



Application Note: AZD051b

Electrical Fast Transient Burst (EFT/B) Quick Guide

(Please refer to AZD051 for the full application note)

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1 Introduction:

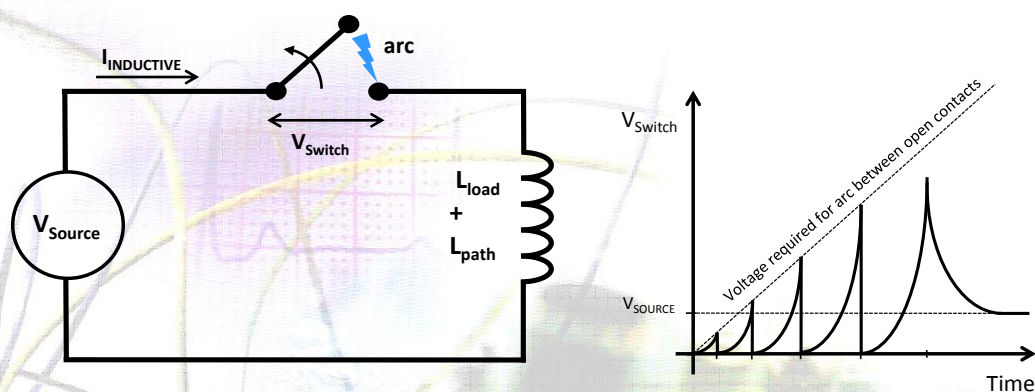


Figure 1: High frequency transients due to arcing contacts in an inductive path.

- EFT/B testing necessary due to spikes caused by inductive current interruption & arcing. Severe EFT/B often encountered in heavy industry – contactors and large electrical machines
- Commercial / residential environment – also EFT/B due to mains outlet switching, power drills etc.
- Relevant international EFT/B testing standard – IEC 61000-4-4:
 - Describes EFT/B generator, test setup, test procedure and immunity requirements.
 - Always use at least 1m x 1m Ground Plane, 0.1m below Device Under Test (DUT), margin of 0.1m all around DUT. EFT/B gen connected with low L braided strap to Ground Plane.
 - Live/Neutral cables between gen and DUT → 0.5m and 1m. L/N connected directly to gen.
 - IEC 61000-4-4 waveforms:
 - Approximately 3 bursts/sec, burst = 75 pulses, repeated for at least 1 min. Spike frequency: 5kHz or 100kHz. For 5kHz: burst period = 15ms. For 100kHz: burst period = 0.75ms. Each pulse rises to 90% in 5ns, rise from/decays back to 50% in 50ns
 - Traditional EFT/B testing done with 5kHz spike repetition within a burst, but 100kHz may be more representative of real life. IEC product committees decide which applies.

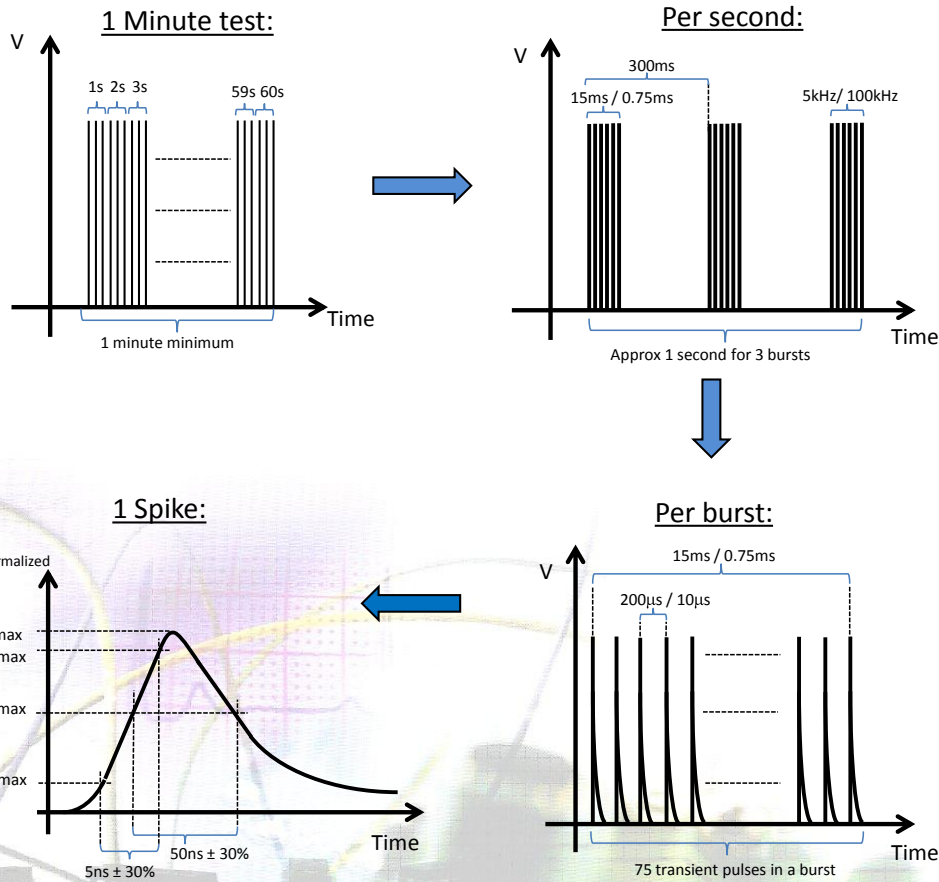


Figure 2: EFT/B transient waveforms prescribed by IEC 61000-4-4

Table 1: Immunity levels for EFT/B, as required by IEC 61000-4-4

<u>Level:</u>	<u>Description:</u>	<u>Example & characteristics:</u>	<u>Immunity up to:</u>
Level 1	Well protected environment	Server rooms, stringent layout principles and filtering applied	0.5V
Level 2	Protected environment	Control room, with some filtering. Also typical environment for consumer and commercial applications of ProxSense design	1kV
Level 3	Industrial environment	Industrial plant, no transient filtering, cables in close proximity to each other	2kV
Level 4	Severe industrial environment	HV Substations, Power Plants. High current contactor switching	4kV

- IEC 61000-4-4 requires testing for both pos and neg polarity, defined relative to Ground Plane. I.e. positive means L/N cables at positive voltage and Ground Plane is at zero.
- IEC standard do not specify coupling, but we advise to test for L+N, L and N, and if power earth is used, also to L+N+E, to L+E and to N+E.



➤ If auxiliary cables run to / from DUT – use a capacitive clamp to couple as specified in std.

- **Azoteq pursues Level 3, or 2kV, immunity, L+N coupling, positive and negative polarity, for all its ProxSense evaluation kits.** Level 4 immunity has been achieved upon request, but typically requires dedicated layout and engineering resources. Please enquire for further details.

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

2 Understanding EFT/B current paths:

From a Power Supply Perspective

- EFT/B is mostly a common-mode test, with EFT/B transients applied between Ground Plane, and Live/Neutral, or auxiliary cables. EFT/B can be seen as RF-test, f-components up to few hundred MHz.
- Air dielectric of 0.1m thickness between DUT and Ground Plane – EFT/B currents are capacitive in nature, and flows via air. Current direction reverses between positive and negative polarity transients.

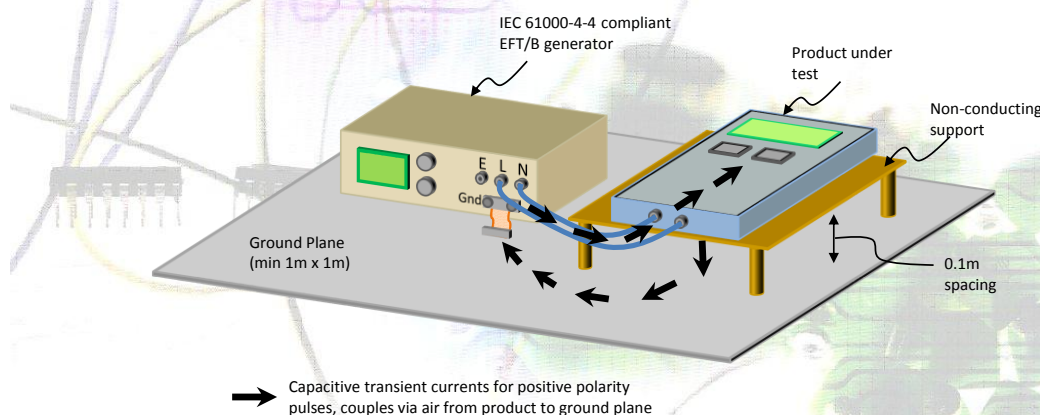


Figure 4: EFT/B as common-mode test, with capacitive transient currents for positive polarity pulses

- EFT/B currents will avoid L, and seek large copper areas to flow as capacitive currents to/from the large Ground Plane underneath. Limited amount of transient energy will couple via power leads to Ground Plane.
- Consider a typical ProxSense design powered by full diode bridge, isolated SMPS, as in Figures 5.
- Transient currents will try to flow to/from Ground Plane at earliest opportunity. If enough grounded copper is not available in Zone 1, transients will flow via grounded copper of Zone 2. If Zone 2 has inadequate grounded copper, transients will couple in Zone 3 to/from the Ground Plane.
- Preferable for EFT/B currents to couple to/from Ground Plane in Zone 1 – highest immunity for ProxSense circuit.
- Negative polarity event– current direction reversed, diode D_{LV} blocks, more direct path available in Zone 1, i.e. possible for EFT/B currents to flow directly from Ground Plane to Zone 1 ground.



- Figure 5 helps to visualize how EFT/B currents injected only into Live, or only into Neutral, will potentially flow.
- EFT/B currents via transistor Q1 is small (pos/neg EFT/B events) due to primary winding inductance
- Figure 6 shows SMPS with only one rectifier diode – pos polarity EFT/B immunity potentially higher.

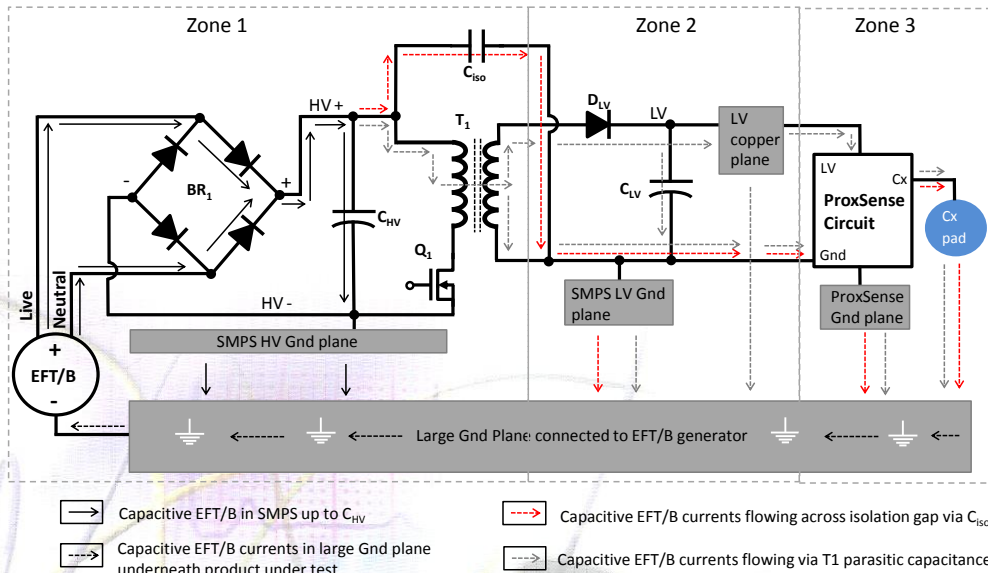


Figure 5: Possible positive polarity EFT/B current paths for an isolated SMPS, as is typical in white goods.

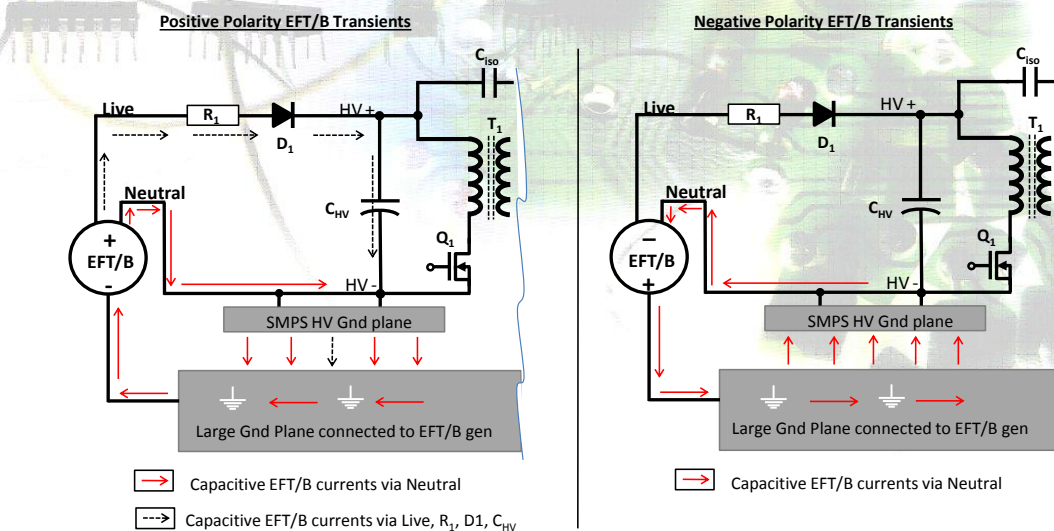


Figure 6: Positive and negative polarity EFT/B currents in SMPS with only single diode rectifier.

From ProxSense Perspective

- EFT/B currents in Zone 3 are detrimental to ProxSense operation: Possibility of ground ref shifting/ground bounce, false touches, data corruption or device hang-up.



- Internal Cx-pin ESD protection diodes (in all ProxSense devices) provides good path for EFT/B transient currents. Amount of EFT/B current via the Cx pads - proportional to the pad size and C to large Ground Plane underneath.
- Typical projected capacitive sensors - more inherent EFT/B immunity - less sensor pad copper area.
- ProxSense devices with an ICTRL pin, (ex. IQS316), require special care with grounding of the resistor attached to pin, as ref current for the whole device is set by resistor. Transient EFT/B currents via pin/resistor, and large EFT/B currents in the ground close to ICTRL, must be avoided.

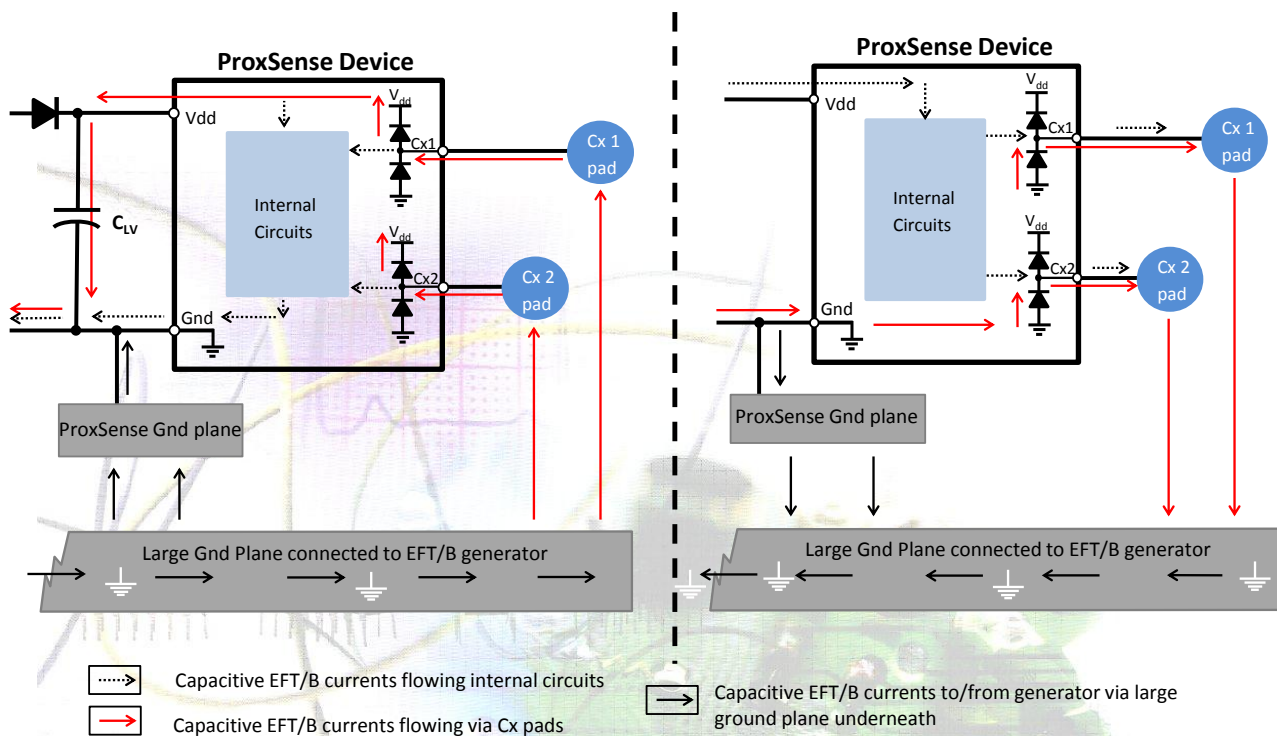
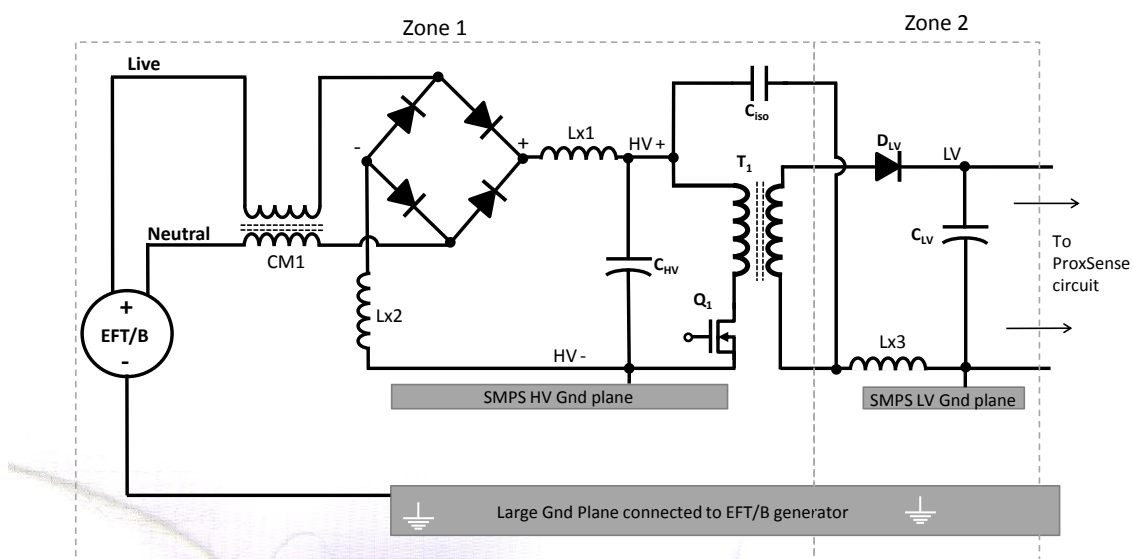
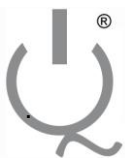


Figure 7: Positive (left) and negative (right) polarity EFT/B currents flowing via bottom internal ESD diodes and Cx pads.

3 Increasing EFT/B Immunity:

- **3 Main Alternatives:** 1) Reflect the EFT/B transient energy back with an open circuit. 2) Reflect the EFT/B transient energy back with a short circuit. 3) Dissipate the EFT/B transient energy.
- **1st Alternative:** Reflect energy with series inductance – approximation of open circuit at high frequency. If lowest EFT/B frequency is 1MHz, and would like 10kΩ impedance at this frequency, require an inductor of 1.59mH.
 - L can be inserted as a common-mode choke around both Live and Neutral lines, right at start of Zone 1 – good practice.
 - For full diode bridge apps – single inductor after diode bridge may work as well.
 - When using inductances to try and reflect EFT/B transient energy, keep in mind that it may lead to EFT/B coupling via other parasitic paths.

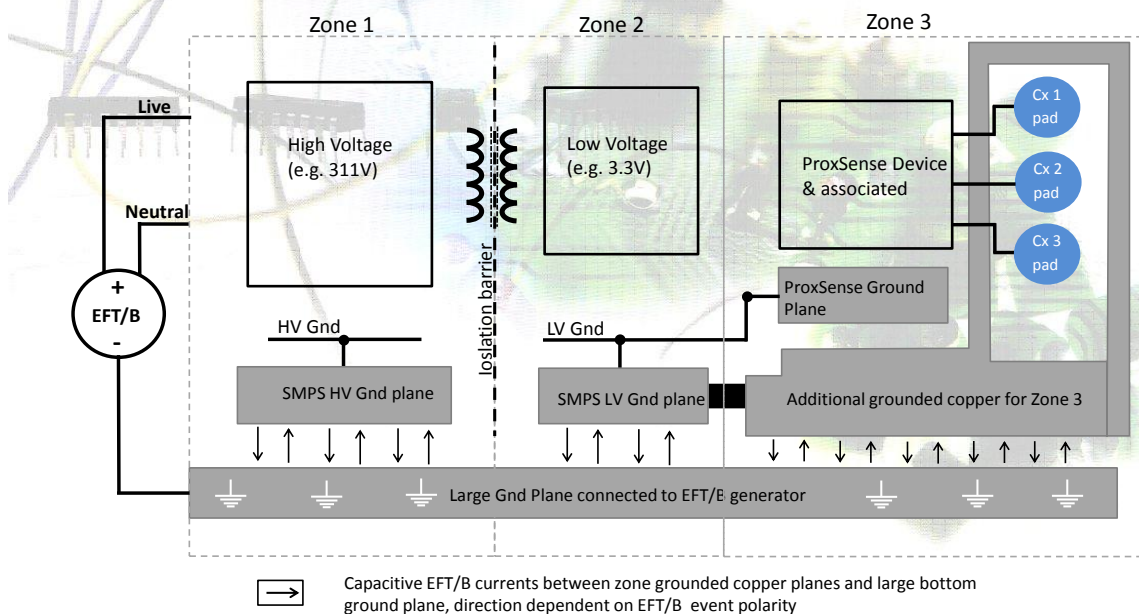


CM1 – Common mode choke to prevent EFT/B currents from entering Zone 1

Lx1,2 – Possible Zone 1 placements of L to reflect EFT/B energy (Lx1 only effective for pos. polarity, and Lx2 for neg polarity EFT/B events.)

Lx3 – Possible Zone 2 placement of L to reflect EFT/B energy (Note that Lx3 will result in more transient current via D_{LV})

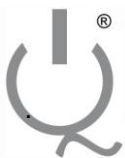
Figure 8: Placing a common mode choke or single inductor to reflect EFT/B energy with series impedance



Capacitive EFT/B currents between zone grounded copper planes and large bottom ground plane, direction dependent on EFT/B event polarity

Figure 9: Additional grounded copper to realise sufficient capacitance with bottom plane to reflect EFT/B

- 2nd Alternative: Reflect energy with parallel capacitance – approximation of short circuit at high frequency. Typically cheapest option – only requires sufficient grounded copper in Zones 1 and 2.
 - Create as large as possible ground plane in Zone 1 of the SMPS, before isolation barrier. If not possible, then create large ground plane in Zone 2 of the SMPS, after isolation barrier.



- If above cannot be done and additional grounded copper must be placed in Zone 3, the ProxSense zone, careful consideration is required, while observing:
 - Connect the additional Zone 3 grounded copper only with low L track directly to Zone 2 ground.
 - If the above not possible, and additional grounded copper must be connected to ProxSense gnd, analyse gnd currents, check if flowing through or close to ICTRL pin.
 - Place additional grounded copper around the Cx pads, but not close enough to reduce touch sensitivity below that which is acceptable for the application at hand.
- **3rd Alternative:** Dissipate EFT/B transient energy. Reliable way to get rid of interference, but difficult to implement. If allowed by power budget – insert resistors in Zones 1 or 2. Or use lossy filters, or power cables with dissipative low-pass characteristic, such as found in automobile ignition system.
- **Filtering and Decoupling:** Blind application of low-pass RC and LC filters likely to result in no improvement of EFT/B immunity, as current may not be shunted by the parallel element of the filter.

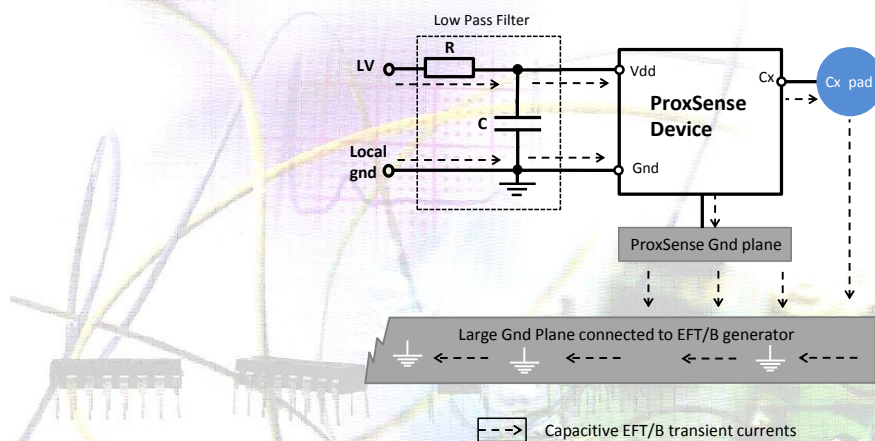


Figure 10: Transient current direction in low voltage power rails, redundancy of classical low-pass filters.

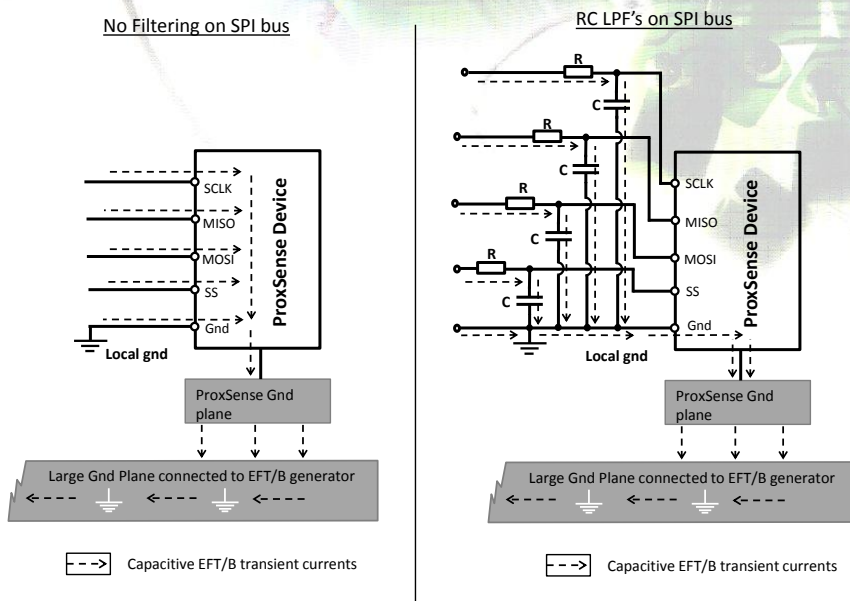


Figure 11: Use of basic low-pass filters on SPI lines to shunt transient currents, and improve immunity



- However, careful analysis of transient paths may identify cases where filters may improve immunity.
- For instance, if transient currents flow via SPI bus lines through the ProxSense device towards the large Ground Plane. By inserting low-pass filters, transient currents can be shunted to local ground before the ProxSense device, improving EFT/B immunity.
- **Cx-pad & track guidelines:** As observed, it is quite likely that capacitive EFT/B currents will try to couple via Cx-pads to the large Ground Plane. To avoid this:
 - Do not realize a design with ProxSense local ground area << Cx pads total copper area.
 - Ideally: Local ProxSense ground copper area >> Cx-pads total copper area.
 - Increase series resistance to each Cx-pad up to 10kΩ, if allowed by sensitivity required.
 - If allowed by required sensitivity, realize Cx-pads with hashed copper.
 - Use thin tracks, which have more L, towards Cx-pads. The same applies for longer tracks (Might reduce Radiated Immunity (See AZD015))
 - If required, place additional, discrete ESD diodes external to the ProxSense device on each Cx pin.

4 Testing alternatives:

- Mechanical switches that create sparks when breaking inductive currents can be used as alternative for EFT/B testing – but does not guarantee conformance to IEC 61000-4-4.
- Observe the following when using alternative EFT/B generators:
 - Provide some sort of LC-filtering to the local mains, before the EFT/B injection point. Otherwise other mains powered equipment may fail or be damaged, and the test may even be illegal!
 - Inject the EFT/B currents via DC blocking capacitors into Live and Neutral lines and always use a sufficiently sized ground plane.
 - It may be sufficient to lay cables containing transient currents alongside power cables of the product under test to recreate failures experienced under a formal IEC 61000-4-4 test.
 - Please take heed of the below warnings.

!! Alternative EFT/B tests typically involve hazardous voltages. Basic electrical safety principles should be applied. If unsure, consult a certified professional.


!! 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.



5 Document History

v1.0, Sept 2011	J.D. van Wyk, Sr. Application & Development Engineer	Creation

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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