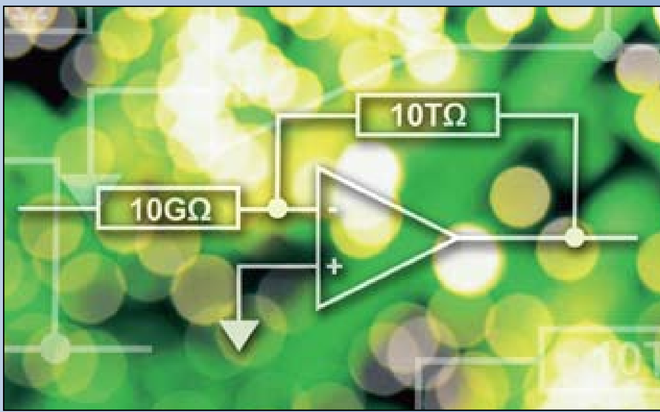
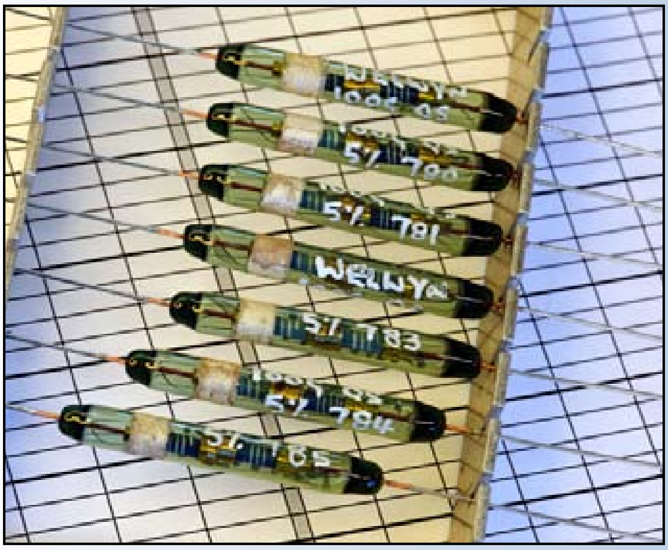
GLASS SEALED RESISTORS WITH GUARD BAND 3810 SERIES - Application Note



Guard Band Principle

When a leakage path exists between two terminals it is nearly always possible to nullify the leakage by interposing a metallic electrode between the two terminals. Although leakage currents may continue to flow, it is possible to divert the leakage current from a critical electrode to some other point in the circuit where its effect is negligible. In many cases, for example in an inverting amplifier, it is sufficient to connect the guard band to ground potential. In other cases, for example in a "follower" type of amplifier, it may be necessary to drive the guard from the output of the amplifier. Details of these circuits are given in the following pages. To meet the requests of our customers we have introduced a guard band on the series 3810 High Value Resistors. This is standard feature on all glass sealed resistors, type numbers 3810, 3811 and 3812 with resistance values above 100G (10^{11}ohms).



3810 series - High value resistors with values up to 100T (10^{14} ohms)

Specialist applications:

- **Gas analysis**
- **Radiation monitoring**
- **Calibration**

Specialist features:

- **Permit measurement of current in the picoampere region**
- **Available to 1% tolerance**
- **Capacitance below 0.5pF**
- **Value of 100G & above are supplied with a guard band to eliminate the effects of leakage current.**

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Mechanical Details

The leakage path to be protected is the one existing on the external surface of the glass envelope. Although other leakage paths exist internally the external one is subject to contamination and humidity effects. The silver band will be screen printed and fired on to the external surface of the glass tube in which the resistor element is finally seated. The position of the band will be displaced from the centre of the resistor to a point located over one end cap and aligned with 1.5mm (as shown in Figure 1).

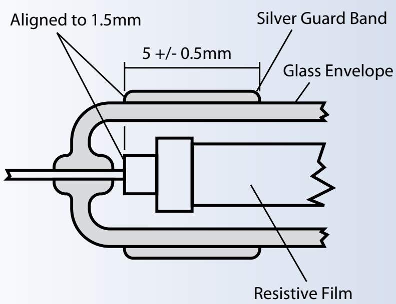

Figure 1

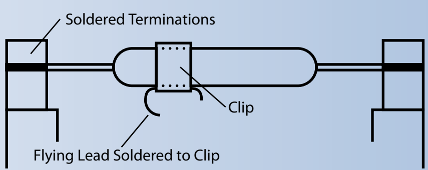

Figure 2

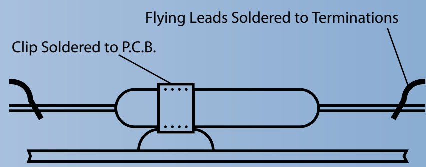

Figure 3

Resistor Mounting and Connection to the Guard Band

To obtain the best advantage from the guard band, and the improved performance that this can provide, connection should be made via the spring clip supplied with the resistor. Soldering a flying lead to the band is not recommended.

The clip may be used solely for connection, or it may be used as a mounting and connector. (See figures 2 and 3.)
Ideally, the resistors should be handled only by their terminations (Warn your Goods Inward Inspection Department). If it is essential to handle the glass envelope, gloves should be worn.

Dynamic Response

High value resistors have long time constants, since even a small amount of self-capacitance can have a significant effect. The guard band can improve the dynamic performance because it forms an electrostatic screen and will reduce the effective capacitance as well as the leakage resistance.

Measurement of High Value Resistors

Ability to make accurate high resistance measurements depends on several factors, but the essential ones are:

i) Access to resistance standards of suitably high value and good stability.
ii) Availability of suitable low current detectors.

Measurement to high accuracies (e.g. 10ppm uncertainty per GΩ) require at least 100 volts dc applied to the resistor, and preferably 500 volts. Measurement of the resistor with less than 100 volts applied presents difficulties because the sensitivity of the detector will fall.

As resistance value and detector sensitivity increase, the need to use three terminal resistors becomes essential to obtain the best uncertainty. The existence of the third terminal to the guard band permits an assessment of the magnitude of the two external leakage paths. If these paths are shown to allow negligible leakage, then the guard band can be left disconnected, restoring the resistor to its original two-terminal form. However, the risk will remain that the two-terminal resistor will be prone to the effects of contamination or humidity.

Fixed Resistors

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Guarding Circuits and Techniques

A resistor RX with leakage RL may be represented by the circuit shown in Figure 4, the guard band technique will introduce a third terminal, splitting RL into two sections, RL1 and RL2 as shown in Figure 5.

In this configuration it is possible to measure the two leakage paths. In most circuits their effects can be nullified by suitably connecting the third terminal.

Figure 4

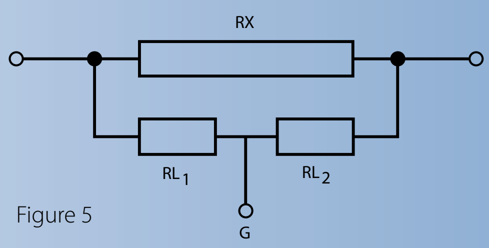

Figure 5

Inverter Amplifiers

The high value resistor with leakage may be placed in the input (Rin) or feedback (RF) positions or both, as shown in Figure 6, but in either case the grounding of the guard band prevents leakage currents at the virtual earth, and the amplifier gain will be –RF/R_{in}.

The input leakage current from Vin flows through the guard terminal G, to ground, and the output leakage current flows through guard terminal G2 to ground.

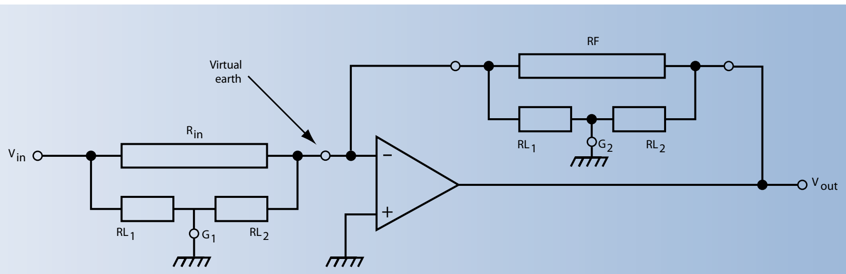

Figure 6

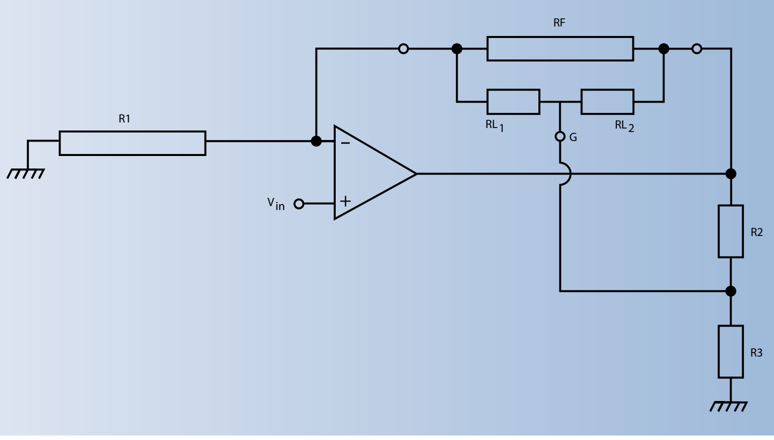

Figure 7

Follower with Gain

In the circuit shown in Figure 7

if $\frac{RF}{R1} = \frac{R2}{R3}$ the potential at the

guard terminal G will be equal to V_{in}

Since there is now zero potential across RL1, there can be no leakage current in this part of the total leakage path. The leakage current flowing in RL2 can be made a negligible quantity if R2 and R3 are low in value compared to RL2. The gain of the amplifier becomes RF/R1.

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Wheatstone Bridge

In Figure 8, by connecting the guard as shown, RL2 is across the detector, and does not affect the balance. RL1 shunts the ratio arm R1 and if R1<<RL1 the error in the value of RX is small, RX ≈ RS(R1/R2) but in any case, if known, can be allowed for.

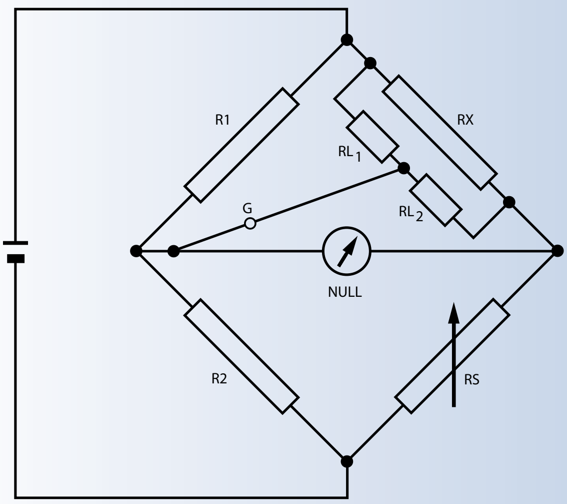

Figure 8

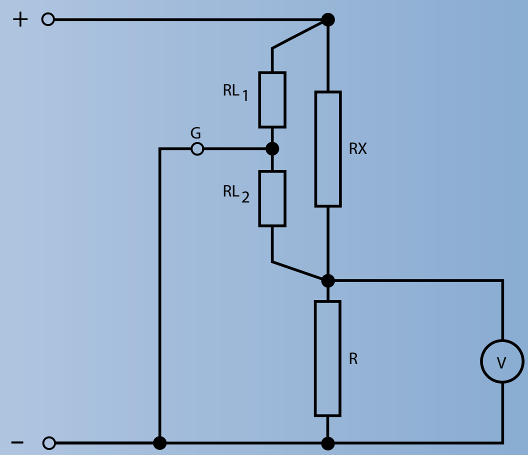

Figure 9

Voltage Divider

In the circuit shown in Figure 9, by making the guard connection the total leakage is again divided into RL1 and RL2, of which RL1 now appears across the supply and will not cause errors. RL2 appears across the low value resistor R and has much reduced ability to produce an error.

Example: With circuit values of $RX = 10^{12}$, $RL1 = 10^{14}$, $R = 10^{8}$
The nominal divider ratio is:

$$\frac{RX + R}{R} = \frac{10^{12} + 10^{8}}{10^{8}} = 10001$$

With the guard terminal unconnected the true ratio will be 9951, an error of –0.5%

Connection of the guard as shown makes the ratio 10001.01 and the error is now 0.0001%.

For additional product information and data sheets or to discuss your specific requirements please contact the Resistor Applications Team using the contact details below.

Note: Circuit diagrams shown for example only.

TT electronics: leading in fixed resistor technology.

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