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UESTC 3031: Engineering Project Management & Finance: Design for Manufacturing

Lecture DFM 1

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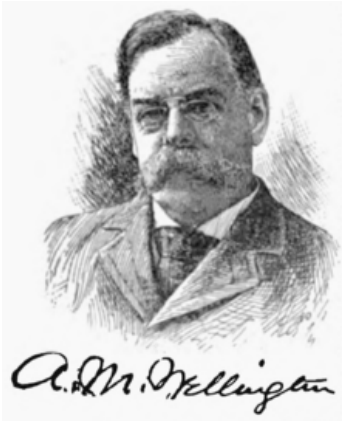
Design for Manufacturing (DfM) Overview

- This section will allow you to: *'Construct a basic cost model for a product taking into account component tolerances and cumulative product yield against a defined specification'*
- This section will include
  1. Introduction to DfM, and its role in electronic manufacturing
  2. Designing products using imperfect components
  3. Process and product quality control & SPC
  4. Estimating the cost of quality on production and product cost

Design for Manufacturing: Background

'An engineer can do for a dollar what any fool can do for two'

Arthur Mellen Wellington (1847-1895)

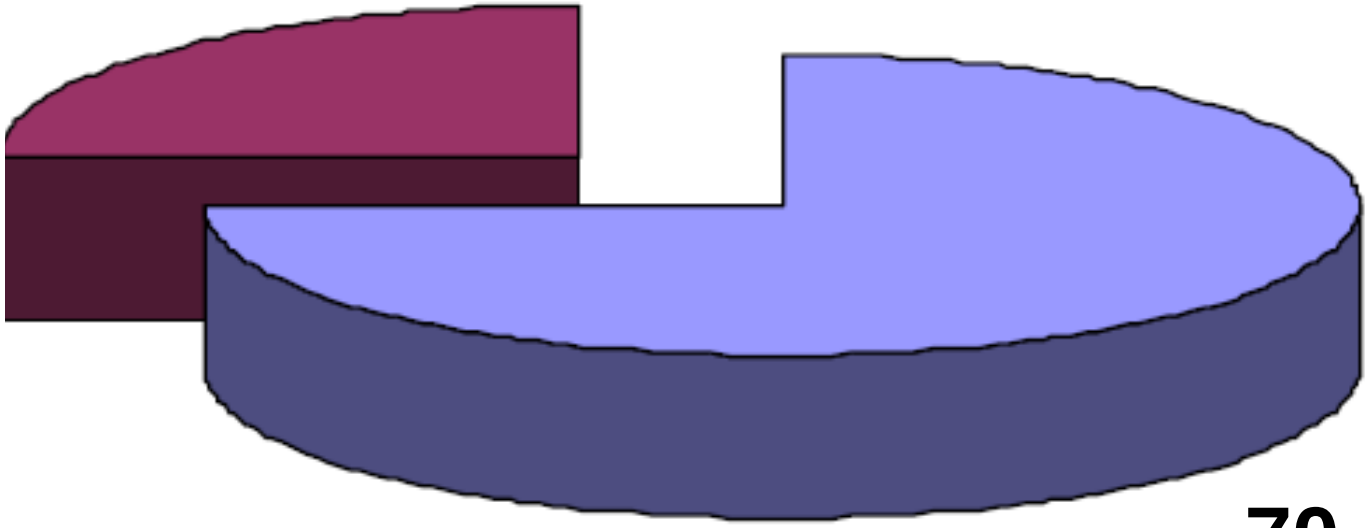


Engineers can impact the price or products in two ways:-

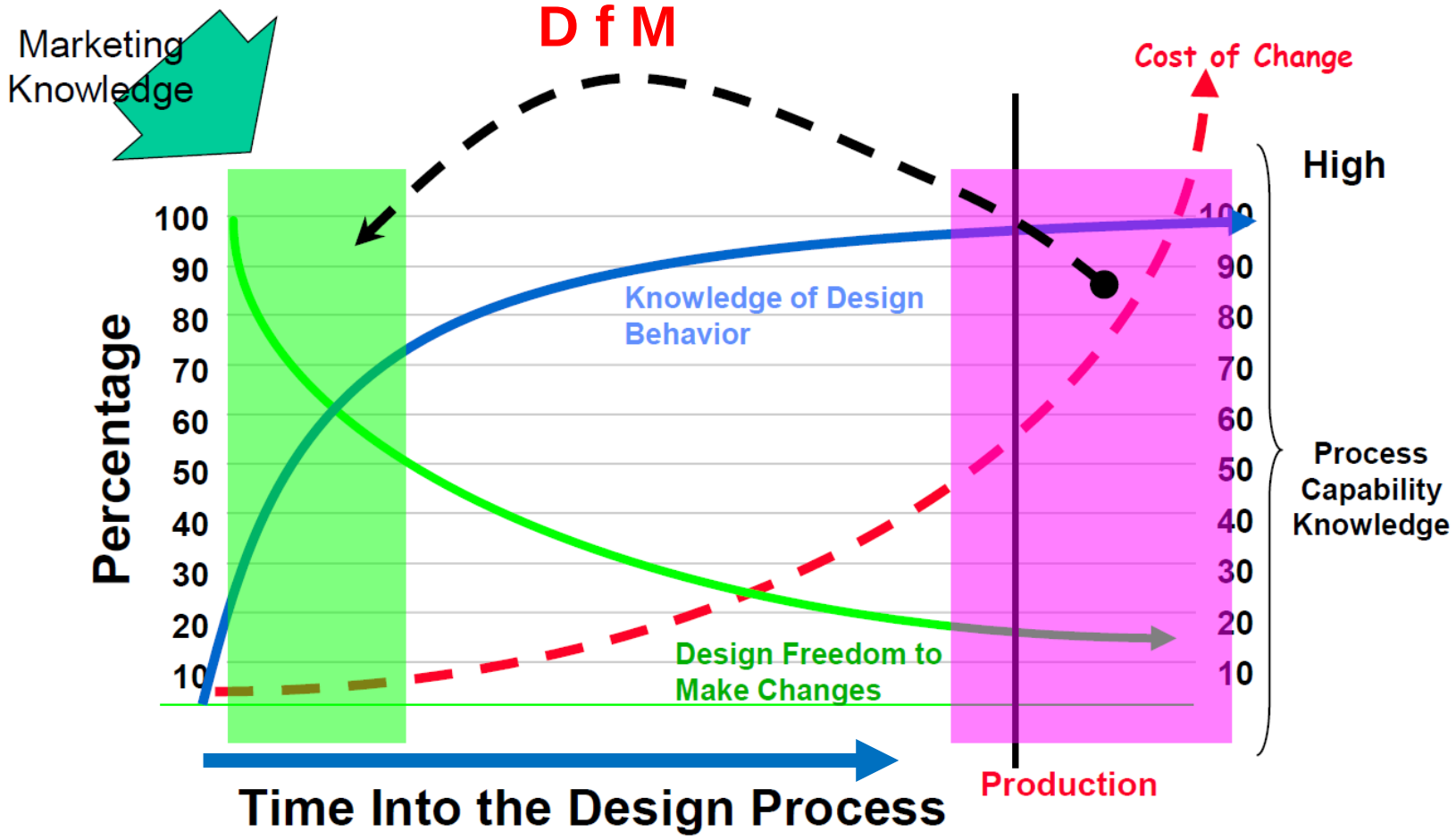
1. Design, Management, and control of the manufacturing process
2. Use clever and intelligent design techniques to reduce the cost of manufacture

Class Question…

- **Who has the most influence over the Price, Quality, and Manufacturing time of products?**



Product Knowledge and Learning



What does DfM mean in practice?

- **A good engineer…**
- **optimises** the product performance to meet the customer specification
- **chooses** the most appropriate (not the cheapest / most expensive) components to meet the required specification and quality
- **can quantify the impact** of the manufacturing process and tolerances on the end product specification and quality
- **can quantify the cost** of sub-standard engineering and the cost of product re-work

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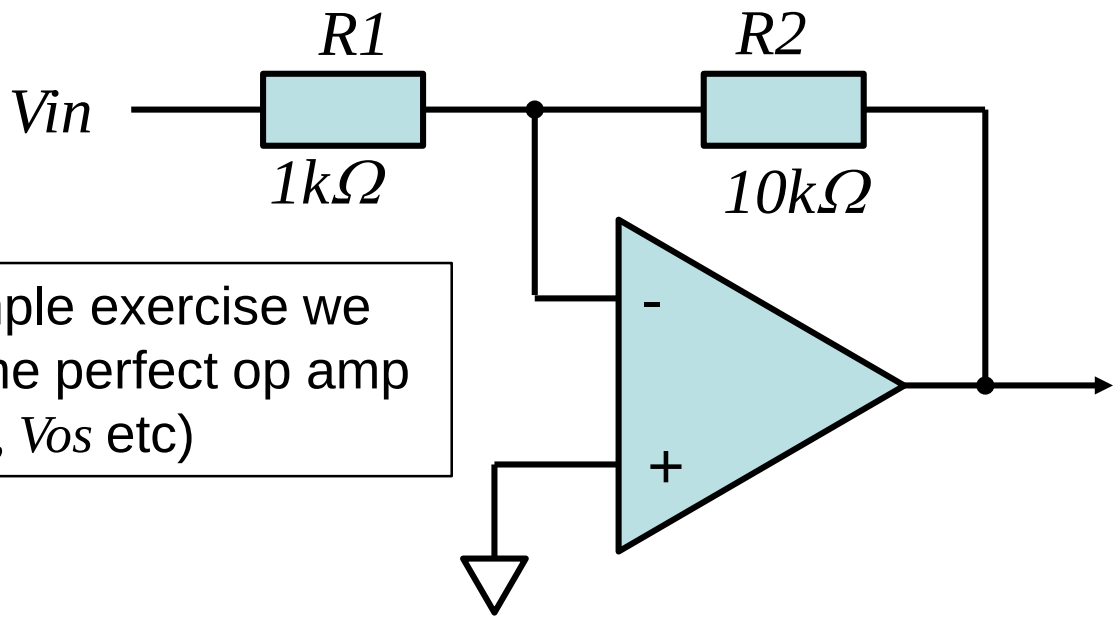
Video

- The design of the Apple Mac Pro

How does this relate to Electronic Engineering?

Consider a very simple amplifier circuit…



$$Vout = \frac{-R2}{R1}$$

In this simple exercise we will assume perfect op amp (no *Ib*, *Ios*, *Vos* etc)

If we use resistors with 10% tolerance, how many amplifiers will have a gain of -10 +/- 0.5 ? (i.e. -10 +/- 5%)

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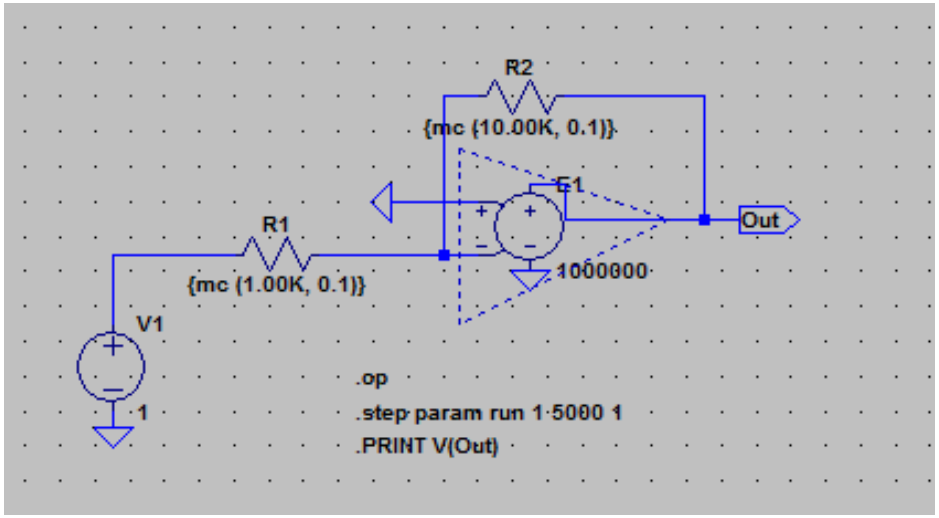
Manual Approach

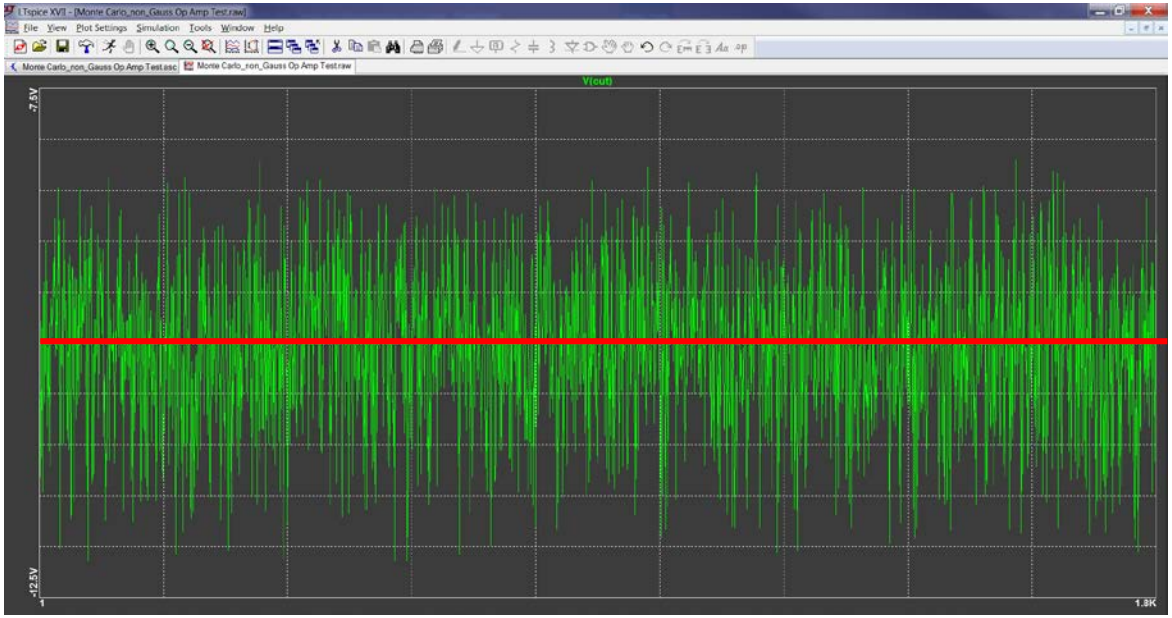
	R1	R2	Gain
Nominal Case	1K	10K	10
Worst Case Low	990	9.90K	10
Worst case High	1.1K	11K	10
‘Other’	990	11k	11.11 X
‘Other’	1.1k	9.9K	9.00 X

- We still don’t know how many will be within +/- 5%

We could ask SPICE…

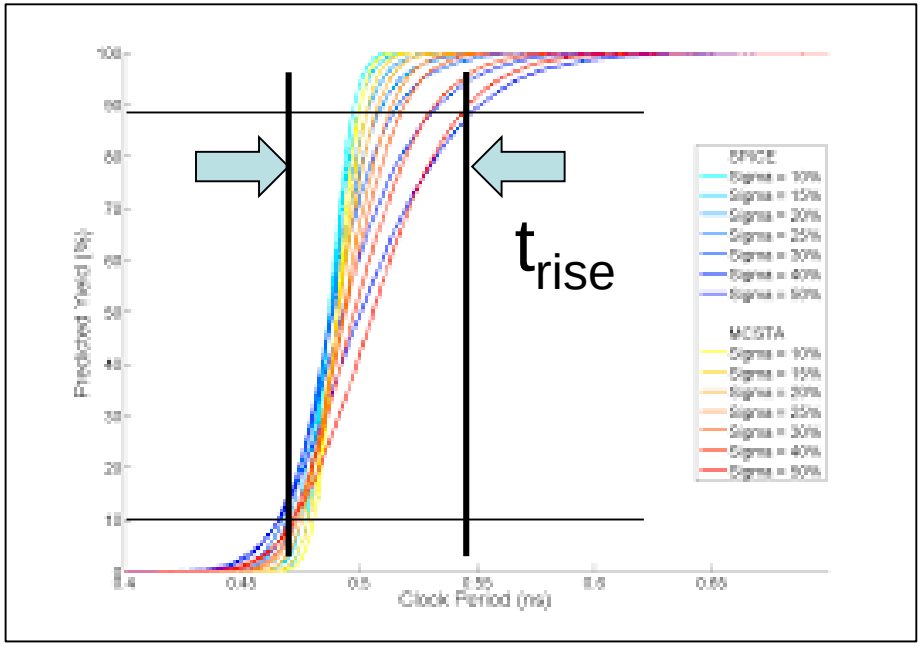
…to run the same simulation many times and change the resistor values…





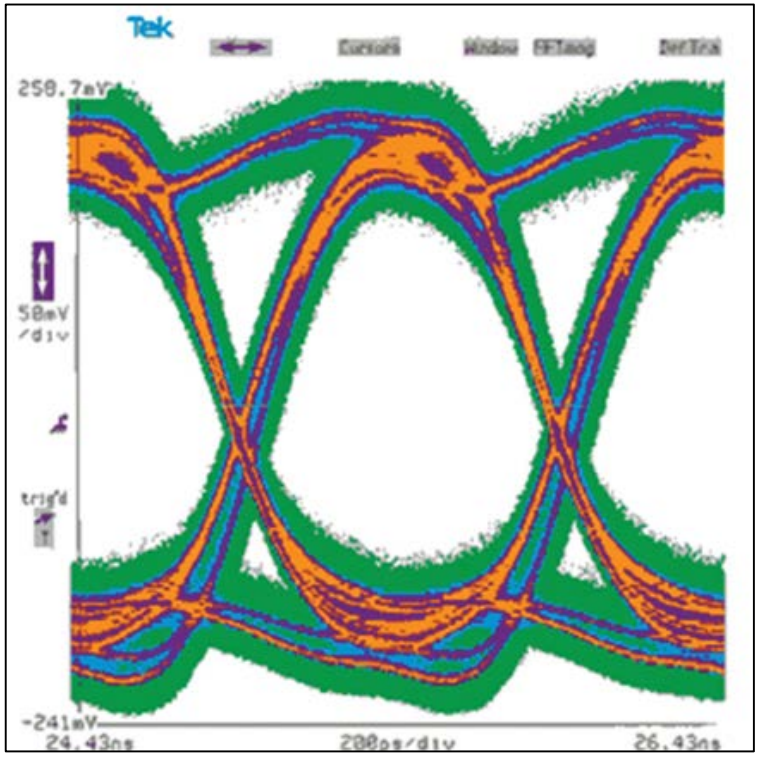
But that still does not tell us how many…

… and digital circuits get equally affected… (you can't escape!!)



Merrit, Asenov et al, 2011

Variations in timing delay through circuit affect fast digital circuits… Memory is especially sensitive



An 'eye' diagram is just a representation of circuit variations

For simplicity (trust me!!) we will stick to a simple amplifier circuit

See Monte Carlo Simulation with statistical sampling; Merret & Zwolinski, 2014

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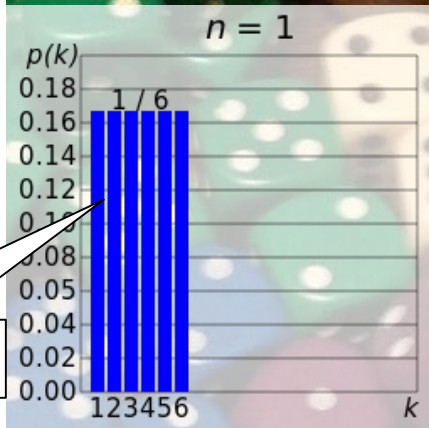
Statistics is our friend…

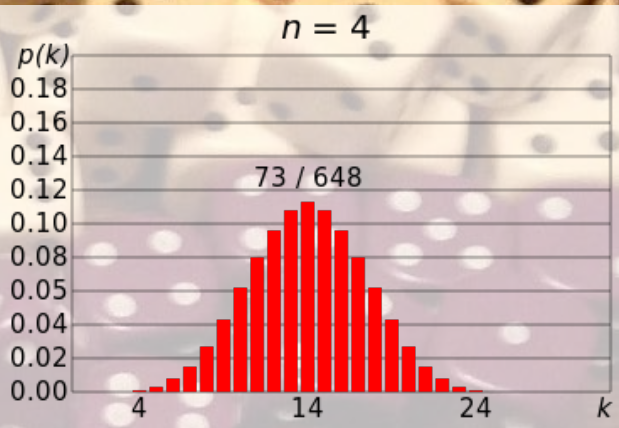
- If we run many simulations (say >5000) we can record the results in a histogram
- If we only have a few parameters (2,3..) we must ensure that each parameter is ‘Normal (Gaussian)’ distributed
- If we have many parameters, we can use the Central Limit Theorem to give a good approximation to normal

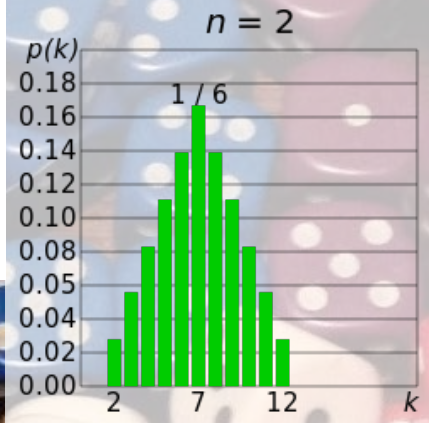
Central Limits Theorem

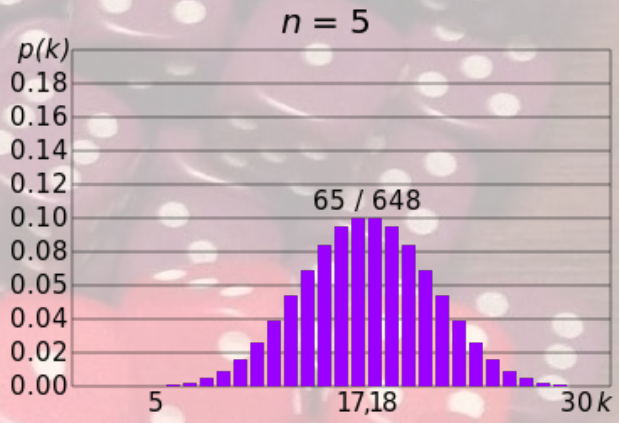
Using simple 6 sides dice, although probability of a single dice is 0.167 and a **Uniform PDF**

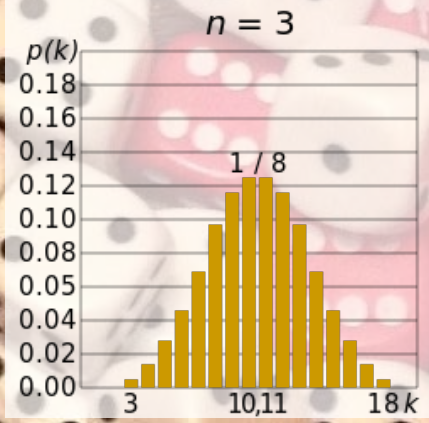
If a number of dice 2,3,4,5 etc are thrown, the distribution of the average score -> a normal distribution

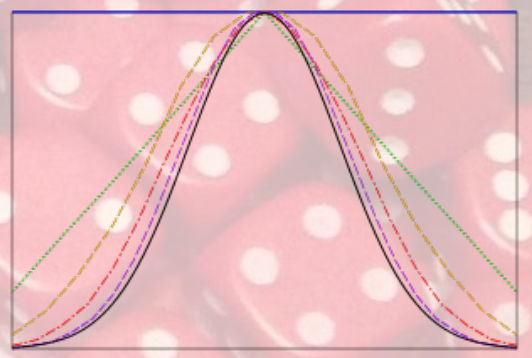




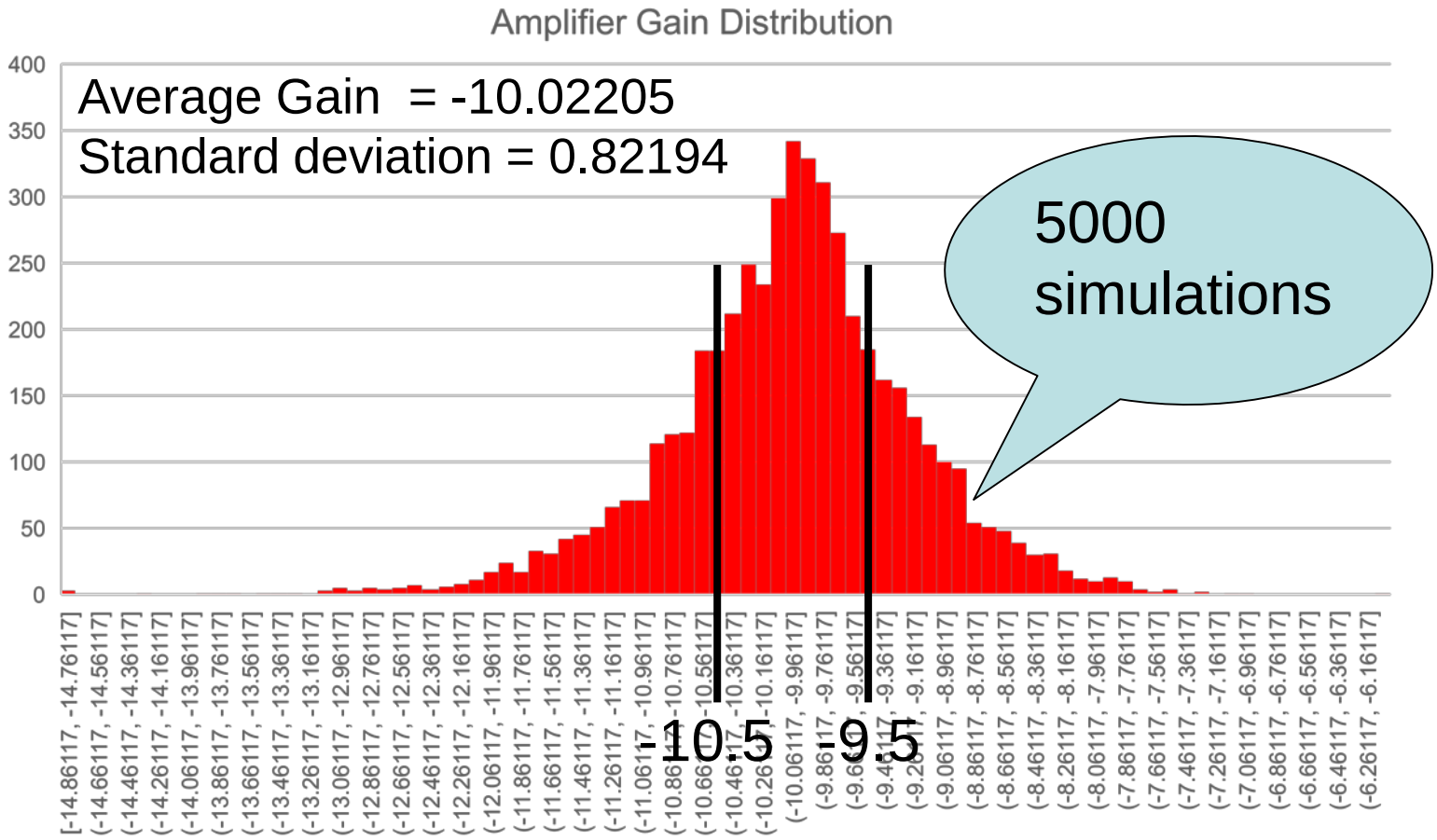




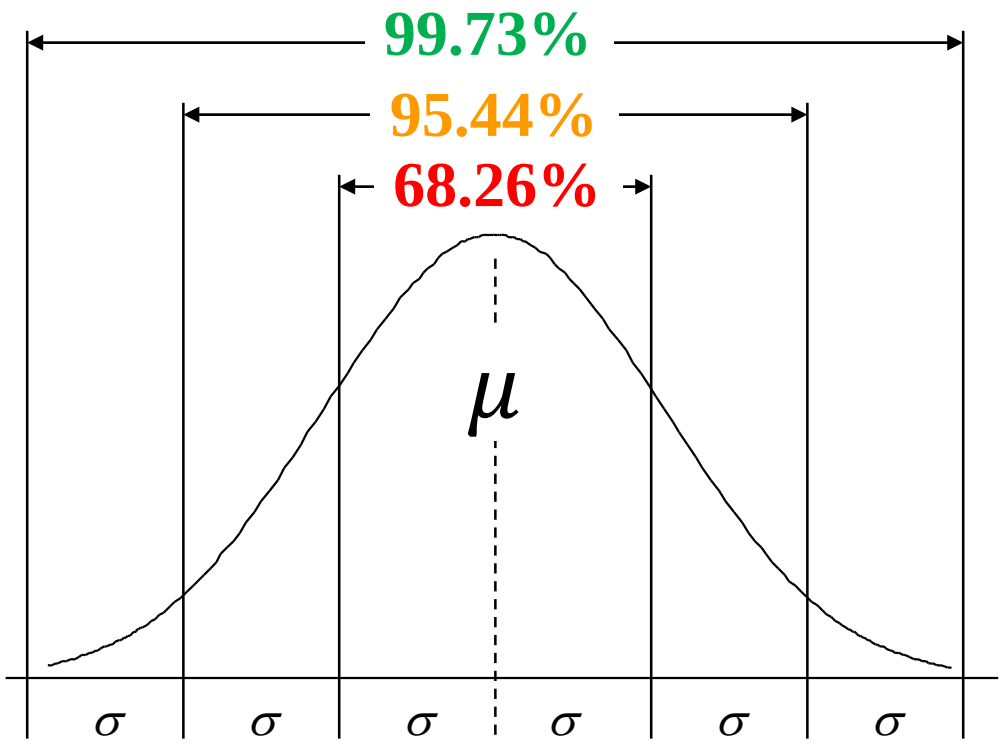




…so how many amplifiers meet the +/- 5% spec?



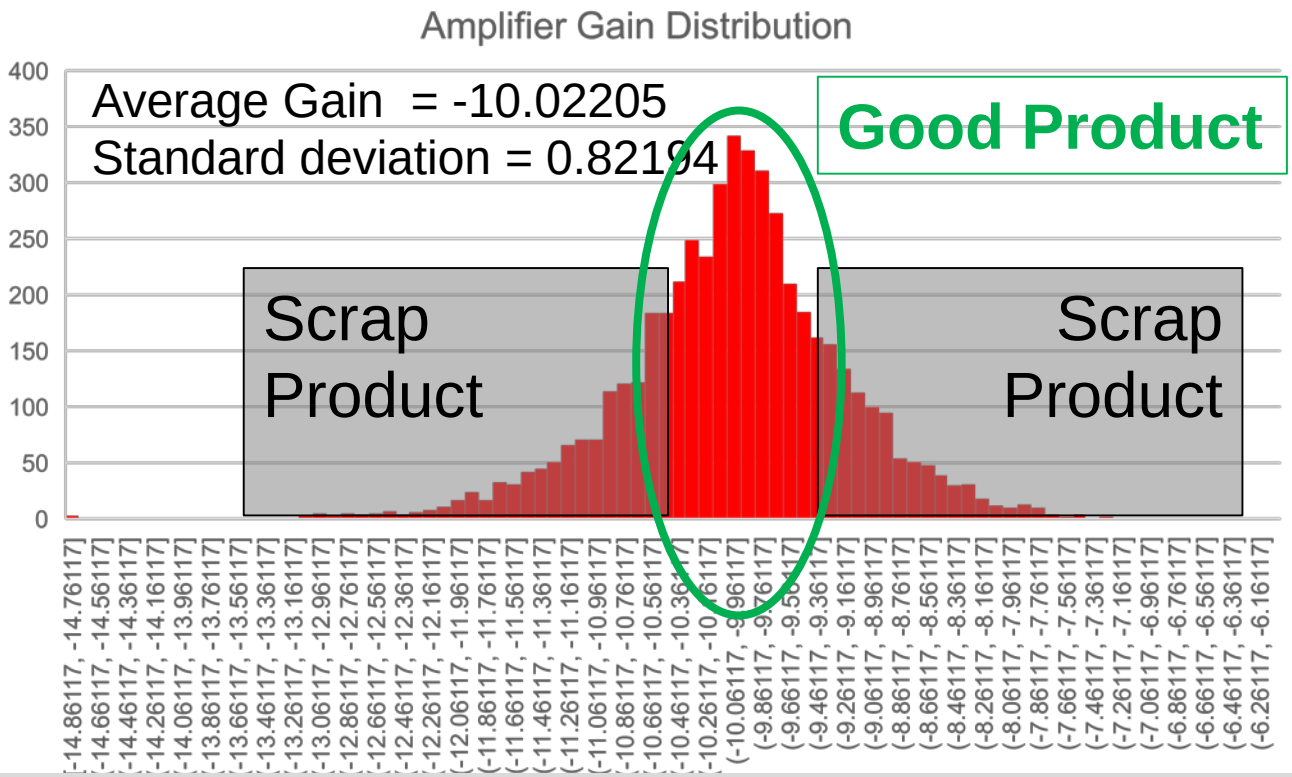
The Normal Distribution



μ = mean
σ = standard deviation
σ^2 = variance

Many things follow a 'Normal' distribution… but not all
(for instance, Ib is not normal [but log (Ib) is…]
*Resistor values **are** normal*

…so how many amplifiers meet the +/- 5% spec?



If spec is +/- 0.5 (9.5 – 10.5)
Then we can calculate we are 0.5 / 0.82
= +/- 0.61 Standard deviations around the mean (-10.02)
From probability tables (or you can count them!) = 45% of circuits
or… You are scrapping 55% of production = $$$$!!!

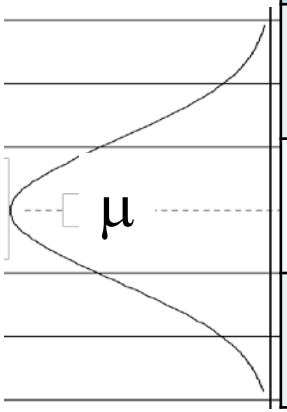
What can you do?

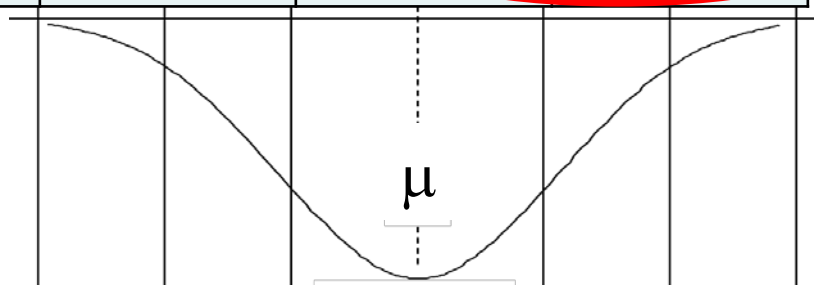
1. Convince the customer that +/- 5% is not required and widen the specification (Sales, Marketing, Applications)
2. Improve you manufacturing control so the ‘spread’ or resistor values does not give you problems (Manufacturing / Production Engineers)
3. Improve your design so you can produce more product inside specification (Design & Development Engineering)
4. Find ‘other’ customers that do not require such high specification (Sales)

In practice: you do all of these !!

Selecting parts (Binning)

Clock / Power	Slow	Nominal	Fast
Low	Long Life Laptop		
Nominal		Standard Product	
High			Desktop Gamers





3 different customers: - just differently specified

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Overclocking CPUs

Professional overclocker Joe “Steponz” Stepongzi carefully pours liquid nitrogen over a running 9th Gen Intel Core i9-9900K processor during an extreme overclocking demonstration Monday, Oct. 8, 2018, at Intel's Fall Desktop Launch in New York City. The i9-9900K has a stock base frequency of 3.6 GHz, but the professional overclockers nearly doubled that to 7.1 GHz on all cores with extreme cooling. (Credit: Intel Corporation)

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Overclocking Tools

- Intel Video

- https://www.intel.co.uk/content/www/uk/en/gaming/overclocking-intel-processors.html

Warning: Altering PC clock or memory frequency and/or voltage may (i) reduce system stability and use life of the system, memory and processor; (ii) cause the processor and other system components to fail; (iii) cause reductions in system performance; (iv) cause additional heat or other damage; and (v) affect system data integrity. Intel assumes no responsibility that the memory, included if used with altered clock frequencies and/or voltages, will be fit for any particular purpose. Check with memory manufacturer for warranty and additional details.

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Summary

- We have looked at the importance of Design for Manufacturing (DfM)
- We have shown the importance of understanding the impact of manufacturing variation on product quality / specifications
- We have shown how to quantify the impact of manufacturing spread on final product quality

- Next lecture
  - How can we establish process capability

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Reading List

- Worst Case Design of Op Amp Circuits: Mancini
- Monte Carlo static timing analysis using statistical sampling; Merrett & Zwolinski (2014)
- Intel Quality Systems Handbook 2014
- Modelling Circuit Performance Variations due to Statistical Variability: Monte Carlo Static Timing Analysis; Merrett, M et al (2011)


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Thank you
谢谢