A PRODUCT DEVELOPMENT PROCESS FOR HIGH VOLTAGE POWER SUPPLIES

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ABSTRACT: Applications requiring high voltage power sources are growing at a healthy rate. In most cases the high voltage power supply must be custom designed for a particular application. In addition, market pressure for reduced cost, increased power, and higher reliability require significant research for new, innovative approaches.

The intent of the paper is to familiarize the user and specifier of high voltage power supplies to the development process, thereby improving future development programs. A typical development time for these new designs will be less than one year. An analysis of this development process is discussed. The development process must include: specification of the product, material and labor cost goals, vendor and component issues, process control analysis, electrical/mechanical/material engineering, definition of experiments, stress testing, safety analysis, regulatory requirements, prototype construction and testing, production documentation, design review milestones, and production start up. These requirements are presented with real world applications involving high voltage insulation systems, packaging concepts, high voltage testing, and electronic designs.

I. INTRODUCTION:

The foundation of any specific product development process is its ability to apply the general methods of project management. Project management tools will allow the successful execution of the process. In general, project management will coordinate all resources required to define, plan, execute, and evaluate the project. The decision to undertake a project may be complex. However, once the decision is made to move forward on a project, the decision to apply methods of project management is easy. By definition, a project signifies that important strategic goals are at stake. Without proper project management the goals will not be achieved.

In the area of high voltage power supply product development, a rigorous and detailed process has been defined and executed with a high success rate. Many areas of work, experimentation, and testing have been proceduralized specifically for high voltage.

II. PRODUCT DEFINITION AND CONCEPTUALIZATION:

Typically, high voltage power supplies are specified by the next level system designer. Rarely are marketing specifications the basis of the product definition. This greatly simplifies the task of finalizing specifications and getting approval to start the project.

The next level system can be defined as the equipment the high voltage power supply will be used in. The system design team will be required to work closely with the engineers designing the high voltage power supply. In most cases, technical discussions can yield a sufficient specification in a matter of days. Other contract issues may cause delayed start to projects and need to be given proper attention.

A. Product Conceptualization:

In parallel with the technical and specification discussion, a conceptual approach will take form. Initially, relaying on existing platform technologies is the best method to reduce risks. Risk reduction analysis at this phase can save significant cost and time further into the project. Risk analysis needs to be considered for the benefit of both parties. Neither party will benefit by unwarranted and unnecessary risks. However, it requires great discipline to overcome the lure of conceptualizing an approach that may seem novel and exciting. Many engineers will fail this test and may pay a price by having program delays, reliability problems and cost overruns. Of course basic research and development cannot be sacrificed and must be carried out separately from the development efforts. The product development process can be crippled if new R&D needs to be accomplished during its phase.

B. The Iterative Design Process:

As stated above, using an existing platform product is the best way to minimize risks. However, even with platform products, some new design concepts will be needed. These will typically involve: new mechanical packaging, new interface circuitry, auxiliary power requirements (filament or grid supplies), etc. Initially, these new ideas will be the starting point for design details. However, if not continuously updated, these "first approach" ideas will invariable not yield the best solution. Simply Stated: Never go with your first idea. It will become outdated quickly once the conceptual design starts to take form. The technique which is best used during these early phases is an iterative design process. Whereby initial concepts are continuously updated as the details take form. From an outside vantage point, the iterations may seem to cause project delays. But in the long run, this process will result in a more solid foundation to insure the strength of the project in its final phases.

At every critical iteration, the user or specifier must participate in the design change. This further insures the validation of the product.

III. PROJECT PLANNING:

Clearly defining the scope of a project is as important as the conceptualization and design of the product. Without a clear understanding of the "who, what, where, when, why, and how", a project can go off course. This can basically be seen as the business side of the project management. "Business" can be seen as a taboo subject to some technical people. This is perfectly understandable and needs to be factored into the decision making process used by the technical design team. Here, the project manager must have full understanding of the strategic business goals associated with the success of the project. The project manager must continually weigh business issues with technical issues. Difficult judgments and decisions will have to be made. It is here that the defined scope of the program will help guide in decision making. In all cases, the project manager must attempt to impart the business strategy and scope to all team members. In many cases, this will allow "buy in" when judgments are made, or a strategic course change is required. In some cases, team members will not relate to the business strategy and scope of the project. This is natural and must be managed.

A. The Work Breakdown Structure:

The work breakdown structure (WBS) is a concept routinely used in classical project management. The WBS clearly defines, in a hierarchal manner, the work to be performed. In larger projects, the details of work may not find their way into a formal WBS analysis. However, in small to moderate sized projects, (such as the development of a high voltage power supply), all WBS details should be made visible. In larger projects the WBS tasks may be assigned to groups or departments, but in the small to moderate sized projects, tasks should always be clearly assigned to an individual. Examples of this type of detail would be: printed wiring board design, magnetics design, experimental definitions and analysis, parts list creation, etc. An example of a WBS for a printed wiring board is shown below:

1.0 CONTROL PWB DESIGN
- 1.1 Electrical Design
  - 1.1.1 Controller EE
  - 1.1.2 Diagnostics
  - 1.1.3 Interface
- 1.2 PWB Layout Design
  - 1.2.1 Mechanical Area Study
  - 1.2.2 Component Symbols Created
  - 1.2.3 Routing
  - Etc.

Based on the WBS outline, the individual or group can now pursue their assigned task by organizing the time and resources required for completion.

B. Resource Allocation:

It is a requirement of the development process that qualified resources be assigned. Invariably, the quantity and capabilities of the team members will determine the success or failure of the project. Insufficient resources, or the unavailability of assigned resources will result in the delayed completion of WBS tasks. Even if sufficient resources are available, capability limits of the individual may also delay task completion.

When assigning resources to tasks, it is critical to specify the project and task goals. They must be specifically defined, assigned clearly to an individual who will be responsible, and with a time base for completion..

Other influencing factors may effect resources and cause delays. Outside services such as consultants, subcontractors, or vendors can seriously hamper progress if their performance is not acceptable. When individuals are responsible for multiple products or projects, unexpected conflicts will occur. For example, a product that has completed its development phases suddenly requires a redesign or changes. This type of unexpected resource loading is typical, but very difficult to manage. Whenever possible, product support engineers should be used to support non-development activities.

C. Project Schedules:

The project schedule is another critical tool for managing the project. A number of project scheduling systems can be used.(1) In this specific process, a project master schedule is implemented using a project planning bar chart or GANTT chart. Here tasks are indicated in order with a sequential time base. The order of the tasks can follow the WBS. This helps to keep the WBS and schedule in one data base for easier management. Once again, as in the case of the WBS, it is important to include as many detailed tasks as practical into the project schedule. Otherwise, these tasks can easily be forgotten. Examples of these types of tasks are:

Design Review Milestones and Preparation

Material and Cost Tracking
Material Ordering
Process Documentation
Shipping Packaging Design
Test Equipment and Procedures
ESS Testing
Manufacturing Tooling
Manufacturing Drawings Release
Etc.

When creating the project schedule it is important to have the project team understand and agree on the time allocations assigned to a task. If the time estimates are not credible, the team members may reject ownership and the task will not be completed. In addition to the team members, senior management should be informed, and individual projects should be loaded into a long term department master schedule.

IV. DESIGN REVIEW GUIDELINES:

The design review forum is a critical part of a project. During these forums, a project review is undertaken in order to inform concerned parties, who are not directly associated with the project team, on the progress of the project. It is important that these design reviews reinforce and amend the progress of the team. In no way can the design review replace daily and weekly project management. By their nature, design reviews occur only at critical phases of a project. Project delays will occur if important decisions are delayed until the design review milestones. A successful technique used for short term review is weekly team meetings. In this forum, the critical team members meet weekly and resolve issues quickly. This group is typically 8-12 people and consist of: project manager, electrical engineers, mechanical engineers, lab personnel, quality control, sales/marketing, and representatives from manufacturing departments.

In the process used for the high voltage power supply development, specific requirements for each design review are required and a checklist is used to insure completion of these requirements. Important design reviews milestones are defined and it is very useful when the end user of the equipment attends design reviews. These milestones occur at the following phases of the project:

A. Conceptual Design Review:

The conceptual design review occurs early in the project. At this stage, product concepts are reviewed along with the specification requirements.

Some of the specific requirements of the conceptual design review are:

Design Compatibility with Specifications
Mechanical Design Concepts
Mechanical Outline Drawings
Electrical Design Concepts
Heat Dissipation Concepts
Software/Hardware Architecture
Reliability and Environmental Stress Screening (ESS)
Manufacturability
Technical and Cost Risks
Testing and Maintenance
Program Schedule
Material and Labor Cost Estimates

Each of these are discussed and reviewed. Inevitably, new tasks are required as questions are raised. These tasks are tracked as "Action Items", and are assigned to an individual along with a completion date. All action items are reviewed at the weekly meetings. This helps to insure prompt attention to these tasks.

B. Critical Design Review:

The critical design review occurs mid-way in the project. Here, detailed design data, experimental data, and breadboard hardware review takes place. Many topics covered in the conceptual design review will be reviewed again. However, at this phase the level of detail should be such as to clearly define and identify the product. These details can be described as:

Preliminary Performance Data (to the specification)
Mechanical Design Detailed Drawings
Electrical Schematics
Heat Dissipation and Efficiency Data
Software Specifications
ESS Test Plan
Engineering Acceptance Test Procedure (ATP)
EMC Test Plan
Breadboard Demonstration
Actual Material Costs and Project Expenditures

Once again, action items are assigned. Previous action items from previous design reviews are discussed and hopefully all issues resolved.

C. Final Design Review:

At this point in the project, verification of the product is reviewed. A completed acceptance test procedure is made available and any open performance or reliability issues are discussed. As before, items from previous design reviews are discussed and hard evidence of completion is presented.

V. ISO9000 STANDARDS:

The process for high voltage power supply design described here operates under the umbrella of the ISO9000 quality system. Specifically, this process was required to be proceduralized to sections 4.3, Contract Review, 4.4, Design Control, and 4.5, Documentation and Data Control, of the ISO9001 International Standard.

It can be demonstrated that all parts of the development process address the ISO standards. Contract review is established early on during the technical specification and project conceptualization phase. Since the high voltage power supply has been defined as a customer driven requirement, the customer is involved in all aspects of the initial review. Changes throughout the product life impact the customer and supplier manage the changes.

Design control adherence will naturally occur if the project planning, design review, and resource allocation are followed and properly documented.

Design verification and design validation requires special attention. Many items covered in the design reviews will document the design verification. Design validation can be accomplished by in house testing to recreate the end user's conditions, or by receiving successful detailed test reports from the end user.

Although documentation and data control may not directly be required during a product development project, important critical documents are created and need to be controlled early on in the project. This will minimize uncertainty when the product release to manufacturing is done.