Power Management Integrated Circuits
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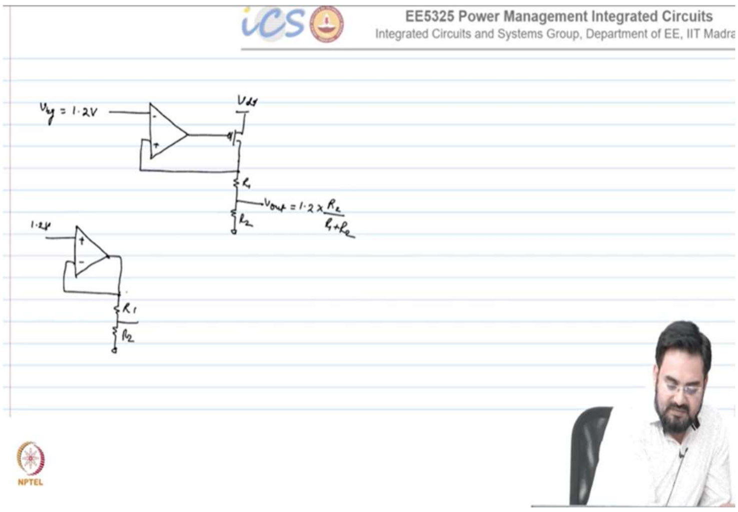
Lecture - 11
Generating Multiple Reference Voltages; Applications of Linear Regulators

If we have a standard band gap and you want a lower voltage, you can still do that by using the circuits shown in below.



If we directly use the resistor divider, then the problem is this resistor divider will load your previous stage and this may disturb the band gap voltage. So, you have to use a buffer as shown in circuit diagrams.

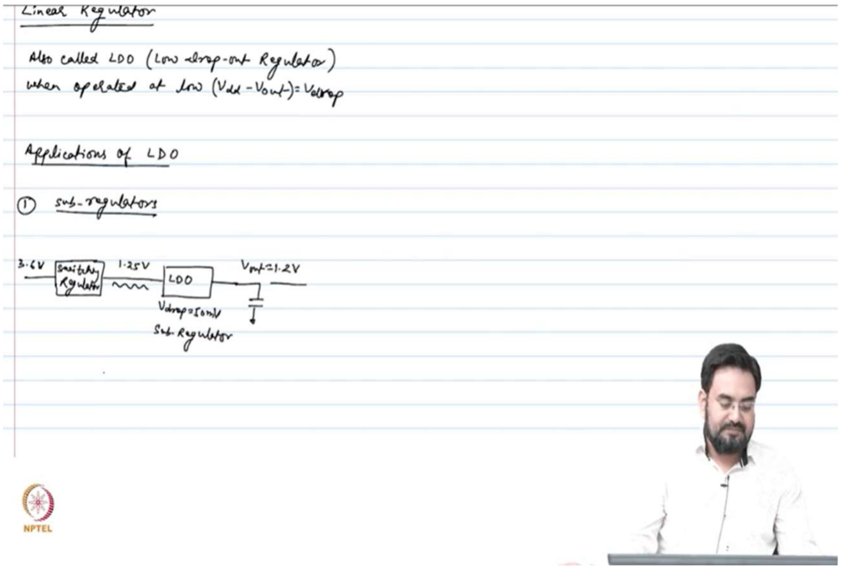
Advantage with the first circuit is if you take the feedback from the voltage across R_2, then it will behave more like an LDO and you can get high voltage also if you want.

So, most of the time if you just need a one voltage which is lower than 1 V or so, you can use the sub-1 V bandgap. But in some cases, we require multiple band gap voltage references. Let's say you need 1.2 V, 0.5 V, 0.4 V all those values. So, you can just tap 1.2 V and use the buffer, resistor divider and tap multiple. So, you can use more resistors and keep tapping the voltages. So, we can generate multiple references out of there as long as the temperature coefficient of these resistors are same. So, it will not affect your band gap curve; it will only scale up or down depending upon the resistor values you choose.

Linear regulator: It is also called as LDO (low dropout regulator) when operated at low V_{drop}. And $V_{drop} = V_{dd} - V_{out}$.

Applications of LDO:

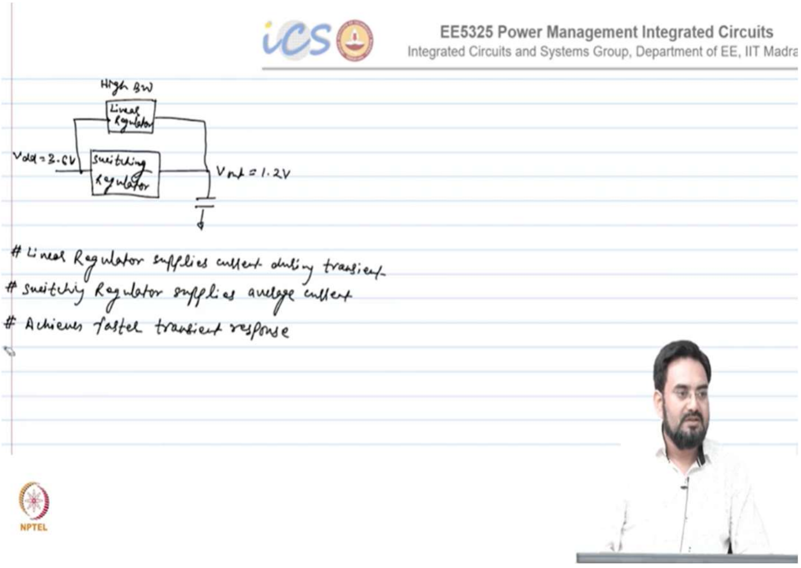
1. Sub-regulators: Consider the block diagram shown in below figure.



The larger step-down ratio is achieved by switching regulator and mainly due to efficiency reasons. We know that switching regulator has ripple and the output of LDO is much cleaner. So, LDO will filter out your ripple and provide you a cleaner output. Commonly it is used in any system especially in noise sensitive application to achieve higher efficiency as well as smaller output ripple.

For example, if we want 1.2 V output; you design the LDO for dropout voltage of 50 mV and your switching regulator will regulate to 1.25 V instead of directly regulating to 1.2 V. 50 mV is the dropout voltage in your LDO. So, the output we get is 1.2 V regulated.

2. Parallel or auxiliary current source: In this case they are connected in parallel as shown in below figure.



Now, this would not be LDO because dropout voltage would be much larger. So, it is a linear regulator.

Let's say your switching regulator has limited bandwidth. So, you make your linear regulator bandwidth much larger than your switching regulator bandwidth. So, during transient all the fast-current requirement will be met by your linear regulator and when output is settled you can back off and all the load will be supplied by your switching regulator.

So, all the average current is being supplied by your switching regulator and linear regulator can supply current during transient only. The advantage is that it achieves faster transient response.

In your cell phone there are two cases like; one current from the battery will be drawn as a steady state current or average current, on top of that you have some activities going on which are like transient activities. They will come for a very short duration and then go away. So, during that time this linear regulator will kick in and supply that current and then back off.

Another advantage with this is, you can share the transient load between switching regulator and linear. So, you do not have to design your switching regulator for a very higher current. Let's say your average current requirement is 1 A, but your peak current requirement might be 2 A or so due to transient. Let us say the transient glitches come for a few microseconds for 2 A and then go away and then again current settles to 1 A.

If you have to cater all 2 A current from the switching regulator, you have to design it for 2 A. Which means you have to use bigger FETs and you may incur more switching losses because gate driver, gate cap size will be larger. So, you design your switching regulator for 1 A average current and 1 A transient will be supplied by your linear regulator.

Since this transient is coming only once in a while then you would not lose that much efficiency. You will lose some efficiency but not that much because most of the time switching regulator will be supplying 1 A average current and the 2 A peak will happen only once in a while. So, it all depends on what kind of system you have. If you require this thing, then you can add this linear regulator in parallel and get a better transient response.

3. Regular power supply: LDO can be used as regular power supply to cater higher load current if V_{drop} is low. Usually for V_{drop} less than 10% of the output voltage. And to cater lighter load current if V_{drop} is high. When I say lighter load current, usually less than 50 mA or so. So, most of the analog applications, your PLLs or your sensors, analog frontend all those can be supplied with these LDOs because they are much cleaner compared to your switching regulator.