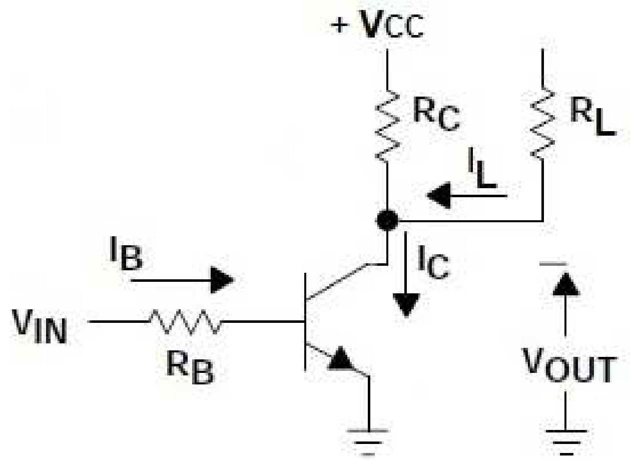
4.Endüstriyel Elektronikte kullanılan Yükselteçler

Transistor kullanılan Yükselteçlerin Elektronik Devreleri,

DC Yükselteç, Transistorun doyumda çalışması

$V_{CC} = +12V$, $V_{OUT} < 0.4V$, $I_L < 10mA$, $\beta = 50$

$V_{IN} < 0.05V$, $V_{OUT} > 10V$, $I_{RC} = 1mA$



$$R_C \le \frac{V_{CC}-V_{OUT}}{I_{RC}} = \frac{12-10}{1mA} = 2k$$

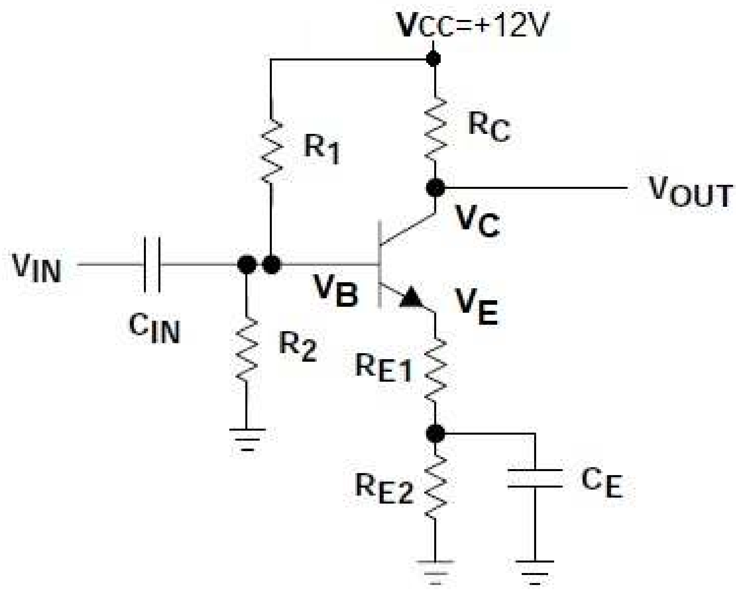
$$I_C = \beta I_B = \frac{V_{CC}-V_{CE}}{R_C} + I_L \approx \frac{12}{2k} + 10mA$$

$$R_B \le \frac{V_{IN}-V_{BE}}{I_B}$$

$$R_B \le \frac{(V_{IN}-V_{BE})\beta}{I_C} = \frac{(12-0,6)50}{\left[\frac{12}{2k}+10mA\right]} = 35,6k$$

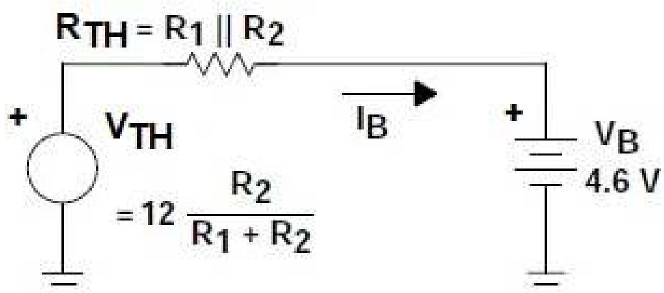
AC yükselteç, Transistorun doğrusal çalışması, Kazanç = 4

V_{CC} = +12V, V_{CE} = 4V, V_C = 8V, I_C = 10mA, β = 100



$$R_C \leq \frac{V_{CC}-V_C}{I_C} = \frac{12V - 8V}{10mA} = 400\Omega$$

$$R_E = R_{E1} + R_{E2} = \frac{V_E}{I_E} = \frac{V_E}{I_B + I_C} \cong \frac{V_E}{I_C} = \frac{4V}{10mA} = 400\Omega$$



$$V_{TH} = \frac{V_{CC}R_2}{R_1 + R_2} = \frac{12 \cdot R_2}{R_1 + R_2} \qquad R_{TH} = \frac{R_1 R_2}{R_1 + R_2}$$

$$I_B = \frac{I_C}{\beta} = \frac{10mA}{100} = 0{,}1mA$$

$$R_{TH} = \frac{0,4V}{I_B} = \frac{0,4V}{0,1mA} = 4k$$

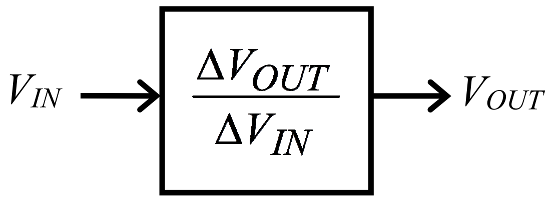
$$V_{TH} = I_B R_{TH} + V_B = 0,4V + 4,6V = 5 = \frac{12 \cdot R_2}{R_1 + R_2}$$

$$R_2 = \frac{7}{5} R_1$$

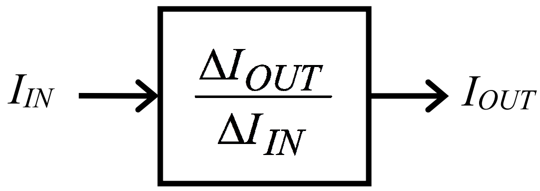
$$R_{E1} = \frac{R_C}{G} = \frac{400}{4} = 100\Omega$$

$$R_{E2} = R_E - R_{E1} = 400 - 100 = 300\Omega$$

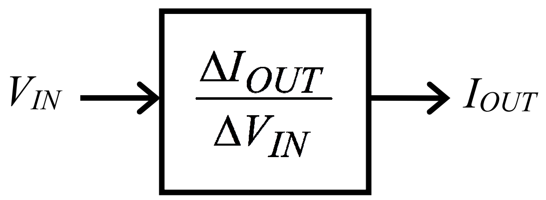
YÜKSELTEÇ TİPLERİ



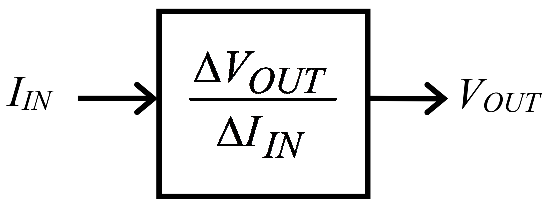
Gerilim Yükselteci



Akım Yükselteci



İletkenlik transfer Yükselteci (Transconductance)



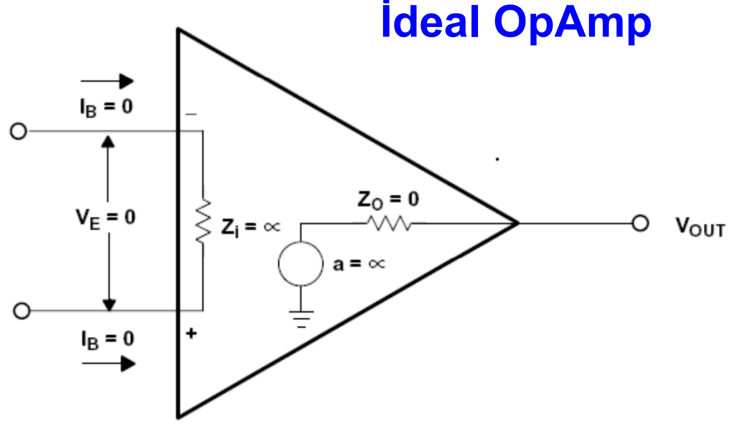
Empedans transfer Yükselteci (Transimpedance)

Operational Amplifiers (OPAMP)
High Speed Current Feedback (CFA)
High Speed Voltage Feedback
Precision, Low Power
High Speed Comparators
Instrumentation Amplifiers
Isolation Amplifiers
Sensor Amplifiers
Bridge Amplifiers
Log Amplifiers

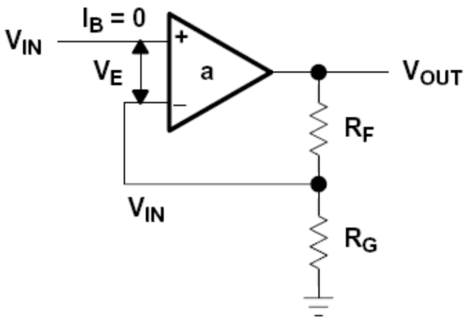
İşlemsel Yükselteçler, Operational Amplifiers (OPAMP)

PARAMETER NAME	PARAMETERS SYMBOL	VALUE
Input current	I_{IN}	0
Input offset voltage	V_{OS}	0
Input impedance	Z_{IN}	∞
Output impedance	Z_{OUT}	0
Gain	a	∞

İdeal OpAmp



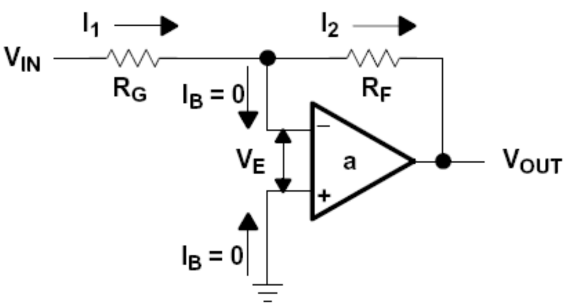
Evirmeyen Yükselteç



$$V_{IN} = V_{OUT} \frac{R_G}{R_G + R_F}$$

$$\frac{V_{OUT}}{V_{IN}} = \frac{R_G + R_F}{R_G} = 1 + \frac{R_F}{R_G}$$

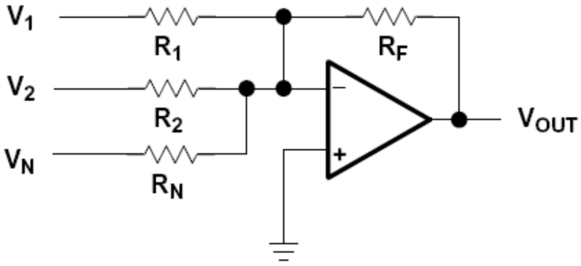
Eviren Yükselteç



$$I_1 = \frac{V_{IN}}{R_G} = -I_2 = -\frac{V_{OUT}}{R_F}$$

$$\frac{V_{OUT}}{V_{IN}} = -\frac{R_F}{R_G}$$

Toplayıcı Yükselteç



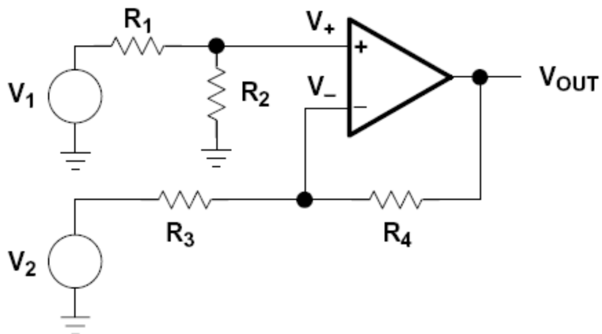
$$V_{OUTN} = -\frac{R_F}{R_N} V_N$$

$$V_{OUT1} = -\frac{R_F}{R_1} V_1$$

$$V_{OUT2} = -\frac{R_F}{R_2} V_2$$

$$V_{OUT} = -\left(\frac{R_F}{R_1} V_1 + \frac{R_F}{R_2} V_2 + \frac{R_F}{R_N} V_N\right)$$

Fark Yükselteci



$$V_{+} = V_1 \frac{R_2}{R_1 + R_2}$$

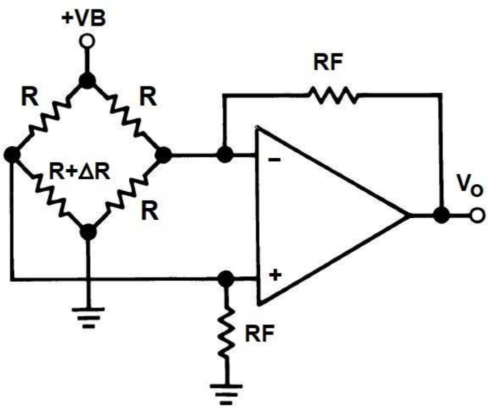
$$V_{OUT1} = V_{+}(G_{+}) = V_1 \frac{R_2}{R_1 + R_2}\left(\frac{R_3 + R_4}{R_3}\right)$$

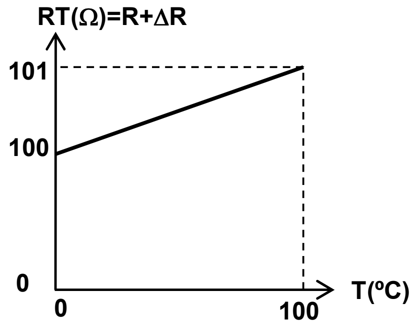
$$V_{OUT2} = V_2\left(-\frac{R_4}{R_3}\right)$$

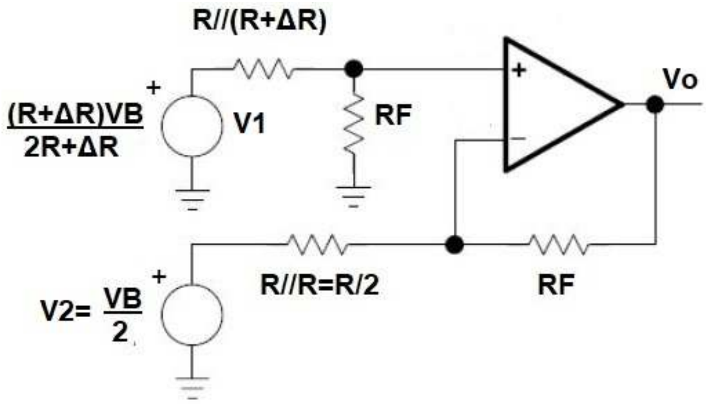
$$V_{OUT} = V_1 \frac{R_2}{R_1 + R_2}\left(\frac{R_3 + R_4}{R_3}\right) - V_2 \frac{R_4}{R_3} \qquad V_{OUT} = (V_1 - V_2)\frac{R_4}{R_3}$$

İşlemsel Yükselteçler (OPAMP), Elektronik Devrelerin Analizi

OPAMP ile Köprü Sensör Yükselteç Devresi ve Eşdeğer Devresi







Köprü Yükselteç Eşdeğer Devresinin Çıkış Gerilimi İfadesinin Analizi

$$\mathrm{V1}=0 \text{ için } \mathrm{VO1}=-\frac{\mathrm{RF}}{(\mathrm{R}/2)}\frac{\mathrm{VB}}{2}=-\frac{\mathrm{RF}}{\mathrm{R}}\mathrm{VB}$$

$$\mathrm{V2}=0 \text{ için } \mathrm{VO2}=\left(\frac{\mathrm{R}+\Delta\mathrm{R}}{2\mathrm{R}+\Delta\mathrm{R}}\right)\cdot\mathrm{VB}\cdot\left(\frac{\mathrm{RF}}{\mathrm{RF}+\left(\frac{\mathrm{R}(\mathrm{R}+\Delta\mathrm{R})}{2\mathrm{R}+\Delta\mathrm{R}}\right)}\right)\frac{\frac{\mathrm{R}}{2}+\mathrm{RF}}{\frac{\mathrm{R}}{2}}=$$

$$\mathrm{VO2}=\frac{(\mathrm{R}+\Delta\mathrm{R})\cdot\mathrm{VB}\cdot\mathrm{RF}}{(2\mathrm{R}+\Delta\mathrm{R})\cdot\mathrm{RF}+\mathrm{R}\cdot(\mathrm{R}+\Delta\mathrm{R})}\cdot\left(\frac{\mathrm{R}+2\mathrm{RF}}{\mathrm{R}}\right)$$

$$\mathrm{VO}=\mathrm{VO1}+\mathrm{VO2}=-\frac{\mathrm{RF}}{\mathrm{R}}\mathrm{VB}+\frac{\mathrm{VB}\cdot\mathrm{RF}\cdot(\mathrm{R}+\Delta\mathrm{R})\cdot(\mathrm{R}+2\mathrm{RF})}{\left[(2\mathrm{R}+\Delta\mathrm{R})\cdot\mathrm{RF}+\mathrm{R}\cdot(\mathrm{R}+\Delta\mathrm{R})\right]\cdot\mathrm{R}}$$

$$\mathrm{VO}=\mathrm{VB}\cdot\frac{\mathrm{RF}}{\mathrm{R}}\left(\frac{(\mathrm{R}+\Delta\mathrm{R})\cdot(\mathrm{R}+2\mathrm{RF})}{\left[(2\mathrm{R}+\Delta\mathrm{R})\cdot\mathrm{RF}+\mathrm{R}\cdot(\mathrm{R}+\Delta\mathrm{R})\right]}-1\right)=\mathrm{VB}\cdot\frac{\mathrm{RF}}{\mathrm{R}}\left(\frac{\mathrm{R}^2+\mathrm{R}\cdot2\mathrm{RF}+\Delta\mathrm{R}\cdot\mathrm{R}+\Delta\mathrm{R}\cdot2\mathrm{RF}}{2\mathrm{R}\cdot\mathrm{RF}+\Delta\mathrm{R}\cdot\mathrm{RF}+\mathrm{R}^2+\mathrm{R}\cdot\Delta\mathrm{R}}-1\right)$$

$$\mathrm{VO}=\mathrm{VB}\cdot\frac{\mathrm{RF}}{\mathrm{R}}\left(\frac{\Delta\mathrm{R}\cdot\mathrm{RF}}{2\mathrm{R}\cdot\mathrm{RF}+\Delta\mathrm{R}\cdot\mathrm{RF}+\mathrm{R}^2+\mathrm{R}\cdot\Delta\mathrm{R}}\right)=\frac{\mathrm{VB}}{\mathrm{R}}\left(\frac{\Delta\mathrm{R}}{\frac{2\mathrm{R}}{\mathrm{RF}}+\frac{\Delta\mathrm{R}}{\mathrm{RF}}+\frac{\mathrm{R}^2}{\mathrm{RF}^2}+\frac{\mathrm{R}\cdot\Delta\mathrm{R}}{\mathrm{RF}^2}}\right)$$

$$\mathrm{RF}>>\mathrm{R} \text{ ve } \Delta<<1 \text{ için } \mathrm{VO}\cong\frac{\mathrm{VB}}{\mathrm{R}}\frac{\Delta\mathrm{R}\cdot\mathrm{RF}}{2\cdot\mathrm{R}}=\mathrm{VB}\cdot\left(\frac{\Delta}{2}\right)\frac{\mathrm{RF}}{\mathrm{R}}$$

Rf Direnç Değerinin Çıkış Gerilimine Etkisinin Analizi

$$Rf = 10100\,\Omega$$ *Doğru değer*

$$VO = \frac{VB \cdot Rf \cdot \Delta R \cdot Rf}{R \cdot \left(2 \cdot R \cdot Rf + \Delta R \cdot Rf + R^2 + R \cdot \Delta R\right)} = 5V$$

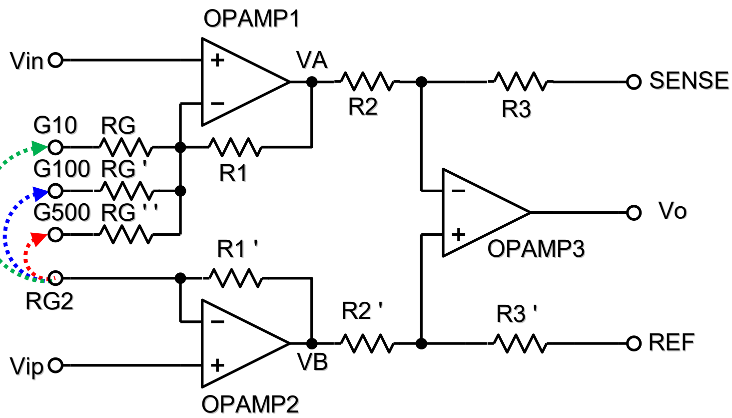
$$VO = VB \cdot \Delta R \cdot \frac{Rf}{2 \cdot R^2} = 5.05V$$ *Yaklaşıklığın etkisi*

$$VO = VB \cdot \Delta R \cdot \frac{Rf}{2 \cdot R^2} = 5$$

$$Rf = \frac{5 \cdot 2 \cdot R^2}{VB \cdot \Delta R} = 10000\,\Omega$$

$$Rf = 10000\,\Omega$$ *Yaklaşık Rf değeri*

Enstrümantasyon Yükselteç (IN AMP) Devresinin Analizi



1) Vip = 0
VA = (1+R1/RG)Vin
VB=(-R1/RG)Vin
Vo1= VB-VA
Vo1= (-R1/RG)Vin-(1+R1/RG)Vin
Vo1= -(1+2R1/RG)Vin
2) Vin = 0
VB = (1+R1/RG)Vip
VA=(-R1/RG)Vip
Vo2= VB-VA
Vo2= (1+R1/RG)Vip-(-R1/RG)Vip
Vo2= (1+2R1/RG)Vip
3) Vo=Vo1+Vo2= (1+2R1/RG)(Vip-Vin)

$V_I = V_{IP} - V_{IN}$ $\quad K = \frac{V_O}{V_I} = 1 + \frac{2R1}{RG}$

$RG = \frac{2R1}{K-1}$ **R1=100kΩ**

		IEC60063- E12	E24	E192
$RG10 = \frac{2 \cdot 100 \cdot 10^3}{10-1}$	RG10=22222Ω	22kΩ	22kΩ	22.3kΩ
$RG100 = \frac{2 \cdot 100 \cdot 10^3}{100-1}$	RG100=2020Ω	2.2kΩ	2kΩ	2.03kΩ
$RG500 = \frac{2 \cdot 100 \cdot 10^3}{500-1}$	RG500=401Ω	390Ω	390Ω	402Ω

Enstrümantasyon Yükseltecinin Köprü tipi Dönüstürücüye bağlanması - 1

$$VN = \frac{R}{R+R}VB = \frac{1}{2}VB$$

$$VP = \frac{R+\Delta R}{R+R+\Delta R}VB = \frac{R+\Delta R}{2R+\Delta R}VB$$

$$VO = VP - VN = \frac{R+\Delta R}{2R+\Delta R}VB - \frac{1}{2}VB$$

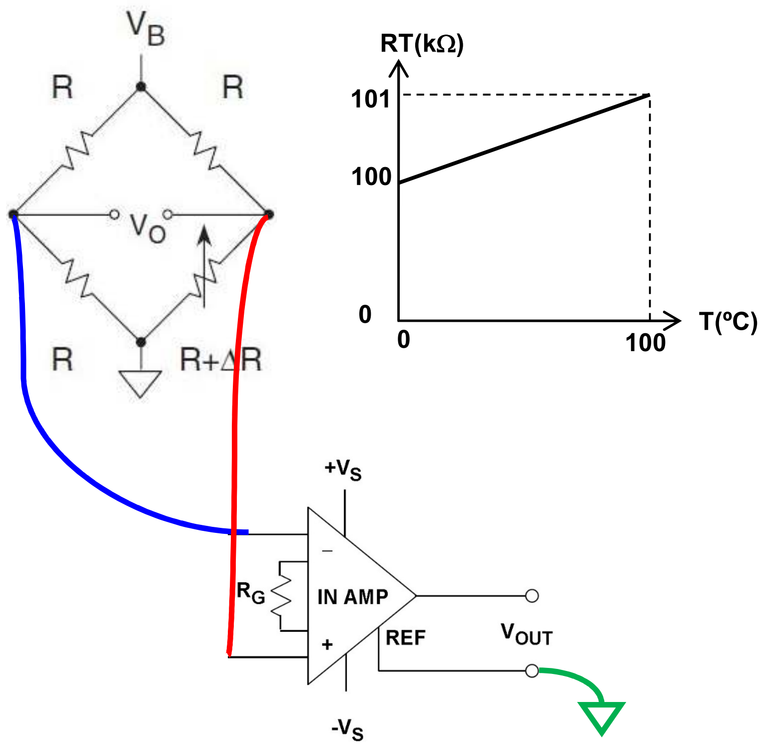
$$VO = \frac{2R+2\Delta R-2R-\Delta R}{4R+2\Delta R}VB$$

$$VO = \frac{\Delta R}{4R+2\Delta R}VB = \frac{VB}{4}\left(\frac{\Delta R}{R+\frac{\Delta R}{2}}\right)$$

$$VO = \frac{10}{4}\left(\frac{1}{100+\frac{1}{2}}\right) \cong \frac{10}{4}\left(\frac{1}{100}\right) \cong \frac{1}{40}$$

$$VO \cong 0{,}025V = 25mV$$

$$V_{OUT}maks = 5V \quad K = \frac{5V}{25mV} \quad K = 200$$



Enstrümantasyon Yükseltecinin Köprü tipi Dönüstürücüye bağlanması - 2

$$VN = \frac{R}{R+R}VB = \frac{1}{2}VB$$

$$VP = \frac{R}{R+R-\Delta R}VB = \frac{R}{2R-\Delta R}VB$$

$$VO = VP - VN = \frac{R}{2R-\Delta R}VB - \frac{1}{2}VB$$

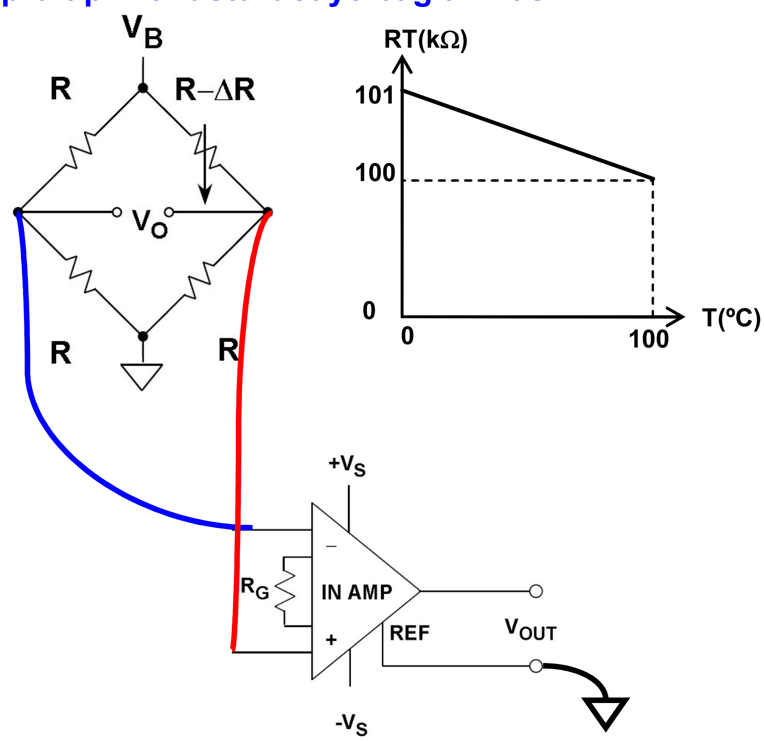
$$VO = \frac{2R-2R+\Delta R}{4R-2\Delta R}VB = \frac{\Delta R}{4R-2\Delta R}VB$$

$$VO = \frac{VB}{4}\left(\frac{\Delta R}{R-\frac{\Delta R}{2}}\right)$$

$$VO = \frac{10}{4}\left(\frac{1}{100-\frac{1}{2}}\right) \cong \frac{10}{4}\left(\frac{1}{100}\right) \cong \frac{1}{40}$$

$$VO \cong 0{,}025V = 25mV$$

$$V_{OUT}maks = 5V \quad K = \frac{5V}{25mV} \quad K = 200$$



Köprü tipi Dönüstürücüde Doğrusallık Hatası ve Duyarlık

$$VO = \frac{VB}{4}\left(\frac{\Delta R}{R + \frac{\Delta R}{2}}\right)$$

Doğrusallık Hatası = maks. sapma / tam ölçek

Ör: VB =10V R=100Ω ΔR=0.1Ω tam ölçek sapma için

$$VO = \frac{10}{4}\left(\frac{0.1}{100 + \frac{0.1}{2}}\right) = \frac{10}{4}\left(\frac{0,1}{100}\right) = \frac{1}{400}$$

$$VO \cong 0,0025V = 2.5mV$$

VO = 2,5mV – 2.49875mV = 0.00125mV

$$\frac{\Delta R}{2}\% = \frac{0,00125mV}{2.5mV} \cdot 100\% = 0.05\%$$

Duyarlık = çıkışın girişin değişimine duyarlığı

Ör: VB =10V tam ölçek çıkış VO=10mV için

Duyarlık = 10mV/10V = 1mV/V

KAYNAKLAR

1. Linear Design Seminar Handbook, Analog Devices, 1987
2. Analog Designer Reference CD-ROM, Analog Devices, 2002
3. OpAmps for Everyone, Ron Mancini, 2005
4. Technical Literature Database CD-ROM, National Semiconductor Corporation, 1997