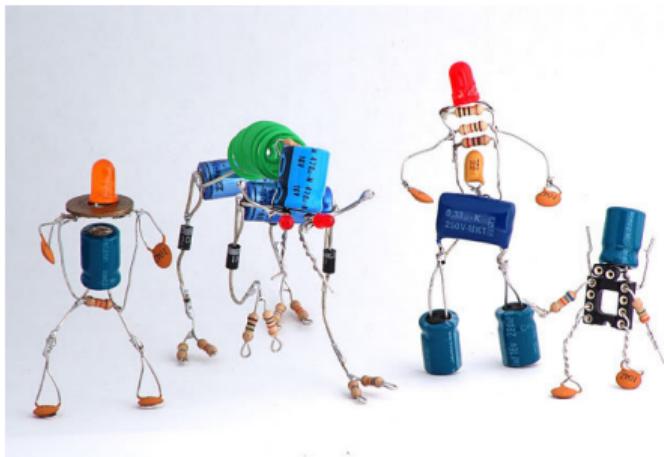


Instrumentación y Control - COMPONENTES ELECTRÓNICOS Y ADQUISICIÓN DE SEÑALES ANALÓGICAS

23 de Abril de 2019



Contenido

Magnitudes útiles

Clasificación de componentes electrónicos

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Objetivos e informe

Magnitudes útiles

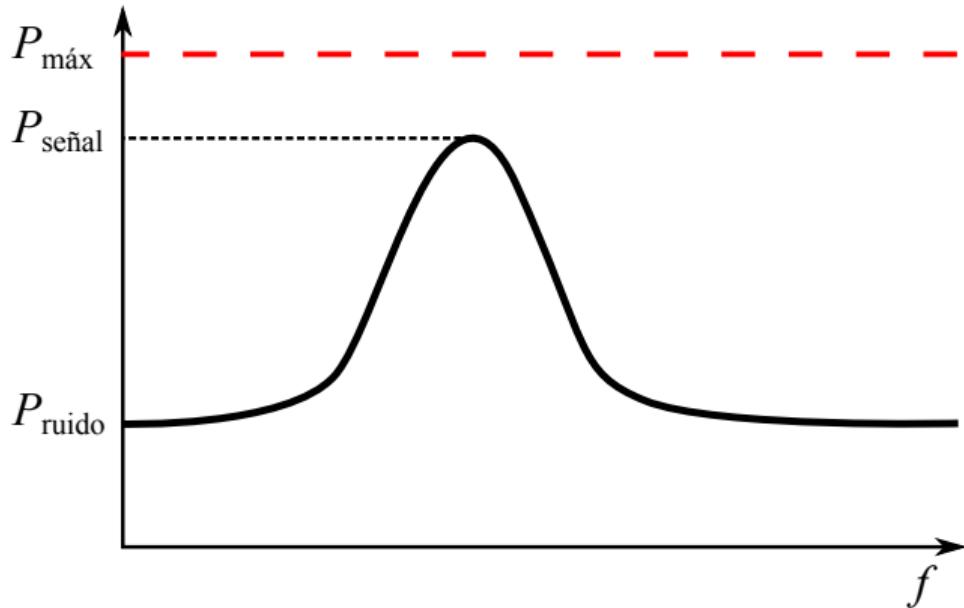
Relación señal-ruido / Rango dinámico / Factor de ruido

$$\text{SNR} = \frac{P_{\text{señal}}}{P_{\text{ruido}}}$$

$$\text{DR} = \frac{P_{\text{max}}}{P_{\text{ruido}}}$$

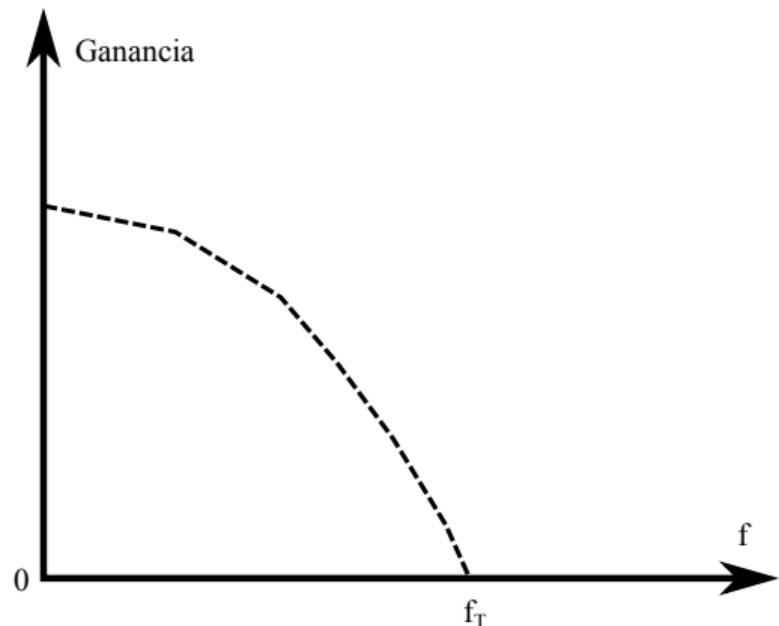
$$F = \frac{\text{SNR}_I}{\text{SNR}_O}$$

$$F(\text{dB}) = \text{SNR}_I(\text{dB}) - \text{SNR}_O(\text{dB})$$



- ▶ 10log o 20log?
- ▶ P en dB o dBm?

Ancho de banda de ganancia unitaria



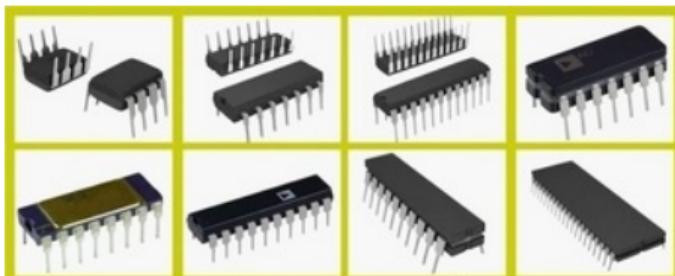
Clasificación de componentes electrónicos

Clasificación según la estructura física

Discretos: elementos individuales que cumplen un tarea específica



Integrados: circuitos compuestos por varios elementos



Clasificación según la función específica

Pasivos: solo consumen o almacenan energía

- ▶ Resistencias
- ▶ Capacitores
- ▶ Inductores

Activos: transfieren energía, modifican el nivel y la forma de las señales

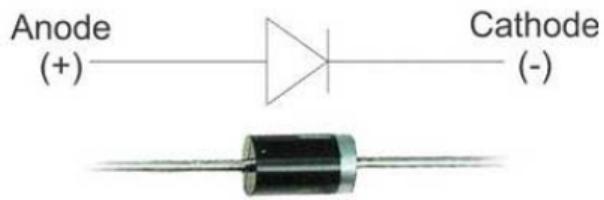
- ▶ Diodos
- ▶ Transistores

Electromecánicos: conjugan operaciones eléctricas y funciones mecánicas

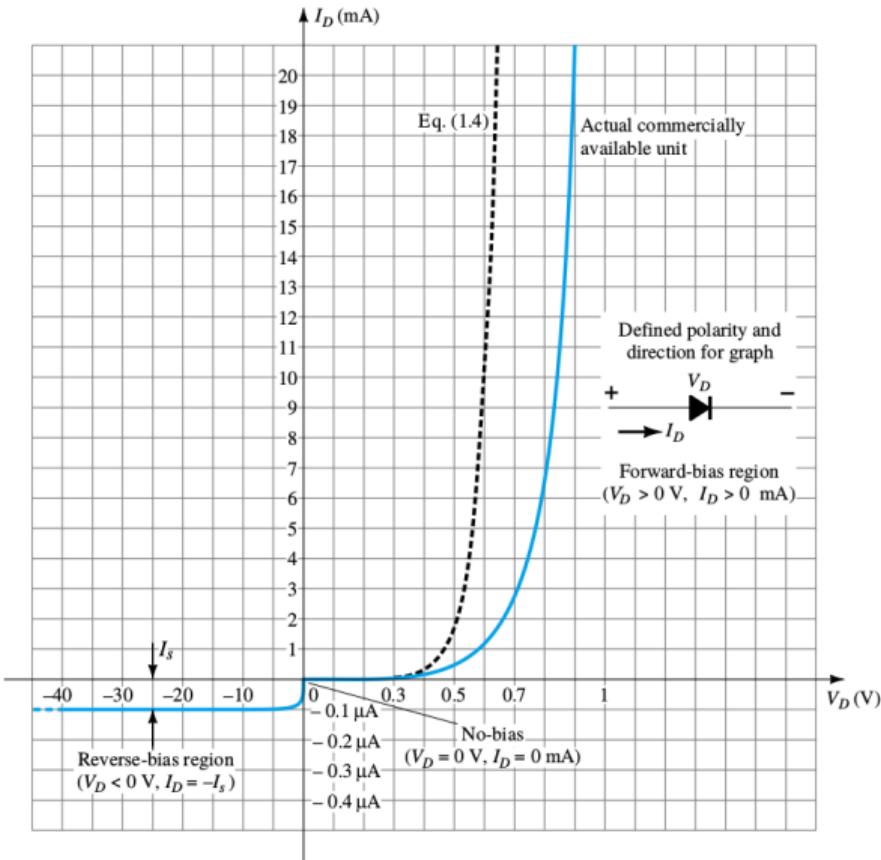
- ▶ Relays
- ▶ Piezoeléctricos
- ▶ Fusibles

Componentes discretos

Diodos: Esquemático y curva característica



$$I_D(V_D) = I_S \left\{ \exp\left(\frac{q V_D}{\eta K_B T}\right) - 1 \right\}$$



Diodos: Especificación de datos

- ▶ Potencial de conducción en directa V_F
- ▶ Corriente máxima en directa I_F
- ▶ Corriente de saturación inversa I_R
- ▶ Potencial de ruptura $PIV / PRV / V(BR) / V_R$
- ▶ Potencia disipada P_D
- ▶ Capacitancia C_T
- ▶ Tiempo de recuperación t_{rr}

Diodos: Hoja de datos

Absolute Maximum Ratings*

$T_A = 25^\circ\text{C}$ unless otherwise noted

Symbol	Parameter	Value	Units
V_{RRM}	Maximum Repetitive Reverse Voltage	100	V
$I_{F(AV)}$	Average Rectified Forward Current	200	mA
I_{FSM}	Non-repetitive Peak Forward Surge Current Pulse Width = 1.0 second Pulse Width = 1.0 microsecond	1.0 4.0	A A
T_{stg}	Storage Temperature Range	-65 to +200	$^\circ\text{C}$
T_J	Operating Junction Temperature	175	$^\circ\text{C}$

Diodos: Hoja de datos

Thermal Characteristics

Symbol	Characteristic	Max	Units
		1N/FDLL 914/A/B / 4148 / 4448	
P _D	Power Dissipation	500	mW
R _{θJA}	Thermal Resistance, Junction to Ambient	300	°C/W

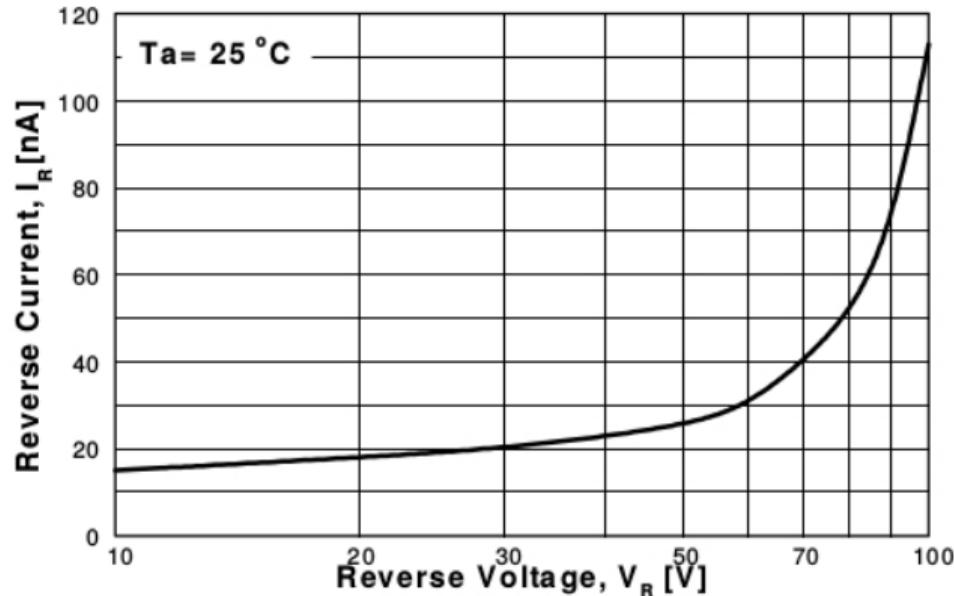
Diodos: Hoja de datos

Electrical Characteristics

$T_A = 25^\circ\text{C}$ unless otherwise noted

Symbol	Parameter	Test Conditions	Min	Max	Units
V_R	Breakdown Voltage	$I_R = 100 \mu\text{A}$ $I_R = 5.0 \mu\text{A}$	100 75		V V
V_F	Forward Voltage 1N914B/4448 1N916B 1N914/916/4148 1N914A/916A 1N916B 1N914B/4448	$I_F = 5.0 \text{ mA}$	620	720	mV
		$I_F = 5.0 \text{ mA}$	630	730	mV
		$I_F = 10 \text{ mA}$		1.0	V
		$I_F = 20 \text{ mA}$		1.0	V
		$I_F = 20 \text{ mA}$		1.0	V
		$I_F = 100 \text{ mA}$		1.0	V
I_R	Reverse Current	$V_R = 20 \text{ V}$ $V_R = 20 \text{ V}, T_A = 150^\circ\text{C}$ $V_R = 75 \text{ V}$		25 50 5.0	nA μA μA
C_T	Total Capacitance 1N916A/B/4448 1N914A/B/4148	$V_R = 0, f = 1.0 \text{ MHz}$		2.0	pF
		$V_R = 0, f = 1.0 \text{ MHz}$		4.0	pF
t_{rr}	Reverse Recovery Time	$I_F = 10 \text{ mA}, V_R = 6.0 \text{ V (60mA)}$, $I_{rr} = 1.0 \text{ mA}, R_L = 100\Omega$		4.0	ns

Diodos: Hoja de datos



GENERAL RULE: The Reverse Current of a diode will approximately double for every ten (10) Degree C increase in Temperature

Figure 2. Reverse Current vs Reverse Voltage
IR - 10 to 100 V

Diodos: Hoja de datos

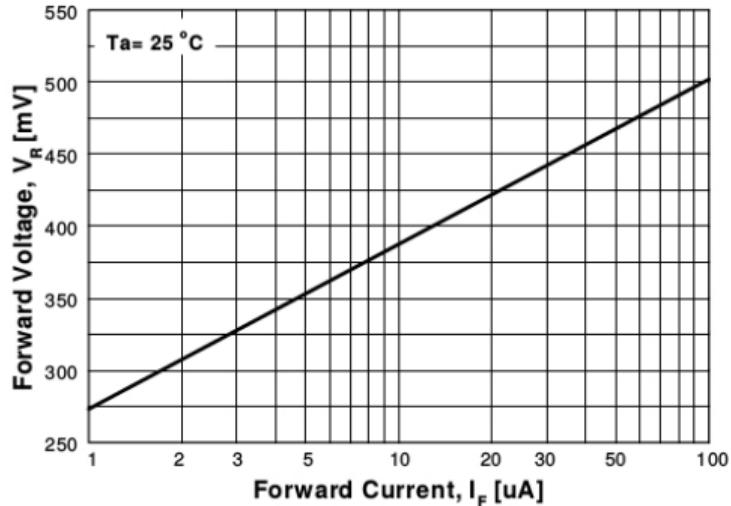


Figure 3. Forward Voltage vs Forward Current
VF - 1 to 100 μA

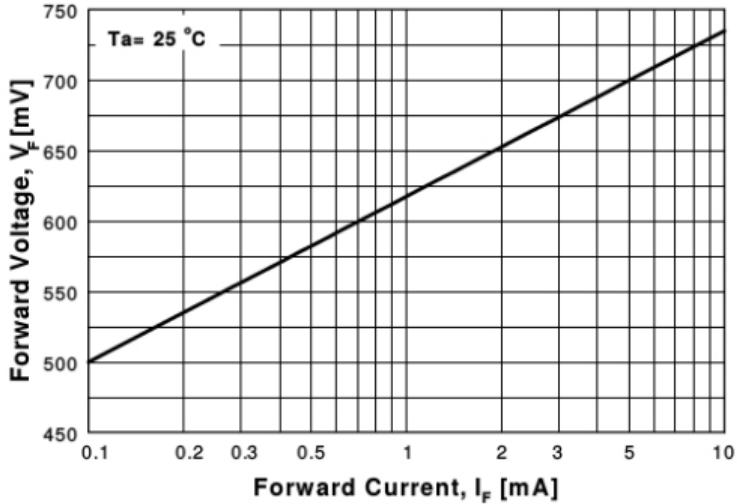


Figure 4. Forward Voltage vs Forward Current
VF - 0.1 to 10 mA

Ojo, pueden haber typos!

Diodos: Hoja de datos

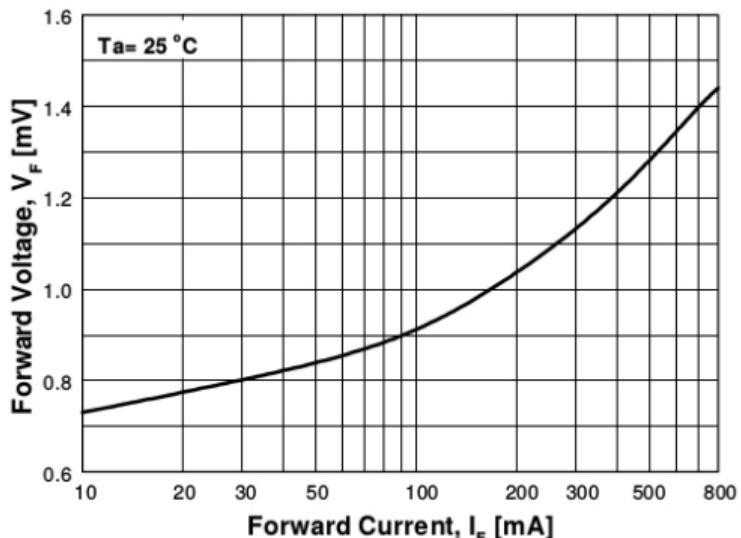


Figure 5. Forward Voltage vs Forward Current
VF - 10 to 800 mA

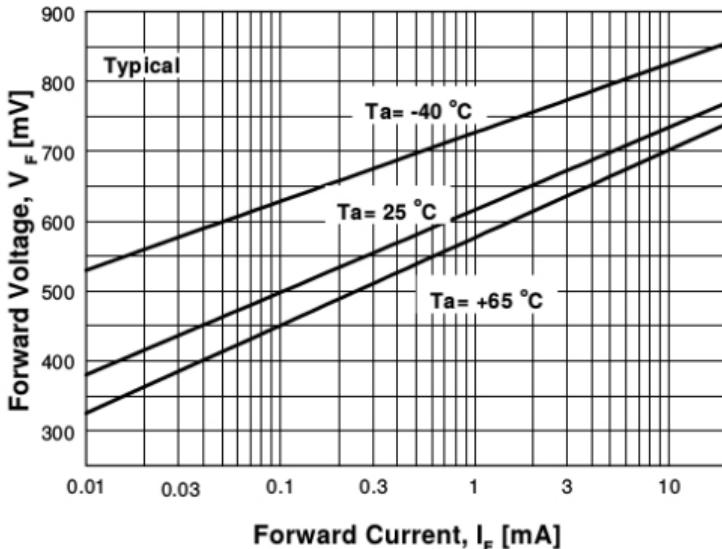


Figure 6. Forward Voltage vs Ambient Temperature
VF - 0.01 - 20 mA (-40 to +65 Deg C)

Diodos: Hoja de datos

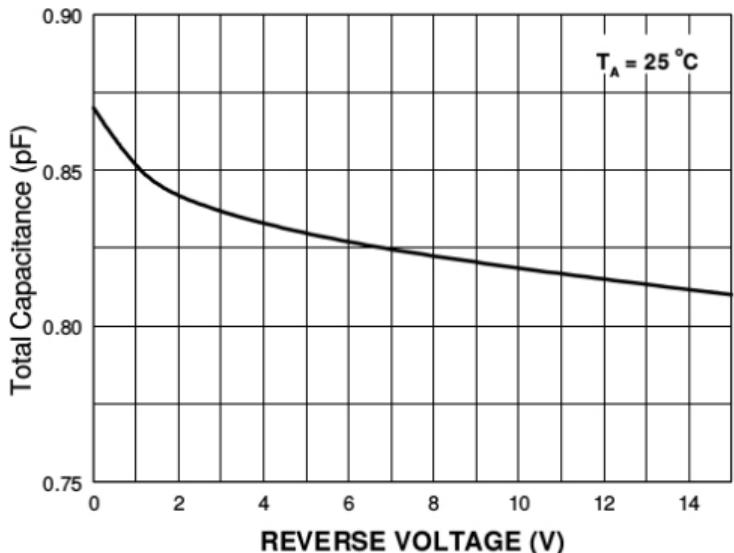


Figure 7. Total Capacitance

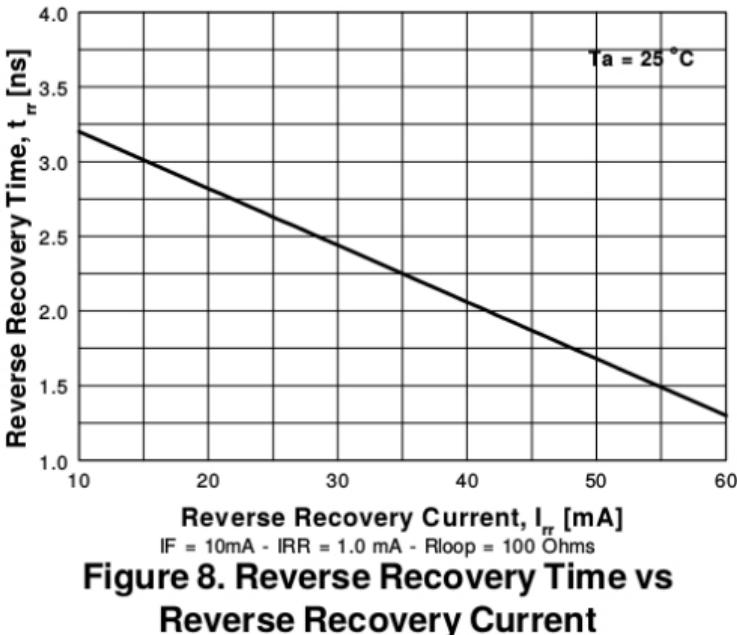


Figure 8. Reverse Recovery Time vs Reverse Recovery Current

Capacitor variable (mirar que pasa con otros diodos)

Diodos: Hoja de datos

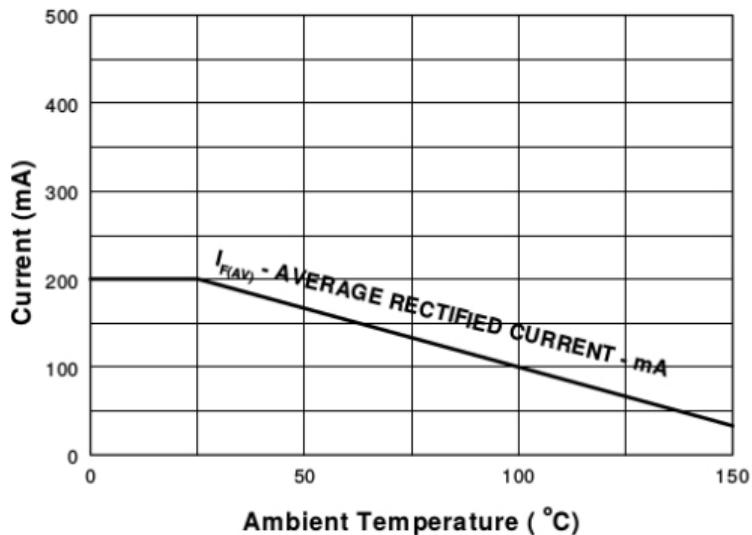


Figure 9. Average Rectified Current ($I_{F(AV)}$) versus Ambient Temperature (T_A)

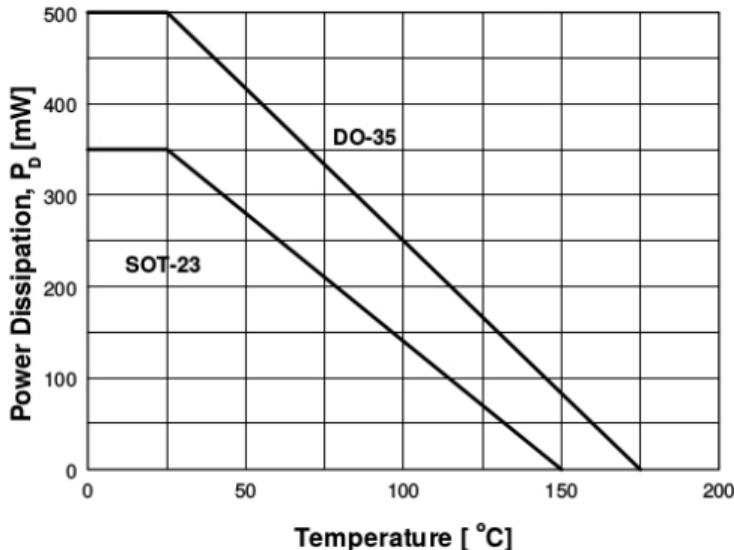
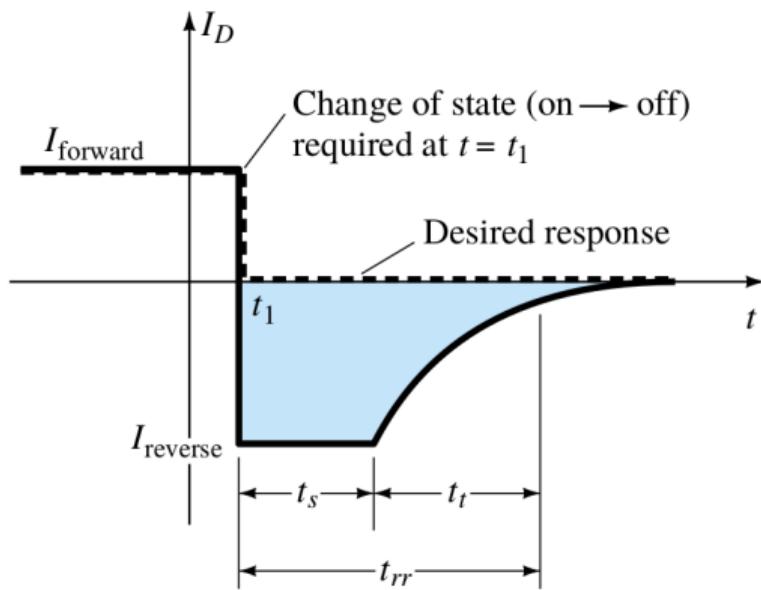


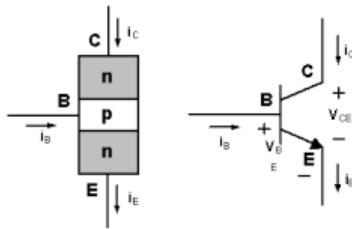
Figure 10. Power Derating Curve

Diodos: tiempo de respuesta inverso



BJT: Esquemático y curvas características

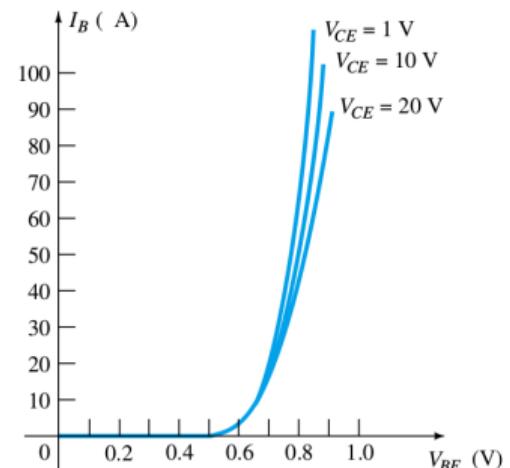
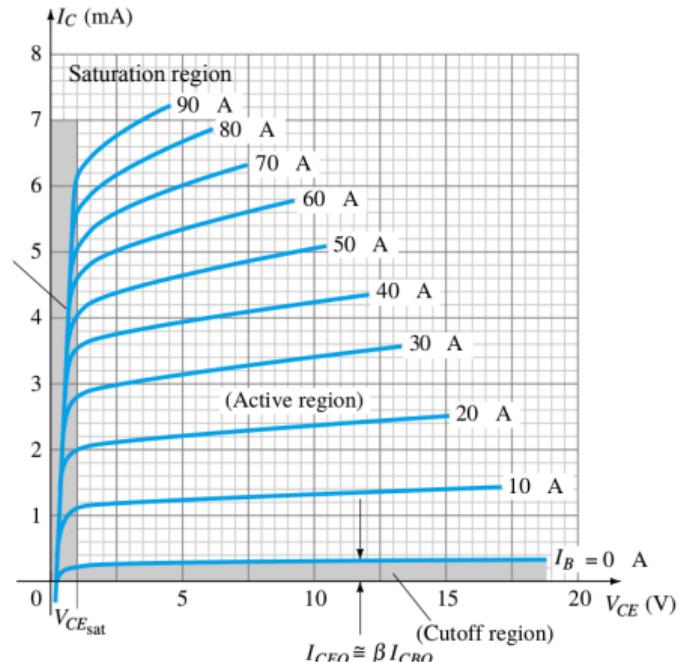
10



$$V_{BE} \approx 0,7 \text{ V}$$

$$I_C + I_B = I_E$$

$$I_C = \beta I_B$$



BJT: Especificación de datos

- ▶ Zona de ruptura
- ▶ Corrientes y temperaturas máximas
- ▶ Factores de ajuste
- ▶ Ganancia de corriente

BJT: Hoja de datos

Absolute Maximum Ratings $T_a=25^{\circ}\text{C}$ unless otherwise noted

Symbol	Parameter	Value	Units
V_{CBO}	Collector-Base Voltage : BC546	80	V
	: BC547/550	50	V
	: BC548/549	30	V
V_{CEO}	Collector-Emitter Voltage : BC546	65	V
	: BC547/550	45	V
	: BC548/549	30	V
V_{EBO}	Emitter-Base Voltage : BC546/547	6	V
	: BC548/549/550	5	V
I_C	Collector Current (DC)	100	mA
P_C	Collector Power Dissipation	500	mW
T_J	Junction Temperature	150	$^{\circ}\text{C}$
T_{STG}	Storage Temperature	-65 ~ 150	$^{\circ}\text{C}$

BJT: Hoja de datos

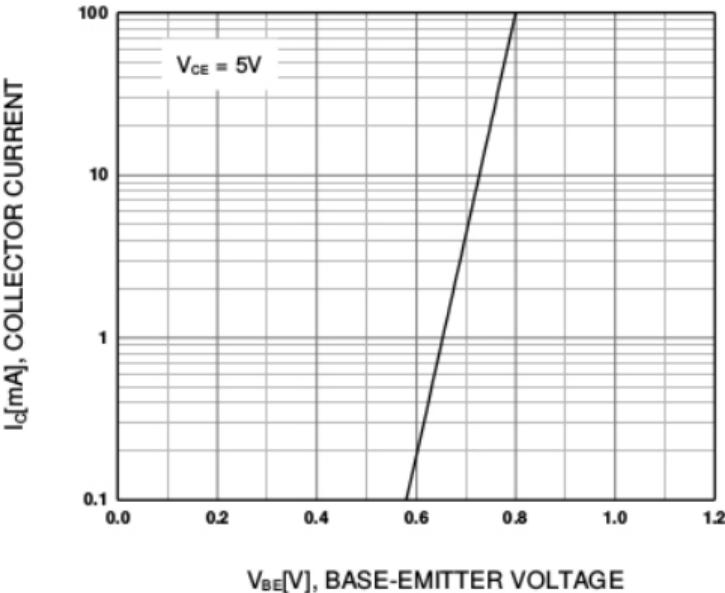
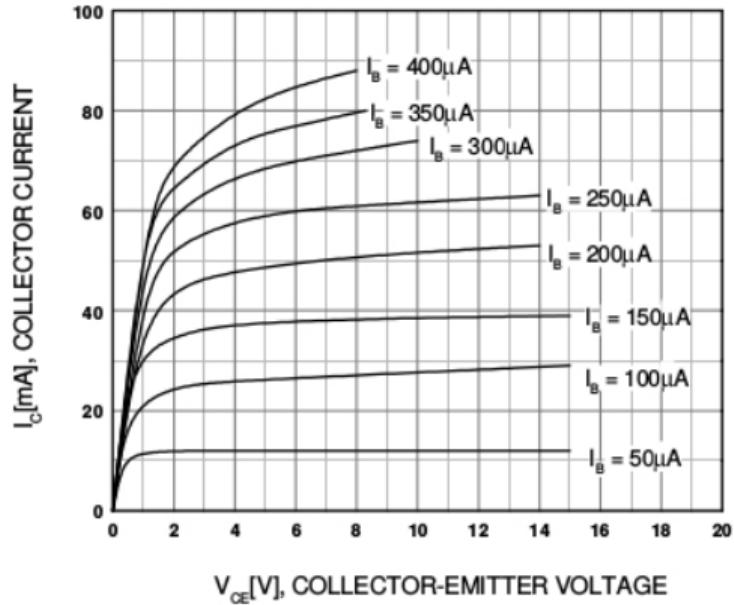
Electrical Characteristics $T_a=25^\circ\text{C}$ unless otherwise noted

Symbol	Parameter	Test Condition	Min.	Typ.	Max.	Units
I_{CBO}	Collector Cut-off Current	$V_{CB}=30\text{V}$, $I_E=0$			15	nA
h_{FE}	DC Current Gain	$V_{CE}=5\text{V}$, $I_C=2\text{mA}$	110		800	
V_{CE} (sat)	Collector-Emitter Saturation Voltage	$I_C=10\text{mA}$, $I_B=0.5\text{mA}$ $I_C=100\text{mA}$, $I_B=5\text{mA}$		90 200	250 600	mV mV
V_{BE} (sat)	Base-Emitter Saturation Voltage	$I_C=10\text{mA}$, $I_B=0.5\text{mA}$ $I_C=100\text{mA}$, $I_B=5\text{mA}$		700 900		mV mV
V_{BE} (on)	Base-Emitter On Voltage	$V_{CE}=5\text{V}$, $I_C=2\text{mA}$ $V_{CE}=5\text{V}$, $I_C=10\text{mA}$	580	660	700 720	mV mV
f_T	Current Gain Bandwidth Product	$V_{CE}=5\text{V}$, $I_C=10\text{mA}$, $f=100\text{MHz}$		300		MHz
C_{ob}	Output Capacitance	$V_{CB}=10\text{V}$, $I_E=0$, $f=1\text{MHz}$		3.5	6	pF
C_{ib}	Input Capacitance	$V_{EB}=0.5\text{V}$, $I_C=0$, $f=1\text{MHz}$		9		pF
NF	Noise Figure : BC546/547/548	$V_{CE}=5\text{V}$, $I_C=200\mu\text{A}$		2	10	dB
	: BC549/550	$f=1\text{KHz}$, $R_G=2\text{K}\Omega$		1.2	4	dB
	: BC549	$V_{CE}=5\text{V}$, $I_C=200\mu\text{A}$		1.4	4	dB
	: BC550	$R_G=2\text{K}\Omega$, $f=30\sim15000\text{MHz}$		1.4	3	dB

h_{FE} Classification

Classification	A	B	C
h_{FE}	110 ~ 220	200 ~ 450	420 ~ 800

BJT: Hoja de datos



BJT: Hoja de datos

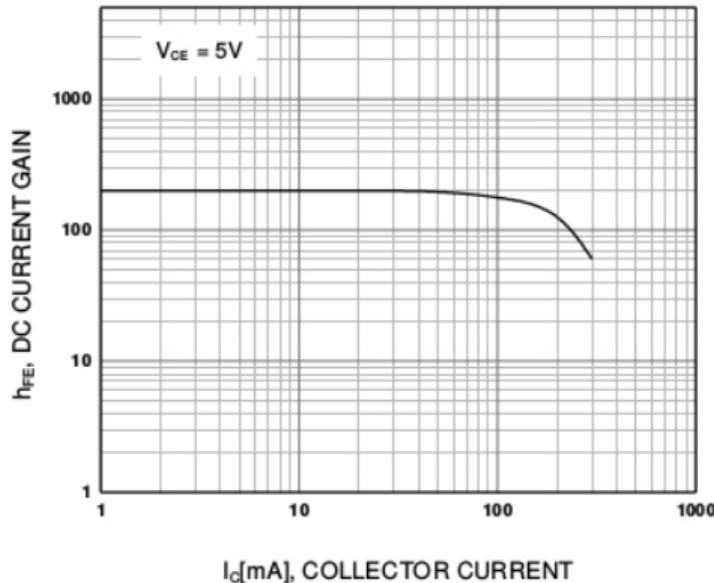


Figure 3. DC current Gain

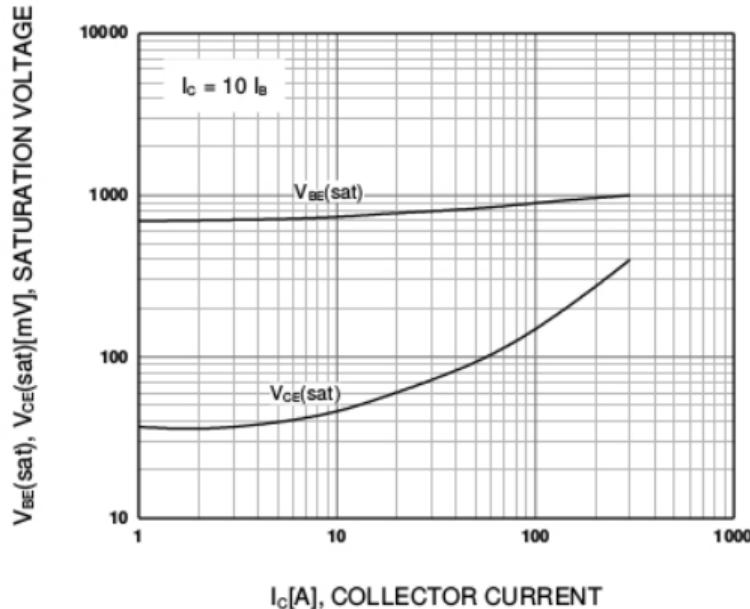


Figure 4. Base-Emitter Saturation Voltage
Collector-Emitter Saturation Voltage

BJT: Hoja de datos

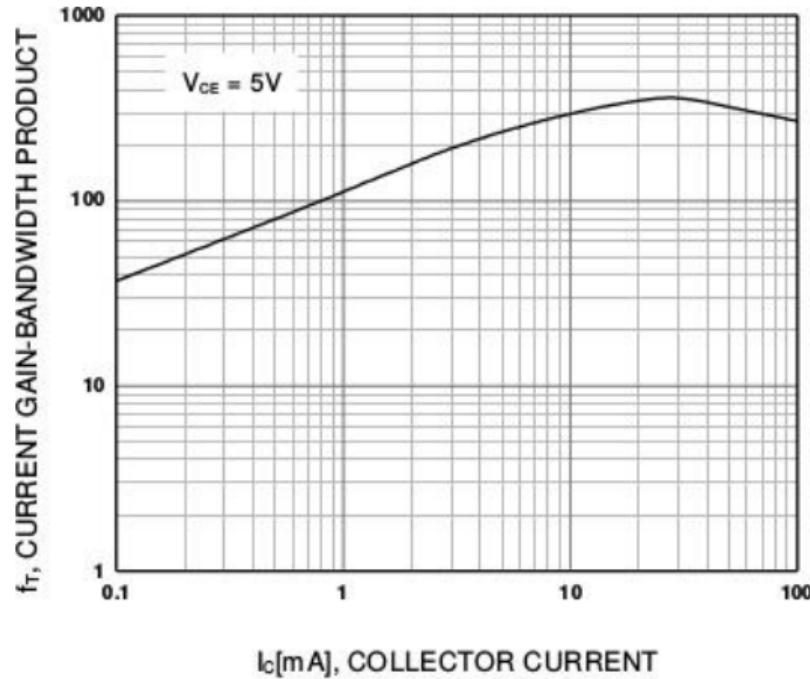
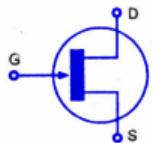
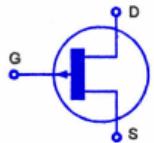


Figure 6. Current Gain Bandwidth Product

JFET: Esquemático y curvas características

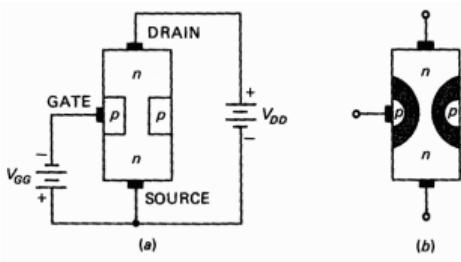


N-Channel JFET



P-Channel JFET

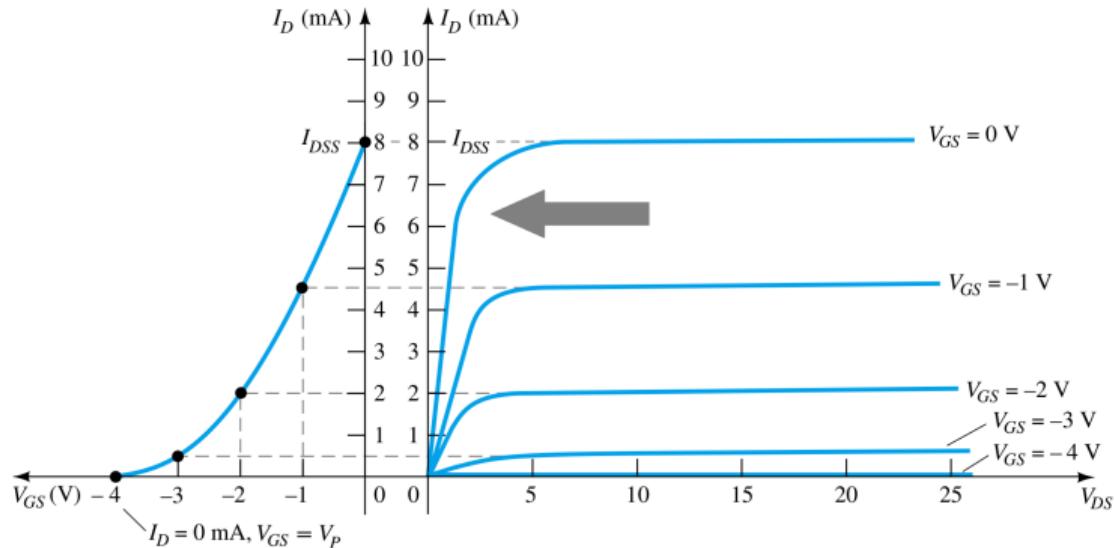
Schematic Symbols For JFETs



$$I_G = 0$$

$$I_D = I_S$$

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



JFET: Hoja de datos

MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Drain–Source Voltage	V_{DS}	25	Vdc
Drain–Gate Voltage	V_{DG}	25	Vdc
Gate–Source Voltage	V_{GS}	-25	Vdc
Gate Current	I_G	10	mAdc
Total Device Dissipation @ $T_A = 25^\circ\text{C}$ Derate above 25°C	P_D	350 2.8	mW mW/ $^\circ\text{C}$
Junction Temperature Range	T_J	125	$^\circ\text{C}$
Storage Temperature Range	T_{stg}	-65 to +150	$^\circ\text{C}$

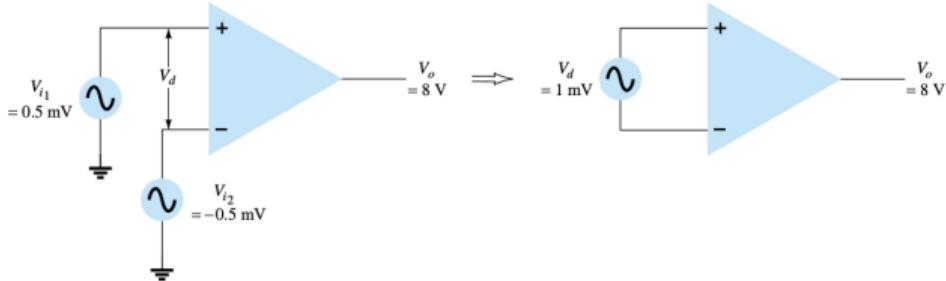
JFET: Hoja de datos

ELECTRICAL CHARACTERISTICS ($T_A = 25^\circ\text{C}$ unless otherwise noted)

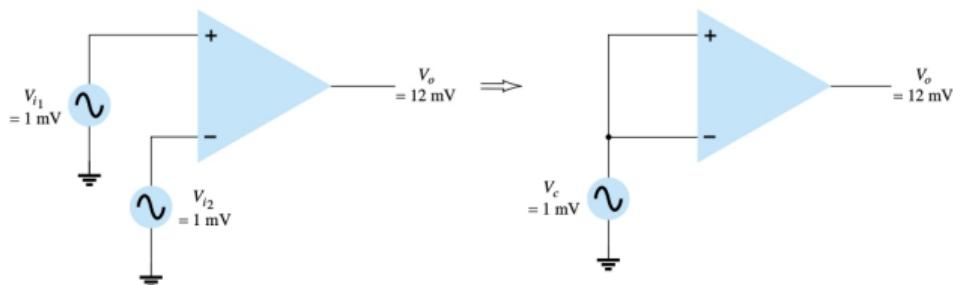
Characteristic	Symbol	Min	Max	Unit
OFF CHARACTERISTICS				
Gate – Source Breakdown Voltage ($I_G = -10 \mu\text{Adc}$, $V_{DS} = 0$)	$V_{(BR)GSS}$	-25	-	Vdc
Gate Reverse Current ($V_{GS} = -15 \text{ Vdc}$, $V_{DS} = 0$) ($V_{GS} = -15 \text{ Vdc}$, $V_{DS} = 0$, $T_A = 100^\circ\text{C}$)	I_{GSS}	-	-2.0 -2.0	nAdc μAdc
Gate – Source Cutoff Voltage ($V_{DS} = 15 \text{ Vdc}$, $I_D = 2.0 \text{ nAdc}$)	$V_{GS(off)}$	-	-8.0	Vdc
Gate – Source Voltage ($V_{DS} = 15 \text{ Vdc}$, $I_D = 0.2 \text{ mAadc}$)	V_{GS}	-0.5	-7.5	Vdc
ON CHARACTERISTICS				
Zero – Gate – Voltage Drain Current (Note 1) ($V_{DS} = 15 \text{ Vdc}$, $V_{GS} = 0 \text{ Vdc}$)	I_{DSS}	2.0	20	mAdc

Componentes integrados

OPAMP: Esquemático / Rechazo modo común



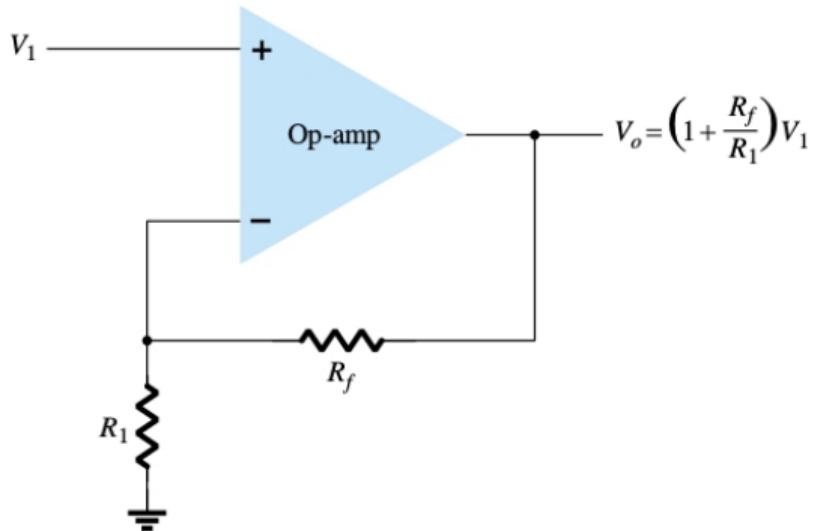
$$V_o = A_d V_d + A_c V_c$$



$$\text{CMRR} = \frac{A_d}{A_c}$$

OPAMP: Aplicaciones

- ▶ Amplificadores
- ▶ Operaciones aritméticas
- ▶ Adaptador de impedancia
- ▶ Filtros
- ▶ Comparadores
- ▶ Etc.



OPAMP: Especificación de datos

- ▶ Tensión de offset de entrada
- ▶ Corriente de polarización de entrada
- ▶ Corriente de offset de entrada
- ▶ Ganancia vs. ancho de banda (*Gain-Bandwidth product*)
- ▶ Slew rate

OPAMP: Hoja de datos

TABLE 14.2 μ A741 Electrical Characteristics: $V_{CC} = \pm 15$ V, $T_A = 25^\circ\text{C}$

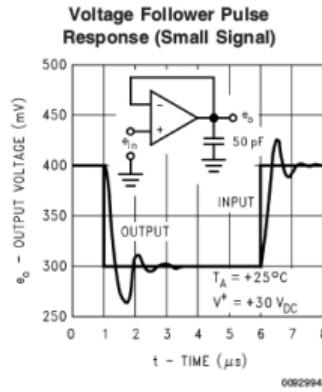
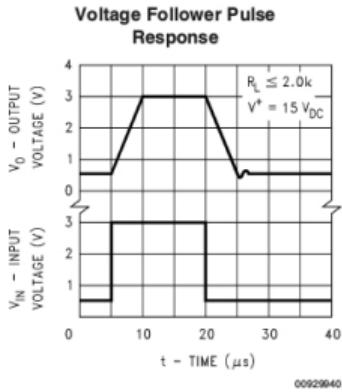
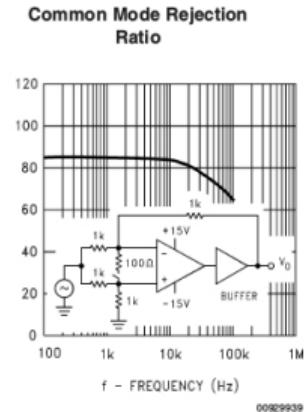
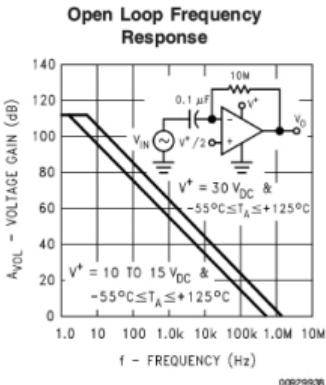
Characteristic	MIN	TYP	MAX	Unit
V_{IO} Input offset voltage		1	6	mV
I_{IO} Input offset current		20	200	nA
I_{IB} Input bias current		80	500	nA
V_{ICR} Common-mode input voltage range	± 12	± 13		V
V_{OM} Maximum peak output voltage swing	± 12	± 14		V
A_{VD} Large-signal differential voltage amplification	20	200		V/mV
r_i Input resistance	0.3	2		M Ω
r_o Output resistance		75		Ω
C_i Input capacitance		1.4		pF
CMRR Common-mode rejection ratio	70	90		dB
I_{CC} Supply current		1.7	2.8	mA
P_D Total power dissipation		50	85	mW

OPAMP: Hoja de datos

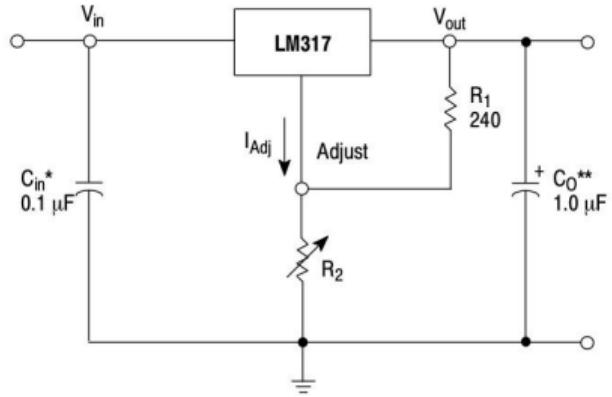
TABLE 14.3 Operating Characteristics: $V_{CC} = \pm 15$ V, $T_A = 25^\circ\text{C}$

Parameter	MIN	TYP	MAX	Unit
B_1 Unity gain bandwidth		1		MHz
t_r Rise time		0.3		μs

OPAMP: Hoja de datos



Regulador: Esquemáticos



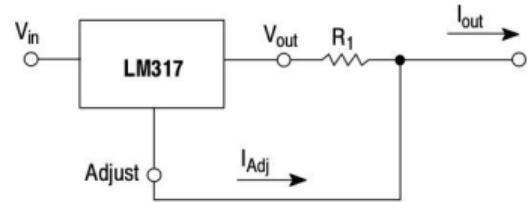
* C_{in}^* is required if regulator is located an appreciable distance from power supply filter.

** C_O is not needed for stability, however, it does improve transient response.

$$V_{out} = 1.25 \text{ V} \left(1 + \frac{R_2}{R_1} \right) + I_{Adj} R_2$$

Since I_{Adj} is controlled to less than 100 μ A, the error associated with this term is negligible in most applications.

Figure 1. Standard Application



$$\begin{aligned} I_{out} &= \left(\frac{V_{ref}}{R_1} \right) + I_{Adj} \\ &= \frac{1.25 \text{ V}}{R_1} \\ 10 \text{ mA} &\leq I_{out} \leq 1.5 \text{ A} \end{aligned}$$

Figure 26. Current Regulator

Regulador: Especificación de datos

- ▶ Regulación de línea
- ▶ Regulación de carga
- ▶ Tensión de referencia
- ▶ Corriente de ajuste
- ▶ Rechazo de ripple

Regulador: Hoja de datos

MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Input–Output Voltage Differential	$V_I - V_O$	-0.3 to 40	Vdc
Power Dissipation Case 221A $T_A = +25^\circ\text{C}$ Thermal Resistance, Junction-to-Ambient Thermal Resistance, Junction-to-Case	P_D θ_{JA} θ_{JC}	Internally Limited 65 5.0	W $^\circ\text{C}/\text{W}$ $^\circ\text{C}/\text{W}$
Case 936 (D ² PAK-3) $T_A = +25^\circ\text{C}$ Thermal Resistance, Junction-to-Ambient Thermal Resistance, Junction-to-Case	P_D θ_{JA} θ_{JC}	Internally Limited 70 5.0	W $^\circ\text{C}/\text{W}$ $^\circ\text{C}/\text{W}$
Operating Junction Temperature Range	T_J	-55 to +150	$^\circ\text{C}$
Storage Temperature Range	T_{slg}	-65 to +150	$^\circ\text{C}$

Regulador: Hoja de datos

ELECTRICAL CHARACTERISTICS

($V_I - V_O = 5.0$ V; $I_O = 0.5$ A for D2T and T packages; $T_J = T_{low}$ to T_{high} (Note 1); I_{max} and P_{max} (Note 2); unless otherwise noted.)

Characteristics	Figure	Symbol	Min	Typ	Max	Unit
Line Regulation (Note 3), $T_A = +25^\circ\text{C}$, $3.0 \text{ V} \leq V_I - V_O \leq 40 \text{ V}$	1	Reg _{line}	–	0.01	0.04	%/V
Load Regulation (Note 3), $T_A = +25^\circ\text{C}$, $10 \text{ mA} \leq I_O \leq I_{max}$ $V_O \leq 5.0 \text{ V}$ $V_O \geq 5.0 \text{ V}$	2	Reg _{load}	– –	5.0 0.1	25 0.5	mV % V_O
Thermal Regulation, $T_A = +25^\circ\text{C}$ (Note 4), 20 ms Pulse	–	Reg _{therm}	–	0.03	0.07	% V_O/W
Adjustment Pin Current	3	I_{Adj}	–	50	100	μA
Adjustment Pin Current Change, $2.5 \text{ V} \leq V_I - V_O \leq 40 \text{ V}$, $10 \text{ mA} \leq I_L \leq I_{max}$, $P_D \leq P_{max}$	1, 2	ΔI_{Adj}	–	0.2	5.0	μA
Reference Voltage, $3.0 \text{ V} \leq V_I - V_O \leq 40 \text{ V}$, $10 \text{ mA} \leq I_O \leq I_{max}$, $P_D \leq P_{max}$	3	V_{ref}	1.2	1.25	1.3	V
Line Regulation (Note 3), $3.0 \text{ V} \leq V_I - V_O \leq 40 \text{ V}$	1	Reg _{line}	–	0.02	0.07	%/V
Load Regulation (Note 3), $10 \text{ mA} \leq I_O \leq I_{max}$ $V_O \leq 5.0 \text{ V}$ $V_O \geq 5.0 \text{ V}$	2	Reg _{load}	– –	20 0.3	70 1.5	mV % V_O
Temperature Stability ($T_{low} \leq T_J \leq T_{high}$)	3	T_S	–	0.7	–	% V_O
Minimum Load Current to Maintain Regulation ($V_I - V_O = 40 \text{ V}$)	3	I_{Lmin}	–	3.5	10	mA
Maximum Output Current $V_I - V_O \leq 15 \text{ V}$, $P_D \leq P_{max}$, T Package $V_I - V_O = 40 \text{ V}$, $P_D \leq P_{max}$, $T_A = +25^\circ\text{C}$, T Package	3	I_{max}	1.5 0.15	2.2 0.4	–	A
RMS Noise, % of V_O , $T_A = +25^\circ\text{C}$, $10 \text{ Hz} \leq f \leq 10 \text{ kHz}$	–	N	–	0.003	–	% V_O
Ripple Rejection, $V_O = 10 \text{ V}$, $f = 120 \text{ Hz}$ (Note 5) Without C_{Adj} $C_{Adj} = 10 \mu\text{F}$	4	RR	– 66	65 80	–	dB
Thermal Shutdown (Note 6)	–	–	–	180	–	°C
Long-Term Stability, $T_J = T_{high}$ (Note 7), $T_A = +25^\circ\text{C}$ for Endpoint Measurements	3	S	–	0.3	1.0	%/1.0 kHrs.
Thermal Resistance Junction-to-Case, T Package	–	R_{ijC}	–	5.0	–	°C/W

Regulador: Hoja de datos

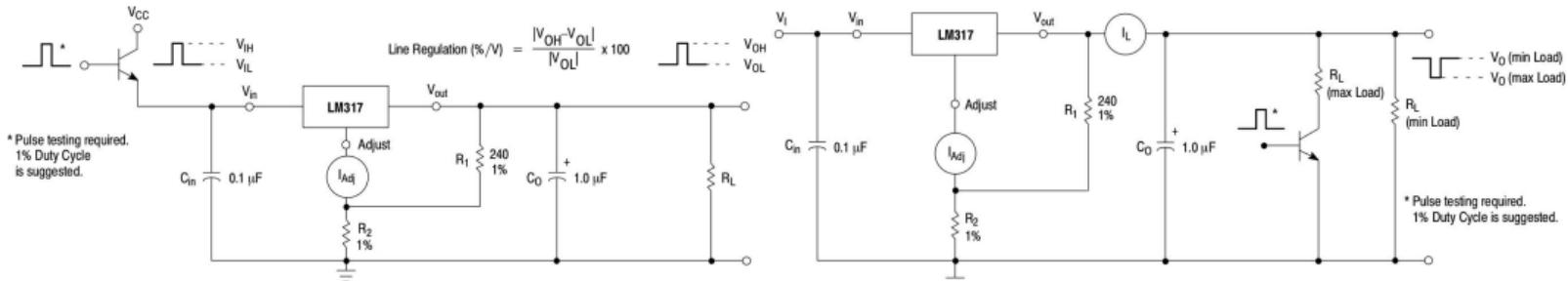


Figure 3. Line Regulation and ΔI_{Adj} /Line Test Circuit

$$\text{Load Regulation (mV)} = V_{O(min\ Load)} - V_{O(max\ Load)}$$

$$\text{Load Regulation (\% } V_O \text{)} = \frac{V_{O(min\ Load)} - V_{O(max\ Load)}}{V_{O(min\ Load)}} \times 100$$

Figure 4. Load Regulation and ΔI_{Adj} /Load Test Circuit

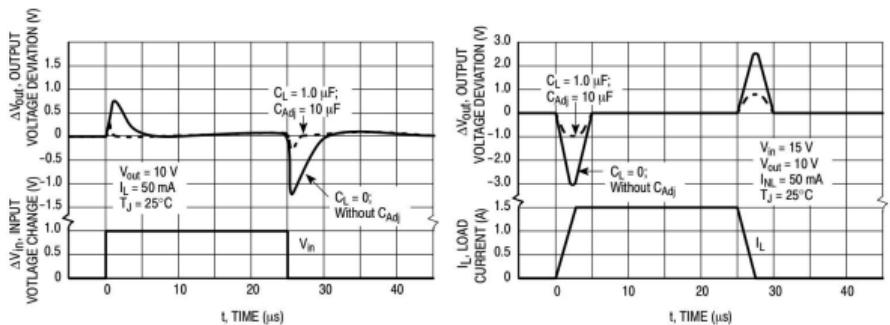


Figure 17. Line Transient Response

Figure 18. Load Transient Response

Regulador: Hoja de datos

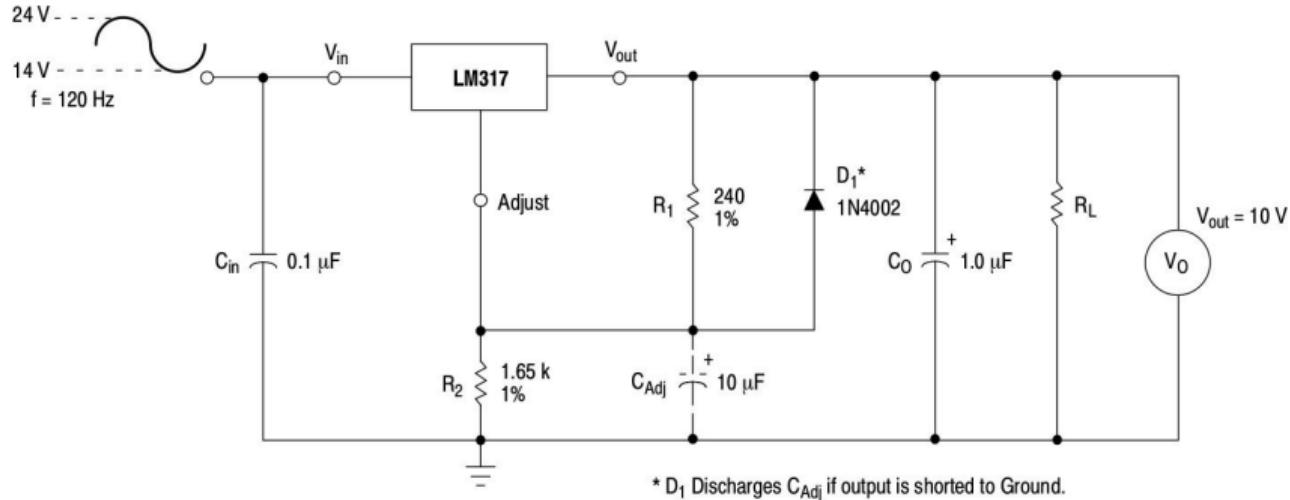
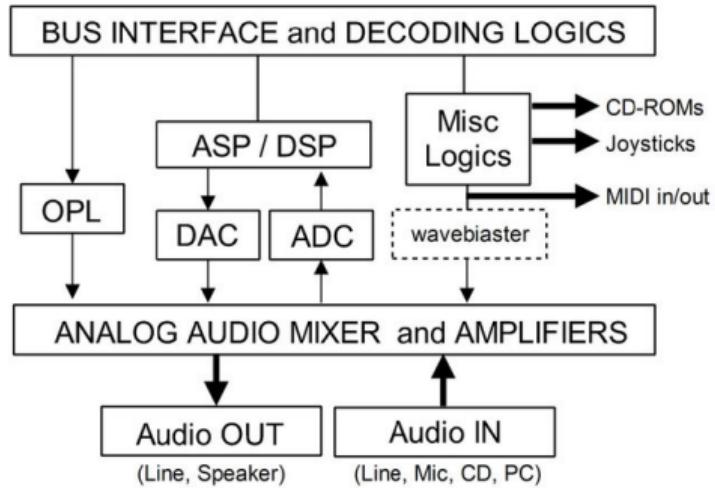


Figure 6. Ripple Rejection Test Circuit

Placa de audio

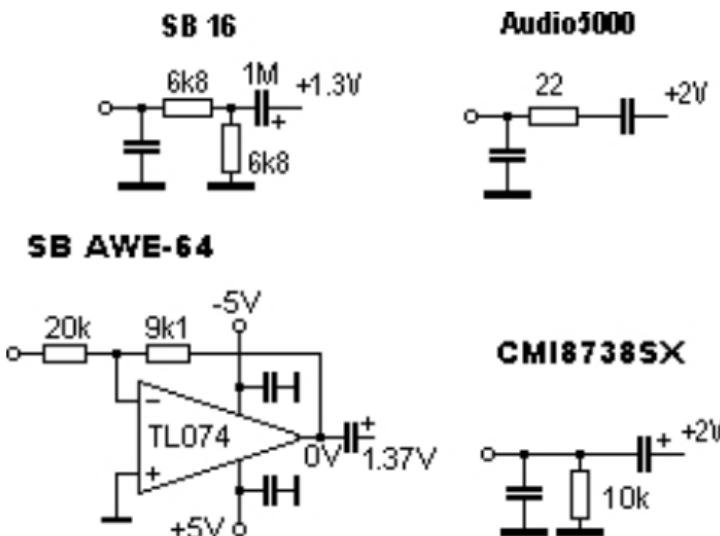
- ▶ ASP/DSP: Procesador analógico/digital de señales
- ▶ DAC/ADC: Conversores D-A/A-D
- ▶ Mixer: Controlado por soft



Placa de audio

Line in

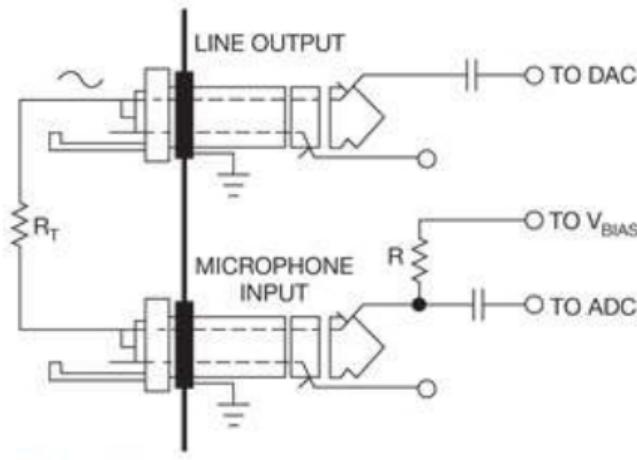
- ▶ Impedancia “alta”
- ▶ Acopladas en alterna
- ▶ Circuito pasabanda



Placa de audio

Mic in

- ▶ Conexión interna para polarizar el micrófono
- ▶ $R = 1/5 \text{ k}\Omega$



Objetivos e informe

Objetivos

Mínima

- ▶ Elegir una librería para el control de la placa de audio
- ▶ Caracterizar entrada y salida de la placa de audio
- ▶ Reemplazar en el programa anterior el generador de funciones o el osciloscopio por la placa de audio
- ▶ Medir una curva de respuesta: Diodo, BJT o JFET
- ▶ Implementar un circuito con OPAMP o Regulador LM317
- ▶ Reportar resultados en una hoja de datos

Objetivos

Máxima

- ▶ Estimación tiempo de respuesta inverso del diodo
- ▶ JFET como resistencia dinámica
- ▶ Estimación tiempo de subida/bajada del OPAMP
- ▶ Medir el rechazo de ripple de un circuito regulador de tensión

Informe

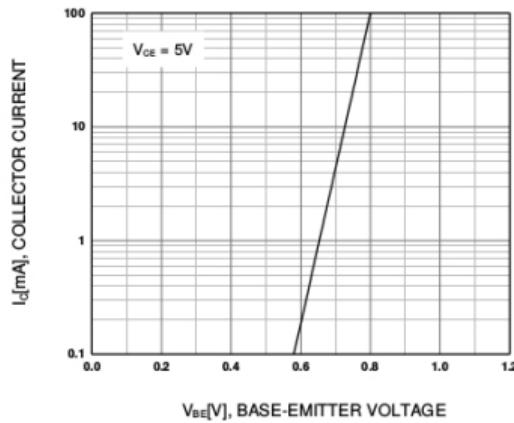
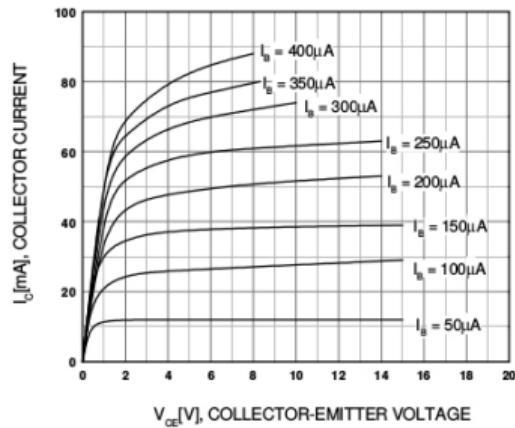
Lineamientos

- ▶ Formato tipo informe técnico
- ▶ Detalles más relevantes del programa (diagrama de flujo, pseudocódigo, etc)
- ▶ Descripción experimental
- ▶ Especificar el programa utilizado para cada medición (si corresponde...)
- ▶ Resumen de resultados tipo “hoja de datos”

Algunas propuestas de trabajo

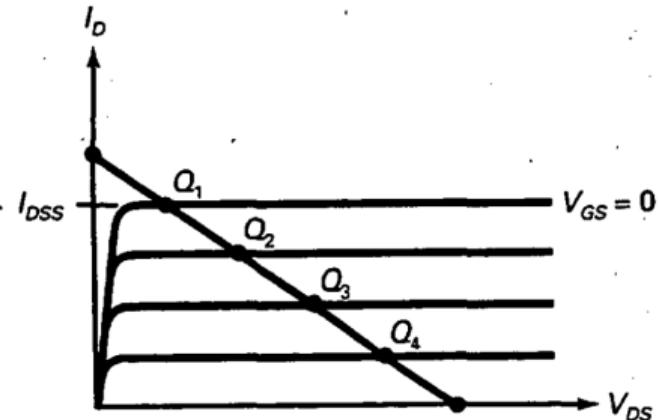
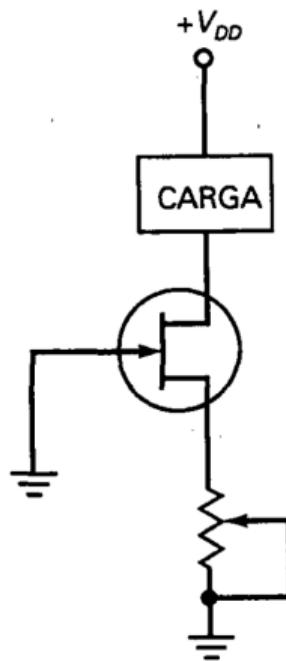
BJT: Propuesta de trabajo

Medir curva caracteristica I_C vs. V_{CE}



JFET: Propuesta de trabajo

Fuente de corriente / Resistencia controlada por tensión



OPAMP: Propuesta de trabajo

Medir ganancia en función de la frecuencia. ¿Se puede estimar el ancho de banda de ganancia unitaria?

¿Será posible estimar el tiempo de subida con la placa de audio?

Regulador: Propuesta de trabajo

Medir rechazo de ripple

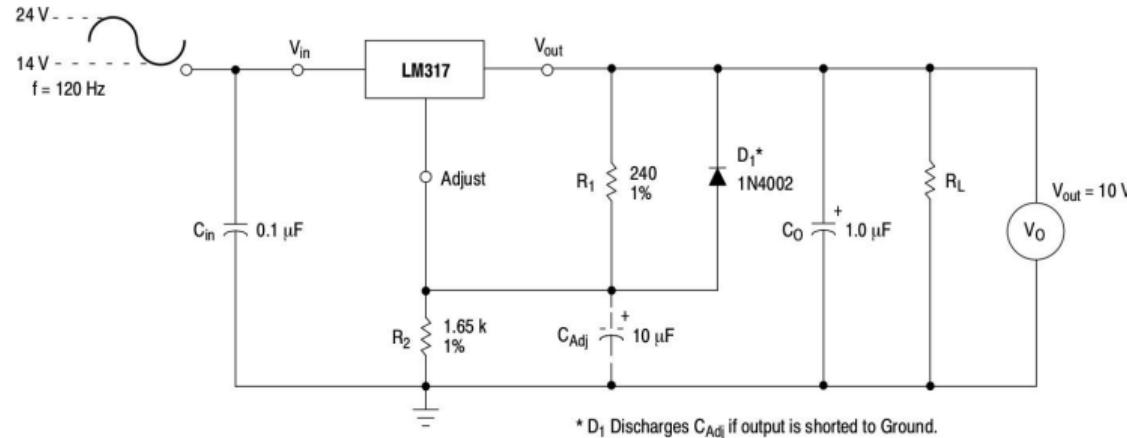


Figure 6. Ripple Rejection Test Circuit