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UNPUBLISHED PRELIMINARY DATA

RECORDING LEAF MOVEMENTS WITH A STRAIN GAUGE

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In our pilot studies concerning the effect of space environments on the circadian leaf movements, we have devised a small lightweight leaf movement recording system using a strain gauge coupled to an amplifier and a recorder.

The need for such a system was dictated by the physical limitations of an orbiting capsule. We have also found that such a system is useful for earthbound experiments. The small size of the sensing unit makes it possible to place several units on a single plant. The monitored plant may easily be placed in a small control chamber. It would be difficult to duplicate these recording capabilities using kymographs. Furthermore, continuous records of several weeks duration may be obtained when the movements are recorded on a strip chart recorder.

Description of the system

The active element of the leaf movement sensing unit is a strain gauge that is 1/32 inch wide and 9/64 inch long. The gauge (EA-09-031DE-120) is made by Micro-Measurements, Inc. of Romulus, Michigan. In our experiments, the strain gauge was glued with Eastman 910 adhesive to the center of a 0.001 inch thick brass shim stock, measuring 1/16 inch wide and $1\frac{1}{4}$ inches long. The brass shim is formed into a half loop with $\frac{1}{4}$ inch long tabs at the ends of the half loop. One of the tabs is glued to the leaf petiole and the other to the midrib of the leaf blade with polyvinylacetate, which is the "white glue" of commerce (see fig. 1). In the amounts used, the glue was not toxic to the plant organs. The strain gauge is part of the bridge circuit that is supplied with D.C. voltage. The signal generated by the movements of the leaf blade is sent to the amplifier of the Minneapolis-Honeywell Brown recorder and the amplified signal is recorded on the strip chart.

The recording system proposed for the orbiting system has the same bridge configuration but has a Philbrick Researches solid state amplifier PP65A instead of the recorder amplifier (see fig. 2). The voltage supply to the amplifier derives its power from a 22.5, 45.0 volt portable "B" battery and the voltage is regulated at 15.0 volts by the IN965 Zener diodes. The differential signal output of this smaller system is at least 0.2 volts with a leaf deflection of around 30°. The weight of this system less power supply is around 1.0 ounce and the dimensions are $\frac{1}{2}$ inch by 1 inch by 2 inches.

Results

The sensing unit was tested for temperature effects and for voltage change effects. When the ambient temperature was varied from 27^{o}C. to 45^{o}C. the leaf angle readings on the Brown recorder varied 2^{o}. Thus a 1^{o}C. change in ambient resulted in an error of 0.11^{o} in the leaf angle reading. This error is considered negligible for our work since the temperature variation on our growth chamber can be kept down to $\pm$ 0.2^{o}C. As a further refinement, the substitution of another strain gauge for the 120 ohm resistor in the bridge will eliminate this error. The inert substituted gauge will act as a standard control. A voltage variation of 1.0 volt supplied to the strain gauge resulted in an error of 10.0^{o} in leaf angle reading. However, the voltage supply can be regulated to within $\pm$ 0.02 volts under most conditions and the resulting leaf error will only be $\pm 0.2^{o}$. This error is considered negligible for our experiments.

To test the reliability and accuracy of the system, the strain gauge unit was attached to a primary leaf of a Pinto bean. A kymograph was also attached to the same leaf and four days of records were obtained. The kymograph recorded the leaf movements by means of a leverage system that had the leaf attached by means of a thread to one end and a pen to the other end. The pen produced a permanent record on a chart calibrated to read out the leaf angles directly. The chart was wrapped around a drum that turned once a week. The strain gauge signals were recorded on the M. H. Brown strip chart recorder. The results of the strain gauge records were compared with the records of the kymograph. The time sequence of the peaks and dips of the two records were identical. Upon further examination it was found that the leaf angle values were not directly correlated between the strain gauge records and the kymograph records. Upon plotting the corresponding points of the kymograph and the strip chart records, it was found that the maximum deviation of the strain gauge records was not more than 5^{o} from the values of the kymograph records (see fig. 3). Since the peaks and dips on the curves are not displaced in time sequence we feel that the deviation is not large enough to invalidate the strain gauge records for cycle length studies.

This unit is being used in experiments testing the effects of light dark cycles on the leaf movements of Pinto beans. The authors wish to thank Dr. Robert Chipman of UCLA Engineering Department and Mr. Raymond Kado and Mr. Stanley Noguchi for their technical assistance and advice. We also wish to thank Dr. J. D. French for his support in this work. The authors gratefully acknowledge the support given the work by the NASA Grant NsG 528 and U. S. Air Force Grant AF-AFOSR 246-63.

Fig. 1. LEAF MOVEMENT SENSING UNIT
The unit is glued to the petiole and midrib of a Pinto bean leaf. Wires lead off unit to rest of bridge and recorder. A Micro-Measurements, Inc. strain gauge (EA-09-031DE-120) is glued to center of unit (Arrow).

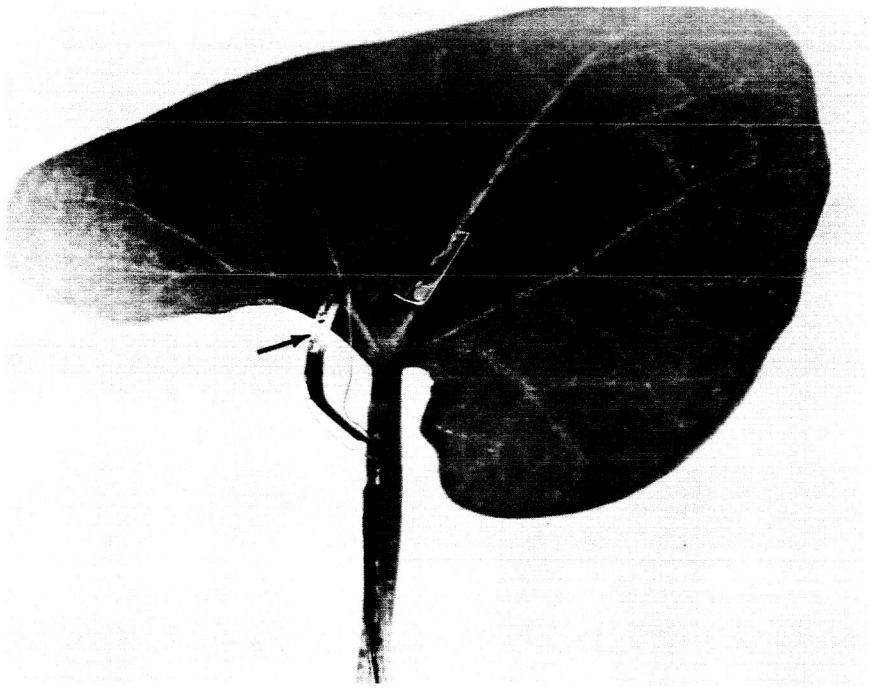
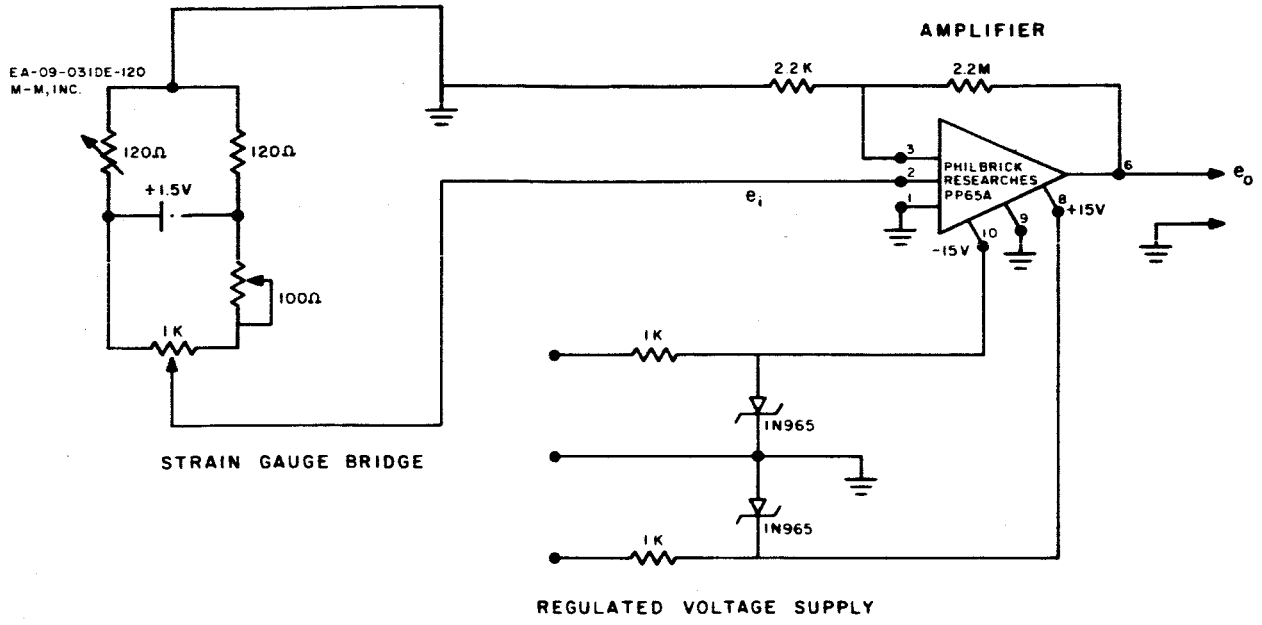


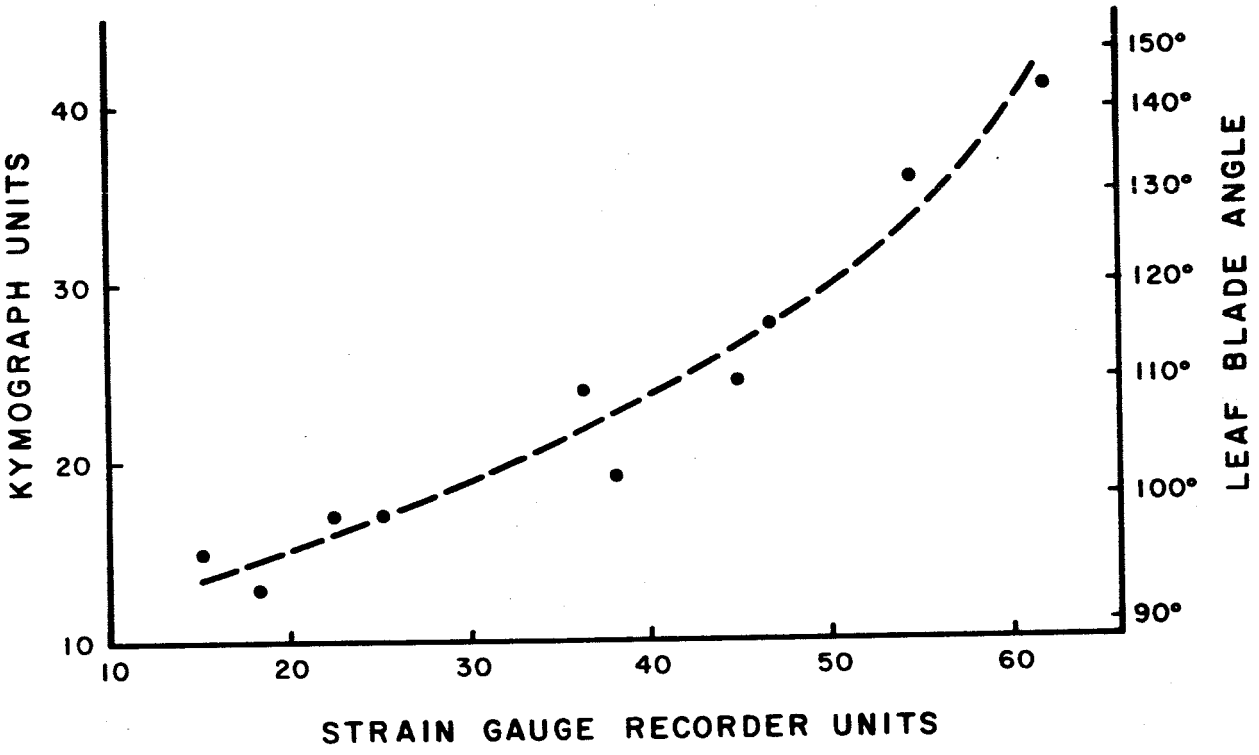
Fig. 2 LEAF MOVEMENT RECORDING CIRCUITY

The system has 3 sections. (1) Bridge circuit with a strain gauge as the leaf movement sensing unit. (2) Amplifier unit with a Philbrick P65A or PP65A unit wired for 1000X amplified output. (3) Regulated voltage supply limited by IN965 Zener diodes.



LEAF MOVEMENT RECORDING CIRCUITRY

Fig 3. STRAIN GAUGE- KYMOGRAPH CORRELATION GRAPH
The curve depicts the relation between strain gauge record and kymograph record taken simultaneously from same leaf. Actual leaf angle is given at right side. Horizontal position is given a value of 90^{o} and vertical down position is given a value of 180^{o}. Dotted curve depicts the ideal correlation curve.


KYMOGRAPH UNITS
40
30
20
10
10
20
30
40
50
60
STRAIN GAUGE RECORDER UNITS
150°
140°
130°
120°
110°
100°
90°
LEAF BLADE ANGLE