

METHODS AND CIRCUITS FOR PROVIDING BOLOMETER BIAS-HEATING CANCELLATION

FIELD OF THE INVENTION

This invention relates to a method for bolometer bias-heating cancellation, and more
5 particularly to circuits for providing bias-heating cancellation for a single bolometer and
a two-dimensional bolometer infrared imaging array.

BACKGROUND OF THE INVENTION

Micromachined bolometers generally suffer from bias heating effects. Bias heating of
bolometers is generally due to minimal thermal conductance of the membrane where the
10 bolometer resides, the temperature of the bolometer increasing when the bias current
flows through it. The noise or offset generated due to bias heating may be many times
higher than the desired infrared (IR) signal. This will in some instances severely impair
the performance of the bolometer.

According to U.S. Pat. No. 4,752,694, bias-heating can be cancelled together with offset
15 caused by non-uniformity of the electrical resistance in a two-dimensional bolometer
array. The method of this prior art does not allow a subsequent integration to be
performed on the readout signal, and hence the signal-to-noise ratio cannot be further
improved. In a method proposed by Ramakrishna, *et al.* in a paper published in the
Journal, *Sensors and Actuators*, Vol 79, pp122 - 127, 2000, with a title of "Highly
20 sensitive infrared temperature sensor using self-heating compensated microbolometers",
a dummy bolometer is employed in a wheatstone bridge to cancel bias heating. In this
method, the dummy bolometer may not have enough time to cool itself down before the
next pixel is accessed. In another method reported in a paper titled "Theoretical analysis
of pulse bias heating of resistance bolometer infrared detectors and effectiveness of bias
25 compensation" by Christer Jansson, Ulf Ringh and Kevin Liddiard, published in the
Proceedings of SPIE, Vol. 2552, pp644-652, 1995, a temperature sensing resistor is used
to sense the temperature of the bolometer element and set the ramp voltage to cancel the
self-heating of the bolometer. This method, however, generally suffers from inconstant
charging current to the integrator capacitor since the current is set by the temperature
30 sensing resistor, the temperature of the bolometer changing during the readout.

OBJECT OF THE INVENTION

The object of the invention is to provide a circuit and method for bolometer bias-heating cancellation for a single bolometer or a two-dimensional bolometer infrared imaging array so that an infrared signal can be easily read out.

5 SUMMARY OF THE INVENTION

According to one aspect of the invention there is provided a circuit for providing bias heating cancellation for a single bolometer comprising:

a Wheatstone bridge formed with one bolometer type radiation sensor and three resistors;

10 a capacitor for replicating the thermal capacitance of said sensor;

a current source for setting the heating rate;

a plurality of switches connecting said sensor to a bias source V_{DD} and the remainder of the bias-heating cancellation circuit; and

15 a difference amplifier for subtracting the bias-heating from the readout signal from said sensor.

According to another aspect of the invention there is provided a circuit for providing bias heating cancellation for two-dimensional array, comprising:

a plurality of bolometer type radiation sensors connected in an array, each of said sensors having electrical resistance which may vary from sensor to sensor;

20 a capacitor for replicating the thermal capacitances of the said sensors;

two memories with associated address generators, one storing the offsets of said sensors and the other storing the thermal capacitances of said sensors;

a current digital-to-analog converter for taking the data from said memory and

setting the discharging current of said capacitor, and generating a replica of the bias heating of said sensors on said capacitor;

a voltage digital-to-analog converter for taking the data from said memory and compensating the offsets from said sensors;

- 5 a plurality of switches connecting said sensors individually to a bias source V_{DD} and the remainder of said bias-heating cancellation circuit; and

a difference amplifier for subtracting the bias-heating from the readout signal from the sensors.

- 10 According to the circuit for providing bias heating cancellation for a single bolometer, in a preferred embodiment, each of the plurality of switches includes a field effect transistor operating in the triode region, the field effect transistors being controlled by either of two clock signals. More particularly, the clock signals operate to turn the field effect transistors on and off. In a preferred embodiment, the current source of the circuit for providing bias heating cancellation also comprises field effect transistors.

- 15 As will be discussed in more detail in the following description of preferred embodiments of the invention, according to one embodiment, the amplifier of the circuit subtracts the bias heating signal at its inverting input from the readout signal from the sensor at its non-inverting input. In this sense, the final readout signal from the sensor without bias-heating effect is left at the out put of the amplifier.

- 20 According to the circuit for providing bias-heating cancellation for a two dimensional array, it is preferred that each of the plurality of switches includes a field effect transistor operating in the triode region, the field effect transistors being controlled by either of two clock signals. As was the case for the circuit for providing bias heating cancellation for a single bolometer, the two clocks which control the field effect transistors generally
25 operate to turn the transistors on and off.

According to this aspect of the invention, it is also preferred that the amplifier subtracts the bias heating signal at its inverting input from the readout signal for the sensors at its

non-inverting input. Again, in this regard, the final readout signal from each of the plurality of sensors without bias-heating effect is at the output of the amplifier.

BRIEF DESCRIPTION OF THE DRAWINGS

- 5 Embodiments of the invention will now be described in more detail with reference to the accompanying drawings in which:

Fig. 1 is a schematic diagram illustrating a bias-heating cancellation circuit for a single bolometer.

- Fig. 2 is a schematic diagram illustrating a bias-heating cancellation circuit suitable for a
10 two-dimensional bolometer infrared imaging array.

DESCRIPTION OF THE EMBODIMENTS OF THE INVENTION

- FIG. 1 illustrates a bias-heating cancellation circuit for a single bolometer. The circuit, and therefore, method, is based on the equivalence between electrical and thermal capacitance. That is, the electrical capacitance is used to mimic the thermal one. By
15 choosing appropriate capacitance value and discharging current, a replica of the bias heating can be generated on the electrical capacitance. This replica is used to cancel the bias heating of the bolometer. In Fig.1, resistors 2, 3, 6 and 7 form a wheatstone bridge circuit where resistor 2 is a bolometer whose resistance is equal to resistor 6 when there is no infrared signal and no self heating, and where resistor 3 equal to resistor 7.

- 20 The circuit operates as follows. Switches 5, 9 and 10 are controlled by a clock $\Phi 1$ (not shown in Fig.1) and switches 1, 4 and 13 by a clock $\Phi 2$ (not shown in Fig.1). Clocks $\Phi 1$ and $\Phi 2$ are complementary. When clock $\Phi 1$ is high, switches 5, 9 and 10 are closed. A capacitor 8 is pre-charged to the voltage at a node 14. The output voltage of an amplifier 11 is equal to zero as its inputs are shorted by switch 10. When clock $\Phi 1$ becomes low
25 and clock $\Phi 2$ high, switches 5, 9 and 10 are open and switches 1, 4 and 13 are closed. The bolometer is biased by a bias source V_{DD} . At the moment when switches 1 and 4 turn on, the voltage at a node 15 is equal the voltage at the node 14, or the voltage across

the capacitor 8 pre-charged in the previous cycle, because the wheatstone bridge is balanced. The voltage at the node 15 is fed to the non-inverting input of the amplifier 11. Due to the bias heating, the voltage at the node 15 will linearly decrease with time during the clock $\Phi 2$, as does the voltage at the non-inverting input of the amplifier 11. As soon
5 as switches 5 and 9 turn off and switch 13 turns on, the capacitor starts discharging itself through a current source 12. Thus, the voltage at the inverting input of the amplifier 11 also linearly decreases with time. The rate of change is determined by the capacitor 8 and its discharging current I1. With the correct choice of the capacitance value of the capacitor 8 and the discharging current of the current source 12, a replica voltage of self
10 heating can be generated across the capacitor 8. This replica voltage, applied to the inverting input, tracks the bias heating voltage at the non-inverting input of the amplifier 11. Hence, bias heating can be cancelled at the input of the amplifier 11, leaving only the infrared signal to be amplified. The amplified infrared signal appearing at the output of the amplifier 11 is a constant dc voltage. This signal can be further integrated through an
15 integrator to improve the signal-to-noise ratio if desired.

FIG. 2 illustrates a bias-heating cancellation circuit suitable for a two-dimensional bolometer infrared imaging array where 2×2 bolometers (pixels) 29, 30, 31 and 32 are shown. Each pixel (bolometer) is connected to the bias-heating cancellation circuit through corresponding switches 25 or 26 and 27 or 28. Due to the irregularities of the
20 fabrication process, the two-dimensional bolometer array is not electrically and thermally uniform. The resistance of the bolometer at each pixel may vary across the array as may the thermal capacitance of each micromachined bolometer. These non-uniformities need to be compensated in order to efficiently read out the infrared signal. The bias heating is cancelled in the same way as that described in FIG 1. The non-uniformities are
25 compensated as follows.

A voltage digital-to-analog converter (D/A) 17 (whose output is a voltage), together with a memory 18 and an address generator 19, is used to cancel the offset at a node 15 caused by the variation of bolometer resistances. The memory 18 stores the offset at the node 15 in the form of binary numbers. These binary numbers are selected sequentially, as each
30 pixel is accessed, from the memory 18 by the address generator 19 controlled by a clock $\Phi 1$ and converted to an analog voltage through the D/A 17. Clocks $\Phi 1$ and $\Phi 2$ are

complementary and run at the pixel rate of the array. The output voltage from the D/A 17 is applied to a conductor 16 so that a proper voltage is set up at a node 14 through a resistor 7 to cancel the offset at the node 15.

5 The non-uniformity caused by mismatch of thermal capacitance of the micromachined bolometers is normally much smaller than that of the electrical resistance. The effect of mismatch of the thermal capacitance on the bias heating is the change of the heating rate. This can be compensated by varying the discharging current I_1 . Similarly to the
10 aforementioned offset cancellation, the information of thermal capacitance of each pixel (bolometer) is stored in a memory 20 as a binary number. During the clock $\Phi 2$, these binary numbers are selected by an address generator 21 according to the sequence in which any the pixels are interrogated. The selected data is converted to a dc current by means of a D/A 22 (whose output is a dc current sink) to set the discharging current I_1 through a conductor 23 for the selected that pixel. Hence the non-uniformity of the thermal capacitance can be compensated.

15 Those skilled in the art will appreciate that the invention described herein is susceptible to variations and modifications other than those specifically described. It is to be understood that the invention includes all such variations and modifications which fall within its spirit and scope. The invention also includes all the steps, features, compositions and compounds referred to or indicated in this specification, individually or
20 collectively, and all combinations of any two or more of said steps or features.



CLAIMS

1. A circuit for providing bias heating cancellation for a single bolometer comprising:
 - a Wheatstone bridge formed with one bolometer type radiation sensor and three resistors;
 - 5 a capacitor for replicating the thermal capacitance of said sensor;
 - a current source for setting the heating rate;
 - a plurality of switches connecting said sensor to a bias source V_{DD} and the remainder of the bias-heating cancellation circuit; and
 - a difference amplifier for subtracting the bias-heating from the readout signal
 - 10 from said sensor.
2. The circuit according to claim 1 in which each of the plurality of switches is a field effect transistor operating in the triode region, said field effect transistors being controlled by either of two clock signals.
3. The circuit according to claim 1 in which said current source comprises field effect
- 15 transistors.
4. The circuit according to claim 1 in which said amplifier subtracts the bias-heating signal at its inverting input from the readout signal from said sensor at its non-inverting input.
5. The circuit according to claim 1 in which the final readout signal from said sensor
- 20 without the bias-heating effect is at the output of said amplifier.
6. A circuit for providing bias heating cancellation for two-dimensional array, comprising:



- a plurality of bolometer type radiation sensors connected in an array, each of said sensors having electrical resistance which may vary from sensor to sensor;
- a capacitor for replicating the thermal capacitances of the said sensors;
- two memories with associated address generators, one storing the offsets of said sensors and the other storing the thermal capacitances of said sensors;
- 5 a current digital-to-analog converter for taking the data from said memory and setting the discharging current of said capacitor, and generating a replica of the bias heating of said sensors on said capacitor;
- 10 a voltage digital-to-analog converter for taking the data from said memory and compensating the offsets from said sensors;
- a plurality of switches connecting said sensors individually to a bias source V_{DD} and the remainder of said bias-heating cancellation circuit; and
- a difference amplifier for subtracting the bias-heating from the readout signal from the sensors.
- 15 7. The circuit according to claim 6 in which each of the plurality of switches is a field effect transistor operating in the triode region, said field effect transistors being controlled by either of two clock signals.
8. The circuit according to claim 6 in which said amplifier subtracts the bias-heating signal at its inverting input from the readout signal from said sensors at its non-inverting input.
- 20 9. The circuit according to claim 6 in which the final readout signal from each of said plurality of sensors without the bias-heating effect is at the output of said amplifier.