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(54) DIGITAL DISPLAY BALANCE

(71) We, METTLER INSTRUMENTE AG, a body corporate organised and existing under the laws of Switzerland, CH-8606, Greifensee, Switzerland, do hereby declare the invention for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:-

The invention relates to a digital display balance.

A digital display has been proposed, comprising a first weighing range or coarse weighing range, and a second, smaller weighing range which forms a fine weighing range. The coarse range provides a display which is coarser by at least one decimal place than the display associated with the fine range. The balance includes a device for switching over from one weighing range to the other.

It will be seen therefore that this construction provides for adaptation of the degree of sensitivity of the balance to the weight of the material to be weighed. In the abovementioned proposed balance, the action of switching over from one weighing range to the other is automatically effected by means of a relay. In another form of such a balance, the switching-over action is effected by a manual range-switching circuit.

A common feature of all the previously proposed balances as just described, is that the weighing ranges have the same zero point. In other words, when the load on the balance reaches a value which corresponds to the highest value in the fine weighing range, further weighing can only be in the coarse range.

However, situations may often arise in which this limitation is troublesome, for example when the balance is used for successively weighing a number of components into a mixture, and/or when a taring operation is to be effected on a balance with a subtractive tare, i.e. a balance in which the weighing range is reduced by the tare value.

According to the present invention, there is provided a digital display balance which provides at least a first weighing range and a second smaller finer weighing range, including: a display means which for the first weighing range provides a display which is coarser than for the second weighing range; and a device for changing over from one weighing range to another, the change-over device including control means operable to produce a change-over to the zero point of the second weighing range, at any point within the first weighing range.

Where the balance has an external tare-actuating element or taring switch, the control means is preferably associated with the taring switch, so that there is no need for an additional range change-actuating element, and changing over to the fine range and taring occur synchronously.

Normally, operation with a two-range balance is such that when the upper limit of the fine range is exceeded, the display is extinguished or a signal lamp indicates that the fine range limit has been exceeded. A preferred embodiment of the balance of the invention however provides that a circuit is associated with the display means, which circuit shortens the displayed weighing result by at least one decimal place when switching over from the fine range to the coarse range. In this way the operator is provided with a display which is correct but which has only been shortened, and there is no need to shift the decimal point, although with this arrangement, it is obviously necessary to accept the disadvantage that the display means must have an additional decimal place. To avoid this, another embodiment provides that a circuit is associated with the display means, which circuit displaces the decimal point by at least one place, when there is a change of range, while the number of decimal places displayed remains constant.

In order to increase the range of possible uses of the balance, a further embodiment of the balance has a switch which prevents a change of weighing range. This switch may be employed in circumstances in which constant absolute precision is required, and therefore weighing is effected only in the coarse range. Also, such a switch provides that the change of range can be prevented when weighing a load which is close to the change-over limit between the ranges, as in such circumstances the balance could jump backwards and forwards from one range to the other, unless the switch were actuated.

In a further embodiment of a balance according to the invention, a respective linearisation means is associated with each weighing range for reducing any non-linearity in the weighing characteristic of the balance, and the change-over from one weighing range to another is coupled to a change-over of the linearisation means. When using a micro-computer, as described in greater detail below, these linearisation means may be in the form of suitable programming.

Frequently, the weighing characteristic of a balance is so curved that its non-linearity markedly increases in the upper part of the weighing range, so that for example the part of the range from 0 to half load will permit a higher degree of display resolution than the part of the range from half load to full load. On the other hand, the users of balances, in particular users who are faced with frequent variations in the weighing operations which they are required to perform, often require a middle range with a constant zero point, in addition to a coarse and a fine range with a variable zero point.

To meet this requirement, a further embodiment of the invention also includes a third weighing range which is greater than the fine range but has a higher degree of display resolution than the coarse range, a switch being operable to switch to and from the third weighing range. Depending on the nature of the balance and the choice of degree of resolution, it may be possible, with this construction, to omit the abovementioned linearisation means.

When the balance is in the form in which the load to be weighed is electromagnetically compensated, using current pulses of constant amplitude, the length of the current pulses being counted by high-frequency clock pulses produced by a timer or clock pulse generator to provide a digital display of the weight, the balance is preferably also provided with a constant current source which can be switched over between different output current strengths, and with a frequency divider connected to the output of the timer or clock pulse generator.

Embodiments of a balance according to the present invention will now be described by way of example with reference to the accompanying drawings, in which:-

Figure 1 shows a block circuit diagram of a first embodiment of the balance,

Figure 2 shows an alternative form of the Figure 1 circuit,

Figure 3 shows a block circuit diagram of a third embodiment of the balance,

Figure 4 shows a block circuit diagram of a fourth embodiment,

Figure 5 shows a block circuit diagram of a fifth embodiment, and

Figure 6 shows a block circuit diagram of a sixth embodiment,

Reference will be made to Figures 1 and 2 showing in diagrammatic form a circuit of a digital display balance in the form of a string balance of known kind (see for example US Patent specifications Nos. 3 788 410 and 3 897 681). The balance 10 includes a pretensioned measuring string which performs a transverse vibrating or oscillating movement at a frequency f_s which varies according to the load on the balance. The string frequency is applied to one input of a gate 12 whose output is applied to a settable up-down counter 14. The output frequency f_r (which may possibly be reduced) of an oscillator 16 is applied to the second input of the gate 12, to determine the period during which the vibration frequency of the string is measured or counted. The pulses which are fed into the counter 14 by the gate 12 within a measuring period (or a predetermined plurality of measuring periods) and which are a measurement of the load to be weighed are passed from the counter 14 to a display store 18 and thence to a five-place display means 20. The Figure 1 circuit also includes an up-down logic unit 22, a tare store 24 and a counter control 26. The balance also has an externally actuated taring switch or button 28 which is actuated to take account of a tare weight whereby the nett weighing result will be displayed in the display means 20.

The circuit arrangement described thus far is known, but the Figure 1 circuit of the invention also includes a connection between an output of the counter 14 and the display means 20 and another between the tare button 28 and the display means 20. The counter 14 has a capacity of 5 places, which can give a coarse range of 1,000 g (maximum display value 999.9 g). At the beginning of each weighing operation, the display is a five-place display. If the weight to be weighed remains in the fine range (10% of the coarse range, that is to say, a range of 100.00 g), then nothing is changed in this respect, and the display means 20 shows the higher degree of sensitivity of the fine range. If the weight is or becomes greater than the upper limit of the fine range, the last place (denoted at reference 30 in Figure 1) is masked; thus, when the fourth decimal place (corresponding to 100.00 g) of the counter 14 is full, the counter 14 gives a signal to the display means 20, which accordingly masks or extinguishes the last displayed place, and the display means now operates in the coarse range, with a display which is shortened by one place after the decimal point.

If now a taring operation is effected, the taring order simultaneously causes reactivation of the last place 30 in the display means 20. As the counter 14 counts the nett weight from zero onwards, after calculation of the tare weight, the entire fine range up to the limit of 100.00 g is again available.

This process can be repeated, for example when weighing in a plurality of components, until the maximum capacity of the coarse range (corresponding to the maximum weighing range of the balance) is reached.

The order for activation of the last place 30 of the display means can either be tapped directly from the taring order or it can be derived from the passage-through-zero of the counter 14.

The oscillator 16 which is used in the illustrated circuit as the time base can be replaced in known manner by a reference string having an oscillation frequency which is independent of the weighing load.

Figure 2 shows an alternative form of a circuit which in many cases may be preferred to the Figure 1 circuit. In Figure 2, use is made of the possibilities afforded by a micro-computer 32. The frequency representing the load to be weighed by the balance and the output frequency f_r of the oscillator 16 are applied to the inputs of the gate 12, as in the Figure 1 circuit, and the gate output frequencies are applied to a counter 14 (which is only a unidirectional counter). The counter states are fed to a micro-processing unit (CPU) 34 which effects calculation of counter states with an operation store or Random Access Memory (RAM) 36 in accordance with programs in a fixed value store or Read Only Memory (ROM) 38, and passes the result to the display means 20'. A taring switch 28' is provided to trigger a taring cycle, as referred to above.

In the Figure 2 circuit the display means 20' has a floating or sliding decimal point, that is to say, when there is a change in the display range, the decimal point 40 is shifted by one place.

As mentioned above, in many cases it may be necessary to prevent a change of range. For the purpose, Figure 2 circuit has a switch 42 for controlling the microcomputer 32. When the switch 42 is actuated, the balance is converted from a dual-range balance into a single-range balance which provides only the coarser display range, irrespective of the magnitude of the weight, and the change of range is thus suppressed.

Using the micro-computer 32 also makes it possible to perform individual linearisation calculations, by suitable programming for the coarse and fine ranges.

Reference will now be made to Figure 3 which shows a third form of balance 10' comprising an electromagnetic compensation arrangement which operates with compensation current pulses, and a taring calculation arrangement as described in detail for example in US Patent specification No. 3 786 884. When a load to be weighed is placed on the balance, a position detecting and transmitting circuit 44 produces a signal which, in a control and comparison circuit 46, periodically determines the length of time for which a compensation current i is cut in; the pulsed compensation current i is thus fed to a compensation coil 11 disposed in the field of a permanent magnet, producing an electromagnetic compensation force. In a condition of equilibrium between the load on the balance and the electromagnetic compensation force, the length of the current pulses is a measurement of the load. This pulse length is counted in a counting and taring circuit 48 by means of high-frequency clock pulses from a timer in the form of an oscillator 16', and the sum of the clock pulses is periodically fed to a display means 20.

In this embodiment also, as in the Figure 1 circuit, the last decimal place 30 in the display means is masked when the counter circuit 48 exceeds a predetermined decade. If a taring operation is initiated, by acutation of a taring switch 28", the last decimal place 30 is re-activated, and the fine weighing range is made available, again for the subsequent weighing operation.

As in the modified circuit shown in Figure 2, a micro-processing unit could be used in the Figure 3 circuit.

Figure 4 also shows the circuit of a balance 10" with an electromagnetic compensation arrangement which however in this embodiment operates in known manner in an analog fashion, that is to say, a continuous direct current i is fed to the compensation coil 11′ to produce the electromagnetic compensation force. The magnitude or amplitude of the continuous direct current *i*, which is proportional to the load to be weighed on the balance, is determined by a signal produced by the position detecting and transmitting circuit 44′ and fed to a control amplifier 50. The strength of the compensation current *i* is tapped off in a voltage form at a measuring resistor 52 and digitised in an analog-to-digital converter 54. The digital output of the converter 54, representing the load-measurement results, is fed to a micro-computer 32′ in which it is processed in accordance with the respective program, as described above with reference to Figure 2.

In this embodiment also, the micro-computer 32′ provides for changing over the display means 20″ from the fine to the coarse range, and vice-versa, after actuation of the taring switch 28‴.

Figure 5 shows an embodiment comprising a spring balance 10‴ which has electrical sensing of the spring movement, as described for example in German Offenlegungsschrift No. 23 25 654. A deflection signal U, which is proportional to the load to be weighed by the balance, is passed to a measuring amplifier 56 whose output is fed to an input of a differential amplifier 58. The output of the amplifier 58 is then passed to an analog-to-digital converter 54′ whose output is there passed to the display means 20‴. Associated with the converter 54′ is a range switching unit 60 including a threshold switch which, for example when the maximum limit of the fine range is reached, switches over the converter 54′ from the fine weighing range to the coarse range, and simultaneously shifts the decimal point 40 in the display means 20‴.

The digital output signal from the converter 54′ also determines by way of a switch 28*a* the magnitude of an opposing voltage produced by a suitable unit 62. For taring purposes, a switch 28⁗is opened and switch 28*a* is closed at the same time. The voltage produced by unit 62 assumes the actual value of the reconverted output signal from the A/D converter 54′. After the switch 28*a* has been opened again and the switch 28⁗ has been closed again, the new opposing voltage 62 is applied to the second input of the differential amplifier 58; thereafter, until there is a further change in the load on the balance 10‴, the difference between the opposing voltage of unit 62 and the load signal U is zero. Therefore zero will appear in the display means 20‴, and the range switching unit 60 is switched over to the fine range again. Upon an increase in load to be weighed on the balance 10‴, the difference between the two inputs of the differential amplifier 58 appears as a nett weight display, in the fine range with the highest degree of resolution.

Reference will now be made to Figure 6 which shows a further development of the embodiment of Figure 3. The Figure 6 balance includes an additional switch 64 which is operatively linked to a further switch 66. The switch 64 is connect by line 65 to the counting and taring circuit 48, which may also be referred to as a digital evaluation circuit, and provides that switching the balance over to the coarser degree of resolution, is not effected in the circuit 48, when the balance reaches the limit of the fine range. Thus, it will be seen that the switch 64 is also connected by line 67 to a constant current source 47 which can be switched over between difference output current strengths by actuation of the switch 64. Switch 66 serves for switching in a frequency divider 17 connectible to an output of the timer or clock pulse generator 16′.

Reference may be made to a numerical example to clarify operation of the Figure 6 balance. The fine range may be for example 300grams, with a degree of resolution of 10 mg, while the coarse range may be 3000 g, with a degree of resolution of 100 mg. When operating as a two-range balance with a variable zero point on the fine range, after each taring operation the balance is switched over its higher degree of resolution (or retains such higher degree of resolution) by actuation of the switch 28″. By way of the circuit 46′, the current source 47 supplies compensation pulses at the full output current strength, which are counted out at the full frequency of the oscillator of clock pulse generator 16′.

If an article or load weighing more than 300 g is to be weighed, the third range which is for example of 1500 g, with a resolution 10 mg and with a constant zero point, is cut in by actuation of the switch 64. At the same time the current source 47 is switched over to half its output current strength, and, by cutting in of the diviider 17, counting pulses at half frequency pass into the circuit 48.

When the balance exceeds the middle range, the display means 20 is controlled to a darkened condition; in order then to cause the weighing result to be displayed in the display means 20, the switch 64 is actuated again, whereupon the weighing result appears with a degree of resolution which is coarser by one position, and the balance then operates again as a two-range balance.

Incorporating the divider 17 in conjunction with the controllable current source 47 provides the advantage that the control and comparison circuit 46′ can operate with a higher degree of precision as the influence of switching flanks and noise effects is markedly reduced. If however such influences can be tolerated, the divider 17 and the switch 66 may be omitted and the current source 47 does not have to be of such a kind that it can be switched over from one output current strength to another.

The embodiment of Figure 6 was described above, as a development of the balance of Figure 3, i.e. with electromagnetic force compensation with current pulses. However it will be understood that the other embodiments may be modified in a similar manner, by reference to Figure 6.

Here also the use of a micro-computer will make it possible to provide more refined embodiments of the invention.

It will be understood that many other variations or modifications may be made without thereby departing from the scope of the invention as defined by the appended claims, and similarly parts of the different embodiments described above may be combined in various ways, so that there is an automatic change in the display when there is a change from one weighing range to another. It will be appreciated that a fresh fine range can be started as often as desired and at any point on the weighing curve, within the overall weighing range of the balance. Operation in this way is of advantage for example when a specific degree of resolution is significant only over the part of the overall weighing range of the balance, because of problems in regard to linearity and temperature, and for example, when carrying out a succession of weighing operations between which the weighing pan is not relieved of load, e.g. when weighing a plurality of components into a mixture, as the range switching action provides the highest available degree of weighing sensitivity for each such successive weighing operation. The invention can in principle be used whenever there is a subtractive tare, that is to say, the overall weighing range is reduced by the tared value. The action of switching over from one weighing range to the other will advantageously have a switching hysteresis effect so that vibration of the balance will not result in "flickering" of the range switching action, i.e. the display repeatedly jumps backwards and forwards when the load being weighed by the balance is at the switching-over limit between the two ranges. On the other hand, it is possible to provide that the automatic range switching-over action occurs only when the balance exceeds fine range, that is to say, when the balance passes from the fine range to the coarse range, whereas when there is a reduction in the load to be weighed, then the display remains in the coarse range until for example a retaring operation has been effected.

The foregoing description relates to a balance construction which is generally the most frequently used, namely a two-range balance, together with an alternative form having a third range with a constant zero point, but it will be appreciated that the invention as claimed herein also includes balances with for example three ranges stepped preferably in a decade manner.

It will be noted that while the two weighing ranges in the above-described embodiments are stepped in a decade manner, other subdivisions are alternatively possible, for example the fine range may equal half the coarse range.

Furthermore, although in the above-described preferred embodiment the display in the coarse range is coarser than the fine range by at least one decimal place, it is not essential that the difference should be at least one decimal place. For example, the displays in the fine and coarse ranges may differ only in the degree of resolution of the last decimal place itself; for example in the fine range the last decimal of the display may be constituted by any number between 0 and 9, whereas in the coarse range the last decimal place may be for example only an even number (0, 2, 4, 6, 8), or may be of an even lower degree of resolution, for example 0 to 5.

Furthermore, for performing weighing operations for the purposes of monitoring or checking, or for operations involving the partial removal of material to be weighed from the weighing pan, the fine range may extend in the direction of reducing weight, that is to say, the fine range may be of negative values.

Finally, for specific cases it is also possible to envisage a balance according to the invention, in which by means of additional switches the balance can be temporarily switched to a fixed zero point in both or all ranges, in which case the balance operates as a conventional multi-range balance, and/or the balance can be switched to a darkened display after the weighing result has exceeded the fine range of the balance.

WHAT WE CLAIM IS:-

1. A digital display balance which provides at least a first weighing range and a second smaller finer weighing range, including: a display means which for the first weighing range provides a display which is coarser than for the second weighing range; and a device for changing over from one weighing range to another, the change-over device including control means operable to produce a change-over to the zero point of the second weighing range, at any point within the first weighing range.

2. A balance according to claim 1 wherein the first and second weighing ranges are stepped in a decade manner.

3. A balance according to claim 1 or claim 2 wherein the control means is associ-

ated with a taring switch.

4. A balance according to claim 1, claim 2 or claim 3 including a circuit which is associated with the display means and which is operative to shorten the displayed weighing result by at least one decimal upon a change from the second weighing range into the first weighing range.

5. A balance according to claim 1, claim 2 or claim 3 including a circuit which is associated with the display means and which is operative to shift the decimal point of the display means by one place, when there is a change from one weighing range to another, with the number of displayed decimals remaining constant.

6. A balance according to any one of the preceding claims further including a switch operable to prevent a change of range.

7. A balance according to any one of the preceding claims including a respective linearisation means associated with each range, the change of range being coupled to the change of linearisation means.

8. A balance according to any one of the preceding claims wherein the display in the first weighing range is coarser than the display in the second weighing range by at least one decimal.

9. A balance according to claim 1 further including a switch for switching over to a third weighing range which is larger than the second range but which has a higher degree of display resolution than the first range.

10. A balance according to any one of the preceding claims including means for electromagnetic compensation of the load to be weighed, by means of current pulses of constant amplitude, a constant current source which can be varied in respect of its output current strength, a clock pulse generator operable to produce high-frequency clock pulses for counting out the load-compensation current pulses and for digital display of the load being weighed, and a frequency divider connected to the output of the clock pulse generator.

11. A digital display balance substantially as hereinbefore described with reference to any figure of the accompanying drawings.

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1566392 COMPLETE SPECIFICATION

3 SHEETS *This drawing is a reproduction of the Original on a reduced scale*

Sheet 1

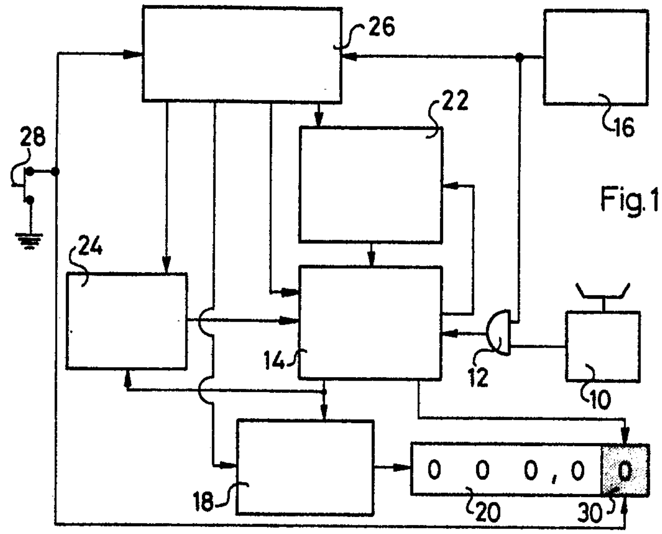


Fig.1

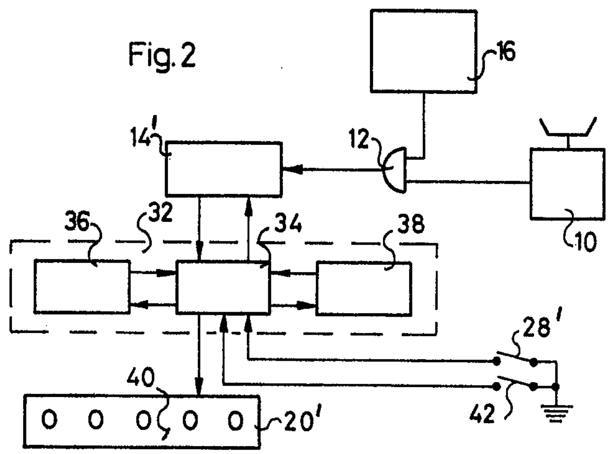


Fig.2

Fig.3

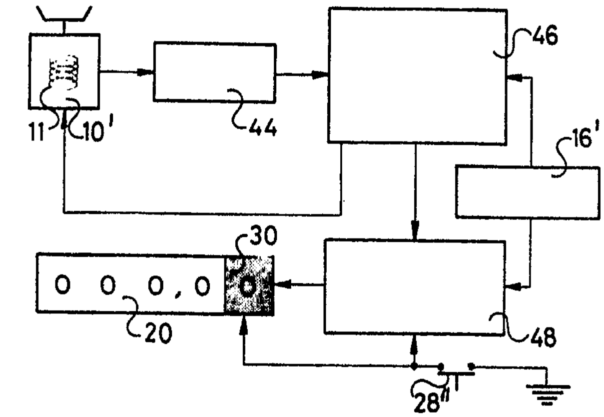
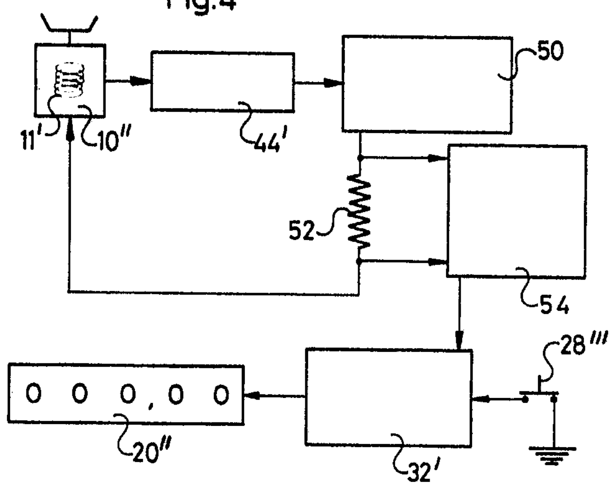


Fig.4



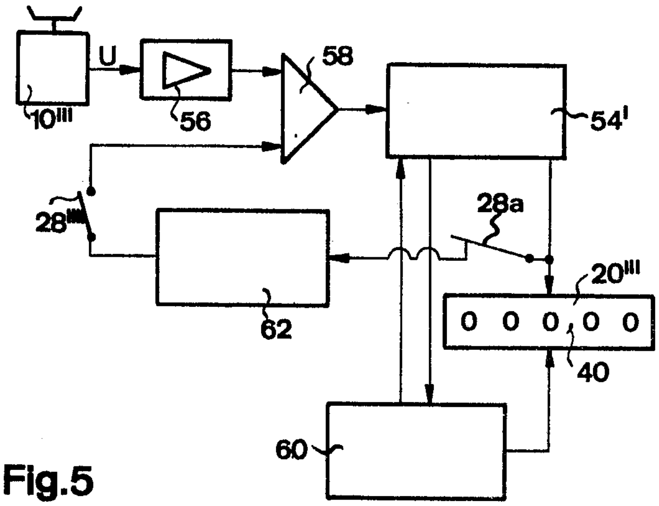

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Fig.5

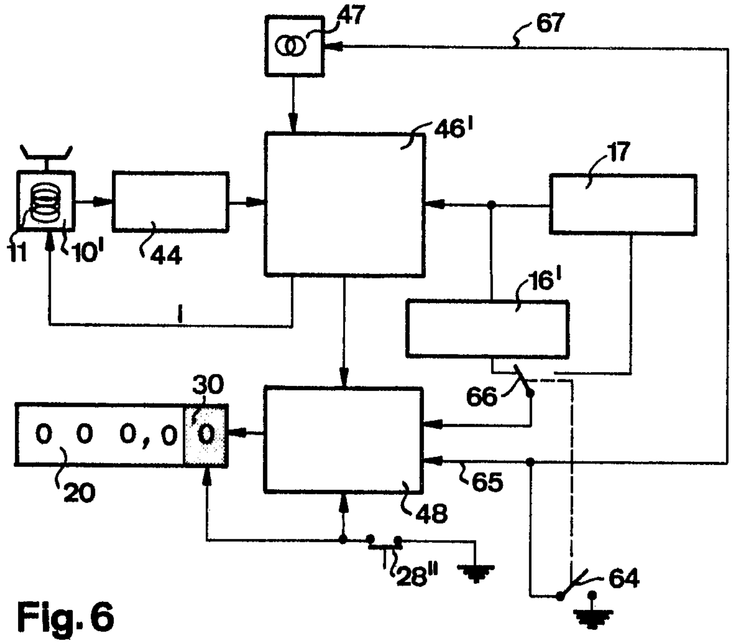
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Fig.6