SimMotor

User Manual

Small Engine Simulator and HIL

V2.3.1

Http://www.ecotrons.com

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Read before you start:

Please use correct power supply:

Use a lab DC power supply with:

DC voltage range: 10V~16V

Higher voltage will result in damaging the SimMotor.
Lower voltage will result in irregular behavior of SimMotor.
SimMotor typical supply voltage is ~12V.
DC current supply requirement: 1.0 A or higher amp-age capability.
Recommended DC power supply: 12V / 1A

ECU will get the 12V power via SimMotor.

Do NOT disconnect or connect wires when SimMotor is powered on!

Why do I need SimMotor?

Top 3 reasons:

- **I don't want to rack my engine with untested ECU software!**
- **My engine does not have a cam-shaft sensor, and I want to use MAP signal to detect the phase and run the sequential injections;**
- **I want to debug my ECU software with a specific operating condition (10,000rpm, for example).**

More reasons:

- **I want to run some advanced Hardware-In-the-Loop (HIL) tests with my ECU…**
- **I want to use some professional test equipment yet within my budget…**
- **More…**

SimMotor hardware required:

The below parts are needed for SimMotor operations:

- **SimMotor (included)**
- **SimMotor harness (included, but the ECU connection shall be done by the user)**
- **12V DC power supply (not included; voltage range: 10-16V, current range: >= 1A)**
- **12V DC power supply cable (+/-, included)**
- **ECU (not included, user provided)**
- **PC computer with Windows XP or later OS (optional, not included);**
- **RS232 Serial cable (optional, not included)**
- **Oscilloscope (optional, 4-channel prefered)**

Introduction

SimMotor is a small engine simulator which simulates inputs/outputs of the small engine control systems for 1-cylinder or 2-cylinder engines. It can be used for small engine control system development and HIL (hardware-in-the-loop) tests.

Figure 1: SimMotor Panel

SimMotor's functions include:

1. Input/Output simulations

- Simulate analog sensor inputs for a small engine control system.
  - VRS – crankshaft position sensor
  - MAP – manifold absolute pressure sensor
  - TPS – throttle position sensor
  - ATEMP – intake air temperature sensor
  - ETEMP – Engine temperature sensor
  - O2 – wideband oxygen sensor
- Simulate digital inputs for a small engine control system.
  - IGNSW - Ignition switch
  - KILLSW - Kill switch
  - CLTSW - Clutch switch
  - NGEARSW - Neutral gear switch
  - KICKSW - Kick-stand switch
  - START - Start relay
- Simulate injection and ignition loads
  - IGN0 - Ignition coil 0
  - INJ0 - Injector 0
  - IGN1 - Ignition coil 1
  - INJ1 - Injector 1

2. Build-in mathematical model of a small engine, which uses TPS input and engine load as primary inputs, to calculate the MAP signal and the engine speed as 2 major outputs. With other inputs/outputs, it provides an HIL testing environment for advanced users;

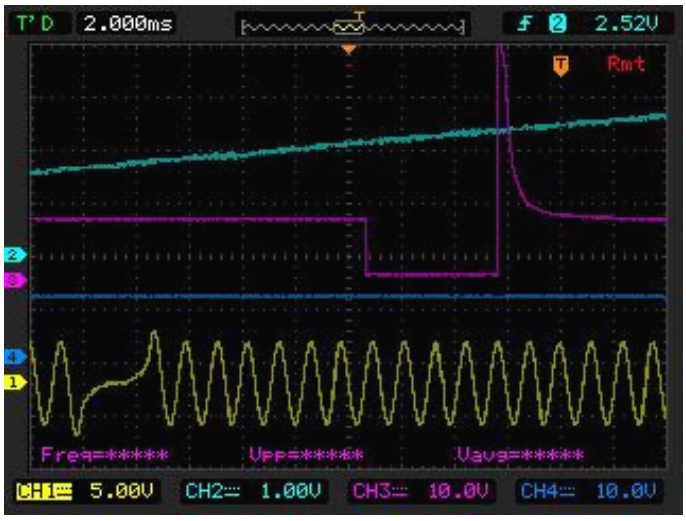

Figure 2: Crank Sensor (Hall) Signal

Note: Channel 1 (Yellow): VRS signal

3. Crank signal / MAP signal are synchronized outputs to ECU, this unique feature makes sequential injection possible without a Cam sensor;

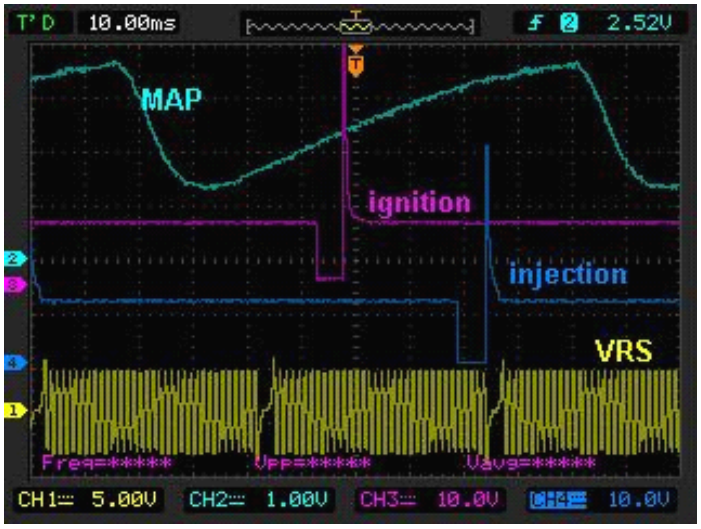

Figure 3: MAP signal and Synchronizations

Note: MAP- Intake manifold air pressure

4. SimMotor can communicate with a PC via a RS232 serial cable. With a PC GUI, the user can configure the SimMotor parameters. Major parameters include:
    - VRS wheel mode (number of teeth, and # of the missing teeth and the position.)
    - Engine displacement
    - Intake manifold volume
    - Throttle diameter
    - # of cylinders
    - Etc.

Operating Environments

SimMotor is designed for the bench test environment.
Ambient temperature range for SimMotor operations: 32 ° F ~ 184 ° F / (0~70°C)

It is NOT suitable for a harsh environment, therefore:

- **Do not expose it to water, or splashing fluid;**
- **Do not use it with the severe vibration;**
- **Do not use it in the very humid environment;**
- **Do not use it in the flammable area;**
- **Do not use it in the strong Electro-Magnetic Interference (EMI) environment;**
- **Do not use it in the dusty environment;**
- **Do not operate the SimMotor with statics.**

Connectors Pin-out: 25-pin Definitions

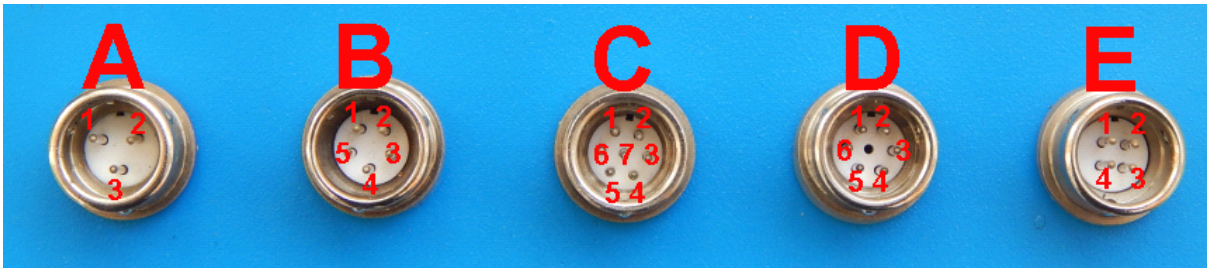

Figure 4: Connectors pin-out

Connector	Pin #	Name	Descriptions	Notes
Connector A	1	GND-R	ground	BLACK
	2	T2	Transmit Data	PURPLE
	3	R2	Received Data	WHITE
Connector B	1	IGN0	Ignition coil output 0	WHITE
	2	INJ1	Injector output 1	GREY
	3	IGN1	Ignition coil output 1	GREY
	4	GND	ground	BLACK
	5	INJ1	Injector output 0	WHITE
Connector C	1	KICKSW	Kick-stand switch	WHITE
	2	CLTCHSW	Clutch switch	BLUE
	3	NGEARSW	Neutral gear switch	GREEN
	4	GND	ground	BLACK
	5	VRSOUTH	Crank sensor positive (Variable-reluctant sensor)	YELLOEW
	6	VRSOUTL	Crank sensor Negative (Variable-reluctant sensor)	PURPLE
	7	KILLSW	Kill switch	GREY
Connector D	1	MAP	Manifold absolute pressure signal output	BLUE
	2	TPS	Throttle Position Sensor signal	PURPLE
	3	CAMOUT	Cam position sensor (Hall type 0-5V)	WHITE
	4	GND	ground	BLACK
	5	O2_OUT1	Oxygen sensor signal, bank 1	YELLOW
	6	O2_OUT2	Oxygen sensor signal, bank 2	GREEN

Connector E	1	ETEMP	Engine Temperature Sensor	YELLOW
	2	GND	ground	BLACK
	3	+12V	Provide the 12 v voltage	RED
	4	ATEMP	Air Temperature Sensor	GREEN

Setup SimMotor

Connect wires / harness

Connect SimMotor to DC Power Supply

SimMotor needs an external 12V DC power supply. The voltage range of DC power supply should be between 10V to 16V. The amp-age capability should be equal or greater than 1A.

DC power supply out of the above range can cause unwanted results, and it can even damage the SimMotor and ECU.
Recommended DC power supply is 12V / 1A.

Connect the positive (+) of DC power supply to SimMotor power supply positive (+).

Connect the negative (-) of DC power supply to SimMotor power supply negative (-).

Connect SimMotor to ECU

Do NOT connect SimMotor to ECU when SimMotor is powered ON.

Please refer to the 25-pin definitions for each wire out of SimMotor. It is user's responsibility to identify the corresponding pins on the ECU side, since users' ECUs can be very different from each other. The user must make sure the wire connections between SimMotor and ECU are correct. Incorrect wire connections can damage SimMotor or ECU.

Note, not all pins from SimMotor have to be connected to the ECU. The minimum set of pins that need be connected, to make the test meaningful, are as below:

- MAP signal
- VRS signal
- GND-S sensor ground

- VCC +5V from ECU
- TPS signal
- GND-P power ground
- VPWR +12V supply to ECU
- Ignition coil output 0
- Injector output 0

Again, it is the user's responsibility to decide which inputs and outputs the ECU needs to get running. Therefore, the user shall decide which pins should be connected to satisfy his/her test needs.

Connect SimMotor to a PC

This is optional, only if the user wants to change the default engine parameters, for example, the wheel mode (i.e. VRS tooth wheel).
The default engine parameters stored in SimMotor are:

- 1-cylinder engine
- 600cc displacement
- 30mm throttle diameter
- 300cc intake manifold volume
- 36-2 tooth wheel for VRS crank signal
- Other non-critical parameters (see chapter "PC GUI")

If the user has a different engine to run, he needs to change the engine parameters in the SimMotor. This is done via a PC. SimMotor can communicate with a PC via a RS232 serial cable (not included). (if user's computer does not have a RS232 port, it is recommended to buy a USB-to-RS232 adapter.)

There is a GUI software developed for SimMotor that can be installed on the PC, and the user can use this GUI to configure the SimMotor parameters. For details of how to install and use the GUI, see Chapter "PC GUI".

Please refer to the 25-pin definitions for each wire out of SimMotor. It is user's responsibility to identify the corresponding pins on the ECU side, since users' ECUs can be very different from each other. The user must make sure the wire connections between SimMotor and ECU are correct. Incorrect wire connections can damage SimMotor or ECU.

Instructions for SimMotor Panel

Turn on the SimMotor Power

Only after all the necessary connections are done can you turn on the SimMotor power.

The way to turn on the SimMotor power: 1) turn on the DC power supply; 2) turn on the Ignition Switch (IGNSW) on the SimMotor Panel (see figure 6)

(If you need to disconnect or reconnect some wires, please turn off the DC-power before you do it, or turn off the IGNSW at the least. Connecting/disconnecting wires with SimMotor powered-on could damage the SimMotor or even ECU).

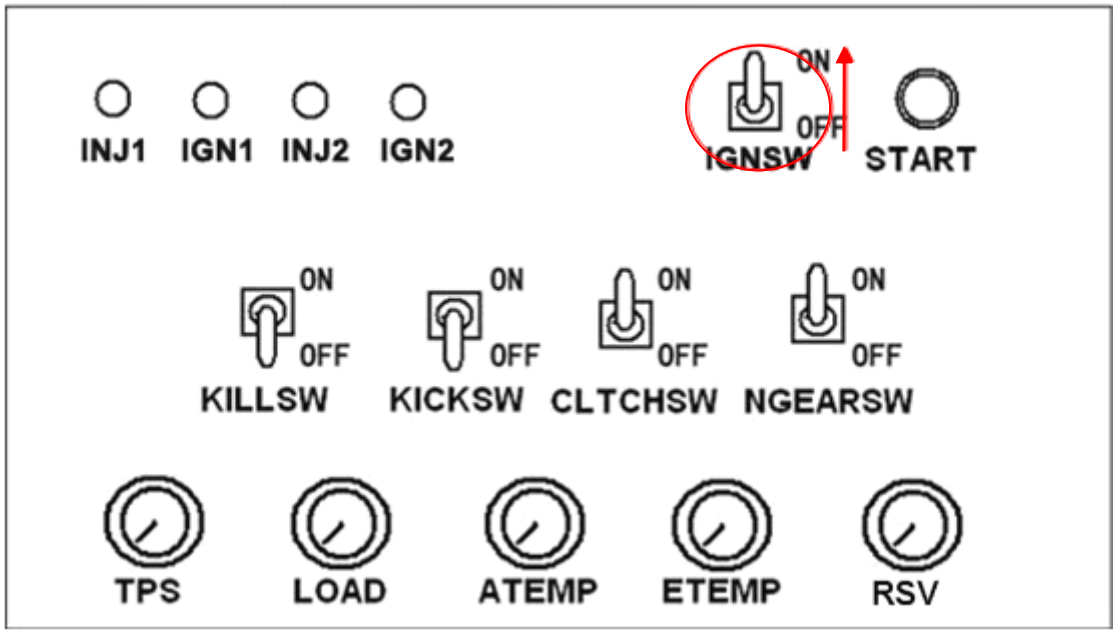

Figure 5: turn on the ignition switch

After the SimMotor is powered on (IGNSW=ON), the whole system is powered on, including SimMotor and ECU; however, the “engine” is not running, and there are no engine speed signal or dynamic MAP signal.

Start the SimMotor

To start the SimMotor, or to start the “engine”, the below conditions must be all satisfied (see Figure 7):

- IGNSW is ON;
- KILLSW is OFF;
- CLTCHSW is ON, or NEGEARSW is ON;
- Press the START button for 1-2s.

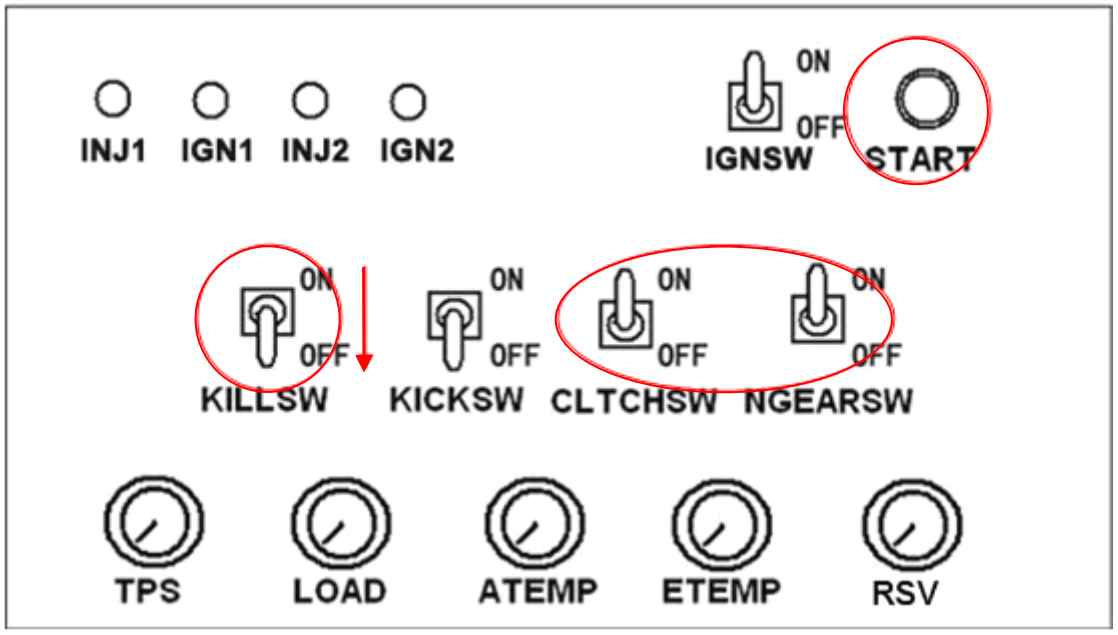

Figure 6: Start the SimMotor

After the engine is started, you should be able to see the VRS crank signal and the dynamic MAP signal on the oscilloscope (refer to Figure 2 or Figure 3).

Adjust the SimMotor signals

Through the SimMotor panel, you can adjust the input/output signals of the SimMotor.

Analog signals

TPS

Turning the TPS knob will change the analog input signal of throttle position sensor (TPS). This signal input to both SimMotor and ECU. SimMotor uses TPS signal as the primary input for Driver's request. It will compute the MAP signal based on the aero dynamics and the intake manifold model. From there, the air charge into the engine is determined. The air charge, plus the external engine load and other inputs (see below), will then be input to a simplified engine model, and output the engine speed.

Note, TPS signal is an analog input to both SimMotor and ECU. It is in range of (0~5V).

The MAP signal is an output of SimMotor, not input. It is based on the math-model, and computed as a digital value, and then through a digital-to-analog converter (DAC), it is an analog input signal to ECU.

The engine speed is also an output of SimMotor and it is digitized and also via a DAC, it is output to ECU as an analog signal (similar to a VRS sensor output).

The key is that the VRS signal and the MAP signal are synchronized (see Figure 3). It is conveniently used for sequential fuel injections. Small engine control systems often do not have a Cam-shaft position sensor (Hall or VRS). To realize the sequential fuel injection, the phase of cam-shaft is something that must be known. The MAP signal of a small engine control system is often used for the phase detection.

LOAD

Not same as the industry definition of "load" of an engine, where load means pure air charge, here LOAD simulates the external engine resistance torque. Turning the LOAD knob will change the engine external load. Together with the air

charge model based on the TPS, it will determine the engine output speed. To get a desired engine speed, you can use the TPS as the coarse input, and LOAD as the fine input, and the final engine speed is the result of a dynamic equilibrium of the TPS-based charge model and the engine load model.

Note, LOAD signal is only an input to SimMotor, not to ECU. It is in range of (0~5V).

ATEMP

It simulates the intake air temperature. It outputs a (0~5V) analog signal.

ETEMP

It simulates the engine temperature. It outputs a (0~5V) analog signal.

O2

It simulates a wide-band oxygen sensor signal. It outputs a linear (0~5V) analog signal.

Note, ATEMP, ETEMP, and O2, need the ECU to provide the +5V sensor power supply. This means, the +5V pin between the SimMotor and ECU must be connected.

Digital signals

IGNSW

It simulates the ignition switch. It outputs to both SimMotor and ECU. It outputs (low:0V, high:12V) digital signal.

KILLSW

It simulates the kill switch (optional for some engines). It outputs to both SimMotor and ECU. It outputs (low:0V, high:12V) digital signal.

KICKSW

It simulates the kick-stand switch (optional for some engines). It outputs ECU

only. It outputs (low:0V, high:12V) digital signal.

CLTCHSW

It simulates the clutch switch (optional for some engines). It outputs to both SimMotor and ECU. It outputs (low:0V, high:12V) digital signal.

NGEARSW

It simulates the neutral gear switch (optional for some engines). It outputs to both SimMotor and ECU. It outputs (low:0V, high:12V) digital signal.

START

It simulates the start button (common on most motorcycles). It outputs to both SimMotor and ECU. It outputs (low: 0V, high: 12V) digital signal.

Note, to start SimMotor, the correct combination of these digital signal status are required. See Chapter xxxx.

Engine speed override

Engine speed can be overridden through the PC GUI. See next chapter for details.

Shut down SimMotor

Turn on the KILLSW (Kill Switch) will stall the engine. However, the SimMotor still has the power. You will lose the VRS and MAP signal. All other signals are still there.

With KILLSW is ON, you can not re-start the engine. It is like you disabled the fuel pump.

To shut down the power of SimMotor, you can turn off the ignition switch (IGNSW). This will also cut the power to the ECU. So both SimMotor and ECU will be off. It is like you keyed off.

Obviously, you can turn off the DC power supply to remove the power from everything.

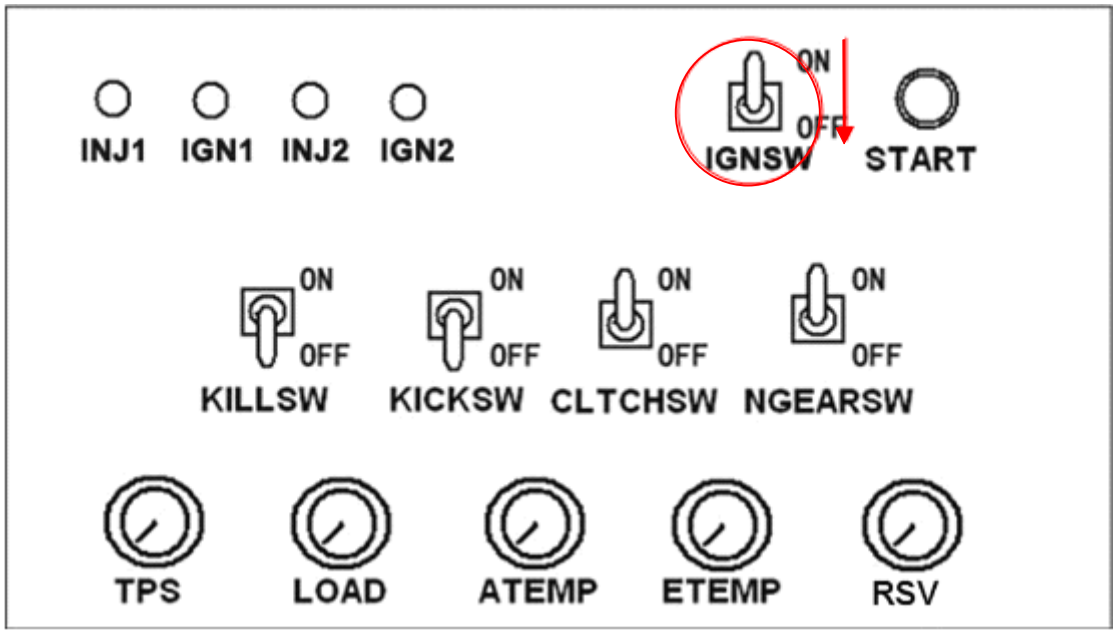

Figure 7: Turn off the SimMotor

PC GUI

SimMotor comes with a personal computer (PC) graphic user interface (GUI). The PC GUI can communicate with the SimMotor through a serial cable. It provide the below features:

- Display the default engine parameters
- Configure the engine parameters;
- Override some engine signals, like engine speed;

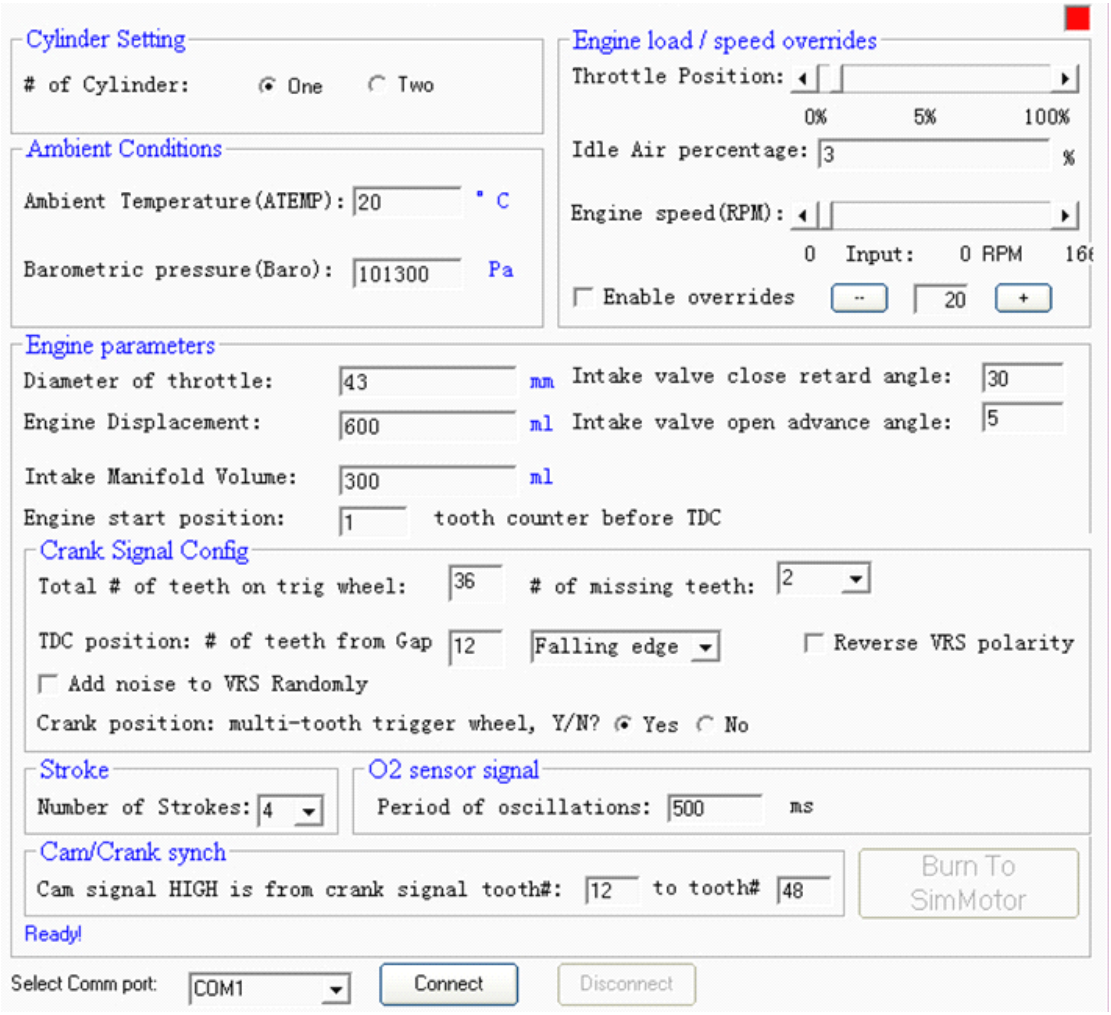

Figure 8: SimMotor GUI

Setup GUI Communication

Follow the below steps to setup the serial communication between the PC GUI and the SimMotor:

1) Power-off the SimMotor if it's on.
2) Physically connect the SimMotor to the PC, via a RS232 cable (if user's PC does not have a RS232 port, a RS232-to-USB adapter can be used through a USB port on the PC).
3) Power up the SimMotor.
4) Start the GUI on the PC
5) Select the correct COM port on the PC, at bottom of GUI (if the PC has one RS232 port, it is usually COM1; if the user uses a RS232-to-USB adapter, it is dependent on which USB port is used, user needs to find out which COM port is the correct one. See MicroSoft Windows' help.)
6) Click the "connect" button on the GUI
7) If the indicator at the upper right corner of GUI turns to green, it means connection is successful. The user will also see "Open the serial port successfully！" message near the bottom of GUI.

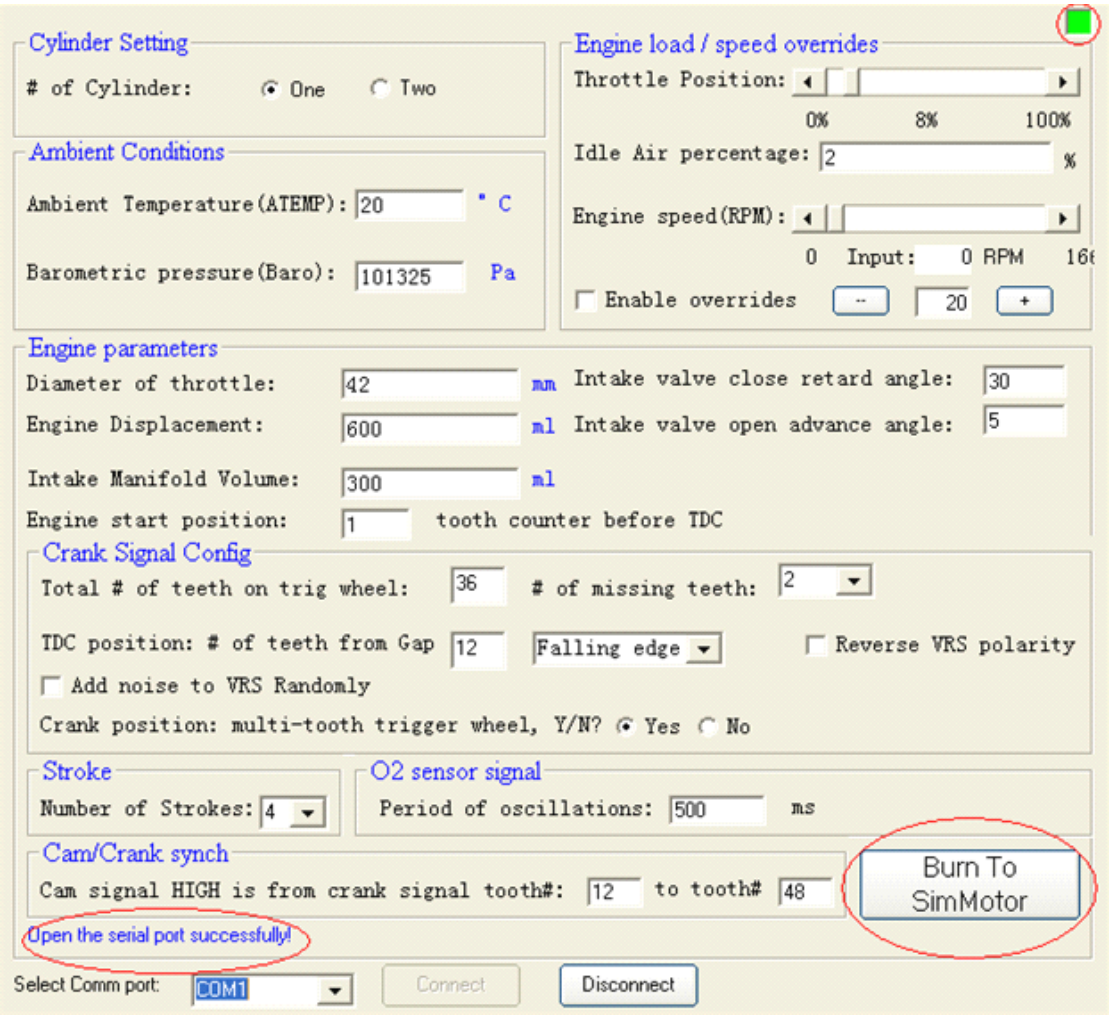

Figure 9: SimMotor GUI connect successful

After the PC GUI is “connected“, it will display all the current engine parameters stored in the SimMotor.

It will also display the current TPS percentage regarding to the TPS knob, and the current engine speed if the SimMotor has already started.

If after the user clicks “connect” button, the GUI shows “Failed to connect to SimMotor” and the indicator at the upper right corner is ‘RED” as in below figure, this means the serial communication setup is not successful.

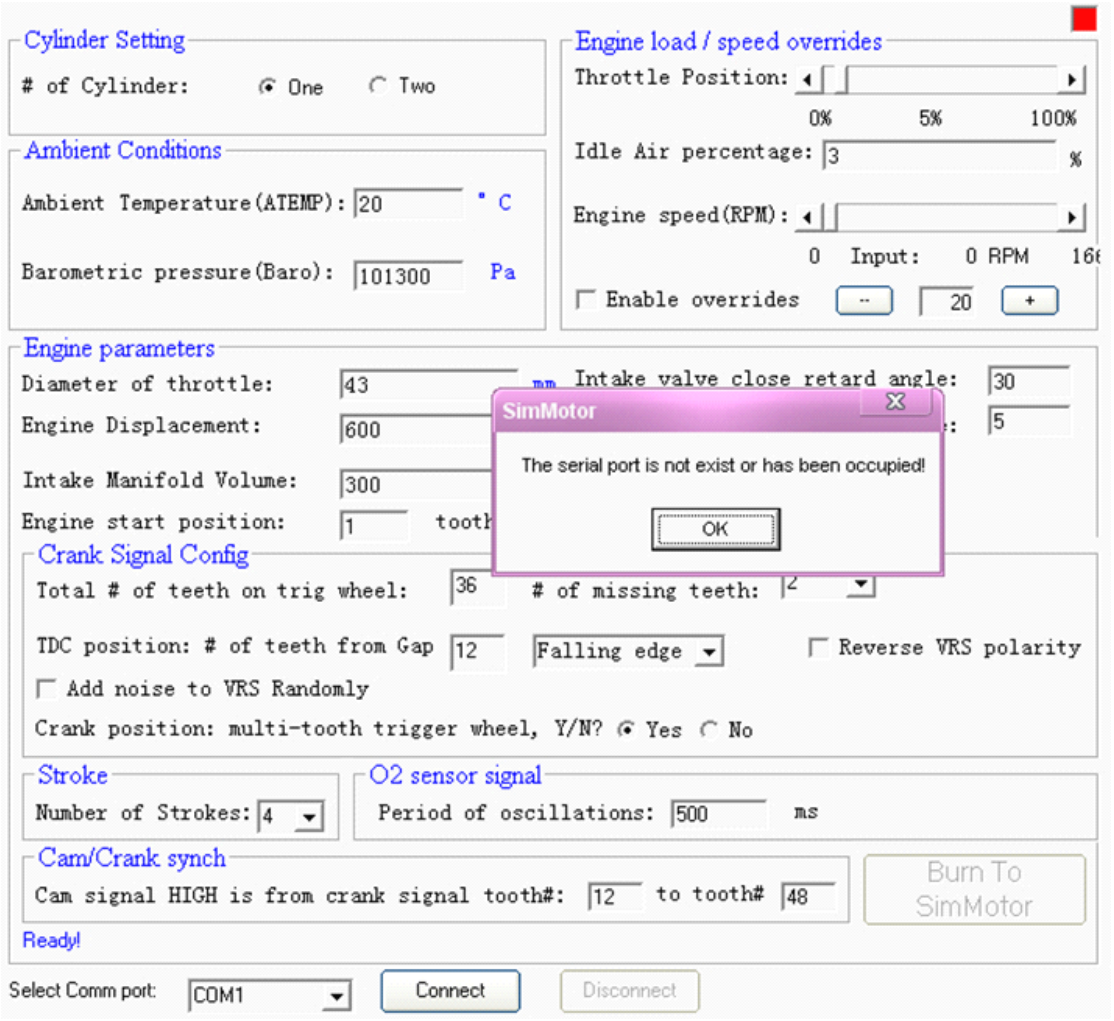

Figure 10: SimMotor GUI connect failed

Usually the No 1 reason for “The serial port is not exist or has been occupied！” is that other Windows applications may be using the COM port. Or the physical serial cable is not connected correctly.

Configure SimMotor via GUI

SimMotor comes with a default setting of engine parameters and these parameters will be displayed on GUI once connected. Mostly likely the user needs to change some of these engine parameters for his applications.

Please compare your ECU software setting of the engine parameters with the current SimMotor parameters. Make sure they are same, before you start your test. If not, please change the SimMotor parameters to match your ECU software settings. Only the parameters shown in the SimMotor GUI need to be matched. Any other engine parameters defined in user's ECU software but not shown in SimMotor GUI are not relevant, and they will not affect the SimMotor functions.

SimMotor GUI descriptions

- Ambient conditions:
  - ambient temperatures (0~70**°C**; default 20**°C**),
  - barometric pressure (700~1020hPa, default 1013 hPa),

  These conditions are used for engine air charge modeling.
- Engine parameters:
  - # of cylinders (1 or 2). Dependent on user's applications, SimMotor supports 1 or 2-cylinder small engines.
  - Throttle diameter. (26~60 millimeter)
  - Displacement of the engine (50~1500 milliliter). Total displacement of the engine.
  - Intake manifold volume (25~3000 milliliter). The volume of intake manifold from throttle plate to intake valve.
  - Intake valve open advance angle (0~50 CrA before TDC).
  - Intake valve close retard angle (0~60 CrA after BDC). Intake valve open angle and close angle are often designed to advance or retard to optimize the volumetric efficiency. These 2 parameters are used to model the air charge and MAP signal.
  - Engine stop position (in # of teeth before TDC, 0~120). This is the position the engine starts to spin from. This is very useful to test the engine start synchronization. User can manually set this position, as # of teeth to TDC.
  - Add random noise to VRS signal. By checking this box, user can add noise to the VRS signal. This is useful to test the ECU's robustness

of VRS signal processing.

- Crank signal configuration (wheel mode):
  - Total # of teeth on the trig wheel (8~60). Small engine trig wheels usually have less than 36 teeth.
  - # of missing teeth (Gap): The # of missing teeth is usually 1 or 2.
  - TDC position: # of teeth to the Gap (0~60): The Gap is usually at a number of teeth in front of the TDC. The user needs to give the value.
  - Falling / Rising edge:TDC is either at the falling edge or rising edge of the tooth provided by the engine design. TDC position is used to model the intake air charge and MAP signal. It is used for synchronization process.
- Engine operating conditions (Load/Speed):
  - Throttle position: this is only for display purpose. It displays the TPS signal from the SimMotor TPS knob, scaled in 0~100%, regarding to 0~5V. Note, the idle air (including the throttle leakage air) should be given in the box below, for example, idle air = 3%. Then the TPS display will be 3%~100%. User can not override TPS from GUI.
  - Engine speed (0~16666rpm): This is for both display and override purposes. First, it displays the engine speed from the SimMotor. Second, user can input a desired engine speed, and by checking the box “enable overrides”, SimMotor will output the user defined engine speed. This is useful if the user wants the SimMotor output a specific engine speed, without having to adjust the sensitive TPS/LOAD knobs.

Note: all above parameters have a physical range. If the user tries to enter a value out of range, the GUI will automatically default to the max/min value.

Save SimMotor parameters

Once the user finishes the SimMotor parameters, he can click “Burn To SimMotor” button near the bottom right corner. All parameters in GUI will be sent to the SimMotor, and saved in the SimMotor’s non-volatile-memory (NVM). Next time the user starts SimMotor, it will use the new parameters.

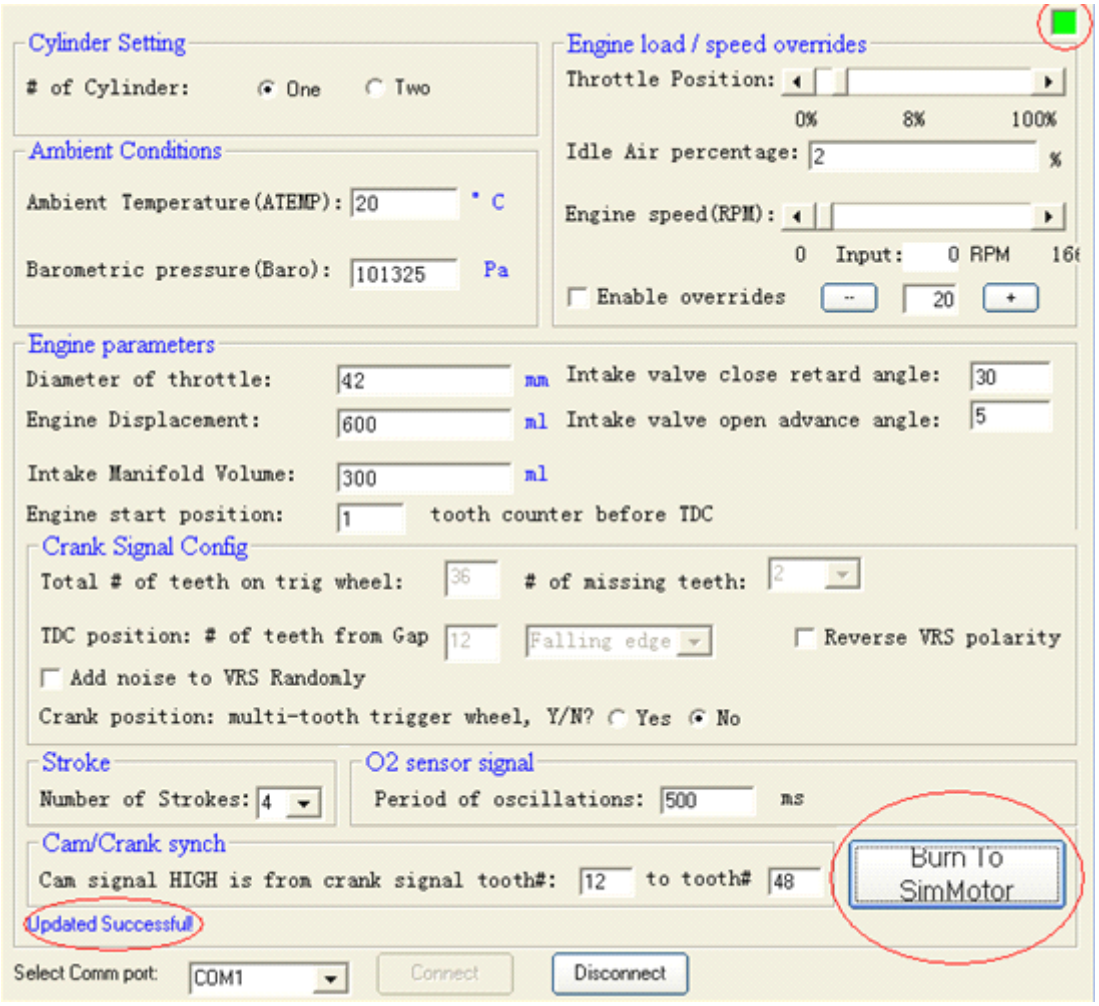

Figure11: SimMotor firmware updated

Disconnect GUI from SimMotor

When the PC GUI is connected with the SimMotor, the user can choose to disconnect them. Click “disconnect” button will turn the upper right corner indictor into “RED”, and also a message “Lost Connection” will shown:

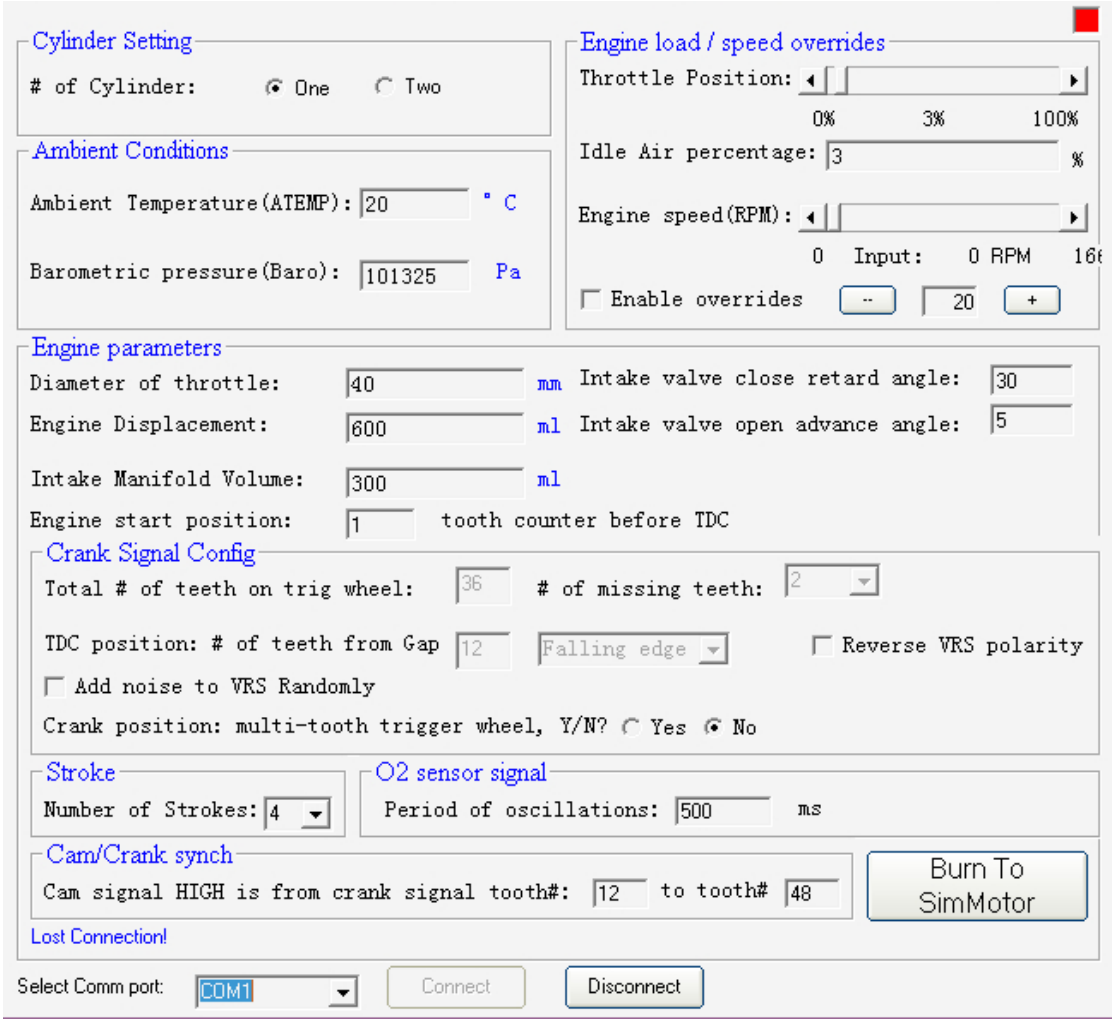

Figure12: SimMotor not connected to PC

