



TRACTIVE SYSTEM INTERFACE MAINTENANCE MANUAL



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LAFAYETTE COLLEGE

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INTRODUCTION

This document is intended describe the current design of the Tractive System Interface board and its intended use. Future improvements, as well as board errata, will also be covered so that future students may understand the pitfalls we encountered, as well as our perceived path forward for the board.

The TSI board's motivation was to accomplish the following tasks. The current board is designed to meet each of these requirements, however, we did not successfully implement them all.

- Brake System
 - Brake Overtravel switch status read by microcontroller
 - Brake pressed signal read and used in system state logic
- Throttle
 - Determine throttle plausibility
 - Isolate (plausible) analog throttle signal and pass to motor controller
 - Accept (over UART) throttle commands from VSCADA
 - Produce "soft throttle" levels via PWM, isolate, and pass to motor controller
- IMD
 - Read (ADC) IMD PWM corresponding to resistance measurement
 - Read IMD status signal
- Voltage/Current measuring
 - Read voltage and current values from TSV
 - Send to VSCADA
- Shutdown System
 - State diagram according to Formula Hybrid rules
 - Drive Button
 - RTDS
 - Drive light
- High Voltage Present Lights

SCHEMATIC

This schematic itself contains many comments and annotations. Additionally, each component should contain a sizable amount of information. This includes footprint, datasheet, and DigiKey part number, among other characteristics. Here we will discuss the reason behind our component selection, as well as their intended functionality.

MAIN SHEET

AIRS MEASUREMENT

This optoisolator takes in the +24V signal from the AIRs, and outputs a Safety_Loop variable to PIN7 of the microcontroller. This may be used to determine the state of the safety loop, and cause the system to fall out of the Drive State.

IMD PWM LPF

The IMD outputs a PWM signal that corresponds to the resistance seen across the TSV. The intent of this filter was to produce an analog voltage that could then be read by the microcontroller (PIN60, ADC), and passed to VSCADA over CAN. At the conclusion of ECE492-SP17, this has not been debugged/used.

CURRENT MEASUREMENT

The current sensor we are using produces a differential output, that we then put through this unity-gain differential amplifier to produce a single-ended output. The signal, I_Measure, then goes into PIN58 of the microcontroller (ADC) to be later passed along to VSCADA over CAN. At the conclusion of ECE492-SP17, this has not been debugged/used.

TEMPERATURE SENSOR

The temperature sensor communicates with the microcontroller over SPI. At the conclusion of ECE492-SP17, this has not been debugged/used.

CURRENT ENABLE

During our CDR, many alumni had expressed concern over the current draw of the Current Sensor. To fix this, we added a low-side switch so that the microcontroller (PIN44) could momentarily power the sensor to take a reading. At the conclusion of ECE492-SP17, this has not been debugged/used.

SPARE ADC SWITCH

The intention of this switch was to give the user spare ADC's for unforeseen future use. Unfortunately, the control signals of the microcontroller all exist on the same pins as the ADC's. Therefore, this switch may be toggled after programming in order to free up these additional pins.

ISOLATORS

THROTTLE

This isolated differential amplifier passes the low-voltage throttle signal (Throttle_LV) to the high voltage side of the board. The voltage divider on the input is intended to bring the voltage down to a 0-2V range. On the high voltage side, the op-amp has a gain such that the signal is back to the 0-5V range used by the motor controller. Note: R58 on the schematic has a 24.9k resistor. This results in incorrect amplification. This has been replaced on the current board with a 15k ohm resistor, and should be changed for future runs of the board. Should also be noted that this configuration is based upon the application described in the part datasheet (here: <https://docs.broadcom.com/docs/AV02-3563EN>).

VOLTAGE MEASUREMENT

This is the same isolator as the one found in the Throttle Isolation circuit described above. The difference here is the voltage divider on the input, intended to divide a 120V TSV to a 0-2V range. The isolated output, V_Measure, then goes to the microcontroller (PIN59) where it may be read by an ADC, and later sent to VSCADA. Preliminary testing was done using probes to check if an isolated voltage could be seen on the low-voltage side of the board, however, this was never done with the full 96V supplied by TSV. At the conclusion of ECE492-SP17, this has not been debugged/used.

CONNECTORS

The P2 and P3 connectors should be replaced. These currently are designed to use ribbon cables, however, the gauge of the ribbon cable is such that connections to the Deutsch Connectors are difficult. Additionally, more attention should be paid to the ordering of the pins. Currently, the locations are such that on the ribbon cables alternating wires go in completely opposite directions. This causes unnecessary difficulties in wiring the board and box. It should also be noted that the headers for P2 and P3 as installed on the board allow for the ribbon cables to be connected backwards.

The remaining connectors for the JTAG programmer, High Voltage connections, as well as spare pins functioned simply and securely.

Connections for the board are covered in greater detail in the Interconnectivity Document (ICD) on the website (here: https://sites.lafayette.edu/ece492-sp17/files/2017/01/TSI_ICD.pdf).

DC/DC CONVERTER

The DC/DC Converter worked fine, and may be confirmed by viewing the PWR LED next to the microcontroller, which turns on whenever 5V is supplied. In future runs, it is recommended that this converter change to a dual output. This is due to the 24V-to-10V regulator (LM7810). This regulator needed to create 10V referenced from the CH_GND, however, since it was regulating from the 24V coming into the DC/DC, isolation had to be sacrificed. This resulted in the +24V_RTN and CH_GND pins being soldered together on the P3 connector.

CAN TRANSCEIVER

The CAN Transceiver is identical to the one found on the PacMan boards. No software supporting communication was written, however, it is assumed that code may be taken from the functioning communication protocol used by the PacMan boards. It is noted on the schematic, but to reiterate, R44 should *not* be populated unless the TSI board is to be a CAN terminator.

THROTTLE PLAUSIBILITY

The majority of the circuitry contained in this sheet was created to comply with the FSAE Hybrid Rules for Throttle Plausibility checks.

10V REGULATOR

This is the regulator discussed above in *DC/DC Converter*. Due to the necessity to create the 10V from the 24V going into the DC/DC, ground isolation was sacrificed. If a dual-output DC/DC is used to replace the current one, creating 5/12V output, this regulator will have to be replaced with a low-dropout equivalent.

APPS 5V OFFSET BIAS

The purpose of these two op-amps is to bias the two pedal potentiometers 5V from one another. As noted on the schematic, several changes should be made to this configuration.

1. Clamping diodes could be added to better protect the inputs
2. R25 and R26 could be replaced with potentiometers so that pedal cluster resistances can be better matched. At the least, these need to be changed to 5k ohm (datasheet of potentiometers incorrectly lists them as 2k).

APPS1 STEP DOWN

This unity gain differential amplifier is used to step the 5-10V APPS1 signal to a 0-5V range for use in the window comparators. This was chosen as the method to step the voltage down, since the MCP6004 uses all four available op-amps on the window comparisons, while we still had one free TS912 on U18.

OPEN/SHORT WINDOW

These window comparators check for open/short circuits coming from the APPS. They currently allow for roughly 93% of the travel to pass without causing an implausibility.

PLAUSIBILITY WINDOW (0.5V)

The differential amplifier finds the difference between the two buffered APPS inputs, then uses a window comparator to check that they are within 10% of the ideal expected value.

THROTTLE SELECT SWITCH

This analog switch allows whichever throttle signal is manually set with the jumper (JP1). The Throttle_SEL signal has a pull-down resistor to ensure that GND is selected upon startup. This switch allows the microcontroller to drive the throttle value to zero based on drive state, or other input signals.

BRAKE PRESSED/BRAKE OVERTRAVEL

These optoisolators are used to step the 24V signals down to 5V for use with the microcontroller. In this way VSCADA can be notified via CAN if the brake overtravel (PIN8) was the responsible for opening the safety loop. Similarly the brake pressed signal (PIN14) is used for Drive State determinations.

MICROCONTROLLER THROTTLE PWM LPF

This filter was designed for a 40 kHz PWM signal, used when taking throttle commands from VSCADA. At the conclusion of ECE492-SP17, this has not been debugged/used.

STATUS LIGHTS

RTDS/DRIVE LED/CRUISE LED

These are the same optoisolators used throughout the rest of the board. The three control signals (PIN47, PIN48, and PIN49) from the microcontroller are used to alert the driver to the status of the system inside the cockpit. At the conclusion of ECE492-SP17, the RTDS and Cruise LED had not been debugged/used.

IMD STATUS SWITCH

This high-side switch was used due to the inverted OK output of the IMD. This particular PMOS was selected due to its high Vgs.

STATUS/DEBUG LEDS

These four LED are placed on the board for debugging/system state tracking of the board. Currently, the Heartbeat LED is blue. The Spare Red LED corresponds to the Drive State (in drive, lit), and the Spare Yellow denotes a throttle implausibility. These may be changed/reconfigured using PIN36, PIN37, or PIN38 of the microcontroller.

HVPL

The buck converter used in this circuit and surrounding circuitry is taken from the datasheet associated with the LTC3638 (here: <http://cds.linear.com/docs/en/datasheet/3638fa.pdf>). The voltage divider on the input is designed to cause the DC/DC to turn on around 27V. The DC/DC was used to comply with FSAE, and was suggested in the FSAE Hybrid rules. This maintains isolation from the HV side.

PCB LAYOUT

The PCB functions as currently fabricated, however, there are several changes that should be made before another board is ordered.

- The Serial Number pad in the top left corner exposes the ground plane. This solder mask should *not* be removed here.
- On U5 (voltage regulator) the solder mask *should* be exposed. This will allow for better heat dissipation.
- P2 and P3 do not have accurate outlines as far as the plastic dimensions. The pin spacing is fine, however, the plastic encroaches on other areas of the circuit. Note, these connectors should be scrapped/replaced entirely anyway.

- More test points are always useful. The current ones could be replaced with smaller pads.

SOFTWARE

Current software is based heavily upon PacMan software. Communication protocol was not setup for our system, however, future implementations should refer to the PacMan code for CAN and/or I2C communication, since it is used on that board.

Programming instructions may be found in our Git (here: <https://github.com/LafayetteFormulaElectricVehicle/TSI>), on our subsystem site in the .zip (here: <http://sites.lafayette.edu/ece492-sp17/subsystems/tsi/>) or as a stand-alone document on TSV's site (here: https://sites.lafayette.edu/ece492-sp17/files/2017/01/PacMAN-Programming-Manual_2017.pdf).

The Makefile, and tasklist.c need to be altered to add/modify tasks.

The TSI is currently using the task_heartbeat, task_safety, and task_button source/header files to control the Drive State and debugging status lights.