Anemometer

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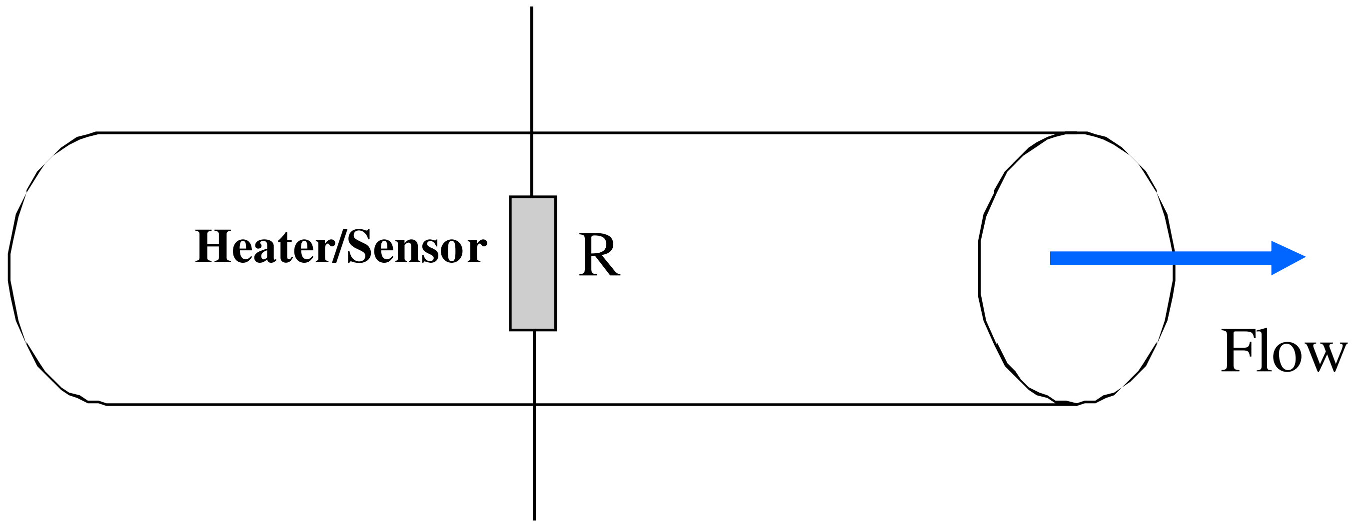
3-13-2013 anemometer_lab.ppt

OUTLINE

Objective
Theory
Experimental Set Up
Measurements
Results
Discussion
References

SINGLE WIRE ANEMOMETER

A single heater/sensor element is placed in the flow. The amount of power supplied to keep the temperature constant is proportional to flow. At zero flow a given amount of power Po will heat the resistor to temperature To. With non zero flow more power Pf is needed to keep the resistor at To.



THEORY

A resistor is heated and placed in fluid flow. Flow causes the temperature of the resistor to change and the temperature change causes a change in mobility that causes a change in the value of the resistance. The change in resistance is related to the velocity of the air flow, temperature of the sensor, temperature of the fluid, the specific heat of the fluid and the physical parameters of the resistor and the air flow chamber.

Units of flow:
sccm = standard cubic cm per min.
Slm = standard liter per min.

THEORY

When electrical current runs through a resistor, power is dissipated as heat.

As a fluid passes over and around the resistor, the heat is removed through convection.

The heat removed is equal to the power dissipated:

$$I^2R = hA(T_w - T_f)$$

Where h is the heat transfer coefficient of the wire, T_w is the wire temperature, T_f is the fluid temperature, and A is the surface area of the wire.

THEORY

The resistance of the wire used will depend on its temperature according to the equation:

$$R_w = R_0[1 + \alpha(T_w - T_0)]$$

The heat transfer coefficient, *h*, can be calculated according to King's law:

$$h = a + bv_f^n$$

Where a, b, and n are calibration coefficients. A value of 0.45 is commonly used for *n* in hot-wire anemometers. The value of *a* can be calculated by taking measurements with no fluid flow, and *b* can be found by using the recorded value of *a* at a known flow rate.

THEORY

Combining these equations, we get:

$$a + bv_f^n = \frac{I^2 R}{A(T_w - T_f)} = \frac{I^2 R_0[1+\alpha(T_w - T_0)]}{A(T_w - T_f)}$$

Solving for v_f:

$$v_f = \left(\frac{\left(\frac{I^2 R_0[1+\alpha(T_w - T_0)]}{A(T_w - T_f)} \right) - a}{b} \right)^{\frac{1}{n}}$$

How does this help?

This means that for a given wire, the fluid velocity is a function of the wire temperature, fluid temperature, and current through the wire.

THEORY

If the wire temperature, fluid temperature, and current through the wire are known, the fluid velocity is known. Fluid temperature can be measured, and the two other unknowns lead to the two types of hot-wire anemometry:

- Constant-Temperature Anemometry: The temperature of the wire is kept constant, and the flow rate is calculated based on the amount of current required.
- Constant-Current Anemometry: The temperature of the wire is determined by measuring its resistance when a constant current runs through it.

At a constant temperature (and hence resistance), the fluid flow is:

$$v_f = \left(\frac{I^2 - a'}{b'} \right)^{\frac{1}{n}}$$

SENSOR/CIRCUIT CHARACTERISTICS

The wire or sense resistor used must have a high TCR value so that it responds well to changes in flow rate. Platinum is a commonly used material.

The resistance of the sensor should allow it to be easily heated by the available current.

In the Wheatstone Bridge circuit, there must be good matching between R1 and R2, as well as between R3 and R0(1+x) at the desired temperature.

R1, R2, and R3 should be kept in a stable environment (outside of flow). The resistance of the leads to the sense resistor must be taken into account.

As used in the null-type circuit, the sensor has good linearity.

CALCULATION OF RESISTANCE

MICROELECTRONIC ENGINEERING 3/22/2010
Rochester Institute of Technology Dr. Lynn Fuller

CALCULATION OF RESISTANCE FROM LENGTH, WIDTH, THICKNESS AND IMPLANT DOSE

To use this spreadsheed change the values in the white boxes. The rest of the sheet is protected and should not be changed unless you are sure of the consequences. The calculated results are shown in the purple boxes.

Calculation of Mobility of Single Crystal Silicon

CONSTANTS	VARIABLES			CHOICES	
Tn = T/300 1.00				1=yes, 0=no	
	Temp=	300	°K	n-type	0
	Concentration from Dose / thickness, N = Dose/t =	1.33E+18	cm-3	p-type	1

Kamins, Muller and Chan; 3rd Ed., 2003, pg 33

mobility = μ = 131 cm2/(V-sec)

Calculation of Resistance

L ength is the drawn length	Length, L =	180	μm
Width is the drawn width	Width, W =	200	μm
Thickness is known if poly, or Xj from Diffusion.XLS	Thickness, t =	1.5	μm
Implanter setting if doped by ion implant or from Diffusion.xls if doped by diffu	Dose =	2.00E+14	/cm2
	Poly ?	0	Yes=1 , No =0
	resistance/poly grain boundary	0.9	ohm

Calculation of Resistance

	approximate number of grain boundaries in path = L / t =	120	
	Average Doping = Dose/Thickness =	1.33E+18	atoms/cm3
	Mobility, μ =	131	cm2/v-sec
q = 1.6e-19 coulomb / ion	Rhos = sheet resistance =1/(q μ Dose) =	239	ohms/sq
	Rho = bulk resistivity =	159	ohm-cm
R = Rho L / W / t	Resistance =	215	ohms
R = Rhos L / W	If Poly the effective sheet resistance =	239	ohms/sq

We assume the grain size is equal to the poly film thickness/2. We calculate the number of grains from the length, divided by the grain size, t/2. We also assume the grain boundary adds a fixed resistance that is not a function of temperature or doping. The resistance of a grain boundary is found from resistance measurements of poly resistors

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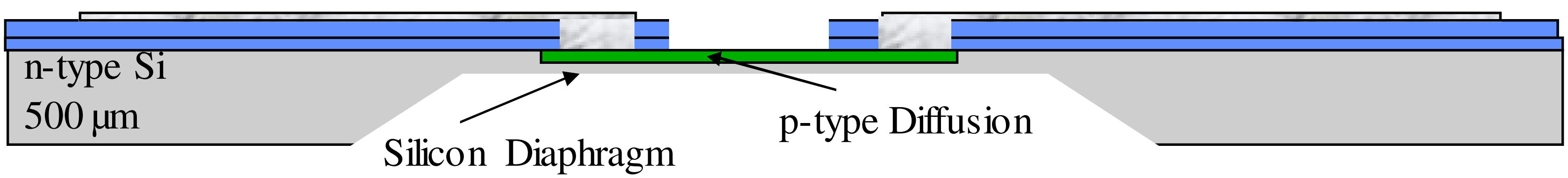
EXPERIMENTAL SET UP QUESTIONS

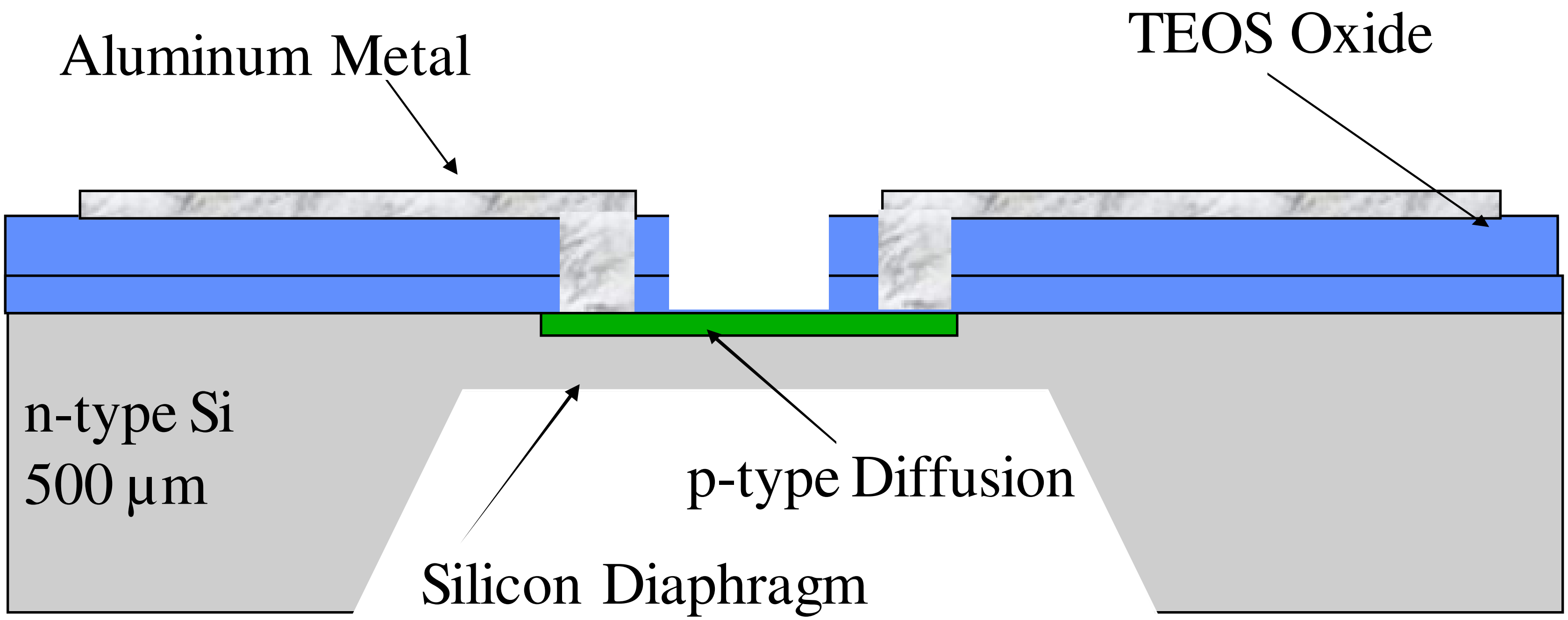
1. How is the anemometer resistor heated? Self heated by applied voltage which is automatically adjusted to keep the resistor at a constant value.

2. What physical properties of the resistor design are important for a good sensor? The resistor should change its value with temperature (single crystal preferred over poly crystal silicon) and it should be insulated on the bottom but in contact with the gas flow on the top.



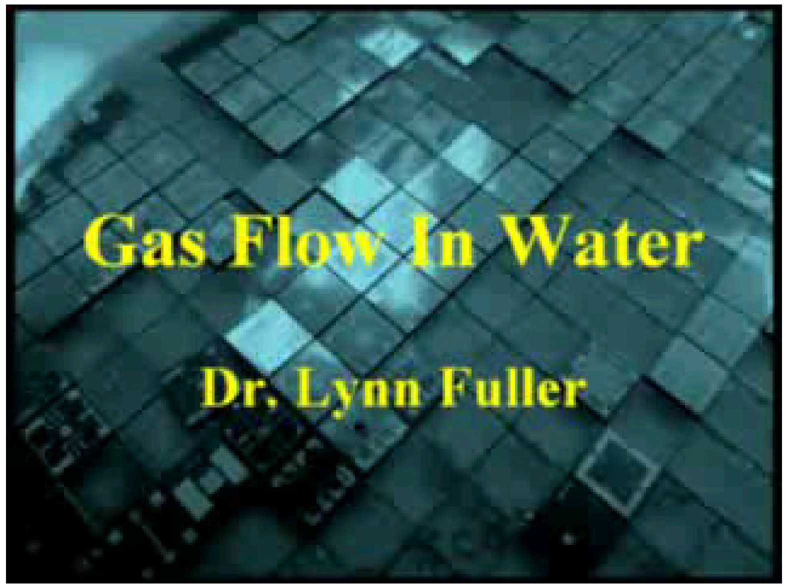
3. We expect the resistance to only change by a small amount. Lets come up with a simple but sensitive measurement technique.

BACKSIDE ETCHED BULK MICROMACHINED POLYSILICON RESISTOR GAS FLOW SENSOR

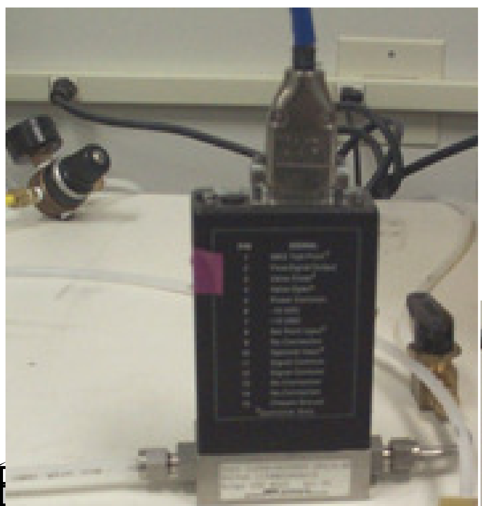


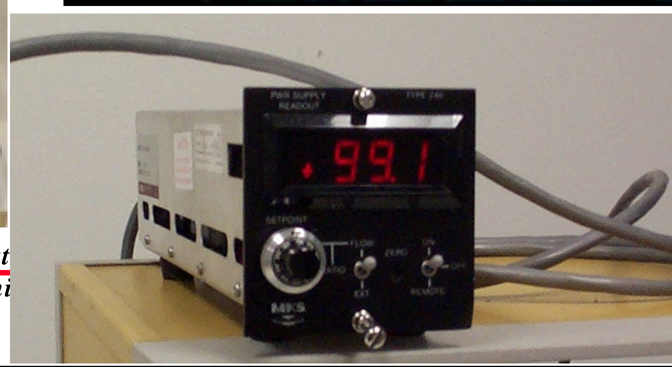
EXPERIMENTAL SETUP

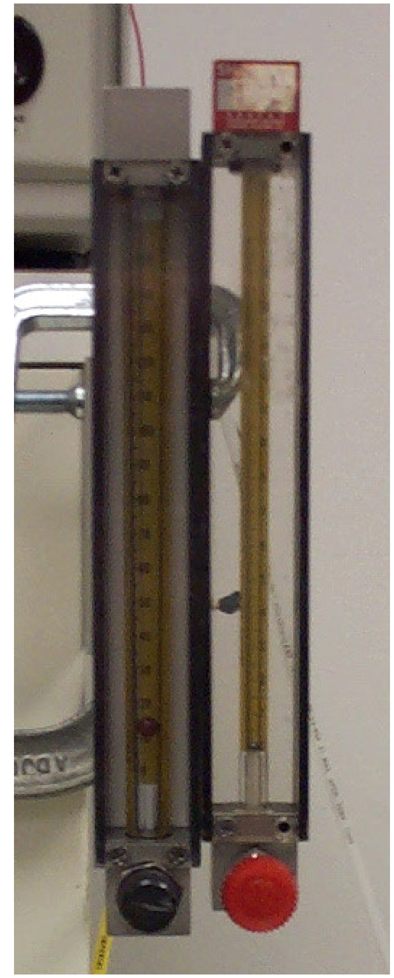
1. How can we control the flow? Pressure?
2. How can we calibrate the flow?



MFC





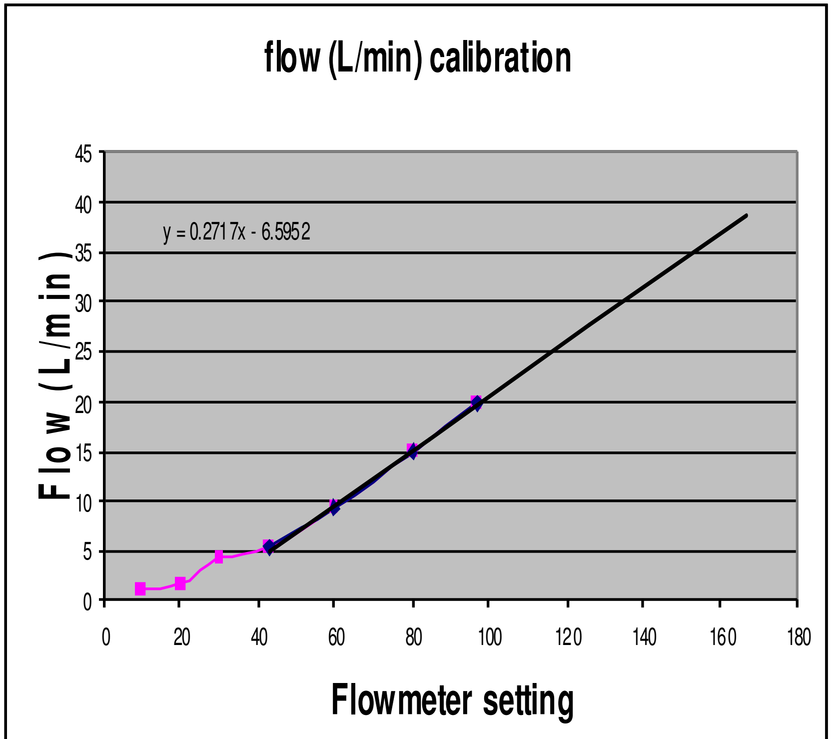


Rotometer

FLOW CALIBRATION

Dr. Pearson calibrated the airflow gauge on the bench by finding the amount of time it took to displace 2L of water in an upside down beaker. Manufacturers data sheet for Sapphire Ball gives 28.6 SLM full scale (marked as 150 on the gauge)

mL	time	setting	flow (mL/s)	SLPM
2000	100	10	20	1.2
2000	75	20	26.66666667	1.6
2000	28	30	71.42857143	4.285714
2000	22	43	90.90909091	5.454545
2000	13	60	153.8461538	9.230769
2000	8	80	250	15
2000	6	97	333.3333333	20
		120		26
		140		31
		150		34



MEASUREMENTS

Transfer Function (Output voltage vs flow in sccm)

Calibration

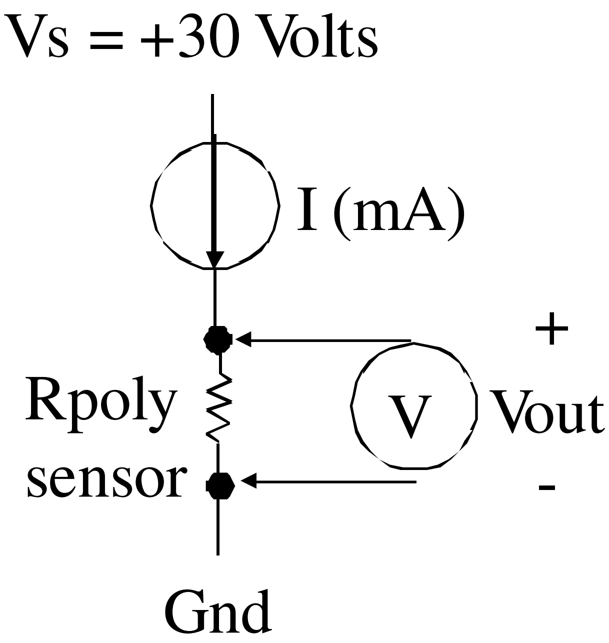
Span

Resolution

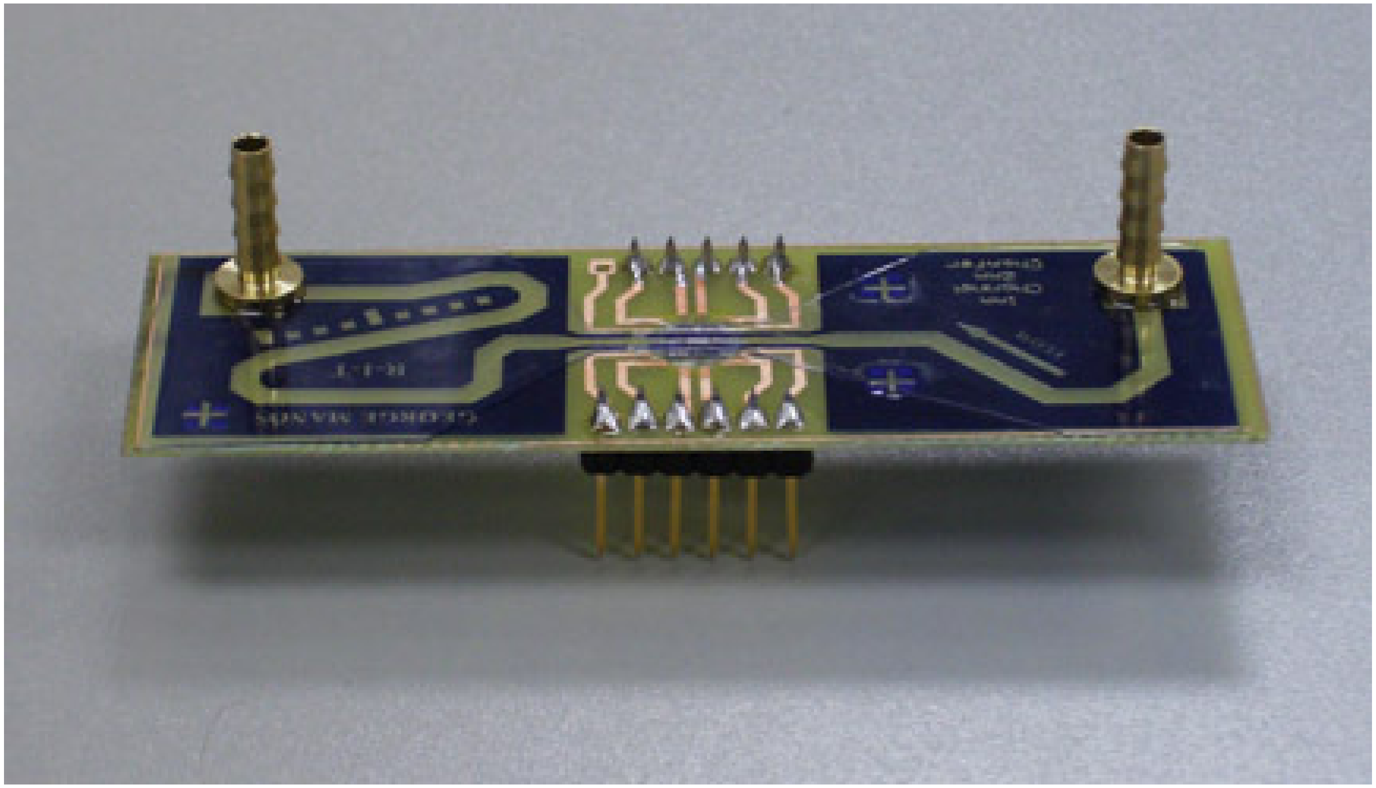
Frequency Response

ANEMOMETER MEASUREMENTS

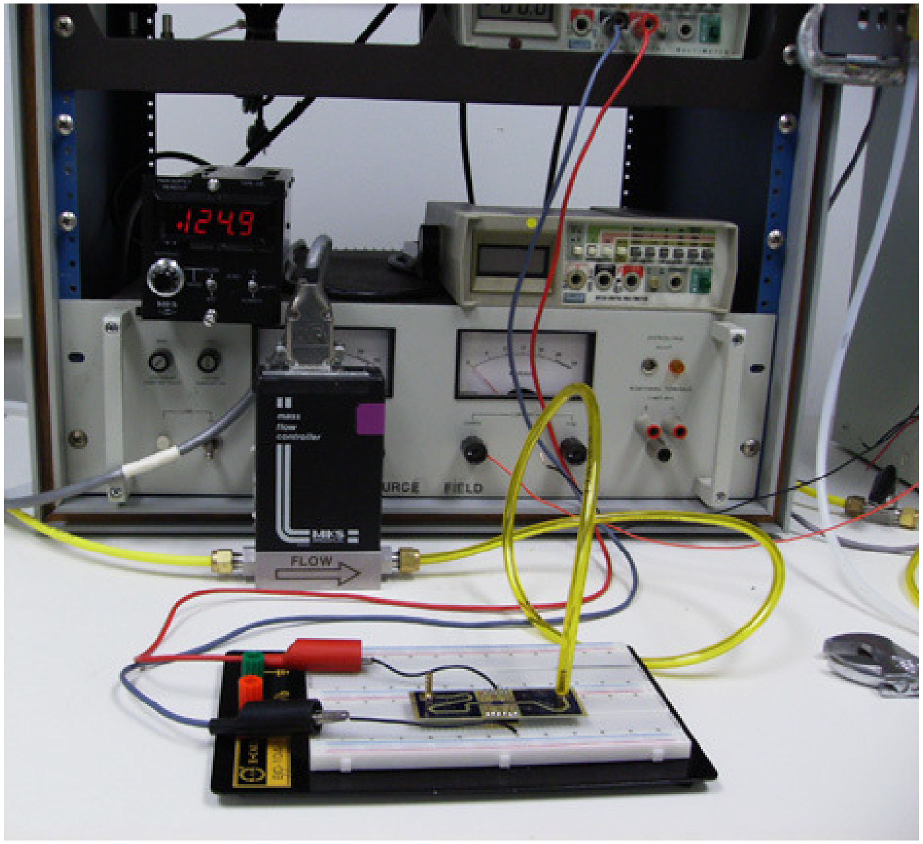
Calculate the current needed to generate ~1 watt in the poly resistor. The poly resistor is self heating and will reach some temperature with no gas flow. The resistance will change if gas flows over the resistor. To measure the response use the simple circuit shown.

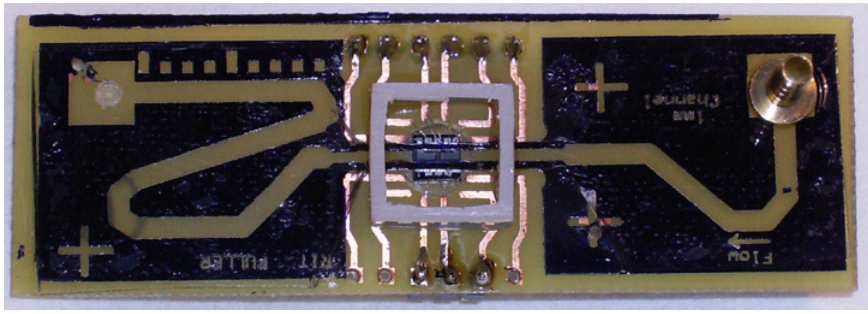


PACKAGE GAS FLOW SENSOR



TEST SET UP FOR GAS FLOW SENSOR

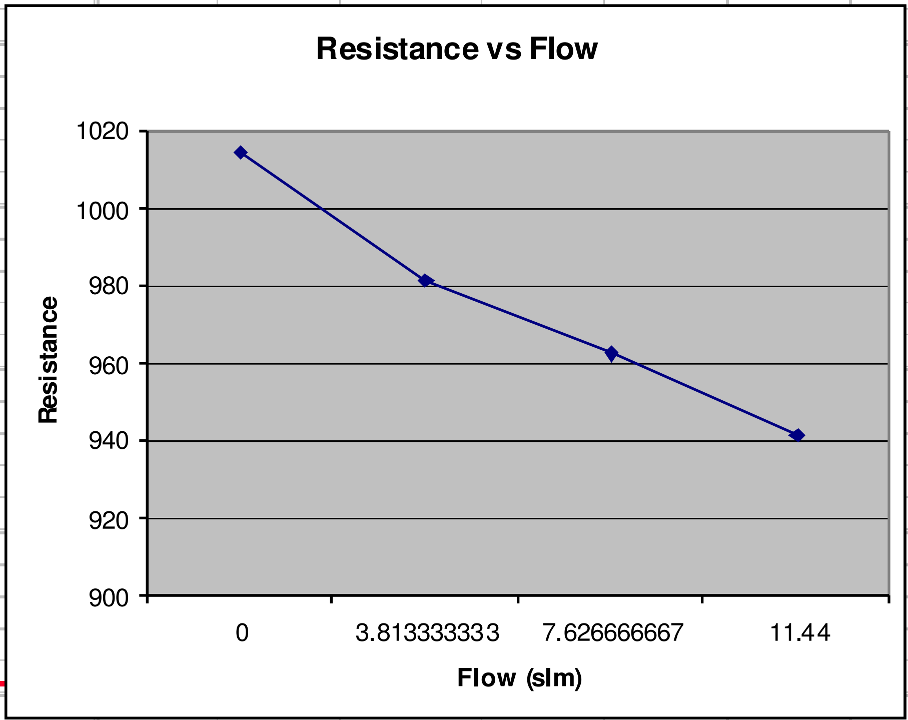


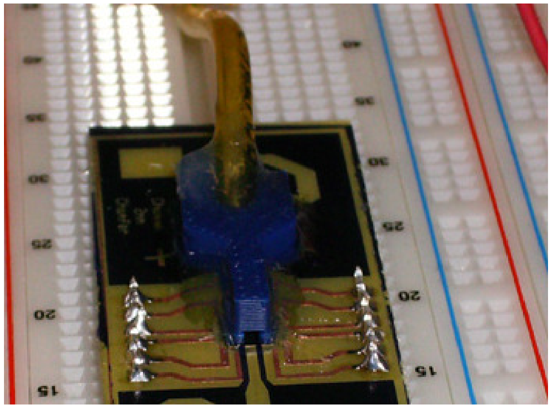


RESULTS FROM PACKAGED SENSOR

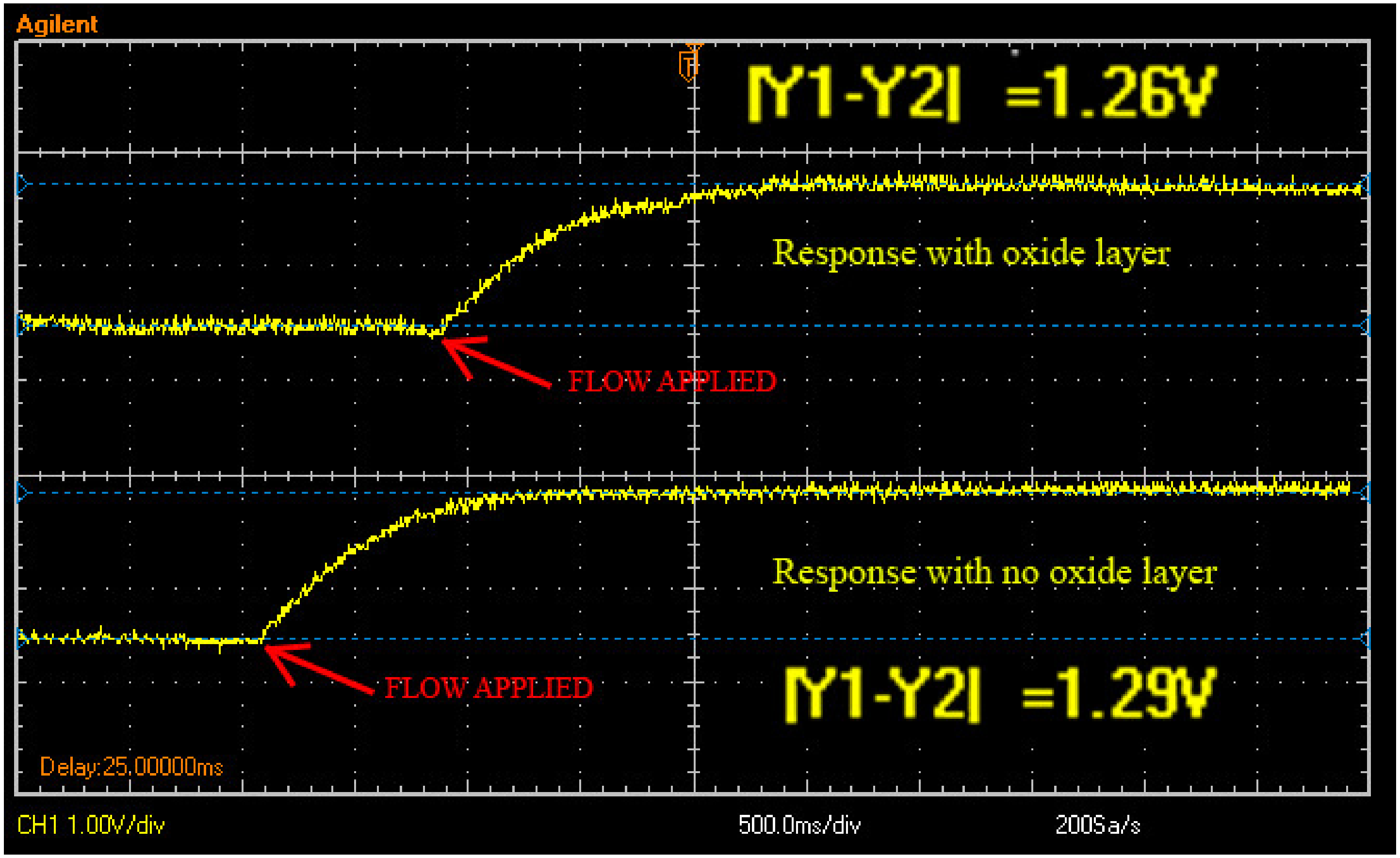
Anemometer Flow Data

Voltage Volts	Current mA	Power watts	Resistance ohms	Flow Rate value (slm)	setting
30.018	29.6	0.888533	1014	0	0
30.018	30.6	0.918551	981	3.813333	20
30.018	31.2	0.936562	962	7.626667	40
30.018	31.9	0.957574	941	11.44	60





STEP RESPONSE



RESULTS

It works!

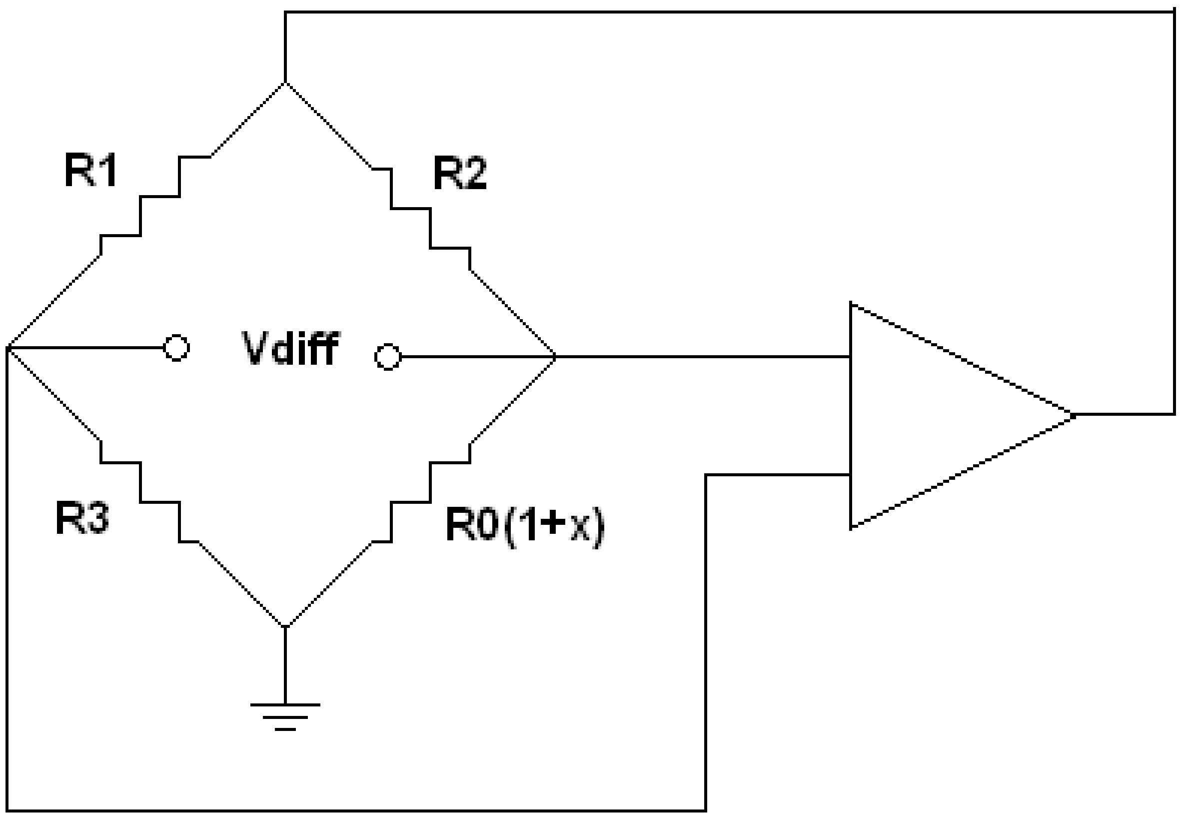
Calibration was achieved by…..

A plot of output versus flow is shown. An equation for this relationship (transfer function) has been obtained and is given below.

We were able to measure air flows from 0 to xxxx (span) with a resolution of yyyy.

The frequency response was determined by zzzz and is given below in graphical and analytical form.

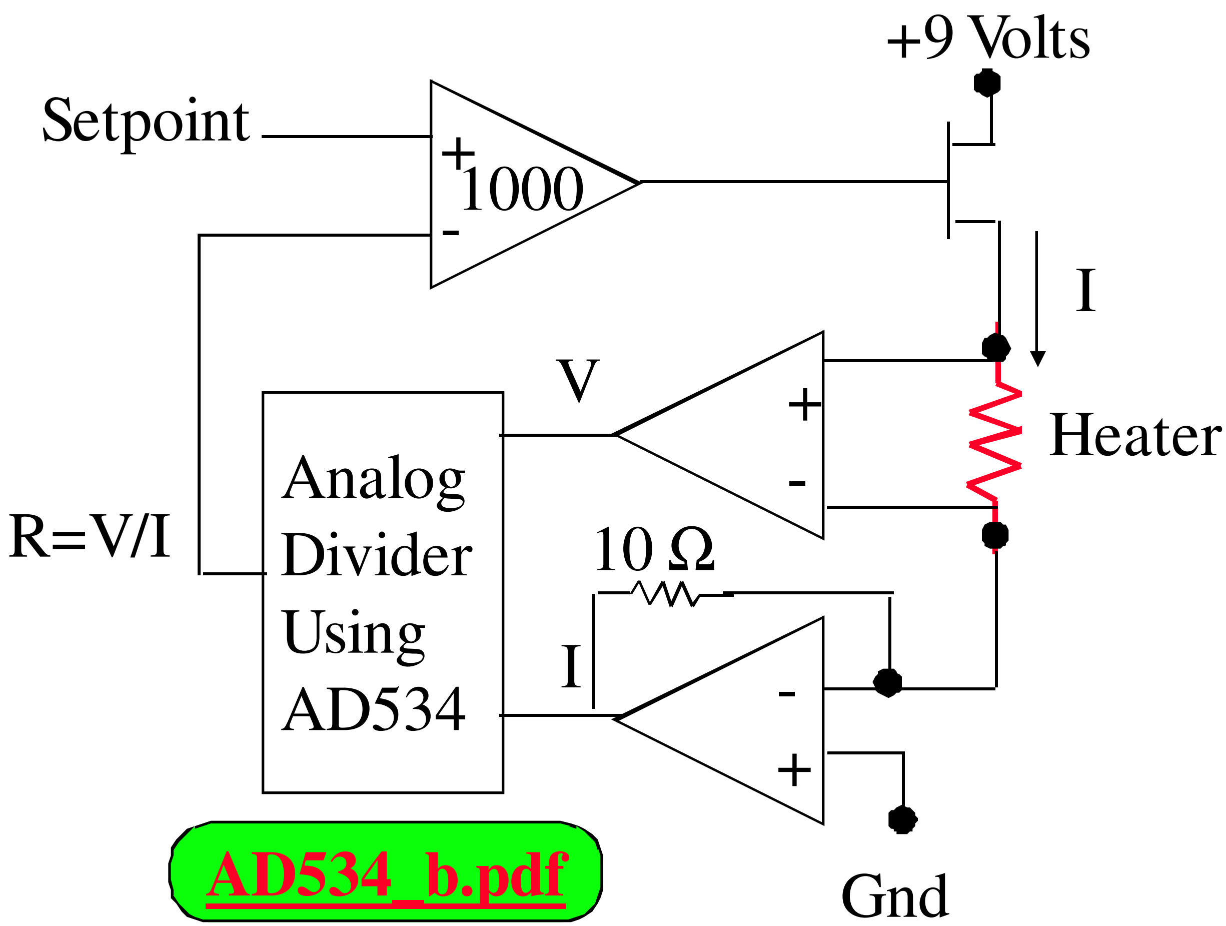
BRIDGE CIRCUIT FOR CONSTANT TEMPERATURE



R1=R2

R3 is equal to the resistance of R0 at the desired temperature

AD534 CONSTANT TEMPERATURE CIRCUIT



AD534_b.pdf

REFERENCES

1. Handbook of Modern Sensors, Jacob Faraden, Springer

HOMEWORK – ANEMOMETER

1. Describe how the circuit on page 22 works. Which lead is + and – on the amplifier?
2. Determine a reasonable value for R3. Make reasonable assumptions.
3. What should the set point be for the circuit on page 23?
4. Write a conclusion for this work by expanding on the sentences on page 21. (Be reasonable)