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

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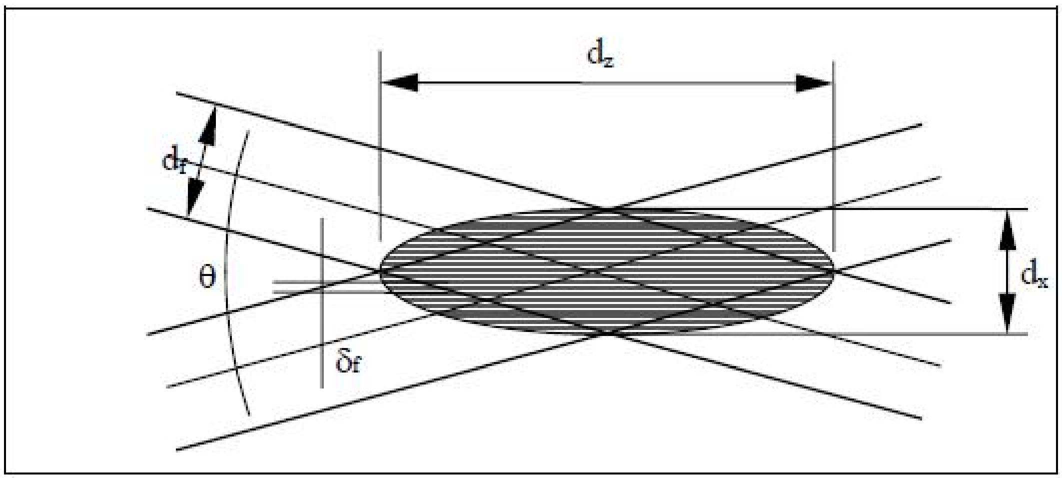
Problem Overview- What is LDV?

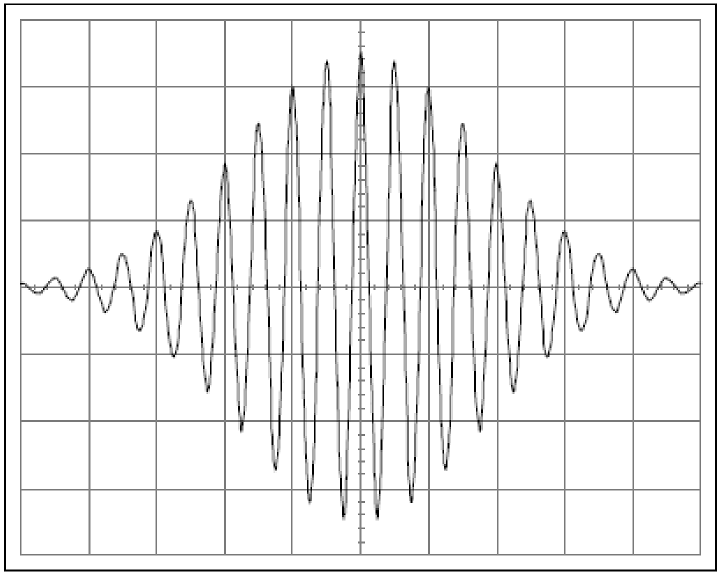
- What is LDV?
  - Offers precise measurements of fluid flows regardless of flow regime
  - Laser Probe emits beams of light that intersect to form a small control volume
  - Through this volume seeded particles on the order of microns pass through

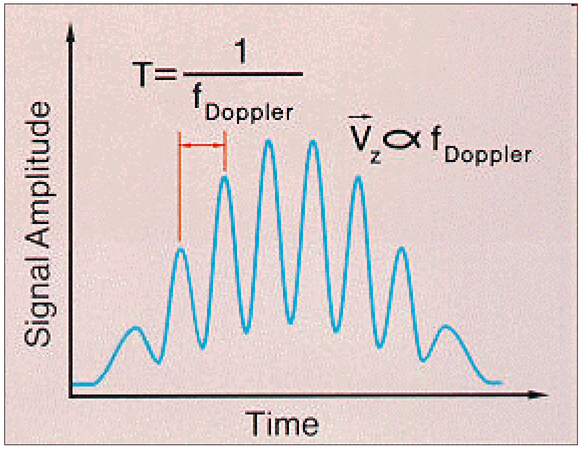


$d_{f=}$:width of incident beam, d_z:length of control volume,d_x:width of control volume, θ: angle of incidence, and δ_f: is the minimum grid size

Problem Overview- What is LDV?

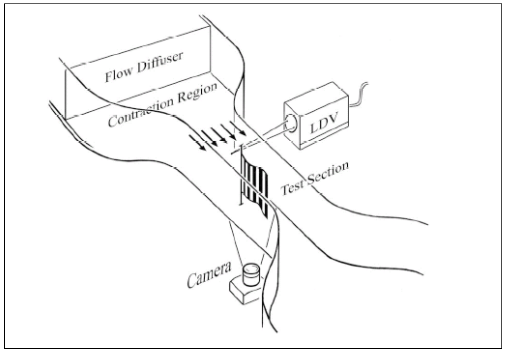
- If on average the level of seeding is less than one particle per signal burst we speak of a burst type doppler signal
- A typical burst type signal can be seen to the right with the DC part removed by a high pass filter
- The flow processor or “brain” of the LDV correlates these signal bursts to velocities 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





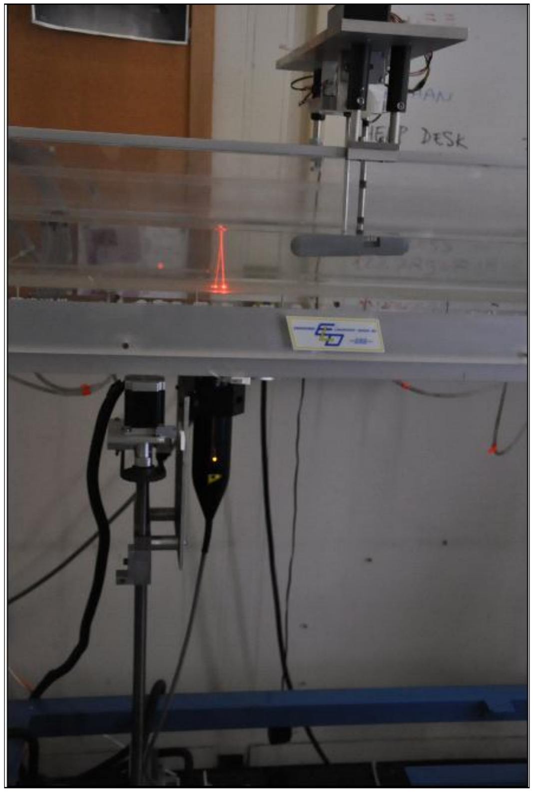
Practical Applications of LDV in the DSL

- 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

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



LDV set up with custom built force balance for flow physics analysis

Mechatronics

- 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

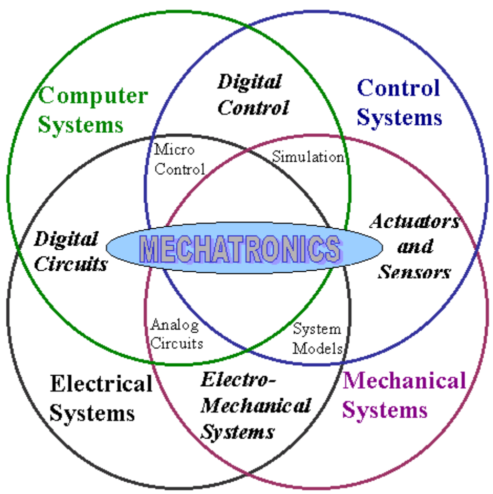
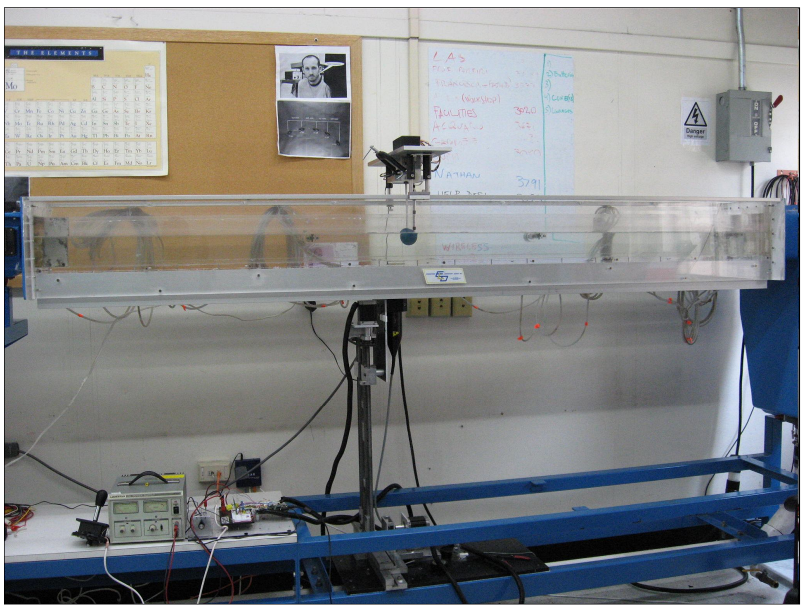


Diagram of the components of mechatronics (courtesy of the University of Waterloo- Department of Mechanical and Mechatronics Engineering)

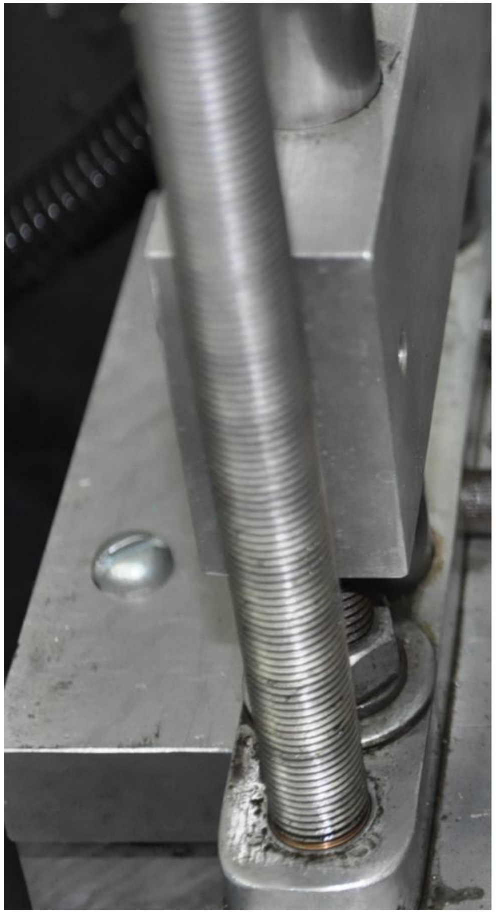
Project Goals

- 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

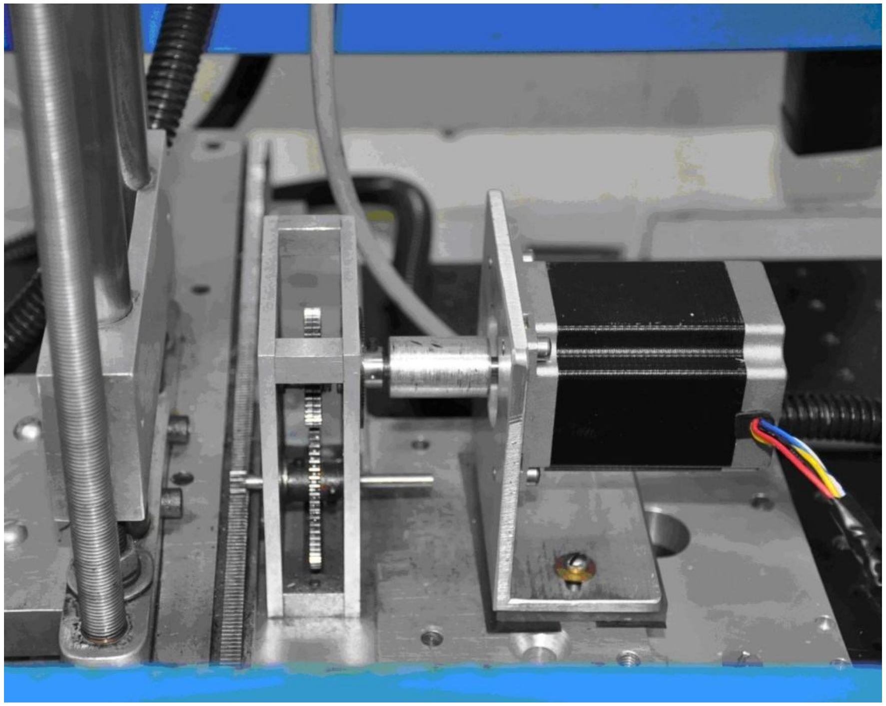
- Lead Screw Assembly
  - The design consisted of two machined lead screws that allowed the optical probe to be translated vertically
  - The screws were selected such that they had 20 threads per inch
  - The high thread count correlated to higher precision
  - The system was programmed to make minimum 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



Lead screw

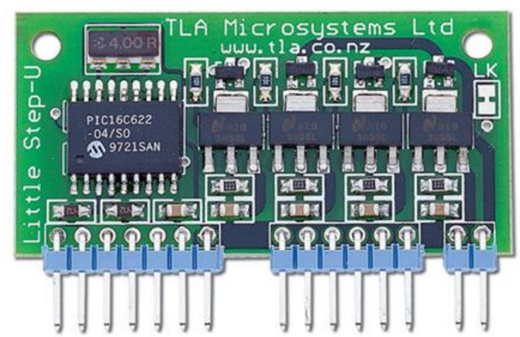
Electro-Mechanical Design & Realization

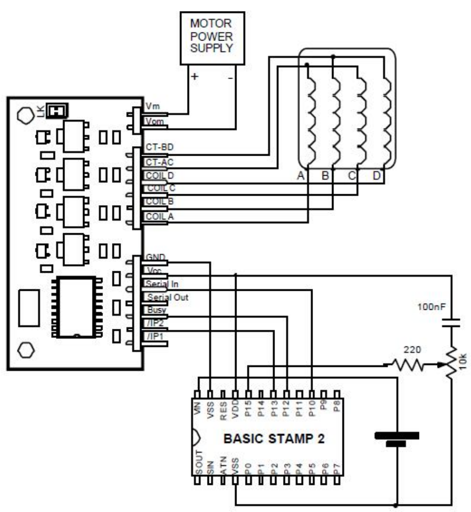
- Motor driving rack and pinion
  - Motor specification:
    - High torque
    - 200 steps per revolution
- Rack and pinion
  - Smooth movement
  - 3 mm between grid points
  - Not optimal choice but readily available and more cost effective

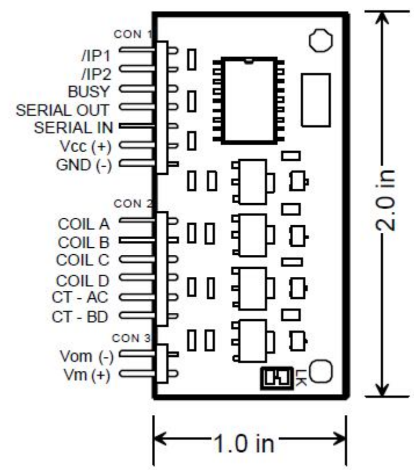


rack, pinion and motor

- 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







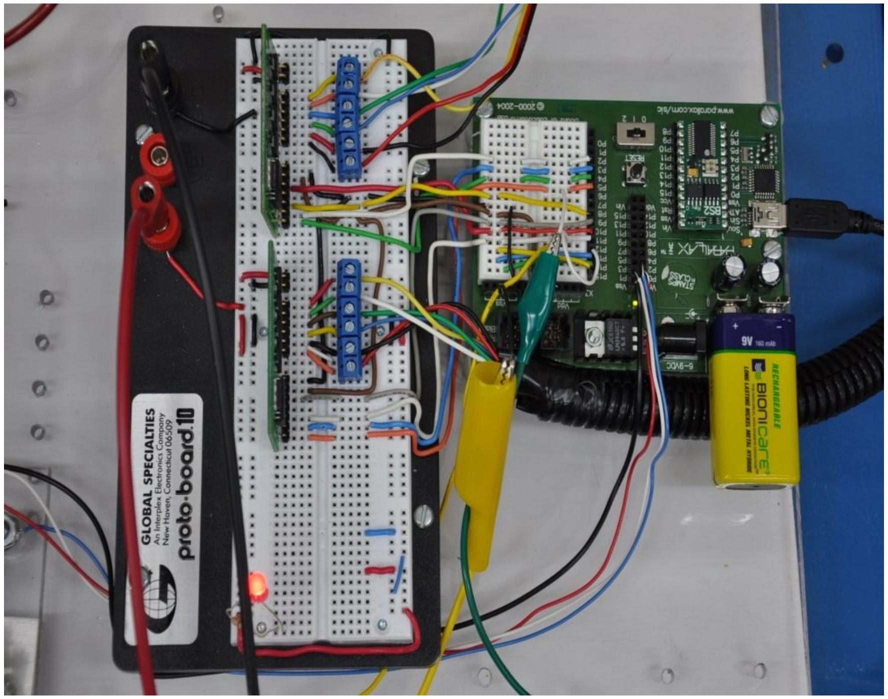
- The Circuit System
  - 2 Little Step-U
  - BS2 microcontroller
  - BOE breadboard
  - ProtoBoard III breadboard
  - 9V battery
  - Lodestar DC Power Supply

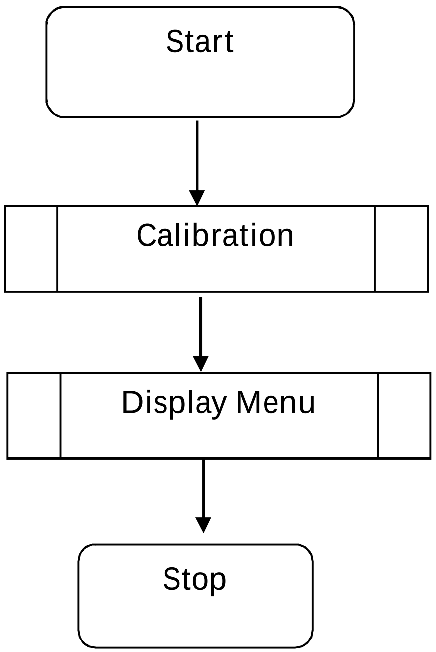
Further work includes:

-optical encoders

-limit switches for feedback control

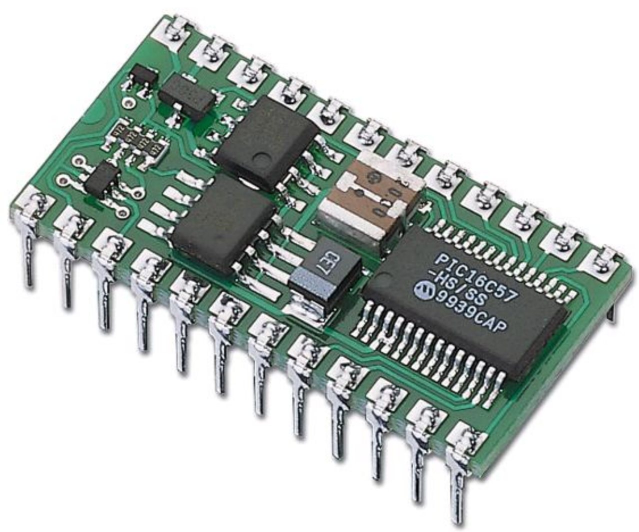
-printing a circuit board

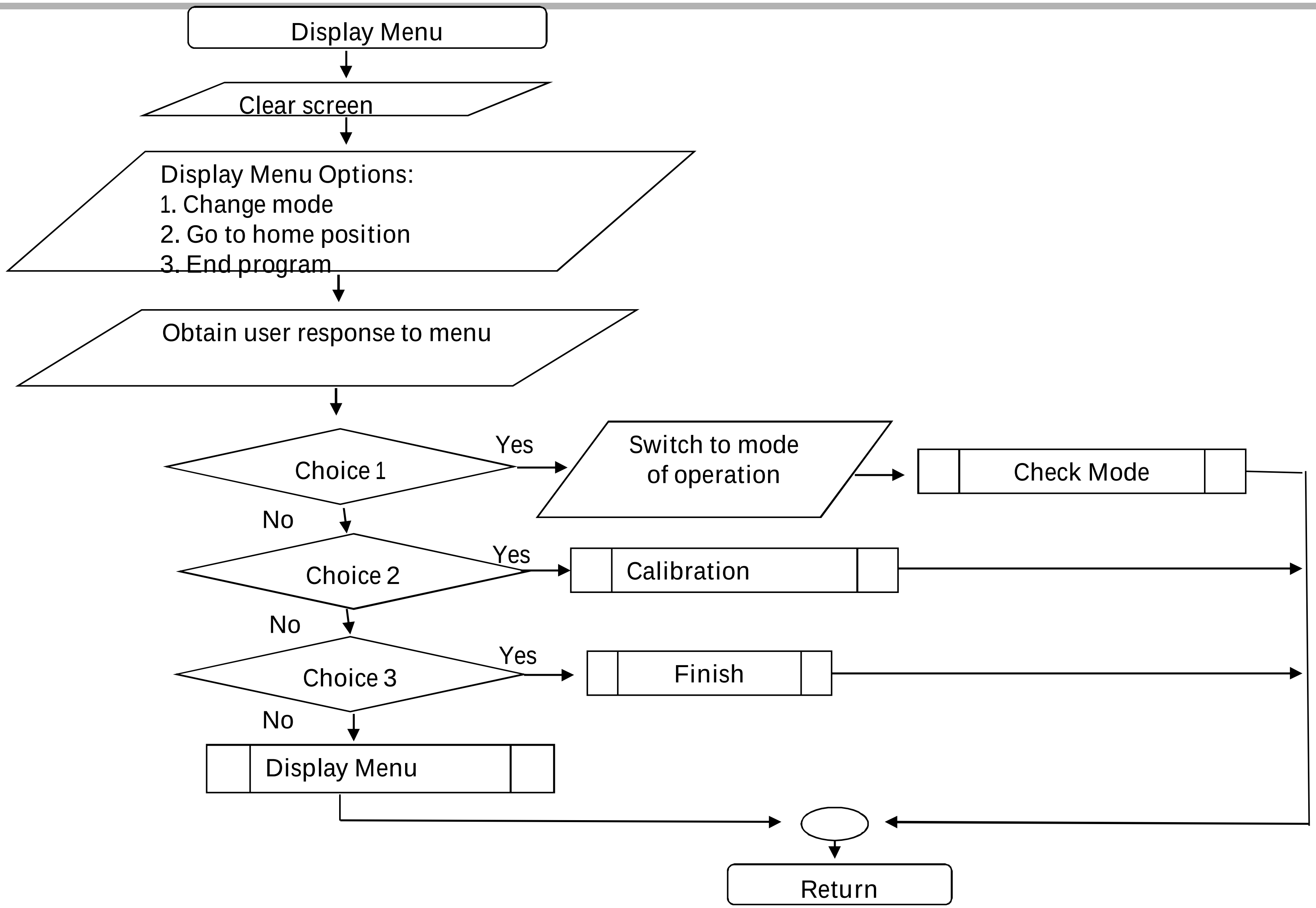




Main routine

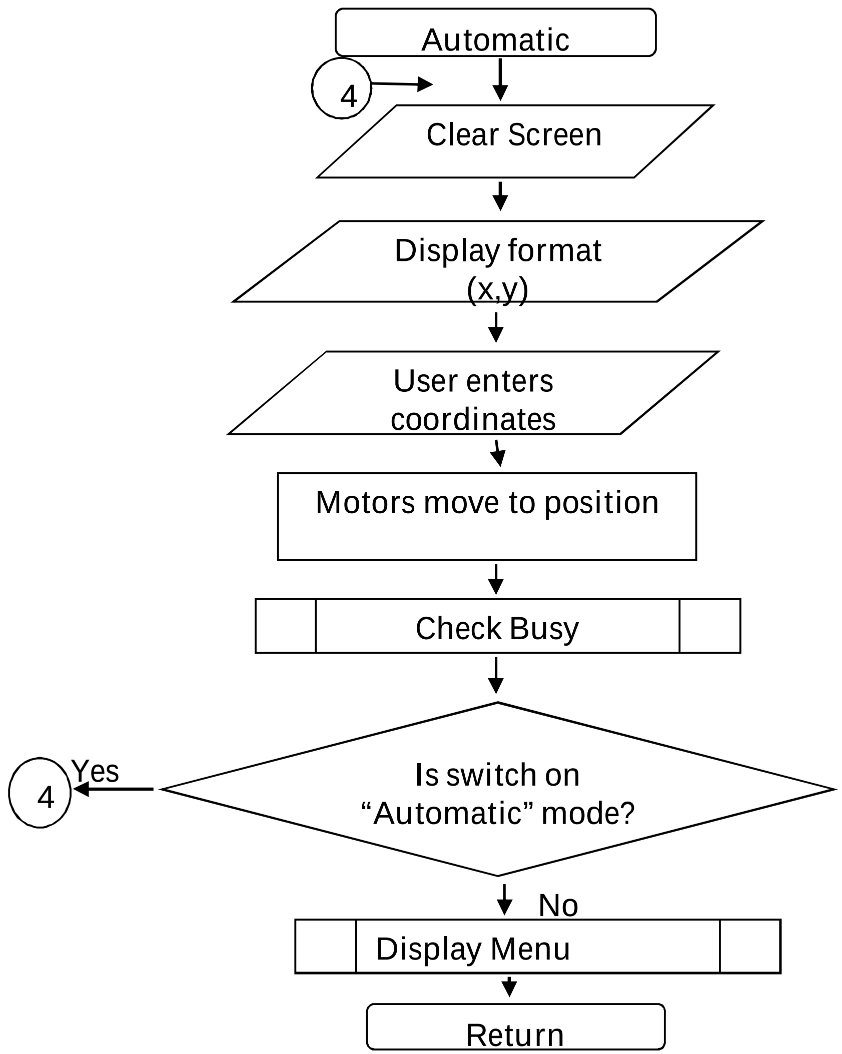
- Flow chart for illustrating the logic of the programs main routine
- All Programming was done using PBASIC and implemented on the BS2



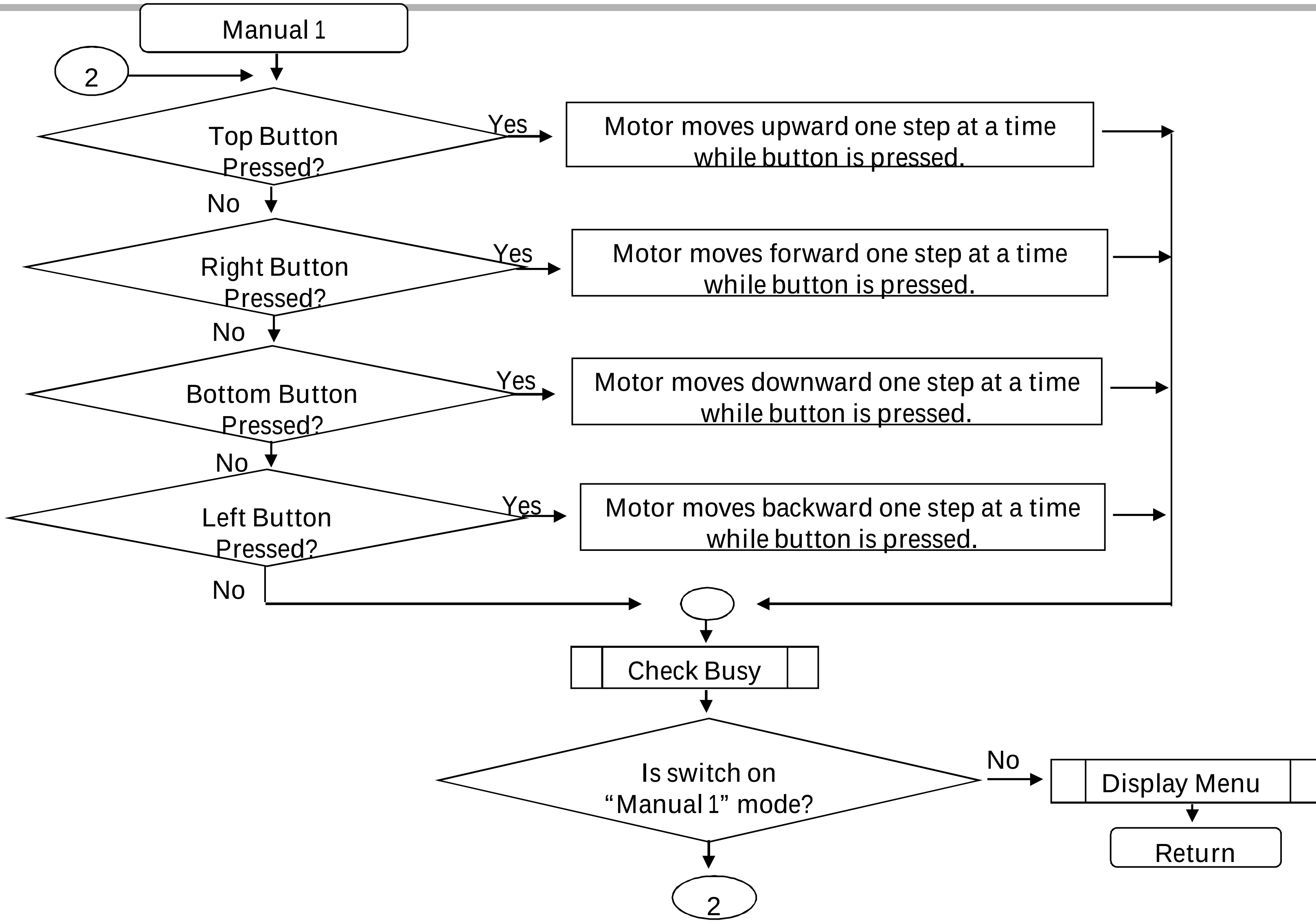


Display Menu subroutine

Software Design & Realization



“Automatic” mode subroutine



"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

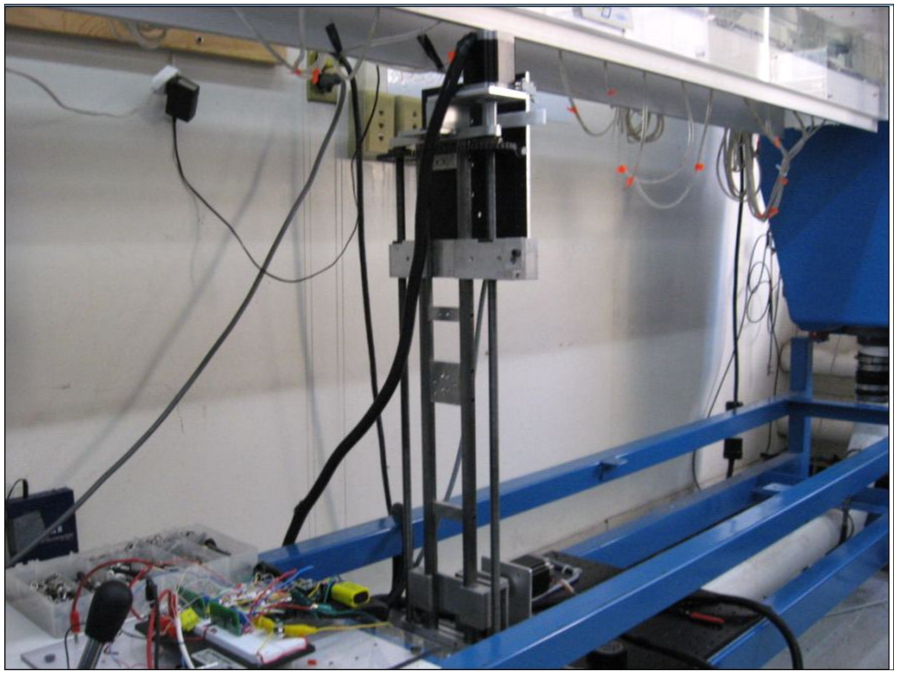
- Positions of the limit switches
  - Front, back, top and bottom.
  - Prevents LDV from moving out of range.
  - Stops motors from spinning.

- 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

Results

- 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

Acknowledgements

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