國 立 陽 明 交 通 大 學

電子研究所

碩 士 論 文

應用於 FlexRay 的高壓雙向靜電放電防護設計與碳化矽製程的靜電放電特性調查

Design of HV Bi-directional ESD Protection for FlexRay Application and Investigation of ESD Characteristics of SiC Process

研 究 生: 李雨鑫 (Yu-Hsin Li)

指導教授: 柯明道教授 (Prof. Ming-Dou Ker)

中 華 民 國 一一一 年 一 月

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摘要

隨著車用電子的發展，車內的多種裝置皆發展成電子化控制，諸如線控煞車(brake-by-wire)、線控轉向(steer-by-wire)，這些裝置對於訊號的速度、訊號的正確性相較於過去有更高的要求。FlexRay 相較於過去 LAN、CAN 具有更高速，更高的安全性的車用通訊規範。FlexRay 的應用電壓範圍為±60V，因此在系統線總(Bus)上需要雙向高壓的靜電放電(ESD)防護以防止內部電路因靜電放電損壞，並且在不影響系統的正常操作。

因此本論文提出兩個符合 FlexRay 雙向高壓所需的 ESD 防護元件，其一是以兩個單向 PNP (uni-directional PNP) 連接而成的雙向 PNP (U2BPNP)，其二是一個單獨的對稱雙向 PNP (BiPNP)。在 U2BPNP 中我們藉由量測其 TLP Vt1 和 It2 以比較各操作電壓單向 PNP 所組成的 U2BPNP 之間的差異。在 BiPNP 中我們改變各參雜層間的距離以達到±60V 的應用電壓。此外並藉由改變元件的尺寸

分析尺寸對 TLP It2 的關係。另外 FlexRay 的規範中也訂定其線總上 BP 和 BM 須分別通過 HBM ±6kV 及 IEC61000-4-2 ±6kV。因此本文也列出了所提出的雙向 PNP 元件的 HBM 和 IEC 等級。另外藉由其 TLP、HBM 及 IEC61000-4-2 量測結果可以得知 BiPNP 相較於 U2BPNP 有更好的面積效率。此外根據量測結果得知本文提出的元件具有 HBM 等級(V)為 2~1.7kΩ 倍的 TLP It2(A)，IEC 等級(V)為 0.6kΩ 倍的 TLP It2(A)的關係。

在高壓應用中，寬能帶元件(wild bandgap device)，如碳化矽(SiC)，砷化鎵(GaAs)，是下個世代很重要的高功率元件。在本論文中，我們也針對 SiC 的 PN 接面二極體 (PN junction diodes) 和金氧半場效電晶體(MOSFET) 的 ESD 特性進行量測，包含 TLP 及 HBM。SiC 的 PN junction diode 中我們發現 HBM 與元件尺寸沒有絕對的關係。在 SiC 的 MOSFET 的量測結果得知，PMOS 具有比 NMOS 更高的 ESD 耐受度及 Vt1。值得注意的是 SiC 的 NMOSFET 相較於傳統 Si 製程的 NMOSFET 沒有回彈(snapback)的現象。

Design of HV Bi-directional ESD Protection for FlexRay Application and Investigation of ESD Characteristics of SiC Process

Student: Yu-Hsin Li **Advisor: Prof. Ming-Dou Ker**

Institute of Electronics

National Yang Ming Chiao Tung University

Abstract

With the development of automotive electronics, various devices in the car have developed into electronic control, such as brake-by-wire and steer-by-wire. The correctness of the signal has higher requirements than in the past. Compared with the LAN and CAN, FlexRay is a faster and safer vehicle communication specification. The application voltage range of a FlexRay system is ±60V, so bidirectional high-voltage electrostatic discharge (ESD) protection is required on the system bus (Bus) to prevent internal circuits from being damaged by electrostatic discharge, meanwhile do not affect the normal operation of the system.

Two kinds of ESD protection devices are proposed in this thesis, U2BPNP, connected by two uni-directional PNPs (uni-directional PNP), and BiPNP, a stand-alone bi-directional PNP. Both of them met the requirement of the FlexRay application. In U2BPNP, the TLP Vt1 and It2 of U2BPNPs, which consists of uni-directional PNP with different operating voltages, were compared. In BiPNP, we varied the distance between the doping layers to achieve an applied voltage of ±60V. The relationships between the size and TLP It2 were also analyzed. In addition, BP and BM of the FlexRay Bus must pass HBM ±6kV and IEC61000-4-2 ±6kV, respectively, which are stipulated in the specification. The HBM and IEC levels of the proposed bi-directional PNPs are also listed. The results of TLP, HBM, and IEC61000-4-2 showed that BiPNPs have better area efficiency than U2BPNPs. In addition, according to the measurement results, the proposed devices have a relationship between the HBM levels (V) is 2~1.7kΩ times TLP It2 (A), and IEC levels (V) is 0.6kΩ times TLP It2 (A).

In high-voltage applications, wide bandgap devices, such as silicon carbide (SiC) and gallium arsenide (GaAs), will be highly developed in the next generation of high-power devices. In this thesis, we measured the TLP It2 and HBM levels to analyze the ESD characteristics of SiC PN junction diodes and MOSFETs. In the SiC PN junction diode, we found that HBM levels do not correlate with devices size. In addition, the measurement results of SiC MOSFET show that PMOSFETs have higher ESD tolerance and Vt1 than NMOSFETs. It is worth noting that the SiC NMOSFETs have no snapback phenomenon, which is different from traditional Si NMOSFET.