Water Leak Detector
Installation and User Manual

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Team Practical Projects

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1. Overview

The primary purpose of the Water Leak Detector (WLD) is to detect leaks and to notify the user in time to contain the damage while it is still minor. To this end, the WLD provides both a local audible and visual notification and a remote notification to the user's mobile phone. The WLD is designed to support two sensors, each of which may be placed anywhere that can be cable connected to the WLD electronics.

Secondarily, the WLD contains an inexpensive temperature and humidity sensor (DHT11) that monitors ambient conditions and may provide useful augmentation to the water leak sensor data; e.g. an indication of a steam leak in a boiler in the basement of a house.

The sensors used in the WLD are actually water level sensors whose data is processed to provide an alarm condition in the event that a puddle of water is detected. The WLD will alarm with a puddle as small as 2 mm deep. An alarm condition exists whenever either of the sensors detects the presence of water. The alarm condition persists until both sensors are dry, in which case the WLD automatically clears out the alarm condition and re-arms for subsequent triggering of a water leak alarm.

The WLD electronics are based upon the Particle Photon module (https://www.particle.io). The Photon contains an advanced 32 bit microcontroller with a built in WiFi capability. The WLD electronics requires a WiFi connection to the Internet and will not work (even locally) unless the Photon can communicate with the Particle cloud over the Internet. The Particle cloud service is available for free to owners of Particle's Photon and Electron (and other) devices.

The printed circuit board that we have designed for this project can alternatively accept the Particle Electron module. The Electron uses the same microcontroller (and firmware) as the Photon; however, it communicates over the Internet via cellular 3G services rather than via WiFi. Particle offers a very low cost cellular data service to go along with the Electron. If WiFi is not available, the Electron may be a suitable alternative. Note however that *while we have designed the electronics to work with the Electron, and while the Electron should work with the same firmware as we have provided for the Photon, we have not tested the WLD with an Electron. The user should take this risk into account before committing to building a WLD with an Electron*.

The WLD is designed to be accessed remotely via a smartphone. WLD uses the free Blynk smartphone app and cloud service (http://www.blynk.cc) for both asynchronous mobile phone notification of a water leak alarm and for monitoring alarm status, temperature and humidity. The WLD is provided with a Blynk project that is used with the Blynk app for this purpose. The app is supported on both iOS and Android smartphones.

Blynk provides a certain level of service for free, after which the user has to pay a fee. The WLD project resources, in total, fall into the free category. However, *if the user modifies the project or if the user has other Blynk projects, the user may need to pay a monthly Blynk fee for this expanded level of service.*

The WLD is offered to all users free of charge for non-commercial use. Any and all use of the information provided in this package is subject to the restrictions described in the document "Terms_of_Use_License_and_Disclaimer.pdf" that is included in this release package. This document can also be found at:
https://github.com/TeamPracticalProjects/WaterLeakSensor/blob/master/Documentation/Terms_of_Use_License_and_Disclaimer.pdf

The WLD is only available as a set of documentation at this time. You must purchase all of the parts yourself and you must assemble the WLD yourself, including soldering of electronic components and cabling, cutting and assembling of plastic material, mounting of materials on walls, setting up of accounts on cloud-based services and smartphones. The project provides extensive written instructions on how to do all this but you must be able to follow those instructions accurately. You will need basic hand tools (screwdrivers, files, knives, drill) and basic through hole soldering tools (soldering iron, long nose pliers, diagonal cutters, wire strippers) and the skills to use these tools properly in order to assemble the WLD.

We have endeavored to provide full, accurate, step by step instructions for each and every step in making a fully operational WLD. However, we explicitly disclaim any responsibility or liability for inaccuracies or confusion in any of our documentation. ***We are not a commercial entity and we cannot offer any guarantee of support or warranty of any kind if you are unable to successfully build and deploy a WLD.*** Therefore, *we urge you to read through all of the documentation for this project and make sure that you are comfortable with everything that you will need to do to make a working WLD before proceeding to order parts or begin the manufacture of any of the WLD components.*

2. Component Parts

An overview of the WLD can be found in the document “Water_Leak_Dectector_Concept.pdf” which is included in this package and can also be found at: https://github.com/TeamPracticalProjects/WaterLeakSensor/blob/master/Documentation/Water_Leak_Detector_Concept.pdf
Please read through this document first so that you are familiar with the WLD overall, before proceeding to read the details below. The WLD project consists of hardware, firmware (for the Photon) and an app for your smartphone. These items are described in this section.

2.1. Hardware.

The WLD hardware consists of the following components:

- The water leak sensors
- The WLD electronics
- Your WiFi router
- Your smartphone

2.1.1. Water Leak Sensors.

Figure 2-1 is a picture of the sensors that are used in this project. A US quarter is included in the photo to provide an indication of the size of these sensors (they are small). The sensors are intended to measure the level of water, where the bottom of the sensor is at the left of the photo and the electronics (right) are at the top.

Figure 2-1. Water Leak Sensor.

Each sensor consists of a set of parallel conductive traces arranged as interleaved “fingers”. These traces are an open circuit when the sensor is dry. However, when the sensor encounters water at some level up from the bottom, the resistance of these traces lowers and the sensor outputs a voltage that is indicative of the level of the water between the bottom (lowest voltage) and the top of the traces (supply voltage).

The WLD is only interested in the presence of water. The WLD firmware in the Photon continuously measures the voltage from each of the sensors and compares this voltage to a threshold. When this threshold is exceeded for a set number of measurements, a water leak alarm is triggered. The alarm remains triggered until both sensors are dried off and thus below the alarm threshold for a set number of measurements. We have empirically set the threshold so that an alarm is triggered by a water level that is less than 2 mm from the bottom of the sensor.

The WLD accommodates two sensors so that one WLD can monitor two different locations; e.g. by a washing machine and by a water heater in a basement or garage. The sensors themselves connect using a 3 pin 0.1” spaced header. In order to cable the sensors to the electronics neatly and securely, the WLD design includes pin headers to RJ11 connector boards. A short pin header cable at the sensor end connects to a miniature circuit board that wires it to an RJ11 telephone connector. A similar board and connector are used in the electronics enclosure to transition back from RJ11 cable to the WLD electronics. RJ11 cables are available on-line and in many hardware stores. They are inexpensive, available pre-terminated in many different cable lengths and in different colors for running along baseboards and up walls. They are jacketed, relatively rugged, and the connectors have a locking mechanism so that the cable won’t fall out of its mating socket. **Make sure that you use 4 wire (not 2 wire) RJ11 cable**. 2 wire RJ11 telephone cables will not work!

2.1.2. Electronics.

The WLD electronics are contained in a plastic enclosure. Figure 2-2 shows this enclosure with sensor cables, power cable and mounting bracket attached.

Figure 2-2. Assembled Electronics Enclosure.

A plastic meter faceplate is attached to the cover of the box. The faceplate is laser cut from 3 mm plastic stock using a CAD file that is included in this project package. If you do not have access to a laser cutter, you can print out a paper copy of this faceplate from the included pdf file and carefully glue it to the cover of the box. (NOTE: We also include instructions for two other enclosure options: an open air 2D box, and a 3D printable chassis.)

The faceplate mounts the “servo” meter, which indicates temperature and humidity locally. The toggle switch to the left of the servo meter is used to select whether the servo meter displays temperature or humidity. Both Fahrenheit and Centigrade scales are included on the faceplate. The humidity scale is always %RH.

The right side of the faceplate contains a backlit pushbutton switch. The backlight lights steady when the WLD is armed and ready. The backlight blinks rapidly when a water leak alarm condition is present. If the backlight is dark refer to the section below on Local Operation. A piezo buzzer inside of the enclosure beeps annoyingly when a water leak condition occurs, but pressing the backlit pushbutton mutes the audible alarm until the system is automatically re-armed after the sensors are dried off.

The project documentation also includes a template for laser cutting a wall mounting bracket for the enclosure. This bracket may optionally be used both as a template for drilling mounting

holes for the circuitry inside of the enclosure as well as providing holes for wall mounting the electronics enclosure after it is assembled and tested.

The two water level sensors are connected to one side of the enclosure using RJ11 cables. The other side of the enclosure contains a USB “B” connector which is used to supply power to the enclosure. *The enclosure must be placed in a location where AC power is available*.

Figure 2-3 shows the inside of the electronics enclosure.

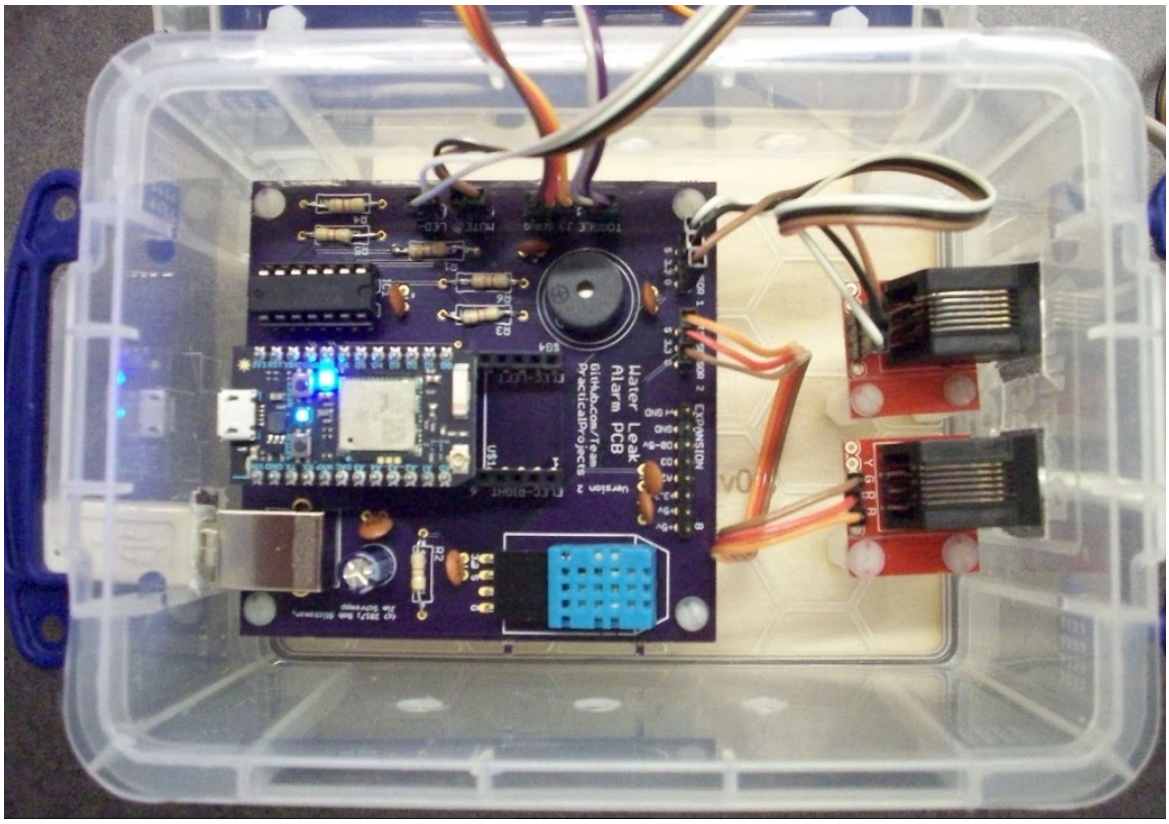

Figure 2-3. Inside View of Electronics Enclosure.

On one side of the enclosure are two small printed circuit boards that transition RJ11 connections to pin header cables. The RJ11 jacks are accessible through holes cut through the side of the box. The main electronics printed circuit board is mounted on the other side of the enclosure with the USB “B” type power connector accessible through a hole cut through the side of the box. Figure 2-3 shows the piezo buzzer glued to the lower side of the box; however, the released version of the main printed circuit board allows the buzzer to be soldered directly to the board, obviating cutting and gluing it to the box itself.

2.1.3. WiFi Router.

The WLD project requires a WiFi connection to the Internet. You must have a WiFi router or gateway that is compatible with the Particle Photon (almost all are) – specifications can be found at:

https://www.particle.io/products/hardware/photon-wifi-dev-kit

If you don't have WiFi capability within range of where you want to mount the electronics but you do have cellular phone service, then you might consider using the Particle Electron instead of the Photon. Note that we have not tested with the cellular data based Electron; however, the printed circuit board is designed to accept the Electron and the firmware is *supposed* to be fully compatible with all Particle hardware.

2.1.4. Smartphone.

The WLD project also requires that you have an app on a smartphone in order to receive leak alarm notifications and to remotely monitor the conditions sensed by the WLD electronics. The smartphone must be capable of supporting the free Blynk app – see http://www.Blynk.cc for details. Blynk supports both iOS and Android smartphones and we have tested the app with both types.

2.2. Firmware.

Firmware is what we call the software that runs on the Particle Photon microcontroller. The released WLD firmware is included in this package and can also be found at: https://github.com/TeamPracticalProjects/WaterLeakSensor/blob/master/Firmware/WaterLeakDetector/src/WaterLeakDetector.ino.

You must have a free account at https://www.particle.io in order to flash the firmware to your Photon device. You must also have a Blynk authentication token from your Blynk app project and you must paste this authentication token into the firmware that we supply before compiling and flashing the firmware to your Photon. Complete instructions for installation of the firmware to your Photon are included in this package ("WLD_Firmware_Installation.pdf") and are available on-line at: https://github.com/TeamPracticalProjects/WaterLeakSensor/blob/development/Documentation/WLD_Firmware_Installation.pdf

2.3. Smart Phone App.

The WLD communicates with an app on your smartphone. The app is a

“project” that runs within the Blynk app. The Blynk app is available for iOS and Android smartphones at http://www.blynk.cc. You must register with Blynk to obtain the app; registration and the app are free, as long as you use the Blynk app only for this project. Complete instructions for installation of the Blynk app and WLD project are included in this package (“Blynk_Installation.pdf”) and are available on-line at: https://github.com/TeamPracticalProjects/WaterLeakSensor/blob/master/Documentation/The%20Blynk%20WLD%20Project.pdf

3. Installation and Placement.

The WLD electronics should be mounted on a wall or otherwise accessible location within cable distance of the sensors. A wall mounting bracket is available as part of this project. The wall mounting bracket allows you to assemble and test the WLD electronics and then to mount it on a wall using two #8 screws. The wall mounting bracket also serves as a template for drilling holes in the bottom of the enclosure box for assembly of the electronic components into the box. The wall mounting bracket is provided as a CorelDraw file with this project and you may use this file to laser cut the bracket out of 3 mm plastic or wood material. If you do not have access to a laser cutter, you will have to fabricate your own means of mounting the WLD electronics to a wall.

The location of the WLD electronics must:

- Be accessible to AC power. A “wall wart” power supply plugs into a standard wall outlet and provides power to the WLD electronics via a standard USB A/B cable. The power cable plugs into a mating USB connector located on the right side of the enclosure.
- Be physically accessible. You will want to mount the WLD electronics enclosure in a location where you can see the servo meter and the backlit pushbutton switch on the face of the enclosure. You should also be able to easily operate the toggle switch and press the backlit pushbutton at this location.
- Be located where sensor cables can be run neatly to the enclosure. RJ11 cables from the two water level sensors plug into mating RJ11 jacks located on the left side of the WLD electronics enclosure.

The two water level sensors must be mounted vertically, with the bottom of the sensor in physical contact with the floor. The back of each sensor is completely blank. We recommend that you use high strength outdoor double sided tape to secure the sensor to a wall, in the proper orientation and location.

The best location for the water level sensors are along a wall that is the lowest point in the room, near where a leak would occur (sink, washing machine, water heater, etc.). If the room has its low point at a drain near the center of the room, you might want to improvise some sort of mount for the sensor, such as a block of wood. Note, however, that the sensor must be cabled to the electronics, so you will need to take care to ensure that the sensor, its mount and the cable run do not interfere with movement through the room. A better solution might be to place a flat pan or other container underneath where leaks are expected, with one edge of the pan against a wall where the sensor wires will run. This way, the water leak can puddle in the pan and trigger a sensor that is cabled along a wall.

Each sensor attaches to a miniature printed circuit board using a 3 wire female-female header cable. The printed circuit board transitions this header cable to a 4 wire RJ11 telephone cable, as shown in figure 3-1.

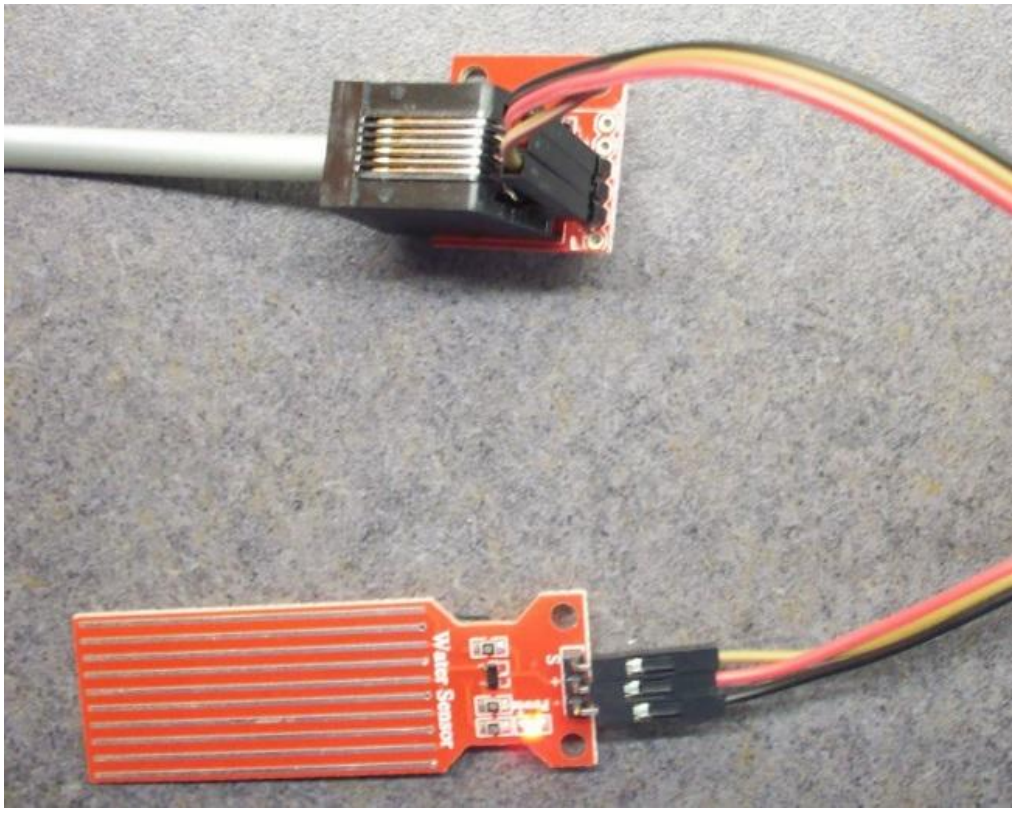

Figure 3-1. Water Level Sensor Transition to RJ11 Telephone Cable.

When locating the water level sensor along a wall or mounting block, provision must be made for similarly mounting this miniature printed circuit board nearby and for neatly routing the telephone cable from the miniature printed circuit board up to the electronics enclosure. We have tested connection of water level sensors to the WLD electronics enclosure using 10 foot long telephone cables. In theory, longer cables (25 feet or even 50 feet) should work fine; however, we have not tested longer cable connections.

Interestingly, these 4-wire RJ11 telephone cables come in two varieties: crossover (for telephone use), and straight (for instrument use). To correctly connect the water level sensors to the WLD, you need to know which variety of cable you have in hand. The crossover (telephone) cables are the most commonly available. To know which variety you have, hold the connectors from the ends of the cable together, both with the release tabs towards you. Look closely at the color of the individual wires in the cables. In a crossover cable the colors will be in a different order in each connector; in a straight cable they are in the same order. See the photos below.

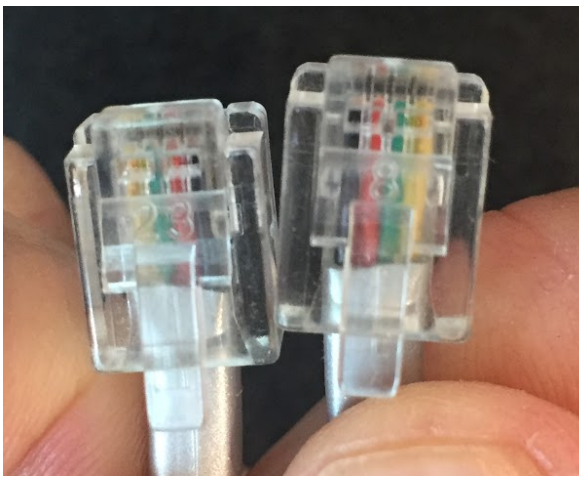

Figure 3-2. Crossover (telephone style) Cable. Note the position of the yellow wire is different in the two connectors.

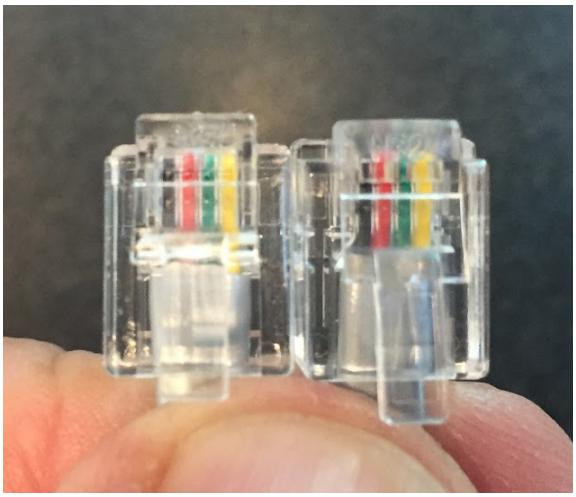

Figure 3-3. Straight (instrument style) Cable. Note that the positions of the colored wires are the same in each connector.

You can also straighten out your cable so that it lies flat and observe the position of the connector locking tabs. If both tabs are facing up or both are facing down, you have a crossover (telephone) type of cable. If one tab is facing up and the other tab is facing down, you have a straight (instrument) type of cable.

Our instructions assume you are using the crossover (telephone) variety of RJ11 telephone cables. Figure 3-4 is a schematic diagram for the wiring of the water level sensors through transitions to and from RJ11 jacks and cable and up to the WLD electronics printed circuit board on the enclosure.

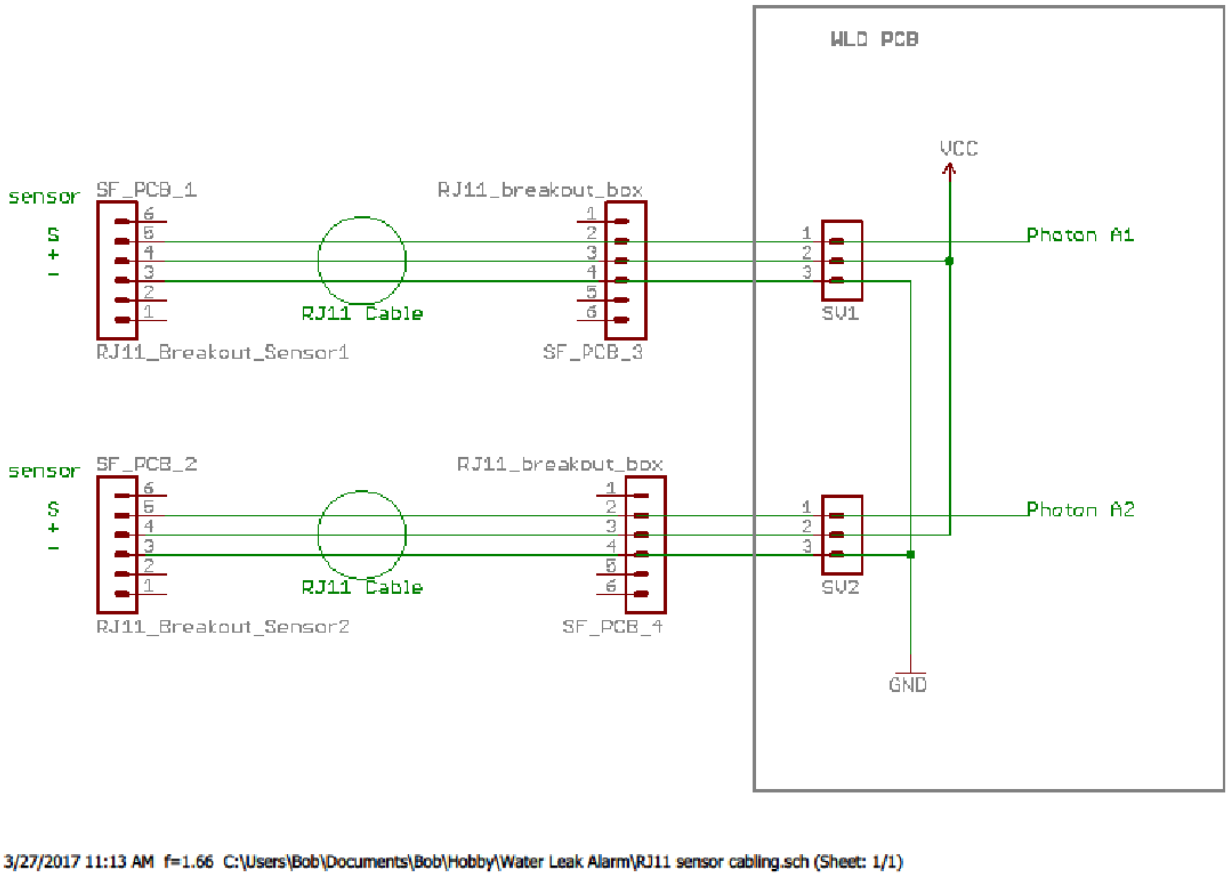

Figure 3-4. Water Level Sensor Cabling to WLD Electronics.

Note that the sensors connect to pins 5, 4 and 3 on the miniature PCB by the sensor, but the corresponding pins at the miniature PCB within the WLD electronics enclosure are pins 2, 3, and 4 respectively. ***Be careful to use the correct pins when wiring sensors to the miniature PCB and the corresponding miniature PCB to the main electronics PCB***. Further details can be found in relevant enclosure build instruction document for the enclosure that you are building (cut plastic box enclosure, 3D printed enclosure, or 2D laser cut enclosure). These documents are included in this package and is also available at:

https://github.com/TeamPracticalProjects/WaterLeakSensor/tree/master/Documentation

If you have a straight (instrument style) cable, then you connect the sensor to the following pins on the miniature PCB instead of as in figure 3-4:

S → pin 2 (instead of pin 5)

\+ → pin 3 (instead of pin 4)

\- → pin 4 (instead of pin 3)

Connect mini PCB at the box end to the main electronics PCB as shown in figure 3-4.
NOTE: The top side of the RJ11 breakout boards have holes labeled YGRB. This labeling corresponds to the numbered hole labeling on the bottom of the breakout board as follows:

Pin 1: no top label
Pin 2: top label B
Pin 3: top label R
Pin 4: top label G
Pin 5: top label Y
Pin 6: no top label

The WLD supports two water level sensors, so that two different locations can be monitored for leaks (e.g. a washing machine and a water heater in a basement or garage). It is best if you use both sensors, even if the sensors are monitoring two locations nearby the same appliance. If you wish to use only one sensor, you must ground the signal input pin at the 3 pin header connector for that sensor on the WLD electronics main PCB. This can be achieved by placing a female-female pin hear jumper between pin 1 and pin 3 on whichever of the sensor connectors are not used. *If you do not install either this jumper or a sensor to one of the sensor input connectors, ambient electrical noise will trigger water leak alarms.*

4. Local Operation.

The WLD has been designed for both local and remote operation. Local operation is described in this section.

In normal circumstances, the WLD is powered up and the green backlit push button is lit continuously. In addition the small blue D7 LED on the Photon board slowly turns on and off at 4 second intervals. This all indicates that the WLD is powered up, connected to the Particle cloud via the Internet, connected to the Blynk cloud via the Internet, reading temperature and humidity from the DHT11 sensor, and that the water leak detection is armed.

If either of the water level sensors detects a leak - or is disconnected from the WLD - the LED in the backlit pushbutton begins to blink and the piezo buzzer makes an annoying loud sound. This provides a local user with both an audible and visual alert to the leak condition. When the local user responds to the alarm, s/he can mute the buzzer sound by pressing the pushbutton. The backlight of the pushbutton will continue to blink until the alarm condition is cleared. The alarm condition is cleared whenever both water level sensors are dry. Clearing the alarm also automatically re-arms the system for subsequent leak detection.

The servo meter on the front of the WLD enclosure continuously displays either the ambient temperature or the ambient humidity, depending upon the position of the toggle switch. When the toggle switch is in the Temperature position, the servo meter indicates the temperature which can be read off of either the Fahrenheit or Centigrade scales on the meter face; whichever scale is desired. When the toggle switch is in the Humidity position, the %RH can be read off of the humidity scale. Flipping the toggle switch position instantly changes the servo meter from temperature to humidity or visa-versa.

If the light on the backlit pushbutton is off (neither flashing nor lit constantly), then the WLD is not up and running properly. This may be due to one of the following conditions:

- Power is off.
- Photon is not connected to the Internet through WiFi.
- Photon is connected to the Internet but not able to connect to the Particle cloud or the Blynk cloud.
- Photon is cloud connected to Particle and Blynk but the DHT11 temperature and humidity sensor is not responding.

If the light on the backlit pushbutton is off, check that the power supply is plugged into a working AC outlet and that the USB cable is connected to the power supply and to the WLD electronics.

If power is connected, unplug the power supply or the power cable for 5 seconds and then plug it back in. The Photon should reset and reestablish all needed connections, if possible. This may take 30 seconds or more. If everything is working, the backlit pushbutton should light continuously. Otherwise, something did not connect properly.

In order to further diagnose a problem, it is necessary to observe the multicolor LED on the Photon module and also the blue "D7" LED on the Photon. These can be seen without removing the faceplate by looking in through the transparent right side of the WLD electronics enclosure. After unplugging and re-plugging the power supply, the following observations can be made:

- Power is on in the electronics. It may take a few seconds, but the Photon's multicolor LED should start flashing different colors after power is applied. If not, there is a power problem.
- Photon acquisition. The Photon should blink green for a while, perhaps blink some other colors (but not red), and finally "breath cyan". Breathing cyan means that the Photon is connected to the Particle cloud via WiFi to the Internet. If the breathing cyan state is not reached after 30 seconds of power, consult the Particle documentation (https://docs.particle.io/guide/getting-started/modes/photon) for further definition of the problem.
- Setup. After the Photon starts breathing cyan, it enters setup mode. In setup mode, the Photon is connecting to the Blynk cloud server and to the DHT11 sensor. This normally takes no more than 3 seconds. If setup mode completes correctly, the Photon enters normal operation with the backlit pushbutton LED on constantly and the servo meter reading the temperature or humidity, as selected by the toggle switch. When in normal operation, the Photon's D7 LED flashes on and off at 4 second intervals. If the D7 LED is not flashing, then the Photon has not exited setup mode and there was a problem with either the Blynk connection or the DHT11 communication. Make sure that the DHT11 is plugged into its socket correctly and solidly. If the D7 LED is flashing on and off but the backlit pushbutton is not lighting, then there is a problem with the wiring to the pushbutton (perhaps a wire has broken off).

5. Remote Operation (App).

Remote access to the WLD is made possible through the WLD project running on the Blynk app on your smartphone. The Blynk app provides both leak notification and a means to remotely view the temperature, humidity, alarm status and WLD history via your smartphone.

5.1. Smart Phone Notification.

A WLD alarm condition will send a notification to your smartphone. In fact, the WLD sends two notifications for each new alarm event, spaced about 30 seconds apart. This is done to help ensure that you get notified. The mobile phone notification service is inherently unreliable. We have found that alarms usually come through within a few seconds after the WLD sends out an alarm notification. However, we have found instances where alarms may be delayed for minutes, even hours, and sometimes never sent to the phone at all. These issues are not related to the WLD firmware, the Blynk app or the type of smartphone that you use.

Figures 5-1a and 5-1b depict a typical series of notifications as they are received on a smartphone.

Figure 5-1a. Water Leak Alarm Notification on Android Smartphone.

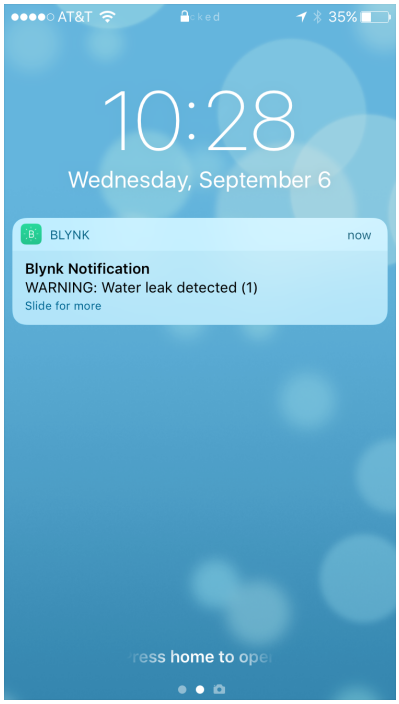

Figure 5-1b. Water Leak Alarm Notification on iPhone Smartphone Lock Screen.

The notifications appear in your phone's notification window even if the Blynk app is closed (running in the background). Each notification message is a simple warning message with the time that it was received (local phone time) and an upcount in parentheses after the warning message. The upcount allows you to see if notifications have been missed (skipped number).

Since the smartphone notification service is not fully reliable, you might want to periodically open the app and view the real-time status there. The app screen is described in the next section.

5.2. Smart Phone App.

The WLD smartphone app is the Blynk app running the WLD project. When you open the Blynk app on your phone (and select the WLD project, if there are more than one Blynk projects in your account), you will see a screen similar to figure 5-2, below.

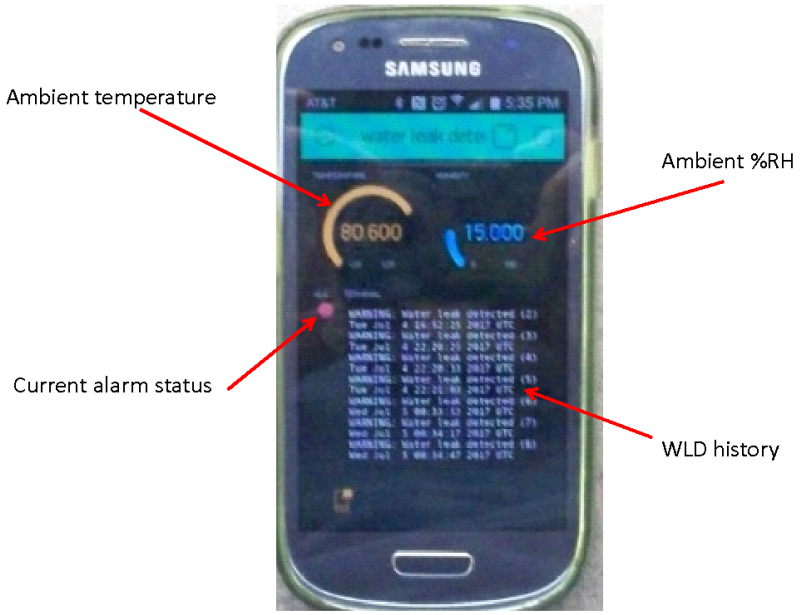

Figure 5-2. Blynk App Screen.

The top row of the screen displays the current temperature and humidity readings in a format that looks like a meter, as well as displaying the numerical values.

A red dot underneath the temperature display shows that an alarm condition currently exists. If there is no red dot in this location, there is no current WLD alarm condition. This alarm condition indicator is independent of the notification system and it is a more reliable way to determine if you have a current water leak alarm condition or not. However, unlike the asynchronous notification system, you must open the app in order to see this status.

The terminal window next to the alarm status indicator provides a scrollable display of the last 25 events that have been received by the WLD app. WLD currently supports two different messages:

- WLD reset message: indicates that the WLD Photon has been reset (restarted).
- WLD water leak alarm message: one message is displayed for each alarm notification that was sent; i.e. two messages are sent (30 seconds apart) for each new water leak alarm condition.

Messages in the terminal window are displayed with the latest message on the bottom. Each message is identified as either “WLD restarted” or “WARNING: water leak detected (x)[1]”. A date/time stamp is appended to each message indicating the date and time when the message

[1] (x) is the same upcount as in the notification.

was sent from the WLD. The date/time is in Universal Coordinated Time (UTC), also known as Greenwich Mean Time (GMT). If you want to know the time that the message was sent in the timezone that the WLD is located in, you will need to apply the timezone correction factor for the location of the WLD installation. You can find many timezone converters on the Internet, e.g. http://www.thetimezoneconverter.com

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