

Digital Design and Verification of I3C protocol

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Abstract— This paper presents the design and FPGA prototyping of an Application-Specific Integrated Circuit (ASIC) implementing the MIPI I3C protocol, version 1.1.1. The I3C protocol, developed by the MIPI Alliance, enhances traditional protocols like I²C by enabling faster data transmission, dynamic address assignment, hot-join capabilities, and power efficiency, while maintaining backward compatibility with legacy I2C devices. The project involves designing a modular I3C controller in Verilog HDL, simulating it, and validating the architecture through Xilinx Vivado-based FPGA implementation and communication testing with an Arduino microcontroller. Performance metrics, including timing, area utilization, and power consumption, were analyzed to ensure the design meets industrial standards. The proposed controller architecture demonstrates reliable, high-speed communication for integration into future mobile and IoT systems.

I. INTRODUCTION

Communication between system components in modern embedded systems necessitates standardized, scalable, and energy-efficient interfaces. I2C and SPI protocols have historically fulfilled this role, but the growing demands of IoT devices highlighted their limitations. The MIPI I3C protocol was introduced to overcome these issues, combining the strengths of both I2C and SPI while offering additional capabilities such as dynamic addressing, in-band interrupts (IBI), and multi-controller support.

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II. METHODOLOGY

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Before you begin to format your paper, first write and save the content as a separate text file. Keep your text and graphic files separate until after the text has been formatted and styled. Do not use hard tabs, and limit use of hard returns to only one return at the end of a paragraph. Do not add any kind of pagination anywhere in the paper. Do not number text heads-the template will do that for you.

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Define abbreviations and acronyms the first time they are used in the text, even after they have been defined in the abstract. Abbreviations such as IEEE, SI, MKS, CGS, sc, dc, and rms do not have to be defined. Do not use abbreviations in the title or heads unless they are unavoidable.

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- Use either SI (MKS) or CGS as primary units. (SI units are encouraged.) English units may be used as secondary units (in parentheses). An exception would be the use of English units as identifiers in trade, such as “3.5-inch disk drive”.
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- Do not mix complete spellings and abbreviations of units: “Wb/m²” or “webers per square meter”, not “webers/m²”. Spell out units when they appear in text: “. . . a few henries”, not “. . . a few H”.
- Use a zero before decimal points: “0.25”, not “.25”. Use “cm³”, not “cc”. (*bullet list*)

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The equations are an exception to the prescribed specifications of this template. You will need to determine whether or not your equation should be typed using either the Times New Roman or the Symbol font (please no other font). To create multileveled equations, it may be necessary to treat the equation as a graphic and insert it into the text after your paper is styled. Number equations consecutively. Equation numbers, within parentheses, are to position flush right, as in (1), using a right tab stop. To make your equations more compact, you may use the solidus (/), the exp function, or appropriate exponents. Italicize Roman symbols for quantities and variables, but not Greek symbols. Use a long dash rather than a hyphen for a minus sign. Punctuate equations with commas or periods when they are part of a sentence, as in

$$\alpha + \beta = \chi. \quad (1)$$

Note that the equation is centered using a center tab stop. Be sure that the symbols in your equation have been defined before or immediately following the equation. Use “(1)”, not “Eq. (1)” or “equation (1)”, except at the beginning of a sentence: “Equation (1) is . . .”

D. Some Common Mistakes

- The word “data” is plural, not singular.
- The subscript for the permeability of vacuum μ_0 , and other common scientific constants, is zero with subscript formatting, not a lowercase letter “o”.
- In American English, commas, semi-/colons, periods, question and exclamation marks are located within quotation marks only when a complete thought or name is cited, such as a title or full quotation. When quotation marks are used, instead of a bold or italic typeface, to highlight a word or phrase, punctuation should appear outside of the quotation marks. A parenthetical phrase or statement at the end of a sentence is punctuated outside of the closing parenthesis (like this). (A parenthetical sentence is punctuated within the parentheses.)
- A graph within a graph is an “inset”, not an “insert”. The word *alternately* is preferred to the word “alternately” (unless you really mean something that alternates).
- Do not use the word “essentially” to mean “approximately” or “effectively”.
- In your paper title, if the words “that uses” can accurately replace the word “using”, capitalize the “u”; if not, keep using lower-cased.

- Be aware of the different meanings of the homophones “affect” and “effect”, “complement” and “compliment”, “discreet” and “discrete”, “principal” and “principle”.
- Do not confuse “imply” and “infer”.
- The prefix “non” is not a word; it should be joined to the word it modifies, usually without a hyphen.
- There is no period after the “et” in the Latin abbreviation “et al.”.
- The abbreviation “i.e.” means “that is”, and the abbreviation “e.g.” means “for example”.

An excellent style manual for science writers is [7].

IV. DISCUSSION

The integration of push-pull signaling, dynamic addressing, and multi-target support makes I3C superior to I2C for high-speed, low-power applications. The modular design of the controller enables easy scalability and reuse. Challenges included maintaining compatibility with legacy devices and managing arbitration in mixed-protocol environments. These were resolved through careful implementation of CCCs and adaptive FSMs.

A. Authors and Affiliations

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Component heads identify the different components of your paper and are not topically subordinate to each other. Examples include Acknowledgments and References and, for these, the correct style to use is “Heading 5”. Use “figure caption” for your Figure captions, and “table head” for your table title. Run-in heads, such as “Abstract”, will require you to apply a style (in this case, italic) in addition to the style provided by the drop down menu to differentiate the head from the text.

Text heads organize the topics on a relational, hierarchical basis. For example, the paper title is the primary text head because all subsequent material relates and elaborates on this one topic. If there are two or more sub-topics, the next level head (uppercase Roman numerals) should be used and, conversely, if there are not at least two sub-topics, then no subheads should be introduced. Styles named “Heading 1”, “Heading 2”, “Heading 3”, and “Heading 4” are prescribed.

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TABLE I. TABLE TYPE STYLES

Table Head	Table Column Head		
	Table column subhead	Subhead	Subhead
copy	More table copy ^a		

a. Sample of a Table footnote. (Table footnote)

Figure 1. Example of a figure caption. (*figure caption*)

We suggest that you use a text box to insert a graphic (which is ideally a 300 dpi TIFF or EPS file, with all fonts embedded) because, in an MSW document, this method is somewhat more stable than directly inserting a picture.

To have non-visible rules on your frame, use the MSWord “Format” pull-down menu, select Text Box >

Figure Labels: Use 8 point Times New Roman for Figure labels. Use words rather than symbols or abbreviations when writing Figure axis labels to avoid confusing the reader. As an example, write the quantity “Magnetization”, or

“Magnetization, M”, not just “M”. If including units in the label, present them within parentheses. Do not label axes only with units. In the example, write “Magnetization (A/m)” or “Magnetization {A[m(1)]}”, not just “A/m”. Do not label axes with a ratio of quantities and units. For example, write “Temperature (K)”, not “Temperature/K.”

V. CONCLUSION

The proposed ASIC design and FPGA prototyping of the MIPI I3C controller prove its applicability in real-world IoT and mobile communication systems. Future work may explore HDR modes, further optimization of power consumption, and silicon fabrication of the ASIC. This work provides a practical foundation for integrating MIPI I3C into next-generation SoC architectures.

APPENDIX

Appendixes should appear before the acknowledgment.

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