EMI Considerations for Inductive Sensing

Rachel Liao, Luke LaPointe

ABSTRACT

This application note explains various EMI reduction techniques to help improve EMI performance for TI's Inductance-to-Digital Converters (LDC). Each section details a general technique with references to other useful online documents. A list of relevant EMI reduction techniques is provided for specific devices within the LDC family of products.

Contents

List of Figures

List of Tables

1 Introduction

When an electronic system or device resides in a harsh and noisy environment, electromagnetic interference (EMI) can occur, disrupting system level functions or causing a product to fail electromagnetic compatibility (EMC) testing. EMI is essentially any unwanted radiated or conducted electrical signals that negatively affect a system or device's performance. Due to the increasing number of radiating wireless devices, it is vital to ensure EMC and adhere to its standards. Each application may have different compliance standards, for example, safety critical system automotive applications have more stringent standards than personal electronics.

TI's inductive sensing products are based on a narrowband resonant sensing architecture which provides inherent immunity to broadband noise and targeted frequency ranges that fall outside of the resonant frequency range. These devices also include internal EMI and deglitch filters to prevent high frequency signals from disrupting the circuitry after the sensors which increases robustness against EMI susceptibility. As part of normal operation, the LDC devices drive an inductive sensor that intentionally radiates a magnetic field to sense nearby conductive objects. Therefore, it is important to be aware of the radiated output spectrum which could disrupt nearby circuits that are sensitive to EMI. For more discussion on the basics of inductive sensing, please refer to the TI Application Note *LDC Device Selection Guide*.

There are a number of factors which affect the strength of the EMI radiated emissions from the LDC. At high frequencies, the PCB traces, wires to remote coils, and the coil itself can serve as antennas that generate far-field RF radiation or receive RF interference from the ambient environment. At low frequencies, long wires to the supply are typically sources of radiation. Different mitigation techniques for each LDC device are outlined below in Table 1 and a more detailed discussion can be found within each section below.

Table 1. Suitable EMI Reduction Techniques

Device	Shielding	Passive Filters	Supply/Return Routing
LDC1101	X	X	X
LDC1312 LDC1314	X	X	X
LDC1612 LDC1614	X	X	X
LDC0851	X		X
LDC2112 LDC2114	X	X	X

2 Design Techniques

2.1 Shielding

Shielding represents an approach to prevent unwanted signals from leaving or entering critical or sensitive areas of the system. Any time there is a moving charge, there will be a generated magnetic field (B-field) and orthogonal electric field (E-field). If unmanaged, these fundamental fields can be the source of potential EMI problems, each with their own coupling mechanisms to victim circuits. For this reason, the orientation of the attacker and/or victim has a significant effect on the magnitude of the interference. The magnetic field is created by current flow in closed loops and sensitive to large di/dt changes that can couple to other loops. The electric field is created by large voltage transients on high impedance lines that can radiate or couple to other high impedance lines which act like antennas to the incoming signal. For inductive sensing products, a magnetic field is emitted by the inductive sensor to sense nearby conductive materials. Therefore, the goal of shielding for the LDC products is to minimize the electric field coupling by reducing the number of high-impedance nodes while still allowing the magnetic field to sense the desired conductive targets.

2.1.1 Trace Shielding

For optimal EMI performance, signal traces should be routed on the middle layers of the PCB with a ground shield (or COM for the LDC211x) above and below. This effectively creates a low impedance shield above and below the traces which helps protect against incoming and outgoing electric fields. If the application requires the sensors to be connected remotely by an external cable, then the cables should be short, shielded, and in a twisted pair whenever possible.

2.1.2 Coil Shielding

For large sensors or sensors that are directly exposed to large voltage transients such as ESD, it can also be helpful to shield the sensor coil from picking up strong E-field emissions nearby. A solid ground plane should not be used directly over the sensor because this would block the B-field, preventing the LDC from sensing intended targets. Instead, the ground shield should have cut-outs to prevent eddy currents from forming on the surface. Figure 1 and Figure 2 show some examples. A coil shield with orthogonal lines to the sensor traces is recommended as it minimizes the parasitic capacitance to the sensor coils underneath.

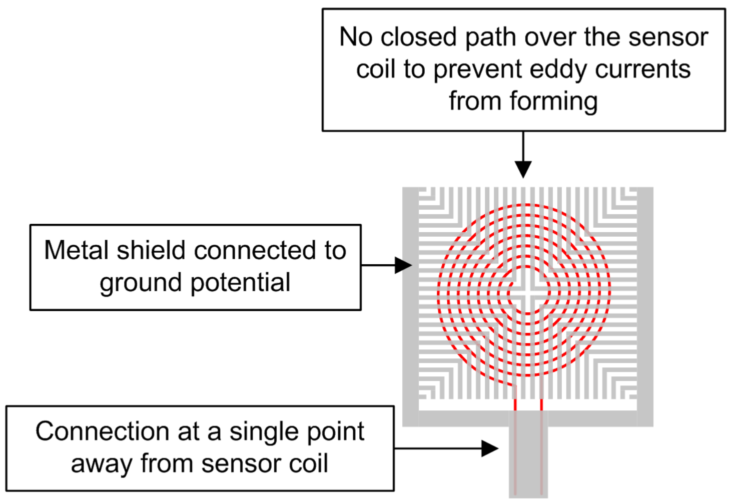

Figure 1. Layout of Effective Coil Shielding

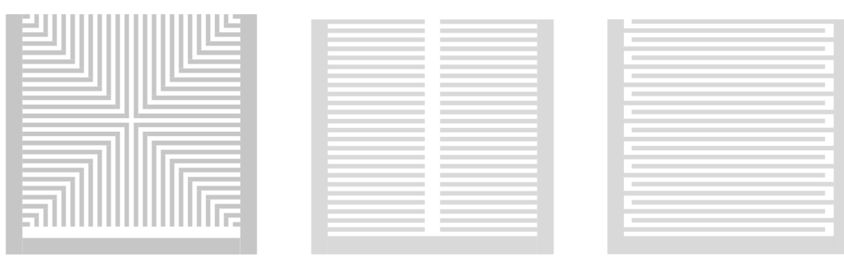

Figure 2. Examples of Effective Coil Shielding Structures

2.1.3 Ground Plane

In addition to shielding the sensors and the routing, adding a solid un-cut ground plane beneath all the components can be one of the biggest factors for improving emissions up to 40 dB [(1)]. See Section 2.3 of the TI Application Note *High-Speed Layout Guidelines* for more discussion.

(1) R. F. German, H. W. Ott and C. R. Paul, "Effect of an image plane on printed circuit board radiation," IEEE International Symposium on Electromagnetic Compatibility, Washington, DC, 1990, pp. 284-291. doi: 10.1109/ISEMC.1990.252775

2.2 Passive Filters

2.2.1 Common-Mode Chokes

There are two significant types of signals that need to be considered when looking at EMI effects. First, there are differential-mode signals. These are signals that appear on the two lines of a closed loop, equal in magnitude and opposite in direction. Differential-mode signals can be conceptualized as the desired signal and it's return path. Long traces or poor supply bypassing often causes differential-mode signals to radiate. Secondly, there are common-mode signals which appear on the two lines of a closed loop but are unequal in magnitude resulting in a net current flow in one direction. Common-mode radiation is one of typical sources of EMI issues, especially with signals that have a large di/dt or dv/dt component. Sources of common-mode signals include return paths that have a shared or common impedance with noisy signals or unintentional coupling to a reference ground or metal chassis through stray capacitance. Good layout can resolve many of these issues, however, shunting the noise at the source or adding a common-mode filter at the source can also provide a significant reduction in EMI if additional suppression is needed. Many commercially available common mode filters exist and can be quite useful in debugging or fixing issues which are identified late in the product development process. A good practice is to integrate the common-mode filter on the PCB itself through the use of a common-mode choke or simple L and C filtering as seen in Figure 3 below. A common-mode choke produces a high-impedance node which prevents any common-mode signals from coupling into the system. In order to effectively use a common-mode choke, the chokes are placed as close to the device under test as possible. This way, any common-mode signals traveling through the device will have a short path, minimizing the possibility of any radiation before being filtered out by the chokes.

2.2.2 Shunt Capacitors

For even further EMI filtering, shunt capacitors can be placed near the device in conjunction with the common-mode chokes. Footprints for these are already implemented on the LDC131x/161x EVMs as seen in Figure 3. These capacitors should be much smaller than the sensor capacitor itself to prevent a loss in sensitivity. The latest LDC devices such as the LDC2114 and LDC2112 have a dedicated COM plane which can incorporate much larger shunt capacitors near the device to more effectively mitigate EMI. Please also refer to Section 3.3.4 EMI Emissions Testing of the TI Application Note *Inductive Sensing Touch-On-Metal Buttons Design Guide* for more discussion on the use of passive filtering for emissions.

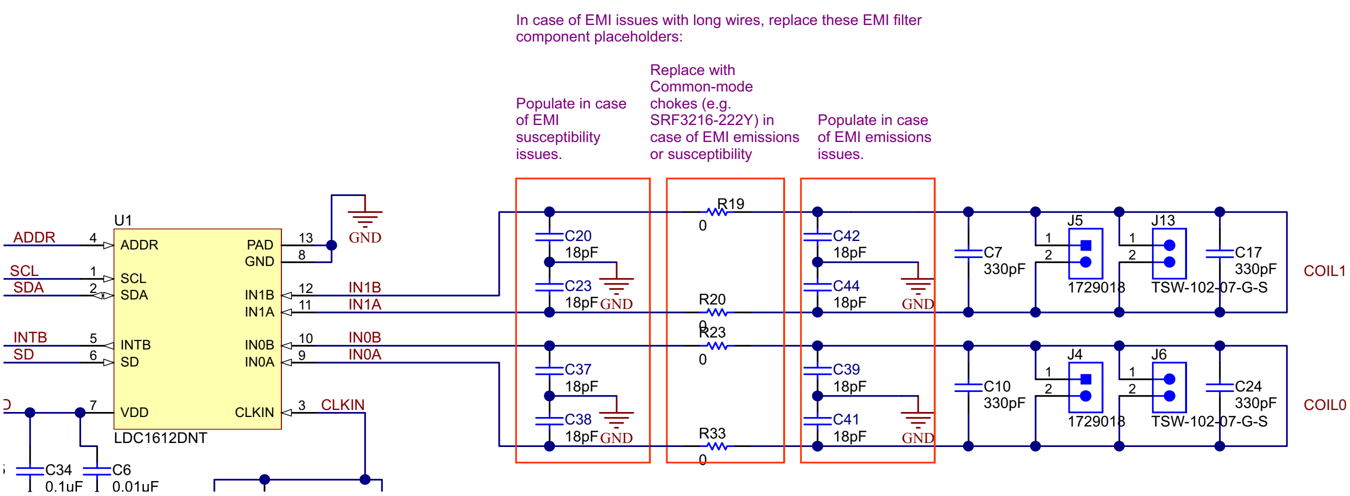

Figure 3. Common-Mode Choke and Capacitor Filtering Network on the LDC EVMs

2.3 Supply/Return Routing

For optimal EMI performance, it is crucial to have a stable and clean power supply and low impedance return routing. For more in-depth discussions on these subjects, please see the references below.

2.3.1 Rise-Time and Fall-Time Considerations

Fast rise and fall times on critical signals can translate directly to EMI problems even if the failing frequencies are outside the expected operating range. See Section 1.2 of the TI Application Note *High-Speed Layout Guidelines*.

2.3.2 Appropriate Bypass Capacitor Selection

Bypass capacitors play a critical role in ensuring stable device operation. Proper selection of the values and location, based on the supply characteristics and device requirements, can greatly improve system performance. Incorrect selections may create unexpected resonances in impedance making the supply lines more susceptible to EMI at those frequencies. See Section 2.4 of the TI Application Note *High-Speed Layout Guidelines*.

2.3.3 Routing Considerations

Long traces can be thought of as antennas which can be sources of radiation and susceptibility depending on its length and excitation signal. The previous generation of LDC devices expects the PCB sensor coil to be placed close to the device, thus limiting the length of the traces. For guidance on the maximum recommended length for trace routing, please refer to the Remote Coil Length tab of the *LDC Calculator Tool*. The latest LDC devices (LDC211x) are designed to incorporate the long traces as part of the sensor and can be represented as transmission lines in series with the PCB coil. This allows the sensor tank capacitor to be placed near the device which provides extra EMI filtering towards any unwanted signals that may have coupled onto the traces after the PCB sensor coil.

For high frequency signals, the lowest impedance return path is directly underneath the forward going signal trace. Therefore, it is important to have a solid return path underneath the trace by minimizing cuts and splits in the ground plane which otherwise forces the return current to flow around the cutout, forming a loop. If unmanaged, additional loops may overlap potentially disrupting sensitive circuits. See Section 2.3 of the *High-Speed Layout Guidelines* application report.

3 Troubleshooting

During EMC testing, it can be important to debug problems in real time. If the PCB fails a radiated EMI test, there are a couple of tips to determine its root cause. For example, if the failure occurs around 300 MHz or less, it is likely that the issue is coming from long external cabling since this frequency has an effective wavelength of 1 m or more. These problems can be mitigated by adding ferrite beads to the cabling and retesting. On the other hand, if the failure occurs at a frequency greater than 300 MHz, it is likely that the issue is coming from the PCB itself either due to issues in routing, shielding, or bypassing. If this is the case, then a board spin with the techniques outlined above may be required.

4 Conclusion

EMI is often a crucial but neglected topic for robust system performance. However, using the techniques discussed above, good EMI performance can be achieved.

5 References

R. F. German, H. W. Ott and C. R. Paul, "Effect of an image plane on printed circuit board radiation," IEEE International Symposium on Electromagnetic Compatibility, Washington, DC, 1990, pp. 284-291. doi: 10.1109/ISEMC.1990.252775

A. Weiler and A. Pakosta, "High-Speed Layout Guidelines", Clock Drivers, Texas Instruments Application Report. SCAA082, November 2006.

C. Oberhauser, "LDC Device Selection Guide", Texas Instruments Application Report. SNOA954A, January 2017.

B. Kasemsadeh and L. LaPointe, "Inductive Sensing Touch-On-Metal Buttons Design Guide", Texas Instruments Application Report. SNOA951, June 2016.

Mailing Address: Texas Instruments, Post Office Box 655303, Dallas, Texas 75265