ROCHESTER INSTITUTE OF TECHNOLOGY
MICROELECTRONIC ENGINEERING

Diode Sensor Lab

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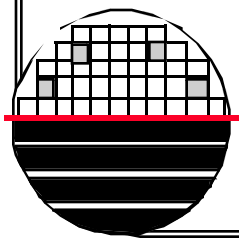
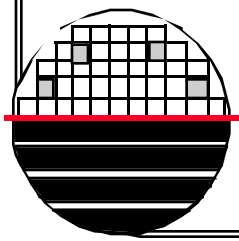
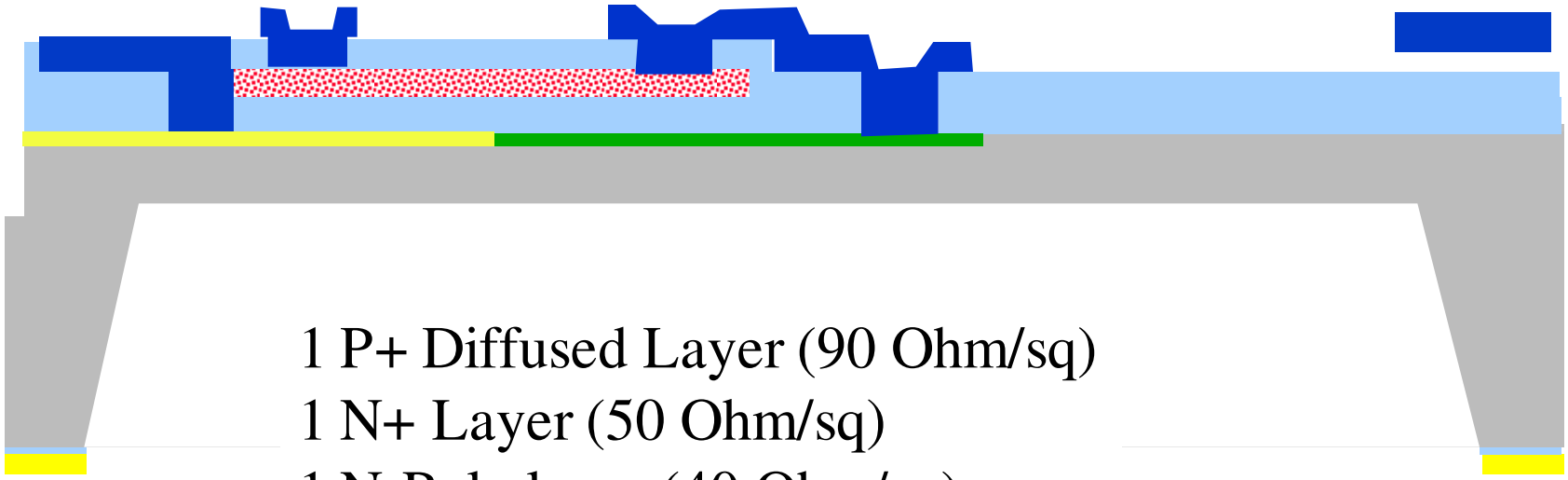


OUTLINE

RIT MEMS Bulk Process
MEMS Sensor Chip Layout
Heater I-V Characteristics
Diode Sensor I-V Characteristics
    Response to Heater
    Response to Light
LED I-V Characteristics
Diode Optical Communication Link

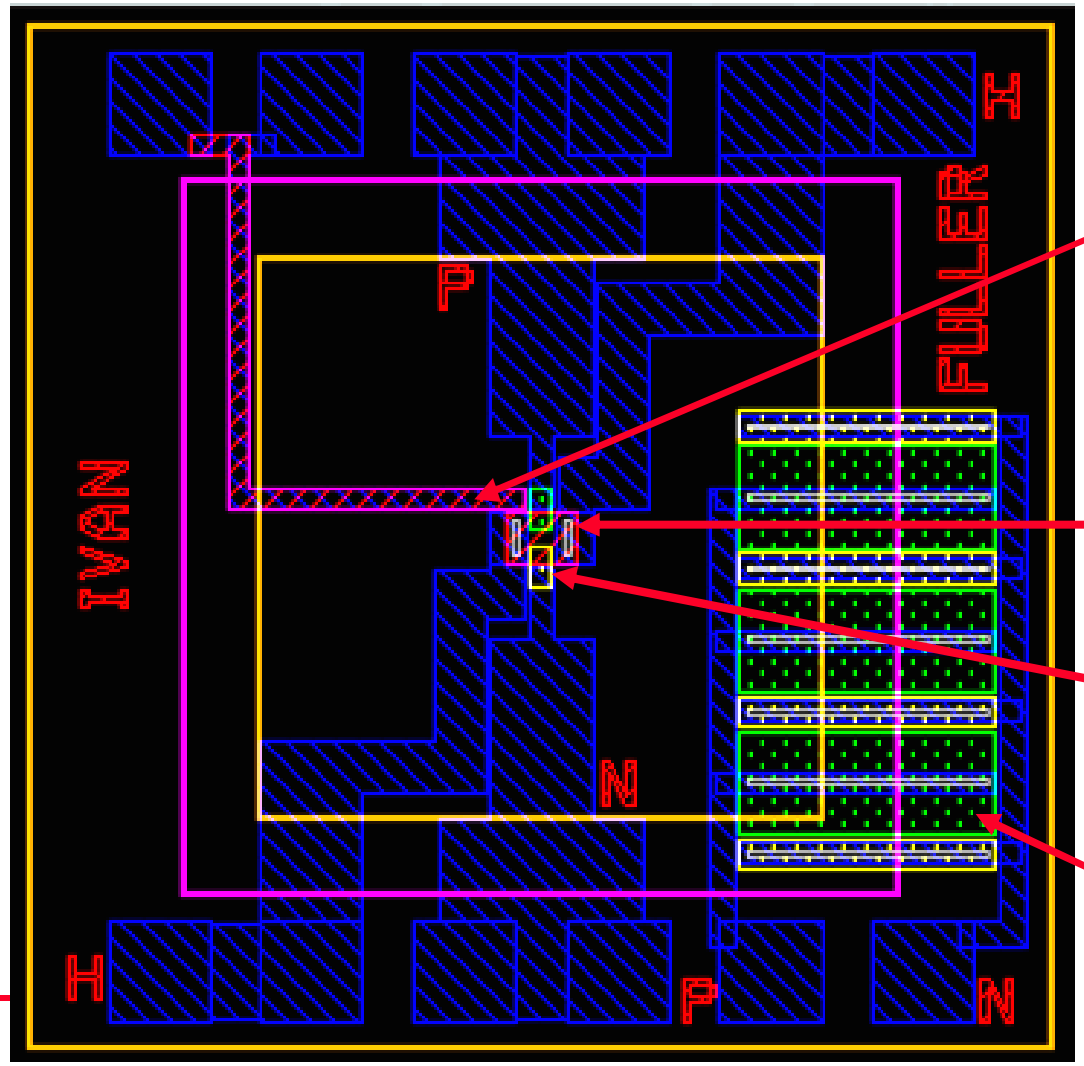


RIT MEMS BULK PROCESS



1 P+ Diffused Layer (90 Ohm/sq)
1 N+ Layer (50 Ohm/sq)
1 N-Poly layer (40 Ohm/sq)
1 metal layer (Al 1µm thick)
30-40 µm Si diaphragm

MEMS SENSORS CHIP LAYOUT



Thermocouple

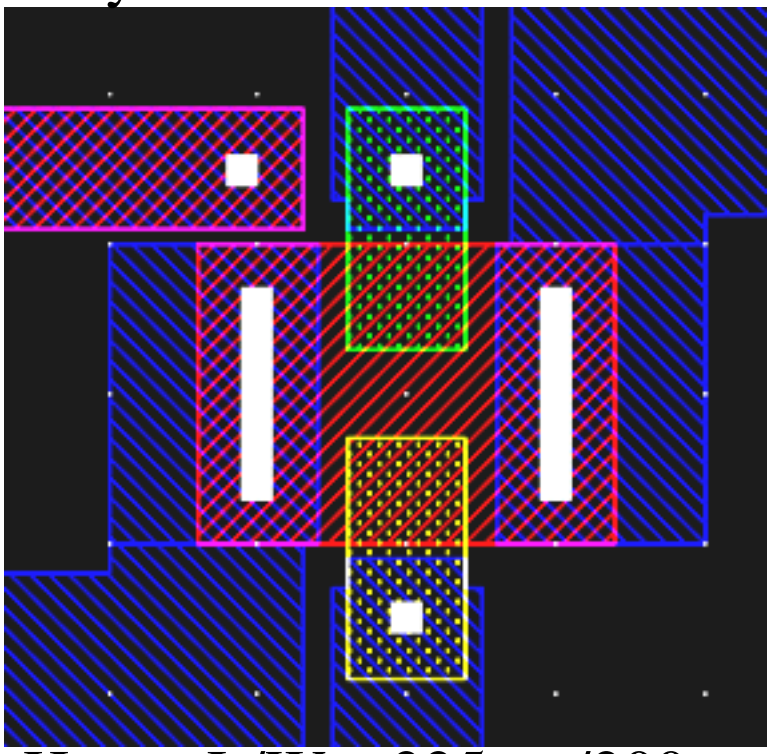
Poly Heater

Diode Temperature Sensor

Photo Diode

CLOSE UP OF MEMS SENSORS CHIP

Poly Heater, Buried pn Diode,
N+ Poly to Aluminum Thermocouple



Heater L/W = 225µm/200µm

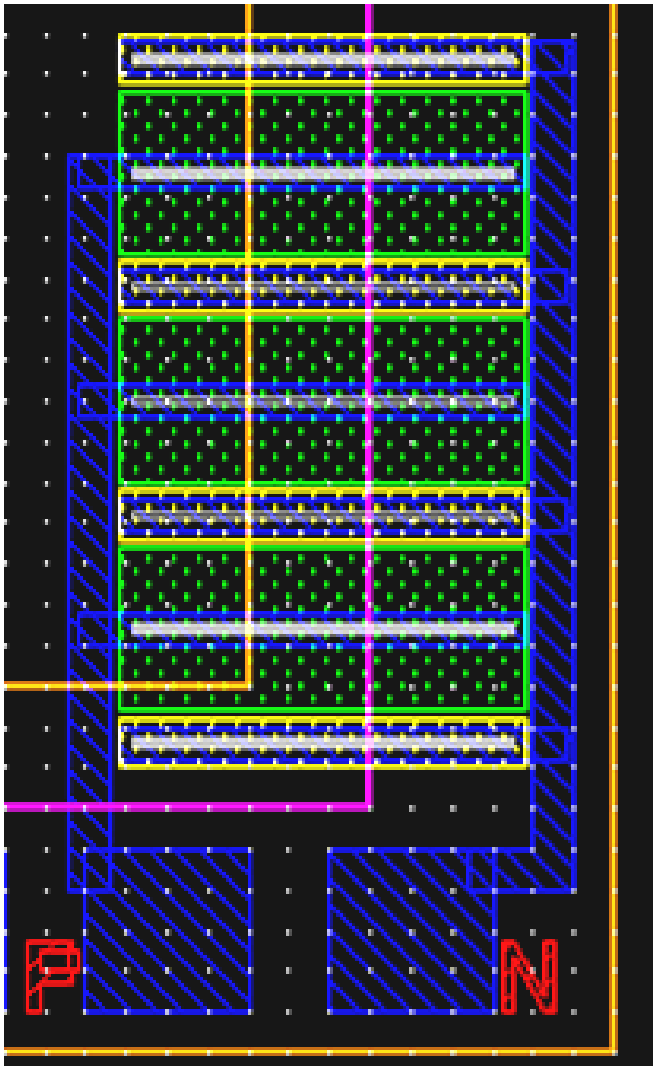
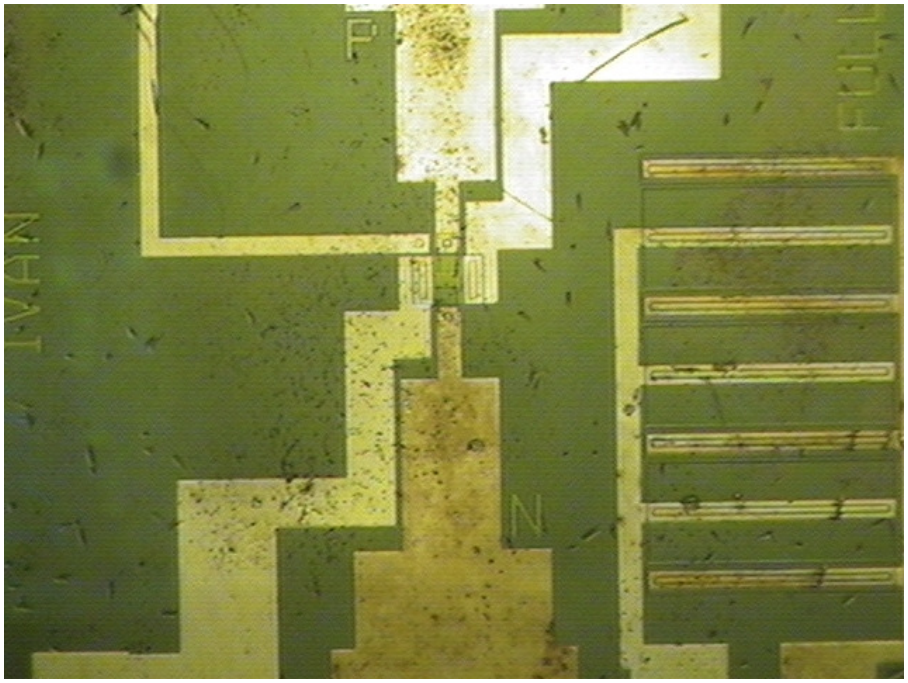
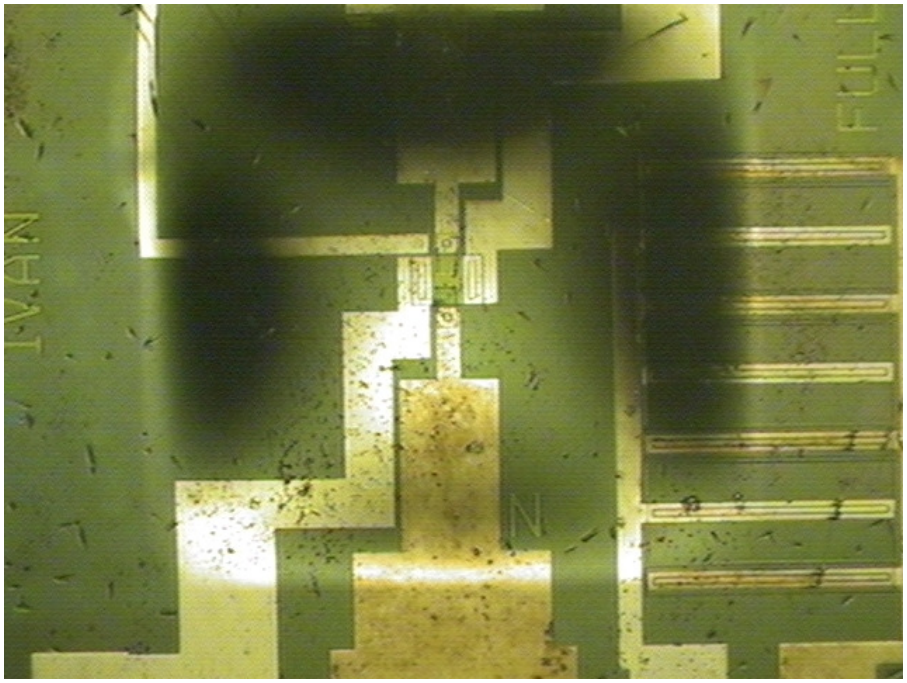


Photo Diode Area = 1mm X 1.5mm

SHOWS DEVICES ARE ON A DIAPHRAGM

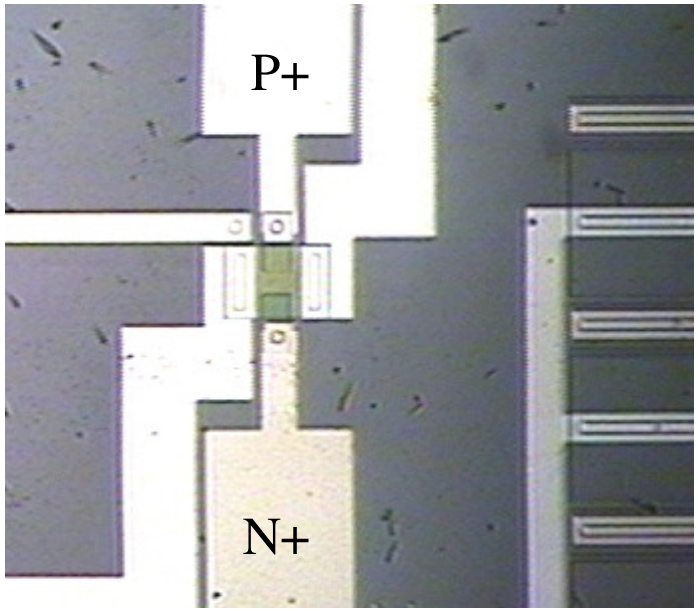




Vacuum applied to back of chip
Diaphragm bends down

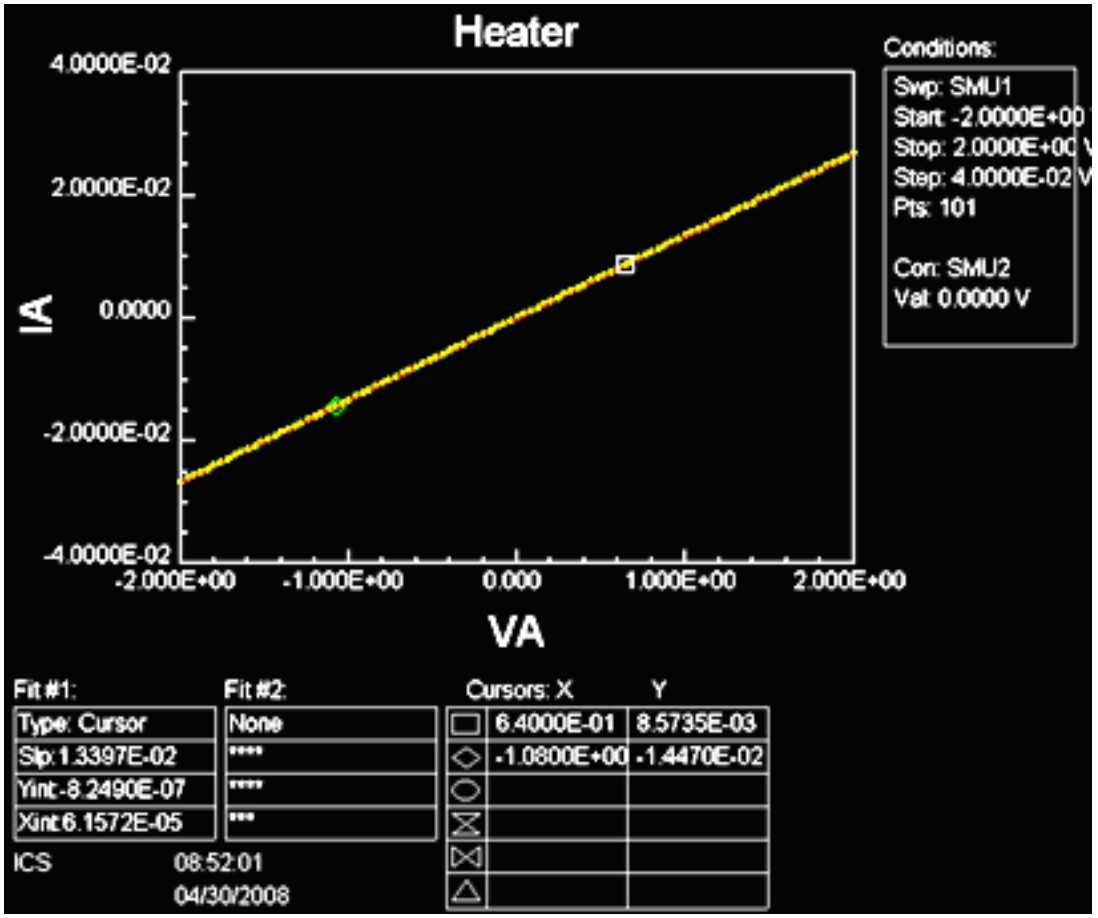
HEATER RESISTOR I-V CHARACTERISTICS

Poly Heater, Buried pn Diode,
N+ Poly to Aluminum Thermocouple



R = Rhos L/W

find Rhos

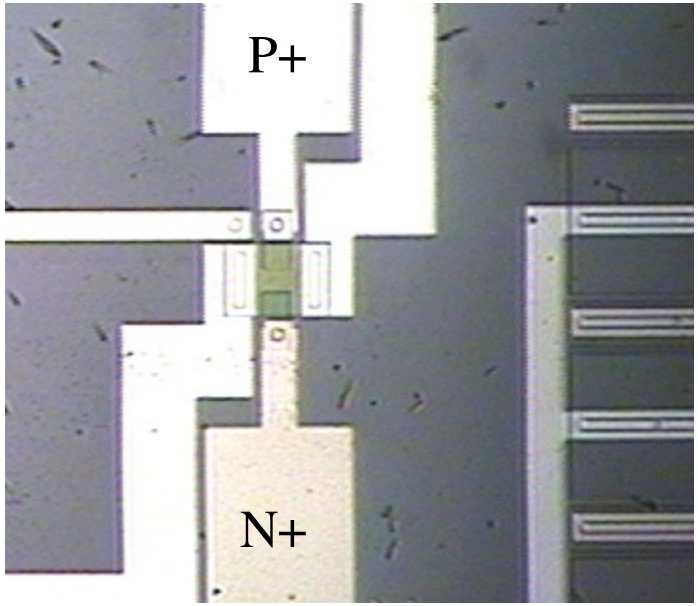


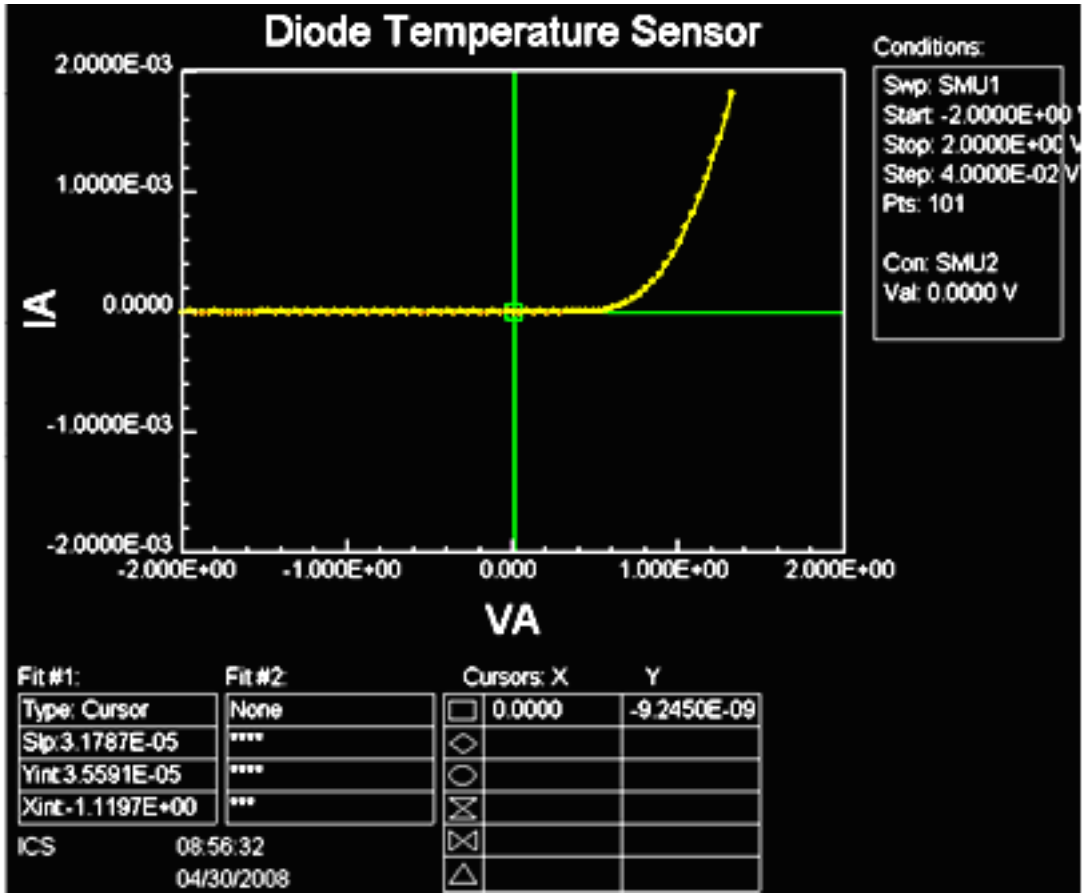
R= 1/1.34E-2

= 74.7 ohms

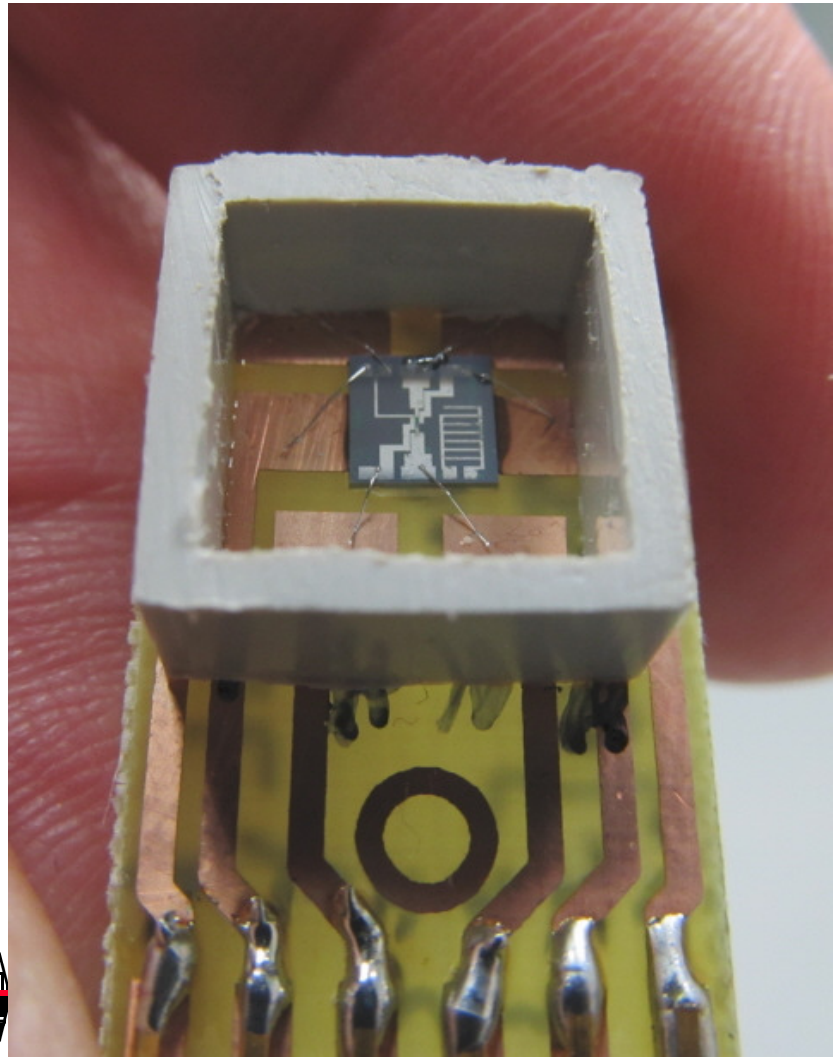
DIODE I-V CHARACTERISTICS

Poly Heater, Buried pn Diode,
N+ Poly to Aluminum Thermocouple



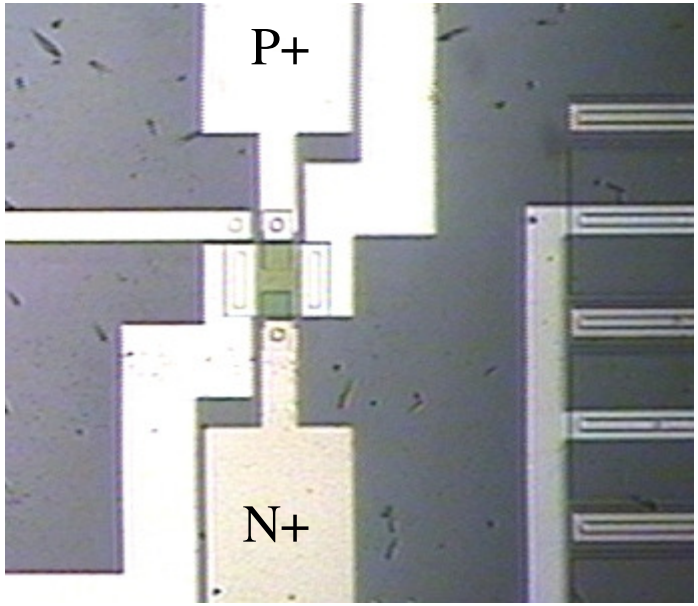


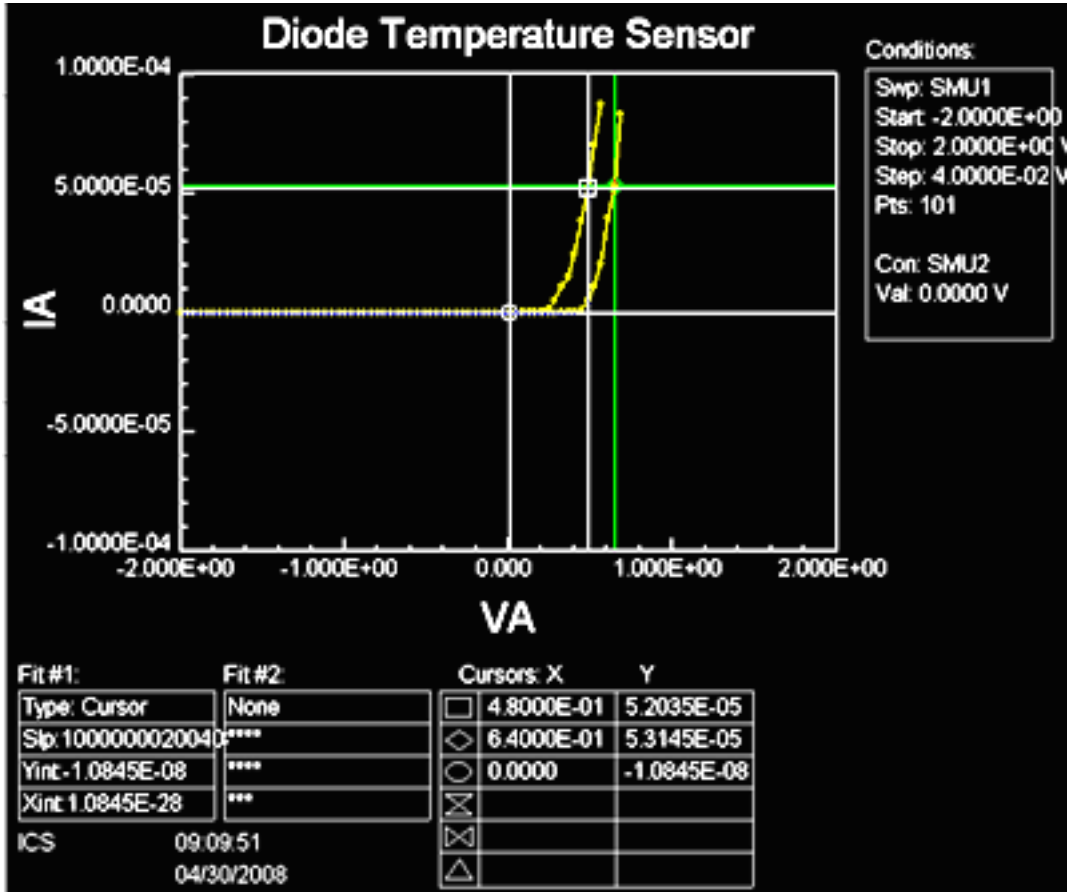
PACKAGED DIODE TEST CHIP



DIODE TEMPERATURE SENSOR RESPONSE

Poly Heater, Buried pn Diode,
N+ Poly to Aluminum Thermocouple





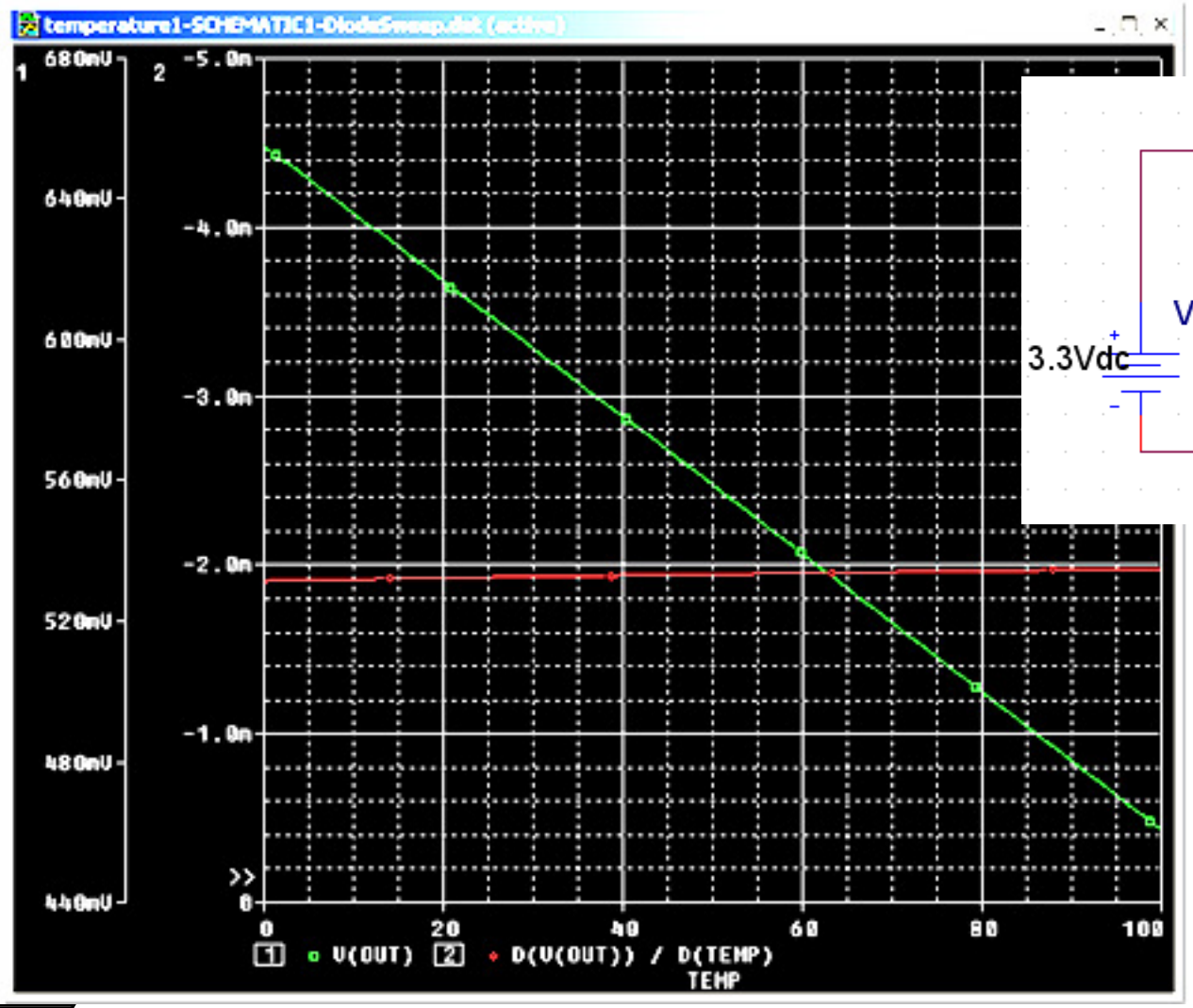
Apply 5 volts (gives ~ 65mA)

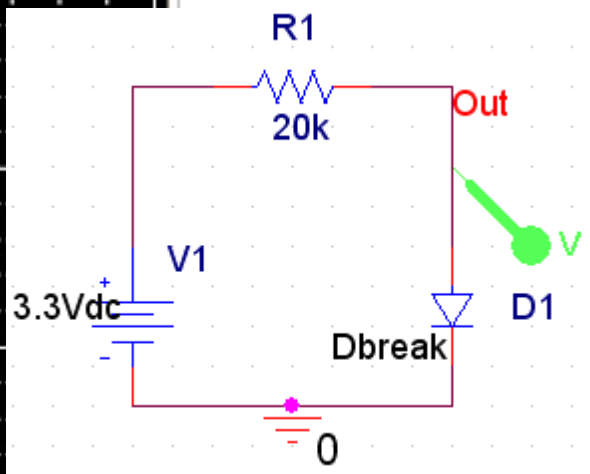
P=IV =0.3 watts

Delta Vd = 0.64 -0.48 = 0.16

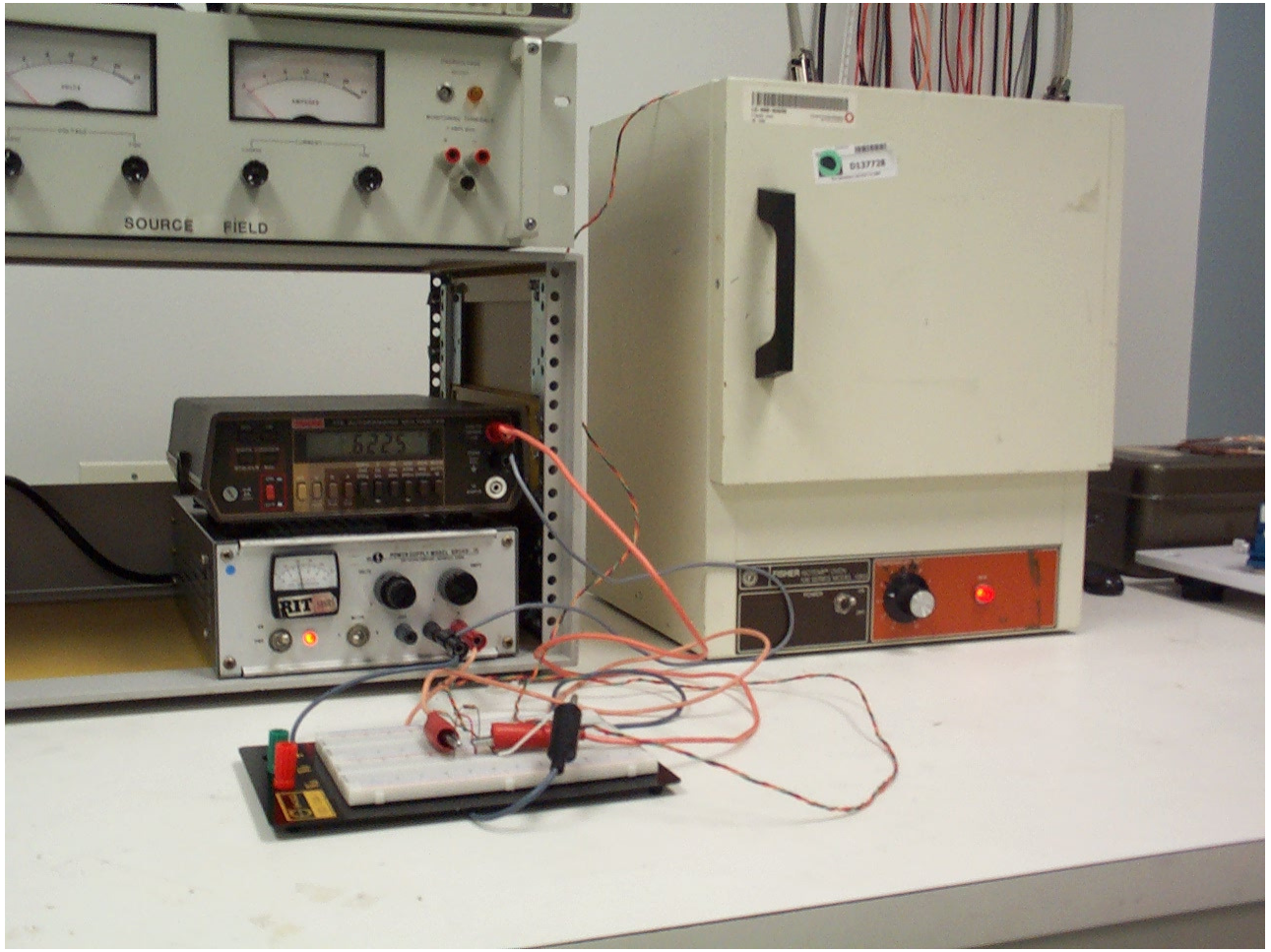
Delta T = 0.16 / 2.2mV = 72.7 °C

SPICE FOR DIODE TEMPERATURE SENSOR



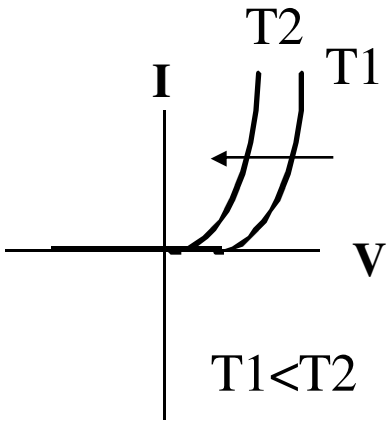


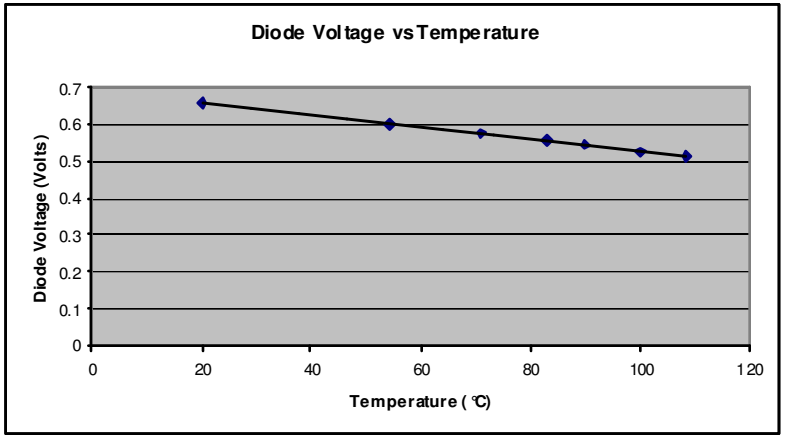
TEST SETUP



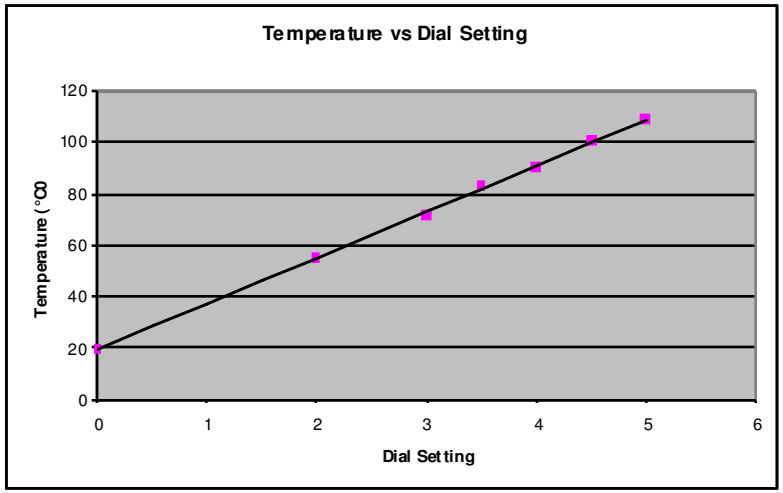
Take data for room T up to 100°C

TEMPERATURE TEST DATA

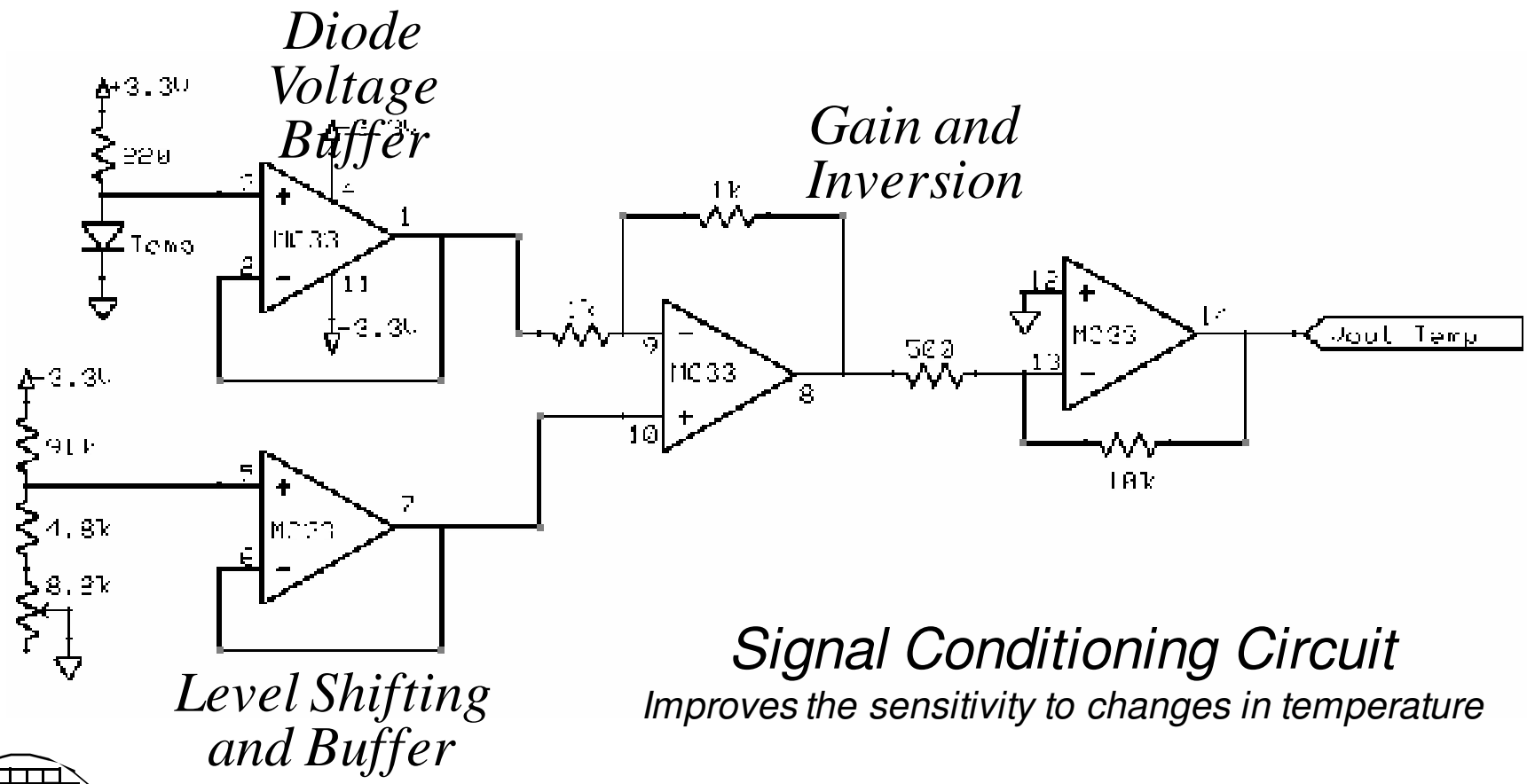




Dial	Vdiode	Temp
0	0.6539	20
0.5		
1		
1.5		
2	0.601	54.5
2.5		
3	0.5747	71
3.5	0.556	83
4	0.543	90
4.5	0.5246	100
5	0.51	108.5



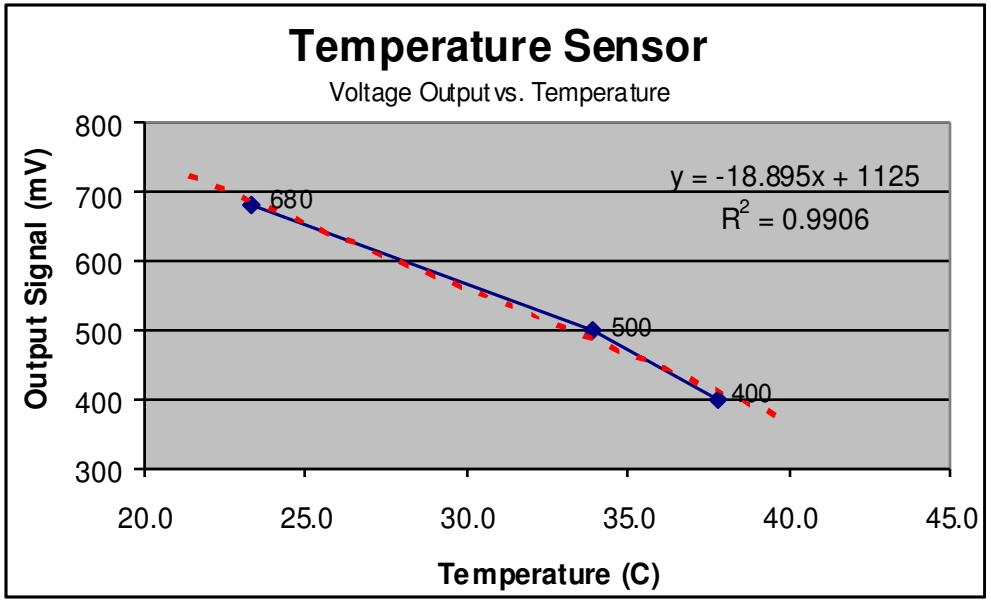
SIGNAL CONDITIONING CIRCUIT



Signal Conditioning Circuit

Improves the sensitivity to changes in temperature

TEMPERATURE TEST RESULTS OF WATER



Measurement of Amplified and Shifted Diode Voltage in Different Temperature Water Baths

The output changes by -19 mV/°C

SEEBECK EFFECT

When two dissimilar conductors are connected together a voltage may be generated if the junction is at a temperature different from the temperature at the other end of the conductors (cold junction) This is the principal behind the thermocouple and is called the Seebeck effect.

$$\Delta V = \alpha_1(T_{cold}-T_{hot}) + \alpha_2 (T_{hot}-T_{cold})=(\alpha_1-\alpha_2)(T_{hot}-T_{cold})$$

Where α_1 and α_2 are the Seebeck coefficients for materials 1 and 2

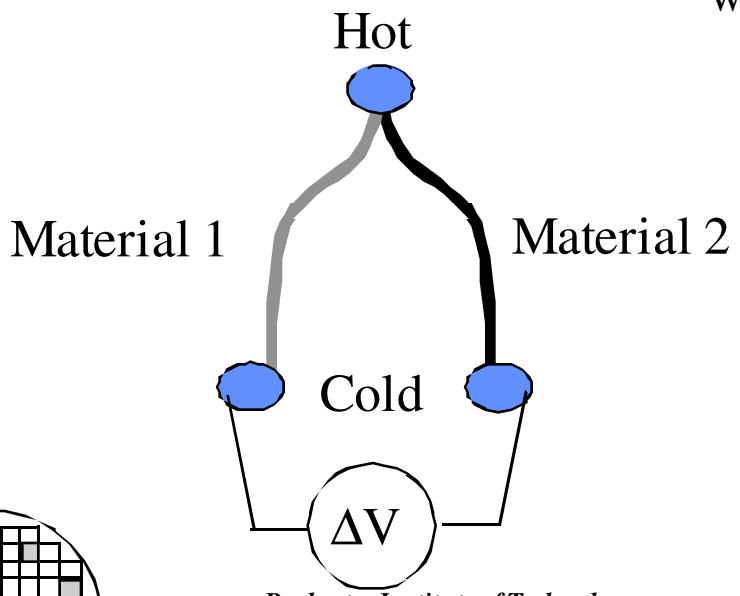


Table 2.6 The Seebeck Coefficients Relative to Platinum for Selected Metals and for *n*- and *p*-Type Polysilicon

	μV/K		μV/K
Bi	−73.4	Ag	7.4
Ni	−14.8	Cu	7.6
Pa	−5.7	Zn	7.6
Pt	0	Au	7.8
Ta	3.3	W	11.2
Al	4.2	Mo	14.5
Sn	4.2	*n*-poly (30 Ω/□)	−100
Mg	4.4	*n*-poly (2600 Ω/□)	−450
Ir	6.5	*p*-poly (400 Ω/□)	270

Note: The sheet resistance is given for the 0.38-μm-thick polysilicon films. Polysilicon is an attractive material for the fabrication of thermocouples and thermopiles because of its large Seebeck coefficient.

Nadim Maluf, Kirt Williams, An Introduction to Microelectromechanical Systems Engineering, 2nd Ed. 2004

THERMOCOUPLE TEMPERATURE SENSOR

Volt Meter

Heater Volts	TC Output Volts	Diode Volts
0	~0	0.7
1	…	….
2	…	….
3	…	….
4	…	….
5	~15mV	0.55

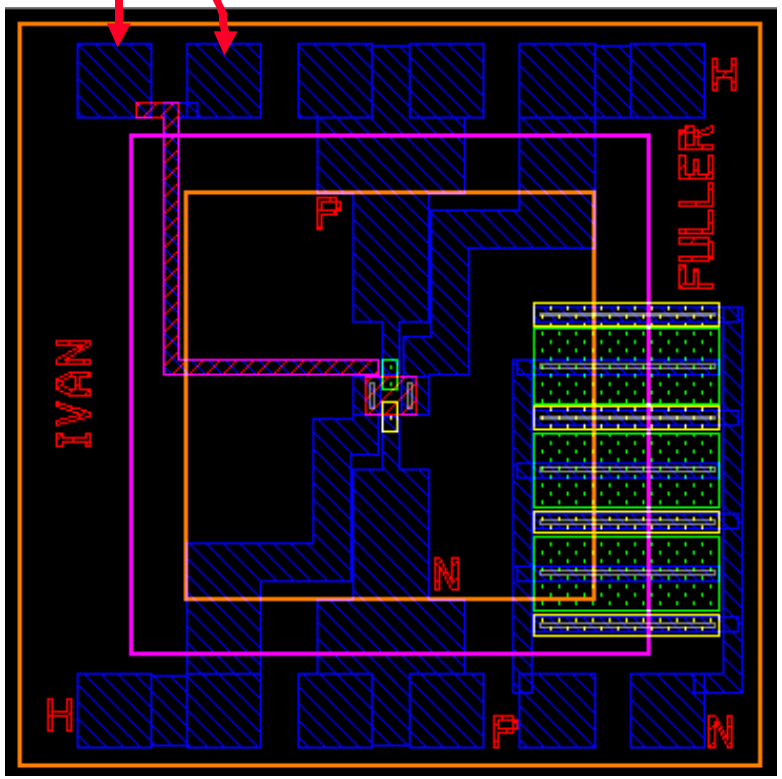


PHOTO DIODE RESPONSE TO LIGHT

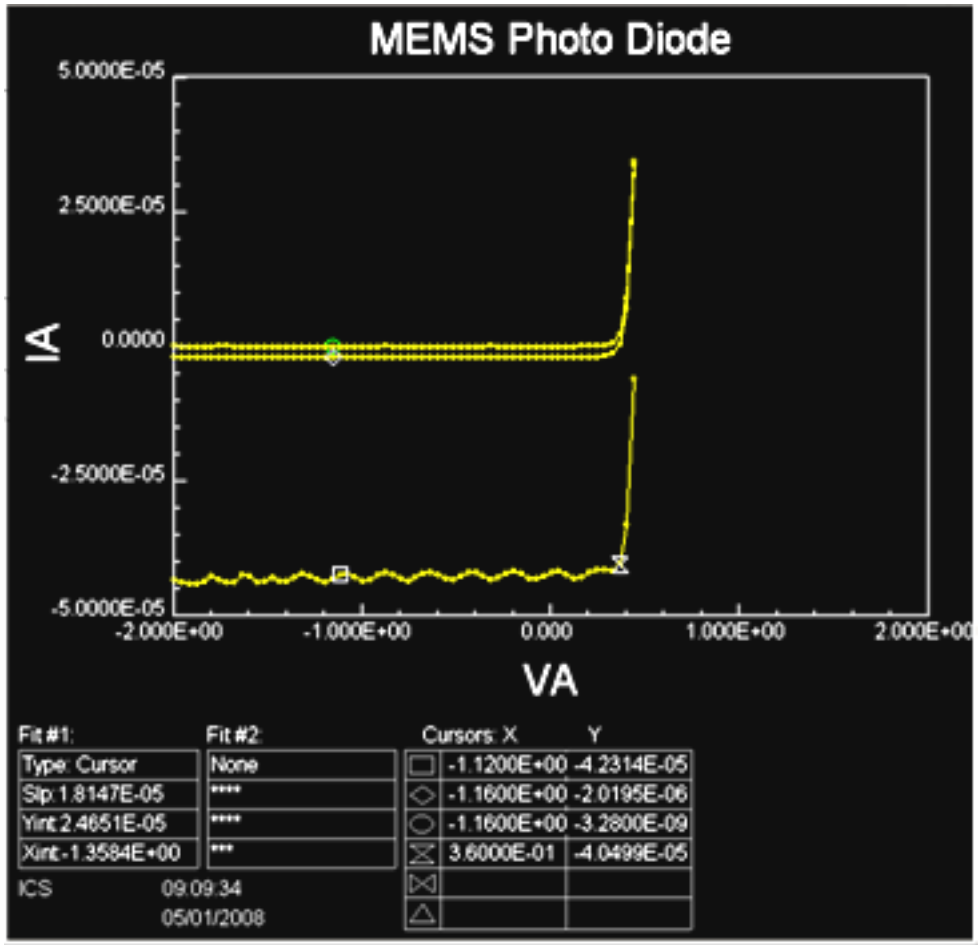
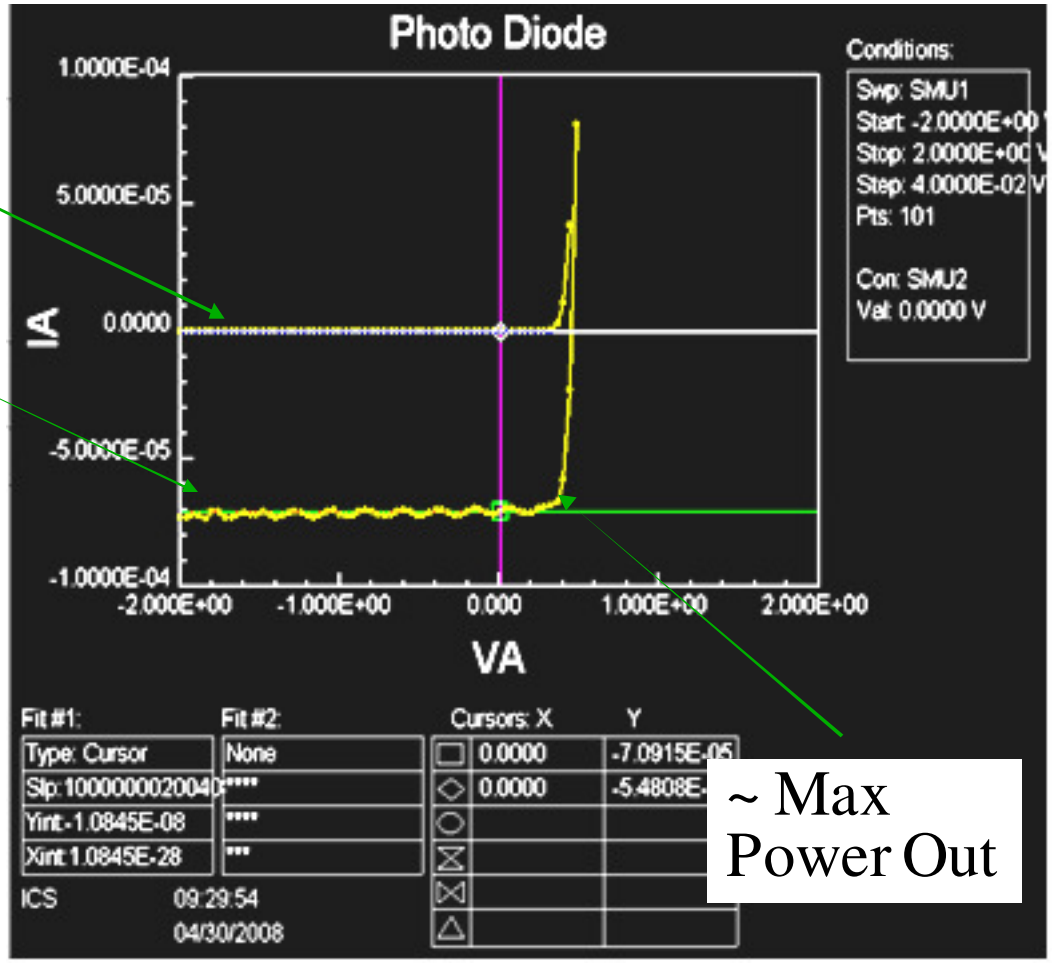


PHOTO DIODE RESPONSE TO LIGHT

No light

Full light



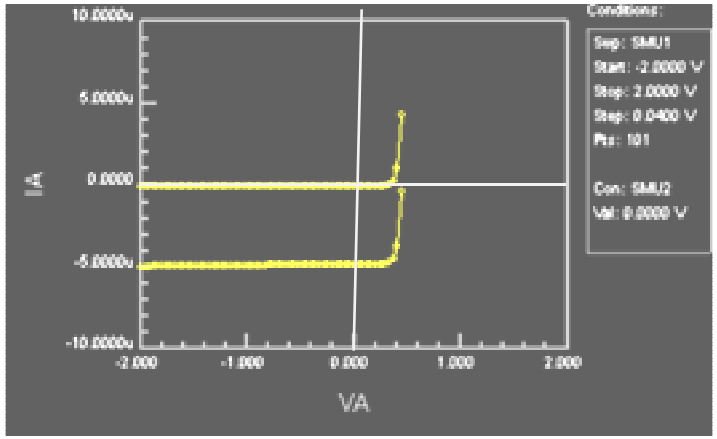
~ Max Power Out

P=IV = (7.09e-5)(0.4)
=28.4μwatts

P/unit area =
28.4e-6/1500e-6/1000e-6
= 18.9watt/m^2

No Light and Max Light Using 8X Objective Lens

UV LED AND PHOTO DIODE SENSOR



Material Characterization
by UV Light Absorption

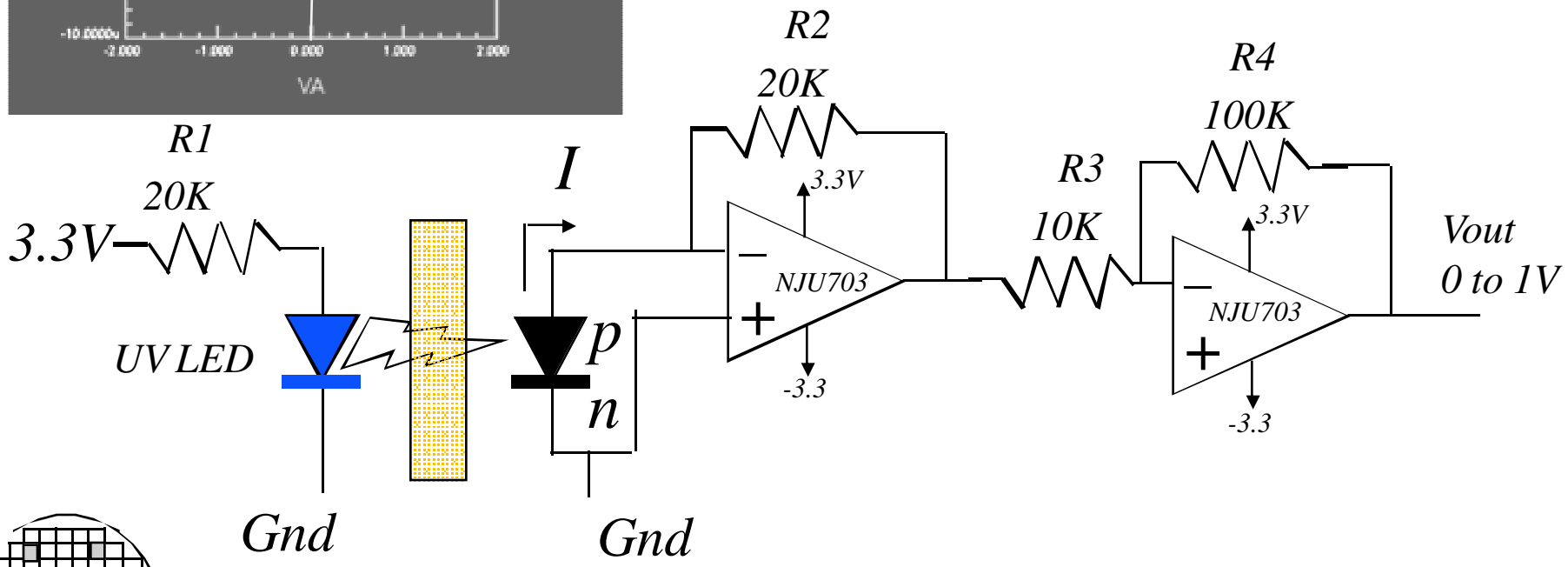
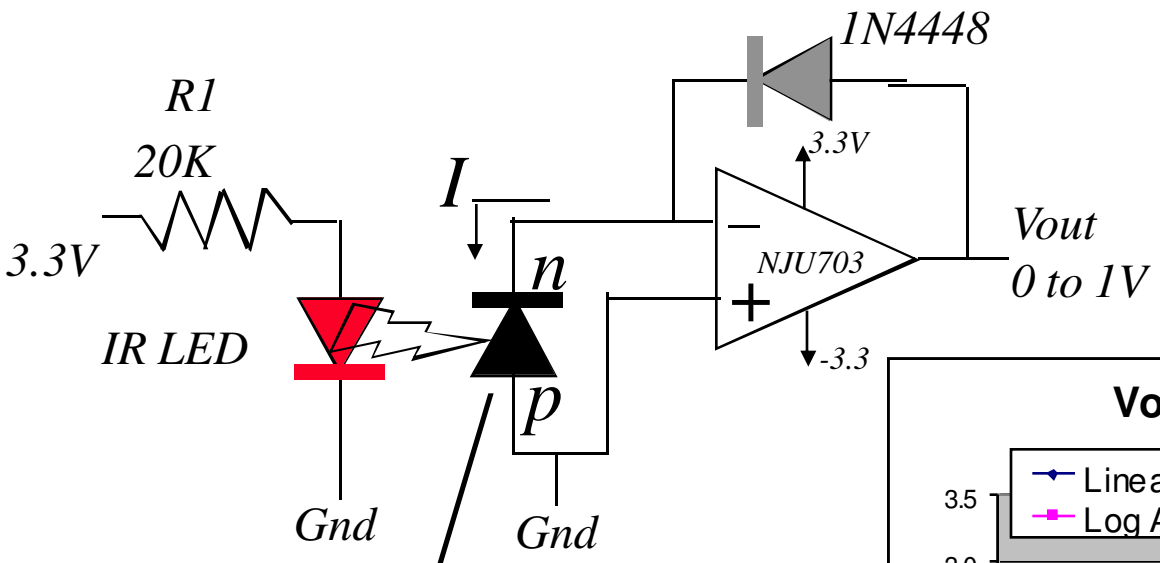
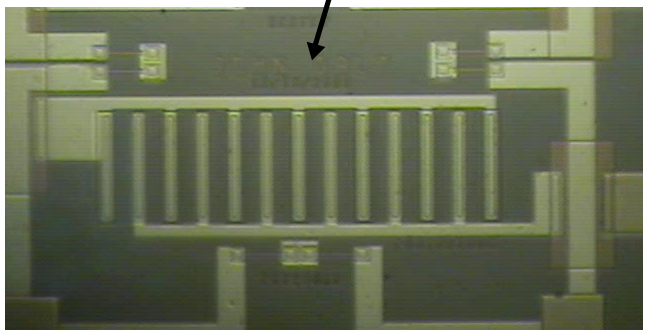


PHOTO DIODE I TO V LOG AMPLIFIER



Linear amplifier uses 100K ohm in place of the 1N4448



Photodiode

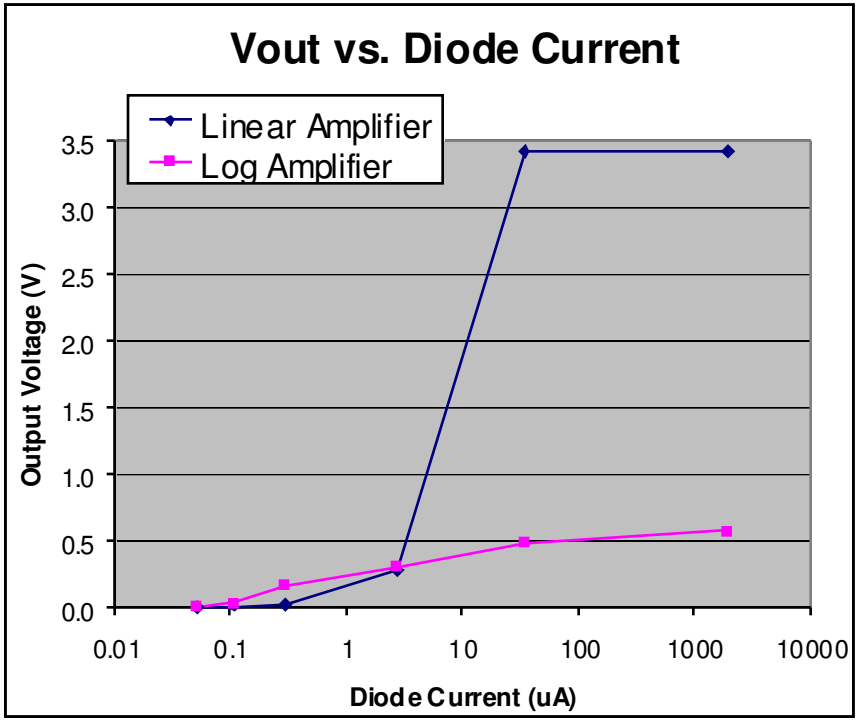
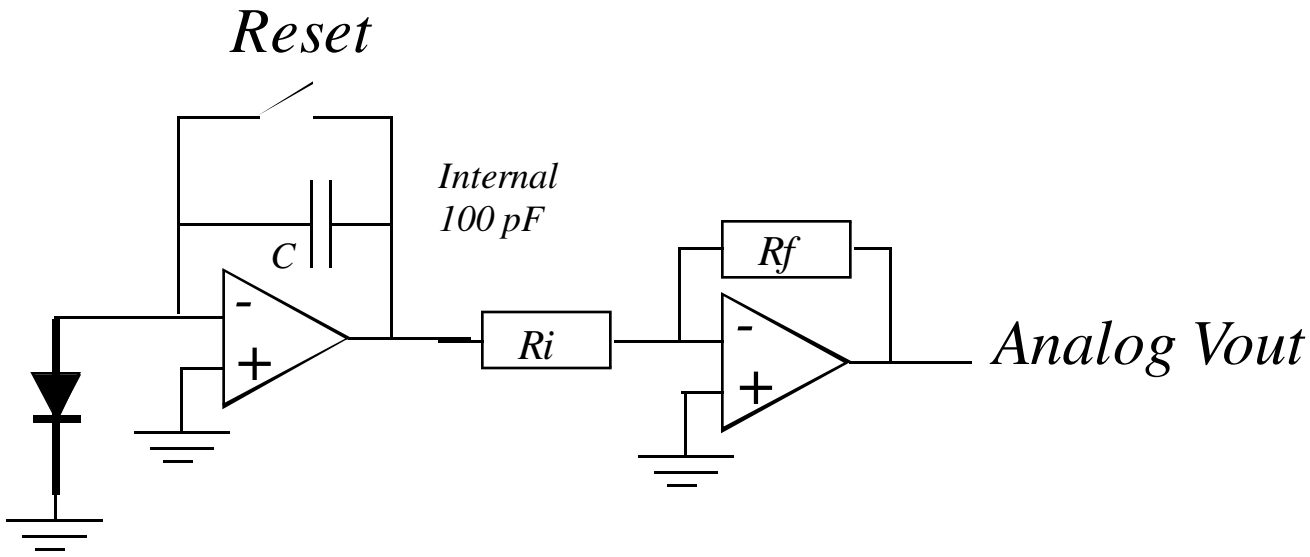


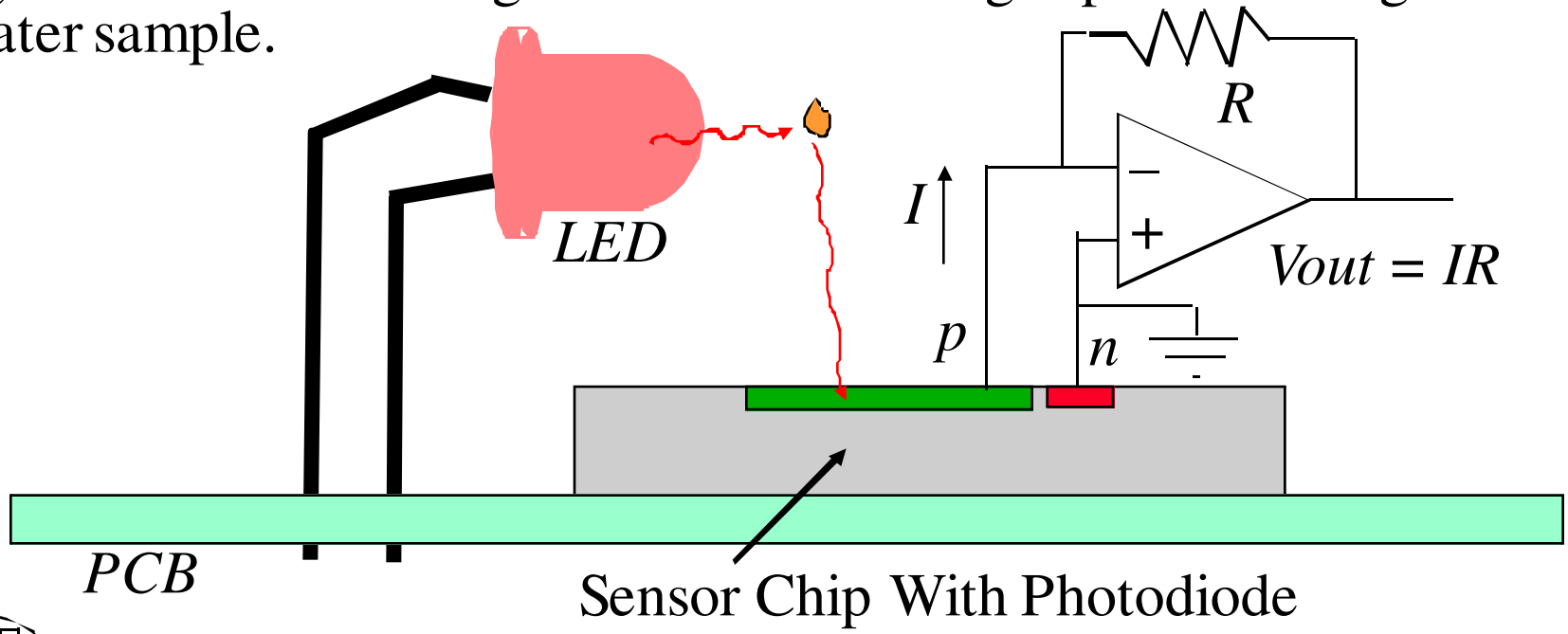
PHOTO DIODE I TO V INTEGRATING AMPLIFIER



Integrator and amplifier allow for measurement at low light levels

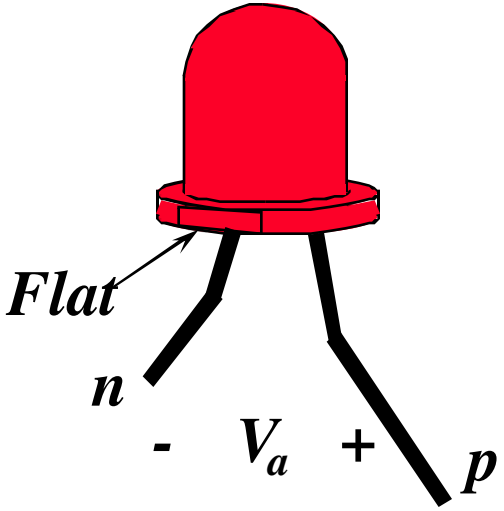
TURBIDITY

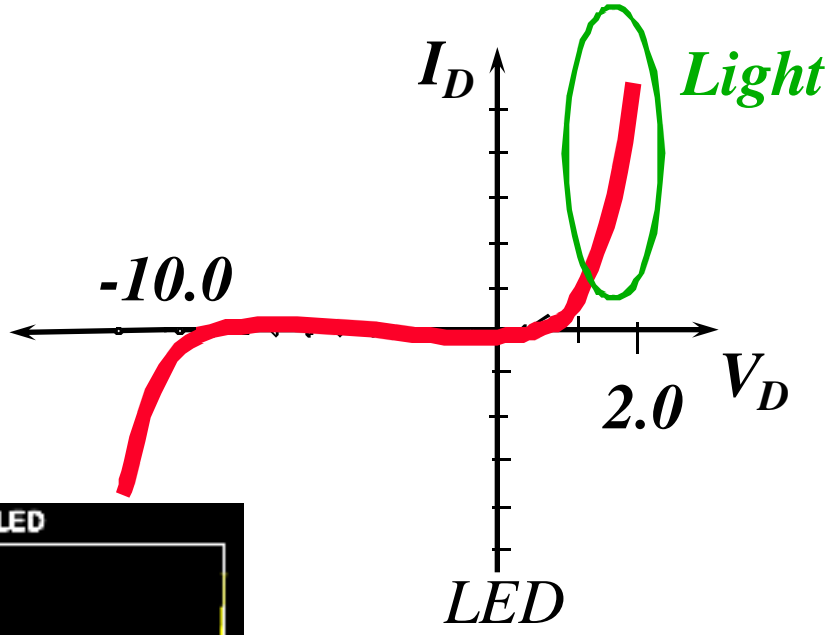
Turbidity = loss of transparancy due to the presence of suspended solids, water < 1-5 NTU (Nephelometric Turbidity Units), measured by a nephelometer or turbidimeter, which measures the intensity of light scattered at 90 degrees as a beam of light passes through a water sample.

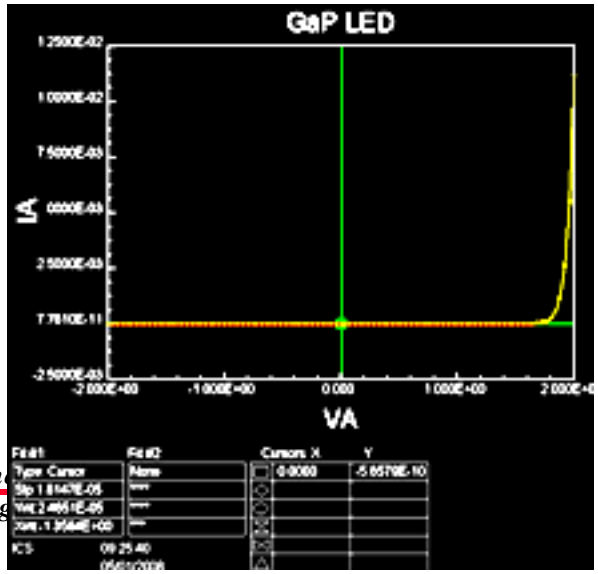


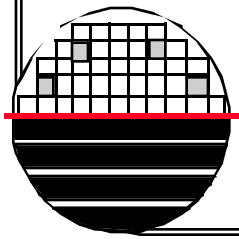
LED IV CHARACTERISTICS

Light Emitting Diode -LED

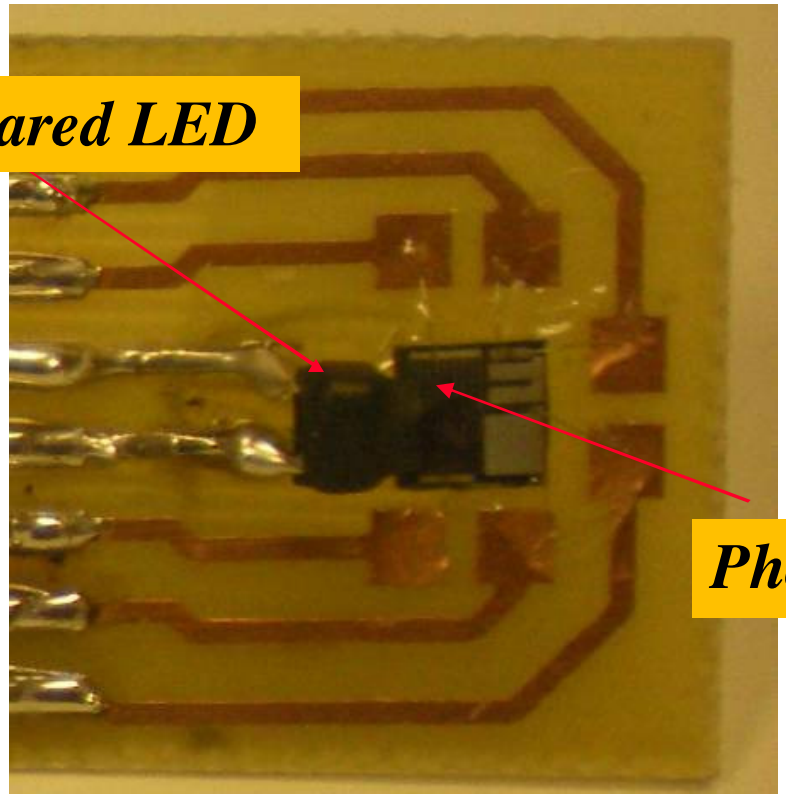




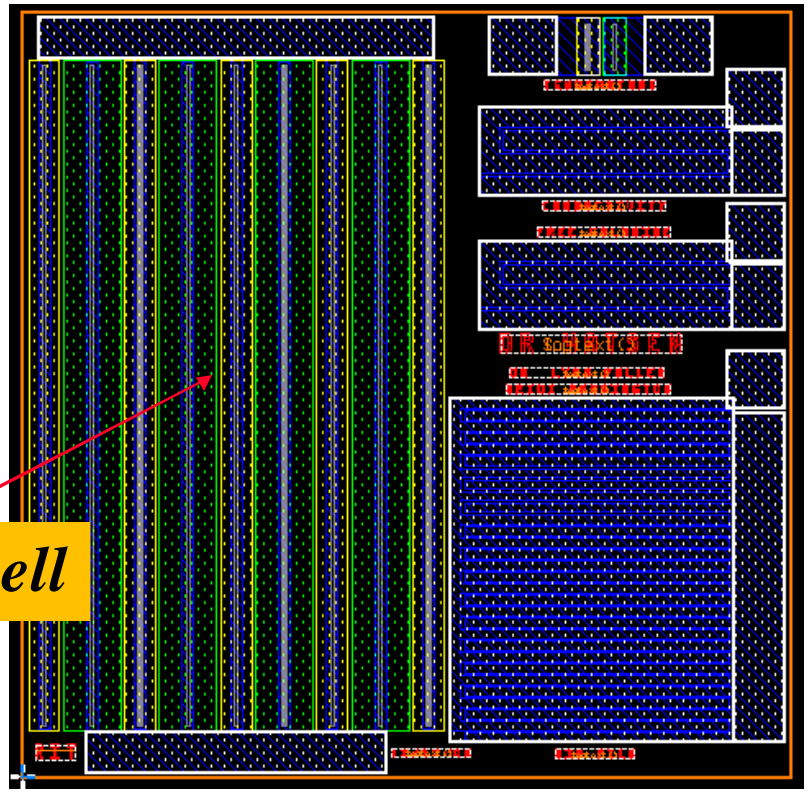




TURBIDITY

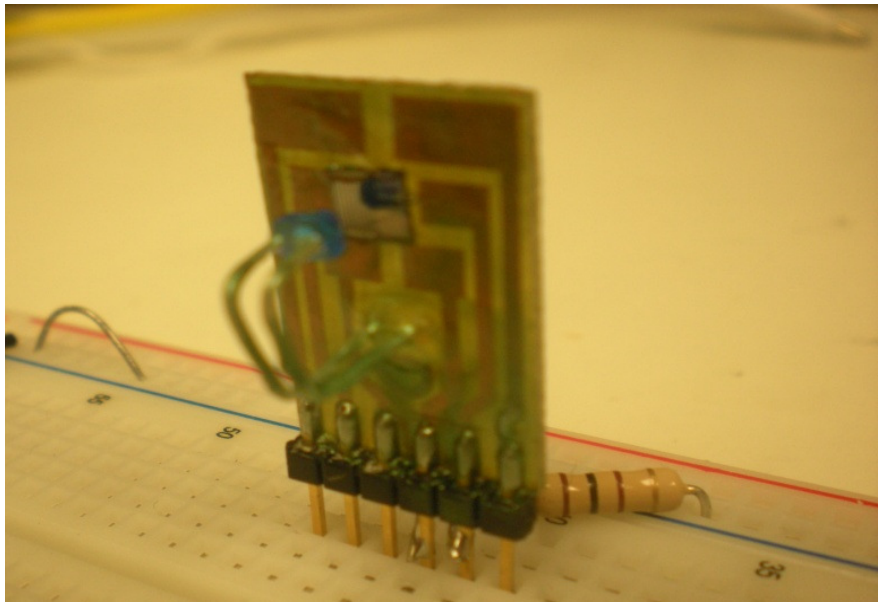


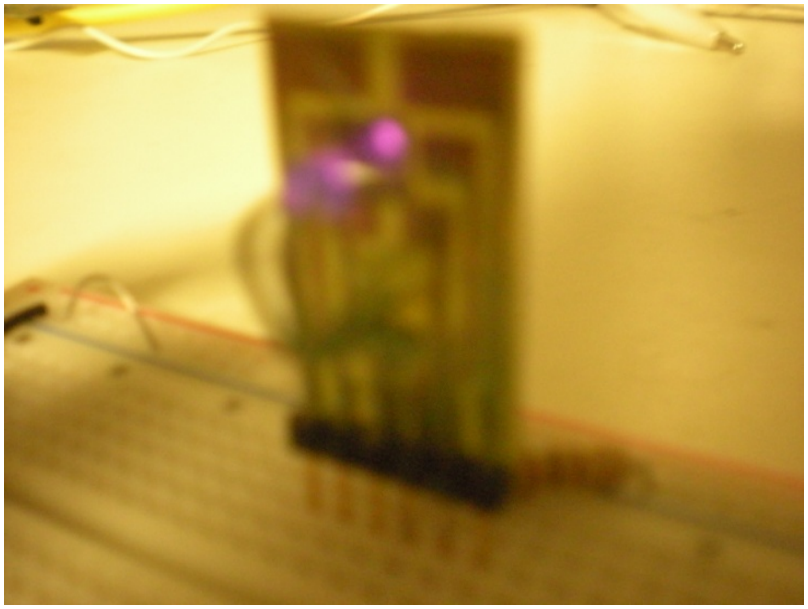
Packaged Sensor Chip and LED



Sensor Chip

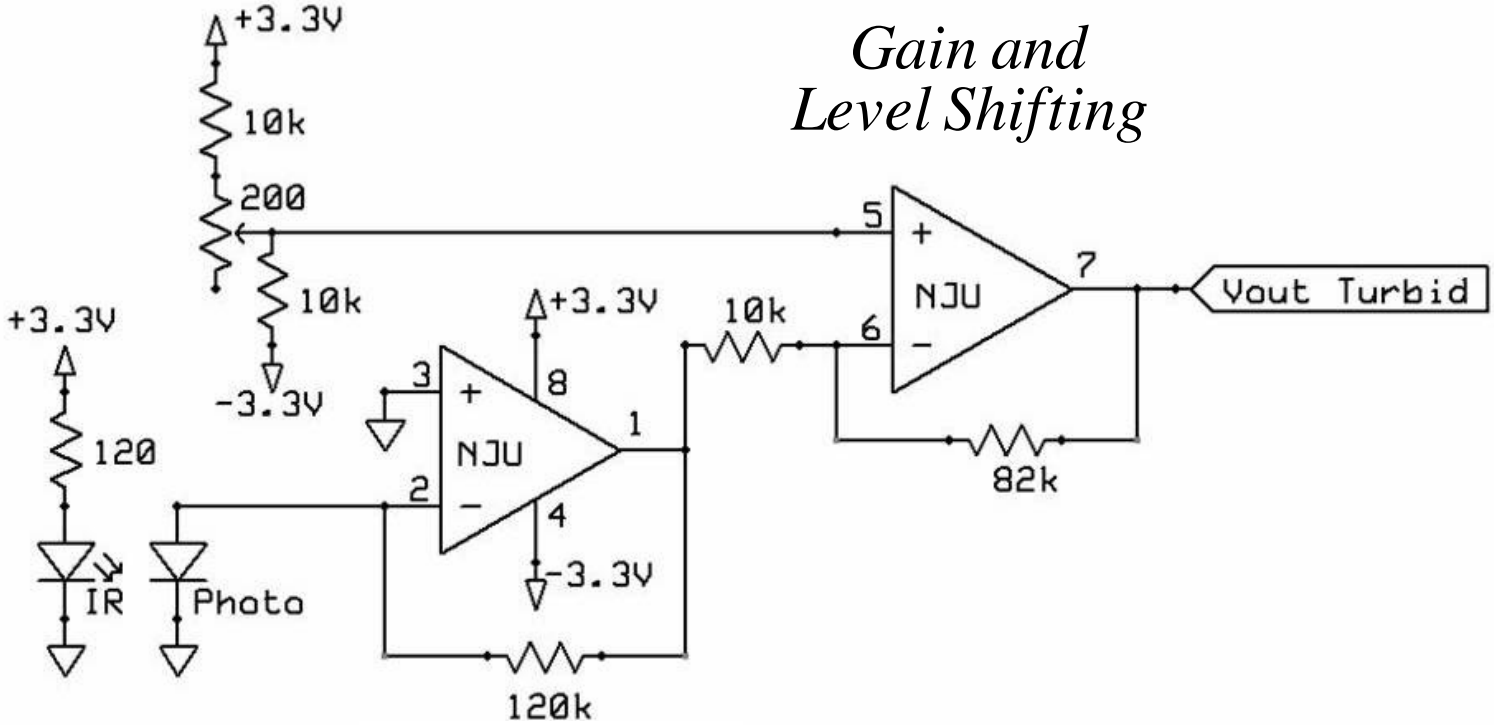
IR LED





Digital Cameras can see the light from an infrared LED that the human eye can not see

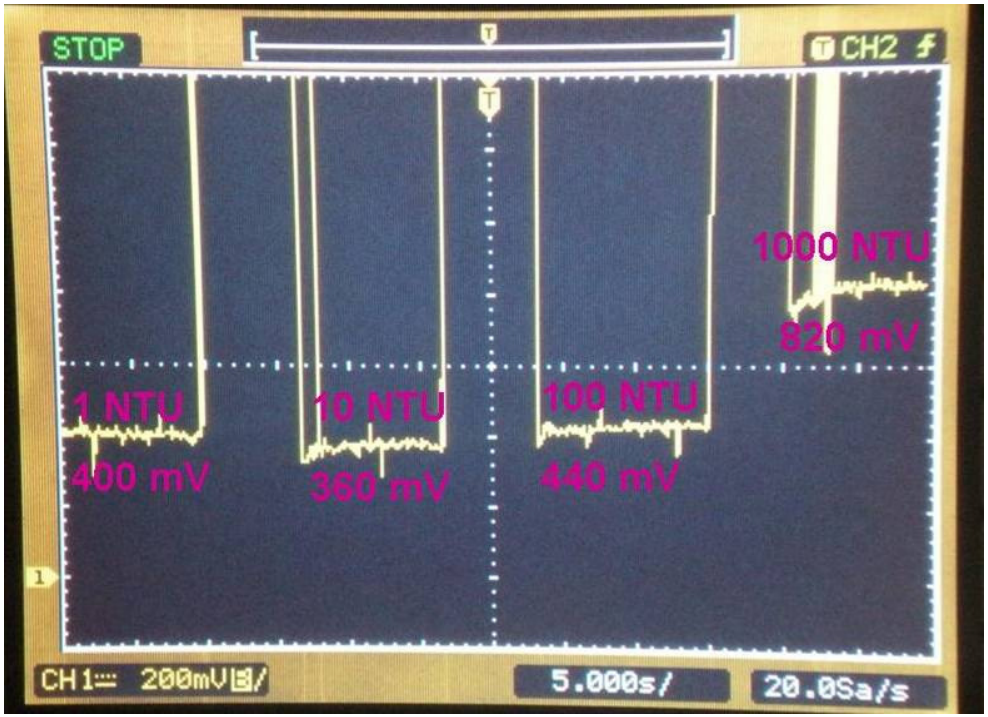
TURBIDITY – SIGNAL CONDITIONING CIRCUIT



Gain and Level Shifting

Photo-Current to Voltage

TURBIDITY TEST RESULTS

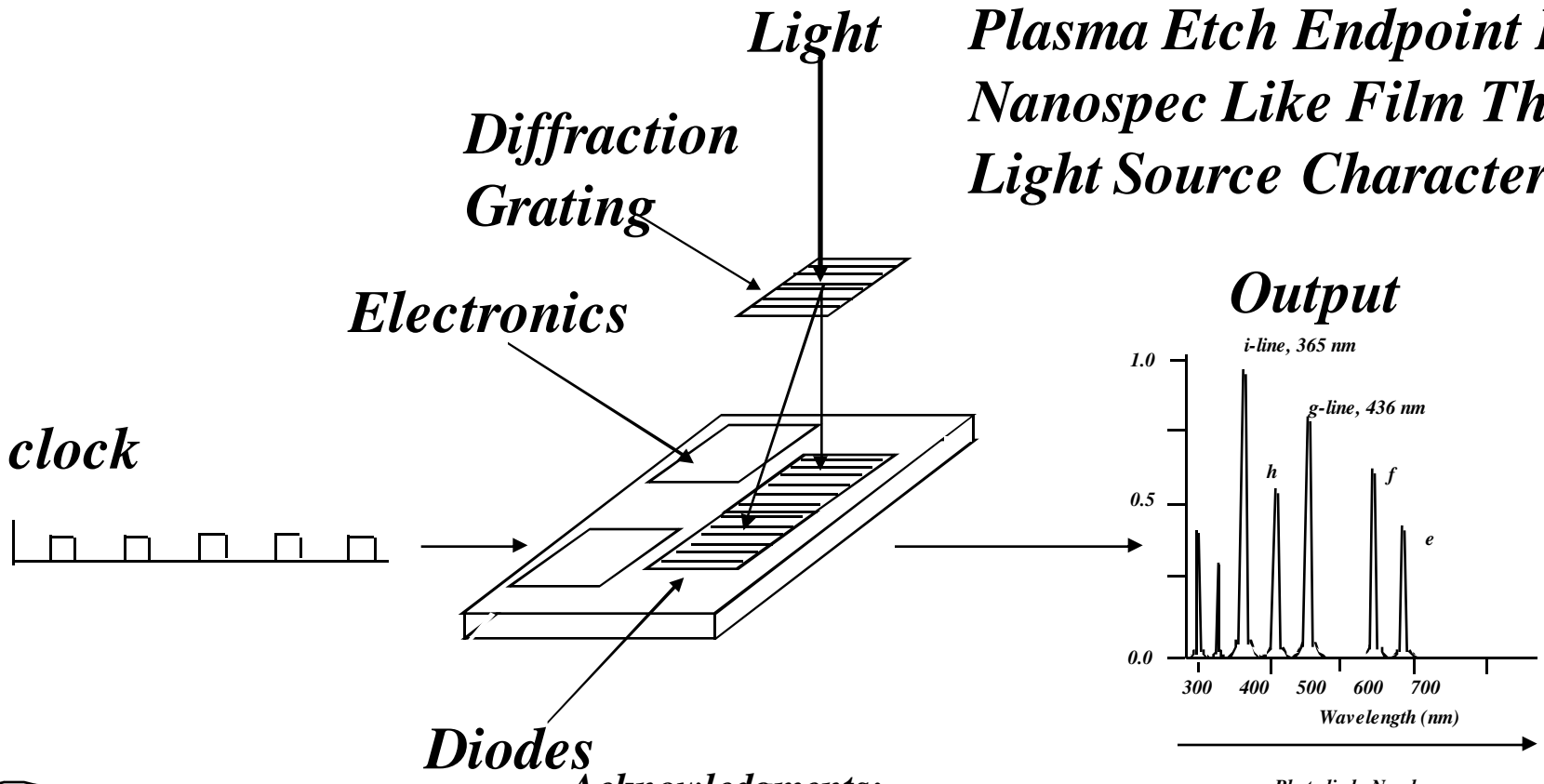


Plot of output voltage for different standard turbidity samples

Dr. WatSen
Turbidity
Sensor Demo

Turbidity Standards

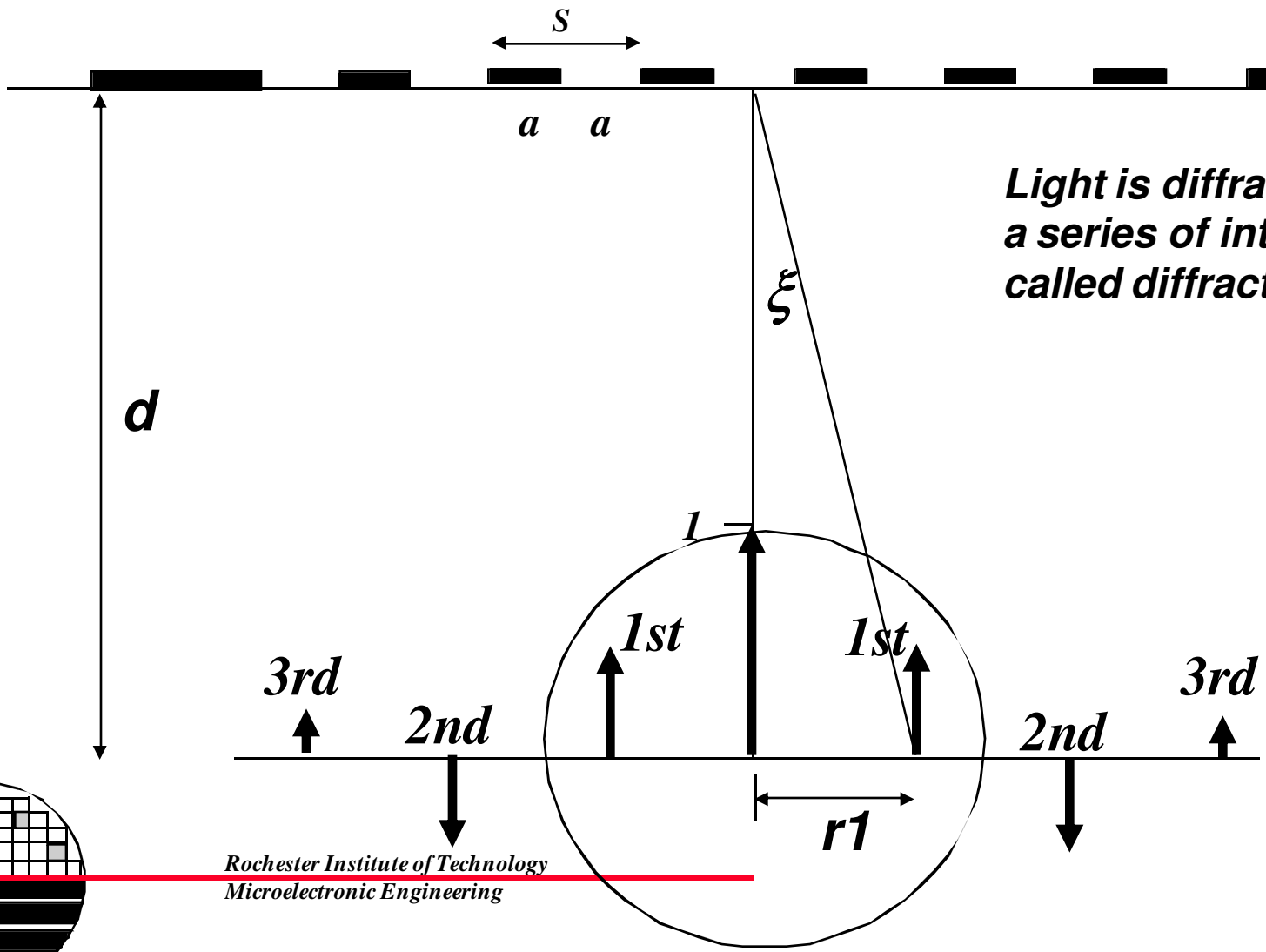
MICRO SPECTRO RADIOMETER



Plasma Etch Endpoint Detect
Nanospec Like Film Thickne
Light Source Characterizatio

Acknowledgments:
Marion Jess, Visiting Scholar from Germany
Wessel Valster, Student of Hogeschool Enschede,The Netherlands
Zoran Uskokovic, RIT, graduate student in MicroE

DIFFRACTION GRATING



Light is diffracted into a series of intensity spots called diffraction orders

CALCULATIONS

Grating of 2 um lines and 2 um space gives S=4 um

k is the diffraction order

λ is wavelength

The angle ξ

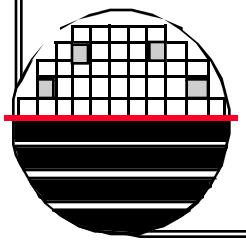
$$\sin \xi = k \lambda / n S$$

and

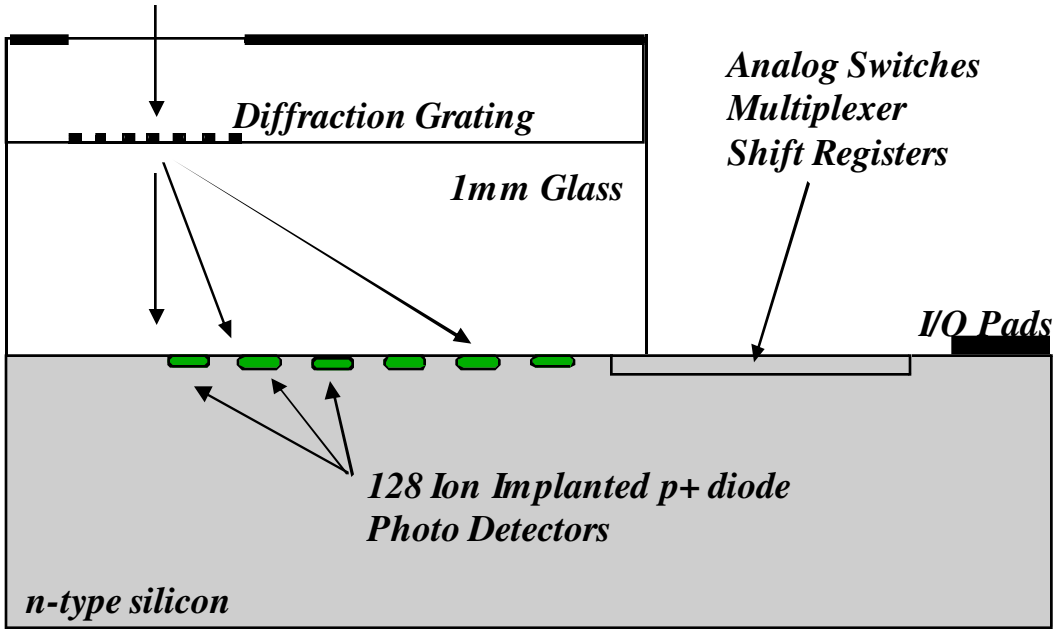
$$\tan \xi = r/d$$

for d = 1000um, and n = 1.5 for glass

	$\xi 1$	$\xi 2$	r1	r2	
350 nm		3.34	6.71	58um	117um
550 nm		5.24	10.6	92um	187um
750 nm		7.17	14.5	126um	259um



MICRO-SPECTRO-RADIOMETER



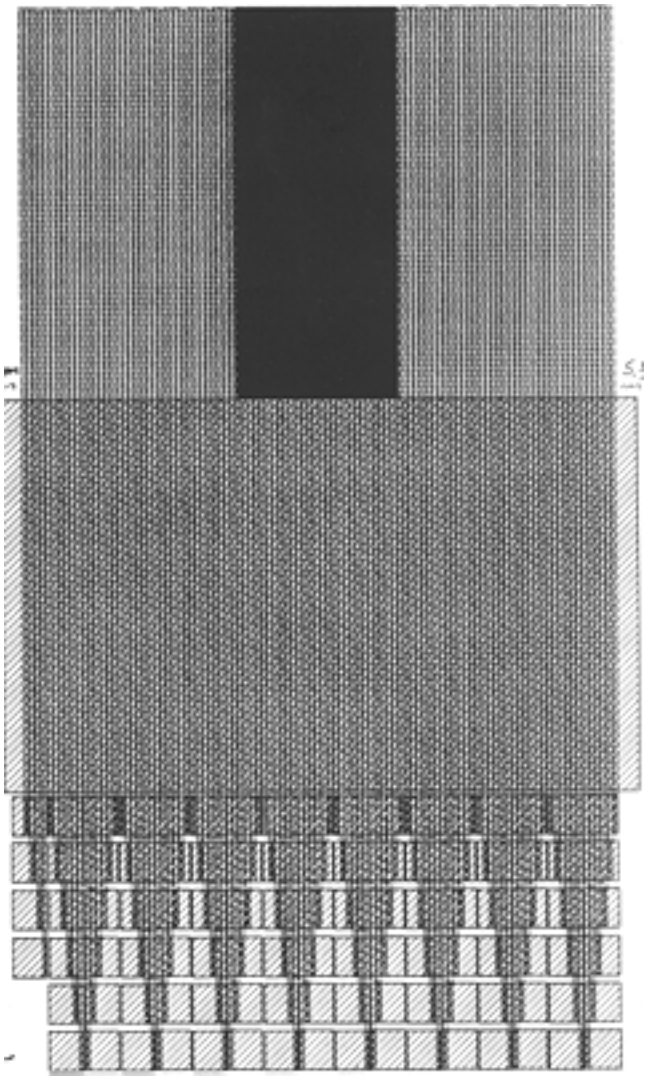
FIRST TEST CHIP

Marion Jess
1996

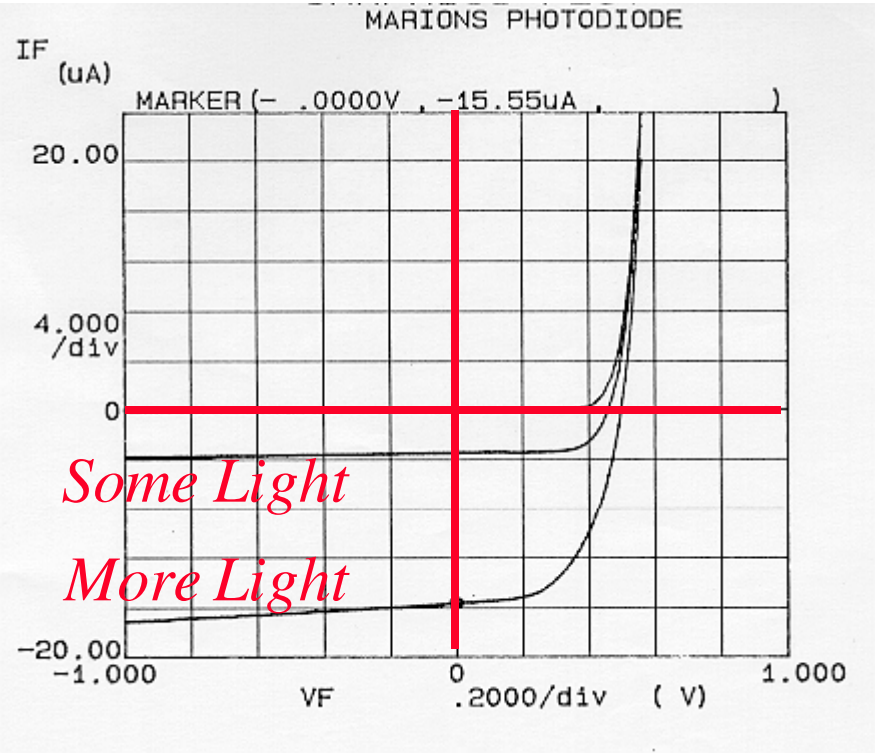
Photo diodes

Shielded area

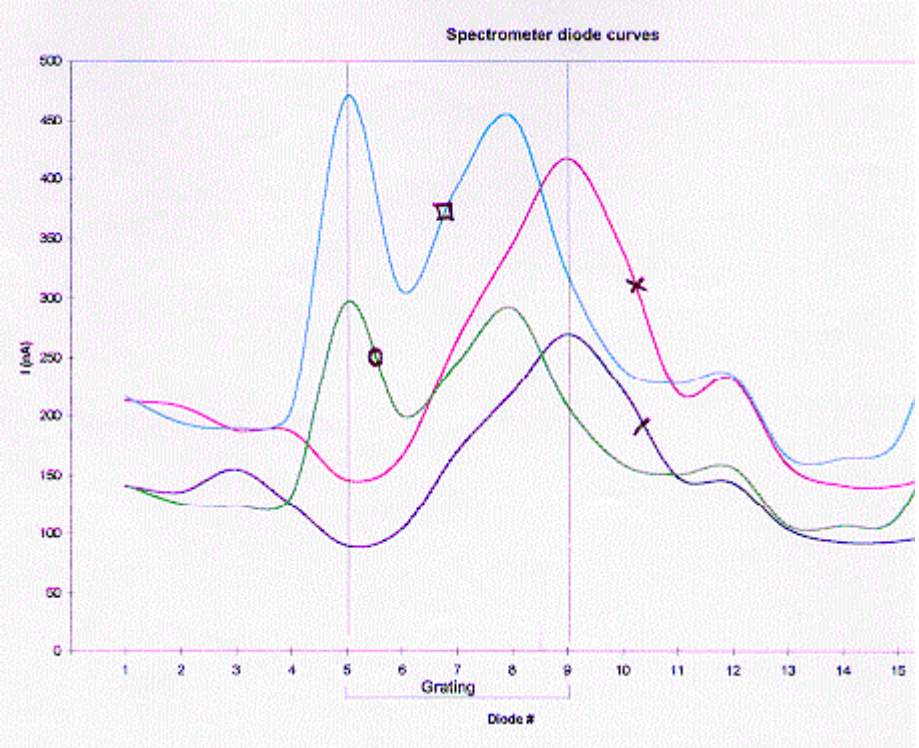
Pads to 128 diodes



RESULTS OF FIRST TEST CHIP

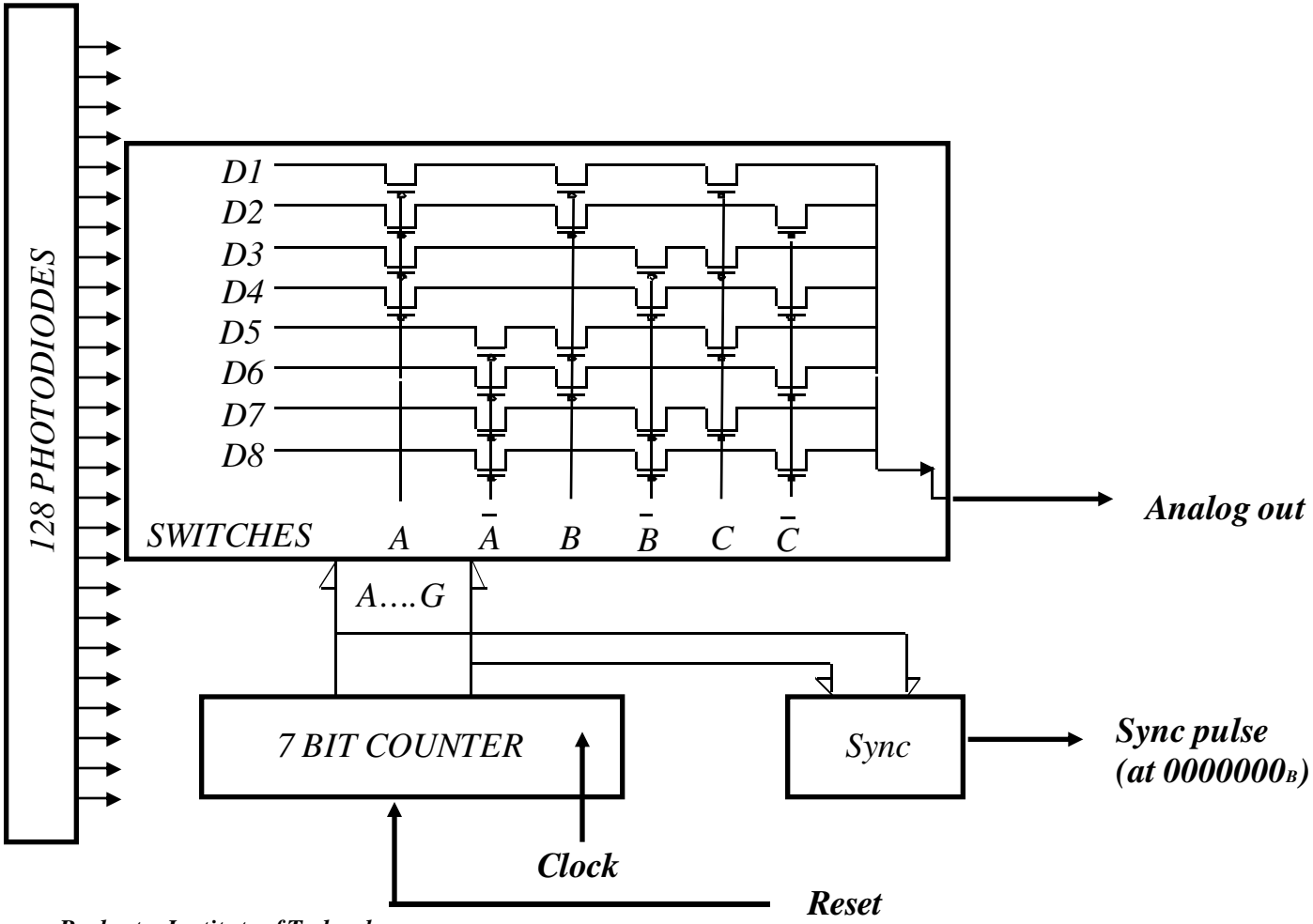


Photodiode Current vs Voltage

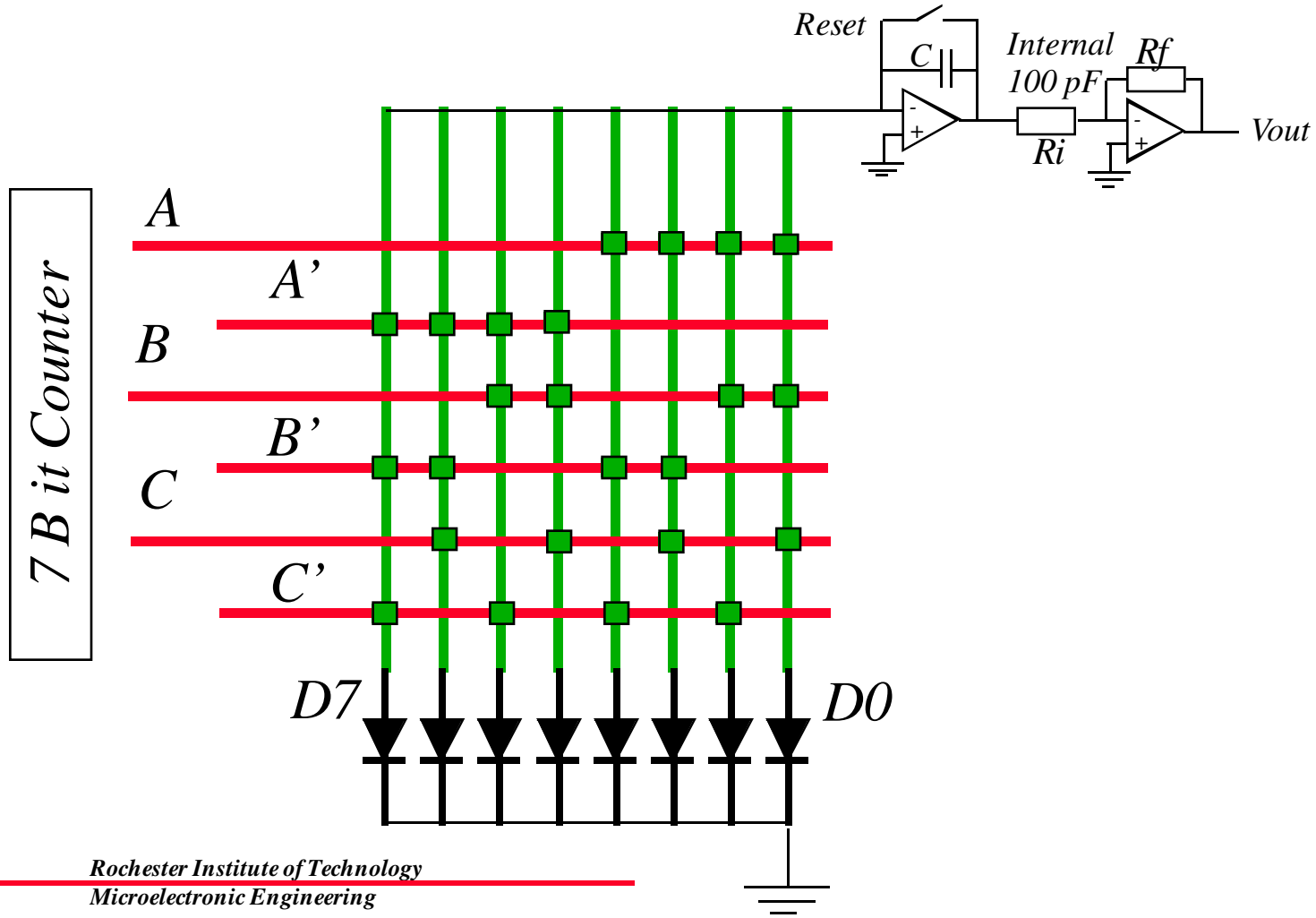


Measurements from 128 diodes illuminated through different color filters

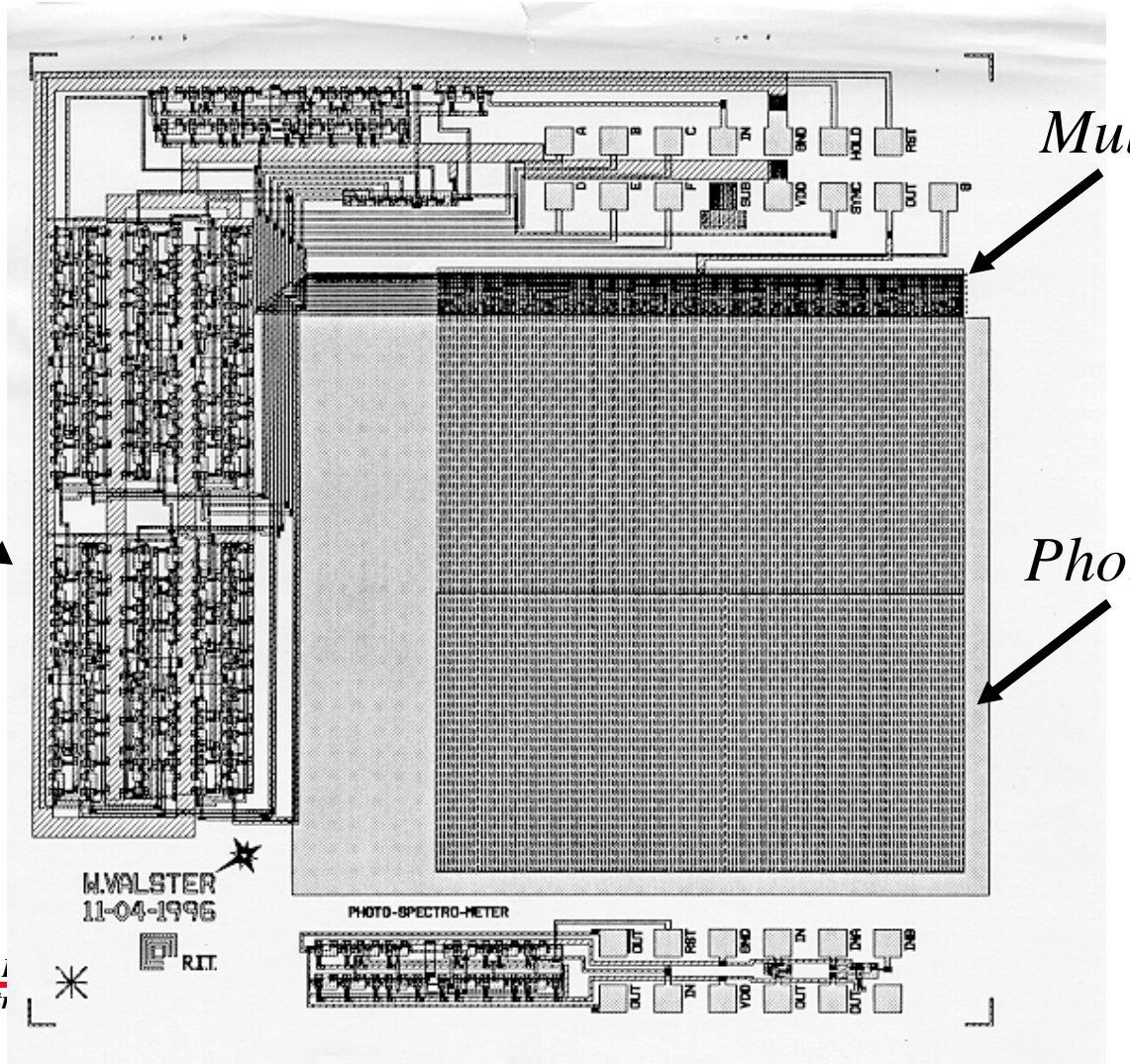
MICRO-SPECTRO-PHOTOMETER ON CHIP ELECTRONICS FOR ELECTRONIC READOUT



POLY GATE PMOS + DEPLETION MODE IMPLANT MULTIPLEXER



SECOND TEST CHIP



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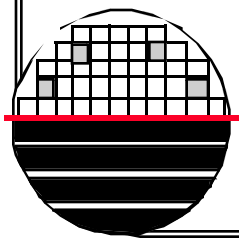
1. Micromachined Transducers, Gregory T.A. Kovacs, McGraw-Hill, 1998.
2. Microsystem Design, Stephen D. Senturia, Kluwer Academic Press, 2001.
3. IEEE Journal of Microelectromechanical Systems.



HOMEWORK – DIODE SENSOR LAB

1. Calculate the sensitivity (mV/°C) from the data on page 13.

2. Calculate reasonable values to fill in the table on page 17. state your assumptions and show equations you used.

3. Calculate the gain (V/μA) of the signal conditioning circuit on page 20.

4. Write an expression for the output voltage of the circuit on page 21 and 22.