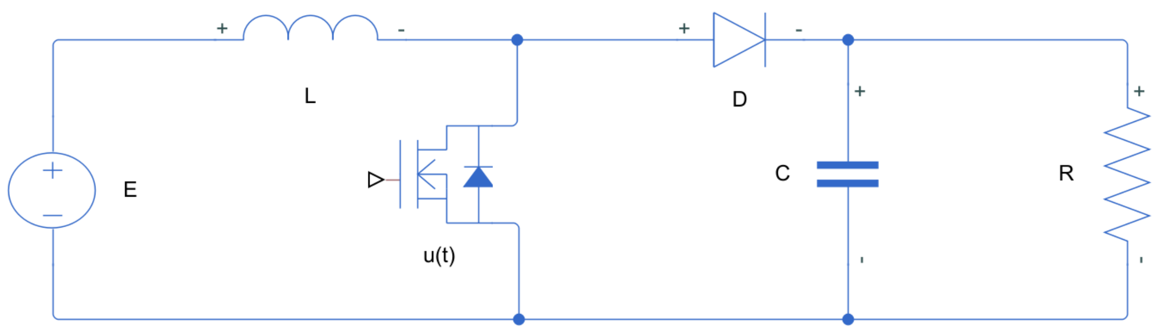
Kovalev V.

Design of a boost converter of 24V to 80V using sliding mode technique.



$E \ = 24V;\ V_R = 80$

Let's power = 64W => $R \ = \frac{V_R^2}{P} = 100\ \Omega$

On the on state: $V_c = \frac{q}{C} = V_R => \Delta V_R = \frac{1}{C}\Delta q = \frac{1}{C}\int^{DT}\frac{V_R}{R} = \frac{1}{CR}V_R DT \ \ (such\ as < i_c > = 0 => \Delta q\ is\ equal\ to\ \Delta q\ at\ off\ state)$

$$\frac{\Delta V_R}{V_R} = \frac{1}{CR}DT = \frac{D}{fCR} => C = \frac{DV_R}{\Delta V_R}\frac{1}{fR}$$

Such as it is boost converter: $\frac{V_R}{E} = \frac{1}{1-D} => D = \frac{V_R - E}{V_R} = 0.7$. And let $f \ = 100Hz, \frac{\Delta V_R}{V_R} = 7\%$

$$C = \frac{DV_R}{\Delta V_R}\frac{1}{fR} = 1mF$$

$$V_L = L\frac{\partial I}{\partial t} = E => I = \frac{Et}{L} + I_0 => \Delta I = \frac{EDT}{L}$$

We know that all DC current ideally goes to resistor => $I_{mean} = I_R$

$$I_{max} = I_R + \frac{\Delta I}{2}$$

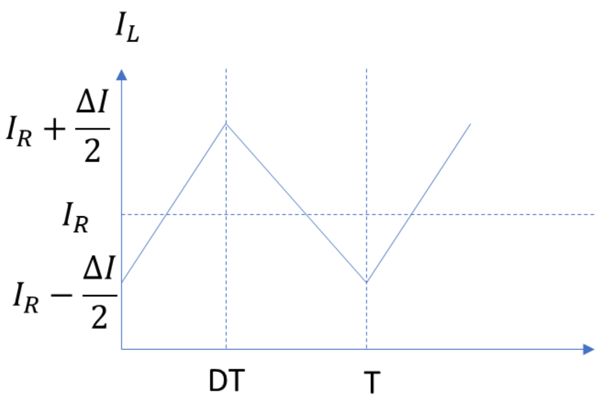
$$I_{min} = I_R - \frac{\Delta I}{2} = \frac{V_R}{R} - \frac{EDT}{2L}$$

Considering continues mode:

$$I_{min} > 0 => \frac{EDT}{2L} < \frac{V_R}{R} =>$$

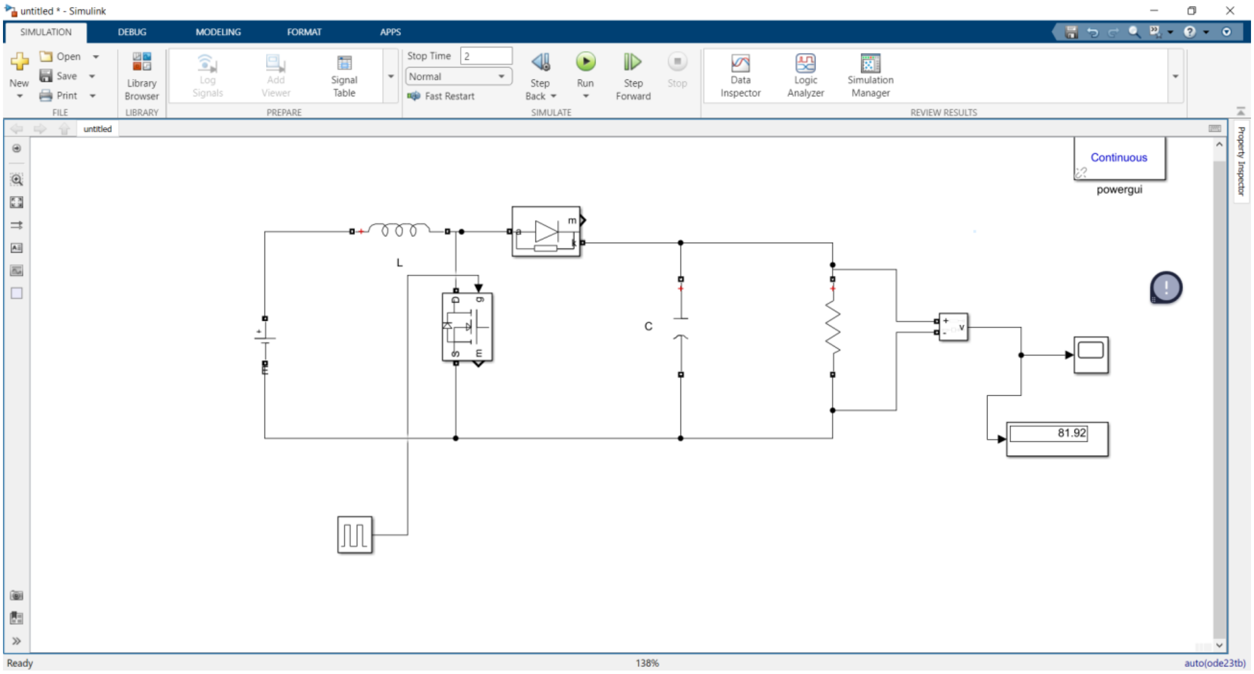
$$L > \frac{EDTR}{2V_R} = 0.105H$$

Let's $L = 1H$

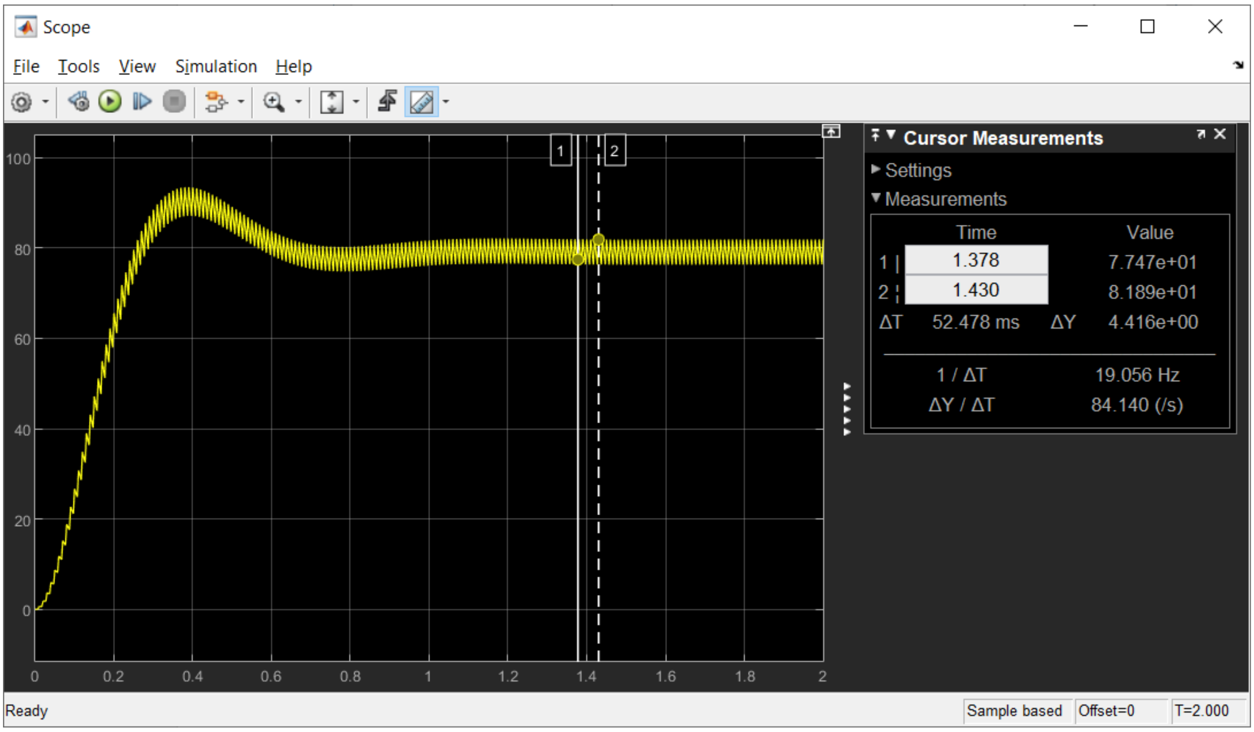


Summing up: $L = 1H,\ C = 1mF,\ R = 100\ \Omega,\ \mathrm{f} = 100\mathrm{Hz}, \mathrm{D} = 0.7,$

Simulation:



Result:



You can see reaple: $4.416/80 = 5.5\%$ (I calculated 7%)

Construction of sliding mode technique:

On state:

$$\begin{cases} E = L\dfrac{\partial I}{\partial t} \\ \dfrac{q}{C} = V_R \end{cases} => \begin{cases} \dfrac{\partial I}{\partial t} = \dfrac{E}{L} \\ \dfrac{\partial V_R}{\partial t} = \dfrac{V_R}{RC} \end{cases}$$

Off state

$$\begin{cases} E = L\dfrac{\partial I}{\partial t} + V_R \\ \dfrac{q}{C} = V_R \end{cases} => \begin{cases} \dfrac{\partial I}{\partial t} = \dfrac{E - V_R}{L} \\ \dfrac{\partial V_R}{\partial t} = \dfrac{I_C}{C} \end{cases} => \begin{cases} \dfrac{\partial I}{\partial t} = \dfrac{E - V_R}{L} \\ \dfrac{\partial V_R}{\partial t} = \dfrac{I - \dfrac{V_R}{R}}{C} \end{cases} => \begin{cases} \dfrac{\partial I}{\partial t} = \dfrac{E - V_R}{L} \\ \dfrac{\partial V_R}{\partial t} = \dfrac{I}{C} - \dfrac{V_R}{RC} \end{cases}$$

Summing up

$$\begin{cases} \dfrac{\partial I}{\partial t} = \dfrac{E}{L} - (1-u)\dfrac{V_R}{L} \\ \dfrac{\partial V_R}{\partial t} = (1-u)\dfrac{I}{C} - \dfrac{V_R}{RC} \end{cases}$$

Where u - switch function $u = [0,1]$ – {off state, on state}

Substitute $I \to x_1, V_R \to x_2$;

$$\begin{bmatrix} \dot{x_1} \\ \dot{x_2} \end{bmatrix} = \begin{bmatrix} 0 & -\dfrac{(1-u)}{L} \\ \dfrac{(1-u)}{C} & -\dfrac{1}{RC} \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \end{bmatrix} + \begin{bmatrix} \dfrac{1}{L} \\ 0 \end{bmatrix} E$$

Consider:

$$S = x_2 x_1 - x_{1r} x_{2r} = 0$$

$$\dot{S} = x_2 \dot{x_1} + \dot{x_2} x_1 = 0;$$

$$x_2^2 \left(-\frac{(1-u)}{L}\right) + \frac{E}{L} x_2 + x_1^2 \frac{(1-u)}{C} + x_1 x_2 \left(-\frac{1}{RC}\right) = -\mathrm{As} - \mathrm{K} * \mathrm{sign(s)}$$

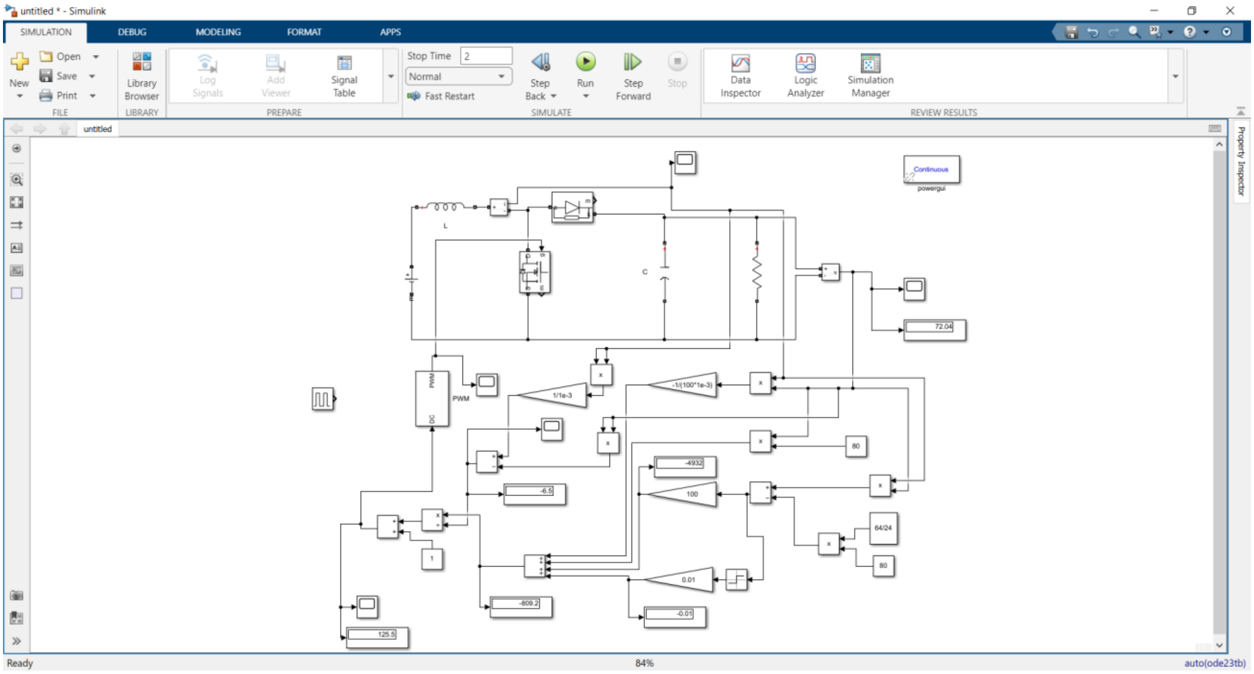
$$(1-u)\left(\frac{x_1^2}{C} - \frac{x_2^2}{L}\right) = -\left(\frac{E}{L} x_2 + x_1 x_2 \left(-\frac{1}{RC}\right)\right) - \mathrm{As} - \mathrm{K} * \mathrm{sign(s)}$$

$$(1-u) = \frac{1}{\left(\dfrac{x_1^2}{C} - \dfrac{x_2^2}{L}\right)} \left(\frac{x_1 x_2}{RC} - \frac{E}{L} x_2 - \mathrm{A} * \mathrm{s} - \mathrm{K} * \mathrm{sign(s)}\right)$$

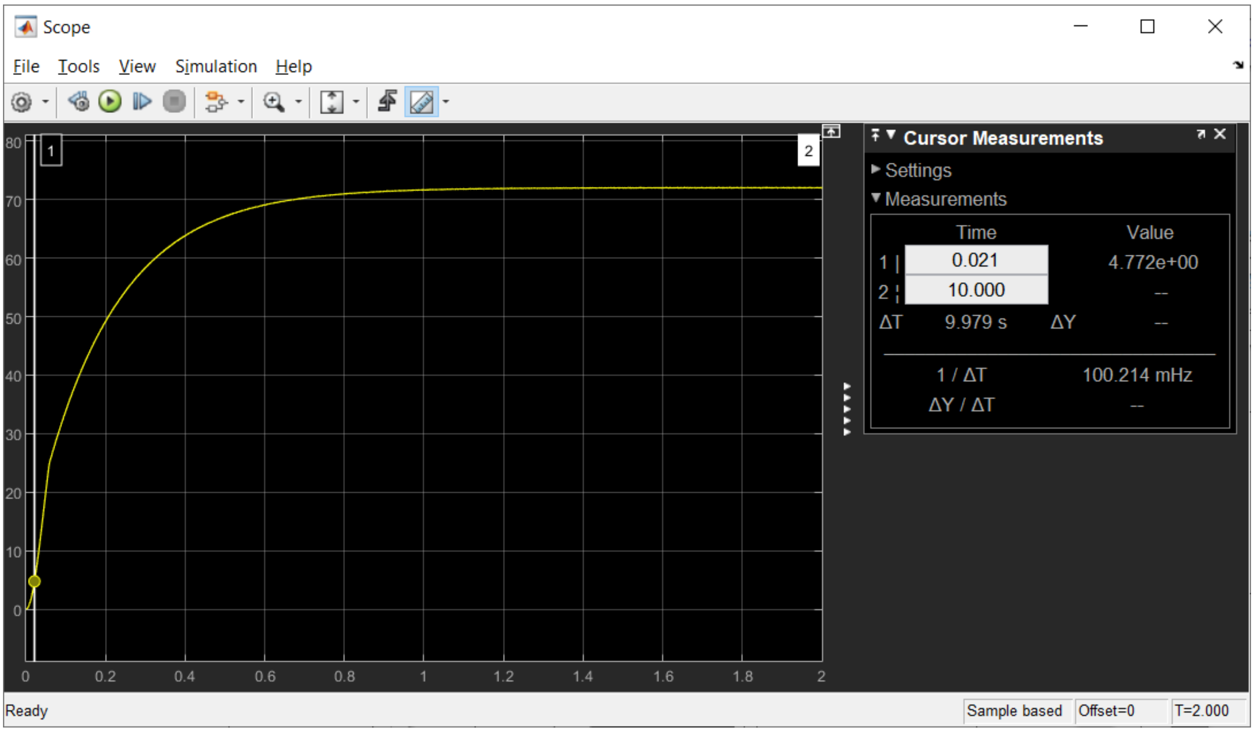
$$u = 1 + \frac{1}{\left(\dfrac{x_1^2}{C} - \dfrac{x_2^2}{L}\right)} \left(-\frac{x_1 x_2}{RC} + \frac{E}{L} x_2 + \mathrm{A} * \mathrm{s} + \mathrm{K} * \mathrm{sign(s)}\right)$$

$$x_{1r} x_{2r} = 80 * \frac{P}{E} = 80 * \frac{64}{24}$$

Unfortunately I am not in electronic at all so I don’t know how to contract such scheme in electronic components so I constructed it schematically.

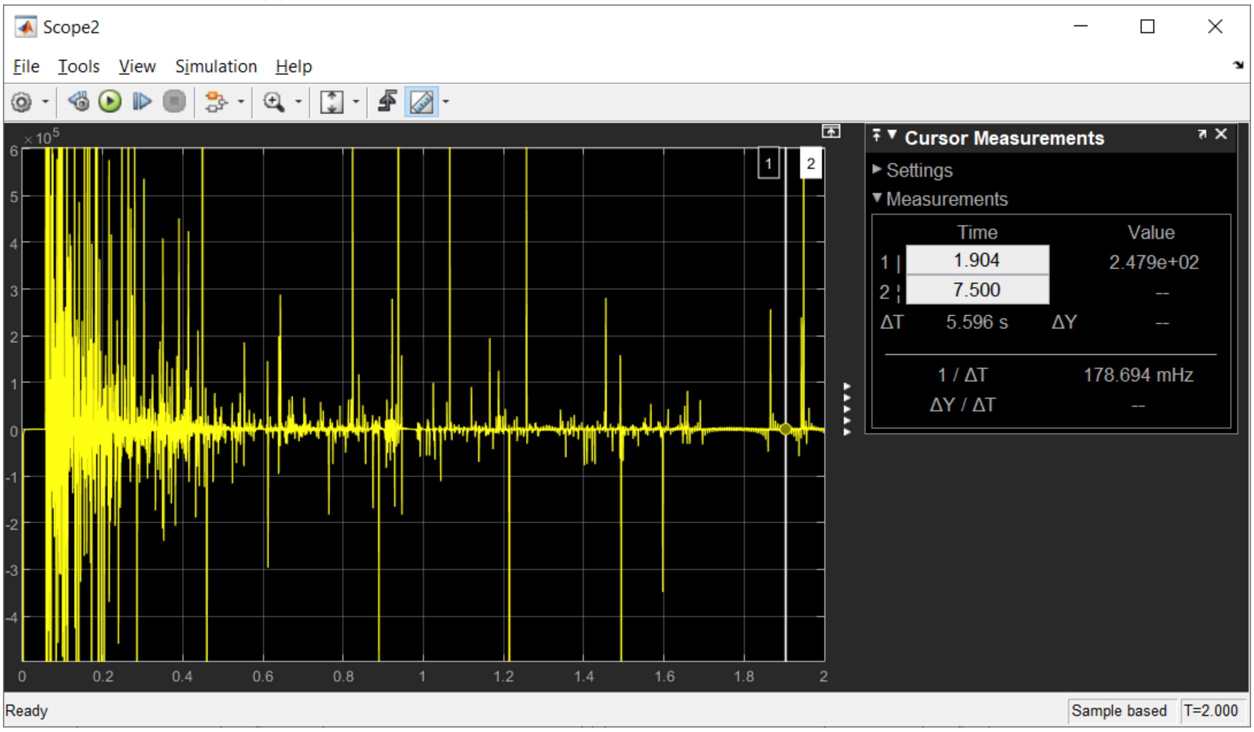


So $u(t)$ goes to PWM and controls transistor.($A = 100(speed\ of\ convergence), K = 0.01(for\ discontinuse\ mode)$)



It is output voltage always goes to 72, but I need 80, don't know where is the problem.

Bellow you can see $u(t)$



Current(I_L):