EE 344: Electronic Design Lab
Final Presentation

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Introduction: What is a Barcode?

- A barcode is a machine-readable, graphical representation of a code.
- Barcodes are widely used in supermarkets and other stores to make billing easy, keep inventory in check and reduce shoplifting.
- They are widely used in the healthcare and hospital settings, ranging from patient identification and accessing patient data.
- They can also be used to keep track of objects and people; they are used to keep track of rental cars, airline luggage, nuclear waste.

- There are many barcode conventions in use around the world, of which UPC (Universal Product Code) is the most widely used. Other variants include EAN and ITF.
- UPC has 2 popular variants: UPC-A, which encodes 12 digits, and UPC-E, which encodes 6 digits.
- Our barcode scanner is designed to scan and decode a UPC-E Barcode.

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Objective

We aim to do the following:

- To design and develop a Barcode Scanning Engine.
- Decode a bit stream generated by the engine to get the actual decoded data.
- Sending the data to a PC using serial communication via USB.

What is desired:

- Reliable decoding
- Universality of chosen barcode convention
- Cheap and robust design
- Reasonably fast operation time

System Design Choices

Our setup: Linear actuation

Pros:

- Easy to build, cheaper
- Clean, easier to decode signals
- More reflected light collected

Cons:

- Slower
- Consumes more power due to motor

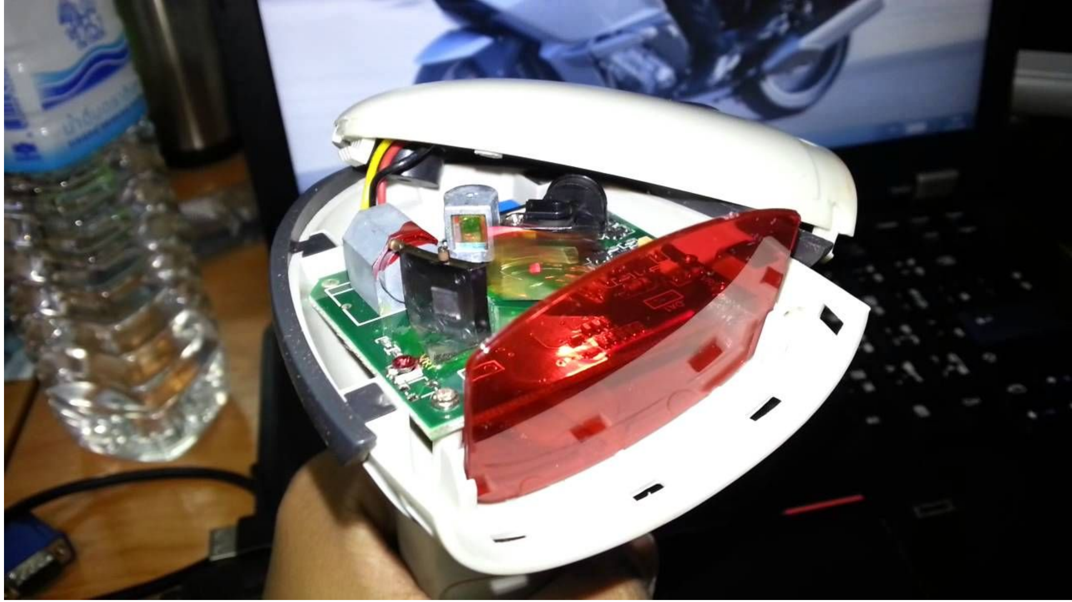
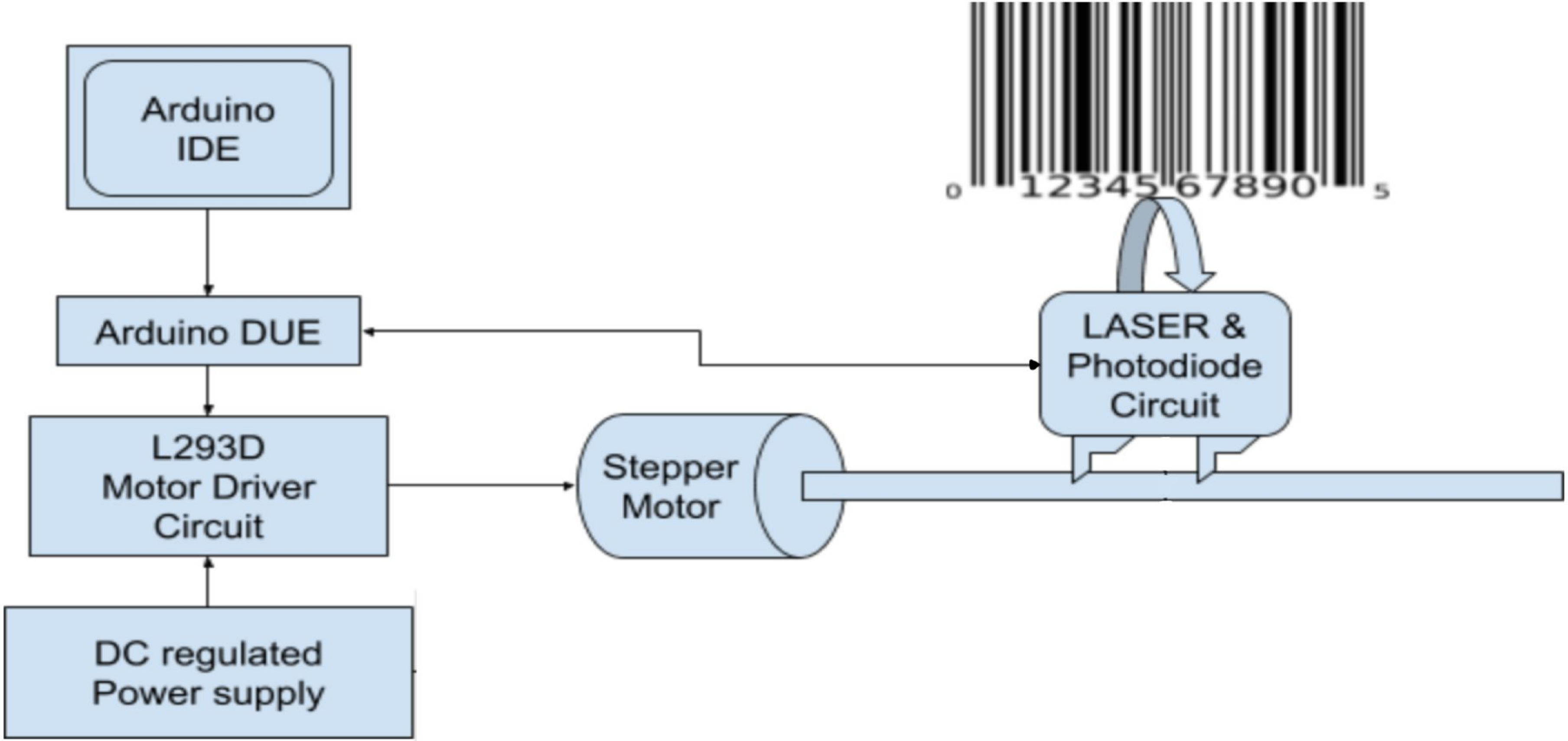
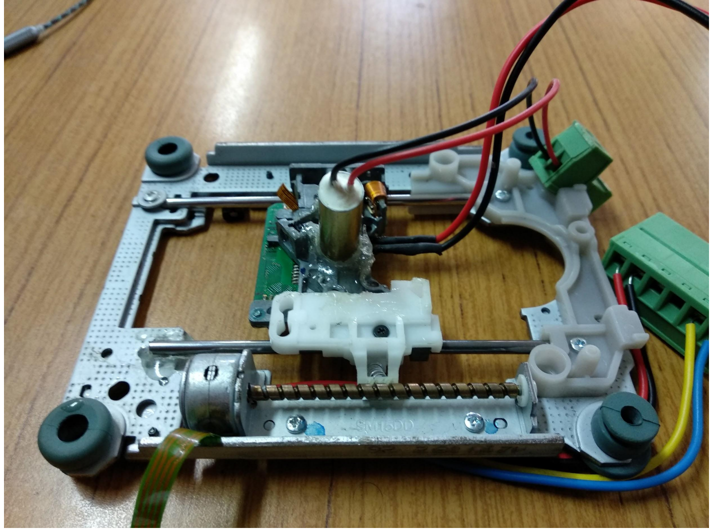


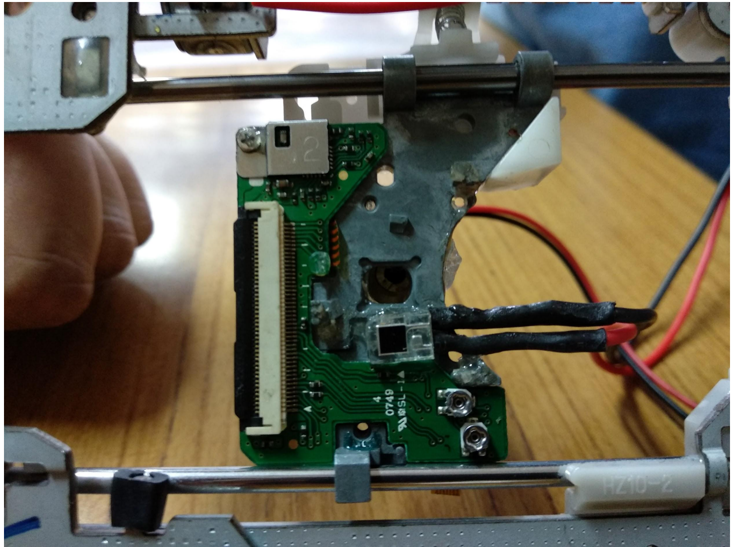
Fig. Commercial laser barcode scanner

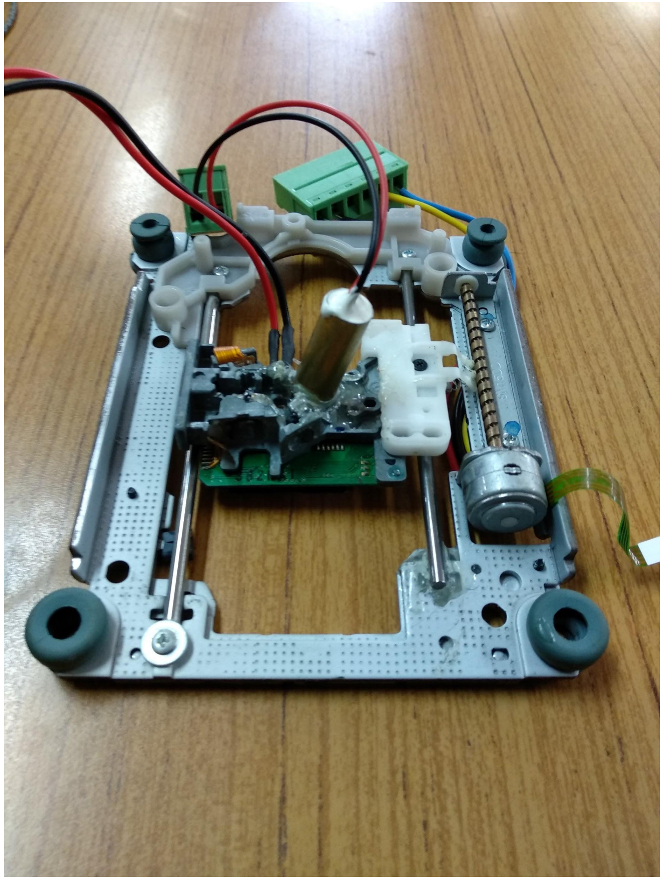
- Many existing setups: Laser with Oscillating Mirror (fig), CCD, Camera based
- Issues with commercial barcode scanner setup: non-linearities, hard to acquire specialised parts, very precise positioning needed.
- Issues with camera and CCD: strongly affected by ambient lighting conditions.

Block Diagram



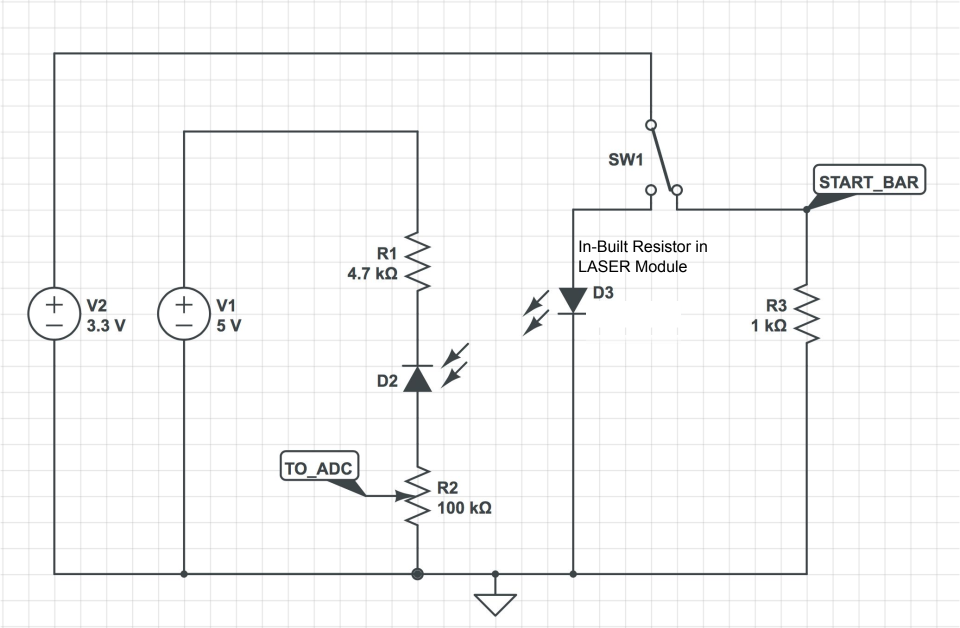






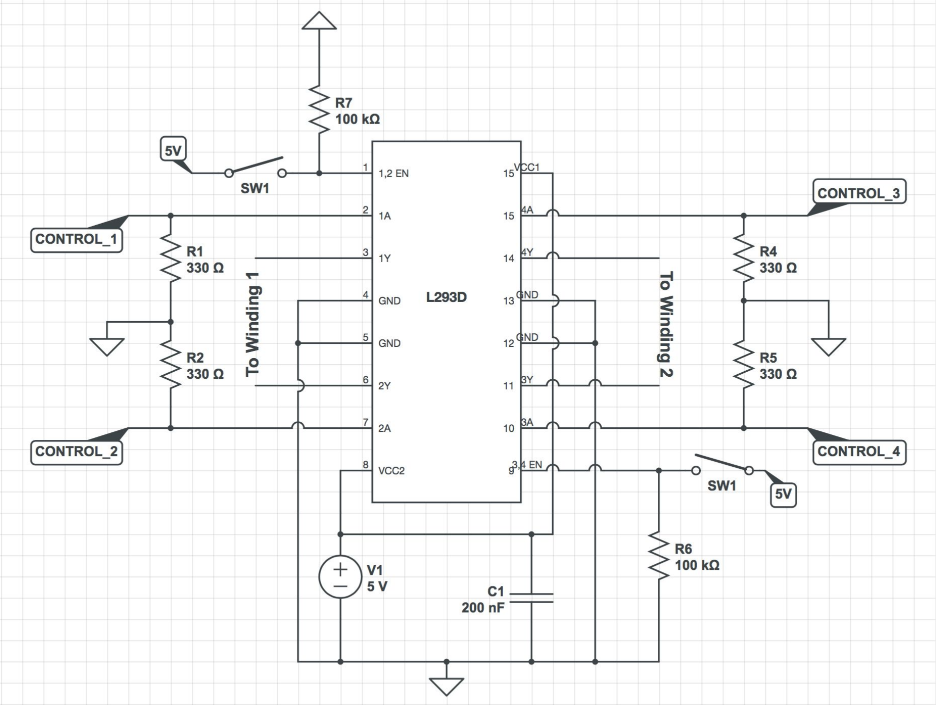
Optical Sub-System

- A LASER is mounted on a movable platform and is pointed at the barcode.
- The reflected light falls on the photodiode and the generated voltage (via R2) is sampled by the ADC and used by the uC to decode.
- A switch is used to turn on the LASER and start the sampling process.
- A variable resistor has been chosen to limit the output to under 3.3V (ADC input limit).



Mechanical Subsystem

- The optical system rests on a platform harvested from a CD Drive.
- The platform is driven by a bipolar 2-phase Stepper motor.
- The motor is driven in both directions via a L293D H-bridge circuit.
- The setup is moved across the barcode and the data is sampled.
- The setup is then moved back to its default position.



Signal Decoding

1. Laser has finite spot width, usually has a Gaussian profile.
2. Output signal is hence the original barcode convolved with this Gaussian (assuming linear additivity of reflected light).
3. The derivative of the signal is hence a sum of shifted Gaussians.
4. Peaks of the derivative correspond to edges, IF Gaussians are spaced far apart (see fig).
5. Input signal is noisy, derivative is hence noisier:
   a. Need to smoothen data before further processing
   b. Eliminate false extrema

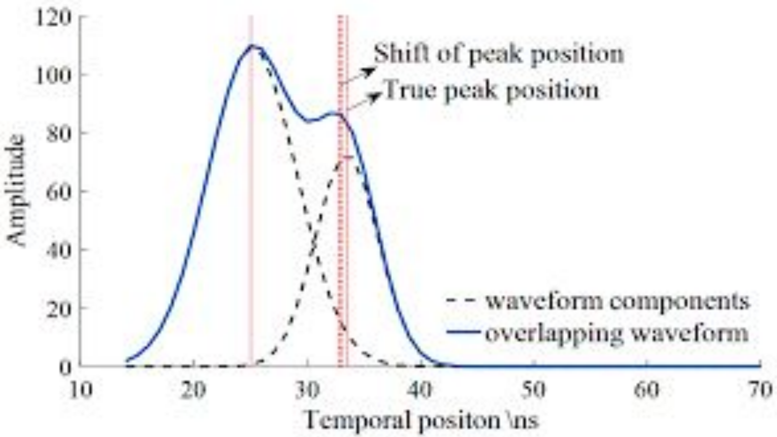


Fig. Effect of large spot width

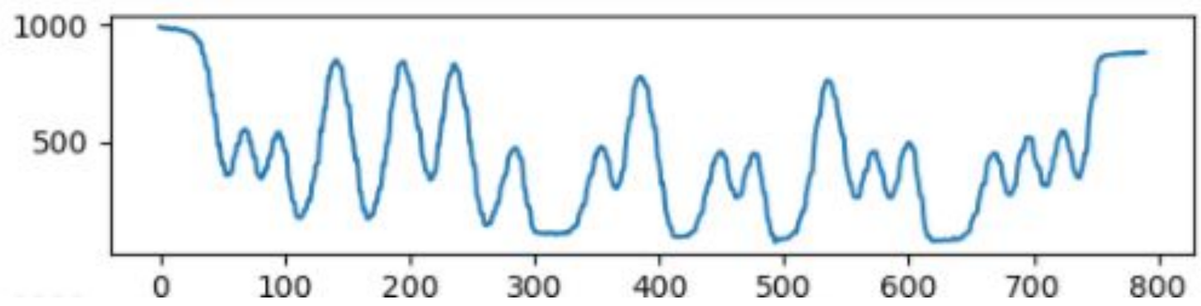


Fig. Effect of large spot width

Pseudocode

1. Smoothen signal acquired from photodiode using a moving window average (window length of 5 was chosen and the data was smoothened 5 times using this window).
2. Compute a new signal which is the numerical derivative of the above signal.
3. Smoothen this new signal if necessary.
4. Compute the maxima and minima of this derivative signal.
5. Discard extrema whose magnitude is small (noisy peaks).
6. Discard saddle points that have been misclassified as extrema.
7. Discard all but one extremum when there are many extrema very close to one another.
8. Compute the widths of black and white bars as the distance between these alternating maxima and minima.
9. Group the 24 relevant widths into 6 groups of 4 each (which corresponds to the 6 encoded digits), normalise and round off to compute the estimates for the barcode widths. Note that this method of locally grouping and then normalising helps improve tolerance to non-uniformity in sampling if any.
10. Correct errors using parity checks.
11. Use these bar widths to decode the signal using the chosen barcode convention, in this case UPC E.

Results

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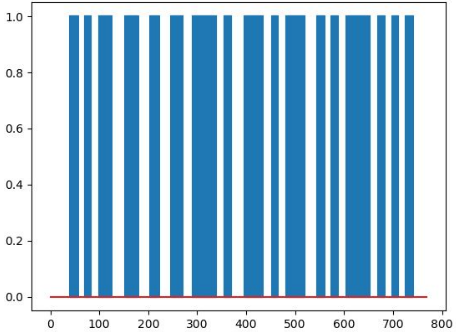
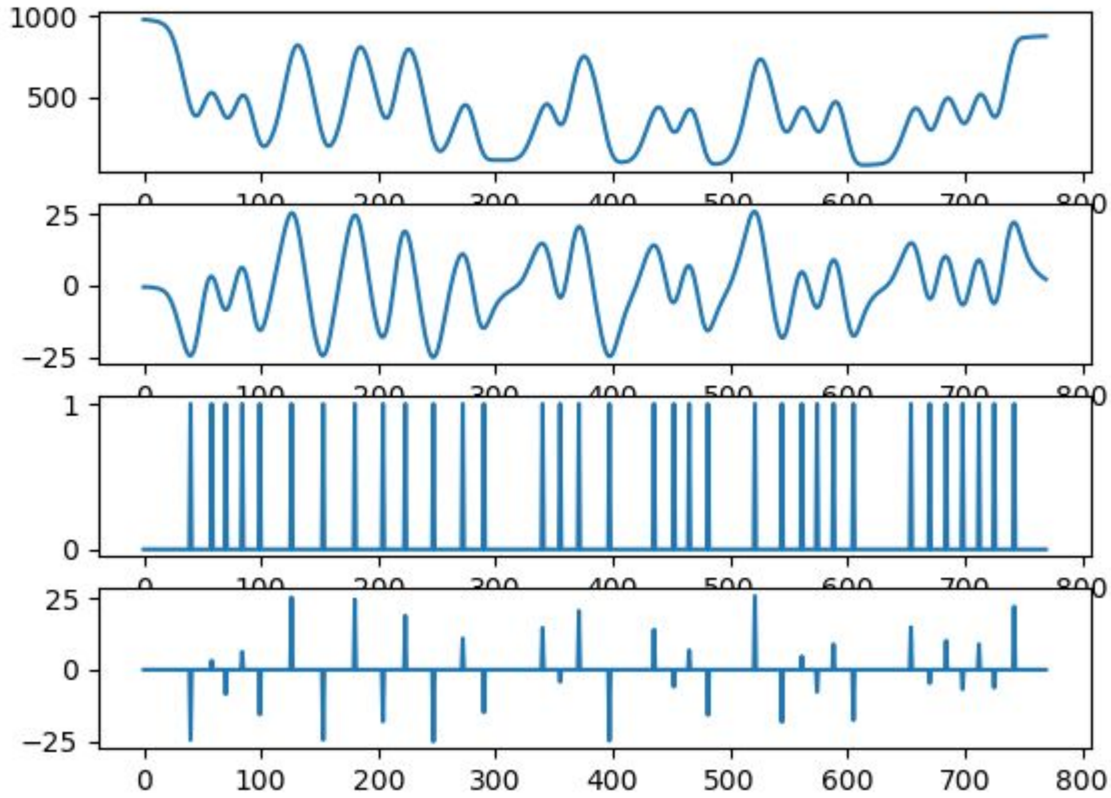



```
[[1 2 2 2]
 [2 1 2 2]
 [1 4 1 1]
 [2 3 1 1]
 [1 3 2 1]
 [1 1 1 4]]
Final Barcode:
[0 1 2 3 4 5 6 5]
[Finished in 6.1s]
```



UPC-E Convention

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UPC-E is a 6 digit compact variation of UPC-A.
Encoding of UPC-E is a bit more convoluted as compared to UPC-A

Physical Structure:

- Left-hand (starting) guard bars encoded as **101**
- Six data characters, each encoded using **7 bars**
- Right-hand guard bars encoded as **010101**

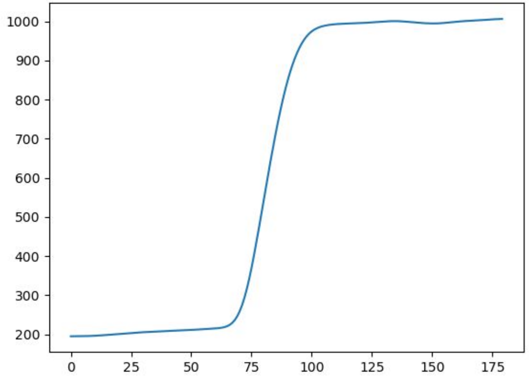
Numerical Structure:

- The first character decides the Number System.
- The last character is the check character.
- In between there are 6 digits which form the actual code.
- The first and last characters does not have their own bars, they are encoded in the encoding scheme of the 6 middle digits.

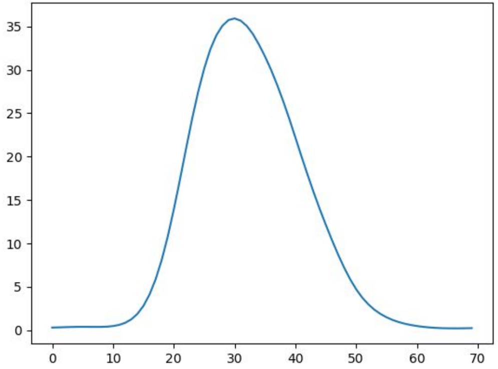
The encoding scheme (Even/Odd parity) of each of the 6 digits is decided by the Number system and Check character jointly.

System Characterisation

1. Photodiode dark current: **110 nA**
2. Laser current : **18mA** (drawn at 3.3V, with an unknown internal series resistance)
3. Current drawn by Stepper motor :
   a. Not operating: **26 mA**
   b. During operation
      i. Average : **144 mA**
      ii. Max : **175 mA**
4. Tilt of laser from vertical axis : **18.8 degrees**
5. Pitch of screw in linear actuator : **0.302 cm** (13.25 revolutions for 4 cm moved)
6. Scan time: **2.4s**
7. Max linear scan length: 4cm, Barcode length: 3.3cm

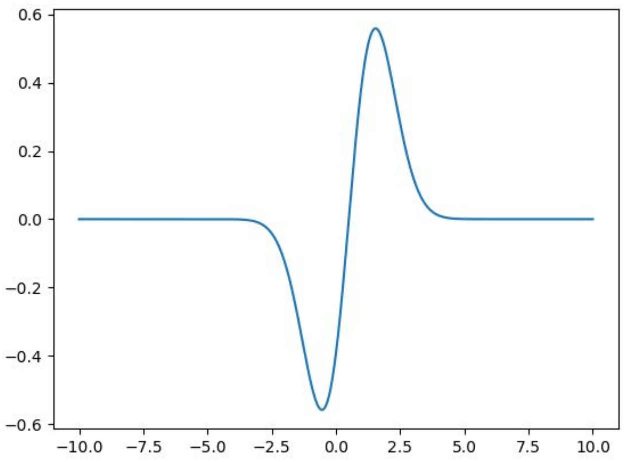


Signal from B-W transition



Spot shape of the laser

Analysis of Errors in Decoding



Difference of two Gaussians of unit variance placed at 0 and 1. Peaks shifted by 0.54

- Smallest bar-width: 13.4 units
- Spot width: 30
- Variance of Gaussian fitted to laser spot: 12
- **Edges shift upto half a bar width!**
- Possible strategy:
    a. Correct edge positions, other easy positions.
    b. Bars are grouped into units of 7: use to correct positions of start and stop edges.
    c. 20 possible cases for the 3 edges between: compute shifts assuming **first order approximation**.
    d. Compare against these 20 configs, choose one which minimizes MMSE.
- The issue: bar-width not known accurately enough. Edge positions diverge.

Thank You