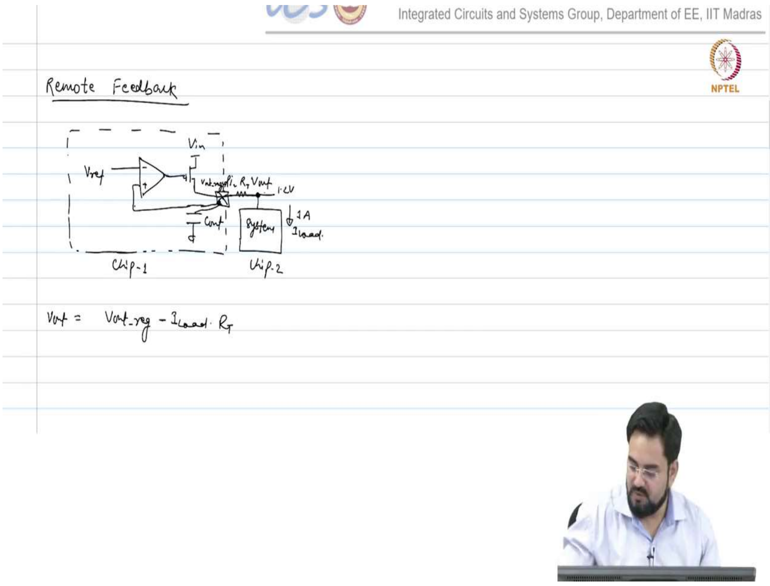
Power Management Integrated Circuits
Dr. Qadeer Ahmad Khan
Department of Electrical Engineering
Indian Institute of Technology, Madras

Lecture – 05
Local vs. Remote Feedback, Point-of-Load Regulators

Consider linear regulator example. So, my system requires 1.2 V and it is drawing 1 A current. So, on your board you have a two chip module where your regulator is one chip. It is an off-chip regulator not integrated in that system and you have your system which is integrated into a different chip.

Just like we saw the mobile example. You had a PMIC which is supplying voltage to the different other modules which could be your RF wireless transceiver or your audio amplifiers or audio processor. So, just assume that you have a two chip module on a board as shown in below figure.



Local feedback:

While connecting on board, the best you can achieve if you take the feedback from the pin($V_{out,reg}$) and your capacitor is also connected to this pin. Usually that is how you do actually, you try to keep pass FET as close as possible to the pin of your chip, so that you do not add any parasitic resistance. So, this linear regulator has a local feedback since we are taking feedback locally from $V_{out,reg}$ and we are regulating that voltage.

So, you have traces running and these traces will have some parasitic resistance, say R_t. So, system will see a lesser voltage than the required.

$$V_{out} = V_{out,reg} - I_{load} R_t$$

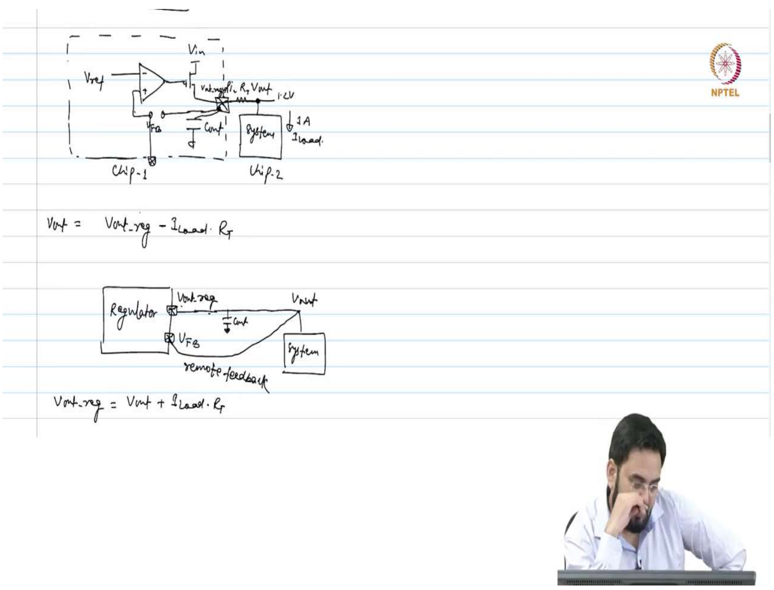
Which means more the load current, your output will drop more but your system has some accuracy requirement. Let's say if R_t is 12 mΩ and load is 1 A then 12 mV drop in the output, which is 1% of output voltage. But 1% error is supposed to be huge actually in terms of inaccuracy. So, how can we fix this.

Student: Wires width can be increased.

No, but that will cost something. You will need more space on the board but you have limited space. So, you cannot just make your wire as fatter as possible.

So, you move your feedback point. Ideally, I want to sense the point which I want to regulate. So, why do I need a feedback from pin rather than I would like to take the feedback from remote point.

<u>Remote feedback:</u> When you design your regulator, you provide not only V_{out} pin but also feedback pin (V_{fb}) so that it can be connected to the farthest point as shown in the below figure.



So, instead of taking feedback locally (from $V_{out,reg}$) take feedback from V_{out}. This is your remote feedback. Now the voltage at the input to your system V_{out} is regulated to 1.2 V.

And the local voltage at the regulator is higher than 1.2 V. And it is given by

$$V_{out,reg} = V_{out} + I_{load}R_t$$

Is there any drawback of this?

Student: R_t and C combination will add a pole.

R_t is very small? R_t is in mΩ, so this pole will be at very high frequency.

Student: More pins means more expensive.

Ok, that is a cost factor, one more pin. What about the efficiency? Will it increase or decrease or remain the same?

Student: Efficiency will decrease.

Why?

Student: Because power is being dissipated in R_t.

But, that was happening earlier also. So, there are a few things here you need to look into. So, when $V_{out,reg}$ was regulated at 1.2 V, V_{out} was below 1.2 V. Let's say your system is a switching system, then CV^2F losses will be slightly lower because system input voltage was reduced. But now with remote feedback, you are regulating the $V_{out,reg}$ or local voltage slightly higher. So, the dropout voltage across the FET is now slightly reduced. So, they may compensate.

So, overall efficiency may not affect much if you consider both the cases. In one case you are gaining efficiency from your system, in the other case you are gaining from your dropout voltage.

I^2R loss is there in both the cases because trace resistor is there, current is flowing. So, whether you do it or not your I^2R losses will remain there. If your accuracy is more important, then you do not have any option you have to do this remote feedback.

Is there any other way I can fix this without putting this remote feedback?

Student: Increase the V_{ref}.

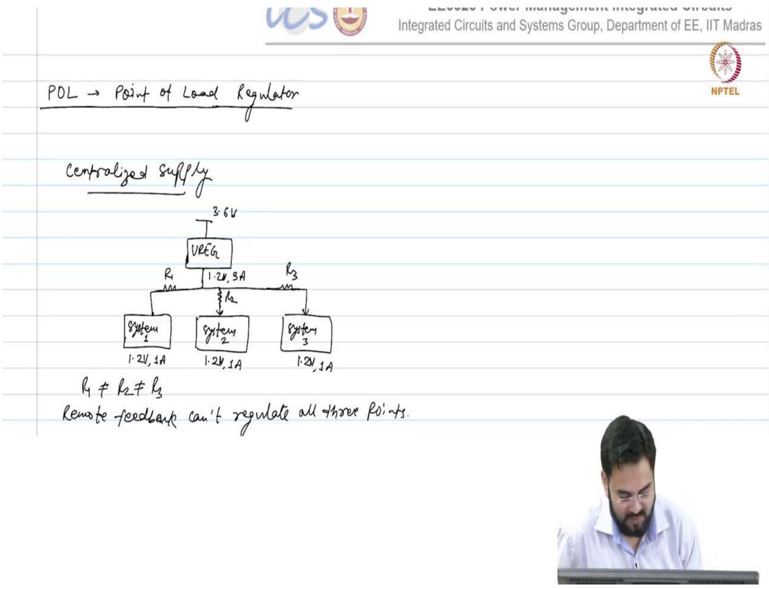
Yeah, you can slightly move the V_{ref}, but you need to know the resistor value or the drop. So, you know that your current is fixed and you can calibrate initially. You can measure and see if V_{out} is coming 1.2 V or not. You keep on changing the V_{ref} unless your output becomes the desired value you need. And you need a fine regulation depending upon what accuracy you require. For example, if you want within 1 mV then you have to change your V_{ref} by 1 mV step.

So, without changing the feedback you can do that, but you have to do that for every load current. When the load current changes then again, this drop across the trace resistor will change and you have to move V_{ref} up or down.

<u>Point of load:</u>

We call it point of load regulator, which means you are putting the regulator at the load point actually. So, you may have two cases.

1. Centralized supply: Let us say we have centralized supply to three systems as shown in below figure.



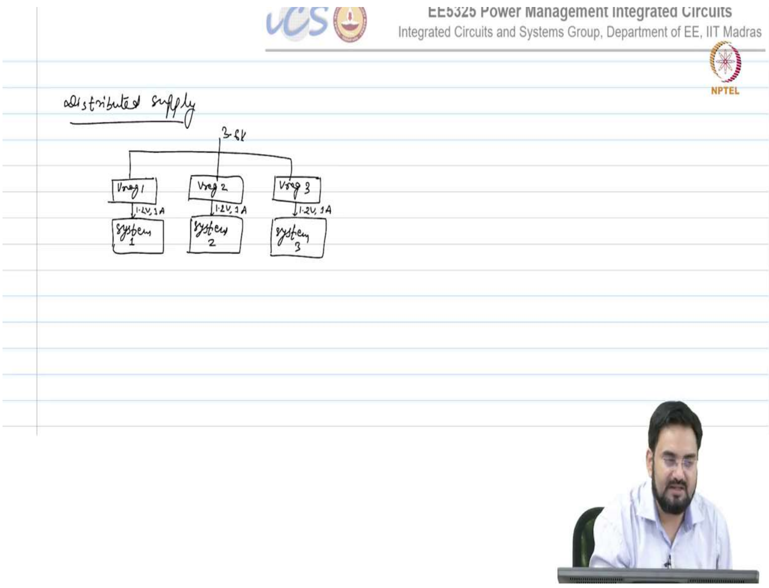
So, the regulator is giving output voltage of 1.2 V with 3 A current and you distribute it to these three modules. Now, can we take remote feedback in this case?

Since these are distributed systems, you do not know which one to take. If you take remote feedback from one system, then other systems might see different voltage because other systems might be at some different location.

So, the trace resistance of all three will be different. In the best case you can have the remote feedback from the point which has a maximum trace resistance. So, others will always be higher and the voltage would not be dropped. But the problem is there might be some reliability concern if they regulate at a higher voltage. So, higher is also a problem not just a lower voltage.

So, from this centralized supply by taking the remote feedback you can regulate only one point, not all the three points.

2. Distributed supply: Instead of designing a regulator which can supply 1.2 V output voltage with 3 A current, use three small regulators of 1 A and place all of them closer to the system as shown in below figure.



Now, we can place these regulators as close as possible to each system. In the previous case if you want to place it closer to the system, you can place only closest to one of the three systems. But, in this case you try to place them as close as possible and the size of these regulators will be smaller because now each regulator is supplying 1 A instead of 3 A. So, overall area impact you may not have that much by doing this but this is always a preferred case for high current systems specially processors and all those. And the same thing is possible if you have let’s say three different supplies. So, you make three regulator chips of different voltages and put as close as possible to each system.