NPTEL ONLINE CERTIFICATION COURSES

DIGITAL CONTROL IN SMPCs AND FPGA-BASED PROTOTYPING

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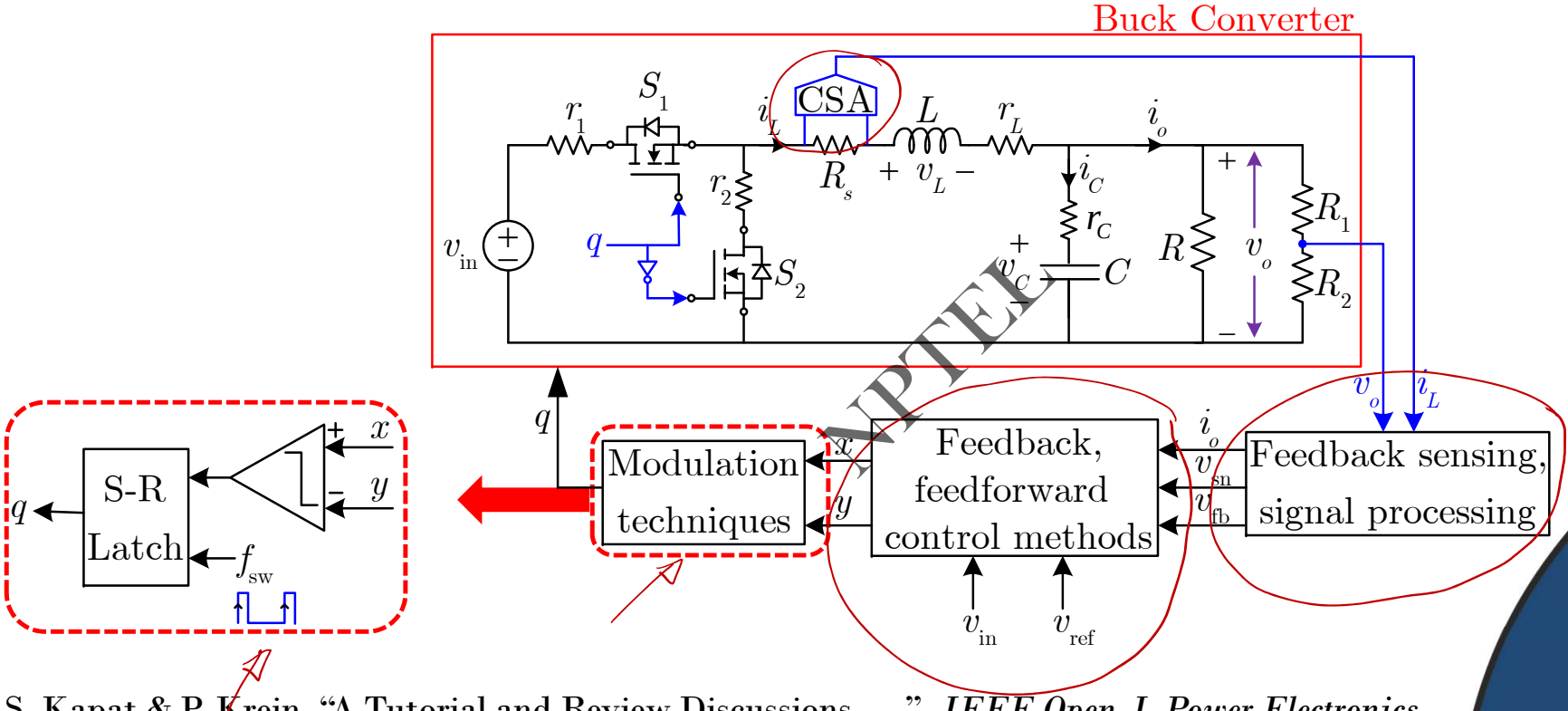
Module 01: Introduction to Digital Control in SMPCs

Lecture 06: Recap of Feedback and Feedforward Control Methods in SMPCs

CONCEPTS COVERED

- Overview of (analog) feedback and feedforward control
- Primary objectives using feedback and feedforward control
- Recap of analog voltage mode control – example of single-loop control
- Recap of analog current mode control – example of two-loop control
- Recap of input voltage and load current feedforward actions

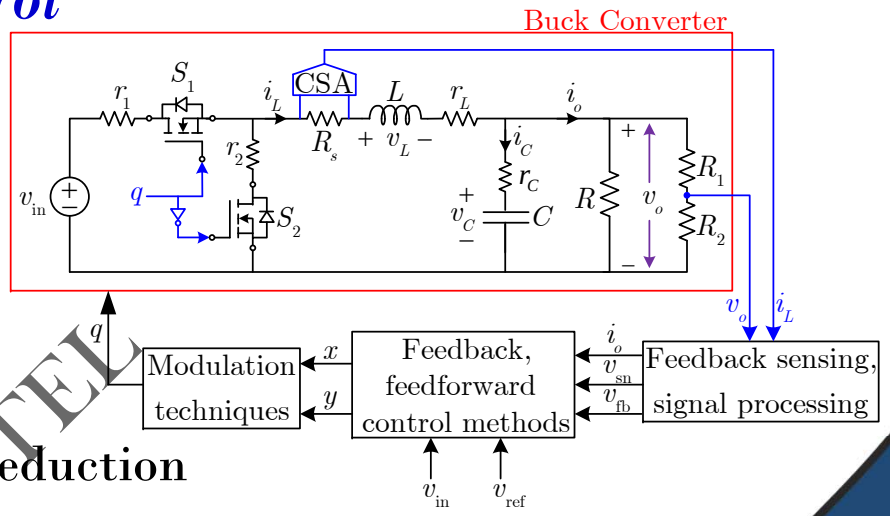
Overview of Feedback/Feedforward Control Methods



S. Kapat & P. Krein, "A Tutorial and Review Discussions …", *IEEE Open J. Power Electronics*

Role of Feedback/Feedforward Control

- Output voltage regulation
- Fast load transient requirements
- Protection using current limit
- Input supply disturbance rejection, EMI reduction
- Nearly flat efficiency curve over a wide load current range
- Consideration: fast scale and large-signal stability
- Constraint: variations in on/off-time as well as frequency

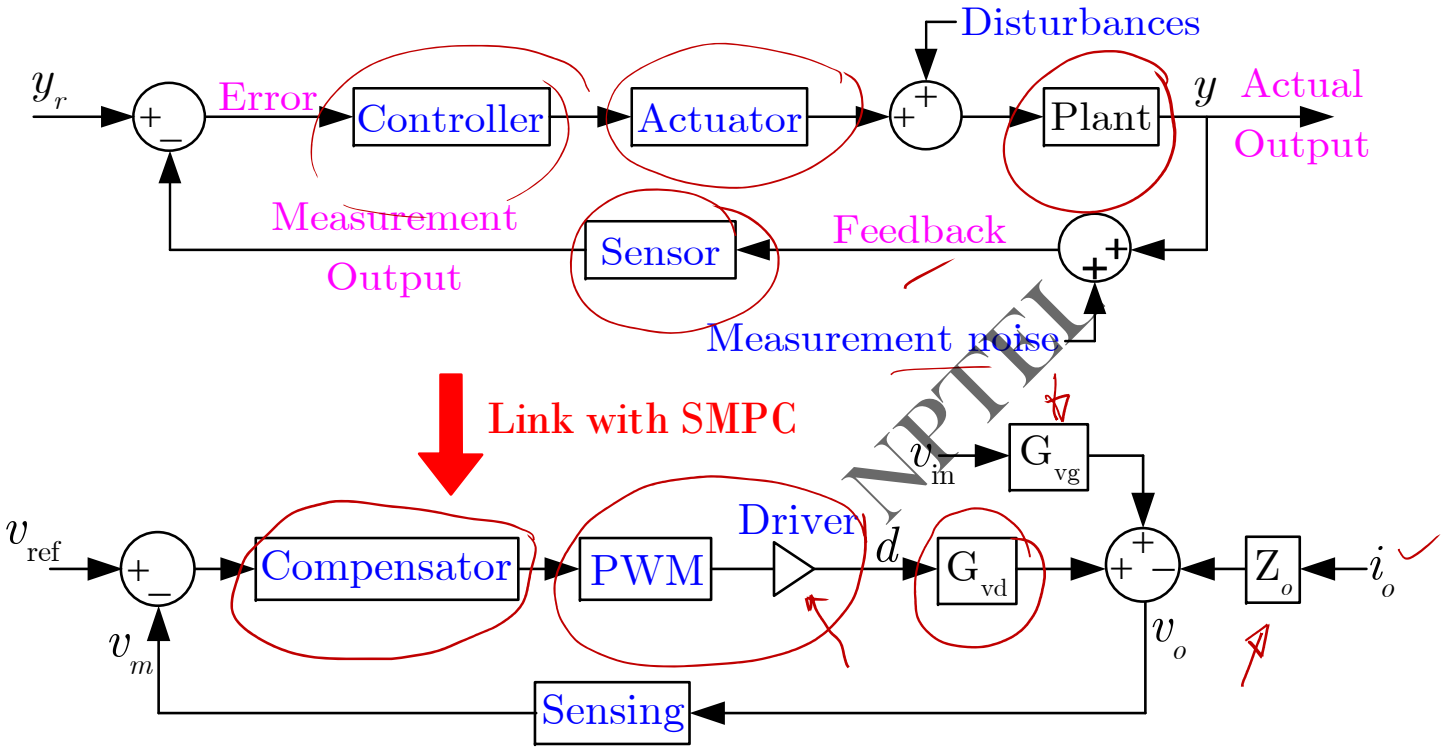


Feedback/Feedforward Control

- Voltage mode control with and without input voltage feedforward
- Current mode control with and without DC droop control (or AVP)
- State feedback control- linear or nonlinear
- Fixed and/or variable frequency control
- Multimode control for wide load range

Interdependency of modulation and control!!

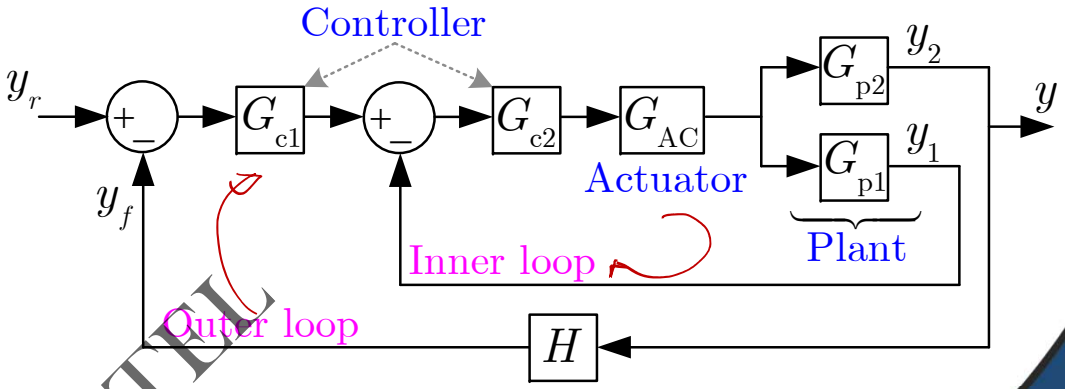
Single Loop Feedback Control in SMPC



[For details, refer to Lecture~15, NPTEL "Control and Tuning Methods …" course (link)

Basic Two Loop Output Feedback Control

- Outer loop → generally (output) voltage loop
- Inner loop:
  - Inductor current
  - Capacitor current
  - Derivative of output voltage
  - Ripple output voltage



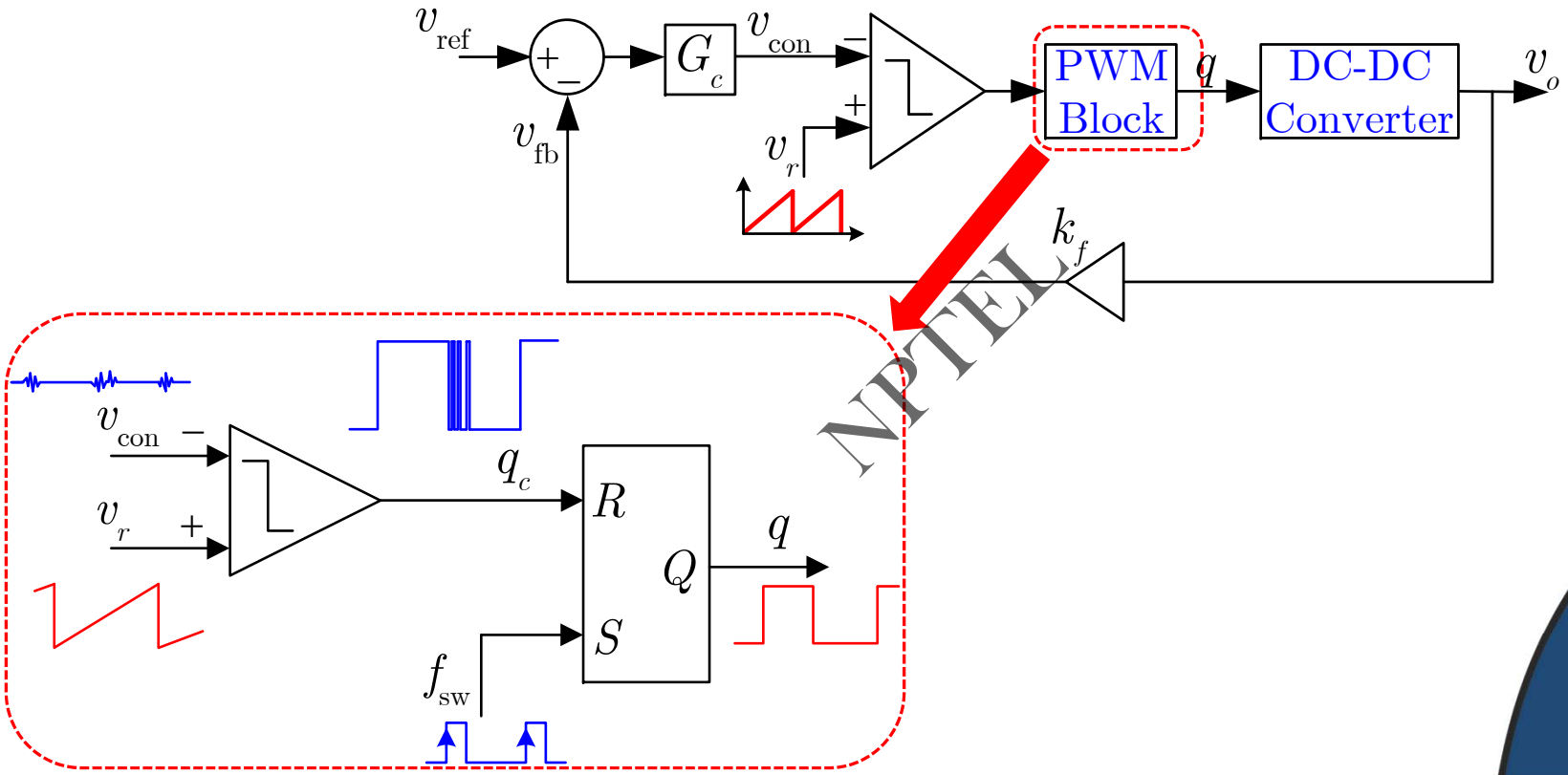
Two loop control

Master / slave control

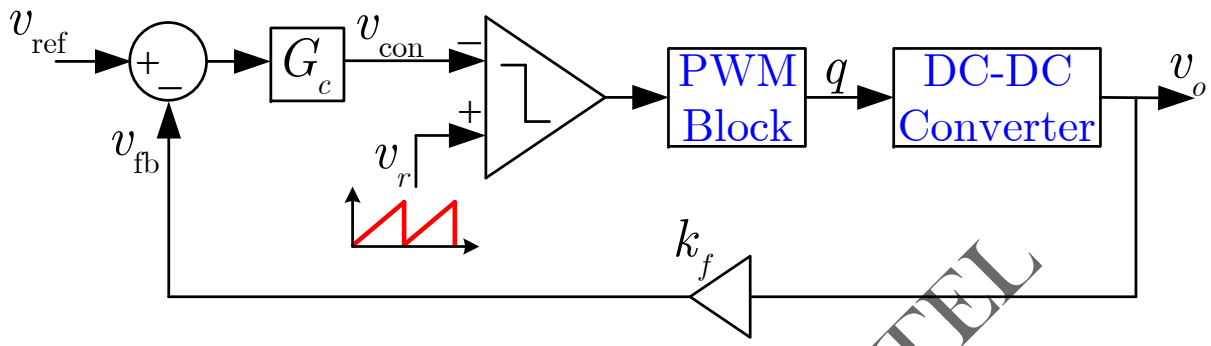
Cascade control

[For details, refer to Lecture~15, NPTEL "Control and Tuning Methods …" course (link)

Single Feedback Loop : Voltage Mode Control

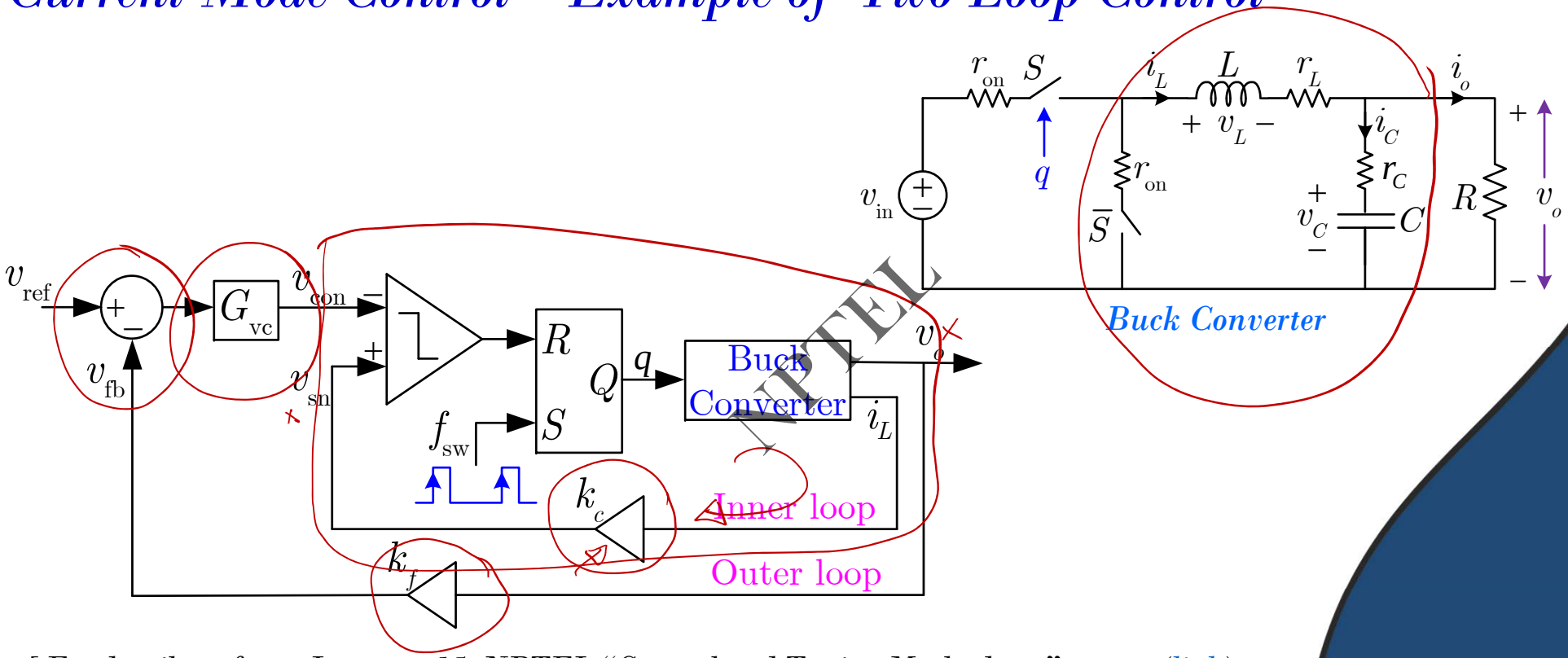


Limitations of Single Loop Voltage Mode Control



- No control over current !!!
- Compensation sensitive to operating conditions
- Fault protection and start-up logics separately needed
- Difficult to optimize transient and start-up performance

Current Mode Control – Example of Two Loop Control



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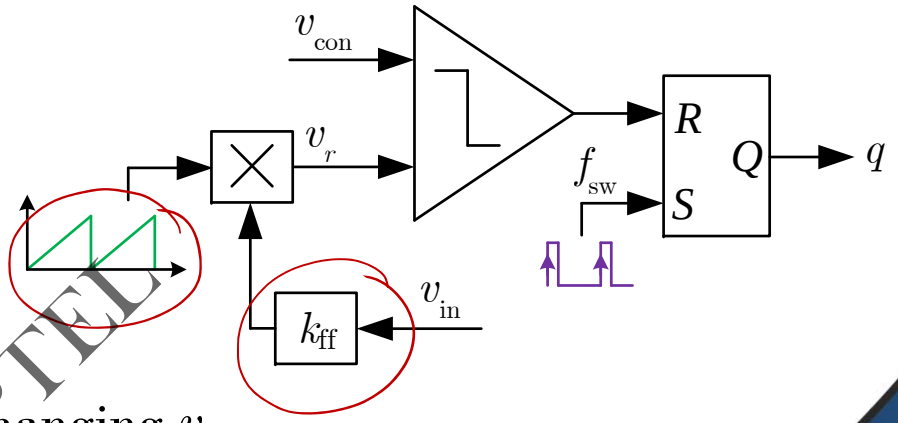
Advantages of Two Loop Current Mode Control

- Possibility of reduced-order system dynamics using time-scale separation
- Simplified controller design with improved robustness
- Higher bandwidth can be achieved without compromising phase margin
- But, sensor requirement increases in current based implementation
- Existence of sub-harmonic instability over wide duty ratio range

Input Voltage Feedforward in Direct Duty Control in a Buck Converter

$$v_o = dv_{\text{in}} = \underbrace{\left(\frac{1}{V_U}\right)}_{F_m} \times v_{\text{con}} \times v_{\text{in}}$$

(modulator gain)

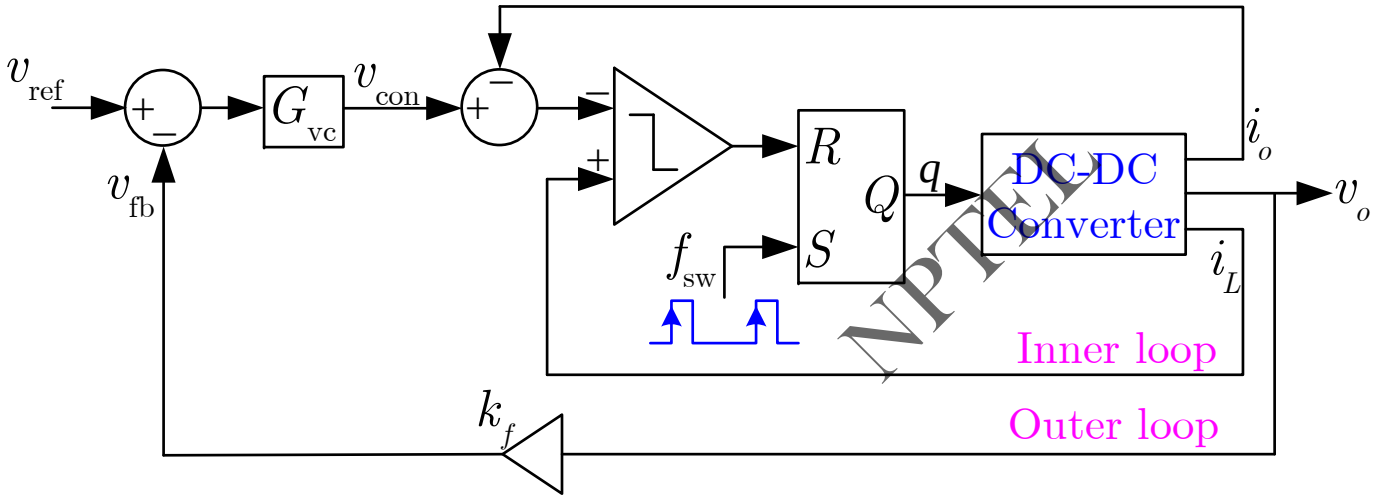


- **Objective is to make Δv_o even without changing v_{con}**

If $V_U = k_{\text{ff}} v_{\text{in}}$ $v_o = \dfrac{1}{k_{\text{ff}} v_{\text{in}}} \times v_{\text{in}} \times v_{\text{con}} = \dfrac{v_{\text{con}}}{k_{\text{ff}} v_{\text{in}}}$ → **Insensitive to input voltage variation**

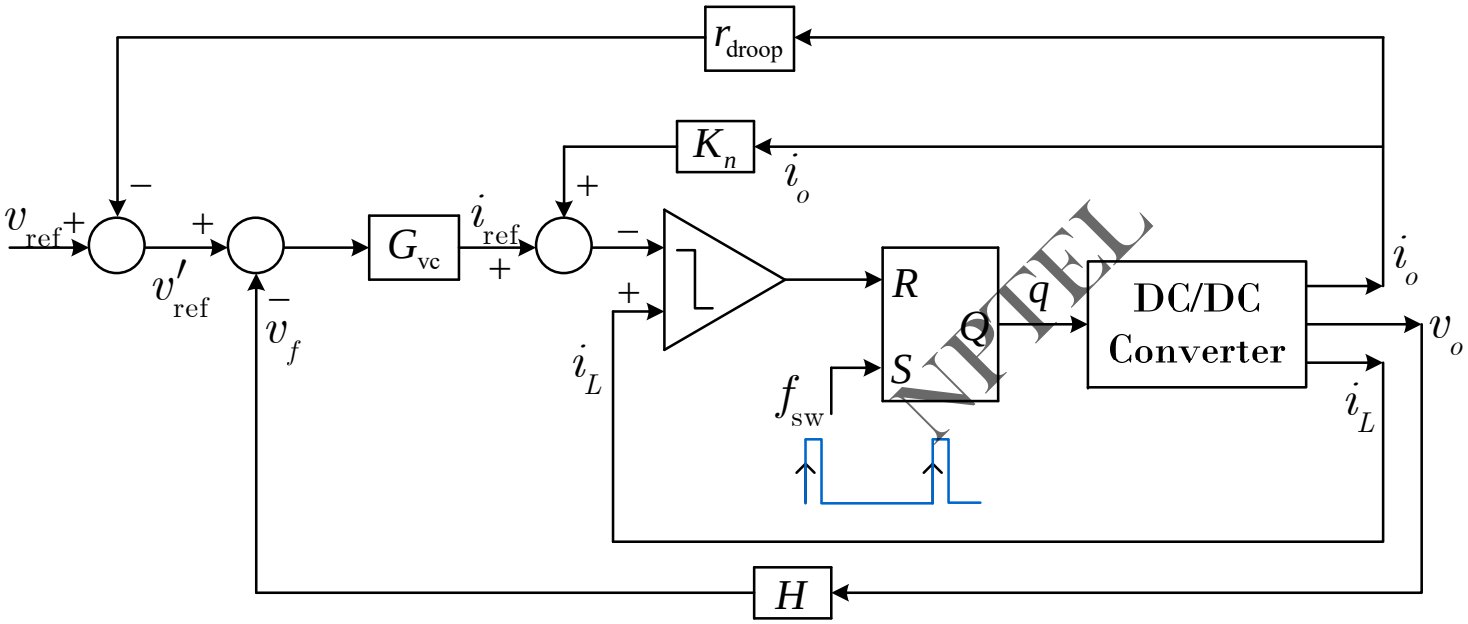
[For details, refer to Lecture~14, NPTEL "Control and Tuning Methods …" course (link)

Load Current Feedforward in Current Mode Control



[For details, refer to Lecture~17, NPTEL "Control and Tuning Methods …" course (link)

Load Current Feedforward with Droop – Adaptive Voltage Positioning



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Questions

- How to digitize single-loop and multi-loop analog feedback control?
- What will design flexibilities using various modulation techniques?
- How many ADC and/or DAC needed?
- How to incorporate feedback forward actions in digital control?

Objectives of this course – coming soon!!

CONCLUSION

- Primary objectives using feedback and feedforward control - discussed
- Recap of analog voltage mode control – example of single-loop control
- Recap of analog current mode control – example of two-loop control
- Recap of input voltage and load current feedforward actions

THANK YOU !