Tuner Studio Operating System Manual

Firmware Version 0.3

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# Summary

This program is intended to run on Arduino based systems programed via the Arduino IDE such as the Arduino Mega2560. It enables communication with Tuner Studio (TS), a calibration and data acquisition tool available from <https://www.tunerstudio.com/>

The basic functionality is to:

1. Define variables which are saved to and recalled from the internal memory (EEPROM) of the Arduino.
2. Send the variables in memory to TS and receive new data when variables in TS are changed.
3. Write (Burn) these variables to the EEPROM.
4. Send measurement variables at a defined rate to TS for display and logging.
5. Receive commands to execute certain functions on the Arduino. i.e. switch an output on or off.
6. Provide a task based timing system to execute tasks with feedback if those tasks have overrun.
7. Implement a simple CAN\_BUS broadcast and message object receive implementation using the MCP2515 transceiver over spi.

This code provides the bare bones of communication and forms the basis for a functionality created by the user to be added to this code.

The Latest release can be found in the ->release sub directory.

Documentation can be found in the ->docs sub directory.

Latest version of this program can be found on github: <https://github.com/HWright9/TunerStudioOS>.

# Quick Start

## Getting Connected

A quick overview to get started compiling and running the program. Details are in the sections below.

1. You need an Arduino Mega2650 Uno or Nano. Just for now run it with no shields or connections other than the USB to the PC.
2. Download Tuner Studio from <https://www.tunerstudio.com/>. For developers the paid version will be the most useful, however the program will work with the free version.
3. Download and install latest Arduino IDE <https://www.arduino.cc/>.
4. Download the entire program folder from github <https://github.com/HWright9/TunerStudioOS>. I Recommend placing it in the Documents -> Arduino directory.
5. Either compile and download the program to the Arduino using the IDE or use the release.hex file in ->release to flash the controller.
   1. Note, if re-using an old Arduino, best to run the EEPROM\_clear sketch from examples to make sure EEPROM does not contain any leftover data.
6. Open tuner studio and start a new project. When prompted browse for the release.ini file in the -> release folder.
   1. Make sure you select the size of the EEPROM in the project configuration. 1KB for UNO or Nano and 8KB for Mega.
7. Open the baseline.msq to load initial variables into Tuner Studio.
8. Connect to the controller on a serial port. The bitrate is 115200. The com port will be the same as used with the Arduino IDE. (Hint: You have to be offline with Tuner Studio to flash new code to the Arduino).
9. If prompted, write all variables to the controller.
10. Make sure the burn is complete.
11. Reset the controller.
12. You should now be connected.

Your screen should look similar to the image below:

A picture containing device, measuring instrument, gauge, clock

Description automatically generated

Figure Main Default Gauge Cluster

## Read Port Data and Control Outputs

The hardware testing button has a few options. Open them all and you will see

1. The status of all digital ports, whether they are input or output. On = green = Logical high (5V).
   1. Note1. The Mega only has 54 ports, even though 64 are shown.
   2. Note2. The port numbering matches that shown on the Arduino case.
2. The Analog inputs as shown on a live graph. They are also available as gauges on the main screen.
3. The Test ports section where you can override the status of a digital port.

A close-up of a computer screen

Description automatically generated with low confidence

Figure Menu Items in Hardware Testing

If you head to the Test Ports section. You should be able to “enable Test Mode.” If it is greyed out you first need to enable “Allow Hardware Test Commands” in system settings.

A screenshot of a computer

Description automatically generated with medium confidence

Figure System settings

Once that is working, you should be able to manually override each port. Note the following:

1. Ports defined in the code as INPUT will change the value seen by the program but will not change the physical port.
2. Ports defined as OUTPUT will change the physical state of the port as well as what is seen by the program.
3. Remember that some ports are used for other functions such as serial communication and you may not be able to change them or changing them causes errors in other functions.
4. Your controller may not actually support all the ports and analogue channels shown.

A screenshot of a computer

Description automatically generated

Figure Hardware Testing and Override View

## Inserting your own code

The code inherits all the normal Arduino libraries. When starting out, it’s best to open the whole project in a reasonable C editor such as notepad++. Open the whole folder as a workspace so you can quickly navigate between files.

Open userfunctions.ino

Write a simple function, such as

A screenshot of a computer program

Description automatically generated with low confidence

Make sure you add the prototype of the function to the userfunctions.h file. Then you head over to the TunerStudio\_OS\_Dev.ino file and find the correct task rate to call the function.

Notes:

1. Avoid writing a lot of code and if statements in the task schedulers in TunerStudio\_OS\_Dev.ino, it gets messy fast. Much better to create a function then just call it from the appopriate FUNC\_XXXmsTask.
2. Note how we are using setDigitalPort and readDigitalPort instead of digitalRead and digitalWrite. This wrapper is what allows the Test port commands to work.

A picture containing text, line, font, screenshot

Description automatically generated

When you are done. Save your work and compile the code in the Arduino. Then download and run the new program.

## Adding a Measure Variable (Sent to Tuner Studio)

To add a new measure variable you need to add a signal to the structure Out\_TS. You do this by editing the Out\_TS\_t typedef in globals.h

Valid measure variable types are:

BitField (8 bytes minimum), U08, S08, U16, S16, U16, S32 or F32.

Once you add it here you can reference it in code using the prefix Out\_TS.Vars.new\_variable\_name

It’s important to make sure that the order, and unit types specified here exactly match what is specified in the TunerStudioOS.ini file otherwise you will have communication problems.

A close-up of a text

Description automatically generated

Figure Out\_TS\_t Typedef Example

In the TunerStudioOS.ini file find the [OutputChannels] section.

Make sure you insert your variable in exactly the same order as in the Out\_TS\_t structure. Use the nextOffset variable to automatically set the next corresponding byte address. If defining a bitfield you have to use lastOffset to prevent incrementing the address for each bit inside a byte address.

It is also possible to exactly specify each byte address, however this gets tedious to renumber all of them if during development you want to insert a new variable between existing variables.

Follow the examples in the source code.

Tuner Studio also needs to know how many bytes to expect with the ochBlockSize variable. The size is the size of the Out\_TS\_t structure, if you know how many bytes you added you can increment this number by that many bytes. If you are unsure, then this number is transmitted to Tuner studio with the ochBlockSizeSent parameter, however it has to be manually updated in the OutputChannels section.

If you have comms issues after an update to the OutputChannels the ochBlockSize being incorrect is usually the cause.

A screenshot of a computer

Description automatically generated

Figure . Example of OutputChannels

The System Settings window contains the correct size of ochBlockSize Variable sent from the Arduino.

A screenshot of a computer

Description automatically generated

Figure . System Settings showing ochBlockSizeSent and page sizes. The values here are calculated and available when connected to the Arduino

Once the .ini file and code are updated, upload the code to the Arduino and then reload the TunerStudio.ini file. TS should automatically connect.

If there are coms issues after an update, you can use the comms debug log in TS to get more information. Most times it is a problem with the ochBlockSize not being correct or the variable order not matching.

## Adding a Calibration Variable (Saved to EEPROM)

A calibration variable exists in the RAM and also is synchronized with the EEPROM and Tuner Studio. The process is:

When the Arduino powers up the EEPROM is copied to the RAM.

When Tuner Studio powers up it will request the RAM copy to be sent via the serial link. Tuner studio then compares this data with it’s own copy of the calibration parameters.

If a variable needs to be updated Tuner Studio sends the variable to Arduino RAM but the data is not actually saved to EEPROM until a burn command is issued. Then the Arduino writes any changes in the RAM variables to EEPROM.

Arduino

EEPROM

RAM

Tuner Studio

(.msq)

On Controller Init

With Burn Command

TS Requests Data by page on connection

TS Sends Data as variables are changed

Serial Link

PC

It’s important to note that the EEPROM write can take 3.6ms per byte, so 8Kb can take up to 30 seconds. If the communications with TS are interrupted TS will reset the Arduino in an attempt to reconnect. So, the EEPROM updates must be performed asynchronously. Also, Tuner Studio breaks the EEPROM into pages to make it more manageable. Pages can be any size, but larger pages take longer to synchronize and send data.

If you need to re-define the page sizing start with the storage.h file. Remember Actual page size should never be greater than the defined page size or the variables will overwrite each other and TS will throw errors.

Variables in EEPROM can be single bits, scalars, or multidimensional arrays.

To define a new calibration variable search for the correct page definition in globals.h.

Add your variable with the correct data type. Note that if using a variable following some bits the bits are always part of a whole byte. The next scalar or array variable will be the nextOffset.

Once defined you can reference your new variable in the code with configPageX. new\_variable\_name.

A close-up of a text

Description automatically generated

Figure Example of Definition of Page 1.

In the TunerStudioOS.ini file find the page = X section. With X corresponding to the page you added your variable. In the same way as [OutputChannels] section you must add your variable in the exact same order and with the exact same units.

nextOffset and lastOffset also work here as they do in OutputChannels.

# Function Documentation

The code provides a number of functions to help with common control tasks and measurement. These can be removed if not required.

## Task Execution and warning bits

The code implements a simple task scheduler.

Make sure your code doesn’t take too long to execute. Any complete loop can’t be longer than 5ms otherwise the 5ms task will miss an execution step.

## Low Pass Filter

uint16\_t lowPassFilter\_u16(uint32\_t input, uint8\_t alpha, uint32\_t prior);

The function implements a low pass filter or lag filter using the new input, the previous input value and an “alpha value” from 1-255 which sets the filtering on the output. High values of alpha increase filtering with 128 being 50% filtering. The code ensures that the output will converge to the input even with very high filtering, the heaviest filter will have the output move closer to the input at a rate of one bit per loop.

The equation is:

Output = Prior \* (1-alpha) + input \* alpha

An example of the filtering is shown below.

A screen shot of a computer

Description automatically generated with low confidence

Figure Example of Low Pass filter. Red signal is filtered, white is the input. Alpha of approximately 200

## CAN

### CAN Overview

A simple implementation of a Controller Aera Network (CAN) Broadcast network is provided in the OS. In this network, each node broadcasts messages onto the Bus at a specific rate. The sender has no knowledge of which modules are receiving the messages.

Every module receives all messages and compares them against a number of pre-defined receive message parsers. The parser decodes the message and loads the data from the message into variables for use internally.

This sort of messaging is typically used in vehicles to transmit data to dashboard displays or to the Transmission controller.

It’s important in this system to detect if an expected message is no longer being received and execute a default “safe” state. Otherwise, the last received value will be held forever.

### Implementation

The code is expecting a MCP2515 controller connected via the SPI interface. The pinout is different depending on the board. Most of the pins and initialisation is configurable via the settings in Tuner Studio. The actual CAN messages are hardcoded in canbus.ino

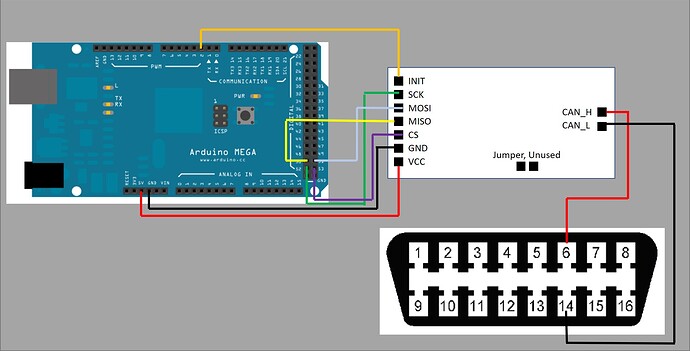


Figure Example of MCP2515 connection on Arduino Mega

If CAN is enabled. The Arduino attempts to initialise the module and begins broadcasting if successful. If not successful, the code will send status bits to Tuner Studio which can be visualized at the bottom of the screen.



If you are having CAN bus errors. Check the following:

1. Are all nodes on the network configured to the same frequency?
2. Do you have appropriate termination resistors? You should have 120ohms at each end of the bus. Most MCP2515 boards have the provision to enable a termination resistor.

### CAN Broadcast

CAN broadcast uses simple functions called from the main task scheduler.

Example: void canBroadcast\_5ms(void)

The message variables can then be parsed into the canmsg[] object and sent at the appropriate rate.

### CAN Receive message

CAN receive uses the interrupt pin from the MCP2515 to tell the Arduino that CAN data is waiting. As of 0.3 implementation it does not actually interrupt the code to receive the message, this pin is polled from the main loop.

If the user does implement the an interrupt don’t forget that variables need to be declared volatile when used in ISR’s, also that heavy CAN bus traffic can cause the controller to become overloaded.

Once a message is received, the ID of the message is checked against each defined message object. Then the length is compared in the object to make sure the full message was received. If both of these checks pass the message is parsed and the timeout counter reset.