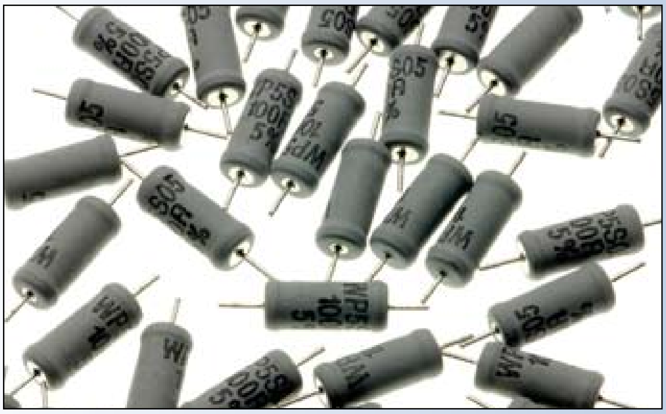
TT electronics

Fixed Resistors

RESISTORS FOR ENERGY METERING - Application Note



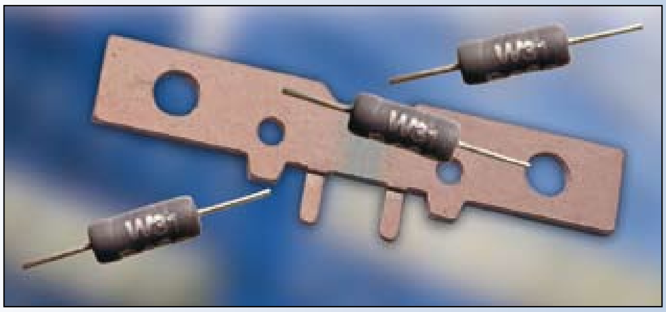
Energy meter design has changed radically in recent years as application specific standard ICs from several vendors have enabled digital designs to replace electromechanical ones at costs compatible with high volume application. Many designs go further down the digital road with flexible multi-rate billing and remote reading. However advanced the digital design is, though, all depend on their analogue front-end components for reliability and accuracy.

TT electronics has many years experience of working with designers to select and tailor optimised resistive product solutions for this application.

For example, input protection components can be provided with established pulse capacity, a critical performance feature which is often omitted from manufacturers' data and which cannot be established with certainty by one-off testing on qualification samples.

The sustained accuracy of the meter after factory calibration depends on the long-term stability of the voltage and current measurement circuits.

This application note aims to guide the designer in selecting the optimum components by providing product data relevant to protection, voltage measurement and current shunt components. It should be read in conjunction with the full product data sheets.



- **High pulse energy line input resistors with guaranteed IEC61000-4-5 pulse performance**
- **Cost-effective precision MELF resistors for voltage measurement dividers**
- **Low value current shunts for direct-connect meters**
- **Special pulse or fuse test and leadforming requirements can be provided**

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Line Input

A typical low-cost transformerless power supply section for an energy meter is shown in Figure 1. Prior to voltage regulation the high voltage supply is stepped down by a capacitive divider and rectified. The remaining components provide protection against supply-bourne EMC disturbances. These include radio frequency interference (RFI), filtered by the choke and X2 capacitor, electrical fast transient (EFT) pulses, shunted mainly by the X2 capacitor and lighting strike transients, clamped by the MOV.

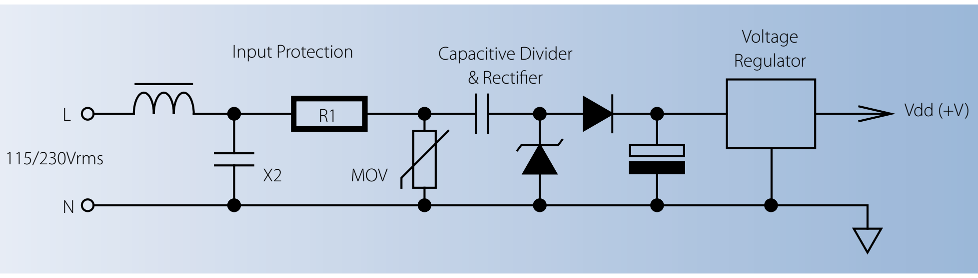

Figure 1

The input protection resistor R1 serves a number of functions here. The first relates to circuit function, namely limiting the zener peak current at switch-on to a safe level. The remainder relate to protection functions. Regarding RFI, a resistor can assist not only by contributing to series inductance, but also by reducing the Q factor of the input network, thereby minimising the effect of any resonances. Critically, it serves to limit the peak MOV current during a lightning strike transient, reducing the stress on the MOV by dissipating a share of the pulse energy. And finally, it can offer failsafe flameproof fusing in the event of a short circuit failure.

The pulse used to test immunity to lightning strike transients defined in IEC61000-4-5 is shown in Figure 2. It is important to realise that a MOV has a finite lifetime and that permanent and progressive changes occur at each pulse event. If a safe number of pulses is exceeded during the product lifetime (see Figure 3) then the MOV voltage will begin to rise then drop rapidly until reaching short circuit failure. The use of an input resistor placed before the MOV as shown can greatly extend the lifetime of the MOV, and also permits lower cost parts to be selected.

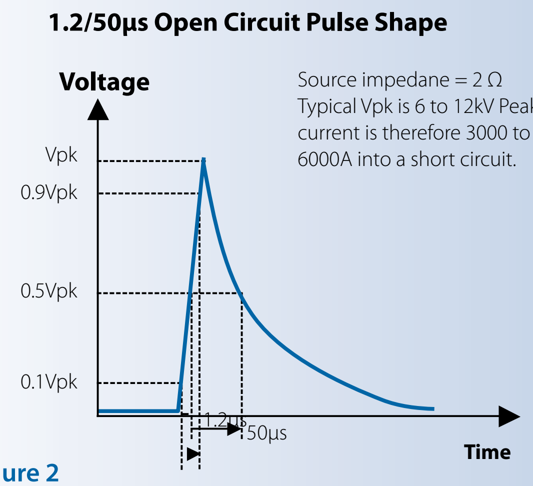

Figure 2

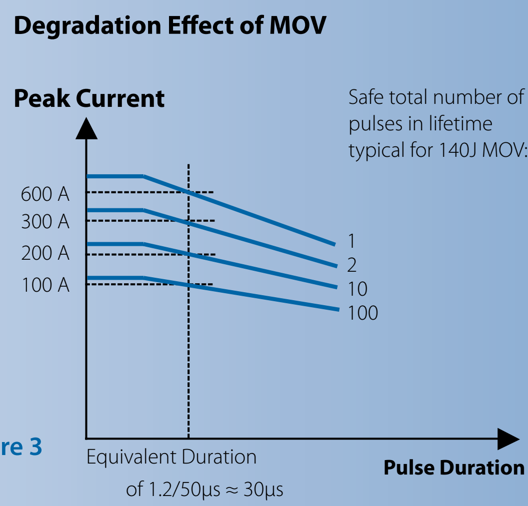

Figure 3

TT electronics has a wide range of standard pulse withstanding resistors for this application with full pulse data available. In addition, variants can easily be created to meet high pulse demands within custom size and cost constraints. Wirewound technology combined with flameproof cement coating is often used, with 3W to 5W sizes generally being chosen.

To achieve safe fusing, whilst choosing a flameproof resistor is necessary, it is not always sufficient. Flameproof status simply means that the resistor coating will not support sustained combustion. However, a flameproof resistor can cause smoking and even fire under moderate overload conditions, as very high body temperatures can be reached prior to fusing. This can cause charring of the PCB or ignition of adjacent components. The two defences against this are defined fusing characteristics and PCB standoff leadforms, both of which are available (see Value Added Options).

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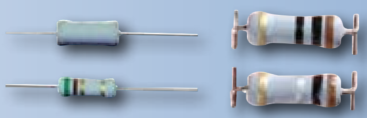
Some suitable standard products are detailed below.

W31, WP3S, WP4S, WP5S



- **Robust all-welded wirewound construction**
- **Established pulse performance**
- **UL94-V0 coating for flameproof failsafe fusing**
- **Leadforming options including "Z-form" for SMT**
- **Typically used at values of 20R to 1K**

Electrical Data

		W31	WP3S	WP4S	WP5S
Power rating @25°C	watts	3.0	3.0	4.0	5.0
Resistance range	ohms	0R01 - 10K	R01 - 2K2	R01 - 10K	R015 - 6K8
Limiting element voltage	volts	100	100	100	150
Resistance tolerance	%	5, 2, 1	<20R: 5 20R: 1, 2, 5	<R10: 5 R10: 1, 2, 5	<20R: 5 20R: 1, 2, 5
Standard values		E24 series preferred			
Thermal impedance	°C/watt	83	82	62	54
Ambient temperature range	°C	-55 to +155			
TCR	ppm/°C	≥1R: 200			

WMO3S

- **Robust metal oxide film.**
- **Established pulse performance**
- **UL94-V0 coating for flameproof failsafe fusing**
- **Typically suitable at values of about 1K and above**

Electrical Data

		WMO3S
Power rating @70°C	watts	3.0
Resistance range	ohms	10R - 100K
Limiting element voltage	volts	350
TCR	ppm/°C	350
Isolation voltage	volts	500
Resistance tolerance	°C	5, 10
Standard values		E24 preferred
Thermal impedance	°C/watt	60
Ambient temperature	°C	-55 to +155

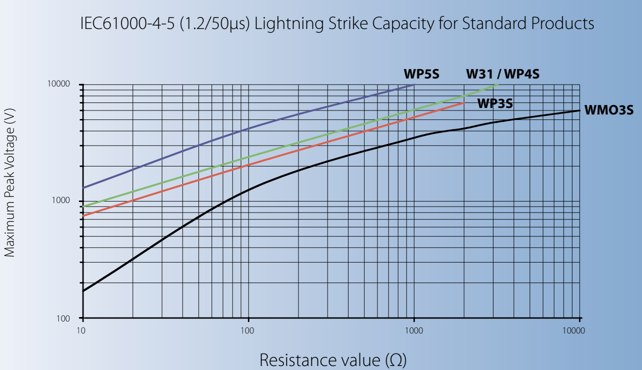


Figure 4

The pulse performance of these selected standard products is shown in Figure 4. Often these peak voltages may be raised by up to 100% by special design, enabling cost savings through using a smaller body size.

When calculating the peak voltage across the line input resistor it is necessary to subtract the clamping voltage of the MOV, typically 700 to 1000V, from the peak voltage applied to the circuit.
An alternative arrangement is to place the MOV in front of the line input resistor, in which case the resistor sees a rectangular pulse at the clamping voltage of around 100µs duration (unless restricted by the series capacitor.) In this case most of the energy is absorbed by the MOV with the input resistor providing a secondary stage of protection.

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Voltage Measurement

The voltage measurement input is derived by resistive division of the line voltage. This entails direct connection to the line input and therefore exposure to the same high voltage pulses as the line input resistor. However, as the divider feeds a high impedance input, much higher ohmic values (typically 470K to 1M0) may be used, so pulse energy is correspondingly reduced.

Figure 5 shows a typical voltage conditioning circuit. The RFI filtering components are those appearing in the line input circuit. R2 plus the optional calibration network forms the required division ratio with R3, and a shunt capacitor provides anti-alias filtering. Calibration may be achieved by varying a resistance in series with R2 as shown, for example by selective shorting of resistors in a binary weighted chain, or by a calibration factor in non-volatile memory. Resistor R3 is typically 100R to 1K0 and may be realised by an ordinary thick film chip resistor of 1206 size or smaller. However R2 must accommodate both the continuous high voltage of the line connection and the high voltage pulses.

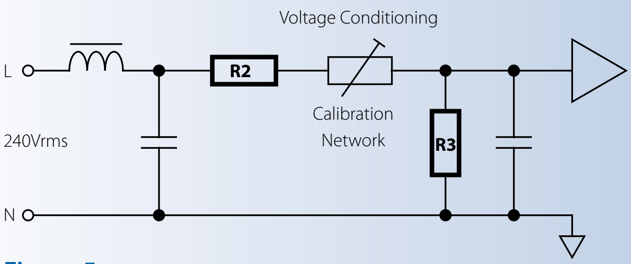

Figure 5

R2 is often implemented by means of a series chain of between four and eight MELF resistors, which provide the required stability and, in series combination, the required rating and pulse capacity. Data relating to pulse performance is given in Figure 6.

Electrical Data

WRM0204, WRM0207

- **Compact SMD solution**
- **Established pulse performance**
- **Stability to 0.5% at typical values**

		WRM0204	WRM0207
Power rating @70°C	watts	0.25	0.4
Resistance range	ohms	R22 - 10M	R22 - 8M2
Limiting element voltage	volts	200	300
TCR	ppm/°C	5, 15, 25, 50	25, 50
Resistance tolerance	%	0.1, 0.25, 0.5, 1.0	
Standard values		E24 & E96	
Thermal impedance	k/W	200	140
Ambient temperature	°C	-55 to +125	
Insulation resistance	ohms	$>10^{10}$	

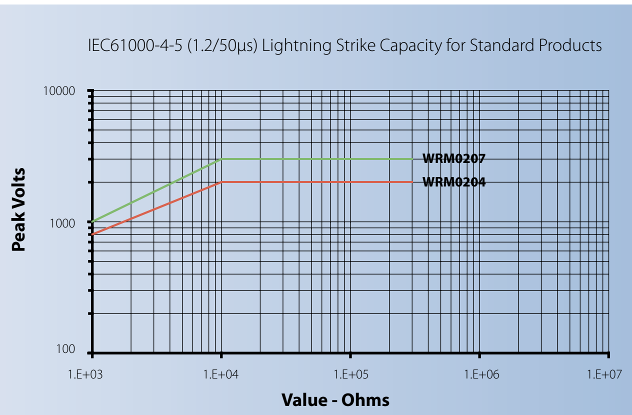

Figure 6

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Current Measurement

To complete the measurement of power it is necessary to measure the current. This calls for a far wider dynamic range, as it is a truly variable quantity, whereas the voltage is essentially constant. The four methods of current sensing in energy meters are summarised in the table below.

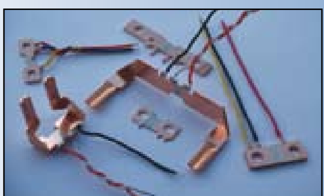
The choice of current transducer therefore depends on several economic and technical factors, but for direct connect meters with maximum current below about 100A the resistive shunt remains the best option. Typical values range from 100µΩ to 10mΩ, depending on the maximum current. In order to minimise I^2R losses the ohmic value should be as low as possible consistent with the minimum voltage signal level required for acceptable accuracy. Typical meter power budgets are set at 2W in order to comply with IEC standards, so typically 1 to 1.5W is available for shunt dissipation (e.g. 100µΩ at 100A dissipates 1W.)

Method:	Resistive Shunt	Current Transformer (CT)	Hall Sensor	Rogowski Coil
Advantages	Low Cost	High Current	High current & wide bandwith	High current, no core to saturate
Disadvantages	High I^2R power loss. No isolation.	Errors incurred if core becomes magnetised	High temperature coefficient & linearity errors. High cost	Requires digital integrator. High cost.
Usage	Common for low cost domestic meters	Common for higher cur-rent domestic & industrial meters	Same application as CT but less common	Increasing use in high performance meters

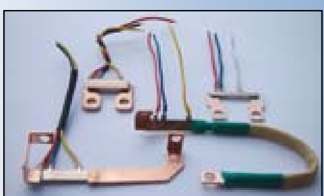
When using shunt resistors of such low values the inductance becomes critical. Typical values lie in the region 2 to 5nH. There are two areas of concern here. Firstly, although the magnitude of impedance may be little affected at power line frequency, the effect on phase mismatch between voltage and current signals can produce errors at low power factors. Secondly, allowance should be made for shunt inductance when designing the anti-aliasing filter, as it will influence overall noise rejection performance if not properly compensated for.

A wide range of high current shunts in conventional or electron-beam welded constructions is available. The current connections are made by high purity copper tabs which may be formed or stamped into custom configurations for terminal or busbar mounting. Kelvin sense connection tabs provide the calibrated voltage output and additional connections can be provided for tamper-proof requirements. Sense termination leads may be pre-fitted to customer requirements.

EBW
Electron beam welded shunts



CWS
Conventionally welded shunts



Range of Capabilities	
Rated current (dc / ac rms)	up to 200A
Output voltages	10 / 60 / 150mV or custom
Power dissipation	1 to 3W typical
Ohmic values	25 to 500µΩ
TCR	100 to 200ppm/°C typical
Tolerance	5 to 10% typical
Operating temperature range	-55 to 170°C
Inductance	<1nH typical
Thermal EMF	Manganin types: 3µV/°C Copper nickel types: 40µV/°C

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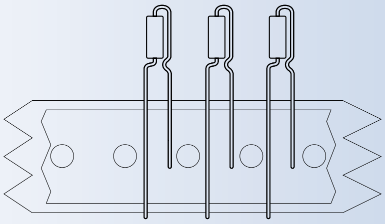
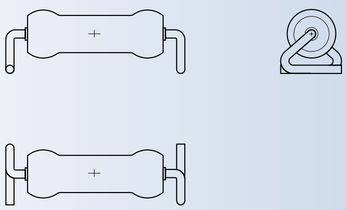
Value Added Options

For critical pulse or fuse requirements a batch release testing service can be provided. Also, the following examples show some of the formats in which many of our leaded parts can be supplied in order to permit minimised manufacturing cost and PCB standoffs for failsafe fusing. Many other leadforms are available and custom enquiries are welcome.



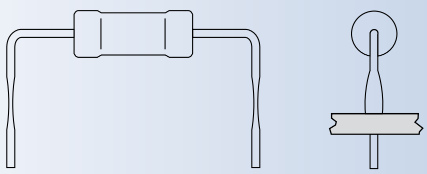
1. Radial Taped

- Order product type with suffix 'R'
- Reel packed
- For automatic radial insertion
- Minimises PCB footprint
- Available in 2.5 x 6.3mm body
- Available in 4.0 x 10mm body



2. Z-Form for SMD

- Order product type with suffix 'Z'
- Packed in plastic blister tape
- For vacuum pick and place and reflow soldering
- Through-hole power performance in SMD format
- Available Range: 3.6 x 9.0mm to 7.0 x 16.5mm body



3. Lancet for PCB standoff

- Order product type with suffix 'L'
- Bulk Packed.
- For manual insertion
- Standoff prevents PCB scorching
- Available Range: 1.7 x 5.5mm to 8.5 x 25mm body

Note: Circuit diagrams are shown for example only.

TT electronics: leading in fixed resistor technology.

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