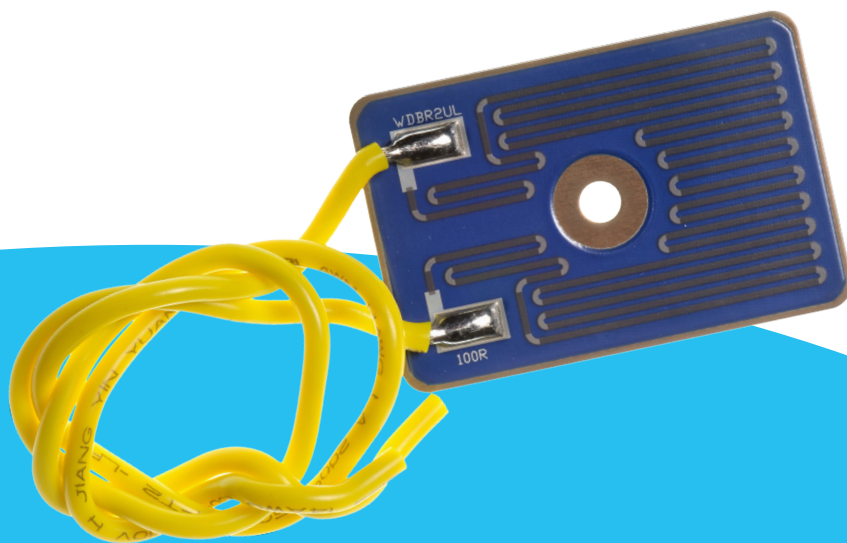


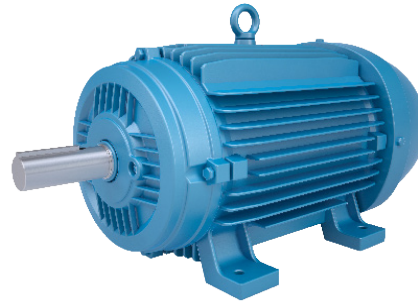
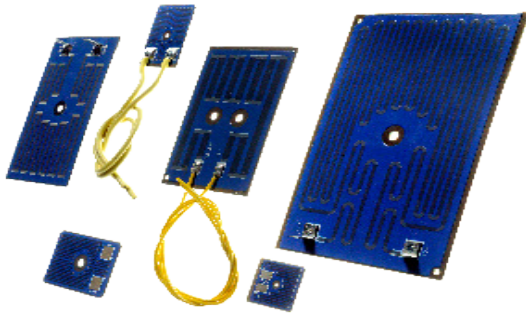
# WDBR Series Application Note **Resistors**

---

BI Technologies IRC Welwyn



## Application Note



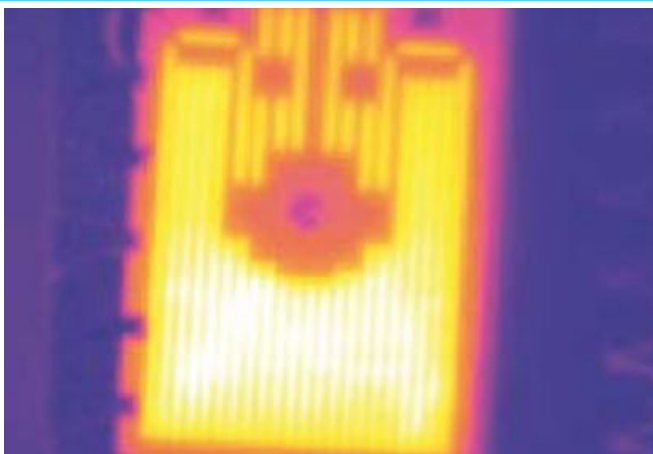
### Background Information

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

TT Electronics 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 3-6mH. 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.



- UL508 approved version WDBR-UL
- Simple construction, lower installation cost
- 0.5kW, 1.5kW, 2kW, 3.5kW, 5kW and 7kW versions
- Failsafe
- Enables reduction in overall product size
- RoHS Compliant

# Application Note

## Background Information

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 1 milli-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

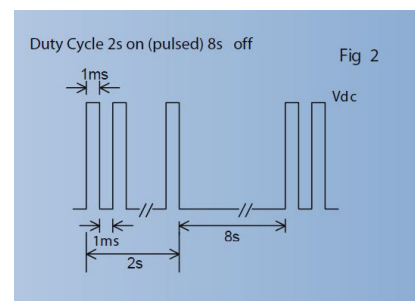
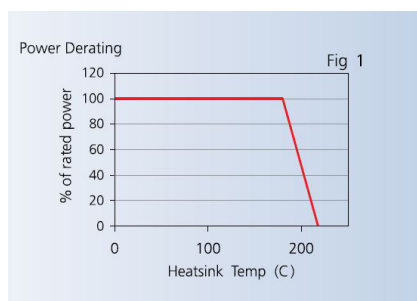
temperature overglaze protects the surface of the resistor. The dielectric layer provides a high voltage insulation breakdown typically in the region of a min. 2.5 kVdc. The WDBR gives a fast thermal response (high power dissipation as heat is rapidly transferred to the heatsink) because of the low thermal mass and an improved temperature 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, compact solution to dynamic braking. Extensive high power pulse laboratory testing has demonstrated good stability and reliability in the WDBR resistor.

## Electrical Data

		WDBR1/2	WDBR1	WDBR2	WDBR3	WDBR5	WDBR7
Resistance Range	ohms	12 to 100	12 to 150				
Resistance tolerance	%	10					
Pulse power rating <sup>1</sup>	kW	0.5	1.5	2.0	3.5	5.0	7.0
Power rating on heatsink <sup>2</sup>	W	160	180	200	260	270	280
Power rating on fan-cooled heatsink <sup>3</sup>	W	300	700	780	900	1000	1490
TCR	ppm/ °C	<+600					
Maximum element temperature	°C	365					
Ambient temperature range (heatsink)	°C	-55 to +200					
Dielectric withstand <sup>4</sup>	V (dc/ac peak)	2500					
Inductance (typical)	μH	<3			<4	<5	<6

Notes:

1. For details of pulse condition see Fig 2 below
2. Mounted on a 0.53°C/W heatsink with no forced air cooling, air temperature 25°C
3. Mounted on a 0.53°C/W heatsink with 5m/s forced air cooling, air temperature 25°C
4. Based on 100% production test, duration 2s minimum



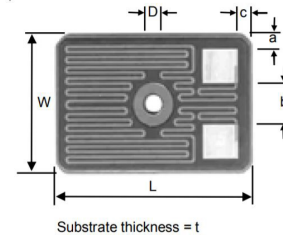
# Application Note

## Physical Data (all dimension in mm)

Dimensions in mm, weight without terminations in g								
	L ±0.1	W ±0.1	t ±0.1	∅D nom	a nom	b nom	c nom	Wt. nom
WDBR1/2	31.9	28.1	0.9	2.2	7.5	3.1	4.3	6.5
WDBR1	49.3	35.9		3.2	3.2	11.2	6.2	12.6
WDBR2	61	40.6		5.3	4.7	13.0	5.8	17.1
WDBR3	101.6	70			13.5	22.0	10.2	50.8
WDBR5	122	70	14.0		23.8	7.4	60.7	
WDBR7	152.4	101.6	1.5		15.0	51.3	9.2	181.8

Substrate thickness = t

Fixing hole is located centrally except on WDBR1/2 where the dimension from the edge by the terminations to the mounting hole centre is 16.68mm



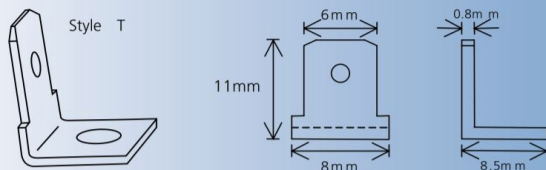
Substrate thickness = t

Fixing hole is located centrally except on WDBR1/2 where the dimension from the edge by the terminations to the mounting hole centre is 16.68mm

## Construction

A high integrity dielectric layer is applied to a machined stainless steel substrate. Thick-film conductor and resistor patterns are printed and fired, then protected with a high temperature overglaze. The termination pads are tinned with solder and optional terminals or leads are soldered on.

STYLES T, standard push-on connections as shown:



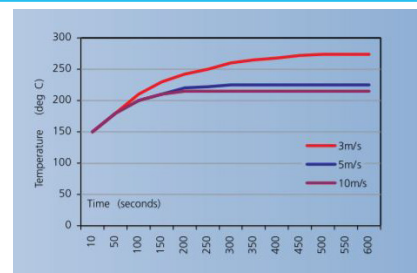
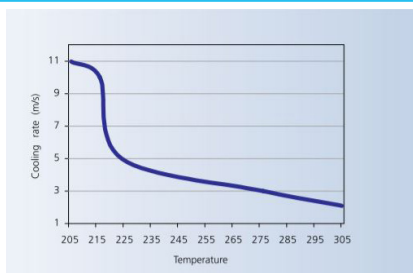
## Termination style

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.

## 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 Of



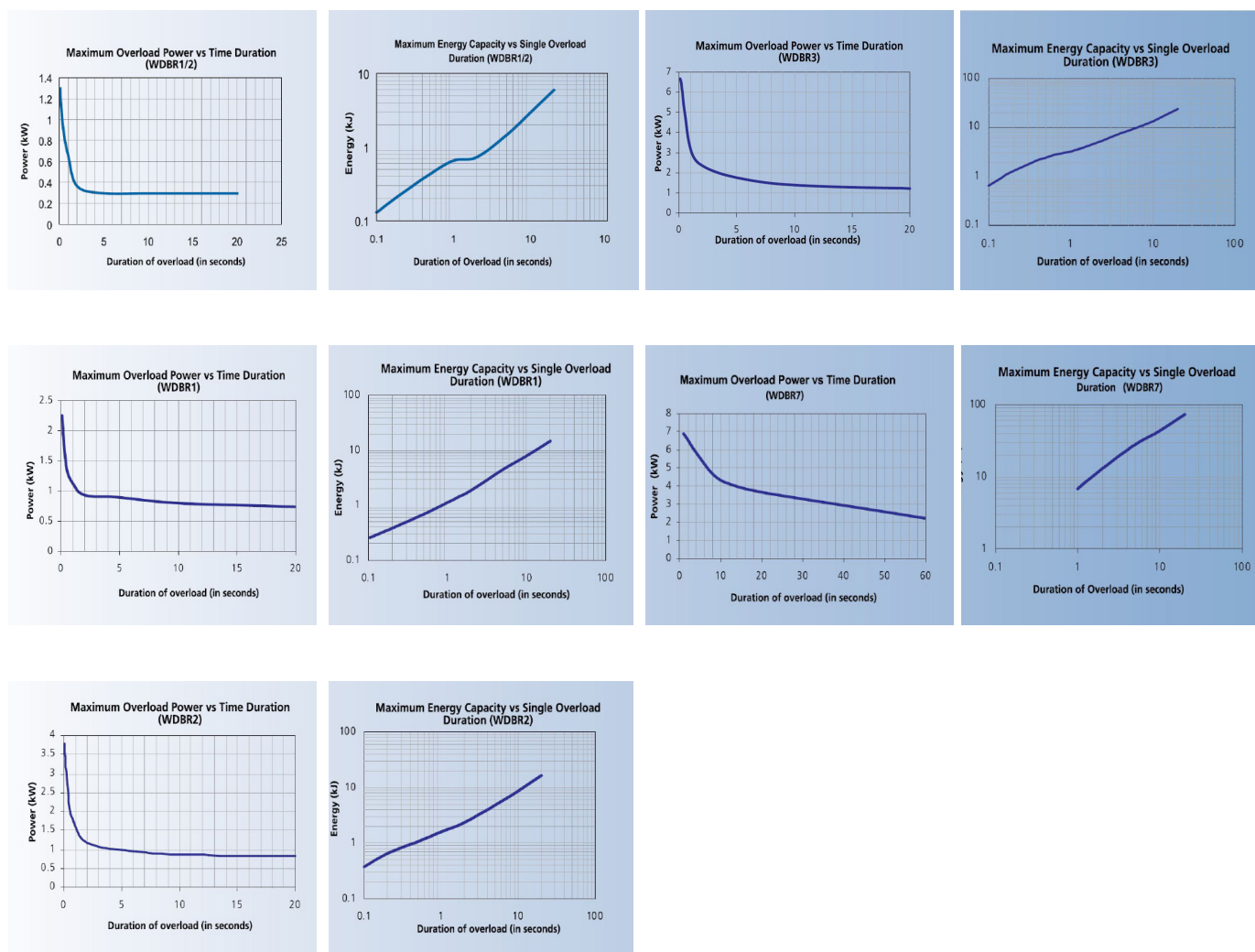
## Application Notes

It is important to select a heatsink with low thermal resistance (typically <0.53°C/W) to enable the component to operate at its continuous power rating. WDBR resistors will 'failsafe' (open circuit) under overload (fault) conditions whilst maintaining a dielectric withstand of 1kV minimum.

- 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 M5 screwhead bolt for the WDBR2, 3, 5 & 7 ranges, and a M3 and M2 screwhead bolt should be used for the WDBR1 and WDBR 1/2 range respectively.
- The mounting area of the heatsink must have a surface finish of <6.3 µm with flatness of <0.05mm.
- Forced air-cooling is required to maintain the specified temperature limits.
- Torque the screwhead bolt to the torque figures listed in the datasheet

# Application Note

## Overload Conditions



### Additional Notes

Please contact our applications team if you would like to discuss, nonstandard resistor values or tolerances for the WDBR range or bespoke designs. Contact details are shown at the base of the document.

WDBR resistors may be customised in various ways including:

- Alternative shapes and dimensions up to 406mm x 406mm
- Integration of temperature measurement elements
- Alternative ohmic values, tolerance & TCR
- Increased dielectric withstand voltage
- Termination cables with connectors fitted

# Application Note

## Additional notes continued

TT Electronics 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. Lead wires and terminals are constructed to the requirements of the application.

Some products use no clean solder. When the product is powered for the

## 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

## Conclusion

TT Electronics 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

## 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,  $R_b$ ,

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.

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

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

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

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

By assuming that the angular deceleration,  $a$ , is constant from the synchronous speed,  $\omega_s$ , to zero, the braking time,  $t_b$  [sec], can be calculated using the effective torque,  $T_e$ . The inertial load,  $J_l$  [kgm<sup>2</sup>], of the drive system determines the brake time:

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  $d_c = t_b / t_{cy}$ .

first time, the flux will be heated and burned off.

Thermal shock and vibration testing has shown TT Electronics 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.

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.

stainless steel offers improved reliability over other substrate systems such as alumina or FR4 for shock, vibration, and heat dissipation. TT Electronics thick film steel is a cost effective solution for power applications with superior performance characteristics.

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

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

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

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

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

thus,  $T_b[\text{sec}] = j_l * \frac{\omega_s}{T_e}$

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

$$\text{Average power of the braking cycle, Pav} = \frac{KE}{T_b}$$

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



# Application Note

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<sup>2</sup>, and the elevated DC link voltage,  $V_e$ , 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:

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

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

The rated torque and maximum available torque are then calculated as

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

$$T_e = T_r * T_o \text{ [Nm]} = 16.4 \text{ Nm} * 1.75 = 28.7 \text{ Nm}$$

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

$$\begin{aligned}T_b \text{ [sec]} &= \frac{J_l * \omega_s}{T_e} \\ &= (1 \text{ kgm}^2 * 188.4 \text{ rad/sec}) / 28.7 \text{ Nm} \\ &= 6.56 \text{ seconds}\end{aligned}$$

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

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

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

$$\begin{aligned}P_i &= 1.75 * 3000 \text{ W} * \\ &= (37.7 \text{ Nm} / 28.7 \text{ Nm}) = 6.9 \text{ KW}\end{aligned}$$

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

$$R_b = (780 \text{ V})^2 / 6.9 \text{ KW} = 88.2 \Omega$$

From the Kinetic Energy equation:

$$\begin{aligned}P_{av} &= \frac{KE}{T_b} = \frac{0.5 * J_l * \omega_s^2}{T_b} \\ &= (0.5 * 1 \text{ kgm}^2 * (188.4 \text{ rad/sec})^2) / 5 \text{ sec} \\ &= 3549 \text{ W}\end{aligned}$$

To determine the continuous rating for the resistor, apply the duty cycle.

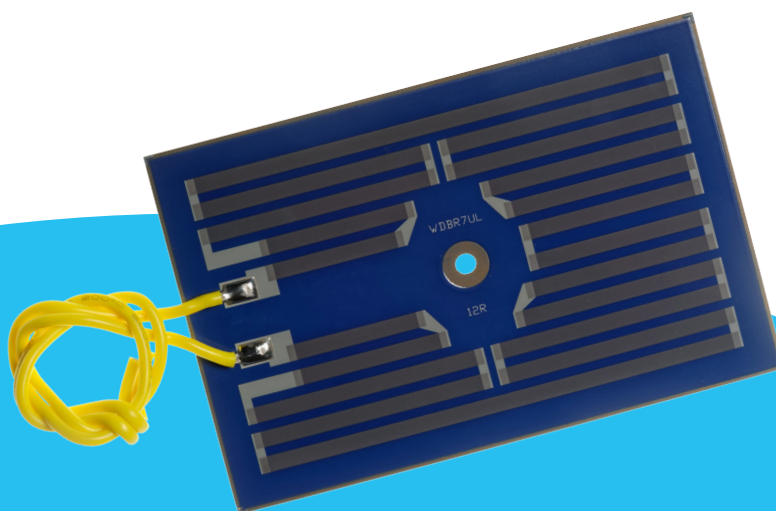
For this example, assume one braking cycle per minute, or 5 seconds per 60 second interval:

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

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 88R resistor has a 10 % tolerance and therefore the lowest possible resistance is 79.2  $\Omega$ . The peak generated current during the braking cycle is then:

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

LIT-AN-WDBR



[www.ttelectronics.com/resistors](http://www.ttelectronics.com/resistors)

TT Electronics, 4222 South Staples St., Corpus Christi, TX 78411, USA

TT Electronics, Welwyn Electronics Park, Bedlington, Northumberland, NE22 7AA, UK

**General Note** TT Electronics reserves the right to make changes in product specification without notice or liability. All information is subject to TT Electronics' own data and is considered accurate at time of going to print.

© TT Electronics plc