Circuit topologies for Peltier effect anemometer

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Abstract

This paper proposes topologies for the circuits of a new anemometer, called "Peltier effect anemometer".
A short introduction to the measurement principle is firstly presented, followed by the necessary circuits for measurement.

1. Introduction

There are many methods of measurement of air velocity [5, 6, 7]. One of these is the hot-wire anemometer. The hot-wire anemometer is largely utilized for integration, for example in MEM's, due to simplicity of sensor construction and the electronic circuits necessary for the device functioning. Meanwhile the hot-wire anemometer possesses many limitations, basically generated by the necessity of heat the sensor element considerably beyond from temperature of air. The major problem presented by this measurement technique is its incapability of measuring velocities below 0.5 m/s. Measurements of low velocities are important, for example, in studies of air flow produced by natural convection. For this range of velocity other techniques are indicated. The Peltier effect anemometer is one of those techniques. For a better understanding of the device, a brief introduction of Peltier and Seebeck effects is given below.

2. Seebeck effect

The Seebeck effect consists in a voltage generated in the junction of two materials, as show in Fig.1.

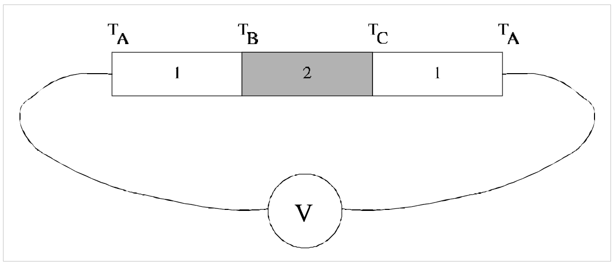

Fig. 1: Seebeck effect

When the two junctions are at distinct temperatures a voltage difference is generated, expressed by:

$$V = (a_1 - a_2)(T_B - T_C)$$

where:
V: Voltage difference [V];
a_1, a_2 : Thermoelectric potential of materials 1 and 2 [V/K];
T_A, T_B, T_C : Junction temperatures [K].

3. Peltier effect

The Peltier effect is characterized by a heat absorption (or generation) by the junction of two materials when a current passes through the junction.

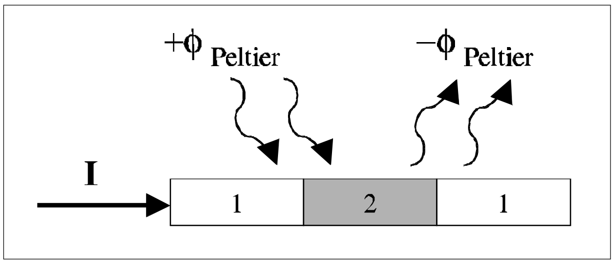

Fig. 2: Peltier effect

The heat flux, which is absorbed or generated depending on the direction of current (Fig. 2) is defined by:

$$f_{Peltier} = (a_1 - a_2)IT$$

where:
$f_{Peltier}$: Heat flux generated or absorbed by Peltier effect [W];
I : Intensity of current through the junction [A];
T : Absolute temperature of junction [K].

4. Deposited electrodes sensor

The sensor utilized in Peltier effect anemometer consists in various thermocouples in serial association. To simplify the manufacturing process, the sensor is implemented using electrolytic (or chemical) deposition of a metallic cover of great electrical conductivity (material 2, Fig. 3) over a metallic support of smaller conductivity and different thermoelectric power (material 1, Fig. 3).

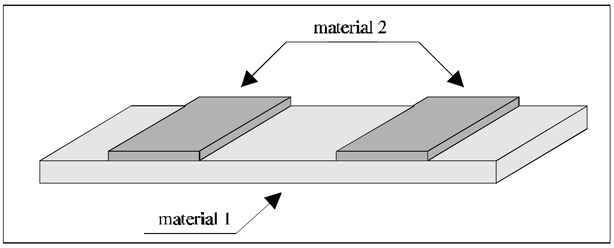

Fig. 3: Deposited electrodes sensor

The thermoelectric characteristics of this type of sensor, determined by Güths [1], are not so as good as the characteristics presented by traditional thermocouples. However, the manufacturing easiness and the smaller sensitivity to the direction of air flux make this manufacturing method interesting.

5. Example of a sensor

One example of a sensor with deposited electrodes sensor, is given in Fig. 4.

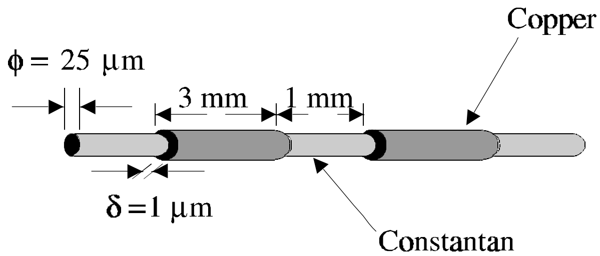

Fig. 4: Physical dimensions

With these physical dimensions and for a current in the sensor of 10 mA, the response curve is given by the Fig. 5.

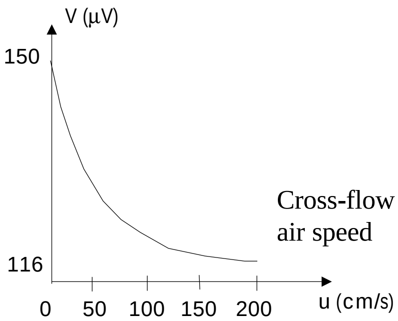

Fig. 5: Response curve of sensor (by cell)

6. Principle of operation

The anemometer operates alternately between the Peltier and Seebeck effects. In a first moment an electric current is applied to the sensor. One of the junctions absorbs heat while the other generates heat both by Peltier effect. The result is a temperature difference between the two junctions. In a second moment, the current is interrupted and the voltage generated by Seebeck effect is quickly measured. The Seebeck effect should be measured trough the open circuit f.e.m. because the Ohm's voltage drop should be zero. The temperature in this interval is supposed to be constant. This temperature difference is basically dependent of fluid velocity. When the velocity increases, the generated temperature difference decreases, as show in Fig. 6.

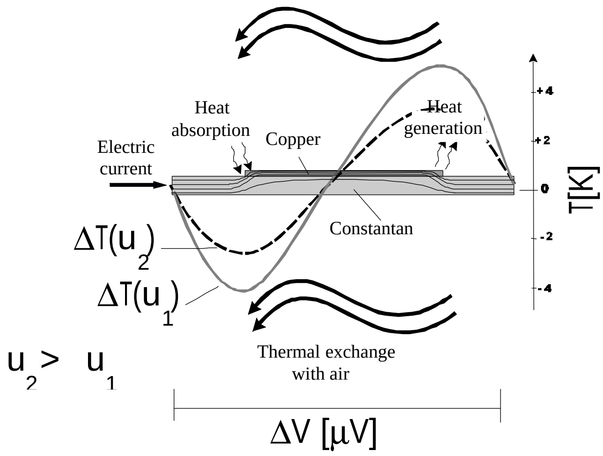

Fig. 6: Peltier effect in a cell

It's worthwhile emphasizing that the increment of the average sensor temperature generated by the Joule effect (of the order of 3mW for the sensor analyzed in this work) is small, being approximately 10°C. This perturbation induced by the sensor (by natural convection) is small, allowing measurement of low velocities (over 2 cm/s in the air).

The Fig.7 show the waveform of the signal applied to the sensor. The direction of the current is changed periodically to overcome the problem generated by the presence of temperature gradients along the sensor.

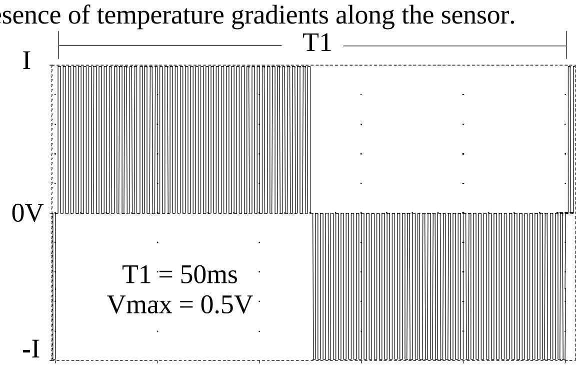

Fig. 7: Injected signal in the sensor

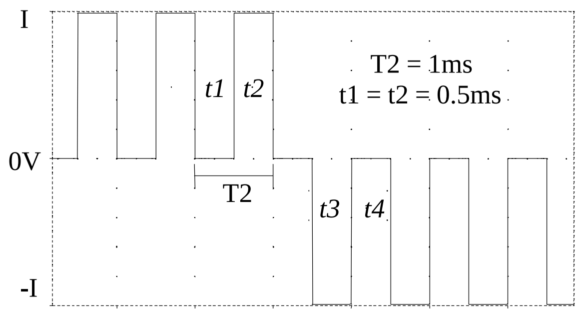

Fig. 8: Zoomed central region of Fig. 7

The output signal is achieved by subtraction of the voltages obtained in the positive (t_1) and negative (t_4) cycles, eliminating the parasitic signal caused by the gradient of temperatures in the fluid. The periods *T1*, *T2*, *t1* and *t2* need to be determined through the characteristics of the sensor response time and minimal acquisition time of the sample-hold circuits.

A simplified block diagram of the anemometer is show in Fig. 9.

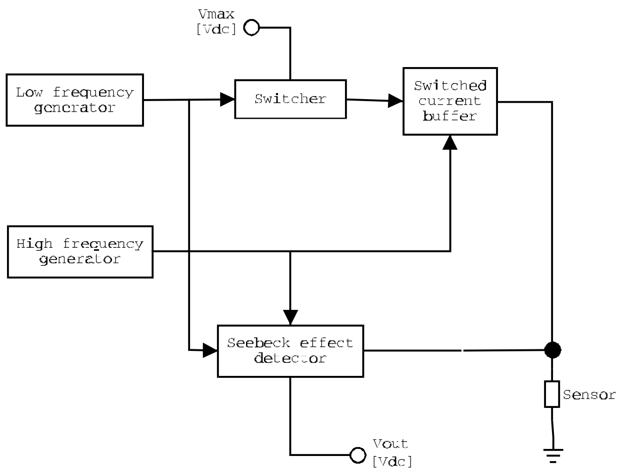

Fig. 9: Simplified block diagram

7. Generation of the signal injected in the sensor

In the prototype in construction the generation of applied voltage to the sensor is performed by the circuit showed in Fig 10.

This block was designed for that control signals *VC1* and *VC2* (Fig. 11) have single polarity. This way the control circuit is simplified and this signals may be compatibles with standard digital logic's.

The comparators are utilized as level shifters for the activation of switches.

In the detection period of Seebeck voltage, is important that the generation stage be isolated of detection stage and this is performed through the switches *SW3* to *SW5* and the diodes *D2* and *D3*.

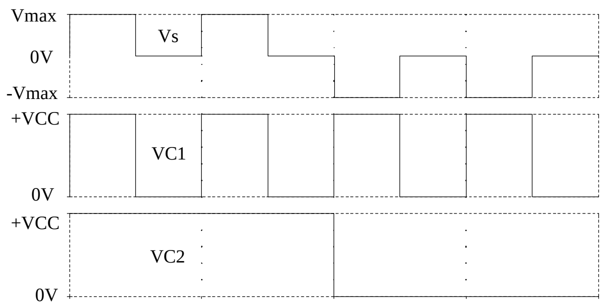

Fig. 11: Control signals *VC1* and *VC2*

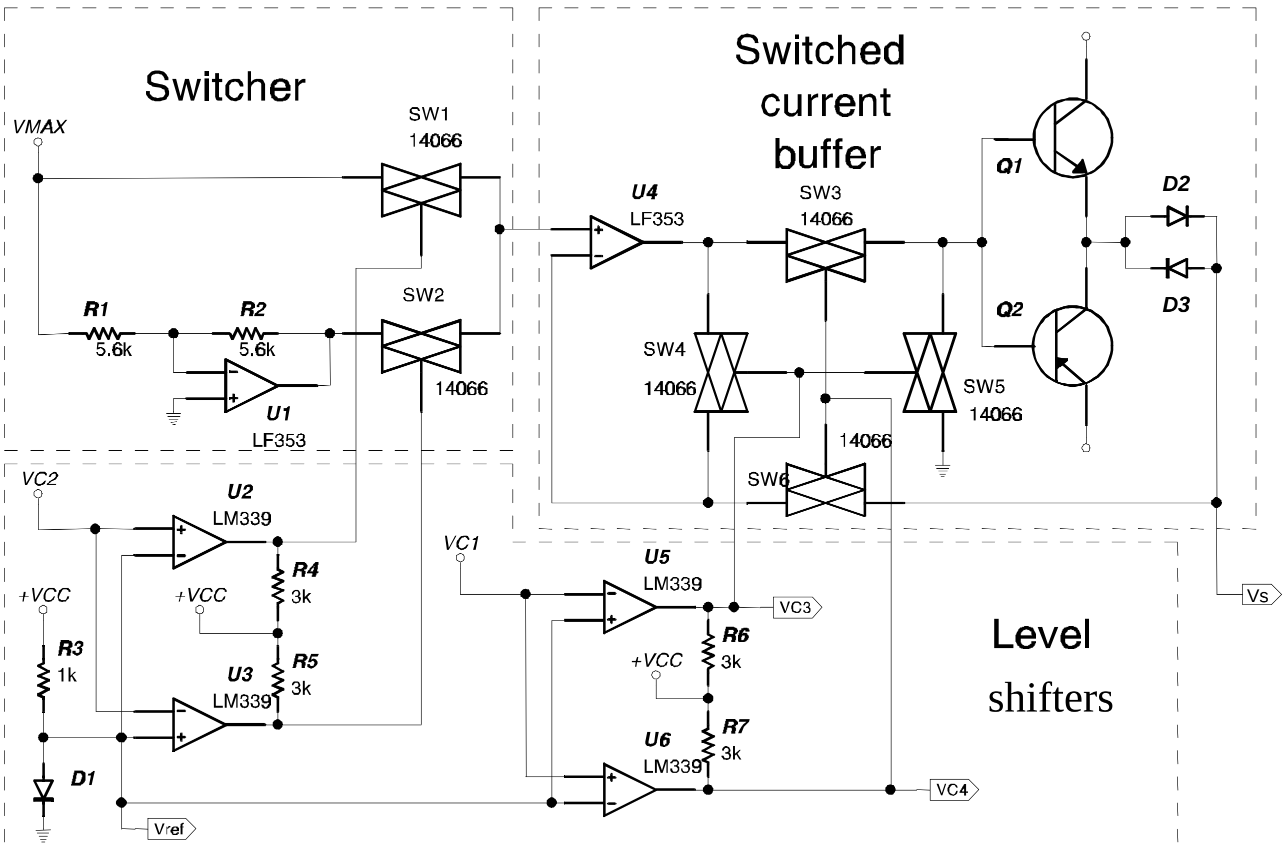

Fig 10: Generation circuit

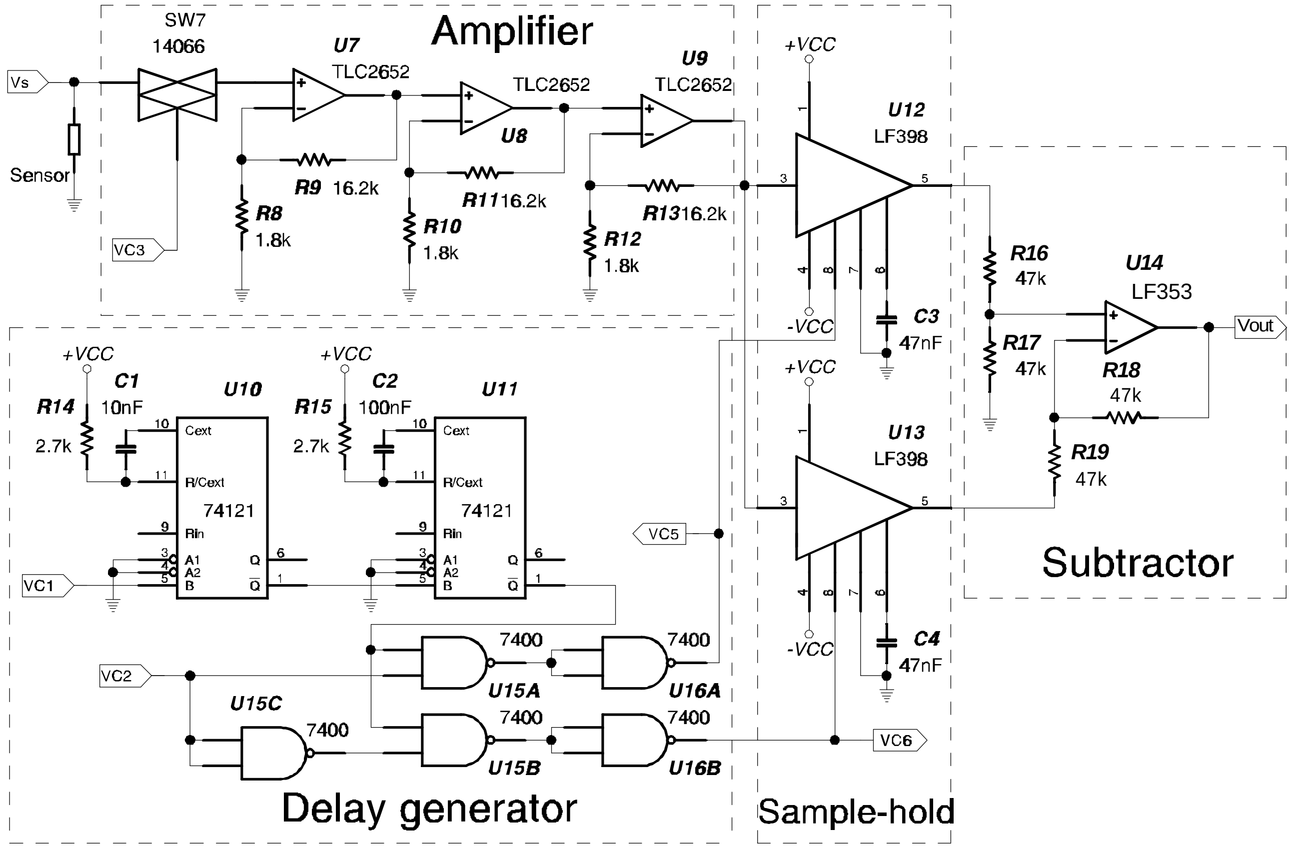

Fig. 12: Detection circuit

8. Detection of Seebeck effect

The detection of Seebeck effect is the more critical stage in the Peltier effect anemometer, because of the voltage level in the sensor (µV).

The detection circuit is showed in Fig. 12. The main idea for this stage is to not allow the circuit input to be connected with the generator stage in the detection interval of Seebeck effect. If that weren't done, it would be generated high glitches that saturate the amplification stages, prejudicing the performance of device.

The isolation of the stages is done through the switch *SW7*. The activation of this switch is performed by the signal showed in Fig. 13.

The Seebeck signal being very small, it is recommendable to utilize OPAMP's of low offset in the initial stages of amplification. In the case of this prototype, it was utilized chopper stabilized amplifiers (*U7* to *U9*). To avoid problems of slew-rate and band-gain product of OPAMP's, the initial stage of amplification was divided into three stages of gain 10. Before this amplification the signal is sampled by two circuits of sample-hold; one for the positive cycle of current injection and other for the negative. This separation is necessary to eliminate of the voltage caused by temperature gradients, as exposed before.

Finally, the signals obtained in the positive and negative cycles are subtracted and the output voltage signal are obtained.

The control signal for the sample-hold circuits are showed in the Fig. 13. It's obtained through two circuits which execute delays in the signal *VC1* and the logic formed by the AND gates. This way, it is obtained the delays (*td*) showed in Fig. 13.

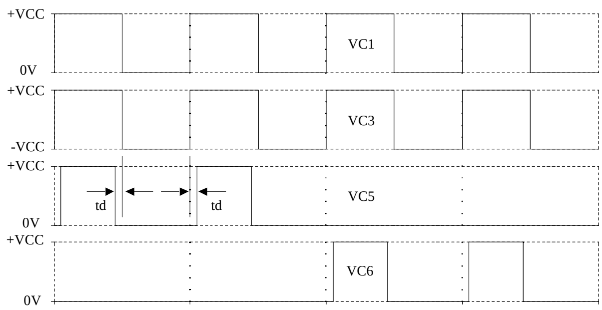

Fig. 13: Control signals for detection circuit

9. Temperature compensation

The voltage supplied by the sensor depends on the air speed and temperature. This implicates in the realization of a compensation step. In the prototype this compensation will be made by software. The temperature sensor can be a typical commercial sensor, such as the LM35.

10. Conclusions

The Peltier effect anemometer demands a more complex electronics than the hot-wire based anemometer, but is a good alternative for flow sensors. It's major application is for low velocities (0.02m/s ≤ u ≤ 0.5m/s), where the traditional hot-wire sensors don't actuate in this range (hot-wire).

This paper has showed just the discreet way mounted circuits, but the integration is possible. The sensor may be constructed away of the rest of the circuit and with the utilization of standard CMOS technologies, the total cost of the device could be strongly reduced.

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