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A PHOTOELECTRIC SEED COUNTER

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ABSTRACT

Small scale yield studies, germination tests, controlled plantings, and packaging often require the counting of large numbers of seeds. The system described in this paper uses a photosensitive detector and a vacuum pickup to count individual seeds and gives a direct digital readout. The count rate is limited only by how quickly the seeds can be fed through the counting tube without clogging it or having them touch each other. This greatly speeds seed counting, eliminates operator error, and reduces operator fatigue.

With the addition of a relatively simple predetermining circuit, a fixed number of seeds may be counted and a control function can be exercised. This capability is immediately applicable to packaging or repetitious batching of seeds. Zero error for any given number of seeds is attainable if the seeds are fed through the count tube carefully because of the completely digital nature of the circuit.

Additional key words: **Optoelectronics, Germination tests, Precision planting.**

HIGH speed counting of the seeds of various agricultural crops is desirable for preparing germination tests, analyzing the results of small scale yield studies, controlling the number of seeds to be planted per unit length of row, and determining the number of seeds per unit weight for precision planting, to name only a few examples. The instrument described in this paper counts seeds at a rate limited only by the capacity of the count tube and the necessity to have seeds spaced so that there is some distance between them as they travel through the tube. It eliminates operator error, reduces operator fatigue, and gives a direct digital readout.

Testing of the instrument at a count rate of approximately 5000 seeds/min produced an error of about 10%. At 2000 seeds/min, this reduced to about 2%. The error further reduced to about 0.1% at approximately 1000 seeds/min, and at more moderate count rates of 200 to 500 seeds/min there was no detectable error. These errors were from low counts, probably due to seeds touching

If a predetermining circuit is added, the counter can exercise a control function, such as disconnecting the vacuum line from the pickup after a given number of seeds is counted.

While the circuit contains a relatively large number of interconnections, it can be assembled by anyone familiar with good hand-soldering techniques using readily available solder sockets for the major components.

The cost of a unit to count only is approximately $150 in parts. With the addition of a predetermining circuit, the parts cost will be approximately $250. The actual total will depend primarily upon the type of readouts used and the type and amperage capacity of the primary control unit for the external load. Total labor will depend mainly upon the type of wiring

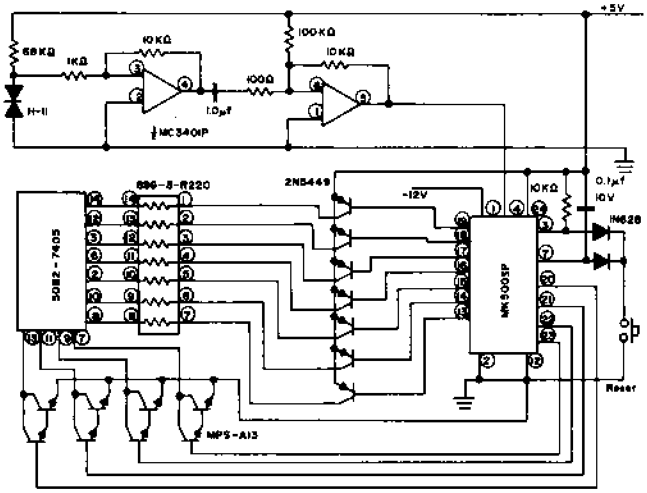

Fig. 1. Schematic of photoelectric seed counter — count only.

system, whether it is the more time-consuming hand-soldering process or one of the faster point-to-point wiring systems. For production quantities, the obvious approach is to make a printed circuit board, but the initial cost of designing such a board makes it prohibitive if only prototype quantities are desired.

All count and control functions are exercised by integrated circuits with the exception of the sensor and part of the display driver interface. The input amplifier is part of a quad single-voltage operational amplifier package, and the heart of the system is a MOS LSI (metal oxide semiconductor, large scale integration) chip. The interface between the LSI counter chip and the displays consists of resistors in DIP (dual inline package) configurations combined with discrete components. The predetermining circuit uses MOS and LPTTL (low power transistor-transistor logic) latches and gates for low power consumption and high noise immunity (Fig. 1).

Basically, the counter operates by passing a seed between a light and a photosensitive card-reader diode. The electrical pulse generated is amplified and passes directly to the LSI counter chip. The total number of pulses produced in this manner is accumulated by the LSI chip until the count is erased by a reset command. The LSI chip contains all the counters and gates necessary for data accumulation, BCD to 7-segment decoding, and digit addressing for driving a display in the multiplexed mode. All that is necessary is to add two external components to the chip to set the scan rate for multiplexing and interface the MOS outputs to the readouts (1).

When a predetermining counter is desired, the BCD outputs from the LSI chip are used in addition to the display outputs. This information is provided to four quad latches in byte-serial format. Strobes for the latches obtained from the digit enable lines of the LSI chip, which allows the byte of information to be stored in the latch for that decade. This information is compared to the settings of the thumbwheel switches representing the total number of seeds to be counted by cascaded 4-bit magnitude comparators. When the two numbers are equal, the control memory latches, either enabling or disabling the pri-

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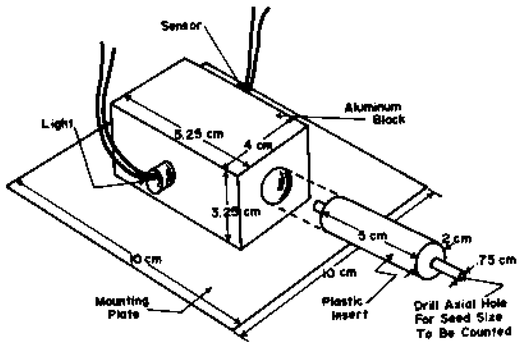

Fig. 2. Sensor assembly

mary control unit, depending upon the control function exercised.

In the authors' model, this control signal is used to deactivate a solid state relay which controls a 115-VC load, but almost an unlimited number of possibilities for control exist, and the actual device used or function exercised will depend upon the particular application.

A reset button clears the accumulated count from the decade counters and resets the control memory unit after the data have been recorded, preparing the instrument for another count.

The sensor assembly is shown in Fig. 2. The metal block and mounting plate are made of aluminum and the insert is machined from clear acrylic plastic. The only critical considerations in constructing the sensor are that the light and photodiode must be axially aligned on a diameter of the larger hole in the block at a distance of no more than about 2 cm, and the hole through the plastic insert must be drilled so that the inside is clear, allowing maximum transmission of light. Scoring the inside surface of this conveying tube will render the entire sensor inoperative.

The inside diameter of the hole through the plastic insert is determined by trial and error. This is drilled to the machinist's number drill size that is the minimum diameter which will let a particular type of seed pass. A pilot hole should be drilled through the insert at least two number sizes smaller than the desired hole to allow water cooling of the bit when drilling the finished hole. This prevents heat scoring of the inside surface of the hole. The outside diameter of the nipples protruding from either end of the insert is slightly larger than the inside diameter of the flexible plastic tubing closest to the diameter of the seeds being counted.

To date, the authors have developed inserts for counting alfalfa (*Medicago sativa* L.), onions (*Allium*), and radishes (*Raphanus raphanistrum* L.), which work very successfully.

With large irregular seeds, such as beans (*Phaseolus vulgaris* L.) and corn (*Zea mays* L.), the plastic insert is not used, but instead a piece of 5-mm (3/8-inch) inside diameter (ID) plastic tubing is inserted completely through the sensor. The outside diameter (OD) of the tubing is increased to the inside diameter of the hole in the sensor with two bands of masking tape, thus centering the tube inside the sensor. Two coils approximately 20 cm in diameter are made around the

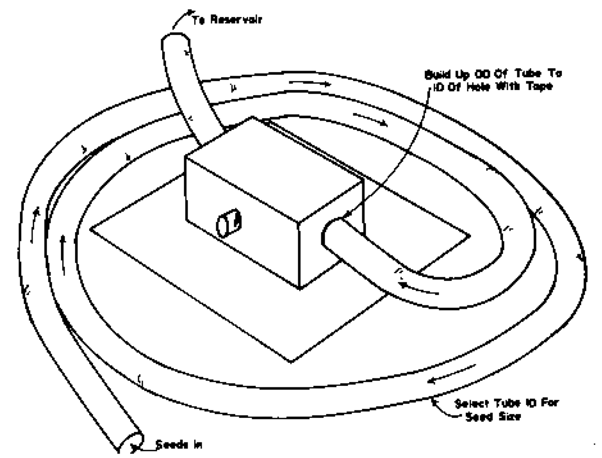

Fig 3. Sensor assembly with tubing for large, irregular seeds.

sensor with the tubing before the tubing enters the counting unit. This circular path orients the seeds in the direction of their long dimension and forces them to travel against the outside surface of the tube approximately half-way up the diameter, thereby insuring that some part of each seed will cross between the light and photosensor. If a seed becomes lodged across the pickup tube, it is quite easy to squeeze the tube and dislodge it. All types of beans, ranging from small pea-beans to large pintos, have been successfully counted with this arrangement. Corn requires a slightly larger 1.25-cm ID (½-inch) hose; small irregular seeds such as wheat (*Triticum aestivum* L.) may be successfully counted with a piece of tubing about 0.3-cm (⅛-inch) ID. With the smaller tubing, it is important that the plane of the arc in the last section of tubing be parallel with the plane between the light and photodiode to insure that the seed passes between these devices.

This counter can be interfaced to commercially available vibratory seed separators by constructing a trough of clear plastic with the photodiode positioned in the bottom and the light mounted directly above it at a distance of about 2 cm. This trough is placed at the end of the separatory helix at an angle so that the seeds will slide down it easily but not so fast that they begin to bounce. Bouncing is still a problem with some light, irregular seeds such as onion, and a different type of sensor may have to be constructed. A vacuum pickup could be used with this separator by positioning the end of the pickup hose at the end of the separatory helix; however, this is like gilding the lily.

For operation, connecting tubes are attached to both ends of the sensor insert (or one continuous tube used in the case of irregular seeds), and then attached to a reservoir which can be anything from a laboratory vacuum flask to a specially constructed cylinder with foam padding in the bottom to absorb the impact of the seeds. The seeds are placed in a large screened-bottom pan and shaken to make them separate (a laboratory soil sieve works well). A solid bottomed pan is much less desirable because the airflow is along the surface of the pan and then into the tube rather than coming directly upward through the screen into the tube. This flow along the bottom of the pan tends to pull in surrounding seeds that clog the tube or perhaps pass 2 together through the tube so they are only counted as one seed.

The vacuum applied to the system is adjusted so that seeds are easily picked up by the tube, but is not so high that surrounding seeds are also moved into the tube. This vacuum level depends on the particular seed being counted and the size of the mesh in the screen. A vacuum cleaner satisfactorily supplies vacuum to pick up such large seeds as beans and corn, but a pinch-clamp must be used on the vacuum line to reduce the airflow when counting smaller seeds such as onions, alfalfa.

There are several commercially available seed counters that operate on approximately the same general principles as the unit outlined in this paper. They have, however, several disadvantages. They cost about $1500 to $2500 each, while the unit described here should not exceed $300, even if housed in a relatively expensive case.

The operation of most commercially available seed counters appears to be based upon the work of Kramer and Decker (2); a bowl feeder is used to feed seeds down a tube containing a photoresistor and lamp assembly. Total count is accumulated on an electromechanical counter and the sensitivity of the input amplifier is adjusted for the seed size.

Several problems arise from this design. The rise and fall times of the specified photocells are about 2 to 6 ms, and seeds arriving at the sensor closer than 4 to 12 ms apart would not be resolved as 2 separate output pulses. These photocells are sensitive to ambient light levels, and hence, the sensor must be shielded to prevent interference. The major limiting factor on counting rate is the electromechanical counter which has a cycle time of approximately 40 ms. One major complaint from users of these counters is that the sensitivity adjustment for counting seeds of various sizes seems to be quite difficult to manipulate. This restricts the counter to use with one seed size or use by a person who has a good "feel" for this adjustment.

The counter outlined in this paper overcomes these problems through use of different components. Instead of the photoresistor, a photodiode is used as the sensing device that permits seeds spaced at 100 μs or longer to be resolved as separate pulses. This photodiode is not affected by ambient light levels, so both sensor and lamp can be completely exposed, if desired. Because counting and display are performed electronically, the maximum count rate is about 250 KHz, which makes the rise and fall times of the photodiode the limiting factor in time resolution of seeds. Once the light and photodiode have been aligned at the correct distance, no further calibration is necessary.

The problem then becomes the mechanical one of insuring that some part of each seed passes between the light and photodiode. In the authors' model, this problem was solved by machining interchangeable inserts with the right diameter axial hole for the sensor so that the seeds had to pass between the light and sensor. All that is necessary to change from one seed size to another is simply to select the correct size insert for the seed to be counted or, in the case of irregular seeds, replace the insert with a piece of tubing passing through the sensor. Mounting the sensor and light assembly on a V-shaped trough may make an assembly that will count seeds ranging in size from pinto beans to alfalfa without having to adjust anything. This is presently under investigation.

LITERATURE CITED

1. Operation of the MK5002P MOS 4-Digit Counter Decoder. 1971. Mostek Corporation Operation Note, Carrollton, Texas.
2. Kramer, H. A., and R. W. Decker. 1962. Electronic Seed Counter. Agr. Eng. 43:346-348.

PARTS LIST[a]

1	- Mostek MK5005P Counter/Decoder
1	- Motorola MC3401P Quad Op. Amp.
1	- Hewlett-Packard 5082-7405 LED Readout
1	- Beckman 899-3-R220 Resistor Array
1	- California Electronic 22-100-512 Power Supply
7	- 2N5447 Transistors
4	- Motorola MPS-A13 Darlington
1	- Texas Instruments H-11 Photodiode
2	- IN628 diodes
3	- 10KΩ ¼ W 10% resistors
1 ea.	- 100Ω, 1KΩ, 68KΩ, 100KΩ 1/4 W 10% resistors
1 ea.	- 0.1mf 10V, 1.0mf 50V capacitors
1	- SPST N.O. pushbutton switch
1	- 24-pin DIP socket
3	- 14-pin DIP sockets
1 m	- Belden 8444 4-conductor cable

[a] Trade names and company names are included for the benefit of the reader and do not imply any endorsement or preferential treatment of the product listed by the U. S. Department of Agriculture.