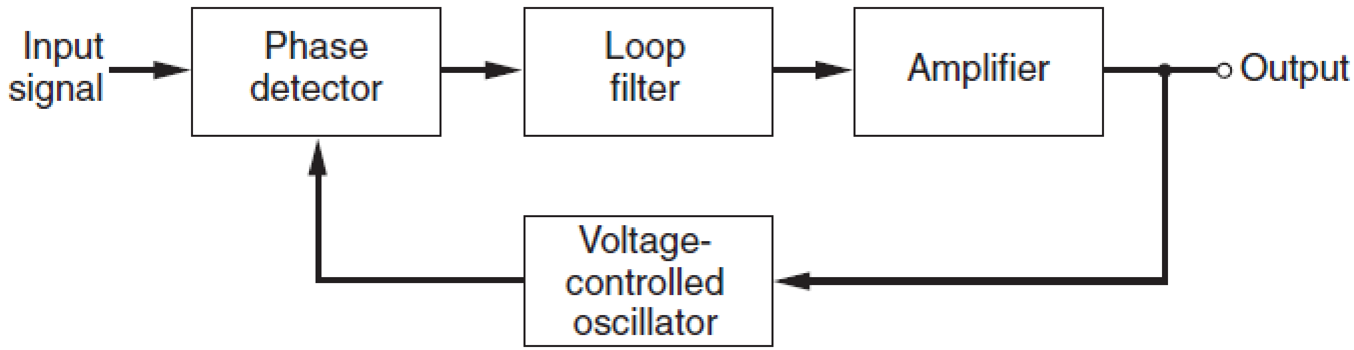
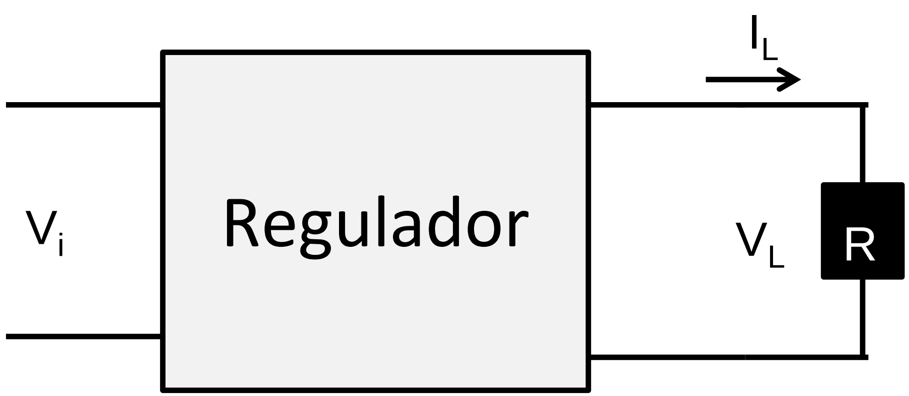
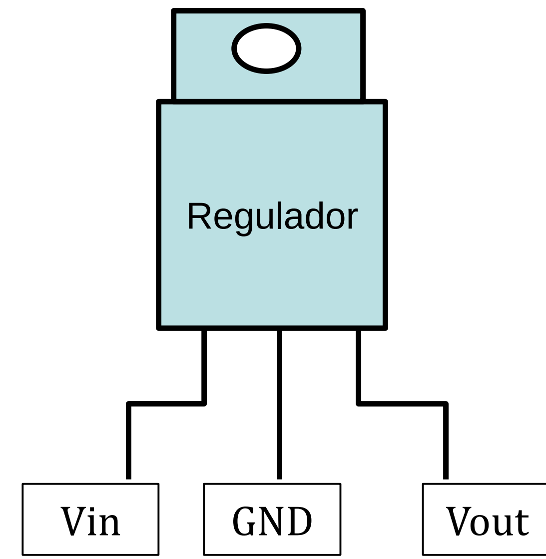
Circuitos Integrados

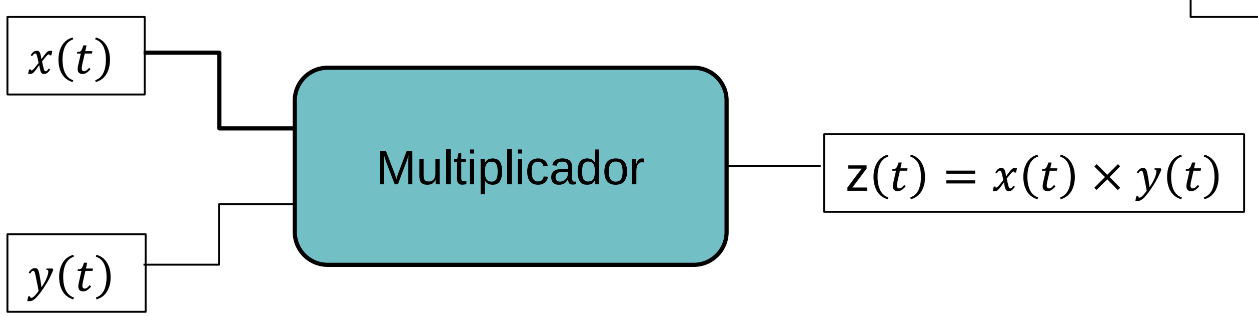
- Circuitos Integrados Monolíticos
  - Analógicos
    - Amplificadores Operacionales
    - Reguladores de Tensión
    - Multiplicadores
    - Lazos de Enganche de Fase (PLL)
    - Conversores
      - D/A
      - A/D
  - Digitales
    - Familias Lógicas
      - TTL
      - ECL
      - NMOS
      - CMOS
    - Memorias
    - μP
    - μ–Controladores



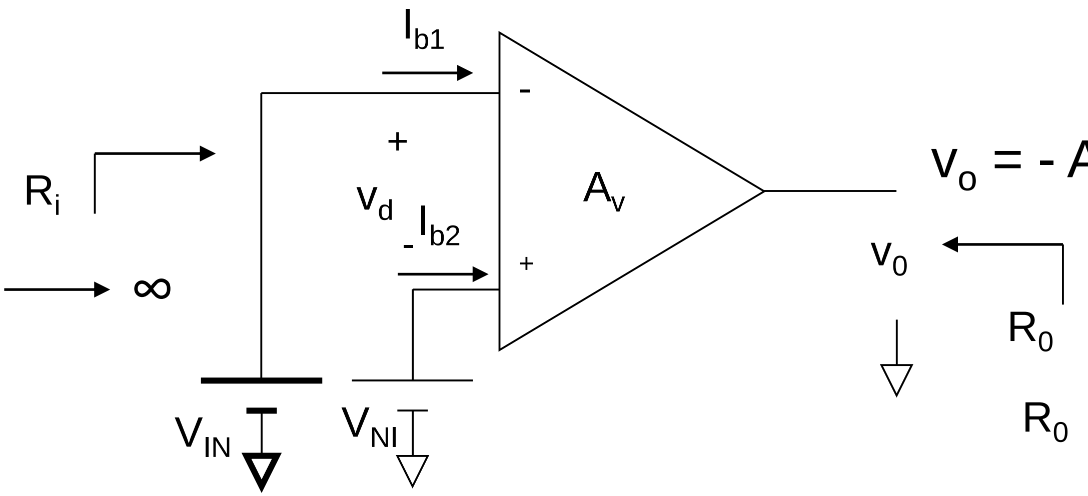
Phase-locked-loop system.







AMPLIFICADOR OPERACIONAL IDEAL



$R_i \longrightarrow \infty$

$v_o = - A_v \, v_d$

$A_v \longrightarrow \infty$

$R_0 \longrightarrow$ **0**

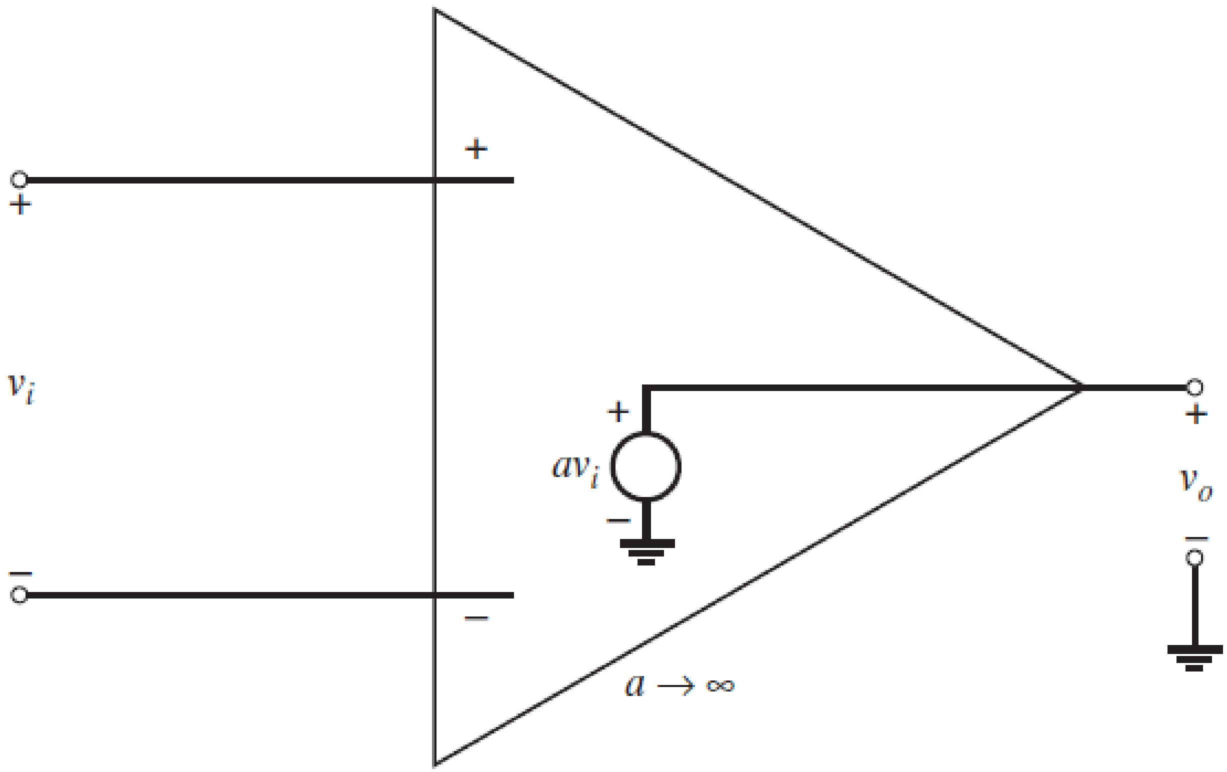
$V_{IN} = V_{NI} = 0 \rightarrow v_0 = 0$

$I_{b1} = I_{b2} = 0$

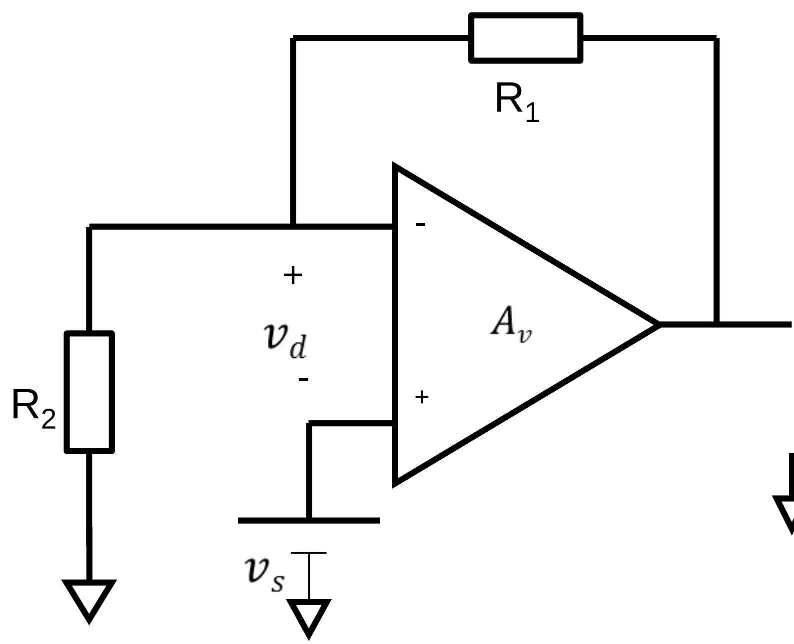
$AB \longrightarrow \infty$

- Sin limite en los valores de las tensiones
- Sin limite de Potencia
- Parámetros independientes de Temperatura
- Como $A_v \rightarrow \infty$ cualquier valor de $v_d \neq 0$ provoca una indeterminación en el valor de v_0

MODELO DEL AMPLIFICADOR OPERACIONAL IDEAL



Amplificador No Inversor



$$k = \frac{R_2}{R_1 + R_2}$$

$$v_0 = -A_v\, v_d$$

$$v_d = v_{R_2} - v_s \qquad v_0 = -A_v\left(v_{R_2} - v_s\right) \qquad v_{R_2} = \frac{v_0 R_2}{R_1 + R_2} \qquad v_0 = -A_v \frac{v_0 R_2}{R_1 + R_2} + A_v v_s$$

$$v_0\left(1 + A_v \frac{R_2}{R_1 + R_2}\right) = A_v v_s \qquad v_0(1 + A_v k) = A_v v_s \qquad \frac{v_0}{v_s} = A_R = \frac{A_v}{(1 + kA_v)}$$

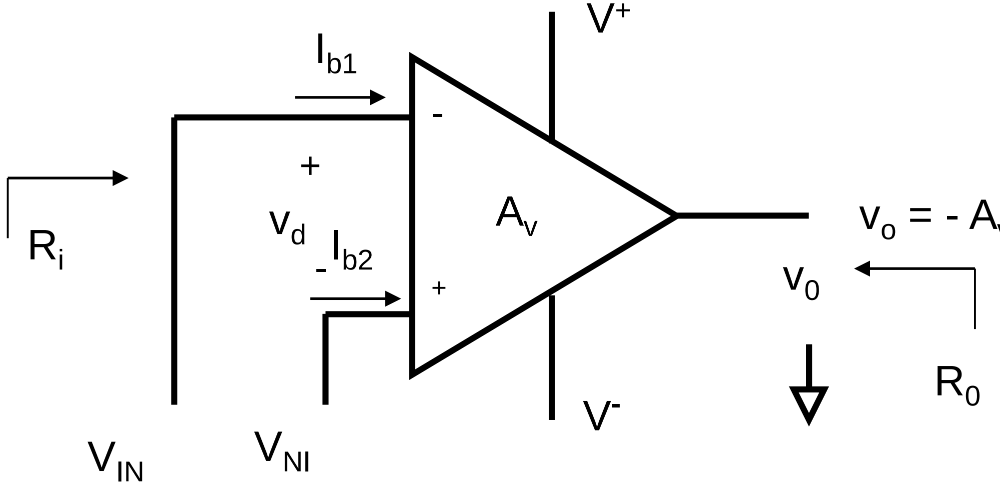
$$A_R = \frac{1}{\left(\frac{1}{A_v} + k\right)} \qquad A_v \to \infty \qquad A_R = \frac{1}{k} \qquad A_R = 1 + \frac{R_1}{R_2}$$

AMPLIFICADOR OPERACIONAL REAL

$v_d = V_{IN} - V_{NI}$,

$v_{MC} = (V_{IN} + V_{NI}) / 2$

$A_v \longrightarrow 10^5$



$v_o = - A_v\, v_d + A_{MC}\, v_{MC}$

$R_i \longrightarrow 10^6\ \Omega$

$R_0 \longrightarrow 10^2\ \Omega$

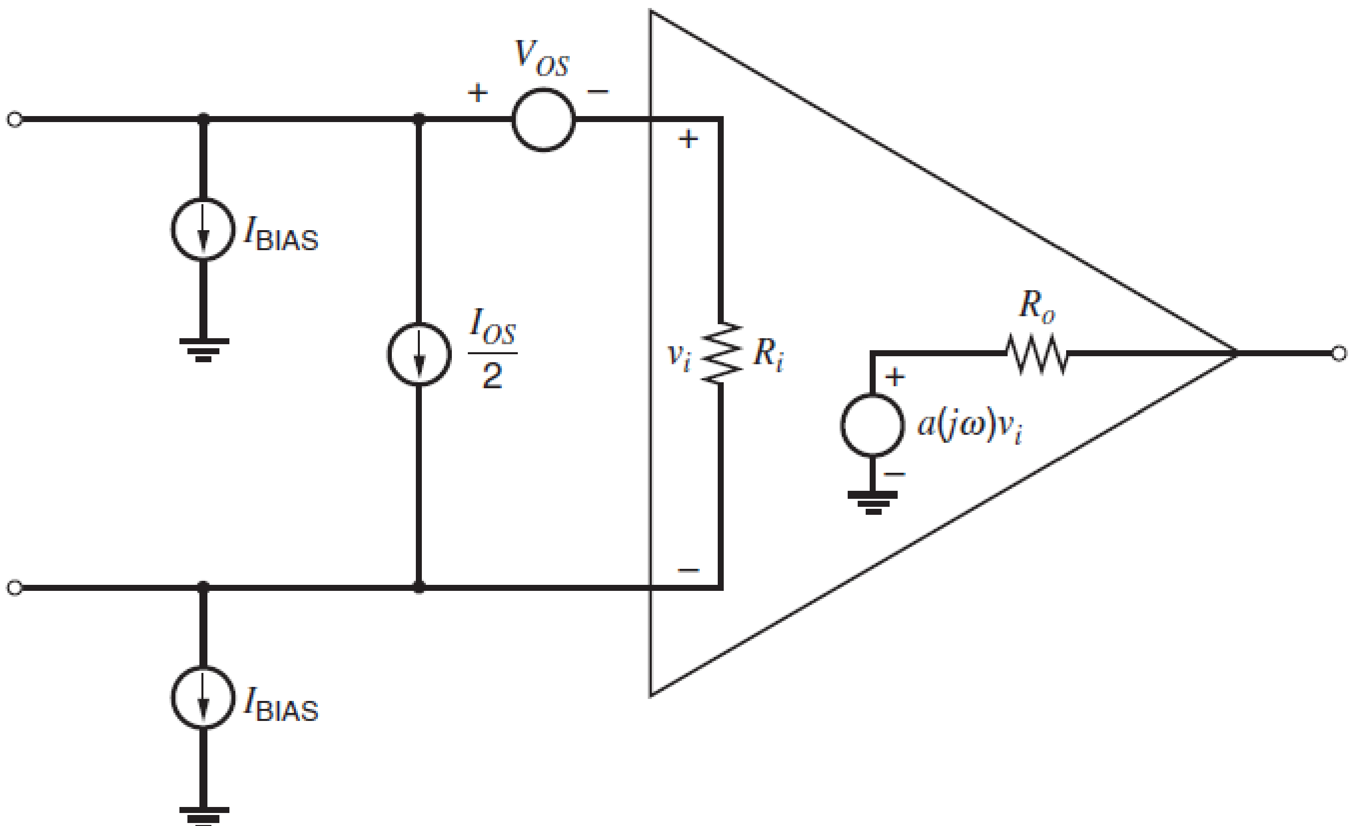
$V_{IN} = V_{NI} = 0 \rightarrow v_0 \neq 0 \rightarrow V_{io}$: Offset de tensión

$I_{b1} \neq I_{b2} \neq 0 \rightarrow I_{io}$: Offset de corriente

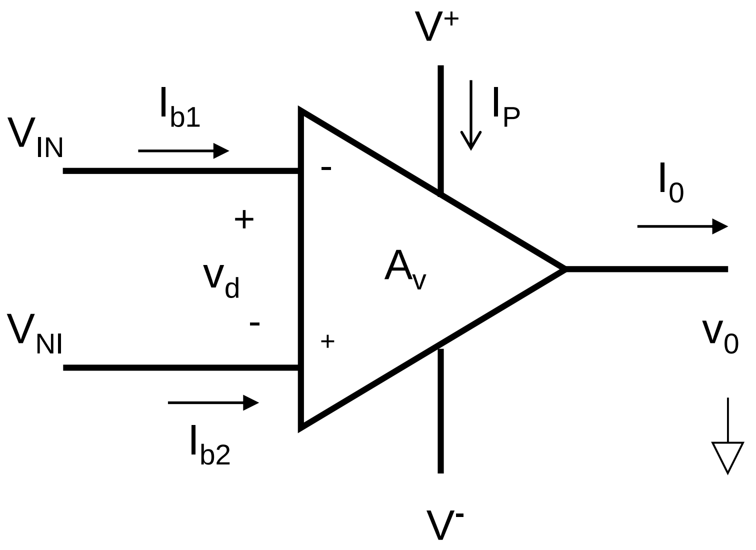
$AB \longrightarrow 10^6$ Hz

Modelo del AMPLIFICADOR OPERACIONAL

- Off-set de tensión V_{OS}
- Off-set de corriente I_{OS}
- Corriente de polarización de entrada I_{BIAS}
- Resistencia de entrada R_i
- Resistencia de salida R_0



ESPECIFICACIONES DE LOS AMP. OP.



Máximos Absolutos

- V^+ y V^-
- P_M
- v_{dMAX}
- V_{INMAX} y V_{NIMAX}
- I_{0MAX} o máxima duración del cortocircuito de salida
- T_{jMAX}

MAXIMOS ABSOLUTOS XX741

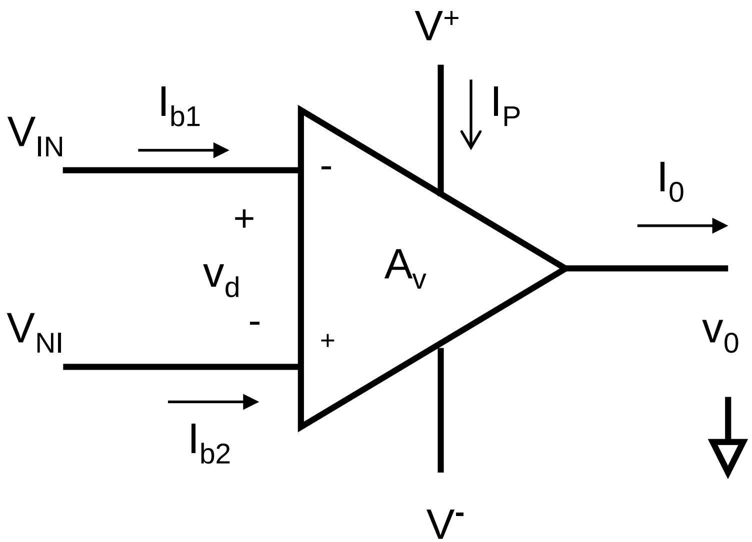
Absolute Maximum Ratings (Note 1)

If Military/Aerospace specified devices are required, please contact the National Semiconductor Sales Office/ Distributors for availability and specifications.

(Note 6)

	LM741A	LM741E	LM741	LM741C
Supply Voltage	±22V	±22V	±22V	±18V
Power Dissipation (Note 2)	500 mW	500 mW	500 mW	500 mW
Differential Input Voltage	±30V	±30V	±30V	±30V
Input Voltage (Note 3)	±15V	±15V	±15V	±15V
Output Short Circuit Duration	Continuous	Continuous	Continuous	Continuous
Operating Temperature Range	−55°C to +125°C	0°C to +70°C	−55°C to +125°C	0°C to +70°C
Storage Temperature Range	−65°C to +150°C	−65°C to +150°C	−65°C to +150°C	−65°C to +150°C
Junction Temperature	150°C	100°C	150°C	100°C
Soldering Information				
N-Package (10 seconds)	260°C	260°C	260°C	260°C
J- or H-Package (10 seconds)	300°C	300°C	300°C	300°C
M-Package				
Vapor Phase (60 seconds)	215°C	215°C	215°C	215°C
Infrared (15 seconds)	215°C	215°C	215°C	215°C
See AN-450 "Surface Mounting Methods and Their Effect on Product Reliability" for other methods of soldering surface mount devices.				
ESD Tolerance (Note 7)	400V	400V	400V	400V

ESPECIFICACIONES DE LOS AMP. OP.



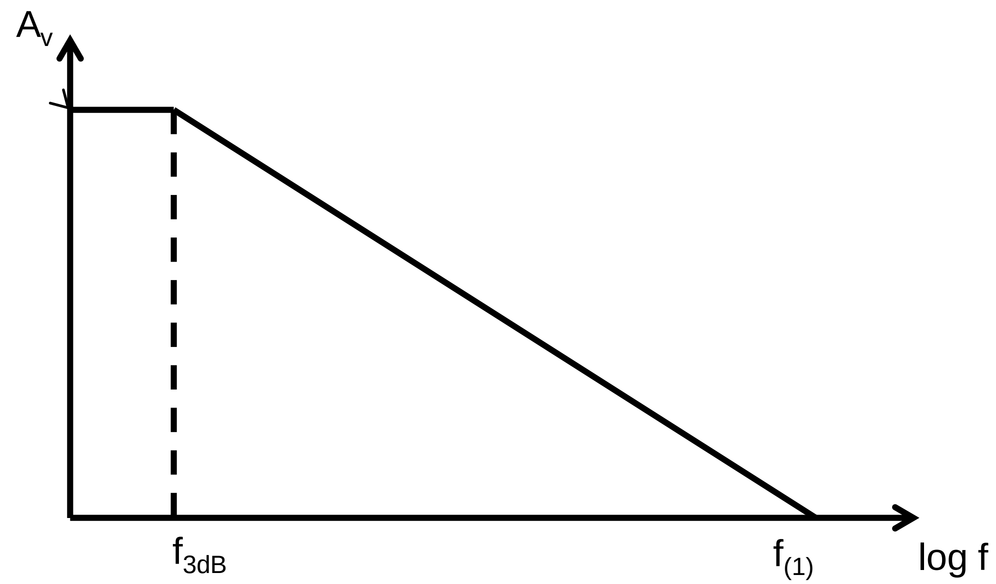
Características Eléctricas

- V_{io}
- $\frac{dV_{io}}{dT}$
- $I_{io} = |I_{b1} - I_{b2}|_{max}$
- $\frac{dI_{io}}{dT}$
- I_b
- R_i
- A_v
- R_0
- Max Excursión de v_0
- I_{omax}
- CMRR
- Relación de Rechazo de fuente
- AB
- I_P
- Slew Rate $\left(\frac{dv_0}{dt}\right)_{max}$

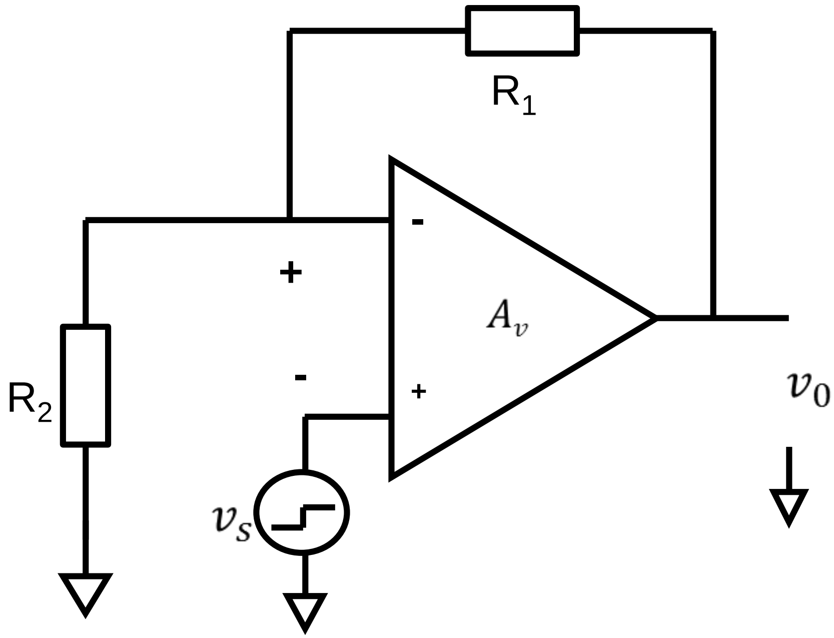
Relación de Rechazo de Modo Común (RRMC) → $RRMC = 20 \log \frac{A_v}{A_{MC}}$

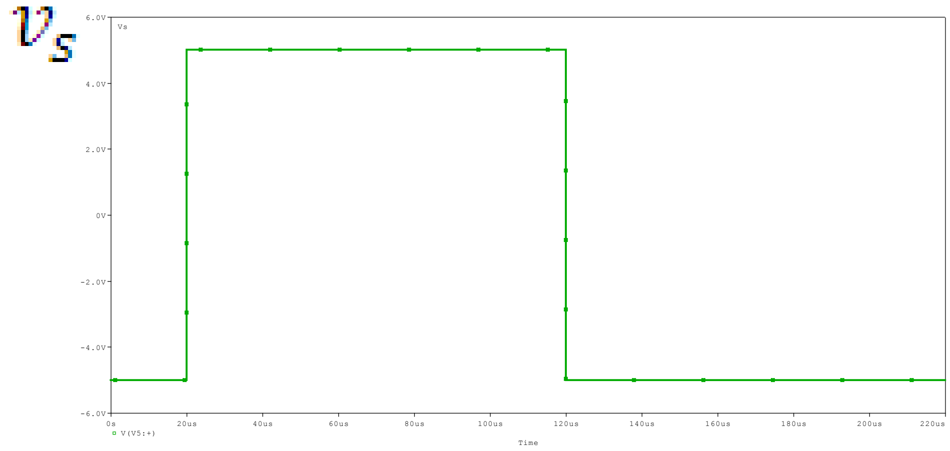
Relación de Rechazo de Fuente → $20 \log \frac{\Delta V_0}{\Delta V^+}$ O $20 \log \frac{\Delta V_0}{\Delta V^-}$

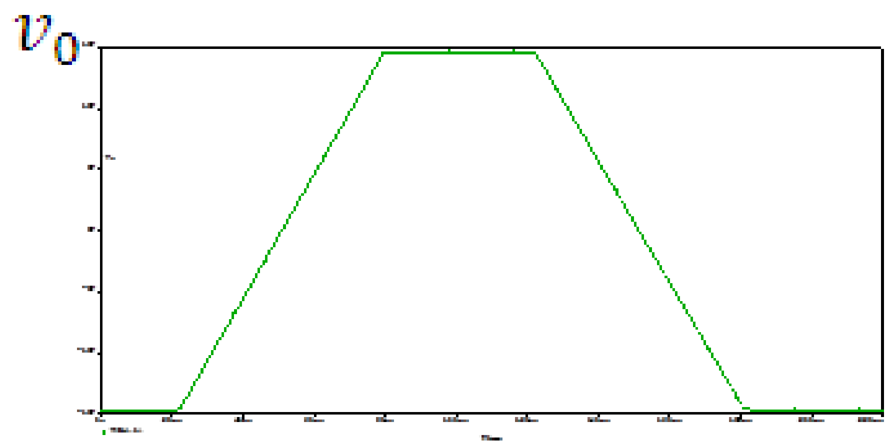
Ancho de Banda



$$Slew - Rate = \left(\frac{dv_0}{dt}\right)_{MAX}$$







CARACTERISTICAS ELECTRICAS DEL XX741

Parameter	Conditions	LM741A/LM741E			LM741			LM741C			Units
		Min	Typ	Max	Min	Typ	Max	Min	Typ	Max	
Input Offset Voltage	$T_A = 25°C$										
	$R_S \leq 10\ k\Omega$					1.0	5.0		2.0	6.0	mV
	$R_S \leq 50\Omega$		0.8	3.0							mV
	$T_{AMIN} \leq T_A \leq T_{AMAX}$										
	$R_S \leq 50\Omega$			4.0							mV
	$R_S \leq 10\ k\Omega$						6.0			7.5	mV
Average Input Offset Voltage Drift				15							μV/°C
Input Offset Voltage Adjustment Range	$T_A = 25°C$, $V_S = \pm 20V$	±10				±15			±15		mV
Input Offset Current	$T_A = 25°C$		3.0	30		20	200		20	200	nA
	$T_{AMIN} \leq T_A \leq T_{AMAX}$			70		85	500			300	nA
Average Input Offset Current Drift				0.5							nA/°C
Input Bias Current	$T_A = 25°C$		30	80		80	500		80	500	nA
	$T_{AMIN} \leq T_A \leq T_{AMAX}$			0.210			1.5			0.8	μA
Input Resistance	$T_A = 25°C$, $V_S = \pm 20V$	1.0	6.0		0.3	2.0		0.3	2.0		MΩ
	$T_{AMIN} \leq T_A \leq T_{AMAX}$, $V_S = \pm 20V$	0.5									MΩ
Input Voltage Range	$T_A = 25°C$							±12	±13		V
	$T_{AMIN} \leq T_A \leq T_{AMAX}$				±12	±13					V

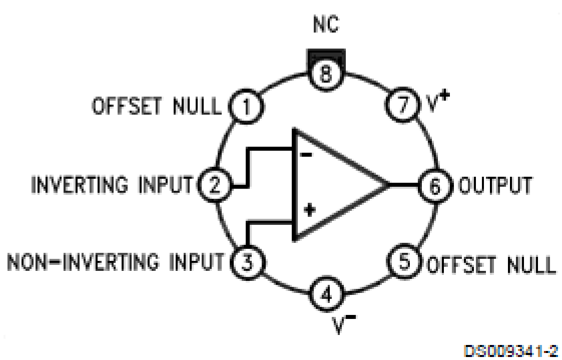
CARACTERISTICAS ELECTRICAS DEL XX741

Parameter	Conditions	LM741A/LM741E			LM741			LM741C			Units
		Min	Typ	Max	Min	Typ	Max	Min	Typ	Max	
Large Signal Voltage Gain	T_A = 25°C, $R_L \geq 2$ kΩ										
	$V_S = \pm 20V$, $V_O = \pm 15V$	50									V/mV
	$V_S = \pm 15V$, $V_O = \pm 10V$				50	200		20	200		V/mV
	$T_{AMIN} \leq T_A \leq T_{AMAX}$,										
	$R_L \geq 2$ kΩ,										
	$V_S = \pm 20V$, $V_O = \pm 15V$	32									V/mV
	$V_S = \pm 15V$, $V_O = \pm 10V$				25			15			V/mV
	$V_S = \pm 5V$, $V_O = \pm 2V$	10									V/mV
Output Voltage Swing	$V_S = \pm 20V$										
	$R_L \geq 10$ kΩ	±16									V
	$R_L \geq 2$ kΩ	±15									V
	$V_S = \pm 15V$										
	$R_L \geq 10$ kΩ				±12	±14		±12	±14		V
	$R_L \geq 2$ kΩ				±10	±13		±10	±13		V
Output Short Circuit	T_A = 25°C	10	25	35		25			25		mA
Current	$T_{AMIN} \leq T_A \leq T_{AMAX}$	10		40							mA
Common-Mode	$T_{AMIN} \leq T_A \leq T_{AMAX}$										
Rejection Ratio	$R_S \leq 10$ kΩ, $V_{CM} = \pm 12V$				70	90		70	90		dB
	$R_S \leq 50Ω$, $V_{CM} = \pm 12V$	80	95								dB
Supply Voltage Rejection	$T_{AMIN} \leq T_A \leq T_{AMAX}$,										
Ratio	$V_S = \pm 20V$ to $V_S = \pm 5V$										
	$R_S \leq 50Ω$	86	96								dB
	$R_S \leq 10$ kΩ				77	96		77	96		dB

CARACTERISTICAS ELECTRICAS DEL XX741

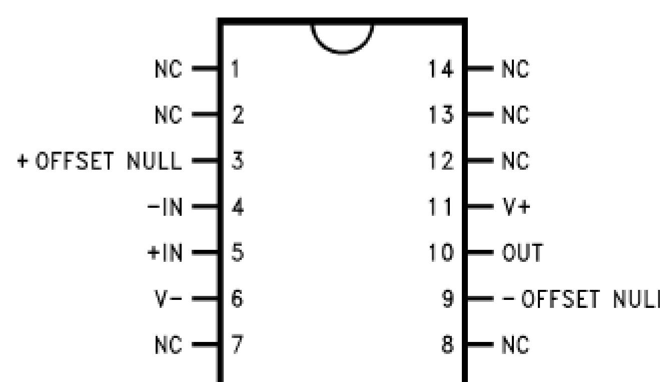
Transient Response	T_A = 25°C, Unity Gain										
Rise Time			0.25	0.8		0.3			0.3		μs
Overshoot			6.0	20		5			5		%
Bandwidth (Note 5)	T_A = 25°C	0.437	1.5								MHz
Slew Rate	T_A = 25°C, Unity Gain	0.3	0.7			0.5			0.5		V/μs
Supply Current	T_A = 25°C					1.7	2.8		1.7	2.8	mA
Power Consumption	T_A = 25°C										
	V_S = ±20V		80	150							mW
	V_S = ±15V					50	85		50	85	mW
LM741A	V_S = ±20V										
	$T_A = T_{AMIN}$			165							mW
	$T_A = T_{AMAX}$			135							mW
LM741E	V_S = ±20V										
	$T_A = T_{AMIN}$			150							mW
	$T_A = T_{AMAX}$			150							mW
LM741	V_S = ±15V										
	$T_A = T_{AMIN}$					60	100				mW
	$T_A = T_{AMAX}$					45	75				mW

Metal Can Package

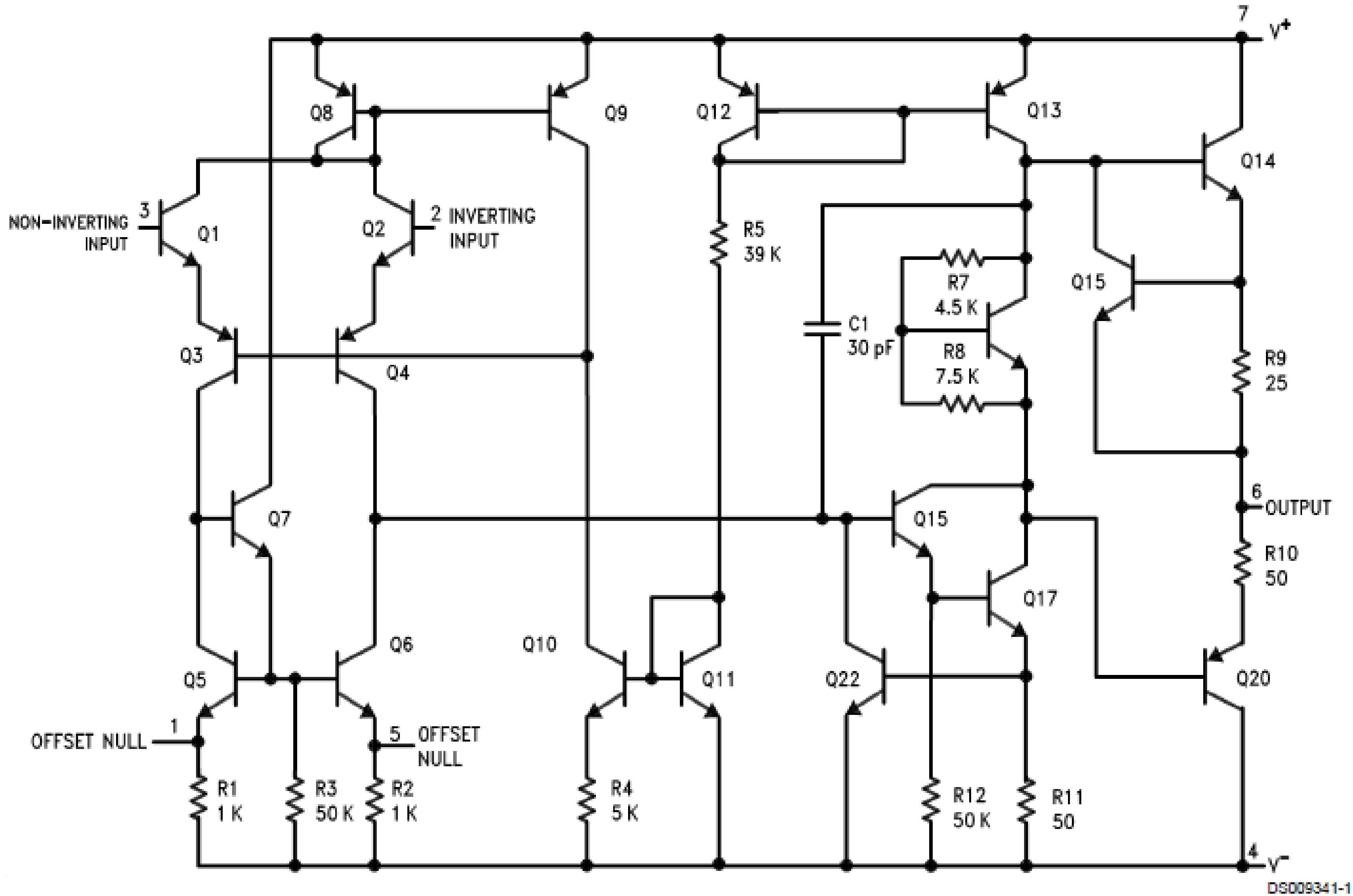


Note 8: LM741H is available per JM38510/10101

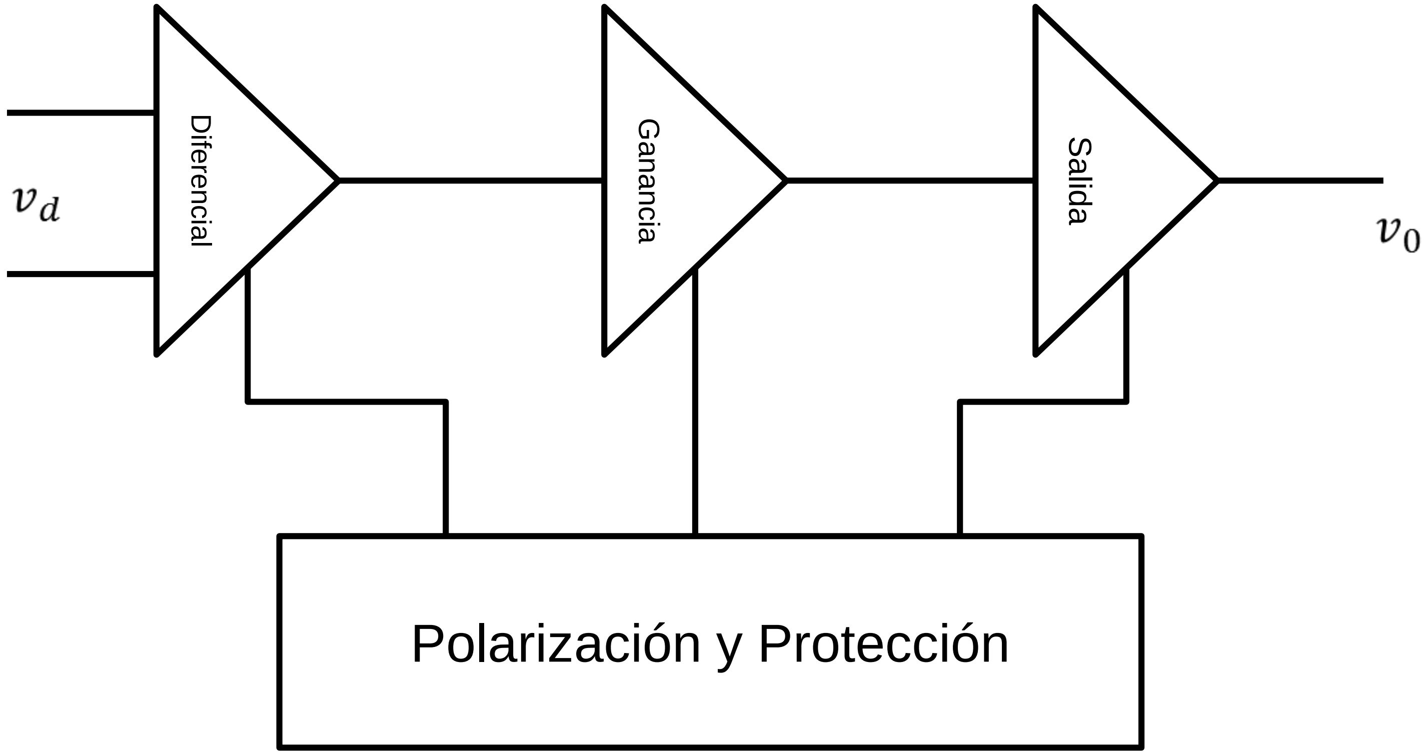
Ceramic Dual-In-Line Package



CIRCUITO INTERNO DEL XX741



ESQUEMA DEL AMPLIFICADOR OPERACIONAL XX741



Diferencial
- Q1 – Q2
- Q3 - Q4
- Q5 - Q6 – Q7
- R1 – R2 – R3

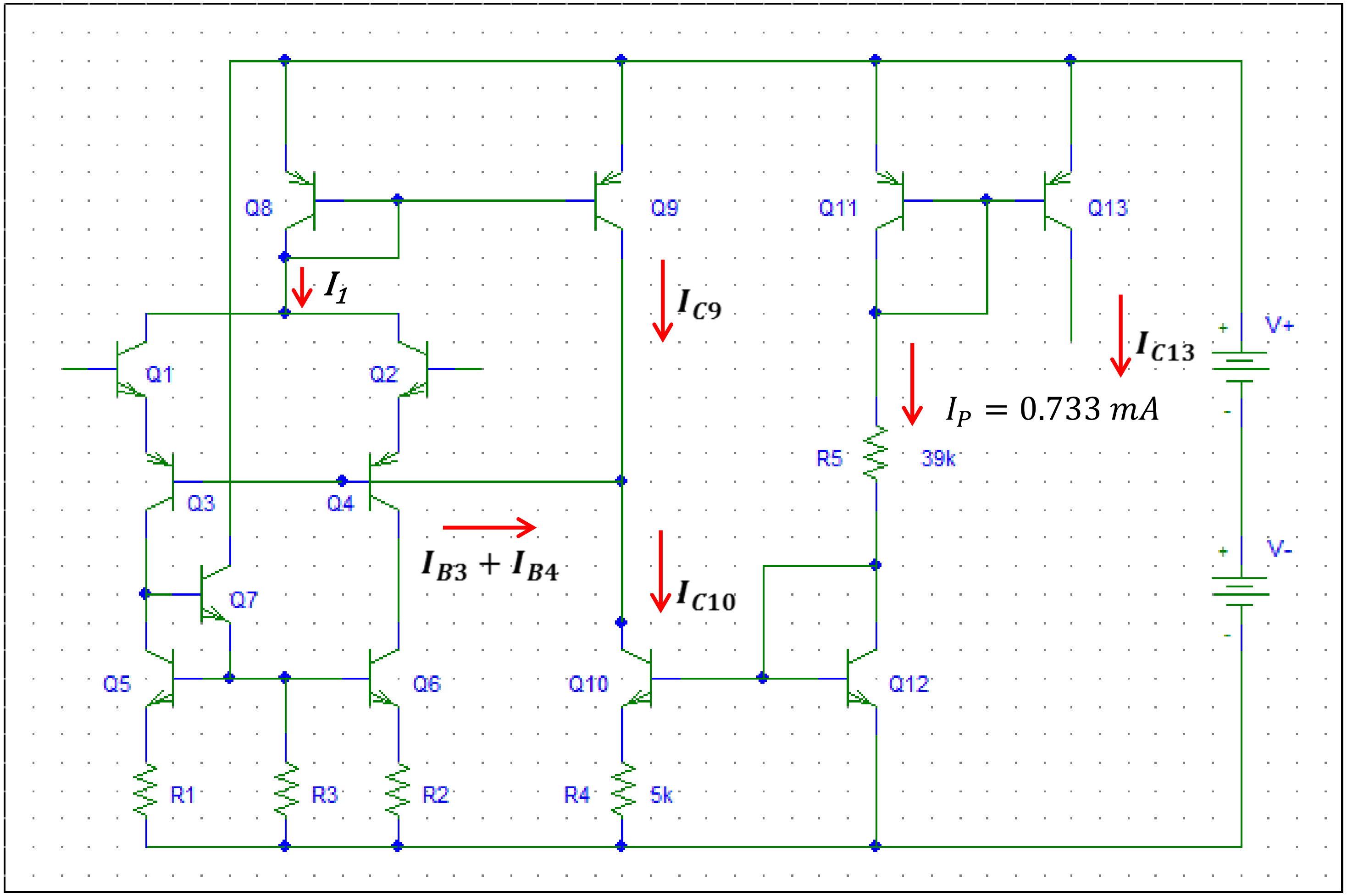
Ganancia
- Q15 – Q17
- R11 – R12

Salida
- Q14 – Q20
- R10

Polarización
- Q8 – Q9 – Q10
- Q11 – Q12 – Q13
- R4 – R5

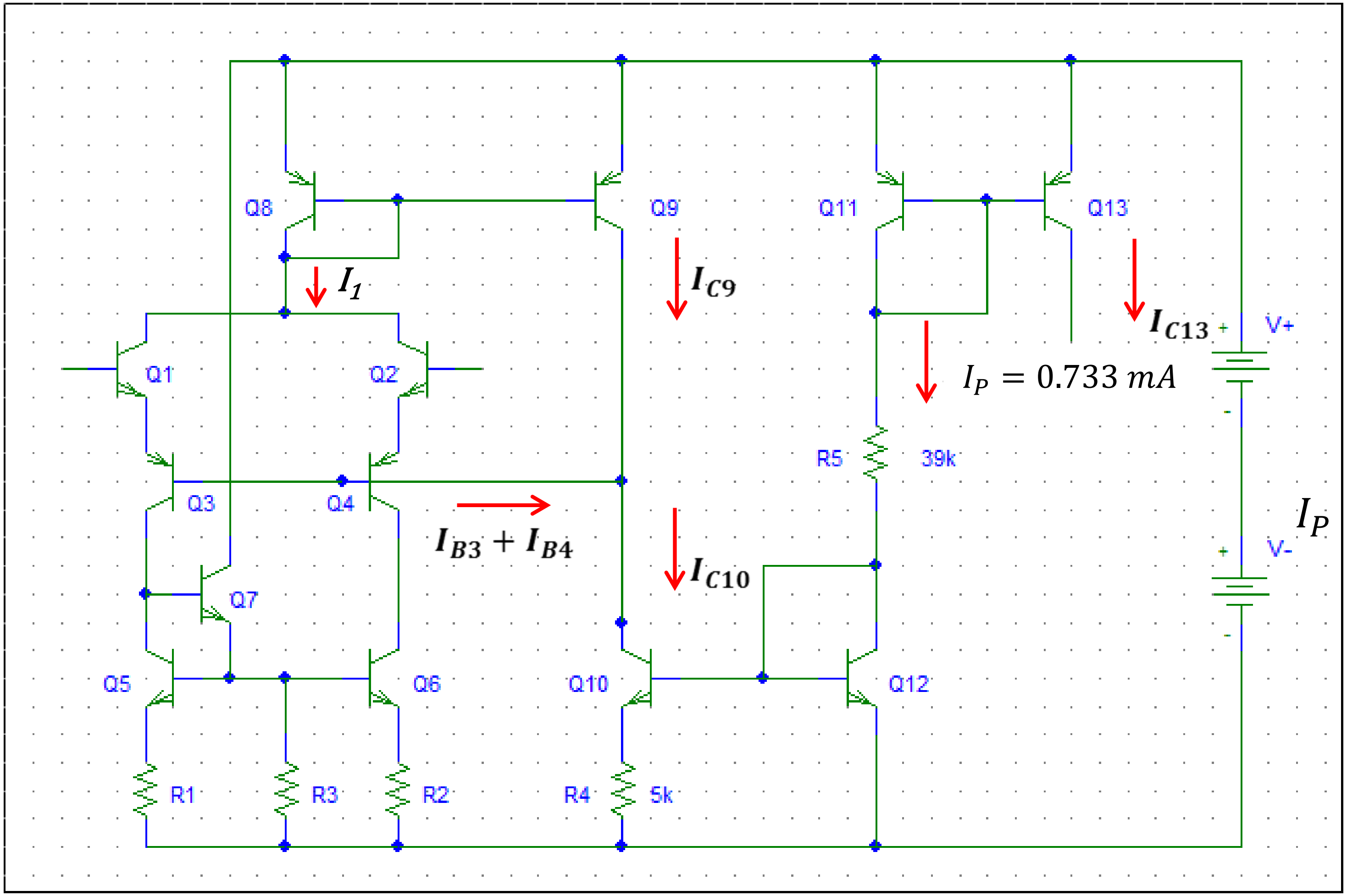
Protección
- Q15 – Q22
- R9 – R11

Corrientes de polarizacion XX741



$V^+ + V^- - V_{BE11} - V_{R5} - V_{BE12} = 0$ $\quad V_{BE11} = V_{BE12} = 0.7V$ $\quad V_{R5} = V^+ + V^- - 2V_{BE}$

$I_P = \dfrac{V_{R5}}{R_5}$ $\quad I_P = \dfrac{V^+ + V^- - 2V_{BE}}{R_5}$ $\quad$ Si $V^+ = V^- = 15V$ $\quad I_P = \dfrac{15V + 15V - 2x0.7V}{39K\Omega}$



$$Q_{11} \equiv Q_{13}$$

$$I_{C13} = \frac{I_P}{\left(1 + \frac{2}{\beta_{PNP}}\right)}$$

$$I_P = I_{C10} \times e^{\left(I_{C10} \times R_4 / U_T\right)}$$

$$I_{C10} = 19\mu A$$

$$I_{C10} = I_{C9} + I_{B3} + I_{B4}$$

$$I_{B3} = I_{B4} = \frac{I_1}{2\ \beta_{PNP}}$$

$$I_{C10} = I_{C9} + \frac{I_1}{\beta_{PNP}}$$

$$I_1 = I_{C8}\left(1 + \frac{2}{\beta_{PNP}}\right)$$

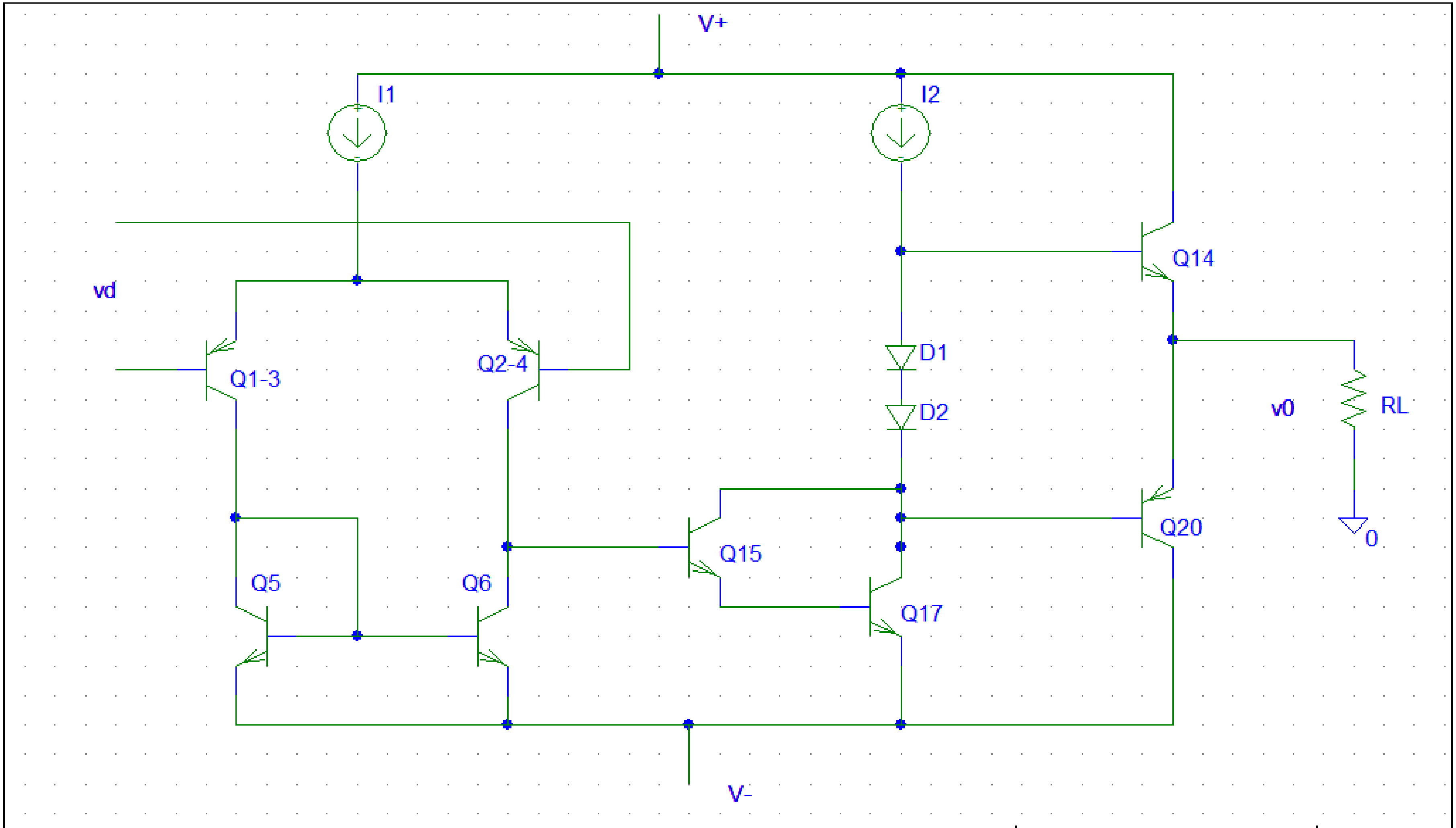
$$I_{C8} = I_{C9}$$

$$I_1 = I_{C9}\left(1 + \frac{2}{\beta_{PNP}}\right)$$

$$I_{C10} = I_1\left(\frac{1}{1 + \frac{2}{\beta_{PNP}}} + \frac{1}{\beta_{PNP}}\right)$$

~ 0.93

Circuito simplificado para calculo Ri Av AB

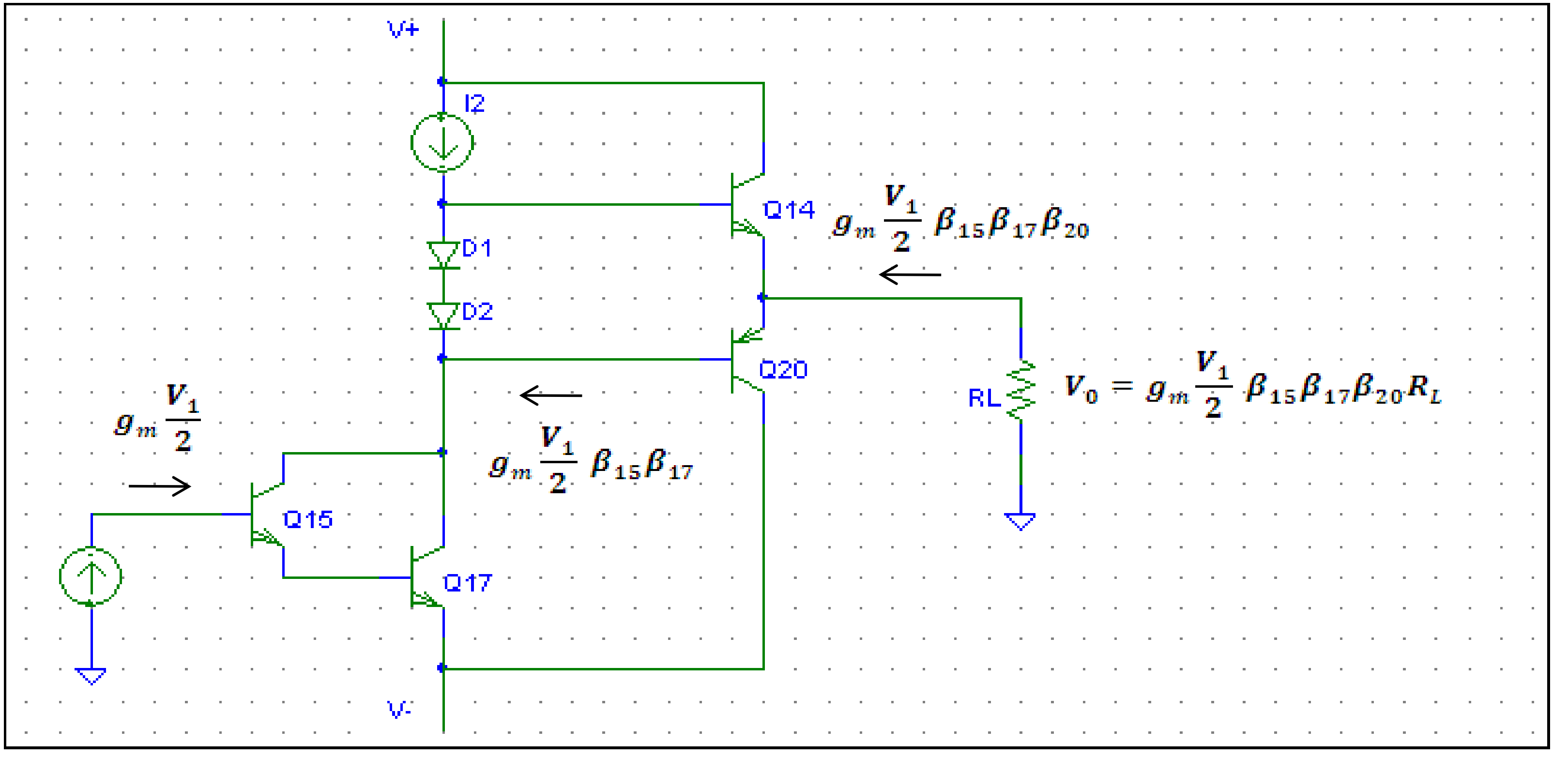


Etapa de entrada
DIFERENCIAL

Etapa de ganancia
DARLINGTON

Etapa de salida
PAR COMPLEMENTARIO

Ganancia del XX741

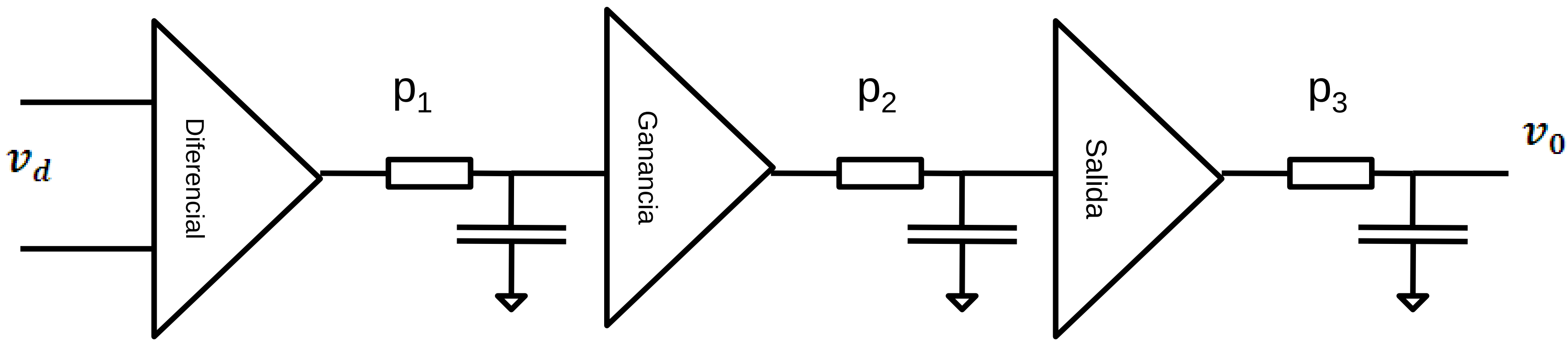


$$A_v = \frac{v_0}{v_1}$$

$$A_v = \frac{g_m}{2} \beta_{15}\beta_{17}\beta_{20} R_L$$

$$A_v = \frac{I_1}{4U_T} \beta_{15}\beta_{17}\beta_{20} R_L$$

RESPUESTA EN FRECUENCIA DEL XX741



Cada polo atrasa 90°   Total atraso polos 270°   Entre v_d y v_0 la fase es 180°

Fase total entre v_d y v_0 450°

Si cuando la fase entre v_d y v_0 *es 360°* $A_v > 1$ ⇨ Inestabilidad

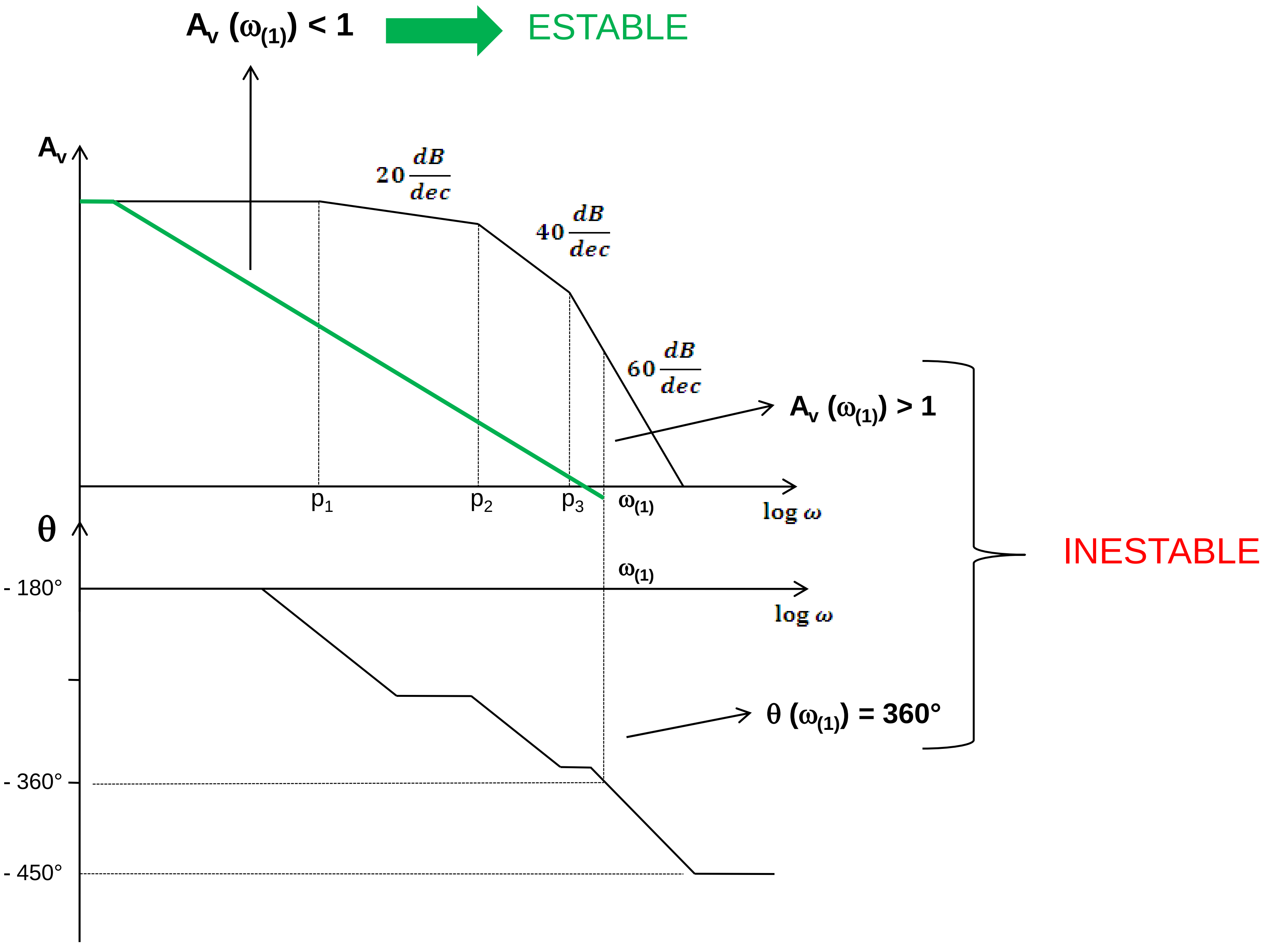
Para hacer estable el circuito ⇨

Cuando la fase entre v_d y v_0 *sea 360°* hacer $A_v < 1$

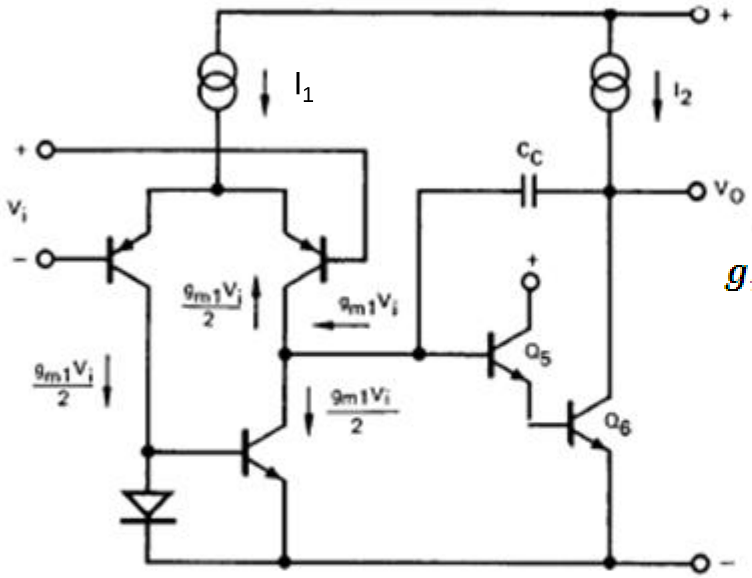
Encontramos la frecuencia ω para la cual $\theta = 360°$ Esta frecuencia es $\omega_{(1)}$

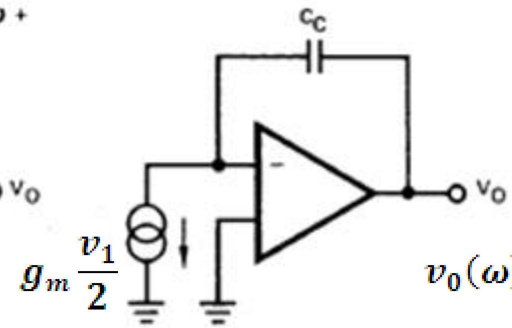
Hacemos que $A_v(\omega) \leq 1$ para $\omega = \omega_{(1)}$

Respuesta en Frecuencia



COMPENSACION DEL AMP. OP. XX741





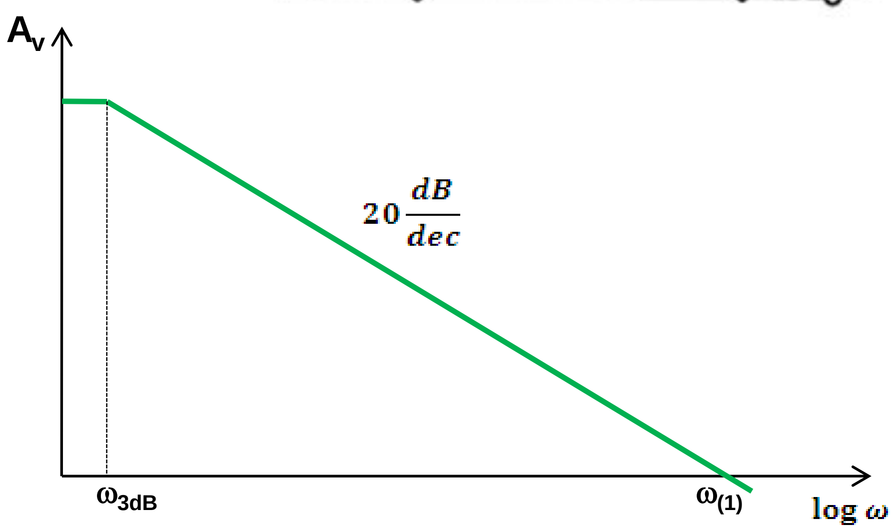
$$v_0(\omega) = \frac{g_m}{2\omega C_c} v_1(\omega)$$

$$A_v(\omega) = \frac{v_0(\omega)}{v_1(\omega)}$$

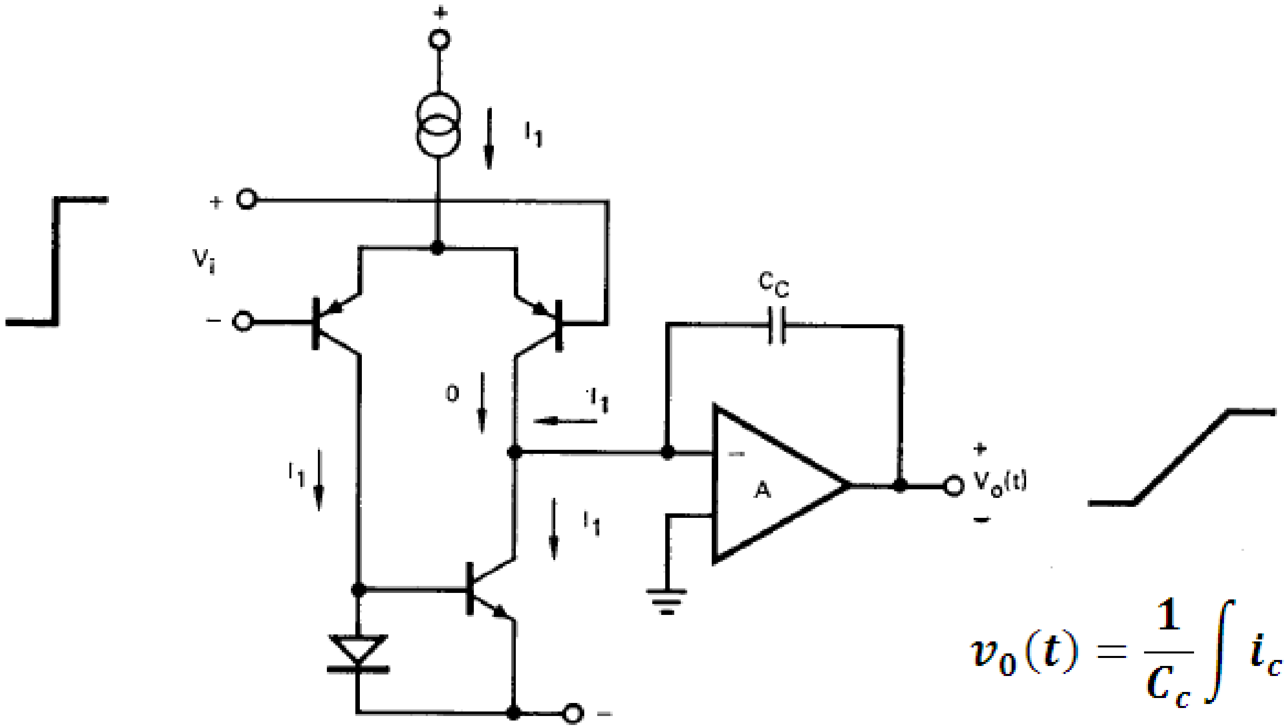
$$A_v(\omega) = \frac{g_m}{2\omega C_c}$$

$$A_v(\omega_{(1)}) = \frac{g_m}{2\omega_{(1)} C_c} = 1$$

$$C_c = \frac{g_m}{2\omega_{(1)}} \qquad g_m = \frac{I_1}{2U_T}$$



Slew Rate



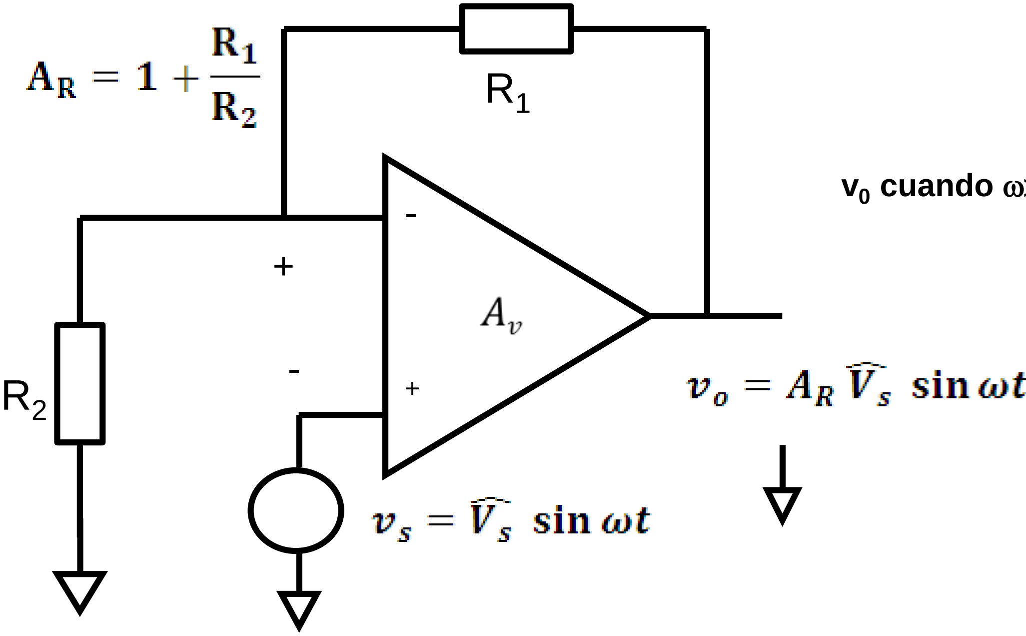
$$v_0(t) = \frac{1}{C_c}\int i_c(t)dt$$

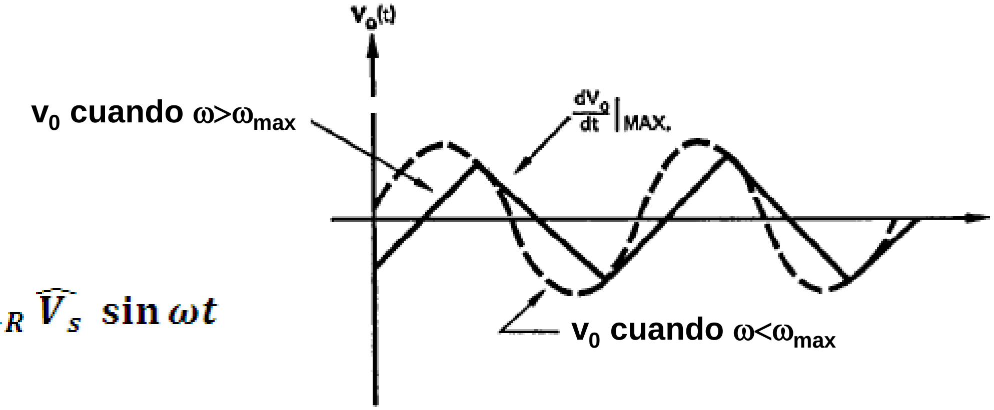
$$v_0(t) = \frac{1}{C_c}\int I_1 dt \qquad v_0(t) = \frac{I_1}{C_c}t \qquad \left(\frac{dv_0(t)}{dt}\right)_{max} = \frac{I_1}{C_c}$$

$$S - R = \frac{I_1}{C_c}$$

$$\left(\frac{g_m v_1}{2}\right)_{MAX} = I_1 \qquad (v_1)_{MAX} = \frac{2I_1}{g_m} \qquad g_m = \frac{I_1}{2U_T} \qquad (v_1)_{MAX} = 4\ U_T$$

Ancho de banda de potencia





$$\frac{dv_0}{dt} = A_R \widehat{V_s} \omega \cos \omega t$$

Cuando $\cos \omega t = 1$

$$\left(\frac{dv_0}{dt}\right)_{max} = A_R \widehat{V_s} \omega$$

Onda senoidal máxima pendiente en el cruce por cero (punto de inflexión)

$$\left(\frac{dv_0}{dt}\right)_{MAX} = \text{S-R} \Rightarrow A_R \widehat{V_s} \omega \leq \text{S-R} \Rightarrow \omega_{max} \leq \frac{S-R}{A_R \widehat{V_s}}$$

Limite del Slew - Rate

$$S-R=\frac{I_1}{C_c} \qquad C_c=\frac{g_m}{2\omega_{(1)}} \qquad S-R=\frac{I_1}{g_m/2\omega_{(1)}} \qquad S-R=2\omega_{(1)}\frac{I_1}{g_m}$$

Para mejorar el S-R:

$\omega_{(1)}$ ⇑ $\qquad$ I_1/g_m ⇑

Cuando la etapa de entrada se implementa con TBJ's

$$g_m=\frac{I_1}{2U_T} \qquad \frac{I_1}{g_m}=2U_T=\text{cte.} \qquad S-R=4U_T\omega_{(1)}$$

Cuando la etapa de entrada se implementa con JFET

$$I_1=I_{DSS}\left(1-\frac{V_{GS}}{V_P}\right)^2 \qquad g_m=2\frac{I_{DSS}}{V_P}\left(1-\frac{V_{GS}}{V_P}\right) \qquad \frac{I_1}{g_m}=\frac{(V_P-V_{GS})}{2}$$

$$\left(\frac{I_1}{g_m}\right)_{max}=\frac{V_P}{2} \qquad (I_1)_{max}=I_{DSS}\rightarrow\text{cuando}\,V_{GS}=0 \qquad S-R=V_P\omega_{(1)}$$

Relacion del S-R de entrada JFET a entrada TBJ

$$\frac{S-R_{(JFET)}}{S-R_{(TBJ)}}=\frac{V_P}{4U_T}$$

CARACTERISTICAS ELECTRICAS AMP-OP-LF411

DC Electrical Characteristics (Note 4)

Symbol	Parameter	Conditions		LF411A			LF411			Units
				Min	Typ	Max	Min	Typ	Max	
V_{OS}	Input Offset Voltage	$R_S = 10\ k\Omega$, $T_A = 25°C$			0.3	0.5		0.8	2.0	mV
$\Delta V_{OS}/\Delta T$	Average TC of Input Offset Voltage	$R_S = 10\ k\Omega$ (Note 5)			7	10		7	20 (Note 5)	$\mu V/°C$
I_{OS}	Input Offset Current	$V_S = \pm 15V$ (Notes 4, 6)	$T_j = 25°C$		25	100		25	100	pA
			$T_j = 70°C$			2			2	nA
			$T_j = 125°C$			25			25	nA
I_B	Input Bias Current	$V_S = \pm 15V$ (Notes 4, 6)	$T_j = 25°C$		50	200		50	200	pA
			$T_j = 70°C$			4			4	nA
			$T_j = 125°C$			50			50	nA
R_{IN}	Input Resistance	$T_j = 25°C$			10^{12}			10^{12}		Ω
A_{VOL}	Large Signal Voltage Gain	$V_S = \pm 15V$, $V_O = \pm 10V$, $R_L = 2k$, $T_A = 25°C$		50	200		25	200		V/mV
		Over Temperature		25	200		15	200		V/mV
V_O	Output Voltage Swing	$V_S = \pm 15V$, $R_L = 10k$		± 12	± 13.5		± 12	± 13.5		V
V_{CM}	Input Common-Mode Voltage Range			± 16	$+19.5$		± 11	$+14.5$		V
					-16.5			-11.5		V
CMRR	Common-Mode Rejection Ratio	$R_S \leq 10k$		80	100		70	100		dB
PSRR	Supply Voltage Rejection Ratio	(Note 7)		80	100		70	100		dB
I_S	Supply Current				1.8	2.8		1.8	3.4	mA

AC Electrical Characteristics (Note 4)

Symbol	Parameter	Conditions	LF411A			LF411			Units
			Min	Typ	Max	Min	Typ	Max	
SR	Slew Rate	$V_S = \pm 15V$, $T_A = 25°C$	10	15		8	15		$V/\mu s$
GBW	Gain-Bandwidth Product	$V_S = \pm 15V$, $T_A = 25°C$	3	4		2.7	4		MHz

CARACTERISTICAS ELECTRICAS AMP-OP-TL081

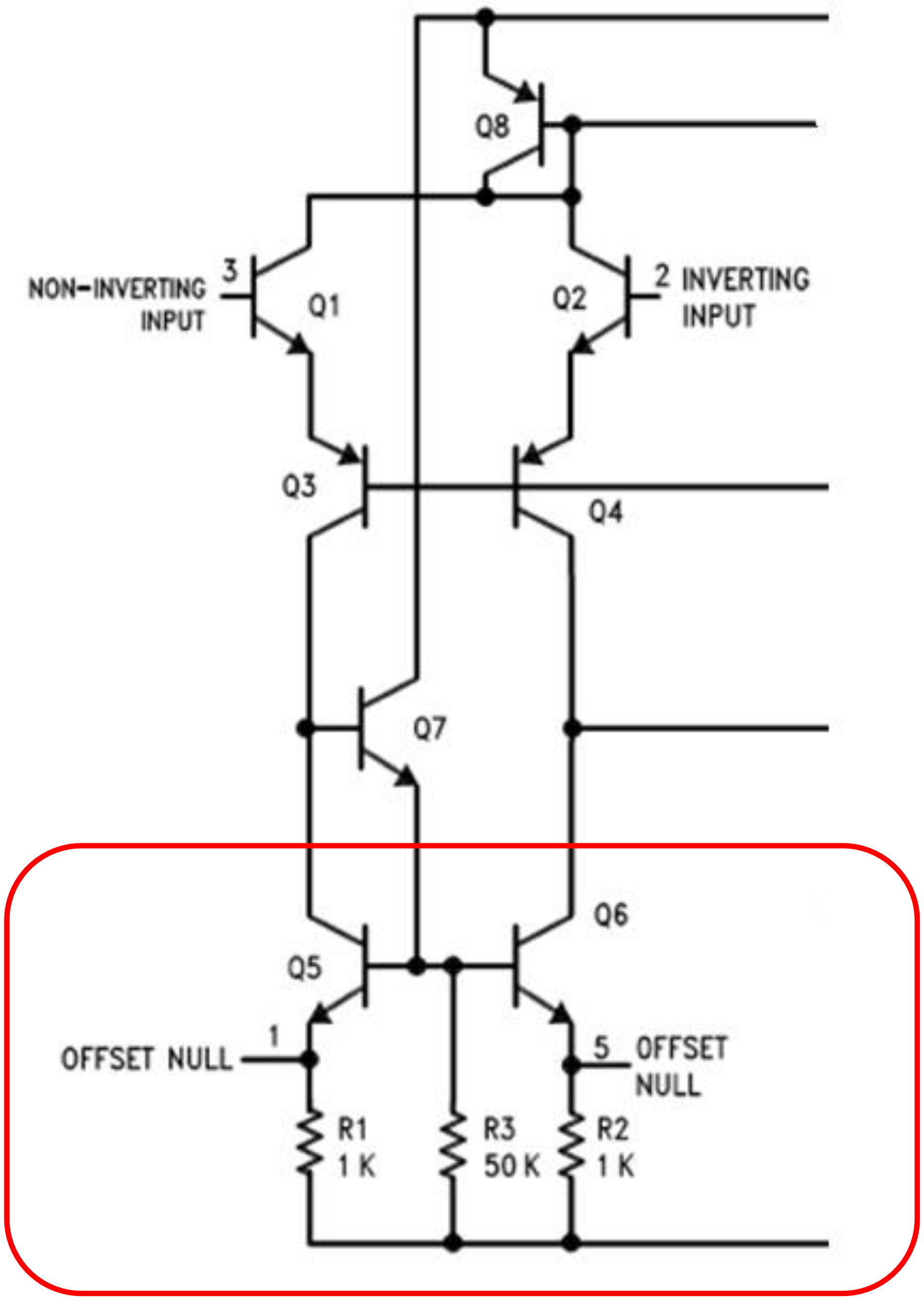
DC Electrical Characteristics (Note 3)

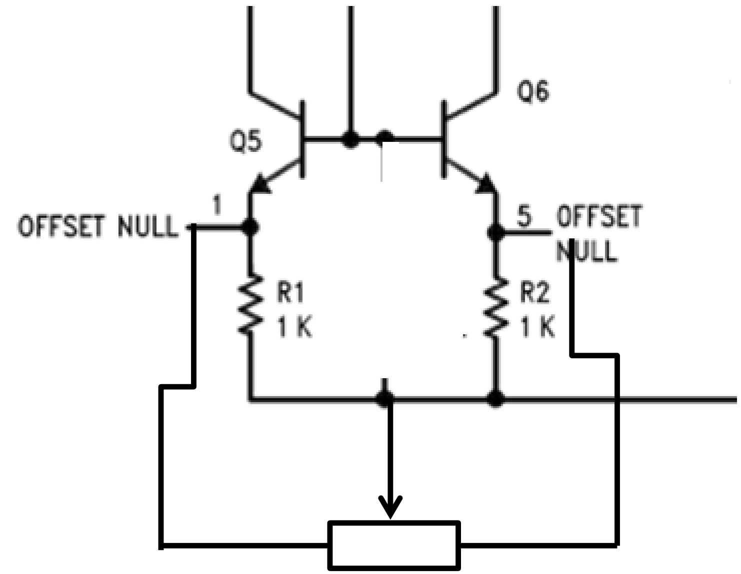
Symbol	Parameter	Conditions	TL081C			Units
			Min	Typ	Max	
V_{OS}	Input Offset Voltage	$R_S = 10\ k\Omega$, $T_A = 25°C$ Over Temperature		5	15 20	mV mV
$\Delta V_{OS}/\Delta T$	Average TC of Input Offset Voltage	$R_S = 10\ k\Omega$		10		$\mu V/°C$
I_{OS}	Input Offset Current	$T_j = 25°C$, (Notes 3, 4) $T_j \leq 70°C$		25	100 4	pA nA
I_B	Input Bias Current	$T_j = 25°C$, (Notes 3, 4) $T_j \leq 70°C$		50	200 8	pA nA
R_{IN}	Input Resistance	$T_j = 25°C$		10^{12}		Ω
A_{VOL}	Large Signal Voltage Gain	$V_S = \pm 15V$, $T_A = 25°C$ $V_O = \pm 10V$, $R_L = 2\ k\Omega$ Over Temperature	25 15	100		V/mV V/mV
V_O	Output Voltage Swing	$V_S = \pm 15V$, $R_L = 10\ k\Omega$	± 12	± 13.5		V
V_{CM}	Input Common-Mode Voltage Range	$V_S = \pm 15V$	± 11	$+15$ -12		V V
CMRR	Common-Mode Rejection Ratio	$R_S \leq 10\ k\Omega$	70	100		dB
PSRR	Supply Voltage Rejection Ratio	(Note 5)	70	100		dB
I_S	Supply Current			1.8	2.8	mA

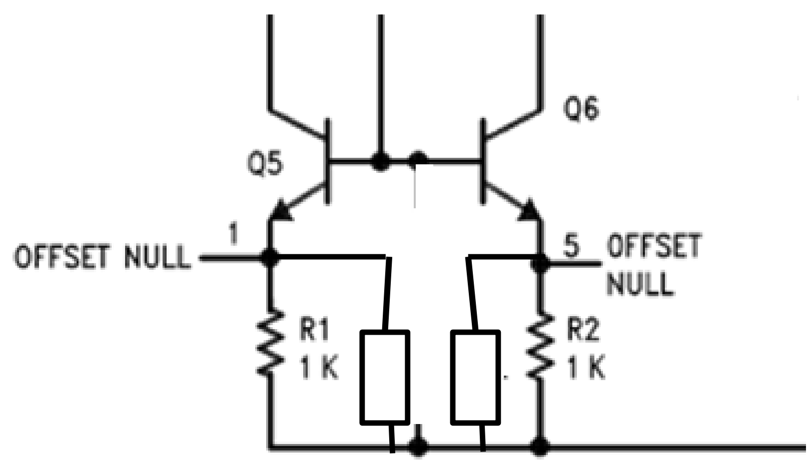
AC Electrical Characteristics (Note 3)

Symbol	Parameter	Conditions	TL081C			Units
			Min	Typ	Max	
SR	Slew Rate	$V_S = \pm 15V$, $T_A = 25°C$		13		$V/\mu s$
GBW	Gain Bandwidth Product	$V_S = \pm 15V$, $T_A = 25°C$		4		MHz

XX741 COMPENSACION OFF-SET







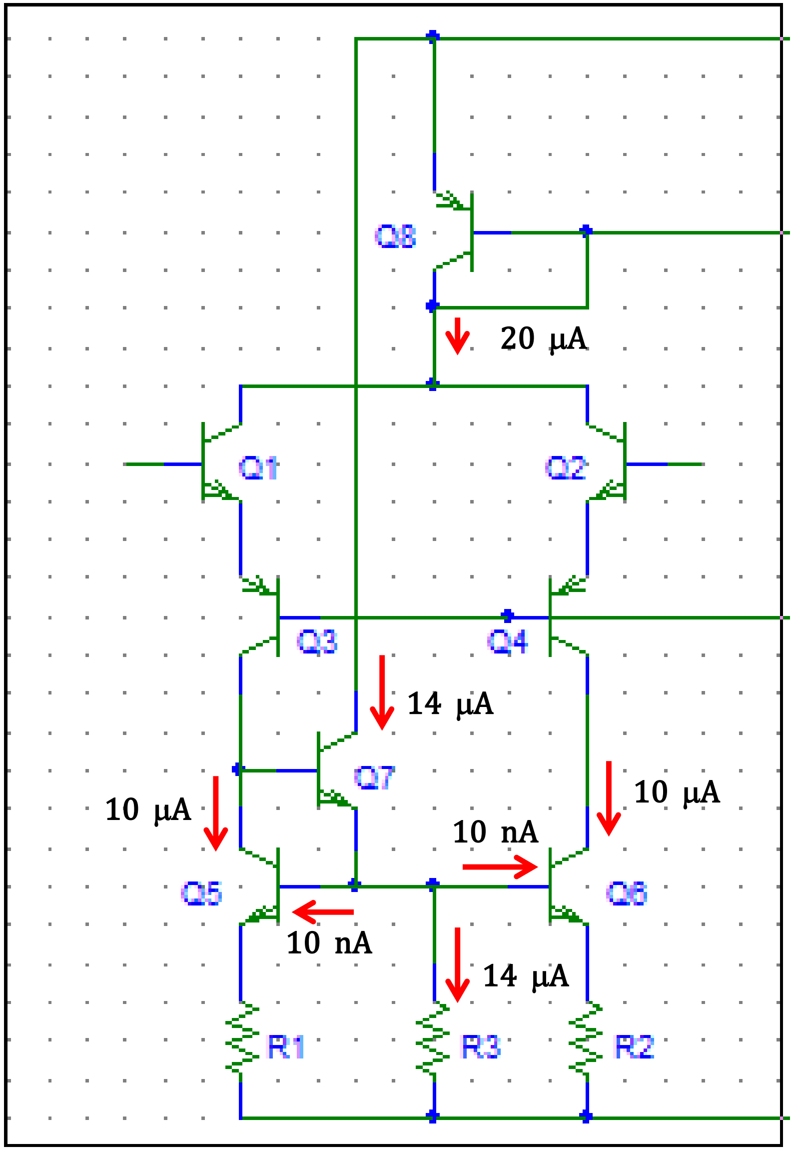
Polarización de Q_7

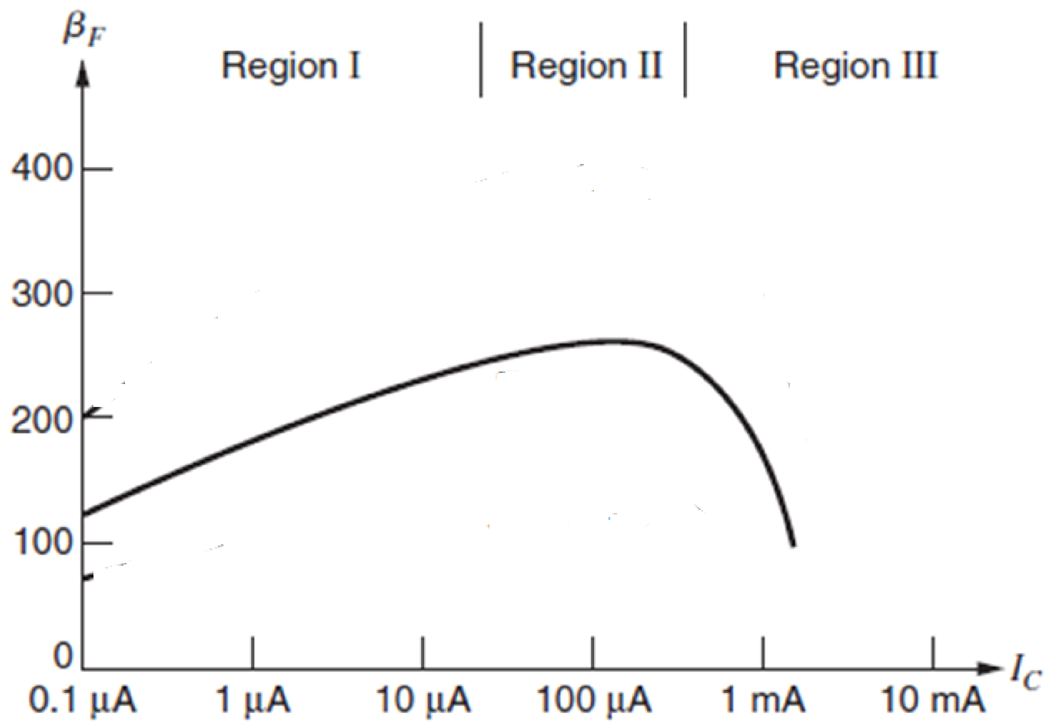
$$V_{R3} = V_{BE1,2} + 10\mu A \times R_{1,2}$$

$$V_{R3} = 0.7\ V$$

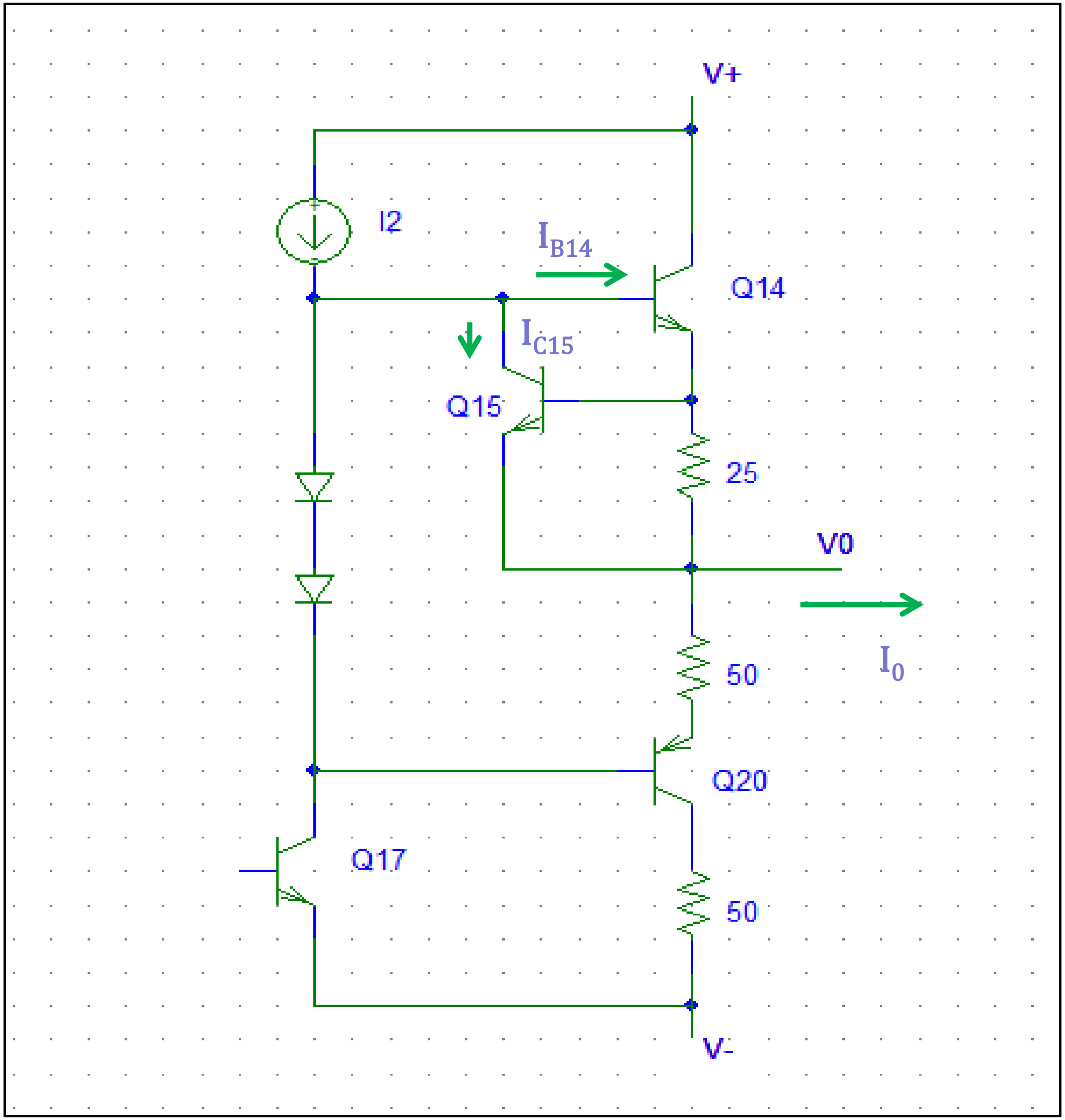
$$I_{R3} = \frac{V_{R3}}{50\ K\Omega} = 14\ \mu A$$

$$I_{R3} \approx I_{C7}$$





XX741 PROTECCION



$$V_{BE15} = I_0 \times 25$$

$$I_0 \times 25 \cong 0.7\ V$$

$$I_{C15} \neq 0$$

Disminuye I_{B14}