AN603

Continuous Improvement

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INTRODUCTION TO MICROCHIP'S CULTURE

The corporate culture at Microchip Technology Inc. is embodied in our *Guiding Values*. This culture has been key to our success in business because of its emphasis on customer satisfaction, quality, continuous improvement, empowerment and communication. The synergy of these values has created a very dynamic, very successful culture. They have impacted many aspects of Microchip, including the EEPROM Technology Team. Two of our *Guiding Values* in particular have steered this group.

Continuous Improvement is Essential

We utilize the concept of “Vital Few” to establish our priorities. We concentrate our resources on continuously improving the Vital Few while empowering each employee to make continuous improvements in their area of responsibility. We strive for constructive and honest self-criticism to identify improvement opportunities.

Products and Technology Are Our Foundation

We make ongoing investments and advancements in the design and development of our manufacturing process, device, circuit, system, and software technologies to provide timely, innovative, reliable, and cost effective products to support current and future market opportunities.

We recognized in the late 1980's that the industry as a whole did not have great endurance on EEPROMs. We were no exception. And this was at a 10,000 E/W cycle level, which is orders of magnitude less than where we are today. We also recognized that there were many uncertainties in the interaction of design, process and customers applications with respect to endurance performance and expectations. It was also clear that the customers were not educated enough on these interactions to be able to say clearly what they needed in a product. This was clearly an “improvement opportunity” that could allow us “to support current and future market opportunities”.

THE EEPROM TECHNOLOGY TEAM

Microchip had been using the team approach to problem solving and continuous improvement activities such as new product introduction in the development groups and defect reduction in the manufacturing area. These had been in place for some time, and were beginning to work extremely well in bringing fast, well thought out and researched solutions to problems that crossed organizational boundaries.

A cross functional team was formed at Microchip that would be the technology management for an entire family of products. The team was comprised of engineers from design, process, test, product, quality, reliability, and yield enhancement, who reported in to different functional groups in the regular organizational structure. This team was charged with setting the technical direction for all EEPROMs at Microchip. This included both areas of development and sustaining, which were always in competition for the same resources.

The Microchip EEPROM Technology team went through the typical early phases of team development. The initial elation of having a great group of technical contributors wore off after a while. The competition for resources lead to some rough areas at the start, but this was overcome with the help of management support and direction. A balance developed, where the development side really understood the need to improve yields today, while the sustaining side understood the need for new products and innovations for the future. The emphasis on the Guiding Values and strong support from management for the team concept greatly helped the group through the early phases.

THE PROCESS

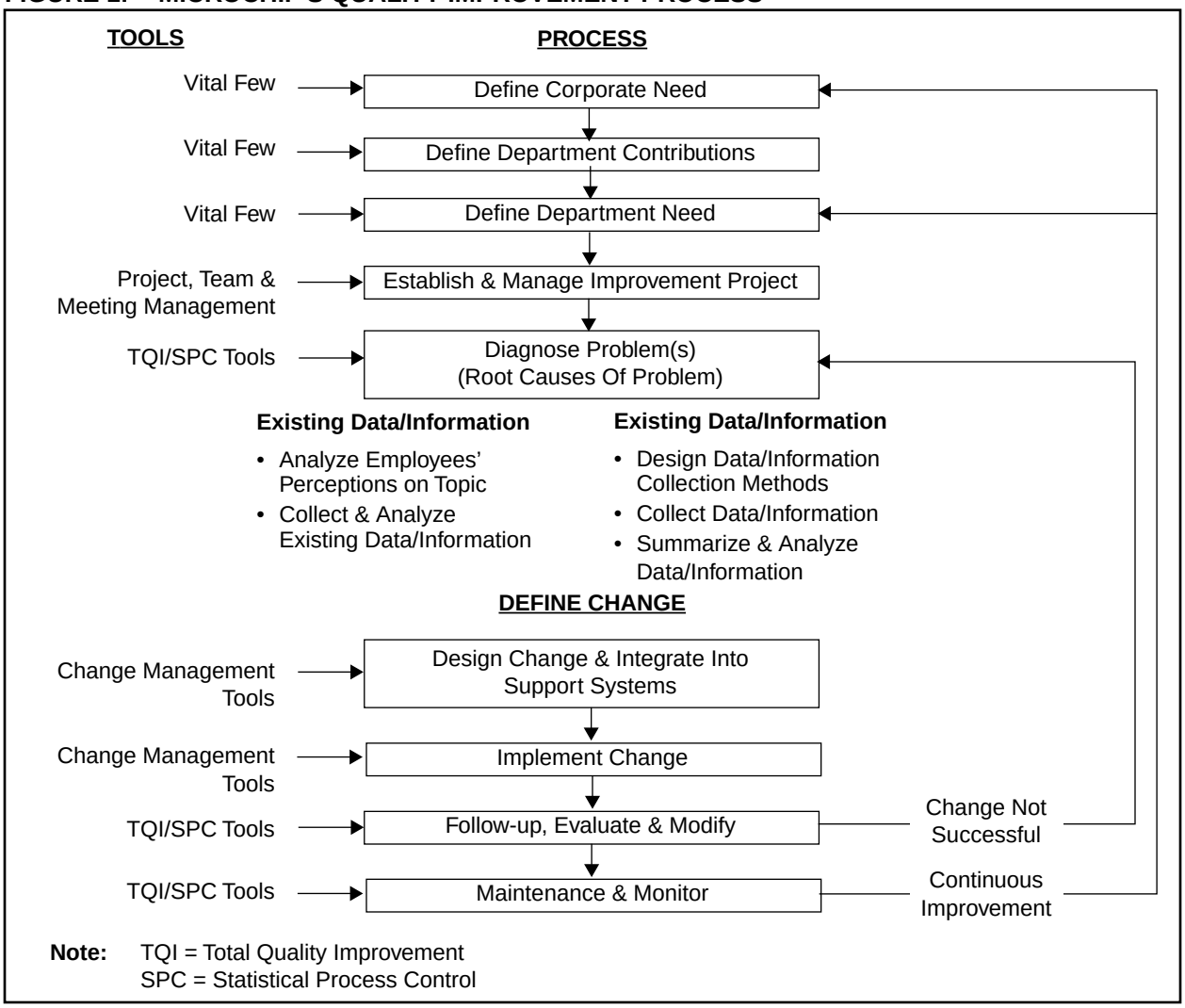
There is a team training program at Microchip that teaches high performance team leadership, and provides training on a set of tools for teams to use. These tools are aimed at improving the teams ability to identify problems, more importantly to identify the real root causes of the problems, to use the Pareto and other techniques to establish the “Vital Few”, to brainstorm ideas on solutions, to investigate solutions prior to implementing, to execute implementations smoothly and accurately, to follow-up to ensure that the fix is as expected, and to re-examine the process to see what other improvements are needed. The key elements of this process are shown in the flowchart (Figure 1).

This process lead to improvements in every area of Microchip’s EEPROM technology: design, process, product, test, quality, reliability, and yield. Most of these changes are confidential and proprietary, and several have been patented. These can only be discussed here in general terms.

The actual EEPROM cell design has been the subject of repeated studies. There have been improvements made to the original that have increased process tolerance, increased yield, and of course dramatically increased endurance performance. “Repeated studies” sounds as if we did not get it right the first time, but in fact is just an acknowledgment that continuous improvement is essential. We have the best design in the industry today, but the EEPROM technology team is still working on improving it.

The process also has gone through many iterations of improvement. During some of the early studies, it was determined that new equipment with better control was needed to ensure the reproducibility of the product. This equipment was purchased, installed, and carefully monitored based on the recommendation from the team. We saw the expected improvement as a results. There have also been ongoing studies to improve control, reproducibility, and defect reduction in many other areas of the process.

FIGURE 1: MICROCHIP’S QUALITY IMPROVEMENT PROCESS



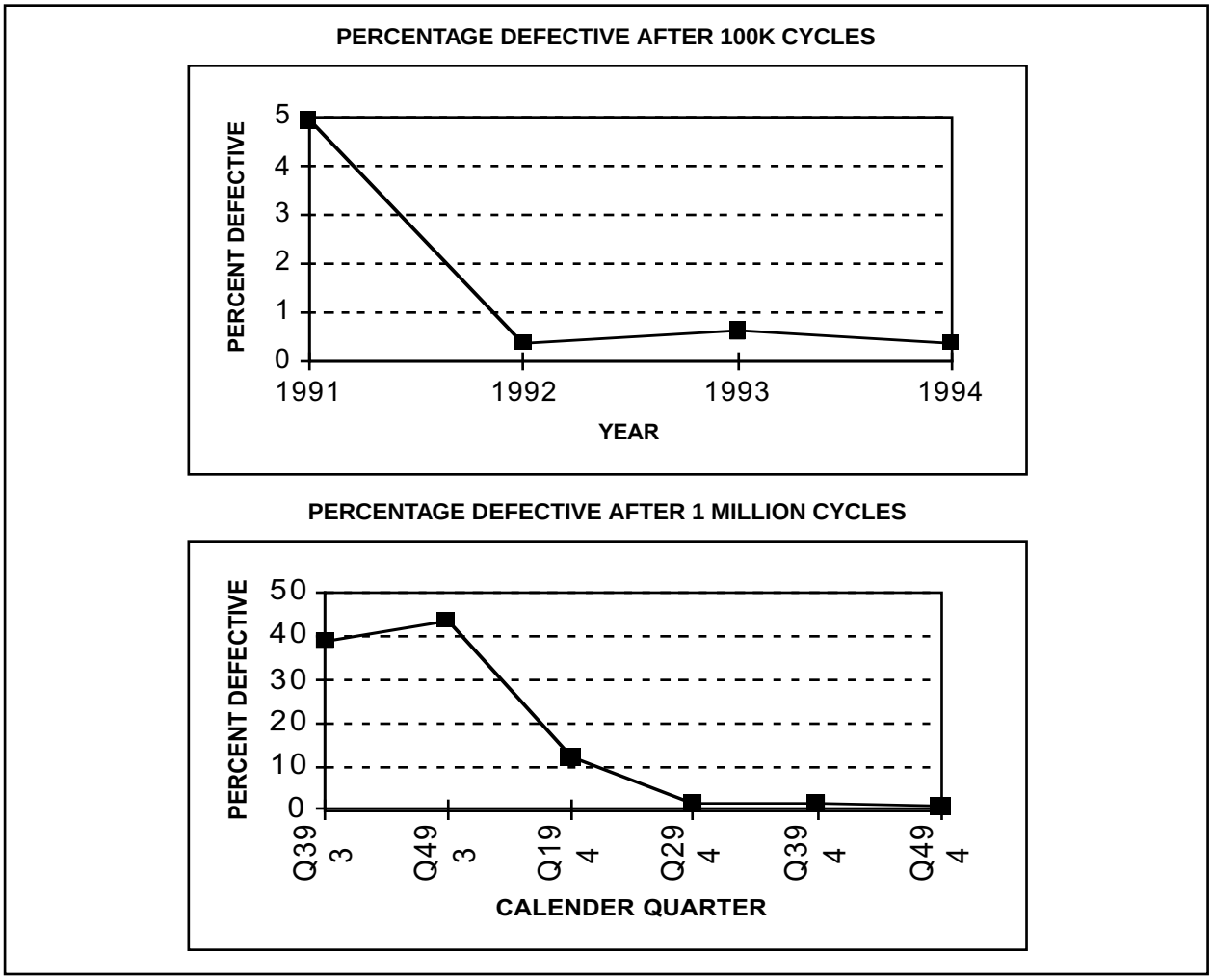
Improvements to the product itself have often shown up in the data sheet. These include reduction in current consumption, or improved timings as a result of improved design as verified by characterization on test equipment. We have greatly expanded the package variety for our Serial EEPROMs as a response to market needs. These activities have all been prioritized by the team with management input, evaluated, and implemented by the team.

The example of a new package introduction highlights the value of the team. A new package requires new test hardware, verification of the test program with the package and hardware, qualification of the package with the reliability group, assurance of acceptable yields based on the yield enhancement engineers involvement, and continued monitoring of the final products outgoing quality. Other companies often have these disciplines separated, with communication by memos back and forth. This is a cumbersome way to do business, and often details are overlooked, or the opportunity for synergy between groups to go the extra step is lost.

Testability is a vital concern for microelectronics. As the feature set grows, the ability to test them accurately can be lost. The introduction of the 64K-bit Serial EEPROM, with its security block and programmable endurance options, presented a concern for testability. By having even the initial design objective discussions in the team environment, with a test engineer, the designers were able to ensure that the new features could be tested thoroughly and cost effectively. This greatly improved our time to market, as well as the quality of the part that reached our customers.

The quality group has been a tremendous contribution to the success of the team. There were initial concerns on some members parts that this group would hold back progress by acting as “policeman” for the status quo. Quite the opposite, the quality group brought the statistical ability to measure the results of proposed changes with accuracy and confidence. So changes that really lead to improvement were actually implemented more quickly than they might have been without quality engineering input at the beginning. The team was also able to move on quickly from proposed changes that did not give measurable improvement as a result of having these measurement tools.

FIGURE 2: ENDURANCE CHARTS



The quality engineering group is also more directly exposed to customer needs than some of the other groups. They heard first hand what some of the areas

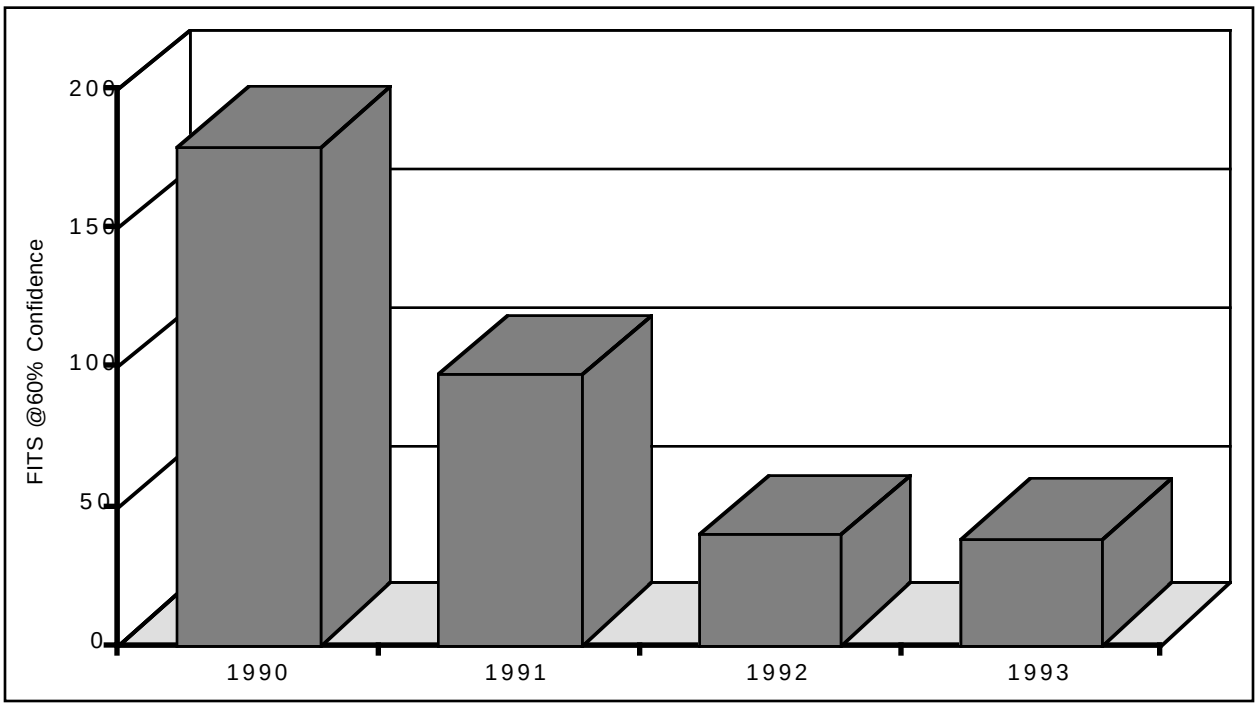
for improvement were from the field. These inputs were brought directly into the team environment, where the breadth of engineering expertise we had was able to apply Microchip's Quality Improvement Process to them.

The dramatic improvement to the endurance performance of Microchip's Serial EEPROMs was a direct result of the reliability group's involvement with the team. This group was able to establish standard methods for testing and measuring endurance on products. This was the first step in determining that this was another area for continuous improvement. Inputs from the business unit were that this was going to develop into a critical point of competition in the industry. We found out later that our standards were significantly higher than most competitors. The reliability group set up competitive analysis and bench marking between vendors that put us on a level playing field. We found that Microchip's endurance was much better than we thought! Even so, the Microchip EEPROM Technology team drove programs for improving endurance that gave impressive results (Figure 2). And the elimination of the root causes of endurance problems gave equally impressive gains in other areas of reliability. This is shown is the reduced failure rates for both dynamic life testing and retention bake (Figure 3 and Figure 4).

The group also kept one eye on the bottom line through the years. Yields have always been a concern, since continuous improvement in that area is also vital to the business. The yield enhancement engineers, like the other groups, brought tools with which to measure and identify problems. As with the others, they were dependent on the rest of the team to help find and implement solutions. They also acted as a conduit to the front end teams that were implementing defect density reduction and process control improvements in the manufacturing process across product families. This coordination between the teams lead to a whole new level of synergy that allowed other products to benefit from improvements from the EEPROM team, and the EEPROM product line to piggyback on improvements aimed primarily at other areas. These other teams were focused on plant wide areas of continuous improvement: oxide integrity, the poly-silicon modules, the metal modules, defect reduction, wafer handling techniques, etc. The result of this cross functional synergy is shown is the yield trend (Figure 5).

As we grew and learned together, each member developed increasing respect and trust for the others. This was critical to the team's development. Not all of the proposed changes were successful. In the stages of implementing, follow-up, and maintenance, some proposals did not hold up. Either they did not really fix a root cause, or the implementation caused other problems to surface. Only by having established respect and trust was the team able to raise and address these issues quickly.

FIGURE 3: EEPROM DYNAMIC LIFE FAILURE RATE



THE RESULTS

The improvements to both areas that this team has made are spectacular. At the time of formation, the industry standard was 10,000 E/W cycles of endurance, and 4K bits of memory. The Microchip lead the world when the efforts of the team lead to introducing:

- The first 10,000,000 E/W cycle guarantee
- The very first 64K bit Serial EEPROM
- The first to put a 64K bit Serial EEPROM in an 8-pin SOIC package
- The first family of Serial EEPROMs to operate at 1.8V
- The first VESA busing compatible Serial EEPROMs

These improvements are orders of magnitude increases in critical areas of market need. They establish Microchip Technology Inc. as the technical leader in EEPROM technology. This is what the EEPROM Technology team set out to do.

The team's efforts continue today to make sure Microchip remains a technical leader. We have the best products in the market today. But that will not be good enough tomorrow. Continuous improvement is essential.

FIGURE 4: EEPROM RETENTION BAKE FAILURE RATE

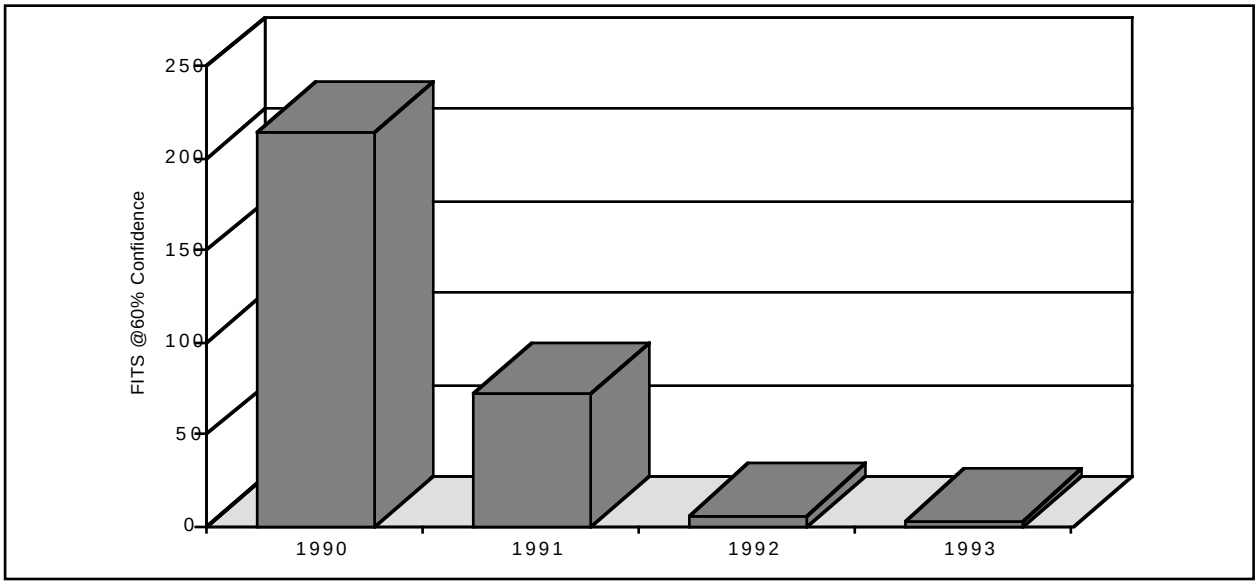
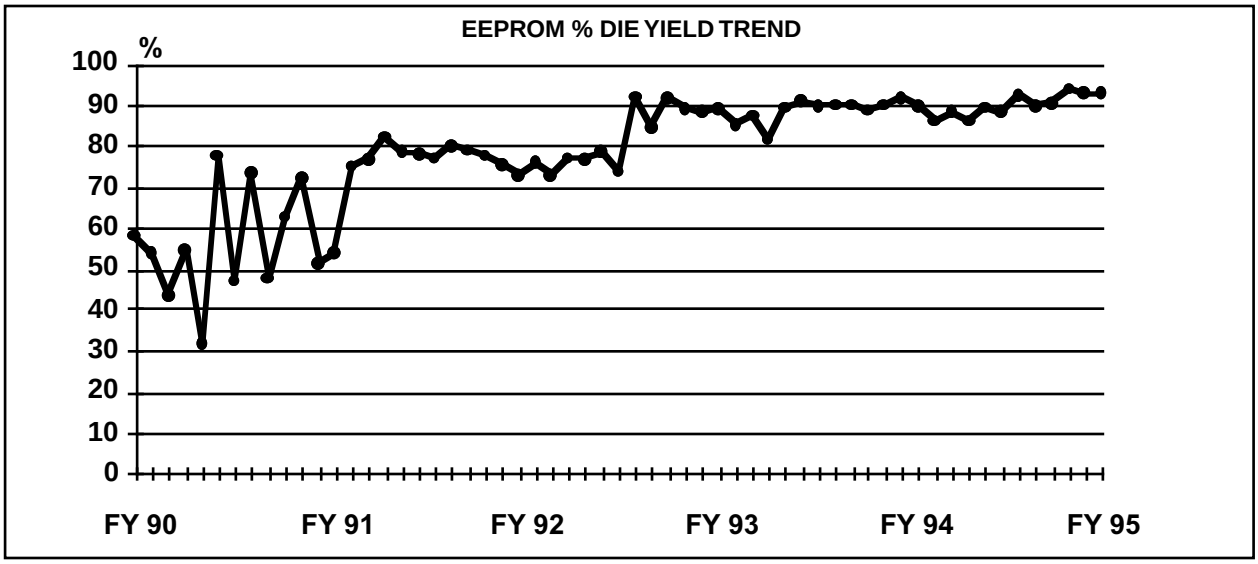


FIGURE 5: WORLD CLASS MANUFACTURING



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Note the following details of the code protection feature on PICmicro® MCUs.

- The PICmicro family meets the specifications contained in the Microchip Data Sheet.
- Microchip believes that its family of PICmicro microcontrollers is one of the most secure products of its kind on the market today, when used in the intended manner and under normal conditions.
- There are dishonest and possibly illegal methods used to breach the code protection feature. All of these methods, to our knowledge, require using the PICmicro microcontroller in a manner outside the operating specifications contained in the data sheet. The person doing so may be engaged in theft of intellectual property.
- Microchip is willing to work with the customer who is concerned about the integrity of their code.
- Neither Microchip nor any other semiconductor manufacturer can guarantee the security of their code. Code protection does not mean that we are guaranteeing the product as “unbreakable”.
- Code protection is constantly evolving. We at Microchip are committed to continuously improving the code protection features of our product.

If you have any further questions about this matter, please contact the local sales office nearest to you.

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Microchip received QS-9000 quality system certification for its worldwide headquarters, design and wafer fabrication facilities in Chandler and Tempe, Arizona in July 1999. The Company’s quality system processes and procedures are QS-9000 compliant for its PICmicro® 8-bit MCUs, KEELOQ® code hopping devices, Serial EEPROMs and microperipheral products. In addition, Microchip’s quality system for the design and manufacture of development systems is ISO 9001 certified.

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