Week 13 extra notes b

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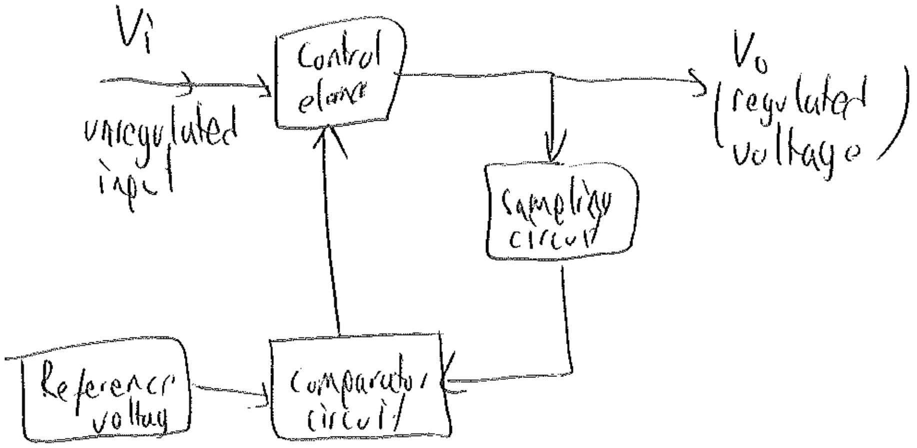
Discrete Transistor Voltage Regulator

There are two types of voltage regulators using transistors

- Series voltage regulators
- Shunt voltage regulators

- Each of these circuits provide an output DC voltage that is regulated or maintained at a set value even if the input voltage varies or if the load connected to the input changes

Series regulator circuit block diagram

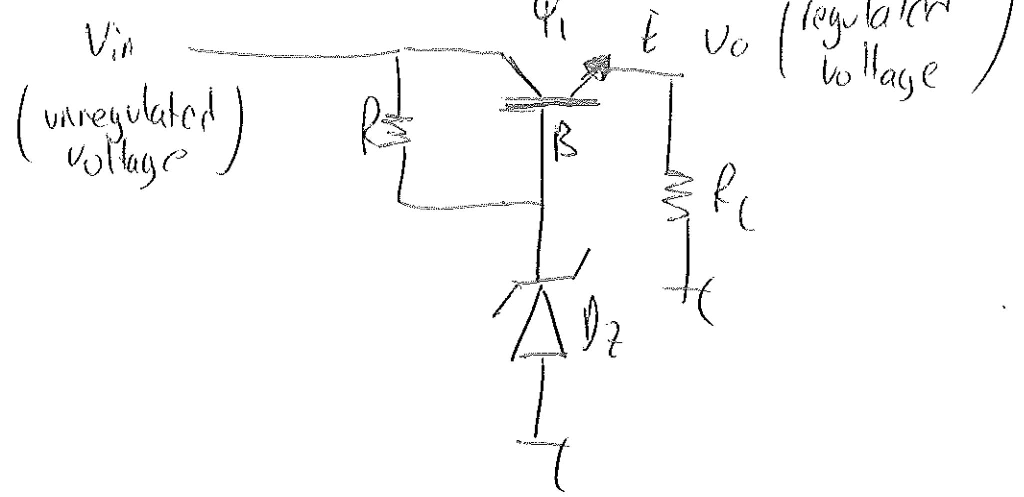


- The series element controls the amount of the input voltage that gets to the output
- The output voltage is sampled by a circuit that provides a feedback voltage to be compared to a reference value (voltage)

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

(b) If the output voltage decrease, the opposite operation happens.

Series Regulator Circuit



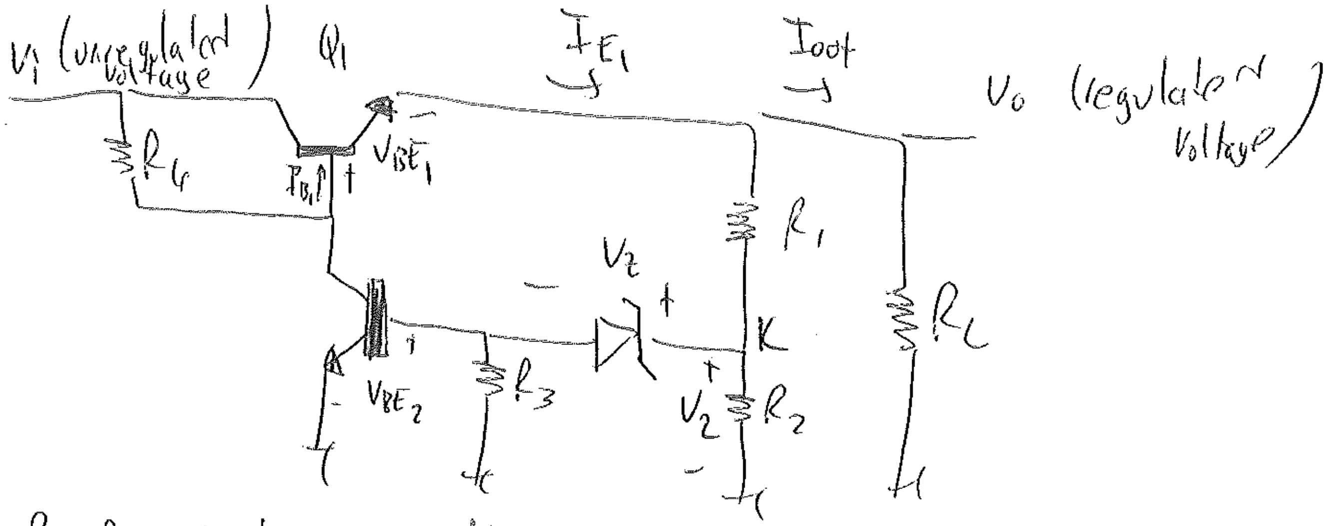
Transistor Q_1 ↓ series control element

zener diode D_Z provides the reference voltage

(a) If V_o ↓ V_{BE} ↑ and Q_1 conducts more current and hence V_o ↑ and it is kept constant by this operation

(b) If V_o ↑, V_{BE} ↓ and Q_1 conducts less current and hence V_o again ↓ and it is kept constant

Improved series regulator



R_1, R_2 → acts as sampling circuit

D_Z → provides reference voltage V_Z

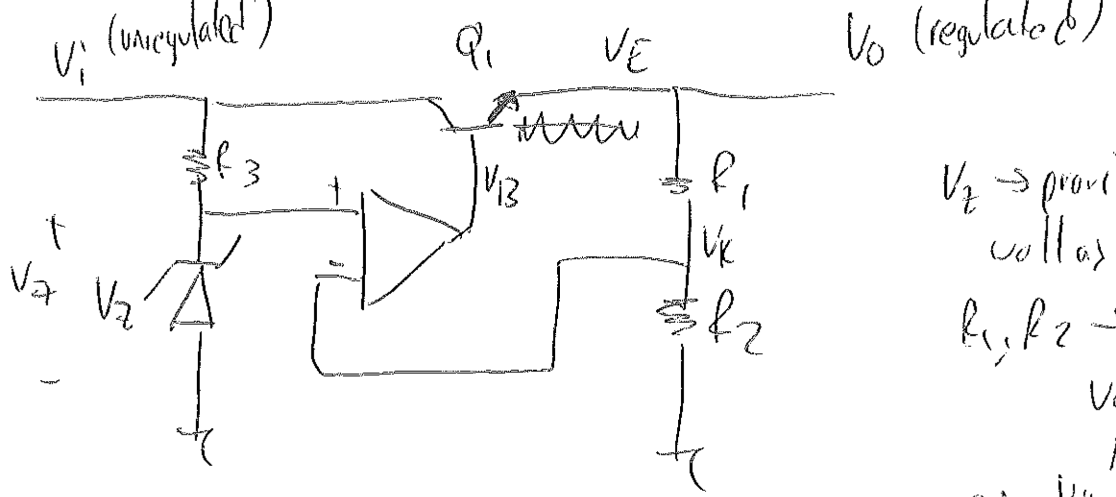
Q_2 → controls base current to transistor Q_1 in order to vary the current passed by transistor Q_1 to maintain output voltage constant if V_0 increase

~~- if $V_0 \uparrow$, $V_K = \frac{V_0}{R_1+R_2} R_2 \uparrow$ $V_{BE_2} = V_2 - V_Z \uparrow$, Q_2 conduct more~~

current, if Q_2 conducts more less current goes to base of Q_1 hence $I_{B_1} \downarrow$. if ~~Q~~ $I_{B_1} \downarrow$ $I_{C_1} \downarrow$ and hence $I_{out} \downarrow$. hence V_0 decreases at the out it is regulated.

- if V_0 decreases the opposite operation is observed

Opamp series regulator

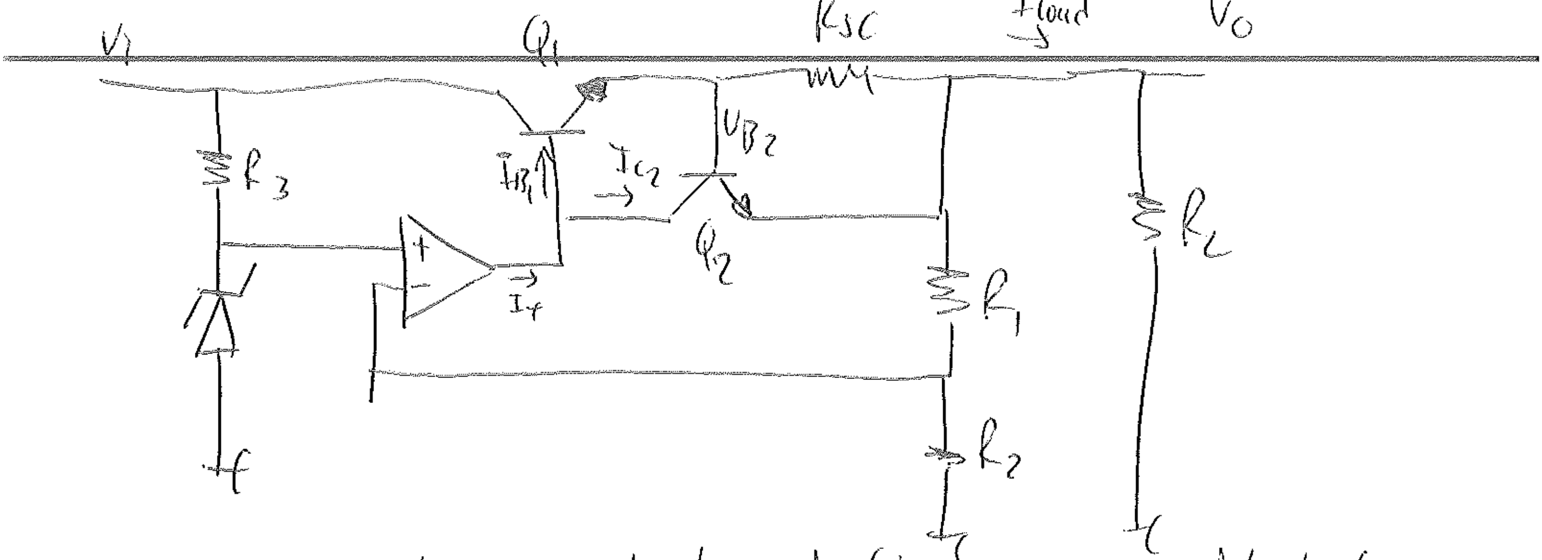


$V_Z \rightarrow$ provides reference voltage

$R_1, R_2 \rightarrow$ provides feedback voltage V_0 from output as $V_K = \frac{R_2}{R_1+R_2} V_0$

if $V_0 \uparrow \Rightarrow V_K \uparrow$, if $V_K \uparrow$ $V_Z - V_K \downarrow$ and as gain of opamp is constant $V_B \downarrow$ as $V_Z - V_K \downarrow$ if $V_B \downarrow$ $V_B - V_E \downarrow$ thus Q_1 conducts less current hence $V_0 \downarrow$ as the result

Current limiting circuit



— Short-circuit or overload protection is provided by this circuit

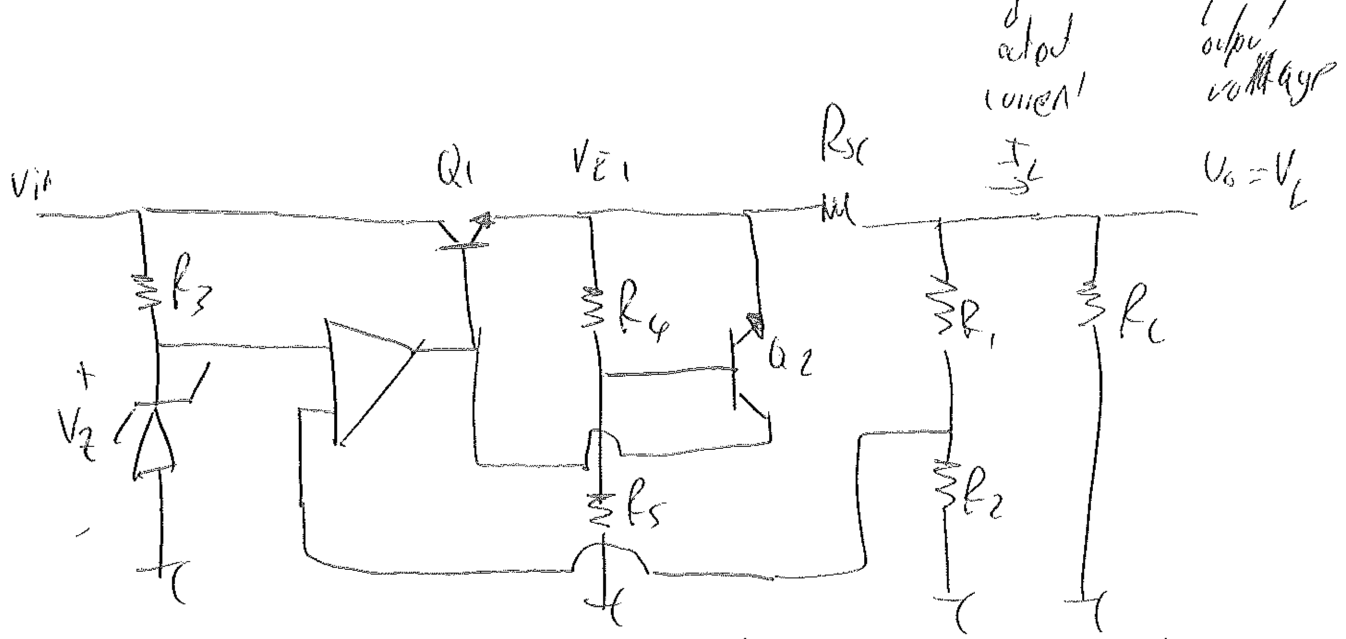
— As $I_{Load}\uparrow$ $V_0\uparrow$ $V_{SC}\uparrow$ (R_{SC} short circuit sensing resistor)

as $V_{SS}\uparrow$ $V_{B2}\uparrow$ it will drive Q_2 on.

if Q_2 becomes of I_{C2} increase and $I_{B1}\downarrow$ as the result since $I_x = I_{C2} + I_{B1}$ constant if $I_{B1}\downarrow$ Q_1 conducts less thus $V_{B2}\downarrow$ $V_{SC}\downarrow$ $I_{Load}\downarrow$ $V_0\downarrow$ at its is regulated

— These actions over R_{SC} and Q_2 provides limiting of the maximum load current I_{Load}

Fold back limiting:
aim: When current exceeds a limiting value, the load voltage decreases. Fold back limiting circuit reduces both I_L and V_o

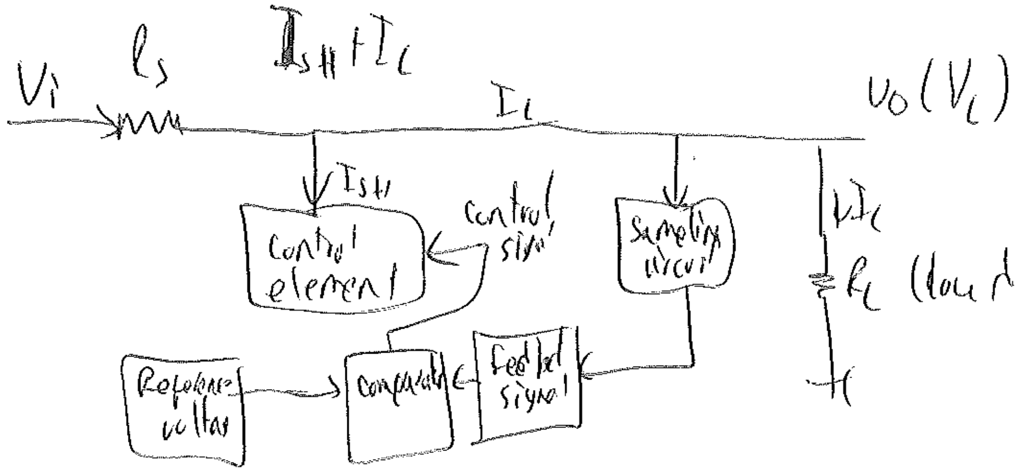


R_4, R_5 → act as voltage divider senses the voltage at V_{E1}

- When I_L increases to maximum value, the voltage over R_{SC} becomes large enough to drive Q_2 on; when Q_2 is on V_{E1} this time decreases and this operation limits I_L.

- if R_L ⇓ V_o ↓ the voltage driving Q_2 on becomes less and I_L drops as result.

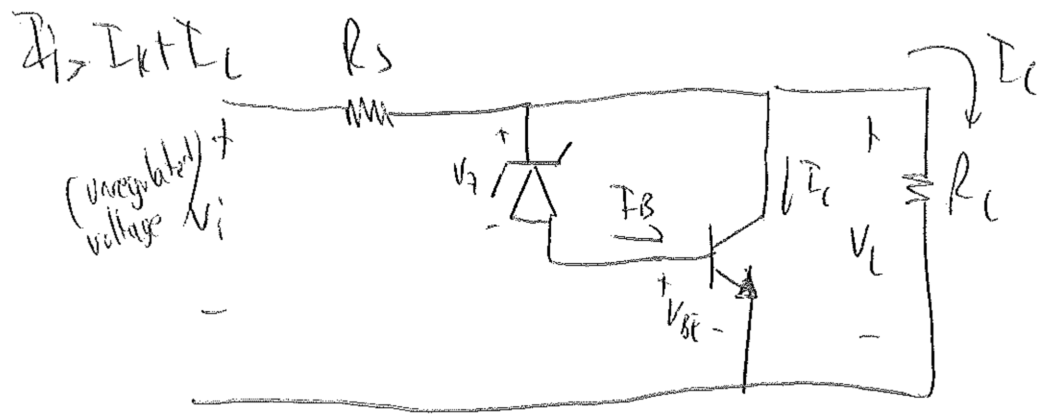
Shunt Voltage regulator: Block diagram as below



- Provides regulation by moving I_{SH} (Shunt current) ~~away for load~~

- Initially V_i provides current to load
- Some current I_{SH} is pulled away by the control element to maintain regulated output voltage across load.
- If V_o changes due to a chang in R_L, sampling circuit feedback signal to comparator, which results with a control signal to vary the amount of current shunted away from the load.
- As output tries to get larger, the sampling circuit provides a feedback signal to comparator circuit, which than provides a control signal to draw increased shunt current, providing less load current keeping regulated voltage from rising

Basic Transistor Shunt Regulator



$R_S \rightarrow$ drops V_i depending of value of I_L

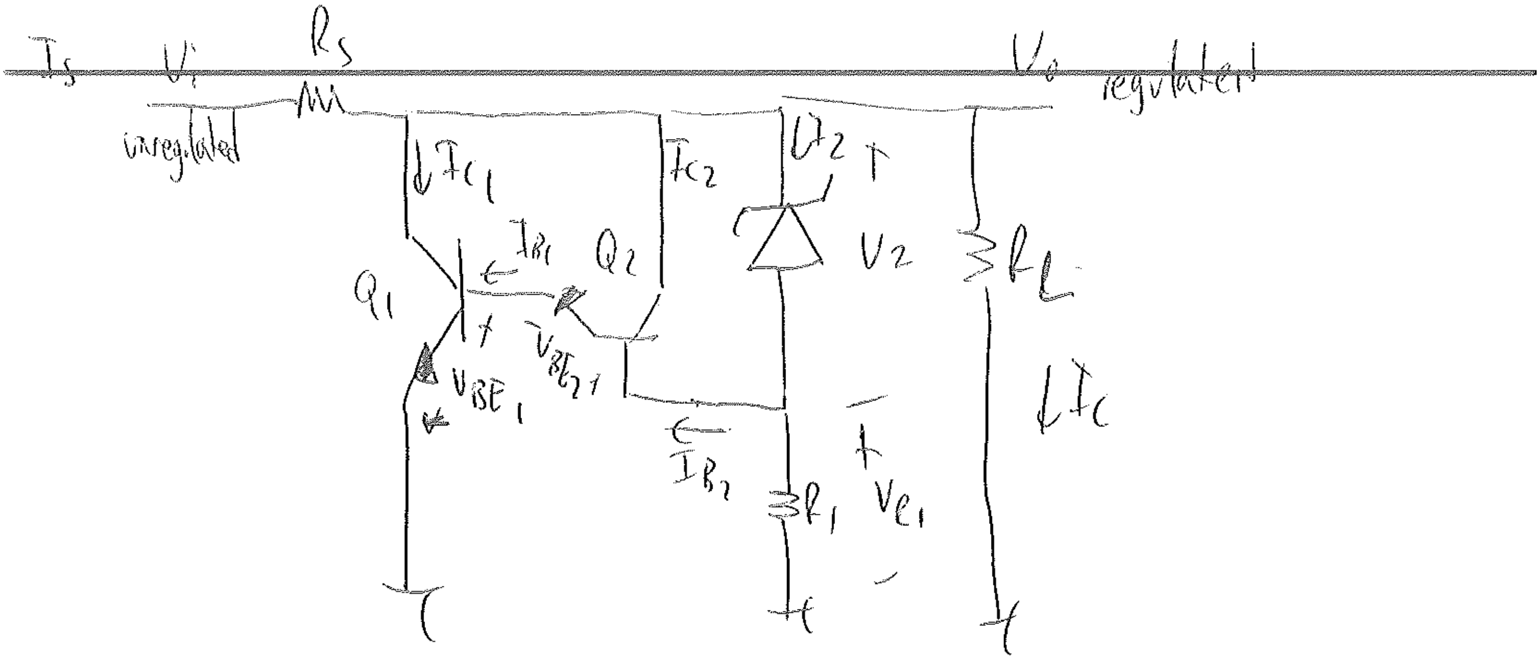
~~$V_{OUT} \approx V_{IN}$~~

$V_L = V_Z + V_{BE}$

if $R_L \downarrow$ ~~I_B of Q_1 decreases~~ initially V_{BE} decrease $V_L = V_Z + V_{BE}$ V_{BE} decrease hence I_B decrease $I_C = \beta I_B$ I_C also decrease if I_C decrease I_i increase increasing I_L once again and V_L is regulated (increased) to same level

(7)

Improved Shunt Regulator



$V_0 = V_L = V_Z + V_{BE_2} + V_{BE_1}$ $\qquad I_s = I_{C_1} + I_{C_2} + I_Z$

V_Z → provides V_{ref}

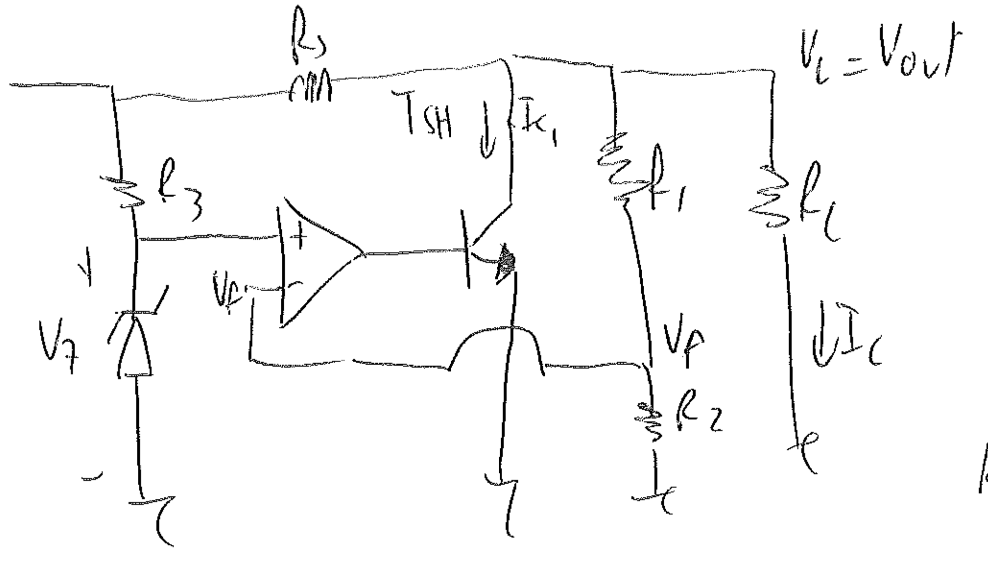
As V_0 changes I_{C_1} varies (as I_L also changes)

$I_{B_1} = I_{E_2}$ changes changing I_{B_2} changing I_{B_2} changes V_{R_1} and V_0 is kept regulated.

Shunt Voltage Regulator using op-amp

V_Z → zener voltage

V_f → feedback voltage



V_Z and V_f are compared and I_{SH} is adjusted by this comparison

R_s → is used to control voltage drop over itself to regulate V_L