HOP: A Formal Model for Synchronous Circuits using Communicating Fundamental Mode Symbolic Automata

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Abstract. We study synchronous digital circuits in an abstract setting. A circuit is viewed as a collection of modules connected through their boundary ports, where each port assumes a fixed direction (input or output) over one cycle of operation, and can change directions across cycles. No distinction is made between clock inputs and non-clock inputs. A cycle of operation consists of the application of a set of inputs followed by the stabilization of the module state before the next inputs are applied (i.e. fundamental mode operation is assumed). The states and inputs of a module are modeled symbolically in a functional notation. This enables us to study not only finite-state controllers, but also large data paths, possibly with unbounded amounts of state. We present the abstract syntax for modules, well-formedness checks on the syntax, the formal semantics in terms of the denotation of a module, and the rule for composing two modules interconnected and operating in parallel, embodied in the operator \textit{par}. It is shown that \textit{par} preserves well-formedness, and denotes conjunction. These results are applicable to virtually every kind of synchronous circuit (e.g. VLSI circuits that employ single or multiphase clocks, circuits that employ switch or gate logic structures, circuits that employ uni- or bi-directional ports, etc.), thanks to the small number of assumptions upon which the HOP model is set up.

1 Introduction

Synchronous digital circuits are, perhaps, one of the most widely studied forms of hardware. The most common definition of a synchronous digital system is that it is globally clocked. This definition is often not directly applicable to all real-world synchronous hardware systems because some real-world synchronous systems employ polyphase clocks, and their submodules use different subsets of the set of global clock phases. An obvious generalization of the above definition of synchronous systems is: “a system with a logical clock that acts as the global time reference, and to which all the actual clock phases are aligned”. Though mathematically accurate, this view of synchronous systems violates the principle

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