Rock On! Using Record Players and LabVIEW to Teach PID

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Agenda

- Class Background and Lab Objectives
- Overview of the Turntable Lab
- Experimental Setup
- Experimental Procedure
- Results
Background and Objectives

Class Background

- Control of Dynamic Systems a.k.a. “Controls”
  - Junior-level Mechanical Engineering Course
  - Modeling, characterizing and controlling dynamic systems
- Labs supplement class material by teaching students how to write code to acquire data, study dynamic systems (Loudspeakers, RC circuits, MagLev) and control simple tasks in LabVIEW

Turntable Lab Objectives

- Teach PID in an engaging, hands-on way with tangible output more exciting than simple motor control
- Provide an instructive, interactive (and admittedly fun) laboratory experiment
- Real life lesson of learning how to use a record player
Turntable Lab

Overview of the Lab Setup

- Modified off-the-shelf record player instrumented with encoder, custom PWM circuit and NI M-Series PCI DAQ
  - Motor disconnected from internal circuitry
- Students tune PID controller to control the speed of the record player motor
- Test controller effectiveness by playing records on controlled motor
  - Still using record player’s on-board speakers
Theoretical Block Diagram
Overview of the System

- Labview sets duty cycle value
- NI DAQ analog out duty cycle out
- PWM generation via analog devices LTC6992
- MOSFET circuit
- NI DAQ counter encoder in
- Oscilloscope
- PID controller - calculate RPM

Circuit components

Computer control

CH1 of scope

CH2
Hardware

Physical Setup

- Turntable: Victrola 3-speed turntable
  - Motor remounted to integrate encoder
- Encoder: CUI AMT102V
  - Set to 100 PPR
- Oscilloscope
- NI PCI-6221 (or equivalent)
  - 1 Counter Input, 1 Analog Output
  - Really, *any* NI device with above specs
    (such as myDAQ or USB-6009)
Hardware

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Hardware

Circuit

- **PWM Generator:**
  - Analog Devices: LTC6992
  - Duty Cycle Input (0-1 V)
  - PWM output

- **N-Channel MOSFET:**
  - PN: STP36NF06L

- **Diode:**
  - MBR1645
Software

- LabVIEW
  - Programmed in DAQmx or with DAQ Assistant
- Control and PID Toolkit
## Cost

Cost to Build Setup

<table>
<thead>
<tr>
<th>Item</th>
<th>Vendor</th>
<th>Part Name</th>
<th>Part Number</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Amazon</td>
<td>Turntable</td>
<td>Victrola 3-Speed Suitcase TT</td>
<td>$39</td>
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<tr>
<td>2</td>
<td>Mouser</td>
<td>Encoder</td>
<td>AMT102-V</td>
<td>$24</td>
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<tr>
<td>3</td>
<td>Mouser</td>
<td>PWM Generator</td>
<td>LTC6992HS6-1#TRPBF</td>
<td>$5.60</td>
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<td>4</td>
<td>Mouser</td>
<td>SOT23 Breakout</td>
<td>BOB-00717</td>
<td>$0.95</td>
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<tr>
<td>5</td>
<td>Mouser</td>
<td>MOSFET</td>
<td>STP36NF06L</td>
<td>$1.50</td>
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<tr>
<td>6</td>
<td>Mouser</td>
<td>Diode</td>
<td>MBR1645</td>
<td>$0.97</td>
</tr>
</tbody>
</table>

**TOTAL:** $72.02

Assumes user has access to electronic gear like scopes, DAQ, power supplies
Experimental Procedure

Rundown of Laboratory Session

1. Write the LabVIEW code
   1. Or have prewritten for students to run
2. Study System when Open-Loop
   1. Observe relationship between Duty Cycle and RPM
   2. View PWM signal through scope
3. Study PID characteristics when Closed-Loop
4. Tune PID Controller
5. PLAY RECORDS!!!!!

About 2 hours for students to complete (if writing code)
LabVIEW Block Diagram
Students follow procedure to build this block diagram

1. Read Encoder Data to get pulses per loop
2. Calculate loop time (SW timed is fine! High res block works best)
3. Convert encoder pulses per loop to platter RPM
3. PID Block, error calculation, output Duty Cycle value to analog output channel

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2. Convert encoders data (requests pulse per loop for high res block works best)
1. Tab Control to switch between open-loop Duty cycle control and closed-loop PID
2. Sliders for PID Gains
3. Monitor system with indicators and waveform chart
Experimental Procedure
Evaluate PID Characteristics

- Students track motor response as speed steps from 0 RPM to 40 RPM under various prescribed PID gain value conditions
  - For example, keep proportional gain constant and vary integral time
  - Or progressively adding each PID component
Experimental Procedure
Evaluate PID Characteristics

- By end of the assignments, students can generate an experimentally determined gain characteristic chart

<table>
<thead>
<tr>
<th>Response</th>
<th>$K_c$</th>
<th>$T_i (1/K_i)$</th>
<th>$T_d$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Steady-State Error (SSE)</td>
<td>Decrease</td>
<td>Decrease</td>
<td>Little to no effect</td>
</tr>
<tr>
<td>Settling Time</td>
<td>Little effect</td>
<td>Increase</td>
<td>Decrease</td>
</tr>
<tr>
<td>Overshoot</td>
<td>Increase</td>
<td>Increase</td>
<td>Decrease</td>
</tr>
</tbody>
</table>
Experimental Procedure

PID Tuning

- Using Ziegler-Nichols method and oscilloscope, students generate a set of experimental PID values
  - Set integral and derivative to zero, increase Kc until system output oscillates
  - Use scope to measure period (Pu) of analog output pre-modulation (duty cycle output)
Experimental Procedure

PID Tuning

- Enter $K_c$ and $Pu$ values into the table for calculated PID Values
  - Table adapted from any Ziegler resource, specifically: http://pages.mtu.edu/~tbc0/cm416/zn.html
- Analyze several different manual tuning theories
Results

Video of Running System
Results

I’ll let Fleetwood Mac take it from here…
Thanks y’all for listening! Interested in learning more? Contact me at ebs27@duke.edu

I’m happy to send LabVIEW files, provide additional information on how to build the setup and to answer any other questions!
Before you go, take the survey.
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