Power Management Integrated Circuits
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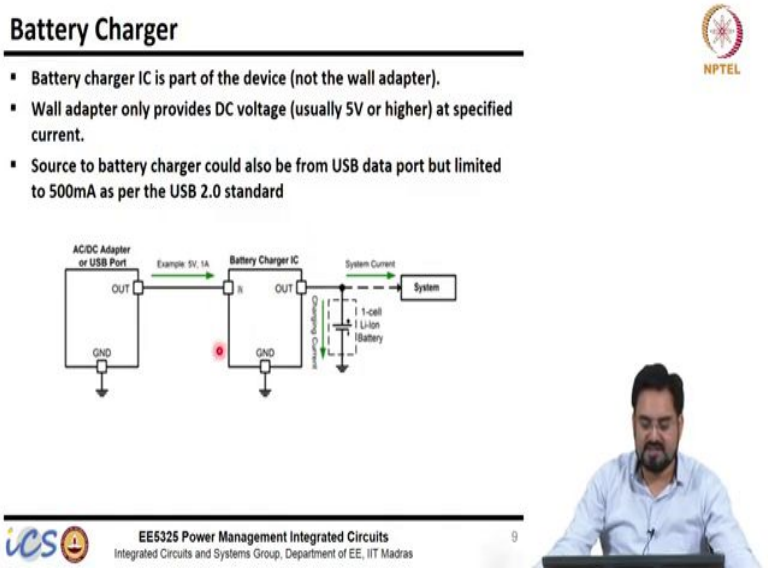
Lecture – 103
Battery Charger IC

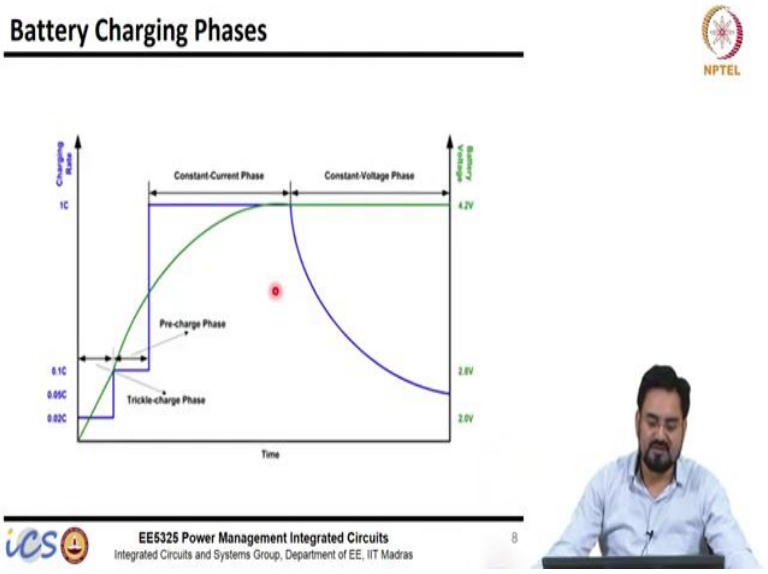


Most of the time, you refer to that wall adapter as your charger but that is not a charger, that is simply an AC to DC converter that takes you 220 volt main supply and converts to 5 volt USB standard. But that is not charging your phone, it is supplying 5 volts to the phone from where your battery is getting charged. So, the charger is sitting inside your phone. The adapter is not the charger, it is only supplying voltage.

Most of these wall adapters will have a specification printed which will say what is input and output. Input will say 220 volt AC and output will say 5 volts 1 amp or 5 volt 500 milliamp something. So, 5 volts will always be there because it is a USB standard and the current may vary. So, if you buy a more expensive wall adapter this current may be higher because you do not know what kind of maximum current your phone can support it all depends on batteries.

So, if you let us say the phone can support 2 amp, but the wall adapter you have plugged in can only supply up to 500 milliamps then your charging will be very slow in that case. So, if you really want to utilize the full capacity of the battery, then your wall adapter should be compatible with your charger specification.

See your USB has four ports; one is your supply, one is ground and the other are D + and D -. So, those are data lines and the data line is completely different from this and you can have a dedicated USB cable for charging only, then D+ and D- will not work at all. So, if you connect that cable for communication purposes, it will fail to communicate. So this takes input from your wall adapter, 5 volts, and then at the output of this charger your battery is connected.

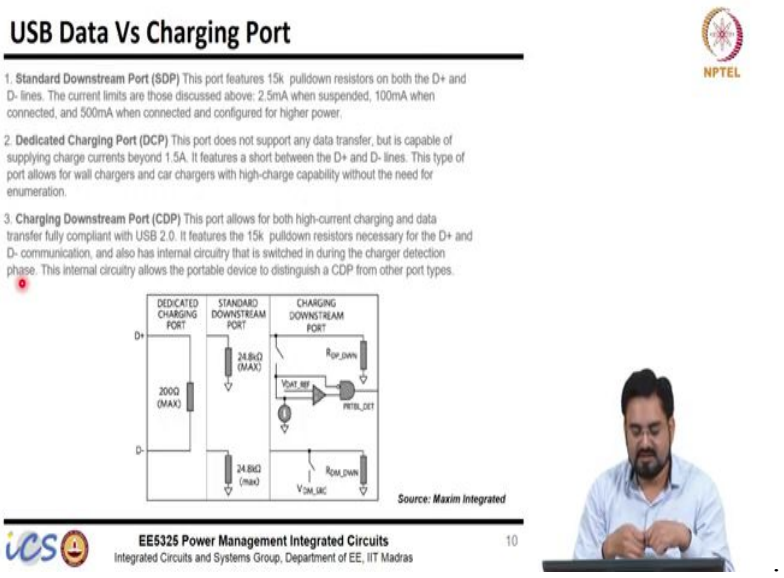


And it basically controls the current based on in which phase your battery is and when it is fully charged, this will cut off this current and will stop drawing any current from your wall adapter. So, sometimes some people say do not keep your charger plugged in for a long time it will reduce the life of your battery but that is not true, this charger takes care of everything. When the battery is fully charged, it will automatically cut off. When I say your battery has a charge discharge cycle of 1000, it is measured with a full charge and full discharge. But if you allow only 10 percent discharge after 90 percent you again plug in then you can get 10000 cycles of charge and discharge.

And also when your battery is fully discharged, the stress on the battery will be more and, but when you do not allow your battery to discharge below a certain level then stress on the battery will be low. If you are charging your battery with a full current for a long time then chances of heating are more. The chances of changing the chemistry of the battery are more at a higher current compared to a lower current.

So, when you never allow your battery to discharge to 0 percent, then you will never leave your battery in pre charge phase for a longer time then you can increase the life of your battery. We fully discharge and charge because we want to measure the capacity of the battery. So, unless you complete the full cycle you will not know the battery capacity. So, in order to measure the capacity of the battery, I have to start at 0. If I am starting with 50 percent, I will not know what capacity the battery has.

A wall adapter only provides DC voltage, usually, 5 volts in case of USB standard or it may be higher in case of fast charging. In fast charging, it requires higher voltage and that will be at a specified current. The source to the battery charger could also be from the USB data port but there is a big difference between the wall adapter and USB data port. The Wall adapter will be charging at 1 amp or 2 amp and the USB port will be charging only at 500 milliamps. The reason is that the USB standard does not allow output current more than 500 milliamps.



USB data versus charging port. So, standard downstream port, which is called SDP. This port features 15 kiloohms pulldown resistors on both D+ and D-. With these resistors, it will determine whether it is a dedicated charge port or a data port. The cable you are plugging in whether is a data cable or it is a charging cable.

Even though the same cable can be used for data as well as a charger, but if you require a very high current for charging your data does not require that much current. So, the quality of the cable which is used for data can be much lower compared to charging cable and the cost will also vary. Let us say you can buy a data cable for 10-20 rupees but if you are looking for a high quality charging cable it may be 200, 300, or 500 rupees, especially if you look for an Apple phone cable it will be very expensive.

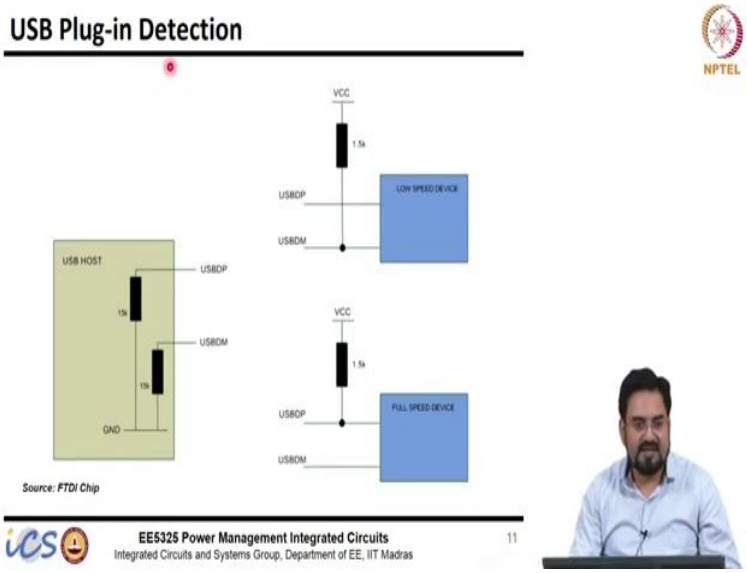
So, then this is from a USB standard itself. So, the maximum value of this resistor is 24.8 kiloohms in the worst case. Based on these resistors which are connected between D+ and D-, your phone will detect whether it is a dedicated charging port or it is a standard cable and this value is very easy to detect, you can just source the current and look at the IR drop or you can put a constant resistor with a Vdd and it will act as a voltage divider.

If you have a dedicated charging port then D+ and D- are shorted actually. So, you cannot use this for communication purposes. In that case, the cable will be only used for charging. So, that cable will not work if you want to transfer any data over USB but it will support a much higher current. In this case, you do not even need to run the two separate wires, you can only have two wires which are your ground and supply because it is a dedicated charging port, D+ and D- are short. These resistors will be mostly connected on the other end of your connector, but your cable is running all the way from your adapter to the other end. So, you can save two wires here. In the same thickness, I got rid of two wires which are data cables and I have increased the thickness of the supply and ground wire. So, it can support a much higher current. That is why these dedicated charging ports do not support data transfer. It is capable of supplying your current beyond 1.5 amp and features a short between D plus and D lines by connecting a couple of 100 ohms resistors between these two.

This type of port allows for wall chargers and car chargers with high charge capability without the need for enumeration. Enumeration means when you connect your USB cable or your USB device, so it goes through an enumeration where it detects what kind of device it is. It is just detection of your USB that is it. Just like when you plug in your USB, it will detect what has been plugged whether it is a real USB device or not based on that it will take the next decision.

Charging Downstream Port (CDP) allows for both high current charging and data transfer fully compliant with USB. So, this guy actually can do both things. It is a combination of high current charging as well as data and this is a much higher quality cable. It features the 15k pulldown resistor necessary for D plus and D minus communication just like this.

You have to support this pulldown resistor in order to communicate over the cable and also has internal circuitry that is switched in during the charging detection phase. When the charger is connected then it will go into the charging phase and when you are transferring the data then it will allow these pulldown resistors to be connected. It automatically detects whether the device you have connected is a wall adapter charger or it is a USB data transfer device.

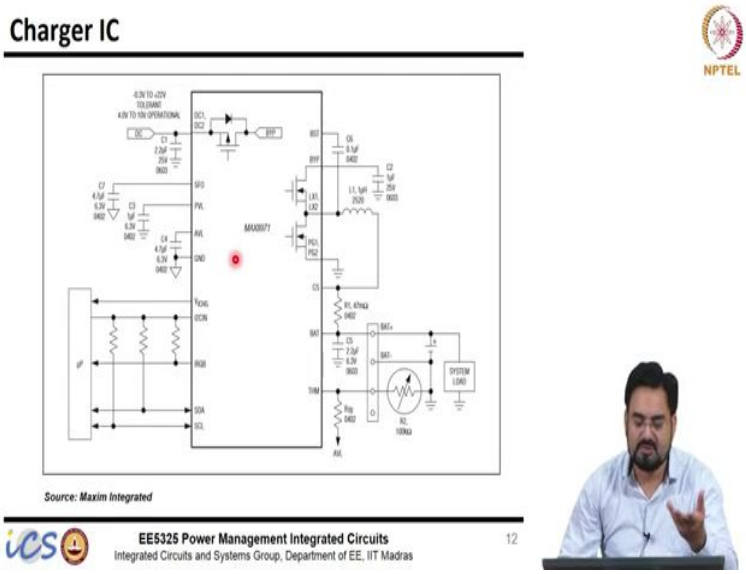


USB plug in detection: when you connect your device or your charger, as I mentioned there is a 15k resistor here with the ground. So, when you connect, you can have a pull-up resistor and then you will get a voltage in between. So, between VCC and ground level depending upon so, this will be 15k over 15k plus 1.5 k. So, it is pretty close to your VCC, slightly below that.

This is a low speed device and if you have a full speed device, the only difference is that the resistor is connected to the negative port in this case and in this case, the resistor is connected to the positive port. So, depending upon where the resistor is connected on the device, it will be detected as a low speed or high speed because in the USB you have two standards; low

speed or high speed. High-speed USB is like 400 Mbps or so and low speed will be 12 Mbps or so.

You can say that standard is improving, but usually what happens, a higher standard is back compatible with the previous standard. So, when you build a host controller, it has to be compatible with everything. So, your device can have a different speed, but your host has to support everything. So, when we say low speed device and full speed device that means, they are two different devices and you can relate that to your USB standard. Now, you have USB 3.0 that is a much higher speed.

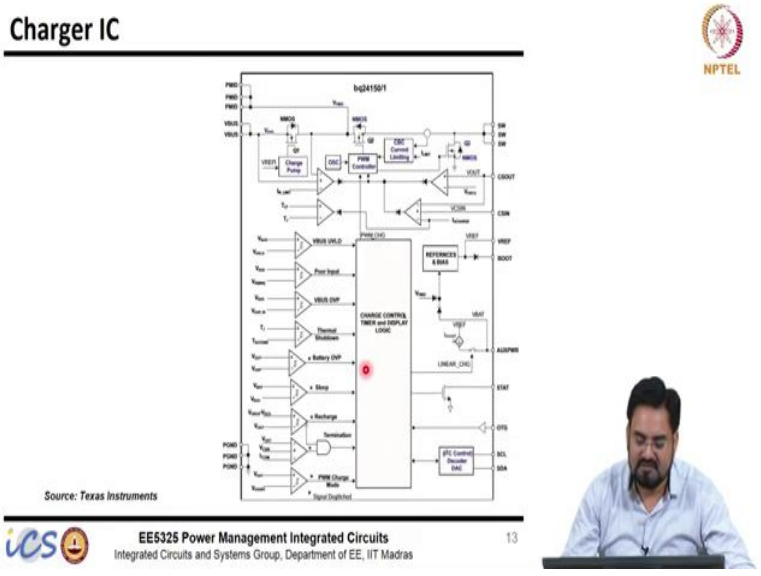


This is how your charger IC looks like and the core of this charger is a buck converter. As I mentioned earlier, everything is built around your DC DC converter, all your advanced power management systems are built around DC DC converter. The core is a DC DC converter that takes the 5 volts from your wall adapter and since the role of this is to supply a constant current. So, this works as a constant current just like your LED driver. So, the LED driver supplies a constant current to the LED and we need to sense the current for that. And we looked into the camera flash. So, it is quite similar to that and the camera flash was drawing like 1 amp and you need to sense the current.

So, sensing can be done by an external resistor. In battery case, accuracy is more important. When you are charging with the full current, then if the battery does not allow you to charge above that and you want to maximize the charging current then you have to make sure that it

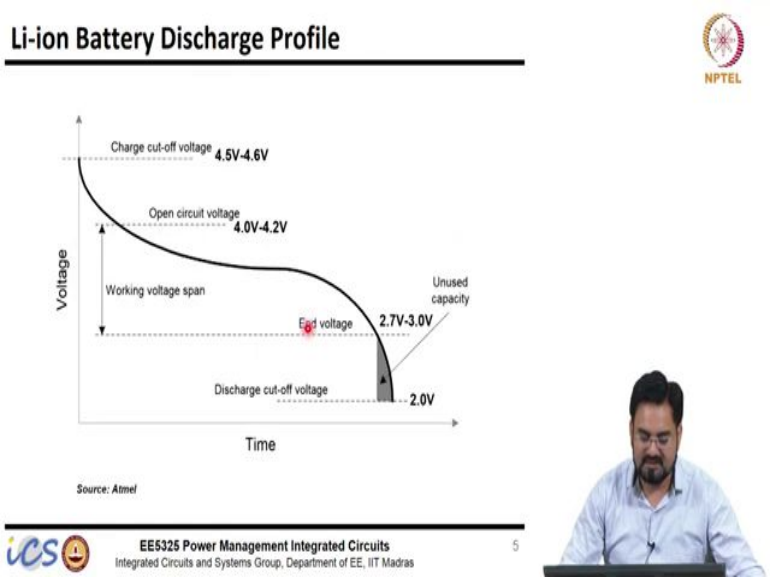
does not cross even 1 percent higher. So, that is why accuracy is more important here. So, in order to get a very high accuracy most of the time, you put an external sense resistor because that is the most accurate.

This is VBAT and that is where your battery will be connected on VBAT then this is your thermistor terminal which is connected to the thermistor and this is your battery. So, it has a BAT plus BAT minus and then the other terminal is BTH and the fourth one was your BATID. So, in this case, BATID is not shown because this looks like a three terminal battery. So, this end is connected to the battery, and then from the battery you have a series resistor and this will give you the current sense. This resistor is fixed and very accurate and whatever voltage drop you get across this it from there you can measure the current so that you can regulate. So, this will be fed back. So, this voltage will be fed back to the controller and that will modulate the duty cycle of this to make sure the current remains constant. After that everything is like a standard voltage mode buck converter which we discussed in previous topics.



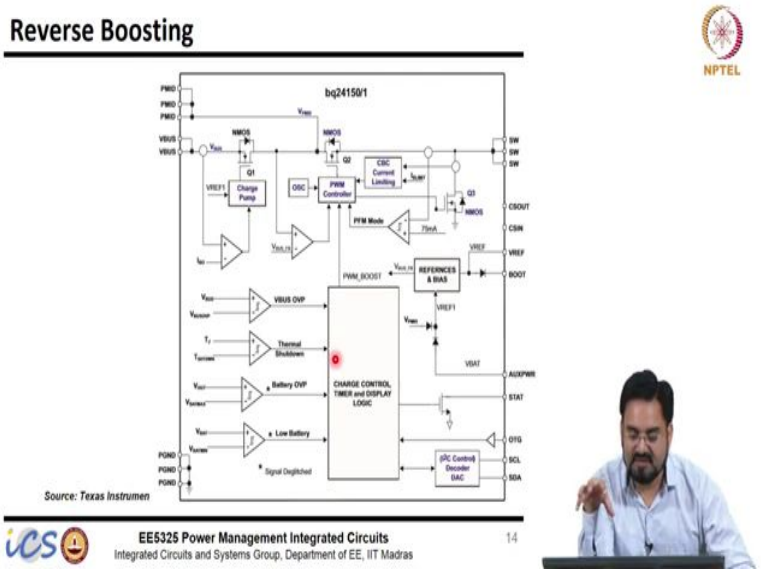
So, there are a lot of other things in your charging. We know that it has to maintain a lot of phases, it has to go between your constant trickle charge then your pre charge phase then constant current and constant voltage phases. It requires a lot of comparators, that is why you see too many comparators here. So, for thermal shutdown you need because you need to detect the voltage across that thermistor and then take the decision.

So, you need to again compare it with some reference in order to enter from constant current to constant voltage phase, you again need to compare the voltage when it is fully charged, again you need to compare the voltage because everything is based on voltage levels if you see this guy here.



If you are between this to this voltage level then it will be your maximum current. If you are above this then you have entered into constant voltage mode, below this you will be in a pre-charge phase, here you will be in a trickle charge phase. So, a lot of comparators are needed here. From 1 bandgap you can tap multiple voltages based on your requirement and then after that everything is done by the DC DC converter.

Then you have a switch here and this switch remains open when your charger is not connected and only closes when your charger is connected because you do not want to allow a reverse current or something from there. In some cases, we allow reverse current, but that is a separate purpose which is the next I will talk about, but this will only turn on this switch when you plug in the charger. It will detect that the charger has been plugged in then it will close the switch and then it starts running this buck, but if you are not charging then you do not need to run this buck.



So, this is something called reverse boosting. Let us say in one case I am charging and in the other case let us say I am connecting and in this USB port you can connect so many things. The charger is one thing and charger is sourcing current but let us say you have connected the flash drive here, just like in the computer you connect to the cell phone, this flash drive will get the power from the USB port itself because they do not have any battery. So, this is a charging port for your phone. Now, if I connect a device here which needs to be powered then it has to be powered from the phone again and that power has to come from this guy. So, again as per the USBs standard this voltage should be 5 volts and my battery's maximum voltage is 4.5 volt or so. So, it needs to be boosted.

In a boost converter, you just interchange the input and output. So, when you are charging this acts as an input port, where you are supplying 5 volts from your wall adapter and your inductor is supplying current to the battery. When you are connecting a device here which needs to be powered you close the switch again and now your battery voltage becomes an input and this becomes output which is supplied to the device. So, you are boosting your battery voltage to whatever level it could be. It may be 3 volts or 3.5 volts, but you have to maintain 5 volts here on the other side. So, it will work like a boost converter in the reverse boost mode.

The same converter can be used for buck or boost. So, the advantage is you are saving one converter here because you cannot charge when you are connecting your device, it is only

one port, you can use it only for one purpose and you cannot use it for multiple purposes at a time. So, when you are charging it will act like a buck and when you are connecting a device that needs to be powered you will boost it and put it in the boost mode that is what we called reverse boosting.

And it can be used for any other purpose, internally also you can utilize it, not just for the external device. Let us say internally your flash requires 4 volts or so, your camera flash requires 4 volts then again it needs to be boosted. So, in that case, you can just utilize this when you are clicking a picture or anything, but in that case, if you are utilizing it for internal purposes as a boost then when your charger is plugged in during the time you are utilizing for other purposes the charging will stop actually. So, if you are using it for camera purposes and all those it is not a very long duration, so you can use it. The main purpose here is like I want to save one converter here and use this single buck converter for multiple purposes.

So, there will be a tiny controller inside which will basically decide when to enter which phase, USB detect, battery plug in, and plug out detection. So, let us say you do not have a battery and you plug in your charger. So, it will not charge anything as such. So, you have to detect the battery presence also whether the battery is there or not. So, there is battery insertion detection, battery removal detection, charger insertion detection, charger removal detection, everything is mostly done by this charger. So, a lot of functionalities are integrated around this buck converter in the charger.

There is a separate IC which we call BMS or Battery Management IC. Here sensing is being done in order to make sure that you are charging at a proper current which is required by the battery, but there is one more sensing is required or for the BMS; battery management system which basically measures the capacity of the battery. So, that is a separate portion where you require a lot of processing actually. So, you need to do Coulomb-counting and everything, take this data then you have to map that into a proper battery model and determine the state of the charge. So, when you are measuring the battery capacity or level of the charge battery, then a lot of processing is required there. So, that is a part of BMS.

So, you have to build a complete algorithm there, but most of the time that algorithm is part of software actually, you do not build those in the hardware because you already have a

processor on your phone, why do you want to put a lot of processing in that device. So, you can save a lot of hardware. So, most of the time, the measurement portion is there and all the processing is pushed into your processor site and into the cell phone itself.

And that is more logical, I mean you already have a high processing unit here then why do you want to use separate hardware in order to do the same job. Unless you require an autonomous battery, but most of the time your cell phone is running. You do not want to measure battery capacity when the cell phone is off.