Auto-titrating pH Meter

PETER BAKER
CAROLE CHEN
MICHAEL HERNANDEZ

FALL 2009
MECHATRONICS
PROF. KAPILA

http://www.techneusa.com/ph/3510.jpg
Outline

- Objective
- Approach
  - Mechanical design
  - Electrical components
  - Flow chart of our program
- Results
- Cost Estimate
- Conclusion
  - Failure/success
  - Suggestions
Objective

- What is pH?
  - pH = -log [H+]
  - How is this important?

- Design a cost-effective pH meter (using BS2 as our microcontroller)

- Continuously check pH of solution

- Be able to create solution of desired pH
  - based on user’s input
Approach: Mechanical Design

- Initial Design
- Final Design
Circuit : Electrical Components

- **Materials needed:**
  - 10K Potentiometer
  - TL082 Dual BiFET OP Amp
  - ADC0831 A/D converter
  - Three continuous servo motors
  - pH probe sensor
  - 9V snap connectors
  - Various resistors
  - Various jump wires
  - 3 Normally Open Push-button switches
Electrical Basis of Project

- Measuring small voltages = .060 V per pH unit change
- Our pH range: pH 1 - pH 7
- Neutral pH 7: 0.0 V

As we move down pH: pH 7 → pH 6, increase in voltage by 0.060 V

e.g. At pH 4, 3 units from neutral pH

\[0.060 \text{ V/pH unit} \times 3 \text{ pH units from neutral pH} = 0.180 \text{ V or 180 mV reading}\]
pH Probe

pH probe model number 03847K : $ 60

High source impedance : glass membrane

Voltages cannot simply be measured with a DMM

In addition, voltages are very low (0-0.360V)

How to interface with BS2?
Operational Amplifier

Originally used an LM358 op-amp included in the BS2 kit

However, all op-amps are not ideal:

   Golden Law of op-amp circuitry: input current into terminals should be zero. In reality, this is not the case

Small current converted into small voltage and also gets amplified!!

Results in output error in calculations

LM358 op-amp did not work with our setup
TL082

- High input impedance, available at local RadioShack: $2
- Powered using 2 9V batteries: $10
- Results using TL082: Priceless
Non-Inverting Amplifier Circuit

\[ V_{out} = V_{in} \left(1 + \frac{R_f}{R_i}\right) \]

Gain : Amplification Factor
\[ \left(1 + \frac{R_f}{R_i}\right) \]

\[ R_f = 10 \, k\Omega \]
\[ R_i = 1 \, k\Omega \]

Gain = 11

Amplified Signal
\[ 0.035 \, V - 4.03 \]
Digitization

Vin (+) : input analog signal from pH probe needed to be digitized

Vin (-) : offset, 0V

Vref : Set to 4V

Span = 4.03 V - 0.035 V = about 4.0 V

Quantization : (4.03 V - 0.035)/256 = ~ 16 mV per step

After amplification each pH unit 60 * 11 = 660 mv per pH unit ~ 42 steps per unit pH change
Circuit Diagram

- **pH probe Input Signal** connected to TLO82
- Output Signal: 0.035 V - 4.03 V
- \( R_f = 10 \, \text{k}\Omega \)
- \( R_i = 1 \, \text{k}\Omega \)

ADC0831 with connections:
- Pin 1: \( /CS \)
- Pin 2: \( V_{in}(+) \)
- Pin 3: \( \text{Offset V} \)
- Pin 4: \( GND \)
- Pin 5: \( V_{in}(-) \)
- Pin 7: \( \text{Clk} \)
- Pin 8: \( \text{Do} \)
Program Flow Chart:

(1) Continuously measure pH
(2) Auto-titrate sample solution to a specific pH value

Display Main Menu:

(1) Continuously monitor pH status of solution; valid only for pH between 4.0 to 7.0 (E.g. useful for monitoring pH of solutions that undergo chemical reactions)

Once complete, use reset button to redirect back to main menu

(2) Get desired pH value from user, (must be between the range of pH 4.0 to 7.0)

Check if pH entered is in range

Yes

Check if pH of sample solution is greater or lower than user’s desired value

Greater

Add acid to solution

Lower

Add base to solution

Loop until desired pH is obtained, by adding base and/or acid (if system overshoots)

No
## Cost Estimate

<table>
<thead>
<tr>
<th>Materials</th>
<th>Estimated Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>10K Potentiometer</td>
<td>*</td>
</tr>
<tr>
<td>ADC0831 A/D convertor</td>
<td>*</td>
</tr>
<tr>
<td>Three continuous servo motors</td>
<td>*</td>
</tr>
<tr>
<td>Various resistors</td>
<td>*</td>
</tr>
<tr>
<td>Various jump wires</td>
<td>*</td>
</tr>
<tr>
<td>3 Normally Open Push-button switches</td>
<td>*</td>
</tr>
<tr>
<td>BS2 kit</td>
<td>$200.00</td>
</tr>
<tr>
<td>TL082 Dual BiFET OP Amp x 3</td>
<td>$6.00</td>
</tr>
<tr>
<td>pH probe sensor</td>
<td>$60.00</td>
</tr>
<tr>
<td>9V snap connectors</td>
<td>$3.00</td>
</tr>
<tr>
<td>Ring clamps x 2</td>
<td>$20.00</td>
</tr>
<tr>
<td>9V Battery x 2</td>
<td>$10.00</td>
</tr>
<tr>
<td>Tools/ misc</td>
<td>$20.00</td>
</tr>
</tbody>
</table>

* = included in BS2 kit

**Total Cost**: $319.00
Problems Encountered

- **Initial design failures/flaws**
  - Leakage
  - Stability

- **BS2’s EEPROM**
  - Used maximum amount of space available
    - Not able to incorporate programming codes for keeping pH within desired range (i.e. not only go to desired pH value)

- **Fluctuations of probe readings**
  - Need to use the shortest lead possible

- **Limited pH range (i.e. 4.0 to 7.0)**
  - Pro: better resolution
  - Con: inability to detect basic pH (from 8.0 to 14.0)
## Results (to be shown in demonstration)

<table>
<thead>
<tr>
<th>Buffer</th>
<th>Salt</th>
<th>pH</th>
<th>mV Start</th>
<th>mV 3 min</th>
</tr>
</thead>
<tbody>
<tr>
<td>50 mM NaPho</td>
<td>500 mM</td>
<td>7.0</td>
<td>49 mV</td>
<td>63 mV</td>
</tr>
<tr>
<td>50 mM NaPho</td>
<td>0 mM</td>
<td>7.0</td>
<td>37 mV</td>
<td>53 mV</td>
</tr>
<tr>
<td>50 mM Tris</td>
<td>500 mM</td>
<td>7.0</td>
<td>5 mV</td>
<td>10 mV</td>
</tr>
<tr>
<td>50 mM Tris</td>
<td>0 mM</td>
<td>7.0</td>
<td>18 mV</td>
<td>55 mV</td>
</tr>
<tr>
<td>100 mM NaPho</td>
<td>500 mM</td>
<td>7.0</td>
<td>48 mV</td>
<td>47 mV</td>
</tr>
<tr>
<td>100 mM NaPho</td>
<td>0 mM</td>
<td>7.0</td>
<td>46 mV</td>
<td>43 mV</td>
</tr>
</tbody>
</table>
Thank you!
Prof. Kapila, Chandresh, Alex, & all of our classmates for your valuable advice

Now ... *drum rolls*
DEMONSTRATION TIME

*cross your fingers*