Course Name: Engine System and Performance
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Lec 13: Introduction to Electronic Control Unit (ECU) and its functions

I welcome you all to the session of engine system and performance. And our today's discussion is on the modern engine management system. As such, in the last few classes, we have discussed about engine system, several components of engine system. Then we have talked about several engine valves, engine other accessories, then thermal management, other heat transfer from engine block, which is broadly energy management in engines.

So today we shall discuss about a topic which is very important topic for this particular course that is engine hardware that is engine management system that in earlier engines everything used to be controlled by mechanical systems say for example if we need to supply fuel and also air because without air fuel mixture we cannot have combustion and if we need to ensure efficient combustion stoichiometric air fuel ratio should be supplied. Now, question is depending on the load demanded by the engine either we need to go for fuel enrichment. So, if we need to supply fuel enrichment, supplying fuel in enrichment or adequate fuel or even reach fuel.

In the air fuel mixture using any mechanical system is not so fast, will not be reliable. Even for any mechanical component, there will be some time lag or delay. So, to this end electronic control unit which is also known as engine management system provides a more flexibility. So today we shall discuss about what is an electronic control unit and then if time permits we shall go for its description illustrating unit or ECU and we will see then how does that particular unit, control several inputs essentially to monitor air fuel mixture and also spark advancement and also temperature of air which would be supplied into the engine. So, to start with, let us discuss about what is electronic control unit.

Electronic control unit, in short, is known as ECU. So, we shall be referring to or using this word frequently. This is also known as the engine management system. From the

name 'engine management system,' you can understand that this system is solely responsible for managing the entire engine operation electronically.

As I said, if we need to control everything using any mechanical arrangement or mechanical components, there will be a time delay, and accounting for that delay, precise and very fast adjustment of anything—be it control of air temperature, very fast supply of fuel, or even a relatively higher rate of fuel supply to the engine—all these things may not be possible instantly. To this end, the electronic control unit or engine management system provides a greater degree of flexibility. So, now, what is the electronic control unit?

This is ECU or engine management system—its function, or rather its primary objective, is to coordinate several subsystems. What are those subsystems? So, basically, the engine management system controls or coordinates several subsystems. Those subsystems are innovatively attached to the engine for better performance, smooth operation, and ensuring maximum efficiency.

The primary objective of the engine management system or ECU is to control or coordinate several other subsystems to ensure smooth and safe operation of the engine, provide maximum or better efficiency, and ensure reduced or controlled emissions. So, these are the objectives. This is the primary objective. Now, the question is: the primary objective is to coordinate several subsystems. Basically, adjust the torque generated by the engine.

So, this is the very first requirement because essentially, we need power output. So, even if we need to maximize the power output at the cost of compromising other things, like emissions from the engine or fuel intake. So, compromising all these things, if the ECU is solely designed to adjust the torque generated by the engine, then again, it will not be a wise or meaningful design of the system. That means ensuring the maximum amount of torque we expect from the engine should be the primary objective, while also ensuring many other functionalities are achieved simultaneously.

What are those? So, those are basically some other functionalities, such as controlling emissions in line with standards certified by the environmental agencies or board. That means we have some restrictions to maintain reduced or permissible emission limits, so that part should also be accounted for.

When we are trying to design or we are designing an ECU. So, an ECU or engine management system is designed not only to provide maximum power output by adjusting the torque that would be developed by the engine, but also to ensure that fuel emissions should be in line with the standards set by environmental agencies or boards. Second, number two is certainly, to control fuel consumption, as I told you, that if we are really targeting maximum power output and for that if we need to compromise with fuel consumption, that would yield the design of the engine management system or ECU. So, that is important. Number three is certainly the primary objective, which is power output (optimum). Number four is to ensure safety and comfort.

So, basically, safety is very important for any type of engine, be it a stationary engine or an automobile engine. Now, for automobile engines, we also need to ensure that comfort should be there. That means, if the engine is operated by mechanically moving or mechanically driven components, which was the case for earlier engines, the operation would be jerky; the operation wouldn't be smooth. In that case, we have to compromise with the comfort level. So, this is also very important. Safety is equally applicable for both stationary engines and automobile engines, but comfort is really important for automobile engines. So, these are basically simultaneous requirements from the electronically controlled unit or engine management system. So, this is what we have written.

Now, the question is, is this electronically or electronic control unit? The electronic control unit is, a very reliable piece of equipment, I should say, or system—very reliable because if we know some requirements from several components of the engine block, say, for example, if we demand more load from the engine, the engine must know that to meet the demand, we have to supply an adequate amount of air mixed with fuel. So, that requirement, if it is instantaneous, the engine should fulfill the need of that instantaneous requirement of an adequate or extra amount of air mixed with fuel, and that should be, very fast and also smooth.

The ECU (Electronic Control Unit) is a very reliable system that can serve that purpose. This is not really possible using any other mechanically driven or moving components. So, let me write here to help you understand better that the ECU is an extremely reliable piece of hardware, which is capable of receiving and simultaneously processing information very fast or promptly.

So, that is what I was discussing. That means if any demand arises instantly, the engine management system or electronic control unit should be able to collect the need and also process it very fast or promptly. So, that is why this is a very or extremely reliable piece of hardware.

Now, if it is so, we also need to know about its structure. But we shall be discussing this unit, the electronic control unit or engine management system, illustrating a schematic depiction of this particular unit. Before doing so, let me briefly mention here that the heart of the ECU, is the microprocessor.

Inputs received from the engine will be interpreted, and output commands will be issued promptly. If the requirement of air to be drawn into the engine is more than what the engine is supplying at any instant of time, then input should be given to the ECU. Upon receiving that input, the ECU should transform or process that particular input and give an output signal to the sensor placed at the intake manifold to open or widely open the throttle valve.

That way, the engine can control the requirement of air to be drawn into the engine cylinder. Similarly, I can give you another example. For example, if it is an SI engine, nowadays all SI engines have separate fuel injectors, but earlier engines, as we discussed, carburetors used to play an important role. So, even if we consider an SI engine with a carburetor, and if the requirement of charge or air-fuel mixture at any instant of engine operation is more than what the engine is getting, then that input signal will go to the ECU. The ECU will process that signal and immediately supply output commands to the sensor placed in the carburetor to supply more air-fuel mixture by adjusting the throttle valve or other units of the carburetor.

Here's another example: if it is a CI engine, and instead of supplying more air, we need to enrich the fuel while keeping the amount of air or mass flow rate of air intact, then, if we need to supply more fuel, the input from the sensor in the fuel injector will go to the ECU. If the requirement is higher, the speed control sensor will detect it. The speed control sensor will sense that, yes, the engine is now experiencing a higher load. That input will go to the ECU, and the ECU will immediately give an adequate output to the fuel injector or fuel nozzle to supply more fuel. That way, everything is controlled precisely, nicely, and promptly, which is not possible using any mechanical or mechanically moving component or system.

So, this is the issue. Now, basically, this microprocessor will receive input, immediately interpret that input, and give output commands to adjust several other auxiliary systems. So the engine will meet the need or requirement. at that particular point in time of its operation. So that means we can understand that the microprocessor, which is the heart of an ECU or engine management system, will receive input, transform or interpret that signal, process it, and immediately give some output commands.

So that processing the input signal, transforming that input signal into output commands, and certainly sending those output commands to another subunit such as the engine. This entire process can be subdivided into a few categories. The process and output functions of the ECU (electronic control unit) can be divided into the following areas:

So, number one is, fuel injection control. That means the input signal might come from several areas or blocks, several units of the engine. Receiving input signals from several units, the engine management system, which is centralized, is responsible for receiving all inputs from the engine and ensuring smooth and safe operation of the engine. So, the electronic control unit or engine management system might receive input signals from fuel injection to control fuel injection.

That means, the example that I gave you—if we need to go for fuel enrichment, certainly we need to control fuel injection. That is, by controlling the gap or by controlling the opening area of the fuel nozzle, we can control the fuel that should be supplied into the engine. So, fuel injection control. Number two is spark advancement control. So, you can understand spark advancement control is certainly, pertinent to SI engines because we need to go for spark retardation or spark advancement.

Probably, you have studied in your undergraduate internal combustion engine course that we need to go for spark retardation and spark advancement to control the combustion rate. So, this is also possible—rather, all these flexibilities should be, integrated, or the engine management system should have all these flexibilities. Then, number three is engine speed control.

I also gave this example: if an automobile engine or if a stationary engine experiences high load, then speed will reduce. If speed reduces, then ultimately, volumetric efficiency is a function of RPM. So, volumetric efficiency will reduce, and then combustion may not be adequate. Then, eventually, to, meet that high load—or when the engine experiences high load—a situation might arise where the engine will stop. So, that means

some control would also be there inside the ECU, so that when engine speed reduces due to high load, some input signal will be received by the ECU.

Then, receiving that input signal, the ECU will process it and again send some output commands to other auxiliary systems like air-fuel mixture, fuel injector, or carburetor, or to supply more air so that there would be more combustion and then more power output will be there, so that the speed would be restored or remain the same. Then four is emission control. Which is also an important part for the engine, and then five is, failure management. Failure management—so this failure management we shall be discussing this part a little later today. So, all these are basically the processes, that means the ECU or engine management system should have some arrangement or some provision to receive signals from all these five areas. The ECU would be able to process those signals and send some output commands immediately, ensuring smooth and safe operation of the engine.

So, if you go to the next slide, now what are the functions performed by the ECU? That means if we need to go for fuel injection control, if we need to go for spark advancement control, if we need to go for engine speed control, if we need to go for emission control, and finally failure management, it might so happen that at the same time we need to go for fuel injection control as well as emission control. So, to accommodate all these, the functions performed by an ECU should be well-defined and well-guided.

Number 1 is the generation of an electrical signal, that is to be sent to the injectors, or rather, fuel injectors. Number two, generation of electric ignition signal. Number 3 is spark advancement controlling signal. Number 4 is basic pulse width calculation and refinement. Basic pulse width calculation: what is the role of pulse width that we will discuss in this module. Number 5 is closed-loop control. Closed-loop control of the engine based on feedback from EGO, which is the exhaust gas sensor.

Why is it needed? As I told you, the electronic control unit or engine management system should be able to or will have the capability of controlling emissions. So that means one sensor should be there in the exhaust manifold, sensing or receiving some input signal from the exhaust manifold. There will be a closed-loop control unit to maintain the emission level. Like temperature of exhaust gases, NOx emissions, and many other things to maintain or comply with the requirements of environmental standards.

Number six is enrichment of the mixture. Certainly, failure of the air mixture in case of strong positive throttle variations which is needed—perhaps you have studied this during

cold start-off and engine warm-up. During cold start-off and engine warm-up, we need to go for a greater degree of throttle valve control. During that time, the enrichment of the fuel-air mixture should be controlled by the electronic control unit or engine management system.

And then, number seven is to trigger the exhaust gas recirculation system. This is also known as EGR, the exhaust gas recirculation system. Why is it needed? Perhaps again, you have studied in your undergraduate internal combustion engine course that we need to recycle back exhaust gas in a turbocharging unit.

Recycling the exhaust gases, if we can run a small turbine, the work output from the turbine would be able to run a small compressor, and by running that compressor, we can increase the pressure of the intake air. So, the entire unit is known as turbocharging.

The question is, what would be the temperature, pressure of the exhaust gas that comes out from the combustion chamber. Also, should be monitored or triggered. So, engine management system should be capable of triggering this part as well.

So now question is, these are the functionalities of engine management system. So, are these only functionalities which an ECU or engine management system, will be having or if I can pose the question that only these are the functionalities we should expect from an ECU or engine management system. No, beyond this, another important functionality or function an ECU or engine management system should have, what is this?

See, as of now we have discussed that engine management systems will receive signals. Signals from where? Signals from different sensors. Sensor will be there in the intake manifold to sense air temperature or intake air temperature. Sensor will be there in the exhaust manifold to sense temperature and pressure of the exhaust gases.

Sensor will be there to sense even engine speed. Sensor will be there in the fuel injector to know whether we need to go for controlling the opening area of the nozzle so as to supply more amount of fuel or not. Sensor will be there in the water jacket, cooling water jacket, so as to sense the temperature of the coolant. So, all these sensors are very important for the efficient operation of ECU or engine management system.

Now sensors might malfunction. So, keeping the provision that sensors malfunction, will not work or at a given point of time because any system cannot run for a longer duration. And if any sensors start malfunctioning during engine operation, then what would be the case? What would be the situation?

Now, I can give an example. Say if engine needs to supply or needs to give more load, more power output, and to obtain more power output than its design capacity, we need to supply more amount of air or more amount of fuel. Now the question is, if the sensor which will give some input signal to engine management system, towards the requirement of more amount of fuel to be supplied by the nozzle, and if that sensor is not capable of supplying that input signal, then what will happen?

So that means, considering the possibilities of failure of sensors, adequate measures should be taken by the ECU, which is very important to know. At this point in time, let us discuss that part. So, that means to take into account the possibilities of sensor failure, some preventive measures should be taken, and we shall be discussing all those preventive measures now. Those preventive measures should be taken by the ECU to have all these preventive measures to ensure all these preventive measures by an ECU by an engine management system. The engine management system will again have some other, subsystems or subcomponents.

So, if we write now that additional functions to be achieved by ECU. So, these additional functions are to be achieved by an ECU only. To take into account the possibilities of sensor failure.

Thus, one is deactivation of the closed-loop control in case of an absent or incorrect signal. EGO, EGO is the exhaust gas sensor. So, if EGO is the sensor in the exhaust manifold, if that sensor is giving an input signal or if the sensor is absent—meaning it is not virtually present—maybe the sensor is there but not working. So, in this case, deactivation of the closed-loop control should be required from the ECU.

Number two is deactivation of the EGR, which is the exhaust gas recirculation system. In case of EGR failure. We have discussed the need for recirculation of exhaust gas. Number three is triggering the fan in case of a signal failure from the coolant temperature sensor.

As I mentioned, the cooling water jacket will be equipped with one sensor, and that sensor will be solely responsible for providing input signals to the ECU about the coolant temperature—whether the coolant is receiving an adequate amount of heat from the engine block. If that sensor malfunctions or provides incorrect input signals, the ECU will trigger the fan to operate immediately to reduce the temperature of the engine block and cylinder. Then, if we go to the next slide, number four is stopping the engine by

shutting down the fuel pump in case of failure. of any of its critical sensors. It means the ECU's engine management system.

So, if any critical sensor of engine management system fails, then ECUs should have adequate arrangement so as to give some signal to the engine to stop the fuel pump and eventually engine will stop and number five which is very important that is replacement of default value of value of faulty signals generated from temperature sensor basically which are needed for coolant and ambient air. If a sensor fails, the engine control system is still able to maintain engine operation, engine control system or engine management system.

So, this is important by how it does we shall be discussing later when we will be discussing any particular type of control system. So, this is very important. The replacement of default value of faulty signals generated from any sensor, from temperature sensor may be coolant and ambient air. If a sensor fails, then engine management system is still able to maintain engine operation.

So, by how it would be possible by the ECU or by engine management system we will discuss this part again in detail now question is all this thing that means a control system essentially engine management system is engine control system so that system is having a few, will receive a few signals, receiving signals that microprocessor will process all those signals and then transform into some output signals So basically this control unit, so engine management system or engine control system. So, we have seen the, requirement or objective or functionalities of an engine management system and considering the possible failure of sensors, there will be again certain preventive measures and the preventive measures should be taken by the control system. Therefore, a control system or engine control system should have a few tasks.

So, if we now write, a control system should, number one, perform its function properly. Number two, it should respond quickly. Number three, it should be stable. And number four, it should respond only to valid inputs. What does it mean? Noise immunity should be present. So, if the engine management system receives noise, it should be able to filter that noise. So, it will respond only to valid inputs.

So, to summarize today's discussion, we have discussed an electronic control unit, which is also known as an engine management system. Then, we briefly discussed the functionalities an engine management system should have.

To have all these functionalities, we will discuss the requirements, circuits, and other details in subsequent classes. Since the engine management system, also known as the electronic control unit or engine control system, it should have provisions for controlling several aspects like speed control, spark advancement control, emission control, exhaust gas recirculation control, and fuel enrichment control. To have all these controls, it should be very precise and reliable as well. Thereafter, we discussed that essentially, the engine management system or electronic control unit will receive a few signals and from sensors. Now, sensors might, start malfunctioning. So, in such a case, again, some preventive, measures should be taken by the electronic control unit or engine management system to ensure smooth and safe operation of the engine. So, with this, I stop here today, and in our next class, we shall discuss this engine management system, illustrating a schematic depiction of several units and blocks.

Thank you very much.