TEXAS INSTRUMENTS

Application Report

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Digital Isolator E-Field Sensitivity

Kevin Gingerich
High-Performance Analog/Interface and Clock Products

Introduction

The small differential signal circuit used in Texas Instruments digital isolators is immune to external electric fields making common-mode voltage the primary constraint. The intensity vector and physical circuit determine the field-induced voltage that appears across the isolation barrier, and common-mode transient immunity (CMTI) characterizes the high-frequency isolation characteristics of an isolator. Figure 1 depicts horizontal and vertical electric field intensity vectors, isolated dice, and inter-die bond wires making the differential circuit.

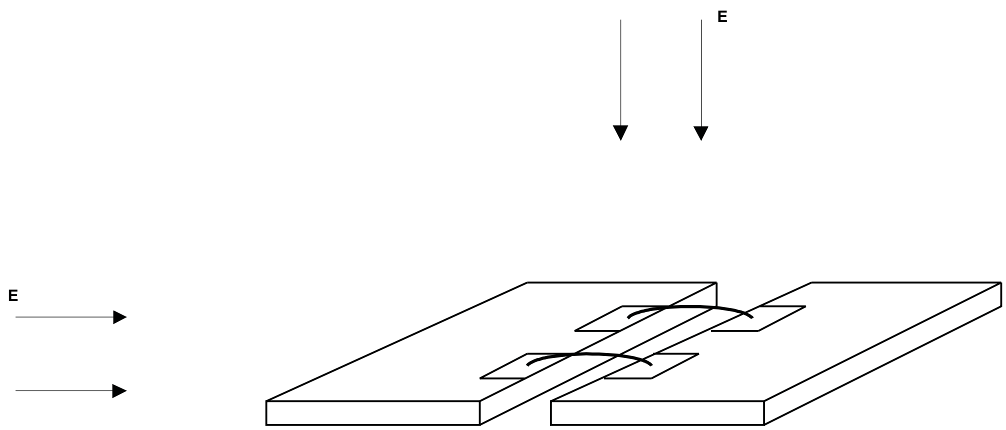

Figure 1. Electric Fields and Isolated Dice

Differential Noise

The only method of externally creating a voltage around the 944×10^{-9} m^2 or smaller differential circuits with an electric field is to expose only one inter-die bond wire (or a portion) to the field without exposing the rest of the loop[(1)]. Intuition says this is extremely unlikely. Maxwell's third equation says this would require a non-zero net flux from an internal volume and a charge density inside the device. This does not exist in real-world applications.

(1) See ISO72X Digital Isolator Magnetic-Field Immunity (Rev. A, slla181a.htm, 0 KB, 22 Feb 2006, Abstract) for the influence from time-varying magnetic fields.

Common-Mode Noise

The voltage induced by an electric field is equal to the summation of the dot product of the electric field intensity and differential length vectors along a path or:

$$v_{AB} = \int_{B}^{A} \bar{E} \bullet d\bar{L}$$

If the field and path are parallel and the intensity is uniform, the voltage is simply E × L. If L is the width of an SOIC package (about 6 mm), external field strength greater than 667×10^3 V/m exceeds a 4-kV-rated isolation barrier. If L is the vertical thickness of a die (about 305×10^{-6} m), external field strength greater than 1.64×10^3 V/m exceeds a 0.5-V noise margin typical of CMOS logic circuits. Table 1 gives field strengths from various sources.

Table 1. Electric Field Strengths (1)

SOURCE	FIELD STRENGTH E ($N.C^{-1}$ or $V.m^{-1}$)
Background radiation in space	3×10^{-6}
In-house wires	0.01
Radio waves	~0.1
Outside an electrified building	~0.1
Center of a typical living room	~3
In a fluorescent tube	10
30 cm from an electric clock	15
30 cm from a stereo	90
Laser beam (low power)	100
Atmosphere (fair weather)	~250
30 cm from electric blanket	250
Built up by splashing water in a shower	800
Sunlight (average)	10^3
Atmosphere (thunderstorm)	10^4
Van de Graaff generator	2×10^6
Breakdown of air	3×10^6
X-ray tube	5×10^6
At cell membrane	10^7
At electron in hydrogen atom	6×10^{11}
Surface of a pulsar	$\sim 10^{14}$
Surface of uranium atom	2×10^{21}

(1) Physics Resource Database, The University of Sydney (Australia), School of Physics (www.physics.usyd.edu.au/teach_res/db/d0006b.htm)

These examples cover a wide range of frequencies. A digital isolator rated to 150 Mbps has a bandwidth of at least 300 MHz to operate. At higher frequencies, gains roll off and transistors need more signal to switch, essentially raising the noise margins. Due to the capacitance of the isolation barrier, common-mode injection to the differential circuit increases with frequency and CMTI specifies it.

The worst-case CMTI rating for these devices is 25×10^9 V/s with a 5-V supply and gives a common-mode voltage slew rate that will not affect the logic state of the device. If the induced common-mode voltage is a sinusoid, $v_{CM} = V \sin(2\pi ft)$ and the slew rate is:

$$\frac{dv_{CM}}{dt} = 2\pi fV \cos(2\pi ft)$$

The constraint is $2\pi fV \cos(2\pi ft) < 25 \times 10^9$ and, taking the magnitude and dividing both sides by 2π, $fV < 4 \times 10^9$. This gives a constraint for the magnitude and frequency of a sinusoidal common-mode voltage. This also indicates that the full 4-kV rating is good to 1 MHz and drops to 4 V at 1000 MHz. This is still 667 V/m based on the analysis above and conservatively assumes the circuit will still respond at 1 GHz (note that few of the listed sources have much, if any, radiation at this frequency).

Conclusion

Clearly, the capacitive isolators from TI have orders of magnitude more immunity to electric fields than the much larger circuits connected to the isolator. Therefore, in most applications, the external circuits or shielding determines the overall equipment susceptibility from external electric fields. Unless a user is planning on operating the isolator unshielded in a thunderstorm or on the surface of a pulsar, the capacitive-isolation technology family from TI gives huge margins with which to work.

IMPORTANT NOTICE