Method to Select the Value of LC Sensor for MSP430™ Extended Scan Interface (ESI)

Thomas Kot

ABSTRACT

This document describes a method that can be used to select an LC sensor for use with the MSP430™ Extended Scan Interface (ESI).

1 LC Sensor Selection

For a sampling rate of $F_s$ and an excitation time of $\Delta t$, the average current consumption of LC sensor is as follows:

For a capacitor, $C = Q/V$, which gives the average current $I = F_s \times Q = F_s \times CV$

For an inductor, $V = L \times \Delta I / \Delta t$, which gives the average current $I = F_s \times (\Delta I \times \Delta t / 2) = F_s \times (V \times \Delta t^2 / 2L)$

Total average current $= F_s \times (C + \Delta t^2 / 2L)$

Total average power $= V \times$ average current $= F_s \times V^2 \times (C + \Delta t^2 / 2L)$

The copper resistance of the inductor consumes some power. However, it is negligibly small, as the current is in the range of microamps. The power of the resistor is $I^2R$, which is very small.

Figure 1 shows the current consumption of an LC sensor with a sampling rate of 500 Hz, excitation time of 1 µs, and a $V$ of $V_{CC}/2$ (1.5 V).

Figure 1. Current Consumption of LC Sensor

From Figure 1, the current consumed becomes smaller when both the inductor value and the capacitor are smaller. Compared to the ESI standby current of a few microamps, the LC current consumption should be selected to be within 1 µA.

As the inductor value increases, the copper resistance also increases. A higher resistance leads to a fast damping of LC oscillation signal. Therefore, a smaller copper resistance is preferred.

MSP430 is a trademark of Texas Instruments.
All other trademarks are the property of their respective owners.
The physical size of the capacitor is small. However, the inductor is much bigger. This is one of the limitations when choosing an inductor of higher value. The casing for the sensor might not provide enough space for two or three sensors.

In addition, the detection distance is related to the area of the metal portion of a rotor plate covered with the magnetic field generated from the inductor and the concentration of magnetic field. If the rotor plate is too small or the physical size of the inductor is too large, the effective covering area can be reduced, which reduces the magnetic energy absorption rate of inductor through the eddy current on the metal portion of the rotor plate.

**Figure 2. LC Oscillation Signals And Latch-In Timing**

From Figure 2, the lower range of LC signal is used to determine the metal and non-metal portions of the rotor plate. The optimal timing to latch in the comparator output is at the time between the two lower peaks. The internal oscillator of the ESI can be used to tune the timing to reach this position.

However, there is a drift of the internal oscillator by 0.35%/°C and by 2%/V. A drifting margin should be provided to avoid too many recalibrations of the oscillator. If setting the margin to be ± 0.5 µs and to set the latch in timing when the LC signal is above its mid-level, the minimum period of the LC signal should be larger than 2 µs (500 kHz).

**Figure 3** shows the oscillation frequency of an LC sensor. The data near 500 kHz are marked in gray for easy reading. In combination with Figure 1, the number of values for the inductor and capacitor are limited to a the area highlighted in light blue in Figure 3.
An additional precaution to the selection of inductor and capacitor is to consider the variation of LC oscillation frequency due to temperature change and aging.

For LC signal period \( T = 2\pi \times \sqrt{LC} \)

Then, \( \frac{\Delta T}{\Delta L} = \frac{T}{2L} \)

Which implies, \( \frac{\Delta T}{T} = \frac{\Delta L}{2L} \)

Similarly, \( \frac{\Delta T}{T} = \frac{\Delta C}{2C} \)

A 10% change in either \( L \) or \( C \) leads to a 5% change for the time period of the LC signal.

By experiment, using 220 pF and 470 µH on the sensor board, a total of 1 µs is increased for a 40 periods of signal when the temperature is increased above 80°C.
**IMPORTANT NOTICE**

Texas Instruments Incorporated and its subsidiaries (TI) reserve the right to make corrections, enhancements, improvements and other changes to its semiconductor products and services per JESD46, latest issue, and to discontinue any product or service per JESD48, latest issue. Buyers should obtain the latest relevant information before placing orders and should verify that such information is current and complete. All semiconductor products (also referred to herein as “components”) are sold subject to TI’s terms and conditions of sale supplied at the time of order acknowledgment.

TI warrants performance of its components to the specifications applicable at the time of sale, in accordance with the warranty in TI’s terms and conditions of sale of semiconductor products. Testing and other quality control techniques are used to the extent TI deems necessary to support this warranty. Except where mandated by applicable law, testing of all parameters of each component is not necessarily performed.

TI assumes no liability for applications assistance or the design of Buyers’ products. Buyers are responsible for their products and applications using TI components. To minimize the risks associated with Buyers’ products and applications, Buyers should provide adequate design and operating safeguards.

TI does not warrant or represent that any license, either express or implied, is granted under any patent right, copyright, mask work right, or other intellectual property right relating to any combination, machine, or process in which TI components or services are used. Information published by TI regarding third-party products or services does not constitute a license to use such products or services or a warranty or endorsement thereof. Use of such information may require a license from a third party under the patents or other intellectual property of the third party, or a license from TI under the patents or other intellectual property of TI.

Reproduction of significant portions of TI information in TI data books or data sheets is permissible only if reproduction is without alteration and is accompanied by all associated warranties, conditions, limitations, and notices. TI is not responsible or liable for such altered documentation. Information of third parties may be subject to additional restrictions.

Resale of TI components or services with statements different from or beyond the parameters stated by TI for that component or service voids all express and any implied warranties for the associated TI component or service and is an unfair and deceptive business practice. TI is not responsible or liable for any such statements.

Buyer acknowledges and agrees that it is solely responsible for compliance with all legal, regulatory and safety-related requirements concerning its products, and any use of TI components in its applications, notwithstanding any applications-related information or support that may be provided by TI. Buyer represents and agrees that it has all the necessary expertise to create and implement safeguards which anticipate dangerous consequences of failures, monitor failures and their consequences, lessen the likelihood of failures that might cause harm and take appropriate remedial actions. Buyer will fully indemnify TI and its representatives against any damages arising out of the use of any TI components in safety-critical applications.

In some cases, TI components may be promoted specifically to facilitate safety-related applications. With such components, TI’s goal is to help enable customers to design and create their own end-product solutions that meet applicable functional safety standards and requirements. Nonetheless, such components are subject to these terms.

No TI components are authorized for use in FDA Class III (or similar life-critical medical equipment) unless authorized officers of the parties have executed a special agreement specifically governing such use.

Only those TI components which TI has specifically designated as military grade or “enhanced plastic” are designed and intended for use in military/aerospace applications or environments. Buyer acknowledges and agrees that any military or aerospace use of TI components which have not been so designated is solely at the Buyer’s risk, and that Buyer is solely responsible for compliance with all legal and regulatory requirements in connection with such use.

TI has specifically designated certain components as meeting ISO/TS16949 requirements, mainly for automotive use. In any case of use of non-designated products, TI will not be responsible for any failure to meet ISO/TS16949.

### Products

<table>
<thead>
<tr>
<th>Audio</th>
<th>Amplifiers</th>
<th>Data Converters</th>
<th>DLP® Products</th>
<th>DSP</th>
<th>Clocks and Timers</th>
<th>Interface</th>
<th>Logic</th>
<th>Power Mgmt</th>
<th>Microcontrollers</th>
<th>RFID</th>
<th>OMAP Applications Processors</th>
<th>Wireless Connectivity</th>
</tr>
</thead>
</table>

### Applications

- Automotive and Transportation: [www.ti.com/automotive](http://www.ti.com/automotive)
- Communications and Telecom: [www.ti.com/communications](http://www.ti.com/communications)
- Energy and Lighting: [www.ti.com/energy](http://www.ti.com/energy)
- Industrial: [www.ti.com/industrial](http://www.ti.com/industrial)
- Medical: [www.ti.com/medical](http://www.ti.com/medical)
- Video and Imaging: [www.ti.com/video](http://www.ti.com/video)
- E2E Community: [e2e.ti.com](http://e2e.ti.com)

Mailing Address: Texas Instruments, Post Office Box 655303, Dallas, Texas 75265
Copyright © 2014, Texas Instruments Incorporated