Application Note: AZD015b

Radiated – Immunity: Quick Guide

(Please refer to AZD015 for the complete Application Note)

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1 Relevant International Standard

- **IEC 61000-4-3**.
- Continuous sweep **26MHz to 1GHz** (**80MHz** often used as starting point), and fields levels of 1V/m, **3V/m, 10V/m**, or 30V/m respectively. Also covers **1.4GHz to 6GHz** band, but not a continuous sweep, only requires immunity at frequencies used by digital radio telephones and other such intentional transmitters.
- Field must be **AM-modulated at 80% depth, 1kHz modulation frequency**.

!! IEC61000-4-3 only applies to commercial products, not to Medical, Maritime, Avionics, Machinery and Automotive products where malfunction/failure due to RF could result in loss of life or large scale financial loss. Stringent international / local standards cover such applications.

2 Low cost in-house test methods

- Cellular telephones. These typically emit up to 2W of RF-power. Close field can be > 30V/m.

- WiFi routers - 2.45GHz.
- Zigbee or BlueTooth transceivers - 2.45GHz band. Higher power Zigbee - 100mW.
- ISM band transmitters – typically emit in the mW range, useful for 370Mhz and 433MHz.
- Two way radios - typically emit a few Watt of RF-power
- Transmitters should be placed in many positions relative to product. Includes height variation and change in product orientation.
- E-field and H-field probes to inject fields into specific sections of the circuit under test.
- Small TEM cells, which can be manufactured from PCB material in a DIY manner.

!! In all the above, care must be taken not to exceed local legal limits for RF-radiation. Severe consequences, some fatal, can result if limits are exceeded. If unsure, consult an EMC specialist.

3 A margin to ensure conformance

- Do not test just to pass, or just below 1GHz. Check above 1GHz at cellular phone / WiFi / WiMax frequencies. We recommend testing up to 30V/m and 6GHz where possible.

4 Decoupling Capacitors

- Make sure decoupling capacitors cover the required frequency band.
- We recommend using 10pF, 100pF, 1nF, 100nF and 1μF.
- For cost and space constrained designs, a combination of 100pF and 1μF may be ok.

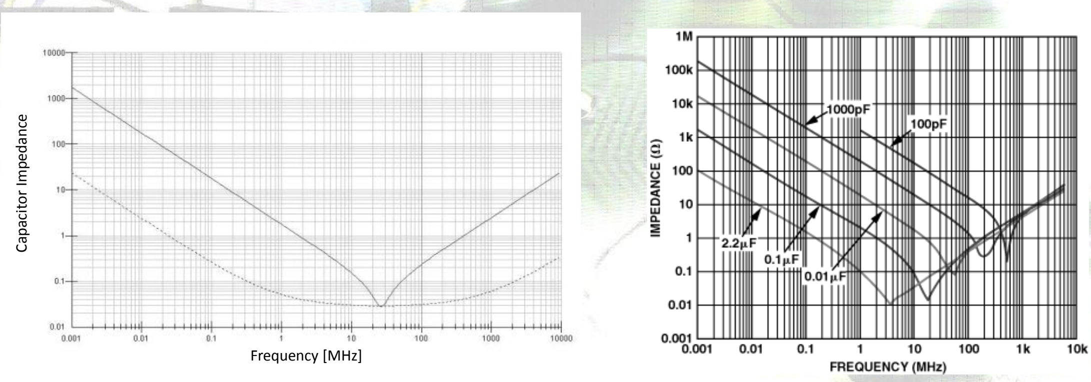

Figure 1: Typical impedance vs. frequency for a surface mount 100nF, 0402 size ceramic capacitor (left), and decrease in decoupling band as ceramic C size decreases (right)

5 RC and LC-filters

- Consider use of classical RC low-pass filter – low cost, small space. Cut-off frequency f_c is inversely proportional to capacitor and resistor value.
- Recommend using values of 5Ω and 100nF, should result in f_c of around 300kHz.
- If sharper roll-off required, cascade more than one stage of single stage RC filter.

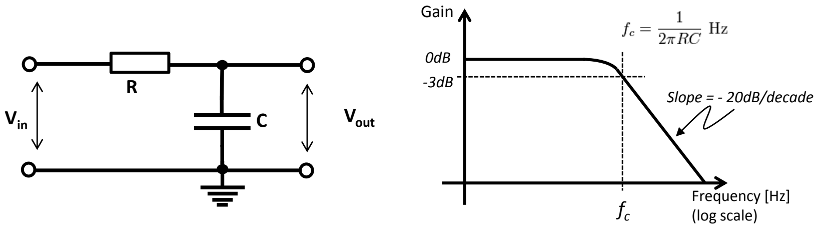

Figure 2: Classical single stage RC low-pass filter as alternative to using only capacitor decoupling

- Also consider classical single stage LC low pass filter for sharper roll-off. Caution: LC filters are resonant circuits – insert a small resistor (few Ω) in series with L to avoid high V around f_c.

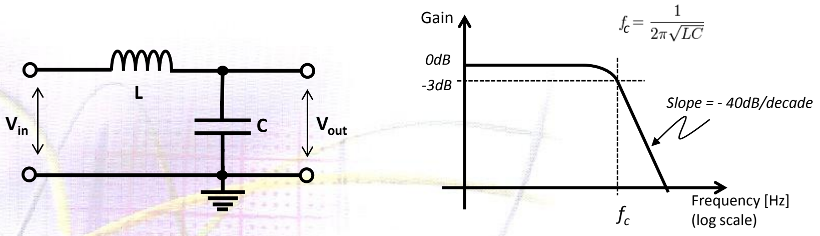

Figure 3: Classical single stage, second order LC low-pass filter

6 Unused / Do Not Place (DNP) Components

- Care should be taken with DNP's for Radiated Immunity. Unused lines can be RF-antennas
- Use solder-links or 0Ω resistors to disconnect unused lines associated with DNP components. Links or 0Ω resistors must be placed as far away as possible from the DNP, or on both ends.

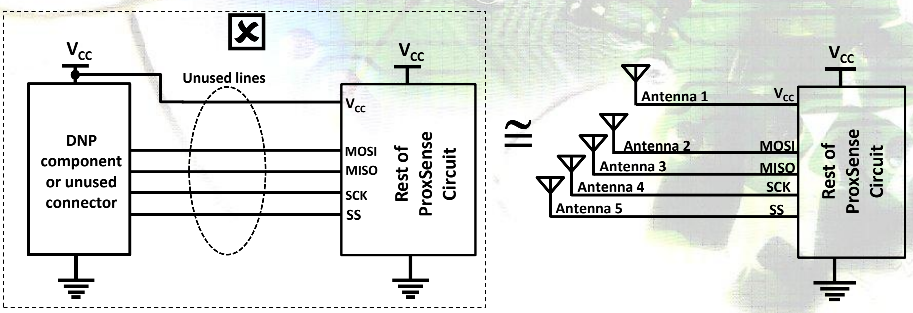

Figure 4: Unused lines towards DNP components or unused connectors may create RF-antennas

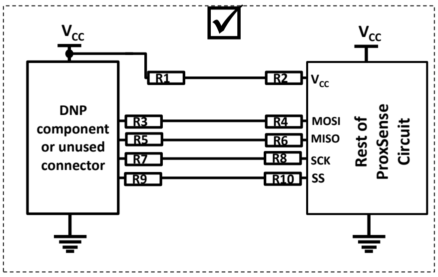

Figure 5: Using 0Ω resistors or solder links to decouple unused lines, to avoid RF-antenna creation

7 Grounding & stitching

- Radio frequency currents avoid inductances and seek capacitances. We must provide low impedance path (small L) for currents that are shunted to ground and returning to source.
- No use to use decoupling C if high L present in return path. Current will seek an alternative.
- Consider Figure 6. Decoupling C placed right at the ProxSense IC, but return path towards the source have high L. RF-currents not shunted by C, but flow through IC via low L path.

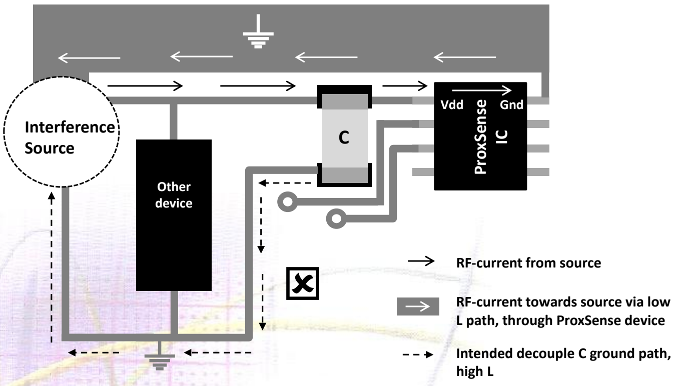

Figure 6: Example to illustrate importance of low L ground

- ➢ Thin GND track = BAD
- ➢ Wide GND track = BETTER
- ➢ GND plane with slots for other lines, and GND sections connected = BETTER
- ➢ Solid GND plane only interrupted by via's = GOOD
- ➢ Solid GND plane only interrupted by via's, "stitched" to GND opposite = BEST

- Overlapping sections of ground on different layers should be "stitched" together with via's.
- For ProxSense IC's which have an ICTRL pin, such as the IQS316, care must be taken with the grounding of the resistor connected to this pin. Ensure a good ground is available.
- **GND should not be close/underneath Cx lines/plates, will reduce touch sensitivity.**

8 Loops & following the current path

- Track forming a loop or a semi-loop will couple RF-energy into the ProxSense circuit. Thus loops should be avoided as far as possible.
- Check for loops on the supply rails. A good method to identify loops is to "follow the current".

9 Tracks as receiving E-field antennas

- Check for tracks ending in series L, but connect to rest of the circuit at other end. Series L decouples RF, thus un-terminated track connected to rest of the circuit – could be antenna.
- Tracks to Cx plates used for proximity / touch sensing may form good RF-antennas. Inserting discrete L into Cx line will reduce RF picked up, but will also reduce touch sensitivity.

- Keep tracks to Cx plates as short as possible. Also make tracks to Cx plates as thin as possible (Maximise distributed L_{Track})
- If discrete inductances are used in severe cases, do not exceed 100µH.

10 Decoupling C placement

- Badly placed decoupling C can result in no decoupling of interference. Always provide decoupling C with minimum L on its feeding and return paths to source.
- Place decouple C very close to ProxSense device. If decoupling C is far away, radiated interference will couple into long tracks. Lowest value C must be closest to the V_{dd} /V_{ddhi} pin.
- If interference is present on IC internal silicon, decouple C that is too far away (large L) will result in interference currents not being shunted via C to ground. Especially true for V_{dd} pin.

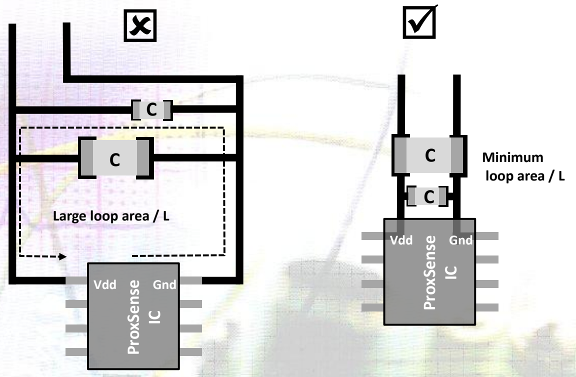

Figure 7: Ensure minimum inductance path between decouple cap and IC

11 Digital communication lines: lengths and routing

- Digital communication lines (SPI & I^2C) are especially susceptible to radiated interference.
- Keep as short as possible and avoid routing communication lines in areas without a protective GND plane. If possible, place GND plane on both sides of communication lines (4 layer PCB).
- If pull-up resistors, RC-filters or LC-filters are used on communication lines, their placement should be carefully considered. Make sure it is on the correct end of line, or both.

12 IQSxxx RF-Detection: Last resort

- Azoteq ProxSense devices can detect too high RF-radiation, and halt logic to avoid false touches or proximity detection.
- We advise to use RF-Detection as a last resort, as it disables touch functionality. Only use once all the guidelines presented here, as well as other, have failed to help.

13 How IQSxxx RF – Detection works

- Correct antenna must to be connected to the RF-pin of the ProxSense device. Place a 51Ω resistor between the RF-pin and GND. A DC-blocking capacitor not necessary.

- If enough radiation at antenna frequency is present, energy into the RF-pin trips an internal comparator, which results in touch and proximity measurements ignored for a fixed period.
- Detection distance is dependent on antenna connected to the RF-pin, the RF-source (frequency and power), environment and ProxSense device settings.

14 Choosing an antenna for RF- Detection

- Not practical to use one RF-detection antenna over whole 80MHz to 6GHz band. (Antennas below 300MHz are fairly large). Omni-directional antennas are also not practical.
- We advise to identify the lowest main threat frequency in area where product will be sold, and to use a ¼ wave monopole antenna on PCB, length one quarter of effective wavelength λ_{eff}.
- Antenna must be 90° to substantial GND plane on the board (at least $\lambda_{eff}/4$ from RF-pin on each side). Areas alongside and below antenna should be copper free, for at least $\lambda_{eff}/4$.

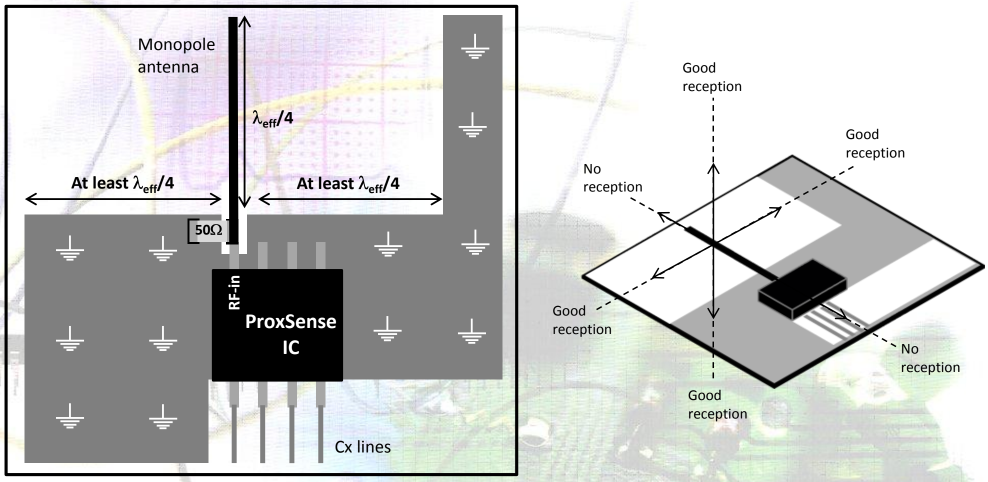

Figure 8: Using a simple ¼ wave PCB monopole to detect RF at the main threat frequency.

- If not enough space for antenna at 90° to GND plane, it can be bent parallel to GND plane, but should not be closer to the plane than $\lambda_{eff}/8$.

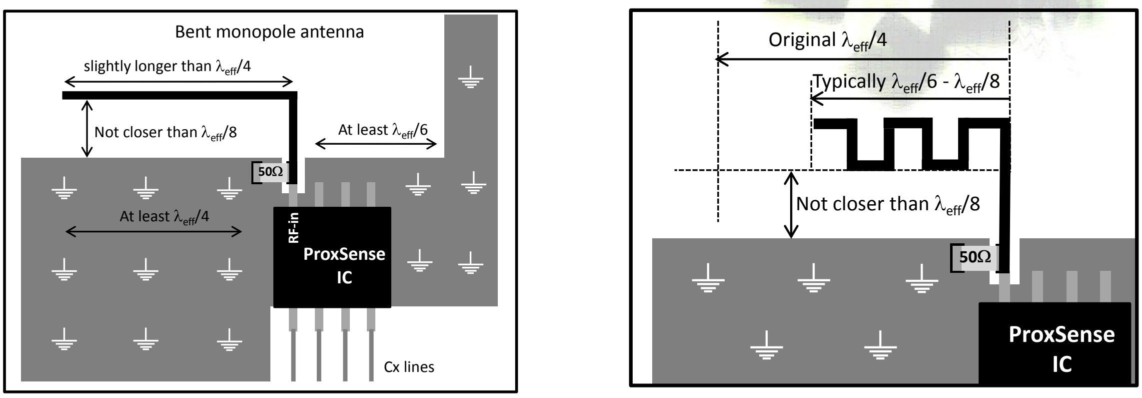

Figure 9: 90° bent ¼ wave antenna to save space (left), and meandering pattern to further reduce size (right)

Table 1: Effective wavelengths and ¼ wave lengths for PCB monopoles

Frequency	Effective wavelength (λ_{eff})	Effective ¼ wavelength (λ_{eff}/4)
433MHz	520mm	130mm
900MHz	250mm	62.5mm
1.8GHz	125mm	31mm
2.45GHz	92mm	23mm

- **Length of antenna ≅ [0.75 * (3*10^{8}m/s) * (threat frequency in Hz)$^{-1}$]**
- Make antenna bit longer than calculated. Tune antenna by cutting shorter until best results are obtained at the threat frequency. Must be done in final enclosure
- If bent antenna also too large – use a meander pattern. However, meandered antenna will have less bandwidth and gain, tuning more NB, and possible 50Ω -match required.
- For all monopole antennas above, if large GND plane is not present antenna will still work, but be very sensitive to changes in its environment, unstable performance.
- Large number of alternative antennas. Most are more costly, complex, require matching, and careful design. Some are: Half-wave Dipole, Helical monopole, Small loop, Inverted-F antenna, Chip antenna

15 Tips to help solve Radiated Immunity failure

- Systematically remove all decouple C's and replace, while testing
- Review PCB layout again, follow current paths.
- Test functional blocks separately for Immunity.
- Insert small series R into different lines to try and find most susceptible part.
- Use shielding. Either to find most susceptible part, or to obtain a pass result.

Document History:

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v1.1, Aug 2011	*J.D. van Wyk, Sr. Application & Development Engineer*	*Update with ref to ICTRL pins*

The following patents relate to the device or usage of the device: US 6,249,089 B1, US 6,621,225 B2, US 6,650,066 B2, US 6,952,084 B2, US 6,984,900 B1, US 7,084,526 B2, US 7,084,531 B2, US 7,119,459 B2, US 7,265,494 B2, US 7,291,940 B2, US 7,329,970 B2, US 7,336,037 B2, US 7,443,101 B2, US 7,466,040 B2, US 7,498,749 B2, US 7,528,508 B2, US 7,755,219 B2, US 7,772,781, US 7,781,980 B2, US 7,915,765 B2, EP 1 120 018 B1, EP 1 206 168 B1, EP 1 308 913 B1, EP 1 530 178 B1, ZL 99 8 14357.X, AUS 761094

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