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Reconstructing Thermochron iButtons to Reduce Size and Weight as a New Technique in the Study of Small Animal Thermal Biology

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Recent developments in small electronic temperature recorders designed for use in the food industry have the potential to revolutionize the collection of thermal data in small animals. Collecting temperature data in small reptiles is most often restricted to laboratory studies in thermal gradients (Greenberg 1976; Licht et al. 1966; Sievert and Hutchison 1991), by the use of physical models placed in the field (Hertz 1992; Porter et al. 1973), or by inserting a cloacal thermocouple/thermometer soon after capture in field studies (Avery 1982; Schwarzkopf and Shine 1991). Thermal gradients measure selected thermal preferences in an artificial environment, models estimate operative temperatures in the field, and cloacal thermocouple/thermometer measurements in field studies can only measure active individuals or those that take refuge in accessible areas. Each of the above techniques alone does not provide a true representation of the animal's "natural" or "field" thermal biology, particularly in periods of inactivity, hibernation or within inaccessible refugia.

With modification, the DS1921 Thermochron iButtons manufactured by Dallas Semiconductor (Texas, USA) (www.ibutton.com/ibuttons/thermochron.html), a small lightweight real time and temperature recording device, can be attached externally or implanted internally into small animals. The unmodified DS1921 Thermochron iButton weighs approximately 3.0 g, is 17 mm in diameter and 6 mm in thickness. By disassembling units and then reconstructing without the external stainless steel housing, the weight can be halved to approximately 1.5 g or less and the dimensions reduce to the size of the circuit board which is 14 mm in diameter and the thickness depends upon the new battery size.

The DS1921 Thermochron iButton integrates a thermometer, real time clock and memory for storing temperature readings. It accurately measures temperatures ± 1°C from as low as –20°C to +85°C in 0.5°C increments. Temperature readings are available in two formats which run concurrently 1) time vs. temperature mode that records temperature and date-stamps when it occurred, 2) histogram mode that measures the frequency of temperature in 2°C increments rather than specific times of occurrence. The DS1921 Thermochron iButton can log up to 2048 consecutive temperature readings in read-only memory, after which readings can be either stopped or enabled to roll over. The histogram mode has 63 bins of memory set at 2°C intervals, and each bin can store 65,000 readings (Greaves 1999). The DS1921 Thermocron iButton's can be launched and downloaded with the use of a reader (Blue Dot Receptor™) connected to an existing PC computer with free software downloaded from Dallas Semiconductor (available at www.iButton.com). Recordings are made at user defined time and rates, with a maximum start delay of 45 days and recording rate ranging from 1 every minute to one every 255 minutes. The life expectancy of the DS1921 Thermochron iButton is more than 10 years or greater than 1 million samples, whichever occurs first (Greaves 1999). To date, our reconstruction of the DS1921

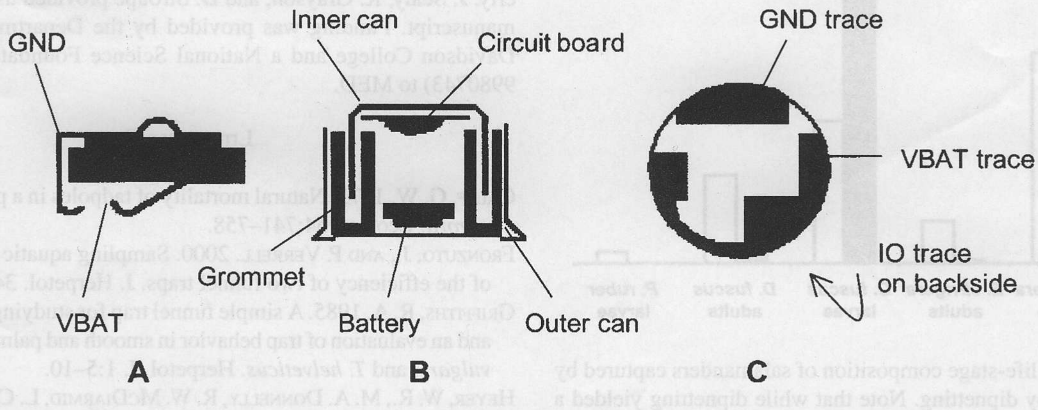

FIG. 1. Construction of the DS1921 Thermochron iButton, (A) Battery (B) Complete unit (C) Circuit board. See text for explanation of components.

Thermochron iButton has not altered the performance or the life expectancy and not a single unit has failed.

Construction of the DS1921 Thermochron iButton.—The DS1921 Thermochron iButton is constructed (Fig. 1) of two stainless steel cups that make up the housing separated by a plastic grommet. The plastic grommet isolates the IO (data) and GND (ground) sections of the circuit board externally and the VBAT (power) and GND connections internally. Springs are welded to the positive and negative terminals of the battery. It is important that the positive and negative terminals do not touch or the battery will short out causing rapid battery drain. The battery "snaps" into the plastic grommet. The circuit board is positioned in the bottom of the inner housing with the crystal facing up. The semicircle trace on the front side of the circuit board is VBAT. The other large trace is GND, corresponding to the springs on the battery. The back of the circuit board is one large IO trace, which makes contact with the bottom of the inner housing. The grommet and battery slides on top of the inner housing with the VBAT and GND terminals aligned. This combination then slides into the outer housing and the GND battery spring makes contact to the outer housing. The outer housing is crimped over the grommet and inner housing, holding the construction together.

De-housing of the DS1921 Thermochron iButton.—To reduce the size and weight of the DS1921 Thermochron iButton for use on small animals the iButton can be opened to remove the internal components and reconstructed without the stainless steel housing that accounts for a large proportion of the weight. A vise should be used to hold the DS1921 Thermochron iButton and a small tooth hacksaw (32 teeth/inch) can be used to make vertical cuts through the outer housing in 3 or 4 evenly spaced cuts around the housing. By using a pair of needle nosed pliers, the outer housing can be pulled away from the inner, not unlike pealing a banana.

Reconstruction of the DS1921 iButton without the housing.—Outside of the housing the circuit board should be soldered to the battery (Fig. 2). To avoid damage to the battery it is best to use new batteries with solder tabs attached which are available upon request from most major battery suppliers. The DS1921 uses a 3 Volt lithium BR1225 battery; a smaller battery such as BR1216 or CR1025, can be substituted, but they have a shorter lifetime. The bottom tab is VBAT and the tab that comes over the top of the battery is GND. If the battery is not insulated, a piece of plastic tape should be used to prevent the GND tab touching the side of the battery which would cause the battery to short. It is important to line the tabs up with the traces on the circuit board and solder them.

To attach the unit to the reader (Blue Dot Receptor®) a rigid wire needs to be soldered to the IO trace and another to the GND trace on the reconstructed unit (Fig. 2). One wire should be thicker in diameter or color coded for easy identification when attaching to the reader. These two wires provide exposed leads for attachment to the reader (Fig. 3). The wire attached to the IO trace connects to the inner contact on the reader and the wire attached to the GND trace connects to the outer contact on the reader. To connect the unit to the reader, one end of a wire needs to be coiled around the inner contact of the reader and the other end with a small alligator

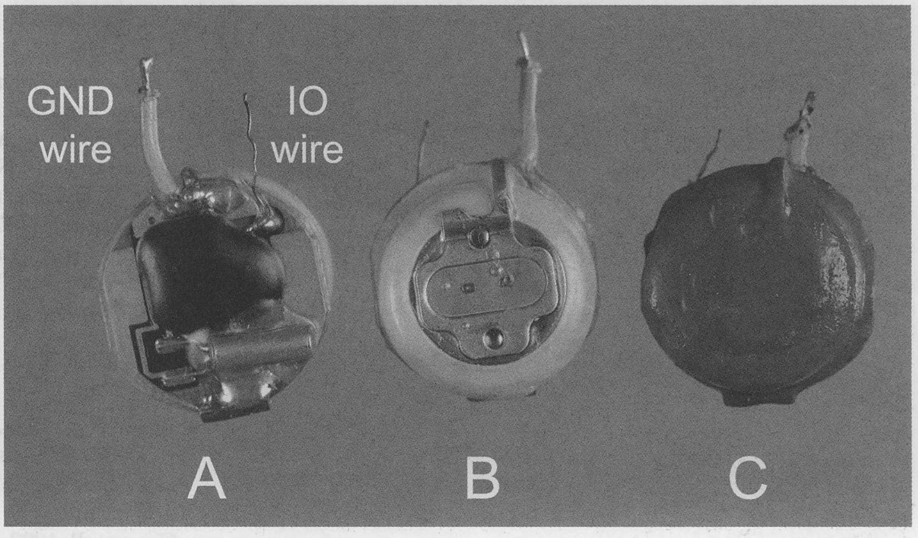

FIG. 2. Reconstructing the DS1921 Thermochron iButton without housing (A) Circuit board soldered to battery with rigid exposed wires attached (B) Insulated battery soldered to circuit board viewed from above (C) Modified unit complete and coated in red Plastidip®.

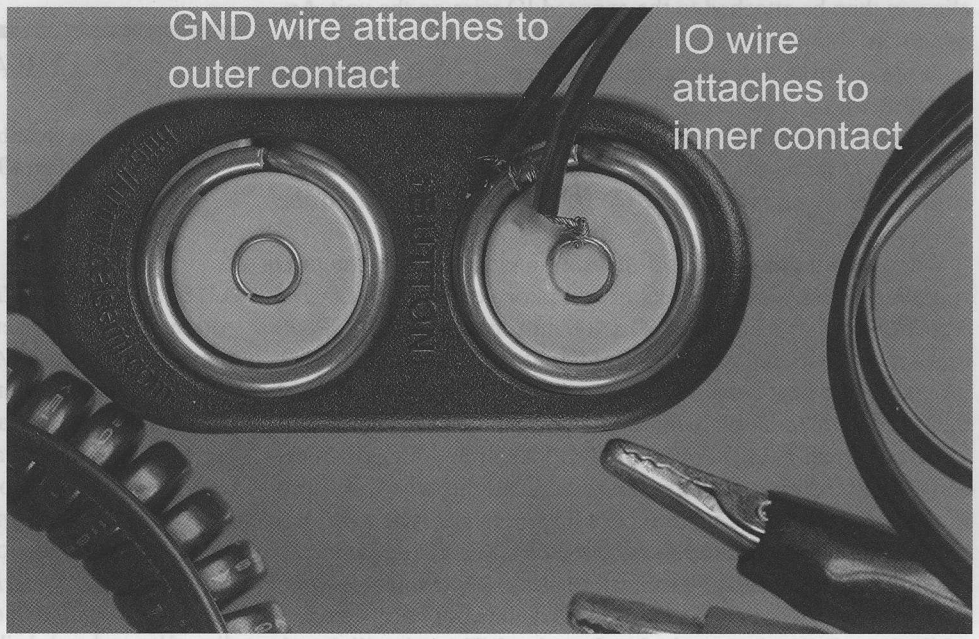

FIG. 3. Reader (Blue Dot Receptor®) showing wires coiled around contact points that then attach to exposed leads on the modified units via alligator clips.

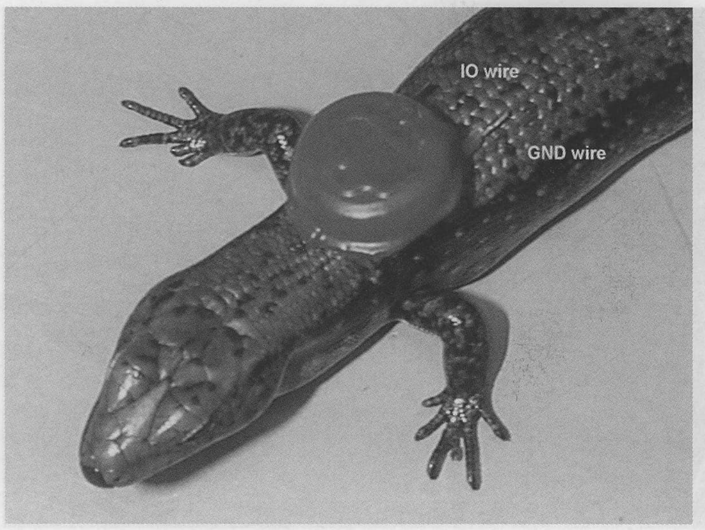

FIG. 4. A female *Eulamprus tympanum* fitted with a modified Thermochron iButton.

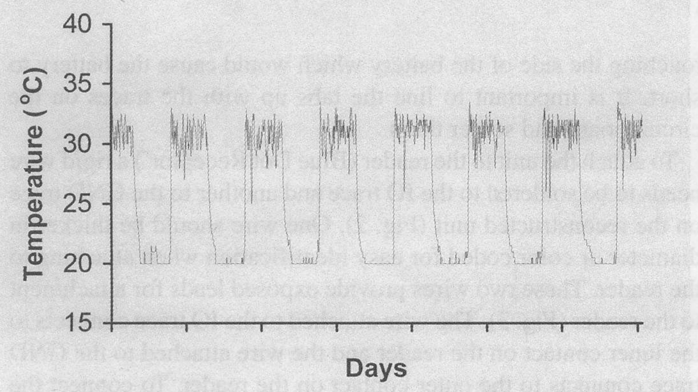

FIG. 5. Thermal profile of a captive female *Eulamprus tympanum* over one-week at a 5-minute sample rate.

clip can then be attached to the exposed IO wire on the unit. Another wire should be coiled around the outer contact of the reader with the opposite end attached to the exposed GND wire on the unit also with a small alligator clip (Fig. 3). After testing the soldered unit, it should be sealed to ensure it is watertight with Plastidip® (Minnesota, USA) (www.PLASTIDIP.com) with the exposed ends of the IO and GND wires emerging from the Plastidip® (Fig. 2).

We tested the modified unit on six gravid female *Eulamprus tympanum* over several weeks in laboratory enclosures. Lizards were housed individually in 620 x 400 mm enclosures with 20–30 mm depth of soil, flat rocks and leaf litter for shelter. Lizards were provided with heat from 100 W incandescent bulbs at one end of their enclosure to allow them to thermoregulate. Enclosures provided a thermal gradient of 20 to 40 ± 1°C during daylight hours and 20 ± 1° C during the night. The modified units where attached to the backs of lizards with Super Glue® (cyanoacrylic glue) behind the head, between the shoulder blades (Fig. 4) and gave continuous measurements of temperature at 5-minute. intervals (Fig. 5). Measurements can be downloaded and units can be re-launched while the unit remains attached to the animal. The unit will detach from reptiles upon shedding or acetone can be applied to the site of attachment to remove the unit prior to shedding.

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NATURAL HISTORY NOTES

Instructions for contributors to Natural History Notes appear in Volume 34, Number 1 (March 2003).

CAUDATA

AMBYSTOMA TIGRINUM (Tiger Salamander). **PREDATION**. Although a wide variety of birds have been documented or implicated as predators of *Ambystoma tigrinum* (Lannoo and Phillips, *in press*. *In* M. J. Lannoo [ed.], Status and Conservation of U.S. Amphibians. Univ. California Press, Berkeley), most of the species target aquatic larval forms. On 19 June 2001 in Taylor County, Georgia, USA, I encountered a cache of numerous animals impaled on a barbed-wire fence by loggerhead shrikes (*Lanius ludovicianus*). Herpetofauna found among the cache included several adult *Hyla squirella* and *H. cinerea*, and one post-metamorphic *A. tigrinum*. Although amphibians have been reported in the diet of loggerhead shrikes (Yosef and Grubb 1993. Condor 95:127–131), I believe this is the first reported observation of loggerhead shrikes predating a salamander.