P09222 FSAE ECU Gen III

Test Plans & Test Results

By: Andrew Rittase, Robert Joslyn, Dereck Bojanowski,

Robert Raymond, Giovanni Sorrentino, Jordan Hibbits

Table of contents

P09222 FSAE ECU Gen III
Test Plans & Test Results

1. MSD I: WKS 8-10 TEST PLAN

1.1. Introduction

1.1.1. The long term goal is to have a working, reliable ECU that will replace a commercial model that is currently in use. The current model in use is too expensive and excessive for the needs of the RIT Formula team and a customized ECU for the car will improve the team's chances of winning the final competition. This is the 3rd FSAE ECU design project following P07222 and P08221, where this project will modify the previous design and conduct further testing to develop an ECU that can be used by the RIT Formula team.

1.2. Project Description; Sub-Systems/ Critical Components Being Tested

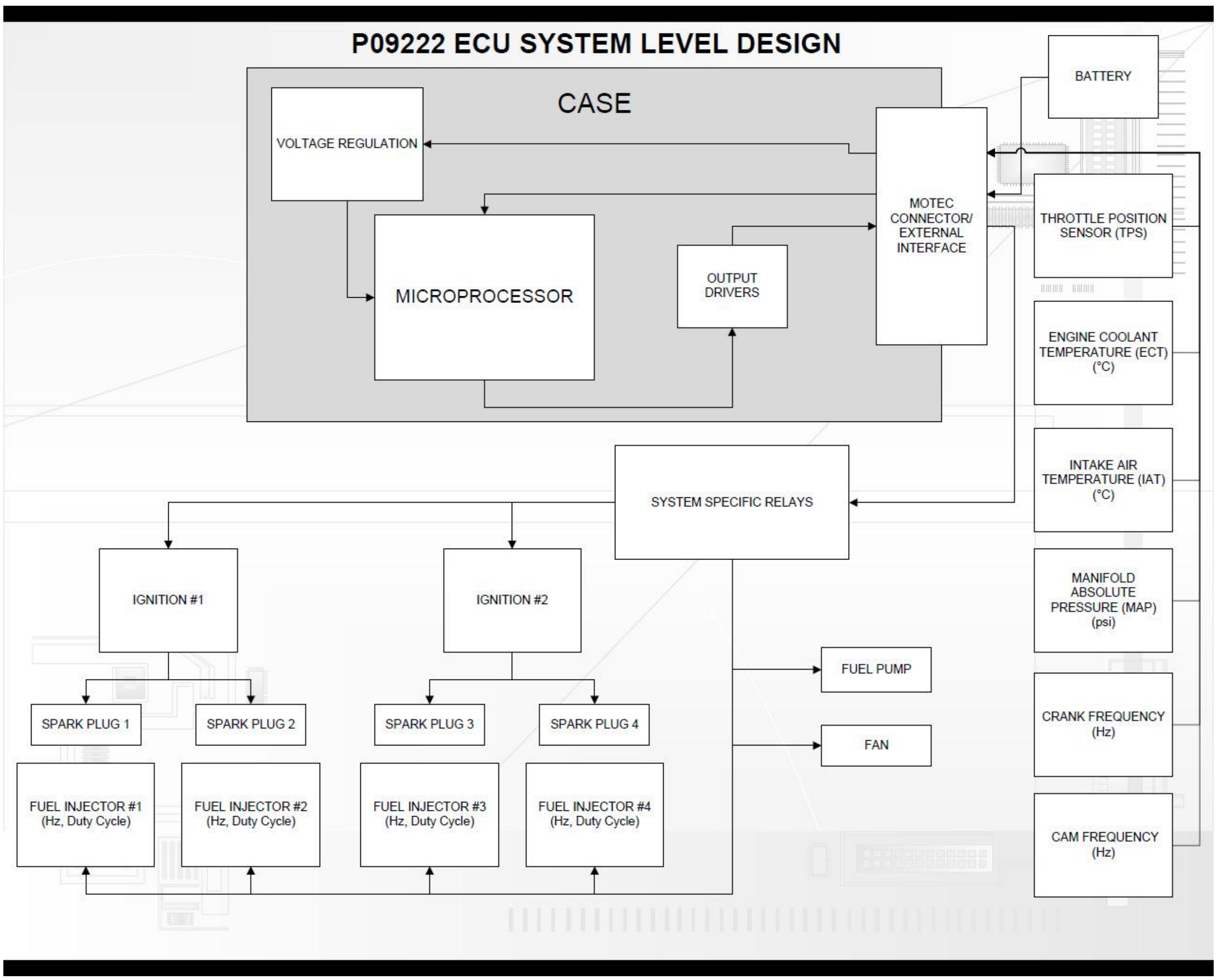

Figure 1 ECU System Level Design Block Diagram

1.3. Approval; Guide, Sponsor

Approved by:

Team Members – Dereck Bojanowski, Jordan Hibbits, Robert Joslyn, Robert Raymond, Andrew Rittase, Giovanni Sorrentino
Guide – Professor Slack, Professor Phillips
Sponsor – Professor Nye, RIT FSAE Team

1.4. Test Strategy

1.4.1. Product Specifications, Block Diagram, and Pass/ Fail Criteria

Specification Number	Customer Need Number	Design Specification	Importance	Unit of Measure	Marginal Value	Ideal Value
1		Size	1	mm	174x105x40	80x50x20
2	1	Weight	1	kg	1	0.5
3		Number of digital inputs	3		8	10
4		Number of digital outputs	3		16	20
5		Serial interface	3	USB	2	2
6		Number of Analog inputs	3		16	20
7		Number of Analog outputs	3		2	4
8		Pulse width modulated outputs	3		4	6
9	2	Timing granularity	9	degrees	1	0.5
10	3	Injector pulse width and time	9	ms	0.1	0.01
11		Processor speed	9	MHz	24	32
12		RAM memory	9	kB	512	512
13		Flash memory	9	kB	512	512
14		Burn in	3	oC/hr.	10-70/10 hrs	10-70/32 hrs
15		Battery transient protection	3	mV	0.1	0.001
16	4	Max RPM	3	RPM	12500	15000
17		Internal temperature range	3	oC	-20-85	-50-125
18		Operating voltage	1	V	9-24	6-24
19		Operating current	1	Amp	10	8
20	5	fuel calibration accuracy	9	us	2	0.042
21	6	Ignition calibration accuracy	3	us	2	0.042
22	7	Tach output	3	RPM	15000	18000

Table 1 Engineering Design Specifications

NI-DAQ Test Bench Values							
	Stop	**Start**	**Idle (2000rpm)**	**Medium (8400rpm)**	**Upper (12000rpm)**	**Acceleration**	**Deceleration**
Cam (Input)	0	13.33 to 133.33	133.3333	280	400	160 to 320	400 to 200
Crank (Input)	0	3.33 to 33.33	33.3333	70	100	40 to 80	100 to 50
Injector (Output)	No NIDAQ	Record	Record	Record	Record	Record	Record
Map (Input)		101.3-80 kPa	80kPa	97.6kPa	90kPa		
TPS (Input)	Non-static	0%	0%	Varies to maintain const. speed		25%-100%	0%
Fan (Output)	OFF	ON>87º;OFF<82º					
Fuel Pump (Output)	OFF	ON	ON	ON	ON	ON	ON
IAT (Input)	No NIDAQ	20C	20C	20C	20C	20C	20C
ECT (Input)	No NIDAQ	80C	70-90C	80C	80C	80C	80C
O2 (Input)	No NIDAQ	1.5min to stabilize	1.06-0.87 λ	1.06-0.87 λ	1.06-0.87 λ	1.06-0.87 λ	1.06-0.87 λ
Spark (Output)	No NIDAQ	Record	Record	Record	Record	Record	Record
Injector Driver	No NIDAQ	Record	Record	Record	Record	Record	Record
*O2 Sensor has a similar trend to throttle - low λ when throttle is high, high λ when throttle is low							

Table 2 NI-DAQ Test Bench Input and Expected Output Values

1.4.2. NI-DAQ Signal Production Testing – Input Variables to Verify

1.4.2.1. **RPM** – RPM specifications are entered manually by typing the desired value or increasing the value via the arrows in the Labview program. Do not test at RPM=0, this will cause an error in the program. Tests will run from RPM=1 to 15000. Determine idle RPM for testing.

1.4.2.2. **Manifold Air Pressure** - Manifold Absolute Pressure is controlled by either moving the slide or entering a value in the box below the slide. The slide is red in color and matches the color of the graph on the sensor tab. This sensor reads the amount of pressure in the intake manifold and will send a 0-8V output to the ECU.

1.4.2.3. **Throttle Position Sensor** - The Throttle Position Sensor is controlled by either moving the slide or entering a value in the box below the slide. The slide is white in color and matches the color of the graph on the sensor tab. This produces an output between 0-5V, and will be entered in a percentage between 0 and 100%. When the Sensor is at 0% throttle it sends 0V and the throttle plate is closed. When it reads 100% throttle the throttle is wide open and sends 5V.

1.4.2.4. **Intake Air Temperature** - Intake Air Temperature sensor is controlled by either moving the slide or entering a value in the box below the slide. The slide is blue in color and matches the color of the graph on the sensor tab. This Signal tells the ECU the temperature of the air entering the engine and is in between 0-5V.

1.4.2.5. **Engine Coolant Temperature** - The Engine Coolant Temperature is controlled by either moving the slide or entering a value in the box below the slide. The slide is green in color and matches the color of the graph on the sensor tab. This will send a 0-5V signal to the ECU where it will determine if a correction is required.

1.4.2.6. **Cam Offset -** In this box you enter how many degrees the cam and crank are offset from each other. This value is in degrees and then the program converts it over to a delay in seconds.

1.4.3. PCB Functionality Testing

1.4.3.1. **Verify Voltage Regulation** - Provide +12V and GND to the ECU on the required pin using a bench power supply. Using a voltmeter, measure the voltage at the output of the 1.9V, 3.3V, 5V, and 8V regulators. Each voltage must be within 100mV of the designed value. If voltage is outside required range, regulator should be replaced and retested. If voltage is very low or if the regulator is very hot, PCB should be checked for a short circuit. Put a resistive load on each regulator to draw the maximum current that can be supplied by each regulator. Verify that the voltage drop does not exceed 100mV.

1.4.3.2. **Verify Microcontroller Operation** - Once the voltage regulation is confirmed to be working, it should be verified that the microcontroller is operating as desired. With the proper 1.9V and 3.3V supplied to the microcontroller, check to make sure that the I/O pins operate normally by running the software. This behavior will be determined by the software. If microcontroller does not respond, check the software to verify operation. It is also possible that the voltage regulator did not initiate the proper start-up sequence. Use the TPS70302 datasheet and an oscilloscope to verify the proper startup sequence.

1.4.3.3. **Fuel Injector Operation** - The fuel injectors need to be tested to make sure that the ECU parts can handle operating them under full load. The correct timing of the injectors will be tested separately with the software and the NI DAQ With the software running, run the fuel injectors at a maximum frequency of 140Hz for 5 minutes. The fuel injectors should run without failing wide open. The MOSFETs controlling the injectors may get warm, but should not get so hot as to cause damage to themselves or the board. If the transistors are too hot to touch, measure the temperature of the components. The maximum operating temperature is 150C. Should the temperature of the MOSFETs exceed the maximum temperature, additional cooling solutions will need to be created.

1.4.3.4. **Injection Operation** - The spark plugs need to be tested to ensure that they can run continuously without failure. Timing analysis will be tested separately with the software and the NI DAQ. With the software running, cycle the spark plugs at a rate of 140Hz for 5 minutes. The output of the ECU should cycle at the rate of the input. If output fails, check to make sure that the microcontroller and the buffer can handle the load being applied.

1.4.3.5. **Fan and Fuel Pump Operation -** Since fan and fuel pump are operated via relays, only the relays need to be connected to the ECU. Connect both the fan relay and the fuel pump relay to the ECU. First, turn on and hold the fan relay for 10 minutes to make sure that the ECU can handle constant operation. After 10 minutes, the relay can be turned off. Next, turn on the fuel pump relay for 10 minutes. After 10 minutes, turn the relay off. Since it is possible for both to be running at the same time that will be tested next. Turn both the fan and fuel pump relays on and hold for10 minutes and then turn off. The MOSFETs that control the relays may get warm, but should not get so hot that they damage themselves or the surrounding components. Measure the temperature of the MOSFETs. The maximum operating temperature is 150C. If the circuits fail due to heat, additional heat dissipation measures will need to be taken. It also may be possible to alter the PCB layout to aid in removing heat.

1.4.4. Programming Testing

1.4.4.1. To test the analog inputs, all inputs, except for the input under test, will be held constant. The outputs (Injection start time/degree before TDS, pulse width, ignition/spark timing, and fan relay output) will be watched on NI-DAQ test bench as inputs are changed from 0 to 5V.

1.4.4.2. To test the timing of the outputs, the system will be connected to the NI-DAQ and will be tested at all RPM values (Cam and Crank frequencies). The pulse timing of the injector, and the spark advance time of the injector will be measured and compared with values measured from the current MOTEC system. The main loop will be tested using a "heartbeat" LED/GPIO. At the end of each main loop cycle, a GPIO will toggle. To accurately measure the main loop duration, interrupts will be disabled for initial testing. The software will also be tested for responsiveness; that is, how quickly it reacts to changes in RPM (Cam/Crank frequencies). This will be done by sweeping the frequency of Cam and crank inputs, and measuring the changes in injector and ignition timing. The requirements for this are TBD. Timing requirements: Injector PWM, Ignition, Main loop (<400 ms), Responsiveness

1.4.5. Test Equipment available

Oscilloscope
Digital Multimeter
Power Supply
NI-DAQ Test Bench
Function Generator

1.4.6. Test Equipment needed but not available

Environmental Chamber

1.4.7. Phases of Testing

1.4.7.1. Component
- Microprocessor (TMS470R1B512)
- Injector Drivers (LM1949)

1.4.7.2. Subsystem
- Fan Relay Control
- O2 Sensor Circuitry
- MAP & TPS Buffer
- Cam and Crank Buffer
- IAT and ECT Buffer
- Fuel Pump Relay Control

1.4.7.3. Integration
- Code debugging
  - --General Code
  - --Temperature Code

1.4.7.4. Reliability
- Vibration Testing on ECU Case
- Burn in Test
- Ansys Modeling

1.4.7.5. Customer Acceptance
- Demonstrate ECU functionality on NI-DAQ Test Bench
- Engine Dyno Testing

1.5. Definitions; Important Terminology; Key Words

1.5.1. Acronyms

MAP – Manifold Absolute Pressure
TPS – Throttle Position Sensor
IAT – Intake Air Temperature
ECT – Engine Coolant Temperature
O2 Sensor – Oxygen or Lambda Sensor
NI-DAQ Test Bench – National Instruments Data Acquisition Test Bench
VI – Virtual Instrument

2. MSD II WKS 2-4: - FINAL TEST PLAN

Introduction: The testing provided in this document will provide verification of the PCB, programming, and case design. The functionality of each subsystem will be proven via the testing described in this plan. Testing will involve various stages of engine operation to ensure proper operation at all scenarios that the car will need to perform at during competition. The test plan should be thoroughly followed to maintain the integrity of the ECU design.

2.1. Data Collection Plan; Sampling Plan

2.1.1. Test Templates/ Tables/ File Locations

NI-DAQ Test Bench Values							
	Stop	**Start**	**Idle (2000rpm)**	**Medium Range (8400rpm)**	**Upper Range (12000rpm)**	**Acceleration**	**Decelleration**
Cam (Input)	0	13.33 to 133.33	133.3333	280	400	160 to 320	400 to 200
Result (Pass/Fail)							
Ref. File Loc.							
Crank (Input)	0	3.33 to 33.33	33.3333	70	100	40 to 80	100 to 50
Result (Pass/Fail)							
Ref. File Loc.							
Injector (Output)	No NIDAQ	Record	Record	Record	Record	Record	Record
Result (Pass/Fail)							
Ref. File Loc.							
Map (Input)		101.3-80 kPa	80kPa	97.6kPa	90kPa		
Result (Pass/Fail)							
Ref. File Loc.							
TPS (Input)	Non-static	0	0	Varries to maintain const. speed		25%-100%	0
Result (Pass/Fail)							
Ref. File Loc.							
Fan (Output)	OFF	ON>87º;OFF<82º					
Result (Pass/Fail)							
Ref. File Loc.							
Fuel Pump (Output)	OFF	ON	ON	ON	ON	ON	ON
Result (Pass/Fail)							
Ref. File Loc.							
IAT (Input)	No NIDAQ	20C	20C	20C	20C	20C	20C
Result (Pass/Fail)							
Ref. File Loc.							
ECT (Input)	No NIDAQ	80C	70-90C	80C	80C	80C	80C
Result (Pass/Fail)							
Ref. File Loc.							
O2 (Input)	No NIDAQ	1.5min to stabilize	1.06-0.87 λ	1.06-0.87 λ	1.06-0.87 λ	1.06-0.87 λ	1.06-0.87 λ
Result (Pass/Fail)							
Ref. File Loc.							
Spark (Output)	No NIDAQ	Record	Record	Record	Record	Record	Record
Result (Pass/Fail)							
Ref. File Loc.							
Injector Driver	No NIDAQ	Record	Record	Record	Record	Record	Record
Result (Pass/Fail)							
Ref. File Loc.							
*O2 Sensor has a similar trend to throttle - low λ when throttle is high, high λ when throttle is low							

Table 3 Traceability and Verification Matrix

2.1.2. Phases of Testing

2.1.2.1. Component
Microprocessor (TMS470R1B512)
Injector Drivers (LM1949)

2.1.2.2. Subsystem
Fan Relay Control
Fuel Pump Relay Control
O2 Sensor Circuitry
MAP & TPS Buffer
Cam and Crank Buffer
IAT and ECT Buffer

2.1.2.3. Integration
Code debugging
--General Code
--Temperature Code

2.1.2.4. Reliability
Vibration Testing on ECU Case
Burn in Test
Ansys Modeling

2.1.2.5. Customer Acceptance
Demonstrate ECU functionality on NI-DAQ Test Bench
Engine Dyno Testing

2.1.3. Sampling Techniques

2.1.3.1. Test values are obtained based on settings in the Labview test programs. The signal quality and timing VI's sample continuously at a rate far exceeding the quarter degree accuracy required.

2.1.4. Sample Size

2.1.4.1. Sample size will be determined statistically based on initial test findings.

2.1.5. Reporting Problems; Corrective Action

Testing failures should be reported to task specific team members via e-mail immediately following test session or during testing if possible. Members who experienced the fault should meet with the task specific member to investigate corrective measures.

VI – Bob and Dereck
Damaged Components – Andrew
PCB – Robert
Programming – Jordan
Case -- Giovanni

2.2. Measurement Capability, Equipment

2.2.1. Testing through the timing VI must ensure variance within +/- 1/4º. Accuracy within the LabView programming far exceeds the necessary specifications for testing this.

2.3. Test Conditions, Setup Instructions

2.3.1. See Test Bench – Timing V3.1 and Test Bench – Signal Quality V3 at: https://edge.rit.edu/content/P09222/public/Home

2.4. Test Procedure, Work Breakdown Structure, Schedule

2.4.1. See most recent schedule at: https://edge.rit.edu/content/P09222/public/Home

3. MSD II – WKS 3-10 DESIGN TEST VERIFICATION

*Note to Teams: Populate the templates and test processes established in **Final Test Plan**.*

These elements can be integrated or rearranged to match project characteristics or personal/team preferences.

3.1. Test Results

3.1.1. Component
Add here or remove as applicable.
3.1.2. Subsystem
Add here or remove as applicable.
3.1.3. Integration
Add here or remove as applicable.
3.1.4. Reliability
Add here or remove as applicable.
3.1.5. Customer Acceptance
Add here or remove as applicable.

3.2. Logistics and Documentation

Where are the test results being performed, logged (i.e. project notebook) and documented (i.e. excel spreadsheet)? EDGE team website structure (i.e. document names, file types, and header location).

3.3. Definition of a Successful Test, Pass / Fail Criteria

3.4. Contingencies/ Mitigation for Preliminary or Insufficient Results

3.5. Analysis of Data – Design Summary

3.6. Conclusion or Design Summary

Can you explain why a particular function doesn't work? Add here or remove how the conclusions are to be reported or summarized (i.e. significance with confidence, pass/fail, etc.) as applicable.

3.7. Function/ Performance Reviews

Note: Some teams organize reviews on a weekly bases starting in week 4 or 5 and other may wish to wait until week 10 or 11. Discuss with your Guide.

3.7.1. Debriefing your Guide and Faculty Consultants

Share test results, conclusions, any follow-on recommendations, design summary.

3.7.2. Lab Demo with your Guide and Faculty Consultants

Perform each of the specifications and features.

3.7.3. Meeting with Sponsor

See Customer Acceptance above. Field Demonstration. Deliver the project. Demonstrate to the Sponsor. Customer needs met / not met.

3.8. References

Add here or remove as applicable.

3.8.1. Add here or remove as applicable.

3.9. Appendices

Add or remove as applicable.

3.9.1. Add here or remove as applicable.