Resistors for Energy Metering

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.

For example, input protection components are required 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. Furthermore, the sustained accuracy of the meter after factory calibration depends on the long-term stability of the voltage and current measurement circuits.

In this article Stephen Oxley, Senior Applications Engineer for TT electronics, explores some of the factors involved in the selection of fixed resistor products for this application.

Line Input

A typical 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.

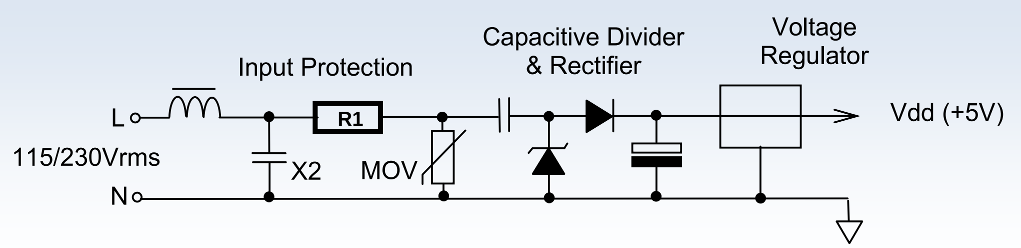

Figure 1

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.

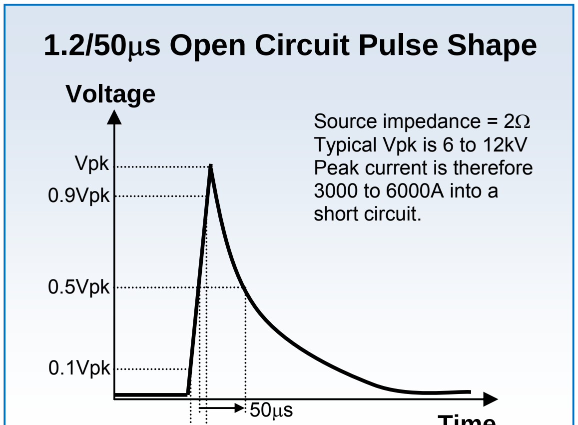

Figure 2

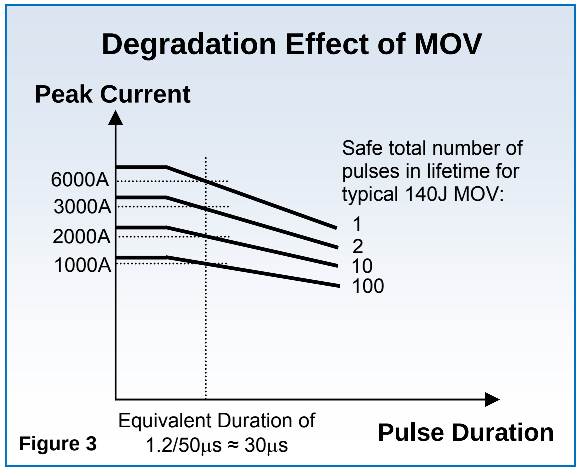

Figure 3

Wirewound technology combined with flameproof cement coating is often used, with 3W to 5W sizes generally being chosen. Care should be taken to ensure that the pulse capability is guaranteed by the manufacturer. Successfully testing a sample may not be sufficient as there is generally some flexibility in winding design causing batch-to-batch variation in the energy capacity of normal wirewound resistors.

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.

The pulse performance of typical products from TT electronics is shown in Figure 4. Often these peak voltages may be raised by up to 100% by special winding design, enabling cost savings through the use of a smaller body size. Note that at ohmic values above about 1K0, it may be possible to use metal oxide technology as a lower cost alternative to wirewound.

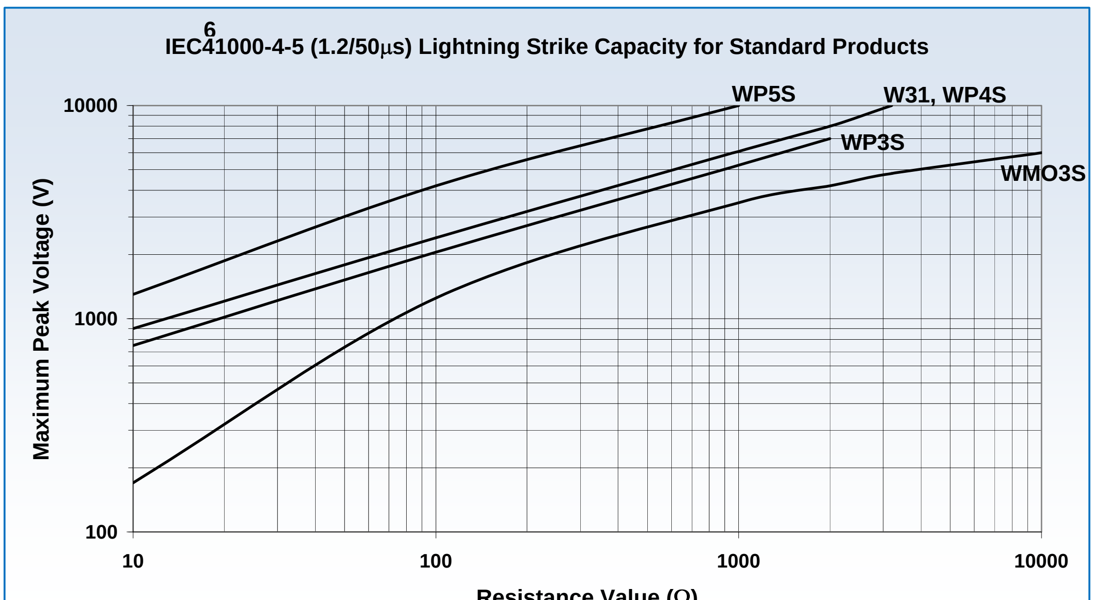

Figure 4

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.

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

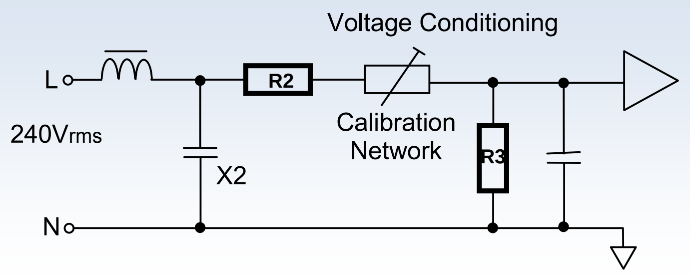

Figure 5

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. 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.

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.

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^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 current domestic & industrial meters	Same application as CT but less common	Increasing use in high performance meters

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.)

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 from TT electronics. 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. Sense termination leads are normally pre-fitted to customer requirements.

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