

Meeting Purpose: Detailed Design Review of P09222 Hardware

Materials Reviewed: Edge Document: Hardware Design

Attendees :

Mark Smith - MSD Coordinator

George Slack - Electrical Engineering

Dr. Daniel Phillips - Electrical Engineering

Dr. Alan Nye - Mechanical Engineering

Todd Fernandez - TA

Bob Raymond - Industrial & Systems Engineering - Team Leader

Dereck Bojanowski - Electrical Engineering - Hardware

Robert Joslyn - Electrical Engineering - Hardware

Andrew Rittase - Electrical Engineering - Hardware

Jordan Hibbits - Electrical Engineering - Software

Giovanni Sorrentino - Mechanical Engineering

Recorded by: Bob Raymond - Team Leader

Meeting Date: Hardware Review 11/3/08

Previous Open Action Items Reviewed (*indicate if any action items (by number) were reviewed and closed from prior reviews or meetings*):

Simulate Op Amps with Load (Relay Control System)	Completed simulation. Op-amp control system was found to have various flaws. The device had too high of a load current to maintain operation for both amplifiers; the power dissipated was too high to prevent device failure; the maximum device voltage gain was insufficient for complete relay switching; and the input current required for operation could not be produced by the microcontroller. Old design was replaced with new PMOS relay control system. Op-amp is now used to turn on/off a PMOS transistor which in turn controls relay operation. Changes made have been done entirely in hardware; no software code changes will be required.
Get surfboards (Hardware testing)	Injector and relay control systems were constructed on surfboards and used in hardware testing. The injector control system data indicated that the new design would greatly increase device reliability, confirming simulation results. Relay control system hardware testing showed that the normal voltage inputs from the microcontroller would not be sufficient alone and required an additional op-amp to turn on/off the PMOS relay controls.

Thevenin Equivalent Circuits	Thevenin equivalent circuits have been created for the fan/fuel pump relays and the injectors. Ignition circuitry was controlled by black box circuitry and could not be modeled. Input devices could also not be modeled at this time since the engine is dismantled and will not be operational for several weeks.
EMF Voltage Surge from Injectors/Pspice Simulation	Injector circuitry has been tested in both hardware and simulation (using the Thevenin equivalent model for simulation). As expected, the injector was found to be creating a back EMF voltage surge which could damage the NMOS transistors. A feedback diode (1N4004) was added to the control circuitry to dissipate off some of the surge voltage and was found to also stabilize PMOS operation in the simulation.
Voltage Regulator Operation Conformation	Voltage regulator was tested and found to be more than adequate for the operations required. Resistive loads added to the regulator to pull more than twice the maximum current required for net logic circuit operation on the ECU had no negative effect on regulator's operation. Regulator was added to the schematic and the PCB. Additional options for the fixed voltage version have been added.
Simulate Spark Operation	ECU has no direct contact with the spark plugs. ECU is instead wired to an Autronic CDI Box which operates the spark plugs based on ECU signal outputs. These outputs have been measured from the Motec ECU during operation by the previous year's design team and implemented in the microcontroller's software.
Copper Heat Pads	Due to heat produced by the voltage regulators and the MOSFETs controlling the fuel injectors on the PCB, large pads were placed under the chips as suggested on the individual datasheets. The MOSFETs controlling the fan and the fuel pump are not a concern as the current flowing through them is low.
PCB Board Manufacturing and Population	PCB Boards have not been purchased as changes to the oxygen circuitry have been made. Once the changes are finalized, bare boards will be ordered and populated by hand. Lead time for PCB manufacturing is 1 week.
Supplementary Sensor Connections	One of the secondary goals of the ECU was the addition of extra sensors so that functionality such as traction control could be added at a later date without the need for a new PCB. These connections were not connected by the previous team, but are now complete.
Order New Board For Testing	It was decided that at the cost of \$400 it was not necessary to purchase an additional board for testing. Testing code and testing the NI DAQ will both require the board, but will both require the NI DAQ system so an additional board would not improve scheduling.

Discussion (describe any relevant discussions not captured in actions / issues / decisions tables):

Action Items					
Item #	Description	Responsible	Due	Complete	Comments
A001	Replacement of current voltage regulator with TPS70302	Andrew	11/10/08	X	
A002	Investigate Injector Control Circuit Failure	Andrew	11/17/08	X	Voltage spike was occurring, feedback diode dampens spike to eliminate error.
A003	Investigate use of level converter	Andrew, Rob	12/3/08	X	Was not implemented. Current circuit was working, but would consider for future versions.
A004	Simulate Injector Control Circuit	Andrew	11/3/08	X	Confirmed to be working.
A005	Investigate multiple diodes in injector control circuit	Andrew	11/10/08	X	Suspected it was done to reduce back EMF. Was not eliminated from design.
A006	Determine Reason for Relay Control Circuit Op Amps	Andrew	12/3/08	X	Simulations show that current spike was damaging op amp. PMOS transistor was used in replacement.
A007	O2 Sensor Circuit Completion	Dereck	2/10/09	X	O2 circuit completed in simplified set up from to eliminate last year's non-working model.
A008	PMOS circuit error with source and drain being reversed	Robert	11/10/08	X	Had been fixed already on PCB, but needed to be updated on schematic.
A009	PCB Files to Edge	Robert/Gio	11/3/08	X	Uploaded immediately
A010	Engine Dyno Testing	Dereck/Andrew	12/19/08	X	Delayed due to engine availability. Thevanin resistances and o2 sensor waveforms recorded
A011	Schematic "Black Boxes"	Robert	2/11/09	X	Boxes were updated to proper schematic symbols

Detailed Design Review Summary – Hardware (11/3/08) (3:00pm – 4:00pm)

The Detailed Design Review began with a summary of the action items from the previous Design Review. Of all the previous action items, only the Thevenin equivalent circuits for the input devices had not been completed due to the engine being offline for the majority of Fall Quarter. The spark operation had no direct connection to the ECU and did not require a more detailed investigation, sending only high/low signals to the ECU. The IAR had been confirmed to run small test programs, although more investigation was needed to confirm the exact configuration settings. The Texas Instruments test bench was also confirmed by Prof. Slack to have a 50% discount, reducing the price from \$400 to \$200.

Moving into the hardware components, the voltage regulator system was the first topic under discussion for the review. The existing voltage regulators from the previous generation design could not operate the microprocessor correctly and required a piggyback system to the Texas Instruments test board to operate properly. This problem had not been fixed due to time constraints; the exact cause of error had only been pinpointed in the final week of P08221's testing. The new design implementing the TPS70302 was revealed along with a variation from the TPS703xx family, either of which can be implemented on the new ECU PCB. It was brought to attention that the resistor values, confirmed in hardware testing, could provide some error due to their tolerances. Examination of the datasheets for the various ECU load circuits in the past had shown all logic circuits fell within the tolerance created by the resistive loads; although changing over to the fixed voltage regulator would completely eliminate those problems.

The second topic of discussion was the occasional failure of the injector control circuits. Testing had revealed that Prof. Slack's suggestion to look for an EMF voltage spike was correct and a voltage build-up of over +30Vdc was observed during testing (both hardware and simulation). This had been countered in hardware and simulation testing with the addition of an injector feedback diode. An error in the pre-read documents was pointed out by Prof. Slack, that the injector driver's ON/OFF descriptions had been reversed. Dr. Phillips also noticed that the +3.3Vdc to +5.0Vdc conversion presently executed by an op-amp could just as easily be completed using a level converter (this also applies to the relay control circuitry). The injector circuitry had been analyzed using Dr. Hoople's RLC meter to create a Thevenin equivalent circuit for use in simulations. Prof. Slack brought up the question of the timing of the injector control circuits from simulation and how it had been selected; simulation was confirmed post-design review to be operating at the engine's max run speed. The question of feedback resistors/diodes was brought up and the reasoning for multiple diodes; no sufficient reasoning could be developed in part due to the lack of information on the existing diodes. Investigation into the populated PCB boards was planned to gain the zener diode part numbers; although it was recommended that they be removed entirely.

Next, the relay control circuit was examined. Simulation had shown that the relay current of 150mA was likely damaging the op-amps. A PMOS transistor was put into use to control the relay with the op-amp aiding in switching the transistor. Dr. Phillips recommended that this too should be replaced with a level shifter. The transistor and the various feedback components were agreed upon by the majority to be overkill for the ECU, but the final decision made was to leave unpopulated spaces for the components on the PCB for testing. An error with the PMOS circuits, reversing the source and drain pins, provided in the pre-read documents was pointed out, although the error had already been fixed on the PCB. NPN bipolar transistors were recommended as a replacement for the PMOS devices and would need investigation to be confirmed.

The PCB layout was then presented before the Design Review. The PCB revisions were found to be missing from the web and needed to be uploaded along with all previous revisions. Prof. Slack again reminded the team that the input impedances (a.k.a. Thevenin equivalent circuits) needed to be added to the design circuit and that the black boxes of the logic circuits needed to be replaced. This process had already been started, but due to its low priority nature, it had been delayed to finish work on the PCB. The engine was confirmed by the Formula Team to be operational later in the week so that Thevenin Equivalent circuits could be developed, esp. the CDI box with its potentially large impedance. The wiring diagram for the pinouts could not be confirmed as matching with the Motec ECU and was promised to be verified at some point in the future. The cam and crank sensors were also planned for testing to discover their current voltage characteristics with the aid of Prof. Slack.

At this point the design review concluded due to time constraints on several major participants.

The second ECU design review for software was planned to commence at 3:00 pm the following day.