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Continuous pH Monitoring and Control: Selecting and Interfacing the Electrode, Controller, and Datalogger

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Continuous pH monitoring and control:

Selecting and interfacing the electrode, controller, and datalogger

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Introduction

pH control is essential to well-managed hydroponics. Here, we describe the selection and interfacing of electrodes, controllers, and loggers.

Selection of an appropriate pH electrode

We have found that sealed single-junction gel pH electrodes are adequate for long-term monitoring in recirculating hydroponics. We have used electrodes from Cole-Parmer (about $100 in 2022), which function about 1 to 2 years when properly maintained before replacement is required.

https://www.coleparmer.com/i/oakton-ph-electrode-single-junction-gel-bnc-connector/5900165.

Double-junction electrodes are more expensive and have not had a longer lifetime in our application. We have used industrial electrodes with increased shielding and grounding to get a stable measurement in electrically noisy environments, but these are more expensive (about $300 in 2022).

https://www.hannainst.com/amplified-amphel-industrial-flat-tip-ph-electrode-with-bnc-lead-connector-pt-100-temperature-sensor-and-5m-cable-for-general-purpose-applications.html

Selection of an appropriate pH controller

We have used a pH controller called the Mini pH Controller (model BL931700-0) from Hanna Instruments (Figure 1).

https://www.hannainst.com/bl931700-ph-mini-controller.html.

Each controller measures one pH electrode and costs $225 (2022). We have used the 12V DC version instead of the 115V AC version to minimize electric shock risk.

Industrial grade pH controllers are available, but they cost about $600 (2022). We have not found these units necessary for our hydroponic systems.

Figure 1: The Mini pH controller from Hanna Instruments.

Cleaning and maintenance of pH electrodes is described in our manuscript on closed hydroponic systems (Langenfeld et al., 2022).

Connecting the electrode to the controller and to the datalogger

The pH controller is the intermediate between the pH electrode and the data logger and is used to open a solenoid valve (Figure 2). This valve can release either acid or base into a hydroponic solution to automatically control pH. Thin wires (greater than 20 AWG) are preferred to ensure they fit into the wiring panel on the back. Solid wires are easier to insert into contacts than stranded wires. If stranded wires are used, they should be tinned for easier insertion.

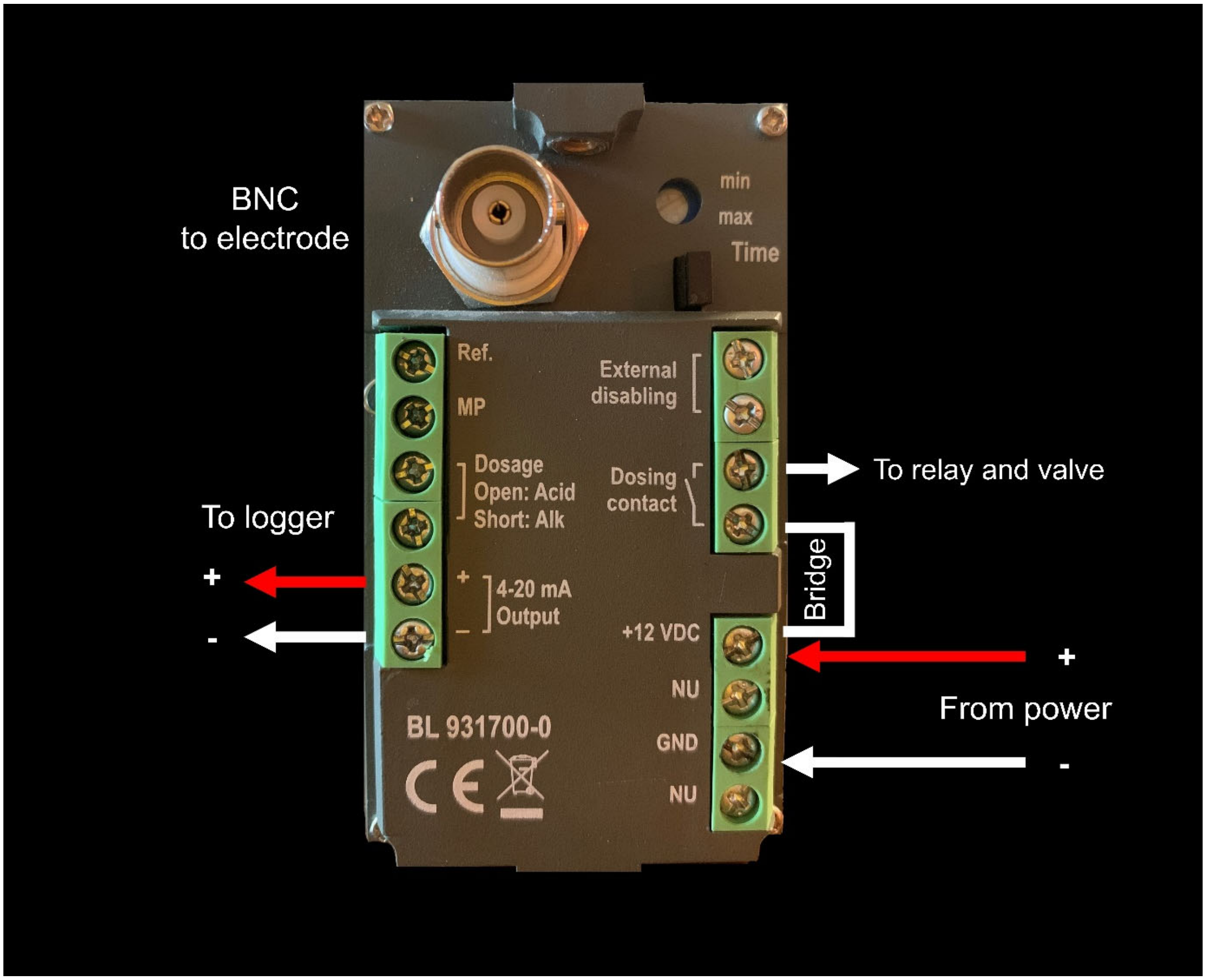

Figure 2: Wiring diagram for the Mini pH controller with an attached solenoid valve.

Time delay relay

The Mini pH controller has an external disabling feature to prevent overdosing, but it is only adjustable from 5 to 30 minutes. This is too long to be useful for tightly controlled systems. We have used a supplemental, standalone time delay relay (Figure 3) adjustable down to 0.01 seconds to prevent overdosing. This is connected inline between the controller and the valve (Figure 4). These relays are available on Amazon.com for $10-$15 (2022):

[https://www.amazon.com/DROK-Controller-Delay-off-0-01s-9999mins-Adjustable/dp/B07RGT5G1X?th=1.](https://www.amazon.com/DROK-Controller-Delay-off-0-01s-9999mins-Adjustable/dp/B07RGT5G1X?th=1)

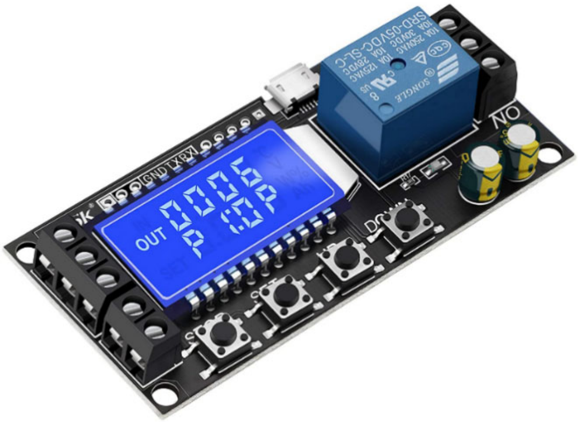

Figure 3: Adjustable time delay relay.

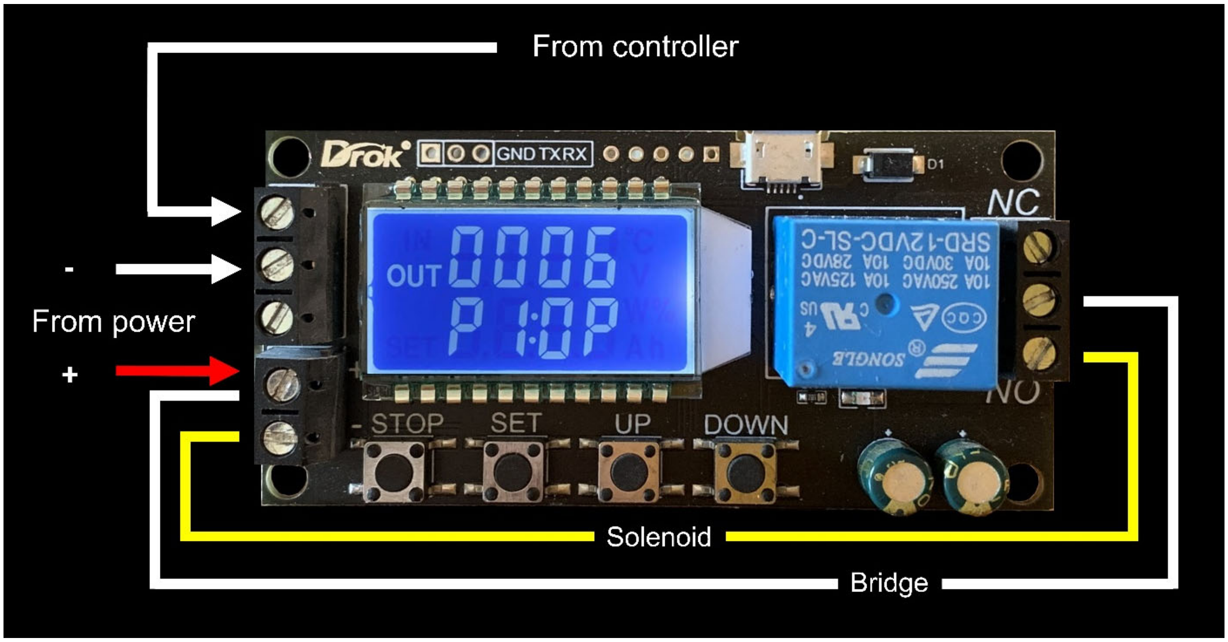

Figure 4: Wiring diagram for time delay relay and solenoid valve.

Interfacing controller to a datalogger

The controller has an output of 4 to 20 mA. A resistor is thus required between the pH controller and the data logger to convert the current output from the controller to a voltage signal measured by the data logger. We have found it easiest to wire the resistor across the contacts on the data logger.

Ohm's law (Equation 1) is used to convert the milliAmp output from the controller into a voltage signal measurable by the data logger.

$$V = I \times R \tag{1}$$

Where: V = voltage in volts, I = current in amps, and R = resistance in ohms (Ω).

The CR1000 and CR1000X data loggers can measure voltages up to +/- 5 VDC. Using Ohm's law, a 250 Ω resistor would convert 20 mA (the maximum output at pH 14) to 5 VDC. Since were have not needed to measure pH values greater than 10, we use a 270 Ω resistor to get a slightly bigger voltage signal.

The maximum input voltage for the CR310 data logger is 2.5 VDC, so a 135 Ω resistor should be used.

Datalogger program

The following code is for programming a pH controller and electrode to be measured and monitored using a Campbell Scientific CR1000 data logger. pH measurements use the VoltDiff command in the CRBasic software. Text following an apostrophe is a descriptive comment and not part of the code.

Example program:

```
Public pH(6) '6 variables in an array to store the pH from 6 tubs
Public multi(6) = {0.0033,0.0033,0.0033,0.0033,0.0033,0.0033}
'multiplier values in array to convert mV signal from controller to pH
Public offset(6) = {-3.60,-3.53,-3.56,-3.57,-3.65,-3.47} 'offset
values in array to convert mV signal to pH

Public apH(6) 'stores the running average of pH for each of 6 tubs

DataTable (TableName,1,-1) 'data table where pH and temperature values
will be stored
  DataInterval (0,5,min,10) 'writes to the data table every 5 minutes
  Sample (6,apH(),FP2) 'samples the running average of pH values for
each tub
EndTable

BeginProg
  Scan (10,Sec,3,0) 'scans for a measurement every 10 seconds
    VoltDiff (pH(),6,AutoRange,1,True,0,_60Hz,multi(),offset())
'determines pH of each tub
    AvgRun (apH(),6,pH(),30) 'average pH over 5 min. of each tub for
graphing
    CallTable TableName
  NextScan
EndProg
```

Calibration

Calibration is usually unique among controllers and electrodes. The multiplier and offset values shown in the above code are determined by calibration. Placing the pH electrode separately in fresh pH 4 and pH 7 buffer and recording the measured voltage generates an x-y plot with two points. Multiplier is analogous to slope and offset is analogous to the y-intercept of the plot.

Running average

The running average smooths pH measurements for monitoring. This does not affect the pH control. We have used a 5-minute running average. Longer intervals cover short term trends; shorter intervals do not sufficiently filter all the noise. An example of a graph created using this monitoring technique is shown in Figure 5.

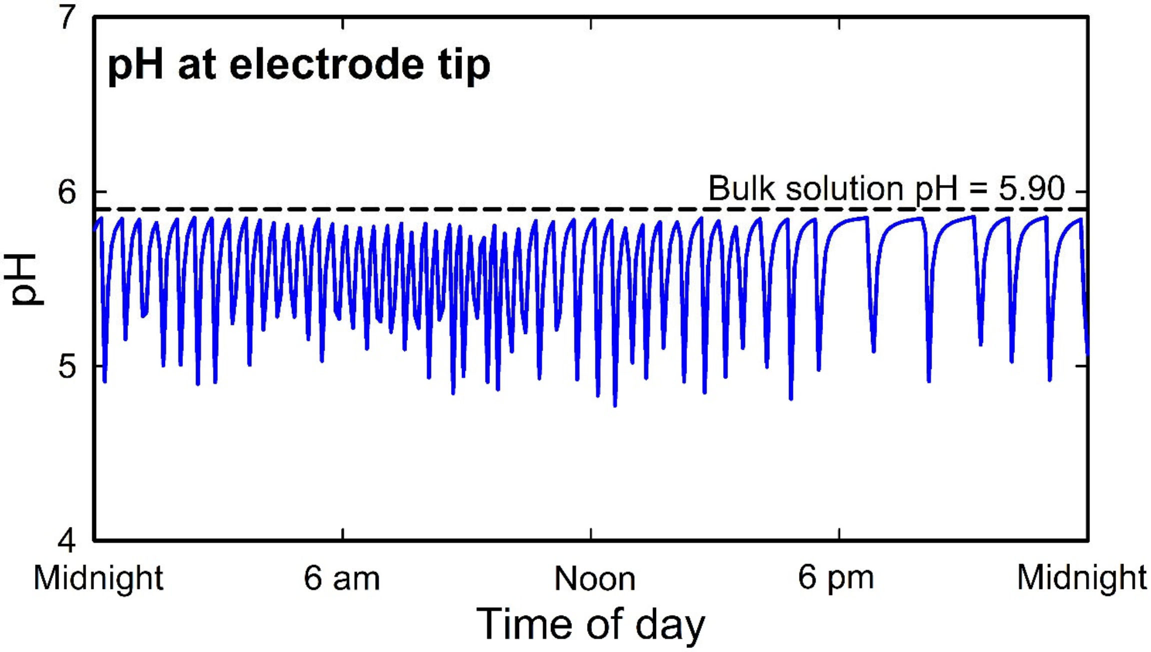

Figure 5: Measurement output from continuous monitoring of pH at the electrode tip collected using a pH control and monitoring system. The downward spikes occur when the solenoid is opened, and acid is added. The inlet should be close to the electrode tip to ensure a rapid response. The goal is to achieve small, frequent doses of acid. The pH of the bulk solution with rapidly growing plants remains near 5.90.

References

Langenfeld, N. J., Pinto, D.F., Faust, J. E., Heins, R., and Bugbee, B. (2022). Principles of nutrient and water management for indoor agriculture. *Sustainability. 14*(16), 10204; https://doi.org/10.3390/su141610204