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Technical report

A miniature daylight level and activity data recorder for tracking animals over long periods

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Abstract: The device has a sensor that periodically measures and records the ambient light level. Following retrieval of the device, the light level records are converted into latitudes and longitudes, which allows the geographic position of the animal to be estimated twice daily. The instrument is also configured to detect and record the history of time spent in water against time spent flying or on land. For seabirds, this can provide time-budget data related to activity and feeding behaviour. Small size, a low profile and robust packaging are crucial for effective deployments on flying birds and diving animals. Long battery life is often essential (e.g. after fledging, juvenile wandering albatrosses *Diomedea exulans* usually remain at sea for at least five to seven years). Low unit and operation costs are also very desirable, together with simplicity of operation. Dimensions of the instrument are 22×19×12 mm. Weight is 9 g in air and 4 g in water. The device is pressure tested to 800 m depth of water, and can log data for up to eight years. The total cost of components is less than \$70. The principles, design specification and circuit description of the device are presented here, together with a representative migration track, obtained during field tests on grey-headed albatrosses *Thalassarche chrysostoma*, to illustrate performance.

key words: geolocation, activity, micropower, tracking

Introduction

Although satellite telemetry is commonly used to track the movements of seabirds (Jouventin and Weimerskirch, 1990; Prince *et al.*, 1992; Georges *et al.*, 1997), this approach has a number of disadvantages. These include high cost, large instrument size and mass, and the difficulty of finding an effective method for long-term attachment. An alternative to satellite-telemetry for determining habitat use is geolocation (Global Location Sensing or GLS logging), in which locations are estimated from light level records (Hill, 1994). GLS loggers incorporate a photoreceptor that records light levels with reference to an internal clock/calendar, and from these data the GMT (Greenwich Meridian Time or Greenwich Mean Time) of local sunrise and of local sunset are estimated on a daily basis. The GMT midway between the times of sunrise and sunset is local noon GMT and local midnight GMT, from which the longitude can be determined. The day length on a particular date determines the latitude, e.g. in June the further north is the location, the longer is the day length, whereas in December the

situation is the opposite. Unfortunately at equinoxes (March 21 and September 21) the latitude cannot be calculated as the day length is the same for any location, but fortunately it can be estimated on the basis of the length of the twilight. The details of the technique, its limitations (*e.g.* at equinoxes), sources of error, advantages and disadvantages in comparison to other techniques are described elsewhere (Delong *et al.*, 1992; Hill, 1994; Welch and Eveson, 1999).

This paper describes the manufacture of a simple daylight level and activity related data recorder. We have considerable experience in the deployment, recovery and analysis of data from similar devices used on seabirds (Afanasyev and Prince, 1993; Viswanathan *et al.*, 1996; Stanley *et al.*, 1996), and our combined GLS and activity recorder was developed primarily for deployment on albatrosses at Bird Island, South Georgia (54°00' S, 38°06' W). The immediate objective of this paper is to demonstrate the advantages of the selected hardware particularly in terms of size, weight, battery life and low cost, and its suitability for tracking albatrosses or other flying birds for long periods of time.

Device description

Recorder design

The system consists of a number of recorders, a purpose-built computer interface and a general purpose computer (Fig. 1).

The recorder is a battery-powered instrument, with an embedded single-chip micro-

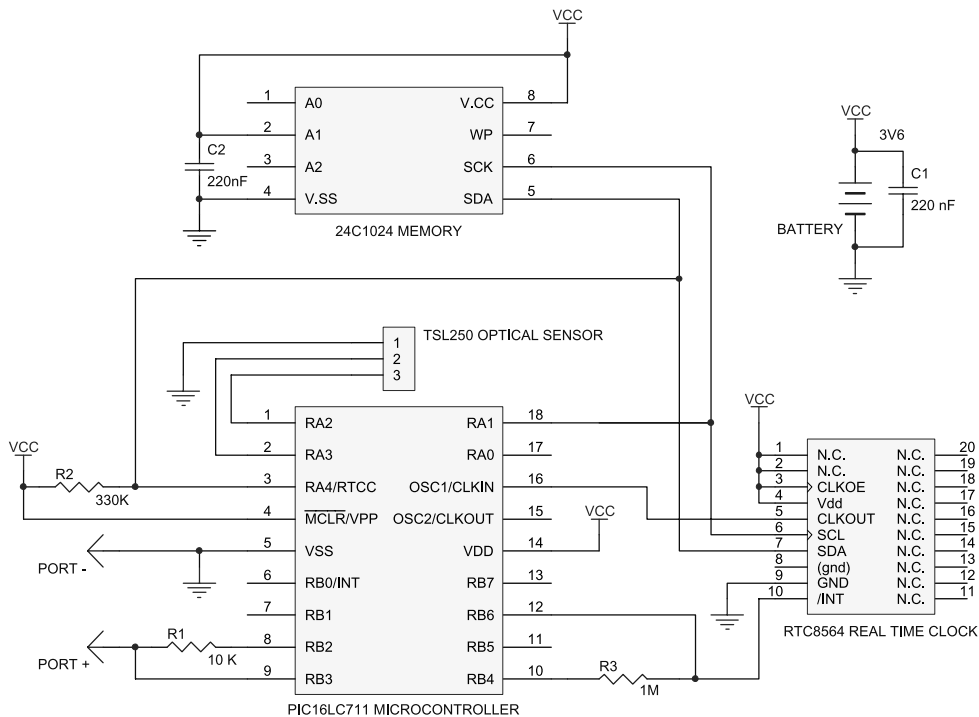


Fig. 1. Miniature daylight level and activity data recorder and computer interface.

computer, Real Time Clock and a peripheral memory device for data storage. It is encapsulated in a clear, water-resistant epoxy package, with two external gold electrodes for commands and data transfers, and for salt water sensing. It is pressure tested to 800 m depth of water, so it can be deployed on diving animals. The recorder can be reused for the life of its battery. The device has a light level sensor that measures the intensity of visible light every 60 s, and records the maximum reading within each 10 min interval. The instrument also incorporates a salt-water switch that checks for immersion in salt water every 3 s, and integrates this information over 10 min intervals. These sampling and recording intervals are pre-set at manufacture and cannot be altered by the user. Output data are heavily compressed raw sensor data. The rate of data storage is not constant; the most detailed data are collected around sunrise and sunset. On average < 20 bytes/day are collected. Following device retrieval, the light level data are downloaded and converted into latitudes and longitudes using standard software such as MultiTrace (Jensen Software Systems, Germany), thereby providing two locations per day (Hill, 1994).

Circuit description (Fig. 2)

MICROCONTROLLER: PIC16LC711 is a low cost, high performance, CMOS, fully static, EPROM based 8-bit microcontroller with on-chip analog to digital converter. It employs an advanced RISC like architecture. A reduced set of 35 instructions, all single word instructions (14 bit-wide), all single cycle instructions except for 2-cycle program branches, instruction pipe-lining and separate instruction and data memory (Harvard architecture) schemes are some of the architectural features used to achieve very high performance. Datasheet is available from:

<http://www.microchip.com/1010/pline/picmicro/category/embctrl/8kbytes/devices/16c711/index.htm>

REAL TIME CLOCK: RTC-8564 is a Real Time Clock Module with a serial interface and a built-in crystal oscillator running at 32.768 kHz. The accuracy of the clock is 25 ppm at 25°C. Any drift can be corrected during post-processing using start and finish times. A full



Fig. 2. Circuit diagram of a light level recorder.

datasheet is available from:

<http://www.epson-device.co.kr/pdf/010810/8564JE.pdf>

OPTICAL SENSOR: TSL250 is a light-to-voltage optical sensor conveniently combining a photodiode and a transimpedance amplifier with feedback components on a single monolithic integrated circuit encapsulated in a clear three-leaded package. The nominal accuracy is 3 dB. A full datasheet is available from:

<http://www.taosinc.com/products.htm>

DATA STORAGE MEMORY: 24C1024 is a 128K×8 bit EEPROM with a serial interface. Data are saved in this non-volatile memory. As the PIC16LC711 microcontroller does not have a serial interface, the communication protocol is implemented in software. A full datasheet is available from:

http://www.atmel.com/dyn/resources/prod_documents/doc1471.pdf

The average operating current of the circuit is under 0.003 mA. In the current design, the circuit is powered by one 3.6 V lithium thionyl chloride primary. At present we are using LTC-3PN battery. Dimensions are 17×15×7 mm. Weight in air is 9 g. Capacity is 350 mAH. Datasheet is available from:

<http://www.powerpacks-uk.com/eagle.htm>

Computer and interface

To operate a recorder, a general purpose computer (*e.g.* IBM- PC compatible, Macintosh, Sun, etc.) and an interface (Fig. 1) are required. The interface is an intelligent purpose-built instrument (dimensions 66×66×28 mm). It has a 2-wire port with two gold plated crocodile clips for connecting it to a recorder and a standard 9 way 'D' plug for connecting it to the computer serial port. The computer should be running a terminal emulating program. The baud-rate, parity, word-length and stop-bits of the communication protocol of the computer must be set to the correct values: 9600, N, 8, 1 respectively. No other software is required.

Results

Accuracy

In field trials at Bird Island, South Georgia, the mean error (great-circle distance) in position estimation of static devices was 85 km, with standard deviations in latitudinal and longitudinal errors of 0.61° and 0.99°, respectively (BAS, unpublished data).

Representative migration track

A representative track from one deployment on a grey-headed albatross *Thalassarche chrysostoma* is shown on Fig. 3. This particular individual dispersed from Bird Island in May 1999 and travelled east to spend the early part of the winter in the south-west Indian Ocean. It then moved more or less directly to the south-west Pacific before returning to the South Georgia area (but not to breed) for much of the following summer. At the end of the summer, it returned again to the same general area of the south-west Indian Ocean for a period, before moving (more rapidly) across the southern Pacific Ocean back to Bird Island in time to breed in late September 2000.

This track was one from two series of deployments of earlier versions of the device

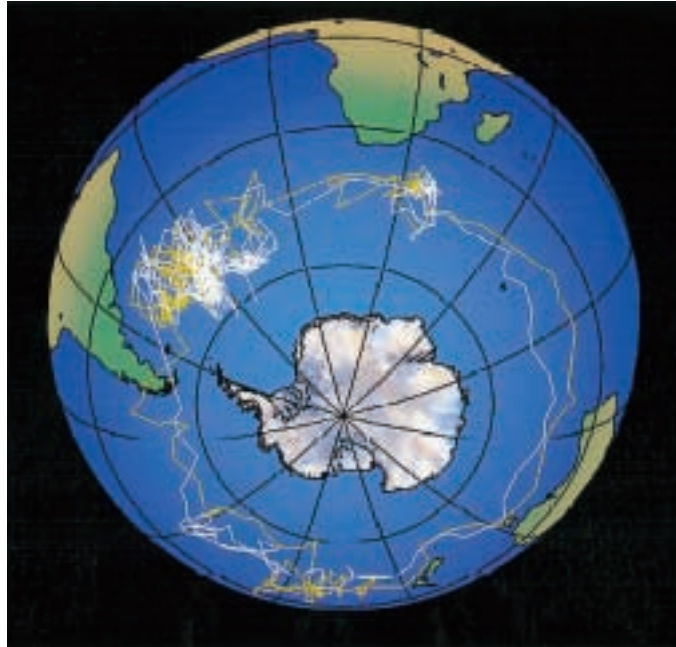


Fig. 3. Dispersal of a female grey-headed albatross *Thalassarche chrysostoma* following a successful breeding season. “White” – Austral winter 1999, “Yellow” – Austral winter 2000.

(with a slightly larger battery), on grey-headed albatrosses at Bird Island. At the end of the breeding season in April 1999, devices were deployed on successful birds whose chicks were about to fledge. The second series of deployments was on incubating adults in November 1999. All these birds subsequently failed because of poor feeding conditions and dispersed away from the colony. This natural event provided the opportunity to compare the behaviour of failed birds with that of the previously successful group over the following nine months. The loggers were attached to standard 30 mm high, plastic bands fitted to the tarsus of each bird. Deployment took less than 60 s and did not require the bird to be restrained. Devices were recovered from both sets of birds on their return to the island to breed in October 2000. Of the 47 devices deployed on successful grey-headed albatrosses, 23 were retrieved, of which 22 downloaded. Of the 30 devices deployed on the failed grey-headed albatrosses, 21 were retrieved, of which 19 downloaded.

Discussion

There are a number of important attributes for loggers intended for deployment on free-ranging animals. One pre-requisite is that the data are retained in the memory until the animal returns and the instrument can be retrieved for data transfer. For deployments on biennially breeding seabirds such as wandering or grey-headed albatrosses the opportunity to recover devices will not usually arise for at least 18 months following post-breeding dispersal (Tickell, 2000). In the case of fledgling albatrosses, birds will not usually return to their natal colony usually until they are at least five to seven years of age (Tickell, 2000).

Consequently, long battery life is crucial. In addition, it is always desirable to reduce the size and weight of any instrument for deployment on a flying bird, in order to minimise potential adverse effects.

Of the batteries suitable for this type of application, the capacity is more or less proportional to the size and weight. Hence the requirement for long battery life is in conflict with the requirement for small overall size and weight of the device. Technically, this translates into the requirement for a battery of high energy density, a circuit with very low power consumption and a need to minimise the number and size of components. In these loggers, the battery is the largest and the heaviest of the components. Small component and pin counts, and straightforward circuit board design also increase the reliability of the devices, as well as result in low manufacturing costs. This is particularly useful for population-level studies of geographic distribution, where it is desirable to maximise sample sizes by keeping unit and operation costs to a minimum.

In conclusion, with low component and pin counts, the above design has resulted in a device of small size and weight, high reliability and low cost, that is easy to start up and download in the field. The low current consumption results in long battery life, and with the present battery the potential lifetime of the instrument is over eight years. To date, a total of over 1600 similar instruments have been manufactured by British Antarctic Survey. With the development of technology, further reduction of size and weight is possible, which should increase the range of suitable target species.

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