ABSTRACT: An automatic water supply control system for a toilet facility, wash basin or the like which features a capacity-sensitive antenna positioned to sense the approach of a user and cause a valve actuator signal to be produced, coupled with a circuit for compensating for slow changes in antenna capacity caused by changes in ambient conditions, such as humidity. The system includes timing and delay circuitry which permit the system to allow for minor movements of the user adjacent to the facility and to shut off after a predetermined period of operation.
AUTOMATIC WATER SUPPLY SYSTEM

This invention relates to an automatic water supply system and, more particularly to an apparatus operable in response to the electrostatic capacity of an object approaching thereto such as a human body or hands to flow water.

Such automatic water supply systems generally include a proximity detector which may comprise a high frequency oscillating circuit, one of the component parts of which is the antenna provided adjacent a wash basin, a stool or a urinal.

When a human body or a portion thereof enters the field of the antenna, the oscillating condition of the oscillator changes. Therefore, the presence or absence of a human body or hands can be detected by such a change in the oscillating output of the oscillator. When a human body or hands enter the field of the antenna, the electrostatic capacity of the antenna changes, with a resulting change in the oscillating output of the oscillator. The electrostatic capacity of the antenna, however, is changed by other causes than the approach thereto of a human body or a portion thereof, so that sometimes the system will erroneously operate in the absence of any user of the toilet. Moisture may be the most important among such other causes, and a toilet is a place which is very likely to be exposed to moisture.

In order to prevent the erroneous operation of the system caused by change in the ambient conditions, it is well known to provide the oscillator with a compensating circuit having a delay element. Generally, the change in the oscillating output condition of the oscillator caused by change in the ambient condition takes place far more slowly than that caused by the approach or removable of a human body or a portion thereof. To put it in detail, when a human body approaches the antenna, the oscillating condition of the oscillator changes within the delay time provided by the delay element, whereas when the ambient condition, say, the humidity of the air around the antenna changes, the oscillating condition of the oscillator continues changing even after lapse of the delay time. Therefore, in the former case, the change in the oscillating condition of the oscillator finishes before the compensating circuit operates, so that the presence of a human body in the antenna field can be detected. In the latter case, however, the compensating circuit operates in response to the change in the oscillating output condition of the oscillator. Therefore, if the arrangement is such that upon operation of the compensating circuit, the oscillating output of the oscillator is fed back to the oscillator to compensate for any change in the oscillating output level, the oscillating output condition remains substantially unchanged, regardless of the change in the ambient condition, so that the system will not operate in error.

A new problem, however, has been posed by the provision of such a compensating circuit. Suppose that after the antenna has detected the body or hands of a user, the user continues to stay there in the field of the antenna even after lapse of the delay time provided by the delay element in the compensating circuit. The compensating circuit will then operate as if there were no human body in the field of the detector. This certainly is very inconvenient.

The problem may be solved by so arranging that when the detector has detected a human body or portions thereof, the compensating circuit will not operate. However, this is not a perfect solution. In the case of a wash basin, for example, water must flow when hands are positioned below the faucet (that is, near the antenna) and then stop when the hands are removed therefrom. If the user has left the basin, however, forgetting a handbag or something placed near the faucet, water continues to flow out. In the case of a stool or a urinal, the arrangement must be such that the stool or urinal must be flushed after use. However, if, in the case of a stool or a urinal, the arrangement is such that a handbag or something placed near the faucet, water continues to flow out. In the case of a stool or a urinal, the arrangement must be such that the stool or urinal must be flushed after use. However, if, in the case of a stool or a urinal, the arrangement is such that a handbag or something placed near the faucet, water continues to flow out.

Another object of the invention is to provide such an automatic water supply system as aforesaid, wherein if the object detecting condition of the system lasts longer than a predetermined period of time, for example, the period of time required for using a wash basin, a stool or a urinal, the non-object detecting condition of the system is forcibly restored.

The system of the invention comprises a detecting circuit such as an oscillator, the output condition of which varies upon entrance of an object to be detected into the field of a capacity sensitive antenna included in the oscillator, and a compensating circuit so arranged that the output of said detecting circuit is fed back to the detecting circuit to compensate for any change in the output thereof caused by the capacity change of the antenna. The compensating circuit includes a delay element having a time constant longer than that required for a change to occur in the output of the detecting circuit due to entrance of an object to be detected into the field of the antenna. The detecting signal from the detecting circuit, that is, the above-mentioned change in the output thereof, is used to actuate a detection signal responsive circuit to produce a signal for actuating a control circuit for a valve thereby to make water flow out.

On the other hand, upon actuation of the detection signal responsive circuit, the compensating circuit is rendered inoperative. So long as the compensating circuit is kept inoperative, it never happens that the detection signal from the detecting circuit is caused to disappear by the operation of the compensating circuit despite the presence of an object in the field of the detector.

Any change in, say, the moisture content of the air around the detector may result in a change in the output of the detecting circuit, but such an output change gradually takes place so that the delay time provided by the delay element in the compensating circuit elapses before the output change of the detecting circuit reaches a level sufficient to actuate the detection signal responsive circuit. Consequently, the compensating circuit operates to compensate for such change in the output of the detecting circuit. This means that no detection signal is produced by the detecting circuit when moisture or other ambient conditions have changed the capacity of the antenna.

The system of the invention is also provided with a timer arranged to begin operating when the compensating circuit is rendered inoperative. The delay time provided by the timer is set to a predetermined period of time which is longer than the period of time required for the use of a wash basin, a stool or a urinal. In the case of a wash basin, the delay time may be set to 2 to 5 minutes. When the delay time is up, the operative condition of the compensating circuit is restored so that the detection signal from the detecting circuit is caused to disappear despite the object existing within the field of the detector.

The timer is provided for the following reason: To take a wash basin for example, when a user's body approaches the antenna, water flows out of the faucet and the compensating circuit is rendered inoperative. When the body is moved away from the field of the antenna, the flowing water stops. Suppose, however, that the user happens to have placed a handbag or something near the antenna and has gone out of the place, leaving the handbag there. The system will then operate as if it were still detecting the body so that water continues flowing out even after the user has left the basin.
However, this condition lasts only 30 seconds after water started to flow out until the delay time is up, whereupon the compensating circuit is restored to the operative condition so that the flowing water is stopped.

In the case of a stool or a urinal, when the antenna detects a human body, the stool or urinal is initially flushed for a predetermined period of time, and at the same time the compensating circuit is rendered inoperative. When the person has left the place after use, the detection signal disappears so that the stool or urinal is again flushed for a predetermined period of time. However, if the user has gone out without turning off the tap or something placed near the antenna, the detection signal continues so that the stool or urinal is not flushed again. However, when the delay time is up, that is, 2–5 minutes after the initial flushing, the compensating circuit is restored to the operative condition to cause the stool or urinal to be flushed again.

The invention will be better understood from the following detailed description of preferred embodiments thereof with reference to the accompanying drawings, wherein like reference symbols and numerals denote corresponding parts and wherein:

FIG. 1 is an electrical circuit diagram of one embodiment of the invention;
FIG. 2 is a diagram similar to FIG. 1 but showing a different embodiment of the invention;
FIG. 3 is a block diagram of part still another embodiment of the invention;
FIG. 4 is a schematic perspective view of a urinal to which the invention is applied; and
FIG. 5 is a schematic side view of a wash basin to which the system of the invention is applied.

Now referring to the drawings, first to FIG. 1, there is shown a detecting circuit in the form of an oscillator 10 of the Colpitts type comprising a plurality of condensers, resistors, and inductance coils and a transistor Tr1. In a condenser circuit of the oscillator there are connected a variable capacity diode CV and a capacity sensitive object detecting antenna 12. The diode CV and the antenna 12 provide part of the capacity required for the oscillating circuit. The diode CV receives a control voltage from a compensating circuit to be described below, so that when the voltage thereon increases, the capacity of the diode decreases, with a resulting decrease in the amplitude of the oscillating output of the oscillator 10, and vice versa. On the other hand, when an object such as a human body enters a portion of the field of the antenna 12, its capacitance increases so that the oscillating output condition changes whereby the amplitude of the output of the oscillator decreases. The antenna 12 may be mounted on the front wall of a casing 16 containing the various component elements of the system and disposed above a urinal 14 as shown in FIG. 4. The antenna may also be provided in the front wall of a basin 18 fixed to a wall 24 of a room as shown in FIG. 5. A faucet 18 is disposed over the basin, at the bottom of which there is a drain pipe 20. In this instance, the casing 16 may be fixed to the drain pipe with a lead line 22 connecting the antenna to the circuit in the casing 16.

The oscillating output from the oscillator 10 is applied to an amplifier 30 comprising a transistor Tr2 through a transformer T and a rectifier comprising a condenser C1 and a diode D1, so that the amplifier 30 produces a direct current voltage corresponding to the oscillating output of the oscillator 10. The amplified output, that is, a detection signal appears at a terminal a. To this terminal there is connected a compensating circuit 32 including a condenser C2, charging resistors R1 and R2, and a normally closed contact S1. The terminal voltage of the condenser C2 is impressed through a line L1 across the previously mentioned variable capacity diode CV.

To the terminal a there is also connected a line L2 leading to a section signal responsive circuit 34, so that a voltage at the terminal a is applied as an input to the circuit 34. The circuit 34 includes a pair of transistors Tr3 and Tr4. A line L3 is connected to the collector of the transistor Tr4 so that the collector voltage appears on the line L3 as a control signal so to be used to open a valve as will be described later in detail.

When the transistor Tr4 becomes nonconducting upon entrance of a human body in the field of the antenna, a condenser C3 is instantly charged through a resistor R3. The condenser C3 is connected in parallel with a resistor R4 to form a delay circuit. When the condenser C3 has been charged to a predetermined voltage level, a transistor Tr5 is rendered conductive, thereby energizing a relay RY. The previously mentioned contact S1 in the compensating circuit 32 is one of the three contacts of this relay RY, the other contacts being connected in a normally closed contact S3. These latter two contacts control the operation of a timer 38 included in a timer circuit 36. The timer 38 comprises a condenser C4 and a charging resistor R5, and the delay time provided by the timer 38 may be 30 seconds for a wash basin and 5 or 2 minutes for a stool or urinal.

When the relay RY is energized, the contact S3 is opened and the contact S2 closed so that the condenser C4 begins to be charged through the resistor R5. When the relay RY is deenergized, the contact S3 is closed again so that the condenser C4 instantly discharged through a resistor R6.

The timer circuit 36 includes another timer consisting of a monostable multivibrator 40 made up of a pair of transistors Tr6 and Tr7 with a condenser and resistors. The terminal voltage of the condenser C4 is applied to the base of the transistor Tr6.

When the monostable multivibrator 40 operates, that is, when the transistor Tr7 becomes nonconductive, the circuit 40 produces an output voltage to be applied to the base of a transistor Tr8 constituting a gate circuit 42 to render the transistor Tr8 has its emitter grounded and its collector connected through a line L4 to the base point b of the previously mentioned transistor Tr5. Therefore, when the transistor Tr8 becomes conductive, the base voltage of the transistor Tr5 is reduced to the ground potential, so that the transistor Tr8 is forcibly rendered nonconductive.

Now suppose that it is a urinal the flushing of which is to be controlled. The signal So on the line L3 is applied to an on-off delay timer 44. If the signal So continues for a less period of time than the delay time provided by the timer 44, such as when a person merely passes by the urinal, the timer 44 does not respond to the signal So, thereby preventing the urinal from being automatically flushed. On the contrary, when the signal So lasts longer than the delay time, the timer 44 produces an output to be applied to an amplifier 56 through a differentiator 46 and a monostable multivibrator 48 on the one hand and through a NOT element 50, a differentiator 52 and a monostable multivibrator 54 on the other.

The output from the amplifier 56 energizes an electromagnetic valve 58 to flush the urinal.

Normally, the compensating circuit 32 operates in the following manner: When the ambient conditions of the antenna change, the capacity thereof varies relatively slowly as previously mentioned. The change in the antenna capacity results in a corresponding change in the amplitude of the oscillating output of the oscillator 10 and, consequently, the output voltage at the terminal a. Let if be assumed that the humidity in the atmosphere surrounding the antenna 12 has decreased. This reduces the antenna capacity so that the voltage at the terminal a increases. The increased voltage charges the condenser C2 through the normally closed contact S1, so that the terminal voltage of the condenser C2 increases. This results in a corresponding increase in the voltage impressed across the variable capacity diode CV with a resulting decrease in the capacity of the diode CV. This causes the amplitude of the oscillating output of the oscillator 10 and, consequently, the voltage at the terminal a to decrease to the original potential level. It will be easily seen that if the capacity of the antenna gradually increases so that the voltage at the terminal a decreases, this change is
compensated for in the manner opposite to that described just above. Thus, any gradual change in the potential level at the terminal a caused by the change in the ambient conditions of the antenna 12 can be compensated for completely.

When a person approaches the urinal 14 to use it, the capacity of the antenna increases so that the voltage at the terminal a decreases. This change takes place more rapidly than that caused by the gradual change in the ambient conditions of the antenna 12. Therefore, before the condenser C2 is sufficiently discharged to increase the capacity of the variable capacity diode CV, the decreased voltage at the terminal a serves as a detection signal. The signal is applied to the line L3 to be applied to the on-off delay timer 44. The output from the timer 44 is applied to the amplifier 56 through the differentiator 46 and the monostable circuit 48.

The amplified output from the amplifier 56 energizes the solenoid 58 to open the valve for the urinal 14. Thus, when a person stands in front of the urinal, water flushes it for a period of time as determined by the output pulse width of the monostable multivibrator 48.

The collector voltage of the transistor TR4 also charges the condenser C3 and at the same time renders the transistor TR5 non-conducting, thereby energizing the relay RY. This opens the closed contact S1 in the compensating circuit 32, thereby breaking the connection between the terminal a and the terminal a. This renders the compensating circuit 32 inoperative, so that the condenser C2 therein is neither further charged or discharged, but maintained at the potential level of the terminal a before the approach of the user to the urinal.

When the person has left the urinal within the delay time provided by the timer 36, the oscillating output of the detecting circuit 10 is restored to the original amplitude, so that the voltage at the terminal a is raised to the initial level. This causes the transistor TR4 to become conductive and, consequently, the signal to disappear, whereupon the NOT element 50 produces an output to be applied to the differentiator 51. The output pulse from the differentiator 50 triggers the monostable multivibrator 54 to produce an output of a predetermined pulse width. This pulse is amplified by the amplifier 56 to energize the electromagnetic valve 58, which flushes the urinal 14 for a posterior cleaning.

When the signal So disappears, the relay RY is deenergized to close the contact S1 again, thereby connecting the compensating circuit 32 between the terminal a and the variable capacity diode CV to restore the operative condition of the circuit 32.

It must be mentioned, however, that when the signal So disappears, the relay RY is not instantly deenergized but only after lapse of the delay time provided by the delay circuit 36. Therefore, the signal So at the output of the NOT element is provided for the following reason: While a person is using a urinal, his body does not always remain stationary but moves to and fro due to, say, breathing. In other words, the distance between the antenna 12 and the body of the user always varies. On the other hand, if the detector has a very high degree of sensitivity, when a person approaches the antenna to operate the system (with the voltage at the terminal a dropping from, say, 6 volts to zero volt and the voltage on the condenser C2 being maintained at the level of 6 volts) and then moves a little away from the antenna, the voltage at the terminal a may increase from zero volt to, say, 1 volt. This may cause the transistors TR3 and TR4 to become conductive so that the relay RY would be deenergized to close the contact S1. As a result, the condenser C2 that had until then maintained at 6 volts would be discharged to about 1–2 volts, thereby increasing the capacity of the diode CV and consequently the voltage at the terminal a to the previous high level of 6 volts. Then the system would no longer respond to the body even when it moves again to a position near the antenna. In other words, the system would not work any longer unless the body approaches nearer to the antenna than it was when the system initially operated.

The positional change of the body while a person is using a urinal, however, usually does not last very long, but ends in a fraction of time. That is, the user's body will soon occupy the original position in the field of the antenna again. Therefore, if the delay time provided by the timer comprising the resistor R4 and condenser C3 is set to a period of time a little longer than that generally required for such positional restoration of the user's body, the positional change of body relative to the antenna will not cause the compensating circuit 32 to operate, so that the above-mentioned defect is eliminated.

Suppose that a user has happened to place a bag or something near the antenna. If the owner has gone out of the place, leaving the bag there within the antenna field, the signal So continues to exist on the line L3, so that water continues flowing out or the urinal will not be flushed posteriorly. To avoid this, the system of the invention is so arranged that the signal So is forcibly caused to disappear after a predetermined period of time, whether the user has left the urinal or not. This is accomplished by providing a timer circuit 36 including a timer 38 and a monostable multivibrator 40. The timer 38 comprises a condenser C4 and a resistor R5, and the monostable multivibrator 40, a pair of transistors TR6 and TR7.

When the relay RY is energized upon detection of a person, the relay contact S2 is closed so that the condenser C4 is charged through a resistor R5 until the charged voltage of the condenser C4 reaches a predetermined level, whereupon the transistor TR6 is turned on to become conductive and, subsequently, the transistor TR7 non-conductive, so that the transistor TR8 of the gate circuit 42 becomes conductive. The conduction of the transistor TR8 results in a sudden drop of voltage at the base point b of the transistor TR5 to substantially zero potential. This renders the transistor TR5 nonconductive, so that the relay RY is deenergized to close the contact S1, whereupon the compensating circuit 32 is restored to the operative condition. The operation of the compensating circuit 32 causes the voltage at the terminal a to increase, just as in the case where the ambient conditions of the antenna change, thereby bringing the detecting circuit 10 to the nonobject detecting condition, that is, as if there were nothing to be detected within the field of the antenna 12. The circuit 40 is so designed that its metastable state lasts for a period of time during which the operation of the compensating circuit 32 is finished, whereupon the circuit 40 is restored to its stable state.

If the system of FIG. 1 is to control a wash basin, the signal So may be directly applied to the amplifier 56, so that water flows so long as a user stands near the antenna.

FIG. 2 shows a different embodiment of the invention, the same reference numerals and symbols as used in FIG. 1 denoting corresponding parts. In FIG. 1, to render the compensating circuit 32 operative again a predetermined period of time after the urinal was initially flushed, the base voltage of the transistor TR5 is reduced to the ground potential, thereby deenergizing the relay RY so that the contact S1 is closed again. In FIG. 2, to accomplish the same result, the terminal voltage of the condenser C4 is applied through a Zener diode ZD to the base of the transistor TR8 which is connected across the condenser C2 by a line L4. Just as in the case of FIG. 1, when the delay time provided by the timer 38 is over, the transistor TR6 becomes conductive, whereupon the condenser C2 discharges through the conducting transistor TR8, so that the capacity of the diode CV increases, thereby increasing the voltage level at the terminal a of the detecting circuit 10 as if there were nothing present in the field of the antenna 12. As a result, the relay RY is deenergized to restore the original condition of the system.

In FIG. 1, the signal So is taken out from the collector of the transistor TR4, while in FIG. 2 it is taken out from the collector of the transistor TR5. In the latter case, the circuit connection is such that the collector output of the transistor TR5 is controlled by the timer including the condenser C3. Therefore, such an on-off delay timer as shown at 44 in FIG. 1 can be dispensed with in FIG. 2 if a similar valve control circuit is to be connected to the line L3.
In FIGS. 1 and 2, the signal $S_o$ is taken out of the collectors of the transistors $T_{r4}$ and $T_{r5}$, respectively. Alternatively, the line $L_3$ may be removed and, instead, the relay $R_Y$ may be additionally provided with a normally closed contact $S_4$ and a normally open contact $S_5$ as shown in FIG. 3 so that a signal produced upon operation of the contact $S_4$ may be used as the control signal $S_o$ in the following manner: FIG. 3 may be combined with either FIG. 1 or FIG. 2, the line $L_3$ and also the blocks in FIG. 1 being removed therefrom. When a person enters the field of the antenna 12, the relay $R_Y$ is energized so that the contact $S_4$ is opened and the contact $S_5$, closed to complete a discharge path for the condenser of a differentiator 62. When the person has gone out of the antenna field, the relay $R_Y$ is deenergized so that the contact $S_5$ is again opened and the contact $S_4$, again closed, whereupon the differentiator 62 produces an output pulse, which triggers a monostable multivibrator 63 to produce an output of a predetermined pulse width. This pulse is amplified by an amplifier 64 and energizes a solenoid 65 for opening a valve. It will be seen that in FIG. 3, the urinal is flushed only after it has been used.

I claim:
1. An automatic water supply control system for a toilet facility or the like comprising:
   
a. a detector circuit including a capacity-sensitive antenna positioned to respond to the approach of a user of the facility and means responsive to a change in antenna capacity to produce an output signal;
   
b. a compensator circuit coupled to said detector circuit and including means sensitive to the rate of change of said output signal and operable in response to rates of change below a predetermined rate to cancel said change and maintain said output signal at a predetermined level;
   
c. water valve control means;
   
d. means for actuating said valve control means including circuit means operable in response to output signal changes not cancelled by said compensating circuit to produce a valve actuating signal; and
   
e. means responsive to said valve actuating signal for deactivating said compensator circuit.

2. The system of claim 1 further including delay means coupled to said deactivating means to maintain the same in its deactivating condition for a predetermined period following termination of said valve actuating signal.

3. The system of claim 1 further including timing means triggered by said valve actuating signal and operable after a predetermined period of delay to reactivate said compensator circuit.

4. The system of claim 3 further including delay means coupled to said deactivating means to maintain the same in its deactivating condition for a predetermined period following termination of said valve actuating signal.

5. The system of claim 4 wherein said deactivating means comprises a relay having a normally closed contact coupled between said detector and compensator circuits, said relay being energized by said actuator signal to open said contact.

6. The system of claim 5 wherein said reactivating means comprises means responsive to termination of said valve actuating signal to deenergize said relay and a delay circuit coupled to said relay to delay deenergization thereof for said predetermined period.

7. The system of claim 5 wherein said reactivating means comprises an RC circuit charged toward a predetermined voltage level in response to said activating signal, and circuit means coupled to the detector circuit and operable when said RC circuit becomes charged to said voltage level to produce a detector circuit output signal corresponding to the absence of a user of said facility, thereby deenergizing said relay and reactivating said compensator circuit.

8. The system of claim 3 wherein said compensator circuit includes a capacitor charged to a level determined by the capacity of said antenna for its ambient conditions, and means for maintaining said level of charge during the period of deactivation of said compensator circuit.