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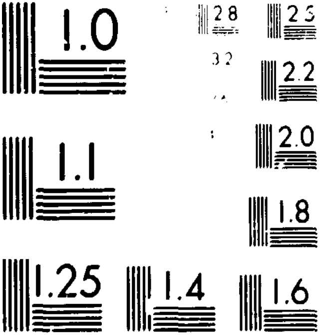

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MICROPROCESSOR APPLICATIONS IN DEVELOPING COUNTRIES*

by

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EXPLANATORY NOTES

Mention of firm names and commercial products does not imply the endorsement of the United Nations Industrial Development Organization (UNIDO).

In addition to the common abbreviations, symbols and terms and those accepted by the International System of Units (SI), the following have been used in this study:

A/D converter	analog to digital converter
ASM	assembly language
ATI	Association of Thai Industries
CMOS	complementary metal oxide semiconductor
CPU	central processing unit
DBMS	data base management system
ECG	electrocardiogram
ML	machine language
MOS	metal oxide semiconductor
PABX	private automated branch exchange
PLA	programmable logic array
PL/M	programming language for microprocessors
PROM	programmable read only memory
RAM	random access memory
ROM	read only memory
SDK	system design kit
TTL	transistor-transistor logic
TV	television
VLSI	very large scale integration

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INTRODUCTION

The role of microelectronics as the economic fabric of developed countries continues its meteoric climb. The contributions and importance of this technology and its progeny, microprocessors, to the continued economic strength of a nation cannot be overstated. The uses to which these relatively new tools can be put are limited only by the imagination of designers and entrepreneurs in their quest to provide either better or newer solutions to problems in industry, information processing, government, and countless other fields. With this technology, new applications can be directed at giving renewed vitality to existing long standing industries such as textiles,manufacturing facilities, and others and to economic sectors such as agriculture, energy, and to increase productivity, capability, and quality. In addition, new innovative applications can spawn healthy products for both industry and service sectors. Many of these innovative applications take advantage of the incredible computing power that can now be placed in a package smaller than the palm of a hand. This computing power can be used for both simple and complex control and monitoring applications that would have been impossible just a few years ago. With all of the attention being paid to this relatively new technology in developed countries and the resultant dramatic successes in an ever increasing range of applications, it is little wonder that developing countries want to exploit the full potential of this technology to reap the full benefits. The question is no longer "should" the developing countries become involved in developing microelectronic applications but rather "how" to best utilize available resources (such as manpower, capital, and equipment) to most effectively enter the field of microelectronics applications and gain control of the direction the technology takes in the country. The importance attached by each country to being self-reliant in the use of the technology and not subservient to its whims (often directed by outsiders whose interests and strategies may not match those of the developing countries) will determine whether or not adequate and timely support of this new field will be given. Both the public and private sectors play a vital role in achieving their common objectives in this area.
This paper is divided into four major sections:

1. Mission objectives
2. Summary of findings and recommendations
3. Developing application strategies in developing countries
4. Specific applications

Section 2 and section 3 detail those factors and recommendations which apply to developing countries in general. Applications identified as being pertinent to developing countries are given in section 4.

1.0 MISSION OBJECTIVES

The UNIDO mission on Selective Microelectronics Applications in Developing Countries was formed to discuss and identify technical problem areas which are viable for microprocessor applications solutions. In addition, the mission was to report on and recommend possible solutions to problems encountered which might inhibit or stop the development of such applications. To this goal, the mission had three primary objectives:

1. To aid in increasing the awareness of decision makers in the developing countries of the role of microprocessors in providing solutions to identified problems;
2. To identify the capabilities of selected examples of the existing technical and business infrastructures in the developing countries which are charged with bringing microprocessor-based applications to the market-place and to make recommendations to increase their effectiveness;
3. To recommend specific applications as examples which are suitable for microprocessor implementation.

The study thus undertaken was by no means an exhaustive analysis of all (or even most) of the capabilities of the countries visited (Egypt, India, Thailand, and Mexico) in the microelectronics application field. The study is rather a snapshot of selected technical and economic sectors, both public and private, at a particular point in time in both the individual countries and regions and an analysis of each of these snapshots. The results, analysis, and recommendations of this study are intended to form a basis for both further discussion and, more importantly, action on the part of both public and private sector interests in the developing countries. It should be noted that one or more of the recommendations made in this paper may have already been implemented in some of these developing countries. These recommendations are included for completeness. The value of the analysis and recommendations lies in their synergy with one another and not necessarily in the individual recommendations.

2.0 SUMMARY

The ability of developing countries to effectively exploit this new technology and become competitive in developing microelectronics applications depends in part on five general factors. These five factors are:

1. Availability of skilled technical manpower;
2. Access to adequate and appropriate development tools;
3. Ready access to required microelectronics components, boards, and/or systems;
4. Effective marketing and distribution network;
5. Coordination of VLSI technology and application strategies.

It would be difficult, if not impossible, to objectively quantify each of these factors. However, it is entirely appropriate to use these factors to determine areas of strengths and weaknesses in the developing countries relative to the development of high technology applications. In so doing, it is possible for each country to build on its strengths and develop programs and/or policies to turn existing weaknesses into needed strengths.
Each of these five factors is developed in more detail in section 3 of this paper. The recommendations outlined below come from the many discussions held with technical managers in both public and private sectors in the developing countries during the mission. Most of the recommmendations are of a general nature and are intended to form the basis for introducing key issues into appropriate governmental and industrial policy-making groups. Each developing country will certainly formulate its own policy based on the unique requirements and strategies in that country.

2.1 AVAILABILITY OF SKILLED TECHNICAL MANPOWER

It is well recognized that no nation, either developed or developing, has all the skilled technical manpower that it could use. There is a worldwide shortage of technical expertise (especially in the area of software engineering). The worldwide competition for these technical resources is a factor which exacerbates the other problems facing developing countries.
One problem facing developing countries is training and RETAINING the required technical manpower. Here developing countries are at a disadvantage compared to developed countries in two important aspects:

1. Training resources (both teachers and equipment) are in very short supply;
2. Internal perception among some technical people in the developing countries that the "really challenging jobs" are outside the developing countries.

The first aspect, that of scarce training resources, limits the number of skilled people that can be trained. The second aspect contributes to the losing of a significant percentage of those few who are trained after a relatively short time in productive work in the developing country. Clearly it is necessary to find solutions to both problems simultaneously in order to avoid the problem of stagnation in the development of microelectronic applications due to lack of manpower. The total solution to this complex problem is clearly beyond the scope of this paper. However, several constructive suggestions were made by nationals in each of the countries visited on how to provide a short-term solution to minimize the impact of the problem.

2.1.1 RECOMMENDATIONS

1. There is a strong consensus among technical managers in both public and private sectors in the developing countries visited that the training of technical manpower must be tied to the development of practical applications. For example, training courses in university classes at the graduate level and extension courses, could be tied (TO SOME EXTENT) to providing solutions to selected problems in an existing microelectronic application design project. The objective is to use the manpower and equipment in a training environment in the dual role of training and application development, thereby maximizing effectiveness of both resources.
Achieving this objective implies a very strong infrastructure between the public and private sectors in which to operate and communicate. While the pieces of the required infrastructure (such as universities, research centres, business groups) exist in all the countries visited, their interaction and communication are not presently structured to achieve the desired objective. Section 3.0 provides more detail into this program suggested by many of the technical managers interviewed.
While this structure of using training resources for the dual role of training and applications development is primarily a short-term solution to a problem, it should form the foundation of a longer range solution. The use of classrooms to solve existing practical problems has many benefits for the trainer, trainee, and their corresponding institutions.

2. The second recommendation (strongly suggested in many of the meetings by those interviewed) is to strengthen and expand the concept of the Cooperative Education Program (CO-OP) in the universities. In this type of program, students are given the opportunity to pursue their studies and be assigned work projects in alternate academic terms (in other words study a semester, work a semester, etc.) The advantage of such a program is that it gives students the chance to apply their theoretical knowlege to practical problems while providing a

skilled resource to the country in their work roles.
It is important to keep in mind that both recommendations 1 and 2 require a strong infrastructure with the ability to communicate among the different organizations to ensure success in the achievements of the project.

3. The third recommendation is to heighten the awareness of the decision makers (in governmental policy-making bodies) of the critical need to retain the trained engineer in the developing country. Retaining of engineers within the developing country should be afforded very high priority in the appropriate governmental policy-making bodies. It is beyond the scope of this paper to suggest more concrete proposals; however, it is essential that factors such as pay, availability of challenging work, work environment, professional advancement opportunities be addressed at the appropriate level to provide strong positive incentives to these technical resources to remain as a national resource. To this end, technology exchange agreements with foreign companies could be structured with the aim of providing conditions that maximize the probability of retaining the technical resources in the developing country.

2.2 ACCESS TO ADEQUATE AND APPROPRIATE DEVELOPMENT TOOLS

The tools required to effectively and efficiently develop microelectronic applications projects depend to a large part on the type of application being developed. It is important to have not only an ADEQUATE supply of development tools but also to have the APPROPRIATE development tools. For example, attempting to use machine language or assembly language tools to develop long and complicated software control programs not only wastes time, money, and manpower resources, but also significantly increases frustration in the design engineers. Likewise, using large-scale mainframe computers to construct relatively simple applications programs can create training problems for the engineer in attempting to learn to communicate with the large-scale mainframe computer. In addition, placing too much emphasis on software development of application programs and not enough emphasis on software/hardware integration tools can seriously impact development schedules (not to mention development success). Because the issue of appropriate development tools is critical to the success of microelectronic applications development, section 3.2.3 is devoted to a discussion of the topic. In summary, the following recommendations are made concerning development equipment:

2.2.1 RECOMMENDATIONS

1. Microelectronic development centres are recommended to be established in selected locations. These centres can be used to provide both application development and training as

outlined in this section. Details of the centres and their functions are given in section 3.0. As discussed, these centres can be equipped for a relatively modest capital investment and, if appropriately structured and managed, can be used as revenue-generating centres on either a non-profit or profit basis.

2. Because of the critical contribution of development tools (both systems and software) to microelectronics application development, it is recommended that the appropriate government agencies/departments review existing and proposed policies (such as import restrictions, duties, taxes, etc.) to ensure minimum impediments to obtaining such equipment especially for the proposed development centres.

2.3 READY ACCESS TO REQUIRED MICROELECTRONICS COMPONENTS

Having a ready access to microelectronics components is important not only to the application development effort but also to the service and maintenance requirements of the application. In many developing countries, as a result of government policies, the importation of microelectronic components and boards can be a time-consuming process. The result can be significant delays to applications programs and/or service and maintenance requirements due to non-availability of required components or boards. It is recognized that the issues involved in these policies are complex and varied. However, it is recommended that the appropriate government agencies review the import policies regarding these components and boards to ensure that the maximum national benefit is achieved for developing applications which have a high added value (see section 3.0).

2.4 EFFECTIVE MARKETING AND DISTRIBUTION NETWORK

An essential point of any microelectronic development program is getting the product into the hands of the user. In developed countries there generally exists a strong marketing infrastructure residing in the various corporations and a strong distribution infrastructure. (The term marketing used in this paper includes functions such as product definition, strategic analysis of application requirements, pricing strategies, service requirements, and direct sales strategies.) It was found that in developing countries the marketing and distribution networks were not as strong or well organized as other aspects of the development program in those countries. It is this area that requires significant attention by both the public and private sectors if the applications, as they are developed, are to be fully utilized in both the internal and export markets.
A fundamental characteristic of the microelectronic market is the rapid introduction of new products and services and the

rapid change in market conditions. To be able to compete in both internal and world markets, it is essential that marketing and distribution networks be able to act and react rapidly to these changing conditions in the market-place. The following recommendations are made regarding the issue of marketing and distribution infrastructures in the developing countries:

2.4.1 RECOMMENDATIONS

1. The cornerstone of establishing an effective marketing and distribution network is to provide strong positive incentives to corporations and individuals to get their products into the market in a timely and orderly fashion. It is recommended that policies be pursued which strongly encourage the formation of distribution networks (for both sales and service) in the internal and export market. With the appropriate government policies in place, the networks should evolve into strong, nimble organizations that are able to react quickly to meet the market requirements.

2. The second recommendation is that a central organization be established that will act as a catalyst group for the development of microelectronic applications. This group (described in more detail in section 3.0) would be charged with bringing together participants in both the public and private sectors to identify application opportunities and to act in an advisory capacity on marketing and distribution issues to both governmental and industrial groups. It is this organization to which industrial, governmental and educational groups could turn for advice regarding the many issues that surface when developing microelectronic applications.

2.5 COORDINATION OF VLSI TECHNOLOGY AND APPLICATION DEVELOPMENT STRATEGIES

Each developing country visited has a very strong policy toward developing its own VLSI technology base (semiconductor manufacturing). The strategies for developing this base continue to be formulated with action being taken in several key areas (such as technology exchange agreements) to implement the strategies. It is obviously essential to ensure that the strategies for VLSI technology development and application development be compatible and complementary. However, there is a strong opinion in some sectors in developing countries to FIRST obtain the VLSI technology and THEN develop applications using these manufactured components. It is strongly felt by many technical managers in the developing countries, that to EXCLUSIVELY follow this strategy will result in being put on a VLSI technology treadmill (by constantly having to develop newer processing capabilities) thereby seriously hampering the introduction of microelectronic applications. It is rather hoped that the policies developed for establishing a base in VLSI technology will be integrated with the policies for developing microelectronic applications to achieve the maximum benefit to the developing country.

3.0 DEVELOPING APPLICATION STRATEGIES IN DEVELOPING COUNTRIES

Developing an application strategy is essentially providing a framework within which both the private and public sectors can operate effectively to define, develop, and market microelectronic products. Each of the three strategic application stages as follows:

1. Product definition
2. Product development
3. Product marketing and distribution

can be analyzed most easily by developing appropriate models for each stage and then analyzing those models. Each of the models described in this section have been developed to address the unique requirements and conditions encountered in developing countries.

3.1 PRODUCT DEFINITION

The purpose of this section is establish a strategy for developing products by two methods:

1. To develop awareness of microelectronic applications to those who have had minimal or no previous exposure to microelectronics;

2. To develop awareness of people in the technical sectors (both public and private) to the requirements of those in 1 above.

There is a classic adage which says "...you have to know what the problem is before you can solve it". One objective of this mission was to identify potential applications. The procedure used to determine potential applications was to talk to people in various economic and business sectors about their problems in those sectors. From even relatively short discussions, it was possible to formulate potential applications that would be beneficial to those economic and business sectors. It was also clear from discussions that it is imperative to have a forum where an open dialogue between users and designers is possible which generates more application ideas.

3.1.1 PRODUCT DEFINITION MODEL

In developed countries, the responsibility for product definition generally rests in such diverse areas as corporate marketing departments, corporate R+D groups, entrepreneurs and the like. To attempt to duplicate this structure in developing countries would not be productive as these infrastructures do not exist in many companies in the developing countries. In developing countries, a central catalyst is needed to heighten the awareness of the potential of microelectronics solutions to the public and private sectors. This catalyst is most easily generated by forming a core group in each developing country where practical applications can be developed. It is the intent of this section to show how such a core group can be established and the function of such a group. The microprocessor-based applications proposed by this group will aid in increasing the awareness of the role of microelectronics in providing new tools and solutions to problems. As this awareness is increased, new product definition will become more self-generating without the need of this group.
As indicated, the objective is to form a central group in each developing country to provide a catalyst for product definition first in a central group. Over time, it is expected that a dispersion in product definition activity will take place in a manner similar to that in developed countries. To be truly effective, product definition should not be generated from a central group, but should rather be dispersed throughout the economic sectors.
A model showing the component parts required to establish an ongoing dialogue between users and design engineers in developing countries is shown in figure I. The model comprises three parts: user base, knowledge base, integrator.

Figure I. Product Definition Model

Each of the component parts has a significant role to play in the development of microelectronic applications if those applications are to meet the requirements of the market into which they are to be introduced. This model builds on the existing strengths in those developing countries visited in that the component parts ALREADY exist. All that remains to be done is to bring the three components together to form the nucleus of what developed countries refer to as marketing strategy. The obvious advantage of such a model is that the three components are comprised primarily of individuals and groups indigenous to the developing country. Outside expertise, if desired at all, can take the form of consulting and/or information exchange.

Before the model can be fully developed, it is necessary to define the component parts.

3.1.1.1 DEFINITIONS OF MODEL

USER BASE

The User Base consists of those people and/or groups who have common interests in categories such as dairy farming, rice growing, textile manufacturing, oil refining, etc. These are the people who have the practical day-to-day knowledge of the operation requirements in their fields of expertise.

Many such groups are already formed in Egypt, India, Thailand, and Mexico. Trade associations, such as the Association of Thai Industries (ATI), represent many different industrial sectors. These sectors contain a wealth of information and knowledge on the characteristics of potential applications.

Some of these groups, by the nature of their own interests, already have significant knowledge of the potential role of microelectronics in their industry. Their major concern is not the potential of microelectronics in their industry, but rather how to implement ANY application program. Other groups have not yet been adequately exposed to the potential of micro-electronics and are therefore unaware of the tools that are available to them. The common thread running through both groups is the need to increase the awareness of the solutions that are available to those people who can implement the solution (the Integrators).

KNOWLEDGE BASE

The Knowledge Base consists of those people and/or groups who are RESEARCH-oriented in fields such as veterinary science, agriculture grain production, petrochemicals, etc. These are the people who have the theoretical knowledge required to establish measuring algorithms and measuring techniques. This Knowledge Base is usually found (in developing countries) in universities and research centres. This base is usually not found in private industrial sectors in the developing countries.

For example, the Agriculture Research Centre in India possesses knowledge derived from extensive research on the factors that increase the quality of milk production of dairy cattle. As discussed in section 4.0, the measurement and analysis of

these factors form the basis of an application for microelectronic control and analysis of milk production.
In most cases, the User Base and Knowledge Base consists of people who have little or no knowledge of the design techniques required to implement a microelectronic design of an application in their field. As a result, they are unaware of the potential tools that are available to them to solve various problems. The objective is to tap these two resources (User Base and Knowledge Base) and use their expertise to develop appropriate microelectronic applications.

INTEGRATOR

The missing component part, at this point, is a person or group who can act as "glue" to bring these two other groups together. Using the inputs of NEED (from the User Base) and the inputs of HOW (from the Knowledge Base) is the task of the INTEGRATOR. The Integrator must be able to translate and transform the requirements and descriptions obtained from the two other groups into a microelectronics application. Each developing country visited has the resources available to function as the Integrator. Typically, these people are found in universities, research centres, and (in some cases) private industry engineering departments. A qualified technical consultant is also a good source for the role of an Integrator. The only requirement is that the Integrator be very knowledgeable in the details of designing with microelectronics components, boards, or systems.

3.1.2 USING THE PRODUCT DEFINITION MODEL

Theoretical models are usually fun to develop. Their worth, however, comes in the ability to execute the objectives toward which the model is directed. The purpose of this section is to outline the practical applications of the Product Definition model and how its operation is envisioned for developing countries.
It is important to emphasize both what the group defined by this model IS and IS NOT. The group defined by this model IS a resource for product definition input to both the public and private sectors. The group IS NOT expected to implement or otherwise be responsible for product development and introduction (see figure II). To best illustrate the role this central group plays in Product Definition the factors in table 1 should be considered. The groups or individuals comprising the User Base are a significant resource for determining the requirements for the Market Characteristics factor. The Product Technical Requirements factor is most effectively addressed by the Knowledge Base group. These two factors can be the most easily combined by the Integrator (or consultant) to form the basis of a technical product definition. A typical organization of the model might be constructed as shown in figure III. As indicated, a coordinator (from a public or

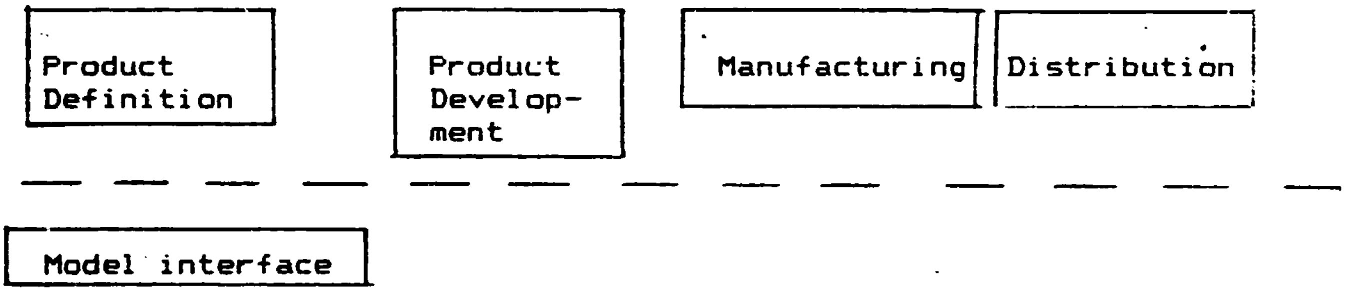
Table 1. Product Definition Factors

FACTOR	EXAMPLE REQUIREMENTS
Market Characteristics	• Sensitivity to cost factors • Volume requirements • Competitive analysis • Export potential • Functional requirements
Product Technical Requirements	• Environmental conditions temperature, dust, humidity, etc. • Form factor limitations (size, weight, etc.) • Upgradability requirements • Service/maintenance requirements • Measuring algorithms
Product Distribution	• Sales outlets • Service outlets
National Objectives	• National "content" requirements • Strengthening strategic industrial sectors • Gaining technological expertise • Gaining technological independence

private sector) is selected to act as a "gate" whose role is to "connect" the appropriate User Base group with the appropriate Knowledge Base group(s) through meetings and/or seminars with the appropriate technical consultants (integrators). The most important function of the coordinator is to set the stage for effective technical discussion which can lead to the definition of new microelectronic applications.

Two remaining factors remain to be addressed by this model. These two factors, Product Distribution and National Objectives usually fall cutside the expertise of all three components of the model. The factor of Product Distribution will be discussed in more detail later in this section.

Figure II. Use of Product Development Model

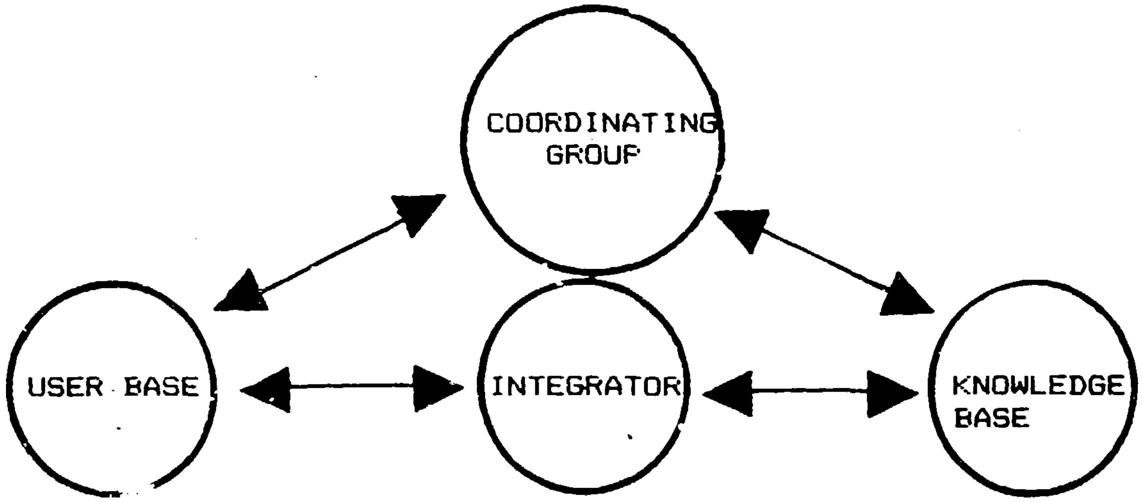


3.1.3 ACHIEVING NATIONAL OBJECTIVES

A major component in the factors outlined in table 1 are the considerations of national objectives during the Product Definition phase. The maximum national benefit will occur when those objectives are integrated into the definition phase and not as an afterthought at the completion of the design cycle. The details of this issue can be exceptionally complex and varied in each of the developing countries. However, no one knows the national objectives better and how to implement them than the technical managers in both the government and industry sectors in that country. This model presents a forum whereby both government and industry can cooperate to achieve national objectives during the product definition phase.

In the developing countries visited, all Governments have defined as a clear national objective the necessity of becoming technologically independent. The path to this independence as well as its definition, of course, varies from country to country. During the Product Definition phase, some important applications may be proposed which require the use of high technology development tools and component parts. If these tools and components parts are not readily available or otherwise restricted because of government policy, the success of the application could be greatly compromised. The result might be the failure of the application without achieving anything for the national objectives, a lose-lose situation. The use of this model allows the early identification of

Figure III. Organizational Model



TYFICAL RESOURCES

Dairy Farming Groups

Medical Associations/ Societies

Trade groups

Small Business Groups

University Professors/ Lecturers

Research Centre Engineers

Outside Engineering Consultants

University Departments

Medical Research Centres

Veterinary Research Centres

Agriculture Research Centres

internal problem areas such as these so that a dialogue can be established early in the design cycle to resolve the issues - the result can be successful product introduction.
It is clearly presumptuous and inappropriate for this paper to suggest possible national objectives for developing countries. It is useful, however, to reflect the need of many microelectronic applications to be competitive in the world markets in such areas as function and cost to achieve the maximum market potential for the application. Developing plans during the Product Definition phase which ultimatly meet national technology objectives can be of benefit to everyone.

3.2 PRODUCT DEVELOPMENT

The second stage in developing an effective application strategy is product development. The resources required for development of those products defined in Section 4.0 depend on where the products lie on the Application Spectrum. The Application Spectrum is a pictorial representation of the characteristic types of applications as shown in figure IV. This subjective representation is useful in determining the types of development tools (hardware and software), skill level of manpower requirements, and the allocation of these scarce skilled resources. Making a very rough judgement regarding the placement of the proposed application along the Application Spectrum shown in figure IV can give the technical manager a quick synopsis of the overall technical requirements of the project. It is therefore not required that an application be placed on the continuum of the Application Spectrum, but rather placed in a more general sense to form some rational basis for determining the required resources. The strategy of developing countries in this phase is to ensure that an adequate supply of development tools are available for application development.
An integral part of Product Development, especially from the national objective standpoint is the concept of added value. Added value is basically a measure of the development effort contributed by the technical resources in the developing countries. Maximum benefit is derived when the added value is at its practical maximum. Since added value is an integral part of the Application Spectrum analysis, this topic will be discussed be discussed before proceeding with the spectrum analysis.

3.2.1 ADDED VALUE

As indicated previously, added value is maximized during the development process when the design is implemented at the lowest PRACTICAL level of integration (system, board, component). This PRACTICAL level is determined in part by the availability of resources necessary to design and produce a product. Table 2 shows the relative order of added value for the major design categories given in table 3.
In developing application strategies, it is important to design at the practical maximum added value for conditions at

Figure IV. Application Spectrum

Low End	Application Spectrum	High End

Characteristics

Low End	High End
- Simple control functions	- Complex control
- Performance generally not critical	- Requires sophisticated software • Operating systems • High level language • Application program
- Relatively simple software design requirements	- High emphasis on performance
- Component implementation most prominent	- Building block implementation most prominent
- Hardware-intensive (form factor important	- Software-intensive 8-bit sophisticated 16-bit
- 8-bit mature microprocessors (single chip, 8085, Z-80, 6800, etc.)	- Microprocessors (6800, 8060, Z8000)

Examples

Low End	High End
- Soil moisture measurement	- Telecommunications
- Milk quality measurement	- Office management system (e.g. DBMS)
- Blood pressure/pulse monitoring	
- Rice quality analysis	

Table 2. Design Category - Added Value

Increasing Added Value ↑

1. Semiconductor Manufacturing
2. Semi-custom Components
3. Standard Components
4. Board Assemblies
5. Subsystems (software added)
6. Complete Systems (software included)

Table 3. Examples of Design Categories

DESIGN CATEGORY	EXAMPLES
Semiconductor Manufacturing	The manufacturing of bipolar and/or MOS devices required to implement microelectronics applications. This category implies capabilities in chip design and masking.
Semi-custom Components	Full chip design capability as well as customized design capability such as with PLA
Standard Components	Use of fully functional devices available on the open market. Examples are TTL logic gates, memory devices. microprocessors, pheripheral controllers, etc.
Board Assemblies	Single board computers, controllers, etc.

the time of the design. For example, if semiconductor manufacturing facilities are small to non-existent in a developing country, then the pratical maximum added value is obtained by number 2 or 3 in table 2. Likewise, if the "market window" is such that a very short design cycle is required (e.g. because of competitive pressures) the practical maximum added value may be obtained by 4 or 5 in table 2.
It should be remembered that even though a product application may be designed at one level of added value it can be later manufactured at another, higher level of added value. For example, if a particular application is first designed to use boards it may be manufactured utilizing components after a short design-in cycle. Designing with this strategy in mind developing countries can achieve both long range national objectives such as maximum market penetration and maximum added value.

3.2.2 APPLICATION SPECTRUM CHARACTERISTICS

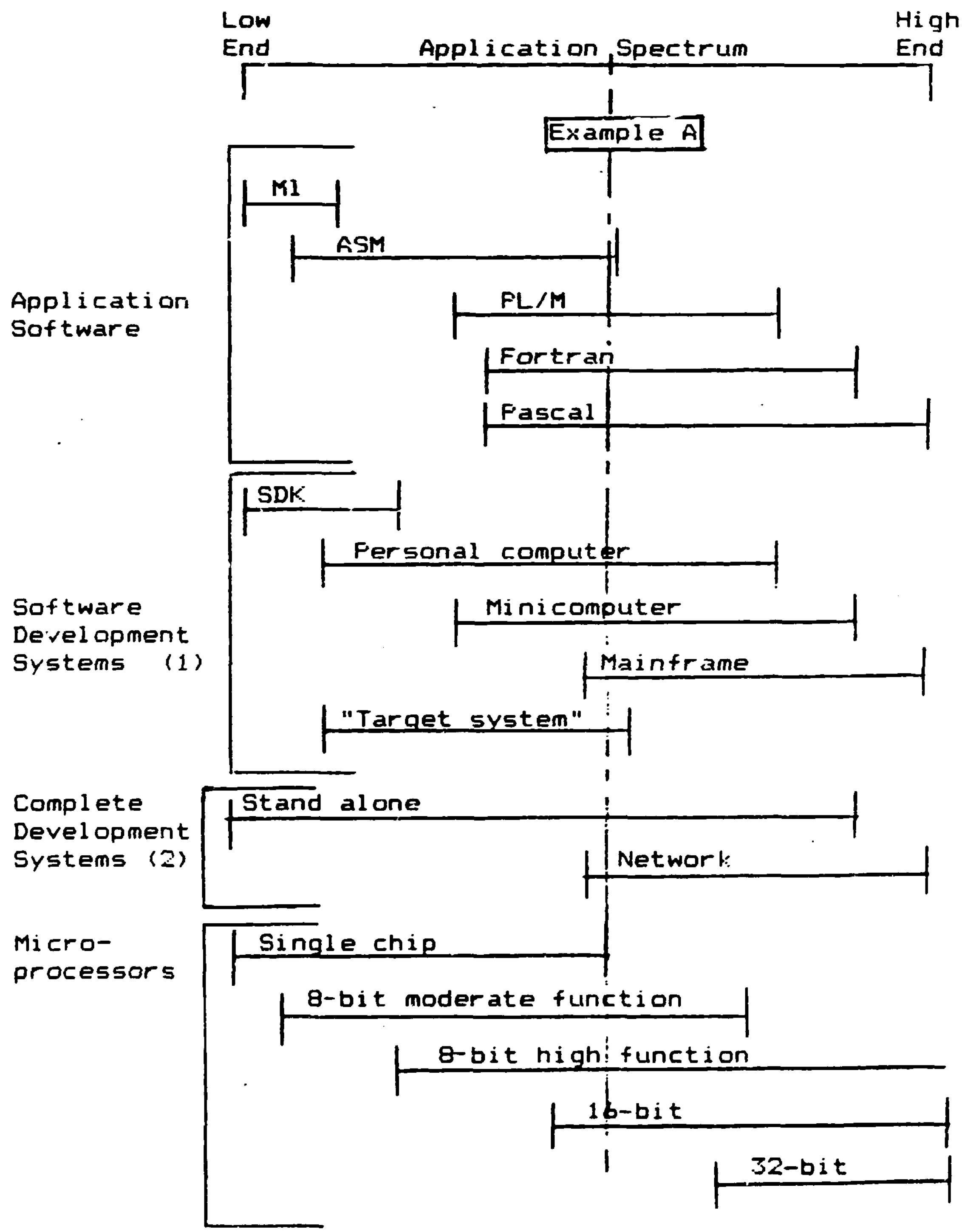
As previously indicated, placing an application on the Application Spectrum will indicate the technical requirements for both development tools and manpower skill levels required for the design. A more detailed summary of requirements along the Application Spectrum is shown in figure V. Placing the application along the Application Spectrum is simply a matter of determining the type of microprocessor best suited to satisfy the technical requirements and observing the range covered on the spectrum. Example A, figure V, indicates that a low to middle range application (such as process control in a textile manufacturing line) would most likely:

1. Require developing the application software in assembly language or PL/M;
2. Use the personal computer, minicomputer, or the target system for software development;
3. Use a stand alone development system for complete software and hardware integration.

This gives a general idea of the types of development tools required and the skill level of manpower particularly in the area of software. This knowlege can then be used in developing countries to ensure the proper equipment and manpower skills are available for the proposed application. It is emphasized that inappropriate use of development tools either above or below the intended application can create significant delays (or worse) in the completion of the intended application. Likewise electing to generate application software in machine language code for any application except the very low end can result in disastrous software documentation and maintenance problems.

3.2.3 DEVELOPMENT EQUIPMENT STRATEGY

Figure V. Application Spectrum Characteristics



The importance of an adequate supply of appropriate development equipment is essential if microelectronic applications are to be developed quickly and efficiently. The capital investment required to acquire these development tools can not only be repaid very quickly, but also many times over as it is used in the product development. The technical and payback arguments of the need for development equipment cannot be challenged - the economic reality of obtaining this equipment in developing countries is something quite different. This reality (lack of money) results in a significant lack of appropriate development equipment. To address this reality, the implementations of a two-part strategy for development equipment is recommended. The two parts of the strategy are:

1. Establishment of Development Centres;
2. Generating software tools to utilize existing computer equipment

The first part of the strategy will allow the rapid development of many applications thereby conserving that most valuable resource, manpower. The second part of the strategy will make more effective use of existing general purpose computer equipment so that this equipment can be used to develop applications using different manufacturers' microprocessors. The establishment of the Development Centres is the cornerstone of the strategy to become independent with regard to the design and use of microelectronics.

3.2.3.1 DEVELOPMENT CENTRES

The establishment of Development Centres in developing countries is a cost effective solution to the hopefully short-term problem of very scarce microprocessor application development resources. This lack of adequate equipment is due in part to the low level of application development which is due in part to the lack of adequate development equipment and so on. Development Centres are designed to break this vicious cycle.
For Development Centres to be used to their fullest potential, several factors must be considered:

1. Development Centre location and type
2. Staffing requirements
3. Initial and sustaining funding sources
4. Training requirements

Development Centres provide the hardware and software tools required for microprocessor-based application development. In addition, the centres can be structured to provide for adequate service and maintenance of the sophisticated equipment. This initial centralization of microprocessor-based equipment simplifies the logistics involved in fixing and maintaining the equipment contributing to its effective use.

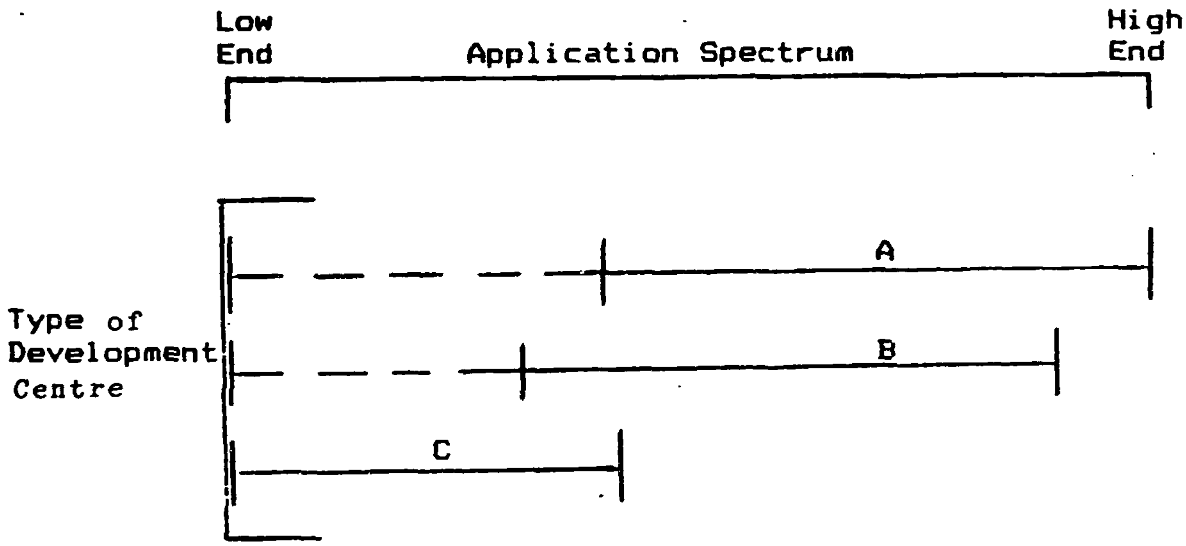
DEVELOPMENT CENTRE LOCATION AND TYPE

The location and type of each Development Centre are tied together. As shown in table 4, the type of Development Centre depends on the type of applications likely to be developed in that location. Because of geographical considerations, several Development Centres are required in most developing countries. It is important to optimize equipment type so that scarce funds will be most efficiently used.
The range of application development which is most appropriate for each type of Development Centre is shown in Figure VI. The most efficient use of each Development Centre is shown by the solid line for that type of centre. Possible (but less efficient) uses for each centre are shown by the dotted line. For example, applications such as development of sophisicated complex simulators would be most effectively developed using Type A centre. The development of a simple data recorder, however, would be most effectively done on a Type C centre. The geographic location of each of these types of centres then depends on the most prevalent type of applications being developed in that area.
The equipment outlined in table 4 can be either general microprocessor applications (equipment from such companies as Tektronix, HP,etc.) or equipment designed for use with specific manufacturers of microprocessors (equipment available from such companies as Intel, Motorola, Siemens,etc.) This

Table 4. Development Centres

TYPE OF CENTRE	EQUIPMENT
A ($150k-200k US)	o Multi-User (6-station network) o Hard disk (35MB minimum) o Dual floppy disks per station o Printer o Emulators for major microprocessors (6800, Z80, 8085, 8088, etc.) o Complete development software packages: -High Level languages -Debug utilities
B ($60k-80k US)	o Stand alone work stations (4) o Selected 8-bit emulators (Z80, 8085, 6800, etc) o Dual floppy drives per station o Printer o Hard disk
C ($20k-40k US)	o Single stand alone work station o Dual floppy disk drive o Selected 8-bit emulators o Selected software development type kits

Figure VI. Role of Development Centres in the Application Spectrum



Dotted line (----)represents less efficient utilization of Centre for range of applications.

equipment supports a wide range of emulators essential to the development of many applications. The use of emulators and their attendant software debug packages greatly simplifies the software/hardware integration phase in design projects. The desirability of Development Centres can be most easily demonstrated by an analysis of a typical design project. The type of design project described is typical of applications from the lower mid-range to the high end application spectrum described in section 3.2.2. Many microprocessor-based applications require an interface to sensors, transducers, controllers and other mechanisms that convert digital signals into other forms. An example of such a system is shown in figure VII and represents a typical control type system. The system shown in this figure consists of five major subsystems:

1. Process/Control interface
2. Analog to digital and digital to analog conversion
3. Central Processing Unit
4. Peripheral Controller interface
5. Peripheral systems

The design of the total system requires that each subsystem perform its task as an independent unit AND to interface to other subsystems properly to ensure operation of the entire system. It is readily seen that in any but the simplest system the degree of detail required to implement the system can easily become overpowering, especially if there is a scarcity of skilled manpower. It is the observation of most experienced designers that the most likely place for design problems to occur is in the interface BETWEEN subsystems and not in the subsystem itself. Much valuable design time is lost trying to sort out the host of interface problems encountered in system debug if the proper design tools are not available. These interface problems can take the form of hardware, software, or a combination of the two. It is in the ferreting out of these interface problems that the development system and the emulator is a most valuable tool. These tools can isolate problems and allow the designer to determine whether the problem is software, hardware or a combination and to most rapidly implement a solution. The development system along with the emulator has one other major advantage; it can aid in the debug of the system in REAL-TIME allowing all of the subsystems to interact as they would in full operation. Many system problems crop up when the system is run at maximum or even designed speed even though each of the subsystems work properly when tested alone. The concept of the Development Centre is to put the proper tools in place to maximize the productivity of the most scarce resource, skilled technical manpower. The faster that more reliable microprocessor-based applications are designed the more applications there are that can be created.

STAFFING REQUIREMENTS

Development Centres require more than capital equipment for operation. As in all business endeavours, these Centres require both technical and management expertise. The previous section outlined the capital equipment requirements. This section will discuss the requirements of staffing the Centre with appropriate manpower (both technical and managerial). The first topic will be the management infrastructure that is required to provide direction to the Centre.

Some form of control both of technical and capital resources is required if the Development Centres are to realize their objectives of providing effective tools for the development of microprocessor-based applications. The most desirable situation is to provide for this control and management in some EXISTING infrastructure within the developing country. As mentioned in previous sections of this paper, there exist many facilities wherein a Development Centre might be located which will provide both the technical and business management functions required. These facilities, such as research centres, university departments, and public and private sector enterprises, offer ready-made infrastructures capable of supplying the required management functions. National objectives then can be achieved most easily and the appropriate channels of accountability can be realized in the minimum amount of time to establish the Development Centres.

The second staffing resource required if the Centre is to achieve the objective of providing design resources is that of skilled technical manpower. This manpower is required if the Centre is to provide a service to those newly emerging companies and industries that know of an application that is required but do not have the resources to COMPLETE the development of the application. Many enterprises in both the public and private sectors can be expected to have a good grasp of fundamental knowledge required to have THOUGHT of the application in the first place, but not have the technical base to complete the entire application design. An example of such a situation can be found by analyzing the system described by figure VII. Here a company might have the expertise to design several (one or more) of the subsystems but not the entire system OR may not have the expertise to design the proper interface between the subsystems. In other words the enterprise has a good overall idea of what is required to complete the application but does not have the expertise to pull all of the pieces of the design together. Figure VIII shows a pictorial representation of the concept described. As shown in this figure, a company or government agency has the capability to conceive of an application and to design most of its component parts, however it does not have the capability to design a certain portion of the system. (An example might be the inability to design an effective operating system required to "tie" all of the application software together in the system.) This restriction can significantly delay an application or even kill the entire program. Clearly some structure is needed to overcome such a situation. (This type of scenario is particularly relevant to developing countries because of the lack of skilled technical

Figure VII. Typical System Configuration

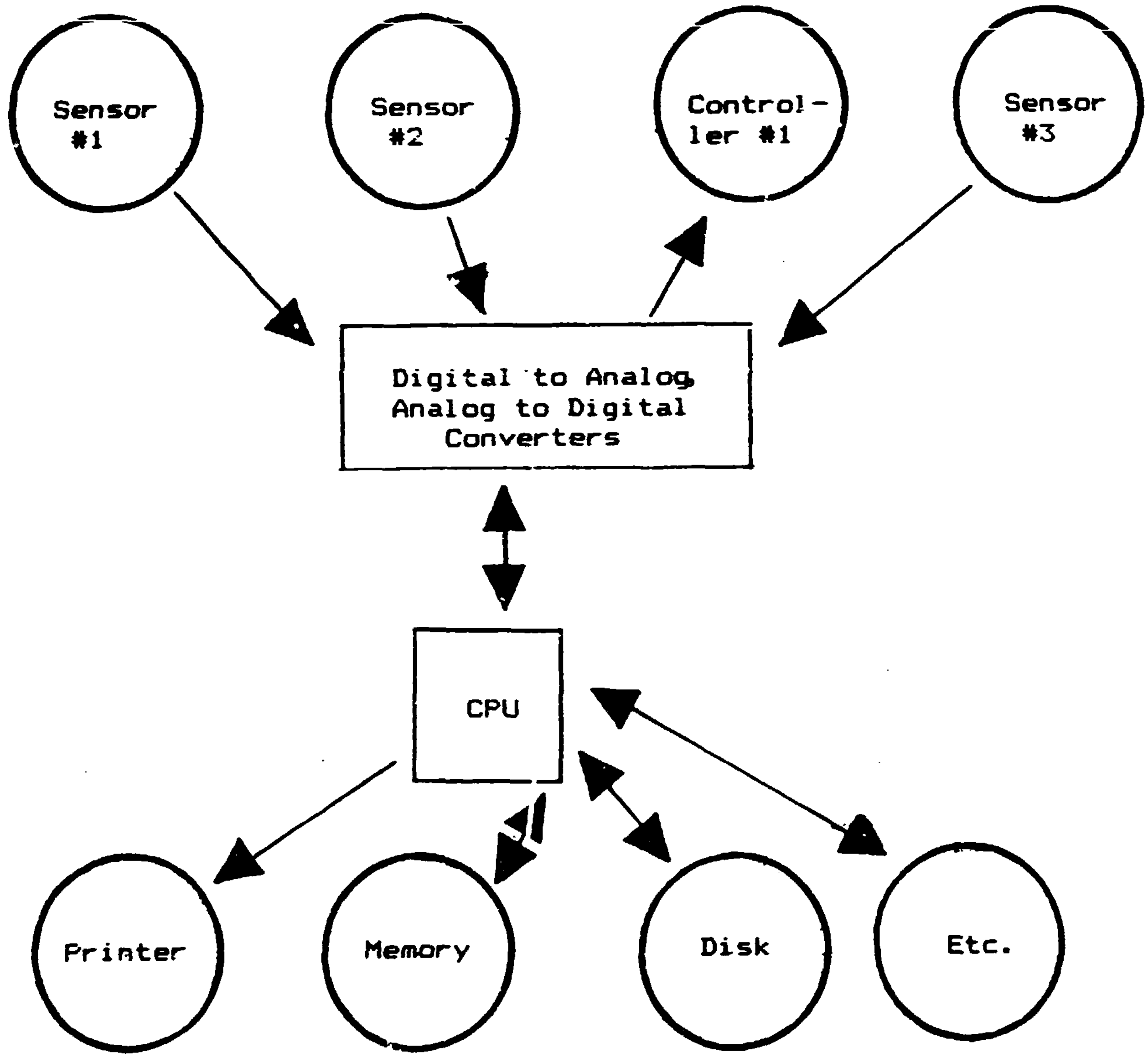
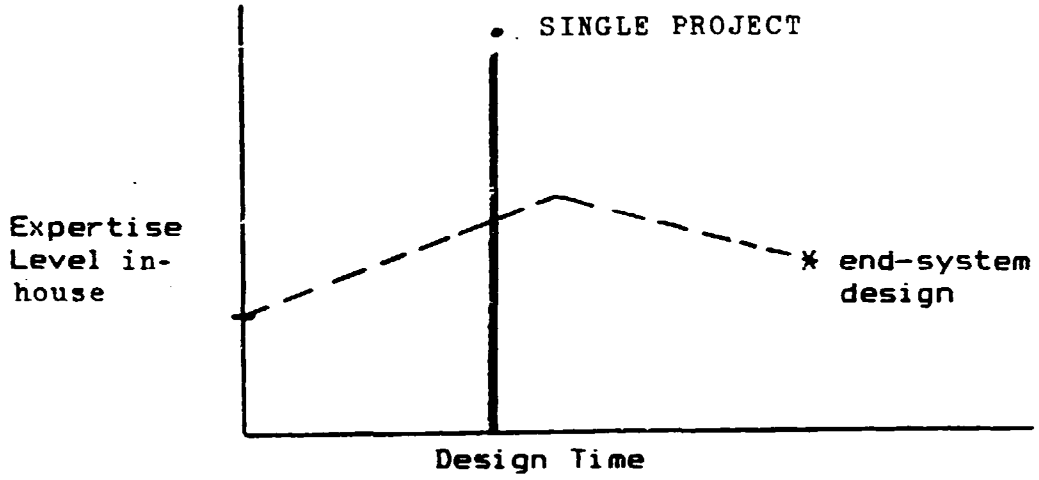


Figure VIII. Expertise Level vs Design Time



manpower resources.) The Development Centres provide an infrastructure to cope with just such a problem.
With the proper management infrastructure in place for the Development Centres skilled technical manpower can be hired and provided with challenging jobs to cover most aspects of design projects which the Centre is likely to encounter. These technical resources could act as either technical consultants to the various enterprises developing applications in the Centre or they could act as the design engineers that are otherwise not available to the enterprise. In either case, the application now has the technical manpower required to complete the application using EXISTING resources within the developing country thereby controlling the great majority of ADDED VALUE for the application.

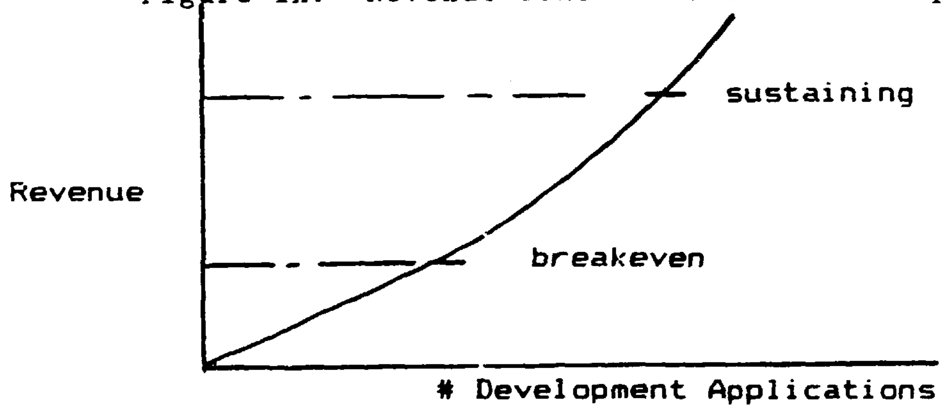
INITIAL AND SUSTAINING FUNDING SOURCES

The concept of Development Centres may make considerable sense from a technical standpoint. A more practical problem needs to be addressed though, where does the money come from to establish and maintain such a Centre? Given the state of the economy in both developing countries and developed countries and the impact of these economies on funding new ventures the problem of finding sources for this capital equipment is no small task. It is therefore very important to establish these Development Centres on a sound economic basis and to operate these Centres from that basis. Seen in this light, the problem of finding adequate monetary funds becomes somewhat more manageable (although not without some problems). It is the intention of this section to suggest some possible economic criteria for the Development Centres which will make them a viable monetary GENERATING Centre and not just another "infinite sink" down which scarce funds are poured. These economic criteria are based on:

1. Capital funding
2. Sustaining funding

As in most business enterprises (whether in the public sector or private sector), some source of funds is required to establish the function. In the case of Development Centres, this source of funds is most likely to come from loans from either the developing country, loans from developed countries, or loans OR equity obtained from private enterprises in the developing country. (This latter source, whereby private industries invest in the Development Centres, is the most interesting since it will ensure that the Centres are run most effectively. It also provides these industries with resources that otherwise would not be available.) But for now discussion will focus on obtaining capital funds from some form of loan either inside or outside the developing country. One key factor in obtaining any loan is showing the lender some reasonable chance that the loan will be repaid in a reasonable time. The funds used to repay the loans AND to provide for the sustaining functions of the Centre come from charging for the use of the Centre. The basic criteria are that applications developed in the Centre have some economic benefit. Whether the benefit is the generation of new foreign currency from exports or the application of a new program of social value, it can be made to "justify" the existence of the Centre as to its usefulness to the objectives of the developing country. A greatly simplified model of the economic value of such a Centre is shown in figure IX.

Figure IX. Revenue Generation from Development Centres



In this model, the number of applications is equated to the generation of funds since each application development will be "charged" for the use of the system. In some cases, this charge will take the form of actual money transferred to the Centre, in other cases this charge can take the form of recognized value added for the use of the Centre. (The latter case is most likely to occur when the Centre is used to develop applications for the public sector such as universities, research centres, and various government agencies. In any case the usefulness and viability of the Centre is demonstrated in a concrete way.) There are two main points of interest shown in figure IX, namely:

1. Breakeven
2. Sustaining

The "breakeven" point shows the level of design activity the Centre must generate to "pay back" the initial capital investment. The "sustaining" point shows the level of activity that must be maintained to continue the Centre with the expenses for maintaining the equipment and paying the salaries of the personnel described previously. In both cases, it is readily apparent that it IS POSSIBLE to use the Centre to generate the funds to establish and maintain the Centre. It is up to each country, of course, to determine the best method of establishing such a Centre.

TECHNICAL STAFF TRAINING REQUIREMENTS

Once established, Development Centres require a staff trained in the use and basic maintenance of the equipment. The purpose of this section is to present some of the training issues faced by the Development Centres and to suggest some potential methods whereby the Centres may implement the required training. To be effective as a Development Centre, the Centre must have a broad technical capability. The basis of this capability is the thorough understanding of both the equipment and its use in a design environment. This requirement, that of a thorough understanding of the equipment, requires a significant committment to training issues by the Centre management. These training issues take two basic forms:

1. Initial training
2. Update training

Initial training refers to the training received by individuals who are new to the Centre and who may not be familiar with the details of the equipment. Update training refers to the training received on an on-going basis by the technical staff of the Centre. This type of training is particularly important in the areas where rapid advances are experienced in technologies and their implementation. Since both types of training are important to the success of the Centre, it is important that management allocates the appropriate resources required to maintain the Centre's expertise. Suggested training modules to implement the initial and update training programs are shown in table 4. In this high technology environment, it is not unusual for the technical staff to require about 15% to 20% of their work time during a year to be devoted to training.

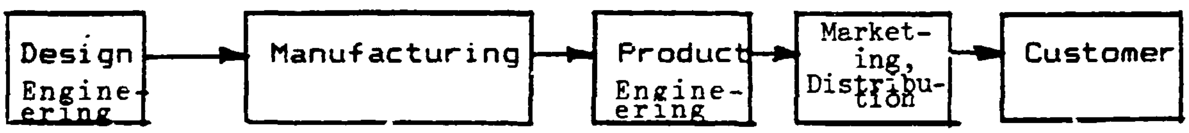
3.2.3.2 UTILIZING EXISTING COMPUTER EQUIPMENT FOR DEVELOPMENT

The technical infrastructure in all developing countries visited had access to sophisticated computers from many manufacturers that can be effectively used to develop software for microprocessor-based applications. While this equipment is capable of supporting software development for microprocessors, it requires the proper software tools and utilities to handle the design effectively. Not all of these tools are readily available. It is the recommendation of this paper that studies be undertaken in each developing country to determine which EXISTING machines are most suitable for use in software development for microprocessors. It is further suggested that appropriate software be developed in the developing country which will allow these classes of machines to be used in microprocessor-application development. The scope of this effort can easily exceed capability if a judicious choice is not made regarding which existing computers will be chosen to have "cross software" packages written for selected microprocessors.

3.3 PRODUCT MARKETING AND DISTRIBUTION

The previous sections of this paper have concentrated on the technical aspects of defining and designing microprocessor-based applications. Once developed, these applications must get into the hands of the people and industries that will use the product. The purpose of this section is to discuss possible marketing and distribution strategies available to developing countries that utilize EXISTING infrastructures within each country to take maximum advantage of the existing strengths to achieve these desired strategies. The importance of building strong marketing and distribution infrastructures in the microprocessor-based application arena cannot be overemphasized. These infrastructures are especially important if one is to be competitive in internal markets as well as the world marketplace.The degree of independence that each country acquires in this new technology will depend to a large extent on the strength of these two areas. A diagram of the place of marketing and distribution in the development of microprocessor_based applications is shown in figure X.

Figure X. Functional Groups in Development Activity



As shown in this figure, this is the function that directly has access to the customer for all the other functional groups.

3.3.1 Product Marketing

Marketing can mean many different things to different people. In some cases marketing is recognized for the vital role it plays in the overall development of new markets. In other cases, marketing is regarded as a function to "convince" people to buy something that they really do not need. This latter view is especially damaging to the very groups that need the function the most. If marketing is viewed as the EYES and EARS of a company or organization regarding what a customer requires and provides feedback on the various aspects of products that a customer has purchased, then the importance of the function is apparent. For the purpose of this discussion, the term product marketing is defined (regarding its functions) as shown in figure XI.
As shown in figure XI, one of the first requirements of a product marketing group is to determine the demand for the product(s) for which it is responsible. The availability of a product (whether it is a computer system or an agriculture

controller-type application) is basically dependent on two factors:

1. Product supply (manufacturing constraints)
2. Customer "demand"

Figure XI. Product Marketing Functions

1. Technical Requirements of Product
2. Demand for Product
3. Monitoring Distribution Outlets
4. Determining Pricing Criteria
5. Competitive Analysis (domestic and foreign)

The issues surrounding these two factors can be (and usually are) complex and varied. If the newly developed applications are to be put to their best use, it is important that expectations of both the customer AND the manufacturer are realistic in terms of availability and functionality. If, for example, the customers' expectations for the product are high and the manufacturer is not able to keep up with demand, serious problems can result if promises for shipment cannot be met. In this case there can be a loss of confidence in the viability of the product - a situation a new product (especially one with a new technology) cannot afford. In the other case, if the demand for the products by customers is significantly below expectations, the question must be asked if the product is addressing the correct technical requirements for the market. Much valuable time and engineering manpower can be wasted if the product does not fit the intended market. Sufficient attention must be given to these two potential problems to prevent a loss of confidence in the technology or the manufacturer. DURING THIS PERIOD OF GROWTH WITH A NEW TECHNOLOGY IT IS IMPORTANT TO ESTABLISH CREDIBILITY IN ALL PHASES OF OPERATION- NOT JUST IN THE TECHNICAL CAPABILITY OF THE PRODUCT.

Being able to predict product availability (even at a gross approximation) is important to the manufacturing and engineering functions (shown in figure XI) of the manufacturer. In one case, the supply is limited by manufacturing constraints (which could be either design-related or demand-related). In the other case, product supply is limited because the need in the market-place is not yet recognized. Product marketing is charged with determining

which is which and recommending a solution.
The importance of this function is most readily apparent in the field of microelectronics where the conditions in the market-place can rapidly change (the effects of rapid change are most noticeable when operating in the international market-place). It is important to recognize that Product Marketing is responsible for IDENTIFYING the correct market conditions (1 and 2 above) and not for providing a solution (although one may be proposed). The responsibility for acting on the available information rests with the management infrastructure (defined in an earlier section).
A second function of Product Marketing is to provide the tools and required materials to train and/or instruct the customer in the proper use of the microprocessor-based equipment that the customer has purchased. This is one of the most important functions since it ensures that the equipment is being used for the function intended. This training of the customer may be no small task when the equipment is to be used by people who may have a very rudimentary or no knowledge of technical requirements of microprocessor-based equipment. Indeed in many cases (especially in developing countries), the basic literacy rate may be such that the user is not to be expected to be able to read the instructions. This is one of the factors that should have been taken into account in the definition and design phase (as discussed earlier in the paper). All of the functions described above could be performed by the design engineers or those in the management infrastructure. However, using these resources can significantly impact the design of future products and can effectively bring to a stop the development of new applications.
A third function of Product Marketing is to act as the intermediary between the customer and the manufacturer (the so-called eyes and ears of the manufacturer). It is this role that is one of the most important of the function. The customer must have some place and someone to contact in some form if the application is to meet with success in the market-place. Nothing will eliminate a product faster than the inability of a customer (whether in agriculture or medicine) to reach a solution to problems which always arise. It is apparent that if a large customer base is to be served by a manufacturer, a very large group of Product Marketing people will be required. This situation can easily become intolerable from both a personnel standpoint and management standpoint.
The solution to this problem lies in the decomposition of the rest of the marketing strategy outlined in figure XII. As shown in figure XII, the Marketing/Distribution function is further subdivided to delineate Distribution. In this model, it is important to note that distribution need not be structured to handle only the products of a given manufacturer. Indeed, the distributor may handle many different manufacturers representing several segments of high technology products.
Using this model, relieves manufacturers of having to staff a very large Product Marketing function thereby diluting their already scarce manpower resources. The Product Marketing group can now interface with representatives of the distributors and

some other individual customers that they have selected. Attention will be given now to the question of where distributors come from in developing countries and what they do.

3.3.2 DISTRIBUTION

Distributors form a vital part of most high technology companies in developed countries. These infrastructures have evolved over a period of many years in the countries and have generally been associated with the economic structure in these developed countries. It is always tempting (although not necessarily proper) to apply what one knows to work elsewhere to solving similar problems in developing countries. In the following discussion regarding distribution, an attempt is made to suggest a possible structure for distribution in developing countries and to address the unique problems facing those countries in trying to set up such an infrastructure. The importance of this section lies in the discussion it will hopefully generate in the developing countries on the setting up of this particular type of infrastructure.

Product distribution takes many forms depending on the type of application being developed and what the "customer" requirements are for his/her type of service. The distributor provides three basic functions:

1. Represents the manufacturer to the customer;
2. Acts as a "local" warehouse for the manufacturer;
3. Acts as billing agent for the manufacturer (if required).

The extent to which the distributor acts in each of the above categories is dependent on the agreement between the distributor and the manufacturer. In developing countries it is most likely that the distribution infrastructure will come from the public sector (at least initially). The setting up of such an infrastructure in the private sector will depend on what types of incentives corporations have to establish the functions. It is beyond the scope of this paper to analyze and/or suggest the various structures possible to effect such an infrastructure. The necessity, however, to have such an infrastructure cannot be over-emphasized. Before addresssing WHERE the distribution infrastructure comes from, the three functions of the distributor will be considered.

The first function of the distributor is to act in a sales capacity for the manufacturer. In this capacity, the distributor is expected to have the technical expertise to handle the technical questions that arise from the sales situation. Since some applications will require demonstrations, it is the responsibility of the distributor to be able to handle the requirement. It is evident that this requires skilled manpower to act in this mode. The advantage, however, in having the distributor handle the sales situation

(versus the manufacturer) is that the distributor can handle more than one product in a high technology product line thereby getting the most use of the already scarce manpower resources.
The second function of the distributor is to act as a "local" warehouse for the manufacturer. In this case, the term local may refer only to being in the same country. As will be shown later, having a local resource for product distribution can significantly reduce delays in both getting the products to the market AND can provide a better source for servicing the product once it is in the customers' hands. The quantity of products stocked by the distributor and the conditions of the stocking (such as product mix and return procedures) are usually negotiated on a case-by-case basis with each manufacturer. The locations of the warehouse will depend on three basic factors:

1. Location(s) of markets served;
2. Transportation capabilities from the manufacturers' location;
3. Capital for setting up the warehouse.

These stocking distributors should be placed as close as possible to the market served to take maximum advantage of the market. Likewise the frequency of available appropriate transportation and communication facilities will dictate to some degree the location of the most appropriate locations. The most important consideration, however, is the money it takes to set up the warehouse in the first place. The important point to remember, though, is the necessity to consider all three factors.
The third function of a distributor (that of acting as the billing agent for the manufacturer) is self-explanatory. In general, in developing countries this function will probably receive low priority (and probably should).
As was shown in an earlier section, a characteristic of the microprocessor-based business is the rapidity with which the market can change. It is therefore imperative that infrastructures be set in place to be able to effectively exploit the changes as they occur. Having these infrastructures in place (or at least working to put them in place) will go a long way toward achieving competitive equality with high technology firms in the developed countries thereby enhancing the prospects for implementing an effective export strategy as well as serving the local markets.
Up to now the relatively easy subject of the function of distributors in developing countries has been considered. The second point of consideration is where do the Distributors COME FROM that will perform those functions. In developing countries where capital expenditures required to set up such an infrastructure are already severly pinched (far more so than in developed countries), the point becomes particularly acute. The temptation is to ignore the

requirement and place it in the category of being a "nice" objective but one that cannot be implemented. For reasons already discussed this could be a particularly shortsighted approach. Rather it is hoped that the creativity applied to developing the applications will now be applied to finding solutions to this thorny problem. The following ideas are advanced to kindle discussion in each of the developing countries regarding the setting up of this infrastructure. There are three basic approaches to establishing the required distribution infrastructure in the developing countries:

1. Use existing technical distributors;
2. Form joint ventures:
3. Establish appropriate economic incentives to encourage "start-up" operations.

The first approach is to set up agreements with those firms that are already doing distribution - type business in the developing country. The type of distributors most likely to have both the interest and the technical capibility to handle the task are those presently engaged in distributing technical products in the country for foreign and domestic manufacturers. The types of products being considered for development and manufacture in the developing countries are most likely to enhance the product line of this type of distributor. In addition, the capital required to set up totally new facilities in key market areas are likely to be reduced since such facilities probably already exist to serve the distributors' present markets. Indeed, in this type of arrangement, the distributor is most likely handling semiconductor components and the like to which microprocessor-based applications systems will significantly enhance business. This scenario can easily be seen to be a WIN-WIN-WIN situation for the manufacturer, distributor, and DEVELOPING COUNTRY.

A second approach might be to set up joint ventures with appropriate foreign firms (either distributors or manufacturers) who already have expertise in the field of distribution. If such ventures were approached with the mutual benefit of all parties in mind, the likelihood of having a successful enterprise would be greatly improved. The advantage of such an arrangement with the appropriate partner is the tapping of a skilled and knowledgeable resource that can add significantly to the overall effort of becoming self-reliant in the field of microprocessor-based technology.

A third approach is to create the appropriate economic climate that will incentivize firms to create distributors in the developing country. This approach while attractive in many respects may be beyond other more basic national policies. Such an approach has the clear advantage, however, that the developing countries need not risk any scarce capital, leaving that risk (with appropriate safeguards) to the new ventures.

3.4 PUTTING THE PIECES TOGETHER

Sections 2.1 through 2.5 outline possible solutions to practical problems faced by developing countries in setting up or expanding their capability in microprocessor-based applications design. The purpose of this section is to propose a model for setting up (or expanding) appropriate infrastructures in developing countries which will meet the national objectives set by those countries in the field of microprocessor/microelectronic development. This model takes into account the conditions observed in as well as discussed in the developing countries and seeks to build on the inherent strengths available in the developing countries while facing the practical realities of shortages in both skills and capital.

An example of this model in action is the work presently underway in India for establishing a strong base in microprocessor design capability. While this Indian program (referred to as Appropriate Automation) is not limited to microelectronic implementation, it does have features that make it highly appropriate for consideration in planning for programs in other developing countries. Indeed, the potential for South-South cooperation in the field of microprocessor-based application design among countries with similar interests and infrastructures (based in part on this model) is significantly enhanced.

3.4.1 ESTABLISHING THE FOUNDATION

As discussed in section 3, the three stages of application development can be characterized as:

1. Product definition
2. Product development
3. Product marketing and distribution

A successful microprocessor-based application development infrastructure should take into account these three stages. The most efficient way for the developing country to bring expertise to bear in these areas is to centralize the development activity into one or more Development Centres as outlined in section 3.2.3.1. The function and details of such Centre(s) are discussed in the referenced section.

The guide, then, to establishing the foundation for application development may be summarized as follows:

1. Select Development Centre sites;
2. Define management infrastructure of Centres;
3. Staff Centres with appropriate technical personnel;
4. Obtain necessary development tools;
5. Define product definition and marketing procedures.

Notable by its absence from the above list is the source of capital to fund these centres. Whether the capital funds come from the developing country or from outside sources, the approval of such funds will almost certainly be dependent on the overall plan for the utilization of such funds --- in other words the PLAN of ACTION. Developing a Plan of Action, based in part on the above five guidelines, will help ensure a coherent structure within which to operate and develop MARKETABLE applications.

3.4.2 PLAN OF ACTION

The Plan of Action for establishing microprocessor-based application development is composed of four basic parts:

1. Creation of central group;
2. Establishment of Development Centre(s);
3. Establishing communication links with public and private sector enterprises;
4. Interface between the Development Centres and semiconductor manufacturing facilities within the developing country.

Before any Plan of Action can be implemented, there must be a central group responsible for overseeing the project and defining its objectives and milestones. The authority to establish such a group rests with different agencies and/or departments in each developing country. For the purpose of this peper, it is assumed that the appropriate agency has taken responsibility for the creation of this core group and has notified others of its formation. THE MAJOR PURPOSE OF THIS CENTRAL GROUP IS TO ACT AS A CATALYST FOR THE CREATION OF DEVELOPMENT CENTRES AND TO PROVIDE A FRAMEWORK WITHIN WHICH THESE CENTRES MAY OPERATE. In the opinion of the author, consultations between interested parties in developing countries and UNIDO regarding the establishment of this central group would be very beneficial. Such consultations could provide important information regarding the establishment of such groups in other developing countries and the potential for cooperation between groups (South-South cooperation).

In establishing a base for microprocessor application development within developing countries, it is desirable to set up Development Centres in those locations which have access to both skilled technical labour and an industrial base. As described earlier in section 3, the Centres can most easily be placed in those public sector facilities such as research centres, universities, or public corporations which have technical and management infrastructures in place. In setting the Centres up in such locations, it is important to obtain a memorandum of understanding BETWEEN THE CENTRAL GROUP AND THE HOST INSTITUTION to assure reasonable autonomy of the Centre with the institution. The specific factors regarding

the establishment of the Development Centres is found in section 3 of this paper.
The third part of the establishment of microprocessor-based application development is one of the most critical to the long-term success of the program - the interface of the Development Centres to the public and private sector companies in the developing countries. It is through these companies that important information regarding product definition and characteristics are obtained. THE USE OF THE DEVELOPMENT CENTRES TO DEVELOP MARKETABLE PRODUCTS CANNOT BE OVER-EMPHASIZED FOR THE LONG TERM SUCCESS OF THE APPLICATION EFFORT. Suggestions for Product Definition/Marketing responsibilities of the Centre(s) are made in section 3 of this paper.
The fourth and last part of the Plan of Action is the interface between the Development Centres and the indigenous semiconductor manufacturing facilities (if any) within the developing country. In the early part of application development, it is important to utilize the appropriate technology (both semiconductor and microprocessor) whether the technology is PERCEIVED as VLSI or LSI. Close cooperation between the Development Centres and these indigenous manufacturers is imperative if both are to achieve their respective national objectives. In this area, the relationship between semiconductor manufacturing facilities and Development Centres is evolving rapidly. Because of this rapid change, it is important for the developing countries to maintain close liasion with UNIDO to discuss problems, plans, and opportunities unique to developing countries in this moving area.

4.0 APPLICATION EXAMPLES

One of the three objectives of the mission (section 1.0) is to identify specific examples of microprocessor-based applications that can be developed to demonstrate the viability of this technology to solve particular problems in the developing countries.Application examples described are those that have been identified by professionals in both the public and private sectors in the countries visited. Furthermore, the examples come from the areas identified as being the most critical to the overall strategic objectives of the developing country. The areas of most importance are:

1. Agriculture
2. Health
3. Industrial (Process Control)
4. Transportation
5. Energy

Concentrating in these areas for the development of microprocessor-based applications gives the dual benefit of establishing a new base in high technology systems AND solving some immediate problems of most importance to the developing countries. Considerable attention has been paid to both unique technical requirements and environmental conditions encountered by the application in the developing countries in the areas described above. It is emphasized that the applications described in the following sections DO NOT represent an exhaustive study of the possibilities for development in a particular country. Rather these examples of applications represent the results of discussions with selected professional and technical personnel in both the public and private sectors regarding their perceptions of the potential applications. The examples chosen also do not represent a thorough analysis of the technical requirements or applicability of the application (in large part due to the very short time period available for the purpose). THESE EXAMPLES SHOULD BE CONSIDERED AS FORMING THE BASIS FOR FURTHER DISCUSSIONS AND ACTIONS IN THE DEVELOPING COUNTRIES REGARDING THEIR VIABILITY AND APPROPRIATENESS.

An excellent research work done on an extensive basis to define appropriate applications and the characteristics of the application is a publication "Electronics in Industries - a Survey" compiled by the Industrial Electronics Promotion Programme of New Delhi, India.This study analyzes in considerable detail the characteristics of selected applications in a variety of industries and sectors (such as agriculture) conducted by people highly knowledgeable in the requirements of the particular industry or sector. This type of in-depth analysis is highly recommended for all who wish to undertake a comprehensive program to revitalize industries and other vital sectors such as agriculture and health with the introduction of appropriate microprocessor-based applications.

Selected application examples from the developing countries visited are arranged by country and follow the following format:

1. Application Description
2. Special Technical/Environmental Considerations
3. System Configuration
4. Implementation Details

The first part of the format is a description of the application along with some detail of its characteristics. The second part of the format is perhaps one of the most important. This part describes the considerations that make the application worth being considered by the developing country as one on which to expend manpower resources to design and produce. In most cases, the special considerations section give those characteristics of the design that make the design most attractive for the developing country to develop - i.e. how does the developing country add significant added value to the application and what will be its competitive advantage in the marketplace.
The last two parts of the format describing applications outline the system configuration and those factors most impacting costs.

4.1 APPLICATION EXAMPLES

Much of the existing activity in microprocessor-based applications observed during the visits to the developing countries centred around 8-bit processors such as 8080, Z80 and 8085. In the applications observed, the primary software tools were machine language and Assembly language level implementations. The general lack of effective compilers for higher level languages is considered a handicap to development engineers in effecting "high end" applications. The applications described below can all be implemented on 8-bit processors (either single chip or processor-oriented) of the types being used in other applications.

4.1.1 PRIVATE AUTOMATED BRANCH EXCHANGE (PABX)

4.1.1.1 DESCRIPTION

The level of telecommunications in the national environment in developing countries varies widely. The present work in telecommunications represents a massive investment in both manpower and capital resources. While this work is going on it is desirable to look at another - less massive - aspect of telecommunications, that of communicating over a relatively small network such as would be encountered in an office building or complex. Such networks are abundant in both the public and private sectors. In these small networks, the timely and effective communication of ideas and information is critical to achieve the most effective use of that very scarce resource - skilled manpower. A Private Automated Branch Exchange (PABX) is an ideal solution to the problems of

communication within a small network. Most PABX equipment available comes from high technology companies in developed countries and may be underutilized in developing countries which cannot take advantage of the full potential of these systems because of the state of the art of the telecommunications infrastructure. Developing a more modest PABX type system gives the advantages of optimizing the equipment for the real world in the existing telecommunications infrastructure and more importantly gives system designers in the developing countries expertise in the development of this most valuable tool in the high technology arena.
The PABX system itself can take advantage of the work already underway in many developing countries in investigations of PABX type systems. This proposed system can be implemented with one or more 8-bit microprocessors. With the design techniques described in section 1, designers can modularize their designs to take advantage of future enhancements to the system as conditions warrant.

4.1.1.2 SPECIAL CONSIDERATIONS

Each of the applications considered in developing countries is reviewed with the intent of optimizing the application to the real world characteristics of the environment in which it will operate. Toward this end several items of special importance are pointed out which enhance the desirability of designing a PABX system which addresses these items directly.
These considerations are:

1. Frequent power outages
2. Input power "quality"
3. Environment (dust, heat, etc.)
4. Human engineering factors
5. State of external telecommunications
6. Cost considerations

Taken together and individually, the above considerations suggest a set of objectives for the designer which will optimize the desirability of such a system for the environment in which it must operate.

4.1.1.3 DESIGN IMPLEMENTATION

The first two special considerations concern the availability and quality of electric power to the system. A basic requirement of the system is that it be capable of recovering from an electric outage (of either a short or long duration) and proceeding from where it left off. These requirements suggest the use of CMOS technology coupled with appropriate batteries to operate the system in a power down mode. Indeed, one characteristic of the system might be to continue operation during power outage at a reduced level of capability while storing for future use those functions temporarily suspended (more will be said on these functions later). The generall high operating temperatures (from the environmental conditions) will have a mitigating effect on the use of batteries to provide backup system operation.

The third special consideration characteristic of desert type environments is the harsh temperature and dust conditions placed on the system. To be practical this system must be expected to operate with no conditioning required in the cooling system. Indeed if cooling is required, it should be of a fan type. This requirement also suggests the use of CMOS technology to implement the system. Dust conditions suggest that the internal circuitry be designed to tolerate a very high dust environment with the need to employ filters that create additional problems in the maintenance of the equipment. Such practices as laminating the printed circuit boards to minimize the chance of "high impedance shorts" developing could be a significant requirement.

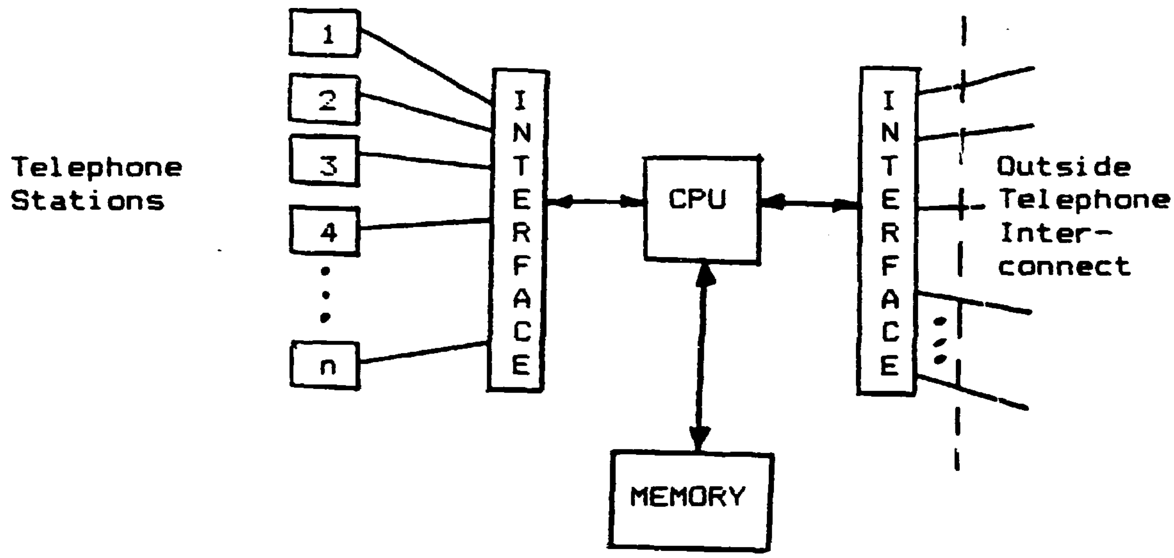
The first three special considerations have strongly indicated that the use of CMOS technology is the most desirable technology to use to implement the system. However the use of this technology is not without its drawbacks - namely cost and availability. This is a case where it may be more practical to implement the first systems in "standard" technologies (MOS, TTL) and later convert through appropriate redesign to the more desirable CMOS technology.

Human engineering is another special consideration to be evaluated during the design of the system. To be most effective, the system should be as easy to use as possible to minimize the training requirements. Indeed, if proper attention is paid to this aspect of the design, the use of highly skilled manpower required to operate the system is diminished. (Thereby conserving this most scarce resource for other more skilled tasks.) The appropriate use of language and numerical displays to direct the operator on a step-by-step basis during operation is highly desirable.

To be most effective, this PABX system should remove some of the problems encountered when operating within the existing telecommunications infrastructure. One of the present characteristics of the telephone system in some developing countries is the difficulty in establishing contact between districts within the country. With an appropriately designed PABX system the delays encountered in establishing contact can be made somewhat more palatable (if not eliminated). Such a characteristic could be accomplished by designing a feature that would allow users to specify where they wish to place the call and have the system repeatedly attempt contact until connection is made. This feature could be extended to allow for users to move to different parts of the network (building) and have the call forwarded to them at the new location. This feature would eliminate much "telephone tag" present in so many situations. The improvement in efficient use of skilled technical and managerial manpower (even within a very small "local" area) would be significant in developing other infrastructures within the country.

Figure XII shows a typical system configuration for such an application.

Figure XII. Reduced Function PABX



4.1.1.4 SYSTEM COSTS

The type of application described is a "high end" application described in section 2. Developing these types of applications requires the proper use of both development tools (hardware and software) and documentation and maintenance requirements for the system. The discussion of these factors is contained in sections 2 and 3 of this paper. Of special interest to the costs of the program is the necessity of a sophisticated operating system to handle the requirements of the PABX system. Even at a reduced level of functionality, the system still needs the control that such an operating system will provide. While it is possible to develop such an operating system, it is more desirable to obtain one on the market from many different sources. System costs will reflect the choice of operating system chosen.

The largest cost for such a system will come from the development of the appliation software required to operate the system. The generation of this software will most effectively be done on a high end development system or mainframe computer. Providing the proper software tools to achieve satisfactory results is of paramount importance to the program. The issues revolving around the documentation and maintenance of the applications program dictate the use of this sophisticated development equipment.(Indeed it is in the design of just such a system that the requirement for effective and timely communication is most critical between members of the design and management teams - exactly what the design is intended to do).

For a truly cost effective system design, the design of the packaging for the components is of great importance. The use of printed circuit card techniques is most important if the cost of manufacture and maintenance is to be minimized. Facilities available in government agencies could be utilized whereby the construction of such boards can be accomplished with minimum delay to the development project. This is of significant importance if the application is to be cost effective in the international marketplace.

4.1.1.5 MARKET CONSIDERATIONS

The desirability of such a system is based on the need for a "reduced function" PABX type system for use in harsh desert environments and operating within a telecommunications infrastructure that is undergoing change. These conditions are encountered in many other countries to both a greater and lesser extent making this application desirable as an export vehicle. With sufficient resources put on the design project, the application can be used to generate new markets in the area of South/South cooperation.

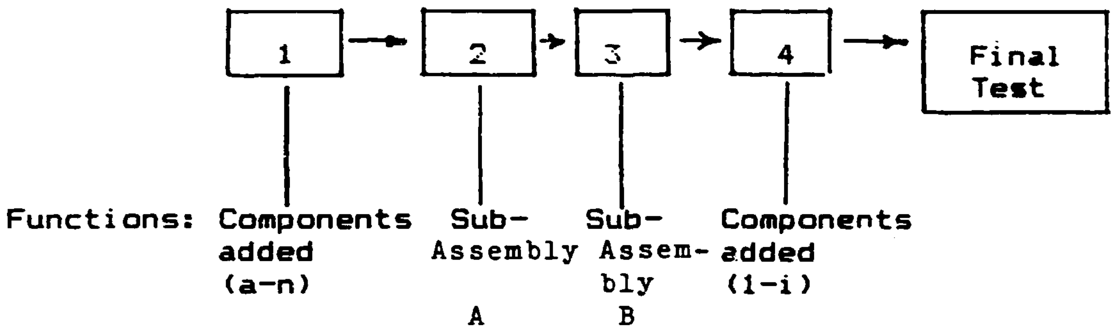
4.1.2 DATA ACQUISITION/ANALYSIS

One of the important industries in developing countries is that of assembly line manufacturing. This industry has been characterized by significant competition particularly in the international market-place. This competition has made it important to increase the productivity in areas such as materials control and quality control monitoring to assure a cost effective operation. The responsibility for putting the appropriate controls in place for improved productivity generally rests with the private sector companies handling the assembly operation. Since any controls that are to be put in place have to be justified from a cost accounting perspective, it is important to demonstrate the viability of any new approach in this area. The application described in this section is intended to be used as a vehicle to improve productivity and quality control in the assembly line manufacturing without incurring significant costs generally associated with more general purpose control/monitoring equipment available for such purposes. This application is intended to be a test vehicle to demonstrate to the companies responsible for assembly operations that such controls are not only possible but also highly desirable in a cost sensitive application.

4.1.2.1 DESCRIPTION

A simplified diagram of one phase of assembly operation in manufacturing is shown in figure XIII.
As shown in this figure, components and sub-assemblies are mounted in a prescribed order as the assembly moves down the line. Each station on the line is responsible for certain operations that utilize certain components and assemblies. The effective control of such an operation requires that accurate logs be kept at each stage to monitor the use of these components and assemblies. Several methods are generally used

Figure XIII. Assembly Operation Block Diagram



to handle such details. One of these methods is manual and is the method generally used in operations in developing countries. This method is sufficient for data collected on the quantity of material used over some period of time but is generally not sufficient or efficient when analyzing and correlating product quality with component and assembly batch identification. It is at this correlation between the identification of the components that make up the product and the quality of the final product that this application is directed.

As components and sub-assemblies are introduced into the line, the identifying characteristics (such as part number, batch number, quantity, etc.) are entered into a nearby terminal or keyboard. (Since each station on the assembly line has a special function the entry of such items as part numbers can be greatly simplified and controlled by the machine.) When the assembled product reaches the end of its particular operation, it is tested to certain parameters and the data recorded. With information on the components and sub-assemblies introduced during the particular phase of operation and the results of the tests performed at the final station, management is able to correlate on a real-time basis the quality of both the assembly operation and the incoming parts used in the assembly to aid in the improvement of both productivity and quality of the final product.

4.1.2.2. SPECIAL CONSIDERATIONS

This application is designed to be used in a factory type application associated with high volume assembly operations found in several industries in developing countries. For the purposes of developing the design and algorithms, it is suggested that the first application be the data acquisition associated with an assembly line for the manufacture of TV sets or other consumer-type goods. Design considerations that can make this application unique to developing country conditions are:

1. Power source variability/quality
2. Environmental conditions (temperature,dust,etc.)
3. Scarcity of skilled managerial manpower
4. Lack of money for capital resources

The first two conditions suggest that CMOS is most likely the appropriate technology to implement this application. Other factors however (such as cost, device availability, etc), may dictate the use of a more standard technology. The determination of which technology to use must await the final design criteria.

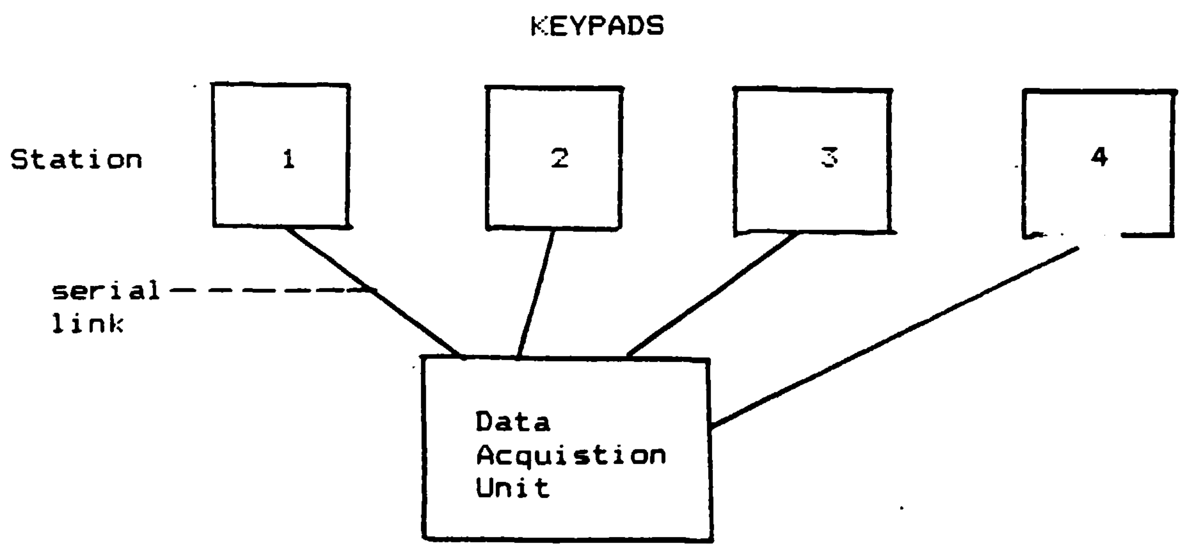
The last two conditions suggest that a special application for data acquisition/monitoring is appropriate for developing countries because of the effects of a scarcity of both skilled manpower and money. The former is a factor because the skilled managerial manpower that is available should have as much data as possible to monitor the overall health of the assembly on a real-time basis (or as close to real-time as possible). This management tool can be used over time to develop the insights into the makings of a smooth and productive assembly operation thereby increasing the productivity of the factory.

The last condition suggests that the cost of the application must be absolutely minimized if the factory is to be able to afford the new design.It is these last two conditions that are most responsible for making this an effective application in developing countries. By simplifying the design of this application, it is possible to reduce the costs of the product significantly making it cost effective for the application.

4.1.2.3 DESIGN IMPLEMENTATION

As suggested in section 4.1.2.2, the preferable technology with which to implement this application is CMOS. The determination of which technology to use, however, will most effectively be determined by the availability of the components and/or subsystems necessary to implement the design.
The key aspects of the implementation are the human interface requirements and simplicity of function which address special considerations 3 and 4 in the previous section. The data entry at each appropriate station is most effectively accomplished by a keypad that has "customized" key functions. These customized functions are implemented in a "soft-key" fashion. The hardware associated with each keypad is identical, the function of each of the keys is determined by software and the location of the keypad in the assembly operation (see figure XIV).

Figure XIV. Keypad Interface to Data Acquisition Unit



The keypads are connected to a simple data acquisition system through a serial link. Data entered through the keypads is stored in the proper format by the data acquisition system to be retrieved at a later time and analyzed.
In addition to the human inputs (through the keypads), the data acquisition unit also accepts data from the automatic test station attached to the unit. (The assembly line observed

had an automatic tester at the end of each major operation on the line.) The system should be configured to automatically put the production data obtained from the keypad stations into the proper internal "files" to allow correlation between the test results and production data.
Data reduction of the results can be handled either by the system itself or by an off line system. Because of cost constraints it is recommended that the reduction be handled off line to the data acquisition system. It is expected that the assembly operation will have access to a general purpose computer that can easily handle the analysis. The major design consideration then becomes one of how to transfer the data between the acquisition system and the computer. The least expensive method of interface is to store the data collected on cassette tape to be physically transferred at the end of the shift or some other appropriate time.

4.1.2.4 MARKETING CONSIDERATIONS

The viability of this type of application depends to a large extent on the management requirements of the assembly operation. It is necessary for the design team to be throughly familiar with the type of data required and the timeliness of the reports if the application is to be accepted as a valuable management tool for production purposes. Its acceptance will be enhanced if the application is perceived to offer a real benefit to management to obtaining insight into the "real costs" involved in the operation. Such things as identifying incoming quality on the piece parts by tracking the parts through manufacturing and noting the results on final test can have a major impact on the management position of the assembly operation. Knowing such data allows the local management to exert more effective control over that portion of the assembly for which they are responsible. In adddition, this tool gives a quick method for evaluating different supply vendors or new designs that may be introduced on the assembly operation. This control is especially necessary if the operation is to have a voice in influencing decisions that directly impact the assembly of the components. If the operation is a captive one, that is if there can be little or no local management involvement, the application will most likely be of no benefit.
One of the most likely advantages for such a system is in those assembly operations which are evaluating new vendors for suppliers (whether internal or external to the country) to determine the quality of the product. Having a real-time feed-back during production on the quality of the components or subsystems is of great advantage.

4.1.4 GENERAL PURPOSE COMPUTER BOARD

4.1.4.1 DESCRIPTION

Many small low end applications (such as some of those outlined in this paper) are implemented by using a small general purpose computer board. The overall development and manufacturing requirements of such an application can be summarized in three parts:

1. Design mode using development systems
2. Debug mode using both development systems and the application system
3. Application system production

In many cases, it is possible to develop a low end application by combining parts 1-3 into one system unit - a general purpose computer board. Such a system is to be used for both development AND the target system. This computer board (properly designed) can be used to develop the application software, debug the hardware/software interface, and be an integral part of the application itself. It is readily seen that the use of such a board (referred to as a "target-development-system") can significantly reduce the design, system integration and debug, and production efforts and costs.
There are many types of these general purpose computer boards on the market - especially from the high technology companies in developed countries. These boards generally have a high level of functionality and are capable of significant computing power. Indeed, in many applications in developing countries, the use of these boards is the most cost effective solution to establishing the market for the application. However, a potential drawback to the use of these boards is their cost (having a higher functionality than may be needed) and the environment characteristics. In the previous two sections on special characteristics, it was shown that the electrical environment encountered by many applications did not match the capability of products designed elsewhere.

4.1.4.2 SPECIAL CONSIDERATIONS

One of the key aspects of the microprocessor-based market is the need to rapidly penetrate new markets. This aspect is most easily realized with the use of board level products. To be the most effective, however, the board level products should closely match the requirements of the intended market. It is in this area that developing countries have a chance to develop a product that will be of general value to its intended market because the product has been designed with that market in mind. Many of the new applications in developing countries can take advantage of the need for reduced functionality in implementing the design. The following are characteristics of this type of market for a general purpose computer board:

1. Form factor
2. Reduced functionality
3. Environmental characteristics
4. Processor independence

Of particular note is the potential for opening new opportunities with a computer board that has a very small physical form factor coupled with reduced functionality. (Actually, the reduced functionality allows the small form factor.) By designing such a product, a "gap" in the market is filled by a new application aiming at the characteristics of many of the emerging applications.
The term "reduced functionality" refers both to reduced computational capability of the application and to the memory available for the application. By selecting the components that will make up the computer board carefully, a significantly lower cost board can be developed with acceptable functionality to meet most applications. The most likely trade-offs that will have to be made will be the processor capability, memory size (both volatile and non-volatile), and peripheral interfaces. (With the proper design techniques, however, the board can be made to be modular so that several different versions can be offered, tailored to customer requirements.)
Environmental characteristics (such as electrical power, temperature, dust, etc.) keep occurring but bear repeating because of their importance. It is in this area that a significant advantage can be gained over that of competition from developed countries in the use of high technology products.
Another aspect of the special considerations is that of making the board as processor-independent as possible. For reasons of national objectives, it may be desirable to offer boards that perform the same function but can be implemented with different microprocessors. While this may be an advantage, it should be pointed out that the software issues involved may make this a more difficult problem than is worth addressing at this point in time.

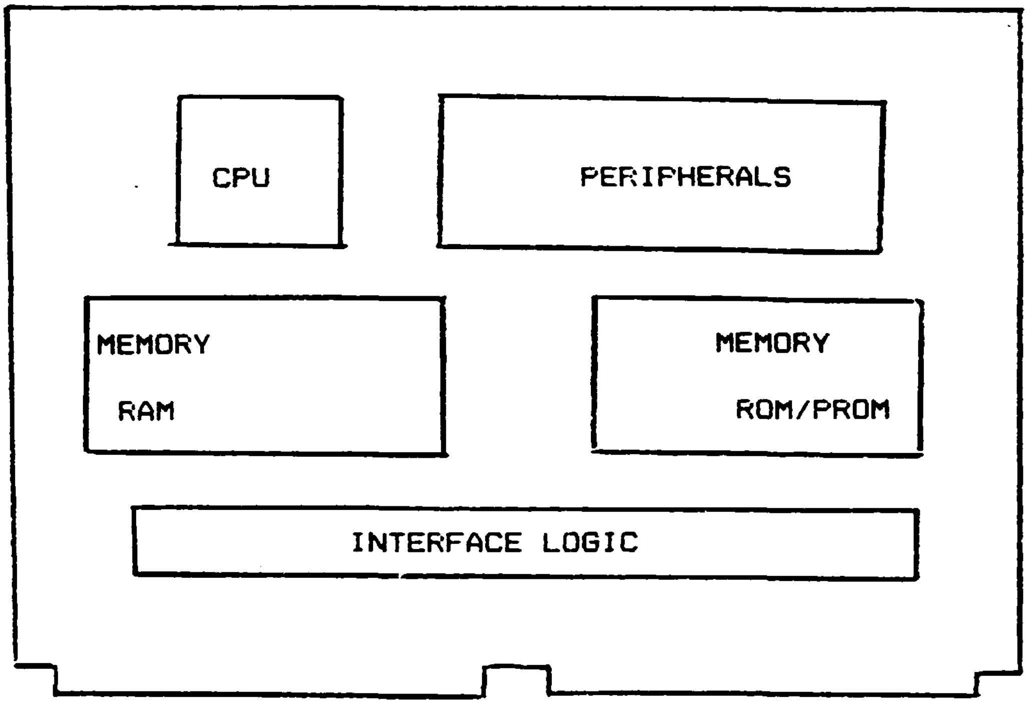
4.1.4.3 DESIGN IMPLEMENTATION

A general outline of a reduced function, general purpose computer board is shown in figure XV.
As shown in this figure, the board has a detachable keypad so that the board can be used in the development stages. The memory consists of ROM/PROM which will contain Monitor type features and a section for RAM. To keep the board as simple as possible it is probably desirable to use static memory type devices. Peripheral devices capable of a serial interface are the simplest to design and implement. The board as described is capable of performing significant computational problems and interfacing to a large variety of external controllers and/or sensors. Such a design can be implemented in a very short period of time and the market established.

4.1.4.4 MARKET CONSIDERATIONS

The advantage of such a board is its capability of being introduced into the market very rapidly. The catalytic effect this product can have on other types of applications can be

Figure XV. General Purpose Computer Board



very appreciable. Applications such as instrumentation (both medical and technical),control for industrial processes, and certain agriculture designs can strongly benefit by having such a product readily available. The most important part of the design is to correctly "read" the market-place requirements to assure the maximum penetration of the product in these new applications. It will do no good if the design is of such low functionality that there is insufficient memory for most low end applications. Likewise, over-designing the product will result in higher than acceptable costs and will place the product in direct competition with other similar type boards.(Compet: with other type boards is not necessarily undesirable - but should be done with sufficient forethought and not by accident.)

4.2 DAIRY DATA ACQUISITION/MONITOR

The application described in this section is intended to be a pilot type project applicable to research institues in the field of dairy farming in developing countries. Its desirability in the private sector areas of dairy farming is probably limited due to the small number of dairy farms large enough to require this application. The usefulness of the application is in providing a solution to real-time data

gathering problems encountered in the research of factors that increase production and quality of milk production.
In the field of dairy research, real-time data is required on a daily basis for the following items:

1. Milk yield
2. Milk quality (fat content)
3. Animal weight
4. Animal identification

As can be seen by the list, the amount of data to be collected daily can be a significant problem for a very large herd typical of a research institute. In discussions with those in the research institutes, it was found that the milk yield and quality was obtained and analyzed on a macro basis (that is an average was determined for a sample size of the herd). Data obtained on an individual basis for the animals is limited due to the sheer magnitude of the problem. Animal weight (obtained on a regular basis) is generally estimated by observation and not by actually weighing the animal - again because of the magnitude of the problem.
The description of this application will concentrate on the microelectronics associated with the application and will not address the characteristics of the sensors required to gather the data. More detail regarding sensors is contained in a later section.
The factors affecting milk production depend heavily on the environment and the available feedstock of the dairy.
As these factors change from country to country, it is necessary to continue research in these areas on a real-time basis to obtain valid results.

4.2.1. SPECIAL CONSIDERATIONS

Unlike other applications described in this paper, this data acquisition system is a semi-custom built system. The details of each of the parts can be standard but the connection depends on the physical environment existing at the farm where each is connected. Because it is a semi-custom design, it is not necessary to analyze other considerations that make the application desirable for development.

4.2.2 DESCRIPTION

The application consists of five basic parts:

1. Measuring milk yield
2. Determining milk quality
3. Weighing the animal
4. Identifying the animal
5. Data collection

The sensors required for each of the above parts requires an

A/D converter to interface with the digital data collection devices. All measurements are made while the animal is being milked during feeding. The animal is identified by a magnetically encoded strip of material atached to its neck. A magnetic sensor can be placed near the location where the animal feeds to read the attached sensor. The animal is weighed on a pressure sensitive pad that is placed where the animal stands during feeding.

4.2.3. DESIGN IMPLEMENTATION

The heart of this application is the data acquisition computer attached to the sensors. This computer can be either of a custom-built variety or can be a standard type general purpose computer. Since the usefulness of this type of application is the generation of readable data on a regular basis, it is recommended that the computer used be capable of acquiring the data as well as analyzing and reporting the data in readable form. The problem then becomes one of application software generation and interface to the sensors in the research station.

4.2.4 MARKET CONSIDERATIONS

The considerations for market conditions are mitigated in this application because of the semi-custom nature of the application. It is evident that this technique can be used in other similar circumstances involving other animals and should therefore be considered as a stepping stone to further research-enhancing opportunities. The unique local conditions encountered by this application make it imperative that the design, production, and service of the application be done in the country where it will be used.

4.3 MEDICAL SCREENING

In most developing countries, the state of medical care for the average person is very limited to non-existent. The problem is exacerbated by the severe shortage of qualified medical personnel and the large populations that must be served. In addressing the health needs of the general population, it is clearly not sufficient to observe the symptoms and characteristics of the conditions addressed by this application. Such major influences as nutrition, hygiene, and sanitation play a significant role in the overall health of an individual. However, screening for selected characteristics (such as blood pressure, blood analysis, ECG, etc.) for a large sample of the population has two advantages:

1. Provides help to individuals with obvious problems.
2. Establishes a data base that can be used to identify widespread or regional health problems.

The hard fact is that even though individuals may be identified as having a problem (severe or not) the likelihood of having resources available to help the patient is remote (especially if the problem affects a large segment of the population). In these unfortunate cases, it becomes important to know that a problem exists even though the problem cannot be immediately corrected.
The development of an application, such as described in this section, depends heavily cn the informed input from qualified medical personnel (the Knowledge Base). The description of the application that follows is a generalization of the requirements which must be significantly refined to provide a useful application.

4.3.1 DESCRIPTION

In attempting to screen for health factors of a large group of people, it is necessary to establish a series of tests that have the following characteristics:

1. Tests can be completed quickly
2. Test results can be used to indicate a wide range of health-related issues that are potentially treatable with the resources available.

Two tests that have the above characteristics are:

1. Blood/urine analysis
2. Blood pressure

Providing screening of large segments of a given population can yield important information both for the individual and for the government health ministries/departments.
A characteristic of tools required for medical screening for large segments of the population is that the tools must be operable by technically qualified people as well as by the medical professionals. Such equipment must therefore be highly automated and give unambiguous results.
The heart of the medical screening device described is the computer that acquires the data from the blood and urine analytical equipment. The computer processes the data into an appropriate format and stores and/or prints out the results. Because the equipment is to be used in a screening of a large segment of the population, it must be portable and made robust.