**Course Name: Engine System and Performance**
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## Lec 23: Functional layout of Electronic Control Unit (ECU)

I welcome you all to the session on engine system and performance. Today, we shall discuss the functional layout of the ECU, that is, the electronic control unit. This unit, precisely the control unit, is also known as the engine management system. We have studied this particular unit in greater detail. We have seen that this control unit houses sensors, actuators, and most importantly, the microprocessor, which is the central part of this unit. For the precise operation of sensors, there are transistors, diodes, and many other semiconductor devices.

This unit houses all these electronic gadgets and electrical components, essentially for its smooth functioning as well as to provide the best control to the engine. We have also studied two different types of control. Now, we all have seen that digital technology provides an extensive array of options for the automotive electronic system. As such, this digital technology provides several options for both the closed-loop and open-loop control systems that we have discussed in one of the previous classes on the automotive control system.

So, the electronic control unit essentially receives signals from the sensors. Upon receiving signals from the sensor or sensors, this particular unit processes data and generates control signals or output signals for the controllers, or more precisely, for the actuators. This unit is responsible for processing the data, and upon processing the data, it is also able to generate control signals for the actuators. So, let us briefly recapitulate the open-loop and closed-loop control systems, the block diagram, and then we shall discuss the functional layout of this particular unit, the ECU. So, if we try to redraw the open-loop control system or unit, then we know that we have inputs, and this is the controller. Essentially, the electronic control unit, then these controllers provide outputs to the plant.

Plant is basically the system that is being controlled and then we have some output from the plant. So, this is the layout of the, I should say this is system output. If it is a closed loop control system, we have studied that there will be a feedback loop So, we will be having controller or controllers, then these are the inputs.

And then again controllers or controller will provide output or data to the plant for the desired output, but there will be a feedback loop. This feedback loop is given or these are the sensors and essentially this is plus minus something. So that means you can see these are the measured output that we have discussed. So essentially this feedback loop is there and this loop allows for changing that, this particular loop allows to adjust for changing conditions.

I should say if the system output is getting affected or if because of some environmental operating conditions. So, this should be sensed by the sensors or a few sensors and then output from these sensors will be accordingly adjusted to gives desired input to the controller so as to correct that as a changed condition. So, that is the need of this feedback loop and this is very popular.

So, what you can see this is also the ECU, the electronic control unit. So today, we shall discuss the components of the ECU and their functionalities. As I told you, the electronic control unit, or engine management system, or ECU, will receive signals from the sensors. After receiving signals, the ECU will be able to process the data and then generate control signals for the actuators. Because essentially, the actuator will be responsible for making corrections to supply the required quantity of input so that the engine can always run in its optimum condition.

I will write a few lines about these, as I have discussed by now: sensors, diodes, transistors, and other electrical components. These controllers, sensors—all these components are installed in this control unit, the ECU, which is also known as hardware. These are installed in a housing made of plastic or metal. So, this ECU essentially receives signals from the sensors.

Then, it processes the data. We shall soon discuss that these signals can be analog signals or digital signals. So, the signal received by the ECU can be an analog signal or a digital signal. But what I am going to discuss now is that the ECU is capable of processing data. It generates control signals for the actuators.

Now, this process is done by an important component that is microprocessor. So, this program/process is executed by a microprocessor. And this microprocessor, so essentially there will be some inbuilt programs and that program is stored in the memory of ECU. So, what we can see, ECU will receive signals from the sensors.

Receiving signals, ECU is capable of processing data to generate control signal for the actuators. That is to provide some measured output that we can see from our previous block diagram of the closed loop control system and to generate control signal again that means the ECU would be able to process or program and that is executed by the microprocessor and that software program is stored or built in the memory of the ECU. So, the software program is stored in the memory of ECU. So, if we go to the next slide, that ECU and other components right. So, ECU is capable of receiving signal will process the data will generate output signal or control signal and to generate control signal and process data again there will be so many other electronic components or electrical components.

So, ECU houses many electronic gadgets and electrical components and that is known as hardware. So, if I write here that the ECU and its components are known as hardware. So, in the memory of ECU, a software program is installed and all the components which are there in the house of plastic or metal and that is known as hardware.

Now what we can see that this ECU is essentially will connect sensors, will connect actuators. So, sensors, actuators, and then power supply. All these things are very important. So, sensor, actuators, and power supply, these are connected to the ECU and this is done, so if I write here, so sensors, actuators, power supply are connected to the ECU and this connection or connections are done by multi-pin pluge. So, this is what we can see. Now question is actuators, so till now we have discussed that ECU will house sensors, actuators and many other components and for the operation of actuators, we need to have high power density device to actuate, to operate actuators. And these high-power density devices will generate some heat.

So, these high-power density devices which are responsible for the operation of actuators are also integrated with this ECU. So, as to have better heat transfer. So, ECU will also house or we will also accommodate high power density electrical device which are used to operate actuators so as to have better heat transfer. So, ECU will accommodate high power density high power density circuits.

So, you see, we will accommodate high-power-density circuits that provide direct control to the actuators. And as I said, this high-power-density device will generate an excessive amount of heat, and that is why these high-power-density circuits are provided inside the ECU to have better heat transfer. So now the question is, a question may arise: why is an

ECU required? To accommodate high-power-density circuits. Why do we need to accommodate high-power-density circuits in the ECU?

So, the reason is these high-power-density circuits are responsible for the actuators; rather, the circuits provide direct control to the actuators. And since these circuits will generate heat, that is why they are built inside the ECU to have better heat transfer. Now, if we briefly discuss the signals. So, the ECU will receive signals and it will also generate signals.

So, the input to the ECU, is a signal or inputs are signals, and outputs are also signals. So, let us discuss this part. Though we have discussed this in the context of several units in one of our previous classes, or we have discussed all these things in our previous classes. So, what we write is that and most of the electronic or electrical components are surface-mounted devices.

So, most of the electronic components are surface-mounted devices or surface-mounted components. So, the control signals from the ECU to the actuators. That means these are the signals or output signals from the ECU.

So, the sensors join the actuators as the peripheral components linking the vehicle and this ECU, the central processing unit of the ECU. So, the sensors control signals from the ECU to the actuators. So basically, say for example, if we need to control the mass flow rate to be introduced inside the engine cylinder during the intake stroke. If we need to supply an adequate or larger amount of air mass, then the ECU will receive that information from the sensor placed in the intake manifold. After receiving this signal, the ECU will process the data and then send feedback or a signal to the actuators to supply the adequate amount. So, to open the throttle valve. So, we need to have a larger throttle opening area, and then, these sensors we need output, and the sensors join the actuators as the peripheral components linking the vehicle and the ECU.

So that means ECU will give some signal to the sensor to have more opening of the throttle valve and that sensor joining the actuator. So essentially actuator will give some, actuator will open. So, it will actuate the throttle. So, this actuator will receive signal from the ECU that throttle position should be wide open and that signal should be convey to the actuators by the sensors and that is why the sensor joins the actuator as the peripheral component linking the vehicle and the ECU. Because the actuator will be in the vehicle itself. So, then this vehicle and ECU and ECU will provide that signal. So, this sensor joins the actuators as the peripheral component. If I go to the signals (input) to

the ECU input signal. So, we had seen that signal received by the ECU are the electrical signal. And these signals are either analog, in most of the cases signals are analog data or analog type, but we can have digital signals as well.

So, the electrical signal These are input signals, input to the ECU. Electrical signals travel through the wiring harness and plug to reach the control unit. So, electrical signals, which are the input signals to the ECU, all these signals travel through the wiring harness and then plug to reach the control unit, that is, the ECU. So, this is fine.

As these input signals can be analog signals; input signals can be digital signals as well. So, let us briefly discuss these two, and then we'll move to another important component. So, input signals can be either analog in most cases or digital signals.

If the signal is analog, then it can have this particular signal, can have any voltage level within a specific range. And it is quite important to know the physical quantities that are monitored as analog signals. So, physical quantities monitored as analog data are induction of air mass, then battery voltage, and intake manifold pressure. Now, question is that microprocessor, so the digital circuit we have talked about in our previous classes can read only two different digital state, two different states. So, if the physical quantity which is monitored as analog data, so analog signal must be converted to digital before processing. So, this analog to digital converter is there, this converter converts analog data to the digital one.

So, analog to digital converter (ADC) converts to digital analog data to digital data in the microcontroller. So, this is done inside the microcontroller. Now, any digital signal has two different states. Each state is identified by a particular level of voltage, typically occurring voltage. Zero volt and another one is 5 or 3.3 volt. So now digital signals have two conditions, two states like this. 1 is high level or high state (logical 1) and number 2 is low level or low state (logical 0) and physical quantities monitor as digital data, digital signal are rotational speed and magneto, so rotational speed pulses. So, this rotational speed can be measured using Hall effect and magneto resistive sensors. Here this is, if it is a digital signal input there is no need of analog to digital converter. Since this is digital signal microprocessor can process this data without any need of prior conversion. So, next that ECU. ECU, electronic control unit has other circuits as well. What are those?

One is known as special circuit. Number two is protective circuits. So, these two different circuits are also housed in or within the ECU. So basically, we are trying to discuss about ECU layout.

So, these two circuits are also built inside the ECU. So, why do we need to have the special circuit and protective circuit? Let us discuss briefly. When the input signal is pulse-shaped. So, here a special circuit.

This circuit transmits. So, when the input signal is pulse-shaped, then this special circuit is there to condition. So, the special circuit is used to suppress the interference pulses while actual pulses—certainly, signal pulses—are converted to digital square-shaped signal.

So, that means if there are pulse-shaped signals, then there will be a few interference pulses. So, if we allow the interference pulses to go into the ECU, then the ECU will not be able to function properly. It will start malfunctioning. And then, if the ECU is unable to function properly, the output from the ECU will again not be correct. So, essentially, the objective of having an ECU will not be there—I mean, it will not be justified.

So, the special circuits are provided to suppress the interference pulses and only allow the actual pulses. Also, the actual pulses will be converted to digital square-shaped signals. What about protective circuits? Number 2, the protective circuit, these are used to limit the voltage of incoming signals. So, these are used to limit the voltage of incoming signals to a level suitable for conditioning. And the name itself is protective circuit. So, the objective is to only allow or limit the voltage of the incoming signals suitable for conditioning. That means superimposed signals will be removed. So, these are the special circuits. And finally, the most important component is the microprocessor of the ECU. So, that the most important digital integrated circuit to evolve has been the microprocessor. So, this is a very important component. Its size is very small, but it has the capability of holding 250,000 gates in a one-fourth square inch area. So, that is very important, and we shall be discussing a few important points about this particular component because we have discussed many components. In the beginning of today's class, we said that the ECU houses many electronic components, electrical components.

And all these components are installed in a house of plastic or metal, and the ECU, along with all these components, is known as hardware. So, let us briefly write a few points about these very important components of the ECU. So, the microprocessor unit is also known as the MPU. So, The MPU unit has broad applications in automatic electronic systems, as we know.

So, this is the central component of the control unit. It has broad applications and controls the operative sequence. So, the control unit controls the operative sequence of the ECU.

And so now, again, this microprocessor also, is an important IC—an integrated circuit that can house two hundred fifty thousand gates in a one-fourth-inch square area. So, you can imagine the ability or capability of this particular IC.

The MPU, or microprocessor unit, incorporates a relatively complicated combination of digital circuits, including ALU, registers, decoding logic, etc. And this MPU—microprocessor unit, apart from the CPU, the central processing unit, contains not only input and output channels but also timer units, random access memory, read-only memory (RAM, ROM), and peripheral assemblies.

Most importantly, all these are integrated on a single chip, so that is the single—I should write microchip. And the output from the microprocessor unit will be the output signals. And there are two different types of output signals from the MPU. I will just write the names here.

So, two types of output signals are considered. So basically, the microprocessor unit or MPU will give some signals to the actuators, meaning the MPU triggers the drive of the controller to actuate actuators. Typically, two different types of signals are considered, which is what I have written here. Let me write these two types: one is the switching signal—the first type—that is a switching signal, which switches the actuator on and off. So, the actuator will actuate based on the signals or input signals that come from the microprocessor unit or MPU.

So, the first type is the switching signal, meaning it will switch the actuator on and off. The second type is known as pulse-width modulated or PWM. So, this pulse-width modulated signal—is used to actuate or control a wide variety of actuators.

So, to summarize today's discussion, we have discussed the electronic control unit and its subcomponents. That means the electronic control unit or control unit houses several components, which are electronic components and electrical components, so as to run the engine always at its optimum condition. Not only that, the control unit has to function always efficiently and maintain the best efficiency of the control unit. This particular unit houses many electronic components, like transistors, sensors, diodes, and many other semiconductor devices, as well as many electrical components. These are how they are connected to the ECU, what the outputs from the ECU are, and to get some output from the ECU again, we need some devices or systems.

We have discussed all these things in today's class. So, with this, I will stop here today, and we shall continue our discussion in the next class.

Thank you.