A Microcontroller based design and realization of a two degree of freedom Laser Doppler Velocimetry traverse system

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Problem Overview - What is LDV?

What is LDV?
- Offers precise measurements of fluid flows regardless of flow regime
- Laser Probe emits beams of light that intersect to form a small control volume
- Through this volume seeded particles on the order of microns pass through

$d_e$: width of incident beam, $d_z$: length of control volume, $d_x$: width of control volume, $\theta$: angle of incidence, and $\delta_f$: is the minimum grid size
Problem Overview - What is LDV?

- If on average the level of seeding is less than one particle per signal burst we speak of a burst type doppler signal.
- A typical burst type signal can be seen to the right with the DC part removed by a high pass filter.
- The flow processor or “brain” of the LDV correlates these signal bursts to velocities at discrete points.
- The picture on the bottom left shows the relationship between the frequency of the signal and the velocity of the flow.
- Doppler frequency is proportional to particle velocity.
Practical Applications of LDV in the DSL

- Flow visualization of Heavy Flags oscillating in water (see Figure 4. courtesy Shelley et al)
- Flow physics of the free locomotion of robotic swimmers as well as live fish
- Drag computations and understanding of a geometrically scaled submarine

![Experimental LDV and Heavy Flags set up](image1)

![Bio-mimetic robotic swimmer propelled by an ionic polymer metal composite (IPMC) and a passive fin](image2)

![LDV set up with custom built force balance for flow physics analysis](image3)
• The combination of robust controlled programming with mechanical and electrical components creates the synergy that is mechatronics.

• Components of mechatronics are used to solve a wide array of practical problems faced in industry and academia.

• We implement concepts inherent in mechatronics to create a precise user controlled laser based measurement system.

Diagram of the components of mechatronics (courtesy of the University of Waterloo-Department of Mechanical and Mechatronics Engineering)
Project Goals

- To design and realize a two dimensional electromechanical traverse to guide a laser probe within a water tunnel (Figure 8)
  - The traverse must have a precise resolution~1mm
  - Should have automatic and manual modes
  - Capable of self calibration
  - Expandable
Electro-Mechanical Design & Realization

- **Lead Screw Assembly**
  - The design consisted of two machined lead screws that allowed the optical probe to be translated vertically
  - The screws were selected such that they had 20 threads per inch
  - The high thread count correlated to higher precision
  - The system was programmed to make minimum steps of approximately 1mm and exactly .04 inches
  - The motors have sufficient torque to spin at 100 steps/sec which corresponds to approximately 1 mm every 1.5 seconds
• Motor driving rack and pinion
  – Motor specification:
    • High torque
    • 200 steps per revolution

• Rack and pinion
  – Smooth movement
  – 3 mm between grid points
  – Not optimal choice but readily available and more cost effective

rack, pinion and motor
Electro-Mechanical Design & Realization

- **Little Step-U**
  - Power Requirements: 4.5 to 5.5 VDC
  - Communication: Serial
  - Dimensions: 1.96 x 0.98 x 0.15 in (50 x 25)
  - Operating Temperature: +32 to +158 °F
• The Circuit System
  – 2 Little Step-U
  – BS2 microcontroller
  – BOE breadboard
  – ProtoBoard III breadboard
  – 9V battery
  – Lodestar DC Power Supply

Further work includes:
- optical encoders
- limit switches for feedback control
- printing a circuit board
• Flow chart for illustrating the logic of the program's main routine
• All Programming was done using PBASIC and implemented on the BS2
Software Design & Realization

Display Menu

Clear screen

Display Menu Options:
1. Change mode
2. Go to home position
3. End program

Obtain user response to menu

Choice 1: Yes → Switch to mode of operation
           Yes → Check Mode
           No → Choice 2

Choice 2: Yes → Calibration
           No → Choice 3

Choice 3: Yes → Finish
           No → Display Menu

Display Menu subroutine
Software Design & Realization

4

Automatic

Clear Screen

Display format (x,y)

User enters coordinates

Motors move to position

Check Busy

Is switch on “Automatic” mode?

Yes

“Automatic” mode subroutine

No

Display Menu

Return
Software Design & Realization

Manual 1

2

Top Button Pressed?

Yes

Motor moves upward one step at a time while button is pressed.

No

Right Button Pressed?

Yes

Motor moves forward one step at a time while button is pressed.

No

Bottom Button Pressed?

Yes

Motor moves downward one step at a time while button is pressed.

No

Left Button Pressed?

Yes

Motor moves backward one step at a time while button is pressed.

No

Check Busy

Is switch on “Manual 1” mode?

No

Display Menu

Return

“Manual 1” mode subroutine
Automatic:

DO

DEBUG CLREOL, 20, 44  
'clears previous user entries.

DEBUG CRSRXY, 20, 13, " Enter the coordinate (x, y): "
DEBUGIN DEC x_RevSteps, DEC y_RevSteps

'motor goes horizontally to absolute location.
SEROUT 10, baud, ["{D", DEC x_RevSteps, " }"]
GOSUB CheckBusy

'motor goes vertically to absolute location.
SEROUT 11, baud, ["{D", DEC y_RevSteps, " }"]
GOSUB CheckBusy2

LOOP WHILE sp3tSwitch0 = 1
GOSUB Display_menu
Calibration

• Positions of the limit switches
  – Front, back, top and bottom.
  – Prevents LDV from moving out of range.
  – Stops motors from spinning.

• Automatic calibration
  – LDV moves to center of a-axis and y-axis after front and top limits are pushed.

• Basic measurements
  – 160 steps = ¼ of an inch
• Data Measurements are possible and forthcoming
• System Specifications:
  – The y direction (lead screw assembly) moves .025 in/sec
  – The (x direction) rack and pinion assembly moves .25 in/sec
  – Minimum possible y – direction resolution (1e-3 in)
  – Programmed y- direction minimum (4e-2 in~1mm)
  – Minimum possible x-direction resolution (.1 in)
Further Work

- Adding a third dimension to the optical traverse
- Adding encoders to create a more efficient feedback control system
- Coding for limit switch in “automatic” mode subroutine
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