

Effect of ESD on Grounding in a Mixed Mode Circuit

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Abstract- Grounding forms an inseparable part of all electronic and electrical designs, from circuit through system up to installation design. All the ground pins of the system should be tied to the analog ground plane, separated from the system's digital logic ground, to achieve optimum performance in a mixed mode circuit. The ESD indirect discharge test is carried out to predict the effect of ESD on data in a mixed mode circuit when the analog and digital grounds are common and separate. The Indirect discharge is done for different voltages and distances. The susceptibility of a circuit to ESD can be greatly reduced by properly grounding it which is observed in the mixed mode circuit. In the mixed mode circuit the data is affected more by the ESD transients based on the discharge voltage given when the analog and digital grounds are common than when compared with the grounds being separate.

Index Terms- Grounding, Indirect ESD, Mixed mode circuit, Analog ground, Digital Ground.

I. INTRODUCTION

The analog nature of our physical world and the growing need for digital signal processing motivates us to design circuits which process both analog and digital signals. As a fact of life, digital circuitry is noisy. Saturating logic, such as TTL and CMOS, draws large, fast current spikes from its supply during switching. However, logic stages, with hundreds of millivolts (or more) of noise immunity, usually have little need for high levels of supply decoupling. On the other hand, analog circuitry is quite vulnerable to noise on both power supply rails and grounds. So, it is very sensible to separate analog and digital circuitry, to prevent digital noise from corrupting the analog performance. Such separation involves separation of both ground returns and power rails, which is a requirement in a mixed signal system. Nevertheless, if a mixed signal system is to deliver full performance capability, it is often essential to have separate analog and digital grounds, and separate power supplies [1-7].

All noisy digital currents flow through the digital power supply to the digital ground plane and back to the digital supply; they are isolated from the sensitive analog portion of the board. The system star ground occurs where the analog and digital ground planes are joined together at the mixed signal device. In a circuit that has both analog and digital circuits, the grounds are usually kept separate to avoid coupling digital signals into the analog circuits. Both analog

and digital ground planes should be tied to the "system" ground as near to the power supplies as possible. This helps to prevent dynamic digital ground currents from modulating the analog ground through common impedance to power ground. For signals that communicate between parts of the equipment or system, the grounding scheme must provide a common reference with minimum ground shift (low common mode noise) between system parts.

There are four important circuit characteristics to be considered during the design of ground system:

- Frequency of signal: digital signal is broadband
- Effective impedance of a path: not the resistance
- Current amplitude: the voltage drop is proportional to the signal current
- Noise voltage threshold: the noise level that a circuit can withstand or generate

The PCB should consist of separate analog and digital power and ground planes. Splitting of the plane is intended to prevent the digital currents from flowing in the analog section of the ground plane [8-10].

Indirect discharge on the horizontal coupling plane (HCP) is performed [11,12]. The ESD indirect discharge test was carried out to verify the ESD immunities of the mixed mode circuit. A comparative study of the effect of ESD on the data in a mixed mode circuit, when the digital and analog grounds are common or separate, is carried out. The Indirect discharge is done for different voltages and distances. The work discusses the effect of ESD on data in a mixed mode circuit when the analog and digital grounds are common and separate.

II. CIRCUIT AND ITS OPERATION

The circuit shown in Figure 1 consists of a 555 timer working as an astable multivibrator (NE555) and an op amp ($\mu\text{A} 741$) designed to function as an inverting amplifier with unity gain. This circuit consists of both the analog and digital design, hence the name mixed mode circuit.

The astable multivibrator is used to produce a clock frequency of 62.5 KHz to 118 KHz. This clock is given as the input to the inverting amplifier which produces the inverted data. The grounding reference required by the astable multivibrator is given by connecting to the earth potential and the grounding reference required by inverting amplifier is given by connecting to the power supply common ground. The experiment has been conducted to analyse the effect of indirect ESD by shorting the analog and digital grounds and by connecting them separately.

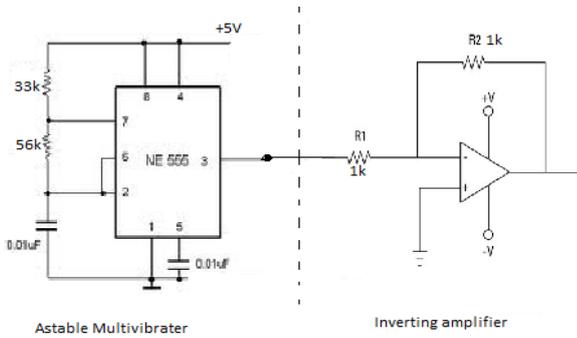


Figure 1: The Mixed Mode circuit

III. EFFECT OF INDIRECT ESD

The initial output of the clock and the data is shown in Figure 2. The waveform at the bottom represents the serial data from the inverting amplifier and the waveform at the top represents the clock from the astable multivibrator.

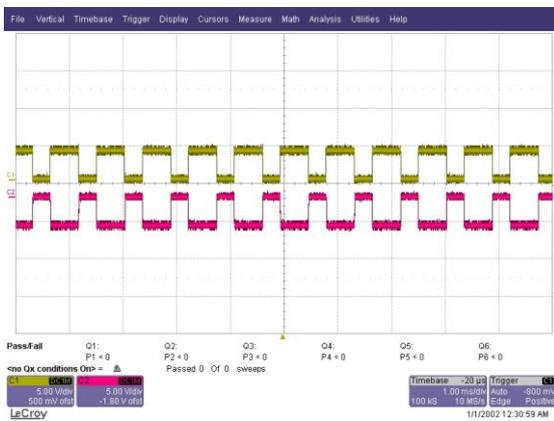


Figure 2: The initial output of clock and data

A. Discharge to the right side of the circuit with common analog and digital grounds

A discharge of 4kV at a distance of 0.7m from the circuit is given and the observed transient voltage of the data is 13V and the transient inverts the data for about 14 µs when the threshold is set at data low. Here the transient occurred when the data bit is high and the clock being low is hardly affected as shown in Figure 3.



Figure 3: Output after a discharge of 4kV at a distance of 0.7m

The transient voltage of around 10V at the data for duration of 8 µs is observed when a discharge voltage of 8kV is applied at a distance of 0.7m from the circuit as shown in the Figure 4. Here the transient occurred when data bit is at low. A spike of 8V in the clock output is also seen. The threshold is set at a data low.

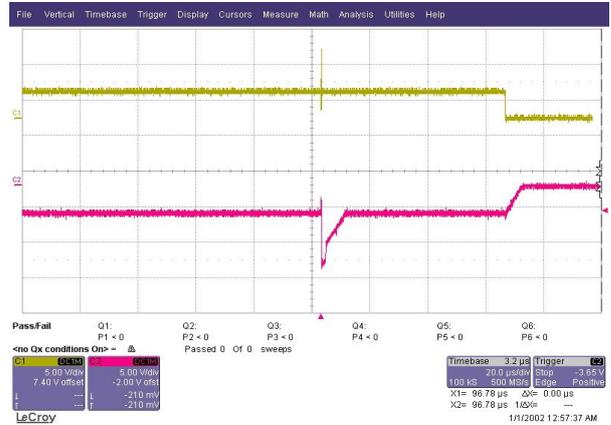


Figure 4: Output after a discharge of 8kV at a distance of 0.7m

When a discharge voltage of 15kV is applied at a distance of 0.7 m the data is affected with a transient of 12V which lasts for 20 µs and the clock being low is hardly affected as shown in Figure 5. The threshold is set at a data high and the transient occurs when the data bit is high.



Figure 5: Output after a discharge of 15kV at a distance of 0.7m

B. Discharge to the left of the circuit with common analog and digital grounds

Upon a discharge of 4kV at distance of 0.9m, the data is affected with a transient whose magnitude is around 12.5V and the duration is 8 µs and the clock at high is affected with a transient of magnitude 6V as shown in Figure 6. The threshold is set at a data high.

A discharge of 8kV at a distance of 0.9m from the circuit is given and the observed transient voltage of the data is 11.5V and the transient exists for about 16 µs when the threshold is set at data high and the transient in the clock at low is 6V as shown in Figure 7.



Figure 6: Output after a discharge of 4kV at a distance of 0.9m



Figure 9: Output after a discharge of 8kV

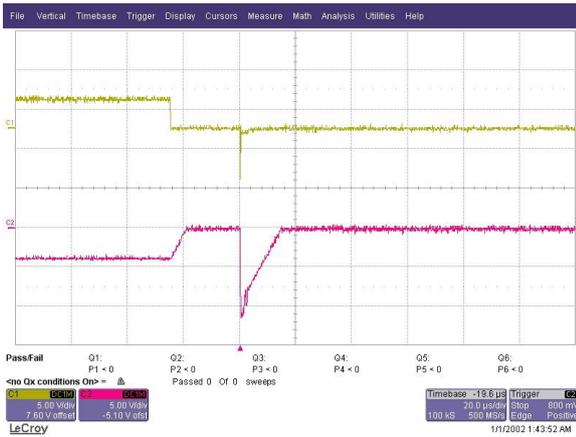


Figure 7: Output after a discharge of 8kV at a distance of 0.9m



Figure 10: Output after a discharge of 12kV

C. Discharge to the circuit by separating the analog and digital ground

The digital ground is connected to the earth point and the analog ground is connected to the common power ground. When the discharge voltage is 4kV, 8kV or 12kV the clock is affected with a transient of 8V which lasts for 10 μ s and the data is hardly affected as shown in Figures 8, 9 and 10 irrespective of the distance. The threshold is set at a data high.

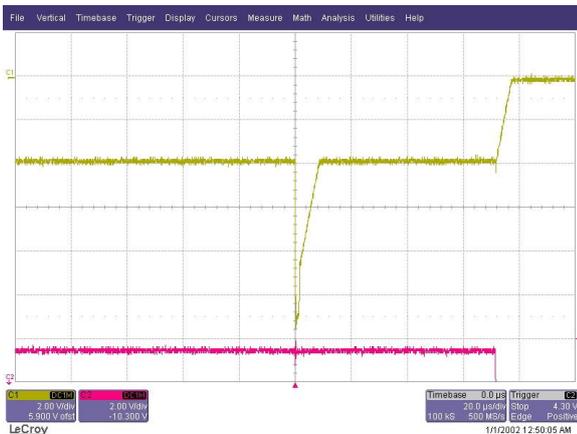


Figure 8: Output after a discharge of 4kV

IV. CONCLUSIONS

In the mixed mode circuit the data is affected more by transients of various voltages based on the discharge voltage given when the analog and digital grounds are common than when compared to the grounds being separate. The clock is affected in the same way whether the two grounds are separate or common since the clock forms the initial part of the circuit. The ESD effect on clock for this circuit does not depend on the grounds being common or separate. The analog ground is for the inverting amplifier circuit. The data which is the output of the inverting amplifier is less affected when the analog and digital grounds are separate. This reiterates the fact that when the analog and digital grounds are separate the high frequency return paths from the digital section (astable multivibrator circuit) do not reach the analog ground and affect the data. Also the analog signals are more sensitive to noise. In conclusion, in the mixed mode circuit the data is affected more by transients of various voltages based on the discharge voltage given when the analog and digital grounds are common than when compared to the grounds being separate.

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