Characterization of an Intelligent Power Switch for LED driving with control of wiring parasitics effects

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Abstract—**The flexibility of an Intelligent Power Switch (IPS) designed in HV-CMOS technology for incandescent lamp in automotive scenarios has been evaluated for the driving of a LED in presence of wiring parasitics. The paper presents how it is possible, through proper reconfiguration of the flexible IPS, to reduce the undesired ringing phenomenon when driving a LED with wiring parasitics thus reducing Electromagnetic Interferences (EMI) and spikes on supply voltage. Electrical simulation and experimental measurements prove the effectiveness of the proposed IPS.**

Keywords—***Intelligent Power Switch; wiring parasitics; LED driving; High Voltage CMOS Circuit; Automotive Electronics***

I. INTRODUCTION *(HEADING 1)*

Today in a modern car the number of bulbs is decreasing quickly, replaced by LED. This trend is driven by the growth of LED technology compared with the old-exhausted bulb technology [1]. The bulbs have the advantage of being easily driven, without harsh requirements in voltage and current control. Yet the LEDs have the advantages that require less power consumption and offer a higher reliability. Now car manufacturers must reduce the total power consumption of cars to meet the harsh regulation of CO_2 emissions and to reduce the fuel consumption. The change from bulbs to LED must be seen in this way, but it is not so easy to do it because LED also require care of the working environment and wiring connection. The wiring parasitics [2] can generate unwanted effects, such as ringing and under/overshoot. The ringing effect is generated by the resonance of the wiring inductance and the capacitance on connectors. Damped oscillations at 10 ÷ 100 KHz are caused by values of parasitic capacitance and inductance typical of wires few meters long. In order to avoid or limit this effect it is necessary that the slope of the current should be below the characteristic frequency of the wiring parasitics. For that reason LED cannot be driven by a simple mechanical relay, but must be driven by an IPS that permits to control the slope of the current and avoid the arise of ringing or other undesired effects. The design of a flexible IPS is required in the large volume automotive market: the IPS shall integrate on-chip the HV driving circuitry plus the low-voltage control/ interface logic towards the automotive control network which today is based on digital ECUs [5-9]. The IPS shall be also configurable to face different loads and wiring configurations.

II. IPS WITH CURRENT SLOPE CONTROL

The design of the IPS, implemented in Austriamicrosystems AG (AMS) HV-CMOS 0.35 µm ASIC technology, has been driven primarily by the constraints to be taken into account for the driving of an incandescent bulb lamp. A linear current limitation loop, added to a *Soft Start* strategy, allows to face the high in-rush current behavior of this kind of non-linear resistive loads [3]. The basic scheme of the IPS is showed in Fig. 1: besides driving an indicator light mounted on the dashboard of a car, the circuit also monitors the voltage on its output to inform an Electronic Control Unit when the ignition key is plugged and engaged. To this aim, the low side main power switch is placed within a voltage regulation loop regulating the output on a reference voltage when the switch, and consequently the load, is turned on. A comparator detects the state of the key switch by comparing the output voltage with a threshold lower than the reference output voltage. A more detailed description of the IPS architecture can be found in [4], limited to bulb driving while this work focuses on characterization when driving LEDs and considering parasitics effects due to wires and connectors in real applications. Other distinguishing features such as *Over-Temperature Protection*, *High Voltage Protection* and *Reverse Polarity Capability*, integrated in the IPS, permit to safely handle the ordinary and extraordinary automotive electrical and environmental conditions. Operating temperatures in the range from -40 °C to 150 °C, robustness against high voltage up to 55 V, reverse polarity up to -15 V, represent indeed some of the features fulfilled, qualifying the IPS as suitable for the harshest requirements of the automotive scenario.

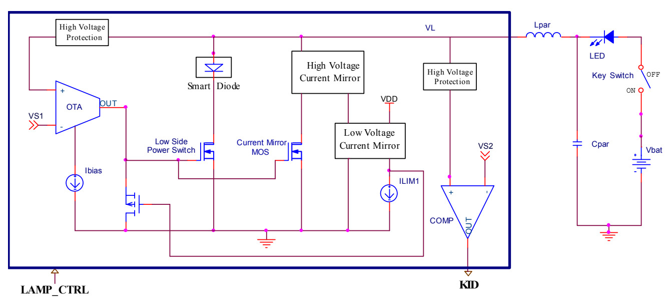

Figure 1. IPS architecture plus wiring parasitics, LED, key switch, battery.

One of the key features of the innovative IPS is flexibility: the *Soft Start* strategy employed to protect the device during the start-up of the incandescent lamp has been made programmable, as well as the level of the current limitation, allowing the device to be adaptable to different loads and environment conditions. In the industrial case study described in this paper, the most useful feature offered by the suppleness of the IPS has been the *Control of Current Slope*. That technique has been easily implemented, since the output current slope during the turn on phase of the load depends on how fast the low side power switch is turned on. By tuning the

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slew rate of the OTA driving the gate of such power MOS, by means of the regulation of the OTA bias current, it is therefore possible to control the load current slope. Such a feature has allowed to reuse the IPS, initially applied to the driving of incandescent lamp, also as a LED driver. As described in the previous section, the wiring parasitics heavily affect the driving of the LED during the turn on transient. If the characteristic frequency of the parasitics is included in the frequency spectrum of the output voltage signal, then ringing starts on output terminal. High current spikes, as consequences of ringing, have to be avoided since they can lead both conducted and radiated interferences causing the malfunctioning of the whole system where the IPS is embedded. Simulations evaluated for all process and temperature corners, sweeping also parasitic capacitance and inductance across realistic values for a wire few meters long, has showed high transient current spikes before tuning down the current load slope (Fig. 2). By means of electrical simulations the appropriate value of the current slope to be set for the specific wire type and length has been estimated in order to avoid the resonance of its parasitics. In the case study a 2 ÷ 3 meter long wire is employed, representing an inductance of 3 ÷ 5 µH and a capacitance of 50 ÷ 200 nF (capacitance varies with the kind of wire used). By setting the current slope to about 3 mA/µs the ringing has been completely erased in the minimum parasitics corners and strongly limited for the maximum ones. In the following section some measurements are reported.

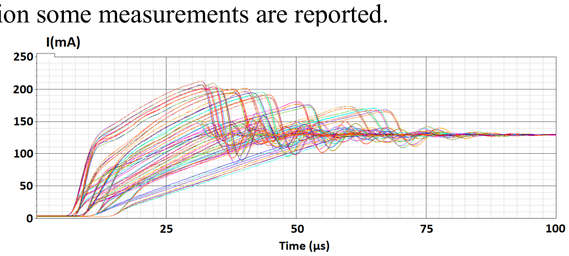

Figure 2. Electrical simulations evaluated for all process, temperature and parasitic capacitance and inductance corners, showing the transient output current during the driving of a LED before tuning the current slope properly.

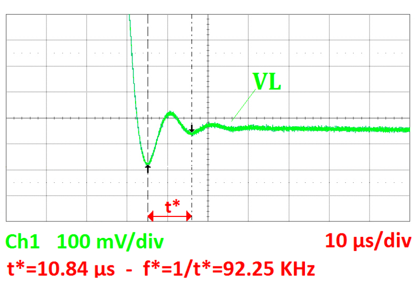

Figure 3. Detail of the output voltage during the turn-on transient of a LED without a proper current slope regulation: a significant ringing phenomenon can be noticed with a characteristic frequency imposed by the wiring parasitic.

III. Experimental Results

Some measurements are done to validate the behavior of the IPS changing both parasitics and current slope, checking the presence of ringing. The parasitics are changing according the case study explained in Section II. If the current slope is set too fast, ringing can arise (Fig. 3) and the ringing frequency is about 90 kHz, as expected for the chosen wire parasitics.

Using a slower current slope of about 3 mA/µs with the same wiring parasitics the ringing is completely disappeared as shown in Fig. 4. An additional testing phase has been accomplished in a real automotive environment. Those measurements are done changing the small 2W bulb on dashboard that indicates a malfunction at an alternator system with a LED and confirmed the right understanding and no ringing problems when the current slope is about 3 mA/µs.

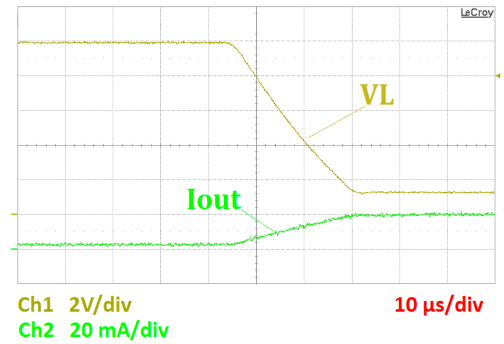

Figure 4. Output voltage and current during the turn-on transient of a LED, by tuning the current slope the ringing has been avoided.

IV. Conclusions

The paper has presented the characterization of an HV-CMOS Intelligent Power Switch for LED driving in automotive scenario in presence of wire and connector parasitics. Reported experimental results prove that it is possible, by reconfiguring the flexible power switch, to reduce the undesired ringing phenomenon when driving LEDs thus reducing EMI and spikes on supply voltage.

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