

[54] **ELECTRONIC SWITCH ACTUATED BY PROXIMITY OF THE HUMAN BODY**
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 [58] Field of Search..... 307/116; 200/DIG. 1; 340/258 C

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[57] **ABSTRACT**
 An improved contact-less electronic switch, adapted to be actuated by the approach of a human hand, with a capacitive probe insulated against the chassis and installed in the zone of approach, and connected to a capacitance detecting circuit which delivers a switching signal when the capacitance is increased by the approach of a hand, wherein the improvement comprises that the switch remains unaffected by the approach of all other substances, such as metals or insulating materials.

13 Claims, 7 Drawing Figures

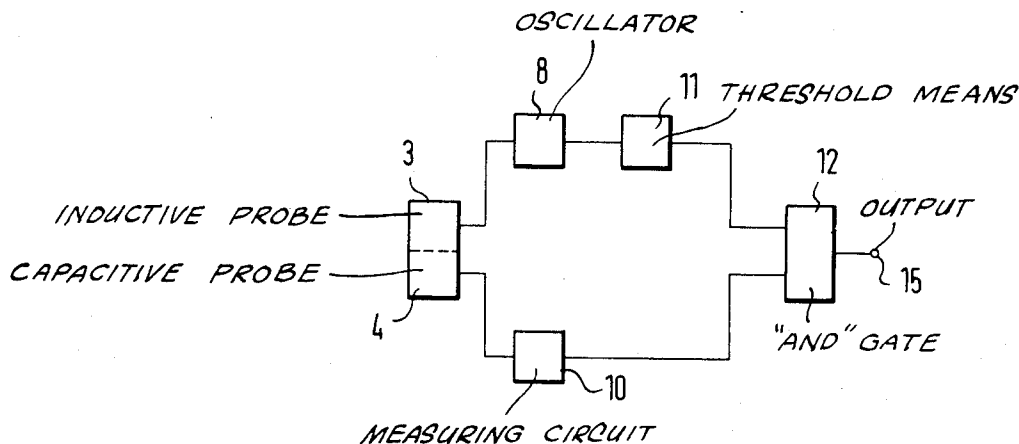


Fig.1

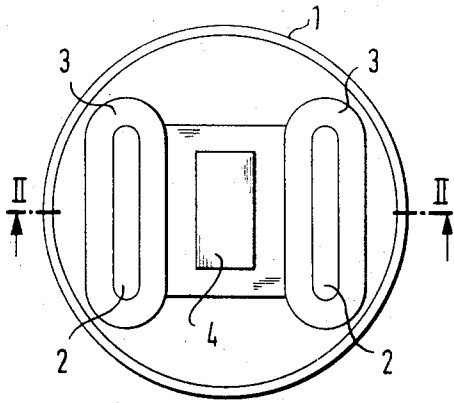


Fig.2

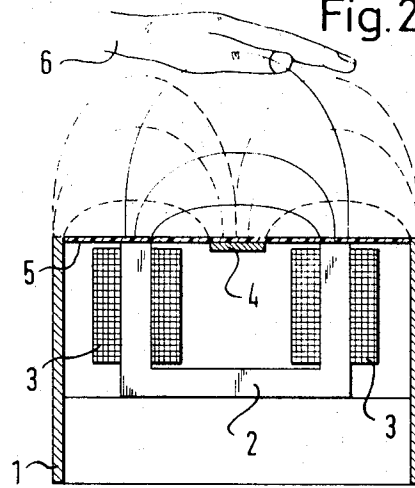


Fig.3

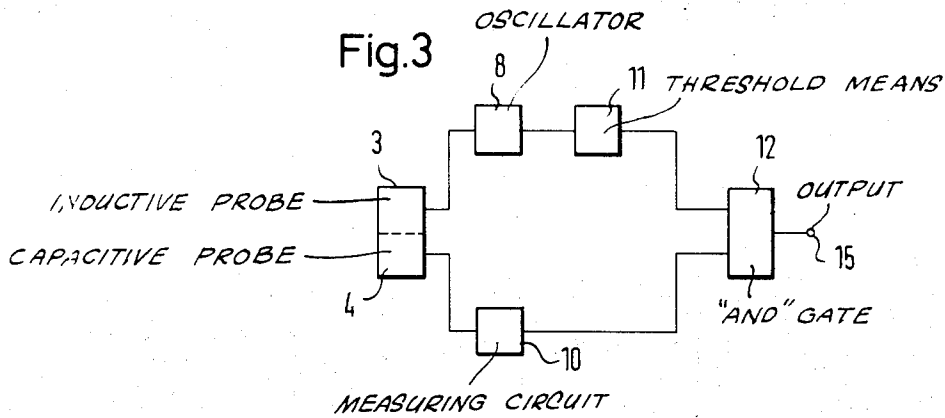


Fig.4

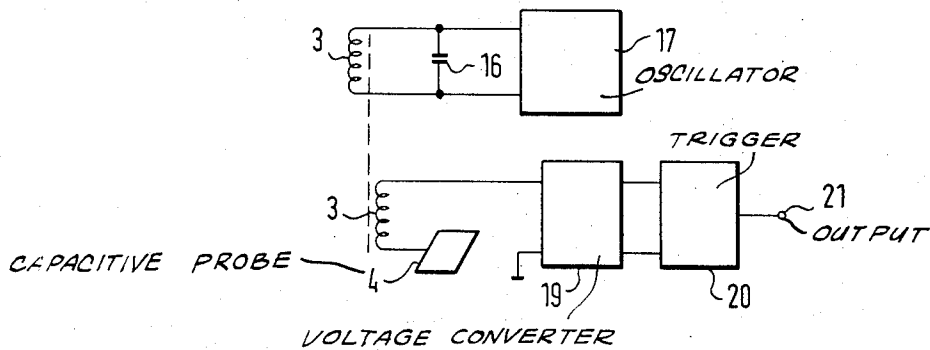


Fig. 5

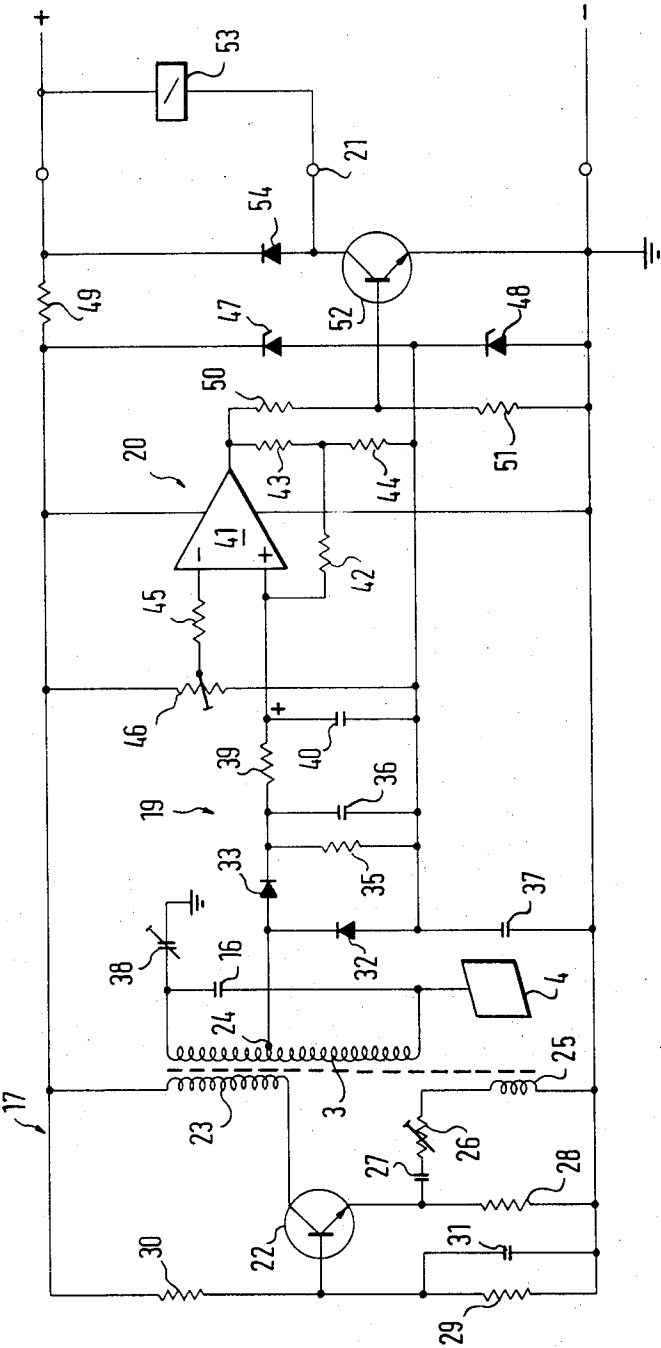


Fig.6

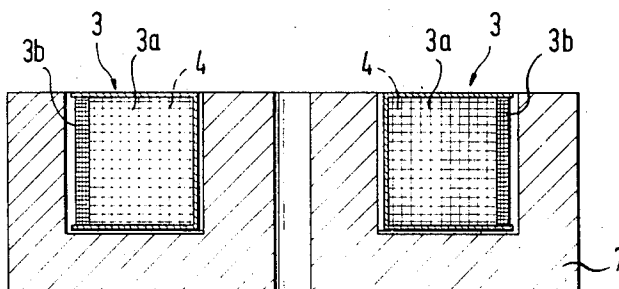
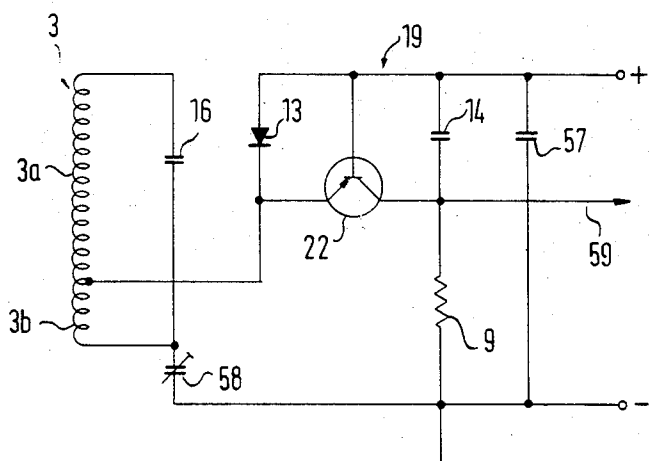


Fig.7



ELECTRONIC SWITCH ACTUATED BY PROXIMITY OF THE HUMAN BODY

BACKGROUND OF THE INVENTION

Such proximity switches are used extensively in engineering for initiating electrical switching processes, e.g. in elevators, in a contact-less manner.

In the case of dangerous machines operated by operators such as, e.g., paper guillotines, punches, or presses, a so-called two-hand operation is usual in which the operator must operate simultaneously two switches located outside the danger zone in order to initiate the potentially dangerous working stroke of the machine. The machine must stop immediately when even only one switch is released. In this manner, the operator is compelled to keep his hands outside the dangerous zone during the performance of the working stroke and is, therefore, protected against injury. Hitherto, the use of known capacitive proximity switches was impossible with these dangerous machines because the switches could also be operated, e.g., by placing on them a piece of metal. In this case, the operator might release his hands during the dangerous working stroke in order to accelerate the operation, which is usually paid according to piece rates, by actuating the switch by a piece of metal, and this is to be avoided under all circumstances.

SUMMARY OF THE INVENTION

It is, therefore, an object of the invention to provide an electronic switch suitable for use in the safety circuits of dangerous machines which responds only to the approach of a human hand or potentially to the approach of another part of the human anatomy, but which remains unaffected by the approach of all other materials, such as metals or insulators.

It is a further object of the invention to provide a switch of the type hereinbefore described, comprising an inductive probe supplied by an oscillator and whose magnetic field permeates the electric field of a capacitive probe mounted in close spatial relationship to the said capacitive probe and supplied a detection circuit which delivers a switching signal on the approach of a metal part at a larger distance than the capacitance measuring circuit, wherein the two switching signals are logically linked capacitance measuring circuit delivers a switching signal whilst the measuring circuit supplied by the inductive probe delivers no such signal. A metal part brought into the vicinity of such an electronic switch triggers off first the inductive measuring circuit, so that the logic interconnection according to the invention makes the release of the electronic switch immediately impossible. The approach of an insulating material, e.g. plastic, wood, glass, leather, paper and the like, does not affect either the inductive detection circuit, nor the capacitance measuring circuit, so that the logic interconnection according to the invention prevents a signal from being delivered also in this case.

If, on the other hand, a human hand approaches the switch, the inductive protection circuit does not respond owing to the low capacitance of the approaching object, whilst the capacitance of the capacitive probe is raised to such an extent that the capacitance measuring circuit delivers a switching signal. In this case, the conditions for the release of an approach signal are met. responds in principle also to the approach of other parts of the human body; misuse may be avoided simply

by mounting the switch in such a position that it can be reached only the operators hand.

According to the invention the capacitance measuring circuit is adjusted to such a low sensitivity that it does not respond to the approach of insulating material but to the approach of an electrically conducting body. Thus, the differential effects on the capacitance of such a probe by insulating materials on the one hand, and by materials with bad electrically conducting properties on the other hand are utilized.

It is a further object of the invention to provide an electronic proximity switch of the type hereinbefore described in which the capacitive probe is mounted in an insulated and earthed metal housing forming the counter electrode. In this manner, the capacitive probe forms a structural unit with the wall of the housing, thereby producing a compact arrangement without externally projecting parts which is also easy to clean.

Where separate oscillators are used, the oscillator supplying the inductive probe has preferably a frequency of a few hundred kc/s, whilst the oscillator connected to the capacitive probe operates preferably with frequency in the Mc/s range. In this manner sufficient currents are produced even with comparatively small probe capacitances.

It is a further object of the invention to provide an electronic switch of the type hereinbefore described in which the capacitive probe is supplied by the same oscillator as the inductive probe, and the sampling of the oscillator is a measure of the degree of approach of a metal part. Preferably, the oscillator operates at a frequency of the order of magnitude of a few hundred kc/s. This construction substantially reduces the complexity of the device and ensures the necessary logic interconnection simply in that the oscillator output voltage strongly declines or even collapses on the approach of a metal part, so that the capacitance measuring circuit does not receive a sufficient input voltage to enable it to indicate an increase in the capacitance.

Preferably, the inductive probe is a coil portion of the oscillator. Also this supports an extremely rational production of the electronic switch according to the invention.

Preferably, the initial capacitance of the capacitive probe is neutralized because this substantially increases the response sensitivity for increases in the capacitance.

To enable the sensitivity of the switch according to the invention to be adjusted, the response threshold of the trigger, and preferably also the regenerative coupling factor of the oscillator are adjustable.

It is a further object of the invention to provide a further structural and technological simplification of the switch hereinbefore described, wherein the oscillator coil or a part of this coil, forming the inductive probe forms simultaneously the capacitive probe. Thus, the invention utilizes the fact that every induction coil also has a capacitance against mass.

The part of the coil serving as capacitive probe is in this case substantially larger than the remaining part of the coil. The remaining part of the coil contributes in this case to the utilization of the initial capacitance.

Preferably, the part of the coil acting as capacitive probe is arranged in space non-symmetrically relative to the remaining part that in the case of the approach of an object changing the capacitance, the changes in the capacitances of the two coil portions against mass

are non-proportional. This is the condition for detecting changes in the capacitances by measuring techniques.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention will be further described by way of example with reference to embodiments shown in the accompanying drawings in which:

FIG. 1 is a plan view of the key portion of an electronic switch arrangement according to the invention;

FIG. 2 is a cross-section along the line II—II in FIG. 1;

FIG. 3 is a block diagram of the basic construction of an electronic switch according to the invention;

FIG. 4 is a block diagram of a substantially simplified embodiment of the electronic switch according to the invention;

FIG. 5 is a detailed circuit diagram of the object shown diagrammatically in FIG. 4;

FIG. 6 is an axial cross-section of a particularly preferred embodiment of a key portion for an electronic switch according to the invention;

FIG. 7 is a preferred circuit for evaluating the signals delivered by the key portion according to FIG. 6.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring now to FIGS. 1 and 2 of the drawing, a key portion of an electronic switch according to the invention is mounted in an earth, or grounded, metal housing 1. A U-shaped core of powdered iron is arranged in the housing 1 in such a manner that the ends of the two legs terminate at the level of the upper wall of housing 1. Induction windings 3, forming the inductive probe, are mounted on the two legs of the core 2.

Mounted symmetrically between the legs of the core 2 is a metal plate 4, which forms the capacitive probe. The top of the housing is covered by an insulating plate 5 on which the capacitive probe 4 may be mounted from the bottom, so that the housing has no protruding parts.

FIG. 2 shows also in solid lines the lines of the magnetic field, in dotted lines the lines of the electric field, and, by way of illustration, a hand 6 approaching the switch.

The earthed, or grounded, metal housing 1 forms the counter-electrode for the capacitive probe 4, so that approaches from the side of the housing remain ineffective.

The block diagram of FIG. 3 shows diagrammatically the connection of the inductive probe 3 and of the capacitive probe 4 forming the permeating fields. The winding of the probe 3 is the coil portion of an oscillator 8, operating at a frequency of a few hundred kc/s. The output voltage of the oscillator 8 is applied to a threshold means 11 with a threshold which supplies an output signal L during the normal operation of the oscillator 8 and an output signal O when the threshold of the oscillator output voltage is not reached.

The output of the threshold means 11 is applied to one input of an AND gate 12.

The capacitive probe 4, which is according to the invention structurally combined with the inductive probe 3, is connected with the housing 1 as counter-electrode to a circuit responding to changes in the capacitance, briefly referred to as capacitance measuring circuit 10; this circuit has also a threshold so that it delivers under

normal conditions an output signal O and supplies an output L' only when a certain increase in the capacitance of the probe 4 is present. The output of the circuit 10 is applied to the other input of the AND gate 12. Preferably, the capacitive probe 4 is supplied by an oscillator with a frequency of several Mc/s.

It is essential for the invention that during the approach of a metal object to the key portion of the electronic switch arrangement, according to FIGS. 1 and 2 the threshold in the threshold means 11 is not reached, before the threshold in the capacitance measuring circuit is exceeded.

Hence, the output 15 of the AND gate 12 delivers an output signal L' only if an L signal and an L' signal is present at its inputs. In all other cases, the output 15 carries the output signal O.

The operation of the electronic switch shown and explained in FIGS. 1 to 3 is as follows:

If a metal part is brought into the proximity of the key according to FIGS. 1 and 2, the oscillator 8 is damped and the output voltage of the oscillator 8 drops below the threshold of the gate 11, so that the corresponding input of the AND gate 12 receives the input signal O. Hence, the output 15 will deliver the signal O irrespective of the output of the capacitance measuring circuit 10. In other words, the switch will not be actuated even by approaching the metal part further to the key.

In the case that an insulating material, such as plastic, wood, glass, leather, paper or the like is approached to the key, the output voltage of the oscillator 8 does not drop below the threshold of the gate 11, so that the corresponding input of the AND gate 12 delivers the signal L even with the insulating material in close proximity. Since according to the invention the threshold of the capacitance measuring circuit 10 is so high that the comparatively low increase in the capacitance, caused by the insulating material, cannot lead to the threshold being exceeded, the second input of the AND gate 12 receives the signal O so that also in this case the output signal will be O. Also in this case, the switch does not respond.

If a human hand 6 approaches the switch, the resulting small damping of the oscillator 8 owing to the correct setting of the threshold in the threshold means 11 does not cause the oscillator voltage to drop below this threshold. The output signal of the threshold means 11 remains, therefore, L. On the other hand, the approach of the hand 6 causes the capacitance of the probe 4 to increase to such an extent that the threshold of the capacitance measuring circuit 10 is exceeded, and the output of the circuit delivers the signal L'. Since now inputs of the AND gate 12 receive the signals L and L', the output 15 delivers the signal L' and the switch according to the invention responds.

The switch may be actuated by human hand 6, even if the hand is protected by a strong leather glove, such as in the case, e.g., of processing sheet metal. The two fields of the switch according to the invention penetrate such a leather glove.

A substantially simplified circuit, operating with only one oscillator whilst still ensuring the logic interconnection required according to the invention, is shown in FIG. 4. In this construction with winding 3 forming the inductive probe is divided into two partial windings of which one forms together with a capacitor 16 the oscillating circuit of an oscillator 17 tuned to a frequency of several kc/h, whilst the other supplies the voltage for

the capacitive probe 4. The partial winding supplying the voltage to the probe 4 is connected to a capacitance current or voltage converter 19, which is followed by a trigger 20 whose output 21 supplies normally the output signal O, but which supplies an output signal L'' when the output current or the output voltage of a converter 19 exceeds the threshold of the trigger 20.

The operation of this circuit is as follows:

The capacitance converter 19 operates in its linear range in accordance with the following relation:

$$A = k.U.\omega.C.$$

In this formula

A = the output direct current or the output d.c. voltage of the converter,

k = a constant,

U = the amplitude of the supply a.c. voltage (which is, therefore, proportional to the output voltage of the oscillator),

ω = the circuit frequency,

C = the capacitance of the probe 4 against earth.

As may be seen from the preceding equation, the approach of a smaller or larger metal component to the key containing the probes 3 and 4 will give rise to an increase in the capacitance, but simultaneously the oscillator damping will cause the voltage U to drop. In other words, the sensitivity of the converter 19 is strongly reduced, so that the threshold of the trigger 20 cannot be exceeded even with a strong increase in the capacitance. In the presence of very large metal parts, the oscillation of the oscillator may even collapse completely, so that the output of the converter 19 no longer presents an output signal.

Thus the logic connection required for the approach of a metal part is assured.

If an insulating part is brought near the key 3, 4, the resulting small rise in the capacitance is insufficient to overcome the threshold in the trigger 20.

Only if a hand is placed near, as shown in FIG. 2, the capacitance of the probe 4 is increased to such an extent that the threshold in the trigger 20 is overcome with small damping of the oscillator, and the output 21 delivers the signal L''.

The function of the simplified circuit of FIG. 4 corresponds, therefore, to that of the basic circuit explained with reference to FIG. 3.

A detailed circuit diagram is shown in FIG. 5.

The oscillator 17 consists substantially of a transistor 22, the collector of which is connected with the winding 3, forming an inductive coupling winding 23 of the inductive probe. The oscillating circuit determining the frequency is formed by the winding 3 and the capacitor 16.

The regenerative feedback is effected by a further winding 25 and a variable resistor 26 serving for adjusting the regenerative feedback factor. A capacitor 27 mounted between resistor 26 and the emitter produces the galvanic decoupling.

Resistors 28, 29 and 30 adjust the working point of the transistor 22, whilst a capacitor 31 connects the base of the transistor 22, operating in a base circuit, to earth. The arrangement is supplied by a d.c. voltage source, shown at +/-.

The winding 3 is divided into two partial coils by a tap 24. The capacitive probe 4 is connected to the lower end of the upper partial coil, whilst the upper end

of the upper partial coil is earthed through a trimming capacitor 38.

The capacitance converter 19 is realized by a known diode pump consisting of diodes 32, 33, a resistor 35, and a capacitor 36. By means of a capacitor 37, the base of the diode is earthed. The diode pump is connected to the tap 24 of the coil 3.

The capacitor 38 is so chosen and adjustable that the initial capacitance of the probe 4 can be neutralized.

Adjacent to the diode pump is a filter member consisting of a resistor 39 and a capacitor 40. The d.c. voltage produced in this manner is applied to the non-inverting input of an operational amplifier 41 which is fed back by means of resistors 42, 43, and 44 in such a way that it behaves like a trigger. The inverting input of the operational amplifier 41 is connected to the tap of a potentiometer 46 through a resistor 45 which is necessary for reasons of compensating the offset. According to the invention, the adjustment of the potentiometer 46 can be used for adjusting the threshold of the trigger formed by the operational amplifier 41.

Zener diodes 47, 48 and a series resistor 49 in the voltage lead serve to stabilize the supply voltages of the circuit. The output of the trigger is connected to a voltage divider consisting of resistors 50, 51 through which the base of a switching transistor 52 is controlled. This transistor controls directly a relay 53. A diode 54 in the collector circuit of the transistor 52 serves to chop inductive voltage peaks.

The capacitance converter may also realize by a circuit other than a diode pump, e.g. the output voltage of the capacitive probe can be rectified as a function of the phase.

The embodiment of FIGS. 6 and 7 shows a further important possibility of simplifying the electronic switch according to the invention, wherein the intrinsic capacitance of the winding 3 is used at least partially for forming the capacitive probe 4. The fact that the intrinsic capacitance of the winding 3 in FIG. 6 is used partially, is indicated in the drawing by marking the relevant part 3a of the winding additionally by a dotted line leading to reference numeral 4.

The winding 3 is arranged in the FIG. 6 embodiment in a high frequency iron pot core 7, in which a tap is provided between the outer partial winding 3b and the larger inner partial winding 3a.

It is an essential feature that the larger partial winding 3a, serving as capacitive probe 4, is arranged in space non-symmetrically to the remainder of the winding 3b, so that the changes in the intrinsic capacitances of the partial windings 3a and 3b, caused by approaching objects, are non-proportional, because otherwise the capacitance converter 19 connected to the windings would deliver no signal in the case of changes in the capacitance.

Even more favourable than the arrangement shown in FIG. 6 is the configuration of the partial winding 3b as a disk-shaped winding on the bottom of the pot core 7.

A preferred, particularly simple circuit for connecting the switch of FIG. 6 is shown in FIG. 7. Here again, the capacitor 16 forms with the winding 3 the oscillating circuit of an oscillator, not shown. The transistor 22, the diode 13, the capacitor 14 and the output resistor 9 form a capacitance converter 19. Between the voltage terminals +/-, there is a capacitor 57, forming a high frequency short circuit. In this circuit, a change

of the capacitance of the partial winding 3a relative to earth brings about a change of the current through the resistor 9.

The lower end of the partial winding 3b is connected to earth through a trimmer capacitor 58, which is constructed and adjustable in such a manner that the initial capacitance of the coil 3 can be neutralized. The output 59 of the circuit may be applied to a trigger 20 as shown in FIGS. 4 and 5.

I claim:

1. In an electronic switching arrangement actuated in a contact-less manner by the approach of a portion of a human body, having a capacitive probe which is insulated from a support chassis, and connected to a capacitance measuring circuit which delivers a signal when a certain increase of the capacitance is caused by a predetermined approach of the portion of the human body into the electric field of the capacitive probe, the improvement which comprises an inductive probe disposed in the proximity of said capacitive probe, means whereby said inductive probe forms a portion of an oscillator circuit and having a magnetic field, the magnetic field of said inductive probe permeated the electric field of said capacitive probe, said inductive probe being connected to an inductive measuring circuit, said inductive measuring circuit being adjusted to deliver a switching signal indicative of the presence of a metal object at a predetermined distance from said support chassis, and said capacitance measuring circuit being adjusted to deliver a switching signal only when the metal object is closer to said support chassis than the predetermined distance, means connected to receive switching signals from said inductive and capacitance measuring circuits and delivering an output signal only if the said capacitance measuring circuit supplies a switching signal and the measuring circuit associated with the inductive probe does not supply such a switching signal.

2. An arrangement as defined in claim 1, wherein are provided to adjust the sensitivity of the said capacitance measuring circuit to deliver a signal on the approach of an electrically conducting body, but not by the approach of a body of insulating material.

3. An arrangement as defined in claim 1, wherein said capacitive probe is mounted on said support chassis and said chassis is grounded and forms the counter-electrode of said capacitive probe.

4. An arrangement as defined in claim 1, wherein said inductive probe consists of a coil mounted on the legs of a U-shaped high frequency iron core and said capacitive probe consists of a metal plate disposed to lie between the two legs of said iron core but in spaced relationship thereto.

5. An arrangement as defined in claim 1, wherein said capacitive probe and said inductive probe are supplied by the same oscillator and means whereby the

damping of the oscillator is used as a measure of the degree of approach of a metal part.

6. An arrangement as defined in claim 1, wherein means are provided whereby the initial capacitance of the said capacitive probe is neutralized.

7. In an electronic switching arrangement comprising a switch actuated in a contact-less manner by the approach of a portion of a human body, comprising a coil divided into two partial windings, means including one of said windings connected to a capacitor to form an oscillator circuit of an oscillator, the other of said windings being connected to a capacitive probe and applying an electrical potential thereto; said capacitive probe being connected to a capacitance voltage converter circuit; said converter circuit being connected to a trigger; said trigger having a response threshold which is above the level of the signal supplied by said converter circuit in the absence of an object in a zone proximate to the switch and means whereby said response threshold of said trigger is exceeded when a portion of a human body is in the zone proximate to the switch.

8. An arrangement as defined in claim 7, wherein said capacitance converter circuit comprises a diode pump.

9. An arrangement as defined in claim 7, wherein means are provided whereby the response threshold of said trigger is adjustable.

10. An arrangement as defined in claim 7, wherein means are provided whereby the regenerative feedback factor of said oscillator is adjustable.

11. In an electronic switching arrangement including a switch actuated in a contact-less manner by the approach of a portion of a human body comprising a high frequency iron pot core, a coil disposed in said core, said coil being tapped to provide two partial windings, one of said partial windings being larger than the other of said partial windings, said one of said partial windings being arranged in space non-symmetrically with respect to said other of said partial windings; means including said coil connected to a capacitor to form an oscillator circuit of an oscillator; said coil being connected to a capacitance converter circuit; said converter circuit being connected to a trigger; said trigger having a response threshold which is above the level of the signal supplied by said converter circuit in the absence of an object in a zone proximate to the switch and means whereby said response threshold of said trigger is exceeded when a portion of a human body is in the zone proximate to the switch.

12. An arrangement as defined in claim 11, wherein said other of said partial windings is disposed outside of said one of said partial windings.

13. An arrangement as defined in claim 11, wherein said other of said partial windings is disposed inside said one of said partial windings.

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