Table 5.1

Parameter Symbol	Parameter Description	Typical Parameter Value n-Channel	p-Channel	Units
V_{T0}	Threshold voltage ($V_{BS} = 0$)	0.7 ± 0.15	-0.7 ± 0.15	V
K'	Transconductance parameter (in saturation)	$110.0 \pm 10\%$	$50.0 \pm 10\%$	$\mu A/V^2$
γ	Bulk threshold parameter	0.4	0.57	$V^{1/2}$
λ	Channel length modulation parameter	0.04 ($L = 1\ \mu m$) 0.01 ($L = 2\ \mu m$)	0.05 ($L = 1\ \mu m$) 0.01 ($L = 2\ \mu m$)	V^{-1}
$2\|\phi_F\|$	Surface potential at strong inversion	0.7	0.8	V

5.1 Determine V_{ref} (Output Voltage) in Fig 5.1 and the conditions under which the TC of V_{ref} is zero. Assume K=10. Assume $(\partial V_T)/\partial T = 0.085mV/°C$, $(\partial V_{BE})/\partial T = -2mV/℃$, $V_{BE} = 0.75V$, $V_T = 26mV$.

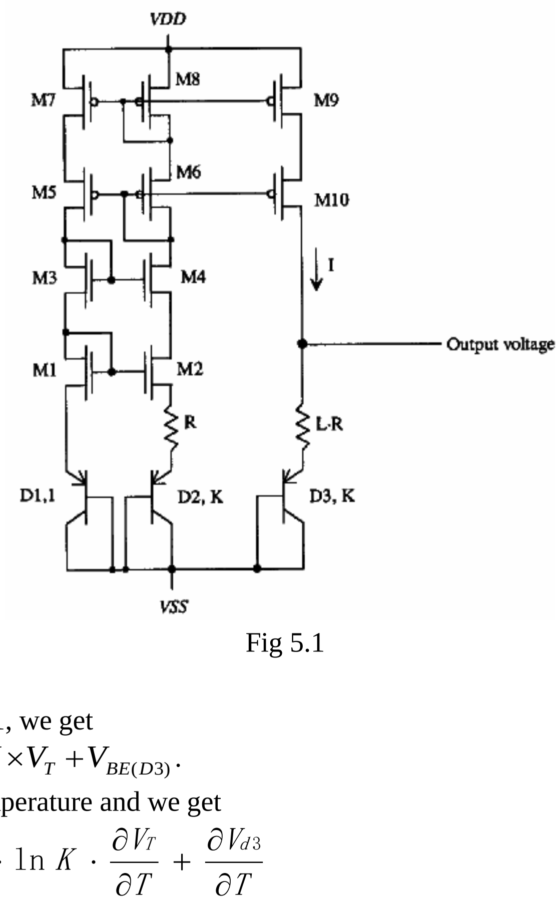

Fig 5.1

解：

For the circuit in Fig 6.1, we get

$$V_{ref} = L \ln K \times V_T + V_{BE(D3)}.$$

V_{ref} is dependent on temperature and we get

$$\frac{\partial V_{ref}}{\partial T} = L \cdot \ln K \cdot \frac{\partial V_T}{\partial T} + \frac{\partial V_{d3}}{\partial T}$$

$$\frac{\partial V_T}{\partial T} = 0.085mV/^{\circ}C \quad \text{and} \quad \frac{\partial V_{d3}}{\partial T} = -2mV/^{\circ}C$$

Let V_{ref} has zero temperature coefficient and get

$$\frac{\partial V_{ref}}{\partial T} = L \cdot \ln K \cdot \frac{\partial V_T}{\partial T} + \frac{\partial V_{d3}}{\partial T} = 0$$

It can be derived that while $L\ lnK$=2/0.085=23.5， $\frac{\partial V_{ref}}{\partial T}=0$, or $TC(V_{ref})=0$.

Assuming K=10，the corresponding L＝10.2≈10

Under these conditions the V_{ref} that has zero TC is

$$V_{REF}=L\ln K\times V_T+V_{BE(D3)}=1.35V$$

5.2 Derive an expression for I_{out} in Fig 5.2. Assume all transistors are in saturation region, and $(W/L)_4=(W/L)_3$, $\lambda=0$.

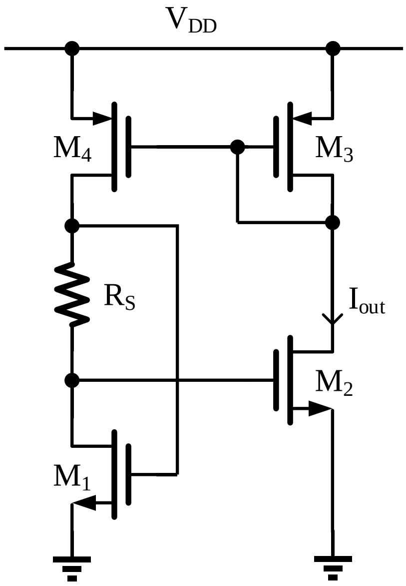

Fig 5.2

解：

$$I_{out}R_S+\sqrt{\frac{2I_{out}}{\mu_n C_{ox}\left(\frac{W}{L}\right)_2}}+V_{TH2}=\sqrt{\frac{2I_{out}}{\mu_n C_{ox}\left(\frac{W}{L}\right)_1}}+V_{TH1}$$

解得：$I_{out}=\frac{2}{\mu_n C_{ox}R_S^2}\left(\sqrt{\left(\frac{L}{W}\right)_1}-\sqrt{\left(\frac{L}{W}\right)_2}\right)^2$

5.3 The circuit of Fig 5.3 is designed with R_3=1kΩ, and a current of 50μA through it. Calculate R_1 and n for a zero TC. Assume $R_1=R_2$. Assume $(\partial V_T)/\partial T$=0.085mV/°C, $(\partial V_{BE2})/\partial T$=-2mV/℃, V_{BE}=0.75V, V_T=26mV.

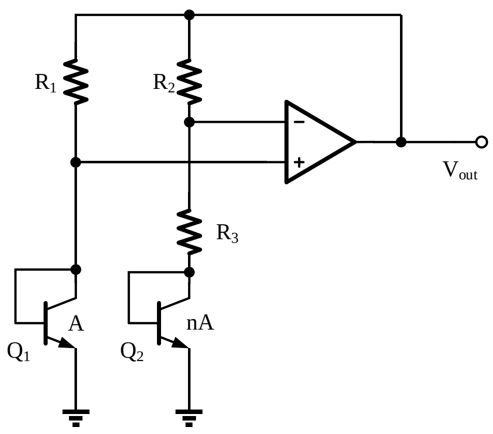

Fig 5.3

解：

$$V_{out} = V_{BE2} + (V_T \ln n)\left(1 + \frac{R_2}{R_3}\right)$$

$$I_{R3} = \frac{V_{out} - V_{BE2}}{R_2 + R_3} = \frac{(V_T \ln n)\left(1 + \frac{R_2}{R_3}\right)}{R_2 + R_3} = 50\mu A$$

$$\frac{\partial V_{out}}{\partial T} = \frac{\partial V_{BE}}{\partial T} + \left(1 + \frac{R_2}{R_3}\right)\ln n \times \frac{\partial V_T}{\partial T} = 0$$

解得：$R_2 = 11.2k\Omega$，$n \approx 6.84$