

[54] INTERFACE CIRCUIT FOR INDUSTRIAL CONTROL SYSTEMS

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[57] ABSTRACT

One contact of a controlling device connects to the input terminal of an industrial control system and the other contact connects to a positive voltage source through a blocking diode and to a high-voltage source through a resistor. A transistor collector is connected to the input terminal of the control system, and a feedback resistor connects its emitter to a negative voltage source. A bias current supplied to the base of the transistor saturates it. When the controlling device contacts close, the high-voltage source applied across them insures that conduction is established. Current then flows through the transistor resulting in a feedback action which brings the transistor out of saturation. The voltage on the transistor's collector and the input terminal to the industrial control system then rises to the potential of the positive voltage source.

12 Claims, 2 Drawing Figures

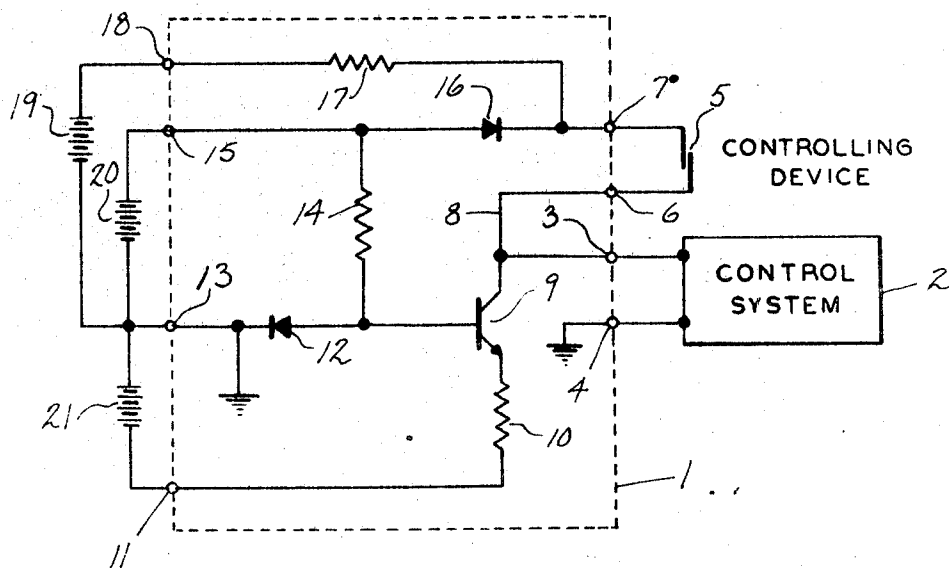


Fig. 1

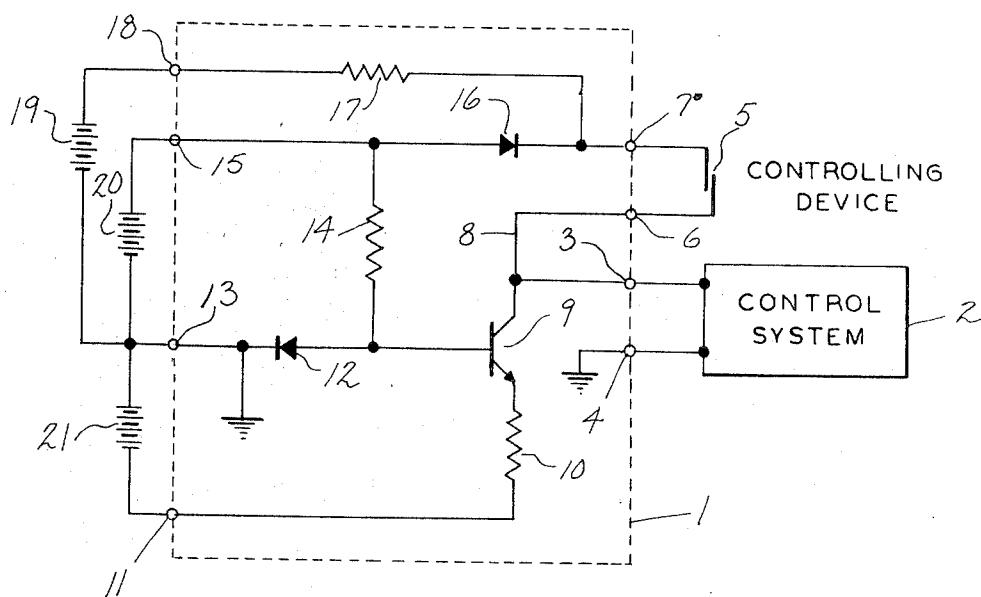
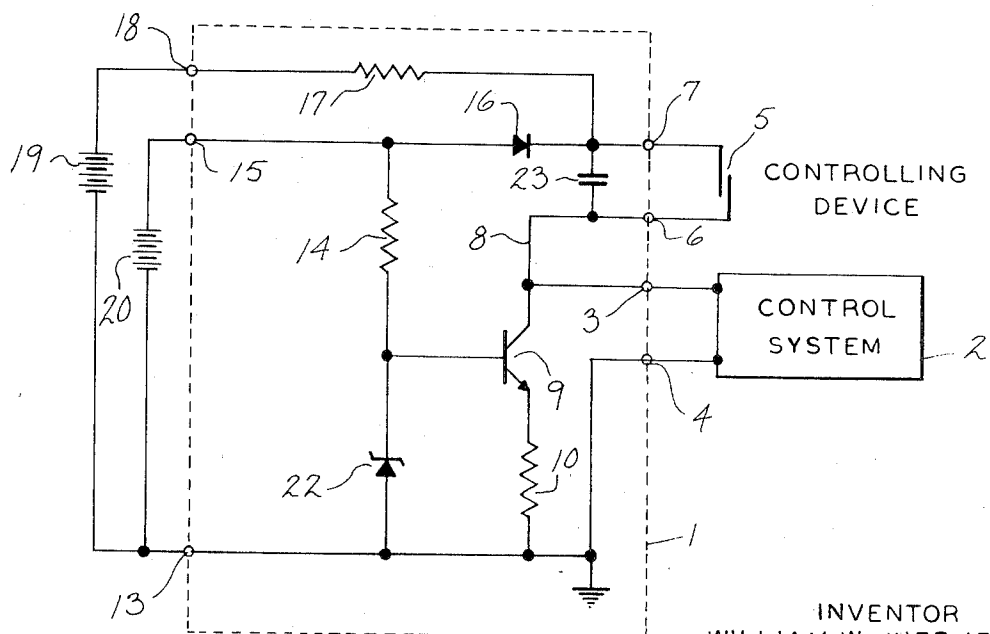


Fig. 2



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INTERFACE CIRCUIT FOR INDUSTRIAL CONTROL SYSTEMS

BACKGROUND OF THE INVENTION

Since the advent of electronic systems there have been a number of reoccurring problems in connecting together the various components of the system. When the output of one component is to control the input of a second component, mismatches in the impedances and operating voltages become troublesome. More particularly, the output voltage of the first component may operate over a wide range and present a high-output impedance to its load. On the other hand, it is very often desirable to drive the input of the second component with a low impedance, low-voltage source.

One example of an industrial system presenting this problem is the numerical control system for machine tools. In these systems the problem is in connecting the sensitive inputs of the electronic control system with the controlling devices on the machine. Contact continuity of hard contact controlling devices, such as mechanical switches, can only be insured by placing a high voltage across the switch when it is not conducting to establish conduction when the contacts are closed by breaking down any nonconductive film that is present. This high voltage is also helpful where contact pressure is low, as when it is dependent on forces external to the switch. This high voltage, however, cannot be applied directly to the input of the typical low-voltage numerical control system.

Also, in their open state, hard contact switches and other controlling devices characteristically have a high impedance between their terminals. Therefore, if they are connected directly to the input of a low-voltage numerical control system, the sensitive input becomes subject to spurious noise signals induced into the lines leading from the controlling device. Because there are numerous such signals in an industrial environment, there is a high possibility of injecting erroneous information into the numerical control system when high impedance controlling devices are connected directly to its input terminals.

A circuit is needed that can be connected between the high voltage, high impedance output of one system component and the low voltage input of a second system component. The circuit must present a low-output impedance and low-voltage output signal to the input of the controlled component.

SUMMARY OF THE INVENTION

The invention resides in an interface circuit for use at the input of a system component, such as a numerical control system, that connects to the output of an external controlling device. More particularly, this circuit includes a transistor and feedback resistor combination connected across the output terminals of the interface circuit and to one input terminal; a bias current source connected to the transistor-feedback resistor combination, to feed bias current to the base of the transistor; a high-voltage resistor connecting the other input terminal of the circuit with a high-voltage terminal; and a blocking diode connecting this same input terminal to a positive voltage terminal.

When a nonconducting control device is connected to the input terminals of the circuit, the transistor is saturated due to the hookup bias current supplied to its base. Consequently, the input of the control system is driven by a very low impedance with an essentially zero voltage output. This low impedance effectively desensitizes the input of the control system to spurious noise signals induced into the control device or its hookup leads.

When the controlling device is open, one of its contacts is held near ground potential by the transistor while the other is at the high-voltage source potential. If the controlling device is closed and no current conduction results because of an insulating film on the contacts, a high voltage applied to the high-voltage terminal is placed directly across this film breaking it down and allowing current to flow. This current flows through

the transistor to produce a voltage drop across the feedback resistor. This decreases the bias current supplied to the transistor base to bring it out of saturation. When this occurs the collector rises to the voltage applied to the positive voltage terminal, indicating to the control system that the controlling device has actuated.

It is a general objective of this invention to provide an interface circuit which allows the application of a high voltage, high impedance across its input terminals, and provides a low impedance, low-voltage output across its output terminals.

Another object is to provide an interface circuit which will accommodate either a normally open or normally closed controlling device, and will have universal application to all popular digital systems and supply voltages.

Still another objective is to provide an interface circuit which is inexpensive, reliable and compact so that it can be assembled on terminal boards.

Other objects and advantages will appear from the description to follow. In the description, reference is made to the accompanying drawings, forming a part hereof, in which there is shown, by way of illustration and not of limitation, two embodiments of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic diagram of the preferred embodiment of the interface circuit; and

FIG. 2 is a schematic diagram of an alternative embodiment of the interface circuit.

DESCRIPTION OF THE PREFERRED EMBODIMENT

The interface circuit is mounted on a terminal board 1 represented schematically in FIG. 1 by the dashed line. The input leads of a numerical control system 2 are connected to output terminals 3 and 4 on the terminal board 1. Typically, the numerical control system 2 will have other inputs which are connected to similar interface circuits mounted on the same terminal board 1. A controlling device represented by the switch 5 is connected across a first input terminal 6 and a second input terminal 7 on the terminal board 1. A line 8 connects the first input terminal 6 with the output terminal 3 and the collector of a transistor 9. The other output terminal 4 is connected to ground. The emitter of the transistor 9 is connected through a feedback resistor 10 to a negative voltage source terminal 11. The base of the transistor 9 is connected through a clamping diode 12 to a ground terminal 13, and also through a bias resistor 14 to a positive voltage source terminal 15. A blocking diode 16 connects the positive voltage source terminal 15 with the second input terminal 7. The second input terminal 7 is also connected through a high-voltage resistor 17 to a high-voltage terminal 18.

The interface circuit of FIG. 1 is supplied with three DC supply voltages. A high-voltage source 19 has its positive terminal connected to the high-voltage terminal 18 and its negative terminal connected to ground terminal 13. A positive voltage source 20 is connected between positive voltage source terminal 15 and ground terminal 13, while a negative voltage source 21 is connected between the negative voltage source terminal 11 and ground terminal 13.

When the switch 5 is open there is no current flowing through the high-voltage resistor 17 and as a result the second input terminal 7 is at a positive voltage equal to that of the high voltage source 19. The blocking diode 16 is reverse biased and there is no current flowing through it.

A bias current sufficient to saturate the transistor 9 is established through the bias resistor 14. The clamping diode 12 is forward biased and serves to clamp the base of the transistor 9 to a slightly positive voltage. Clamping the base voltage in this manner insures that the collector of the transistor 9 does not go negative when the transistor 9 is saturated. Because many numerical control systems may be damaged when a small negative voltage is applied to their input terminals, and the collector of transistor 9 is connected

directly to such an input terminal, the clamping diode 12 is important in this embodiment to prevent possible damage when the feedback resistor 10 is connected to a negative voltage source.

As long as the switch 5 is open, very little current flows into the collector of transistor 9, this current originating from the input circuit of the numerical control system 2. This small collector current flows out the emitter and through the feedback resistor 10 to the negative voltage terminal 11. It causes very little voltage drop in the feedback resistor 10 and the transistor 9 remains saturated by the substantial bias current flowing into its base. In this saturated state, the transistor 9 keeps the impedance low between the output terminals 3 and 4 of the interface circuit. This low-output impedance of the interface circuit substantially improves the noise immunity of the numerical control system 2 by effectively shunting the noise signals to ground.

Because the collector of the transistor 9 is essentially at ground potential when the switch 5 is open, the voltage across first and second input terminals 6 and 7, and consequently across the contacts of the switch 5, is equal to that of the high-voltage source 19. When the contacts on the switch 5 are closed this high voltage is applied directly across any insulating film which may have accumulated on the contacts. The high-voltage aids in breaking such films down to allow conduction of current through the switch 5.

This initial conduction of current flows from the high-voltage source 19 and through the high-voltage resistor 17, causing the voltage at the second input terminal 7 to drop until it is slightly below that of the positive voltage source 20. At this instant, the blocking diode 16 becomes forward biased and substantial current flows through it from the positive voltage source 20, through the switch 5, and transistor 9. This same high current also flows through the feedback resistor 10 that is connected to form a loop comparison, loop-sampling feedback circuit with the transistor 9. Consequently, as this current increases after switch 5 is closed, the bias current flowing into the base of switching transistor 9 decreases allowing the transistor 9 to come out of saturation. The value of the feedback resistor 10 is chosen so that the circuit will stabilize with the collector voltage of the transistor 9 slightly below that of the positive voltage source 20. Thus, when the switch 5 is closed the transistor 9 and feedback resistor 10 act as a voltage developing device and the voltage at the output terminal 3 jumps from about zero volts to a substantial positive voltage. This voltage step constitutes a bit of information for the numerical control system 2.

When the switch 5 is subsequently opened, current flow through the transistor 9 and feedback resistor 10 decreases. Through the feedback action of the transistor current amplifier and the resistor feedback network, this decrease in current results in an increase in bias current to the base of the transistor 9 which drives it back into saturation with the consequent drop in voltage at output terminal 3.

In the preferred embodiment described above, the positive voltage source 20 is the system voltage source of the numerical control system 2. The high-voltage source 19 and the negative voltage source 21 must be provided separately. The high voltage must be sufficient to break through insulating films on the switch contacts but not so large as to cause damaging arcing. Control devices are generally designed to operate between 100 and 200 volts and high-voltage sources in this range have proven quite satisfactory. Because many numerical control input circuits must be held near zero volts when the controlling device is open, the negative voltage supply 21 is added as part of the feedback network to keep the collector of the transistor 9 at or near zero volts when the transistor is saturated. Some numerical control systems, however, do not require that their inputs be held near ground potential, and with these systems the negative voltage source 21 can be eliminated as in the alternative embodiment now to be described.

The interface circuit of FIG. 2 shows an embodiment of the invention in which a negative voltage source is not needed. In this alternative circuit the terminal board 1 has output terminals 3 and 4 connected to the input of the numerical control system 2. Output terminal 4 is connected directly to ground and output terminal 3 is connected to the collector of transistor 9. The emitter of the transistor 9 is connected to ground through a feedback resistor 10, and its base is connected to ground through a bias diode 22. The bias diode 22 is a zener diode having a breakdown voltage sufficiently high to forward bias the base emitter junction of the transistor 9 when the controlling device is not conducting current. The base is also connected to the positive voltage source terminal 15 through a bias resistor 14. The collector of the transistor 9 is connected to a first input terminal 6 and one lead of a discharge capacitor 23. The other lead of the discharge capacitor 23 is connected to a second input terminal 7 and to a high-voltage terminal 18 through a high-voltage resistor 17. The two contacts of the switch 5 are connected to the first and second input terminals 6 and 7. A blocking diode 16 connects the positive voltage source terminal 15 to the second input terminal 7. A DC high-voltage source 19 is connected between the high-voltage terminal 18 and a ground terminal 13. A positive DC voltage source 20 is connected between positive voltage source terminal 15 and the ground terminal 13.

The operation of the alternative embodiment of the interface circuit is very similar to that of the preferred embodiment shown in FIG. 1. The alternations made are due primarily to the elimination of the negative voltage source 21. Without this negative voltage source there is no need to clamp the base of the transistor 9 because the collector cannot possibly go below zero potential. A bias voltage is established by using bias diode 22 in combination with the bias resistor 14. The voltage provides a bias current to the base of transistor 9. It should be apparent to those skilled in the art that numerous other biasing circuits for accomplishing the same result could be used in lieu of the bias resistor 14 and diode 22.

The discharge capacitor 23 is connected directly to the contacts of the switch 5. Although it is shown in the alternative embodiment of FIG. 2, it is equally applicable to the preferred embodiment of FIG. 1. The discharge capacitor 23 has a relatively large value and when the switch contacts are open it is charged to the high-voltage source potential by current flowing through the high-voltage resistor 17. When the switch 5 is closed, the discharge capacitor 23 relinquishes its charge through the switch 5 to aid in breaking down any nonconductive film which might be present on its contacts. The capacitor 23 also serves to filter out noise signals appearing at the input terminals 6 and 7.

When the switch 5 is open, the transistor 9 is saturated by the base bias current established by the bias resistor 14, and consequently, its collector is held at a very low positive voltage. When the switch 5 is closed, substantial current begins to flow through the feedback resistor 10. The resulting feedback action effectively reduces the bias current applied to the base of the transistor 9 bringing it out of saturation and allowing its collector to stabilize at a voltage slightly below that of the positive voltage source 20. This alternative embodiment of the invention provides a low-output impedance across the output terminals 3 and 4 to decrease the noise sensitivity of the numerical control system. This embodiment also allows the application of a high voltage across the contacts of the switch 5 to insure that good contact is made when it is closed. As in the preferred embodiment of the invention, this circuit allows application of a high voltage across the controlling device while insulating the input of the numerical control system from it.

As used herein, the term current amplifier includes not only a transistor, but any current controlling device or circuit such that the current flowing in the output circuit of the current amplifier is controlled by current flowing in its input circuit. A four terminal current amplifier is also usable if an output terminal and an input terminal are combined to form a common connection terminal similar to the emitter on the transistor

current amplifier shown herein. Also, the feedback network may include a resistor as shown in the second embodiment herein or a resistor and a voltage source such as the negative voltage source shown in the first embodiment of the invention.

The aforesaid description of the invention, and the manner of making and using it, is in such full, clear, concise and exact terms as to enable any persons skilled in the art to which it pertains, or with which it is most nearly connected, to make and use the same, and sets forth the best mode contemplated by the inventor of carrying out his invention.

In contrast to the foregoing description, the following claims particularly point out and distinctly claim the subject matter which the applicant regards as his invention.

I claim:

1. An interface circuit for connecting a controlling device to a controlled system the combination comprising:

a current amplifier having an input connection, a common connection and an output connection, said output connection adapted to connect with a first terminal on the controlling device and a first terminal on the controlled system;

a bias current source connected to the input connection of said current amplifier and adapted to supply sufficient bias current to saturate said current amplifier;

a feedback network connected between the common connection of said current amplifier and said bias current source such that the controlling device controls current flow through said current amplifier and feedback network, and the current flow through said feedback network operates to decrease the bias current supplied to said current amplifier.

2. The interface circuit of claim 1 wherein: the current amplifier is a transistor and the feedback network is a resistor.

3. The interface circuit of claim 2 wherein: a blocking diode is connected between a second terminal on the controlling device and a positive voltage source, and a high-voltage resistor is connected between said second terminal and a high-voltage source.

4. The interface circuit of claim 1 wherein: said feedback network is comprised of a resistor and a negative voltage source.

5. The combination of claim 4 wherein: there is a clamping diode connected between said input connection to said current amplifier and a second terminal on said controlled system.

6. An interface circuit for connection between a controlling device and a controlled system the combination comprising:

a blocking diode connected between a voltage source and a first terminal on said controlling device;

a high-voltage resistor connected between a high-voltage

source and said first terminal on the controlling device; and

a voltage developing device having a common connection to a second terminal on said controlling device and a first terminal on the controlled system, and connected across the first and second input terminals of the controlled system;

whereby said voltage developing device applies substantially zero voltage across said input terminals when no current flows through said controlling device, and develops a voltage limited by said voltage source when a current flows through said controlling device.

7. The interface circuit of claim 6 wherein: the voltage developing device is a transistor having its collector connected to the second terminal of said controlling device and the first input terminal of said controlled system, a feedback network connected between the emitter of said transistor and the second input terminal of said controlled system, and a bias current supply connected between the base of said transistor and the second input terminal of said controlled system.

8. The interface circuit of claim 7 wherein: said feedback network is comprised of a resistor.

9. The interface circuit of claim 7 wherein: said feedback network is comprised of a resistor and a negative voltage source.

10. The interface circuit of claim 9 wherein: there is a clamping diode connected between the base of said switching transistor and the second input to the controlled system.

11. An interface circuit for connecting first and second terminals on a controlling device to first and second terminals of a controlled device, the combination comprising:

a transistor having its collector connected to the first terminals on said controlling and controlled devices;

a feedback resistor connected between the emitter of said transistor and the second terminal of said controlled device;

a bias current supply connected between the base of said transistor and the second terminal of said controlled device; and

a voltage source connected between the second terminal of said controlling device and the second terminal of said controlled device.

12. An interface circuit as recited in claim 11, which includes:

a blocking diode connected between said voltage source and said second controlling device terminal; and

a high-voltage resistor connected to said second controlling device terminal and a high-voltage source.

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