

CONSTANT TEMPERATURE ANEMOMETER WITH DUTY-CYCLE OUTPUT CONVERSION

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ABSTRACT

A constant temperature anemometer (CTA) with ON-OFF power feedback and duty cycle output is described. Two IC temperature sensors are used; one overheated and the other to compensate ambient temperature. Smart output processing allows velocity measurement without A/D conversion. PSPICE modeling of the anemometer and time response comparison of CTA vs. constant power mode is presented.

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1. INTRODUCTION

In constant temperature anemometers, air velocity increases power of the self heated sensor. Power feedback is required to maintain constant temperature in the heated temperature sensor because air velocity changes its heat loss. A circuit with simple ON-OFF power feedback is presented in this paper that allows temperature of the heated element to be kept 5°C above air temperature of the second reference sensor. The linear 10 mV/°C output of both IC sensors simplifies overheating temperature control through a Schmitt trigger comparator.

Frequency or duty cycle conversion of measured signal has the advantage of direct digital measurement without A/D conversion [1]. Duty-cycle conversion using charge and discharge of a capacitor via a Schmitt trigger has been used in temperature sensor measurements [2].

In this paper a different approach without a capacitor makes sensor input power directly proportional to output signal duty-cycle, which is proportional to air velocity.

PSPICE simulation of CTA time response advantage over constant power mode is presented.

Digital measurement procedure of duty-cycle is briefly discussed and measurements in the 0-1 m/s interval are performed.

2. CIRCUIT DIAGRAM OF THE ANEMOMETER

In Figure 1 the output difference of two linear IC temperature sensors with 10 mV/°C sensitivity is amplified

ten times by an instrumentation amplifier and compared to a reference voltage by a Schmitt trigger comparator; whose output is minus V_{CC} when the sensors' output difference is below the reference voltage. Then, a current $\frac{V_{CC}}{R_1}$ (neglecting S_1 output voltage) is pulled down from sensor S_1 to increase its temperature T_1 until it exceeds in 5°C air temperature T_2 of sensor S_2 . Power fed back to S_1 will switch ON-OFF from a DC level $\frac{V_{CC}^2}{R_1}$ to practically zero, maintaining the constant temperature difference of 5°C.

Power feedback waveform, under stationary conditions, is shown in Figure 2, and its average value is given by the expression:

$$P_{AV} = p \frac{(V_{CC}^2)}{R_1} \quad (1)$$

where p is the duty-cycle.

As air velocity increases, the average power fed back to S_1 will increase approximately according to:

$$P_{AV} = \Delta T \left(A_0 + B_0 V^{1/2} \right) \quad (2)$$

From these expressions it can be seen that output signal duty-cycle is a function of air velocity.

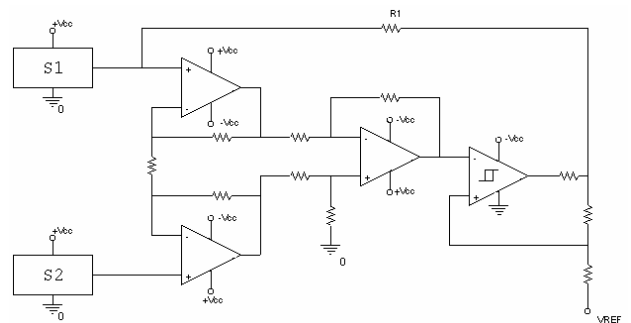


Figure 1: Circuit diagram of the anemometer

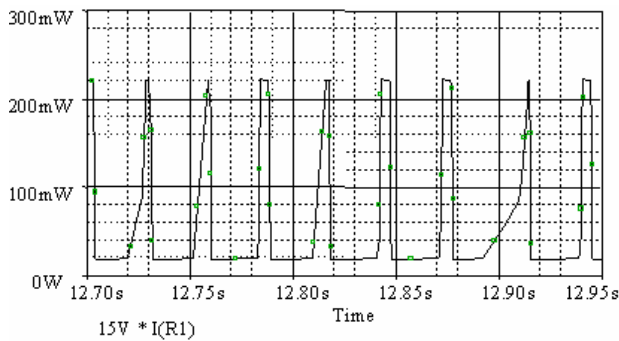


Figure 2: Power feedback waveform under stationary conditions

3. PSPICE simulation

A PSPICE model of the temperature sensor was developed, including the sensor sensitivity of 10 mV/°C and the overheating effect due to a pull down current. Figure 3 shows the PSPICE schematic.

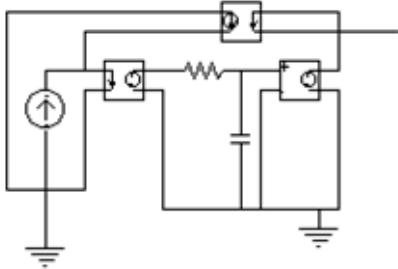


Figure 3. PSPICE model of the IC temperature sensor

The temperature sensors were substituted by their PSPICE model and two configurations were simulated: constant temperature and constant power. It has been reported that CTA anemometers improve significantly the time response in comparing with constant power mode [3].

Figure 4 shows the time response of the CTA and Figure 5 shows the time response of the constant power anemometer, under similar conditions.

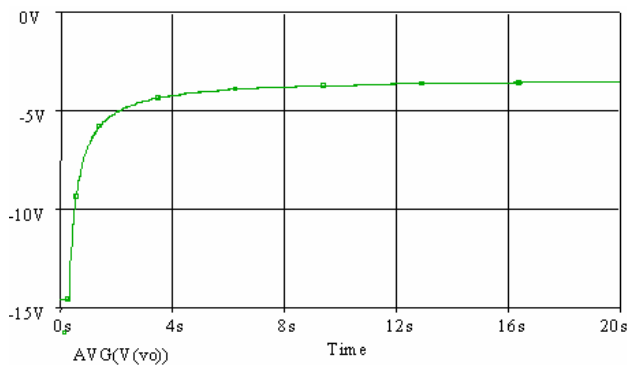


Figure 4: Time response of the CTA

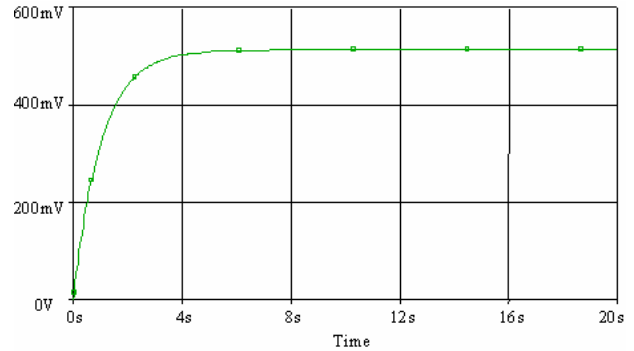


Figure 5: Time response of the constant power anemometer

It can be seen that the CTA mode time constant is almost half of constant power mode.

4. DUTY-CYCLE MEASUREMENT

Duty-cycle measurement of digital signals is rather simple because most state of art μC have internal counters and in the past few years their operation frequency has increased significantly allowing a more accurate measurement. Such procedure has been presented in a thermal sensor with duty-cycle output [2].

In the anemometer presented here the minimum pulse duration under still air conditions exceeds 200 ms, for other values of air velocity in the 0-1 m/s pulse duration will be larger.

With a typical 12 MHz frequency μC , sample intervals down to 1 μs can be attained. In Table 1, experimental results in the 0-1 m/s interval are shown.

An elementary wind tunnel is used; air velocity is measured with a Dantek 54T21 omnidirectional anemometer and duty-cycle is measured with a Hameg digital oscilloscope.

V m/s	duty-cycle
0	0.4134
0.034	0.5038
0.082	0.5335
0.128	0.5542
0.164	0.5885
0.195	0.6033
0.276	0.6201
0.344	0.6603
0.408	0.6572
0.508	0.6783
0.72	0.6892
0.85	0.7086
0.927	0.7326

Table 1. Experimental results of duty-cycle vs. air velocity

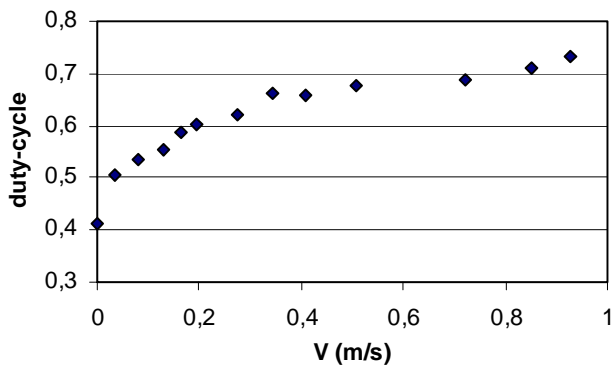


Figure 6: Experimental results of duty-cycle output in the 0-1 m/s interval

5. DISCUSSION AND CONCLUSIONS

Both TO92 encapsulated IC temperature sensors are directly exposed to the flow and no laminar behavior is expected [4]. At such low air velocity the zero flow power is also significant and therefore no attempt is made to match experimental results to a theoretical function. Nevertheless experimental results show that this simple anemometer with duty-cycle output is very sensitive at low air velocities. It can be possible to express output duty-cycle as a function of air velocity .

PSPICE modeling and simulation shows the time response advantage of CTA anemometer over constant power mode.

6. REFERENCES

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