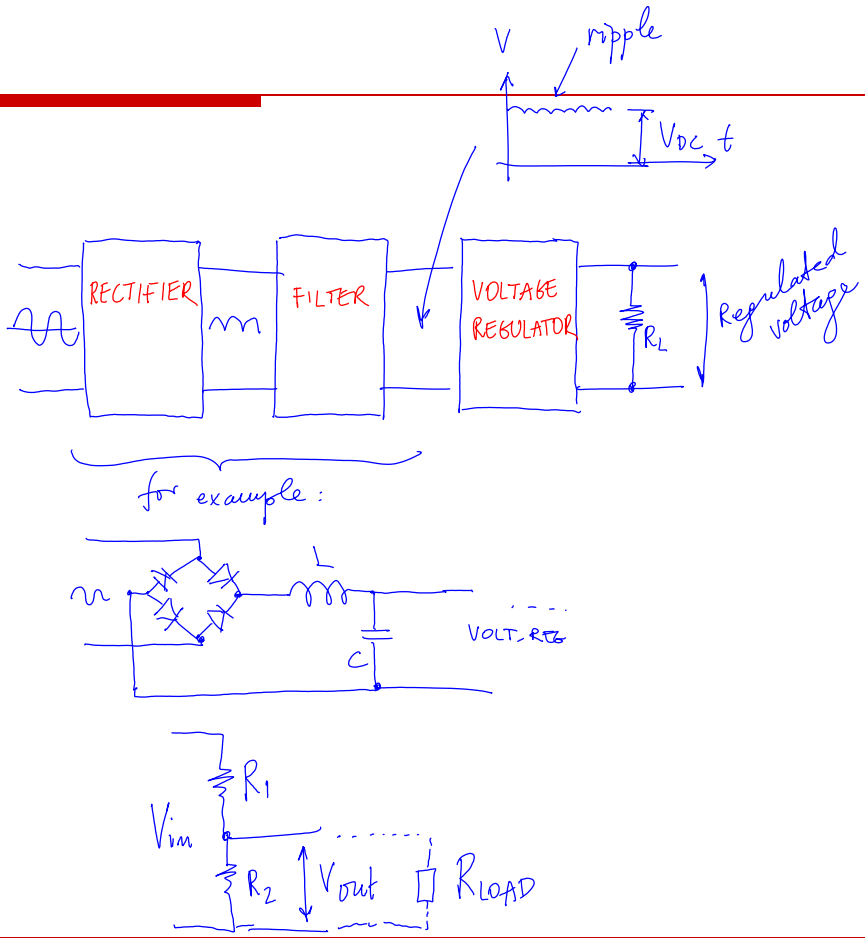
UNIVERSITY OF ALASKA FAIRBANKS

EE 444/645: Embedded Systems Design

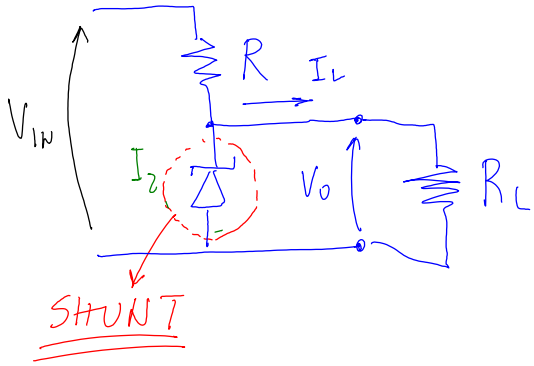
Voltage Regulators

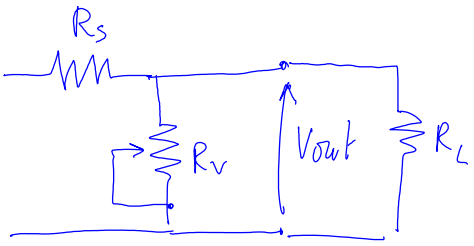
Spring 2023. Set: **8**

Instructor: Dr. Dejan Raskovic

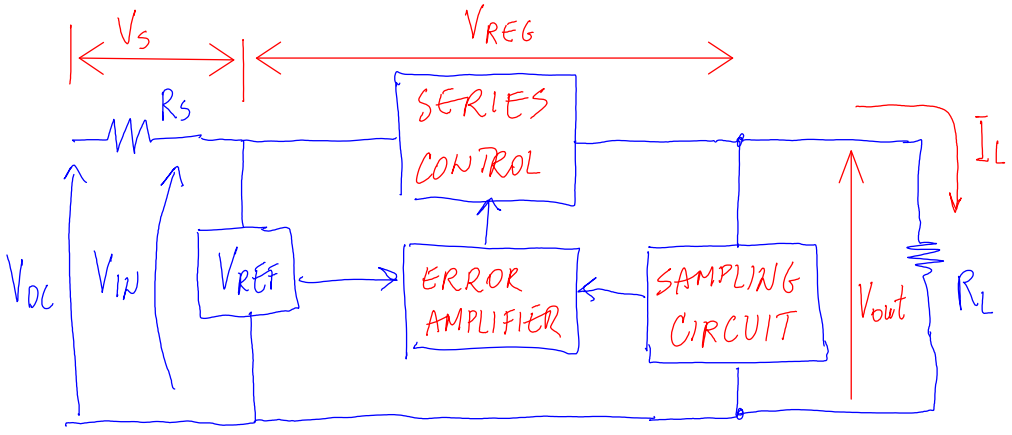


Linear voltage regulators

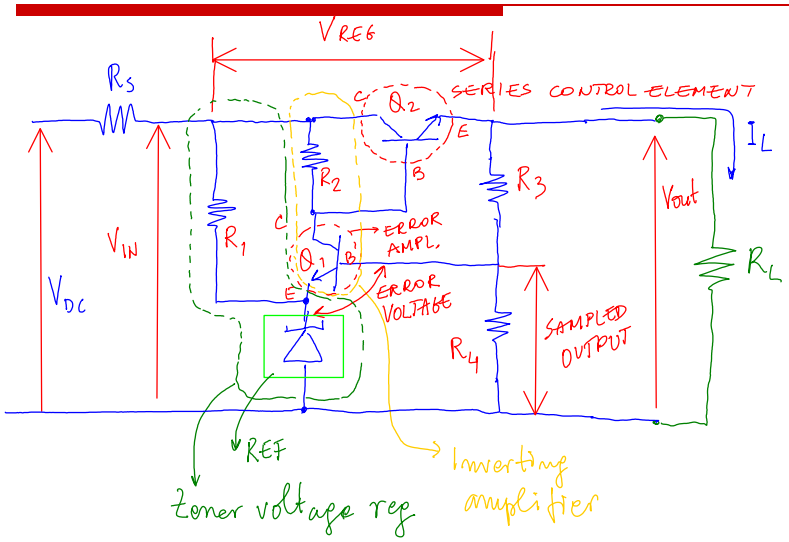




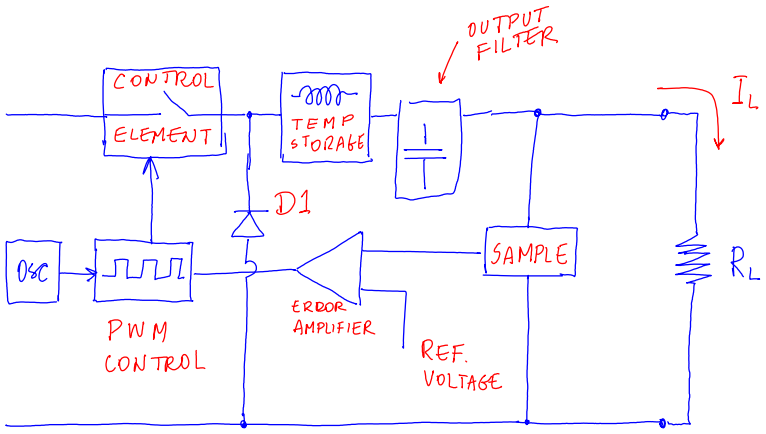
Linear series voltage regulators



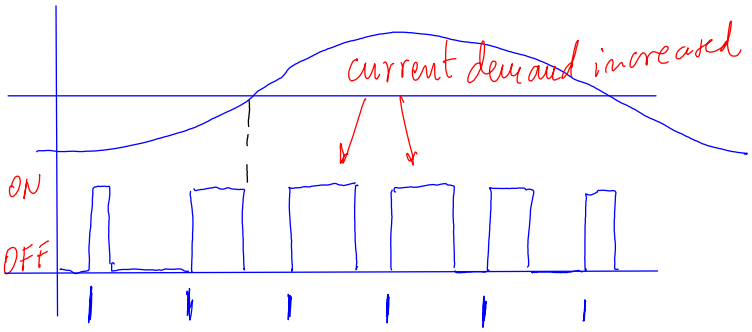
Linear series voltage regulators



Switching regulators

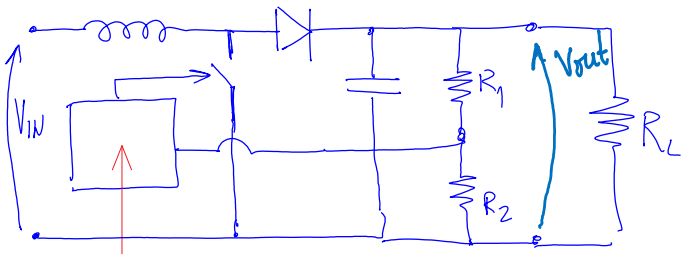


Regulation



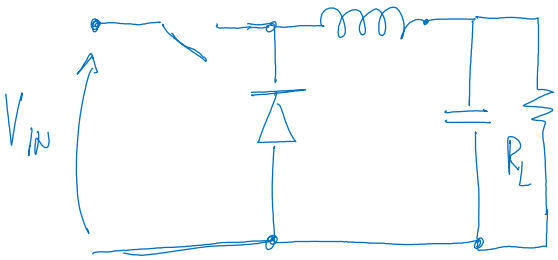
Keep the grounds separated

Boost (step-up) converter

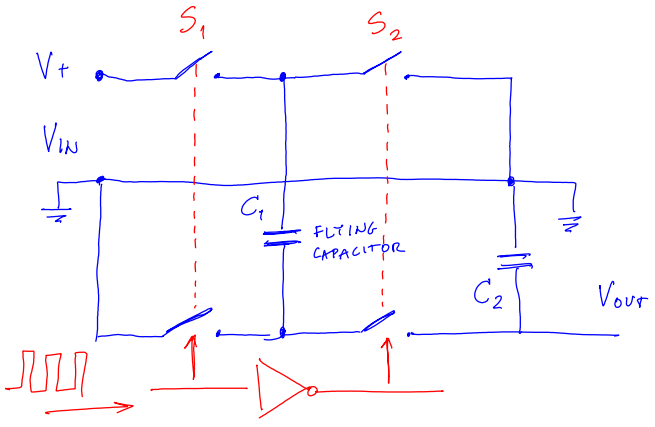


Sampling, Error Amplifier, PWM, Oscillator

Buck



Charge pump



This one is inverting voltage.

Charge pump

From: Palumbo and Pappalardo, "Charge Pump Circuits:…," *IEEE Circuits and Systems Magazine*, First Quarter 2010, pp. 31-45

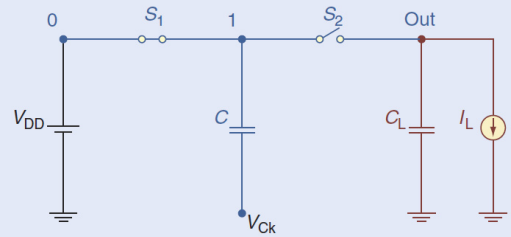


Figure 1. Ideal one-stage CP.

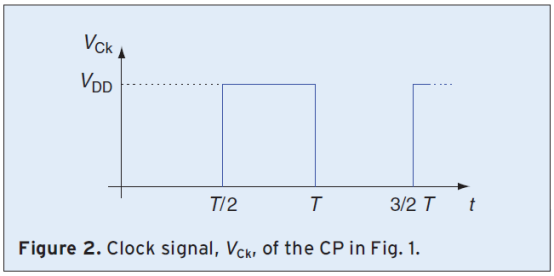


Figure 2. Clock signal, V_{Ck}, of the CP in Fig. 1.

$$V_{\text{Out}}|_{\text{Steady State}} = 2V_{\text{DD}} - \frac{I_L \cdot T}{C}.$$

For an n-stage CP:

$$V_{\text{Out}}|_{\text{Steady State}} = (N+1)V_{\text{DD}} - N\frac{I_L \cdot T}{C}.$$

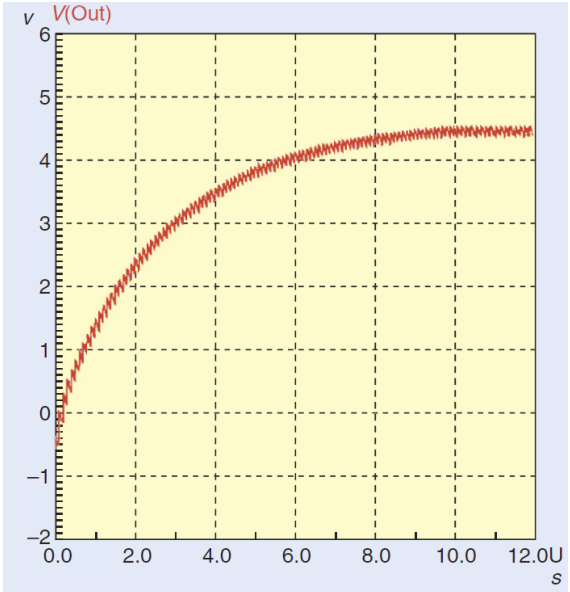


Figure 4. Output voltage of the one stage charge pump.

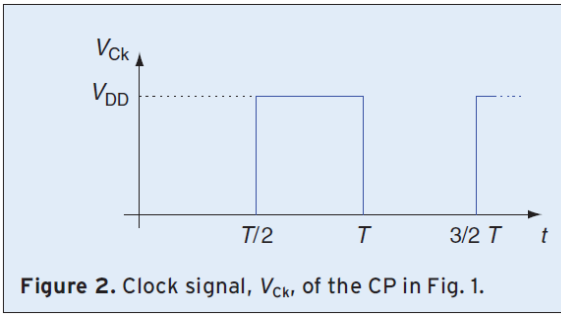


Figure 2. Clock signal, V_{Ck}, of the CP in Fig. 1.

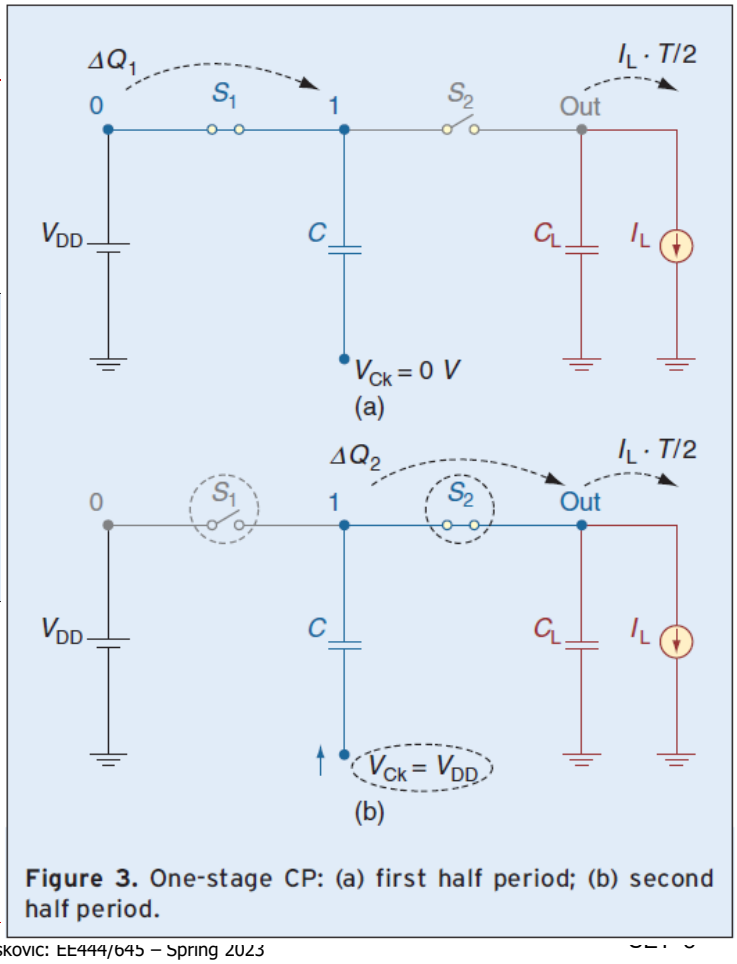
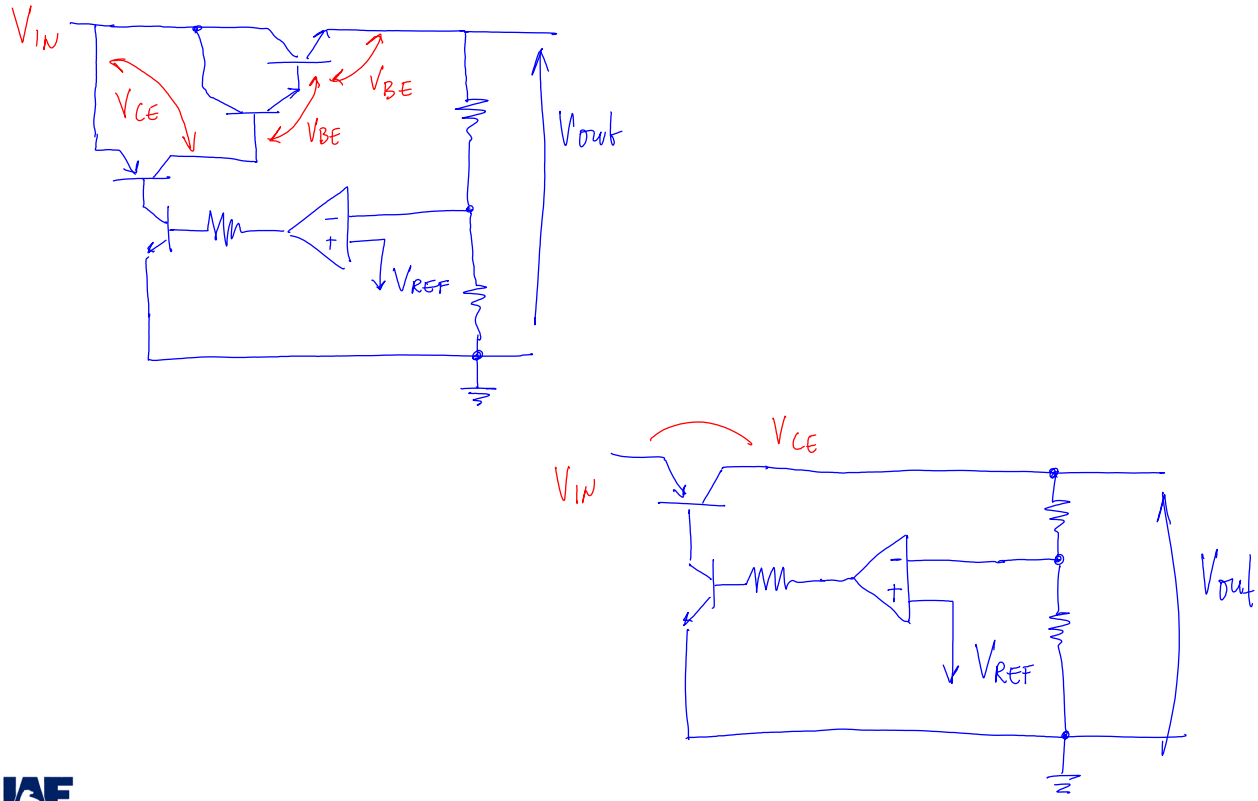


Figure 3. One-stage CP: (a) first half period; (b) second half period.

Low Dropout Regulator (LDO)



PROs and CONs of linear/switching VRs

- Linear
  - PRO: low output noise
  - PRO: fast response to changes in Vin/Vout
  - PRO: at our power levels – usually smaller and cheaper
  - CON: inefficient (can be as bad as 30%-50%, be careful when selecting)
  - CON: acoustic noise
  - CON: **can't boost voltage**
  - …
- Switching
  - PRO: more efficient
  - PRO: Can boost voltage
  - CON: switching noise (RFI)
  - …

When you can't make up your mind…

- Three buck VRs
- Three LDO linear VRs
- A Buck-boost regulator
- Li-Ion Battery charger
- Two Load Switches
- Up to 7 regulated voltages
- All programmable through I^2C