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SANKEN POWER TRANSISTORS

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Transistor Selection Guide

■ V_{CEO}-I_C

Collector–Emitter Voltage V_{CEO}(V) / Collector Current I_C(A)

V_{CEO}(V) \ I_C(A)	2	3	4	5	6	7	8	10	12	14	15	16	17	18	25
800		C3678 C4020 C4299 C4304 C4445 C4908		C3679 C4300		C3680 C4301 C5002 C5003		C5124							
600		C5249								C4706					
550		C4517 C4517A C5239		C4518 C4518A C5287				C3927 C4557							
500					C3830 C4907			C3831							
400				C4073 C4418 C4662 C5130		C3832 C3890 C4130 C4546		C4138 C4296	C3833 C4297 C5071		C4139 C4298 C4434			C4140	
380					D2141										
300	C2023 C5333														
250					D2017										
230											A1294 C3263		A1295 C3264		
200	A1668 C4382	D2016		C5271 D2557 D2558							A1493 C3857		A1494 C3858		
180	A1859A C4883A										A1386A A1492 A1673 C3519A C3856 C4388		A1216 C2922		
160											A1215 A1386 C2921 C3519				
150	A1667 A1859 C4381 C4883						B1559 B1587 D2389 D2438	A1186 B1560 B1588 C2837 D2390 D2439	B1570 D2401	A1303 A1860 C3284 C4886	B1647 B1649 D2560 D2562		B1648 D2561		
140								A1695 A1909 C4468 C5101							
120			D2015		D1769 D1785 D2045	C3834 C3835 C4153	A1694 A1908 C4467 C5100	B1259 D2081				B1382 B1420 D2082			B1383 D2083
110					B1624 B1625 B1626 B1659 D2493 D2494 D2495 D2589										
100					B1258										
80		C3852A	A1488A C3851A D2014		A1693 A1725 A1726 A1907 C4466 C4511 C4512 C5099										
60		C3852	A1262 A1488 B1257 C3179 C3851 D1796						A1568 B1351 B1352 C4065						
50		C4495						C4024	A1567 A1746 C4064		C4131				
40									C5370						

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Transistors for Switch Mode Power Supplies (for AC80–130V input)

V_{CBO}(V)	V_{CEO}(V)	I_C(A)	MT-25 (TO220)	FM20 (TO220F)	MT–100 (TO3P)	FM100 (TO3PF)
250	200	5		C5271		
500	400	5		C4073		
				C4418		
				C4662		
		7	C3832	C3890		
				C4130		
		10			C4138	C4296
		12			C3833	C4297
					C5071	
		15			C4139	C4298
					C4434	
		18			C4140	
600	400	5		C5130		
		7		C4546		
	500	6	C3830	C4907		
		10			C3831	
	600	3		C5249		

Transistors for Switch Mode Power Supplies (for AC180–280V input)

V_{CBO}(V)	V_{CEO}(V)	I_C(A)	MT-25 (TO220)	FM20 (TO220F)	MT–100 (TO3P)	FM100 (TO3PF)
900 (1000)	550	3	C5239	C4517(A)		
		5		C4518(A)	C5287	
		10			C3927	C4557
	600	14			C4706	
900	800	3	C4020	C4908		
					C3678	C4299
				C4304		C4445
		5			C3679	C4300
		7			C3680	C4301

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Transistors for Audio Amplifiers

Single Transistors

Single Emitter

Type No.	PC(W)	VCEO(V)	IC(A)	hFE(min)	fT(MHz)	Package
2SA1725/2SC4511	30	80	6	50	20	FM20 (TO220F)
2SA1726/2SC4512	50					MT-25 (TO220)
2SA1693/2SC4466	60					MT-100 (TO3P)
2SA1907/2SC5099	60					FM100 (TO3PF)
2SA1908/2SC5100	75	120	8			
2SA1694/2SC4467	80					MT-100 (TO3P)
2SA1909/2SC5101	80	140	10			FM100 (TO3PF)
2SA1673/2SC4388	85	180	15			
2SA1695/2SC4468	100	140	10			MT-100 (TO3P)
2SA1492/2SC3856	130	180	15			
2SA1493/2SC3857	150	200	15			MT-200 (2-screw mount)
2SA1494/2SC3858	200		17			

LAPT (Multi emitter for High Frequency)

Type No.	PC(W)	VCEO(V)	IC(A)	hFE(min)	fT(MHz)	Package
2SA1860/2SC4886	80	150	14	50	50	FM100 (TO3PF)
2SA1186/2SC2837	100		10		60	MT-100 (TO3P)
2SA1303/2SC3284	125		14		50	
2SA1386/2SC3519	130	160	15		40	
2SA1386A/2SC3519A	130	180				
2SA1294/2SC3263	130	230			35	
2SA1215/2SC2921	150	160			50	MT-200 (2-screw mount)
2SA1216/2SC2922	200	180	17		40	
2SA1295/2SC3264	200	230			35	

Transistor Selection Guide

Darlington Transistors

Type No.	Pc(W)	VCEO(V)	Ic(A)	hFE(min)	fT(MHz)	Package
2SB1626	30	110	6	5000	100	FM20 (TO220F)
2SD2495					60	
2SB1659	50				100	MT-25 (TO220)
2SD2589					60	
2SB1624	60				100	MT-100 (TO3P)
2SD2493					60	
2SB1625	60				100	FM100 (TO3PF)
2SD2494					60	
2SB1587	75	150	8		65	
2SD2438					80	
2SB1559	80		10		65	MT-100 (TO3P)
2SD2389					80	
2SB1588	80		15		50	FM100 (TO3PF)
2SD2439					55	
2SB1649	85	200			45	
2SD2562					70	
2SB1560	100	150	10		50	MT-100 (TO3P)
2SD2390					55	
2SB1647	130		15		45	
2SD2560					70	
2SB1570	150	150	12		50	MT-200 (2-screw mount)
2SD2401					55	
2SB1648	200		17		45	
2SD2561					70	

Temperature compensation Transistors and Driver Transistors

Type No.	Pc(W)	VCEO(V)	Ic(A)	hFE(min)	fT(MHz)	Package	Remarks
2SC4495	25	50	3	500	40	FM20 (TO220F)	Temperature compensation
2SC4883	20	150	2	60	120		Driver, Complement 2SA1859
2SC4883A		180					Driver, Complement 2SA1859A
2SA1859	20	–150	–2	60	60		Driver, Complement 2SC4883
2SA1859A		–180					Driver, Complement 2SC4883A

Reliability

1. Definition of Reliability

The word reliablity is an abstract term which refers to the degree to which equipment or components, such as semiconductor devices, are resistant to failure. Reliability can be and is often measured quantitatively. Reliability is defined as "whether equipment or components (such as a semiconductor device) under given conditions perform the same at the end of a given period as at the beginning."

2. Reliability Function

In general, there are three types of failure modes in electronic components:

1. Infant failure
2. Random failure
3. Wear-out failure

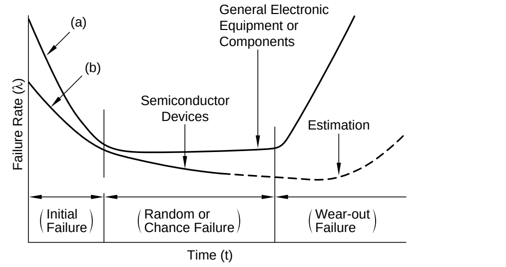


Figure 1 Bath Tub Curve

These three types of failure describe "bathtub curve" shown in Figure 1. Infant failures can be attributed to trouble in the production process and can be eliminated by aging befor shipment to customers, stricter control of the production process and quality control measures. Semiconductor devices such as transistors, unlike electronic equipment, take a considerable amount of time to reach the stage where wear-out failure begins to occur. And, as shown in Figure 1 (b), they also last much longer than electronic equipment. This shows that the longer they are used the more stable they actually become.

The reduction that occurs in random failures can be approximated by Weibull distribution, logarithmic normal distribution, or gamma distribution, but Weibull distribution best expresses the phenomenon that occurs with transistors.

3. Quantitative Expression of Reliability

While there are many ways to quantitatively express reliability, two criteria, failure rate and life span, are generally used to define the reliability of semiconductors such as transistrors.

a) Failure Rate (FR)

Failure rate often refers to instantaneous failures or λ (t). In general of reliability theory, however, the cumulative failure rate, or Reliability Index, is

$$F \cdot R = \frac{r(t)}{N \cdot t} \quad \cdots\cdots (1)$$

Where N = Net quantity used, and
r(t) = Net quantitiy failed after t hours

If we assign t the arbitrary

$$F \cdot R = \frac{r}{N} \times 100 \text{ (\%/1,000 hours)} \quad \cdots\cdots (2)$$

In situations where the cumulative failure rate is small, failure is expressed in units of one Fit, 10^{-9} (failures/hours).

b) Life Span(L)

Life Span can be expressed in terms of average lifespan or as Mean Time Between Failure (MTBF), but assuming that random failure is shown by the Index Distribution [λ (t) = constant], then Life Span or L can be shown by the equation

$$L = \frac{1}{F \cdot R} \text{(hours)} \quad \cdots\cdots (3)$$

4. Applications Considered on Reliability

a) The type and specifications of our transistors and semiconductor devices vary depending on the application that will be required by their intended use. Customer should, therefore, determine which type will best suit their purposes.

b) Note that high temperratures or long soldering periods must be avoided during soldering, as heat can be transmitted through external leads into the interior. This may cause deterioration if the maximum allowable temperature is exceeded.

c) When using the trasistor under pulse operation or inductive load, the Safe Operating Area (SOA) for the current and voltage must not be exceeded (Figure 2).

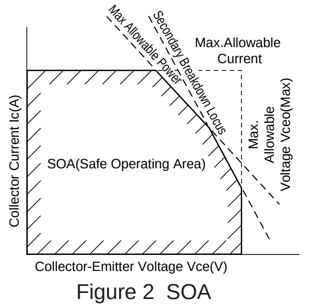


Figure 2 SOA

d) The reliability of transistors and semiconductor devices is greatly affected by the stress of junction temperature. If we accept in general proceed in the form of Arrhenius equation, the relationship between the junction temperature Tj and lifespan L can be expressed with the following empirical formula

$$\ell n\, L = A + \frac{B}{Tj} \quad \cdots\cdots (4)$$

It is, hence, very important to derate the junction temperature to assure a high reliability rate.

5. Reliability Test

Sanken bases its test methods and conditions on the following standards. Tests are conducted under these or stricter conditions, The details of these are shown in Table 1.

- MIL-STD-202F (Test method for electrical and electronic components)
- MIL-STD-750C (Test method for semiconductor equipment)
- JIS C 7021 (Endurance test and environmental test method for individual semiconductor devices)
- JIS C 7022 (Endurance test and environmental test method for integrated circuits of semiconductors)

6. Quality Assurance

To ensure high quality and high reliability, quality control and production process control procedures are executed from the receipt of parts through the entire production process. Our quality assurance system is shown in Figure 3.

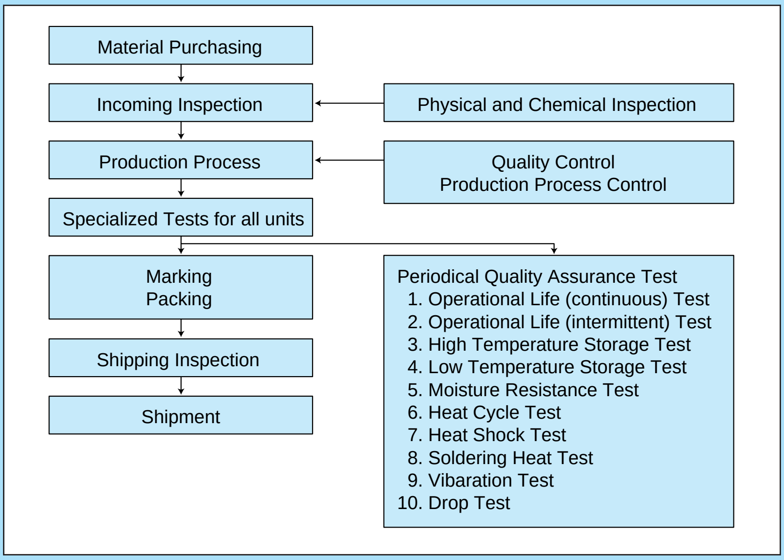
Reliability

Table 1: Test Methods and Conditions

Test	Details of the Testing Method	LTPD(%)
Continuous Operations Test	Collector dissipation with maximum junction temperature is applied continuously at room temperature to judge lifespan and reliability under transistor operating conditions.	*5/1000hrs
Intermittent Operation Test	Power equal to that used in the Continuous Operations Test is applied intermittently to test the transistor's lifespan and reliability under on and off conditions.	5/1000hrs
High Temperature Storage Test	Confirms the highest storage temperature and operating temperature of transistors.	5/1000hrs
Low Temperature Storage Test	Confirms the lowest storage temperature of transistors.	5/1000hrs
Moisture Resistance Test	Tested at RH=85% and TA=85°C for the effects of the interaction between temperature and humidity, and the effects of surface insulation between electrodes and high temperature/high humidity.	5/1000hrs
Heat Cycle Test	Tested at Tstg min – Room temp. – Tstg max – Room temp. for 10 cycles (one cycle 30 min. –5 min. –30 min. –5 min.) to detect mechanical faults and characteristic changes caused by thermal expansion and shrinkage of the transistor.	5
Heat Shock Test	Tested at 100°C (5 min.), 25°C (within 3 sec.), 0°C (5 min.) for 10 cycles to check for mechanical faults and characteristic changes caused by thermal expansion and shrinkage of transistor.	5
Soldering Heat Test	Tested at 260 ± 5°C, 10 ± 1 sec, by dipping lead wire to 1.5mm from the seating plane in solder bath to check for characteristic changes caused by drastic temperature rises of exterior lead wire.	5
Vibrations Test	Tested at amplitude 1.52mm, vibration frequency 10-55 Hz in directions of X, Y, Z, for 2 hours each (total 6 hours) to check for characteristic changes caused by vibration during operation and transportion.	5
Drop Test	Tested by dropping 10 times from 75 cm height to check for mechanical endurance and characteristic changes caused by shock during handling.	5

＊Reliability Standard : 60%

Figure 3 Quality Assurance System



7. Notes Regarding Storage, Characteristic Tests, and Handling

Since reliability can be affected adversely by improper storage environment and handling methods during Characteristic tests, please observe the following cautions.

a) Cautions for Storage

1. Ensure that storage conditions comply with the standard temperature (5 to 35°C) and the standard relative humidity (arround 40 to 75%) and avoid storage locations that experience extreme changes in temperature or humidity.
2. Avod locations where dust or harmful gases are present, and avoid direct sunlight.
3. Reinspect for rust in leads and solderbility that have been stored for a long time.

b) Cautions for Characteristic Tests and Handling

1. When characteristic tests are carried out during inspection testing and other standard test periods, protect the transistor from surges of power from the testing device, shorts between the transistor and the heatsink

c) Silicone Grease

When using a heatsink, please coat the back surface of the transistor and both surfaces of the insulating plate with a thin layer of silicone grease to improve heat transfer between the transistor and the heatsink.

Recommended Silicone Grease
- G-746 (Shin-Etsu Chemical)
- YG6260 (Toshiba Silicone)
- SC102 (Dow Corning Toray Silicone)

d) Torque when Tightening Screws

Thermal resistance increases when tightening torque is small, and radiation effects are decreased. When the torque is too high, the screw can cut, the heatsink can be deformed, and/or distortion can arise in the product's frame. To avoid these problems, Table 2 shows the recommended tightening torques for each product type.

Table 2. Screw Tightening Torques

Package	Screw Tightening Torque
MT25 (TO-220)	0.490 to 0.686 N · m (5 to 7kgf · cm)
FM20 (TO-220 Full Mold)	0.490 to 0.686 N · m (5 to 7kgf · cm)
MT100 (TO-3P)	0.686 to 0.822 N · m (7 to 9kgf · cm)
FM100 (TO-3P Full Mold)	0.686 to 0.822 N · m (7 to 9kgf · cm)
MT200 (TO-3P two-point mount)	0.686 to 0.822 N · m (7 to 9kgf · cm)

e) Soldering Temperature

In general, the transistor is subjected to high temperatures when it is mounted on the printed circuit board, whether from flow solder from a solderbath, or, in hand operations from a soldering iron. The testing method and test conditions (JIS-C-7021 standards) for a transistor's heat resistance during soldering are:

At a distance of 1.5mm from the transistor's main body, apply 260°C for 10 seconds, and 350°C for 3 seconds.

However, please stay well within these limits and for as short a time as possible during actual soldering.

Reliability

Temperature Derating in Safe Operating Area

Flange (case) temperature is typically described as 25°C, but it must be derated subject to the operating temperature.
This derating curve is determined by manufacturing conditions of devices, materials used etc. and in case of a silicon transistor, breakdown voltage and DC Current Gain are significantly deteriorated in the temperature range of 260°C to 360°C.
Hence, the collector current must be derated by using the derating curve in Fig.2 where the breakdown point is set at 260°C.

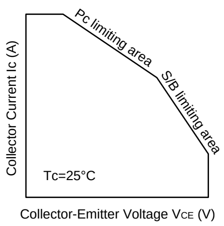


Fig.1 Safe Operating Area

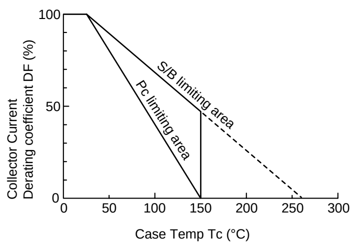


Fig.2 Derating Curve of Safe Operating Area

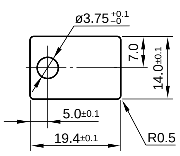
Derating coefficient is obtained from temperature in Fig.2 and it must be applied to the current value of the safe operating area in order to obtain the derated current.

Accessories

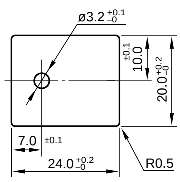
☆ Sanken Transistors do not include accessories. Accessories may be attached at a cost if requested.
☆ Sanken transistor case is a standard size, and can be used with any generally sold accessories.

• Insulater: Mica, with a thickness of 0.06mm, +0.045 –0.005 allowance

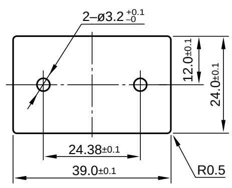
Type Name:Mold(10)Mica



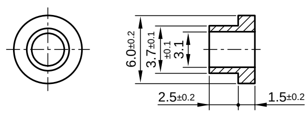
Type Name:Mold(14)Mica



Type Name:Mold(9)Mica



• Insulation Bush for MT-25 (TO220)

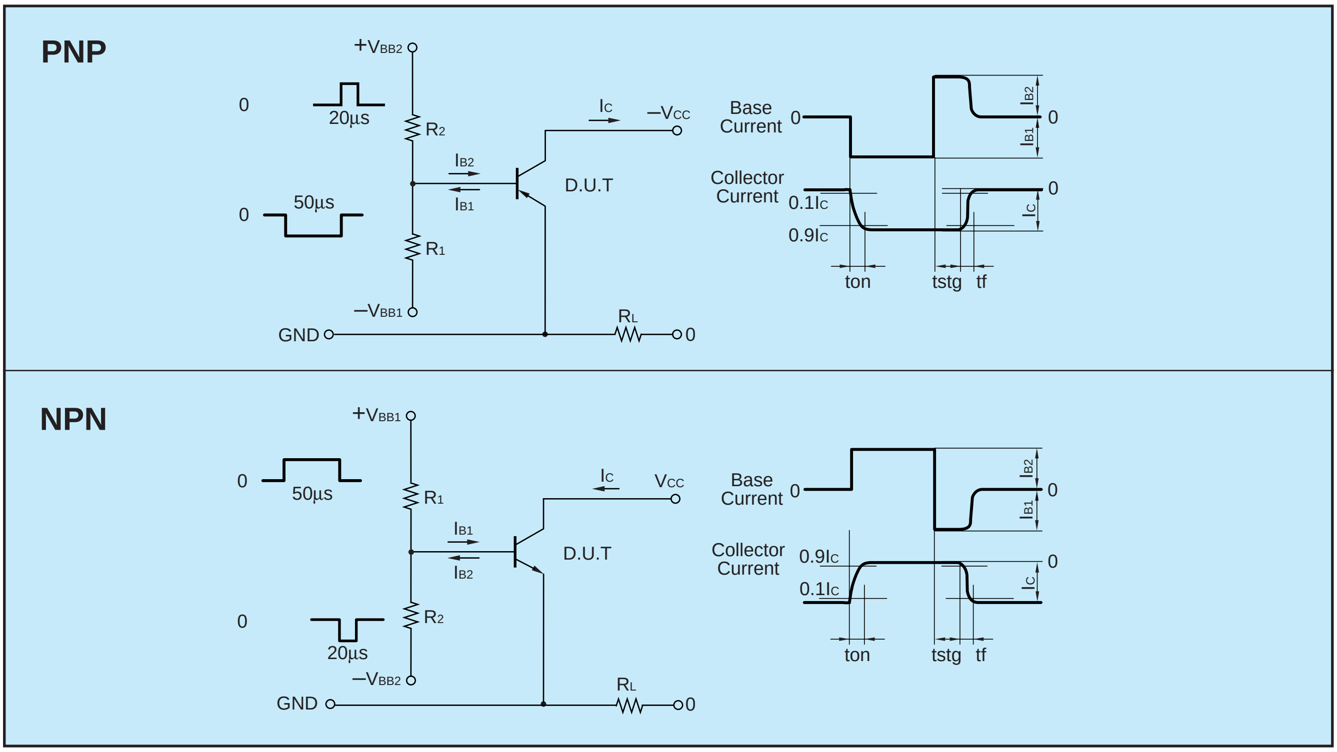


Switching Characteristics

Typical Switching Characteristics (Common Emitter)

V_{CC} (V)	R_L (Ω)	I_C (A)	V_{B2} (V)	V_{BB1} (V)	V_{BB2} (V)	I_{B1} (A)	I_{B2} (A)	tr (μs)	tstg (μs)	tf (μs)

Switching Characteristics Test Circuit/Measurement Wave Forms



Symbols

Symbol	Item	Definition
V_{CBO}	Collector-Base Voltage	DC Voltage between Collector and Base when Emitter is open
V_{CEO}	Collector-Emitter Voltage	Voltage between Collector and Emitter when Base is open and voltage is reversely applied to Collector junction
V_{EBO}	Emitter-Base Voltage	DC voltage between Emitter and Base when Collector is open
I_C	Collector Current	DC current passing through Collector electrode
I_B	Base Current	DC current passing through Base electrode
P_C	Collector Power Dissipation	Power consumed at Collector junction
Tj	Operating Junction Temperature	Maximum allowable temperature value at absolute maximum ratings
Tstg	Storage Temperature	Maximum allowable range of ambient temperature at non-operation
I_{CBO}	Collector Cutoff Current	Collector current when Emitter is open and a specified reverse voltage is applied between Collector and Base
I_{EBO}	Emitter Cutoff Current	Emitter current when Collector is open and a specified reverse voltage is applied between Emitter and Base
$V_{(BR)CEO}$	Collector-Emitter Saturation Voltage	Breakdown voltage between Collector and Emitter when Base is open
h_{FE}	DC Current Gain	Ratio of DC output current and DC input current at a specified voltage and current (Emitter common)
V_{CE}(sat)	Collector-Emitter Saturation Voltage	DC voltage between Collector and Emitter under specified saturation conditions
V_{BE}(sat)	Base-Emitter Saturation Voltage	DC voltage between Base and Emitter under specified saturation conditions
V_{FEC}	Emitter-Collector Diode Forward Voltage	Diode forward voltage between Emitter and Collector when Base is open
f_T	Cut-off Frequency	Frequency at the specified voltage and current where h_{FE} is 1 (0dB)
Cob	Collector Junction capacitance	Junction capacitance between collector and Base at a specified voltage and frequency

• Ta=25°C unless otherwise specified.

Discontinued Parts Guide

Discontinued Parts	Replace ment Parts
2SA744to745	2SA1694to1695
2SA746to747	2SA1695
2SA764to765	2SA1725to1726
2SA807to808	2SA1693to1694
2SA878	–
2SA892	2SB1351
2SA907to909	2SA1215to1216,1295
2SA971	–
2SA980to982	2SA1694
2SA1067	–
2SA1068	–
2SA1102	2SA1693
2SA1103	2SA1694
2SA1104	2SA1694
2SA1105	2SA1695
2SA1106	2SA1695
2SA1116	2SA1493
2SA1117	2SA1494
2SA1135	2SA1693
2SA1169	2SA1493
2SA1170	2SA1494
2SA1187	–
2SA1205	2SA1746
2SA1355	2SA1262,1488
2SB622	–
2SB711to712	2SB1259,1351
2SB1005	2SB1257
2SB1476	2SB1624
2SB1586	2SB1625
2SC1107	2SC3179,3851
2SC1108	2SC3851A
2SC1109	2SC3179,3851
2SC1110	2SC3851A
2SC1111to1112	2SC4467to4468
2SC1113	2SC4511to4512
2SC1114	–
2SC1115to1116	2SC4468
2SC1402to1403	2SC4467to4468
2SC1436	–
2SC1437	–
2SC1440to1441	–
2SC1442to1443	–
2SC1444to1445	2SC4511to4512
2SC1454	–
2SC1477	–
2SC1504	2SC2023
2SC1577to1578	2SC3833,3831
2SC1579to1580	2SC4706
2SC1584to1585	2SC2921-2922,3264
2SC1618to1619	2SC4466-4467
2SC1629	2SD2045
2SC1664	2SC4558
2SC1768	–
2SC1777	–
2SC1783	–
2SC1786	–
2SC1828	2SC3832,3830

Discontinued Parts	Replacement Parts
2SC1829	–
2SC1830	2SD2082,2083
2SC1831	–
2SC1832	–
2SC1888to1889	2SC3852,3852A
2SC2022	2SC2023
2SC2147	–
2SC2198	2SC4024
2SC2199	2SC4131
2SC2256	–
2SC2260to2262	2SC4467
2SC2302	2SC3832
2SC2303	2SC3833
2SC2304	2SC3833
2SC2305	–
2SC2306	2SC4140
2SC2307	2SC3833
2SC2317	2SD2016
2SC2354	2SC2023
2SC2364	–
2SC2365	2SC3831
2SC2491	2SC4024
2SC2492	–
2SC2493	–
2SC2577	2SC4466
2SC2578	2SC4467
2SC2579	2SC4467
2SC2580	2SC4468
2SC2581	2SC4468
2SC2607	2SC3857
2SC2608	2SC3858
2SC2665	2SC4466
2SC2723	2SC4140
2SC2761	–
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2SC2900	–
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2SD90to94	2SC3179,3851,3851A
2SD163to166	2SC4468
2SD201to203	2SC4466to4467
2SD211to214	2SC4468

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2SD556to557	2SC4468
2SD593to594	2SC4020
2SD605	–
2SD606	–
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2SA1490	2SA1694
2SA1491	2SA1695
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2SA1671	2SA1908
2SA1672	2SA1909
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2SC1983to1984	2SC3852,3852A
2SC1985to1986	2SC4511,4512
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2SC2810	2SC3890
2SC3300	2SC4131
2SC3853	2SC4466
2SC3854	2SC4467
2SC3855	2SC4468
2SC4385	2SC5099
2SC4386	2SC5100
2SC4387	2SC5101
2SC4503	2SD2083
2SC4558	2SD2495

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