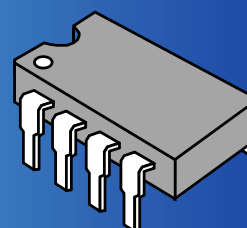


Analog Electronics

Lecture #4

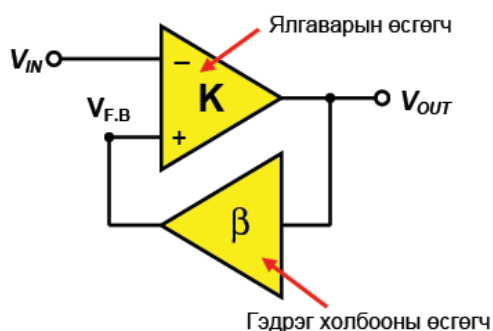


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Operational Amplifier

Ch.9

FEED BACK



$\beta > 1$: Өсгөгч
 $\beta < 1$: Бууруулагч хэлхээ (Идэвхгүй хэлхээ)

$$K_{F.B} = \frac{V_{OUT}}{V_{IN}}$$

$$V_{OUT} = K \cdot (V_{F.B} - V_{IN})$$

$$V_{F.B} = \beta \cdot V_{OUT}$$

$$V_{OUT} = K \cdot (\beta \cdot V_{OUT} - V_{IN})$$

$$V_{OUT} = -\frac{K}{1 - K\beta} \cdot V_{IN} \Rightarrow K_{F.B} = -\frac{K}{1 - K\beta}$$

$$\dot{K}_{F.B} = \frac{\dot{K}}{1 - \dot{K}\dot{\beta}}$$

FEED BACK

$$\dot{K}_{F.B} = \frac{\dot{K}}{1 - \dot{K}\dot{\beta}}$$

$\dot{\beta} = 0$ үед $\dot{K}_{F.B} = \dot{K}$ болох буюу гэдрэг холбоогүй өсгөгч болно.

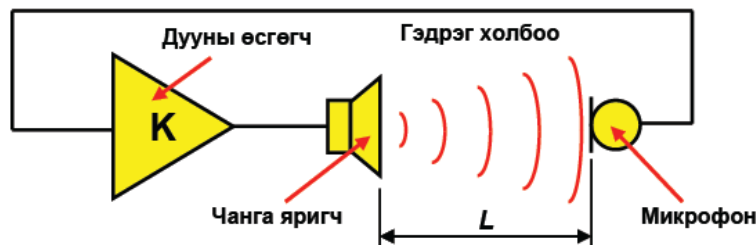
$\dot{\beta} < 0$ буюу сөрөг утгатай үед $1 - \dot{K}\dot{\beta} > 1 \Rightarrow \dot{K}_{F.B} < \dot{K}$ болж өсгөлтийн коэффициент буурна.

$\dot{\beta} > 0$ буюу эерэг утгатай үед $1 - \dot{K}\dot{\beta} < 1 \Rightarrow \dot{K}_{F.B} > \dot{K}$ болж өсгөлтийн коэффициент өснө.

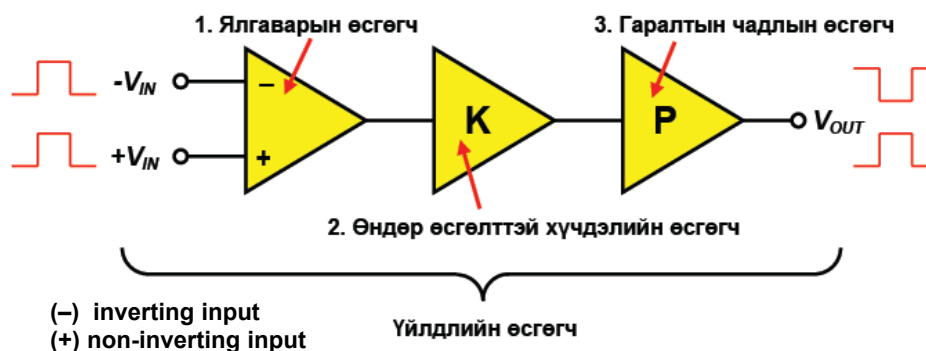
Сөрөг гэдрэг холбооны давуу талууд нь:

- Шугаман бус өсгөлт болон өсгөлтийн гажуудлыг арилгадаг.
- Өсгөгчийн өсгөх зурвасыг өргөсгөдөг зэрэг болно.

Өсгөгч болон гэдрэг холбооны нийт фаз эргүүлэлт тэгш π байвал эерэг гэдрэг холбоо болно.

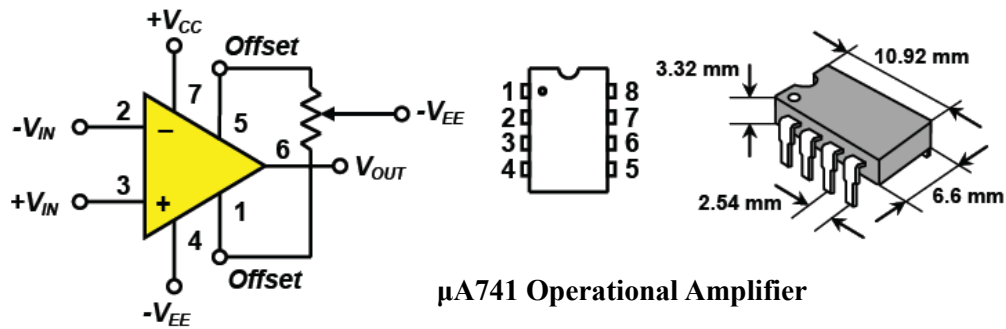


WHAT IS OP-AM?



1. Дифференциал өсгөгчийн оролтын эсэргүүцэл $R_{IN} = \infty$ учир аль ч оролтын гүйдэл $I_{IN} = 0$ буюу оролтоор ямарч гүйдэл гүйхгүй гэж үзнэ.
2. Үйлдлийн өсгөгч нь сөрөг гэдрэг холбоотой үедээ оролтын хүчдэлүүдийн зөрөөг $V_{IN} = 0$ байлгахыг эрмэлздэг.
3. Сөрөг гэдрэг холбоогүй үйлдлийн өсгөгчийн $K = \infty$ учир оролтын хүчдэлүүдийн зөрөө өчүүхэн бага байхад зөрөө нь эерэг бол $V_{OUT} = +\infty$, сөрөг бол $V_{OUT} = -\infty$ болно.

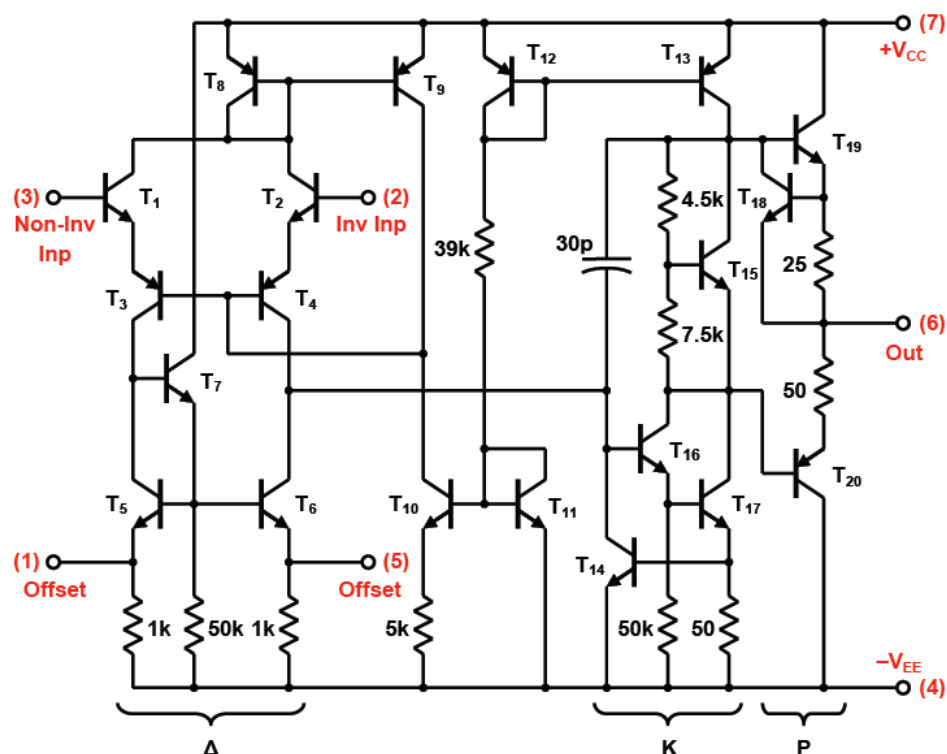
GENERAL PURPOSE OP-AM



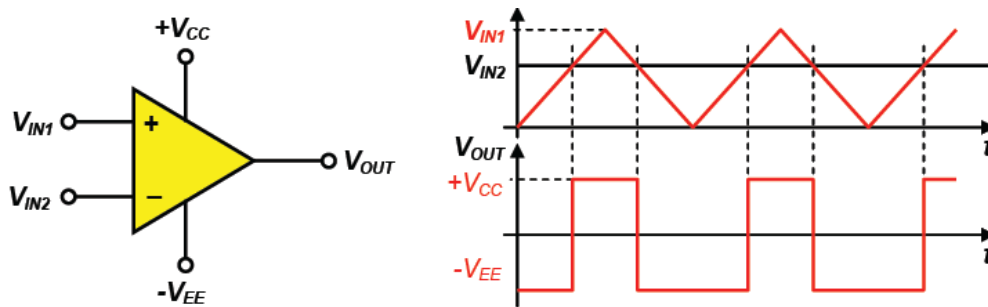
ABSOLUTE MAXIMUM RATINGS

Symbol	Parameter	UA741M	UA741I	UA741C	Unit
V_{CC}	Supply voltage	± 22			V
V_{id}	Differential Input Voltage	± 30			V
V_i	Input Voltage	± 15			V
P_{tot}	Power Dissipation	500			mW
T_{oper}	Operating Free-air Temperature Range	-55 to +125	-40 to +105	0 to +70	$^{\circ}C$
T_{stg}	Storage Temperature Range	-65 to +150			$^{\circ}C$

INTERNAL STRUCTURE

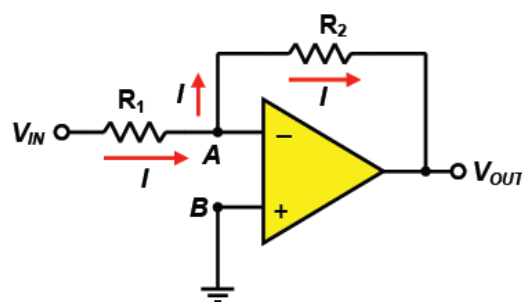


OP-AM AS A DISCRIMINATOR



Audio Level Indicator

INVERTING AMPLIFIER

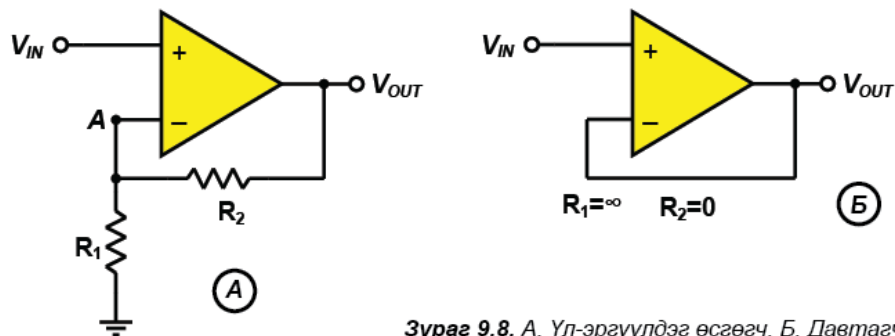


$$K = \frac{V_{OUT}}{V_{IN}} = -\frac{R_2}{R_1}$$

By 2nd Rule: $\Delta V_{IN} = 0V$; $V_B = 0V \Rightarrow V_A = 0V$

By 1st Rule: $I = \frac{V_{IN}}{R_1}$ $I = \frac{-V_{OUT}}{R_2}$

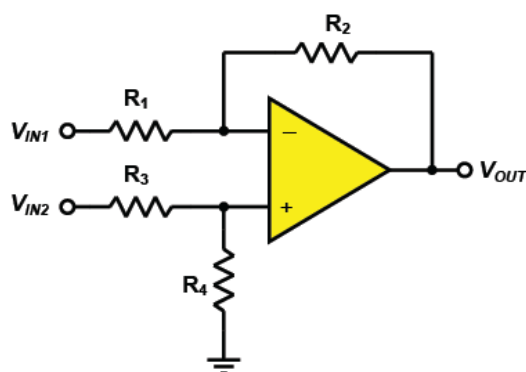
NON-INVERTING AMPLIFIER



Зураг 9.8. А. Үл-эргүүлдэг өсгөгч, Б. Давтагч.

By 2nd Rule: $V_{IN} = V_A = V_{OUT} \cdot \frac{R_1}{R_1 + R_2} \Rightarrow K = \frac{V_{OUT}}{V_{IN}} = 1 + \frac{R_2}{R_1}$

DIFFERENTIAL AMPLIFIER



$$V_{IN2} = 0$$

$$V_{OUT} = -\frac{R_2}{R_1} \cdot V_{IN1}$$

$$V_{IN1} = 0$$

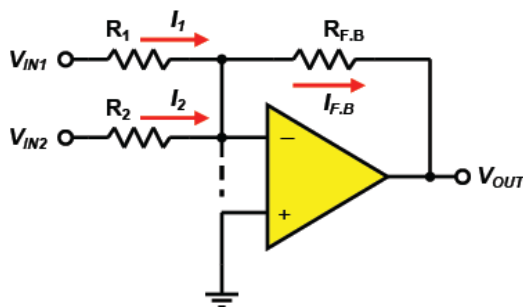
$$V_{OUT} = \left(1 + \frac{R_2}{R_1}\right) \cdot \left(\frac{R_4}{R_3 + R_4}\right) \cdot V_{IN2}$$

$$V_{OUT} = \left(1 + \frac{R_2}{R_1}\right) \cdot \left(\frac{R_4}{R_3 + R_4}\right) \cdot V_{IN2} - \frac{R_2}{R_1} \cdot V_{IN1}$$

$$R_1 = R_2 = R_3 = R_4 \Rightarrow$$

$$V_{OUT} = V_{IN2} - V_{IN1}$$

SUMMING (MIXING) AMPLIFIER



$$I_{F.B} = I_1 + I_2 + \dots + I_N$$

$$V_{OUT} = -I_{F.B} \cdot R_{F.B}$$

$$V_{OUT} = -(I_1 + I_2 + \dots + I_N) \cdot R_{F.B} \Rightarrow V_{OUT} = -\left(\frac{V_{IN1}}{R_1} + \frac{V_{IN2}}{R_2} + \dots + \frac{V_{INN}}{R_N}\right) \cdot R_{F.B}$$

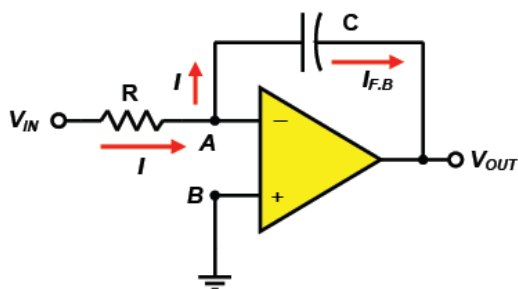
$$V_{OUT} = -\frac{R_{F.B}}{R} \cdot (V_{IN1} + V_{IN2} + \dots + V_{INN})$$

$$R_{F.B} = R \Rightarrow V_{OUT} = -(V_{IN1} + V_{IN2} + \dots + V_{INN})$$

$$R_{F.B} = \frac{R}{N} \Rightarrow V_{OUT} = -\frac{1}{N} \cdot (V_{IN1} + V_{IN2} + \dots + V_{INN})$$

Average Value

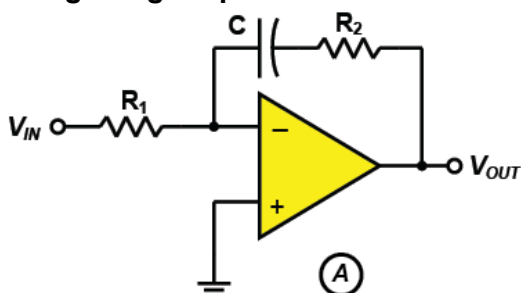
INTEGRATOR



$$V_C = \frac{1}{C} \int I_C \cdot dt \Rightarrow V_{OUT} = -\frac{1}{C} \int I_{F.B} \cdot dt$$

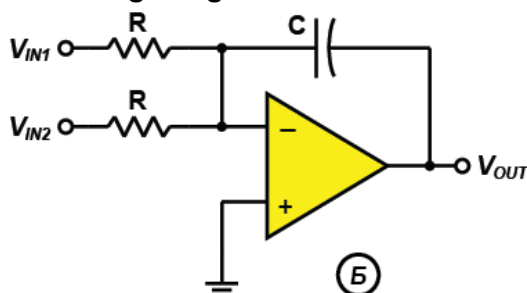
$$V_{OUT} = -\frac{1}{C} \int \frac{V_{IN}}{R} \cdot dt = -\frac{1}{RC} \int V_{IN} \cdot dt$$

Integrating Amplifier



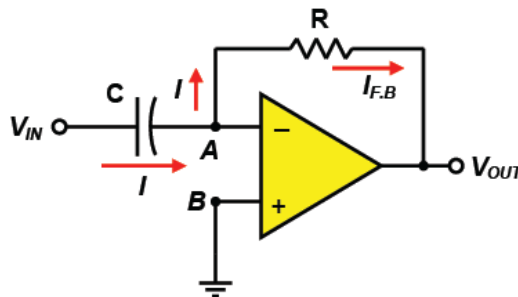
$$V_{OUT} = -\frac{R_2}{R_1} \cdot \frac{1}{R_1 C} \int V_{IN} \cdot dt$$

Summing Integrator



$$V_{OUT} = -\frac{1}{RC} \int (V_{IN1} + V_{IN2} + \dots + V_{INN}) \cdot dt$$

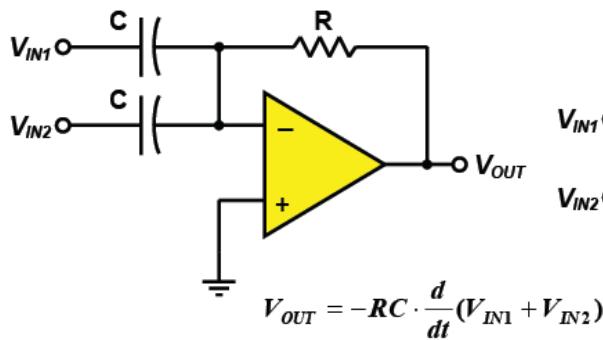
DIFFERENTIATOR



$$I_C = C \cdot \frac{dV_{IN}}{dt}$$

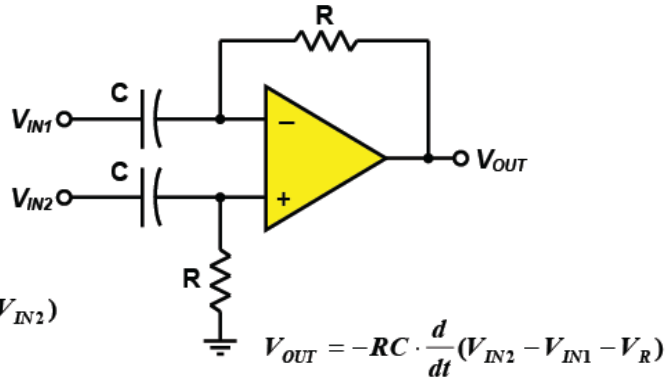
$$I_C = I_{F.B} = C \cdot \frac{dV_{IN}}{dt}$$

$$V_{OUT} = -I_{F.B} \cdot R = -RC \cdot \frac{dV_{IN}}{dt}$$



$$V_{OUT} = -RC \cdot \frac{d}{dt}(V_{IN1} + V_{IN2})$$

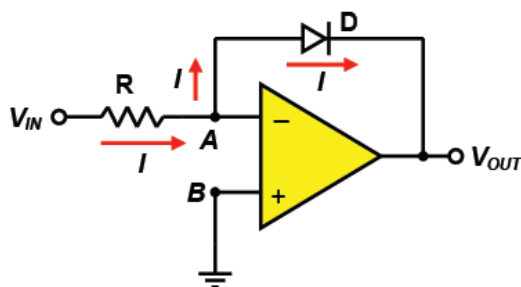
Summing Differentiator



$$V_{OUT} = -RC \cdot \frac{d}{dt}(V_{IN2} - V_{IN1} - V_R)$$

Differential Differentiator

LOGARITHMIC & ANTI-LOGARITHMIC AMPLIFIER



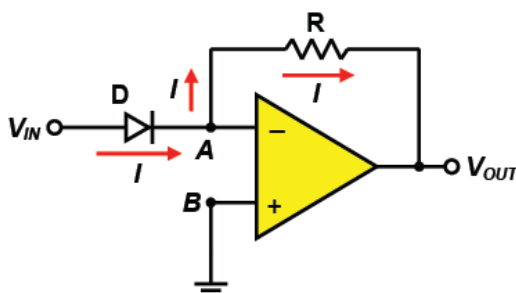
$$I_D = I_0 \cdot (e^{V_D/V_T} - 1)$$

$$V_D \gg V_T \Rightarrow I_D \approx I_0 \cdot e^{V_D/V_T}$$

$$\frac{V_D}{V_T} = \ln\left(\frac{I_D}{I_0}\right)$$

$$V_D = V_T \cdot \ln\left(\frac{I_D}{I_0}\right) = -V_{OUT}$$

$$I_D = I_R = \frac{V_{IN}}{R} \Rightarrow V_{OUT} = -V_T \cdot \left[\ln\left(\frac{V_{IN}}{R}\right) - \ln(I_0) \right]$$

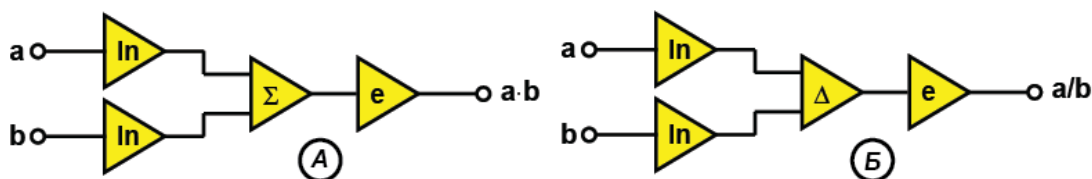


$$V_{OUT} = -I_R \cdot R \quad I_R = I_D$$

$$V_{OUT} = -I_D \cdot R = -R \cdot I_0 \cdot (e^{V_D/V_T} - 1)$$

$$V_{OUT} = -R \cdot I_0 \cdot e^{V_{IN}/V_T}$$

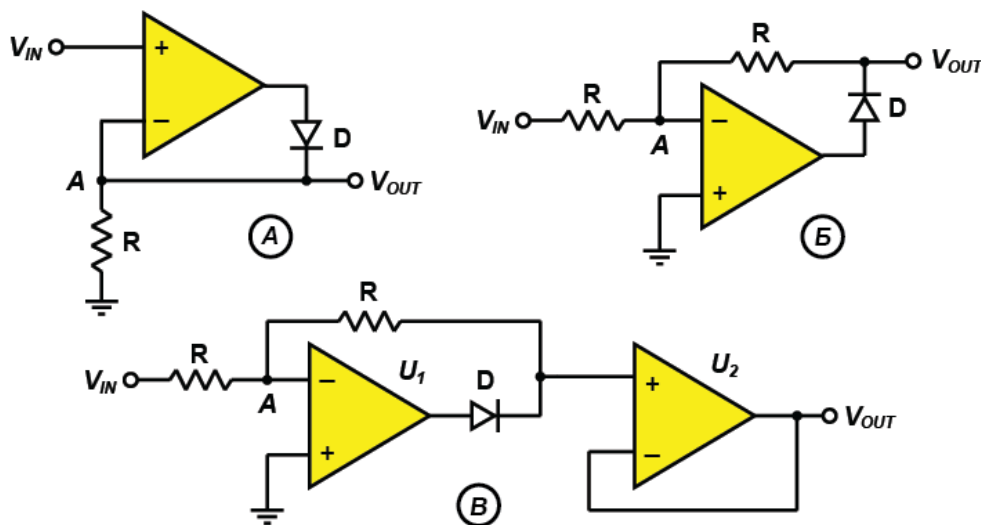
OP-AM AS ANALOG COMPUTER



Зураг 9.19. А. Үржүүлэгч, Б. Хуваагч.

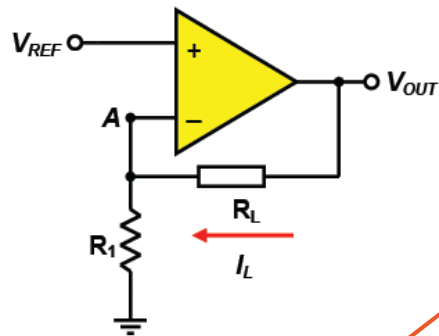
$$\ln(a \cdot b) = \ln(a) + \ln(b) \quad a \cdot b = e^{\ln(a) + \ln(b)}$$

ACTIVE RECTIFIERS



Зураг 9.20. А. Эерэг туйлийг нэвтрүүлэх, Б. Сөрөг туйлийг нэвтрүүлэх
В. Бүтэн үеийн шулуутгагчууд.

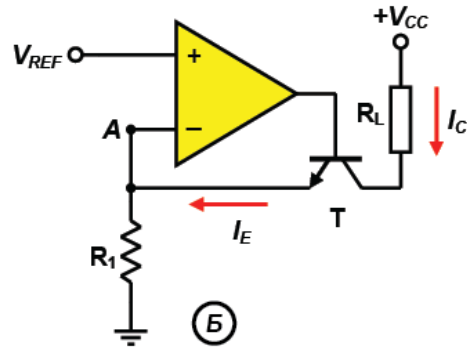
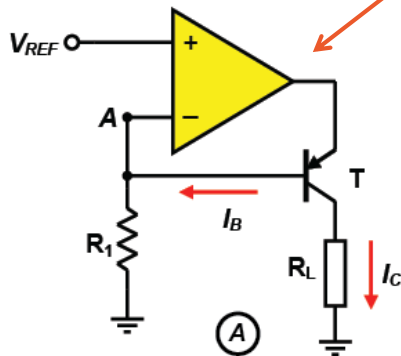
OP-AM CURRENT SOURCE



$$I_L = I_{R1}; \quad I_{R1} = \frac{V_{REF}}{R_1}$$

$$I_L = I_C = \beta \cdot I_B = \beta \cdot \frac{V_{REF}}{R_1}$$

$$I_L = I_C = I_E = \frac{V_{REF}}{R_1}$$



Thank You !