Laborübung
Spannungsstabilisierung

Rene Hampölz, Gruppe 6

HTBLA Weiz, 5BHET

17. Oktober 2022

Inhaltsverzeichnis

1 Einführung **2**

2 Spannungsstabilisierung mit Kollektorschaltung **2**
2.1 Einführung 2
2.2 Schaltung 2
2.3 Berechnungen 2
2.3.1 Vorwiderstand R_V 2
2.3.2 Minimaler Lastwiderstand $R_{L_{min}}$ 3
2.4 Simulation 3
2.5 Auswertung 4
2.5.1 Messdaten 4
2.5.2 Grafische Darstellung 4
2.5.3 Bemerkung 4
2.6 Verwendete Komponenten 5

3 Spannungsstabilisierung mit Operationsverstärker **6**
3.1 Einführung 6
3.2 Schaltung 6
3.3 Berechnungen 6
3.3.1 Widerstand R_V der Referenzspannungsquelle 6
3.3.2 Widerstände R_1 und R_2 der Sollwerteinstellung 7
3.3.3 Minimaler Lastwiderstand $R_{L_{min}}$ 8
3.4 Simulation 8
3.5 Auswertung 8
3.5.1 Messdaten 8
3.5.2 Grafische Darstellung 9
3.5.3 Bemerkung 9
3.6 Verwendete Komponenten 9

4 Datenblätter **11**
4.1 BZD23-C5V1 11
4.2 BC546C 18
4.3 OP27 23

1 Einführung

Es soll eine einfache Spannungsstabilisierung/steuerung mit einer Kollektorschaltung dimensioniert und aufgebaut werden. Des Weiteren soll als Vergleich eine Spannungsstabilisierung/regelung mit einem Operationsverstärker dimensioniert und aufgebaut werden. Mit Simulationen sollen die Funktionsweisen der Schaltungen überprüft werden.

Allgemeine Angaben: $I_{a_{max}} = 0{,}05\,\mathrm{A}$, $I_{ZD} = 0{,}001\,\mathrm{A}$

Datenblatt: $U_{ZD} = 5{,}1\,\mathrm{V}$, $U_{ZD} = 5{,}1\,\mathrm{V}$, $U_{ZD_{max}} = 5{,}4\,\mathrm{V}$, $U_{BE} = 0{,}66\,\mathrm{V}$, $U_{O_{OPV}} = 13{,}8\,\mathrm{V}$

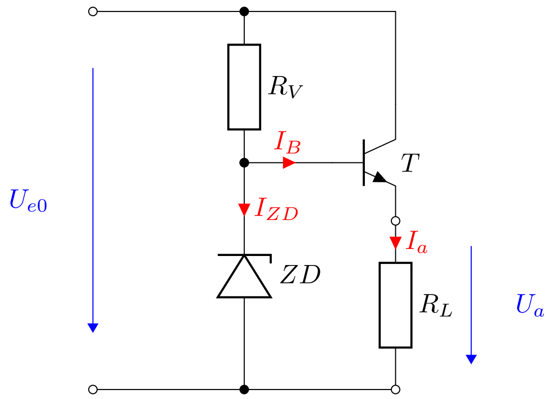
2 Spannungsstabilisierung mit Kollektorschaltung

2.1 Einführung

Die Basis eines NPN-Transistors ist an einem Spannungsteiler durch R_V und der Z-Diode ZD angeschlossen. Die Spannung an der Z-Diode U_{ZD} bleibt nahezu konstant. Somit wird die Spannungsdifferenz U_{BE} zwischen Basis und Emitter des Transistors kleiner, wenn die Ausgangsspannung U_a *(welche am Emitter anliegt)* steigt. Dadurch verringert sich der Basisstrom I_B sowie auch der Kollektor- und Emitterstrom bzw. der Ausgangsstrom I_a, aufgrund der Stromverstärkung des Transistors. Dies führt dazu, dass die Ausgangsspannung bei Laständerungen konstant bleibt.

Schaltungsspezifische Angaben: $U_{e0} = 10\,\mathrm{V}$

2.2 Schaltung



2.3 Berechnungen

2.3.1 Vorwiderstand R_V

Um den von der Z-Diode benötigten Strom I_{ZD} zu liefern und um den Arbeitspunkt einzustellen, wird der Vorwiderstand R_V benötigt. Die Eingangsspannung U_{e0} fällt somit an der Z-Diode ZD sowie am Vorwiderstand R_V ab:

$$
\begin{aligned}
U_{R_V} &= U_{e0} - U_{ZD} \\
U_{R_V} &= 10 - 5{,}1 \\
U_{R_V} &= 4{,}9\,\mathrm{V}
\end{aligned}
$$

Der Strom, welcher durch den Vorwiderstand R_V fließt, setzt sich aus dem Strom I_{ZD} der Z-Diode und dem Basis-Strom I_B des Transistors zusammen. Der Basis-Strom I_{ZD} ist jedoch meist so klein, dass dieser vernachlässigt werden kann.

Nach dem Ohmschen Gesetz ergibt sich somit der Vorwiderstand R_V:

$$R_V = \frac{U_{R_V}}{I_{ZD} + I_B} \qquad I_B = \quad \ll \quad \textit{(vernachlässigbar)}$$

$$\begin{aligned} R_V &= \frac{U_{R_V}}{I_{ZD}} \\ R_V &= \frac{4{,}9}{0{,}001} \\ R_V &= 4900\,\Omega \end{aligned}$$

2.3.2 Minimaler Lastwiderstand $R_{L_{min}}$

Die Zener-Spannung U_{ZD} *(bzw.* $U_{ZD_{max}}$*, da der minimale Lastwiderstand gesucht ist)* teilt sich in die Basis-Emitter-Spannung U_{BE} des Transistors und in die Ausgangsspannung U_a *(bzw.* $U_{a_{max}}$*)* auf. Daraus ergibt sich für die maximale Lastspannung $U_{a_{max}}$:

$$\begin{aligned} U_{a_{max}} &= U_{ZD_{max}} - U_{BE} \\ U_{a_{max}} &= 5{,}4 - 0{,}66 \\ U_{a_{max}} &= 4{,}74\,\mathrm{V} \end{aligned}$$

Nach dem Ohmschen Gesetz ergibt sich schließlich der minimale Lastwiderstand $R_{L_{min}}$:

$$\begin{aligned} R_{L_{min}} &= \frac{U_{a_{max}}}{I_{a_{max}}} \\ R_{L_{min}} &= \frac{4{,}74}{0{,}05} \\ R_{L_{min}} &= 94{,}8\,\Omega \end{aligned}$$

2.4 Simulation

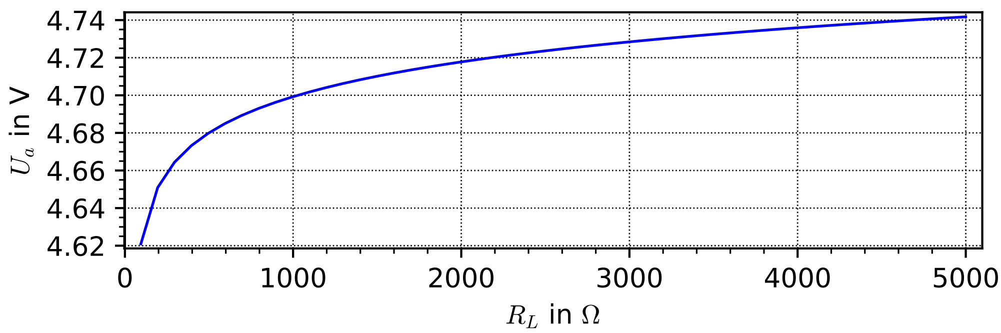


Abbildung 1: Ausgangskennlinie $U_a = f(R_L)$ der Simulation

Die Simulation konnte nicht mit der gleichen Z-Diode wie bei der Messung durchgeführt werden. Daher weicht der Wertebereich in der Ausgangskennlinie der Simulation *(Abb. 1)* etwas von dem der Messung *(Abb. 2)* ab.

2.5 Auswertung

2.5.1 Messdaten

R_L in Ω	U_a in V	I_a in mA
100	3,96	38,2
120	3,96	32,0
130	3,93	29,5
140	3,94	27,4
150	3,95	25,7
160	3,94	24,1
170	3,92	22,6
200	3,91	19,2
250	3,95	15,6
300	3,98	13,2
400	4,05	10,0
500	4,10	8,2
600	4,17	7,0
700	4,22	6,0
800	4,23	5,3
1000	4,29	4,3
2000	4,30	2,2

2.5.2 Grafische Darstellung

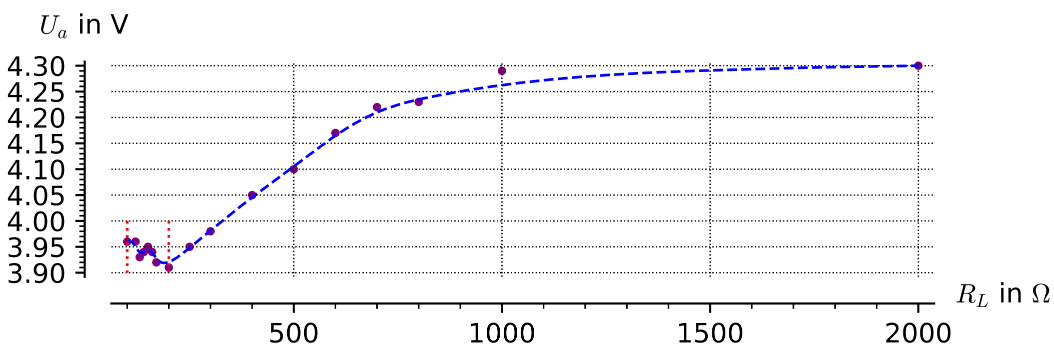


Abbildung 2: Ausgangskennlinie $U_a = f(R_L)$ mit gemessene Werte

Die Schwankungen der Ausgangsspannung U_a im Bereich von $100\,\Omega \rightarrow 200\,\Omega$ in der Ausgangskennlinie mit gemessenen Werte *(Abb. 2)* sind auf mögliche Störgrößen, wie Änderungen der Eingangsspannung oder Erwärmung der Bauteile, zurückzuführen.

2.5.3 Bemerkung

Die Schaltung liefert ab dem ermittelten minimalen Lastwiederstand $R_{L_{min}}$ eine annähernd konstante und stabile Ausgangsspannung U_a mit Abweichungen von wenigen Millivolt. Bei größeren Lastwiederständen verhält sich die Ausgangsspannung etwas stabiler. Da die Schaltung jedoch keine Rückkopplung besitzt, ist sie sehr anfällig für Störgrößen.

2.6 Verwendete Komponenten

Geräteart	**Inventar-Nummer**	**Bezeichnung**
Widerstands-Dekade	`ET-MTL1-RD23`	R_V
	`ET-MTL1-RD29`	R_L
Multimeter	`ET-MTL1-DM20`	I_a
	`ET-MTL1-DM22`	U_a
Z-Diode	`BZD23-C5V1`	ZD
Transistor	`BC546C`	T

3 Spannungsstabilisierung mit Operationsverstärker

3.1 Einführung

Der Operationsverstärker führt einen Soll-Istwert Vergleich durch. Dabei wird eine Referenzspannung mit der Spannung der Rückkopplung verglichen. Eine Differenz der beiden Spannungen führt zu einer Ausgangsspannung.

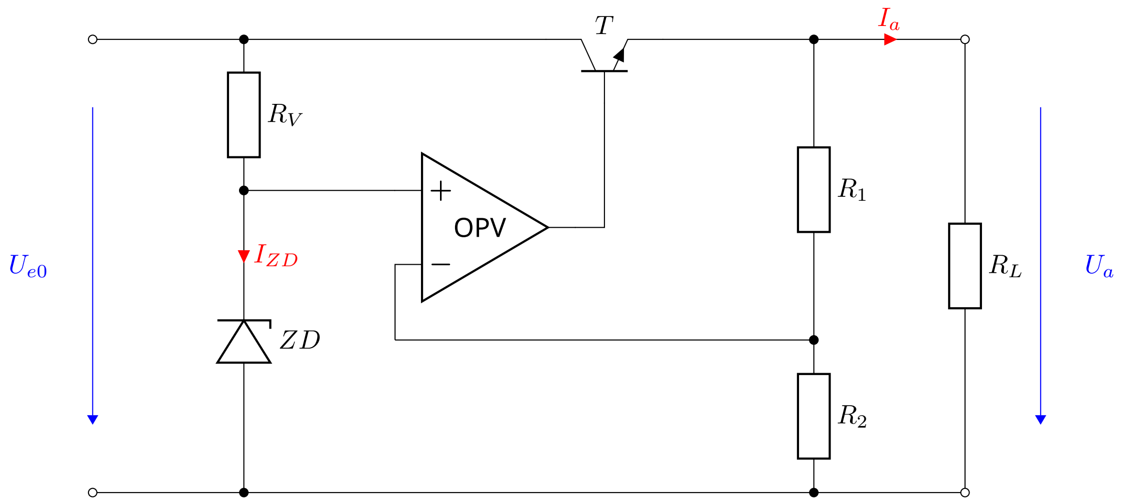
Für die Referenzspannungsquelle wird eine einfache Z-Dioden Stabilisierung mit dem Widerstand R_V und der Z-Diode ZD verwendet.

Die Referenzspannungsquelle wird an den nichtinvertierenden Eingang des OPVs angeschlossen. Am invertierenden Eingang wird (für die Rückkopplung) über die Widerstände R_1 und R_2 der Sollwert der Ausgangsgröße beeinflusst. Der Ausgang des OPVs steuert schließlich einen NPN-Transistor, welcher somit auch den Ausgangsstrom I_a steuert, um die Ausgangsspannung bei Laständerungen konstant zu halten.

Die Ausgangsspannung U_a kann auf einen beliebigen Wert zwischen der Zener-Spannung U_{ZD} und (fast) der Eingangsspannung U_{e0} eingestellt werden.

Schaltungsspezifische Angaben: $U_{e0} = 15\,\mathrm{V}$, $U_a = 7\,\mathrm{V}$

3.2 Schaltung



3.3 Berechnungen

3.3.1 Widerstand R_V der Referenzspannungsquelle

Um den von der Z-Diode benötigten Strom I_{ZD} zu liefern, wird der Vorwiderstand R_V benötigt. Die Eingangsspannung U_{e0} fällt somit an der Z-Diode ZD sowie am Vorwiderstand R_V ab:

$$
\begin{aligned}
U_{R_V} &= U_{e0} - U_{ZD} \\
U_{R_V} &= 15 - 5{,}1 \\
U_{R_V} &= 9{,}9\,\mathrm{V}
\end{aligned}
$$

Nach dem Ohmschen Gesetz ergibt sich somit der Vorwiderstand R_V:

$$\begin{aligned} R_V &= \frac{U_{R_V}}{I_{ZD}} \\ R_V &= \frac{9{,}9}{0{,}001} \\ R_V &= 9900\,\Omega \end{aligned}$$

3.3.2 Widerstände R_1 und R_2 der Sollwerteinstellung

Um den Sollwert der Ausgangsspannung U_a zu beeinflussen, werden die beiden Widerstände R_1 und R_2 benötigt. Ohne dieser Sollwerteinstellung würde am Ausgang die Referenzspannung anliegen.

Nach dem Kirchhoffschen Gesetz ergeben sich folgende Machenregeln und somit auch die Spannungsabfälle der Widerstände:

$$\begin{aligned} U_{O_{OPV}} &= U_{BE} + U_{R_{1(max)}} \\ U_{R_{1(max)}} &= U_{O_{OPV}} - U_{BE} \\ U_{R_{1(max)}} &= 13{,}8 - 0{,}66 \\ U_{R_{1(max)}} &= 13{,}14\,\mathrm{V} \end{aligned}$$

$$\begin{aligned} U_a &= U_{R_{1(max)}} + U_{R_{2(max)}} \\ U_{R_{2(max)}} &= U_a - U_{R_{1(max)}} \\ U_{R_{2(max)}} &= 7 - 13{,}14 \\ U_{R_{2(max)}} &= -6{,}14\,\mathrm{V} \end{aligned}$$

Mit diesen Werten kann schließlich das Widerstands-Verhältnis der beiden Widerstände ermittelt werden. Aufgrund der negativen Spannung $U_{R_{2(max)}}$ kehrt sich das Verhältnis um:

$$\begin{aligned} \frac{R_1}{R_2} &\sim -\frac{U_{R_{1(max)}}}{\left|U_{R_{2(max)}}\right|} \\ \frac{R_1}{R_2} &\sim \frac{\left|U_{R_{2(max)}}\right|}{U_{R_{1(max)}}} \\ \frac{R_1}{R_2} &\sim \frac{6{,}14}{13{,}14} \\ \frac{R_1}{R_2} &\sim \frac{600\,\Omega}{1300\,\Omega} \end{aligned}$$

Die tatsächlichen Widerstandswerte wurden unter Berücksichtigung des erforderlichen Widerstandsverhältnis frei angenommen.

Für ein vorhersehbareres Schaltungsverhalten sollten die Widerstandswerte jedoch über einen gewählten maximal fließenden Strom berechnet werden.

3.3.3 Minimaler Lastwiderstand $R_{L_{min}}$

Der minimale Lastwiderstand $R_{L_{min}}$ wird schließlich durch das Ohmsche Gesetz mit der vorgesehenen konstanten Ausgangsspannung U_a und mit dem maximal fließenden Ausgangsstrom $I_{a_{max}}$ berechnet:

$$R_{L_{min}} = \frac{U_a}{I_{a_{max}}}$$
$$R_{L_{min}} = \frac{7}{0{,}05}$$
$$R_{L_{min}} = 140\,\Omega$$

3.4 Simulation

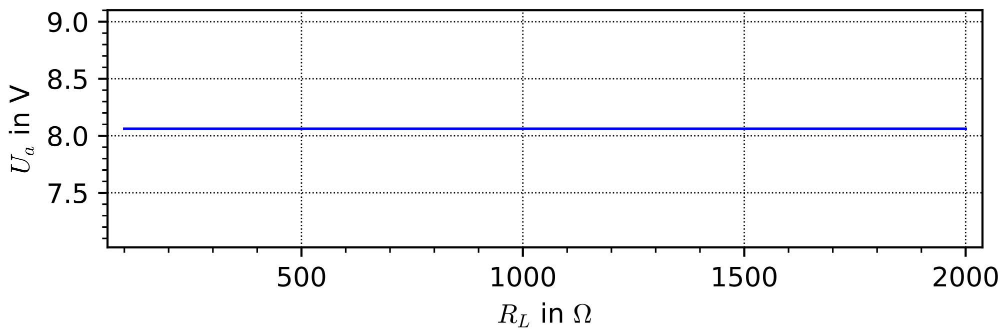


Abbildung 3: Ausgangskennlinie $U_a = f(R_L)$ der Simulation

Die Simulation konnte nicht mit der gleichen Z-Diode wie bei der Messung durchgeführt werden. Daher weicht der Wertebereich in der Ausgangskennlinie der Simulation *(Abb. 3)* etwas von dem der Messung *(Abb. 4)* ab.

3.5 Auswertung

3.5.1 Messdaten

R_L in Ω	U_a in V	I_a in mA
140	6,8	47
160	6,8	41
200	6,8	33
250	6,8	27
300	6,8	22
400	6,8	17
500	6,8	13
1000	6,8	7

3.5.2 Grafische Darstellung

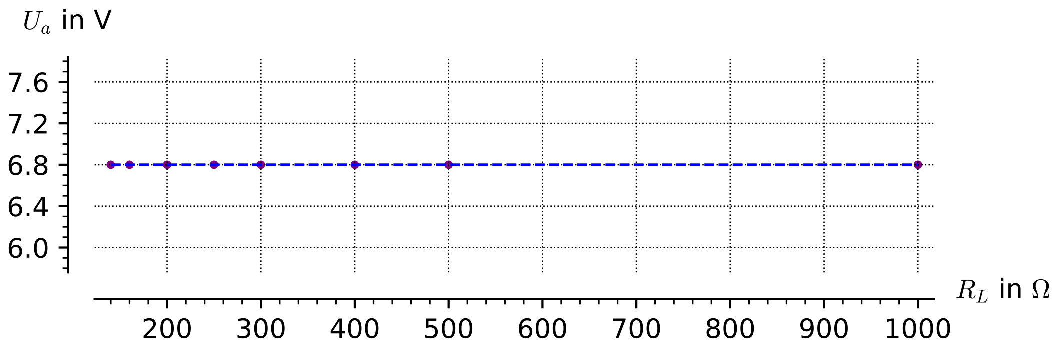


Abbildung 4: Ausgangskennlinie $U_a = f(R_L)$ mit gemessene Werte

3.5.3 Bemerkung

Die Schaltung liefert ab dem ermittelten minimalen Lastwiederstand $R_{L_{min}}$ eine komplett konstante und stabile Ausgangsspannung U_a ohne erkennbare Abweichungen.

Da die Schaltung eine Rückkopplung besitzt, kann die Ausgangsspannung *(im Gegensatz zur Spannungsstabilisierung mit Kollektorschaltung)* trotz möglicher Störgrößen stabil geregelt werden.

3.6 Verwendete Komponenten

Geräteart	Inventar-Nummer	Bezeichnung
Widerstands-Dekade	ET-MTL1-RD09	R_V
	ET-MTL1-RD14	R_1
	ET-MTL1-RD28	R_2
	ET-MTL1-RG26	R_L
Multimeter	ET-MTL1-DM20	I_a
	ET-MTL1-DM22	U_a
Z-Diode	BZD23-C5V1	ZD
Transistor	BC546C	T
Operationsverstärker	OP27	OPV

Änderungsverlauf

2023-06-19	1488d86 by github-actions[bot] chore: Merge changes from template (#2)
2023-06-08	a3d1140 by hampoelz chore: Merge changes from template
2023-04-17	7567582 by github-actions[bot] chore: Merge changes from template (#1)
2023-04-15	988dc9d by hampoelz chore: Improve section headings
2023-04-15	dfe87e3 by hampoelz refactor: Improve plot code

FEATURES

- Glass passivated
- High maximum operating temperature
- Low leakage current
- Excellent stability
- Zener working voltage range: 3.6 to 270 V for 46 types
- Transient suppressor stand-off voltage range: 6.2 to 430 V for 45 types
- Available in ammo-pack.

DESCRIPTION

Cavity free cylindrical glass package through Implotec™(1) technology. This package is hermetically sealed and fatigue free as coefficients of expansion of all used parts are matched.

(1) Implotec is a trademark of Philips.

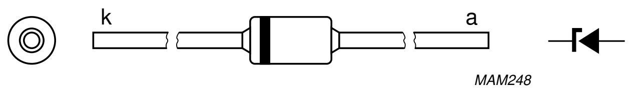


Fig.1 Simplified outline (SOD81) and symbol.

LIMITING VALUES

In accordance with the Absolute Maximum Rating System (IEC 134).

SYMBOL	PARAMETER	CONDITIONS	MIN.	MAX.	UNIT
P_{tot}	total power dissipation	T_{tp} = 25 °C; lead length 10 mm; see Figs 2 and 3			
	BZD23-C3V6 to -C6V8		–	2.0	W
	BZD23-C7V5 to -C510		–	2.5	W
P_{tot}	total power dissipation	T_{amb} = 55 °C; see Figs 2 and 3; PCB mounted (see Fig.7)			
	BZD23-C3V6 to -C6V8		–	1.0	W
	BZD23-C7V5 to -C510		–	1.0	W
P_{ZSM}	non-repetitive peak reverse power dissipation	t_p = 100 µs; square pulse; T_j = 25 °C prior to surge; see Figs 4 and 5			
	BZD23-C3V6 to -C6V8		–	300	W
	BZD23-C7V5 to -C510		–	300	W
P_{RSM}	non-repetitive peak reverse power dissipation	10/1 000 µs exponential pulse (see Fig.8); T_j = 25 °C prior to surge			
	BZD23-C7V5 to -C510		–	150	W
T_{stg}	storage temperature				
	BZD23-C3V6 to -C6V8		–65	+200	°C
	BZD23-C7V5 to -C510		–65	+175	°C
T_j	junction temperature				
	BZD23-C3V6 to -C6V8		–65	+200	°C
	BZD23-C7V5 to -C510		–65	+175	°C

ELECTRICAL CHARACTERISTICS

Total series

T_j = 25 °C unless otherwise specified.

SYMBOL	PARAMETER	CONDITIONS	MAX.	UNIT
V_F	forward voltage	I_F = 0.2 A; see Fig.6	1.2	V

Per type when used as voltage regulator diodes

T_j = 25 °C unless otherwise specified.

TYPE No. SUFFIX (1)	WORKING VOLTAGE V_Z (V) at I_Z			DIFFERENTIAL RESISTANCE r_{dif} (Ω) at I_Z		TEMPERATURE COEFFICIENT S_Z (%/K) at I_Z		TEST CURRENT I_Z (mA)	REVERSE CURRENT at REVERSE VOLTAGE I_R (μA)	V_R (V)
	MIN.	NOM.	MAX.	TYP.	MAX.	MIN.	MAX.		MAX.	
C3V6	3.4	3.6	3.8	4	8	–0.14	–0.04	100	100	1
C3V9	3.7	3.9	4.1	4	8	–0.14	–0.04	100	50	1
C4V3	4.0	4.3	4.6	4	7	–0.12	–0.02	100	25	1
C4V7	4.4	4.7	5.0	3	7	–0.10	0.00	100	10	1
C5V1	4.8	5.1	5.4	3	6	–0.08	–0.02	100	5	1
C5V6	5.2	5.6	6.0	2	4	–0.04	0.04	100	10	2
C6V2	5.8	6.2	6.6	2	3	–0.01	0.06	100	5	2
C6V8	6.4	6.8	7.2	1	3	0.00	0.07	100	10	3
C7V5	7.0	7.5	7.9	1	2	0.00	0.07	100	50	3
C8V2	7.7	8.2	8.7	1	2	0.03	0.08	100	10	3
C9V1	8.5	9.1	9.6	2	4	0.03	0.08	50	10	5
C10	9.4	10	10.6	2	4	0.05	0.09	50	7	7.5
C11	10.4	11	11.6	4	7	0.05	0.10	50	4	8.2
C12	11.4	12	12.7	4	7	0.05	0.10	50	3	9.1
C13	12.4	13	14.1	5	10	0.05	0.10	50	2	10
C15	13.8	15	15.6	5	10	0.05	0.10	50	1	11
C16	15.3	16	17.1	6	15	0.06	0.11	25	1	12
C18	16.8	18	19.1	6	15	0.06	0.11	25	1	13
C20	18.8	20	21.2	6	15	0.06	0.11	25	1	15
C22	20.8	22	23.3	6	15	0.06	0.11	25	1	16
C24	22.8	24	25.6	7	15	0.06	0.11	25	1	18
C27	25.1	27	28.9	7	15	0.06	0.11	25	1	20
C30	28	30	32	8	15	0.06	0.11	25	1	22
C33	31	33	35	8	15	0.06	0.11	25	1	24
C36	34	36	38	21	40	0.06	0.11	10	1	27
C39	37	39	41	21	40	0.06	0.11	10	1	30
C43	40	43	46	24	45	0.07	0.12	10	1	33
C47	44	47	50	24	45	0.07	0.12	10	1	36

TYPE No. SUFFIX (1)	WORKING VOLTAGE V_Z (V) at I_Z			DIFFERENTIAL RESISTANCE r_{dif} (Ω) at I_Z		TEMPERATURE COEFFICIENT S_Z (%/K) at I_Z		TEST CURRENT I_Z (mA)	REVERSE CURRENT at REVERSE VOLTAGE I_R (μA)	V_R (V)
	MIN.	NOM.	MAX.	TYP.	MAX.	MIN.	MAX.		MAX.	
C51	48	51	54	25	60	0.07	0.12	10	1	39
C56	52	56	60	25	60	0.07	0.12	10	1	43
C62	58	62	66	25	80	0.08	0.13	10	1	47
C68	64	68	72	25	80	0.08	0.13	10	1	51
C75	70	75	79	30	100	0.08	0.13	10	1	56
C82	77	82	87	30	100	0.08	0.13	10	1	62
C91	85	91	96	60	200	0.09	0.13	5	1	68
C100	94	100	106	60	200	0.09	0.13	5	1	75
C110	104	110	116	80	250	0.09	0.13	5	1	82
C120	114	120	127	80	250	0.09	0.13	5	1	91
C130	124	130	141	110	300	0.09	0.13	5	1	100
C150	138	150	156	130	300	0.09	0.13	5	1	110
C160	153	160	171	150	350	0.09	0.13	5	1	120
C180	168	180	191	180	400	0.09	0.13	5	1	130
C200	188	200	212	200	500	0.09	0.13	5	1	150
C220	208	220	233	350	750	0.09	0.13	2	1	160
C240	228	240	256	400	850	0.09	0.13	2	1	180
C270	251	270	289	450	1000	0.09	0.13	2	1	200

Note

1. To complete the type number the suffix is added to the basic type number, e.g. BZD23-C51.

Per type when used as transient suppressor diodes

T_j = 25 °C unless otherwise specified.

TYPE NUMBER	REVERSE BREAKDOWN VOLTAGE	TEMPERATURE COEFFICIENT		TEST CURRENT	CLAMPING VOLTAGE		REVERSE CURRENT at STAND-OFF VOLTAGE	
	$V_{(BR)R}$ (V) at I_{test}	S_Z (%/K) at I_{test}		I_{test} (mA)	$V_{(CL)R}$ (V)	at I_{RSM} (A) note 1	I_R (μA)	at V_R (V)
	MIN.	MIN.	MAX.		MAX.		MAX.	
BZD23-C7V5	7.0	0.00	0.07	100	11.3	13.3	1500	6.2
BZD23-C8V2	7.7	0.03	0.08	100	12.3	12.2	1200	6.8
BZD23-C9V1	8.5	0.03	0.08	50	13.3	11.3	100	7.5
BZD23-C10	9.4	0.05	0.09	50	14.8	10.1	20	8.2
BZD23-C11	10.4	0.05	0.10	50	15.7	9.6	5	9.1
BZD23-C12	11.4	0.05	0.10	50	17.0	8.8	5	10
BZD23-C13	12.4	0.05	0.10	50	18.9	7.9	5	11
BZD23-C15	13.8	0.05	0.10	50	20.9	7.2	5	12
BZD23-C16	15.3	0.06	0.11	25	22.9	6.6	5	13
BZD23-C18	16.8	0.06	0.11	25	25.6	5.9	5	15
BZD23-C20	18.8	0.06	0.11	25	28.4	5.3	5	16
BZD23-C22	20.8	0.06	0.11	25	31.0	4.8	5	18
BZD23-C24	22.8	0.06	0.11	25	33.8	4.4	5	20
BZD23-C27	25.1	0.06	0.11	25	38.1	3.9	5	22
BZD23-C30	28	0.06	0.11	25	42.2	3.6	5	24
BZD23-C33	31	0.06	0.11	25	46.2	3.2	5	27
BZD23-C36	34	0.06	0.11	10	50.1	3.0	5	30
BZD23-C39	37	0.06	0.11	10	54.1	2.8	5	33
BZD23-C43	40	0.07	0.12	10	60.7	2.5	5	36
BZD23-C47	44	0.07	0.12	10	65.5	2.3	5	39
BZD23-C51	48	0.07	0.12	10	70.8	2.1	5	43
BZD23-C56	52	0.07	0.12	10	78.6	1.9	5	47
BZD23-C62	58	0.08	0.13	10	86.5	1.7	5	51
BZD23-C68	64	0.08	0.13	10	94.4	1.6	5	56
BZD23-C75	70	0.08	0.13	10	103.5	1.5	5	62
BZD23-C82	77	0.08	0.13	10	114	1.3	5	68
BZD23-C91	85	0.09	0.13	5	126	1.2	5	75
BZD23-C100	94	0.09	0.13	5	139	1.1	5	82
BZD23-C110	104	0.09	0.13	5	152	1.0	5	91
BZD23-C120	114	0.09	0.13	5	167	0.90	5	100
BZD23-C130	124	0.09	0.13	5	185	0.81	5	110
BZD23-C150	138	0.09	0.13	5	204	0.73	5	120
BZD23-C160	153	0.09	0.13	5	224	0.67	5	130

TYPE NUMBER	REVERSE BREAKDOWN VOLTAGE	TEMPERATURE COEFFICIENT		TEST CURRENT	CLAMPING VOLTAGE		REVERSE CURRENT at STAND-OFF VOLTAGE	
	$V_{(BR)R}$ (V) at I_{test}	S_Z (%/K) at I_{test}		I_{test} (mA)	$V_{(CL)R}$ (V)	at I_{RSM} (A) note 1	I_R (μA)	at V_R (V)
	MIN.	MIN.	MAX.		MAX.		MAX.	
BZD23-C180	168	0.09	0.13	5	249	0.60	5	150
BZD23-C200	188	0.09	0.13	5	276	0.54	5	160
BZD23-C220	208	0.09	0.13	2	305	0.50	5	180
BZD23-C240	228	0.09	0.13	2	336	0.45	5	200
BZD23-C270	251	0.09	0.13	2	380	0.40	5	220
BZD23-C300	280	0.09	0.13	2	419	0.36	5	240
BZD23-C330	310	0.09	0.13	2	459	0.33	5	270
BZD23-C360	340	0.09	0.13	2	498	0.30	5	300
BZD23-C390	370	0.09	0.13	2	537	0.28	5	330
BZD23-C430	400	0.09	0.13	2	603	0.25	5	360
BZD23-C470	440	0.09	0.13	2	655	0.23	5	390
BZD23-C510	480	0.09	0.13	2	707	0.21	5	430

Note

1. Non-repetitive peak reverse current in accordance with *"IEC 60-1, Section 8"* (10/1000 μs pulse); see Fig.8.

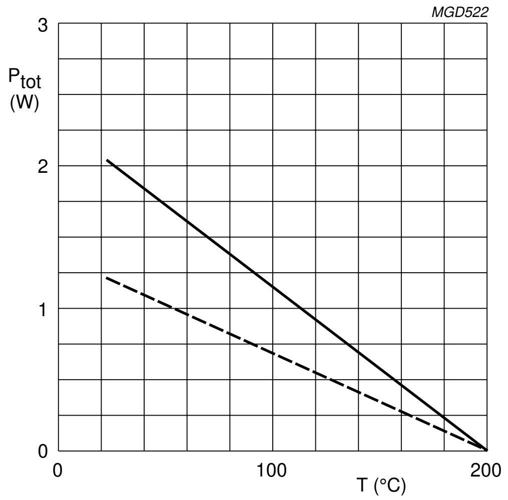
THERMAL CHARACTERISTICS

SYMBOL	PARAMETER	CONDITIONS	VALUE	UNIT
$R_{th\ j\text{-}tp}$	thermal resistance from junction to tie-point	lead length = 10 mm		
	BZD23-C3V6 to -C6V8		87	K/W
	BZD23-C7V5 to -C510		60	K/W
$R_{th\ j\text{-}a}$	thermal resistance from junction to ambient	note 1		
	BZD23-C3V6 to -C6V8		145	K/W
	BZD23-C7V5 to -C510		120	K/W

Note

1. Device mounted on an epoxy-glass printed-circuit board, 1.5 mm thick; thickness of Cu-layer ≥40 μm, see Fig.7. For more information please refer to the *"General Part of associated Handbook"*.

GRAPHICAL DATA

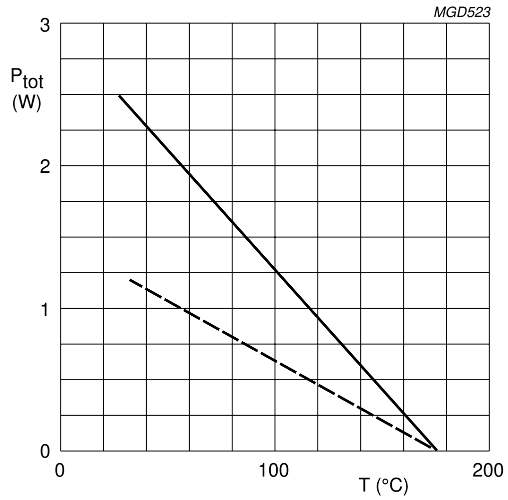


Types BZD23-C3V6 to -C6V8

Solid line: tie-point temperature; lead length = 10 mm.

Dotted line: ambient temperature; PCB mounted as shown in Fig.7.

Fig.2 Maximum total power dissipation as a function of temperature.

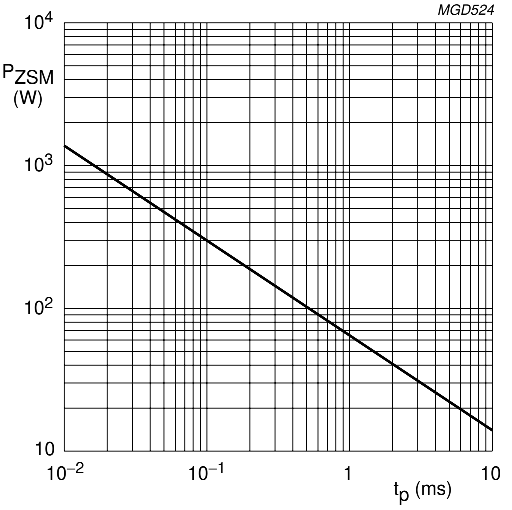


Types BZD23-C7V5 to -C510

Solid line: tie-point temperature; lead length = 10 mm.

Dotted line: ambient temperature; PCB mounted as shown in Fig.7.

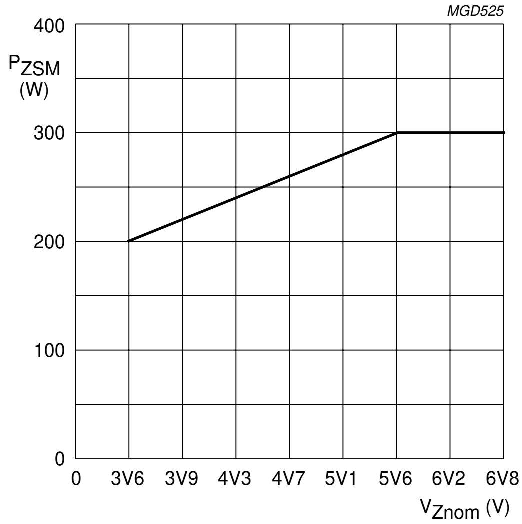
Fig.3 Maximum total power dissipation as a function of temperature.



T_j = 25 °C prior to surge.

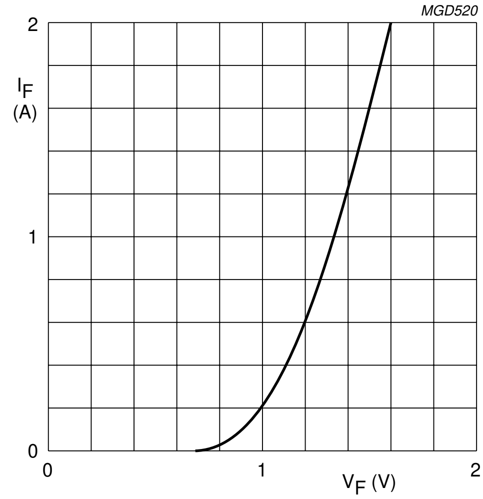
See also Fig.5.

Fig.4 Maximum non-repetitive peak reverse power dissipation as a function of pulse duration (square pulse).



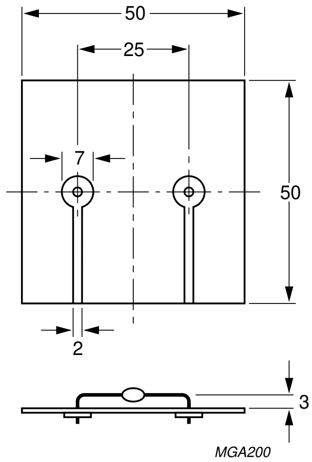
T_j = 25 °C prior to surge.

Fig.5 Maximum non-repetitive peak reverse power dissipation as a function of nominal working voltage.



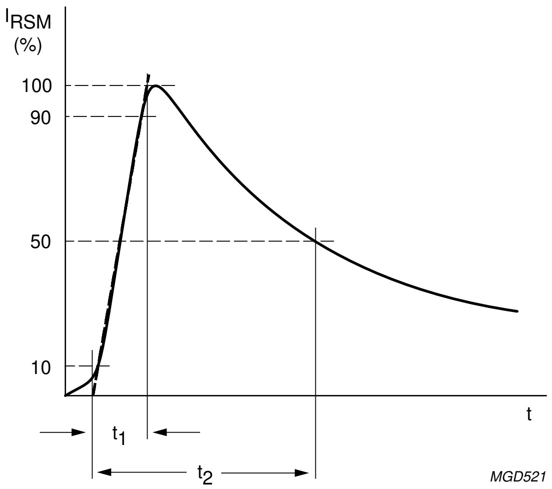
T_j = 25 °C.

Fig.6 Forward current as a function of forward voltage; typical values.



Dimensions in mm.

Fig.7 Device mounted on a printed-circuit board.



In accordance with *"IEC 60-1, Section 8"*.

t_1 = 10 μs.

t_2 = 1000 μs.

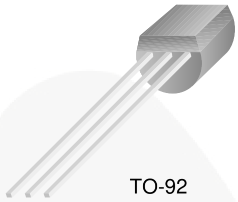
Fig.8 Non-repetitive peak reverse current pulse definition.

November 2014

BC546 / BC547 / BC548 / BC549 / BC550
NPN Epitaxial Silicon Transistor

Features

- Switching and Amplifier
- High-Voltage: BC546, V_{CEO} = 65 V
- Low-Noise: BC549, BC550
- Complement to BC556, BC557, BC558, BC559, and BC560



1. Collector 2. Base 3. Emitter

Ordering Information

Part Number	Marking	Package	Packing Method
BC546ABU	BC546A	TO-92 3L	Bulk
BC546ATA	BC546A	TO-92 3L	Ammo
BC546BTA	BC546B	TO-92 3L	Ammo
BC546BTF	BC546B	TO-92 3L	Tape and Reel
BC546CTA	BC546C	TO-92 3L	Ammo
BC547ATA	BC547A	TO-92 3L	Ammo
BC547B	BC547B	TO-92 3L	Bulk
BC547BBU	BC547B	TO-92 3L	Bulk
BC547BTA	BC547B	TO-92 3L	Ammo
BC547BTF	BC547B	TO-92 3L	Tape and Reel
BC547CBU	BC547C	TO-92 3L	Bulk
BC547CTA	BC547C	TO-92 3L	Ammo
BC547CTFR	BC547C	TO-92 3L	Tape and Reel
BC548BU	BC548	TO-92 3L	Bulk
BC548BTA	BC548B	TO-92 3L	Ammo
BC548CTA	BC548C	TO-92 3L	Ammo
BC549BTA	BC549B	TO-92 3L	Ammo
BC549BTF	BC549B	TO-92 3L	Tape and Reel
BC549CTA	BC549C	TO-92 3L	Ammo
BC550CBU	BC550C	TO-92 3L	Bulk
BC550CTA	BC550C	TO-92 3L	Ammo

Absolute Maximum Ratings

Stresses exceeding the absolute maximum ratings may damage the device. The device may not function or be operable above the recommended operating conditions and stressing the parts to these levels is not recommended. In addition, extended exposure to stresses above the recommended operating conditions may affect device reliability. The absolute maximum ratings are stress ratings only. Values are at T_A = 25°C unless otherwise noted.

Symbol	Parameter		Value	Unit
V_{CBO}	Collector-Base Voltage	BC546	80	V
		BC547 / BC550	50	
		BC548 / BC549	30	
V_{CEO}	Collector-Emitter Voltage	BC546	65	V
		BC547 / BC550	45	
		BC548 / BC549	30	
V_{EBO}	Emitter-Base Voltage	BC546 / BC547	6	V
		BC548 / BC549 / BC550	5	
I_C	Collector Current (DC)		100	mA
P_C	Collector Power Dissipation		500	mW
T_J	Junction Temperature		150	°C
T_{STG}	Storage Temperature Range		-65 to +150	°C

Electrical Characteristics

Values are at T_A = 25°C unless otherwise noted.

Symbol	Parameter		Conditions	Min.	Typ.	Max.	Unit
I_{CBO}	Collector Cut-Off Current		V_{CB} = 30 V, I_E = 0			15	nA
h_{FE}	DC Current Gain		V_{CE} = 5 V, I_C = 2 mA	110		800	
V_{CE}(sat)	Collector-Emitter Saturation Voltage		I_C = 10 mA, I_B = 0.5 mA		90	250	mV
			I_C = 100 mA, I_B = 5 mA		250	600	
V_{BE}(sat)	Base-Emitter Saturation Voltage		I_C = 10 mA, I_B = 0.5 mA		700		mV
			I_C = 100 mA, I_B = 5 mA		900		
V_{BE}(on)	Base-Emitter On Voltage		V_{CE} = 5 V, I_C = 2 mA	580	660	700	mV
			V_{CE} = 5 V, I_C = 10 mA			720	
f_T	Current Gain Bandwidth Product		V_{CE} = 5 V, I_C = 10 mA, f = 100 MHz		300		MHz
C_{ob}	Output Capacitance		V_{CB} = 10 V, I_E = 0, f = 1 MHz		3.5	6.0	pF
C_{ib}	Input Capacitance		V_{EB} = 0.5 V, I_C = 0, f = 1 MHz		9		pF
NF	Noise Figure	BC546 / BC547 / BC548	V_{CE} = 5 V, I_C = 200 µA, f = 1 kHz, R_G = 2 kΩ		2.0	10.0	dB
		BC549 / BC550			1.2	4.0	
		BC549	V_{CE} = 5 V, I_C = 200 µA, R_G = 2 kΩ, f = 30 to 15000 MHz		1.4	4.0	
		BC550			1.4	3.0	

h_{FE} Classification

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

Typical Performance Characteristics

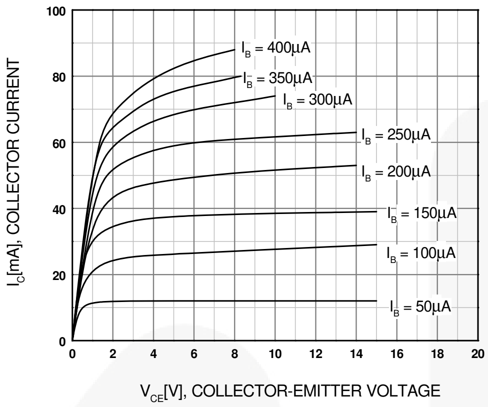


Figure 1. Static Characteristic

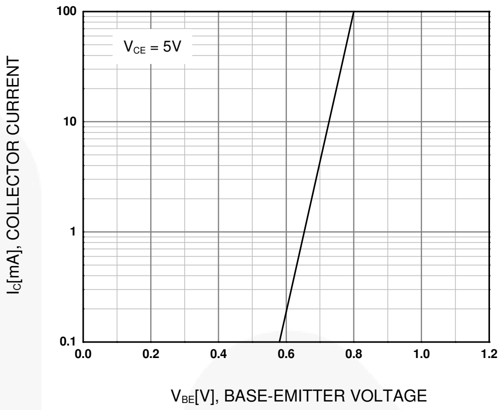


Figure 2. Transfer Characteristic

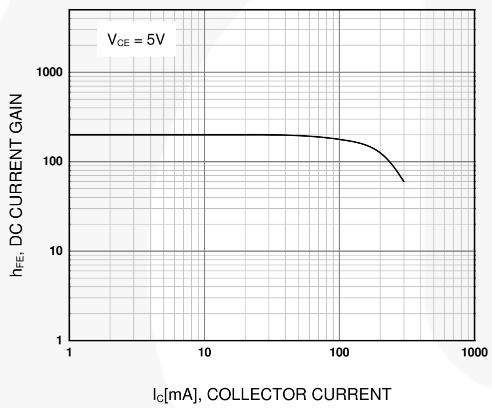


Figure 3. DC Current Gain

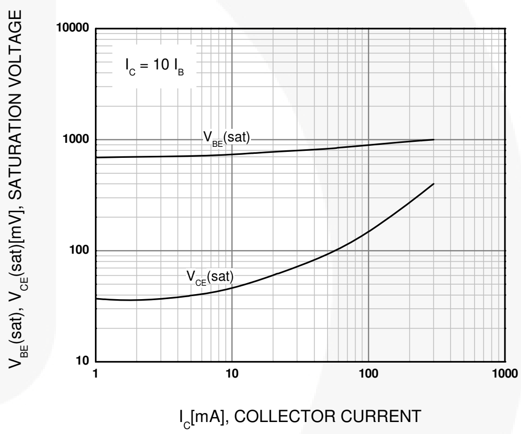


Figure 4. Base-Emitter Saturation Voltage and Collector-Emitter Saturation Voltage

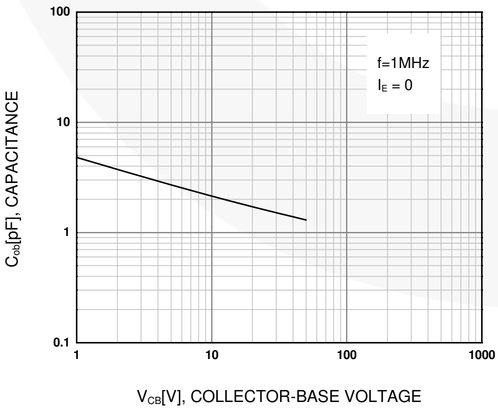


Figure 5. Output Capacitance

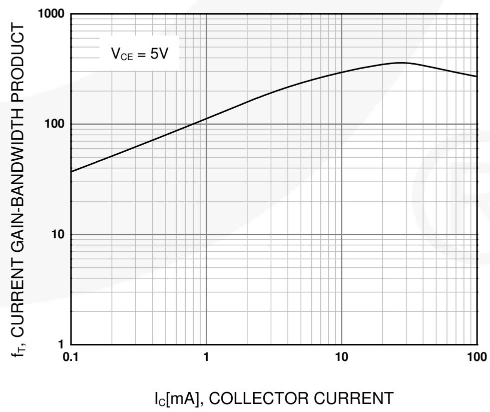
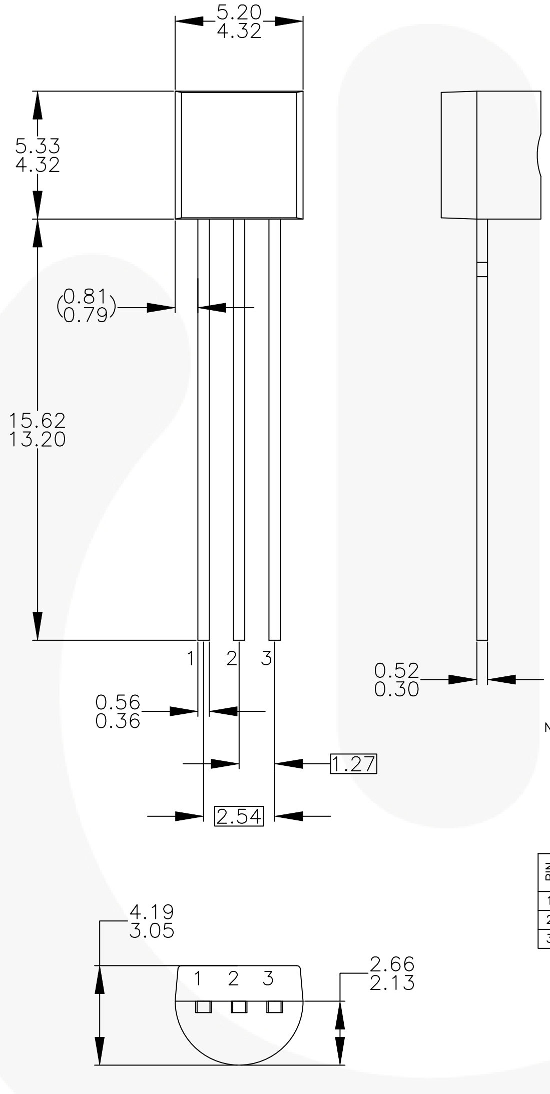


Figure 6. Current Gain Bandwidth Product

Physical Dimensions



NOTES: UNLESS OTHERWISE SPECIFIED

A) DRAWING WITH REFERENCE TO JEDEC TO-92 RECOMMENDATIONS.
B) ALL DIMENSIONS ARE IN MILLIMETERS.
C) DRAWING CONFORMS TO ASME Y14.5M-1994.
D) TO-92 (92,94,96,97,98) PIN CONFIGURATION:

PIN	92			94			96			97			98		
	P	F	M	P	F	M	B	F	M	P	F	M	P	F	M
1	E	S	S	E	S	S	B	D	G	C	G	D	C	G	D
2	B	D	G	C	G	D	E	S	S	B	D	G	E	S	S
3	C	G	D	B	D	G	C	G	D	E	S	S	B	D	G

LEGEND:
P - BIPOLAR
F - JFET
M - DMOS
E - EMITTER
B - BASE
C - COLLECTOR
D - DRAIN
S - SOURCE
G - GATE

E) FOR PACKAGE 92, 94, 96, 97 AND 98: PIN CONFIGURATION DRAIN "D" AND SOURCE "S" ARE INTERCHANGEAGLE AT JFET "F" OPTION.
F) DRAWING FILENAME: MKT-ZA03DREV3.

Figure 7. 3-Lead, TO-92, JEDEC TO-92 Compliant Straight Lead Configuration, Bulk Type

Physical Dimensions (Continued)

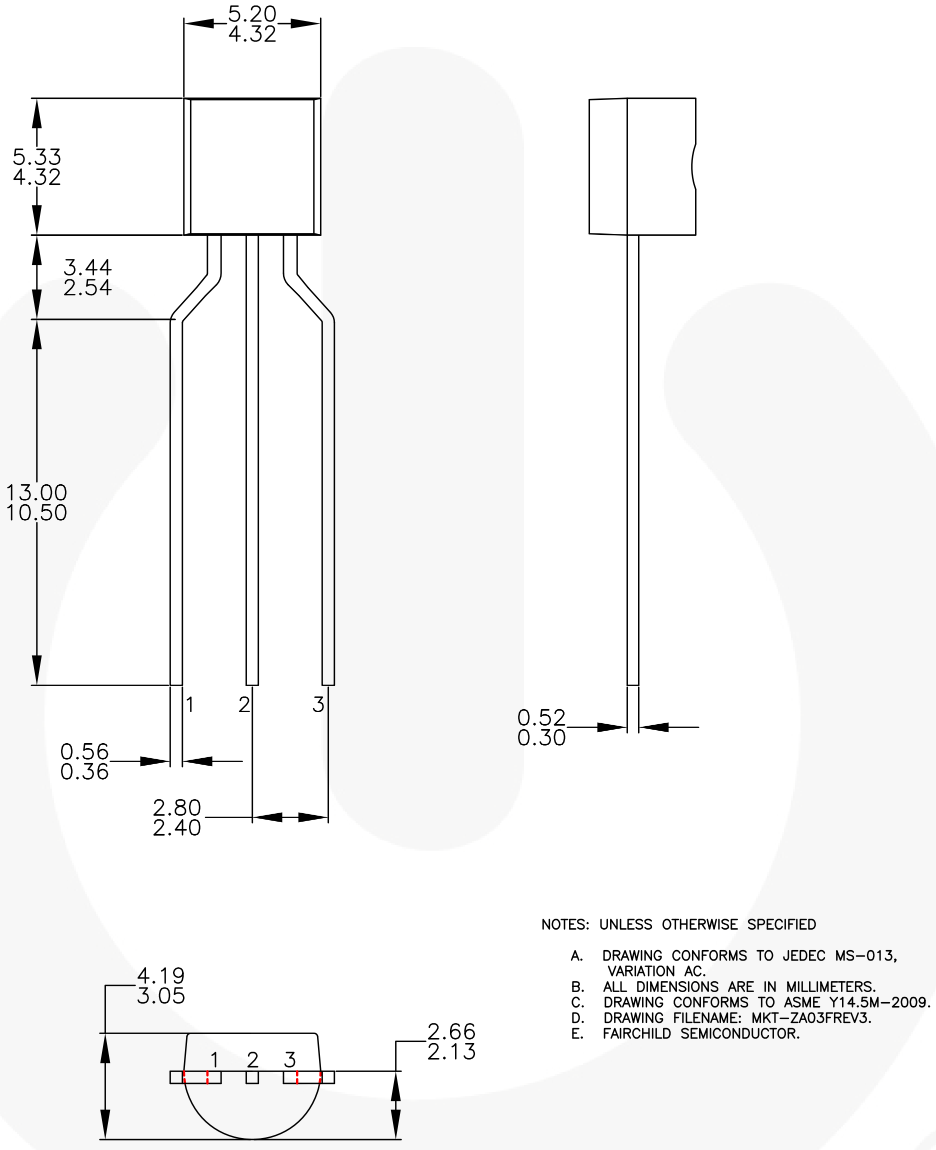


Figure 8. 3-Lead, TO-92, Molded, 0.2 In Line Spacing Lead Form, Ammo, Tape and Reel Type

absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

Supply voltage, V_{CC+} (see Note 1)		22 V
Supply voltage, V_{CC-} (see Note 1)		– 22 V
Input voltage, V_I		$V_{CC\pm}$
Duration of output short circuit		unlimited
Differential input current (see Note 2)		±25 mA
Continuous power dissipation		See Dissipation Rating Table
Operating free-air temperature range:	OP27A, OP27C, OP37A, OP37C	– 55°C to 125°C
	OP27E, OP27G, OP37E, OP37G	– 25°C to 85°C
Storage temperature range		– 65°C to 150°C
Lead temperature 1,6 mm (1/16 inch) from case for 60 seconds: JG or FK package		300°C
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds : P package		260°C

NOTES: 1. All voltage values are with respect to the midpoint between V_{CC+} and V_{CC-} unless otherwise noted.
2. The inputs are protected by back-to-back diodes. Current-limiting resistors are not used in order to achieve low noise. Excessive input current will flow if a differential input voltage in excess of approximately ± 0.7 V is applied between the inputs unless some limiting resistance is used.

DISSIPATION RATING TABLE

PACKAGE	$T_A \le 25°C$ POWER RATING	DERATING FACTOR ABOVE $T_A = 25°C$	$T_A = 85°C$ POWER RATING	$T_A = 125°C$ POWER RATING
JG	1050 mW	8.4 mW/°C	546 mW	210 mW
FK	1375 mW	11.0 mW/°C	715 mW	275 mW
P	1000 mW	8.0 mW/°C	520 mW	N/A

recommended operating conditions

		OP27A, OP37A			OP27C, OP37C			UNIT
		MIN	NOM	MAX	MIN	NOM	MAX	
Supply voltage, V_{CC+}		4	15	22	4	15	22	V
Supply voltage, V_{CC-}		–4	–15	–22	–4	–15	–22	V
Common-mode input voltage, V_{IC}	$V_{CC\pm} = \pm 15$ V, $T_A = 25°C$	±11			±11			V
	$V_{CC\pm} = \pm 15$ V, $T_A = -55°C$ to 125°C	±10.3			±10.2			
Operating free-air temperature, T_A		–55		125	–55		125	°C

electrical characteristics at specified free-air temperature, $V_{CC\pm} = \pm 15$ V (unless otherwise noted)

PARAMETER		TEST CONDITIONS	T_A†	OP27A, OP37A			OP27C, OP37C			UNIT
				MIN	TYP	MAX	MIN	TYP	MAX	
V_{IO}	Input offset voltage	$V_O = 0$, $V_{IC} = 0$, $R_S = 50\ \Omega$, See Note 3	25°C		10	25		30	100	µV
			Full range			60			300	
α_{VIO}	Average temperature coefficient of input offset voltage		Full range		0.2	0.6		0.4	1.8	µV/°C
	Long-term drift of input offset voltage	See Note 4			0.2	1		0.4	2	µV/mo
I_{IO}	Input offset current	$V_O = 0$, $V_{IC} = 0$	25°C		7	35		12	75	nA
			Full range			50			135	
I_{IB}	Input bias current	$V_O = 0$, $V_{IC} = 0$	25°C		±10	±40		±15	±80	nA
			Full range			±60			±150	
V_{ICR}	Common-mode input voltage range		25°C	11 to –11			11 to –11			V
			Full range	10.3 to –10.3			10.5 to –10.5			
V_{OM}	Peak output voltage swing	$R_L \geq 2$ kΩ		±12	±13.8		±11.5	±13.5		V
		$R_L \geq 0.6$ kΩ		±10	±11.5		±10	±11.5		
		$R_L \geq 2$ kΩ	Full range	±11.5			10.5			
A_{VD}	Large-signal differential voltage amplification	$R_L \geq 2$ kΩ, $V_O = \pm 10$ V		1000	1800		700	1500		V/mV
		$R_L \geq 1$ kΩ, $V_O = \pm 10$ V		800	1500			1500		
		$R_L \geq 0.6$ kΩ, $V_O = \pm 1$ V, $V_{CC\pm} = \pm 4$ V		250	700		200	500		
		$R_L \geq 2$ kΩ, $V_O = \pm 10$ V	Full range	600			300			
$r_{i(CM)}$	Common-mode input resistance				3			2		GΩ
r_o	Output resistance	$V_O = 0$, $I_O = 0$	25°C		70			70		Ω
CMRR	Common-mode rejection ratio	$V_{IC} = \pm 11$ V	25°C	114	126		100	120		dB
		$V_{IC} = \pm 10$ V	Full range	110			94			
k_{SVR}	Supply voltage rejection ratio	$V_{CC\pm} = \pm 4$ V to ±18 V	25°C	100	120		94	118		dB
		$V_{CC\pm} = \pm 4.5$ V to ±18 V	Full range	96			86			

† Full range is – 55°C to 125°C.

NOTES: 3. Input offset voltage measurements are performed by automatic test equipment approximately 0.5 seconds after applying power.
4. Long-term drift of input offset voltage refers to the average trend line of offset voltage versus time over extended periods after the first 30 days of operation. Excluding the initial hour of operation, changes in V_{IO} during the first 30 days are typically 2.5 µV (see Figure 3).

recommended operating conditions

		MIN	NOM	MAX	UNIT
Supply voltage, V_{CC+}		4	15	22	V
Supply voltage, V_{CC-}		−4	−15	−22	V
Common-mode input voltage, V_{IC}	$V_{CC\pm} = \pm15$ V, $T_A = 25°C$	±11			V
	$V_{CC\pm} = \pm15$ V, $T_A = -55°C$ to 125°C	±10.5			
Operating free-air temperature, T_A		−25		85	°C

electrical characteristics at specified free-air temperature, $V_{CC\pm} = \pm15$ V (unless otherwise noted)

PARAMETER		TEST CONDITIONS	T_A†	OP27E, OP37E			OP27G, OP37G			UNIT
				MIN	TYP	MAX	MIN	TYP	MAX	
V_{IO}	Input offset voltage	$V_O = 0$, $V_{IC} = 0$, $R_S = 50\ \Omega$, See Note 3	25°C		10	25		30	100	µV
			Full range			60			220	
αV_{IO}	Average temperature coefficient of input offset voltage		Full range		0.2	0.6		0.4	1.8	µV/°C
	Long-term drift of input offset voltage	See Note 4			0.2	1		0.4	2	µV/mo
I_{IO}	Input offset current	$V_O = 0$, $V_{IC} = 0$	25°C		7	35		12	75	nA
			Full range			50			135	
I_{IB}	Input bias current	$V_O = 0$, $V_{IC} = 0$	25°C		±10	±40		±15	±80	nA
			Full range			±60			±150	
V_{ICR}	Common-mode input voltage range		25°C	11 to −11			11 to −11			V
			Full range	10.3 to −10.3			10.5 to −10.5			
V_{OM}	Peak output voltage swing	$R_L \geq 2\ k\Omega$		±12	±13.8		±11.5	±13.5		V
		$R_L \geq 0.6\ k\Omega$		±10	±11.5		±10	±11.5		
		$R_L \geq 2\ k\Omega$	Full range	±11.5			10.5			
A_{VD}	Large-signal differential voltage amplification	$R_L \geq 2\ k\Omega$, $V_O = \pm10$ V		1000	1800		700	1500		V/mV
		$R_L \geq 1\ k\Omega$, $V_O = \pm10$ V		800	1500			1500		
		$R_L \geq 0.6\ k\Omega$, $V_O = \pm1$ V, $V_{CC\pm} = \pm4$ V		250	700		200	500		
		$R_L \geq 2\ k\Omega$, $V_O = \pm10$ V	Full range	600			450			
$r_{i(CM)}$	Common-mode input resistance				3			2		GΩ
r_o	Output resistance	$V_O = 0$, $I_O = 0$	25°C		70			70		Ω
CMRR	Common-mode rejection ratio	$V_{IC} = \pm11$ V	25°C	114	126		100	120		dB
		$V_{IC} = \pm10$ V	Full range	110			96			
k_{SVR}	Supply voltage rejection ratio	$V_{CC\pm} = \pm4$ V to ±18 V	25°C	100	120		94	118		dB
		$V_{CC\pm} = \pm4.5$ V to ±18 V	Full range	96			90			

† Full range is – 25°C to 85°C.

NOTES: 3. Input offset voltage measurements are performed by automatic test equipment approximately 0.5 seconds after applying power.
4. Long-term drift of input offset voltage refers to the average trend line of offset voltage versus time over extended periods after the first 30 days of operation. Excluding the initial hour of operation, changes in V_{IO} during the first 30 days are typically 2.5 µV (see Figure 3).

OP27 operating characteristics over operating free-air temperature range, $V_{CC\pm} = \pm 15$ V

PARAMETER		TEST CONDITIONS		OP27A, OP27E			OP27C, OP27G			UNIT
				MIN	TYP	MAX	MIN	TYP	MAX	
SR	Slew rate	$A_{VD} \geq 1$,	$R_L \geq 2$ kΩ	1.7	2.8		1.7	2.8		V/μs
$V_{N(PP)}$	Peak-to-peak equivalent input noise voltage	f = 0.1 Hz to 10 Hz, See Figure 34	$R_S = 20$ Ω,		0.08	0.18		0.09	0.25	μV
V_n	Equivalent input noise voltage	f = 10 Hz,	$R_S = 20$ Ω		3.5	5.5		3.8	8	nV/√Hz
		f = 30 Hz,	$R_S = 20$ Ω		3.1	4.5		3.3	5.6	
		f = 1 kHz,	$R_S = 20$ Ω		3	3.8		3.2	4.5	
I_n	Equivalent input noise current	f = 10 Hz,	See Figure 35		1.5	4		1.5		pA/√Hz
		f = 30 Hz,	See Figure 35		1	2.3		1		
		f = 1 kHz,	See Figure 35		0.4	0.6		0.4	0.6	
	Gain-bandwidth product	f = 100 kHz		5	8		5	8		MHz

OP37 operating characteristics over operating free-air temperature range, $V_{CC\pm} = \pm 15$ V

PARAMETER		TEST CONDITIONS		OP37A, OP37E			OP37C, OP37G			UNIT
				MIN	TYP	MAX	MIN	TYP	MAX	
SR	Slew rate	$A_{VD} \geq 5$,	$R_L \geq 2$ kΩ	11	17		11	17		V/μs
$V_{N(PP)}$	Peak-to-peak equivalent input noise voltage	f = 0.1 Hz to 10 Hz, See Figure 34	$R_S = 20$ Ω,		0.08	0.18		0.09	0.25	μV
V_n	Equivalent input noise voltage	f = 10 Hz,	$R_S = 20$ Ω		3.5	5.5		3.8	8	nV/√Hz
		f = 30 Hz,	$R_S = 20$ Ω		3.1	4.5		3.3	5.6	
		f = 1 kHz,	$R_S = 20$ Ω		3	3.8		3.2	4.5	
I_n	Equivalent input noise current	f = 10 Hz,	See Figure 35		1.5	4		1.5		pA/√Hz
		f = 30 Hz,	See Figure 35		1	2.3		1		
		f = 1 kHz,	See Figure 35		0.4	0.6		0.4	0.6	
	Gain-bandwidth product	f = 10 kHz		45	63		45	63		MHz
		$A_V \geq 5$,	f = 1 MHz		40			40		

TYPICAL CHARACTERISTICS

Table of Graphs

			FIGURE
V_{IO}	Input offset voltage	vs Temperature	1
ΔV_{IO}	Change in input offset voltage	vs Time after power on vs Time (long-term drift)	2 3
I_{IO}	Input offset current	vs Temperature	4
I_{IB}	Input bias current	vs Temperature	5
V_{ICR}	Common-mode input voltage range	vs Supply voltage	6
V_{OM}	Maximum peak output voltage	vs Load resistance	7
$V_{O(PP)}$	Maximum peak-to-peak output voltage	vs Frequency	8, 9
A_{VD}	Differential voltage amplification	vs Supply voltage vs Load resistance vs Frequency	10 11 12, 13, 14
CMRR	Common-mode rejection ratio	vs Frequency	15
k_{SVR}	Supply voltage rejection ratio	vs Frequency	16
SR	Slew rate	vs Temperature vs Supply voltage vs Load resistance	17 18 19
ϕ_m	Phase margin	vs Temperature	20, 21
ϕ	Phase shift	vs Frequency	12, 13
V_n	Equivalent input noise voltage	vs Bandwidth vs Source resistance vs Supply voltage vs Temperature vs Frequency	22 23 24 25 26
I_n	Equivalent input noise current	vs Frequency	27
	Gain-bandwidth product	vs Temperature	20, 21
I_{OS}	Short-circuit output current	vs Time	28
I_{CC}	Supply current	vs Supply voltage	29
	Pulse response	Small signal Large signal	30, 32 31, 33

TYPICAL CHARACTERISTICS†

INPUT OFFSET VOLTAGE OF REPRESENTATIVE INDIVIDUAL UNITS vs FREE-AIR TEMPERATURE

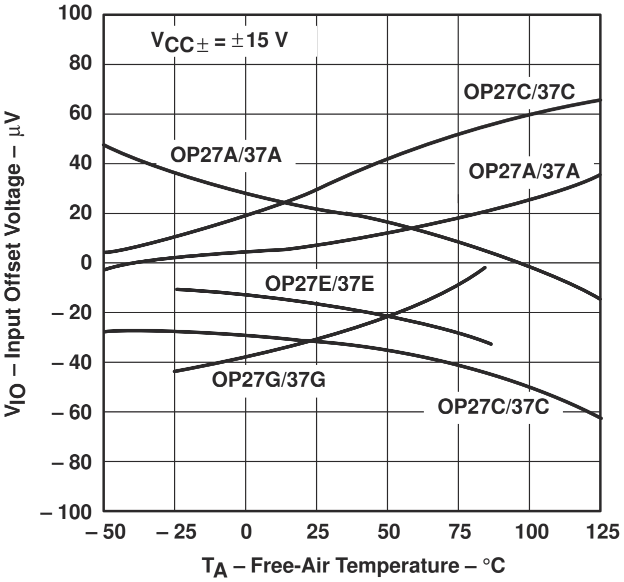


Figure 1

WARM-UP CHANGE IN INPUT OFFSET VOLTAGE vs ELAPSED TIME

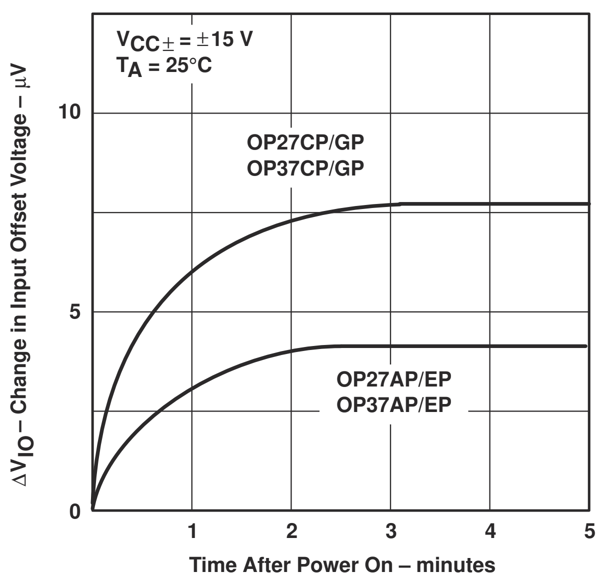


Figure 2

LONG-TERM DRIFT OF INPUT OFFSET VOLTAGE OF REPRESENTATIVE INDIVIDUAL UNITS

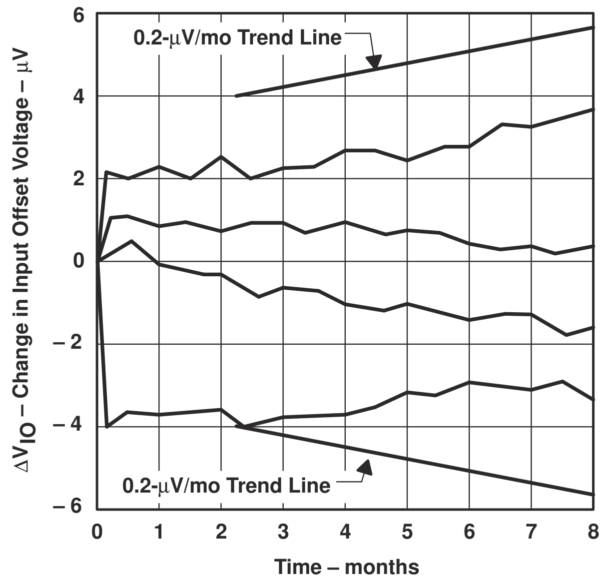


Figure 3

† Data for temperatures below – 25°C and above 85°C are applicable to the OP27A, OP27C, OP37A, and OP37C only.

TYPICAL CHARACTERISTICS†

INPUT OFFSET CURRENT vs FREE-AIR TEMPERATURE

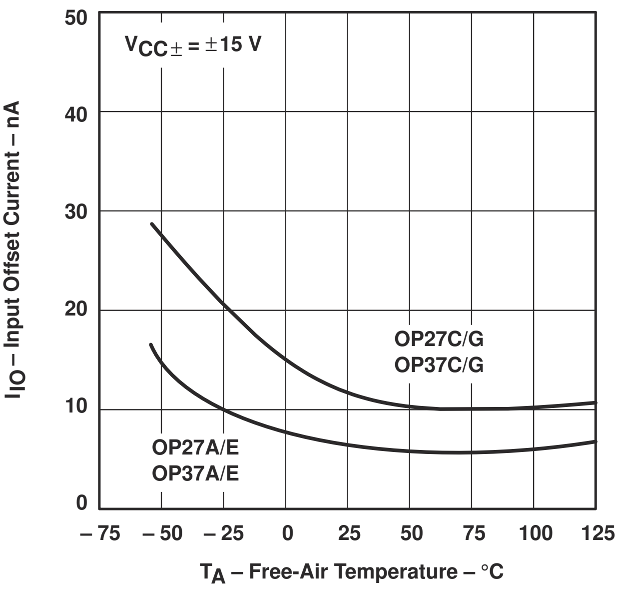


Figure 4

INPUT BIAS CURRENT vs FREE-AIR TEMPERATURE

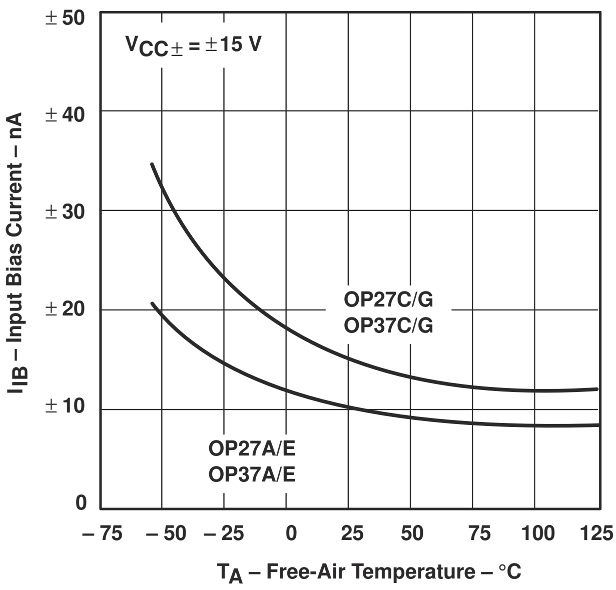


Figure 5

COMMON-MODE INPUT VOLTAGE RANGE LIMITS vs SUPPLY VOLTAGE

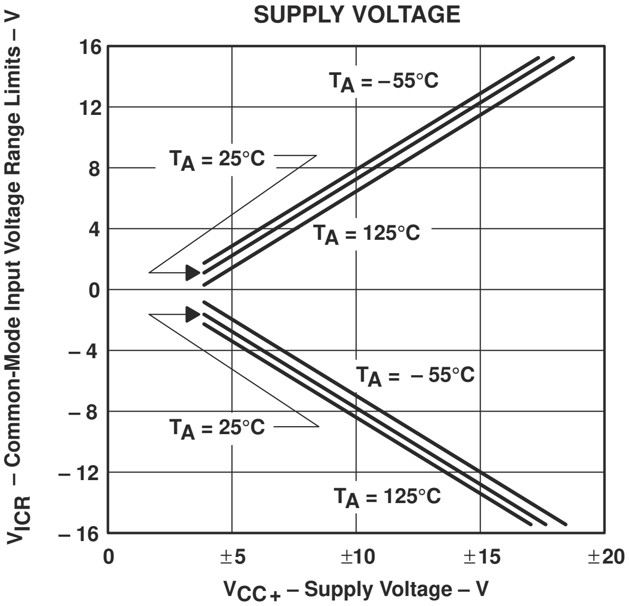


Figure 6

MAXIMUM PEAK OUTPUT VOLTAGE vs LOAD RESISTANCE

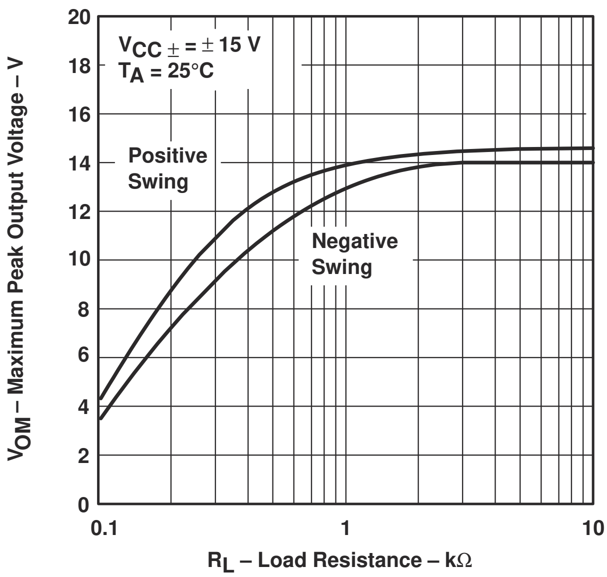


Figure 7

† Data for temperatures below – 25°C and above 85°C are applicable to the OP27A, OP27C, OP37A, and OP37C only.

TYPICAL CHARACTERISTICS

OP27
MAXIMUM PEAK-TO-PEAK OUTPUT VOLTAGE vs FREQUENCY

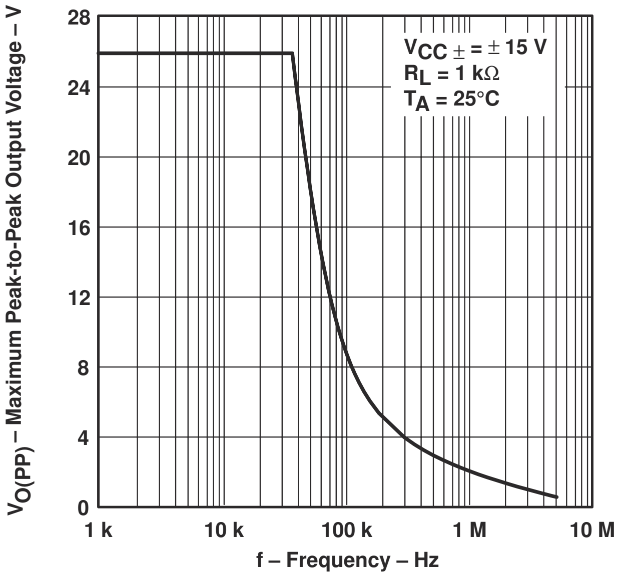


Figure 8

OP37
MAXIMUM PEAK-TO-PEAK OUTPUT VOLTAGE vs FREQUENCY

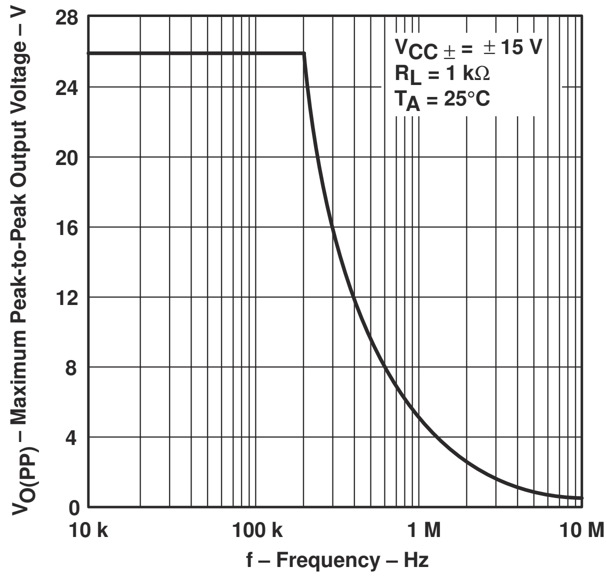


Figure 9

OP27A, OP27E, OP37A, OP37E
LARGE-SIGNAL DIFFERENTIAL VOLTAGE AMPLIFICATION vs TOTAL SUPPLY VOLTAGE

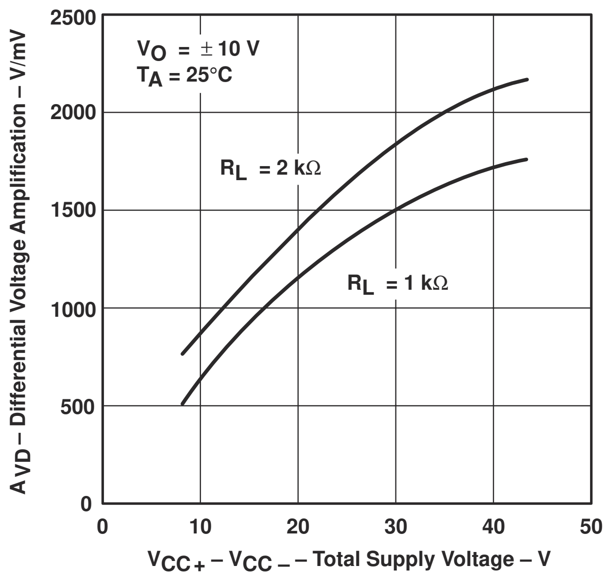


Figure 10

OP27A, OP27E, OP37A, OP37E
LARGE-SIGNAL DIFFERENTIAL VOLTAGE AMPLIFICATION vs LOAD RESISTANCE

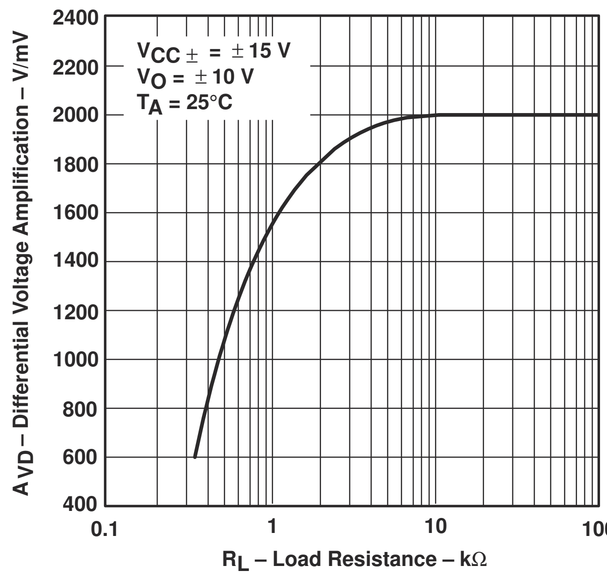


Figure 11

TYPICAL CHARACTERISTICS

OP27
LARGE-SIGNAL DIFFERENTIAL VOLTAGE AMPLIFICATION AND PHASE SHIFT vs FREQUENCY

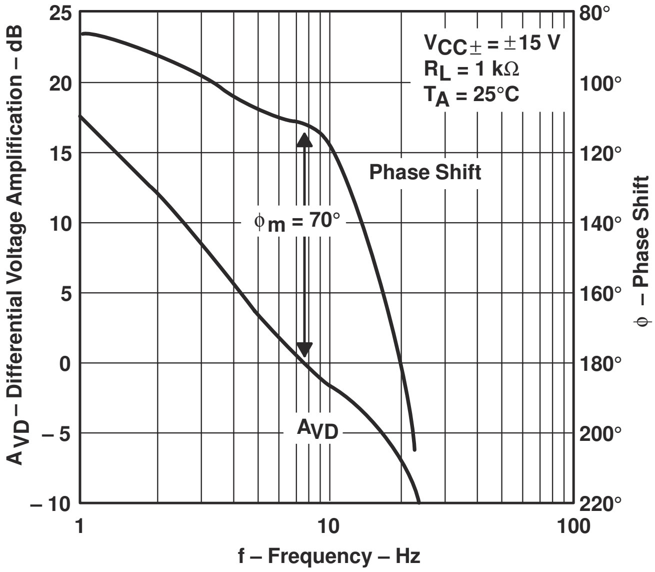


Figure 12

OP37
LARGE-SIGNAL DIFFERENTIAL VOLTAGE AMPLIFICATION AND PHASE SHIFT vs FREQUENCY

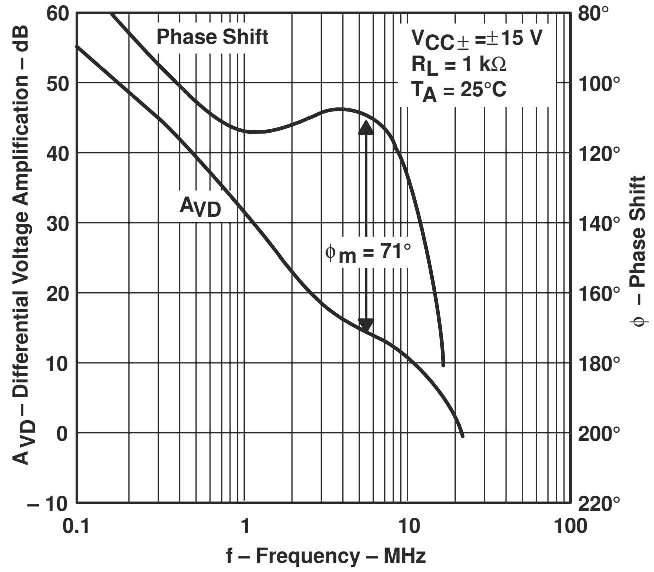


Figure 13

OP27A, OP27E, OP37A, OP37E
LARGE-SIGNAL DIFFERENTIAL VOLTAGE AMPLIFICATION vs FREQUENCY

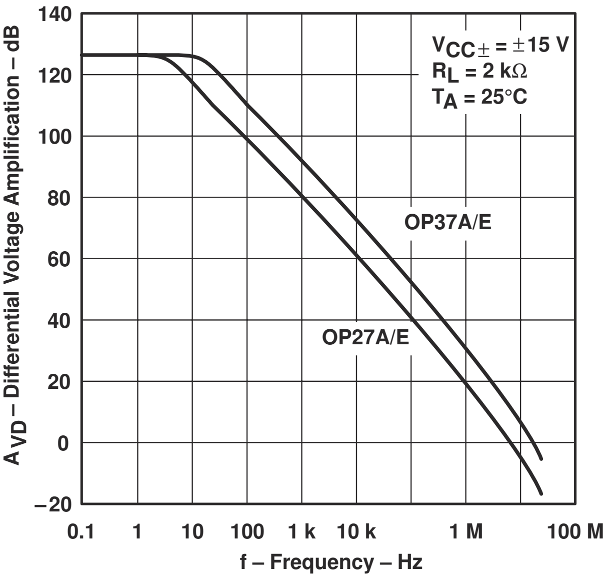


Figure 14

OP27A, OP27E, OP37A, OP37E
COMMON-MODE REJECTION RATIO vs FREQUENCY

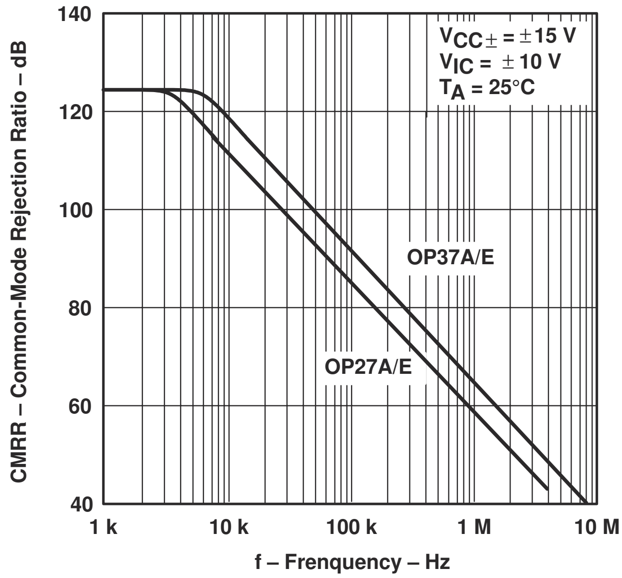


Figure 15

TYPICAL CHARACTERISTICS†

SUPPLY VOLTAGE REJECTION RATIO vs FREQUENCY

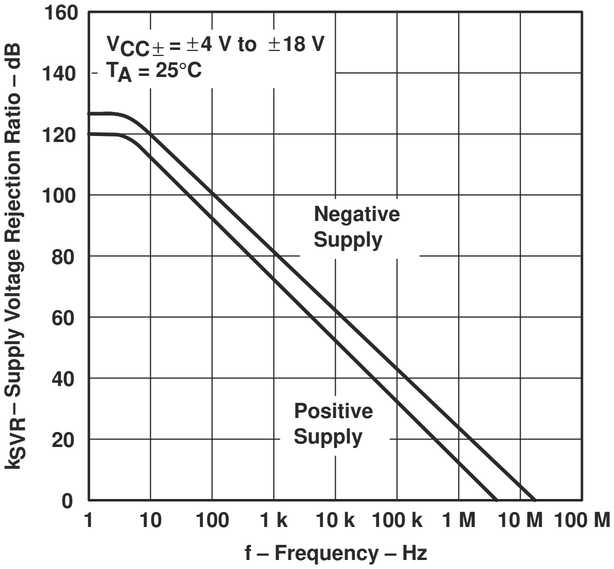


Figure 16

SLEW RATE vs FREE-AIR TEMPERATURE

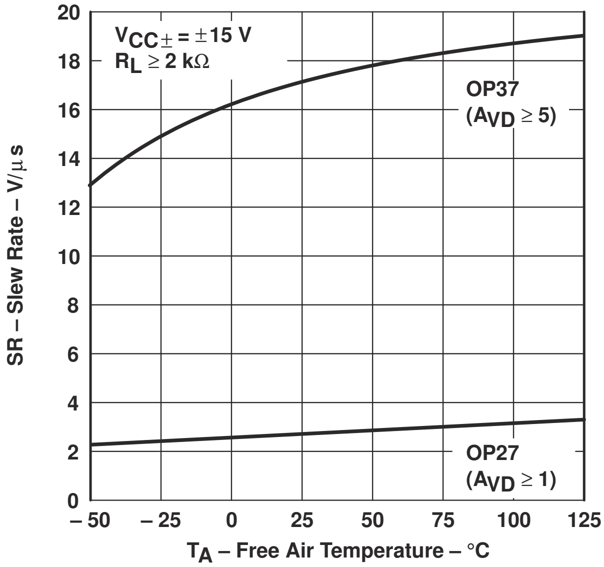


Figure 17

OP37 SLEW RATE vs SUPPLY VOLTAGE

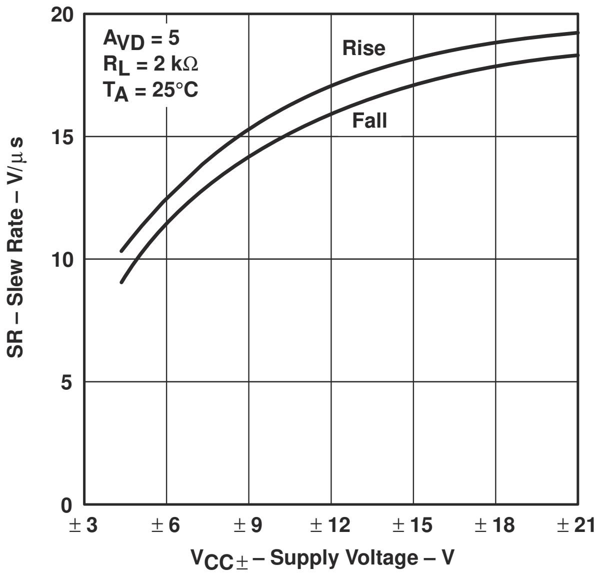


Figure 18

OP37 SLEW RATE vs LOAD RESISTANCE

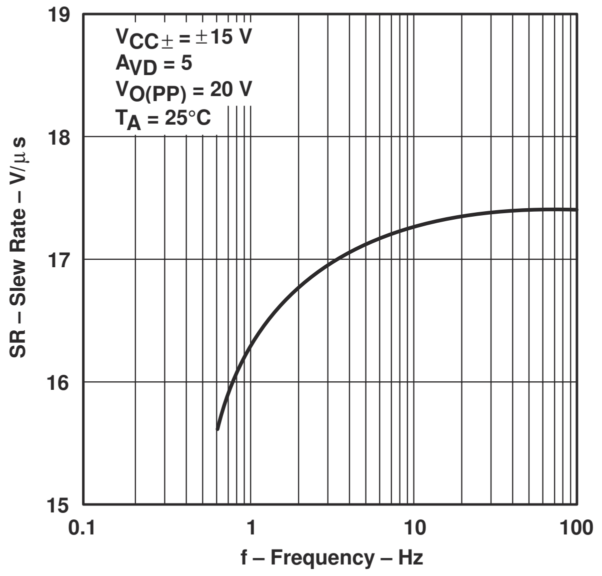


Figure 19

† Data for temperatures below – 25°C and above 85°C are applicable to the OP27A, OP27C, OP37A, and OP37C only.

TYPICAL CHARACTERISTICS†

OP27
PHASE MARGIN AND GAIN-BANDWIDTH PRODUCT vs FREE-AIR TEMPERATURE

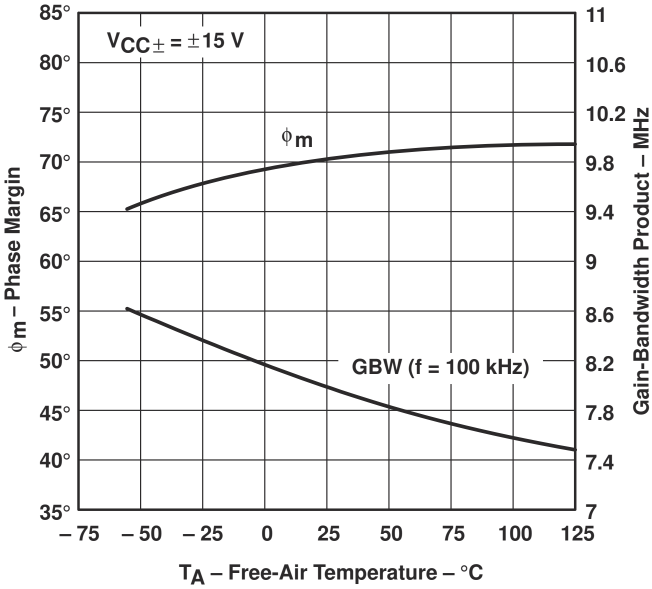


Figure 20

OP37
PHASE MARGIN AND GAIN-BANDWIDTH PRODUCT vs FREE-AIR TEMPERATURE

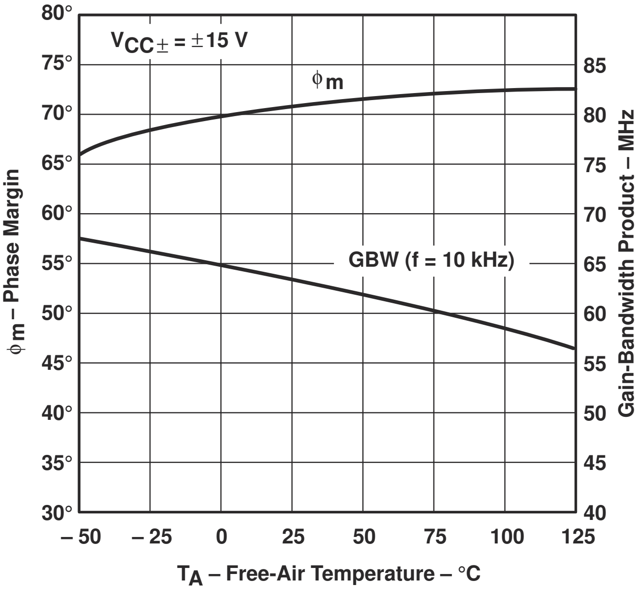


Figure 21

EQUIVALENT INPUT NOISE VOLTAGE vs BANDWIDTH

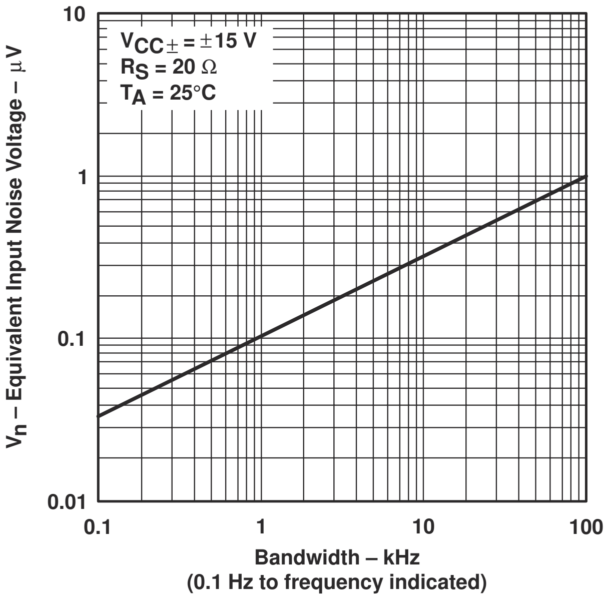


Figure 22

TOTAL EQUIVALENT INPUT NOISE VOLTAGE vs SOURCE RESISTANCE

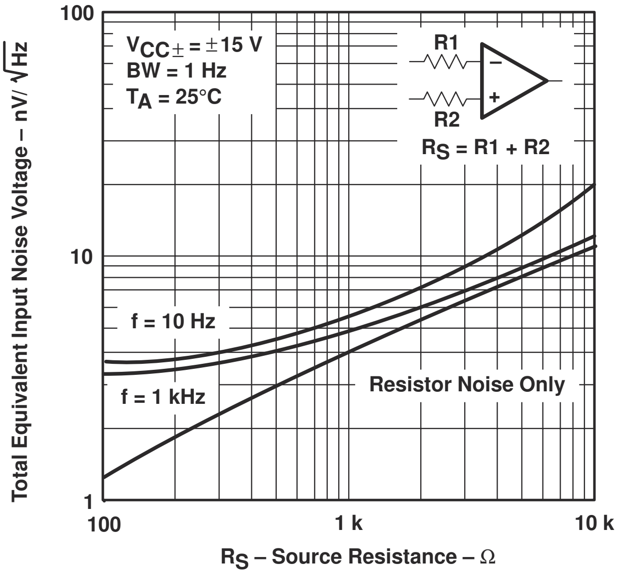


Figure 23

† Data for temperatures below – 25°C and above 85°C are applicable to the OP27A, OP27C, OP37A, and OP37C only.

TYPICAL CHARACTERISTICS†

OP27A, OP27E, OP37A, OP37E
EQUIVALENT INPUT NOISE VOLTAGE vs TOTAL SUPPLY VOLTAGE

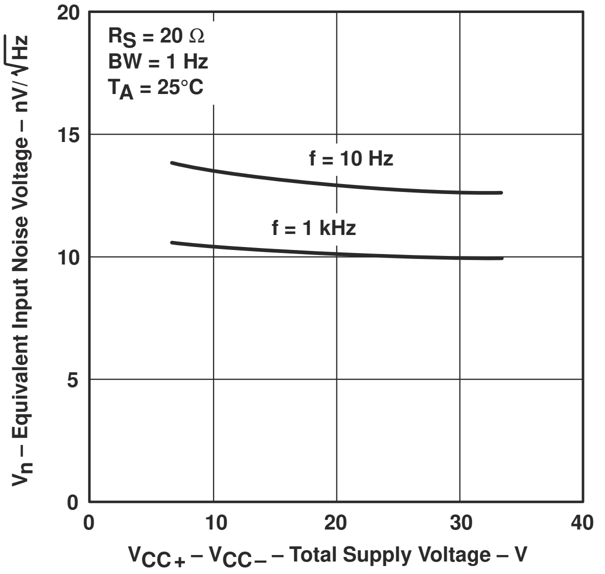


Figure 24

OP27A, OP27E, OP37A, OP37E
EQUIVALENT INPUT NOISE VOLTAGE vs FREE-AIR TEMPERATURE

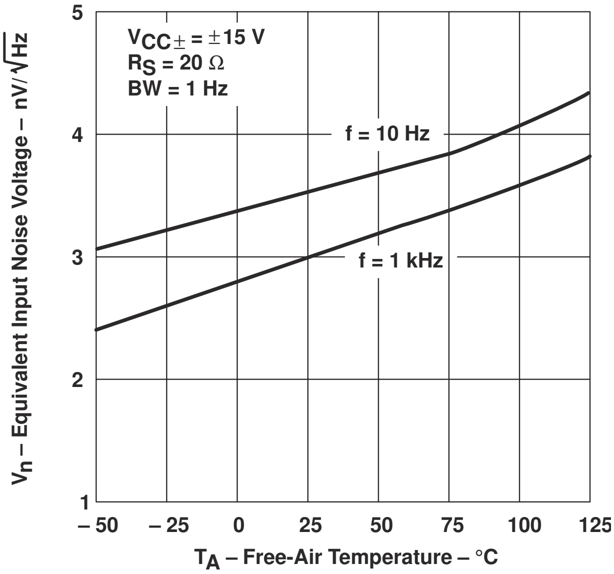


Figure 25

OP27A, OP27E, OP37A, OP37E
EQUIVALENT INPUT NOISE VOLTAGE vs FREQUENCY

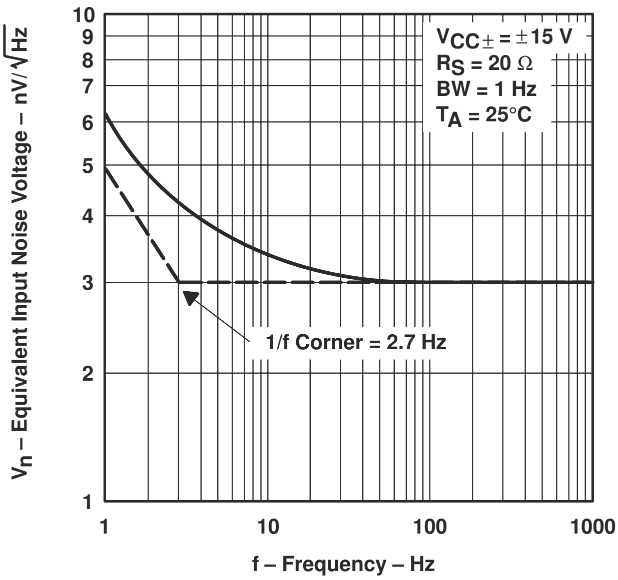


Figure 26

EQUIVALENT INPUT NOISE CURRENT vs FREQUENCY

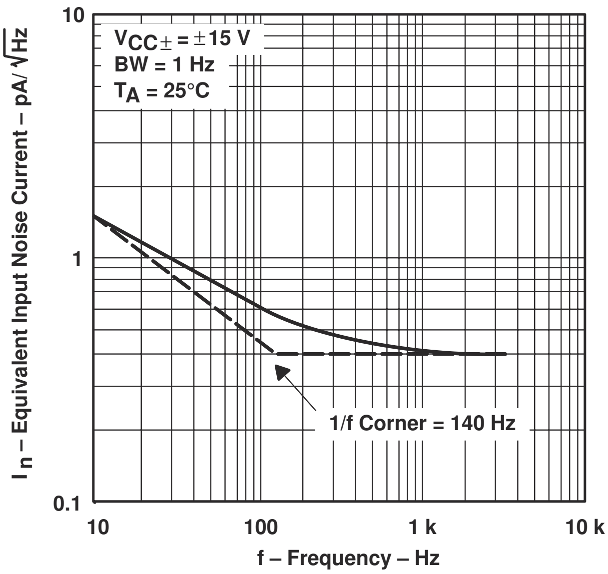


Figure 27

† Data for temperatures below – 25°C and above 85°C are applicable to the OP27A, OP27C, OP37A, and OP37C only.