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MASTERs 2007

11076 TCH

“The Magic Touch” – Capacitive Touch Sensors

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Class Objective

When you finish this class you will:

- Explain the environmental factors affecting capacitance
- Demonstrate a capacitive touch sensor interface
- Write software that can differentiate a touch from environmental factors

Agenda

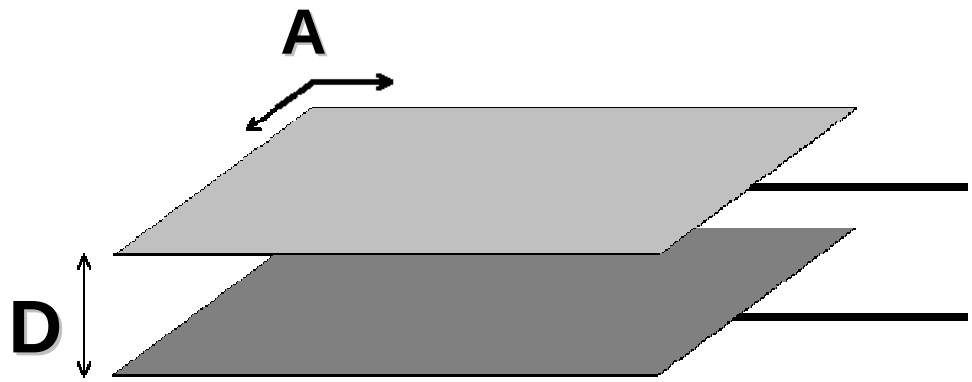
- **Basics of Capacitance**
- **Measuring capacitance**
- **Detecting a touch**
  - Basic system
  - Multi-Button systems
  - Advanced topics

Capacitance Basics

Capacitance

Any two conductors form a capacitor

$$C = \frac{\varepsilon_0 \varepsilon_r A}{D}$$



C	Capacitance (Farads)
ε_o	Permitivity of free space (8.854 pico-Farad/meter)
ε_r	Relative permitivity of dielectric material (unit-less)
A	Area of plate (meters)
D	Distance between plates (meters)

Factors Driving Capacitance

- **Size of sensor Pad**
- **Amount of Finger covering sensor**
- **Material covering the sensor**
- **Thickness of Material covering Sensor**
  - Protective coverings
- **Materials on fingers**
  - Gloves
  - Paint

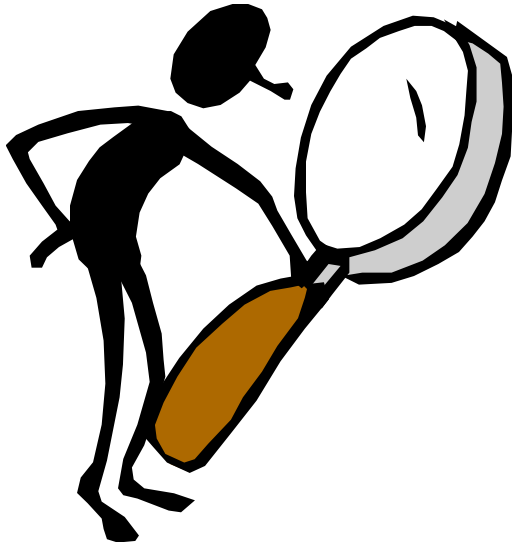
Touch Button Control

- **Hand effects in radios**
  - Holding the knob affected tuning
  - Armatures of tuning capacitors were grounded to stop effect
- **The Theremin or Thereminvox was the first fully electronic musical instrument**
- **Touch Lamps**

Measuring Capacitance

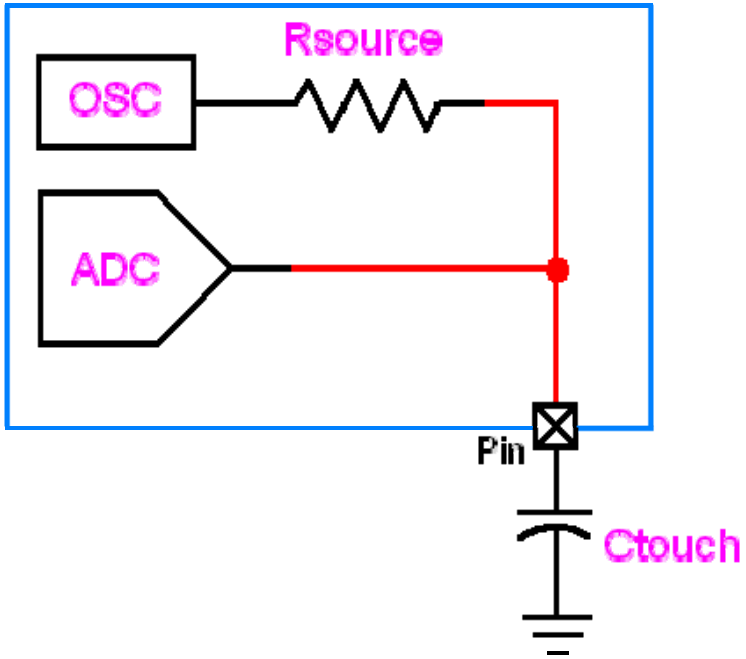
Capacitance Measurement

- **Measurement Challenges**
  - Typical sensor capacitance between 8 and 100pF
  - Typical shift due to touch 0.5% - 10%
  - Possible environmental shifts of 1% - 15%



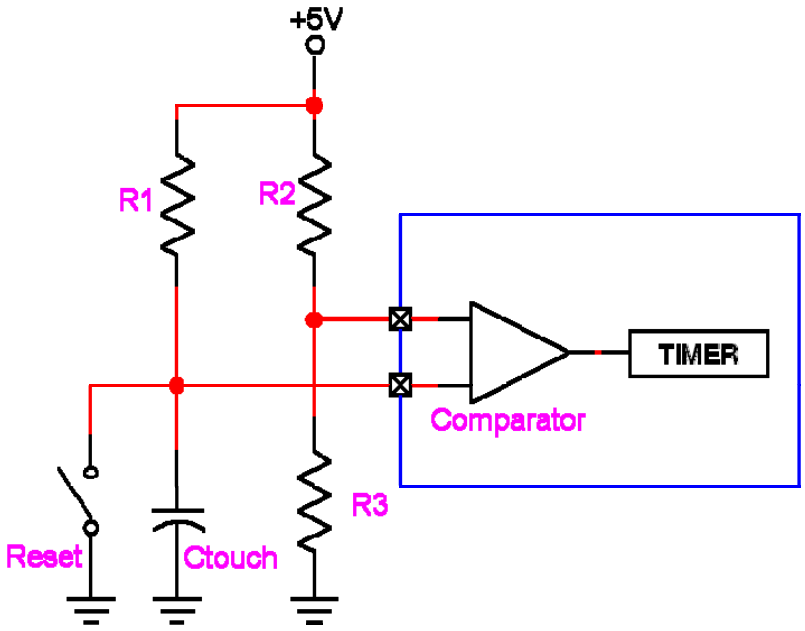
Impedance Method

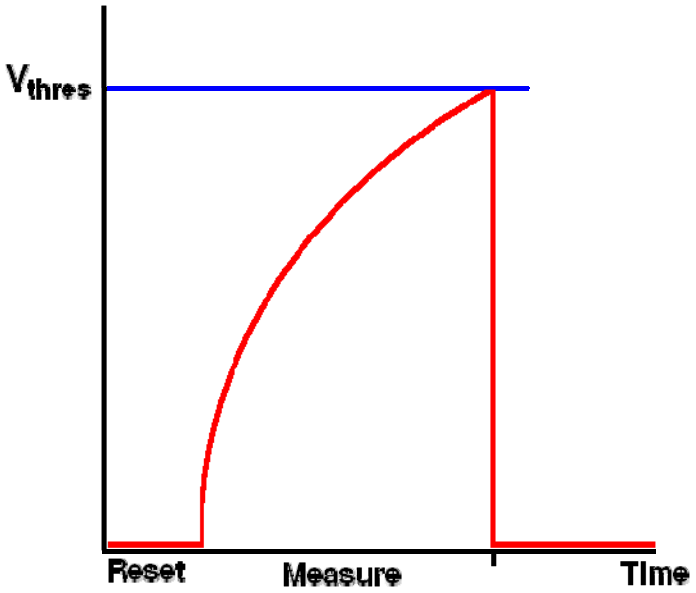
- **Touch increases capacitance resulting in greater attenuation of oscillator signal**



Time Measurement

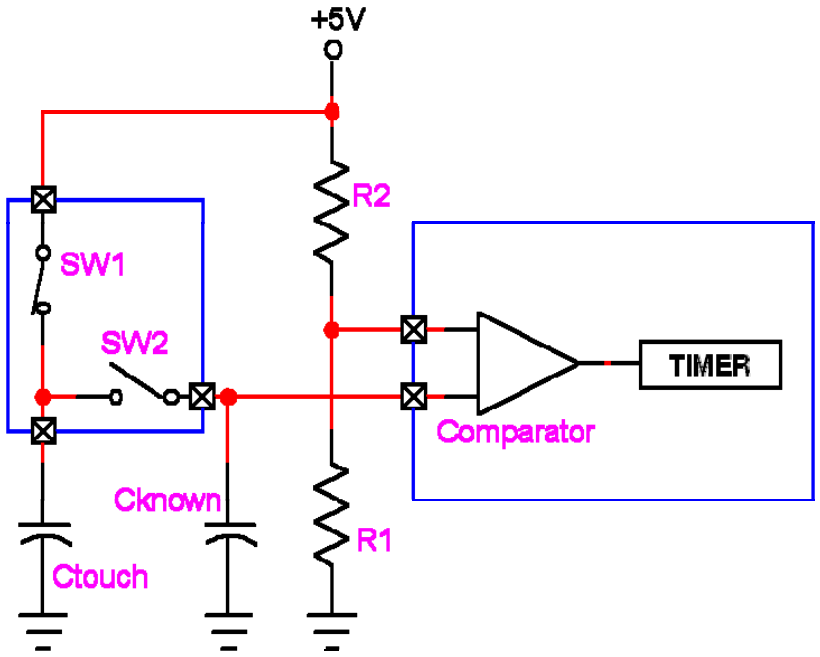
- Capacitor is charge from a fixed resistor until a threshold voltage is reached
- Small Capacitance and current, limit time of charge and resolution

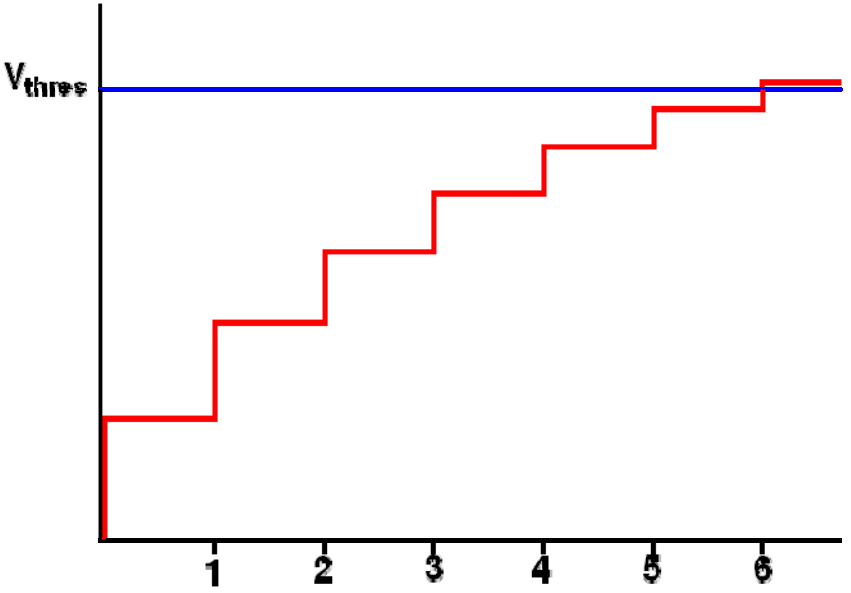




Charge Balancing

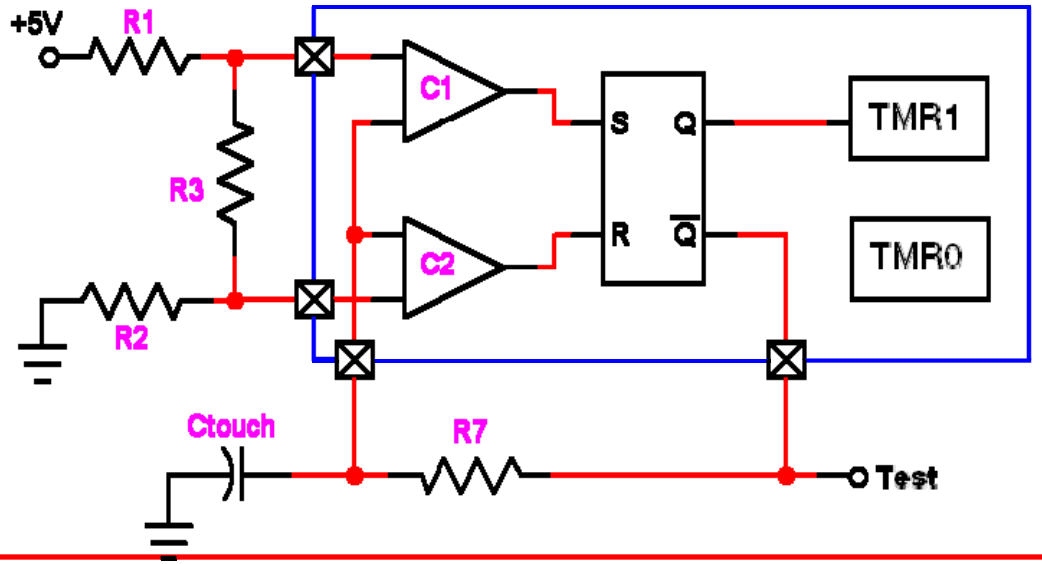
- Unknown (touch) capacitor is charge to known voltage
- Switched in parallel to know capacitor
- Count number of unknowns to charge known capacitor

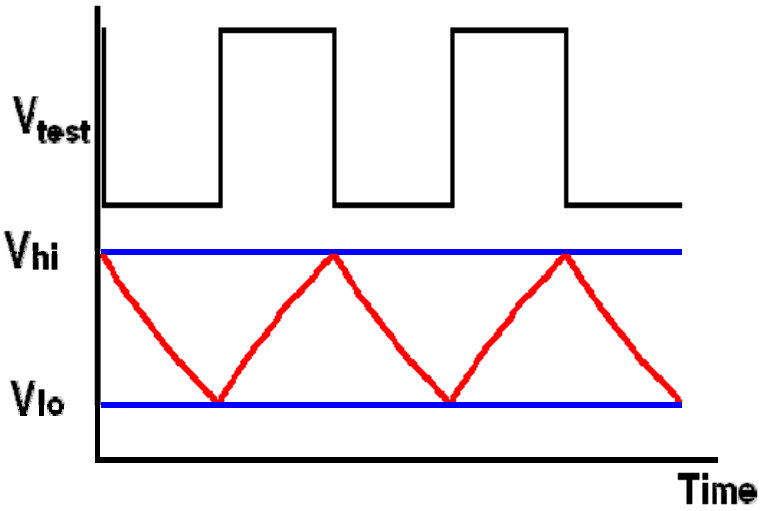




Frequency Measurement

- Touch sensor is the C in an RC oscillator
- Counters form frequency counter
- Longer period increases resolution
- Method tends to average noise





Frequency Method and Tool Demo

Microcontrollers with the SR latch mode

- **The SR latch mode of the comparators is relatively new**
  - PIC16F616, PIC16HV616
  - PIC16F690 family
  - PIC16F88X family
  - New! PIC16F72X with expanded sensor inputs and T1G enhancement

The dielectric constant of materials

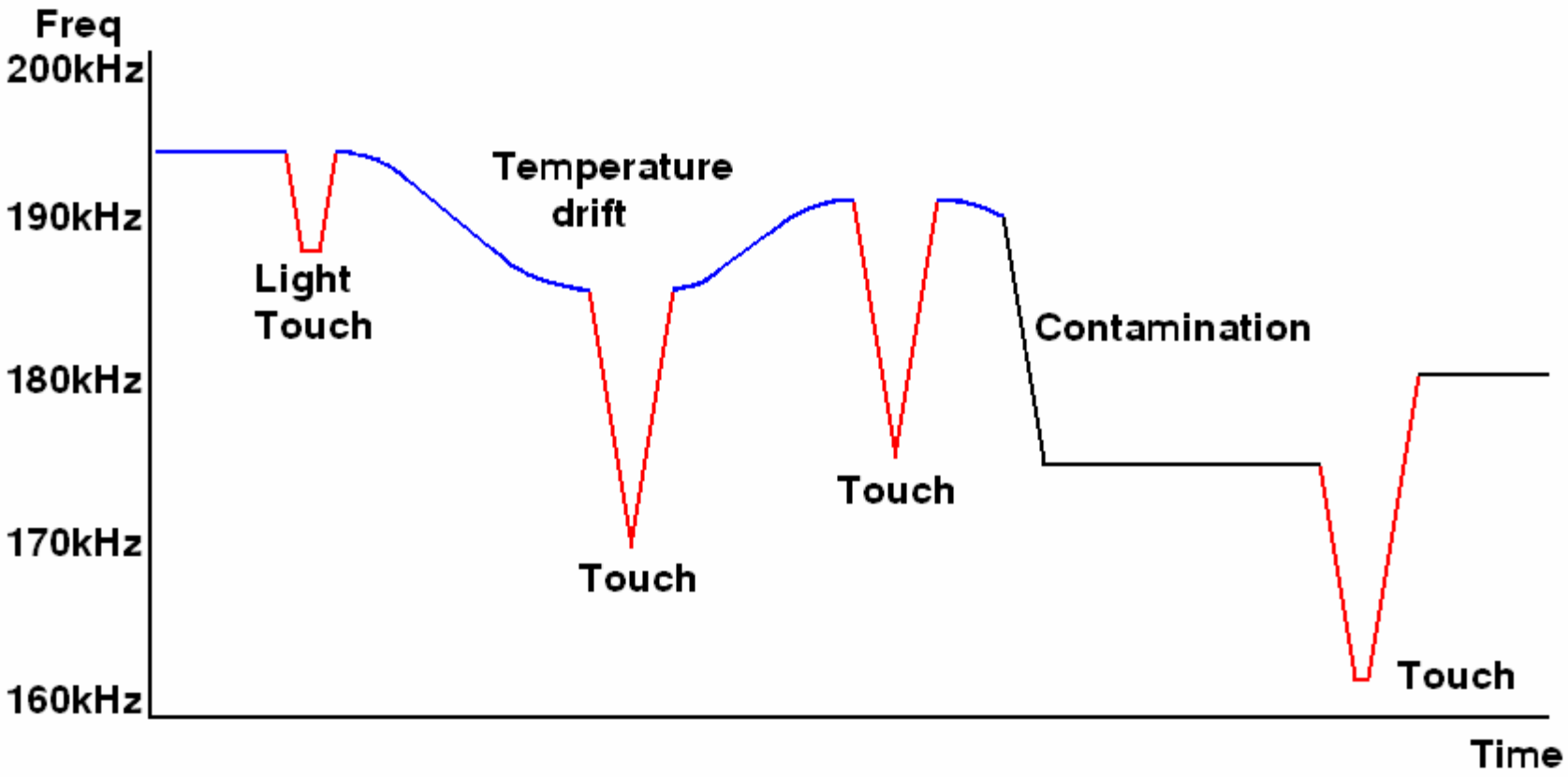
- **Glass:**
  - Iron-sealing glass 8.38 to 8.30
  - Soda-borosilicate 4.97 to 4.84
  - Fused quarts 3.78
- **Plastic**
  - Acitate 3.48 to 3.30
  - Epoxy resin 3.67 to 3.52
  - Polycarbonate 3.02 to 2.96
  - Polyethylene 2.26
- **FiberGlass**
  - FR-4 4.20 to 4.70
- **Other**
  - Liquid water 78.20
  - Ketchup / Mustard 24.0
  - Ice 4.15
  - Snow 1.55

Differentiating a Touch

Touch versus environment

- Heat, Humidity, adjacent metal, and environmental shift 5% - 25%
- Touch, with good sensors .8% - 20%
- The difference is the rate of change!
- What we need is a reference level

Touch versus environment



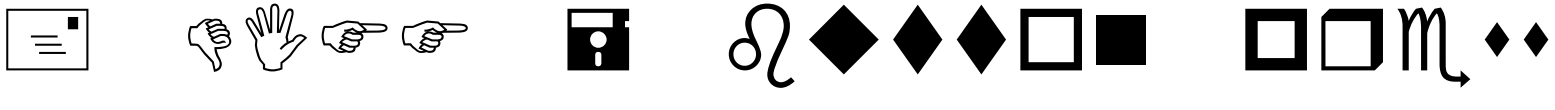
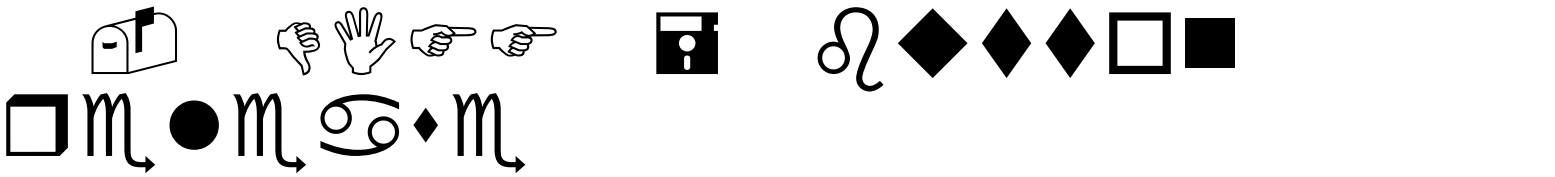
Sources of Stray Capacitance

- **Adjacent pins**
- **Adjacent traces**
- **Metal cabinet**
- **Tables / chairs**
- **Hemoglobin**
  - Hands, Fingers, other body parts

Reference Methods

- **Periodic Calibration**
  - Every 3-20 seconds grab a new average
- **Gated Average**
  - If value is outside of guard band don't include in average
- **Slow Average**
  - Include every 8^{th} -10^{th} sample in continuous running average

Two-Byte, 16 cell average

- Typical average requires storage of last 16, two byte values
- RC filter style average requires just two bytes.
  - 
  - 

```
DIFF = AVG – (LAST * 16)
DIFF = DIFF / 16
AVG  = AVG + DIFF
```

Gated Average

- **Gate value defines window of values included in average**
  - Fast change in environment can push new average outside window
- **Threshold, referenced to average, determines minimum shift for touch**
  - Lower thresholds have greater sensitive
  - Low threshold can cause phantom touch when other sensors are touched

Slow Average

- **Requires samples for average to be periodic**
  - May miss quick changes resulting in slower tracking of environment
- **Requires Set/Reset type of debounce**
  - Threshold operates on either side of average for press and release
  - Requires an intelligent debounce routine to handle touch and release as a press

Gated and Slow Average Demos

Multi-Button Touch

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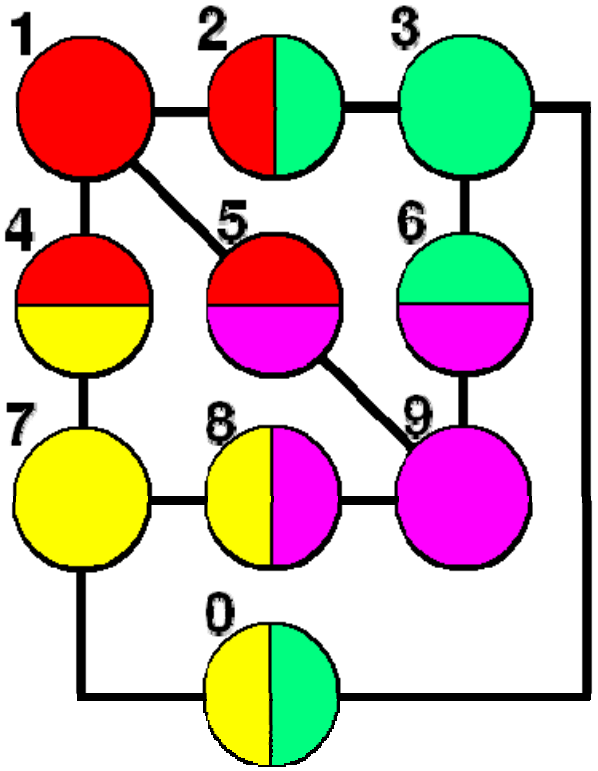
More than 4 buttons

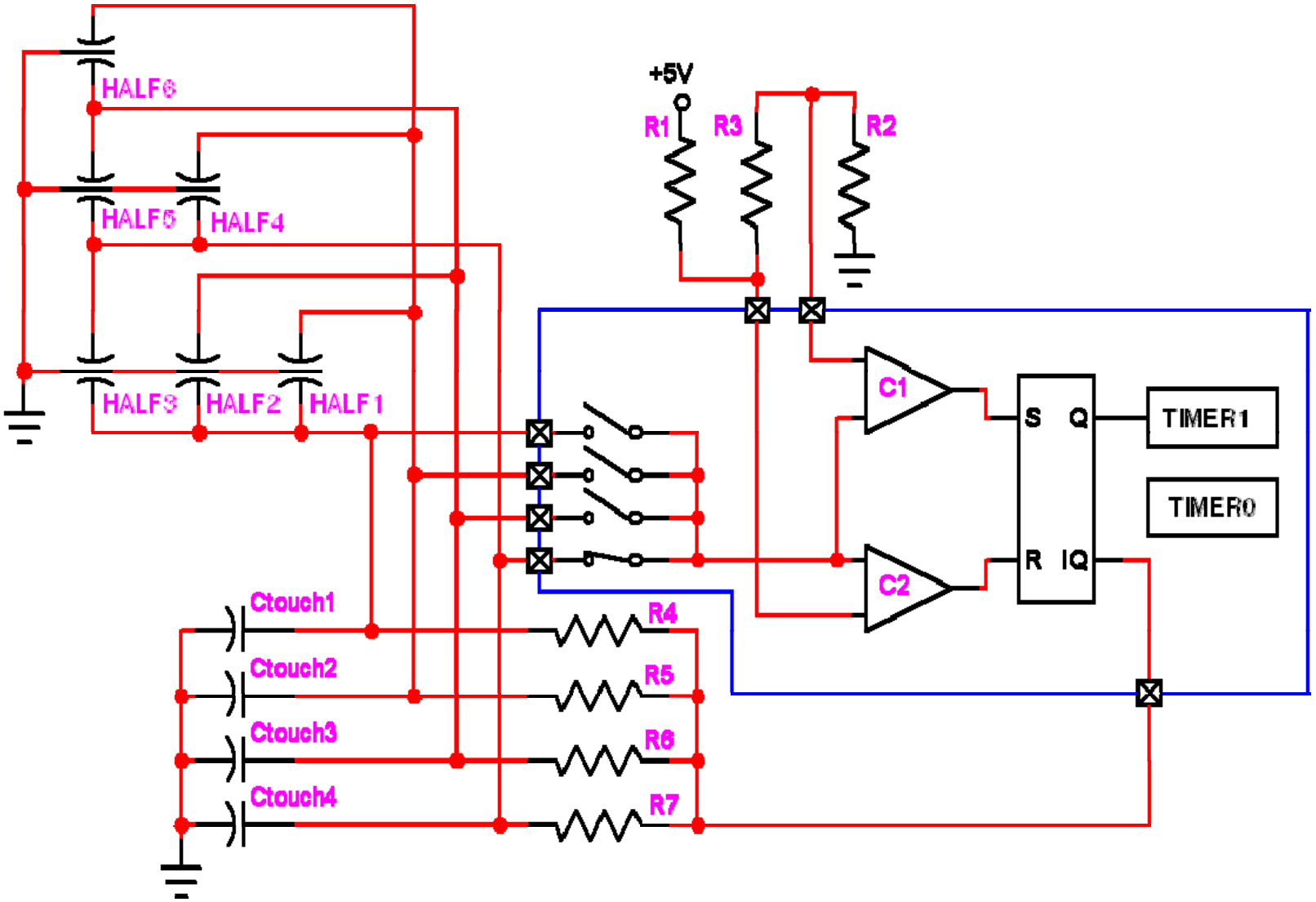
- **Comparators have 4:1 analog mux**
- **Expansion through "paired press" method**
  - Complicated decoding of buttons
  - Only requires 4 average values for 10 buttons
- **Expansion through external multiplexer**
  - Requires additional hardware
  - Requires an additional average value for each button
- **Hybrid of both solutions**

“Paired press” Method

- **Expands 4 buttons to 10**
- **1, 3, 7, & 9 are whole buttons**
- **2, 4, 5, 6, 8, & 0 are paired press buttons**
  - Paired press only produces ½ the capacitance shift
  - Requires scan of all buttons for a valid decode
  - Can not differentiate two buttons pressed from a paired press



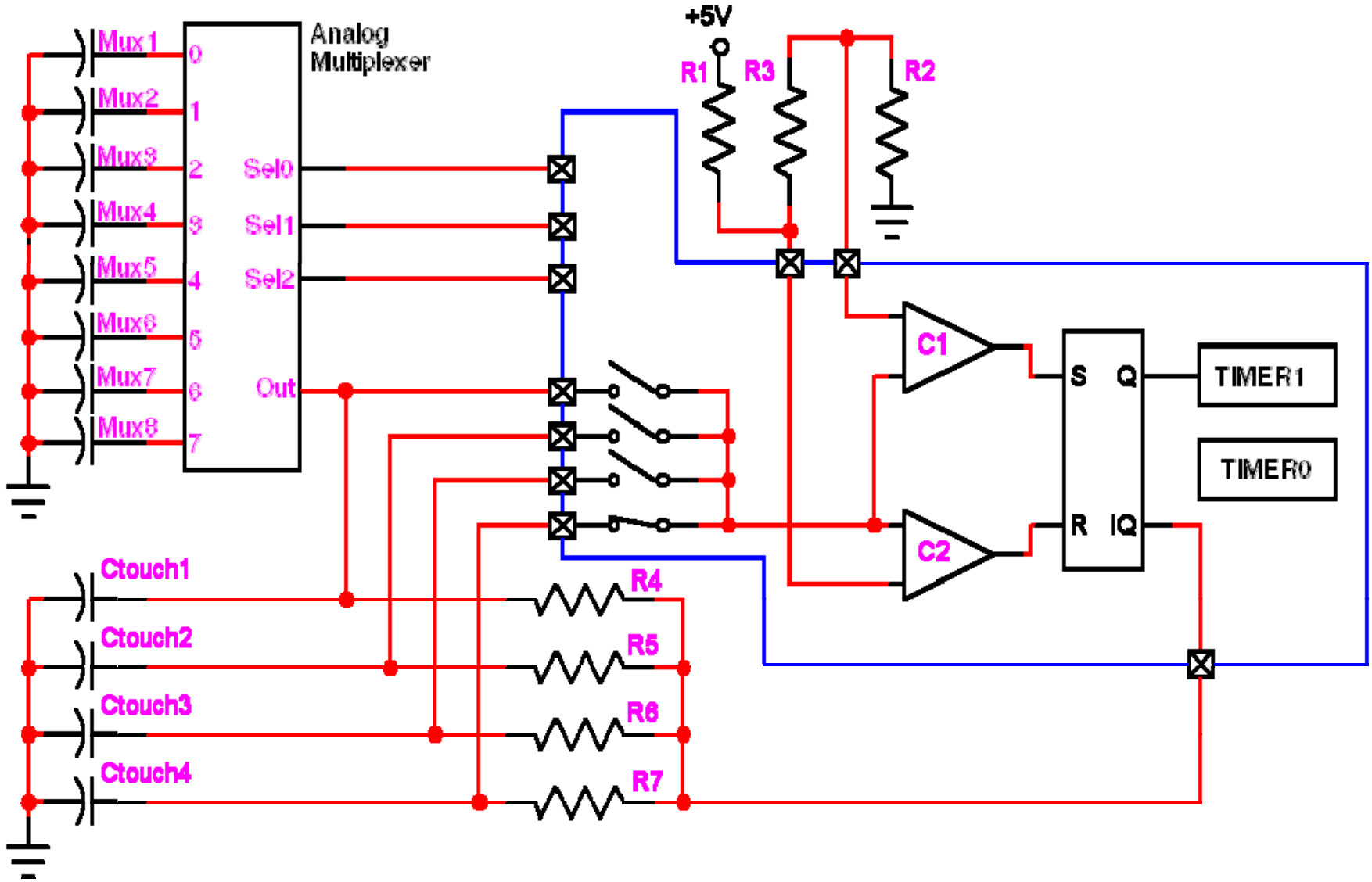
Paired Press Schematic



Multiplexer

- **Requires I/O to drive select lines**
- **Requires average value for each button**
  - Is not limited to single button press

Multiplexer Schematic



Multi-Touch Demo

Advanced Topics

Prior Press

- **Button pressed at code start**
  - Gated average requires logic to recognize positive frequency shift at release and resets average
  - Slow Average ignores a release without a press

Water Hazard

- **Water couples touch to all wet buttons**
  - Use surface that “beads” the water
  - Isolate buttons with ground plane
  - To differentiate correct touch
    - **First determine percentage of touch**
    - **Compare with all buttons**
    - **Most touched button is primary touch**

Condiment Conundrum

- **Catsup & Mustard will hold an offset in the average**
  - If slow average, ignore and average will drift to new value
  - If gated average, add logic to detect shift on shift, or add a timeout for press that resets the average
  - Valid press must have press and release

Metal Tops and Holding Hands

- **Environment shifts all buttons together**
  - Determine degree of touch
  - If multiple buttons pressed equally
    - **Gated Average**

      Reset average to new level
    - **Slow Average**

      Ignore press

Touch Demo

Summary

- Capacitance is formed by any two conductors separated by a dielectric
- Capacitive sensor are affected by touch, and their environment
- Measuring capacitance is a hardware / legal challenge
- Determining a touch is primarily a software challenge

References

- AN-1101 Intro to Capacitive Touch
- AN-1102 Touch Sensor Layout
- AN-1103 Touch Sensor Software
- AN-1104 Implementing Multibutton
- DemoBoards (TBA)

Demo Board / Software used in Class

- Basic Four Button Demo board
- Paired Press Demo board
- Multiplexed Demo board
- Touch button GUI

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