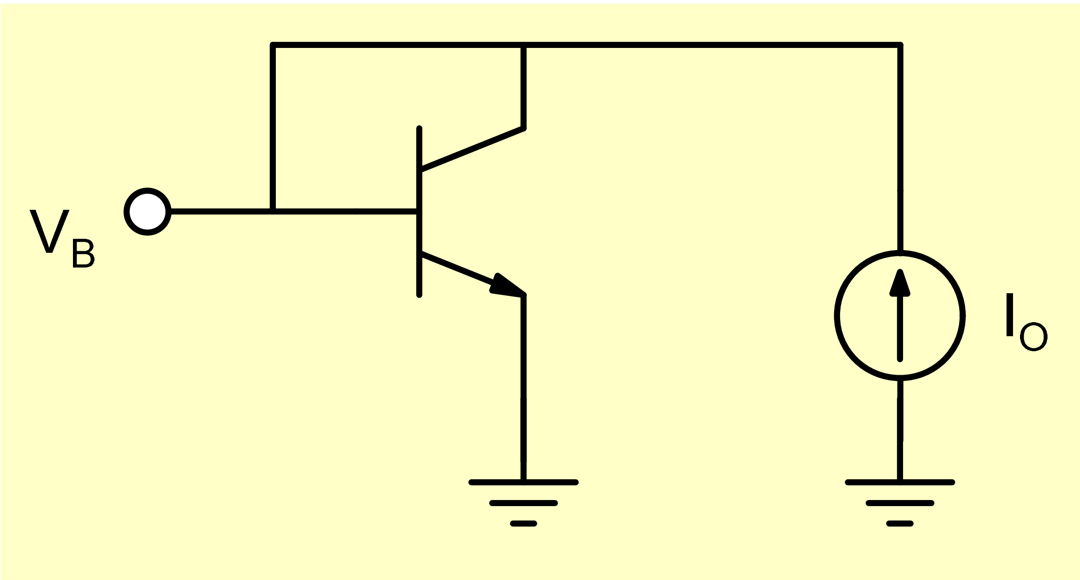
EE381: Exp-2

Design and Implementation of a Temperature Sensor

B. Mazhari
Dept. of EE, IIT Kanpur

Temperature measurement using a diode/BJT

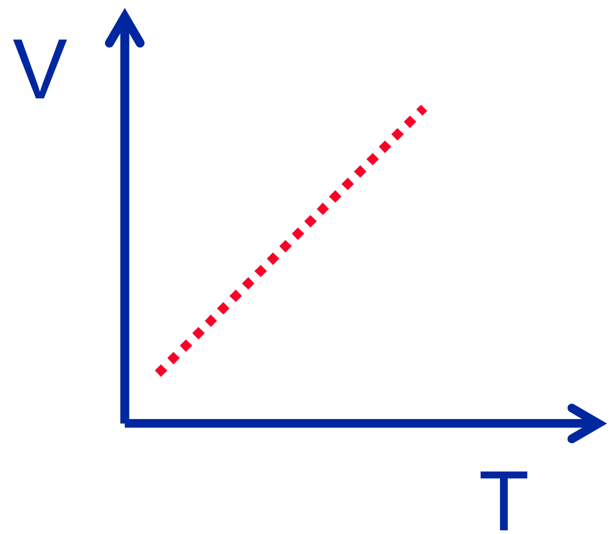


$$I_O \sim I_C = I_S \times \exp\left(\frac{V_B}{V_T}\right)$$

$$V_B = \frac{kT}{q} \times \ln\left(\frac{I_O}{I_S}\right)$$

Basic principle

Complete Circuit

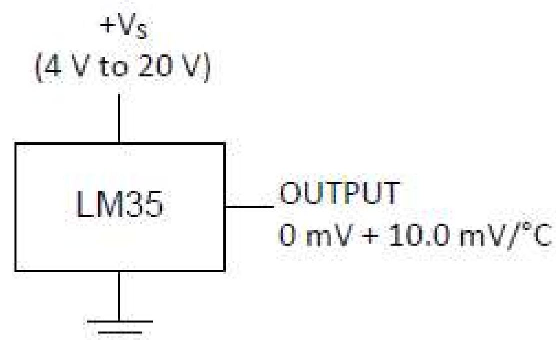


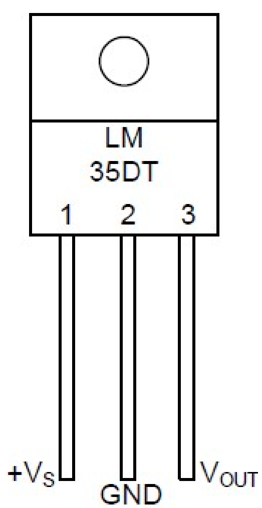
LM35 Precision Centigrade Temperature Sensors

1 Features

- Calibrated Directly in Celsius (Centigrade)
- Linear + 10-mV/°C Scale Factor
- 0.5°C Ensured Accuracy (at 25°C)
- Rated for Full −55°C to 150°C Range
- Suitable for Remote Applications
- Low-Cost Due to Wafer-Level Trimming
- Operates From 4 V to 30 V
- Less Than 60-µA Current Drain
- Low Self-Heating, 0.08°C in Still Air
- Non-Linearity Only ±¼°C Typical
- Low-Impedance Output, 0.1 Ω for 1-mA Load

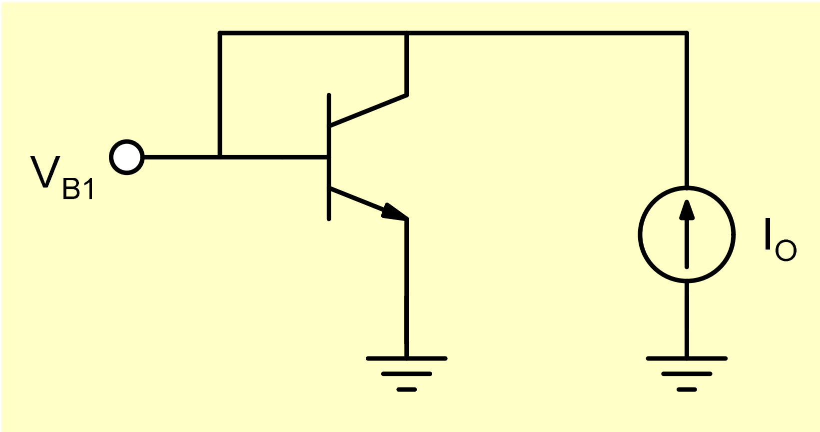
Basic Centigrade Temperature Sensor (2°C to 150°C)

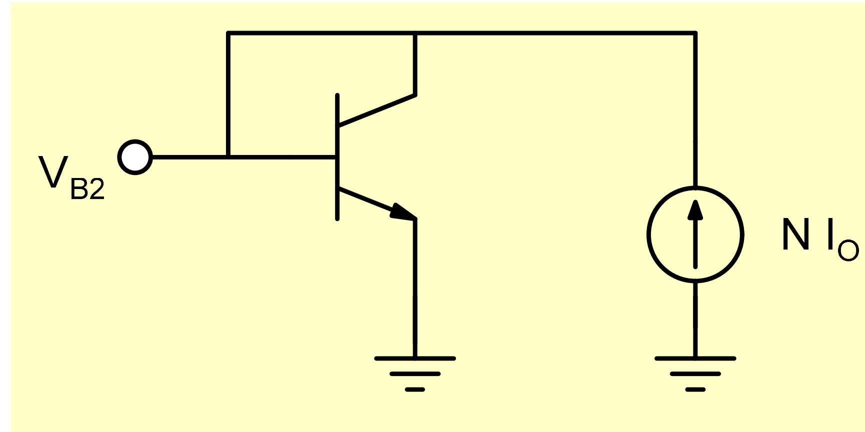




G-Number

Design Methodology





$$V_{B1} = \frac{kT}{q} \times \ln\left(\frac{I_O}{I_S}\right)$$

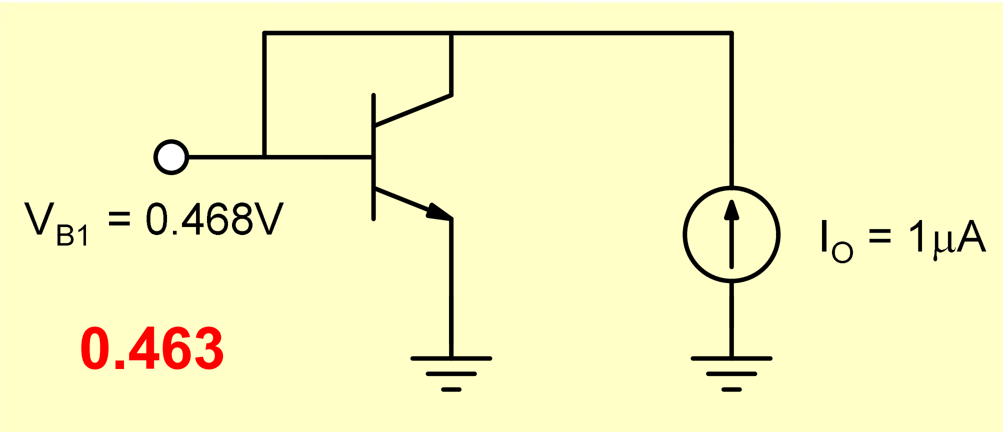
$$V_{B2} = \frac{kT}{q} \times \ln\left(\frac{N \times I_O}{I_S}\right)$$

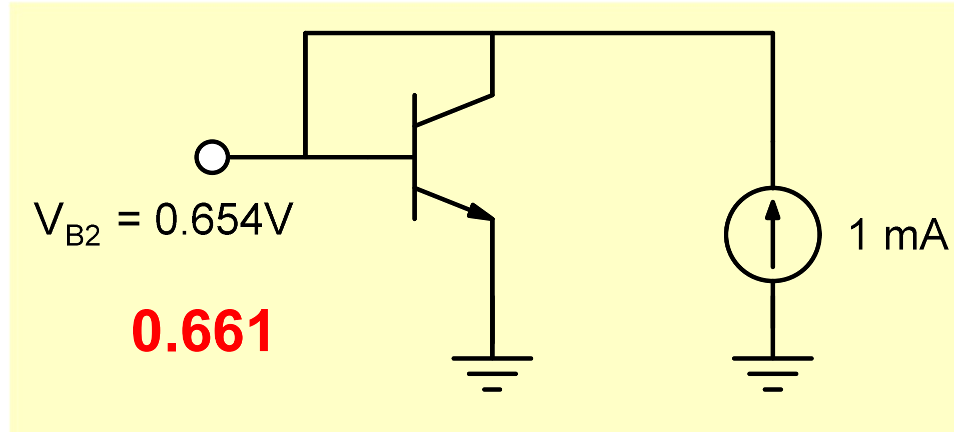
$$V_{B2} - V_{B1} = \frac{kT}{q} \times \ln(N)$$

$$T(^{o}C) = \left(\frac{V_{B2} - V_{B1}}{\ln(N)}\right) \times \left(\frac{300}{.02588}\right) - 273$$

G-Number

Example





$$V_{B2} - V_{B1} = \frac{kT}{q} \times \ln(N)$$

$$0.187 = \frac{kT}{q} \times 6.908 \Rightarrow T = 313K$$

331.8K

6%

$$T(^{o}C) = \left(\frac{V_{B2} - V_{B1}}{\ln(N)}\right) \times \left(\frac{300}{.02588}\right) - 273 = 40\,^{o}C$$

58.8 °C

47%

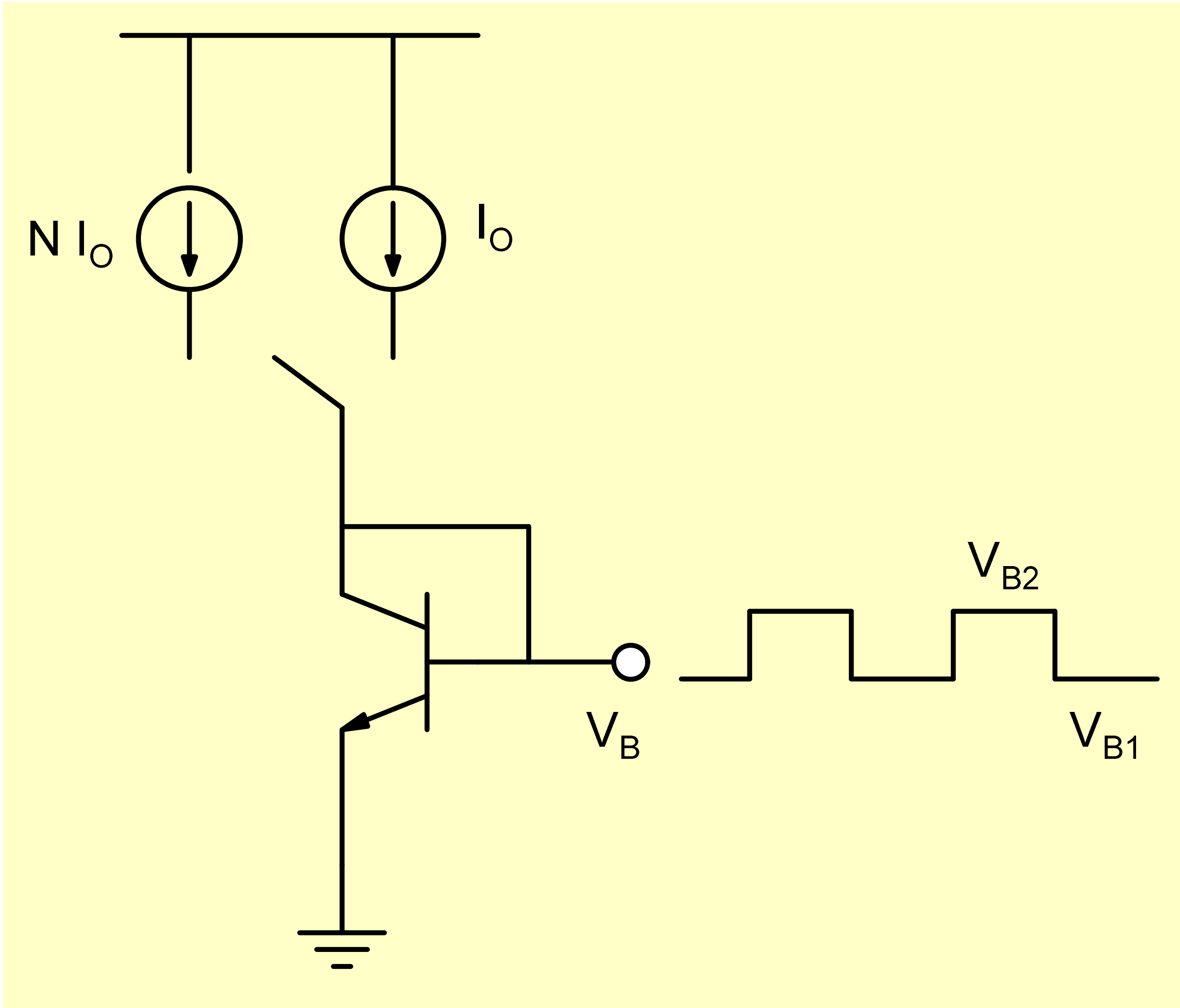
Impact of 1% error in measurement

$$T(^oC) = \left(\frac{V_{B2} - V_{B1}}{\ln(N)}\right) \times \left(\frac{300}{.02588}\right) - 273$$

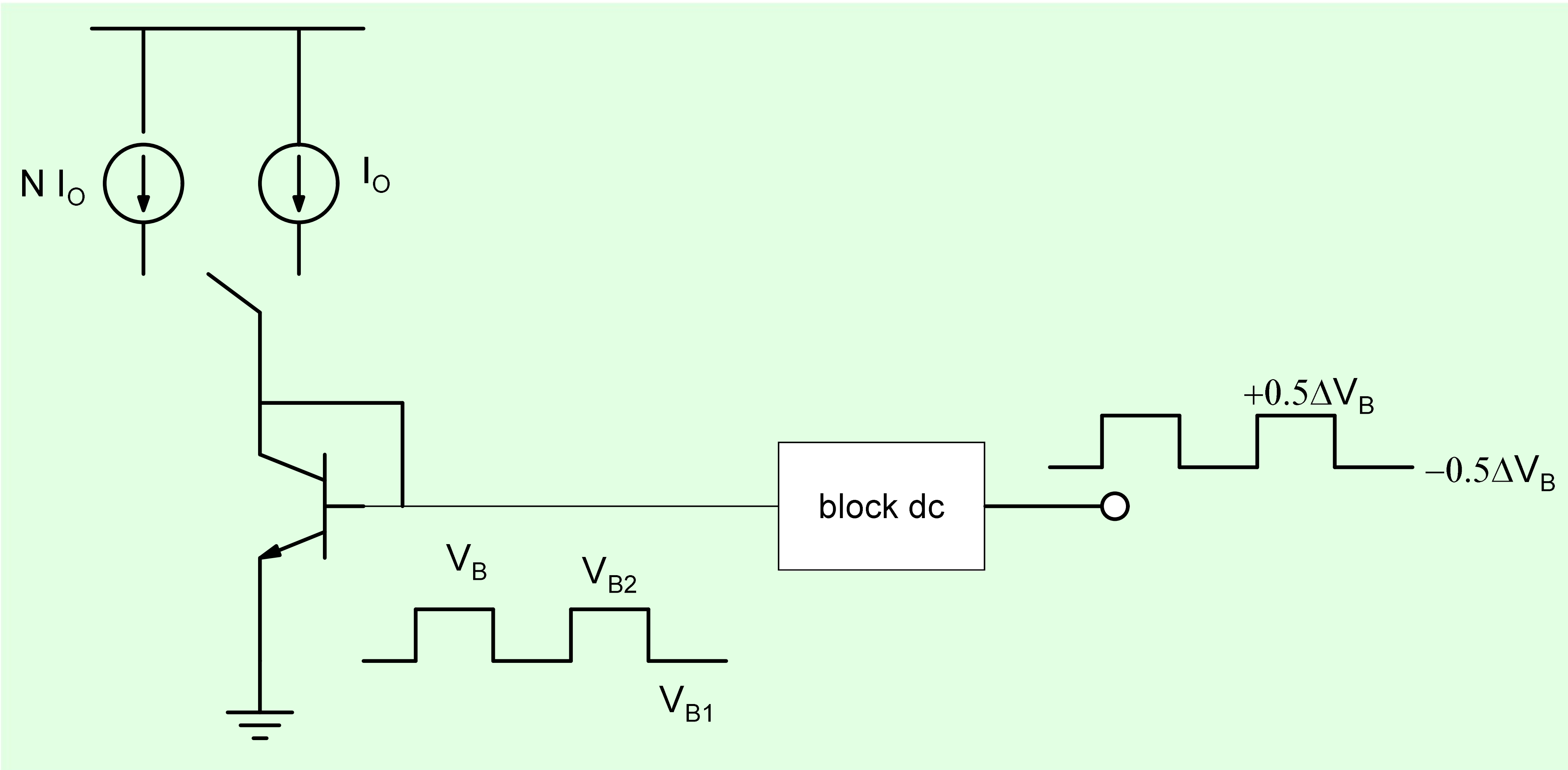
$$T(^oC) = \left(\frac{\Delta V_B}{\ln(N)}\right) \times \left(\frac{300}{.02588}\right) - 273$$

0.187V → 40.8 ^{o}C

A 1% error in measurement of ΔV_B causes 7.7% error in T

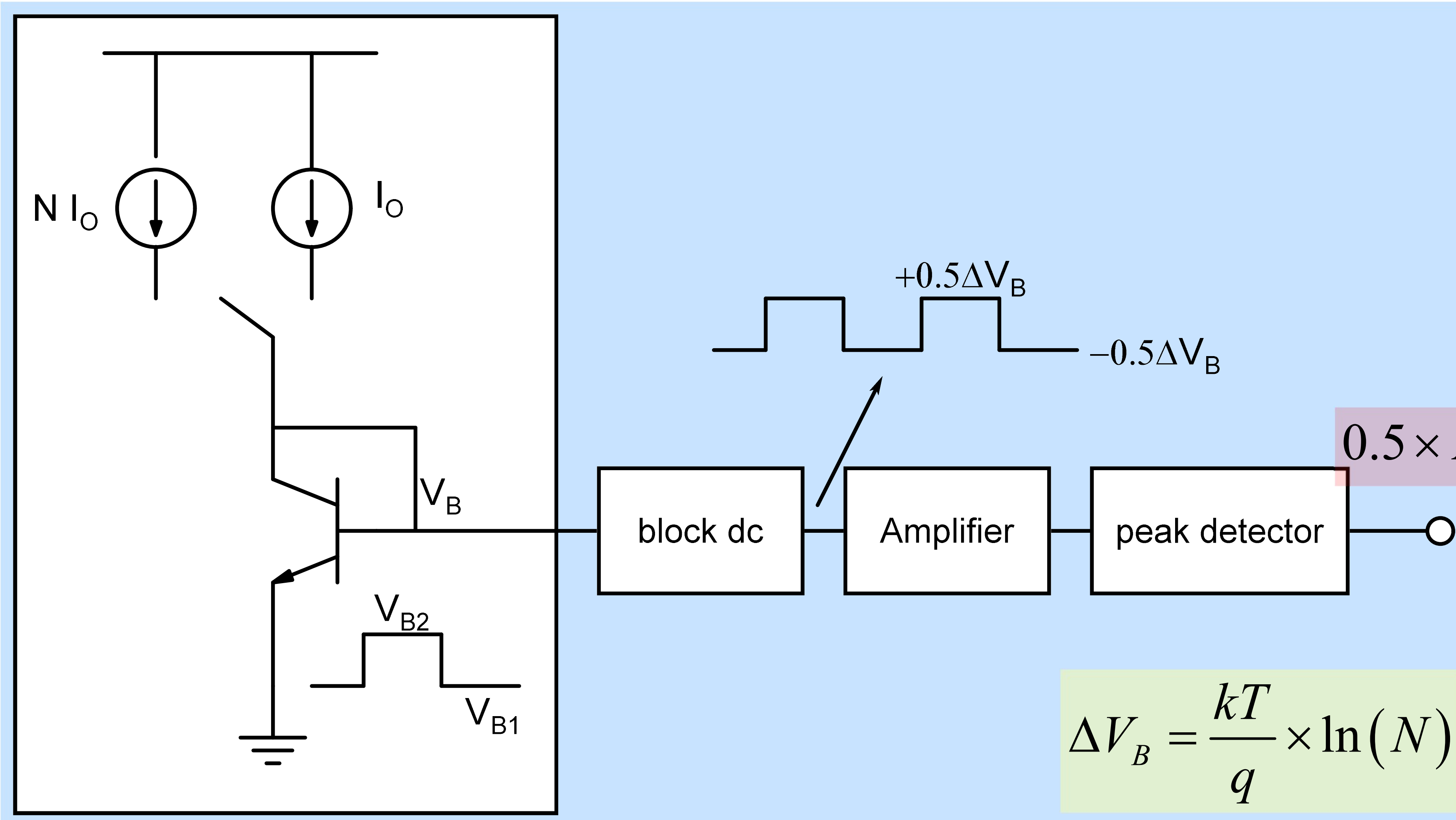


Switching current from I_O to $N \times I_O$ generates base voltage V_B



G-Number

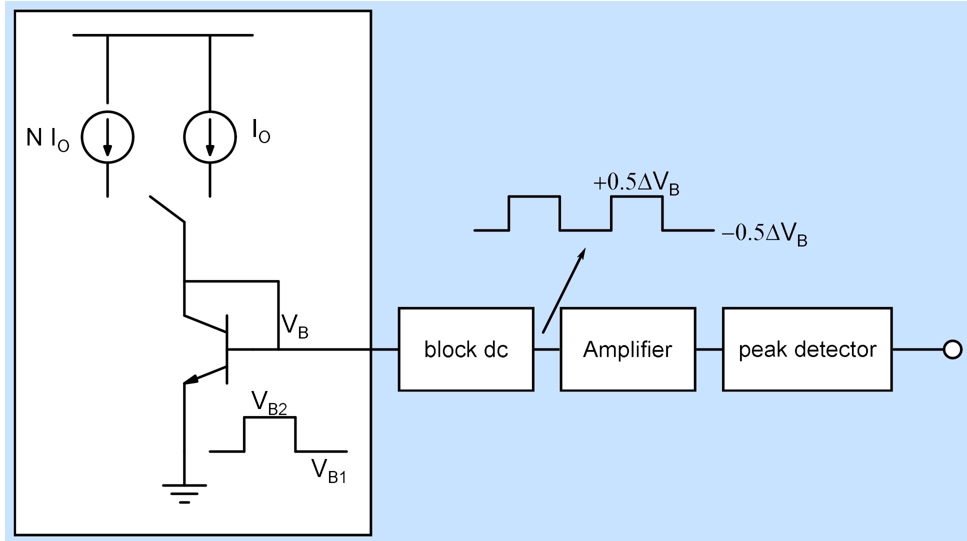
System Block diagram

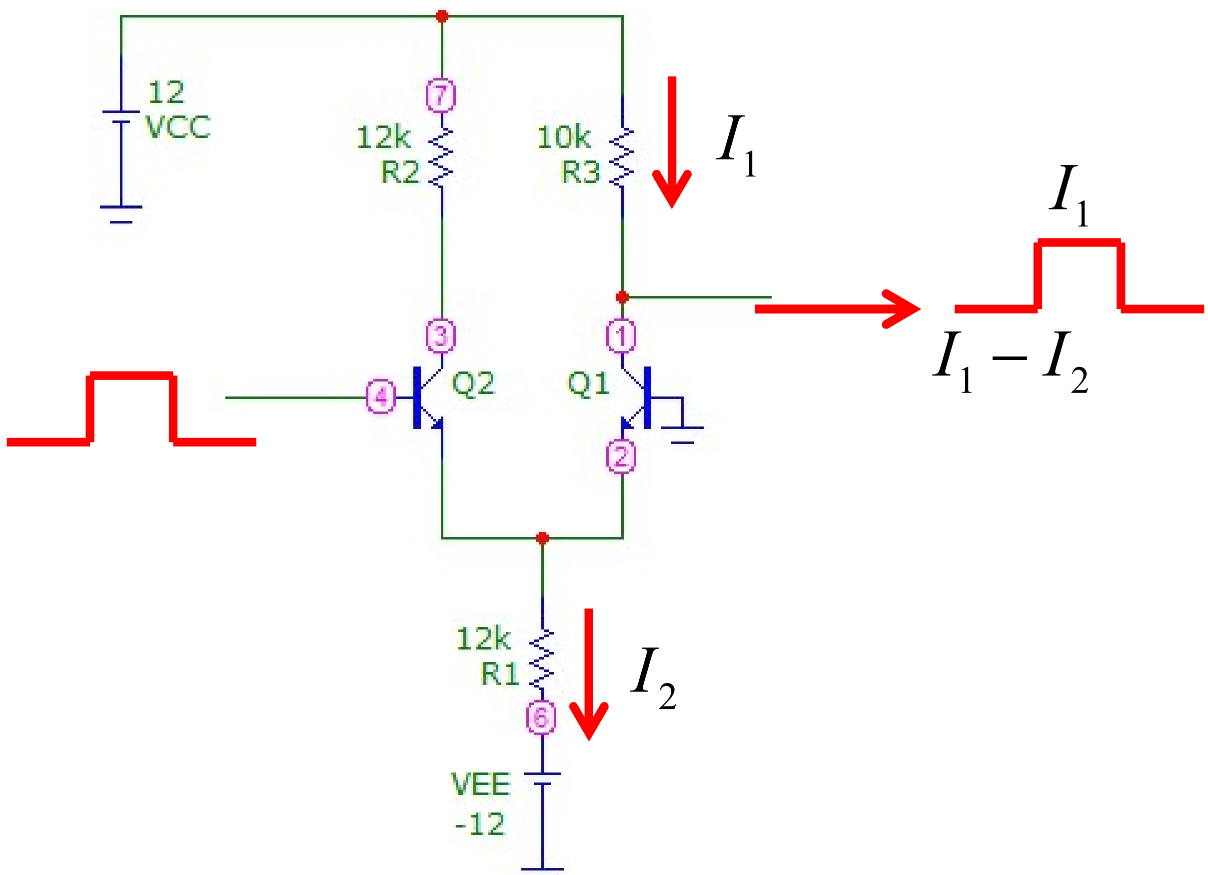


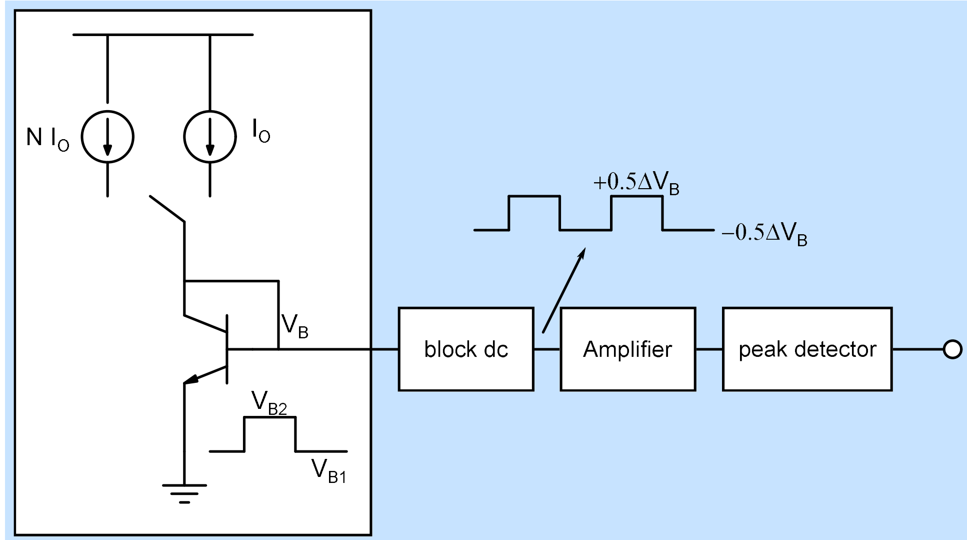
$0.5 \times A \times \Delta V_B$

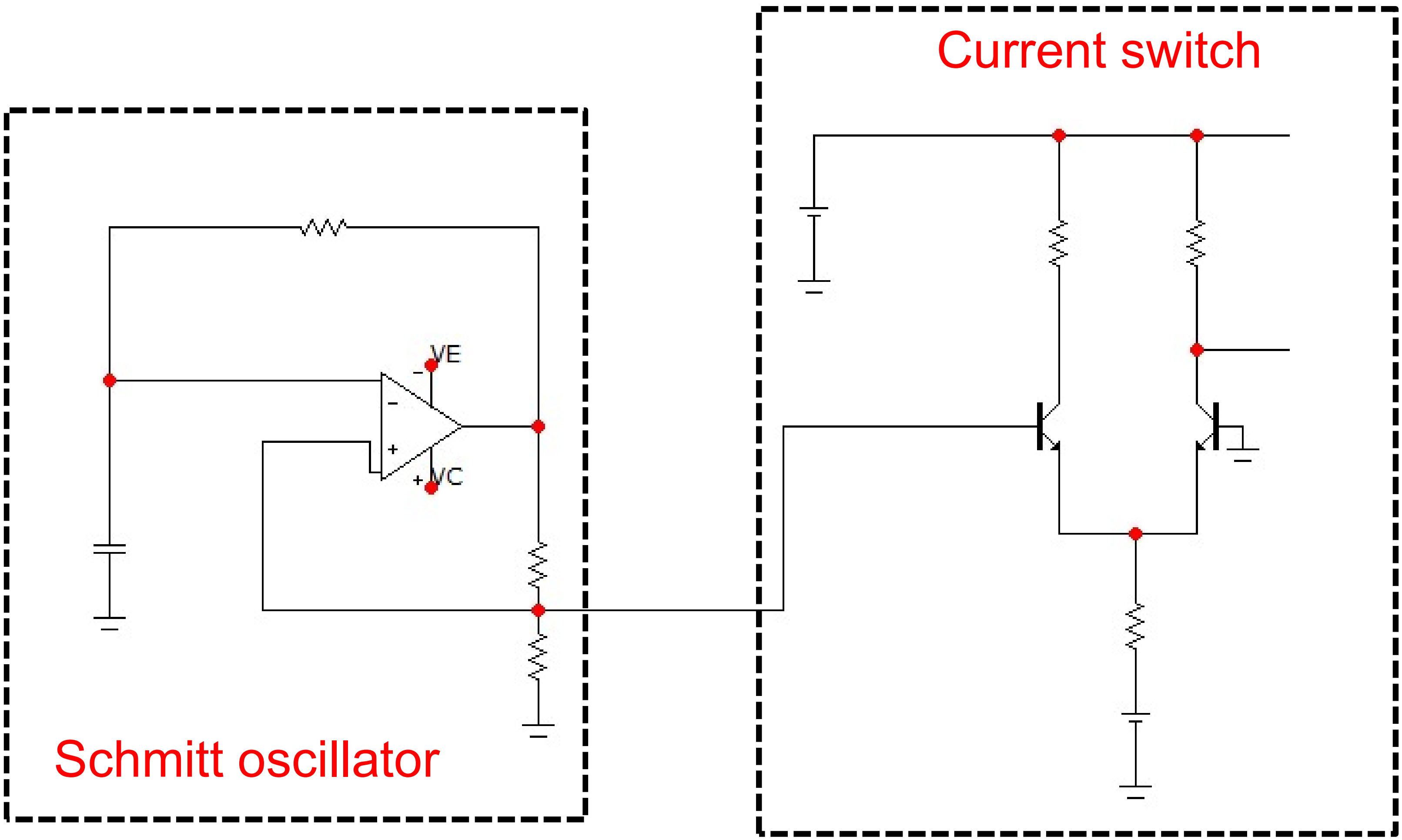
$$\Delta V_B = \frac{kT}{q} \times \ln(N)$$

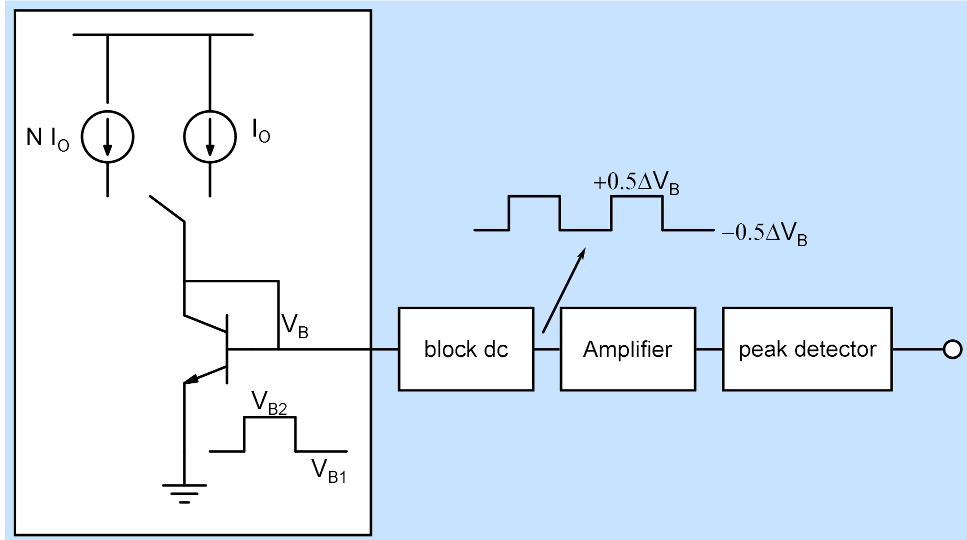
The output is proportional to absolute value of temperature

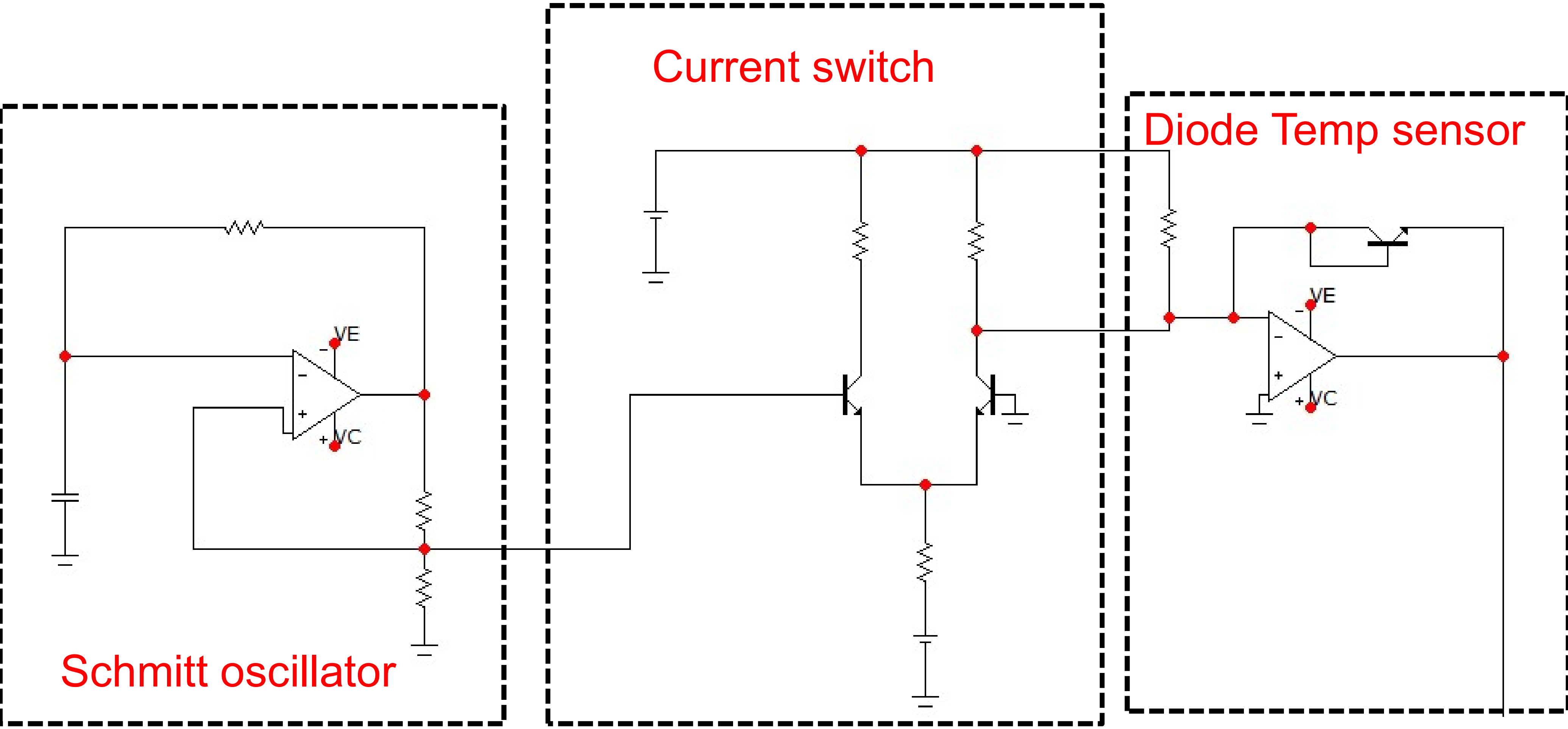

N I_O
I_O
V_B
V_B2
V_B1
+0.5ΔV_B
−0.5ΔV_B
block dc
Amplifier
peak detector


12
VCC
12k
R2
10k
R3
I_1
Q2
Q1
I_1 − I_2
12k
R1
I_2
VEE
-12

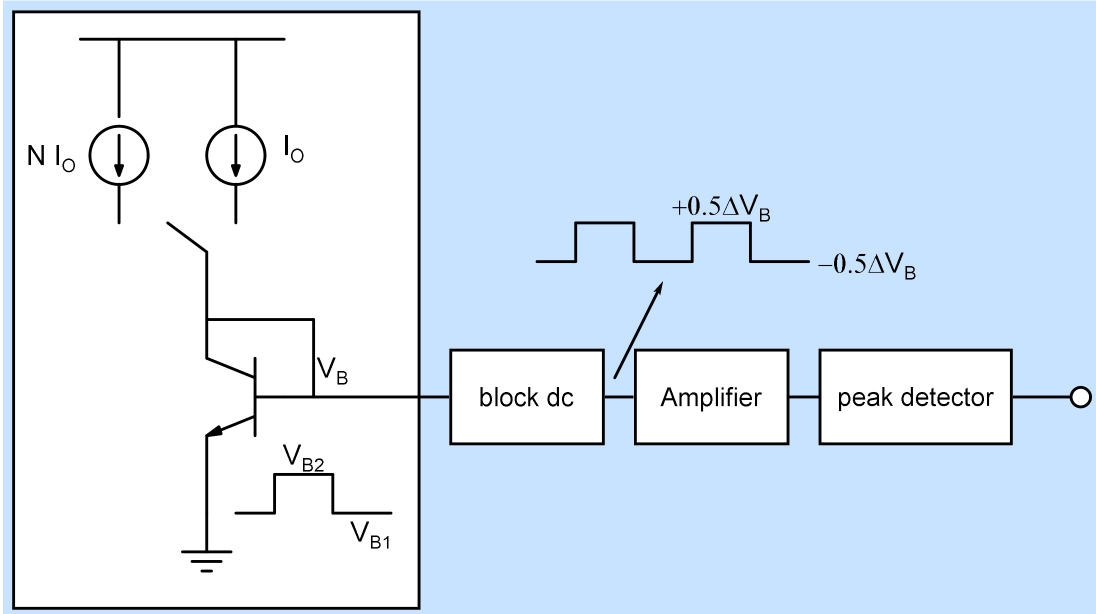

N I_O
I_O
+0.5ΔV_B
−0.5ΔV_B
V_B
block dc
Amplifier
peak detector
V_B2
V_B1

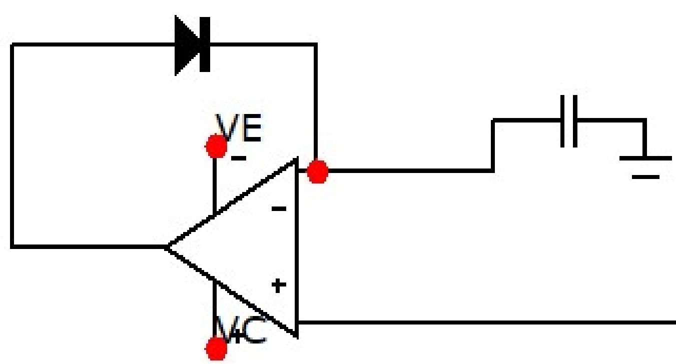

Current switch
VE
VC
Schmitt oscillator


N I_O
I_O
+0.5ΔV_B
−0.5ΔV_B
V_B
block dc
Amplifier
peak detector
V_B2
V_B1

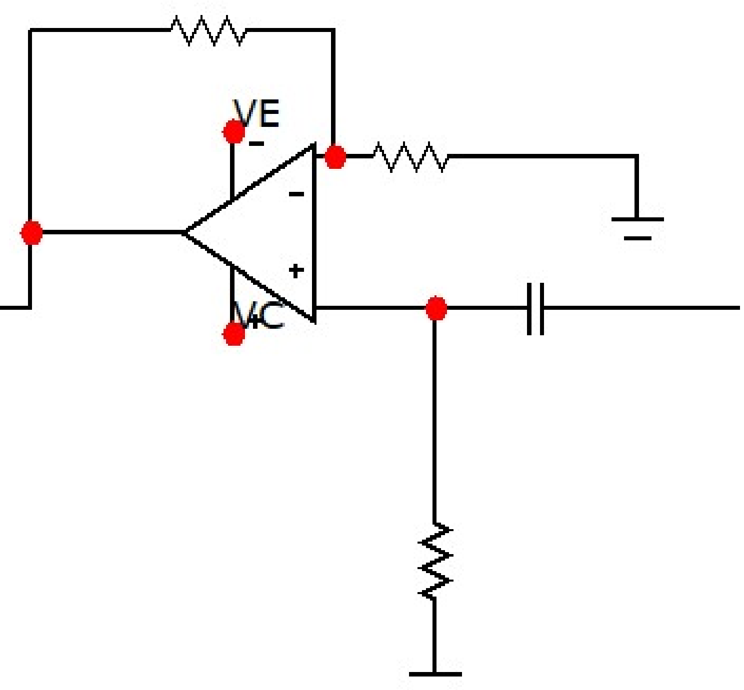

Current switch
Diode Temp sensor
VE
VC
VE
VC
Schmitt oscillator

G-Number





Peak detector



Amplifier + dc offset elimination

Complete circuit