

Appendices

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Appendix 1-1

1N914 through 1N917 Switching Diodes

absolute maximum ratings at 25°C ambient temperature (unless otherwise noted)

V_R	Reverse Voltage at -65 to +150°C
I_A	Average Rectified Fwd. Current
I_{A1}	Average Rectified Fwd. Current at -150°C
i_R	Recurrent Peak Fwd. Current
$i_{R(surge)}$	Surge Current, 1 sec
P	Power Dissipation
T_A	Operating Temperature Range
T_{stg}	Storage Temperature Range

1N914	1N914A	1N914B	1N915	1N916	1N916A	1N916B	1N917	Unit	
75	75	75	50	75	75	75	30	v	
75	75	75	75	75	75	75	50	ma	
10	10	10	10	10	10	10	10	ma	
225	225	225	225	225	225	225	150	ma	
500	500	500	500	500	500	500	300	ma	
250	250	250	250	250	250	250	250	mw	
								-65 to +175	°C
								200	°C

maximum electrical characteristics at 25°C ambient temperature (unless otherwise noted)

BV_R	Min Breakdown Voltage at 100 μ a
I_R	Reverse Current at V_R
I_{R1}	Reverse Current at -20 v
I_{R2}	Reverse Current at -20 v at 100°C
I_{R3}	Reverse Current at -20 v at -150°C
I_{R4}	Reverse Current at -10 v
I_{R5}	Reverse Current at -10 v at 125°C
I_F	Min Fwd Current at $V_F = 1$ v
V_F	at 250 μ a
V_F	at 1.5 ma
V_F	at 3.5 ma
V_F	at 5 ma
V_F	Min at 5 ma
C	Capacitance at $V_R = 0$

100	100	100	65	100	100	100	40	v
5	5	5	5	5	5	5		μ a
0.025	0.025	0.025		0.025	0.025	0.025		μ a
3	3	3	5	3	3	3	25	μ a
50	50	50		50	50	50		μ a
			0.025				0.05	μ a
								μ a
10	20	100	50	10	20	30	10	ma
							0.64	v
							0.74	v
							0.83	v
		0.72	0.73			0.73		v
			0.60					v
4	4	4	4	2	2	2	2.5	pf

operating characteristics at 25°C ambient temperature (unless otherwise noted)

t_{rr}	Max Reverse Recovery Time
V_r	Fwd Recovery Voltage (50 ma Peak Sq. wave, 0.1 μ sec pulse width, 10 nsec rise time, 5 kc to 100 kc rep. rate)

**4	**4	**4	*10	**4	**4	**4	*3	nsec
%	%	%		%	%	%		nsec
2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	v

* Trademark of Texas Instruments

* Lumatron (10 ma I_F , 10 ma I_R , recover to 1 ma)** EGCC (10 ma I_F , 6x V_R , recover to 1 ma)

Appendix 1-2

1N4001 through 1N4007 Rectifier Diodes



CASE 59

Low-current, passivated silicon rectifiers in subminiature void-free, flame-proof silicone polymer case. Designed to operate under military environmental conditions.

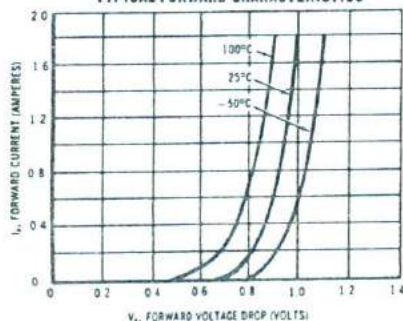
MAXIMUM RATINGS (At 60 cps Sinusoidal Input, Resistive or Inductive Load)

Rating	Symbol	1N4001	1N4002	1N4003	1N4004	1N4005	1N4006	1N4007	Unit
Peak Repetitive Reverse Voltage DC Blocking Voltage	$V_{RM(rep)}$ V_R	50	100	200	400	600	800	1000	Volts
RMS Reverse Voltage	V_r	35	70	140	280	420	560	700	Volts
Average Half-Wave Rectified Forward Current (75°C Ambient) (100°C Ambient)	I_O	1000 750	1000 750	1000 750	1000 750	1000 750	1000 750	1000 750	mA mA
Peak Surge Current 25°C (1/2 Cycle Surge, 60 cps)	$I_{FM(surge)}$	30	30	30	30	30	30	30	Amps
Peak Repetitive Forward Current	$I_{FM(rep)}$	10	10	10	10	10	10	10	Amps
Operating and Storage Temperature Range	T_J, T_{stg}	-65 to +175							°C

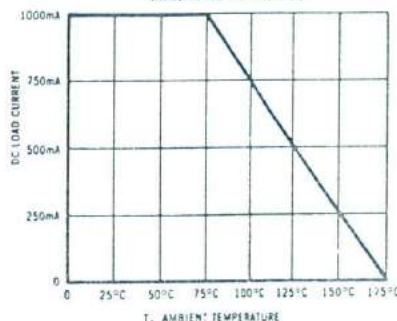
ELECTRICAL CHARACTERISTICS

Characteristic	Symbol	Rating	Unit
Maximum Forward Voltage Drop (1 Amp Continuous DC, 25°C)	V_F	1.1	Volts
Maximum Full-Cycle Average Forward Voltage Drop (Rated Current @ 25°C)	$V_{F(AV)}$	0.8	Volts
Maximum Reverse Current @ Rated DC Voltage (25°C) (100°C)	I_R	0.01 0.05	mA
Maximum Full-Cycle Average Reverse Current (Max Rated PIV and Current, as Half-Wave Rectifier, Resistive Load, 100°C)	$I_{R(AV)}$	0.03	mA

TYPICAL FORWARD CHARACTERISTICS



MAXIMUM DC OUTPUT



Appendix 1-3

1N5391 through 1N5399 Low-power Rectifiers

*MAXIMUM RATINGS

Rating	Symbol	1N5391	1N5392	1N5393	1N5395	1N5397	1N5398	1N5399	Unit
Peak Repetitive Reverse Voltage	VRRM	50	100	200	400	600	800	1000	Volts
Working Peak Reverse Voltage	VRWM								
DC Blocking Voltage	VR								
Nonrepetitive Peak Reverse Voltage (Halfwave, Single Phase, 60 Hz)	VRSM	100	200	300	525	800	1000	1200	Volts
RMS Reverse Voltage	VR(RMS)	35	70	140	280	420	560	700	Volts
Average Rectified Forward Current (Single Phase, Resistive Load, 60 Hz, $T_L = 70^\circ\text{C}$, 1/2" From Body)	I_O	1.5							Amp
Nonrepetitive Peak Surge Current (Surge Applied at Rated Load Conditions. See Figure 2)	IFSM	50 (for 1 cycle)							Amp
Storage Temperature Range	T_{stg}	-65 to +175							$^\circ\text{C}$
Operating Temperature Range	T_L	-65 to +170							$^\circ\text{C}$
DC Blocking Voltage Temperature	T_L	-150							$^\circ\text{C}$

*ELECTRICAL CHARACTERISTICS

Characteristic and Conditions	Symbol	Typ	Max	Unit
Maximum Instantaneous Forward Voltage Drop ($I_F = 4.7$ Amp Peak, $T_L = 170^\circ\text{C}$, 1/2 Inch Leads)	vF	-	1.4	Volts
Maximum Reverse Current (Rated dc Voltage) ($T_L = 50^\circ\text{C}$)	I_R	250	300	μA
Maximum Forward-Cycle Average Reverse Current (1) ($I_{RG} = 1.5$ Amp, $T_L = 170^\circ\text{C}$, 1/2 Inch Leads)	$I_{R(AV)}$	-	300	μA

* Courtesy of Motorola, Inc.

Appendix 1-4

Zener Diodes: 1N745 thru 1N759, 1N957A thru 1N986A, 1N4370 thru 1N4372

MAXIMUM RATINGS

Rating	Symbol	Value	Unit
DC Power Dissipation @ $T_L = 50^\circ\text{C}$, Lead Length = 1.8 *JEDEC Registration *Derate above $T_L = 50^\circ\text{C}$ Motorola Device Ratings Derate above $T_L = 50^\circ\text{C}$	P_D	400 3.2 500 3.33	mW mW/ $^\circ\text{C}$ mW mW/ $^\circ\text{C}$
Operating and Storage Junction Temperature Range *JEDEC Registration Motorola Device Ratings	T_J, T_{stg}	-65 to +175 -65 to +200	$^\circ\text{C}$

*Indicates JEDEC Registered Data

ELECTRICAL CHARACTERISTICS ($T_A = 25^\circ\text{C}$, $V_F = 1.5\text{ V}$ max at 200 μA for all types)

Type Number (Note 1)	Nominal Zener Voltage $V_Z @ I_{ZT}$ (Note 2) Volts	Test Current I_{ZT} mA	Maximum Zener Impedance (Note 3)		*Maximum DC Zener Current I_{ZM} (Note 4) mA	Maximum Reverse Leakage Current		
			$Z_{ZT} @ I_{ZT}$ Ohms	$Z_{ZK} @ I_{ZK}$ Ohms		$T_A = 25^\circ\text{C}$ $I_R @ V_R = 1\text{ V}$ μA	$T_A = 150^\circ\text{C}$ $I_R @ V_R = 1\text{ V}$ μA	
1N4370	2.4	20	30		150	190	100	200
1N4371	2.7	20	30		135	165	75	150
1N4372	3.0	20	29		120	150	50	100
1N746	3.3	20	28		110	135	10	30
1N747	3.6	20	24		100	125	10	30
1N748	3.9	20	23		95	115	10	30
1N749	4.3	20	22		85	105	2	30
1N750	4.7	20	19		75	95	2	30
1N751	5.1	20	17		70	85	1	20
1N752	5.6	20	11		65	80	1	20
1N753	6.2	20	7		60	70	0.1	20
1N754	6.8	20	5		55	65	0.1	20
1N755	7.5	20	6		50	60	0.1	20
1N756	8.2	20	8		45	55	0.1	20
1N757	9.1	20	10		40	50	0.1	20
1N758	10	20	17		35	45	0.1	20
1N759	12	20	30		30	35	0.1	20

Type Number (Note 1)	Nominal Zener Voltage V_Z (Note 2) Volts	Test Current I_{ZT} mA	Maximum Zener Impedance (Note 3)			*Maximum DC Zener Current I_{ZM} (Note 4) mA	Maximum Reverse Current			
			$Z_{ZT} @ I_{ZT}$ Ohms	$Z_{ZK} @ I_{ZK}$ Ohms	I_{ZK} mA		I_R Maximum μA	Test Voltage V_R	Vdc 10%	
1N957A	6.8	18.5	4.5	700	1.0	4.7	61	150	5.2	4.9
1N958A	7.5	16.5	5.5	700	0.5	4.2	55	75	5.7	5.4
1N959A	8.2	15	6.5	700	0.5	3.8	50	50	6.2	5.9
1N960A	9.1	14	7.5	700	0.5	3.5	45	25	6.9	6.6
1N961A	10	12.5	8.5	700	0.25	3.2	41	10	7.6	7.0
1N962A	11	11.5	9.5	700	0.25	2.8	3.7	5	8.4	8.0
1N963A	12	10.5	11.5	700	0.25	2.6	3.4	5	9.1	8.6
1N964A	13	9.5	13	700	0.25	2.4	3.2	5	9.9	9.4
1N965A	15	8.5	16	700	0.25	2.1	2.7	5	11.4	10.8
1N966A	16	7.8	17	700	0.25	1.9	3.7	5	12.2	11.5
1N967A	18	7.0	21	750	0.25	1.7	2.3	5	13.7	13.0
1N968A	20	6.2	25	750	0.25	1.5	2.0	5	15.2	14.4
1N969A	22	5.6	29	750	0.25	1.4	1.8	5	16.7	15.8
1N970A	24	5.2	33	750	0.25	1.3	1.7	5	18.2	17.1
1N971A	27	4.6	41	750	0.25	1.1	1.5	5	20.6	19.4
1N972A	30	4.2	49	1000	0.25	1.0	1.3	5	22.8	21.6
1N973A	33	3.8	58	1000	0.25	0.9	1.2	5	25.1	23.8
1N974A	36	3.4	70	1000	0.25	0.8	1.1	5	27.4	25.9
1N975A	39	3.2	80	1000	0.25	0.8	1.0	5	29.7	28.1
1N976A	43	3.0	93	1500	0.25	0.7	0.9	5	32.7	31.0
1N977A	47	2.7	105	1500	0.25	0.6	0.8	5	35.8	33.0
1N978A	51	2.5	125	1500	0.25	0.5	0.8	5	38.8	36.1
1N979A	56	2.2	150	2000	0.25	0.4	0.7	5	42.6	40.2
1N980A	62	2.0	185	2000	0.25	0.4	0.7	5	47.1	44.6
1N981A	68	1.8	230	2000	0.25	0.4	0.6	5	51.7	49.0
1N982A	75	1.7	270	2000	0.25	0.3	0.5	5	55.0	54.0
1N983A	82	1.5	330	3000	0.25	0.3	0.5	5	62.2	59.0
1N984A	91	1.4	400	3000	0.25	0.3	0.4	5	69.2	65.5
1N985A	100	1.3	500	3000	0.25	0.3	0.4	5	76	72
1N986A	110	1.1	750	4000	0.25	0.2	0.4	5	83.6	79.2

NOTE 1. TOLERANCE AND VOLTAGE DESIGNATION

Tolerance Designation

The type numbers shown have tolerance designations as follows:

1N4370 series: $\pm 10\%$, suffix A for $\pm 5\%$ units,
C for $\pm 2\%$, D for $\pm 1\%$.

1N746 series: $\pm 10\%$, suffix A for $\pm 5\%$ units,
C for $\pm 2\%$, D for $\pm 1\%$.

1N957 series: $\pm 10\%$, suffix A for $\pm 10\%$ units,
C for $\pm 2\%$, D for $\pm 1\%$,
suffix B for $\pm 5\%$ units,
C for $\pm 2\%$, D for $\pm 1\%$.

Appendix 1-5

2N3903 and 2N3904 NPN BJTs

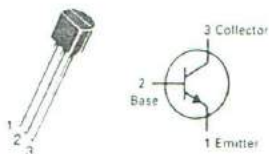
MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector-Emitter Voltage	V_{CE0}	40	Vdc
Collector-Base Voltage	V_{CBO}	60	Vdc
Emitter-Base Voltage	V_{EBO}	6.0	Vdc
Collector Current — Continuous	I_C	200	mA dc
Total Device Dissipation \ddagger $T_A = 25^\circ\text{C}$ Derate above 25°C	P_D	625 5.0	mW mW/°C
*Total Device Dissipation \ddagger $T_C = 25^\circ\text{C}$ Derate above 25°C	P_D	1.5 12	Watts mW/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-55 to +150	°C

*THERMAL CHARACTERISTICS

Characteristic	Symbol	Max	Unit
Thermal Resistance, Junction to Case	$R_{\theta JC}$	83.3	°C/W
Thermal Resistance, Junction to Ambient	$R_{\theta JA}$	200	°C/W

†Indicates Data in addition to JEDEC Requirements.

2N3903
2N3904CASE 29-04, STYLE 1
TO-92 (TO-226AA)GENERAL PURPOSE
TRANSISTORS

NPN SILICON

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

Characteristic	Symbol	Min	Max	Unit
OFF CHARACTERISTICS				
Collector-Emitter Breakdown Voltage(1) ($I_C = 1.0\text{ mA dc}, I_B = 0$)	$V_{(BR)CEO}$	40	—	Vdc
Collector-Base Breakdown Voltage ($I_C = 10\text{ }\mu\text{A dc}, I_E = 0$)	$V_{(BR)CBO}$	60	—	Vdc
Emitter-Base Breakdown Voltage ($I_E = 10\text{ }\mu\text{A dc}, I_C = 0$)	$V_{(BR)EBO}$	6.0	—	Vdc
Base Cutoff Current ($V_{CE} = 30\text{ Vdc}, V_{EB} = 3.0\text{ Vdc}$)	I_{BL}	—	50	nA dc
Collector Cutoff Current ($V_{CE} = 30\text{ Vdc}, V_{EB} = 3.0\text{ Vdc}$)	I_{CEX}	—	50	nA dc
ON CHARACTERISTICS				
DC Current Gain(1) ($I_C = 0.1\text{ mA dc}, V_{CE} = 1.0\text{ Vdc}$)	h_{FE}	20 40	—	—
($I_C = 1.0\text{ mA dc}, V_{CE} = 1.0\text{ Vdc}$)		35 70	—	
($I_C = 10\text{ mA dc}, V_{CE} = 1.0\text{ Vdc}$)		50 100	150 300	
($I_C = 50\text{ mA dc}, V_{CE} = 1.0\text{ Vdc}$)		30 60	—	
($I_C = 100\text{ mA dc}, V_{CE} = 1.0\text{ Vdc}$)		15 30	—	
Collector-Emitter Saturation Voltage(1) ($I_C = 10\text{ mA dc}, I_B = 1.0\text{ mA dc}$) ($I_C = 50\text{ mA dc}, I_B = 5.0\text{ mA dc}$)	$V_{CE(sat)}$	—	0.2 0.3	Vdc
Base-Emitter Saturation Voltage(1) ($I_C = 10\text{ mA dc}, I_B = 1.0\text{ mA dc}$) ($I_C = 50\text{ mA dc}, I_B = 5.0\text{ mA dc}$)	$V_{BE(sat)}$	0.65 —	0.85 0.95	Vdc
SMALL-SIGNAL CHARACTERISTICS				
Current-Gain — Bandwidth Product ($I_C = 10\text{ mA dc}, V_{CE} = 20\text{ Vdc}, f = 100\text{ MHz}$)	f_T	250 300	—	MHz

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

Characteristic	Symbol	Min	Max	Unit
Output Capacitance ($V_{CB} = 5.0\text{ Vdc}$, $I_E = 0$, $f = 1.0\text{ MHz}$)	C_{obe}	—	4.0	pF
Input Capacitance ($V_{BE} = 0.5\text{ Vdc}$, $I_C = 0$, $f = 1.0\text{ MHz}$)	C_{ibo}	—	8.0	pF
Input Impedance ($I_C = 1.0\text{ mAdc}$, $V_{CE} = 10\text{ Vdc}$, $f = 1.0\text{ kHz}$)	h_{ie}	1.0 1.0	8.0 10	k ohms
Voltage Feedback Ratio ($I_C = 1.0\text{ mAdc}$, $V_{CE} = 10\text{ Vdc}$, $f = 1.0\text{ kHz}$)	r_{re}	0.1 0.5	5.0 8.0	$\times 10^{-4}$
Small-Signal Current Gain ($I_C = 1.0\text{ mAdc}$, $V_{CE} = 10\text{ Vdc}$, $f = 1.0\text{ kHz}$)	h_{fe}	50 100	200 400	—
Output Admittance ($I_C = 1.0\text{ mAdc}$, $V_{CE} = 10\text{ Vdc}$, $f = 1.0\text{ kHz}$)	h_{oe}	1.0	40	μmhos
Noise Figure ($I_C = 100\text{ }\mu\text{A}$, $V_{CE} = 5.0\text{ Vdc}$, $R_S = 1.0\text{ k ohms}$, $f = 1.0\text{ kHz}$)	NF	—	6.0 5.0	dB

SWITCHING CHARACTERISTICS

Delay Time	(V _{CC} = 3.0 Vdc, V _{BE} = 0.5 Vdc, I _C = 10 mAdc, I _{B1} = 1.0 mAdc)	2N3903 2N3904	t_d	—	35	ns
Rise Time			t_r	—	35	ns
Storage Time	(V _{CC} = 3.0 Vdc, I _C = 10 mAdc, I _{B1} = I _{B2} = 1.0 mAdc)	2N3903 2N3904	t_s	—	175 200	ns
Fall Time			t_f	—	50	ns

(1) Pulse Test. Pulse Width $\leq 300\text{ }\mu\text{s}$; Duty Cycle $\leq 2.0\%$.

Appendix 1-6

2N3905 and 2N3906 PNP BJTs

MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector-Emitter Voltage	V_{CE0}	-40	Vdc
Collector-Base Voltage	V_{CBO}	-40	Vdc
Emitter-Base Voltage	V_{EBO}	-5.0	Vdc
Collector Current — Continuous	I_C	-200	mAdc
Total Device Dissipation @ $T_A = 25^\circ\text{C}$ Derate above 25°C	P_D	625 5.0	mW mW/°C
Total Power Dissipation @ $T_A = 60^\circ\text{C}$	P_D	250	mW
Total Device Dissipation @ $T_C = 25^\circ\text{C}$ Derate above 25°C	P_D	1.5 12	Watts mW/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-55 to +150	°C

*THERMAL CHARACTERISTICS

Characteristic	Symbol	Max	Unit
Thermal Resistance, Junction to Ambient	$R_{\theta JA}$	200	°C/W
Thermal Resistance, Junction to Case	$R_{\theta JC}$	83.3	°C/W

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

Characteristic	Symbol	Min	Max	Unit
OFF CHARACTERISTICS				
Collector-Emitter Breakdown Voltage (1) ($I_C = -1.0$ mAdc, $I_B = 0$)	$V_{(BR)CEO}$	-40	—	Vdc
Collector-Base Breakdown Voltage ($I_C = -10$ μ Adc, $I_E = 0$)	$V_{(BR)CBO}$	-40	—	Vdc
Emitter-Base Breakdown Voltage ($I_E = -10$ μ Adc, $I_C = 0$)	$V_{(BR)EBO}$	-5.0	—	Vdc
Base Cutoff Current ($V_{CE} = -30$ Vdc, $V_{EB} = -3.0$ Vdc)	I_{BL}	—	-50	nAdc
Collector Cutoff Current ($V_{CE} = -30$ Vdc, $V_{EB} = -3.0$ Vdc)	I_{CEX}	—	-50	nAdc

ON CHARACTERISTICS(1)

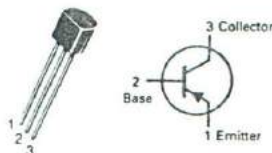
DC Current Gain $I_C = -0.1$ mAdc, $V_{CE} = -1.0$ Vdc	2N3905 2N3906	h_{FE}	30 60	—	—
($I_C = -1.0$ mAdc, $V_{CE} = -1.0$ Vdc)	2N3905 2N3906		40 80	—	—
($I_C = -10$ mAdc, $V_{CE} = -1.0$ Vdc)	2N3905 2N3906		50 100	150 300	—
($I_C = -50$ mAdc, $V_{CE} = -1.0$ Vdc)	2N3905 2N3906		30 60	—	—
($I_C = -100$ mAdc, $V_{CE} = -1.0$ Vdc)	2N3905 2N3906		15 30	—	—
Collector-Emitter Saturation Voltage ($I_C = -10$ mAdc, $I_B = -1.0$ mAdc) ($I_C = -50$ mAdc, $I_B = -5.0$ mAdc)		$V_{CE(sat)}$	— —	-0.25 -0.4	Vdc
Base-Emitter Saturation Voltage ($I_C = -10$ mAdc, $I_B = -1.0$ mAdc) ($I_C = -50$ mAdc, $I_B = -5.0$ mAdc)		$V_{BE(sat)}$	-0.65 —	-0.85 -0.95	Vdc

SMALL-SIGNAL CHARACTERISTICS

Current-Gain — Bandwidth Product ($I_C = -10$ mAdc, $V_{CE} = -20$ Vdc, $f = 100$ MHz)	2N3905 2N3906	f_T	200 250	—	MHz
Output Capacitance ($V_{CB} = -5.0$ Vdc, $I_E = 0$, $f = 1.0$ MHz)		C_{obo}	—	4.5	pF

2N3905
2N3906*

CASE 29-04, STYLE 1
TO-92 (TO-226AA)



**GENERAL PURPOSE
TRANSISTORS**

PNP SILICON

*This is a Motorola
designated preferred device.

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

Characteristic	Symbol	Min	Max	Unit
Input Capacitance ($V_{EB} = -0.5\text{ Vdc}$, $I_C = 0$, $f = 1.0\text{ MHz}$)	C_{ibo}	—	10.0	pF
Input Impedance ($I_C = -1.0\text{ mAdc}$, $V_{CE} = -10\text{ Vdc}$, $f = 1.0\text{ kHz}$)	h_{ie}	0.5 2.0	8.0 12	k ohms
Voltage Feedback Ratio ($I_C = -1.0\text{ mAdc}$, $V_{CE} = -10\text{ Vdc}$, $f = 1.0\text{ kHz}$)	h_{re}	0.1 0.1	5.0 10	$\times 10^{-4}$
Small-Signal Current Gain ($I_C = -1.0\text{ mAdc}$, $V_{CE} = -10\text{ Vdc}$, $f = 1.0\text{ kHz}$)	h_{fe}	50 100	200 400	—
Output Admittance ($I_C = -1.0\text{ mAdc}$, $V_{CE} = -10\text{ Vdc}$, $f = 1.0\text{ kHz}$)	h_{oe}	1.0 3.0	40 60	μmhos
Noise Figure ($I_C = -100\ \mu\text{A}$, $V_{CE} = -5.0\text{ Vdc}$, $R_S = 1.0\text{ k ohm}$, $f = 1.0\text{ kHz}$)	NF	— —	5.0 4.0	dB

SWITCHING CHARACTERISTICS

Delay Time	$V_{CC} = -3.0\text{ Vdc}$, $V_{BE} = -0.5\text{ Vdc}$ $I_C = -10\text{ mAdc}$, $I_{B1} = -1.0\text{ mAdc}$	t_d	—	35	ns	
Rise Time		t_r	—	35	ns	
Storage Time	$V_{CC} = -3.0\text{ Vdc}$, $I_C = -10\text{ mAdc}$, $I_{B1} = I_{B2} = -1.0\text{ mAdc}$	t_s	2N3905	—	200	ns
			2N3906	—	225	
Fall Time		t_f	2N3905	—	50	ns
			2N3906	—	75	

(1) Pulse Width $\leq 300\ \mu\text{s}$. Duty Cycle $\leq 2.0\%$.

Appendix 1-7

2N3251 PNP BJT

MAXIMUM RATINGS

Rating	Symbol	2N3250 2N3251	2N3251A	Unit
Collector-Emitter Voltage	V_{CE}	-40	-60	Vdc
Collector-Base Voltage	V_{CBO}	-50	-60	Vdc
Emitter-Base Voltage	V_{EBO}	-5.0		Vdc
Collector Current	I_C	-200		mAdc
Total Device Dissipation @ $T_A = 25^\circ\text{C}$ Derate above 25°C	P_D	0.36 2.06		Watt mW/°C
Total Device Dissipation @ $T_C = 25^\circ\text{C}$ Derate above 25°C	P_D	1.2 6.9		Watts mW/°C
Operating and Storage Temperature Temperature Range	T_J, T_{stg}	-65 to +200		°C

THERMAL CHARACTERISTICS

Characteristic	Symbol	Max	Unit
Thermal Resistance, Junction to Ambient	$R_{\theta JA}$	486	°C/W
Thermal Resistance, Junction to Case	$R_{\theta JC}$	146	°C/W

2N3250
2N3251,A*

CASE 22-03, STYLE 1
TO-18 (TO-206AA)




**GENERAL PURPOSE
TRANSISTORS**

PNP SILICON

*2N3251A is a Motorola
designated preferred device.

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

Characteristic	Symbol	Min	Max	Unit
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OFF CHARACTERISTICS

Collector-Emitter Breakdown Voltage(1) ($I_C = -10$ mAdc)	2N3250, 2N3251 2N3251A	$V_{(BR)CEO}$	-40 -60	—	Vdc
Collector-Base Breakdown Voltage ($I_C = -10$ μ Adc)	2N3250, 2N3251 2N3251A	$V_{(BR)CBO}$	-50 -60	—	Vdc
Emitter-Base Breakdown Voltage ($I_E = -10$ μ Adc)		$V_{(BR)EBO}$	-5.0	—	Vdc
Collector Cutoff Current ($V_{CE} = -40$ Vdc, $V_{EB} = -3.0$ Vdc)		I_{CEX}	—	-20	nA
Base Cutoff Current ($V_{CE} = -40$ Vdc, $V_{EB} = -3.0$ Vdc)		I_{BL}	—	-50	nAdc

ON CHARACTERISTICS

DC Forward Current Transfer Ratio ($I_C = -0.1$ mAdc, $V_{CE} = -10$ Vdc)	2N3250	h_{FE}	40	—	—	
	2N3251, 2N3251A		80	—	—	
	($I_C = -1.0$ mAdc, $V_{CE} = -1.0$ Vdc)		2N3250	45	—	—
			2N3251, 2N3251A	90	—	—
($I_C = -10$ mAdc, $V_{CE} = -1.0$ Vdc)(1)	2N3250	50	150	—		
	2N3251, 2N3251A	100	300	—		
($I_C = -50$ mAdc, $V_{CE} = -1.0$ Vdc)(1)	2N3250	15	—	—		
	2N3251, 2N3251A	30	—	—		
Collector-Emitter Saturation Voltage (1) ($I_C = -10$ mAdc, $I_B = -1.0$ mAdc) ($I_C = -50$ mAdc, $I_B = -5.0$ mAdc)		$V_{CE(sat)}$	— —	-0.25 -0.5	Vdc	
Base-Emitter Saturation Voltage (1) ($I_C = -10$ mAdc, $I_B = -1.0$ mAdc) ($I_C = -50$ mAdc, $I_B = -5.0$ mAdc)		$V_{BE(sat)}$	-0.6 —	-0.9 -1.2	Vdc	

SMALL-SIGNAL CHARACTERISTICS

Current-Gain — Bandwidth Product ($I_C = -10$ mAdc, $V_{CE} = -20$ Vdc, $f = 100$ MHz)	2N3250 2N3251, 2N3251A	f_T	250 300	— —	MHz
Output Capacitance ($V_{CB} = -10$ Vdc, $I_E = 0$, $f = 1.0$ MHz)		C_{obo}	—	6.0	pF
Input Capacitance ($V_{EB} = -1.0$ Vdc, $I_C = 0$, $f = 1.0$ MHz)		C_{ibo}	—	8.0	pF

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

Characteristic		Symbol	Min	Max	Unit
Input Impedance ($I_C = 1.0\text{ mA}$, $V_{CE} = 10\text{ V}$, $f = 1.0\text{ kHz}$)	2N3250, 2N3250A	h_{ie}	1.0	6.0	kohms
	2N3251, 2N3251A		2.0	12	
Voltage Feedback Ratio ($I_C = 1.0\text{ mA}$, $V_{CE} = 10\text{ V}$, $f = 1.0\text{ kHz}$)	2N3250, 2N3250A	h_{re}	—	10	$\times 10^{-4}$
	2N3251, 2N3251A		—	20	
Small-Signal Current Gain ($I_C = 1.0\text{ mA}$, $V_{CE} = 10\text{ V}$, $f = 1.0\text{ kHz}$)	2N3250, 2N3250A	h_{fe}	50	200	—
	2N3251, 2N3251A		100	400	
Output Admittance ($I_C = 1.0\text{ mA}$, $V_{CE} = 10\text{ V}$, $f = 1.0\text{ kHz}$)	2N3250, 2N3250A	h_{oe}	4.0	40	μmhos
	2N3251, 2N3251A		10	60	
Collector Base Time Constant ($I_C = 10\text{ mA}$, $V_{CE} = 20\text{ V}$, $f = 31.8\text{ MHz}$)		$\tau_{b,CC}$	—	250	ps
Noise Figure ($I_C = 100\text{ }\mu\text{A}$, $V_{CE} = 5.0\text{ V}$, $R_S = 1.0\text{ k}\Omega$, $f = 100\text{ Hz}$)		NF	—	6.0	dB

SWITCHING CHARACTERISTICS

Characteristic		Symbol	Max	Unit
Delay Time	$V_{CC} = 3.0\text{ Vdc}$, $V_{BE} = 0.5\text{ Vdc}$ $I_C = 10\text{ mAdc}$, $I_{B1} = 1.0\text{ mA}$	t_d	35	ns
			t_r	
Storage Time	$I_C = 10\text{ mAdc}$, $I_{B1} = I_{B2} = 1.0\text{ mAdc}$ $V_{CC} = 3.0\text{ V}$	2N3250, 2N3250A 2N3251, 2N3251A	175 200	ns
Fall Time		t_f	50	ns

(1) Pulse Test: PW = 300 μs , Duty Cycle = 2.0%.

Appendix 1-8

2N3055 and MJ2955 Complementary Power BJTs

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

Characteristic	Symbol	Min	Max	Unit
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*OFF CHARACTERISTICS

Collector-Emitter Sustaining Voltage (1) ($I_C = 200\text{ mA dc}$, $I_B = 0$)	$V_{CE(sus)}$	60	—	Vdc
Collector-Emitter Sustaining Voltage (1) ($I_C = 200\text{ mA dc}$, $R_{BE} = 100\ \Omega$)	$V_{CER(sus)}$	70	—	Vdc
Collector Cutoff Current ($V_{CE} = 30\text{ Vdc}$, $I_B = 0$)	I_{CEO}	—	0.7	mA dc
Collector Cutoff Current ($V_{CE} = 100\text{ Vdc}$, $V_{BE(off)} = 1.5\text{ Vdc}$) ($V_{CE} = 100\text{ Vdc}$, $V_{BE(off)} = 1.5\text{ Vdc}$, $T_C = 150^\circ\text{C}$)	I_{CEX}	—	1.0 5.0	mA dc
Emitter Cutoff Current ($V_{BE} = 7.0\text{ Vdc}$, $I_C = 0$)	I_{EBO}	—	5.0	mA dc

*ON CHARACTERISTICS (1)

DC Current Gain ($I_C = 4.0\text{ A dc}$, $V_{CE} = 4.0\text{ Vdc}$) ($I_C = 10\text{ A dc}$, $V_{CE} = 4.0\text{ Vdc}$)	h_{FE}	20 5.0	70 —	—
Collector-Emitter Saturation Voltage ($I_C = 4.0\text{ A dc}$, $I_B = 400\text{ mA dc}$) ($I_C = 10\text{ A dc}$, $I_B = 3.3\text{ A dc}$)	$V_{CE(sat)}$	—	1.1 3.0	Vdc
Base-Emitter On Voltage ($I_C = 4.0\text{ A dc}$, $V_{CE} = 4.0\text{ Vdc}$)	$V_{BE(on)}$	—	1.5	Vdc

SECOND BREAKDOWN

Second Breakdown Collector Current with Base Forward Biased ($V_{CE} = 40\text{ Vdc}$, $t = 1.0\ \mu\text{s}$, Nonrepetitive)	$I_{s/b}$	2.87	—	A dc
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DYNAMIC CHARACTERISTICS

Current Gain — Bandwidth Product ($I_C = 0.5\text{ A dc}$, $V_{CE} = 10\text{ Vdc}$, $f = 1.0\text{ MHz}$)	f_T	2.5	—	MHz
*Small-Signal Current Gain ($I_C = 1.0\text{ A dc}$, $V_{CE} = 4.0\text{ Vdc}$, $f = 1.0\text{ kHz}$)	h_{fe}	15	120	—
*Small-Signal Current Gain Cutoff Frequency ($V_{CE} = 4.0\text{ Vdc}$, $I_C = 1.0\text{ A dc}$, $f = 1.0\text{ kHz}$)	f_{hfe}	10	—	kHz

* Indicates Within JEDEC Registration. (2N3055)

(1) Pulse Test: Pulse Width $\leq 300\ \mu\text{s}$, Duty Cycle $\leq 2.0\%$.

MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector-Emitter Voltage	V_{CEO}	60	Vdc
Collector-Emitter Voltage	V_{CER}	70	Vdc
Collector-Base Voltage	V_{CB}	100	Vdc
Emitter-Base Voltage	V_{EB}	7	Vdc
Collector Current — Continuous	I_C	15	A dc
Base Current	I_B	7	A dc
Total Power Dissipation @ $T_C = 25^\circ\text{C}$ Derate above 25°C	P_D	115 0.657	Watts $W/^\circ\text{C}$
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-65 to +200	$^\circ\text{C}$

THERMAL CHARACTERISTICS

Characteristic	Symbol	Max	Unit
Thermal Resistance, Junction to Case	$R_{\theta JC}$	1.52	$^\circ\text{C/W}$

Appendix 1-9

2N6121 and 2N6124 Complementary Power BJTs

COMPLEMENTARY SILICON PLASTIC
POWER TRANSISTORS

... designed for use in power amplifier and switching circuits, — packaged in the compact TO-220AB outline. TO-66 leadform also available.

*MAXIMUM RATINGS

Rating	Symbol	2N6121 2N6124	2N6122 2N6125	2N6123	Unit
Collector-Emitter Voltage	V_{CE0}	45	60	80	Vdc
Collector-Base Voltage	V_{CB}	45	60	80	Vdc
Emitter-Base Voltage	V_{EB}	← 5.0 →			Vdc
Collector Current	I_C	← 4.0 →			Adc
Base Current	I_B	← 1.0 →			Adc
Total Power Dissipation @ $T_C = 25^\circ\text{C}$ Derate above 25°C	P_D	← 40 →			Watts
Operating and Storage Junction Temperature Range	T_J, T_{stg}	← -65 to +150 →			$^\circ\text{C}$

THERMAL CHARACTERISTICS

Characteristic	Symbol	Max	Unit
Thermal Resistance, Junction to Case	$R_{\theta JC}$	3.12	$^\circ\text{C}/\text{W}$

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

Characteristic	Symbol	Min	Max	Unit
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OFF CHARACTERISTICS

Collector-Emitter Sustaining Voltage (1) ($I_C = 0.1 \text{ Adc}, I_B = 0$)	2N6121, 2N6124 2N6122, 2N6125 2N6123	$V_{CE0(sust)}$	45 60 80	—	Vdc
Collector Cutoff Current ($V_{CE} = 45 \text{ Vdc}, I_B = 0$) ($V_{CE} = 60 \text{ Vdc}, I_B = 0$) ($V_{CE} = 80 \text{ Vdc}, I_B = 0$)	2N6121, 2N6124 2N6122, 2N6125 2N6123	I_{CEO}	—	1.0 1.0 1.0	mAdc
Collector Cutoff Current ($V_{CE} = 45 \text{ Vdc}, V_{EB(off)} = 1.5 \text{ Vdc}$) ($V_{CE} = 60 \text{ Vdc}, V_{EB(off)} = 1.5 \text{ Vdc}$) ($V_{CE} = 80 \text{ Vdc}, V_{EB(off)} = 1.5 \text{ Vdc}$) ($V_{CE} = 45 \text{ Vdc}, V_{EB(off)} = 1.5 \text{ Vdc}, T_C = 125^\circ\text{C}$) ($V_{CE} = 60 \text{ Vdc}, V_{EB(off)} = 1.5 \text{ Vdc}, T_C = 125^\circ\text{C}$) ($V_{CE} = 80 \text{ Vdc}, V_{EB(off)} = 1.5 \text{ Vdc}, T_C = 125^\circ\text{C}$)	2N6121, 2N6124 2N6122, 2N6125 2N6123 2N6121, 2N6124 2N6122, 2N6125 2N6123, 2N6126	I_{CEX}	—	0.1 0.1 0.1 2.0 2.0	mAdc
Collector Cutoff Current ($V_{CB} = 45 \text{ Vdc}, I_E = 0$) ($V_{CB} = 60 \text{ Vdc}, I_E = 0$) ($V_{CB} = 80 \text{ Vdc}, I_E = 0$)	2N6121, 2N6124 2N6122, 2N6125 2N6123	I_{CBO}	—	0.1 0.1 0.1	mAdc
Emitter Cutoff Current ($V_{BE} = 5.0 \text{ Vdc}, I_C = 0$)		I_{EBO}	—	1.0	mAdc

ON CHARACTERISTICS

DC Current Gain (1) ($I_C = 1.5 \text{ Adc}, V_{CE} = 2.0 \text{ Vdc}$) ($I_C = 4.0 \text{ Adc}, V_{CE} = 2.0 \text{ Vdc}$)	2N6126, 2N6124 2N6122, 2N6125 2N6123 2N6121, 2N6124 2N6122, 2N6125 2N6123	h_{FE}	25 25 20 10 10 7.0	100 100 80 — — —	—
Collector-Emitter Saturation Voltage (1) ($I_C = 1.5 \text{ Adc}, I_B = 0.15 \text{ Adc}$) ($I_C = 4.0 \text{ Adc}, I_B = 1.0 \text{ Adc}$)		$V_{CE(sat)}$	—	0.6 1.4	Vdc
Base-Emitter On Voltage (1) ($I_C = 1.5 \text{ Adc}, V_{CE} = 2.0 \text{ Vdc}$)		$V_{BE(on)}$	—	1.7	Vdc

DYNAMIC CHARACTERISTICS

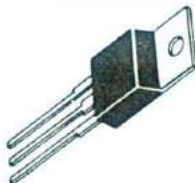
Small-Signal Current Gain ($I_C = 0.1 \text{ Adc}, V_{CE} = 2.0 \text{ Vdc}, f = 1.0 \text{ kHz}$)		h_{fe}	25	—	—
Current-Gain-Bandwidth Product ($I_C = 1.0 \text{ Adc}, V_{CE} = 4.0 \text{ Vdc}, f = 1.0 \text{ MHz}$)		f_T	2.5	—	MHz

(1) Pulse Test: Pulse Width $\leq 300 \mu\text{s}$, Duty Cycle $\leq 2.0\%$.

*Indicates JEDEC Registered Data.

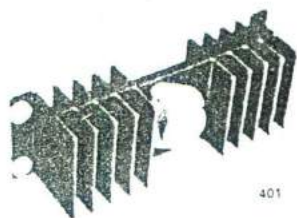
4 AMPERE
POWER TRANSISTORS
COMPLEMENTARY SILICON

45-80 VOLTS
40 WATTS



Appendix 1-10

Transistor Heat Sinks



401

**MODEL 401
NATURAL CONVECTION COOLER**

Produces maximum semiconductor cooling per unit volume, often eliminating the need for costly redesigns required to accommodate bulkier, less efficient coolers. Unexcelled where space is critical. Additionally affords excellent forced convection characteristics, with a thermal resistance under 0.5 C/W at moderate air flows. Uses 3 Teflon mounting washers.



403

**MODEL 403
NATURAL CONVECTION COOLER**

Affords heat dissipation characteristics which are difficult to equal with less expensive products. A thermal resistance of 1.8°C/W under medium power input permits adequate cooling in all but the most stringent applications. Under forced convection conditions, a thermal resistance of only 0.2 C/W is achieved with moderate air flows. Permits safe, reliable operation of the semiconductor under most power requirements where space is limited and allowable temperature rise is restricted. Uses 4 Teflon mounting washers.



413, 421

**MODEL 421
NATURAL CONVECTION COOLER**

Permits design engineers to free themselves from the question of how to maintain their power transistors at safe operating temperatures. Requiring no greater chassis base mounting area than that required by Model 403, this unit affords a still lower thermal resistance that is generally adequate for most high-power applications. Natural convection thermal resistance as low as 1.3 C/W; forced convection thermal resistance as low as 0.3 C/W. Uses 4 Teflon mounting washers.



423

**MODEL 423
NATURAL CONVECTION COOLER**

Will provide semiconductor cooling never before possible under natural convection conditions, with thermal resistance as low as 0.8 C/W, and only 0.25°C/W with moderate air flows. Ideally suited to high-power transistors, rectifiers, and silicon-controlled rectifiers. Where installation area is not greatly restricted, and design conditions do not permit forced convection, Model 423 will achieve the lowest possible temperature rise per unit volume — and at the lowest possible cost.



441

**MODEL 441
NATURAL CONVECTION HEAT SINKS**

Model 441 is designed for mounting on a vertical surface (no special brace required) to take better advantage of natural convection. Thermal resistance of 5.5°C/W at higher power levels is obtained. With moderate forced convection, thermal resistance of 1.8°C/W may be achieved. Electrical isolation may be achieved by the use of 4 Teflon mounting washers (not included).

Appendix 1-11

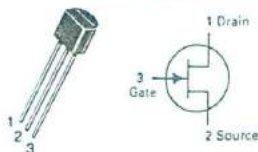
2N5457 FET

MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Drain-Source Voltage	V_{DS}	25	Vdc
Drain-Gate Voltage	V_{DG}	25	Vdc
Reverse Gate-Source Voltage	V_{GSR}	-25	Vdc
Gate Current	I_G	10	mAdc
Total Device Dissipation $\frac{1}{2}$ $T_A = 25^\circ\text{C}$ Derate above 25°C	P_D	310 2.82	mW mW/°C
Junction Temperature Range	T_J	125	°C
Storage Channel Temperature Range	T_{stg}	-65 to +150	°C

**2N5457
thru
2N5459***

CASE 29-04, STYLE 5
TO-92 (TO-226AA)



**JFETs
GENERAL PURPOSE**

N-CHANNEL — DEPLETION

*These are Motorola
designated preferred devices.

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

Characteristic	Symbol	Min	Typ	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}	—	—	-1.0 -200	nAdc	
Gate Source Cutoff Voltage ($V_{DS} = 15 \text{ Vdc}$, $I_D = 10 \text{ nAdc}$)	$V_{GS(off)}$	2N5457 2N5458 2N5459	-0.5 -1.0 -2.0	— — —	Vdc	
Gate Source Voltage ($V_{DS} = 15 \text{ Vdc}$, $I_D = 100 \mu\text{Adc}$) ($V_{DS} = 15 \text{ Vdc}$, $I_D = 200 \mu\text{Adc}$) ($V_{DS} = 15 \text{ Vdc}$, $I_D = 400 \mu\text{Adc}$)	V_{GS}	2N5457 2N5458 2N5459	— — —	-2.5 -3.5 -4.5	Vdc	
ON CHARACTERISTICS						
Zero-Gate-Voltage Drain Current* ($V_{DS} = 15 \text{ Vdc}$, $V_{GS} = 0$)	I_{DSS}	2N5457 2N5458 2N5459	1.0 2.0 4.0	3.0 6.0 9.0	5.0 9.0 15	mAdc

SMALL-SIGNAL CHARACTERISTICS

Forward Transfer Admittance Common Source* ($V_{DS} = 15 \text{ Vdc}$, $V_{GS} = 0$, $f = 1.0 \text{ kHz}$)	$ y_{fs} $	2N5457 2N5458 2N5459	1000 1500 2000	— — —	5000 5500 6000	μmhos
Output Admittance Common Source* ($V_{DS} = 15 \text{ Vdc}$, $V_{GS} = 0$, $f = 1.0 \text{ kHz}$)	$ y_{os} $		—	10	50	μmhos
Input Capacitance ($V_{DS} = 15 \text{ Vdc}$, $V_{GS} = 0$, $f = 1.0 \text{ MHz}$)	C_{iss}		—	4.5	7.0	pF
Reverse Transfer Capacitance ($V_{DS} = 15 \text{ Vdc}$, $V_{GS} = 0$, $f = 1.0 \text{ MHz}$)	C_{rss}		—	1.5	3.0	pF

*Pulse Test: Pulse Width $\leq 630 \text{ ms}$; Duty Cycle $\leq 10\%$.

Appendix 1-12

2N4856 FET

N-CHANNEL JUNCTION FIELD-EFFECT
TRANSISTORS

Depletion Mode symmetrical Field-Effect transistors designed for low power switching and chopper applications.

- Low Drain-Source "ON" Resistance –
 $r_{DS(on)} = 25 \text{ Ohms (Max) @ } f = 1.0 \text{ kHz} - 2N4856.A, 2N4859.A$
- Low Drain Cutoff Current –
 $I_{D(cutoff)} = 250 \text{ pA dc (Max) @ } V_{DS} = 15 \text{ Vdc}$

N-CHANNEL JUNCTION
FIELD-EFFECT TRANSISTORS

*MAXIMUM RATINGS

Rating	Symbol	2N4856.A 2N4857.A 2N4858.A	2N4859.A 2N4860.A 2N4861.A	Unit
Drain-Source Voltage	V_{DS}	+40	+30	Vdc
Drain-Source Voltage	V_{DS}	+40	+30	Vdc
Forward Gate-Source Voltage	V_{GSR}	-40	-30	Vdc
Forward Gate Current	I_{GF}		50	mA dc
Total Device Dissipation (TA = 25°C)	P_D		360	mW
Derate above 25°C			2.4	mW/°C
Storage Temperature Range	T_{stg}		-65 to +200	°C

*Indicates JEDEC Registered Data.

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

Characteristic		Symbol	Min	Max	Unit	
OFF CHARACTERISTICS						
Gate-Source Breakdown Voltage ($I_G = 1.0 \mu\text{Adc}$, $V_{DS} = 0$)	2N4856, A, 2N4857, A, 2N4858, A 2N4859, A, 2N4860, A, 2N4861, A	$V_{(BR)GSS}$	-40 -30	-	Vdc	
Gate-Source Cutoff Voltage ($V_{DS} = 15 \text{ Vdc}$, $I_D = 0.5 \text{ nAdc}$)	2N4856, A, 2N4859, A 2N4857, A, 2N4860, A 2N4858, A, 2N4861, A	$V_{GS(off)}$	-4.0 -2.0 -0.8	-10 -6.0 -4.0	Vdc	
Gate Reverse Current ($V_{GS} = -20 \text{ Vdc}$, $V_{DS} = 0$) ($V_{GS} = -15 \text{ Vdc}$, $V_{DS} = 0$) ($V_{GS} = -20 \text{ Vdc}$, $V_{DS} = 0$, $T_A = 150^\circ\text{C}$) ($V_{GS} = -15 \text{ Vdc}$, $V_{DS} = 0$, $T_A = 150^\circ\text{C}$)	2N4856, A, 2N4857, A, 2N4858, A 2N4859, A, 2N4860, A, 2N4861, A 2N4856, A, 2N4857, A, 2N4858, A 2N4859, A, 2N4860, A, 2N4861, A	I_{GSS}	-	0.25 0.25 0.5 0.5	nAdc μAdc	
Drain Cutoff Current ($V_{DS} = 15 \text{ Vdc}$, $V_{GS} = -10 \text{ Vdc}$) ($V_{DS} = 15 \text{ Vdc}$, $V_{GS} = -10 \text{ Vdc}$, $T_A = 150^\circ\text{C}$)		$I_{D(off)}$	-	0.25 0.5	nAdc μAdc	
ON CHARACTERISTICS						
Zero-Gate Voltage Drain Current (1) ($V_{DS} = 15 \text{ Vdc}$, $V_{GS} = 0$)	2N4856, A, 2N4859, A 2N4857, A, 2N4860, A 2N4858, A, 2N4861, A	I_{DSS}	50 20 8.0	- 100 80	mAdc	
Drain-Source "ON" Voltage ($I_D = 20 \text{ mAdc}$, $V_{GS} = 0$) ($I_D = 10 \text{ mAdc}$, $V_{GS} = 0$) ($I_D = 5.0 \text{ mAdc}$, $V_{GS} = 0$)	2N4856, A, 2N4859, A 2N4857, A, 2N4860, A 2N4858, A, 2N4861, A	$V_{DS(on)}$	- - -	0.75 0.5 0.5	Vdc	
SMALL-SIGNAL CHARACTERISTICS						
Drain-Source "ON" Resistance ($V_{GS} = 0$, $I_D = 0$, $f = 1.0 \text{ kHz}$)	2N4856, A, 2N4859, A 2N4857, A, 2N4860, A 2N4858, A, 2N4861, A	$r_{ds(on)}$	- - -	25 40 60	Ohms	
Input Capacitance ($V_{DS} = 0$, $V_{GS} = -10 \text{ Vdc}$, $f = 1.0 \text{ MHz}$)	2N4856 thru 2N4861 2N4856 A thru 2N4861 A	C_{iss}	-	18 10	pF	
Reverse Transfer Capacitance ($V_{DS} = 0$, $V_{GS} = -10 \text{ Vdc}$, $f = 1.0 \text{ MHz}$)	2N4856 thru 2N4861 2N4856 A, 2N4859 A 2N4857 A, 2N4858 A, 2N4860 A, 2N4861 A	C_{rss}	-	8.0 4.0 3.5	pF	
SWITCHING CHARACTERISTICS (See Figure 1) (2)						
Turn-On Delay Time	Conditions for 2N4856, A, 2N4859, A: ($V_{DD} = 10 \text{ Vdc}$, $I_{D(on)} = 20 \text{ mAdc}$, $V_{GS(on)} = 0$, $V_{GS(off)} = -10 \text{ Vdc}$)	2N4856, 2N4859 2N4856A, 2N4859A 2N4857, 2N4860 2N4857A, 2N4860A 2N4858, 2N4861 2N4858A, 2N4861A	$t_{d(on)}$	- - - - - -	6.0 5.0 6.0 6.0 10 8.0	ns
Rise Time	Conditions for 2N4857, A, 2N4860, A: ($V_{DD} = 10 \text{ Vdc}$, $I_{D(on)} = 10 \text{ mAdc}$, $V_{GS(on)} = 0$, $V_{GS(off)} = -6.0 \text{ Vdc}$)	2N4856, A, 2N4859, A 2N4857, A, 2N4860, A 2N4858, 2N4861 2N4858A, 2N4861A	t_r	- - - -	3.0 4.0 10 8.0	ns
Turn-Off Time	Conditions for 2N4858, A, 2N4861, A: ($V_{DD} = 10 \text{ Vdc}$, $I_{D(on)} = 5.0 \text{ mAdc}$, $V_{GS(on)} = 0$, $V_{GS(off)} = -4.0 \text{ Vdc}$)	2N4856, 2N4859 2N4856A, 2N4859A 2N4857, 2N4860 2N4857A, 2N4860A 2N4858, 2N4861 2N4858A, 2N4861A	t_{off}	- - - - - -	25 20 50 40 100 80	ns

*Indicates JEDEC Registered Data.

 (1) Pulse Test: Pulse Width = 100 ms, Duty Cycle $\leq 10\%$.

 (2) The $I_{D(on)}$ values are nominal, exact values vary slightly with transistor parameters.

Appendix 1-13

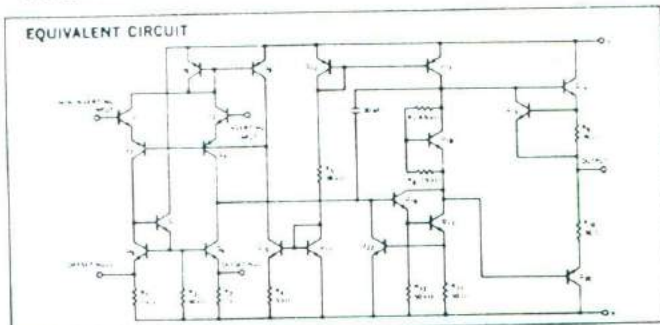
741 Operational Amplifier

GENERAL DESCRIPTION — The μ A741 is a high performance monolithic Operational Amplifier constructed using the Fairchild Planar[®] epitaxial process. It is intended for a wide range of analog applications. High common mode voltage range and absence of "latch-up" tendencies make the μ A741 ideal for use as a voltage follower. The high gain and wide range of operating voltage provides superior performance in integrator, summing amplifier, and general feedback applications.

- NO FREQUENCY COMPENSATION REQUIRED
- SHORT CIRCUIT PROTECTION
- OFFSET VOLTAGE NULL CAPABILITY
- LARGE COMMON MODE AND DIFFERENTIAL VOLTAGE RANGES
- LOW POWER CONSUMPTION
- NO LATCH UP

ABSOLUTE MAXIMUM RATINGS

Supply Voltage	
Military (741)	-22 V
Commercial (741C)	-18 V
Internal Power Dissipation (Note 1)	
Metal Can	500 mW
DIP	670 mW
Mini DIP	310 mW
Flatpak	570 mW
Differential Input Voltage	-30 V
Input Voltage (Note 2)	+15 V
Storage Temperature Range	
Metal Can, DIP, and Flatpak	-65°C to +150°C
Mini DIP	-55°C to +125°C
Operating Temperature Range	
Military (741)	-55°C to +125°C
Commercial (741C)	0°C to +70°C
Lead Temperature (Soldering)	
Metal Can, DIP, and Flatpak (50 seconds)	300°C
Mini DIP (10 seconds)	260°C
Output Short Circuit Duration (Note 3)	Indefinite

EQUIVALENT CIRCUIT

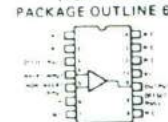
Notes on following pages.

CONNECTION DIAGRAMS
**8 LEAD METAL CAN
(TOP VIEW)
PACKAGE OUTLINE 5B**

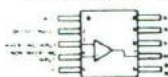

Note: Pin 4 connected to case

ORDER INFORMATION

TYPE	PART NO.
741	741HM
741C	741HC

**14 LEAD DIP
(TOP VIEW)
PACKAGE OUTLINE 5A**
**ORDER INFORMATION**

TYPE	PART NO.
741	741DM
741C	741DC

**10 LEAD FLATPAK
(TOP VIEW)
PACKAGE OUTLINE 3F**
**ORDER INFORMATION**

TYPE	PART NO.
741	741FM

**8 LEAD MINIDIP
(TOP VIEW)
PACKAGE OUTLINE 9T**
**ORDER INFORMATION**

TYPE	PART NO.
741C	741TC

*Planar is a patented Fairchild process.

ELECTRICAL CHARACTERISTICS ($V_S = \pm 15\text{ V}$, $T_A = 25^\circ\text{C}$ unless otherwise specified)

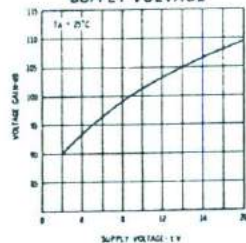
PARAMETERS (see definitions)	CONDITIONS	MIN.	TYP.	MAX.	UNITS
Input Offset Voltage	$R_S < 10\text{ k}\Omega$		1.0	5.0	mV
Input Offset Current			20	200	nA
Input Bias Current			80	500	nA
Input Resistance		0.3	2.0		M Ω
Input Capacitance			1.4		pF
Offset Voltage Adjustment Range			± 15		mV
Large Signal Voltage Gain	$R_L > 2\text{ k}\Omega$, $V_{OUT} = \pm 10\text{ V}$	50,000	200,000		
Output Resistance			75		Ω
Output Short Circuit Current			25		mA
Supply Current			1.7	2.8	mA
Power Consumption			50	85	mW
Transient Response (Unity Gain)	Risetime	$V_{IN} = 20\text{ mV}$, $R_L = 2\text{ k}\Omega$, $C_L < 100\text{ pF}$	0.3		μs
	Overshoot		5.0		%
Slew Rate	$R_L > 2\text{ k}\Omega$		0.5		V/ μs

 The following specifications apply for $-55^\circ\text{C} < T_A < +125^\circ\text{C}$:

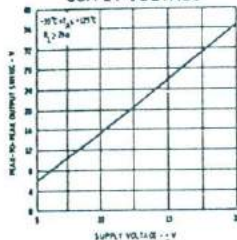
Input Offset Voltage	$R_S < 10\text{ k}\Omega$		1.0	6.0	mV
Input Offset Current	$T_A = +125^\circ\text{C}$		7.0	200	nA
	$T_A = -55^\circ\text{C}$		85	500	nA
Input Bias Current	$T_A = +125^\circ\text{C}$		0.03	0.5	μA
	$T_A = -55^\circ\text{C}$		0.3	1.5	μA
Input Voltage Range		± 12	± 13		V
Common Mode Rejection Ratio	$R_S < 10\text{ k}\Omega$	70	90		dB
Supply Voltage Rejection Ratio	$R_S < 10\text{ k}\Omega$		30	150	$\mu\text{V/V}$
Large Signal Voltage Gain	$R_L > 2\text{ k}\Omega$, $V_{OUT} = \pm 10\text{ V}$	25,000			
Output Voltage Swing	$R_L > 10\text{ k}\Omega$	± 12	± 14		V
	$R_L > 2\text{ k}\Omega$	± 10	± 13		V
Supply Current	$T_A = +125^\circ\text{C}$		1.5	2.5	mA
	$T_A = -55^\circ\text{C}$		2.0	3.3	mA
Power Consumption	$T_A = +125^\circ\text{C}$		45	75	mW
	$T_A = -55^\circ\text{C}$		60	100	mW

TYPICAL PERFORMANCE CURVES FOR 741

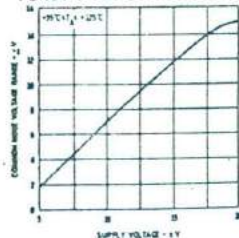
OPEN LOOP VOLTAGE GAIN AS A FUNCTION OF SUPPLY VOLTAGE



OUTPUT VOLTAGE SWING AS A FUNCTION OF SUPPLY VOLTAGE



INPUT COMMON MODE VOLTAGE RANGE AS A FUNCTION OF SUPPLY VOLTAGE

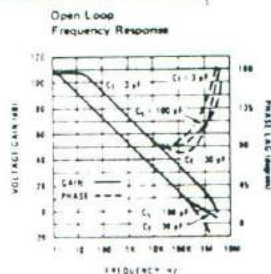


Appendix 1-14

108 and 308 Operational Amplifiers

Absolute Maximum Ratings

	LM108/LM208	LM308
Supply Voltage	-20V	±18V
Power Dissipation (Note 1)	500 mW	500 mW
Differential Input Current (Note 2)	±10 mA	±10 mA
Input Voltage (Note 3)	±15V	±15V
Output Short-Circuit Duration	Indefinite	Indefinite
Operating Temperature Range (LM108)	-55°C to +125°C	0°C to +70°C
(LM208)	-25°C to +85°C	
Storage Temperature Range	-65°C to +150°C	-65°C to +150°C
Lead Temperature (Soldering, 10 seconds)	300°C	300°C



Electrical Characteristics (Note 4)

PARAMETER	CONDITIONS	LM108/LM208			LM308			UNITS
		MIN	TYP	MAX	MIN	TYP	MAX	
Input Offset Voltage	$T_A = 25^\circ\text{C}$		0.1	2.0	2.0	1.5		mV
Input Offset Current	$T_A = 25^\circ\text{C}$		0.05	0.2	0.2	-		nA
Input Bias Current	$T_A = 25^\circ\text{C}$		0.8	2.0	1.5	-		nA
Input Resistance	$T_A = 25^\circ\text{C}$	30	70		10	40		MΩ
Supply Current	$T_A = 25^\circ\text{C}$		0.3	0.6	0.3	0.8		mA
Large Signal Voltage Gain	$T_A = 25^\circ\text{C}$, $V_S = \pm 15\text{V}$, $V_{OUT} = +10\text{V}$, $R_L = 10\text{k}\Omega$	50	300		25	200		V/mV
Input Offset Voltage				3.0		10		mV
Average Temperature Coefficient of Input Offset Voltage			3.0	15	6.0	30		$\mu\text{V}/^\circ\text{C}$
Input Offset Current				0.4		1.5		nA
Average Temperature Coefficient of Input Offset Current			0.5	2.5	2.0	10		$\mu\text{A}/^\circ\text{C}$
Input Bias Current				3.0		10		nA
Supply Current	$T_A = 125^\circ\text{C}$		0.15	0.4				mA
Large Signal Voltage Gain	$V_S = \pm 15\text{V}$, $V_{OUT} = \pm 10\text{V}$, $R_L \geq 10\text{k}\Omega$	25			15			V/mV
Output Voltage Swing	$V_S = \pm 15\text{V}$, $R_L = 10\text{k}\Omega$	±13	±14		±13	±14		V
Input Voltage Range	$V_S = \pm 15\text{V}$	±13.5			±14			V
Common-Mode Rejection Ratio		85	100		80	100		dB
Supply Voltage Rejection Ratio		80	96		80	96		dB

Note 1: The maximum junction temperature of the LM108 is 150°C, for the LM208, 100°C and for the LM308, 85°C. For operating at elevated temperatures, devices in the TO-5 package must be derated based on a thermal resistance of 150°C/W, junction to ambient, or 45°C/W, junction to case. The thermal resistance of the dual in-line package is 100°C/W, junction to ambient.

Note 2: The inputs are shunted with back-to-back diodes for overvoltage protection. Therefore, excessive current will flow if a differential input voltage in excess of 1V is applied between the inputs unless some limiting resistance is used.

Note 3: For supply voltages less than ±15V, the absolute maximum input voltage is equal to the supply voltage.

Note 4: These specifications apply for $\pm 5\text{V} \leq V_S \leq \pm 20\text{V}$ and $-65^\circ\text{C} \leq T_A \leq 125^\circ\text{C}$, unless otherwise specified. With the LM208, however, all temperature specifications are limited to $-25^\circ\text{C} \leq T_A \leq 85^\circ\text{C}$, and for the LM308 they are limited to $0^\circ\text{C} \leq T_A \leq 70^\circ\text{C}$.

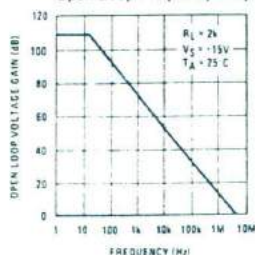
Appendix 1-15

353 BIFET Operational Amplifier

Absolute Maximum Ratings

Supply Voltage	±18V
Power Dissipation (Note 1)	500 mW
Operating Temperature Range	0°C to +70°C
T _J (MAX)	115°C
Differential Input Voltage	±30V
Input Voltage Range (Note 2)	±15V
Output Short Circuit Duration (Note 3)	Continuous
Storage Temperature Range	-65°C to +150°C
Lead Temperature (Soldering, 10 seconds)	300°C

Open Loop Frequency Response



DC Electrical Characteristics (Note 4)

SYMBOL	PARAMETER	CONDITIONS	LF353A			LF353B			LF353			UNITS
			MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	
V _{OS}	Input Offset Voltage	R _S = 10 k Ω ; T _A = 25°C Over Temperature		1	2		3	5		5	10	mV
$\Delta V_{OS}/\Delta T$	Average TC of Input Offset Voltage	R _S = 10 k Ω		10	20		10	30		10		$\mu V/^{\circ}C$
I _{OS}	Input Offset Current	T _J = 25°C (Notes 4, 5) T _J = 70°C		25	100		25	100		25	100	μA
I _B	Input Bias Current	T _J = 25°C (Notes 4, 5) T _J = 70°C		50			50	200		50	200	μA
R _{IN}	Input Resistance	T _J = 25°C		10 ¹²			10 ¹²			10 ¹²		Ω
A _{VOL}	Large Signal Voltage Gain	V _S = +15V; T _A = 25°C V _O = -10V; R _L = 2 k Ω Over Temperature	50	100		50	100		25	100		V/V
V _O	Output Voltage Swing	V _S = +15V; R _L = 10 k Ω	-12	-13.5		12	13.5		12	13.5		V
V _{CM}	Input Common Mode Voltage Range	V _S = +15V	-11	+15		-11	+15		-11	+15		V
CMRR	Common Mode Rejection Ratio	R _S = 10 k Ω	80	100		80	100		70	100		dB
PSRR	Supply Voltage Rejection Ratio	(Note 6)	80	100		80	100		70	100		dB
I _S	Supply Current		3.6	5.6		3.6	5.6		3.6	6.5		mA

AC Electrical Characteristics (Note 4)

SYMBOL	PARAMETER	CONDITIONS	LF353A			LF353B			LF353			UNITS
			MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	
	Amplifier to Amplifier Coupling	T _A = 25°C; f = 1 Hz - 20 kHz (Input Referred)		120			120			120		dB
SR	Slew Rate	V _S = +15V; T _A = 25°C	10	13		13			13			V/ μs
GBW	Gain Bandwidth Product	V _S = +15V; T _A = 25°C	3	4		4			4			MHz
e _n	Equivalent Input Noise Voltage	T _A = 25°C; R _S = 100 Ω f = 1000 Hz		16			16			16		$\mu V/\sqrt{Hz}$
i _n	Equivalent Input Noise Current	T _J = 25°C; f = 1000 Hz		0.01			0.01			0.01		$\mu A/\sqrt{Hz}$

Note 1: For operating at elevated temperature, the device must be derated based on a thermal resistance of 160°C/W junction to ambient for the N package, and 150°C/W junction to ambient for the H package.

Note 2: Unless otherwise specified the absolute maximum negative input voltage is equal to the negative power supply voltage.

Note 3: The power dissipation limit, however, cannot be exceeded.

Note 4: These specifications apply for V_S = ±15V and 0°C ≤ T_A ≤ +70°C. V_{OS}, I_B and I_{OS} are measured at V_{CM} = 0.

Note 5: The input bias currents are junction leakage currents which approximately double for every 10°C increase in the junction temperature, T_J. Due to limited production test time, the input bias currents measured are correlated to junction temperature. In normal operation the junction temperature rises above the ambient temperature as a result of internal power dissipation, P_D. T_J = T_A + θ_{JA} P_D where θ_{JA} is the thermal resistance from junction to ambient. Use of a heat sink is recommended if input bias current is to be kept to a minimum.

Note 6: Supply voltage rejection ratio is measured for both supply magnitudes increasing or decreasing simultaneously in accordance with common practice.

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(Not authorized for use as critical components in a life support system.)

Appendix 1-16

723 Voltage Regulator

	Min	Typ	Max
Continuous voltage V_{CC+} to V_{CC-}			40 V
Input-output voltage differential			40 V
Input voltage range	9.5 V		37 V
Output voltage range	2 V		37 V
Output current			150 mA
Standby current		2.3 mA	3.5 mA
Reference voltage	6.95 V	7.15 V	7.35 V
Current from V_{ref}			15 mA
Maximum power dissipation at or below 25°C free air temperature:			
Metal can			1000 mW
DIP			12.5 W

Appendix 1-17

SCRs - Comparison of Typical Parameters

Parameter		Device		
		2N1597	2N5170	2N6400
V_{RRM}	Peak repetitive blocking voltage	200 V	400 V	50 V
$I_{T(rms)}$	RMS on-state current	1.6 A	20 A	16 A
V_{TM}	Peak on-state voltage	1.1 V	1.5 V	1.7 V
I_{GT}	Gate trigger current	2 mA	40 mA	5 mA
V_{GT}	Gate trigger voltage	0.7 V	1.5 V	0.7 V
I_H	Holding current	5 mA	50 mA	6 mA
t_{gt}	Turn-on time	0.8 μ s	1 μ s	1 μ s
t_q	Turn-off time	10 μ s	20 μ s	15 μ s

Appendix 1-18

UJT's - Comparison of Typical Parameters

Parameter		Device		
		2N4870	2N4949	2N2017
P_D	Maximum power dissipation	300 mW	360 mW	300 mW
	Derate linearly at	3 mW/°C	2.4 mW/°C	3 mW/°C
R_{BB}	Interbase resistance	6 k Ω	7 k Ω	7 k Ω
η	Intrinsic stand-off ratio	0.56 to 0.75	0.55 to 0.82	0.68 to 0.82
$V_{EB1(sat)}$	Emitter - B1 saturation voltage	2.5 V	2.5 V	3.5 V
I_p	Peak point current	1 μ A	0.6 μ A	1 μ A
I_v	Valley point current	5 mA	4 mA	10 mA
$I_{E(rms)}$	Maximum rms emitter current	50 mA	50 mA	50 mA
i_E	Peak emitter pulse current	1.5 A	1 A	2 A
V_{B1B2}	Maximum B1 - B2 voltage	35 V	35 V	35 V
V_{B2E}	Maximum emitter reverse voltage	30 V	30 V	30 V

Appendix 2-1

Typical Standard-Value Resistors

10% tolerance resistors

Ω	Ω	Ω	k Ω	k Ω	k Ω	M Ω	M Ω
-	10	100	1	10	100	1	10
-	12	120	1.2	12	120	1.2	12
-	15	150	1.5	15	150	1.5	15
-	18	180	1.8	18	180	1.8	18
-	22	220	2.2	22	220	2.2	22
2.7	27	270	2.7	27	270	2.7	-
3.3	33	330	3.3	33	330	3.3	-
3.9	39	390	3.9	39	390	3.9	-
4.7	47	470	4.7	47	470	4.7	-
5.6	56	560	5.6	56	560	5.6	-
6.8	68	680	6.8	68	680	6.8	-
8.2	82	820	8.2	82	820	8.2	-

5% tolerance resistors

Ω	Ω	Ω	k Ω	k Ω	k Ω	M Ω	M Ω
-	10	100	1	10	100	1	10
-	11	110	1.1	11	110	1.1	11
-	12	120	1.2	12	120	1.2	12
-	13	130	1.3	13	130	1.3	13
-	15	150	1.5	15	150	1.5	15
-	16	160	1.6	16	160	1.6	16
-	18	180	1.8	18	180	1.8	18
-	20	200	2	20	200	2	20
-	22	220	2.2	22	220	2.2	22
-	24	240	2.4	24	240	2.4	-
2.7	27	270	2.7	27	270	2.7	-
3	30	300	3	30	300	3	-
3.3	33	330	3.3	33	330	3.3	-
3.6	36	360	3.6	36	360	3.6	-
3.9	39	390	3.9	39	390	3.9	-
4.3	43	430	4.3	43	430	4.3	-
4.7	47	470	4.7	47	470	4.7	-
5.1	51	510	5.1	51	510	5.1	-
5.6	56	560	5.6	56	560	5.6	-
6.2	62	620	6.2	62	620	6.2	-
6.8	68	680	6.8	68	680	6.8	-
7.5	75	750	7.5	75	750	7.5	-
8.2	82	820	8.2	82	820	8.2	-
9.1	91	910	9.1	91	910	9.1	-

1% tolerance resistors (Basic values in Ω)For values above 10 Ω multiply by 10, 100, etc.

1.00	6.04	11.0	20.0	36.5	66.5	121	221
1.10	6.19	11.3	20.5	37.4	68.1	124	226
1.21	6.34	11.5	21.0	38.3	69.8	127	232
1.30	6.49	11.8	21.5	39.2	71.5	130	237
1.50	6.65	12.1	22.1	40.2	73.2	133	243
1.62	6.81	12.4	22.6	41.2	75.0	137	249
1.82	6.98	12.7	23.2	42.2	76.8	140	255
2.00	7.15	13.0	23.7	43.2	78.7	143	261
2.21	7.32	13.3	24.3	44.2	80.6	147	267
2.43	7.50	13.7	24.9	45.3	82.5	150	274
2.67	7.68	14.0	25.5	46.4	84.5	154	280
3.01	7.87	14.3	26.1	47.5	86.6	158	287
3.32	8.06	14.7	26.7	48.7	88.7	162	294
3.57	8.25	15.0	27.4	49.9	90.9	165	301
3.92	8.45	15.4	28.0	51.1	93.1	169	309
4.32	8.66	15.8	28.7	52.3	95.3	174	316
4.75	8.87	16.2	29.4	53.6	97.6	178	324
4.99	9.09	16.5	30.1	54.9	100	182	332
5.11	9.31	16.9	30.9	56.2	102	187	340
5.23	9.53	17.4	31.6	57.6	105	191	348
5.36	9.76	17.8	32.4	59.0	107	196	356
5.49	10.0	18.2	33.2	60.4	110	200	365
5.62	10.2	18.7	34.0	61.9	113	205	374
5.76	10.5	19.1	34.8	63.4	115	210	383
5.90	10.7	19.6	35.7	64.9	118	215	392

Potentiometers

Ω	Ω	k Ω	k Ω	k Ω	M Ω
10	100	1	10	100	1
-	150	1.5	15	-	-
20	200	2	20	200	2
-	250	2.5	25	250	2.5
-	350	3.5	35	-	-
50	500	5	50	500	-
-	750	7.5	75	750	-

Appendix 2-2

Typical Standard-Value Capacitors

pF	pF	pF	pF	μF	μF	μF	μF	μF	μF	μF
5	50	500	5000	-	0.05	0.5	5	50	500	5000
-	51	510	5100	-	-	-	-	-	-	-
-	56	560	5600	-	0.056	0.56	5.6	56	-	5600
-	-	-	6000	-	0.06	-	6	-	-	6000
-	62	620	6200	-	-	-	-	-	-	-
-	68	680	6800	-	0.068	0.68	6.8	68	680	6800
-	75	750	7500	-	-	-	-	75	-	-
-	-	-	8000	-	-	-	8	80	-	-
-	82	820	8200	-	0.082	0.82	8.2	82	-	-
-	91	910	9100	-	-	-	-	-	-	-
10	100	1000	-	0.01	0.1	1	10	100	1000	10000
-	110	1100	-	-	-	-	-	-	-	-
12	120	1200	-	0.012	0.12	1.2	-	-	-	-
-	130	1300	-	-	-	-	-	-	-	-
15	150	1500	-	0.015	0.15	1.5	15	150	1500	15000
-	160	1600	-	-	-	-	-	-	-	-
18	180	1800	-	0.018	0.18	1.8	18	180	-	-
20	200	2000	-	0.02	0.2	2	20	200	2000	-
22	220	2200	-	-	0.22	2.2	22	220	2200	22000
24	240	2400	-	-	-	-	-	240	-	-
-	250	2500	-	-	0.25	-	25	250	2500	-
27	270	2700	-	0.027	0.27	2.7	27	270	-	-
30	300	3000	-	0.03	0.3	3	30	300	3000	-
33	330	3300	-	0.033	0.33	3.3	33	330	3300	-
36	360	3600	-	-	-	-	-	-	-	-
39	390	3900	-	0.039	0.39	3.9	39	-	-	-
-	-	4000	-	0.04	-	4	-	400	-	-
43	430	4300	-	-	-	-	-	-	-	-
47	470	4700	-	0.047	0.47	4.7	47	470	4700	-

Appendix 3

Answers for Odd-Numbered Problems

- 2-1 $4.25 \Omega, 1.5 \times 10^9 \Omega$
 2-3 $13 \Omega, 1.7 \Omega$
 2-5 6 V
 2-7 Pt. A (0 mA, 0.7 V), Pt. B (300 mA, 0.85 V)
 2-9 $170 \text{ mA}, 260 \text{ mA}$
 2-11 9.1 V
 2-13 625 mA
 2-15 $1.7 \text{ A}, 1.25 \text{ A}$
 2-17 $26.7 \text{ mA}, 28 \text{ mA}$
 2-19 20 ns
 2-21 80 ns
 2-23 $800 \text{ V}, 1.5 \text{ A}$
 2-25 $2 \text{ V/cm}, 200 \Omega, 0.5 \text{ V/cm}$
 2-27 $44 \text{ mA}, 33.4 \text{ mA}$
- 3-1 $34.7 \text{ V}, 57.8 \text{ mA}, 35.4 \text{ V}$
 3-3 536 mW
 3-5 $34 \text{ V}, 56.6 \text{ mA}, 14 \text{ mW}, 35.4 \text{ V}$
 3-7 $3300 \mu\text{F}$
 3-9 $50.4 \text{ V}, 200 \text{ mA}, 4.38 \text{ A}, 1\text{N}4002, 0.84 \Omega$
 3-11 $34.4 \text{ V}, 300 \text{ mA}, 3.68 \text{ A}, 1\text{N}4001, 0.57 \Omega$
 3-13 $1500 \mu\text{F}$
 3-15 $25.9 \text{ V}, 200 \text{ mA}, 2.2 \text{ A}, 1\text{N}4001, 0.86 \Omega$
 3-17 $21.2 \text{ V}, 300 \text{ mA}, 1.54 \text{ A}, 1\text{N}4401, 0.7 \Omega$
 3-19 $0.4 \text{ V}, 0.5 \text{ V}, 3.3\%, 4.2\%$
 3-21 $19\%, 2.08\%$
 3-23 $680 \Omega, 0.27 \text{ W}, \pm 3.7 \text{ mA}$
 3-25 $129 \text{ mV}, 1.16 \text{ V}, 5.85 \times 10^{-2}$
 3-27 $4.59 \text{ V}, 5.61 \text{ V}, 92.2 \Omega$
 3-29 $10 \text{ k}\Omega, 12 \text{ V}, 1 \text{ mA}$
 3-31 $23 \text{ mA}, 7 \text{ V}$
 3-33 $2.7 \text{ k}\Omega, 6 \text{ V}, 1.96 \text{ mA}$
 3-35 $\pm 3.3 \text{ V}, 6.8 \text{ k}\Omega$
 3-37 $1\text{N}756, 1 \text{ k}\Omega$
 3-39 $1\text{N}751, 820 \Omega$
 3-41 132 mV
 3-43 $2.7 \mu\text{F}, 5.6 \text{ k}\Omega$
 3-45 $+3.6 \text{ V}, -12.4 \text{ V}, 4.4 \text{ V}$
 3-47 $1\text{N}759, 1.5 \mu\text{F}, 1.5 \text{ k}\Omega$
 3-49 $1.5 \mu\text{F}, 3 \mu\text{F}$
 3-51 $1.2 \text{ k}\Omega$
- 4-1 $1.62 \text{ mA}, 1.67 \text{ mA}, 32.3$
 4-3 $1.98 \text{ mA}, 2 \text{ mA}$
 4-5 1 mA
 4-7 120
 4-9 68
 4-13 4 mA
 4-15 $40 \mu\text{A}$
 4-17 $7.7 \text{ mA}, 3.7 \text{ mA}, 123$
 4-19 9.3 V
- 4-21 200
 4-23 $133, 100 \mu\text{A}$
 4-25 $7.46 \Omega, -0.993, 746 \text{ mS}$
 4-27 $20 \mu\text{S}, 125$
 4-29 333Ω
 4-31 $0.992, 2.48 \text{ M}\Omega$
 4-33 $0.1 \text{ V/cm}, 20 \text{ k}\Omega, 50 \text{ mV/cm}$
- 5-1 $(0.97 \text{ mA}, 7.7 \text{ V}), (9.4 \text{ mA}, 4.5 \text{ V})$
 5-3 $\pm 7.3 \text{ V}, \pm 4.5 \text{ V}$
 5-5 $2.8 \text{ V}, 2.35 \text{ V}, 12.8 \text{ V}$
 5-7 $5.95 \text{ mA}, 4.3 \text{ V}$
 5-9 $25 \text{ V}, 4 \text{ V}$
 5-11 $5.45 \text{ mA}, 5.1 \text{ V}$
 5-13 $33.2, 3.86 \text{ V}$
 5-15 $4.7 \text{ mA}, 6.5 \text{ V}$
 5-17 10.6 V
 5-19 5.93 V
 5-21 $(1.5 \text{ V}, 10.72 \text{ V}), (4.46 \text{ V}, 8.7 \text{ V}), (6.98 \text{ V}, 7.66 \text{ V})$
 5-23 $V_{CE} = 0.45 \text{ V}$
 5-25 $4.7 \text{ k}\Omega$
 5-27 $10.7 \text{ V}, (\approx 0.2 \text{ V})$
 5-29 $270 \text{ k}\Omega, 2.2 \text{ k}\Omega$
 5-31 $270 \text{ k}\Omega, 4.7 \text{ k}\Omega$
 5-33 $220 \text{ k}\Omega, 56 \text{ k}\Omega, 15 \text{ k}\Omega, 5.6 \text{ k}\Omega$
 5-35 $100 \text{ k}\Omega, 33 \text{ k}\Omega, 2.7 \text{ k}\Omega$
 5-37 $7.8 \text{ V}, 1.4 \text{ mA}$
 5-39 $680 \Omega, 1.2 \text{ k}\Omega, 1.8 \text{ k}\Omega$
 5-41 $2.7 \text{ k}\Omega, 6.8 \text{ k}\Omega$
 5-43 $10 \text{ k}\Omega, 5.6 \text{ k}\Omega, 1.2 \text{ k}\Omega, 470 \Omega$
 5-45 $39.5 \mu\text{A}, 12.3 \mu\text{A}, 2.6 \mu\text{A}$
 5-47 $16 \mu\text{A}, 33 \mu\text{A}, 50 \mu\text{A}$
 5-49 9.9
 5-51 $1.8 \text{ k}\Omega, 10 \text{ k}\Omega$
 5-53 $5.6 \text{ k}\Omega, 22 \text{ k}\Omega$
- 6-1 $7.92 \text{ V}, 6 \text{ V}$
 6-3 point A $U_C = 0, V_{CE} = 18 \text{ V}$;
 point B $U_C = 1.6 \text{ mA}, V_{CE} = 0$;
 point Q $U_C = 0.9 \text{ mA}, V_{CE} = 7.8 \text{ V}$;
 point C $U_C = 0, V_{CE} = 12.1 \text{ V}$
 $\Delta V_C = \pm 4.3 \text{ V}$
 6-5 point A $U_C = 0, V_{CE} = 15 \text{ V}$;
 point B $U_C = 1.39 \text{ mA}, V_{CE} = 0$;
 point Q $U_C = 1 \text{ mA}, V_{CE} = 4 \text{ V}$;
 point C $U_C = 0, V_{CE} = 12.1 \text{ V}$
 6-7 $1 \text{ k}\Omega, 62.5 \mu\text{S}, 135$
 6-9 123
 6-11 $50 \mu\text{S}$
 6-13 15.4Ω
 6-15 $893 \Omega, 5.54 \text{ k}\Omega, -425$

6-17	1.29 k Ω , 3.28 k Ω , -98.3	10-37	5.2 V
6-19	1.48 k Ω , 3.29 k Ω , -213	10-39	8.9 V
6-21	8.2 k Ω , -0.88	10-41	(5.6 M Ω + 2.2 M Ω), 1 M Ω , 1.8 k Ω
6-23	13.1 k Ω , 18.5 Ω	10-43	3.9 M Ω , 1 M Ω , 2.2 k Ω , 2.2 k Ω
6-25	62.9 k Ω , 55 Ω	10-45	1 M Ω , 1 Ω , 5.5 V
6-27	11.6 Ω , 5.5 k Ω , 425	10-47	1 M Ω , 10 k Ω , -5 V
6-29	31.4 Ω , 1.8 k Ω , 54.9	10-49	0.6 Ω , 5.7 V
6-31	7.9 Ω , 3.28 k Ω , 380		
6-33	(12.9 k Ω to 13.3 k Ω), (21 Ω to 42.3 Ω)	11-1	$R_{L(dc)} = 5.4$ k Ω , $R_{L(ac)} = 2.7$ k Ω
		11-3	$R_{L(dc)} = 3.6$ k Ω , $R_{L(ac)} = 1.6$ k Ω
8-1	60 V, 4 A, 5 V, 25, 100	11-5	880 k Ω , 3.7 k Ω , -12.5
8-3	-1.25 dB	11-7	470 k Ω , 4.5 k Ω , -19.3
8-5	1.26 V	11-9	9.1 k Ω , -36
8-7	141 pF	11-11	470 k Ω , 4.5 k Ω , -1.8
8-9	100 k Ω	11-13	629 k Ω , 161 Ω , 0.96
8-11	430 μ s	11-15	820 k Ω , 241 Ω , 0.96
8-13	2.79 pF	11-17	685 k Ω , 318 Ω , 0.95
8-15	1038 pF, 31.94 nF, 938 pF	11-19	160 Ω , 3.7 k Ω , 21.2
8-17	19.13 μ s	11-21	266 Ω , 3.7 k Ω , 12.5
8-19	417	11-23	241 Ω , 6.4 k Ω , 14.1
8-21	31 V	11-25	1.3 V
8-23	78.4 $^{\circ}$ C	11-27	693 mV, 217 mV
8-25	8.1 k Ω		
8-27	44.8 $^{\circ}$ C, 58.5 $^{\circ}$ C	12-1	100 k Ω , 56 k Ω , 6.8 k Ω , 5.6 k Ω
8-29	4.6 $^{\circ}$ C/W	12-3	620, 493 Ω , 5.3 k Ω
		12-5	15 μ F, 200 μ F, 0.33 μ F, 430 pF
9-1	5 mA, 5 V	12-7	56 k Ω , 39 k Ω , 3.9 k Ω , 3.9 k Ω
9-3	9 mA, 8 V	12-9	360, 958 Ω , 3.4 k Ω
9-5	2 mS	12-11	0.039 μ F, 15 μ F, 0.39 μ F, 510 pF
9-7	40 V, 360 mW, -6 V, 100 mA, 40 Ω	12-13	3.3 M Ω , 1 M Ω , 6.8 k Ω , 6.8 k Ω
9-9	540 μ S, 1150 μ S	12-15	24.3, 767 k Ω , 6.8 k Ω
9-11	20 mS, 30 mS	12-17	0.027 μ F, 15 μ F, 0.39 μ F
9-13	20 mS, 30 mS		
9-15	25 V, 310 mW, 6 V, 5 mA	12-19	(56 k Ω + 1.5 k Ω), 47 k Ω , 3.9 k Ω , 4.7 k Ω , (56 k Ω + 1.5 k Ω), 47 k Ω , 3.9 k Ω , 4.7 k Ω
9-17	± 0.5 V, ± 0.1 V, 5, 1	12-21	15 701, 491 Ω , 3.9 k Ω
9-19	3.3 k Ω	12-23	5.6 μ F, 100 μ F, 3 μ F, 100 μ F, 0.2 μ F
9-21	4 V, 2.5 V, 12.5 W	12-25	100 k Ω , 47 k Ω , 8.2 k Ω , 4.7 k Ω , 6.8 k Ω , (8.2 k Ω + 560 Ω)
9-23	5.7 V, 1.5 V, 7.5 W	12-27	29 343, 492 Ω , 6.8 k Ω
10-1	-1.5 V	12-29	20 μ F, 500 μ F, 240 μ F, 0.33 μ F
10-3	4 k Ω	12-31	33 k Ω , 56 k Ω , 3.3 k Ω , 4.7 k Ω , 6.8 k Ω , 3.9 k Ω , 25 μ F, 330 μ F, 330 μ F, 0.25 μ F
10-5	2.3 mA, 8.1 V	12-33	-389
10-7	7.8 V, 19.7 V	12-35	-256
10-9	11.9 V, 19.1 V	12-37	36 464
10-11	7.5 V, 18.4 V	12-39	8.2 k Ω , 220 k Ω , 220 k Ω , 3.3 k Ω , 22 μ F, 1.2 μ F, 75 μ F
10-13	17.3 V	12-41	3.3 k Ω , 120 k Ω , 220 k Ω , 3.3 k Ω , 15 μ F, 1 μ F, 15 μ F
10-15	6.5 V, 9.2 V	12-43	6.8 M Ω , 820 k Ω , 3.9 k Ω , 3.9 k Ω , (120 k Ω + 15 k Ω), 39 k Ω , 12 k Ω , 4.7 k Ω
10-17	9.6 V, 14.2 V	12-45	3818, 732 k Ω , 12 k Ω
10-19	-0.9 V, 1 M Ω , 3.3 k Ω	12-47	0.068 μ F, 15 μ F, 150 μ F, 0.18 μ F
10-21	1 M Ω , 5.6 k Ω , 1 k Ω	12-49	1 M Ω , 6.8 k Ω , 2.2 k Ω , 220 k Ω , 68 k Ω , 18 k Ω , 6.8 k Ω , 0.02 μ F, 25 μ F, 22 μ F, 330 μ F, 0.1 μ F
10-23	3.9 M Ω , 1 M Ω , 3.3 k Ω , 3.3 k Ω		
10-25	(6.8 M Ω + 1.8 M Ω), 1 M Ω , 3.9 k Ω , 3.9 k Ω		
10-27	1 M Ω , 3.9 k Ω , 10 k Ω		
10-29	1 M Ω , 4.7 k Ω , 10 k Ω		
10-31	1.8 M Ω , 1 M Ω , 3.3 k Ω , 3.3 k Ω		
10-33	6.8 M Ω , 1 M Ω , 3.9 k Ω , 3.9 k Ω		
10-35	(82 k Ω + 1.5 k Ω), 27 k Ω , 3.9 k Ω , 2.7 k Ω		

- 12-51 1 M Ω , 6.8 k Ω , 2.2 k Ω , 12 k Ω , 3.3 k Ω ,
0.02 μ F, 25 μ F, 330 μ F, 0.1 μ F
- 12-53 0.82 μ F, 0.15 μ F
- 12-55 (33 k Ω + 3.3 k Ω), 22 k Ω , 6.8 k Ω , 2.2 k Ω , 6.8
k Ω , (33 k Ω + 3.3 k Ω), 22 k Ω , 2.2 μ F, 0.3 μ F
- 12-57 3.9 k Ω , 27 k Ω , 2.7 k Ω , 2.7 k Ω , 22 μ F, 240 μ F,
0.82 μ F
- 12-59 (56 k Ω + 3.3 k Ω), 18 k Ω , 33 k Ω , 4.7 k Ω ,
3.3 k Ω , 20 μ F, 20 μ F, 200 μ F, 0.39 μ F
- 12-61 15.1 k Ω
- 12-63 1.91 k Ω
- 13-1 124.9, 123.9
- 13-3 44.3 Ω , 629 Ω
- 13-5 470 Ω , (22 k Ω + 1 k Ω), 2.7 k Ω , 4.7 μ F
- 13-7 470 Ω , (82 k Ω + 2.2 k Ω), 3.9 μ F, 2.2 μ F
- 13-9 15 μ F, 220 Ω , (15 k Ω + 1.2 k Ω), 15 μ F
- 13-11 27 k Ω , 220 Ω , 30 μ F, 36 μ F
- 13-13 18 k Ω , 220 Ω , 8 μ F, 6 μ F, 180 pF
- 13-15 2.7 k Ω , 150 Ω , 15 μ F
- 13-17 4.7 k Ω , 10 k Ω , 5.6 k Ω , 10 k Ω , 820 k Ω , 4.7 k Ω ,
4.7 k Ω , 12 k Ω
- 13-19 10 k Ω , 6.8 k Ω , 3.9 k Ω , 6.8 k Ω , (680 k Ω + 68 k Ω),
10 k Ω , 2.7 k Ω , 8.2 k Ω
- 13-21 100 k Ω , 47 k Ω , 10 k Ω , 180 Ω , 4.7 k Ω , 2.7 μ F, 18
 μ F, 0.2 μ F
- 13-23 $R_{E1} = 270 \Omega$, 2.2 μ F, 10 μ F, 0.39 μ F
- 13-25 ($R_4 = 82 \Omega$), ($R_9 = 150 \Omega$), 5 μ F, 75 μ F, 2 μ F, 33
 μ F, 0.47 μ F
- 13-27 1535, 6.5 k Ω , 6.3 k Ω
- 13-29 8.2 k Ω , 270 Ω , 270 k Ω , 6.8 k Ω , 270 Ω , 4.7 k Ω , 1
 μ F, 10 μ F, 0.27 μ F
- 13-31 18 k Ω , 12 k Ω , 390 k Ω , 15 k Ω , 560 Ω , 4.7 k Ω ,
0.68 μ F, 1.5 μ F
- 13-33 12 k Ω , 8.2 k Ω , 330 k Ω , 4.7 k Ω , 270 Ω , 2.7 k Ω , 8
 μ F, 2.7 μ F
- 13-35 0.006%
- 13-37 22.5 MHz
- 14-1 2 M Ω , 80 nA, 75 Ω , 25 mA, 1.7 mA,
50 mW
- 14-3 3.6 mA, 100 dB, ± 13.5 V, 1 mV
- 14-5 180 k Ω , 180 k Ω , 82 k Ω
- 14-7 1 M Ω , 1 M Ω , 470 k Ω , 8.75 V, 8.75 V, 8.985 V
- 14-9 $10^{11} \Omega$, $0.5 \times 10^{-3} \Omega$
- 14-11 68 k Ω , 0.2 μ F, 1.5 μ F
- 14-13 1 k Ω , 120 k Ω , 1 k Ω
- 14-15 15 k Ω , 1 M Ω , 15 k Ω
- 14-17 $5.9 \times 10^9 \Omega$, 1.5 k Ω
- 14-19 22 k Ω , 1 M Ω , 22 k Ω
- 14-21 820 Ω , (150 k Ω + 15 k Ω), 820 Ω , 820 Ω
- 14-23 (47 k Ω + 3.3 k Ω), 1 M Ω , 47 k Ω
- 14-25 680 Ω , 33 k Ω , 680 Ω , 6 μ F, 3.3 μ F
- 14-27 1.2 k Ω , (56 k Ω + 3.9 k Ω), 120 k Ω , 120 k Ω ,
1.8 μ F, 4.7 μ F
- 14-29 60 μ A, 80 μ A, 140 μ A, -1.4 V
- 14-31 -0.528 V
- 14-33 5.6 mV, -5.92 mV, -0.11 mV
- 14-35 50 μ A, 50 μ A, 50 μ A, 22.2 μ A, 22.2 μ A, 88.9 μ A,
88.9 μ A, +1.8 V, +450 mV,
+150 mV, -1.2 V, 2.4 V, -0.6 V, 3 V
- 14-37 (270 k Ω + 22 k Ω), 39 k Ω
- 14-39 39 k Ω , 330 k Ω
- 14-41 4.7 k Ω , (39 k Ω + 6.8 k Ω),
(82 k Ω + 10 k Ω)
- 15-1 $\theta_L = -370^\circ$ (unstable)
- 15-3 $\theta_m = 45^\circ$ (stable)
- 15-5 44° , 1.1°
- 15-7 200 pF
- 15-9 800 kHz, 20 kHz
- 15-11 80 kHz, 3.4 MHz
- 15-13 20 kHz, 5.6 kHz
- 15-15 31.8 kHz, 159 kHz
- 15-17 39.8 kHz, 3.97 V (peak)
- 15-19 0.4 pF, 15.4 pF
- 15-21 8.2 pF
- 15-23 4.4 pF, 0.4 pF
- 15-25 265 pF
- 15-27 147 pF
- 15-29 265 pF
- 16-1 6.8 k Ω , 220 k Ω , 6.8 k Ω , 3300 pF, 6.8 k Ω
- 16-3 39 k Ω , 22 k Ω , 1.2 k Ω , 2.2 k Ω , 2.2 k Ω ,
2.2 k Ω , 3300 pF, 25 μ F
- 16-5 0.5 μ F, 0.068 μ F
- 16-7 8.2 k Ω , 82 k Ω , 8.2 k Ω , 3900 pF, 470 pF
- 16-9 0.06 μ F, 5600 pF, 0.082 μ F, 220 k Ω ,
82 k Ω , 12 k Ω , 8.2 k Ω , 0.68 μ F
- 16-11 17.8 kHz
- 16-13 1300 pF, 8.2 k Ω , 1300 pF, 8.2 k Ω , 18 k Ω , 8.2 k Ω ,
45 kHz, 1.2 V/ μ s
- 16-15 10.5 kHz
- 16-17 220 Ω , 1.5 k Ω , 5.6 k Ω
- 16-19 0.015 μ F, 3.3 k Ω , 0.015 μ F, 3.3 k Ω , 3.3 k Ω , 5.6
k Ω , 1.5 k Ω
- 16-21 ± 12 V, 1.35 kHz
- 16-23 (1.5 k Ω + 15 k Ω pot.), 1 μ F, (15 k Ω + 1.5 k Ω),
470 Ω
- 16-25 10 k Ω , 0.27 μ F, 1 k Ω , (10 k Ω + 1 k Ω)
- 16-27 ± 1.95 V, 282 Hz
- 16-29 crystal in series with $R_1 = 270 \Omega$, 0.24 mW
- 16-31 1.5 k Ω , 2.2 k Ω , 4.7 k Ω , 2.2 k Ω , 330 pF, 330 pF,
0.85 mW
- 17-1 220 Ω , IN758, 8.2 k Ω
- 17-3 36 mA, 19.6 mA, 0.77 mA, 21.4 mA
- 17-5 12.5 mV, 10 mV, 0.07%, 0.06%
- 17-7 680 Ω , 470 Ω , IN758, 5.6 k Ω , 10 k Ω
- 17-9 0.3%, 0.15%, 33 dB

17-11	1.2 k Ω , 8.2 k Ω , 2.5 k Ω
17-13	2.7 k Ω , 15 k Ω
17-15	3.3 k Ω , 1N758, 470 Ω , 3.9 k Ω , 8.2 k Ω , 2.5 k Ω , 15 k Ω
17-17	470 Ω , (2 x 1N758)
17-19	1N751, 3.9 k Ω , 1.8 k Ω , 23 V
17-21	2.27 Ω , 4.4 W
17-23	1 A, 313 mA
17-25	220 Ω , 2.2 k Ω , 4.7 k Ω , 2.5 k Ω , 12 k Ω , 1N754
17-27	$0.75 \times 10^{-3}\%$, $0.4 \times 10^{-3}\%$
17-29	25 V, 6.8 k Ω , 4.7 k Ω , 2.5 k Ω , 37.5 mA
17-31	-17 V, 1 k Ω , 3.9 k Ω , 400 mW
17-33	61.5%, 82.5%
17-35	330 μ H, 15 μ F
17-37	1.2 k Ω , (12 k Ω + 1.8 k Ω), 0.55 Ω , 620 pF
17-39	1.2 k Ω , (10 k Ω + 820 Ω), 0.39 Ω , 510 pF
18-1	Point A: (0 mA, 20 V), Point Q: (49.7 mA, 15 V), Point B: (49.7 mA and 20 V from Q)
18-3	Point A: (0 mA, 25 V), Point Q: (1.19 mA, 22.3 V), Point B: (1.19 mA and 9.6 V from Q)
18-5	Point Q: (0 mA, 40 V), Point B: (92.6 mA, 0 V)
18-7	16.1 V, 16.2 V
18-9	386 mW
18-11	90 V, 900 mA, 2.8 W
18-13	Point Q: (183 mA, 19 V), Point A: (0 mA, 24 V), Point B: (19.03 V and 183 mA from Q)
18-15	12 V, 24 V, 144 mA, 215 mW
18-17	23 k Ω , 1.8 k Ω , 1.5 k Ω , 25 Ω , 180 Ω
18-19	± 15 V, 30 V, 492 mA, 675 mW
18-21	± 21 V, Q_2 , Q_3 : (2.7 W, 42 V, 778 mA), Q_4 , Q_5 : (135 mW, 42 V, 39 mA)
18-23	± 15 V, 3.3 k Ω , 50 Ω , 680 Ω , 1.5 Ω , 1.5 Ω
18-25	5.6 k Ω , 1.2 k Ω , 1 k Ω
18-27	330 Ω , 400 μ F, 53 V
18-29	1.8 k Ω , 250 Ω , 1.8 k Ω , 1 k Ω , 1 k Ω , 2.2 Ω , 2.2 Ω
18-31	18 μ F, 68 μ F, 680 pF
18-33	1.72 W, 30 V, 644 mA
18-35	0.85 mA, 1.01 A
18-37	± 23 V, 2.4 W
18-39	4.7 k Ω , 18 k Ω , 10 k Ω , 330 Ω , 4.7 k Ω , 100 k Ω , 1.2 M Ω , 1.8 M Ω , 100 k Ω , 4.7 μ F, 6 μ F, 0.2 μ F, 0.2 μ F
18-41	± 19 V
18-43	4.7 k Ω , 15 k Ω , 8.2 k Ω , 180 Ω , 4.7 k Ω , 100 k Ω , 680 k Ω , 1 M Ω , 100 k Ω , 8.2 μ F, 22 μ F, 0.47 μ F, 0.47 μ F
18-45	15 k Ω , (560 Ω + 82 Ω), 15 k Ω , 560 Ω , 560 Ω
18-47	($R_8 = R_9 = R_{10} = R_{11} = 2.2$ k Ω), 5 μ F, 17 V
18-49	± 28 V, 14.3 V, ± 1.25 V
18-51	± 15 V
18-53	2.7 μ F, 4 μ F, 1600 pF, 240 pF
18-55	0.53 Ω

19-1	2N1595	2N6167	
	V_{DRM}	50 V	100 V
	$I_{T(rms)}$	1.6 A	13 A
	V_{TM}	1.1 V	1.5 V
	I_H	5 mA	3.5 mA
	I_{GT}	2 mA	2.1 mA
	V_{GT}	0.7 V	0.63 V
19-3	2N1597, 1.27 V		
19-5	1.5 k Ω , 100 Ω , 12 Ω		
19-7	560 Ω , 22 k Ω , 200 k Ω		
19-9	12.8 V, 680 Ω		
19-11	56 k Ω , 6 μ F, 0.43 V		
19-13	2N6071	2N6343	
	V_{DRM}	200 V	400 V
	$I_{T(rms)}$	4 A	8 A
	V_C	1.4 V	0.9 V
19-15	49 $^\circ$		
19-17	3.3 k Ω , 180 Ω , 10 k Ω , 3.3 k Ω , 0.82 μ F, 0.15 μ F		
19-19	1 V, 15 V, 830 μ A, 2 mA		
19-21	165 mW, 34 V		
19-23	435 Hz		
19-25	6.8 k Ω , 10 k Ω , 100 Ω , 330 Ω , 0.56 μ F		
19-27	25 k Ω , (12 k Ω + 2.2 k Ω), 3.9 k Ω		
19-29	15 k Ω , (8.2 k Ω + 820 Ω), 15.7 V, 0.9 V, 24 k Ω , 5.6 k Ω		
20-1	184 W		
20-3	4.72×10^{14} Hz, 5.15×10^{14} Hz, 5.31×10^{14} Hz		
20-5	$R_F = 270$ Ω		
20-7	10 k Ω , 820 Ω		
20-9	690 μ W		
20-11	4.7 k Ω , 10 lx		
20-13	2 mA, 26 mA		
20-15	120 Ω , -0.12 V, -7 mA		
20-17	0.38 V		
20-19	102		
20-21	1.2 k Ω		
20-23	13 V, 5.5 mA		
20-25	330 Ω		
20-27	5.7 V		
20-29	9 mA, 4.4 mA, 49%		
21-1	3.6 MHz, 796 kHz		
21-3	15 k Ω , 20 k Ω , 150 k Ω		
21-5	390 pF, 15		
21-7	30 $^\circ$ C		
21-9	9.8 V, 10.2 V, 10.3 V		
21-11	146 Ω		
21-13	120 Ω , 225 mV, ± 145 mV, 5.6		

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