Automotive Industry Trends and Effects over Analog Circuit Design

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Abstract – **This paper presents the current tendency in automotive industry, analyses the influence into the Integrated Circuit (IC) design, and proposing project and process transferable solutions for overcoming some of the common problems.**
Keywords – **Automotive, simulation based design, EMC, High Voltage, design procedures**

I. Introduction

The automotive market with its constant grow is very interesting for IC (Integrated Circuits) components design companies. According the market researches, electrical and electronics parts account for 20% to 25% of the cost of an average vehicle, while in hybrid vehicles those parts account for 50% of the cost [1]. In area with constant and growing competition, new developing markets, companies need to constantly improve their strategy to survive in these hard days. The IC shall be cost effective, while managing with the constantly increasing functionality, power efficiency requirements, temperature range, and the specific for the industry high Electromagnetic Compatibility (EMC), reliability and functional safety requirements [1], [2]. At same time companies are following other trends: customers are giving more value of personalized solutions, connectivity to mobile devices, internet, cars-to-cars and infrastructure.

Even in this changing environment, from the practice it can be seen that no small part of circuits and design problems are repetitive. This could be seen as same small blocks architectures, sizing task, simulation test approach, High Voltage (HV) design, or big IC development tasks related to Functional Safety, EMC and power management, which are usually part of Automotive IC requirements.

Another growing task for decreasing project risk is to perform more and more simulations instead on relying on expensive prototype evaluation, and to decrease risk of design re-spin. As the performed simulations have different targets and simulation environment, the best suitable models are build depending on specific verification targets.

In chapter A. is given example of automated design sizing based on simulations of a very popular current bias source.

Chapter B. discuss tendency in modeling, in respect of development stage of product life.

Chapter C briefly comment Functional Safety.

In chapter D. discuss EMC simulation for IC.

Chapter E. is focused on HV design.

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A. Design reuse by Soft IPs

In electronic design a semiconductor intellectual property core, IP core, or IP block is a reusable unit of logic, cell, or chip layout design that is the intellectual property of one party [9]. The IP are hard core IP, including fixed layout format, and soft core IP which are offered as synthesizable RTL.

The most of analog IP can be categorized in the follow circuit type:

- AFE (Gain amplifiers, active filters, ADC, DAC)
- Timing IP (clock circuits line PLL and DLL)
- PVT monitoring IP (temperature, battery, power, performance sensing)
- Power IP(LDO low-drop out regulators)
- Peripheral/Interface IP
- Memory IPs

There are many pros and cons about the use of analog IPs. Benefits of reusing silicon proven Analog Hard IPs are project risk decrease about:

- Schematic/design development time
- Physical layout representation
- Complete documentation
- Models, supporting verification at different design development step
- Silicon proven electrical parameters, including qualification
- Easy connection to other IPs from same IP provider.

Negative aspects of analog IPs start with ASIC requirements diversity. It can be needed very small circuit adaptation, but will cause changes starting from schematics and going through components of IP package. Another disadvantage is that analog IP is linked to specific FAB technology node and it revision.

Those are the main reason most of the analog IPs to be a complex blocks, like ADCs, PLLs, Interfacing circuits and etc., where risk of design iteration is very high. Although big part of analog blocks designs are custom, consuming significant part of project resources.

Analog design process is far behind Digital design regarding design automation, formal verification, transferability from one technology node to another, and “open design source” for implementing design adaptation. To overcome those negative aspects, can be reused some of design approaches from digital design and expand existing practices like:

- Creation of libraries basic blocks, a technology independent schematics, with some of most popular block architectures;
- Verification IPs: test benches, simulation setups, post-simulation parameters extraction and reporting;

- Tools, linking design to new or existing design sizing and design optimization software products;
- Enhance use of verification tools, using package of checks, based on experience. Some of this tools use netlist, where are recognized specific structures. This provides very fast rules violation check.
- Developed automated design procedures linked to specific structures. The literature provide significant amount of design procedures, which automation will increase significantly the quality of new designs.

The listed above can be part of Analog Soft IP, or synthesizable version of analog circuit, making it manufacture process, size, parameters process independent. All given examples above have the common characteristics that they step on design experience, which can give short development time and predictable final results.

One of the key factors for success of automation design task is proper circuit selection. A current CMOS bias source, working in week inversion for example is a popular architecture, suitable for implementation in Low Voltage (LV), as well possible to extend for High Voltage (HV) CMOS process [3]. The typical characteristics achieved with this architecture are:

- Reference current from few 100 nA to 100uA. The achieved current consumption is in the same range.
- Wide supply voltage operating range: from 2 transistors threshold voltage (Vth) in LV systems and one more Vth for the HV systems, up to maximum supply for the system, which for HV automotive systems can be up to 25V for 12V battery system or even 50V for 42V systems.
- Precision mainly defined by used resistors process variation.
- Linear behavior in wide range, which is good base for applying optimization algorithms for automated design sizing.

B. Modeling during product development

To cover all functional, parametric, EMC, ESD, temperature profiles, quality and safety targets, with every electronic component are performed significant experiments and measurement, sometimes with negative results.

As many of characteristics cannot be evaluated without the components to be integrated in the system, automotive industry invest more and more efforts in SoC modeling. The models vary on abstraction level, simulation environment, the used description language. From practice can be distinguished the follow models categories, with some example from automotive electronic circuit design industry:

- Depending of product or project hierarchy, by used model languages can be grouped to(but not limited to – system (SystemC, SystemVerilog, MATLAB Simulink), Printed Circuit Board (PCB) (IBIS, transmition lines, 3D chip (VerilogAMS), block(Verilog, Spectre)
- Depending project stage could be requirements definition oriented and circuit synthesis (Verilog, VHDL, Simulink), or verification oriented (SystemC, SystemVerilog, VerilogAMS).
- Depending to what precision level the model replicate the electronic circuit they could be include single case mathematical or behavior representation, or they could include process or temperature parameters dependency.

The simulations in microelectronics are extensively used from few decades. The OEMs companies are integrating electronic components from different companies, which are produced at different technologies, developed with different software tools, integrating the same with sensors using physical simulators, and possibility for software development and evaluation ate early stage. The OEM companies respectively demand these models to be provided by electronic components producing companies. Those models have to cover the main function, error conditions detection and/or limitation, process variation etc. By these models are secured not only the actual system performance, but also is provided possibility to be simulated the system in case of change – due to new functionality, environment requirements change, or even in case of changed supplier of electronic components [4].

C. Functional Safety

ISO 26262 is one of most cited standard by automotive company in the last years. Published 2011, it is an adaptation of Functional Safety standard IEC 61508 for electrical and electronic (E/E) systems, adapted for automotive industry. In ISO 26262 the risk of hazardous operational situations is qualitatively assessed and safety measures are defined to avoid or control systematic failures and to detect or control random hardware failures, or mitigate their effects. It covers Quality Management (QM), engineering and testing requirements. It is guideline based on many years' experience of OEMs and ECU suppliers.

From design point of view is important to be understood that meeting all parametric and functional requirements in product specification, to be compliant with EMC standards, does not guarantee product safety, although this are base topics that shall be met. It is also encouraged to be reused existing, proven in practice technical solutions and methods.

D. EMC simulations for IC

Electromagnetic Interference (EMI), Compatibility (EMC) and Environmental Effects (E3) are important considerations in any electronics product development and critical for systems integration. Legally, products must comply with international EMC standards which have been developed to control conducted and radiated emissions from electrical and electronics systems [7], [9]. Early prediction by simulation of the IC EMC problems and same time meeting the all IC requirements presents major challenges to engineers. Not passing the EMC tests with first prototypes have to be solved in new prototype design iteration or adding filtering components.

Compared to embedded system domain, tools for EMC simulations in IC are very few. The IC-EMC software [8] is one, where is a demonstrated handling the modeling, simulations and comparison with real measurement data of emission of integrated circuits.

Modeling of complex circuit is non-trivial task regarding finding the minimum needed precision of the model for the simulation. Another aspect is non-linear effects of active components as diodes and transistors. Based on that use of simplified schematic or block extract of main influencing/influenced components verified with known, existing design methods and tools from the embedded system domain could give the needed tradeoff of precision and design efforts [6].

E. HV design

HV design is part of almost all automotive IC. This is due to the battery supply range, automotive communication interfaces, specific sensors operating range or EMC requirements. The international and government regulations for decreasing CO2 emissions busted the development of 24V and 48V automotive systems, high efficient DC converters, LED drivers.

In the 24V and 48V systems, big part of new designs can step and reuse significant part of existing 12V systems schematics, mainly by replacing the HV devices. HV transistors have usually worst dynamic characteristics, higher threshold voltage and low area density, compared to basic process LV transistors. Due to that the typical uses of HV transistors in analog circuits are:

- HV switch, used in switching application.
- Cascoding switch, protecting the LV transistors from Drain-Source and Drain-Bulk brake-down. This cascoding is used in current source, active loads in amplifier, levelshifters, and serial switch.
- Voltage reference: the threshold voltage of HV transistors is usually higher than the same of the LV transistors from same process option. The transistor is used in diode connection.
- Reverse voltage protection: HV switch can be used as serial reverse voltage protection diode, where the used process is not offering HV diode or HV schottky diode with the required characteristic. The HV transistor drain and source position is swapped. When transistor is off, it acts as serial forward connected diode. When transistor is turned on, it is as switch, with much lower voltage drop than usual HV diode can have.
- Active voltage clamp (zenner): in that transistor application the gate of HV transistor is connected to static reference level, the source is connected to the net that voltage level has to be limited. When the voltage on the source change that HV transistor gate-source voltage is higher than HV transistor Vth, transistor is turned on and pass through it the unwonted current.

The first two listed use of HV devices cover about 90% of HV transistors application in HV circuits, which is providing good reference for new ASICs design partial reuse. Next listed examples are more process specific dependent, but can provide recognizable advantage for the circuit.

Looking on high efficiency on DC convertors, developed for LED drivers, it shouldn't be underestimated the cost of required external components, also electromagnetic missions due to switching. Depending on specific circuit application and requirements, it could be found power, cost and EMC compatible HV solution, which to use continuous biasing and driving, using floating HV-switches, sill having an efficient solution [5].

HV design is often suffering from incorrect or missing gate-source and/or drain source protection. Simulation of Safe Operating Area cases with transient simulations is one of most popular approach for identifying that something is unprotected or in risk but is highly dependent from skills of designers. To decrease risk of failure in new silicones, ASIC companies still relay on internal or external experts, to provide best practice recommendations and to review design regarding mistakes. To cover this verification challenge, companies attempt to develop tools, verifying analog circuit design based on experience and best practices.

II. Conclusion

Automotive Industry is requesting from microelectronic manufactures safer, energy efficient, and environment robust design. Together with cost pressure, high dependent of first time right design, analog microelectronic design need to change it design methodologies. Key success factors are selection and reuse of stable solutions, which are easy applicable in many of the projects, technologies, reuse design methodologies and practices from OEMs, invest on development of analog Soft-IPs and design best-practice verification tools.

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