

A New Method to Control Fuel-Saving Eco-Motorbike at the Competition “Honda 2018 Fuel-Saving Eco-Motorbike Driving”

Mien,Trinh Luong¹, Hung,Truong Manh²

^{1,2} *University of Transport and Communications, Hanoi, Vietnam.*

¹ORCID: 0000-0003-4305-7130

Abstract

The article presents a new method to control UTC fuel-saving eco-motorbike, that is combining the 3-time-opening-driving engineering on each lap and controlling forced operating engine in present modes on the race by using the electronic device adjusting input variables of electronic fuel injection. This electronic device is made based on STM32 microcontroller-SIM800 module-GPSL70 module, allows to create signals equivalent to the measured signals of ECU input variables, can adjust these values in local or remote through Wi-Fi network on the supervisory control interface on smartphone. The experimental results show that the proposed new solution ensures eco-motorcycle stability, safety, efficient operation engine, reducing 10% fuel, reducing operations for driver.

Keywords: fuel saving, efficiency-fuel driving, eco-driving, eco-engine, electronic fuel injection.

I. INTRODUCTION

Fuel economy is very important not only for users but also for automobile and motorcycle manufacturers due to the exhaustion of traditional fossil energy sources [7]. In order to have fuel-saving solution, automobile and motorbike manufacturers in the world have constantly researched and improved technology and organized contests to seek initiatives to save fuel. Honda manufacturer has organized the contest "Fuel-efficient eco-driving" in Vietnam and ASEAN region every year. University of Transport and Communications (UTC) participated actively in this competition and won 02 first prizes in Vietnam in 2014, 2015 with effective technical improvement to UTC eco-motorbike.

Articles in the world and Vietnam [2-12] on technology for motorbike operation and fuel economy showed that in addition to the driver's experience, the optimal operation mode of the engine on the racetrack will determine primarily the fuel consumption of the vehicle. Mark Archer and Greg Bell [6] presented PI (Port Injection), SePI (Synerject electronic Port Injection) methods to interfere with the electronic fuel injection system (EFI) applied to 4-period engines to reduce fuel consumption. and reduce emissions. Mohd et al. [8] present simulation results and experiment with PI method for 4-period engine. Hayakawa [9], Ujiie [10], Nakamura [11] Tamaki [12], presented methods of interfering with electronic fuel injection systems to reduce emissions of pollution and reduce fuel. In general, these studies have achieved certain success, but

technology and solutions are either implemented or kept confidential or very expensive.

From the above studies, the UTC authors have come up with a new solution presented in this paper, which is to combine the driving technique of opening the engine three times on each lap and using electronic assistive devices. driver Electronic equipment is researched and manufactured by the author group, allowing direct intervention in electronic fuel injection system to force the operation mode of the engine on the eco-car, in accordance with the driving mode on the road. Racing pre-installed. The structure of this article includes the following sections: part 1 issues, part 2 presents an overview of UTC eco-cars and an improved electronic fuel injection system for Honda 110cc engine on UTC eco vehicles, Part 3 designs the manufacture of electronic devices that directly interfere with the electronic fuel injection system on UTC eco-vehicles, part 4 is the test results, finally the conclusions.

II. UTC ECO-MOTORBIKE

II.1. Characteristics of UTC eco-motorbike

UTC eco-motorbike is a self-made racing motorbike at the laboratory at the University of Transport and Communications, used to participate in the contest "Honda 2018 fuel-saving eco-motorbike driving". UTC eco-motorbike are designed and manufactured to meet the requirements of Honda [3], with the following basic technical features:

- + Dimension LxWxH: 3500 x 2500 x 1800mm
- + Weight: 45kg
- + Average speed: 25km/h
- + Motorbike with 3 wheels 2 compartments (driver, engine)
- + Motorbike uses 4-period Honda wave 110cc engine
- + Motorbike is equipped with two separate brakes controlled independently.
- + Motorbike is equipped with fuel tank and standard carburetor; auxiliary start system, 12V-5A battery.



Fig.1. UTC eco- motorbike

II.2. Improved EFI system for UTC eco-motorbike

The original fuel injection of Honda wave 110cc is a mechanical carburetor [1]. When improving UTC eco-motorbike, the authors modified the original carburetor into an electronic fuel injection system, with the circuit diagram shown in Fig.2.

Electronic fuel injection system (EFI) on eco-motorbike consists of three main groups of equipment: Measurement sensors (input signals to go into ECU); electronic control unit/module ECU/ECM; actuators (output signal from ECU).

The operation principle of the EFI system is as follows: Based on the information measured from the sensors on the engine (such as engine temperature, air temperature, O₂ concentration of exhaust, crankshaft position, crankshaft speed, throttle position, ...) ECU calculates according to the algorithm programmed "hard" on the ECU, to determine the operation mode of the engine and give the control signal (turn on/off pump, time of opening/closing injector, ...).

Basic operation mode of engine and fuel consumption is as follows: start-up and reheat mode - large amount of fuel; acceleration mode - large amount of fuel; Velocity stable running mode - the least amount of fuel; idling mode - the minimum amount of fuel for the engine to run at the smallest spin without dying. These modes require a different amount of fuel injection, programmed "hard" on the ECU and depending on the measurement signal from the sensor sent to the ECU.

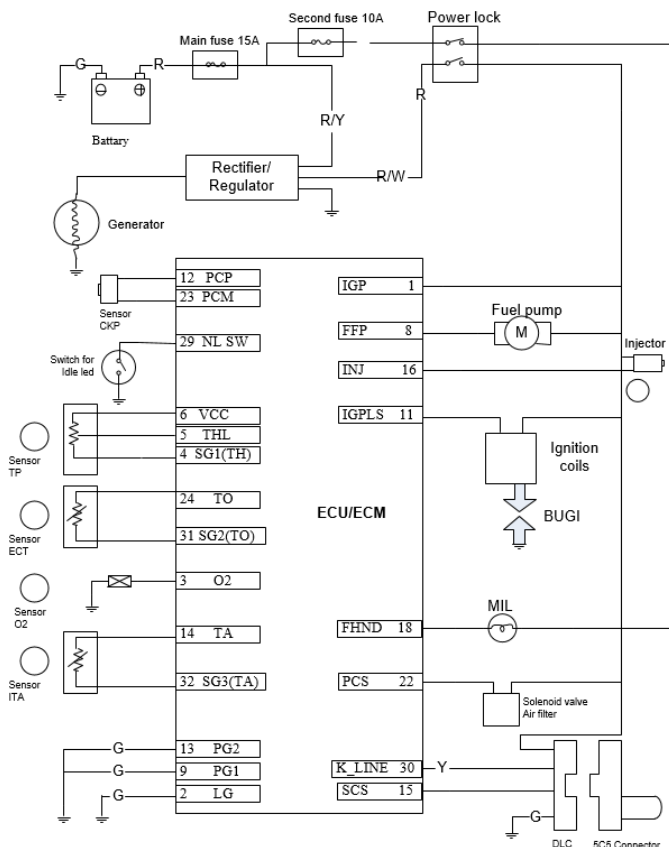


Fig.2. Circuit diagram of basic electronic fuel injection system of Honda wave 110cc engine

II.3. Determine the value of the EFI input variables

When eco-motorbikes run on the racetrack, people often focus onto two modes of operation of the engine: the cool mode and the stable mode. The cool mode is used to start the engine, warm up the engine at the beginning of racetrack. and the stable mode is used as the hot engine, i.e. eco-motorbike on racetrack.

Table 1. Resistance values corresponding to the measured information from the basic parts of EFI

Measured-information at EFI parts	Resistor value at the cool engine (Ω)	Resistor value at the hot engine (Ω)	Note
Spray needle	13,8	13,8	
Crankshaft position sensor	140÷180	140÷180	
Engine temp. sensor	100	2000	25÷90°C
Intake air temperature sensor	1000	2000	25÷90°C

To obtain the values of the EFI input variables corresponding to the engine operating modes, as a basis for forced engine control on the racetrack, authors directly measure the resistance values/voltages corresponds to the measurement information that the sensors collected on the 110cc Honda wave engine of the eco-motorbike. The resistance/voltage values measured on the UTC eco- motorbike engine is shown in Tab.1.

Table 2. Voltage values corresponding to information measured from the basic parts of EFI

Information measured at EFI parts	Voltage (VDC)	Note
Throttle position sensor		
ECU power supply	3 ÷ 5	
Open throttle	3 ÷ 5	
Throttle is fully closed	0,1 ÷ 1	
Engine temperature sensor	1,4 ÷ 2,6	25÷90°C
Intake air temperature sensor	1 ÷ 3	25÷90°C
Battery	12÷14	
MAP sensor		
ECU voltage	3 ÷ 5	
Voltage sent to ECU	0,3 ÷ 0,5	100 mmHg
	0,7 ÷ 0,9	200 mmHg
	1,1 ÷ 1,3	300 mmHg
	1,5 ÷ 1,7	400 mmHg
	1,9 ÷ 2,1	500 mmHg

Table 1 and table 2 are the basis data for designing and manufacturing electronic devices that directly impact on the electronic fuel injection system to replace the real-sensor information, to force the operation modes of the UTC eco-

motorbike's engine, suitable for driving on the racetrack, to save fuel, is detailed in part 4.

III. NEW METHOD FOR FUEL-SAVING ECO-MOTORBIKE DRIVING

III.1. Characteristic of the racing road in 2018

The racing-road in 2018 is shown in Fig.3, consisting of straight, curved and folded sections connecting each other to form a closed racetrack with a circumference of 1200 m/lap. Each participating vehicle must run 8 laps with a total length of racetrack 9600m.

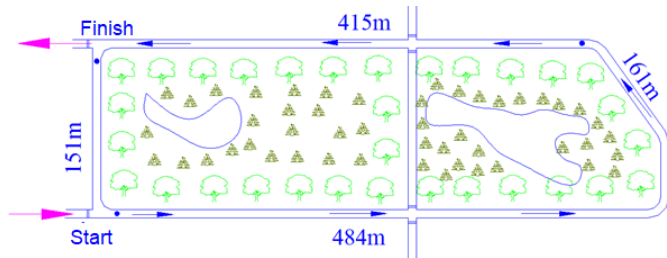


Fig.3. Honda racing-road in 2018

III.2. Proposing new method for the fuel-saving eco-motorbike driving

With a minimum speed of 25 km/h, after the calculation and test-run, the authors propose the operation plan of UTC eco-car as follows: Each lap (1200m) the driver just needs to start engine 3-times. The first-time opened-engine, from the starting position, the eco-motorbike accelerates from 0 (only for the first lap) or 20km/h (for the next lap) to a stable-speed of about 50 km/h then the eco-motorbike runs according to inertia, decreases the speed of about 20 km/h. The second-time opened-engine, the eco-motorbike continuously runs from 20km/h to 50 km/h, then the vehicle follows the inertial and decreases speed of 20km/h. The 3-time opened-engine, the eco-motorbike is on 20km/h only needs to accelerate to about 35 km/h to bring the vehicle back to the starting position of the new racetrack.

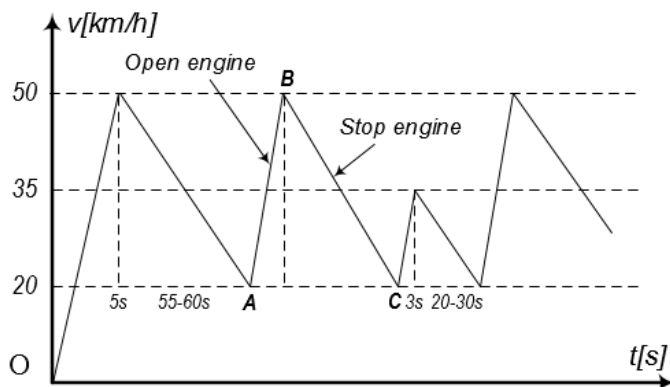


Fig.4. Three-time opened-engine on lap 1200m

From the eco-driving operation graph in Fig.4, it shows that the UTC eco-motorbike's engine does not operate continuously (run only 3 to 5 seconds) so if it is not "force" controlled, the engine will always be in start-up mode and speed up when driver accelerates or hit the pedal, therefore the engine consumes a lot of fuel. To overcome this problem, in order to save fuel consumption, the authors propose a new method, which is to combine the operation of the vehicle with 3-times opened-engine and to control "force" the operation of the engine by using the electronic device. This electronic device directly impacts on the EFI system (called iEFI device), as follows:

+ The iEFI device will give the equivalent electrical signals to the measuring signals of the ECU input variable, so that to feed forced into the ECU, so that the engine operates according to the desired mode (cool mode to start the engine, hot mode when the car runs on the racetrack, combined with the fuel pump control on the nozzle).

+ Before starting the engine, set the resistor values on the iEFI device of the ECU input variables corresponding to the variable values: engine temperature and the intake air temperature in the cooling mode as shown in Table 1.

+ When the eco-motorbike runs on the racetrack in the hot mode, we set the resistance values on the iEFI device of the ECU input variables corresponding to the variable values: engine temperature and the intake air temperature in the hot mode as shown in the Table 1.

IV. MANUFACTURING THE ELECTRONIC DEVICE iEFI TO ADJUST EFI INPUT VARIABLES

IV.1. Requirements of the iEFI device

With the minimum fuel consumption criterion on the racetrack Fig.3, the driver must take advantage of the vehicle's inertia by turning on/off the engine on the racetrack with the least number of times. However, turning on/off the engine, to operate in the desired mode, only succeeds when ECU is properly provided with the values of the ECU input variables. The value of the ECU input variables will usually be transmitted from actual measurement sensors installed on the Honda wave110cc engine on UTC eco-motorbike.

In this article, the authors fabricate the electronic device that directly impacts on EFI system (called iEFI device) to generate electrical signals equivalent to the measured signals of the ECU input variables, in order to force the engine working in the desired mode. In other words, the iEFI electronic device impacts on the EFI system, having the following basic requirements:

+ Generate an electrical signal equivalent to the engine temperature signal, measured by the engine temperature sensor, and then to be forced into the ECU.

+ Generate an electrical signal equivalent to the intake air temperature signal, measured by the intake air temperature sensor, and then to be forced into the ECU.

+ Generate an electrical signal equivalent to the oxygen concentration signal in the exhaust gas, measured by the oxygen concentration sensor, and then to be forced into the ECU.

+ Give an electrical signal to forcedly control the cyclic injector/nozzle with the suitable opening/closing time to reduce fuel consumption.

IV.2. Adding iEFI device to EFI system

UTC eco-motorbike operates in two basic modes: start-up mode (cool engine) and acceleration mode (hot engine). In order to fuel-saving, in this paper, the author has created an additional iEFI electronic device to add in the EFI system. The iEFI device creates the forced input signals for ECU, to force the ECU selecting the pre-set operation mode of engine, calculating the fuel injection time required on the racetrack.

The block diagram of the EFI control system is complemented with the iEFI typical device to force the operation of the 110cc Honda wave engine, as shown in Fig.5.

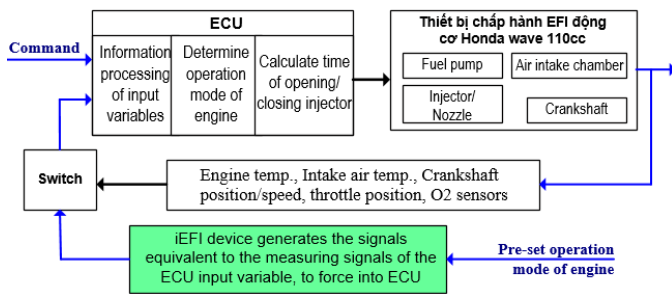


Fig.5. iEFI device added to the EFI system

In this diagram, ECU continuously updates and processes information of input variables, then determines the driving mode on the racetrack, calculates the time of opening/closing the injector to spray fuel into the nozzle. Information of ECU input variables or collected from sensors installed on Honda wave 110cc engine, or taken from iEFI device. The iEFI device generates a forced input signal for the ECU (equivalent to the measurement signal of the ECU input variables in the corresponding mode), to force the ECU to select the operating mode of the desired engine and calculate timing of fuel injection required on the racetrack. The process of opening and closing injectors is interrupted. The time to open the injector depends on the control pulse output from the ECU and PWM block. The pulse width varies depending on the engine's operation mode. To ensure safety in case of equipment malfunction, the driver can switch the switch so that the engine runs in the original mode.

IV.3. The iEFI device structure block diagram

The diagram block of the iEFI device is fabricated and added to the EFI system as shown in Fig.6.

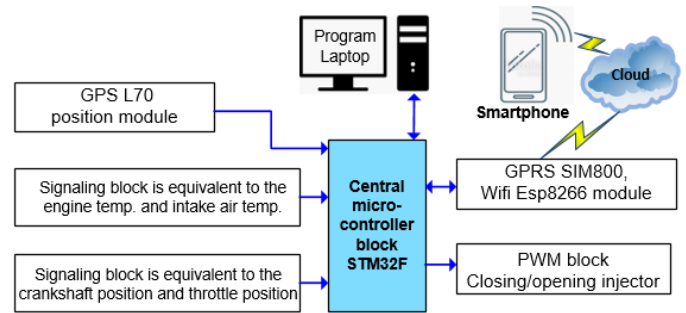


Fig.6. iEFI device structure block diagram

The iEFI device includes the following main function blocks: source block; central microcontroller block using ARM Cortex STM32F 32-bit microcontroller; The electrical signal generation block (resistance value) is equivalent to the engine temperature/intake air temperature, to be forced into the ECU; The electrical signal generation block (resistor value) is equivalent to the crankshaft position/injector position, to be forced into the ECU; The PWM block sends out the suitable signal to force the injector/nozzle cycle with the appropriate opening/closing time to save fuel; GPRS SIM800/Wi-Fi Esp8266 communication block allows setting the resistance values equivalent to the signal of engine temperature/intake air temperature remotely via Wi-Fi/GPRS network on the smartphone, to force the engine to run according to the demand regime; GPS-L70 position module, to update the eco-motorbike's journey on Google Map in real time.

IV.4. Principle circuit diagram of the iEFI device

The principle circuit diagram of the iEFI device is presented in Fig.7.

The mimic electrical signal generation block uses IC MCP42010 of Microchip. This block works to mimic the ECU input sensor signals, acting as the variable resistors.

The resolution of the input variables is as follows:

$$R_{adj} = 10000 / 2^8 = 39.0625 \text{ Ohm}$$

Thus, it is possible to adjust 256 levels of resistance value with each step of 39.0625 Ohm, maximum of 10K Ohm to put on the ECU.

RPOT1 and RPOT2 are resistor outputs, to be included in ECU. MCP42010 communicates with microcontroller STM32 via SPI standard.

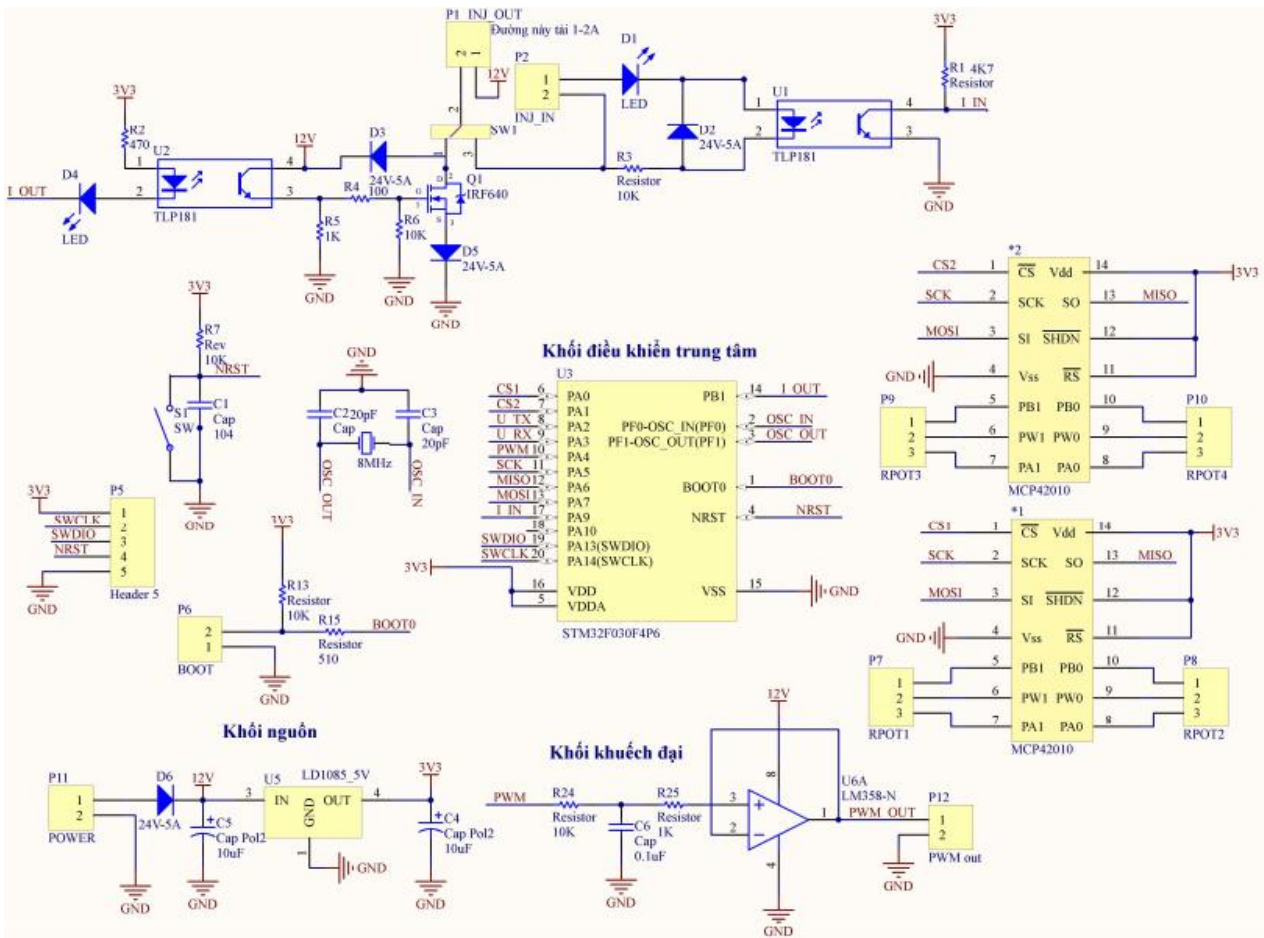


Fig.7. Principle circuit of iEFI device: source block; central microcontroller block; signal generation block; PWM block

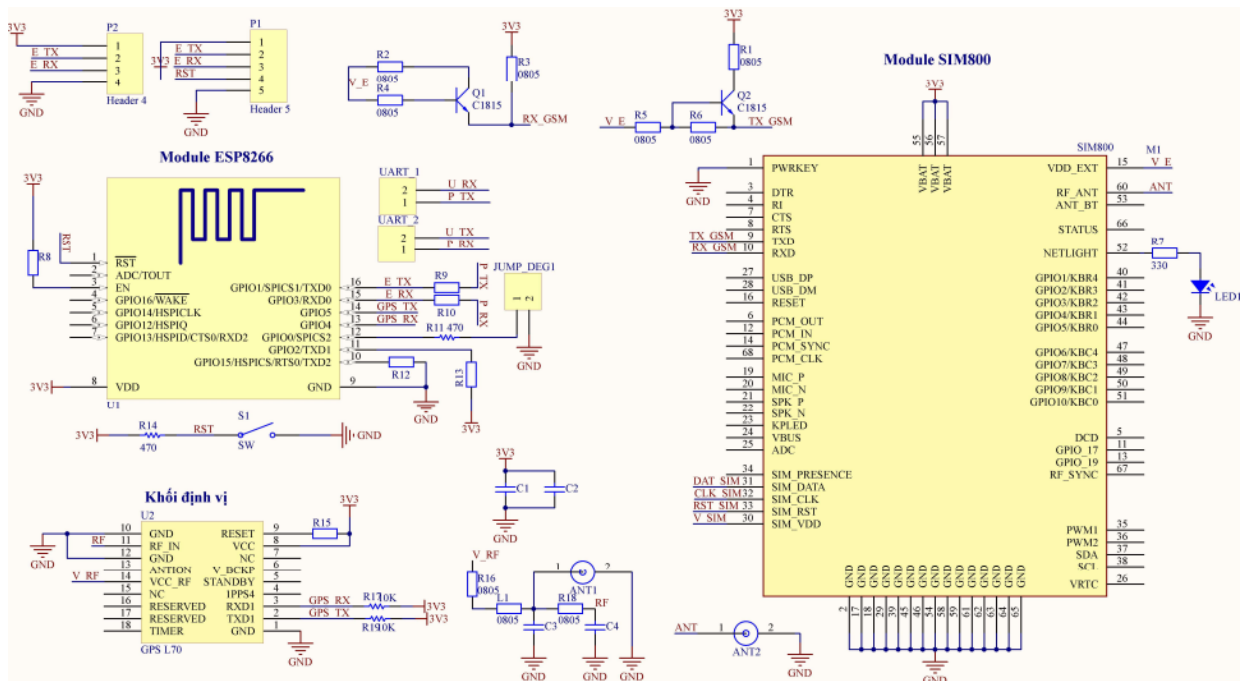


Fig.8. Principle circuit of iEFI device: communication block; position module

The PWM block uses FET IRF640 with 12VDC, 1Mhz. it is necessary to have the signal switch circuit: from 3.3V to 12V. This block controls the injector from the output signal of STM32F to save fuel.

The GPRS SIM800/Wi-Fi Esp8266 communication block handle communication between the STM32F and cloud for monitoring and control purposes.

The GPS-L70 position block is connected to the microcontroller's STM32 UART, with the removable antenna 1575.42Mhz ensuring accurate positioning.

IV.5. Printed circuit diagram of iEFI device

The printed circuit diagram is shown in Fig.9.

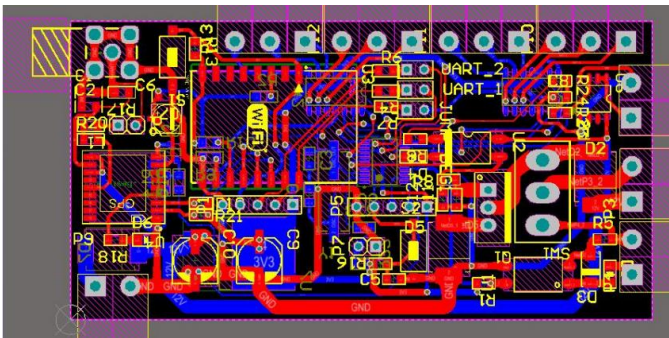


Fig.9. Printed circuit of iEFI device

Hardware product image after assembling the event as Fig.10. The iEFI device connects to phones and/or computers via Wi-Fi. Resistance value (or voltage value), equivalent to the signal measured from sensors mounted on a Honda wave 110cc engine, forcing into ECU, adjusted directly on the smartphone, while displaying eco-motorbike's journey on Google Map.

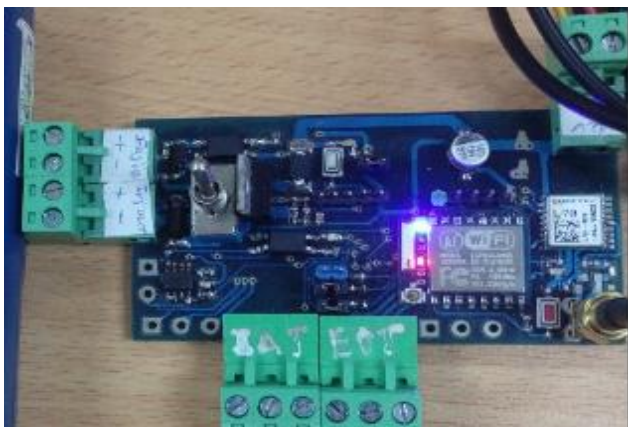


Fig.10. The hardware real-image of the iEFI device

IV.6. Embedded control algorithm for the iEFI device

Assuming the pressure difference before and after the nozzle is stabilized by the pressure stabilizer, then the amount of fuel injection depends only on the opening/closing time of the

nozzle. Control algorithm for programming for STM32F on the device iEFI electronics are shown in Fig.11.

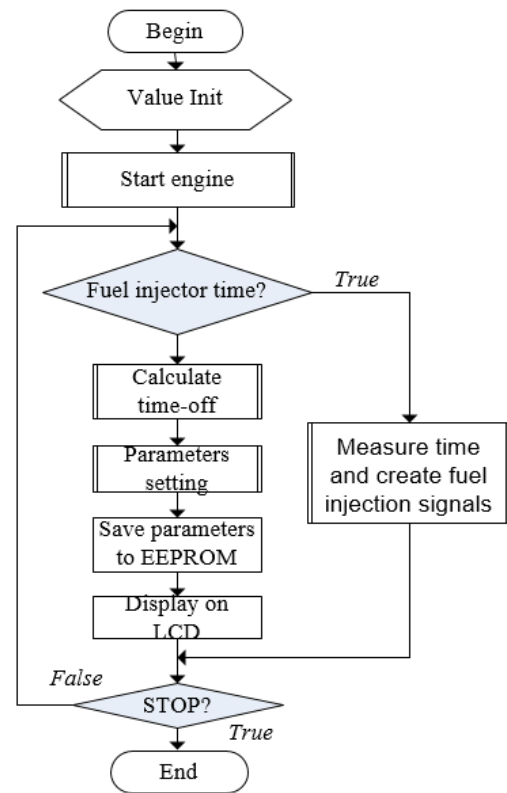


Fig.11. Embedded control algorithm for iEFI device

IV.7. Control and monitoring interface of eco-motorbike

To monitor the journey for eco-motorbike on the racetrack and adjust the signal value (on the iEFI device) for the ECU input variables through the Wi-Fi network from the smartphone, authors proceed to build the web-software based on QT framework and MQTT protocol.

The result of building software to control remote monitoring on the smartphone as shown in Fig.13. System data is installed, uploaded/downloaded and accessed directly on Cloud at Server M14.cloudmqtt.com. Basic features of monitoring control software:

- + Monitoring the operating status of UTC eco-motorbike engine on smartphones/computer;
- + Display the position, journey of UTC eco-motorbike on Google map on smartphones/computer;
- + Remote adjustment via Wi-Fi network on software interface to control signal values (on iEFI device) ECU input variables, including engine temperature, intake air temperature, O2 concentration;
- + Display crankshaft rotation speed;
- + Turn on/off UTC eco-motorbike engine remotely through smartphones/computer using the on/off button on the interface.

V. TESTING iEFI DEVICE ON UTC ECO-MOTORBIKE

V.1. Installing the iEFI device on UTC eco-motorbike

Carry out the installation of iEFI device on UTC eco-motorbike as shown in Fig.12.

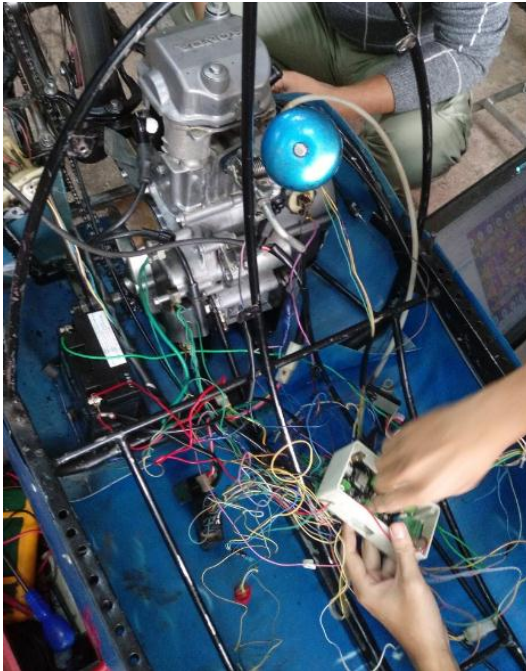


Fig.12. Installation the iEFI device on UTC eco-motorbike

V.2. Tested results of the iEFI devices on eco-motorbike on the racetrack

Table 3. The first time tested results

The IEF's part getting measurement signal	Without iEFI	With iEFI		Note
	Environment temp. 30°C	Cool mode	Hot mode	
Engine temperature sensor (Ω)	1500	150	1500	
Intake air temperature sensor (Ω)	1500	1200	1500	
Driving time (min)	24	24		9.6km
Fuel consumption (cc)	22,9	21,6		5,7%

Running UTC eco-motorbike by opening the engine three times at each lap, when do not and using iEFI device, then use MST-100P standard measurement device, supplied by Honda, to

synthesize the data on each test of the racetrack, the tested results are shown in Table 3, Table 4, Table 5.

Table 4. The second time tested results

The IEF's part getting measurement signal	Without iEFI	With iEFI		Note
	Environment temp. 30°C	Cool mode	Hot mode	
Engine temperature sensor (Ω)	1500	150	1500	
Intake air temperature sensor (Ω)	1500	1500	1500	
Driving time (min)	24	24		9.6km
Fuel consumption (cc)	22,9	20,8		9,2%

Table 5. The third time tested results

The IEF's part getting measurement signal	Without iEFI	With iEFI		Note
	Environment temp. 30°C	Cool mode	Hot mode	
Engine temperature sensor (Ω)	1500	150	1500	
Intake air temperature sensor (Ω)	1500	1500	1500	
Driving time (min)	24	24		9.6km
Fuel consumption (cc)	22,9	20,6		10,0%

Based on the data tables of UTC eco-driving tested results on the racetrack, it shows that when applying the UTC eco-driving method by opening the engine three times on each lap and using iEFI device, the eco-motorbike runs smoothly, save fuel up to 10% (corresponding to 20% fuel injection pulse reduction time).

Controlling eco-motorbike on web-software installed on smartphone via Wi-Fi network, we obtained some results images displaying and adjusting values (on the iEFI device) on the interface software corresponding to the ECU input variables and the journey on the racetrack as shown in Fig.13, Fig.14.

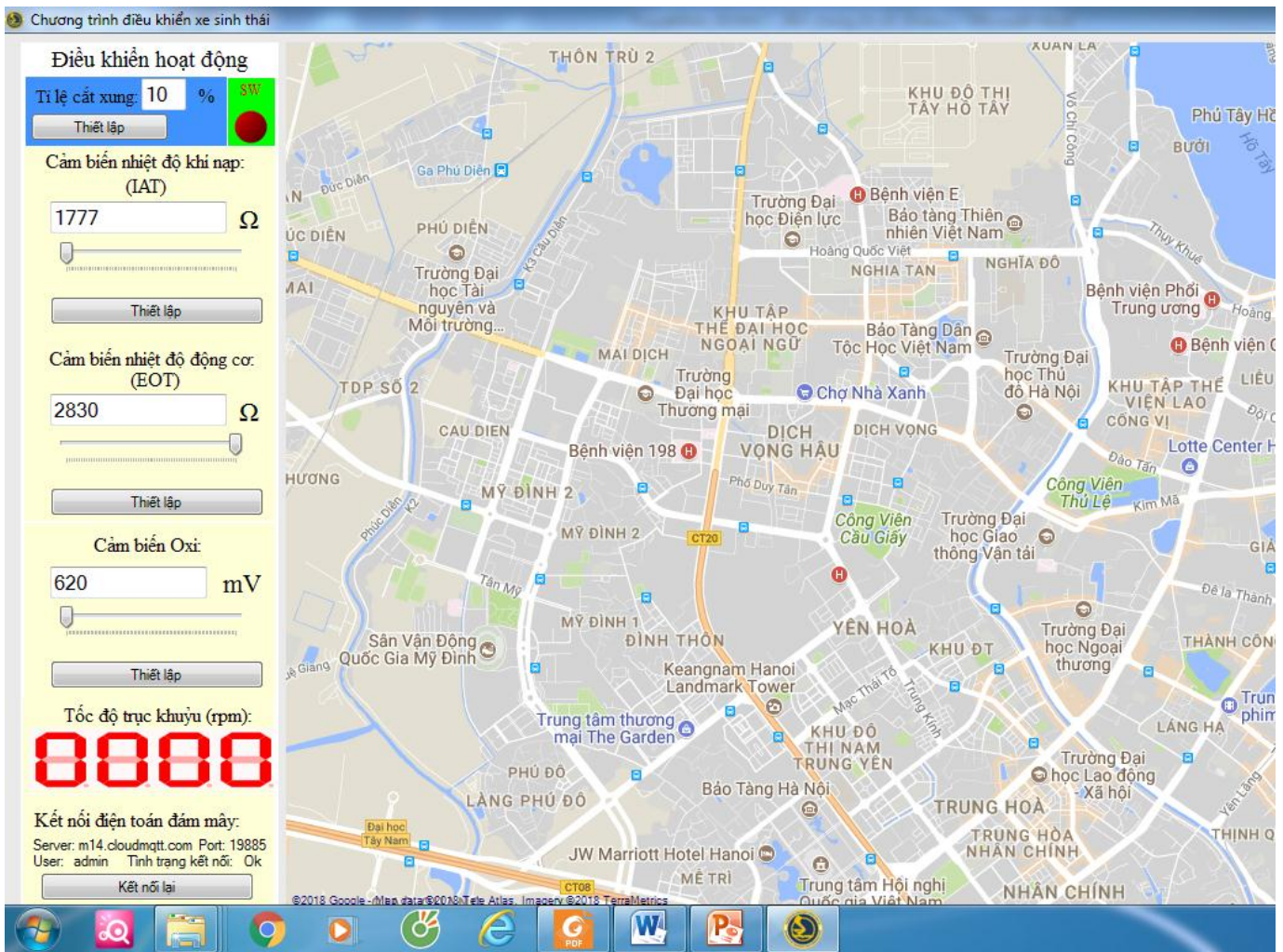


Fig.13. Adjusting the ECU input variables remotely via Wi-Fi network on smartphone

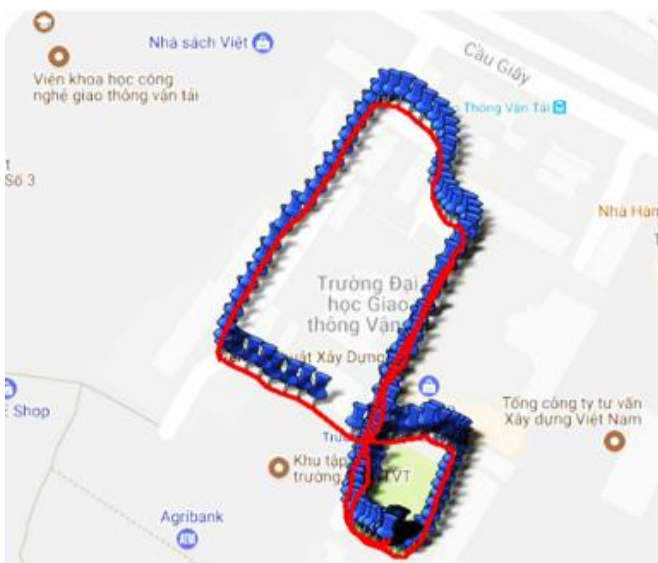


Fig.14. Monitoring the eco-motorbike-journey on smartphone

V.3. Test result comments

From the above test results, we have the following conclusions:

- + The iEFI device allows adjustment of signal values of ECU input variables, locally or remotely on smartphone.
- + Using the iEFI device on UTC eco-motorbike, in the cases where the vehicle has no load/with load; or starting, or accelerating, the eco-motorbike run stably, ensure safety, ECU has no errors, engine's parameters meet Honda standards.
- + New method to control eco-motorbike in the competition: the driver opens the engine three times at each lap and use the iEFI device to generate signals equivalent to the signals of the ECU input variables to "force" the engine operating in pre-set mode on the racetrack, allowing fuel-saving of up to 10% (compared to the case of do not using iEFI device).
- + Update the position and travel journey of UTC eco-motorbike on Google Map on the smartphone in real time.
- + Control on/off the engine, adjust/set the engine operation mode and monitor some of the motor's operating parameters remotely on smartphone.

VI. CONCLUSION

The article presents a new method to control the UTC eco-motorbike on the racetrack in order to save fuel, which is driving the eco-motorbike by opening the engine three times in each lap combined using iEFI device to generate electrical signals, equivalent to the engine temperature signal, intake air temperature signal, exhaust's oxygen concentration signal of the ECU input variables. Based on these mimic signals, the engine is forced to operate in the pre-set mode on the racetrack (the engine does not operate following the "hard" programme about fuel injection level of Honda EFI system). The iEFI device is built using STM32F microcontroller, SIM800/Wi-Fi Esp8266 module, GPS L70 position module, which allows to adjust the value of ECU input variables, locally or remotely on the smartphone's screen.

The new eco-driving method by opening the engine three times on each lap using iEFI device to ensure stably and safely, meeting Honda's technical requirements and 10% reduction in fuel. UTC eco-motorbike journey is updated on Google Map on smartphone in real-time.

The success of this research allows to continue the research on improving quality of the control system of electronic fuel injection system, electronic ignition system for 2-period/4-period gasoline engines to reduce fuel consumption.

REFERENCES

- [1] Truong Manh Hung (2018), Research, design, manufacture equipment to adjust input parameters of electronic fuel injection system for vehicle participating in the contest "Fuel-saving eco-driving environment protection" organized by Honda Vietnam, University of transport and communications.
- [2] Pham Minh Tuan (2003), Internal combustion engine, Science and Technology Publisher.
- [3] Honda (2018), Guide to fuel-saving eco-motorbike driving in Vietnam, Honda Vietnam.
- [4] Roland S.Burns (2001), Advanced Control Engineering, Department of Mechanical and Marine Engineering University of Plymouth, UK.
- [5] Allan W.M. Bonnick (2001), Automotive Computer Controlled Systems, Butterworth-Heinemann, UK.
- [6] Mark Archer, Greg Bell (2001), Advanced Electronic Fuel Injection Systems – An Emissions Solution for both 2- and 4-stroke Small Vehicle Engines, SIAT26.doc – MDA/GBB.
- [7] Jiun-Horng Tsai, et al. (2018), Fuel Economy and Volatile Organic Compound Exhaust Emission for Motorcycles with Various Running Mileages, Aerosol and Air Quality Research, 18, 2018.
- [8] Mohd Faisal Hushim and el. (2014), Port-Fuel Injection System for Small 4-Stroke Single Cylinder Engine: An Experimental Framework, Automotive Research Group.
- [9] Hayakawa, K., et al. (2004), 125cc Small Engine Fuel Injection System with Low Emissions Solutions. SAE Technical Paper, No.2004-32
- [10] Ujiie, T., et al. (2005). Development of Fuel Injector and Fuel Pump for a Fuel Injection System to Use in Small Motorcycles. SAE Technical Paper, No.2005-01-0047.
- [11] Nakamura, M., et al. (2003). Fuel Injection System for Small Motorcycles. SAE Technical Paper, No.2003-32-0084.
- [12] Tamaki, K., et al. (2004). Control Device of Electronically Controlled Fuel Injection System of Air-cooled Engines for Small Motorcycles. SAE Technical Paper, No.2004-01-0901.