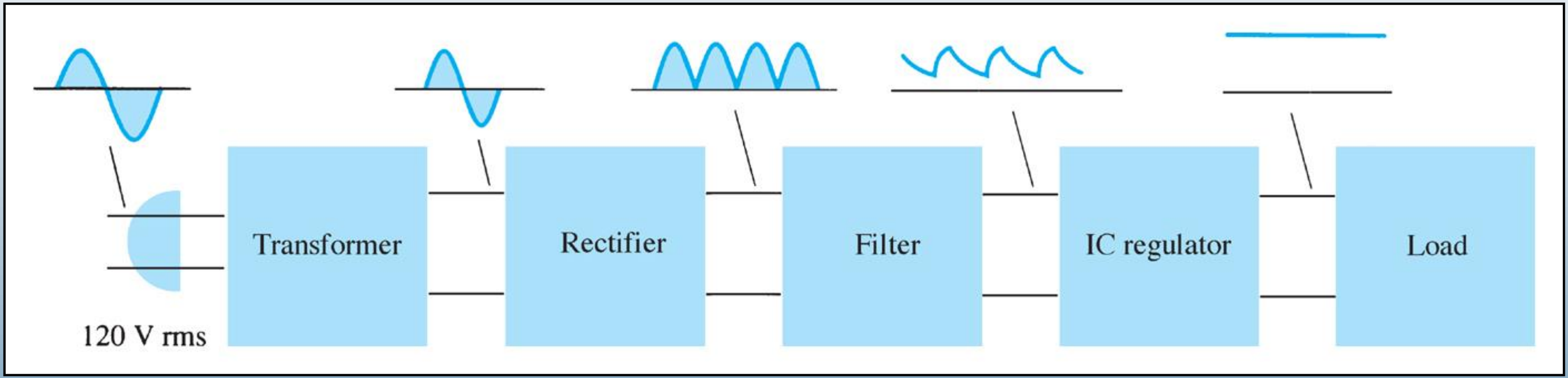
Electronic Devices and Circuit Theory

Boylestad

Power Supplies (Voltage Regulators)

Chapter 15

Power Supply Diagram



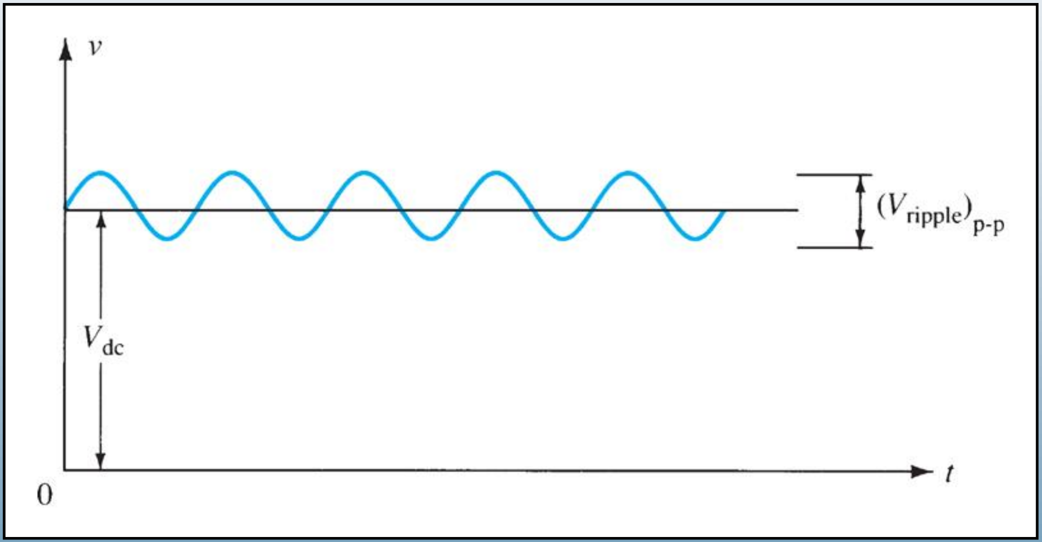
Filters

The output from the power supply **rectifier** is a pulsating DC.

The **filter** reduces the peak-to-peak pulses to a small ripple voltage.

Ripple Factor

After the filter circuit a small amount of AC is still remaining. The amount of ripple voltage can be rated in terms of **ripple factor** (*%r*).



$$\%r = \frac{\text{ripple voltage (rms)}}{\text{dc voltage}} = \frac{V_{r(rms)}}{V_{dc}} \times 100$$

Rectifier Ripple Factor

Half-Wave

DC output:

$$V_{dc} = 0.318 V_m$$

AC ripple output:

$$V_{r(rms)} = 0.385 V_m$$

Ripple factor:

$$\%r = \frac{V_{r(rms)}}{V_{dc}} \times 100$$
$$= \frac{0.385 V_m}{0.318 V_m} \times 100 = 121\%$$

Full-Wave

DC output:

$$V_{dc} = 0.636 V_m$$

AC ripple output:

$$V_{r(rms)} = 0.308 V_m$$

Ripple factor:

$$\%r = \frac{V_{r(rms)}}{V_{dc}} \times 100$$
$$= \frac{0.308_{Vm}}{0.636_{Vm}} \times 100 = 48\%$$

Types of Filter Circuits

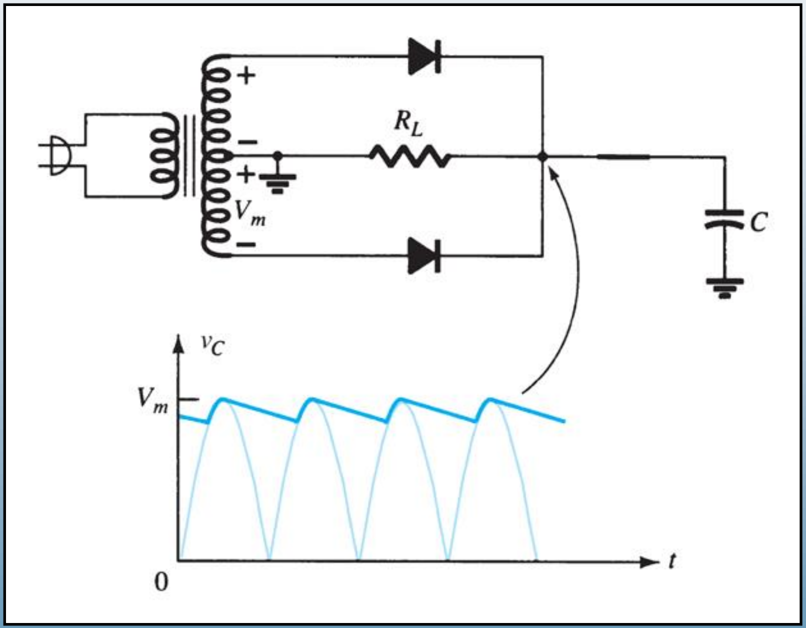
Capacitor Filter

RC **Filter**

Capacitor Filter

Ripple voltage

$$V_{r(rms)} = \frac{I_{dc}}{4\sqrt{3}fC} = \frac{2.4I_{dc}}{C} = \frac{2.4V_{dc}}{R_L C}$$



DC output

$$V_{dc} = V_m - \frac{I_{dc}}{4fC} = V_m - \frac{4.17I_{dc}}{C}$$

Ripple factor

$$\%r = \frac{V_{r(rms)}}{V_{dc}} \times 100 = \frac{2.4I_{dc}}{CV_{dc}} \times 100 = \frac{2.4}{R_L C} \times 100$$

Diode Ratings With Capacitor Filter

The greater the value of the capacitor, the higher the current drawn through the rectifier diode(s).

Peak Current vs. capacitance:

$$I = \frac{CV}{t}$$

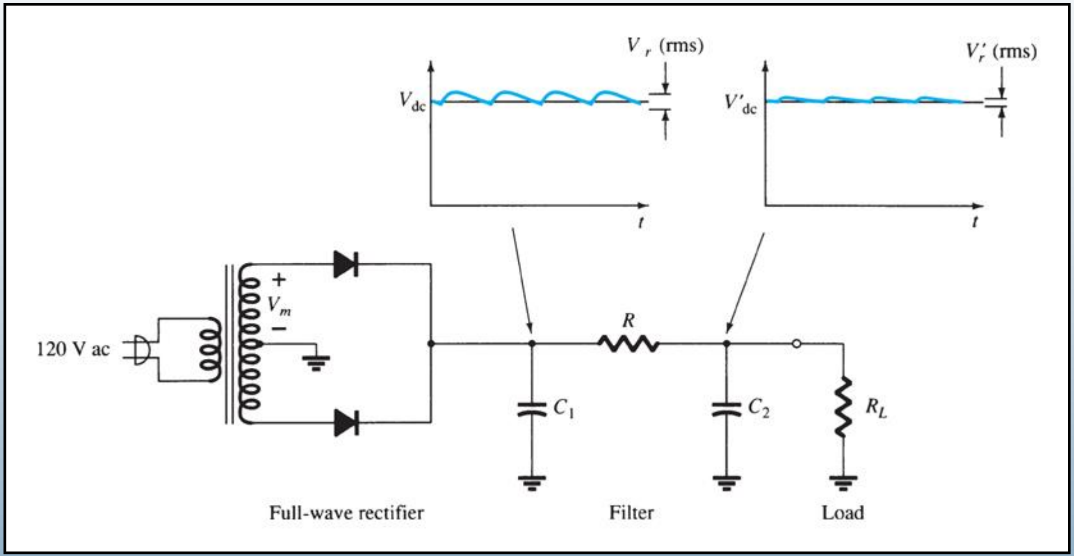
where

C = capacitance
V = change in capacitor voltage during charge/discharge
t = the charge/discharge time

RC Filter Circuit

Adding an RC section further reduces the ripple voltage and decrease the surge current through the diodes.

$$V'_{r(rms)} \approx \frac{X_C}{R} V_{r(rms)}$$



$V'_{r(rms)}$ = ripple voltage after the RC filter
$V_{r(rms)}$ = ripple voltage before the RC filter
R = resistor in the added RC filter
X_C = reactance of the capacitor in the added RC filter

$$\%V_R = \frac{V_{NL} - V_{FL}}{V_{FL}} \times 100\%$$

V_{NL} = no-load voltage
V_{FL} = full-load voltage

Voltage Regulation Circuits

There are two common types of circuitry for voltage regulation:

Discrete Transistors

IC's

Discrete-Transistor Regulators

Series voltage regulator

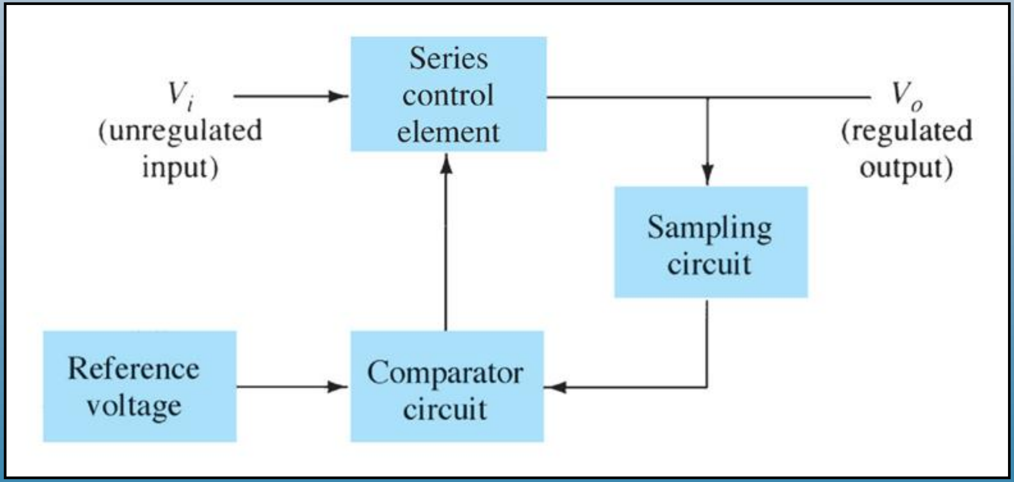
Current-limiting circuit

Shunt voltage regulator

Series Voltage Regulator

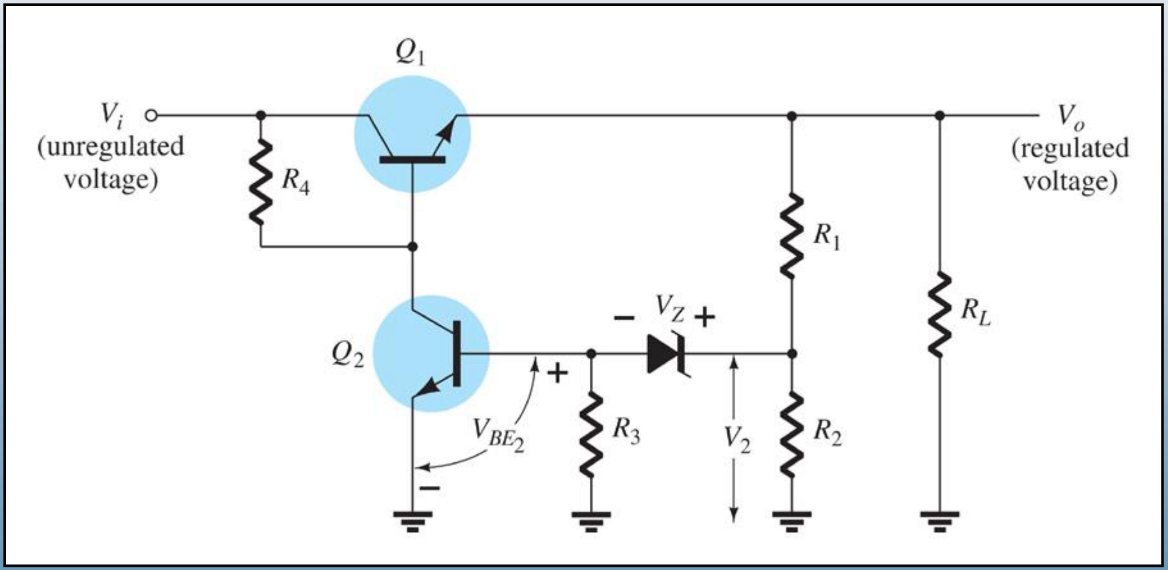
The series element determines how much of the input voltage that passes through to the output.

If the output voltage increases (or decreases), the comparator circuit provides a control signal to cause the series control element to decrease (or increase) the amount of the output voltage.



Series Voltage Regulator

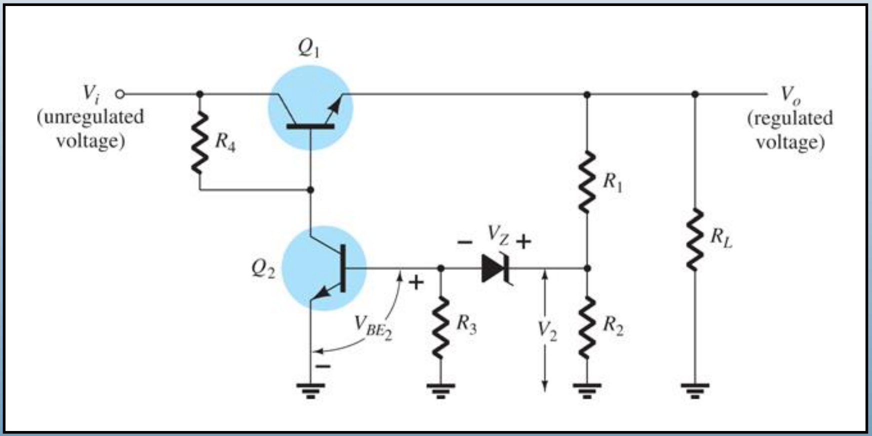
- R_1 and R_2 act as the sampling circuit
- The zener provides the reference voltage
- Q_2 controls the base current to Q_1
- Q_1 maintains the constant output voltage



Series Voltage Regulator

When the output increases:

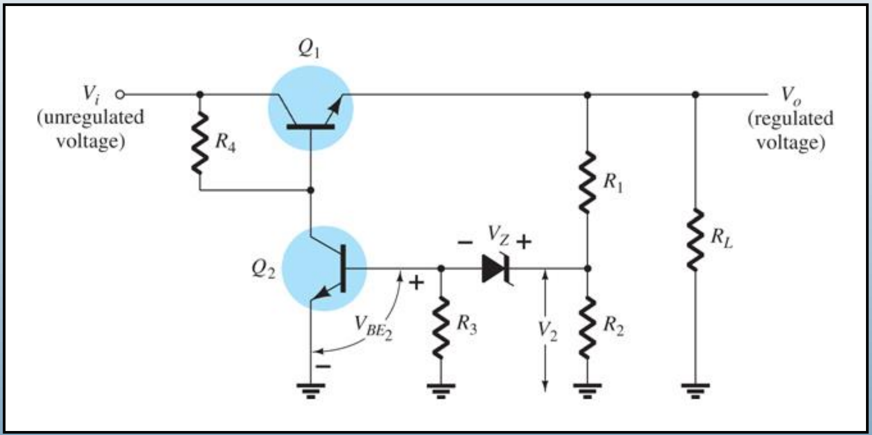
1. The voltage at V_2 and V_{BE} of Q_2 increases
2. The conduction of Q_2 increases
3. The conduction of Q_1 decreases
4. The output voltage decreases



Series Voltage Regulator

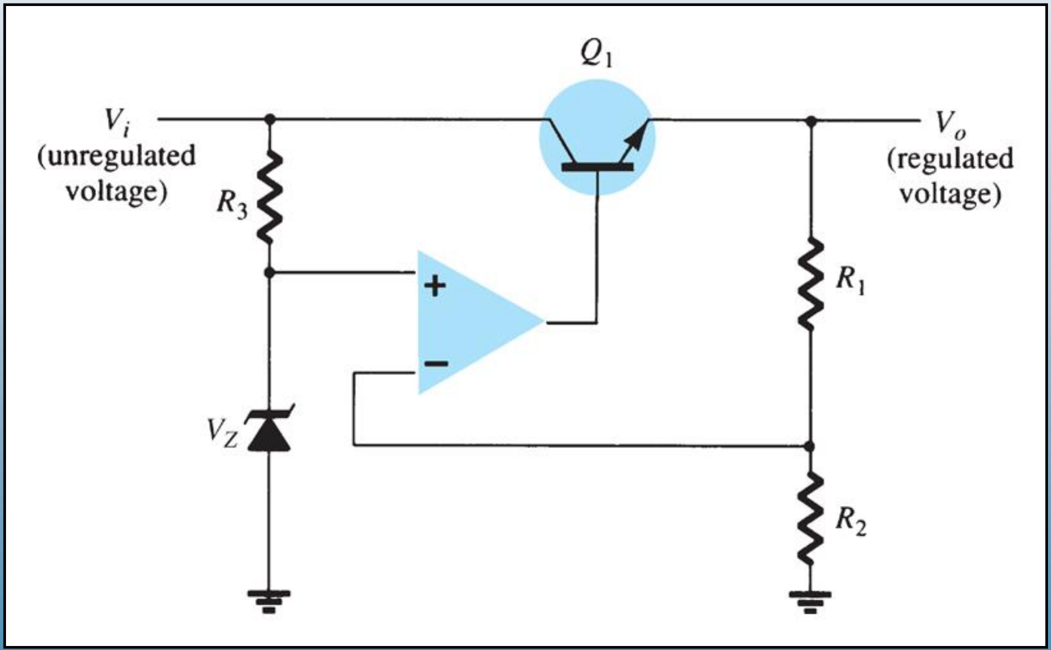
When the output decreases:

1. The voltage at V_2 and V_{BE} of Q_2 decreases
2. The conduction of Q_2 decreases
3. The conduction of Q_1 increases
4. The output voltage increases



Series Voltage Regulator

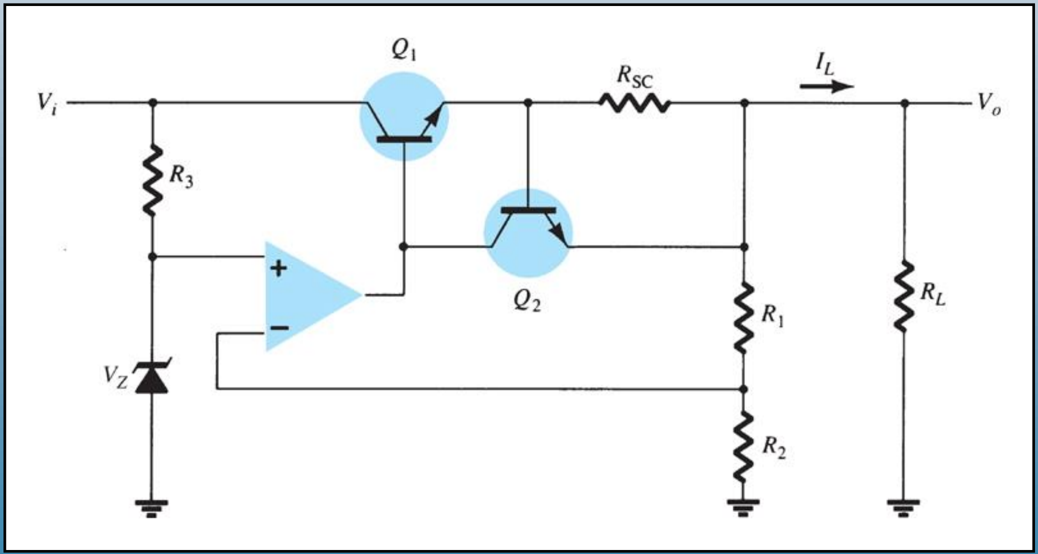
The op-amp compares the Zener diode voltage with the output voltage (at R_1 and R_2) and controls the conduction through Q_1.



Current-Limiting Circuit

When I_L increases:

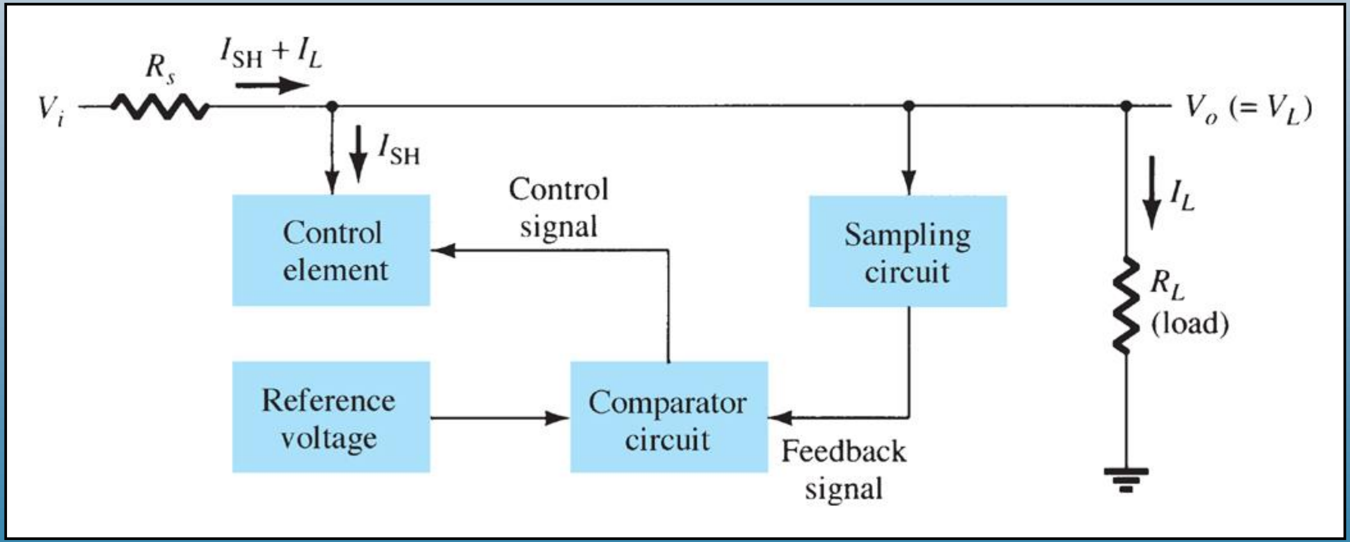
1. The voltage across R_{SC} increases
2. The increasing voltage across R_{SC} drives Q_2 on
3. Conduction of Q_2 reduces current for Q_1 and the load



Shunt Voltage Regulator

The shunt voltage regulator shunts current away from the load.

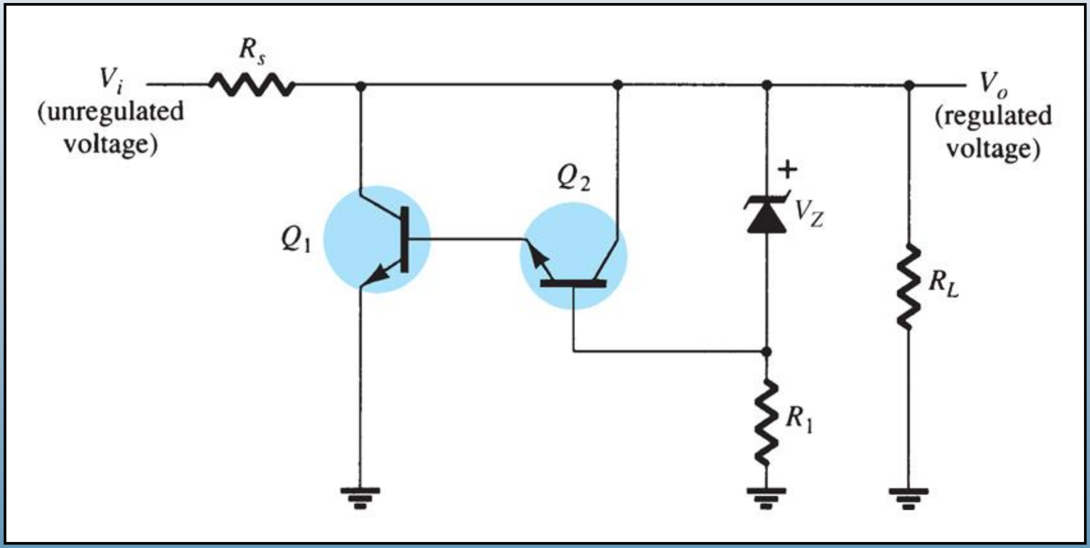
The load voltage is sampled and fed back to a comparator circuit. If the load voltage is too high, control circuitry shunts more current away from the load.



Shunt Voltage Regulator

When the output voltage increases:

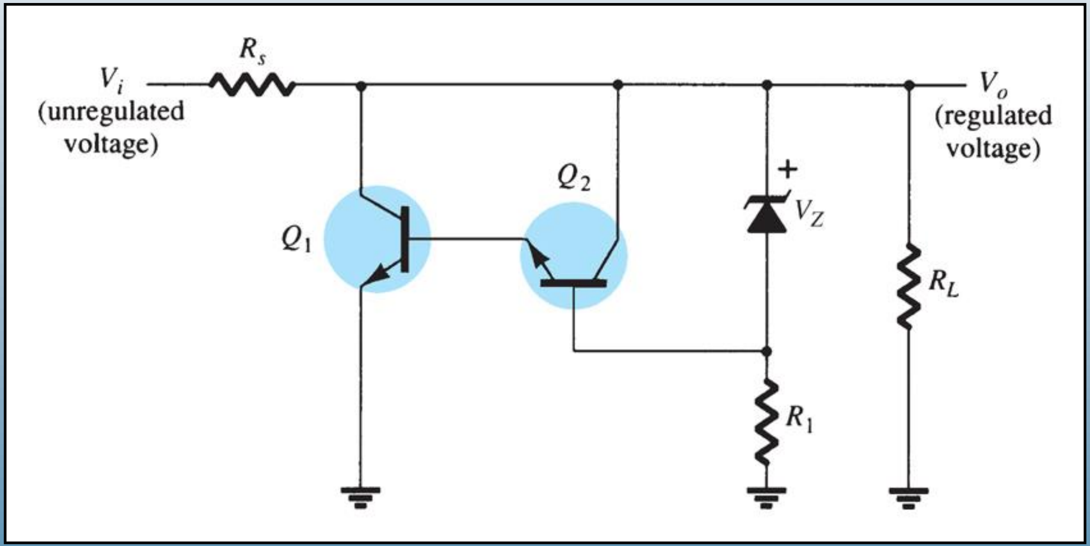
- The zener current increases
- The conduction of Q_2 increases
- The voltage drop at R_S increases
- The output voltage decreases



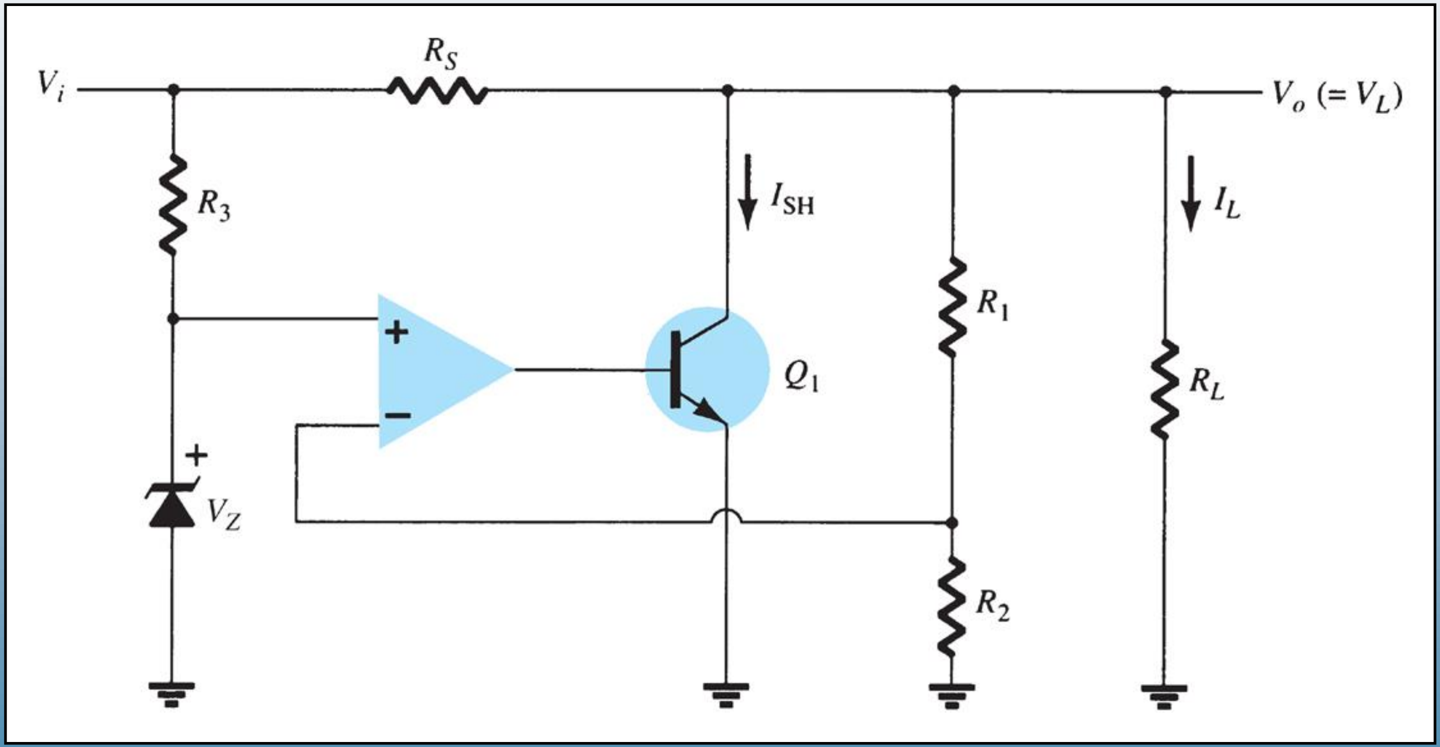
Shunt Voltage Regulator

When the output voltage decreases:

- The zener current decreases
- The conduction of Q_2 decreases
- The voltage drop at R_S decreases
- The output voltage increases



Shunt Voltage Regulator



IC Voltage Regulators

Regulator ICs contain:

Comparator circuit
Reference voltage
Control circuitry
Overload protection

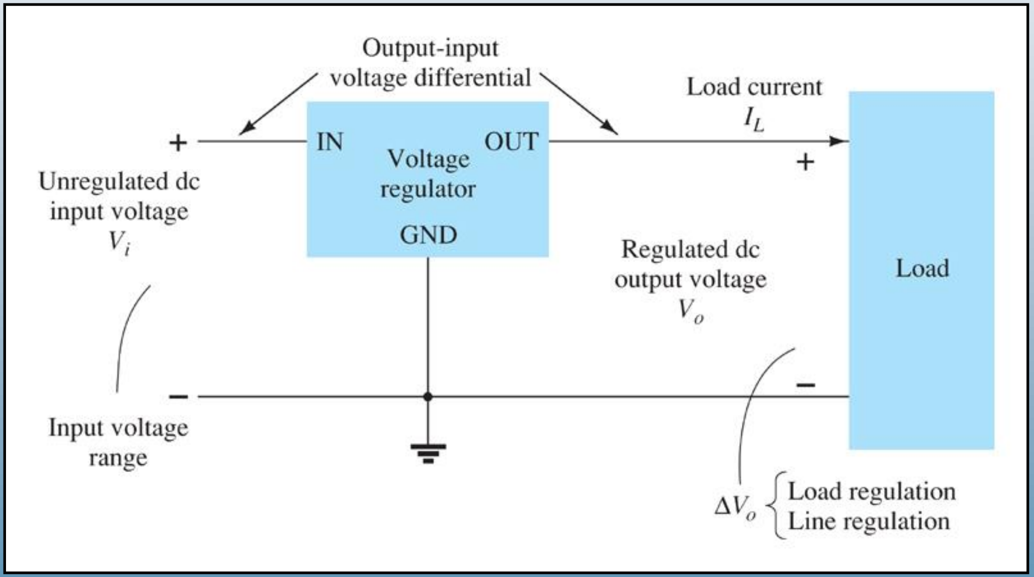
Types of three-terminal IC voltage regulators:

Fixed positive voltage regulator
Fixed negative voltage regulator
Adjustable voltage regulator

Three-Terminal Voltage Regulators

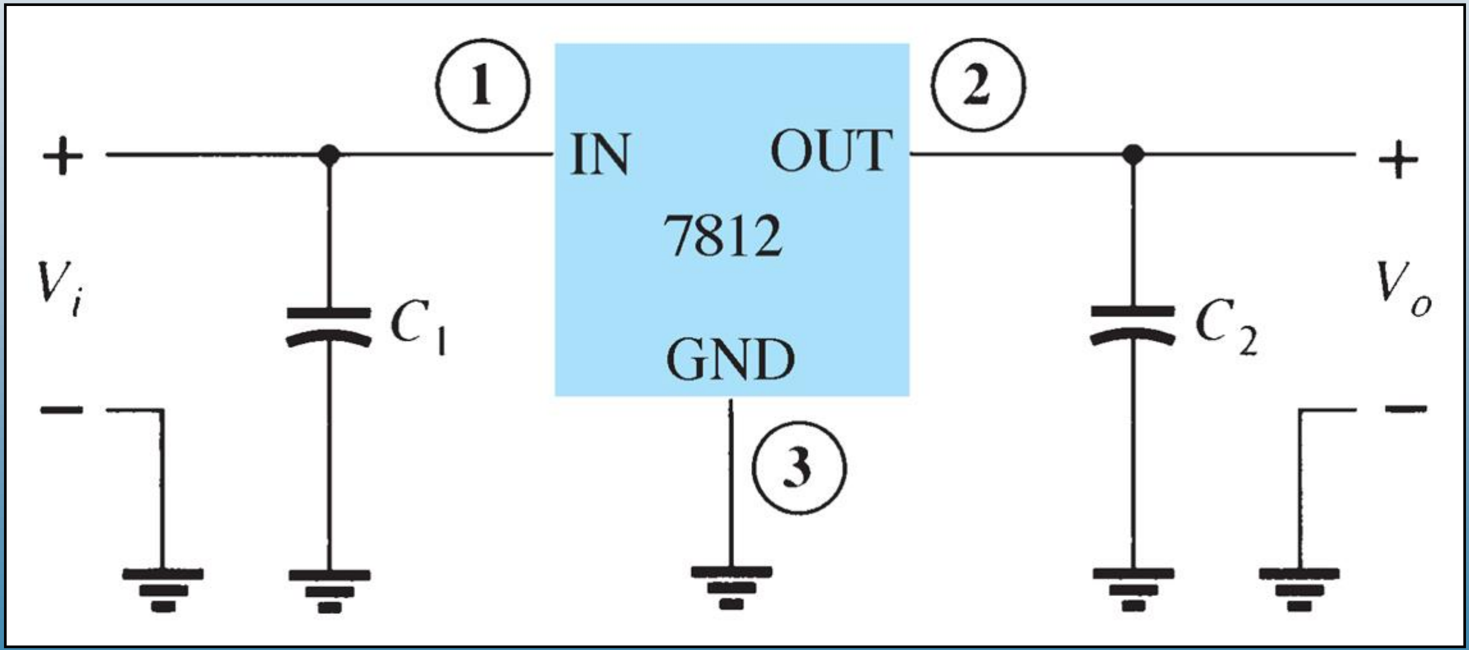
The specifications for this IC indicate:

- The range of input voltages that can be regulated for a specific range of output voltage and load current
- Load regulation—variations in output voltage with variations in load current
- Line regulation—variations in output voltage with variations in input voltage



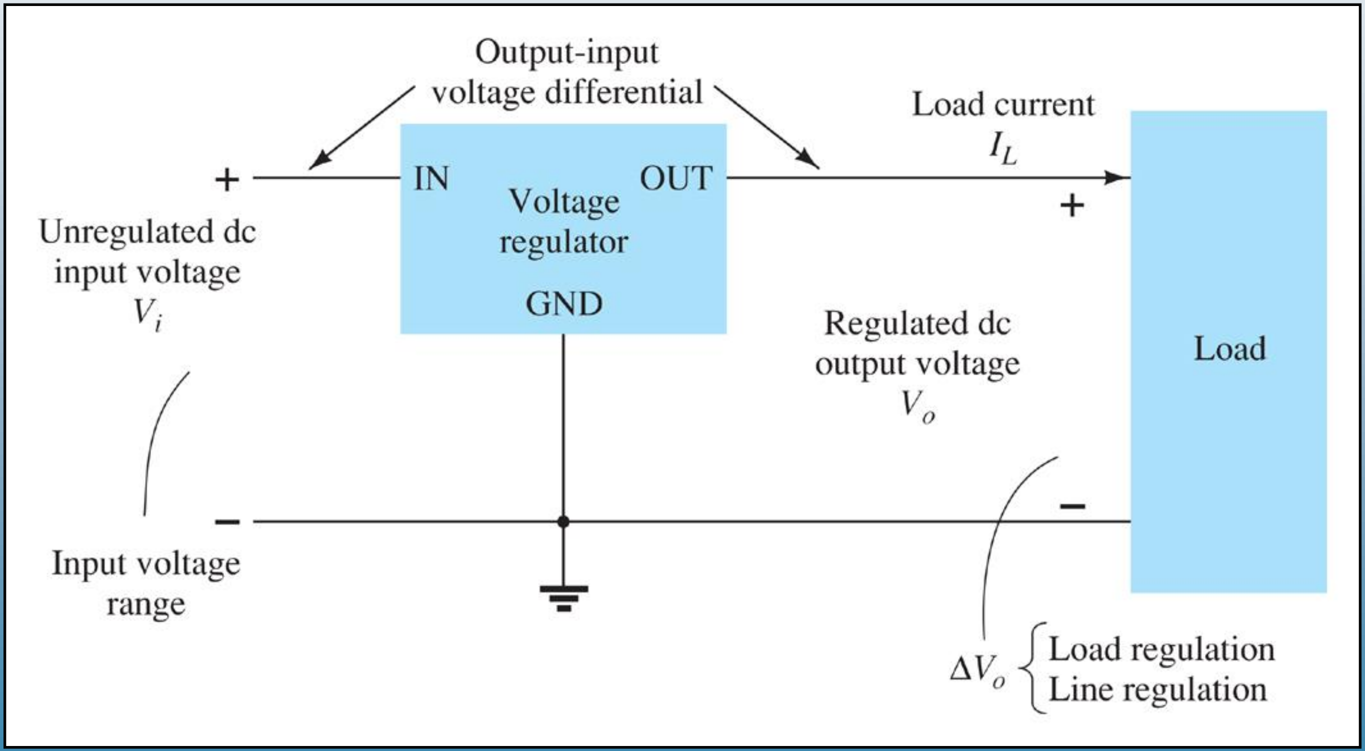
Fixed Positive Voltage Regulator

These ICs provide a fixed positive output voltage.



Fixed Negative Voltage Regulator

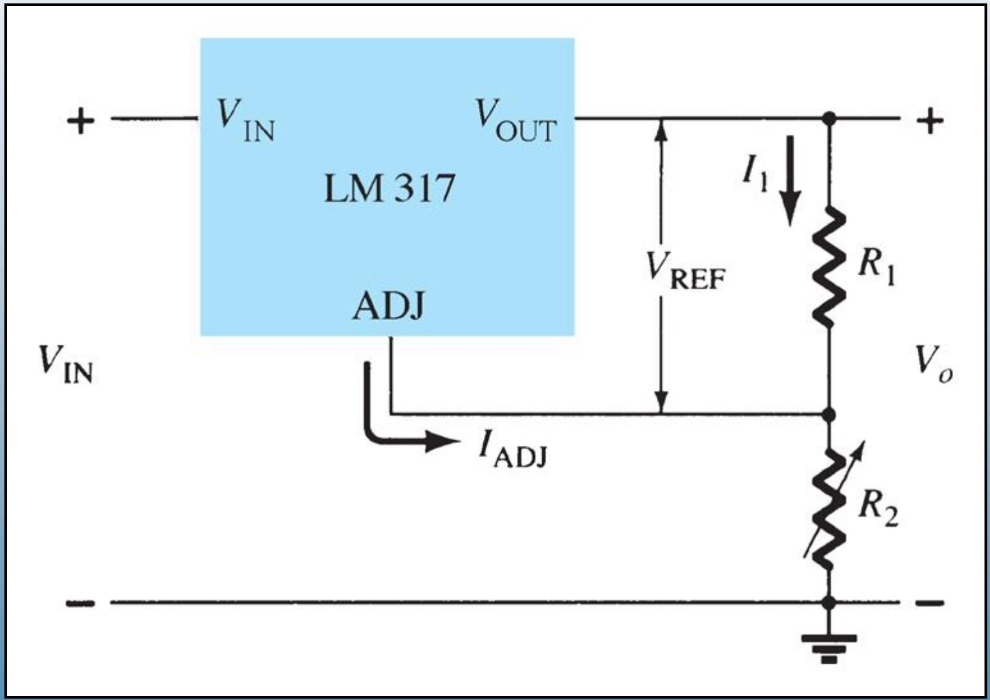
These ICs output a fixed negative output voltage.



Adjustable Voltage Regulator

These regulators have adjustable output voltages.

The output voltage is commonly selected using a potentiometer.



Practical Power Supplies

DC supply (linear power supplies)

Chopper supply (switching power supplies)

TV horizontal high voltage supply

Battery chargers