Lecture 20 (10th March)

Finals will be released Friday midnight / Saturday early morning.

You will have approx. 72 hrs. to solve

HW 6 due now. (if you want extension, mail me — max possible till midnight today).

Finals

(lecture simulation)

- It is heavily reliant on <u>motor modeling simulation</u>
- Use as much as possible from HW 5, 6.
- Main aim of finals is digital control & System integration.

$$\underbrace{\underbrace{\text{System integration}}_{\text{boost + motor model}}}_{\text{simulation} \sim \text{as close to hardware implementation as possible}}$$

- Less focus on control design
- 10 marks for conceptual question.

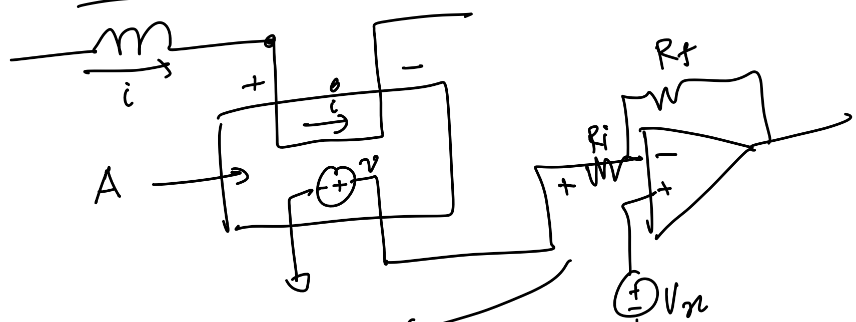
- Try your best to attempt all problems.
  - partial marks.
- Contact me by Teams.

  ask away anything

① <u>Sensor</u>

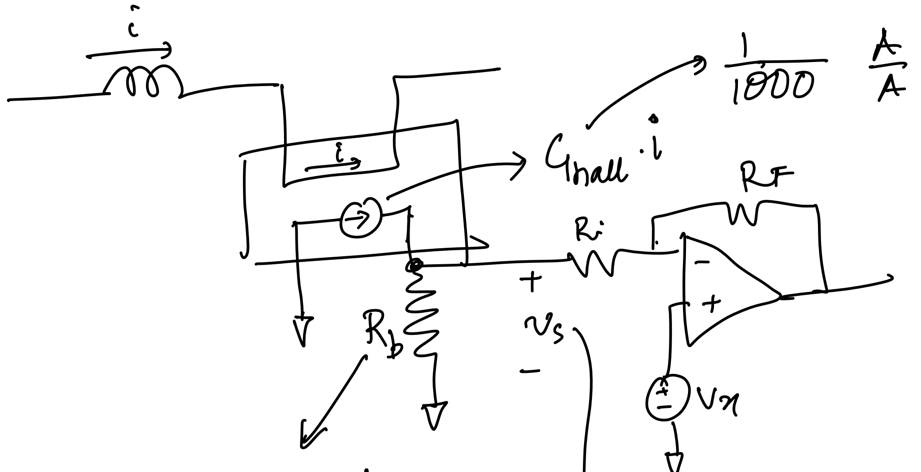
Current Sensor.

(hall effect sensor — flavour A)



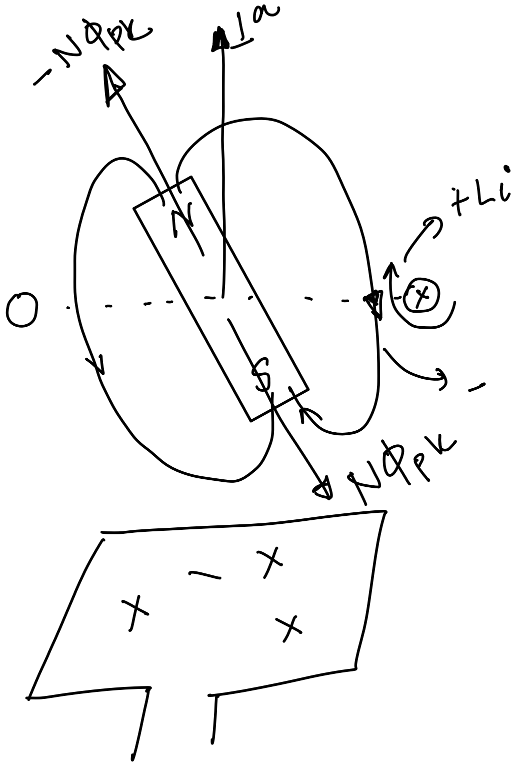
$v_s = i.A$

(sensor — flavour B)

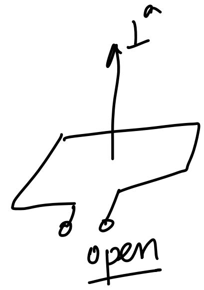


burden / bleedor resistor

$$v_s = \underbrace{R_b . G_{hall}}_{\text{new gain.}} . i$$



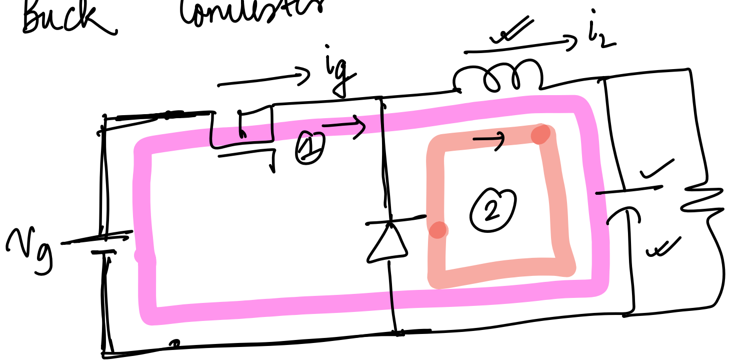
-NΦpk
N
S
+Li
NΦpk

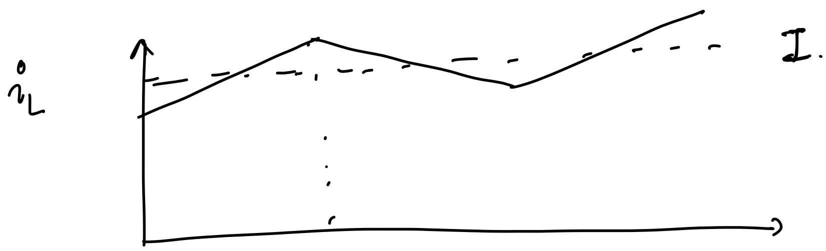


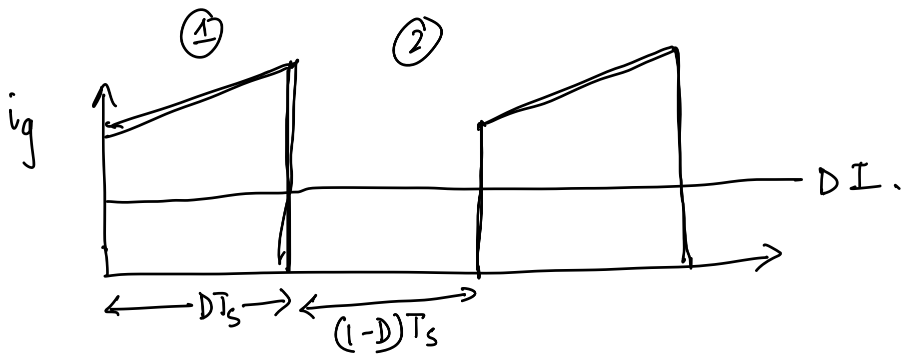
open

Input Filter design

Buck Converter



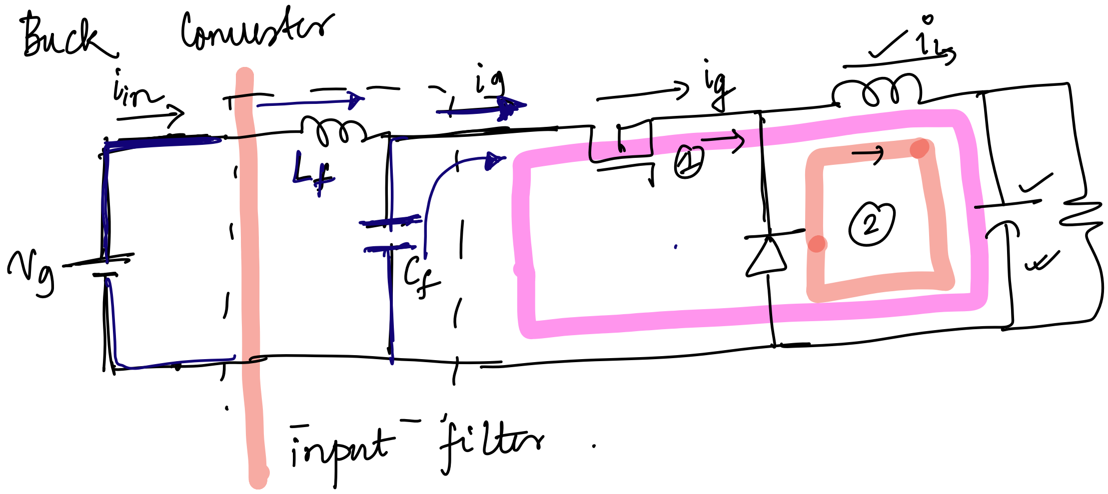


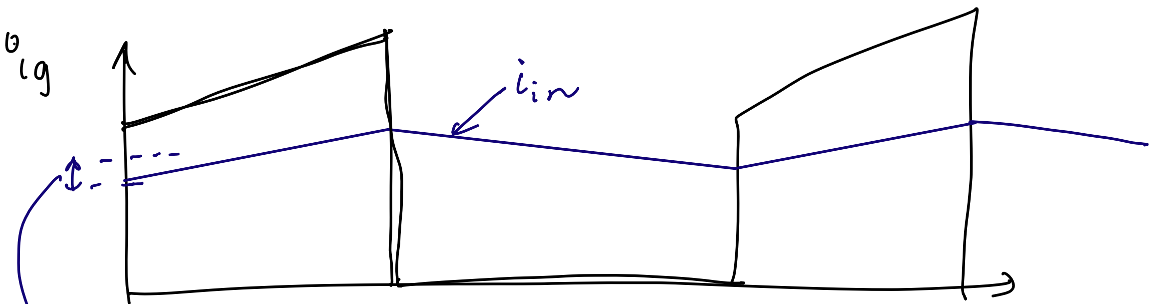


$$i_g(t) = DI + \sum_{k=1}^{\infty} \frac{2I}{k\pi} \sin(k\pi D)\cos(k\omega t)$$

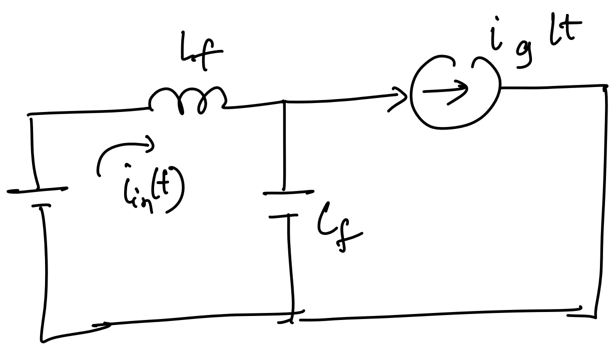
conducted electromagnetic interference.

Buck Converter





$\Delta i_{in} \sim 10\,\mu A$ to $100\,\mu A$.



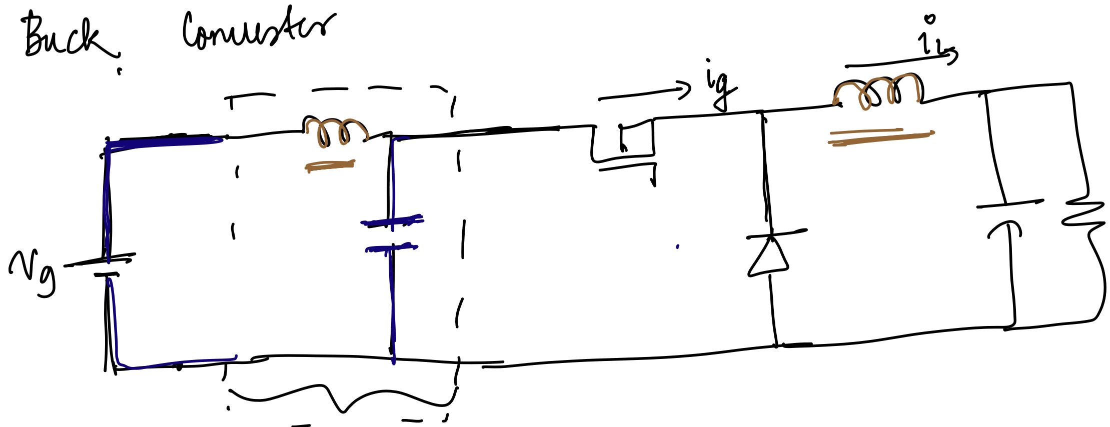
$$i_{in}(s) = i_g(s) \cdot \underbrace{\frac{1/sC_f}{sL_f + 1/sC_f}} = i_g(s) \cdot \frac{1}{s^2 L_f C_f + 1}$$

$H(s)$ = filter transfer function

$$i_g(t) = \underbrace{DI}_{dc} + \underbrace{\sum_{k=1}^{\infty} \frac{2I}{k\pi} \sin(k\pi D) \cos(k\omega t)}$$

$$i_{in}(t) = \underbrace{D \cdot H(0) \cdot I} + \underbrace{\sum_{k=1}^{\infty} \boxed{|H(k\omega t)|} \cdot \frac{2I}{k\pi} \sin(k\pi D) \cos(k\omega t + \angle H(k\omega t))}$$

Buck Converter



$$G_{vd} = \frac{\tilde{v}}{\tilde{d}}\bigg|_{\tilde{v}_g = 0} \qquad G_{id} = \frac{\tilde{i}}{\tilde{d}}\bigg|_{\tilde{v}_g = 0}$$

① Design your controller by imagining that there is no input filter.

② Now force the input filter to satisfy 2 design criterias.

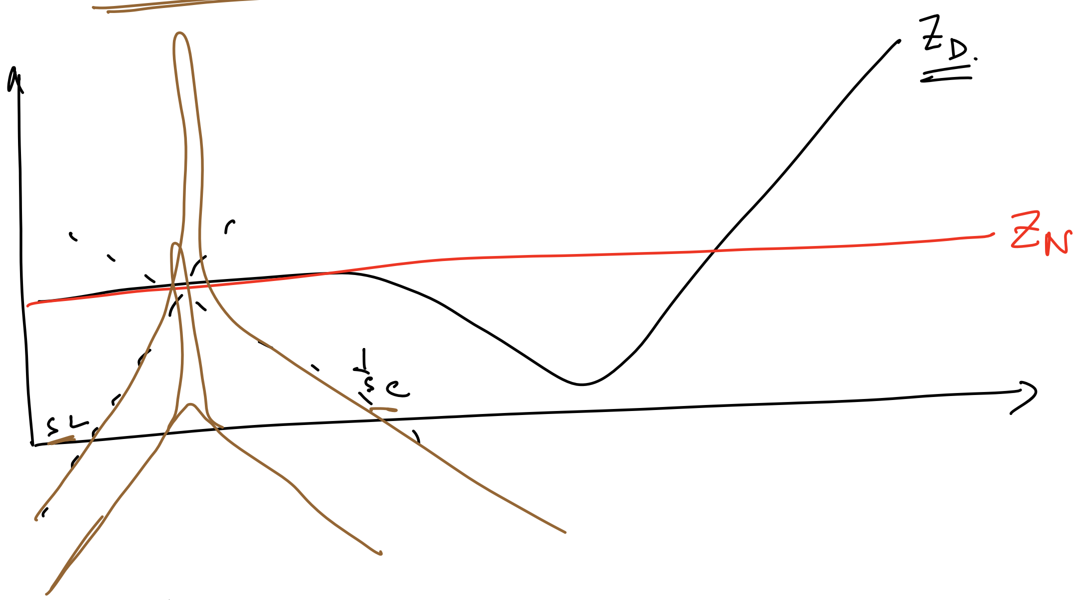
$$\underbrace{G_{vd}\Big|_{\substack{\text{with input}\\ \text{filter}}}} = \underbrace{G_{vd}\Big|_{\substack{\text{without}\\ \text{input}\\ \text{filter}}}} \cdot \underbrace{\frac{\left(1+\frac{Z_o(s)}{Z_N(s)}\right)}{\left(1+\frac{Z_o(s)}{Z_D(s)}\right)}}$$

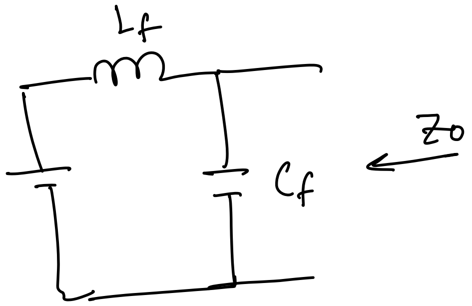
$\underline{Z_o(s)}$ = output impedance of the input filter

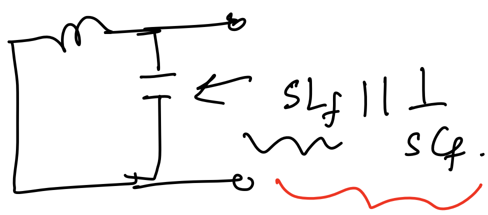
$\left.\begin{matrix} Z_N(s) \\ Z_D(s) \end{matrix}\right\}$ parameters are tabulated in book.

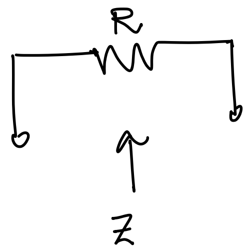
$\rightarrow$ Table 10.1

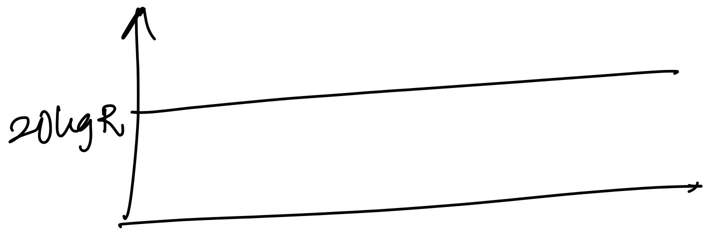
$\underline{Z_o \ll Z_N}$; $\underline{Z_o \ll Z_D}$ ✓

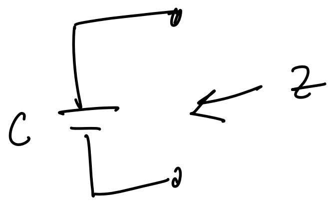




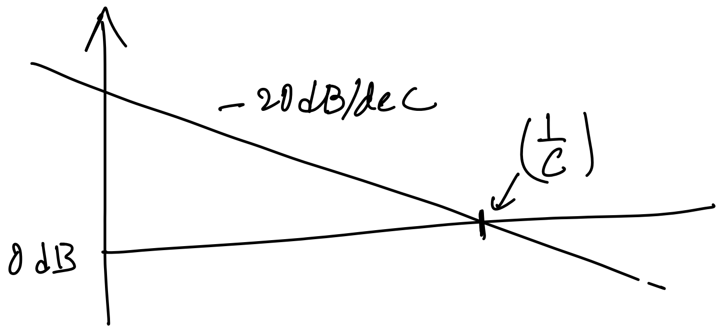


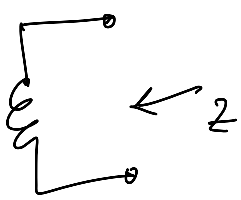




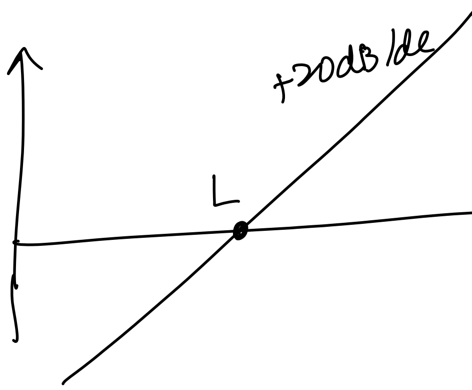


$Z = \frac{1}{sC}$

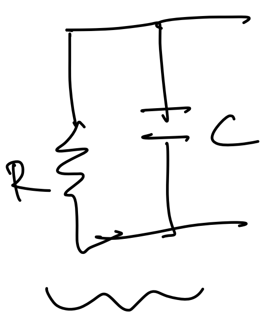


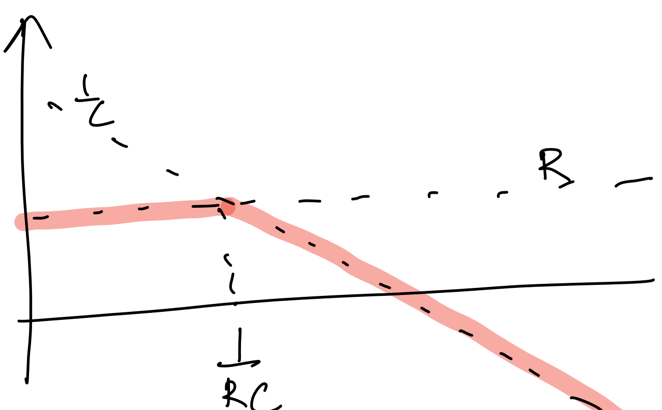


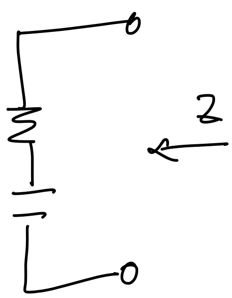
$Z = sL$

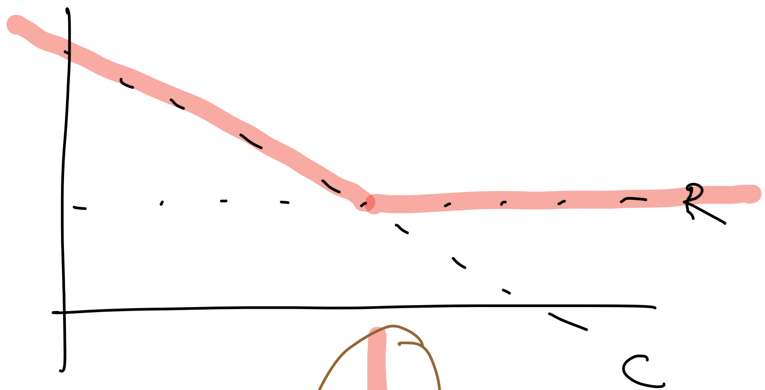


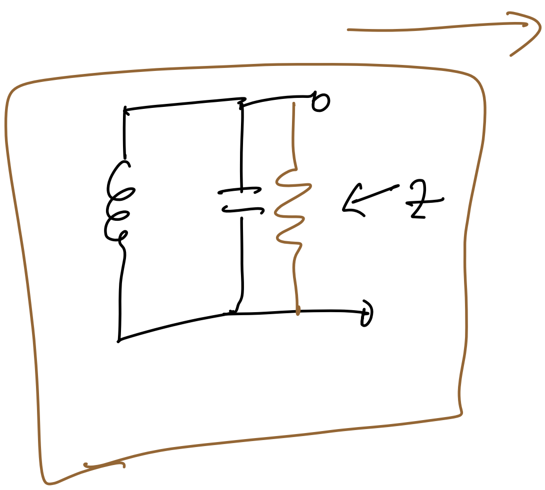
① Asymptotes in parallel = minimum
" " series = maximum

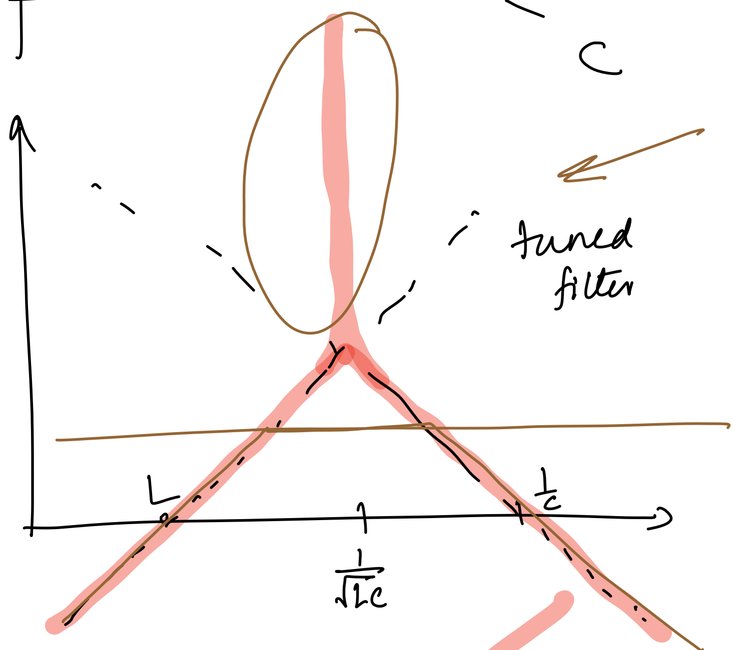


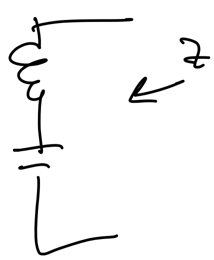


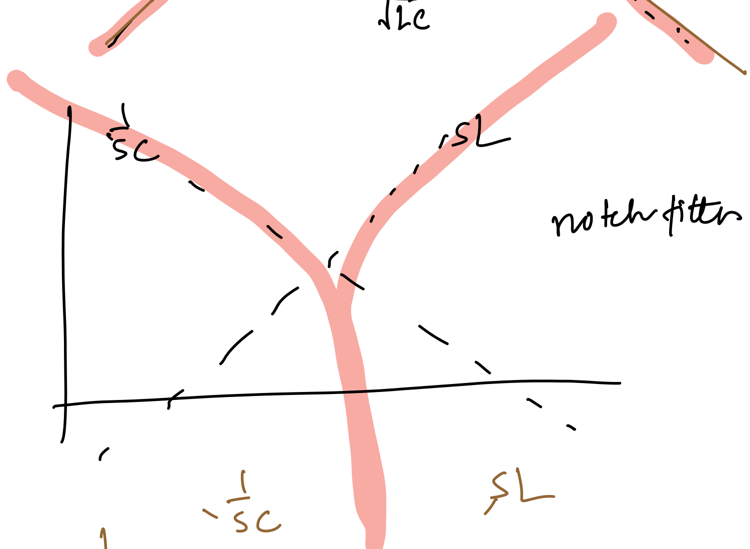

Z

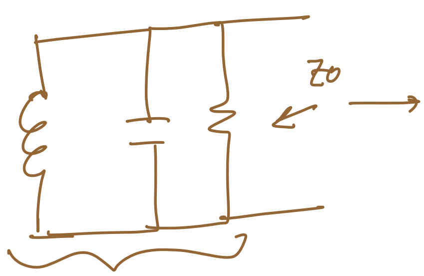

R
C

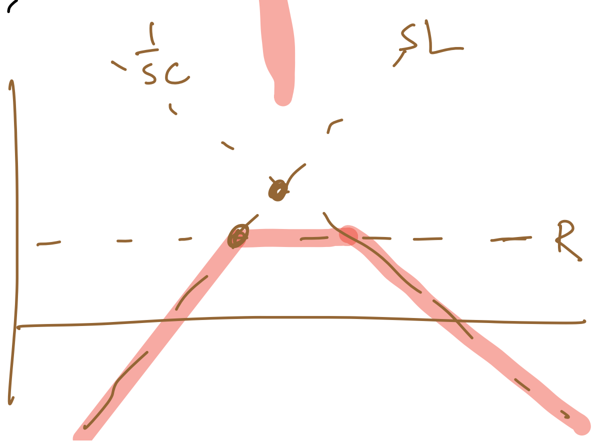

Z


L
1/√LC
1/C
tuned filter

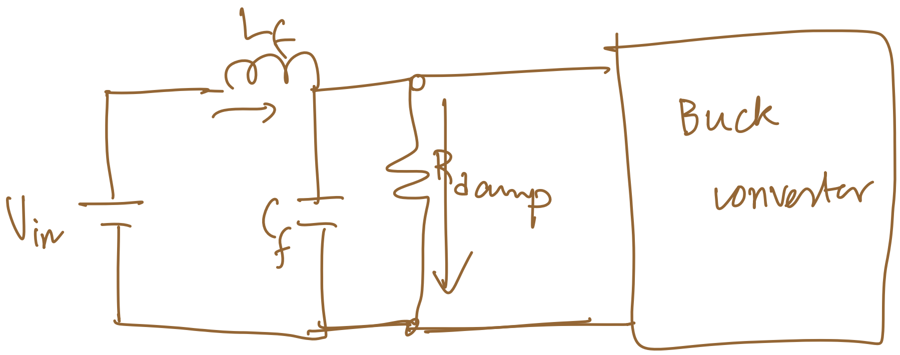

Z


1/sC
sL
notch filter


Z0

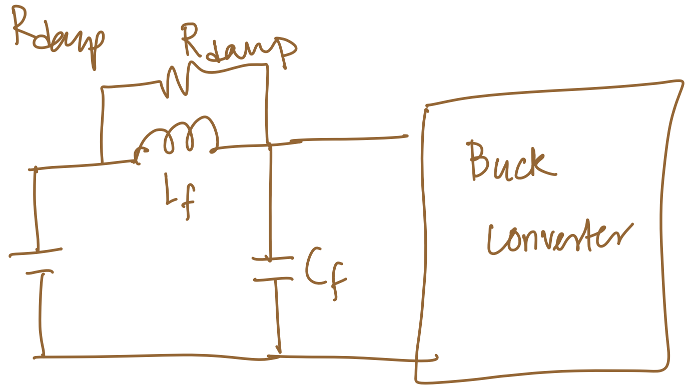

1/sC
sL
R

ⓐ

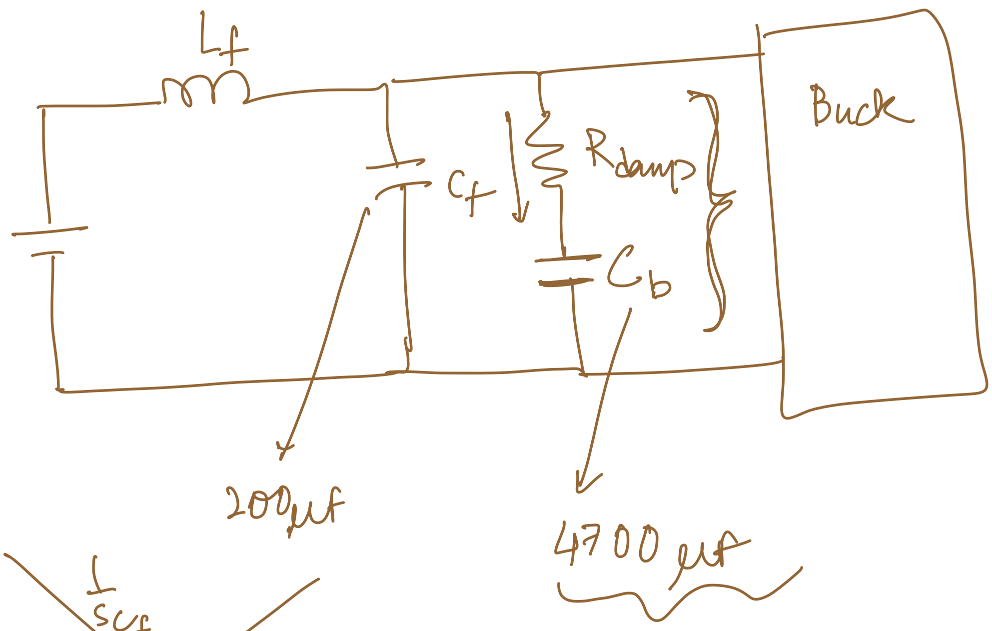


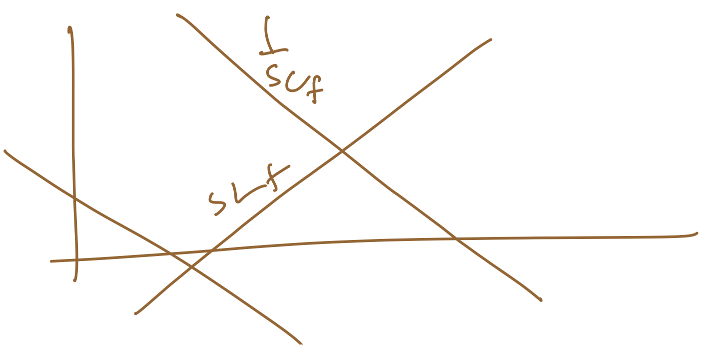
$\frac{V_{in}^2}{R_{damp}}$

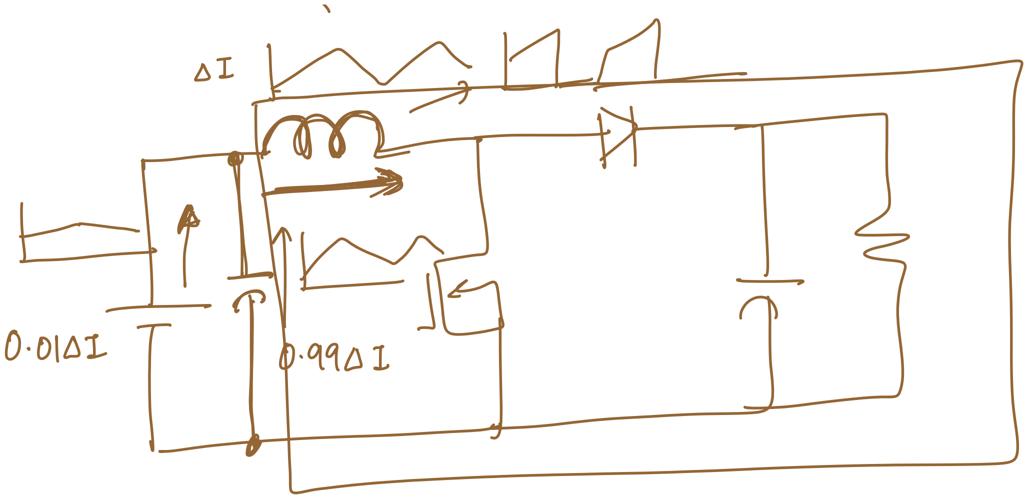
ⓑ



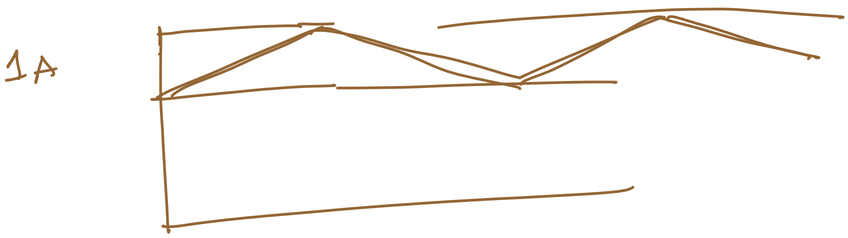
ⓒ

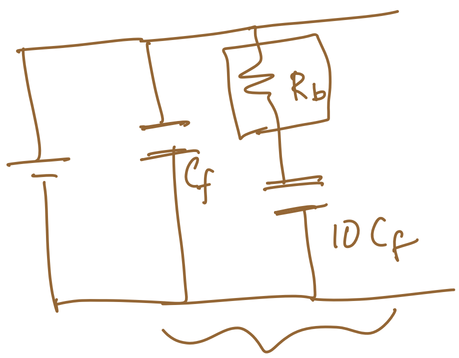




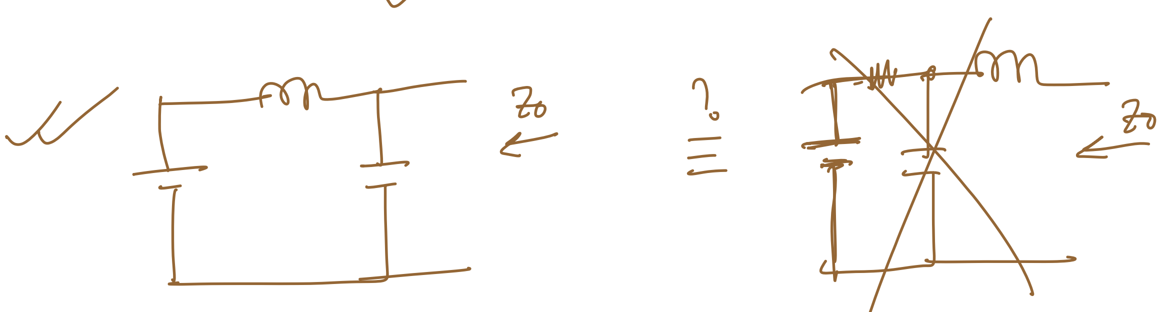


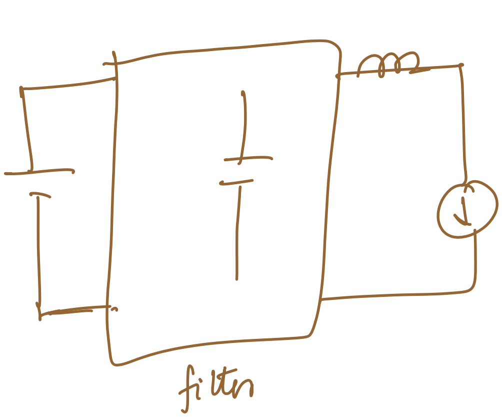
Boost converter

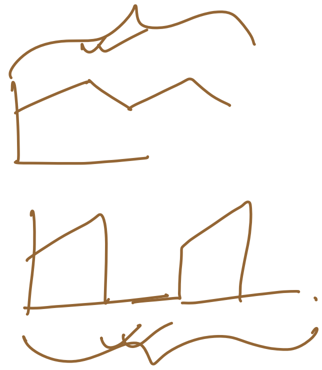




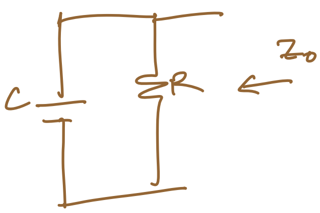
Boost converter

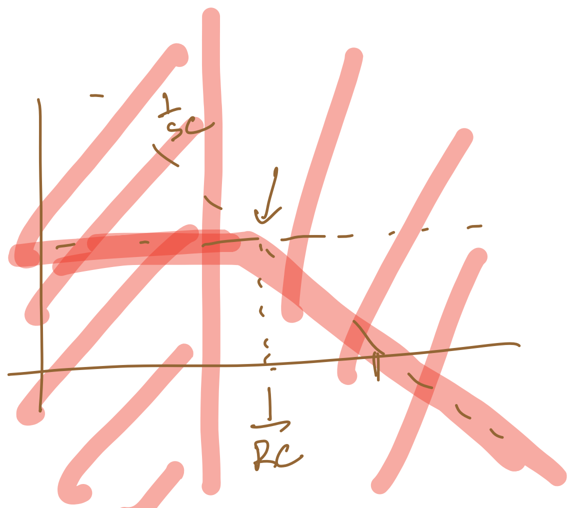


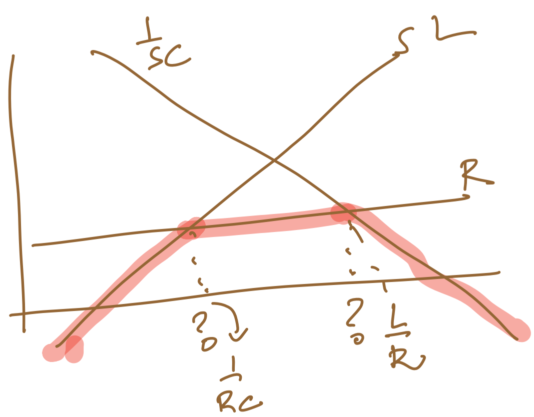

filtr



5:40pm


C
R
Z_o

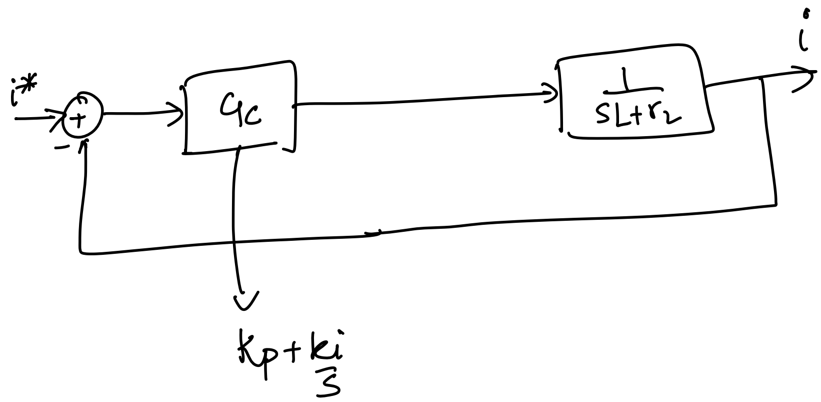

$\frac{1}{sC}$
$\frac{1}{RC}$


$\frac{1}{sC}$
sL
R
ω_o
$\frac{1}{RC}$
ω_o
$\frac{L}{R}$

① CC. $\frac{1}{1+s\tau_i}$

Boost converter :

After implementing feed forward



$$\underbrace{l = \frac{\omega_{g,i}}{s}}$$

$$l = \left(K_p + \frac{k_i}{s}\right) \cdot \left(\frac{1}{sL + r_L}\right)$$

$$\frac{\omega_{gi}}{s} = \left(\frac{sk_p + k_i}{s}\right) \cdot \frac{1}{sL + r_L}$$

$$\underbrace{\begin{matrix} K_p = L \cdot \omega_{g,i} \\ K_i = r_L\,\omega_{g,i} \end{matrix}}$$

$$i^* \xrightarrow{i} i$$

$$i = \frac{l}{1+l} \cdot i^* = \frac{\omega_{gi}/s}{1 + \omega_{gi}/s}\, i^*$$

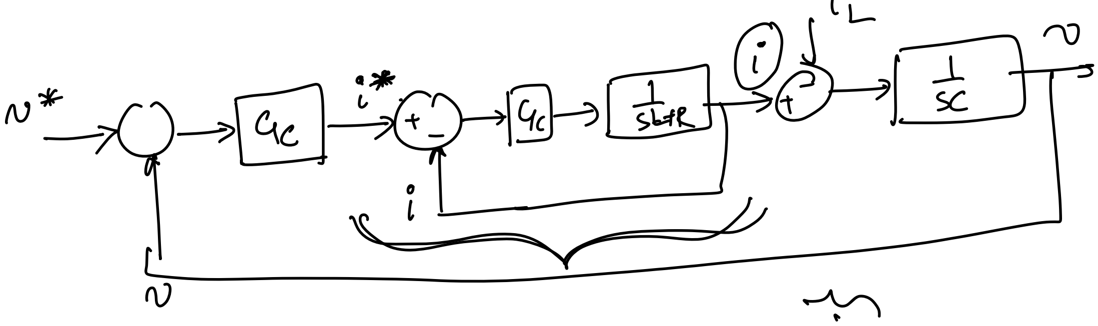
$$i = \frac{\omega_{gi}}{s + \omega_{gi}}\, i^*$$

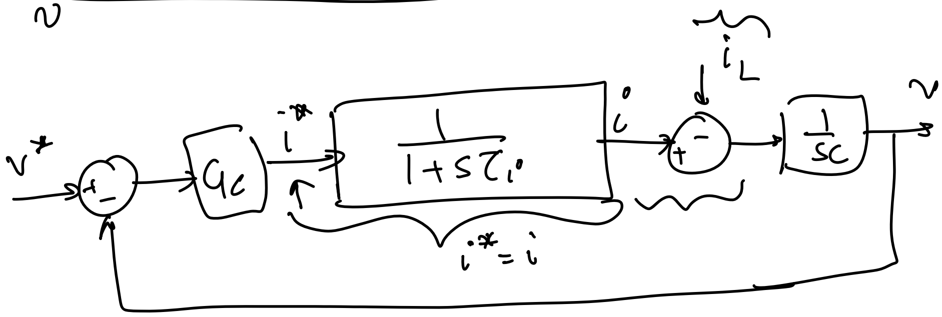
$$i = \frac{1}{s/\omega_{gi} + 1}\, i^*$$

$$\omega_{gi} = \frac{\omega_{sw}}{10} = \frac{2\pi \cdot f_s}{10} = \frac{2\pi \cdot 10 \times 10^3}{10}$$

$$\boxed{i = \frac{1}{\underbrace{s\tau_i + 1}} \, i^*}$$ ← Closed loop T.F.

$$\boxed{\tau_i = \frac{1}{\omega_{gi}} = \frac{10}{\omega_{sw}}}$$

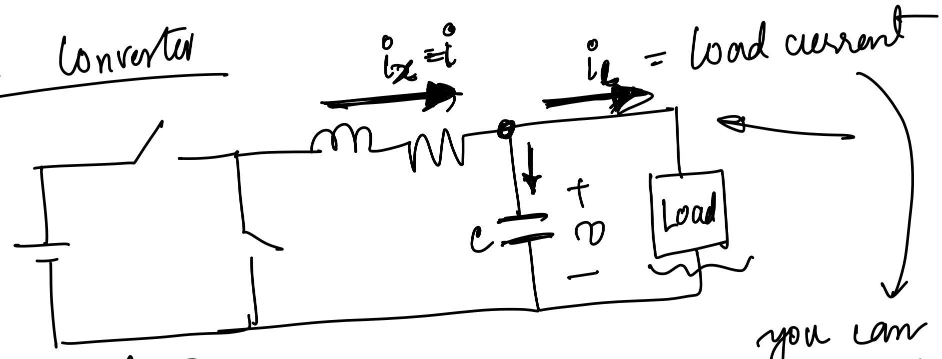




inner current control → actuation signal = d (duty ratio)

outer voltage " → " " = i^* (inner CC reference)

Buck Converter



you can measure this current by a sensor.

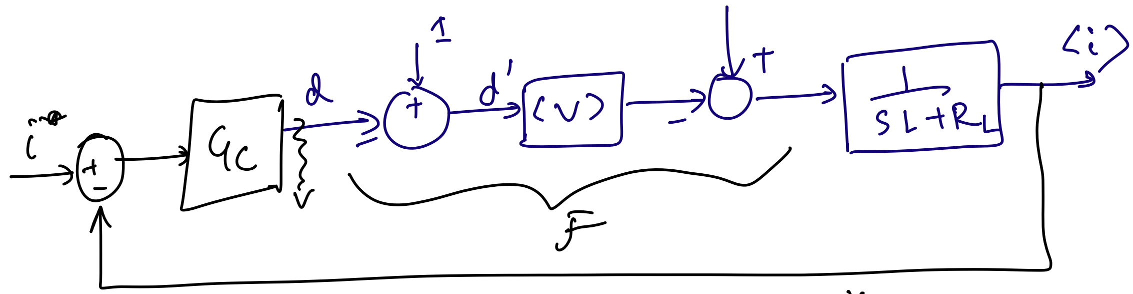
$$\underbrace{i - i_L} = \underbrace{sCv}$$

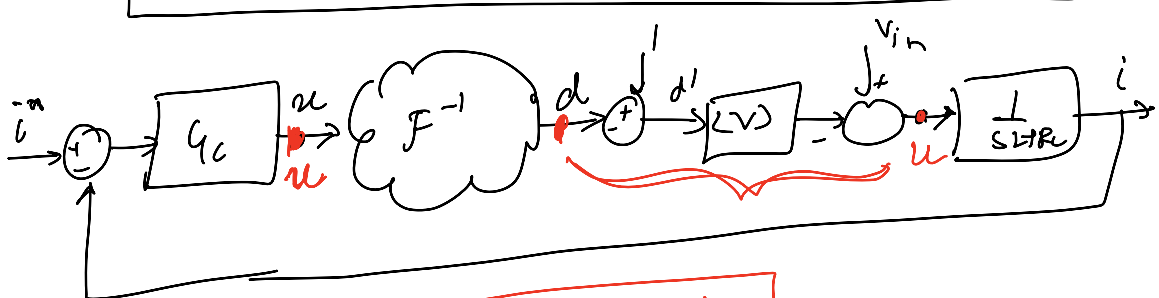
$$\boxed{v = \underbrace{\frac{i - i_L}{sC}}}$$

Boost Converter

or,

$$\frac{\langle V_{in}\rangle - \langle v\rangle d}{sL + R_L} = \langle i\rangle$$





$$\boxed{u = V_{in} - (1-d)v} \quad F.$$

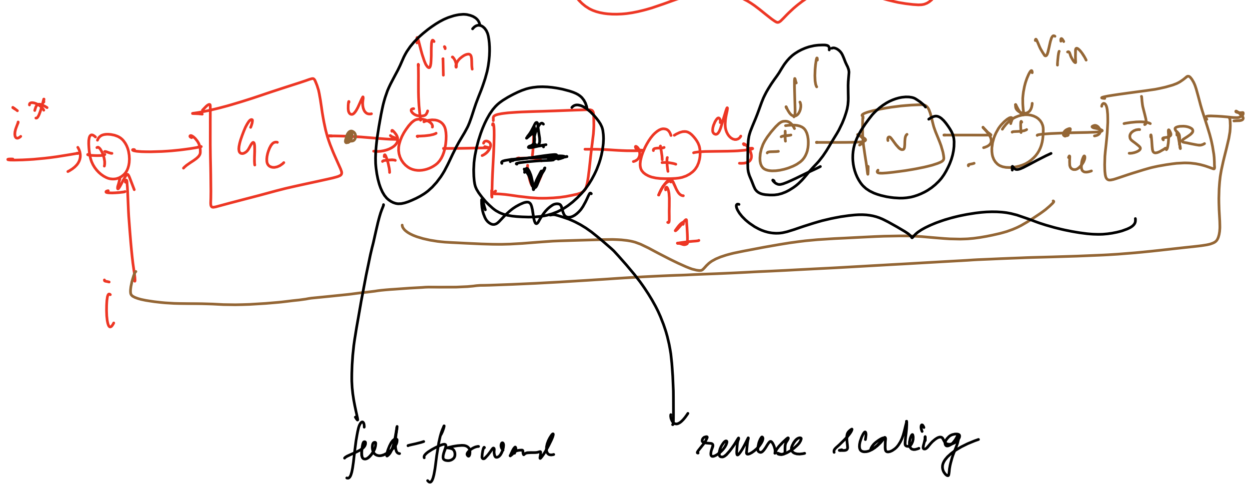
$$u = V_{in} - (1-d)V$$

$$u - V_{in} = -(1-d)V$$

$$-(u - V_{in}) = (1-d)V$$

$$-\frac{(u-V_{in})}{V} = 1-d$$

$$\therefore d = \underbrace{1 + \frac{(u-V_{in})}{V}}$$



max (sensed voltage, 0.001)