Computer-Aided Engineering

Adapted from

C.N.Nightingle and J.K.Fidler ., Computer-Aided Circuit and System Design.,U.K +IEEE papers

Lecture 2

Prof .Dr.Eng.ARN

Coefficient Matching Error Function

The use of coefficient matching approach was first reported in 1965, and since then has been studied by many authors. The error function is formulated by obtaining the coefficients of a desired network function and comparing these with the coefficients stored as specification. The element values of the network are to be adjusted by iterative optimization until the error is reduced to zero (or near-zero), the coefficients of the realized network function match the specified coefficients.

The algorithm of the coefficient matching method can be formulated as follows:

$$H_s(s) = \frac{\sum_{i=0}^{n} a_{si} s^i}{\sum_{i=0}^{m} b_{si} s^i}$$

where Hs (s) is the specified voltage transfer funct

$$H_r(s) = \frac{\sum_{i=0}^{n} a_{ri} s^i}{\sum_{i=0}^{m} b_{ri} s^i}$$

Coefficient Matching Error Function

- where $H_r(s)$ is the realized VTF. The numerator and denominator coefficients (i.e. a_{ri} . and b_{ri} .) are functions of the element values. Also, it can be shown that each coefficient is no more than a first order function of the given element . Bode shows that lumped linear network function coefficients are multi-linear functions of the network elements and a full proof of this property is to be presented.

The realization of H (s) is obtained when f=0 where f is equal to

$$f = \sum_{i=0}^{m} (b_{si} - b_{ri})^2 + \sum_{i=0}^{n} (a_{si} - a_{ri})^2$$

The a_{ri} . and b_{ri} can be written in the following form using the bi-linear characteristic of coefficients:-

$$a_{ri} = C_{ij} \underline{x}_j + K_{ij}$$

and similarly

$$b_{ri} = C'_{ij} \underline{x}_j + K'_{ij}$$

Coefficient Matching Error Function

where x_j. is the j_{th} element value and C_{ij} , C'_{ij} and K_{ij} , K'_{ij} **<u>are multi-linear functions of other network elements</u>**. Substituting the values of a_{ri} and b_{ri} from above equations yields :-

$$f = \sum_{i=0}^{m} [b_{si} - (C'_{ij} \underline{x}_j + K'_{ij})]^2 + \sum_{i=0}^{n} [a_{si} - (C_{ij} \underline{x}_j + K_{ij})]^2$$

Coefficient Matching Error Function

In gradient optimization methods the values of the first partial Derivatives are required. Therefore, df/dxj has to be evaluated for all elements. This can be done by differentiating bilinear relationship with respect to xj. yielding:-

$$\frac{\partial f}{\partial x_j} = 2\left[\sum_{i=0}^{m} C'_{ij}\,(b_{ri} - b_{si}) + \sum_{i=0}^{n} C_{ij}(a_{ri} - a_{si})\right]$$

Coefficient Matching Error Function

It can be seen from the above equation that the coefficient matching objective function is quadratic in x_j . This indicates that there is a unique turning point which represents the minimum parallel to the x_j axis. Also

$$C'_{ij} \quad \text{and} \quad C_{ij}$$

have to be defined to locate the position of the minimum. This can be obtained easily by simple perturbation Δx **to** x_j **in equation as follows:**

Coefficient Matching Error Function

$$a'_{ri} = C_{ij}(x_j + \Delta x_j) + K_{ij}$$

$$= C_{ij}\, x_j + C_{ij}\, \Delta x_j + K_{ij}$$

$$= a_{ri} + C_{ij}\, \Delta x_j$$

Coefficient Matching Error Function

Now C_{ij} can be found from equation (3.58) as:-

$$C_{ij} = \frac{a'_{ri} - a_{ri}}{\Delta x_j}$$

and similarly

$$C'_{ij} = \frac{b'_{ri} - b_{ri}}{\Delta x_j}$$

Coefficient Matching Error Function

By allowing Δxj to equal 1 , then the practical partial derivatives of the numerator and denominator coefficients can be found easily as a difference between those coefficients, which have been incremented and current coefficients of the voltage transfer functions as shown in the following equations:-

$$C_{ij} = a'_{ri} - a_{ri}$$

and

$$C'_{ij} = b'_{ri} - b_{ri}$$

for the numerator and denominator coefficients respectively.

Above equations provide an exact evaluation of the numerator and denominator coefficient partial derivatives. These derivatives are required for the calculation of the Jacobian matrix in least squares optimization method and also for the estimation of amplitude VTF sensitivity.

It has been shown by several papers that coefficient matching approach provides a rapid and efficient optimization of a very wide range of electrical networks. The coefficient matching method is a natural first choice ,provided that the approximation problem can be simplified by selecting acceptable standard network functions The advantages of the method are :

(a) If the coefficient objective function can be minimized to zero or near-zero solution (f <= 10E-10), then an exact match is possible between the realized and specified frequency responses.

(b) The error space is simple and can lead to quicker location of the minimum .

(c) Considerable saving in network analyses compared with amplitude matching and the CPU time is low.

The disadvantage of the coefficient matching approach is the accuracy problem , Therefore, it is necessary to provide polynomial coefficients which are accurate to many significant figures. This minimizes the effect of accumulated rounding errors due to limited word length employed in the computer.

Introduction

OPTIMIZATION-BASED

COMPUTER-AIDED CIRCUIT DESIGN

OPTIMIZATION-BASED COMPUTER-AIDED CIRCUIT DESIGN

The word 'optimum' generally means 'best', 'minimum' or 'maximum value' of some function. In computer-aided design, for example, optimization is used to determine parameter values, of a given particular system configuration, which satisfy a set of specifications or optimize a performance function.

OPTIMIZATION-BASED COMPUTER-AIDED CIRCUIT DESIGN

The necessity for the design by analysis approach simply reflects the complexity of the design problems presented to the modern engineer. This can be simplified by using the high-speed digital computer as a main tool. The computer nowadays is an almost indispensable tool in the design process as an analyzer, a mathematical modeler, a simulator, and an optimizer of electrical networks .

Introduction

Filter Design and Digital Computer

Digital computers were used probably for the first time in engineering design, in the area of conventional LCR-filter synthesis .

Filter Design and Digital Computer

The digital computer provides a very powerful and convenient tool for assisting the design engineer in the design process, since it allows the practical application of many of the sophisticated and complicated filters, which have been known for some time.

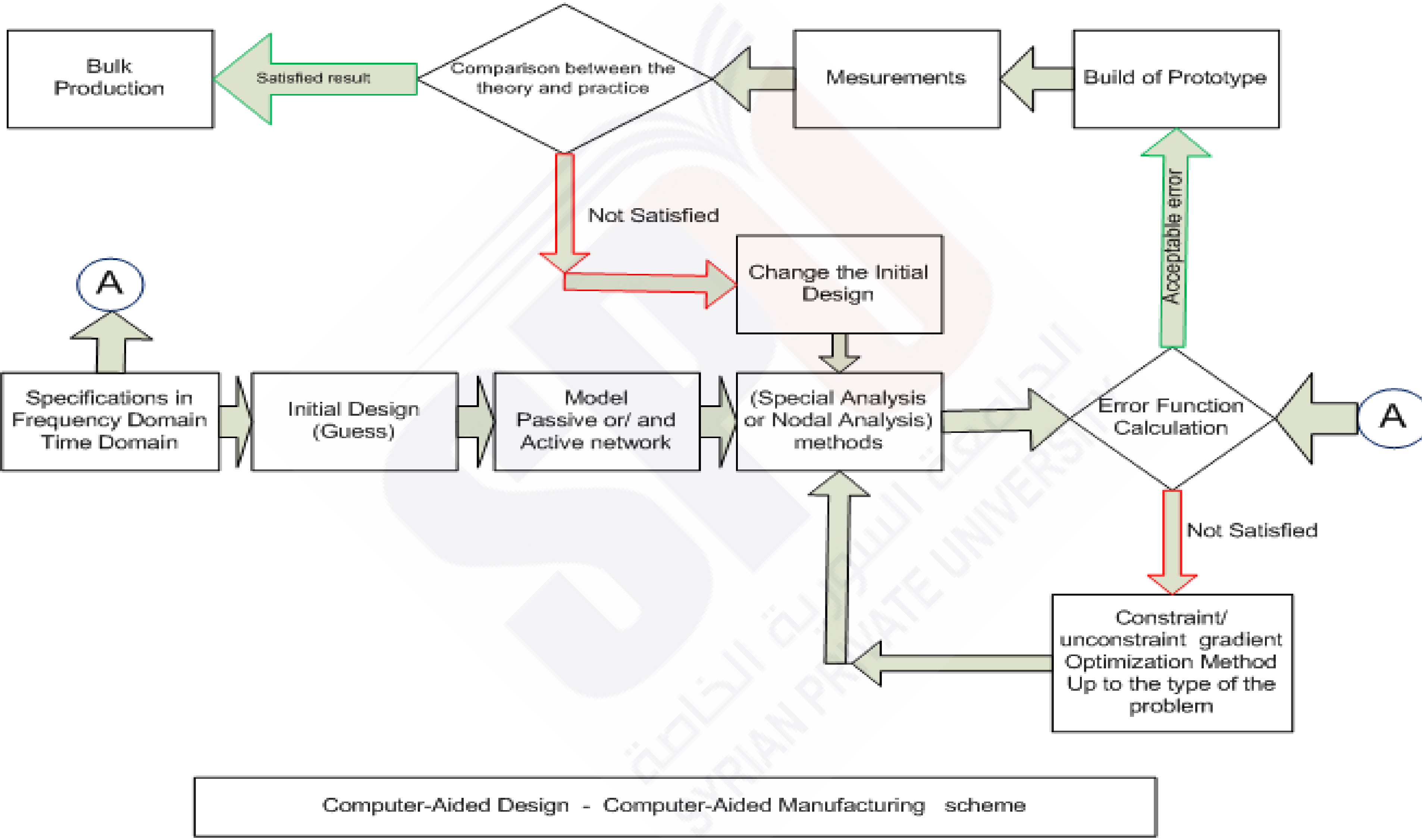
Filter Design and Digital Computer

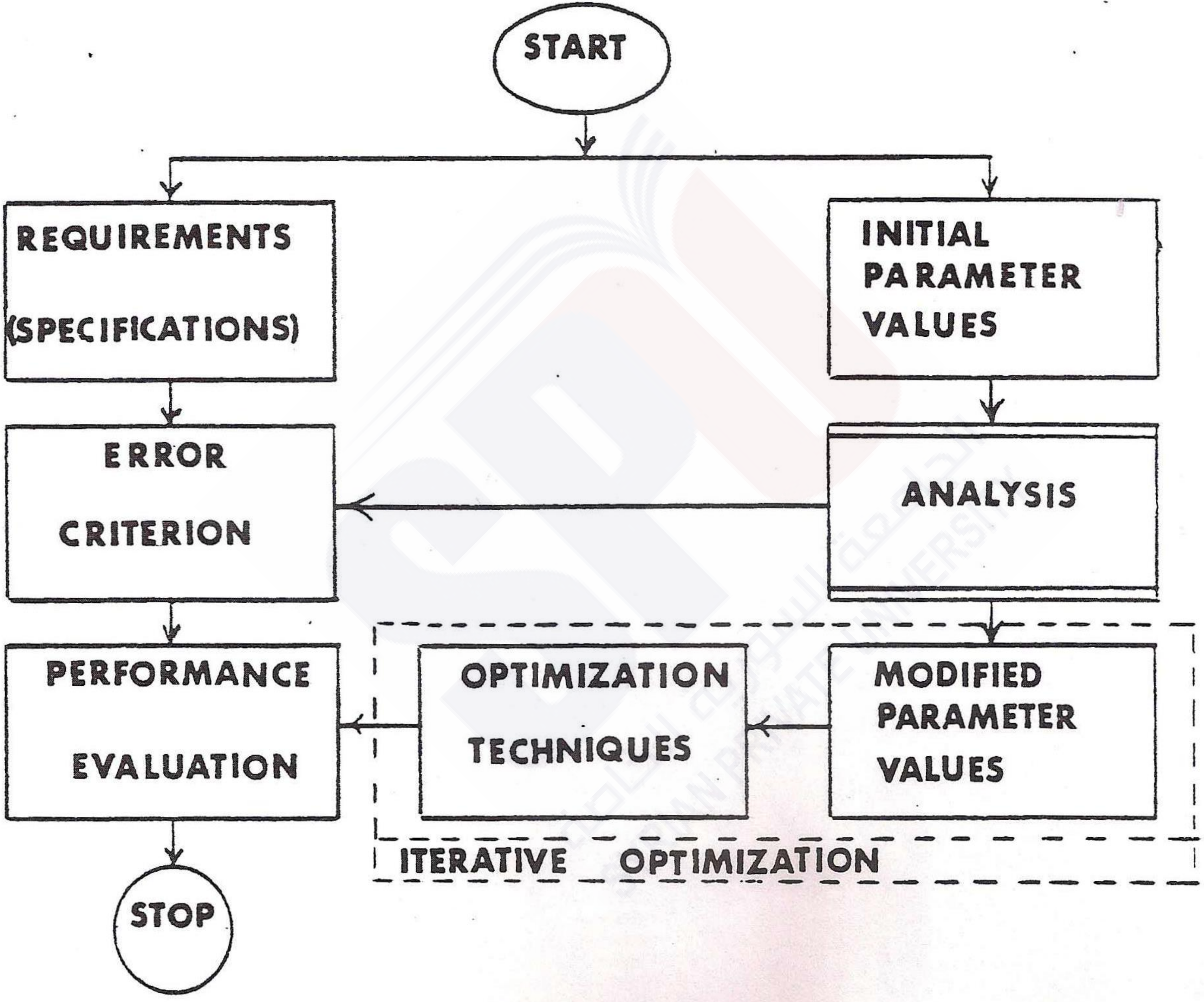
For example, taking account of arbitrary component parasitic, to meet certain amplitude requirements, where there is no synthesis procedure available, involves considerable numerical calculation even in the simplest cases. A typical problem may involve several hundred circuit analysis:-

Filter Design and Digital Computer

Circuits which could not be designed using conventional methods have been successfully produced, because of the optimization process. The computer-aided design approach to filter synthesis, or to any system design, is based on the scheme shown in the following Figure .

Computer-Aided Circuit Design Scheme




START
REQUIREMENTS (SPECIFICATIONS)
INITIAL PARAMETER VALUES
ERROR CRITERION
ANALYSIS
PERFORMANCE EVALUATION
OPTIMIZATION TECHNIQUES
MODIFIED PARAMETER VALUES
ITERATIVE OPTIMIZATION
STOP

Introduction

Block diagram of the CAD-CAM Scheme contains :-

- *START REQUIREMENTS (SPECIFICATIONS)*
- *INITIAL PARAMETER VALUES (Guess)*
- *ERROR CRITERION*
- *ANALYSIS*
- *PERFORMANCE EVALUATION*
- *OPTIMIZATION TECHNIQUES*
- *MODIFIED PARAMETER VALUES STOP*
- *ITERATIVE OPTIMIZATION*

Introduction

- (a) With regard to the specifications, the designer chooses the network configuration which should yield the desired frequency response and order together with, an estimation of the initial element values. In practice, the initial guess values for the design variables or/and the choice of the configuration may not be suitable. Therefore, it is necessary to include additional stopping criteria to detect these conditions.

Introduction

- (b) An analysis procedure determines the current values of the performance measures referred to in the specification (e.g. voltage transfer function coefficients, pole/zero locations, amplitude and/or phase response at, say, 20 frequency points, etc.) and these values are compared with the specified levels.

Introduction

- (c) If there is a discrepancy, the design variables are altered so as to improve the discrepancy- and the process is repeated as shown in Figure until there is no further improvement in the objective function or if one of the stopping criteria is satisfied, for example, maximum number of analysis or maximum number of calling the optimization algorithm may be restricted.

Introduction

- The iterative technique, referred to as "OPTIMIZATION", plays a fundamental role in the CAD scheme. It ensures that the objective function is reduced to an adequate level, or, at least minimized, subject to constraints imposed by the specification, choice of system configuration and starting element values.

Introduction

- It is inevitable that where classical methods to not exist or are inapplicable, optimization provides the simplest and most satisfactory way of solving the design problem .

Introduction

- Because of the iterative nature of a computer-aided design scheme outlined in Figure , its economic practicality depends on the availability of efficient algorithms, and in particular, efficient optimization methods, since they define the number of iterations of the process, that will be required to realize a given specification. In the following sections, the nature of optimization will be considered.