AN EXPERT SYSTEM FOR MICROWAVE AMPLIFIER DESIGN

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ABSTRACT

An expert system to assist in the design of different classes of linear microwave amplifiers for MIC/MMIC circuits is presented for the first time. The principal stages in the design of such a circuit are outlined and the decision to implement the expert system justified. Two important aspects of the design process are addressed ; the choice of optimum circuit topology for a given specification and the selection of a suitable FET or FETs for that topology. The overall structure of the expert system is described and its operation demonstrated using a typical amplifier design.

INTRODUCTION

Expert systems provide a means of capturing the knowledge and expertise of an expert within a specific domain and making this knowledge available to many. They are essentially computer programs which simulate the problem solving strategy used by such experts and exhibit behaviour which is considered intelligent when observed in humans.

The development of an expert system to assist in a particular task can only be justified if there is a marked difference between expert and non-expert performance in the execution of that task. Many applications within the field of microwave engineering fall into this category with a designer usually relying on a mixture of previous experience, rules of thumb and heuristics to solve such problems. Microwave expert systems have been reported for filter and circulator design [1,2].

In this paper the implementation of an expert system to assist in microwave amplifier design is described. The system deals with two main aspects of the design process ;

(i) the choice of a circuit which will meet the requirements specification for the amplifier,
(ii) the selection of a FET or FETs for that topology. Although only FETs are considered at present, the system could easily be extended to cover HBT, HEMT or PMHEMT devices.

AMPLIFIER DESIGN

The requirements specification for an amplifier is usually expressed in terms of functional characteristics such as gain, frequency bandwidth, noise figure etc. For these requirements the optimum circuit topology must first be chosen. When selecting a topology the designer must consider the wide range of circuits available, for example ; balanced, feedback or distributed amplifiers. Also, the number of stages required to meet the specification must be decided. For an inexperienced designer the design choices can be complex and time-consuming, often involving several consultations with experts or technical design manuals.

Having chosen the appropriate amplifier topology, a FET or FETs must be selected. The designer's choice of FET for a given amplifier specification will involve the technical characteristics of the device together with its cost and availability. This is an iterative trial and error process which is time consuming and can result in sub-optimal FETs being chosen.

For the selected topology and FET(s) the input, interstage and output networks of the circuit are designed. Commercial software packages such as TOUCHSTONE™ or SUPER COMPACT™ are then used for circuit simulation and optimisation. If the simulation does not meet the specification, some optimisation or redesign is necessary, either in the matching circuits or, more seriously, in the selection of a different FET and/or amplifier topology. The design process therefore becomes an iterative one with several iterations often required before an acceptable design is achieved. On completion a layout for the circuit is produced using a commercial package such as GaS STATION™.

It is intended that the expert system overcome these problems associated with amplifier design, in particular those relating to circuit topology and FET selection. The aim is to enable a designer to produce a circuit which meets the functional specifications on the first pass, without any lengthy tuning and design iteration. The user is guided through each stage of the design process from circuit specification to physical layout, receiving as much assistance as is required. Novices

CH3141-9/92/0000-0861$01.00 © 1992 IEEE

in the field would rely heavily on advice and recommendations given by the system, while experienced designers may treat the system as a framework of all the data and commercial packages needed to design a circuit. At all stages of the design the user is given the option of rejecting recommendations given by the system, and pursuing their own design.

THE EXPERT SYSTEM PROCESS

A rule-based expert system is being developed which consists of three main components ; a knowledge base, an inference engine and a user interface [3].

Knowledge Base

The *knowledge base* is the section of the expert system which contains all of the domain facts and heuristics relating to the problem. For this particular system the knowledge base is formulated using production rules [4] and is composed of three main sections. One section contains a comprehensive set of facts and rules relating to the range of amplifier topologies available. The second section of the knowledge base deals with FET selection. It is intended that the suitable FETs be chosen from a wide range of commercial devices. However, at present the only FETs considered are those manufactured under the Plessey F20 process for MMIC design. Details of these devices are held in database files which can be directly accessed. The final section of the knowledge base contains the rules for producing a physical layout of the circuit using GaS STATION.

Inference Engine

The knowledge base is processed by the *inference engine* which applies one or more search strategies against the contents of the knowledge base and derives whatever conclusions can be deduced. A number of control strategies can be used in the inference engine to process the contents of the knowledge base. Rule based systems commonly use backward, forward or hybrid chaining control structures, each differing in the way in which rules are processed. Backward chaining operates by establishing an overall goal (or top-level rule), and attempting to prove this goal from low-level rules and facts.

In the case of forward chaining there is no specific goal, and the starting point is a set of known low-level facts. These facts are then used to build up any conclusions which can be drawn.

Mixed chaining refers to the strategy of combining backward and forward chaining within a single knowledge base. There are various forms of mixed chaining. For example forward chaining could be used as the default control strategy which would then be complemented by backward chaining as required.

User Interface

The *user interface* provides the means by which the user interacts with the system, to provide input and to obtain results and recommendations.

Knowledge acquisition is an important and early step in the development of any expert system which involves consultation with experts to build up the knowledge base for the system. The knowledge base must be continuously updated to cover any new amplifier designs or devices as they are published.

EXPERT SYSTEM STRUCTURE

The expert system has been developed using Prolog-2 [5], a PC based version of the Prolog programming language which runs under the Microsoft Windows™ 3.0 environment [6]. Figure 2 shows the overall structure for the system, incorporating the three main expert system components, that is the knowledge base, inference engine and user interface.

The knowledge base is composed of three separate modules containing the Prolog facts and rules for amplifier topology, FET selection and circuit layout. The inference mechanism commences with the requirements specification for the amplifier and, operating on the knowledge base, searches for an acceptable design. Since the input data is the starting point for the inference process the system requires an element of forward chaining. However backward chaining is also incorporated, resulting in a complex hybrid control structure. Prolog compilers use backward chaining as the default control structure, but may be modified to use forward chaining by the addition of a user-written chaining algorithm.

The expert system has been implemented as a standard Windows application using the Windows Software Development Kit and, as such, the user interface makes full use of the facilities supported by the Windows Graphical User Interface (GUI). This permits user-friendly interaction with the system incorporating drop-down menus, dialogue boxes and graph plotting facilities. The user provides the requirements specification for the amplifier in terms of gain, frequency, bandwidth, noise figure etc, via the user interface, and system results are displayed in graphical format.

Several external links are supported between the expert system and commercial software packages. An interface is provided to TOUCHSTONE, MICROWAVE HARMONICA and GaS STATION for circuit simulation and layout. Also dBASE III™ files are used to record the Plessey device data required by the system.

Operation of the system is illustrated using a specific example, where a FET is chosen for a small signal, low-noise amplifier with the following requirements specification ;

Minimum Gain : 11.5 dB

Maximum Noise Figure	:	1.2 dB
Centre Frequency	:	9.5 GHz

Figure 1 shows the system results for this circuit design, including a plot of s_{21}, and a physical layout produced by interfacing to GaS STATION.

CONCLUSIONS

The paper discusses the application of expert systems to microwave amplifier circuit design. In the longer term, this will make up one module of a comprehensive expert system which will cover other aspects such as oscillator or filter design. The system may also be combined with an existing framework for a MMIC design environment [7], producing a comprehensive design suite. The ultimate aim is to create a unified environment incorporating all aspects of the design process.

ACKNOWLEDGEMENTS

The author would like to acknowledge the support of the Department of Education for Northern Ireland.

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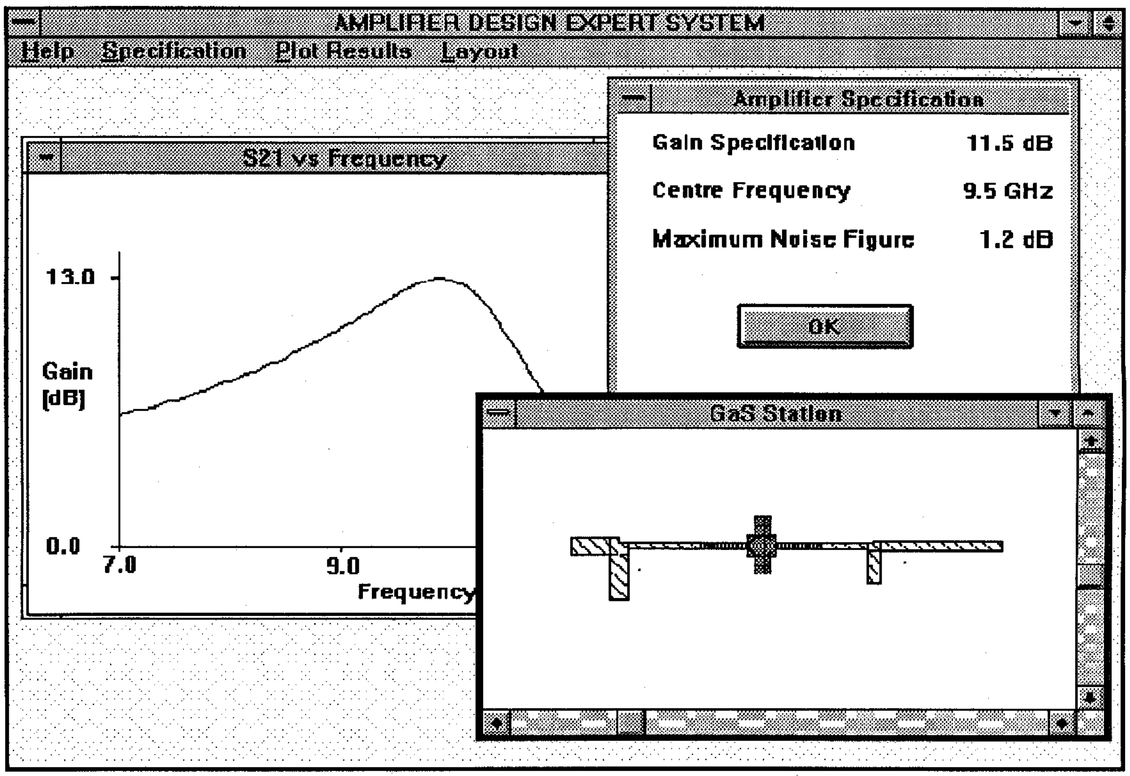

FIGURE 1 : TYPICAL AMPLIFIER DESIGN

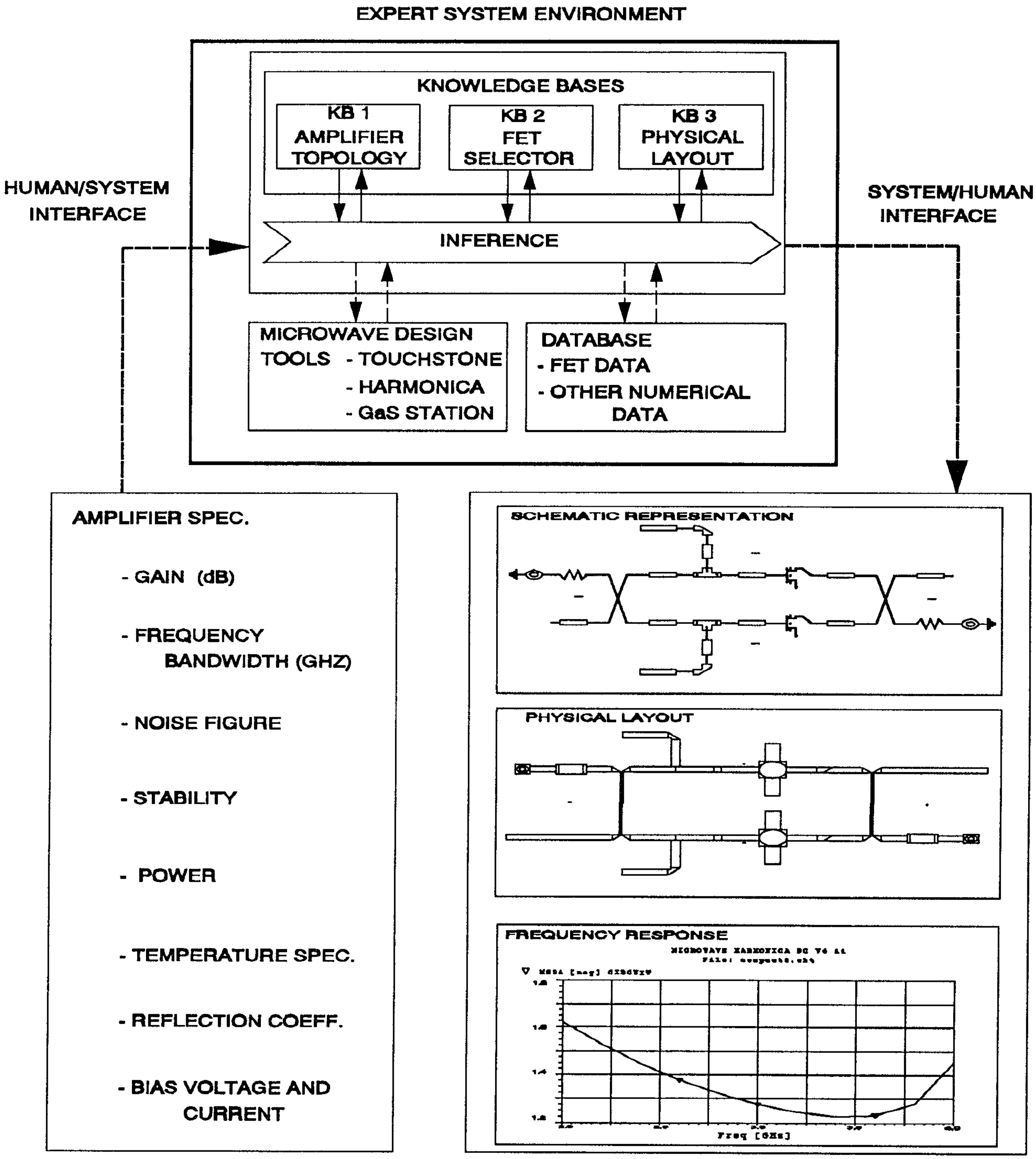

FIGURE 2 : EXPERT SYSTEM FOR AMPLIFIER DESIGN