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SHORT COMMUNICATION

A SIMPLE MINIATURE CAPACITATIVE POSITION TRANSDUCER

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A widely used technique for recording the position or motion of animal body parts in the laboratory was described by Sandeman (1968), and subsequently modified (e.g. Forman & Brumbley, 1980). The basis of the technique is to attach a small wire wand to the body part to be monitored, and to transmit through this wire a high-frequency oscillating signal. The phase relationship between signals induced in two nearby detectors can then easily be converted into a voltage signal proportional to the position of the wand between the two detectors.

The devices reported previously use a signal frequency of about 40 kHz, and they need two relatively large detectors mounted some 10 cm apart. They are therefore not suitable to record motion of one body part relative to a second, unless the second part can be immobilized. This limitation has required us to modify and miniaturize the device, and we report here details of a version in which the detectors are small enough to be mounted on a moving, semi-restrained animal. We are employing this to record the head movement of a locust flying within an experimental flight chamber and free to rotate about its roll axis.

The main modification to Sandeman's method was to increase the carrier frequency from around 40 kHz to about 1 MHz (Fig. 1). This allows the detectors to be formed simply from two wires separated by between 10 and 40 mm. We used insulated 50 μm diameter wires of the kind routinely used for electromyogram recording. These are approximately 20 cm long, but to limit the total electrical impedance they reached a head stage *via* shielded, larger-diameter cable. As much as possible of the detector and transmitter feeder wires should be shielded in any particular application. A small plastic block was fashioned to hold the detector wires (Fig. 2), allowing easy attachment to the animal with resin/beeswax mix, and ensuring that the detectors were always separated by a uniform distance.

The transmitting wand and its feeder wire were also made from a 20 cm length of 50 μm diameter insulated wire, reaching the head stage *via* shielded cable. It was important that the exposed and moving portion of the transmitter feeder wire was separated by at least 10 mm from the two detector wires, but these two did not need to be separate from each other. In fact, differential interference from the transmitter motion was minimized by twisting the two detector wires together until

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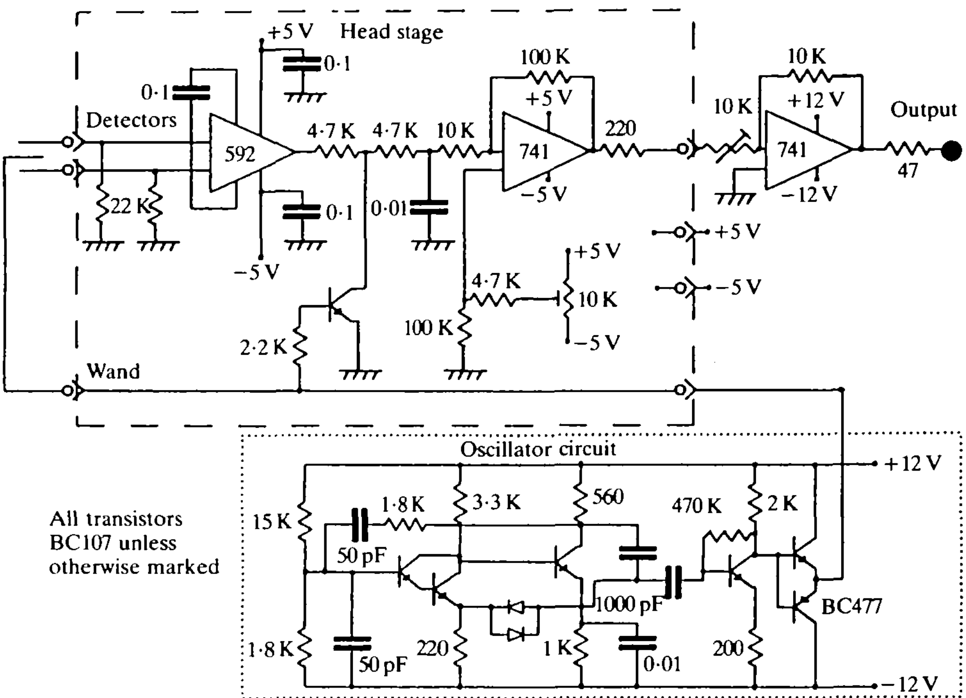

Fig. 1. Circuit diagram. The transmitter feeder wire and two detector wires are shown on the upper left, entering a head stage amplifier (dashed box) that is separated for convenience from the main box containing power supply, oscillator circuitry (dotted box, below) and output amplification (right). Two potentiometers provide adjustment of gain and shift of the output signal.

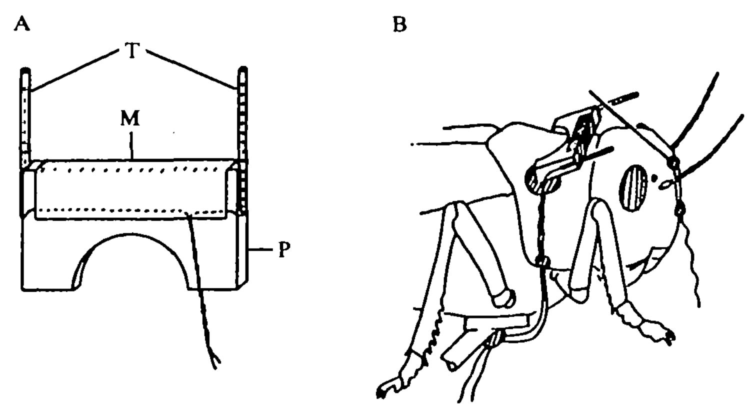

Fig. 2. (A) Details of the supporting block used to hold the detector wires with a separation of 11 mm. The wires are supported by nylon capillary tubing (T), and are glued to a shaped Perspex block (P). M, metal foil acting to shield the wires as they cross the block from differential interference from the transmitted signal. (B) The block attached to a locust, with the transmitter attached to the insect's head. An earth wire is also placed in the abdomen (not shown).

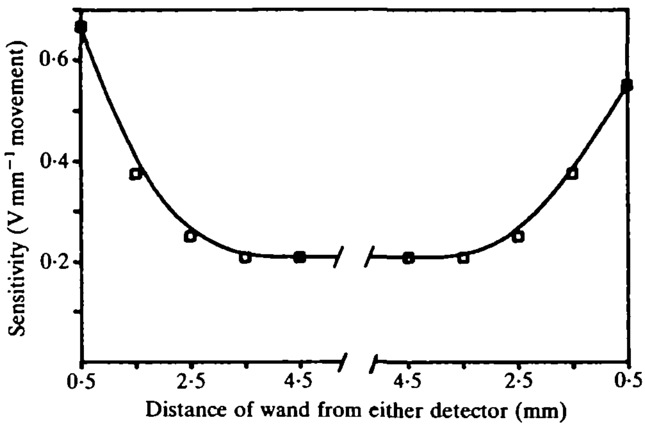

Fig. 3. Output sensitivity of the device when used with 11 mm between detectors. The position signal is linear as long as the transmitter wand lies within the central region of the detector block, but the outlying non-linear regions should be avoided for best results. The extent of these outer regions is essentially independent of the distance separating the detectors within a range of 10–40 mm, so a wider central linear region can be obtained if the detectors can be placed further apart.

they joined the shielded cable. Movement of the transmitter feeder wire further than 20 mm from the detectors caused such an attenuated signal that it could be ignored in most instances.

A further advantage of using a 1 MHz carrier signal is that the frequency is well outside the bandwidth of most recording equipment such as tape recorders and electrophysiological amplifiers. It is therefore not necessary to filter the output signal, or to shield other instruments.

The design used is simple and requires only standard components. The 1 MHz oscillator was an amplitude-limited Wein bridge type. Note that the values of the capacitances (Fig. 1) had to be reduced from theoretical values to compensate for effects of transistor input impedance at this frequency. It was also necessary to use a wide-band video amplifier (592) in the input stage. Synchronous detection was provided by a BC107 transistor chopper. We have not incorporated the sensitivity and drift-immunity improvements reported by Forman & Brumbley (1980), but highly reproducible results are achieved if the device is allowed a few minutes to settle after initial switch-on.

The device has similar accuracy and linearity to the original Sandeman (1968) design. As long as care is taken to ensure that the transmitting wand does not approach close to either detector, linearity is good (Fig. 3). A wider linear response region can be obtained by greater separation of the detector wires than used here, if space allows.

Two difficulties that can reduce accuracy have been found in using the device. The first is that the insect itself can act as a carrier of the 1 MHz signal. In our application, the transmitting wand is attached with resin/beeswax mix to the head of a locust, and the detector block is waxed to the dorsal prothoracic shield

(Fig. 2B). In some cases, movement of the wings or legs caused interference in the recorded position record. This was avoided by ensuring that the animal was earthed relative to the transmitter *via* a bare 50 μm diameter wire placed in the abdomen.

The second problem was caused by attempting to stiffen the transmitter wand with a coating of epoxy resin (Rapid Araldite). This coating apparently formed a high-resistance leak between the transmitter and ground (the insect's body). Strangely, this leak was sensitive to air currents – presumably because of moisture in the air – and the device then did not measure motion of the experimental animal but recorded the breathing of the experimenter! Again, the problem was easily avoided by stiffening the wand, if necessary, with non-conductive materials such as glass or nylon capillary tubing. We have found that it need not be stiffened at all if the free end is about 15 mm or less in length.

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