

TECHNICAL REPORT

Study for the derating curve of surface mount fixed resistors – Derating curves based on terminal part temperature

INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

ICS 31.040.10

ISBN 978-2-8322-4368-8

Warning! Make sure that you obtained this publication from an authorized distributor.

CONTENTS

FOREWORD.....	7
INTRODUCTION.....	9
1 Scope.....	10
2 Normative references	10
3 Terms and definitions	10
4 Study for the derating curve of surface mount fixed resistors	11
4.1 General.....	11
4.2 Using the derating curve based on the terminal part temperature	12
4.3 Measuring method of the terminal part temperature of the SMD resistor	13
4.4 Measuring method of the thermal resistance $R_{th\ shs-t}$ from the terminal part to the surface hotspot	19
4.5 Conclusions	21
Annex A (informative) Background of the establishment of the derating curve based on ambient temperature	22
A.1 Tracing the history of the mounting and heat dissipation figuration of resistors.....	22
A.2 How to establish the high temperature slope part of the derating curve	24
A.2.1 General	24
A.2.2 Derating curve for the semiconductors.....	26
A.2.3 Derating curve for resistors.....	29
Annex B (informative) The temperature rise of SMD resistors and the influence of the printed circuit board	40
B.1 Temperature rise of SMD resistors.....	40
B.2 The influence of the printed circuit boards.....	45
Annex C (informative) The influence of the number of resistors mounted on the test board	49
C.1 General.....	49
C.2 The influence of the number of resistors mounted on the test board.....	49
C.3 The delay of correspondence for current products with nonstandard dimensions	51
Annex D (informative) Influence of the air flow in the test chamber	52
D.1 General.....	52
D.2 Influence of the wind speed	52
Annex E (informative) Validity of the new derating curve.....	60
E.1 Suggestion for establishing the derating curve based on the terminal part temperature	60
E.2 Conclusion.....	65
Annex F (informative) The thermal resistance of SMD resistors	67
Annex G (informative) How to measure the surface hotspot temperature	72
G.1 Target of the measurement	72
G.2 Recommended measuring equipment	72
G.3 Points to be careful when measuring the surface hotspot of the resistor with an infrared thermograph.....	72
G.3.1 General	72
G.3.2 Spatial resolution and accuracy of peak temperature measurement.....	73
G.3.3 Influence of the angle of the measurement target normal line and the infrared thermograph light axis	75

Annex H (informative) How the resistor manufacturers measure the thermal resistance of resistors.....	79
H.1 The measuring system.....	79
H.2 Definition of the two kinds of temperatures.....	80
H.3 Errors in the measurement.....	83
Annex I (informative) Measurement method of the terminal part temperature of the SMD resistors.....	88
I.1 Measuring method using an infrared thermograph.....	88
I.2 Measuring method using the thermocouple.....	89
I.3 Estimating the error range of the temperature measurement using the thermal resistance of the thermocouple.....	90
I.3.1 General.....	90
I.3.2 When using the type T thermocouples.....	97
I.4 Thermal resistance of the board.....	97
I.5 Conclusion of this annex.....	100
Annex J (informative) The variation of the heat dissipation fraction caused by the difference between the resistor and its mounting configuration.....	101
J.1 Heat dissipation ratio of cylindrical resistors wired in the air.....	101
J.2 Heat dissipation ratio of SMD resistors mounted on the board.....	102
J.3 Heat dissipation ratio of the cylindrical resistors mounted on the through-hole printed board.....	104
Annex K (informative) Influence of airflow on SMD resistors.....	105
K.1 General.....	105
K.2 Measurement system.....	105
K.3 Test results (orthogonal).....	106
K.4 Test results (parallel).....	110
Annex L (informative) The influence of the spatial resolution of the thermograph.....	115
L.1 The application for using the thermograph when measuring the temperature of the SMD resistor.....	115
L.2 The relation between the minimum area that the accurate temperature could be measured and the pixel magnification percentage.....	115
L.3 Example of the RR1608M SMD resistor hotspot's actual measurement.....	120
L.4 Conclusion.....	121
Annex M (informative) Future subjects.....	122
Bibliography.....	123
Figure 1 – Existing derating curve based on ambient temperature.....	12
Figure 2 – Suggested derating curve based on terminal temperature.....	12
Figure 3 – Attachment position of the thermocouple when measuring the temperature of the terminal part.....	13
Figure 4 – Attaching type K thermocouples.....	14
Figure 5 – Wiring routing of the thermocouple.....	15
Figure 6 – The true value and the actual measured value of the terminal part temperature.....	16
Figure 7 – Thermal resistance $R_{th\ eq}$ of the FR4 single side board (thickness 1,6 mm).....	17
Figure 8 – Length that cause the heat dissipation and the thermal resistance of the type-K thermocouple (calculated).....	18
Figure 9 – Example of calculation of the measurement error ΔT caused by the heat dissipation of the thermocouple.....	19

Figure 10 – Recommended measurement system of T_{shs} and T_t for calculating R_{th} shs-t	20
Figure A.1 – Wired in the air using the lug terminal	22
Figure A.2 – Heat path when wired in the air using the lug terminal	23
Figure A.3 – Test condition for resistors with category power 0 W	24
Figure A.4 – Test condition for resistors with category power other than 0 W	25
Figure A.5 – Example of reviewing the derating curve	26
Figure A.6 – T_j , T_C and $R_{th j-c}$ of transistors	27
Figure A.7 – Derating curves for transistors	28
Figure A.8 – Trajectory of T_j when P is reduced according to the derating curve	29
Figure A.9 – Leaded resistors with small temperature rise	30
Figure A.10 – Leaded resistors with large temperature rise	31
Figure A.11 – Trajectory of T_{hs} for the lead wire resistors with small temperature rise	31
Figure A.12 – Trajectory of T_{hs} for the lead wire resistors with large temperature rise	33
Figure A.13 – Trajectory of T_{hs} for resistors with category power other than 0 W	34
Figure A.14 – T_{sp} and MAT for lead wire resistors with large temperature rise	35
Figure A.15 – T_{sp} and MAT for lead wire resistors with small temperature rise	36
Figure A.16 – Resistors for which the hotspot is the thermally sensitive point	37
Figure A.17 – Resistor that have derating curve similar to the semiconductor	38
Figure B.1 – Temperature distribution of the SMD resistors mounted on the board	41
Figure B.2 – Temperature rise of the SMD resistors from the ambient temperature	42
Figure B.3 – Measurement system layout and board dimension	43
Figure B.4 – Temperature rise of RR2012M (thickness 35 μ m, 0,25 W applied)	44
Figure B.5 – Temperature rise of RR2012M (thickness 70 μ m, 0,25 W applied)	45
Figure B.6 – Trajectory of the terminal part and hotspot temperature of the SMD resistors	46
Figure B.7 – Operating temperature of the resistor on the board with narrow patterns	47
Figure C.1 – Test board compliant with the IEC standard for RR1608M	50
Figure C.2 – Relation between the number of samples and the surface hotspot temperature rise	50
Figure C.3 – Infrared thermograph image in the same scale when power is applied to 5 samples and 20 samples	51
Figure D.1 – Wind speed and the terminal part temperature rise of the RR6332M	53
Figure D.2 – Test system for the natural convection flow	53
Figure D.3 – Observing the influence of the agitation wind in the test chamber	55
Figure D.4 – Wind speed and the terminal part temperature rise of the RR5025M	56
Figure D.5 – Wind speed and the terminal part temperature rise of the RR3225M	56
Figure D.6 – Wind speed and the terminal part temperature rise of the RR3216M	57
Figure D.7 – Wind speed and the terminal part temperature rise of the RR2012M	57
Figure D.8 – Wind speed and the terminal part temperature rise of the RR1608M	58
Figure D.9 – Wind speed and the terminal part temperature rise of the RR1005M	58
Figure E.1 – Derating conditions of SMD resistors on the resistor manufacturer test board	60
Figure E.2 – New derating curve provided by the resistor manufacturer to the electric/electronic designers	63

Figure E.3 – Derating curve based on the terminal part temperature	64
Figure E.4 – Derating curve based on the terminal part temperature	65
Figure F.1 – Definition of the thermal resistance in a strict sense	68
Figure F.2 – Thermal resistance of the resistor	69
Figure G.1 – Difference of the measured hotspot temperature caused by the spatial resolution	74
Figure G.2 – Measuring system for the error caused by the angle	76
Figure G.3 – Error caused by the angle of the optical axis and the target surface (natural convection)	77
Figure G.4 – Error caused by the angle of the optical axis and the target surface (0,3 m/s air ventilation from the side)	77
Figure H.1 – Measuring system for calculating the thermal resistance between the surface hotspot and the terminal part	80
Figure H.2 – Simulation model	81
Figure H.3 – Temperature distribution of the copper block surface (calculated)	84
Figure H.4 – Isothermal line of the fillet part (calculated)	86
Figure I.1 – Temperature drop caused by the attached thermocouple	89
Figure I.2 – Example of the printed board	90
Figure I.3 – Printed board shown with the thermal network	91
Figure I.4 – Equivalent circuit of the printed board shown with the thermal network	92
Figure I.5 – Equivalent circuit when the thermocouple is connected	93
Figure I.6 – Ambient temperature and the space need for the heat dissipation of the thermocouple	94
Figure I.7 – Equivalent circuit when the thermocouple is connected	95
Figure I.8 – Length that causes the heat dissipation and the thermal resistance of the type K thermocouple (calculated)	96
Figure I.9 – Length that cause the heat dissipation and the thermal resistance of the type T thermocouple (calculated)	97
Figure I.10 – Thermal resistance $R_{th eq}$ of the FR4 single side board (thickness 1,6 mm)	98
Figure I.11 – Calculating the thermal resistance of the board from the fillet side	99
Figure J.1 – Simulation model of the lead wire resistors wired in the air	101
Figure J.2 – Heat dissipation ratio of the leaded cylindrical resistors (calculated)	102
Figure J.3 – Measurement system of the heat dissipation ratio of SMD resistors mounted on the board	103
Figure K.1 – Measurement system	106
Figure K.2 – Relationship between the terminal part temperature rise and the wind speed for the RR6332M (orthogonal)	107
Figure K.3 – Relationship between the terminal part temperature rise and the wind speed for the RR5025M (orthogonal)	107
Figure K.4 – Relationship between the terminal part temperature rise and the wind speed for the RR3225M (orthogonal)	108
Figure K.5 – Relationship between the terminal part temperature rise and the wind speed for the RR3216M (orthogonal)	108
Figure K.6 – Relationship between the terminal part temperature rise and the wind speed for the RR2012M (orthogonal)	109
Figure K.7 – Relationship between the terminal part temperature rise and the wind speed for the RR1608M (orthogonal)	109

Figure K.8 – Relationship between the terminal part temperature rise and the wind speed for the RR1005M (orthogonal)	110
Figure K.9 – Relationship between the terminal part temperature rise and the wind speed for the RR6332M (parallel)	111
Figure K.10 – Relationship between the terminal part temperature rise and the wind speed for the RR5025M (parallel)	111
Figure K.11 – Relationship between the terminal part temperature rise and the wind speed for the RR3225M (parallel)	112
Figure K.12 – Relationship between the terminal part temperature rise and the wind speed for the RR3216M (parallel)	112
Figure K.13 – Relationship between the terminal part temperature rise and the wind speed for the RR2012M (parallel)	113
Figure K.14 – Relationship between the terminal part temperature rise and the wind speed for the RR1608M (parallel)	113
Figure K.15 – Relationship between the terminal part temperature rise and the wind speed for the RR1005M (parallel)	114
Figure K.16 – Terminal part temperature rise of RR6332M, difference between the windward and leeward sides when placed parallel	114
Figure L.1 – Step response of the Gaussian filter of the various cut-off spatial frequencies (calculated).....	116
Figure L.2 – Temperature distribution (cross-section) when measuring the object that becomes high temperature only in the range of 0,2 mm in diameter	117
Figure L.3 – Measuring system of spatial frequency filter of the infrared thermograph.....	118
Figure L.4 – Actual measured value of the step response of various magnifier lenses.....	119
Figure L.5 – Comparison of the actual measured value and the calculated value (step response)	120
Figure L.6 – Comparison of the actual measured value and the calculated value (surface hotspot of the resistor)	121
Table D.1 – Number of samples mounted and the applied power	54
Table H.1 – Results of the fillet part temperature simulation (calculated value)	82
Table H.2 – Simulation result of the fillet part's temperature where it is measurable (calculated value)	82
Table H.3 – Simulation result of the fillet part's temperature where it is measurable (calculated value)	83
Table H.4 – Thermal resistance simulation results between the surface hotspot and the terminal part based on the copper block temperature (calculated value)	85
Table J.1 – Analysis result of the heat dissipation ratio of SMD resistors (calculated value and value actually measured)	104

INTERNATIONAL ELECTROTECHNICAL COMMISSION

STUDY FOR THE DERATING CURVE OF SURFACE MOUNT FIXED RESISTORS –

Derating curves based on terminal part temperature

FOREWORD

- 1) The International Electrotechnical Commission (IEC) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, IEC publishes International Standards, Technical Specifications, Technical Reports, Publicly Available Specifications (PAS) and Guides (hereafter referred to as "IEC Publication(s)"). Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation. IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.
- 2) The formal decisions or agreements of IEC on technical matters express, as nearly as possible, an international consensus of opinion on the relevant subjects since each technical committee has representation from all interested IEC National Committees.
- 3) IEC Publications have the form of recommendations for international use and are accepted by IEC National Committees in that sense. While all reasonable efforts are made to ensure that the technical content of IEC Publications is accurate, IEC cannot be held responsible for the way in which they are used or for any misinterpretation by any end user.
- 4) In order to promote international uniformity, IEC National Committees undertake to apply IEC Publications transparently to the maximum extent possible in their national and regional publications. Any divergence between any IEC Publication and the corresponding national or regional publication shall be clearly indicated in the latter.
- 5) IEC itself does not provide any attestation of conformity. Independent certification bodies provide conformity assessment services and, in some areas, access to IEC marks of conformity. IEC is not responsible for any services carried out by independent certification bodies.
- 6) All users should ensure that they have the latest edition of this publication.
- 7) No liability shall attach to IEC or its directors, employees, servants or agents including individual experts and members of its technical committees and IEC National Committees for any personal injury, property damage or other damage of any nature whatsoever, whether direct or indirect, or for costs (including legal fees) and expenses arising out of the publication, use of, or reliance upon, this IEC Publication or any other IEC Publications.
- 8) Attention is drawn to the Normative references cited in this publication. Use of the referenced publications is indispensable for the correct application of this publication.
- 9) Attention is drawn to the possibility that some of the elements of this IEC Publication may be the subject of patent rights. IEC shall not be held responsible for identifying any or all such patent rights.

The main task of IEC technical committees is to prepare International Standards. However, a technical committee may propose the publication of a technical report when it has collected data of a different kind from that which is normally published as an International Standard, for example "state of the art".

IEC TR 63091, which is a technical report, has been prepared by IEC technical committee 40: Capacitors and resistors for electronic equipment.

The text of this technical report is based on the following documents:

Enquiry draft	Report on voting
40/2502/DTR	40/2532/RVDTR

Full information on the voting for the approval of this technical report can be found in the report on voting indicated in the above table.

This document has been drafted in accordance with the ISO/IEC Directives, Part 2.

The committee has decided that the contents of this document will remain unchanged until the stability date indicated on the IEC website under "<http://webstore.iec.ch>" in the data related to the specific document. At this date, the document will be

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

A bilingual version of this publication may be issued at a later date.

INTRODUCTION

Work began in 2012 to adopt the new derating curve suitable for the surface mount fixed resistors that use the terminal part temperature as the horizontal axis.

The derating curves for surface mount fixed resistors are defined in JIS C 5201-8:2014.

However, the principle of the derating curve was established when the resistors were cylindrically shaped, wired in the air and the heat was dissipated directly from the resistor body into the ambient environment. Therefore, it is not suitable for the surface mount fixed resistors that use the printed circuit boards as the main heat path.

It is necessary to fulfill the demands from the electric and electronic device manufacturers for raising the power ratings safely. Additionally, it is required to establish a new derating curve that is suitable for the surface mount fixed resistors so that they can be used safely in a high temperature environment, typically in automotive electronic devices.

Making a change of the temperature rule for evaluation of the fixed resistors from the ambient temperature to the temperature of the connection point (terminal part temperature of the resistor) will affect many defined contents of multiple standards in the IEC 60115 series. Additionally, it will mean changing the users' evaluation rules, so the impact will be enormous. Therefore, it has been decided to issue the Technical Report first to attract attention of the relevant market players and then, we will start working on changing the defined contents of the IEC 60115 series.

STUDY FOR THE DERATING CURVE OF SURFACE MOUNT FIXED RESISTORS –

Derating curves based on terminal part temperature

1 Scope

This Technical Report is applicable to SMD resistors with sizes equal or smaller than the RR6332M, including the typical rectangular and cylindrical SMD resistors mentioned in IEC 60115-8.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 60115-1:2008, *Fixed resistors for use in electronic equipment – Part 1: Generic specification*

IEC 60115-8:2009, *Fixed resistors for use in electronic equipment – Part 8: Sectional specification: Fixed chip resistors*