

# Resistors for Energy Metering Applications



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 Welwyn Components 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
- High-voltage single element solutions for measurement dividers
- Cost-effective precision MELF resistors for calibration networks
- Low value current shunts for direct-connect meters
- Special pulse or fuse test and leadforming requirements can be provided

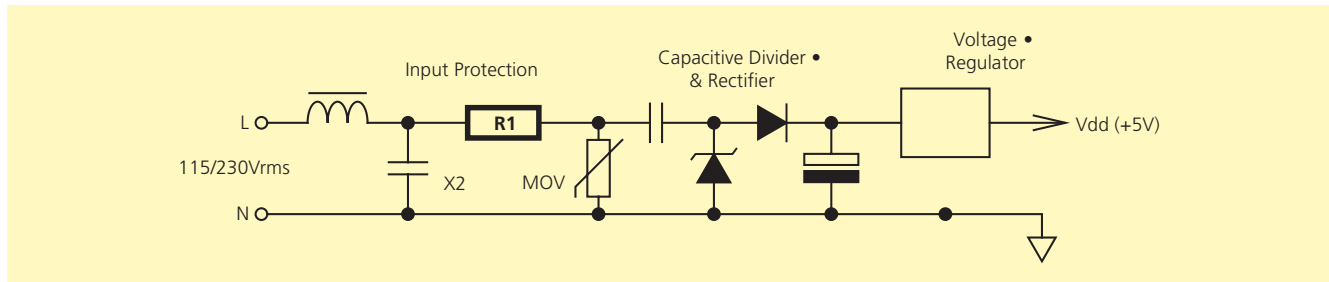


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## Line Input

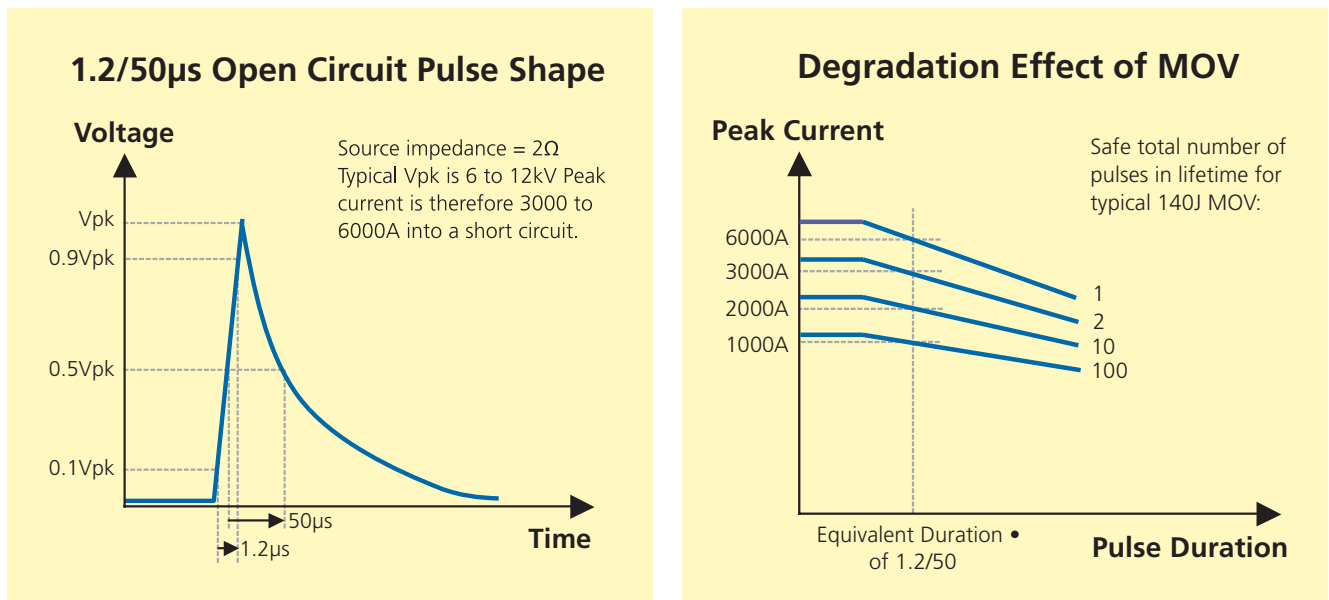
A typical low-cost transformerless power supply section for an energy meter is shown in Figure 1. Prior to voltage regulation the high voltage supply is stepped down by a capacitive divider and rectified. The remaining components provide protection against supply-borne EMC disturbances. These include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

The most demanding condition is high humidity, but Welwyn seals the resistive element using a specially formulated high-density epoxy material to achieve typical resistance changes below 0.25% after 56 days at 95% RH and 40°C.



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.

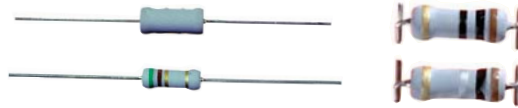
The pulse used to test immunity to lightning strike transients defined in IEC61000-4-5 is shown in Figure 2. It is important to realise that a MOV has a finite lifetime and that permanent and progressive changes occur at each pulse event. If a safe number of pulses is exceeded during the product lifetime (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.



Welwyn 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.

For higher ohmic values our pulse resistant oxides are suitable. For example, unlike commodity metal oxide parts, MO3S is manufactured using a Chemical Vapour Deposition (CVD) process for a more robust film and better thermal conduction from the film to the ceramic rod for accelerated heat dispersal. This gives a pulse performance approaching that of wirewound technology at higher ohmic values.

Some suitable standard products are detailed below.



## W31, WP3S, WP4S, WP5S

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

## 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	0.01 ohms <1000 0.033 ohms <500 0.091 ohms <200 10 ohms <150 10K ohms <100		< 1R: 350 1R: 200	

## Electrical Data

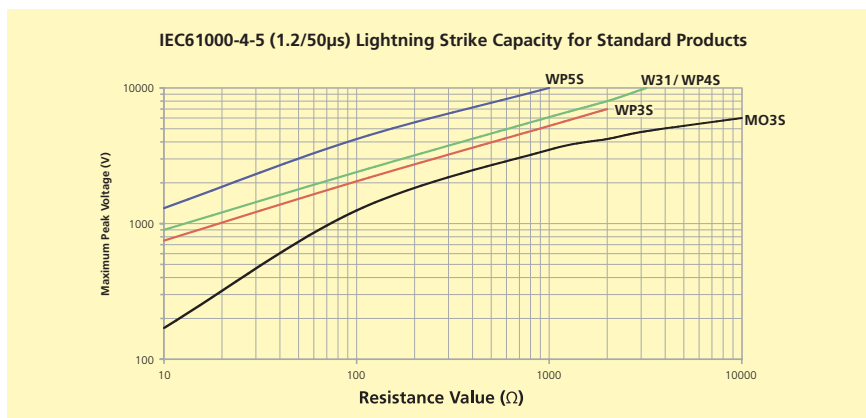


### MO3S

- Oxide applied by Chemical Vapour Deposition for optimum pulse capacity
- Established pulse performance
- UL94-V0 coating for flameproof failsafe fusing
- Typically suitable at values of about 1K and above

		MO3S
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	%	5, 10
Standard values		E24 preferred
Thermal impedance	°C/watt	60
Ambient temperature range	°C	-55 to +155

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.



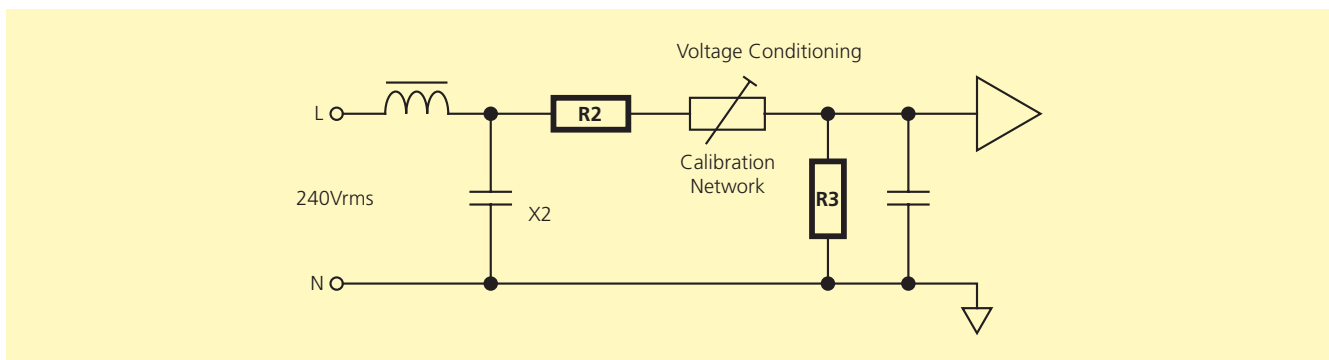
When calculating the peak voltage across the line input resistor it is necessary to subtract the clamping voltage of the MOV, typically 700 to 1000V, from the peak voltage applied to the circuit.

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.

## 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 1M $\Omega$ ) 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 1K $\Omega$  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.



This is often achieved 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. Depending on the cost of component placement and constraints on PCB footprint, a single element solution may be preferred. Data relating to both approaches is given below.

### WRM0204, WRM0207

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



### Electrical Data

		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 range	°C	-55 to +125	
Insulation resistance	ohms	>10 <sup>10</sup>	

### MH37

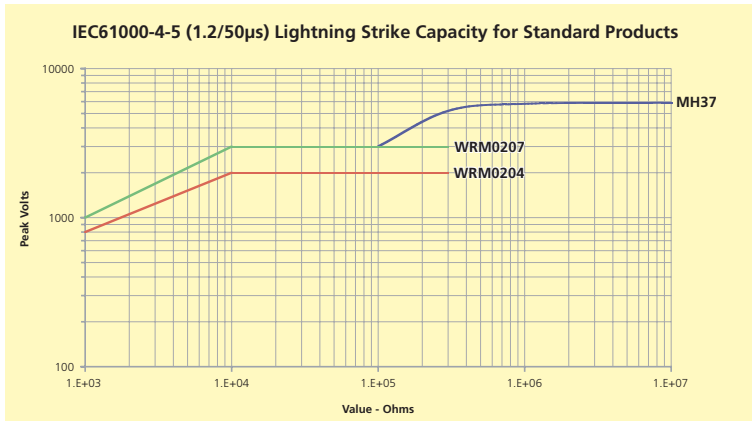
- High voltage single element solution
- Established high voltage pulse performance
- Leadforming options including "Z-form" for SMT



### Electrical Data

		MH37
Power rating @70°C max	watts	0.5
Resistance range	ohms	100k - 3M
Limiting element voltage	volts dc or ac peak	3,500
Isolation voltage	volts	700
TCR	ppm/°C	100
Resistance tolerance	%	1, 2, 5
Standard values		E24 and E96 preferred
Thermal impedance	°C/watt	112
Ambient temperature range	°C	-55 to 155

## 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 100 $\mu$ O to 10mO, depending on the maximum current. In order to minimise I<sup>2</sup>R 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. 100 $\mu$ O at 100A dissipates 1W.)

Method:	Resistive Shunt	Current Transformer (CT)	Hall Sensor	Rogowski Coil
Advantages	Low Cost	High current	High current & wide bandwidth	High current, no core to saturate
Disadvantages	High I <sup>2</sup> R 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 current 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 selection of suitable standard products is shown below, but customer enquiries are welcome.

### BCS8 & BHCS

- Low TCR
- Low inductance
- Ideal for high current meters



### OAR Series

- Compact metal element shunt
- Welded copper terminations
- Compact solution for low current meters



## Electrical Data

Model	BCS8		BHCS		
Package Style	5025		Chassis Mount		
Current Rating, (Amps)	90 Maximum	100*	400	600	1000
Operating Voltage/Power rating	- / 8 Watts		60 mV or 100mV /-		
Operating Temp. Range (°C)	-55 to +175		-55 to +155		
<b>Resistance</b>					
Value (Milliohms)	0.5, 1, 2, 3, 4, 5	0.6 or 1	0.15 or 0.25	0.1 or 0.167	0.06 or 0.1
Tolerance, (%)	1, 5		1		
TCR, ppm/°C	Less than 50		100		
<b>Dimensions</b>					
Body Length (mm)	12.8		100		
Mounted height (mm)	2.5	10	20		
Body Width (mm)	6.4	30	70		

\* Other values up to 2000A available

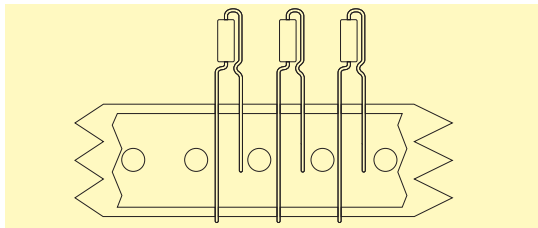
## Electrical Data

		OAR-1	OAR-3	OAR-5
Power rating at 85°C	watts	1	3	5
Resistance range	ohms	0R005* to 0.10	0R005 to 0.10	0R005 to 0.05

\* Contact factory for values below 0R005 ohms

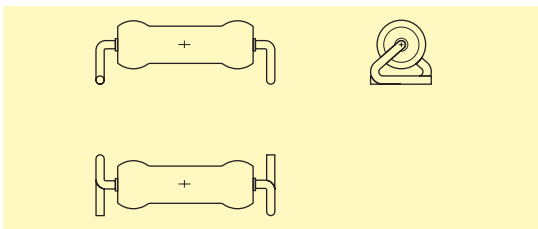
### Value Added Options

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. Many other leadforms are available and custom enquiries are welcome.



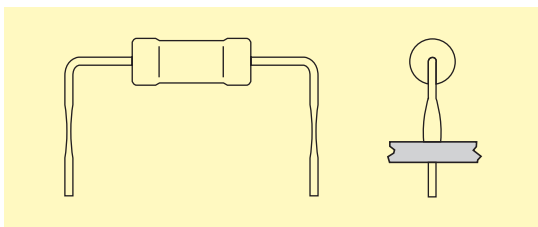
#### 1. Radial Taped

- 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



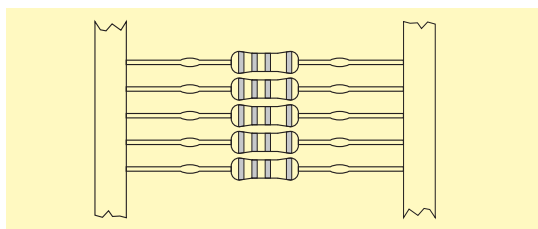
#### 2. Z-Form for SMD

- 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



#### 4. Lancet in tape

- Order product type with suffix 'LT'
- Ammo Packed
- For automatic axial insertion with standoff
- Available Range: 1.7 x 5.5mm to 8.5 x 25mm body

Note: Circuit diagrams are shown for example only.

**Welwyn Components Ltd has over 70 years experience in designing and manufacturing resistive parts.**

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

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