THERMAL PARAMETERS

Heat generated by Linear Disc Resistors is dissipated mainly by radiation and convection from the exposed surface areas. Within restricted domains, mathematical models may be employed to permit heat transfer estimations.

Symbols

T = Temperature Rise (°C)
W_a = Watts / Unit Exposed Surface Area ($W.cm^{-2}$)
v = Volume / Disc (cm^3)
c_m = Specific Heat Capacity of Active Material = 2J. cm^{-3}.°C^{-1}
Do = Disc Outside Diameter (mm)
τ = Resistor Thermal Time Constant (s)

Radiation and Convection $W_a = 0.00026(\ T)^{1.4}$
(T = 50°C to 175°C, Do = 19 mm to 152 mm, Ambient 25°C)

Dynamic Energy
Since the active material has a negative Temperature Coefficient of Resistance, estimated energies based on Bridge Resistance will be lower than the actual. If the Temperature Coefficient is considered then a true Dynamic Energy will result.

If
E_B = Energy in Joules based on a Bridge Resistance
E_D = True Dynamic Energy
α = Temperature Coefficient of Resistance (TCR)

Then

$$E_D = \frac{2}{\alpha}(1-\Box(1-\alpha E_B))\ \text{Joules}$$

In this relationship, α is the fractional (not %) value and the negative sign has been included in the equation.

Thermal Conductivity	0.04 W / cm^2.°C / cm
Maximum Insertion Energy Ratings	Disc diameters □112 mm : □600 Joules / cm^3 (Infrequently)
	Disc diameters > 112 mm : □500 Joules / cm^3 (Infrequently)
Recommended Operating Temperatures	Disc diameters □112 mm : □300 °C (Infrequently)
	Disc diameters > 112 mm : □250 °C (Infrequently)
	All Discs diameters : □150 °C (Continuous)
Temperature Rise from Energy Injection	T (°C) = Joules (per disc) / v x c_m (Free Air)
Thermal Time Constant	τ (s) = Max Joules @ 25°C / Max Watts @ 25°C
Full Cooling	□4τ

Repetitive Thermal Impulsing:
Assuming that the Heat Transfer Coefficient α (W / cm^2.°C / cm) is constant over the operating temperature range, then the Peak Temperature Rise (Tp) associated with repetitive impulsing can be estimated by way of reference to a classical geometric progression ...

$$Tp\ (°C) = \ T \times (1 - (e^{-(t/\tau)})^n) \div (1 - e^{-(t/\tau)}) ....1$$

where:
T is the Temperature Rise associated with each electrical impulse (°C)
τ is the Resistor Thermal Time Constant (s)
t is the Repetition Rate (s)
n is the number of impulses

If the number of impulses (n) → □ (ie continuous duty), then equation 1 can be simplified thus ...

$$Tp\ (°C) = \ T \div (1 - e^{-(t/\tau)}) ....2$$

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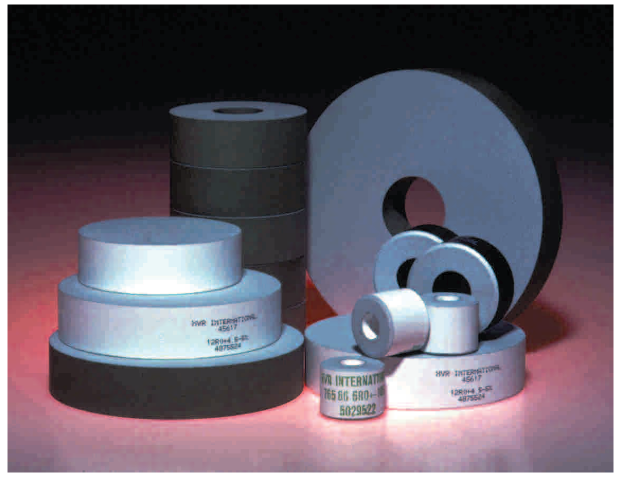
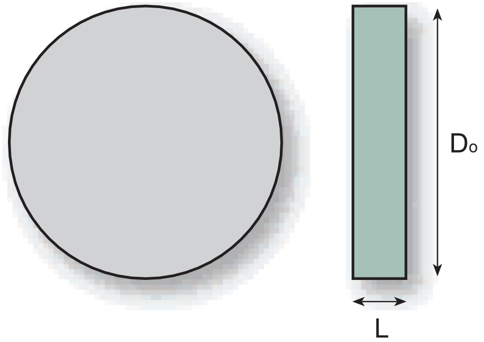
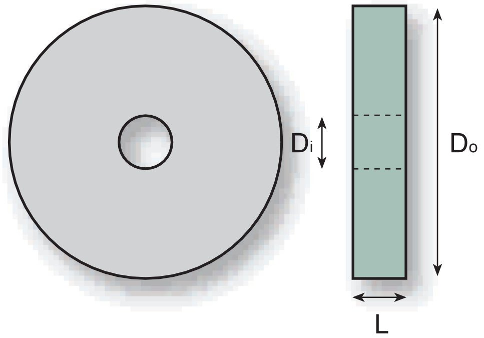
Linear Disc Resistors

- 100% Active Material
- High Surge Energy Rating
- High Voltage Withstand
- Essentially Non-Inductive
- Wide Resistivity Range
- Wide Range of Geometries
- Air / Oil / SF6 Environments
- Single Disc or Modular Assemblies
- Custom Solutions Readily Available
- Free Design Service







HVR Linear Disc Resistors are manufactured from a carefully blended mixture of clays, alumina and carbon. After blending, the material is pressed to the required shape, with diameters ranging from 3 to 150mm. The Resistors are then fired at high temperature in a tunnel kiln with controlled atmosphere.

This produces a Ceramic Carbon Resistor which is 100% active material and therefore of minimum size. Aluminium is then flame-sprayed onto the flat surfaces of the resistor to provide electrical contact, and an anti-track coating is applied to the periphery to improve dielectric withstand.

With the capability of sustaining energies ranging from Joules to Mega-Joules, at frequencies up to Mega-Hz, HVR Linear Disc Resistors can be used in even the most demanding applications such as electrical transmission, traction, AC/DC drives, pulse power, dummy loads, induction heating and pulse forming networks.

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Technical Specifications

STYLE	OUTSIDE DIAMETER (Do)	RESISTOR TYPES INSIDE DIAMETER (Di)						VOLUME $v = □/40 \times (D_o^2 - D_i^2) \times L$ (v)				MAXIMUM JOULES @ 25°C			
		SOLID	11	14	20	26	34								
Units	(mm)	(mm)						(cm³)				(J)			
M001A	19	AB 378	AB 379					7.2	4.8			1800	1200		
M001	24	AB 704	AB 380					11.5	9.1			2875	2275		
M001B	31	AB 419	AB 335	AB 984				19.2	16.8	15.3		4800	4200	3825	
M002A	42	AB 350		AB 381	AB 045			35.2		31.3	27.2	8800		7825	6800
M002	50	AB 061			AB 851			50.0	42.0			12500	10500		
M002B	60	AB 389			AB 046	AB 387		72.0	64.0	58.0		18000	16000	14500	
M003	74	AB 443			AB 039	AB 399	AB 409	110.0	100.0	96.0	86.0	27500	25000	24000	21500
M003B	82	AB 395			AB 801	AB 564	AB 886	134.0	126.0	120.0	110.0	33500	31500	30000	27500
M004A	94	AB 444			AB 675	AB 902	AB 565	176.0	168.0	162.0	154.0	44000	42000	40500	38500
M004	102	AB 917			AB 919	AB 923	AB 926	208.0	200.0	194.0	184.0	52000	50000	48500	46000
M004B	112	AB 456			AB 070	AB 029	AB 403	250.0	242.0	236.0	228.0	62500	60500	59000	57000
M005	127	AB 935			AB 038	AB 967	AB 460	322.0	314.0	308.0	298.0	80500	78500	77000	74500
M005B	137	AB 968			AB 974	AB 978	AB 946	374.0	366.0	360.0	352.0	93500	91500	90000	88000
M006	151	AB 449			AB 622	AB 808	AB 410	454.0	446.0	442.0	432.0	113500	111500	110500	108000
		<-------- DISC LENGTHS (L) 25.4 mm -------->													

STYLE	MAXIMUM WATTS @ 25°C	THERMAL TIME CONSTANT (τ)				WEIGHT (Volume x 2.25g / cm³)				A / L $A/L = □/40 \times (D_o^2 - D_i^2) \div L$				RESISTANCE RANGE MINIMUM	MAXIMUM
Units	(W)	(Seconds)				(g)				(cm)				Ohms	
M001A	3.5	510	340			16.0	11.0			1.1	0.7			3R9	27K0
M001	4.0	720	570			26.0	20.5			1.8	1.4			2R0	15K0
M001B	5.5	870	760	700		43.0	38.0	34.5		3.0	2.6	2.4		1R2	10K0
M002A	7.5	1170		1040	910	79.0		70.5	61.0	5.5		4.8	4.2	0R68	5K6
M002	9.0	1390	1170			112.5	94.5			7.7	6.5			0R43	3K6
M002B	10.5	1710	1520	1380		162.0	144.0	131.0		11.1	9.9	9.0		0R33	2K4
M003	13.0	2120	1920	1850	1650	248.0	225.0	216.0	194.0	16.9	15.7	14.8	13.4	0R22	1K0
M003B	14.0	2390	2250	2140	1960	302.0	284.0	270.0	248.0	20.8	19.6	18.7	17.2	0R18	820R0
M004A	16.5	2670	2550	2450	2330	396.0	378.0	365.0	347.0	27.3	26.1	25.2	23.7	0R12	560R0
M004	17.5	2970	2860	2770	2630	468.0	450.0	437.0	414.0	32.2	30.9	30.1	28.6	0R10	470R0
M004B	19.5	3210	3100	3030	2920	565.0	545.0	530.0	515.0	38.8	37.6	36.7	35.2	0R082	390R0
M005	22.0	3660	3570	3500	3390	725.0	705.0	695.0	670.0	49.9	48.6	47.8	46.3	0R068	180R0
M005B	23.5	3980	3890	3830	3740	840.0	825.0	810.0	790.0	58.0	56.8	55.9	54.5	0R056	150R0
M006	26.0	4370	4290	4250	4150	1020.0	1005.0	995.0	970.0	70.5	69.3	68.4	66.9	0R047	120R0

PHYSICAL / MECHANICAL PARAMETERS

Dimension Range Outside Diameter (Do) 3 to 152mm Standard Length (L) 25.4mm Length (L) 10 to 50 mm

Density Nominally 2.25 g / cm^3

Shock and Vibration Linear Disc Resistors are robust and capable of absorbing transmitted mechanical shock provided direct impact is avoided.

Coefficient of Linear Expansion $+ 4 \times 10^{-6}$ to $+ 10 \times 10^{-6}$ per °C

Youngs Modulus 3×10^6 N cm^{-2} **Crushing Strength** Average value 12000 N cm^{-2}

Assembly Mounting Force Linear Disc Resistors may be assembled directly to the busbar or assembled into stacks by mounting on an appropriate tie rod. Sufficient assembly force must be maintained to provide good electrical interdisc contact over long periods of time. HVR recommend the use of several disc spring washers in series (reduces stiffness ratio) to provide the reliable mounting force described below :

Force (kg) = $24 \times (D_0 - D_i)^{0.7}$ (±50%)

As a guide the total compression (deflection), from 'just nip' condition should be :

Total compression = 2 + (Number of Discs x 0.1) mm

Greater compressive forces are permissible provided the disc contact surfaces are ground flat and are free from foreign bodies, thereby minimising the risk of destructive induced bending moments.

Disc Terminations Metallised contacts are flame sprayed onto the opposing flat surfaces of the Resistor Discs. Standard metallised contacts include Aluminium, Copper, Brass, Nickel and Silver.

Anti-Track Coating Epoxy and Silicone based anti-track coatings are utilised for improvement of dielectric withstand in Air and SF6 gas.

Environmental Protection Resistor Discs can be impregnated with Silicone Varnish to reduce moisture ingress and terminals Electroless Nickel Plated to minimise corrosion.

Resistor Drying Ceramic Resistors are porous and absorb moisture, this should be removed from the discs prior to use. Dry the discs in an oven at 110 - 120°C for 24 hours. Place discs in a sealed container with silica gel.

ELECTRICAL PARAMETERS

Resistance Values Whilst E24 values are preferred, other values are readily available at no additional cost.

Resistance Tolerance +/- 20%, +/- 10% and +/- 5% available as standard.

Resistivity Range - ρ 3 Ohm cm to 30000 Ohm cm ρ = R x A/L where R = Resistance Value

Temperature Coefficient - TCR -0.05% to -0.15% per °C Temperature Rise depending on Resistivity Value.

$TCR = 0.16 \times e^{-(\log\rho/1.4)} - 0.135$ (%/°C Temperature Rise)

Voltage Coefficient - VCR -0.5% to -7.5% / kV / cm

$VCR = -0.62 \times \rho^{0.22}$ (%/kV/cm) For ρ domain 10 to 7500 Ohm cm

Inductance This is negligible (nH) and the resistors may be described as non-inductive. In practice the inductance of connecting leads will be greater than that of the resistors.

Dielectric Constant (Permittivity) ε_r This is very difficult to measure and will vary according to material resistivity. As an order of merit : $\varepsilon_r \sim 5$

Maximum Working Voltage Withstand per cm of Disc Length ($V_{working}$)

Volts (rms)	SF6	$V_{working} = 1.00 \times (R/t \times A/L)^{0.335}$	kV / cm	t Domain 10 to 50 ms	ρ Domain 10 to 7500 Ohm cm
	AIR	$V_{working} = 0.87 \times (R/t \times A/L)^{0.3}$	kV / cm	t = Insertion time in ms	
Volts (Impulse)	SF6	$V_{working} = 8.0 \times {}^{1.2}□Log(R/2.54 \times A/L)$	kV / cm	1.2 / 50 µs Waveform	
	AIR	$V_{working} = 4.3 \times {}^{1.2}□Log(R/2.54 \times A/L)$	kV / cm	1.2 / 50 µs Waveform	
	AIR	$V_{working} = 3.0 \times Log(R/2.54 \times A/L)$	kV / cm	50 / 1000 µs Waveform	
	AIR	$V_{working} = 1.5 \times (Log(R/2.54 \times A/L))^{1.25}$	kV / cm	100 / 10000 µs Waveform	

SOLID	11	14	20	26	34

Colour code shows different inside diameters.

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