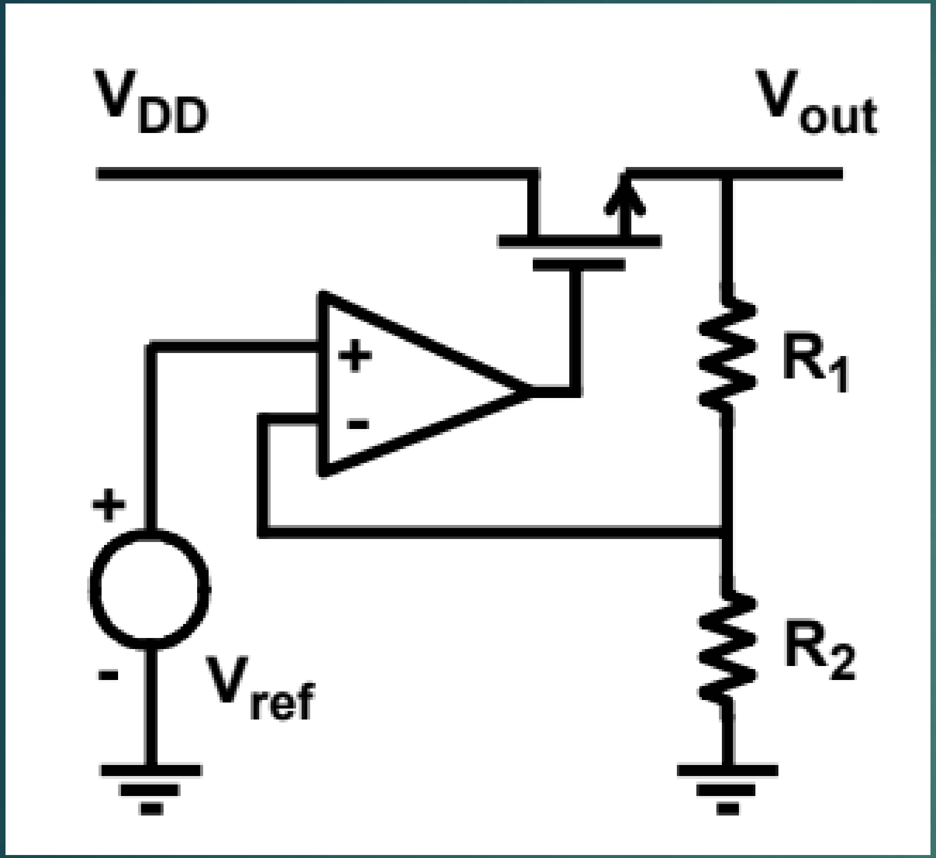
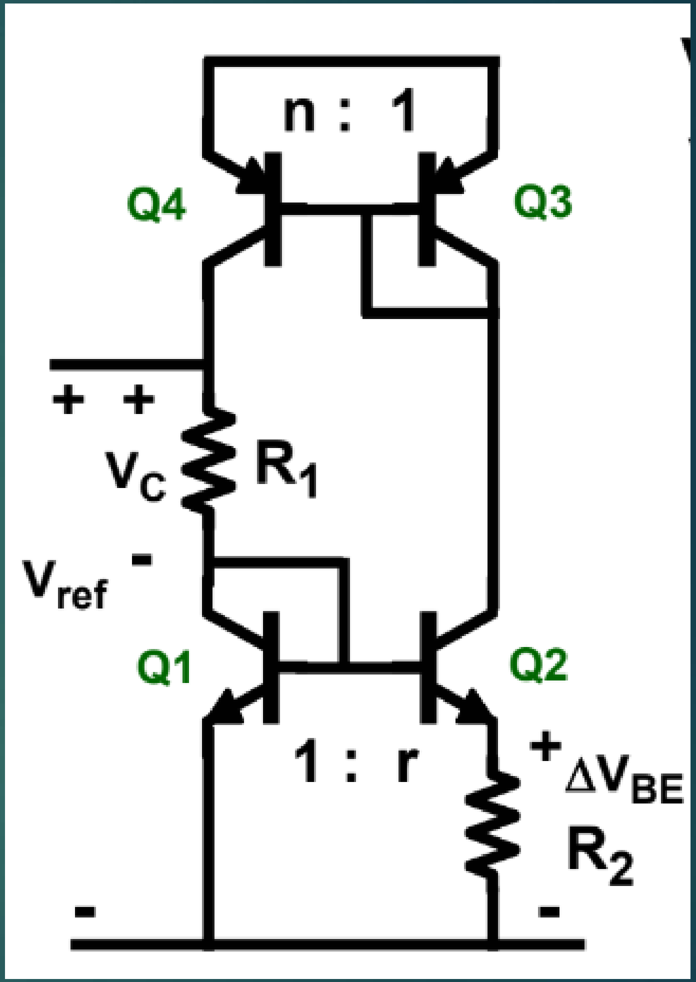
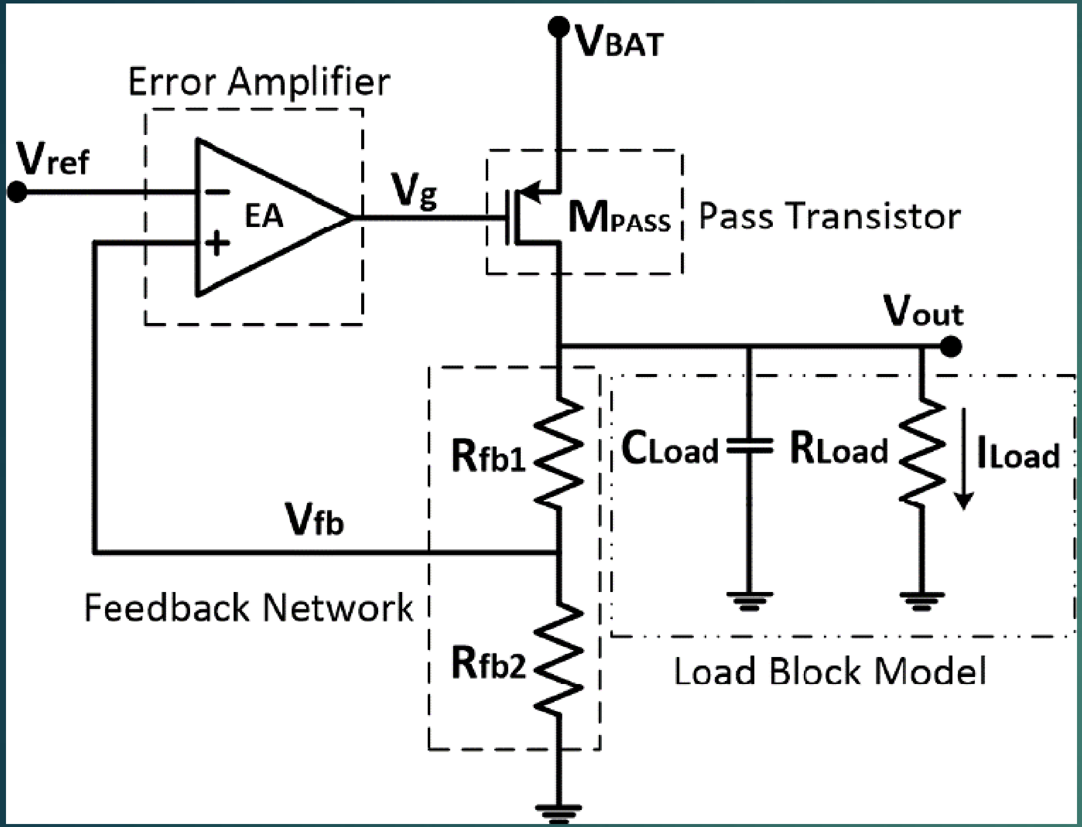
LDO



Bandgap Reference



LDO – Low Dropout Voltage Regulator



$$V_{fb} = V_{ref} = V_{out}\frac{R_{fb2}}{R_{fb1} + R_{fb2}}$$

$$V_{out} = V_{ref}\frac{R_{fb1} + R_{fb2}}{R_{fb2}}$$

- Low dropout indicates that it can regulate Vout with a very small difference (dropout) between VDD and Vout. Typically, 50-200mV.

- Regulator indicates it stabilizes the voltage and maintains it constant across a range of supply voltage and load fluctuations.

- Vref is given by the bandgap reference circuit and is stable across a wide temperature range: -40 to 125 degrees.

- The circuit consists of:

➢ PMOS pass transistor in SAT mode – gate voltage sets current through the feedback network and the load

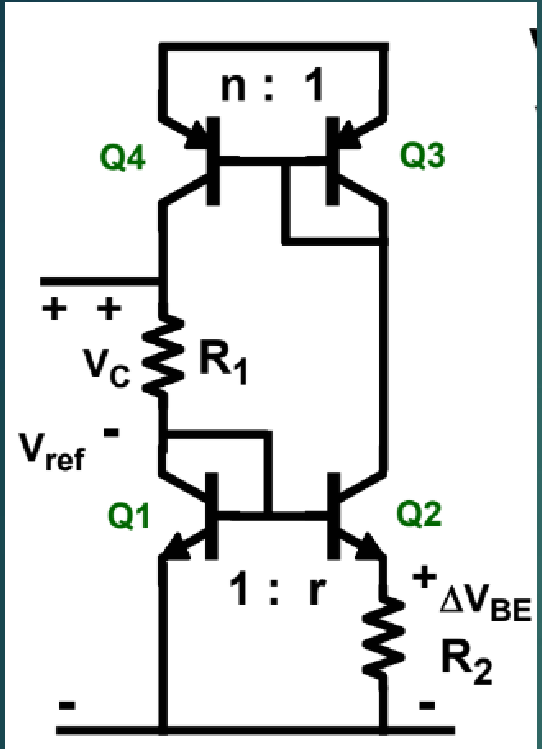
➢ Feedback network – two resistors that form a voltage divider.

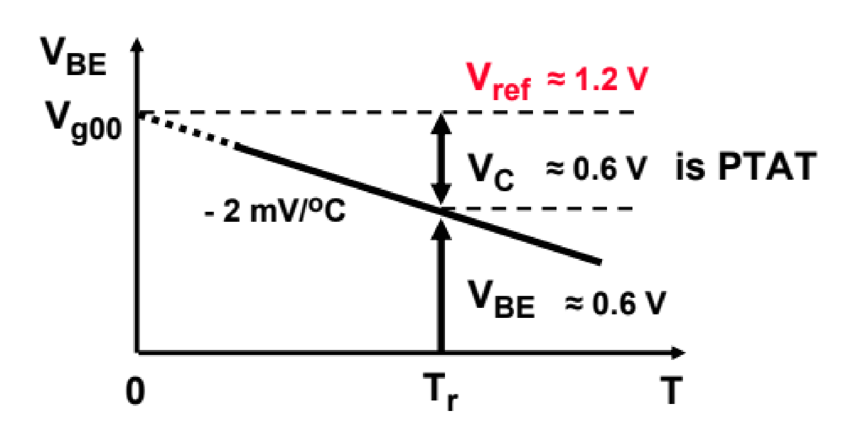
➢ Op amp – compares feedback system with the ref voltage and generates the error signal to control the output voltage.

$$\text{If } V_{fb} > V_{ref} \rightarrow V_g\uparrow \rightarrow V_{sg}\downarrow \rightarrow I_{SD}\downarrow \rightarrow V_{fb}\downarrow$$
$$\text{If } V_{fb} < V_{ref} \rightarrow V_g\downarrow \rightarrow V_{sg}\uparrow \rightarrow I_{SD}\uparrow \rightarrow V_{fb}\uparrow$$

$$I_{SD}=k(V_{GS}-V_t)^2(1+\lambda V_{SD})$$

Bandgap Reference Circuit





$$V_{ref} = V_{BE} + V_{R_{PTAT}} = 1.2V$$

- Bandgap reference circuit provides a constant output voltage across a wide temperature range.

- The circuit consists of:
  - CTAT – a negatively proportional to absolute temperature component, in this case the base-emitter junction voltage of a BJT transistor in FA mode.
  - PTAT – a positively proportional to absolute temperature component with the same temperature coefficient, in this case the resistor.
  - Combined, the output voltage remains constant across this temperature range.

$$I_C = CT^{\eta} \exp\left(\frac{V_{BE} - V_{g0}}{kT/q}\right)$$

$$V_{BE} = V_{g00} - \lambda T + c(T)$$

$$\Delta V_{BE} = V_{BE1} - V_{BE2} = \frac{kT}{q} \ln \frac{I_{S2}}{I_{S1}}$$

$$\Delta V_{BE} = \frac{kT}{q} \ln nr$$

$$I_{C2} = \frac{kT}{qR_2} \ln nr$$

$$V_C = n \frac{R_1}{R_2} \frac{kT}{q} \ln nr$$