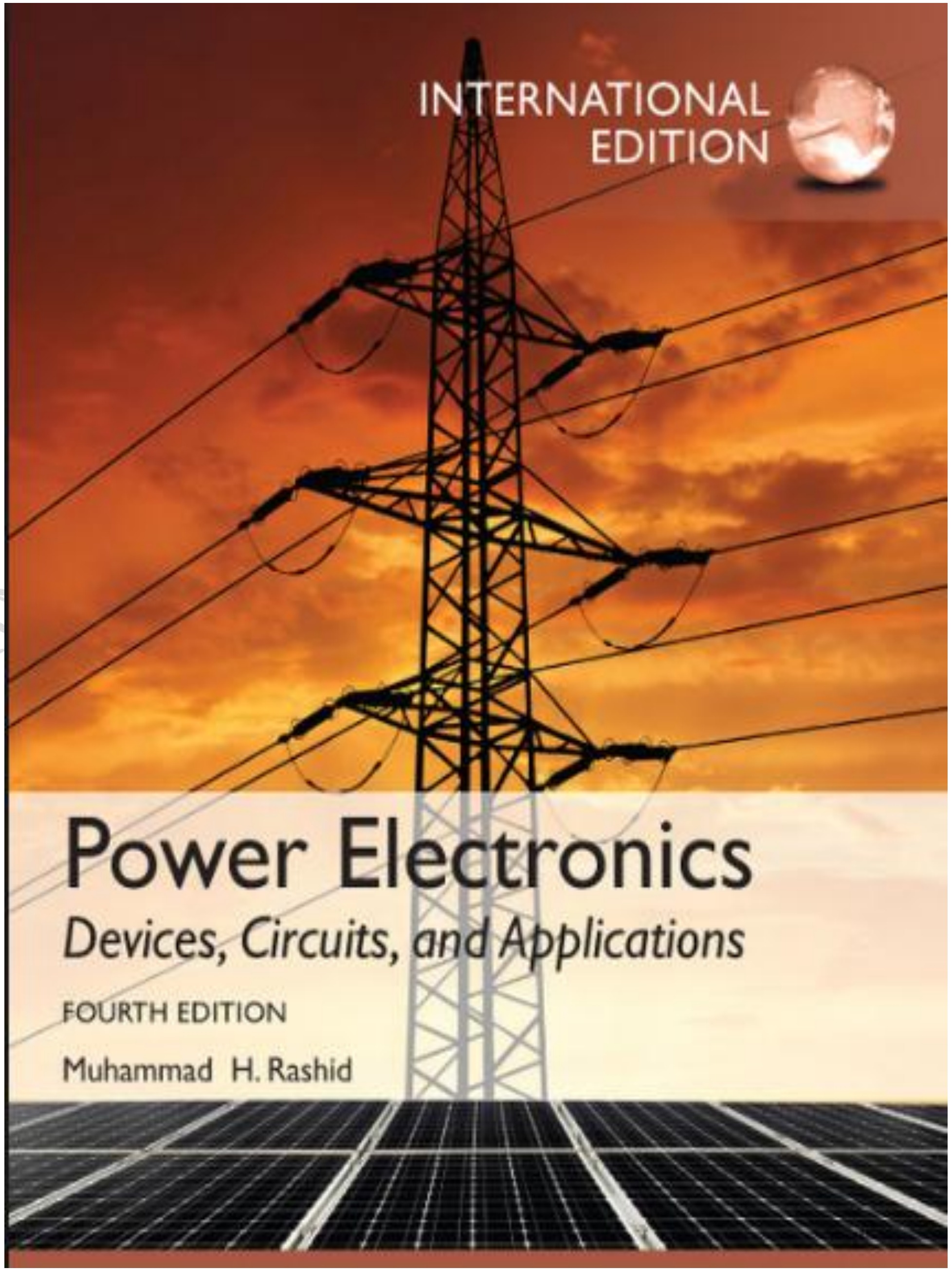
University of Technology
Laser and Optoelectronic Engineering Department
Power Electronics/2018-2019)
For the third years (Laser Engineering)



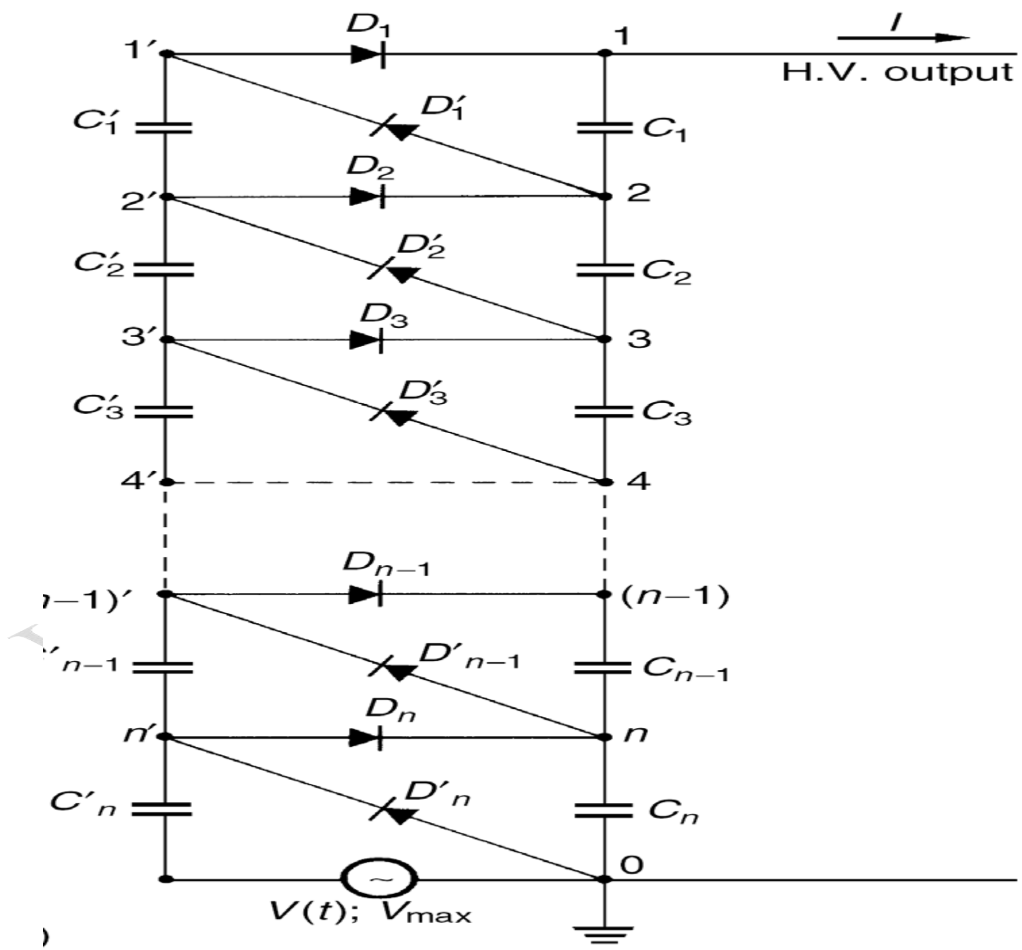
Prepared by: Lec. Dr. Mothana Amaar Hassan
Laser and Optoelectronic Engineering Department

Ref: Power Electronics 4th edition/ Muhammed H. Rashid

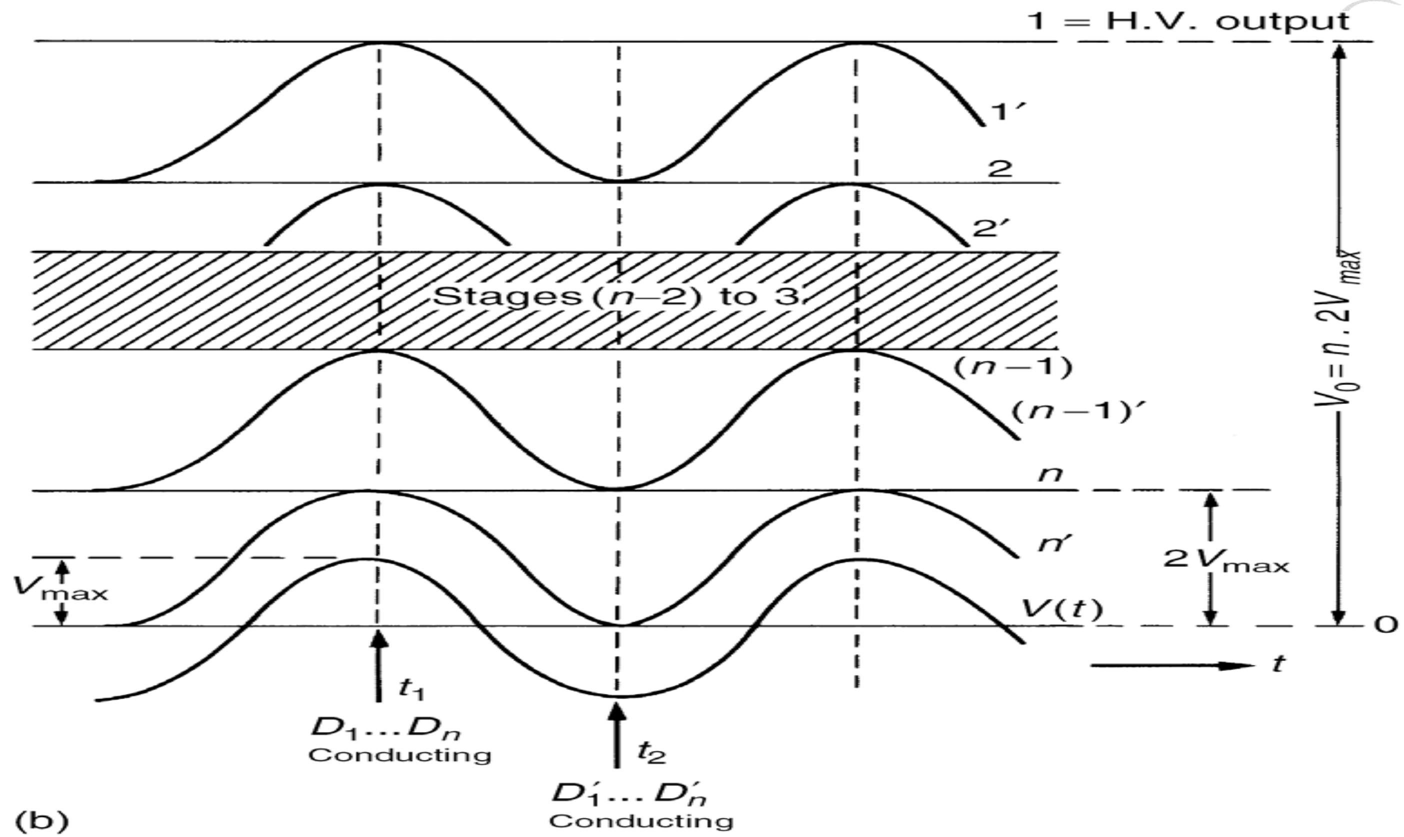
Lecture No. 6

Cascade Voltage Multiplier

To demonstrate the principle only, an n-stage single-phase cascade circuit of the 'Cockcroft–Walton type', shown in figure below, will be presented.



HV output open-circuited: **I = 0**. The portion (0 -n' -V(t)) is a half-wave rectifier circuit in which C'_n charges up to a voltage of $+V_{max}$ if V(t) has reached the lowest potential, $-V_{max}$. If C_n is still uncharged, the rectifier D_n conducts as soon as V(t) increases. As the potential of point n' swings up to $+V_{2max}$ during the period T = 1/f, point **n** attains further on a steady potential of $+2V_{max}$ if V(t) has reached the highest potential of $+V_{max}$. The part (n' - n – 0) is therefore a half-wave rectifier, in which the voltage across D'_n can be assumed to be the a.c. voltage source.

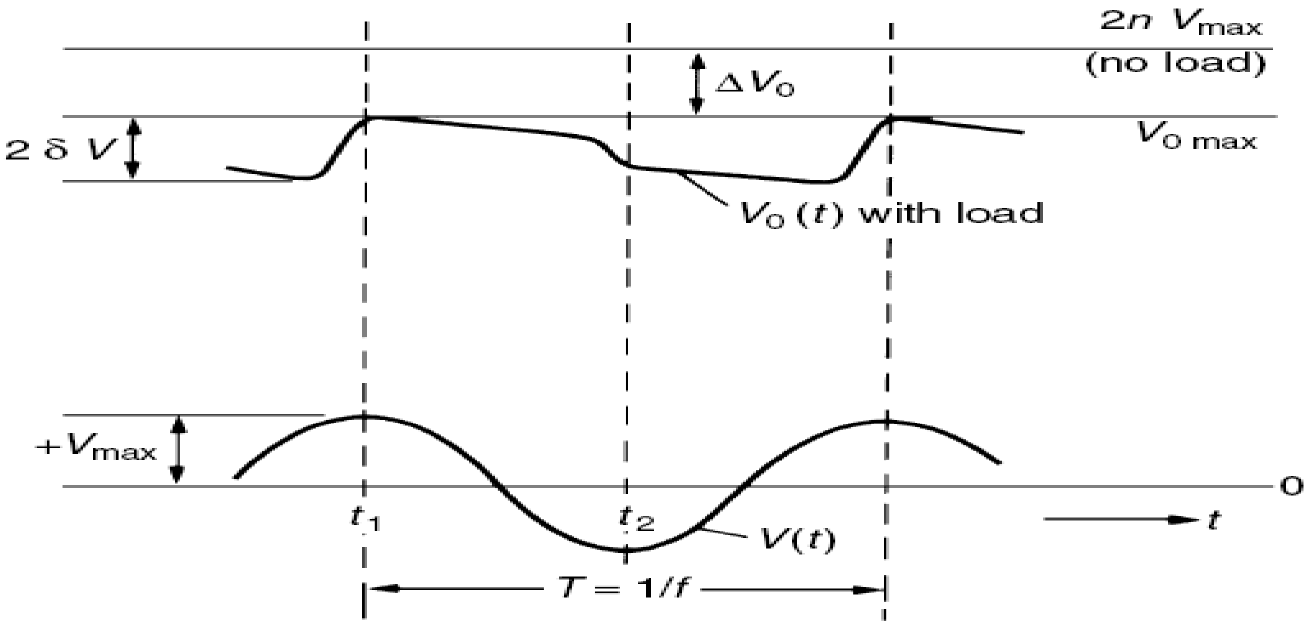


The current through D_n that charged the capacitor C_n was not provided by D'_n, but from V(t) and C'_n. We can assume that the voltage across C_n is not reduced if the potential n' oscillates between zero and $+2V_{max}$. If the potential of n', however, is zero, the capacitor C'_{n-1} is also charged to the potential of n, i.e. to a voltage of +2Vmax. The next voltage oscillation of V(t) from -Vmax to +Vmax will force the diode D_{n-1} to conduct, so that also C_{n-1} will be charged to a voltage of $+2V_{max}$.

The steady state potentials at all nodes of the circuit are sketched for the circuit for zero load conditions. From this it can be seen, that:

1 The potentials at the nodes **(1', 2' . . . n')** are oscillating due to the voltage oscillation of V(t);
2 The potentials at the nodes **(1, 2 . . . n)** remain constant with reference to ground potential;
3 The voltages across all capacitors are of d.c. type, the magnitude of which is 2Vmax across each capacitor stage, except the capacitor C'_n which is stressed with V_{max} only;
4 Every rectifier $\mathbf{D_1, D'_1 \ldots D_n, D'_n}$ is stressed with $2V_{max}$ or twice a.c. peak voltage; and
5 The HV output will reach a maximum voltage of $2nV_{max}$.

H.V. output loaded: **I > 0.** If the generator supplies any load current I, the output voltage will never reach the value $2nV_{max}$.There will also be a ripple on the voltage, and therefore we have to deal with two quantities: the voltage drop ΔV_o and the peak-to-peak ripple $2\delta V$. The sketch in figure below shows the shape of the output voltage and the definitions of
ΔV_o and $2\delta V$.



Let a charge q be transferred to the load per cycle, which is obviously q = I x T. This charge comes from the smoothing column, the series connection of $C_1 \ldots C_n$. If no charge would be transferred during **T** from this stack via $D'_1 \ldots D'_n$ to the oscillating column. However, just before the time instant t2 every diode $D'_1 \ldots D'_n$ transfers the same charge q, and each of these charges discharges all capacitors on the smoothing column between the relevant node and ground potential, the ripple will be:

$$\delta V = \frac{I}{2f}\left(\frac{1}{C_1} + \frac{2}{C_2} + \frac{3}{C_3} + \ldots \frac{n}{C_n}\right)$$

Thus in a cascade multiplier the lowest capacitors are responsible for most ripple and it would be desirable to increase the capacitance in the lower stages. This is, however, very inconvenient for H.V. cascades, as a voltage breakdown at the load would completely overstress the smaller capacitors within the column. Therefore, equal capacitance values are usually provided, and with $C = C_1 = C_2 = C_3 \ldots C_n$,

$$\delta V = \frac{I}{fC} \times \frac{n(n+1)}{4}$$

To calculate the total voltage drop ΔV_o, we will first consider the stage n. Although the capacitor C'_n at time t_1 will be charged up to the full voltage V_{max}, if ideal rectifiers and no voltage drop within the a.c.-source are assumed,

$$\Delta V_o = \frac{I}{fC}\left(\frac{2n^3}{3} + \frac{n^2}{2} - \frac{n}{6}\right)$$

For a given number of stages, this maximum voltage or also the mean value $V_o = V_{omax} - \delta V$ will decrease linearly with the load current **I** at constant

Where $\mathbf{V_{o\,max} = 2nV_{max} - \Delta V_o}$