RET Summer Presentation “MEMS”

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Mentor: Rajashree Baskaran

Advisor: Prof. Kimberly Turner

Funding: NSF

Background MEMS from Sandia National Labs

Summer Research

- I worked in Prof. Turner's MEMS Characterization Lab with Rajashree Baskaran.

Introduction

The purpose of the research I was involved in was to characterize a MEMS device “C2”, built by Rajashree Baskaran.

MEMS

- √What are they?
- What are they

What are MEMS?

I said, "What are MEMS?"

- Micro - very *small* device (less than 1 mm)
- ElectroMechanical - turns mechanical energy into electrical energy or vice versa
- Systems - used with other electrical products, mostly as sensors

A MEMS device on a human hair

I said, "How small is a MEMS?"

A MEMS device 30 µm across

Human hair 100 µm across

Think of the possibilities…

You could have multiple MEMS devices installed on your hair!!

MEMS

- What are they?
- √ What are they good for?
- How are they made?

MEMS Saving Lives!

MEMS are used as sensors to deploy air bags!!

MEMS Saving Lives!

MEMS Saving Lives!

MEMS Saving Lives!

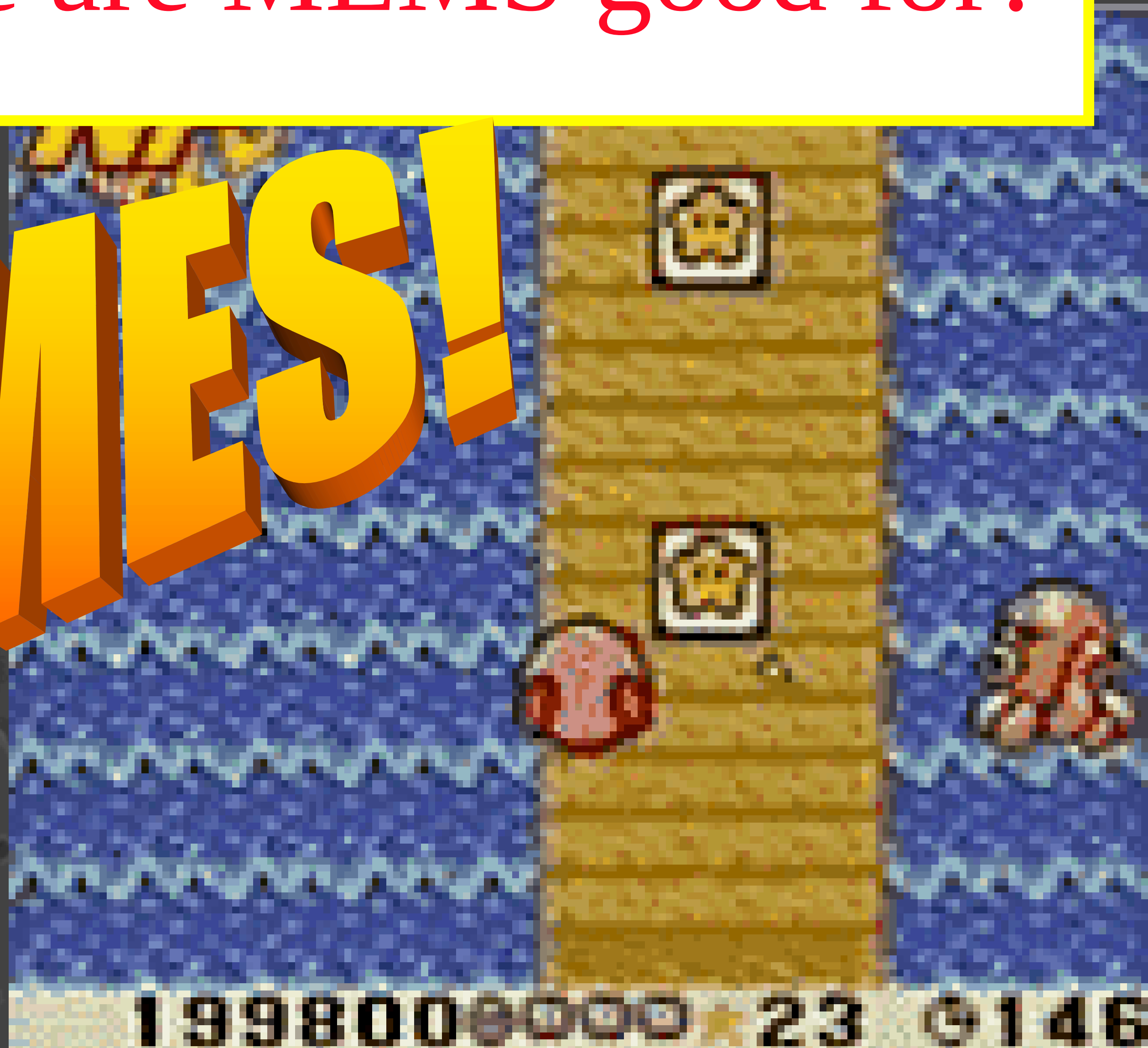
- The C-Leg is fitted with microprocessors and sensors that mimic the stability and step of a natural leg.

The C-Leg

- Curtis Grimsley fitted with the C-Leg was able to walk down 70 flights of stairs at the same speed of most others fleeing the World Trade Center during Sept. 11’s terrorist attacks

What else are MEMS good for?

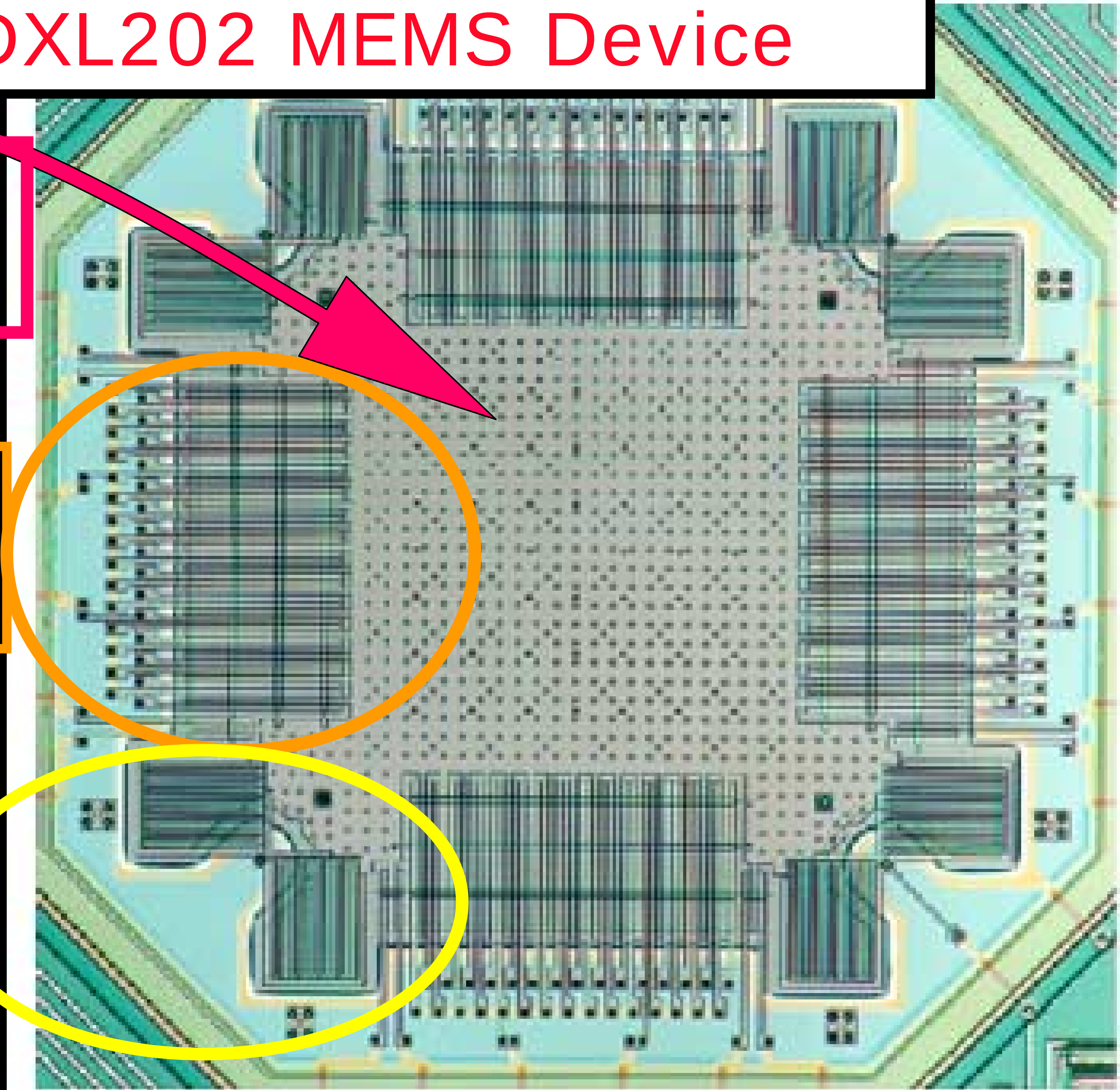
GAMES!



Inside the Kirby Tilt n' Tumble Game

- A MEMS device and electrical circuits needed to operate the device.
- Let's examine the MEMS device inside the game.

The ADXL202 MEMS Device

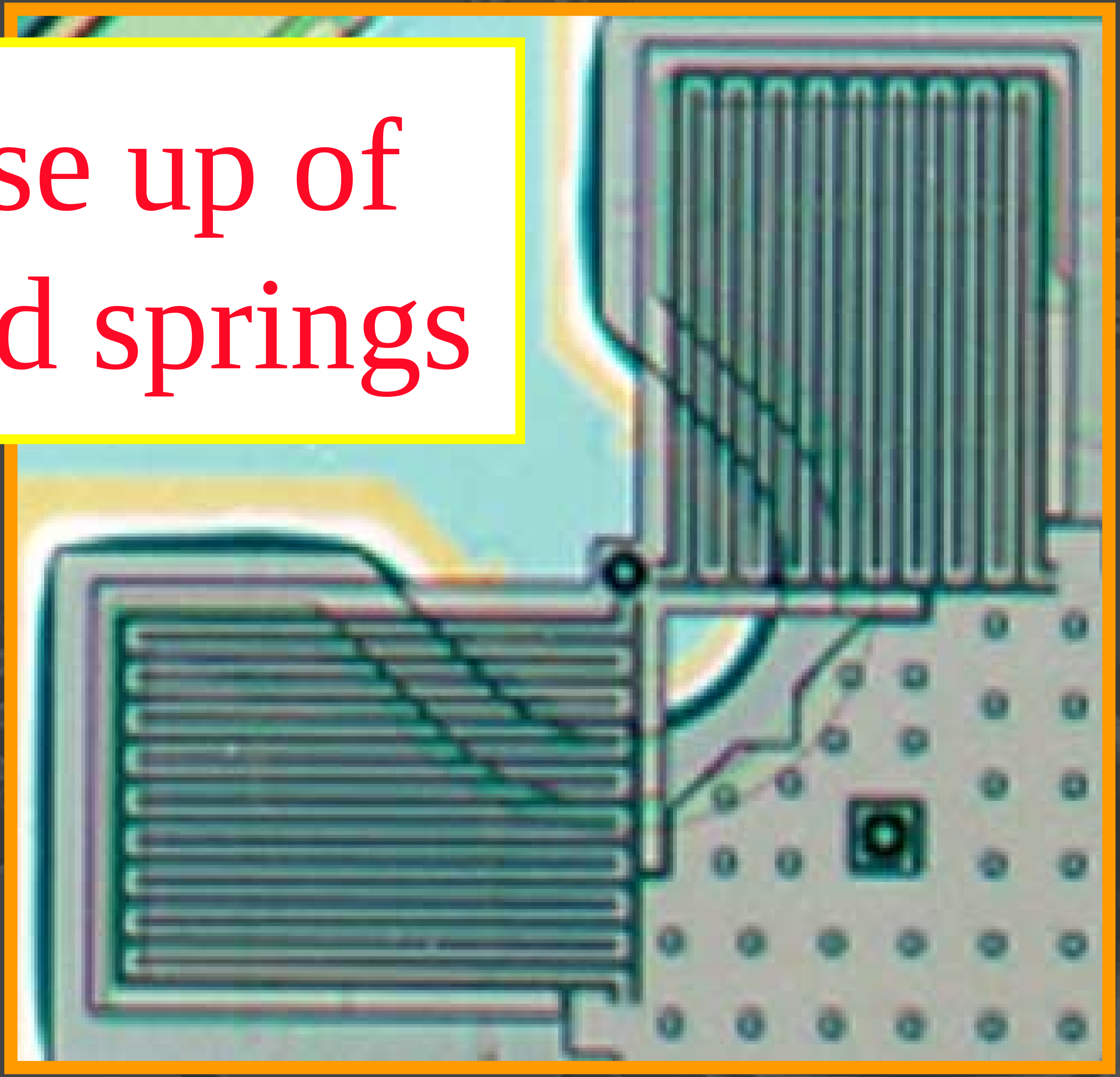


Movable Mass

Capacitors “Combs”

Folded Springs

Close up of folded springs



A close up of the capacitor “comb”

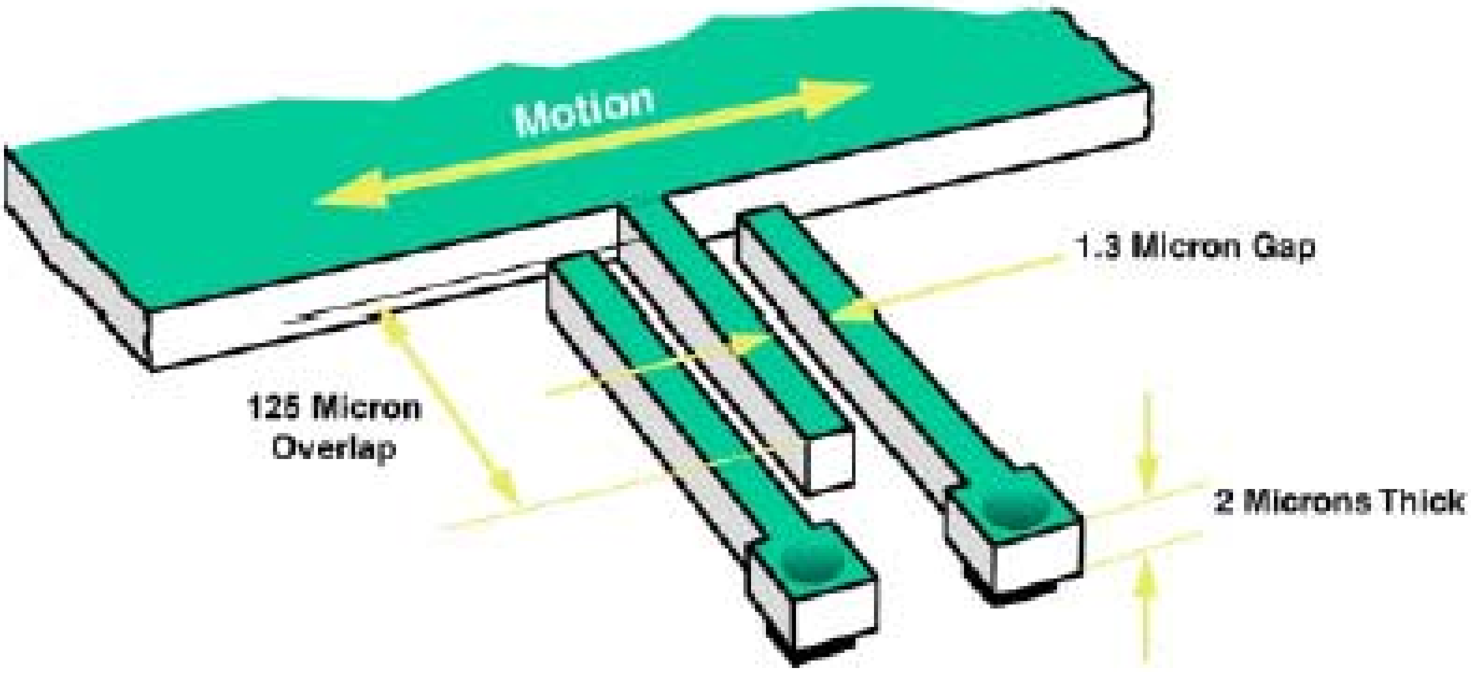


Figure 1. Beam Dimensions for a Single Finger.

Movement

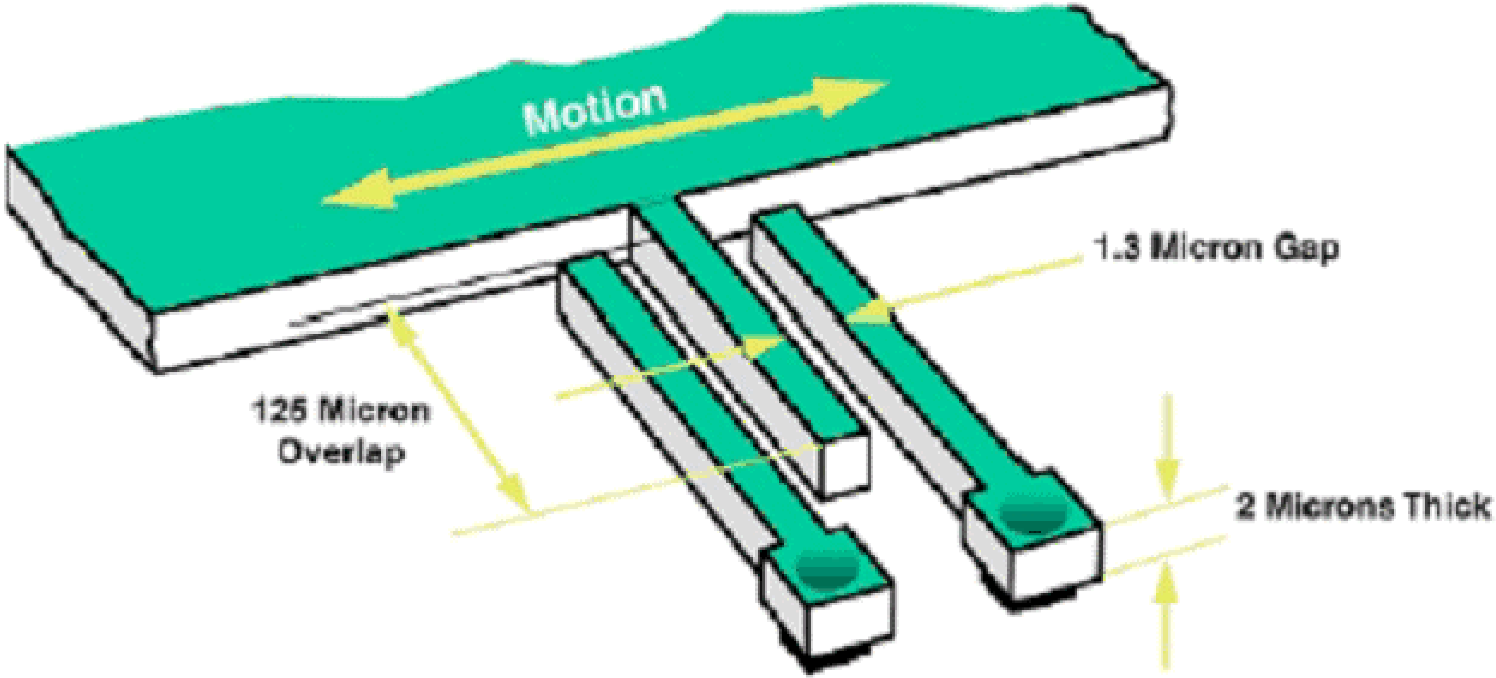
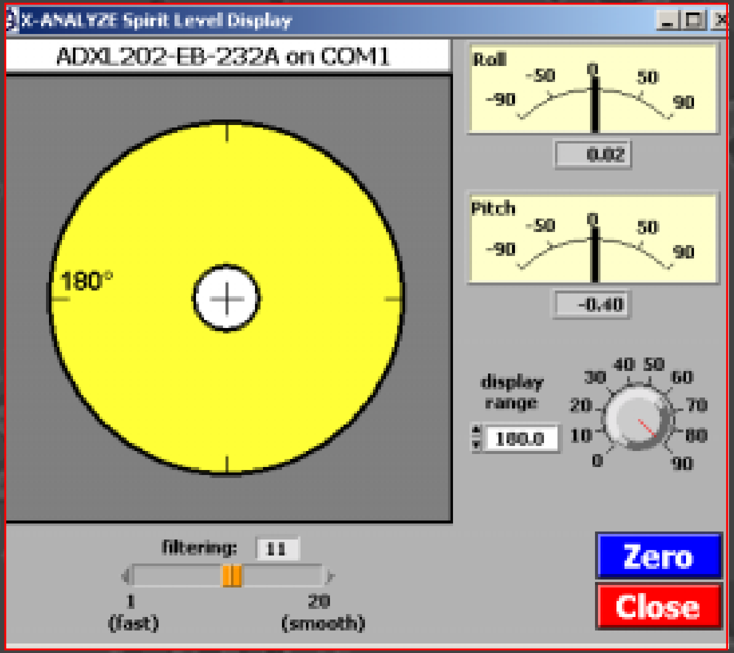


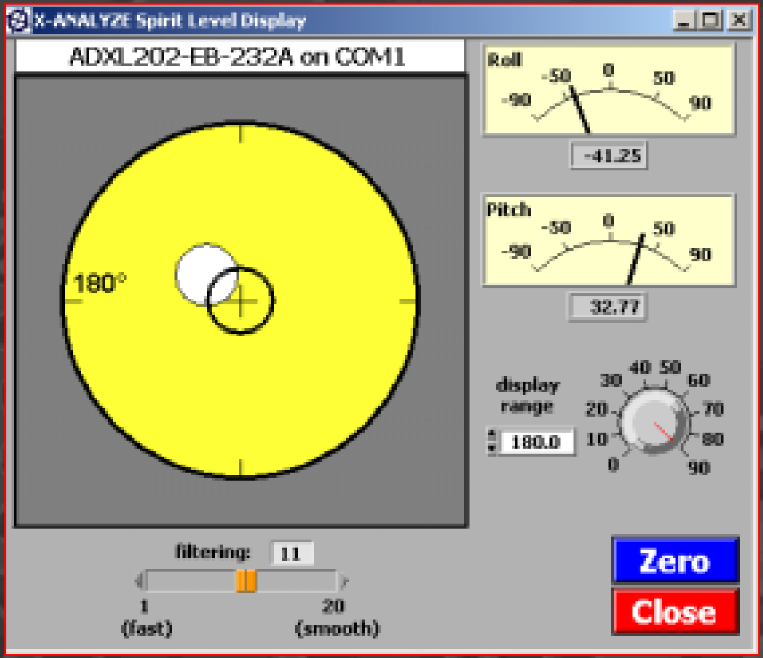
Figure 1. Beam Dimensions for a Single Finger.

How does Kirby's MEMS work?

- When the device is tilted:
- The mass moves
- The springs expand/compress
- The capacitor combs "sense" a change in voltage.
- The circuitry processes.

Computer Image of Accelerometer MEMS



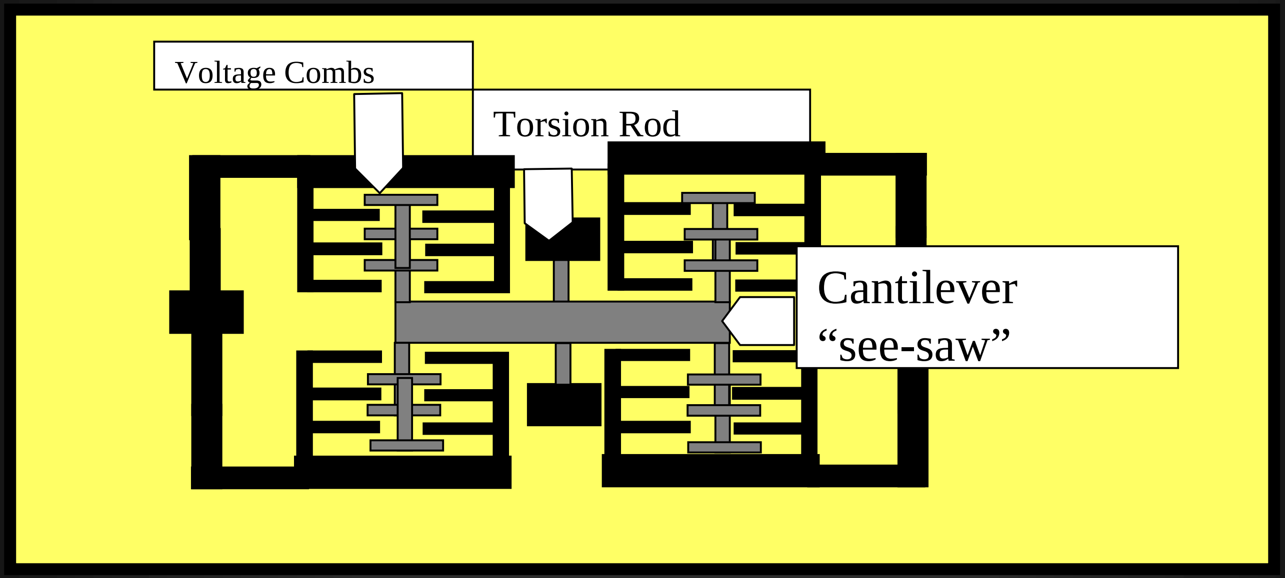


The image on the right is when the game is tilted.

Methods

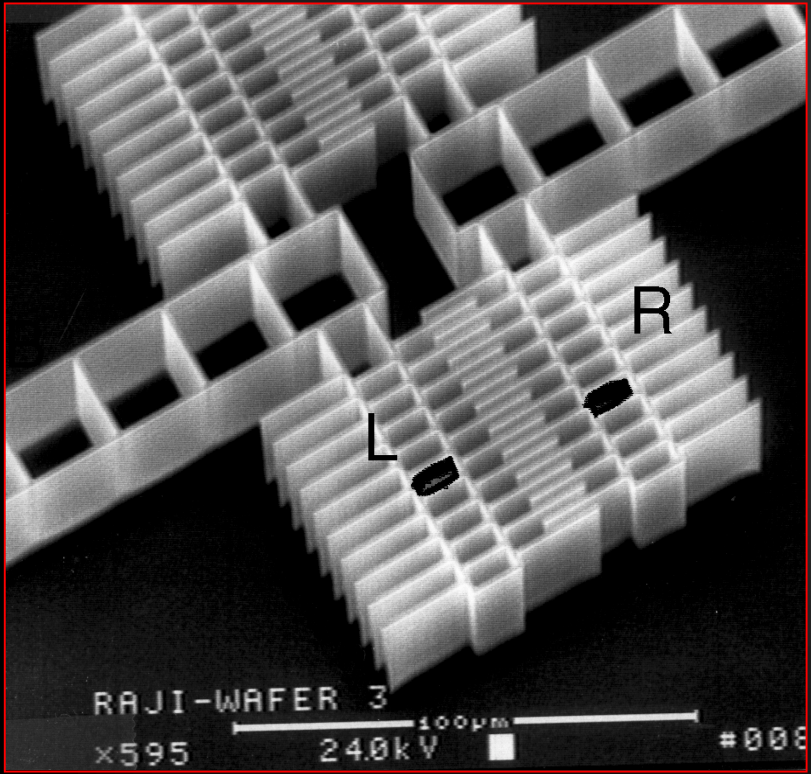
- The device we are testing is designed to vibrate when voltage is applied.
- Our tests are to determine what the highest velocity of vibrations will be for selected voltages.

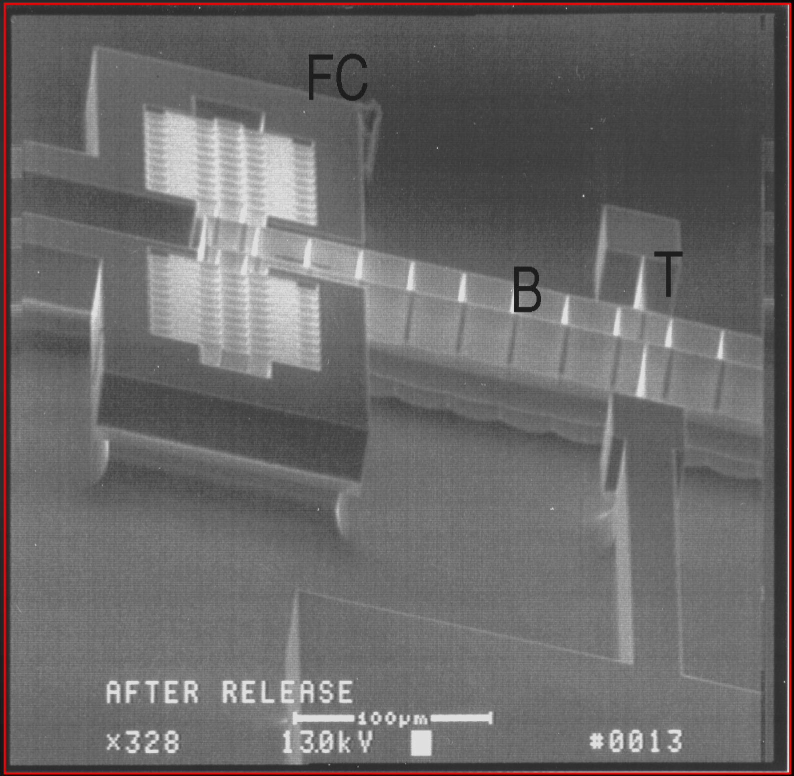
Overview of Testing Device "C2"



A torsional oscillator. The black parts are fixed to the substrate, and the gray parts are movable. The length of the cantilever is approximately 144μm (micro meters).

Scanning Electron Micrographs of Coupled Oscillators





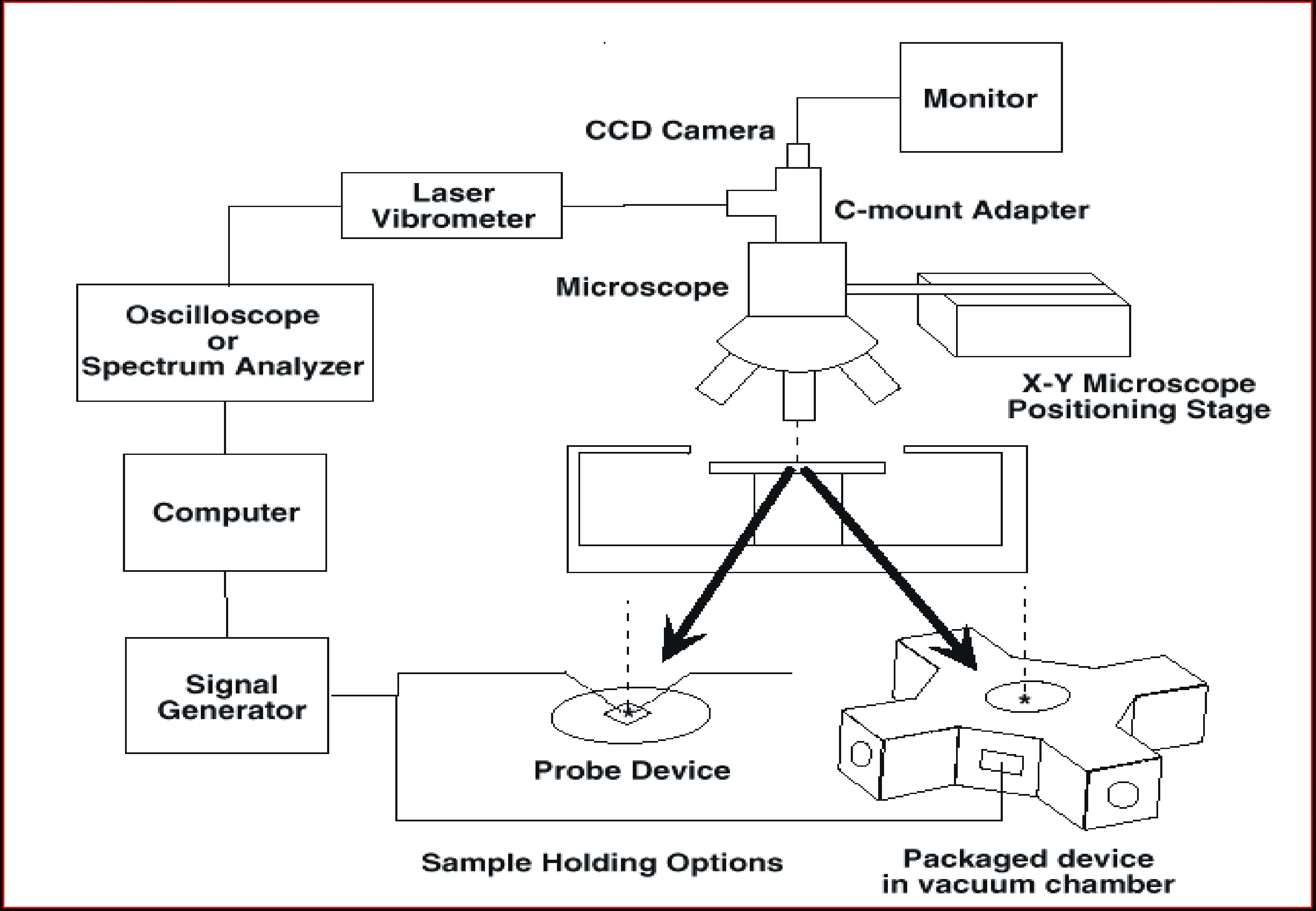
The Math Behind the Device

The formula below is the differential equation for motion and its solution. Raji uses this to calculate the resonance frequency of the device before it is built. The results of the test data are compared to the initial calculations.

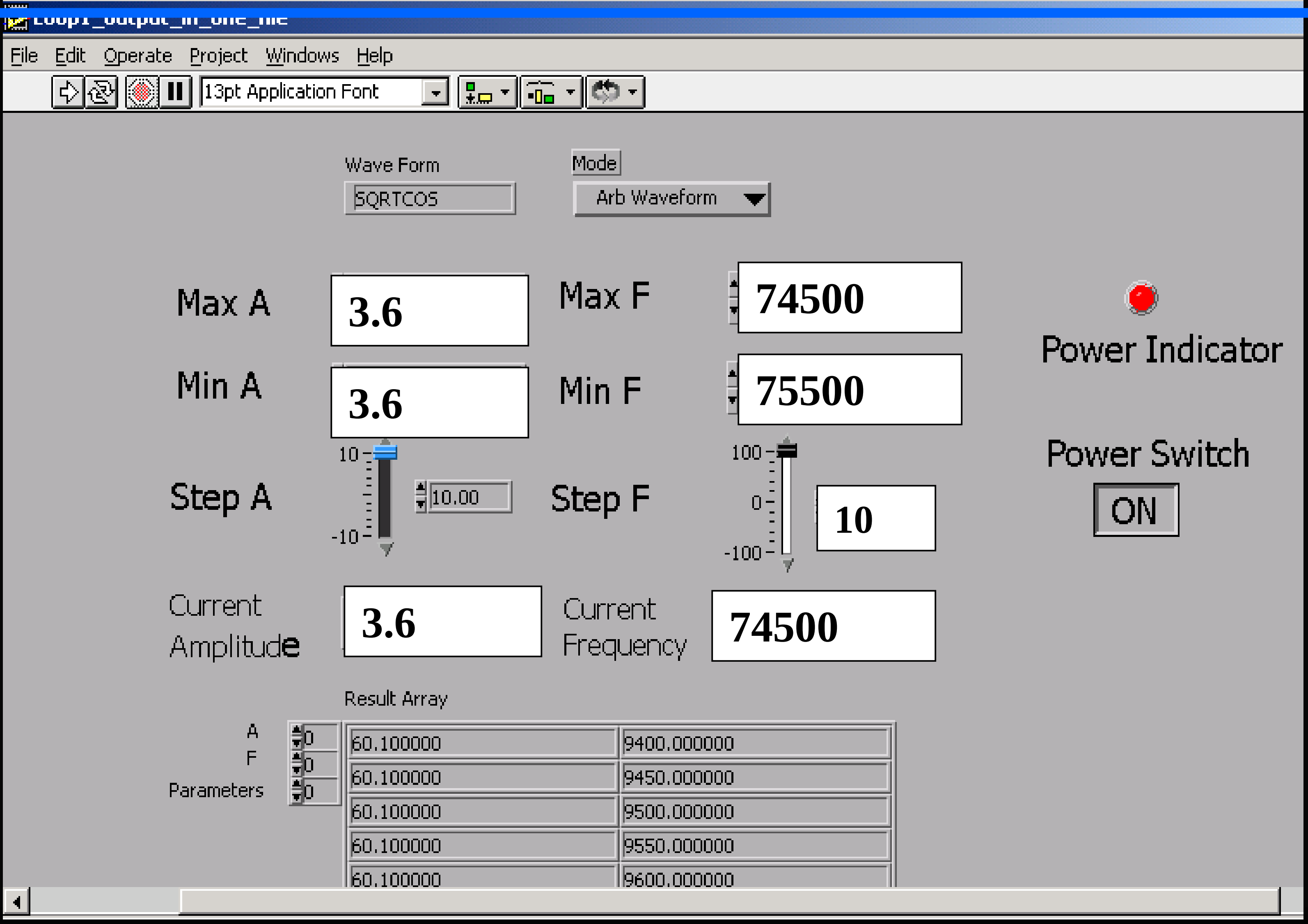
$$m\frac{d^2x}{dt^2} + c\frac{dx}{dt} + kx = -k_e V_A \cos(\varpi t)$$

$$Velocity=(m_1/x)/\sqrt{(m_2)^2 - x^2)^2 + 4(m_3)^2x^2}$$

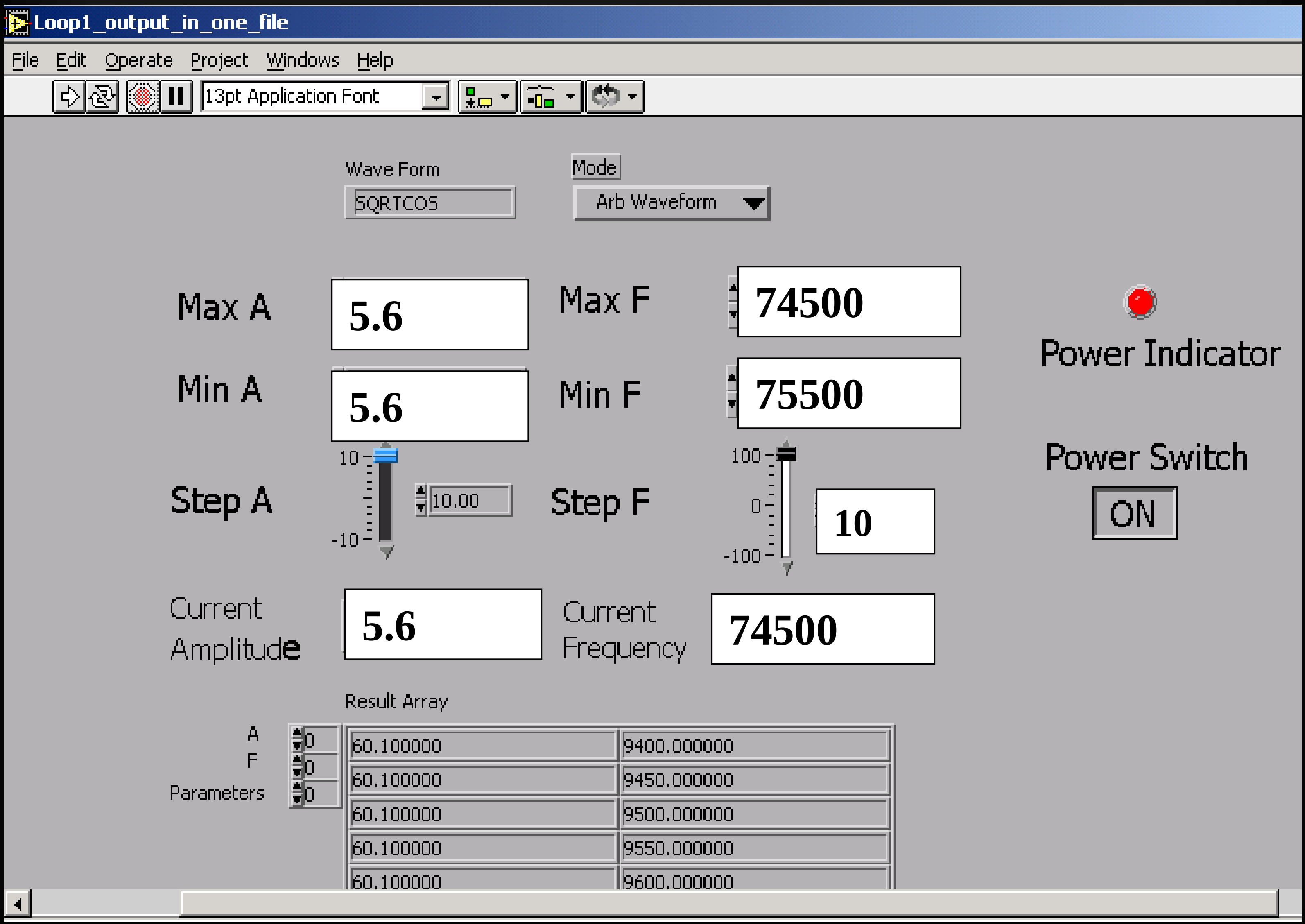
Laser Vibrometer Characterization Suite



Tektronix Oscilloscope Computer Interface: Testing at 3.6 Voltage



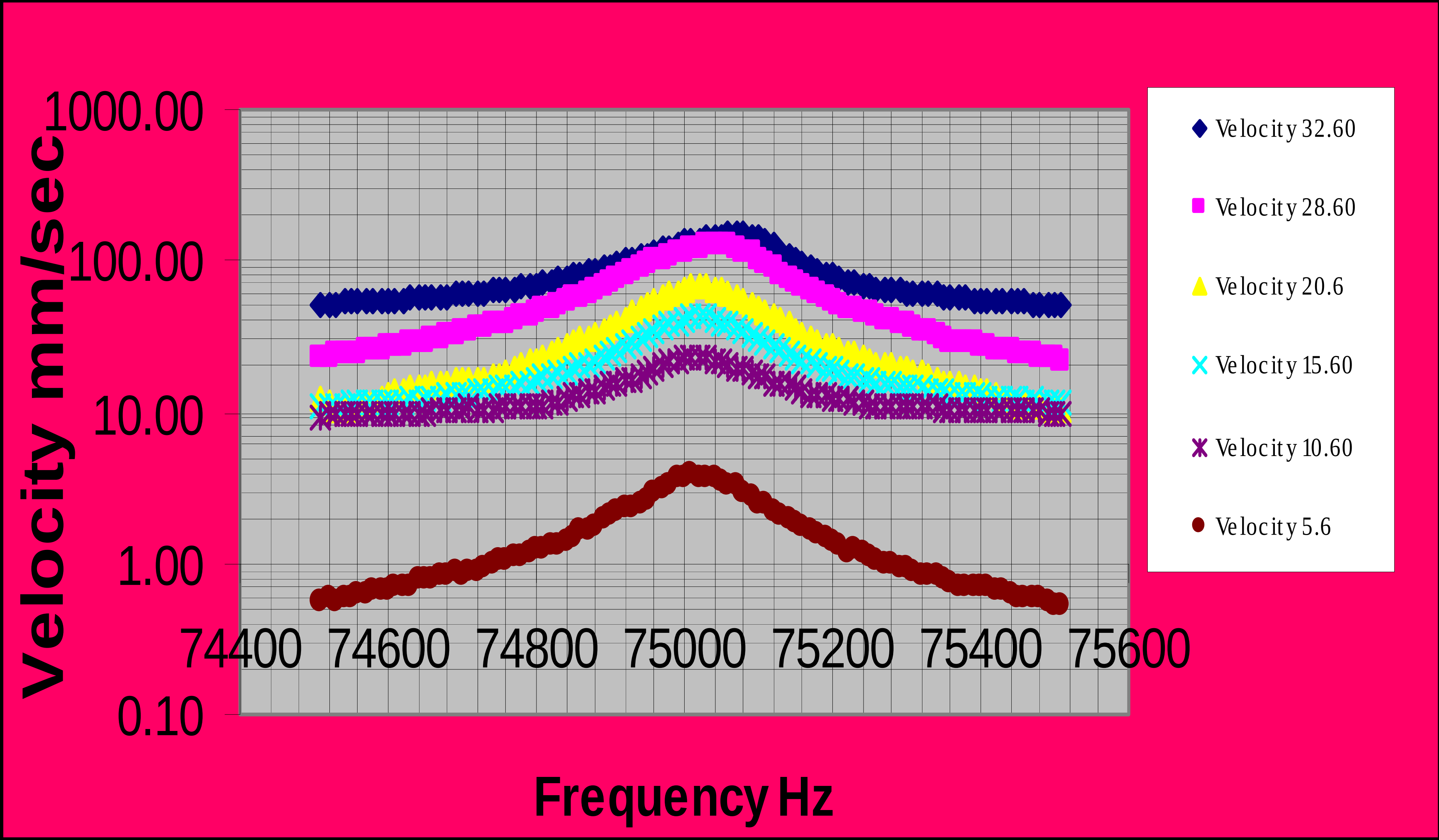
Testing at 5.6 Voltage



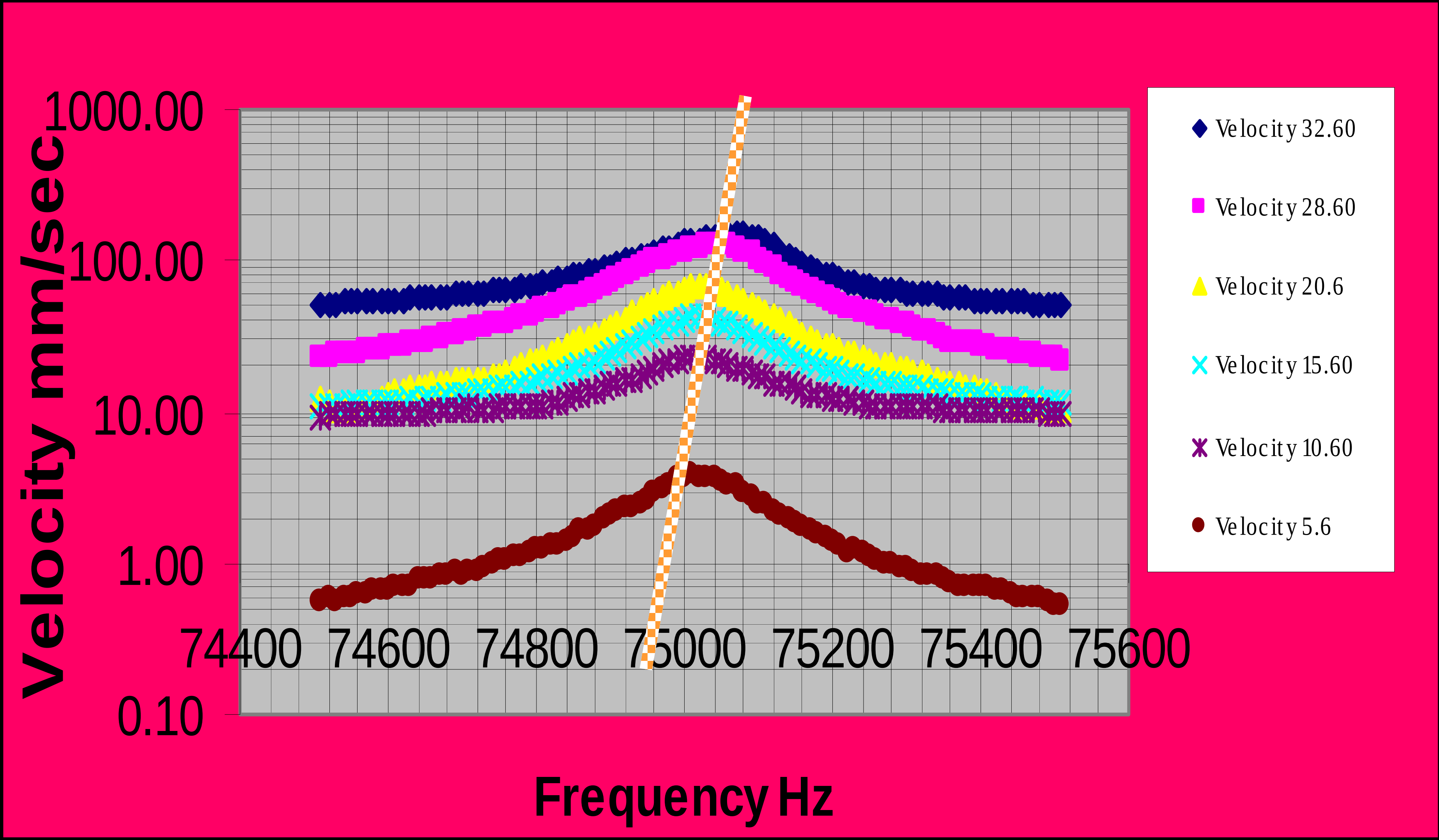
Peak Velocities are highlighted

Frequency of Input Voltage	Velocity 32.60	Velocity 28.60	Velocity 20.6	Velocity 15.60	Velocity 10.60	Velocity 5.6	Velocity 3.6
74970	119.00	103.50	56.75	35.50	20.1	3.104	1.122
74980	123.50	107.88	59.60	37.50	21.2	3.326	1.22
74990	127.50	112.63	62.38	39.30	22	3.596	1.353
75000	131.50	116.38	64.75	40.70	22.5	3.724	1.362
75010	135.00	120.88	66.13	41.80	22.80	3.84	1.43
75020	138.50	123.00	67.00	42.20	22.8	3.612	1.424
75030	141.50	126.50	66.63	41.90	22.4	3.642	1.362
75040	144.50	125.63	65.63	40.80	22.2	3.6	1.402
75050	146.50	127.48	64.00	39.30	21.5	3.392	1.318
75060	148.00	124.13	61.13	37.30	20.76	3.254	1.202
75070	148.50	121.63	58.00	35.40	19.6	3.206	1.164
75080	148.00	114.88	54.63	33.60	19	2.964	1.112
75090	146.00	111.13	51.63	31.70	18.2	2.818	1.048

C2 Frequency v. Velocity

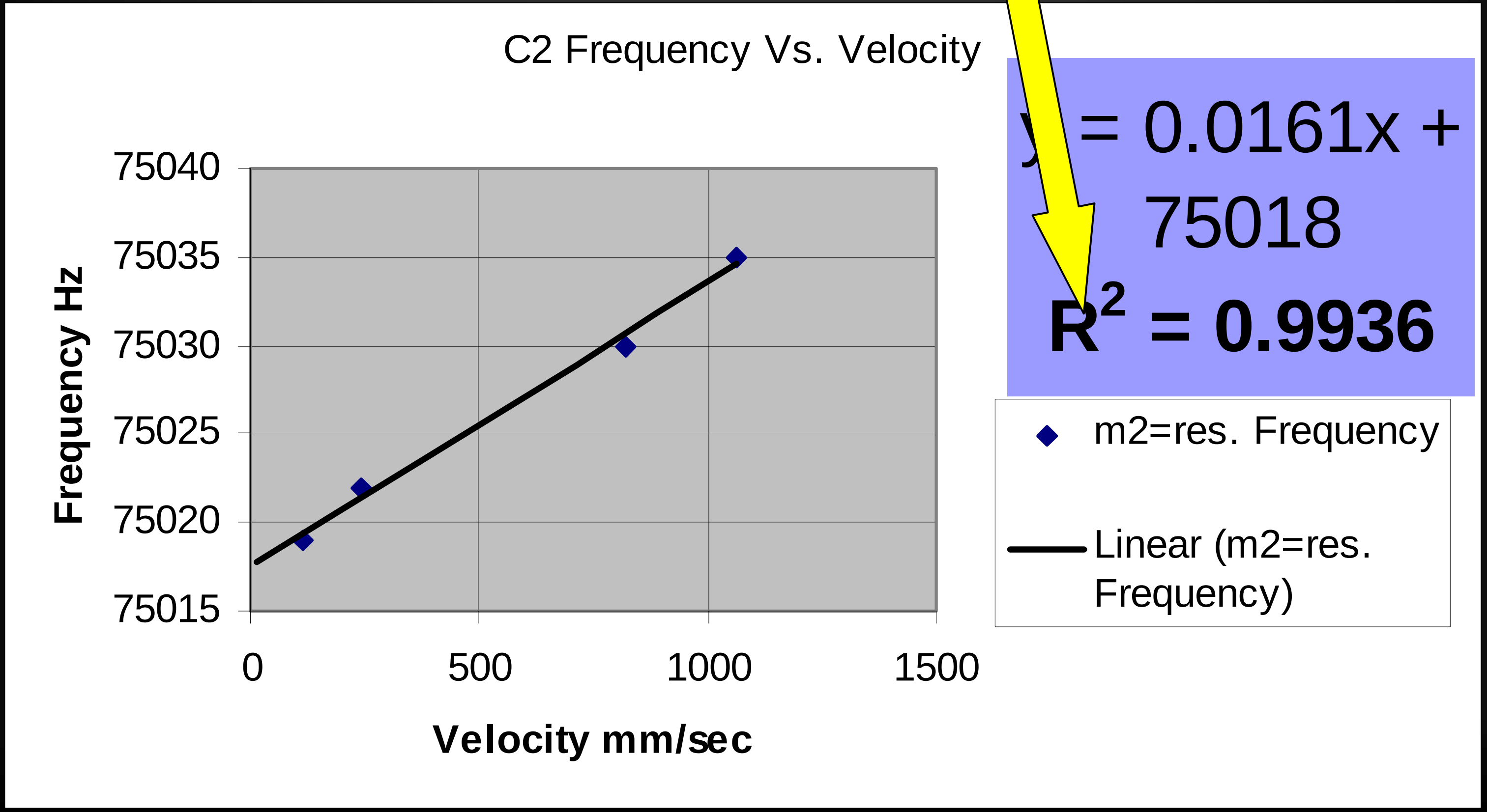


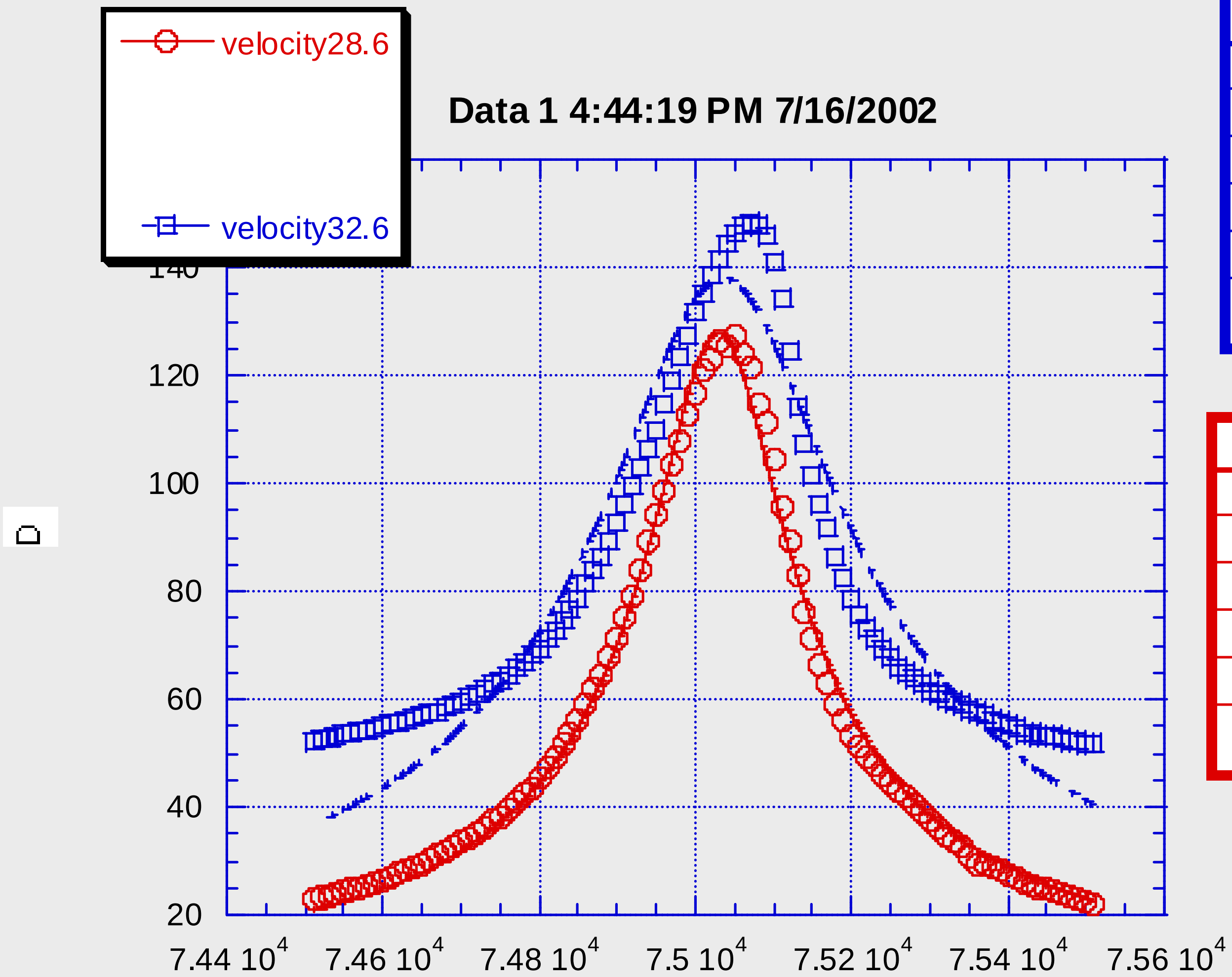
C2 Shift of Peak Velocity



C2 Frequency Vs. Velocity

The linear equation calculated by Raji fits almost perfectly into the data collected. When $R^2 = 1$, the fit is perfect.





y = m1*M0/sqrt((m2*m2-m0*m0)...		
	Value	Error
m1	40096	912.16
m2	75035	3.9297
m3	145.27	4.9165
Chisq	7282.1	NA
R^2	0.91978	NA

y = m1*M0/sqrt((m2*m2-m0*m0)...		
	Value	Error
m1	21828	157.91
m2	75030	0.86549
m3	85.323	0.96636
Chisq	503.8	NA
R^2	0.99506	NA

The top curve does not fit well into the solution because at this voltage, the velocity is not linearly related.

What did I learn this summer?

- Engineering is cool.
- Engineers solve problems for people.
- When you test something, you test all your variables millions of times against the control.
- Engineers write **everything** down in numbered log books.


Thanks to Raji and Kim for the time you gave me, and the opportunity to learn…time to go fishing.