Chapter 4 Design Considerations

This chapter introduces the Electronic Product Development Cycle and discusses the various design considerations.

4.1 Electronic Product Development Cycle

Developing a product is the process of articulating a mental concept, a picture in the mind's eye, into a concrete electrical hardware representation, a prototype, that is ready to be reproduced on the production line. This concept may be an entirely new idea or an improvement to an existing product. In any case there are several steps in the process.

Concept Development and Feasibility Evaluation

This is the initial meeting of minds, talents and ideas. It is a preliminary attempt to define a proposed electronic product in the terms of sales and profitability for your company. Concurrently, the development of the proposed product continues in terms of a set of electronic functions. Questions arise as to the economical and appropriate implementation of the current state of the art in electronics and the availability of design resources.

Figure 4.1 Concept Development and Feasibility Evaluation

Schematic Representation

The schematic representation (schematic diagram) is the foundation for the development of the electronic product. Its correct construction diagrams all the electrical functions and how they are interconnected and lays the foundation for all the electronic product's capabilities and restrictions. Once the electronic product is represented schematically all the electrical functions of the product can be discussed and modified.

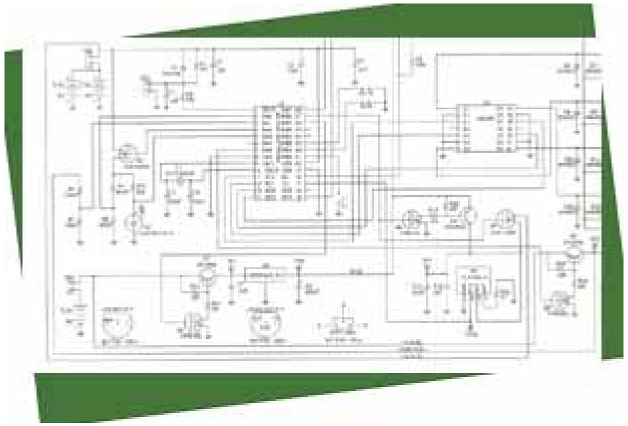

Figure 4.2 Schematic Representation

Printed Wiring Board Layout

The Printed Wiring Board (PWB) layout is developed and completed after it is determined the schematic representation adequately depicts the desired electronic hardware configuration. The PWB provides the foundation for testing the selected electronic components and modules as an integrated prototype. During development of the PWB not only must the components be properly interconnected but it must be done in a fashion that facilitates the proper operation of the components.

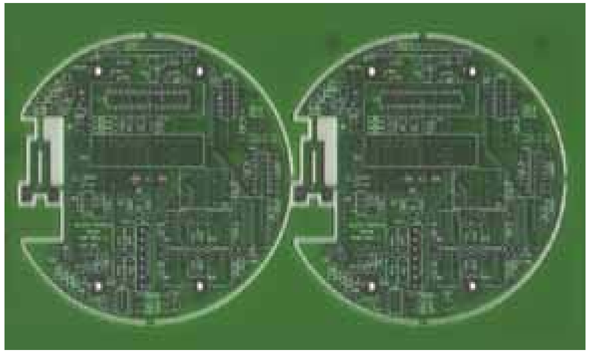

Figure 4.3 Printed Wiring Board Layout

Firmware Development

The personality of the electronic product resides in the firmware, the embedded instructions in a micro-controller. The micro-controller with its instructions tell the electronic product, step by step, how to respond to a specific set of existing conditions. The existing conditions may be internal, an internal counter reaching a specified value, or they may be external, the closure of a switch connected to the micro-controller. To allow the micro-controller to respond a set of these instructions is provided by the manufacture of the micro-controller. The programmer must skillfully select and place in a specific order these instructions. A properly ordered set of instructions yields good firmware and produces a well behaved electronic product.

Figure 4.4 Firmware Development

Production Prototype

The production prototype is the first opportunity to see if the electronic design and its various functions are going operate together in the expected manner. The production prototype is the result of the combination of the concept and its evaluation, the schematic representation, the printed wiring board layout and its assembly and the firmware development and integration process. The definitive test of an electronic product development cycle is in the testing and evaluation of the prototype. It is at this time of evaluation that all aspects of the prototype operation must be carefully examined. The production assembly, production testing, quality control and many other considerations are brought to the fore at this point in the electronic product development program.

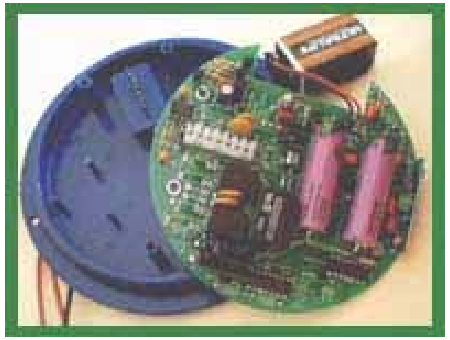

Figure 4.5 Production Prototype

Production

Once the production prototype passes the assembly, testing, quality control and many other considerations, the product can be put into actual production

Figure 4.6 Production

4.2 Design for the Life Cycle

Typical Product Life cycle

Figure 4.7 shows a typical Product Life Cycle.

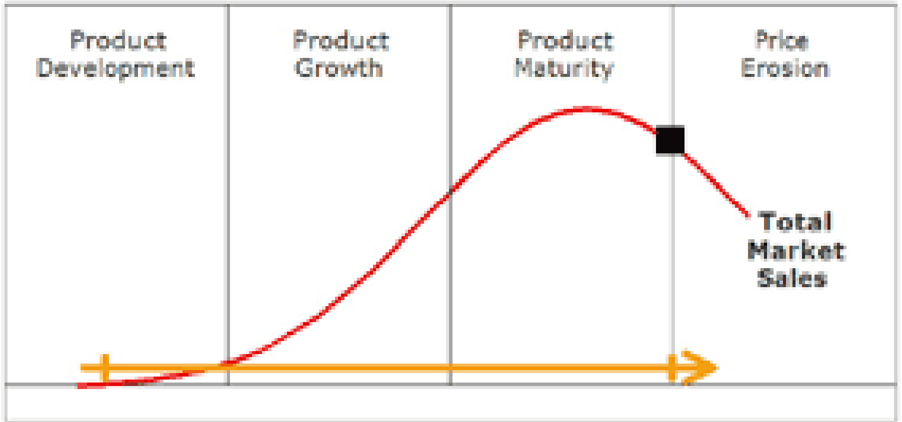

Figure 4.7 Typical Product Life Cycle

Most electronic parts pass through several life cycle stages corresponding to changes in part sales. Figure 4.7 is a representative life cycle curve of units shipped per time, which depicts the four common life cycle part stages: Product Development, Product Growth, Product Maturity and Price Erosion.

Product Development: development stage is usually characterized by design costs and frequent modifications.

Product Growth: growth stage is characterized by the part's market acceptance. Increased sales during this stage may justify the development and use of specialized equipment for production, which in turn improves economies of scale of production. Mass production, mass distribution, and mass marketing often bring about price reductions. This stage often consists of the largest number of competitors, as opportunity seeking firms are attracted by the part's profit potential and, strategic acquisitions and mergers have not yet taken place.

Product Maturity: maturity stage of the part life cycle is characterized by high-volume sales. Competitors with lower cost of production may enter the market, or domestic competitors may shift production facilities to less expensive locations to enable them to lower manufacturing costs.

Price Erosion: decline stage is characterized by decreasing demand and generally decreasing profit margin. Towards the end of the decline stage, only a few specialized manufacturers remain in the market.

Design for the Life Cycle

The economic viability of any system/IC is in large part affected by the productivity that can be brought to bear on the design. This in turn depends on the efficiency with which the design may be converted from concept to architecture, to logic and to circuit.

A good system design should be based on the design parameters such as performance (speed, power, function, etc), size of the design (number of components required), the time to design and the ease of testing the system. The key focus is to reduce the complexity of the system and the techniques are described below.

For many durable goods, there are a variety of other design considerations related to the total product life cycle. For consumable products, some of these life cycle factors may be of lesser importance. Life cycle factors that may need to be addressed during product design include manufacturability, testability, reliability and serviceability.

The relative importance of these factors and their orientation will vary from industry to industry and product to product. However, there are general design principles for these life cycle requirements that will be generally applicable to many items. A basic integrated product development concept is the parallel design of support processes with the design of the product. This parallel design requires early involvement and early consideration of life cycle factors (as appropriate) in the design process. However, in many organizations, consideration or design of the support processes is an after-thought and many of these developmental activities are started after the design of the product is well under way if not essentially complete.

Design for Manufacturability

Figure 4.8 Design for Manufacturability

In the past, products have been designed that could not be produced. Products have been released for production that could only be made to work in the model shop when prototypes were built and adjusted by highly skilled technicians.

Generally, the designer works within the context of an existing production system that can only be minimally modified. However in some cases, the production system will be designed or redesigned in conjunction with the design of the product. When design engineers and manufacturing engineers work together to design and rationalize both the product and production and support processes, it is known as *integrated product and process design*. The designer's consideration of design for manufacturability, cost, reliability and maintainability is the starting point for *integrated product development*.

The application of DFM must consider the overall design economics. It must balance the effort and cost associated with development and refinement of the design to the cost and quality leverage that can be achieved. In other words, greater effort to optimize a products design can be justified with higher value or higher volume products. Design effectiveness is improved and integration facilitated when:

- Fewer active parts are utilized through standardization, simplification and group technology retrieval of information related to existing or preferred products and processes.
- Producibility is improved through incorporation of DFM practices.
- Design alternatives are evaluated and design tools are used to develop a more mature and producible design before release for production.
- Product and process design includes a framework to balance product quality with design effort and product robustness.

Design for Manufacturability and *Integrated Product Development* may require additional effort early in the design process. However, the integration of product and process design through improved business practices, management philosophies and technology tools will result in a more producible product to better meet customer needs, a quicker and smoother transition to manufacturing, and a lower total program/life cycle cost.

Design for Testability

Figure 4.9 Design for Testability

Test and inspection processes can consume a significant amount of effort and the development or acquisition of test equipment can require considerable time and expense. Early involvement of the test engineering or quality assurance functions can lead to design choices that can minimize the cost of developing or acquiring necessary equipment and the effort to test or inspect the product. A starting point is to establish a common understanding between Engineering, their customers, and other functional departments regarding the requirements for product qualification, product acceptance after manufacture, and product diagnosis in the field. With this understanding, a design team can begin to effectively design products and test and inspection processes in parallel. Specific principles which need to be understood and applied in the design of products are:

- Use of Geometric Dimensioning and Tolerancing (GD&T) to provide unambiguous representation of design intent
- Specification of product parameters and tolerances that are within the natural capabilities of the manufacturing process
- Provision of test points, access to test points and connections, and sufficient real estate to support test points, connections, and built-in test capabilities
- Standard connections and interfaces to facilitate use of standard test equipment and connectors and to reduce effort to setup and connect the product during testing
- Automated test equipment compatibility
- Built-in test and diagnosis capability to provide self test and self-diagnosis in the factory and in the field
- Physical and electrical partitioning to facilitate test and isolation of faults

In addition, test engineering should be involved at an early stage to define test requirements and design the test approach. This will lead to the design or specification of test equipment that better optimizes test requirements, production volumes, equipment cost, equipment utilization, and testing effort/cost. Higher production volumes and standardized test approaches can justify development, acquisition, or use of automated test equipment. The design and acquisition of test equipment and procedures can be done in parallel with the design of the product which will reduce lead time. Design of products to use standardized equipment can further reduce the costs of test equipment and reduce the lead time to acquire, fabricate, and setup test equipment for both qualification testing and product acceptance testing.

Design for Reliability

Figure 4.10 Design for Reliability

Reliability consideration has tended to be more of an after-thought in the development of many new products. Many companies' reliability activities have been performed primarily to satisfy internal procedures or customer requirements. Where reliability is actively considered in product design, it tends to be done relatively late in the development process. Organizations will go through repeated (and planned) design/build/test iterations to develop higher reliability products. Overall, this focus is reactive in nature, and the time pressures to bring a product to market limit the reliability improvements that might be made.

In an *Integrated Product Development* environment, the orientation toward reliability must be changed and a more proactive approach utilized. Reliability engineers need to be involved in product design at an early point to identify reliability issues and concerns and begin assessing reliability implications as the design concept emerges

Company should establish a mechanism to accumulate and apply "lessons learned" from the past related to reliability problems as well as other producibility and maintainability issues. These lessons learned can be very useful in avoiding making the same mistakes twice. Specific Design for Reliability guidelines include the following:

- Design based on the expected range of the operating environment.
- Design to minimize or balance stresses and thermal loads and/or reduce sensitivity to these stresses or loads.
- De-rate components for added margin.
- Provide subsystem redundancy.
- Use proven component parts & materials with well-characterized reliability.
- Reduce parts count & interconnections (and their failure opportunities).
- Improve process capabilities to deliver more reliable components and assemblies.

Design for Serviceability

Figure 4.11 Design for Serviceability

Serviceability tends to be an after-thought in the design of many products. Personnel responsible for maintenance and service need to be involved early to share their concerns and requirements. The design of the support processes needs to be developed in parallel with the design of the product. This can lead to lower overall life cycle costs and a product design that is optimized to its support processes.

When designing for maintainability/serviceability, there needs to be consideration of the trade-offs involved. In high reliability and low cost products or with consumable products, designing for maintainability/serviceability is not important. In the case of a durable good with a long life cycle or a product with parts subject to wear, maintainability/serviceability may be more important than initial product acquisition cost, and the product must be designed for easy maintenance. In these situations, basic design rules need to be considered such as:

- Identify modules subject to wear or greater probability of replacement. Design these modules, assemblies or parts so that they can be easily accessed, removed and replaced.
- Use quick fastening and unfastening mechanisms for service items.
- Use common hand tools and a minimum number of hand tools for disassembly and re-assembly.
- Minimize serviceable items by placing the most likely items to fail, wear-out or need replacement in a small number of modules or assemblies. Design so that they require simple procedures to replace.
- Use built-in self-test and indicators to quickly isolate faults and problems.

- Eliminate or reduce the need for adjustment.
- Use common, standard replacement parts.
- Mistake-proof fasteners so that only the correct fastener can be used in re-assembly. Mistake-proof electrical connectors by using unique connectors to avoid connectors being mis-connected

In addition, service and support policies and procedures need to be developed, service training developed and conducted, maintenance manuals written, and spare parts levels established. As these tasks are done in parallel with the design of the product, it reduces the time to market and will result in a more satisfied customer when inevitable problems arise with the first delivery of a new product.