An Inexpensive Electronic Balance and Data Recording System.—The measurement of body weights can provide useful information on the condition and energetics of birds. Repeated weight measurements of individual birds have been obtained by a number of methods including the recapture of birds (e.g., studies of chick growth rates), the use of modified spring balances (Carpenter et al., Proc. Natl. Acad. Sci. U.S.A. 80:7259–7263, 1983), the use of analytic balances (Carpenter et al. 1983; Westerterp et al., Ardea 70:153–162, 1982), and the use of electronic balances constructed for specific applications (ground nesting birds: Sibley and McCleery, J. Appl. Ecol. 17:323–327, 1980; perching birds: Poole and Shoukimas, J. Field Ornithol. 33:409–414, 1982). To obtain repeated weights of Glaucous-winged Gulls (*Larus glaucescens*) throughout the breeding season I designed and built balances using a plan similar to that of Poole and Shoukimas (1982) but modified to allow the use of a platform as a perch.

The use of a platform as a perching site presents a problem in the construction of a balance because the weight to be measured may not be centered on the balance platform. If the balance design is based on a plunger that exerts force on a fixed spot on a strain gauge transducer (cf. Poole and Shoukimas 1982) then the result of an off-center force will be a decrease in accuracy because of an increase in the friction of the plunger. This problem can be avoided by placing the platform directly on the transducer beam and wiring the strain gauge circuit so that the difference in the moment of bending is measured rather than simply the flexing of the beam.

Electronic field data have traditionally been recorded on strip chart recorders or on relatively expensive data-loggers. Inexpensive portable computers are now available for use as data recorders. I describe the assembly of such a system below.

The plan of the balance and the circuit diagram of the amplifiers are shown in Figures 1 and 2. Four strain gauges are glued to the aluminum beam, wired as shown in Figure 2, and covered first with polyurethane and then with silicon sealant. The strain gauges must be placed symmetrically to minimize the balance error. Although the gauges are temperature compensated both internally and in the circuit itself, the balances proved to be temperature sensitive (5% drift over 15°C). In many applications it is possible to correct

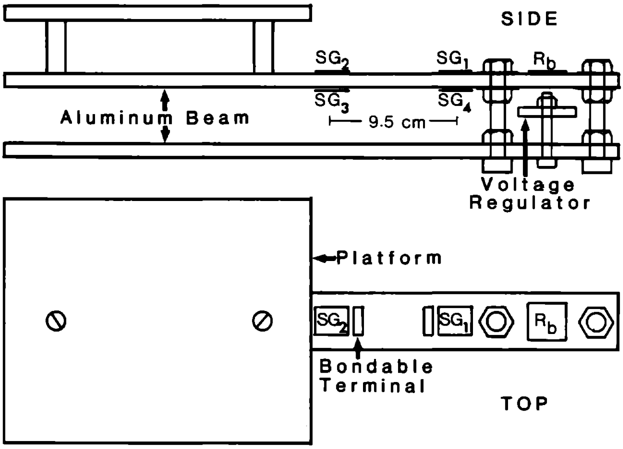

FIGURE 1. Balance design. The transducer beam (35 × 3.8 cm) is constructed from 4-mm aluminum; the platform (17.5 × 15.0 cm) is constructed from 3-mm plywood. Stainless steel bolts (5 mm) hold the two beams apart and a smaller bolt holds the voltage regulator card between the beams. The balance can be mounted on existing perches with clamps or screwed directly to permanent sites. The dimensions shown give an adequate voltage output for a weight range of 0–1500 g (SG_1–SG_4 are strain gauges; R_b is a bondable resistor).

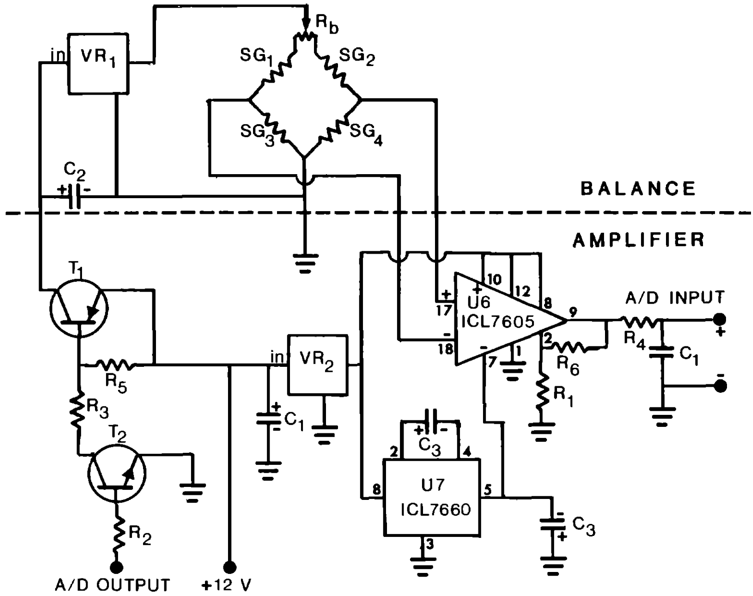

FIGURE 2. Circuit diagram for the strain gauges and voltage regulator (located at the balance), and the amplifier and control switch (located with the data recorder). Electrical components used are: strain gauges SG_1, SG_2, SG_3, SG_4: Micro-measurements CEA-13-125UW-350; bondable resistor R_b (required for zero adjustment of the strain gauge bridge): Micro-measurements EA-13-E01-00180 (Measurements Group Inc. Raleigh, NC); transistors: T_1: MPS U95; T_2: 2N2222; voltage regulators: VR_1: LM7805; VR_2: 78L05; resistor values: R_1: 1K; R_2: 10K; R_3: 47K; R_4: 100K; R_5: 240K; R_6: 1M; capacitor values: C_1: $1\mu F$; C_2: $1.5\mu F$; C_3: $10\mu F$. The remainder of the components (Intersil part numbers shown in figure) are available from Intersil Inc., Cupertino, CA. Four capacitors ($1\mu F$, 50 V; Sprague 923CZU105M050F, not shown) must be placed between pins 3 and 4, 5 and 6, 13 and 14, and 15 and 16 of the amplifier (U6). Note that placement of the strain gauges in the proper locations (see Fig. 1) is critical for proper operation.

for this drift by repeated tare calibrations. It is also possible to remove the temperature sensitivity by placing a short length of copper magnet wire in the strain gauge bridge circuit. The entire transducer portion of the balance is covered with a thin aluminum box. Small clamps can be attached to the lower beam to allow the balances to be readily moved between perch sites. The weighing platform is raised 3.5 cm above the transducer beam to prevent the birds from standing on the beam.

The strain gauge circuit (Fig. 2) generates a voltage output, for a given weight, that is insensitive to the location of the weight on the beam. However, the full range output of the balance is extremely small (<40 micro-volts). Because of the low output, an amplifier (Fig. 2) is necessary for each balance. Any relay that could switch the output from several balances into a single amplifier would introduce too much noise into the circuit. Amplifiers for the 8 balances that I used were housed in a 10 × 5 × 15-cm plastic box located with the data recorder. I used the balances at distances of up to 35 m with 22-gauge 4-strand telephone cable connecting the balances to the amplifiers. It may be necessary to reduce this distance in areas with excessive electrical noise, again because of the low output signal. Materials for each balance cost approximately $40; parts for each amplifier cost $30.

The output from the balance amplifier was sent to an ADC-1 16-channel Analog to

Digital (A/D) Converter (Remote Measurements Inc. Seattle, WA; $400) and then to a NEC PC-8201 computer (NEC Inc., IL; $700). The computer, A/D converter and balance amplifier were housed in an ammunition box that was shaded on sunny days to minimize temperature extremes. The computer has a relatively small operating temperature range (5–37°C) and would require insulation in some field situations.

The computer was programmed to turn on all 8 balances (through the digital output of the A/D converter) once every 2 min and sample each balance momentarily to determine the presence or absence of a bird. If the presence of a bird that had not been previously weighed was noted, then the power remained on and the balances were sampled until a constant weight was obtained (typically within 5 s). The weight from any balance with a "new" bird and the time of day were then stored in memory. Regression equations for the balance calibrations were also stored in memory so that all readings could be directly converted to grams. Tare weights were verified every 15 min, permitting adjustments of the equations for each balance. The computer memory could store several hundred weight records in addition to the operation program; on reaching capacity the system would automatically transfer the weight records to cassette tape. The computer program used with this system is available on request and a copy has been deposited in the Van Tyne Library.

The entire system (balances and recorder) was powered by a 12-V, 6.5-amp sealed lead-acid battery. The strain gauges were the main source of power consumption. Because the balances were not running continuously, each battery lasted for approximately 40 h of use.

This balance design results in a somewhat lower accuracy than designs where it is possible to have the weight centered on a single point (greatest accuracy is obtained from suspended perches since the weight in such a situation is self-centering). Under field conditions these balances ranged in accuracy from ±1% to ±2%. Under extreme weather conditions it is expected that temperature sensitivity will add to this error. Accuracy is directly related to the size of the platform used. The accuracy of the balance along the axis parallel to the beam can be improved through accurate placement of the strain gauges but the transverse error of the transducer is unavoidable. I have used this design to record weights of entire nests with the incubating bird, however, because of the large size of the nest platform it was necessary to use 2 transducers under each nest.

There is a great deal of variation among birds with respect to their tendency to use the balances as perches. The balances were most effective at nest sites where visibility was impaired due to grass or brush.

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Permanent Nest Marker for Long Term Field Studies of Birds.—Long term avian studies of pair bonds and breeding biology require permanent markers at individual nests. After several prototype markers were either eaten by birds, blown away, moved by growing vegetation, or corroded by salt spray, we devised a nest marker that is easy to find and lasts for several years at least: livestock identification flex nylon tags, about 5 cm × 7.6 cm with a 1.3 cm (½ in) hole fitted over the end of 1.3 cm (½ in) PVC pipe about 7 cm from the top, and sealed with outdoor caulking compound. We use 50 cm long pipe in tall grass and 30 cm pipe around bushes. The ear tags come in several colors and are consecutively numbered on both sides. The numbers are deeply etched into the plastic and are white. We found red tags to be the most visible, although in bright sun they fade faster than other colors.

The tags cost $0.55 each and are available from NASCO, 901 Janesville Ave., Ft. Atkinson, WI 53538, Model C1447N; telephone 414/563-2446. The pipe and caulking compound are available in most hardware stores. The PVC is easily cut with a saw or hand cutter. So far these nest markers have lasted for 3 yrs with no deterioration other