Design for Image Quality: Using Design for Excellence Principles in the Development and Evaluation of Flatbed Scanners

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Abstract

The philosophy of Design for Excellence (DFX) is to design and manufacture a product quickly and economically while maintaining the highest possible standards. The concept of DFX has been used in the manufacturing industry for several decades. In the highly competitive and price conscious world of scanners, there is a competitive need to utilize the ideas of DFX to achieve high-quality, low-cost scanners that can be brought to market quickly. Since image quality is the predominant factor in the overall success or failure of a scanner, it is important to ensure that all aspects of the design and manufacturing of a scanner are evaluated with image quality in mind. Integrating the concept of DFX into the image quality domain yields the result of Design for Image Quality (DFIQ). DFIQ is a structured process of a scanner's design and evaluation during initiation, development and release phases of the product life cycle to ensure that image quality standards are being met while accounting for cost goals as well as delivery goals. The DFIQ process incorporates a clear reporting structure with defined checkpoint reviews. Analytical test data are combined with psychometric reviews to clearly show if original design objectives for image quality are being achieved. DFIQ's goal is to improve all scanners aspects for the overall benefit of the customer.

Introduction

In today's society, flatbed scanners are commonplace in households and offices around the globe. During this growth, there has been a constant demand to make the scanners perform better while continuing to reduce the selling price. From a design and manufacturing perspective, this has equated to compressed schedules and significant design constraints with respect to cost. These challenges have continually challenged the flatbed scanner industry.

To address these issues, a concept known as DFX was implemented. "The goal of DFX is greater customer satisfaction through improved quality and reduced life cycle costs."[1] The "X" term in DFX can be attributed to many areas of design, such as manufacturing, cost, serviceability, environment, etc. DFX has shown that 'Time to Market' can be reduced by up to 50%.[2] By adapting this concept to the product life cycle of a desktop scanner, the idea of DFIQ was conceived.

DFIQ is defined as a philosophy for using best practices to achieve product goals. It involves design reviews early in the product life cycle to define the image quality goals of the project. Then, through design reviews, evaluations are done to determine if these design goals are being met. A score card is developed to evaluate the scanner's image quality, which is then reviewed at three different stages: the beginning of the project (to evaluate if the definition of the scanner will meet image quality goals); at the middle of the project (to highlight image quality concerns at a point where they can be addressed); and at the end of the project (to use as a guideline for release to manufacturing).

DFIQ Process

Initiation Phase

The first phase of the DFIQ process is called the Initiation Phase. It is assumed during this phase that the project price point and basic scanner characteristics have been defined. The Initiation Phase is defined as follows:

The first step is to analyze psychometric test data to determine how previously released scanners faired against the competition, as well as how well they performed compared to the developed image quality ruler. Additionally, product reviews from the previous generation of scanner releases are analyzed. These two factors are used to set initial image quality goals for the forthcoming scanner projects.

The second step is for the Image Quality Engineer to meet with the rest of the design team to understand pertinent design constraints (such as cost limitations, technology availability, initial experimental data, etc.) and to set image quality specifications for the project.[†] These specifications are then recorded in the External Reference

[†] This step is scaled down if the scanner being developed is a refresh of a currently shipping scanner compared to a new and/or innovative design in the new scanner project.

Specification (ERS), which is distributed to the project team.

The final step in this phase is to write a DFIQ report to review the design parameters for image quality and to determine how well they were adhered to. The report is then reviewed with the development team where the following system is used:

- Green Flag: There are no design concerns with the image quality parameter being evaluated.
- Yellow Flag: There is some level of design concerns about the image quality parameter being evaluated and needs to be monitored closely.
- Red Flag: There are clear design concerns that will inhibit the project meeting image quality specifications.

Development Phase

The second phase of the project is called the Development Phase. This phase occurs when scanner prototypes are being developed and test results are available. The important assumption, with regard to this phase, is that there is still time available to make some level of changes to ensure image quality specifications are met.

The first step is for the Image Quality Engineer to test and analyze the scanners with regard to image quality. It is also critical to test and analyze any accessories associated with the product (such as transparency adapters, document feeders, etc.). During this testing stage, image quality parameters are evaluated at all native scanning resolutions and associated bit depths. Testing includes standardized image quality testing, and specialized testing depending on the product requirements. A parallel step that happens during this phase is the manufacturing team creates a detailed Statistical Process Control (SPC)[3] report that includes data trends, dual-sourced parts analysis, control charts with regard to final test results and more specifically the image quality parameters measured.

The second step is to run Spatial Frequency Response (SFR)[4] tests to determine how the scanner is performing compared to previous scanners as well as competitor scanners.

The final step is to write a DFIQ report to review the design parameters for image quality and to determine how well they were adhered to. The report is then reviewed with the development team where the following system is used:

- Green Flag: There are no concerns with the image quality parameter being evaluated.
- Yellow Flag: There is some level of concern about the image quality parameter being evaluated, and it needs to be addressed. However, there is a defined solution that needs to be verified during subsequent builds.
- Red Flag: There are clear concerns that will inhibit the project meeting image quality specifications. There is no solution defined, and the risk is very high.
- Uncompleted Task: This indicates that an image quality parameter was not evaluated during this phase of the project, but this was expected and not an issue.
- Uncompleted Task (caution): This indicates that an image quality parameter was not evaluated during this phase of the project, but it was expected to be ready to evaluate. This indicates there are design parameters that are behind schedule inhibiting the task from being completed.
- Completed Task: This indicates that an activity that the Image Quality Engineer is required to do has been completed for the project with regard to a specific image quality parameter.

Release Phase

The final phase of the process is called the Release Phase. This phase occurs before the product’s final release to manufacturing. The goal of this phase is to determine if the product is ready to be released or if there are any problems that need to be resolved first.

The first step is for the Image Quality Engineer to perform testing and analysis of the scanners with regard to image quality, as well as any testing and analysis on any accessories associated with the product (such as transparency adapters, document feeders, etc.). During this testing, image quality parameters are evaluated at all native scanning resolutions and associated bit depths. Testing includes standardized image quality testing and specialized testing depending on the product requirements. A parallel step that takes place during this phase is the manufacturing team creates a detailed SPC report that includes data trends, dual sourced parts analysis, control charts with regard to final test results and more specifically the image quality parameters measured.

After this data is gathered, the manufacturing team conducts a test limit review. The review’s purpose is to determine if the scanner is ready for Manufacturing Release (MR). The process is to analyze the data from the image quality testing as well as the SPC data and to evaluate the following:

1. The image quality parameter is meeting design specifications and no further action is necessary.
2. The image quality parameter is meeting design specifications, however, statistical data show that in production, there will be manufacturing fallout for this parameter. In this case, one of three actions can occur.
    a. It is determined that it is appropriate to change the test limit to improve manufacturing yields.
    b. It is determined that it is appropriate to change the test limit to improve manufacturing yields, but clear action plans must be defined to rapidly achieve original design specifications. This plan must address the fact that image quality parameters can be highly correlated and assure that the changes do not adversely affect any other parameter.

   c. It is determined that the test limit cannot be changed, as this is an essential image quality attribute. This will cause lower yield rates than desired. A clear action plan needs to be developed at this point to determine how to improve the performance of the image quality attribute.
3. The image quality parameter is not meeting design specifications. In this case, there are two actions that can occur:
   a. It is determined that the test limit for the image quality attribute will be adjusted to allow production to ramp, however, there must be a clear action plan defined to rapidly improve the image quality parameter.
   b. It is determined that MR needs to be delayed until a satisfactory solution for resolving the issue can be achieved.

The second step is to perform psychometric testing on the scanner to judge how well it is performing. Image quality parameters are analyzed by human judging to give an insight into how the scanner will be perceived, as well as what could be changed in subsequent projects. Also, data is collected so that future product design specifications can be established.

The final step in this process is to write a DFIQ report to review the design parameters for image quality and to report if they had been achieved. The report is then reviewed with the development team where the following system is used:

- Green Flag: The image quality parameter's design specification has been achieved.
- Yellow Flag: The image quality parameter's design specification will not be achieved in high-volume manufacturing. The action plan developed in the first step of this phase is then reviewed.
- Red Flag: The image quality parameter's design specification was not achieved, and it is the recommendation of the Image Quality Engineer that the scanner cannot be released to manufacturing until the issue is resolved.
- Uncompleted Task: This indicates that a necessary task has not been completed yet for the product to be released. There needs to be a clear plan defined about how to complete the task.
- Completed Task: This indicates that an activity that the Image Quality Engineer is required to do has been completed for the project with regard to a specific image quality parameter.

Conclusion

In the fast paced world of flatbed scanners there is a definite need to have standardized processes in place to assure quality products while closely monitoring cost and schedule. DFIQ is the right tool to use for managing these deliverables. Although simple in concept, the results are expected to be dramatic and make important impacts on scanner design and development.

Over time, the DFIQ process will continue to grow as new and innovative features make their way into future scanner products. The power of DFIQ lies in the fact that it allows for change as necessary while keeping sound development processes defined.

Future work will include measuring DFIQ results on future scanner releases.

References

1. James G. Bralla, Design for Excellence, McGraw Hill, North Jackson, PA, pg 22, pp3-16.
2. Mark L. Crossley, The Desk Reference of Statistical Quality Methods, ASQ Quality Press, Milwaukee, Wi, pp 215-221.
3. DFMA Website - Boothroyd and Dewhurst www.dfma.com/software/dfaben.html (2003).
4. Peter D. Burns and Donald Williams, Slanted Edge MTF for Digital Cameras and Scanner Analysis, IS&T, Portland, OR, 2000, pp 135-138.

Biography

Justin Tehrani received his B.S. degree in Civil Engineering from Colorado State University. Justin is an Image Quality Engineer at HP's research and development in Digital Imaging. Justin currently leads the Scanner Performance Team, which focuses on image quality and scanner technology. Justin has worked on numerous scanners, evaluating image quality, test development and bringing them to manufacturing release. Justin is a current member of IS&T.