Thermally Stable Telemeter for Thermoregulation Studies

Abstract. *Of the numerous designs published for temperature biotelemeters, not one is suitable for external mounting on animals which are subject to considerable fluctuations in their environmental temperature. A transmitter has been developed which is simple and insensitive to changes in environmental temperatures between 10° and 50° Celsius; it emits a pulsed, narrow bandwidth signal in the 0.5 to 2 megahertz band.*

Field environment studies of thermoregulation of lizards and hypothermia in echidnas (*Tachyglossus* sp.) have prompted the need for a temperature-measuring technique which imposes little or no constraint upon the animal. Consequently a wide variety of temperature transmitters based on blocking oscillators and multivibrators have been tried (*1*). When externally mounted these showed poor immunity to fluctuations in environmental temperature. Telemeters have also been implanted, but this process involved a surgical operation which was not feasible for small or armored lizards. Thus it became essential to design a telemeter which overcame these disadvantages.

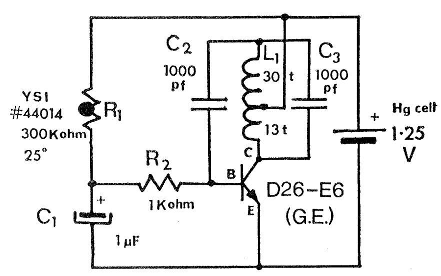

Fig. 1. Circuit diagram of telemeter: $R_{1,2}$, resistors; C_{1-3}, capacitors; *L*, inductance; *B*, base; *C*, collector; *E*, emitter.

The basis of the telemeter is a one-transistor pulsed Hartley oscillator (Fig. 1). Pulse rate, and hence pulse interval, is controlled by the time constant of resistance R_1 times capacitance C_1, and is thus dependent on the temperature being sensed. The pulse interval in milliseconds is roughly given by $0.5R_1C_1$, where R_1 is in kilohms and C_1 is in microfarads.

Pulse width is in the order of 1 msec, and the pulse interval is about 100 msec at a probe temperature of 36°C, giving a duty cycle of 1 percent. Current drain in the oscillating condition is about 10 ma, and 10 μa in the quiescent state, giving an average battery drain of 110 μa. Use of a mercury cell of 350 ma-hr results in a transmitting life of 130 days at this body temperature. On animals with high average body temperatures it may be advantageous to increase the value of C_1, with consequent reduction in duty cycle and increase in transmitter life.

Thermal stability is aided by the use of transistors exhibiting a small shift in turn-on voltage (V_{be}) with temperature. Microtab transistors of the General Electric D26-E6 family have proved most satisfactory in this respect. The effects of the small, but inevitable, spread in V_{be} resulting from manufacturing can be overcome by judicious selection of devices. For operation at animal temperatures below 12°C, care has to be taken to select transistors with a low base leakage current because the circuit will not operate if this current becomes equal to the charging current through R_1.

Thermal stability is also affected by the stability of C_1. Microsolid tantalum capacitors (Nippon Electric Co., Tokyo, Japan; SST series) were the most satisfactory choice for C_1. These capacitors have a small positive temperature coefficient (less than 0.1 percent/°C) which helps offset the effect of the slight lowering in V_{be} of the transistor.

Figure 2 shows a calibration curve for a typical transmitter. The four inset graphs show drift in indicated temperature readings with change in environmental temperature. For environmental temperatures in the range of 10° to 50°C, the body temperature can be read to 0.2°C or better. Over the range from 0° to 10°C the accuracy is 0.5°C or better. If the environmental temperature is known, the readings may be corrected to attain greater accuracy for the deviation is constant for any given transmitter. When the transmitter is used as an endoradiosonde, or deep in the fur of most animals, accuracy will be limited only by the methods used to decode the signal and by the tolerances of the thermistor. Mercury cells of constant voltage (Mallory R series) should be used to reduce calibration drift caused by cell aging (*2*).

Range depends upon coil diameter and orientation, but is in excess of 2 m with an average AM broadcast receiver. The pulse output from the receiver can be decoded by measuring the time occupied by a fixed number of pulses, or by feeding them into a rate meter (*3*).

Another considerable advantage conferred by this design over blocking oscillator telemeters is the narrow bandwidth occupied by the signal. This increases efficiency, and permits a number of suitably tuned telemeters to be used in the one enclosure without mutual interference.

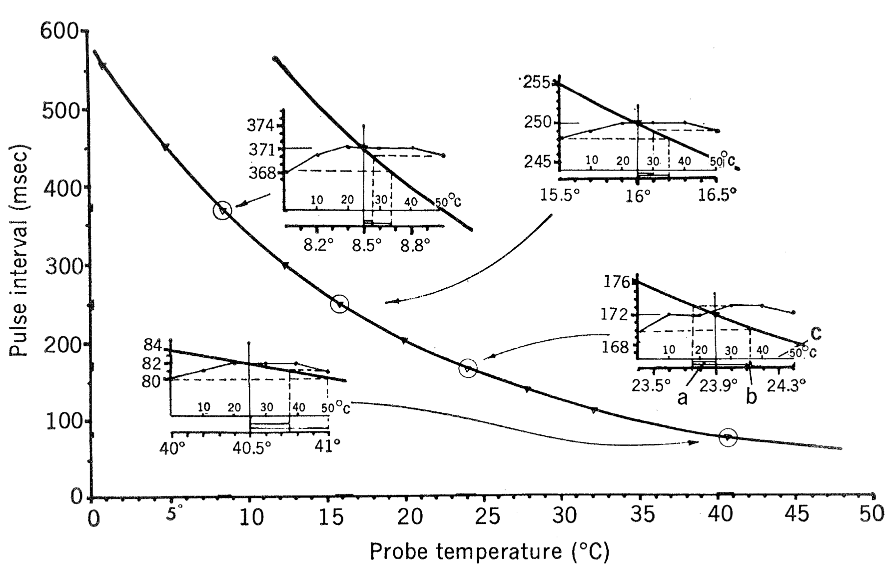

Fig. 2. Graphs of performance of a typical telemeter. The small insert graphs are expanded sections of the calibration curve at the points circled. Superimposed on this is a plot of the deviation in pulse interval against environmental temperature (scale *c*). Line (*a*) indicates the extent of shift in temperature reading when the telemeter is exposed to environmental temperatures from 10° to 50°C; (*b*) 0° to 50°C. The main calibration curve was made with the telemeter at a temperature of 25°C.

This circuit is extremely flexible.

I have employed it as a subminiature endoradiosonde (0.5 cm³), as a variety of surface mounted units, and as a driver for a long-range crystal-controlled transmitter.

Construction is straightforward, subminiature components being used throughout. Tuning can be accomplished by embedding ferrite chips in the potting wax near coil L_1 to lower the frequency slightly, or removing coil turns to raise it.

The thermistor probes used can be of two types. For most work Yellow Springs Instrument Co. precision thermistors are best, and permit the calibration of the telemeter with a decade resistance box. However, they are too large (> 2 mm) for rectal insertion in small animals or for endoradiosondes. Here I used bead thermistors (Philips or Noreleco No. B8 320 02P/470KS). These are less than 1 mm in diameter and are mounted in nylex catheter tubing after leads are attached; the lumen of the tube is filled with silicone rubber (Dow Corning Sylgard 184).

The telemeters are encapsulated in polyester resin applied over a layer of dental impression wax. For externally mounted units a limpet shape is best because it is extremely difficult for the animal to scratch off. Bear contact cement (Norton Assoc.), applied to the cleaned and shaven skin of the animal, and allowed to become almost dry to the touch before joining, is a very satisfactory adhesive for long-term use.

The telemeters described are cheap, simple, and accurate, and all but the subminiature types are easy to construct. They are eminently suited for use in both short- and long-term experiments on a routine basis—in almost any environment encountered in the laboratory or field.

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References and Notes

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Obligatory Sperm Storage in the Skink Hemiergis peronii

Abstract. *Female* Hemiergis peronii *ovulate in the spring; males' testes are small and without sperm in the spring, enlarge to a maximum in late summer, and decrease in the winter. Females' oviducts contain sperm over the winter. It follows that females are inseminated in autumn and store sperm until they ovulate in spring.*

Females of several species of lizards store sperm in small pockets in the walls of their oviducts (*1*). In some chameleons and the iguanid *Uta stansburiana*, stored sperm can fertilize eggs for weeks after insemination (*2*). But in all these lizards the males are in breeding condition when the females ovulate, so sperm storage is not essential to their reproduction.

In the Australian skink *Hemiergis peronii*, by contrast, the males are out of breeding condition when the females ovulate (Fig. 1). Females bear two to four young in late February or early March, at the end of the Australian summer (*3*). At that time the ovarian follicles are small whereas the males' testes are large. Sperm can be found in stained smears of oviducts of some females each month from May to November. Females ovulate in October or November when the testes of the males are smallest. We infer that *H.*

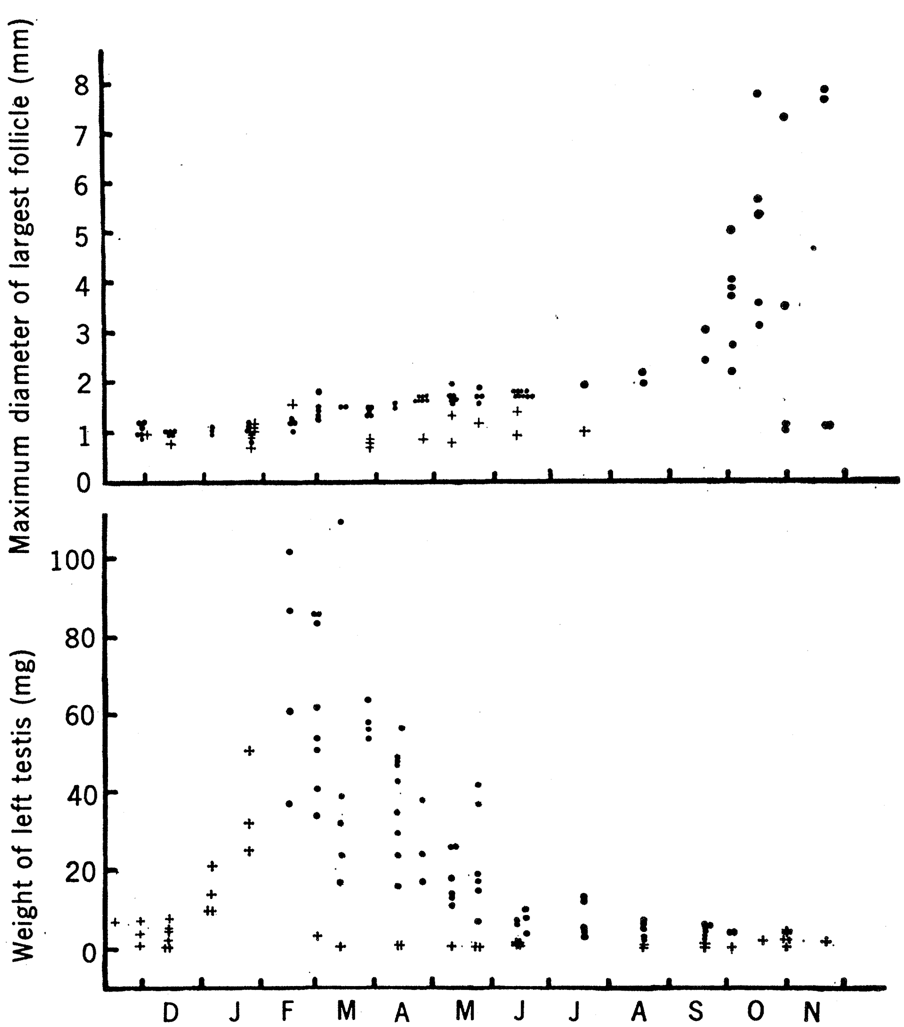

Fig. 1 (Top). The maximum diameters of the largest ovarian follicles of female *H. peronii* from Port Gawler, South Australia. Measurements for immature females are marked by a cross. Females were classed as immature if their follicles were small when those of other females were enlarged, or if they were not pregnant when other females were. They were in all cases smaller animals than those classed as mature. (Bottom) Weights of the left testes of male *H. peronii*. The right testis was smeared onto a microscope slide, stained, and examined for sperm; where no sperm were seen, testis weight is marked with a cross.