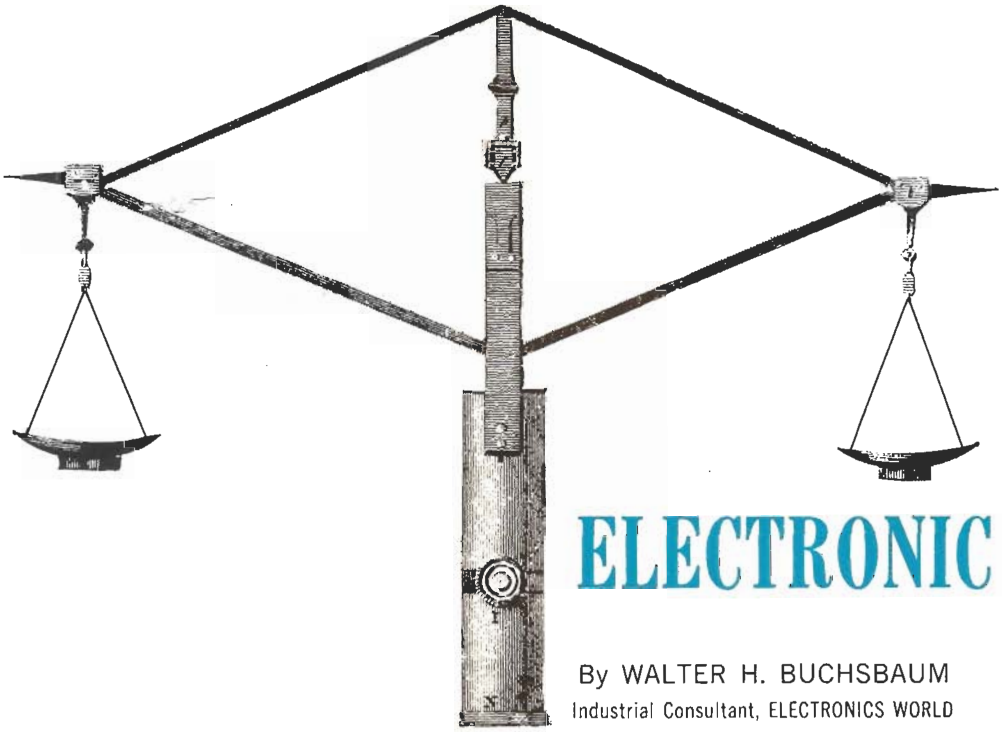


ELECTRONIC WEIGHING

By WALTER H. BUCHSBAUM
Industrial Consultant, ELECTRONICS WORLD

Electronic devices speed up automated weighing, mixing, and packaging operations and assure higher product uniformity in many industries.

NOT SO many years ago we were accustomed to go to the grocery store and have the clerk weigh out a pound of sugar by dipping the scoop into the barrel and pouring the sugar slowly on the scale. When we consider the labor that would be involved if we were to depend on hand weighing for all the things available in a modern supermarket, we realize how important automatic weighing processes are. Few of us, however, are aware of the important part that electronics plays in weighing, nor does the layman appreciate how widespread and vital automatic weighing is to all phases of our economy.

In addition to food, practically all chemicals, plastics, and other raw materials of modern industry are weighed prior to processing. Weighing is an important industrial process not only for packaging but also in mixing. Weight is further used as a measure of quality control on such diverse items as steel pipe and foundry sand. In pipe it is a measure of pipe uniformity and in foundry sand it indicates the amount of moisture present.

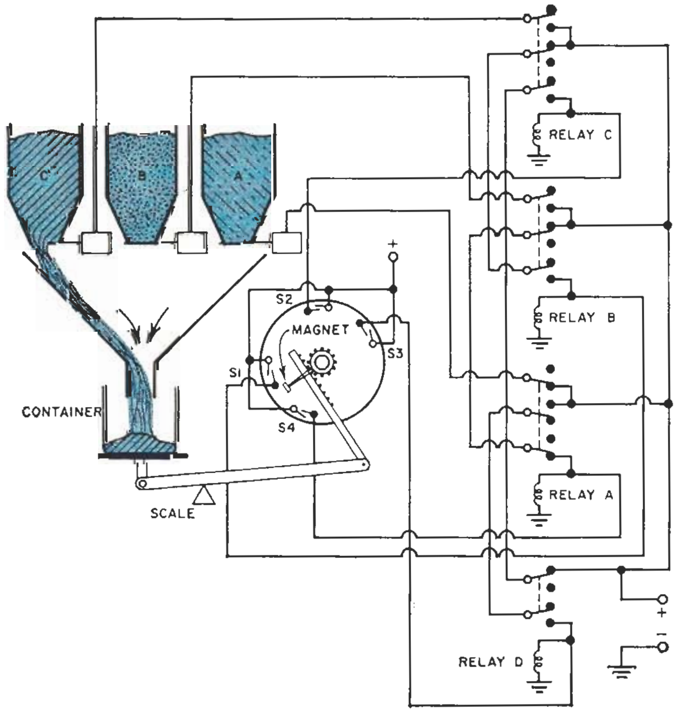
The field of weighing is large and well established but the addition of electronics is a new feature. While the electronic principles involved are well known and not very sophisticated, all-electronic weighing systems can become quite complex. The examples given here are intended to illustrate the basic configurations which are widely used where electronics and scales are combined.

The Functions of Electronics

The contribution that electronics makes to automatic weighing is in three separate areas. Electronic devices are used to detect when the scales are balanced, they also measure the weight itself, and they record the weight. In many automatic weighing systems the weighing and recording are an integrated process, almost entirely dependent on electronic circuits, but these systems usually deal with relatively large weights, not pounds or ounces. Where weighing is part of an automatic packaging process, such as filling sugar bags, the scale is usually a mechanical balance, similar to the one the druggist uses. The electronic device senses when balance is reached and actuates a shut-off gate. Because electronic devices operate almost instantaneously, the weight will be exact, without overflow or underweight.

In practically all industrial scales the counterweight is much less than the weight to be measured and balance is obtained by mechanical leverage. A very simple system of balance sensing involves a switch actuated by the scale-beam motion, as shown in Fig. 2. While industrial systems are usually more complex, this illustration contains the basic elements which make up more complex systems. As the material pours into the bag, the scale beam tilts upward until, at the correct weight, the switch is tripped. This opens the holding circuit for the solenoid which controls the flow of material. The spring working against the solenoid now pulls the shut-off gate across the loading funnel. When the full bag has been replaced by an empty one, the scale indicator will move down, closing the switch and actuating the solenoid again. The flow of material starts again. There is a moment in this cycle, when the full bag is removed and before the empty one is in place, when the solenoid gate should be closed to prevent material from spilling. This is accomplished by inserting a latching

Fig. 1. Simplified schematic of a reed-switch batching scale system.



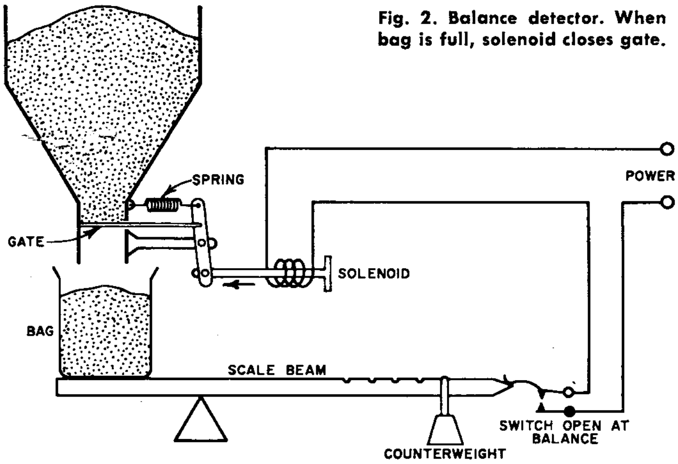


Fig. 2. Balance detector. When bag is full, solenoid closes gate.

relay between the shut-off switch and the solenoid. A second switch then resets the latching relay either after a fixed time or when the empty bag is in place. Here is room for additional electronic controls such as a photo-electric system to detect the presence of an empty bag.

Industrial scales use a variety of motion-sensing devices for balance detection. Typical of them are variable capacitors, variable inductors, photocells, magnet-operated switches, and differential transformers. In one unique system made by *The Howe Scale Company* an ordinary circular dial scale is converted to automatic balance detection by attaching a small Alnico magnet to the scale pointer. A second stationary pointer containing a miniature reed switch is then set to the desired scale reading. When the regular scale pointer comes up to the preset pointer the magnet pulls the reed switch together and the electronic circuit then actuates whatever controls are required to stop the flow of material.

Fig. 1 illustrates how a set of four such reed switches can be applied to mix three different materials into a single-batch container. As material *A* pours into the container on the scale, the pointer carrying the magnet approaches switch S_1 which closes and energizes relay *B*. When relay *B* is energized, it removes power from the holding contact on relay *A*, causing it to open, thereby closing the gate on material *A*. Relay *B*, when energized, supplies power to the solenoid in material *B*'s bin. Relay *B* is held closed by its holding contact which receives power from relay *C*, as long as relay *C* is open.

When the magnet pointer reaches the next weight level, switch S_2 closes and energizes relay *C* which shuts off material *B* and lets material *C* flow into the container. At the final weight switch S_3 is closed and *C* is shut off. Only when the pointer returns to the weight of the empty container and the magnet closes switch S_1, and through it relay *A*, is material *A* again allowed to flow. Each switch is closed only during the time that the magnet pointer is opposite it. It is therefore necessary to use holding contacts on each relay to keep it closed. Each successive relay supplies holding power when it is open to the preceding relay. The arrangement is a typical ring-relay circuit that can be replaced by a four-position stepping switch.

Probably the most widely used device for balance detecting is the differential transformer. This device is also used in motion-sensing of many industrial devices and its principles should be understood by anyone interested in industrial electronics. The circuit diagram of Fig. 3A shows that the output signal at the secondary will depend on the amount of coupling provided by the movable iron core. The motion of the core is mechanically linked to the balance beam of the scale, or to whatever motion the device is intended to report. A more complex differential transformer is shown in Fig. 3B. Here the output voltage of one secondary winding will increase as the other one decreases. When the core is exactly in the center the two secondary outputs will be equal. As the core moves, their difference is a measure of core motion. Most differential transformers use bifilar windings so that primary and secondary wires are wound together for maximum coupling.

One reason why differential transformers are so widely used is because their output signal is a sine wave, directly applicable to servo control systems. In a more sophisticated version of the basic system shown in Fig. 2, the output of a differential transformer would drive a servo system which would then control the flow of material.

Electronic Weight Measurement

All mechanical scales operate on the principle of balancing the gravitational force of the unknown weight with a known force, either as counterweight or spring tension. To determine weight by electronic means, the gravitational force is often measured directly by means of transducers. These devices convert force into an electrical signal. Probably the simplest such transducer is the strain gage in which the change in resistance of a wire grid due to elongation is proportional to

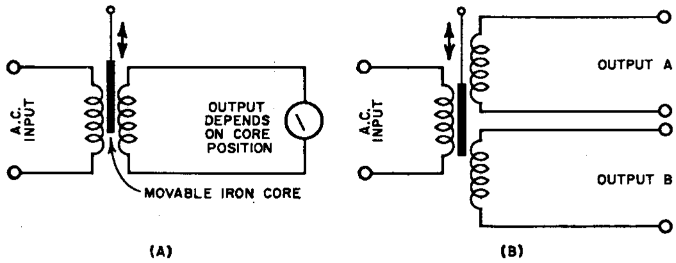


Fig. 3. Basic single (A) and dual (B) differential transformers.

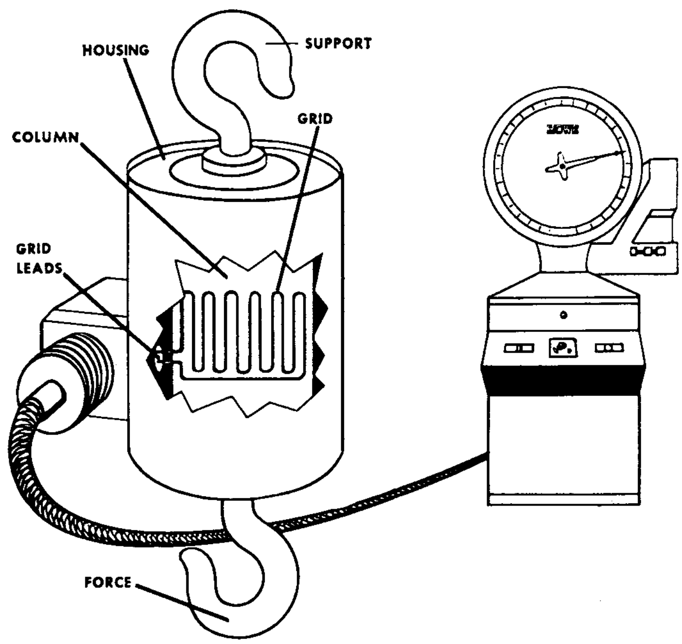
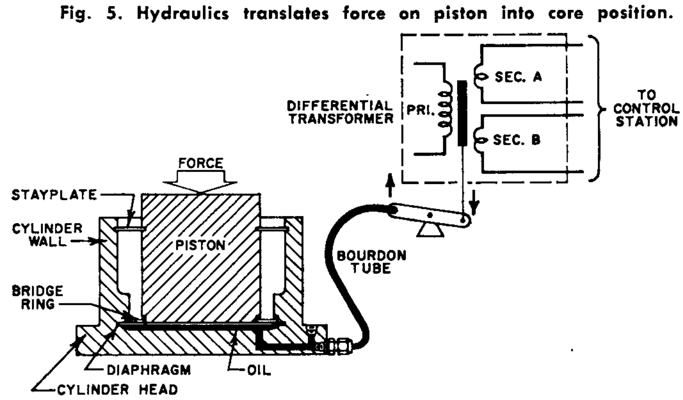


Fig. 4. In strain-gage transducer, weight changes resistance of grid.

Fig. 5. Hydraulics translates force on piston into core position.



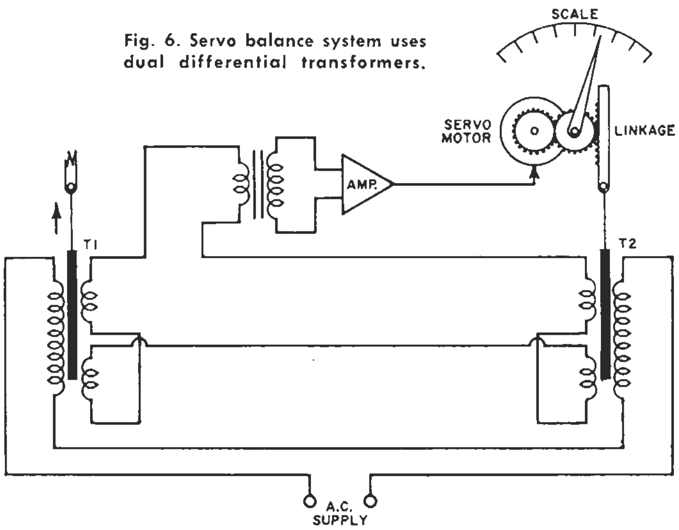


Fig. 6. Servo balance system uses dual differential transformers.

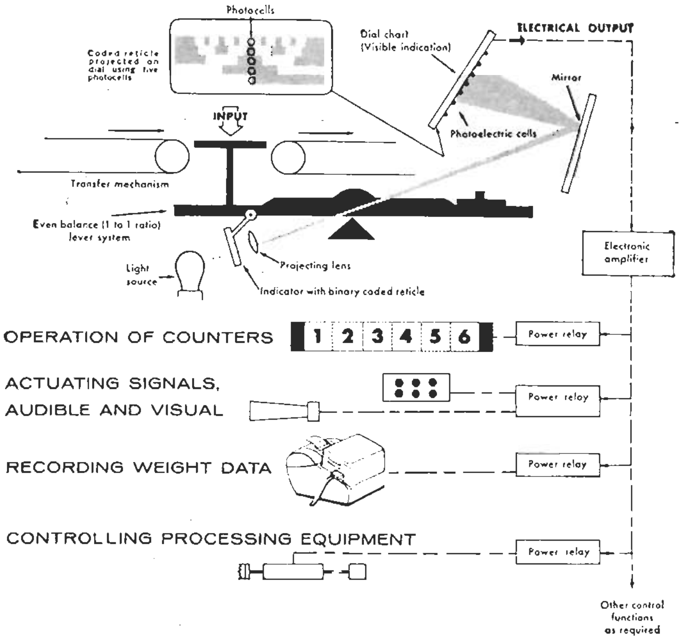


Fig. 7. Outputs of shadowgraph scale system have several functions.

the force applied. Fig. 4 shows such a resistance grid bonded to the column. When the column is stretched, the grid will stretch too. This reduces the cross-section of the vertical conductors and therefore increases their resistance. If the grid is part of a balanced Wheatstone bridge, the change in resistance will upset the balance and cause an error signal, proportional to the weight, to appear across the meter. Strain gages are widely used in industrial electronics and were described in some detail in the May, 1960 issue of this magazine.

In electronic weighing, the assembly which converts weight into a signal is usually called a load cell; the most widely used type is basically hydraulic. Electronics enters only to convert the hydraulic force into an electrical signal which can conveniently be transmitted and measured. A basic hydraulic load cell, shown in Fig. 5, consists of a large diameter piston, held concentric by the stayplate and the bridge ring, which "floats" on oil. As the piston is forced down, it exerts pressure on the oil which is passed through a very narrow tube. Although the motion of the piston may only be .005 inch maximum, the difference in diameter between the piston and the tube results in a much larger motion of oil in the tube in accordance with hydraulic principles. If the tube is curved and sealed at the end, it will be stretched as the pressure increases. This is called a bourdon tube and is used in many hydraulic systems to indicate oil pressure. In electronic weighing systems the motion of the bourdon tube is sensed by a differential transformer whose movable core is mechanically linked to the end of the tube as shown in Fig. 5.

The basic circuit for null balancing is shown in Fig. 6; it is used in practically all weighing systems which depend on differential transformers. Note that both primaries and secondaries of the transformers are connected in series although in other systems this is not always the case. A matching transformer links the difference signals to the input of the servo amplifier but in other systems a resistor network performs the same function. As long as a difference signal exists at the servo amplifier, power will be supplied to the control winding of the servo motor which will turn to pull the core of transformer T_2 to match the position of the core of T_1, the sensing device for the load cell.

Electronic Weight Indication

If we add another gear train and a counter to the linkage of the circuit of Fig. 6, the weight can be indicated directly in numbers instead of by the pointer on the scale. If the servo system were replaced by a digital voltmeter which measures the output of differential transformer T_1 we would have an indication of weight in digital form, both visually and electrically. Actually the most widely used means of reading weight electronically is with a digital shaft-position encoder. This device translates shaft position into a binary number by means of a printed-circuit pattern on a disk and a set of stationary contacts. The position of the shaft determines the electrical connections that are made. If the shaft is geared to the servo motor then the output of the encoder can be used directly to furnish binary data to a computer or automatic printer. There are also a number of all-electronic devices which convert an a.c. or d.c. voltage into pulse trains with binary codes. These so-called A/D (analog-to-digital) converters constitute a highly specialized field in themselves and while they will often be found in industrial installations, their servicing should be left to qualified specialists.

Practically all electronic weighing systems that provide a numerical display or which furnish data to a computer use some means of converting the analog output of the scale into a digital signal. One unique method of providing both a visual scale indication and a digital read-out is used in the so-called shadowgraph scale. As illustrated in Fig. 7 the scale is an even-balance type with a counterweight. The indication is by means of a light beam which is formed by a reticle mounted on the scale beam. By adding a binary coded portion to the reticle and a set of photocells adjacent to the dial chart a binary output of weight indication is obtained.

This binary signal can be used either to drive a counter, actuate certain signals, drive a data printer or some other control equipment. This type of scale is used in such special applications as coin counting as shown in Fig. 8. A carefully counted roll of coins is used as a checkweight and the shadowgraph indicator shows the amount of over- or under-weight. At the same time this information can be recorded to keep count of large amounts of coins. ▲

Fig. 8. Shadowgraph coin-counting scale is basically the same device shown in Fig. 7. Roll of coins is balanced against an exact count of coins in another roll. Over or underweight condition is indicated by projecting a line on translucent scale.