Due to existing needs, many modern electronic circuits and apparatus experience transient pulses and surges. This in turn has led to the need to “design in” transient surge protection especially in circuits like motor controllers. When a motor starts, the current drawn at this point is excessive and can cause failure in resistors. Similarly if capacitors are used for motor starting, the current – limiting resistors in the circuit experience very high overloads during the capacitor charge / discharge cycles.
At this point it is pertinent to mention that while there is a plethora of information available on this subject for active devices like semiconductors, passive devices such as resistors are often neglected and their role in withstanding transient pulses/surges is not yet fully grasped by the designer.
Since resistors are often located in areas likely to experience transient pulses / surges, it is indeed critical for the designer to be fully aware of this phenomenon and design in the correct resistors for his particular application. HTR has worked closely with designers to produce custom built resistor solutions for specific protection applications and a summary of information / data obtained over the years is now given below for the benefit of the design engineer:

## OVERLOADING OF WIRE WOUND RESISTORS

Under normal conditions and on a continuous basis, a resistor should never be subjected to more than its Maximum Working Voltage / Voltage Rating / Limiting Voltage. This can be theoretically deduced by using the following formula:

$$MWV = \sqrt{P \times R}$$

Where,
MWV = Maximum Working Voltage / Voltage Rating / Limiting Voltage.

P = Power rating in watts.

R = Nominal resistance in ohms.

Having said this, wire wound resistors are best capable of handling both short time overloads as well as surges both – over current and over voltage experienced in modern circuits, as compared to thin film and even thick film resistors due to the nature of their construction as given below:

- Under conditions of extreme voltage stress, thick film resistors show signs of deterioration due to voltage induced conduction from the normally non conductive materials in the film, wire wound resistors are not generally subject to this phenomenon.
- The mass of a resistors element either film or wire, is critical in determining the devices capability in withstanding surges and in the case of wire wound resistors the mass of the wire element that can be wound on the core exceeds the mass possible in either thick or thin film resistors.
- During a surge the energy in the form of Joules has to be dissipated effectively to avoid damage to the component. Thick film resistors, which are better than thin film resistors in absorbing surges, are generally rated to maximum 3 Joules. Where wire wound resistors can even dissipate 200 Joules, by say a 10 watt resistor made with correctly selected wire and winding technique. A further interesting phenomenon has also been observed that when a wire wound resistor is wound by the “Aryton Perry” method for low inductance, the resistor also displays enhanced surge handling capability due to increased mass of resistance wire to absorb the surge.

The first step in making sure power surges do not cause resistor failure is for the circuit designer to ascertain whether the stress will be a “short time overload” or a “surge”.
Short time overload is when the excessive voltage / current has a duration of >0.5 sec, up to typically 5 seconds. This does cause the resistor to get heated but it also gives the substrate of the resistor – normally ceramic core, time to dissipate the heat generated by the increased current.
In sharp contrast to this, a “surge” occurs over a much shorter period of time <0.5 sec and so the substrate has no opportunity to contribute to dissipate the heat and the energy has to be completely absorbed by the resistive element itself.
Common types of surges experienced are capacitor charge / discharge – normally <1m sec and motor startup, typically < 0.5 sec.
Based on this information the application lab at HTR has put together some interesting data / information which should be taken into account by the design engineer when selecting a resistor for a circuit which will encounter either short-time overload or surge conditions.

**The short time overload rating of HTR's wire wound resistors are calculated as given below:**

For resistors up to 3 watt, the STOL voltage is calculated as :
STOL voltage = √(5 times x Power rating x Resistance value) for a period of 5 secs.

For resistors above 3 watt, the STOL voltage is calculated as :
STOL voltage = √(10 times x Power rating x Resistance value) for a period of 5 secs.

For e.g. HTR's HTA series H2BA type 4K0 ± 5% resistor has a STOL voltage / rating which is calculated as :
STOL voltage = √(5 x 2.5 x 4000) = 223.6 volts &

Similarly, HTR's HTA series H9A type 27K777 ± 5% resistor has a STOL voltage / rating which is calculated as :
STOL voltage = √(10 x 9 x 27777) = 1581.12 volts.

It can be seen that in the above case the H2BA type which is rated as 2.5W is capable of dissipating 12.5W for 5 seconds. In terms of energy, this corresponds to 62.5 Joules.
The danger over here is that it might be thought that this device is capable of handling 62.5 Joules irrespective of the overload duration.
At this point it must be remembered that it takes a finite time for the heat produced to be properly distributed through out the resistor body and therefore it is necessary to impose limits on the applied pulse energy so as to prevent excessive stresses due to thermal shock damaging the component.
Now suppose the same 2.5W 4K0 ± 5% resistor is subjected to 10000 volts for 1.5 milliseconds, the energy is 37.5 Joules as per the formula given below:

E = (V2/R) x t = (10000 x 10000/4000) x 0.0015 sec. = 37.5 Joules.

Now, 37.5 Joules is within the 62.5 Joules shown above but it must be remembered that it would take longer than 1.5 milliseconds for the heat produced in the wire to flow into the surrounding materials and therefore the temperature of the wire would rise far beyond what it was intended to handle and if the wire is subjected to temperatures which are beyond its operating limits the resistance value of the resistor will change excessively, the coating can be damaged and in extreme cases the resistance wire itself can melt which will render the component useless.
Therefore since resistors can be subjected to different types of pulses, it is very necessary to take into consideration the pulse width duration and the applied pulse voltage / power.
A general point to be noted is that the average power of the pulse applied should not exceed the rated power of the resistor.
Also the term pulse implies a single pulse applied to a resistor, which is not already dissipating power and is in an ambient temperature of 70°C or less.
HTR has collected data for 3 different pulse ratings for their most popular standard wire wound resistors which should be referred to as given below for the safe operations of the resistors.
For very short pulses which are < 1 mili sec (1.2/50 Micro sec as defined by IEC 61000-4-5 & ANSI C 62.41), please refer to Table-1.
For longer pulses from > 1 mili sec to 100 mili sec, please refer to Table-2.
For pulses > 100 milliseconds up to 5 seconds, the short time overload capability (STOL) calculation as shown above should be referred to

| HIA Series | | | |
|---|---|---|---|
| **Sr. No.** | **Type** | **Table-1** | **Table-2** |
| 1. | H1 | 1200 V | 750 V |
| 2. | H2 | 1800 V | 120 V |
| 3. | H3A | 2000 V | 1300 V |
| 4. | H3 | 3500 V | 2250 V |
| 5. | H4 | 4000 V | 2500 V |
| 6. | H5A | 5000 V | 3250 V |
| 7. | H5 | 6500 V | 4250 V |
| 8. | H7A | 8500 V | 6250 V |
| 9. | H7 | 10500 V | 7000 V |
| 10. | H10/H10A | 12000 V | 9500 V |
| 11. | H15 | 15000 V | 12250 V |

| HTA Series | | | |
|---|---|---|---|
| **Sr. No.** | **Type** | **Table-1** | **Table-2** |
| 1. | H1BA | 600 V | 525 V |
| 2. | H2BA | 1500 V | 1000 V |
| 3. | H6A | 3000 V | 2000 V |
| 4. | H9A | 7500 V | 5000 V |
| 5. | H12A | 11250 V | 7500 V |

| HIP Series | | | |
|---|---|---|---|
| Sr. No. | Type | Table-1 | Table-2 |
| 1. | H3P | 2000 V | 1300 V |
| 2. | H5P | 6500 V | 4000 V |
| 3. | H7P | 10500 V | 7000 V |
| 4. | H10P | 12000 V | 8500 V |

| HFP Series | | | |
|---|---|---|---|
| SrNo | Type | Table-1 | Table-2 |
| 1. | F2P | 1800 V | 1250 V |
| | 0/1/C/CA/CZ | | |
| 2. | F4P | 3250 V | 2000 V |
| | 0/1/C/CA/CZ | | |
| 3. | F5P | 4750 V | 3250 V |
| | 0/1/C/CA/CZ | | |
| 4. | F7P | 6750 V | 4500 V |
| | 0/1/C/CA/CZ | | |
| 5. | F8P | 8750 V | 6000 V |
| | 0/1/C/CA/CZ | | |

| HSR Series | | | |
|---|---|---|---|
| Sr. No. | Type | Table-1 | Table-2 |
| 1. | SR8 | 10000 V | 6750 V |
| 2. | SR11 | 13000 V | 8750 V |

| HCL Series | | | |
|---|---|---|---|
| Sr. No. | Type | Table-1 | Table-2 |
| 1. | CL10 | 9000 V | 6000 V |
| 2. | CL20 | 14500 V | 7000 V |
| 3. | CL40 | 22000 V | 14750 V |

| HEA Series | | | |
|---|---|---|---|
| Sr. No. | Type | Table-1 | Table-2 |
| 1. | C2A | 1500 V | 1000 V |
| 2. | C4 | 2750 V | 2050 V |
| 3. | C5B | 3500 V | 2500 V |
| 4. | C6 | 4500 V | 3000 V |
| 5. | C7B | 4800 V | 3250 V |
| 6. | C7A | 5750 V | 3750 V |
| 7. | C9/C10A | 6500 V | 4500 V |
| 8. | C11 | 9000 V | 6000 V |
| 9. | C17 | 13250 V | 8750 V |

| HFA Series | | | |
|---|---|---|---|
| Sr. No. | Type | Table-1 | Table-2 |
| 1. | F1 | 1200 V | 750 V |
| 2. | F2 | 1800 V | 1200 V |
| 3. | F3 | 2500 V | 1750 V |
| 4. | F5 | 4200 V | 3000 V |
| 5. | F7 | 6250 V | 4000 V |
| 6. | F9 | 7750 V | 5250 V |
| 7. | F10 | 8500 V | 5750 V |

| HSV / HSVA / HSVAU Series | | | |
|---|---|---|---|
| Sr. No. | Type | Table-1 | Table-2 |
| 1. | SV4/ SV4A | 2750 V | 2000 V |
| | / SV4AU | | |
| 2. | SV5/ SV5A | 3500 V | 2500 V |
| | / SV5AU | | |
| 3. | SV7/ SV7A | 4800 V | 3250 V |
| | / SV7AU | | |
| 4. | SV7B/ SV7BA | 5750 V | 3750 V |
| | / SV7BAU | | |
| 5. | SV9/ SV9A | 6500 V | 4500 V |
| | / SV9AU | | |
| 6. | SV11/ SV11A | 9000 V | 6000 V |
| | / SV11AU | | |
| 7. | SV17/ SV17A | 13250 V | 8750 V |
| | / SV17AU | | |

| HCP Series | | | |
|---|---|---|---|
| Sr. No. | Type | Table-1 | Table-2 |
| 1. | CP3A | 3000 V | 2000 V |
| 2. | CP5/ CP5A | 4250 V | 3000 V |
| | / CP5Z | | |
| 3. | CP7/ CP7A | 6250 V | 4000 V |
| | / CP7Z | | |
| 4. | CP10/ CP10A | 9000 V | 6000 V |
| | / CP10Z | | |
| 5. | CP15/ CP15A/ | 10500 V | 7000 V |
| | CP15B/ CP15C | | |
| | / CP15Z | | |
| 6. | CP20/ CP20A/ | 14500 V | 9500 V |
| | CP20B/ CP20C | | |
| | / CP20Z | | |

The data provided above should merely serve as a very general guide to pulse handling capacity of wire wound resistors. It is at all times a prudent measure to validate the information provided above by asking Heynen for samples which can be used to ascertain the practical suitability of the pulse resistor being considered for purchase in a particular application.
It would be most useful if the request for samples of resistors for overload / surge applications were framed as given below:

**Data required to design a tailor made pulse / overload / surge resistor:**
In order to design a tailor made resistor suitable for pulse applications, our QA team has put together a questionnaire of data required so that the resistor can be effectively designed.

**Questionnaire of data required from customers in order to design pulse / surge / overload resistor**

- Power rating in watts – resistance value – tolerance
- Max peak pulse voltage – V peak
- Max peak pulse voltage – P max
- Pulse duration/Time constant – T
- Pulse shape
- Pulse repetition rate/period – t
    - Max peak pulse voltage – This is the highest voltage the resistor will be subjected to.
    - Max peak pulse wattage – This is the maximum wattage that will be dissipated at the time of the pulse.
    - Pulse duration – The time period for which the pulse is applied to the resistor or the duration between pulse start and stop time.
    - Pulse shape – The shape of the wave form – whether it is a square pulse or exponential waveform.
- Pulse repetition period – The time interval between the pulse start time of the first pulse waveform and the pulse start time of the immediately following pulse waveform in a periodic pulse train.

On receipt of this information Heynen would be pleased to submit samples for validation on a practical basis in the circuit being designed.