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AN OPTICAL TACHOMETER FOR MEASUREMENT OF THE WING-BEAT FREQUENCY OF FREE-FLYING INSECTS

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The wing-beat frequency of flying insects has generally been measured by acoustic methods, but even with modern condenser microphones and frequency-selective amplification the signal available from smaller insects may be inadequate. A microphone had to be placed within 1 cm of the midge *Smittia aterrima* (Mg.) to produce a satisfactory signal and no signals could be obtained from *Thrips* sp. (Thysanoptera). Acoustic recordings of flying insects in the laboratory may also be degraded by the excited resonant frequencies of the cage material. The optical tachometer uses the minute changes in the intensity of ambient light reflected from an insect's beating wings to produce an amplified electrical output at the wing-beat frequency, producing an adequate signal from a very much greater range than would be obtained by acoustic methods. With this device *Smittia aterrima* could be measured at a distance of 1 m, *Drosophila melanogaster* Mg, at 1·2 m, and larger insects from a much greater range: *Calliphora vicina* (R-D.) 7 m, and *Bombus* sp. 10 m. No difficulty is found when making measurements through the sides of transparent flight cages. The sensitivity of the device seems sufficient for recording *Thrips*, although this has not yet been tested.

The circuit diagram of the tachometer is shown in Fig. 1. The signal from a silicon photo-diode passes through a two-stage selective amplifier with a maximum gain of 10000. The low-frequency gain is deliberately limited by the inter-stage coupling

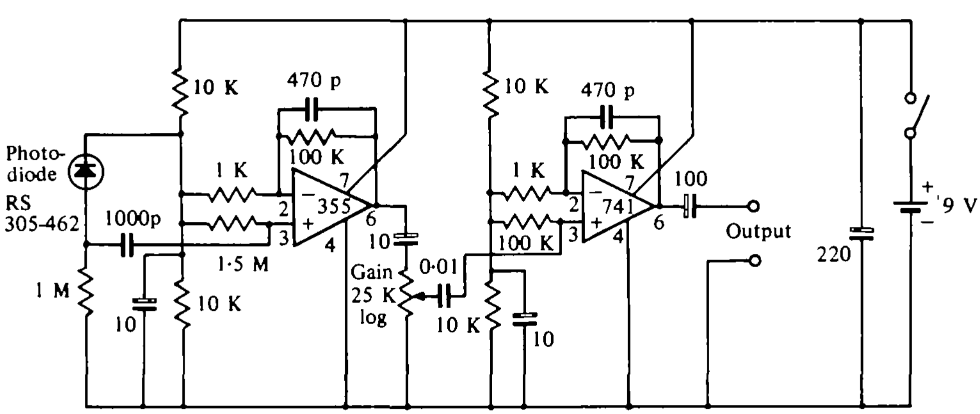

Fig. 1. Circuit diagram of the optical tachometer. Resistances are in ohms and capacitances in microfarads unless stated.

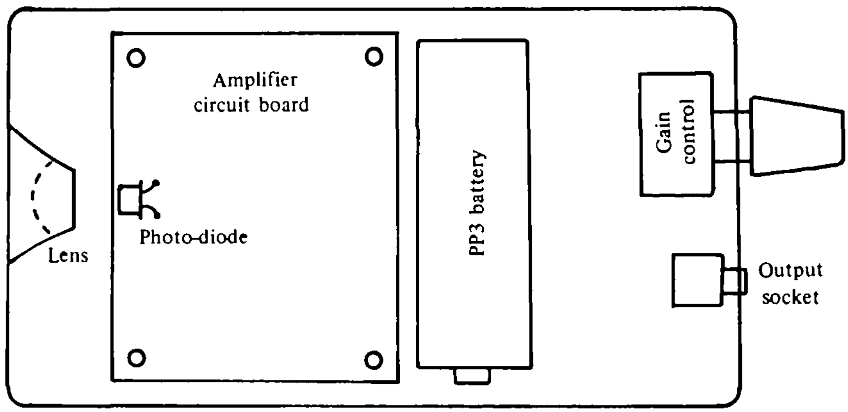

Fig. 2. Layout of the tachometer, which is built in a moulded polystyrene case, 120 × 65 × 40 mm (R. S. Components Ltd., ref. 509–579).

networks so that large-amplitude signals due to movement of the sensor relative to the background do not block the amplifier. The output of the amplifier is −3 dB at 500 Hz and −20 dB at 50 Hz relative to the output at 1 kHz. High-impedence headphones may be connected directly to the output.

The layout of the tachometer is shown in Fig. 2. The optical system consists of a large aperture lens of short focal length; the prototype incorporates a lens of 7 mm focal length and an aperture of about f/0·5 (the top part of the condenser lens from a Watson monocular microscope). The angle of acceptance of the optical system is 6°, which is sufficiently broad to enable insects to be located without difficulty by pointing the device in the approximate direction and monitoring the output with headphones. The use of lenses of longer focal length will produce a larger output but make the location of the insect more difficult. The photo-diode is mounted on the printed-circuit board that carries the amplifier, and the lens is positioned so that an object at 1 m is in focus at the target of the photo-diode. It is essential that the insect is illuminated by daylight or by lamps powered from a smooth direct current supply. The use of artificial lighting powered from an alternating supply results in so large an output at 100 Hz that the signal is masked completely.