# Background & Overview

Gentex Corporation is a high volume Teir 1 automotive supplier of rearview mirror, vision and sensing systems with design and manufacturing located in Zeeland, MI. Nearly all environmental and electromagnetic compatibility product testing is also performed on-site at our certified laboratory. As we advance in technology, it’s imperative to accurately characterize new advanced integrated circuit (IC) packages and solder materials to meet product lifespan requirements.

Printed circuit board assemblies (PCBAs) designed and built at Gentex primarily use surface mount technology (SMT) where solder paste is applied to the surface of the bare PCB using a stencil, surface mount devices (SMDs) are picked and placed on the solder pads, and then the part is passed through a conveyorized oven to melt the solder paste. The melted solder bonds to the PCB and SMDs and creates the mechanical bond and electrical connection to complete the circuit.

To meet product lifespan requirements, an important factor to consider in design is how temperature fluctuations in service affect the assembly. All SMDs, PCB materials, and solder alloys have different mechanical properties such as coefficient of thermal expansion (CTE) and elastic modulus. Since these components and materials are bonded together during assembly, different rates of expansion and contraction with temperature cause stresses in the materials. In service, parts see repeated cycles of hot and cold both from power cycling the device and from environmental fluctuations (day vs night, sun vs clouds, seasonally etc.). This repeated stress load eventually causes the solder joint to fatigue and crack.

During product development, Gentex uses environmental chambers to simulate thermal cycling by exposing the product to hot and cold temperature extremes typically in the range of 300 – 3000 cycles depending on requirements. There are models that correlate accelerated thermal cycling to service lifespan in the field depending on location and environmental conditions. The primary way to predict service life and qualify new materials and assemblies is to perform thermal cycling tests and evaluate the solder joints visually if possible and through a relatively small number of cross sections used to inspect the inside of the solder joint to look for fatigue or cracks.

# Problem/Opportunity Statement

As mentioned above, the evaluation method for solder joints is visual and through cross section analysis. Although cross section analysis gives good information about the state of the solder joint after thermal cycling, it is very time consuming, and the sample size is extremely small. The number of thermal cycles to failure for solder joints typically follows a Weibull distribution, so in other words, they do not all fail at the same time. With a small sample size, there is a high probability that we could come to the wrong conclusions about the solder joint life through a few cross sections.

This project aims to solve this problem by electronically monitoring continuity of dozens if not hundreds of solder joints during the thermal cycling test. The cycles to failure data we collect from this testing will allow us to gather meaningful statistics and predict field lifespan.

The goal for this project is to create a fully functioning DAQ system. This includes relevant hardware, software, and design files. Gentex will coordinate assembling the PCBA for each stage, software bring-up and all other revisions needed to complete the final system.

# Project Significance

The current method for monitoring solder joint continuity is to use an external data acquisition unit (DAQ). Each channel requires two wires ~10 ft long to be routed into the chamber and connected to the PCBA. This can get very cumbersome when the sample size is high. Test setup is also very time consuming, and mistakes are easily made with many connections. If the functional requirements below are met, the ease of test setup will allow us to qualify new parts and materials much more frequently, with more samples, and collect much more meaningful data simultaneously.

Likewise, this project provides MTU students a real-world problem whose open-ended solution requires critical thinking, creativity, and application of science, engineering, and business concepts.

**Illustration, Drawing, Image, or Graphic Describing the Project**

**A green circuit board with many small chips

Description automatically generated A large machine with a glass door

Description automatically generated with medium confidence**

Figure: Typical PCBA manufactured by Gentex and environmental chamber used for thermal cycling

# Anticipated Outcomes of the Student Team

**Project Definition:** Working with the project sponsor and the project summary document, define and prioritize objectives, constraints, and relevant standards. Define metrics for key objectives to use later in modeling and/or testing.

**Background Research:** Become familiar with PCBA manufacturing including an understanding of solder processes and issues. Perform background research on testing methodology and past data provided by the sponsor. A site visit may be allowed to see the process firsthand.

**Concept development:** Brainstorm several possible high-level conceptual approaches that have the potential to address the project objectives and constraints. Continue research into supporting technologies/approaches in support of this phase. Prioritize and down select the most promising concept(s) using a decision matrix. Share findings with the sponsor and get feedback before proceeding with detailed design. Investigate previous existing information provided by the sponsor.

**Solution Development:** Develop one or more detailed solutions with specifications, economic analysis, and estimated effectiveness. Include testing plans and alternatives.

**Model/Prototype:** Work with the sponsor to develop modifications to the testing apparatuses and protocols. Identify key parameters and a plan to test the proposed equipment.

**Testing/Proof of Concept:** Test the design as equipment and time allows. Test several design conditions/parameters and document findings.

**Documentation and Presentation:** Prepare a comprehensive final project report, final presentation, and media for Design Expo.

# Key Functional Requirements of the Material, Product, Process, or System

1. High channel count (256) continuity monitoring for statistically significant data.
2. Reduce wire routing into the chamber to a minimum. DAQ unit placed in the chamber along with the device under test.
3. Simple connection method to a dedicated PCBA test vehicle to reduce test setup time.
4. Continuity measurements logged / stored in such a way that the data can be easily exported to a spreadsheet.
5. Measurements shall not be lost even in the event of loss of power.
6. Real-time channel monitoring on an external display so the test engineer can check progress.

**Special Notes**

Gentex employees will primarily be communicating with students through email and Microsoft Teams calls. It’s preferred to use Mentor Xpedition Designer for the design so that we can more easily import it into our system and build the prototypes on-site. Students are welcome to visit Gentex to learn more about PCBA design, state-of-the-art electronics manufacturing, and the company as a potential future career opportunity.

If larger items are needed to be purchased to construct the system, discuss with the sponsor about potential needs prior to purchasing.