AZD115 – INDUCTIVE SENSING
Inductive sensing with IQS62x and IQS269 devices

Contents

1 Overview 2

2 Introduction to inductive sensing 2

3 Inductance equations for planar spiral coils 3
   3.1 Single layer coils ................................................. 3
   3.2 Multilayer layer coils ............................................. 4

4 Inductive sensing modes 5
   4.1 Self inductance mode ............................................. 5
   4.2 Mutual inductance mode ......................................... 6

5 LC tank resonant circuit 7
   5.1 LC tank design .................................................. 9
      5.1.1 Inductor model .............................................. 9
      5.1.2 Equivalent LC tank circuit ................................. 10
      5.1.3 Design steps ................................................ 10

6 ProxFusion® inductive sensing device overview 11

7 Design considerations 11
   7.1 Coil sensing range .............................................. 11
   7.2 Inductor coil shapes ............................................ 12
   7.3 Calculating the coil inductance ............................... 13
   7.4 Selecting LC tank capacitor ................................. 13
   7.5 Excitation frequency ............................................ 14
   7.6 Temperature effects ............................................ 14

8 Inductive sensing applications 14
   8.1 Rotary position encoder ..................................... 15
   8.2 Rotary speed sensor ........................................... 15
   8.3 Linear slider .................................................... 16
Overview

As the need for more robust and ubiquitous sensors increases, inductive sensing is increasingly gaining momentum as a favourable sensing technology. The contactless nature of inductive sensing allows for designs that have a longer life span and can withstand harsh environmental conditions while maintaining predictable results and performance.

Azoteq’s ProxFusion® series of devices offer cutting-edge, low cost and low power inductive sensing solutions that can be used in various applications from inductive sliders to rotational encoders.

Introduction to inductive sensing

Inductive sensing detects the change in inductance of an inductor as a conducting metal object/target is brought in close proximity to the inductor. The sensing inductor is usually made up of a winding wire or a spiral PCB track. Change in inductance of the sensor is dependant on the sensor-target distance, as well as the composition and size of the target.

When an oscillating AC signal is applied to the sensing coil, a time varying electromagnetic (EM) field is generated around the coil. As a conducting metal target is brought within proximity of the coil, the time varying EM field around the coil induces eddy currents in the target as shown in Figure 1.

![Figure 1: Induced eddy currents on metal target](image)

The direction of the induced eddy currents in the target is such that it generates an opposing EM field that reduces the overall inductance of the sensing coil. This change in inductance caused by the metal target on the sensing coil is measured by ProxFusion® devices on a CRx pin.
Inductance equations for planar spiral coils

Single layer coils

The inductance value, $L_s$, for a single layer planar PCB coil [1] can be approximated as:

$$L_s = \frac{\mu_n n^2 d_{avg} c_1}{2} \left( \ln \left( \frac{c_2}{\rho} \right) + c_3 \rho + c_4 \rho^2 \right), \quad (1)$$

where

- $\mu_n$ is the permeability of free space, $4\pi \times 10^{-7}$ H/m,
- $n$ is the number of turns in the coil,
- $d_{avg}$ is the average diameter, calculated as:
  $$d_{avg} = 0.5(d_{out} + d_{in}), \quad (2)$$
- $\rho$ is the fill ratio, defined as:
  $$\rho = \frac{(d_{out} - d_{in})}{(d_{out} + d_{in})}, \quad (3)$$
- and $c_i$ is geometric dependant coefficients given in Table 1.

![Diagram of spiral coil shapes](image)

*Figure 2: Spiral coil shapes*
### Table 1: Planar coil coefficients for inductance expression

<table>
<thead>
<tr>
<th>Geometry</th>
<th>$c_1$</th>
<th>$c_2$</th>
<th>$c_3$</th>
<th>$c_4$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Square</td>
<td>1.27</td>
<td>2.07</td>
<td>0.18</td>
<td>0.13</td>
</tr>
<tr>
<td>Hexagonal</td>
<td>1.09</td>
<td>2.23</td>
<td>0.00</td>
<td>0.17</td>
</tr>
<tr>
<td>Octagonal</td>
<td>1.07</td>
<td>2.29</td>
<td>0.00</td>
<td>0.19</td>
</tr>
<tr>
<td>Circle</td>
<td>1.00</td>
<td>2.46</td>
<td>0.00</td>
<td>0.20</td>
</tr>
</tbody>
</table>

**Multilayer layer coils**

The total inductance of a two layer inductor coil is given in Equation (4), where the inductance of the coil on the first layer $L_1$ and second layer $L_2$ are calculated from Equation (1), [2].

$$L_{Total} = L_1 + L_2 \pm 2M$$  \hspace{1cm} (4)

The mutual inductance $M$ between the coils is related to the coupling factor, $K_C$ as follows

$$M = K_C \sqrt{L_1 \times L_2}$$  \hspace{1cm} (5)

The coupling factor is defined as

$$K_C = \frac{n^2}{ax^3 + bx^2 + cx + d} \times (1.67n^2 - 5.84n + 65) \times 0.64,$$  \hspace{1cm} (6)

where $x$ is the distance between the two layers in mm, $n$ is the number of inductor turns on a given layer, $a = 0.184$, $b = -0.525$, $c = 1.038$, and $d = 1.001$. For multi-layered coils the orientation of the coils on each layer should be such that the current flows in the same direction, as shown in Figure 3.

![Figure 3: Multi-layer spiral coil](image)

For an inductor with more than 2 layers, there are more than 2 coupling factors that need to be calculated. The 4 layered inductor in Figure 3 has in total 6 coupling factors, $K_{C12}$, $K_{C13}$, $K_{C14}$, $K_{C23}$,
$K_{C_{ij}}$ and $K_{C_{ij}}$ where $K_{C_{ij}}$ is the coupling factor between layers $i$ and $j$. The total inductance of the 4 layered coil is given by

$$L_{total} = L_1 + L_2 + L_3 + L_4 + 2(K_{C_{12}} + K_{C_{13}} + K_{C_{14}} + K_{C_{23}} + K_{C_{24}} + K_{C_{34}}) \times \sqrt{L_1 \cdot L_2}. \quad (7)$$

Since the coils on each layer have the same geometric shape, the 4 layer inductance can be expressed as

$$L_{total} = 4L_s + 2(K_{C_{12}} + K_{C_{13}} + K_{C_{14}} + K_{C_{23}} + K_{C_{24}} + K_{C_{34}}) \times L_s \quad (8)$$

**Inductive sensing modes**

The ProxFusion® devices are capable of measuring inductance in 2 operational modes:

- Self inductance mode
- Mutual inductance mode

In the self inductance mode, each channel uses a single coil for both the excitation and sensing and in the mutual inductance mode, the excitation and sensing of each channel takes place on different coils.

**Self inductance mode**

Self inductance mode has 2 sensing configurations:

- Direct sensing
- Biased sensing

Both sensing configurations require a single sensing coil as shown in Figures 4 and 5. The EM field around the coil is generated by the excitation signal at the CTx pin while the inductance measurement of the coil is carried out on the CRx pin. For the biased sensing configuration, the $V_{Bias}$ pin is used to provide a forward bias voltage on the CRx pin which is required by some devices for proper inductive sensing operation, (refer to Table 2).
The series resistor, $R$, decouples the CTx pin form the CRx pin and prevents loading of the internal CTx circuitry. The $R$ value should be small enough to allow sufficient current through the inductor but large enough to decouple the CTx pin. Typical design values for $R$ are in the range of $47\,\Omega$ to $470\,\Omega$.

For the self inductance mode, the inductance measurement takes place on the same coil that generates the EM field. When a metal target is brought in close proximity to the sensor coil, the inductance of the coil is reduced as a result of the induced eddy currents.

**Mutual inductance mode**

For the mutual inductance mode, at least two coils are required as shown in Figure 6. A dedicated Tx coil generates the EM field from the excitation signal at the CTx pin. The generated EM field induces an excitation current on the Rx coil, which also generates an EM field at the Rx coil. Since the EM field at the Rx coil is dependant on the Tx coil, there exists a mutual inductance between the Tx and Rx coils.

Only the biased sensing configuration can be used in mutual inductance mode. The $V_{Bias}$ pin is
used to provide a forward bias voltage on the CRx pin which, is required in some devices for proper inductive sensing operation, (refer to Table 2).

Similar to the self inductance mode, the series resistor $R$ is placed at the Tx coil to isolate the CTx pin from ground and prevent loading of the CTx internal circuitry.

Measurement of the mutual inductance is carried out on the Rx coil at the CRx pin. When a metal target is brought in close proximity to the Rx coil, the mutual inductance between the Tx and Rx coil is reduced by the induced eddy currents.

Multiple sensors can be used in mutual inductance mode by adding more Rx coils within close proximity to the EM filed generated by the Tx coil.

<table>
<thead>
<tr>
<th>Sensor Mode</th>
<th>Sensing Configuration</th>
<th>IQS269A</th>
<th>IQS620A</th>
<th>IQS621</th>
<th>IQS624</th>
<th>IQS680</th>
</tr>
</thead>
<tbody>
<tr>
<td>Self</td>
<td>Direct</td>
<td>✓</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>Biased</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>–</td>
</tr>
<tr>
<td>Mutual</td>
<td>Biased</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>–</td>
</tr>
</tbody>
</table>

**LC tank resonant circuit**

A suitable inductive sensing EM field can be generated using a parallel LC tank resonant circuit as shown in Figure 7.

![LC tank resonant circuit](image)

The LC tank resonates at frequency $f_{\text{res}}$ given by

$$f_{\text{res}} = \frac{1}{2\pi \sqrt{LC}}. \quad (9)$$

Figure 8 shows the response of the LC tank voltage $V_L$ as the excitation frequency $f_{tx}$ is swept from 1 MHz to 10 MHz. This particular tank circuit is tuned to resonate at 4 MHz, where $V_L$ has its
maximum amplitude.
At the resonant frequency, the impedance of the LC tank circuit is also at a maximum. This limits the current through the inductor coil and prevents loading at the CTx pin. Due to this high impedance, less current is required to generate the EM field, which is crucial for low power applications.

![Figure 8: LC tank response with 4 MHz resonant frequency](image1)

![Figure 9: LC tank Response with metal target](image2)

When a metal target is in close proximity to the sensing coil, the inductance $L$ is reduced. From
Equation (9), a decrease in $L$ increases $f_{res}$ of the LC tank as shown in Figure 9. Assuming a fixed excitation frequency $f_{tx}$ of 4 MHz, the proximity of a metal target will result in a $V_L$ attenuation of about 39 dB which can be measured as a change in inductance at the CRx pin.

The LC tank circuit can be applied to both self and mutual inductance sensing modes. In mutual inductance mode, the LC tank tuning can be applied to both the Tx and Rx coils to increase the sensitivity.

**LC tank design**

**Inductor model**

In practice, the inductor coil is modelled by the pure inductance $L$ in series with a frequency and temperature dependant resistor $R_{ac}$.

$$R_{ac} = \frac{\rho_t \times l}{A_{eff}} \cdot [1 + \alpha \cdot (\text{temp} - 25)]$$  \hspace{1cm} (10)

Where:

- $\rho_t$ is the temperature dependant relative resistivity of copper, $1.713 \times 10^{-8} \Omega \cdot m$ at 25°C
- $l$ is the coil length in m
- $A_{eff}$ is the effective cross sectional area of the trace in $m^2$
- $\alpha$ is the temperature coefficient of copper, $3.9 \times 10^{-3} \cdot ^\circ C^{-1}$
- $\text{temp}$ is the ambient temperature in °C

For a rectangular PCB trace of width $w$ and height $h$, $A_{eff}$ decreases with frequency as a result of the skin depth $\delta$ and is given by:

$$A_{eff} = w \times \delta \cdot \left(1 - e^{-\frac{h}{\delta}}\right)$$  \hspace{1cm} (11)

The skin depth $\delta$ at frequency $f$ is given by

$$\delta = \sqrt{\frac{\rho_t}{\mu_r \mu_o \pi f}}$$  \hspace{1cm} (12)

Where

- $\mu_r$ is the relative permeability of copper, 1
- $\mu_o$ is the permeability of free space, $4\pi \times 10^{-7} \text{ H/m}$
- $f$ is the Tx signal frequency in Hertz
Equivalent LC tank circuit

The equivalent LC tank circuit is shown in Figure 10. This equivalent circuit is also applicable for the biased self inductance mode since for an AC signal the DC bias point $V_{bias}$ is equivalent to a GND reference voltage.

![Figure 10: Equivalent LC tank circuit](image)

The resonant frequency of the equivalent LC tank circuit is given as

$$f_{res} = \frac{1}{2\pi} \sqrt{\frac{1}{LC} - \left(\frac{R_{ac}}{L}\right)^2}$$  \hspace{1cm} (13)

At the resonant frequency, the parallel impedance of the LC tank circuit, $R_p$, is given as

$$R_p = \frac{L}{CR_{ac}}$$  \hspace{1cm} (14)

Using the voltage division expression, the value of $R_{tx}$ is determined using (15) and is dependant on the required tank voltage $V_{tank}$ at resonance.

$$R_{tx} = \left(\frac{V_{tx}}{V_{tank}} - 1\right) \frac{L}{CR_{ac}}$$  \hspace{1cm} (15)

At resonance the current sourced by the CTx pin is given by

$$I_{tx} = V_{tx} \left(\frac{CR_{ac}}{CR_{tx}R_{ac} + L}\right)$$  \hspace{1cm} (16)

Design steps

- Design the coil shape and size depending on required application. Using (1) to (8) calculate the inductance of the coil $L$.
- For the required Tx frequency (which is $f_{res}$), calculate the AC resistance $R_{ac}$ of the coil using (10).
• Calculate the capacitor value required to resonate the \( LC \) tank circuit at \( f_{\text{res}} \) using (13).
• Calculate the series resistor value \( R_{tx} \) using (15).

ProxFusion\textsuperscript{®} inductive sensing device overview

There are a number of ProxFusion\textsuperscript{®} IQS devices capable of inductive sensing to choose from. Table 3 provides a device feature list for comparison.

Table 3: IQS inductive sensing device feature overview

<table>
<thead>
<tr>
<th></th>
<th>IQS269A</th>
<th>IQS620A</th>
<th>IQS621</th>
<th>IQS624</th>
<th>IQS680</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of inductive channels</td>
<td>3/6 (^1)</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Supply voltage [V]</td>
<td>1.8 - 3.6</td>
<td>1.8 - 3.6</td>
<td>1.8 - 3.6</td>
<td>2.0 - 3.6</td>
<td>1.8 - 3.6</td>
</tr>
<tr>
<td>External MCU required</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Internal reference oscillator</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Communication interface</td>
<td>I2C</td>
<td>I2C</td>
<td>I2C</td>
<td>I2C</td>
<td>I2C/GPIO</td>
</tr>
<tr>
<td>Capacitive</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>SAR</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Hall effect</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>ALS</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Temperature</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
</tr>
</tbody>
</table>

Design considerations

When designing for inductive sensing, a number of considerations need to be addressed to allow for proper operation.

Coil sensing range

For coil shapes with equal dimensions such as circular and square coils, the perpendicular sensing range \( h \) is determined by the outer diameter \( D_{\text{out}} \) of the coils. As general a rule of thumb, a coil with outer diameter \( D_{\text{out}} \) will have an effective sensing range of up to half \( D_{\text{out}} \).

For coil shapes with unequal dimensions such as rectangular coils, \( D_{\text{out}} \) is defined by the smallest dimension of the coil. The inductance value has little significance on the sensing range of the coil.

\(^1\)3 channels for biased self configuration and 6 channels for biased mutual configuration
Inductor coil shapes

Depending on the metal target shape and available space on the PCB design, the sensing coil can take on a number of shapes. Circular coils generate a symmetric EM field that allows for uniform sensitivity.

Arc-shaped coils are useful in applications that require sensing of a rotating target. The arc shape allows for the placement of multiple close proximity coils in a circular pattern. This is useful in applications where space is limited and multiple sensors are required. The geometrical dimensions of the shape allow for a larger inductance value compared to a circular coil in the same space.
Rectangular shaped coils allow for an increased sensing area along the coil length while restricting the sensing region along the coil width. These coils are commonly used in applications that require the sensing of lateral movement along a given axis.

Calculating the coil inductance

There are a number of free online calculators that can be used to approximate the inductance of a given PCB coil, see Link1 or Link2. These calculators are capable of approximating the inductance values of standard planer coil shapes such as square, circular, hexagonal, and octagonal.

Selecting LC tank capacitor

The choice of $C$ depends on the excitation frequency $f_{tx}$ at the CTx pin and the calculated/measured $L$ value. To ensure the appropriate response, the $C$ value is chosen such that the LC tank resonant frequency $f_{res}$, given in (9), is greater than or equal to $f_{tx}$. Meeting this condition ensures that the reduction in $L$ as a metal target is brought in proximity to the sensor coil corresponds only to a decrease in $V_L$. 
Considering a coil sensor with inductance value \( L = 1.583 \mu \text{H} \) and excitation frequency \( f_{tx} = 4 \text{ MHz} \). From (9), selecting \( C = 1 \text{nF} \) gives a tank resonant frequency of \( f_{res} = 4 \text{ MHz} \). Thus the LC tank resonant frequency is correctly tuned to the excitation frequency \( (f_{res} = f_{tx}) \).

However, due to tolerances in the capacitor values, a slightly smaller \( C \) value should be selected to ensure the appropriate response condition as mentioned earlier, i.e. select \( C = 820 \text{pF} \) gives \( f_{res} = 4.4 \text{ MHz} \).

**Excitation frequency**

Each of the devices have selectable predefined \( f_{tx} \) frequencies that can be sourced on the the CTx pin as given in Table 4.

<table>
<thead>
<tr>
<th>Device</th>
<th>Selectable frequency ( (f_{tx}) )</th>
</tr>
</thead>
<tbody>
<tr>
<td>IQS269A</td>
<td>16 MHz, 8 MHz, 4 MHz</td>
</tr>
<tr>
<td></td>
<td>2 MHz, 1 MHz, 500kHz</td>
</tr>
<tr>
<td>IQS620A</td>
<td>16 MHz, 4 MHz</td>
</tr>
<tr>
<td>IQS621</td>
<td>16 MHz, 8 MHz</td>
</tr>
<tr>
<td>IQS624</td>
<td>16 MHz, 8 MHz</td>
</tr>
<tr>
<td>IQS680</td>
<td>8 MHz</td>
</tr>
</tbody>
</table>

As a general rule of thumb, using a higher \( f_{tx} \) improves sensitivity especially in applications that require detection of up to a few millimetres. At higher frequencies the induced eddy currents tend to get concentrated on the metal target surface due to skin effect. This increases the strength of the induced eddy currents at the target surface and thus increases the change in inductance.

**Temperature effects**

Changes in ambient temperature affect the channel counts for a given sensing channel. In inductive sensing mode, an increase in temperature causes an increase in channel counts and vice versa. The channel count response against temperature for a specific temperature range can be approximated by a linear response. For applications that require knowledge of the state of the sensor on start-up, the temperature variations may result in false channel triggering. The temperature UI in specific devices, (see Table 3), can be used as feedback for mitigation against temperature variations on start-up.

Further mitigation against temperature variations can be achieved by using COG capacitors for the LC tank circuit. As a general rule, smaller LC tank capacitors provide less temperature variations. To get smaller tank capacitor values, design for higher frequencies or larger inductance values.

**Inductive sensing applications**

Inductive sensing offers a great deal of versatility over a wide range of applications. Some of these applications include, but are not limited to:
Rotary position encoder

![Image of rotary position encoder](image)

*Figure 15: Rotary position encoder*

Rotary speed sensor

![Image of rotary speed sensor](image)

*Figure 16: Rotary speed sensor*
Linear slider

Figure 17: Linear slider

References


## Contact Information

<table>
<thead>
<tr>
<th>Physical Address</th>
<th>USA</th>
<th>Asia</th>
<th>South Africa</th>
</tr>
</thead>
<tbody>
<tr>
<td>6507 Jester Blvd</td>
<td>6507 Jester Blvd</td>
<td>Rm1227, Glittery City</td>
<td>1 Bergsig Avenue</td>
</tr>
<tr>
<td>Bldg 5, suite 510G</td>
<td>Bldg 5, suite 510G</td>
<td>Shennan Rd</td>
<td>Paarl</td>
</tr>
<tr>
<td>Austin</td>
<td>Austin</td>
<td>Futian District</td>
<td>7646</td>
</tr>
<tr>
<td>TX 78750</td>
<td>TX 78750</td>
<td>Shenzhen, 518033</td>
<td>South Africa</td>
</tr>
<tr>
<td>USA</td>
<td>USA</td>
<td>China</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Postal Address</th>
<th>USA</th>
<th>Asia</th>
<th>South Africa</th>
</tr>
</thead>
<tbody>
<tr>
<td>6507 Jester Blvd</td>
<td>6507 Jester Blvd</td>
<td>Rm1227, Glittery City</td>
<td>1 Bergsig Avenue</td>
</tr>
<tr>
<td>Bldg 5, suite 510G</td>
<td>Bldg 5, suite 510G</td>
<td>Shennan Rd</td>
<td>Paarl</td>
</tr>
<tr>
<td>Austin</td>
<td>Austin</td>
<td>Futian District</td>
<td>7620</td>
</tr>
<tr>
<td>TX 78750</td>
<td>TX 78750</td>
<td>Shenzhen, 518033</td>
<td>South Africa</td>
</tr>
<tr>
<td>USA</td>
<td>USA</td>
<td>China</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Tel</th>
<th>USA</th>
<th>Asia</th>
<th>South Africa</th>
</tr>
</thead>
<tbody>
<tr>
<td>+1 512 538 1995</td>
<td>+86 755 8303 5294 ext 808</td>
<td>+27 21 863 0033</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Fax</th>
<th>USA</th>
<th>Asia</th>
<th>South Africa</th>
</tr>
</thead>
<tbody>
<tr>
<td>+1 512 672 8442</td>
<td></td>
<td>+27 21 863 1512</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Email</th>
<th>USA</th>
<th>Asia</th>
<th>South Africa</th>
</tr>
</thead>
<tbody>
<tr>
<td><a href="mailto:info@azoteq.com">info@azoteq.com</a></td>
<td><a href="mailto:info@azoteq.com">info@azoteq.com</a></td>
<td><a href="mailto:info@azoteq.com">info@azoteq.com</a></td>
<td></td>
</tr>
</tbody>
</table>

Visit [www.azoteq.com](http://www.azoteq.com) for a list of distributors and worldwide representation.


AirButton®, Azoteq®, Crystal Driver®, IQ Switch®, ProxSense®, ProxFusion®, LightSense™, SwipeSwitch™, and the ® logo are trademarks of Azoteq.

The information in this Datasheet is believed to be accurate at the time of publication. Azoteq uses reasonable effort to maintain the information up-to-date and accurate, but does not warrant the accuracy, completeness or reliability of the information contained herein. All content and information are provided on an “as is” basis only, without any representations or warranties, express or implied, of any kind, including representations about the suitability of these products or information for any purpose. Azoteq disclaims all warranties and conditions with regard to these products and information, including but not limited to all implied warranties and conditions of merchantability, fitness for a particular purpose, title and non-infringement of any third party intellectual property rights. Azoteq assumes no liability for any damages or injury arising from any use of the information or the product or caused by, without limitation, failure of performance, error, omission, interruption, defect, delay in operation or transmission, even if Azoteq has been advised of the possibility of such damages. The applications mentioned herein are used solely for the purpose of illustration and Azoteq makes no warranty or representation that such applications will be suitable without further modification, nor recommends the use of its products for application that may present a risk to human life due to malfunction or otherwise. Azoteq products are not authorized for use as critical components in life support devices or systems. No licenses to patents are granted, implicitly, express or implied, by estoppel or otherwise, under any intellectual property rights. In the event that any of the above-mentioned limitations or exclusions does not apply, it is agreed that Azoteq’s total liability for all losses, damages and causes of action (in contract, tort (including without limitation, negligence) or otherwise) will not exceed the amount already paid by the customer for the products. Azoteq reserves the right to alter its products, to make corrections, deletions, modifications, enhancements, improvements and other changes to the content and information, its products, programs and services at any time or to move or discontinue any contents, products, programs or services without prior notification. For the most up-to-date information and binding Terms and Conditions please refer to [www.azoteq.com](http://www.azoteq.com).


info@azoteq.com