IoT Review Guide

Wk 1

Process

- Requirements
    - Architecture
        - Coding
            - Testing
                - Maintenance
- System feasibility
    - Specification
        - Prototype
            - Initial systems
                - Enhanced systems
- Requirements start with shall
    - Customer, sales, marketing, management, engineering
- Architecture start with what and how
- Components-> design and build
- System integrations -> putting it all together

Staffing

- Scope
    - A measure of the design space
- Schedule
    - When does the project need to be completed, according to management and customers (qualification units)
- Resources

Heap Chart

AUC represents one of the costs of doing business (OpEx)

Note the engineers ratio: verification 3, software 2, hardware 1

Roles and Responsibilities

Architecture

All technical decision authority should lie with these person(s)

Project Process

- Designs
    - Architecture
        - Requirement docs

        - Architecture docs
        - Build schedule top down
        - Performance models
    - Design Planning
        - Vendor quotes
        - Low level spec docs
        - Testbench specs
        - Schedule bottom up
- Develops
    - Software
    - Electronics
    - Physical/Verification
        - Testplan, checker, coverage, vectors
    - Manufacture
- Deploys
    - Validation
        - Virtual test cases
        - Veloce, palladium
        - FPGA
        - Validate security
    - Production

Temps

Military	-55 to 125 C
Auto	-40 to 125 C
AECq100	-40 to 105 C
Ext industrial	-40 to 125 C
Industrial	-40 to 85 C
Commercial	0 to 85 C

Agile

Iterative
Taks are broken into smaller sections called stories, scrums and sprint, 2 weeks
Builds trust
Lower stress
Higher quality
Minimizes dev costs

Documentation

Project management

Documentation is central
Captures requirements
Defines traceability

Project cycle

Plan, execute, learn

Wk 2

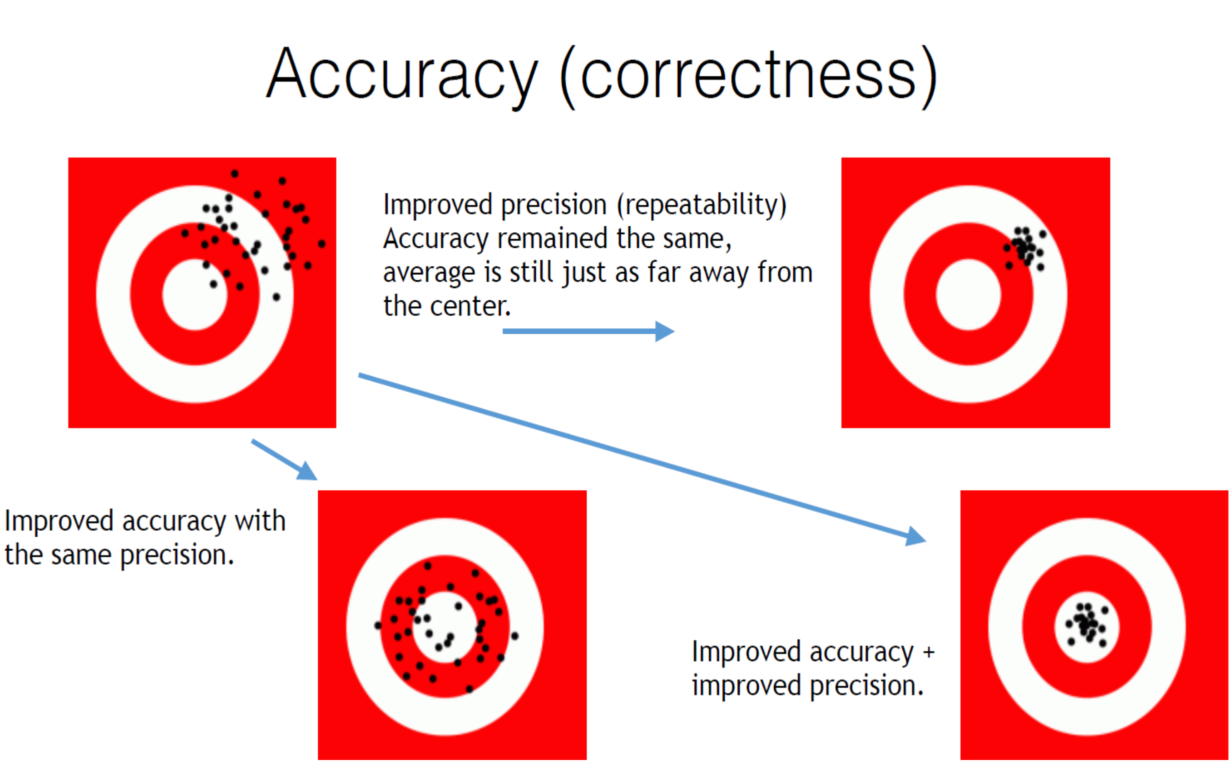
Thermistor
- 2 wire device that changes resistance as a fx of temp

Resolution
- The fineness of an instrument

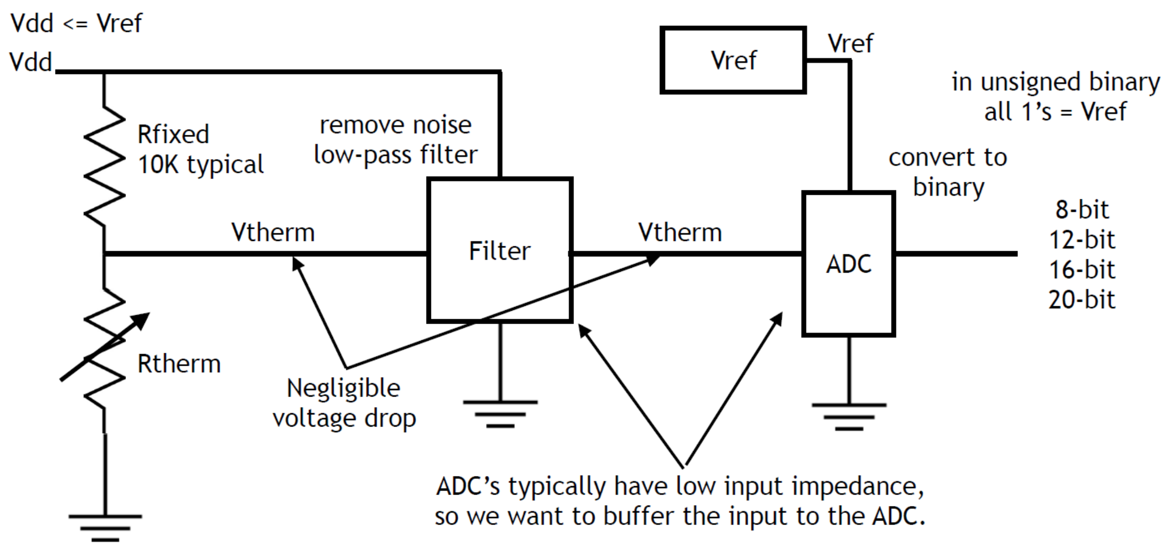
Precision
- How repeatable a measurement is

Accuracy
- The correctness of a measurement

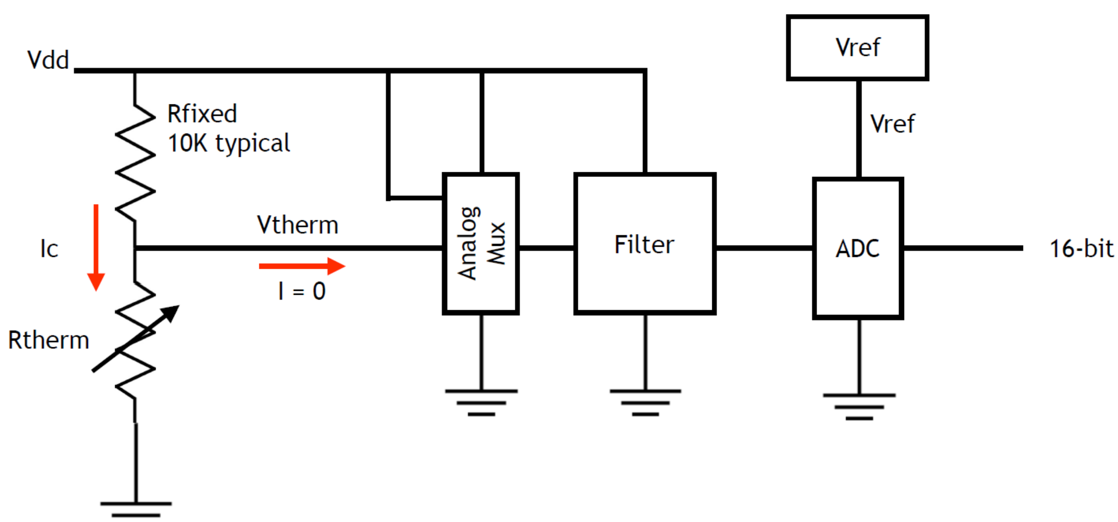
Tolerance
- Combines precision (repeatability) and accuracy (correctness)



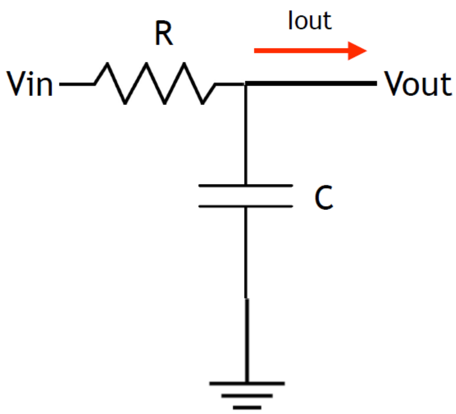
Basic Sensor Circuit



Advanced Sensor Circuit



Simple Passive Filter



Cutoff frequency is given by:
fc = 1 / (2*pi*R*C) Hz

We choose:
R = 100 ohms
fc = 1 Khz

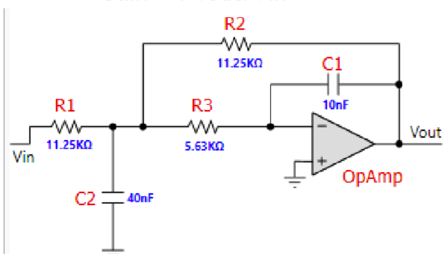
1000 = 1 /2 *pi*R*C
C*R*pi*2 = 1/1000
C = 1/1000*R*pi*2
C = 1.6 uF

Vout = Vin in steady state, Iout = 0

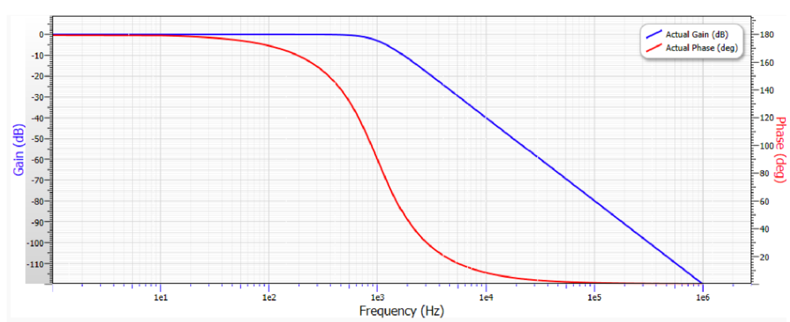
Also doesn't provide any buffering

Simple Active Filter

Gain = 1 Vout/Vin



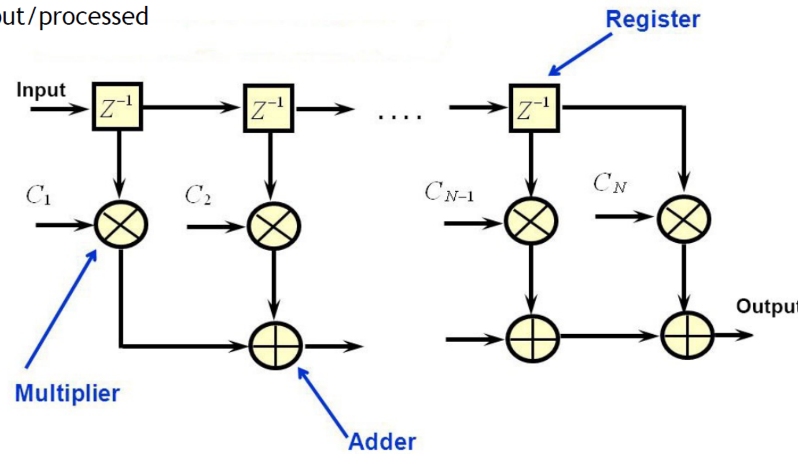
Filter Stage:	1
Passband Gain(Ao) :	1
Cutoff Frequency(fn):	1 kHz
QualityFactor (Q):	0.71
Filter Response:	Butterworth
Circuit Topology:	MultipleFeedback
Min GBW reqd.:	71 kHz



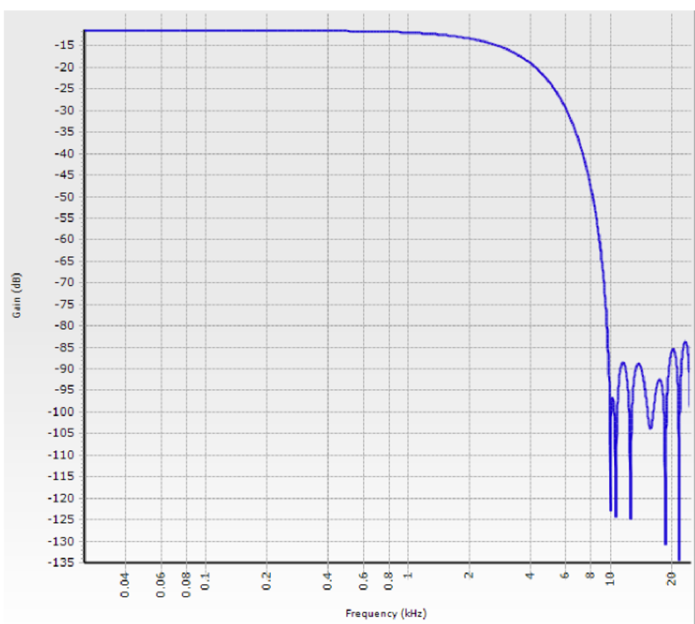
Digital FIR Filter

- Finite Impulse Response Filter

Note: There is a clock, samples are input/processed at the filter sample frequency, FF_s



Digital FIR Filter Response



Block Devices

- SATA = Serial ATA
- SAS = Serial attached SCSI
- USB = Universal serial bus
- Drives store data in blocks called sectors

- Each block has a logical block address or LBA
- A drive can only transfer in units of sectors

Object Devices
- Data is referred to by an Object ID
- Objects can be of arbitrary size

Key Value Devices
- Data is referred to as a Key
- Values can be of arbitrary size
- Key creation can use a hash

Solid State Drive
- NAND cannot write in place
- Have to erase before writing again
- Firmware maintains a table that maps the LBAs to physical locations in the NAND array

Network File System
- Allows remote directories to be accessed as though they were local directories
- Runes over TCP/IP
- OS and architecture of the server can be different from the client

Sizes
- Terabyte (TB) = 1000 Gb
- Petabyte (PB) = 1000 TB
- Exabyte (EB) = 1000 PB
- Zettabyte (ZB) = 1000 EB

Parallel Distributed File Systems
- Similar to storage compute=> push compute to where the data is located
- Lustre
  - Run on Linux
  - Scale capacity and performance
  - Genearal IO, not write once read many
- Hadoop
  - Mitigate hardware failure
  - Write one read many
- Ceph
  - Object, block, and file storage
  - General IO

Wk 3

AI Background

- AI is build on the hypothesis that mechanized thought is possible
- 17^{th} century: Gottfied Leibniz, Thomas Hobbes, Rene Descartes discussed the potential for rationalizing all thought as math symbols
- 1950: Alan Turing published Computing Mac;hinery and Intelligence
- 1959: Arthur Samuel, Field of study that gives computers the ability to learn without being explicitly programmed.
- 3 contributing factors to the rise and fall of AI
  - Improved algorithms
  - Faster computing
  - Large data set
- People confuse a machine getting better at its job (learning) with awareness (consciousness)
- Machines are better at:
  - Capturing data
  - Communicating data
  - Analyzing data

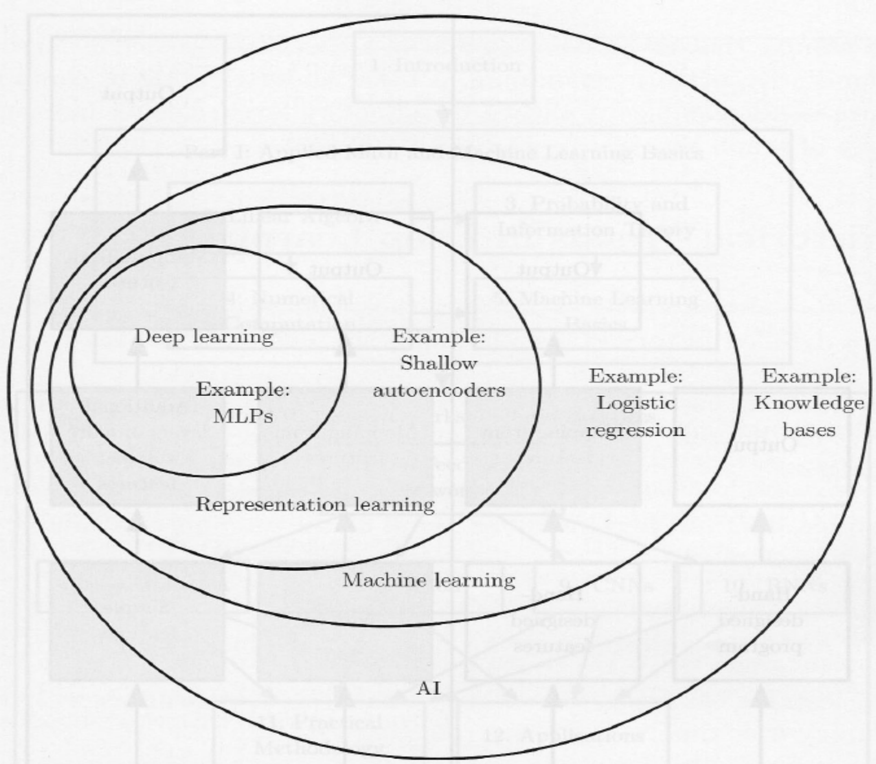


Figure 1.4: A Venn diagram showing how deep learning is a kind of representation learning, which is in turn a kind of machine learning, which is used for many but not all approaches to AI. Each section of the Venn diagram includes an example of an AI technology.

Failure is more common than success in machine learning

Categories of ML

- Supervised
    - Regression
    - Classification
- Unsupervised
- Reinforcement
    - Make a sequence of decisions over time

Gradient Descent

- Gradient descent is an optimization algorithm used to minimize a loss function (or cost function) by iteratively adjusting the parameters of a model
- Gradient descent computes the gradient (derivative) of $J(\theta)$ and updates θ in the opposite direction of the gradient.
- Types of GD
    - Batch Gradient Descent – uses all data at once to compute the gradient (slow but stable)
    - Stochastic Gradient Descent – uses one data point at a time (faster but noisier)
    - Mini-Batch Gradient Descent – uses a small group of data points

Bayes Theorem

- Names after Rev Thomas Bayes
- An equation that allows new evidence to update beliefs
- Probability measures a degree of belief
- Links the degree of belief in a proposition before and after accounting for evidence
- P(A) – the initial degree of belief in A, prior
- P(A|B)- the degree of belief in A having accounted for B, posterior
- P(B|A)/P(B) – represents the support B provides for A

Naïve Bayes

- It is called naïve because it makes a strong assumption that all of the x1's are independent
- After modeling P(Y) called class priors and P(X|Y), the algorithm can use Bayes theorem to derive the posterior prediction on Y given X
- P(Y|X) = P(X|Y)/P(X)*P(Y)
- Written another way: P(Y|X) = P(X|Y)·P(Y) / P(X)
- P(Y|X) = Posterior probability of class Y given data X
- P(X|Y) = Likelihood of data X given class Y
- P(Y) = Prior probability of class Y
- P(X) = Evidence or overall probability of data X

Support Vector Machines

- Support Vector Machine is a supervised machine learning algorithm used for classification and sometimes regression tasks. Its main goal is to find the best boundary (called a hyperplane) that separates different classes of data
- SVM tries to draw a line (or plane or hyperplane) between data points of different classes so that:
    - The margin (distance) between the closest points of each class and the boundary is as wide as possible.
    - Those closest points are called support vectors.
- If the data is Non-Linear
    - Soft Margin: Allows some misclassifications to improve generalization.
    - Kernel Trick: Maps data to a higher-dimensional space where it can be linearly separated
        - Linear
        - Polynomial
        - Radial Basis Function or Gaussian

K means

- K-Means is an unsupervised machine learning algorithm used for clustering data — meaning it groups similar data points into K clusters, where K is a number you choose
- No negative distances
- Distance from point 1 to point 2 is the same as the distance from point 2 to point 1 (symmetry)
- Uses Euclidean distance
    - Euclidean distance to measure how close a data point is to a centroid
    - Distance = Square root of $(x1-x2)^2 + (y1-y2)^2$

Reinforcement Learning

- Reinforcement Learning is a type of machine learning where an agent learns to make decisions by interacting with an environment to maximize rewards over time.

Deep Learning

- Deep learning is a type of machine learning that uses neural networks with many layers to automatically learn patterns in large amounts of data
- It's called "deep" because the network has multiple layers (also called hidden layers) between input and output
- Each layer processes the data and passes it to the next. With more layers, the model can learn increasingly complex features
- The model learns by adjusting its internal weights using algorithms like gradient descent and backpropagation (error correction)
- Types
- Feedforward Neural Network (FNN / MLP)
    - Use case: Basic classification/regression
    - Simplest deep learning model

    - Information flows in one direction (input → output)
    - Also called Multilayer Perceptron (MLP)
- Convolutional Neural Network (CNN)
    - Use case: Image processing, object detection, medical imaging
    - Uses convolutional layers to automatically detect patterns like edges, shapes
    - Handles spatial data like images very well
- Recurrent Neural Network (RNN)
    - Use case: Time series, sequential data, natural language processing
    - Has "memory" — remembers previous inputs using loops
    - Good for sequences, but can struggle with long-term memory
- Long Short-Term Memory (LSTM)
    - Use case: Language modeling, speech recognition, ECG signals
    - A special type of RNN
    - Can remember information for long periods
    - Solves the "vanishing gradient" problem in RNNs
- Gated Recurrent Unit (GRU)
    - Use case: Similar to LSTM, faster to train
    - Like LSTM but with fewer gates (simpler)
    - Balances performance and speed for sequence data
- Transformer
    - Use case: NLP, translation, ChatGPT, BERT, etc.
    - Replaces recurrence with self-attention mechanisms
    - Can handle long sequences efficiently
    - Foundation of most modern language models
- Autoencoder
    - Use case: Dimensionality reduction, noise removal, anomaly detection
    - Learns to compress (encode) and then reconstruct (decode) input data
    - Used in unsupervised learning
- Generative Adversarial Network (GAN)
    - Use case: Image generation, deepfakes, art creation
    - Two networks compete: a generator and a discriminator
    - Can generate realistic synthetic data
- Deep Belief Network (DBN)
    - Use case: Feature learning, pretraining deep networks
    - Stacked layers of Restricted Boltzmann Machines (RBMs)
    - Used less now, but important historically

ML in IoT

- Automotive and Transportation
- Industrial
- Building Automation
- Oil and Gas
- Agriculture

Wk 4

Characteristic of Big Data

- Volume
- Velocity
- Variety
- Value
- Veracity
- Visibility

Predictive Analytics

- Processing power
- Data storage increased
- Refined machine learning algorithms
- Combines stats, data mining, ML

Learning algorithms rely on 3 components

- Representation
- Evaluation
- Optimization

The Bayesian Way

- The future won't differ too much from the past
- Base future predictions on past data employing random sampling
- The distribution of your present samples will closely resemble the distribution of future samples

Sample Bias

- Bias is the offset in a data set (selection bias)

Sample variance

- The average of the squared differences from the mean
- How fare a dataset is spread out

Cross-validation

- Produces k error measurements, which can then be used to produce a mean error
- Works well regardless of dataset size

Good Data

- Sufficient quantity of data for your algorithms that represents the features you care about

Smart Data

- Cleaned and prepared

Equations

Revenue = (units sold * reseller price) + (units sold * dist price)

Profit = Revenue – (BOM cost * units sold) – (CapEx + OpEx)

Acc of an ADC: 2^ the bit * tolerance

    Ex: 16 bit ADC with a 0.01 tol

        2^16 * 0.0001 = 6.554

        Any measurement is +/- 3.3

Rtherm

    Measure Vdd = MVdd

    Measure Vtherm = MVtherm

    Compuate current lc = (MVdd – Mvtherm) / Rfixed

    Rtherm = (MDvv /lc) – Rfixed

    Rfixed tolerance will impact accuracy

    Tolerance for MVdd and Mvtherm will cancel each other out