Solution notes

Specification and Verification II 2005 – Paper 9 Question 13 (MJCG)

(*a*) Discuss the challenge of modelling transistors in a way that is both tractable for formal verification and accurate enough to be useful. [5 marks]

Electrically accurate models, like those used by SPICE circuit simulators, are too complex to be handled by existing formal methods (either algorithmic or user-guided deduction). Models that can be handled are normally discrete, approximate and electrically naive. The challenge is first to identify the kind of properties one wants to check and then to choose the simplest model that is up to the job.

(*b*) Discuss the accuracy of the simple switch model of transistors and discuss how the model can be improved. [5 marks]

One inaccuracy of the simple switch model is that it does not represent the physical behaviour that n-transisors conduct `Lo` *better then* `Hi` *when there is a* `Hi` *on the gate (and, dually, p-transisors conduct* `Hi` *better then* `Lo` *when there is a* `Lo` *on the gate). This inaccuracy can be reduced by changing the simple switch model:*

```
NTRAN(g,s,d) = g ==> (s = d)
```

to the 'difference switching model' of Fourman:

```
NTRAN(g,s,d) = (g=Hi) ==> ((s=Lo) <=> (d=Lo))
```

This model blocks `NTRAN(Hi,Hi,Hi)` *and can be used to block the false positive verification of circuits that only work if this holds. (one also needs the dual change to the model of p-transistors.)*

Another major inaccuracy of the simple switch model is that it doesn't represent sequential behaviour due to capacitative effects (see following part of the question).

(*c*) Outline how transistor circuits that use precharging can be formally modelled in higher order logic. Discuss briefly potential inaccuracies of such models. [5 marks]

Capacitative effects like precharging can be modelled by introducing a value `Fl` *to represent 'floating' states. One then sets up a sequential model in which 'strong' values (e.g.* `Hi` *and* `Lo`*) persist if the current driving value is* `Fl`*. The known models are unidirectional, and thus require transistors to be assigned an orientation (i.e. have a fixed input and output). Getting the orientation wrong may lead to invalid models.*

(*d*) Describe how to specify that a bit-level circuit with 4-bit inputs a and b and an 8-bit output *prod* performs multiplication. [5 marks]

To specify a 4-bit multiplier, M say, one needs to define abstraction functions, `Abs4` *say, from 4-bit words to numbers and* `Abs8` *say, from 8-bit words to numbers. The specification is then something like:*

$M(in_1, in_2, output) = (\texttt{Abs8}(output) = \texttt{Abs4}(in_1) \times \texttt{Abs4}(in_2))$

Context

This question is about modelling in logic (specifically transistor level modelling) and relates to the first part of the course on specification in logic.

Marking Scheme

For each section:

5 marks : well-written answer that goes beyond pure regurgitation of course material and shows evidence of understanding going beyond rote learning;

4 marks : complete answer, but lacking in the flair needed for 5 marks;

3 marks : evidence of basic grasp of material, but some omissions or inaccuracies;

2 marks : partial answer lacking some key material or serious inaccuracies;

1 mark : something at least vaguely relevant detectable.