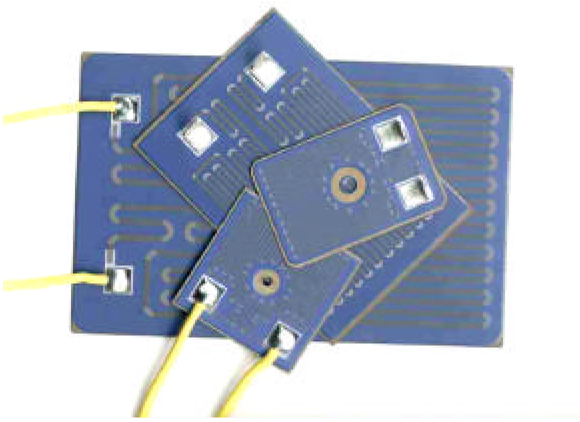


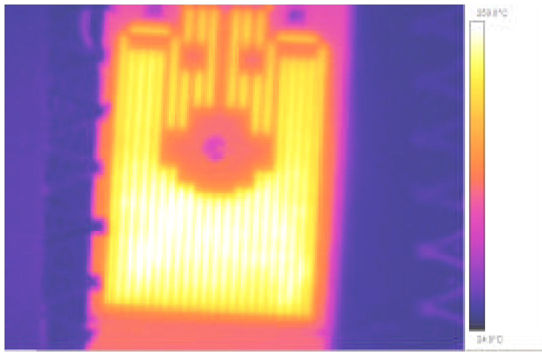
WDBR Series (RoHS compliant)

This new range of thick film planar power resistors on steel, offering high pulse withstand capability, compact footprint and low profile, to many demanding applications including dynamic motor braking and industrial welding.

Additional properties:

- Simple construction, lower installation cost
- 1kW, 2kW, 3.5kW, and 7kW versions
- Failsafe
- Low inductance
- Enables reduction in overall product size

Background information



Welwyn thick film planar power resistors are generally used for ‘dumping’ energy from a motor when the speed is significantly slowed down. In this instance, the motor behaves as a generator, which then returns the energy to the circuit where it is dissipated as heat in the braking resistor. An example of this application is found in a lift, where the smooth deceleration to a complete stop is achieved by braking the motor and this braking energy is subsequently lost as heat in the resistor. The resistor is normally mounted onto a heatsink with or without cooling.

The design of a braking resistor must consider peak power, average power, maximum applied voltage, ohmic value, duty cycle, temperature range and heat transfer conditions. The resistor should also be intrinsically safe and flameproof. Due to the planar design, the WDBR has a low inductance figure, typically 3-6μH. In an AC machine drive, the mains fed AC is rectified to DC then inverted by electronic switching to variable frequency AC. The brake resistor is connected in series with the electronic switch across the DC voltage source. Under braking conditions, power will flow back into the DC rail and as the reverse ‘DC’ current cannot return to the AC supply because of the rectifier stage, the energy flow into the link capacitor causes the DC link voltage to rise. When the DC link voltage reaches the maximum permitted limit, the electronic braking circuit switches on and off in a pulse mode. The pulse is usually 1milli-second time interval during its normal ‘on’ period for up to two seconds and with a duty cycle of perhaps 1:5 to 1:10. However, there appears to be no unifying standard in industry as to what this duty cycle should be.

In an overload or fault condition, the braking resistor is designed to go open circuit in a fail-safe manner with no short circuit to earth and be flame retardant. A low inductance on the resistor is generally preferred to allow effective electronic switching.

A Welwyn Dynamic Braking Resistor is an insulated stainless steel substrate on to which a thick film circuit/resistor is printed. A high temperature overglaze protects the surface of the resistor. The dielectric layer provides a high voltage insulation breakdown typically in the region of a min. 2.5 kV_{dc}. The WDBR gives a fast thermal response (high power dissipation as heat is rapidly transferred to the heatsink) because of the low thermal mass and an improved temperature

Welwyn Components reserves the right to make changes in product build and specification without notice or liability.
All information is subject to Welwyn’s own test data and is considered accurate at time of print.

©**Welwyn Components Limited** Welwyn Electronics Park, Bedlington, Northumberland, NE22 7AA, England.
Web: www.welwyn-tt.com Tel: 01670 822181 Fax: 01670 829465 email: WDBR@welwyn-tt.com

distribution from effective element designs. In addition, the substrate itself also behaves as a heatsink and provides mechanical strength and robustness. These coupled with excellent closely matched thermal expansion coefficients between the stainless steel and the dielectric film enable the resistor to withstand severe temperature cycling (up to 400°C) in high power pulse applications. The intrinsic robustness, thermal capacity, effective resistive track designs and electrical performance of the thick film on steel braking resistor offer a high performance, cost competitive solution to dynamic braking. Extensive high power pulse laboratory testing has demonstrated good stability and reliability in the WDBR resistor.

Electrical Data

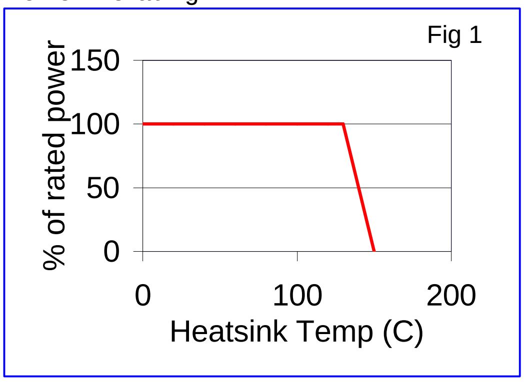
note: data is provided for non-standard WDBR1.5, data for the WDBR1 to follow in August 2006

Category:	WDBR1.5	WDBR2	WDBR3	WDBR7
Resistance range (ohms)	12, 22, 47, 100 and 150			47, 100, 150
Resistance tolerance	±10%			
Max pulse power (>50000 cycles as per Fig 2) *(Ref 1)*	1kW	2kW	3.5kW	7kW
Stability (nominal load) after 50000 cycles	ΔR <±5%			
Maximum resistor 'hot spot' temperature	365 °C			
Minimum dielectric withstand voltage	2500 V DC			
Maximum continuous load without cooling *(Ref 2)*	160W	200W	260W	280W *1
Maximum continuous load with cooling *(Ref 1)*	560W	780W	900W	1490W *1
Derating	See Fig 1			
Inductance (Typical)	<3µH	<3µH	<4µH	<6µH

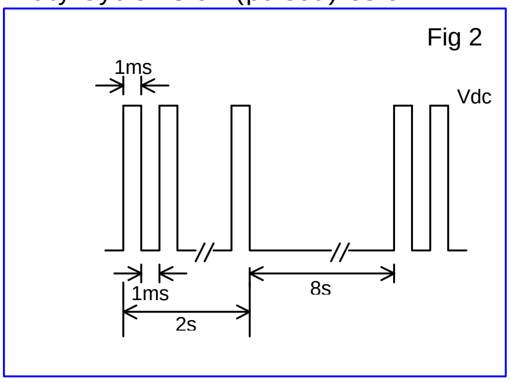
Ref 1 *Testing carried out on a heatsink (thermal resistance 0.67°C/W), force cooled at 5 m/s air velocity for 50K cycles.*
Ref 2 *Testing carried out on a heatsink (thermal resistance 0.53°C/W) with no air-cooling, RT=25°C.*
*1 *Limited by the solder type, the Maximum continuous load can be improved with alternative solders.*

Please contact our Applications Team on WDBR@welwyn-tt.com if you would like to discuss, non-standard resistor values or tolerances for the WDBR range or bespoke designs.

Power Derating



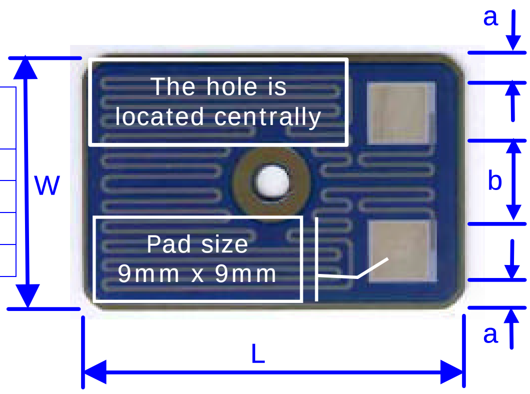
Duty Cycle 2s on (pulsed) 8s off



Welwyn Components reserves the right to make changes in product build and specification without notice or liability.
All information is subject to Welwyn's own test data and is considered accurate at time of print.

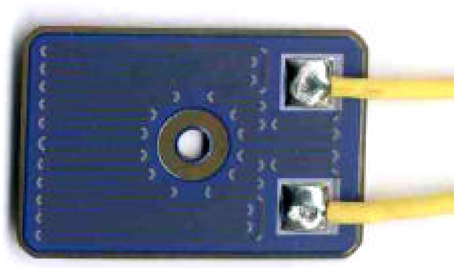
Physical Data (all dimensions in mm)

Type	L	W	Substrate thickness	∅D	a	b
WDBR1	49.3	35.85	0.9	3.2	3.2	11.2
WDBR2	60.96	40.64	0.9	5.3	4.7	13.0
WDBR3	101.6	70	0.9	5.3	13.5	22.0
WDBR7	152.4	101.6	1.5	5.3	15.0	51.3



Note 1: Substrate tolerances ±0.1mm

Note2: The product is identified by the type and resistor value
Example: WDBR 100R

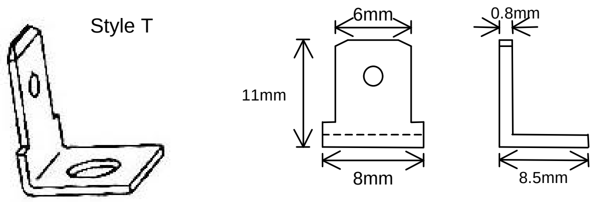


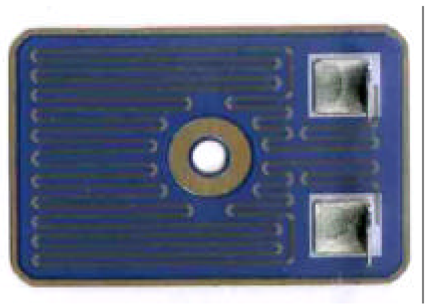
Termination Style

WDBR resistors are available with solder coated conductors (I), flying leads (L) or push-on connections (T) as shown:

Style L, flying leads, 250mm long are attached to the resistor these are rated up to 40A. The cable used conforms to UL3134.

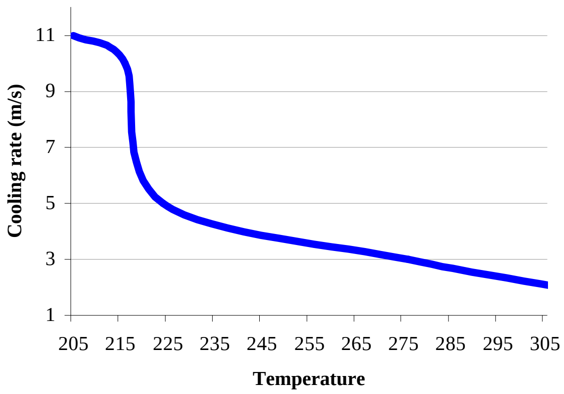
STYLES T, standard push-on connections as shown:

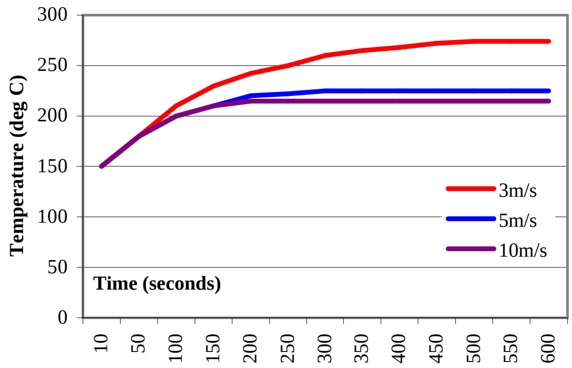




Airflow effects upon temperature (Example is for a WDBR7)

3 m/s, 5m/s & 10m/s cooling WDBR 100R, 2 secs on pulsed (1ms On:Off) & 8 Secs Off





Welwyn Components reserves the right to make changes in product build and specification without notice or liability.
All information is subject to Welwyn's own test data and is considered accurate at time of print.

Ó**Welwyn Components Limited** Welwyn Electronics Park, Bedlington, Northumberland, NE22 7AA, England.
Web: www.welwyn-tt.com Tel: 01670 822181 Fax: 01670 829465 email: WDBR@welwyn-tt.com

Application Notes

It is important to select a heatsink with low thermal resistance (typically $\leq$0.12°C/W) to enable the component to operate at its continuous power rating. Data for heatsinks with higher thermal resistance are shown in the Electrical Data.

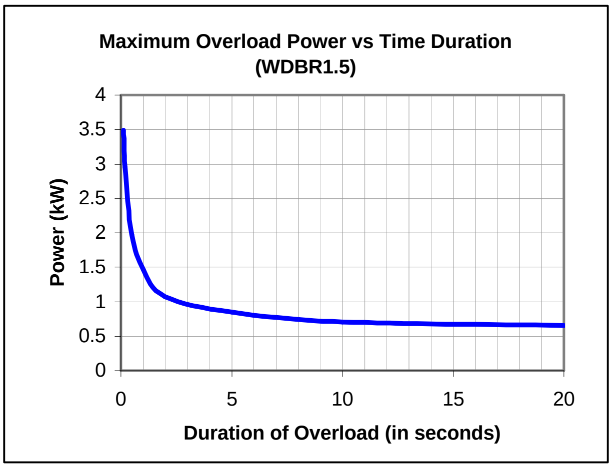
WDBR resistors will ‘failsafe’ (open circuit) under overload (fault) conditions whilst maintaining a dielectric withstand of 1kV minimum.

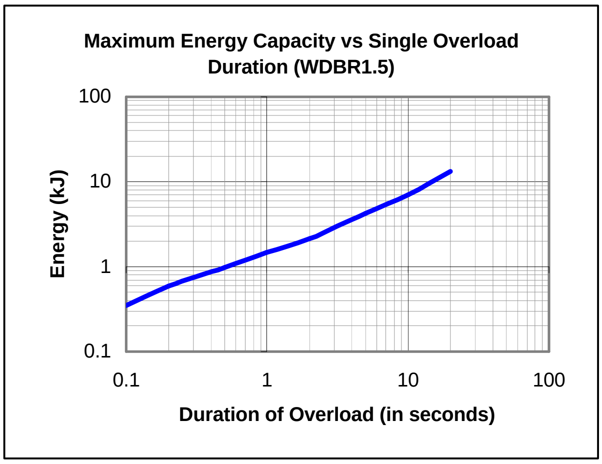
Please follow the guideline below:

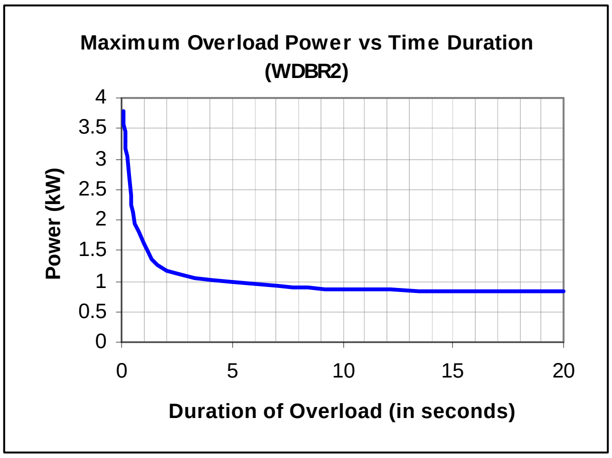
- A thermal grease (e.g. Dow Corning DC340 or equivalent), should be applied between the heatsink and the resistor.
- The resistor should be mounted using an M4 screw head bolt for the WDBR2, 3 & 7 range, and a M3 screw head bolt should be used for the WDBR1 range.
- Torque the screw head bolt to a maximum of 2.5 ±10% Nm.
- The mounting area of the heatsink must have a surface finish of $\leq$6.3µm with flatness of $\leq$0.05mm.
- Forced air-cooling is required to maintain the specified temperature limits.

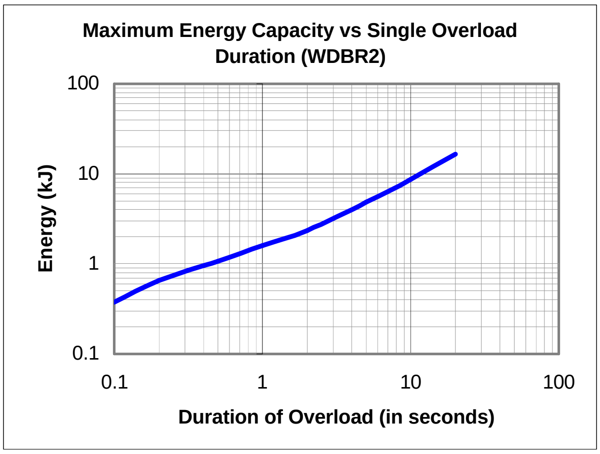
Overload conditions

note: data is provided for non-standard WDBR1.5, data for the WDBR1 to follow in August 2006



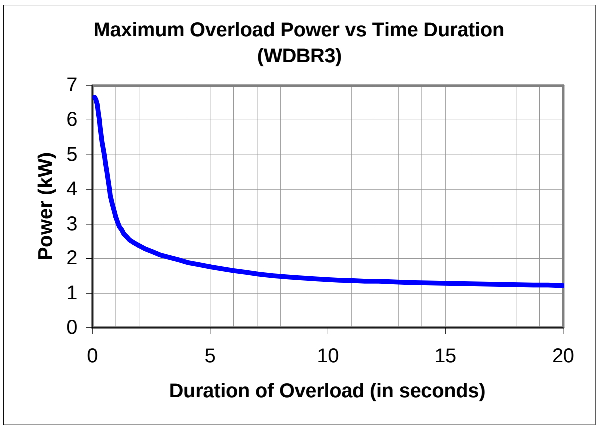


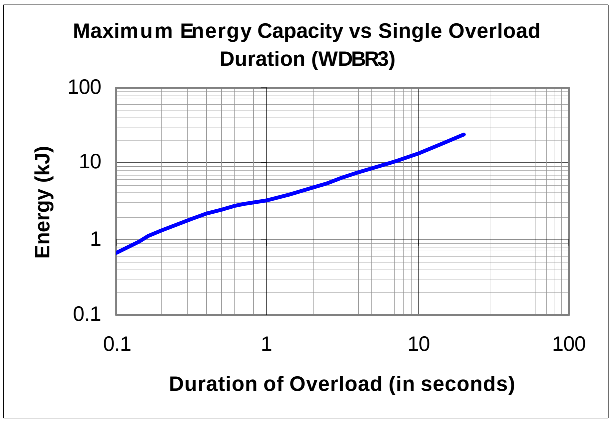


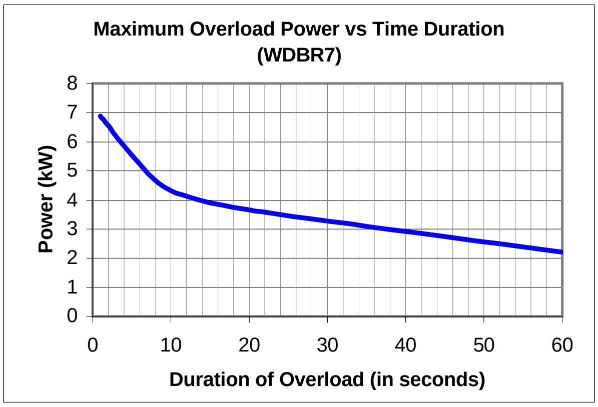


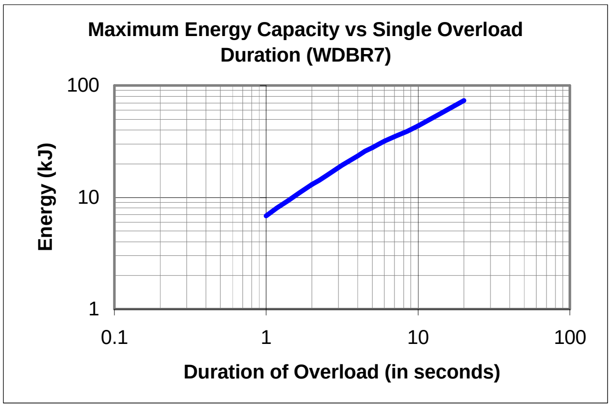
Welwyn Components reserves the right to make changes in product build and specification without notice or liability.
All information is subject to Welwyn’s own test data and is considered accurate at time of print.

Overload conditions (continued)









Welwyn Components reserves the right to make changes in product build and specification without notice or liability.
All information is subject to Welwyn's own test data and is considered accurate at time of print.

©**Welwyn Components Limited** Welwyn Electronics Park, Bedlington, Northumberland, NE22 7AA, England.
Web: www.welwyn-tt.com Tel: 01670 822181 Fax: 01670 829465 email: WDBR@welwyn-tt.com

Ordering Procedure

Specify type reference etc as shown in this example of a WDBR2 120R 10% with flying leads.

WDBR 2 -120R L K W

- Type — WDBR
- Power rating — 2
  - 1 1kW
  - 2 2kW
  - 3 3.5kW
  - 7 7kW
- Resistor value — 120R
- Termination style — L
  - I Solder only
  - L Flying leads
  - T Push-on connectors
- Tolerance K=10% — K

Example:

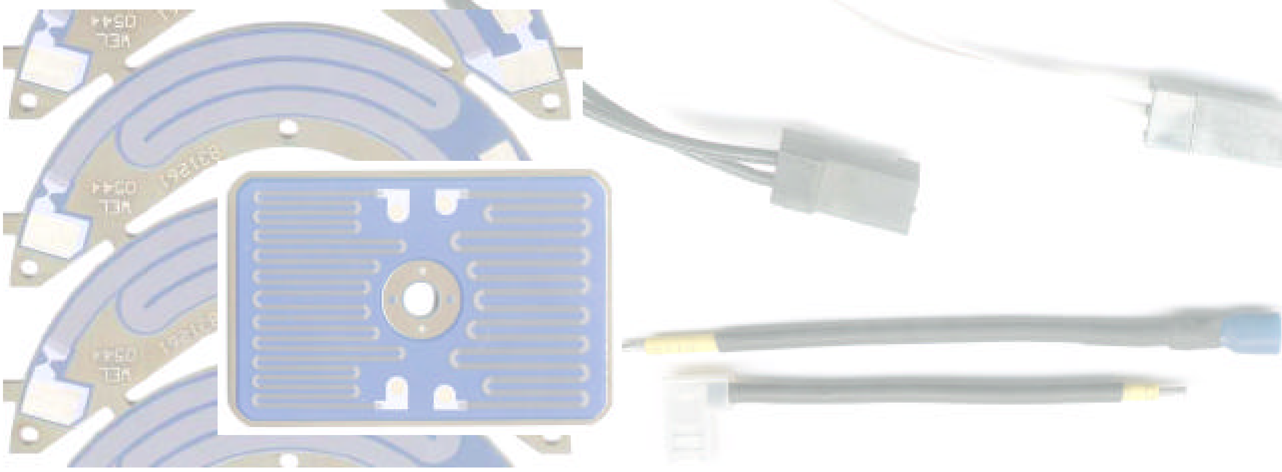
WDBR2-120RLKW

Additional notes

Please contact our Applications Team on WDBR@welwyn-tt.com if you would like to discuss, non-standard resistor values or tolerances for the WDBR range or bespoke designs. Further contact details are shown at the base of the document.

Protective covers (as shown above) are available for the WDBR2 range, purchased in addition to the resistor. Protective covers for other product can be made available upon request.

A variety of lead types and connectors are also available upon request.



Welwyn Components reserves the right to make changes in product build and specification without notice or liability.
All information is subject to Welwyn's own test data and is considered accurate at time of print.

©**Welwyn Components Limited** Welwyn Electronics Park, Bedlington, Northumberland, NE22 7AA, England.
Web: www.welwyn-tt.com Tel: 01670 822181 Fax: 01670 829465 email: WDBR@welwyn-tt.com

Additional notes (continued)

Welwyn thick film steel offers excellent thermal transfer that allows high power densities for surge handling as well as continuous operation. With proper heat sinking, this power range can be greatly increased. Various air and water cooled Aluminium heat sinks are readily available. The thermal conductivity is also improved when thermal greases or pads are used to interface the heat sink and resistor. The heat sink is typically mounted to the resistor with screws as the fastener; however, rivets, staking, or clamp assemblies are viable alternatives. Lead wires and terminals are constructed to the requirements of the application.

Thermal shock and vibration testing has shown Welwyn thick film steel Technology to be superior to other resistor technologies available on the market. Thermal shock test results of 20,000 cycles of a dry boil and quench test show no performance degradation. The accelerated testing consists of heating the resistor up to 140°C and then quenching the resistor in water at 26°C repeatedly. The stainless steel substrate is resilient to vibration testing where typical ceramic substrates are brittle and fail.

Braking resistors

When specifying the braking resistor, the power requirements should be identified as the instantaneous power or surge, the average power and braking cycle, and the continuous power required for the application. The environmental temperature and the maximum resistor operating temperature should also be designated if your application has constraints.

Because the inertial loads will vary for each drive application, resistor sizes will vary for the same motor coupled to the different systems. In order to limit the number of resistance values required, the designer should consider a few values that can be linked in series for a higher total resistance, or in parallel to lower the total resistance. This allows for less resistance values to be inventoried and greater flexibility to properly size the brake for each application.

Conclusion

Welwyn thick film steel technology offers significant advantages over competing technologies, with exceptional thermal transfer characteristics, power density, and size qualities, this product is an overall improvement to existing resistor configurations. The robust nature of stainless steel offers improved reliability over other substrate systems such and Alumina or FR4 for shock, vibration, and heat dissipation. Welwyn thick film steel is a cost effective solution for power applications with superior performance characteristics.

There is a standard range of products available, please contact our Applications Team on WDBR@welwyn-tt.com if you would like to discuss, non-standard resistor values or tolerances for the WDBR range or bespoke designs. Further contact details are shown at the base of the document.

Welwyn Components reserves the right to make changes in product build and specification without notice or liability.
All information is subject to Welwyn's own test data and is considered accurate at time of print.

Ó**Welwyn Components Limited** Welwyn Electronics Park, Bedlington, Northumberland, NE22 7AA, England.
Web: www.welwyn-tt.com Tel: 01670 822181 Fax: 01670 829465 email: WDBR@welwyn-tt.com

Sizing the braking resistor

In order to determine the relationship of the instantaneous power, P_i, generated during the braking cycle, the formula derived from Ohms Law is used to compare the elevated DC link voltage, V_e, and the braking resistance, R_b,

$$P_i = \frac{V_e^2}{R_b} \quad \text{or} \quad R_b = \frac{V_e^2}{P_i}$$

This is important when defining the surge characteristics required for the resistor rating.

A factor in determining the minimum resistance value, R_{bmin}, is the current limit of the switching mechanism, I_s. By design, the resistor should be sized so that the generated current of the motor does not exceed the rating of the electronic switch.

$$R_{bmin} = V_e / I_s$$

For synchronous speed, W_s = 2? f/N_p [rad/sec], where f is the power frequency and N_p is the number of induction pole pairs. Using the actual rotor speed, W_r [rad/sec], the motor slip, S, is calculated by:

$$S = \frac{\omega_s - \omega_r}{\omega_s} \quad \text{which is typically} < 0.05$$

The rated power of the drive, P_r, is used to calculate the rated torque, T_r.

$$P_r\,[W] = T_r\,[Nm] * \omega_r\,[rad/sec] \quad \text{or} \quad T_r = \frac{P_r}{\omega_r}$$

Taking into account the torque overload factor, T_o, usually between 150% and 200%, the effective torque, T_e, for braking calculations is

$$T_e = T_r * T_o\,[Nm]$$

by assuming that the angular deceleration, a, is constant from the synchronous speed, W_s, to zero, the braking time, t_b [sec], can be calculated using the effective torque, T_e. The inertial load, J_l [kgm^2], of the drive system determines the brake time:

$$T_e = J_l * \alpha \quad \text{where} \quad \alpha = \frac{\omega_s}{T_b}$$

$$\text{thus,} \quad t_b\,[sec] = \frac{J_l * \omega_s}{T_e}$$

Welwyn Components reserves the right to make changes in product build and specification without notice or liability.
All information is subject to Welwyn's own test data and is considered accurate at time of print.

Ó**Welwyn Components Limited** Welwyn Electronics Park, Bedlington, Northumberland, NE22 7AA, England.
Web: www.welwyn-tt.com Tel: 01670 822181 Fax: 01670 829465 email: WDBR@welwyn-tt.com
Issue 3 08/08/06 RD

Other data can be obtained from the following equations in understanding the requirements of your application.

$$\textit{Kinetic Energy, KE,} = 0.5 * J_l * \omega_s^2$$

$$\textit{Average Power of the braking cycle, } P_{av} = \frac{KE}{t_b}$$

To calculate the continuous power rating, P_c, the duty cycle of the braking interval is considered. Where the duty cycle is calculated by the braking and cycle time $d_c = t_b / t_{cy}$.

$$P_c = P_{av} * d_c$$

And with the thermal resistance of the heat sink, R_{th}, the temperature rise of the resistor can be estimated by:

$$\Delta T = P_c * R_{th}$$

EXAMPLE

Calculate the braking resistor needed for a 3 KW drive system. This drive consists of a 4 pole induction motor, a 10A rated switching mechanism, the rotational speed is 1750 rpm at 60 Hz, the coupled inertial load is 1 kgm^2, and the elevated DC link voltage, Ve, is 780 V.

Assuming a 175% overload factor, or T_o= 1.75, and calculating the number of pole pairs, 4/2, or 2, the synchronous and rotational speed are:

$$\omega_s = 2\pi f/N_p \text{ [rad/sec]} = 2\pi(60) / 2 = 188.4 \text{ rad/sec}$$

$$\omega_r = 2\pi (1750/60) = 183.2 \text{ rad/sec}$$

The rated torque and maximum available torque are then calculated as

$$T_r = \frac{P_r}{\omega_r} = 3000 \text{ W} / 183.2 \text{ rad/sec} = 16.4 \text{ Nm}$$

$$T_e = T_r * T_o \text{ [Nm]} = 163.8 \text{ Nm} * 1.75 = 28.7 \text{ Nm}$$

Assuming constant angular deceleration, the braking time is then calculated by:

$$t_b \text{ [sec]} = \frac{J_l * \omega_s}{T_e} = (1 \text{ kgm} * 188.4 \text{ rad/sec}) / 28.7 \text{ Nm} = 6.56 \text{ seconds}$$

If the desired nominal braking time is 5 seconds, then:

$$T_e = (1 \text{ kgm}^2 * 188.4 \text{ rad/sec}) / 5 \text{ sec} = 37.7 \text{ Nm}$$

Welwyn Components reserves the right to make changes in product build and specification without notice or liability.
All information is subject to Welwyn's own test data and is considered accurate at time of print.

©**Welwyn Components Limited** Welwyn Electronics Park, Bedlington, Northumberland, NE22 7AA, England.
Web: www.welwyn-tt.com Tel: 01670 822181 Fax: 01670 829465 email: WDBR@welwyn-tt.com

And the instantaneous resistor power, P_i, is determined to be:

$$P_i = 1.75 * 3000W * (37.7\ Nm / 28.7\ Nm) = 6.9\ KW$$

With the upper rail voltage of 780 V, the resistor is calculated to be

$$R_b = (780\ V)^2 / 6.9\ KW = 88.2\,\Omega$$

From the Kinetic Energy equation:

$$P_{av} = \frac{KE}{t_b} = \frac{0.5 * J_l * \omega_s^2}{t_b} = (0.5 * 1\ kgm^2 * (188.4\ rad/sec)^2) / 5\ sec = 3549\ W$$

To determine the continuous rating for the resistor, apply the duty cycle. For this example, assume one braking cycle per minute, or 5 seconds per 60 second interval:

$$P_c = P_{av} * (t_b / t_c) = 3549W * (5\ sec / 60\ sec) = 296\ W$$

In summary, the resistor needs to meet the following parameters in order to handle the dissipated energy for a 5 second braking cycle:

- Instantaneous Power = 6900 W
- Average Power = 3549 W
- Continuous Power = 296 W
- Resistance value = 88.2 O

To verify that the generated current is within the current limit of the switching device, which is 10A, the lowest resistance value is considered. The 88O resistor has a 10% tolerance and therefore the lowest possible resistance is 79.2O The peak generated current during the braking cycle is then:

$$I_s = V_e / R_{bmin} = 780V / 79.2\,\Omega = 9.85\ A$$

This is less than the switch rating of 10A and the assumption that the switch is on continuously is worst case. However, further safety for the switch may lead the designer to change the device to a higher rating such as 15A. By upgrading the switch to a higher rating, the system can be modified for faster braking if the application requirements change.

Welwyn Components reserves the right to make changes in product build and specification without notice or liability.
All information is subject to Welwyn's own test data and is considered accurate at time of print.

Ó**Welwyn Components Limited** Welwyn Electronics Park, Bedlington, Northumberland, NE22 7AA, England.
Web: www.welwyn-tt.com Tel: 01670 822181 Fax: 01670 829465 email: WDBR@welwyn-tt.com