MEMS Capacitor Sensor Laboratory

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4-11-13 capacitor_Lab.ppt

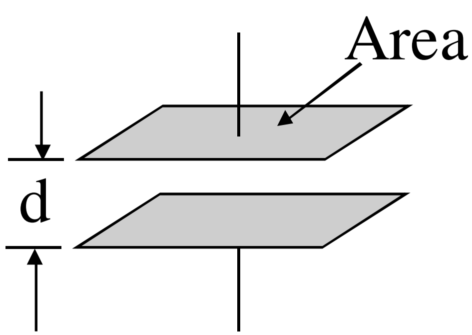
OUTLINE

Parallel Plate Capacitors – Force/Position Sensor
Water Level Sensor
RC Oscillator
Capacitance to Analog to Digital Output
Resonant LC Wireless Capacitor Sensor
Bluetooth Wireless Capacitor Sensor

CAPACITORS

Capacitor –

$C = \varepsilon o\ \varepsilon r\ Area/d$ where εo is the permitivitty of free space
εr is the relative permitivitty
Area is the overlap area of the two conductor separated by distance d



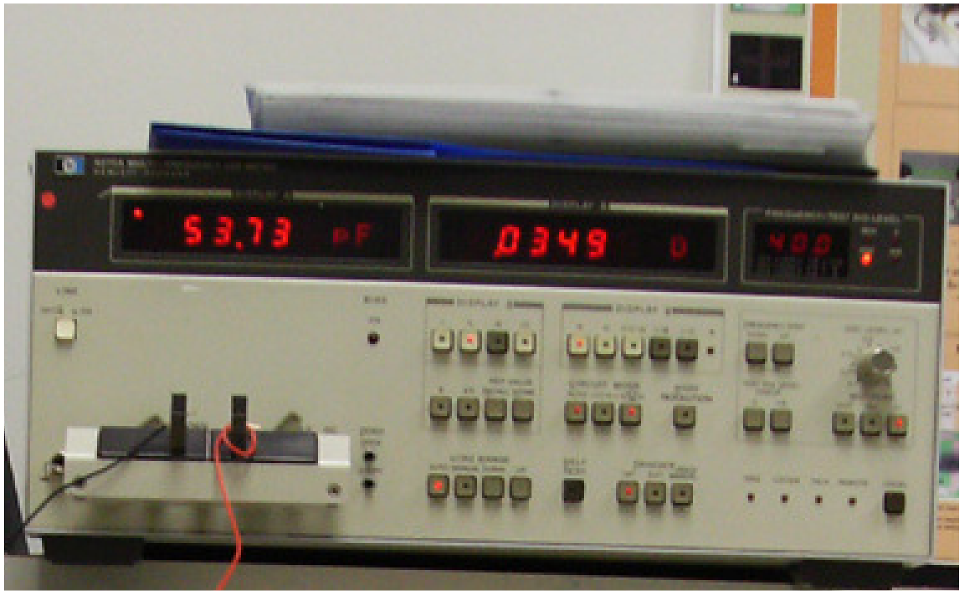
$\varepsilon o = 8.85E\text{-}14$ F/cm
εr air = 1
$\varepsilon r\ SiO_2 = 3.9$

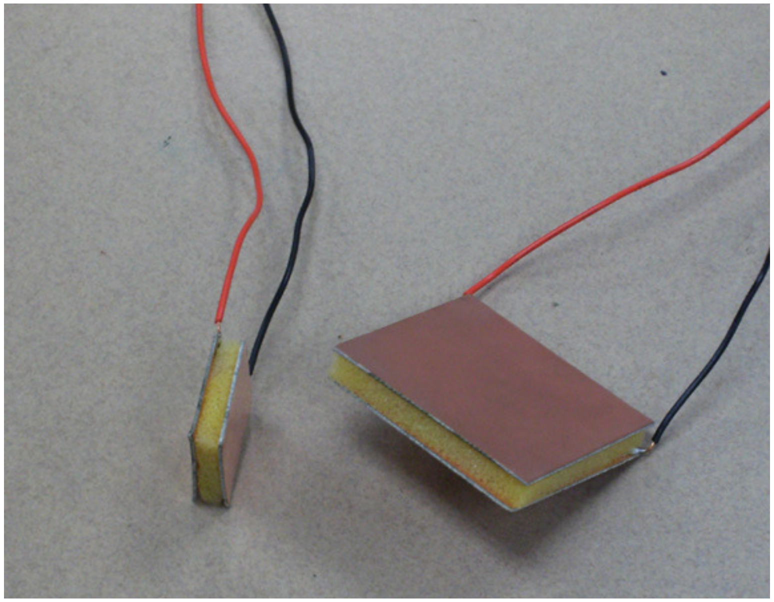
CAPACITOR CALCULATIONS

Rochester Institute of Technology								8-Apr-08
Dr. Lynn Fuller	Microelectronic Engineering, 82 Lomb Memorial Dr., Rochester, NY 14623							
To use this spread sheet enter 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 results are displayed in the purple boxes.								
Capacitance of Two Parallel Plates								
Capacitance = eoer Area/d					C =	3.43E-11	F	
				eo = Permitivitty of free space		8.85E-14	F/cm	
				er = relative permitivitty =		2		
					Area =	5.81E+01	cm2	
				number of pairs of plates, N =		1		
				distance between plates, d =		3000	µm	
				If round plates, Diameter =		0	µm	
				If rectangular plates, length =		7.62E+04	µm	
				If rectangular plates, width =		7.62E+04	µm	
Force Between Two Parallel Plates					Force =	5.71E-07	N	
Electrostatic Force= eoer Area V²/2d²				Applied Voltage, V =		10	volts	

CAPACITANCE BETWEEN TWO PLATES

Design and build capacitors made of two metal plates separated by a thin foam insulator that can be compressed for various applied forces. Calculate capacitance and measure capacitance, compare results to theoretical.





εr air < εr foam < εr rubber
1 < εr foam < 3

Capacitance of two wires 3' long
Capacitance of 2" x 2" plates ½" gap
Capacitance of 1" x 1" plates ¼" gap

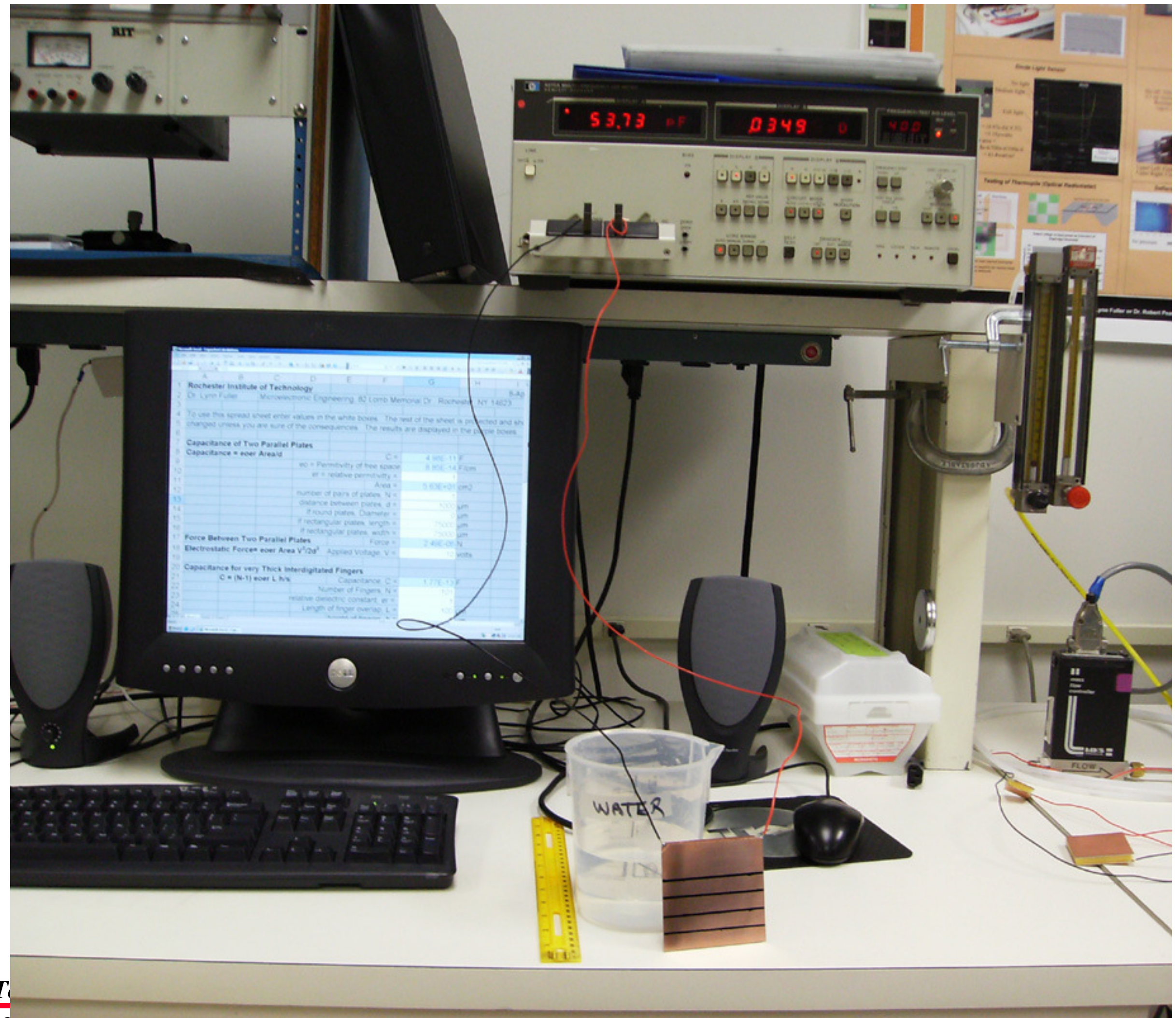
CAPACITIVE FORCE SENSOR

LIQUID LEVEL CAPACITOR SENSOR

Calculate Capacitance,
3” x 3” plates
1/32” gap

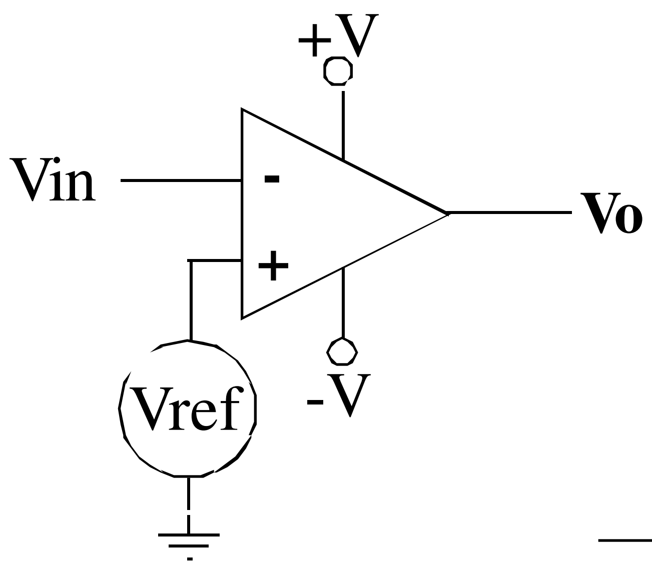
Measure Capacitance
Immersed in Water
at ½, 1, 1 ½ and 2”

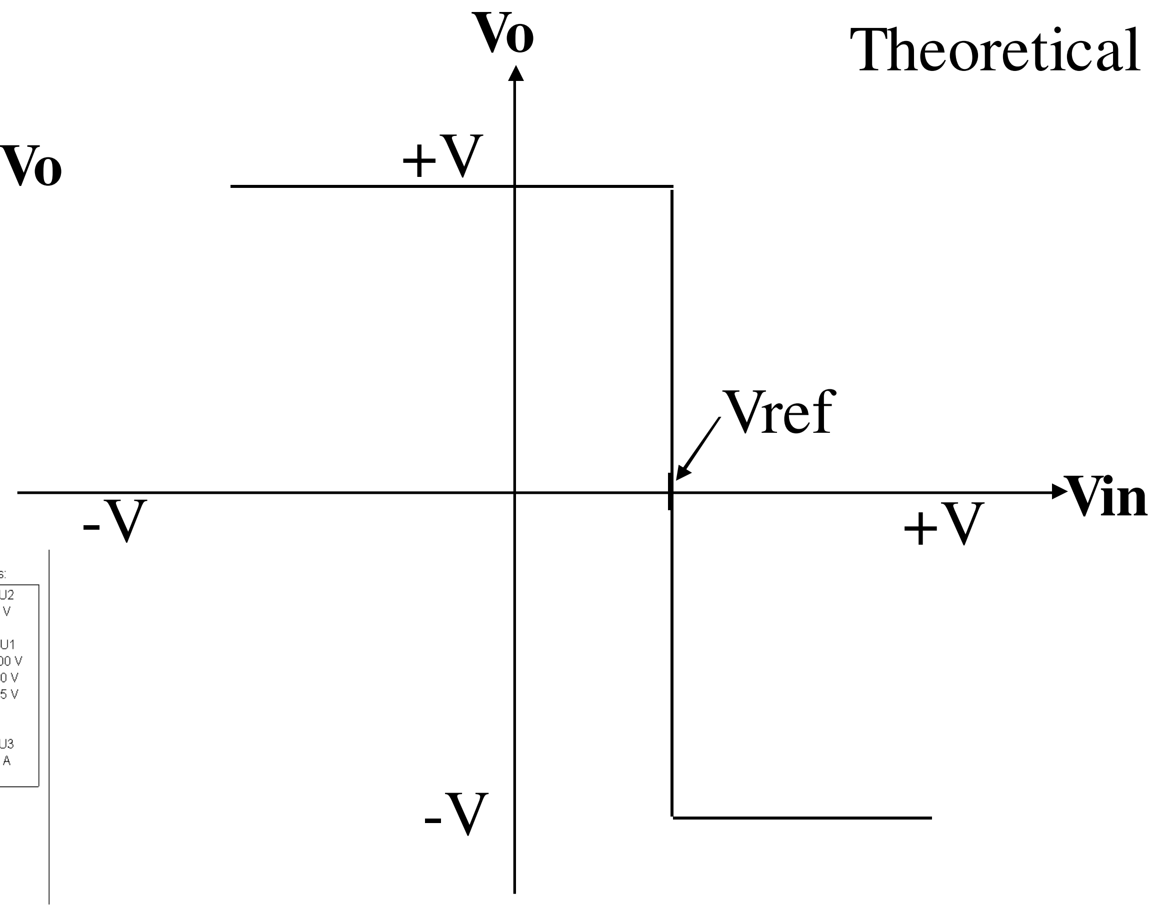
εr = ~80 for water

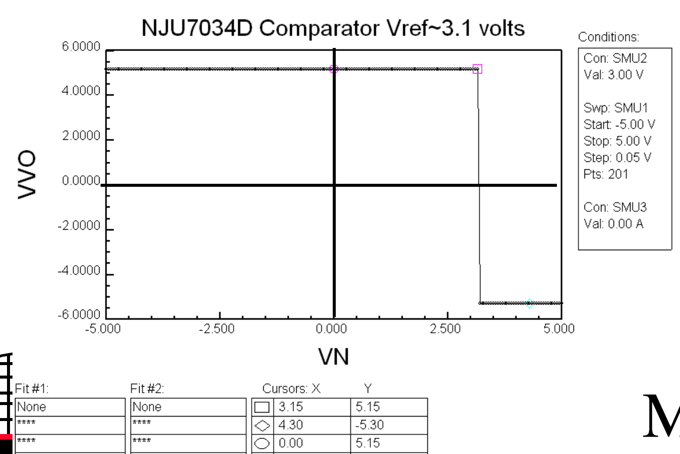


CAPACITIVE WATER LEVEL SENSOR

COMPARATOR

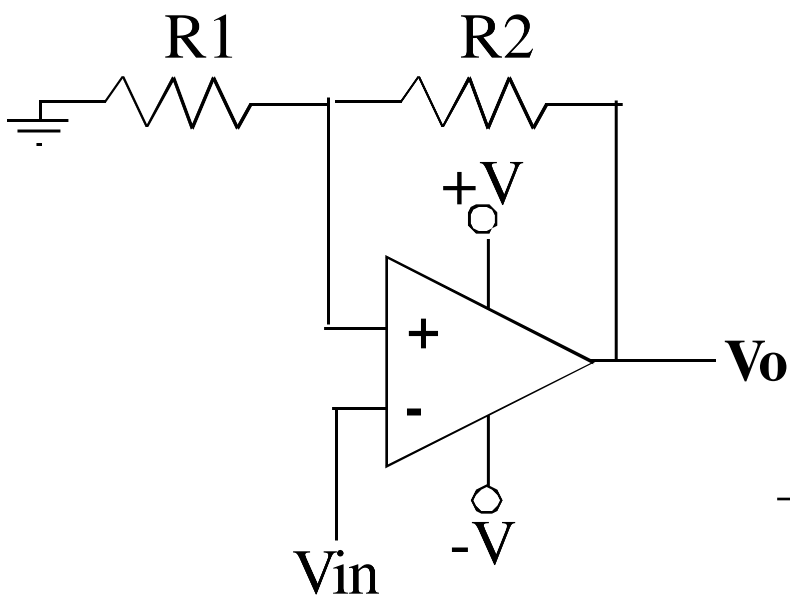


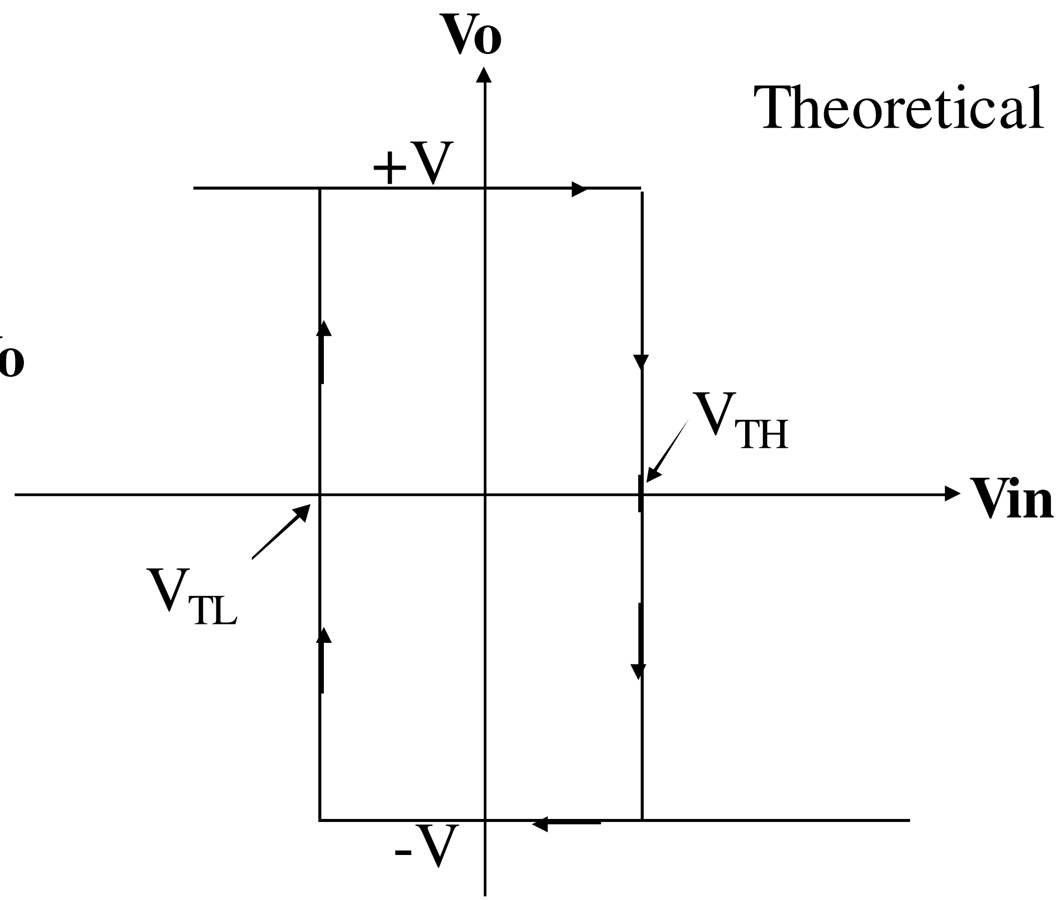




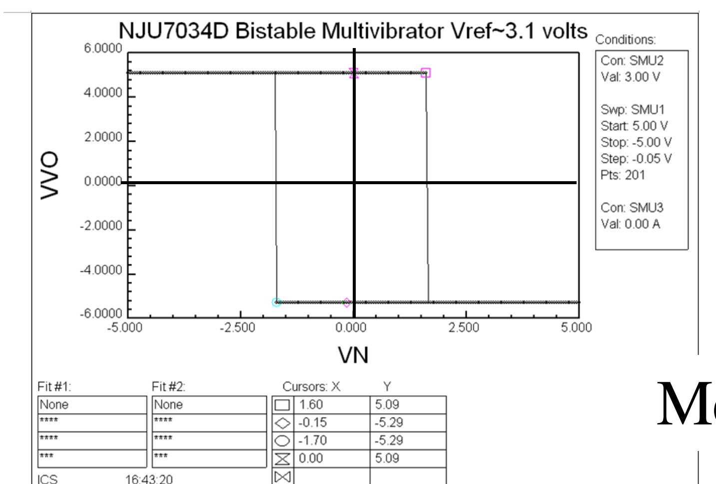
Measured

BISTABLE CIRCUIT WITH HYSTERESIS





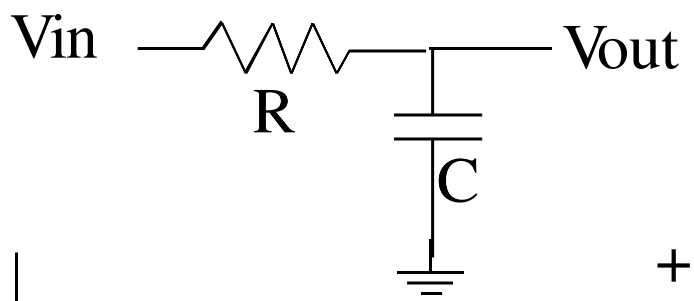
Theoretical

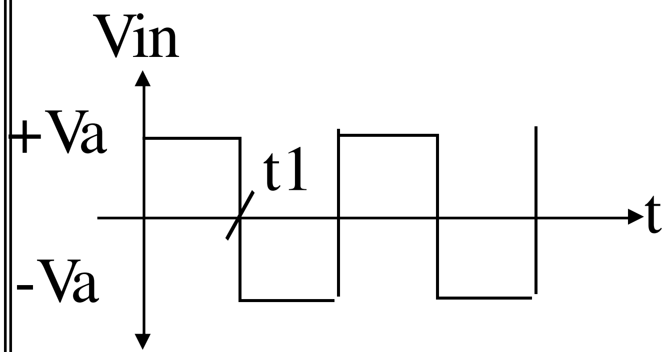


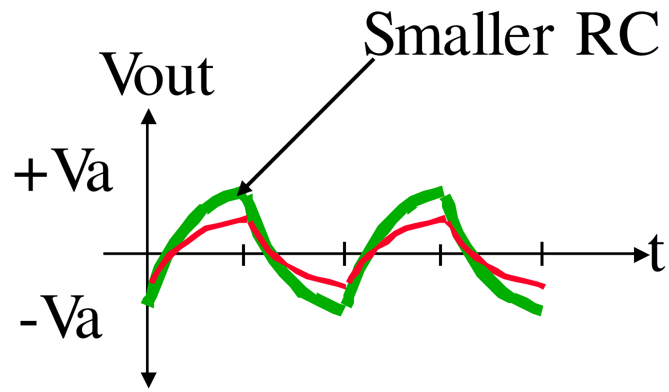
Measured

Sedra and Smith pg 1187

RC INTEGRATOR



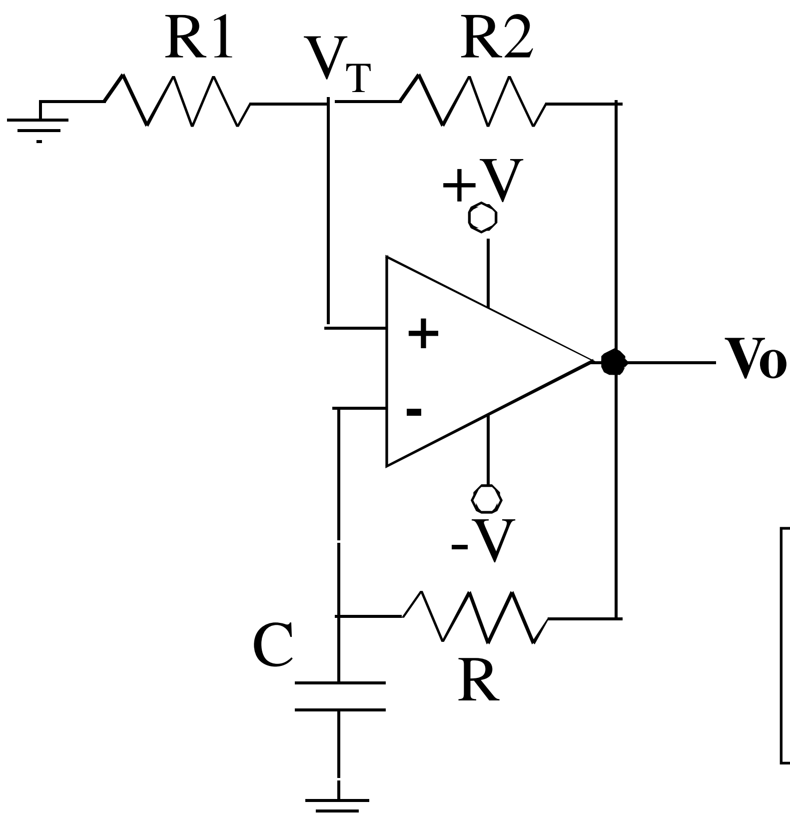


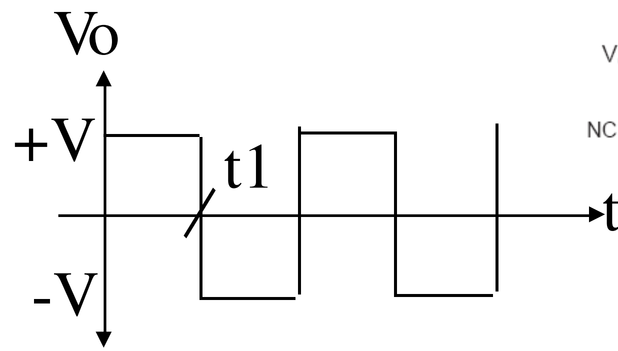


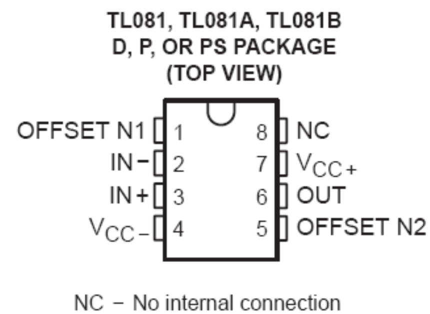
$$Vout = (-Va) + [2Va(1-e^{-t/RC})] \quad \text{for } 0<t<t1$$

If R=1MEG and C=10pF find RC=10us
so t1 might be ~20us

OSCILLATOR (MULTIVIBRATOR)



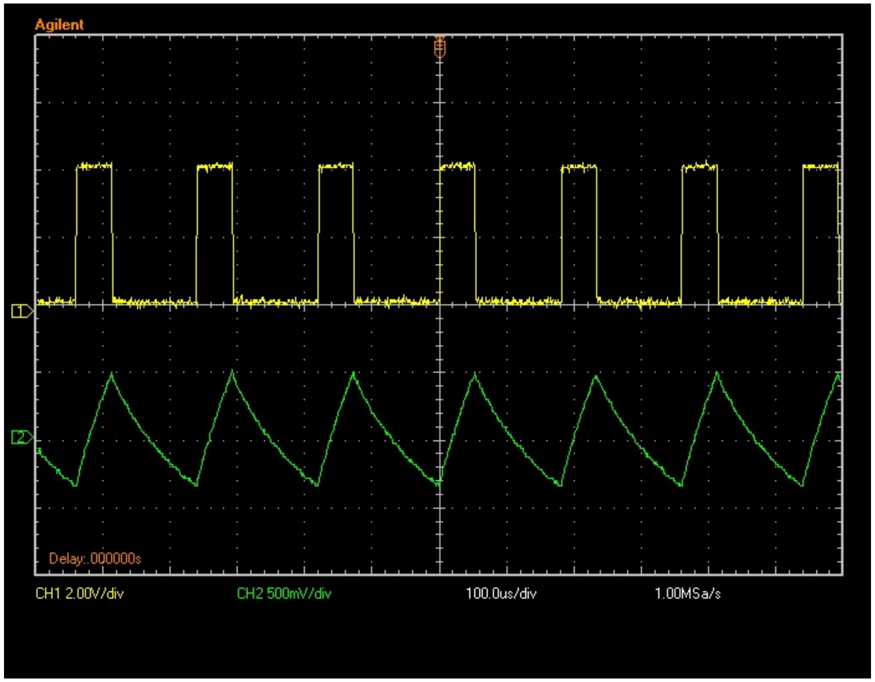




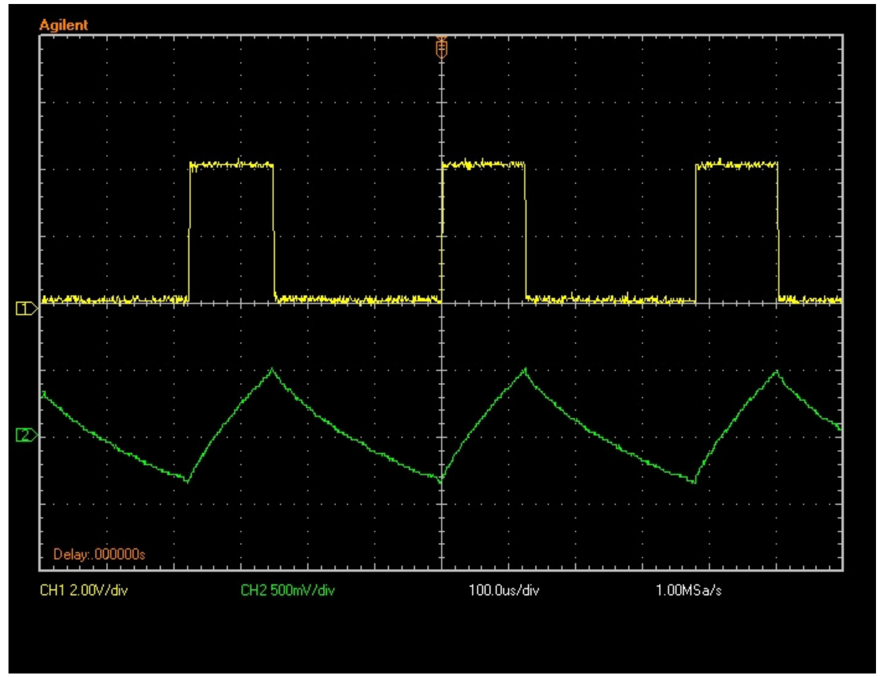
$$\text{Period} = T = 2RC \ln \left(\frac{1+Vt/V}{1-Vt/V} \right)$$

Bistable Circuit with Hysteresis and RC Integrator

OSCILLATOR OUTPUT

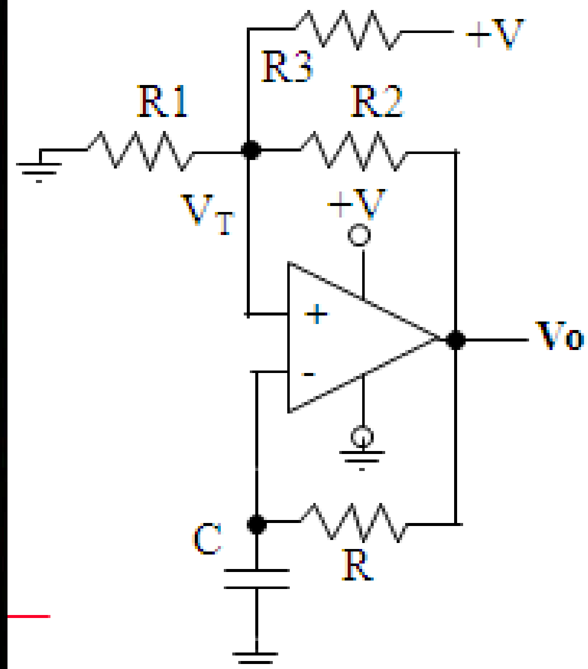


1.2 Mohm No Force Applied C ~50pf



1.2 Mohm with Force Applied C~100pf

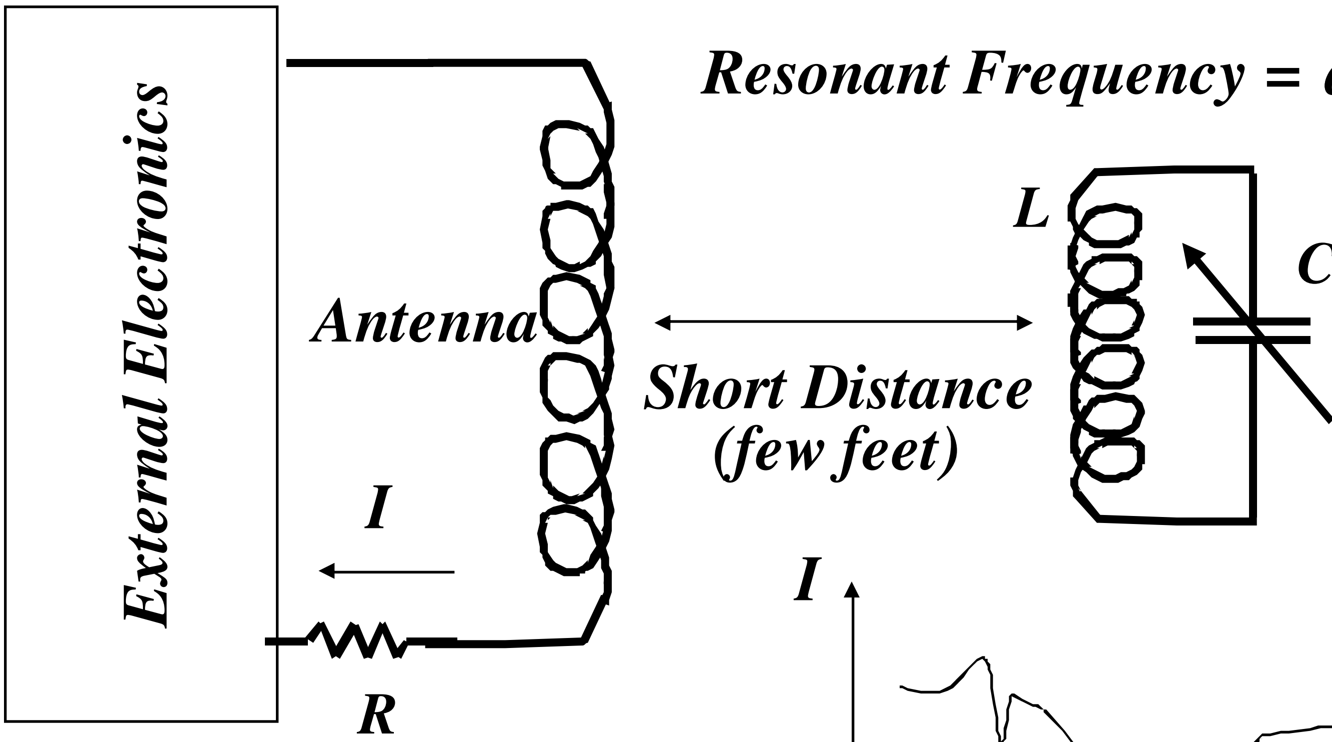
CAPACITIVE SENSOR AND RC OSCILLATOR

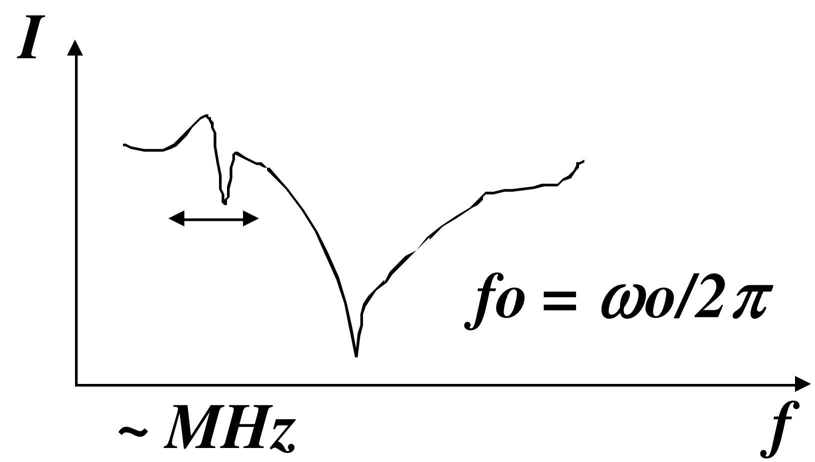


RC Oscillator movie

BASIC IDEA

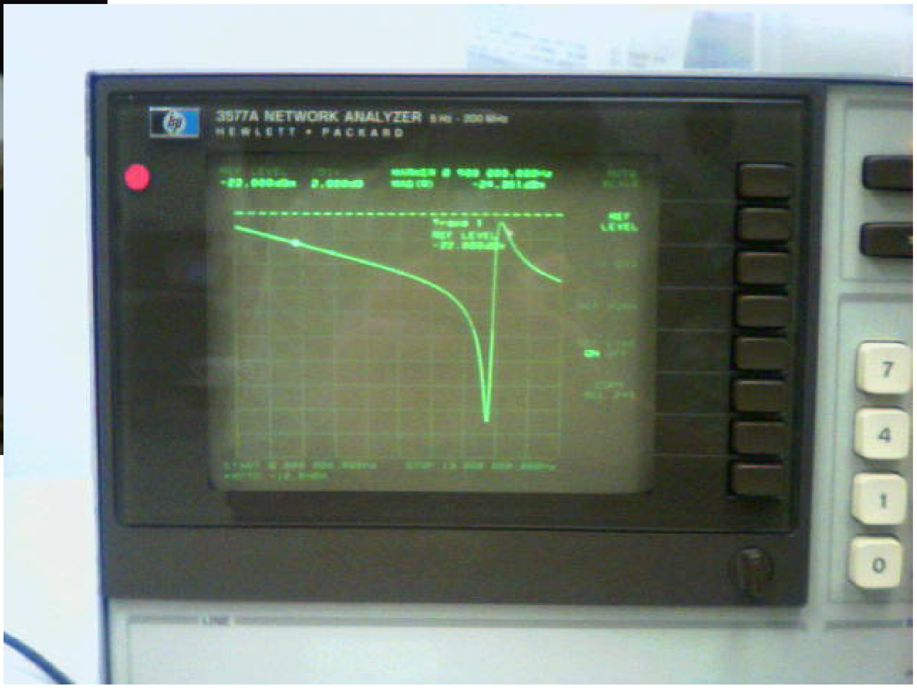
Resonant Frequency = $\omega o = 1/(LC)^{0.5}$





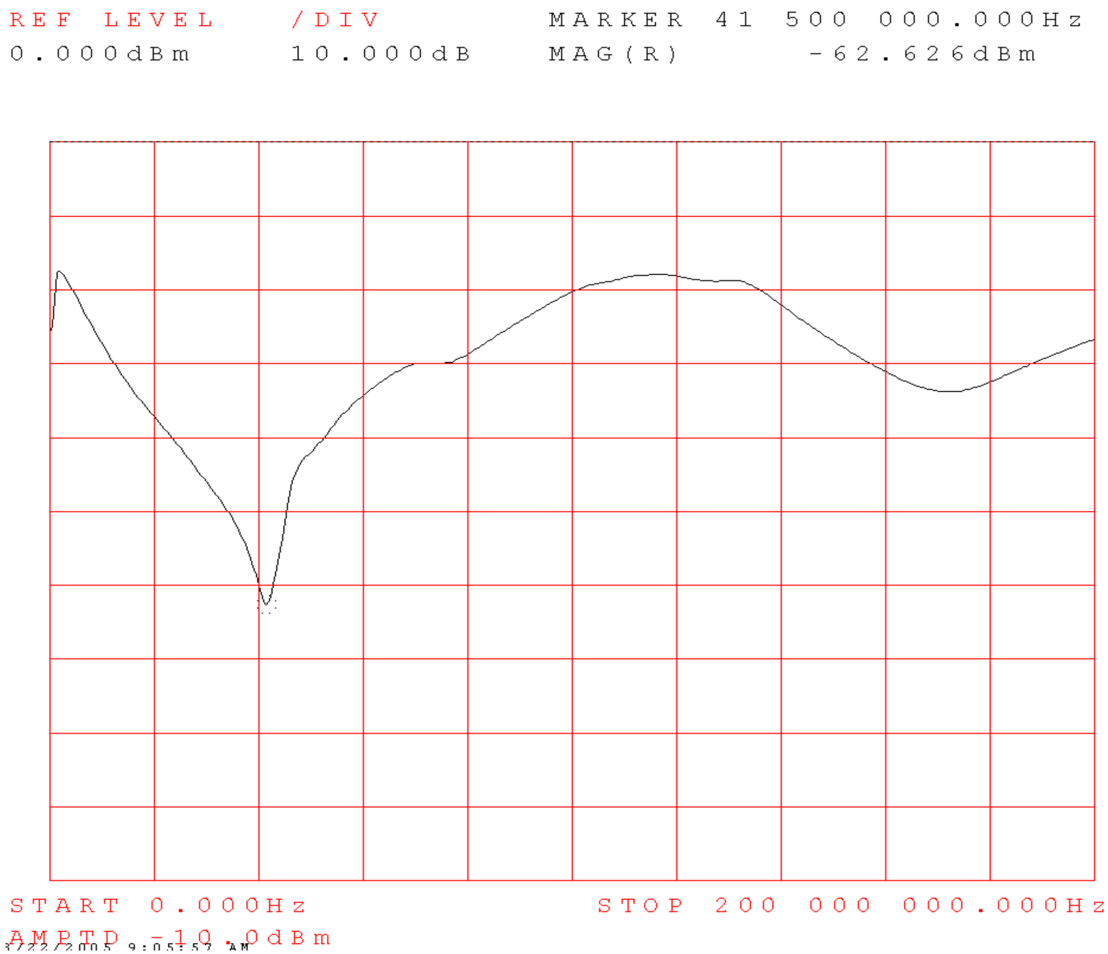
INVESTIGATE RESONANT LC CIRCUIT

Network Analyzer

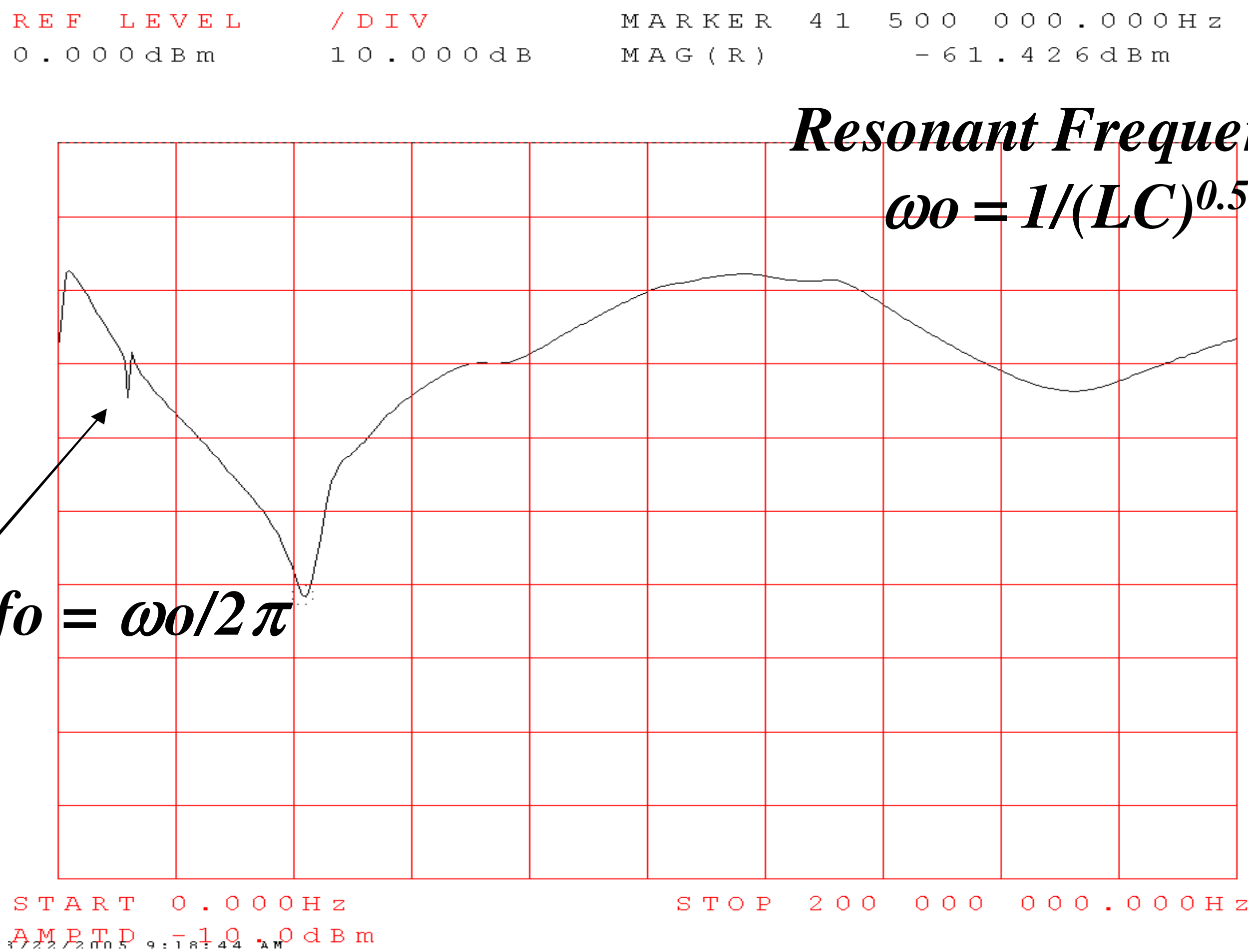


I vs. Frequency

PICKUP COIL CURRENT WITHOUT RESONANT CIRCUIT



PICKUP COIL CURRENT WITH RESONANT CIRCUIT



Resonant Frequency

$$\omega o = 1/(LC)^{0.5}$$

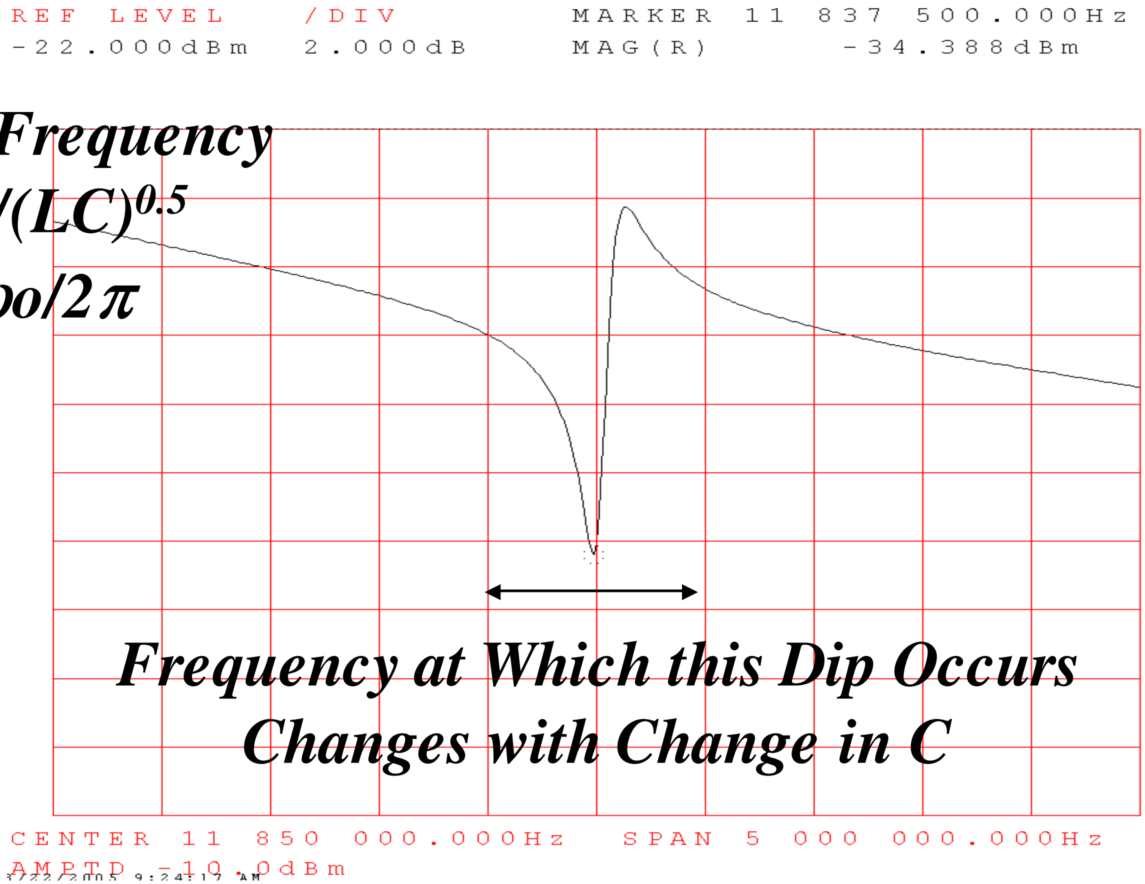
Due to, $fo = \omega o/2\pi$

ZOOM IN ON RESONANCE DUE TO LC

Resonant Frequency

$$\omega o = 1/(LC)^{0.5}$$

$$fo = \omega o/2\pi$$

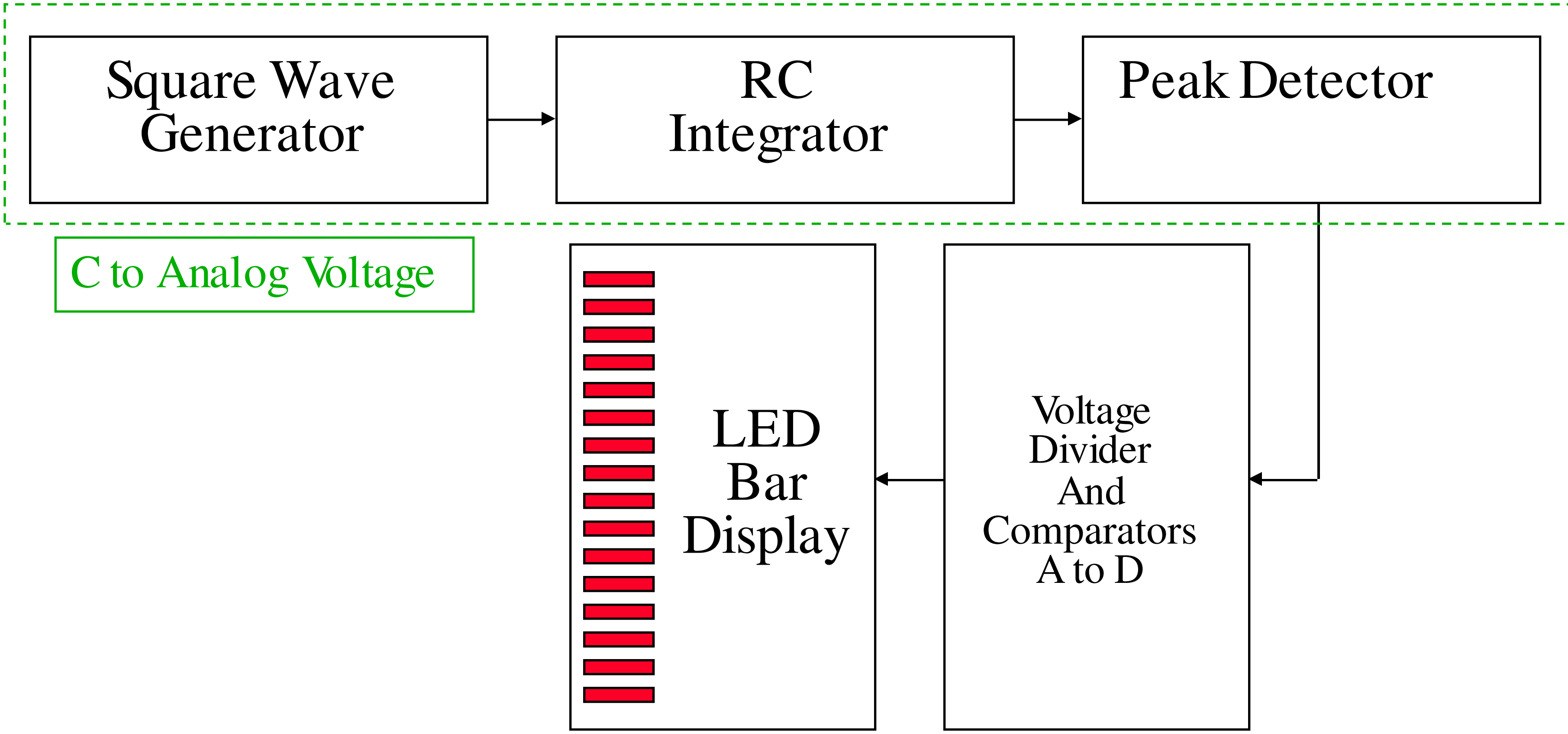


Frequency at Which this Dip Occurs Changes with Change in C

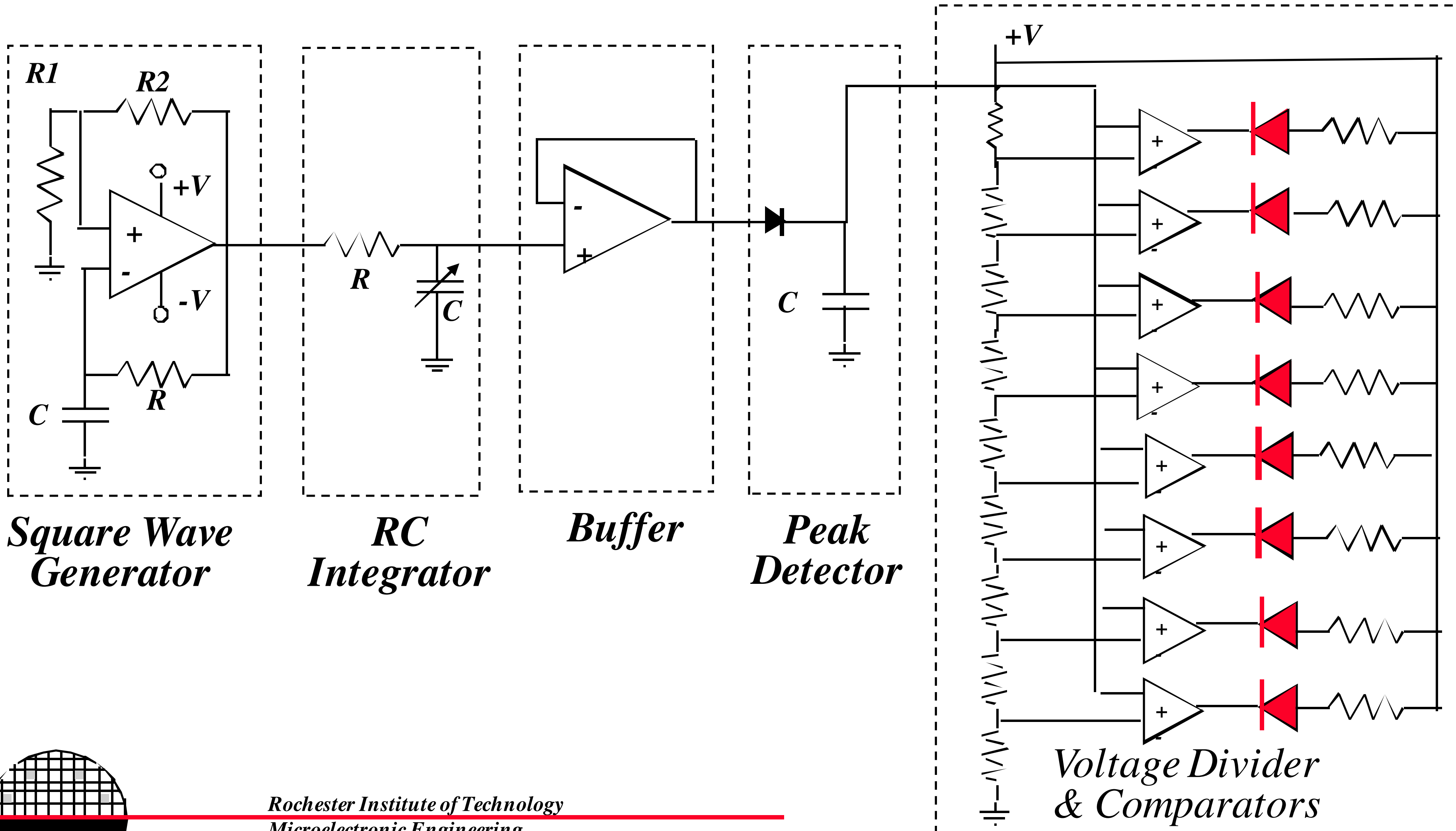
RESONANT LC SENSOR FOR TEMPERATURE

BATMON
movie

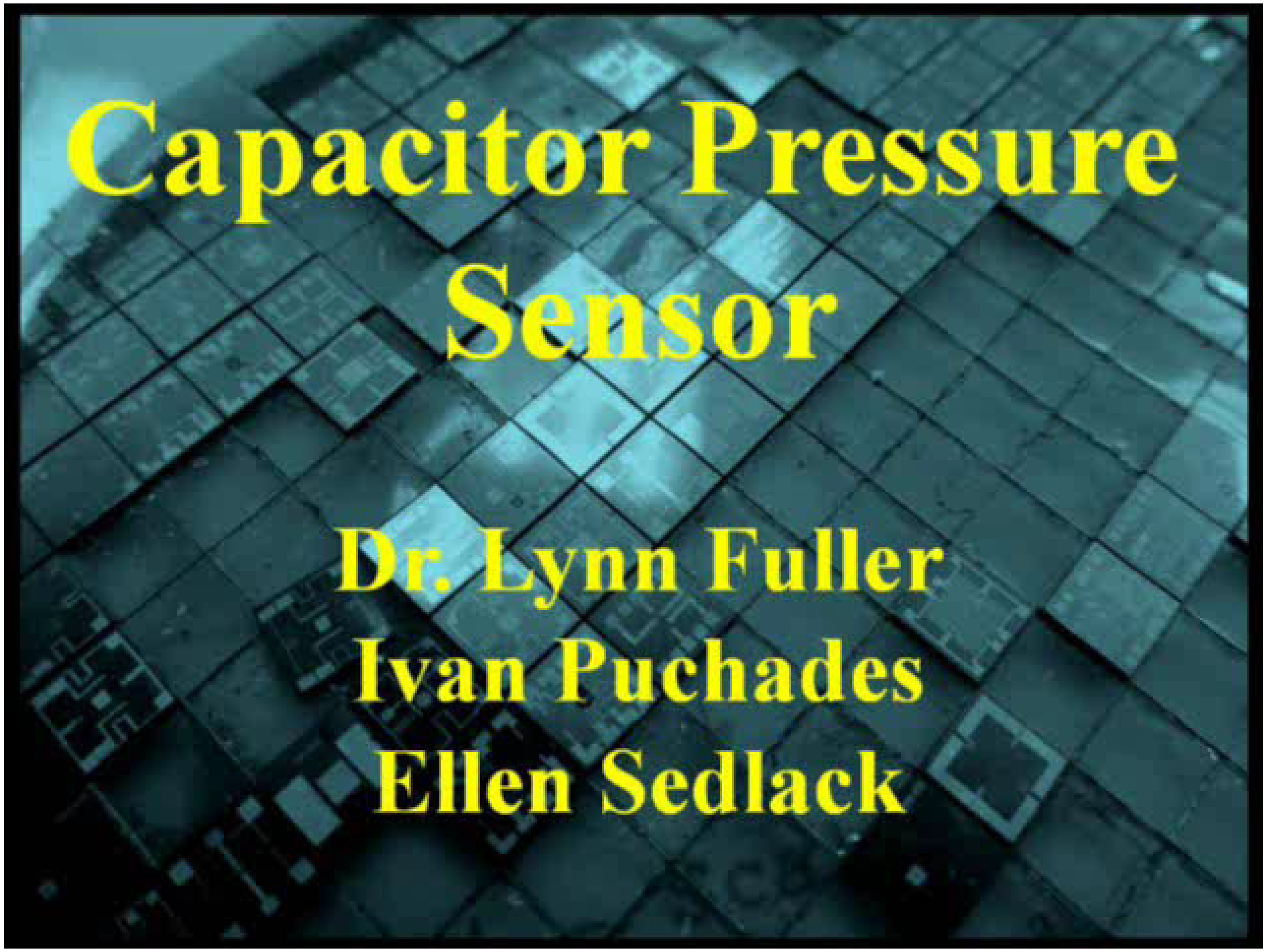
CAPACITANCE TO ANALOG VOLTAGE TO DIGITAL



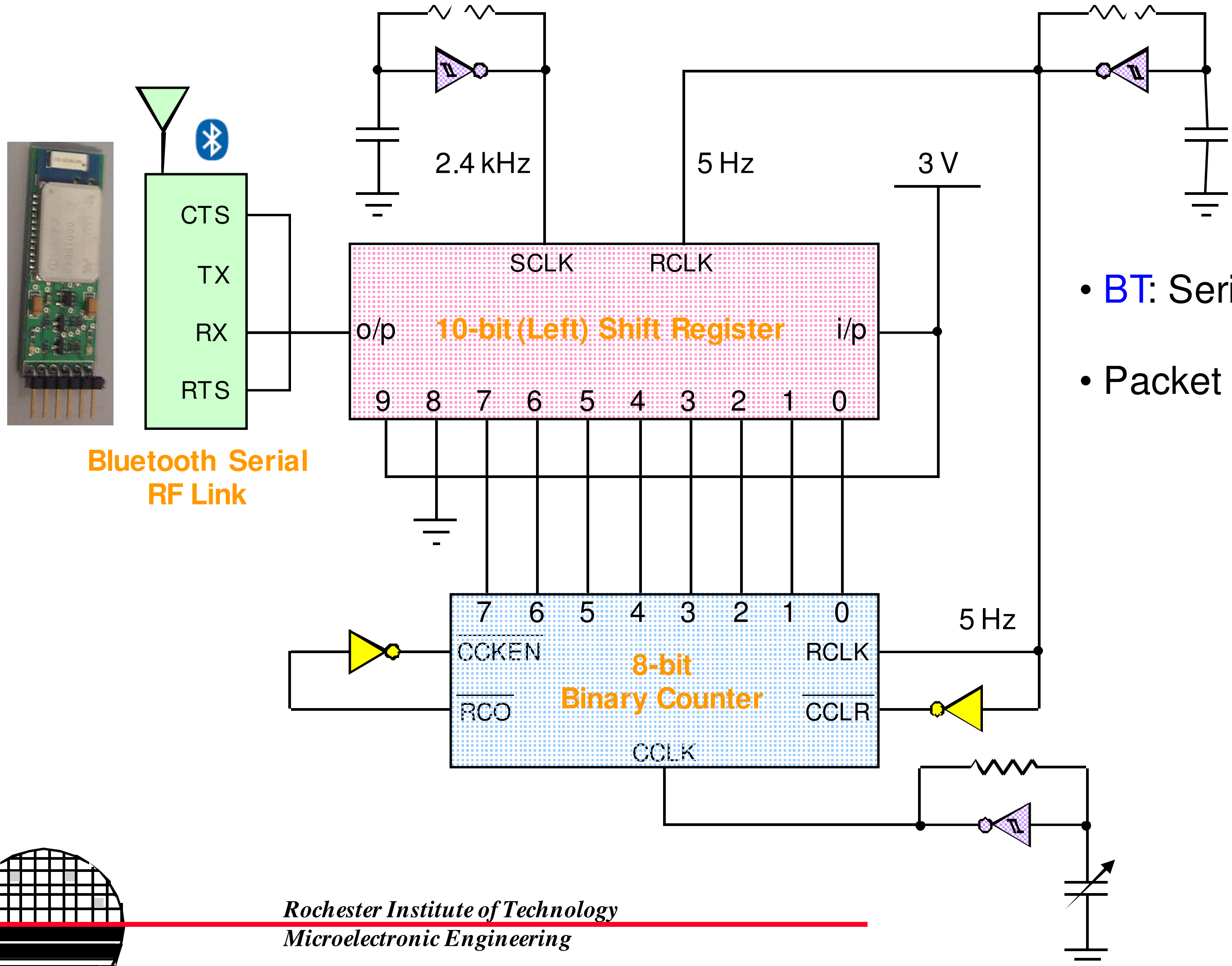
CAPACITOR SENSOR ELECTRONICS



CAPACITANCE SENSOR AND SIGNAL CONDITIONING



BLUETOOTH WIRELESS CAPACITOR SENSOR



- BT: Serial Port Profile (RS232)
- Packet Specification :

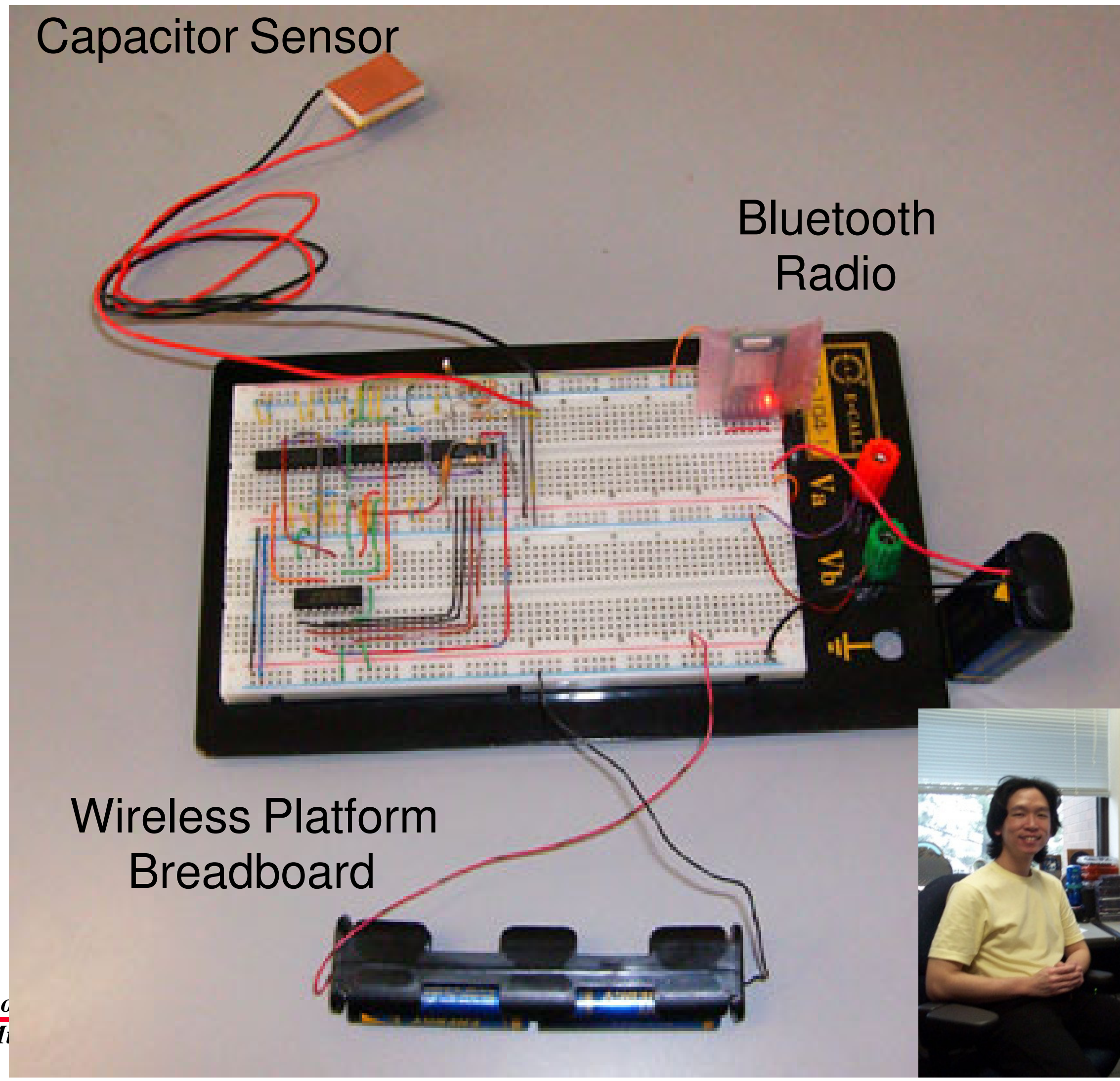
  Baud rate: 2400

  Data bits: 8

  Parity: None

  Stop bits: 1

BLUETOOTH WIRELESS CAPACITOR SENSOR



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2. Electromagnetics, by John D Kraus, Keith R. Carver, McGraw-Hill Book Co.1981, ISBN 0-07-035396-4
3. Fundamentals of Microfabrication, M. Madou, CRC Press, New York, 1997
4. Mechanics of Materials, by Ferdinand P. Beer, E. Russell Johnston, Jr., McGraw-Hill Book Co.1981, ISBN 0-07-004284-5
5. Switched Capacitor Circuits, Phillip E. Allen and Edgar Sanchez-Sinencio, Van Nostrand Reinhold Publishers, 1984.

HOMEWORK - CAPACITOR SENSOR LAB

1. Calculate the capacitance of the two parallel plate sensors with foam between the plates.
2. Calculate the change in capacitance for a capacitive analog oil level sensor.
3. Calculate the capacitance for a silicon diode at 25, 50, 75, and 100°C.

INSTRUCTORS NOTES: CAPACITOR SENSORS

1. Calculate the capacitance of a parallel plate capacitor.
2. Measure it.
3. Move the plate spacing, measure it.
4. Measure height of water.
5. Build RC Oscillator for measuring C.
6. Other ways to measure Capacitance
    - 6.1 Resonant Frequency
    - 6.2 Peak Detector
    - 6.3 Blue Tooth Wireless