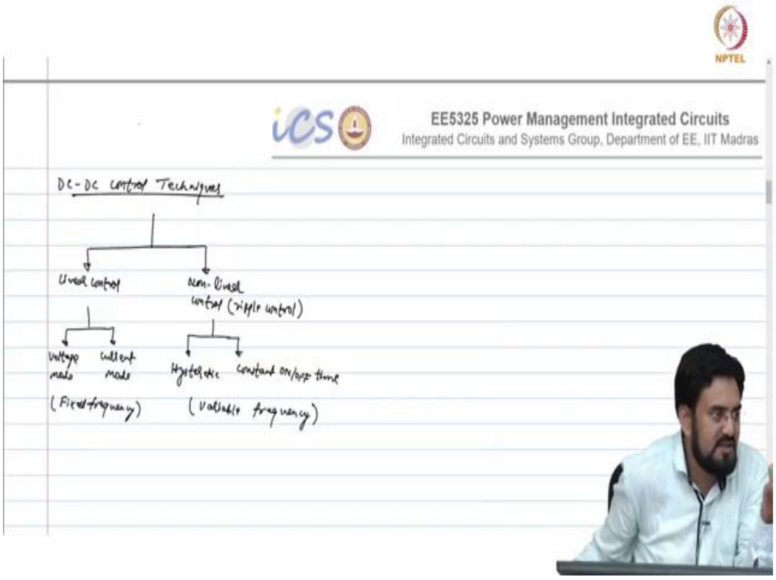
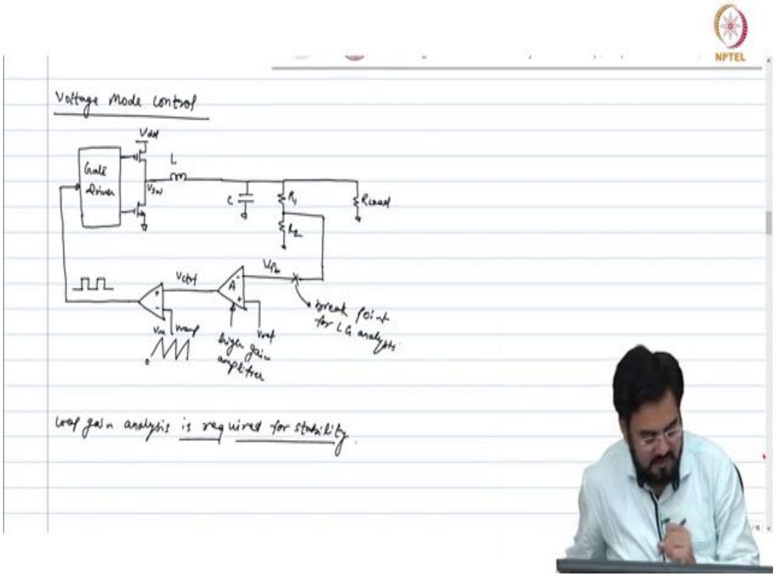
Power Management Integrated Circuits
Dr. Qadeer Ahmad Khan
Department of Electrical Engineering
Indian Institute of Technology, Madras

Lecture – 46
DC-DC Converter Control Techniques, Stability Analysis of Voltage-Mode Buck Converter – Part 1



We cannot just directly fix the duty cycle as V_O/V_{IN} and need control techniques to regulate the output in DC-DC converters because the load is varying and when your load changes, IR drop in the power stage changes and thus duty cycle to regulate the output voltage changes. So, that is why you need a feedback control, so that whenever any changes in controller parameters such as temperature, load current, V_{IN}, etc. will get compensated by the feedback loop and output is regulated.

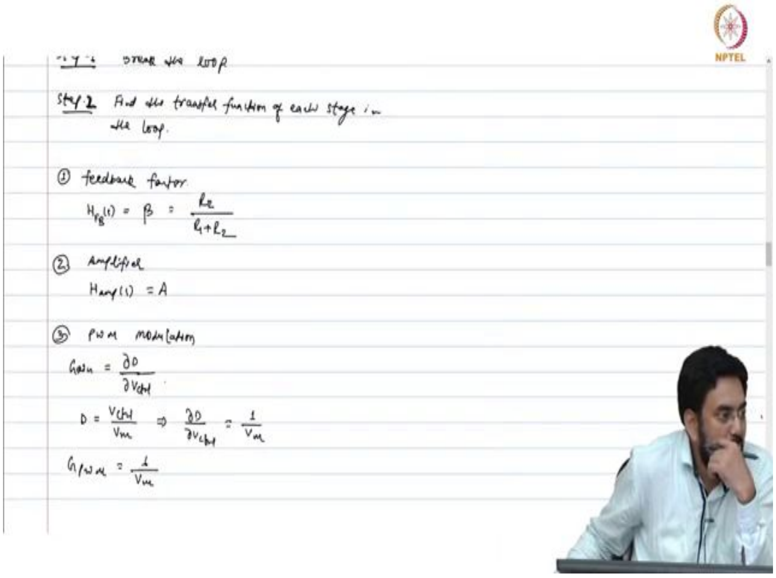
The types of control techniques are shown in the above image. We will start with the voltage mode control technique.



The above image shows the figure of the controller with voltage-mode control. The reason we call it voltage-mode control because the duty cycle is only controlled by the voltage. We need an amplifier because we have to regulate feedback voltage to V_{REF}, so we need a very high DC gain which means the amplifier has to be a very high gain amplifier.

The amplifier will take the difference between V_{REF} and V_{FB} and change the control voltage. For example, the gain of the amplifier is 1000 and 1V difference in V_{CTRL} changes duty cycle from 0 to 100%, so 1 millivolt difference in amplifier input could change the V_{CTRL} by 1V which means the difference between V_{FB} and V_{REF} is always less than 1mv. The error will increase as the amplifier gain decreases.

We will now do the loop gain analysis of the controller to analyze its stability. We will find the transfer functions of individual stages. Loop breakpoint is shown in the above image.



The first step is to break the loop. We usually prefer to break the loop at high impedance input.

The second step is to find the transfer function of each stage in the loop. The transfer function of each stage is :

1. Feedback Factor :

$$H_{fb}(s) = \beta = \frac{R_2}{R_1+R_2}$$

2. Amplifier :

The amplifier should have a high gain and bandwidth, so we can assume that pole due to this amplifier is outside ugb and it has a high gain A.

$$H_{amp}(s) = A$$

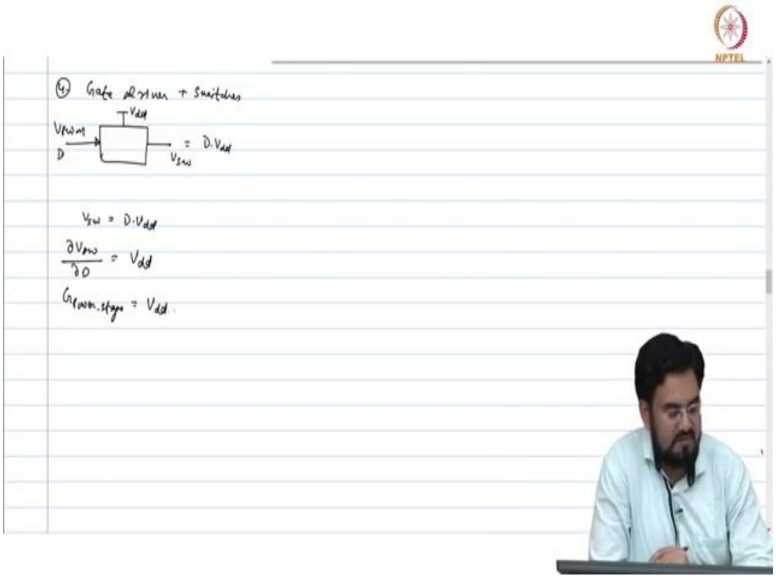
3. PWM modulator :

Input and output to the PWM modulator are V_{CTRL} and duty cycle respectively. The gain of the PWM modulator will be

$$G_{PWM} = \frac{\delta D}{\delta V_{CTRL}}$$

Now if you are comparing V_{CTRL} with a ramp that is going from 0 to V_m then your duty cycle will be V_{CTRL}/V_m. The gain of PWM modulator after substituting D will be :

$$G_{PWM} = \frac{1}{V_M}$$



4. Gate Driver plus Switches :

Input and output to gate driver plus switches are D and V_{SW} respectively. Since the output of the third stage is D, so the input to the fourth stage should be the duty cycle and not V_{PWM}. The gain will be :

$$G_{Pow-Stage} = \frac{\delta V_{SW}}{\delta D}$$

We know that V_{SW} is equal to D times Vdd. After differentiating V_{SW} we get :

$$\frac{\delta V_{SW}}{\delta D} = Vdd$$

$$G_{Pow-Stage} = \frac{\delta V_{SW}}{\delta D} = \mathrm{Vdd}$$