Advanced IOT Applications
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Lecture – 21
Diagnostic services and fuel-injection ratio control unit

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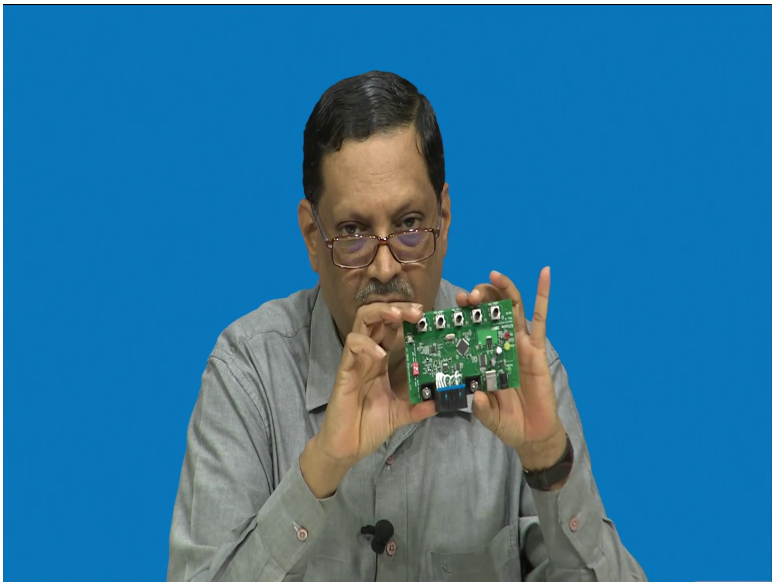

So, now, we have to get into the details of how to use this ECU simulator. So, before we get into the detail there are many things as an IOT person you should know. I mention to you that there are these 5 knobs shown above, which essentially talk about 5 different sensor outputs, which are available from an ECU, typically from an ECU. One of the important things that we see as an output here is the mass air flow, we will come that in a very short while, then there is oxygen, and then there is engine RPM, then there is speed temperature, coolant temperature, these are the sensors that are available.

Yes, also we looked at engine manifold and if you look at the throttle body, which is just connected to the engine manifold. To provide the required ratio of air to fuel mixing there are several things. This is essentially referring to that ECU, which is talking about the engine manifold and the corresponding throttle body, which is essentially forming the complete system as far as the engine fuel injection is concerned. So, this is I would say more for fuel injection combination of the engine manifold as well as the throttle body.

In IOT the one thing you have to be very clear, that if you want to work in a particular domain area if it is on air quality, or on automotive, or on energy systems, or any one of you know current topics. You must get into some detailing from sensors perspective, from embedded programming perspective, and also from a high level understanding perspective. Without which I do not think you will be able to make any good progress, in your and in your development of IOT systems or even in the area related to where IOT can be applied.

So, keeping this in mind, let us go and do a little more study on all these aspects. You see there is a connector. That connector I mentioned to you is called the OBD II connector; On Board Diagnostics version 2. One is over it is all gone forget it. So, 2 what is now most prevalent. If, you own a car, it will be a good exercise to find out where is your OBD II connector.

In my car it is just below the steering somewhere on the right side, there is a lever to open you know engine compartment. Somewhere in that region if you look down in little deeper you will see a connector. And, that connector is essentially the OBD II connector to which you can connect something. Some small scan tool equipment you can connect and start observing the diagnostic information about the car.

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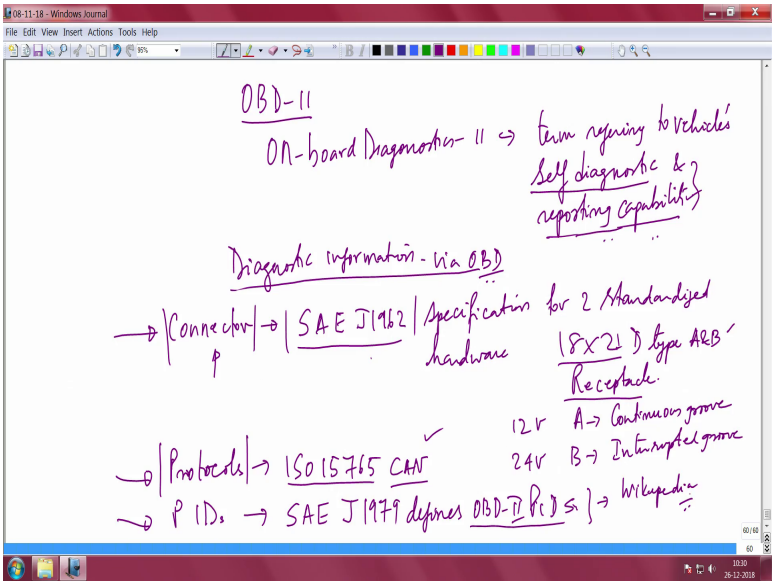

So, what does the OBD II in a high level sense do ? it is a term referring to vehicle self-diagnostic and reporting capability, Not only trying to find out if there is a fault within

by doing some very intelligent tests, but it is also support to have a capability to report a fault condition. So, this diagnostic information is available via this OBD II port.

Now, if you read literature on the OBD 2, you will find very confusing documents lot of lot of information is available out there. Just to give you a very quick overview I have put down 3 protocols of interest. One is related to connector and some hardware specification related. The second thing is protocol related and the other is with respect to the parameter ids or also called the PIDs as it is called.

If, you look at the connector related information, there is a specification from SAE; Society of Automotive Engineers J-1962 specification. You will have type A and type B in them. And, you cannot essentially have D type; you do not want A to meet into B and so on. And, therefore, the receptacle is slightly while the receptacle housing looks the same the groove that you see in the middle is continuous.

So, you can just move your pencil or whatever just I directly and then you see that there are no cuts. Whereas, there will be an interruption somewhere in the middle if it is type B. So, you will see that you cannot take A and put it into B and vice versa. So, that is essentially the idea.

The second thing is what is the protocol running? Because IOT folks will be interested in the protocol part, because that is where all the intelligence and algorithms that IOT people would like to you know sort of program the system into, that part of the protocol is essentially supported by ISO 15765. I mentioned you so many other protocols. But, this appears to be the most popular one CAN which is also something that Bosch, you know came up with this specification, you have low speed CAN and high speed CAN and so, CAN is a very important protocol.

Now, the parameter ids themselves have a specification and that is the SAE J 1979. And, these define the parameter OBD 2 PIDs. My suggestion is if you want to know more about PIDs it is best to look up Wikipedia; Wikipedia and you will find a wealth of information on OBD II. So, I do not want to repeat what you can easily find, but we should take an example to connect everything together.

So, for that purpose what I will do is, I will take whatever I am most comfortable on this engine ECU. It is obvious right if you want to demonstrate something. And, it is good to

take one sensor and go a little more into detail and look at the parameter ids and so on of that particular sensor.

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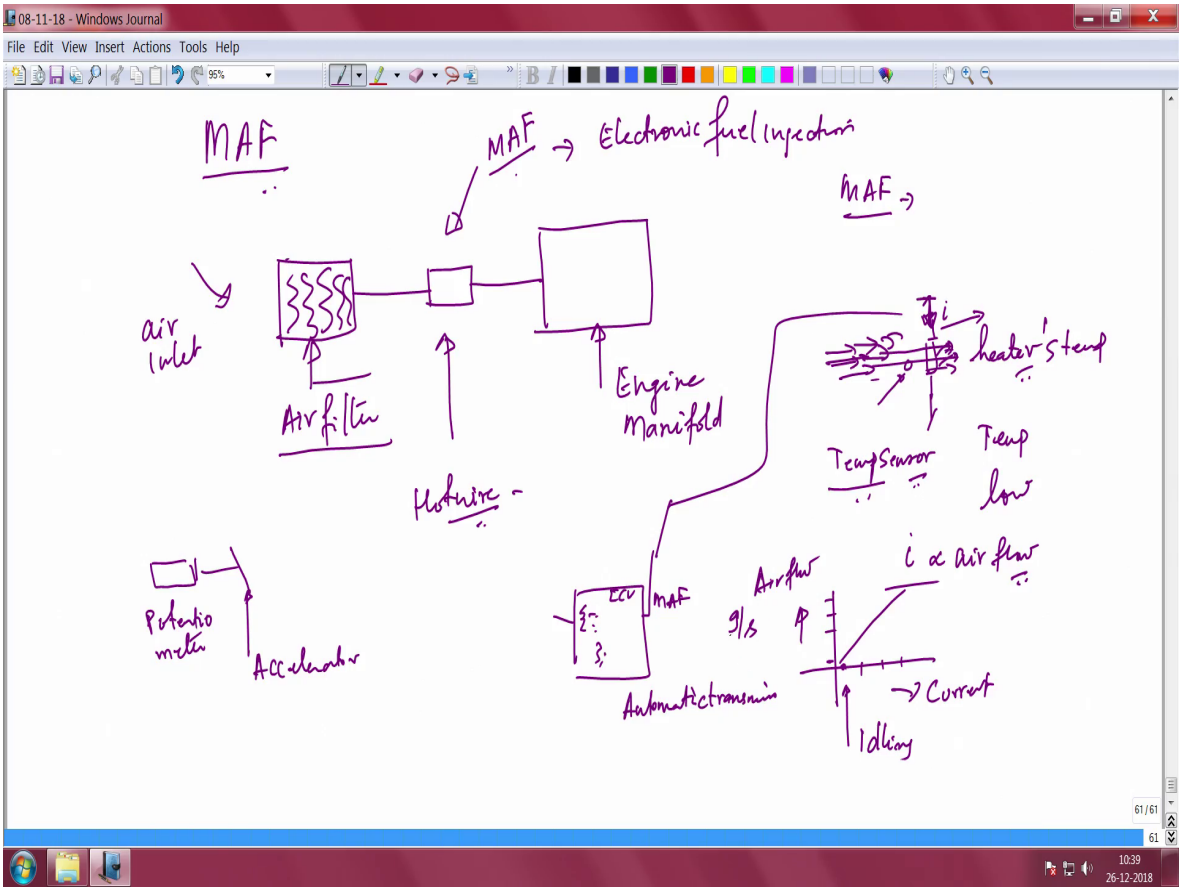

For that purpose I have chosen mass air flow MAF. MAF is an important sensor. Now, what is this MAF sensor, how does it work, what are the problems? All that let us get into details this is the engine manifold. It is the engine manifold. And, you see the air filter. Now MAF essentially is in the middle. And it is a very crucial one for any electronic fuel injection system.

So, what happens here is the air is coming in. So, there is air inlet, the air filter essentially removes all the particulate matter. It removes particulate matter, all materials all particles, which can actually destroy an engine head if the particles go inside, they can actually destroy the engine. So, you have to remove all those unwanted particles which are suspended in the air particles. Therefore, you put a air filter by the way, if air filter blocks you will have a another set of problems we will not get into that we will just concentrate on the MAF part.

It is a mass air flow measurement device and it is an interesting sensor by the way. So, it is a very interesting sensor. The way it works is very simple. How do you measure mass air flow? How do you measure air flow at all in the first place? Imagine that there is a heater. And, I will apply some voltage to it and it starts heating. Now to this I somewhere close by I will put a temperature sensor. Now, it is all inside this by the way. So, the heater is essentially maintained at some temperature, you are measuring the temperature.

Now, if air is there and there is a flow typically I think a laminar flow, flow across the heater. If the flow rate is low right, you do not need too much current to keep the heater at that given temperature. So, that the temperature sensor is measuring the temperature of the heater. At what temperature current is passing? And therefore, what is the heaters temperature heaters temperature is measured, but if the air flow increases much higher. If you have a much higher air flow, you need to pass higher currents, you need to pass higher current in order to maintain the same temperature.

So, the current that is flowing is directly proportional to the airflow. I have given you a very high level view. So, now, you plot what is the current and what is the current versus airflow? So, nice linear relationship fantastic nothing like it is a good linear sensor. I think airflow here is measured in grams per second mass air flow. So, you say in terms of grams and this is the current in either milliamperes or amperes if you pass this much current this is actually the airflow you can directly calibrate.

So, this is what is sitting inside, it is measuring through what is known as a hotwire, this is also called the hotwire, hotwire measurement device. So, essentially mass air flow sensor measures the amount of air, which is entering the engine which is also called the airflow. Now, so, the simple electrically heated wire which is nothing, but the hotwire is the one, that actually measures the air flow.

So, now if so, this condition is low current is typically when the engine is idling, when the engine is idling you do not need too much of air flow around it. So, it takes very small amount of current you can see this current is also very small, but when you press the accelerator, Your leg is pressed on the accelerator remember I had connected it to a potentiometer.

If you press on the accelerator pedal which your leg, the throttle will open and that will allow more air flow through the hotwire. It will allow more hot flow through the hotwire

and that will be proportional to that air flow you want to measure. And in order to keep it hot at a given temperature, you need to pass an electric current which is more. And, that information of how much current you are passing is given to the engine ECU. So, directly you will get MAF a value for MAF is available to the engine ECU.

Now, what this engine ECU does? there is a piece of code, everything is software inside there is a piece of code running inside the ECU, the algorithm that is there in the ECU, And, this a MAF is taken and it shifts the transmission, if it is an automatic transmission system based on the MAF value, if it is let us say gearless vehicles moment you press on the pedal you will have to increase the speed. So, it shifts to the automatic transmission, transmission signal is given and then the speed picks up.

So, this is as simple as this, but while I have written what I have written here appears very simple, what can go wrong, what is the issue with this is there any problem at all, if it is such a lovely system to work and all that. You will see, that is where IOT will play a very important role. Let us now go to what can happen, what can happen with this MAF sensor, and how IOT can play an important role?

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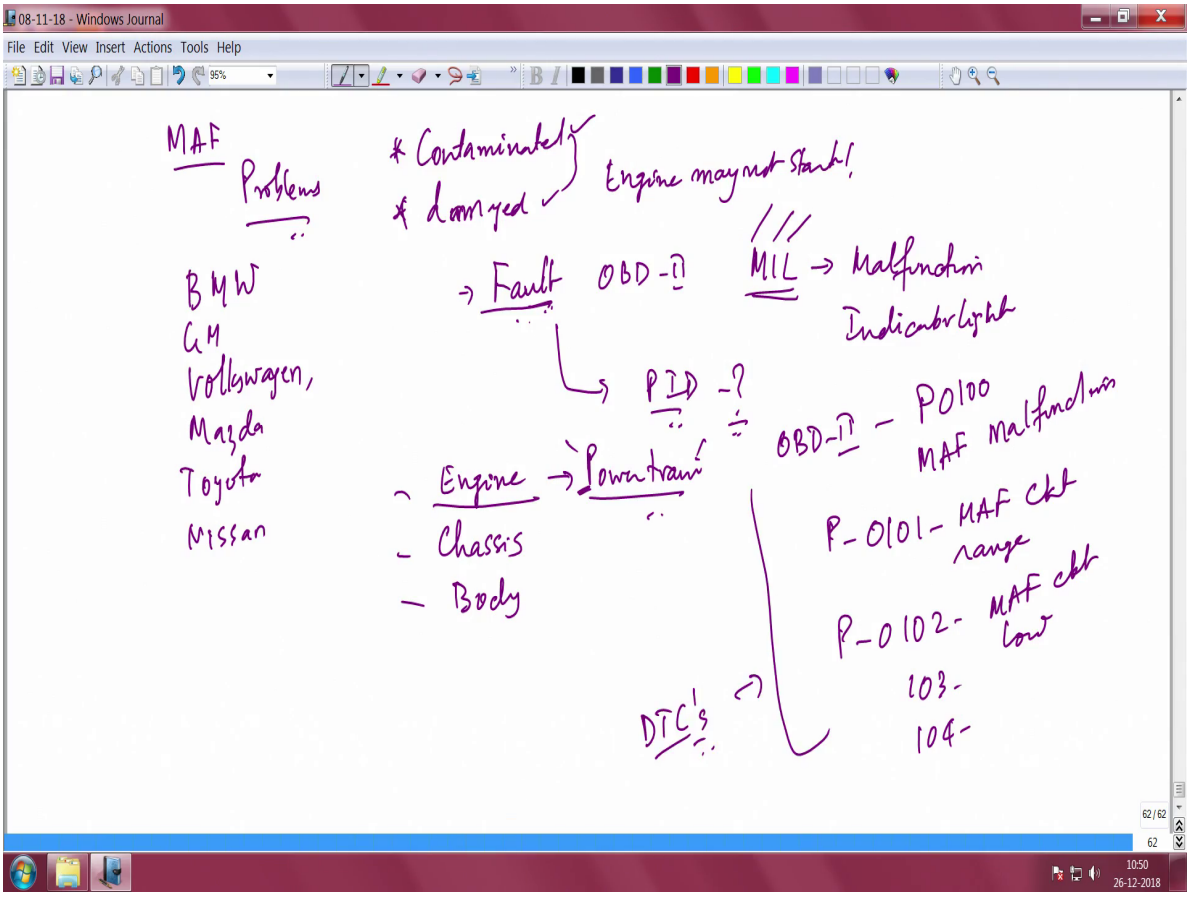

MAF problems; first thing is let me give you an overview. There has been no world leader vendor in this area, which have not had problems with MAF.

BMW, has had problems with MAF sensor. GM have problems with it, , Volkswagen, then Mazda, then Toyota, then Nissan, all these companies big companies both Japanese as well as German companies manufacturers big massive giants, who have been manufacturing for several decades have had problems with the MAF sensor. So, therefore, it is a very critical sensor.

First thing is it can get contaminated, it is easy to see that, it can get contaminated, it can get damaged. If you go back and look at the picture, if your air filter is horribly bad, if you do not change your air filter your MAF can go bad, the hotwire element can get contaminated.

So, it is because it is in a very critical position which is taking something from the environment. See do not forget the bad air which we are breathing in cities like Delhi,

where the air quality index is, I do not know 2 and a half times the safe levels, while on the one hand the worst suffering can is happening to humans right. It is not that cars are anywhere safe also. They are also having this problem, because that whole you know particulate matter will come and sit on this air filter air inlet on this filter. Filter will had to work twice it is gets contaminated faster, and if it gets saturated then the MAF will go bad.

So, if you buy an expensive 1 crore car, and, if it's air filter is contaminated quickly MAF sensor goes bad, this can also happen. So, polluted air can be a cause of concern, while automotive manufacturers have to be blamed for not adhering to pollution norms. And, they are the cause for several of these problems, which are happening in larger cities like Delhi. It is not that the vehicles that they manufacturer are also you know redeemed of this problem it is not that they are also suffering from the same kind of issues that humans are.

So, the problem is horrible when humans are involved and because we end up with lot of breathing problems, and high levels of contamination can create problems to our lung, and all that so, very bad thing to happen.

But, you see how the vicious circle has developed, vehicle, vehicle polluting, creating problems to humans and also creating problems to vehicles and so on. I feel that IOT should do something at in this kind of space. This is the most important thing you have to bare what can I do, what can we do, if we know and we have access to cheap sensors. And, we know how to write code? Even in a very expensive 1 crore rupee car or a 2 crore rupee car we are still have access to several sections like what we discussed before you should be able to do something. So, that is the goal.

So, now next go back and look at the so, MAF can get contaminated, it can get damaged very quickly and you know once this fails, you cannot start the engine anymore. The air flow sensor could cause the engine to crank, but not to start. So, engine crank can happen, engine may not start also may not start that is the problem. So, when the air flow sensor signal varies over and above an expected range, the mass air flow sensor can record a fault, straight away the OBD II becomes extremely useful to you know record this fault.

What actually happens is the following. If, you own a car and you put in your car key the first thing you will see on the left side is a set of lights that glow right. One of them that you can easily spot which looks a little peculiar apart from fuel which shows a small can, and a drop there, and then the handbrake signal, and battery signal and all that you will find 1 MIL indicator. It is called MIL just remember it as MIL this is called malfunction indicator light, malfunction indicator light.

Some people call it by check indicator or something like that, but I think the most popular appears to be mal indicator light. It has a symbol which you cannot forget. You please look up that symbol for MIL indicator light, and you will see it directly on the dashboard. Moment you start the car that you expected that the whole thing, the dashboard, that you see on top completely vanishes except the handbrake. Moment you release the handbrake even that light goes away, then you know your panel is clear and now it is good to start and it is good to go.

All; that means, that it is doing some self-tests; it is doing self-diagnostic, and if there is if that light does not go. The MIL light does not go. Clearly, it will record it in the ECU and you can retrieve it. It will record it in terms of a some OBD II data, it is called it will indicate a PID this is called the parameter id, it will indicate the PID and it will indicate and moment you look up connect a scan device to it, you should be able to read the parameter id and find out what that fault was.

If, you take a car or a if you take a vehicle we have the engine, we have the chassis, and we have the body, the engine part was also called by power train. So, the actual power coming from the engine and therefore, it is called the power part, and then the chassis part, and the body part.

Therefore, since there is a P, you will see that the OBD II code corresponding anything with respect to engine will start with P. Typically you will see P 01010 which is MAF it can be MAF malfunction, it will directly indicate this is standard parameter id. So, it is something that is defined in that standard I mentioned to you.

And, which is that standard you may want to go back and recall the standard. The standard for PID is J-1979. As per J-1979 OBD II parameter ids are already defined, vendors can add their own, and they can define it and all that. But, standard parameter id have to is something that vendors have to implement essentially.

Similarly, you have P0101 which can correspond to a mass air flow circuit range, mass air flow circuit range, it is beyond range and P 0102 is mass air flow circuit low circuit low. So, you can have circuit high which is 103, then you can have 104, there is a circuit intermittent and so on. So, you will have what are known as DTC's Diagnostic Trouble Codes.

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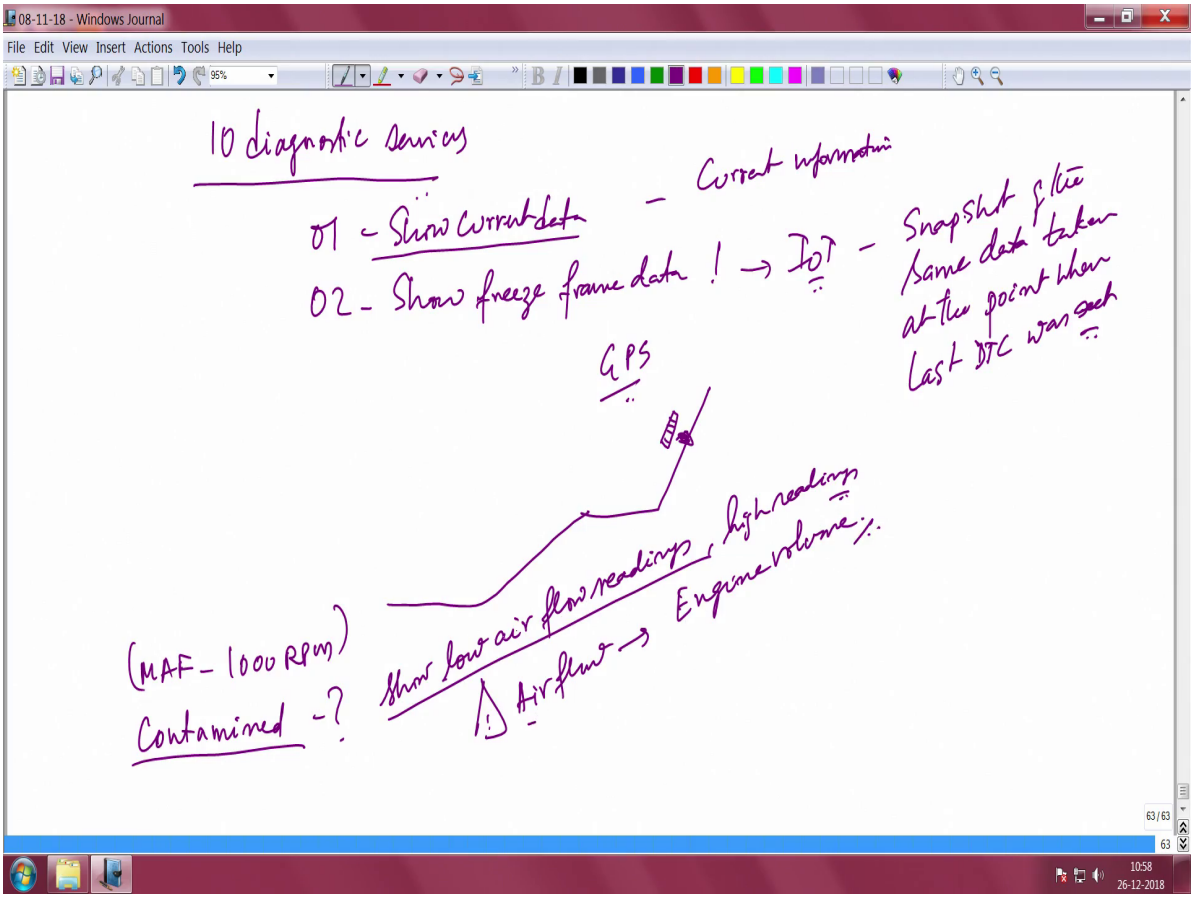


It will essentially indicate a diagnostic trouble codes. There are essentially 10 diagnostic services. In this actually you can look this up in Wikipedia, but for completion I will just write it 01 is show current data.

And, 02 is indicating show freeze frame data, very useful for IOT guys. I tell you why? 0 1 provides current information. Whereas, 02 to provides a snapshot of the same data taken at the point when last diagnostic trouble code was set, last DTC was set. So, this has some sort of time information. This is useful that if you take it at a snapshot. Essentially is you are freezing the time at which these malfunction actually occurred. So, you have some time information.

Now, look at it this way, if you have the time information, and if your vehicle had a GPS associated with it. And, you know where and what point in time this MAF sensor give a alert or gave a malfunction, you essentially know something more about the fault. For example, supposing in the road and then there is a hill, and then there is a flatting, and then there is a much deeper hill. And, you find that the 0 2 code was recorded somewhere here, you clearly know you have additional information that the MAF sensor failed here, when the car was climbing.

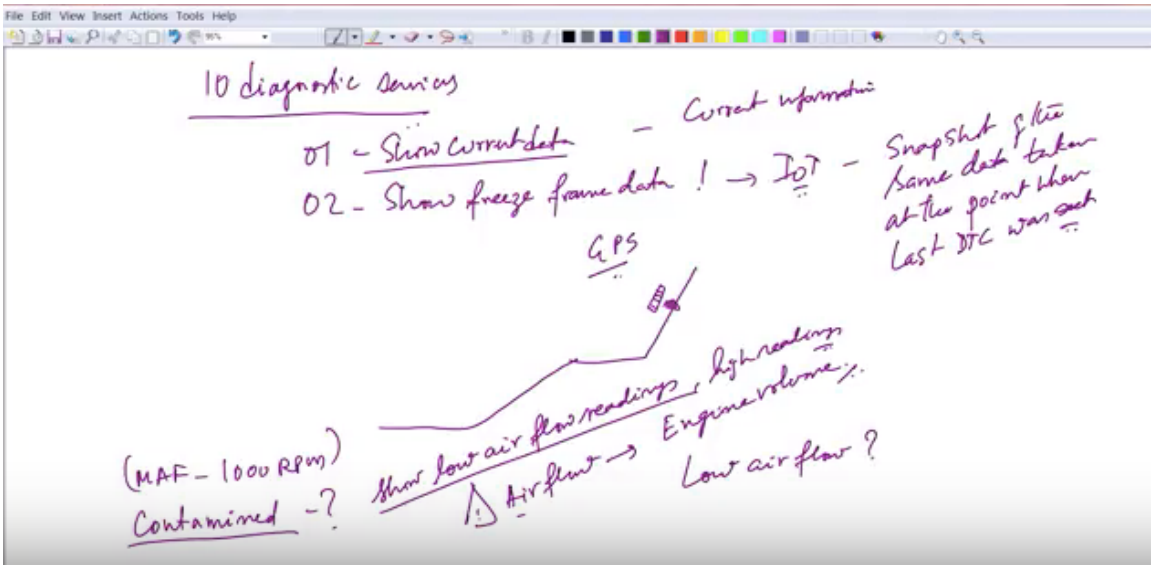
Now, whether you can use that information to further improve is another story, but the fact that you get a lot of data moment you know at what time the MAF malfunction happened will be useful. The P 01 will simply show some current data, that there is a fault. It will just indicate that and leave it, but it gives you the freeze information which is adding a lot more value to the whole system.

So, one can essentially debug better by using this DTC; Diagnostic Trouble Codes, and OBD II data, and then you can essentially repair your systems or quickly identify the fault in your systems. So, often you will see that the mass air flow sensor readings you measure at different RPMs. You measure MAF at 1000 RPM, then you measure the MAF at 2000 so on 3000. If, you find that if it is contaminated, because we started with that; If it is contaminated you will find that it is a bad air flow, it will show lower air flow lower air flow readings, then a good one.

So, if it is contaminated you will find that the air flow is lower. And, in some rare cases can also show some high readings very high readings, it is just malfunctioning right, it is contaminated it is malfunctioning. So, you have no way of saying what is the safe range? And, you have to note that when you talk about MAF, you cannot generalize a given number, depends on the engine, type it depends on the manufacturer.

So, many related parameters. It will just give you a number and send you that, this is what the issue is, it will tell you about the issue. Now, what should be the table which corresponds to air flow and current consumption and all that, that will have to be based on the type of MAF sensor that is being used for that given engine. So, that you have to note in mind, but never the less it gives you an idea that, you can do a troubleshooting with this.

So, I will just summarize all this the air flow will essentially depend on what it will depend on the engine volume, which means from different engines will have, different values.



So, it is an important point you have to make a note. So, also you have to note that this low air flow. So, when you say low air flow. What does it mean? Does it mean that there is a bad sensor not necessarily? It could be the filter. The MAF could be clogged. If, you perhaps replace the air filter, the air flow may come back.

And therefore, it is useful. So, mechanic actually will be able to have the trick of saying whether the MAF has gone bad, or whether it is really the air filter that is clogged. So, that is a lot of practice.

But, you know if you are able to capture that wisdom into algorithms in an effective manner, then you have actually used IOT sensors and embedded programming to solve a very important problem in vehicles. See before we go on to show you a demo of this I want to tell you where IOT will actually come in here, this lot more things that you can do in terms of algorithmic work. We should take 1 or 2 use cases of an algorithm and try and implement that algorithm in it.

So, let us spend little time on understanding a simple way to sort of track the sensors, sensors and how we can model something about the sensors in an automotive world.