ELECTROSTATIC DISCHARGE DATA

Electrostatic damage (ESD) to semiconductor devices has plagued the industry for years. Special packaging and handling techniques have been developed to protect these sensitive devices. While many of Motorola's semiconductors devices are not susceptible to ESD, all products are revered as sensitive and handled accordingly.

The data in this section was developed using the human-body model specified in MIL-STD-750C, Method 1020. The threshold values (Eth, kV) of ten devices was recorded, then the average value calculated. This data plus the device type, device source, package type, classification, polarity and general device description are supplied. Devices listed are mainly JEDEC registered 1N and 2N numbers. Military QPL devices and some customer specials are also in this database. The data in this report will be updated regularly, and the range will be added as new data becomes available.

The sensitivity classifications listed are as follows:

Class 1 . . .1 to 1999 volts

Class 2 . . .2000 to 3999 volts

Class 3 . . .4000 to > 15500 volts

The code "N/S" signifies a non-sensitive device. "SEN" are considered sensitive and should be handled according to ESD procedures. Of the various products manufactured by the Communications, Power and Signal Technologies Group, the following lists general device families by not sensitive to extremely sensitive.

Not sensitive	FET current regulators
Least sensitive	Zener diodes (on a square mil/millijoule basis)
Less sensitive	Bipolar transistors
More sensitive	Bipolar darlington transistors
Very sensitive	Power TMOS devices
Extremely sensitive . .	Hot carrier diodes and MOSFET transistors without gate protection

The data supplied herein, is listed in numerical or alphabetical order.

DEVICE	LINE	CASE	Eth,kV	CLASS	POLARITY	PRODUCT DESCRIPTION
1N747	ZL4140	DO–204	>15.50	3 – N/S		ZENER DIODE
1N748	ZL4150	DO–204	>15.50	3 – N/S		ZENER DIODE
1N749	ZL4160	DO–204	>15.50	3 – N/S		ZENER DIODE
1N750	ZL4170	DO–204	>15.50	3 – N/S		ZENER DIODE
1N751	ZL4180	DO–204	>15.50	3 – N/S		ZENER DIODE
1N752	ZL4190	DO–204	>15.50	3 – N/S		ZENER DIODE
1N753	ZL4205	DO–204	>15.50	3 – N/S		ZENER DIODE
1N754	ZL4210	DO–204	>15.50	3 – N/S		ZENER DIODE
1N755	ZL4220	DO–204	>15.50	3 – N/S		ZENER DIODE
1N756	ZL4230	DO–204	>15.50	3 – N/S		ZENER DIODE
1N757	ZL4245	DO–204	>15.50	3 – N/S		ZENER DIODE
1N758	ZL4250	DO–204	>15.50	3 – N/S		ZENER DIODE
1N759	ZL4270	DO–204	>15.50	3 – N/S		ZENER DIODE
1N821	ZL41675	DO–204	>15.50	3 – N/S		REFERENCE DIODE
1N823	ZL41675	DO–204	>15.50	3 – N/S		REFERENCE DIODE
1N825	ZL41675	DO–204	>15.50	3 – N/S		REFERENCE DIODE
1N827	ZL41675	DO–204	>15.50	3 – N/S		REFERENCE DIODE
1N829	ZL41675	DO–204	>15.50	3 – N/S		REFERENCE DIODE
1N938	ZL22075	DO–204	>15.50	3 – N/S		REFERENCE DIODE
1N941	ZL23075	DO–204	>15.50	3 – N/S		REFERENCE DIODE
1N943	ZL23075	DO–204	>15.50	3 – N/S		REFERENCE DIODE
1N962	ZL4260	DO–204	>15.50	3 – N/S		ZENER DIODE
1N963	ZL4270N	DO–204	>15.50	3 – N/S		ZENER DIODE
1N964	ZL4280	DO–204	>15.50	3 – N/S		ZENER DIODE
1N965	ZL4295	DO–204	>15.50	3 – N/S		ZENER DIODE
1N966	ZL4300	DO–204	>15.50	3 – N/S		ZENER DIODE
1N967	ZL4315	DO–204	>15.50	3 – N/S		ZENER DIODE
1N968	ZL4325	DO–204	>15.50	3 – N/S		ZENER DIODE
1N969	ZL4330	DO–204	>15.50	3 – N/S		ZENER DIODE
1N970	ZL4340	DO–204	>15.50	3 – N/S		ZENER DIODE
1N971	ZL4350	DO–204	>15.50	3 – N/S		ZENER DIODE
1N972	ZL4360	DO–204	>15.50	3 – N/S		ZENER DIODE
1N973	ZL4370	DO–204	>15.50	3 – N/S		ZENER DIODE
1N974	ZL4380	DO–204	>15.50	3 – N/S		ZENER DIODE
1N976	ZL4400	DO–204	>15.50	3 – N/S		ZENER DIODE
1N977	ZL4410	DO–204	>15.50	3 – N/S		ZENER DIODE
1N978	ZL4420	DO–204	>15.50	3 – N/S		ZENER DIODE
1N979	ZL4430	DO–204	>15.50	3 – N/S		ZENER DIODE
1N980	ZL4440	DO–204	>15.50	3 – N/S		ZENER DIODE
1N981	ZL4450	DO–204	>15.50	3 – N/S		ZENER DIODE

DEVICE	LINE	CASE	Eth,kV	CLASS	POLARITY	PRODUCT DESCRIPTION
1N984	ZL4485	DO–204	>15.50	3 – N/S		ZENER DIODE
1N985	ZL4490	DO–204	>15.50	3 – N/S		ZENER DIODE
1N987	ZL4510	DO–204	>15.50	3 – N/S		ZENER DIODE
1N988	ZL4520	DO–204	>15.50	3 – N/S		ZENER DIODE
1N992	ZL4570	DO–204	>15.50	3 – N/S		ZENER DIODE
1N2818	YZL14320	DO–5	>15.50	3 – N/S		ZENER DIODE
1N2831	YZL14420	DO–5	>15.50	3 – N/S		ZENER DIODE
1N2835	YZL14460	DO–5	>15.50	3 – N/S		ZENER DIODE
1N2837	YZL14480	DO–5	>15.50	3 – N/S		ZENER DIODE
1N2838	YZL14490	DO–5	>15.50	3 – N/S		ZENER DIODE
1N2846	YZL14580	DO–5	>15.50	3 – N/S		ZENER DIODE
1N2970	ZL10210	DO–203	>15.50	3 – N/S		ZENER DIODE
1N2971	ZL10220	DO–203	>15.50	3 – N/S		ZENER DIODE
1N2974	ZL10250	DO–203	>15.50	3 – N/S		ZENER DIODE
1N2982	ZL10310	DO–203	>15.50	3 – N/S		ZENER DIODE
1N3000	ZL10440	DO–203	>15.50	3 – N/S		ZENER DIODE
1N3016	ZL8210	DO–13	>15.50	3 – N/S		ZENER DIODE
1N3018	ZL8230	DO–13	>15.50	3 – N/S		ZENER DIODE
1N3019	ZL8240	DO–13	>15.50	3 – N/S		ZENER DIODE
1N3020	ZL8250	DO–13	>15.50	3 – N/S		ZENER DIODE
1N3022	ZL8270	DO–13	>15.50	3 – N/S		ZENER DIODE
1N3023	ZL8280	DO–13	>15.50	3 – N/S		ZENER DIODE
1N3024	ZL8290	DO–13	>15.50	3 – N/S		ZENER DIODE
1N3025	ZL8300	DO–13	>15.50	3 – N/S		ZENER DIODE
1N3026	ZL8310	DO–13	>15.50	3 – N/S		ZENER DIODE
1N3027	ZL8320	DO–13	>15.50	3 – N/S		ZENER DIODE
1N3028	ZL8330	DO–13	>15.50	3 – N/S		ZENER DIODE
1N3029	ZL8340	DO–13	>15.50	3 – N/S		ZENER DIODE
1N3030	ZL8350	DO–13	>15.50	3 – N/S		ZENER DIODE
1N3032	ZL8370	DO–13	>15.50	3 – N/S		ZENER DIODE
1N3033	ZL8380	DO–13	>15.50	3 – N/S		ZENER DIODE
1N3034	ZL8390	DO–13	>15.50	3 – N/S		ZENER DIODE
1N3037	ZL8420	DO–13	>15.50	3 – N/S		ZENER DIODE
1N3040	ZL8450	DO–13	>15.50	3 – N/S		ZENER DIODE
1N3041	ZL8460	DO–13	>15.50	3 – N/S		ZENER DIODE
1N3042	ZL8470	DO–13	>15.50	3 – N/S		ZENER DIODE
1N3044	ZL8490	DO–13	>15.50	3 – N/S		ZENER DIODE
1N3045	ZL8500	DO–13	>15.50	3 – N/S		ZENER DIODE
1N3048	ZL8540	DO–13	>15.50	3 – N/S		ZENER DIODE
1N3049	ZL8550	DO–13	>15.50	3 – N/S		ZENER DIODE
1N3051	ZL8580	DO–13	>15.50	3 – N/S		ZENER DIODE
1N3154	ZL22100	DO–204	>15.50	3 – N/S		REFERENCE DIODE
1N3157	ZL22100	DO–204	>15.50	3 – N/S		REFERENCE DIODE
1N3821	ZL8130	DO–13	>15.50	3 – N/S		ZENER DIODE
1N3822	ZL8140	DO–13	>15.50	3 – N/S		ZENER DIODE
1N3823	ZL8150	DO–13	>15.50	3 – N/S		ZENER DIODE
1N3824	ZL8160	DO–13	>15.50	3 – N/S		ZENER DIODE
1N3826	ZL8180	DO–13	>15.50	3 – N/S		ZENER DIODE
1N3827	ZL8190	DO–13	>15.50	3 – N/S		ZENER DIODE
1N3828	ZL8200	DO–13	>15.50	3 – N/S		ZENER DIODE
1N3891	RL5038C	DO–203	11.00	3 – N/S		FAST RECOVERY RECTIFIER
1N3998	ZL11200	DO–203	>15.50	3 – N/S		ZENER DIODE
1N4007	RL524B	DO–41	>15.50	3 – N/S		STANDARD RECOVERY RECTIFIER
1N4101	ZL4230	DO–204	>15.50	3 – N/S		ZENER DIODE
1N4102	ZL4240	DO–204	>15.50	3 – N/S		ZENER DIODE
1N4103	ZL4245	DO–204	>15.50	3 – N/S		ZENER DIODE
1N4104	ZL4250	DO–204	>15.50	3 – N/S		ZENER DIODE
1N4105	ZL4260	DO–204	>15.50	3 – N/S		ZENER DIODE
1N4106	ZL4270	DO–204	>15.50	3 – N/S		ZENER DIODE
1N4107	ZL4280	DO–204	>15.50	3 – N/S		ZENER DIODE
1N4108	ZL4290	DO–204	>15.50	3 – N/S		ZENER DIODE
1N4109	ZL4295	DO–204	>15.50	3 – N/S		ZENER DIODE
1N4110	ZL4300	DO–204	>15.50	3 – N/S		ZENER DIODE
1N4111	ZL4310	DO–204	>15.50	3 – N/S		ZENER DIODE

DEVICE	LINE	CASE	Eth,kV	CLASS	POLARITY	PRODUCT DESCRIPTION
1N4112	ZL4315	DO–204	>15.50	3 – N/S		ZENER DIODE
1N4113	ZL4320	DO–204	>15.50	3 – N/S		ZENER DIODE
1N4116	ZL4340	DO–204	>15.50	3 – N/S		ZENER DIODE
1N4117	ZL4345	DO–204	>15.50	3 – N/S		ZENER DIODE
1N4118	ZL4350	DO–204	>15.50	3 – N/S		ZENER DIODE
1N4120	ZL4360	DO–204	>15.50	3 – N/S		ZENER DIODE
1N4121	ZL4370	DO–204	>15.50	3 – N/S		ZENER DIODE
1N4122	ZL4380	DO–204	>15.50	3 – N/S		ZENER DIODE
1N4128	ZL4440	DO–204	>15.50	3 – N/S		ZENER DIODE
1N4131	ZL4460	DO–204	>15.50	3 – N/S		ZENER DIODE
1N4133	ZL4470	DO–204	>15.50	3 – N/S		ZENER DIODE
1N4370	ZL4100	DO–204	>15.50	3 – N/S		ZENER DIODE
1N4371	ZL4110	DO–204	>15.50	3 – N/S		ZENER DIODE
1N4372	ZL4120	DO–204	>15.50	3 – N/S		ZENER DIODE
1N4554	ZL12200	DO–5	>15.50	3 – N/S		ZENER DIODE
1N4562	ZL14200	DO–5	>15.50	3 – N/S		ZENER DIODE
1N4565	ZL41605	DO–204	>15.50	3 – N/S		REFERENCE DIODE
1N4566	ZL41605	DO–204	>15.50	3 – N/S		REFERENCE DIODE
1N4567	ZL41605	DO–204	>15.50	3 – N/S		REFERENCE DIODE
1N4568	ZL41605	DO–204	>15.50	3 – N/S		REFERENCE DIODE
1N4570	ZL41610	DO–204	>15.50	3 – N/S		REFERENCE DIODE
1N4571	ZL41610	DO–204	>15.50	3 – N/S		REFERENCE DIODE
1N4572	ZL41610	DO–204	>15.50	3 – N/S		REFERENCE DIODE
1N4573	ZL41610	DO–204	>15.50	3 – N/S		REFERENCE DIODE
1N4614	ZL4130E	DO–204	>15.50	3 – N/S		ZENER DIODE
1N4615	ZL4140E	DO–204	>15.50	3 – N/S		ZENER DIODE
1N4616	ZL4145E	DO–204	>15.50	3 – N/S		ZENER DIODE
1N4618	ZL4155E	DO–204	>15.50	3 – N/S		ZENER DIODE
1N4619	ZL4160E	DO–204	>15.50	3 – N/S		ZENER DIODE
1N4620	ZL4165E	DO–204	>15.50	3 – N/S		ZENER DIODE
1N4622	ZL4173E	DO–204	>15.50	3 – N/S		ZENER DIODE
1N4624	ZL4180E	DO–204	>15.50	3 – N/S		ZENER DIODE
1N4626	ZL4190E	DO–204	>15.50	3 – N/S		ZENER DIODE
1N4627	ZL4205E	DO–204	>15.50	3 – N/S		ZENER DIODE
1N4732	ZL5170	DO–41	>15.50	3 – N/S		ZENER DIODE
1N4937	RL575B	DO–41	13.83	3 – N/S		FAST RECOVERY RECTIFIER
1N5221	ZL4100	DO–204	>15.50	3 – N/S		ZENER DIODE
1N5230	ZL4170	DO–204	>15.50	3 – N/S		ZENER DIODE
1N5233	ZL4200	DO–204	>15.50	3 – N/S		ZENER DIODE
1N5250	ZL4325	DO–204	>15.50	3 – N/S		ZENER DIODE
1N5255	ZL4355	DO–204	>15.50	3 – N/S		ZENER DIODE
1N5260	ZL4400	DO–204	>15.50	3 – N/S		ZENER DIODE
1N5264	ZL4440	DO–204	>15.50	3 – N/S		ZENER DIODE
1N5267	ZL4460	DO–204	>15.50	3 – N/S		ZENER DIODE
1N5270	ZL4485	DO–204	>15.50	3 – N/S		ZENER DIODE
1N5283	ZL19283	DO–204	>15.50	3 – N/S		FET CURRENT REGULATOR
1N5284	ZL19284	DO–204	>15.50	3 – N/S		FET CURRENT REGULATOR
1N5285	ZL19285	DO–204	>15.50	3 – N/S		FET CURRENT REGULATOR
1N5287	ZL19287	DO–204	>15.50	3 – N/S		FET CURRENT REGULATOR
1N5288	ZL19288	DO–204	>15.50	3 – N/S		FET CURRENT REGULATOR
1N5289	ZL19289	DO–204	>15.50	3 – N/S		FET CURRENT REGULATOR
1N5290	ZL19290	DO–204	>15.50	3 – N/S		FET CURRENT REGULATOR
1N5291	ZL19291	DO–204	>15.50	3 – N/S		FET CURRENT REGULATOR
1N5292	ZL19292	DO–204	>15.50	3 – N/S		FET CURRENT REGULATOR
1N5295	ZL19295	DO–204	>15.50	3 – N/S		FET CURRENT REGULATOR
1N5296	ZL19296	DO–204	>15.50	3 – N/S		FET CURRENT REGULATOR
1N5297	ZL19297	DO–204	>15.50	3 – N/S		FET CURRENT REGULATOR
1N5298	ZL19298	DO–204	>15.50	3 – N/S		FET CURRENT REGULATOR
1N5299	ZL10299	DO–204	>15.50	3 – N/S		FET CURRENT REGULATOR
1N5301	ZL19301	DO–204	>15.50	3 – N/S		FET CURRENT REGULATOR
1N5304	ZL19304	DO–204	>15.50	3 – N/S		FET CURRENT REGULATOR
1N5305	ZL19305	DO–204	>15.50	3 – N/S		FET CURRENT REGULATOR
1N5306	ZL19306	DO–204	>15.50	3 – N/S		FET CURRENT REGULATOR
1N5307	ZL19307	DO–204	>15.50	3 – N/S		FET CURRENT REGULATOR

DEVICE	LINE	CASE	Eth,kV	CLASS	POLARITY	PRODUCT DESCRIPTION
1N5308	ZL19308	DO–204	>15.50	3 – N/S		FET CURRENT REGULATOR
1N5310	ZL19310	DO–204	>15.50	3 – N/S		FET CURRENT REGULATOR
1N5311	ZL19311	DO–204	>15.50	3 – N/S		FET CURRENT REGULATOR
1N5312	ZL19312	DO–204	>15.50	3 – N/S		FET CURRENT REGULATOR
1N5313	ZL19313	DO–204	>15.50	3 – N/S		FET CURRENT REGULATOR
1N5314	ZL19314	DO–204	>15.50	3 – N/S		FET CURRENT REGULATOR
1N5406	RL533B	PL267	>15.50	3 – N/S		STANDARD RECOVERY RECTIFIER
1N5518	ZL4130	DO–204	>15.50	3 – N/S		ZENER DIODE
1N5522	ZL4170G	DO–204	>15.50	3 – N/S		ZENER DIODE
1N5523	ZL4180F	DO–204	>15.50	3 – N/S		ZENER DIODE
1N5524	ZL4190G	DO–204	>15.50	3 – N/S		ZENER DIODE
1N5525	ZL4205G	DO–204	>15.50	3 – N/S		ZENER DIODE
1N5528	ZL4230G	DO–204	>15.50	3 – N/S		ZENER DIODE
1N5529	ZL4245G	DO–204	>15.50	3 – N/S		ZENER DIODE
1N5530	ZL4250G	DO–204	>15.50	3 – N/S		ZENER DIODE
1N5531	ZL4260	DO–204	>15.50	3 – N/S		ZENER DIODE
1N5534	ZL4290	DO–204	>15.50	3 – N/S		ZENER DIODE
1N5538	ZL4315	DO–204	>15.50	3 – N/S		ZENER DIODE
1N5542	ZL4340	DO–204	>15.50	3 – N/S		ZENER DIODE
1N5546	ZL4370	DO–204	>15.50	3 – N/S		ZENER DIODE
1N5772	FAD1103		8.66	3 – N/S		DIODE ARRAY
1N5817	RL754A	DO–41	>15.50	3 – N/S		SCHOTTKY RECTIFIER
1N5818	RL754A	DO–41	7.68	3 – N/S		SCHOTTKY RECTIFIER
1N5819	RL754A	DO–41	8.55	3 – N/S		SCHOTTKY RECTIFIER
1N5820	RL755A	PL267	13.80	3 – N/S		SCHOTTKY RECTIFIER
1N5821	RL755A	PL267	>15.50	3 – N/S		SCHOTTKY RECTIFIER
1N5822	RL755A	PL267	13.90	3 – N/S		SCHOTTKY RECTIFIER
1N6391	YRL772H	DO–203	>15.50	3 – N/S		SCHOTTKY RECTIFIER
1N6392	YRL775H	DO–5	>15.50	3 – N/S		SCHOTTKY RECTIFIER
2N706	SL6073A	TO–206	4.20	3 – N/S	NPN	SWITCHING TRANSISTOR
2N718	SL6103A	TO–206	>15.50	3 – N/S	NPN	SWITCHING TRANSISTOR
2N869A	SL8044A	TO–206	3.13	2 – SEN	PNP	SWITCHING TRANSISTOR
2N918	SL072	TO–72	1.90	1 – SEN	NPN	HIGH FREQUENCY AMPLIFIER
2N930	SL6218A	TO–206	8.30	3 – N/S	NPN	GENERAL PURPOSE TRANSISTOR
2N1132	SL8733R	TO–205	>15.50	3 – N/S	PNP	SWITCHING TRANSISTOR
2N1613	SL6107R	TO–205	>15.50	3 – N/S	NPN	GENERAL PURPOSE TRANSISTOR
2N1893	SL6107R	TO–205	12.70	3 – N/S	NPN	GENERAL PURPOSE TRANSISTOR
2N2060	DL006W	TO–78	9.95	3 – N/S	NPN	GENERAL PURPOSE TRANSISTOR
2N2219	SL6103R	TO–205	8.90	3 – N/S	NPN	SWITCHING TRANSISTOR
2N2222	SL6103A	TO–206	9.60	3 – N/S	NPN	SWITCHING TRANSISTOR
2N2369	SL6073A	TO–206	2.20	2 – SEN	NPN	SWITCHING TRANSISTOR
2N2481	SL6073A	TO–206	6.88	3 – N/S	NPN	SWITCHING TRANSISTOR
2N2484	SL6218A	TO–206	4.40	3 – N/S	NPN	GENERAL PURPOSE TRANSISTOR
2N2605	SL555S	TO–46	>15.50	3 – N/S	PNP	GENERAL PURPOSE TRANSISTOR
2N2608	FM125A	TO–206	0.46	1 – SEN	PCH	JFET TRANSISTOR
2N2609	FM125A	TO–206	0.77	1 – SEN	PCH	JFET TRANSISTOR
2N2857	RF5153C	TO–72	1.90	1 – SEN	NPN	RF LOW POWER TRANSISTOR
2N2896	SL6107A	TO–206	13.00	3 – N/S	NPN	GENERAL PURPOSE TRANSISTOR
2N2905	SL8233R	TO–205	>15.50	3 – N/S	PNP	SWITCHING TRANSISTOR
2N2907	SL8233A	TO–206	>15.50	3 – N/S	PNP	SWITCHING TRANSISTOR
2N2919	DL418W	TO–78	5.04	3 – N/S	NPN	GENERAL PURPOSE TRANSISTOR
2N2920	DL418W	TO–78	6.80	3 – N/S	NPN	GENERAL PURPOSE TRANSISTOR
2N3013	SL6076B	TO–52	12.30	3 – N/S	NPN	SWITCHING TRANSISTOR
2N3019	SL6107R	TO–205	>15.50	3 – N/S	NPN	GENERAL PURPOSE TRANSISTOR
2N3227	SL6073A	TO–206	7.20	3 – N/S	NPN	SWITCHING TRANSISTOR
2N3251	SL8235A	TO–206	4.03	3 – N/S	PNP	SWITCHING TRANSISTOR
2N3253	SL6027R	TO–205	>15.50	3 – N/S	NPN	SWITCHING TRANSISTOR
2N3330	FM125C	TO–72	0.49	1 – SEN	PCH	JFET TRANSISTOR
2N3375	RF142	TO–213	>15.50	3 – N/S	NPN	RF HIGH POWER TRANSISTOR
2N3439	SL7242R	TO–205	>15.50	3 – N/S	NPN	HIGH VOLTAGE TRANSISTOR
2N3440	SL7242R	TO–205	>15.50	3 – N/S	NPN	HIGH VOLTAGE TRANSISTOR
2N3442	PL458	TO–204	11.30	3 – N/S	NPN	POWER TRANSISTOR
2N3444	SL6027R	TO–205	>15.50	3 – N/S	NPN	SWITCHING TRANSISTOR
2N3467	SL8437R	TO–205	>15.50	3 – N/S	PNP	SWITCHING TRANSISTOR

DEVICE	LINE	CASE	Eth,kV	CLASS	POLARITY	PRODUCT DESCRIPTION
2N3499	SL6126R	TO–205	>15.50	3 – N/S	NPN	SWITCHING TRANSISTOR
2N3501	SL6126R	TO–205	>15.50	3 – N/S	NPN	SWITCHING TRANSISTOR
2N3507	SL022R	TO–205	>15.50	3 – N/S	NPN	SWITCHING TRANSISTOR
2N3553	RF5140R	TO–205	4.50	3 – N/S	NPN	RF HIGH POWER TRANSISTOR
2N3585	PL308	TO–204	>15.50	3 – N/S	NPN	POWER SWITCH
2N3635	SL8454R	TO–205	>15.50	3 – N/S	PNP	SWITCHING TRANSISTOR
2N3637	SL8454R	TO–205	2.82	2 – SEN	PNP	SWITCHING TRANSISTOR
2N3700	SL6107A	TO–206	10.20	3 – N/S	NPN	GENERAL PURPOSE TRANSISTOR
2N3715	PL002	TO–204	>15.50	3 – N/S	NPN	POWER TRANSISTOR
2N3716	PL002	TO–204	>15.50	3 – N/S	NPN	POWER TRANSISTOR
2N3724	SL6027R	TO–205	10.20	3 – N/S	NPN	SWITCHING TRANSISTOR
2N3735	SL6027R	TO–205	>15.50	3 – N/S	NPN	SWITCHING TRANSISTOR
2N3737	SL027S	TO–46	>15.50	3 – N/S	NPN	SWITCHING TRANSISTOR
2N3739	PL032	TO–204	>15.50	3 – N/S	NPN	POWER SWITCH
2N3741	PL037	TO–204	>15.50	3 – N/S	PNP	POWER TRANSISTOR
2N3743	SL8452R	TO–205	>15.50	3 – N/S	PNP	GENERAL PURPOSE TRANSISTOR
2N3762	SL8260R	TO–205	>15.50	3 – N/S	PNP	SWITCHING TRANSISTOR
2N3763	SL8260R	TO–205	4.40	3 – N/S	PNP	SWITCHING TRANSISTOR
2N3764	SL260S	TO–46	>15.50	3 – N/S	PNP	SWITCHING TRANSISTOR
2N3765	SL260S	TO–46	2.29	2 – SEN	PNP	SWITCHING TRANSISTOR
2N3766	PL031	TO–204	14.18	3 – N/S	PNP	POWER SWITCH
2N3767	PL031	TO–204	>15.50	3 – N/S	PNP	POWER SWITCH
2N3791	PL457	TO–204	>15.50	3 – N/S	PNP	POWER TRANSISTOR
2N3792	PL457	TO–204	>15.50	3 – N/S	PNP	POWER TRANSISTOR
2N3799	SL8555A	TO–206	4.33	3 – N/S	PNP	GENERAL PURPOSE TRANSISTOR
2N3810	DL555W	TO–78	6.35	3 – N/S	PNP	GENERAL PURPOSE TRANSISTOR
2N3811	DL555W	TO–78	7.72	3 – N/S	PNP	GENERAL PURPOSE TRANSISTOR
2N3821	FM131C	TO–72	2.90	2 – SEN	NCN	JFET TRANSISTOR
2N3822	FM131C	TO–72	3.50	2 – SEN	NCN	JFET TRANSISTOR
2N3836	RF5198S	TO–206	3.10	2 – SEN	NPN	RFCC
2N3823	FM146C	TO–72	1.00	1 – SEN	NCN	JFET TRANSISTOR
2N3866	RF5151R	TO–205	0.50	1 – SEN	NPN	RF LOW POWER TRANSISTOR
2N3868	PL813	TO–204	>15.50	3 – N/S	PNP	POWER TRANSISTOR
2N3902	PL976	TO–204	>15.50	3 – N/S	NPN	DEFLECTION AMPLIFIER
2N3906	EL276	TO–226	9.60	3 – N/S	PNP	GENERAL PURPOSE TRANSISTOR
2N3924	RF138		8.00	3 – N/S	NPN	RFCC
2N3959	RF093	TO–206	1.10	1 – SEN	NPN	RF LOW POWER TRANSISTOR
2N4033	SL8350R	TO–205	>15.50	3 – N/S	PNP	GENERAL PURPOSE TRANSISTOR
2N4209	SL8445A	TO–206	1.70	1 – SEN	PNP	GENERAL PURPOSE TRANSISTOR
2N4236	SL7245R	TO–205	>15.50	3 – N/S	PNP	SWITCHING TRANSISTOR
2N4261	SL065	TO–72	1.50	1 – SEN	PNP	SWITCHING TRANSISTOR
2N4399	PL003	TO–204	>15.50	3 – N/S	PNP	POWER TRANSISTOR
2N4405	SL8350R	TO–205	>15.50	3 – N/S	PNP	GENERAL PURPOSE TRANSISTOR
2N4416	FM146C	TO–72	0.90	1 – SEN	NCN	JFET TRANSISTOR
2N4427	RF5161R	TO–205	3.80	2 – SEN	NPN	RFCC
2N4428	RF5193A	TO–205	1.10	1 – SEN	NPN	RF HIGH POWER TRANSISTOR
2N4453	SL256	TO–46	2.94	2 – SEN	PNP	SWITCHING TRANSISTOR
2N4854	DL226W	TO–78	>15.50	3 – N/S	N/P	DUAL GEN. PURPOSE TRANSISTOR
2N4856	FM140A	TO–206	1.10	1 – SEN	NCN	JFET TRANSISTOR
2N4858	FM140A	TO–206	4.10	3 – N/S	NCN	JFET TRANSISTOR
2N4948	TL158	TO–206	>15.50	3 – N/S		UNIJUNCTION THYRISTOR
2N4949	TL158	TO–206	>15.50	3 – N/S		UNIJUNCTION THYRISTOR
2N4957	RF5057C	TO–72	1.20	1 – SEN	PNP	RF LOW POWER TRANSISTOR
2N5031	RF5191C	TO–206	0.70	1 – SEN	NPN	RF LOW POWER TRANSISTOR
2N5038	PL786	TO–204	>15.50	3 – N/S	NPN	POWER SWITCH
2N5108	RF5192R	TO–205	0.90	1 – SEN	NPN	RFCC
2N5109	RF5172R	TO–205	2.40	2 – SEN	NPN	RF LOW POWER TRANSISTOR
2N5157	YPL656	TO–204	>15.50	3 – N/S	NPN	HIGH VOLTAGE POWER AMPLIFIER
2N5157	YPL656	TO–204	>15.50	3 – N/S	NPN	HIGH VOLTAGE POWER AMPLIFIER
2N5160	RF5310R	TO–205	2.41	2 – SEN	PNP	RF HIGH POWER TRANSISTOR
2N5210	EL1335K	TO–226	8.52	3 – N/S	NPN	GENERAL PURPOSE TRANSISTOR
2N5302	PL004	TO–204	>15.50	3 – N/S	NPN	POWER TRANSISTOR
2N5303	PL004	TO–204	>15.50	3 – N/S	NPN	POWER TRANSISTOR

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2N5339	PL082	TO–204	>15.50	3 – N/S	NPN	POWER TRANSISTOR
2N5344	PL077	TO–204	>15.50	3 – N/S	PNP	POWER TRANSISTOR
2N5401	EL2554	TO–226	1.17	1 – SEN	PNP	GENERAL PURPOSE TRANSISTOR
2N5416	SL7247R	TO–205	>15.50	3 – N/S	PNP	HIGH VOLTAGE TRANSISTOR
2N5551	EL8613	TO–226	1.50	1 – SEN	NPN	HIGH VOLTAGE TRANSISTOR
2N5582	SL103S	TO–46	>15.50	3 – N/S	NPN	SWITCHING TRANSISTOR
2N5583	RF5059R	TO–205	2.40	2 – SEN	PNP	RF LOW POWER TRANSISTOR
2N5629	PL004	TO–204	>15.50	3 – N/S	NPN	POWER TRANSISTOR
2N5636	RF163	244A–01	8.00	3 – N/S	NPN	RFCC
2N5684	PL1845	TO–204	>15.50	3 – N/S	PNP	POWER TRANSISTOR
2N5685	PL1846	TO–204	>15.50	3 – N/S	NPN	POWER TRANSISTOR
2N5686	PL1846	TO–204	>15.50	3 – N/S	NPN	POWER TRANSISTOR
2N5745	PL003	TO–204	>15.50	3 – N/S	PNP	POWER TRANSISTOR
2N5796	DL260W	TO–78	3.16	2 – SEN	PNP	GENERAL PURPOSE TRANSISTOR
2N5874	PL002	TO–204	>15.50	3 – N/S	NPN	POWER TRANSISTOR
2N5877	PL002	TO–204	>15.50	3 – N/S	NPN	POWER TRANSISTOR
2N6040	PLA545	TO–220	>15.50	3 – N/S	PNP	POWER TRANSISTOR
2N6055	PL010	TO–204	>15.50	3 – N/S	NPN	POWER DARLINGTON
2N6058	PL030	TO–204	>15.50	3 – N/S	NPN	POWER DARLINGTON
2N6193	PL081	TO–204	>15.50	3 – N/S	PNP	POWER TRANSISTOR
2N6213	PL309	TO–204	5.27	3 – N/S	PNP	POWER SWITCH
2N6277	PL770	TO–204	>15.50	3 – N/S	NPN	POWER SWITCH
2N6284	PL472	TO–204	>15.50	3 – N/S	NPN	POWER TRANSISTOR
2N6287	PL473	TO–204	>15.50	3 – N/S	PNP	POWER TRANSISTOR
2N6298	PL411	TO–204	>15.50	3 – N/S	PNP	POWER DARLINGTON
2N6299	PL411	TO–204	>15.50	3 – N/S	PNP	POWER DARLINGTON
2N6301	PL410	TO–204	>15.50	3 – N/S	NPN	POWER DARLINGTON
2N6306	PL476	TO–204	>15.50	3 – N/S	NPN	DEFLECTION AMPLIFIER
2N6308	PL476	TO–204	>15.50	3 – N/S	NPN	DEFLECTION AMPLIFIER
2N6379	PL769	TO–204	>15.50	3 – N/S	PNP	POWER SWITCH
2N6384	PL010	TO–204	>15.50	3 – N/S	NPN	POWER DARLINGTON
2N6385	PL010	TO–204	>15.50	3 – N/S	NPN	POWER DARLINGTON
2N6437	PL793	TO–204	>15.50	3 – N/S	PNP	POWER SWITCH
2N6438	PL793	TO–204	>15.50	3 – N/S	PNP	POWER SWITCH
2N6547	PL478	TO–204	>15.50	3 – N/S	NPN	DEFLECTION AMPLIFIER
2N6603	RF101		4.76	3 – N/S	NPN	RF LOW POWER TRANSISTOR
2N6604	RF112		6.50	3 – N/S	NPN	RF LOW POWER TRANSISTOR
2N6649	YPL625	TO–204	>15.50	3 – N/S	PNP	POWER DARLINGTON
2N6650	YPL625	TO–204	>15.50	3 – N/S	PNP	POWER DARLINGTON
2N6679	RF218E		1.50	1 – SEN	NPN	RF LOW POWER TRANSISTOR
2N6762	PF2248	TO–204	1.50	1 – SEN	NCH	POWER TMOS TRANSISTOR
2N6770	PF2254	TO–204	7.90	3 – N/S	NCH	POWER TMOS TRANSISTOR
2N7000	FP610	TO–226	0.14	1 – SEN	NCH	TMOS TRANSISTOR
2N7051	EL2207C	TO–226	8.30	3 – N/S	NPN	GENERAL PURPOSE TRANSISTOR
3N155	FM123C	TO–72	0.40	1 – SEN	PCN	TMOS TRANSISTOR
3N169	FM122C	TO–72	0.80	1 – SEN	PCN	TMOS TRANSISTOR
3N170	FM122C	TO–72	0.22	1 – SEN	PCN	TMOS TRANSISTOR
3N201	FM977C	TO–72	7.80	3 – N/S	PCN	TMOS TRANSISTOR
4N22 (D)	ODL086B		>15.50	3 – N/S		OPTOCOUPLER
4N22 (E)	ODL086B		>15.50	3 – N/S		OPTOCOUPLER
4N24 (D)	ODL086B		>15.50	3 – N/S		OPTOCOUPLER
4N24 (E)	ODL086B		>15.50	3 – N/S		OPTOCOUPLER
BC847BT	MCF001	TO–236	8.05	3 – N/S	NPN	GENERAL PURPOSE TRANSISTOR
BFR90	RF103A	317A–01	1.80	1 – SEN	NPN	RFCC
BFR96	RF105A	317A–01	4.50	3 – N/S	NPN	RFCC
BFW924X	RF109A	317A–01	2.00	2 – SEN	NPN	RFCC
BFY90	RF5199C	TO–206	2.05	2 – SEN	NPN	RFCC
CA2830C	RLP7603	714F	1.50	1 – SEN	N/A	CATV LIN
CA2832C	RLP7604	714F	8.00	3 – N/S	N/A	CATV LIN
CA5801S	RA5801S	714P–02/1	8.00	3 – N/S	N/A	CATV LIN
CA901	RA901	714P–02/2	4.00	3 – N/S	N/A	CATV LIN
CA922	RA922	714P–02/2	5.00	3 – N/S	N/A	CATV LIN
CR2428	RR2428T	431A–02	8.00	3 – N/S	N/A	CATV–AMP
CR3428	RR3428T	431A–02	8.00	3 – N/S	N/A	CATV–AMP

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IRFZ40	PF3190	TO–204	2.37	2 – SEN	NCH	POWER TMOS TRANSISTOR
M1MA151A	XE2003P	SC–59	0.47	1 – SEN		SWITCHING DIODE
M1MA151WA	XE2060P	SC–59	7.17	3 – N/S		SWITCHING DIODE
M1MA151WK	XE2010P	SC–59	0.62	1 – SEN		SWITCHING DIODE
MBAV–70	XT2010P	TO–236	0.93	1 – SEN		SWITCHING DIODE
MBAV–99	XT2001P	TO–236	0.57	1 – SEN		SWITCHING DIODE
MBD101	VL7285	TO–226	0.84	1 – SEN		SCHOTTKY DIODE
MBD201	VL7284	TO–226	1.93	1 – SEN		SCHOTTKY DIODE
MBD301	VL7284	TO–226	2.89	2 – SEN		SCHOTTKY DIODE
MBD501	VL7282	TO–226	0.34	1 – SEN		SCHOTTKY DIODE
MBD701	VL7282	TO–226	0.37	1 – SEN		SCHOTTKY DIODE
MBR030HX	YRL702H	DO–204	>15.50	3 – N/S		SCHOTTKY RECTIFIER
MBR040HX	YRL702H	DO–204	>15.50	3 – N/S		SCHOTTKY RECTIFIER
MBR1060	RL974	TO–220	>15.50	3 – N/S		SCHOTTKY RECTIFIER
MBR5825H1	YRL758H	DO–203	12.30	3 – N/S		SCHOTTKY RECTIFIER
MBR5831H1Y	RL761H	DO–203	>15.50	3 – N/S		SCHOTTKY RECTIFIER
MFF224B	RFF324B	825A	2.00	2 – SEN	N/A	CATV FF
MFOE1202	ODL1610		>15.50	3 – N/S		OPTOCOUPLER
MHM25N20	PFC3194	TO–254	>15.50	3 – N/S	NCH	POWER TMOS TRANSISTOR
MHW1244	PC028	714	4.00	3 – N/S	N/A	CATV
MHW5182	PC319–2	714–06	8.00	3 – N/S	N/A	CATV
MHW6181	PC319–2	714–06	4.00	3 – N/S	N/A	CATV
MHW6185B	PC357		4.00	3 – N/S	N/A	CATV
MHW6342	PC336	714	4.00	3 – N/S	N/A	CATV
MHW707–2	PC528–2	301J–04	4.00	3 – N/S	N/A	POWER
MHW7182	PC1017		6.00	3 – N/S	N/A	CATV
MHW7222	PC1022		6.00	3 – N/S	N/A	CATV
MHW803–1	PC512	MOD	3.74	2 – SEN		RF MODULE
MHW903	PC524–2	413A	1.00	1 – SEN	N/A	PWR MOD
MJ1000	PL010	TO–204	>15.50	3 – N/S	NPN	POWER DARLINGTON
MJ10016	PL936	TO–204	>15.50	3 – N/S	NPN	HIGH VOLTAGE POWER AMPLIFIER
MJ12002	PL332	TO–204	>15.50	3 – N/S	NPN	DEFLECTION AMPLIFIER
MJ12005HX	PL946	TO–204	>15.50	3 – N/S	NPN	DEFLECTION AMPLIFIER
MJ2500	PL025	TO–204	>15.50	3 – N/S	PNP	POWER TRANSISTOR
MJ2501	PL025	TO–204	>15.50	3 – N/S	PNP	POWER TRANSISTOR
MJ4031	PL473	TO–204	>15.50	3 – N/S	PNP	POWER TRANSISTOR
MJ4032	PL473	TO–204	>15.50	3 – N/S	PNP	POWER TRANSISTOR
MJD44H11	PLC3070	TO–326	>15.50	3 – N/S	NPN	POWER SWITCH
MJE350	PLE035	TO–218	>15.50	3 – N/S	PNP	POWER TRANSISTOR
MJF15030	PLB4532	TO–220	>15.50	3 – N/S	NPN	POWER SWITCH
MJF15031	PLB4533	TO–220	>15.50	3 – N/S	PNP	POWER SWITCH
MM3009	SL6006R	TO–205	9.10	3 – N/S	NPN	GENERAL PURPOSE TRANSISTOR
MMBT2907A	XT261	TO–236	5.60	3 – N/S	PNP	SWITCHING TRANSISTOR
MMBT3904	MB105P	TO–236	7.83	3 – N/S	NPN	SWITCHING TRANSISTOR
MPS651	EL8102	TO–226	>15.50	3 – N/S	NPN	GENERAL PURPOSE TRANSISTOR
MPS918	EP246	TO–226	3.87	2 – SEN	NPN	HIGH FREQUENCY AMPLIFIER
MPSA56	EL2550	TO–226	>15.50	3 – N/S	PNP	GENERAL PURPOSE TRANSISTOR
MRA1000–7L	R6261EPA	145D(.380)	1.30	1 – SEN	NPN	RFCC
MRF140	RF365	211–11	8.00	3 – N/S	NPN	RFCC
MRF150	RF363	368–02	0.90	1 – SEN	NPN	RFCC
MRF151	RF871	211–11	0.60	1 – SEN	NPN	RFCC
MRF175LU	RF397	333–03	0.30	1 – SEN	NPN	RFCC
MRF177M	RF976	390B–01	8.00	3 – N/S	NPN	RFCC
MRF182	RF981	360B	1.00	1 – SEN	NPN	RFCC
MRF183	RFL183		0.15	1 – SEN	NPN	RFCC
MRF247	RF737	316–01	8.00	3 – N/S	NPN	RFCC
MRF327	RF763	.5 CQ	8.00	3 – N/S	NPN	RFCC
MRF392	RF772	744A	8.00	3 – N/S	NPN	RFCC
MRF455	RF723	211–07	8.00	3 – N/S	NPN	RFCC
MRF515	RF5083R	TO–205	1.00	1 – SEN	NPN	RFCC
MRF521	RF133A	317A–01	1.35	1 – SEN	NPN	RFCC
MRF531	RF5091R	TO–205	3.60	2 – SEN	NPN	RFCC
MRF524	RF5309C	TO–72	3.03	2 – SEN	PNP	RF HIGH POWER TRANSISTOR
MRF544	RF5203R	TO–205	1.60	1 – SEN	NPN	RF LOW POWER TRANSISTOR

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MRF545	RF5204R	TO–205	4.95	3 – N/S	PNP	RF LOW POWER TRANSISTOR
MRF571	RF132A	317A–01	1.10	1 – SEN	NPN	RFCC
MRF581	RF130A	317A–01	1.45	1 – SEN	NPN	RFCC
MRF607	RF5488R	TO–205	3.40	2 – SEN	NPN	RFCC
MRF837	RF206A	317A–01	0.48	1 – SEN	NPN	RFCC
MRF859	RF624		3.90	2 – SEN	NPN	RFCC
MRF891S	RF665S	319A	2.25	2 – SEN	NPN	RFCC
MRF899	RF863	375A	8.00	3 – N/S	NPN	RFCC
MRF911	RF100A	317A–01	2.15	2 – SEN	NPN	RFCC
MRF931	RF106A	317A–01	0.25	1 – SEN	NPN	RFCC
MRF941	RF213A	317A–01	0.75	1 – SEN	NPN	RFCC
MRF952	RV214E		3.98	2 – SEN	NPN	RF LOW POWER TRANSISTOR
MRF966	RF136	MACRO–X	3.09	2 – SEN	NPN	RF LOW POWER TRANSISTOR
MRF1090MA	RF817	.280 STUD	5.60	3 – N/S	NPN	RFCC
MRF8372R1	RF7206	SO–8	1.40	1 – SEN	NPN	RF LOW POWER TRANSISTOR
MRF9331LT1	RF6216L	SOT–143	0.80	1 – SEN	NPN	RFCC
MRF9511LT1	RF214KL	SOT–143	0.80	1 – SEN	NPN	RFCC
MRF9820	RF120KL	SOT–143	0.85	1 – SEN	NPN	RFCC
MRF15090	REBEEDT	375A/1	8.00	3 – N/S	NPN	RFCC
MRFIC0001	MRFIC0001	TSSOP	0.20	1 – SEN	N/A	RFIC
MRFIC288	RF288		0.75	1 – SEN	N/A	RFIC
MSA1022B	XP2190P	SC–59	3.05	2 – SEN	PNP	GENERAL PURPOSE TRANSISTOR
MSA1461	MCF076	SC–59	4.34	3 – N/S	PNP	SWITCHING DIODE
MSB709	XT2286P	SC–59	4.57	3 – N/S	PNP	GENERAL PURPOSE TRANSISTOR
MSB710	XT2490P	SC–59	>15.50	3 – N/S	PNP	GENERAL PURPOSE TRANSISTOR
MSB779	XT2692P	SC–59	11.10	3 – N/S	PNP	GENERAL PURPOSE TRANSISTOR
MSC1621	XE2031P	SC–59	5.30	3 – N/S	NPN	SWITCHING TRANSISTOR
MSC2295	XP2140P	SC–59	3.02	2 – SEN	PNP	GENERAL PURPOSE TRANSISTOR
MSC2404	XP2144P	SC–59	3.20	2 – SEN	NPN	GENERAL PURPOSE TRANSISTOR
MSC3130	XP2142P	SC–59	2.45	2 – SEN	PNP	GENERAL PURPOSE TRANSISTOR
MSD132B	XT2640P	SC–59	8.95	3 – N/S	NPN	GENERAL PURPOSE TRANSISTOR
MSD601	XT2236	SC–59	7.04	3 – N/S	NPN	GENERAL PURPOSE TRANSISTOR
MSD602	XT2440P	SC–59	14.13	3 – N/S	NPN	GENERAL PURPOSE TRANSISTOR
MSP911	EP8304	TO–226	4.18	3 – N/S	NPN	HIGH FREQUENCY AMPLIFIER
MTM15N05L	PFA3426	TO–220	0.68	1 – SEN	NCH	POWER TMOS TRANSISTOR
MTM6N60	PF2282	TO–204	1.35	1 – SEN	NCH	POWER TMOS TRANSISTOR
MTP12N10	PFA2146	TO–220	1.22	1 – SEN	NCH	POWER TMOS TRANSISTOR
MTP15N06L	PFA3426	TO–220	0.54	1 – SEN	NCH	POWER TMOS TRANSISTOR
MTP25N05	PFA2128	TO–220	1.58	1 – SEN	NCH	POWER TMOS TRANSISTOR
MTP3055E	PFA2358	TO–220	0.85	1 – SEN	NCH	POWER TMOS TRANSISTOR
MTP3055EL	PFA3458	TO–220	0.71	1 – SEN	NCH	POWER TMOS TRANSISTOR
MTP5N05	PFA2122	TO–220	0.52	1 – SEN	NCH	POWER TMOS TRANSISTOR
MUR3015PT	RL425P	TO–218	>15.50	3 – N/S		ULTRAFAST RECOVERY RECTIFIER
MWA0211	RF960	SOT–143	6.38	3 – N/S		RF AMPLIFIER
MWA0311	RF965	SOT–143	10.45	3 – N/S		RF AMPLIFIER
P BEARS	RF2120		1.30	1 – SEN	N/A	RFCC
PHL7004	RA9125		8.00	3 – N/S	N/A	CATV
PHW3528	RR3528T	CT (LP)	8.00	3 – N/S	N/A	CATV LIN
PHW5153	PC1603–1		1.00	1 – SEN	N/A	POWER
PRF927	RF233F		0.50	1 – SEN	NPN	RFCC
RFIC0914	RF519	TO–206	0.20	1 – SEN	NPN	RFIC
SBR7002H1	YRL758H	DO–203	7.99	3 – N/S		SCHOTTKY RECTIFIER
SBR7007H	YRL758H	DO–203	10.41	3 – N/S		SCHOTTKY RECTIFIER
SBR7014H1	YRL720H	DO–203	>15.50	3 – N/S		ZENER RECTIFIER
SCR1959H	YTL287		>15.50	3 – N/S		SCR
SCR1987H	YTL675		>15.50	3 – N/S		SCR
SCR2105H	YTL580X	STUD	>15.50	3 – N/S		SCR
SCR2112H	YTL580X	STUD	>15.50	3 – N/S		SCR
SCR7001H	YTL011		>15.50	3 – N/S		SCR
SCR7026H	YTL569V	STUD	>15.50	3 – N/S		SCR
SHW3000	PC373	MOD	1.51	1 – SEN		RF MODULE
SHW5092	PC701–2	420A–01	0.20	1 – SEN	N/A	PWR MOD
SHW5113	PC608–1		1.00	1 – SEN	N/A	PWR MOD
SHW5114	PC606		3.00	2 – SEN	N/A	PWR MOD

DEVICE	LINE	CASE	Eth,kV	CLASS	POLARITY	PRODUCT DESCRIPTION
SHW5123	PC503–2	SPECIAL	4.00	3 – N/S	N/A	PWR MOD
SHW5125	PC602	420J–01	1.50	1 – SEN	N/A	PWR MOD
SHW5131	PC603–2	420R–02	1.75	1 – SEN	N/A	POWER
SHW5131	PC603–2	420R–02	1.00	1 – SEN	N/A	POWER
SHW5135	PC701	420A–01	1.00	1 – SEN	N/A	PWR MOD
SHW5149	PC2735–1	438A–01	1.00	1 – SEN	N/A	POWER
SHWE5142	PC610F2	301AB–01	1.00	1 – SEN	N/A	PWR MOD
SJ17056H	YPL1746	TO–204	>15.50	3 – N/S	NPN	DEFLECTION AMPLIFIER
SJ1860H	YPL625	TO–204	>15.50	3 – N/S	PNP	POWER DARLINGTON
SJ5741H	YPL608	TO–204	>15.50	3 – N/S	NPN	DEFLECTION AMPLIFIER
SJ5760H1	YPL608	TO–204	>15.50	3 – N/S	NPN	DEFLECTION AMPLIFIER
SJ5875HX	YPL662	TO–204	>15.50	3 – N/S	NPN	POWER DARLINGTON
SJ5876H1	YPL663	TO–204	>15.50	3 – N/S	PNP	POWER DARLINGTON
SJ6510H	YPL794	TO–204	>15.50	3 – N/S	NPN	GENERAL PURPOSE TRANSISTOR
SJ6686H3	YPL860	TO–204	>15.50	3 – N/S	NPN	GENERAL PURPOSE TRANSISTOR
SJ8200H	YPL079	TO–204	4.92	3 – N/S	PNP	POWER TRANSISTOR
SJC816H	DPL1098	CHIP	>15.50	3 – N/S	PNP	SILICON POWER CHIP
SJC930	DPL1096	CHIP	>15.50	3 – N/S	NPN	SILICON POWER CHIP
SJE7030H	PLA1568	TO–220	>15.50	3 – N/S	NPN	POWER TRANSISTOR
SM5367–5	SL2080	TO–205	2.47	2 – SEN	PNP	SWITCHING TRANSISTOR
SMBF1035L	MB606	TO–236	0.21	1 – SEN	NCH	TMOS TRANSISTOR
SMBR991LT1	RF401NL	318–07	0.20	1 – SEN	NPN	RFCC
SMBZ1113L	MB15VDL	TO–236	>15.50	3 – N/S		ZENER DIODE
SRF3102H	YRF772		>15.50	3 – N/S	NPN	RF POWER TRANSISTOR
SRFIC03D08	RF262	SOIC8	0.20	1 – SEN	NPN	RFIC
SRFIC11N01	RF299	SOIC8	0.40	1 – SEN	NPN	RFIC
SRFIC40K01	RF275	SOIC16	0.25	1 – SEN	NPN	RFIC
SRFM25C17	RF847	319	2.00	2 – SEN	NPN	RFCC
SRFM33P54	RF848	SOIC8	8.00	3 – N/S	NPN	RFCC
SRFM33P60	RF686		0.20	1 – SEN	NPN	RFCC
SRFM9552	RF5082R	TO–205	2.00	2 – SEN	NPN	RFCC
STP5002	PF1394	TO–204	0.70	1 – SEN	NCH	POWER TMOS TRANSISTOR
XCA4800C	RA4900	714P–02/2	6.00	3 – N/S	N/A	CATV LIN
XHW2902	PC664	420L–03	0.50	1 – SEN	N/A	PWR MOD
XHW2902	PC664F1	420L–03	0.50	1 – SEN	N/A	PWR MOD
XHW5089	PC550	301AC–01	8.00	3 – N/S	N/A	PWR MOD
XHW5111	PC508F2	420–D	4.00	3 – N/S	N/A	PWR MOD
XHW5125	PC602–1	420B–03	2.00	2 – SEN	N/A	PWR MOD
XHW5126	PC603–1	420R–01	0.75	1 – SEN	N/A	PWR MOD
XHW5128	PC508–1	420D–02	8.00	3 – N/S	N/A	PWR MOD
XHW5132	PC603–4	420R–01	1.00	1 – SEN	N/A	PWR MOD
XHW5135	PC701–6	420A–01	2.00	2 – SEN	N/A	PWR MOD
XHW5139	PC733–3	420–01	1.00	1 – SEN	N/A	PWR MOD
XHW5139	PC763–3	420–01	1.00	1 – SEN	N/A	PWR MOD
XHW5149	PC2735–1	438A–01	1.00	1 – SEN	N/A	PWR MOD
XHW5149	PC2735–1	438A–01	1.00	1 – SEN	N/A	PWR MOD
XHW5151	PC607–1	SPECIAL	2.00	2 – SEN	N/A	PWR MOD
XHW5151	PC607–1	SPECIAL	2.00	1 – SEN	N/A	PWR MOD
XHW802	PC1050		4.00	3 – N/S	N/A	CATV
XHW920	PC564–2	420U–01	4.00	3 – N/S	N/A	PWR MOD
XHWE5133	PC733–3	420–01	1.00	1 – SEN	N/A	PWR MOD
XHWE5145	PC557		2.00	2 – SEN	N/A	POWER
XRF255	RF1105	211–11	0.20	1 – SEN	NPN	RFCC
XRF9812	RF2120		0.30	1 – SEN	NPN	RFCC
XRFIC08K07	3VGSM1PA		0.50	1 – SEN	NPN	RFIC
XRFIC2403	RF280		0.50	1 – SEN	NPN	RFIC
XRFIC2404	RF292	SOIC8	0.30	1 – SEN	NPN	RFIC
XWH5131	PC603–2	420R–01	0.50	1 – SEN	N/A	PWR MOD

RELIABILITY DATA ANALYSIS

Reliability is the probability that a semiconductor device will perform its specified function in a given environment for a specified period. In other words, reliability is quality over time and environmental conditions. The most frequently used reliability measure for semiconductor devices is the failure rate (λ). The failure rate is obtained by dividing the number of failures observed by the product of the number of devices on test and the interval in hours, usually expressed as percent per thousand hours or failures per billion device hours (FITS). This is called a point estimate because it is obtained from observations on a portion (sample) of the population of devices.

To project from the sample to the population in general, one must establish confidence intervals. The application of confidence intervals is a statement of how "confident" one is that the sample failure rate approximates that for the population. To obtain failure rates at different confidence levels, it is necessary to make use of specific probability distributions. The chi-square ($\chi 2$) distribution that relates observed and expected frequencies of an event is frequently used to establish confidence intervals. The relationship between failure rate and the chi-square distribution is as follows:

$$\lambda = \frac{\chi 2\ (\alpha,\ \text{d. f.})}{2t}$$

where:

λ = failure rate

$\chi 2$ = chi-square function

α = (100 – confidence level) /100

d.f. = degrees of freedom = 2r + 2

r = number of failures

t = device hours

Chi-square values for 60% and 90% confidence intervals for up to 12 failures are shown in Table 1–1.

Table 1–1 Chi-Square Table

Chi-Square Distribution Function			
60% Confidence Level		**90% Confidence Level**	
No. Fails	**$\chi 2$ Quantity**	**No. Fails**	**$\chi 2$ Quantity**
0	1.833	0	4.605
1	4.045	1	7.779
2	6.211	2	10.645
3	8.351	3	13.362
4	10.473	4	15.987
5	12.584	5	18.549
6	14.685	6	21.064
7	16.780	7	23.542
8	18.868	8	25.989
9	20.951	9	28.412
10	23.031	10	30.813
11	25.106	11	33.196
12	27.179	12	35.563

The failure rate of semiconductor devices is inherently low. As a result, the industry uses a technique called accelerated testing to assess the reliability of semiconductors. During accelerated tests, elevated stresses are used to produce, in a short period, the same failure mechanisms as would be observed under normal use conditions. The objective of this testing is to identify these failure mechanisms and eliminate them as a cause of failure during the useful life of the product.

Temperature, relative humidity, and voltage are the most frequently used stresses during accelerated testing. Their relationship to failure rates has been shown to follow an Eyring type of equation of the form:

$$\lambda = A\ \exp(\phi kT) \bullet \exp(B/RH) \bullet \exp(CE)$$

Where A, B, C, ϕ , and k are constants, more specifically B, C, and ϕ are numbers representing the apparent energy at which various failure mechanisms occur. These are called activation energies. "T" is the temperature, "RH" is the relative humidity, and "E" is the electric field. The most familiar form of this equation (shown on following page) deals with the first exponential term that shows an Arrhenius type relationship of the failure rate versus the junction temperature of semiconductors. The junction temperature is related to the ambient temperature through the thermal resistance and power dissipation. Thus, we can test devices near their maximum junction temperatures, analyze the failures to assure that they are the types that are accelerated by temperature and then by applying known acceleration factors, estimate the failure rates for lower junction temperatures.

Figure 1–1 shows a curve that gives estimates of typical failure rates versus temperature for semiconductors.

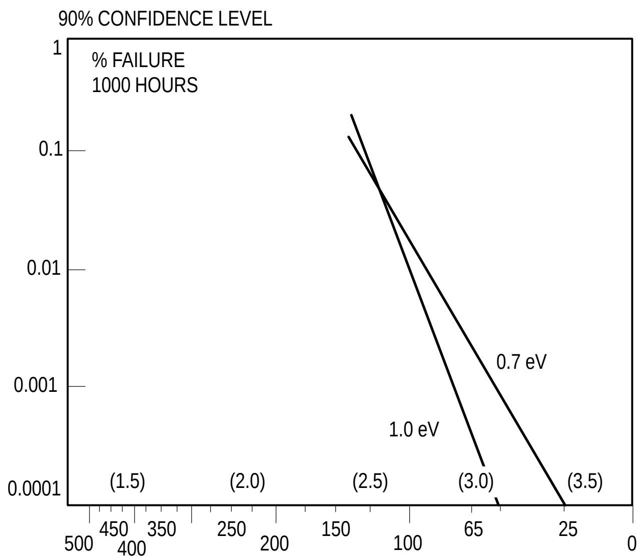


Figure 1–1 – Typical Failure Rate versus Junction Temperature

Arrhenius type of equation:

$$\lambda = A \exp \frac{\phi}{kT}$$

where:

λ = failure rate
A = constant
ε = 2.72
ϕ = activation energy
k = Boltzman's constant, 8.62 x 10^{-5}eV/°K
T = temperature in degrees Kelvin (T_j ° C + 273.15)

Temperature acceleration factors for a particular failure mechanism can be expressed as the ratio of the failure rates at two different levels of stress:

$$Fa = \exp(\phi\ /k) \bullet \frac{1}{Tr} \pm \frac{1}{Tt}$$

where:

Fa = acceleration factor
ϕ = activation energy
k = Boltzman's constant, 8.62 x 10^{-5}eV/°K
Tr = junction temperature, °K at the rated ambient temperature

Since device junction temperature and activation energy for observed failure mechanisms are "critical" parameters in estimating failure rate, the following additional information on these two parameters is presented below.

Tt = junction temperature,°K at the life test ambient temperature

See Figure 1–2 as an example.

THERMAL RESISTANCE

Circuit performance and long-term circuit reliability are affected by die temperature. Normally, both are improved by keeping the junction temperatures low.

Electrical power dissipated in any semiconductor device is a source of heat. This heat source increases the temperature of the die about some reference point, normally the ambient temperature of 25° C in still air. The temperature increase, then, depends on the amount of power dissipated in the circuit and on the net thermal resistance between the heat source and the reference point.

The temperature at the junction depends on the packaging and mounting system's ability to remove heat generated in the circuit from the junction region to the ambient environment. The basic formula for converting power dissipation to estimated junction temperature is:

$$T_J = T_A + P_D\,(\bar{\theta}JC + \bar{\theta}CA) \qquad (1)$$

or:

$$T_J = T_A + P_D\,(\bar{\theta}JA) \qquad (2)$$

where:

T_J = maximum junction temperature
T_A = maximum ambient temperature
P_D = calculated maximum power dissipation, including effects of external loads when applicable
$\bar{\theta}JC$ = average thermal resistance, junction to case
$\bar{\theta}_{CA}$ = average thermal resistance, case to ambient
θ_{JA} = average thermal resistance, junction to ambient

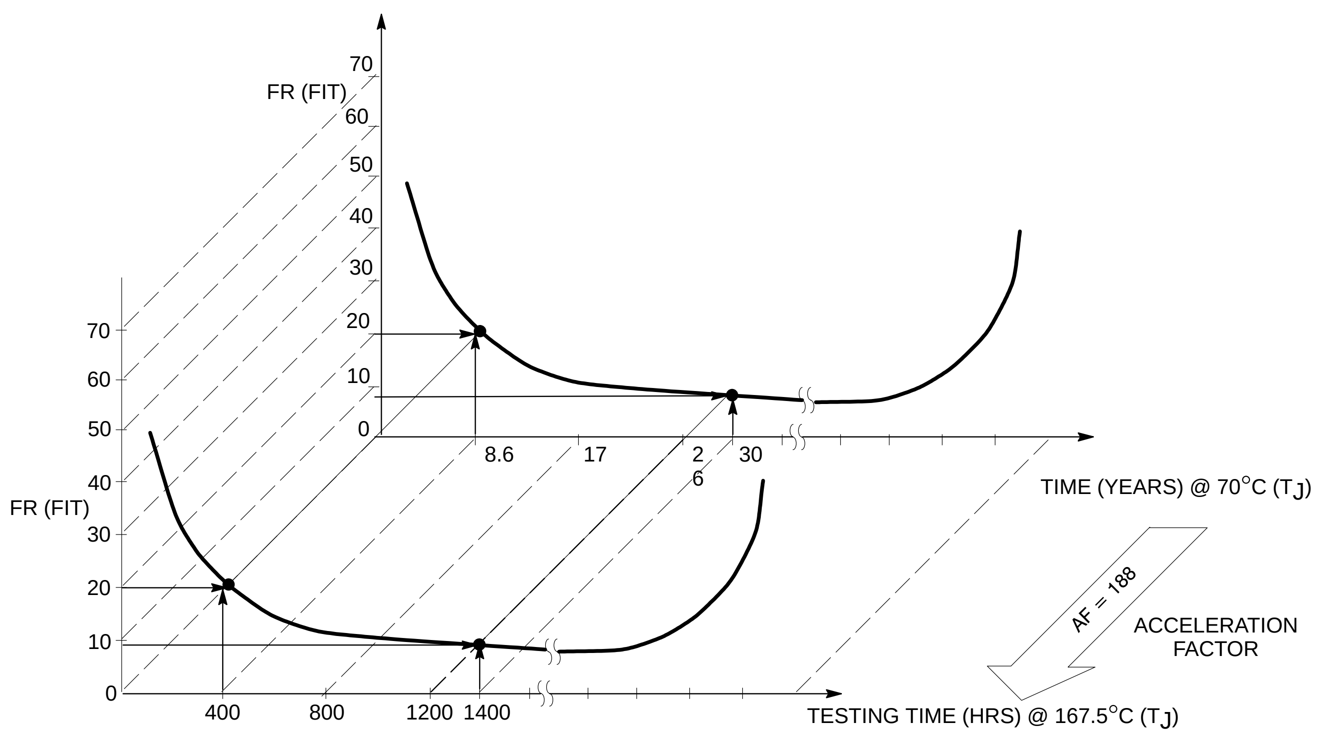


Figure 1–2– Example of Temperature Acceleration Factor (0.7 eV Activation Energy)

This Motorola recommended formula has been approved by RADC and DESC for calculating a "practical" maximum operating junction temperature for MIL-M-38510 devices.

Only two terms on the right side of equation (1) can be varied by the user, the ambient temperature and the device case-to-ambient thermal resistance, $\bar{\theta}CA$. (To some extent the device power dissipation can also be controlled, but under recommended use the supply voltage and loading dictate a fixed power dissipation.) Both system air flow and the package mounting technique affect the $\bar{\theta}CA$ thermal resistance term. $\bar{\theta}JC$ is essentially independent of air flow and external mounting method, but is sensitive to package material, die bonding method, and die area.

For applications where the case is held at essentially a fixed temperature by mounting on a large or temperature controlled heat sink, the estimated junction temperature is calculated by:

$$T_J = T_C + P_D\,(\bar{\theta}JC) \qquad (3)$$

where T_C = maximum case temperature and the other parameters are as previously defined.

AIR FLOW

Air flow over the packages (due to a decrease in $\bar{\theta}CA$) reduces the thermal resistance of the package, therefore permitting a corresponding increase in power dissipation without exceeding the maximum permissible operating junction temperature.

For thermal resistance values for specific packages, see the Motorola Data Book or Design Manual for the appropriate device family or contact your local Motorola sales office.

ACTIVATION ENERGY

Determination of activation energies is accomplished by testing randomly selected samples from the same population at various stress levels and comparing failure rates due to the same failure mechanism. The activation energy is represented by the slope of the curve relating to the natural logarithm of the failure rate to the various stress levels.

In calculating failure rates, the comprehensive method is to use the specific activation energy for each failure mechanism applicable to the technology and circuit under consideration. A common alternative method is to use a single activation energy value for the "expected" failure mechanism(s) with the lowest activation energy.

Table 1–2, on the following page, shows observed activation energies with references.

Table 1–2 – Time Dependent Failure Mechanisms in Semiconductor Devices (Applicable to Discrete and Integrated Circuits)

Device Association	Process	Relevant Factors	Accelerating Factors	Typical Activation Energy in eV	Model	Reference
Silicon Oxide Silicon-Silicon Oxide Interface	Surface Charges Inversion, Accumulation	Mobile Ions E/V, T	T, V	1.0	Fitch, et al. Peck	1A 2
	Oxide Pinholes	E/V, T	E, T	0.7 - 1.0 (Bipolar) 1.0 (Bipolar)	1984 WRS Hokari, et al.	18 5
	Dielectric Breakdown (TDDB)	E/V, T	E, T	0.3-0.4 (MOS) 0.3 (MOS)	Domangue, et al. Crook, D.L.	3 4
	Charge Loss	E, T	E, T	0.8 (MOS) EPROM	Gear, G.	11
Metallization	Electromigration	T, J	J, T	1.0 Large grain Al (glassivated)	Nanda, et al.	6
		Grain Size		0.5 Small grain Al	Black, J.R.	7
		Doping		0.7 Cu-Al/Cu-Si-Al (sputtered)	Black, J.R.	12
	Corrosion Chemical Galvanic Electrolytic	Contamination	H, E/V, T	0.6-0.7 (for electrolysis) E/V may have thresholds	Lycoudes, N.E.	8
Bond and Other Mechanical Interfaces	Intermetallic Growth	T, Impurities Bond Strength	T	1.0 (Au/Al)	Fitch, W.T.	9
Various Wafer Fab, Assembly, and Silicon Defects	Metal Scratches Mask Defects, etc. Silicon Defects	T, V	T, V	0.5-0.7 eV 0.5 eV	Howes, et al. MMPD	10 13

V = voltage; E = electric field; T = temperature; J = current density; H = humidity

NO. REFERENCE

1A 1.0 eV activation for leakage type failures.
Fitch, W.T.; Greer, P.; Lycoudes, N.; "Data to Support 0.001%/1000 Hours for Plastic I/C's." Case study on linear product shows 0.914 eV activation energy which is within experimental error of 0.9 To 1.3 eV activation energies for reversible leakage (inversion) failures reported in the literature.

1B 0.7 To 1.0 eV for oxide defect failures for bipolar structures. This is under investigation subsequent to information obtained from 1984 Wafer Reliability Symposium, especially for bipolar capacitors with silicon nitride as dielectric.

2 1.0 eV activation for leakage type failures.
Peck, D.S.; "New Concerns About Integrated Circuit Reliability"' 1978 Reliability Physics Symposium.

3 0.36 eV for dielectric breakdown for MOS gate structures.
Domangue, E.; Rivera, R.; Shedard, C.; "Reliability Prediction Using Large MOS Capacitors", 1984 Reliability Physics Symposium.

4 0.3 eV for dielectric breakdown.
Crook, D.L.; "Method of Determining Reliability Screens for Time Dependent Dielectric Breakdown", 1979 Reliability Physics Symposium.

5 1.0 eV for dielectric breakdown.
Hokari, Y.; et al.; IEDM Technical Digest, 1982.

6 1.0 eV for large grain Al-Si (compared to line width).
Nanda, Vangard, Gj-P; Black, J.R.; "Electromigration of Al-Si Alloy Films", 1978 Reliability Physics Symposium.

7 0.5 eV Al, 0.7 eV Cu-Al small grain (compared to line width).
Black, J.R.; "Current Limitation of Thin Film Conductor'' 1982 Reliability Physics Symposium.

8 0.65 eV for corrosion mechanism.
Lycoudes, N.E.; "The Reliability of Plastic Microcircuits in Moist Environments", 1978 Solid State Technology.

9 1.0 eV for open wires or high resistance bonds at the pad bond due to Au-Al intermetallics.
Fitch, W.T.; "Operating Life vs Junction Temperatures for Plastic Encapsulated I/C (1.5 mil Au wire)'', unpublished report.

10 0.7 eV for assembly related defects.
Howes, M.G.; Morgan, D.V.; "Reliability and Degradation, Semiconductor Devices and Circuits'' John Wiley and Sons, 1981.

11 Gear, G.; "FAMOUS PROM Reliability Studies", 1976 Reliability Physics Symposium

12 Black, J.R.: unpublished report.

13 Motorola Memory Products Division; unpublished report.

RELIABILITY STRESS TESTS

The following are brief descriptions of the reliability tests commonly used in the reliability monitoring program. Not all of the tests listed are performed by each product division. Other tests may be performed when appropriate.

AUTOCLAVE (aka, PRESSURE COOKER)

Autoclave is an environmental test which measures device resistance to moisture penetration and the resultant effects of galvanic corrosion. Autoclave is a highly accelerated and destructive test.

Typical Test Conditions: $T_A = 121°$ C, rh = 100%, p = 1 atmosphere (15 psig), t = 24 to 96 hours
Common Failure Modes: Parametric shifts, high leakage and/or catastrophic
Common Failure Mechanisms: Die corrosion or contaminants such as foreign material on or within the package materials. Poor package sealing

HIGH HUMIDITY HIGH TEMPERATURE BIAS (H3TB or H3TRB)

This is an environmental test designed to measure the moisture resistance of plastic encapsulated devices. A bias is applied to create an electrolytic cell necessary to accelerate corrosion of the die metallization. With time, this is a catastrophically destructive test.

Typical Test Conditions: $T_A = 85°$ C to 95° C, rh = 85% to 95%, Bias = 80% to 100% of Data Book max. rating, t = 96 to 1750 hours
Common Failure Modes: Parametric shifts, high leakage and/or catastrophic
Common Failure Mechanisms: Die corrosion or contaminants such as foreign material on or within the package materials. Poor package sealing

HIGH TEMPERATURE FORWARD BIAS (HTFB)

This test is designed to measure the stability of the devices under a forward bias condition at high temperature.

Typical Test Conditions: $T_A = 85°$ C to 100° C, Bias = 100% of Data Book max. rating, t = 120 to 1000 hours
Common Failure Modes: Parametric drifts in repetitive peak off–state and reverse currents, gate trigger current and voltage
Common Failure Mechanisms: Random oxide defects and ionic contamination
Military Reference: MIL-STD-750, Method 1042

HIGH TEMPERATURE GATE BIAS (HTGB)

This test is designed to electrically stress the gate oxide under a bias condition at high temperature.

Typical Test Conditions: $T_A = 150°$ C, Bias = 80% of Data Book max. rating, t = 120 to 1000 hours
Common Failure Modes: Parametric shifts in gate leakage and gate threshold voltage
Common Failure Mechanisms: Random oxide defects and ionic contamination
Military Reference: MIL-STD-750, Method 1042

HIGH TEMPERATURE REVERSE BIAS (HTRB)

The purpose of this test is to align mobile ions by means of temperature and voltage stress to form a high-current leakage path between two or more junctions.

Typical Test Conditions: $T_A = 85°$ C to 150° C, Bias = 80% to 100% of Data Book max. rating, t = 120 to 1000 hours
Common Failure Modes: Parametric shifts in leakage and gain
Common Failure Mechanisms: Ionic contamination on the surface or under the metallization of the die
Military Reference: MIL-STD-750, Method 1039

HIGH TEMPERATURE STORAGE LIFE (HTSL)

High temperature storage life testing is performed to accelerate failure mechanisms which are thermally activated through the application of extreme temperatures.

Typical Test Conditions: $T_A = 70°$ C to 200° C, no bias, t = 24 to 2500 hours
Common Failure Modes: Parametric shifts in leakage and gain
Common Failure Mechanisms: Bulk die and diffusion defects
Military Reference: MIL-STD-750, Method 1032

INTERMITTENT OPERATING LIFE (IOL)

The purpose of this test is the same as SSOL in addition to checking the integrity of both wire and die bonds by means of thermal stressing.

Typical Test Conditions: $T_A = 25°$ C, Pd = Data Book maximum rating, $T_{on} = T_{off} = \Delta$ of 50° C to 100° C, t = 42 to 30000 cycles
Common Failure Modes: Parametric shifts and catastrophic
Common Failure Mechanisms: Foreign material, crack and bulk die defects, metallization, wire and die bond defects
Military Reference: MIL-STD-750, Method 1037

LED BURN-IN

The purpose of this test is to evaluate the LED's ability to emit light at a specified current and temperature over time.

Typical Test Conditions: $T_A = 25°$ C, $I_F = 50$ Ma, t = 72 hours
Common Failure Modes: Degradation of light output power
Common Failure Mechanisms: Generation of non-radiative recombination sites on the surface or in the gallium arsenide of the die

MECHANICAL SHOCK

This test is used to determine the ability of the device to withstand a sudden change in mechanical stress due to abrupt changes in motion as seen in handling, transportation, or actual use.

Typical Test Conditions: Acceleration = 1500 g's, Orientation = X_1, Y_1, Y_2 plane, t = 0.5 msec, Blows = 5
Common Failure Modes: Open, short, excessive leakage, mechanical failure
Common Failure Mechanisms: Die and wire bonds, cracked die, package defects
Military Reference: MIL-STD-750, Method 2015

MOISTURE RESISTANCE

The purpose of this test is to evaluate the moisture resistance of components under temperature/humidity conditions typical of tropical environments.

Typical Test Conditions: T_A = –10° C to 65° C, rh = 80% to 98%, t = 24 hours/cycle, cycle = 10
Common Failure Modes: Parametric shifts in leakage and mechanical failure
Common Failure Mechanisms: Corrosion or contaminants on or within the package materials. Poor package sealing
Military Reference: MIL-STD-750, Method 1021

RF MODULE BURN-IN

The purpose of this test is monitor and evaluate module defects (if any) resulting from manufacturing aberrations that are manifested as time and stress-dependent failures.

Typical Test Conditions: T_A = 110° C, Bias = V_{S1} = V_{S2} = 12.4 V, t = 96 hours
Common Failure Modes: Parametric shifts and catastrophic
Common Failure Mechanisms: Foreign material, crack die, bulk die, metallization, wire and die bond defects

SOLDERABILITY

The purpose of this test is to measure the ability of device leads/terminals to be soldered after an extended period of storage (shelf life).

Typical Test Conditions: Steam aging = 8 hours, Flux = R, Solder = Sn60, Sn63
Common Failure Modes: Pin holes, dewetting, non-wetting
Common Failure Mechanisms: Poor plating, contaminated leads
Military Reference: MIL-STD-750, Method 2026

SOLDER HEAT

This test is used to measure the ability of a device to withstand the temperatures as may be seen in wave soldering operations. Electrical testing is the endpoint criterion for this stress.

Typical Test Conditions: Solder Temperature = 260° C, t = 10 seconds
Common Failure Modes: Parameter shifts, mechanical failure
Common Failure Mechanisms: Poor package design **Military Reference:** MIL-STD-750, Method 2031

STEADY STATE OPERATING LIFE (SSOL)

The purpose of this test is to evaluate the bulk stability of the die and to generate defects resulting from manufacturing aberrations that are manifested as time and stress-dependent failures.

Typical Test Conditions: T_A = 25° C, P_D = Data Book maximum rating, t = 16 to 1000 hours
Common Failure Modes: Parametric shifts and catastrophic
Common Failure Mechanisms: Foreign material, crack die, bulk die, metallization, wire and die bond defects **Military Reference:** MIL-STD-750, Method 1026

TEMPERATURE CYCLING (AIR TO AIR)

The purpose of this test is to evaluate the ability of the device to withstand both exposure to extreme temperatures and transitions between temperature extremes. This testing will also expose excessive thermal mismatch between materials.

Typical Test Conditions: T_A = –65° C to 200° C, cycle = 10 to 4000
Common Failure Modes: Parametric shifts and catastrophic
Common Failure Mechanisms: Wire bond, cracked or lifted die and package failure
Military Reference: MIL-STD-750, Method 1051

THERMAL SHOCK (LIQUID TO LIQUID)

The purpose of this test is to evaluate the ability of the device to withstand both exposure to extreme temperatures and sudden transitions between temperature extremes. This testing will also expose excessive thermal mismatch between materials.

Typical Test Conditions: T_A = 0° C to 100° C, cycle = 20 to 300
Common Failure Modes: Parametric shifts and catastrophic
Common Failure Mechanisms: Wire bond, cracked or lifted die and package failure
Military Reference: MIL-STD-750, Method 1056

VARIABLE FREQUENCY VIBRATION

This test is used to examine the ability of the device to withstand deterioration due to mechanical resonance.

Typical Test Conditions: Peak acceleration = 20 g's, Frequency range = 20 Hz to 20 KHz, t = 48 minutes.
Common Failure Modes: Open, short, excessive leakage, mechanical failure
Common Failure Mechanisms: Die and wire bonds, cracked die, package defects
Military Reference: MIL-STD-750, Method 2056

STATISTICAL PROCESS CONTROL

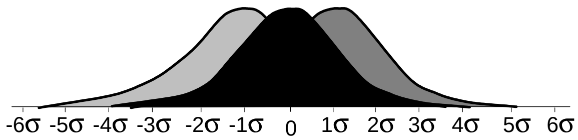
Motorola's Communications, Power and SIgnal Technologies Group (CPSTG) is continually pursuing new ways to improve product quality. Initial design improvement is one method that can be used to produce a superior product. Equally important to outgoing product quality is the ability to produce product that consistently conforms to specification. Process variability is the basic enemy of semiconductor manufacturing since it leads to product variability. Used in all phases of Motorola's product manufacturing, STATISTICAL PROCESS CONTROL (SPC) replaces variability with predictability. The traditional philosophy in the semiconductor industry has been adherence to the data sheet specification. Using SPC methods assures the product will meet specific process requirements throughout the manufacturing cycle. The emphasis is on defect prevention, not detection. Predictability through SPC methods requires the manufacturing culture to focus on constant and permanent improvements. Usually these improvements cannot be bought with state-of-the-art equipment or automated factories. With quality in design, process and material selection, coupled with manufacturing predictability, Motorola can produce world class products.

The immediate effect of SPC manufacturing is predictability through process controls. Product centered and distributed well within the product specification benefits Motorola with fewer rejects, improved yields and lower cost. The direct benefit to Motorola's customers includes better incoming quality levels, less inspection time and ship-to-stock capability. Circuit performance is often dependent on the cumulative effect of component variability. Tightly controlled component distributions give the customer greater circuit predictability. Many customers are also converting to just-in-time (JIT) delivery programs. These programs require improvements in cycle time and yield predictability achievable only through SPC techniques. The benefit derived from SPC helps the manufacturer meet the customer's expectations of higher quality and lower cost product.

Ultimately, Motorola will have Six Sigma capability on all products. This means parametric distributions will be centered within the specification limits with a product distribution of plus or minus Six Sigma about mean. Six Sigma capability, shown graphically in Figure 1–3, details the benefit in terms of yield and outgoing quality levels. This compares a centered distribution versus a 1.5 sigma worst case distribution shift.

New product development at Motorola requires more robust design features that make them less sensitive to minor variations in processing. These features make the implementation of SPC much easier.

A complete commitment to SPC is present throughout Motorola. All managers, engineers, production operators, supervisors and maintenance personnel have received multiple training courses on SPC techniques. Manufacturing has identified 22 wafer processing and 8 assembly steps considered critical to the processing of semiconductor products. Processes, controlled by SPC methods, that have shown significant improvement are in the diffusion, photolithography and metallization areas.



Distribution Centered		Distribution Shifted ± 1.5
At ± 3 σ	2700 ppm defective 99.73% yield	66810 ppm defective 93.32% yield
At ± 4 σ	63 ppm defective 99.9937% yield	6210 ppm defective 99.379% yield
At ± 5 σ	0.57 ppm defective 99.999943% yield	233 ppm defective 99.9767% yield
At ± 6 σ	0.002 ppm defective 99.9999998% yield	3.4 ppm defective 99.99966% yield

Figure 1–3 – AOQL and Yield from a Normal Distribution of Product With 6σ Capability

To better understand SPC principles, brief explanations have been provided. These cover process capability, implementation and use.

PROCESS CAPABILITY

One goal of SPC is to ensure a process is **CAPABLE**. Process capability is the measurement of a process to produce products consistently to specification requirements. The purpose of a process capability study is to separate the inherent **RANDOM VARIABILITY** from **ASSIGNABLE CAUSES**. Once completed, steps are taken to identify and eliminate the most significant assignable causes. Random variability is generally present in the system and does not fluctuate. Sometimes, these are considered basic limitations associated with the machinery, materials, personnel skills or manufacturing methods. Assignable cause inconsistencies relate to time variations in yield, performance or reliability.

Traditionally, assignable causes appear to be random due to the lack of close examination or analysis. Figure 1-4 shows the impact on predictability that assignable cause can have. Figure 1-5 shows the difference between process control and process capability.

A process capability study involves taking periodic samples from the process under controlled conditions. The performance characteristics of these samples are charted against time. In time, assignable causes can be identified and engineered out. Careful documentation of the process is key to accurate diagnosis and successful removal of the assignable causes. Sometimes, the assignable causes will remain unclear requiring prolonged experimentation.

Elements which measure process variation control and capability are Cp and Cpk respectively. Cp is the specification width divided by the process width or Cp = (specification width) / 6σ. Cpk is the absolute value of the closest specification value to the mean, minus the mean, divided by half the process width or Cpk = | closest specification $- \bar{X}$ /3σ.

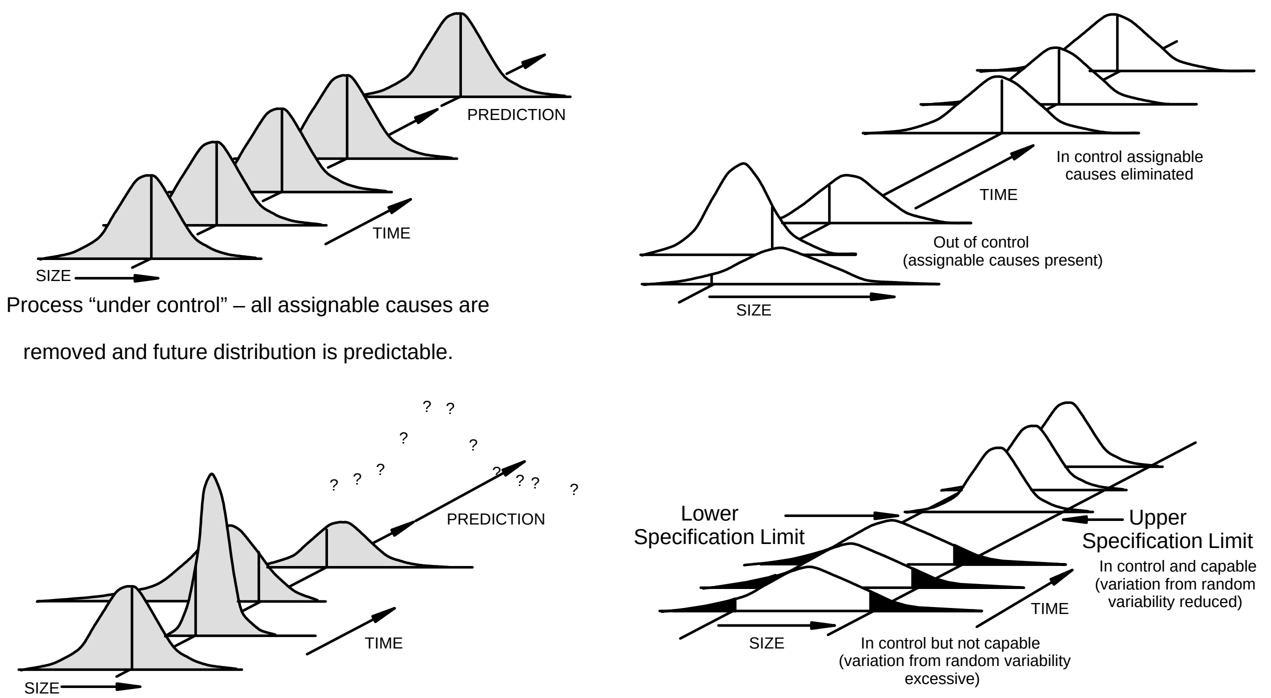


Figure 1–4 – Impact of Assignable Causes on Process Predictable

Figure 1–5 – Difference Between Process Control and Process Capability

At Motorola, for critical parameters, the process capability is acceptable with a Cpk = 1.33. The desired process capability is a Cpk = 2 and the ideal is a Cpk = 5. Cpk, by definition, shows where the current production process fits with relationship to the specification limits. Off center distributions or excessive process variability will result in less than optimum conditions

SPC IMPLEMENTATION AND USE

DMTG uses many parameters that show conformance to specification. Some parameters are sensitive to process variations while others remain constant for a given product line. Often, specific parameters are influenced when changes to other parameters occur. It is both impractical and unnecessary to monitor all parameters using SPC methods. Only critical parameters that are sensitive to process variability are chosen for SPC monitoring. The process steps affecting these critical parameters must be identified also. It is equally important to find a measurement in these process steps that correlates with product performance. This is called a critical process parameter.

Once the critical process parameters are selected, a sample plan must be determined. The samples used for measurement are organized into **RATIONAL SUBGROUPS** of approximately 2 to 5 pieces. The subgroup size should be such that variation among the samples within the subgroup remain small. All samples must come from the same source e.g., the same mold press operator, etc.. Subgroup data should be collected at appropriate time intervals to detect variations in the process. As the process begins to show improved stability, the interval may be increased. The data collected must be carefully documented and maintained for later correlation. Examples of common documentation entries would include operator, machine, time, settings, product type, etc.

Once the plan is established, data collection may begin. The data collected will generate $\bar{X}$ and R values that are plotted with respect to time. $\bar{X}$ refers to the mean of the values within a given subgroup, while R is the range or greatest value minus least value. When approximately 20 or more $\bar{X}$ and R values have been generated, the average of these values is computed as follows:

$$\bar{\bar{X}} = (\bar{X} + \bar{X}2 + \bar{X}3 + ...)/K$$
$$\bar{R} = (R1 + R2 + R3 + ...)/K$$

where K = the number of subgroups measured.

The values of $\bar{\bar{X}}$ and $\bar{R}$ are used to create the process control chart. Control charts are the primary SPC tool used to signal a problem. Shown in Figure 1–6, process control charts show $\bar{X}$ and R values with respect to time and concerning reference to upper and lower control limit values. Control limits are computed as follows:

R upper control limit = $UCL_R = D4\ \bar{R}$
R lower control limit = $LCL_R = D3\ \bar{R}$
$\bar{X}$ upper control limit = $UCL_{\bar{X}} = \bar{\bar{X}} + A2\ \bar{R}$
$\bar{X}$ lower control limit = $LCL_{\bar{X}} = \bar{\bar{X}} - A2\ \bar{R}$

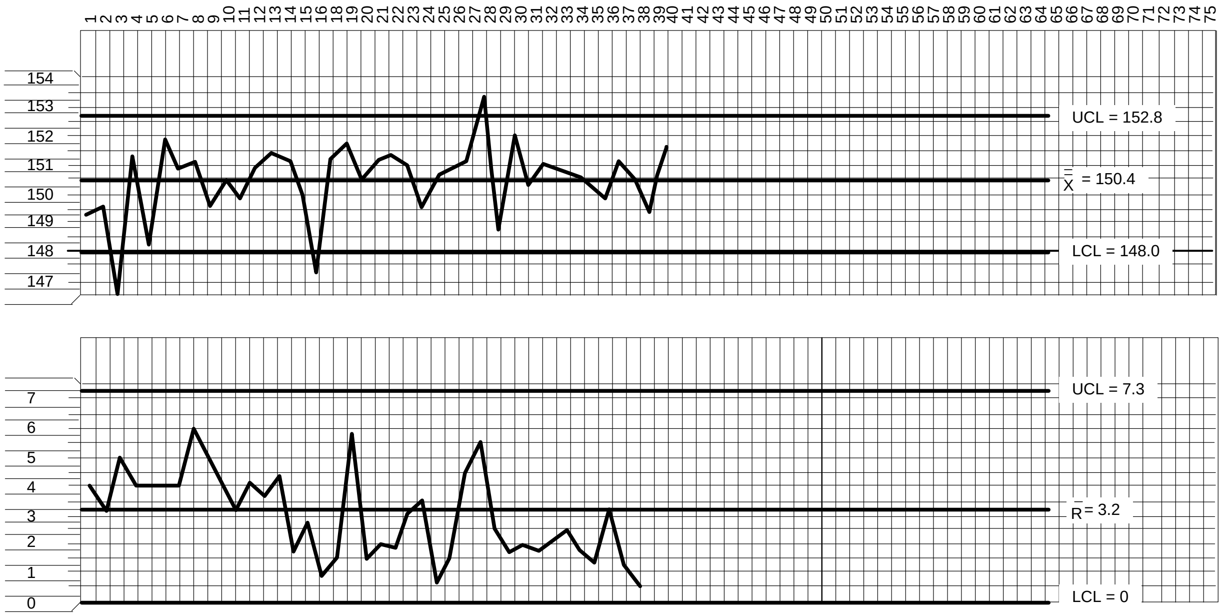


Figure 1–6 – Example of Process Control Chart Showing Oven Temperature Data

Where D4, D3 and A2 are constants varying by sample size,with values for sample sizes from 2 to 10 shown in the following partial table:

n	2	3	4	5	6	7	8	9	10
D_4	3.27	2.57	2.28	2.11	2.00	1.92	1.86	1.82	1.78
D_3	*	*	*	*	*	0.08	0.14	0.18	0.22
A_2	1.88	1.02	0.73	0.58	0.48	0.42	0.37	0.34	0.31

* For sample sizes below 7, the LCL_R would technically be a negative number; in those cases there is no lower control limit; this means that for a subgroup size 6, six "identical" measurements would not be unreasonable.

Control charts are used to monitor the variability of critical process parameters. The R chart shows basic problems with piece to piece variability related to the process. The X chart can often identify changes in people, machines, methods, etc. The source of the variability can be difficult to find and may require experimental design techniques to identify assignable causes.

Some general rules have been established to help determine when a process is **OUT-OF-CONTROL**. Figure 1–7 shows a control chart subdivided into zones A, B, and C corresponding to 3 sigma, 2 sigma, and 1 sigma limits respectively. In Figure 1–8 through Figure 1–11 four of the tests that can be used to identify excessive variability and the presence of assignable causes are shown. As familiarity with a given process increases, more subtle tests may be employed successfully.

Once the variability is identified, the cause of the variability must be determined. Normally, only a few factors have a significant impact on the total variability of the process. The importance of correctly identifying these factors is stressed in the following example. Suppose a process variability depends on the variance of five factors A, B, C, D and E. Each has a variance of 5, 3, 2, 1 and 0.4 respectively.

Since:

$$\sigma\ tot = \sqrt{\sigma A^2 + \sigma B^2 + \sigma C^2 + \sigma D^2 + \sigma E^2}$$

$$\sigma\ tot = \sqrt{5^2 + 3^2 + 2^2 + 1^2 + (0.4)^2} = 6.3$$

Now if only D is identified and eliminated then;

$$\sigma\ tot = \sqrt{5^2 + 3^2 + 2^2 + (0.4)^2} = 6.2$$

This results in less than 2% total variability improvement. If B, C and D were eliminated, then;

$$\sigma\ tot = \sqrt{5^2 + (0.4)^2} = 5.02$$

This gives a considerably better improvement of 23%. If only A is identified and reduced from 5 to 2, then;

$$\sigma\ tot = \sqrt{2^2 + 3^2 + 2^2 + 1^2 + (0.4)^2} = 4.3$$

Identifying and improving the variability from 5 to 2 gives us a total variability improvement of nearly 40%.

Most techniques may be employed to identify the primary assignable cause(s). Out-of-control conditions may be correlated to documented process changes. The product may be analyzed in detail using best versus worst part comparisons or Product Analysis Lab equipment. Multi-variance analysis can be used to determine the family of variation (positional, critical or temporal). Lastly, experiments may be run to test theoretical or factorial analysis. Whatever method is used, assignable causes must be identified and eliminated in the most expeditious manner possible.

After assignable causes have been eliminated, new control limits are calculated to provide a more challenging variability criteria for the process. As yields and variability improve, it may become more difficult to detect improvements because they become much smaller. When all assignable causes have been eliminated and the points remain within control limits for 25 groups, the process is said to be in a state of control.

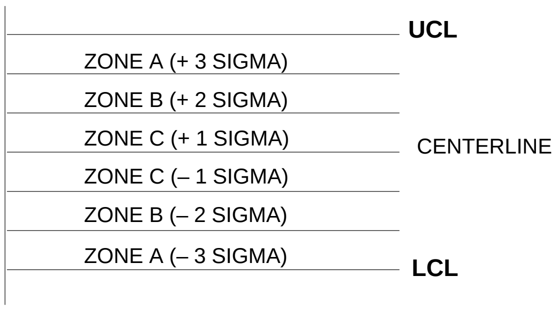


Figure 1–7– Control Chart Zones

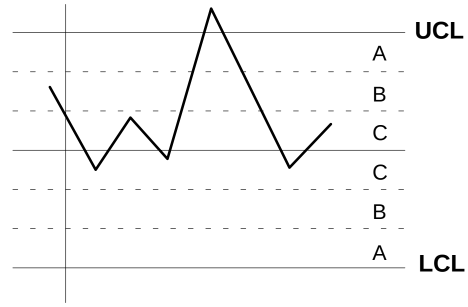


Figure 1–8– One Point Outside Control Limit Indicating Excessive Variability

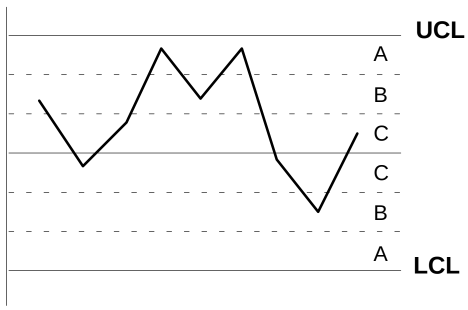


Figure 1–9– Two Out of Three Points in Zone A or Beyond Indicating Excessive Variability

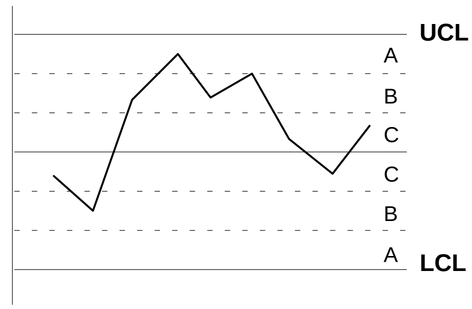


Figure 1–10– Four Out of Five Points in Zone B or Beyond Indicating Excessive Variability

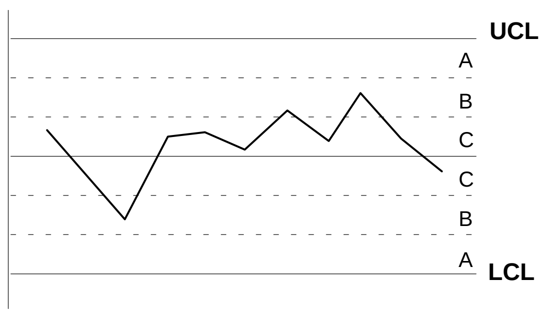


Figure 1–11– Seven Out of Eight Points in Zone C or Beyond Indicating Excessive Variability

SUMMARY

Motorola is committed to the use of STATISTICAL PROCESS CONTROLS. These principles, used throughout manufacturing, have already resulted in many significant improvements to the processes. Continued dedication to the SPC culture will allow Motorola to reach the Six Sigma and zero defect capability goals. SPC will further enhance the commitment to **TOTAL CUSTOMER SATISFACTION**.