

AN IMPACT DETECTING CIRCUIT

Field of the Invention

5 This invention relates to an impact detecting circuit and particularly to an impact detecting circuit that is significantly less sensitive to variations in ambient temperatures.

Background of the Invention

10

As is known, an impact detecting circuit is used in automobiles to detect the force of an impact on an automobile during a collision. When the detected force exceeds a predetermined magnitude, the impact detecting circuit provides a trigger signal to an air bag inflating mechanism which
15 inflates one or more air bags in the passenger compartment of the automobile to reduce the risks of serious injury to passengers

It will be appreciated that it is essential for the impact detecting circuit to be able to detect the force of the impact accurately over a range of ambient temperatures, as erroneous inflation of airbags can be dangerous.

20

Known impact detecting circuits use piezo electric or capacitive accelerometers to detect vibrations caused by the force of an impact, and provide an output signal indicating the magnitude of the force.

The force of an impact on the piezo electric accelerometer vibrates the piezo electric crystal which produces an alternating signal. The
25 magnitude of the alternating signal indicates the magnitude of the detected force. A disadvantage of the piezo electric accelerometer is that the magnitude of the alternating signal does not change linearly with linear changes in temperature or changes in the frequency of vibration.

The capacitive accelerometer has a diaphragm located parallel to a
30 surface which together form a capacitor. The diaphragm vibrates in accordance with vibrations resulting from the force of an impact, which causes the capacitance between the diaphragm and the surface to vary. The difficulty with this type of accelerometer is the need for complex circuitry to convert the change in capacitance to an output signal. In addition, a
35 disadvantage of the capacitive accelerometer is that it has a non-linear temperature coefficient, and consequently it does not provide an output



signal that accurately indicates the magnitude of the detected force across a range of different temperatures.

Another known accelerometer that can be used in an impact detecting circuit is a semiconductor accelerometer. The semiconductor accelerometer consists of a metal oxide semiconductor field effect transistor (MOSFET) having a channel region formed between the source and the drain on a substrate, and having a movable gate which is mounted on the substrate and resiliently supported parallel to the channel region. The movable gate vibrates in a direction perpendicular to the channel region of the MOSFET, in accordance with the force of an impact. The vibration results in variation in the distance between the gate and the channel region, and this variation in distance causes the drain-source current to vary. The magnitude of the variation of the drain-source current indicates the magnitude of the detected force.

An advantage of using the semiconductor accelerometer in an impact detecting circuit is that it can be directly coupled to other components in the circuit. However, a disadvantage of using the semiconductor accelerometer is that the detection sensitivity of the movable gate is susceptible to variations caused by changes in ambient temperature, which leads to inaccurate detection of the force of an impact by the impact detecting circuit.

Brief Summary of the Invention

The present invention therefore seeks to provide an impact detecting circuit which is significantly less sensitive to changes in ambient temperature.

Accordingly, the invention provides a circuit comprising: a field effect transistor (FET) having a drain coupled to one leg of a current mirror, a source coupled to a constant current source and a gate biased with a reference voltage; a FET sensor having a movable gate, a bias input, a drain coupled to another leg of the current mirror, and a source coupled to the constant current source; an amplifier having an input coupled to an output of the current mirror and coupled to an output; and a feedback circuit coupled to the output for receiving an output signal therefrom when current mirror indicates the drain current of the FET and the drain current of the FET sensor are not substantially equal, and having a first output coupled to the movable gate and a second output coupled to the bias input, the feedback circuit for providing a potential difference between the movable gate and the bias input in accordance with the output signal, thereby causing the movable gate to move such that the current mirror indicates that the drain current of the FET and the drain current of the FET sensor are substantially equal.

Brief Description of the Drawings

An embodiment of the invention will now be more fully described, by way of example, with reference to the drawings, of which:

FIG. 1 shows a side sectional view of a semiconductor accelerometer with an applied compensation voltage; and

FIG. 2 shows a circuit employing the accelerometer in FIG. 1 in accordance with the embodiment of the present invention.

Detailed Description of the Drawings

FIG. 1 illustrates an accelerometer 1 having a metal oxide semiconductor field effect transistor (MOSFET) 2 formed on a substrate 21. The MOSFET 2 has a channel region 15 located between a drain region 17 and a source region 19. A movable gate 4 is formed by a resilient polysilicon

beam structure mounted on the substrate 21 by an anchor 5. The movable gate 4 has a pivot section 7, a support section 9, a pivot section 10, and an end section 13. The support section 9 positions the detection end 13 parallel to the channel region 15 and is separated a predetermined distance d_1 from the channel region 15. In addition, the support section 9 pivots about the pivot section 7 and the detection end 13 pivots about the pivot section 10. A plate 30 is located on the substrate 21 below the support section 9 and separated by a distance d_2 from the plate 30.

An accelerative or decelerative force imposed on the accelerometer 1 causes the detection end 13 to move about the pivot section 10. However, the force of an impact on the accelerometer causes the detection end 13 to vibrate or swing up and down about the pivot section 10.

The vibration of the detection end 13 causes the distance d_1 between the detection end 13 and the channel region 15 to vary. This causes the drain-source current flowing between the drain region 17 and the source 19 to vary and provide an alternating drain-source current which is indicative of the vibration. The greater the force of an impact on the accelerometer 1, the greater the magnitude of the vibration of the detection end 13 i.e. the greater the swing of the detection end 13 up and down. This results in a greater magnitude of the alternating the drain-source current.

When the ambient temperature changes, the movable gate 4 expands or contracts dependent on whether the ambient temperature rises or falls. The expansion and contraction of the movable gate 4 causes the end 13 to move. Hence, even without an accelerative or decelerative force or the force of an impact being imposed on the accelerometer 1, d_1 can be changed by variation in ambient temperature.

It should be noted that the movement of the movable gate 4 caused by variation in temperature occurs at a slower rate, while the movement of the movable gate by vibration resulting from the force of an impact has a significantly higher rate or frequency.

The plate 30 and the movable gate 4 are coupled to opposite polarities of a variable direct current (DC) voltage source 35 which provides a voltage V . The variable DC voltage source 35 causes an electrostatic force, which is proportional to the applied DC voltage V , to be created between the plate 30 and the support section 9. The electrostatic force causes the support section 9 to be moved relative to the plate 30 against the opposing force of the spring constant at the pivot section 7. By varying the

voltage V , the gate 4 can be moved between an upper position 31 and a lower position 32.

When a DC voltage is set by the variable direct current (DC) voltage source 35, the resulting electrostatic force on the support section 9 causes the movable gate 4 to move against the spring force of the pivot section 7. The movable gate 4 stops moving when the two forces, the electrostatic force and the spring force, are equal i.e. in equilibrium. Hence, by varying the voltage V , the distance d_1 between the detection end 13 and the channel region 15 can be controlled to neutralise the effect of variations in the distance d_1 caused by changes in temperature.

FIG. 2 shows a circuit 50 wherein a voltage is applied between the movable gate 4 and the plate 30 of the accelerometer 1 via a feedback circuit 58. The circuit 50 includes a terminal 41 for coupling to a DC power supply. The terminal 41 is coupled to a current mirror 42 having a first output leg coupled to the drain of a MOSFET 45, and a second output leg coupled to the drain of the accelerometer 1. The source of the MOSFET 45 and the source of the accelerometer 1 are coupled to a constant current source 55 which sinks a constant current to ground 53. A DC voltage source 35 is coupled between ground 53 and the gate of MOSFET 45 to apply a voltage to the gate of the MOSFET 45.

The current mirror 42 has an output coupled to an amplifier 61, which in turn is coupled to an output 63. The feedback circuit 58 has an input which is coupled to the output 63, and has a first output coupled to the movable gate 4 and a second output coupled to the plate 30. The feedback circuit 58 is a programmable voltage source that provides an output voltage between its first and second output in accordance with the voltage received from the output of the amplifier 61. Hence, the voltage received from the output of amplifier 61 sets or programs the voltage provided by the feedback circuit 58.

In operation, the voltage provided by the DC variable voltage source 35 is set to a DC magnitude such that the voltage at the output 63 has the same DC magnitude. When this is done, the drain-source current of accelerometer 1 is equal to the drain-source current of MOSFET 45, and the voltage at the gate 4 is equal to the voltage at the gate of MOSFET 45.

When the gate 4 of the accelerometer 1 moves due to changes in ambient temperature, the drain-source current of the accelerometer 1 changes, as described earlier. The change in drain-source current of the

accelerometer 1 relative to the drain-source current of the MOSFET 45 is detected by the current mirror 42 which provides an output voltage i.e. an error voltage, indicating the change in the drain-source current. The error voltage is provided to the amplifier 61 which amplifies the error voltage, and provides the amplified error voltage to the output 63. It should be noted that the error voltage is a stable voltage level and can be regarded as a DC level

The amplified error voltage is also provided to the feedback circuit 58. In response, the feedback circuit 58 applies an output voltage to the gate 4 and the plate 30 of the accelerometer 1 which causes the gate 4 to move such that the transconductance g_m of the accelerometer 1 is changed to reduce the change in the drain-source current of the accelerometer 1.

As the difference in drain-source current between the accelerometer 1 and the MOSFET 45 is reduced, the error voltage from the current mirror 42 reduces. Consequently, the output of the feedback circuit 58 reduces the voltage applied to the gate 4 and the plate 30 of the accelerometer 1.

When the movable gate 4 is in equilibrium, the error voltage reduces to approximately zero, and the effect of the change in ambient temperature on the gate 4 is neutralised. Consequently, the force of an impact on the accelerometer 1 which causes the movable gate 4 to vibrate results in an alternating current (AC) signal at the output 63 which is not affected by the change in temperature.

The impact detecting circuit 50, in accordance with the described embodiment, advantageously enables the distance d_1 to be changed to neutralise the effect of variations in d_1 caused by temperature changes, thereby providing an output signal that more accurately indicates the force of an impact on the accelerometer 1 across a range of ambient temperatures.

In addition, without the neutralising effect provided by the impact detecting circuit 50, the relationship between the force of an impact on the accelerometer 1 and the resultant change in the distance between the movable gate 4 and the channel region is not linear. There are several reasons for such non-linearity.

A first reason is, the spring constants of the pivot sections 7 and 10 change with use over a period of time due to deterioration of the resilience of the polysilicon beam structure. A second reason is, the resilience of the movable gate 4 changes with the degree of displacement or bending of the movable gate 4, and a third reason for the non-linearity is, the drain-source

current of the accelerometer 20 does not vary linearly with the movement of the movable gate 4.

5 The non-linearity gives rise to an error voltage at the output of the current mirror, and as described above, the impact detecting circuit 50 will neutralise the effect of this non-linearity.

10 Hence, the described impact detecting circuit advantageously neutralises the effects of temperature variations, manufacturing variations, and non-linearity of the accelerometer. This is accomplished by providing compensation to the accelerometer, thus enabling the displacement of the detection end by factors other than that of vibration due to an impact force, to be substantially reduced.

15 Thus, in accordance with the described embodiment of the present invention, the drain-source current of an accelerometer is compared with a reference provided from a similar type of semiconductor device. When a difference is detected, a feedback circuit detects the difference and provides an output that affects a change in the accelerometer to neutralise the difference. However, high frequency variations caused by vibration from the force of an impact produces an output signal which is indicative of the vibration.

20 Hence, the described impact detecting circuit is significantly less susceptible to variation in sensitivity caused by manufacturing variations, variations in ambient temperature and non-linearity of the accelerometer.

Claims



1. A circuit comprising:
 - a field effect transistor (FET) having a drain coupled to one leg of a
 - 5 current mirror, a source coupled to a constant current source and a gate biased with a reference voltage;
 - a FET sensor having a movable gate, a bias input, a drain coupled to another leg of the current mirror, and a source coupled to the constant current source;
 - 10 an amplifier having an input coupled to an output of the current mirror and coupled to an output; and
 - a feedback circuit coupled to the output, having a first output coupled to the movable gate, and having a second output coupled to the
 - 15 bias input, wherein the feedback circuit receives a signal from the output when the current mirror indicates the drain current of the FET and the drain current of the FET sensor are not substantially equal, and provides in response thereto a potential difference between the movable gate and the bias input in accordance with the signal received from the output to
 - 20 cause the movable gate to move.
2. A circuit in accordance with claim 1 wherein the feedback circuit comprises a power divider.
- 25 3. A circuit in accordance with any one of the preceding claims wherein the FET and the FET sensor are metal oxide semiconductor (MOS) devices.
- 30 4. A circuit in accordance with claim 3 wherein the MOS devices are NMOS devices.
- 35 5. A circuit in accordance any one of the preceding claims wherein the constant current source comprises a variable current source having an input coupled to the output of the amplifier for setting the voltage at the gate of the FET to be equal to the voltage detected at the output of the amplifier.



6. A circuit substantially as described herein with reference to and as illustrated by the accompanying drawings.