

# SHUNT-DIODE BARRIERS

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## SCOPE

This application note describes the use of shunt-diode (zener) barriers for standard load cell installations in hazardous areas. The barrier provides two basic protective functions. Firstly it limits current and voltage entering the hazardous area to levels below that at which ignition can take place for a particular explosive atmosphere. Secondly it diverts any large fault current into a high integrity, low-impedance return path, thus preventing dangerous voltages being generated in the hazardous area.

The technique for preventing explosions by limiting the electrical energy available in circuits is called *Intrinsic Safety (EEx(i))*. It is essentially a low-power technique, so exceptionally suitable for load cells. Equipment in the hazardous area must be certified as intrinsically safe or be non-energy-storing "*simple apparatus*".

## LOAD CELL CERTIFICATION

Specially for the use in intrinsic safe installations, Revere Transducers offers certification for the majority of load cells produced. All load cells have been tested and certified by KEMA, a certified body under EC regulations, EN 50014 (General requirements) and EN 50 020 (Intrinsic safety "i").

The supply circuit and the output circuit are galvanically connected and may only be used in conjunction with certified intrinsically safe circuits (barriers) within the tolerances represented in the table below.

	Load cell marking	
	EEx ib IIC T6	EEx ib IIC T4
$\Sigma U$ ( V )	19,1	19,1
$\Sigma I$ ( mA )	323	323
$\Sigma P$ ( W )	1,25	2,75

The effective internal capacitance and inductance of load cells are negligibly small. Each certified load cell is individually tested and must have at least 500 V insulation to earth.

## BARRIERS

Barriers placed in a load cell circuit, not only limit the energy that may be transferred to the hazardous area under fault conditions, but also restrict the operating voltage that may be applied to the Wheatstone bridge. This restriction becomes increasingly severe if bridges are connected in parallel within the hazardous area. An excitation supply of 9V can be developed across one 350 $\Omega$  bridge, but if four bridges are connected in parallel, it is possible that the excitation could drop to less than 4V. This can be overcome by considering application of barriers operating in parallel.

In addition to this fact a temperature effect is introduced by the use of barriers.

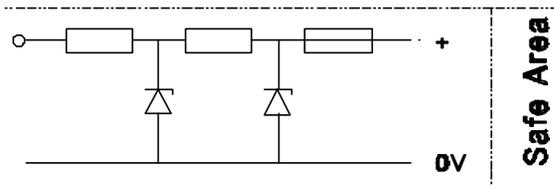


Figure 1

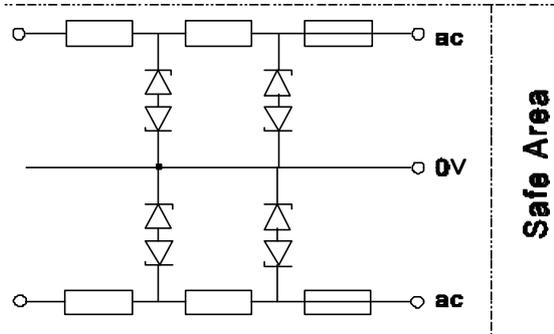


Figure 2

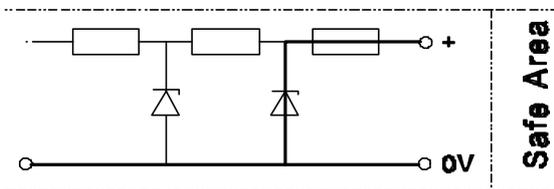


Figure 3

There are three basic types of simple resistive passive barriers used for standard weighing installations. A barrier which will sustain a positive voltage with respect to the 0 V is called a positive barrier and is configured as shown in figure 1.

The configuration for a negative barrier is the same with the exception of the zener diodes which are placed in the opposite direction.

**Care must be taken in connecting polarised barriers, connecting the wrong polarity will certainly destroy the barrier!**

A barrier capable of transmitting a signal of either polarity or alternating current signal uses two zener diodes connected in series. Many barriers have two voltage and current-limiting networks inside, connected between the appropriate terminals. These are known as 2-channel barriers and are applicable to the majority of circuits, saving time, money and space. A 2-channel, non-polarised barrier is configured as shown in figure 2. Often the two channels are used within the same circuit. **Using more than one barrier channel in a circuit means that the combination of voltages and currents must be assessed as being safe in that particular**

**hazardous area.**

Figure 3 shows the fault path which occurs if the voltage to the barrier is too high. The zener diode will conduct this voltage to earth and the fuse will blow due to the increase of current present.

## TERMINOLOGY

### Safety description

The description of a barrier, eg "10V 50Ω 200mA" refers to the maximum voltage of the terminating zener or forward diode whilst the fuse is blowing, the minimum value of the terminating resistor and the corresponding maximum short-circuit current.

It is an indication of the fault energy that can be developed in the hazardous area and not of the working voltage or end-to-end resistance.

### End-to-end resistance

The resistance between the two ends of a barrier channel at 20 EC, ie of the resistors and fuse.

### Working voltage (V<sub>wkg</sub>)

The greatest steady voltage, of a appropriate polarity, that can be applied between the safe area terminal of a "basic" barrier channel and earth at 20 EC for the specified leakage current, with the hazardous area terminal open circuit.

### Maximum voltage (Vmax)

The greatest steady voltage, of a appropriate polarity, that can be applied continuously between the safe-area terminal of any barrier channel and earth at 20 EC without blowing the fuse.

For "basic" barriers, it is specified with the hazardous terminal open circuit; if current is drawn in the hazardous area the maximum voltage for these barriers is increased slightly.

### Fuse rating

The greatest current that can be passed continuously (for 1000 hours at 35 EC) through the fuse.

### Example: barrier descriptions

MTL Model	Safety description			Polarity	End-to-end resistance $\Omega$	Vwkg at 10(1) $\mu$ A V	Vmax V	Fuse mA
	V	$\Omega$	mA					
761*	9	90	100	ac	145	6,0	7,5	100
761P*	9	350	25	ac	384	7,0	8,1	50
766*	12	150	80	ac	185	10,0	11,2	50
764*	12	1000	12	ac	1075	10,0	11,2	50

\* Two channel barriers, description for each channel

MTL Model	Number of single channels inter-connected in hazardous area	Maximum permissible cable parameters for group IIC(hydrogen)			Matched power W
		Capacitance $\mu$ F	Inductance mH	L/R ratio $\mu$ H/ $\Omega$	
764ac	1	1,6	230	900	0,04
	2	1,6	60	345	0,08
766ac	1	1,4	5,8	150	0,24
	2	1,4	1,5	58	0,48

## ACCEPTABLE CABLES

The choice of cable is frequently determined by the specific requirements of the installation. The main environmental conditions which should be considered are as follows:

- # attack by chemicals, sunlight and other radiation.
- # attack by water and corrosion (particularly aluminium).
- # excessive vibration.
- # excessive temperature in either direction.
- # the possibility of the cable causing danger by transmitting gas along its length.

*Cables used when installing an intrinsically safe system are required to conform to the relevant requirements of the certificated documentation for the system. Cables must always be suitable for the environment in which they are to be used.*

Certification documents of a system specify certain cable parameters which should be taken into account, since it is possible that the distributed capacitance and conductance of a cable can store energy. The capacitive and inductive effects are always treated separately since they do not appreciably interact. In general it is desirable to check the parameters on an installation with cables longer than 100 metres. Manufacturer's specified characteristics can be used if the cable length does not exceed 100 metres. It is unlikely that cable parameters will present a system configuration problem in gas environments other than that of IIC.

## OPERATING VOLTAGE

As mentioned previously, the operating voltage applied to the bridge of the load cell will be less than the voltage supplied by the indicator, this is caused by the end-to-end resistance of the barrier channels introduced into the circuit. The operating voltage on the bridge (or multiple load cell bridges) when a barrier with end-to-end resistance  $R_b$  is interposed in each line, can be calculated by :

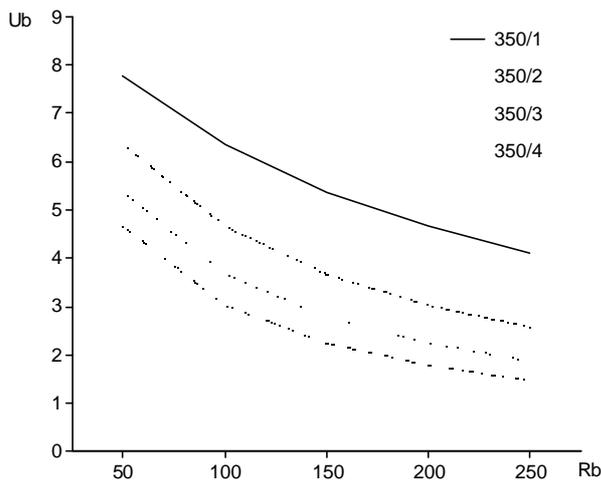
$$R_{ii} = R_i / N$$

$$I = U / (R_{ii} + 2R_b)$$

$$U_b = U * R_{ii} / (R_{ii} + 2R_b)$$

Where :

- I : Current
- $U_b$  : Operating voltage of the load cell(s)
- U : Excitation voltage supplied by the indicator
- N : Number of load cells present in the installation
- $R_i$  : Input resistance of the load cell
- $R_{ii}$  : Combined resistance of multiple load cells placed in parallel
- $R_b$  : End-to-end resistance of the barrier channel used into the excitation circuit



The diagram shows the operating voltage of the load cells, when a barrier channel with end-to-end resistance  $R_b$  is introduced in each line, at an excitation of 10 V, supplied by the indicator.

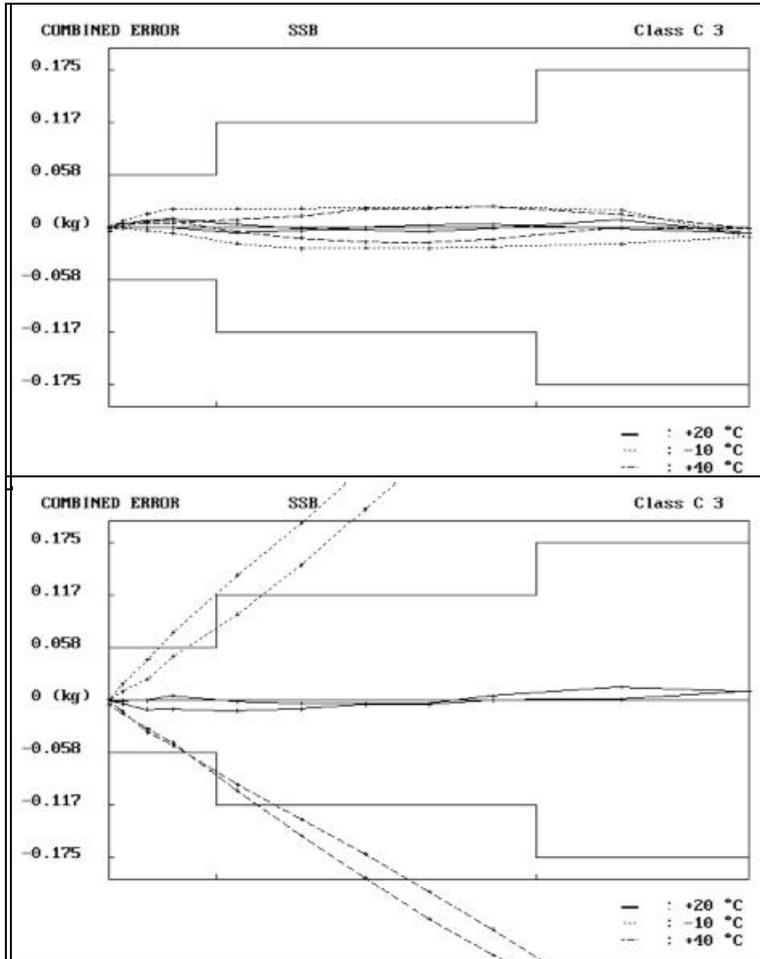
Any additional resistance introduced by barriers in the sense and output lines of the load cell will not cause a voltage drop. This is due to the low current present in these lines.

# SYSTEM ACCURACY

Introducing barriers into a weighing system creates the introduction of a temperature effect.

- 1) **The end-to-end resistance of the barrier will change with any change of ambient temperature.**
- 2) **The leakage current through the zener diodes will change with any change of ambient temperature.**

These effects which appears to be very small at first sight, will nevertheless cause a considerable error to the system.



The graph opposite shows the result of a temperature test performed on a SSB type load cell with a maximum capacity of 500kg.

According to OIML recommendation R-60, the limits of error shall refer to that error envelope as defined in the figure. The load cell was directly connect to a HBM DK38 indicator which supplies the load cell with an excitation of 10 Vac / 225 Hz.

In the 2nd graph the same test was performed with zener barriers interposed between the indicator and load cell.

The maximum error, caused by a temperature drop from 20 to -10 EC at 500 kg was 0,614 kg, which equals 0,122%.

The maximum error, caused by a temperature raise from 20 to 40 EC at 500 kg was -0,434 kg, which equals 0,087%.

In case of a process weighing application, such an error development might be acceptable, but the installation will never be approved by the Weights and Measures authorities.

There are two basic options in avoiding errors caused by temperature effects when using barriers. The first option is to keep the barriers at a constant temperature. This is for example possible if the process-control room where the barriers are located is air-conditioned.

The second option is the use of sense lines in a balanced bridge circuit. The sense lines actually sense the operating voltage at the load cells. This method is critical when the installation must be approved by Weights and Measures. There are two basic methods of compensating the voltage drop caused by barriers (and extension cables!) based on the feed-back of sense lines :

- # Increase of the excitation voltage supplied by the indicator.
- # Increase of the amplifier-rate of the indicator.

Most indicators compensate by increasing the voltage output. **Care must be taken not to pass the compensation limit of the indicator!**

# BALANCED BRIDGE CIRCUITS

The leakage current through the zener diodes to earth will not influence the operating voltage of the load cell when sense lines are used. However the output signal of the load cell and the sense signal, are influenced by this effect.

The leakage current will increase with an increase of voltage over the zener diodes and also the error caused by a change in ambient temperature. To minimize the voltage over the zener diode a balanced bridge circuit should be used.

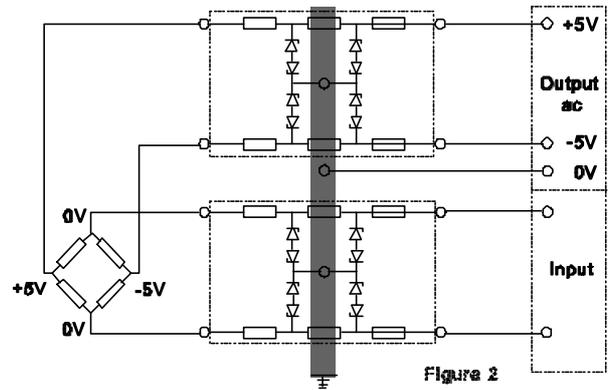
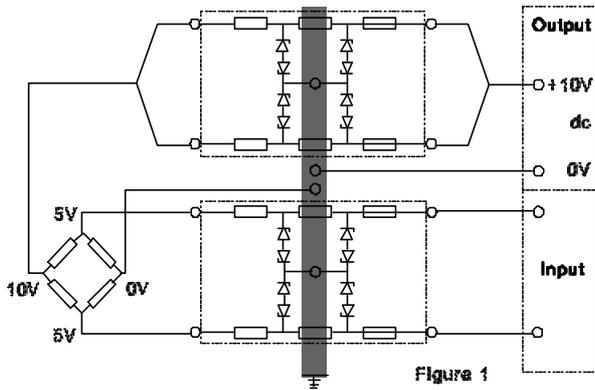
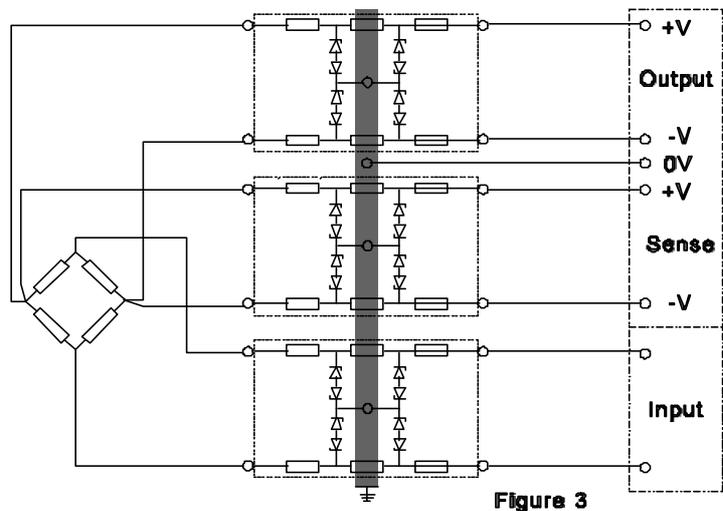


Figure 1 shows a non-balanced or basic bridge circuit. A voltage of 10 Vdc is applied to the bridge, which will result in a potential of 5 V on each output line in a no-load situation. The voltage between the two output lines will be 0 V. In the case of a 2 mV/V load cell at full load, the potential at one output line will decrease to 4.99 V and the potential at the second line will increase to 5.01 V. The voltage between the two output lines will then be 0.02 V = 20 mV.

Figure 2 shows a balanced bridge circuit. A voltage of 10 Vac is applied to the bridge, which will result in a potential of +5 V at one input line and -5 V at the second line. Both output lines have a potential of 0 V in a no-load situation. In the case of a 2 mV/V load cell at full load, the potential at one output line will decrease to -0.01V and the potential at the second line will increase to +0.01 V. The voltage between the two output lines will again be 0.02 V = 20 mV.

Note All potentials are measured to earth.

Figure 3 shows a balanced bridge circuit with sense line connections.



# BASIC SYSTEM CIRCUITS

Figure 4: Basic system configuration with six-wire load cells.

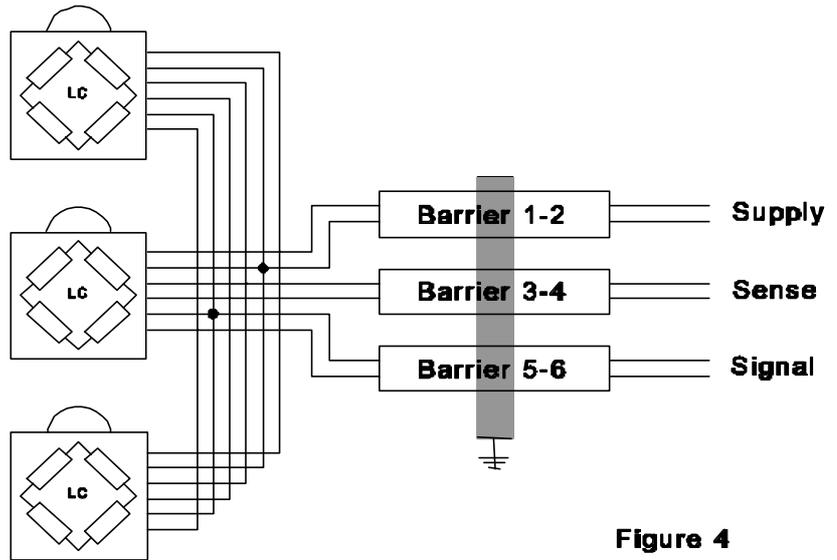


Figure 4

Figure 5: Basic system configuration with four-wire load cells. The cable forms part of the temperature compensation circuit of the load cell and should never be cut.

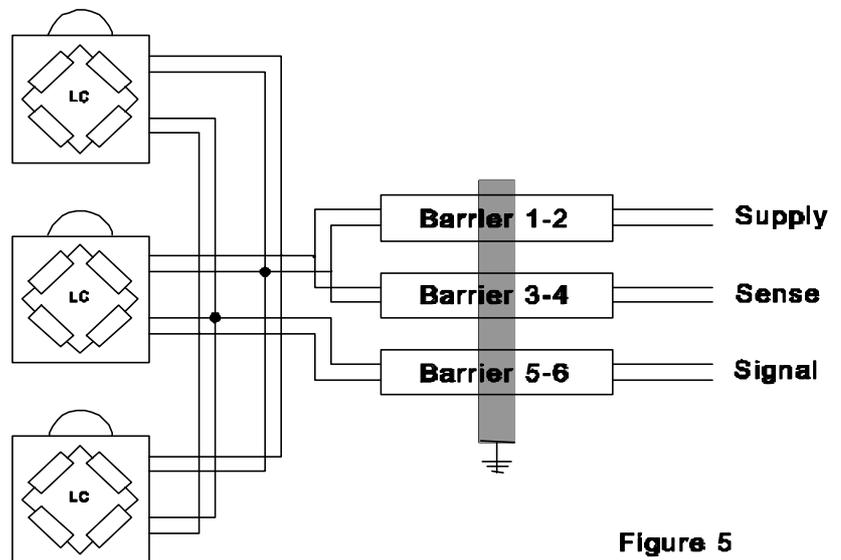


Figure 5

Figure 6: The cable screens within an intrinsically safe installation must be earthed at only one point, the barrier busbar. This is required for safety reasons and is also desirable for minimising interference. The figure opposite confirms that all screens are earthed at the barrier busbar only. The load cell housings may be earthed by joining them together. From this point they should be connected directly to a structural earth, **not the barrier busbar earth.**

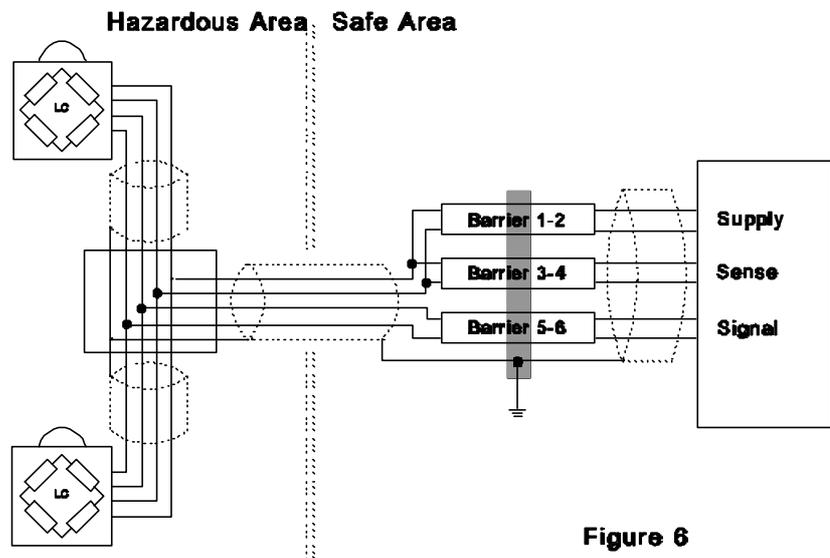


Figure 6

## SIMPLE APPARATUS

Perhaps the most generally beneficial clause in the CENELEC standards is clause 1.3 of EN 50.014 which states:

*Devices in which, according to the manufacturer's specifications, none of the values 1,2V, 0,1A, 20mI or 25mW is exceeded need not be certified or marked.*

Most simple detectors which are the basic tools of intrinsic safety and form the majority of intrinsic safe applications all rely on this clause to avoid certification. Switches, thermocouples, resistance thermometers, potentiometers and strain gages are all regarded as simple apparatus.

It is important to realise that the voltage, current and power mentioned are self generated. Higher voltages and currents can be imposed on the simple apparatus from certified safe-area apparatus (barriers or certified power sources). For example a load cell would typically have 10V imposed across its 350Ω with a total power of 286mW, but the strain gage itself would still be simple apparatus. Each of the requirements must be met individually.

The temperature classification allocated to simple apparatus is **T4 (135EC)**, provided the matched power is less than **1,3W at 40EC, 1,2W at 60EC and 1,0W at 80EC**, provided that the component has a surface area greater than 20mm<sup>2</sup>, which is the case when load cells are involved.

Another requirement of simple apparatus is that the apparatus must be insulated to withstand a 500V rms test to earth. Revere Transducers is able to supply load cells with a test certificate, confirming that the test has been carried out.

The choice to use a certified load cell (see page one) or a non-certified load cell (simple apparatus), should be made based on the requirements for a particular environment or the end-user's demands.

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This application note is written as a short guide in understanding the considerations which must be taken into account for intrinsically safe weighing systems. No attempt has been made to provide the complete information necessary for manufacturing intrinsically safe weighing systems.

### Customer support:

The Revere Transducers group combines fifty years of load cell manufacturing with fifty years of application know how. For any further question, please contact our manufacturing operation or any one of our regional sales offices.

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