Course Name: Engine System and Performance
Professor Name: Pranab Kumar Mondal
Department Name: Mechanical engineering
Institute Name: Indian Institute of Technology, Guwahati
Week - 06
Lecture – 20

Lec 20: Introduction to electronic devices and circuits

I welcome you all to this session on Engine System and Performance, and today we shall discuss electronic devices and circuits. So, in our last few classes, we have discussed sensors, we have discussed electronic electronic control units, and engine management systems. We have also discussed actuators. We have seen that the electronic control unit is an important component for modern engines.

To run the ECU, we need actuators and sensors because essentially, that is the control unit. So, the objective should be to receive a few inputs from different components of the engine block. After receiving these inputs, the ECU has the provision to compare them. If they do not match the stored data in the ECU, then the ECU will provide feedback to the actuators to adjust the engine operation, to adjust several functionalities like fuel injection, mass flow, mass of air to be introduced in the engine cylinder, temperature of the engine block, temperature of the incoming air, temperature of the exhaust gas—all these things so as to restore them to the design data. I mean, if we can have the engine running under its designed conditions, then efficiency will be maximum, and emission levels will be minimum.

So, in continuation of that, let us now discuss the electronic devices, which are very important for the construction of all modern engines. And then we shall discuss circuits. But before discussing this part, let us first discuss two important signals that we could not cover in our last class. These signals are analog and digital signals.

So, analog signals and digital signals. We have seen that typically, the input to the sensors is any physical variable, and that sensor output is an electrical signal. Now, the signal may be an analog signal or a digital signal. Receiving that signal, the ECU—that is, the CPU or computer of the control unit—will try to give some feedback to other components, maybe to move or to actuate the actuators. And accordingly, physical variables will be optimized so as to ensure that the engine can run quite efficiently, whether it is a locomotive engine or a stationary engine. Now, before going to discuss the electronic circuits and electronic devices, this is very important to know.

Though in recent times, analog electronic circuits are getting replaced by digital circuits, our aim should be to discuss analog circuits. Rather, we can start our discussion with analog circuits. Because it is very easy to understand—or, I should say, it can be better understood quite intuitively—rather than the digital circuit. Now, what we know until today is that for any sensor, the output is an electrical signal. Now, the input to the sensor is any physical variable. Now, any input is converted to an electrical signal—a physical variable.

The sensor will receive whether the input is the optimum input or it is deviating from the optimum value. The sensor produces a proportional electrical signal. I mean, upon receiving input, the sensor produces a proportional electrical signal. Now, the question is: input quantity or input quantities may vary with time. So, if that is the case, then since sensors produce a proportional electrical signal, it is very likely to expect that if the physical quantities change with time, then the electrical signal will also vary in time.

If the signal is varying in time, it can be a continuous variation. It can b, a kind of discontinuous variation. So, if that is the case, then what type of signal is it?

Essentially, an analog signal is such a type of signal that produces a signal and amplitude with time. So, let us write a few lines and then a few important points that will help you to understand more clearly. So, sensors produce or convert the input variables to a proportional electrical signal.

Now, if that is the case, then, if the input quantity varies, the sensor output voltage will also vary. So, if the input quantity varies, the output voltage will vary proportionally. So, that means the output signal will vary proportionally depending on the variation of the input quantity. A signal, if we go to the next slide.

A signal that produces continuously varying voltage and amplitude. with respect to time is an analog signal. So, there are many examples are throttle position that we have already discussed or throttle position (TP) sensor and so throttle position sensor which incorporates variable resistor to produce analog signal.

Similarly, we can have other temperature sensors, all these things because engine temperature can or may change with time and if we need to get input so basically if the sensor that is receiving input that is temperature a physical quantity that sensor output also will change the voltage will change continuously so that will produce an analog signal. So, that is what is an analog signal. Now question is typically that all analog inputs are supplied with 5 volts with reference to the ground state or ground potential. So, just for your information if all analog signals are provided with 5 volts with reference to the ground potential.

So, this is very important to know at least. what I would wanted to say that because ECU will receive all these signals because that is these signals are the sensors output. Now ECU should have a provision of converting all these analog signals to the digital value or digital signal before giving some information to the actuators. So, this is very important.

That electronically controlled unit or electronic controlled unit converts these analog signals to digital signals before processing the information. Because the information will be given to the actuators to do some or to resolve the problem to perform some task, but before the ECU provides some information to the actuators. Does the ECU need to convert this analog signal to the digital one?

So now this is all about the kind of analog signal. If we draw a schematic depiction. So, this is, you can understand.

So, this is the analog signal. So, it will change continuously with time. Now, if we talk about the digital. So, from the definition we had in the context of analog signals, you can now understand that analog signals produce that if we go back to the previous slide, we can see that analog signals produce continuously varying voltage and amplitude with time. So, if the signal produces, in contrast to continuously varying voltage and amplitude with time, rather discrete in time, then that should be the digital one.

So, to write a few lines and a few important pieces of information about digital signals. From the definition, understanding we have about analog signals. Digital signals do not produce continuously varying voltage and amplitude over time. Rather, the signal in contrast to an analog signal, or analog electronic circuits that operate in continuous time, a digital system operates at discrete instants of time. Digital electronic systems operate with or operate at discrete instances of time, so that you can understand.

This is the digital signal. If we go to the next slide, then we can write that means a signal that produces or represents just two voltage levels is termed as a digital signal. So, this is a digital signal. That means, from the definition itself, we can tell that a digital signal has only two states. So, a digital signal has 2 states: 0 and 1.

So, in typical automotive electronic circuits, a typical digital signal is either 0 (OFF) volt or plus 5 volts, which is ON. So, this is all about the digital signal. Now, as we have discussed, the ECU cannot process data or information unless the analog signal is converted into a digital signal system of the circuit. That means the circuit that converts sampled analog data to binary values is called an analog-to-digital converter (ADC). So, this is very important. As I said, the ECU cannot process data with an analog signal, so there must be a converter to convert all analog signals into binary values. There must be a provision if we need to convert these binary values back into an analog signal, especially if the device is analog, as in the case of an actuator for a control system, the output binary number must be converted to analog format data.

So, this conversion—that means if the device itself is analog, as in the case of an actuator for a control system—the binary output number must be converted to analog data, and this conversion is done by a device, known as a digital-to-analog converter (DAC). So, that is what is important.

So, if the device is analog, as in the case of an actuator for a control system output, the binary system must be converted to analog data, and that conversion is done in a digital-to-analog converter using this. So, we have understood what an analog-to-digital converter is, what a digital-to-analog converter is, and the need for having these two converters in the ECU. So, with this, now let us discuss the electronic devices, and then, if time permits, we shall discuss these devices. So, what we have understood is that semiconductor devices or solid-state devices are the basic building blocks for the ECU, the electronic control unit.

So, basically without any semiconductor device or devices, the ECU cannot run. So, if we need to have a very sensitive ECU—that means receiving signals from the sensor, the ECU will do some calculations, perform some tasks, give some information to the actuator to correct the problem, and provide some information to the actuator to make a decision on what to do next. So, all these things are done using the ECU in modern engines, and the functionality or efficiency of this particular unit depends on the solid-state devices or semiconductor devices.

So, there are many types of semiconductor devices, but typically, for the automotive electronic system, we shall look into two important types of semiconductor devices, and those are the diode and the transistor. Now, these semiconductor devices are the most important elements for constructing almost all modern engines. So, our focus will be on the two important types of semiconductor devices: the diode and the transistor. As I said, there are many other common linear semiconductor components or semiconductor devices, like transformers and inductors, but our focus for this particular class or subject—essentially for the automotive electronic system or unit.

This is the discussion of two important semiconductor devices, and those are the diode and transistor. So, if I now go to discuss these semiconductor devices, what should I say about electronic devices? So, for the Automotive electronic system or circuit. As I told you, semiconductor or solid-state devices are very important and we shall discuss two important types. These semiconductor devices have two important types. One is the diode another one is the transistor.

There are, these two very important semiconductor devices for the construction of almost all modern engines. But it is not that these two devices are the only semiconductor devices; there are many others that are quite different. There are many other semiconductor devices, but these two are quite different from common linear components, such as inductors, resistors, transformers, capacitors, etc. So, if I write here, these two devices are quite different from common linear components like capacitors, resistors, inductors and transformers. So now, in this class, we shall be focusing on these two: diodes and transistors. So, let us first discuss diodes, and then, if time permits, we shall discuss transistors.

So, now draw the schematic depiction. So, we all know, from our basic understanding of, rather, understanding of basic electronic, electronics subject—that a diode essentially, acts, all diodes act like a one-way valve. So, it allows current to flow in one direction.

So, this is basically a diode. So, this is the cathode; this is the anode. All diodes act much like a one-way valve, allowing current to flow in only one direction. So, a diode is a two-terminal electric device. So, essentially, it is a two-terminal electrical device, having one electrode called the anode.

And this is essentially a p-type semiconductor and, So, we can see from the schematic definition that we have the two-terminal electrical device. It means that the device has two terminals, electrical terminals. One is called the anode, which is the p-type semiconductor, and another terminal is the cathode.

This is an n-type semiconductor. So, these devices act like a one-way valve, meaning they will only allow current to flow in one direction. Now, depending on the bias of these two, the polarity voltage or bias across the anode and cathode—we can classify this again. So, let us briefly discuss these two.

So, though these devices allow current to flow in only one direction, depending on the bias—that is, the polarity of voltage—this current flow will take place. So, typically, diodes will allow current to flow in one direction depending on the bias. That is, between these two electrodes—the polarity of voltage. Now, when current flows in the forward direction with a plus voltage on the anode. So, as I said, diodes allow current to flow in one direction.

Depending on the polarity of voltage—that is, the bias across the anode and cathode. When current flows in the forward direction with a plus voltage, diodes have low resistance. So, when the anode has a positive voltage and current is flowing in the positive direction, the diode is said to have low resistance. We shall discuss all these parts in greater detail, together with discussion on transistors. As I said, these two important elements are the most important for automotive electronic circuits. So, we need to have a little more discussion on these two components—their different types, configurations, characteristics—and this part we will discuss in the next class. So, with this, I stop here today.

Thank you.