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THERMAL RESISTANCE CALCULATIONS - GENERAL INFORMATION

When using ARCOL 'HS' Aluminium Housed Resistors it is essential that the maximum hot spot temperature of 220°C is not exceeded. To ensure that this does not occur it is important that the resistors are mounted on a heatsink of the correct thermal resistance for the power to be dissipated. In order to calculate this thermal resistance figure it is necessary to know the resistor internal thermal resistance figures which have been determined under practical operating conditions.

RTH1	Thermal resistance (°C/W) wire element to Aluminium Housing.
RTH2	Thermal resistance (°C/W) Aluminium Housing to Air.
RTH3	Thermal resistance (°C/W) Aluminium Housing to Heatsink.
RTH4	Thermal resistance (°C/W) Resistor surface to heatsink.
W max	Maximum required load per resistor. (Watts).
T max	Maximum hotspot temperature. (Tmax < 220°C, in the interest of safety this should be reduced by 20 - 30°C).
T amb	Ambient temperature.
RTH	Thermal resistance of the heatsink.
TH	Heatsink Temperature (Chassis).
T^	Temp on top of the Aluminium profile.
T	Temperature rise of the heatsink due to other components.

The Following Conditions are Possible

1 RTH of the heatsink is known.

Then $T^{\wedge} = W_{\max} (RTH4 + RTH) + T_{\text{amb}}$. Check that $T_{\max} = W_{\max} (RTH1 + RTH3 + RTH) + T_{\text{amb}} + T < 220^{\circ}\text{C}$.

2 TH temperature of the heatsink is known.

$T^{\wedge} = (W_{\max} \times RTH4) + TH$. Check that $T_{\max} = W_{\max} (RTH1 + RTH3) + TH < 220^{\circ}\text{C}$.

3 Resistor in free air without a Heatsink.

Check that $T_{\max} = RTH1 \times W_{\max} + RTH2 \times W_{\max} = T_{\text{amb}} < 220^{\circ}\text{C}$.

For maximum heat transfer it is recommended that a heatsink compound be applied between the resistor base and the heatsink/chassis interface. The following calculations it is assumed that the air around the resistors is stationary.

	HS25	HS50	HS75	HS100	HS150	HS200	HS300
RTH1	3.2	1.9	1.23	1.03	0.79	0.36	0.19
RTH2	4.05	2.44	1.26	1.24	0.83	0.79	0.71
RTH3	0.06	0.06	0.05	0.07	0.02	0.02	0.03
RTH4	0.25	0.28	0.08	0.10	0.08	0.12	0.06

Calculation Example

An HS100 is required to dissipate 100 Watts at $T_{\text{amb}} = 25^{\circ}\text{C}$

$T_{\max} = 220^{\circ}\text{C}$, $RTH1 = 1.03^{\circ}\text{C/W}$ and $RTH3 = 0.07^{\circ}\text{C/W}$

What thermal resistance is required for the Heatsink?

$$RTH = \frac{T_{\max} - T_{\text{amb}}}{P} - (RTH1 + RTH3)$$

$$RTH = \frac{220 - 25}{100} - (1.03 + 0.07)$$

$$RTH = 0.85^{\circ}\text{C/W}.$$

Please note. These figures are worst case. Thermal resistance element to case varies according to resistance value.

CRITICAL RESISTANCE & VOLTAGE VALUES - HS/NHS STYLE RESISTORS

The critical resistance value of a wirewound resistor is determined by the number of turns of the resistance element that will not breakdown when a voltage is applied to the helix to achieve the resistors rated dissipation. The number of turns possible on any resistor is governed by it's core dimensions in relation to the resistance element section and the optimum spacing between winding according to wattage size. Above the critical resistance value the voltage will remain critical and so the wattage is reduced proportionately.

The formula :- $W = \frac{V^2}{R}$

Where W = Wattage for a given resistor.

R = Critical resistance value.

V = Limiting Voltage.

Critical Resistances HS

HS10 2K56	HS75 26K13	HS200 18K05
HS15 4K68	HS100 36K10	HS250 19K36
HS25 12K10	HS150 41K66	HS300 20K83
HS50 31K25		

Low Inductance Resistors

In manufacture of a low inductance resistor it is necessary to wind half the number of turns of a standard helix in one direction with the remaining half wound on top in the opposite direction. The magnetic fields produced due to current flow in each element will be equal and opposite in polarity. Consequently the resistance value will be $R/4$. The critical voltage will then be reduced to $V/2$, as it is applied to half the number of turns.

To dissipate the wattage rating W it is necessary to apply the following formula :-

$$W = \frac{V^2/R}{R/4} = \frac{V^2}{2} \times \frac{4}{R} = \frac{2V^2}{R}$$

The critical voltage for a low inductance resistor is therefore the critical voltage for the standard HS Resistor divided by the square root of 2.

$$V_{crit} = \frac{V}{\sqrt{2}}$$

HEATSINKS RECOMMENDED FOR THE HS STYLE POWER RESISTOR RANGE

SURFACE CONTACT

As detailed in our Sales literature 007/* we recommend that a form of heat conductive grease/paste be utilised at the interface between the resistor and heatsink. Where this is not possible the commercial wattage rating should be reduced by 15%.

Listed below are the Heatsinks of recommended, minimum thermal conductivity (C°/W) to achieve rated dissipation @ 25°C ambient temperature.

Resistor Type	Recommended Heatsink (C°/W)	Wattage Rating	
		With HS Compound	Without HS Compound
HS10	6.00	10 Watts	8.50 Watts
HS15	5.40	15 Watts	13.75 Watts
HS25	4.20	25 Watts	21.25 Watts
HS50	3.00	50 Watts	42.50 Watts
HS75	1.25	75 Watts	63.75 Watts
HS100	1.00	100 Watts	85.00 Watts
HS150	1.00	150 Watts	127.50 Watts
HS200	0.65	200 Watts	170.00 Watts
HS250	0.40	250 Watts	212.50 Watts
HS300	0.40	300 Watts	265.00 Watts
HSW600	0.40	600 Watts	510.00 Watts

Please note. Recommended heatsink applies to all values <1k Ohm. For higher values, please refer to worst case calculation on TI001.

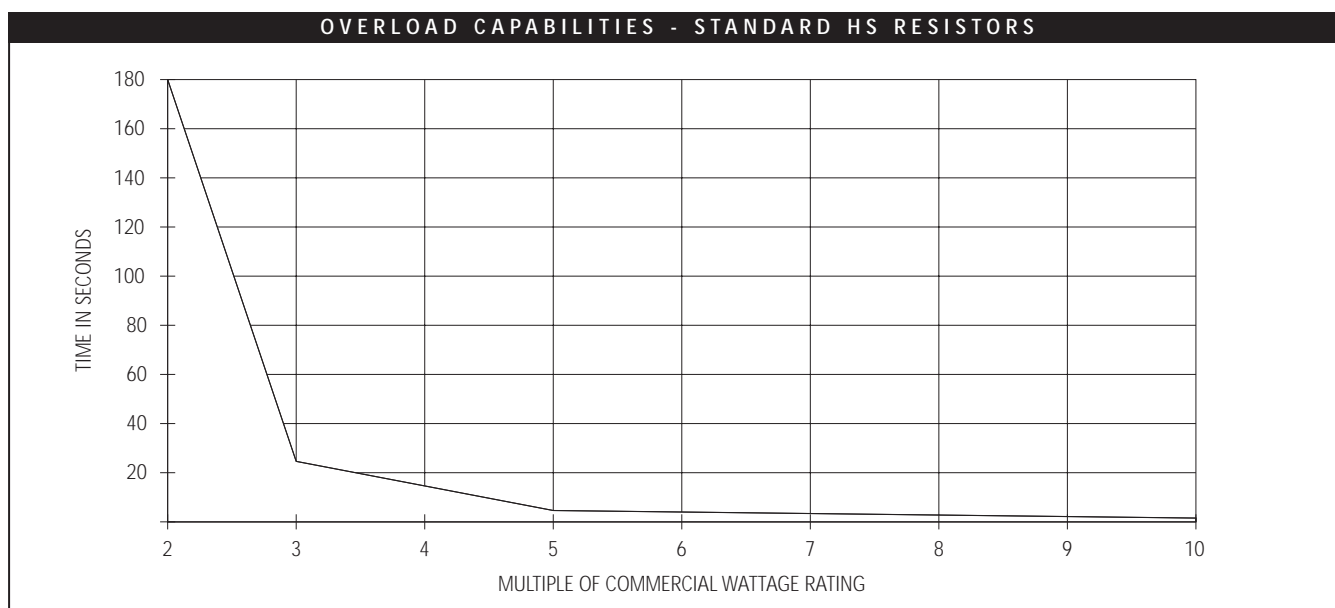
TYPICAL OVERLOAD CAPABILITIES OF THE STANDARD HEATSINK (HS) RESISTOR

CONDITIONS

The graph shown below gives typical overload capabilities of the standard Heatsink (HS) style resistor with the provision that the conditions laid out below are satisfied.

- 1 The Resistor/Heatsink are maintained at an ambient Temperature of 25°C
- 2 The Resistor is mounted on a heatsink of the recommended thermal conductivity as detailed on **Arcol Technical Information Sheet No.TI003**, and that thermally conductive compound is applied to the interface between the resistor base and the heatsink.
- 3 The Critical Voltage and Resistance values are adhered to.

Shown below is a graphic representation of allowable overload duration versus pulse magnitude



- 10 Times commercial wattage rating for 1 second
- 5 Times commercial wattage rating for 5 seconds
- 2 Times commercial wattage rating for 3 minutes

DEFINITIONS OF TERMS TAKEN FROM IEC 115-1

CRITICAL RESISTANCE

The **Critical Resistance** is that resistance value at which the **Rated Voltage** is equal to the **Limiting Element Voltage**. At an ambient temperature of 25°C, the maximum voltage which may be applied across the termination's of a resistor, is either the **rated voltage**, if the resistance is less than the **critical resistance**, or the **limiting element voltage** if the resistance is equal to or greater than the **critical resistance**.

RATED VOLTAGE

The DC or AC rms voltage calculated from the square root of the product of unit resistance and the **rated dissipation** (commercial dissipation rating). This is dependent on the **Limiting Element Voltage & Critical Resistance**.

CRITICAL VOLTAGE

Please see **Technical Information Sheet No.002. (Critical Resistance / Voltage Values)**.

RATED DISSIPATION (COMMERCIAL DISSIPATION RATING)

The **Rated Dissipation** of a resistor is the maximum allowable dissipation at an ambient temperature of 25°C when mounted in accordance with recommended conditions.

LIMITING ELEMENT VOLTAGE

The **Limiting Element Voltage** is the maximum value of the voltage that may be applied continuously to the terminations of the resistor. (**Limiting Element Voltage** may become critical dependent on the value of the resistance).

ISOLATION VOLTAGE

The **Isolation Voltage** is the maximum peak voltage which may be applied under continuous operating conditions between any of the resistor termination's and any conducting mounting surface. The value of the **Isolation Voltage** shall be not less than 1.42 times the **Limiting Element Voltage**.

VOLTAGE PROOF TEST (STANDARD)

An alternating voltage of 40-60 Hz and with a peak value of not less than 1.42 times the **Isolation Voltage** shall be applied instantaneously between the termination's and the case of the resistor with **no breakdown or flashover allowable**.

VOLTAGE PROOF TEST (SPECIAL)

As for standard, in addition the voltage shall be applied for a period 1 minute. The voltage shall be applied gradually at a rate of 100 Volts / Second with **no breakdown or flashover allowable**.

PARTIAL DISCHARGE TEST (SPECIAL ONLY)

Standard test applied to 'High Voltage' resistors upon special request. An alternating voltage of 40-60 Hz applied for a duration of 1 minute between the terminations of the resistor and a conductive mounting plate.

Maximum allowable discharge:- (a) 40 pico-Coulombs @ 2KV rms (b) 400 pico-Coulombs @ 2.8KV rms

INSULATION RESISTANCE

500V DC applied to the termination's of the resistor connected together as one and a conductive mounting plate, duration is for sufficient period to achieve a stable reading. **Standard for the HS resistor range:- Not less than 10,000 MOhms.**

DERATING CURVE

The **Derating Curve** shows the maximum allowable dissipation of a Heatsink Mounted resistor at ambient temperatures between 25°-200°C. See **Technical Information Sheet No.TI 007**.

TYPICAL INDUCTANCE VALUES FOR THE STANDARD HS STYLE RESISTOR

Unit Type	Value (Ohms)	Power Rating Watts	Typical Inductivity (microHenries)
HS10	1	10	0.066
HS10	10	10	0.46
HS10	100	10	2.4
HS10	1000	10	5.1
HS10	5000	10	37
HS15	1	15	0.25
HS15	10	15	0.7
HS15	100	15	3.7
HS15	1000	15	8.8
HS15	5000	15	33.5
HS25	1	25	0.59
HS25	10	25	1.65
HS25	100	25	6
HS25	3300	25	23.5
HS25	6800	25	98.9
HS25	10000	25	103
HS25	15000	25	140
HS25	22000	25	206
HS25	25000	25	138
HS50	1	50	0.73
HS50	10	50	4
HS50	100	50	7.7
HS50	1000	50	40
HS50	3300	50	67
HS50	6800	50	115
HS50	10000	50	82
HS50	15000	50	185
HS50	22000	50	192
HS50	25000	50	150
HS50	33000	50	259
HS50	36000	50	308
HS50	47000	50	525
HS50	50000	50	594
HS75	1	75	0.84
HS75	10	75	6.4
HS75	100	75	15.5
HS75	1000	75	80
HS75	3300	75	135.5
HS75	6800	75	158
HS75	10000	75	340
HS75	15000	75	219
HS75	22000	75	473
HS75	36000	75	960
HS75	40000	75	803
HS75	47000	75	818
HS75	50000	75	822

Unit Type	Value (Ohms)	Power Rating Watts	Typical Inductivity (microHenries)
HS100	1	100	1.247
HS100	10	100	5.4
HS100	100	100	22.5
HS100	1000	100	79.8
HS100	3300	100	114
HS100	6800	100	240
HS100	10000	100	216
HS100	15000	100	487
HS100	22000	100	300
HS100	25000	100	387
HS100	33000	100	675
HS100	40000	100	750
HS100	47000	100	1035
HS100	50000	100	1170
HS150	1	150	0.53
HS150	10	150	9.37
HS150	100	150	27.3
HS150	1000	150	100
HS150	3300	150	215
HS150	6800	150	292
HS150	10000	150	307
HS150	15000	150	290
HS150	21500	150	623
HS150	25000	150	230
HS150	33000	150	402
HS150	40000	150	590
HS150	47000	150	596
HS150	50000	150	925
HS200	1	200	1.65
HS200	10	200	13.65
HS200	100	200	38.85
HS200	1000	200	206.28
HS200	3300	200	466.42
HS200	6800	200	420.67
HS200	10000	200	908.29
HS200	12000	200	639.12
HS200	15000	200	998
HS200	22000	200	897
HS200	25000	200	1158
HS200	33000	200	688
HS200	40000	200	850
HS200	47000	200	1173
HS200	50000	200	1328

TYPICAL INDUCTANCE VALUES FOR THE STANDARD HS STYLE RESISTOR

Unit Type	Value (Ohms)	Power Rating Watts	Typical Inductivity (microHenries)
HS250	1	250	2.02
HS250	10	250	16
HS250	100	250	53
HS250	1000	250	140
HS250	3300	250	363
HS250	6800	250	580
HS250	10000	250	680
HS250	15000	250	750
HS250	22000	250	1610
HS250	25000	250	2070
HS250	33000	250	1510
HS250	40000	250	2200
HS250	47000	250	3080
HS250	50000	250	3180
HS250	56000	250	3020
HS250	56000	250	3512
HS250	68000	250	1560

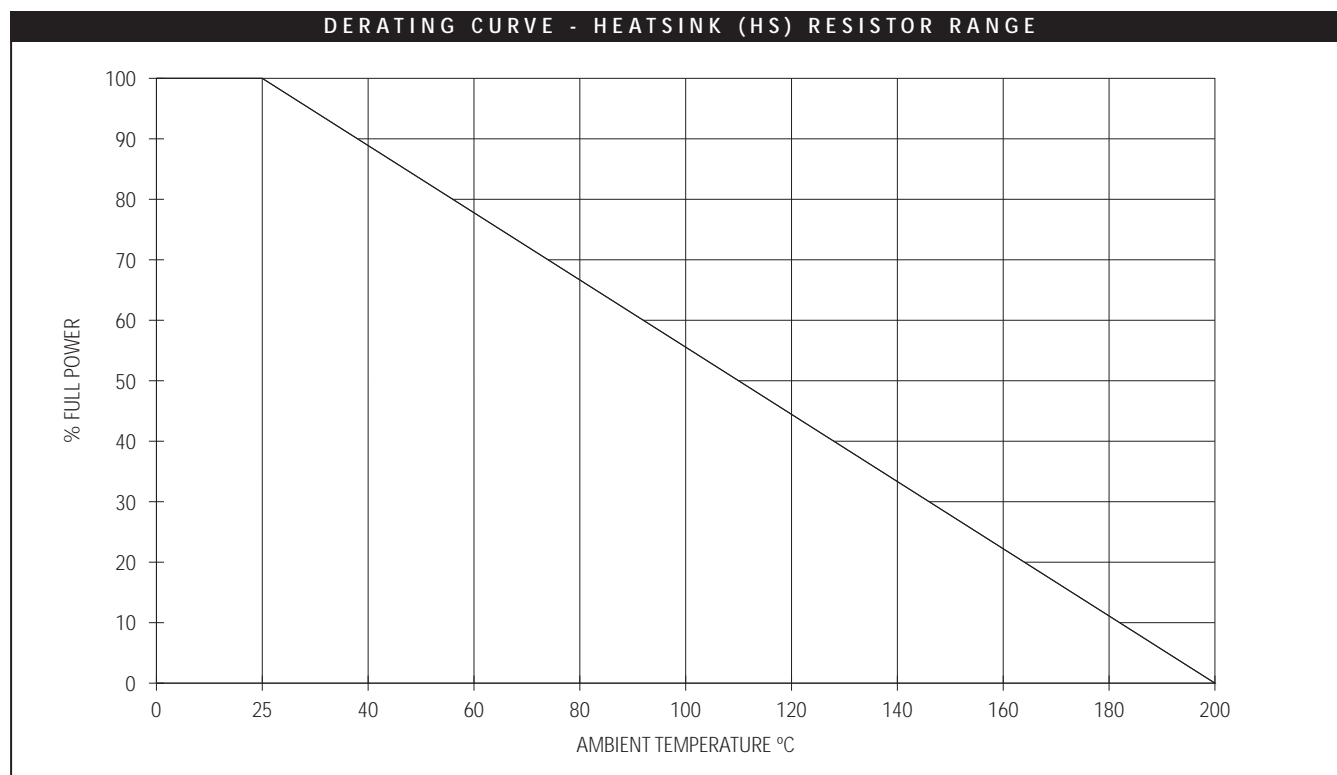
Unit Type	Value (Ohms)	Power Rating Watts	Typical Inductivity (microHenries)
HS300	1	300	2.3
HS300	10	300	19
HS300	100	300	54
HS300	1000	300	167
HS300	3300	300	438
HS300	6800	300	690
HS300	10000	300	977
HS300	15000	300	772
HS300	15000	300	1207
HS300	22000	300	1268
HS300	25000	300	1638
HS300	33000	300	1192
HS300	40000	300	1750
HS300	47000	300	2420
HS300	50000	300	2740
HS300	56000	300	3435
HS300	68000	300	1450

Note The inductance information given above is in relation to the standard HS (Heatsink) style resistor, the equivalent information for the NHS (Low inductance unit) is approximately one tenth of that detailed above for the the same value. Where a resistor outside those values detailed above is required, please contact ARCOL for Inductance information.

DERATING OF RESISTORS BETWEEN 25°C - 200°C.

Where a resistor is mounted on a heatsink with an ambient temperature between 25 - 200°C the maximum Rated Dissipation must be reduced in line with the derating curve shown below.

If a thermally conductive compound cannot be used at the base interface, the rated dissipation must be further derated by 15%.



THERMAL CAPACITY, MAXIMUM VALUES & LIMITING ELEMENT VOLTAGES FOR THE HS/NHS RESISTOR

Unit Type	Thermal Capacity j/°C	(Typical) Unit Weight (Gms)	Standard Voltage Proof (V rms)	Maximum Working/Limiting (DC/AC rms)	Critical Resistance Value	Maximum Resistance Value
HS10	2.6	3	1000	160	2560	5000
HS15	4.45	6	1000	265	4680	10000
HS25	10.7	12.5	2500	550	12100	25000
HS50	19.78	25	2500	1250	31250	50000
HS75	55.99	65	4500	1400	26130	50000
HS100	76.7	90	4500	1900	36100	70000
HS150	115.3	140	4500	2500	41660	100000
HS200	330.3	385	5000	1900	18050	39000
HS250	392.4	475	5000	2200	19360	51000
HS300	475.2	575	5000	2500	20830	63000
NHS10	2.6	3	1000	115	1322	1250
NHS15	4.45	6	1000	190	2400	2500
NHS25	10.7	12.5	2500	390	6090	6250
NHS50	19.78	25	2500	885	15665	12500
NHS75	55.99	65	4500	990	13070	12500
NHS100	76.7	90	4500	1350	18225	17500
NHS150	115.3	140	4500	1775	21000	25000
NHS200	330.3	385	5000	1350	9110	9750
NHS250	392.4	475	5000	1555	9675	12750
NHS300	475.2	575	5000	1775	10500	15750

ELECTROMAGNETIC COMPATIBILITY (EMC)

INTERPRETATION

The EMC Directive refers particularly to Apparatus not to components.

Guidance by the Commission regarding the EMC directive Art1 of **89/336/EEC** States that by definition:-

A Component having no intrinsic function of it's own, not intended as an entity for the end user, is not in the scope of the EMC Directive. A component such as a solid state device or resistor.

HS RANGE TERMINATIONS, MAXIMUM TORQUE/FORCE WITHSTAND FIGURES

Sales Data Sheet	Type	Wattage Size	Termination Type	Termination Material	Maximum Torque (Newtons Metres)	Termination Robustness (Newtons)	Pull Test Cable Only (Newtons)	Related Standards
007	HS STD	10-50	Solder Lug		N/A	20	N/A	CECC 40203-006
007	HS STD	75-150	Solder Lug		N/A	40	N/A	None
007	HS STD	200-300	M6 Thread	(Steel)	5	50	N/A	None
007	HS E3	25-50	M3 Thread	(Steel)	2	30	N/A	None
007	HS E4	75-100	M4 Thread	(Steel)	3	40	N/A	None
007	HS E6	75-150	M6 Thread	(Steel)	4	50	N/A	None
None	HS E6	200-300	M6 Non Mag	(Brass)	3	30	N/A	None
None	HS D	75-300	Moulded in Leads		N/A	N/A	10	None
004	HS E3	25-50	M3 Thread	(Steel)	2	30	N/A	None
004	HS E4	75-150	M4 Thread	(Steel)	3	40	N/A	None
004	HS E6	75-150	M6 Thread	(Steel)	4	50	N/A	None
004	HS F	10-300	Moulded in Leads		N/A	N/A	10	None
004	HS J	10-50	Plain Pin		N/A	20	N/A	None
004	HS J	75-150	Plain Pin		N/A	40	N/A	None
004	HS M	10-50	Amp Style 6.3 Male Spade		N/A	30	N/A	None
004	HS M	75-150	Amp Style 6.3 Male Spade		N/A	40	N/A	None
004	HS X	25-50	Increased Creepage		N/A	15	N/A	None
004	HS X	75-150	Increased Creepage		N/A	30	N/A	None
004	HS X	25-50	Increased Creepage		N/A	15	N/A	None
046	MIHS STD	100-150	Attached Lead		N/A	N/A	10	None
046	MIHS STD	300-500	M6 Thread	(Steel)	5	50	N/A	None
046	MIHS F	300-500	Attached Lead		N/A	N/A	10	None