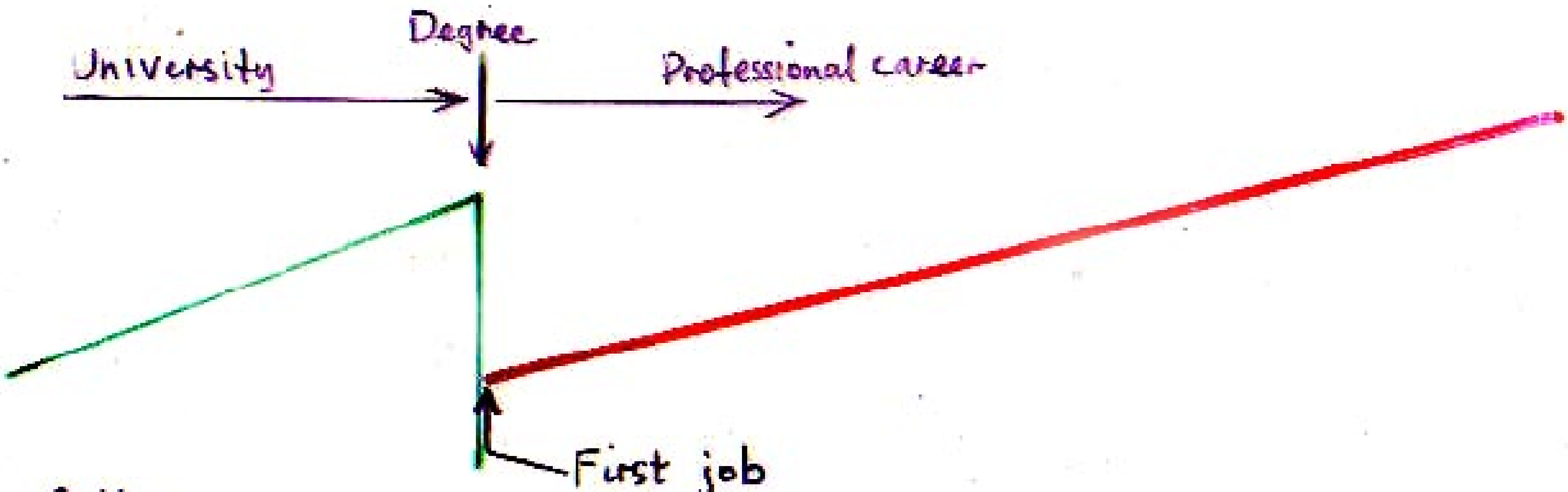
1

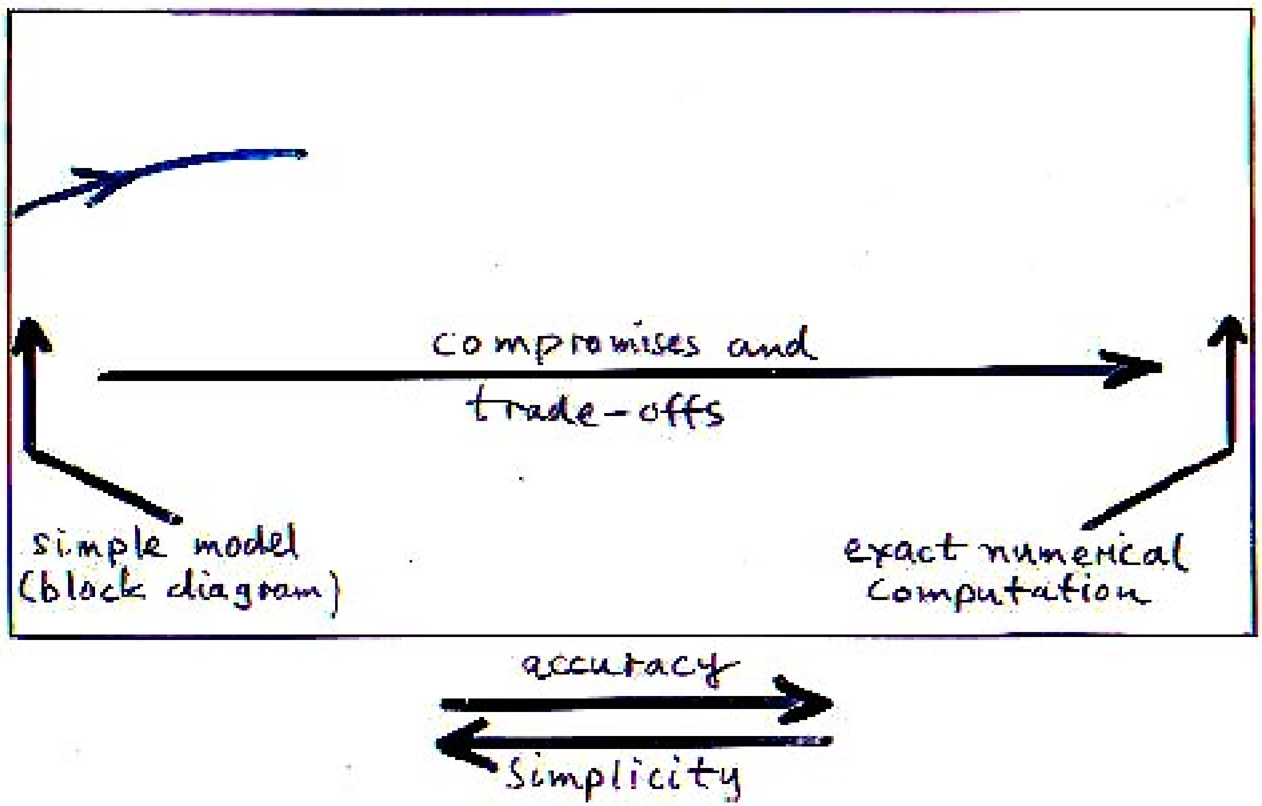
MOTIVATION AND BACKGROUND

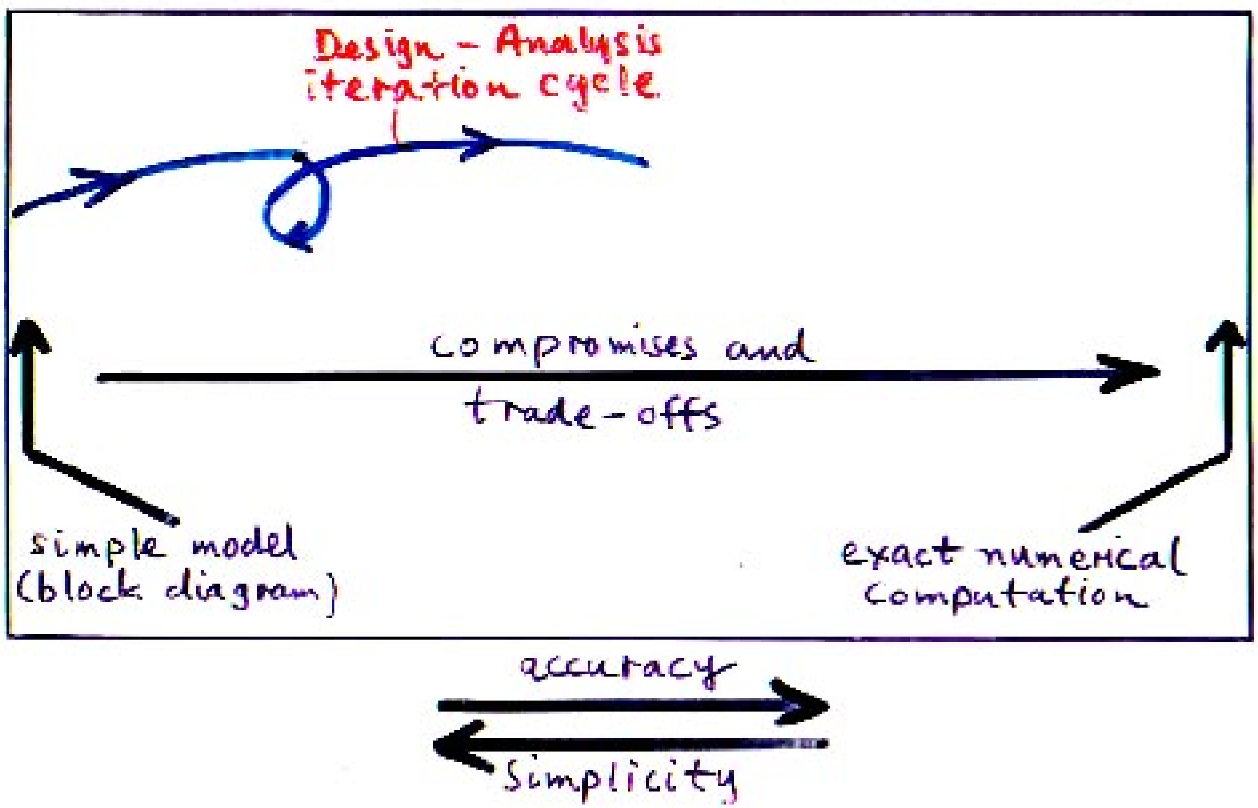


Problem:

New graduate engineers are unable to translate the principles and methods they have learned to the real world.

What can be done?


compromises and
trade-offs
simple model
(block diagram)
exact numerical
computation
accuracy
simplicity


Design - Analysis
iteration cycle
compromises and
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simple model
(block diagram)
exact numerical
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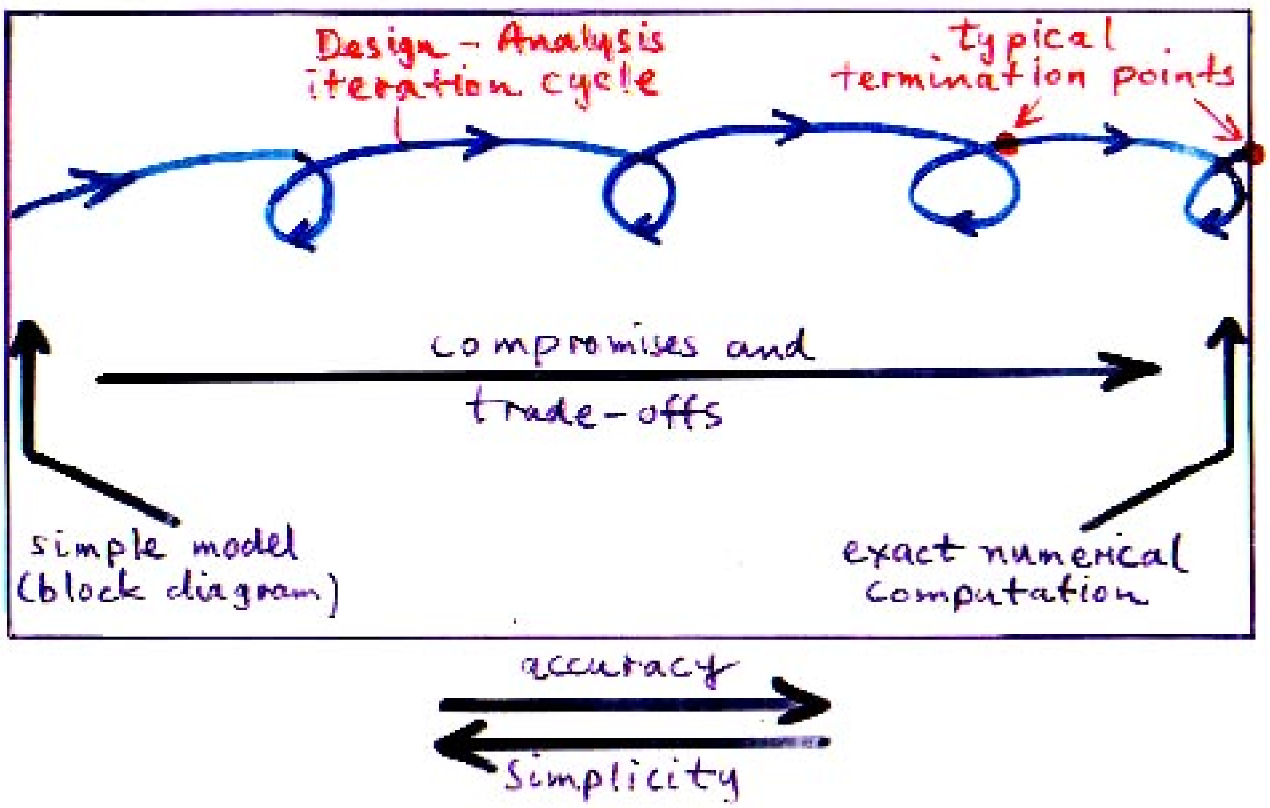
Design - Analysis
iteration cycle
typical
termination points
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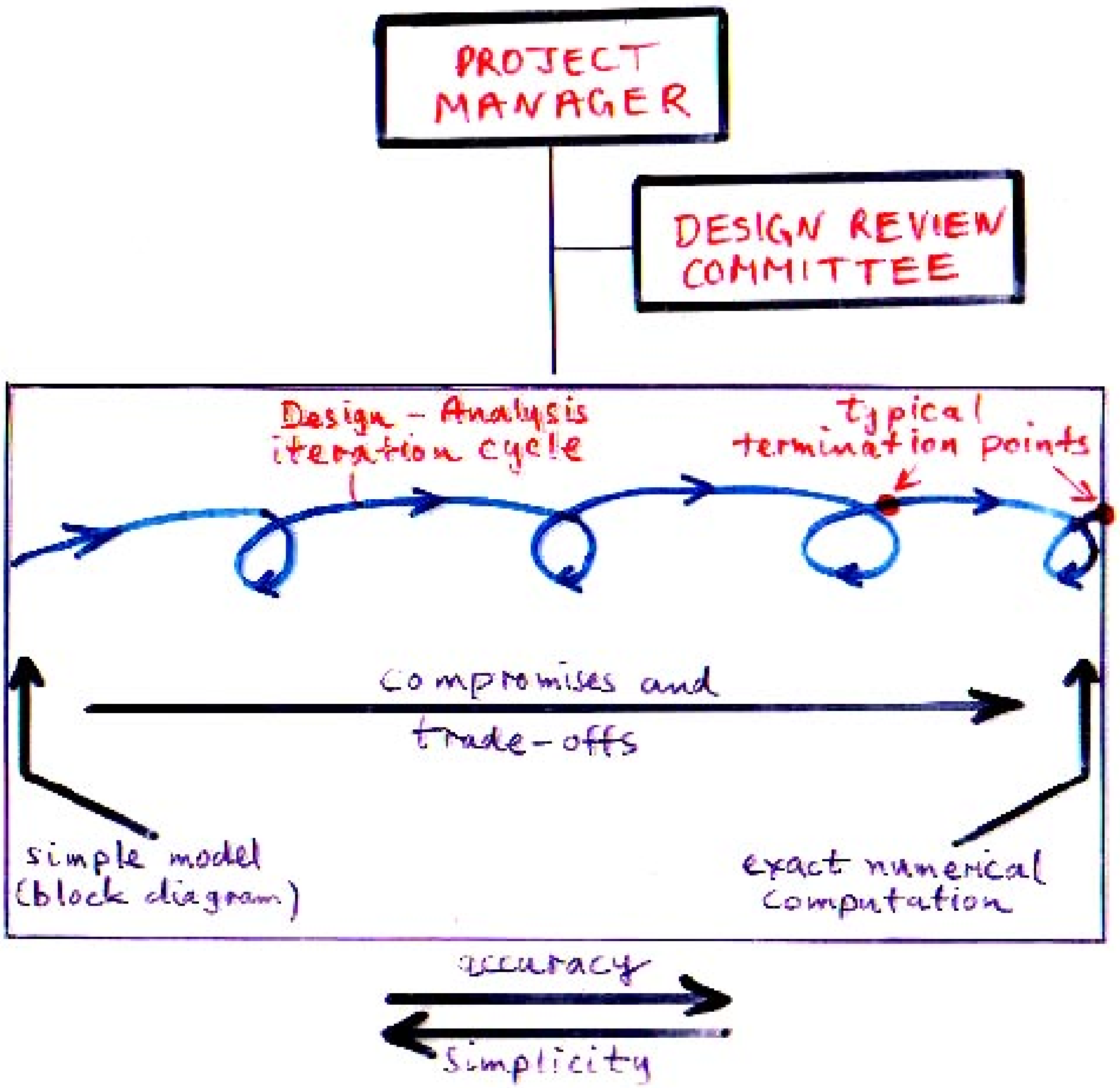
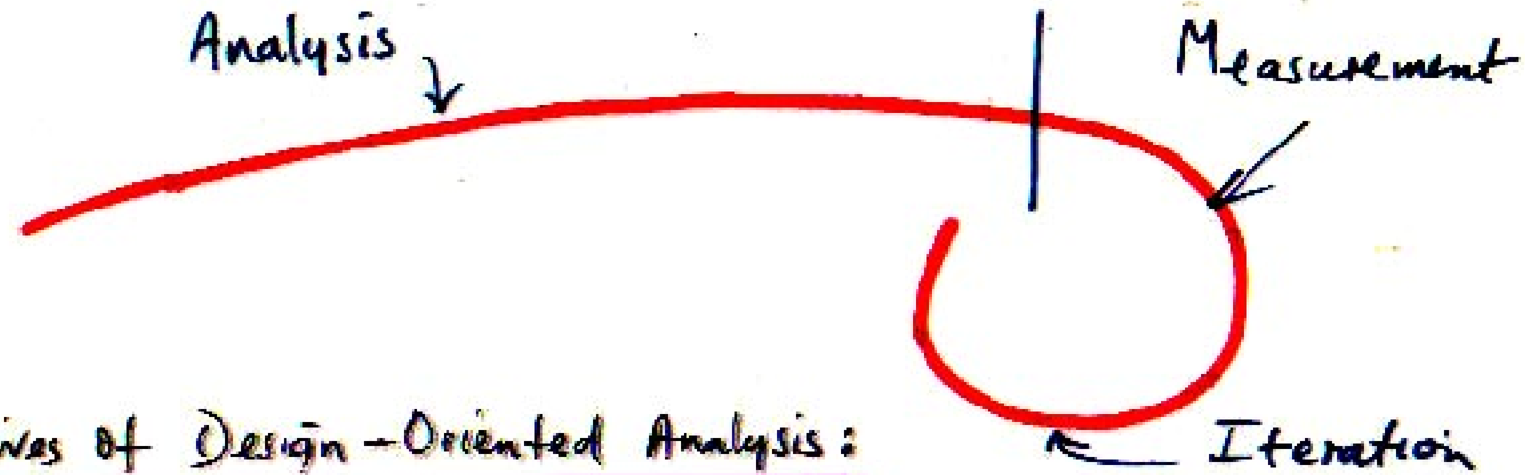

PROJECT MANAGER
DESIGN REVIEW COMMITTEE
Design - Analysis iteration cycle
typical termination points
compromises and trade-offs
simple model (block diagram)
exact numerical computation
accuracy
simplicity

DESIGN-ORIENTED ANALYSIS

DESIGN-ORIENTED ANALYSIS



Objectives of Design-Oriented Analysis:

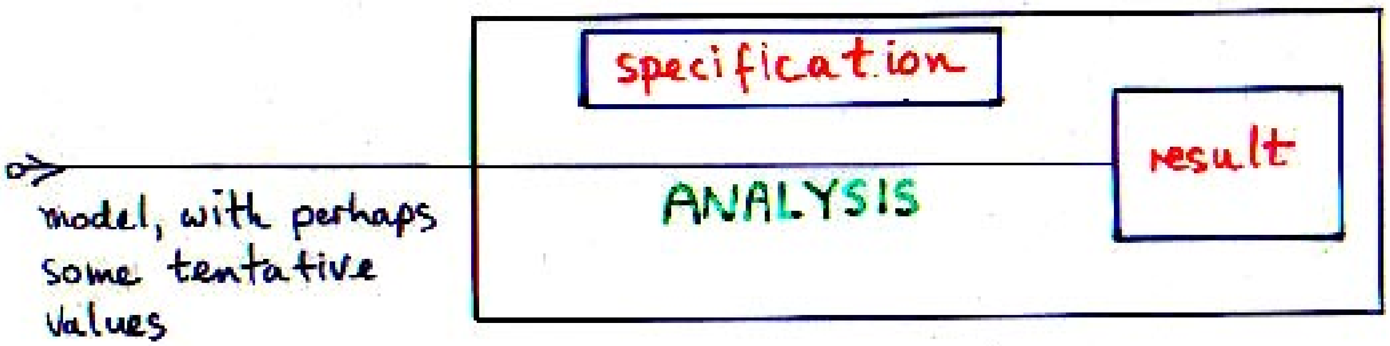
To get an Analytic Answer in a form useful for Design,

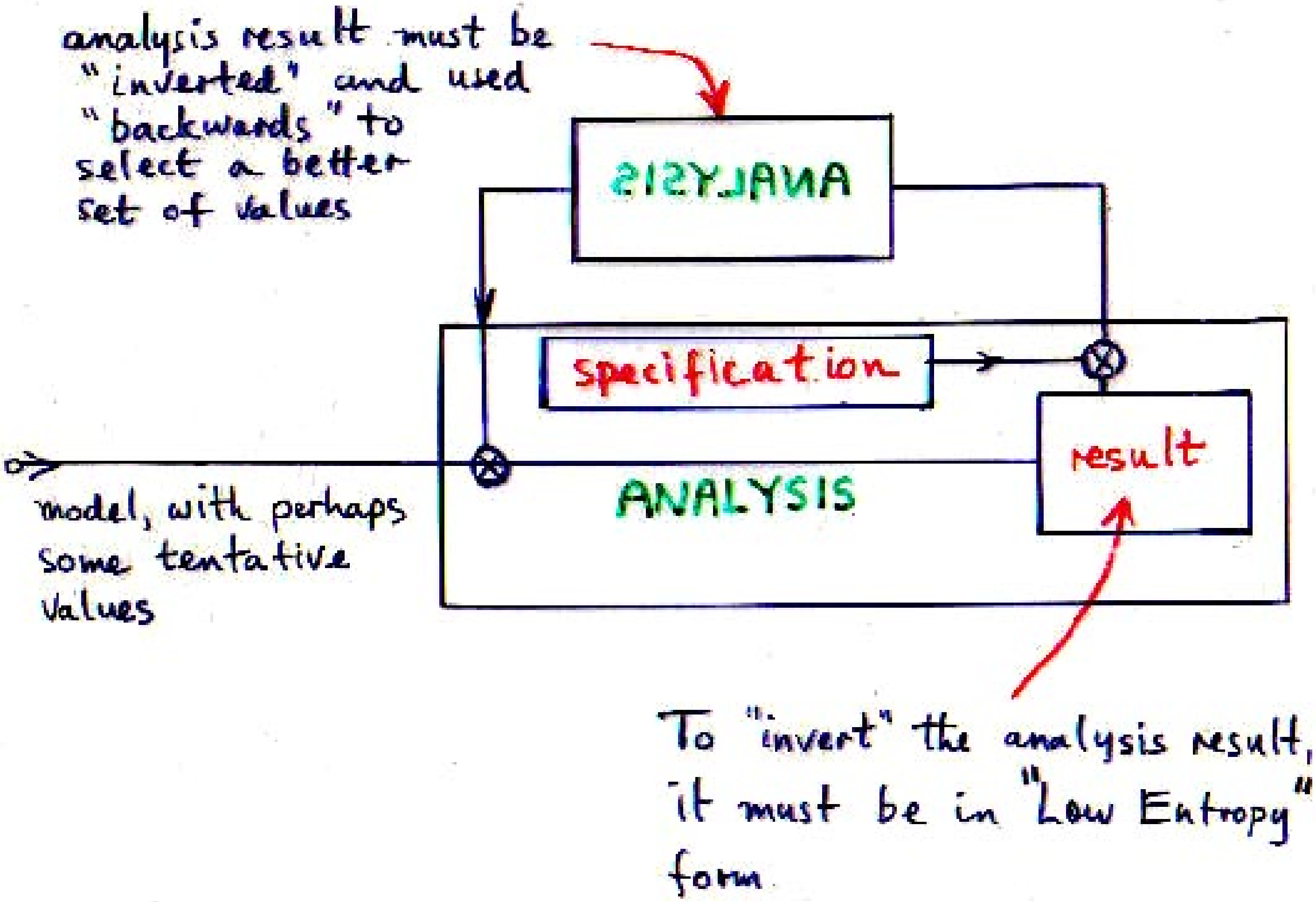
because:

Design is the Reverse of Analysis

because:

The Starting-Point of the Design Problem (the Specification) is the Answer to the Analysis Problem


specification
result
ANALYSIS
model, with perhaps some tentative values


analysis result must be "inverted" and used "backwards" to select a better set of values
ANALYSIS
specification
result
ANALYSIS
model, with perhaps some tentative values
To "invert" the analysis result, it must be in "Low Entropy" form.

Techniques of Design-Oriented Analysis

Lowering the Entropy of an expression
Doing the algebra on the circuit diagram.
Doing the algebra on the graph.
Using inverted poles and zeros.
Using numerical values to justify analytic approximations.
Improved formulas for quadratic roots
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Lowering the Entropy of an Expression

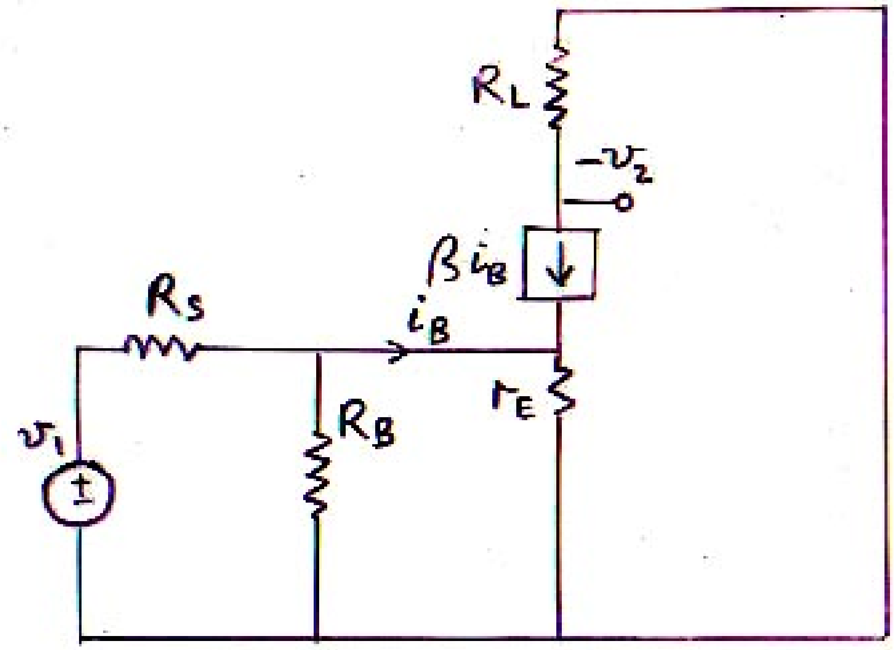
Entropy is a measure of Disorder.

A High-Entropy Expression is one in which the arrangement of terms and element symbols conveys no information other than that obtained by substitution of numbers.

An Objective of Design-Oriented Analysis is to lower the Entropy, by ordering and grouping the terms and elements so that their physical origin and relative importance are apparent. Only in this way can one change the values in an informed manner in order to change the analysis answer (that is, to make it meet the Specification).

Solution for gain:

$$A_m \equiv \frac{v_2}{v_1}$$



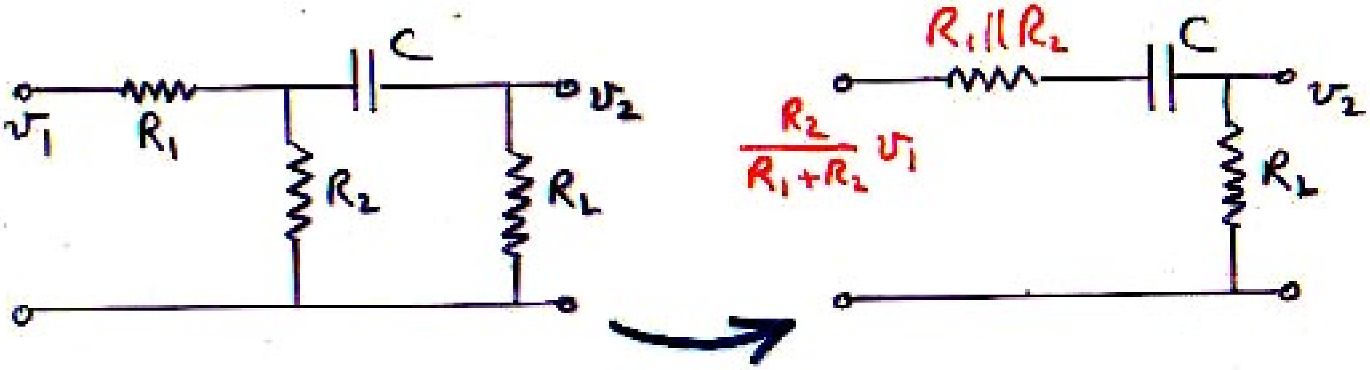
High-entropy form:

$$A_m = \frac{\beta R_B R_L}{(1+\beta) r_E R_S + (1+\beta) r_E R_B + R_S R_B}$$

Low-entropy form:

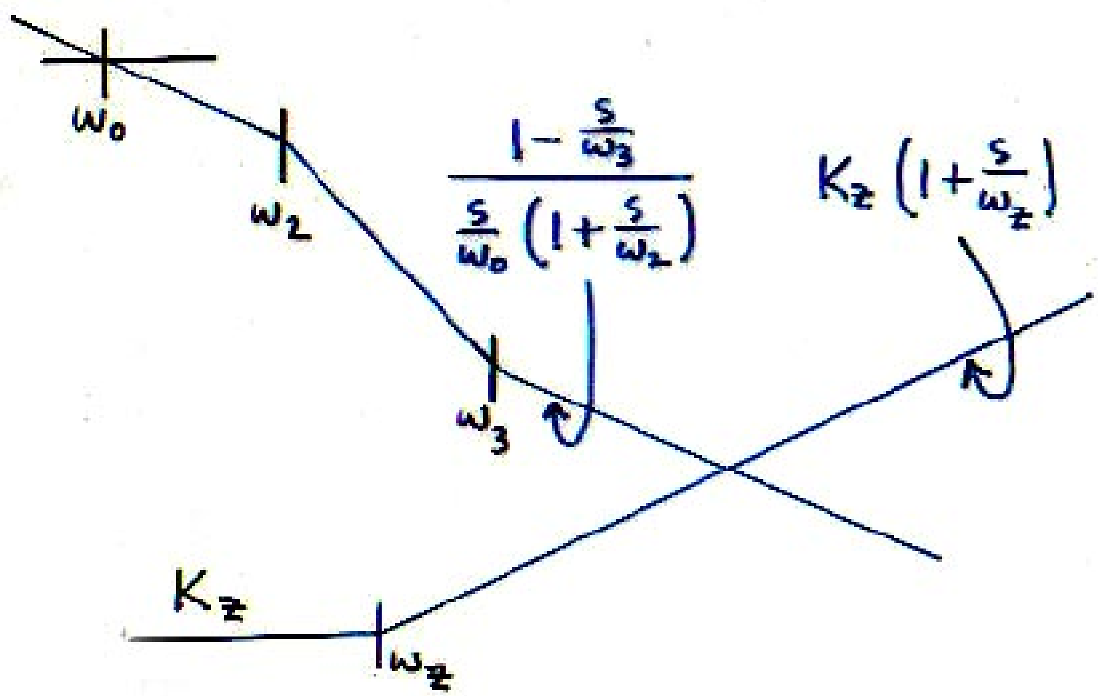
$$A_m = \frac{R_B}{R_S + R_B} \cdot \frac{\alpha R_L}{\underbrace{r_E}_{(1)} + \underbrace{(R_S \| R_B)/(1+\beta)}_{(2)}}$$

Doing the Algebra on the Circuit Diagram



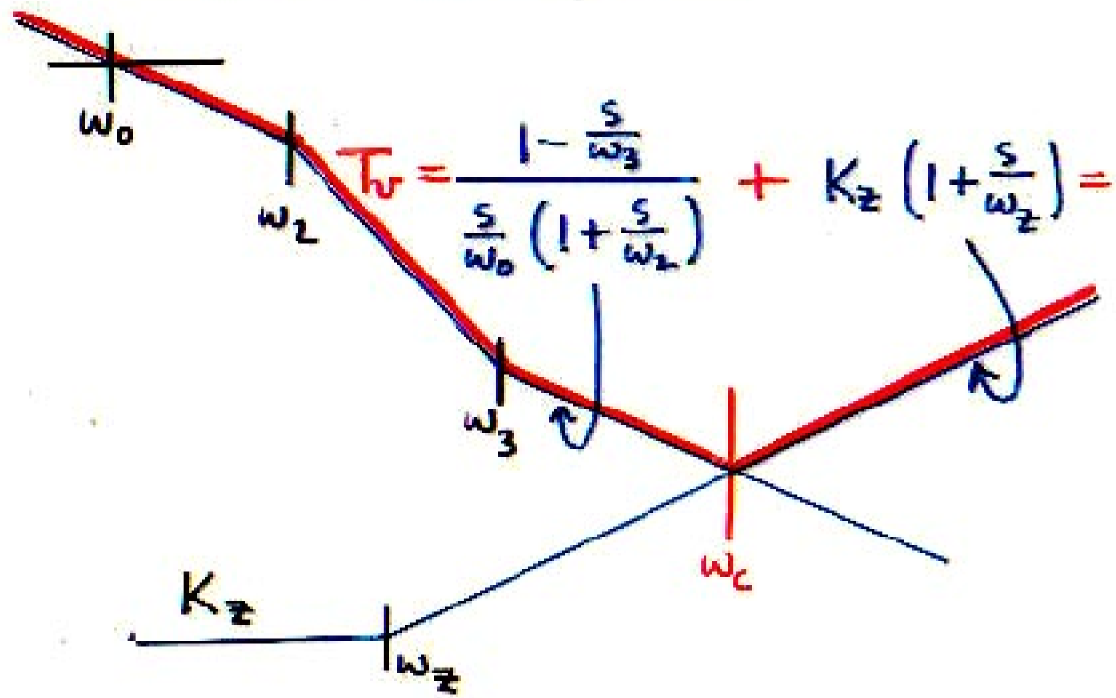
This is how (low-entropy) element groupings arise naturally, through successive loop and node reduction by Thevenin's and Norton's theorems.

Doing the algebra on the graph

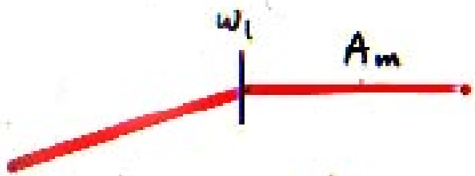


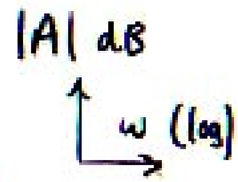
Doing the algebra on the graph

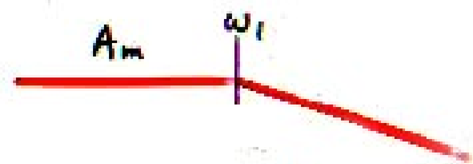
$$T_v = \frac{1-\frac{s}{\omega_3}}{\frac{s}{\omega_0}\left(1+\frac{s}{\omega_2}\right)} + K_z\left(1+\frac{s}{\omega_z}\right) = \frac{\left(1-\frac{s}{\omega_3}\right)\left(1-\frac{s}{\omega_c}\right)\left(1+\frac{s}{\omega_c}\right)}{\frac{s}{\omega_0}\left(1+\frac{s}{\omega_2}\right)}$$



Normal and inverted poles and zeros:

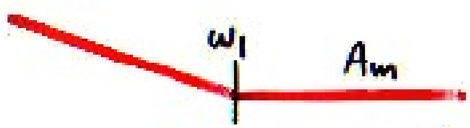






$$A = A_m \frac{1}{\left(1+\frac{\omega_1}{s}\right)}$$ ← inverted pole

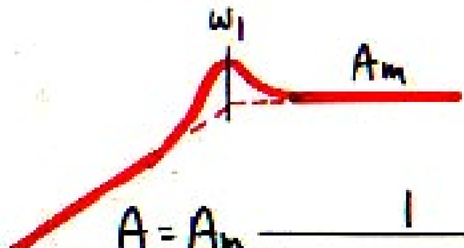
$$A = A_m \frac{1}{\left(1+\frac{s}{\omega_1}\right)}$$ ← normal pole



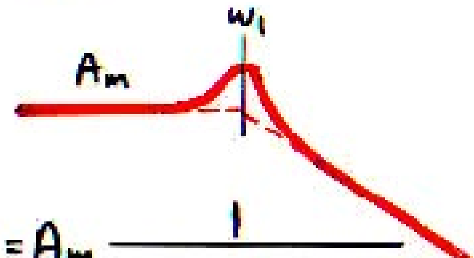
$$A = A_m\left(1+\frac{\omega_1}{s}\right)$$ ← inverted zero

$$A = A_m\left(1+\frac{s}{\omega_1}\right)$$ ← normal zero

Quadratic normal and inverted poles and zeros:

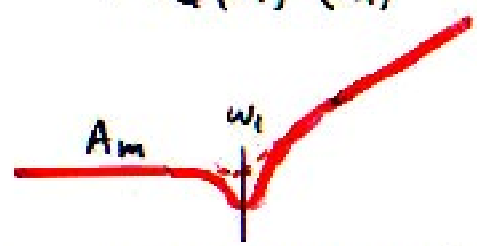


$$A = A_m \frac{1}{1 + \frac{1}{Q}\left(\frac{\omega_1}{s}\right) + \left(\frac{\omega_1}{s}\right)^2}$$



$$A = A_m \frac{1}{1 + \frac{1}{Q}\left(\frac{s}{\omega_1}\right) + \left(\frac{s}{\omega_1}\right)^2}$$

$$A = A_m \left[1 + \frac{1}{Q}\left(\frac{\omega_1}{s}\right) + \left(\frac{\omega_1}{s}\right)^2\right]$$

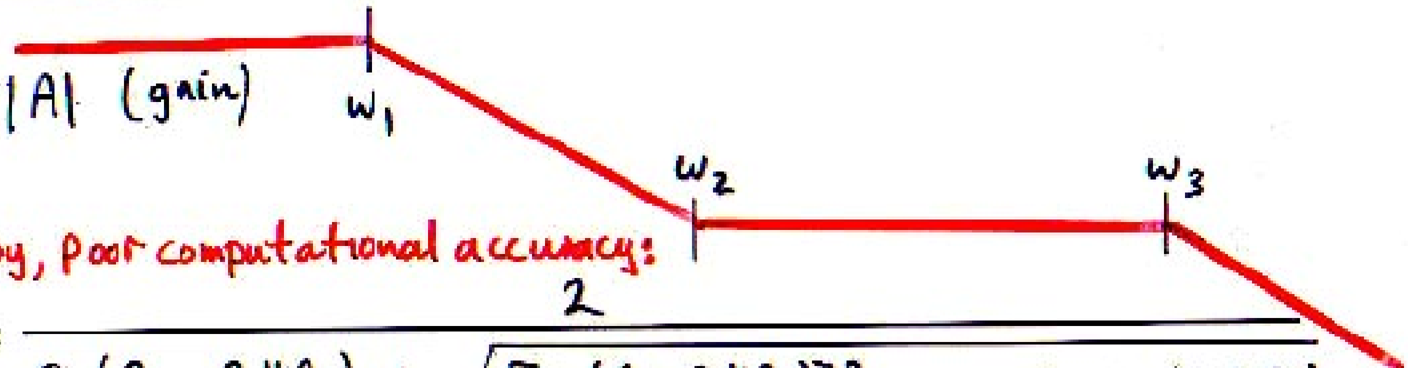


$$A = A_m \left[1 + \frac{1}{Q}\left(\frac{s}{\omega_1}\right) + \left(\frac{s}{\omega_1}\right)^2\right]$$

Use of numerical values to justify analytic approximations

$$A = \frac{R_L}{R_1 + R_L} \; \frac{1 + C_1 R_2 s}{1 + [C_1(R_2 + R_1 \| R_L) + \cancel{C_2(R_1 \| R_L)}]s + [C_1 C_2 R_2 (R_1 \| R_L)]s^2}$$

Improved formulas for quadratic roots:



High entropy, poor computational accuracy:

$$\omega_{1,3} = \frac{2}{C_1(R_2 + R_1 \| R_L) \pm \sqrt{[C_1(R_2 + R_1 \| R_L)]^2 - 4 C_1 C_2 R_2 (R_1 \| R_L)}}$$

Low entropy, superior computational accuracy:

$$\omega_1 = \frac{1}{C_1(R_2 + R_1 \| R_L)} \qquad \omega_3 = \frac{1}{C_2(R_1 \| R_2 \| R_L)}$$

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Input/Output Impedance Theorem

$$Z_i = \frac{Z_s A|_{Z_s \to \infty}}{A|_{Z_s \to 0}} \qquad Z_o = \frac{A|_{Z_L \to \infty}}{\frac{A}{Z_L}\Big|_{Z_L \to 0}}$$

Feedback Theorem

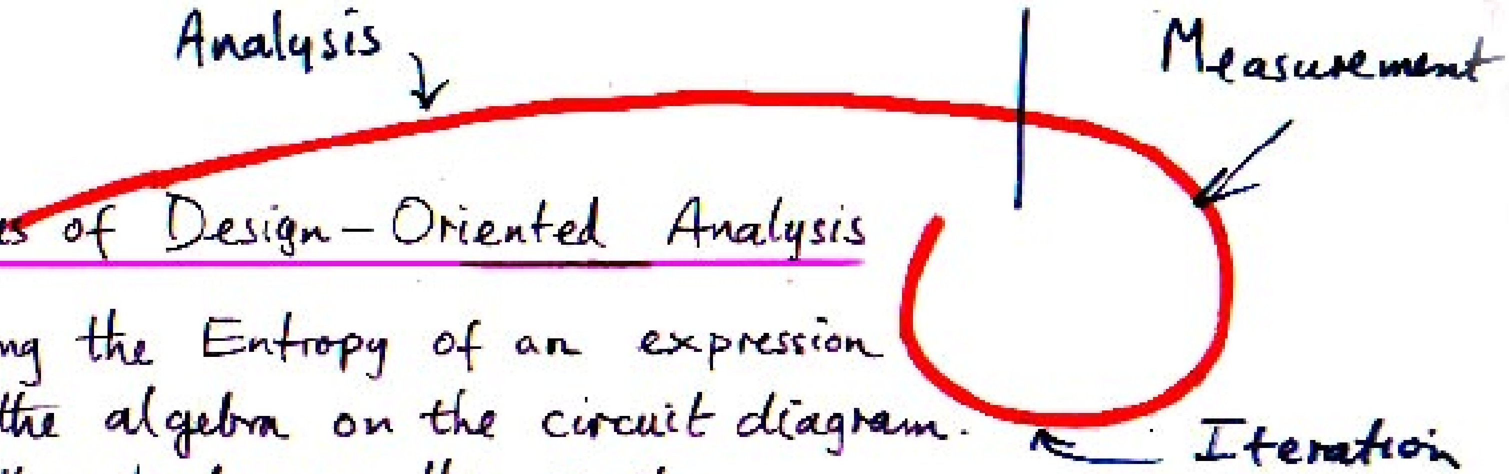
design specification

$$G = \frac{A}{1+AK} = \frac{1}{K}\,\frac{AK}{1+AK} \equiv G_\infty \frac{T}{1+T}$$

discrepancy factor

Avoids having to find A by opening the loop.

DESIGN-ORIENTED ANALYSIS



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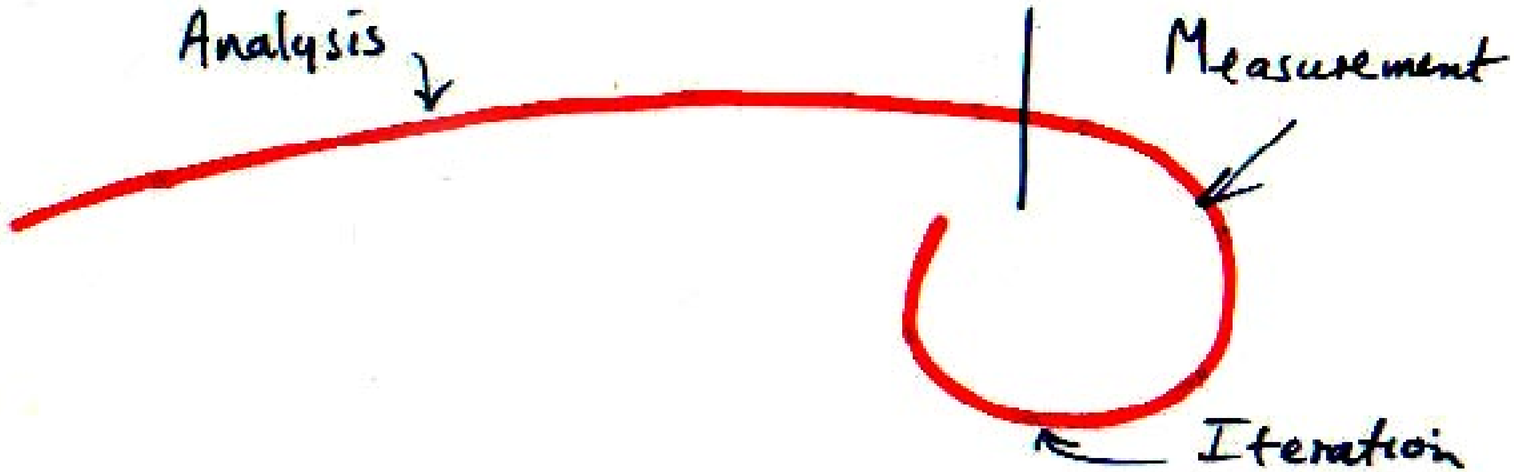

Iteration

Null Double Injection leads to:

Extra Element Theorem (EET)

$$A\big|_{Z} = A\big|_{Z=\infty} \frac{1 + \frac{Z_n}{Z}}{1 + \frac{Z_d}{Z}}$$

Also useful for breaking the analysis of a complicated circuit into sequential easier pieces, as is the:

Two Extra Element theorem (2EET)