

ECE 480 DESIGN TEAM 6

Automated Inspection Device for Electric Fan Clutch Actuators

For BorgWarner, Inc.

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Pre-Proposal

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Executive Summary

The inspection of fan clutch actuators is vital in ensuring proper operation of radiator cooling fans in automobiles. The current inspection method is manually-driven, using multiple connections and the hand-recording of measurements. BorgWarner, Inc. has tasked ECE 480 Design Team 6 with developing an automated inspection device to replace the current method. The team proposes an inspection device which will interface with any USB-enabled PC. The device will interface with the fan clutch actuator using a single connection, and inspection results will be stored in a database,

as well as on a hardcopy printout. This solution promises higher levels of automation and data storage in inspecting fan clutch actuators.

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1. Introduction

Fan clutch actuators are responsible for engaging the radiator cooling fan in automobiles, which maintain or lower the engine coolant fluid temperature inside the radiator. Mechanical fan clutch actuators exist as bi-metallic coils that contract when hot and expand when cold, and in turn, engaging or disengaging the radiator cooling fan. BorgWarner, Inc. has developed an electric fan clutch actuator that uses an electronic temperature sensor in place of the mechanical relay. Electric actuators have a significant advantage over their mechanical counterparts in obtaining more accurate temperature readings, therefore being able to engage or disengage the radiator cooling fan faster, as well as run the fan at speeds commensurate to the temperature.

However, electric actuators also have a greater design complexity than mechanical actuators, and require more stringent inspection methods to verify proper operation. BorgWarner, Inc.'s current inspection method for their electric fan clutch actuators is a manual process. Isolated circuit metering systems are manually used to retrieve voltage, current, resistance and capacitance measurements. These measurements are manually recorded on a system requirements sheet.

ECE 480 Design Team 6 will develop an automated inspection device for BorgWarner, Inc.'s electric fan clutch actuators. The device will interface with a PC through USB, and will automatically take required voltage, current, resistance and capacitance measurements for various actuator units under test. The measurements will be stored in a database for later lookup and comparison, as well as on a hardcopy printout identical to the system requirements sheets currently used under the manual inspection method. The Automated Actuator Inspector will significantly increase inspection efficiency and comparison efforts compared to its manual counterpart.

2. Background

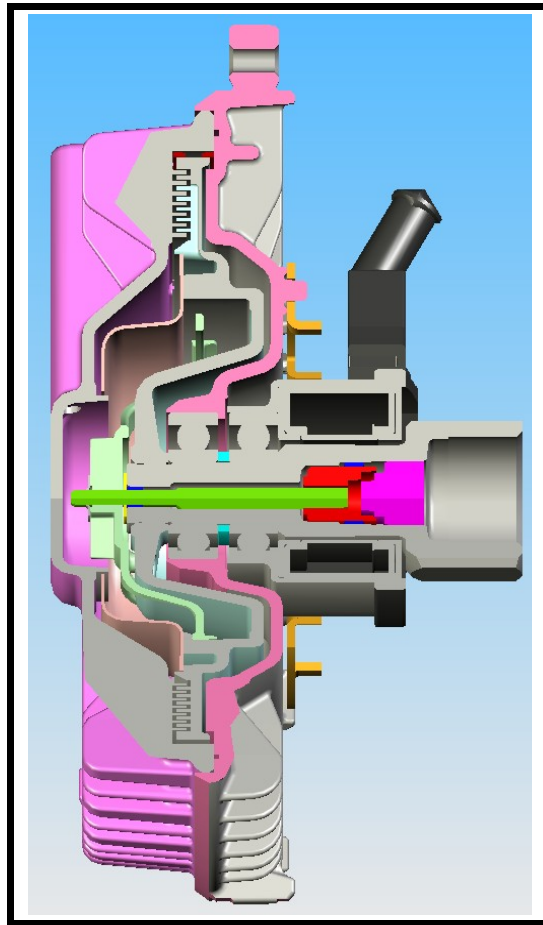


Figure 1. BorgWarner, Inc. Gen II Actuator Subassembly [1]

A cross-sectional view of BorgWarner, Inc.'s Gen II electric fan clutch actuator can be seen in Figure 1. It contains various electronic devices to aid in the operation of the radiator cooling fan in automobiles. An electronic temperature sensor monitors the temperature of the engine coolant fluid, determining the engaging and disengaging of the radiator cooling fan. A solenoid-like device controlled by a certain amount of current regulates the amount of viscous fluid released into the clutch for proper operation. An edge-sensing Hall Effect device monitors the speed of the radiator cooling fan, and regulates its speed in accordance with the desired engine coolant fluid temperature. A general electrical schematic of the electric fan clutch actuator can be seen in Figure 2.

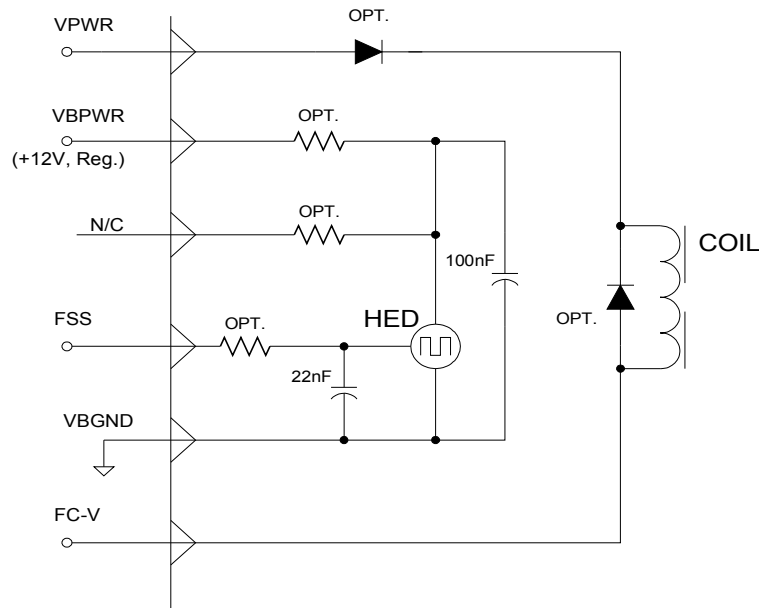


Figure 2. BorgWarner, Inc. Gen II Actuator Electrical Schematic [1]

As these devices are vital in the proper operation of the radiator cooling fan – and in turn, the automobile as a whole – stringent inspection methods are required to ensure their correct functioning. BorgWarner, Inc.’s current inspection method is a manual measurement of voltages, currents, resistances and capacitances through a device containing off-the-shelf metering systems. This method involves multiple connections and the hand-recording of measurements. While this is suitable for validation, a more unified and automated method is desired.

3. Design Specifications and Objectives

In designing the Automated Actuator Inspector, the following design specifications must be met:

- **Measurements:** Voltage, current, resistance and capacitance measurements as listed on various system requirements sheets for BorgWarner, Inc. Gen I and Gen II actuators
- **Statistics:** Coil current time plot, speed pulse rise and fall time, speed sensor pulse time plot, speed pulse edge-to-edge time, coil magnetic field, mechanical travel (linear and angular) versus coil current

In addition, the following design objectives must be met:

- **Automation:** Automated measuring and storage process
- **Accuracy:** Accurate voltage/current/resistance/capacitance measurements
- **Expandability:** Future measurement additions
- **Storage:** Sufficient database and hardcopy processing
- **Safety:** Short circuits, protection during speed sensor testing
- **Cost:** Reasonable total device cost
- **Size:** Workbench-fitting footprint
- **Power:** Efficient power consumption

4. FAST Diagram

FAST Diagram is to be included in final proposal.

5. Conceptual Design Descriptions

Listed are ECE 480 Design Team 6's conceptual designs for the Automated Actuator Inspector:

5.1. Commercial Meter Interfacing

The commercial meter interfacing design improves upon BorgWarner, Inc.'s manual inspection method. The PC interfaces with metering systems purchased off-the-shelf, which are directly attached to the electric fan clutch actuator. The PC stores the metering systems' measurements in a database, as well as on a hardcopy printout. This ensures the great measurement accuracy given by professionally-developed metering systems. However, the cost in purchasing these metering systems is also great. Interfacing with the metering systems may also prove to be difficult if they do not have a USB or GPIB mode control and measurement output.

5.2. Data Acquisition and Processing

The data acquisition and processing design emulates the functionality of metering systems by utilizing the PC to perform calculations. Preconditioning circuits designed by ECE 480 Design Team 6 will transform and scale raw data signals from the electric fan clutch actuator into measurable waveforms. These waveforms are communicated to the PC through USB using a data acquisition module, from which calculations are made to derive voltage, current, resistance and capacitance measurements. The cost of this design is relatively inexpensive, in designing metering circuitry in-house. However, accuracy may prove to be an issue for the same reason. Additionally, upgrading the system to take on new sets of measurements after the tenure of ECE 480 Design Team 6 may be problematic.

6. Ranking of Conceptual Designs

Design Criteria	Weight	Commercial Meter Interfacing	Data Acquisition and Processing
Automation	5	5	5
Accuracy	5	5	3
Expandability	4	3	2
Storage	4	5	5
Safety	4	4	3
Cost	3	1	5
Size	3	2	5
Power	3	2	4
	Totals	113	122

Table 1. Conceptual Design Feasibility Matrix

Table 1 shows the rankings of ECE 480 Design Team 6's conceptual designs through a feasibility matrix. Based on importance of design criteria, the team will proceed with the data acquisition and processing design. Considerations from the commercial meter interfacing design, as well as from other ideas, will still be taken into account throughout the design process.

7. Proposed Design Solution

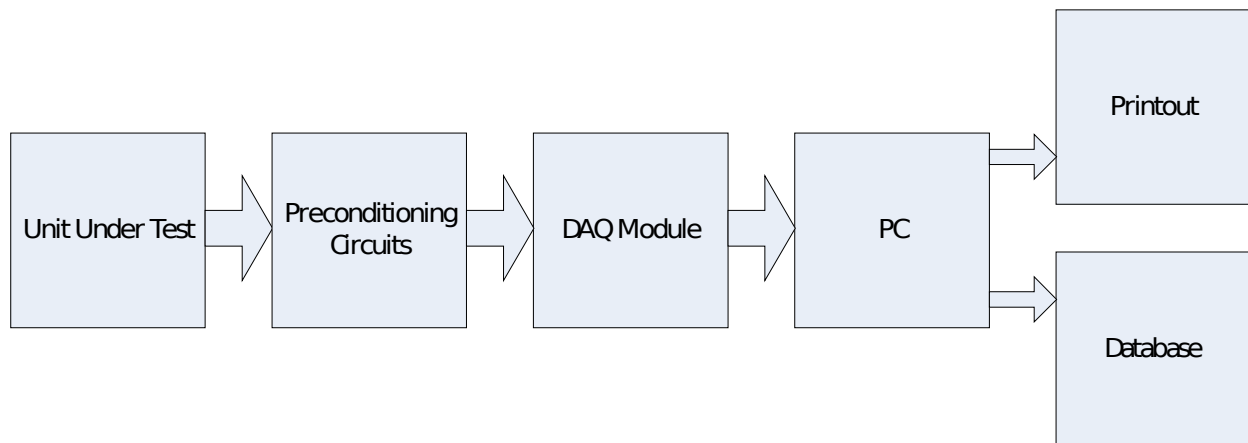


Figure 3. Automated Actuator Inspector Block Diagram

ECE 480 Design Team 6 will implement the Automated Actuator Inspection design shown in Figure 3. The unit under test interfaces directly with preconditioning circuits designed by the team. These circuits transform and scale the raw signals received from the unit under test into usable inputs, as defined by the data acquisition module specifications.

The data acquisition module to be used is a National Instruments USB-6008 Multifunction DAQ module, featuring twelve analog inputs, two analog outputs, and twelve digital input/output lines. [2] The module interfaces with a PC using USB, as the preconditioned inputs are communicated to a National Instruments LabVIEW environment. The LabVIEW environment performs waveform analysis and other calculations to derive the desired voltage, current, resistance and capacitance measurements, as well as plots the desired statistics outlined in the design specification.

The derived information from LabVIEW is then input into Microsoft Access where an inspection history database can be compiled, as well as input into Microsoft Excel, where a hardcopy printout identical to the manual inspection method is made.

The circuitry of the device is enclosed in a box, with the electric fan clutch actuator under test mounted on top. The box will have displays for measurement results, as well as a drill motor on the base to facilitate turning for the speed sensor test. Safety considerations are made in creating a Plexiglas cover for the device, which will be hooked up to a relay. The inspection procedure will not begin until the cover is closed.

The device will be powered through a power supply designed by the team. It will convert a standard wall outlet 120V AC into 5V DC, 12V DC and 300V DC for inspection purposes, as well as power the team's preconditioning circuits.

8. Risk Analysis

The main point of concern in implementing the proposed design solution for the Automated Actuator Inspector is accuracy. Great attention must be taken in the design of the preconditioning circuits to guarantee precise and reliable measurements. The circuits must also be protected from any unexpected overloads, as can be seen in a testing environment.

A safety concern also arises in generating high voltages and currents. Precautions must be taken to avoid all unintentional contact at risk of injury.

9. Budget

Qty.	Item	Cost
3	National LM2917 Frequency-to-Voltage Converter (experimental) [3]	\$5.10
1	NI USB-6008 Data Acquisition Module	\$152.10
1	Handheld Drill	\$30.00
1	PCB Fabrication	\$100.00
1	Device Enclosure Fabrication	\$65.00
	Total Cost	\$352.

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Table 2. Proposed Expenditures

ECE 480 Design Team 6 was presented with an initial budget of \$500.00 for the Automated Actuator Inspector. Table 2 shows the team's proposed expenditures. Many of the parts needed to develop the preconditioning circuits are provided free of charge, courtesy of the ECE Shop.

10. Project Management Plan

10.1. Team Member Roles

Each member of ECE 480 Design Team 6 is responsible for technical aspects of the Automated Actuator Inspector design, as well as administrative aspects in organizing the design process. Although they are responsible for overseeing the development of these aspects, the project is a team effort as a whole, and members work in conjunction with one another to facilitate completion.

10.1.1 Jacob Co

PC Interfacing, Documentation Preparation

Jacob is responsible for the development of the LabVIEW interface, including communication with the NI DAQ module for signal input, and with the Microsoft Office API for output into database and hardcopy storage. He is also responsible for the preparation of technical documents, which will be submitted to faculty and sponsors for review.

10.1.2. Joshua DuBois

Power Generation, Website Information Management

Joshua is responsible for the supply of power to the team's preconditioning circuits, drill motor and measurement displays, as well as the generation of voltages required for inspection. He is also responsible for the development of

the team website, from which students, faculty and sponsors can be kept up-to-date on the team's current progress.

10.1.3. Stephen Sutara

Device Enclosure Design, General Management

Stephen is responsible for the design of the device enclosure, which includes the integration of all the components into a single, usable package. He is also the team's general manager, and is responsible for Gantt Chart progress updates, budget tracking, and ensuring design specifications are met. He also facilitates communication between the team, faculty advisors and sponsors.

10.1.4. Codie Wilson

Signal Preconditioning, Presentation Preparation and Laboratory Coordination

Codie is responsible for the preconditioning of the raw actuator signals into usable inputs for the NI DAQ module. He is also responsible for gathering input and organizing information for team presentations, as well as supplying the team with needed materials in the lab and ordering components. He assists the general manager in budget tracking.

10.2. Proposed Schedule

Date Range [business days]	Task(s)
1/14/09 – 1/29/09 [12 days]	Initial Organization - Team formation - Facilitator meeting - Sponsor meeting (information, samples) - Define project specifications and objectives
1/30/09 – 2/16/09 [12 days]	Brainstorming and Research - Metering methods - PC interfacing methods - Accuracy and cost considerations 2/6/09 – Pre-proposal due 2/13/09 – Presentation practice to facilitator
2/17/09 – 2/23/09 [5 days]	Idea Finalization - Best fit for project specifications and objectives 2/20/09 – Final proposal due 2/23/09 – Presentation to class 2/23/09 – Design Day page due
2/24/09 – 3/11/09 [12 days]	Design Phase - Preconditioning circuits - Power supplies - PC interface - Product housing
3/12/09 – 3/30/09 [13 days]	Prototyping Phase - Integration testing and fixes - Comparison with project specifications and objectives 3/20/09 – Progress report 1 due 3/20/09 – Demonstration 1 3/20/09 – Notebooks due
3/31/09 – 4/8/09 [7 days]	Project Finalization - Finished working project 4/3/09 – Application notes due
Buffer time	Deliverables - Complete reports, poster 4/10/09 – Progress report 2 due 4/10/09 – Demonstration 2 4/13/09 – Design issues due 4/22/09 – Self-assessment due 4/27/09 – Evaluations due

	4/29/09 – Final report due 5/1/09 – Design Day 5/1/09 – Notebooks due
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Table 3. Proposed Team Schedule

11. References

- [1] BorgWarner, Inc., “MSU Senior Design Project: Automated Actuator Tester,”
Presentation, Marshall, MI, Jan 2009.
- [2] National Instruments USB- 6008 Datasheet.
<http://www.ni.com/pdf/products/us/20043762301101dlr.pdf>
- [3] National Semiconductor LM2917 Datasheet.
<http://cache.national.com/ds/LM/LM2907.pdf>