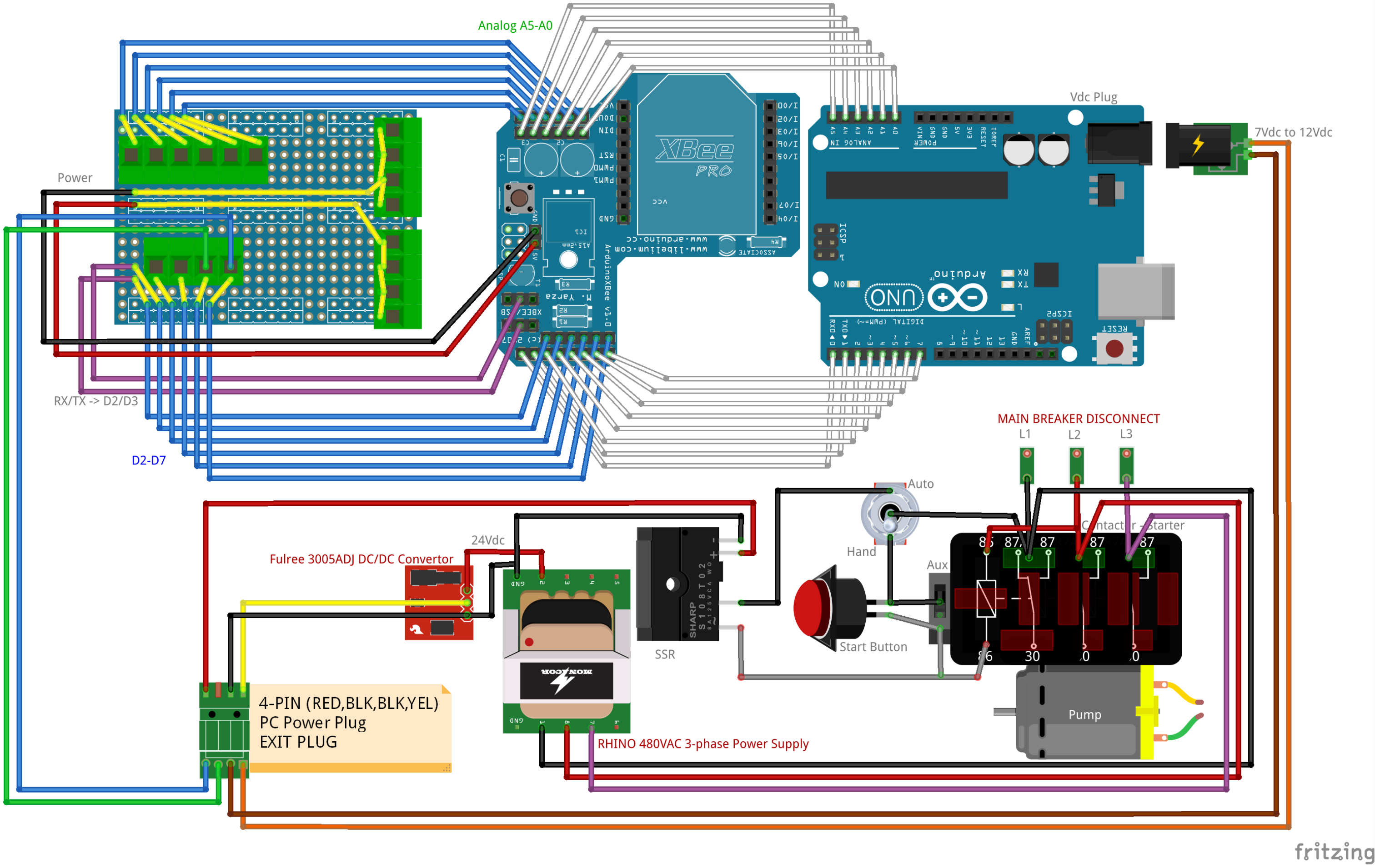
C. Alarms

D. Customizing

3. PUMP-CONTROLLER

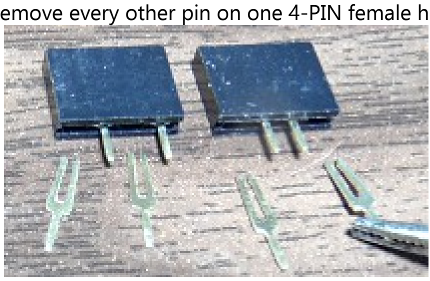
✔ Automation
- ○ Automatically turn off the pump if no water exists
- ○ Set to Automatically turn on pump when water height is okay

Wiring Diagram of the Pump Controller - (Screw Terminal Perfboard → Zigbee Shield → Arduino UNO)

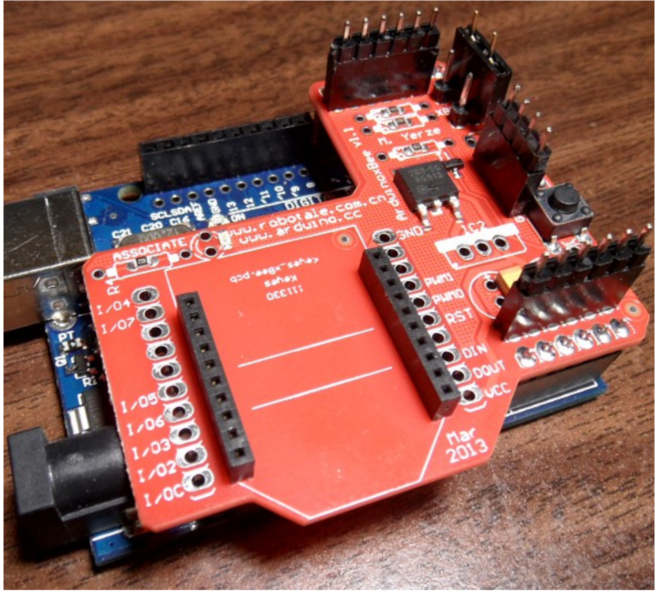


3.1 Perfboard Assembly

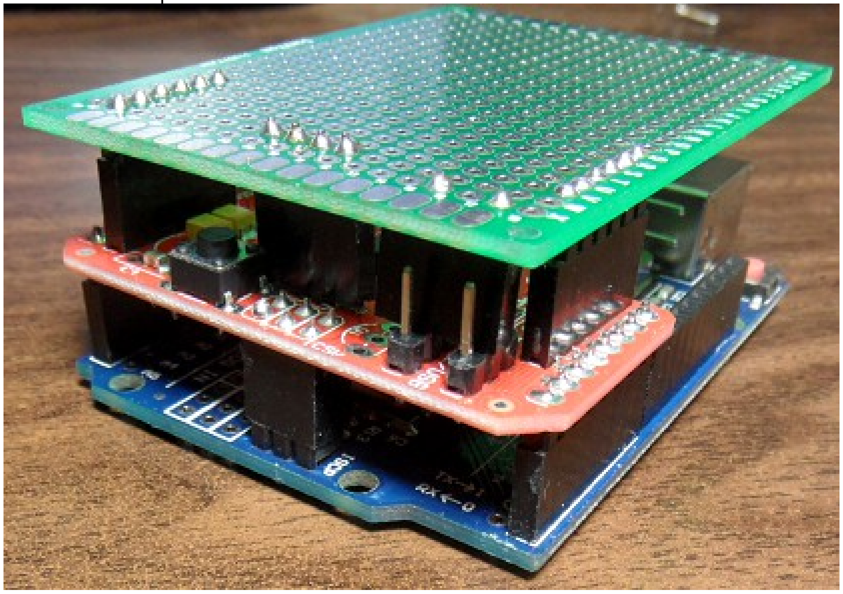
1. Install Headers
   a) Remove outer pins on one 4-PIN female header (POWER)
   b) Remove every other pin on one 4-PIN female header (RX/TX)



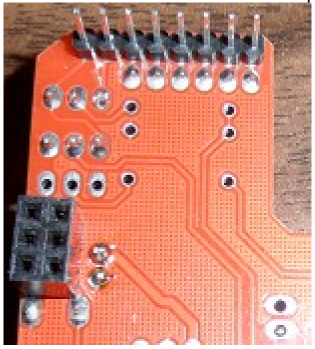
c) Remove the (2) Green Jumpers on the Zigbee Shield and plug it onto the Arduino UNO
d) Plug a 6-Pin Male Header into the Analog Header of the Zigbee Shield (A5 → A0)
e) Plug a 6-Pin Male Header into the Digital Header of the Zigbee Shield (D2 → D7)
f) Insert the POWER female header from step #a into the Zigbee Shield holes labeled 5V & GND (next to the reset button)
g) Plug a 4-Pin Male Header into the top of the POWER female header
h) Insert the RX/TX female header from step #b ACROSS the two center male header (XBEE/USB) pins of the Zigbee Shield



2. Solder the header pins to a 5cmx7cm 2.54mm pitch Perfboard
a) Align and place the Perfboard onto the header pins
b) Solder the header pins to the Perfboard



3. Solder the Zigbee female POWER header pins
a) Unplug the Arduino UNO from the Zigbee Shield leaving the Perfboard attached
b) Solder the female POWER header pins to the holes of the Zigbee shield



4. Add wires to the header pins
    a) Cut (12) wires approximately 1" long and strip one end.
    b) Cut (2) wires approximately 3" long and strip one end.

    c) Unplug the Perfboard from the Zigbee Shield
    d) Insert (6) 1" wires from the Zigbee-side of the Perfboard into the holes just **below** the analog male pin headers, bend and solder
    e) Insert (4) 1" wires from the Zigbee-side of the Perfboard into the 4-right (D4-D7) holes just **above** the digital male pin headers, bend and solder
    f) Insert (2) **3"** wires from the Zigbee-side of the Perfboard into the right of the POWER male pin headers (Center-2), bend and solder
    g) Attach (2) 1" wires from the Top-side of the Perfboard across RX/TX female pin headers and solder to D3, D4 Digital pins as shown and trim.

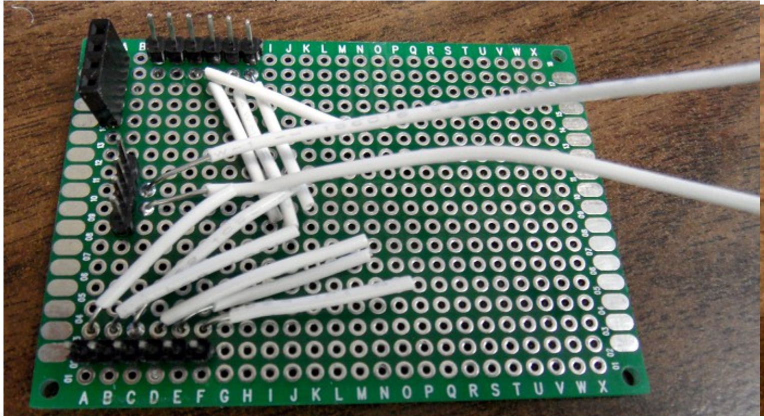


Illustration 21: Perfboard Zigbee-Side (Bottom)

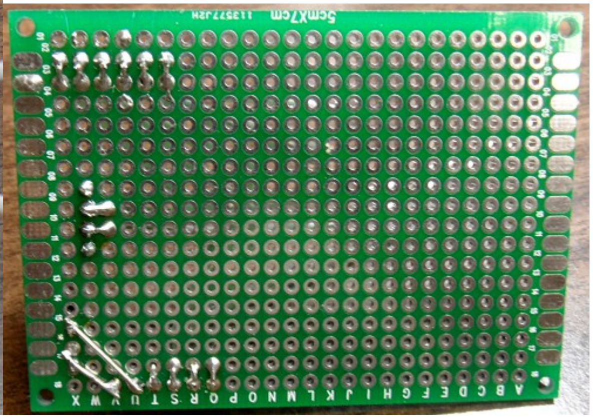
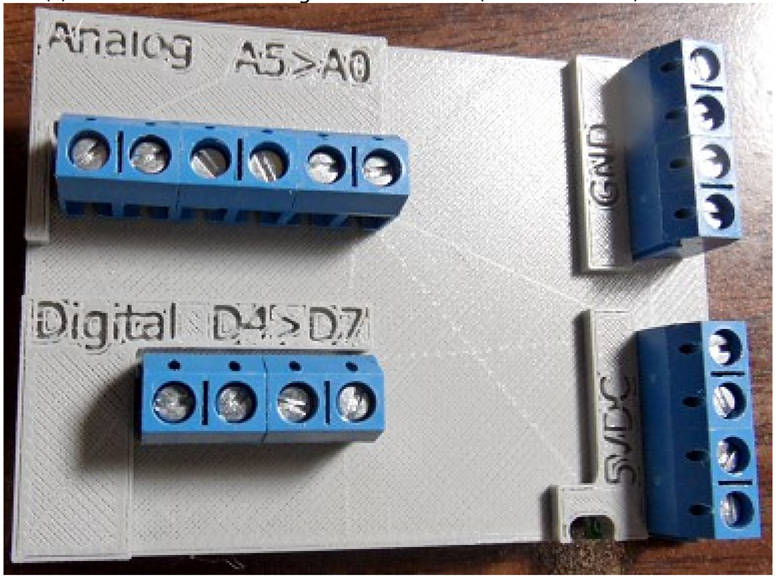
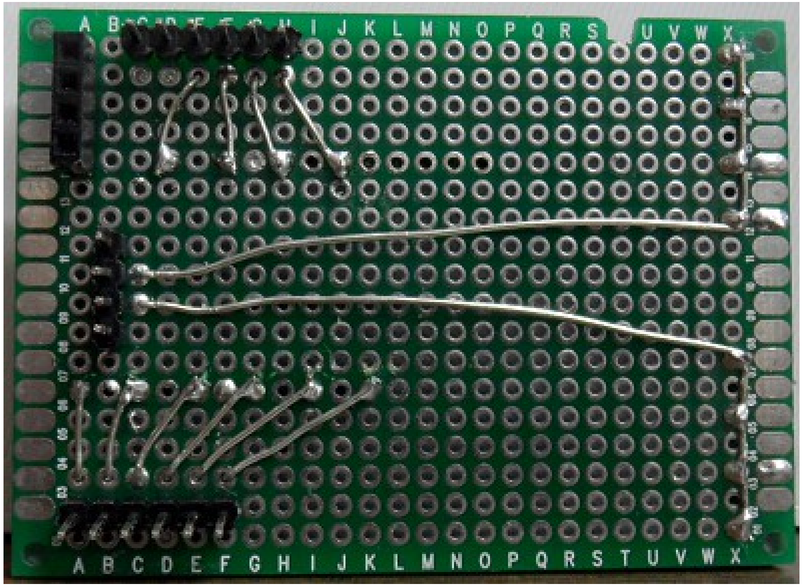


Illustration 22: Perfboard Top-Side

5. Install the Screw Terminals
    a) Place the HandRemote-PerfboardCover.stl 3D-Print on the top of the Perfboard lining up grooves with header pin solder joints
    b) Insert (3) 2x Screw Terminals along the Analog section starting at the Right and working left to allow sliding the blocks together at their edges
    c) Insert (2) 2x Screw Terminals along the Digital section with the same method above
    d) Insert (2) 2x Screw Terminals along the 5VDC section (same as above)
    e) Insert (2) 2x Screw Terminals along the GND section (same as above)



6. Solder the Screw Terminals to their corresponding header wires
    a) Turn the Perfboard over holding the screw terminals into place
    b) Sold each screw terminal pin to the Perfboard
    c) Pull the Insulation off the wires, bend them flat with the Perfboard and solder them to their corresponding pin (See picture or Wiring Diagram)


A B C D E F G H I J K L M N O P Q R S U V W X
A B C D E F G H I J K L M N O P Q R S T U V W X

3.2 Hardware Assembly

A. Print Models (3D-Prints)

✔ 3D-Print the Following Models @ https://github.com/tgit23/AgIrrigationRemoteControl/tree/master/PumpController/3D-Prints-STL
- ○ PumpController-Case.stl
- ○ PumpController-Cover.stl
- ○ PumpController-USBCover.stl
- ○ PumpController-AntennaCover.stl

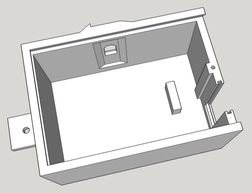


Illustration 23: Case.stl

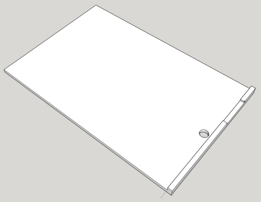


Illustration 24: Cover.stl

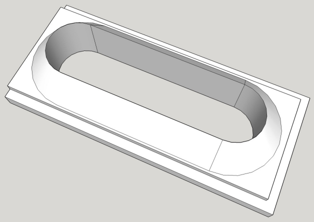


Illustration 25: USBCover.stl

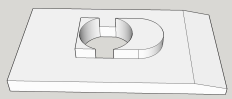
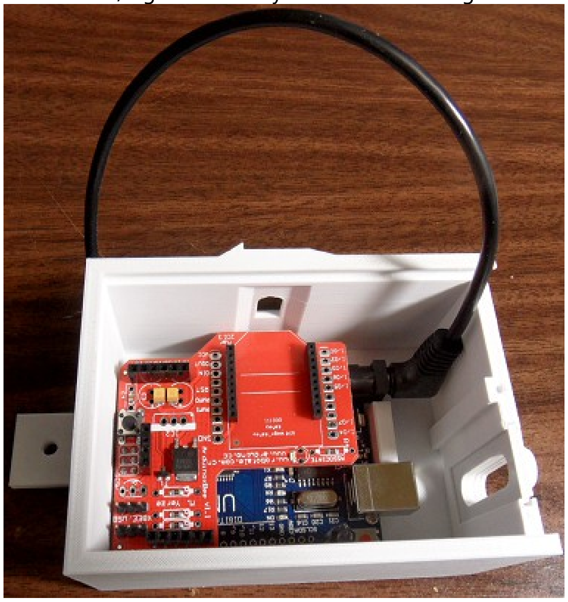


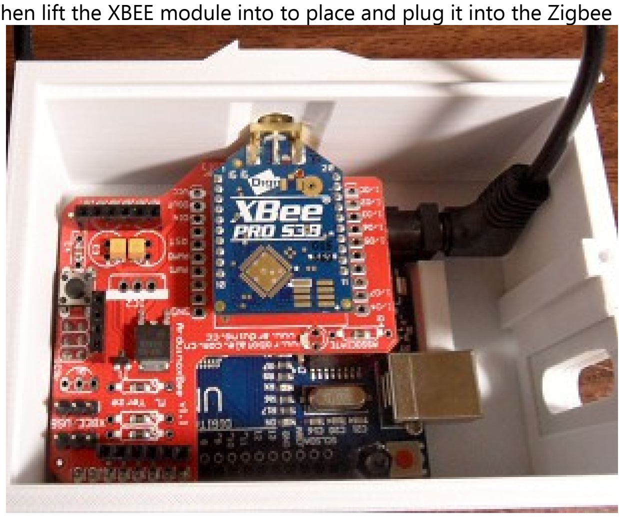
Illustration 26: AntennaCover.stl

B. Install Electronics

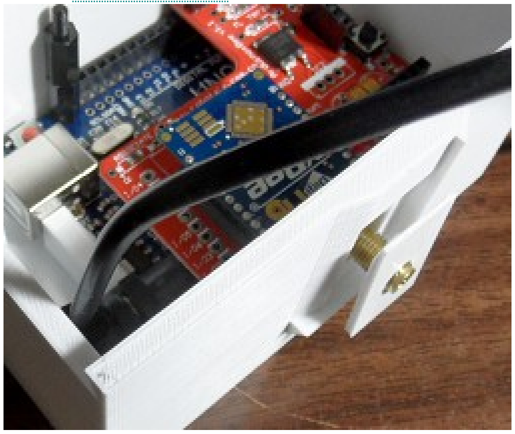
1. Install UNO and Zigbee connected into the Case
   a) Remove the Screw Terminal Perfboard if attached and connect the Arduino UNO & Zigbee Shield
   b) Plug in the Right-Angle 9Vdc Power Plug for Arduino Power Jack
   c) Insert the Uno/Zigbee assembly into the case letting the USB and power Jack sit on each side of the case stub.



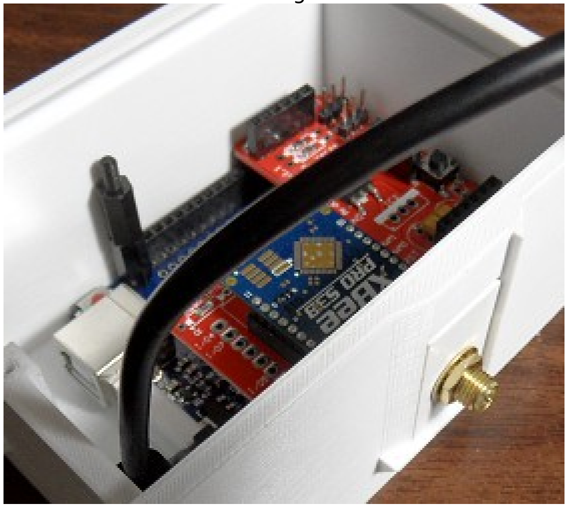
2. Install the XBEE module
   a) First slide the XBEE RPSMA Connector into the case slot
   b) Then lift the XBEE module into to place and plug it into the Zigbee Shields Xbee plug-in



3. Install the Xbee Antenna Cover
   a) Slide the ANTENNACOVER.STL 3D-Print onto the RPSMA connector from the outside of the case



b) Attach the washer and nut and tighten



4. Plug the Perfboard into the Zigbee shield

3.3 Installation Instructions

3.3.1 Prepare for Installation

A. DIN Rail Components

1. Cut to Length a portion of DIN Rail
   a) A length that will comfortably fit the Power Supply, Solid State Relay, and Fulree DC/DC Converter
   b) A length that will fit comfortably somewhere inside the Pump Power Panel
   c) Recommending approximately 5-1/2" or 4-hole slots in length

2. Wire RHINO power supply to Fulree DC/DC Converter
   a) Attach the RED(+) IN wire of the Fulree DC/DC Converter to the RHINO power supply at the top labeled (24VDC+)
   b) Attach the BLACK(-) IN wire of the Fulree DC/DC Converter to the RHINO power supply at the top labeled (24VDC-)

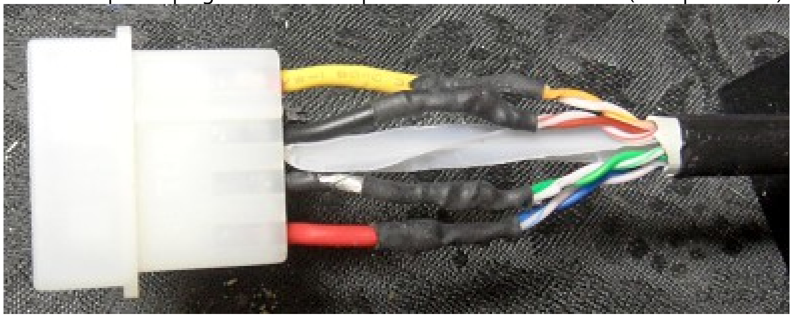
3. Wire GND to the Solid State Relay
   a) Attach a wire (Recommend BLACK or GREEN) from the "other" 24VDC- on top of the RHINO power supply to A1 of the Solid State Relay

B. Pump-Controller Power Cable

1. Select a place to mount the Pump-Controller on the Pole next to the Pumps electrical panel
   a) Measure and cut a length of Cat5e outdoor cable to reach from that spot to the bottom of the electrical panel

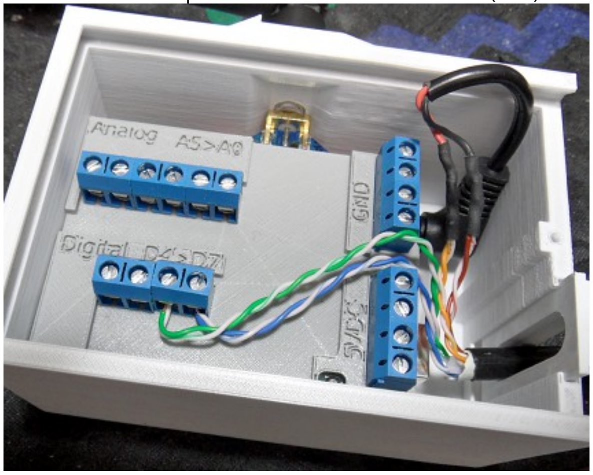
2. Create Cable to connect the PUMP-CONTROLLER → PUMP-PANEL-**EXIT PLUG** which will be installed in 3.3.2-Section D-Step#3
   a) Separate the two connecting ends of a Computer power plug (shown in the BOM) by cutting the wires in the middle
   b) Wire up the **MALE end** of the cable and save the FEMALE end for the PUMP-PANEL-**EXIT PLUG**
   - Strip the wire ends of the Cat5e twisted pair wires
   - Strip the wire ends of the male Computer power plug
   - Solder the Computer power plug to the twisted pair wires as shown

◦ Yellow power plug → Orange twisted pair	(9Vdc+)
◦ Black next to Yellow power plug → Brown twisted pair	(9Vdc GND)
◦ Black next to Red power plug → Green twisted pair	(Extra Accessory Wire)
◦ Red power plug → Blue twisted pair	(Pump Control)



c) Wire up the Pump-Controller end (Other end of the same wire in step#a above)

- Strip the outer insulation from the Cat5e Cable approximately 4" from the end
- Strip and wire the twisted pairs as follows
  - ◦ Orange twisted pair → Red wire of the angled 9Vdc UNO Power plug
  - ◦ Brown twisted pair → Black wire of the angled 9Vdc UNO Power plug
  - ◦ Green twisted pair → Perfboard screw terminal (D6)
  - ◦ Blue twisted pair → Perfboard screw terminal (D7)



3.3.2 Wiring Power & Control

This section is a guide to installing the required power supply and pump ON/OFF switching mechanisms inside the pumps electrical panel.

✔ The following **SUPPLIES** will be needed

- ○ DIN Rail cut to length (Recommend 5-1/2")
- ○ The RHINO Power Supply
- ○ The Fulree DC/DC Converter mounted to the PumpController-FulreeDINMount.stl 3D-Print
- ○ The Solid State Relay
- ○ 12-Gauge wire rated at 600V or more

✔ The following **TOOLS** will be needed

- ○ Voltmeter that reads up to or beyond 500VAC
- ○ Cordless drill
- ○ Center tap
- ○ Bit (#21 for #10-32 Machine Screw)
- ○ Threading tap (#10-32 for #10-32 Machine Screw)
- ○ (2)-Machine Screws
- ○ Protective insulated and flash protection personal gear
- ○ Wire strippers and cutters

BE SURE THE MAIN BREAKER IS TURNED OFF AND CAREFULLY CHECK THAT THERE IS NO VOLTAGE ON THE OUTPUT OF THE MAIN BREAKER WITH A PROPER METER!!! 480VAC is deadly; and can cause severe flash burn and/or death. (e.g. A meter on the wrong setting can "flash" explode causing "flash" burns on you even at a distance away). I DISCLAIM ANY AND ALL RESPONSIBLITY FOR ANY RISK OR HARM OCCURED BY FOLLOWING ANY INSTRUCTION IN THIS MANUAL.

See https://www.youtube.com/watch?v=6hpE5LYj-CY

A. Observe Pumps Electrical Panel

Most 3-phase irrigation pumps that do not have variable frequency drives(VFD) or inverters are setup similarly. Below is the details of two pump panels as an ***example or reference*** to the pumps power circuit. This information was gathered to determine the wiring and power needed to control the pumps power.

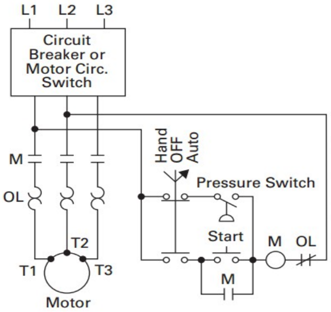
✔ Details

- ○ Box - Eaton Irrigation Pump Control Type 3R Enclosure Rainproof
  - ▪ http://www.eaton.com/Eaton/ProductsServices/Electrical/ProductsandServices/AutomationandControl/EnclosedControl/NEMA/PumpPanels/index.htm

Type 3R Industrial Pump Panel— C440 SSOL

Wiring Diagram

Typical Wiring Diagram



- ○ Wiring Diagram Description
  - ▪ Labels
    - ▫ L1, L2, L3 - Are the three HOT wires of the 3-Phase Power
    - ▫ M - The Starter Contactor (see Panel picture; white block with a blue center) contains:
      - ◦ Activation Coil - Shown as a circle in the wiring diagram just right of the Start Button (Activates the "Hammer")
      - ◦ Main Contacts - The Contacts that connect the L1,L2,L3 lines → OL → Motor (Sometimes called the "Hammer")
      - ◦ Hold Contact - The Contact wired in parallel with the Start Button and mounted on the Right-Side of the Starter Contactor Block

*When **HAND** is selected the "control circuit" (L1 → L2 loop) is still open until the Start Button is pressed. When the Start button is pressed it activates the (M) Coil which in-turn activates the "Hold Contact" (the --| |-- in parallel to the Start Button). This right-side contactor holds the "control circuit" closed until there is a power failure bump or the Hand-Off-Auto Switch breaks open the circuit loading the (M) activate coil.*

*This Projects SSR-Relay will be connected where the "Pressure Switch" is shown in this wiring diagram and will use the **AUTO** switch selection. This setup will require that the Arduino **NOT re-activate** power after a power failure has occurred until a specified time delay or turned back on. The click in HAND circuit is setup so the power company can re-activate power after a power failure without the over-load of all motors kicking on at the same time.*

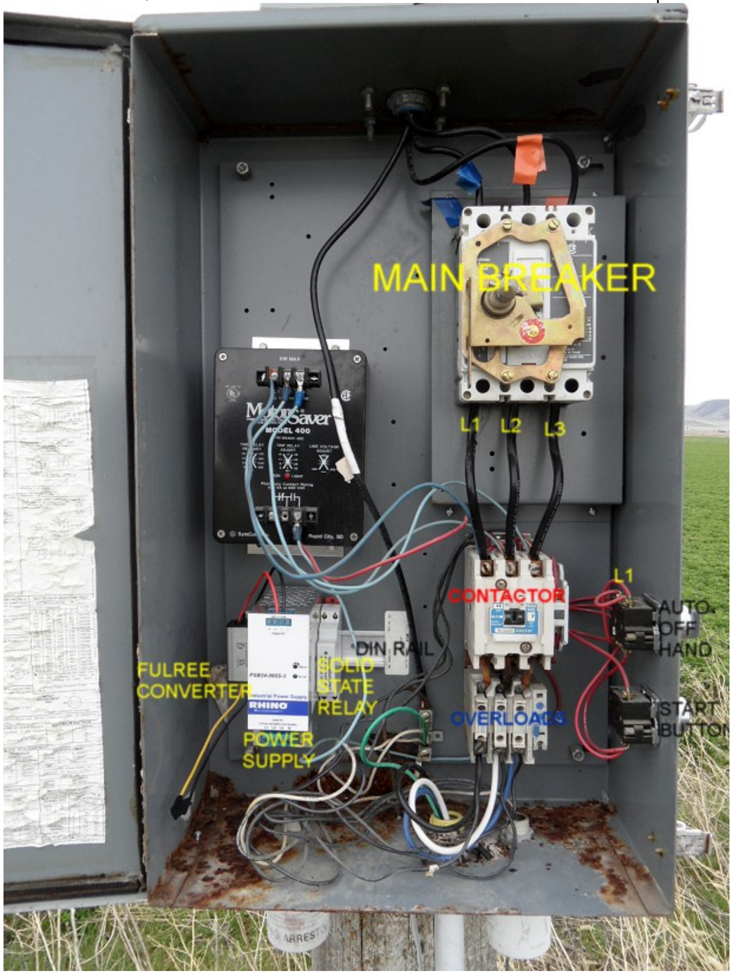
- ○ Starter Contactor - Eaton-Cuttler/Hammer 45-Amp Model # AN16GNO Series B1 (Need to check Contactor Model #)
  - ▪ MODEL # Decoding
    - ▫ A = Starter
    - ▫ N = NEMA
    - ▫ 1 = Non-Reversing
    - ▫ 6 = Starter w/C306 Over Load Relay
    - ▫ G = NEMA Size #2 (45-Amp)
    - ▫ N = Normally Open
    - ▫ O = Horizontal Mount
  - ▪ https://www.galco.com/buy/Cutler-Hammer-Div-of-Eaton-Corp/AN16GN0AB
  - ▪ http://www.eaton.com/Eaton/index.htm
  - ▪ http://www.eaton.com/Eaton/ProductsServices/Electrical/ProductsandServices/AutomationandControl/ContactorsStarters/ElectromechanicalContactorsandStarters/FreedomSeries/FreedomSeries/index.htm#tabs-2

- ○ Starter Contactor (Coil) Amperage
  - ▪ See Page 9 “AC COIL DATA” for NEMA Size #2 Shows 230VA(Volt-amperes which is VA=V*A) so 230VA/480Vac = 0.479Amps @ 480V
  - ▪ http://www.eaton.com/ecm/idcplg?IdcService=GET_FILE&allowInterrupt=1&RevisionSelectionMethod=LatestReleased&noSaveAs=0&Rendition=Primary&dDocName=998056282226
- ○ Auxiliary Contact - Cutler Hammer Model #C320KGS1 10-Series A2 (480VAC @ 1.5 Amps?)

B. DIN-Rail Components

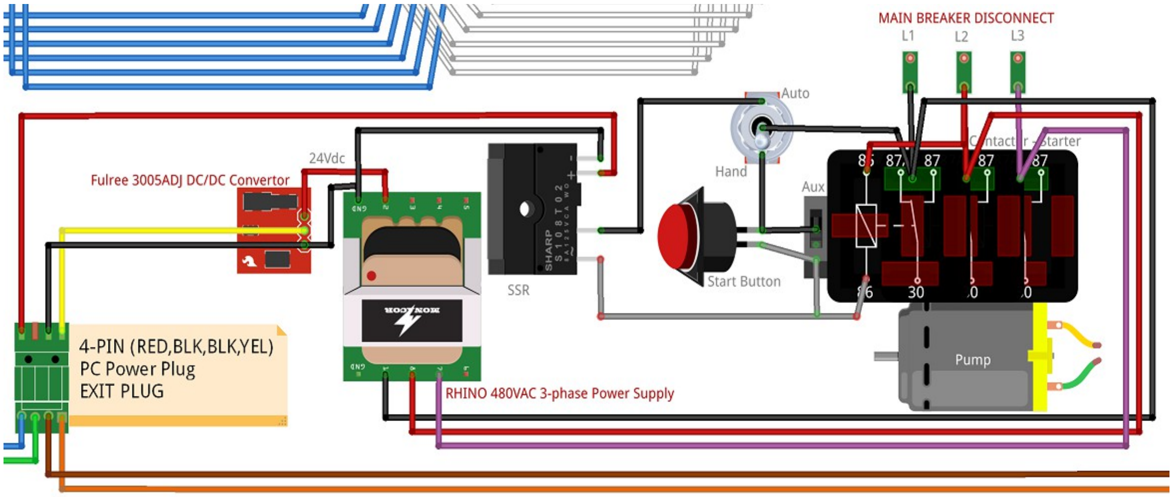
1. Drill two holes in desired location, punch, tap-thread, and mount the DIN rail horizontally
   a) Recommend using a #10-32 x 1/2” Machine Screw
   b) Drill bit size for #10-32 is #21 – 5/32” - 0.1590”

2. Snap on the RHINO power supply to the DIN rail in the center
3. Snap on the Solid State Relay to the DIN rail on the right of the RHINO power supply
4. Snap on the Fulree DC/DC Converter to the DIN rail to the left of the RHINO power supply



C. Pump Panel wiring

NOTICE: All wiring in this section should be done with 600V rated wire



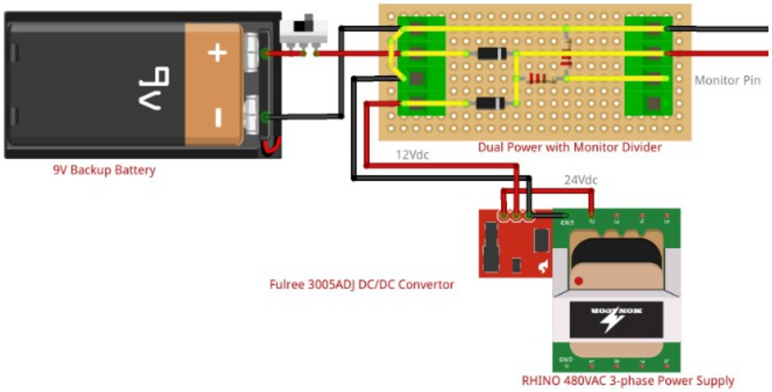
1. Wire the RHINO Power Supply
   a) Connect RHINO terminal L1, L2, L3 to the top terminals of the Contactor (i.e. Starter / Hammer) L1, L2, L3 terminals
   b) Connect RHINO GRND terminal to a bold on the panels back-plane

2. Wire the Solid State Relay
   a) Connect Solid State Relay (15) → **AUTO** Terminal of the HAND-OFF-AUTO switch
   b) Connect Solid State Relay (16) → Contactor Activation Coil side connected to the Auxiliary Contact & Start Button (BUT NOT THE HAND SIDE)

3. Wire in the female **Exit Plug**
   a) With the **Female end** of the Computer power plug from 3.3.1.A **Exit Plug** insert wires through a bottom hole in the Pumps Electrical Panel
   b) Connect the **Yellow & Black wires from the Fulree** DC/DC converter to the Yellow/Black wires of the female end of the Computer power plug
   c) Connect the Solid State Relay **(A2) to the RED** wire of the female end of the Computer power plug
   d) Tape off the Black wire next to the Red wire (*Can be used as with an "optional" auxiliary contact to verify pumps power status*)

3.4 Optional Accessories

A. Power Alternatives


9V
+
-
9V Backup Battery
Monitor Pin
12Vdc
Dual Power with Monitor Divider
24Vdc
Fulree 3005ADJ DC/DC Convertor
RHINO 480VAC 3-phase Power Supply

✔ Car Battery for Main Pump-Controller Power (Currently No Implementation Plan)
- ○ Requires an auxiliary contact to monitor the Pumps power source so the pump can wait a while after a power bump to restart the pump.

✔ Emergency Backup 9V Battery Power (Currently No Implemented Plan)
- ○ Requires either
  - ▪ An auxiliary contact to monitor the Pumps power source
  - ▪ A voltage monitor that can determine when the emergency power has started and the Pumps power source is gone.
- ○ Advantages
  - ▪ Allows reading of water levels during a power outage
  - ▪ Allows (though risky) the automatic restarting of the pump once power is restored
  - ▪ The case is already designed to hold a 9VDC Battery Case

** After considering the benefit and risk the back-up power implementation plan was canceled for the time being

B. Pressure Transducer ($9.59)

✔ 5V 0-1.2 MPa Pressure Transducer Sensor Oil Fuel Diesel Gas Water Air Sensor
- ○ http://www.banggood.com/Pressure-Transducer-Sensor-Oil-Fuel-Diesel-Gas-Water-Air-Sensor-p-1007341.html - $9.59

Wiring: red +, black -, yellow output

C. Ultrasonic Water Level ($10.77)

✔ DC 5V Waterproof Ultrasonic Module Distance Measuring Transducer Sensor
- ○ http://www.banggood.com/DC-5V-Waterproof-Ultrasonic-Module-Distance-Measuring-Transducer-Sensor-p-1094462.html - $ 10.77

✔ Benefits
- ○ Offers a way to monitor the water level in a ditch

D. Auxiliary Contact ($43.75)

- ✔ Auxiliary contact, side mounted, 1 N.O. Contact (**NOTE: This must match/fit the pump panels Contactor Unit**)
  - ○ https://www.automationdirect.com/adc/Shopping/Catalog/Motor_Controls/Eaton_Cutler-Hammer_Contactors_-z-_Starters_-z-_Overloads/Auxiliary_Contacts/C320KGS1 - $43.75/ea

- ✔ Notes
  - ○ Auxiliary Contactor must be purchased according to the contactor they will FIT on.
    - ▪ The above suggested purchase will ONLY work with the NEMA-2 Model # AN16GNO Series B1 Contactor
  - ○ The Auxiliary Contactor typically already used by the Start-lock CANNOT be used for this purpose as it has 480V wires already attached to it.
  - ○ Often a used aux contactor can be found much cheaper on ebay

- ✔ Benefits
  - ○ Offers a way to monitor the actual (i.e. directly) the pump power status

E. Water Meter

4. SYSTEM OPERATIONS

4.1 XBEE Setup

The XBEE RF Module is setup from the factory to work without any additional changes. However, often it is very wise to assign non-factory setting in order to keep your RF communications from being interfered with by other XBEE devices in the neighborhood.

1. Upload Firmware with XBEE Configuration Set
   a) To change the XBEE settings – Follow Steps #1 to #3 in [#4.2.A SYSTEM OPERATIONS|Firmware|Uploading](#)

   With the Firmware file open find the following line of code which should be very close to the top

```
#define XBEECONFIG 0              // 1 to enter XBEE Configuration Mode
```

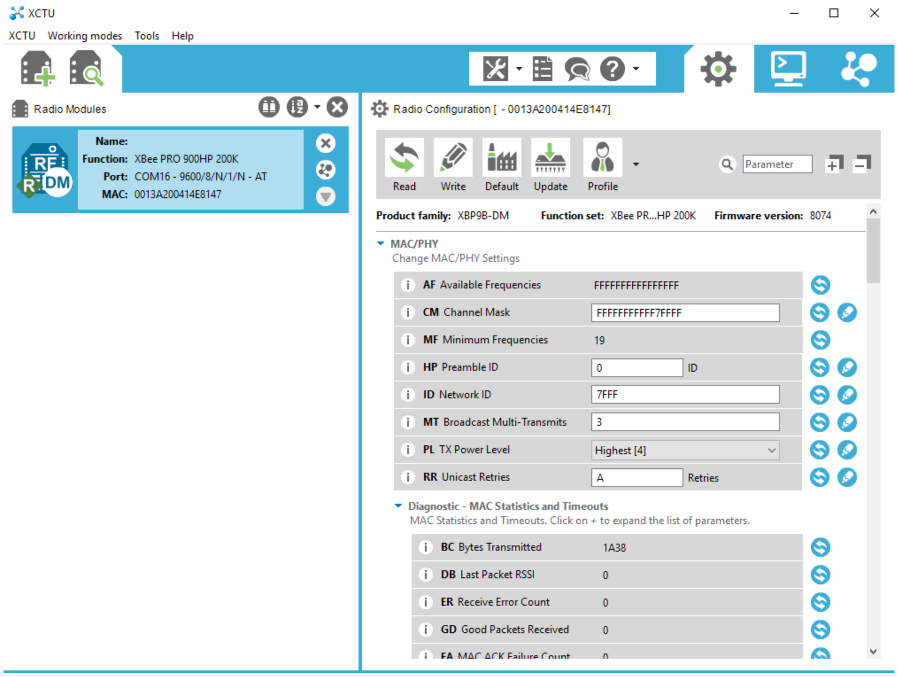
   Change to

```
#define XBEECONFIG 1              // 1 to enter XBEE Configuration Mode
```

   b) Then proceed to upload the firmware to the Unit as outline in Step #4 in [#4.2.A SYSTEM OPERATIONS|Firmware|Uploading](#)

2. Install Digi-XCTU
   a) The Digi XCTU software can be gotten from https://www.digi.com/products/xbee-rf-solutions/xctu-software/xctu

3. Run Digi-XCTU



Name:
Function: XBee PRO 900HP 200K
Port: COM16 - 9600/8/N/1/N - AT
MAC: 0013A200414E8147

Product family: XBP9B-DM   Function set: XBee PR...HP 200K   Firmware version: 8074

MAC/PHY
Change MAC/PHY Settings

AF Available Frequencies	FFFFFFFFFFFFFFFF	
CM Channel Mask	FFFFFFFFFFF7FFFF	
MF Minimum Frequencies	19	
HP Preamble ID	0	ID
ID Network ID	7FFF	
MT Broadcast Multi-Transmits	3	
PL TX Power Level	Highest [4]	
RR Unicast Retries	A	Retries

Diagnostic - MAC Statistics and Timeouts
MAC Statistics and Timeouts. Click on + to expand the list of parameters.

BC Bytes Transmitted	1A38
DB Last Packet RSSI	0
ER Receive Error Count	0
GD Good Packets Received	0
EA MAC ACK Failure Count	0

   a) Using the + mark in the top left corner enter the unit's COM port (The Arduino COM Port)
   b) The main values that may be of interest are:
      - ID Network ID - This sets a Unique "Channel" to keep your units communications separate from any others out there (Must be same on all units)
      - PL TX Power Level - If devices are close; a lower power setting can preserve battery life

4. Save Settings to the Xbee and Reload Firmware
   a) Be sure to click the "Write" button in XCTU to save any settings that were made
   b) Close XCTU
   c) In Arduino Sketch IDE restore the following line to its original

```
#define XBEECONFIG 0              // 1 to enter XBEE Configuration Mode
```

   d) Upload the Firmware to the Unit again as outline in Step #4 in [#4.2.A SYSTEM OPERATIONS|Firmware|Uploading](#)

4.2 Firmware

A. Uploading

1. Install Arduino Sketch IDE *(If NOT installed already)* https://www.arduino.cc/en/Main/Software

2. Install the PeerIOSerialControl Library *(If NOT installed already)*
   a) In a web-browser; go to https://github.com/tgit23/PeerIOSerialControl
   b) On Green Clone or download Choose Download Zip
   c) Save to a place you'll remember – like Documents or Desktop
   d) Run the Arduino Sketch IDE
   e) Choose Menu Item Sketch → Include Library → Add .zip Library
   f) Select the PeerIOSerialControl Library file saved in step 'b' above

3. Download the Firmware
   a) In a web-browser; go to https://github.com/tgit23/AgIrrigationRemoteControl
   b) On Green Clone or download Choose Download Zip
   c) Save to a place you'll remember – like Documents or Desktop
   d) Unzip the Folder
   e) In Arduino Sketch IDE choose File → Open and Select
      - File HandRemote.ino for the HandRemote Firmware
        - Location Example: \Downloads\AgIrrigationRemoteControl-master\AgIrrigationRemoteControl-master\HandRemote
      - File PumpController.ino for the PumpController Firmware
        - Location Example: \Downloads\AgIrrigationRemoteControl-master\AgIrrigationRemoteControl-master\PumpController\PumpRemote

4. Compile and Upload the Firmware
   a) Setup the unit to "**Upload-Mode**" by removing both Zigbee Shield jumpers
   b) Plug in a USB cable from the Computer to the unit
   c) Select the Port the units USB is connected to; in Sketch menu Tools → Port
      - To determine Port; Open Windows Device Manager → Ports (COM & LPT) a new COM?? port appears right after plugging in the cable
   d) Select the Board; Sketch menu Tools → Board → Arduino/Genuino UNO
   e) In Arduino Sketch IDE; Press the Right-Arrow next to the Check mark in the Top-Left Corner to upload the firmware onto the unit

B. Virtual Pins

C. Customizing

✔ Overview

○ Downloaded firmware includes menu items for;

▪ Pump Controller Selection	- Ability to control multiple Pump Controllers from one Hand-Remote Unit
▪ Power	- Sets or Read the Pump Power as either ON or OFF
▪ Water Level	- An Accessory IO-Monitor to check the canal or ditch water level
▪ Battery	- Reads the Battery Voltage Level
▪ Pressure	- An Accessory IO-Monitor to check the water pressure
▪ Alarms	- Various Alarms for the monitoring the readings above

The menu items are defined in the **SetupMenu()** *Function identified by line 'void SetupMenu() {'. Each item in the Menu has a numeric index (i.e. Menu[index-#]).*

```
/*******************************************************************************************************************//**
 * @brief  Setup the LCD menu
 * @remarks
 * - Allows a single spot customization to users configuration
 * @code
 *   exmaple code
 * @endcode
***********************************************************************************************************************/
void SetupMenu() {

  // Be sure to change 'MENUITEMS' when adding/deleting items
  Menu[PUMPIDX].Text = "Pump";
  Menu[PUMPIDX].ValueLocation = EPROM;
  Menu[PUMPIDX].Option[0].Text = "Canal";
  Menu[PUMPIDX].Option[0].TransceiverID = 10;           // Target TRANSCEIVER_ID
  Menu[PUMPIDX].Option[1].Text = "Ditch";
  Menu[PUMPIDX].Option[1].TransceiverID = 11;           // Target TRANSCEIVER_ID
  Menu[PUMPIDX].LastOption = 1;
  Menu[PUMPIDX].Poll=false;                             // Poll for Updates
  Menu[PUMPIDX].Val[SET].Active = true;

  Menu[1].Text = "Power";
  Menu[1].ValueLocation = REMOTEPIN_DIGITAL;
  Menu[1].Option[0].Text = "Off";
  Menu[1].Option[0].Value = LOW;
  Menu[1].Option[1].Text = "On";
  Menu[1].Option[1].Value = HIGH;
  Menu[1].LastOption = 1;
  Menu[1].Pin = 7;
  Menu[1].Val[SET].Active = true;             // Allows Value to be 'SET'
  Menu[1].Val[LOALARM].ID = 'p';
  Menu[1].Val[HIALARM].ID = 'P';

  Menu[2].Text = "Water L.";
  Menu[2].ValueLocation = REMOTEPIN_ANALOG;
  Menu[2].Pin = 64;
  Menu[2].Val[LOALARM].ID = 'l';
  Menu[2].Val[HIALARM].ID = 'L';

  Menu[3].Text = "Battery";
  Menu[3].ValueLocation = LOCALPIN_ANALOG;
  Menu[3].Pin = BATT_PIN; // Analog A2
  Menu[3].Val[LOALARM].ID = 'b';

  Menu[4].Text = "Pressure";
  Menu[4].ValueLocation = REMOTEPIN_ANALOG;
  Menu[4].Pin = 3; // Analog A3
  Menu[4].Val[LOALARM].ID='r';
  Menu[4].Val[HIALARM].ID='R';

  // Read all values at start-up
  GetItem(PUMPIDX);
  SetPump( Menu[PUMPIDX].Option[ Menu[PUMPIDX].Val[MAIN].Value ].TransceiverID );
  idx = STARTIDX;
}
```

✔ To delete a Menu Item

- ○ Find the menu items index (ie. Menu[index]) you'd like to delete by identifying it by its' Menu[Index].Text setting
- ○ Select ALL Menu[index] lines with the same index
- ○ Press delete
- ○ Starting from the top make sure the indexes are in order; for example if you deleted [3], change [4] to [3], [5] to [4] and etc.. for all entries
- ○ Up towards the top of the program (~line 50) change value of '#define MENUITEMS ?' to the number of menu items that exist now

✔ To add a Menu Item

- ○ Start a new line below the last one defined and enter the attributes that need to be set
  - ▪ Menu[?].Text - The text that will display on the LCD
  - ▪ Menu[?].Value - Typically not set; holds the value of the item
  - ▪ Menu[?].ValueSettable - TRUE/FALSE determines if the user can change the value
  - ▪ Menu[?].ValueLocation - PROG/LOCALPIN/REMOTEPIN/EPROM; Determines where the value of the item is set/retrieved
  - ▪ Menu[?].Pin - Arduino Pin# associated with the item
  - ▪ Menu[?].Analog - TRUE/FALSE; Default is FALSE, Set to 'true' if using an Analog pin for the value
  - ▪ Menu[?].AlarmCompare - LESS/GREATER/EQUAL; Defines how an alarm will compare its limit value to the ValueIdx Value
  - ▪ Menu[?].AlarmValueIdx - The Menu[Index].Value this alarm item will compare itself with
  - ▪ Menu[?].Option[?].Poll - TRUE/FALSE; Default is true. Set to false if the value doesn't need to be refreshed and displayed

  Options are how a limited amount of select-able items are defined for a value. For example ON or OFF would be two options.

  - ▪ Menu[?].Option[?].LastOption - Counting from 0-> ; How many options are defined
  - ▪ Menu[?].Option[?].Text - Option[?].Text defines an option that can be selected like 'ON'
  - ▪ Menu[?].Option[?].DrivePin - Option[?].DrivePin LOW or HIGH when this option gets selected

- ○ Up towards the top of the program (~line 50) change value of '#define MENUITEMS ?' to the number of menu items that exist now