Intrinsically Safe Circuits at Radio Frequencies

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Background

Historically one of the most commonly used pieces of RF equipment on industrial sites was the hand-held PMR radio, but other technologies such as satellite uplinks were also used. Today however, the installation of wireless data networks, GSM-equipped data terminals, wireless SCADA systems and similar technologies are becoming more common in industrial environments, and this naturally increases the demand for their installation in the hazardous areas of these sites.

Identification of Hazards

The risks associated with the use of RF transmitting equipment in a hazardous area can be divided into two categories;

- *Hazards related to the **electrical signals** between the transmitter and antenna*
- *Hazards related to the **RF radiation** emitted from the antenna.*

Electrical Signals

The RF signal generated by a transmitter circuit is simply a high-frequency AC waveform. As such it can be described in terms of its voltage, current and power and therefore conventional rules for the prevention of ignition in hazardous areas apply. For example, it may be possible to assess the transmitter circuit as Intrinsically Safe in accordance with EN60079-11[a] or to protect the transmitter and antenna by encapsulation in accordance with EN60079-18[b]. However, such methods may be impractical depending on the nature of the device concerned.

RF Radiation

The electromagnetic field radiated from an antenna can present an ignition hazard in two ways; through the direct heating of gasses close to the antenna, and through the induction of currents in nearby conductive structures.

The direct heating of gasses and water vapours by RF is generally discounted during safety assessments on the basis that the power required to generate a significant temperature rise in a gas is very high (for example a microwave oven relies on very efficient coupling of RF energy at a specific wavelength, and a power of several hundred Watts, into the water in the food to effect a significant temperature rise).

Conductive structures exposed to an RF field can act as an antenna themselves, and therefore can have significant currents induced in them. If this current is sufficiently large, and a discontinuity in the structure exists, there is the potential for an incendive spark to be

a *BS EN60079-11:2007 - Explosive atmospheres - Part 11: Equipment protection by intrinsic safety 'I'*

b *BS EN60079-18:2008 - Explosive atmospheres - Part 18: Equipment protection by encapsulation 'm'* generated across the discontinuity. The requirements of EN60079-0:2009 6.6.1[c] (based on guidance provided in BS6656:2002[d]) define maximum permissible EIRP[e] levels for different gas groups, and maximum energy thresholds for pulsed signals.

Compliance with RF radiation power limits

The maximum EIRP levels defined in EN60079-0:2009 6.6.1 are designed to allow easy assessment of low-power transmitters without the need for the often complex assessment of nearby structures. However, it must be demonstrated that transmitting equipment cannot exceed these limitations. EN60079-0:2009 6.6.1 states that programmable RF power output levels must either be limited by hardware or by non-user-accessible software. This presents a significant challenge for some radio equipment such as wireless networking devices where RF output power levels are commonly accessible via a web interface and the EIRP can easily exceed the permitted level if high-gain antennas are used.

Problems with existing protection concepts for radio equipment

It is relatively straightforward to construct a radio transmitter so that it can be installed in a hazardous area. For example, Extronics produce a range of wireless networking equipment housed in Ex d enclosures, for Zone 1 applications. Clearly housing an antenna in an aluminium enclosure is not practical. Therefore Extronics use an 'increased-safety' Ex e antenna in a plastic housing with this equipment. However, this is not a low-cost option, and the antenna is a simple omni-directional device, limiting the range of applications to which it is suited. Other options such as encapsulating an application-specific antenna require significant investment, and such antennas cannot be disconnected from the transmitter as suitable Ex d RF connectors are not available .

To allow ultimate flexibility in the types of antennas available, and for minimal cost, an Intrinsically Safe (IS) output from the transmitter is the optimal solution. With certain equipment which can be assessed as IS from circuit diagrams and layouts, this is feasible. However, the nature of complex radio transceivers often means that their power supply requirements make this impractical. In addition, access to and control over complete design documentation is often difficult to obtain.

iWAP103 Ex d Access Point with Ex e Antenna

Therefore the only realistic option is a safety-barrier circuit to interface between a transmitter (either protected in some way or installed outside of the hazardous area) and the antenna and cable located within the hazardous area. The antenna and cable can then be assessed as 'simple apparatus' in accordance with EN60079-11:2007

c *EN60079-0:2009 - Explosive atmospheres - Part 0: Equipment - General Requirements*

d *BS6656:2002 - Assessment of inadvertent ignition of flammable atmospheres by radio frequency radiation (guide)*

e *EIRP – Effective Isotropic Radiated Power - radiated power from an antenna taking into account the antenna gain relative to an ideal isotropic radiating element* section 5.7. This requires a basic assessment of the antenna and cable assembly in terms of stored energy and thermal characteristics (made against the output safety parameters of the barrier circuit), which can be done by the manufacturer or user without reference to a notified body.

The certification of suitable equipment can be separated into two categories; providing an IS RF output from equipment for which some technical detail is available, and providing an IS RF output from a 'black box' about which no constructional details are known.

Providing IS RF outputs from known equipment

The conventional route to assessing the output of a piece of apparatus as intrinsically safe is to assess the available voltage and current available to the equipment from external sources. If necessary, the inputs to the equipment can be limited with barrier circuits to safe levels. Provided that the equipment cannot store significant energy or elevate voltages to unsafe levels, the output can then be declared as IS. However, this is commonly impractical for a number of reasons. Firstly, equipment commonly requires more power than can be supplied within the limits of IS current and voltage. Secondly, the available output safety parameters (maximum voltage, current, power, inductance and capacitance) may not match the desired load. Therefore it is common to place a safety barrier on the equipment output to allow the desired safety parameters to be achieved.

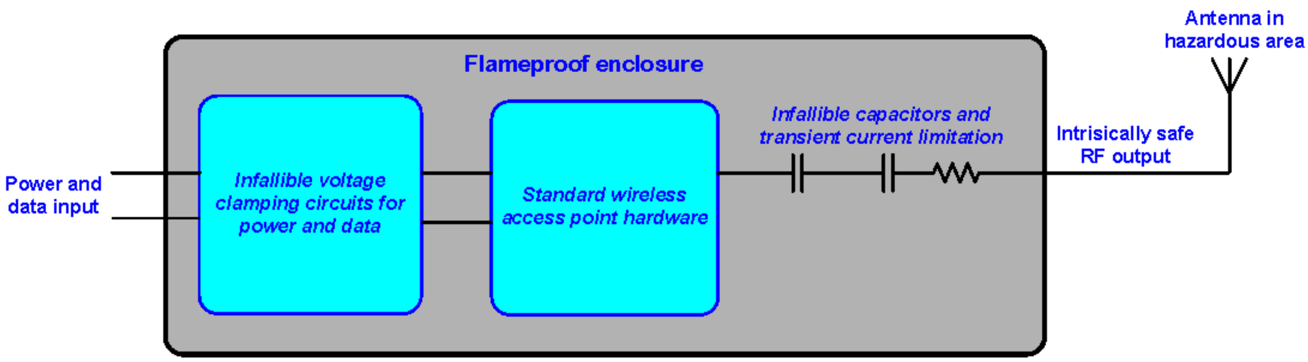
Conventional safety barrier circuits generally rely on semiconductor devices such as Zener diodes, which 'clamp' output voltages to defined levels. At DC and low frequencies these devices are very effective and do not generally modify the wanted output signal in any significant way. However, as the frequency of the output signal increases (above approximately 100KHz), conventional Zener diodes and similar devices can cause significant attenuation of the wanted signal. This is mainly due to the relatively high capacitance of such devices, which presents an exponentially decreasing impedance to earth as the frequency of the signal increases.

It is possible to design barrier circuits using devices with lower capacitance, but this can only be done with signals up to a few tens of MHz. Radio equipment for most applications operates at significantly higher frequencies (400MHz to 6GHz and above is common).

In the past, this issue has been addressed by some companies by simply placing a pair of infallible capacitors in series with the RF output of an un-defined transmitter. However, there two key safety problems associated with this method; the in-band and out-of-band RF power[f] that could be generated by a transmitter under fault conditions is not controlled, and transient fault currents which could pass through the capacitors are not limited.

To overcome these identified problems, Extronics has developed a range of wireless access points with IS RF outputs. These are based on transmitter hardware for which circuit diagrams were made available by the manufacturer. The power supply and data interfaces were infallibly

f *In-band RF power is the output from a transmitter within its designed operating frequency, whereas out-of-band power encompasses all other radio frequencies (although an upper and lower limit are generally placed on this range)* voltage clamped, and the RF output DC-decoupled with a pair of infallible capacitors. In addition, a transient-current limiting resistor was added as shown in the diagram below.



The capacitors present a total block to DC signals, and a high-impedance to low frequency AC signals. A careful assessment was made of the maximum possible frequency of AC signals which can be generated under fault conditions by the equipment being assessed (typically from switching regulators). The voltage of these faults was taken to be the maximum clamping voltage of the supply input due to the nature of the switching regulator design. The value of the DC-blocking capacitors was then selected to ensure that the current of these AC fault signals is limited to IS levels.

RF signals within the operating frequency range of the transmitter (which are not current-limited by the DC-blocking capacitors) were assessed by the notified body to be IS provided that their power was limited to 2W and that this cannot be exceeded by user settings. This decision was made on the basis that a 2Wrms dissipation into a matched 50Ω antenna gives a peak voltage of 14.14V and a peak current of 200mA, which is well within the permitted values for IIC gasses (even accounting for significant cable inductance and capacitance).

The transient current limiting resistor was selected to ensure that any fast transients passing through the capacitors are limited to a defined current. The value of this resistance is based on the maximum voltage of the transients available at the RF output. This fault voltage is known because the equipment is powered from an infallibly voltage clamped supply and an assessment of voltage generating circuits within the equipment. This resistance value also allows a maximum load inductance to be defined; whilst the maximum load capacitance is defined from the power supply clamping voltage.

Providing IS RF outputs from unknown equipment

Where the internal structure of a piece of equipment is unknown, it must be assumed that an incendive voltage and current of any frequency (up to the maximum operating frequency of the equipment) will be present at the RF output under fault conditions. Traditional Zener barriers or isolating barriers rely on the fact that they will limit any fault to a safe voltage and current up to the maximum operating frequency of the equipment. However, this specification appears to have been based on the assumption that the equipment concerned is inherently operating at a low frequency, and is powered from a low-frequency supply. This coupled with the many years of safe use of such barriers means that the risk of them being ineffective in such applications is extremely low.

However, where apparatus is designed to operate at high frequencies e.g. radio transmitters, a typical Zener barrier will not be operating within its design parameters, and therefore may not provide the intended level of protection. This is somewhat irrelevant as the barrier will also attenuate the wanted signal excessively and therefore is very unlikely to be connected to such equipment. However, any barrier designed to operate at radio frequencies must be capable of safely limiting signals to a defined voltage and current at frequencies up to the maximum operating frequency of the transmitter.

It is arguable that the apparatus may generate incendive signals at frequencies ***above*** its maximum normal operating frequency. However, it is not clear at the present time how far one should go in protecting from such faults, as there is no clear guidance on this from the notified bodies or standards committees, beyond limiting voltage and current at the maximum operating frequency.

The radiated RF power limit defined in EN60079-0:2009 6.6.1 must also be taken into account. If the RF power of the transmitter can be user-set to a hazardous level, and there is no way of disabling this feature, then an external circuit will be required to limit the power in some way.

Extronics is currently developing potential solutions with the aim being to enable the installation of any radio transmitter either in an Ex d enclosure or in a safe location, and to use any antenna and cable configuration desired (provided they meet the safety parameters of the barrier and the RF EIRP limitations). The aim of this research is to provide the optimal solution in terms of unit cost and flexibility of installation. By investing in this research and through the many other developments made in the area of hazardous area wireless networking, Extronics is enabling customers to take full advantage of the flexibility offered by wireless technology in the vast majority of production areas.

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