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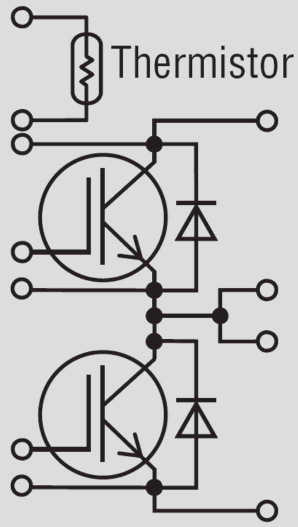

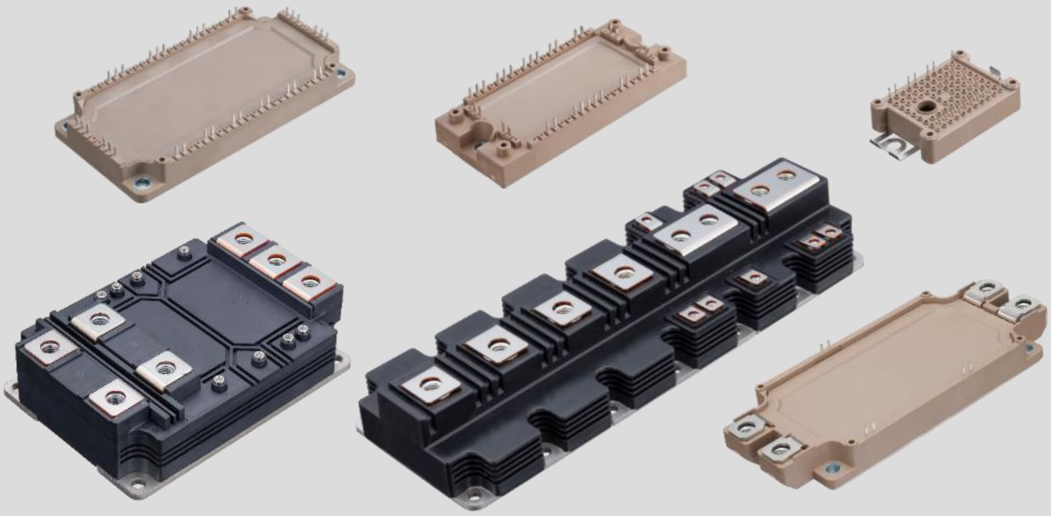

Using the NTC thermistor

Technical Document

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CONTENTS

IGBT Modules have products with a NTC thermistor inside. The purpose of this thermistor is temperature detection in thermal equilibrium state such as during steady-state operation.

This document describes the basic characteristics of the thermistor and the temperature detection method.

1. Module internal structure and thermal flow

1.1 Module internal structure

As shown in Fig. 1, NTC thermistor is mounted at an adjoining location on the same DCB board as the chip for accurate temperature sensing.

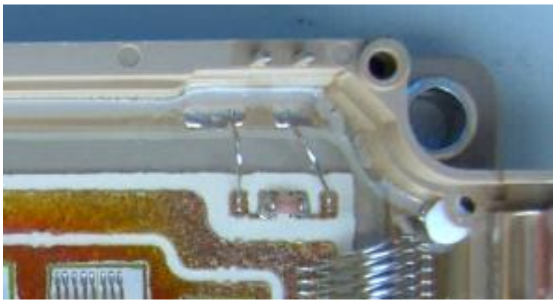

Fig.1 Example of the internal structure of an IGBT module with a NTC thermistor

1.2 Thermal flow within a module

The thermal conduction is replaced by the equivalent circuit shown in Fig. 2.

Since there is a thermal resistance $R_{th(j\text{-}NTC)}$ between the chip and thermistor, the thermistor temperature T_{NTC} will be at a lower temperature than the junction temperature T_{vj}.

$R_{th(j\text{-}NTC)}$ depends on the thermal conductivity and thickness of the thermal grease, the thermal conductivity and dimensions of the heat sink, etc.

Also, there is a thermal resistance $R_{th(c\text{-}NTC)}$ between the case and thermistor, so the case temperature T_c and thermistor temperature T_{NTC} are not the same temperature.

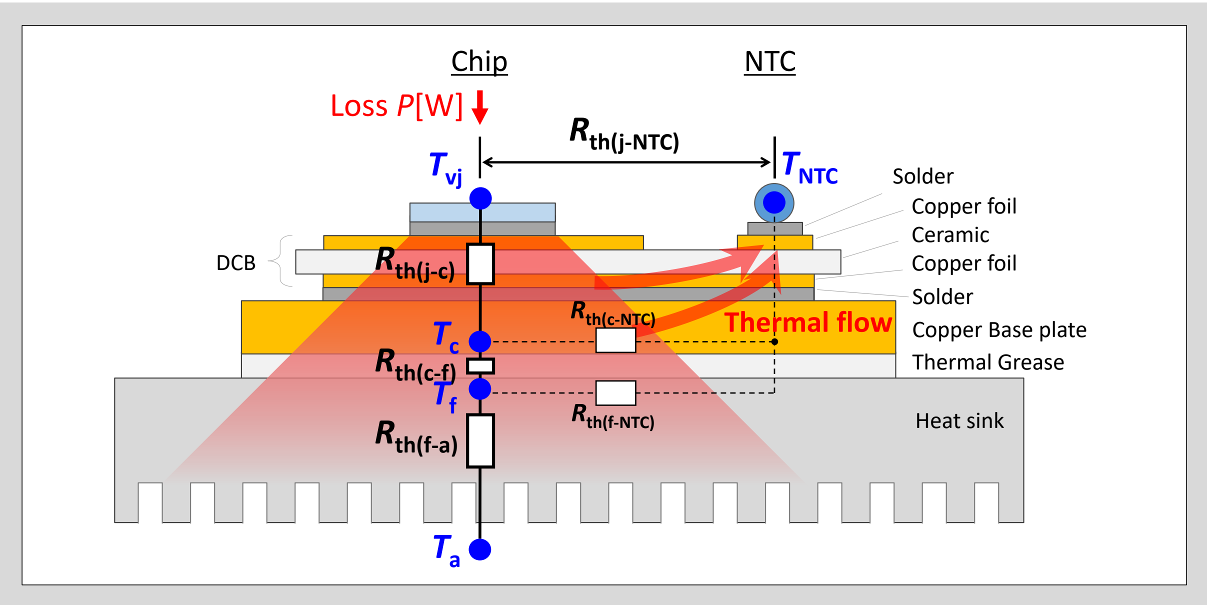

Fig.2 Image and equivalent circuit of thermal model

T_{vj} : Junction temperature
T_c : Case temperature (Copper base surface temperature directly below the chip)
T_f : Heatsink temperature (Heatsink temperature directly below the chip)
T_a : Ambient temperature
T_{NTC} : NTC thermistor temperature
P : Device generated losses

$R_{th(j\text{-}c)}$: Thermal resistance junction to case
$R_{th(c\text{-}f)}$: Thermal resistance case to heatsink
$R_{th(f\text{-}a)}$: Thermal resistance heatsink to ambient
$R_{th(j\text{-}NTC)}$: Thermal resistance junction to NTC thermistor
$R_{th(c\text{-}NTC)}$: Thermal resistance case to NTC thermistor

2. Basic characteristics of NTC thermistor

2.1 Resistance

The resistance of NTC thermistor decreases exponentially with temperature, as shown in Fig. 3. The resistance can be expressed by formula (1).

$$R_1 = R_0 \exp B\left(\frac{1}{T_1} - \frac{1}{T_0}\right) \quad \cdots\cdots(1)$$

R_0 : Resistance at absolute temperature T_0 [K]
R_1 : Resistance at absolute temperature T_1 [K]
B : B value

*Absolute temperature T[K]=t [°C]+273.15

Resistance under certain conditions are listed in the data sheet as shown in Table 1.

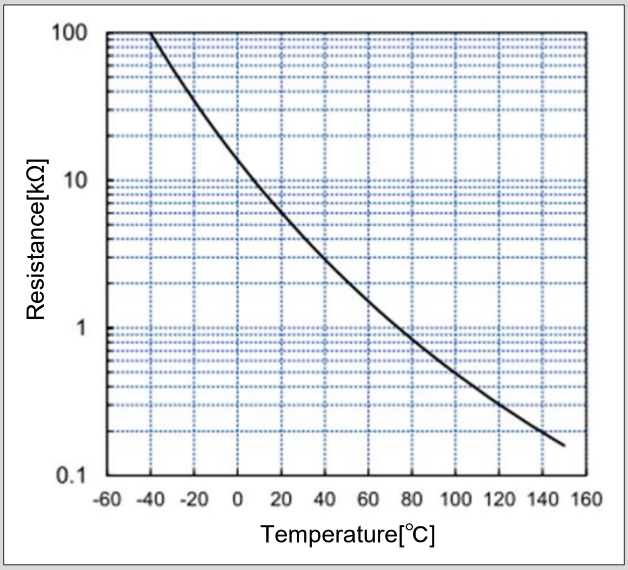

Fig.3 Temperature characteristics of NTC thermistor

2.2 B value

The B value indicates the slope of the change in resistance of the thermistor due to temperature change, and can be expressed by formula (2) based on formula (1).

$$B = l_n\left(\frac{R_1}{R_0}\right) \Big/ \left(\frac{1}{T_1} - \frac{1}{T_0}\right) \quad \cdots\cdots(2)$$

The B value changes slightly with temperature. Therefore, the B value differs depending on the defined temperature.
As shown in Table 1, the data sheet contains the value B(25/50) defined at 25°C and 50°C.

Table 1 Example of resistance value and B value of NTC thermistor (excerpt from data sheet)

Items		Symbols	Conditions	Characteristics min.	Characteristics typ.	Characteristics max.	Units
Thermistor	Resistance	R	T = 25°C	-	5000	-	Ω
			T = 100°C	465	495	520	
	B value	B	T = 25/50°C	3305	3375	3450	K

2.3 Thermal dissipation constant

The thermal dissipation constant is a constant that represents the power required to raise the thermistor temperature by 1°C through self-heating in a thermal equilibrium state.

In the ambient temperature T_1, when the power P (mW) is consumed and the thermistor temperature becomes T_2, the relationship is expressed by formula (3).

$$P = C(T_2 - T_1) \qquad \cdots\cdots(3)$$

C (mW/°C) is the thermal dissipation constant. Thermal dissipation constant varies depending on the thermistor shape, dimensions, condition of the object being measured, and atmosphere.

The thermal dissipation constant of NTC thermistor mounted inside Fuji IGBT modules is approximately 7mW/°C in actual measurements.

2.4 Time response

Since the thermistor has a thermal time constant, the thermistor temperature does not follow immediately even if the temperature rises due to the heat generated by IGBT chip.

The thermal time constant is the time required for the thermistor held in any temperature T_0 to change to the temperature T_1 when it is moved suddenly to a temperature T_1 atmosphere (temperature chamber, etc.). It is a constant that expresses the degree of thermal responsiveness of the thermistor.

Fig. 4 shows an example of the time response of an IGBT chip and the thermistor temperature. Note that this varies depending on the environment conditions of the IGBT module (such as the heat dissipation capacity of the heat sinks and the driving conditions of the IGBT module).

As shown in Fig. 4, there is a difference in the starting time of temperature rise between the IGBT chip and the thermistor time response.

In the time domain shorter than 100msec, only the chip temperature rises while the thermistor temperature hardly rises. As can be seen from the fact that the temperature difference between IGBT chip temperature and the thermistor increases, the thermistor temperature cannot follow the chip temperature change until the temperature difference becomes constant (saturation).

On the other hand, in the short circuit mode in which high current flows while a voltage is applied, the short circuit capability is about 10μs (Note that the short circuit capability varies depending on the series, voltage class, conditions of use, etc.), so that the thermistor temperature does not rise during this short circuit period.

In other words, it is difficult to perform short circuit protection by detecting the thermistor temperature. From this point of view, it is necessary to use overcurrent detector or $V_{CE(sat)}$ method for short circuit protection.

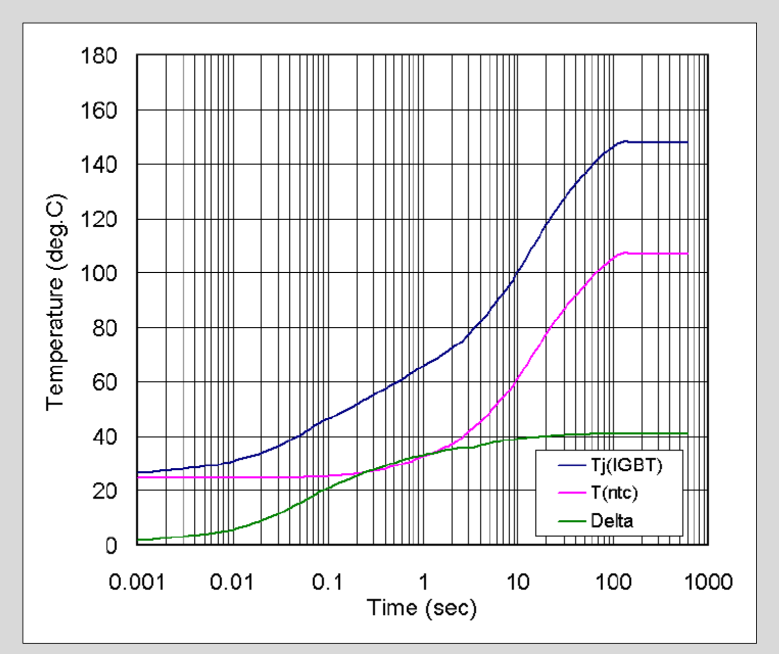

Fig.4 Junction temperature and time response of thermistor temperature

3. Temperature detection method of NTC thermistor

This section describes the temperature detection method of NTC thermistor.
Fig. 5 shows an example of a temperature detection circuit of NTC thermistor.
By configuring a voltage divider circuit between the NTC thermistor and the fixed resistor R, and converting the resistance R_{NTC} into a voltage V_{NTC}, the control circuit can detect the resistance that varies with the thermistor temperature as a voltage value.
The voltage value V_{NTC} of NTC thermistor is obtained by formula (4).

$$V_{\mathrm{NTC}} = \frac{R_{\mathrm{NTC}}}{R + R_{\mathrm{NTC}}} V_{\mathrm{in}} \qquad \cdots\cdots(4)$$

R : Fixed resistor
R_{NTC}: Resistance of NTC thermistor
V_{NTC}: Voltage of NTC thermistor
V_{IN} : Input voltage

From formula (4) and formula (1) which shows the relationship between the resistance and temperature characteristics of NTC thermistor, T_{NTC} is obtained using formula (5).
Depending on the thermistor temperature, you can set actions such as increasing the fan wind speed or outputting an alarm to reduce the module temperature.

$$T_{\mathrm{NTC}} = \frac{1}{\left(l_n \frac{R_{\mathrm{NTC}}}{R_{25}} \middle/ B\right) + \frac{1}{T_1}} \qquad \cdots\cdots(5)$$

R_{25}=5000Ω : Resistance of NTC thermistor at T_1=25°C
T_1=298.15K

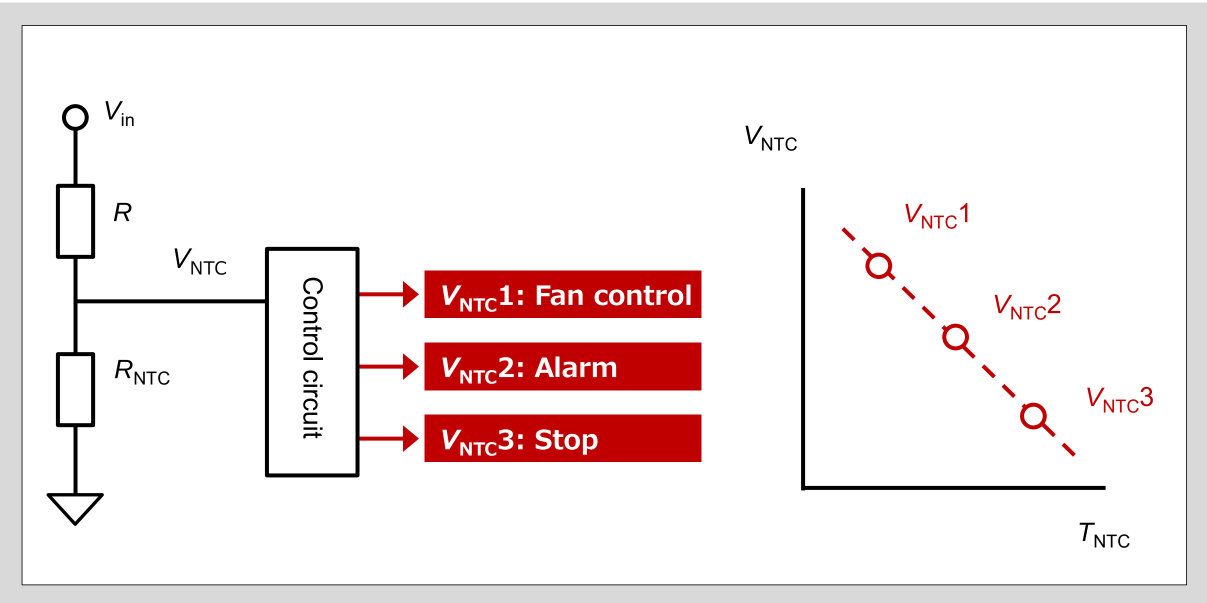

Fig.5 Example of a temperature detection circuit

As mentioned above, the B value varies with the temperature range.

Although the data sheet provides B(25/50), in order to calculate the temperature accurately, it is necessary to use the B value of the temperature range actually used.

The resistances and B value for -40°C~150°C (at 1°C intervals) are listed on page 8.

Also, if the current flowing through the thermistor is too small, the detected voltage will be small, and the accuracy of the measured value decreases. On the contrary, if the current is excessive, the self-heating of the thermistor becomes large, and in this case too, the measured value is not accurate. Therefore, it is important to select the resistor R considering the self-heating of the thermistor.

The thermal dissipation constant of NTC thermistor inside Fuji IGBT module is 7mW/°C in actual measurements. Assuming that the allowable temperature for self-heating of the thermistor is 1°C, the allowable power loss P_{max} is 7mW.

When the thermistor temperature is assumed to be 100°C, the current flowing through the thermistor is obtained by formula (6).

$$I_{\text{max}} = \sqrt{\frac{P_{\text{max}}}{R_{100}}} \qquad \cdots\cdots(6)$$

R_{100}=495Ω : Resistance of NTC thermistor at T_1=100°C

Therefore, a current of about I_{max}=3.76mA is appropriate for the thermistor.

The resistor R is obtained by formula (7).

$$V_{\text{in}} = I_{\text{max}}(R + R_{100})$$

$$R = \frac{V_{\text{in}}}{I_{\text{max}}} - R_{100} \qquad \cdots\cdots(7)$$

When V_{in}=5V, I_{max}=3.76mA, the fixed resistor R is approximately 835Ω.

For the E24 series, 820Ω is usually chosen.

Resistance and B value for NTC thermistor

Temp. [℃]	Rtyp [kΩ]	Rmin [kΩ]	Rmax [kΩ]	Bvalue [K]
-40	99.09	84.46	116.0	3194
-39	93.69	79.96	109.5	3197
-38	88.62	75.72	103.5	3199
-37	83.86	71.74	97.78	3202
-36	79.38	67.99	92.45	3205
-35	75.17	64.46	87.44	3207
-34	71.20	61.13	82.73	3210
-33	67.48	58.00	78.31	3213
-32	63.96	55.05	74.14	3215
-31	60.66	52.26	70.23	3218
-30	57.54	49.63	66.55	3220
-29	54.61	47.15	63.08	3223
-28	51.84	44.18	59.81	3225
-27	49.23	42.60	56.74	3228
-26	46.76	40.52	53.84	3230
-25	44.44	38.54	51.10	3233
-24	42.24	36.68	48.53	3235
-23	40.17	34.92	46.09	3238
-22	38.21	33.25	43.80	3240
-21	36.35	31.67	41.63	3242
-20	34.60	30.18	39.58	3245
-19	32.95	28.76	37.65	3247
-18	31.38	27.42	35.82	3249
-17	29.89	26.15	34.09	3251
-16	28.49	24.95	32.45	3254
-15	27.16	23.81	30.91	3256
-14	25.90	22.72	29.44	3259
-13	24.70	21.70	28.06	3260
-12	23.57	20.72	26.74	3263
-11	22.50	19.80	25.50	3266
-10	21.48	18.92	24.32	3268
-9	20.51	18.09	23.20	3270
-8	19.59	17.29	22.14	3271
-7	18.72	16.54	21.14	3274
-6	17.89	15.82	20.18	3275
-5	17.11	15.14	19.28	3279
-4	16.36	14.50	18.42	3280
-3	15.65	13.88	17.60	3282
-2	14.98	13.29	16.83	3285
-1	14.33	12.73	16.09	3286
0	13.72	12.20	15.39	3288
1	13.14	11.70	14.73	3291
2	12.59	11.21	14.09	3294
3	12.06	10.75	13.49	3295
4	11.56	10.31	12.92	3298
5	11.08	9.895	12.37	3299
6	10.62	9.496	11.85	3300
7	10.19	9.115	11.36	3304
8	9.773	8.752	10.89	3305
9	9.378	8.405	10.44	3307
10	9.001	8.074	10.01	3309
11	8.641	7.758	9.600	3311
12	8.297	7.455	9.211	3312
13	7.969	7.167	8.840	3314
14	7.656	6.891	8.485	3316
15	7.357	6.627	8.147	3318
16	7.071	6.375	7.824	3320
17	6.798	6.133	7.516	3322
18	6.537	5.902	7.221	3324
19	6.287	5.681	6.940	3325
20	6.048	5.470	6.671	3326
21	5.820	5.267	6.414	3330
22	5.601	5.074	6.169	3330
23	5.392	4.888	5.934	3332
24	5.192	4.710	5.709	3338
25	5.000	4.539	5.494	-
26	4.816	4.376	5.288	3344
27	4.641	4.219	5.091	3334
28	4.472	4.069	4.903	3340
29	4.311	3.925	4.722	3339
30	4.156	3.787	4.549	3342
31	4.007	3.654	4.383	3346
32	3.865	3.527	4.224	3346
33	3.728	3.405	4.072	3350
34	3.597	3.288	3.926	3351
35	3.472	3.175	3.786	3351
36	3.351	3.067	3.652	3353
37	3.235	2.963	3.523	3355
38	3.124	2.863	3.400	3356
39	3.017	2.767	3.281	3358
40	2.914	2.675	3.168	3361
41	2.816	2.586	3.058	3361
42	2.721	2.501	2.953	3363
43	2.63	2.419	2.853	3364
44	2.542	2.340	2.756	3367
45	2.458	2.264	2.663	3368
46	2.377	2.191	2.573	3369
47	2.299	2.120	2.487	3371
48	2.224	2.052	2.405	3373
49	2.152	1.987	2.325	3374
50	2.083	1.924	2.249	3375
51	2.016	1.864	2.175	3376
52	1.952	1.806	2.104	3377
53	1.890	1.749	2.036	3379
54	1.830	1.695	1.971	3381
55	1.773	1.643	1.908	3381
56	1.717	1.593	1.847	3384
57	1.664	1.544	1.788	3384
58	1.612	1.497	1.732	3387
59	1.563	1.452	1.678	3387
60	1.515	1.408	1.625	3389
61	1.469	1.366	1.575	3390
62	1.424	1.326	1.526	3392
63	1.381	1.287	1.479	3393
64	1.340	1.249	1.434	3394
65	1.300	1.212	1.391	3395
66	1.261	1.177	1.348	3397
67	1.224	1.143	1.308	3398
68	1.188	1.110	1.269	3400
69	1.153	1.078	1.231	3401
70	1.120	1.047	1.194	3402
71	1.087	1.018	1.159	3404
72	1.056	0.9888	1.125	3405
73	1.026	0.9610	1.092	3405
74	0.9966	0.9342	1.061	3407
75	0.9683	0.9082	1.030	3408
76	0.9410	0.8830	1.000	3409
77	0.9146	0.8587	0.9717	3410
78	0.8890	0.8362	0.9440	3412
79	0.8643	0.8124	0.9173	3413
80	0.8404	0.7904	0.8914	3414
81	0.8173	0.769	0.8664	3415
82	0.7949	0.7483	0.8422	3416
83	0.7732	0.7283	0.8188	3417
84	0.7522	0.7090	0.7962	3419
85	0.7319	0.6902	0.7743	3420
86	0.7123	0.6720	0.7531	3421
87	0.6932	0.6544	0.7326	3422
88	0.6748	0.6373	0.7127	3423
89	0.6570	0.6208	0.6935	3424
90	0.6397	0.6047	0.6749	3425
91	0.6229	0.5892	0.6569	3426
92	0.6066	0.5741	0.6394	3427
93	0.5909	0.5595	0.6225	3428
94	0.5756	0.5453	0.6061	3430
95	0.5608	0.5316	0.5903	3431
96	0.5465	0.5182	0.5749	3432
97	0.5326	0.5053	0.5600	3433
98	0.5191	0.4927	0.5455	3434
99	0.5060	0.4805	0.5315	3435
100	0.4933	0.4687	0.5179	3436
101	0.4810	0.4568	0.5052	3437
102	0.4690	0.4452	0.4929	3438
103	0.4574	0.4340	0.4809	3439
104	0.4462	0.4231	0.4693	3440
105	0.4352	0.4125	0.458	3441
106	0.4246	0.4023	0.4471	3442
107	0.4143	0.3923	0.4364	3443
108	0.4043	0.3827	0.4261	3443
109	0.3946	0.3733	0.416	3444
110	0.3851	0.3642	0.4063	3446
111	0.376	0.3554	0.3968	3446
112	0.3671	0.3468	0.3875	3447
113	0.3584	0.3385	0.3786	3448
114	0.35	0.3304	0.3698	3449
115	0.3418	0.3225	0.3614	3450
116	0.3338	0.3148	0.3531	3451
117	0.3261	0.3074	0.3451	3452
118	0.3186	0.3002	0.3373	3453
119	0.3113	0.2932	0.3297	3453
120	0.3042	0.2864	0.3223	3454
121	0.2973	0.2797	0.3151	3455
122	0.2905	0.2733	0.3081	3456
123	0.284	0.267	0.3013	3457
124	0.2776	0.2609	0.2947	3458
125	0.2714	0.255	0.2882	3459
126	0.2654	0.2492	0.2819	3459
127	0.2595	0.2436	0.2758	3460
128	0.2538	0.2381	0.2699	3461
129	0.2483	0.2328	0.2641	3462
130	0.2428	0.2277	0.2584	3463
131	0.2376	0.2226	0.2529	3463
132	0.2324	0.2177	0.2475	3464
133	0.2274	0.2129	0.2423	3465
134	0.2226	0.2083	0.2372	3466
135	0.2178	0.2038	0.2323	3467
136	0.2132	0.1994	0.2274	3467
137	0.2087	0.1951	0.2227	3468
138	0.2043	0.1909	0.2181	3469
139	0.2	0.1868	0.2136	3470
140	0.1959	0.1829	0.2093	3470
141	0.1918	0.179	0.205	3471
142	0.1878	0.1752	0.2008	3472
143	0.184	0.1716	0.1968	3472
144	0.1802	0.168	0.1928	3473
145	0.1765	0.1645	0.189	3474
146	0.173	0.1611	0.1852	3474
147	0.1695	0.1578	0.1815	3475
148	0.1661	0.1546	0.178	3476
149	0.1627	0.1514	0.1745	3477
150	0.1595	0.1483	0.1711	3477

Warning:

This manual contains the product specifications, characteristics, data, materials, and structures as of July 2025.
The contents are subject to change without notice for specification changes or other reasons. When using a product listed in this manual, be sure to obtain the latest specifications.

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