LWET—Leaf Wetness Sensor

monitoring surface moisture in agriculture and industry

In agriculture, warm, wet weather promotes fungus and moisture-loving insects.   For example, the Mills Tables developed at Cornell University are based on the hours that foliage remain wet while the temperatures are warm. Danger arises as periods of warm wet weather are prolonged, and the danger passes only after a substantial dry period.

Direct measurements of surface wetness are also useful when the exact time of the onset of rainfall is of interest, for example, as part of a control system that automatically opens and closes windows or schedules irrigation. A rain gage is not so useful for this purpose, because there is a delay before the it accumulates enough water to signal its first count. Direct surface wetness measurements also find application in science and industry, for example in studies of respiration or corrosion.

The LWET from EME Systems is an artificial leaf surface constructed on a thin fiberglass circuit board. Moisture present on the surface increases the signal output from an integrated oscillator circuit. The LWET provides both voltage and frequency output modes, which accommodate different types of data processing   It has its AC excitation built in, so that it is not necessary to provide special excitation from the data logger. AC excitation is necessary in order to prevent corrosion of the grid. It is available with the grid painted with a formulation of exterior latex to make the response more akin to a natural leaf.

Specifications:

- Size:
  4" x 0.875" x 0.031" thick
  top sensor grid is 3" x 0.75".
- Supply Voltage: 5–15 VDC
- Frequency output
  50 Hz dry @ ∞ ohms
  10 khz wet @ 0 ohms
  open drain square wave.
- Voltage output
  0.2 volt dry to 1+ volt wet
  less than 0.01% per Volt supply variation.
- Supply Current:
  0.2 mA dry to 1+ mA wet
  dry current tolerance 0.19 to 0.21 mA
- Operating Temperature: 0°C to +70°C
  no meaningful signal below 0°C
- connection to data logger, 5 foot cable
  4 wire flat telephone cable
  red: + 5 to 15 volts DC
  black: common
  green: frequency output signal
  yellow or white: voltage output signal
  Please refer to wiring diagram.
- lifetime depends on deployment conditions

How to order:

Order item/option   description/options
LWET............. standard   with 3' cable, unpainted by default
/P .... painted detection surface

Wiring the LWET/F to your data logger

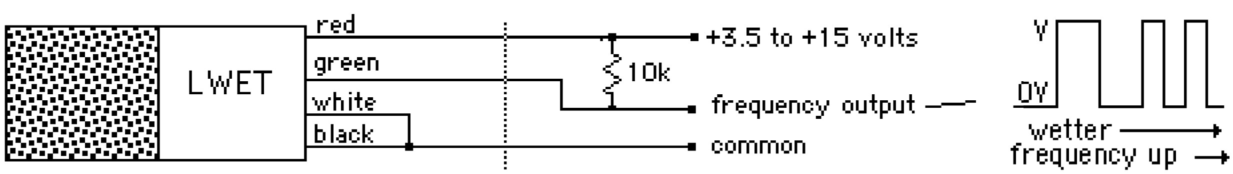
Figure 2 shows how to connect the LWET to data processing equipment.

Frequency output requires a pullup resistor (10kohms, value not critical) which can pull up to any voltage from 2.5 to 15 volts dc. The output signal then is a square wave, and its frequency varies from 50 Hz when the sensor is bone dry, up to 10000 hertz when the sensor is soaking wet. This output can be measured using a COUNT function on the data logger.

The supply current into the LWET is approximately 0.2 milliamp when the sensor is bone dry and 1.6 milliamps when it is soaking wet. This current can be used as a signal if desired, as shown in the second diagram. The current can be converted to a voltage by putting a resistor in series with the LWET power on the common side. Note that only two wires are necessary for this mode. The voltage across the sensor module needs to be >3.3 volts at all times.

For voltage signal output, connect the wires as shown in the third figure. This voltage signal of approximately 0.2 to 1 volt can be read using an analog to digital converter, or a simple voltmeter.

The 100µF capacitor shown in parallel with the LWET output is optional. It reduces fluctuations in the reading.



Frequency output

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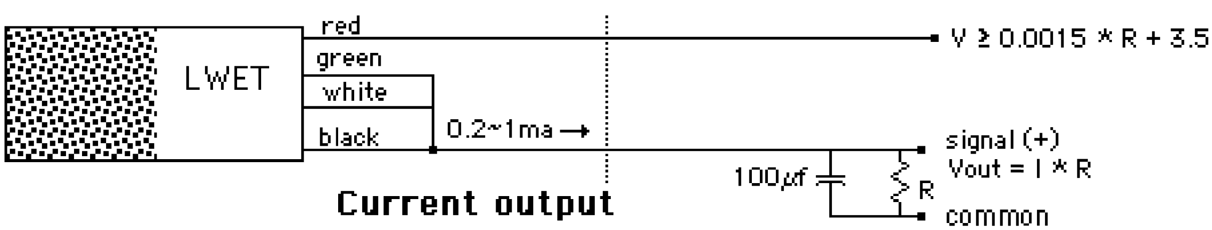
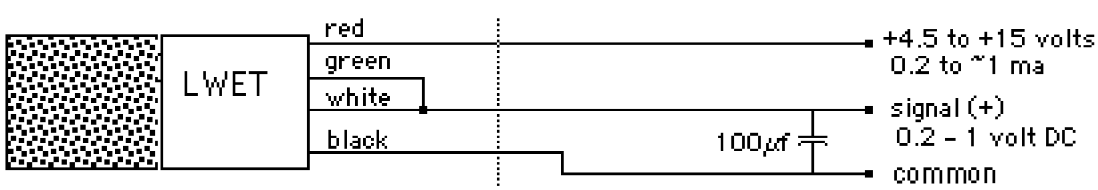


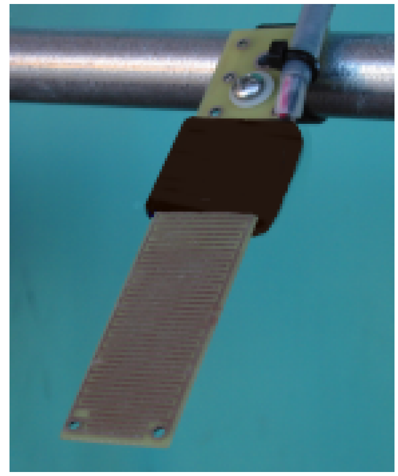
Current output



Voltage output

Installation and Maintenance

•Placement of the sensor: The sensor should be placed in a representative location. Sky and wind exposure are very important in dew deposition and in evaporation. Facing the sensor toward the open northern sky (in the northern hemisphere) will maximize the capture and retention of moisture. Place the sensor at a 45° angle from the horizontal, so that rain will not pool up. The mounting loop facilitates the mounting at the 45° angle.



, Figure 3, 4: mounting options.

The sunlight resistant clamp can be attached to a 3/4" o.d. pipe or tube or dowel, a mounting arm as shown in the photo to the right

For mounting on a vertical round post, thread a stainless steel hose clamp of the proper size through the nylon clamp, as shown in the photograph below.

The clamp can be drilled in order to attach it to a horizontal surface vertical such as the roof of a weather shelter.

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• PAINTING: You can order the LWET painted from EME Systems. Painting minimizes the effect of contaminants. Furthermore, the consensus among agricultural engineers is that painting this type of surface wetness detector makes it a better mimic of the wetting / drying characteristics of a leaf surface. The paint formulation is slightly conductive, so that even low conductivity pure rainwater will consistently result in a good signal, through the early and later phases of a rainfall episode.

You can paint the surface of the sensor yourself. We use Ace 103A100 Premium Exterior White Flat Latex House Paint, with one gram of gypsum (plaster of paris) added per 30cc of paint The gypsum acts as a conductivity buffer. . Use only one thin coat of paint. IMPORTANT: If you paint the sensor yourself, be sure it is clean. Prior to painting, abrade the surface with wet 1500 grit polishing cloth. Wash the sensor with warm water and detergent, and remove all dust. Rinse clean, and wipe with isopropyl alcohol. Dry thoroughly. Use a high quality 3/4“ soft bristle brush to apply a thin coat of paint formulation evenly on both the top and bottom surfaces. Allow to dry thoroughly.

Notes on operation

• Once installed, spray the sensor with water to check its operation. The output when dry should be near 50 hertz, or 200 microamps, or 0.2 volts, depending on the connection mode you have chosen. Water on the surface should increase the signal, and when the sensor is immersed or drenched the output should be near 10000 hertz, 1000 microamps, or 1.0 volts. If the sensor is left immersed, you may see slow drift in the signal. This is especially true if the sensor is painted, as the response is delayed and the drying time is prolonged.

•What is wet? The threshold level of electrical signal that corresponds to "wet" must be determined empirically, by observation. A thin film of condensation on the bare sensor will increase the frequency to 300-1000 hertz, (or 0.2 to 0.3 volts). Rain water is not usually very conductive, and in a storm with rain and wind, the signal on the sensor may hover around 300 hertz. It will increase in a steady quiet rain as more water will accumulate on the sensor. A painted sensor will indicate higher readings, because moisture will be absorbed by the coating and will its conductivity buffer.

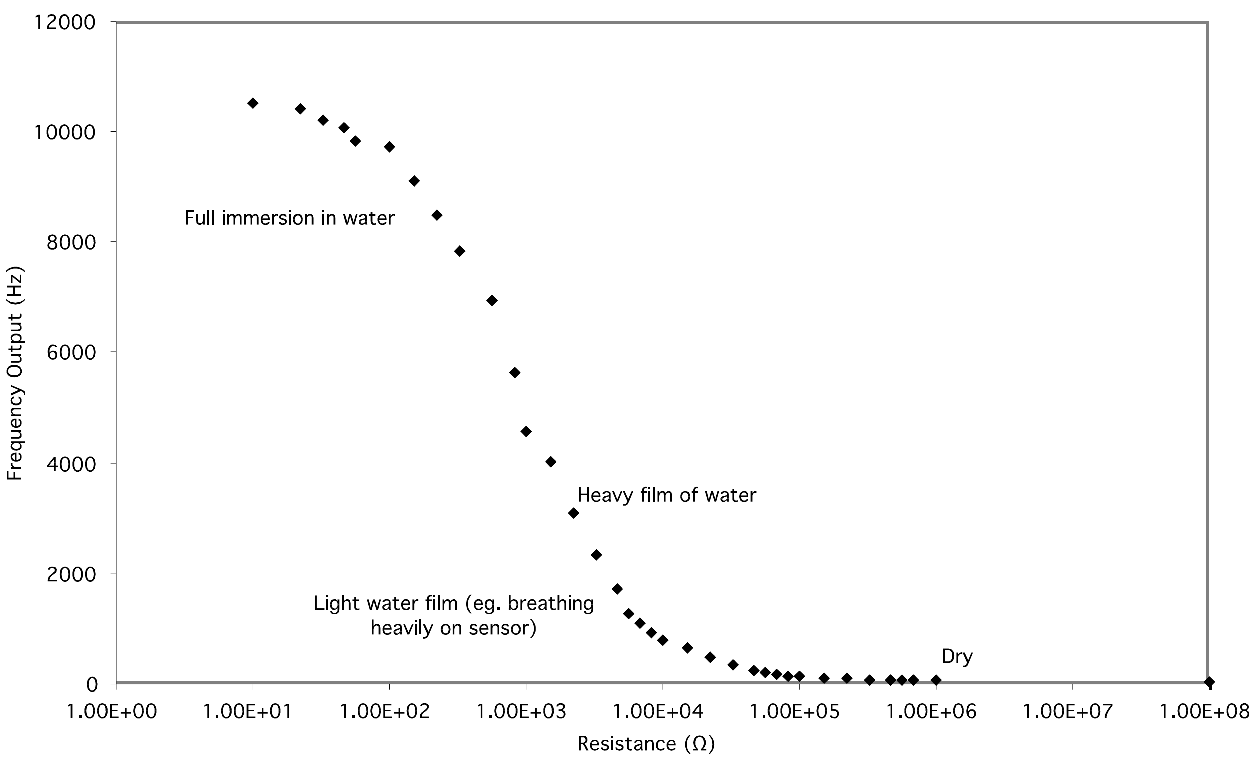
•Avoid exposure to agricultural sprays and exhaust fumes. Contaminants such as copper or sulfur deposited on the sensor surface will shift the response curve up, so that a given electrical response is caused by a smaller amount of moisture. The conductivity buffer in the painted sensor reduces thshifts that are due to contamination.

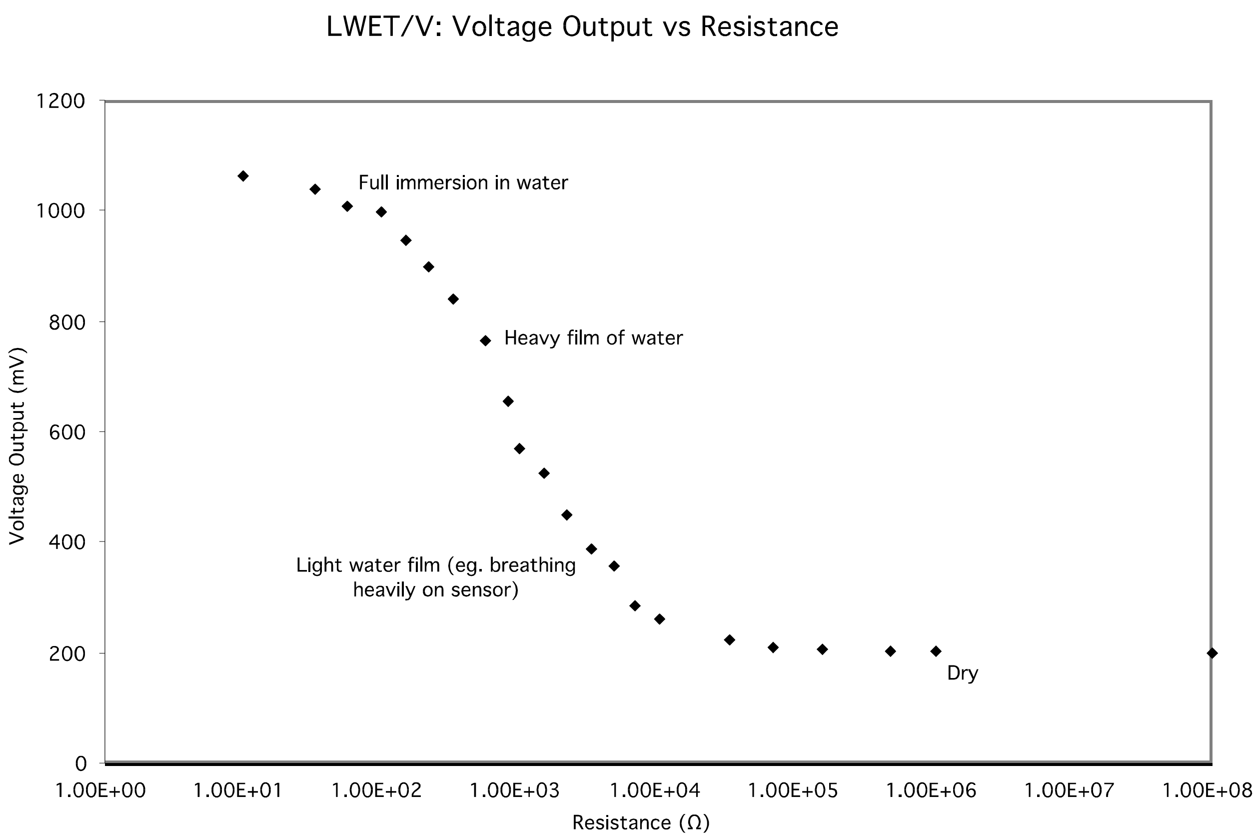
• If possible, turn on the power to the sensor only when required to make a measurement. While the current through the sensing grid is AC in order to minimize corrosion, the less the current is on, the better. If a reading needs to be taken once per minute, then if possible turn on the power, take the reading, and then turn off the power for the interim. Allow 0.1 second for the sensor to warm up.

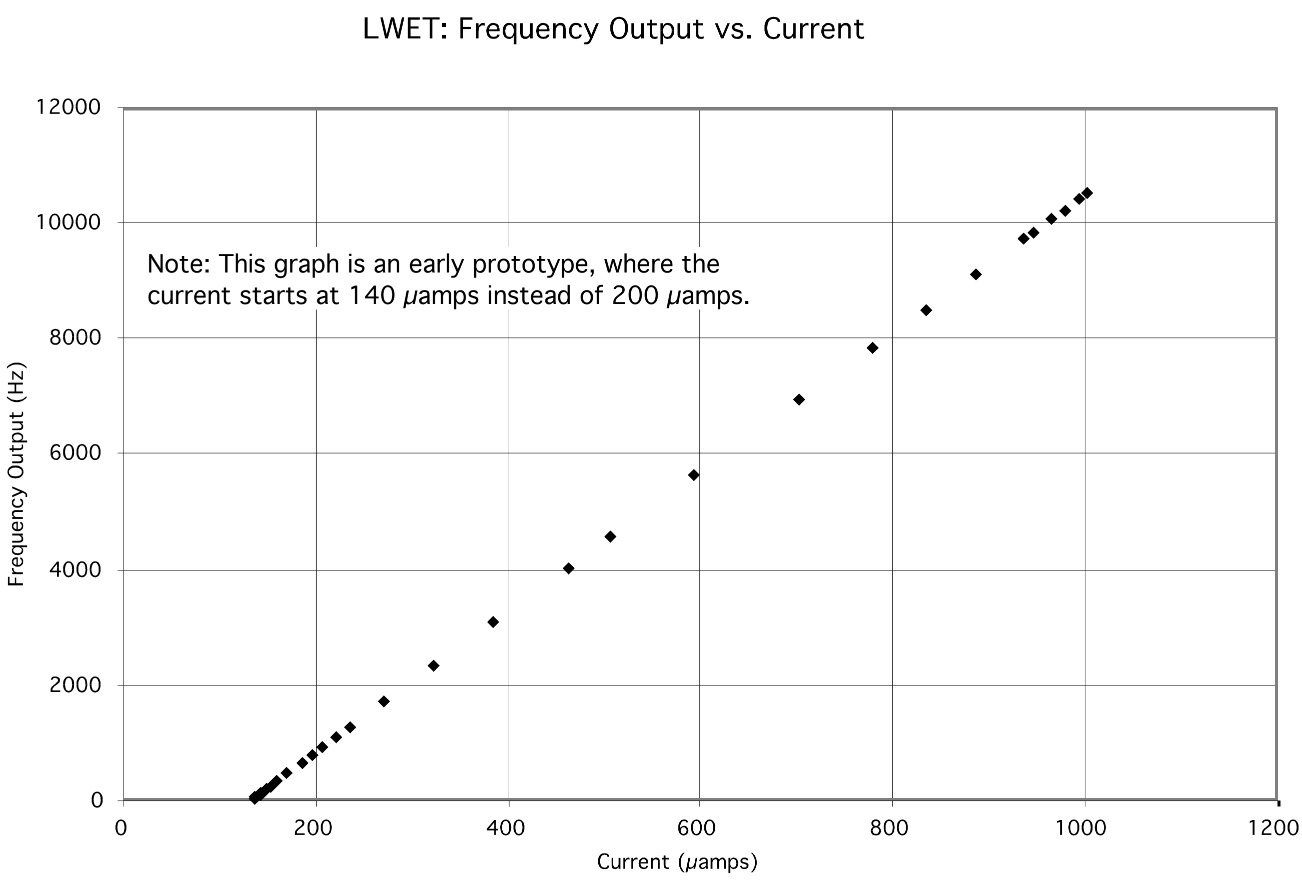
• An excellent source for information about leaf wetness issues in agriculture is to be found at:
http://www.nysaes.cornell.edu/pp/faculty/seem/magarey/leafwet/

•Maintenance: Clean the surface occasionally with a mild detergent solution and rinse with clear water. This is especially important if sulfur or other sprays have been applied.

LWET: Frequency Output vs Resistance




LWET/V: Voltage Output vs Resistance
Full immersion in water
Heavy film of water
Light water film (eg. breathing heavily on sensor)
Dry
Voltage Output (mV)
Resistance (Ω)
1200
1000
800
600
400
200
0
1.00E+00
1.00E+01
1.00E+02
1.00E+03
1.00E+04
1.00E+05
1.00E+06
1.00E+07
1.00E+08


LWET: Frequency Output vs. Current
Note: This graph is an early prototype, where the current starts at 140 μamps instead of 200 μamps.
Frequency Output (Hz)
Current (μamps)
12000
10000
8000
6000
4000
2000
0
0
200
400
600
800
1000
1200

Notes on reading the sensor signal.

Connect the LWET as in figure 2, for digital frequency output. The following programs are in PBASIC for the BASIC Stamp. The programs use the PBASIC command COUNT to determine the oscillation frequency of the LWET.

```
' simple test of the sensor operation.
x         VAR  Word
DO
  COUNT 12,1000,x      ' count lwet 1000 mS on Stamp p12
  DEBUG ? x             ' show the result
LOOP
```

Here is a refinement that counts for 0.1 second, and it clamps the result at the 100% value, set at a count of 1000 per 0.1 second.

```
' refined program, for OWL2e.  Presents result as % LWET
' counts for 0.1 second and clamps result at 100%
result   VAR Word
lwetp_pin  12
lwet:
DO
  COUNT,lwetp,100,result    ' count for 0.1 sec
  result = result MAX 999 / 10   ' for 0 to 99%
  DEBUG dec2 result, "%LWET"
LOOP
```

Circuit description:

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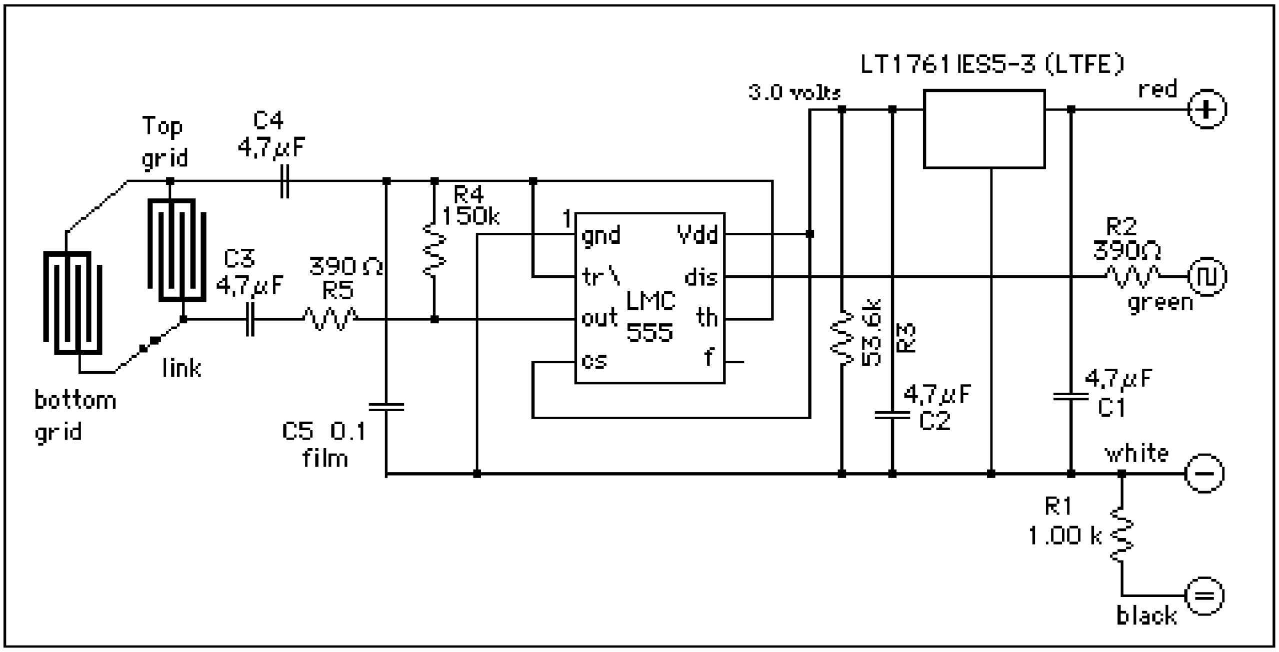

Figure 8: schematic of LWET

The power supply voltage is regulated at 3.3 volts by the LT1761 low dropout regulator. The supply voltage can be as low as 3.4 volts and as high as 15 volts. The LMC555 timer operates with feedback from totem pole output, pin 3, back to the threshold inputs, pins 2 and 6. The 0.1 µf film capacitor charges and discharges through the network of fixed resistors in series/parallel with the conductive sensing grid. When the grid is dry, the 150kΩ resistor sets a minimum oscillator frequency of 50 hertz. When the grid is wet, or short circuited, the 390Ω in series with the grid limits the upper frequency to about 11 khz. The current through the sensing grid is AC. The 4.7µF capacitors in series with the grid enforce the AC balance of current.

The output frequency is transmitted to the logger from the open collector DIS output pin. (green wire) For frequency output signal, an pullup resistor is required, to give voltage transitions at the logger. A 390 Ω resistor is in series inside the LWET in order to protect the pin from fault circuits to a + supply.

The supply current drawn by the LWET varies linearly with the frequency due to the charge and discharge cycles of the 0.1µF capacitor. The supply current is proportional to wetness. The supply current is converted to a voltage by the internal 1 kohm resistor. The cable is connected to provide the voltage output signal on the white (or yellow) wire.

The resistor shown as 53.6kΩ is adjusted on a batch basis in order to calibrate the dry current to 200 +/- 10 microamps.