Bandgap reference,schematic and performance parameter

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Bandgap voltage reference

- A **bandgap voltage reference** is a temperature independent voltage reference circuit widely used in integrated circuits.
- It produces a fixed(constant) voltage. irrespective of power supply variations, temperature changes and the loading on the device. Usually it has an output voltage around 1.25 V, close to the theoretical 1.22 eV band gap of silicon at0 K.
- This circuit concept was first published by David Hilbiber in 1964.

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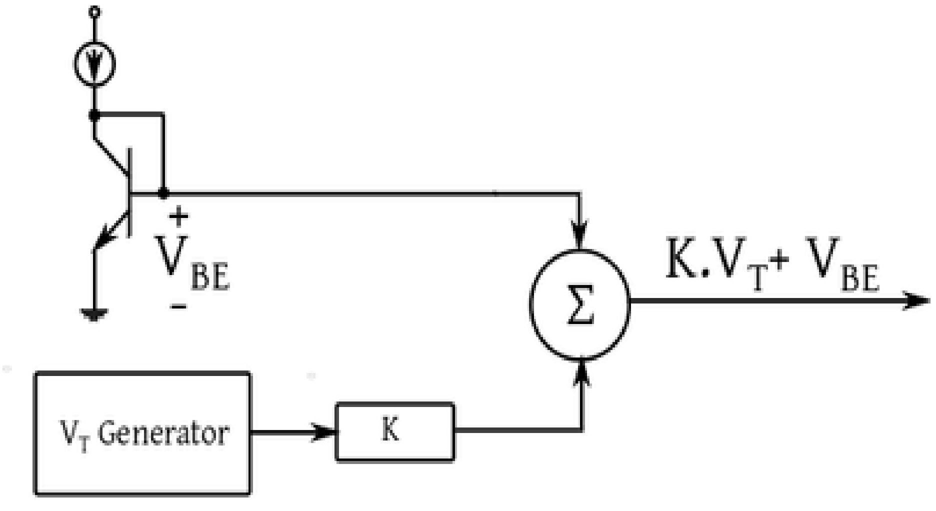
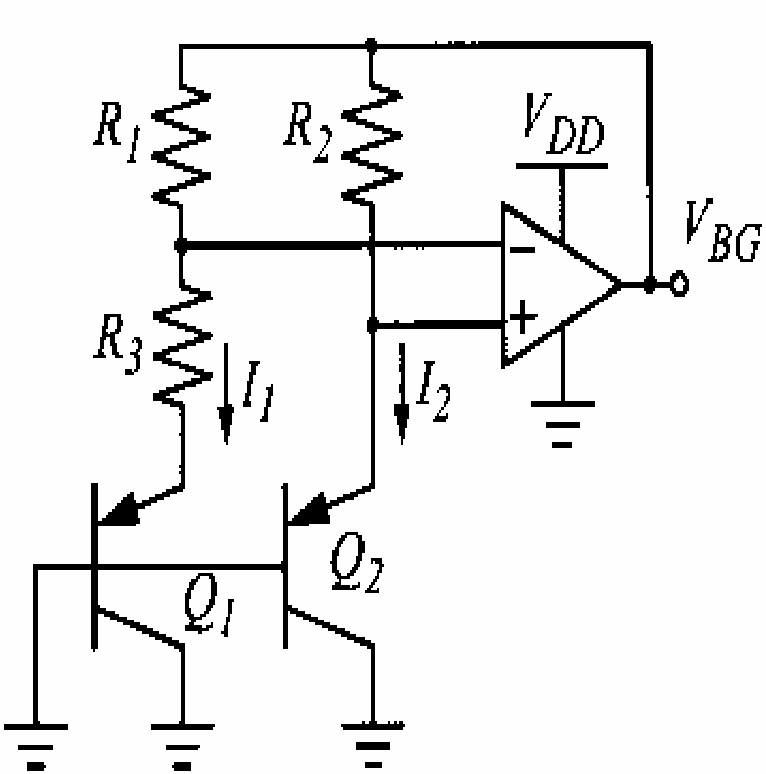
Bandgap Reference

• Generate an inverse PTAT and a PTAT and sum them appropriately.
– VBE is inverse PTAT at roughly -2.2 mV/°C at room temperature
– Vt = kT/q is PTAT that has a temperature coefficient of +0.085 mV/°C at room temperature.
• Multiply Vt by a constant M and summed with the VBE to get

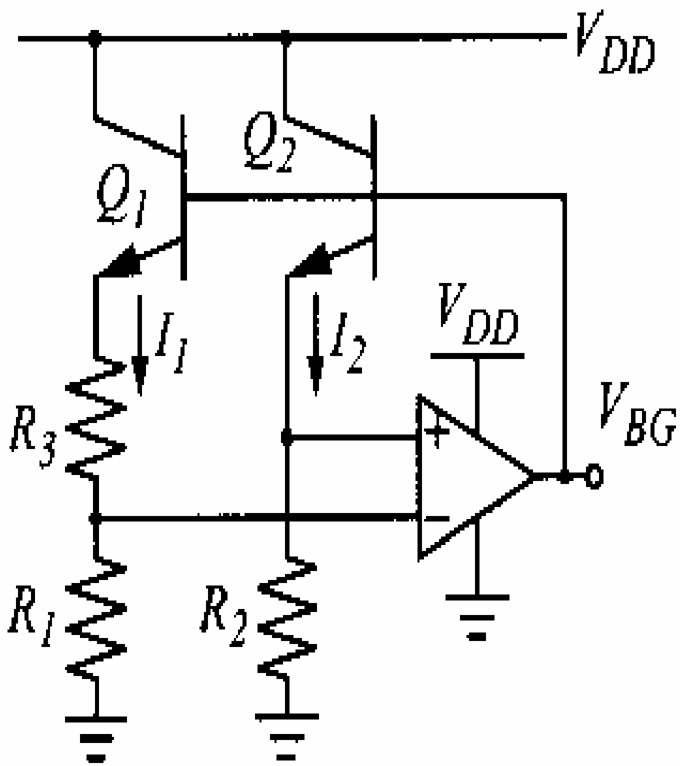
$$VREF = VBE + MVt$$



implementation



n-well CMOS process



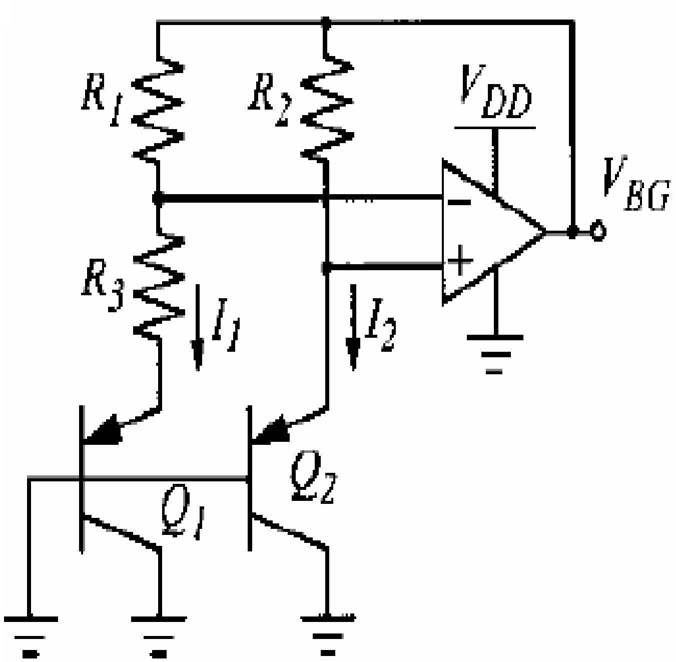
p-well CMOS process

operation

$$V_{BG} = V_{EB2} + V_{R2}$$

- Assume the opamp has very large gain and very small input currents such that its input terminals are at the same voltage, then

$$V_{R3} = V_{EB2} - V_{EB1} = \Delta V_{EB}$$



n-well CMOS process

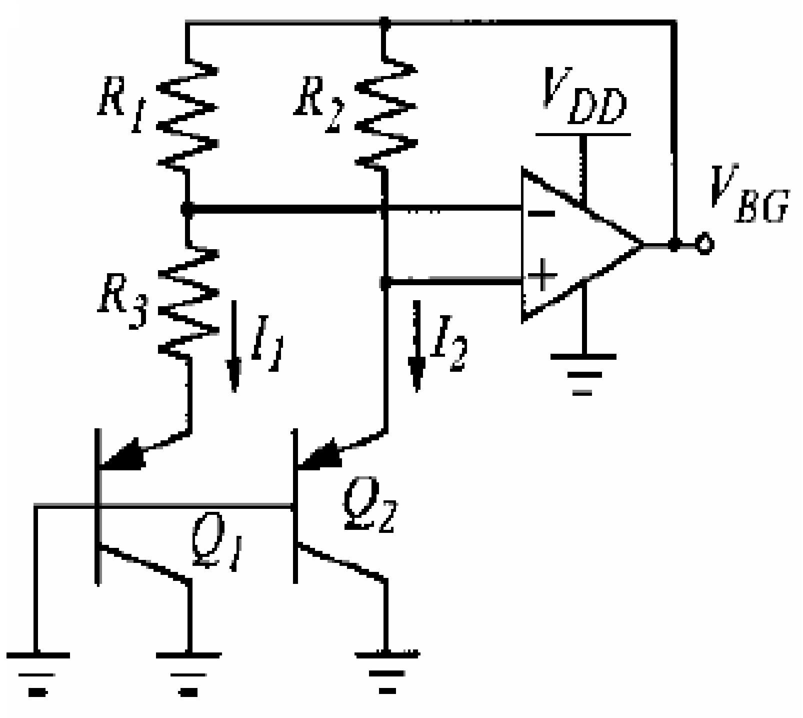
- Since the current through R1 is same as R3

$$\frac{V_{R1}}{R_1} = \frac{V_{R3}}{R_3} \quad or \quad V_{R1} = \frac{R_1}{R_3} V_{R3} = \frac{R_1}{R_3} \Delta V_{EB}$$

$$\Rightarrow V_{BG} = V_{EB2} + \frac{R_1}{R_3} \Delta V_{EB}$$

Cont.

- In CMOS realization, the bipolar transistors are often taken the same size, and different current densities(I_C/I_S) are realized by taking R_1 greater than R_2, which causes I_2 to be greater than I_1:



n-well CMOS process

$$V_{R1} = V_{R2} \Rightarrow I_1 R_1 = I_2 R_2 \quad \text{or} \quad \frac{I_2}{I_1} = \frac{R_1}{R_2}$$

$$\Delta V_{EB} = V_{EB2} - V_{EB1} = \frac{kT}{q} \ln\left(\frac{I_2}{I_1}\right)$$

$$\Rightarrow V_{BG} = V_{EB2} + \frac{R_1}{R_3} \frac{kT}{q} \ln\left(\frac{R_1}{R_2}\right)$$

Performance Parameters

- The primary requirements of a voltage reference are accuracy and stability. Some important parameters are:

- Load Regulation = $\Delta V_o / \Delta I_o$ (usually expressed in mV/mA or mV/A) or
  Load Regulation = $100(\Delta V_o / \Delta I_o)$ (in %/mA or %/A)

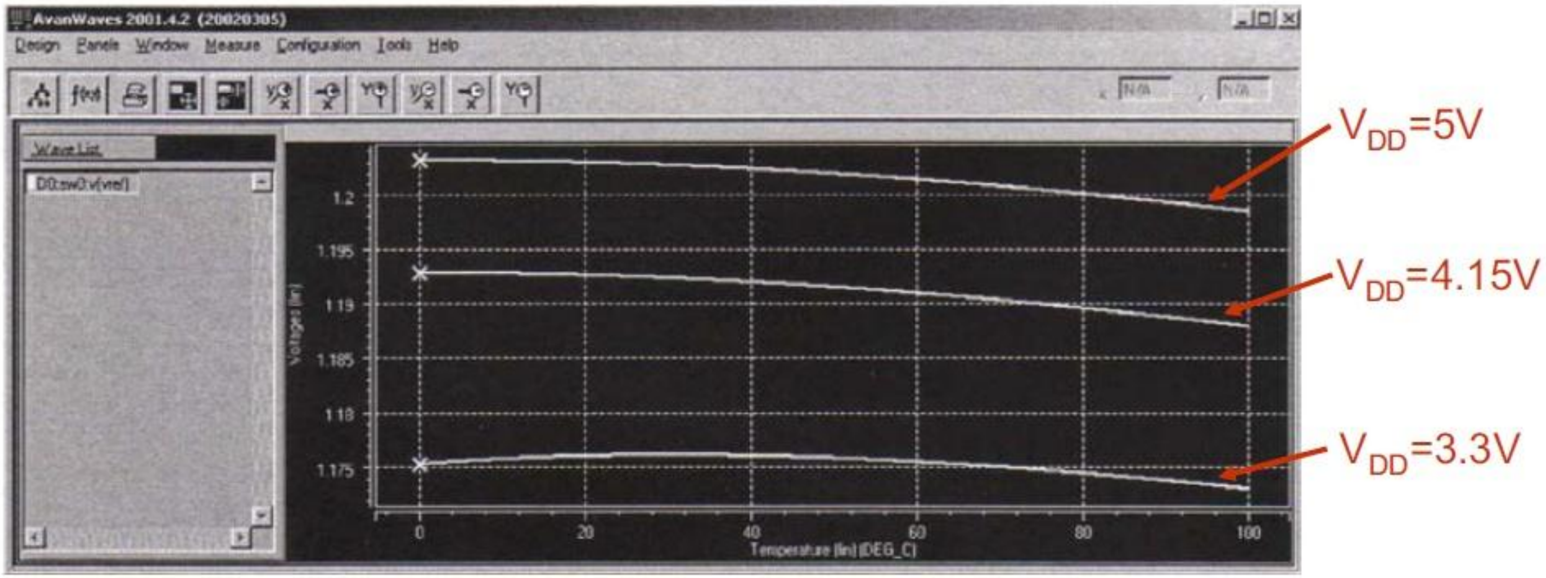
- Line Regulation = $\Delta V_o / \Delta V_{in}$ (usually expressed in mV/V) or
  Line Regulation = $100(\Delta V_o / \Delta V_{in})$ (in %/V)

- Power Supply Rejection Ratio (PSRR) is a measure of the ripple in the reference voltage due to the ripples in the supply voltage

$$\mathrm{PSRR} = 20\log_{10}\frac{V_{ri}}{V_{ro}} \quad (\text{in dB})$$

Performance Parameters

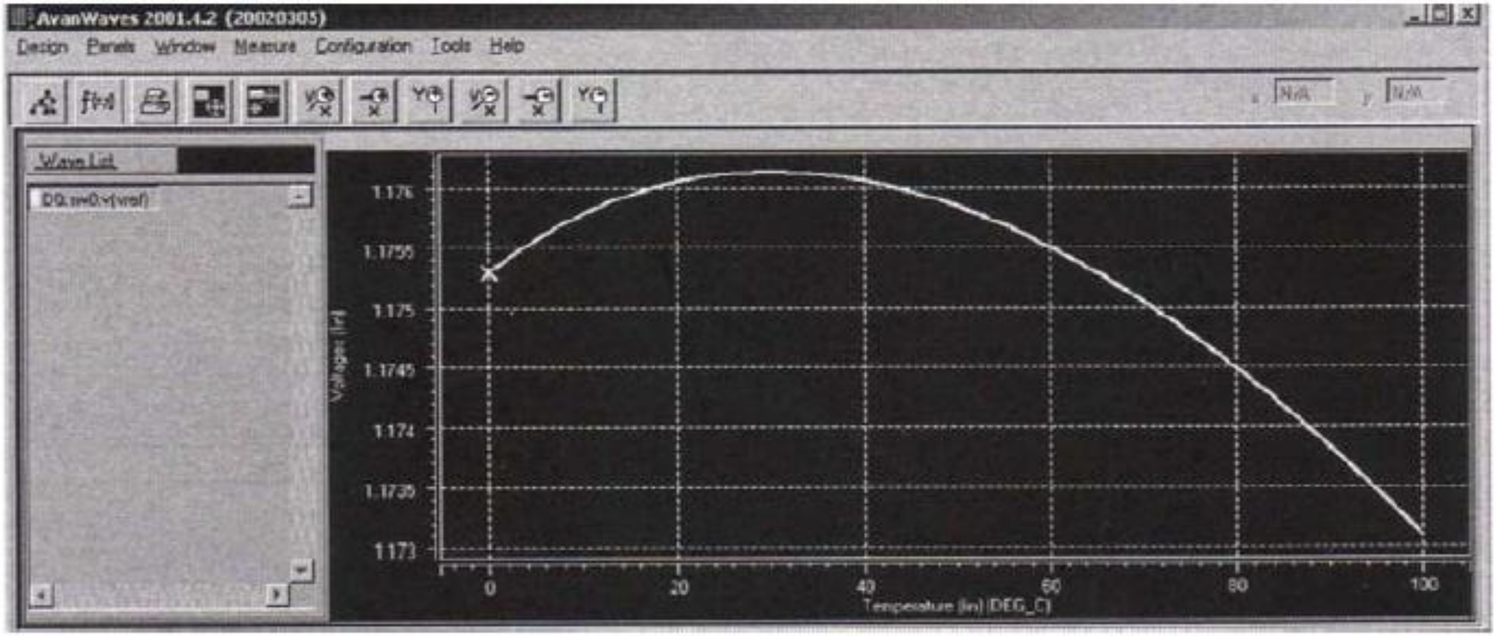
- Example of line regulation / supply-voltage dependence at V_{DD} = 3.3, 4.15 and 5V (step size of 0.85V)



Line regulation at T 27°C is

$$\frac{V_{ref}(V_{DD}=5V)-V_{ref}(V_{DD}=3.3V)}{5-3.3}=\frac{1.201-1.176}{5-3.3}=14.7mV/V$$

Performance Parameters



- The maximum ($V_{ref(max)}$) and minimum ($V_{ref(min)}$) reference voltages are1.1761V and 1.1731V, respectively. The reference voltage at T = 27°C (Vref) is 1.1761V. The tempco in ppm/°C can be found by

$$\frac{V_{ref(\max)} - V_{ref(\min)}}{V_{ref}} \times \frac{10^6}{(T_{\max} - T_{\min})} = \frac{1.1761 - 1.1731}{1.1761} \times \frac{10^6}{(100-0)} = 25.5\,ppm/°C$$

THANK YOU.