BENHA UNIVERSITY
FACULTY OF ENGINEERING AT SHOUBRA

ECE-322
Electronic Circuits (B)

Lecture #7
Voltage Regulators

Instructor:
Dr. Ahmad El-Banna

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Agenda

- Voltage Regulation
- Basic Linear Series Regulators
- Basic Linear Shunt Regulators
- Intro. to Switching Regulators

VOLTAGE REGULATION

Intro.

- **Two** basic **categories** of voltage regulation are:
  - Line regulation
  - Load regulation

- The **purpose** of **line regulation** is to maintain a nearly **constant output** voltage **when** the **input** voltage **varies**.
- The **purpose** of **load regulation** is to maintain a nearly **constant output** voltage **when** the **load varies**.

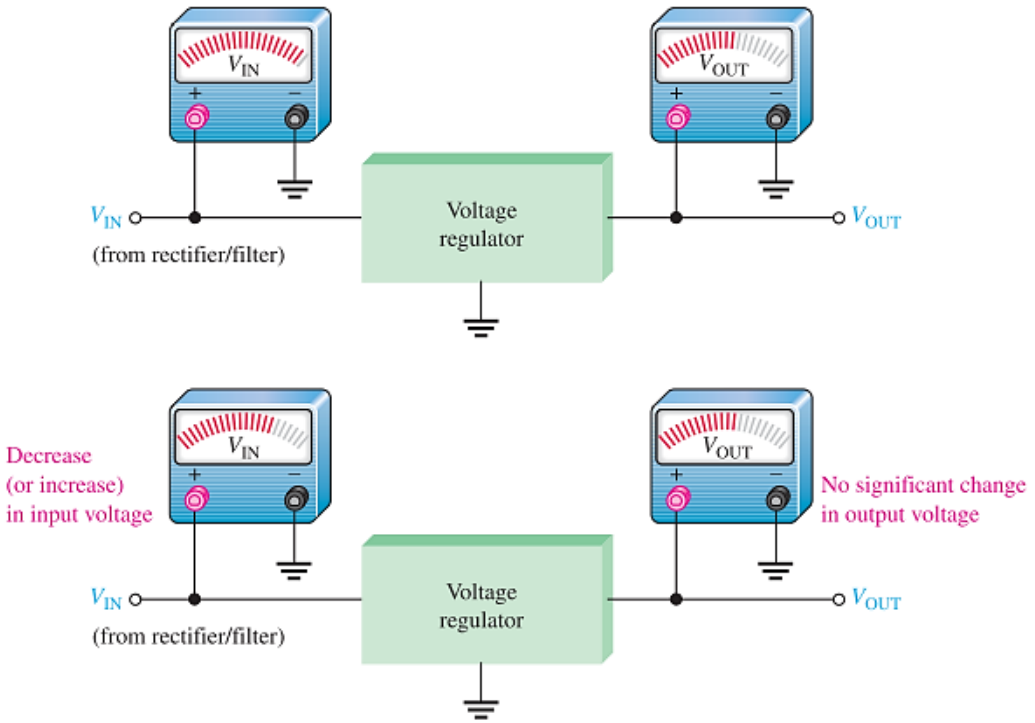
Line Regulation

- When the ac input (line) voltage of a power supply changes, an electronic circuit called a **regulator** maintains a nearly constant output voltage.
- **Line regulation** can be defined as the percentage change in the output voltage for a given change in the input voltage

$$\text{Line regulation} = \left(\frac{\Delta V_{OUT}}{\Delta V_{IN}}\right)100\%$$

- Line regulation can also be expressed in units of **%/V**

$$\text{Line regulation} = \frac{(\Delta V_{OUT}/V_{OUT})100\%}{\Delta V_{IN}}$$

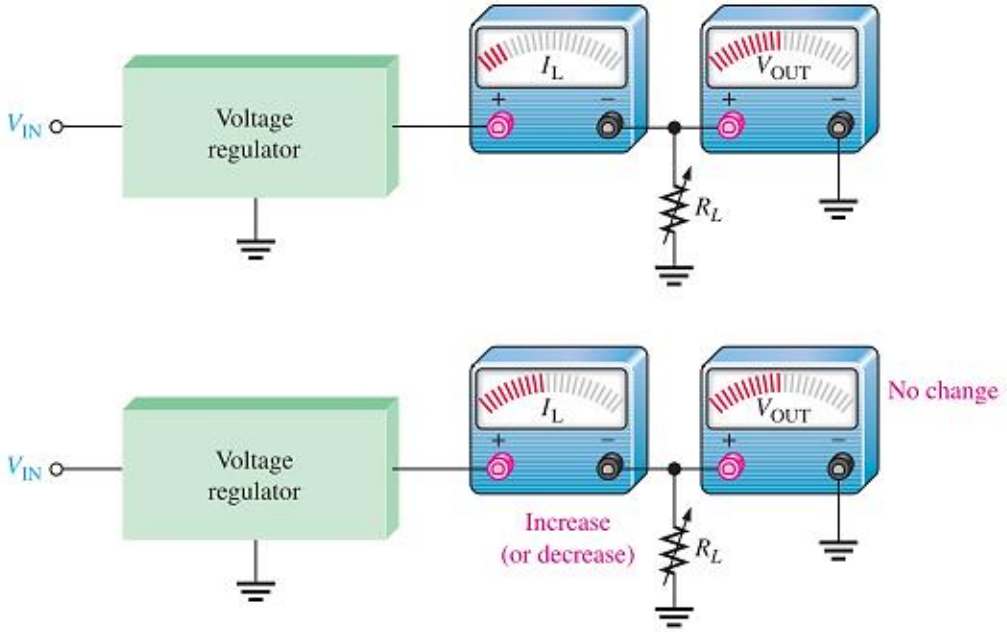


Load Regulation

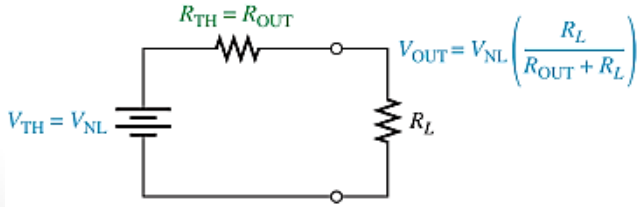
- Load regulation can be defined as the percentage change in output voltage for a given change in load current.
- One way to express load regulation is as a percentage change in output voltage from no-load (NL) to full-load (FL).

$$\text{Load regulation} = \left(\frac{V_{NL} - V_{FL}}{V_{FL}}\right)100\%$$

- The load regulation can be expressed as a percentage change in output voltage for each mA change in load current.



- Using R_{OUT}, Thevenin equivalent circuit for a power supply with a load resistor.



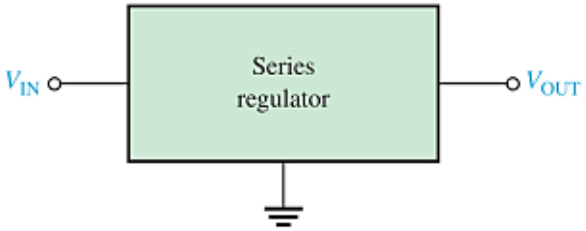
$$\text{Load regulation} = \left(\frac{R_{OUT}}{R_{FL}}\right)100\%$$

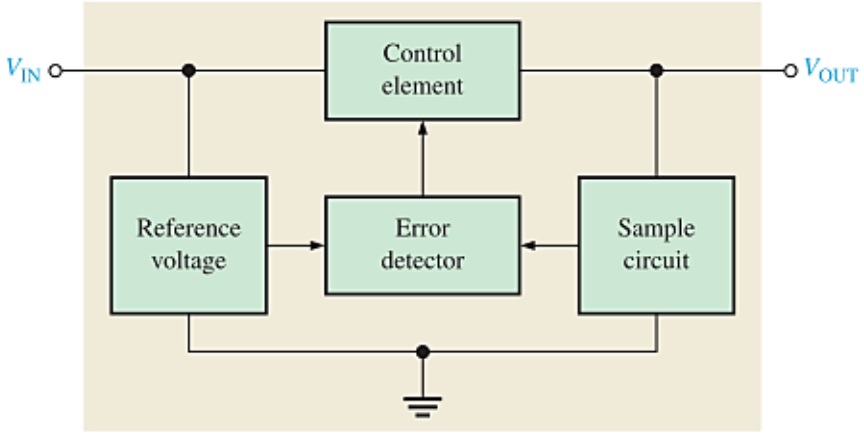
BASIC LINEAR SERIES REGULATORS

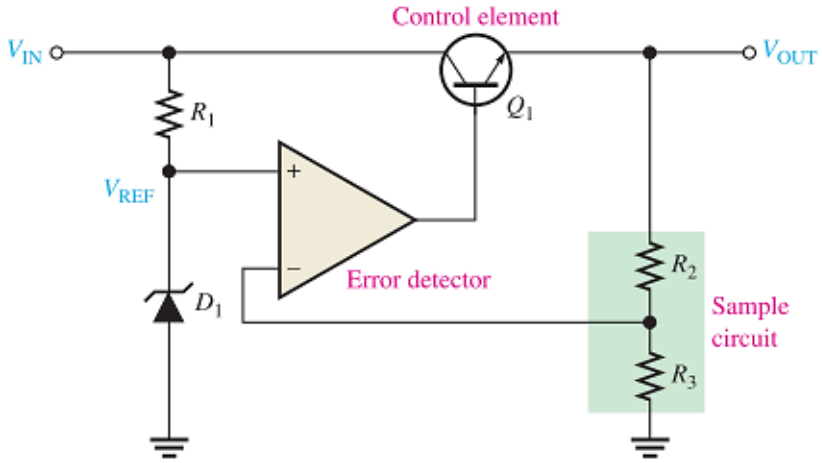
Regulators Classification

- The fundamental classes of voltage regulators are:
  - linear regulators
  - switching regulators
- Both of these are available in integrated circuit form.
- Two basic types of linear regulator are
  - series regulator
  - shunt regulator

Series Voltage Regulator



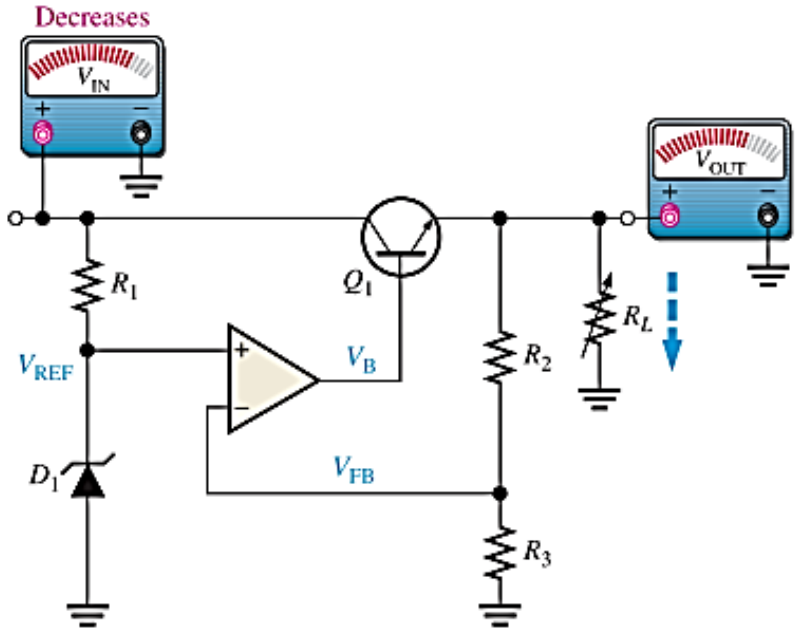




Basic op-amp series regulator

Regulating Action

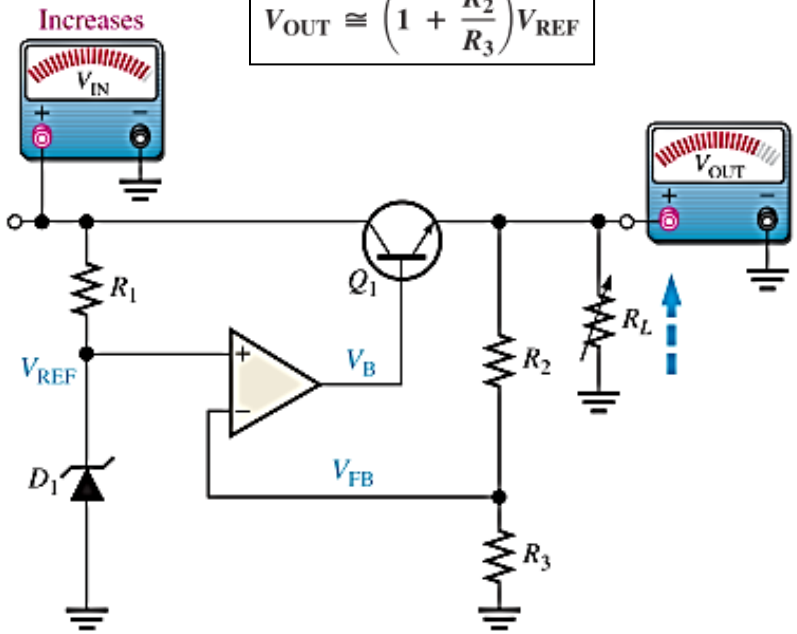
- Illustration of series regulator action that keeps V_{OUT} constant when V_{IN} or R_L changes.



(a) When V_{IN} or R_L decreases, V_{OUT} attempts to decrease. The feedback voltage, V_{FB}, also attempts to decrease, and as a result, the op-amp's output voltage V_B attempts to increase, thus compensating for the attempted decrease in V_{OUT} by increasing the Q_1 emitter voltage. Changes in V_{OUT} are exaggerated for illustration.

When V_{IN} (or R_L) stabilizes at its new lower value, the voltages return to their original values, thus keeping V_{OUT} constant as a result of the negative feedback.

$$V_{OUT} \cong \left(1 + \frac{R_2}{R_3}\right) V_{REF}$$

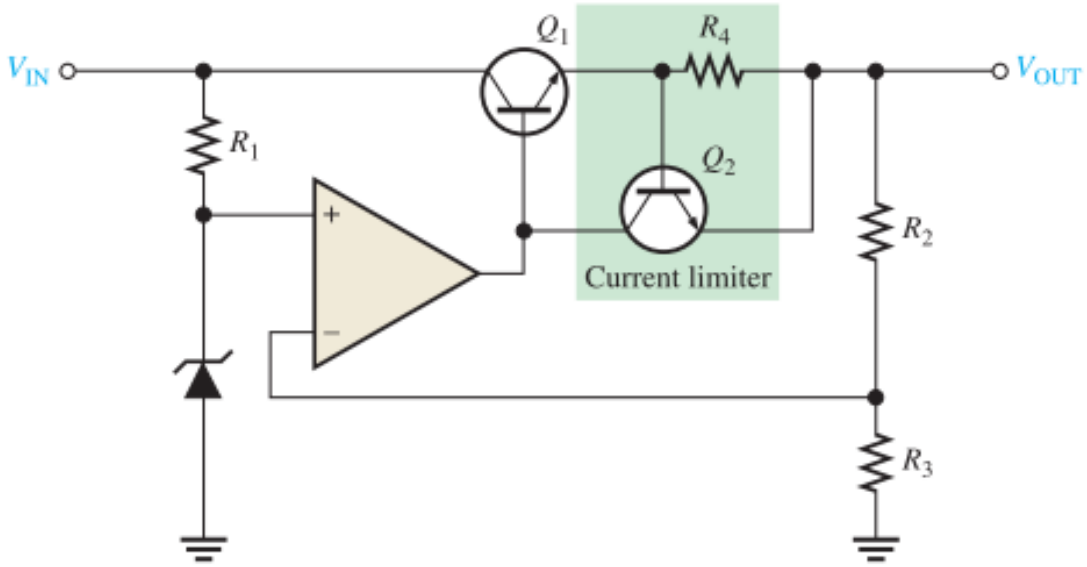


(b) When V_{IN} or R_L increases, V_{OUT} attempts to increase. The feedback voltage, V_{FB}, also attempts to increase, and as a result, V_B, applied to the base of the control transistor, attempts to decrease, thus compensating for the attempted increase in V_{OUT} by decreasing the Q_1 emitter voltage.

When V_{IN} (or R_L) stabilizes at its new higher value, the voltages return to their original values, thus keeping V_{OUT} constant as a result of the negative feedback.

Short-Circuit or Overload Protection

- If an **excessive** amount of **load current** is drawn, the series-pass **transistor** can be quickly damaged or **destroyed**.
- Most regulators use some type of excess **current protection** in the form of a current-limiting mechanism.
- one method of current limiting to prevent overloads called **constant-current limiting**.

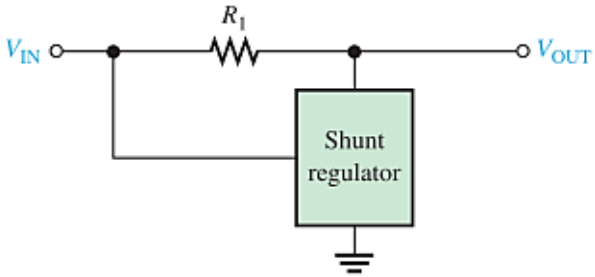


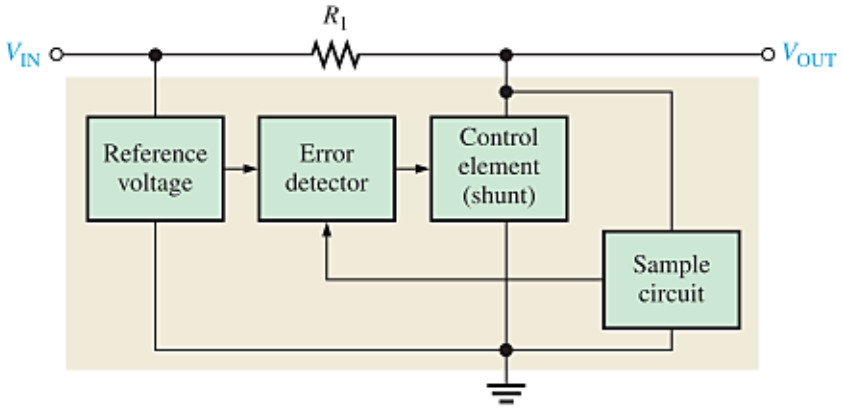
$$I_{L(max)} = \frac{0.7\ V}{R_4}$$

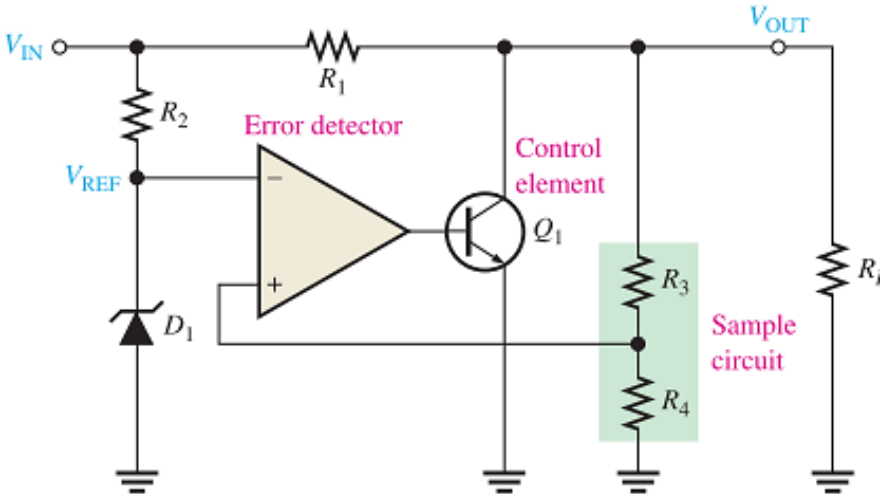
BASIC LINEAR SHUNT REGULATORS

Shunt Regulator

- In the shunt regulator, the control element is a transistor in parallel (shunt) with the load.

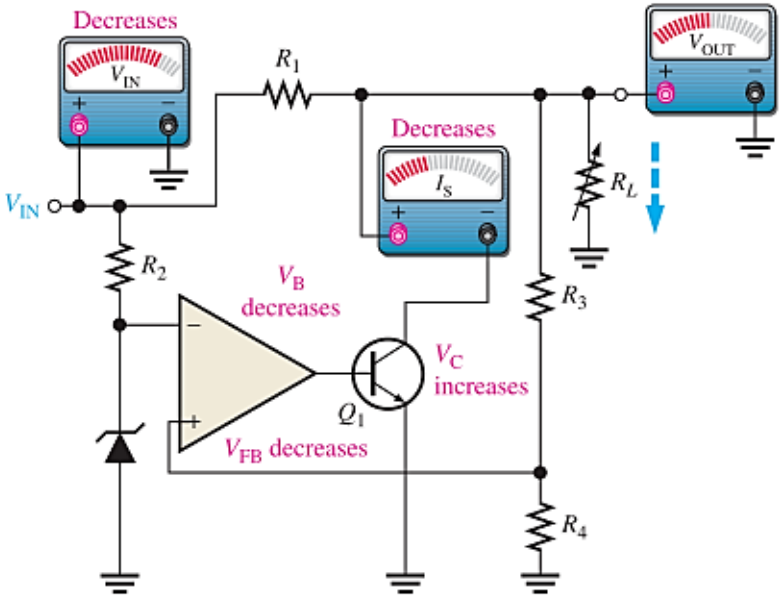




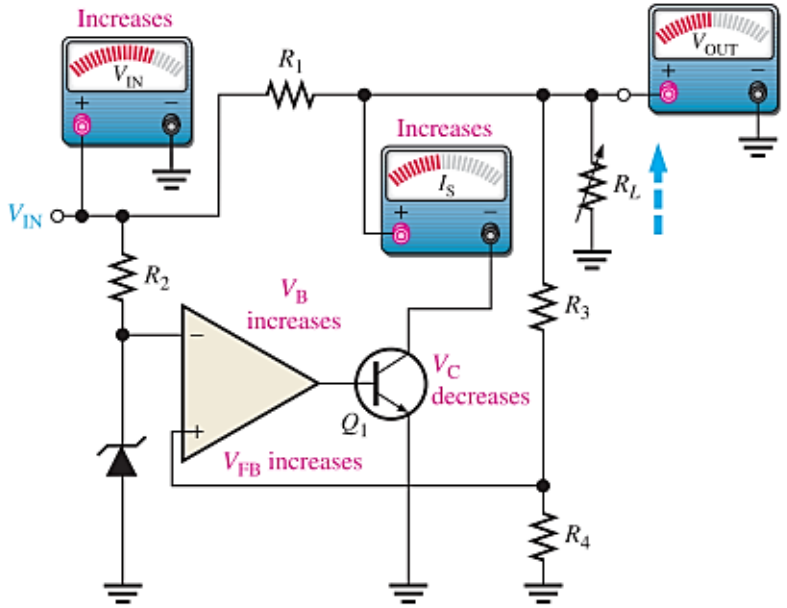


Regulating Action

- Sequence of responses when V_{OUT} tries to decrease as a result of a decrease in R_L or V_{IN} (opposite responses for an attempted increase)



(a) Response to a decrease in V_{IN} or R_L



(b) Response to an increase in V_{IN} or R_L

$$\Delta I_S = \frac{\Delta V_{IN}}{R_1} \qquad I_{L(max)} = \frac{V_{IN}}{R_1}$$

- It offers inherent short-circuit protection

INTRO. TO SWITCHING REGULATORS

Switching Regulators

- The two types of **linear regulators**, series and shunt, have **control elements** (**transistors**) that are **conducting all the time**, with the amount of conduction varied as demanded by changes in the output voltage or current.
- The **switching regulator** is different because the **control element** operates as a **switch**.

- A much **greater efficiency** can be realized with a switching type of voltage regulator than with the linear types because the transistor switches on and off and dissipates power only when it is on.
- Efficiencies can be greater than **90%**.

- **Three** basic **configurations** of switching regulators are **step-down**, **step-up**, and **inverting**.
- In **some cases**, such as **a laptop computer**, **all three types may be employed** for various parts of the system.
- For **example**, the **display** typically will use an **inverting** type, the **microprocessor** would use a **step-down** type, and the **disk** drive may use a **step-up** type.

- For more details, refer to:
  - Chapter 17, T. Floyd, **Electronic Devices**, 9th edition.
- The lecture is available online at:
  - http://bu.edu.eg/staff/ahmad.elbanna-courses/12135
- For inquires, send to:
  - ahmad.elbanna@feng.bu.edu.eg