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An inexpensive chamber apparatus for multiple measurements of dissolved oxygen uptake or release

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Abstract. We describe an inexpensive, multi-channel signal conditioner for the automated measurement of dissolved oxygen concentration in up to six chambers. The apparatus has been used successfully to measure in situ photosynthesis and respiration rates of microbial populations on substrata from streams at Coweeta Hydrologic Laboratory.

Key words: stream metabolism, respiration, photosynthesis, oxygen measurement.

Changes in dissolved oxygen concentration in recirculating chambers equipped with dissolved oxygen probes have been used to measure respiration of the benthos in streams (Bott et al. 1978, Cuffney et al. 1990). To apply this method to a multi-chambered, replicated system, we needed a multi-channel dissolved-oxygen meter. However, inexpensive systems are not commercially available. The signal conditioner described below can be built at relatively low cost and used to compare oxygen changes in each of six chambers incubated at the same temperature regime. We developed an apparatus that included the signal conditioner, six recirculating chambers with YSI Inc. dissolved oxygen probes, and a Campbell 21x micrologger (Fig. 1). The signal conditioner is battery-operated for field use, and data output is measured in mg/L or % saturation.

Materials

The signal conditioner consists of two circuits: a dissolved oxygen circuit (Fig. 2) and a temperature circuit (Fig. 3). The dissolved oxygen circuit is a current-to-voltage converting amplifier which accepts input from a YSI (Model 5739) dissolved oxygen probe and puts out a proportional voltage to a Campbell micrologger (YSI Inc. 1968). The circuit requires two forms of temperature compensation: one to account for the variable flow rate of oxygen across the probe membrane surface and the other to account for the variable solubility of oxygen in water caused by temperature changes. The YSI probe has two onboard thermistors incorporated into the circuit and located in the feedback loop to independently regulate the required temperature compensation. The feedback thermistor is responsible for membrane temperature compensation, and the output voltage divider thermistor adjusts for variability in oxygen solubility as a function of temperature so that % saturation can be determined. Compensation for variations in atmospheric pressure are handled numerically in the datalogger program by multiplying the signal by a factor that corrects for altitude (APHA 1989). The probes require an 800-mv excitation voltage provided by the datalogger. A voltage source must be provided if the datalogger is not used. Because the circuit used is an inverting amplifier, the output voltage is negative. A second inverting amplifier can be incorporated, if needed, to provide a positive output voltage.

Because both probe thermistors are dedicated in the circuit, a separate thermistor is needed for direct measurement of water temperature (Fig. 3). We recommend a Radio Shack thermistor because of its widespread availability, low cost, linearity over the required range, and ease of calibration. The temperature circuit consists of a Wheatstone Bridge probe configuration and a voltage amplifier, which provides gain, offset, and common mode rejection to eliminate interference (Horowitz and Hill 1987). The probe is connected to the amplifier with four-conductor twisted-pair wire (e.g., telephone wire).

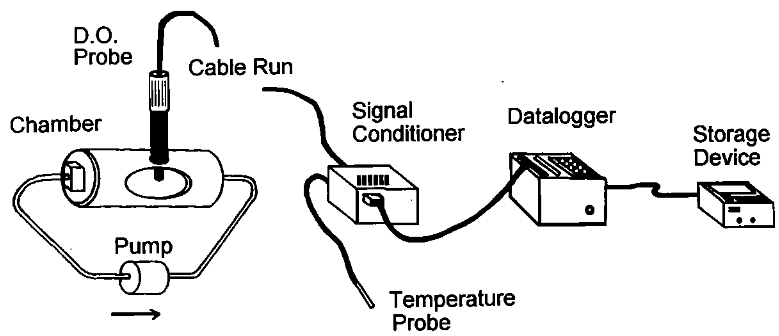

FIG. 1. Field apparatus for measuring dissolved oxygen uptake or release. The chamber, dissolved oxygen probe, and temperature probe are placed in the stream. The signal conditioner, datalogger, and storage device are on the bank.

Operational amplifiers require a split voltage supply, so a battery and charger are incorporated to provide the positive and negative voltages. Their presence means that a complex AC-DC converter is unnecessary, and they also eliminate power supply noise. Nickel-cadmium batteries are well suited for this purpose. A constant current source is used to charge the batteries (Fig. 4).

A probe simulator is used to provide a known signal to test that the apparatus is working properly and is accomplished by selecting a temperature in the operating range and substituting fixed resistors for the two thermistors. A third resistor is substituted for the probe electrodes at the value that provides a current equal to a probe in oxygen-saturated water at the selected temperature. Our simulator was constructed using an Amphenol connector identical to those used with the YSI dissolved oxygen probes (Fig. 5).

Good quality operational amplifiers (e.g., FET input) ensure that reliable results are obtained over a wide temperature range. Signal changes resulting from environmental temperature change over a 12-h period were minimal compared with the dissolved oxygen changes recorded for an incubation.

The dissolved oxygen circuit (Fig. 2) puts out a voltage proportional to % saturation and is optimized for a median temperature of 10°C. A voltage proportional to mg/L dissolved oxygen is achieved by shorting thermistor R4 and substituting R2 with a 900-ohm resistor.

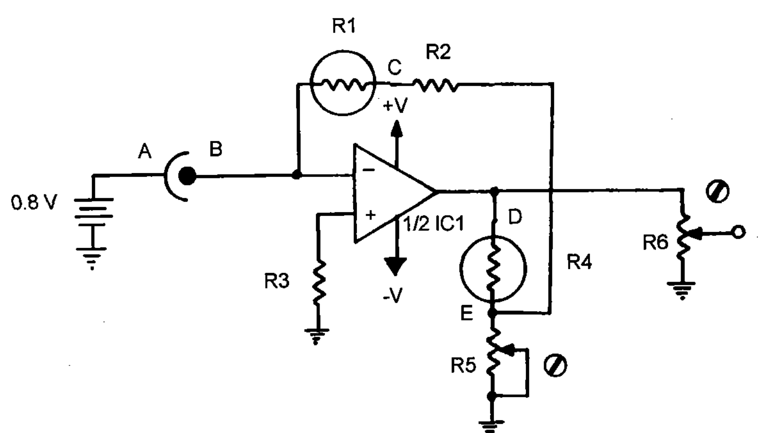

FIG. 2. Schematic diagram for the dissolved oxygen amplifier. **R1**—thermistor onboard YSI probe; **R2**—22 K ¼ w 5% resistor; **R3**—3.3 K ¼ w 5% resistor; **R4**—thermistor onboard YSI probe; **R5**—2 K ¼ w 5% resistor; **R6**—10 K 10-turn precision potentiometer; **IC1**—TL072 dual FET operational amplifier. Letters designate YSI probe pins.

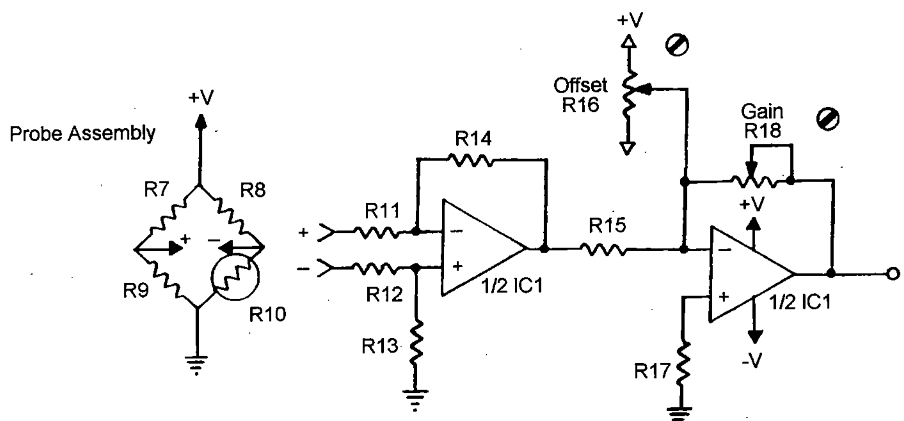

FIG. 3. Schematic diagram for the temperature amplifier. **R7–R9**—18 K ¼ w 5% resistors; **R10**—thermistor 10 K @ 25°C (Radio Shack); **R11–R14**—10 K ¼ w 5% resistors; **R15**—1 K ¼ w 5% resistor; **R16**—5 K 10-turn PC potentiometer; **R17**—900 ohm ¼ w 5% resistor; **R18**—5 K 10-turn PC potentiometer; **IC1**—TL072 dual FET operational amplifier.

Procedure

The datalogger is programmed to convert the six independent signals (in millivolts) from the signal conditioner to corresponding dissolved oxygen concentrations (in mg/L). We designated 15 mg/L as the maximum dissolved oxygen value of the range that would be obtained under our environmental conditions. The datalogger full-scale input voltage used was −50 mv. Therefore, by scaling the voltage from the signal conditioner by −0.02, one gets a reading of % of full-scale mg/L dissolved oxygen. This value can then be multiplied by the designated full-scale value. In addition, the signal for temperature from the signal conditioner (in volts) is converted to °C by dividing by 10.

Calibration of the system can be accomplished in either of two ways. The most precise method is calibration against the dissolved oxygen concentration of a streamwater sample determined by the Winkler method (APHA 1989). The calibration potentiometers for all six probes are set such that the datalogger value for each channel equals the Winkler value. Alternatively, the probes can be calibrated against oxygen-saturated air using the temperature probe to measure ambient air temperature. Dissolved oxygen concentration is calculated as:

$$\text{mg } O_2/L = 468/(31.6 + t)$$

where t = temperature in °C at sea level (Cole 1979). A conversion factor is needed for alti-

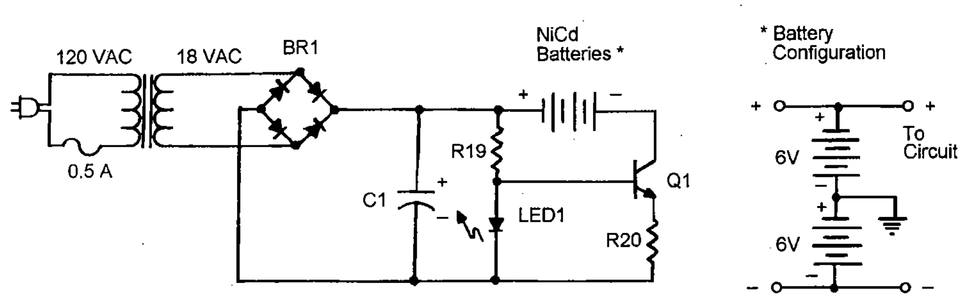

FIG. 4. Schematic diagram for the battery charger. **R19**—2 K ¼ w 5% resistor; **R20**—5 ohm 5 w power resistor; **C1**—220 μF 35 v electrolytic capacitor; **BR1**—5 amp bridge rectifier; **LED1**—light emitting diode; **Q1**—2N3055 NPN power transistor; miscellaneous—120 VAC-18 VAC 3-amp transformer, 1500-mAhr NiCd batteries, associated hardware.

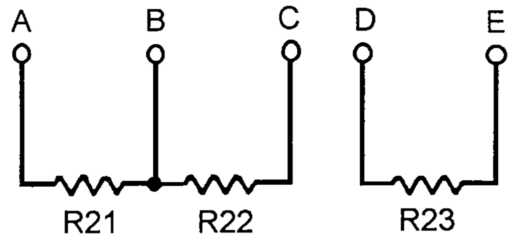

FIG. 5. Schematic diagram for the probe simulator. **R21**—59 K ¼ w 5% resistor; **R22, R23**—2.7 K ¼ w 5% resistor. Letters designate connector pins.

tudes above sea level (APHA 1989). The converted value becomes the new full scale value (instead of 15 mg/L as used above). The probes are left in air, and the potentiometers for each channel are adjusted to obtain the saturated air value.

The multi-channel signal conditioner provides an affordable, automated, multiport method to measure dissolved oxygen change in chambers. The apparatus has been used routinely to measure microbial respiration on sticks and leaves (Tank et al. 1993) and photosynthesis (E. F. Benfield and J. R. Webster, VPI & SU, unpublished data) in streams at Coweeta Hydrologic Laboratory in North Carolina.

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