# DESIGN AND PERFORMANCE OF AN ELECTRONIC SEED COUNTER

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A general purpose electronic seed counter which counts seeds during free fall is described. Counting errors of less than 0.4% at counting speeds of 400 to 1,180 seeds/min were obtained for seeds of nine different species ranging in size from corn (*Zea mays* L.) to trefoil (*Lotus corniculatus* L.). Under some conditions, the seed dispenser, a vibratory small parts feeder, segregated wheat kernels (*Triticum aestivum* L.) into weight classes dispensing heavier kernels first into the counting system.

On trouvera ci-dessous la description d'un compteur électronique polyvalent permettant le comptage des semences en chute libre. Les erreurs de comptage obtenues à un débit de 400 à 1,180 semences par minute sont inférieures à 0.4% pour neuf espèces différentes de semences dont la taille variait entre celle du maïs (*Zea mays* L.) et du lortier corniculé (*Lotus corniculatus* L.). Sous certaines conditions, le distributeur de semences, petit récipient vibrateur, a séparé les grains de blé (*Triticum aestivum* L.) selon leur poids en laissant d'abord passer dans l'appareil les grains les plus lourds.

In biological research it is frequently necessary to count seeds. To alleviate the laborious nature of this task, many types of seed counters and seed counting aids have been developed. Reid and Buckley (1974) refer to a number of the seed counting devices which are described in the literature.

In many of the electronic seed counters, a vibratory small parts feeder is used to dispense seeds, one at a time, into the counting system. In Goulden and Mason's (1958) seed counter, seeds are dropped from the feeder onto the top of an inclined chute, slide down the chute and strike a peizo-electric crystal detector after falling off the lower end of the chute. Pfeifer et al. (1956) and Kramer and Decker (1962) also used an inclined chute but fitted it with a photo-electric sensing system. Seeds interrupt a light beam while sliding down the chute. Reid and Buckley (1974) used a tapered vertical collimating tube to guide seeds from the feeder through a narrow light beam. They made a number of different sizes of tubes to correspond with the different seed types to be counted. The collimating principle was also employed by Brach and Reid (1971) and Carlow and Irvine (1961).

Accuracy figures reported for the above counters vary from 0.4 to 7% at counting rates of 150–700 seeds/min. These performance figures were considered unsatisfactory. We undertook to design a seed counter with greater accuracy and higher counting rates.

## DESCRIPTION

The seed counter consists of a standard small parts feeder, a vertical chute, an electro-optical sensing system, and an electronic pulse shaping and counting circuit (Fig. 1). Vibrations in the feeder bowl (Syntron Model EB-00, Davis Tool and Engineering Co., Montgomery, Illinois) cause the seeds to move up the spiral ramp in the bowl. A variable width apron, a modification for seed counting by Davis

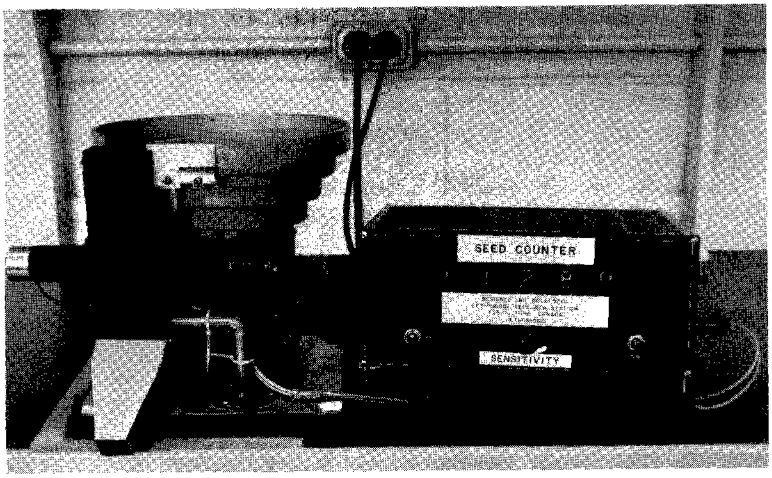

Fig. 1. Electronic seed counter showing vibratory feeder, vertical chute with free fall sensing system and electronic counter.

Tool and Engineering Co., near the top of the ramp is adjusted according to seed size, permitting only a single row of seeds to move over the apron with the excess falling down to the next level. Seeds drop one at a time off the end of the ramp, fall down a vertical chute and pass through a thin horizontal light beam.

The vibratory feeder is generally capable of dispensing seeds in an orderly fashion at rates much faster than counting rates reported for previous seed counters. Seed bounce in the collimating tube or inclined chute appears to be the factor which limits the counting rate at which acceptable accuracy can be obtained. We designed the vertical chute to eliminate seed bounce. The chute cross section is 2 × 5 cm which is much larger than collimating tubes used in previous seed counters. Seeds dispensed by the feeder pass through the light beam during free fall. They do not touch the chute walls until after they have passed through the light bean. The purpose of the chute is merely to cut out excess light and to guide the seeds into a container after they have been counted.

The chute is constructed from 0.4-cm clear plexiglass and is painted flat black (Fig. 1 and 2). The electro-optical sensing system is mounted 7.5 cm below the top of the spiral ramp on the feeder bowl. Seeds dispensed from the feeder bowl accelerate by gravity to a velocity of approximately 100 cm sec $^{-1}$ before passing through the sensing system. Acceleration of the seeds allows them to separate, reducing the

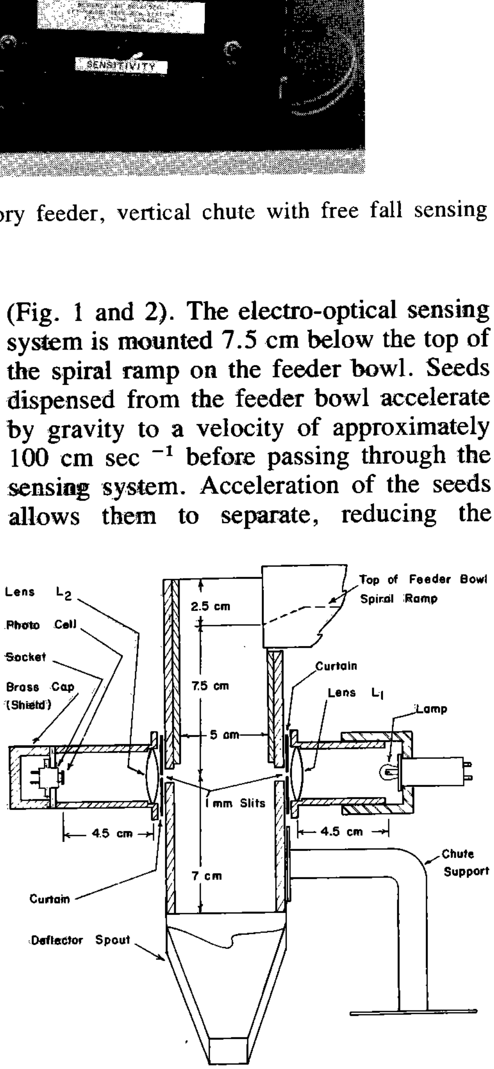

Fig. 2. Sectional diagram of vertical chute showing optical sensing system.

chances of overlapping seeds passing through the sensing system.

The light beam is generated by a 12-volt lamp placed at the focal point of the convex lens, $L_1$ (27-mm diam, 45-mm focal length). An identical lens, $L_2$, on the opposite side of the chute focuses the parallel rays of the beam on the photocell. An opaque curtain with a 0.1 × 2.0-cm horizontal slit is placed between each lens and the chute wall, leaving only a 0.1-cm thick × 2 cm-wide light beam across the chute.

When a seed passes through the light beam, a portion of the beam is interrupted. The decrease in quantity of light falling on the photo cell causes a change in voltage across the cell. This voltage pulse is amplified by a variable gain AC amplifier (Fig. 3) and if its magnitude is sufficient, the Schmitt trigger fires. This supplies base current through $C_5$ to the interface transistor $Q_5$, which provides a negative pulse to the counter advancing it by one digit. The Schmitt trigger acts as both a level discriminator and pulse shaper. Once the Schmitt trigger has fired, further changes in light intensity will not have any effect until the Schmitt trigger resets. Due to its inherent hysteresis, a reset will not occur until the light level returns to its original level. This helps to avoid double counts since the seed must be completely through the light beam before the Schmitt trigger resets to a state where it can generate another pulse to feed into the counter. The time required for the Schmitt trigger to reset is in the low microsecond range.

The electronic circuit is designed to respond only to rapid changes in the quantity of light falling on the photo cell such as that produced by a seed falling through the light beam. It will ignore slowly varying changes such as those produced by changes in the supply voltage or by changes in the light bulb characteristics. The sensitivity of the circuit is adjusted according to seed size by altering the 5K potentiometer on the emitter of $Q_1$. This changes the gain of the amplifier.

The advantage of this design is that interruption of only a small portion of the light beam (equivalent to the seed width) is necessary to trigger the circuit and register as one count. Since the light beam is uniform over the cross-sectional area of the vertical chute, a seed passing through any part of the beam will generate the same signal. This eliminates the need for collimation or guiding the seed through the light beam.

## PERFORMANCE

### Accuracy

The seed counter has been in use for 2 yr and no major problems were encountered. The seed must be reasonably clean for counting as large pieces of chaff or other

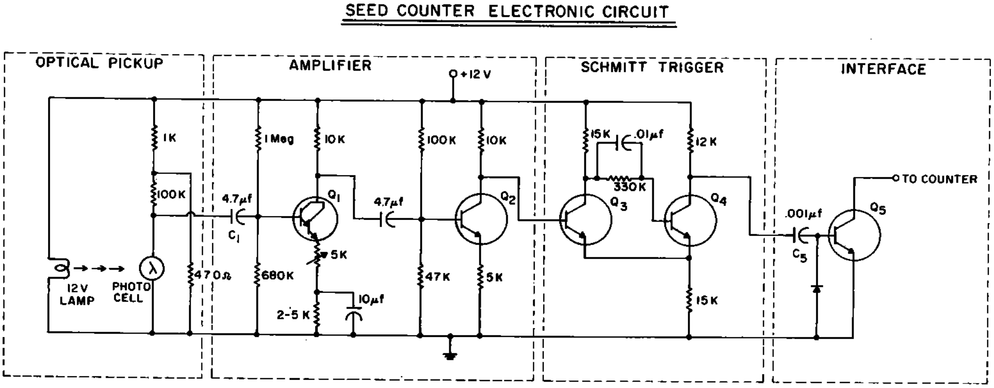
SEED COUNTER ELECTRONIC CIRCUIT

Fig. 3. Seed counter electronic signal processing circuit.

foreign objects are counted as well as the seed. Particles of dirt much smaller than the seed are below the threshold level of the signal processing circuit and are therefore ignored. Accumulation of dust in the vertical chute and on the lenses requires occasional dismantling and cleaning.

We determined the optimum settings of vibrator amplitude, apron width and sensitivity for nine different seed species ranging in size from birdsfoot trefoil (*Lotus corniculatus* L.) to corn (*Zea mays* L.). The optimum sensitivity was determined by dropping seeds of the particular species through the light beam and slowly decreasing the sensitivity until the seed counter failed to count some of the seeds. The sensitivity was then increased by changing the resistance on the 5K potentiometer (Fig. 3) by 33% providing a factor of safety to ensure that some seeds would not be missed. Counting rate and accuracy were determined for various combinations of apron width and vibrator amplitude. The optimum settings were chosen as those which would give the highest counting rate at an acceptable level of accuracy. Good accuracy was considered to be more important than high counting rates.

The results of accuracy tests performed at the optimum settings are given in Table 1. The range in error and the mean error are based on 10 replicates of counting 1,000-seed samples. For all species tested, the maximum error encountered (1,000-seed sample) was 0.4%. Faster counting rates were attainable with a corresponding increase in error: for alfalfa (*Medicago sativa* L.), the error was about 1% at 2,000 seeds/min.

The counting errors for our seed counter are considerably smaller than the 0.4–7% obtained on the seed counters referred to in the introduction. Our counting rates are much higher. The good accuracy and high counting rates are attributed largely to the design of the free fall counting system.

## Segregation

Goulden and Mason (1958) suggested that the action of the vibrating feeder bowl may

Table 1. Optimum settings of seed counter, counting rate and counting error for seeds of different species

| Species | Avg seed width (mm) | Apron width (mm) | Vibrator amplitude† | Sensitivity‡ | Count rate (seeds /min) | Counting error | |
|---|---|---|---|---|---|---|---|
| | | | | | | Range (%) | Mean (%) |
| Corn<br>(*Zea mays*) | 9.8 | 8.0 | 6.0 | 715 | 400 | −0.0–+0.1 | +0.01 |
| Beans<br>(*Phaseolus vulgaris*) | 6.7 | 7.0 | 7.0 | 815 | 640 | −0.1–+0.1 | −0.02 |
| Sainfoin<br>(*Onobrychis viciae folia*) | 4.6 | 5.0 | 6.0 | 860 | 930 | −0.0–+0.3 | +0.13 |
| Barley<br>(*Hordeum vulgare*) | 3.5 | 4.0 | 5.5 | 905 | 590 | −0.0–+0.1 | +0.10 |
| Wheat<br>(*Triticum aestivum*) | 3.4 | 4.0 | 5.5 | 870 | 670 | −0.1–+0.0 | −0.05 |
| Oats<br>(*Avena sativa*) | 2.7 | 4.0 | 5.5 | 907 | 520 | −0.0–+0.4 | +0.13 |
| Milk vetch<br>(*Astragalus cicer*) | 2.1 | 2.0 | 4.5 | 931 | 700 | −0.2–+0.2 | +0.02 |
| Alfalfa<br>(*Medicago sativa*) | 1.3 | 2.0 | 5.0 | 973 | 1180 | −0.1–+0.1 | 0.00 |
| Trefoil<br>(*Lotus corniculatus*) | 1.1 | 1.5 | 3.5 | 980 | 890 | −0.4–+0.4 | +0.02 |

†Optimum setting of the vibrator control knob on a 0–10 scale.

‡Optimum setting on the 5K 10-turn potentiometer (amplifier gain) on a 0–1,000 scale.

Table 2. Segregation of seeds (wheat) by weight as indicated by successive increments of 200-seed lots dispensed from the vibrator bowl

| Sample | Group | Vibrator amplitude | | | |
|---|---|---|---|---|---|
| | | 7.0 | 6.0 | 6.0† | 5.0 |
| | | *% deviation from mean wt of 1,000 seeds* | | | |
| Uniform kernel size (cv. Red Bobs) | 1st | +3.8 *ab* | −0.4 *a* | +1.7 *a* | −0.6 *a* |
| | 2nd | +4.3 *a* | +2.4 *b* | +1.4 *a* | +0.4 *a* |
| | 3rd | +1.4 *b* | +2.6 *b* | +1.0 *a* | +0.2 *a* |
| | 4th | −3.8 *c* | −0.2 *a* | +0.9 *a* | 0.0 *a* |
| | 5th | −5.8 *c* | −4.4 *c* | −5.1 *b* | 0.0 *a* |
| Nonuniform kernel size (cv. 7740) | 1st | +3.9 *a* | +0.8 *a* | +1.1 *a* | +0.3 *a* |
| | 2nd | +4.9 *a* | −0.1 *ab* | +1.0 *a* | −0.5 *a* |
| | 3rd | +3.0 *a* | +0.4 *ab* | +0.8 *a* | +0.7 *a* |
| | 4th | −2.9 *b* | +1.1 *a* | +0.8 *a* | +0.6 *a* |
| | 5th | −9.0 *c* | −2.2 *b* | −3.5 *b* | −1.0 *a* |

†Apron width for this column was 6.0 mm. For the other three columns, it was 4.5 mm.

*a–c* Figures within a column for the same cultivar and followed by the same letter do not differ significantly ($P = 0.05$) according to Tukey's test of significance.

Plus sign indicates seeds are heavier than mean wt; minus indicates they are lighter.

promote feeding of larger seeds first, resulting in selective counting. We investigated the tendency for the feeder to segregate wheat (*Triticum aestivum* L.) into weight classes. Groups of about 1,000 kernels were taken at random from a large sample. They were dumped into the bottom of the feeder bowl and allowed to move up the spiral ramp in the normal fashion. Seeds were collected as they were dispensed in five consecutive groups of about 200 seeds each and the average seed weight was determined for each 200-seed group. The test was repeated on 10 different 1,000-kernel groups for each of four combinations of apron width and vibrator amplitude. Both a uniform kernel size (cv. Red Bobs) and a nonuniform kernel size (bulk cross designated 7740) wheat were used.

The general trends were for heavier kernels to be counted out first and for greater segregation at larger vibrator amplitudes (Table 2). With a vibrator amplitude of 5.0 (about 500 seeds/min) there was no significant segregation by weight.

When designing experiments where the seed counter is to be used, segregation should be anticipated for seed of all species and steps taken to minimize the effects. Significant errors can occur when counting out successive lots of seed from a large batch for average seed weight determination. The effects of segregation can be nullified by dumping a randomly selected lot of seed into the feeder bowl and counting out the entire lot before dumping the next lot in. Average seed weight can be calculated on the basis of the number of seeds in each lot.

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