TOSHIBA

Radio-Frequency Semiconductors
Diodes

TOSHIBA CORPORATION
Semiconductor Company

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Preface

Thank you for choosing Toshiba semiconductor products. This is the year 2006 edition of the databook entitled Radio-Frequency Semiconductor Devices – Diodes.

From this edition, the Radio-Frequency Semiconductor Devices is published in separate volumes: Radio-Frequency Semiconductor Devices – Diodes, Radio-Frequency Semiconductor Devices – Transistors, FETs and Cell Packs, and Radio-Frequency Semiconductor Devices – Power Devices. Please select the suitable databook for your application.

This databook is designed to be easily understood by engineers who are designing Toshiba radio-frequency small-signal devices into their products for the first time. No special knowledge of these devices is assumed - the contents includes basic information about the radio-frequency small-signal devices and the application fields in which they are used. In addition, complete technical specifications facilitate selection of the most appropriate radio-frequency small-signal device for any given application.

Toshiba are continually updating technical publications. Any comments and suggestions regarding any Toshiba document are most welcome and will be taken into account when subsequent editions are prepared. To receive updates to the information in this databook, or for additional information about the products described in it, please contact your nearest Toshiba office or authorized Toshiba dealer.

September 2006

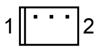
TOSHIBA CORPORATION
Semiconductor Company

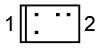
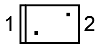
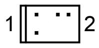
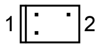
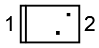
Contents

[1]　Part Number Index

[1] Part Number Index

Part Number	Marking	Page
1SS154	BA	149
1SS268	BF	151
1SS269	BG	153
1SS271	BD	155
1SS295	BH	157
1SS312	BF	159
1SS313	BG	161
1SS314	TY	163
1SS315	S2	165
1SS364	BF	167
1SS381	TY	169
1SV101	V101	171
1SV102	V102	174
1SV103	V103	177
1SV128	BB	179
1SV147	V147	181
1SV160	V1	184
1SV172	BE	186
1SV214	T1	188
1SV215	T2	190
1SV216	T4	192
1SV225	V3	194
1SV228	V4	196
1SV229	T8	199
1SV230	T7	201
1SV231	TA	203
1SV232	T9	205
1SV237	BB	207
1SV239	TC	209
1SV242	V5	211
1SV245	T3	213
1SV252	BE	215
1SV262	TD	217
1SV269	TE	219
1SV270	TF	221
1SV271	TG	223
1SV276	TL	225
1SV277	TO	227
1SV278B	• T1	229
1SV279	T8	231
1SV280	TC	233
1SV281	TF	235
1SV282	TD	237
1SV283B	• TE	239
1SV284	TL	241
1SV285	TO	243
1SV286	T7	245
1SV287	TK	247
1SV288	TJ	248
1SV290B	• TJ	250
1SV291	TK	252
1SV302	TT	253
1SV303	TT	255
1SV304	TV	257
1SV305	TV	259
1SV306	T8	261
1SV307	TX	263
1SV308	TX	265
1SV309	T3	267
1SV310	V1	269
1SV311	V1	271
1SV312	BB	273
1SV313	V6	274
1SV314	V6	276
1SV322	V7	278
1SV323	V7	280
1SV324	V8	282
1SV325	V8	284
1SV328	V2	286
1SV329	V2	288
1SV330	V9	290
1SV331	V9	292
HN1V01H	1V01H	294
HN1V02H	1V02H	296
HN2V02H	2V02H	298
JDH2S01FS	Z	300
JDH2S02FS	T	301
JDH3D01FV	BH	304

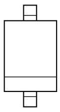
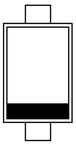
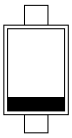
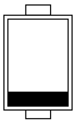
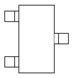
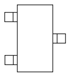
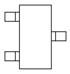
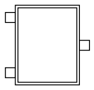
Part Number	Marking	Page
JDH3D01S	BH	307
JDP2S01S	1	310
JDP2S02ACT	02	312
JDP2S02AFS	2	315
JDP2S02AS	2	317
JDP2S04E	TG	319
JDP2S05CT	03	321
JDP2S05FS	03	324
JDP2S08SC		327
JDP4P02AT	TX	329
JDP4P02U	TX	331
JDS2S03S	0	333
JDV2S01E	FA	335
JDV2S01FS	G	337
JDV2S01S	G	339
JDV2S02E	FB	341
JDV2S02FS	T	343
JDV2S02S	H	344
JDV2S05E	FE	346
JDV2S05FS	K	348
JDV2S05S	K	350
JDV2S06FS	A	352
JDV2S06S	A	354
JDV2S07FS	D	356
JDV2S07S	D	358
JDV2S08FS	C	360
JDV2S08S	C	362
JDV2S09FS	B	364
JDV2S09S	B	366
JDV2S10FS	F	368
JDV2S10S	F	369
JDV2S13FS	E	371

Part Number	Marking	Page
JDV2S13S	E	372
JDV2S16FS	N	374
JDV2S16S	N	375
JDV2S17S	J	376
JDV2S19FS	M	378
JDV2S19S	M	379
JDV2S22FS	R	380
JDV2S22S	R	382
JDV2S25FS	D	384
JDV2S25SC		386
JDV2S26FS	A	388
JDV2S26SC		390
JDV2S27FS	C	392
JDV2S27SC		394
JDV2S28FS	B	396
JDV2S28SC		398
JDV2S29FS	E	400
JDV2S29SC		402
JDV2S71E	FJ	404
JDV3C11	FF	406
JDV3C34	FJ	408
JDV3S25CT	63	410
JDV3S26CT	60	412
JDV3S27CT	62	414
JDV3S28CT	61	416
JDV3S29CT	64	418
JDV4P08T	TV	420
JDV4P08U	TV	422

[2] Selection Guide by Packages and Applications

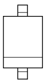
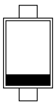
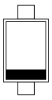
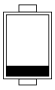
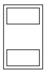
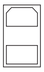
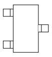
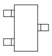
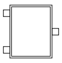
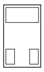
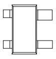
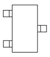
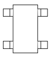
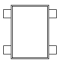
[2] Selection Guide by Packages and Applications

1. Diodes for TV Tuners

Application		Package Type							
		2 pin				3 pin			
		USC	ESC	sESC	fSC	S-MINI	USM	SSM	VESM
									
UHF	Tuning	1SV214	1SV278B*						
	AFC	1SV216							
	Mixer	1SS315			JDH2S01FS* JDH2S02FS*	1SS295 1SS514 1SS271		JDH3D01S	JDH3D01FV*
VHF	Tuning	1SV214 1SV215 1SV231 1SV232 1SV262 1SV269 1SV288 1SV302	1SV278B* 1SV282 1SV283B* 1SV290B* 1SV303			1SV242			
	Band Switch	1SS314	1SS381	JDS2S03S*		1SS268 1SS269	1SS312 1SS313	1SS364	
	AFC	1SV216							

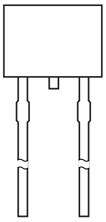
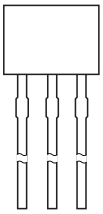
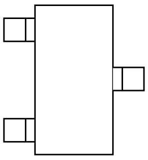
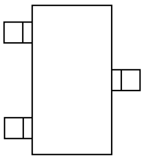
*: New product

2. Diodes for VHF to UHF Band

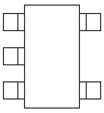
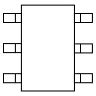
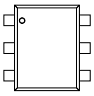
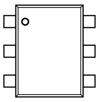
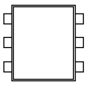
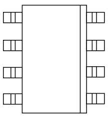
Application		Package Type													
		2 pin						3 pin				4 pin			
		USC	ESC	sESC	fSC	CST2	SC2	S-MINI	SSM	VESM	CST3	SMQ	USM	USQ	TESQ
															
Attenuator, Switch (PIN)	Single	1SV271 1SV307	JDP2S04E 1SV308	JDP2S02AS JDP2S01S	JDP2S02AFS JDP2S05FS	JDP2S02ACT JDP2S05CT	JDP2S08SC*	1SV128							
	Dual							1SV172				1SV237	1SV252	1SV312 JDP4P02U	JDP4P02AT*
Mixer (SBD)	Single	1SS315			JDH2S01FS* JDH2S02FS*			1SS154							
	Dual							1SS271 1SS295	JDH3D01S	JDH3D01FV*					
Tuning		1SV229 1SV230 1SV239 1SV245 1SV270 1SV276 1SV277 1SV287 1SV304 1SV310 1SV313 1SV322 1SV324 1SV328 1SV330*	1SV279 1SV286 1SV280 1SV309 1SV281 1SV284 1SV285 1SV291 1SV305 1SV311 1SV314 1SV323 1SV325 1SV329 1SV331 JDV2S01E JDV2S02E JDV2S05E JDV2S71E*	JDV2S06S JDV2S07S JDV2S08S JDV2S09S JDV2S10S JDV2S13S* JDV2S01S JDV2S02S JDV2S05S JDV2S16S* JDV2S17S* JDV2S19S* JDV2S20S JDV2S22S	JDV2S06FS JDV2S07FS JDV2S08FS* JDV2S09FS JDV2S10FS* JDV2S13FS* JDV2S01FS JDV2S02FS JDV2S05FS* JDV2S16FS* JDV2S19FS* JDV2S22FS JDV2S25FS* JDV2S26FS* JDV2S27FS* JDV2S28FS* JDV2S29FS*		JDV2S25SC* JDV2S26SC* JDV2S27SC* JDV2S28SC* JDV2S29SC*				JDV3S25CT* JDV3S26CT* JDV3S27CT* JDV3S28CT* JDV3S29CT*			1SV306 JDV4P08U	JDV4P08T*

*: New product

3. Diodes for AM and FM Tuners

Application		Package Type			
		2 pin	3 pin		
		Mini MOD	Mini	S-MINI	USM
					
FM Tuning	High VT		1SV103	1SV225	
	Low VT	1SV101	1SV147	1SV228 JDV3C11 JDV3C34	
AM Tuning	High VT	1SV102			
	Low VT				
AFC				1SV160	
Attenuater, SW (PIN)	Single			1SV128	
	Dual			1SV172	1SV252

4. Dual-chip Devices

Application	Package Type					
	5 pin	6 pin				8 pin
	SMV	TU6	ES6	sES6	fS6	FM8
						
AM Tuning						HN1V01H HN1V02H HN2V02H

[3]　Main Characteristics

[3] Main Characteristics

1. Variable Capacitance (varicap) Diodes for TV Tuners and VHF to UHF Band

Application	Part Number	V_R	I_R		C_T (1)		C_T (2)		C_T (1)/ C_T (2)	r_s (typ.)			Package
		(V)	(nA)	V_R (V)	(pF)	V_R (V)	(pF)	V_R (V)		(Ω)	V_R (V)	f (MHz)	
AFC	1SV216	30	10	28	10.5 to 16	2	3.3 to 5.7	10	2.5 to 3.4	0.55	5	470	USC
VHF Tuning (CATV)	1SV215♦	30	10	28	26 to 32	2	2.5 to 3.2	25	5.9 min	0.6	5	470	USC
	1SV231♦	30	10	28	41 to 49.5	2	2.7 to 3.4	25	14 min	1.05	5	470	USC
	1SV232	30	10	28	28 to 32	2	2.75 to 3.1	25	10 min	0.55	5	470	USC
	1SV242	30	10	28	36 to 4.2	1	2.43 to 3.0	28	13.4 min	0.65	5	470	S-MINI
	1SV262	34	10	32	33 to 38	2	2.6 to 3.0	25	12 min	0.6	5	470	USC
	1SV282♦												ESC
	1SV269♦	34	10	32	29 to 34	2	2.5 to 2.9	25	10.8 min	0.55	5	470	USC
	1SV283B*♦						2.5 to 3.0		10.6 min				ESC
VHF/UHF Tuning	1SV214♦	30	10	28	14.16 to 16.25	1	2.11 to 2.43	25	9.5 to 7.15	0.4	5	470	USC
	1SV278B*♦					2	2.01 to 2.43		5.9 to 7.28				ESC
UHF Tuning (BS 2nd C/V) (CATV)	1SV245	30	10	28	3.31 to 4.55	2	0.61 to 0.77	25	5.0 min	1.2	1	470	USC
	1SV309												ESC
	1SV287	30	10	28	4.2 to 5.7	2	0.53 to 0.68	25	7.6 typ.	1.9	1	470	USC
	1SV291												ESC
	1SV302	30	10	28	42 to 51	2	2.1 to 3.1	25	17.5 typ.	1.05	5	470	USC
	1SV303												ESC
	JDV2S71E*	30	10	28	6 to 7.2	1	0.49 to 0.64	25	11.5 typ.	1	5	470	ESC
VHF/UHF VCO	1SV229	15	3	15	14 to 16	2	5.5 to 6.5	10	2.0 min	0.2	5	470	USC
	1SV279												ESC
	1SV306												USQ
	1SV270	10	3	10	15 to 17	1	7.3 to 8.7	4	1.8 min	0.28	1	470	USC
	1SV281												ESC
	1SV276	10	3	10	15 to 17	1	7.0 to 8.5	4	1.8 min	0.22	1	470	USC
	1SV284												ESC
	JDV2S06S									0.27			sESC
	JDV2S06FS												fSC

♦: Manufactured at an overseas factory

*: New product

Application	Part Number	V_R	I_R		C_T (1)		C_T (2)		C_T (1)/ C_T (2)	r_s (typ.)			Package
		(V)	(nA)	V_R (V)	(pF)	V_R (V)	(pF)	V_R (V)		(Ω)	V_R (V)	f (MHz)	
L-Band VCO	1SV239	15	3	15	3.8 to 4.7	2	1.5 to 2.0	10	2.0 min	0.45	1	470	USC
	1SV280												ESC
	1SV277	10	3	10	4.0 to 4.9	1	1.85 to 2.35	4	2.0 min	0.42	1	470	USC
	1SV285												ESC
	JDV2S07S												sESC
	JDV2S07FS												fSC
UHF Wideband VCO	1SV304	10	3	10	17.3 to 19.3	1	5.3 to 6.6	4	3 typ.	0.27	1	470	USC
	1SV305												ESC
	JDV4P08U									0.35			USQ
	JDV4P08T												TESQ
	JDV2S08S												sESC
	JDV2S08FS												fSC
	1SV310	10	3	10	9.7 to 11.1	1	4.45 to 5.45	4	1.8 min	0.28	1	470	USC
	1SV311												ESC
	JDV2S09S									0.33			sESC
	JDV2S09FS												fSC
	1SV313	10	3	10	7.3 to 8.4	0.5	2.75 to 3.4	2.5	2.4 min	0.35	1	470	USC
	1SV314												ESC
	JDV2S10S												sESC
	JDV2S10FS												fSC
UHF VCO	1SV328	10	3	10	5.7 to 6.7	1	1.85 to 2.45	4	2.8 typ.	0.55	1	470	USC
	1SV329												ESC
	JDV2S13S									0.55			sESC
	JDV2S13FS												fSC
	JDV2S01E	10	3	10	2.85 to 3.45	1	1.35 to 1.81	4	1.8 min	0.5	1	470	ESC
	JDV2S01S												sESC
	JDV2S01FS												fSC
	JDV2S02E	10	3	10	1.8 to 2.3	1	0.83 to 1.23	4	1.8 min	0.6	1	470	ESC
	JDV2S02S												sESC
	JDV2S02FS												fSC
	JDV2S05E	10	3	10	3.85 to 4.55	1	1.94 to 2.48	4	1.7 min	0.3	1	470	ESC
	JDV2S05S												sESC
	JDV2S05FS												fSC
	JDV2S16S	10	3	10	3.59 typ.	0.5	1.8 typ.	2.5	2.0 typ.	0.5	1	470	sESC
	JDV2S16FS												fSC
	JDV2S17S	10	3	10	1.9 typ.	1	0.9 typ.	4	2.1 typ.	0.6	1	470	sESC

Application	Part Number	V_R	I_R		C_T (1)		C_T (2)		C_T (1)/ C_T (2)	r_s (typ.)			Package
		(V)	(nA)	V_R (V)	(pF)	V_R (V)	(pF)	V_R (V)		(Ω)	V_R (V)	f (MHz)	
UHF VCO	JDV2S19S	10	3	10	3.66 typ.	1	2.0 typ.	4	1.82 typ.	0.35	1	470	sESC
	JDV2S19FS												fSC
	JDV2S22S	10	3	10	3.24 to 3.62	1	1.77 to 1.99	3	1.82	0.5	1	470	sESC
	JDV2S22FS												fSC
	JDV2S25FS*	10	1	5	5.62 to 5.99	1	1.91 to 2.12	4	2.77 to 2.98	0.49	1	470	fSC
	JDV3S25CT*									0.47			CST3
	JDV2S25SC*				5.57 to 5.93		1.88 to 2.08		2.81 to 3				SC2
	JDV2S26FS*	10	1	5	15.35 to 16.31	1	5.27 to 5.6	4	2.82 to 3	0.4	1	470	fSC
	JDV3S26CT*									0.37			CST3
	JDV2S26SC*				15.33 to 16.29		5.25 to 5.58		2.83 to 3.01	0.36			SC2
	JDV2S27FS*	10	1	5	8.06 to 8.56	1	2.79 to 2.98	4	2.79 to 2.98	0.49	1	470	fSC
	JDV3S27CT*									0.48			CST3
	JDV2S27SC*				8 to 8.5		2.75 to 2.93		2.81 to 3				SC2
	JDV2S28FS*	10	1	5	10.2 to 10.83	1	4.66 to 5.05	4	2.08 to 2.22	0.39	1	470	fSC
	JDV3S28CT*								2.09 to 2.23	0.38			CST3
	JDV2S28SC*				10.13 to 10.77		4.62 to 5.01		2.1 to 2.24				SC2
	JDV2S29FS*	10	1	6	3.59 to 3.87	1	1.26 to 1.40	4	2.73 to 2.91	0.66	1	470	fSC
	JDV3S29CT*									0.64			CST3
	JDV2S29SC*				3.54 to 3.83		1.22 to 1.37		2.73 to 2.92				SC2
CATV Conv. OSC	1SV230	30	10	28	13.9 to 16.6	2	1.7 to 2.1	20	7.1 min	0.73	5	470	USC
	1SV286♦				14.5 to 16.1		1.56 to 1.86			0.75			ESC
Wideband Tuning (CATV)	1SV288	30	10	28	41 to 49.5	2	2.5 to 3.2	25	16 typ.	0.92	5	470	USC
	1SV290B*♦												ESC
VCXO	1SV322	10	3	10	26 to 30	1	6 to 7.1	4	4 min	0.4	4	100	USC
	1SV323												ESC
	1SV324	10	3	10	43 to 49.5	1	8.5 to 12.2	4	4 min	0.4	4	100	USC
	1SV325												ESC
	1SV330	10	3	10	18	1	5.1	4	3.5 typ.	0.45	1	470	USC
	1SV331												ESC

♦: Manufactured at an overseas factory

*: New product

2. Varicap Diodes AM and FM Tuners

Application	Part Number	V_R	I_R		C_T (1)		C_T (2)		Q (r_S (Ω) typ.)			Package
		(V)	(nA)	V_R (V)	(pF)	V_R (V)	(pF)	V_R (V)	Min (—)	V_R (V)	f (MHz)	
AM Tuning	1SV102	30	50	30	360 to 460	2	15 to 21	25	200	2	1	MINI
FM Tuning	1SV101	15	10	15	28 to 32	3	12 to 14	9	(0.3)	C = 30 pF	50	MINI
FM Tuning (Dual)	1SV103	32	50	30	37 to 42	3	13.2 to 16.2	30	(0.35)◊	C = 20 pF	50	MINI
	1SV228	15	10	15	28.5 to 32.5◊	3	11.7 to 13.7◊	8	(0.3)◊	3	100	S-MINI
	1SV147		50							C = 30 pF	50	MINI
	1SV225	32	50	30	18.5 to 21◊	3	6.6 to 7.7◊	30	(0.35)◊	3	100	S-MINI
	JDV3C11	20	10	20	65.8 to 74.2	1	11.5 to 14.3	4.5	(0.4)	1.5	100	S-MINI
	JDV3C34	12	10	10	67.9 to 72.1	2	26.1 to 27.8	6	(0.2)	2	100	S-MINI
AFC	1SV160	15	100	4	7 to 14	4	—	—	(0.7)	4	50	S-MINI

◊: Series-connected capacitance

3. Multi-Chip Varicap Diodes for AM Tuners

Application	Part Number	V_R	I_R		C_T (1)		C_T (2)		Q			Constituent Parts	Package
		(V)	(nA)	V_R (V)	(pF)	V_R (V)	(pF)	V_R (V)	Min (—)	V_R (V)	f (MHz)		
AM Tuning	HN1V01H	16	20	16	435 to 540	1	19.9 to 26.7	8	200	1	1	1SV149 × 4	FM8
	HN1V02H											1SV149 × 2	
	HN2V02H											1SV149 × 3	

4. PIN Diodes for TV Band Switches

Application	Part Number	V_R	I_R		V_F (max)		C_T (typ.)		r_S (typ.)			Package
		(V)	(μA)	V_R (V)	(V)	I_F (mA)	(pF)	V_R (V)	(Ω)	I_F (mA)	f (MHz)	
Single	1SS314♦	30	0.1	15	0.85	2	0.7	6	0.5	2	100	USC
	1SS381											ESC
	JDS2S03S						0.8					sESC
Dual	1SS268	30	0.1	15	0.85	2	0.8	6	0.6	2	100	S-MINI
	1SS312♦											USM
	1SS364						0.85					SSM
	1SS269	30	0.1	15	0.85	2	0.8	6	0.6	2	100	S-MINI
	1SS313											USM

♦: Manufactured at an overseas factory

5. PIN Diodes for AM/FM to UHF Band

Application	Part Number	V_R	I_R		V_F (max)		C_T (typ.)		r_s (typ.)			Package
		(V)	(µA)	V_R (V)	(V)	I_F (mA)	(pF)	V_R (V)	(Ω)	I_F (mA)	f (MHz)	
Single	1SV128	50	0.1	50	0.95 typ.	50	0.25	50	7	10	100	S-MINI
	1SV271				1				3			USC
	JDP2S04E											ESC
	1SV307	30	0.1	30	1	50	0.3	1	1	10	100	USC
	1SV308											ESC
	JDP2S02AS											sESC
	JDP2S02AFS											fSC
	JDP2S02ACT											CST2
	JDP2S01S	30	0.1	30	0.95	50	0.65	1	0.65	10	100	sESC
	JDP2S05FS	20	0.1	20	0.94	50	0.32	1	1.5	1	100	fSC
	JDP2S05CT											CST2
	JDP2S08SC*	30	0.1	30	0.95	50	0.21	1	1	10	10	SC2
Dual	1SV237	50	0.1	50	0.95 typ.	50	0.25	50	3	10	100	SMQ
	1SV172								4			S-MINI
	1SV252				0.98		0.2		3.5			USM
	1SV312				1		0.25		3			USQ
	JDP4P02U	30	0.1	30	1	50	0.3	1	1	10	100	USQ
	JDP4P02AT											TESQ

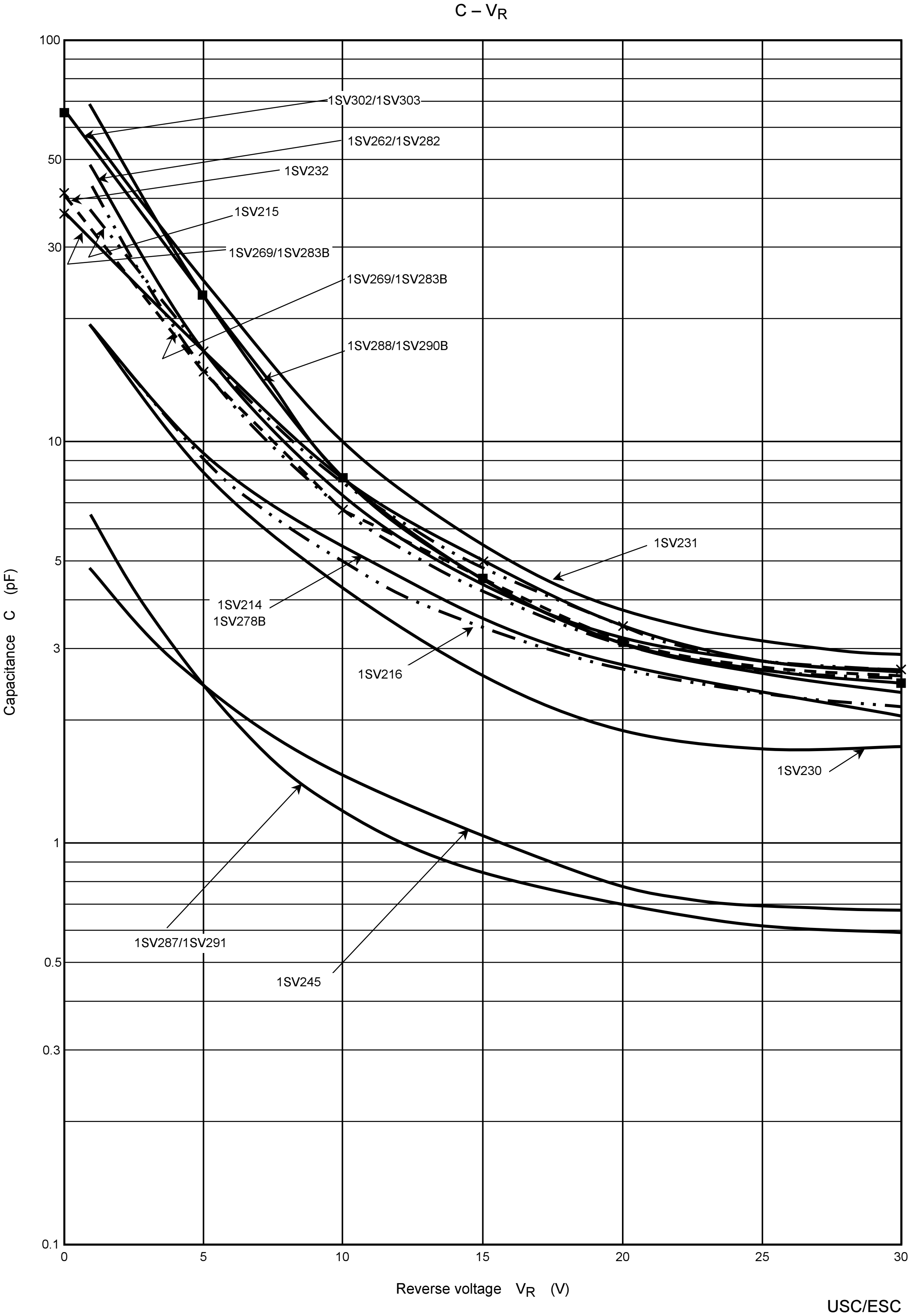
*: New product

6. Schottky Barrier Diodes for VHF to UHF Mixers

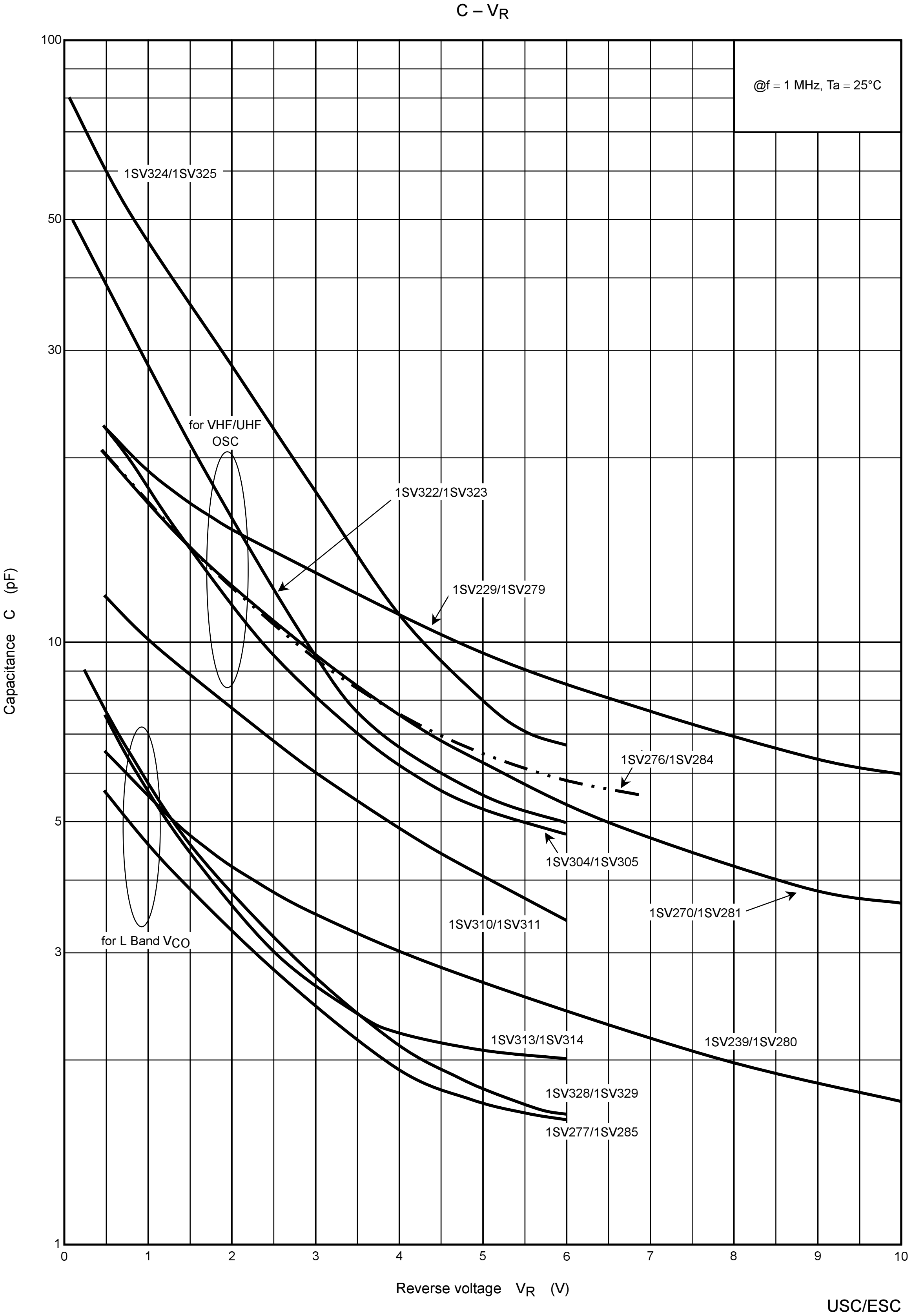
Application	Part Number	V_R V_{RM} Δ	I_F	V_F (typ.)		C_T (typ.)		Package
		(V)	(mA)	(V)	I_F (mA)	(pF)	V_R (V)	
Single	1SS154	6	30	0.5	10	0.8	0	S-MINI
	1SS315	5Δ	30	0.25	2	0.6	0.2	USC
	JDH2S01FS	4	2.5	0.25	2	0.6	0.2	fSC
	JDH2S02FS*	10	10	0.24	1	0.3	0.2	fSC
Dual	1SS271	6	30	0.5	10	0.8	0	S-MINI
	1SS295	4	30	0.25	2	0.6	0.2	S-MINI
	JDH3D01S	4	2.5	0.25	2	0.6	0.2	SSM
	JDH3D01FV	4	2.5	0.25	2	0.6	0.2	VESM

*: New product

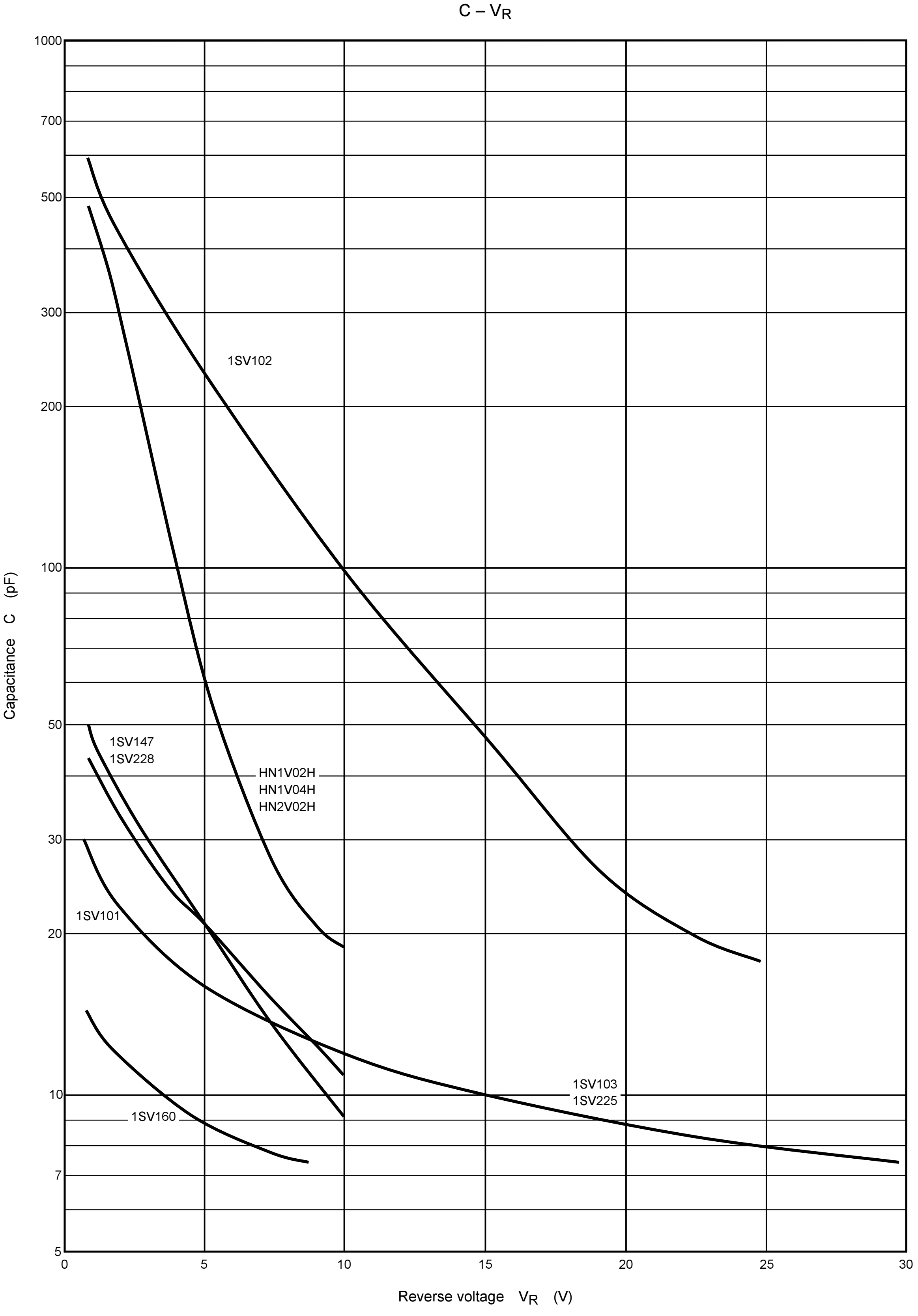
7. Capacitance – Reverse Voltage Characteristics of Varicap Diodes for TV Tuners and BS Tuners



8. Capacitance – Reverse Voltage Characteristics of Varicap Diodes for Communications



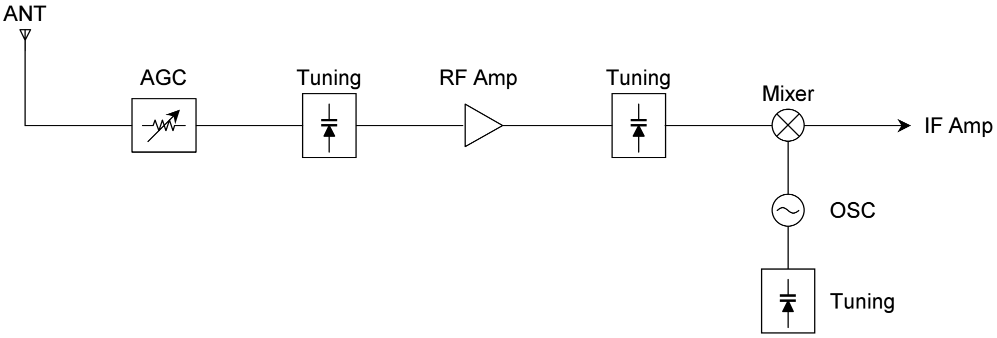
9. Capacitance – Reverse Voltage Characteristics of Varicap Diodes for Audio Tuners



[4] Block Diagrams for Suggested Applications

[4] Block Diagrams for Suggested Applications

1. Radio-Frequency Devices for AM Tuners



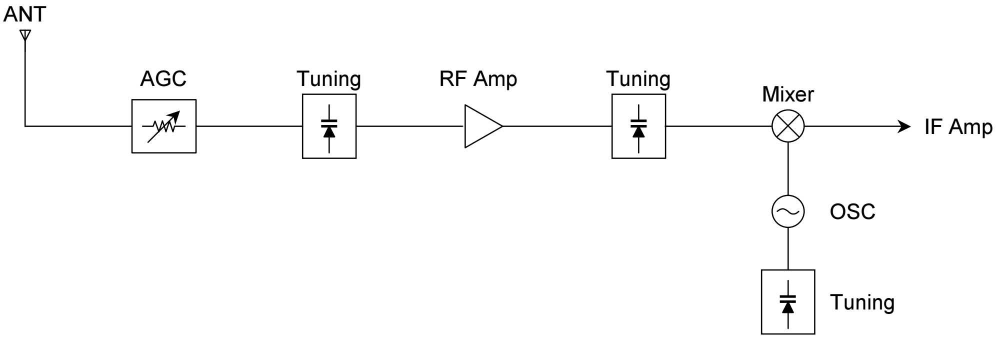
Application	Type		Package	Part Number
AGC	PIN diode	Single	S-MINI	1SV128
			USC	1SV271 1SV307
			ESC	1SV308 JDP2S01E JDP2S04E
		Dual	S-MINI	1SV172
			SMQ	1SV237
			USM	1SV252
			USQ	1SV312 JDP4P02U

Application	Type	Package	Part Number
AGC	Bipolar transistor	MINI	2SC2458
		S-MINI	2SC2712
RF Amp	JFET	TO-92	2SK709
		MINI	2SK710
		S-MINI	2SK711
		USM	2SK1875
	Dual transistor	SMV	HN3G01J

Application	Type	Package	Part Number
Tuning	Tuning varicap diode	MINI	1SV102 1SV149-B
		FM8	HN1V01H HN1V02H HN2V02H

Application	Type	Package	Part Number
Mixer	Bipolar transistor	TO-92	2SC380TM 2SC941TM
		MINI	2SC2669 2SC2670
		S-MINI	2SC2715 2SC2716

2. Radio-Frequency Devices for FM Tuners



Application	Type		Package	Part Number
AGC	PIN diode	Single	S-MINI	1SV128
			USC	1SV271 1SV307
			ESC	1SV308 JDP2S01E JDP2S04E
		Dual	S-MINI	1SV172
			SMQ	1SV237
			USM	1SV252
			USQ	1SV312 JDP4P02U
	Schottky diode	Single	USC	1SS315
			fSC	JDH2S01FS
		Dual	S-MINI	1SS295
			SSM	JDH3D01S*
			VESM	JDH3D01FV*

*: New product

Application	Type	Package	Part Number
RF Amp	Dual-gate MOSFET	SMQ	3SK195
			3SK225 3SK226
		USQ	3SK257 3SK258
	Single-gate MOSFET	MINI	2SK241
		S-MINI	2SK302
		USM	2SK882
		SMQ	2SK1771
	Bipolar transistor	MINI	2SC2668
		S-MINI	2SC2714
		USM	2SC4215
	JFET	MINI	2SK161 2SK192A
		S-MINI	2SK211 2SK210
		USM	2SK881

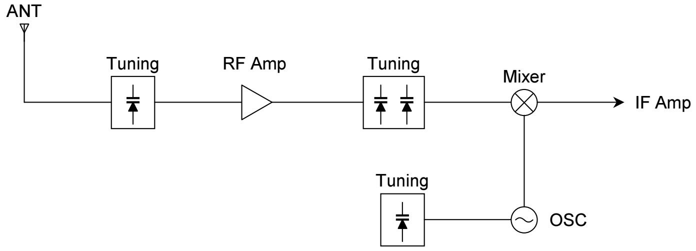
Application	Type		Package	Part Number
Tuning	Tuning varicap diode	Dual	MINI	1SV101
			S-MINI	1SV225 1SV228 JDV3C11 JDV3C34*
	AFC varicap diode	Single	S-MINI	1SV160

*: New product

Application	Type	Package	Part Number
Mixer	Dual-gate MOSFET	SMQ	3SK195
		USQ	3SK260
	Bipolar transistor	MINI	2SC2668
		S-MINI	2SC2714
		USM	2SC4215
		SSM	2SC4915

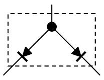
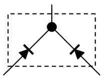
Application	Type	Package	Part Number
OSC	JFET	MINI	2SK192A
		S-MINI	2SK210
	Bipolar transistor	MINI	2SC2668 2SC2995
		S-MINI	2SC2714 2SC2996
		USM	2SC4215
		SSM	2SC4915

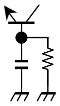
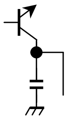
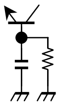
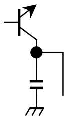
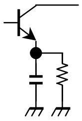
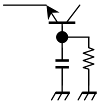
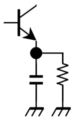
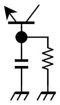
3. Radio-Frequency Devices for TV and VTR Tuners



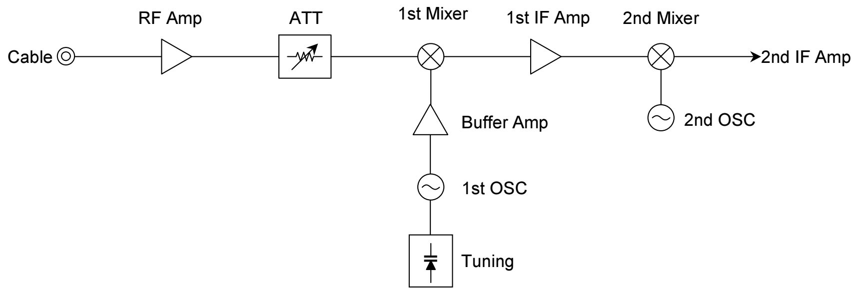
Application	Type	Band	Package	Part Number
Tuning	Tuning varicap diode	Wideband VHF	USC	1SV215 1SV262 1SV288 1SV231 1SV232 1SV269 1SV302
			ESC	1SV282 1SV290B 1SV283B 1SV303
			S-MINI (dual type)	1SV242
		UHF	USC	1SV214
			ESC	1SV278B
	AFC diode	VHF to UHF	USC	1SV216
RF Amp	Dual-gate FET	Wideband VHF	SMQ	3SK195 3SK225 3SK226 3SK292
			USQ	3SK259 3SK257 3SK258 3SK294
		UHF	SMQ	3SK199 3SK207 3SK232 3SK291
			USQ	3SK256 3SK249 3SK293
Mixer	Dual-gate FET	VHF and wideband VHF	USQ	3SK260 3SK259
	Schottky diode	UHF	S-MINI	1SS295 (dual)
			USC	1SS315
			SSM	JDH3D01S* (dual)
			fSC	JDH2S01FS
			VESM	JDH3D01FV* (dual)

*: New product

Application	Type		Band	Internal Connection	Package	Part Number
Tuning	Band switch	Single	VHF and wideband VHF	—	USC	1SS314
					ESC	1SS381
					sESC	JDS2S03S
		Dual		 Common anode	S-MINI	1SS269
						1SS268
					USM	1SS313
				 Common cathode	USM	1SS312
					SSM	1SS364

Application	Type	Band	Circuit Diagram	Package	Part Number
RF Amp	Bipolar transistor	UHF	 Common base	USM	2SC4244
				SMQ	2SC4214
OSC	Bipolar transistor	Wideband VHF	 Common collector	USM	2SC4251 2SC4246 2SC4252
				S-MINI	2SC3124 2SC3121
		UHF	 Common base	USM	2SC4246
				S-MINI	2SC3121
			 Common collector	USM	2SC4247
				S-MINI	2SC3547A
Mixer	Bipolar transistor	Wideband VHF	 Common emitter	USM	2SC4250 2SC4245
				S-MINI	2SC3123 2SC3120
			 Common base	USM	2SC4253 2SC4251 2SC4246
				S-MINI	2SC3125 2SC3124 2SC3121
		UHF	 Common emitter	S-MINI	2SC3120 2SC3862
				S-MINI	2SC3547A
			 Common base	USM	2SC4245
				USM	2SC4247

4. Radio-Frequency Devices for CATV Converters



Application	Type	Package	Part Number
RF Amp	Bipolar transistor	SMQ	2SC5087 *2SC5087R MT4S03A MT4S04A
		USQ	MT4S03AU MT4S04AU MT4S100U MT4S101U *MT4S102U *MT4S104U
		TESQ	MT4S100T MT4S101T *MT4S102T *MT4S104T

Application	Type		Package	Part Number
ATT	Pin diode	Single	S-MINI	1SV128
			USC	1SV271 1SV307
			ESC	1SV308 JDP2S01E JDP2S04E
		Dual	S-MINI	1SV172
			SMQ	1SV237
			USM	1SV252
			USQ	1SV312 JDP4P02U
			TESQ	JDP4P02AT

Application	Type		Package	Part Number
1st Mixer	Schottky diode	Single	S-MINI	1SS154
			fSC	JDH2S01FS
		Dual	S-MINI	1SS271
			SSM	*JDH3D01S
			VESM	*JDH3D01FV

Application	Type	Package	Part Number
1st IF Amp	Bipolar transistor	S-MINI	MT3S03A MT3S04A
		SMQ	MT4S03A MT4S04A MT4S06 MT4S07
		USQ	MT4S03AU MT4S04AU MT4S06U MT4S07U
	Si dual-gate MOSFET	SMQ	3SK199 3SK232 3SK291 3SK292
		USQ	3SK249 3SK293 3SK294

Application	Type	Package	Part Number
2nd Mixer	Schottky diode	S-MINI	1SS154 (single) 1SS271 (dual)
	Si dual-gate MOSFET	SMQ	3SK199 3SK232 3SK291
		USQ	3SK249 3SK293
	Cell pack	SM8	TA4107F

Application	Type	Package	Part Number
Buffer Amp	Bipolar transistor	S-MINI	MT3S03A MT3S04A
		SMQ	MT4S03A MT4S04A MT4S06 MT4S07
		USQ	MT4S03AU MT4S04AU MT4S06U MT4S07U

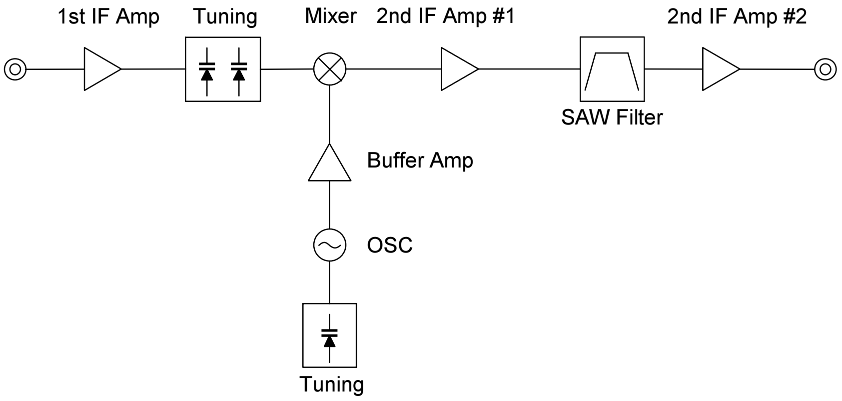
Application	Type	Package	Part Number
1st OSC	Bipolar transistor	S-MINI	2SC5084 MT3S03A MT3S04A
		USM	MT3S03AU MT3S03AU

Application	Type	Package	Part Number
Tuning	Tuning varicap diode	USC	1SV214 1SV230
		ESC	1SV278B

Application	Type	Package	Part Number
2nd OSC	Bipolar transistor	USM	2SC4246
		S-MINI	2SC3121

*: New product

5. Radio-Frequency Devices for SHF 2nd Converters



Application	Type	Package	Part Number
1st IF Amp	Bipolar transistor	SMQ	MT4S03A MT4S04A MT4S06 MT4S07 2SC5092
		USQ	2SC5088 2SC5093 2SC5319 MT4S06U MT4S07U MT4S100U MT4S101U *MT4S102U *MT4S104U
		TESQ	MT4S100T MT4S101T *MT4S102T *MT4S104T

Application	Type	Package	Part Number
Tuning	Preselector and tuning varicap diode	USC	1SV245 1SV287 JDV2S71E
		ESC	1SV309 1SV291 JDV2S71E

Application	Type	Package	Part Number
Mixer	Bipolar transistor	SMQ	2SC5092
	Schottky diode	S-MINI	1SS154 (single) 1SS271 (dual)
		SSM	*JDH3D01S (dual)
		fSC	JDH2S01FS
		VESM	*JDH3D01FV (dual)
	Cell pack	SM8	TA4107F

Application	Type	Package	Part Number
2nd IF Amp #1	Cell pack	SMQ	TA4002F

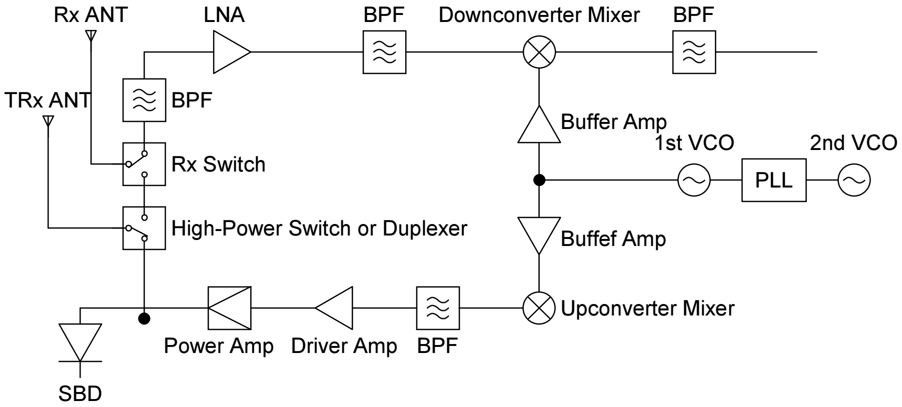
Application	Type	Package	Part Number
2nd IF Amp #2	Cell pack	SM6	TA4000F
		TU6	TA4017FT
		SM8	TA4018F
			TA4019F

Application	Type	Package	Part Number
Buffer Amp	Bipolar transistor	USQ	2SC5088 2SC5093 2SC5319

Application	Type	Package	Part Number
OSC	Bipolar transistor	S-MINI	2SC5089
		USQ	*MT4S200U

*: New product

6. Radio-Frequency Devices for 800-MHz Analog and Digital Cell Phones



Application	Type	Package	Part Number
Power Amp	Si MOSFET	PW-MINI	2SK2854
			2SK2855

Application	Type	Package	Part Number
Rx Switch	GaAs MMIC	TU6	TG2210FT *TG2211AFT
		sES6	TG2213S TG2214S
		CST6B	*TG2217CTB
	PIN diode	fSC	JDP2S02AFS JDP2S05FS
		CST2	JDP2S02ACT JDP2S05CT
		SC2	JDP2S08SC
	Band switch	sESC	JDS2S03S

*: New product

Application	Type	Package	Part Number
Buff Amp	Si cell pack	ESV	TA4011AFE
			TA4012AFE

Application	Package / Type	USC	fSC	SSM	VESM
Detector	SBD	1SS315	JDH2S01FS	JDH3D01S	*JDH3D01FV

*: New product/Dual

Varicap Diode

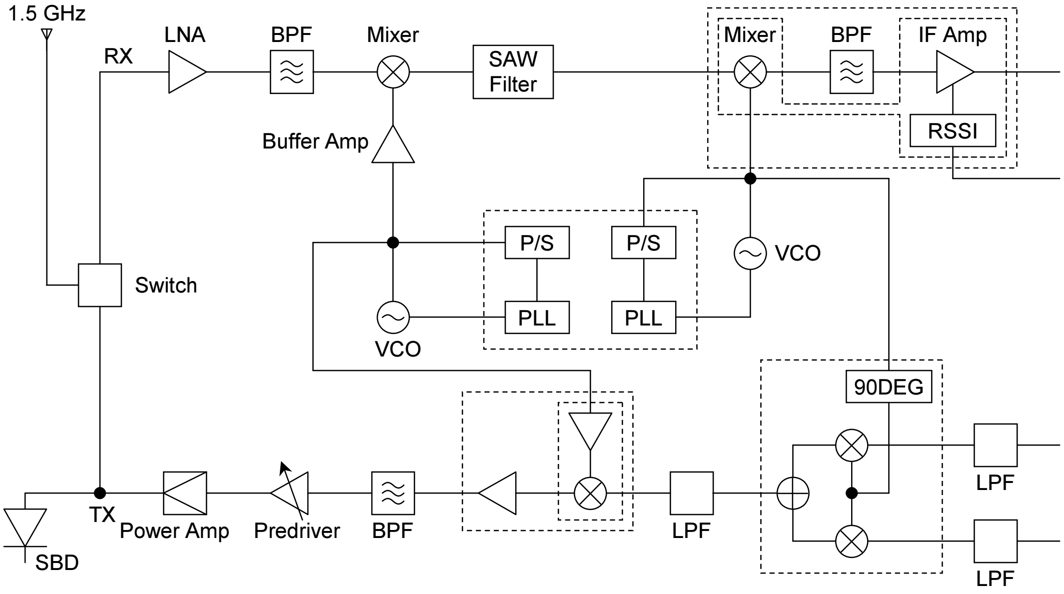
Application	Package Type	USC	ESC	sESC	fSC	CST3	SC2
VCO	VCD	1SV229	1SV279				
		1SV270	1SV281				
		1SV276	1SV284	JDV2S06S	JDV2S06FS		
		1SV304	1SV305	JDV2S08S	JDV2S08FS		
		1SV310	1SV311	JDV2S09S	JDV2S09FS		
					*JDV2S26FS	*JDV3S26CT	*JDV2S26SC
					*JDV2S27FS	*JDV3S27CT	*JDV2S27SC
					*JDV2S28FS	*JDV3S28CT	*JDV2S28SC
							*JDV2S31SC

*: New product

Application	Package Type	TESM	fSM	SMQ	USQ	fS6	CST3	CST6
LNA, Buff Amp	Bipolar transistor	2SC5066FT						
		2SC5086FT		2SC5087	2SC5088			
		2SC5091FT		2SC5092	2SC5093			
		2SC5096FT		2SC5097	2SC5098			
		MT3S03AT	MT3S03AFS					
		MT3S06T	MT3S06FS	MT4S06	MT4S06U			
		MT3S07T	MT3S07FS	MT4S07	MT4S07U			
		MT3S14T	*MT3S14FS					
		MT3S18T	*MT3S18FS					
		MT3S35T	MT3S35FS					
		MT3S36T	MT3S36FS					
		MT3S37T	MT3S37FS					
		MT3S41T	MT3S41FS					
					MT4S32U			
Mixer	Bipolar transistor	2SC5066FT						
		2SC5086FT		2SC5087	2SC5088			
		2SC5108FT						
		2SC5111FT						
VCO	Bipolar transistor	2SC5086FT						
		2SC5464FT						
		2SC5066FT						
		2SC5108FT						
		2SC5111FT						
		MT3S03AT	MT3S03AFS					
		MT3S04AT	MT3S04AFS					
		MT3S05T	MT3S05FS					
		MT3S06T	MT3S06FS					
		MT3S07T	MT3S07FS					
		MT3S08T	MT3S08FS					
		MT3S11T	MT3S11FS				*MT3S11CT	
		MT3S12T						
		MT3S14T	MT3S14FS					
		MT3S18T	MT3S18FS					
		MT3S35T	MT3S35FS					
		MT3S36T	MT3S36FS					
		MT3S37T	MT3S37FS					
		MT3S41T	MT3S41FS					
		MT3S45T	MT3S45FS					
			*MT3S106FS				*MT3S106CT	
			*MT3S107FS					
						MT6L63FS		
						MT6L64FS		
						MT6L65FS		
						*MT6L66FS		*MT6L66CT
						*MT6L67FS		*MT6L67CT
						MT6L68FS		
						MT6L71FS		
						MT6L72FS		
						*MT6L73FS		*MT6L73CT
						*MT6L74FS		*MT6L74CT
						*MT6L75FS		*MT6L75CT
						*MT6L76FS		*MT6L76CT
						*MT6L77FS		*MT6L77CT
						MT6L78FS		

*: New product

7. Radio-Frequency Devices for PDC Phone (1.5 GHz)



Application	Package / Type	ESC	sESC	fSC	CST3	SC2
VCO	VCD	JDV2S05E 1SV285 1SV305 1SV311 1SV314 1SV329	JDV2S05S JDV2S07S JDV2S08S JDV2S09S JDV2S10S JDV2S13S	JDV2S05FS JDV2S07FS JDV2S08FS JDV2S09FS JDV2S10FS JDV2S13FS *JDV2S25FS *JDV2S26FS *JDV2S27FS *JDV2S28FS	*JDV2S25CT *JDV2S26CT *JDV2S27CT *JDV2S28CT	*JDV2S25SC *JDV2S26SC *JDV2S27SC *JDV2S28SC *JDV2S31SC

*: New product

Application	Package / Type	ESV
Buff Amp	Si cell pack	TA4011AFE TA4012AFE

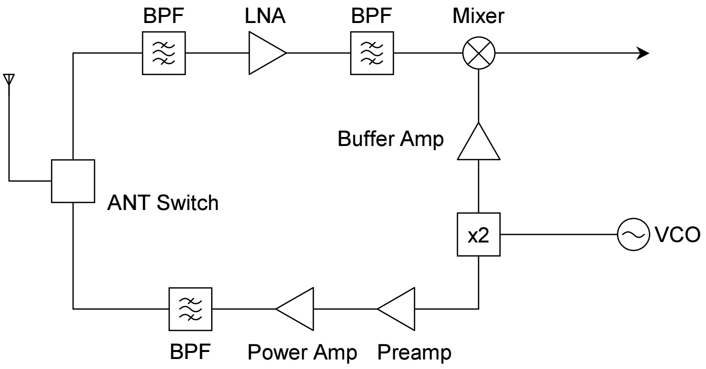
Application	Package / Type	USC	fSC	SSM	VESM
Detector	SBD	1SS315	JDH2S01FS	JDH3D01S	*JDH3D01FV

*: New product/Dual

Application	Package Type	TESM	fSM	USQ	TESQ	fS6	CST3	CST6
LNA, Buff Amp	Bipolar transistor	2SC5317FT MT3S03AT MT3S06T MT3S07T *MT3S14T *MT3S18T MT3S35T MT3S36T MT3S37T MT3S41T	MT3S06FS MT3S07FS *MT3S14FS *MT3S18FS MT3S35FS MT3S36FS MT3S37FS MT3S41FS	2SC5319 MT4S06U MT4S07U MT4S100U MT4S101U	MT4S100T MT4S101T			
Mixer (downconv.)	Bipolar transistor	2SC5317FT 2SC5086FT						
VCO	Bipolar transistor	MT3S03AT MT3S04AT MT3S05T MT3S06T MT3S07T MT3S08T MT3S11T MT3S12T MT3S14T MT3S18T MT3S35T MT3S36T MT3S37T MT3S41T MT3S45T	MT3S03AFS MT3S04AFS MT3S05FS MT3S06FS MT3S07FS MT3S08FS MT3S11FS MT3S12FS MT3S14FS MT3S18FS MT3S35FS MT3S36FS MT3S37FS MT3S41FS MT3S45FS *MT3S106FS *MT3S107FS			MT6L63FS MT6L64FS MT6L65FS *MT6L66FS *MT6L67FS MT6L68FS MT6L71FS MT6L72FS *MT6L73FS *MT6L74FS *MT6L75FS *MT6L76FS *MT6L77FS MT6L78FS	*MT3S11CT *MT3S106CT	*MT6L66CT *MT6L67CT *MT6L73CT *MT6L74CT *MT6L75CT *MT6L76CT *MT6L77CT

*: New product

8. Radio-Frequency Devices for 900-MHz, 2.4-GHz and 5.8-GHz Band Cordless Phones



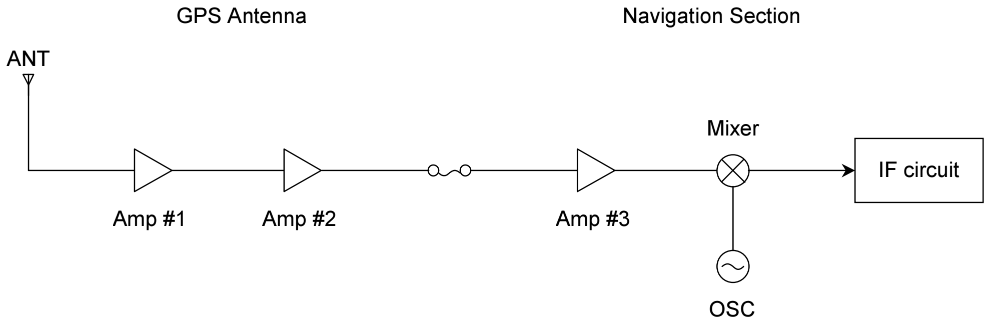
	Package	USC	ESC	sESC	fSC	CST2	SC2
Application	Type						
ANT Switch	900 MHz	1SV271 1SV307 1SS314	JDP2S04E 1SV308 1SS381	JDP2S02AS JDS2S03S	JDP2S02AFS	JDP2S02ACT	JDP2S08SC
	2.4 GHz	1SV271 1SV307	JDP2S04E 1SV308	JDP2S02AS	JDP2S02AFS JDP2S05FS	JDP2S02ACT JDP2S05CT	
	5.8 GHz				JDP2S05FS	JDP2S05CT	
VCO & Diode	900 MHz	1SV214 1SV229 1SV276 1SV304 1SV310 1SV313	1SV278B 1SV279 1SV284 1SV305 1SV311 1SV314	JDV2S06S JDV2S08S JDV2S09S JDV2S10S	JDV2S06FS JDV2S08FS JDV2S09FS JDV2S10FS		
	2.4 GHz		JDV2S01E JDV2S02E JDV2S05E	JDV2S01S JDV2S02S JDV2S05S JDV2S16S JDV2S19S	JDV2S01FS JDV2S02FS JDV2S05FS JDV2S16FS JDV2S19FS		
	5.8 GHz		JDV2S02E	JDV2S02S *JDV2S17S *JDV2S22S	JDV2S02FS *JDV2S22FS		

*: New product

	Package	USM	SSM	TESM	SMQ	USQ	TESQ
Application	Type						
VCO Buffer Amp Mixer Power Amp Preamp LNA	900 MHz	2SC5065 2SC5085 MT3S06U *MT3S16U	2SC5066 2SC5086 MT3S06S	2SC5066FT 2SC5086FT MT3S06T *MT3S16T *MT3S18T	2SC5087 MT4S06	2SC5088 MT4S06U	
	2.4 GHz	MT3S06U	MT3S06S	2SC5317FT MT3S06T *MT3S18T MT3S35T MT3S37T MT3S45T	MT4S06	2SC5319 MT4S06U MT4S101U MT4S32U	MT4S101T
	5.8 GHz			MT3S35T MT3S37T		MT4S100U MT4S101U MT4S102U MT4S104U *MT4S200U	MT4S100T MT4S101T MT4S102T MT4S104T

*: New product

9. Radio-Frequency Devices for Global Positioning System (GPS)



GPS Antenna Section

	Package	ES6	USQ	TESQ
Application	Type			
Amp #2	Bipolar transistor		2SC5319 MT4S32U MT4S100U MT4S101U MT4S102U MT4S104U *TA4S200U	MT4S100T MT4S101T MT4S102T MT4S104T
	Si cell pack	TA4016AFE		*TA4020FT

*: New product

Navigation Section

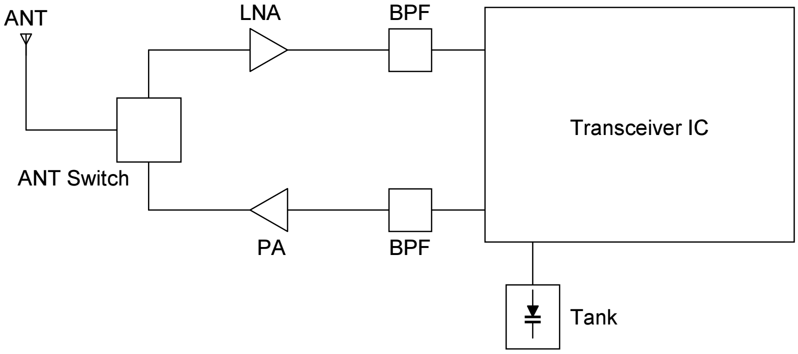
	Package	USQ	TESQ
Application	Type		
Amp #3	Bipolar transistor	2SC5319 MT4S06U MT4S32U MT4S100U MT4S101U *MT4S102U *MT4S104U	MT4S100T MT4S101T *MT4S102T *MT4S104T
Mixer, OSC	Bipolar transistor	2SC5319 MT4S06U	

*: New product

	Package	ESC	sESC	fSC
Application	Type			
OSC	Varicap diode	1SV314 1SV329 JDV2S01E JDV2S02E JDV2S05E	JDV2S10S JDV2S13S JDV2S01S JDV2S02S JDV2S05S JDV2S16S *JDV2S17S JDV2S19S *JDV2S22S	JDV2S10FS JDV2S13FS JDV2S01FS JDV2S02FS JDV2S05FS JDV2S16FS JDV2S19FS *JDV2S22FS

*: New product

10. 2.4-GHz Wireless LAN and Bluetooth^{TM}



ANT Switch

Application	Type	Package	Part Number
ANT Switch for 2.4G WLAN and Class-1 BT	GaAs MMIC	UF6	TG2216TU
ANT Switch for Class-2/3 BT		TU6	TG2210FT *TG2211AFT
		sES6	TG2213S TG2214S
		CST6B	*TG2217CTB

*: New product

Application	Package / Type	USQ	TESQ
LNA	Bipolar transistor	MT4S100U MT4S101U MT4S102U MT4S104U	MT4S100T MT4S101T MT4S102T MT4S104T

Application	Package / Type	ESC	sESC	fSC
VCO	Varicap diode	1SV314 1SV329 JDV2S01E JDV2S02E JDV2S05E	JDV2S10S JDV2S13S JDV2S01S JDV2S02S JDV2S05S JDV2S16S JDV2S19S	JDV2S10FS JDV2S13FS JDV2S01FS JDV2S02FS JDV2S05FS JDV2S16FS JDV2S19FS

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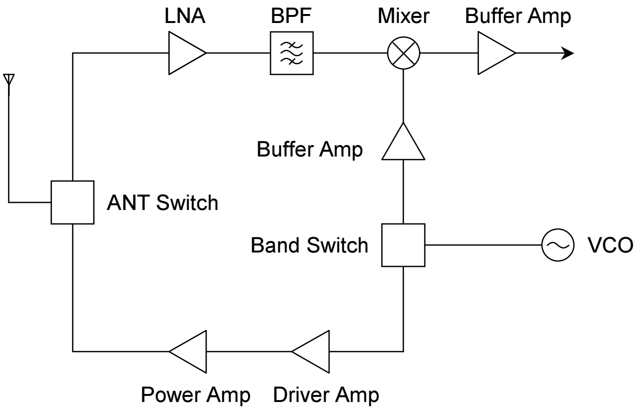
11. Radio-Frequency Devices for FRS and GMRS



Application	Package Type	USC	ESC	sESC	fSC	CST2	CT2
ANT Switch	FRS, GMRS	1SS314 1SV271 1SV307	1SS381 JDP2S04E 1SV308	JDS2S03S JDP2S02AS	JDP2S02AFS JDP2S05FS	JDP2S02ACT JDP2S05CT	JDP2S08SC
VCO		1SV214 1SV229 1SV276 1SV304	1SV278B 1SV279 1SV284 1SV305 1SV282	JDV2S06S JDV2S08S	JDV2S06FS JDV2S08FS		

Application	Package Type	USM	SSM	TESM	SMQ	USQ
VCO Driver Amp Buffer Amp Mixer LNA	FRS, GMRS	2SC5065 2SC5085 MT3S06U *MT3S16U	2SC5066 2SC5086 MT3S06S	2SC5066FT 2SC5086FT MT3S06T *MT3S16T *MT3S18T	2SC5087 MT4S06	2SC5088 MT4S06U

*: New product

Application	Package Type	PW-MINI	PW-X
Power Amp	FRS	2SK3078A *2SK3656	
	GMRS		2SK3079A *2SK3756

*: New product

[5] Maximum Ratings and Electrical Characteristics

[5] Maximum Ratings and Electrical Characteristics

1. Definition of Maximum Ratings

1.1 Maximum Ratings for Switching Diodes and Schottky Barrier Diodes

1) Reverse voltage (V_R)

Maximum permissible value of reverse voltage that can be applied at the specified ambient temperature

2) Peak reverse voltage (V_{RM})

Maximum permissible instantaneous value of reverse voltage (DC + AC signals combined) that can be applied at the specified ambient temperature

3) Forward current (I_F)

Maximum permissible value of forward current that can flow at the specified ambient temperature

4) Junction temperature (T_j)

Permissible junction temperature range for device operation. The maximum forward current and operating temperature levels of the device must be set so that the junction temperature always remains within the T_j range.

5) Storage temperature (T_{stg})

Ambient temperature range within which the device must be stored while not being used. Toshiba guarantees that the device will not be degraded if it is stored at a temperature within the T_{stg} range.

1.2 Maximum Ratings for Variable-Capacitance Diodes

1) Reverse voltage (V_R)

Maximum permissible value of reverse voltage that can be applied at the specified ambient temperature

2) Peak reverse voltage (V_{RM})

Maximum permissible instantaneous value of reverse voltage (DC + AC signals combined) that can be applied at the specified ambient temperature

3) Junction temperature (T_j)

Permissible junction temperature range for device operation. The maximum operating temperature level of the device must be set so that the junction temperature always remains within the T_j range.

4) Storage temperature (T_{stg})

Ambient temperature range within which the device must be stored while not being used. Toshiba guarantees that the device will not be degraded if it is stored at a temperature within the T_{stg} range.

2. Definition of Electrical Characteristics

2.1 Electrical Characteristics for Variable-Capacitance Diodes

Parameter	Symbol	Description
Reverse voltage	V_R	Reverse voltage when the specified reverse current flows
Reverse current	I_R	Leakage current that flows when the specified reverse voltage is applied
Capacitance	C_{*V}	Equivalent capacitance between pins when the specified reverse-bias voltage ($*V$) is applied at the specified frequency
Capacitance ratio	$C_{*}{}^{1}{}_{V} / C_{*}{}^{2}{}_{V}$	Ratio of capacitance at reverse voltage $*{}^{1}V$ to capacitance at reverse voltage $*{}^{2}V$
Series resistance	r_s	Equivalent series resistance when the specified reverse-bias voltage is applied at the specified frequency
Performance figure	Q	Performance figure when the specified reverse-bias voltage is applied at the specified frequency

2.2 Electrical Characteristics for Switching Diodes

Parameter	Symbol	Description
Reverse voltage	V_R	Reverse voltage when the specified reverse current flows
Reverse current	I_R	Leakage current that flows when the specified reverse voltage is applied
Forward voltage	V_F	Voltage between pins that is generated when the specified forward current flows
Capacitance	C_T	Equivalent capacitance between pins when the specified reverse-bias voltage is applied at the specified frequency
Series resistance	r_s	Equivalent series resistance when the specified reverse-bias voltage is applied at the specified frequency
Minority carrier lifetime	τ	Minority carrier lifetime when the specified forward current flows and then the specified reverse current flows

2.3 Electrical Characteristics for Schottky Barrier Diodes

Parameter	Symbol	Description
Reverse voltage	V_R	Reverse voltage when the specified reverse current flows
Reverse current	I_R	Leakage current that flows when the specified reverse voltage is applied
Forward voltage	V_F	Voltage between pins that is generated when the specified forward current flows
Forward current	I_F	Forward current that flows when the specified forward voltage is applied
Capacitance	C_T	Equivalent capacitance between pins when the specified reverse-bias voltage is applied at the specified frequency

[6] Device Features in Detail

[6] Device Features in Detail

1. Diodes for Radio-Frequency Devices

1.1 Capacitance Diodes

Variable-capacitance diodes are generally called varicap diodes. Rectifiers and switching diodes use the rectification property of the PN junction, and the constant-voltage diode uses the Zener drop and avalanche drop. Varicap diodes, however, use the change in PN junction capacitance caused by the reverse-bias voltage.

These diodes are used in AFTs and AFCs in TV and FM tuners, or as FM modulators.

Due to progress in semiconductor technology, ICs that integrate automatic tuning control functions by means of varicap diodes are now widely used in TV and FM/AM tuners. These tuners are thin, compact and lightweight when compared to conventional mechanical tuners. Varicap diodes are currently used in a wide range of electronic fields, from consumer electronics, such as TVs and radios, to telecommunications.

1.1.1 Basic Operating Principle

When the PN junction diode is reverse-biased, the depletion layer is affected by the reverse-bias voltage V_R. The PN junction capacitance depends on the width of the depletion layer.

If the depletion layer is wide, the capacitance is small; conversely, if the range is narrow, the capacitance is large.

Therefore the junction capacitance is controlled by the reverse-bias voltage V_R.

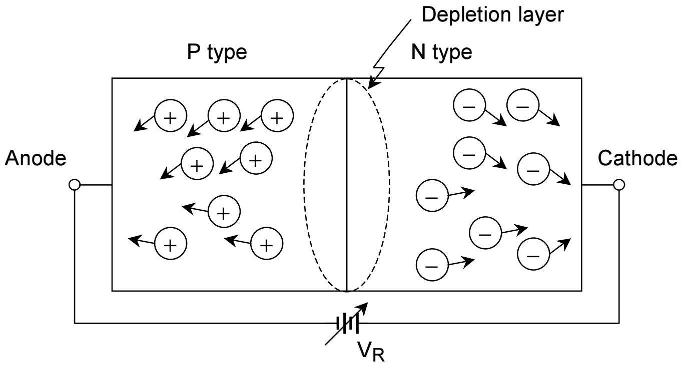
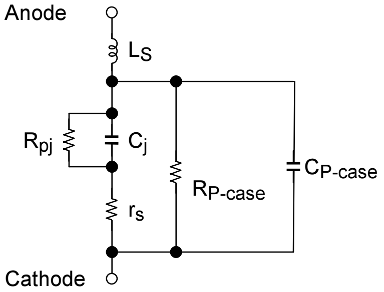


Figure 1.1 Operation Diagram

1.1.2 Equivalent Circuit

Figure 1.2 shows a varicap diode expressed by its equivalent circuit.



C_j	: Junction capacitance
r_s	: Series resistance
R_{pj}	: Junction power loss resistance
$R_{P\text{-case}}$	: Package power loss resistance (depending on tan δ of the resin package used)
$C_{P\text{-case}}$	: Package capacitance
L_S	: Lead inductance

Figure 1.2 Equivalent Circuit of a Variable-Capacitance Diode

When the frequency is low, lead inductance L_S can be ignored; when junction capacitance C_j is large, the package capacitance $C_{P\text{-case}}$ can be ignored.

1.1.3 Varicap Diode Types and Features

Varicap diodes can be classified into three types according to their impurity density distribution: graded junction, abrupt junction, and hyperabrupt junction.

These types are shown in Table 1.1.

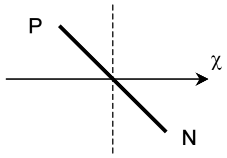
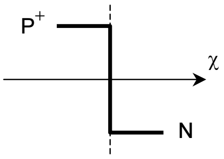
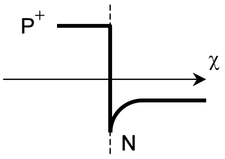
In the equation below, the exponent n is an important factor in determining the characteristic at capacitance (c) versus reverse voltage (V_R).

$$C = K (V_R + \phi)^{-n} \text{ .... } (1)$$

K: determined by impurity density distribution, dielectric constant, junction area

ϕ : diffusion potential

Table 1.1 Variable-Capacitance Diode: Types and Features

Classification	Impurity Density Distribution	$\frac{1}{n}$	Application	Features
Graded junction		$\frac{1}{3}$	General-purpose switching	Narrow variable range of capacitance; not used as a varicap diode.
Abrupt junction		$\frac{1}{2}$	AFC tuning modulation	Stability in C-V curve is high; pairing is unnecessary when used for tuning. Capacitance change rate is small and high control voltage is required.
Hyperabrupt junction		above $\frac{1}{2}$	Tuning	Capacitance change rate can be large even when the working voltage range is narrow; on the other hand, a large number of diffusion processes are required, and the C-V curve has low stability.

1.1.4 Basic Parameters of a Varicap Diode

V_R: reverse voltage

Applied allowable voltage in a reversed-bias state varicap diode.

C_T: capacitance between terminals

Figure 1.2 shows the total capacitance between anode and cathode in the equivalent circuit.

C_{3V}: capacitance between terminals with $V_R = 3$ V (the same as C_{9V} and C_{25V})

C_{3V}/C_{9V}: capacitance ratio between terminals with $V_R = 3$ V, 9 V

(used in varicap diodes for tuning purposes)

K: capacitance ratio

$$K = \frac{\begin{pmatrix}\text{capacitance between pins}\\ \text{at the device voltage}\end{pmatrix} - \begin{pmatrix}\text{capacitance between pins}\\ \text{at reference voltage}\end{pmatrix}}{\text{capacitance between pins at reference voltage}}$$

Q: performance characteristic

In a circuit or a material, this is the proportion of energy stored out of the total energy consumed by a resistance component.

In the equivalent circuit shown in Figure 1.2, when lead inductance L_S and case capacitance $C_{P\text{-case}}$ are ignored, Q can be expressed as

$$Q = \frac{1}{\omega C_j r_s + \left(\frac{1}{R_{pj}} + \frac{1}{R_{p\text{-case}}}\right) / \omega C_j} \quad \text{.......... (2)}$$

in which

r_s= series resistor.

Generally, it is expressed as

$$Q = \frac{1}{\omega C_j r_s} \quad \text{.......... (3)}$$

r_s is one of the most important parameters influencing the performance characteristic Q and can be expressed by the following:

$$r_s = \frac{1}{S_j}\int \frac{d\chi}{q\mu_n N(\chi)} + \frac{1}{S_j}\int \frac{d\chi}{q\mu_p P(\chi)} + R_c \quad \text{.......... (4)}$$

in which S_j = junction area;

μ_n = electron mobility;

μ_p = electron-hole mobility;

$N(x)$ = impurity density distribution on side N;

$P(x)$ = impurity density distribution on side P;

R_c = contact resistance.

Matching:

For tuning varicap diodes, the C vs. V_R characteristics for all diodes must be identical when they are used in the same tuner.

This is required to guarantee the tracking of a tuner. Generally, the pairing deflection of capacitance between terminals for each reverse voltage V_R is 3% or below.

1.1.5 Voltage Dependency in a Capacitance

According to their impurity density distribution rates, varicap diodes can be classified into three types: graded junction, abrupt junction, and hyperabrupt junction.

When an N-type impurity distribution is defined by a known function N (x), the voltage potential E can be expressed as

$$E = \int \frac{qN(\chi)}{\varepsilon_r \varepsilon_0} d\chi \tag{5}$$

$$V = -\int E(\chi) d\chi \tag{6}$$

$$C_j = \frac{\varepsilon_r \varepsilon_0 S_j}{\chi} \tag{7}$$

in which ε_0 = dielectric constant in a vacuum

ε_r = specific dielectric constant

Also, the relationship between a capacitance and the corresponding reverse voltage is expressed by $C = K (V_R + \phi)^{-n}$.

For the graded junction diode type, n = 1/3; for the abrupt junction type, n = 1/2; and for hyperabrupt junction, n = 1/2 or above. Figure 1.3 shows an example of capacitance versus reverse voltage characteristics.

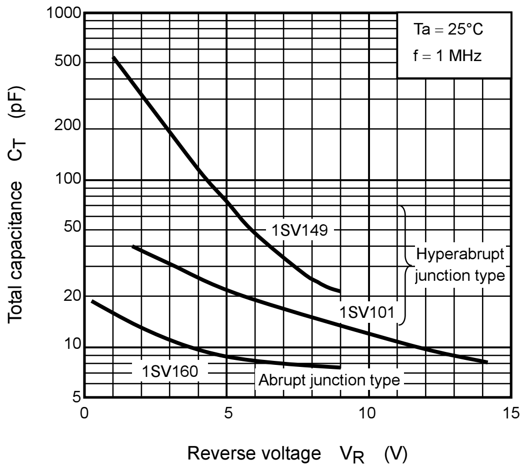


Figure 1.3 Capacitance versus Reverse Voltage Characteristics: Varicap Diode

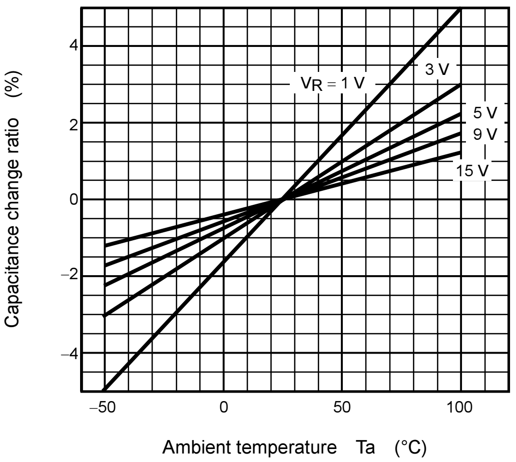


Figure 1.4 Capacitance Change Ratio versus Ambient Temperature Characteristics: Varicap Diode (1SV101)

1.1.6 Temperature Dependency of a Capacitance

In a varicap diode, change in capacitance due to change in temperature is caused by [1] temperature-induced change in diffusion voltage potential and [2] temperature-induced change in the dielectric constant.

Both of these relationships can be expressed by the following equation:

$$\frac{1}{C_j}\cdot\frac{\partial C_j}{\partial_T} = \frac{1}{K}\cdot\frac{dK}{dT} - \frac{n}{V_R+\phi}\cdot\frac{d\phi}{dT} \quad \text{.......... (8)}$$

The temperature-induced change in the dielectric constant in the first term is 35 ppm/°C (silicon).

In the second term, the temperature-induced change in diffusion potential is approximately −2 mV/°C.

It is impossible completely to eliminate temperature dependency in a capacitance where there is a voltage dependency. However, as long as the capacitance ratio remains the same, which will be the case when the same two measurement points are used, the temperature dependency can be decreased to a certain extent, depending on the value chosen for 'n' in the setting of the reverse voltage V_R.

Figure 1.4 shows the temperature dependency in the capacitance of the varicap diode 1SV101.

1.1.7 Average Capacitance Fluctuation in AC Signal Voltage

A varicap diode changes the thickness of the depletion layers by changing the value of the reverse-bias voltage at the PN junction. This change in the depletion layers is used for the change in junction capacitance. Therefore, as shown in Figure 1.5, in a state where AC signals are superimposed on a DC bias voltage, the AC signals affect the depletion layers.

For this reason, average values of capacitance differ depending on whether AC signals are applied or not.

This is because the relationship between the capacitance and the reverse voltage expressed in Equation (1) does not in general become a linear function.

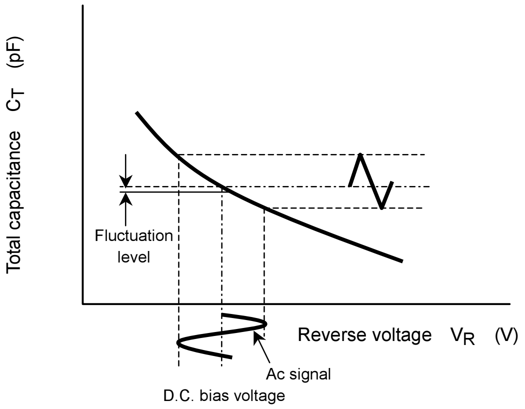


Figure 1.5 Capacitance Fluctuation in the Relationship between Capacitance and Reverse Voltage

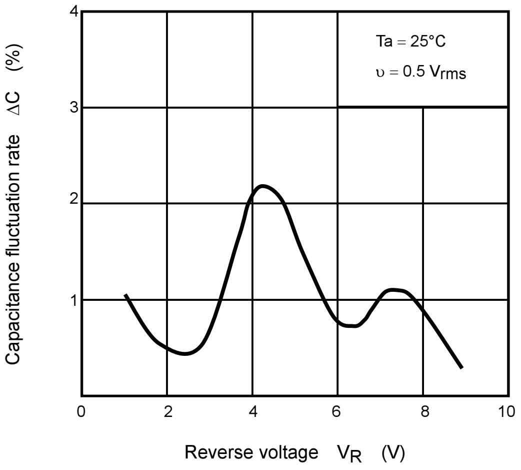


Figure 1.6 Typical Capacitance Fluctuation Rate versus Reverse Voltage Characteristics (1SV149)

Fluctuation in average capacitance is expressed by the equation below:

$$\frac{C_{jac}}{C_{jDC}} = \frac{1}{2\pi}\int_0^{2\pi}\left\{1+\frac{\upsilon_{\sin\omega}t}{V_R+\phi}\right\}^{-n} d(\omega t) \quad \text{.......... (9)}$$

in which C_{jac} = capacitance when AC signals are applied;
C_{jDC} = capacitance when DC bias voltage is applied;
$\upsilon_{\sin\omega}t$ = AC signal level.

The capacitance fluctuation rate ΔC is expressed as follows:

$$\Delta C = \frac{C_{jac} - C_{jDC}}{C_{jDC}} \times 100\ (\%) \quad \text{.......} \quad (10)$$

$$C_{jac} = \frac{1}{2\pi}\int_0^{2\pi} K\left(V_R + \phi + \upsilon_{sin}\omega t\right)^{-n} d\,(\omega t) \quad \text{.......} \quad (11)$$

Equations (9) to (11) are valid only for a section where ‘n’ is close to a constant value. In the case of a hyperabrupt junction diode, the designer should beware of increased distortion due to changes in ‘n’ resulting from changes in the reverse voltage.

As in the case of the temperature dependency characteristic of a capacitance, it is impossible entirely to suppress fluctuation in average capacitance in a varicap diode when an AC signal voltage is present.

However, even when the same capacitance fluctuation ratio has been chosen, the fluctuation can be decreased to some extent through selecting the value of ‘n’ corresponding to a certain reverse voltage V_R.

Figure 1.6 shows the characteristics diagram for capacitance fluctuation ratio versus reverse voltage in the 1SV149 varicap diode.

1.1.8 Voltage and Frequency Dependency of Q

The performance characteristic ‘Q’ changes according to the reverse voltage because both the junction capacitance C_j and the series resistance r_S also change.

However, the change occurring in C_j is very large compared to that in r_S; therefore, the voltage dependency of C_j greatly affects that of Q.

Figure 1.7 shows the voltage dependency characteristics of Q for certain illustrative devices.

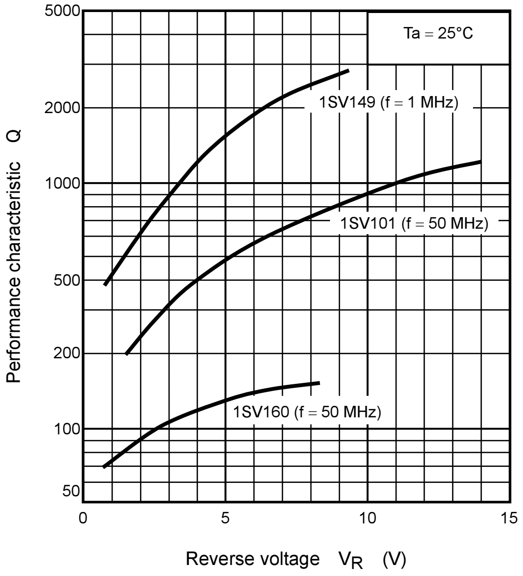


Figure 1.7 Illustrative Voltage Dependency Characteristics of Q

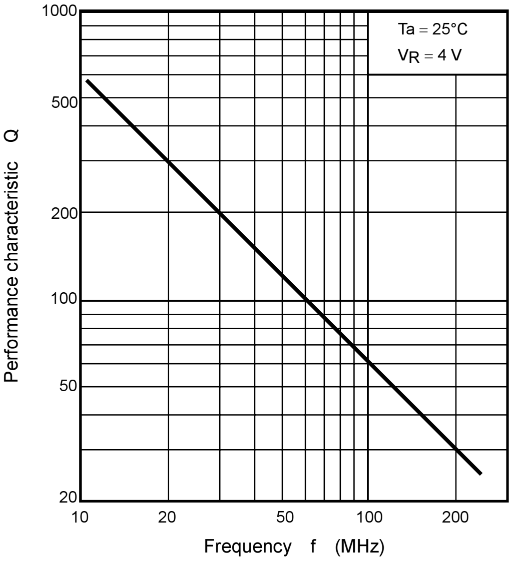


Figure 1.8 Frequency Dependency Characteristics of Q (1SV160)

By Equation (3), the frequency characteristic of Q is inversely proportional to the frequency when the serial resistance r_S is constant.

However, when the frequency is high, Q may also be affected by the lead inductance L_S or by the case-loss resistance $R_{P\text{-}case}$, which may lower its value.

1.1.9 Application of Variable-Capacitance Diodes to Tuning Circuits

Variable-Capacitance Diode Bias Method

In contrast to tuners using conventional variable capacitors or μ-tuning, electronic tuners require DC voltage to be applied to a variable-capacitance diode. The following shows that bias method.

Table 1.2 Variable-Capacitance Diode Bias Method

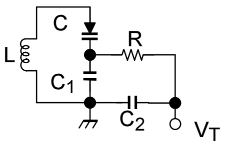
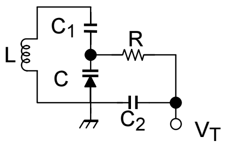
	Bias Circuit Example (1)	**Bias Circuit Example (2)**
Circuit	 $C_1, C_2 \gg C$	 $C_1, C_2 \gg C$
Circuit Q	$C_1 = C_2 = 0.1$ μF, R = 100 kΩ $\omega = 1/\sqrt{LC}$ Representing the Q of L as Q_L, and the Q of the C of the varicap as Q_C, the circuit Q is $Q = \frac{Q_C Q_L}{Q_C + Q_L}$ ....Equation (2-1) Compared to C, C_1 is very high. As R is not applied in parallel to C and L, the circuit Q is not affected by R. Therefore, R does not necessarily have to be large.	$C_1 = C_2 = 0.1$ μF, R = 100 kΩ $\omega = 1/\sqrt{LC}$ Representing the Q of L as Q_L, and the Q of the C of the varicap as Q_C, the circuit Q is: $Q = \frac{1}{\frac{1}{Q_C} + \frac{1}{Q_L} + \frac{1}{R}\sqrt{\frac{L}{C}}}$ ....Equation (2-2) As R is applied in parallel to C and L, circuit Q is affected by R and falls, as shown in Equation (2-2). The effect of R is particularly large when C is small.
Recommended Circuit Stage	This is ideal for a stage requiring high circuit Q. For example: AM tuner/antenna circuits, RF FM tuner/antenna circuits, RF, OSC	This is ideal for a stage not requiring high circuit Q, or a stage in which Q is intentionally set low. For example: AM tuner/OSC

Table 1.2 shows two examples of the variable-capacitance diode bias method. These are very effective if selected according to the stage in which they are to be used. Note also that the resistance R for the bias should be 200 kΩ maximum because of leakage current.

Determining the Tracking Circuit Constants

Superheterodyne tuners create an intermediate frequency f_{IF} from the reception frequency f_s and the local oscillation frequency f_0. The following equation shows the relationship between f_s, f_0, and f_{IF}:

$f_{IF} = |f_0 - f_s|$ .... (2-3)

$$\begin{cases} \text{AM: } f_{IF} = 450\text{ kHz (set with consideration for interfacing with a PLL IC)} \\ \text{FM: } f_{IF} = 10.7\text{ MHz} \end{cases}$$

In FM tuner circuits, simply substitute variable-capacitance diodes for the variable capacitors of the conventional circuit. After this, the circuit constants and tracking circuits can be designed in the conventional way.

In AM tuners, the antenna tuning circuits and the RF tuning circuits are the same as those of conventional circuits using non-tracking variable capacitors, but the local oscillation circuits are different.

In the case of non-tracking variable capacitors, obtain the IF frequency by altering the capacitance-rotation angle characteristics for the local oscillation using the capacitance-rotation angle characteristics of the antenna and RF tuner to satisfy Equation (2-3) for a given L. Then, because the voltage characteristics for the capacitance of the variable-capacitance diodes are the same for all stages, modify the local oscillation circuit to satisfy Equation (2-3).

The following are formulae for calculating the constants, using typical circuit examples.

(1) Calculating FM tracking circuit constants

Replacing an LC resonance circuit with the equivalent circuit, the following shows how to calculate two-point tracking circuit constants under the given conditions. For two-point tracking, adjust the f_{IF} value to 10.7 MHz at only two points in the reception frequency range (usually the maximum and minimum frequencies).

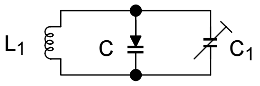
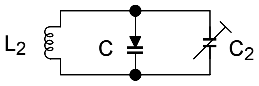
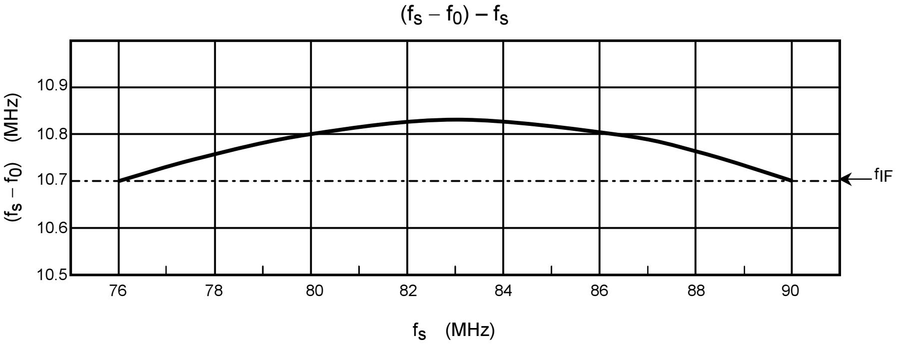
(a) Variable-capacitance diode voltage range: V_T = Vmin to Vmax

(b) Variable-capacitance diode capacitance variation range: C = Cmax (atVmin) to Cmin (atVmax)
All variable-capacitance diode C-vs-V_T characteristics used at each stage are assumed to be the same.

(c) Reception frequency range: $f_s$min (atCmax) to $f_s$max (atCmin)

(d) Local oscillation frequency range: $f_0$min (atCmax) to $f_0$max (atCmin) and $f_0$min = $f_s$min ± 10.7 MHz, $f_0$max = $f_s$max = $f_0$max ± 10.7 MHz
(Note that Japan uses "–" while the United States and Europe use "+".)

Table 1.3 Calculating FM Tuner Two-Point Tracking Circuit Constants

<table>
<tr><th></th><th>Antenna, RF Circuit</th><th>Local Oscillation Circuit</th></tr>
<tr><td>Equivalent Circuit</td><td>
C1: Total capacitance, including the adjustment trimmer capacitance, circuit capacitance, and active device capacitance</td><td>
C2: Total capacitance, including the adjustment trimmer capacitance, circuit capacitance, and active device capacitance</td></tr>
<tr><td>Circuit Constant Formulae</td><td>$f_s = \frac{1}{2\pi\sqrt{L_1(C+C_1)}}$ ....Equation (2-4)
Accordingly
$\left(\frac{f_s\mathrm{max}}{f_s\mathrm{min}}\right)^2 = \frac{\mathrm{Cmax}+C_1}{\mathrm{Cmin}+C_1}$ ....Equation (2-5)
Therefore
$C_1 = \frac{\mathrm{Cmax} - \left(\frac{f_s\mathrm{max}}{f_s\mathrm{min}}\right)^2 \mathrm{Cmin}}{\left(\frac{f_s\mathrm{max}}{f_s\mathrm{min}}\right)^2 - 1}$ ....Equation (2-6)
And
$L_1 = \frac{1}{4\pi^2 f_s\mathrm{max}^2(\mathrm{Cmin}+C_1)}$ ....Equation (2-7)</td><td>$f_0 = \frac{1}{2\pi\sqrt{L_2(C+C_2)}}$ ....Equation (2-8)
Accordingly
$\left(\frac{f_0\mathrm{max}}{f_0\mathrm{min}}\right)^2 = \frac{\mathrm{Cmax}+C_2}{\mathrm{Cmin}+C_2}$ ....Equation (2-9)
But $\left\{\begin{array}{l} f_0\ \mathrm{max} = f_s\mathrm{max} \pm f_{IF} \\ f_0\ \mathrm{min} = f_s\mathrm{min} \pm f_{IF} \end{array}\right.$
Therefore
$C_2 = \frac{\mathrm{Cmax}\left(\frac{f_0\mathrm{max}}{f_0\mathrm{min}}\right)^2 \mathrm{Cmin}}{\left(\frac{f_0\mathrm{max}}{f_0\mathrm{min}}\right)^2 - 1}$ ....Equation (2-10)
And
$L_2 = \frac{1}{4\pi^2 f_0\mathrm{max}^2(\mathrm{Cmin}+C_2)}$ ....Equation (2-11)</td></tr>
<tr><td>Examples of Circuit Constant Calculation</td><td colspan="2">Using a 1SV101 varicap diode, the following results are obtained for L_1, L_2, C_1, and C_2 in a Japanese band FM tuner circuit.
When Vmin = 3 V and Vmax = 8 V, in the 1SV101, Cmax = 30 pF and Cmin = 14.7 pF. Also, as $f_s$min = 76 MHz, $f_s$max = 90 MHz, and f_{IF} = 10.7 MHz, then $f_0$min = 65.3 MHz and $f_0$max = 79.3 MHz. Using these data in the above equations yields the following L_1, L_2, C_1, and C_2 values.
$L_1 = 0.08224\ \mu H$, $L_2 = 0.1250\ \mu H$, $C_1 = 23.33$ pF, $C_2 = 17.53$ pF
Calculating the $(f_s - f_0) - f_s$ characteristics from the constants calculated above results in the following:

As the above diagram shows, the deviation of $(f_s - f_0)$ from f_{IF} (10.7 MHz) is 132 kHz max; therefore there will be no problem in demodulating to match the fixed frequency of a later-stage IC.</td></tr>
</table>

(2) Calculating AM (medium-wave) tracking circuit constants

Because AM medium waves have a large reception frequency variation ratio compared to FM waves, at some points f_{IF} deviates considerably from 450 kHz if two-point tracking is used for AM. Therefore, three-point tracking based on the padding capacitor method is required. In three-point tracking, f_{IF} must be 450 kHz only at the maximum, middle, and minimum points in the reception frequency range. At other frequencies, f_{IF} may deviate slightly from 450 kHz. However, this deviation is not great enough to cause a problem in actual operation. The following are the conditions under which the tracking circuit constants should be calculated:

(a) Variable-capacitance diode voltage range: V_T = Vmin to Vmax

(b) Variable-capacitance diode capacitance variation range: C = Cmin (atVmax) to Cmax (atVmin)
All variable-capacitance diode C-V_T characteristics used at each stage are assumed to be the same.

(c) Reception frequency range: $f_s = f_s\text{min}$ to $f_s\text{max}$

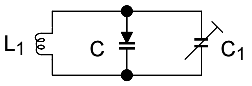
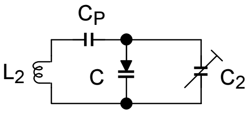
(d) Local oscillation frequency range: $f_0 = f_0\text{min}$ to $f_0\text{max}$

(e) Reception frequency, three tracking points: f_{s1} (atC_{s1}), f_{s2} (atC_{s2}), f_{s3} (atC_{s3})

(f) Local oscillation frequency, three tracking points: f_{01} (atC_{s1}), f_{02} (atC_{s2}), f_{03} (atC_{s3})

$$\begin{cases} f_{01} = f_{s1} + 450\text{ kHz} \\ f_{02} = f_{s2} + 450\text{ kHz} \\ f_{03} = f_{s3} + 450\text{ kHz} \end{cases}$$

Table 1.4 Calculating AM (Medium-Wave) Tuner Three-Point Tracking Circuit Constants

	Antenna, RF Circuit	Local Oscillation Circuit
Circuit	 C_1: Total capacitance, including the adjustment trimmer capacitance, circuit capacitance, and active device capacitance	 C_P: Padding capacitance C_2: Total capacitance, including the adjustment trimmer capacitance, circuit capacitance, and active device capacitance
Circuit Constant Formulae	$f_s = \dfrac{1}{2\pi\sqrt{L_1(C+C_1)}}$ .... Equation (2-12) Accordingly $\left(\dfrac{f_s\mathrm{max}}{f_s\mathrm{min}}\right)^2 = \dfrac{\mathrm{Cmax}+C_1}{\mathrm{Cmin}+C_1}$ .... Equation (2-13) Therefore $C_1 = \dfrac{\mathrm{Cmax}\left(\dfrac{f_s\mathrm{max}}{f_s\mathrm{min}}\right)^2 \mathrm{Cmin}}{\left(\dfrac{f_s\mathrm{max}}{f_s\mathrm{min}}\right)^2 - 1}$ .... Equation (2-14) And $L_1 = \dfrac{1}{4\pi^2 f_s\mathrm{max}^2(\mathrm{Cmin}+C_1)}$ .... Equation (2-15)	$f_{0\kappa} = \dfrac{1}{2\pi\sqrt{L_2\dfrac{C_P(C_{sk}+C_2)}{C_{sk}+C_2+C_P}}}$ ($_k = 1, 2, 3$) .... Equation (2-16) And $C_{S\kappa} = \dfrac{1}{4\pi^2 f_{sk}{}^2 L_1} - C_1$ .... Equation (2-17) ($k = 1, 2, 3$) Therefore $C_2 = \dfrac{\left(f_{01}{}^2 - f_{02}{}^2\right) C_{S1}C_{S2} + \left(f_{02}{}^2 - f_{03}{}^2\right) C_{S2}C_{S3} +}{\left(f_{01}{}^2 - f_{02}{}^2\right) C_{S3} + \left(f_{02}{}^2 - f_{03}{}^2\right) C_{S1} +}$ $\dfrac{\left(f_{03}{}^2 - f_{01}{}^2\right) C_{S1}C_{S3}}{\left(f_{03}{}^2 - f_{01}{}^2\right) C_{S2}}$ .... Equation (2-18) $C_P = \dfrac{\left(f_{02}{}^2 - f_{01}{}^2\right)(C_{S2}+C_{S1})(C_2+C_{S2})}{\left(f_{01}{}^2 - f_{02}{}^2\right) C_2 + f_{01}{}^2 C_{S1} - f_{02}{}^2 C_{S2}}$ And .... Equation (2-19) $L_2 = \dfrac{C_{S1}+C_2+C_P}{4\pi^2 f_{01}{}^2 C_P(C_2+C_{S1})}$ .... Equation (2-20)

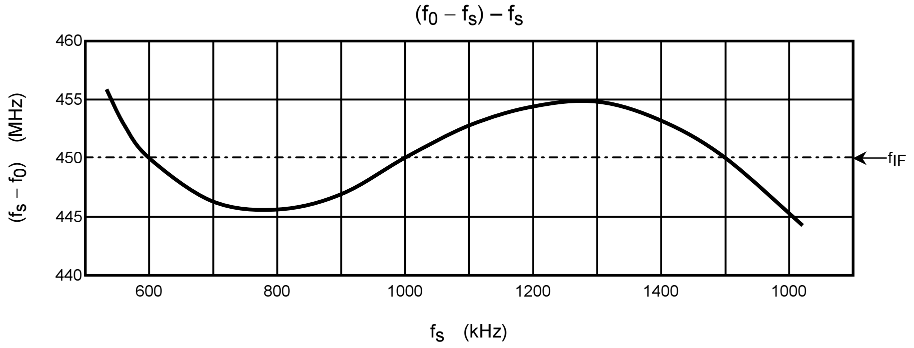
<table>
<tr><th></th><th>Antenna, RF Circuit</th><th>Local Oscillation Circuit</th></tr>
<tr><td>Examples of Circuit Constant Calculation</td><td colspan="2">

Through the use of a 1SV100 varicap diode, the following results are obtained for L_1, L_2, C_1, C_2 and C_P in a Japanese-band AM (medium-wave) tuning circuit.

When Vmin = 1.5 V and Vmax = 8 V, in the 1SV100, Cmax = 400 pF and Cmin = 25.5 pF. Also, as $f_s$min = 531 kHz, $f_s$max = 1602 kHz, and f_{IF} = 450 kHz, then $f_0$min = 981 kHz and $f_0$max = 2052 kHz. If the tracking pointers are set to f_{s1} = 600 kHz, f_{s2} = 1000 kHz, and f_{s3} = 1500 kHz, then f_{01} = 1050 kHz, f_{02} = 1450 kHz, and f_{03} = 1950 kHz. Using these data in the above equations yields the following L_1, L_2, C_1, C_2 and C_P values:

L_1 = 213.53 μH, L_2 = 122.82 μH, C_1 = 20.723 pF, C_2 = 30.342 pF, C_P = 417.15 pF

Calculating the ($f_s - f_0$) − fs characteristics from the constants calculated above results in the following:



As the above diagram shows, the deviation of ($f_s - f_0$) from f_{IF} (450 kHz) is around ±6 kHz max.

</td></tr>
</table>

Circuit Design Notes

Pay special attention to the following notes when using variable-capacitance diodes.

The basic difference between variable-capacitance diodes and variable capacitors or μ-tuning is that the dimensions of the parameters that vary the capacitance of the variable capacitors (or the inductance in the case of μ-tuning) are completely different from the dimensions of the signals; whereas the dimensions (V) of the parameters that change the capacitance of the variable-capacitance diodes match the dimensions of the signals (V). Accordingly, the capacitance of the variable-capacitance diodes is affected by the signals, resulting in capacitance fluctuation. Also, the steeper the gradient of these capacitance-voltage characteristics (capacitance: logarithmic scale, voltage: linear scale), the larger the capacitance fluctuation; therefore a specific problem arises with AM variable-capacitance diodes. The variable-capacitance diodes in (1) and (2) below are affected by signals and exhibit capacitance fluctuation:

(1) Local oscillation circuit variable-capacitance diodes;
(2) Antenna and RF circuit variable-capacitance diodes, when strong input signals are present.

In particular, the local oscillation circuit variable-capacitance diodes of (1) above can pose fatal problems in AM tuners. As an additional circuit design point, note that the antenna capacitance in AM car radios is particularly high. Therefore insert a buffer stage to prevent this capacitance from affecting the tuning circuit.

1.2 PIN Diode

A PIN diode provides an “I” layer (intrinsic semiconductor) in an otherwise-ordinary PN-junction diode.

By controlling the forward current in its PIN junction, the PIN diode acts as a radio-frequency variable resistor that can change the radio-frequency series resistor r_S. PIN diodes now have many applications, including microwave line switching, band switching in TV/radio, and AGC.

Recently, to prevent intermodulation and cross modulation in commercial car audio equipment, PIN diodes are being widely used as PIN AGCs. In the future, PIN diodes are expected to find an increased number of applications in consumer electronics fields.

1.2.1 Operation Principle and Configuration Diagram of a PIN Diode

As shown in Figure 1.9, when forward bias voltage is applied to the diode, electrons and electron holes are injected into the I layer.

Injected electrons and electron holes are then reconnected. Some of them serve as forward current and others are stored in the I layer.

Electrons and electron holes stored in the I layer increase the dielectric constant of the layer and decrease the series resistance r_S in the radio-frequency range, so enabling the PIN diode to operate as a radio-frequency variable resistor.

Figure 1.10 shows a structure diagram of a PIN diode.

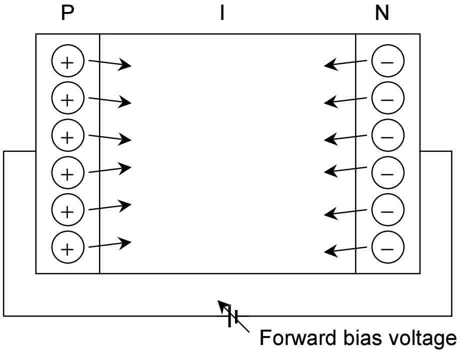


Figure 1.9 Operation Diagram

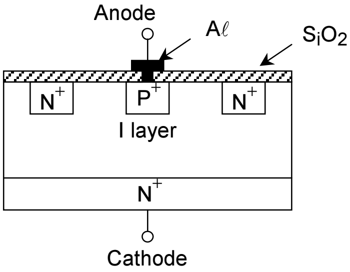


Figure 1.10 Structure Diagram

1.2.2 Basic Parameters of a PIN Diode

r_S: series resistance

The PIN diode series resistance r_S in the forward bias can be expressed as

$$r_S = r_i + r_C \quad \text{........ (1)}$$

in which

r_i = I-layer resistance,

r_C = semiconductor contact resistance.

In turn,

$$r_i = \frac{\ell^2}{I_F\tau(\mu_e + \mu_h)} \quad \text{........ (2)}$$

in which

ℓ = I-layer thickness,

I_F = DC current,

μ_e = drifting mobility of an electron,

μ_h = drifting mobility of an electron hole,

τ = carrier lifetime in an I layer;

and

$$r_c = \frac{\rho_{n^+}\ell_{n^+}\rho_{P^+}\ell_{P^+}}{A} + \frac{\rho_{cn^+}}{A} + \frac{\rho_{cP^+}}{A}$$

$$= \frac{\bar{\rho}_c}{A} \quad \text{........ (3)}$$

in which

ρ_{n^+}, ρ_{P^+} = specific resistance between n^+ and P^+ layers,

ℓ_{n^+}, ℓ_{P^+} = thickness of n^+ and P^+ layers,

ρ_{cn^+} = specific contact resistance of a and n^+ layers,

ρ_{cP^+} = specific contact resistance of a and P^+ layers,

$\bar{\rho}_c$ = total equivalent specific contact resistance,

A = diode area.

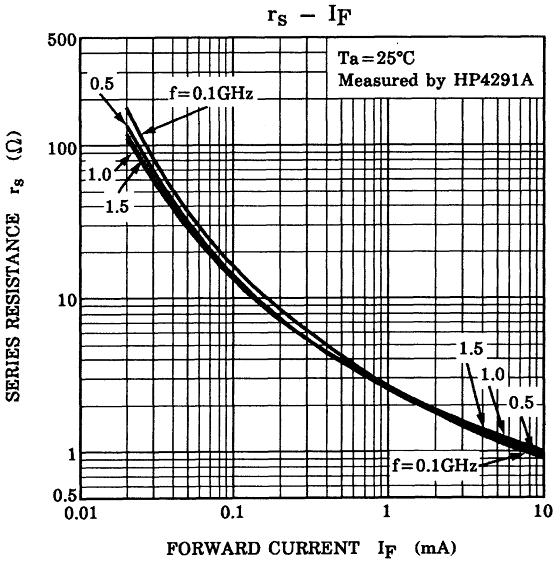


Figure 1.11 Typical r_S–I_F Characteristics (1SV308 PIN diode)

From equations (2) and (3),

$$r_S = \frac{\ell^2}{I_F \tau (\mu_e + \mu_h)} + \frac{\bar{\rho}_c}{A} \quad \cdots\cdots\cdots\cdots \quad (4)$$

C_T: Total capacitance

Junction capacitance and case capacitance are the dominating components in anode-cathode total capacitance.

1.2.3 Typical Application Circuit

Figure 1.12 shows a typical AGC circuit in an FM front-end.

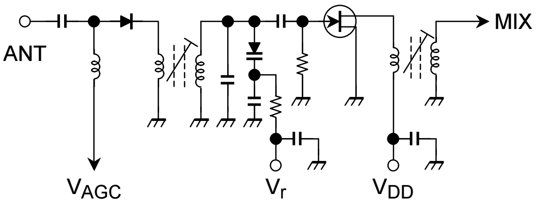


Figure 1.12 FM Front-End

Figure 1.13 and Figure 1.14 show examples of a π-type ATT circuit and a radio-frequency switching circuit, respectively.

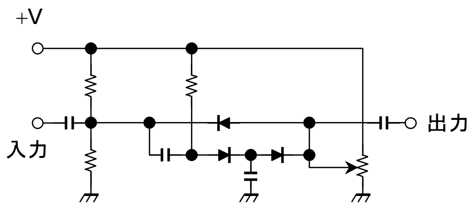


Figure 1.13 π-Type ATT

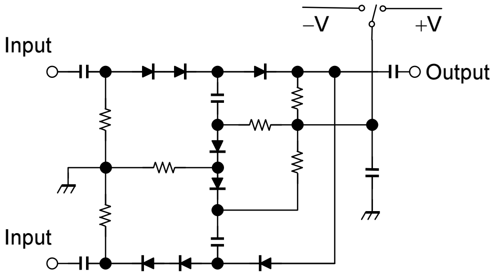


Figure 1.14 Radio-Frequency Switch

1.3 Schottky Barrier Diode

The Schottky barrier diode makes use of the rectification properties of metal-to-semiconductor contacts.

One of its characteristics is that it creates a Schottky barrier between the evaporated metal and an N-type epitaxial layer.

Typical metals used for Schottky barriers are molybdenum (Mo) and titanium (Ti).

As with the Ge diode, forward-bias voltage in the Schottky barrier diode is low. Unlike the point-contact diode, it has no complex requirements, such as stylus force; therefore handling it in the manufacturing processes is easy.

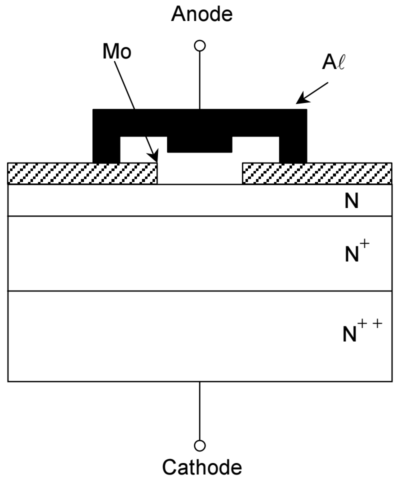


Figure 1.15 Structure Diagram

This type of diode is used mainly in mixer circuits and in wave-detector circuits for bands above UHF. Its advantages are that its noise characteristics are 2 dB lower than those of point-contact diodes and that it is mechanically and electrically reliable.

Figure 1.15 shows a configuration diagram of a Schottky barrier diode.

2. Tape Packing Specifications

2.1 Tape Specifications by Type of Device Package

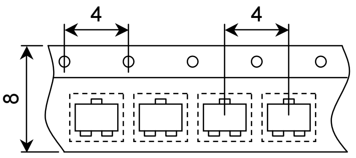
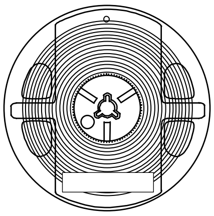
2.1.1 ○ Super-Mini Package Group: S-MINI, SMQ, SMV (SSOP5-P-0.95) and SM6 (SSOP6-P-0.95)

○ Ultra-Super-Mini Package Group: USM, USQ, USV US6

○ Small Super-Mini (SSM)

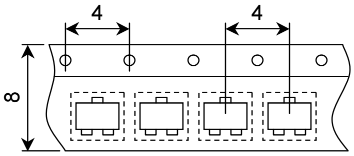
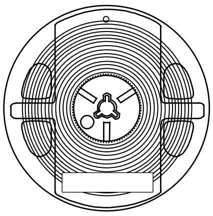
○ Thin Extreme-Super-Mini Package (TESM)

○ Thin Ultra-Super-Mini 6 pin Package (TU6)

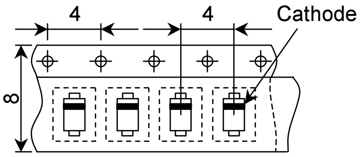
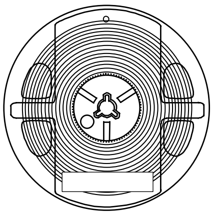
Packing Type	Tape Type Suffix	Tape Dimensions (Unit: mm)	Reel Appearance	Packing Quantity
Embossed tape	TE85L			3000 per reel (Note 1)
	TE85L2 (only for s-mini, SMV and USM)			10000 per reel

Note 1: TESM: 4000 per reel.

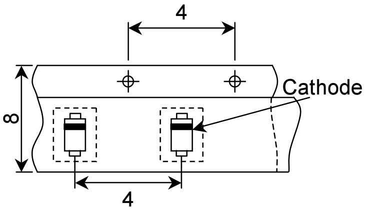
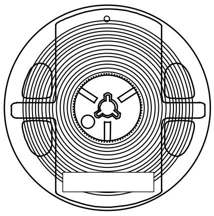
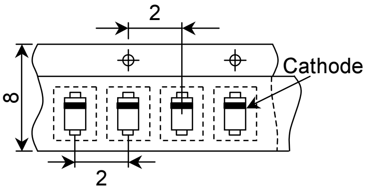
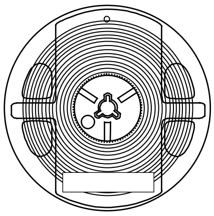
2.1.2 Super-Mini Package for Varicap Diode

Packing Type	Tape Type Suffix	Tape Dimensions (Unit: mm)	Reel Appearance	Pair	Packing Quantity
Embossed tape	TPH2			○	3000 per reel
	TPH3			×	
	TPH4			○	
	TPH6			○	600 to 3000 per reel
	TPH7			○	3000 per reel

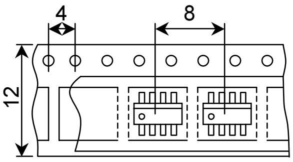
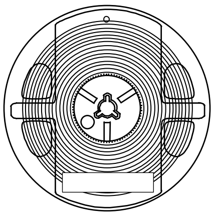
2.1.3 Ultra-Super-Mini Coaxial Package (USC)

Packing Type	Tape Type Suffix	Tape Dimensions (Unit: mm)	Reel Appearance	Pair	Packing Quantity
Embossed tape	TPH2			○	2400 to 3000 per reel
	TPH3			×	3000 per reel
	TPH4			○	2400 to 3000 per reel

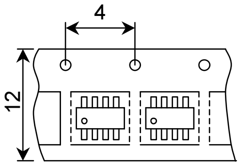
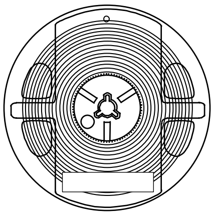
2.1.4 Extreme-Super-Mini Coaxial Package (ESC)
Thin Extreme-Super-Mini Coaxial Package (TESC)

Packing Type	Tape Type Suffix	Tape Dimensions (Unit: mm)	Reel Appearance	Pair	Packing Quantity
Embossed tape	TPH2			○	3200 to 4000 per reel
	TPH3			×	4000 per reel
	TPL2			○	6400 to 8000 per reel
	TPL3			×	8000 per reel

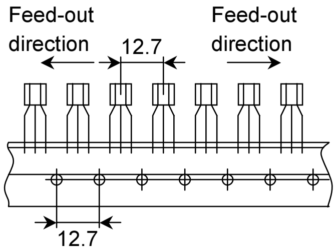
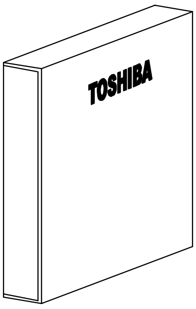
2.1.5 Flat-Mini Package (FM8)

Packing Type	Tape Type Suffix	Tape Dimensions (Unit: mm)	Reel Appearance	Packing Quantity
Embossed tape	TE12L			1000 per reel

2.1.6 Flat-Super-Mini Package (SM8) (SSOP8-P-0.65)

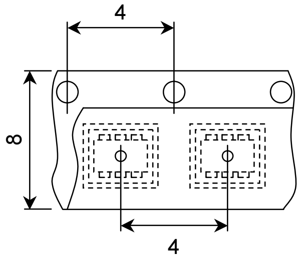
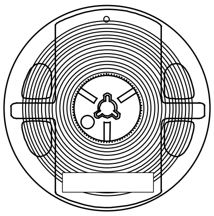
Packing Type	Tape Type Suffix	Tape Dimensions (Unit: mm)	Reel Appearance	Packing Quantity
Embossed tape	TE12L			3000 per reel

2.1.7 Mini Package (MINI)

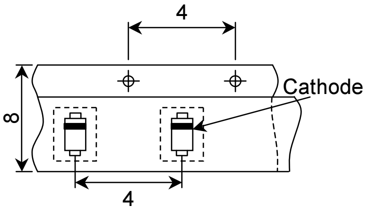
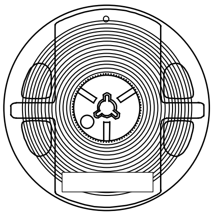
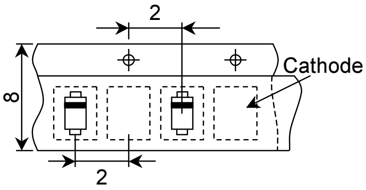
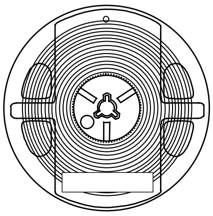
Packing Type	Tape Type Suffix	Tape Dimensions (Unit: mm)	Reel Appearance	Packing Quantity
Ammo pack	TPE4			5000 per carton

2.1.8 Extreme-Super-Mini 6 pin Package (ES6)

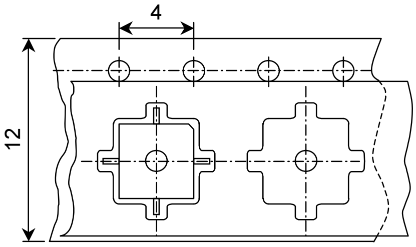
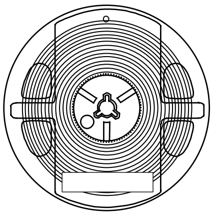
Small Extreme-Super-Mini 6 pin Package (sES6)

Packing Type	Tape Type Suffix	Tape Dimensions (Unit: mm)	Reel Appearance	Packing Quantity
Embossed tape	TE85L			4000 per reel

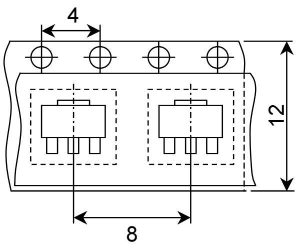
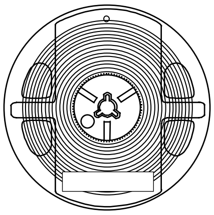
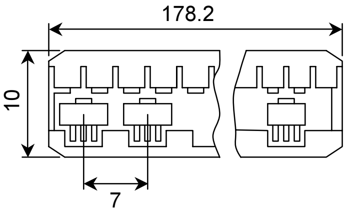
2.1.9 Small Extreme-Super-Mini Coaxial Package (sESC)

Packing Type	Tape Type Suffix	Tape Dimensions (Unit: mm)	Reel Appearance	Pair	Packing Quantity
Embossed tape	TPH3			×	5000 per reel
	TPL3			×	10000 per reel

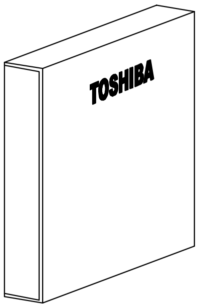
2.1.10 PW-X Package

Packing Type	Tape Type Suffix	Tape Dimensions (Unit: mm)	Reel Appearance	Packing Quantity
Embossed tape	TE12L			1000 per reel

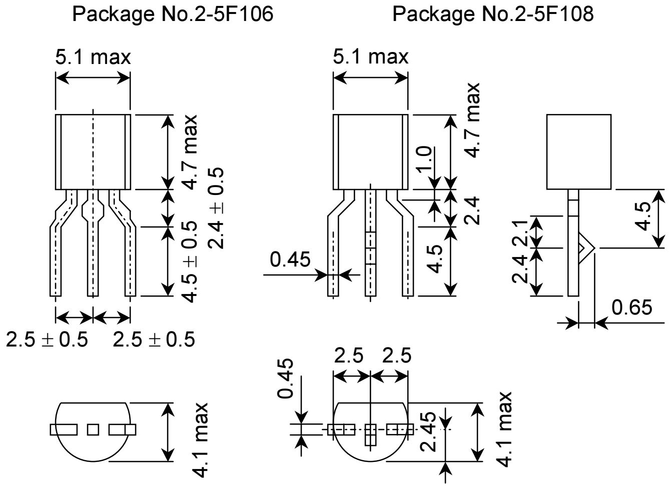
2.1.11 Power Mini Transistor Package (PW-MINI)

Packing Type		Tape Type Suffix	Tape Dimensions (Unit: mm)	Reel Appearance	Packing Quantity
Tape	Pack type	TE12L			1000 per reel
Magazine	Stick type	—			25 per magazine

2.1.12 TO-92/Mini Devices

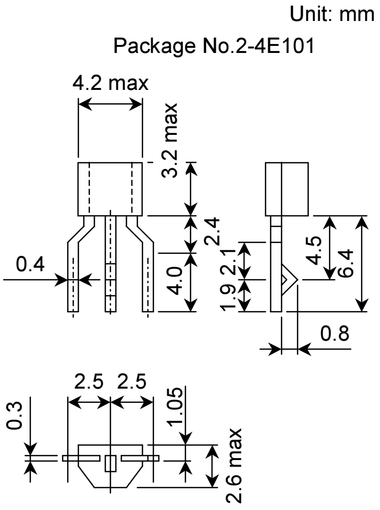
Tape Type Suffix	Applied Package Type	Packing Type	Packing Quantity	Reel Appearance
TPE2	TO-92 (2-5F)	Ammo pack	3000 pcs	
TPE4	MINI (2-4E)	Ammo pack	5000 pcs	

2.2 Lead Formed TO-92 and Mini Transistor Package Dimensions



Snap forming: center lead

Figure 2.1 Lead-Formed TO-92 Transistor Package Dimensions



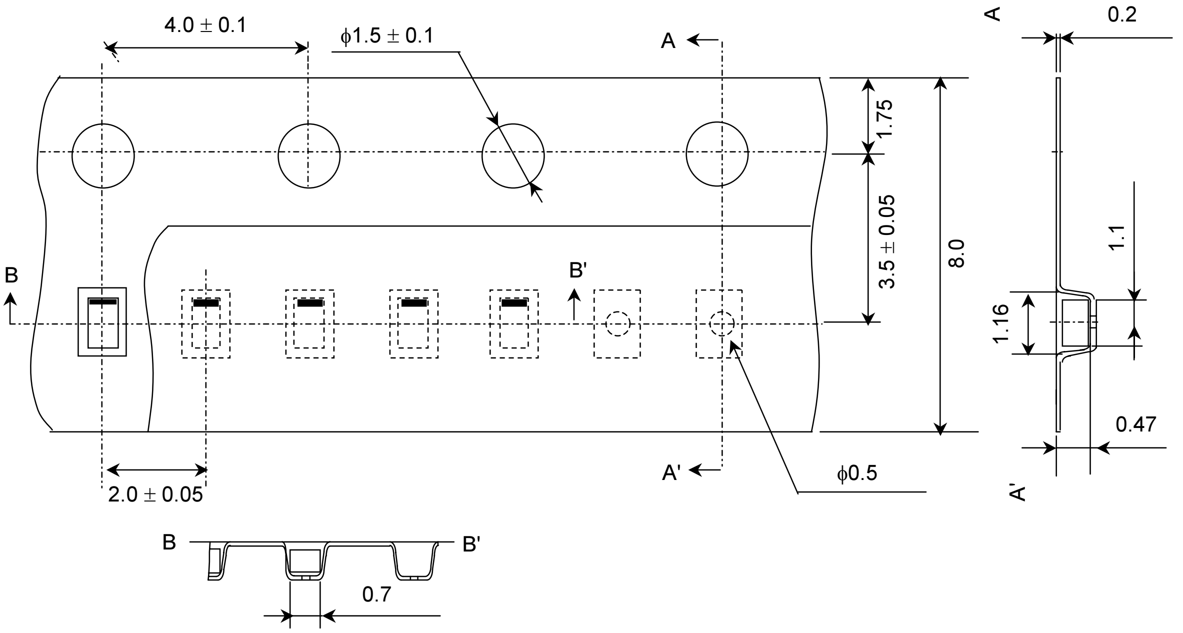
Snap forming: center lead

Figure 2.2 Lead-Formed Mini Transistor Package Dimensions

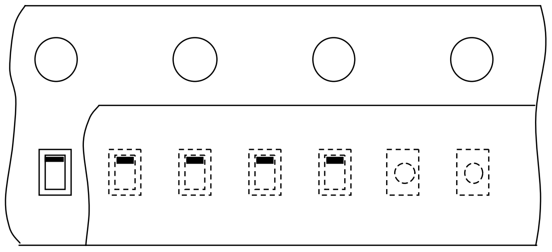
2.3 Tape Dimensions

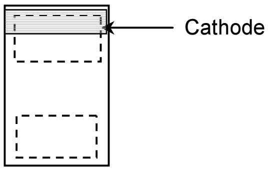
2.3.1 Tape Layout for Chip Scale Package Thin Type 2 Pin…(CST2)

Unit: mm



Device orientation

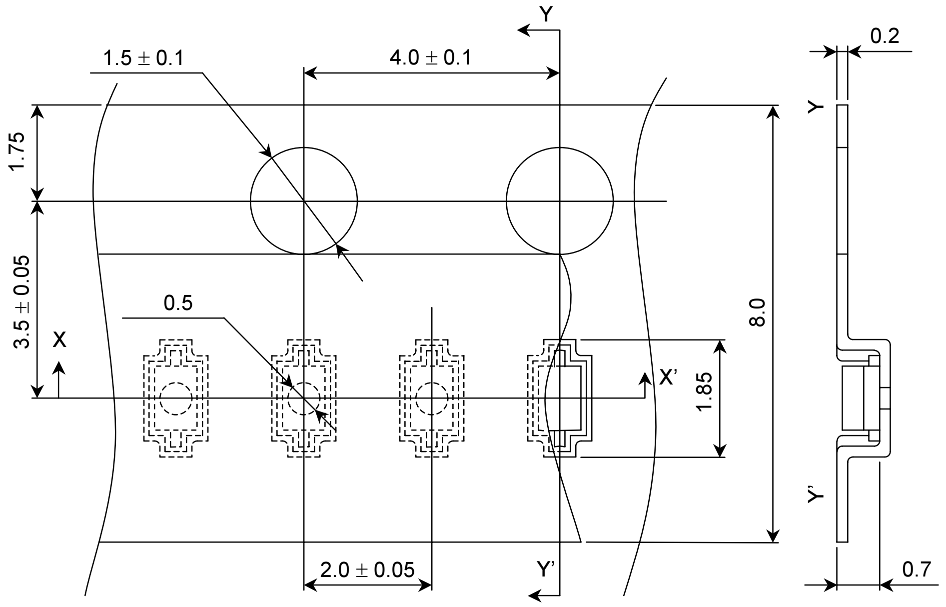


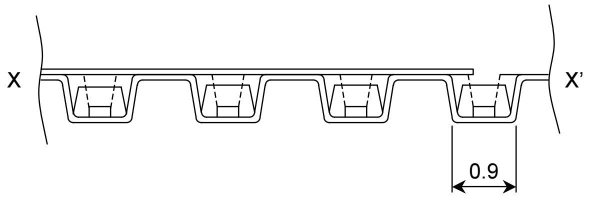


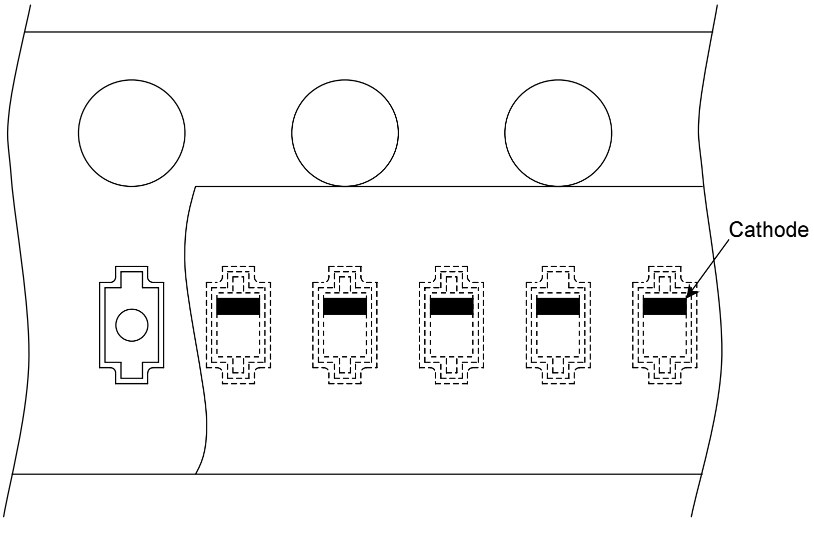
2.3.2 Tape Layout for Extreme-Super-Mini Coaxial…(ESC)
Tape Layout for Thin Extreme-Super-Mini Coaxial…(TESC)

2 mm Pitch Type

Unit: mm

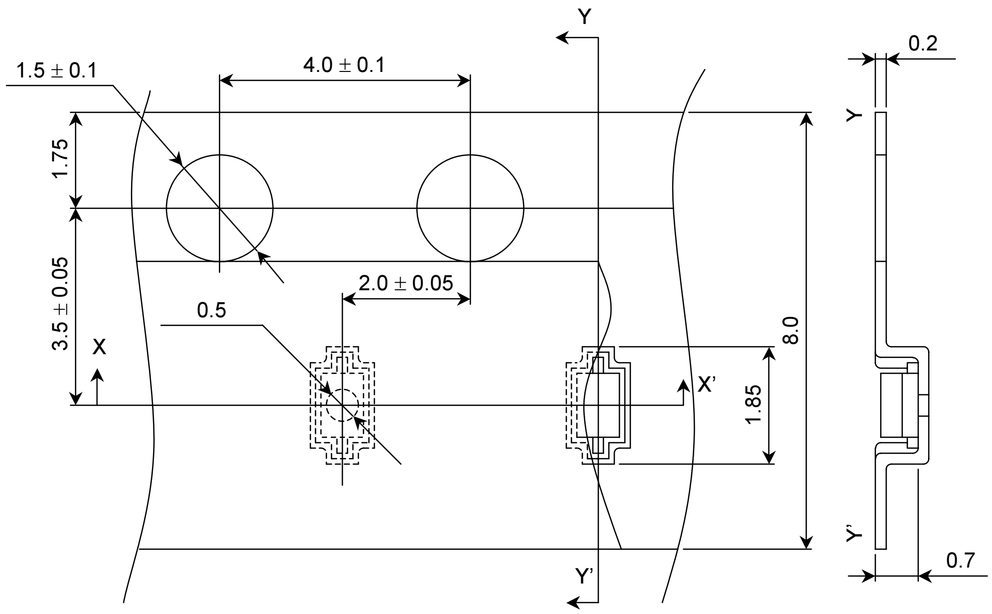


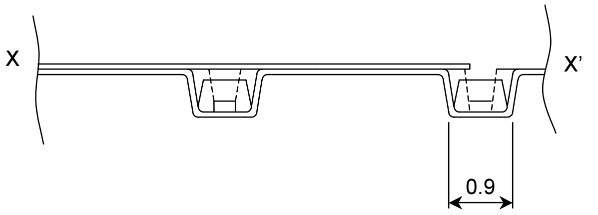


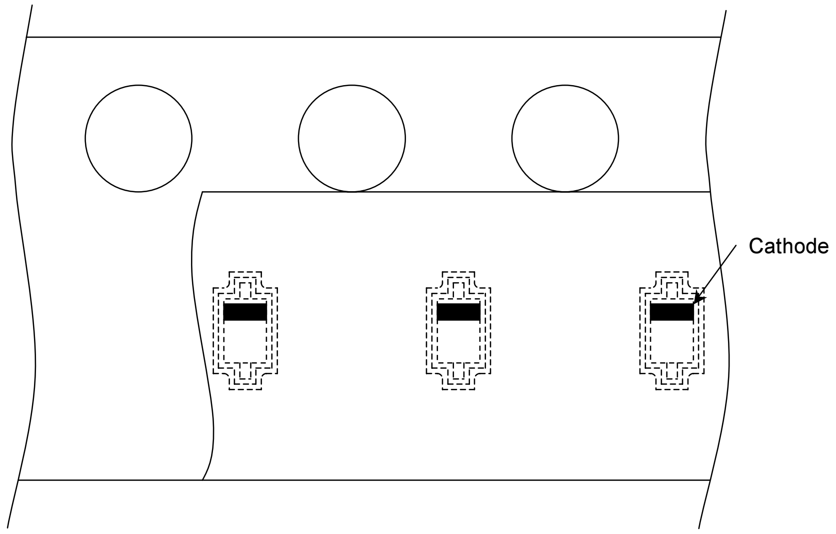


4 mm Pitch Type

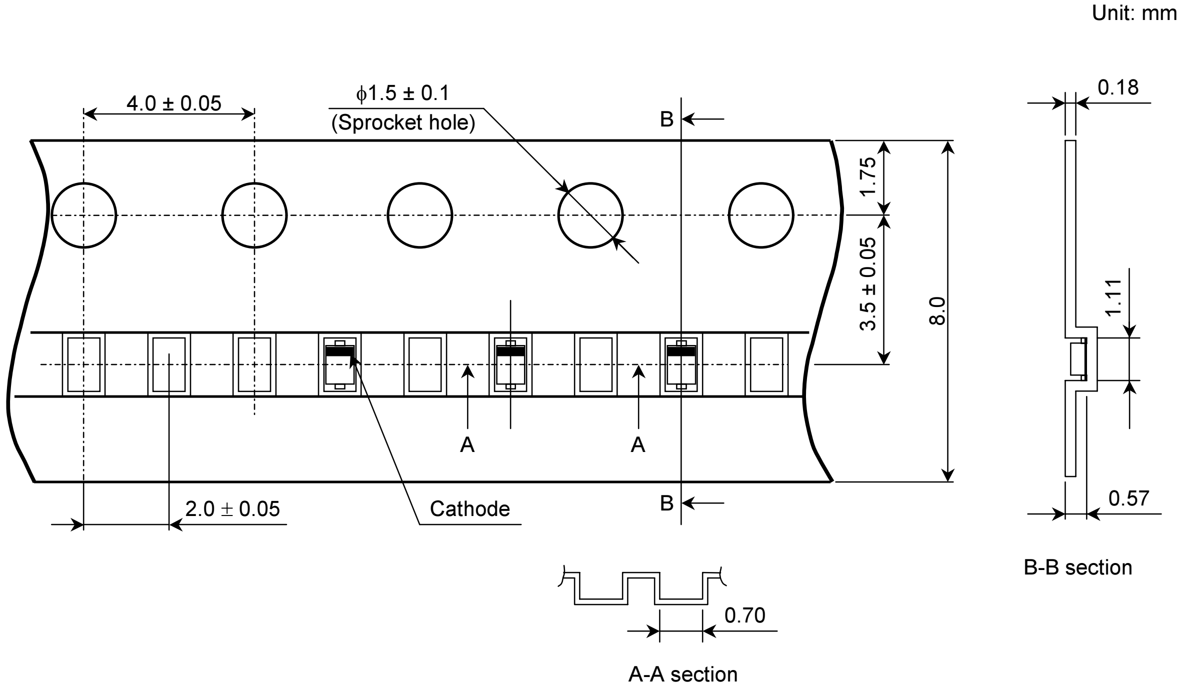
Unit: mm



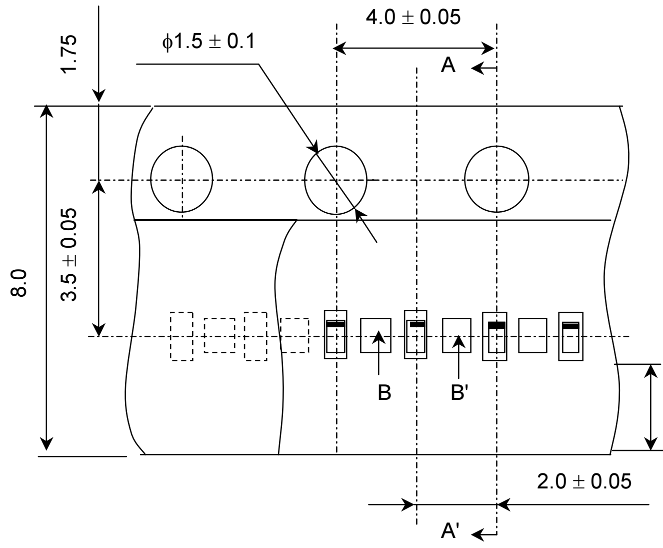


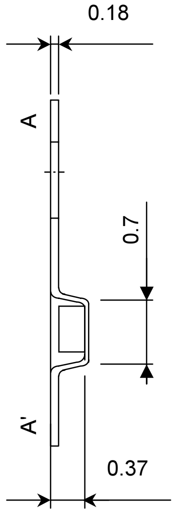


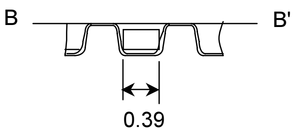
2.3.3 Tape Layout for Fine Pitch Super-Mini Coaxial…(fSC)



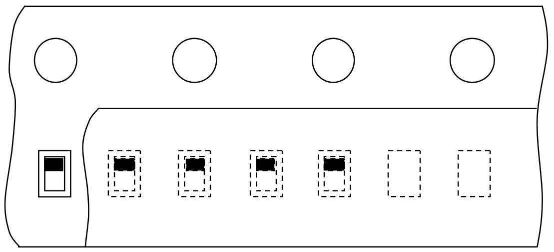
2.3.4 Tape Layout for Small Chip Scale Package 2 Pin…(SC2)

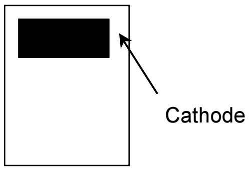






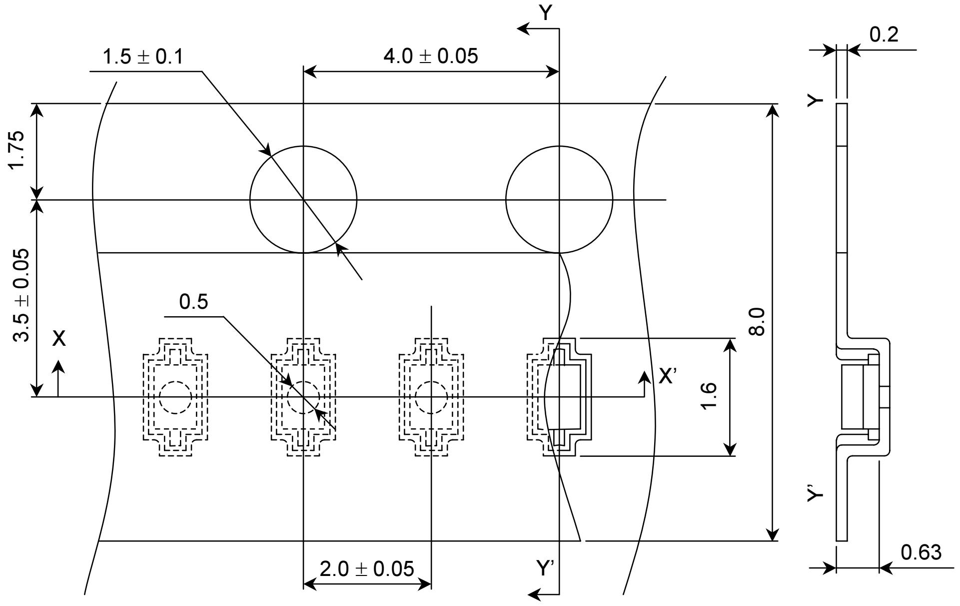
Device orientation

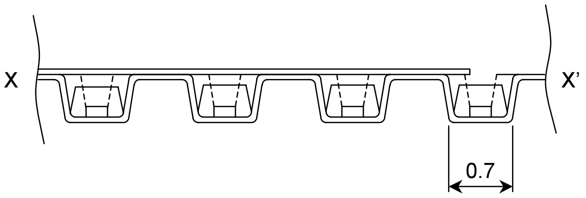


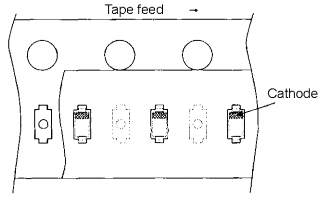


2.3.5 Tape Layout for Small-Extreme-Super-Mini Coaxial…(sESC)

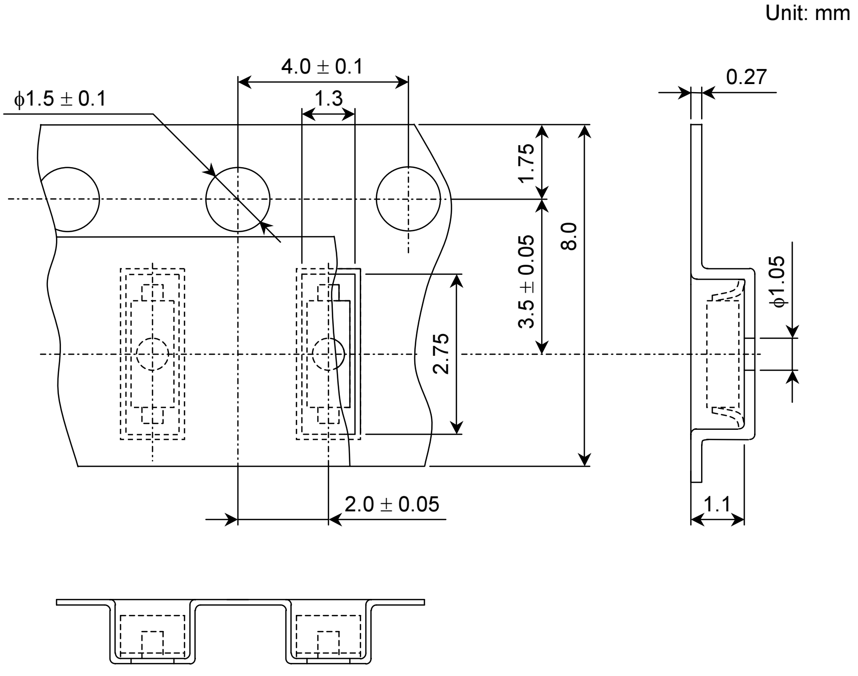
Unit: mm



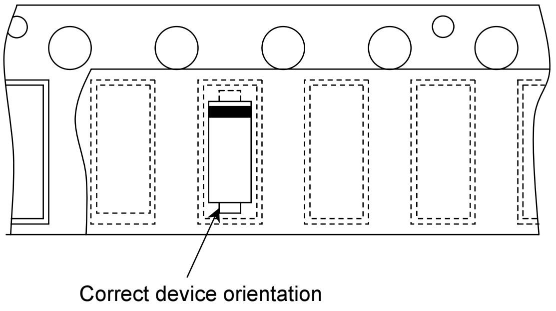




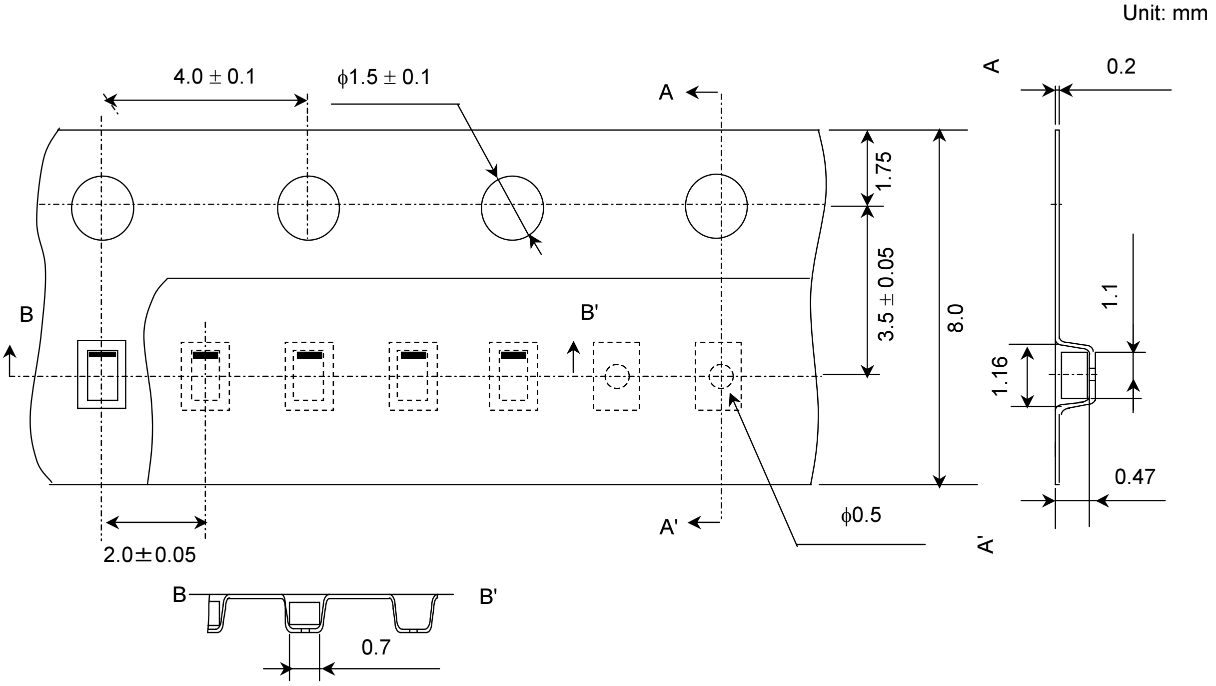
2.3.6 Tape Layout for Ultra-Super-Mini Coaxial…(USC)



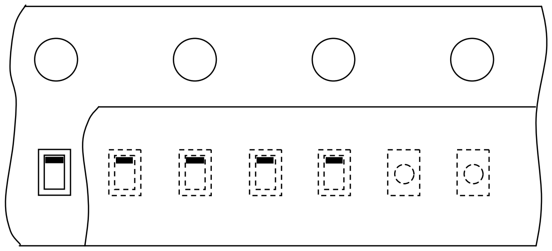
Device orientation

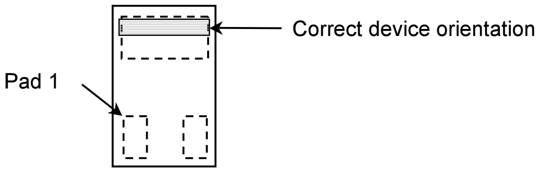


2.3.7 Tape Layout for Chip-Scale Package Thin Type 3 Pin…(CST3)

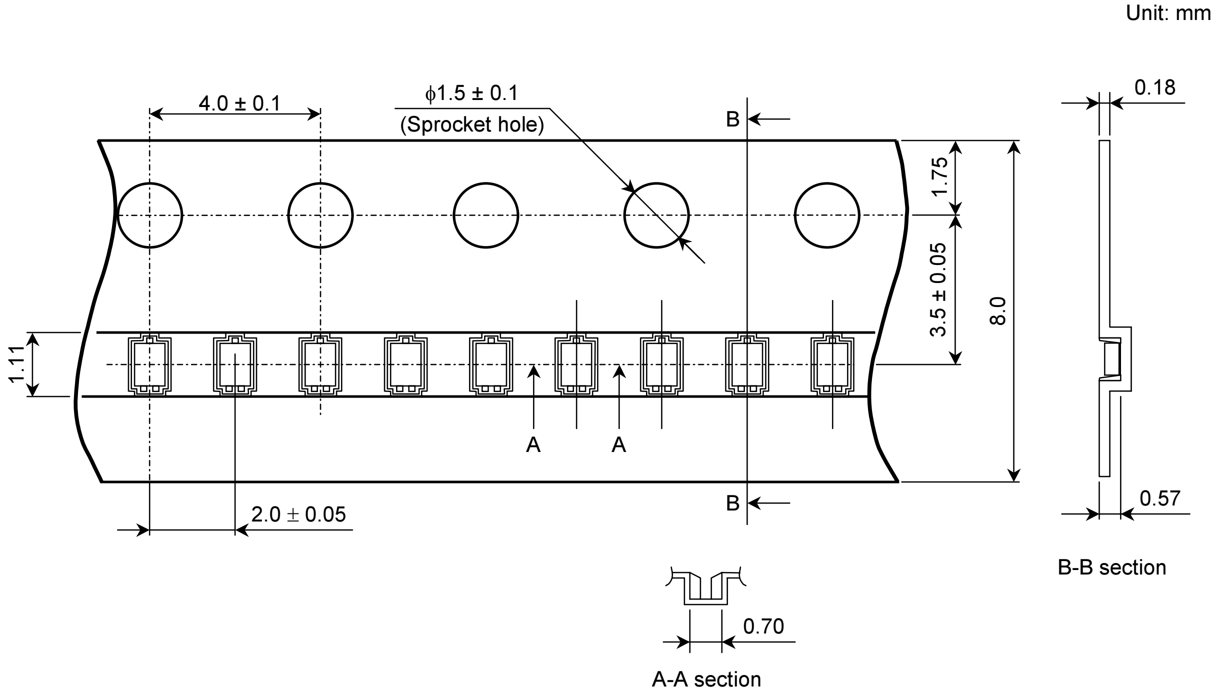


Device orientation



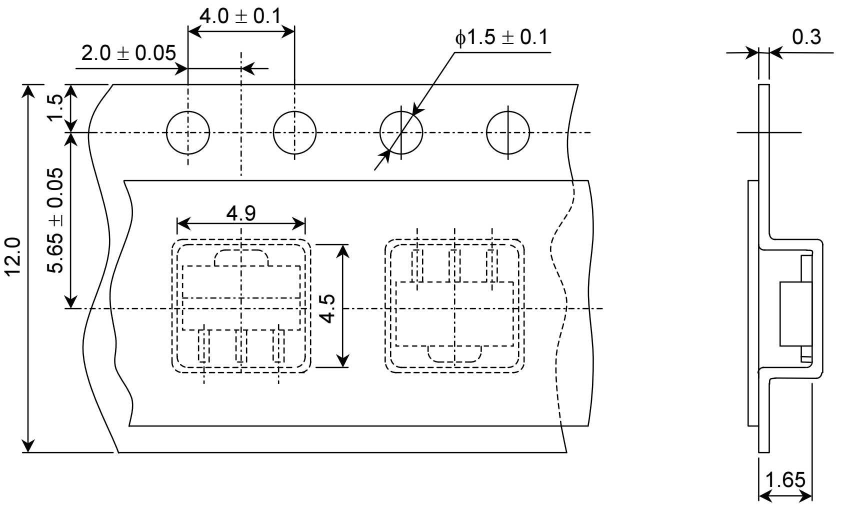


2.3.8 Tape Layout for Fine Pitch Super-Mini Mold…(fSM)

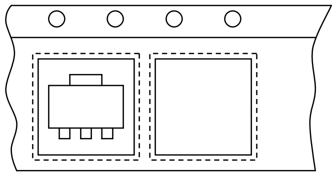


2.3.9 Tape Layout for Power Mini…(PW-MINI)

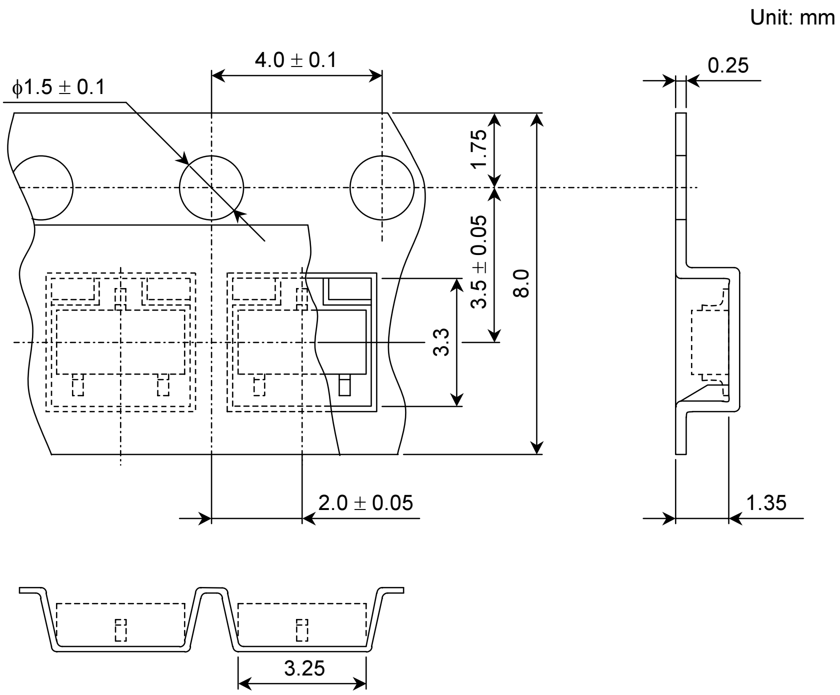
Unit: mm



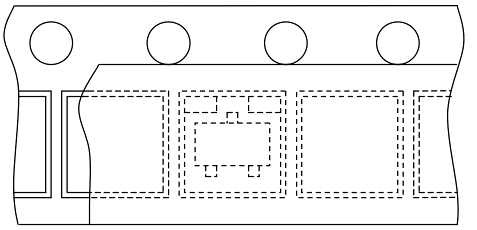
Device orientation



2.3.10 Tape Layout for Super-Mini…(S-MINI)

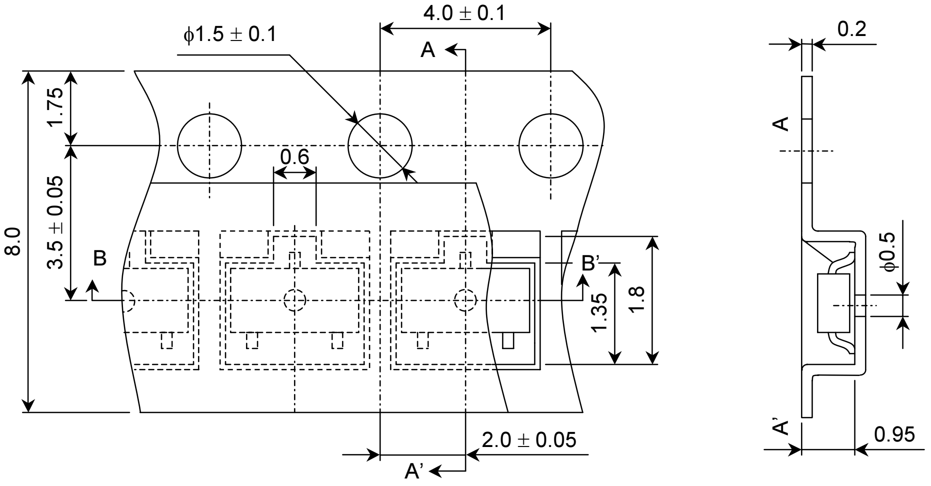


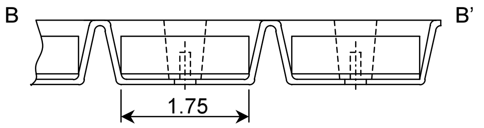
Device orientation



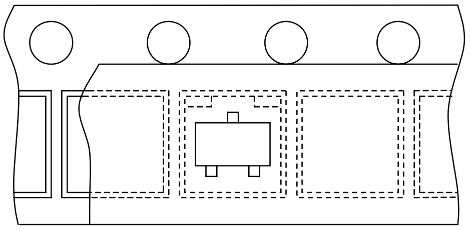
2.3.11 Tape Layout for Small-Super-Mini…(SSM)

Unit: mm

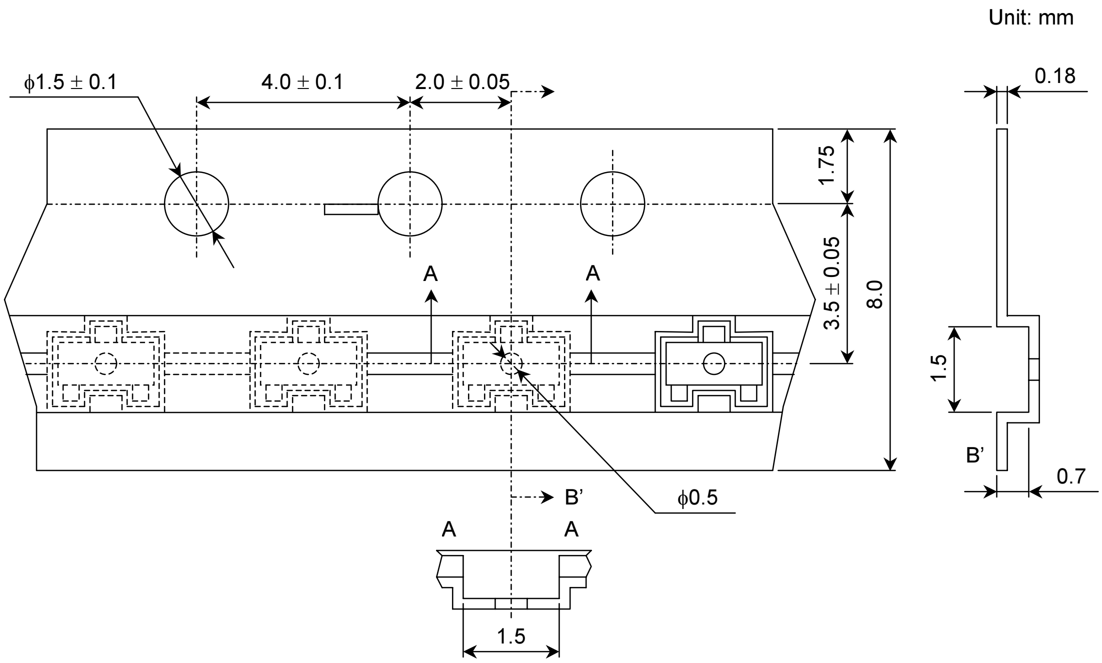




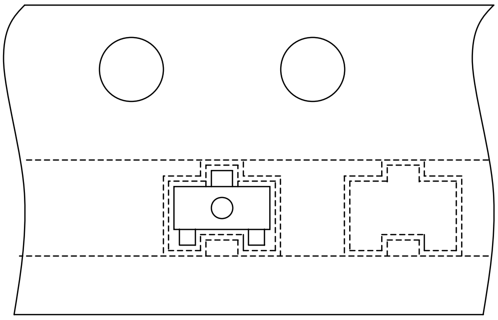
Device orientation



2.3.12 Tape Layout for Thin-Extreme-Super-Mini…(TESM)

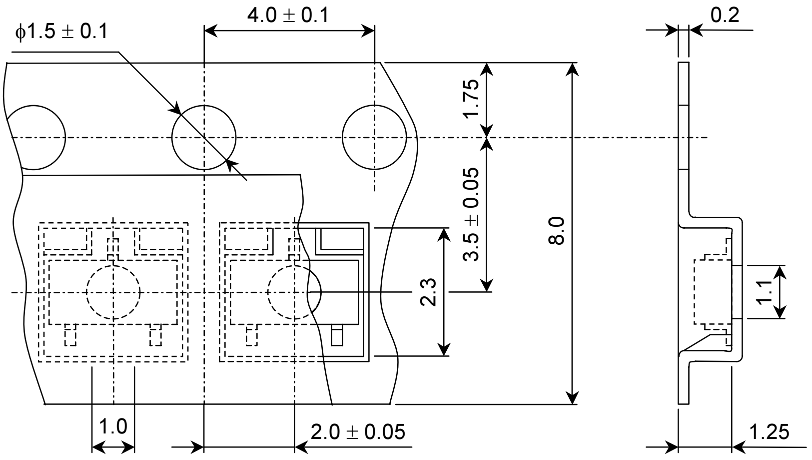


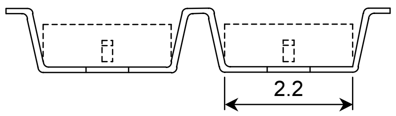
Device orientation



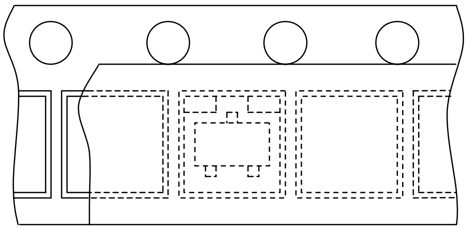
2.3.13 Tape Layout for Ultra-Super-Mini…(USM)

Unit: mm



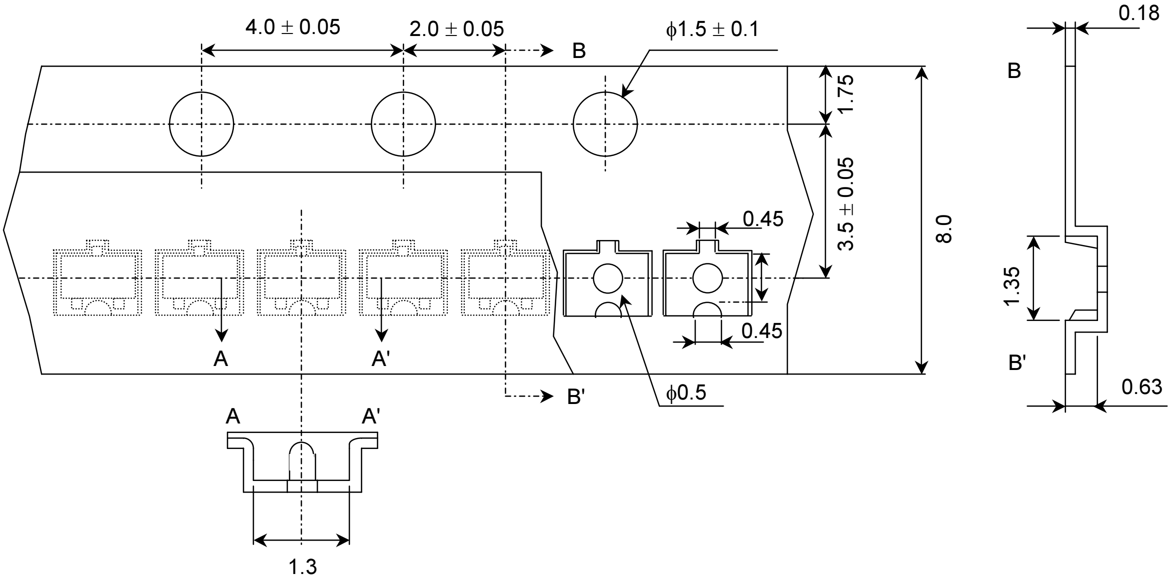


Device orientation

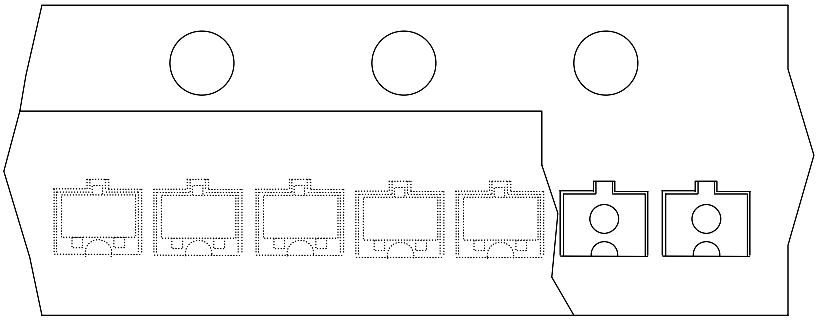


2.3.14 Tape Layout for Very Thin Extreme-Super-Mini…(VESM)

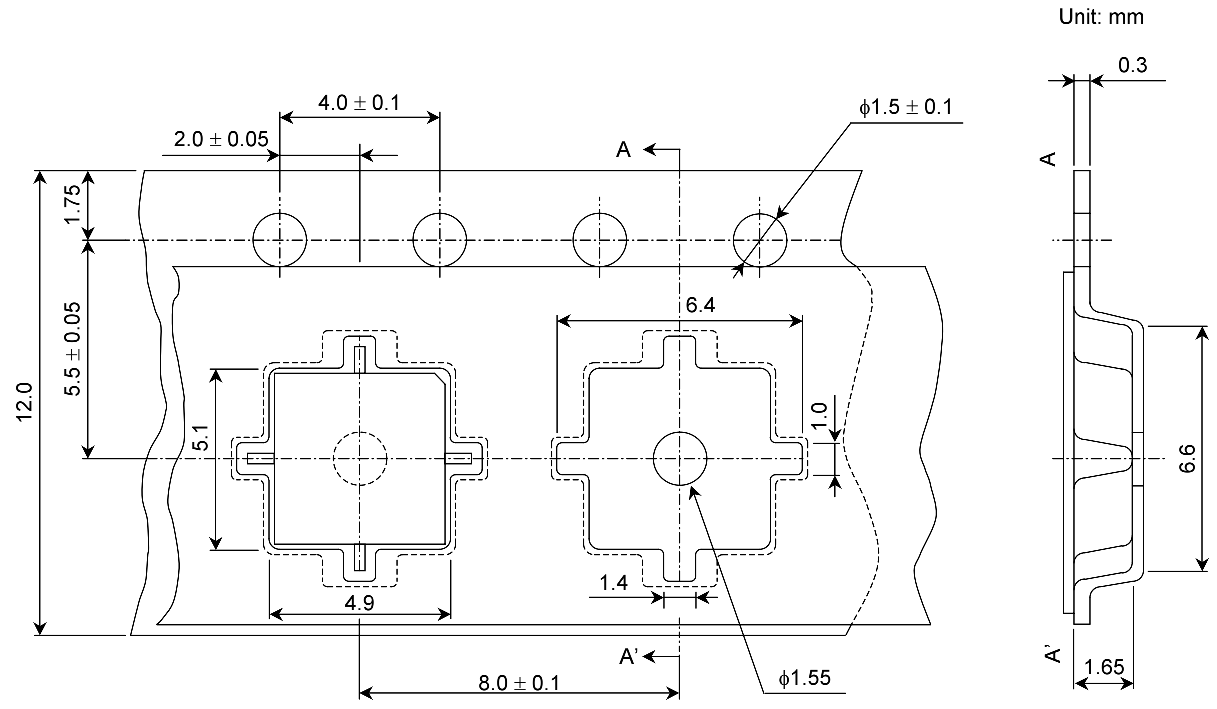
Unit: mm

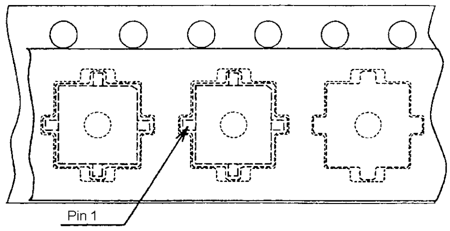


Device orientation

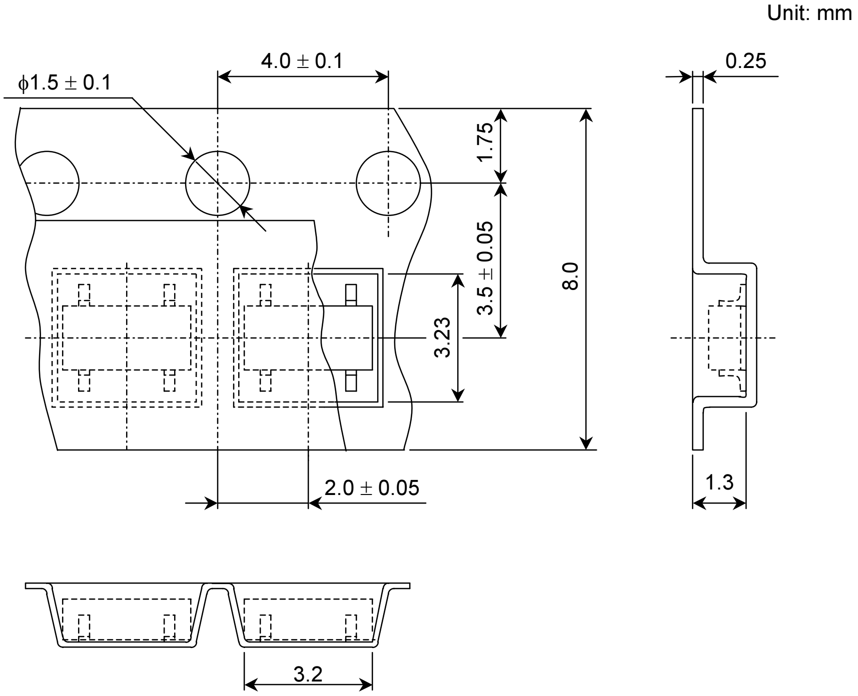


2.3.15 Tape Layout for Power X…(PW-X)

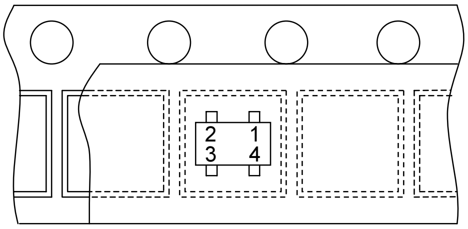




2.3.16 Tape Layout for Super-Mini Quad…(SMQ)

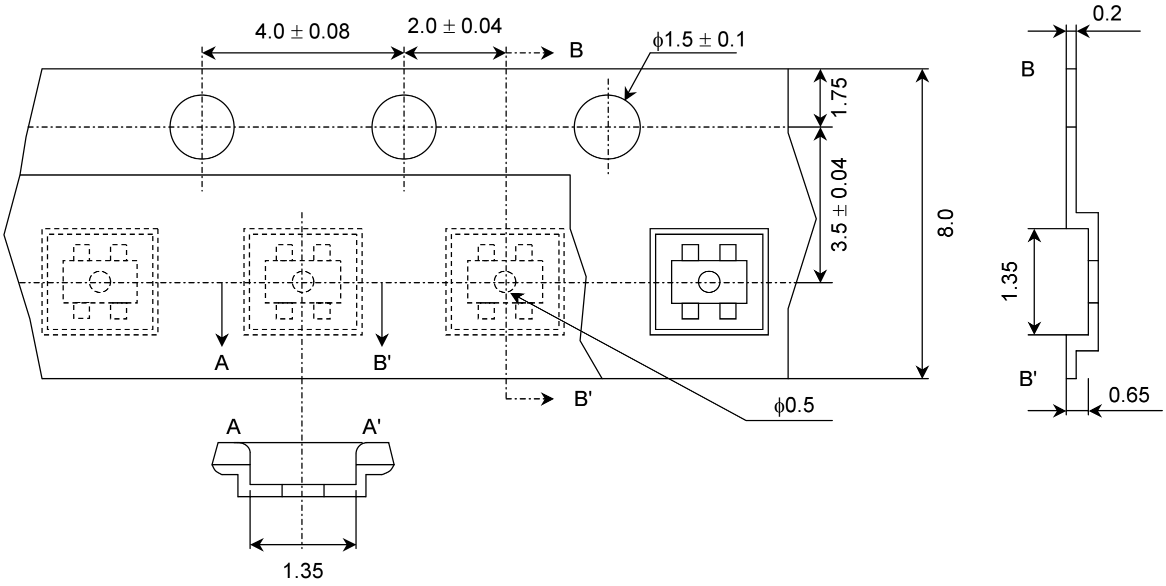


Device orientation

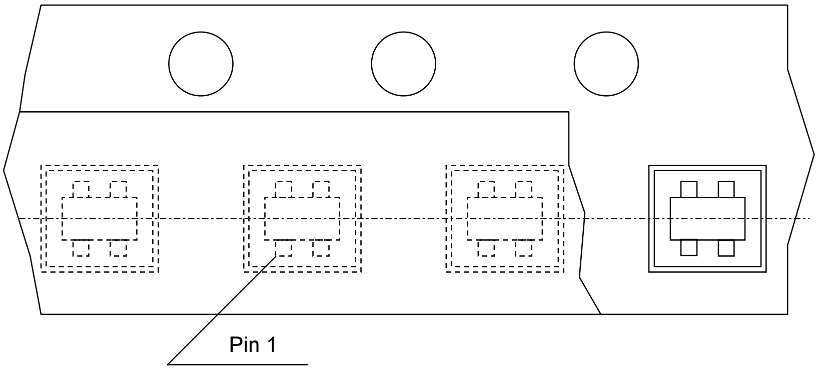


2.3.17 Tape Layout for Thin Extreme-Super-Mini Quad…(TESQ)

Unit: mm

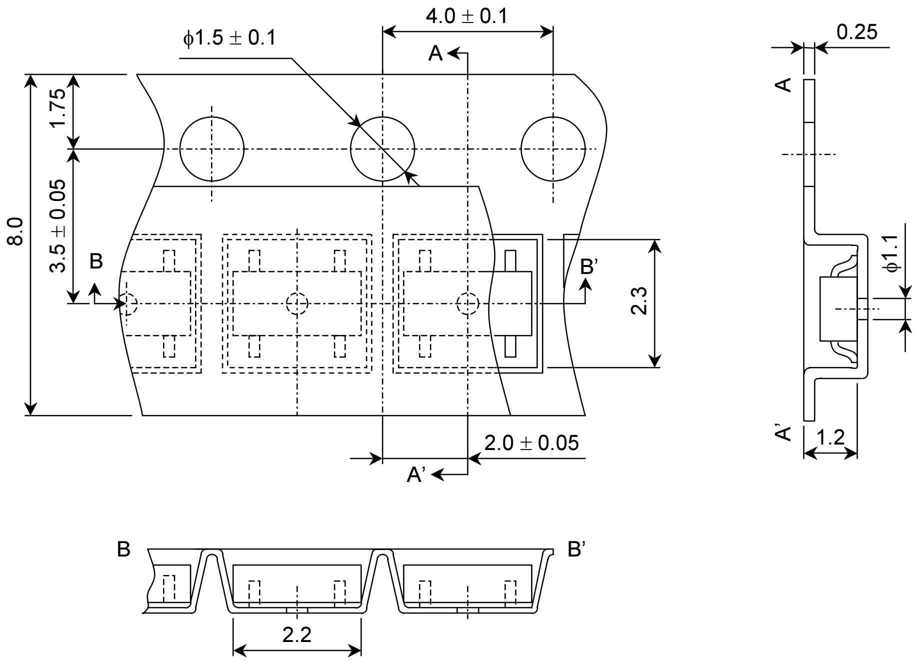


Device orientation

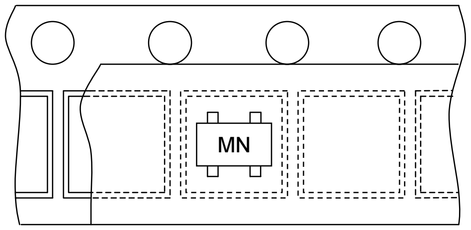


2.3.18 Tape Layout for Ultra-Super-Mini Quad…(USQ)

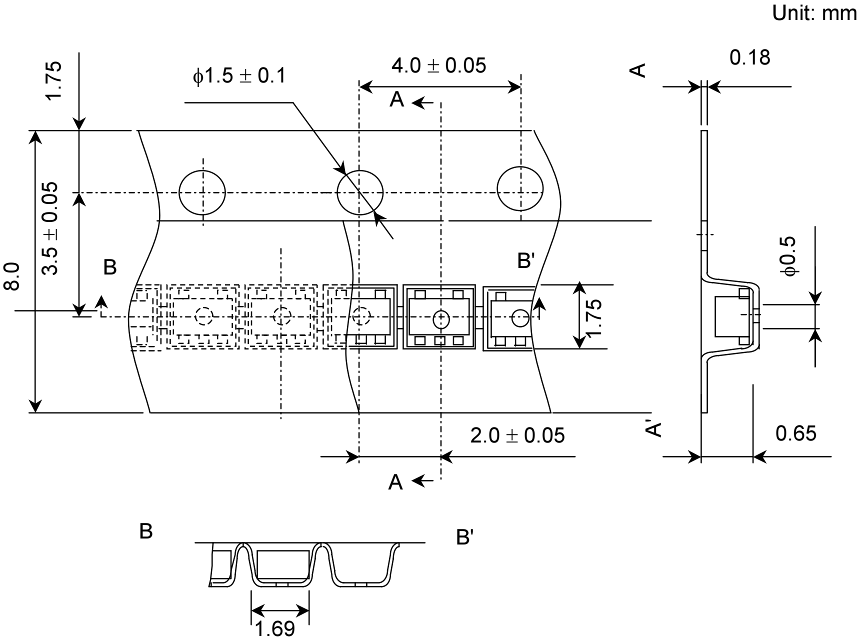
Unit: mm



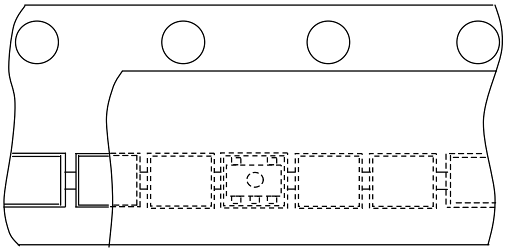
Device orientation



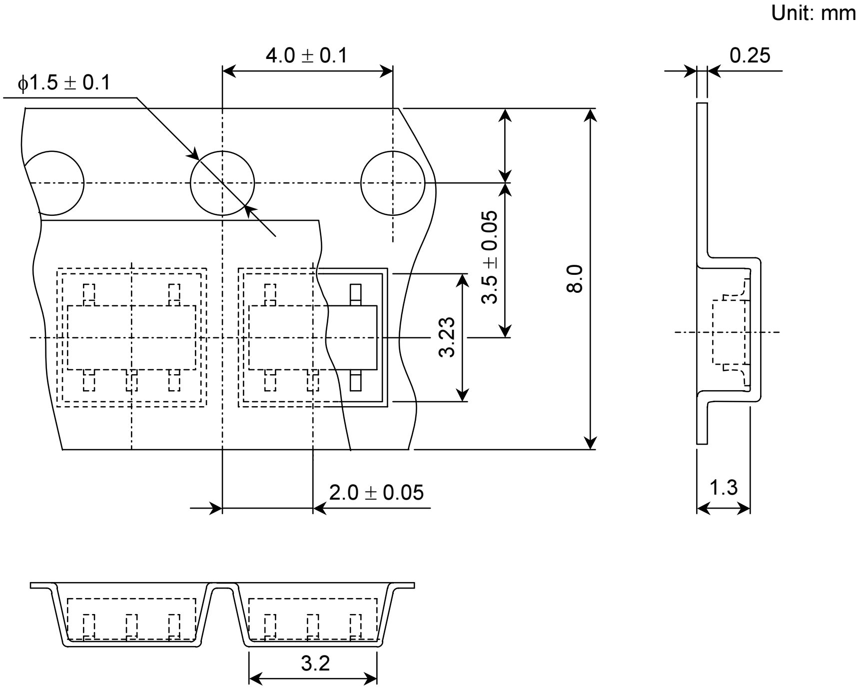
2.3.19 Tape Layout for Extreme-Super-Mini V…(ESV)



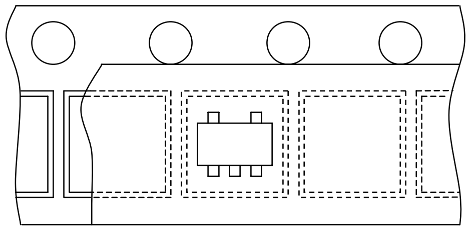
Device orientation



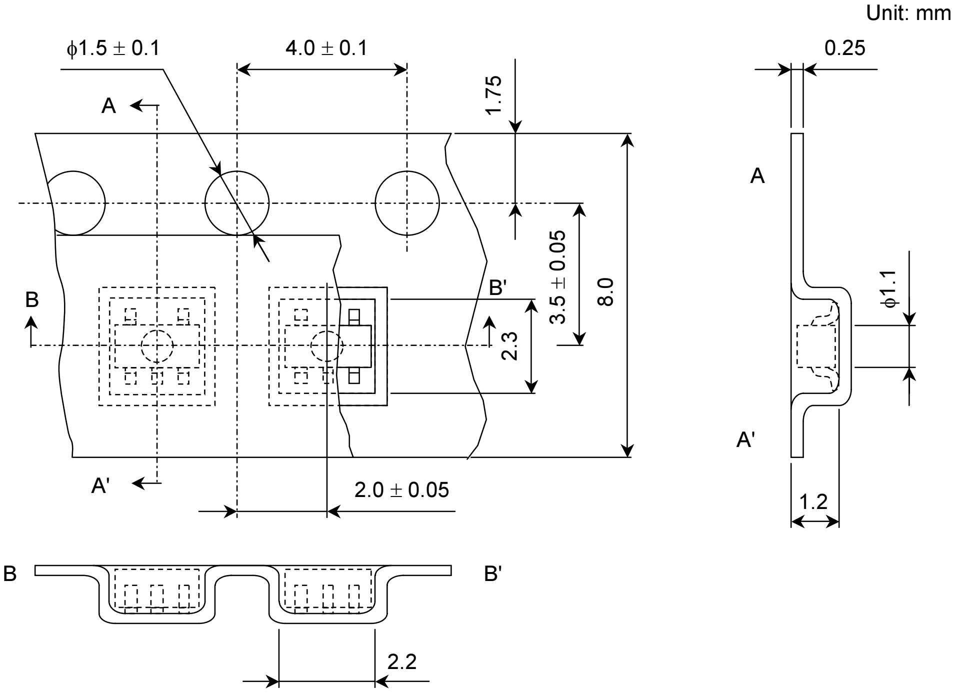
2.3.20 Tape Layout for Super-Mini V…(SMV)



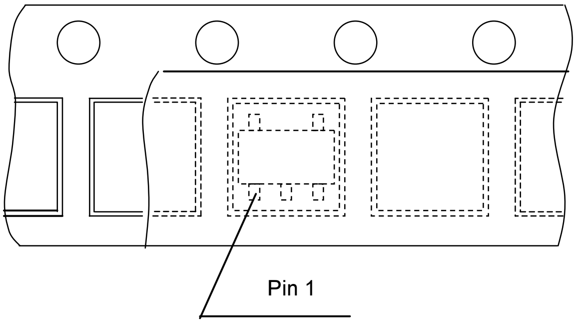
Device orientation



2.3.21 Tape Layout for Ultra-Super-Mini V…(USV)

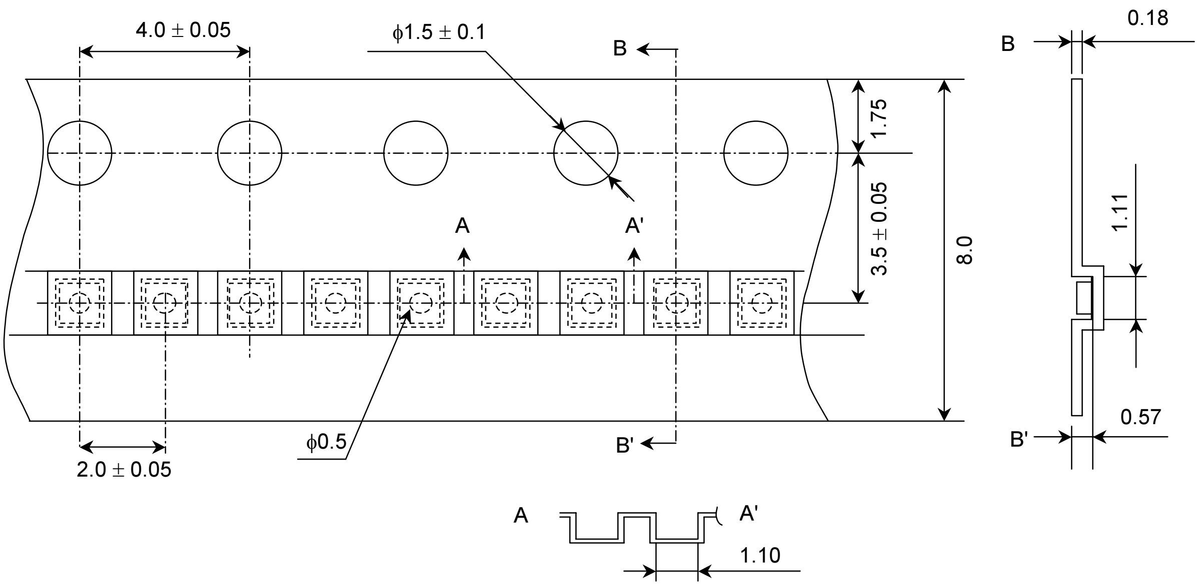


Device orientation

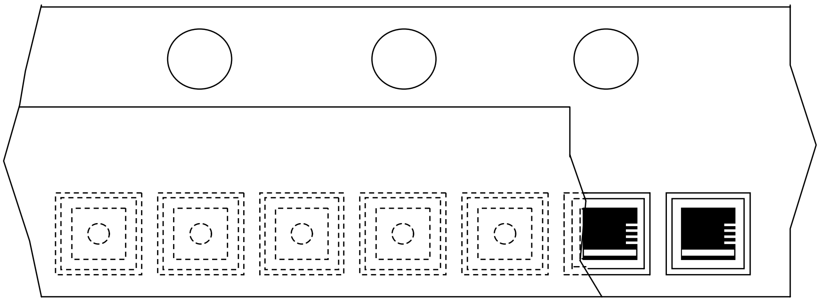


2.3.22 Tape Layout for Chip Scale 6…(CS6)

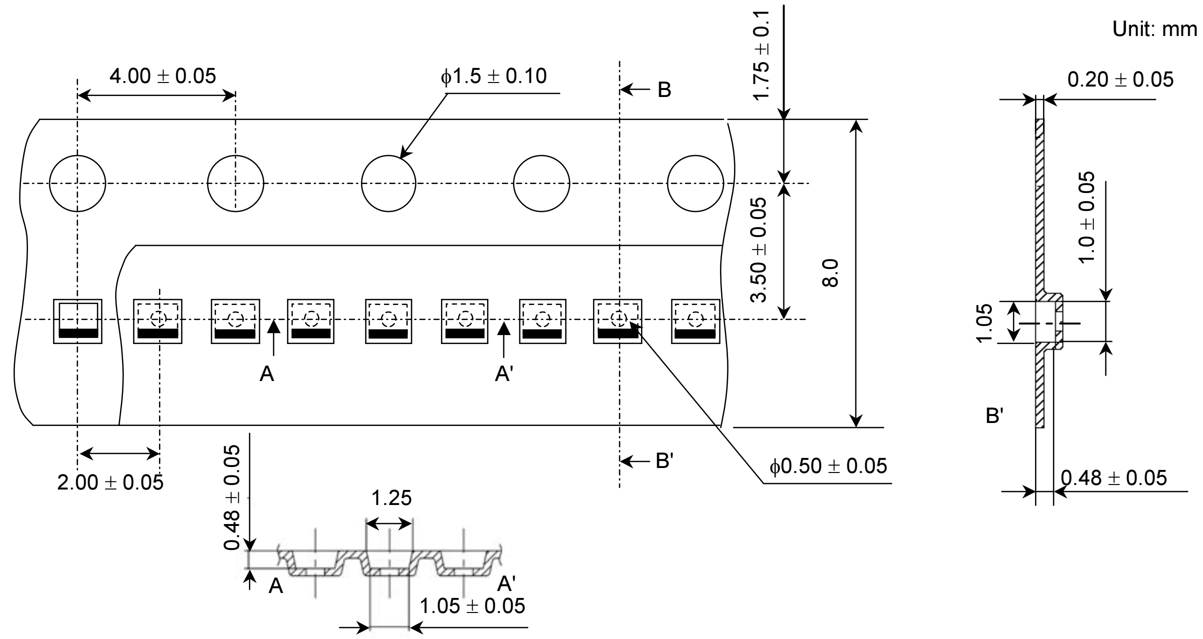
Unit: mm



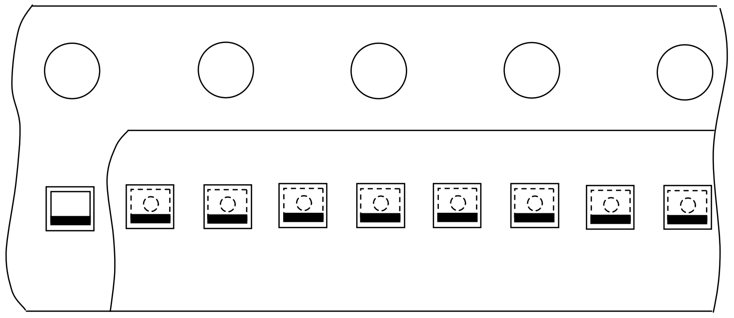
Device orientation

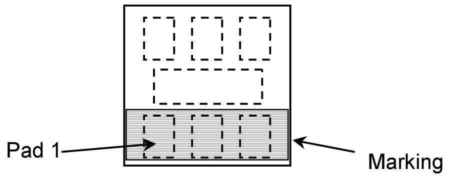


2.3.23 Tape Layout for Chip Scale Package Thin Type 6 Pin…(CST6B)

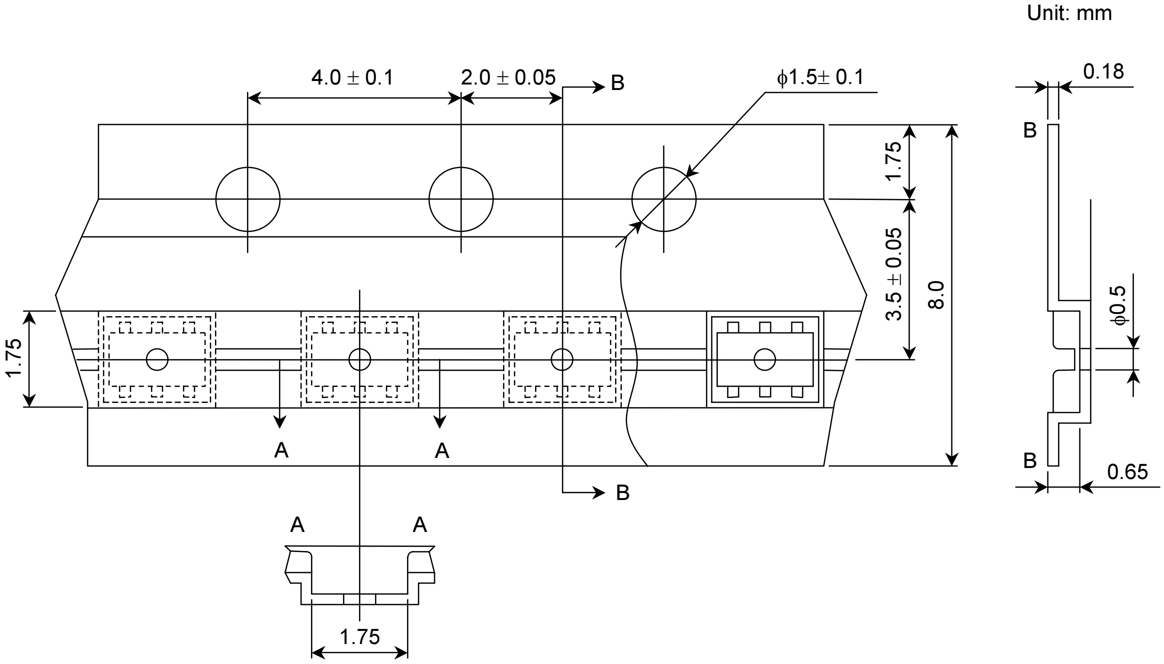


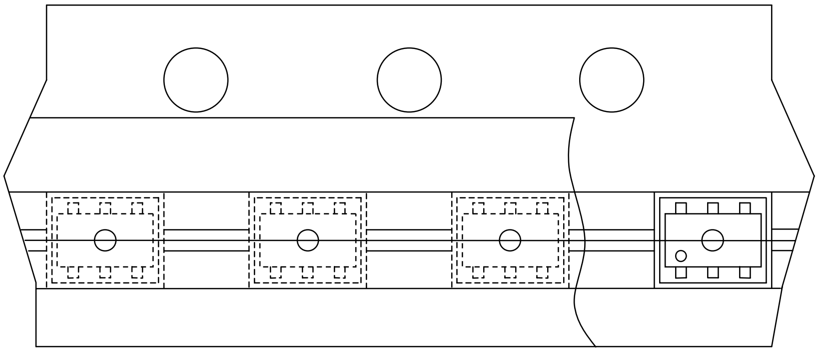
Device orientation





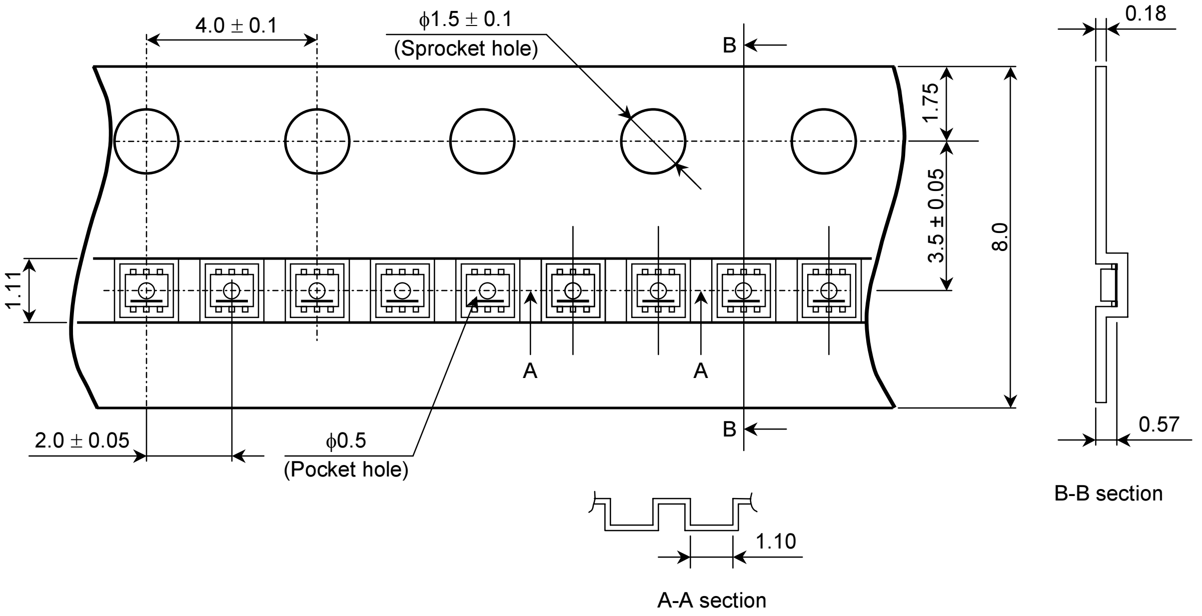
2.3.24 Tape Layout for Extreme-Super-Mini 6 Pin…(ES6)





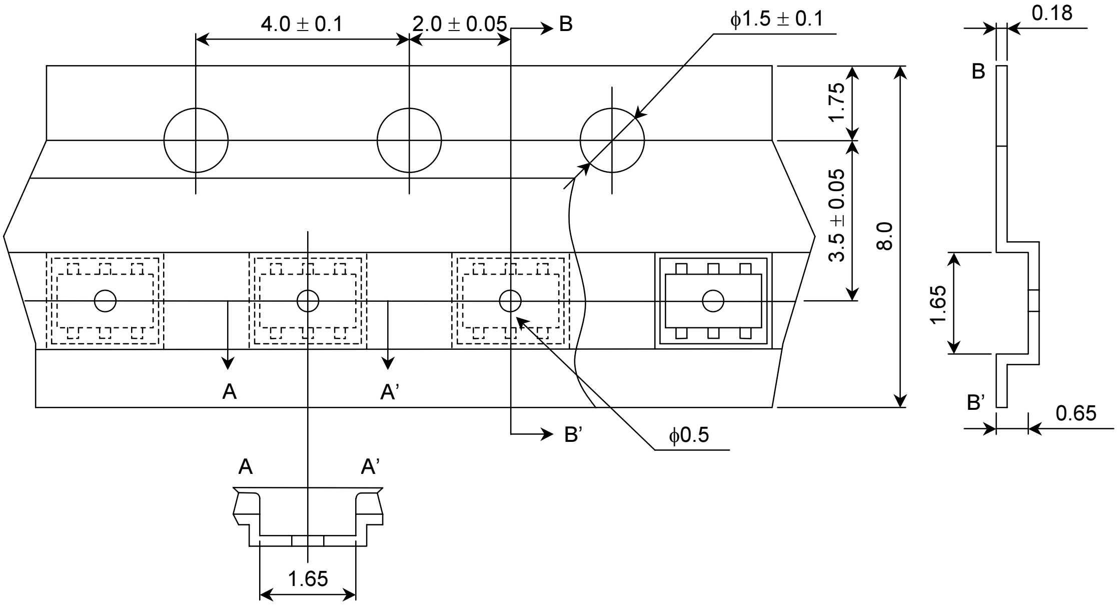
2.3.25 Tape Layout for Fine Pitch Extreme-Super-Mini 6 Pin…(fS6)

Unit: mm

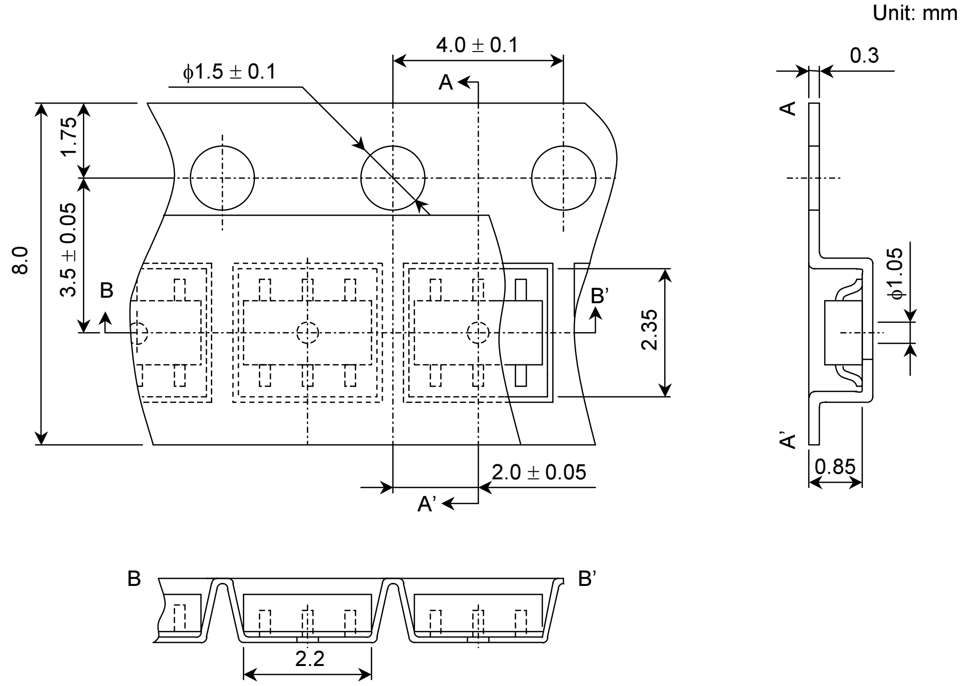


2.3.26 Tape Layout for Small Extreme-Super-Mini 6 Pin…(sES6)

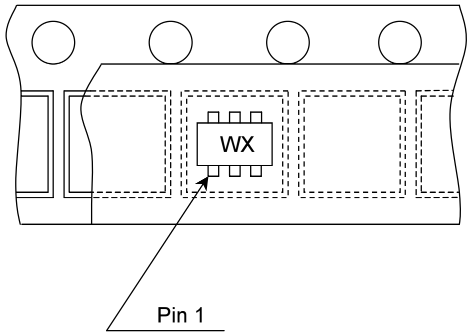
Unit: mm



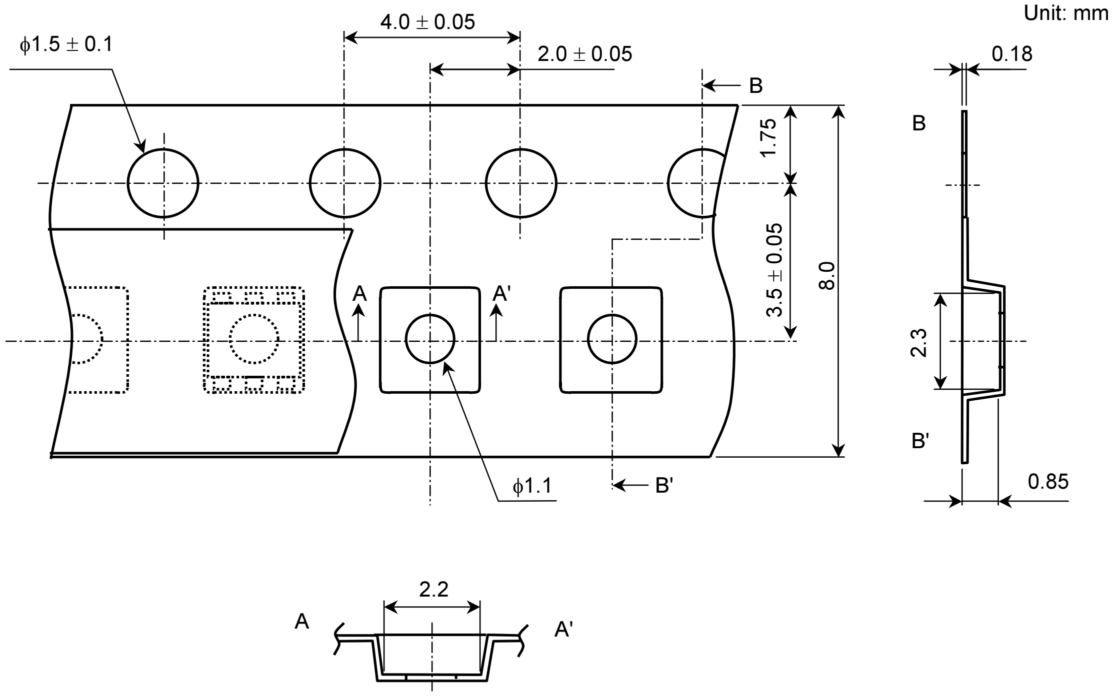
2.3.27 Tape Layout for Thin Ultra-Super-Mini 6 Pin…(TU6)



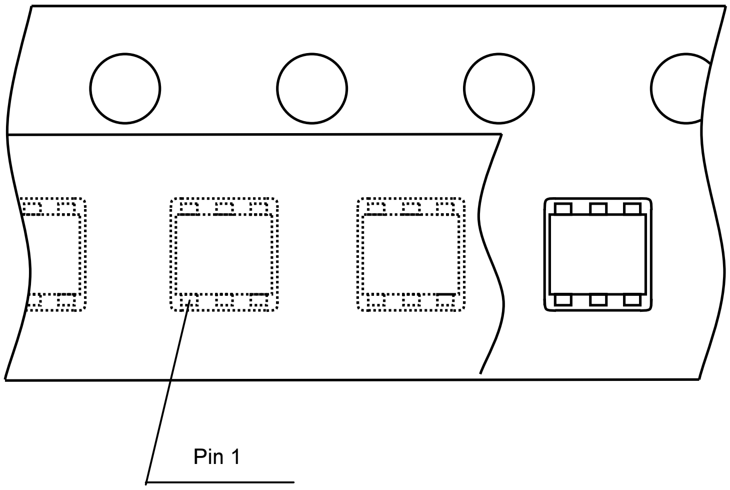
Device orientation



2.3.28 Tape Layout for Ultra-Flatlead 6 Pin…(UF6)

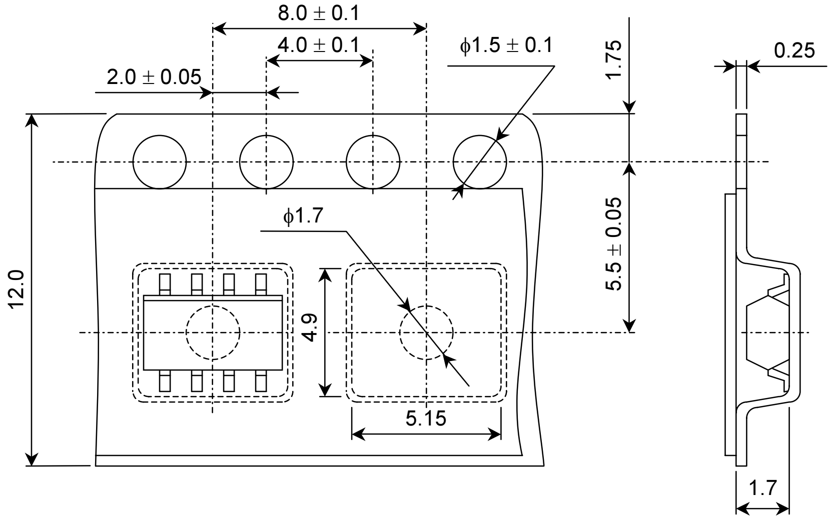


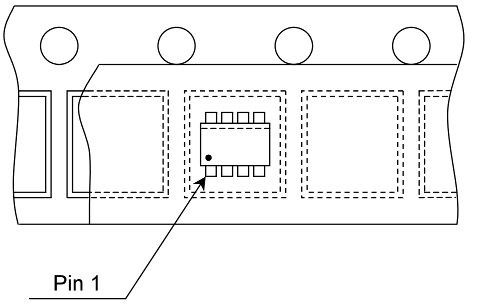
Device orientation



2.3.29 Tape Layout for Flat Mini 8 Pin…(FM8)

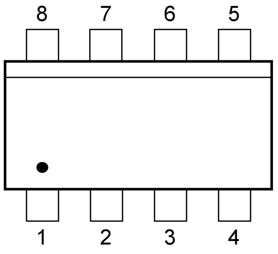
Unit: mm





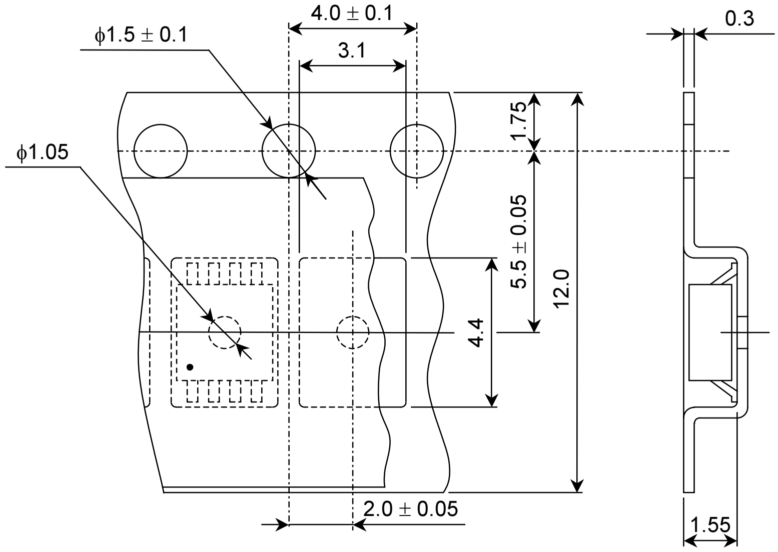
Pin 1 is on the lower left of the marking.

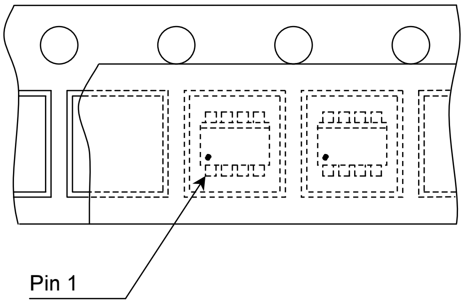
Example: Top View



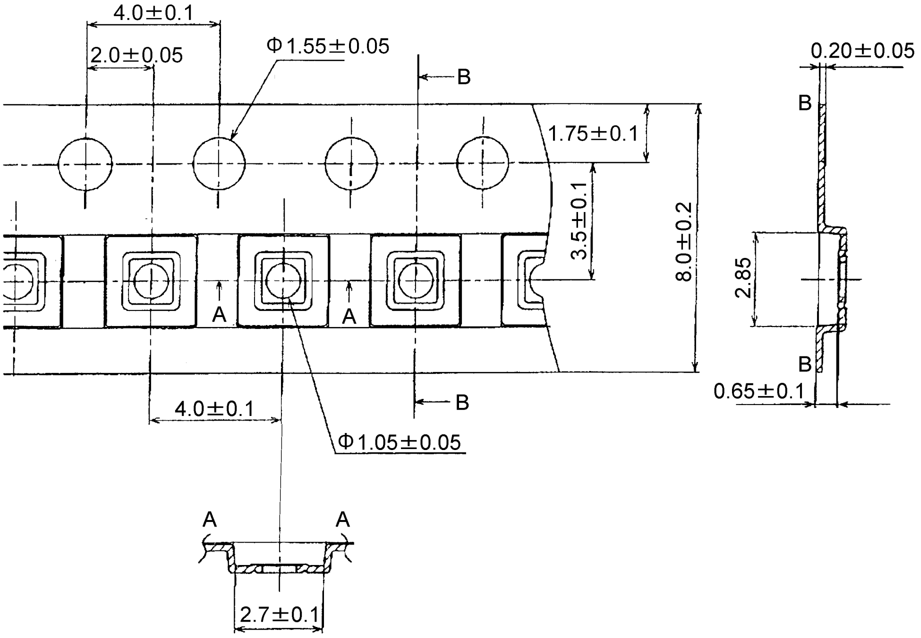
2.3.30 Tape Layout for Super-Mini 8 Pin…(SM8)

Unit: mm

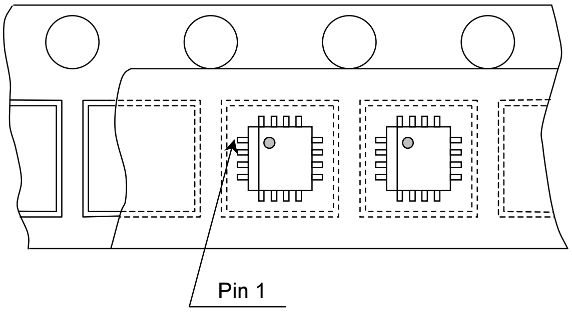




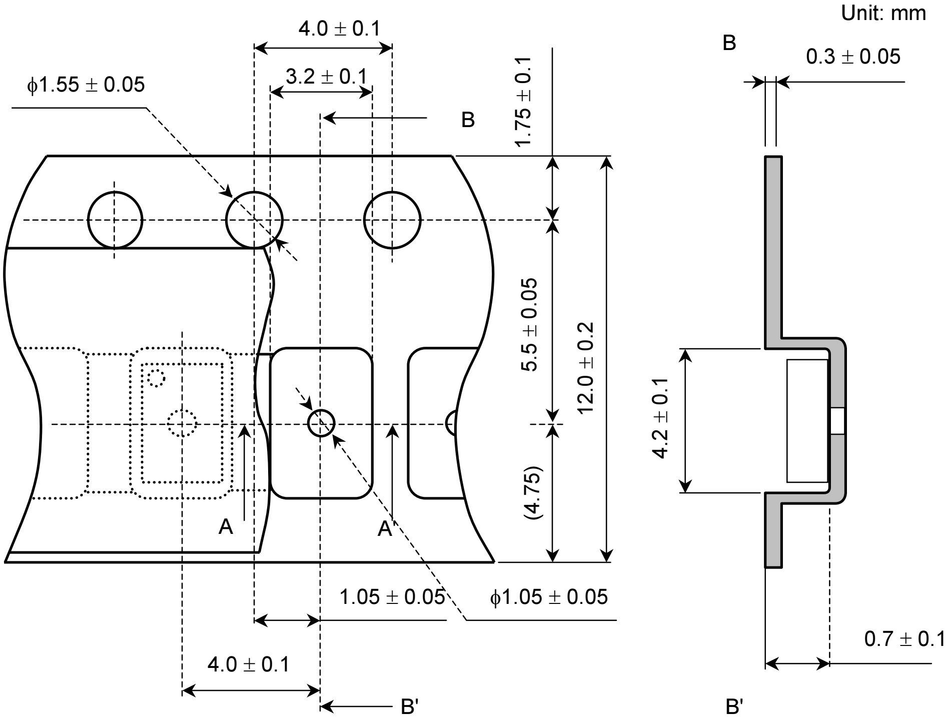
2.3.31 Tape Layout for Quad Small 16 Pin…(QS16)



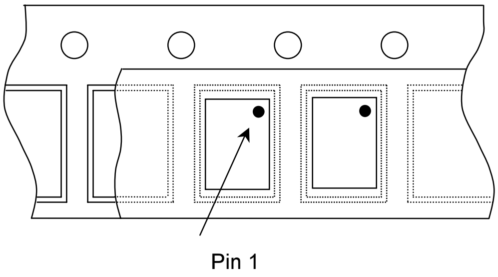
Device orientation



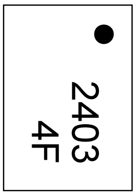
2.3.32 Tape Layout for Chip Scale Package Thin Type 20 Pin…(CST20)



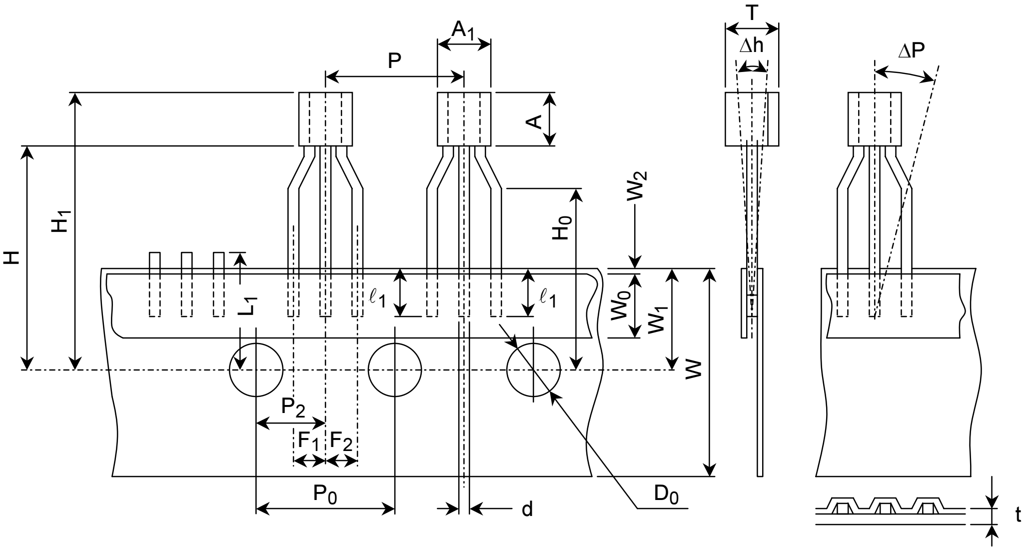
Device orientation



Example: Top View

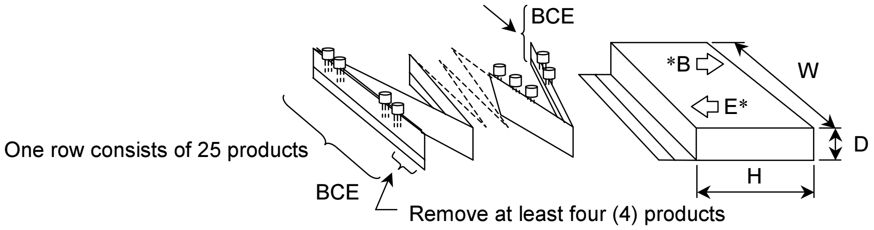


2.3.33 Radial Tape Layout for TO-92 and Mini Package



Measurement	Symbol	Dimensions			Unit: mm	Remarks
		TO-92 (SC-43)	MINI	TO-92MOD	MSTM	
Product width	A_1	6.0 max	4.5 max	5.1 max	7.1 max	Refer to each technical datasheet for more details
Product height	A	9.0 max	3.5 max	8.2 max	4.7 max	
Product thickness	T	6.0 max	2.6 max	4.1 max	2.7 max	
Lead width	d	0.45□ typ.	0.4□ typ.	0.67□ max	0.45□ typ.	
Attached lead length	ℓ_1	2.5 min		3.5 min	2.6 min	
Pitch between products	P	12.7 ± 1.0			12.7 ± 0.5	
Feed hole pitch	P_0	12.7 ± 0.3			12.7 ± 0.2	Cumulative pitch error rate: ±1 mm/20 pitches
Feed hole center to lead center	P_2	6.35 ± 0.4				
Lead spacing	F_1/F_2	$2.5^{+0.6}_{-0.3}$			$2.54^{+0.3}_{-0.2}$	
Vertical skew	Δh	0 ± 2.0			0 ± 1.0	
Tape width	W	$18.0^{+1.0}_{-0.5}$				
Sealing tape width	W_0	6.0 ± 0.3				
Tape edge to feed hole center	W_1	$9.0^{+0.75}_{-0.5}$		9.0 ± 0.5		
Carrier tape edge to sealing tape edge	W_3	0.5 max				
Package to feed hole center	H	20 max	$20^{+0.75}_{-0.5}$	20 max	19 ± 0.5	
Lead clinch to feed hole center	H_0	16.0 ± 0.5			—	
Product protrusion from feed hole center	H_1	32.25 max			25.0 max	
Feed hole diameter	D_0	4.0 ± 0.2				
Tape thickness	t	0.6 ± 0.2				
Length of shipped lead	L_1	11.0 max				
Horizontal skew	ΔP	0 ± 1.0				

Ammo Pack and Ammo Pack Dimensions



Unit: mm

Package Type	W	H	D
TO-92 (SC-43)	336 ± 3	250 ± 3	47 ± 3
MINI	336 ± 3	260 ± 3	47 ± 3
TO-92MOD	336 ± 3	190 ± 3	47 ± 3
MSTM	336 ± 3	230 ± 3	47 ± 3

*: Indicates the first electrode of a lead.

Example: E: Emitter

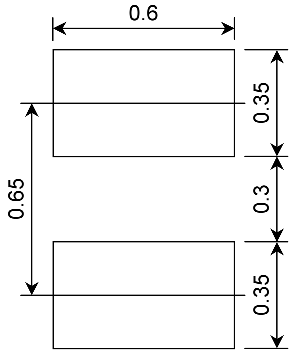
B: Base

3. Reference Pad Dimensions

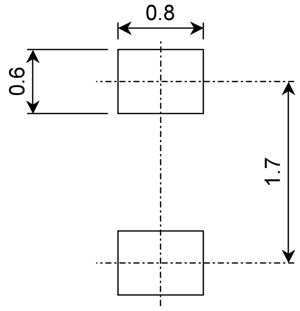
The following shows the reference pad dimensions for when a device is mounted on a board.

Unit: mm

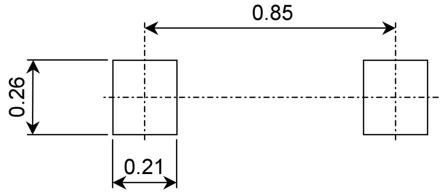
(1) CST2



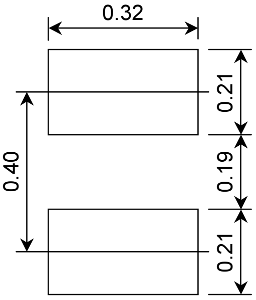
(2) ESC



(3) fSC

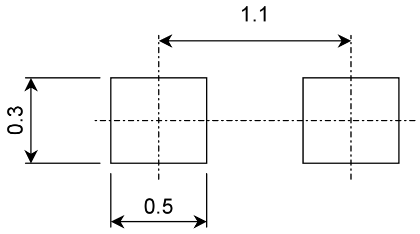


(4) SC2

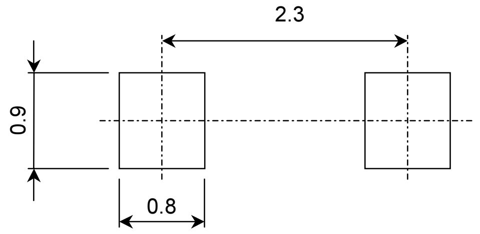


Unit: mm

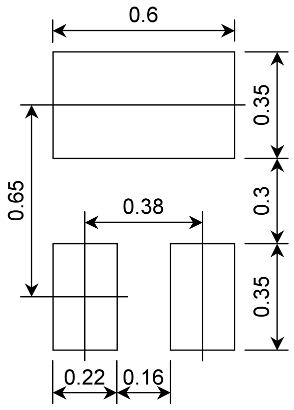
(5) sESC



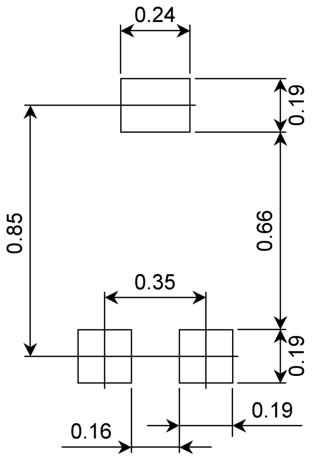
(6) USC



(7) CST3

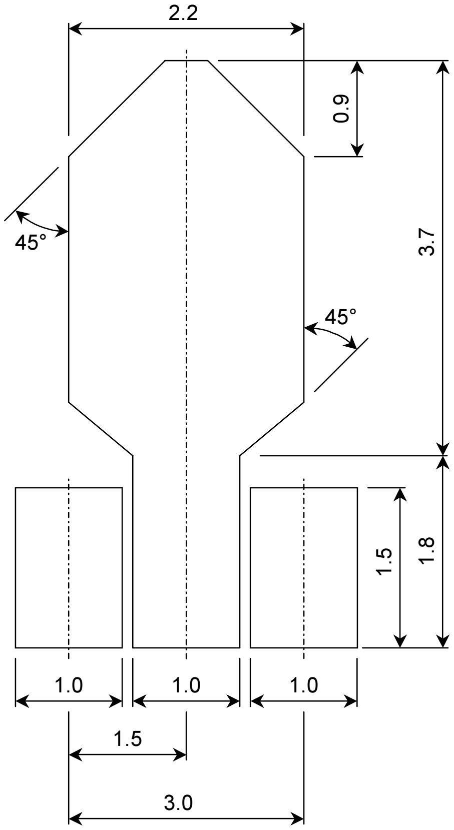


(8) fSM

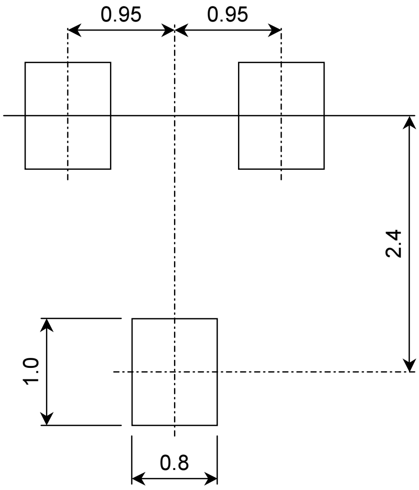


Unit: mm

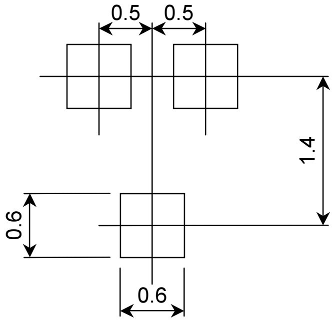
(9) PW-MINI



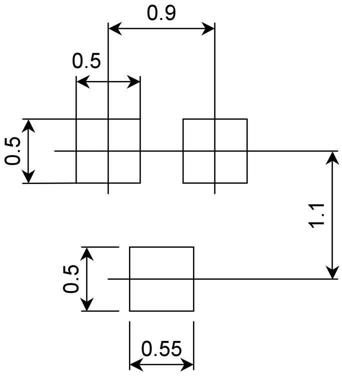
(10) S-MINI



(11) SSM

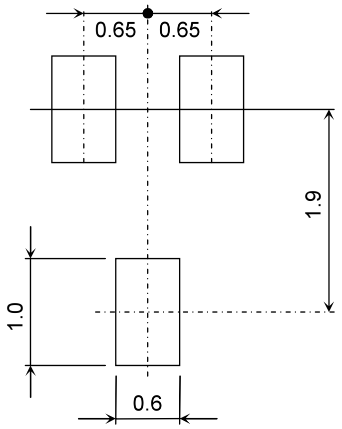


(12) TESM

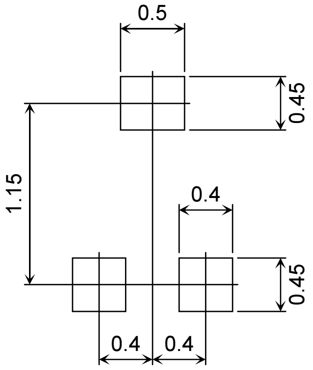


Unit: mm

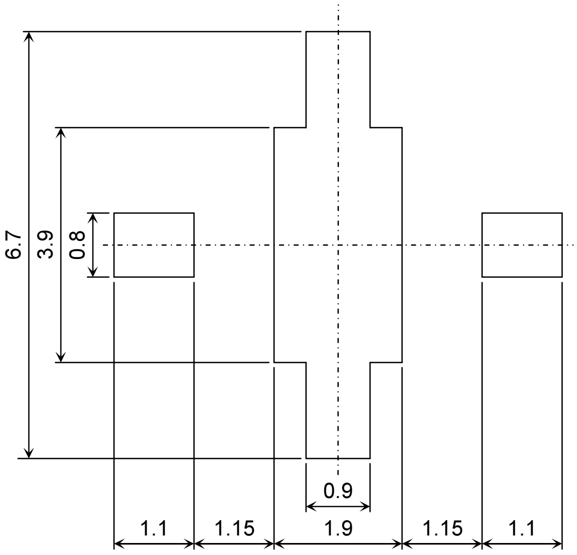
(13) USM



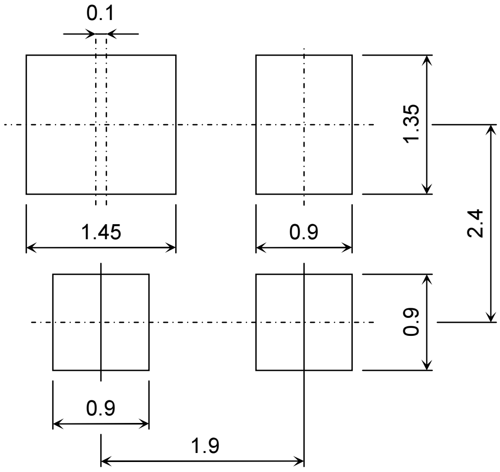
(14) VESM



(15) PW-X

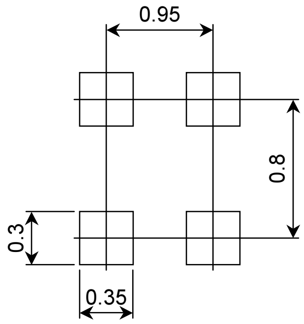


(16) SMQ

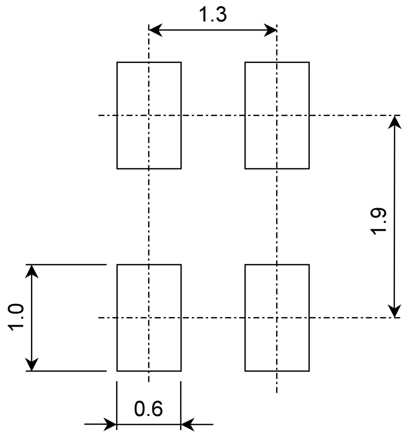


Unit: mm

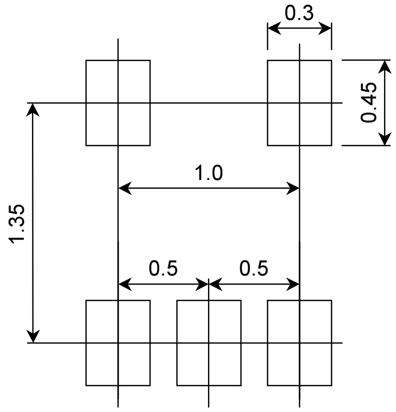
(17) TESQ



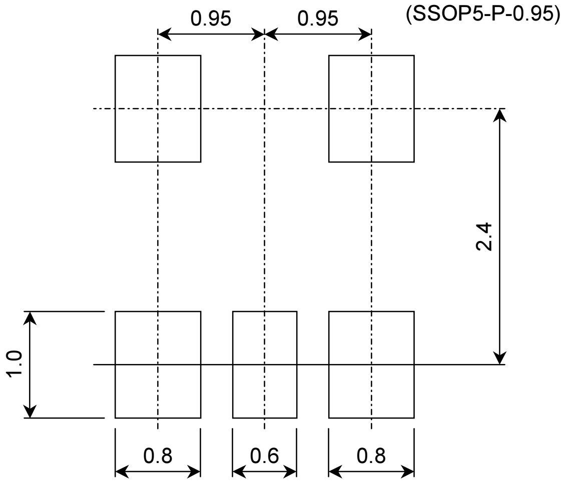
(18) USQ



(19) ESV

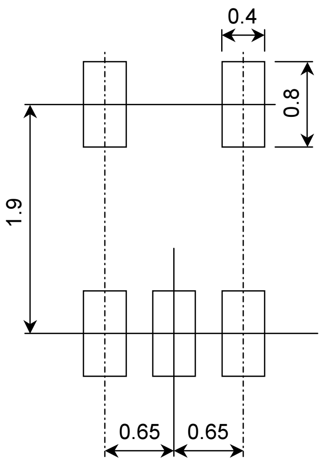


(20) SMV

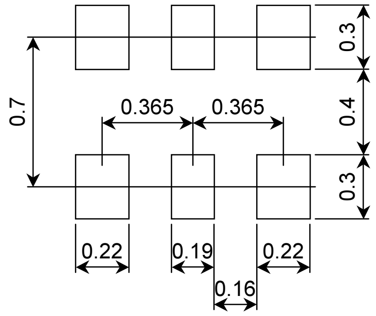


Unit: mm

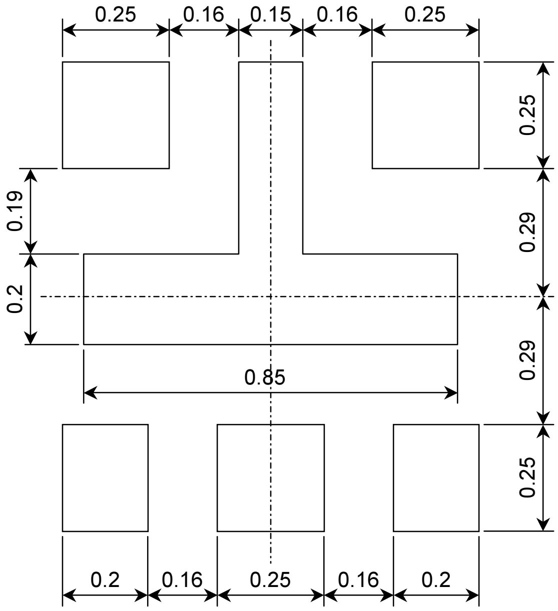
(21) USV



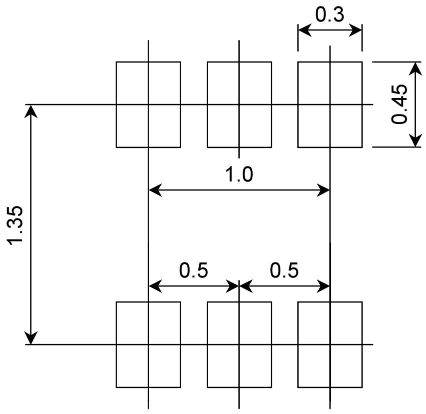
(22) CS6



(23) CST6B

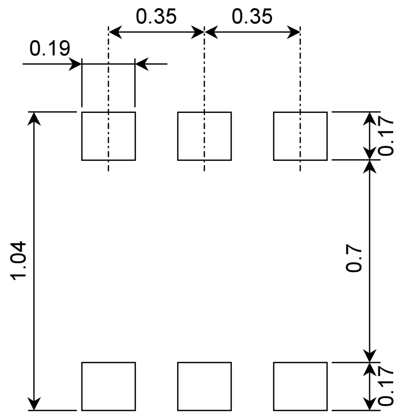


(24) ES6

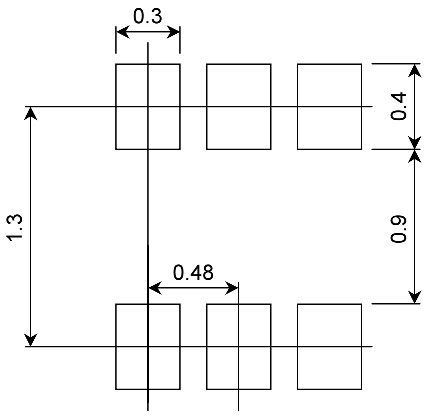


Unit: mm

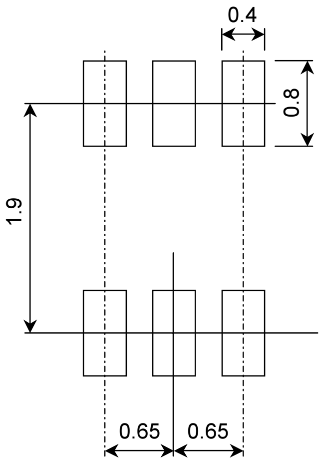
(25) fS6



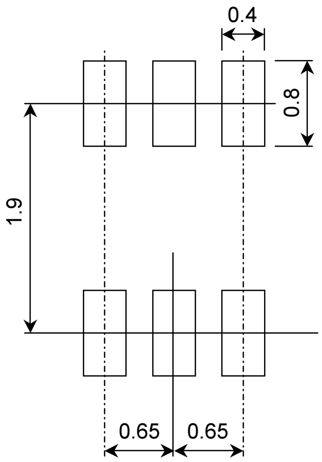
(26) sES6



(27) TU6

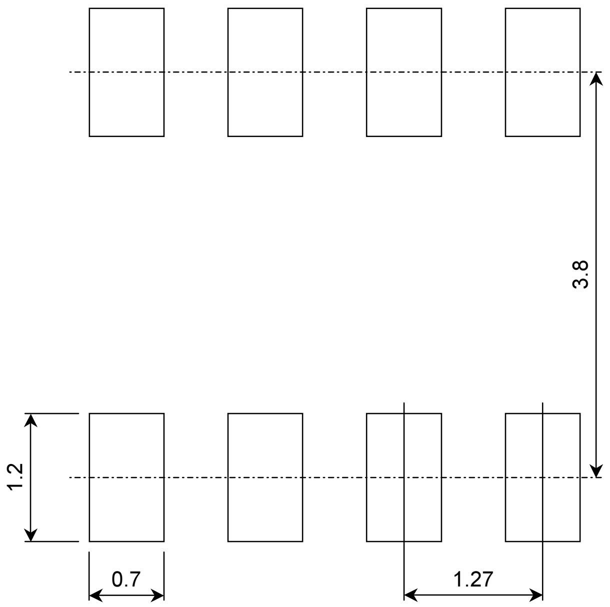


(28) UF6

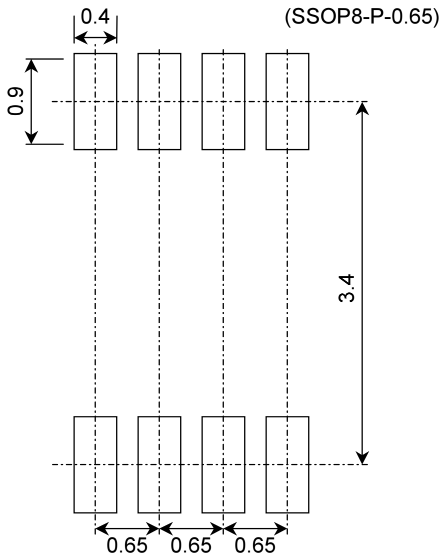


Unit: mm

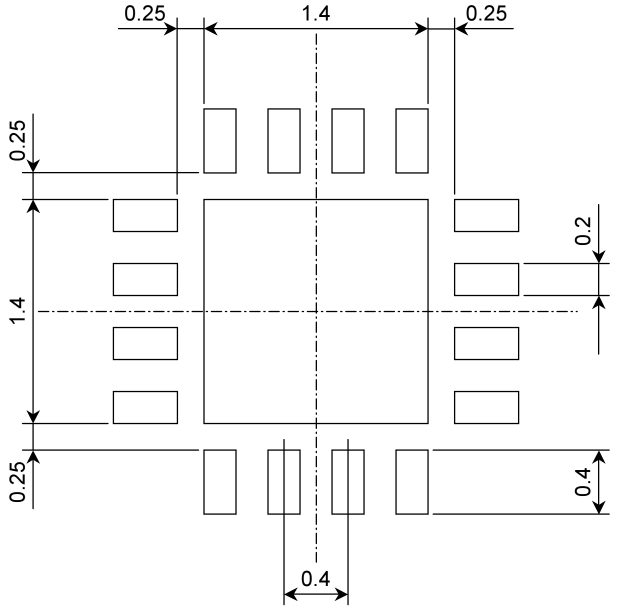
(29) FM8



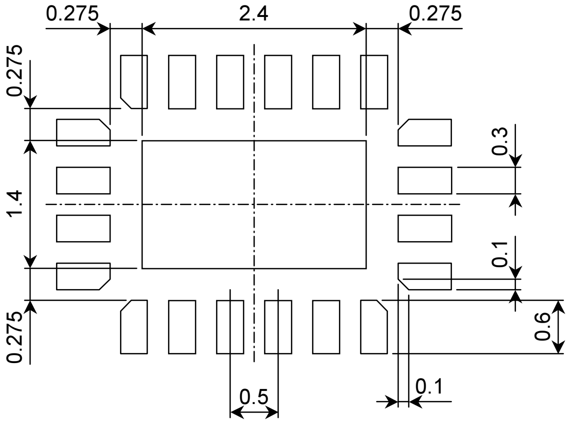
(30) SM8



(31) QS16



(32) CST20



[7] Handling Precautions

[7] Handling Precautions

1. Using Toshiba Semiconductors Safely

TOSHIBA is continually working to improve the quality and reliability of its products. Nevertheless, semiconductor devices in general can malfunction or fail due to their inherent electrical sensitivity and vulnerability to physical stress. It is the responsibility of the buyer, when utilizing TOSHIBA products, to comply with the standards of safety in making a safe design for the entire system, and to avoid situations in which a malfunction or failure of such TOSHIBA products could cause loss of human life, bodily injury or damage to property.

In developing your designs, please ensure that TOSHIBA products are used within specified operating ranges as set forth in the most recent TOSHIBA products specifications. Also, please keep in mind the precautions and conditions set forth in the “Handling Guide for Semiconductor Devices,” or “TOSHIBA Semiconductor Reliability Handbook” etc..

The TOSHIBA products listed in this document are intended for usage in general electronics applications (computer, personal equipment, office equipment, measuring equipment, industrial robotics, domestic appliances, etc.). These TOSHIBA products are neither intended nor warranted for usage in equipment that requires extraordinarily high quality and/or reliability or a malfunction or failure of which may cause loss of human life or bodily injury (“Unintended Usage”). Unintended Usage include atomic energy control instruments, airplane or spaceship instruments, transportation instruments, traffic signal instruments, combustion control instruments, medical instruments, all types of safety devices, etc.. Unintended Usage of TOSHIBA products listed in this document shall be made at the customer’s own risk.

2. Safety Precautions

This section lists important precautions which users of semiconductor devices (and anyone else) should observe in order to avoid injury and damage to property, and to ensure safe and correct use of devices.

Please be sure that you understand the meanings of the labels and the graphic symbol described below before you move on to the detailed descriptions of the precautions.

[Explanation of Labels]

⚠ DANGER	Indicates an imminently hazardous situation which will result in death or serious injury if you do not follow instructions.
⚠ WARNING	Indicates a potentially hazardous situation which could result in death or serious injury if you do not follow instructions.
⚠ CAUTION	Indicates a potentially hazardous situation which if not avoided, may result in minor injury or moderate injury.

2.1 General Precautions Regarding Semiconductor Devices

⚠CAUTION

Do not use devices under conditions exceeding their absolute maximum ratings (e.g. current, voltage, power dissipation or temperature).

This may cause the device to break down, degrade its performance, or cause it to catch fire or explode resulting in injury.

Do not insert devices in the wrong orientation.

Make sure that the positive and negative terminals of power supplies are connected correctly. Otherwise the rated maximum current or power dissipation may be exceeded and the device may break down or undergo performance degradation, causing it to catch fire or explode and resulting in injury.

When power to a device is on, do not touch the device's heat sink.

Heat sinks become hot, so you may burn your hand.

Do not touch the tips of device leads.

Because some types of device have leads with pointed tips, you may prick your finger.

When conducting any kind of evaluation, inspection or testing, be sure to connect the testing equipment's electrodes or probes to the pins of the device under test before powering it on.

Otherwise, you may receive an electric shock causing injury.

Before grounding an item of measuring equipment or a soldering iron, check that there is no electrical leakage from it.

Electrical leakage may cause the device which you are testing or soldering to break down, or could give you an electric shock.

Always wear protective glasses when cutting the leads of a device with clippers or a similar tool.

If you do not, small bits of metal flying off the cut ends may damage your eyes.

2.2 Bipolar ICs (for use in automobiles)

⚠CAUTION

If your design includes an inductive load such as a motor coil, incorporate diodes or similar devices into the design to prevent negative current from flowing in.

The load current generated by powering the device on and off may cause it to function erratically or to break down, which could in turn cause injury.

Ensure that the power supply to any device which incorporates protective functions is stable.

If the power supply is unstable, the device may operate erratically, preventing the protective functions from working correctly. If protective functions fail, the device may break down causing injury to the user.

3. General Safety Precautions and Usage Considerations

This section is designed to help you gain a better understanding of semiconductor devices, so as to ensure the safety, quality and reliability of the devices which you incorporate into your designs.

3.1 From Incoming to Shipping

3.1.1 Electrostatic Discharge (ESD)

When handling individual devices (which are not yet mounted on a printed circuit board), be sure that the environment is protected against electrostatic electricity. Operators should wear anti-static clothing, and containers and other objects which come into direct contact with devices should be made of anti-static materials and should be grounded to earth via an 0.5- to 1.0-MΩ protective resistor.

Please follow the precautions described below; this is particularly important for devices which are marked “Be careful of static.”.

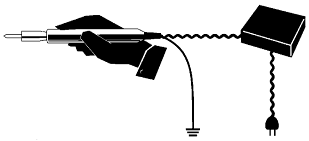
(1) Work environment

- When humidity in the working environment decreases, the human body and other insulators can easily become charged with static electricity due to friction. Maintain the recommended humidity of 40% to 60% in the work environment, while also taking into account the fact that moisture-proof-packed products may absorb moisture after unpacking.
- Be sure that all equipment, jigs and tools in the working area are grounded to earth.
- Place a conductive mat over the floor of the work area, or take other appropriate measures, so that the floor surface is protected against static electricity and is grounded to earth. The surface resistivity should be 10^4 to 10^8 Ω/sq and the resistance between surface and ground, 7.5×10^5 to 10^8 Ω
- Cover the workbench surface also with a conductive mat (with a surface resistivity of 10^4 to 10^8 Ω/sq, for a resistance between surface and ground of 7.5×10^5 to 10^8 Ω). The purpose of this is to disperse static electricity on the surface (through resistive components) and ground it to earth. Workbench surfaces must not be constructed of low-resistance metallic materials that allow rapid static discharge when a charged device touches them directly.
- Pay attention to the following points when using automatic equipment in your workplace:
  (a) When picking up ICs with a vacuum unit, use a conductive rubber fitting on the end of the pick-up wand to protect against electrostatic charge.
  (b) Minimize friction on IC package surfaces. If some rubbing is unavoidable due to the device’s mechanical structure, minimize the friction plane or use material with a small friction coefficient and low electrical resistance. Also, consider the use of an ionizer.
  (c) In sections which come into contact with device lead terminals, use a material which dissipates static electricity.
  (d) Ensure that no statically charged bodies (such as work clothes or the human body) touch the devices.

(e) Make sure that sections of the tape carrier which come into contact with installation devices or other electrical machinery are made of a low-resistance material.
(f) Make sure that jigs and tools used in the assembly process do not touch devices.
(g) In processes in which packages may retain an electrostatic charge, use an ionizer to neutralize the ions.

- Make sure that CRT displays in the working area are protected against static charge, for example by a VDT filter. As much as possible, avoid turning displays on and off. Doing so can cause electrostatic induction in devices.
- Keep track of charged potential in the working area by taking periodic measurements.
- Ensure that work chairs are protected by an anti-static textile cover and are grounded to the floor surface by a grounding chain. (suggested resistance between the seat surface and grounding chain is 7.5×10^5 to 10^{12} Ω.)
- Install anti-static mats on storage shelf surfaces. (suggested surface resistivity is 10^4 to 10^8 Ω/sq; suggested resistance between surface and ground is 7.5×10^5 to 10^8 Ω.)
- For transport and temporary storage of devices, use containers (boxes, jigs or bags) that are made of anti-static materials or materials which dissipate electrostatic charge.
- Make sure that cart surfaces which come into contact with device packaging are made of materials which will conduct static electricity, and verify that they are grounded to the floor surface via a grounding chain.
- In any location where the level of static electricity is to be closely controlled, the ground resistance level should be Class 3 or above. Use different ground wires for all items of equipment which may come into physical contact with devices.

(2) Operating environment

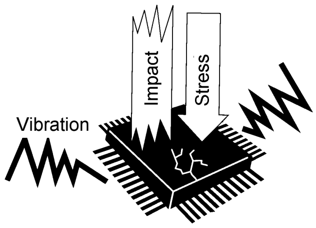


- Operators must wear anti-static clothing and conductive shoes (or a leg or heel strap).
- Operators must wear a wrist strap grounded to earth via a resistor of about 1 MΩ.
- Soldering irons must be grounded from iron tip to earth, and must be used only at low voltages (6 V to 24 V).
- If the tweezers you use are likely to touch the device terminals, use anti-static tweezers and in particular avoid metallic tweezers. If a charged device touches a low-resistance tool, rapid discharge can occur. When using vacuum tweezers, attach a conductive chucking pat to the tip, and connect it to a dedicated ground used especially for anti-static purposes (suggested resistance value: 10^4 to 10^8 Ω).
- Do not place devices or their containers near sources of strong electrical fields (such as above a CRT).
- When storing printed circuit boards which have devices mounted on them, use a board container or bag that is protected against static charge. To avoid the occurrence of static charge or discharge due to friction, keep the boards separate from one other and do not stack them directly on top of one another.
- Ensure, if possible, that any articles (such as clipboards) which are brought to any location where the level of static electricity must be closely controlled are constructed of anti-static materials.

- In cases where the human body comes into direct contact with a device, be sure to wear anti-static finger covers or gloves (suggested resistance value: $10^8\ \Omega$ or less).
- Equipment safety covers installed near devices should have resistance ratings of $10^9\ \Omega$ or less.
- If a wrist strap cannot be used for some reason, and there is a possibility of imparting friction to devices, use an ionizer.
- The transport film used in TCP products is manufactured from materials in which static charges tend to build up. When using these products, install an ionizer to prevent the film from being charged with static electricity. Also, ensure that no static electricity will be applied to the product's copper foils by taking measures to prevent static occurring in the peripheral equipment.

3.1.2 Vibration, Impact and Stress

Handle devices and packaging materials with care. To avoid damage to devices, do not toss or drop packages. Ensure that devices are not subjected to mechanical vibration or shock during transportation. Ceramic package devices and devices in canister-type packages which have empty space inside them are subject to damage from vibration and shock because the bonding wires are secured only at their ends.



Plastic molded devices, on the other hand, have a relatively high level of resistance to vibration and mechanical shock because their bonding wires are enveloped and fixed in resin. However, when any device or package type is installed in target equipment, it is to some extent susceptible to wiring disconnections and other damage from vibration, shock and stressed solder junctions. Therefore when devices are incorporated into the design of equipment which will be subject to vibration, the structural design of the equipment must be thought out carefully.

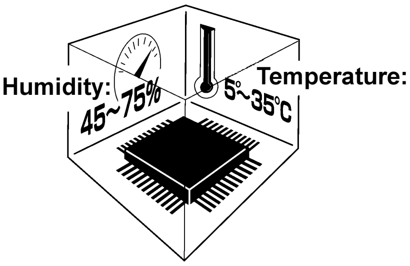
If a device is subjected to especially strong vibration, mechanical shock or stress, the package or the chip itself may crack. In products such as CCDs which incorporate window glass, this could cause surface flaws in the glass or cause the connection between the glass and the ceramic to separate.

Furthermore, it is known that stress applied to a semiconductor device through the package changes the resistance characteristics of the chip because of piezoelectric effects. In analog circuit design attention must be paid to the problem of package stress as well as to the dangers of vibration and shock as described above.

3.2 Storage

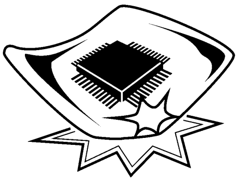
3.2.1 General Storage

- Avoid storage locations where devices will be exposed to moisture or direct sunlight.
- Follow the instructions printed on the device cartons regarding transportation and storage.
- The storage area temperature should be kept within a temperature range of 5°C to 35°C, and relative humidity should be maintained at between 45% and 75%.
- Do not store devices in the presence of harmful (especially corrosive) gases, or in dusty conditions.
- Use storage areas where there is minimal temperature fluctuation. Rapid temperature changes can cause moisture to form on stored devices, resulting in lead oxidation or corrosion. As a result, the solderability of the leads will be degraded.
- When repacking devices, use anti-static containers.
- Do not allow external forces or loads to be applied to devices while they are in storage.
- If devices have been stored for more than two years, their electrical characteristics should be tested and their leads should be tested for ease of soldering before they are used.



3.2.2 Moisture-Proof Packing

Moisture-proof packing should be handled with care. The handling procedure specified for each packing type should be followed scrupulously. If the proper procedures are not followed, the quality and reliability of devices may be degraded. This section describes general precautions for handling moisture-proof packing. Since the details may differ from device to device, refer also to the relevant individual datasheets or databook.



(1) General precautions

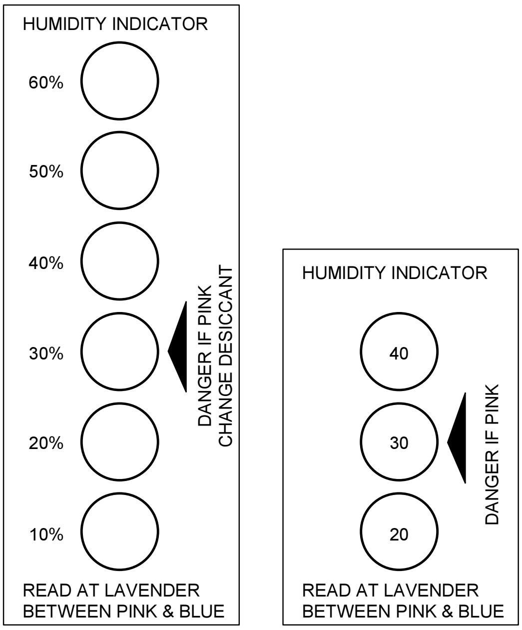
Follow the instructions printed on the device cartons regarding transportation and storage.

- Do not drop or toss device packing. The laminated aluminum material in it can be rendered ineffective by rough handling.
- The storage area temperature should be kept within a temperature range of 5°C to 30°C, and relative humidity should be maintained at 90% (max). Use devices within 12 months of the date marked on the package seal.

- If the 12-month storage period has expired, or if the 30% humidity indicator shown in Figure 3.1 is pink when the packing is opened, it may be advisable, depending on the device and packing type, to back the devices at high temperature to remove any moisture. Please refer to the table below. After the pack has been opened, use the devices in a 5°C to 30°C. 60% RH environment and within the effective usage period listed on the moisture-proof package. If the effective usage period has expired, or if the packing has been stored in a high-humidity environment, back the devices at high temperature.

Packing	Moisture Removal
Tray	If the packing bears the “Heatproof” marking or indicates the maximum temperature which it can withstand, bake at 125°C for 20 hours. (some devices require a different procedure.)
Tube	Transfer devices to trays bearing the “Heatproof” marking or indicating the temperature which they can withstand, or to aluminum tubes before baking at 125°C for 20 hours.
Tape	Deviced packed on tape cannot be baked and must be used within the effective usage period after unpacking, as specified on the packing.

- When baking devices, protect the devices from static electricity.
- Moisture indicators can detect the approximate humidity level at a standard temperature of 25°C. 6-point indicators and 3-point indicators are currently in use, but eventually all indicators will be 3-point indicators.



(a) 6-point indicator (b) 3-point indicator

Figure 3.1 Humidity Indicator

3.3 Design

Care must be exercised in the design of electronic equipment to achieve the desired reliability. It is important not only to adhere to specifications concerning absolute maximum ratings and recommended operating conditions, it is also important to consider the overall environment in which equipment will be used, including factors such as the ambient temperature, transient noise and voltage and current surges, as well as mounting conditions which affect device reliability. This section describes some general precautions which you should observe when designing circuits and when mounting devices on printed circuit boards.

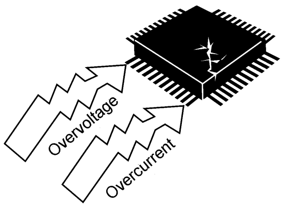
For more detailed information about each product family, refer to the relevant individual technical datasheets available from Toshiba.

3.3.1 Absolute Maximum Ratings

⚠CAUTION

Do not use devices under conditions in which their absolute maximum ratings (e.g. current, voltage, power dissipation or temperature) will be exceeded. A device may break down or its performance may be degraded, causing it to catch fire or explode resulting in injury to the user.

The absolute maximum ratings are rated values which must not be exceeded during operation, even for an instant. Although absolute maximum ratings differ from product to product, they essentially concern the voltage and current at each pin, the allowable power dissipation, and the junction and storage temperatures.



If the voltage or current on any pin exceeds the absolute maximum rating, the device's internal circuitry can become degraded. In the worst case, heat generated in internal circuitry can fuse wiring or cause the semiconductor chip to break down.

If storage or operating temperatures exceed rated values, the package seal can deteriorate or the wires can become disconnected due to the differences between the thermal expansion coefficients of the materials from which the device is constructed.

3.3.2 Recommended Operating Conditions

The recommended operating conditions for each device are those necessary to guarantee that the device will operate as specified in the datasheet.

If greater reliability is required, derate the device's absolute maximum ratings for voltage, current, power and temperature before using it.

3.3.3 Derating

When incorporating a device into your design, reduce its rated absolute maximum voltage, current, power dissipation and operating temperature in order to ensure high reliability.

Since derating differs from application to application, refer to the technical datasheets available for the various devices used in your design.

3.3.4 Unused Pins

If unused pins are left open, some devices can exhibit input instability problems, resulting in malfunctions such as abrupt increase in current flow. Similarly, if the unused output pins on a device are connected to the power supply pin, the ground pin or to other output pins, the IC may malfunction or break down.

Since the details regarding the handling of unused pins differ from device to device and from pin to pin, please follow the instructions given in the relevant individual datasheets or databook.

CMOS logic IC inputs, for example, have extremely high impedance. If an input pin is left open, it can easily pick up extraneous noise and become unstable. In this case, if the input voltage level reaches an intermediate level, it is possible that both the P-channel and N-channel transistors will be turned on, allowing unwanted supply current to flow. Therefore, ensure that the unused input pins of a device are connected to the power supply (V_{CC}) pin or ground (GND) pin of the same device. For details of what to do with the pins of heat sinks, refer to the relevant technical datasheet and databook.

3.3.5 Latch-Up

Latch-up is an abnormal condition inherent in CMOS devices, in which V_{CC} gets shorted to ground. This happens when a parasitic PN-PN junction (thyristor structure) internal to the CMOS chip is turned on, causing a large current of the order of several hundred mA or more to flow between V_{CC} and GND, eventually causing the device to break down.

Latch-up occurs when the input or output voltage exceeds the rated value, causing a large current to flow in the internal chip, or when the voltage on the V_{CC} (V_{DD}) pin exceeds its rated value, forcing the internal chip into a breakdown condition. Once the chip falls into the latch-up state, even though the excess voltage may have been applied only for an instant, the large current continues to flow between V_{CC} (V_{DD}) and GND (V_{SS}). This causes the device to heat up and, in extreme cases, to emit gas fumes as well. To avoid this problem, observe the following precautions:

(1) Do not allow voltage levels on the input and output pins either to rise above V_{CC} (V_{DD}) or to fall below GND (V_{SS}). Also, follow any prescribed power-on sequence, so that power is applied gradually or in steps rather than abruptly.
(2) Do not allow any abnormal noise signals to be applied to the device.
(3) Set the voltage levels of unused input pins to V_{CC} (V_{DD}) or GND (V_{SS}).
(4) Do not connect output pins to one another.

3.3.6 Input/Output Protection

Wired-AND configurations, in which outputs are connected together, cannot be used, since this short-circuits the outputs. Outputs should, of course, never be connected to V_{CC} (V_{DD}) or GND (V_{SS}).

Furthermore, ICs with tri-state outputs can undergo performance degradation if a shorted output current is allowed to flow for an extended period of time. Therefore, when designing circuits, make sure that tri-state outputs will not be enabled simultaneously.

3.3.7 Load Capacitance

Some devices display increased delay times if the load capacitance is large. Also, large charging and discharging currents will flow in the device, causing noise. Furthermore, since outputs are shorted for a relatively long time, wiring can become fused.

Consult the technical information for the device being used to determine the recommended load capacitance.

3.3.8 Thermal Design

The failure rate of semiconductor devices is greatly increased as operating temperatures increase. As shown in, Figure 3.2 the internal thermal stress on a device is the sum of the ambient temperature and the temperature rise due to power dissipation in the device. Therefore, to achieve optimum reliability, observe the following precautions concerning thermal design:

(1) Keep the ambient temperature (Ta) as low as possible.

(2) If the device's dynamic power dissipation is relatively large, select the most appropriate circuit board material, and consider the use of heat sinks or of forced air cooling. Such measures will help lower the thermal resistance of the package.

(3) Derate the device's absolute maximum ratings to minimize thermal stress from power dissipation.

$\theta ja = \theta jc + \theta ca$

$\theta ja = (Tj - Ta)/P$

$\theta jc = (Tj - Tc)/P$

$\theta ca = (Tc - Ta)/P$

in which θja = thermal resistance between junction and surrounding air (°C/W)

θjc = thermal resistance between junction and package surface, or internal thermal resistance (°C/W)

θca = thermal resistance between package surface and surrounding air, or external thermal resistance (°C/W)

Tj = junction temperature or chip temperature (°C)

Tc = package surface temperature or case temperature (°C)

Ta = ambient temperature (°C)

P = power dissipation (W)

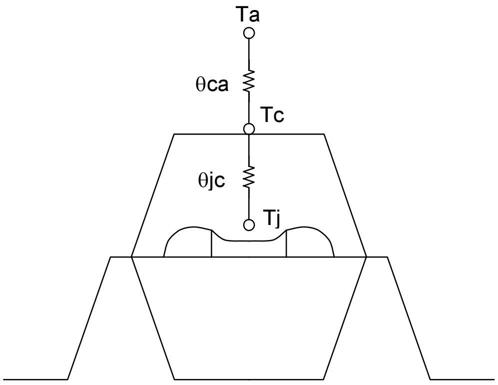


Figure 3.2 Thermal Resistance of Package

3.3.9 Interfacing

When connecting inputs and outputs between devices, make sure input voltage (V_{IL}/V_{IH}) and output voltage (V_{OL}/V_{OH}) levels are matched. Otherwise, the devices may malfunction. When connecting devices operating at different supply voltages, such as in a dual-power-supply system, be aware that erroneous power-on and power-off sequences can result in device breakdown. For details of how to interface particular devices, consult the relevant technical datasheets and databooks. If you have any questions or doubts about interfacing, contact your nearest Toshiba office or distributor.

3.3.10 Decoupling

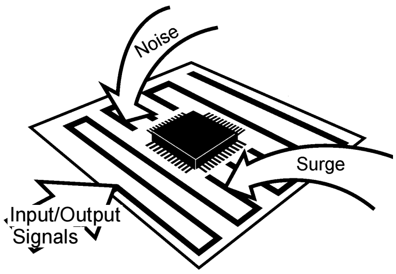
Spike currents generated during switching can cause V_{CC} (V_{DD}) and GND (V_{SS}) voltage levels to fluctuate, causing ringing in the output waveform or a delay in response speed. (the power supply and GND wiring impedance is normally 50 Ω to 100 Ω.) For this reason, the impedance of power supply lines with respect to high frequencies must be kept low. This can be accomplished by using thick and short wiring for the V_{CC} (V_{DD}) and GND (V_{SS}) lines and by installing decoupling capacitors (of approximately 0.01 μF to 1 μF capacitance) as high-frequency filters between V_{CC} (V_{DD}) and GND (V_{SS}) at strategic locations on the printed circuit board.

For low-frequency filtering, it is a good idea to install a 10- to 100-μF capacitor on the printed circuit board (one capacitor will suffice). If the capacitance is excessively large, however, (e.g. several thousand μF) latch-up can be a problem. Be sure to choose an appropriate capacitance value.

An important point about wiring is that, in the case of high-speed logic ICs, noise is caused mainly by reflection and crosstalk, or by the power supply impedance. Reflections cause increased signal delay, ringing, overshoot and undershoot, thereby reducing the device's safety margins with respect to noise. To prevent reflections, reduce the wiring length by increasing the device mounting density so as to lower the inductance (L) and capacitance (C) in the wiring. Extreme care must be taken, however, when taking this corrective measure, since it tends to cause crosstalk between the wires. In practice, there must be a trade-off between these two factors.

3.3.11 External Noise

Printed circuit boards with long I/O or signal pattern lines are vulnerable to induced noise or surges from outside sources. Consequently, malfunctions or breakdowns can result from overcurrent or overvoltage, depending on the types of device used. To protect against noise, lower the impedance of the pattern line or insert a noise-canceling circuit. Protective measures must also be taken against surges.



For details of the appropriate protective measures for a particular device, consult the relevant databook.

3.3.12 Electromagnetic Interference

Widespread use of electrical and electronic equipment in recent years has brought with it radio and TV reception problems due to electromagnetic interference. To use the radio spectrum effectively and to maintain radio communications quality, each country has formulated regulations limiting the amount of electromagnetic interference which can be generated by individual products.

Electromagnetic interference includes conduction noise propagated through power supply and telephone lines, and noise from direct electromagnetic waves radiated by equipment. Different measurement methods and corrective measures are used to assess and counteract each specific type of noise.

Difficulties in controlling electromagnetic interference derive from the fact that there is no method available which allows designers to calculate, at the design stage, the strength of the electromagnetic waves which will emanate from each component in a piece of equipment. For this reason, it is only after the prototype equipment has been completed that the designer can take measurements using a dedicated instrument to determine the strength of electromagnetic interference waves. Yet it is possible during system design to incorporate some measures for the prevention of electromagnetic interference, which can facilitate taking corrective measures once the design has been completed. These include installing shields and noise filters, and increasing the thickness of the power supply wiring patterns on the printed circuit board. One effective method, for example, is to devise several shielding options during design, and then select the most suitable shielding method based on the results of measurements taken after the prototype has been completed.

3.3.13 Peripheral Circuits

In most cases semiconductor devices are used with peripheral circuits and components. The input and output signal voltages and currents in these circuits must be chosen to match the semiconductor device's specifications. The following factors must be taken into account.

(1) Inappropriate voltages or currents applied to a device's input pins may cause it to operate erratically. Some devices contain pull-up or pull-down resistors. When designing your system, remember to take the effect of this on the voltage and current levels into account.

(2) The output pins on a device have a predetermined external circuit drive capability. If this drive capability is greater than that required, either incorporate a compensating circuit into your design or carefully select suitable components for use in external circuits.

3.3.14 Safety Standards

Each country has safety standards which must be observed. These safety standards include requirements for quality assurance systems and design of device insulation. Such requirements must be fully taken into account to ensure that your design conforms to the applicable safety standards.

3.3.15 Other Precautions

(1) When designing a system, be sure to incorporate fail-safe and other appropriate measures according to the intended purpose of your system. Also, be sure to debug your system under actual board-mounted conditions.

(2) If a plastic-package device is placed in a strong electric field, surface leakage may occur due to the charge-up phenomenon, resulting in device malfunction. In such cases take appropriate measures to prevent this problem, for example by protecting the package surface with a conductive shield.

(3) With some microcomputers and MOS memory devices, caution is required when powering on or resetting the device. To ensure that your design does not violate device specifications, consult the relevant databook for each constituent device.

(4) Ensure that no conductive material or object (such as a metal pin) can drop onto and short the leads of a device mounted on a printed circuit board.

3.4 Inspection, Testing and Evaluation

3.4.1 Grounding

⚠CAUTION

Ground all measuring instruments, jigs, tools and soldering irons to earth.
Electrical leakage may cause a device to break down or may result in electric shock.

3.4.2 Inspection Sequence

⚠CAUTION

1) Do not insert devices in the wrong orientation. Make sure that the positive and negative electrodes of the power supply are correctly connected. Otherwise, the rated maximum current or maximum power dissipation may be exc0eeded and the device may break down or undergo performance degradation, causing it to catch fire or explode, resulting in injury to the user.

2) When conducting any kind of evaluation, inspection or testing using AC power with a peak voltage of 42.4 V or DC power exceeding 60 V, be sure to connect the electrodes or probes of the testing equipment to the device under test before powering it on. Connecting the electrodes or probes of testing equipment to a device while it is powered on may result in electric shock, causing injury.

(1) Apply voltage to the test jig only after inserting the device securely into it. When applying or removing power, observe the relevant precautions, if any.

(2) Make sure that the voltage applied to the device is off before removing the device from the test jig. Otherwise, the device may undergo performance degradation or be destroyed.

(3) Make sure that no surge voltages from the measuring equipment are applied to the device.

(4) The chips housed in tape carrier packages (TCPs) are bare chips and are therefore exposed. During inspection take care not to crack the chip or cause any flaws in it.
Electrical contact may also cause a chip to become faulty. Therefore make sure that nothing comes into electrical contact with the chip.

3.5 Mounting

There are essentially two main types of semiconductor device package: lead insertion and surface mount. During mounting on printed circuit boards, devices can become contaminated by flux or damaged by thermal stress from the soldering process. With surface-mount devices in particular, the most significant problem is thermal stress from solder reflow, when the entire package is subjected to heat. This section describes a recommended temperature profile for each mounting method, as well as general precautions which you should take when mounting devices on printed circuit boards. Note, however, that even for devices with the same package type, the appropriate mounting method varies according to the size of the chip and the size and shape of the lead frame. Therefore, please consult the relevant technical datasheet and databook.

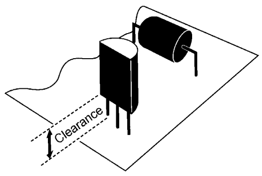
3.5.1 Lead Forming

⚠CAUTION

1) Always wear protective glasses when cutting the leads of a device with clippers or a similar tool. If you do not, small bits of metal flying off the cut ends may damage your eyes.
2) Do not touch the tips of device leads. Because some types of device have leads with pointed tips, you oay prick your finger.

Semiconductor devices must undergo a process in which the leads are cut and formed before the devices can be mounted on a printed circuit board. If undue stress is applied to the interior of a device during this process, mechanical breakdown or performance degradation can result. This is attributable primarily to differences between the stress on the device's external leads and the stress on the internal leads. If the relative difference is great enough, the device's internal leads, adhesive properties or sealant can be damaged. Observe these precautions during the lead-forming process (this does not apply to surface-mount devices):

(1) Lead insertion hole intervals on the printed circuit board should match the lead pitch of the device precisely.
(2) If lead insertion hole intervals on the printed circuit board do not precisely match the lead pitch of the device, do not attempt to forcibly insert devices by pressing on them or by pulling on their leads.
(3) For the minimum clearance specification between a device and a printed circuit board, refer to the relevant device's datasheet and databook. If necessary, achieve the required clearance by forming the device's leads appropriately. Do not use the spacers which are used to raise devices above the surface of the printed circuit board during soldering to achieve clearance. These spacers normally continue to expand due to heat, even after the solder has begun to solidify; this applies severe stress to the device.



(4) Observe the following precautions when forming the leads of a device prior to mounting.

- Use a tool or jig to secure the lead at its base (where the lead meets the device package) while bending so as to avoid mechanical stress to the device. Also avoid bending or stretching device leads repeatedly.
- Be careful not to damage the lead during lead forming.
- Follow any other precautions described in the individual datasheets and databooks for each device and package type.

3.5.2 Mounting on Printed Circuit Board

When soldering the leads on the printed circuit board, be careful not to leave stress on the leads.

Leads must be shaped and aligned to the hole size, and space must be left between the device and the board (Figure 3.6). If leads are not shaped but forced into holes or stress is applied by a tool, corrosion or whiskers may occur where stress is applied, resulting in cutout or shorting of leads. Thus, hole size must be aligned to the lead interval.

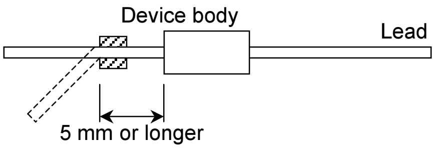


Figure 3.3 How to Bend Leads

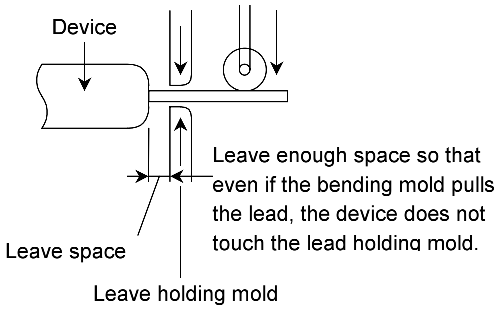


Figure 3.4 How to Bend Leads Using Metal Mold

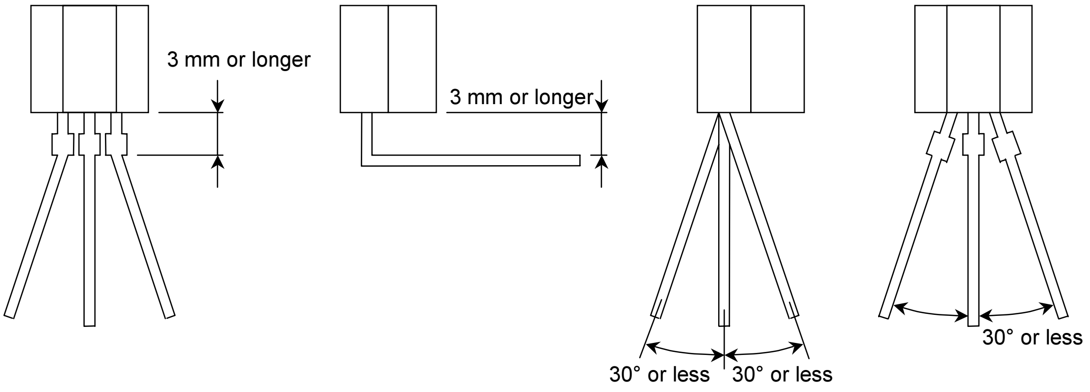


Figure 3.5 How to Bend Leads

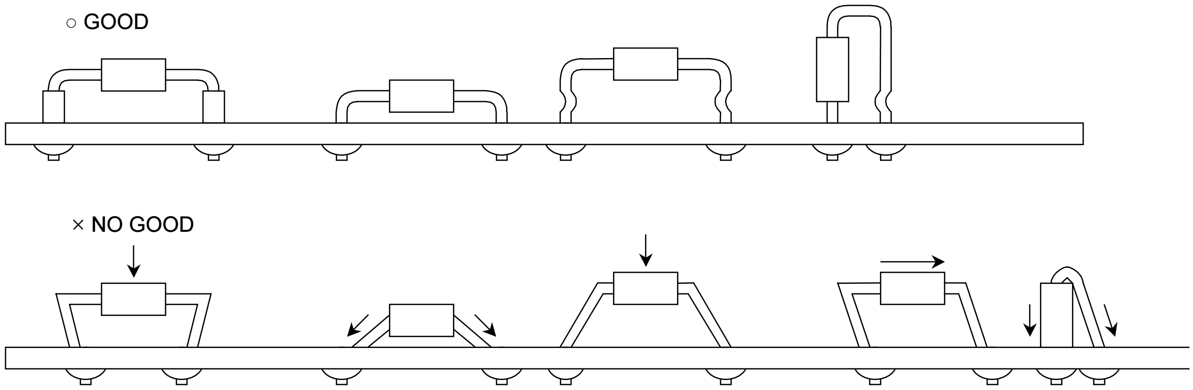


Figure 3.6 Example of Mounting on Printed-Circuit Board

3.5.3 Socket Mounting

(1) When socket mounting devices on a printed circuit board, use sockets which match the inserted device's package.

(2) Use sockets whose contacts have the appropriate contact pressure. If the contact pressure is insufficient, the socket may not make a perfect contact when the device is repeatedly inserted and removed; if the pressure is excessively high, the device leads may be bent or damaged when they are inserted into or removed from the socket.

(3) When soldering sockets to the printed circuit board, use sockets whose construction prevents flux from penetrating into the contacts or which allows flux to be completely cleaned off.

(4) Make sure the coating agent applied to the printed circuit board for moisture-proofing purposes does not stick to the socket contacts.

(5) If the device leads are severely bent by a socket as it is inserted or removed and you wish to repair the leads so as to continue using the device, make sure that this lead correction is only performed once. Do not use devices whose leads have been corrected more than once.

(6) If the printed circuit board with the devices mounted on it will be subjected to vibration from external sources, use sockets which have a strong contact pressure so as to prevent the sockets and devices from vibrating relative to one another.

3.5.4 Soldering Temperature Profile

The soldering temperature and heating time vary from device to device. Therefore, when specifying the mounting conditions, refer to the individual datasheets and databooks for the devices used.

(1) Using a soldering iron

Complete soldering within ten seconds for lead temperatures of up to 260°C, or within three seconds for lead temperatures of up to 350°C.

(2) Using medium infrared ray reflow

- Heating top and bottom with long or medium infrared rays is recommended (see Figure 3.7).

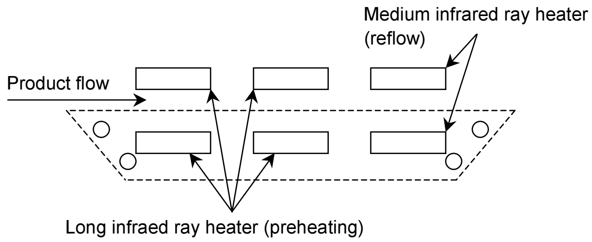


Figure 3.7 Heating Top and Bottom with Long or Medium Infrared Rays

- Complete the infrared ray reflow process within 30 seconds at a package surface temperature of between 210°C and 240°C.
- Refer to Figure 3.8 for an example of a good temperature profile for infrared or hot air reflow.

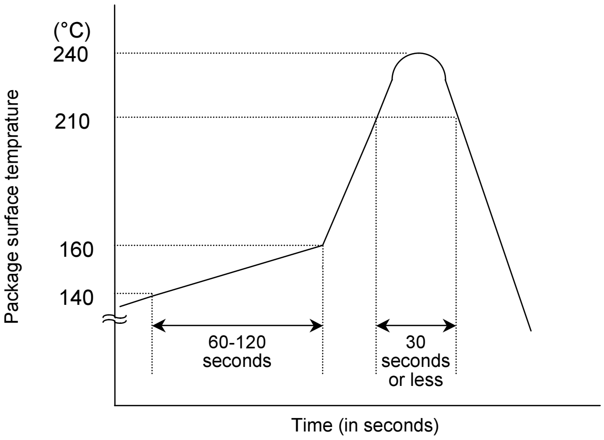


Figure 3.8 Sample Temperature Profile for Infrared or Hot Air Reflow

(3) Using hot air reflow

- Complete hot air reflow within 30 seconds at a package surface temperature of between 210°C and 240°C.
- For an example of a recommended temperature profile, refer to Figure 3.8 above.

(4) Using solder flow

- Apply preheating for 60 to 120 seconds at a temperature of 150°C.
- For lead insertion-type packages, complete solder flow within 10 seconds with the temperature at the stopper (or, if there is no stopper, at a location more than 1.5 mm from the body) which does not exceed 260°C.
- For surface-mount packages, complete soldering within 5 seconds at a temperature of 250°C or less in order to prevent thermal stress in the device.

- Figure 3.9 shows an example of a recommended temperature profile for surface-mount packages using solder flow.

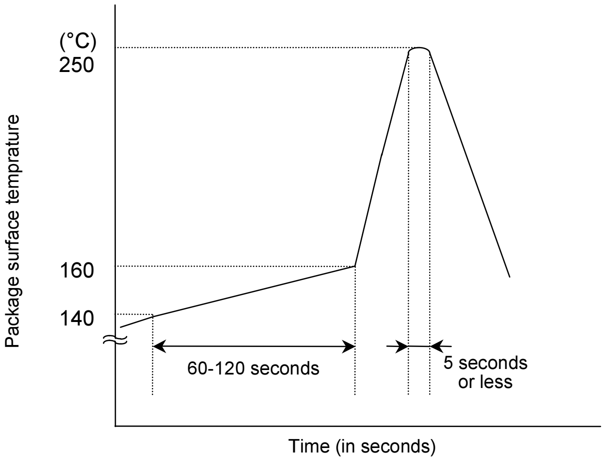


Figure 3.9 Sample Temperature Profile for Solder Flow

3.5.5 Flux Cleaning and Ultrasonic Cleaning

(1) When cleaning circuit boards to remove flux, make sure that no residual reactive ions such as Na or Cl remain. Note that organic solvents react with water to generate hydrogen chloride and other corrosive gases which can degrade device performance.

(2) Washing devices with water will not cause any problems. However, make sure that no reactive ions such as sodium and chlorine are left as a residue. Also, be sure to dry devices sufficiently after washing.

(3) Do not rub device markings with a brush or with your hand during cleaning or while the devices are still wet from the cleaning agent. Doing so can rub off the markings.

(4) The dip cleaning, shower cleaning and steam cleaning processes all involve the chemical action of a solvent. Use only recommended solvents for these cleaning methods. When immersing devices in a solvent or steam bath, make sure that the temperature of the liquid is 50°C or below, and that the circuit board is removed from the bath within one minute.

(5) Ultrasonic cleaning should not be used with hermetically-sealed ceramic packages such as a leadless chip carrier (LCC), pin grid array (PGA) or charge-coupled device (CCD), because the bonding wires can become disconnected due to resonance during the cleaning process. Even if a device package allows ultrasonic cleaning, limit the duration of ultrasonic cleaning to as short a time as possible, since long hours of ultrasonic cleaning degrade the adhesion between the mold resin and the frame material. The following ultrasonic cleaning conditions are recommended:

Frequency: 27 kHz to 29 kHz
Ultrasonic output power: 300 W or less (0.25 W/cm^2 or less)
Cleaning time: 30 seconds or less

Suspend the circuit board in the solvent bath during ultrasonic cleaning in such a way that the ultrasonic vibrator does not come into direct contact with the circuit board or the device.

3.5.6 No Cleaning

If analog devices or high-speed devices are used without being cleaned, flux residues may cause minute amounts of leakage between pins. Similarly, dew condensation, which occurs in environments containing residual chlorine when power to the device is on, may cause between-lead leakage or migration. Therefore, Toshiba recommends that these devices be cleaned.

However, if the flux used contains only a small amount of halogen (0.05 W% or less), the devices may be used without cleaning without any problems.

3.5.7 Mounting Tape Carrier Packages (TCPs)

(1) When tape carrier packages (TCPs) are mounted, measures must be taken to prevent electrostatic breakdown of the devices.

(2) If devices are being picked up from tape, or outer lead bonding (OLB) mounting is being carried out, consult the manufacturer of the insertion machine which is being used, in order to establish the optimum mounting conditions in advance and to avoid any possible hazards.

(3) The base film, which is made of polyimide, is hard and thin. Be careful not to cut or scratch your hands or any objects while handling the tape.

(4) When punching tape, try not to scatter broken pieces of tape too much.

(5) Treat the extra film, reels and spacers left after punching as industrial waste, taking care not to destroy or pollute the environment.

(6) Chips housed in tape carrier packages (TCPs) are bare chips and therefore have their reverse side exposed. To ensure that the chip will not be cracked during mounting, ensure that no mechanical shock is applied to the reverse side of the chip. Electrical contact may also cause a chip to fail. Therefore, when mounting devices, make sure that nothing comes into electrical contact with the reverse side of the chip.
If your design requires connecting the reverse side of the chip to the circuit board, please consult Toshiba or a Toshiba distributor beforehand.

3.5.8 Mounting Chips

Devices delivered in chip form tend to degrade or break under external forces much more easily than plastic-packaged devices. Therefore, caution is required when handling this type of device.

(1) Mount devices in a properly prepared environment so that chip surfaces will not be exposed to polluted ambient air or other polluted substances.

(2) When handling chips, be careful not to expose them to static electricity.
In particular, measures must be taken to prevent static damage during the mounting of chips. With this in mind, Toshiba recommend mounting all peripheral parts first and then mounting chips last (after all other components have been mounted).

(3) Make sure that PCBs (or any other kind of circuit board) on which chips are being mounted do not have any chemical residues on them (such as the chemicals which were used for etching the PCBs).

(4) When mounting chips on a board, use the method of assembly that is most suitable for maintaining the appropriate electrical, thermal and mechanical properties of the semiconductor devices used.

*: For details of devices in chip form, refer to the relevant device’s individual datasheets.

3.5.9 Circuit Board Coating

When devices are to be used in equipment requiring a high degree of reliability or in extreme environments (where moisture, corrosive gas or dust is present), circuit boards may be coated for protection. However, before doing so, you must carefully consider the possible stress and contamination effects that may result and then choose the coating resin which results in the minimum level of stress to the device.

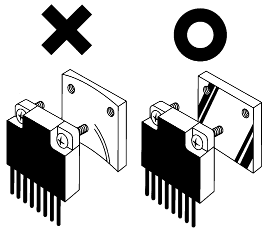
3.5.10 Heat Sinks

(1) When attaching a heat sink to a device, be careful not to apply excessive force to the device in the process.

(2) When attaching a device to a heat sink by fixing it at two or more locations, evenly tighten all the screws in stages (i.e. do not fully tighten one screw while the rest are still only loosely tightened). Finally, fully tighten all the screws up to the specified torque.

(3) Drill holes for screws in the heat sink exactly as specified. Smooth the surface by removing burrs and protrusions or indentations which might interfere with the installation of any part of the device.

(4) A coating of silicone compound can be applied between the heat sink and the device to improve heat conductivity. Be sure to apply the coating thinly and evenly; do not use too much. Also, be sure to use a non-volatile compound, as volatile compounds can crack after a time, causing the heat radiation properties of the heat sink to deteriorate.



(5) If the device is housed in a plastic package, use caution when selecting the type of silicone compound to be applied between the heat sink and the device. With some types, the base oil separates and penetrates the plastic package, significantly reducing the useful life of the device. Two recommended silicone compounds in which base oil separation is not a problem are YG6260 from Toshiba Silicone.

(6) Heat-sink-equipped devices can become very hot during operation. Do not touch them, or you may sustain a burn.

3.5.11 Tightening Torque

(1) Make sure the screws are tightened with fastening torques not exceeding the torque values stipulated in individual datasheets and databooks for the devices used.

(2) Do not allow a power screwdriver (electrical or air-driven) to touch devices.

3.5.12 Repeated Device Mounting and Usage

Do not remount or re-use devices which fall into the categories listed below; these devices may cause significant problems relating to performance and reliability.

(1) Devices which have been removed from the board after soldering
(2) Devices which have been inserted in the wrong orientation or which have had reverse current applied
(3) Devices which have undergone lead forming more than once

3.6 Protecting Devices in the Field

3.6.1 Temperature

Semiconductor devices are generally more sensitive to temperature than are other electronic components. The various electrical characteristics of a semiconductor device are dependent on the ambient temperature at which the device is used. It is therefore necessary to understand the temperature characteristics of a device and to incorporate device derating into circuit design. Note also that if a device is used above its maximum temperature rating, device deterioration is more rapid and it will reach the end of its usable life sooner than expected.

3.6.2 Humidity

Resin-molded devices are sometimes improperly sealed. When these devices are used for an extended period of time in a high-humidity environment, moisture can penetrate into the device and cause chip degradation or malfunction. Furthermore, when devices are mounted on a regular printed circuit board, the impedance between wiring components can decrease under high-humidity conditions. In systems which require a high signal-source impedance, circuit board leakage or leakage between device lead pins can cause malfunctions. The application of a moisture-proof treatment to the device surface should be considered in this case. On the other hand, operation under low-humidity conditions can damage a device due to the occurrence of electrostatic discharge. Unless damp-proofing measures have been specifically taken, use devices only in environments with appropriate ambient moisture levels (i.e. within a relative humidity range of 40% to 60%).

3.6.3 Corrosive Gases

Corrosive gases can cause chemical reactions in devices, degrading device characteristics.

For example, sulphur-bearing corrosive gases emanating from rubber placed near a device (accompanied by condensation under high-humidity conditions) can corrode a device’s leads. The resulting chemical reaction between leads forms foreign particles which can cause electrical leakage.

3.6.4 Radioactive and Cosmic Rays

Most industrial and consumer semiconductor devices are not designed with protection against radioactive and cosmic rays. Devices used in aerospace equipment or in radioactive environments must therefore be shielded.

3.6.5 Strong Electrical and Magnetic Fields

Devices exposed to strong magnetic fields can undergo a polarization phenomenon in their plastic material, or within the chip, which gives rise to abnormal symptoms such as impedance changes or increased leakage current. Failures have been reported in LSIs mounted near malfunctioning deflection yokes in TV sets. In such cases the device's installation location must be changed or the device must be shielded against the electrical or magnetic field. Shielding against magnetism is especially necessary for devices used in an alternating magnetic field because of the electromotive forces generated in this type of environment.

3.6.6 Interference from Light (ultraviolet rays, sunlight, fluorescent lamps and incandescent lamps)

Light striking a semiconductor device generates electromotive force due to photoelectric effects. In some cases the device can malfunction. This is especially true for devices in which the internal chip is exposed. When designing circuits, make sure that devices are protected against incident light from external sources. This problem is not limited to optical semiconductors and EPROMs. All types of device can be affected by light.

3.6.7 Dust and Oil

Just like corrosive gases, dust and oil can cause chemical reactions in devices, which will adversely affect a device's electrical characteristics. To avoid this problem, do not use devices in dusty or oily environments. This is especially important for optical devices because dust and oil can affect a device's optical characteristics as well as its physical integrity and the electrical performance factors mentioned above.

3.6.8 Fire

Semiconductor devices are combustible; they can emit smoke and catch fire if heated sufficiently. When this happens, some devices may generate poisonous gases. Devices should therefore never be used in close proximity to an open flame or a heat-generating body, or near flammable or combustible materials.

3.7 Disposal of Devices and Packing Materials

When discarding unused devices and packing materials, follow all procedures specified by local regulations in order to protect the environment against contamination.

4. Precautions and Usage Considerations Specific to Each Product Group

This section describes matters specific to each product group which need to be taken into consideration when using devices.

4.1 Bipolar Ics

4.1.1 ICs for Use in Automobiles

(1) Design

⚠CAUTION

1) If your design includes an inductive load such as a motor coil, incorporate diodes into your design to prevent negative current from flowing in. Otherwise the device may malfunction or break down due to rush currents or counter electromotive force generated when the device is powered on and off. For information on how to connect the diodes, refer to the relevant individual datasheets for automobile ICs. Breakdown of the devices may result in injury.
2) Ensure that the power supply to any device which incorporates protective functions is stable. If the power supply is unstable, the device may operate erratically, preventing the protective functions from working correctly.
   If protective functions fail, the device may break down, causing the device to explode and resulting in injury to the user.

- Heat radiation

  System power supply and driver ICs generate heat. When using these devices, refer to the technical databooks entitled Bipolar ICs for Use in Automobiles and General-Purpose Bipolar IC Databook, and incorporate sufficient heat radiation for the devices used into your design, so that the heat generated will not exceed the stipulated junction temperature (Tj) at which the ICs' internal heat-isolating protective circuits are activated.
- Power supply fuses

  These ICs contain various protective circuits to prevent them from breaking down due to faulty wiring or when pulses of noise are input to the power supply. However, should the IC break down, a large current may continue to flow. To prevent this, use a fuse of the appropriate capacity for the power supply.

  For information about the various types of protective circuit incorporated into the ICs, refer to the individual datasheets for the devices used.
- Power supply

  Do not abruptly increase or decrease the power supply to a device.

(2) Mounting

- Heat sinks

  Depending on the type of package used (e.g. an HSIP7-P-2.54), a device's characteristics may be degraded if the package is attached to a heat sink using screws. In such cases please consult Toshiba or a Toshiba distributor.

4.1.2 Communication Equipment ICs

(1) Design

When using these devices in power amps or system power supplies, be aware that since the effective current capacity of the output pins is 100 mA or higher, a device's DC output current may increase if there is any problem caused by an external component (in particular, leak current from a feedback resistor or a negative feedback capacitor). In some cases this will cause the product to generate heat or to catch fire. Take this into account when designing your product and choosing which components to use. For more detailed information, please refer to the individual datasheets or databooks.

(2) Mounting

Trends toward lightweight and compact design in mobile communications have resulted in the device-mounting board becoming vulnerable to distortion or deformation due to a lack of strength. This causes the devices to be imperfectly connected when mounted on the board. Therefore, carefully examine the board design and mounting methods to ensure that device pins are firmly connected to the board.

4.1.3 Audio/Video Equipment ICs

These devices are designed for use in consumer electronics, typically in television and audio equipment. When using these devices in low-frequency audio amps, system power supply ICs, driver ICs or power ICs, pay attention to the following points:

(1) Design

- Circuit design

  Large leakage current in input or negative feedback capacitors causes the DC output voltage of power ICs to increase. In this case, if the speaker's DC input withstand voltage is low, the speaker may emit smoke or catch fire.

  This must be fully taken into account when selecting the types of capacitor and speaker to use, especially in the case of power ICs of the BTL (bridge-tied load) connection type, in which the DC output voltage is input directly to the speaker.

- Heat radiation

  Power ICs, system power supply ICs and driver ICs generate heat. When using these devices, and incorporate sufficient heat radiation for the devices used into your design, so that the heat generated will not exceed the stipulated junction temperature (Tj = 150°C) at which the ICs' internal thermal shutdown protective circuits are activated. For more detailed information, refer to the individual product datasheets and to the general audio/car audio LSI databooks.

  Also, take into account the operating temperature ranges and characteristics of the peripheral components used with power ICs.

- Power supply fuses

  These ICs contain various protective circuits to prevent them from breaking down due to faulty wiring or noise pulses on the power supply input. However, should the IC break down, a large current may continue to flow. To prevent this, use a fuse of the appropriate capacity for the power supply.

4.1.4 ICs for Motors

(1) Design

- When designing a circuit incorporating a motor, be sure to incorporate a diode to act as a current-limiting resistance and to absorb any counter electromotive force so that the starting current or counter electromotive force does not cause any malfunction or breakdown in the IC. For detailed information concerning this type of design, refer to the relevant individual datasheets or databooks for ICs for motors.
- Circuits which are used to protect ICs from excessive current do not always work. If an IC is used outside its absolute maximum ratings, the IC may break down before the protective circuit is activated.
- Be sure to use a stable power supply for the IC. If the power supply is unstable, the internal circuits of the IC may function erratically, possibly causing the IC to break down.

(2) Heat radiation

- When using a driver IC, be sure to incorporate heat radiation so that the junction temperature (Tj) will never exceed 150°C. Since ICs generate considerable heat, ICs may break down if adequate heat radiation is not provided.
- Circuits which are used to protect devices from excessive heat do not always work. If an IC is used outside its absolute maximum ratings, it may break down before the protective circuit is activated.
- When attaching a heat sink to the driver IC, avoid excessive mechanical stress. Also note that some ICs inhibit the action of silicone rubber.
- When incorporating heat radiation or attaching heat sinks, refer to the relevant individual datasheets or databooks for ICs for motors.

(3) Power supply fuses

In order to prevent excessive current from flowing continuously when the IC breaks down, use a power supply fuse of an appropriate capacity. An IC may break down when used outside its absolute maximum ratings, or when wires or loads induce unusual pulse noise. The fuse capacity must be carefully determined in order to minimize any negative effect in the case of an IC breakdown and the resulting large current flow.

4.1.5 Cautions about Power Dissipation (Constant State)

A transistor by itself will often differ from a board- mounted transistor in its power dissipation characteristics. Changes in power dissipation for representative package types, due to board mounting, are described below.

Each representative package type and the power dissipation change is explained below.

4.1.5.1 Super-Mini Transistors

Allowable power dissipation of a super-mini transistor is 100 to 150 mW as a single unit.

However, when it is mounted on a ceramic board, this value increases depending on the board size. this is shown in Figure 4.1 (transistors used: 2SA1162 and 2SC2712).

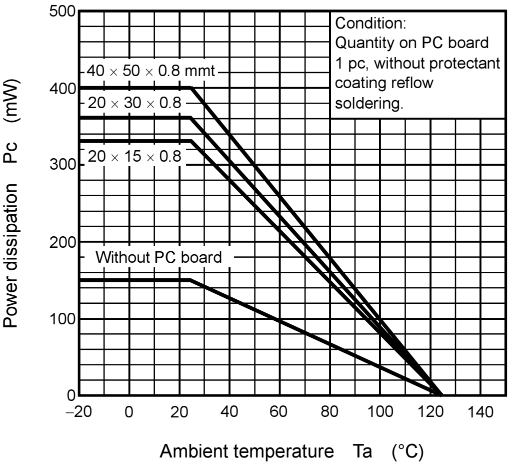


Figure 4.1 Pc (max) when Mounted on Alumi-Ceramic Board
Ta Characteristic (2SA1162, 2SC2712)

4.1.5.2 Power-Mini Transistors

Since power-mini transistors are of compact size, Pcmax is only 500 mW; however, when they are mounted on a circuit board, thermal diffusion from a drain fin to the board will be high. The drain power dissipation will then range from 1.0 W to 2.0 W, and a circuit design capability equivalent to that of the TO-92MOD (800 to 900 mW) or TO-126 (1.0 to 1.2 W) is possible. Figure 4.2 shows the drain power dissipation for a typical case of circuit-board mounting of a 2SC2873 or 2SA1213.

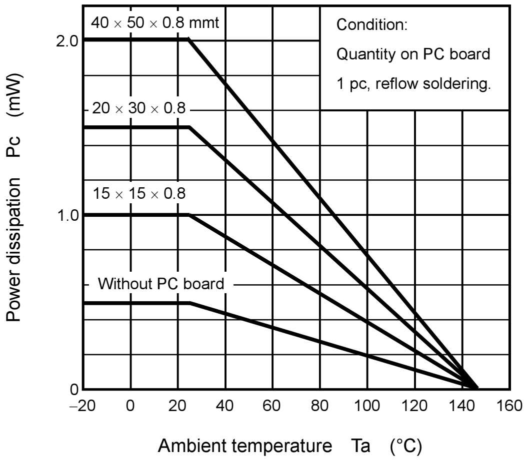


Figure 4.2 Pc (max) when Mounted on Alumi-Ceramic Board
Ta Characteristic (2SC2873, 2SA1213)

4.1.5.3 Power-Mold Transistors

For straight-type power-mold transistors, the power dissipation (Pc) = 1 W However, when LB-type transistors have a drain-fin, their installed power dissipation increases significantly. When a power-mold transistor is soldered to an alumina-ceramic board, Pc (1) (1,000 mm^2) = 2 W, Pc (2) (2,500 mm^2) = 3 W Figure 4.3 show the relationship between drain power dissipation Pc and ambient temperature Ta for the transistors 2SC3074 and 2SA1244.

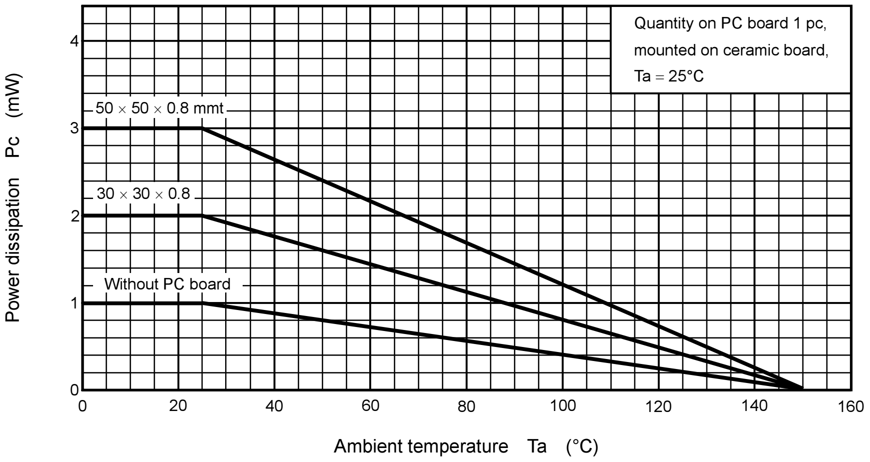


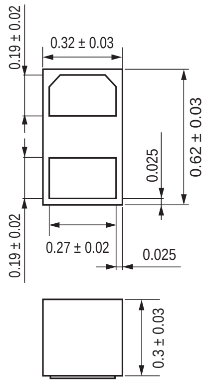
Figure 4.3 Power Dissipation Pc and Ambient Temperature Ta when Transistors are Mounted on Alumina-Ceramic Boards (for 2SC3074 and 2SA1244 devices)

[9]　Package Dimensions

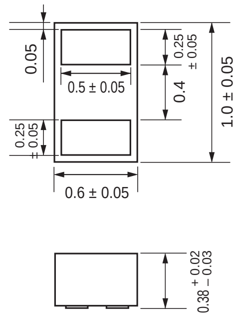
[9] Package Dimensions

Unit: mm

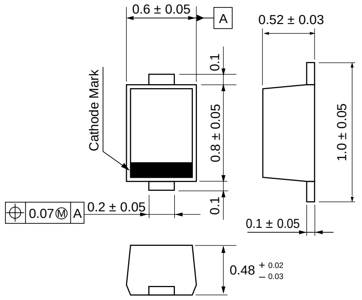
SC2



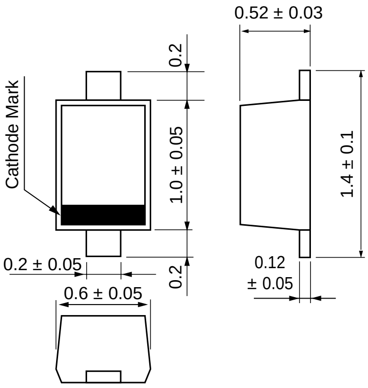
CST2



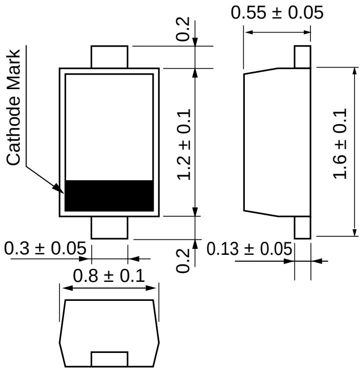
fSC



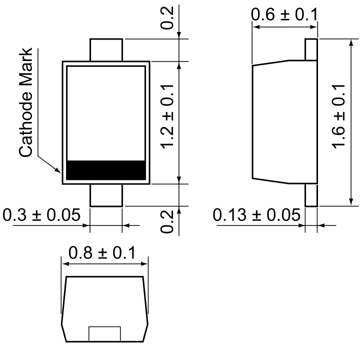
sESC



TESC



ESC



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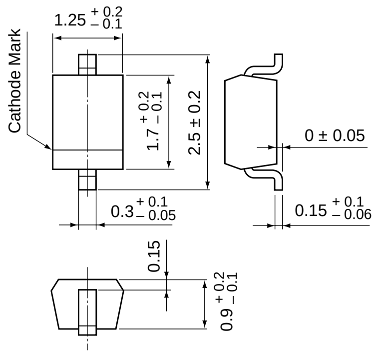

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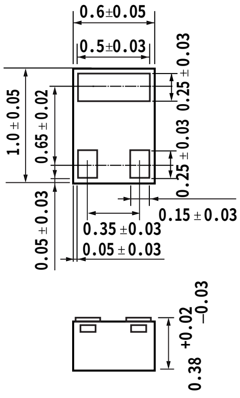
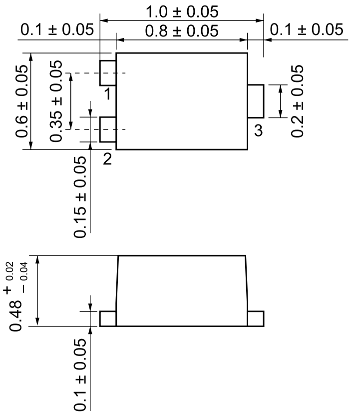
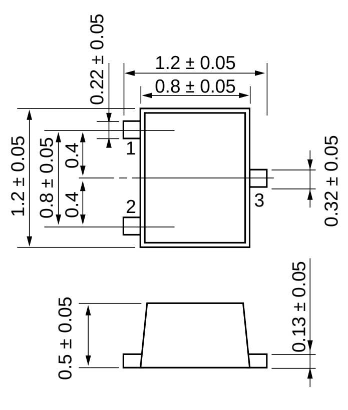


fSM

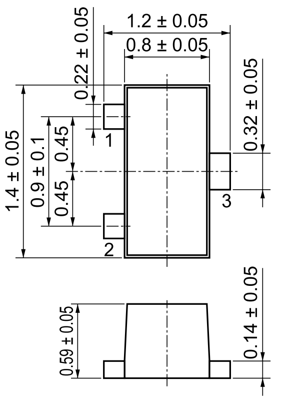


Unit: mm

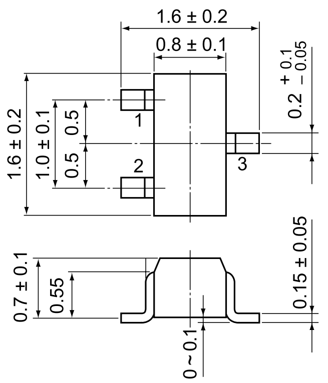
VESM



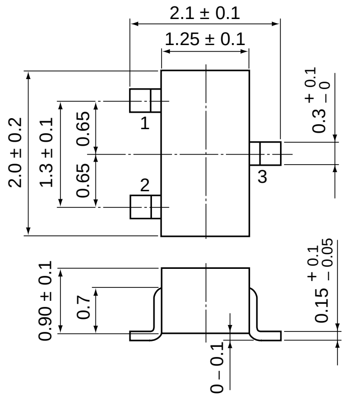
TESM



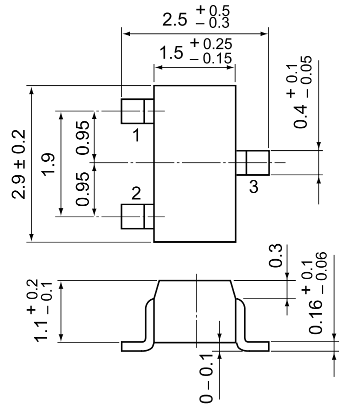
SSM



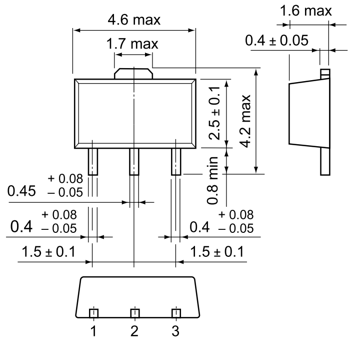
USM



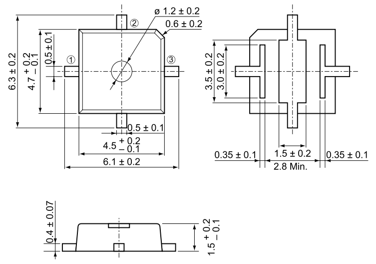
S-MINI



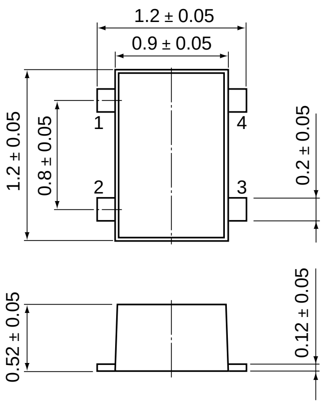
PW-MINI



PW-X



TESQ



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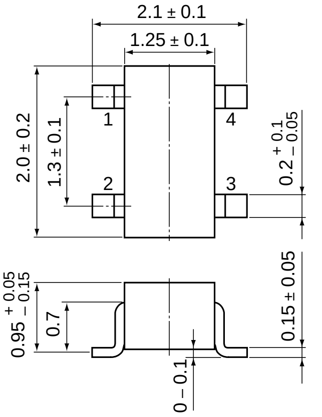
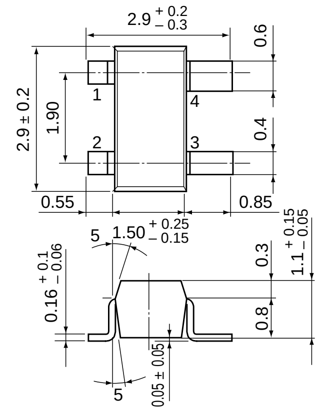
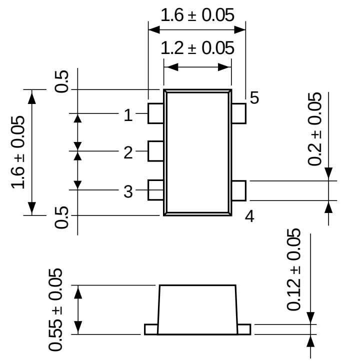


Unit: mm

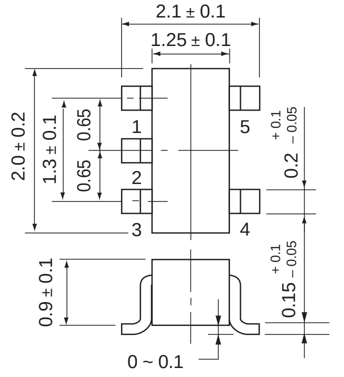
SMQ



ESV



USV



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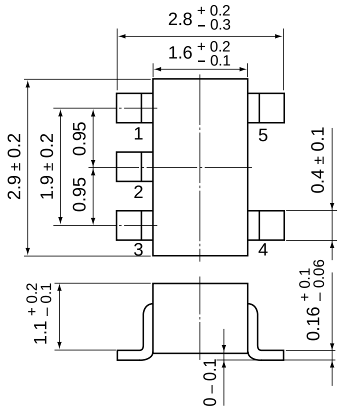
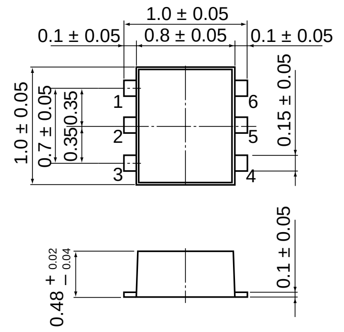
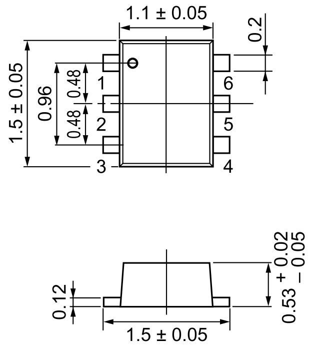


fS6



sES6



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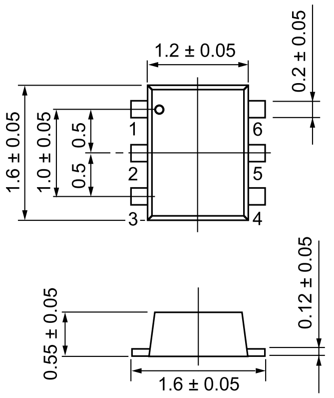

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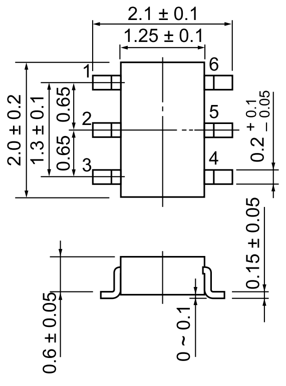

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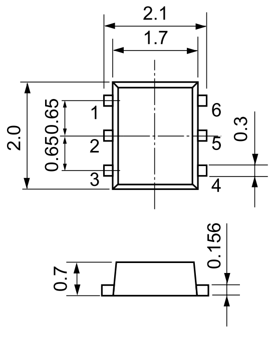

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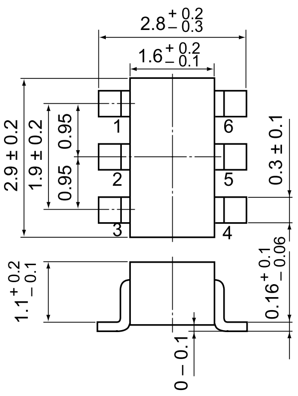
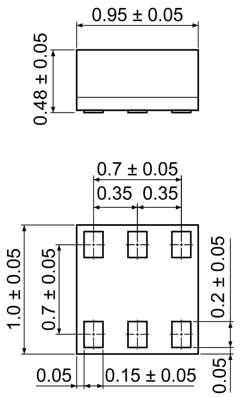
SM6



CS6



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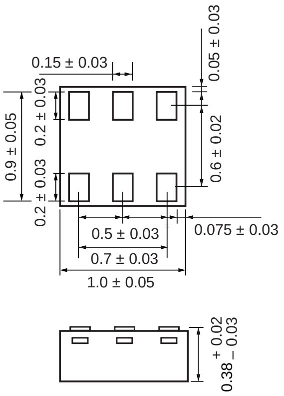

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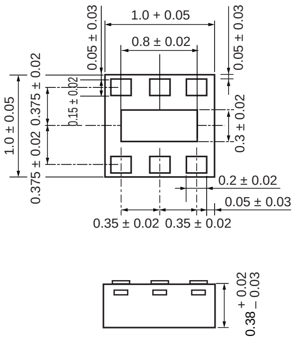
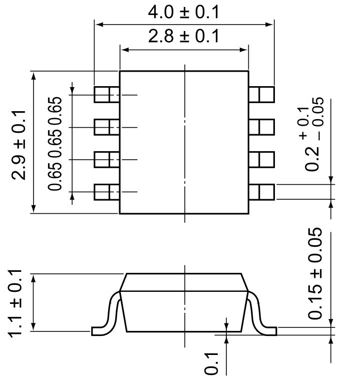


SM8



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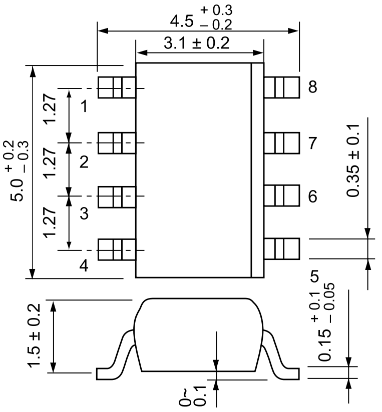

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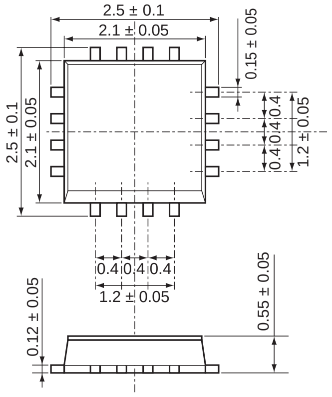

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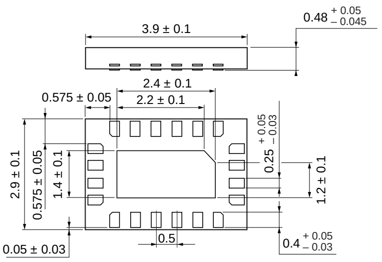
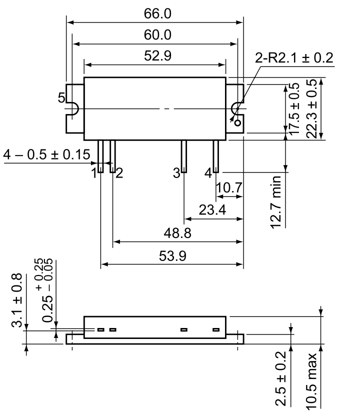
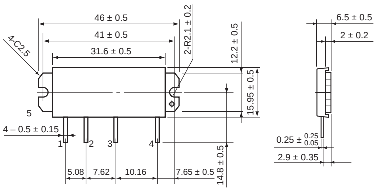


5-53P



Unit: mm

5-32F



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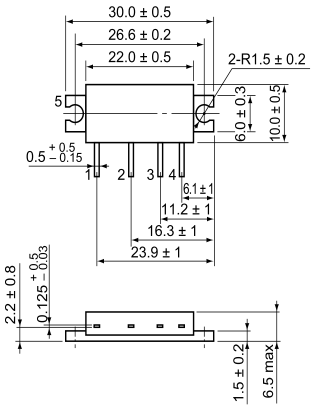

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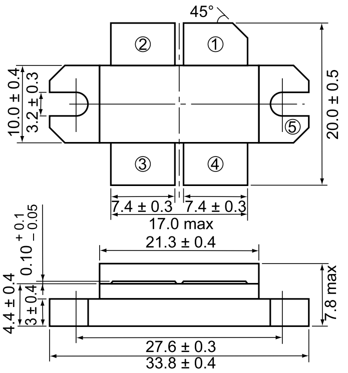

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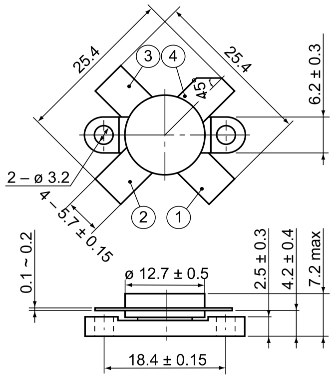

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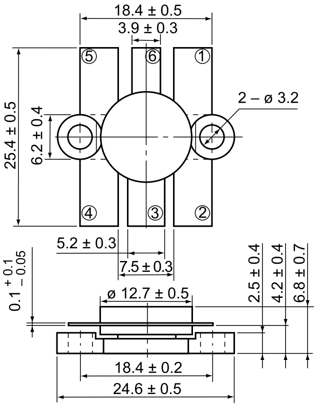

[10] List of Final-Phase Products

[10] List of Final-Phase Products

The following listed products will soon be discontinued. Refer to the recommended replacement devices in the adjacent column.

Final-Phase Products

Part Number	Recommended Replacement	Part Number	Recommended Replacement	Part Number	Recommended Replacement
1S2186	1SS341	2SC5313	—	MT6P03AE	—
1S2236	1SV160	2SC5317	MT3S07T	MT6P03AT	—
1SS238	1SS312, 1SS314	2SK3179	—	MT6P04AE	—
1SS239	1SS154, 1SS271	3SK240	—	MT6P04AT	—
1SS241	1SS314, 1SS381	3SK250	—	S-AU26	—
1SS242	1SS315, 1SS295	3SK274	—	S-AU27AL	S-AU83L
1SV149	—	3SK283	—	S-AU27AM	S-AU83H
1SV153	1SV214	3SK284	—	S-AU27AH	S-AU83H
1SV153A	—	3SK320	—	S-AU35AH	—
1SV161	1SV215	3SK59	3SK126	S-AV6	S-AV35
1SV186	1SV245	HN3C07F	—	S-AV7	S-AV33
1SV204	1SV216	HN3C08F	—	S-AV10L	S-AV33
1SV211	1SV262	HN3C10F	—	S-AV10H	S-AV33
1SV212	1SV229	HN3C13FU	—	S-AV17	S-AV36
1SV217	1SV262	HN3C14FT	—	S-AV22A	—
1SV224	1SV230	HN9C02FT		TA4006F	—
JDV2S10T	JDV2S10S	HN9C03FT		TA4007F	—
2SC2348	—	HN9C07FT	—	TA4008F	TA4011FU, TA4011AFE
2SC2509	—	HN9C10FT	—	TA4009F	TA4012FU, TA4012AFE
2SC2548	—	HN9C13FT	—	TA4011F	TA4011FU, TA4011AFE
2SC2644	—	HN9C16FT	—	TA4012F	TA4012FU, TA4012AFE
2SC3011	—	HN9C18FT	—	TA4013FU	—
2SC3122	—	HN9C19FT	—	TA4102F	—
2SC3602	—	HN9C21FT	—	TA4103F	—
2SC3662	—	HN9C22FT	—	TA4300F	—
2SC3745	—	MT3S01T	MT3S11T	TA4301F	—
2SC3828	—	MT3S02T	MT3S11T	TG2000F	—
2SC4200	—	MT3S31T	—	TG2003V	—
2SC4201	—	MT3S46T	—	TG2202F	—
2SC4249	—	MT3S46FS	—	TG2205F	TG2216TU
2SC4255	2SC4252	MT4S34U	—	TG2206F	TG2216TU
2SC4392	2SC5107	MT6L69FS	—		
2SC5312	—	MT6L70FS	—		

[11] List of Discontinued Products

[11] List of Discontinued Products

The following listed products have been discontinued. Refer to the recommended replacement devices in the adjacent column.

Discontinued Products

Part Number	Recommended Replacement
1S2094	—
1S2187	1SS315
1SS42	—
1SS148	—
1SS155	1SS314
1SS240	—
1SV100	—
1SV123	1SV214
1SV158	1SV215
1SV226	1SV288
1SV238	1SV269
1SV255	—
1SV256	1SV216
1SV257	1SV279
1SV258	—
1SV260	1SV280
1SV261	1SV309
1SV274	1SV282
1SV275	1SV283
2SC381TM	2SC1923
2SC381TMA	2SC1923
2SC382	—
2SC382TM	—
2SC384	2SC1923
2SC385	2SC2349
2SC385A	2SC2349
2SC385ATM	2SC2349
2SC386	2SC2349
2SC386A	2SC2349
2SC387	2SC2347
2SC387A	2SC2347
2SC387A (G)	2SC2347
2SC387A (G) TM	2SC2347
2SC387ATM	2SC2347
2SC389	2SC1923
2SC389A	2SC1923
2SC390	2SC2347
2SC391	2SC2347
2SC391A	2SC2347
2SC392	2SC2498
2SC392A	2SC2347
2SC393	—
2SC396	2SC1923
2SC397	2SC2347
2SC784	2SC1923
2SC784TM	2SC1923
2SC784TMA	2SC1923
2SC785	2SC1923
2SC786	2SC1923
2SC787	—
2SC864	2SC383TM
2SC941	2SC941TM
2SC1236	2SC5084
2SC1558	2SC5087
2SC1559	2SC5087
2SC1743	2SC5087
2SC2099	—
2SC2114	—
2SC2115	—
2SC2328	—
2SC2395	—
2SC2531	—
2SC2638	—
2SC2639	—
2SC2640	—
2SC2641	—
2SC2642	—
2SC2643	—
2SC2652	—
2SC2663	2SC5087
2SC2783	—
2SC2805	2SC3121
2SC2876	2SC5087
2SC3006	—
2SC3147	—
2SC3301	2SC3607
2SC3302	2SC5087
2SC3445	2SC5084
2SC3608	MT4S04
2SC4316	2SC5089
2SC4318	—
2SC4319	MT4S03
2SC4323	2SC5097
2SK19	2SK192A
2SK19TM	2SK192A
2SK61	2SK161
2SK61LV	2SK161
2SK192	2SK192A
2SK1028	—
2SK1310	2SK1310A
2SK1739	2SK1739A
2SK2496	—
2SK2497	—
2SK2856	—
2SK3276	—
3SK22	—
3SK23	2SK192A
3SK28	2SK192A
3SK73	3SK195
3SK77	—
3SK78	3SK195
3SK90	—
3SK101	3SK195
3SK102	—
3SK112	—

Part Number	Recommended Replacement	Part Number	Recommended Replacement	Part Number	Recommended Replacement
3SK114	3SK126	S1255	2SC2644	S-AV24	—
3SK115	3SK291	S1256	2SC2644	S-AV26H	—
3SK121	—	S1297	2SC2498	S-AV28	—
3SK140	—	S2531	2SC2498	S-AV29H	—
3SK145	3SK291	S2676	—	S-AV30H	—
3SK146	3SK232	S9A61	—	TG2002V	—
3SK152	3SK292	S-AU6L	—	TG2005F	TG2006F
3SK159	3SK292	S-AU6VL	—	TG2200AF	TG2216TU
3SK160	3SK225	S-AU39	—	TG2200F	TG2216TU
3SK198	3SK291	S-AU64	—	TG2203F	TG2210FT
DLP238	1SS314	S-AU80	—	TG2204F	TG2216TU