Fundamentals of Electric Vehicles: Technology and Economics
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Lecture 14: BMS Design of Electric Vehicle - Part 2

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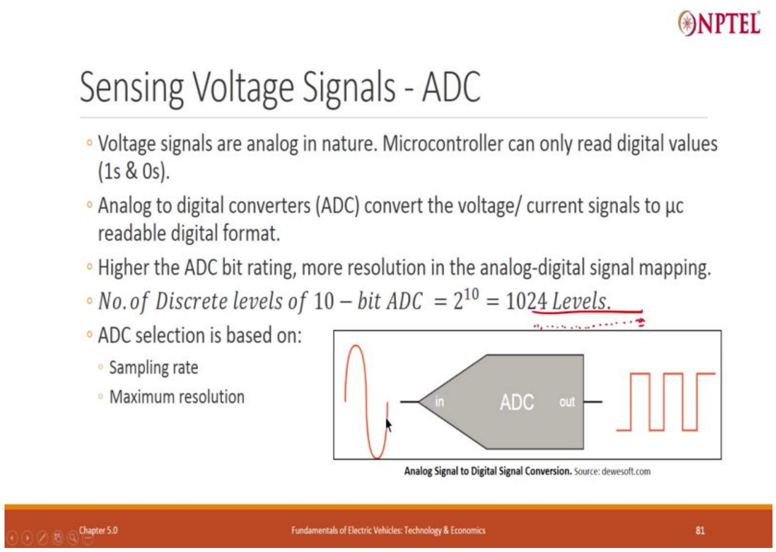

So, for a 10 bit ADC what we have, 2 to the power 10 level, so that means if I am converting this line into digital signal, this is the analog, this solid line is analog. However, this dotted line is digital signal, so I am converting this into 1024 levels that means I have 1024 dots here. If it would have been 5 bit ADC, what would, what would be the resolution in that case? So, 2 to the power 5, 4, 8, 16, 32, so 32.

So, that means only 32 dots are there in between these end to end point. So, higher the bit of ADC you can have better resolution. So, ADC selection is generally based on what is your sampling rate, 10 millisecond, 100 millisecond, or 1000 millisecond, or 100 microsecond. And, what is the maximum resolution you require. So, what you are getting an analog signal in, and what you are getting out is a digital signal, as a 0 or 1, 0 or 1 here, but it is everything between 0 and 1. Any question till now?

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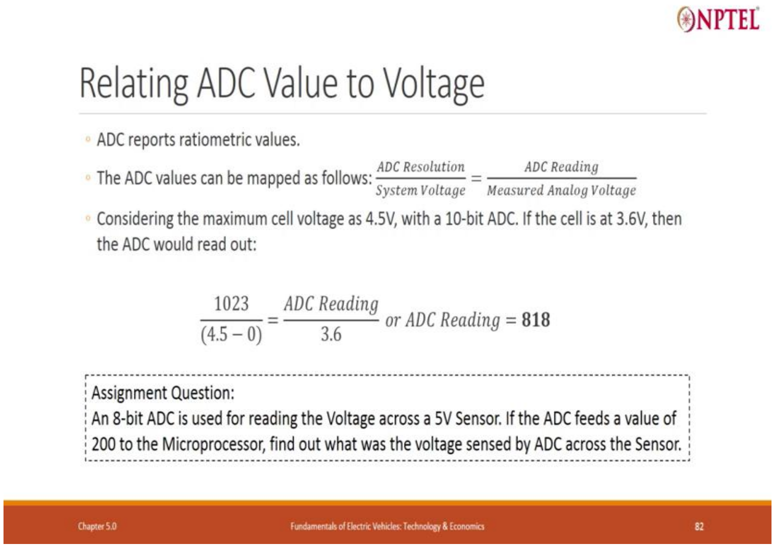

Now relating ADC value to voltage, it could be current, it could be temperature as a example I am putting here, a relating ADC value to voltage. So, how do we relate our signal, analog signal to the digital signal? So basically ADC reports ratiometric values. So the ADC value can be mapped as fellow, as follow, ADC resolution, what is the ADC resolution which we have just talked now, for that you need to know what bit of ADC you are using from that you can get the ADC resolution by system voltage and that is what ADC reading but measured analog voltage.

So considering the maximum cell voltage as 4 point 5 volt with a 10 bit ADC. What is the 10 bit ADC's resolution, 0 to 1023. Now, if the cell is at 3 point 6 volt, what ADC will read out? Simple, so total 1023, 0 to 1023 divided by what is my range, 4 point 5 volt to 0 volt, that is system voltage. So what is supposed to be the ADC reading for 3 point 6 volt? We do not know, we need to find out. Bottom is 3 point 6 volt.

So for that ADC reading comes 818. So total level of 1024 or 1023, for that, for this ADC reading is where, it is 818. This is how we convert from analog voltage to digital voltage. 818, 818 can be written as binary form, that is what microprocessor reads. Here I am giving you a simple arithmetic thing, 818 level can be written back as in binary form. So that microcontroller can read that one.

Now a small assignment, an 8 bit ADC is used for reading the voltage across a 5 volt sensor. If ADC when I say 5 volt sensor means 0 to 5 volt. If the ADC feeds a value for, value of 200 to the microprocessor, obviously it does not fit 200 to the microprocessor, it fits corresponding binary value to the microprocessor. Find out what was the voltage sensed by ADC across the sensor. Similar way, now you have formulation, feed all these values, you can get the result.

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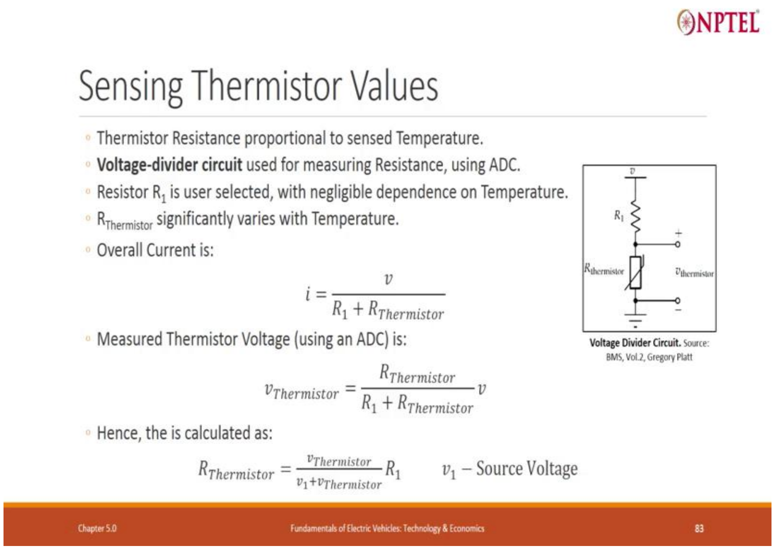

What another important thing is sensing thermistor value. How do we do that? Here I will not talk about ADC, I will talk about how the thermistor works, because once you know how thermistor work it can always be converted to digital signal. Generally, a voltage divider circuit is used for measurement of resistance, how does a thermistor works, it works basically with the principle of resistance, voltage. And this resistance is basically a variable resistance, depending upon the voltage, depending upon the temperature, the resistance changes, so voltage changes.

So, generally we select a resistor R1 with negligible dependence on temperature. That means, this additional resistance will not have any or if it has, it has negligible (dependence) dependence on temperature. However, resistor resistance is dependent upon temperature, this is the external resistance. This is thermistor resistance, but thermistor resistance is dependent upon temperature it changes in change in temperature.

So, overall current if you measure in this path, overall current i equal to v, R1 plus R thermistor. The measured thermistor voltage using ADC is v thermistor equal to R thermistor divided by R1 plus R thermistor into v. So, how do you calculate? R thermistor is nothing but you just rearrange all this terminology that becomes v thermistor divided by v1 plus v thermistor into R1 where v1 is a source voltage, what you are providing source voltage here. Any question on this?

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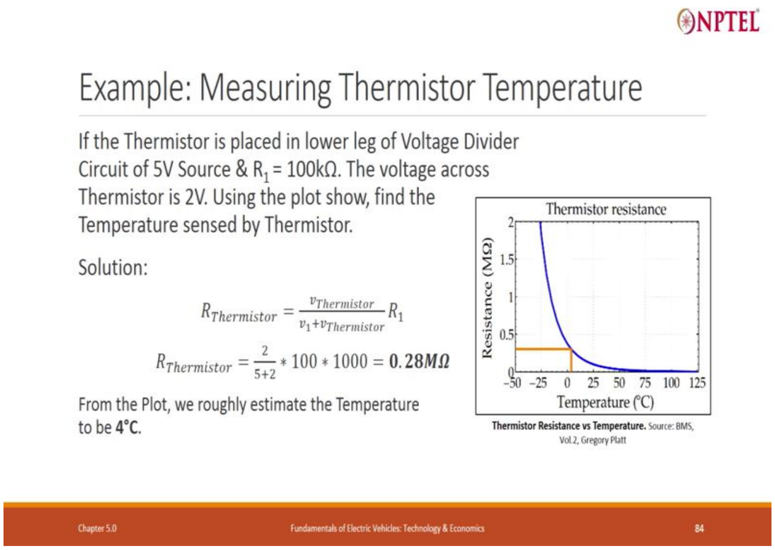

So, there is a small example how do we do that. So, if the thermistor is placed in lower leg of a voltage divider, this is lower leg of voltage divider of 5 volt source, so your source voltage is also known as 5 volt. And the resistance R1 which we select as a external resistance is 100 kilo ohm. The voltage across thermistor is 2 volt, this v thermistor is 2 volt. Using the plot (show), plot shown here find the temperature sensed by thermistor.

So, what is R thermistor comes here is 0 point 28 mega ohm. Now, for that particular resistance we have the temperature, this is tabulated experimentally. What you are measuring basically is, is voltage which is connected back to the resistance of thermistor and then we have already a measured or tabulated form where if I know the resistance I can say what would be the temperature.

So 0 point 28 ohm, my temperature is 4 degree centigrade, because now I have a temperature versus thermistor resistance plot. How do we do this? What we do, we convert this line into tabular form and that tabular form we feed into microprocessor or in flash memory. So whenever it is what is sensory is sensing is resistance or in fact voltage, across the thermistor which is converted back into the resistance and then resistance is mapped, is matched to the map value in a stored table, and then it says this is a temperature now.

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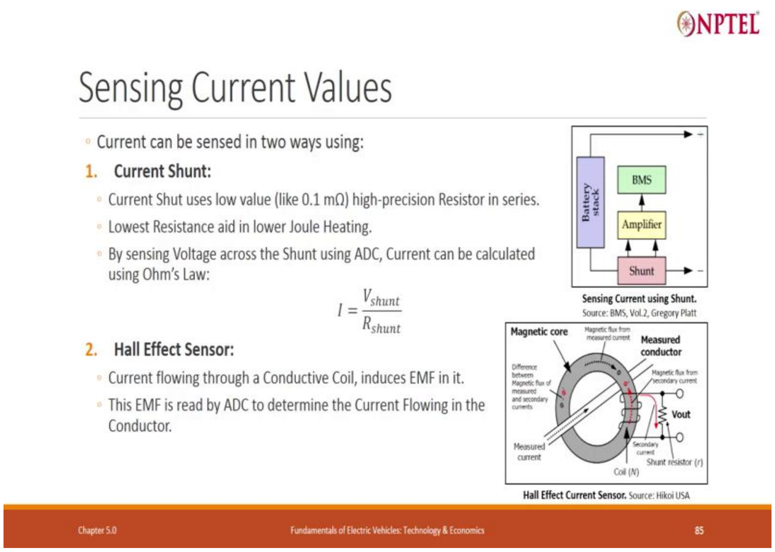

Sensing current values, current can be sensed in two ways; either using shunt, current shunt or using Hall Effect sensor. So, the shunt what we use, is having very low value of resistance and we know it is a very precise, we measure it precisely, and would be in series. Why, why low resistance? This also helps that it will not get heated up. And what we do, we measure the voltage across the shunt.

And then from the formula I is nothing but V shunt by R shunt, what is the voltage and what is the, because we know resistance of shunt, we have measured the voltage, we know what is the current flowing on in. So that is why R shunt, when we say we already know that means it is a very precise value, it is already measured. So, it is already calibrated in the, in the manufacturing unit. Second one we use mostly is Hall Effect sensor.

So, the current flowing through a conductive coil, so here current is flowing like this there would be a wire over that you put the hall sensor. So it, because of this a EMF would be induced in the coil in Hall sensor and this EMF, what is EMF, electromotive force, it is basically voltage. And based upon this EMF measured here we estimate what is the current flowing in the wire.

We use it lot of places non-contact type of measurement is always being done by this, however in shunt you have to, it has to be in path. However, for Hall sensors, it need not to be touching anything, it is a non-contact measurement. But then your wire and everything has to be properly aligned with, otherwise it will give you variable voltage or variable EMF which may not be correct. So the position, the wire crossing through this has to be maintained properly.

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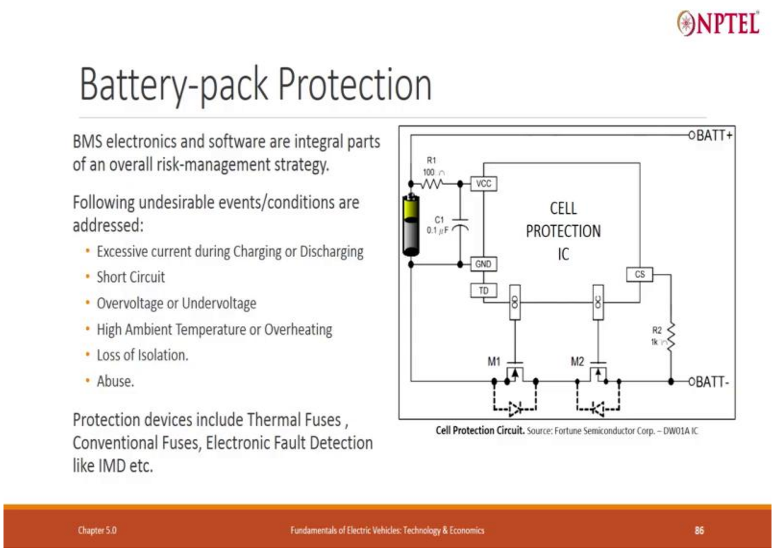

Now, next we will move first then that part. So, what was needed first, measurement. So we have discussed about measurement. The second important thing is safety because unless we do not measure we cannot provide any safety or we cannot provide any protection.

Student: (())(13:19).

Professor: I will come back again at the end. So the BMS electronic and software are integral parts, and both work together to provide overall risk management. So, if I have to protect the cells, it will be connected with different sensors and all those thing, connectors, open, close and all the condition. In any time if we see the excessive current during the charge and discharge, so either we send a signal that reduce the current or it will close, or it will open the contactor or MOSFETS or relays.

In case of short circuit, now there is a high current surge there, in such cases it can detect and that, that frequency is in microseconds, 100 microseconds, it will detect and immediately switch off or open the contactor or open the MOSFETS, so that no current flows. Over voltage or under voltage, during the charging, it can go to overvoltage, as soon as that happens it senses and it protects no more charging that means it is again cut off the current, or open the contactor, or open the MOSFET.

High ambient temperature, if my system is designed for some particular temperature limit and you are going through a fire, nearby fire so, it may detect as a abnormal condition, very high ambient temperature in that case, again it will try to cut off and isolate the system. In case of loss of isolation, either your wire insulation has been removed by wear and tear, or accidents, so it will lose its isolation.

So, it will immediately protect the battery pack by cutting off, or isolating itself. In case of abuse, you try to accelerate very high, it will demand lot of current at that moment. What it will do? It cannot control the exact current how much it is going, but what it can control, I will not allow any current to go by opening the contactor or by opening the MOSFET switches.

The protection device includes thermal fuses which is not dependent upon BMS, but however, there is a, it can, beyond the rating of the fuse it will open up. So, it will basically isolate your system, it will not allow any current to go beyond a particular temperature. Conventional fuses, it will burn and it will open up the circuit. Electronic fault detection, like IMD, insulation monitoring device.

So, some of these devices may communicate with BMS, but these are also independently can stop an abuse condition or a safety concern. Sometimes what happens when you are connecting motor, there is a short in motor, what it will do? It will try to draw more current, so the fuse will go, even BMS has not taken, if BMS somehow handle that moment has not taken a preventive action, this is, this is independent redundancy, so fuse will go away.

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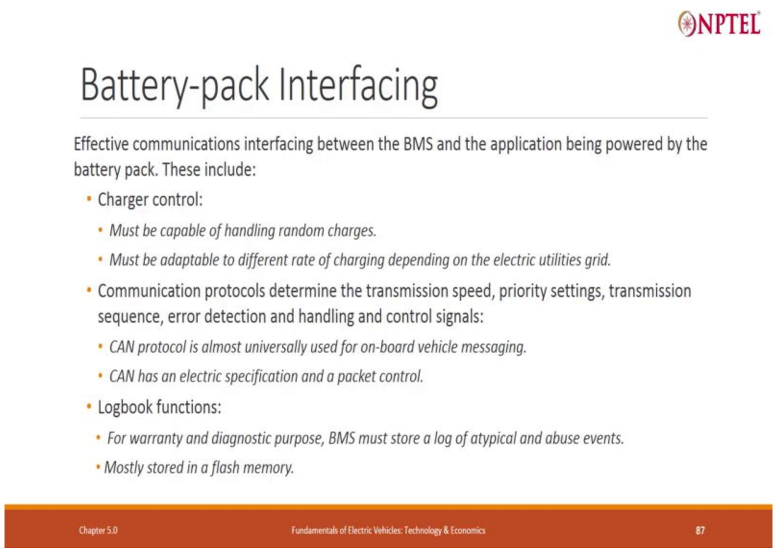

Now interfaces, so battery has to interface with a discharging unit, maybe motor or a charging unit, a charger. So, it had to communicate while charging with the charger, while discharging with the units like motor or vehicle. It should be able to give you the, the required current, it should be able to take random charges, obviously within the limit, what limit you have already set in. The communication protocol determines the transmission speed of energy priority setting, what is your priority, you want to charge it fast or you want to charge it slow.

Transmission sequence between one hardware module to another hardware module, within the same hardware module also, which incident is or which, which one is the most important sequence, a communication between MCU and current sensing IC is most important or a communication between MCU and contactor is most important, it can, you can, it can set the priority. So in safety events, communication between MCU and contactor is most important.

So, these all the flags interrupts can be set upon. And how does it communicates with each other, the most widely used communication protocol is CAN and it has its own specification and packets, packets is data control. Logbook functions, in case of any event going beyond the limits, it will log. Where it will log, in database, in flash memory. Any abuse event and not a typical event which you do not, which you do not encounter on day by day basis, these are logbook functions.

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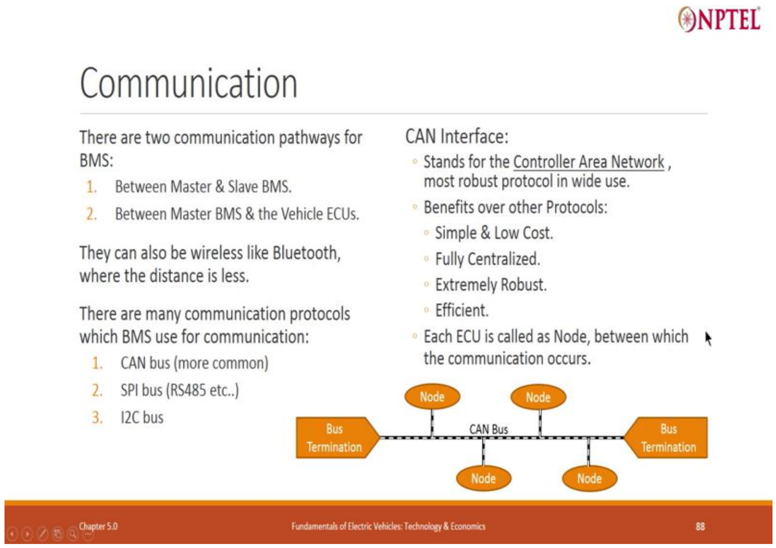

Now (communicate) communication, there are two communication pathways between master and slave BMS, this is one of the architecture where master BMS is separate, slave BMS is separate. So you need to communicate between BMS and other, like with charger or with a vehicle or with a motor controller. They can be also wireless like Bluetooth where the distance is less or WLAN. So, what are the communication protocol generally used for BMS function? CAN bus, it is, it is a quite common most of the places. SPI bus RS485, you would have heard most of the time.

I2C bus, there is another communication also Modbus, one mode, daisy chain these are proprietary to some particular companies. So what CAN interface stand for, Controller Area Network, most robust protocol in wide use and that is why it is most popular. What is benefit over other protocols? It is simple and low cost, fully centralized, extremely robust, most efficient on other, what we have talked about I2C, SPI. Modbus, daisy chain.

So the CAN, the CAN interface or CAN communication is widely used because it has a simple and low cost, fully centralized, extremely robust, efficient. Now how does it look like? Each ECU, each control unit is considered as one node, the CAN bus is running through, it is connected with that CAN bus and based upon the priority set by microcontroller, it will be taking commands from each of them, you have done or not done, this work is done or not done, based upon the interrupt signals. Any question till now?